The Innovation Hub

for Affordable Heating and Cooling

Design Studio Outcomes Report (100% Milestone)

IDS-11 WCC Ribbonwood Community Centre – Outcomes Report

Project IDS11

19 November 2021

University of Wollongong

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

The IDS-11 Wollongong City Council Ribbonwood Community Centre Integrated Design Studio investigates design innovation to reduce net energy consumption of Wollongong City Council (WCC) soon to be renovated Ribbonwood Community Centre in Dapto. Over a 14-week period, a group of multidisciplinary students work collaboratively to respond to environmental challenges faced by WCC Ribbonwood Community Centre, with a particular focus on how WCC can achieve their organisational commitment of net zero emissions for its own operations by 2030.

Numerous councils and community centres alike are now making net zero emissions targets and are facing many challenges along this journey. Not least is the reliance on natural gas and the need for increased levels of thermal comfort whilst reducing energy consumption.

Based on WCC's commitment to move towards net zero emissions for its own operations by 2030 and a brief that was informed by representatives from WCC, students explore novel approaches to address Net Zero Carbon principles with a particular focus given to renewable energy technologies and strategies to improve the value of renewable energy. Considerations are given to capital versus operation and life cycle costs and identifying opportunities for staging or future replacement/staging of technologies.

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1 SUMMARY

1.1 Purpose

This report summarises the findings obtained from IDS-11, marking the 100% completion milestone at the project end. This report contains key information previously presented in the 50% milestone report, with additional findings from the vetting reports, submitted assessments, and participant feedback. The knowledge compiled within this report will feed directly into the 'Lessons Learned' associated with IDS-11, and will further be disseminated under the IDS knowledge sharing strategy.

1.2 Executive summary

The IDS-11 WCC Ribbonwood Community Centre builds upon lessons learnt from the previous integrated design studios undertaken by the University of Melbourne (UoM). This design studio was initiated early March 2021 after substantial stakeholder engagement that commenced in Q4 of 2020. In the first week of autumn semester, the WCC client introduced the Ribbonwood Community Centre and provided the project participants with a brief on the planned upgrades that are scheduled for 2022/23. The aim of the upgrades is to take the facility beyond current standards and provide an adaptive environment that can adjust with changing community needs and climate for the next 20 years. This brief set the goals and constraints of the integrated design process.

Multi-disciplinary teams of architectural engineering, civil engineering, environmental engineering, and mechanical engineering students produced a number of return briefs with guidance from industry consultants and student tutors. The design studio combines the input of three subjects from two separate schools at both an undergraduate and master's level. The student outcomes for the subjects were aligned to focus on producing integrated solutions that target 'Net Zero' design. Due to the impact of COVID-19 the studios were delivered via a mixed online and face-to-face platform with most participants choosing to attend the weekly studios in person where they could interact with team members, the consultants, and tutors.

Work progressed with students generating a number of design solutions to meet the client's needs. They evaluated the designs via self-generated evaluation matrices, with final design evaluations having been presented to both the consultants and clients. These finalised designs involved students completing a detailed design and analysis of expected outcomes compared against a business-as-usual (BAU) baseline. This process has resulted in a number of innovative design solutions, which are further examined through the vetting report.

The most important findings in relation to the integrated design process were:

- A concurrent collaborative design has significant benefits and empowers architects and engineers to overcome their perceptions about their capabilities in terms of exploring design solutions.

- A well-defined framework of the integrated design studio process is essential and guides the designers to produce a plethora of interesting design solutions.

- Feedback mechanisms and interactions between clients, consultants, academics and students are important for the success of the project.

- Challenges arise when developing integrated design solutions for existing buildings in terms of flexibility of the approaches taken, however existing buildings also offer some advantages such as the possibility to discuss issues with occupants, the option to undertake spot measurements as well as identify inefficient technologies or systems.

- Overcoming initial communication hesitancies witnessed in students is key to productive idea generation and discussion, assisting in facilitating a positive and creative design environment.

In terms of technical findings suitable for the building type and climate, the design solutions included:

- Optimised passive solar principles
- High performance façade
- Heat recovery ventilation
- Operational improvements
- Additional PV

Overall, the IDS process has proven valuable for all participants and is now intended to become a permanent approach in the training of students. The IDS has empowered participants to overcome constraints in relation to their field of expertise – architecture and engineering – to improve technical outcomes and enable the architecture rather than compromising on it as is often the case.

2 PROJECT CONTEXT AND INCEPTION

2.1 Context to the WCC Ribbonwood Community Centre Integrated Design Studio

The Wollongong City Council Ribbonwood Community Centre in Dapto was constructed in 2000 and provides a wide variety of much needed services to the community. The centre holds a library, two large halls, five smaller rooms, and two offices that are available for the community to hold numerous events and activities (Figure 1). The facility is scheduled for an upgrade in 2022/23 which aims to take the facility beyond current standards and provide an adaptive environment that can adjust with changing community needs and climate for the next 20 years. In addition, Wollongong City Council has set an ambitious target of reaching net zero emissions by 2030. The Ribbonwood Centre refurbishment seeks to meet this target while improving its accessibility, enabling more community members with a broader range of abilities to access the benefits of the centre.

The centre already boasts a 100kWp solar array, but the air conditioning system has reached its end of life, providing a great opportunity for exploring solutions that meet the thermal comfort needs while achieving the ambition of net zero emissions by 2030. The lighting system has also reached its end of life with an interest of reviewing organic response lighting solutions. This refurbishment seeks to create an inviting, adaptable, and comfortable, and inclusive environment for all community members while minimising energy consumption.

The output of this IDS will be used to form the scoping document of the refurbishment, driving future processes and outcomes in the Ribbonwood Community Centre upgrade.

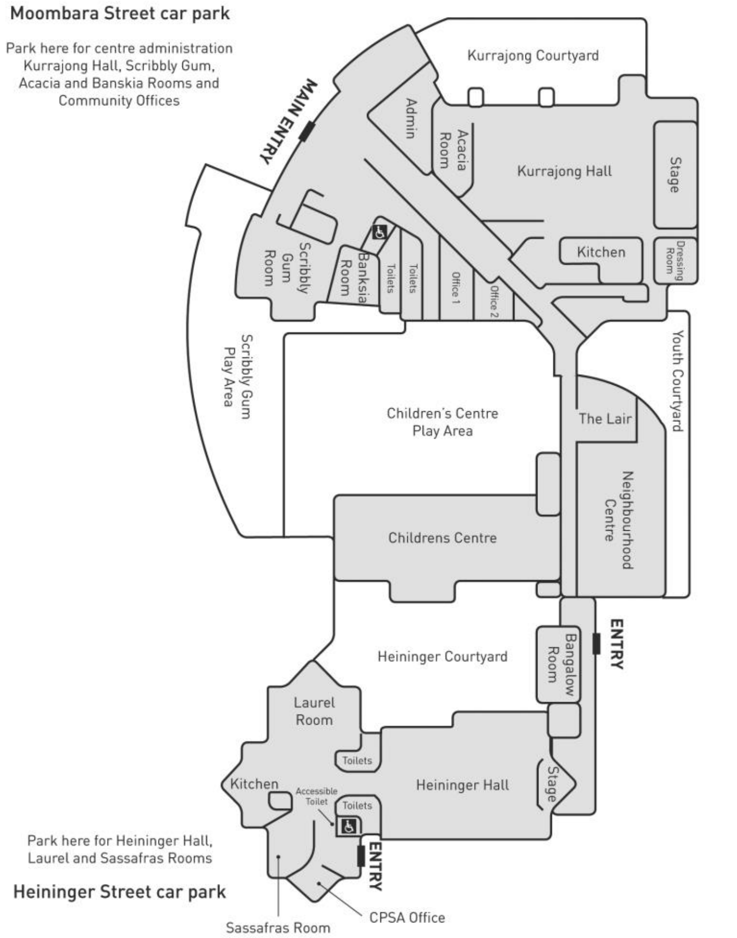

Figure 1. Schematic Representation of the WCC Ribbonwood Community Centre Ground Floor Plan

2.2 Studio Inception

Prior to the commencement of autumn semester 2021, a number of meetings were held with the University of Melbourne's Integrated Design Studio project team where there was an exchange of knowledge and lessons from previous design studios. Lessons learnt from the University of Melbourne's experience were taken into account, for example with regard to avoiding delays with ethics approvals and ensure an efficient running of the studios. This was followed by the team engaging in a broad industry scoping to identify prospective design studio case studies to be investigated and consultants to support these studios. Two case-studies were selected to run in parallel over the course of autumn semester 2021 which commenced 1st March and runs until the 24th June.

The WCC Ribbonwood Community Centre facility was one of these two case studies selected to be investigated within the IDS program. A consultation process followed with WCC which provided a refinement of the brief and problem statements to be provided to the IDS participants at the start of semester. The design studio team went on to develop the subject assignments to align the IDS outcomes with the existing curriculum. A series of collaboration agreements and IP Deeds were generated to manage the expectations of the studios and UOW internal Ethics Approval was sought. In the early weeks of semester, the WCC client presented the brief to the studio participants providing an opportunity for students, consultants, and tutors to clarify any expectations of the brief. This was followed with an opportunity to submit Request for Information (RFI's) to the client before producing their return briefs.

Figure 2. WCC Ribbonwood Community Centre

2.3 Client Engagement

With the involvement of WCC representatives, the project collaborated with a Buildings & Facilities Sustainability Planner who has extensive knowledge in sustainability and HVAC equipment. With the building and its existing plant now reaching 20 years old, and with the WCC commitment to net zero emissions by 2030, this IDS provides a perfect testing ground for the client to explore opportunities to meet this ambition. The client offered continued support to the project participants and joined the mid semester and end of semester presentations where the studio teams presented their proposed solutions. The outcomes of this IDS in combination with an engaged client have great potential to provide a lasting impact to this sector.

2.4 **Site Visit**

The WCC Ribbonwood Community Centre is located only 15 km south of the University of Wollongong's main campus and can be accessed via bus or train services (Figure 3). Most spaces of the facility are open to the public during normal operating hours, but a site visit was organised with the client providing a tour of the facility and its associated plant equipment that is seeking replacement.

This site tour gave the IDS participants the opportunity to have a behind the scenes look at the facility and clarify with the client and the facility staff any issues that they are experiencing. This returned a large amount of feedback regarding the current thermal comfort issues within the facility along with accessibility issues that limit some community members from accessing all of the facilities resources.

Figure 3. WCC Ribbonwood Community Centre Site Visit

3 DESIGN STUDIO PROGRESSION

3.1 Setup for Collaborative Design Integration

Prior to the start of Autumn semester, the subject coordinators for the three participating subjects cooperated on designing the course content so that it encourages cross disciplinary collaboration between the participants. The content was designed to equip the participants with the fundamental aspects of design and provides an understanding of building performance and thermal comfort. The content also provides a deeper overview of building simulation models for estimating performance and comfort. This provides the participants with an understanding and the tools required to assess the expected impact of their design concepts.

The following discussion is an excerpt from the University of Melbourne's studios and provided guidance on the creation and operation of the IDS detailed in this report.

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**, instil 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 and apply end-use performance metrics
  - What are the mechanisms to address them in **early**-stage design?
  - What are the mechanisms to address them in the **advanced** design stages?
- Develop an iterative Architecture/Engineering process for **optimising performance** (Optioneering)
- Search for integrated design responses to human **comfort** and environmental **loads** and understand how various aspects of the Architectural and Engineering design are connected.
- Search for **synergies** via design **innovation rather than** relying only on **mechanical** solutions (passive over active)
- 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

3.2 Schedule for Interdisciplinary Engagement

The studios have been designed around two group reports (return brief/proposal, and schematic design development & interim report) with a group presentation which facilitates cross disciplinary conversations and collaborations. This is supported through weekly interactions with the studio tutors and industry consultants. A final design report and presentation is undertaken individually where the students are required to undertake a deeper analysis on the selected design and its expected impact. This individual contribution has a requirement that participants address how this solution will interact with their group members selected solutions which encourages ongoing interdisciplinary interactions while still meeting the required subject outcomes at both the undergraduate and master levels.

3.3 Weekly interaction between Design Studio Participants

The IDS program consists of a weekly lecture delivering a variety of course content supplemented with additional learning material where required. This is followed by a weekly two-hour studio facilitated by the tutors and in collaboration with the industry consultants. The first two weeks focused on an introduction to design studios followed by site analysis, brief analysis, and design precedence. This provided the foundation for the students to create their return briefs. Week 3 to 4 shifted towards thermal comfort and natural ventilation, and provided an understanding of Heating, Ventilation & Air-Conditioning Systems. This was followed by two weeks of energy performance assessment and building performance simulation. The following 6 weeks examined building regulations and certification schemes (e.g. Basix, NatHERS etc.), retrofit and construction strategies, solar and storage technologies, and building monitoring.

The topics covered in these lectures serve to supplement student knowledge on sustainable design practices, giving them the necessary tools to undertake a design appropriate to the brief with the support of industry experts and the tutors. The industry consultants worked together with the students on providing detailed advice and they also give high-level advice to the participants at the conclusion of each studio. The consultants were also available outside of the standard studio hours for group consultations. The studio saw the participants learning to communicate across disciplines and convey their respective ideas or disciplinary advice to each other while generating innovative solutions to meet the client's needs. To help facilitate this, the participants were required to produce an evaluation matrix to review and score each design solution across a range of criteria.

The first presentation to the clients was met with enthusiasm with both the client and consultants providing valuable feedback and direction. The following weeks saw students taking the ideas developed as an interdisciplinary team and developing these ideas individually with the guidance of the consultants. Students were encouraged to discuss their ideas openly within the class and within smaller groups. The finalised designs were presented at the end of semester to the clients, consultants, and peers.

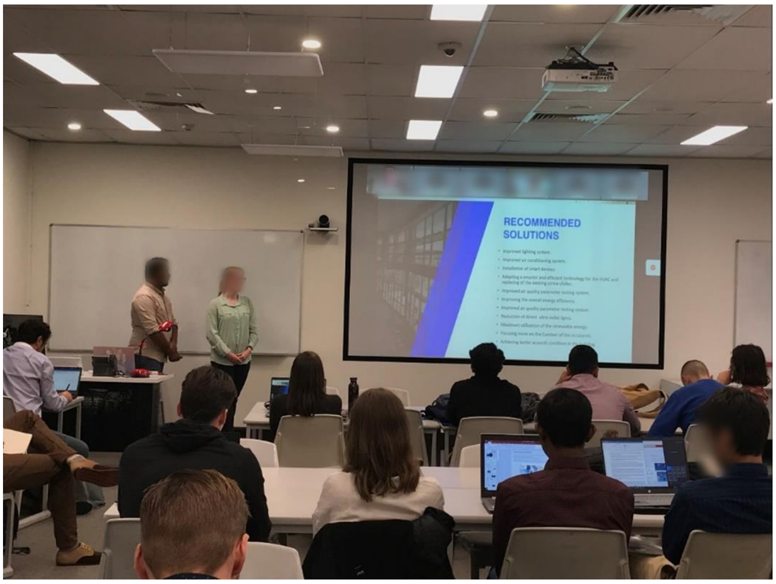

Figure 4: Students presenting initial design ideas to clients, consultants and academics

3.4 **Impact of COVID-19 on Semester Planning, Level of Engagement and Studio Outcomes**

The COVID-19 pandemic continues to impact universities across Australia, particularly with international students being unable to enter the country which affects master level subjects more so than undergraduate. This has resulted in lower student availability; however, a sufficient number of students were recruited to enable the IDS to proceed. In addition to lower student numbers, the course content has had to be developed to be delivered in both an online and face-to-face platform. Although the vast majority of participants were attending in person, this has enabled continued participation remotely and enabled additional colleagues of the consultants to also participate at times. Students and consultants worked well with each other, including navigating dual-mode (i.e. virtual/in-person) communication methods.

Figure 5: Consultants discussing detailed design ideas with students

4 DESIGN STUDIO FINDINGS

The findings from the Integrated Design Studio IDS-11 have been separated into three main categories for further examination:

1. Key observations recorded during the studio workshops
2. Feedback from participating industry consultants, studio tutors and the client, and
3. Feedback from participating students

Observations made during the studio workshops give insight into what worked well (or did not work well) in the overall running of the IDS, either in terms of student learning outcomes, or work completed, whereas the feedback from industry consultants, studio tutors, clients and students give a reflection on how things may be changed to run better in the future.

4.1 Key Observations during the studio

4.1.1 Engineering and Architecture: Perceptions and benefits from collaborative design

Collaborative studios involving students, academics and consultants provide effective opportunities for all participants from different disciplines and backgrounds to get a mutual understanding of the different disciplines and their typical constraints.

There seems to be a perception amongst the students that are closer to the field of architecture that some tasks involving energy related considerations are very difficult for them. The engineering Masters students on the other hand prefer more predefined tasks where someone would tell them the problem at hand and the calculation methods for addressing them without considering alternative designs and flexibility in deriving to the most optimum design solutions. The interactions between the students in the studios and the encouragement and support they receive from the academics and the consultants has empowered them to start producing integrated designs that use a multi-disciplinary approach. The studios have enabled students to acquire significant technical knowledge of key design elements and challenged them to structure strategies as a team around creating better briefs, defining comprehensive decision making and developing performance-based outcomes. Creating groups with consultants and students from different disciplines provides better opportunities to review the project goals towards various aspects and uncover more ideas and limitations. The students have developed holistic thinking and multi-disciplinary solutions to enabling a better utilisation of renewable energy, energy efficiency and indoor environmental quality within their projects, with students in differing disciplines contributing more discipline knowledge to the project, for example:

- Civil Engineering – Embodied energy and embodied CO2
- Mechanical Engineering – HVAC and active energy efficiency
- Architecture – Façade, Indoor Environmental Quality (IEQ) and passive energy efficiency

4.1.2 Defined design process framework leads to multiple useful outcomes

Innovative design solutions require a process where flexibility is given to the students and the consultants to develop all possible thoughts into design options and interrogate them across a range of criteria. Students were given a framework of work that acts as a guide and follows the following generic predefined steps:

i. Site analysis, user requirements and identification of opportunities

ii. Business-as-usual study

iii. Development of a matrix that ranks proposed net zero energy design measures at least in relation to relevant prescribed criteria (e.g. feasibility, capital and operation cost estimates, energy and carbon savings potential, innovation, potential impact on the rating produced by existing green building certification schemes or Standards).

iv. Detailed quantification of the impact of selective design solutions.

While the design process is flexible, this framework outlined smaller achievable goals for the students to work towards, progressing them from an initial conceptual design towards a finalised design. This framework was presented to the students in the form of assessments, with each subsequent assessment built on the work completed previously. This progression assuaged the overwhelming nature that design can have, and reinforced the development of constructive design principals, with a design progressing step-by-step with changes being made based on feedback.

The inclusion of a design matrix assisted in students examining the many sustainable technologies that exist, and the different factors affecting each. Through comparing different technologies against one another, some technologies stood out as 'better' depending on which criteria the students as most critical within the brief. The primary factors affecting each technology in the matrix were:

- Cost (Capital and Operational) – Are the costs beneficial over time or is it a short term benefit?
- Feasibility – Is the technology appropriate and viable for inclusion within the design?
- Building Regulations and Certification – Do different certification schemes assess these technologies, and how well do they perform?
- Energy/Carbon Savings – Does the system save on energy/carbon compared to alternative systems?

Table 1: Selected extracts from student work - Evaluation matrix

Net zero Energy Design Strategy		Brief Description	Cost	Feasibility	Energy Saving Potential	Carbon Saving Potential	Materials	IEQ	Impact on Sustainability Rating Systems	Maintenance & Reliability	Innovation	Total
Weighting			8%	10%	14%	8%	12%	20%	10%	6%	12%	5
Glazing	Pseudo Double Glazing	Double Glazing traps a layer of air between panes which acts as an insulating barrier	4	4.5	2.5	4.5	5	3.75	3	4	3	3.7
	Timber Window Frames	Timber has better insulating properties than aluminium	4.5	5	2.5	4	4.75	3.5	2	4	3	3.6
	Tinting Film for Windows	Polymers inside the tinting film block some infrared waves which are responsible for heat gains	3.5	4.5	2.5	4.5	4	3.67	2	4	2	3.3

In general, following a predefined framework, students thought thoroughly about how to meet client specifications and addressed conflicts of interest in terms of design.

4.1.3 Importance of feedback mechanisms

Receiving response/feedback from client in regards to the return brief and overall project iteration was very beneficial for the progress of the project. The inter-disciplinary background of the consultants also led to important discussions and feedback on the suitability of the design solutions, for example whether a specific solution was feasible in terms of modelling it in a building performance simulation tool while at the same time that solution satisfied all potential structural requirements of the building structure.

One area of improvement is finding mechanisms to encourage studio participants to benefit even more greatly from engaging with each other more thoroughly via the forums, offline discussions and other online tools available to them. Sometimes the students have appeared to be reluctant to interact with consultants outside the 2-hour studio class. As the subject progressed, the students became more comfortable with the IDS structure and of the consultant personnel, which increased student engagement and the production of design outcomes.

Larger working groups (~8 students, two consultants and one academic) seem to work better than smaller groups. This allows for deeper interaction between the students, consultants and academics. Moreover, when in larger groups the students become aware of what designs and methods the other smaller groups are considering.

Outputs improved over the weeks. The questions and dialogs between students, consultants and academics were of a higher level as the weeks pass. This clearly shows interest and effort to research new solutions.

4.1.4 **Existing building vs. new building design for community centres**

There is less flexibility on the potential solutions for improving the design of an existing building due to its fixed geometry. However, "low hanging fruit" solutions such as those around the use of more efficient lighting are in some cases possible. In addition, undertaking an integrated design study for existing buildings allows for potential discussions with existing building occupants during, for example, site visits. During these discussions previously unknown issues were raised, for example, issues around thermal comfort when using dividers for separating large halls that are served by one HVAC system and in cases where the thermostat sensors are not close to where the occupants are most often positioned in the building. In existing buildings, it is also possible to undertake spot measurements, although these were not utilised extensively in this integrated design studio.

It is suggested that future integrated design studios for existing buildings involved tasks of simple spot measurements on site (e.g. illuminance and acoustic related measurements can be simply undertaken even with phone apps nowadays). These tasks are relatively simple, and give students additional information which they are able to consider through the design process.

4.1.5 **Interdisciplinary Communication**

While there was a clear divide between the focus and specialities of the different student disciplines, there were no communication issues observed between participating students. The architectural students specifically are studying a Bachelor of Architectural Engineering and have a good understanding of core engineering principles and terminology. This benefited them when working within an interdisciplinary team, as there were no obstacles to overcome when discussing designs with engineering students (i.e. civil, mechanical etc.). This indicates students who receive additional education (even at a basic level) of other disciplines can participate actively in interdisciplinary discussions, having a less siloed focus on design.

4.1.6 **Limitations of dual delivery**

Due to the impact of Covid-19, the classes were offered via dual delivery (online and face-to-face). This appeared to suit everyone well, with students participating via both modes, with some students alternating between delivery modes. This also suited consultants, as they were also able to participate via either mode. While this dual delivery did offer advantages in being able to join remotely, it also presented delivery limitations.

A fully face-to-face learning environment allows students to communicate in person with consultants, fully participating in discussions. Students who are present are easier to engage, with a higher likelihood that consultants and tutors can draw them into a conversation, persuading them to partake in ongoing discussions. This is less likely when students participate online, especially if a webcam/microphone is disabled as tutors/consultants are unable to discern if a student is observing the conversation or not.

Students participating online are also limited in group discussions. While it is a simple exercise for a present cohort to split into smaller groups for discussion, it is more difficult for online participants, who are reliant on the tutors to facilitate breakout rooms via the web-conferencing software (Zoom or Webex). This also requires a present member of the group to connect to the breakout room to communicate with their member who is participating online. As they are not fully present, the online group member may feel isolated and less likely to interact within the discussion. Discussion is also limited to one online member at a time, meaning if multiple people are participating online, only one may be conversing at a time, limiting open discussions.

These behaviours were also observed in studio consultants, limiting their input in discussions. This is not ideal when the experiential knowledge offered by the consultants is highly valued and beneficial to the students. This limits student design development in the weeks consultants participate online. While students were still able to develop their designs through this dual delivery, it was observed that the numerous inconveniences that it causes slows the progress of the studio and limits the outputs of the design studio.

4.1.7 **Communication outside the studio environment**

Though the opportunity existed, the students showed little initiative in communicating with the participating consultants outside of the design studio hours. While students were capable of developing the design individually or as part of a team, they were not utilising all the resources available to them as part of the design studio. This was noted previously in Section 4.1.3, and while they became more comfortable with the structure and running of the IDS as the subject progressed, this was still an unutilised resource which was available.

These communication issues could be due to several reasons, including:

- Working professionals – Students may consider the consultants to be busy individuals, and hesitant to contact them as they don't want to interrupt their work
- Different class dynamic – For the participating students, the IDS offers new and different opportunities in the way the class runs, however, for this same reason, students may not fully understand that they are able to contact the consultants outside of class.
- Other commitments – While participating fully in the class and design activities, students have other classes which they also participate in and may have other commitments. While the opportunity exists for students to contact the consultants outside of class hours, they may have other commitments which are a higher priority.

4.1.8 **Observing researcher notes**

In addition to the general observations of researchers, additional observations were conducted throughout the design studios by an observing researcher who did not take an active role in the running of the studio, keeping interactions between themselves and studio participants to a minimum. The observing researcher took unbiased notes, to highlight important positive and negative aspects, to identify any additional learning outcomes relevant to the studio. These notes have been evaluated, with key findings being extracted and discussed further in this section. The complete set of notes can be found in Appendix D.

The observing researcher identified that earlier weeks of the studio were slow, with students being *hesitant to divulge details of what they were working on*, a behaviour which appears common across varying years and disciplines. Speculation could be made as to why this is so, however the more important learning is that this is a behaviour which should be corrected. Any discipline which can share ideas and seek the advice of others will ultimately achieve a more holistic design, especially when undertaking integrated design practices. The earlier weeks of design were also found to be periods where consultants were invaluable, offering much needed guidance in beginning the design process, but also filling a facilitatory roll. Consultants were found to be asking many leading questions of the students (e.g. Have you considered…?, What do you think about…?), which promoted discussion and encouraged idea generation.

These discussions were noted as becoming *more focused* in later weeks of the IDS, with consultants being engaged more towards there specialisations, allowing them to move on from a facilitator role into a consultant role. These allowed for more technical and specialised conversations, though there was a noted *increase of jargon* which left other group members excluded from the conversation. It was observed that consultants sometimes were the drivers in conversations, though in other instances it was students driving the conversations with consultants being left out. This could be due to the students becoming more comfortable with the working environment, becoming more confident in their understanding of the topic and their design, but may also be due to the consultants (sometimes) participating online due to an inability to attend in person. Whatever the cause, a greater appreciation for open discussion was attained.

The observing researcher also witnessed the *somewhat overwhelming* nature of the project at times, with students becoming confused and lost with the many possibilities available to them. Consultant experiences were of great benefit in these situations, sharing issues faced in the past and how they were overcome. These experiences also gave students insight into important issues which students had not previously examined, allowing students the opportunity to impose bounds on their own designs to mitigate possible consequences which could arise.

4.2 Feedback from participating industry consultants, studio tutors and the client

Feedback from participating industry consultants, studio tutors and the client were obtained through conducting short interviews. The scope of the interview was to allow interviewees the opportunity to reflect on the design studios and discuss any factors which either facilitate or impede the integrated design process in either the environment of the design workshop, or in industry itself. Throughout this questioning, the importance of integrated design was explored in a tertiary setting, examining the benefits that this may provide to students and industry in the future. The interviewees were asked to reflect on the principals which worked or did not work in the design studio setting, and what changes may be beneficial to include to maximise the potential opportunities afforded to all participants in any further IDS's. A full set of transcribed interviews can be found in Appendix B.

Note: As IDS11 was conducted in parallel with another design studio (IDS10), interviews with consultants and studio tutors are the overall views of the interviewees to both of these studio's projects, while the views of the client are unique to the respective IDS. Some of the responses from the consultants and studio tutors relate specifically to this IDS project project, however most responses are general and relate to both. Any similarities witnessed between the analysis of these interviews and those outlined in the IDS10 studio report are the result of these generalised responses.

4.2.1 Integrated design drivers

The interviewees offered a diverse view on what they believed to be the key factors influencing the integrated design process. While some of these views were related specifically to the design studios, they may still be considered as important factors in any undertaking of integrated design. These key drivers can be summarised as facilitation, discussion, engagement, experience, and time. While integrated design can occur without all of these factors, these were identified by the consultants as key factors impacting the degree of success for integrated design.

Facilitation of the design process was identified as being of primary importance, meaning that someone (or multiple people) is required to generate discussion between participants. Without a facilitator of some sort, conversation becomes stagnant and limited, a negative environment for idea generation. An ideal pairing with good facilitation is engagement of participants, individuals who are likeminded in their pursuit of pushing typical design boundaries to develop ideas which diverge from the norm. Good facilitation and engagement result in healthy discussion, which generates holistic ideas developed outside of a siloed framework. These types of feedback mechanisms (whether from the consultant or studio tutor) promote engaging conversations free of criticism, allowing for an open and risk-free examination of ideas

I think it is mainly about the facilitator, because a lot of good integrated design happens when you have someone who is able to get people talking… – Consultant 3 (ESD Consultant)

Really it's about getting conversation started - sometimes students are reluctant to open up and put themselves and their ideas out there, they fell like there is a risk. – Studio Tutor 2

One consultant identified the timeframe of the project being too short, specifically *12 weeks was not enough for the work that was asked of the students*. While this may be a sufficient timeframe in industry, the design studios were not run in industry, and the students undertaking the studios did not have the experience which would be expected of a consultant. The combination of timeframe and inexperience resulted in a *lack of quality*, though it is difficult to quantify what this was benchmarked against. This statement likely comes from a position of greater expectation, as the consultant also believed that the return brief *took them 4 weeks when it should have taken them 1.* This was not the position of all consultants though, with most believing that the primary output should be inspiring the students, educating and preparing them for what to expect in real practice.

We want to inspire people with a different experience so they can work collaboratively and openly together, removing the hierarchy to teach and inspire them for real practice. – Consultant 4 (ESD Consultant)

4.2.2 The client brief

Client briefs can be varied in what is provided, ranging from vague and flexible, to restrictive and detailed. Interviewees appeared to generally agree that the client brief provided for the Ribbonwood retrofit was quite detailed, outlining the specific requirements in sufficient level of detail. All studio tutors, while in principle agreeing with this sentiment, were all of the opinion that the brief was very focussed on HVAC, an observation which was echoed by only one of the consultants. Everyone who raised this issue within the interviews feared that it skewed the students focus primarily towards active systems, with other potential solutions being neglected.

…it was heavily skewed towards the HVAC side of things. – Studio Tutor 3

The concern was also made that the client brief was *too specialised*, with the technical aspects associated with HVAC not being entirely understood by all students. This is a concern when not all students are as familiar with HVAC systems as others. While two studio tutors were concerned about the brief being too detailed, the client was concerned that the brief was too *dumbed down*. The client believed that a true brief should be used, not a *dumbed down version* so that students could be challenged and treated as real designers. These two perspectives are interesting, as the tutors did not want to overwhelm the students, rather desiring a simplified wording of the brief so that the inexperienced students could better understand the design process, while the client wanted to treat the students as professionals and provide them with a real-world example of a true client brief.

The level of detail was too detailed… Studio Tutor 2

I accept that we are dealing with students who would struggle with that concept, but if we are going to be serious about calling it an integrated design studio they need to be challenged – Client (WCC)

While the specificity of the brief itself could be argued, it was agreed by all that the most beneficial aspect of the 'brief' was the site visit, with students having access to both the client, and to the operators of the building. The client was able to discuss the specifics of the brief in more detail with students, while they were able to interact with the building users/operators and obtain differing perspectives, which was all *information that they used to guide their decisions* throughout the design process.

The brief is the key to providing direction to the team and consultants around how to start the project and understand the project details. – Consultant 4 (ESD Consultant)

All interviewees found the clients insightful, with most believing that t*he stakeholders were really engaged and had a lot of stuff and experiences they wanted to share.* Having these interactions with clients and stakeholders provides students with a unique experience outside of the stock-standard brief they are usually provided with for assessments. While these interactions were found to be beneficial, one consultant believed that they were too infrequent, stating that *there is a lot more face time interaction and talking in industry.* On this aspect, the client appears to agree. *…I was happy for them to come back and clarify what we are looking at and ask any questions but no one took those opportunities. That is an area for improvement… greater interaction throughout the process.* However, this is not necessarily an issue associated with the client or the client brief, but rather the engagement and initiative of the students.

4.2.3 Consultant and studio tutor contributions

The consensus among consultants was that some of the best advice was offered through sharing professional experiences and case studies. These discussions provided evidence that there is no singular solution which can best improve building performance, rather that solutions are dependant on the desired outcomes of the client or the existing restrictions/constraints. These solutions need to be tailored to the specific project under examination. A solution will always be different dependant on the many factors affecting the project, such as existing structure, budgetary constraints, prior thermal performance or spatial functionality. These shared experiences offered the students different perspectives on how they may address the design requirements in ways which had not previously been explored.

Where students struggled to progress their designs, one studio tutor found it beneficial to bridge these barriers by breaking down target objectives into manageable components which are able to be addressed individually. Working through these smaller components in a logical manner removed the larger, sometimes overwhelming scope of the project, giving the students the opportunity to generate ideas before finally relating them back to the overall design.

The consultants found in some situations that their unique specialisations were not always required, and instead found that their greater contributions (at those times) were being a participant in conversations and asking questions that would generate further discussion and idea generation. These idea generating discussions were highlighted by multiple consultants and gave students an idea of the multitude of possible solutions available to them. It was found by some of the consultants that these discussions were more inclusive and received greater engagement when in-person rather than online. While discussions online (i.e. via Zoom or Webex) were sufficient, these methods limited engagement and often restricted the number of participants involved in the discussion.

I was also able to contribute by demonstrating how you sit in a studio and ask questions and engage with ideas – Consultant 2 (Civil/Structural Consultant)

Ultimately, the consultants all found that they were able to contribute in a variety of ways. While for some, there contribution was more technical, others found their greatest impetus was to assist students in objectively examining the project free from bias. This allowed students to work more productively as a group and determine holistic solutions, rather than obtaining results which were found through a narrow lens which did not consider other design requisites.

Technical answers can come from anywhere, but the industry experience and recounting stories of how working together gets a better solution than everyone working independently was most helpful – Consultant 3 (ESD Consultant)

Studio tutors (like the consultants) found that they were best able to assist students in a variety of ways, however these differed from the ways in which the consultants were able to contribute. In some instances, these contributions were simple, such as working through a process logically to help students progress their design and have a clear path forward. Most of these contributions though were in assessment setup, and implementation of design frameworks. The greatest of these (as mentioned by two studio tutors and multiple consultants) were the evaluation matrices. These strategies (implemented by tutors) gave students a method of assessing solutions against one another when they didn't appear to have any comparable metrics.

4.2.4 **Critical decision-making**

Interviewees offered conflicting sentiments on what they believed surrounding critical decision-making. Some consultants found that the greatest decision-making issues facing the students was making any decision at all. A lack of prior design experience in an unfamiliar setting resulted in delayed decisions on how the design should progress.

…they didn't have much experience in design, so they were struggling to advance their ideas to meet the project requirements – they didn't have enough time. – Consultant 4 (ESD Consultant)

Some students wanted direction on what exactly they were supposed to calculate, failing to recognise that they needed to make decisions regarding their preliminary design before any calculations were required. Others knew what they were supposed to be undertaking but lacked the skills and understanding on where to begin. The experienced consultants were able to guide students through these initial steps and provide them with tools and knowledge on how to undertake a preliminary design. However, these delays slowed initial progress, impacting the development of solutions in later weeks.

Studio tutors and the client commented that the solutions which were implemented were *low hanging fruit solutions* which suited the brief but didn't necessarily offer any many innovative solutions. While some ideas were considered 'out of the box' by studio tutors, the client did not necessarily believe this was the case, finding suggested solutions to be *high level* but typical. From the responses, it almost appears that the client was seeking new technology never considered before, however this was never an expected outcome of the design studio. One consultant believed that the students had no major issue in creating design solutions but had a greater struggle in evaluating the solutions. This was an area in which the consultants excelled, as they are more familiar with comparing different solutions in a variety of environments.

You need to have a level of understanding of detail of each of the systems you are proposing so they can be ranked, and this was a challenging exercise. – Consultant 2 (Civil/Structural Consultant)

The students were also provided with an evaluation matrix, so they were better able to compare technologies. A general outline was provided, with the students having to develop the details of the matrix and determine what they believed to be an appropriate weighting system. Again, they consultants were a great benefit in this regard, as more detailed explanations of different industry metrics could be described (i.e. NABERS, Greenstar, etc.) which could be incorporated within this framework.

Several consultants identified the difficulties faced in working in groups. While all engineering (and architectural engineers) students work within groups in their respective degrees, they do not typically work in multi-disciplinary teams. This found some students struggling to *work in groups with people who have different mindsets, skills and goals*. While one studio tutor commented that they believed students did well in their groupwork, they were unsure if this was *real collaboration*, or rather students just completing *a parcel of work*. It would be greatly beneficial to know if students did truly benefit from the cross-discipline collaboration, though this is difficult to quantify.

Students were often found to be splitting work for assessments (which is typical) to complete everything on time. However, the work was often separated in a manner where solutions were determined individually based on student discipline, with everything being combined at the end. This process is counter-productive and did not align with the integrated design process. This often resulted in the consultants having open discussions with student groups about the bigger picture of design, to have them examine the problems from a wider perspective, rather than the narrow focus they are comfortable with. This was not always the observed case, with students being seen to collaborate, though this was mostly *in the first two thirds of the studio*. Once students were free from their group work, a decline was seen in the level of collaboration.

I didn't see them continue the collaboration beyond where they were required to work in groups – Studio Tutor 2

While the views relating to issues surrounding critical decision-making were varied, almost every interviewee reiterated that time was the greatest limitation on which decisions were made. Some interviewees offered possible solutions, such as *constraining the scope of the project that they are doing to allow them more time to explore within that*, however most just identified that *they didn't have enough time*.

13 weeks is not long enough for students to go through the integrated design process – Studio Tutor 2

4.2.5 Aesthetic and functional compromises

Most interviewees have a similar consensus, that the aesthetic aspects of the project were not as widely considered when compared to the technical, calculable aspects, especially during earlier stages of the design studios. Some of the consultants speculated on this, reasoning that it may be due to lack of familiarity, nature of the project (existing building), lack of specification from the client brief or time to complete the project.

I don't think we discussed aesthetics as all. Maybe because the Ribbonwood library already exists - there was never a suggestion of making it look better – Consultant 2 (Civil/Structural Consultant)

Initial design hesitancies of the students were witnessed by consultants in the earlier weeks of the IDS. These hesitations were overcome in time; however, it was time which could not be afforded. Initial delays in the project result in ideas left unexplored, and a less-detailed finalised design. A restricted timeframe lessens the potential for integrated design, ultimately leading to additional aesthetic or functional compromises. This is iterated by the consultants.

This was just a matter of time – if they had more time they could go a bit deeper in that, by the time they decided what they wanted to do it was almost too late to look at the aesthetics for the solution – Consultant 1 (Architecture Consultant)

If they had more time they could come up with more details for a better range of ideas. – Consultant 4 (ESD Consultant)

An extended project period may prove more beneficial and allow students more time to explore different solutions while delivering a more technical and detailed design. Additionally, students may be more familiar with the outline of the IDS, allowing for further outreach between students and consultants. While time may have impacted the student's investigation of building aesthetic, this does not necessarily mean that there was no assessment completed or that aesthetic was entirely neglected. One consultant sited one specific piece of work, where students completed a *really (good) visualisation of a brise soleil* which they believed to be *evocative,* providing insight and understanding to other students, giving them a better understanding of beneficial integrated design solutions, which may enhance the building aesthetic while also improving the functional thermal efficiency of the envelope.

I think the real benefit they got was the exposure to other people's thinking about the same challenge – Consultant 3 (ESD Consultant)

The outlined client brief focuses primarily on technical, active strategies rather than passive or aesthetic features. The reasoning for this was likely due to the bias of the client, who is familiar with HVAC systems, but also due to the building being scheduled for HVAC upgrades. While the client was *open to all ideas*, the lack of specificity surrounding passive or aesthetic design in the client brief resulted in many of these aspects being an afterthought rather than a point of primary focus.

A lot of what I was looking at was the air conditioning side of things or the lighting. – Client (WCC)

…there wasn't much guidance or constraints given to aesthetics, so the students didn't care for it – Consultant 3 (ESD Consultant)

Further clarification on the client brief will be beneficial in future projects, as the lack of defined aesthetic criteria inhibited integrated design. While the client brief may have lacked in diverse focus, the assessment criteria did not, which resulted in students evaluating various passive and active strategies using a decision matrix. Most interviewees gave a positive response on the effect of including a decision matrix, specifying that it gave students the opportunity to investigate a variety of different strategies (both passive and active), allowing for a wider scope of expertise, rather than just focusing on technical aspects.

The comparison matrix helped students look at all the aspects of the design and try to weigh up and balance these aspects… – Studio Tutor 1

The only drawback of the decision matrix was its focus on passive strategies, rather than the overall building aesthetic. While passive strategies do not necessarily conflict with the aesthetic, there is a lesser focus on how the building looks, with the primary concern being how the building acts.

It would be interesting to see if aesthetics was not considered as a category in the matrix assessment, I suspect that is wasn't. – Consultant 2 (Civil/Structural Consultant)

Overall, the students did consider the aesthetic of the building, though it was not a primary concern. A greater focus should be placed on this in the future, either through the client brief, or through the assessment criteria. If building aesthetic is considered as being less important, then it defeats the purpose of integrated design.

4.2.6 **Integrated design definitions**

Integrated design was typically described (by consultants, clients, and studio tutors alike) as the process whereby a multidisciplinary team collaboratively design together with a common philosophy surrounding the final design, as opposed to the typical individualistic design approach common in industry. The strengths of each discipline (and individual) are utilised to create a single, holistic design, building upon the ideas of one another rather than combining a series of successful ideas.

…no single discipline guides (integrated design) unless the brief requires it – it is unharnessed from any ownership by a single person, it is the outcome of the group – the collaborators. Good designers working together towards one solution. – Consultant 3 (ESD Consultant)

While these sentiments were echoed by all interviewees (though through slightly different wording), some specifically focussed on the details of the integrated design process, specifying that it is something which must be undertaken from day one, rather than being adapted part way through a project.

You can force and integrate services and disciplines, but it won't be an integrated design – this requires collaboration from the beginning and input from all people – Consultant 1 (Architecture Consultant)

…if you get everyone in the room together to start with and work together at the same time, you can potentially save time and energy. – Studio Tutor 2

While it may be argued that this idea is not necessarily true, and that integrated design can be undertaken at varying stages of a project, a holistic integrated design is not possible without multidisciplinary collaboration from a project's outset.

4.2.7 **Constraints impacting engagement and interdisciplinary collaboration**

The consensus of the interviewees is that one of the largest constraints impacting integrated design is project budget and time allocation.

There is a destructive logic in the construction industry that you can save money by doing things quickly and paying people less - but engineers and architects would all be of the opinion that if given more money and time, they would save more by giving a better and cleverer design. - Consultant 2 (Civil/Structural Consultant)

Industry appears to be driven by minimising capital cost, which ultimately leads to sufficient designs which meet requisite codes but are not the best possible design. It is clear that integrated design is desired by both architects and engineers, with evidence being seen *through things like the Architects Declare movement and the Engineers Declare movement*, where individuals are banding together to push for changes in industry to further enable integrated design. However, these aspirations do not necessarily align with the cost minimisation focus of some clients.

I tend to engage with consultants outside the projects – doing workshops that neither architects or engineers get paid for, but they learn to collaborate in early stages. Even if the client doesn't want to pay for it - we can then show the client what the benefit of this would be. Most of the time, the client wants to have the design for the DA without having to pay the consultant other than the minimum required. – Consultant 1 (Architecture Consultant)

Once the consultants and the money is committed, time then becomes an issue because the owner is not keen to wait – they want it documented and built straight away. – Consultant 3 (ESD Consultant)

While the desires of both architects and engineers may align in designing the best possible structure, both professions are ultimately subject to the wishes of the client. While the benefits of integrated design are clear, this is largely seen as an unnecessary expense to a client who is looking to maximise potential profits. Until this mentality shifts, integrated design will likely continue to be seen as unnecessary additional expense.

An additional aspect raised by multiple interviewees is ego. This comment was raised in passing in multiple interviews though was not discussed in depth.

There is a challenge with ego - really good collaborations happen when you can let go of ego. – Consultant 3 (ESD Consultant)

While some consultants directly specify ego as being an issue, other consultants imply that there are other issues relating to ego, a sense of self-worth, and a lack of appreciation for other disciplines. Some have also mentioned the *historic cultural angst between some engineering disciplines and some architects.* While most recognise existing discordance between the two specialisations and actively work to bridge these divides to benefit the construction industry, some still perceive the other as an opponent rather than another expert, neglecting that there is benefit in working together rather than competing to achieve your desired design. These perceptions exist within all architecture and engineering communities, whether it is during education or in industry, and is a perception which needs to be overcome to progress both fields for the benefit of all.

…this point of education is a great time to start addressing breaking down some of those stigmas that do exist between the disciplines – Studio Tutor 2

While this is not intended to create a divide, it is necessary for all consultants (engineers and architects alike) to reflect on their own preferences and identify the desires of others. This will likely require compromise, which is a necessary stage within integrated design, and a key part of the integrated design studios.

Being able to strike a compromise that meets everyone's objectives is the challenge. – Client (WCC)

4.2.8 **Value of experience of integrated design at university**

All interviewees agreed that the integrated design experience was very beneficial to students undertaking higher degree education. This sentiment was iterated across all interviews, with most elaborating that this experience offers something new to students, which is atypical in a traditional classroom setting.

I think that this was really good and useful, this is an amazing experience for the students – we pushed the boundaries in a completely different way that (no other) assignment at university would – Consultant 1 (Architecture Consultant)

As a real project it allowed students to get exposed to some of these tools – you can make mistakes now and get a lot of feedback now, rather when they start working – Studio Tutor 3

The design studios offer students the opportunity to work together in a multidisciplinary setting, in a supportive, learning environment. This exposes students to the varying strengths and weaknesses of other disciplines, while highlighting that collaboration can result in the best possible design through utilising the strengths of each individual team member, while also allowing them the opportunity to reflect on how a design offered by one designer may not be suitable for other design methodologies. This self-reflection is crucial when being a member of a team.

I think it is really important for students to go out into industry understanding that theirs is not going to be the only perspective, that they need to collaborate with people from different disciplines and they have to learn to communicate with people who don't have the same knowledge as them. – Studio Tutor 2

4.3 **Feedback from participating students**

Feedback from consenting students was obtained through conducting anonymised surveys which students could voluntarily complete. The students were asked in a series of question to rank their various experiences within the IDS and give written feedback in response to the following criteria:

- Understanding and experiences of environmental and sustainable design
- Factors impacting integrated design
- Information provided via the client brief
- Personal assessment of consultant involvement
- Balancing engineering and architectural priorities

Through evaluating the responses of the students, these factors can be assessed to determine if the student participants found the IDS's beneficial overall, what experiences were most beneficial, and if any aspects of the IDS should be adjusted to improve student interaction and engagement in the future. For a full breakdown of student responses, please see the Appendix C.

4.3.1 **Environmental and sustainable design**

The following responses relate to Questions 1, 2, 6 and 12 from the student survey found in the Appendix C

Of the students who participated in the survey, 29% had never (prior to the IDS) participated or experienced involvement in either environmental or sustainable design practices. Of the remaining respondents, 43% indicated being either slightly or somewhat familiar with environmental or sustainable design, with the remained being moderately familiar. These results indicate a uniform spread of familiarity throughout the participants, with no respondent being extremely familiar with the process. Due to the anonymisation of the survey, it cannot be determined if there are any commonalities between these participants (i.e. studying the same major, prior work experience etc.), possibly leading to either a higher or lower degree of experience.

Based on the experience gained within the IDS, students were asked to select which options they believed were key design-drivers affecting the success of environmental design, specifically relating to renewables and zero-carbon. The responses to each of these factors is broken down in Figure 6. Of the five options available, *"Software skills to simulate and analyse building performance"* was the most frequently selected response, with 86% of participants selecting this as one option. This selection indicates that respondents believe the knowledge and application of simulation based software is key in successfully delivering performance based sustainable design solutions within the built environment.

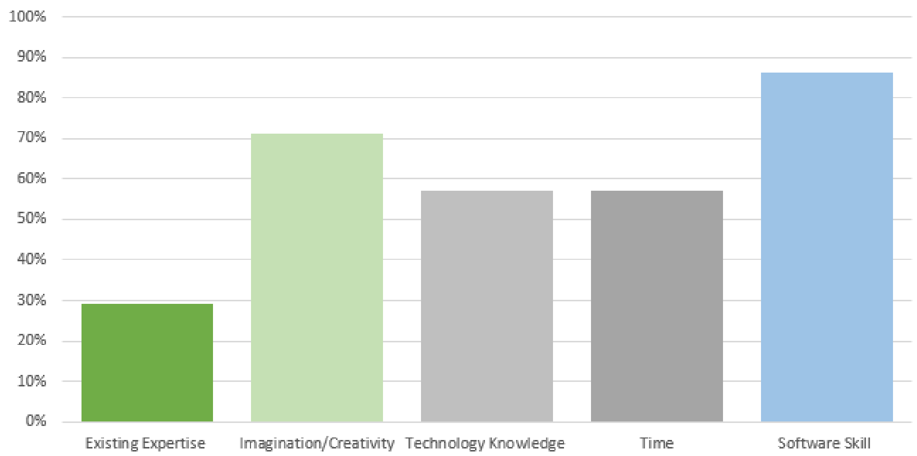

Figure 6: Simplified breakdown of student responses (Student Survey - Question 2)

Three other options (*"Imagination and creativity", "In depth knowledge of technology and collaboration"* and *"Time assigned to dialogue between Architects and Engineers"*) were also highly considered, with respondents selecting these options 71%, 57% and 57% respectively, implying that the respondents believe that these are also quite important factors. The most infrequent selection (selected by 29% of respondents) was *"Level of existing expertise of individual contributors"*. It can be inferred that most of the respondents do not consider a high level of prior experience is necessary to develop a successful environmental design.

Considering the limited experience in environmental and sustainable design among the cohort, it was of interest to gauge students' inspiration for design solutions. The knowledge for this undertaking was drawn from varying sources, with some students looking to design strategies such as *Passviehaus design principles* and *current architectural trends,* while others drew on established *energy reduction retrofit precedents.* These students showed initiative in conducting their own research, though other students used information and experience more readily available, drawing their inspiration from *discussions among team members and with the various consultants*. It is obvious that a variety of inspirational options are available to the students, though most sought it out for themselves through research, with only a single respondent indicated that the consultants were the key source of inspiration.

Following on from where inspiration was drawn from, the question was asked to ascertain where students had the greatest struggle in advancing the design. Multiple respondents believed that project constraints were some of the greatest limitations to advancing designs, but for different reasons. While imposing some constraints (i.e. minimising waste) was important to the client, participants found that this limited possible solutions, restricting innovative design possibilities. Others found that *a lack of practical experience* made it difficult to fully understand the implications of the constraints on the project as a whole.

Some found the limited understanding of other disciplines (*mechanical and architectural engineering*) *made design-oriented thinking extremely difficult*, believing that *prerequisite subjects or additional material/teachings* would help eliminate this. While this is likely true, it also defeats the purpose of integrated design, where designers from various disciplines discuss ideas and design together, relying on their own knowledge and trusting that their team understands their discipline specific competencies. Respondents also found it difficult to design given the lack of provided data (e.g. cost or technology performance data). While it is true that data was not readily provided, students had ample opportunity to search for data, and had opportunity to ask tutors and consultants advice on how to appropriately (and accurately) source data required. Having said this, it could also be a consideration in future IDS's to provide strategies to students about how to source data for use in practical projects being undertaken.

4.3.2 **Factors impacting integrated design**

The following responses relate to Questions 13, 14 and 15 from the student survey found in the Appendix C

In examining the collaboration between architects and engineers, students were asked which factors they found to be the biggest barriers or constraints which existed between the two disciplines outside of the design process. Interestingly, of the five options to choose from, the least important barrier was said to be *Inability to define joint goals*, with 0% of respondents selecting this as a factor. This indicates that the respondents believe that architects and engineers are very much capable of having joint goals which they can achieve together, rather than individualistic designs which conflict with one another. The respondent's 0% feedback specify that this is not seen a constraint or barrier restricting collaborative design.

Alternatively, 100% of respondents felt that *Knowledge gaps* were a key contributing constraint which most inhibits collaboration between architects and engineers. This highlights that having a basic level of other disciplines foundational knowledge is believed will improve interdisciplinary collaboration. This is not to suggest that integrated design does not or cannot work, though participants believe that knowledge gaps are a primary contributor in restricting non-design related collaboration. All options (and their participant responses) can be seen in more detail Figure 7.

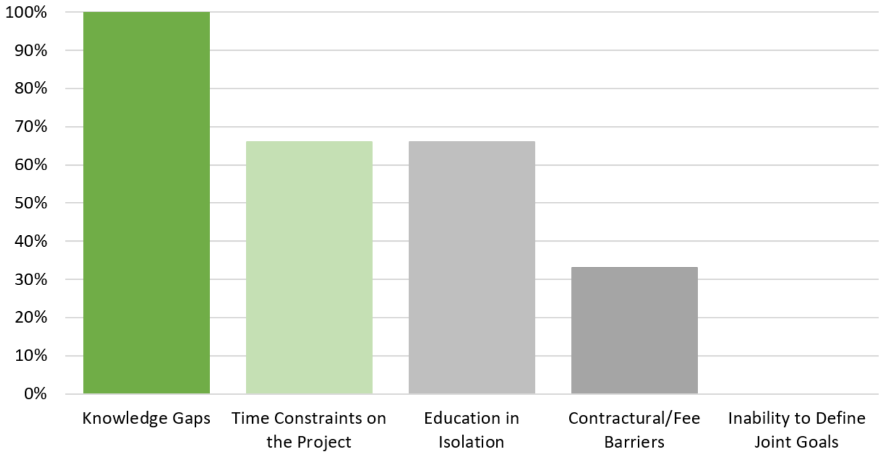

Figure 7: Simplified breakdown of student responses (Student Survey - Question 13)

Descriptions of the integrated design process found approximately 60% of respondents believing that *all disciplines working together to achieve a common goal*, resulting in a *more wholesome approach to design which removes the barriers between the two professions* (i.e. engineering and architecture). While most respondents believed that this generated better solutions in general, some believed that the solutions created through the integrated design approach focused specifically on *human comfort and sustainability*, which could *compromise the form of the building*. The reason for this this description is likely due to the desired outcomes of the client focusing primarily on comfort conditions and sustainable design.

When asked about whether the Integrated Design Studio was beneficial to the student participants, the response was overwhelmingly positive, with 83% of respondents finding the studio *very* or *extremely useful*. The remaining 17% of respondents found the experience *moderately useful* which can still be taken as a positive outcome. It can be said from these results that all respondents for the design studio found participation beneficial to their educational experience at university.

4.3.3 **The client brief**

The following responses relate to Questions 3 and 4 from the student survey found in the Appendix C

In response to the client feedback, all of the student respondents found that the information supported their ability to achieve a balanced engineering/architectural design. 57% of the respondents found the information *moderately supportive*, while the remaining 43% found the brief *very supportive*. These results were further supported by more detailed feedback, specifically that *the description of the client brief was well articulated* and that the *requirements of the building was clear.* In addition to the client brief itself, *the attached proposals and plans assisted with completing calculations*, and the *site visit and feedback provided from the staff were helpful*. Overall, the general response is that the client brief was helpful and outlined the requirements clearly. While the consensus of the client brief was positive, some specified that it was *moderately adequate* without providing further comment. One respondent did provide additional feedback regarding the client brief being *heavily focused on HVAC systems*, expressing a desire for the brief to be more holistic, and would have preferred to see it *extended to cover more aspects of the overall design*. This is a fair comment to make, as an integrated design should incorporate solutions from many different disciplines. If a brief is focused on solutions from one specific area, then the final solution may not be an integrated design at all.

4.3.4 **Personal assessment of consultant involvement**

The following responses relate to Questions 7, 8 and 9 from the student survey found in the Appendix C

The consultants involved in the IDS were there to support and guide the students in their design process, being able to give industry expertise relevant to the project. The guidance offered by the consultants varied, with the students being able to ask any questions throughout the IDS. When asked about which advice was most beneficial the each respondent, the feedback was varied, covering many aspects of the project, including (but not limited to):

- Software utility and feasibility
- Experiential design solutions
- Passive cooling strategies
- General mentoring
- Sourcing of reliable and relatable information
- Advise on benefits of passive vs. active strategies

While the responses of the students were largely varied, this indicates that students obtained a vast amount of knowledge and experience from their time spent with the consultants. This alone is indicative of the benefit in having access to consultants within an educational environment. Additionally, while the information provided by the consultants was diverse and informative, one student highlighted the benefit of open classroom discussion with the consultants, as *the problems/solutions that other students encountered was helpful for my own learning.* While the involvement of the consultants enhanced the experience within the classroom, these open discussions can be held without consultants and still offer potential benefits to the entire cohort.

The students were asked to expand on these aspects, and how consultant engagement could be improved to further enhance future participants experiences. These responses were more limited, with most respondents choosing not to respond, or specifying that *nothing* needed to be changed about the consultant involvement. The only feedback of note was regarding the individual designs undertaken by the students at the end of the design studio, with the respondent expressing a desire to *begin work on our individual design proposals earlier, allowing us to get more detailed information and ideas from the consultants.* It can be argued that this was still possible in a group environment. It has also been previously highlighted in Section 0 that participants did not fully utilise the consultants outside of the design studio environment (which was indicated to the participants on numerous occasions), so starting the individual design sooner would have resulted in a lesser focus on integrated design, and prioritised a more individualised design which is not the focus of the IDS.

A poll was provided to the respondents, to gauge the effect of the consultants on student learning, determining if an increase in understanding was noticed for environmental issues and associated solutions. All respondents gave positive feedback, stating that at least a *moderate* degree of support was experienced in improving understanding. Of the feedback received, 67% or respondents felt the consultants were either *very* or *extremely supportive* of improving the participants understanding of environmental issues and associated solutions. While it is difficult to measure qualitative responses, the feedback for questions 7, 8 and 9 all support that consultant involvement throughout the IDS was overwhelmingly positive, with all students benefiting from the expertise offered by industry professionals.

4.3.5 **Balancing engineering and architectural priorities**

The following responses relate to Questions 5, 10 and 11 from the student survey found in the Appendix C

Environmental and sustainable design solutions are imperative in the design process for both engineers and architects. Students were asked to elaborate on this, expressing what they believed to be the most critical decision-making points/questions when balancing engineering and architectural solutions. Though the wording of the responses differed, many defined the most difficult problem to be determining a solution which *balances cost, aesthetics, practicality, efficiency and effectiveness.* 40% of respondents identified these criteria directly, while another 40% identified these criteria indirectly (i.e. though different wording or summarising of information).

Some participants approached this problem by weighing up the *rate of return on carbon emissions*, determining either active or passive strategies which address the client brief while also considering carbon cost and offset period. Other groups approached this from a different perspective, firstly identifying *which system was most lacking*, followed by determining *which retrofit will bring the most significant impact.*

While most respondents outlined specific metrics they associate with *critical decision-making points*, only one respondent ignored all the available metrics, outlining that (for them) the most critical point was to *determine the problems faced by the client in the building, and what they expected us to do during the rectification process.* While the client may have outlined certain limitations (e.g. cost), for this respondent the most important aspect was to determine a solution which best addresses the issues being faced by the client.

From polling, it was found that 50% of respondents believed that either building aesthetic or functional design aspects were moderately compromised while trying to address the architectural or engineering concerns of the client. 33% of the respondents believe that there was only a slight compromise made, with the remaining 17% believing that there was no compromise made to either aesthetic or functional design aspects. While it is hardly unanimous, the majority of respondents agree that there is at least some degree of compromise required to achieve an integrated design solution. It is surprising that 17% found there to be no compromise. It may be that these respondents were able to implement all their own recommended design solutions (neglecting the desires of others), or every member of their group was able to without any compromise being necessary. This does seem unlikely, but not impossible. With the architectural and engineering aspects being closely interlinked, it would be expected that there is some degree of compromise within the project, but this may not always necessarily be true.

Additional feedback reveals that while compromise was required, some believe that this can be avoided through implementing *imaginative and innovative* strategies, as well as considering how implemented strategies will behave in the future. An example was provided by one respondent, highlighting how a green wall may be considered as aesthetic initially, however without adequate maintenance, it may become unmanageable and compromise the aesthetic of the building. This is rather insightful, and consideration should be made regarding the perceptions and longevity of the implemented strategies.

4.4 Summary

It is difficult to measure the effect of the Integrated Design Studio, especially with a lack of quantitative data. However, based on the information outlined from the studio observations, client, consultant and tutor interviews, and survey feedback from studio participants, it can be generally stated that the Integrated Design Studios were successful on a number of qualitative merits. Studio observations identified positive aspects contributing to the integrated design process, while also determining limitations which may inhibit integrated design. Some strategies were recommended on how these limitations may be overcome. Consultants identified a number of areas in which the studio may be improved, but agreed that integrated design is greatly beneficial, especially in regard to the additional skills and knowledge provided to participating students. Student survey responses were generally positive for the design studios, with the most beneficial aspect of the studio being the involvement of industry professionals. The student respondents appear to agree that the design studios overall were beneficial to their studies.

5 STUDIO OUTPUTS – SELECT STUDENT EXAMPLES

The following section summarises the design solutions identified by students participating in the design studios. The designs outlined within this section represent the culmination of solutions for the students who consented for their work to be included within this report. This does not reflect all the solutions examined by the whole cohort of students. For a summary of all reports assessed for this project, please see Appendix A.

5.1. Passive Design Measures

While not a primary focus specified in the client brief, the participants were encouraged to investigate passive design strategies to implement as part of the Ribbonwood retrofit. These strategies were required to be in keeping with the general requirements of the client brief, while also addressing the requirements of the assessment, and keep embodied CO_2, energy saving potential, cost and feasibility in mind. The passive measures investigated encompass a wide range of strategies, examining many different aspects associated with the building envelope.

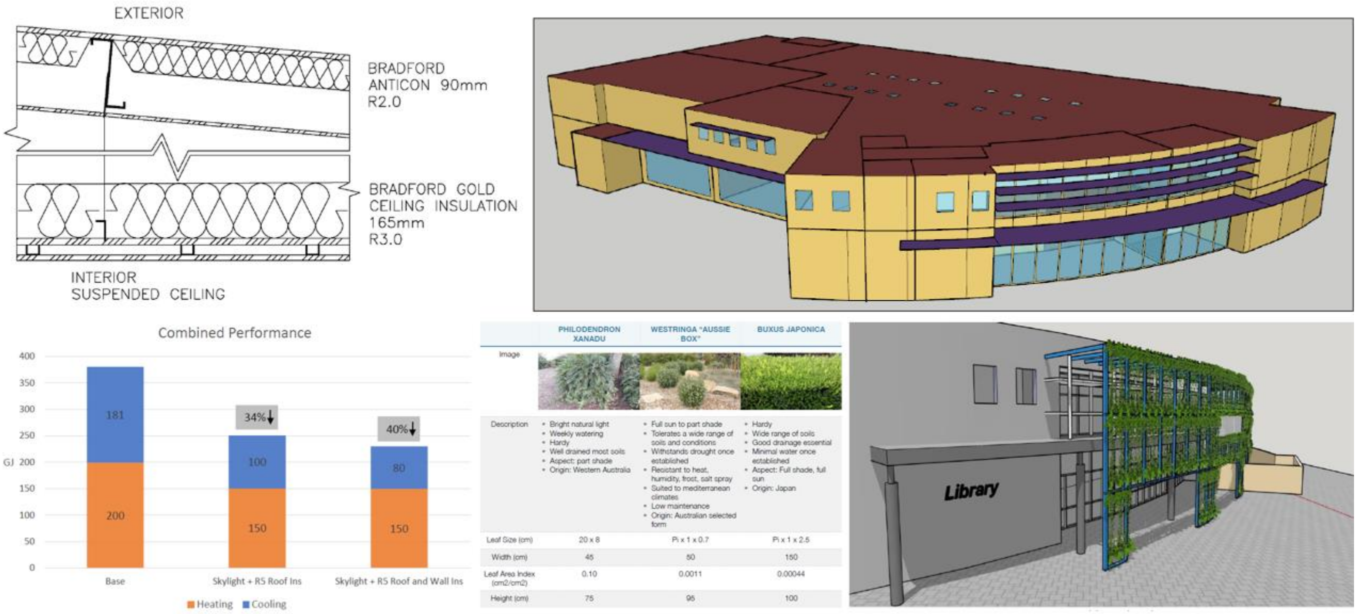

Figure 8: Passive design strategies - Extracts from student submissions

The following examples were proposed across the student reports, with some examples highlighted in Figure 8. **Note:** Not all of these initiatives were investigated in detail, though all were considered at least on a preliminary basis via the selection matrix.

- Improved glazing (e.g. double glazing) to reduce thermal gains
- Window film to reduce solar gains
- Additional window mesh to reduce solar gains
- Additional insulative materials within the building envelope (e.g. walls, roofs, etc.)
- Improved natural lighting
- Passive shading (e.g. addition of louvers)
- Green walls/Green façade
- Improved airtightness to minimise air-changes

5.2 Active Design Measures

The client brief outlined a greater focus on active strategies, with a specific focus on HVAC. For many students, these were unfamiliar topics, with a majority tending to favour passive strategy implementation rather than active strategies. Nevertheless, some students investigated a variety of active options, with some of these being selected as final design solutions.

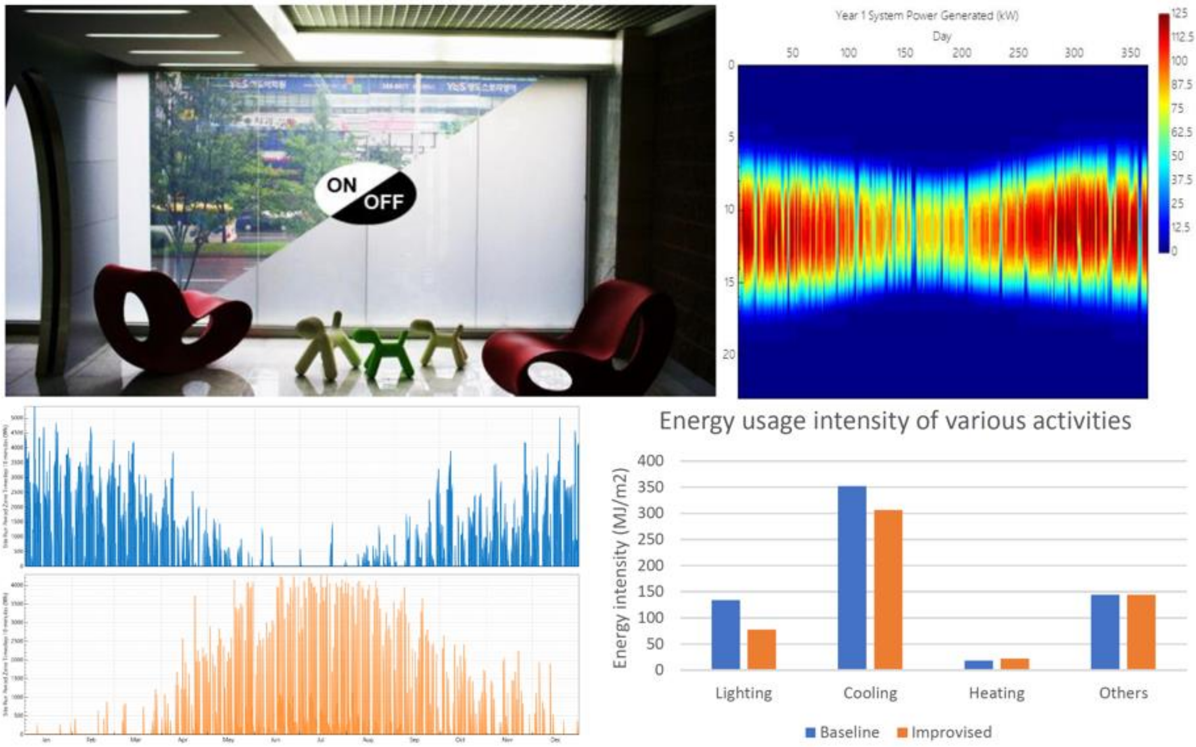

Figure 9: Active design strategies and simulations - Extracts from student work

The following examples were proposed across the student reports, with some examples highlighted in Figure 9. **Note:** Not all of these initiatives were investigated in detail, though all were considered at least on a preliminary basis via the selection matrix.

- Reduce lighting energy consumption (e.g. install LED's)
- Increased size of active PV system
- PDLC window film (activated via electric current)
- Installation of a buffer tank to regulate internal comfort conditions
- Phase Change Materials (i.e. thermal battery)
- Solar Heating
- PV windows (windows with embedded PV panels which permit light intrusion)
- HVAC upgrades

5.3 Hybrid Design Measures

While many of the design solutions fall into either the category of passive or active, there were some which suit more in a hybridized category. These strategies are outlined below, with examples of these strategies in-situ shown in Figure 10. These strategies are:

- Increased solar footprint / site accessibility improvements
- Increased solar footprint / vehicle shade structures

Figure 10: Hybrid design strategies - Extracts from student work

These design strategies both impact the users of the building (i.e. the community – the client requested exploring improvements in relation to making the building more accessible to the public), while not having a direct impact on the structure itself. The implementation of an accessible ramp improves structural access, benefiting those with mobility issues while also increasing the shaded footprint of the site so additional PV systems may be installed (see Figure 10 – left). Similarly, the vehicle shade structures offer limited protection to vehicles from the environment, but again also increase the shaded footprint of the site for additional PV system installation while enabling the charging options for electric vehicles (EV) in the near future. While neither strategy offers a passive or active strategy impacting the Indoor Environmental Quality (IEQ) of the internal spaces, they do offer benefits to the community, and increase the solar generation of the Ribbonwood grid.

6 SUMMARY OF CONSULTANT VETTING

The individual design reports of consenting participants have been further assessed by the consultants, where the merit and efficacy of key design solutions have been examined and compared against a business-as-usual baseline. These design solutions have been categorised as either passive or active measures, with the various strategies having been compared though the vetting report. The following sections outline summarised information from the vetting report, highlighting key strategies which were examined by both students and consultants. The complete vetting report can be found as an appendix to this document (Appendix E)

6.1 Existing Opportunities

Due to the building in question already existing, the number of potential opportunities is more limited than for a new building. Nevertheless, a large number of potential opportunities still exist which are able to be explored. The consultants identified the key opportunities outlined by the students, before identifying their own additional strategies which could be explored to incorporate within the building envelope, as seen in Figure 11.

Student Ideas
Façade Improvement
Window Replacement – DGU
Window Replacement – Low-E Coating
Window Replacement – Non-metal frame
Install Venetian Blinds
Tinted Windows
Smart Window Film
Increase Wall Insulation
Increase Roof Insulation
Incorporate additional shading
Window mesh treatment to redirect light
Improving building air sealing
Services Improvement
Upgrade lighting system
Rooftop Solar
Solar Water Heating
Upgrade HVAC system through audit
BMCS-controlled Natural ventilation
Innovations / Other
Phase Change Materials
Install Trellis to provide shading

Additional Ideas Explored
Façade Improvement
Automated blinds
Replace and upgrade window/door seals
Services Improvement
Lighting Control sequence
Re-arrange mechanical systems to provide appropriate zoning
Battery Storage for excess PV production
Occupancy detection
Daylight Dimming
Sub-metering, analytics and management
Relaxed setpoints
Adaptive comfort through ceiling fans, HVLS
EC Plug fans
Energy Recovery Ventilators
Night Purge
Remove hot water from amenities taps
Replace gas with Electric systems
Replace cooling plant with synthetic low GWP refrigerant

Figure 11: Student and consultant design solutions - Excerpt from vetting report

Between the students and consultants, a substantial number of design solutions were considered to improve the energy performance of the Ribbonwood Community Centre. Of these potential solutions, the consultants highlighted five systems which would likely offer the greatest benefit, having been implemented within numerous past projects, and given they are readily available commercial solutions. These solutions were:

- Optimised passive solar principles
- High performance façade
- Heat recovery ventilation
- Operational improvements
- Additional PV

6.2 **Improvements vs. Business As Usual (BAU)**

Given the initial building typology and state of existing systems, a business-as-usual case was developed to establish a building baseline from which improvements could be implemented. These improvements (specified in Section 6.1) are generalised, and encompass multiple solutions specified in Figure 11. For example, high performance façade can refer to changes to the building fabric, while also referring to changes made to the glazing. The following is a more detailed overview of these solutions.

Passive Solar Principles

To reduce thermal gains, any reduction in direct solar irradiance will impact the energy consumption of the building to offset these gains. To reduce solar gains, shading will be added to the structure's exterior and interior. Exterior shading elements will shield glazing during the hotter summer months, while allow for solar intrusion in the cooler winter months, to reduce the heating requirements. Interior blinds will assist with this strategy, particularly in warmer months.

High-Performance Façade

Improvements can be made to the existing building envelope through upgrading/installing insulation within the walls and roof. Upgrades can also be made to the glazing, through additional glazing layers and improved window seals, with glazing coatings and alternate window frames also being considered. Additionally, airtightness can be examined, with air-leaks being eliminated to reduce the number of unwanted air-changes.

Heat Recovery

To mitigate energy losses, a heat recovery system can be installed. This system is recommended to be installed on all mechanical air systems which process >500L/s.

Operational Improvements

Operational improvements encompass many of the operational systems typically working throughout the day. These may include hot water systems, artificial lighting, HVAC systems, etc. To reduce the operational energy of these systems, multiple strategies can be implemented, including:

- Relaxing temperature set points while maintaining internal comfort conditions
- Reducing hot water usage through restricting hot water flow, or through eliminating hot water to public areas.
- Adaptive light diming throughout the day
- Occupancy detection to disable systems in zones not currently in use

Additionally, maintenance, commissioning, and cleaning of existing HVAC systems will improve operational efficiency and reduce overall energy usage.

Additional PV

Through adapting student designed shade structures for car parks and accessible ramps, there can be an increase in shaded footprint, allowing for an increased number of PV systems to be installed. These additional PV systems allow for energy to be offset from existing active systems.

6.3 Key Findings

The strategies outlined by the consultants show that through a combination of commercially available solutions, energy reductions of between 25%-30% are possible (as seen in Figure 12) without any structural alterations. This is in keeping with the requirements specified in the client brief. These strategies also appear to be cost effective, and mitigate any large capital costs associated with replacing a HVAC system.

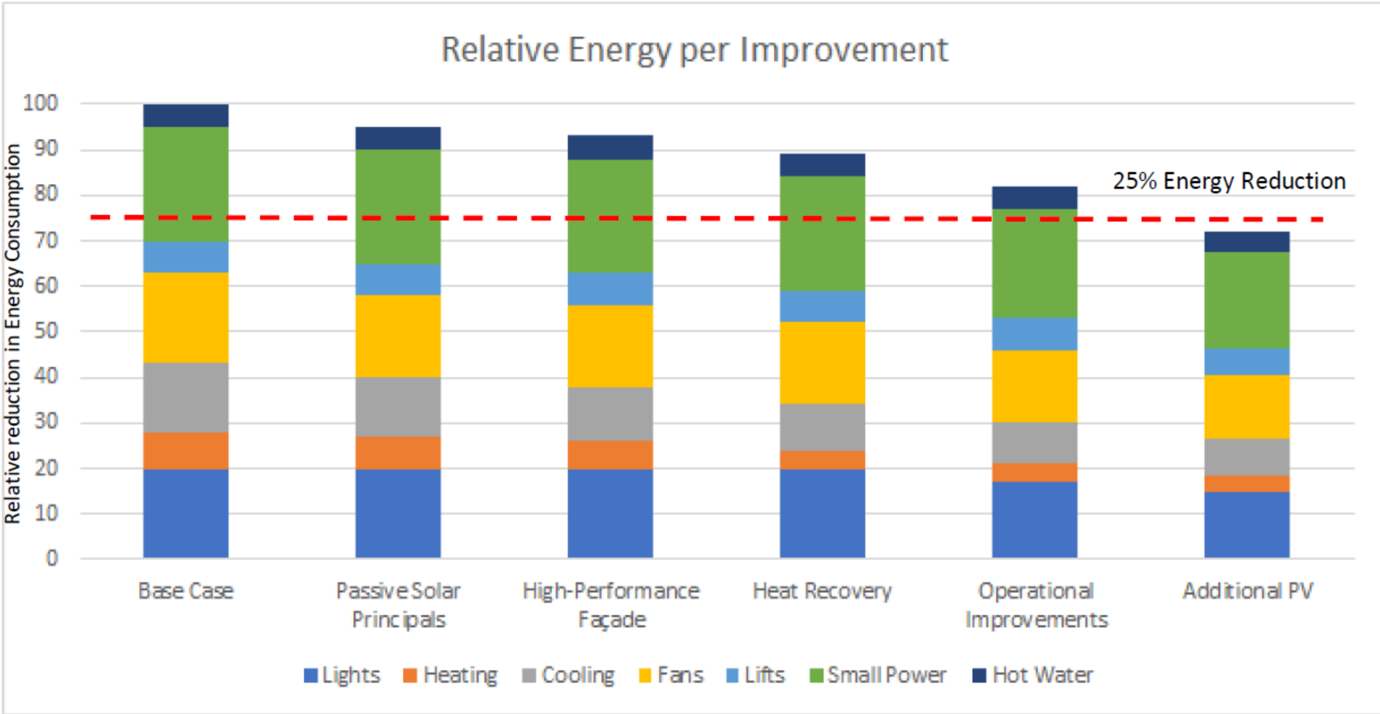

Figure 12: Relative energy improvement per strategy - Excerpt from vetting report

It can be concluded that for existing community buildings, significant reductions in energy consumption are possible without substantial structural changes be made to the buildings. It is also clear that some factors have greater impacts than others, however all strategies investigated make a difference to energy consumption. Retrofitting commercially available products is a viable way to reduce the overall energy consumption of larger existing structures and improve their IEQ without the need for a full refurbishment or redevelopment.

7 CONCLUSIONS

It is clear that the WCC Ribbonwood Community Centre IDS is considered to have been a great success. Considering that the project was conducted throughout the advent of Covid 19, limiting the interaction between project participants, the IDS was still considered to be a major success from many of participants involved.

Progress of the studio was observed by the IDS research team over the course of the 13-week period, noting the development of the students and their respective designs. A well-defined framework of the integrated design process was found to be essential, guiding the student designers in advancing their respective designs. Concurrent collaborative design empowered students to consider solutions outside of their own specialisations, making them more aware of the requirements of other designers. These designs benefitted from feedback provided by all participants in the design studios, whether it be consultants, clients, studio tutors, or even from comments raised by peers. These discussions were undertaking in a supportive environment, assisting students in improving their own skills through the receipt of constructive feedback both with regard to their own design, but also through witnessing the feedback received by other student teams. These feedback mechanisms became more prevalent once initial communication hesitancies were overcome.

The findings during the studio have identified interesting perceptions between the architecture and engineering related students and consultants. However, the benefits of the collaborative integrated design have become obvious to all involved in this integrated design studio. The outputs produced by students represent a vast array of possible solutions to implement on within the building, assessing both passive and active design strategies whilst also considering the function of the space and improving building operations. Some student designs were innovative, warranting specific mention by the consultants within the vetting report, whilst most of the designs investigated by students reflected the recommendations of the consultants to reduce Ribbonwood's net energy usage.

The positive feedback received from the client, consultants, studio tutors and students alike strongly support future integrated design endeavours within tertiary education to provide students with experiences which will benefit them in their future careers.

APPENDIX A – SELECTED STUDENT WORK

UNIVERSITY OF WOLLONGONG

ENGG947 (S121) Advanced Building Design for Energy Efficiency and Sustainability

Final Design Report

AUTUMN SESSION, 2021

June 4, 2021

EXECUTIVE SUMMARY

The main objective of the report is to understand the concept of green façade or the trellis on a building. The Dapto Ribbonwood centre is the building that needs to be retrofitted by giving a green star rating and have a net zero carbon according to the Austrian standards. Throughout the report the design model has been created using the SketchUp and the simulation has been done using the openstudio. The main area of focus is in the main entrance area of the building where the temperature rise is high, and the cooling load needed in that area is high thus consuming high electricity. The proposed design idea is a green façade or a trellis system at the front of the building covering the whole glass windows of the building. Comparative study has been done to find the temperature difference in the building before and after the installation of the façade. From the simulation results it has been noted that the temperature shows a significant drop when the façade has been placed and the internal cooling load can be reduced to a greater extent. At the appendix a hybrid design solution has also been proposed because the simulation of the hybrid require a lot of time than the given time frame of submission and has limitation in the openstudio software of running the simulation. But the idea shown in the appendix is considered the best solution and throughout the report a part of idea was simulated and compared.

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LIST OF FIGURES

INTRODUCTION

The aim of the report is to modify the existing Dapto Ribbonwood building into an eco-friendlier building to attain the green star rating according to the Austrian standards. The Dapto Ribbonwood building was commissioned in 2000 with one library, two large halls small five rooms and two office spaces. The location of the building is Princess highway in Dapto. The usual office hours from 9 am to 5 pm from Monday to Friday. Due to the current COVID-19 situation the seating capacity is restricted by the NSW policies. The Number of visitors is increasing from each year when we examine the data from the Corrimal library. A decrease in the usage of the building has been found in the past year from 2019-2021 due to the restriction from the NSW government due to the COVID-19.

Several issues have been raised from the building due to the improper designing of the building from the initial. Some of the important issue found that needs immediate solutions are the excessive heating in the building and the excess consumption of the electricity that comes after that. A huge design flaw leads to this key issue in the building. A viable and time-consuming solution must be made to resolve the present situation. Another key issue is the improper installation of the air vents in the building. This leads to the facts that all the regions are not maintained in an ambient temperature for the users while they are in the building. Another major concern is the using of the aged lighting system in the building, the lighting system in the building is outdated and they consume more energy and produce a large amount of heat in the building which accounts for excessive use of the HVAC system thereby the electricity consumption is increased. One of the daily visitors in the building has added an issue about the accessibility of the elderly people. The elderly people in the wheelchair have no easy accessibility in the building in case of an emergency they must depend on others or their own safety. The issue raised by the Wollongong city council is that the need to replacement of the existing screw chiller which has less acoustic property making disturbance for the people in the library. This are some of the main issues that needs to do quickly.

When considering the electricity consumption in the building the data from the Corrimal library was clearly giving the idea how the consumption over the year from 2013 to 2021. The data reviles that from the period 2013 to 2017 the electricity consumption is increasing and from the period 2017 to 2019 the data shows a decrease in the value due to the installation of the solar panels from the roof tops of the building. When going through the data from the period

2019 to 2021 there has been huge decline in the consumption due to the COVID restriction and the number of users has been decreased. The Figure 1 shows the graphical representation of the electricity consumption.

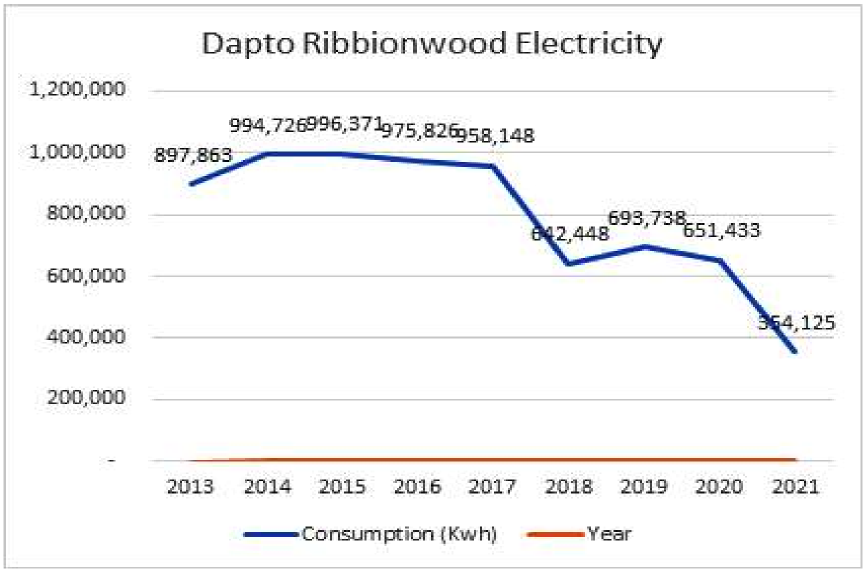


Figure 1: Electricity consumption from 2013-2021

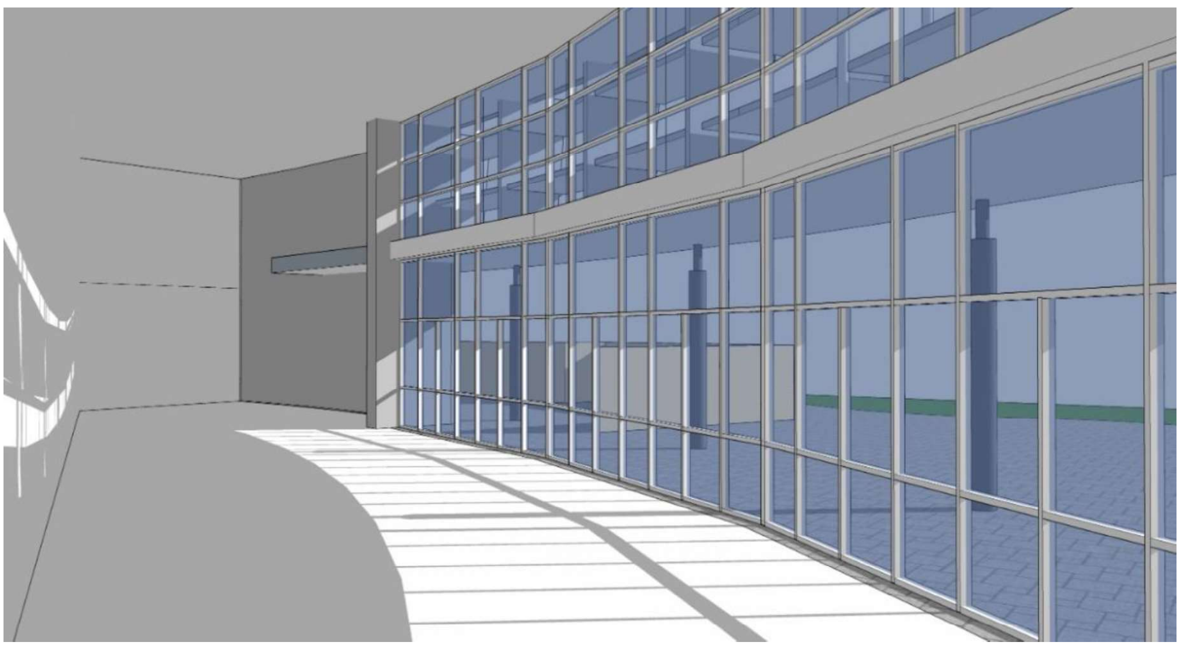
DESIGN SOLUTION

The design solution can be identified as passive measures and active measures. The difference between active and passive is that the active solutions are the one that has to do with the electrical equipment's in the building such as lighting system, HVAC system and so on. While the passive measures are the one which has the impact on the non-electrical equipment's that can contribute to the design solution such as windows, walls, ceilings, etc. The main idea behind the retrofitting of the building is to develop a building model that can produce a sustainable building which can give a net zero carbon energy. The net zero carbon design should be done so that the green star rating of the building can be attained according to the Australian standards.

The proposed design plan is from the passive measure giving the importance to the front glass area of the building where the heat generation is high and can't be controlled by the exciting condition. An adaptive, time consuming and cost-efficient method has been proposed. The trellis or a green façade has been constructed in the design idea so that the amount of direct UV radiation into the building at the front face of the building is reduced. This compliments with the idea of the green star rating and the net zero carbon design of the

building. Installing the green façade won't affect the exciting building structure as the idea is to construct a metal frame in the building and growing the green plants on the frame to block the incoming UV radiation from the outside and less direct sunlight hits the inside of the building. This decreases the amount of temperature gain inside the building and thereby the amount of cooling required from the HVAC system can be reduced. The cooling load required when the green façade will be less, and the electricity consumption can be reduced.

The Figure 2 shows the amount of direct UV radiation or the amount of direct sunlight coming into the main entrance of the building. This area is the main concern in the proposed design idea. When the green façade is installed in the building the amount of UV radiation hitting



inside the building is reduced show in the Figure 3.

Figure 2: UV radiation inside before trellis

The Figure 2 and Figure 3 were produced from the SketchUp software to simulate the difference between the shading in the main entrance area before and after the installation of the trellis or the green façade. The figure 3 clearly depicts that the internal UV radiation is reduced to almost more than half of the intensity than before. This method is cost efficient and eco-friendly. Also, the trellis can be more time consuming to construct and almost zero waste is produced.

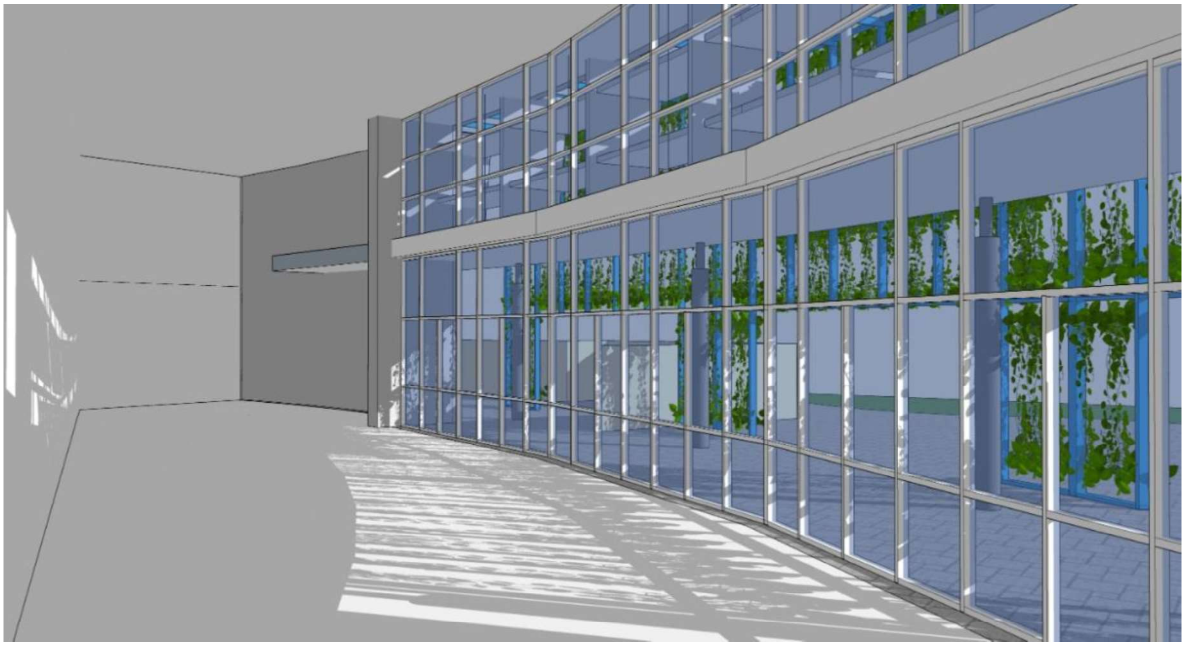


Figure 3: UV radiation after installation of trellis

METHODOLOGY

The methodology used for the proposed idea was modelling the exciting Dapto ribbonwood centre using the available plan from the Corrimal library. The model was made with the help of SketchUp and Openstudio. The SketchUp was used to model the existing building and the simulation on the data were done with the help of openstudio. The openstudio has the capability to calculate different parameters of the building using the given inputs. The calculation of the cooling load, heating load generated, the temperature inside and outside the building etc. can be obtained by using the openstudio. For the openstudio the weather data must be given, the data from Nowra has been inputted for the simulation process. The weather data is provided by the energyplus website for the simulation. The SketchUp model before the installation of the metal frame with green façade and after has been shown in figure 4 and 5.

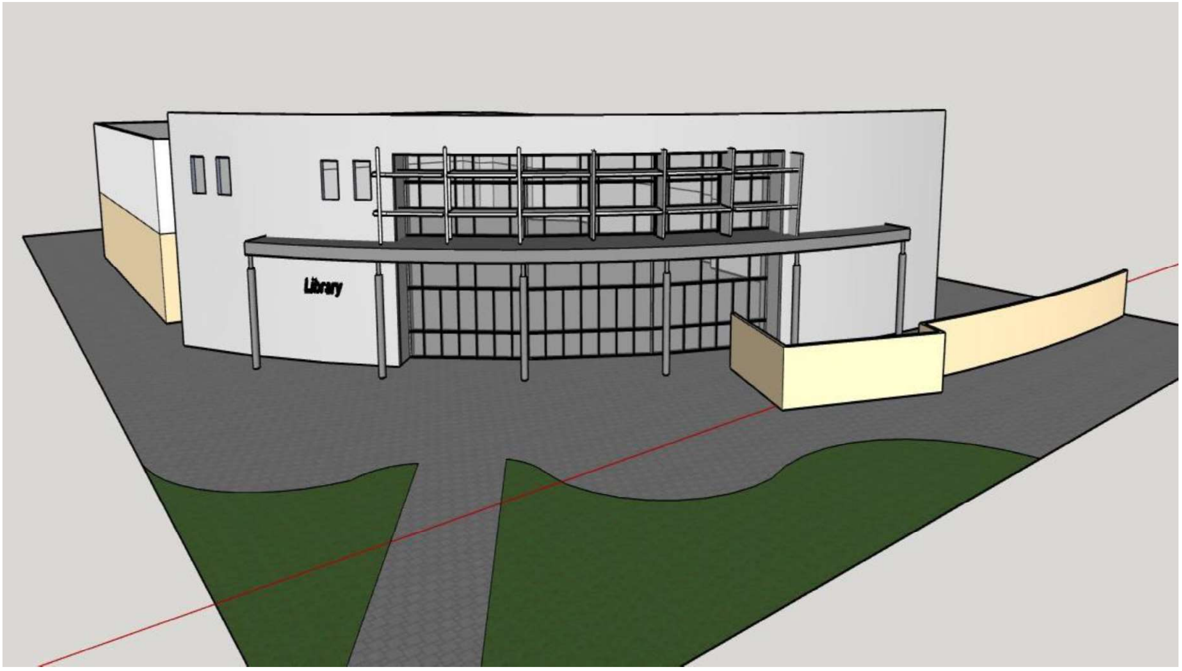


Figure 4: SketchUp model of existing building

Figure 5 shows the installation of the metal frame to the building creating a façade to the glass window at the front. As the figure represents it's easy to retrofit into the building with less time and cost-efficient method. In this model the metal frame can hold not just the vegetation, but some different ideas can also be implemented like using of the terracotta tiles.

Figure 5: SketchUp model of proposed design idea of metal frame

For the purpose of simulation, the proposed idea is to use the vegetation on metal frame so that it has ascetic appearance and provide eco-friendly environment. The simulation is done on the openstudio using the green wall as the green façade for the simplification.

Figure 6: Proposed design idea front view

Figure 7: Proposed design idea side view

RESULTS

The model has been created using the SketchUp software and the simulation has been done on the openstudio. The comparison between the model before and after the simulation has been shown in the result.

SKETCHUP MODEL:

The SketchUp model has been created using different tools in the software. Initially the plan has been imported and the plan has been scaled to the required level. Using the scaled line, the whole base of the plan has been created. The produced base figure is then saved in the openstudio, and the floor height and number of floors has been given then the model is completed according to the aesthetic view. Two models have been made in the SketchUp to compare the temperature difference in the main area of the building.

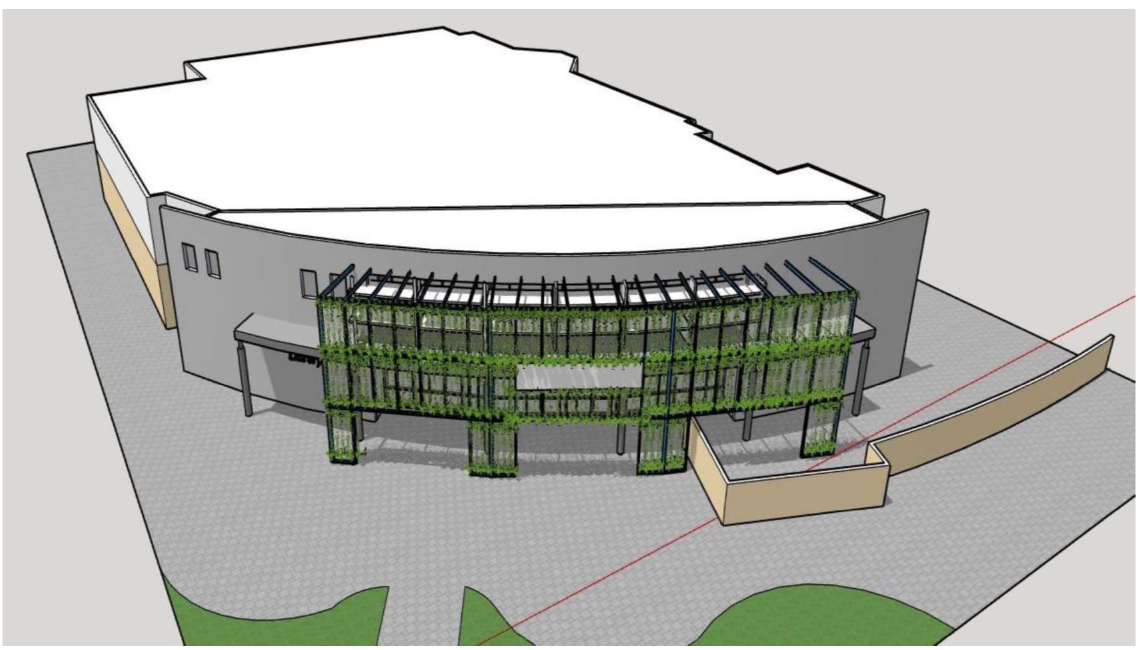


Figure 8: SketchUp model

OPENSTUDIO SIMULATION

The model from the SketchUp is then processed in the openstudio for the simulation. The weather data as to be given and the weather from Nowra has been set for the simulation purpose. The weather data is available from the energyplus website. Different areas of the building are assigned with the material property from the library of the openstudio. Some of the data for the simulation was not available from the library so these data are downloaded from the https://bcl.nrel.gov/ the comments required for the simulation were available on the website. The green vegetation was not directly available in the openstudio so a green wall with light transmission rate of 0.74 was used and the component was sgl3mm. This green screen act as the green façade for the building for the simulation. After inputting the required data and components to the openstudio simulation was run and the following results for the temperature was identified for the zone 1 and zone 2. The upper level was assigned zone 1 and lower level was assigned zone 2. For finding out the temperature difference before and after the installation of the green façade.

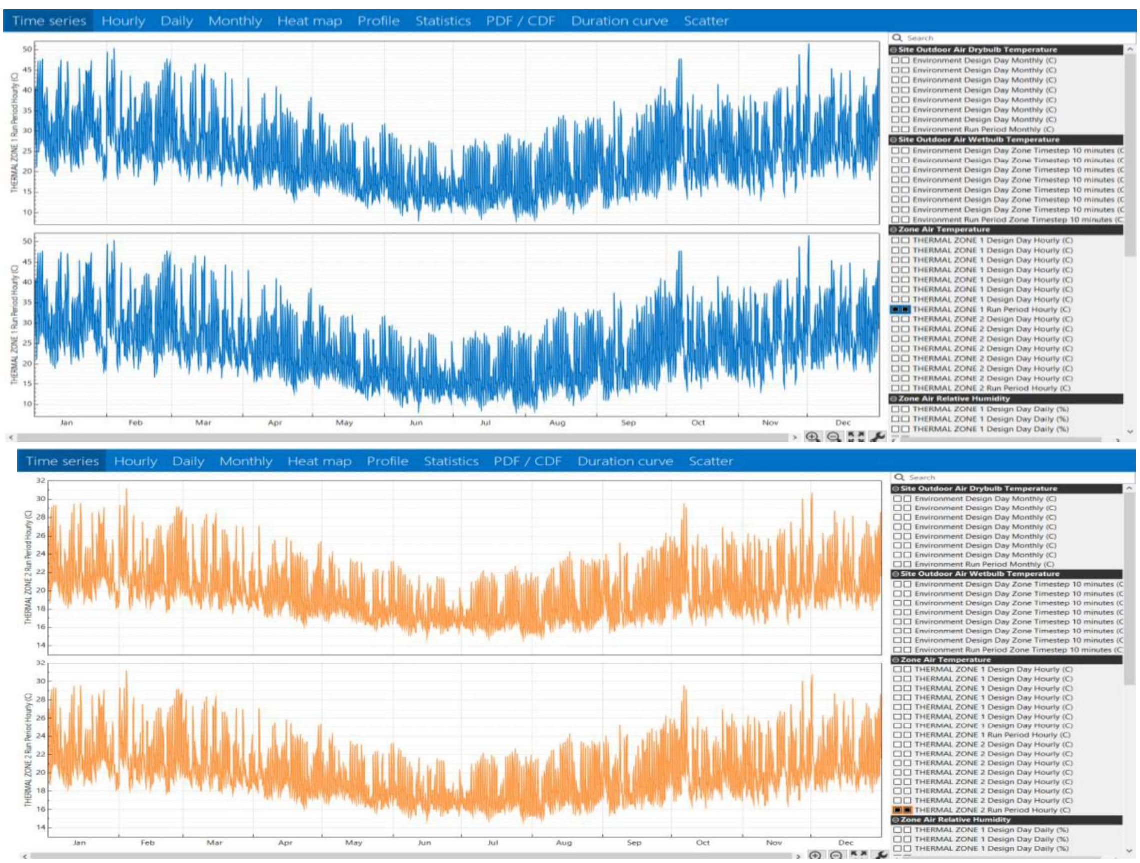


Figure 9: Simulated temperature graph result before facade

Figure 9 shows the graph of the temperature formed in the building before the green façade was installed. We can see that in the first graph it gives the data for zone 1 where the maximum attained temperature was 50°C and for the zone 2 the maximum temperature of the inside area was 32°C. This simulation was done before the façade and when no cooling temperature load was given inside the building simulation.

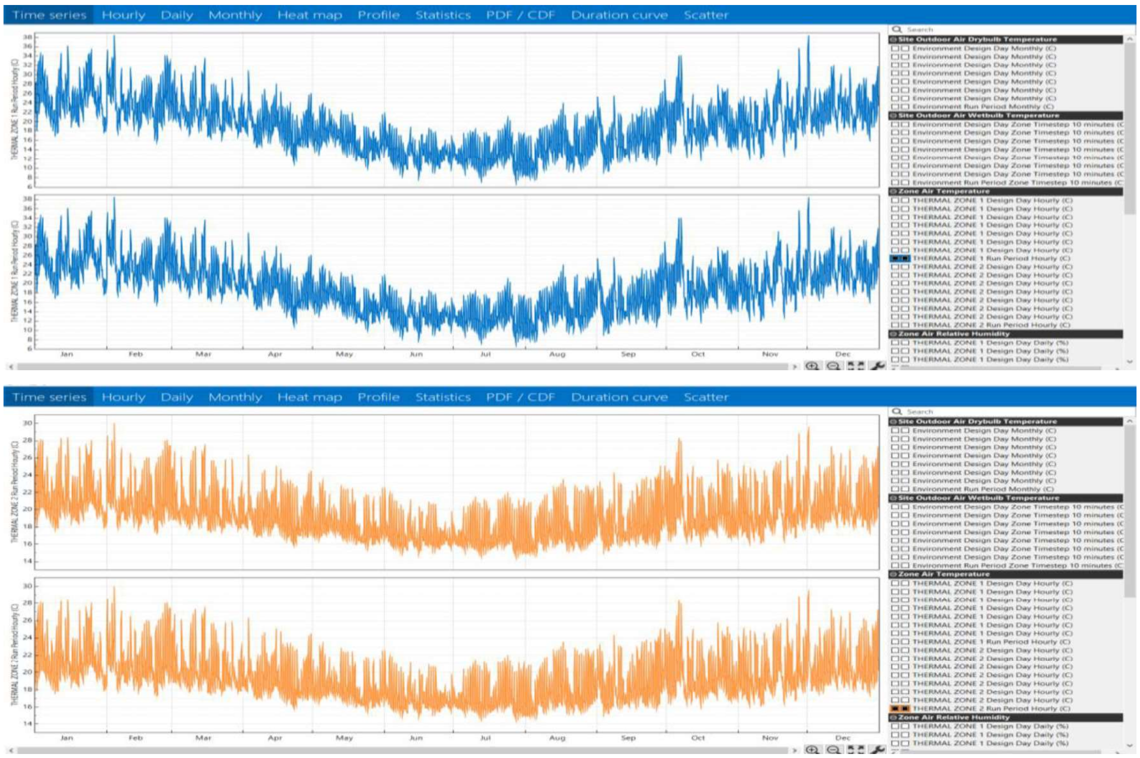


Figure 10: Simulated temperature graph after facade

Figure 10 shows the simulation graph after the façade was installed. The simulated result shows that when the green façade was placed the temperature of the zone 1 was decreased to 38°C and for the zone 2 the temperature was decreased to 29°C. The simulation was done at no cooling load and the resultant value was obtained.

From the comparison of both the graphs it's clear that the green façade or the trellis can provide a temperature control in the front area of the building. The above results were obtained with zero cooling load on the interior of the building so that this temperature has only to be cooled for the HVAC system in the building. So, the consumption of the electricity in the building can be reduced to a greater extent.

DISCUSSION AND CONCLUSION

The proposed idea of installing a green façade to the building with an external metal frame attached to the front side of the building covering the glass windows can decrease the temperature inside the front area of the building. The simulation has been done to demonstrate the temperature difference of two cases. These data may not be accurate but can be used for understanding the importance of giving the green shading at the building which helps to provide greenify view and reduces the amount direct sunlight inside the building so that the temperature accumulated will be deceased.

The main factors of setting this layout to the building is that its cost efficient and easy to install. The time is also a factor while doing a retrofitting in a building so this idea takes less time and has more potential in temperature control. The proposed idea has net zero carbon effect on the atmosphere and helps to attain the green star rating for the building. No demolishing of the exciting building or new infrastructure changes must be made in the building. aesthetic view when the green plants grown will be impeccable.

The only negative side that can be explained for this green façade can be the trimming of the plants in the trellis and maintenance of the trellis. But this is just a small amount of work of the daily cleaners in the building. While considering the purpose the trellis severs to the building the maintenance job can be compromised.

Some of the other plans that can be used in same metal frame is that terracotta tiles can be added so that the terracotta property can be utilised properly. A hybrid design of terracotta tile and green vegetation was the initial idea but due to the limitation in simulation of the materials the report was narrow down to just green façade. The terracotta has a property of maintaining an ambient temperature in any season. So, when using a small hole design in the terracotta tile the hot air from the surrounding when passed through the small hole the air cools down and hit the glass window a cool downed air making the inside temperature low. The small hole design is called the *Jali* system, and the terracotta made from the pure earth sand makes the air cooler. The hybrid *Jali* system with terracotta tile and vegetation makes the air around the glass window cooler and will create an ambient temperature inside the building. The detailed idea of this system in shown in appendix.

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APPENDIX

The hybrid system was the main idea for the Dapto Ribbonwood centre but due to the limitation on the simulation software the vegetation only has to be used. The terracotta is made of sand from that has a property of maintaining the air around it in an ambient mode. This property with the *Jali* system where the air when passe through a small hole cools down will be helpful to make the direct sunlight radiation into the building to a lower level. The *Jali* system has been used form the ancient history onwards where the cooling in the building was maintained just by the design of the building. One of such design models is the *Jali* model where a dome like model with small holes of any design was made to maintain the temperature inside the building. When there was no HVAC system to cool down in summer in the ancient times terracotta materials helps to maintain the temperature inside the buildings. So, the main idea proposed is that a hybrid combination of the *Jali* system with terracotta tile and a green plant in the metal frame can help reduce the temperature inside the building to a great extent. The Figure 11 below shows the proposed design model.

Figure 11: Hybrid Design model

Dapto Ribbonwood Centre

Design Solution Analysis

& Final Report

Table of Contents

Chapter 1 – Executive Summary

The analysis of a proposed design package of the installation of an additional 50kWp solar PV system along with the application of smart window film across the building was undertaken. The proposed design solutions were modelled and simulated to then quantify the impact of the design package against the benchmark case. There were several assumptions utilized in the simulations and a simple sensitivity analysis was undertaken to account for any uncertainties in these assumptions. The System Advisor Model (SAM) was used to model the installation of the additional 50kWp solar PV system on the Dapto Ribbonwood Centre. The simulation found that the additional system would produce 70,298kWh of energy per annum. Therefore, the total on-site generated energy would be increased to 210,849kWh per annum. The HVAC renewable energy fraction was used to quantify the impact of this design solution compared to the benchmark case. There was an increase from 0.61 to 0.92, indicating that after installation almost all the HVAC consumption would be offset by on-site generated energy. Sketch-up was used to model halls 1 and 2 of the Dapto Ribbonwood Centre, with the Open Studio plug-in used to simulate the heating and cooling loads of the rooms after application of smart window film to the room's windows. The total energy consumption for the building decreased 7%, from 60,463kWh to 56,703 per annum. This highlights the excellent potential for reduction in HVAC energy consumption after installation of the smart window film. Overall, it is made apparent how both design solutions complement each other to address the key issues of improving user comfort and achieving net zero energy.

Chapter 2 – Design Solutions Proposed

2.1 – Additional Solar Panels

The first proposed design solution to be analysed is the installation of additional solar panels to the existing 100kWp PV system at Dapto Ribbonwood Centre. This design solution was one of the highest scoring solutions in our design matrix, which was scored against a range of criteria such as feasibility, cost, reliability, lifecycle, energy savings and carbon savings. This solution is simple yet extremely effective in addressing one of the major issues provided by the client to aim to achieve net zero energy. The initial proposed suggested an additional 100kWp system to be installed, however after examining the building drawings provided by Wollongong Council it was deemed unfeasible due to a lack of roof space. Therefore, it is suggested that an additional 50kWp Photovoltaic (PV) system is installed alongside the current 100kWp system. A typical 50kWp will need around 350m^2 of roof space. Looking at the aerial shot of the Ribbonwood Centre in figure 1, the roof space above hall 1 outlined in red will provide around 280m^2 of space, with then the space above Heininger Hall outlined in green providing the rest of the required space.

This solution was selected as it has excellent energy and carbon savings potential, along with being reliable and having reasonable costs. It was chosen as part of a package with design solution 2, whereby both solutions will complement each other in addressing the key issues associated with the building and improving overall building performance.

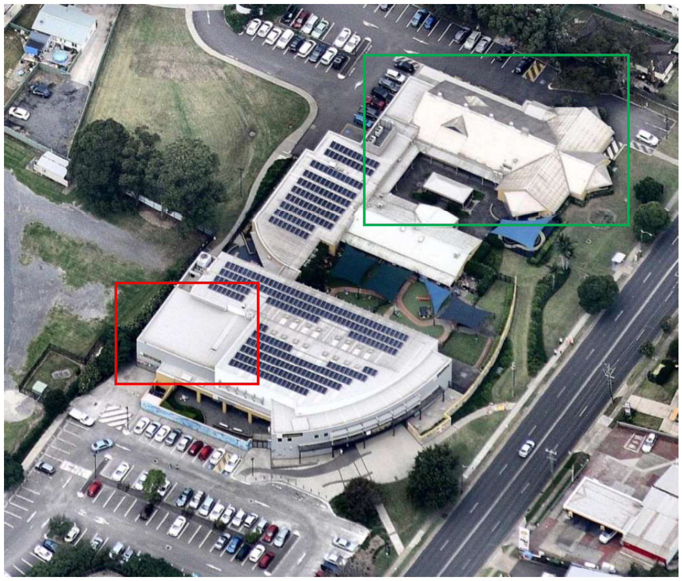

Figure 1 – Ribbonwood South View

2.2 – Smart Window Film

The second design solution proposed is the installation of smart window film on the building's windows. This film can be adjusted from clear to fully opaque when a small voltage is applied. This design solution also scored highly in our design matrix that used criteria outlined earlier. This strategy is the innovative future of windows and will be effective in addressing one of the key issues of the building being improving user comfort.

This solution was chosen as it can be used to advantage in allowing for more sunlight into rooms in cooler periods and blocking UV rays in hotter periods. This gives huge potential in decreasing the required HVAC load of the building, which accounts for an estimated 35% of the total current energy consumption. It was also chosen to operate in conjunction with the first design solution of additional solar panels to complement each other in one overall design package.

Figure 2 – Smart Window Film

2.3 – Whole Design Package

The two solutions are being presented to the client as a design package that will address the two major issues of improving user comfort and achieving net zero energy. The installation of the smart window film is critical in reducing the energy usage of the building, along with improving user comfort. The additional solar panels will then aim to provide close to if not all the remaining energy consumed by the building by means of on-site generated power. Therefore, it can be seen how the two solutions are able to complement each other upon their application on the building while also addressing the key issues identified by the client.

Chapter 3 – Business as Usual (Benchmark) Case

A business-as-usual case has been explored in order to quantify the performance of the proposed design solutions in comparison to this benchmark case. The Ribbonwood Centre has normal operating hours of 9am-5pm, Monday to Friday. The latest annual building energy consumption recorded was 651,433kWh in 2020. The HVAC system was estimated to account for 234,000kWh of the total consumption equating to 35% of total energy usage. It is also recognised that the building is using more energy cooling rather than heating in the current situation. The installation of the 100kWp PV system in 2018 reduced the total energy consumption from 975,826kWh in 2015 to 642,448kWh in 2018. Analysing the HVAC renewable energy fraction = of the benchmark case annually gives $\frac{140,612}{230,000} = 0.61$.

Chapter 4 – Methodology & Assumptions

There were two software packages used in the modelling and simulation of the proposed design package.

4.1 – System Advisor Model (SAM)

The System Advisor Model (SAM) was used to model the proposed additional 50kWp PV system. This simulation was used to gather results in relation to the energy to be generated on-site after the installation of the additional 50kWp PV system. There were several assumptions that were made for the simulation including:

- Weather data used from Sydney, NSW as it was the closest data available to site
- Solar panels installed at a tile angle of 20 degrees
- Solar panels installed to be North facing
- Solar panel inverter set to 96% efficiency

4.2 – Open Studio Plug-In

The second software package used was Open Studio plug-in for Sketch-up. This software was used to simulate the installation of the smart window film in the Ribbonwood Centre. Halls 1 and 2 were designed using Sketch-up as these rooms had a sufficient number of windows to analyse the performance of the design solution. The heating and cooling loads of the building were then analysed using the Open Studio plug-in to examine the impact of the proposed design solution. There were also several assumptions that were made for the simulation including:

- Weather data was used from Sydney, NSW as it was the closest data available to site
- Benchmark case U-value assumed to be 5.6 Wm^2K
- Smart window case U-value assumed to be 0.1 Wm^2K
- Heating and cooling loads assumed for medium office building

Chapter 5 – Results

5.1 – Energy Generated On-Site (SAM)

The additional 50kWp system was modelled on SAM using the outlined assumptions. The simulation outlined that this system would generate an additional 70,298kWh per annum of on-site energy. This highlights the potential energy savings of the proposed strategy. The overall 150kWp PV system that would be present on the Dapto Ribbonwood Centre after the additional solar panels are installed was modelled and simulated. Using the same assumptions, the simulation showed that the system would generate 210,849kWh per annum. January and October were the months with the highest amount of generation as seen below in figure 3.

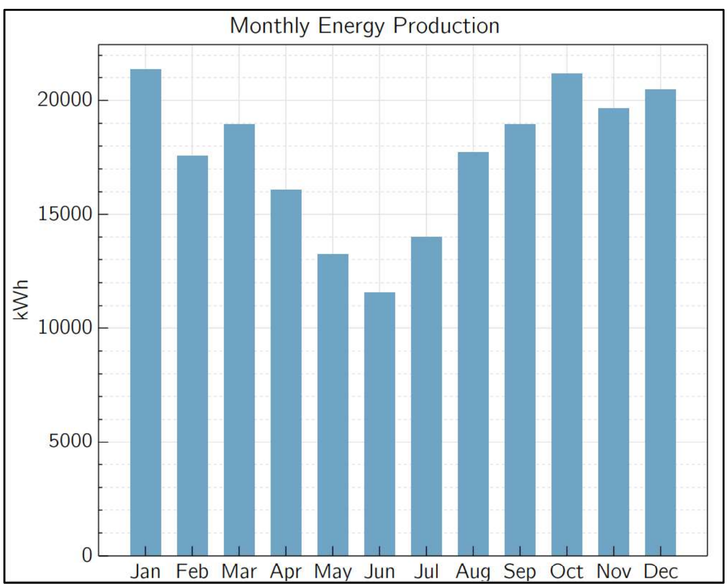

Figure 3 – Monthly On-Site Energy Generation

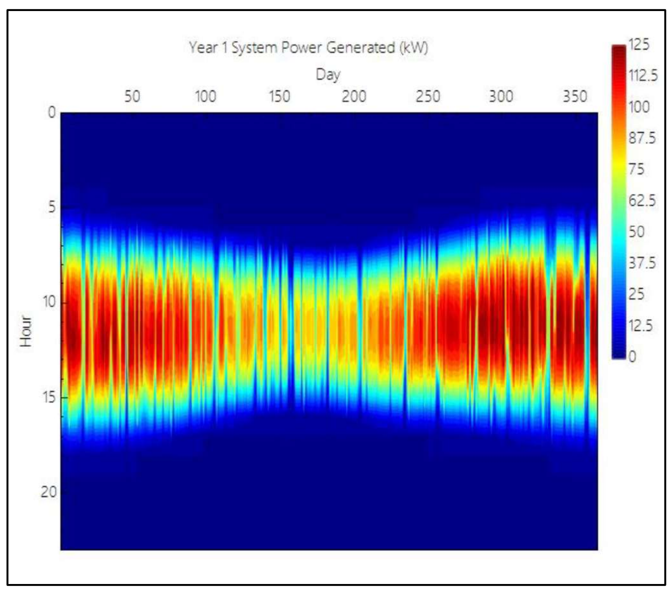

Figure 4 – Generation by Day/Hour

5.2 – Heating and Cooling Loads (Open Studio)

Halls 1 and 2 were modelled on Sketch-up as they included a sufficient amount of windows to analyse the performance of the smart window film. Using Open Studio, the heating and cooling loads of the rooms were then simulated and analysed. The sketch-up model of the halls can be seen below in figure 5.

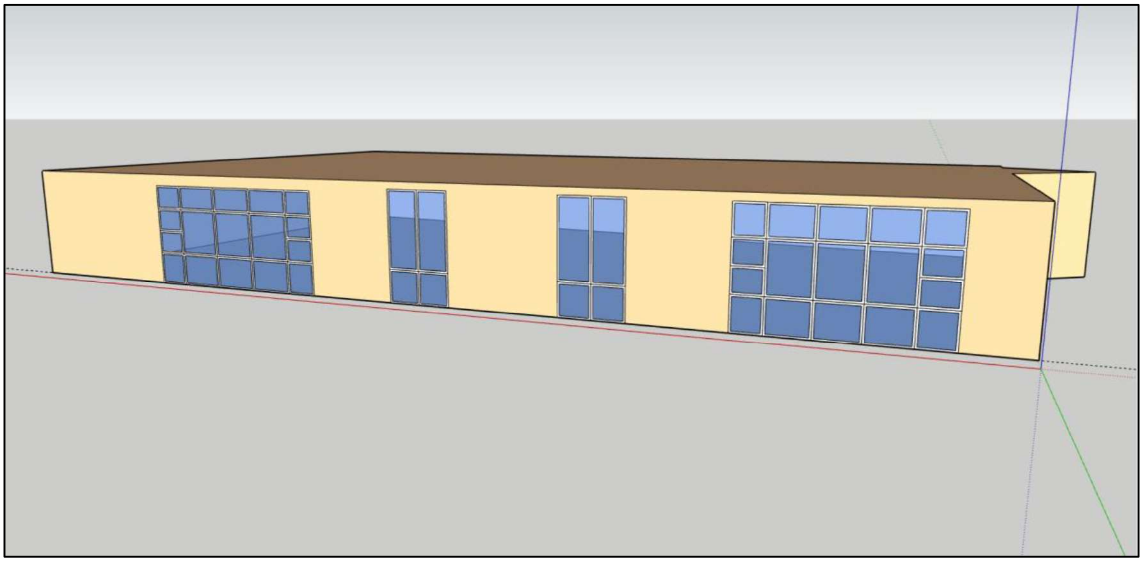

Figure 5 – Halls 1 & 2 Modelled

Heating and Cooling Loads Benchmark case:

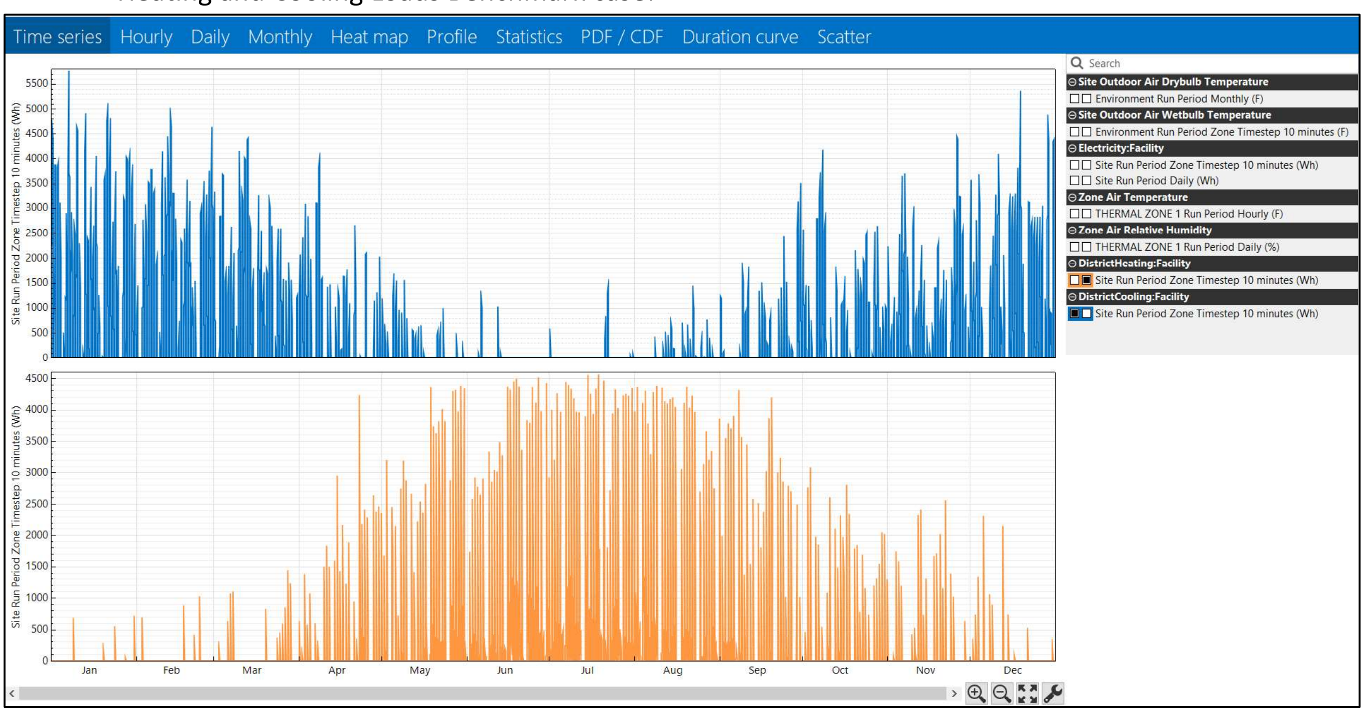

Figure 6 – Yearly Heating and Cooling Loads

The heating and cooling loads for the benchmark case of modelled halls 1 and 2 with can be seen above in figure 6. The cooling load accounted for 33,750kWh per annum and the heating load 26,713kWh. Therefore, the total energy consumed by hall 1 and 2 is 60,463kWh per annum.

Heating and Cooling Loads Application Smart Window Film:

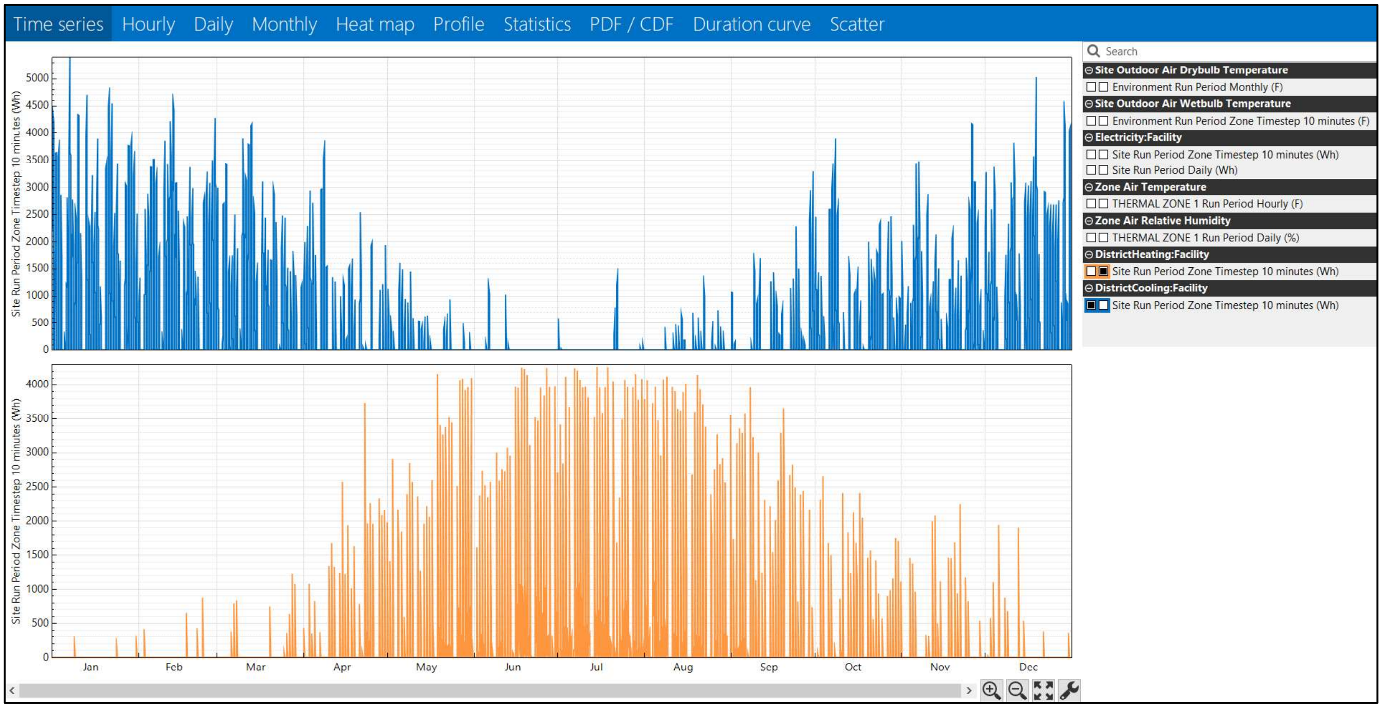

Figure 7 – Yearly Heating and Cooling Loads

After the modelling of the application of the smart window film, there was a 7% decrease in the yearly energy consumption. The cooling load now made up 31,767kWh and the heating load 24,936kWh equating to 56,703kWh per annum. The application of the smart film highlights reduction in the energy consumption from the HVAC system, essentially helping improve user comfort also.

5.3 – Calculations and Metrics

A range of metrics were analysed to quantify the impact of the design solutions compared to the benchmark case. The HVAC renewable energy fraction was calculated annually after the addition of the 50kWp system. The new equation yields $\frac{210{,}849}{230{,}000}$, which equals a HVAC REF of 0.92. This has increased from the benchmark case that yielded a value of 0.61, outlining a sufficient improvement towards achieving net zero energy. Therefore, the energy usage from the current HVAC system will almost entirely be offset by on-site generated energy. This also does not consider any reduction in energy usage from the HVAC system as a result of the installation of the smart window film.

The potential energy and carbon savings of the design package was also analysed. After modelling the additional PV system on SAM, it showed potential energy savings of 70,298kWh/a, equating to a potential carbon savings of 55 tons per annum. Modelling of the application of the smart window film with Open Studio outlined potential energy savings of 3,760kWh/a for halls 1 and 2 only. Considering this savings is only for two rooms, when the smart film is applied to the whole building there will be great potential for further energy and carbon savings.

Chapter 6 – Sensitivity Analysis

A simple sensitivity analysis was conducted to account for any uncertainties in assumptions that may affect the performance of the design solutions. The input weather data was altered from Sydney to Darwin to assess the performance of the solutions under altered conditions. Darwin was chosen to simulate the possibility of increasing temperatures in the future due to climate change.

As seen below, altering the weather data to Darwin in SAM increased the simulated energy production to 232,793kWh per annum. The increase in energy generation from the PV system is due to the increase in solar irradiance as a result of increased overall temperatures. This highlights how the proposed design solution of additional solar panels will still perform considerably well under altered conditions.

Chapter 7 – Discussion & Conclusions

Looking at the presented design package and simulation of each proposed strategy, it is made apparent that there is a great potential for excellent energy and carbon savings. It can be seen how both solutions contribute to addressing the two key issues of improving user comfort and achieving net zero energy. The additional 70,298kWh produced per annum by the additional 50kWp solar PV system will push the building towards net zero energy. When implemented in conjunction the 3,760kWh saved per annum in only halls 1 and 2 by the smart window film, there is a great potential to reach net zero when installing the smart window film across the rest of the building.

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RIBBONWOOD CENTER SOLUTIONS ANALYSIS REPORT

ENGG 947

Executive Summary

The Dapto Ribbonwood center is a mixed-use community center that is experiencing internal environmental quality problems due to its outdated equipment and general wear and tear. Out of the solutions proposed previously to mitigate this issues, this report analyses the impact switching to LED's, tinting the windows and using non-metal frames would have on the energy consumption in the building.

After modelling the building in SketchUp the simulation was run using OpenStudio. The weather selected was Nowra and various other assumptions had been made where clear data was not available. The roof was modelled as metal deck and the walls were modelled as concrete blocks. The building was modelled as having operating hours of 9:00 AM to 5:00 PM and the activity levels of people for various spaces were set. The standard of ASHRAE 289.1-2009 were utilized for people/m2, equipment, ventilation and infiltration. The values that were primarily tested were the difference in energy consumption that occurs when lighting is switched to follow NCC 2019 recommendation, impact of tinted windows and the impact of non-metal frames.

The testing revealed that switching to NCC 2019 recommended light intensity levels using LED's offered the best energy saving overall, in terms of cooling load, energy requirements for lighting and overall energy requirements. Switching to tinted windows yielded some minor energy savings. The tests for non-metal window framing were inconclusive with the results being dependent on the light intensity present in the thermal zones.

In conclusion it can be recommended that Dapto ribbonwood Center switch to NCC 2019 standards of lighting and apply darker tints on all their windows. This is considering the massive monetary and internal environmental quality benefits that this change would bring. The decision on whether to change the window frames to nonmetal ones should be made after a more in-depth study.

Contents

1 Introduction

Dapto Ribbonwood center is a mixed-use community center offering facilities such as library, community spaces as well as auditoriums which can be rented out for various purposes. Moreover, this building serves as a focal point for community interactions in the form of various clubs and homeless services. The purpose of the project was to generate innovative ideas to solve various issues that rose primarily from the age of the building and its associated equipment's. The client also wanted the building to cater better to an evolving and varied demographic of users.

The initial examination of the building revealed a litany of issues that can be traced back to HVAC (Heating, Ventilation and Airconditioning) equipment's. These included pockets of hot air, inadequate circulation of air and acoustic issues related to the chiller. A list of solutions had been proposed and passed through a selection matrix to ensure their feasibility. The previous report contains a detailed review of the matrix and weighting criteria. Attached below is table 1 which gives a quick recap of the proposed solutions and their scoring. The highlighted solutions are the ones that had been selected for further consideration in that report.

It is acknowledged that these measures on their own will not be capable of solving most of the above mentioned issues. However, these measures will work in tandem with the already proposed HVAC upgrades to ensure an efficient operation of the building. It is expected that the below suggested solutions will increase the occupant comfort due to more uniform thermal distribution in the building. The solutions are also expected to significantly decrease the cooling load of the building while causing a slight increase in the heating load of the building. The purpose of this report is to quantify the differences made in heating and cooling loads due to these solutions and to examine the overall impact of these solution on the energy consumption of the building.

2 Design Solutions Considered

Given below is a are two solutions that is being studied using Open Studio simulations to gain a better understanding of their advantages and disadvantages.

- Applying Smart Window Film
- Using intelligent LED Lighting systems

2.1 Applying Smart Window Film and thermal insulation for frames

The solar gain of the building essentially means the amount of short wave radiation let into the building through the fabric of the building or through an opening such as windows The solar gain can be reduced in a variety of ways. Listed below are some of the popular ones:

- Adding tints or additional materials that break the thermal bridges formed in windows
- Adding insulation to the walls to reduce the transfer of heat from outside.
- Adding insulation to the roof that reduce heat transferred into the building.
- Adding additional shading structures externally that prevent the hot sun rays from hitting the building directly.

Out of the above solutions this report focuses on reducing the solar load being transferred into the building through the windows panes. In the previous report submitted by our team, we had highlighted the advantages of adding tints to the windows as well as breaking up the thermal bridges created by the utilization of metal frames for the windows. That report however did not have any simulation aspect to it, which would have provided some more in-depth information regarding this idea. This report seeks to clarify the potential advantages and disadvantages of the proposed solutions using a simulation of the building in the Energy Plus software.

2.2 Intelligent LED Lighting Systems

The thermal loads within the building can be classified as any entity that generates heat. Usually any living being or electrical equipment that generates heat can be classified as a thermal load. The thermal load generated by living organisms can vary according to the activity currently being performed and biological differences. The heat generated by electrical equipment is usually a function of the units of electricity consumed by it. The thermal load generated by many equipment's such as computers, microwaves or other equipment's are usually not a major factor and controlling them can be a difficult proposition. An electrical equipment that has a major impact on the thermals of the building as well as that can be easily controlled is the lights. The building currently utilizes halogen lights in the form of bulbs and T5's that are currently generating a lot of heat. Simply replacing them with LED's that bring them in line with National Construction Code 2019 (NCC 2019) (Lighting Council Australia and IALD 2019) guidelines should have an impact on the thermal loads within the building. Supplementing the LED's with intelligent controls (programmable dimming systems) should further Improve the thermals within the building by reducing the energy consumption upto 15% (Lighting Council Australia and IALD 2019). The report details the lighting energy intensity for various types of spaces and these have been followed during the simulation.

	Feasibility	Cost	Reliability and maintainability	Energy Saving Potential	Potential Impact on star ratings	Carbon Saving Potential	Lifecycle	Innovation	Total
Weightage	0.1	0.1	0.1	0.15	0.2	0.15	0.05	0.15	1
Architecture									
Green wall	6	3	2	3	8	3	2	5	4.45
Transpired solar collector	8	6	9	6	6	6	9	3	6.2
Electrical Based									
Additional Solar Panels	8	4	8	9	9	9	9	3	7.4
Solar Panel Window	4	1	7	3	2	2	5	9	3.95
Intelligent LED Lighting System	7	6	8	8	9	8	4	5	7.25
Smart Window Film	4	3	6	6	5	6	5	8	5.55
Hvac Based									
Buffer Tank	8	9	8	3	3	3	7	5	5.1
Energy Valve	7	8	6	3	3	3	4	7	4.85
Passive Thermal insulation for windows	6	2	7	4	6	4	8	3	4.75
Phase change material	3	1	9	5	5	5	3	8	5.15
Solar Water Heating	4	7	5	4	5	4	5	3	4.5

Table 1 Selection Matrix

3 Methodology and Main Assumptions

3.1 Recreating the Building

Figure 1 Building Model in SketchUp

The building was recreated in SketchUp using the plans provided from the client. The image file containing the floor plan was imported into SketchUp. It was scaled to size and rotated to get the correct orientation for the building. The outer structure of the building was drawn. The internal walls were drawn. This would enable us to assign individual thermal zones for the zones as required. Here I have clubbed some of the smaller rooms that have similar characteristics (e.g.: Female and Male amenities) into one thermal zone.

After drawing the floor plan, the OpenStudio toolbar has to be used. The diagram was turned into a space using the " The create spaces from Diagram option". The windows and doors were drawn. The dimensions were taken from the floorplans provided by the client. The doors that are made of glass have been drawn as windows here as it would not make any significant difference in terms of thermal performance whether they were assigned as doors or windows. The second floor was drawn in a similar manner on the roof of the first floor and windows and doors were drawn.

Following this each thermal zone was given the attributes as required. The space type, building story, construction set, thermal zones and other settings were declared.

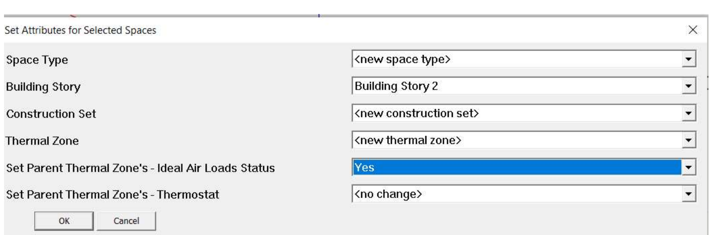

Figure 2 Giving Attributes to spaces

The next step was to draw the external shading. This was done using the "create new external shading group" button. Following this surface matching was applied. This concludes the portion of the simulation that utilizes the SketchUp GUI. The next steps were completed in the OpenStudio GUI. The OpenStudion GUI was launched using the “Launch Open Studio” button on the OpenStudio toolbar.

3.2 Simulation of Thermal and Energy Performance

The first step in the simulation was to load the weather data file. The possible options for Dapto included Nowra and Sydney. Nowra was chosen due to its approximation with Dapto in terms of urban development compared to Sydney. The files for the weather as well as the design days were downloaded from www.energyplus.net/weather. The simulation was run for the year 2021

The next step was to create the schedules, activity levels and heating/cooling temperatures.

The schedules were set as 9:00 AM to 5:00 PM which represents the working hours of the building. The activity levels were set as 120 W/Person for people in Offices, conference rooms and most other places which represents normal activity levels. The activity level was set at 100 W/Person for the people in the library. The heating was set to achieve 21 Deg during operating hours and set to achieve 23 degrees during the working hours of the buildings.

The construction of the building was set as a metal decked roof with walls made of concrete blocks. The windows glass and type along with light Watts/space floor area was an element on which sensitivity analysis was performed. The people/space floor area was left at ASHRAE 189.1-2009 according to the various types of spaces as the data regarding that, specific to the ribbonwood center was not available. The same is true for the equipment levels, ventilation levels and air infiltration levels with the default values for 4-8 persons for the respective type of zones being utilized.

4 Simulations Performed

The aim of this report is to identify the impact various solutions proposed would have on the heating and cooling loads of the building. For this a sensitivity analysis would have to performed and the ideal combination of factors have to be selected. To come to the required answers a number of simulations which contain either one or a combination of the proposed solutions were tested. They are listed as follows

- Building with 14.5 Watt/m2 light intensity ,ordinary glass windows and glass window-Worst case scenario for cooling loads
- Building with default light intensity, ordinary glass windows and metal frame-Current Likely condition of the building
- Building with default light intensity, tinted windows and nonmetal frame
- Building with default light intensity with tinted windows and thermal breaks for the frame
- Building with NCC 2019 recommended W/m2 light levels, ordinary glass windows and metal frame.
- Building with NCC 2109 recommended W/m2 light levels, tinted windows and metal frame.
- Building with NCC 2019 recommended W/m2 light levels, tinted windows nonmetal frame

5 Results

5.1 Building with 14.5 Watt/m2 light intensity ,ordinary glass windows and metal frame

This test was done with the 14.5 Watt/m2 value because a study conducted by Department of Climate Change and Energy Efficiency discovered that several older buildings had a light intensity value of 14.5 Watt/m2 (Department of Climate Change and Energy Efficiency 2010). Since the Dapto Ribbonwood building is around 20 years old, there is a very good possibility that the light intensity there actually corresponds to 14.5 watt/m2.

Annual Cooling Requirements	108822.2 kWh
Annual Heating Requirements	81219.4 kWh
Annual Interior Lighting Requirements	167472.2 kWh
Total Energy Consumption	**357538.9 kWh**

Although this was initially considered as the worst-case scenarios, the total energy consumption for HVAC and Interior lighting only came to 357538.9 kWh/Annum. The Business-as-usual analysis performed for the interim report suggested a combined a consumption of 507000 kWh/ annum. This indicates that perhaps the building is running even more inefficiently than previously predicted since the actual value is 30% higher than the predicted value. It is acknowledged here that the energy consumption value obtained from the simulation is from running under ideal conditions and likely is underestimating the energy consumed. To maintain consistency throughout the report the next results would be compared to the values obtained from the simulation.

5.2 Building with ASHRAE 189.1-2009 level light intensity, ordinary glass windows and metal frames

The results are for annual cooling, heating and interior lighting is as follows

Annual Cooling Requirements	87222.2 kWh
Annual Heating Requirements	86008.3333 kWh
Annual Interior Lighting Requirements	118788.889kWh
Total Energy Consumption	**292080.5556 kWh**

Using default ASHRAE standards from 2009 for lighting resulted in an approximate saving of 20% and 30% for the cooling load and interior lighting energy consumption, respectively. The heating load however did increase by 6% giving us a total saving in energy consumption of 19% or 65458.344 kWh per annum over the previous scenario (Section 5.1).

5.3 Building with ASHRAE 189.1-2009 level light intensity and tinted glass windows

The results are for annual cooling, heating and interior lighting is as follows

Annual Cooling Requirements	87644.4 kWh
Annual Heating Requirements	78975 kWh
Annual Interior Lighting Requirements	118788.889kWh
Total Energy Consumption	**285408.3333kWh**

This simulation was to test the effect of adding a tint to all the clear glass windows. There was a 0.5 % increase in cooling load and a 1 % decrease in heating load. Overall, there was a 3% or 6672.2kWh decrease energy consumption compared to previous scenario (Section 5.2).

5.4 Building with ASHRAE 189.1-2009 level light intensity, tinted glass windows and non metal frames

The results are for annual cooling, heating and interior lighting is as follows

Annual Cooling Requirements	87836.1111
Annual Heating Requirements	74777.778 kWh
Annual Interior Lighting Requirements	118788.889kWh
Total Energy Consumption	**281402.7778kWh**

This simulation was to test the effect of replacing the metal frames with non metal frames for the tinted windows. There was no significant change in cooling load and but there was a 5 % decrease in heating load. Overall, there was a 1% or 4000 kWh decrease energy consumption compared to previous scenario (section 5.3).

5.5 Building with NCC 2019 level light intensity, ordinary glass windows and metal frames

Annual Cooling Requirements	62586.1111
Annual Heating Requirements	100308.333 kWh
Annual Interior Lighting Requirements	47486.1111kWh
Total Energy Consumption	**210380.556kWh**

This simulation aims to test the impact of switching to LED lighting when keeping the glass clear with metal framed windows. There was a significant decrease in annual cooling requirements of close to 40% compared to our base case. The interior lighting energy requirements also reduced 60%. It should be noted that the heating increased by 15%. Overall switching to LED Lighting would yield an estimated total energy saving of 28% or 81700kWh per Annum compared to the base case(Section 5.1).

5.6 Building with NCC 2019 level light intensity, tinted glass windows and metal frames

Annual Cooling Requirements	62505.5556kWh
Annual Heating Requirements	92102.7778kWh
Annual Interior Lighting Requirements	47486.1111kWh
Total Energy Consumption	**202094.444kWh**

This simulation aims to test the impact of tinting the window panes when utilizing LED Lights. There was no significant decrease in cooling load . The heat load reduced by 9% as a result switching to tinted windows. of Overall using tinted windows along with LED lighting would yield an estimated total energy saving of 4% or 8280 kWh per Annum over the previous case(section 5.5).

5.7 Building with NCC 2019 level light intensity, tinted glass windows and non-metal frames

Annual Cooling Requirements	62525kWH
Annual Heating Requirements	97088.8889kWh
Annual Interior Lighting Requirements	47486.1111kWh
Total Energy Consumption	**207100kWh**

This simulation was to test the effect of replacing the metal frames with nonmetal frames for the tinted windows while utilizing LED Lights. There were no significant change in cooling load and but there was a 5% increase in heating load. Overall there was a 2% or 5000kWh increase in total energy consumption compared to previous scenario (Section 5.6).

6 Discussions

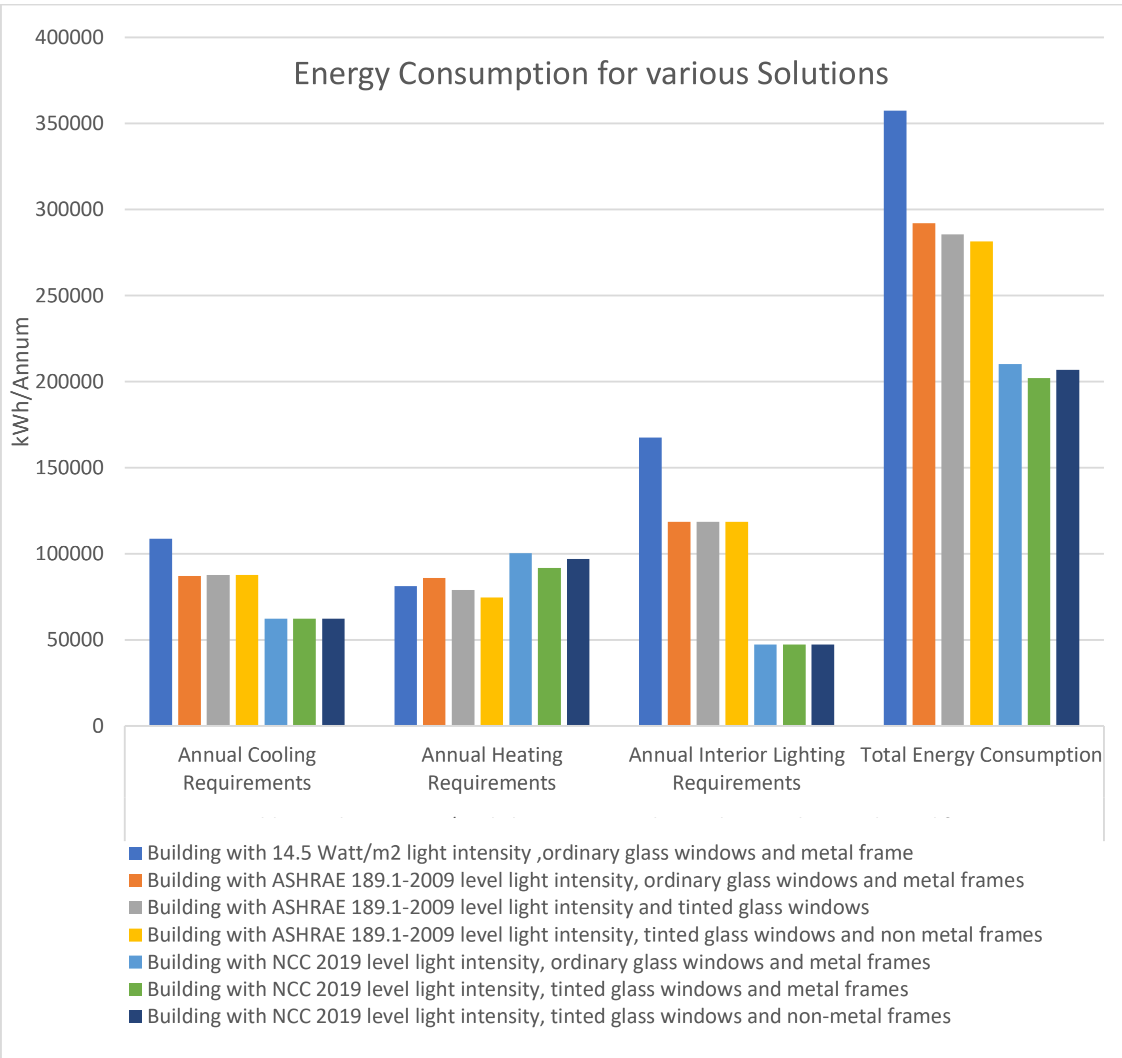

Chart 1: Comparison of all energy consumption

Given above is a graph that illustrates how the cooling load, heating load, lighting energy requirement and combined energy requirements change as the various factors are introduced.

6.1 Impact of Switching to Intelligent LED Lighting

As expected the cooling load and heating load act as functions of the interior lighting energy intensity. As the lighting energy intensity decreases (switching to LED's) the cooling load decreases and the heating load increases. However, the decrease in cooling load is usually more than enough to offset the increase in heating load in all above cases. This combined with the decreased energy requirements for lighting means that switching to LED lighting is the factor of all three tested that has the most impact in terms of energy savings. Switching to LED alone and following NCC 2019 lighting guidelines accounted for 28% energy savings compared to base case.

6.2 Impact of using Tinted Windows

This did not have the expected impact on cooling or heating load. There was no significant decrease in cooling loads and but there was a decrease in heating load. This is likely due to any of the approximations that have been made. One possible reason is that the lighting in the OpenStudio program is controlled on a Watt/m2 basis. Using tints resulted in a higher requirement of lights thus producing more heat. This could have resulted in the unexpected results from heating and cooling load. If this theory was true, it should have resulted in a proportional increase in lighting energy consumption which cannot be observed from the results. Overall, even though the results were not as expected it did result in an average reduction in energy consumption of 3.5% due to the reduction in heating load.

6.3 Impact of using nonmetal Frames

The simulations for testing the impact of non-metal frames proved inconclusive. There was no significant change in cooling load in any case. Utilizing non-metal frames when ASHRAE 189.1-2009 standards were followed for lighting resulted in a 5% decrease in heating load compared to metal frames. Utilizing non-metal frames when NCC 2019 lighting standards were followed resulted in a 5% increase in heating load compared to metal frames. This is likely due to the ASHRAE standards producing more heat from the lights thus reducing the heating load. In the case of NCC 2019 standards and non-metal windows, the increase in heating loads is likely due to the LED lights not producing enough heat to offset the lack of radiated heat from sun rays hitting the frame entering the building.

7 Conclusions

The Dapto Ribbonwood center is experiencing several issues that are primarily due to the age of the building and its equipment's. Switching to NCC 2019 levels of light intensity,tints on window panes and thermally insulated windows were recommended as solutions to mitigate some of the problems. Following simulations using SketchUp and Open Studio, the following conclusions can be drawn.

Switching to NCC 2019 levels of light intensity would provide the most saving in terms of energy and can be whole heartedly recommended. Tinting the windows provide some energy saving and should be done only after considering the cost/benefit ratio. Tests regarding benefits of non metal window frames proved inconclusive and should be considered after further analysis.

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Dapto Ribbonwood Centre

Prepared for: Wollongong City Council

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EXECUTIVE SUMMARY

The Dapto Ribbonwood Centre, under the jurisdiction of Wollongong City Council, is to undergo major upgrades over the next four years in order to ensure the building meets modern standards and functionality requirements. The Integrated Design Studio (IDS) developed a design matrix of potential passive and active measures that would form part of the strategy for the major works, specifically the upgrade of the current HVAC system. From the best ranking proposed ideas from Task Two, as determined by weighting the criteria according to the client's needs, a design package was developed to analyse using building simulation and modelling. The modelling software chosen by the IDS for the design package was SketchUp and the OpenStudio plugin, as well as Microsoft Excel to aid in analysing the results produced.

The primary solution that formed the premise of the design package was the installation of a green wall on the north-western facade which would reduce the thermal load placed on the building by blocking direct solar radiation. The predicted advantages of this design solution include a reduction in temperature fluctuations within the building, improved indoor environmental quality, a reduction in energy consumption (particularly for cooling loads) and improvements to occupant well-being as a result of the salutogenic design appeal. The IDS chose to specifically investigate the type of species that would suit the climatic conditions of the site and whether indoor temperature variation would be reduced.

After rigorous simulations, it was determined that the Buxus Japonica species was most effective at maintaining temperature and was suited to the climatic conditions of the site, thus was recommended for use in the proposed green wall. However, when considering the feasibility of a green wall on the north-western facade of the building, which is the driest and hottest elevation, it was deemed unviable as there is a limited number of plants that could handle the orientation specific microclimate created. Although the chosen species is robust, it doesn't have the aesthetic appeal usually associated with green walls, thus diminishing its value as a design solution. Further, maintenance, access and irrigation costs associated with the proposed solution's location also negatively influence its viability. As a result, it is recommended that simulation of the influence of other design solutions, not considered in the report, such as planting a large tree on the western site boundary or the installation of an indoor green wall, be undertaken to determine their effectiveness in achieving similar benefits to those achieved by the green wall solution.

INTRODUCTION

The Dapto Ribbonwood Centre is a community building consisting of a library, meeting rooms, halls, kitchens and offices, constructed in 2000. The building is under the jurisdiction of Wollongong City Council who has called upon the Integrated Design Studio (IDS) to develop a strategy to replace the current HVAC system to enable it to meet current functionality requirements. Over the past five years the building has undergone some minor upgrades including updating the hot water system with heat pumps, replacing the HVAC plant in Heininger Hall and the installation of a 100kWP photovoltaic system on the roof. To bring the rest of the building up to date, Wollongong Council has developed a four year infrastructure delivery program, of which replacing the current HVAC system is a primary focus. While developing this strategy the condition with respect to the age of the asset was considered, as well as the net-zero energy requirement set out by iHub.

The design solutions considered were derived from the top results calculated, all receiving a score of 3.7 or higher out of five, in the design matrix from Task Two and are as follows;

- Mircoshade mesh in windows on north-western facade
- Replace existing lights with LEDs
- Exterior green wall on north-western facade
- Sealing air leaks within the building

From these design options a design package was created that will be most effective at improving the indoor environmental quality, energy saving potential, carbon saving potential and aesthetics of the Dapto Ribbonwood Centre. The design package created includes,

- External green wall to be constructed as a series of planters on awning, thus increasing shading of the first floor of the north-western facade which will reduce the thermal gains associated with direct sunlight.
- Automatic louvres operated using model predictive controls as part of a building management system that will optimise natural ventilation to reduce load on existing HVAC system.
- Energy audit of the current HVAC system to determine which components should be upgraded to bring the system up to modern standards, as well as ensuring the design and location of components is in a configuration that optimises the efficiency of the system.

This design package aims to reduce the thermal load placed on the existing HVAC system by increasing shading of the north-western facade, thus negating the need for a system upgrade. Improving the air quality and reducing the extreme temperatures experienced in the space will improve user experience and make the Dapto Ribbonwood Centre an enjoyable place to have meetings, club activities and study. The installation of a green wall simultaneously makes the building more approachable and welcoming, effectively creating an urban oasis which is essential for a community building.

From the design package described above, the focus of the building simulation was on the influence of the green wall on the temperature of the foyer space and peak cooling loads. This was simulated using SketchUp 2017 and OpenStudio as described in the following sections of the report.

METHODOLOGY & ASSUMPTIONS

A parametric analysis is used to determine the influence of the proposed design package on the building's energy needs. In order to test the effectiveness, a SketchUp model was created and the building simulations were run through OpenStudio. By measuring the difference of the outside surface temperature of the wall and indoor operative temperature before and after application of the green system, the influence of insulation and plant species can be determined thus allowing heating and cooling loads to be optimised. Data was analysed on a daily and seasonal basis for the building.

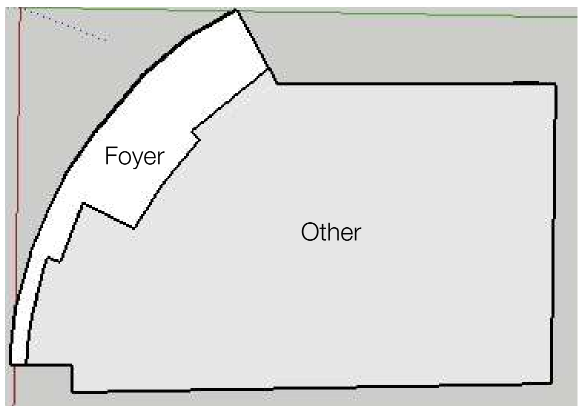

Figure 1: Thermal Zones of Building

The Dapto Ribbonwood Centre has a floor space of approximately 2000 m², was built in 2000 and is located approximately 100km south of Sydney in a temperature climate. The building is rectangular in shape with a curved north-western facade, as seen in figure 1, and is surrounded by single storey highway infrastructure (i.e. petrol stations, fast food, etc.), thus shadowing effects can be neglected. The model created aimed to mimic the building and site conditions as accurately as possible, however, due to constraints of time and resources some assumptions were made which will influence the accuracy of the results derived. These assumptions are as seen below;

- The weather file used was from Bellambi which is located approximately 20km north of the site but is still considered to be in the same climate zone according to the NCC.
- The closest building type offered by OpenStudio was an office, thus the associated loads were used during building simulation. According to the NCC, offices are a class 5 building whilst the Ribbonwood Centre can be classified as a class 5, 6 or 9b, thus there are some differences in the operational requirements. Offices are generally occupied 9-5pm five days a week and the Dapto Ribbonwood Centre's usual hours of operation reflect this, however, the meeting rooms, offices and halls within the building can be hired until midnight for various activities, thus the office building type isn't entirely accurate.
- The building is composed of two rooms, one of which is the foyer on the western side of the building and the other encompasses all other areas in the building.
- The green wall will be entirely composed of the same species of plant.

- It was assumed that air loads and the HVAC system were ideal.
- Only 2020 weather data was used in simulation to gauge an idea of a typical day.
- HVAC set-point to be 20°C.

The building is a double storey commercial building constructed on reinforced concrete columns and deep pears along with a reinforced slab throughout all floor levels. It is important to note that the foyer of the building, located on the western facade, extends across both storey's and is the area of focus for this study. The HVAC system consists of heat pumps for hot water and a screw-chiller with multiple outlets throughout the building provide a source of cooling.

Two thermal zones have been created, one that considers the western foyer area and the rest of the building, as can be seen in figure 1. The main inputs used during the simulation were occupants, lighting and HVAC loading, with table 1 below depicting the schedules used taking a week day where the building is open from 9am-5pm and the library is open 9:30am-7pm.

Table 1: Thermal Zones Modelling

		FOYER	OTHER (I.E. LIBRARY)
Occupant	Density (people/m2)	0.05	0.08
	Metabolic Rate (W/person)	180	100
	Activity Schedule	00:00 - 08:00, 0 08:00 - 09:30, 0.5 09:30 - 17:00, 1 17:00 - 19:00, 0.5 19:00 - 24:00, 0	00:00 - 08:00, 0 08:00 - 09:30, 0.2 09:30 - 17:00, 1 17:00 - 19:00, 0.2 19:00 - 24:00, 0
Lighting	Power Density (W/m2)	8	10
	Operating Schedule	00:00 - 08:00, 0.1 08:00 - 19:00, 1 19:00 - 24:00, 0.1	00:00 - 08:00, 0.1 08:00 - 09:30, 0.7 09:30 - 17:00, 1 17:00 - 19:00, 0.7 19:00 - 24:00, 0.1
Electrical Equipment	Power Density	1.7	5.81
	Operating Schedule	00:00 - 07:00, 0.2 07:00 - 09:30, 0.5 09:30 - 18:00, 1 18:00 - 19:00, 0.5 19:00 - 24:00, 0.2	00:00 - 07:00, 0.2 07:00 - 09:30, 0.5 09:30 - 19:00, 1 19:00 - 24:00, 0.2

Due to time and resource constraints the green facade was unable to be simulated in detail and take into account factors such as heat transfer processes (radiative exchange), evapotranspiration phenomenon and effective of vegetation and soil on convective and conduction heat transfer. Rather the final model formulated accounts for the difference between the outside temperature and the inside surface of glazing when the set temperature of the building is 20°C.

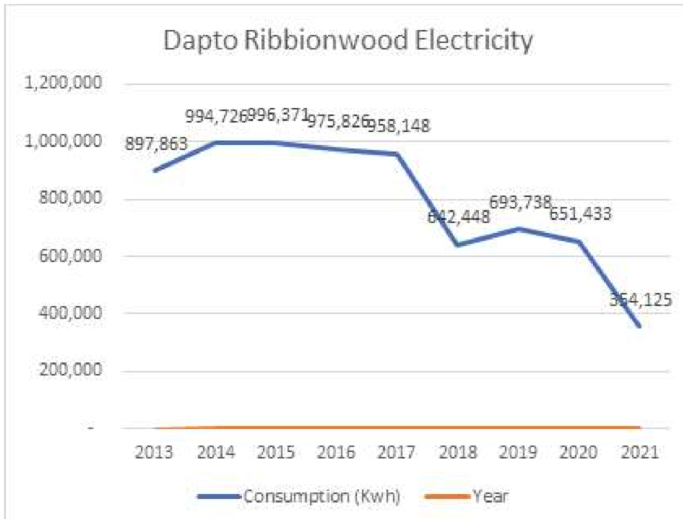

Figure 2: Energy Consumption Trend

The historical electricity consumption of the building is as seen in figure 2 above. HVAC accounts for approximately 40% of a buildings energy consumption, as such the installation of a green wall will reduce the thermal load placed on the building by blocking some direct UV radiation, thus energy consumption will also decrease.

Three different species of plant were simulated through the use of an approximate leaf area index value calculated as seen in table 2 below, to determine which would be most effective at reducing temperature fluctuation within the building. The leaf area index of a plant refers to the area of the leaf over the surface of area of ground the canopy covers, it is more commonly used for large trees thus the results calculated were very small. Essentially the leaf area index is a measure of how much light, and subsequently heat, are able to pass through a species. As such, this value was used to determine the amended area of glazing exposed to direct sunlight.

Table 2: Species Breakdown

	PHILODENDRON XANADU	WESTRINGA "AUSSIE BOX"	BUXUS JAPONICA
Image			
Description	• Bright natural light • Weekly watering • Hardy • Well drained most soils • Aspect: part shade • Origin: Western Australia	• Full sun to part shade • Tolerates a wide range of soils and conditions • Withstands drought once established • Resistant to heat, humidity, frost, salt spray • Suited to mediterranean climates • Low maintenance • Origin: Australian selected form	• Hardy • Wide range of soils • Good drainage essential • Minimal water once established • Aspect: Full shade, full sun • Origin: Japan
Leaf Size (cm)	20 x 8	Pi x 1 x 0.7	Pi x 1 x 2.5
Width (cm)	45	50	150
Leaf Area Index (cm2/cm2)	0.10	0.0011	0.00044
Height (cm)	75	95	100

RESULTS

The building simulation conducted found the Buxus Japonica to be most effective at reducing temperature fluctuation within the building. As seen in the figure below, the green line is representative of the ambient outdoor temperature, whilst the dark blue line represents the base case for the Dapto Ribbonwood Centre, i.e. without any shading. All three species of plant used are effective at maintaining temperature at approximately 20°C, HVAC set point, despite the outside environmental conditions. The dark green line closest to the 20°C is that of the Buxus Japonica, whilst the Westringa and Xanadu are overlaid just below, maintaining temperatures between 18-20°C.

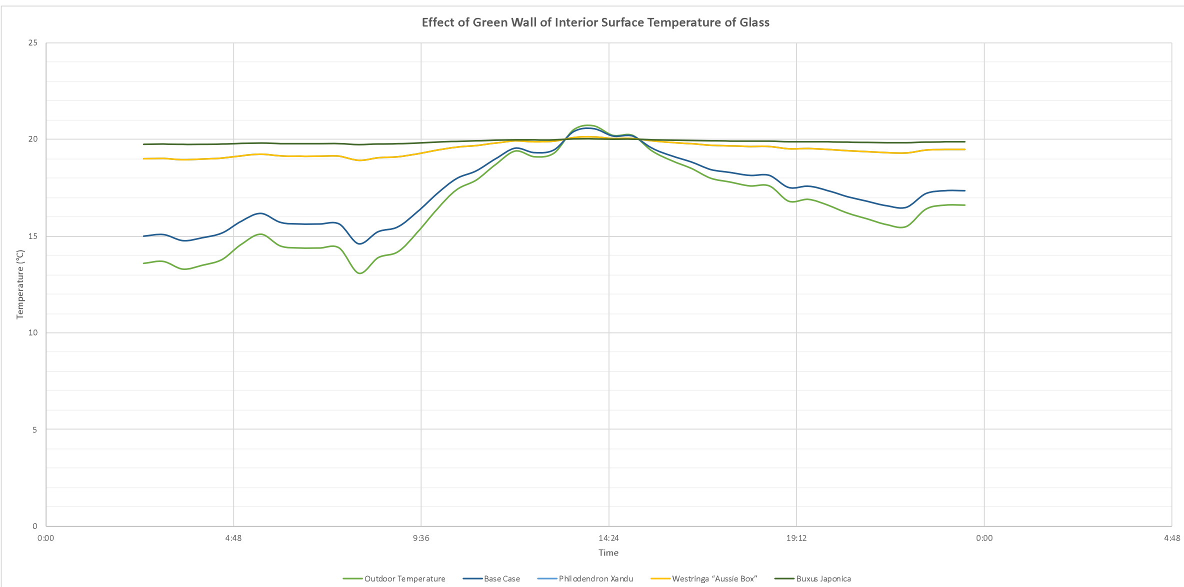

Figure 3: Species Comparison

Given the Buxus Japonica was the best performing plant species, it was tested under a range of different conditions to determine the extent to which the species was able to remain an effective shade. Below is a graph of the species performance on the summer and winter solstice in comparison to the outdoor temperature and the base case. Since the Dapto Ribbonwood Centre is located in a cooling dominant climate, the best case for the winter solstice falls just below the 20°C, whilst the summer solstice is almost exactly in-line with it, with a temperature variation of approximately 1°C. However, given the assumptions this temperature variation would most likely be much larger in practice.

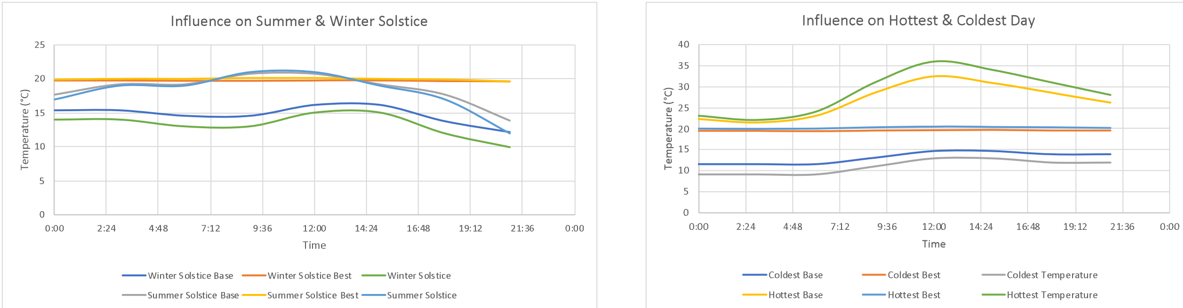

Figure 4 & 5: Testing Extremes

Another parameter tested was the hottest, 23/01, and coldest, 07/08, days of 2020 to determine how the proposed solution performs under extreme temperature conditions. As seen in figures 4 & 5 above, the hottest day data for the Buxus Japonica (best) is exactly on the 20°C line while the coldest is at around 19°C due to the heating dominant climate of Dapto.

The final case simulated was a typical day in each season to investigate how the green wall will perform year round, as depicted in figure 6 below. Aforementioned, the heating dominant climate is highlighted by the best practice data lines for winter and spring which are slightly below 20°C, while the summer and autumn are exactly on the 20°C line. Despite this, it is sufficiently evident that a green wall using the Buxus Japonica will effectively reduce temperature fluctuations on the inside surface of the glazing.

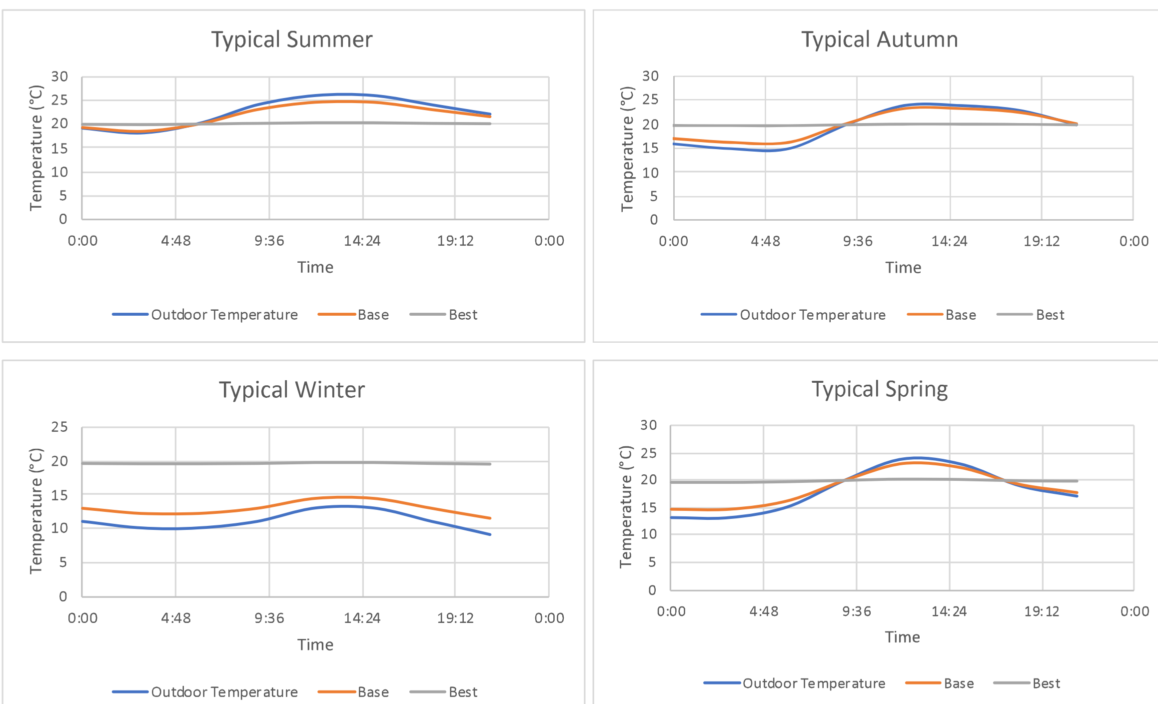

Figure 6: Typical Day in Each Season

The results obtained from the simulation process can be considered consistent as they align with the research conducted into the influence of green walls on temperature fluctuation as well as the type of plant species that would offer the greatest benefits. However, the results cannot be considered accurate due to the assumptions made and lack of time, knowledge and resources of using the building simulation software. Other sources of error that may have influenced the accuracy of the results is that factors such as heat transfer processes, evapotranspiration phenomenon of plants and the effect of vegetation and soil on convective and conductive heat transfer, weren't considered or accounted for in the simulation. Additionally, the results can be considered valid as the building simulation aimed to determine the influence of a green wall on reducing temperature fluctuations within the building, which was achieved as outlined above. To improve the accuracy and relevance of the results to the site, further investigation and simulation of the relationship between temperature stabilisation and a reduction in energy consumption, specifically for peak cooling loads, is necessary. Overall, the results obtained reveal that the installation of a green wall using the Buxus Japonica, on the north-western facade to provide shading, will significantly benefit the indoor environmental quality and user experience.

DISCUSSION

Despite what the data reveals it is important to consider the feasibility of the design in relation to the existing building. Taking the criteria from task two, it can be seen in table 3 below that the proposed solution may be viable.

Table 3: Task Two Matrix Analysis

MATRIX CRITERIA	COMMENTS	SCORE
Cost	For the installation of a permanent green wall, there is a high capital cost associated with setting up the irrigation piping and pumps, planter boxes, reinforcement design and procurement of plants. There are also operational costs associated with maintenance, i.e. monthly inspections and biannual pruning & feeding, to ensure the plants remain in a condition that continues to provide benefits.	3
Feasibility	There is limited additional infrastructure required for this solution to be implemented. The lower row of louvres on the first floor will be removed to make way for planter boxes of approximately 400mm deep. Little to no reinforcement will be required as the awning is a concrete slab. Irrigation pipes will need to be installed that redirect stormwater from the roof to the vegetation.	4
Energy Saving Potential	From preliminary literature review research, differential temperatures of 0-14°C can be experienced when comparing the outside surface temperature of the building with and without green shading. The lower differential temperature is experienced in winter, as green walls are most effective at reducing peak cooling loads rather than providing increased insulation.	3
Carbon Saving Potential	The embodied carbon for this retrofit is minimal as the planter's can be sourced from recycled materials and the plants are carbon positive. Similarly, the operational carbon will be minimal as the only energy consumer will be the irrigation pump to be used during times of low rainfall.	3
Materials	Materials can be sourced relatively locally as there are many wholesale nurseries in the greater Sydney and Illawarra region such as Andreasens Green.	5
IEQ	Green walls have numerous benefits to indoor environmental quality including; improved air quality, acoustic insulation, reduction in temperature fluctuation, cooling effect of evaporative transpiration process of plants, reduction in energy consumption particularly for cooling loads, thermal insulative effects of vegetation, panels and substrate, protection from wind thus reducing cooling effect but convection and increased longevity of external building material.	5
Innovation	The notion of green walls is becoming increasingly common in new building designs due to the biophilic design which aids in occupant health and well-being.	3

MATRIX CRITERIA	COMMENTS	SCORE
Maintenance	Irrigation of the green wall would be through redirection of stormwater from the roof and automated to be pumped back up during periods of little to no rainfall. Further, the vegetation should be inspected for disease, etc. on a monthly basis and pruned and feed biannually to ensure the benefits can be fully experienced.	1
Impact on Rating Systems	This design solution addresses all nine categories of the Green Star Operational Performance of Buildings rating system, as described in detail in the appendix section of this report.	5
	Total	3.8

CONCLUSION & RECOMMENDATIONS

Simulation of the proposed green wall solution, revealed it to be highly effective at shading the north-western facade and subsequently reducing temperature fluctuations in indoor temperature. The Buxus Japonica was the species most effective at achieving this, as evident in figure 3 which reveals a 0-2°C temperature difference between the HVAC output and the interior surface of the glazing unit.

However, a key criteria the matrix didn't take into account that is specific to green walls is the practicality of the solution in relation to the site conditions. The design solution proposes to install the green wall on the north-western facade which is the hottest and driest elevation of a building that is highly exposed to north-westerly winds. These conditions aren't conducive to plant growth, as such, the species of plant and the likelihood that the vegetation will grow as needed to provide the aforementioned benefits is severely limited. Therefore, it can be concluded that in theory a green wall design solution will be highly beneficial in aiding with shading of the north-western facade, but when considering the practical implications, the solution becomes unviable. As a result, other design solutions to be considered, that weren't modelled due to time constraints, include;

- Increasing shading of building through installation of a large tree in the grass area to the west of the building. There is currently one tree located in this location, but the addition of a native tree such as an Illawarra Flame tree, which can grow up to 12m tall, will in time, provide adequate shading of this facade. This type of tree is deciduous and can grow in a wide range of soils and climates making it an ideal choice for the conditions of the site. This design option would require less maintenance and costs, and produce similar advantages to those discussed for the green wall solution.
- Used in conjunction with the above design solution, the installation of an internal green wall in the foyer area, such as the 'Breathing Wall' by Jungelfly would achieve a range of benefits including improved air quality, reduction in temperature fluctuations, salutogenic/ biophilic design draws, acoustic insulation and reduction in reliance on HVAC systems of up to 33% (THE JUNGLEFY BREATHING WALL n.d.). The available wall space, and potentially some of the glazed space, could actively contribute to user experience and well-being rather than being a passive element.

Figure 6 & 7: Illawarra Flame Tree & Jungelfy Green Wall

Ultimately, it is evident that the practical application of the design solution to the specific site microclimate allowed its short-comings to be realised. As such, it is recommended that the client undergoes further research and simulation into the benefits of the installation of an internal green wall, which still allows for potential expansion of PV system through building integrated PV (solar glazing), and the addition of a large tree for shading on the western lawn.

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APPENDICES

APPENDIX A: INFLUENCE ON GREEN STAR

There are nine categories of the Green Star Operational Performance of Buildings rating scheme and the proposed design solution is able to address all criteria as detailed below.

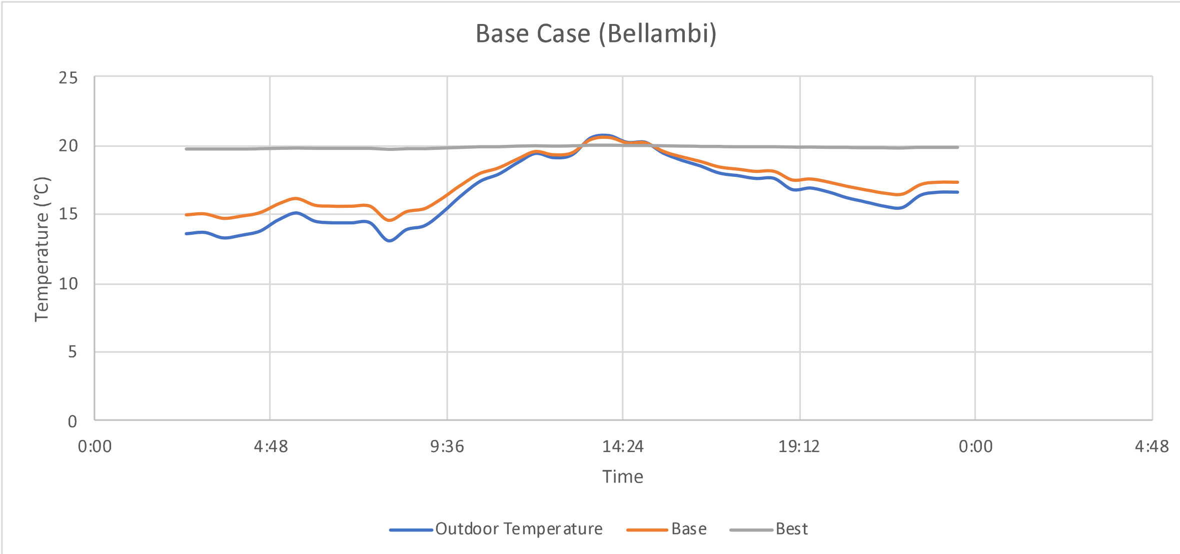
- Management: by implementing a design strategy that strives toward net-zero energy, the “project’s sustainability performance” will be significantly improved. The Ribbonwood Centre would become a ‘green icon’ in the Illawarra and demonstrate the steps toward achieving best practice in terms of sustainability.
- Indoor Environment Quality (IEQ): green walls have many benefits including improved air quality, reduction in temperature fluctuation and a salutogenic design appeal. As such, this solution not only improves an occupants experience of the space, but also positively contributes to their well-being.
- Energy: aforementioned, green walls reduce temperature fluctuations within a building which is most noticeable when considering cooling loads. The peak cooling load of a building will be reduced, thus the “building’s operation energy use” will be reduced during the associated periods, especially when comparing this to building’s constructed to similar standards in 2000.
- Transport: the Ribbonwood Centre is located a 10-minute walk from the train station, there are two bus stops located directly in front of the building and there is a bike stand. As such, the building inadvertently influences “community habits,” which if utilised by the occupant will reduce the greenhouse gas emissions associated with the building.
- Water: the downpipes from the roof are located on the southern end of the north-western facade, as such this stormwater collected on the roof can be redirected to irrigate the green wall via gravitational means. Therefore, the use of “potable water in building operations” is reduced as required by this criteria of the rating system.
- Materials: a single row of horizontal louvres is required to be removed from the building which can be melted down and recycled for another use. The plants used are carbon positive and both the vegetation and planter boxes can be sourced relatively locally, i.e. from greater Sydney and Illawarra regions. The planter boxes can be made from a range of recycled materials such as green concrete, recycled bricks, etc.
- Land Use and Ecology: the installation of an external green wall will encourage biodiversity within the area, thus “encouraging the restoration of natural environments.” However, it should be noted that the small size of the proposed green wall may not result in any increase in biodiversity, but this criteria can still be addressed as site runoff may be cleaner.
- Emissions: by implementing a passive solution, rather than active, to updating the existing HVAC system, the “point source” pollution generated by the building will be significantly reduced. Further, the building already has a 100kWP PV system, which has greatly reduced reliance on grid electricity as discussed in the business-as-usual analysis.
- Innovation: although the use of a green wall isn’t as ‘cutting-edge’ as some other active and passive sustainable solutions being developed, it still isn’t commonplace in public buildings, thus allowing the Ribbonwood Centre to address this criteria.

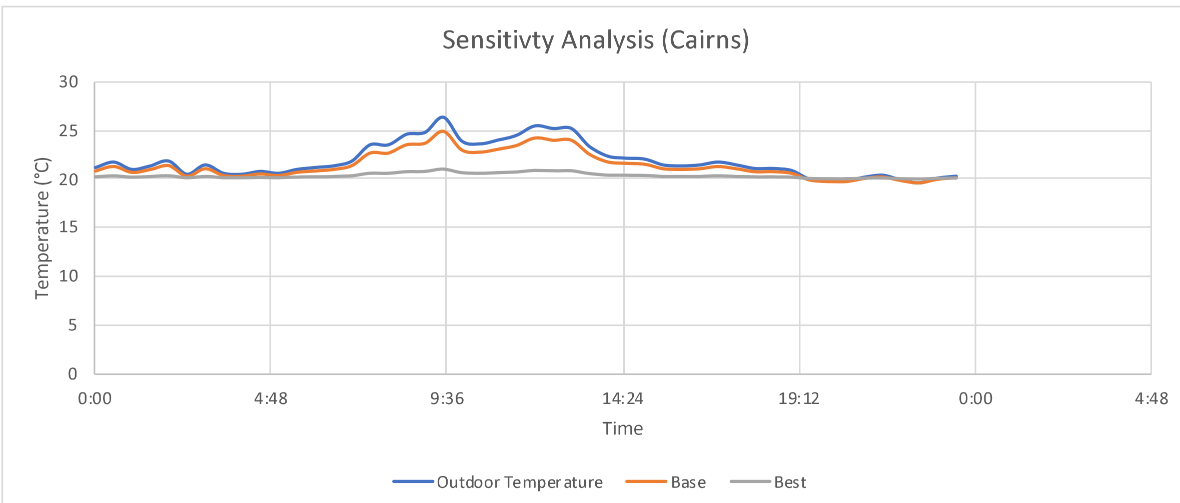
Evidently, the proposed design solution will have a significant impact on the building's ability to achieve a 5 Star Green Star rating as desired by the client. Figure X below describes the the minimum expectations to achieve a 5 Star Green Star rating, with the box on the right side exploring the headings addressed above.

APPENDIX B: SENSITIVITY ANALYSIS

A sensitivity analysis was conducted on the base case in order to determine its accuracy and reliability. This was achieved by changing the weather file from Bellambi to Cairns, which may mimic the climatic conditions that would be experienced at the site as a result of climate change. As such, this simultaneously allowed the building's resilience to change to be analysed. An arbitrary day was chosen, 01/06/2021, to provide a basis for comparison and the outputs from this analysis can be seen in figure X and X below.

In both simulations, the HVAC temperature was kept at 20 degrees C, therefore since outdoor temperatures are cooler in Bellambi, the indoor temperature line is on top, whilst the opposite holds true for Cairns as expected, thus the simulations can be considered accurate.





APPENDIX C: REFLECTION ON BUILDING SIMULATION EXPERIENCE

I found the process of simulating the building using SketchUp and OpenStudio extremely difficult considering my lack of experience with the software, the limitations of my laptop and time constraints to learn, produce and analyse results in a manner that would be able to do my proposed solution justice. I experienced many setbacks when undertaking the process and spent many hours trying to troubleshoot these to no avail, as such the results I managed to derive were simple and not to the extent or variety I had set out to do. Overall, I found the process of simulating a building an extremely useful tool in theory but much more intricate and complex than expected.

<u>Advanced Building Design for Energy Efficiency and Sustainability</u>

(ENGG947)

Assessment 3

Report on

'Optimization of Energy Performance of Dapto Ribbonwood Centre'

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1. Executive Summary

Dapto Ribbonwood Centre was subjected for renovation. During the site analysis, based on the client requirements, building standards and the user feedbacks, the major energy performance and sustainability issues were identified. Potential solutions were suggested to rectify these issues. Among the suggested solutions, the window system as well as lighting system was found to be most promising, and their effects were quantified using software simulations.

Upgrades on window system was commonly adopted during most of the building renovation. The ease for retrofitting and the economy of the operation were the major factors for their popularity. Moreover, windows severely affect the solar heat gain and heat loss in a building. There were also client complaints regarding high solar gain and lack of comfort especially in the lobby and Kurrajong hall. Therefore, the effects of different retrofit measures, mainly the replacements for the glazing surface were analysed in detail in this study. Similarly, the lighting system also have a high energy saving potential. They directly affect the energy consumption and the thermal conditions inside a space. Moreover, the lighting systems were outdated on regards to the new building standards. The cooling dominant conditions of the building also verifies the relevance of the selections.

To analyse these solutions, OpenStudio was found to be the most compatible software. A baseline model was created by incorporating certain assumptions. ASHRAE 189.1 standards were used in situations when the necessary data was unavailable. Since, only the relative advantages were analysed, the operation can be considered valid. By virtually modifying the building with the different systems individually, the effects of each system were identified, and a comparative study was organized.

Among the window system the tinted glasses were found to be the most optimal solution regarding the energy consumption. It can save up to 17.34GJ of energy. However, this will limit the ability to effectively utilize the natural lighting. Likewise, among the lighting scheme the National Construction Code (NCC) 2019 based system reduces the lighting load by almost one-third and reduces the total energy consumption by 16.04 %. Therefore, it is highly recommended to replace the current fluorescent lighting with high efficiency LED lighting. These modifications were adopted to simulate the results of the proposed model. It was found that the final energy consumption was 17.18% lower than the baseline results. The simulation results indicates that the building can be rated with 5 stars using NABERS based on the energy intensity. This study depicts various evidence for the processes mainly related to the energy optimization of the Dapto Ribbon wood Centre.

2. Design solution

The table 1 indicates the section of the selection matrix solutions used in the analysis of Dapto Ribbonwood Centre. In this process we have focused mainly on the impacts on the sustainability aspects of the buildings. The mentioned solutions were above the cut-off grade used in the selection process. The present study was organized to quantify the effects of **lighting systems** and **window systems** on Ribbonwood Centre.

	Feasibility	Cost	Reliability and maintainability	Energy Saving Potential	Potential Impact on star ratings	Carbon Saving Potential	Lifecycle	Innovation	Total
Weightage	0.1	0.1	0.1	0.15	0.2	0.15	0.05	0.15	1
Lighting System	7	6	8	8	9	8	4	5	**7.25**
Window Systems	6	2	7	4	6	4	8	3	**4.75**

Table 1: Selection matrix

The lighting system is one of the highly ranked solutions for the sustainability issues of the building. And it has a high feasibility value. Therefore, it has a great scope during the renovation process. The current building was installed with T5 type fluorescent lighting. However, they are highly energy consuming and generates large amount of heat energy inside the building. Replacement of these system with LED can reduce the energy consumption to a maximum of up to 50%. Since the energy consumption and the greenhouse emissions are related, the sustainability perspectives of these replacements are high. These systems coupled with organic response and intelligent lighting technology can further improve their efficiency. Many of the software platform cannot design these advanced technologies. However, they can provide a basic overview of the LED replacements. In here we analyse the effects of lighting schemes based on 2016 and 1019 National Construction Codes. And it is guaranteed that the final outcome of these combined system will be more than the baseline value. The table below represents the difference between the NCC schemes.

Space Type	**NCC 2016 (MJ/m^2)**	**NCC 2019 (MJ/m^2)**	**Percentage Reduction**
Office	9	4.5	50%
Hall/Auditorium	10	8	20%
Library	10	4.5	55%
Corridor	8	5	37.5%
Plant room	5	4	20%
Lobby	15	9	40%
Restroom	6	3	50%
Storage	8	1.5	81%
Kitchen	8	4	50%

Table 2: Comparison of NCC lighting schemes of 2016 and 2019 (Abcb.gov.au, 2016; Abcb.gov.au, 2019)

The figure 1 indicates the common types of renovations carried out among the 33 buildings studied (Miezis et al., 2016)

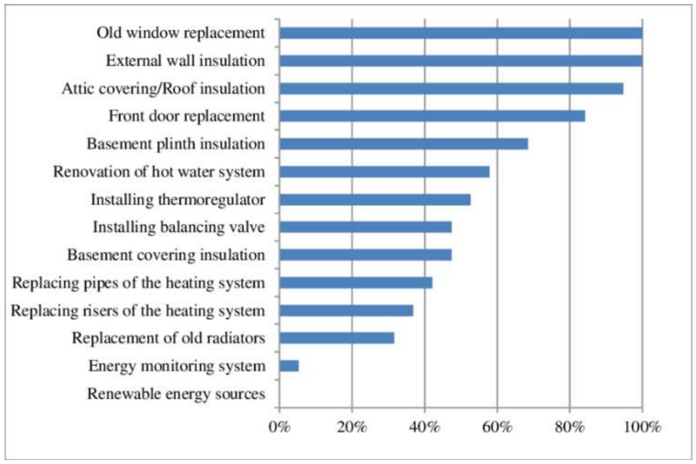


Figure 1Share of energy efficiency measures implemented (Miezis et al., 2016)

It can be observed that all these buildings have adopted measures to improve their window systems. This was because renovations and modern systems can improve the internal comfort conditions of a building (Miezis et al., 2016). The selection matrix was highly biased on the energy saving potential. Therefore, the ranking of window system was lower. However, they are great for retrofits and these procedures are more economical. Because of these reasons, windows were selected for this analysis from the list of solutions.

The simulations involved in this study analyses the effects of clear glass, double glazing, venetian blinds, glasses with low-E film and the tinted glasses. Software simulation mainly quantifies the performance aspects of the window systems. But in actual situation, some of the described solutions can provide additional benefits such as acoustic insulation, vapor barrier, infiltration prevention, solar transmittance control etc. Moreover, these are passive thermal control measures without any additional operational cost and less maintenance requirements.

The relevance of the current selection can be validated from the general analysis of the simulation results. The detailed description of these selection are also described on the simulation section of this report.

3. Methodology

To quantify the effectiveness of the proposed solutions software simulations were used. They can create a baseline value that can be calibrated with the utility bills. They can also provide capabilities for dynamic analysis and have provisions for real time comparisons. Moreover, virtual modifications were possible to obtain an optimized result (BBC Bitesize, n.d.). That was the reason why simulation was used in the process. The software used was OpenStudio, which runs on the energy plus engine. This was due to the nature of the solutions selected for analysis. The window system and the lighting systems are related to the solar heat gain/loss as well as the internal load. They are the factors which affect the thermal conditions inside the building. Furthermore, energy saving potential as well as their related reduction in emissions were the focal point of the study. OpenStudio is one of the best software that can be easily operated with only a fundamental understanding, to analyse the energy performance related to the thermal and internal loads. Therefore, they can provide close to accurate results for the present scenario.

The current study demands a virtual model to be designed based on the existing model. The SketchUp software was used to design the model in accordance with the architectural drawings. The different rooms were designed as different thermal zones and the corresponding internal loads were defined. To simulate the performance and thereby establishing a baseline an Energyplus weather data of the closest location were used.

The brief analysis has described about the different methods by which a window system could be modified. Some of them complements each other, while some were contradictory. Therefore, the potential changes were simulated individually to find their effectiveness independent of others. Similar, process was also established for the lighting systems. There were no extensive details available on the present lighting system. A standard lighting system was used to create the baseline for this case and the other schemes were compared to find the relative advantages. The outcomes were critically analysed to obtain the best solutions from the list of solutions, and they were combined together to simulate the scenario. This was compared with the baseline data to illustrate the advantage of the proposed modifications.

3.1. Assumptions

The simulation was conducted only to analyse the relative advantage of different solutions. Moreover, the limitations in time and data demands the use of various assumptions to simulate similar conditions. Few of those assumptions are mentioned below.

- Only the building A was modelled since it was observed that most of the frequently used facilities are located inside this main building. They contribute to the major share in the energy consumption.
- The weather data for Dapto were not available on for energyplus. The closest available locations to the Dapto were Sydney and Nowra. All these locations belong to the climatic zone 5 (Australian Building Codes Board, 2015). Since Nowra was different to a metropolitan area like Sydney, Dapto was found to be most similar to Nowra.
- In the absence of necessary data to run the simulation, ASHRAE 189.1-2009 standards were used. It provides a satisfactory result since only a comparative study was performed. Moreover, OpenStudio runs on the ASHRAE 2009 standards (American Society Of Heating, Refrigerating And Air-Conditioning Engineers et al., 2010). It helps to maintain the uniformity between various functions used.
- One of the potential solutions was the replacement of the current lighting system with the LEDs. However, there was no provisions for simulating the exact situation. The software provided options to only vary the energy intensity of lighting. Therefore, different lighting schemes were used for the comparison. These schemes have already included the effects of new lighting technology in their design.

4. Results

4.1. General observations

The figure 2 represents the baseline energy consumption of the simulated model. It can be observed that 1438.45GJ of energy is consumed annually. The site energy represents the actual consumed energy whereas the source energy includes the production and delivery losses included (energystar-mesa.force.com, n.d.). Since the software was designed with 2009 standards the source values are highly unlikely. Therefore, Site energy consumption was selected as the major parameter.

	Total Energy [GJ]	Energy Per Total Building Area [MJ/m2]	Energy Per Conditioned Building Area [MJ/m2]
Total Site Energy	1438.45	570.28	570.28
Net Site Energy	1438.45	570.28	570.28
Total Source Energy	2703.01	1071.62	1071.62
Net Source Energy	2703.01	1071.62	1071.62

Figure 2: Energy consumption of the baseline scenario

The energy consumed in various factions of utility can be observed on the figure 3 below. The table illustrates that almost 62% of energy was utilized in the colling process and 23% for the lighting.

	Electricity Intensity [MJ/m2]	District Cooling Intensity [MJ/m2]	District Heating Intensity [MJ/m2]	Water Intensity [m3/m2]
Lighting	133.58	0.00	0.00	0.00
HVAC	0.00	351.74	18.34	0.00
Other	66.61	0.00	0.00	0.00
Total	200.20	351.74	18.34	0.00

Figure 3: Energy intensities of various faction in baseline scenario

The energy consumption of the heating and cooling during the mid winter and mid summer are depicted in the figure 4. The data provide an accurate indicater that unlike the cooling requirement that requires almost constant energy requirement throughout the year, the heating requirements are less and it fluctuates. This result along with the previous observations, indicates that cooling requirements are dominant

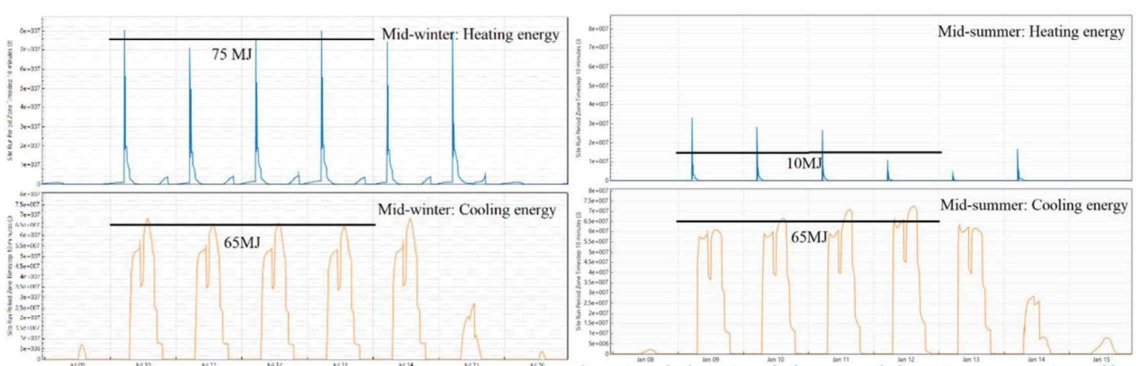


Figure 4: Energy consumption for heating and cooling

Therefore, it is recommended to adopt measures to reduce the cooling requirements. Two ways to resolve this are to reduce the internal heat generation and to reduce the solar gain into the building. The lighting system is one of the major energy consumer as well as the source for heat generation. Hence, it can significantly reduce the energy consumption. Secondly the window system plays an important role in regulating the solar gain into a building. The figure 5 also indicates that, at average 14% of the total surface are window openings and thereby it can affect the thermal performance. Thus, the selection of these solutions is relevant for Ribbonwood Center.

	Total	North (315 to 45 deg)	East (45 to 135 deg)	South (135 to 225 deg)	West (225 to 315 deg)
Gross Wall Area [m2]	1726.14	412.12	435.96	503.89	374.18
Above Ground Wall Area [m2]	1726.14	412.12	435.96	503.89	374.18
Window Opening Area [m2]	235.27	55.49	2.72	57.25	119.82
Gross Window-Wall Ratio [%]	13.63	13.46	0.62	11.36	32.02
Above Ground Window-Wall Ratio [%]	13.63	13.46	0.62	11.36	32.02

Figure 5: Window to wall ratio

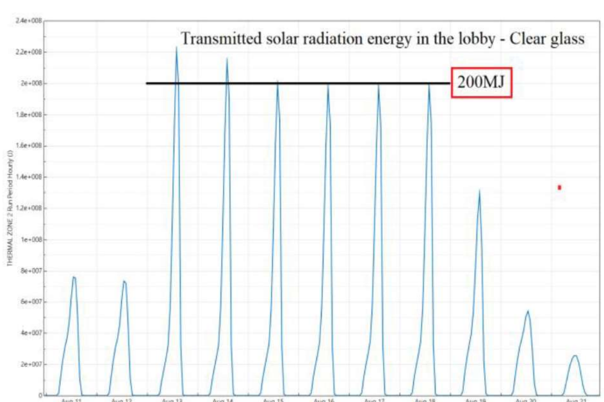
4.2. Window system

The baseline case was created using the clear glass as the window material. The attributes indicates the parameters used to define the material in OpenStudio. The key performance used for the comparison indicators were the total energy consumption and their effects on the heating and cooling. Since the lobby was a zone having the largest window to wall ratio as well as the area of issue indicated in the client requirement section, the transmitted solar radiation energy of this area was also used for the process of analysis.

Attributes	
Number of Panes	Single pane
Tint	Clear
Overall U-factor	5.894 W/m^2 K
Solar Heat Gain Coefficient	0.861
Visible Light Transmittance	0.898
OpenStudio Type	OS:Construction

	District Cooling Intensity [MJ/m2]	District Heating Intensity [MJ/m2]
Lighting	0.00	0.00
HVAC	351.74	18.34
Other	0.00	0.00
Total	351.74	18.34

Heating and cooling - Clear glass



	Total Energy [GJ]	Energy Per Total Building Area [MJ/m2]	Energy Per Conditioned Building Area [MJ/m2]
Total Site Energy	1438.45	570.28	570.28
Net Site Energy	1438.45	570.28	570.28
Total Source Energy	2703.01	1071.62	1071.62
Net Source Energy	2703.01	1071.62	1071.62

Total energy - Clear glass

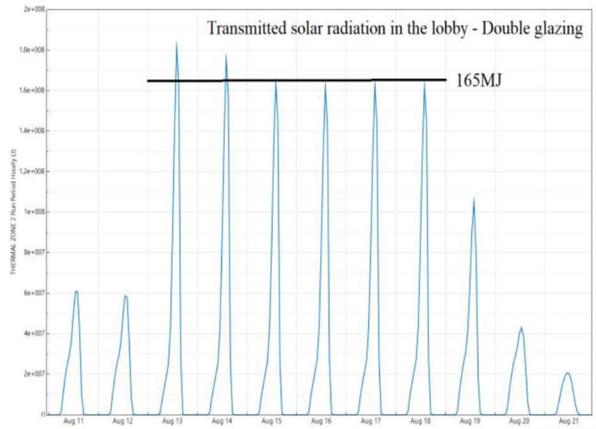
Figure 6:Simulation results for clear glass (baseline)

Double glazing: The figures below indicates the performance of the double glazing windows when used throughout the building. It can save 13.77GJ of energy. It is the best solution when the natural day light utilisation and themal perfomance improvements are required.

Attributes	
Number of Panes	Double pane
Gas Fill	Air
Tint	Clear
Overall U-factor	3.122 W/m^2 K
Solar Heat Gain Coefficient	0.762
Visible Light Transmittance	0.812
OpenStudio Type	OS:Construction

	District Cooling Intensity [MJ/m2]	District Heating Intensity [MJ/m2]
Lighting	0.00	0.00
HVAC	349.98	14.64
Other	0.00	0.00
Total	349.98	14.64

Heating and cooling - Double glazing



	Total Energy [GJ]	Energy Per Total Building Area [MJ/m2]	Energy Per Conditioned Building Area [MJ/m2]
Total Site Energy	1424.68	564.82	564.82
Net Site Energy	1424.68	564.82	564.82
Total Source Energy	2664.61	1056.40	1056.40
Net Source Energy	2664.61	1056.40	1056.40

Total energy - Double glazing

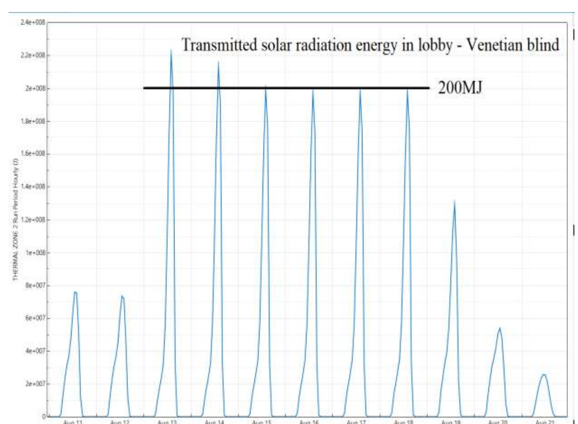
Figure 7: Simulation results for double glazing

Venetian blinds: These are attachment type system used when the amount of transmitted lights needed to be adjusted (manual adjustments). Theoretically, this should have provided better result. However, the attributes provided was insufficient to describe the material. Hence, the results obtained was faulty and were similar to the results of clear glass.

Attributes	
Visible Light Transmittance	0.01
Visible Light Transmittance Specular Percentage	100 %
Tint	Clear
Interior Shade Layer Type	Blind

	District Cooling Intensity [MJ/m2]	District Heating Intensity [MJ/m2]
Lighting	0.00	0.00
HVAC	352.03	18.19
Other	0.00	0.00
Total	352.03	18.19

Heating and cooling - Venetian blind



	Total Energy [GJ]	Energy Per Total Building Area [MJ/m2]	Energy Per Conditioned Building Area [MJ/m2]
Total Site Energy	1438.78	570.41	570.41
Net Site Energy	1438.78	570.41	570.41
Total Source Energy	2702.36	1071.36	1071.36
Net Source Energy	2702.36	1071.36	1071.36

Total energy - Venetian blind

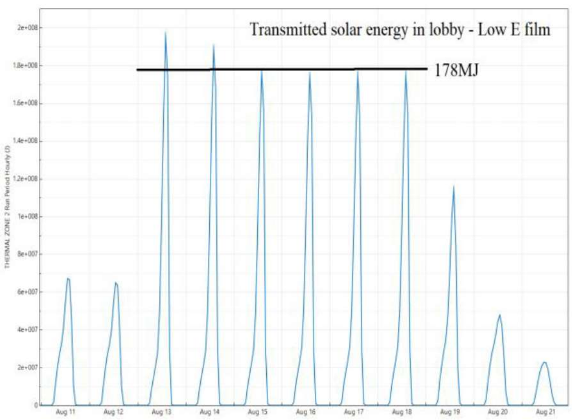
Figure 8: Simulation results for window with venetian blinds

Low-E film: These low emissive films are attached on the glazing in order to reduce the radiant rays. The Results indicates that it can save upto 8.46GJ of energy by reflecting the radiant solar rays. As observed from the figure 9, these have high transmittance for visible light. They are economical and easy for retrofits. It can be an effective replacement when cost becomes an issue and major performance improvisations were required.

Attributes	
Number of Panes	Single pane
Tint	Clear
Overall U-factor	3.835 W/m^2 K
Solar Heat Gain Coefficient	0.768
Visible Light Transmittance	0.821
OpenStudio Type	OS:Construction

	District Cooling Intensity [MJ/m2]	District Heating Intensity [MJ/m2]
Lighting	0.00	0.00
HVAC	352.16	14.97
Other	0.00	0.00
Total	352.16	14.97

Heating and cooling - Low E film



	Total Energy [GJ]	Energy Per Total Building Area [MJ/m2]	Energy Per Conditioned Building Area [MJ/m2]
Total Site Energy	1430.99	567.32	567.32
Net Site Energy	1430.99	567.32	567.32
Total Source Energy	2673.37	1059.87	1059.87
Net Source Energy	2673.37	1059.87	1059.87

Total energy - Low E film

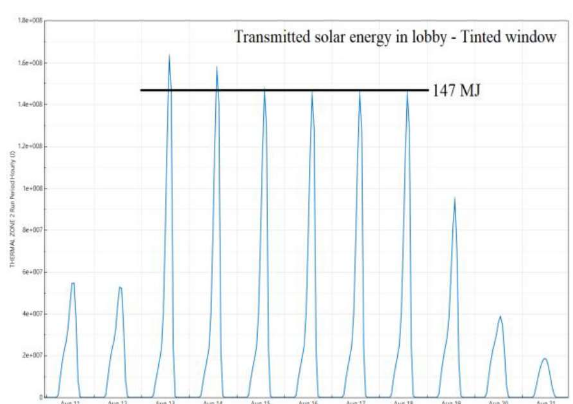
Figure 9: Simulation results for window with low-E film

Tinted windows: They have an energy savings of 17.34GJ. This was the solution with the lowest energy consumption among the alternatives. This also provides the least solar energy transmittance into the lobby.

Attributes	
Number of Panes	Single pane
Tint	Grey
Overall U-factor	5.894 W/m^2 K
Solar Heat Gain Coefficient	0.716
Visible Light Transmittance	0.611
OpenStudio Type	OS:Construction

	District Cooling Intensity [MJ/m2]	District Heating Intensity [MJ/m2]
Lighting	0.00	0.00
HVAC	344.55	18.66
Other	0.00	0.00
Total	344.55	18.66

Heating and cooling - Tinted window



	Total Energy [GJ]	Energy Per Total Building Area [MJ/m2]	Energy Per Conditioned Building Area [MJ/m2]
Total Site Energy	1421.11	563.41	563.41
Net Site Energy	1421.11	563.41	563.41
Total Source Energy	2686.75	1065.17	1065.17
Net Source Energy	2686.75	1065.17	1065.17

Total energy - Tinted window

Figure 10: Simulation results for tinted window

4.3. Lighting Schemes

The figure 11 was the indicator of the energy performance of the NCC 2016 lighting schemes. The major parameters used for the comparison in this section were the energy consumption, lighting energy intensity and energy intersity for the lighting and cooling. The energy consumption of NCC 2016 was 1330.08GJ compared to the 1438.45GJ of the baseline scenario.

	Total Energy [GJ]	Energy Per Total Building Area [MJ/m2]	Energy Per Conditioned Building Area [MJ/m2]
Total Site Energy	1330.08	527.32	527.32
Net Site Energy	1330.08	527.32	527.32
Total Source Energy	2457.43	974.26	974.26
Net Source Energy	2457.43	974.26	974.26

Total energy - NCC 2016

	Electricity Intensity [MJ/m2]	District Cooling Intensity [MJ/m2]	District Heating Intensity [MJ/m2]	Water Intensity [m3/m2]
Lighting	108.37	0.00	0.00	0.00
HVAC	0.00	333.51	18.82	0.00
Other	66.61	0.00	0.00	0.00
Total	174.98	333.51	18.82	0.00

Share of energy intensity - NCC 2016

Figure 11: Simulation results for NCC 2016 Scheme

The NCC 2019 was obviously the better choice due to their least energy requirement. There was significant improvement in the cooling requirement along with the lighting energy.

	Total Energy [GJ]	Energy Per Total Building Area [MJ/m2]	Energy Per Conditioned Building Area [MJ/m2]
Total Site Energy	1207.70	478.80	478.80
Net Site Energy	1207.70	478.80	478.80
Total Source Energy	2182.40	865.22	865.22
Net Source Energy	2182.40	865.22	865.22

Total energy - NCC2019

	Electricity Intensity [MJ/m2]	District Cooling Intensity [MJ/m2]	District Heating Intensity [MJ/m2]	Water Intensity [m3/m2]
Lighting	77.41	0.00	0.00	0.00
HVAC	0.00	313.00	21.77	0.00
Other	66.61	0.00	0.00	0.00
Total	144.03	313.00	21.77	0.00

Share of energy intensity - NCC 2109

Figure 12: Simulation results for NCC 2019 scheme

4.4. Proposed model

As identified from the best solutions from the diverse options were selected and combined to provide an overview of the upgraded model. This includes the use of the tinted windows along with the NCC 2019 lighting schemes. The result are illustrated in the figure 13 below. It has a final energy consumption of 1191.28GJ with an energy intensity of 472.29 MJ/m^2.

	Total Energy [GJ]	Energy Per Total Building Area [MJ/m2]	Energy Per Conditioned Building Area [MJ/m2]
Total Site Energy	1191.28	472.29	472.29
Net Site Energy	1191.28	472.29	472.29
Total Source Energy	2167.77	859.42	859.42
Net Source Energy	2167.77	859.42	859.42

	Electricity Intensity [MJ/m2]	District Cooling Intensity [MJ/m2]	District Heating Intensity [MJ/m2]	Water Intensity [m3/m2]
Lighting	77.41	0.00	0.00	0.00
HVAC	0.00	306.07	22.19	0.00
Other	66.61	0.00	0.00	0.00
Total	144.03	306.07	22.19	0.00

Figure 13: Simulation results of the improvised model

5. Discussion

Window system:

The energy savings by using different glazing materials are indicated in the table below.

Material	**Total Energy (GJ)**	**Energy Saving (GJ)**
Clear glass	1438.45	Baseline
Double glazing	1424.68	13.77
Venetian blind	1438.78	-0.33
Low-E film	1430.99	8.46
Tinted window	1421.11	17.34

Table 3: Comparison of window material

It can be observed that the tinted windows have the best results among the various alternatives. Therefore, it was selected as the best option for the proposed model. This 17. 34 GJ of energy is equivalent to a carbon saving potential of 3.95 tonnes of carbon dioxide equivalent (Powershop, 2019). However, this system prevents the utilization of the natural lighting. As mentioned earlier, if the intelligent lighting system is used this may contradict the situation. During that time the glazed windows will be more efficient. It have high transmittance, low thermal conductivity, good acoustic insulation and its performance can be improved by filling the gap with low conductive gases or PCMs (Li et al., 2016).

Lighting system:

Similar comparisons can be performed to analyse the effectiveness of the different lighting schemes. The table 4 represents the advantages of various lighting schemes. It has to be considered that the simulation used the energy intensity as the input. This might not be able to accurately model certain areas such as the stage section of Kurrajong hall or the lobby with a high concentration of bulbs placed. It also eliminates the effects of active control system that was proposed in the initial briefings. The new schemes was designed on the fact that high efficient bulbs are being used while providing the same lux level of brightness. It basically implies the use of LED instead of current lighting. As indicated in table 4 the NCC 2019 can save upto 230.75GJ of energy which was around 16% of the baseline energy consumption. It saves 52.56 tonnes of CO_2 equivalent.

Scheme	Lighting Energy (MJ/m^2)	Total Energy (GJ)	Energy Saving (%)
ASHRAE 189.1	133.58	1438.45	Baseline
NCC 2016	108.37	1330.08	7.53% (108.37GJ)
NCC 2019	77.41	1207.70	16.04% (230.75GJ)

Table 4: Comparison of lighting scheme

Proposed solution:

When the upgrades were compared with the baseline data, the following results were obtained. It was used to create the energy intensity comparison as well as the energy saving comparison as shown in the figure 15 and 16.

Model	Energy intensity (MJ/m^2)				Total energy consumption (GJ)
	Lighting	Cooling	Heating	Others	
Baseline	133.58	351.74	18.34	144.03	1438.45
Improvised	77.41	306.07	22.19	144.03	1191.28

Figure 14: Comparisons of final results

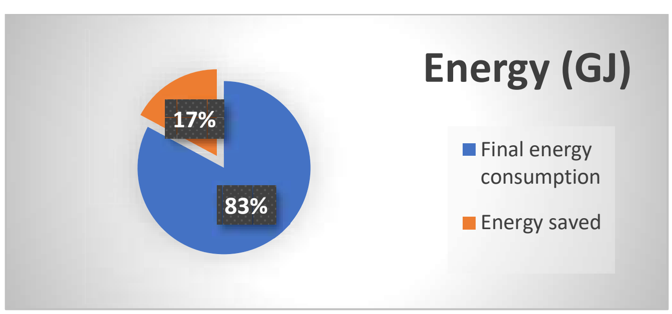


Figure 15: Energy saving potential

The pie chart indicates that the proposed solution can save 17% of the baseline energy usage and the bar chart shows that Cooling load remains the highest even when there was some reductions. Lighting load have also reduced while others remain almost same.

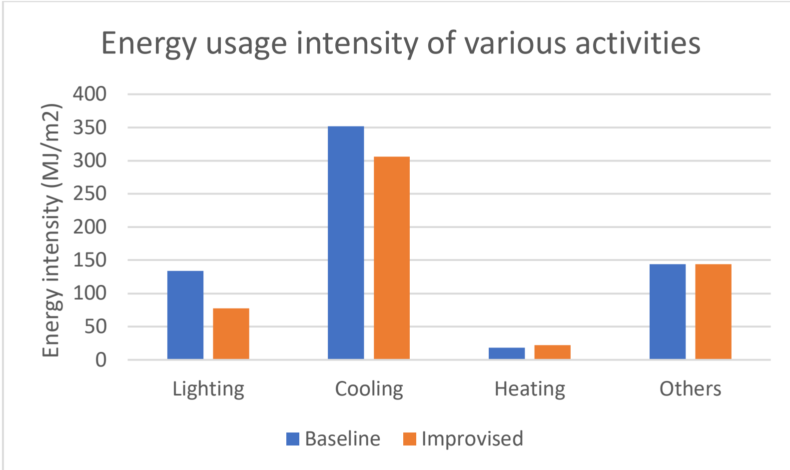


Figure 16: Energy intensity comparison

According to NABERS energy performance analysis a savings of 223500kWh can increase the rating by 1 star. However, the final savings obtained were only 68658.3333kWh (247.17GJ), which indicates that the NABERS sustainability rating remains same. Also, there were indicators that 408 MJ/m^2 was 5 stars and 612 MJ/m^2 was 6 stars (NABERS, 2019). The final result of 472.29 MJ/m^2 denotes the Dapto Ribbonwood Centre to be a 5 star building.

6. Conclusion

A portion of Dapto Ribbonwood Centre was modelled with ASHRAE 189.1 standards to create a baseline for the study. The impacts of reforms in the two best choices, which are the window material and lighting schemes were analysed using the open studio simulations. The crucial findings obtained are.

- The Cooling requirements are dominant.
- The tinted window system provides the best results with 17.34GJ worth of energy saving. However, it might affect the capacity for natural lighting.
- The NCC 2019 lighting scheme can save up to 16.04% of the consumed energy. The benefits will further improve with active control. It is highly recommended to change the current lighting with LED lighting.
- Proposed solution has a combined effect of tinted window and NCC 2019 lighting system and can save 17% of the baseline consumption and can save 56.3 tonnes of CO_2 equivalent.
- The Building was identified to be 5 stars rated according to NABERS.

Reference

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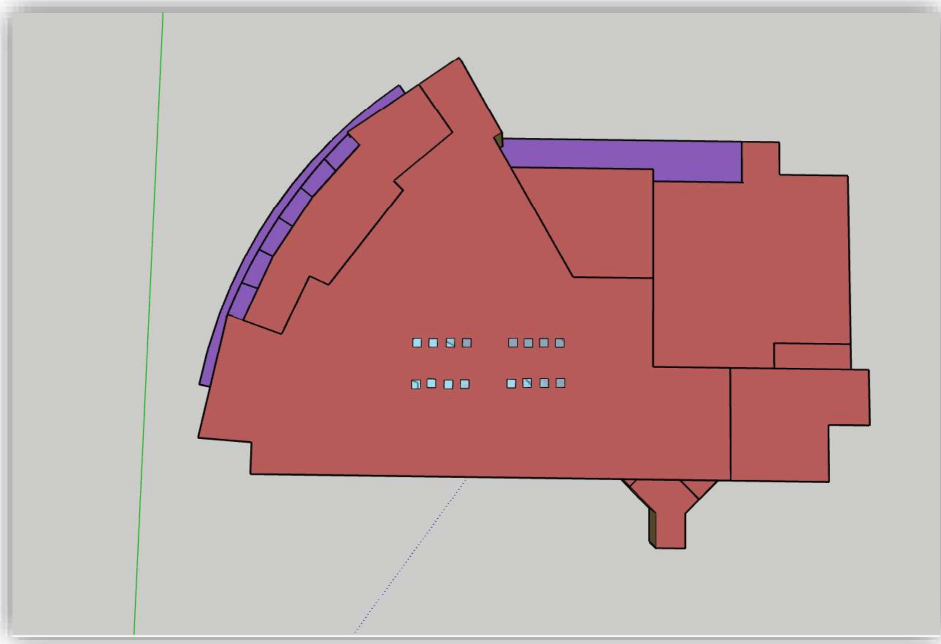
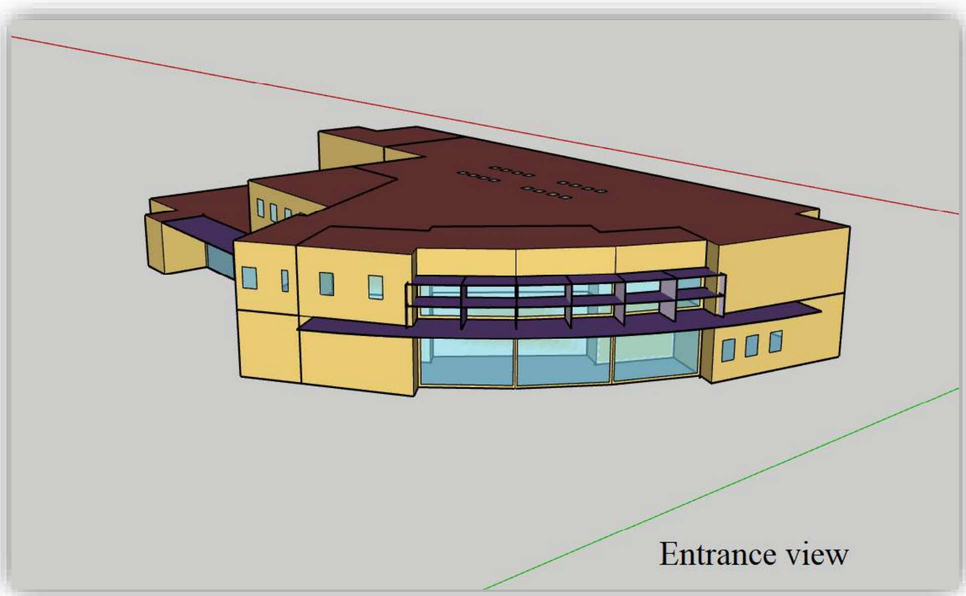
Appendix

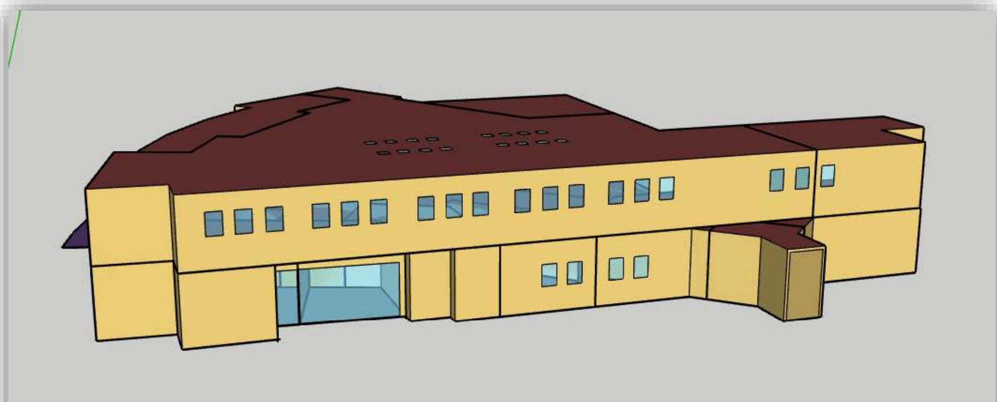
OpenStudio Models:



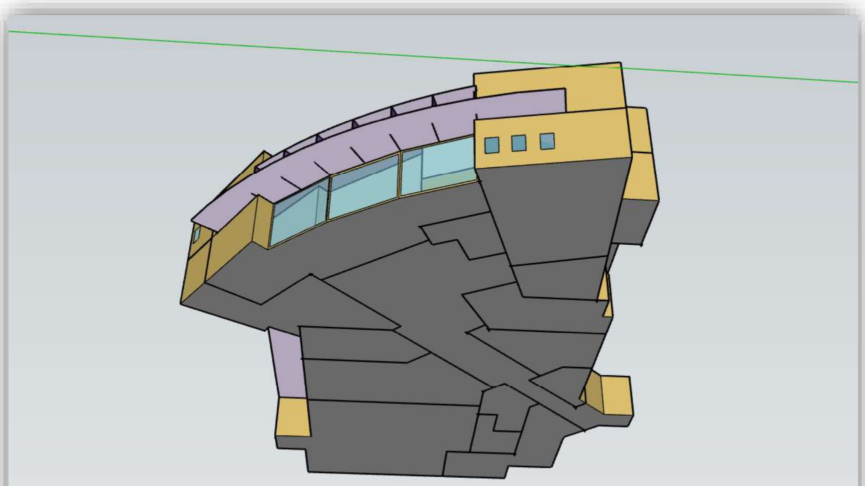


Entrance view

North side view



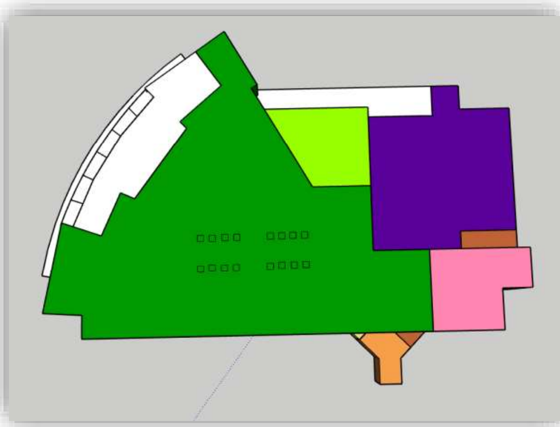
South side view

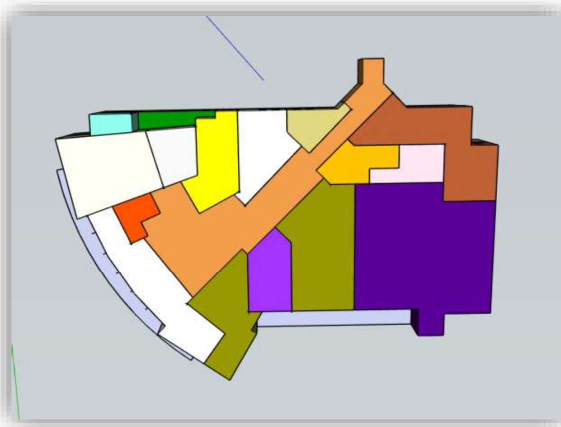


Bottom view - zone divisions

Space Types:

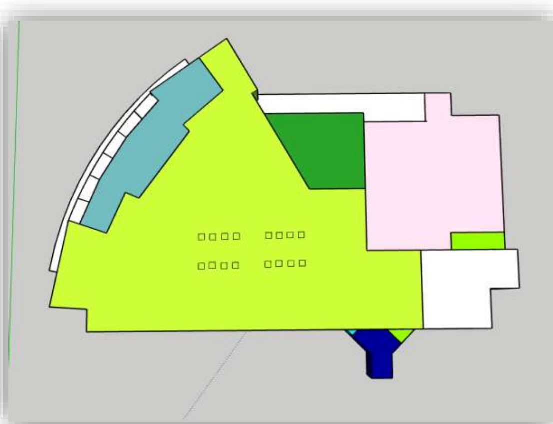
Total of 18 space types

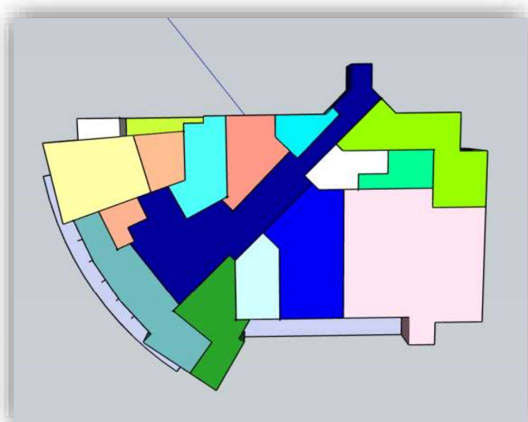




Thermal zones:

Total of 18 thermal zones





ENGG447 | Assessment Task 3

1.0 - Executive summary

This report outlines the design options presented in order to upgrade the existing Ribbonwood Center in Dapto. The building was initially constructed in 2000 and is in need of a retrofit. For the purpose of this report, changes to strive towards a net zero emissions building and a 5 or 6 Star Green Star Rating.

This report outlines a design solution to both increase the energy production on site and make improvements to accessibility. It should be noted that in order to achieve all the goals set by this subject, the solutions presented in this report should be utilised in combination with energy-reduction solutions presented by my peers in the subject.

The solutions to be presented are:

- **Carport with rooftop solar:** The goal of this option was to increase the surface area of the Ribbonwood Center that can be utilised for solar energy production. With the new rood area created by this option, it is estimated that an additional 154 657 kWh/year, or 34 kWh/yr.m^2 per GFA can be generated for the site.

  With the additional energy generated on site if this option were proceeded with, the new benchmark for energy usage goals at the Ribbonwood Centre would be 79 $kWh/yr.m^2$

- **Ramp access to the library:** On the site visit to the Ribbonwood Center, a regular user of the building identified the need for a ramp access to the library, on the first floor of the community centre.

  The investigation demonstrated that the spatial requirements of this ramp limited the locations it can be placed. The location finally chosen was the eastern side of the building. This would require much structural work, and by the end of the assignment it was decided that while the ramp access can be added, it will require a lot of effort.

2.0 - Design solutions considered

2.1 - Carport and additional solar panels

To increase the potential for solar energy production on site, carports are to be added to maximise roof space of the Ribbonwood Centre.

It is proposed that an electric vehicle (EV) charging space is also provided beneath one of the carports. This would be extremely beneficial as it promotes the Ribbonwood Center as a site ready for advances in a sustainable future, the source of energy right above the parking space makes this a suitable option. It is recommended that while EVs are an emerging technology, only two spaces are saved for EVs. If the demand for more EV parking spaces arises in the future they can be added at that stage.

Figure 2.1 - Areas for additional roofing and solar panels

The feasibility of this option has been rated in accordance to the matrix utilised in assignment 2. The most relevant feasibility factors have been outlined in Table 2.1 below, the full decision matrix has been supplied in Appendix C.

Table 2.1 - Decision matrix of additional roofing with solar panels

Proposal	Capital costs	Operational costs	Net Zero Impact	Site specific feasibility	Resilience to climate change	Total (/180)
Carport with additional solar panels	High	Saves money by cutting electricity costs	Positive	Moderate - Feasible to build, but will require the car park to be closed temporarily.	High - Will generate more energy (using Darwin data)	122

2.2 - Ramp access to library

On the site visit to the Ribbonwood Center, a regular user of the building brought up the issue of accessibility to the library on the upper floor. Although there is an elevator installed for the purpose of accessibility, the elevator poses the issue of maneuverability for wheelchair users. Additionally, in the case of an emergency evacuation where the elevator cannot be used, it poses a safety risk for those unable to utilize the stairs.

Although the spatial requirements make this an unfavourable option, as demonstrated in Table 2.2, a Sketch Up model will be proceeded with in this report to gain a visual understanding of how this option may be approached.

Table 2.2 - Decision matrix of ramp access to library

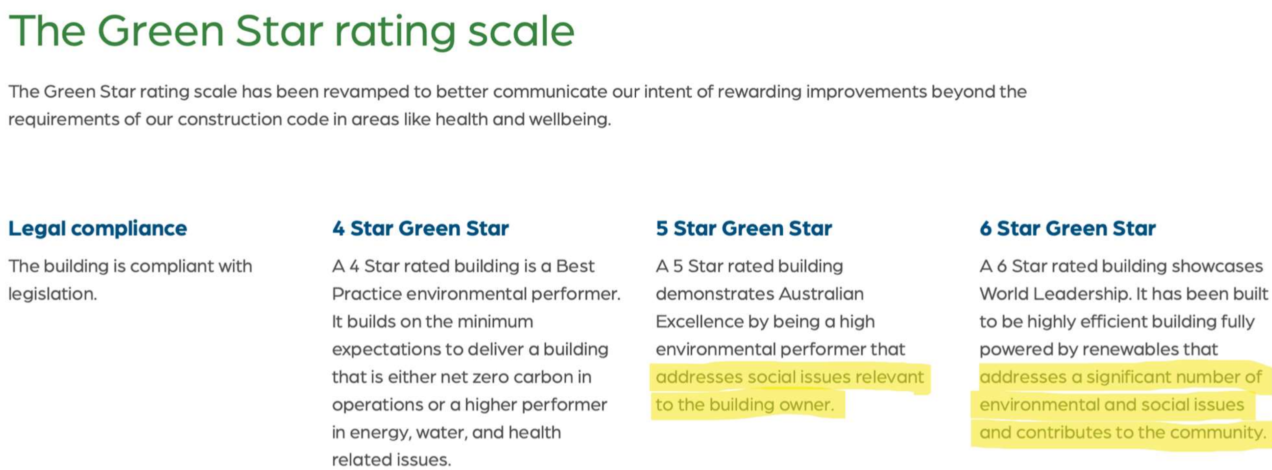
Proposal	Impact on Green Star buildings	Site specific feasibility	Accessibility criteria	Occupant experience	Energy performance increase	Total (/180)
Ramp access to library	Slightly positive as it addresses social issues	The spatial requirements make this a low feasibility solution	Positive impact	High - meets a demand users have requested	Neutral	117

3.0 - Methodology and main assumptions

3.1 - Benchmarking

The benchmarking techniques will be briefly re-stated to give context to the design solutions proposed in this report. To achieve net zero emissions in the built environment, the energy consumption from the building must be lower than the on site energy production. The options to be presented in this report are aimed at achieving the latter, increasing the energy production so that it exceeds that utilised by the community centre. The options to be presented in this report are to be utilised in conjunction with energy-reducing options presented by other students.

An additional goal for the design options presented in this report is retrofits to strive towards a 5- or 6- star energy rating. To achieve either of these ratings, as a community centre, the building should address social issues of the wider Dapto community.



The Green Star rating scale

The Green Star rating scale has been revamped to better communicate our intent of rewarding improvements beyond the requirements of our construction code in areas like health and wellbeing.

Legal compliance

The building is compliant with legislation.

4 Star Green Star

A 4 Star rated building is a Best Practice environmental performer. It builds on the minimum expectations to deliver a building that is either net zero carbon in operations or a higher performer in energy, water, and health related issues.

5 Star Green Star

A 5 Star rated building demonstrates Australian Excellence by being a high environmental performer that addresses social issues relevant to the building owner.

6 Star Green Star

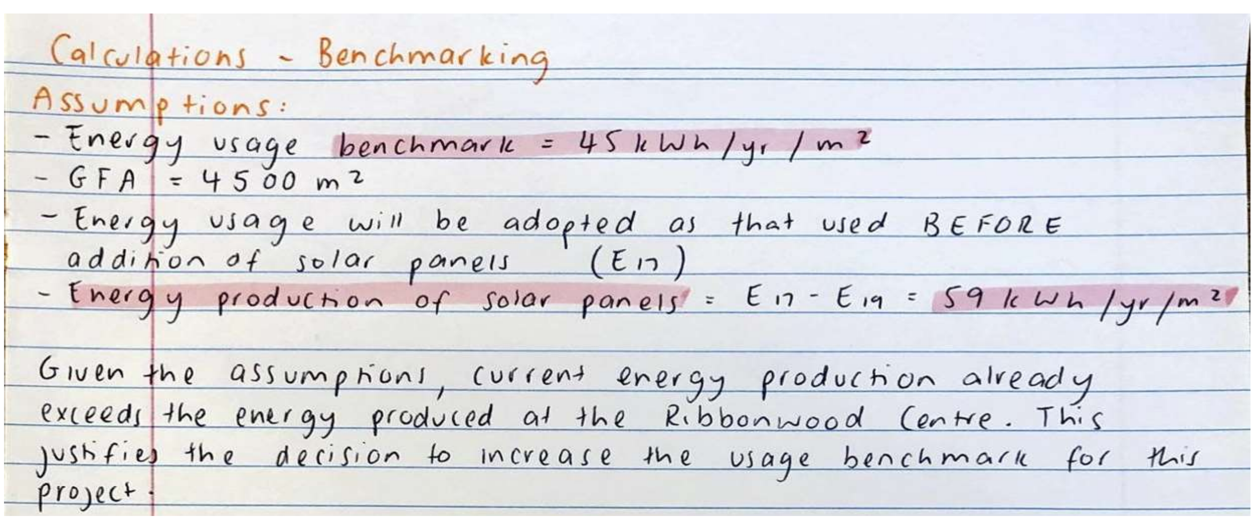
A 6 Star rated building showcases World Leadership. It has been built to be highly efficient building fully powered by renewables that addresses a significant number of environmental and social issues and contributes to the community.

Figure 3.1 - The Green Star rating scale (Green Building Council of Australia, 2021)

During the initial site visit to the community centre, the issue of accessibility was raised by both the consultants and regular users of the Ribbonwood Centre. Hence, improvements to accessibility is another benchmark that will be utilised during assessment of options.

Energy usage benchmark:

The benchmark utilised for the previous report, per a (City of Sydney, 2021) report, of proposed 45 kWh/yr/m^2 per Gross Floor Area (GFA) will not be used for this assignment. This is because it is estimated that the energy generated by the existing solar panels already exceeds this benchmark, justification of which is given below in Figure 3.2.



Calculations - Benchmarking

Assumptions:

- Energy usage benchmark = 45 kWh/yr/m^2
- GFA = 4500 m^2
- Energy usage will be adopted as that used BEFORE addition of solar panels (E_{17})
- Energy production of solar panels = $E_{17} - E_{19}$ = 59 kWh/yr/m^2

Given the assumptions, current energy production already exceeds the energy produced at the Ribbonwood Centre. This justifies the decision to increase the usage benchmark for this project.

Figure 3.2 - Justification for increasing energy consumption benchmark

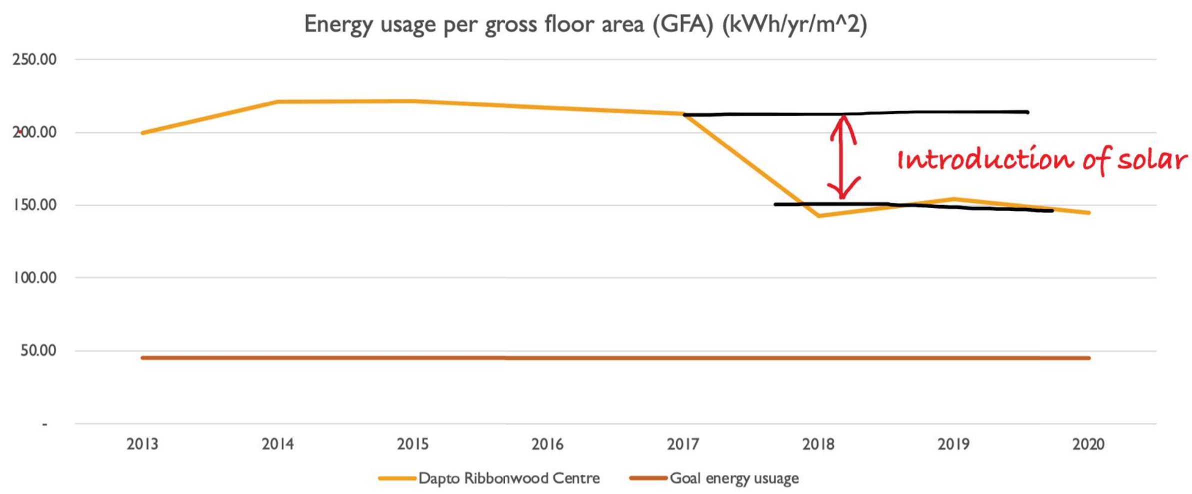


Figure 3.3 - Energy usage per gross floor area

As an alternative, the energy that is currently generated, plus the energy generated from the proposed option will be used to suggest a new benchmark that should be adopted for the Ribbonwood Centre.

Assumptions: the GFA of the ribbonwood centre is approximately 4500 m^2; the energy usage in 2017 (E_{17}) is representative of the consumption of energy the building generally uses; the energy generated by the solar panels is E_{17}-E_{19} = 59 kWh/yr.m^2.

3.2 - Carports and additional solar panels

Assumptions:

- No additional solar panels are to be placed on the roof of the Ribbonwood Center. This is due to the fact there are existing panels on the center, the reason as to why they excluded some spaces on the roof is unknown. Therefore, as there may be structural or installation related complications, this has been discounted.
- Weather data for the solar analysis was utilised from Nowra (as this is the closest site to Dapto using the selected solar analysis tool). The energy production final value is based on the assumption that weather patterns at Dapto are suitably similar to that in Nowra.

Figure 3.4 below shows the site analysis of the northern car park. When analysing the car park, it was noted from aerial imagery that the northern and western border of the car park (shown in pink) was shaded from surrounding trees. Additionally, drainage pits (shown in red) are located within the driving lane. In order to retain the existing drainage, the carport does not cover the driving lane and roofs are sloped so that rainfall is directed into these pits.

Figure 3.4 - Northern carpark site analysis (Aerial image source: SIX Maps, 2018)

Although the design aims to have minimal interference with the existing car park, four trees (shown in blue) will need to be removed to make space for the proposed car park.

Solar Energy production estimation

To determine the solar potential of the proposed design, the PhotoVoltaic Watts calculator, provided by the National Renewable Energy Laboratory was utilised. The data below in Table 3.1 shows the input values used in the PV calculator.

In research for this proposal, it was indicated that the SunPower Maxeon 5 solar panel is the most efficient panel on the market as of 2021 (Svark, 2021). For the purpose of this report, use of this panel has been assumed.

Table 3.1 - Solar energy calculation inputs

Module efficiency	22%	Module efficiency of the SunPower Maxeon 5 (SunPower, 2020)
Array area (m^2)	≈ 80% roof area = 821 m^2	
DC System size (kW)	180	= Array area*1kW/m^2*Module efficiency (Alliance for Sustainable Energy, 2021)
Declination angle of panels	31°	Optimal tilt for solar panels in Sydney, NSW (Jacobson & Jadhav, 2018)
System losses	15%	Recommended default value (PhotoVoltaic Software, 2018)
Azimuth angle	210 °	

This resulted in energy production of 154 657 kWh/year. In terms of the Ribbonwood Center gross floor area, the energy production is 34 kWh/yr.m^2.

3.3 - Ramp access to library

As this design is aimed to increase the accessibility and the roof area was considered in the section of 3.2, there is no numerical data for this design in terms of energy reductions/production.

Assumptions: The design criteria for the option is as follows:

- Ramp access slope (V:H) must be between 1:14 to 1:20 (Barker, 2021). For the purpose of this design, a slope of 1:14 has been adopted.
- The width of the ramp must be at least 1000mm (Barker, 2021). For this design, a width of 1200mm has been adopted.
- The elevation difference between the first and second floor is 4.5m. Therefore, the ramp must be 65m horizontally.

4.0 - Results

4.1 - On Site energy generation & new energy usage benchmark

The total energy production of the site is as follows:

$$Total\ energy\ generation\ (kWh/yr.m^2) = existing\ solar\ production\ +\ proposed\ solar\ production$$

$$= 59 + 34 = 93\ kWh/yr.m^2$$

Note: Calculations on estimated variability of results have been included in Appendix D. Accounting for standard deviation, the total energy generation is: $93 \pm 14\ kWh/yr.m^2$

When determining the new energy consumption benchmark, the lower end of the energy generation is used. Hence, the new energy usage benchmark is:

$$= 93 - 14 = 79\ kWh/yr.m^2$$

4.2 - HVAC renewable energy fraction

The HVAC renewable energy fraction has been calculated for one time period for both:

- Before addition of solar panels at the community centre (pre-2017 condition)
- After addition of solar panels at the community centre (existing condition)
- Post addition of proposed solar panels

As only one time period is being utilised, the formula is:

$$REF_{HVAC,1} = \frac{E_{PV,gross}}{E_{HVAC}}$$

Assumptions: As the amounts of energy utilised for HVAC systems alone have not been determined in this report, the average energy use (before addition of solar) multiplied by 40% (estimation for office buildings; Department of the Environment and Energy, 2013). This value will be used for all three cases.

Table 4.1 - Renewable energy fraction calculations

	$REF_{HVAC,1}$
Pre- 2017	$\frac{0}{214} = 0\%$

Existing Condition	$\frac{59}{214} = 28\%$
Proposed solar panels implemented	$\frac{93}{214} = 43\%$

4.3 - Ramp access to the library

Given the spatial requirements of the ramp, placing the ramp in the front foyer space was not feasible. Instead, the ramp was attached to the outside of the eastern side of the building.

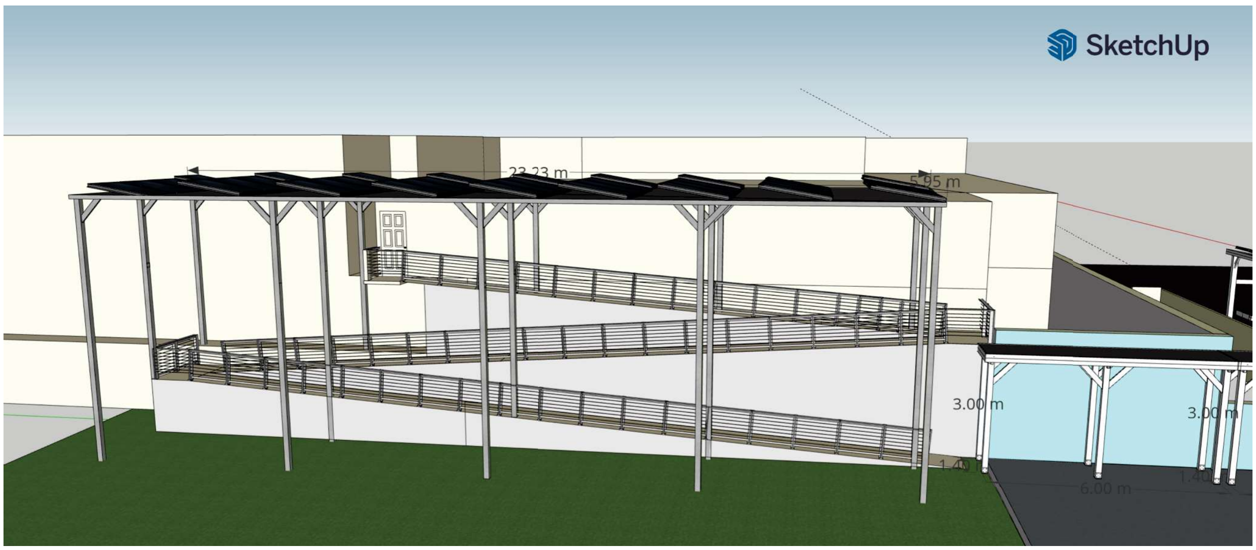


Figure 4.1 - Ramp access to library Sketch up model

If this proposal were to be proceeded with, the following issues were come across while making the model:

- About 100m^2 of land from the Dapto Showgrounds would need to be acquired. This land has existing trees that should be relocated to the new boundary of the two sites.
- The design would result in two entrances to the library. The layout of the library interior would need to be reconsidered should the design be proceeded with.
- The access to the library would need to go through existing free roof space. The structural integrity of the building should be reassessed with additional second story loading this option would create.

5.0 - Discussion and conclusions

5.1 - Discussion

This proposal for the Ribbonwood Center addressed the energy production half to the net zero building equation, and focused on accessibility improvement to strive towards a 5- or 6- Green Star building.

If the option of increasing additional solar energy production at the Ribbonwood Center were to be pursued, the following points should be addressed in that investigation:

- What is the reason solar panels are only placed on some parts of the roof? Is there a possibility that more solar panels can be placed on existing roofs of the community center?
- Further investigation into how an electric vehicle charging station can be set up in the existing car park.
- Investigation into battery storage of the power generated from the solar panels. Monthly energy consumption could be graphed with monthly energy generation to decide if battery storage is needed/what battery capacity is required.

The option of adding a ramp access to the library had a lot of cons. In particular, the structural implications of making a walkway through the existing roof; and the library set out needs further investigation.

It is suggested that before this investigation would be further proceeded with, conversation with come Ribbonwood Centre users should be had in discussion as to what degree the elevator access to library makes the users uncomfortable.

It should additionally be expressed that addition of this option should be paired with a Changing Places bathroom, as proposed in Assignment 2. This was another accessibility related issue that was pointed out during the site visit.

5.2 - Conclusion

In conclusion, the design solutions presented in this report have been aimed at increasing on site energy production and improving accessibility of the Ribbonwood Center. In combination with the energy saving solutions presented by peers in this subject, the Center will be well on their way to achieving net zero emissions.

6.0 - References

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7.0 - Appendix

Appendix A - Reflection

JV2 Green Star

ACT Appendix

(a) For a Class 3, 5, 6, 7, 8 or 9 building, or common area of a Class 2 building, compliance with JP1 is verified when—

(i) the building complies with the simulation requirements, and is registered, for a *Green Star* – Design & As-Built rating; and

(ii) the *annual greenhouse gas emissions* of the proposed building are less than 90% of the *annual greenhouse gas emissions* of the *reference building*; and

(iii) in the proposed building, a *thermal comfort level* of between a *Predicted Mean Vote* of -1 to +1 is achieved across not less than 95% of the *floor area* of all occupied zones for not less than 98% of the annual *hours of operation* of the building; and

(iv) the building complies with the additional requirements in Specification JVa.

(b) The calculation method used for (a) must comply with—

(i) ANSI/ASHRAE Standard 140; and

(ii) Specification JVb.

JV3 Verification using a reference building

(a) For a Class 3, 5, 6, 7, 8 or 9 building or common area of a Class 2 building, compliance with JP1 is verified when—

(i) it is determined that the *annual greenhouse gas emissions* of the proposed building are not more than the *annual greenhouse gas emissions* of a *reference building* when—

(A) the proposed building is modelled with the proposed *services*; and

(B) the proposed building is modelled with the same *services* as the *reference building*; and

(ii) in the proposed building, a *thermal comfort level* of between a *Predicted Mean Vote* of -1 to +1 is achieved across not less than 95% of the *floor area* of all occupied zones for not less than 98% of the annual *hours of operation* of the building; and

(iii) the building complies with the additional requirements in Specification JVa.

(b) The *annual greenhouse gas emissions* of the proposed building may be offset by—

(i) *renewable energy* generated and used on *site*; and

(ii) another process such as reclaimed energy, used on *site*.

(c) The calculation method used for (a) and (b) must comply with—

(i) ANSI/ASHRAE Standard 140; and

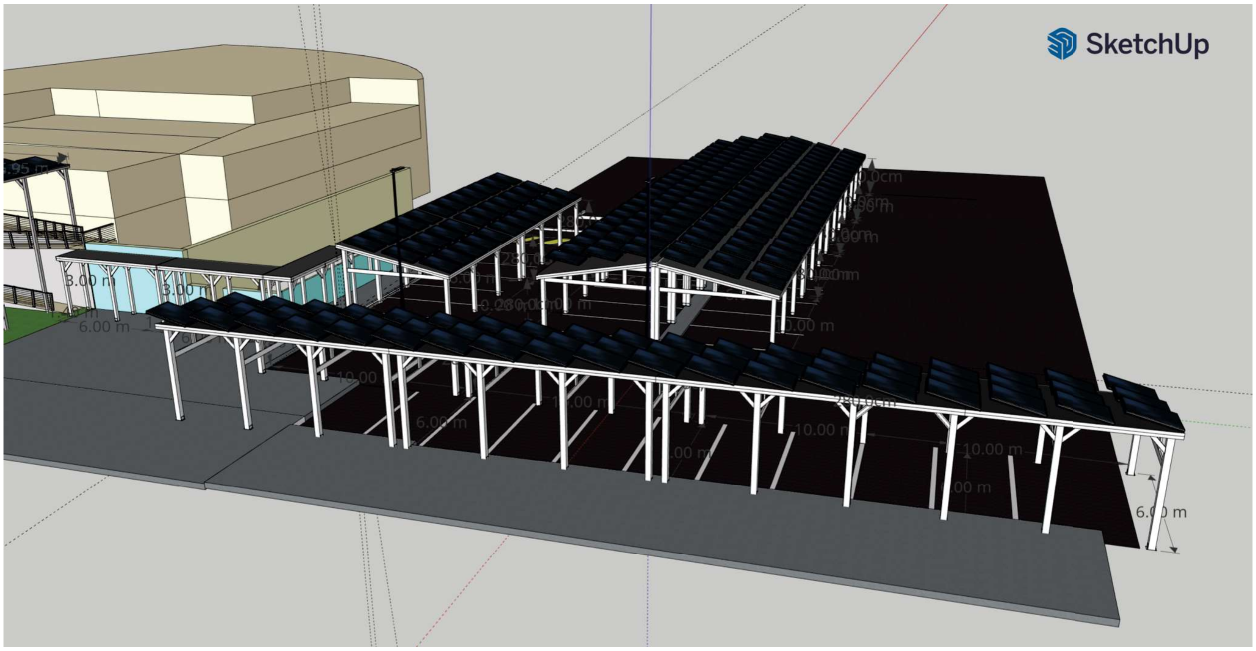
(ii) Specification JVb.

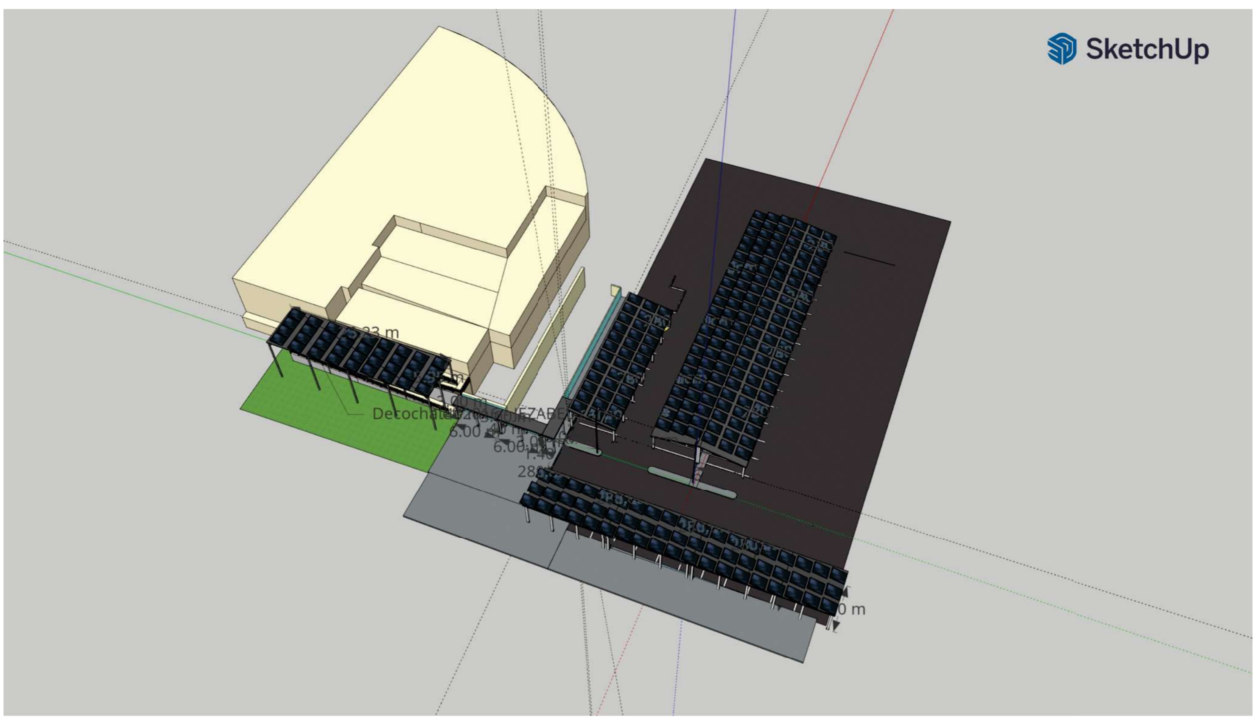
Figure 7.1 - Criteria for Green Star and JV3 certifications

In accordance with the NCC building classifications, the Ribbonwood Center is a class 9B building. The options proposed in this report increase the renewable energy generated on site which will help achieve the renewable energy goals required for both Green Star and JV3 certification.

As demonstrated in Figure 7.1, there are many additional requirements that the proposed design does not aim to meet. As a conclusion, while the proposed design helps achieve the renewable energy targets in the criteria, it is crucial that the design solution is combined with another proposal that aims to address these other criteria.

Appendix B - Sketch up models





Appendix C: Decision matrix

Proposal	Brief Descript	Code	Capital Cost	Operational Cost	Service Requirements	Net Zero Impact	Impact on GreenStar Buildings	Life Cycle Energy Analysis	Embodied Carbon	Energy Source	Energy Performace Increase	Site Specific Feasibility	Technology Readiness Levels (TRLs)	Innovation	Accessibility Criteria	Thermal Comfort	Lighting Improvements	Occupant Experience (Comfort, Noise, Mental/Physical Wellbeing)	Connections to Nature/Biophilia	Resilience to Climate Change	Total
Ramp access to library	Ramp with slope 1V:14H, spacial requirements of 65x1.2m	A	Medium	Neutral	None	Neutral	Slightly positive - the accessibility improvements addresses the social issues required to achieve a 5 and 6 star rating	Neutral	Neutral	N/A - doesn't require energy	0%	The spacial impact is large for this proposal, needs further investigation into where this could be installed	9	4	Positive Impact	Neutral	Neutural	High - rated for accessibility improvements that users have expressed a need for	Neutural	Medium	117
Carport with additional solar panels	Carports added to increase surface area of the Ribbonwood center for an increase in solar energy production potential]	B	High	Saves mony by cutting electricity costs	Moderate	Positive impact	Positive impact	Positive	Neutral	Produces energy	100% +	This is feasibile to construct, however construction will require temporary closing of the carpark.	9	7	No impact	Neutral	Neutural	Neutural	Neutural	High, will generate more energy (using case of Darwin)	122
Weighting		A	7	8	9	5	7	5	5	10	5	3	10	4	10	5	5	9	5	5	
		B	3	10	5	8	9	7	5	8	10	5	10	7	5	5	5	5	5	10	

Appendix D: Calculations of variability of solar generated

Existing energy generation sensitivity analysis

To gain a rough estimate of the standard deviation of the existing energy generation, the standard deviation of energy usage both before and after installation of solar panels was conducted, as shown below in Table 7.1. Note only data until 2019 has been used due to the impact of Covid-19.

Table 7.1 - Standard deviation of energy usage

	Year	Energy consumption ($kWh/yr.m^2$)	Standard deviation
Before solar panels	2013	199.53	8.98
	2014	221.05	
	2015	221.42	
	2016	216.85	
	2017	212.92	
After solar panels	2018	142.77	8.06
	2019	154.16	

Therefore, it is estimated that the standard deviation when subtracting the (before solar panels) value from the (after solar panels) is:

$$\sqrt{8.98^2 + 8.06^2 = 12} \text{ kWh/yr.m}^2$$

Hence, the total current energy generated on site is estimated to be 34 ± 8 $kWh/yr.m^2$

Additional roofing energy generation sensitivity analysis

For the sensitivity analysis, the solar energy production has been calculated while changing some of the parameters. Likelihood if the event occurring will be rated out of 5 and this factor will be used to weight the amount of times this value is used to the standard deviation calculation. The standard deviation will be used to provide a conservative accuracy of this result.

Table 7.2 - Energy generation for varying cases

Case	Energy production ($kWh/yr.m^2$)	Likelihood
Calculated case	34	**5** (all parameters were entered as best to the ability using the mentioned tools)
Climate change (use weather data for Dawin)	46	**2** (extremely likely, but not to that extent in near future)
Increased system losses (using 20%)	32	**3**
Decreased panel efficiency over time (using panel efficiency = 18%)	28	**2** (likely to have small decrease over time, but not to this extent)
Weather patterns for colder regions experienced (use weather data for Melbourne)	33	**1**
Area calculated for panels cannot be achieved (use area 70% of estimated)	20	**3**

Standard deviation of results = 8 $kWh/yr.m^2$.

Hence, the energy generated by additional on site solar is estimated to be 34 ± 8 $kWh/yr.m^2$.

Total standard deviation of energy generated on site

$\sqrt{12^2 + 8^2} = 14$ $kWh/yr.m^2$

AENG301
FINAL DESIGN REPORT
RIBBONWOOD CENTRE

EXECUTIVE SUMMARY

This report investigated three passive design solutions for the retrofitting of the Dapto Ribbonwood centre on behalf of the Wollongong City Council. The design elements included upgrading the building fabric through increasing the wall and roof insulation, increasing the window performance with glazing films, and improving solar gains through the implementation of skylights and shading.

The buildings energy performance was modelled using the Openstudio plugin for SketchUp Make with assumptions being made about the current building envelope as well as lighting levels and activity. Each design iteration was simulated with individual results available in section 4 of the report.

The results derived from the simulations show conclusive performance increase in terms of building total heating and cooling load by the implementation of the passive design solutions. The combination of increasing total roof insulation to an R-Value of 5 as well as the installation of skylights with specified shading resulted in a 34% decrease in the buildings heating and cooling load. This translated into a saving of 30 tonnes of CO_2 equivalent by the reduction of energy demands from the grid, however this figure does not take into account the embodied CO_2 or energy require to initially construct the proposed elements.

The performance could be increased to a 40% reduction by upgrading the wall insulation to an R-Value of 5 as well, however as this would require expansion and remodelling of the walls it was therefore discounted. Upgrading the windows of the centre to double glazing saw only a 2% increase in performance, and as a glazing film would provide less benefit than that it was deemed not worth the material waste and cost of upgrading.

Overall, the recommendation of this report was to upgrade the roof insulation to an R-Value of at least 5, as well as the addition of properly shaded skylights. Implementing these passive design elements will improve the buildings performance by over one third and will ensure that a smaller HVAC system will be needed once the current plant is replaced. A sensitivity analysis was also undertaken showing that the proposals still provided a performance increase in changing climate.

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1 INTRODUCTION

This report investigates design solutions for the retrofitting of the Dapto Ribbonwood centre for the Wollongong City Council. The goal is to simulate the energy performance of the building under different circumstances to produce a recommendation for the client that can be validated with generated data.

2 DESIGN SOLUTIONS

A passive design solution was chosen to be implemented at the Ribbonwood site consisting of upgrades to the following three elements:

- Building fabric: Wall and Roof Insulation
- Window Performance: Glazing Films
- Solar Gains: Skylights and Shading

Once installed, these passive elements require no additional energy to run and will work in tandem to reduce the combined heating and cooling load of the building. This will reduce the Ribbonwood centre's reliance on its aging HVAC system and as it is due to be replaced, will allow for the installation of a smaller system that performs more optimally in this reduced range. Overall, the design solutions will reduce the energy usage of the centre and bring it closer to achieving the Wollongong City Council's goal of achieving Net Zero Energy.

2.1 Building Fabric

Upgrades to the building fabric will include increasing the quality and amount of wall and roofing insulation present in the Ribbonwood centre. Increasing the total R-Value of the wall and roof systems will reduce the amount of heat transfer both into and out of the building envelope. This is advantageous as during summer it will limit the outside heat that is able to enter the building and during the colder months will help to retain the buildings warmth provided through activity, lighting, solar, and the HVAC system.

2.2 Window Performance

Improving the performance of the window system is another key area to increasing the effectiveness of the buildings envelope. However, changing a building from single to double or triple glazed often requires replacing the entire window and frame as well as modifications to the surrounding opening to accommodate the change. This can cause a large amount of material waste that counteracts the original goal of the upgrade to increase the performance of the building in relation to sustainability. For this reason, it was deemed more appropriate in the context of retrofitting the Ribbonwood centre to investigate the application of a glazing film. A glazing film is applied directly to the existing glass and therefore does not require any additional modifications to the window. The film itself improves the properties of the glass by limiting the amount of solar UV radiation that can pass through, (Ultrashield, 2016). This strategy is much cheaper and easier to install than double glazing however it will be less effective.

2.3 Solar Gain

The last proposal is to alter the buildings design to allow for a greater admittance of passive solar energy. This provides not only a way of passively heating the building but also increases the level of natural light within the space that will be a benefit to the occupant experience. Figure 2.3.1 shows the proposed skylight upgrade above the library that seeks to replace the existing, ineffective skylights with two larger ones that have been angled towards true north to better allow for the capture of sunlight.

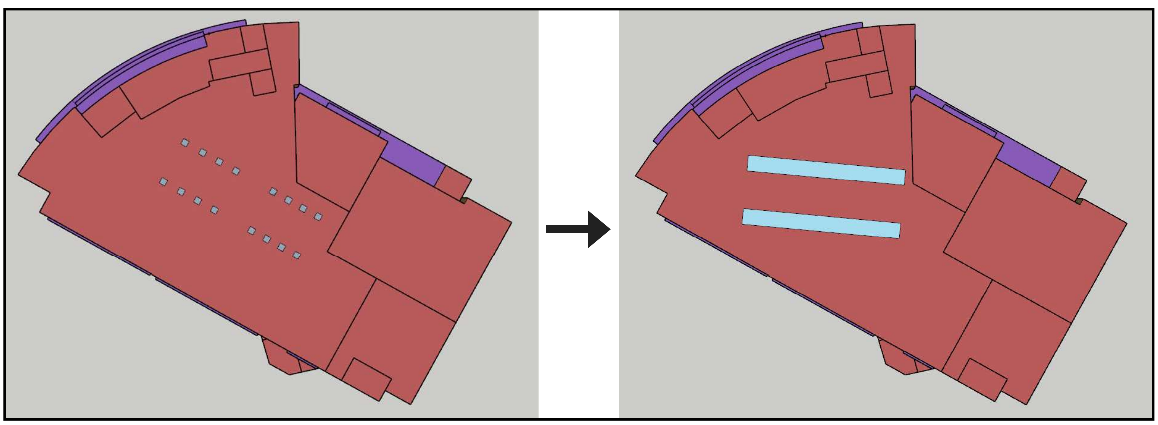

Figure 2.3.1 Skylight Upgrade

Through passive solar design it is also important to ensure that direct sunlight is only entering the space when it is need and therefore a shading structure needs to also be added to the skylights. Figure 2.3.2 shows an example of a shading element that could be implemented to the design which is angled to allow sunlight to enter the library through the skylight only during the colder months of the year when the sun is lower in the sky. During summer sunlight is almost completely blocked.

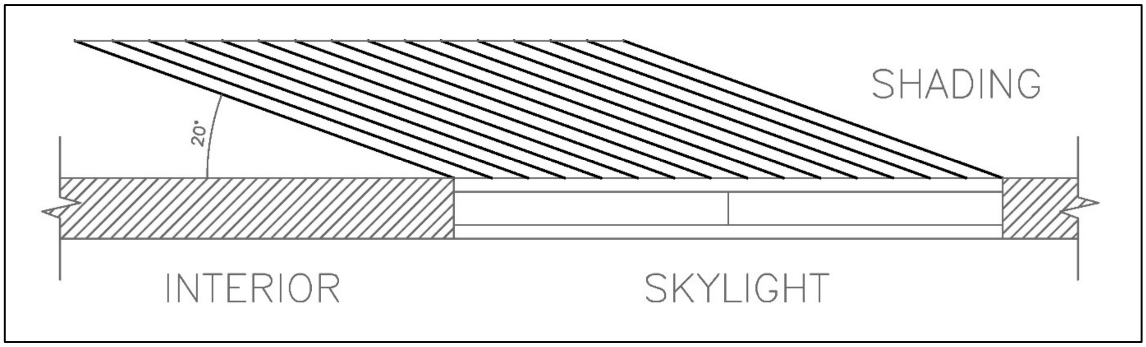

Figure 2.3.2 Skylight Shading Drawing

3 ASSUMPTIONS AND METHODOLOGY

3.1 Design Assumptions

As the information about the Ribbonwood centre was limited several assumptions had to be made about the design to create a base case from which the design proposals could be compared to. Firstly, the R-Value of the exterior wall and roof insulation needed to be determined. The current NCC 2019 BCA Volume One Amendment 1 states in table J1.5a (pg. 360) that a minimum R-Value of 1.4 must be obtained for a class 5 office building in the Wollongong area, classified as climate zone 5 (Australian Building Codes Board, 2019). As this is the current standard the Ribbonwood centre itself would likely be less given it was built two decades ago however this gives a valid base value for testing.

Figure 3.1.1 shows part of the roof section from the provided CAD drawings of the Ribbonwood centre. From the drawing it can be measured that the current roof insulation is only around 75 mm in width and that there is still a large amount of room in the structure to accommodate further insulation. As the national construction code at the time had no minimum value for roof insulation and taking in to account the fact that the current insulation is minimal an assumed R-Value of 1 was accepted for the base case.

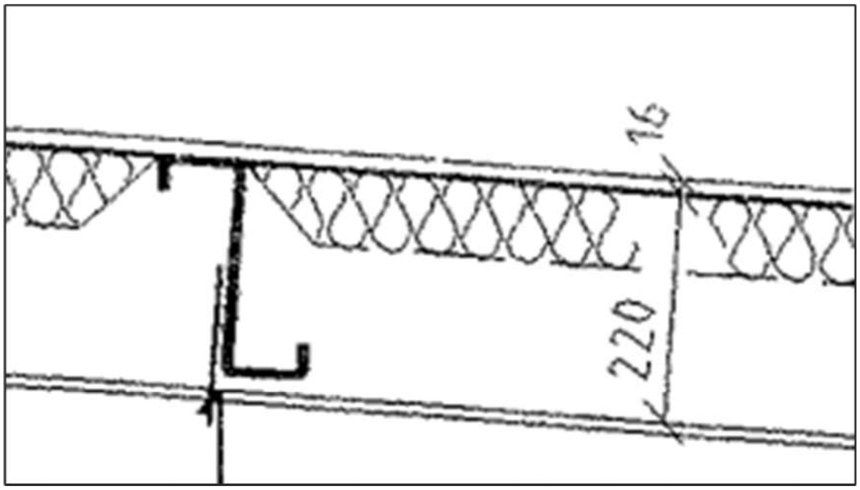

Figure 3.1.1 Ribbonwood Roof Section

Lastly a U-Value was assumed for the windows using the BASIX Default Window Data (n.d.). For a single glazed, tinted glass with a fixed aluminium frame BASIX provides a U-Value of 6.6. All the design assumptions that will be used in the creation of the Ribbonwood centre base case simulation are listed in table 3.1.1.

Table 3.1.1 Design Assumptions

Wall R-Value	Roof R-Value	Window U-Value
1.4	1	6.6

3.2 Openstudio Assumptions and Methodology

The building performance simulation was done using the Openstudio plugin for SketchUp. The model, demonstrated in figures 3.2.1 and 3.2.2, was created from scaled floor plans to get accurate dimensions for the building. As the design proposals focus on the building's envelope, special consideration was taken to recreate the exterior as accurately as possible, especially the large, curved glass façade and associated shading.

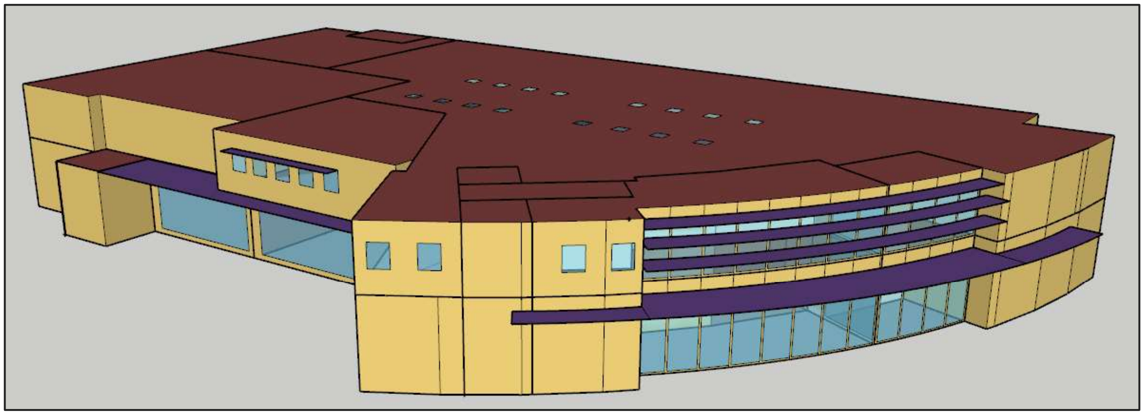

Figure 3.2.1 Ribbonwood Model View 1

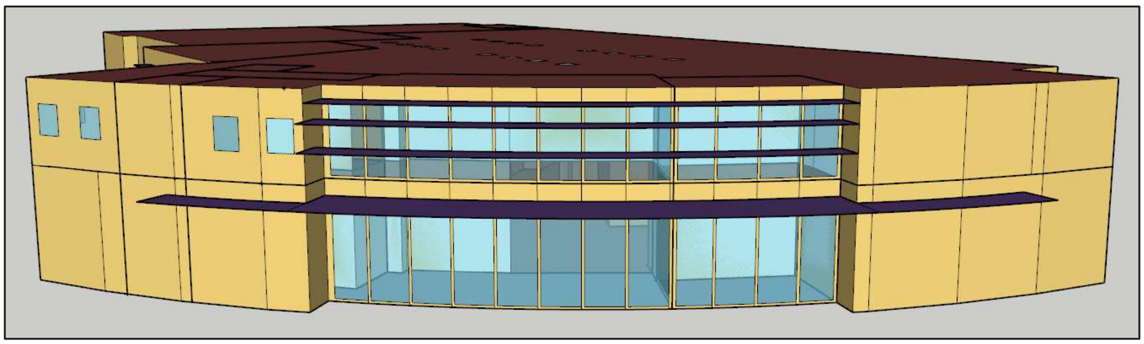

Figure 3.2.2 Ribbonwood model View 2

Through Openstudio, rooms with a similar purpose were assigned with the same space type to simplify analysis, e.g., bathrooms and office spaces, and the layout of spaces can be seen in figures 3.2.3 and 3.2.4.

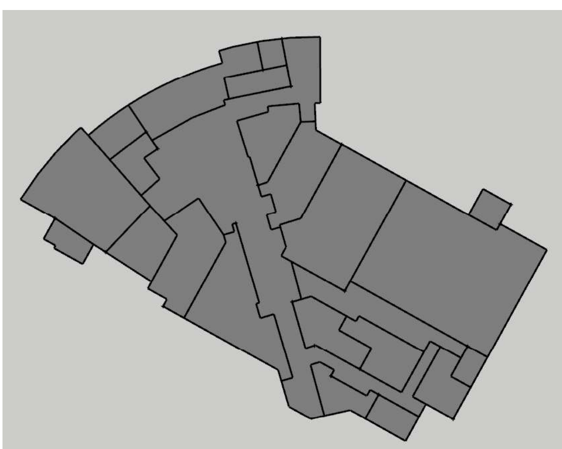

Figure 3.2.3 Ground Floor Layout

Figure 3.2.4 First Floor Layout

The scheduling for the model was done using ASHRAE 189.1-2009 Office rulesets that were edited to reflect the Ribbonwood centres hours of operation and the lighting for the majority of the building was set to a value of 5 W/m^2. The weather file used for the simulation was for Mascot – Sydney Airport (EnergyPlus), as this was the closest available and the difference is latitude was negligible. After the model and conditions had been completed an initial simulation was run to create the business as usual case for the building. From there, the variables for each design proposal were changed with a new simulation being run with each iteration to develop a set of results from which the buildings performance could be compared.

4 RESULTS

4.1 Wall and Roof Insulation

Once the base case was recorded, two additional cases for the exterior wall insulation were simulated. An R-Value of 3, a moderate increase, and 5, a high increase, achieved only a 4% and 5% reduction respectively in the combined heating and cooling load as shown in figure 4.1.1.

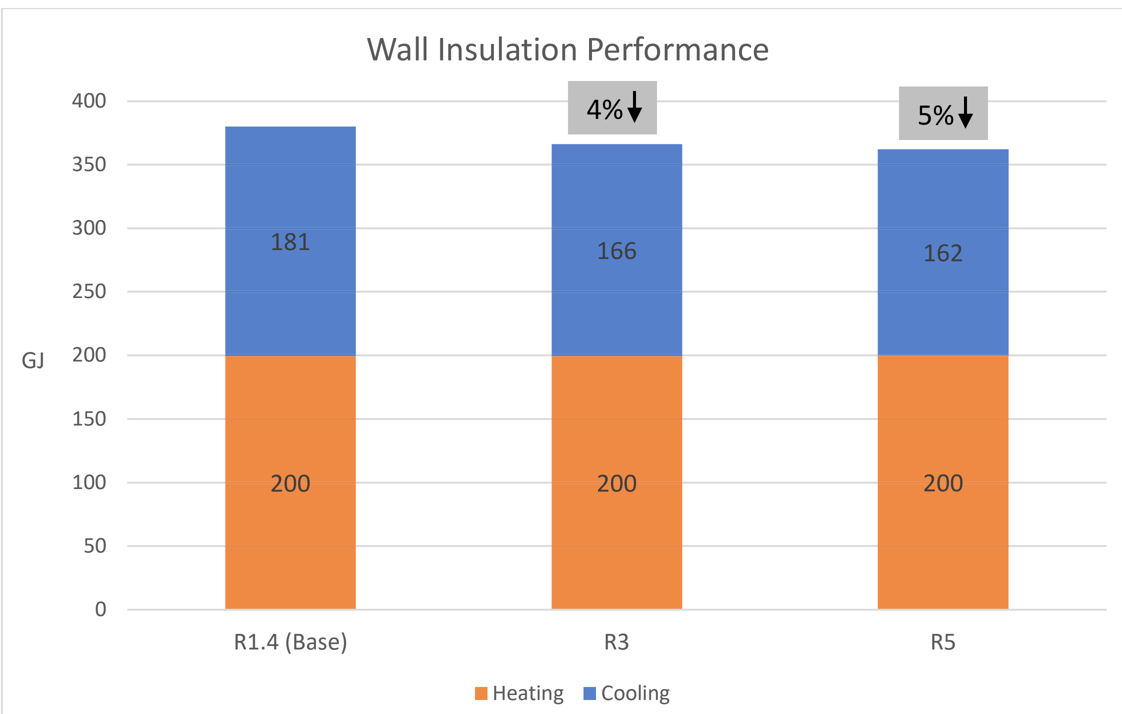

Figure 4.1.1 Wall Insulation Performance

The roof insulation was tested from the base value of 1 up to an R-Value of 6 and the results in figure 4.1.2 show a much greater increase in performance when compared to that of the wall insulation. It can be seen from the graph that after an R-Value of 5 the results start to plateau, indicating the diminishing returns that would be achieved by increasing the insulation past this point. It should also be noted that for a class five office building the minimum total R-Value for a roof system is 3.7 (Australian Building Codes Board, 2019), which highlights that just by improving the existing roof to the current standard the building would see between a 22-25% reduction in the combined heating and cooling load.

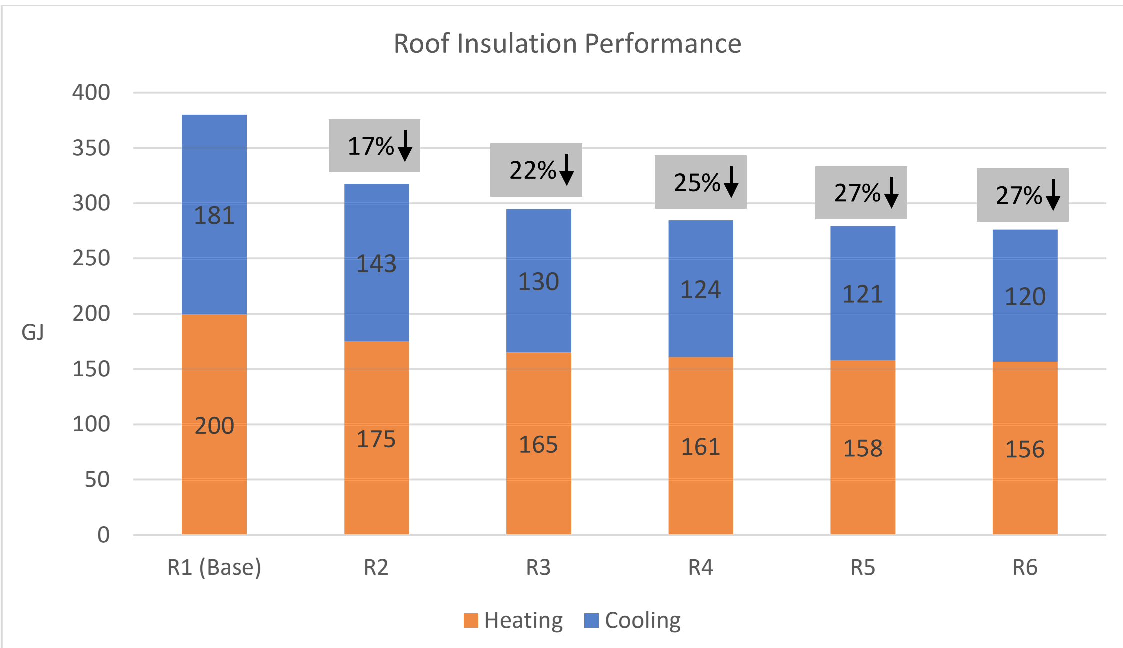

Figure 4.1.2 Roof Insulation Performance

Because of the diminish returns an R-Value of 5 for the roof was chosen and compared with the results of the wall simulations in figure 4.1.3. A further simulation combining the two shows a 32% performance increase which is a decrease of almost a third of the energy required by the HVAC system to heat and cool the building.

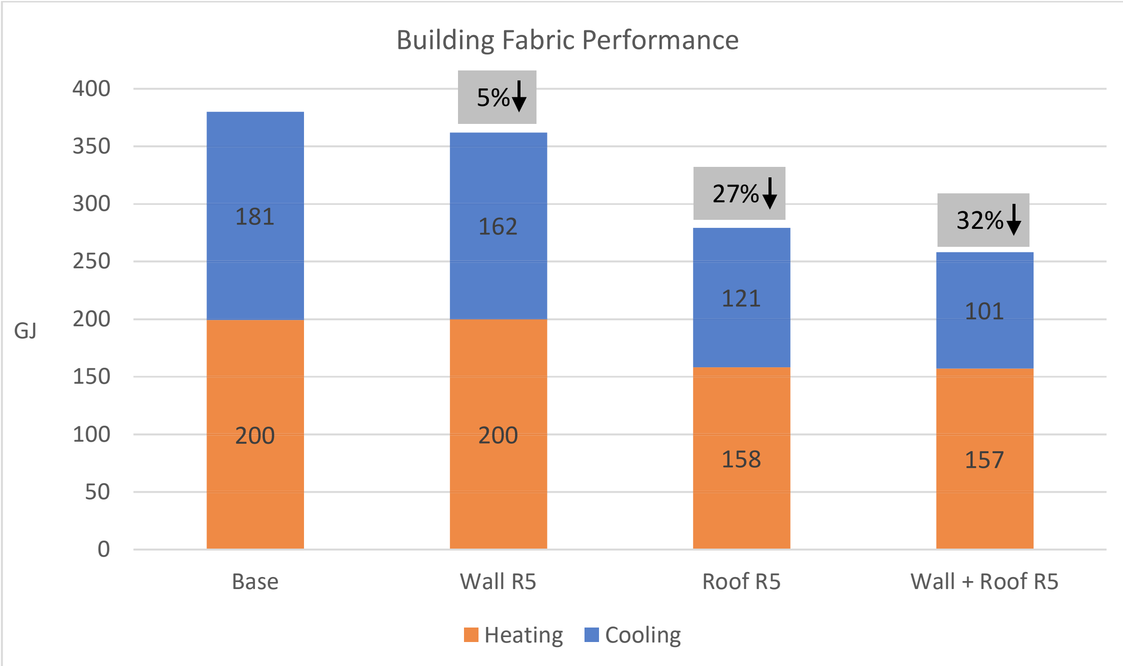

Figure 4.1.3 Building Fabric Performance

4.2 Glazing

Although the goal was the application of a glazing film it was decided to run the simulation to evaluate the buildings performance when a window system with a U-Value of 2.5, an average value for double glazing, and 1, a high performance, PassivHaus standard was applied. The results, displayed in figure 4.2.1, show only a 2% and 3% decrease in total heating and cooling load, respectively.

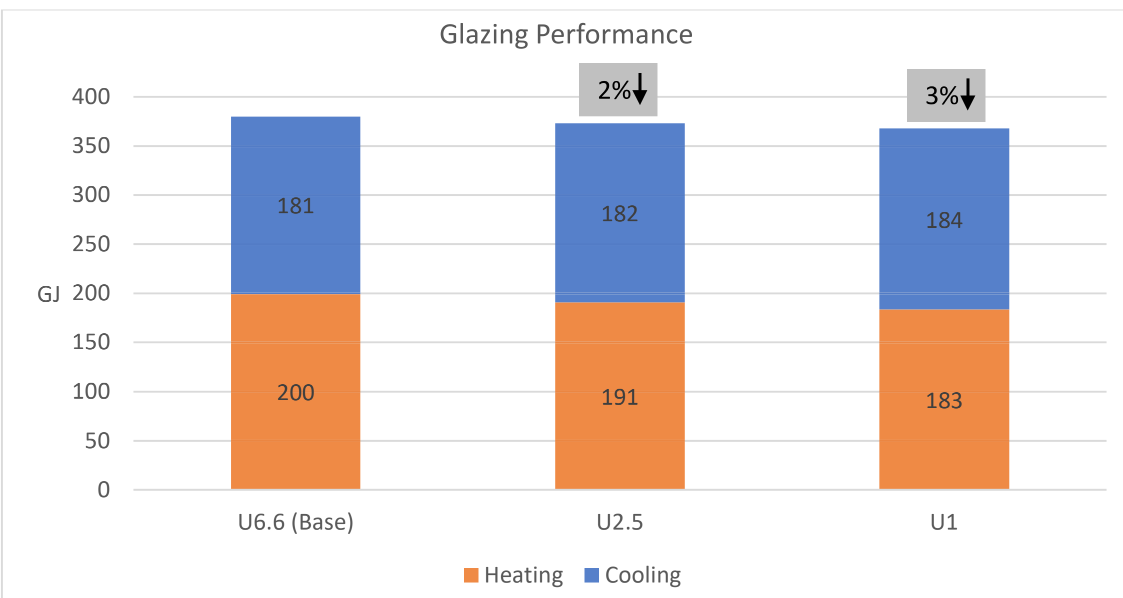

Figure 4.2.1 Glazing Performance

4.3 Skylights and Shading

The introduction of skylights, detailed in section 2.3, saw a 16% increase in the building's performance. It should be noted from figure 4.3.1 that the cooling load was reduced by more than the heating load. This indicates that during the warmer months when the building is too hot, excess heat can more easily be emitted from the space through the glass.

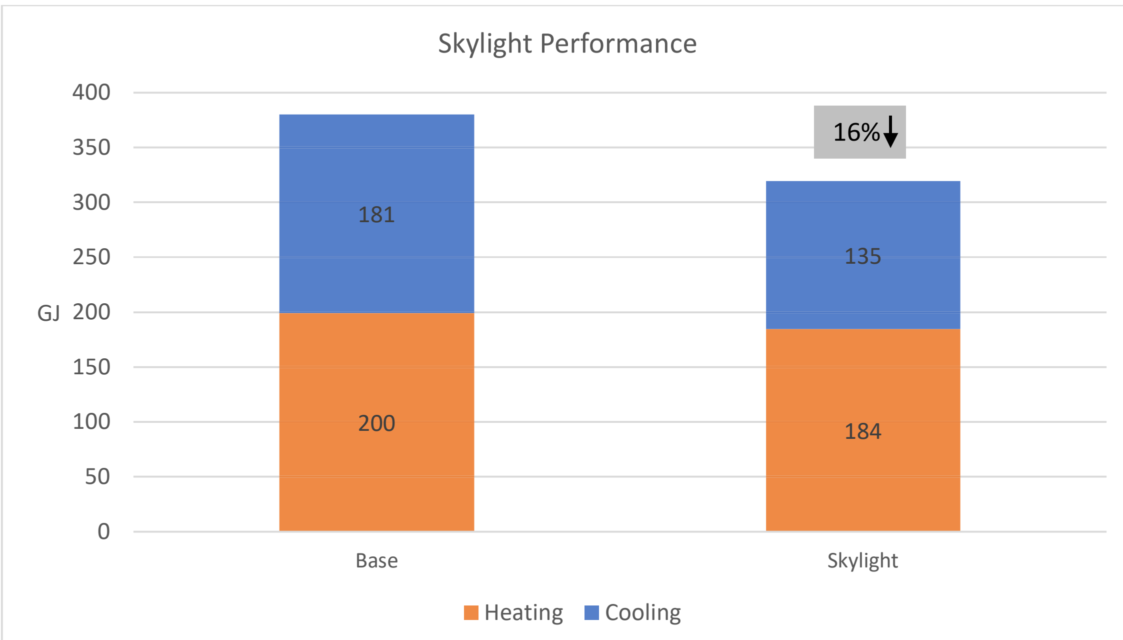

Figure 4.3.1 Skylight Performance

4.4 Combined Performance

Further simulations were then run combining the insulation and skylights design proposals. Figure 4.4.1 shows that the combination of skylights and R5 roof insulation increases the buildings performance by 34%. Adding R5 wall insulations increases it by 40% which almost halves the current energy demands of the Ribbonwood centres HVAC system.

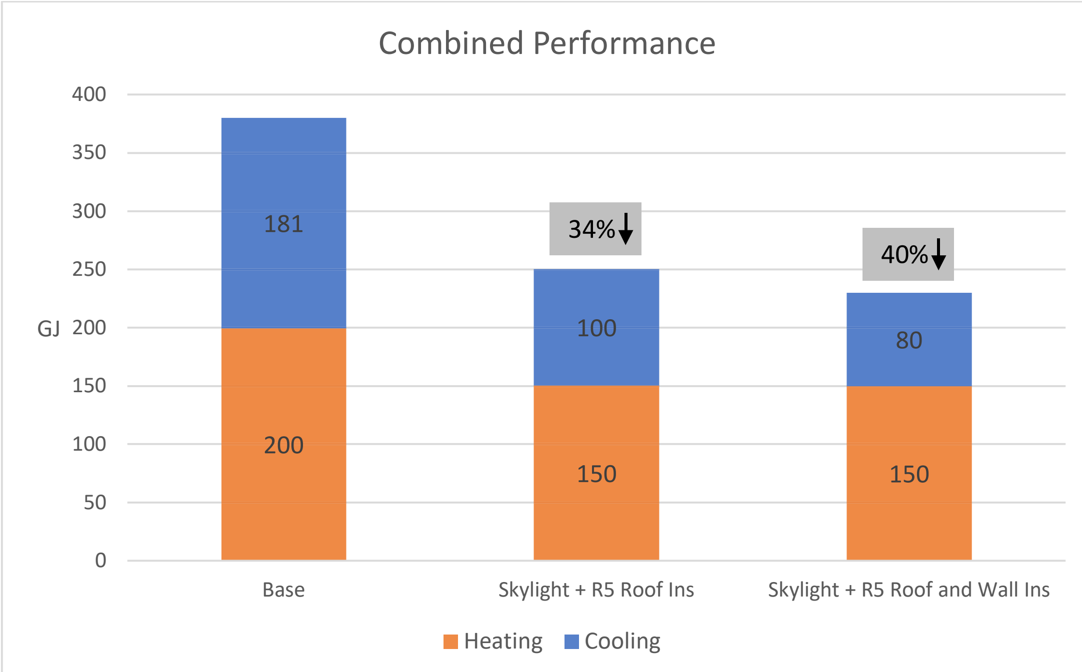

Figure 4.4.1 Combined Performance

A brief sensitivity analysis was then run by changing the weather file used by Openstudio to Cairns, simulating a much hotter climate, and then to Hobart, a colder climate. The red line across figure 4.4.2 represents the current base case for the Ribbonwood centre and there is still a general increase in performance in each climate. The combination of design proposals remains below the red line for both Cairns and Hobart climates showing that the upgrades will still perform better than the current building in a changing climate that could be brought about by climate change.

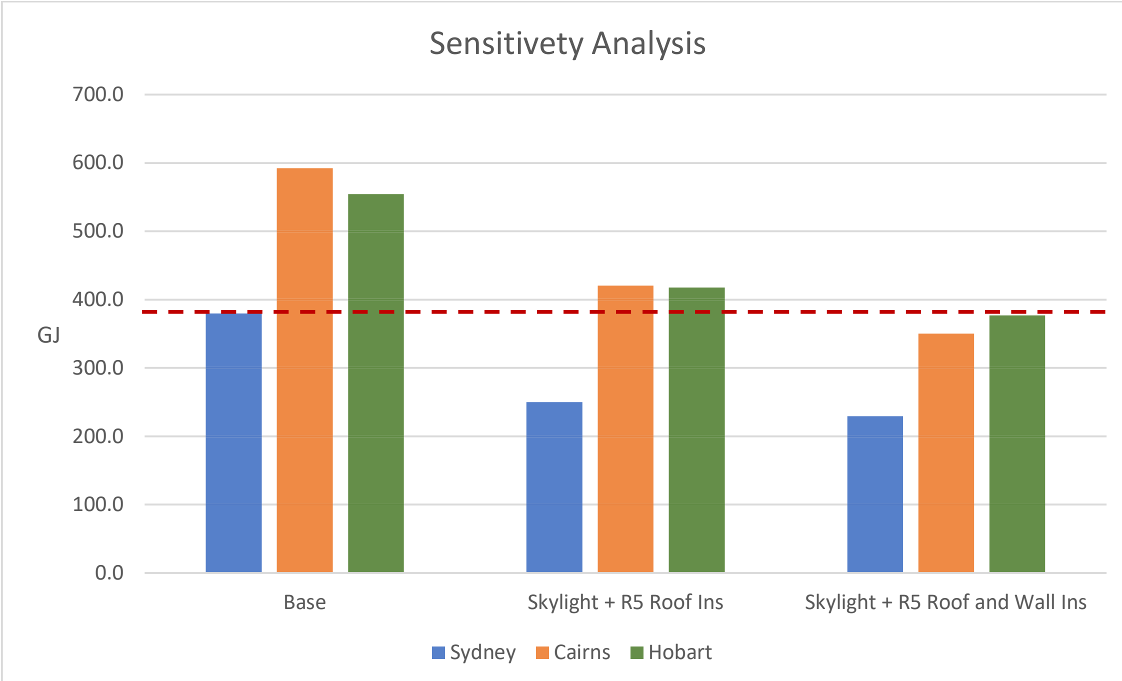

Figure 4.4.2 Sensitivity Analysis

The simulated business as usual case was used to calculate the yearly reduction in CO_2 equivalent emissions that the proposals would provide through decreasing energy demands from the grid. Emission factors for NSW were taken from the National Greenhouse Accounts Factors (Australian Government: Department of the Environment and Energy, 2017) and the results were entered into table 4.4.1.

Table 4.4.1 Emissions Reduction

Proposal	**Simulated BAU (GJ)**	**Reduction (%)**	**Energy Saved (GJ)**	**Energy Saved (kWh)**	**Emission Factor (kg CO_2-e/kWh)**	**Emissions Reduction (tonnes CO_2-e)**
Skylight + R5 Roof Ins	380	34	129	35833	0.83	30
Skylight + R5 Roof and Wall Ins	380	40	152	42222	0.83	35

5 DISCUSSION AND RECOMMENDATIONS

The results derived from the Openstudio simulations show conclusive benefits to the implementation of the proposed passive design solutions. The combination of increasing the total roof insulation to an R-Value of 5 as well as the implementation of skylights with associated shading reduces the buildings combined heating and cooling load by 34%, just over one third. Consequently, this saves 30 tonnes of CO_2 equivalent from being emitted each year from the reduction in energy demand from the grid. However, this figure does not take into account the embodied CO_2 or energy required to initially construct the passive proposals as well as the fact that the CO_2-e emission factor should be dropping as Australia hopefully supplies more of its grid energy from renewable sources. As seen in section 3.1, there is currently more than enough room in the roof space to allow for upgrades to the insulation as well as the potential of adding additional insulation needed on top of the suspended ceiling.

The performance can be increased further to a 40% reduction in heating and cooling load by additionally upgrade the exterior walls to an R-Value of 5 however this would require expansion and extensive remodelling of the walls to accommodate this change. It was also found that upgrading the windows from single to double glazed only provided a 2% increase to the building's performance, and as a proposed glazing film would provide less benefit than this it was deemed not worth the material waste and cost to upgrade.

Taking everything into consideration it is the recommendation of this report that the Ribbonwood centre be retrofitted with a total roof R-Value of at least 5, as well as the addition of properly shaded skylights to increase solar performance. The reduced heating and cooling load provided by the passive design elements will ensure that a smaller HVAC system will be needed once the current aging plant is replaced. The sensitivity analysis undertaken as well shows that the addition of these passive elements still provides the building with a performance increase in a changing climate. A further positive for the retrofit is that installation of both proposals occurs in the roof structure, limiting the amount of disruption to the building that will occur.

An example of a roofing system for the Ribbonwood centre is provide in figure 5.1 which utilises 90mm Bradford Anticon Roofing blanket and 165mm Bradford Gold Ceiling Insulation providing an R value of 2.0 and 3.0, respectively. Combined this is an R-Value of 5 achieving the design specifications from the insulation alone. The Bradford Gold Ceiling Insulation itself is made from "up to 80% recycled glass" and is "100% bio-soluble"

(Bradford). The recycled nature of the product ensures that the embodied CO_2 is low aligning with the goals of the project to move towards Net Zero Energy and Emissions.

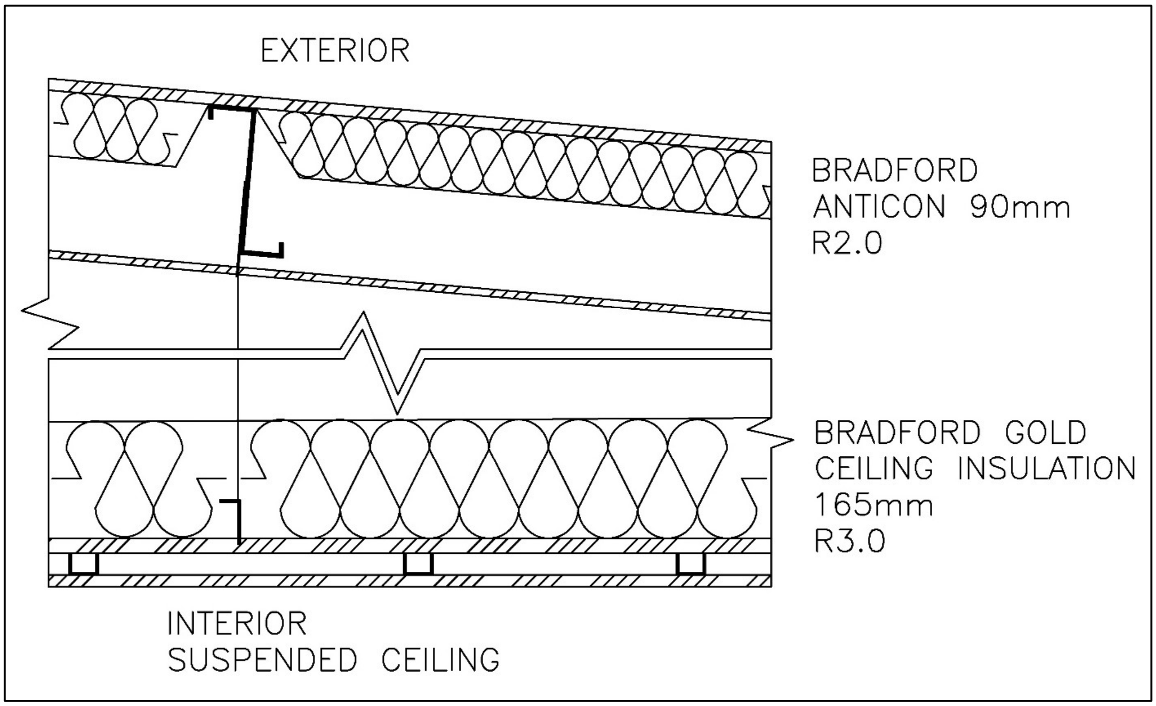

Figure 5.1 Proposed Roof Ins. Option

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7 APPENDIX

Appendix A – Reflection

All though none of the proposed design elements are ground breaking they are all passive in nature, requiring no additional energy to be used once installed. Ratings schemes like GreenStar Buildings have a large focus on energy efficiency and renewable power which is important, however a greater emphasis could be place on passive measures. Designing a building from the ground up to maximise its performance passively through strategies such as the implementation of thermal mass and passive solar reduces its reliance on active measures and decreases the performance gap that needs to be covered by power from either renewable or fossil fuel sources.

Appendix B – Openstudio Simulation Data

Wall Insulation	Heating (GJ)	Cooling (GJ)	Increase (%)
R1.4	199.5	180.5	0
R3	199.6	166.5	4
R5	200.1	162.0	5

Roof Insulation	Heating (GJ)	Cooling (GJ)	Increase (%)
R1	199.5	180.5	0
R2	174.7	142.5	17
R3	164.9	129.8	22
R4	160.7	123.7	25
R5	158.1	121.1	27
R6	156.5	119.8	27

Glazing	Heating (GJ)	Cooling (GJ)	Increase (%)
U6.6	199.5	180.5	0
U2.5	190.7	182.3	2
U1	183.3	184.2	3

Skylights	Heating (GJ)	Cooling (GJ)	Increase (%)
Base	199.5	180.5	0
Skylight	184.4	135.0	16

Combined	Heating (GJ)	Cooling (GJ)	Increase (%)
Base	199.5	180.5	0
Skylights + R5 Roof Ins	150.5	99.8	34
Skylights + R5 Roof and Wall Ins	150.0	79.9	40

Combined	Sydney (GJ)	Cairns (GJ)	Hobart (GJ)
Base	380.0	592.6	554.3
Skylights + R5 Roof Ins	250.2	420.4	417.7
Skylights + R5 Roof and Wall Ins	229.8	350.2	377.4

APPENDIX B – TRANSCRIPTS OF INDUSTRY/TUTOR INTERVIEWS

Interview 1: Integrated Design Studio 11 – WCC Ribbonwood Community Centre – Interview with Consultant 1 (Architecture Consultant)

Q1. What enables successful Integrated Design in the studio setting?

The time that the students have to develop their ideas is very important – the amount of tasks that they are asked to do and the time they have to do them. For this project, 12 weeks was not enough for the work that was asked of the students, and their inexperience showed in the lack of quality. Site analysis was an example – this should not take long, but with inexperience of some students it took them 4 weeks when it should have taken 1. In my opinion the last exercise was the key one- coming up with a solution and testing it, then coming up with a recommendation for the client. Understanding their skills and capabilities and being realistic with the tasks that they are asked to do will help to achieve the outcomes.

Q2. Please tell us about the studio brief's impact on achieving integrated design solutions (considering the way it was written & communicated). Please reflect on the level of detail and the language of the brief.

The brief presented were quite good – I don't think that the briefs were a problem, they had good information and the students had a chance to talk directly with the client. I found it interesting that the students could go on site with the client too. The brief for the tasks could have been more specific, but the aim was to give them a bit of freedom for them to find what they wanted to investigate and put effort into. The problem with sustainability is that it is so broad, it can be a huge challenge. Being more specific about what we expect from them could help them. Having a reference of what other students did could help them understand what they need to do.

Q3. What were the most critical decision-making points/questions to answer when balancing architectural and engineering input for generating environmentally optimised design solutions? Where did the inspiration for the students' solutions come from? How did the engineering consultant(s) contribute to the authorship of those solutions? What was the impact of engineering and architecture student collaboration on the project outcomes? What impact did the timing of the engineer/architecture collaborations have on the development of the project?

The students struggled with the timing- they only had 4 weeks to develop their solutions, so they struggled to get good outputs, just because of the timing. Some of the engineering students struggled with bringing solutions- for them it was more about calculating, they seemed shy to provide recommendations and instead were eager for us to tell them what to calculate rather than understanding the impact on the building. The architectural students were a bit more comfortable with giving solutions and finding the balance between architectural and engineering.

Some of the students struggled with learning to work in groups with people who have different mindsets, skills and goals. Perhaps having clearly defined different tasks for different disciplines could speed up this process. The almost were splitting everything into separate sections that they worked on individually rather than working all together. Solutions came individually, as they were working independently by this time – but overall the groups did not seem to work together, it was difficult to see the groups in the classroom sometimes.

Q4. What guidance by you was most useful for the students (and why)? How did your input increase their 'level of understanding of' environmental issues and associated solutions? What would you change in order to maximise your input (if anything)?

One of the things that the consultants provided was explaining to students that they needed to give an opinion and recommendations, this was probably the most positive thing of the entire studio – for the students to go from just analysing numbers to understand that they need to give an opinion. Make sure that they understand that they are the experts and the client was looking for their recommendations.

We spent quite a lot of time talking about the façade and how to improve the façade -perhaps we gave them too many options and they got confused with that – perhaps reducing the number of options would have made it easier for them, but we wanted to show them that there are plenty of design options and they just need to pick the right one. Some of the students got it, because they came back with different analysis of shading devices and glass types and with a matrix of solutions that was quite interesting.

It was good having conversations three ways with the students – but it was a shame that most of these conversations happened over zoom. I don't think I would reduce the amount of information given. The other thing is I would encourage them to try things, not just to stick to one option.

Students struggled to engage with the consultants outside the allotted class time - perhaps they were shy or lacked time. Perhaps they could be assigned specific consultants as mentors as the start to encourage closer links with some of the students and make them more accessible.

Q5. How did students cope with balancing aesthetic/functional design aspects with engineering concerns? What was the impact of engineering and architecture student collaboration on the project outcomes? What impact did the timing of the engineer/architecture collaborations have on the development of the project?

I think there was a bit of a mix – some of the engineers felt more comfortable calculating so they almost ignored the other side of things. For the Ribbonwood project, some students when they looked into the façade and reducing heat gain, they were trying to understand which would look better and what impacts it would have. The Lendlease project was brand new, so I thought they would play more with the aesthetics, but they did not go into this much. Definitely some of them did try and they enjoyed that bit of designing, not just the numbers. This was just a matter of time – if they had more time they could go a bit deeper in that, by the time they decided what they wanted to do it was almost too late to look at the aesthetics for the solution. I could see this as a 2-semester project, where the first semester involves analysis and understanding solutions, and the second is where they go and independently develop their solutions. From the beginning if they could choose one topic, and then focus in that topic it might be easier to explore solutions in depth, but then this may not be what we want.

Most of the students went towards looking at solar panels or the façade of the building because these were the easiest and the shortest options to investigate

Q6. What did students struggle most with when asked to advance their design-thinking with environmental/engineering constraints in mind?

My feeling is because the students didn't have to look at the design from the beginning, they were instead focusing on things like the site analysis and not thinking about what they design would look like in the space. I think the thing the students struggled most with was making decisions – they wanted to be told what to calculate and investigate from the beginning, they struggled to decided what they wanted to do. Once they decided what to focus on, the understood more what they could analyse. At the end, most of them got it – what they produced, even in only 4 weeks, they got the idea of testing different things and balancing out efficiency with costs or aesthetics.

Some of the engineers were uncomfortable trying to find solutions – they were literally asking "What should I be analysing?" We were trying to tell them we need you to give us your advice.

Q7. What barriers and constraints to architect/engineer collaboration exist (outside of the actual design process)? Time-poor/fees/contracts/…?

Definitely time and fees are usually barriers. Egos can also be a big barrier. Having engineers at the beginning of projects is very useful, especially ESD and structural – but it comes back to fees and time. Having to do things in a rush does not help for collaboration in projects, and having engineers involved from the start involves higher fees. I tend to engage with consultants outside the projects – doing workshops that neither architects or engineers get paid for, but they learn to collaborate in early stages. Even if the client doesn't want to pay for it - we can then show the client what the benefit of this would be. Most of the time, the client wants to have the design for the DA without having to pay the consultant other than the minimum required.

The more input you have at the beginning, the better then end product us, but the general feeling in architecture is that there is always time to change things.

Q8. How would you describe integrated design?

Integrated design is when collaboration happens from day one. You can force and integrate services and disciplines, but it won't be an integrated design – this requires collaboration from the beginning and input from all people, a design that comes out organically through conversations with different disciplines.

Q9. How useful was it for students to experience an integrated design processes as part of their higher degree education?

I think that this was really good and useful, this is an amazing experience for the students – we pushed the boundaries in a completely different way that any other assignment at university would push them. They had constraints they don't normally have, they had to talk with people with different viewpoints, and overall I think this was a good experience for the students.

Interview 2: Integrated Design Studio 11 – WCC Ribbonwood Community Centre – Interview with Consultant 2 (Civil/Structural Consultant)

Q1. What enables successful Integrated Design in the studio setting?

Being able to adapt the format and see what works with the students - initially students were in smaller groups, with consultants moving between them, but the discussion was limited. This changed to bring students together in larger groups and enable more conversation between the groups which seemed to get more discussion going.

An important role of the consultants was not just to be answering questions, but to be asking them. I could do an important job of asking the dumb questions of the other consultants to stimulate discussion and demonstrate by example how to relate to those with other viewpoints. As the consultant you also need to be more across what they actually need to do and what information they are actually working with.

Q2. Please tell us about the studio brief's impact on achieving integrated design solutions (considering the way it was written & communicated). Please reflect on the level of detail and the language of the brief.

The Ribbonwood brief was an accurate representation of a real world scenario – the client didn't really know what they wanted the students to do, and students had to reverse brief the client, decide on a course of action and how they were going to target their exercise. There was a strong focus from the discussion with the client on building services, but this leads to the question of whether they should look into other things. This is a good lesson in how designs are happening in a real world.
The Lendlease brief was a bit vague – this wasn't the worst thing though as it meant everything was up for grabs, however it wasn't always clear what direction they should take. The brief was a bit muddled and no one knew what to make of it for a while – but this is probably how it should be.

Q3. What were the most critical decision-making points/questions to answer when balancing architectural and engineering input for generating environmentally optimised design solutions? Where did the inspiration for the students' solutions come from? How did the engineering consultant(s) contribute to the authorship of those solutions? What was the impact of engineering and architecture student collaboration on the project outcomes? What impact did the timing of the engineer/architecture collaborations have on the development of the project?

A lot of the inspiration came from the classes through lectures, this was a catalyst for lots of their ideas. The consultants did not seem to add any new ideas, rather they provided technical advice and helped the students with developing ideas. The backgrounds of the students was not always obvious – except when it came to which initiatives to research and detail. The conceptual nature of the design meant that the interactions between the disciplines did not really get drawn out. Some of the groups collaborated well, but it was difficult with remote learning – including having the consultants on zoom. People are less inclined to engage over zoom.

Q4. What guidance by you was most useful for the students (and why)? How did your input increase their 'level of understanding of' environmental issues and associated solutions? What would you change in order to maximise your input (if anything)?

As a structural consultant, my guidance was a bit limited. There were times when looking at adding or changing things on the building – I was able to discuss what you would need to look at. There were times when looking at ideas around the façade – I was able to discuss what you would need to look at. I was also able to contribute by demonstrating how you sit in a studio and ask questions and engage with ideas.

Q5. How did students cope with balancing aesthetic/functional design aspects with engineering concerns? What was the impact of engineering and architecture student collaboration on the project outcomes? What impact did the timing of the engineer/architecture collaborations have on the development of the project?

I don't think we discussed aesthetics as all. Maybe because the Ribbonwood library already exists - there was never a suggestion of making it look better. They didn't have to develop the shape of the building for the Lendlease development, although there was an opportunity to nominate a façade type. It would be interesting to see if aesthetics was not considered as a category in the matrix assessment, I suspect that is wasn't.

Q6. What did students struggle most with when asked to advance their design-thinking with environmental/engineering constraints in mind?

My impression was that they seemed fine coming up with ideas, but the process of evaluating those ideas was a challenge. This was a key part of a lot of the assignments. You need to have a level of understanding of detail of each of the systems you are proposing so they can be ranked, and this was a challenging exercise. This is where some of the consultants were really useful – they have a lot of knowledge in their heads of where to find information, how to build up the matrices and comparing the options.

Q7. What barriers and constraints to architect/engineer collaboration exist (outside of the actual design process)? Time-poor/fees/contracts/…?

Generally engineers and architects sincerely want to coordinate and collaborate, but we would all say that the majority of the projects we work on don't have the program or the budget to do that effectively. There is a destructive logic in the construction industry that you can save money by doing things quickly and paying people less - but engineers and architects would all be of the opinion that if given more money and time, they would save more by giving a better and cleverer design. Another barrier is not having the tools and skills to interact. 3D modelling is becoming more normal in architecture but not amongst engineers, in Wollongong at least. Finally, it is important to find architects and engineers who have a shared philosophy of holistic design. It is more work to coordinate and share ideas and think holistically about projects.

Q8. How would you describe integrated design?

Integrated -or holistic – design is the idea that everyone working on the project has a philosophy of thinking about the bigger picture of design, rather than working in silos or dealing with their own patch. Any engineer can sit down and design something and it will be fine – but to make a great design is a lot of effort and thinking about not just what is best for your design, but how your design can make other peoples designs better.

Q9. How useful was it for students to experience an integrated design processes as part of their higher degree education?

Having this studio at university is very valuable because it is lived out real world interactions. The key lesson of the studio is saying as you go out in the world, don't just sit at your desk and be an engineer, get up and talk to people and ask questions – how can you integrate your design with people to make the whole project better.
For the modern engineer who has to deal with changing technology, new materials, new types of buildings, new methods of architecture and new systems - having these skills of being able to interact and work within a team are really important.

Interview 3: Integrated Integrated Design Studio 11 – WCC Ribbonwood Community Centre – Interview with Consultant 3 (ESD Consultant)

Q1. What enables successful Integrated Design in the studio setting?

I think it is mainly about the facilitator, because a lot of good integrated design happens when you have someone who is able to get people talking, get them to collaborate and spot synergies. The students you have in the class are the people you have to work with, so the facilitator is the person who is able to get the best out of them.

There was a lot of time when the students were left to themselves and not going anywhere – the studio relies on people talking and sharing – sometimes people need a bit of prodding to share.

Q2. Please tell us about the studio brief's impact on achieving integrated design solutions (considering the way it was written & communicated). Please reflect on the level of detail and the language of the brief.

In industry, there is a lot more access to the client and stakeholders – the way that solutions are developed involves more direct consultation with the client, including review of ideas and insights. The written brief is usually brief, and will then be clarified with the client. This is not reflected in the way the IDS is run. There is a lot more face time interaction and talking in industry.

The brief provided in the IDS was very detailed, and full of information and had a lot of the existing reports. The stakeholders were really engaged and had a lot of stuff and experiences they wanted to share.

The project was fairly early in design, and while there was a concept prepared there was not a group of people to challenge on the concept. Without the constant interaction with the client it becomes hard to integrate design ideas. The feedback given by the client part way through the project was very good, this would have been helpful earlier on but I don't know if she got a chance to provide that feedback earlier.

Q3. What were the most critical decision-making points/questions to answer when balancing architectural and engineering input for generating environmentally optimised design solutions? Where did the inspiration for the students' solutions come from? How did the engineering consultant(s) contribute to the authorship of those solutions? What was the impact of engineering and architecture student collaboration on the project outcomes? What impact did the timing of the engineer/architecture collaborations have on the development of the project?

The students seemed a bit quiet, so I think a lot of the inspiration for a good number of the students came from ideas put forward by the tutors or extracted from the brief. There were some students who embraced it and asked questions, but for a lot of them there was too much responding to ideas from ideas rather than putting forward ideas.

I tried to make them curious – asking questions about why things might be the way they are or what could potentially happen so they could generate ideas out of that. It is very guided, but at least they come up with the solutions themselves.

In industry when you put good architects and good engineers in a room together its impressive to watch how quickly they can develop an idea, but that's not what you saw in the IDS. What you saw was architectural engineering or engineering students or engineers realising their biases and I think that was really good – they get to see other peoples points of view, but its not the same outcome as you would expect in industry.

Sometimes in the tutorials I tried to challenge the students like the client – ask them what about this? I think they benefit from being challenged or questioned like that because it makes them think not only about their own stuff but also about all the other stuff they have an impact on.

Sometimes I would have little discussions with another consultant in the groups around structure and embodied energy and the trade off between energy efficiency and embodied energy – it felt wrong at the time because we were the only ones talking, but then I saw that the students in the background and they were really interested watching us interact – I perceive that as good integrated design studios. Because they are not experts in their field yet, so they are a bit scared of putting forward their ideas.

In terms of the timing, I think they should work individually first, and then come together and work collaboratively – the reason in when they develop their ideas independently – so if they are mechanically biased they might develop a really

efficient mechanical system but then they go and try to fit in into an overall design they realise that a less efficient design that fits in better with the architecture might be the overall better design.
It did challenge them up front to work with others. Sometimes the role I had was to pull their head out and get them to look at the overall picture rather than focusing on their specifics because sometimes they got stuck in what they know and develop something that works with what they know.

Q4. What guidance by you was most useful for the students (and why)? How did your input increase their 'level of understanding of' environmental issues and associated solutions? What would you change in order to maximise your input (if anything)?

The best guidance I could provide was providing examples of how I have given un stuff working in integrated design 0 making compromises to get a better outcome. Technical answers can come from anywhere, but the industry experience and recounting stories of how working together gets a better solution than everyone working independently was most helpful.
When the students put together the matrix of solutions - a lot of them didn't know where to go, or just went straight back to what they knew and worked on that. My input was to get them to stand back and refocus their efforts on what the brief said or what task they had been set, and how they could focus their teams efforts on finding the initiatives that actually addressed that.
The thing I would chance would be to attend in person. It was so much harder doing it over the screen - it was difficult to read body language and encourage conversation.

Q5. How did students cope with balancing aesthetic/functional design aspects with engineering concerns? What was the impact of engineering and architecture student collaboration on the project outcomes? What impact did the timing of the engineer/architecture collaborations have on the development of the project?

They were really focused on the technical design.

There was one team that did a really visualisation of a brise soleil – I think that was really evocative for the other students to see it. Seeing it made it much easier for the others to understand what they were proposing.

I am not sure that their specific project outcomes were modified that much by specific things that were fed back by other disciplines – I think the real benefit they got was the exposure to other peoples thinking about the same challenge.

This comes back a bit to the stakeholder engagement – most of the brief is technical, so that is easier to respond to. Most of the feedback on aesthetics comes back to the stakeholder engagement – there wasn't much guidance or constraints given to aesthetics so the students didn't care for it. There was only one project that attempted to address aesthetics.

No one looked at changing the shape or orientation of the building, they just took it as the blocks that were given, and looked at how they could tack something on to meet the specific requirements.

Q6. What did students struggle most with when asked to advance their design-thinking with environmental/engineering constraints in mind?

The students focused on the briefed technical requirements. A lot struggled with time management and were starting assignments very late. The other thing was that they google the specific requests and then just take the first answer and try and mould that to what they need to. They are starting from scratch with experience, so their way is to either ask the tutors or just google for ideas, so you see a lot of similar ideas that are specific technology responses to a challenge rather than a fully integrated design.
This could be addressed by constraining the scope of the project that they are doing to allow them more time to explore within that.
For example, in this project there was a specific wall that had an issue with thermal comfort – it had an architectural issue with a temporary wall. That room could have been investigated on its own – this limits them in some ways built also allows them to explore more integrated solutions. The problem with that model is that you may end up with every

group focusing on the same solution. Perhaps you could split the building up into specific areas and get each group to focus on one area – but then when you put all the ideas back together in a whole building it might not work.
It is possibly a good thing to show how the consultants would work through a project, take some videos of them brainstorming – so the students can see the aspiration to work towards.

Q7. What barriers and constraints to architect/engineer collaboration exist (outside of the actual design process)? Time-poor/fees/contracts/…?

A lot of good thinking is embedded early on in the project, often even before consultants are engaged or there are fees for the project. For example – the water cube in Beijing is an interesting project in integrated design – a significant compromise was made on fire performance to achieve good structure and thermal efficiency. That whole project and design was setup by a few experienced people early on and then the design team had to solve all the design problems that were created later on. The challenge is that you are not onboard as a consultant, you are not part of the first ideation. Once the consultants and the money is committed, time then becomes an issue because the owner is not keen to wait – they want it documented and built straight away.

Also, getting the right people together in the room at the right times. Getting all the stakeholders, clients and consultants together at the right time is a challenge. There is a challenge with ego - really good collaborations happen when you can let go of ego.

Q8. How would you describe integrated design?

Integrated design is efficient – the outcome is efficient – it is not harnessed by a single discipline. You can have good design in every single discipline and put it together and it works. But in integrated design, no single discipline guides it unless the brief requires it – it is unharnessed from any ownership by single person, it is the outcome of the group – the collaborators. Good designers working together towards one solution. It makes sense -everyone realises that is right and it works.

Q9. How useful was it for students to experience an integrated design processes as part of their higher degree education?

It is really important to show that there are different points of view. My team employs two graduates a year and we don't accept any who hasn't got experience working across at least two disciplines or with multiple disciplines. Anytime we have employed someone who was a high achiever from any single discipline it has failed – or it has been hard to get them to work in a team. Communication is really important too – this studio forces students to communicate with people who are not the same style or thinking as them. I really like the idea of the IDS and would have appreciated having a wider exposure to other disciplines when I was at uni.

Interview 4: Integrated Design Studio 11 – WCC Ribbonwood Community Centre – Interview with Consultant 4 (ESD Consultant)

Q1. What enables successful Integrated Design in the studio setting?

Integrated design is bringing together multiple disciplines to produce the design solutions to meet the whole of the project vision. Successful integrated design studios need collaborations from major disciplines and consultants to help them reflect the areas of opportunity and value in real practice. Experience level is very important for the capability. We want to inspire people with a difference experience so they can work collaboratively and openly together, removing the hierarchy to teach and inspire them for real practice.

Q2. Please tell us about the studio brief's impact on achieving integrated design solutions (considering the way it was written & communicated). Please reflect on the level of detail and the language of the brief.

The brief is the key to providing direction to the team and consultants around how to start the project and understand the project details.
For this project, the details provided were very broad – what the students were asked to design and develop in their projects. Sometimes this makes them very unsure and confused how to prepare their scope of work in a limited time. The brief provided was comprehensive, the project was big and in its early stage – so a lot was asked of the students. A range of questions or at least minimum areas to cover would make it more clear to the students where to start.
This project brief was concise and clear what the students needed to cover, this led to students being more focused. It allowed them to prepare their ideas and propose their designs.
It would be good if we could make it more clear for the students in the initial weeks what is expected of them – it is not just about them submitting assignments, it is about teaching them how the real world works.

Q3. What were the most critical decision-making points/questions to answer when balancing architectural and engineering input for generating environmentally optimised design solutions? Where did the inspiration for the students' solutions come from? How did the engineering consultant(s) contribute to the authorship of those solutions? What was the impact of engineering and architecture student collaboration on the project outcomes? What impact did the timing of the engineer/architecture collaborations have on the development of the project?

From the beginning, producing design solutions was challenging – teams with students from different backgrounds had conflicting opinions coming together. At first they had to define as a team what they wanted to achieve, then they could bring their ideas – however some of these ideas where conflicting, they couldn't be achieved at the same time. The students then challenged each other to evaluate their ideas, and by considering other opinions they could come up with most balanced result.

When we are talking about sustainability, we shouldn't put boundaries or restrictions on certain aspects such as cost. For Lendease we didn't have this boundary. For the WCC project, cost was a boundary, but eventually it was balanced out with cost, techology and design solutions at the end.

Ideas came from student research – working together with different disciplines and with the different consultants inspired different ideas within the teams, and encouraged them to investigate different ideas. Reviewing the brief and preparing goals for the project required collaboration and took about 80% of the time, and then for the remainder 20% they spent analysing their ideas and looking at how their design could achieve the outcomes. If they had more time, the design and details may have been more developed.

Q4. What guidance by you was most useful for the students (and why)? How did your input increase their 'level of understanding of' environmental issues and associated solutions? What would you change in order to maximise your input (if anything)?

We tried to discuss ideas in details and how they could work in real practice – sharing real world examples of what could be done. I think this was good to bring them knowledge of what is currently happening in the industry. This gives the students a chance to understand what is important and what is not and prepare them for the workplace. All of us have a lot of options, but you cannot apply all of them in your project, we need to choose ideas based on the specific project. The approach for each of the projects needs to be different for different levels of detail. The WCC library was limited in the options available, but there was sufficient time to achieve the outcomes. Lendlease was very broad so we discussed a lot of different options but it was hard to get the goals that we defined during the timeline of the project.

Q5. How did students cope with balancing aesthetic/functional design aspects with engineering concerns? What was the impact of engineering and architecture student collaboration on the project outcomes? What impact did the timing of the engineer/architecture collaborations have on the development of the project?

Students in the IDS had a really good understanding of the brief, constraints and opportunity that they had. For the WCC library- there was an issue with thermal comfort and an issue with the west façade. Some of the students knew they needed to considering daylighting in the library, and double-glazing windows, whereas mechanical students were focused on reducing solar heat gains. Aspects like shading had mechanical and architectural impacts. Some groups came up with seasonal shading – bringing green walls during summer and allowing sun in winder. For the Lendlease, they didn't have any issues to solve – the just needed to bring a solution to design better. So each discipline could present their ideas and then match ideas next to each other, they could apply all of these options to their design as there were no cost limitations. Ideas were benchmarked against Greenstar but this was a broad range of evaluations criteria. The students evaluated options through the matrix, rating against the project goals.

Lendlease had more options in their matrix and they considered a broader range of ideas. If they had more time they could come up with more details for a better range of ideas.

The boundaries for the library were clear so they could develop their ideas well and evaluate them effectively.

As a consultant we tried to help them with the communication and the design that they selected, but we didn't have the time or the willingness of students to engage with the consultants outside the tutorial hours.

Q6. What did students struggle most with when asked to advance their design-thinking with environmental/engineering constraints in mind?

The students were let down when they tried to conceptualise how the design could come together. It is very obvious that difference students have different views, and their different ideas conflicted with each other. The students were really good in capable in the research and analysis, but they didn't have much experience in design. So they were struggling to advance their ideas to meet the project requirements – they didn't have enough time. The consultants tried to make the students more familiar with how to identify problems and help them work together. They also had some issues with the tools and skills needed – such as energy assessment. They also struggled to know where to start and which area to cover first.

Q7. What barriers and constraints to architect/engineer collaboration exist (outside of the actual design process)? Time-poor/fees/contracts/…?

I believe conflicting design requirements and potential unequal hierarchy for the design brief. Architects usually take a leadership role and they consume most of the time and work of the project and dictate what they want - other disciples need to change and revise their design based on what the architects prefer. We try to make a bridge between engineering and architecture and bring sustainability into it, but we still have a lot of issues with architects. Architects need more training towards sustainability and working collaboratively.

Q8. How would you describe integrated design?

When we are working together from different disciples and perspectives and views to develop the best possible outcome for the project. We need to work towards a healthy experience and bring this to students to learn it and use their skills for their future designing in this environment so they can learn from how real practice works, working towards different ideas and how to fit it in their project.

Q9. How useful was it for students to experience an integrated design processes as part of their higher degree education?

I think in this IDS they learned how to prepare themselves for the real world. It takes the project out of the theoretical thought to the actual design process - they face what the clients might ask them. It was really encouraging for them to learn how to work together, develop their ideas together and be connected to the team, because they see how one of their ideas and solutions might not be a solution from the other side of the project. They learn how to work as a group towards the one target, not just individually.

Interview 5: Integrated Design Studio 11 – WCC Ribbonwood Community Centre – Interview with Studio Tutor 1 (University of Wollongong)

Q1. What enables successful Integrated Design in the studio setting?

The main thing for me is willingness for the students to engage and participate in the studio. This requires acceptance from the students primarily but also the stuff, to acknowledge that it is a non-typical subject. I think it is important that there is a well-structured method to bring the students up s to speed with the content and the expectations in the subject. I felt that no matter how much experience was brought in by the experts, the transfer of knowledge was most successful when both the students and the consultants were highly engaged. I thought the tutors and the consultants did a great job engaging the students.

Q2. Please tell us about the studio brief's impact on achieving integrated design solutions (considering the way it was written & communicated). Please reflect on the level of detail and the language of the brief.

The briefs presented were clear in terms of establishing overall objectives without over-constraining the solutions. I think some of the language used was potentially a bit too specialised – particularly technical aspects of the HVAC - to be understood by the entire classroom, however as stated the aims and objectives were nonetheless very clear from the presentations. Supplementary information provided was good. The aims and objectives were clear from the presentations. Supplementary information provided was good.

Q3. What were the most critical decision-making points/questions to answer when balancing architectural and engineering input for generating environmentally optimised design solutions? Where did the inspiration for the students' solutions come from? How did the engineering consultant(s) contribute to the authorship of those solutions? What was the impact of engineering and architecture student collaboration on the project outcomes? What impact did the timing of the engineer/architecture collaborations have on the development of the project?

I thought the key decision making points and questions were a) does the solution fulfill the objectives of the client brief and b) does this solution appropriately prioritise satisfying the most important objectives in the brief – i.e. reflecting the balance between net zero and other goals in the objects in a way that satisfies what the client was after. Inspiration for the students solutions were primarily drawn from their own interests – they seemed to choose aesthetically prominent solutions (such as façade and landscaping improvements) over functionally impactful solutions such as a more energy efficient HVAC design. I think the consultants stimulated discussion around solutions once the problems and objectives were identified. Primarily they contributed by providing complimentary information, such as design and analysis tools, rating and performance metrics or novel technological solutions that the students might not have been exposed to, to better define and quantify their solutions and its benefits.
I think the students disciplines had a significant weighting in what drove their interests towards addressing a particular problem.
Collaboration seemed directed towards delivering holistic and rounded outputs in the group assessments, and in individual assessments the collaborative efforts were to assess the feasibility at a high level, but maybe not as much in terms of analysis.

Q4. What guidance by you was most useful for the students (and why)? How did your input increase their 'level of understanding of' environmental issues and associated solutions? What would you change in order to maximise your input (if anything)?

I think I provided a method to the students to think about how to best approach the problem logically, this enabled them to make progress in their assignments. Particularly when the tutorial content is not as readily digestible as a standard subject – this was a lot more open ended so there was a lot of inertia and it was hard to get started on the problem. So trying to break it into small steps was something I tried to help them with. If there were more examples of the solutions to help the students – a lot of what they did was self-guided learning and engagement with the consultants which not a lot of the students were involved in.

These days the concept of green and environmental design is well understood by students, but there is limited understanding around the relative magnitude of the environmental impact that different parts of a building can have.

Concepts of embodied and operational carbon for power generation versus energy efficiency – assessing things quantitatively to try and deliver the best solution.

Q5. How did students cope with balancing aesthetic/functional design aspects with engineering concerns? What was the impact of engineering and architecture student collaboration on the project outcomes? What impact did the timing of the engineer/architecture collaborations have on the development of the project?

I think initially the students were drawn to solutions that involved aesthetic impacts – mostly façade solutions and were less concerned for engineering practicality, but over the course of the subject, particularly in the way the assignments were set out. The comparison matrix helped students look at all the aspects of the design and try to weigh up and balance these aspects. They often brought engineering concerns to the consultants to understand how to evaluate or measure them.

When it came to filling out the matrix, different backgrounds of students helped the groups to not miss anything, and different skillsets of individuals helped with presentation of the brief and results. The less defined problem provided more room for creativity and aspects of both architecture and engineering to be explored further.

As the problem was well established, there were two clear approaches – either the architectural façade and shading, or the mechanical technological route. I didn't see much overlap between those two approaches.

Q6. What did students struggle most with when asked to advance their design-thinking with environmental/engineering constraints in mind?

I thought given the short time and the broad scope of the project, it was tough for the students to analyse the brief, decide to focus upon a specific problem and then develop and quantify a solution for that specific problem. I think the consultants facilitated getting around these problems, but I noticed that some students took a long time to make significant progress. Many of the problems that the students wanted to address were too complex to be addressed given the timeframe and the skillset of the students. One on one time with the consultants was offered to help the students with this, but many of the students did not utilise these opportunities as much as they could. Some might have perceived a more complex solution as being too risky in relation to their grade, so they decided to focus on a simpler issue.

Q7. What barriers and constraints to architect/engineer collaboration exist (outside of the actual design process)? Time-poor/fees/contracts/…?

Between the two disciplines there needs to be an appreciation for the nuances and processes involved in each others' disciplines that should be respected and understood in order to enhance the collaboration.

Q8. How would you describe integrated design?

The idea of integrated design would be to approach multiple aspects at once and I could see this would be highly beneficial in projects. Seeing architects and consultants work together to develop a solution that achieves the clients goals, especially environmentally friendly solutions.

Q9. How useful was it for students to experience an integrated design processes as part of their higher degree education?

I think it is very valuable to them to have a taste of the real world – meeting real clients rather than just hypothetical scenarios, and actual consultants. Experiencing the interaction and going through these processes is not something a regular subject offers. This will help make them more comfortable in applying for graduate roles.
The original goal of the IDS was to develop radical and innovative environmental outcomes – however the students were not really able to deliver on this, often because they focused on the simpler solutions. But the IDS succeeds in replicating a real world project and gives the students a real appreciation for the processes involved in a project

Interview 6: Integrated Design Studio 11 – WCC Ribbonwood Community Centre – Interview with Studio Tutor 2 (University of Wollongong)

Q1. What enables successful Integrated Design in the studio setting?

We ran this studio in dual mode - I think we were fortunate that the majority of the students were in the space and we did manage to come up with solutions to join people into the groups. Really it's about getting conversation started - sometimes students are reluctant to open up and put themselves and their ideas out there, they fell like there is a risk. They need an encouraging environment where no idea is criticised and people are encouraged to share. It is important hat the students are engaging with each other. They are engaging with the teaching staff and industry partners but they are also trying to reflect on each other's ideas and suggestions. You need an element of trust and openness between the participants.

Q2. Please tell us about the studio brief's impact on achieving integrated design solutions (considering the way it was written & communicated). Please reflect on the level of detail and the language of the brief.

The Lendlease brief was informative and yet open, it was for a new build. The client had a board and holistic overview of what was important, and that was reflected in the diversity of responses from the students. It may also be down to the fact that it was a new build.
The WCC client brief was very focused on our particular contact's area of interest and expertise – being the HVAC system. It may have been difficult because it was a retrofit. The level of detail was too detailed, but having said that, when we went on the site visit and spoke to the users of the building – both client and staff – the students were able to get perspectives on other things that were important. Whilst the brief was targeted at HVAC, we could see from what the students responded with that they picked up on some of those verbal cues from the users of the building. That wasn't written into the brief, but it was information that they used to guide their decisions.

Q3. What were the most critical decision-making points/questions to answer when balancing architectural and engineering input for generating environmentally optimised design solutions? Where did the inspiration for the students' solutions come from? How did the engineering consultant(s) contribute to the authorship of those solutions? What was the impact of engineering and architecture student collaboration on the project outcomes? What impact did the timing of the engineer/architecture collaborations have on the development of the project?

Firstly, I will say that 13 weeks is not long enough for students to go through the integrated design process. The Lendlease solutions were really only focused on sustainable design solutions more so than integrated design solutions. I feel like the solutions were more research based – the students got some guidance from the industry partners but I didn't see a huge amount of them bouncing off each other – it was more between a team and one or two industry consultants. I feel like most of the inspiration came from research that they had done. On that basis, it probably isn't necessarily an innovation, but I just it depends how you define innovation.
I think the consultants helped students to analyse, reflect on and evaluate whether their solutions were appropriate– through signposting towards resources, flagging when there were issues. I don't think they were coming up with the solutions, my feeling is that the students were tabling things and then they were discussed. Consultants were asking pointed questions to help them make decisions and refine what they were working on.

I think they did well in their group work at the point of doing their matrices – but it is hard to know how much of this is people given a parcel of work to do compared to real collaboration. We were aware of some team dynamic issues in some of the teams. I would be interested to know how much the students benefited from that cross-discipline collaboration - I am sure they were exposed to more perspectives that what they would usually, but I am not sure to what extent this had an impact.

Most of the collaboration happened in the first two thirds of the studio. I didn't see them continue the collaboration beyond where they were required to work in groups. It was in identifying the solutions to be explored further where collaboration happened, but then exploring those solutions happened individually. It was a benefit to the architectural engineering students to have to simulate and test their ideas and quantify a relative impact, so you wouldn't want that role just being done by a mechanical engineering student and perpetuating that traditional split..

Q4. What guidance by you was most useful for the students (and why)? How did your input increase their 'level of understanding of' environmental issues and associated solutions? What would you change in order to maximise your input (if anything)?

I think we gave a framework for the students to work in. We introduced some concepts, but I think that we weren't pushing students down a certain path. There was a lot of reiteration around what we were asking them to do – trying to keep the students on track, clarifying expectations. Whether that was because it wasn't clear from the start or because it was so different to other courses the students had done. We took a back seat in terms of the live tutorial sessions – we delivered the lecture content then provided the space for the students to work with the consultants. Next time I would try to provide better examples of what was expected sooner, so they could see a pathway of where they were expected to go. None of them seemed to understand 'business as usual' or what the matrix of ideas should be, so I would find good examples of how to do things, while at the same time making sure that you don't just give them something they could copy.

Q5. How did students cope with balancing aesthetic/functional design aspects with engineering concerns? What was the impact of engineering and architecture student collaboration on the project outcomes? What impact did the timing of the engineer/architecture collaborations have on the development of the project?

I think there was a strong focus on engineering concerns, which contains functional design in some ways. There were aspects of architectural design in the there but there wasn't a strong focus on it. Some of the students were more conscious of this than others. There was a focus on having a net zero outcome and the way to do that being through an engineering solution.
A worry about needing to include the architectural or functional aesthetic aspects stressed some of the engineering students, whereas the modelling stressed some of the architectural engineering students.

Q6. What did students struggle most with when asked to advance their design-thinking with environmental/engineering constraints in mind?

Some of the students were advancing design thinking. Students in the Ribbonwood centre were trying to tackle the front façade and integrating shading solutions. When students thought of something that wasn't a pure engineering solutions, sometimes that was then difficult to simulate or quantify, so they struggled with how to evidence the impact of that.

Q7. What barriers and constraints to architect/engineer collaboration exist (outside of the actual design process)? Time-poor/fees/contracts/…?

There is some historic cultural angst between some engineering disciplines and some architects. Architects have perceptions of engineers and engineers have a certain perception of architects but it is not always the case. A client needs to be willing to bring people on board maybe earlier than they would normally and that will have a cost implication. People have to be driven to want to do it. Industry is changing and I feel like there is a drive for this. You can see this through things like the Architects Declare movement and the Engineers Declare movement and these two movements trying to get together and an acknowledgement that people need to have conversations sooner to stop some potential solutions being designed out and enable that potential integrated design. I feel that at the point of education is a great time to start addressing breaking down some of those stigmas that do exist between the disciplines.

Q8. How would you describe integrated design?

A process in which people are able to collaborate from the position of their own expertise but welcoming the expertise of others to help to inform the best solutions and I think it really is a prerequisite for properly sustainable buildings. It can save time as well – if you are wanting to design a sustainable building and you did it in a traditional way, where the architect designs something and then it does to the engineers to check it and back to the architect to amend it, that can take a huge amount of time and energy. Whereas if you get everyone in the room together to start with and work together at the same time, you can potentially save time and energy. I don't know if anyone has looked at that – whether you are aborting costs, or coming up with solutions that are a lower build cost because they have been considered earlier then that is a real win potentially.

Q9. How useful was it for students to experience an integrated design processes as part of their higher degree education?

I think it is really important for students to go out into industry understanding that theirs is not going to be the only perspective, that they need to collaborate with people from different disciplines and they have to learn to communicate with people who don't have the same knowledge as them. All of that is a really great and important learning process.

Interview 7: Integrated Design Studio 11 – WCC Ribbonwood Community Centre – Interview with Studio Tutor 3 (University of Wollongong)

Q1. What enables successful Integrated Design in the studio setting?

A successful integrated design requires feedback from different disciplines if you don't have this feedback during the design or retrofit, then the traditional designs seem to be very much a business-as-usual case where you maximise operational functionality, minimise cost and maximise future cash flows. There is very little around thermal comfort, visual comfort, energy use. Where feedback between clients, engineers and architects is integrated, each of the disciplines will inform around aesthetics and functionality. It is useful to have constraints from the client to provide a challenge and to see an impact. If it not there, the design is all around functionality, cost and cash flow. Integrated design will also be different for different projects – an empty site, an existing building, or a design that has been geometrically designed and submitted for DA approval. This affects the way you process the designs and suggest solutions.

Q2. Please tell us about the studio brief's impact on achieving integrated design solutions (considering the way it was written & communicated). Please reflect on the level of detail and the language of the brief.

The client brief was well defined, and had an ambition to minimise gas use/achieve carbon neutrality –this vision/ambition allowed the students to think beyond the traditional costs, functionality aspects. The level of detail was very high, but I think that the expertise required for that brief to be delivered was too specialised – it was heavily skewed towards the HVAC side of things. During the site visit a lot of things came up – so the site visit was very beneficial and would be required if it is an existing building. The brief needed to be accompanied by discussion with the client.
The brief was very detailed, and the client was very skillful in critiquing opinions, and she had a team behind her who had thought of everything already. The students solved the geometrical definition of the design early, which really didn't give them the ability to be creative in anyway. They didn't make a lot of modifications around that. It would be best to not give the design or floorplan early to the team, but given them time to think about things earlier and optimised functionality of the spaces and then see where they can integrate this into the site.

Q3. What were the most critical decision-making points/questions to answer when balancing architectural and engineering input for generating environmentally optimised design solutions? Where did the inspiration for the students' solutions come from? How did the engineering consultant(s) contribute to the authorship of those solutions? What was the impact of engineering and architecture student collaboration on the project outcomes? What impact did the timing of the engineer/architecture collaborations have on the development of the project?

Because this project was an existing building, the students and consultants looked first at the low hanging fruit solutions – lighting, dealing with skylights to bring in natural light, shading to prevent west facing façade solar gains. Most students looked into these type of solutions. There was creativity by some students, which came from the constraints that were put around the brief and the requirements by Arena. If we didn't ask for the site to have zero energy design, some of the solutions would not have been considered. There was an example of a student who looked into if there wasn't sufficient roof area for solar, then looking at modifying the carpark to include carports with solar panels – that would not have happened if the net zero constraint was not there.
Inspiration also came from the fact that we asked them to brainstorm ideas and assess them in a matrix based on traditional criteria such as cost and feasibility, but also in terms of carbon and energy.
We tried to ensure that the groups had both Masters engineering and undergraduate engineering and architectural engineering students. Masters students included a mixture of students – some contributed a lot in the team project, put themselves forward to take responsibility for HVAC side of the building, helped with development of the BAU case.
However there was also a misconception that they could not do specific things because of their discipline, whereas someone else in their group who was that discipline. In reality I would say that both disciplines could address the issues around the building.
The impact of collaboration was significant- many of the solutions that were identified would not typically have been considered at this stage of the project – such as atriums, some of the solar innovations etc. It was also very useful to have the structural engineering consultant in the discussions because he helped to interrogate any proposal from the students in terms of what can/can't be built.

Q4. What guidance by you was most useful for the students (and why)? How did your input increase their 'level of understanding of' environmental issues and associated solutions? What would you change in order to maximise your input (if anything)?

The idea of having constraints early in the design stage affected the design brief, and the requirements of the net zero building design. I think that getting the students to evaluation solutions within a matrix t, including those extra criteria around carbon reductions, energy etc, was an essential step. This gave them a framework to work with, and helped to keep reminding them that these are issues they need to consider. I also gave them examples during the class discussions of things that may or may not work from a a daylighting/energy point of view.

During the final stage of the design studio, I think we made a mistake in allowing them a lot of flexibility in the choice of design solutions without giving them a target (such as baseline design to improve upon or change in energy use) – as this led to them choosing the easy solutions. It would be best to include an extra step of asking to demonstrate that the design performs better than the typical design you would see for things such as energy usage.

Q5. How did students cope with balancing aesthetic/functional design aspects with engineering concerns? What was the impact of engineering and architecture student collaboration on the project outcomes? What impact did the timing of the engineer/architecture collaborations have on the development of the project?

I would say that we saw this balance – all the proposals were okay in terms of aesthetics – they considered shading on the west façade. All the PV oriented proposals came from engineering students. The students took for granted the geometrical aspect of the building – they add an atrium, shading, PV panels - that was pretty much the design solutions they came up with in the final solutions. It was important to have both disciplines there to talk around some of the issues.

The timing is also very important -without bringing everyone together the optimisation of the design does not happen.

Q6. What did students struggle most with when asked to advance their design-thinking with environmental/engineering constraints in mind?

They struggled with making design the more specific – the concept design was fine, but when it came to putting dimensions around this and optimising/quantifying the impact of this, it required the use of tools that often were used by specialists. Also considering the match between energy demand and supply is not in the minds of the designers in the early stage – not just the overall requirements, but also the timing of the demand versus the availability throughout the day. The environmental aspects need to be prescribed – it is not normally there in design thinking. Giving them a framework and asking them to critically weight the importance of each of the criteria in that framework helped to improve this.

Q7. What barriers and constraints to architect/engineer collaboration exist (outside of the actual design process)? Time-poor/fees/contracts/…?

I think time is a big thing – people don't have the time to go and sit down with the architect, the architect will do what he is charging for such as site analysis and brief floorplan and will not often go beyond this. The design will then be developed later one, where requirements such as energy efficiency might be applied – so what the architect did in the beginning will change a lot over time. Time is cost. It may be a simple case of having an intern student that can comment on the environmental aspects of the design that could add a lot of value in these kids of projects, or there could be a checklist for architects of things that they could consider, but it is often very difficult to do these things early on.

Q8. How would you describe integrated design?

Integrated design Is the design that addresses those criteria we have in the matrix – feasibility, cost, energy, carbon, innovation, functionality and you take all of these into account and iterate between a basic plan that incorporates all the functionality and optimal from all aspects – energy use, thermal comfort, acoustics etc. Something that people shouldn't just take their own area and develop independently, but something that they should work on together.

Q9. How useful was it for students to experience an integrated design processes as part of their higher degree education?

I think it was extremely useful – as a work-integrated learning project, and empirical project-based class. As a real project it allowed students to get exposed to some of these tools – you can make mistakes now and get a lot of feedback now, rather when they start working. I will try to keep it for as long as I can. It helps to give the students skills that they need after graduation to work in an office and on projects.

Interview 8: Integrated Design Studio 11 – WCC Ribbonwood Community Centre – Interview with Client (Wollongong City Council)

Q1. What enables successful Integrated Design in the studio setting?

I think collaboration between the Client and the students, and potentially the teaching staff. That was one of the gaps I saw – I had a site meeting with the students and then they went off under the guidance of the teaching staff. I said I was happy for them to come back and clarify what we are looking at and ask any questions but no one took those opportunities. That is an area for improvement in terms of being a successful studio – more of the experience from a client relationship perspective and greater interaction throughout the process.

I like to operate as a partnership with consultancy, with informal discussions to bounce ideas off each other. I think that encouraging the students to bounce those ideas off the client would be helpful.

Q2. Please tell us about the studio brief's impact on achieving integrated design solutions (considering the way it was written & communicated). Please reflect on the level of detail and the language of the brief.

I wrote the brief similar to what would go to a consultancy, but was told the students might find that a bit daunting so provided a dumbed down version. I know I was talking about air-conditioning and tying it in with lighting and building footprints, and a lot of other things, because that is the whole way they have to think about it. I accept that we are dealing with students who would struggle with that concept, but if we are going to be serious about calling it an integrated design studio they need to be challenged with lots of things. The ley things I making it realistic for the students.

Q3. What were the most critical decision-making points/questions to answer when balancing architectural and engineering input for generating environmentally optimised design solutions? Where did the inspiration for the students' solutions come from? How did the engineering consultant(s) contribute to the authorship of those solutions? What was the impact of engineering and architecture student collaboration on the

project outcomes? What impact did the timing of the engineer/architecture collaborations have on the development of the project?

When we did the walkthrough I was pretty descriptive in what we were looking for in each of the spaces; there was nothing that came through that hadn't been covered in the brief or on the walkthrough that day. So I think a lot of it was taken from information they gathered from that document and site meeting. There was nothing that I would say was innovative in the student ideas. The suggestions were very high level – including solar on roof or replacing lighting with LED, and did not consider what was discussed on the site – such as the organic lighting system in the admin building. They didn't pick up on those connections. I had a discussion about ventilation in light of COVID thinking – what we might need to do with inline treatment and ventilation rates, and I didn't see any follow up from the students in that area. This may have been because they weren't comfortable or weren't enabled from the university end.
My only exposure to the students beyond the site visit was the halfway and final presentations. I think it would be helpful to have a session before the progress report where the client comes in and has a focused conversation with each collaborative group to ask them about their journey and what they are focusing on and provide greater client guidance in that sense.

Q4. What guidance by you was most useful for the students (and why)? How did your input increase their 'level of understanding of' environmental issues and associated solutions? What would you change in order to maximise your input (if anything)?

It is important for the client to provide a fully detailed brief as if we were to go to market. Perhaps we could then include as an appendix to this, a simplified brief that is easier for the students to digest that and understand what they are being asked for. Having small group meetings - a phone hook-up or site visits will benefit the students in terms of testing their ideas. The consultancy team does not know the intricacies of how it operates, why it operates that way and that may constrain the direction and keep them on a path that is more realistic.

Q5. How did students cope with balancing aesthetic/functional design aspects with engineering concerns? What was the impact of engineering and architecture student collaboration on the project outcomes? What impact did the timing of the engineer/architecture collaborations have on the development of the project?

From recollection, I think the students were mainly engineering based – there wasn't much about the integration between form and function. A lot of what I was looking at was the air conditioning side of things or the lighting. I was hoping that some of them might look at the foyer and include some form of architectural lighting there. One of them did have a discussion about the atrium at the front – this is a difficult area to work with, my expectations were not that high for the students. Some of the guidance around solutions should have come from the consultancy team for areas where things are not as simple as what you think it is. I tried not to constrain their ideas, I tried to say I was open to all ideas to allow for that cherry to be found.

Q6. What did students struggle most with when asked to advance their design-thinking with environmental/engineering constraints in mind?

I think part of their challenge might be awareness of what is out there- products and what you can and can't do. For example, a 4 pipe chiller is not a commonly used piece of equipment in Australia but we are incorporating it in some of our designs. Unless the consultancy team or client mentions things like these, they might not be aware of them. I spoke about not wanting a screw chiller because of acoustics but I did get a couple of screw chillers. I think it just needs guidance across the board and a greater level of interaction. It is a pretty big task to be expecting the students to tackle. If I was to do it again, I would pull the project back to a smaller project such as tourist park cabin.

I think both myself and the teaching staff lost sight to some degree of the capabilities of the students and the timeframe they were working with.

Q7. What barriers and constraints to architect/engineer collaboration exist (outside of the actual design process)? Time-poor/fees/contracts/…?

I think competing priorities is one of the big ones – often architects are focused on how it looks, how it feels rather than how if functions. When it is looked at from an engineering perspective it is more about functionality. You often end up with compromised functionality, when things are changed because they clash with the architectural design. My typical experience is that there is a different language between architects and engineers. Another example is having 40 different types of lights in a building which is a maintenance issue. Being able to strike a compromise that meets everyone's objectives is the challenge.

Q8. How would you describe integrated design?

Having the engagement of all of the parties from the get go. A shared understanding and having a huge amount of collaboration between the architects and the building systems designers and the clients throughout the process. To me, that is critical – having tight meshed discussions throughout the process. We need the art and the solution to be driving each other – using collaboration in its true essence is that working throughout that process. I am yet to see many successful projects in my realm where this is the case.

Q9. How useful was it for students to experience an integrated design processes as part of their higher degree education?

I think it is critical – if they are going to move into this world, then this is how it needs to function. We are all setting targets to improve efficiency, minimising embodied carbon etc. The only way we are going to get that is by having that really close relationship between the designer of the building from an aesthetic perspective, working closely with the engineering team that are going to make that building work. So I think getting a taste of that and how is works is really valuable for the students. Getting exposure to a brief, and what a client might ask for and then looking at where they focus effort and where they don't. Improving the interaction between the client and the students will make that more realistic to how it works, so when they do go out and work in a consultancy, they have that familiarity of how the process works.

APPENDIX C – TRANSCRIPTS OF STUDENT RESPONSES

The following is the questionnaire and student responses from an anonymous voluntary survey provided to consenting students participating in the Design Studio. Where there is a selection of responses to choose from, a breakdown is given outlining the percentage of student responses for each of the given options. For written responses, all student responses have been transcribed.

1) Have you had any experience with Environmental Design prior to this Integrated design studio? Please select one option.

Response options	Frequency of response selected
Not familiar at all	29%
Slightly familiar	29%
Somewhat familiar	14%
Moderate familiar	29%
Extremely familiar	0%

2) What are the key design-drivers that affect the success of environmental design to achieve renewables/zero carbon goals on a community centre project? Please select all that apply.

Response options	Frequency of response selected
Level of existing expertise of individual contributors	29%
Imagination and creativity	71%
In depth knowledge of technology for collaboration	57%
Time assigned to the dialogue between Architects and Engineers	57%
Software skills to simulate and analyse building performance	86%

3) Did the client's brief support you in achieving a balance between architectural and engineering design? Please select one option. *Client brief means the brief provided by the client, in this case Wollongong City Council, rather than the subject assessment brief.

Response options	Frequency of response selected
Not at all supportive	0%
Slightly supportive	0%
Somewhat supportive	0%
Moderate supportive	57%
Very supportive	43%

4) Please tell us about the impact the brief had, and the way it was written/communicated? Was it adequate? (if not, what could be changed?)

- The client brief was heavily focused on the HVAC system and extending it to cover more aspects of the overall design would have been more helpful
- Brief dictated focus of project. Moderately adequate.
- The description was well articulated in the brief by the client brief.
- The client brief was clear in the requirements of the building. The attached proposals and plans were a massive help for the calculations
- The brief was good moreover the site visit and the feedback from the staffs were helpful.

5) What were the most critical decision-making points/questions to answer when balancing architectural and engineering input for generating environmentally optimised design solutions? Describe in your own words.

- Determining the intersection between functionality, and performance, as well as user experience, and aesthetics
- At the balance of cost, aesthetics, practicality/ efficiency/ effectiveness
- the most important points were the problems faced by the client in the existing building and what they expect us to do during the process of rectification. The ideas from the experts helps to improve the imagination of the individual during the course.
- The architectural solution were more focused on passive measures while the engineering solutions were focused more on active measures. The critical decision making point was deciding the rate of return on any investment in terms of carbon emissions as well as savings. Architectural solution proposed were often low cost low return approach and engineering was vice-versa
- Which system was lacking the most (as well as the clients are expecting) and which retrofits can bring the most significant impact?

6) Where did the inspiration for your solutions come from?

- PassivHaus design principles
- Current architectural trends
- the inspiration of green and sustainable building and minimization of the material waste.
- Information taught during the subject, research on energy reduction retrofit precedents
- The inspirations mostly came from the discussions among the team as well as the with the various consultants. They were able to point us in the general required direction.
- Online research as well as the similar projects in i-Hub

7) What guidance by the consultants was most useful for you (and why)? Describe in your own words.

- The consultants gave helpful input into the creation of the building simulation as well as helping to sort out the details of my proposal
- The realistic side of a design solution due to their experience
- The idea of sustainable building and greenifying the building by using the existing natural method rather than the artificial cooling technique
- I think the weekly consultations in which you could ask for the guidance you require was useful, also hearing problems/solutions that other students encountered was helpful for my own learning
- The guidance regarding the projects they were working on and informing what was realistic and what was not. Their advice regarding resources for information was also invaluable.
- Whether to prioritise active measures or passive measures.

8) What would you change in order to maximise their input (if anything?)

- Being able to work on our individual design proposals earlier in the semester would have allowed us to get more into the knitty gritty of the ideas and allowed for more in depth input from the consultants
- N/A
- Nothing
- For me the data was sufficient enough.

9) Did the input by the consultants increase your 'level of understanding of' environmental issues and associated solutions? Please select one option.

Response options	Frequency of response selected
Not at all supportive	0%
Somewhat supportive	0%
Moderate supportive	33%
Very supportive	50%
Extremely supportive	17%

10) Were aesthetic and functional design aspects compromised when balancing architectural and engineering concerns?

Response options	Frequency of response selected
Not at all compromised	17%
Slightly compromised	33%
Somewhat compromised	0%
Moderate compromised	50%
Very compromised	0%

11) If you agree that aesthetic and functional design aspects were compromised when balancing architectural and engineering concern? Do you think this can be avoided? If so, please explain how.

- Through imagination and innovation
- The green walls has a drawback that the way the plant grow can't be predicted in advance so the aesthetic design may affect in the future.
- Depend on the option chosen. Using a tinted glass comes with the disadvantages of reduced light transmission. Therefore, an improvisation in lighting system is required. Similarly each ideas have its own pros and cons when coupled with other retrofits.

12) What did you struggle most with when asked to advance your design-thinking with environmental/engineering constraints in mind? Describe in your own words.

- Developing ideas that did not require major refurbishments of the site that would have created more waste and gone against the client brief
- Lack of experience in the field made it difficult to understand the implications of real-life constraints
- I think the lack of pre-learning in mechanical & architectural engineering made it design-thinking extremely difficult. I wish for students of other disciplines that there was a prerequisite subjects and/or computer workshops to help with modelling were in place to avoid that.
- Most of the proposed solutions were unrealistic or it was difficult to calculate costs due to unavailability of data.
- My primary solution was PCM materials. However the lack of practical data (on-use) and limitation in simulation compelled me to change my proposed solution.

13) Please list the barriers/constraints (outside the actual design process) that exist in architects/engineer collaboration? Please select all that apply.

Response options	Frequency of response selected
Knowledge gaps	100%
Time constraints on projects	66%
Education in isolation	66%
Contractual/fee barriers	33%
Inability to define joint goals	0%

14) How would you describe integrated design.

- Similar in essence to a designer from classical times that was both an engineer and architect, creating a more wholesome approach to design that removes the barriers between the two professions
- All disciplines and fields working together to achieve a common goal
- working with other group of people helps in the way of thinking new ideas and imporved imgination .
- As an engineer I understood what architects were looking for when they design/retrofit a building. I understood which human elements to consider and how aesthetics play into the building. I would describe integrated design as design which focuses on human comfort and sustainability which might result in some compromises to the form of the building
- can quantify the benefits

15) How useful was it for you to learn about integrated design processes as part of your university education? Please select one option.

Response options	Frequency of response selected
Not at all useful	0%
Somewhat useful	0%
Moderate useful	17%
Very useful	50%
Extremely useful	33%

APPENDIX D – OBSERVING RESEARCHER NOTES

The following are the notes taken by the observing researcher throughout the 13 weeks of the design studio. These observations were made based on the interactions between students, consultants, clients and studio tutors. The observations made are the opinion of a third-party researcher who has had no prior interaction with the creation of the design studio, nor with the studio participants (either students, consultants, clients or studio tutors) in relation to the studio. Any identifying information within these observations has been replaced with a pseudonym to protect the confidentiality of the studio participant.

Integrated Design Studio 10 – Lendlease Aged Care – Design Studio Workshop Observations – Notes of the Observing Researcher

In the initial weeks of the design, the students involved were hesitant to divulge details of what they were working on – whether that was because of the presence of other groups (and fear of copying) or whether a fear of exposure. The workshops were driven mostly by the consultants asking leading questions – Had they considered…? What were they thinking about….?

There seemed to be a lot of different aspects to take in and to consider, which was somewhat overwhelming to the students, especially the engineering students who looked to focus on the details.

The consultants brought their real-world experience and examples into the workshops to highlight important issues to consider in the design, such as the human aspects of building control or maintenance/operational issues, or even just what demand loads they had used in other projects. Architects brought in bigger picture thinking to explore advantages of options as well as views of how surrounding area could be used. Also shared their expertise in finding the easiest way to solve problems quickly, e.g. using simplified geometry for initial modelling, then adding in complexities when established.

Client involvement during workshops was limited, but during the initial presentations, they provided feedback on bringing the designs back to the context and use required.

One incident highlighted the overwhelming nature of taking people outside their comfort zone and having to deal with things they are not comfortable with, such as using energy modelling programs not exposed to before. Helps them see that their problems are not isolated – that they need to consider other aspects and other points of view that they might not be familiar with in their design analysis.

As the workshops progressed, the group discussions became more focused, however this also often lead to concentrations of one discipline focusing with a relevant consultant with an increase of jargon and technical focus that excludes others within the groups. Often found that some consultants would gravitate to certain students within groups, there would not always be as much larger discussion. Sometimes consultants online would drive conversations, other times they would get left out of conversations all together, although at this point, they instead interacted with students online.

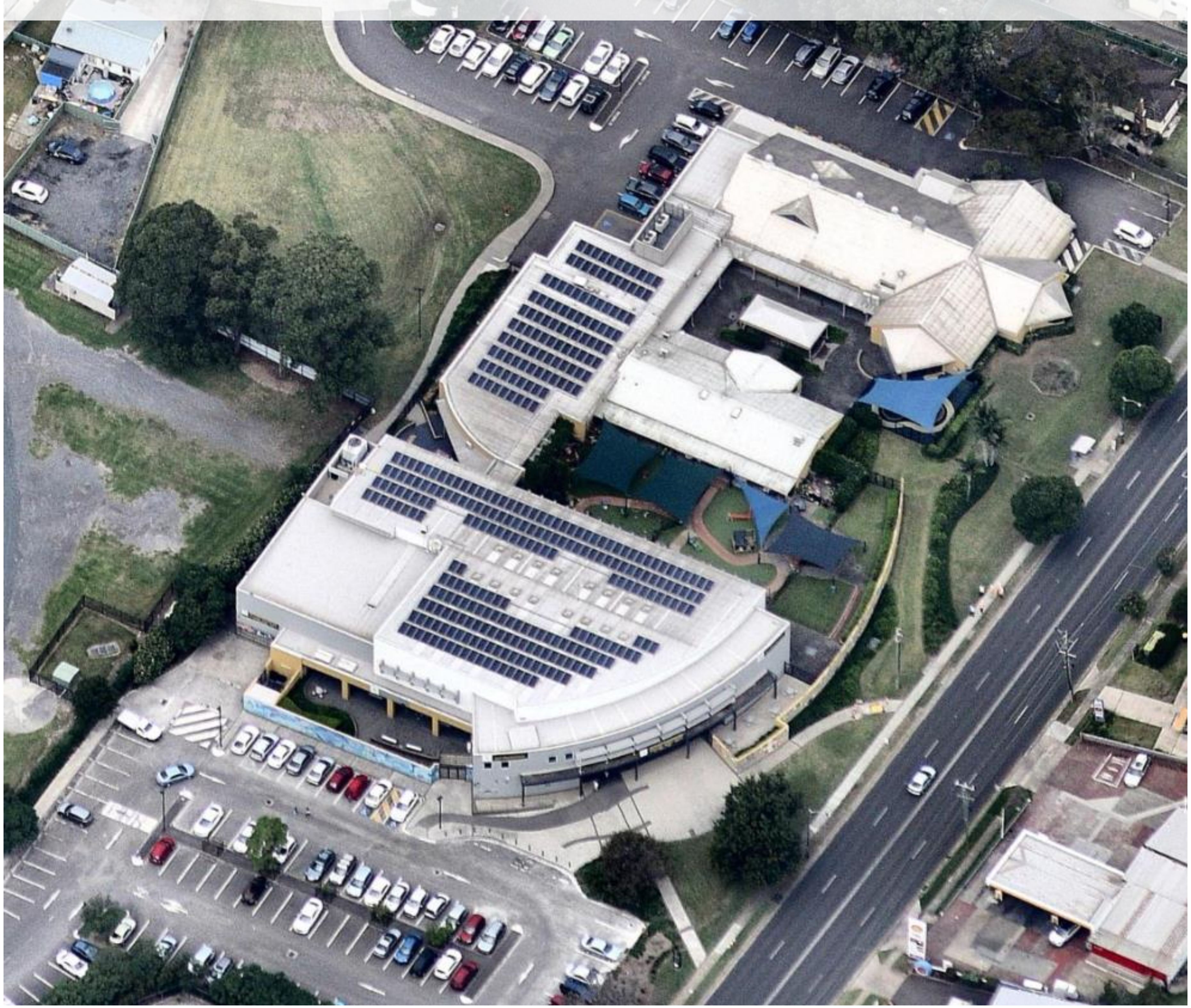
Towards the end of the semester, students were much more open with sharing their designs, including showing their models and designs, and sharing methods and ideas to help each other to get better outcomes. At this point, the discussions were more led by the students, with consultants merely answering questions or guiding troubleshooting, working through design details.

APPENDIX E – CONSULTANT VETTING REPORT

IDS11 – **WCC Ribbonwood Community Centre**

UoW and Wollongong City Council

Vetting Report 11th November 2021



NearMaps Image 2021

IDS11 – **Dapto Ribbonwood Centre**

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Overview

The iHub IDS-11 studio project included Architectural and Engineering majors at the University of Wollongong during the first semester of 2021.

The studio investigated design innovations to reduce net energy consumption at the Dapto Ribbonwood library and community centre. The studio aimed to explore concepts and solutions to reach net zero carbon in future operation through the use of passive and active measures and on-site renewables.

This summary report outlines the vetting process undertaken by the supporting consultants following the studios to capture the recommendations developed by the students, faculty, and industry consultants over the course of the semester. The studio design and analysis demonstrated that significant performance improvements are possible on "business as usual" by implementing a series of sustainability strategies.

Key to this design is a high-performance building envelope, with mechanical ventilation and heat recovery, an all-electric heat pump solution, supplemented by additional roof-top solar panels. This combination enables the building to achieve a performance improvement beyond a 25% reduction in operational energy.

The indoor environment quality of the building must also be a key focus as these community spaces require sufficient access to fresh air and natural light throughout all seasons. High-quality thermal comfort is needed to foster wellbeing and optimal comfort in the use of these shared spaces.

Ribbonwood Centre Entrance

Ribbonwood Centre Entrance during site visit - UoW 2021

Introduction

I-Hub is a program run by the Australian Institute of Refrigeration, Air Conditioning and Heating (AIRAH) alongside the University of Wollongong and supported by the Australian Renewable Energy Agency (ARENA). It aims to facilitate the HVAC industry's transition to a low emissions future, stimulate jobs growth and showcase HVAC innovation within buildings.

The Integrated Design Studios are a part of this initiative, and explore innovative solutions for achieving net zero carbon on complex design projects.

University of Wollongong students in the IDS11 design studio were given the task of designing a sustainable, net-zero, retrofit of the Dapto Ribbonwood Centre for Wollongong City Council. A range of feasible opportunities for minimising the project carbon footprint and energy usage were to be considered including active and passive solutions.

Weekly studios were held over the semester, supported by the engineering faculty and industry consultants from Cox Architects, Arup, Northrop, E-LAB, and MIEngineers.

IDS Participants

Australian Government
Australian Renewable Energy Agency

ARENA

NORTHROP

UNIVERSITY OF WOLLONGONG AUSTRALIA

wollongong
city of innovation

AIRAH

ARUP

COX

E-LAB Consulting

MIENGINEERS

Net Zero Carbon

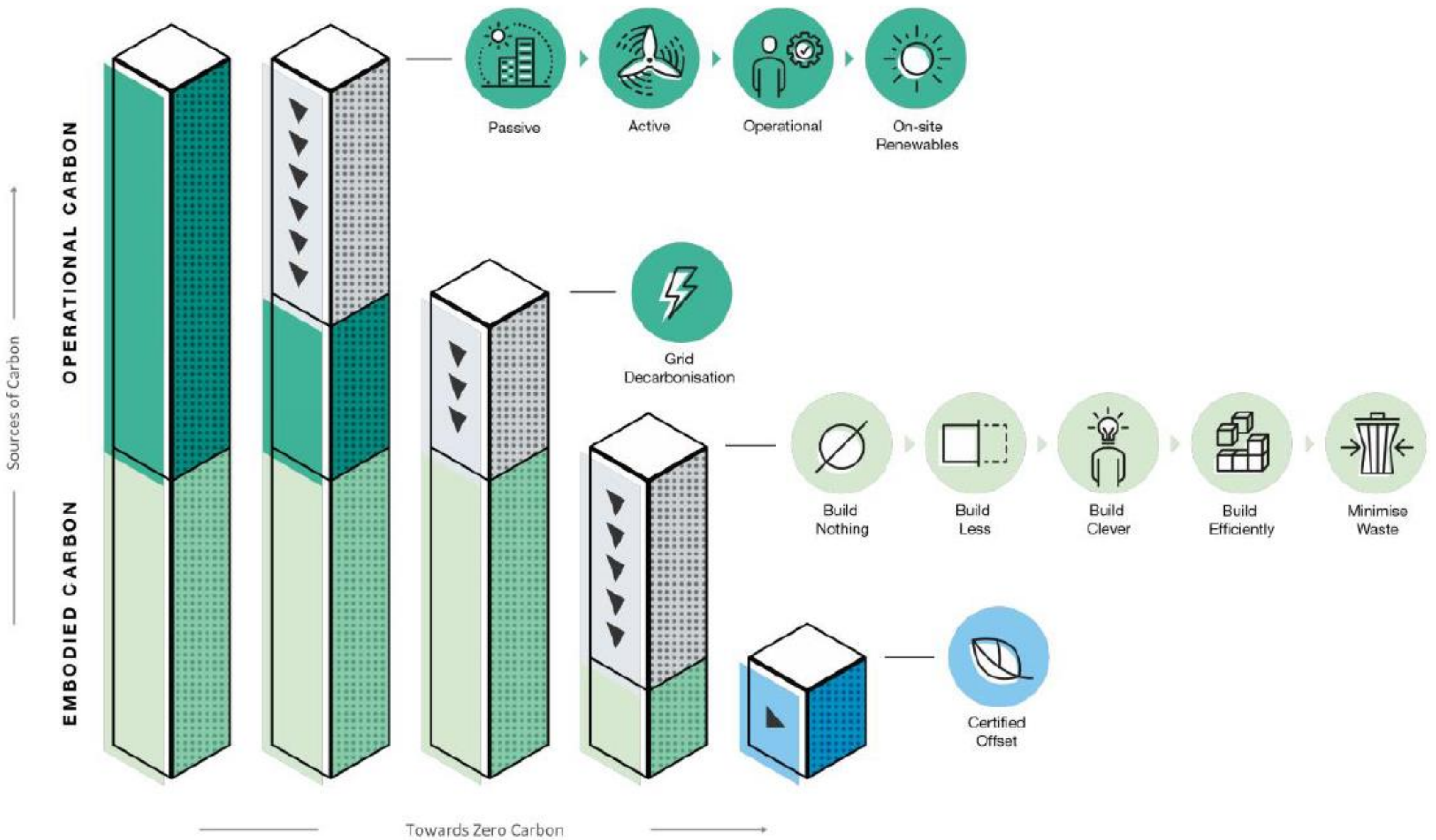
This term is commonly used across industry but its definition varies due to a lack of consensus on where the boundary for assessment is defined for a given building.

For the purposes of this studio, the term 'net zero carbon' encapsulates both the **operational** carbon emissions and **embodied** carbon emissions.

Operational carbon emissions are those that are generated over the service life of the building.

Embodied carbon typically refers to carbon emissions generated by the construction, maintenance and demolition of the building with a particular focus on the construction phase as the most understood and quantifiable metric.

A truly net zero building considers the whole lifecycle, with the emissions associated with building materials, construction, operation, and end of life all quantified and accounted for. Thus any emissions generated by embodied carbon during to construction must ultimately be offset during the operation of the building to achieve an overall net-zero.



from: Arup.com - Net zero carbon buildings: three steps to take now (2020)

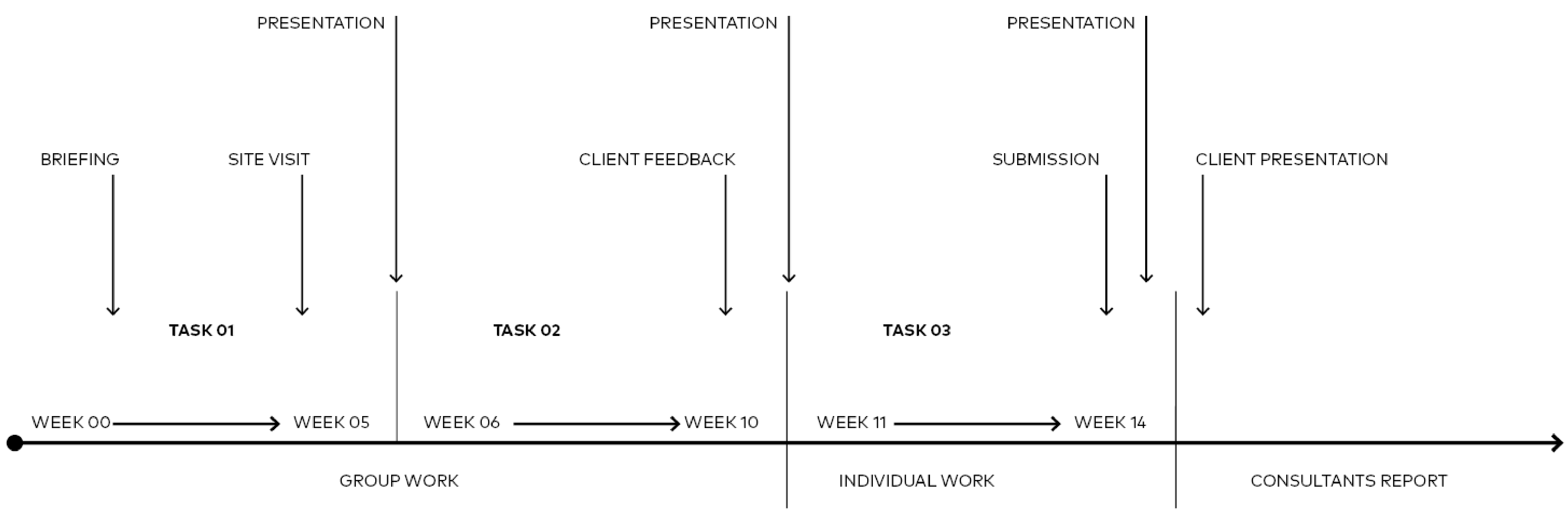
Studio Structure

The students met weekly throughout the semester to workshop and discuss ideas with the engineering faculty and industry consultants.

In the first few weeks, students were provided with a written design brief and video conference with the client from Wollongong City Council to direct the avenue of inquiry. This was followed by a site visit with the client to review the existing building and appreciate some of the issues around usage, thermal comfort and wellbeing.

Following this, a range of initiatives were developed and assessed in a detailed matrix which included feasibility, cost, constructability, and a number of other criteria. These options were refined over the course of the semester to identify key changes that would have the most impact towards moving the building to net-zero.

The studio was structured around three assessment tasks where students presented their written submissions to the class and the clients. The first two tasks were developed in groups that required collaboration between a 'design team' of students from different engineering majors. For the final assessment, each student selected one or two key initiatives to examine in more detail and included computer modelling of building performance.



The Site

The Ribbonwood Centre site is located in the Dapto CBD, just south of the train station.

Map of Illawarra showing location of Ribbonwood Centre – NSW SixMaps

Satellite View of Ribbonwood Centre - NearMaps Image 2021

The Building

The Dapto Ribbonwood Centre was constructed in 2000 as a library and community centre that offers a wide variety of activities for people of all aged groups.

The building is two levels; one a slab-on-ground; the other a suspended reinforced concrete slab covered by a steel framed roof.

The building facade is typically a mix of glazing and fibre-cement sheeting supported by insulated stud framing.

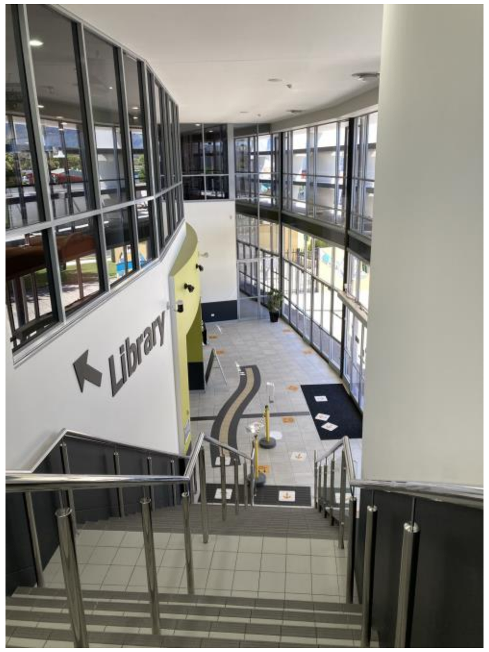
Louvres and sunshades are used in some areas to provide shading, however areas such as the entrance atrium were identified as having poor thermal performance in spite of the shading provided.

An existing HVAC system was reported to be inefficient and uneven in its distribution of hot and cold air and the noise from the chiller interrupts the usage of the library.

The roof already has extensive coverage by solar panels limiting the ability to target net zero by improving energy generation by this means.

View of Entrance Atrium from Princes Highway

Satellite View - NearMaps Image 2021



View of Entrance Atrium from L1

Constraints

The Redevelopment has been constrained by the landlord, and is limited by the following:

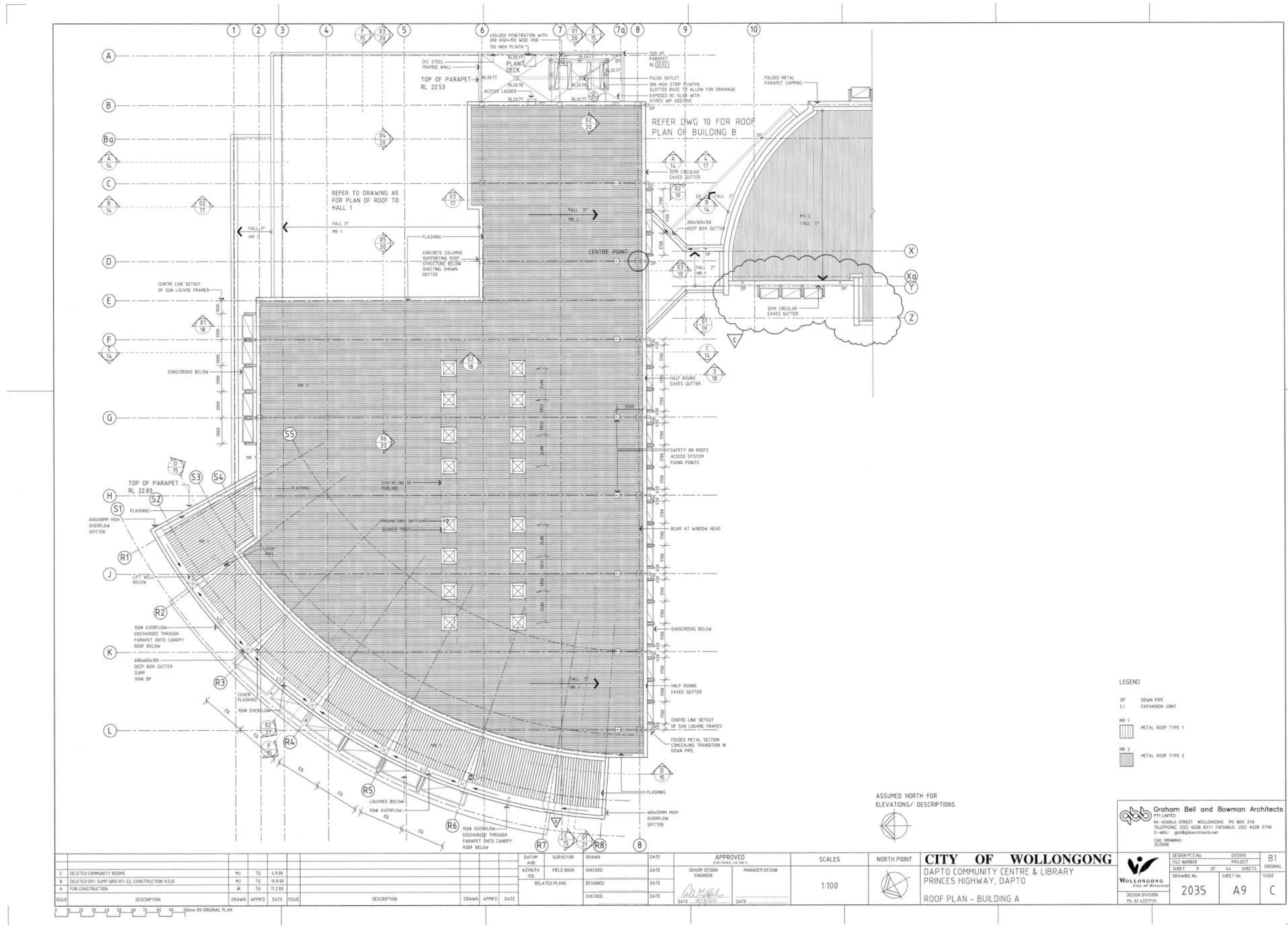
- Physical envelope cannot grow in space
- Existing mechanical and services systems must remain operational or only have short period of shutdown
- Limited control information is available for the existing building
- The project is approximately 20 years old and most plant is reaching it's end of life.
- Significant HVAC and services upgrades are scheduled over the coming years 2022-25

Integrated Design Studio

Through the IDS process, the students and tutors worked to explore alternate design elements and positive actions that could be taken to improve the current performance and help the building move towards net zero carbon in operation.

Students would suggest ideas within the context of the Ribbonwood Centre, and together teams would assess the viability of these options in the context of the project.

These were tested through literature reviews, exploring the site-specific restraints and modelling the performance improvements in programs used in industry to assess thermal and overall energy performance.



Architectural drawing of roof – GBB Architects

Design Solutions

Throughout the IDS, multiple ideas were presented by students. These were tested and modelled to calculate the overall improvements that were expected to be realised. The lists below highlight these ideas, as appropriate to an existing community centre.

Student Ideas
Façade Improvement
Window Replacement – DGU
Window Replacement – Low-E Coating
Window Replacement – Non-metal frame
Install Venetian Blinds
Tinted Windows
Smart Window Film
Increase Wall Insulation
Increase Roof Insulation
Incorporate additional shading
Window mesh treatment to redirect light
Improving building air sealing
Services Improvement
Upgrade lighting system
Rooftop Solar
Solar Water Heating
Upgrade HVAC system through audit
BMCS-controlled Natural ventilation
Innovations / Other
Phase Change Materials
Install Trellis to provide shading

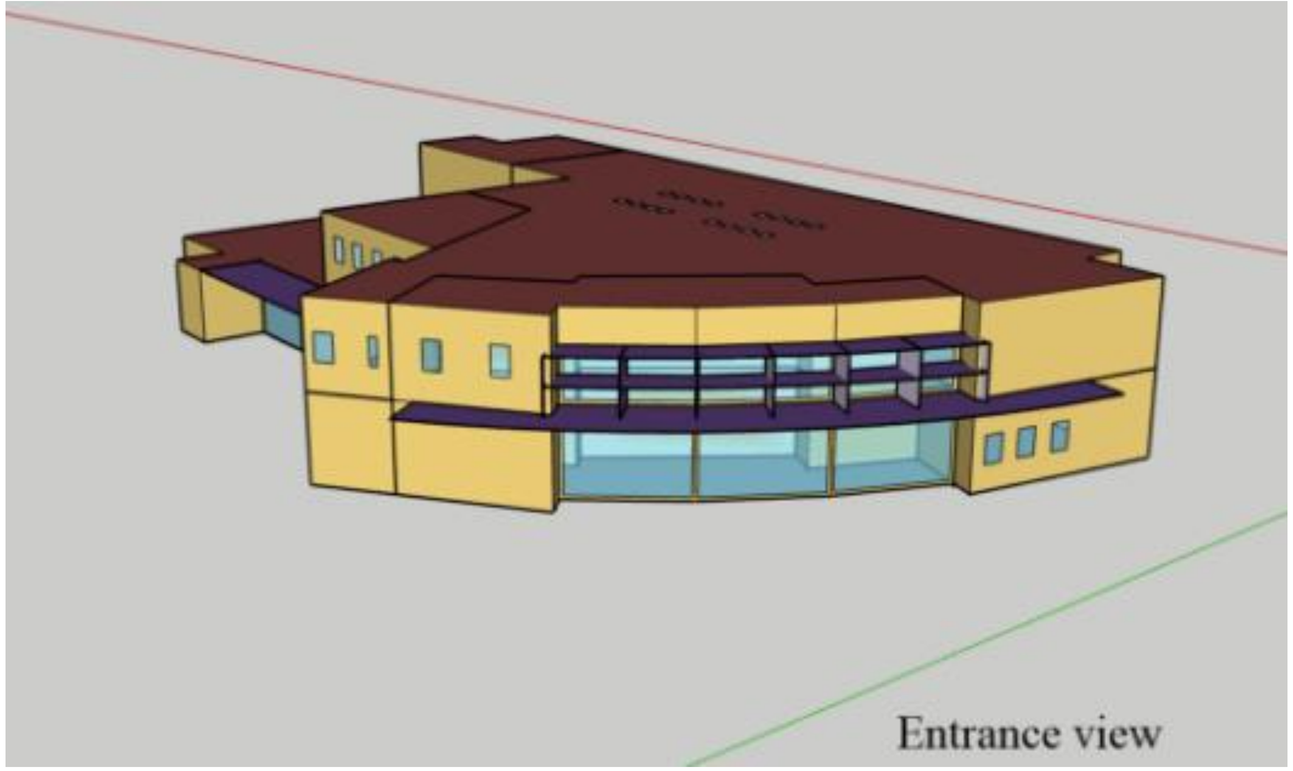
Additional Ideas Explored
Façade Improvement
Automated blinds
Replace and upgrade window/door seals
Services Improvement
Lighting Control sequence
Re-arrange mechanical systems to provide appropriate zoning
Battery Storage for excess PV production
Occupancy detection
Daylight Dimming
Sub-metering, analytics and management
Relaxed setpoints
Adaptive comfort through ceiling fans, HVLS
EC Plug fans
Energy Recovery Ventilators
Night Purge
Remove hot water from amenities taps
Replace gas with Electric systems
Replace cooling plant with synthetic low GWP refrigerant

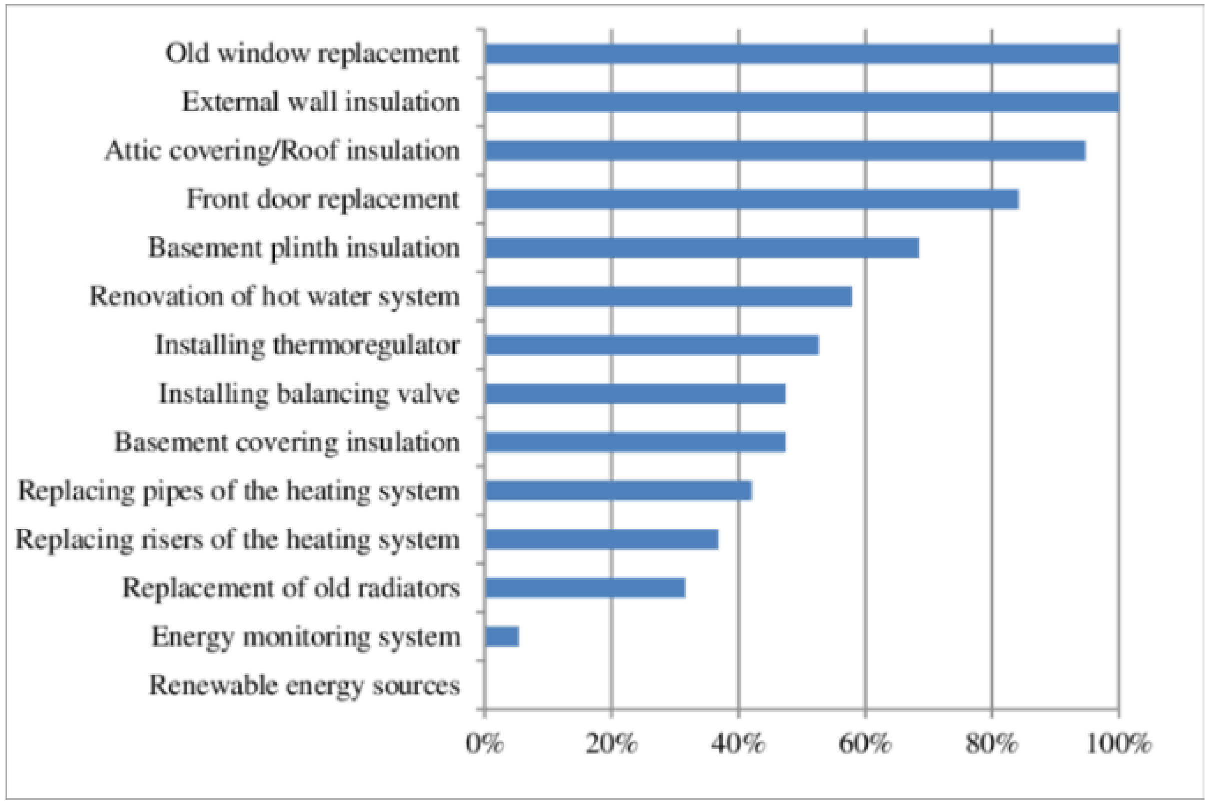
Benchmarks

The work aims to demonstrate that a set of sustainability measures can be applied to achieve a cumulative energy saving of up to 25% compared to "business as usual" case. There may also be potential to generate significantly more energy on site than the building uses on an annual basis, thus demonstrating that a net zero carbon approach is achievable.

The systems, improvements and technology proposed are all tried and tested local solutions available in the market and can are appropriate design responses to this scale of project. The key systems offering greatest benefit are:

- Optimised Passive Solar principles for winter heating and summer control
- High-performance building fabric through enhanced U-values of the building fabric
- Improvement of Window performance
- Mechanical ventilation with heat recovery for energy saving benefit in addition to other indoor environmental quality and health benefits
- Photovoltaic panels increased across the roof and supporting car park.
- Optimised Operation through detailed commissioning and maintenance of equipment





Share of energy efficiency measures implemented (Miezis et al., 2016) Note – Typical Values only - not project specific

Design for well-being

The development had a clear focus on user health being delivered throughout the design. It is critical that the development is not only low-carbon, but also responds to human needs.

To ensure this, many elements of design are proposed to encourage health. These include access to high-quality outdoor spaces, connection to nature and natural elements such as plants and sky, and biophilic designs inspired by nature. This includes natural products.

Within the space, thermal comfort was a key focus, alongside improving the thermal envelope to ensure comfort. Natural ventilation is explored to reduce the operational energy of the development and offset fan energy. This provides great levels of outdoor air, free cooling and excellent connection to nature when the external conditions are favourable, but introduces control requirements by an operator and potentially acoustic/air quality issues.

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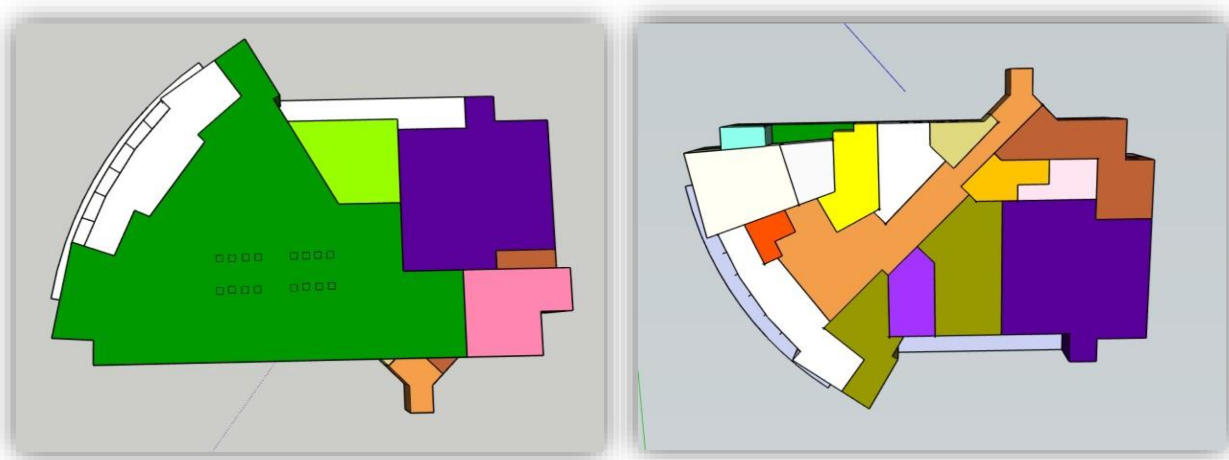
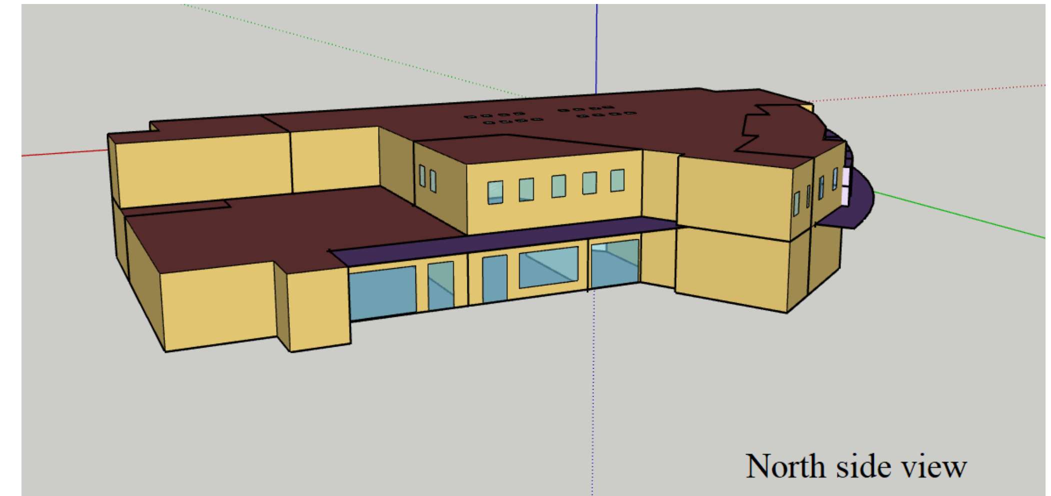
Discussions between client and Students UoW 2021

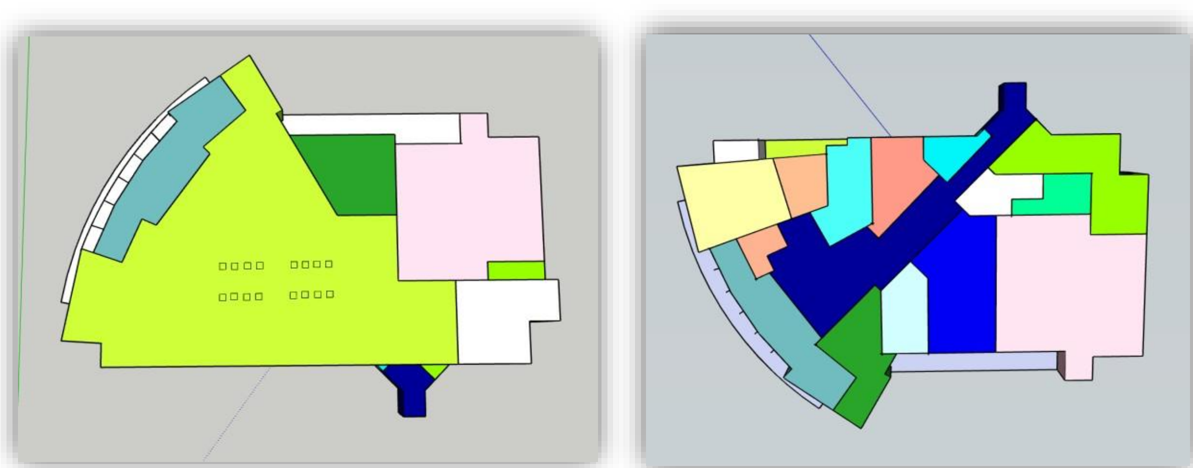
Analysis



18 Space Types

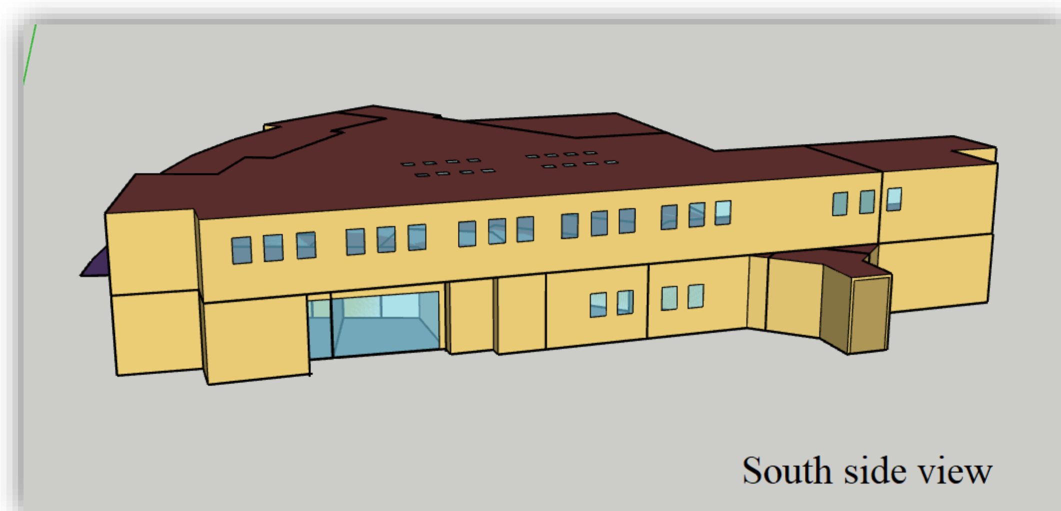


North side view



18 Thermal Zones

Different colours represent the range of uses and differing purposes within the building



South side view

Passive Design

'Passive design' aims to exclude direct sun during hot weather, admit direct sun during cold weather, optimise natural daylight, control glare - and in naturally ventilated buildings, maximise access to favourable breezes at the right time of year. The project has the ability to provide greater passive performance by upgrading its window suite. Replacing old and leaky single glazed windows with double glazed, triple glazed or windows with automated shading will significantly improve the performance without impacting the shape, form and function.

External shading could be added around large glazed areas to reduce direct solar gains, improving internal thermal comfort and providing a more equal thermal gradient through the mechanical system.

Optimising the size of external windows is important - for curtain walls a raised sill is helpful. A narrow floor plate is desirable, atria can be included, and often a central core is preferable. Signage around the health benefits of walking at the lift/stair junction can also help by reducing lift energy use.

Façade and Building Envelope

The analysis during the design studio reviewed the impact of both passive and active measures on the overall energy demand of the development.

Improvements to the building envelope have a large impact on the heating and cooling demand, but when a heat pump is used, the proportional impact is seen to be less due to its high coefficient of performance. However, the building envelope performance is key for establishing acceptable levels of thermal comfort, whilst helping to mitigate the impact of future climate shocks.

For the Wollongong climate, it is typically recommended that ***the thermal transmittance of the entire façade system of the building envelope averages minimum 1.40W/m2K, in order to maintain internal surface temperatures above 16°C, as is recommended to avoid discomfort with temperature asymmetry.***

Airtightness of the building envelope is also key to establishing thermal comfort, mitigating draughts caused by gaps and cracks at interfaces between constructions. A façade air tightness test audit, through blower door testing or whole building testing could assist in identifying unwanted air leaks in the building

Operational

Operational efficiencies are key to driving sustainability and moving towards net zero. A building that is appropriately commissioned, maintained and serviced can consume up to 40% less energy than a building that is not maintained.

- Commissioning and providing seasonal tuning ensures all elements are working per the design. Often buildings that "hold temperature" and are lit are assumed to be efficient, but this is not always the case.
- Dirty mechanical filters add significant pressure to systems and consume far more energy to move air around the building. These must be cleaned and replaced in line with manufacturer's recommendations
- Plant at end of life will see a significant reduction in performance. Regular maintenance and investigations will allow facilities management to know when plant is due to be serviced or replaced.

These must be maintained on an ongoing basis to reduce wasted energy.

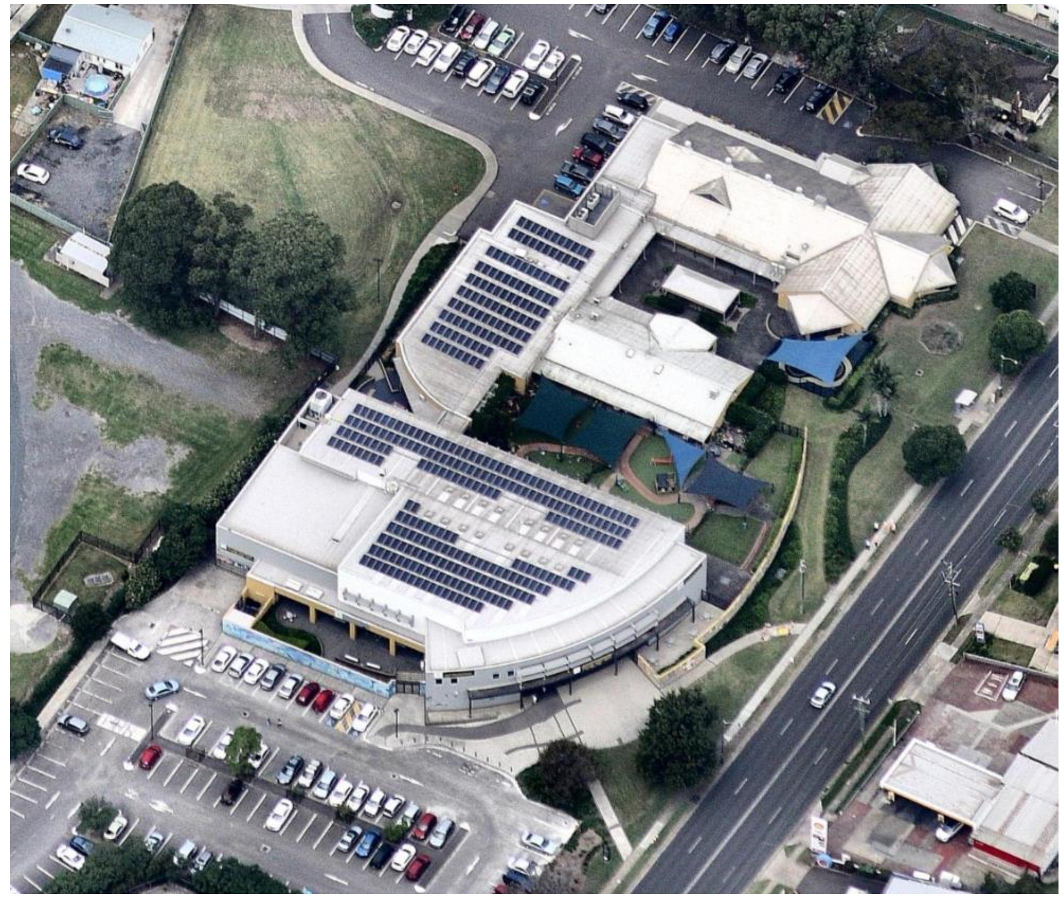
Benchmarks and Aspirations

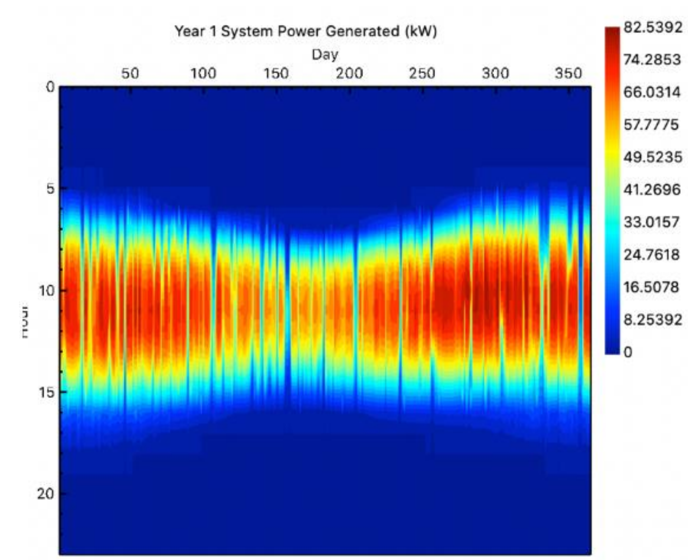
On site Renewables

On-site renewables are a simple and incredibly effective way to offset electricity consumption within the built form. All buildings providing amenity will consume energy. Once the building's energy consumption has been reduced as far as possible, the next step is to offset it through renewables.

Solar power is by far the most appropriate solution on a single building scale. Wheras wind and other technologies work at large and industrial scales, solar can work on any scale.

Ribbonwood already has a significant PV array on the roof. This has been maximised so complimentary solutions such as battery storage may be necessary to increase the usefullness of the electricity production on site.



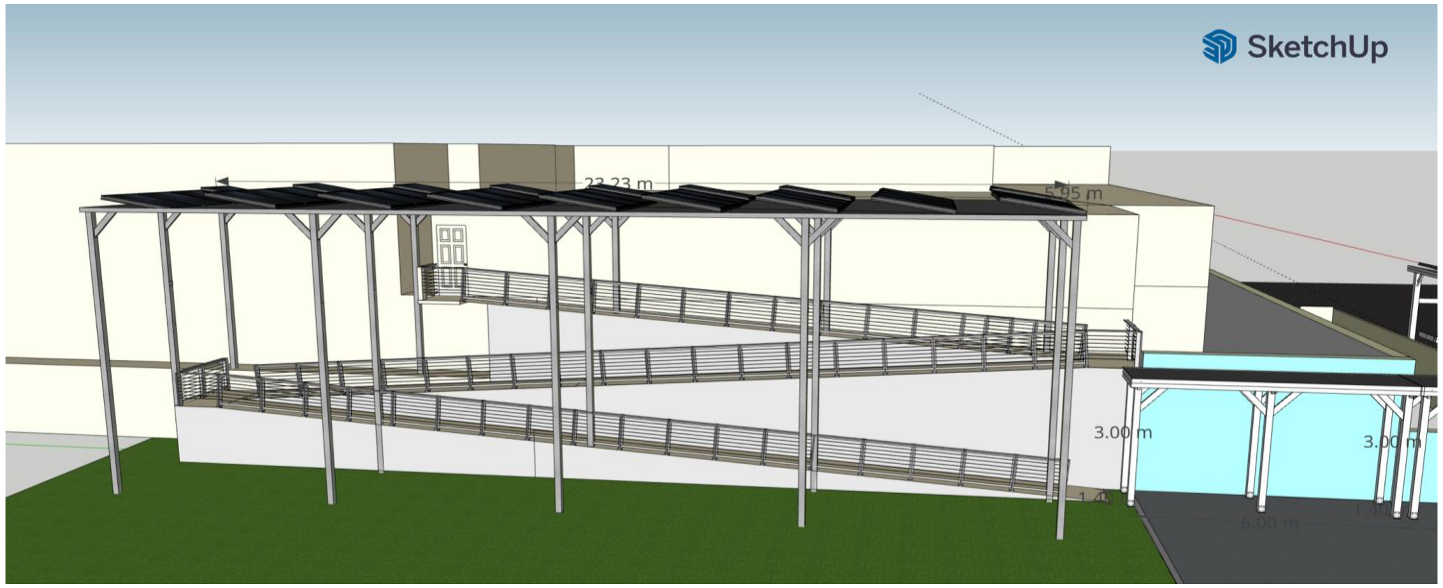


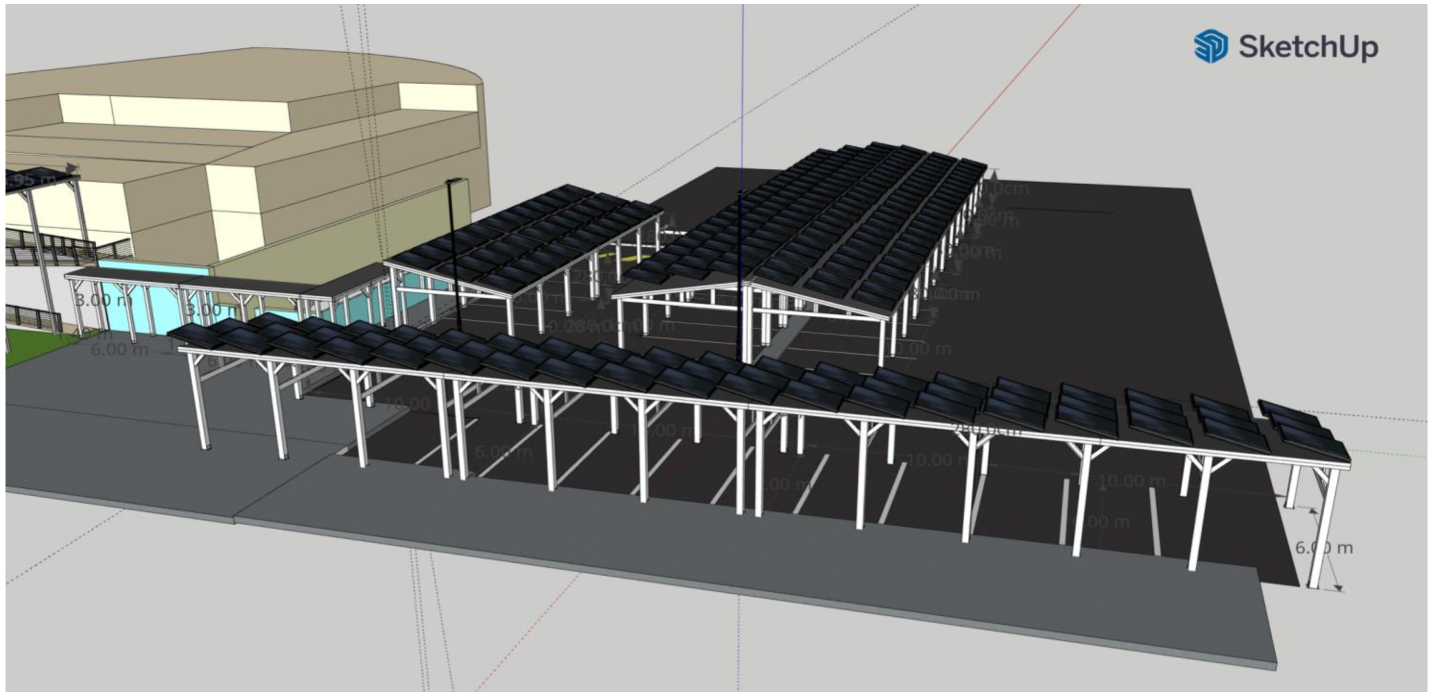
Carport with Solar Panels

Due to the limited space available on the roof of the existing roof for additional solar panels, additional areas were explored to increase the renewable energy on site. The option to create additional roofing systems above the adjacent car park is explored. This idea allows the use of third-party proprietary framing and PV systems, installed on existing infrastructure. This will double up as shading, improving the amenity above walkways, as well as providing shade to cars below.

Such systems need to be coupled with good air movement below as solar panels can become quite hot underneath with insufficient movement.

Additional power, coupled with batteries could also assist the transition to electric vehicle by providing carbon neutral charging stations with the surplus energy





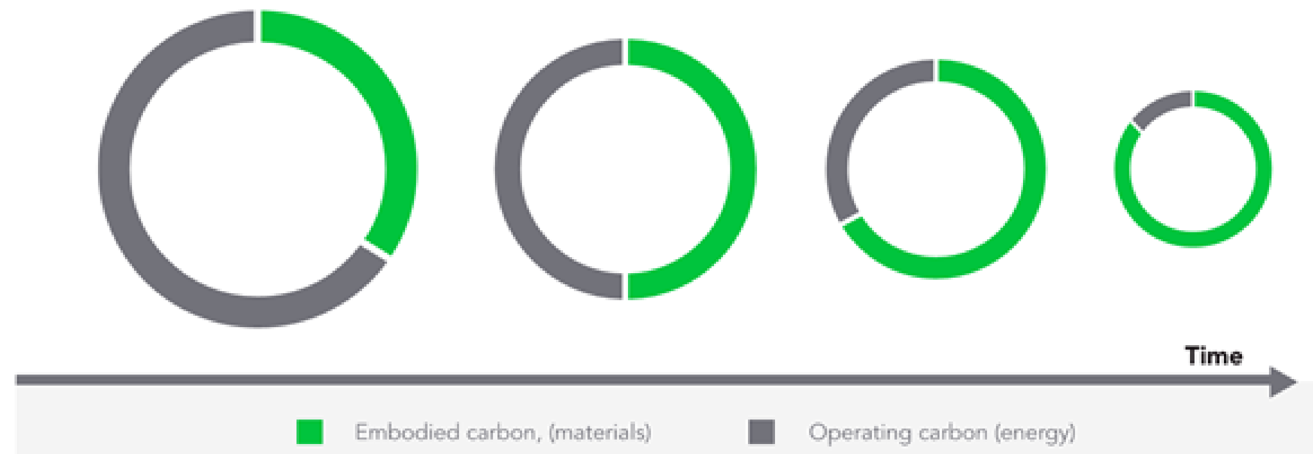
Embodied Carbon

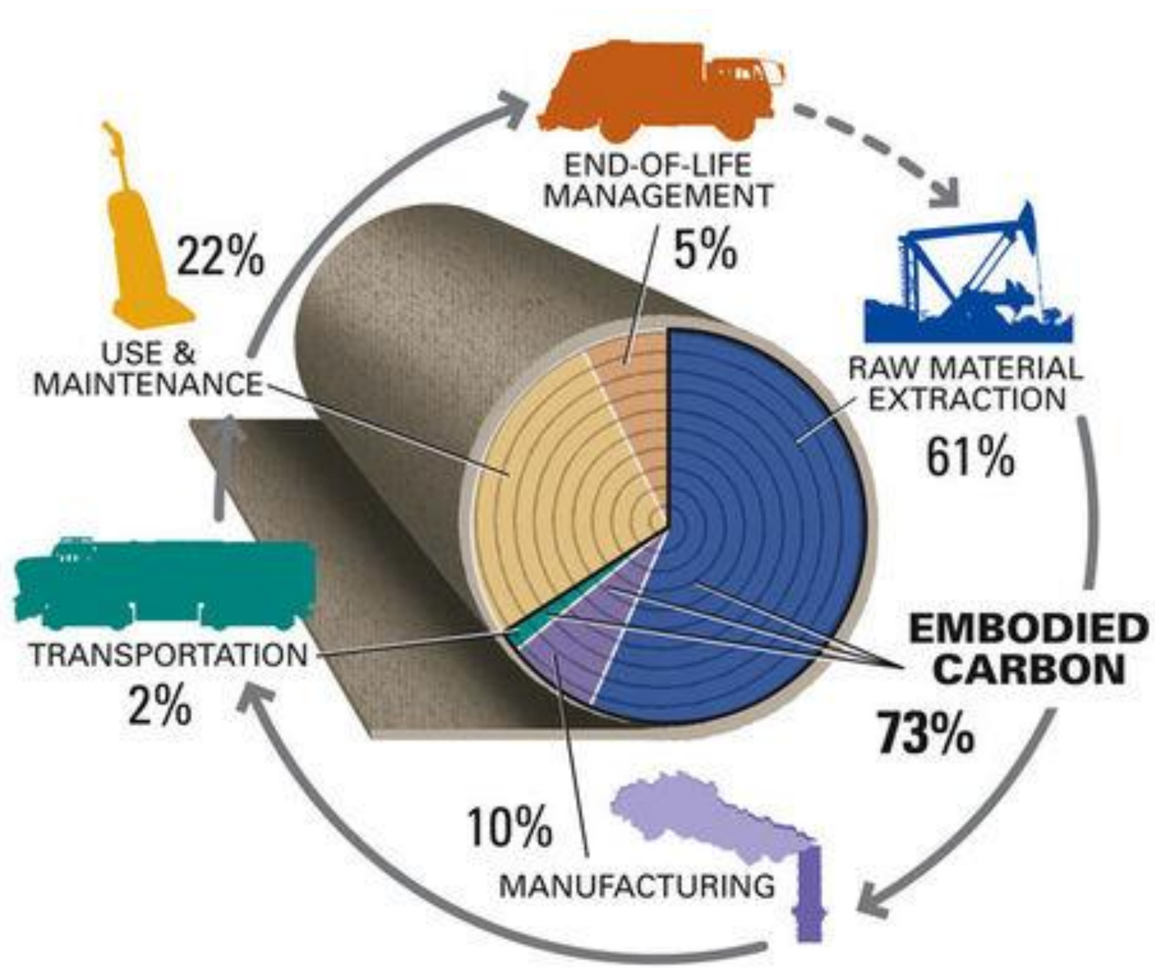
"The best building is the one that is already built" is an adage that summarises the use of embodied carbon in design. As the grid decarbonises, the importance of embodied carbon within the design continues to increase. In time, embodied carbon and materiality will be the most important metric in sustainable design.

Selection of low-process and low-carbon materials, minimisatrion and optimisation are key design elements within embodied design. Structural design efficiencies are key as building more with less has an immediate reduction in carbon.

Using alternate materials such as timber, muds, clays, or recycled/repurposed/upscaled or reused products will reduce the embodied carbon of any development.

This process should always be coupled with a Material Life Cycle Assessment to ensure the advice and decisions being made do in fact lead to lower embodied carbon outcomes.





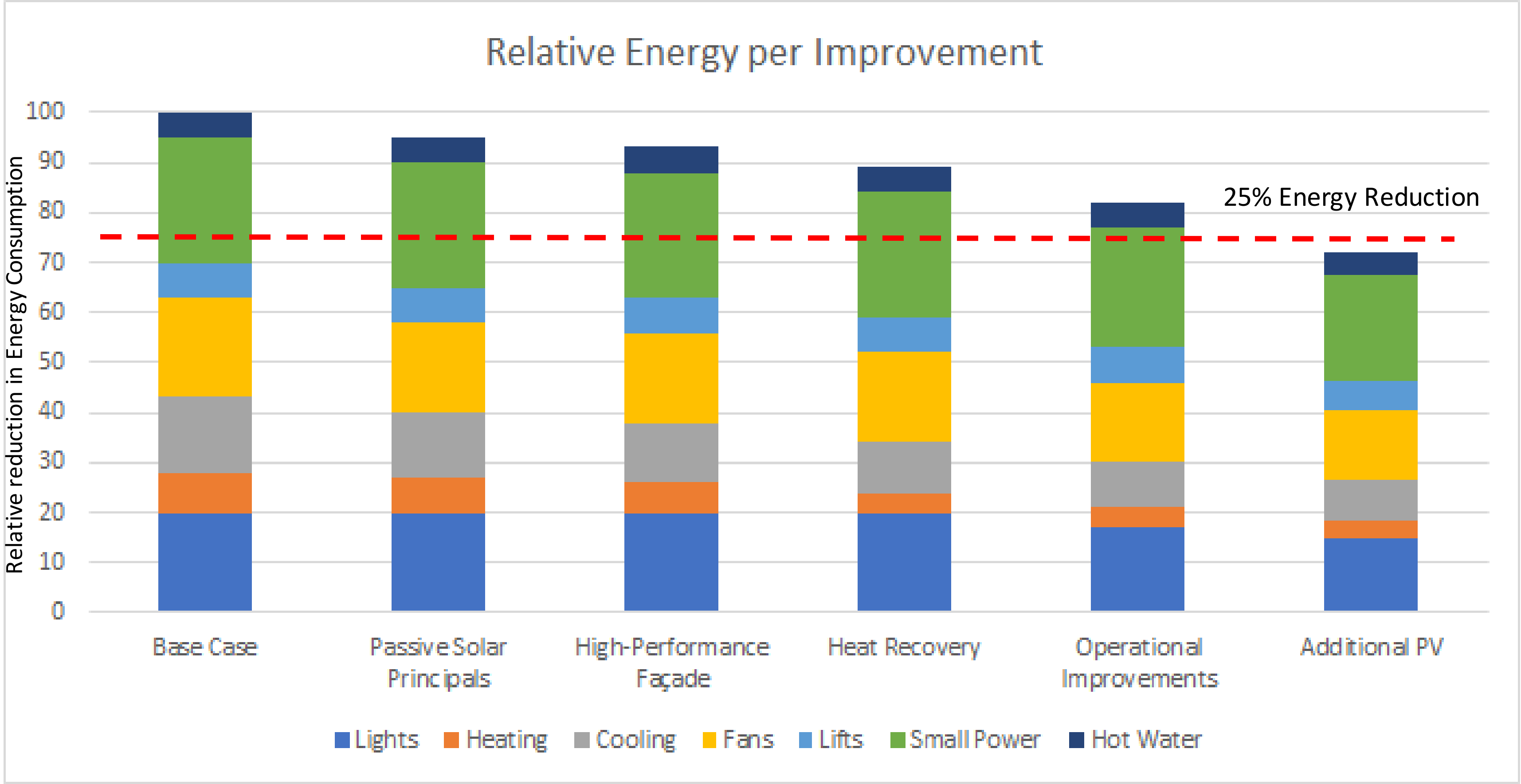
Improvement on Business as Usual

The work and modelling has shown there is the potential to economically reduce the operational energy by over 25% , and has the potential to go much further than this by installing additional renewable resources.

Business as usual has been set as the current operational performance of the WCC Ribbonwood Community Centre, using this as a baseline for predicted improvements

The key focus in the first instance is to reduce loads, and then offset those loads that cannot be reduced on site or are critical as part of the building operations.

The graph to the right shows the relative improvements from implementing the proposed concepts. This demonstrates an overall total reduction of >25% .



Base Case – Current Performance of Ribbonwood
Passive Solar – Additional Shading elements internally and externally
High-Performance Façade - Glazing upgrade and insulation improvement
Heat Recovery – Installed on all mechanical air systems >500L/s
Operational – Commissioning, new filters, maintenance back to design
Additional PV – including an extra 99kW through the carpark or roof.

Conclusions

The design and analysis demonstrated that significant improvements to the building fabric and building services have the potential to reduce the energy usage. Focus is also given to the design and performance of the services to improve efficiency.

Generation from onsite roof-top solar panels and also the adjacent car park have been nominated as the solution with the lowest barrier to improving performance on site.

Given the importance of the interior environment and its impact on the wellbeing and usage of the community spaces, the beneficial impact that building envelope and ventilation initiatives have on indoor environment quality, in particular thermal comfort and air quality, should also be considered and prioritised.

It is critical carbon reduction design does not occur in a vacuum, and all elements of design and human-use are considered to ensure the most sustainable outcome both upstream from the manufacturers and downstream to the end user.