The Innovation Hub

for Affordable Heating and Cooling

Design Studio Outcomes Report (100% Milestone)

IDS-04 Ambulance Victoria

Project IDS04

30 May 2021

The University of Melbourne

About i-Hub

The Innovation Hub for Affordable Heating and Cooling (i-Hub) is an initiative led by the Australian Institute of Refrigeration, Air Conditioning and Heating (AIRAH) in conjunction with CSIRO, Queensland University of Technology (QUT), the University of Melbourne and the University of Wollongong and supported by Australian Renewable Energy Agency (ARENA) to facilitate the heating, ventilation, air conditioning and refrigeration (HVAC&R) industry's transition to a low emissions future, stimulate jobs growth, and showcase HVAC&R innovation in buildings.

The objective of i-Hub is to support the broader HVAC&R industry with knowledge dissemination, skills-development and capacity-building. By facilitating a collaborative approach to innovation, i-Hub brings together leading universities, researchers, consultants, building owners and equipment manufacturers to create a connected research and development community in Australia.

This Project received funding from ARENA as part of ARENA's Advancing Renewables Program.
The views expressed herein are not necessarily the views of the Australian Government, and the Australian Government does not accept responsibility for any information or advice contained herein.

Primary Project Partner

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

The IDS-04 Ambulance Victoria Integrated Design Studio investigates design innovation to reduce net energy consumption through the use of renewables and other energy technologies. Over a 14-week period, a group of architecture and engineering students work jointly with Engineering experts to develop an Ambulance Station. This type of facility is known to have high operational energy requirements.

Based on a dedicated project brief by Ambulance Victoria (AV) representatives, students explore novel approaches to develop an ambulance station within the wider Melbourne area. Particular focus is given to the intrinsic nature of the layout of such centres and their environmental affordances, by integrating novel technologies that provide synergies with various programmatic requirements, functional considerations, and overall aesthetics, thereby significantly reducing its carbon footprint.

Lead organisation	The University of Melbourne		
Sub-Project number	IDS-04		
Sub-Project commencement date	1st July 2020	Completion date	30th May 2021
Report date	30 May 2021		
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1. SUMMARY

1.1 Purpose

This report summarises all findings taken from IDS-04 and marks the 100% completion milestone at the end of the project. Information inherent to this report will flow directly into the 'Lessons Learned' from IDS-04 and they will be further disseminated under the IDS Knowledge Sharing strategy associated to the program.

1.2 Executive summary

The IDS-04 Ambulance Victoria was initiated late July 2020, after substantial stakeholder engagement with their client representatives back in Q4 of 2019. In contrast to the IDS run in Semester 1 2020, it was clear from that start that this IDS had to be run entirely online due to COVID-19 access restrictions to Melbourne University campus; for the same reason, semester start was postponed by one week. One other main difference to the IDS undertaken in Semester 1, is the fact that the IDS organising team at the University of Melbourne, was able to secure the participation of four students from the Melbourne School of Engineering in this IDS.

Over the course of semester, work progressed within four main themes, namely:

- Energy (embodied),
- Energy (operational),
- Water, and
- Waste and Wind

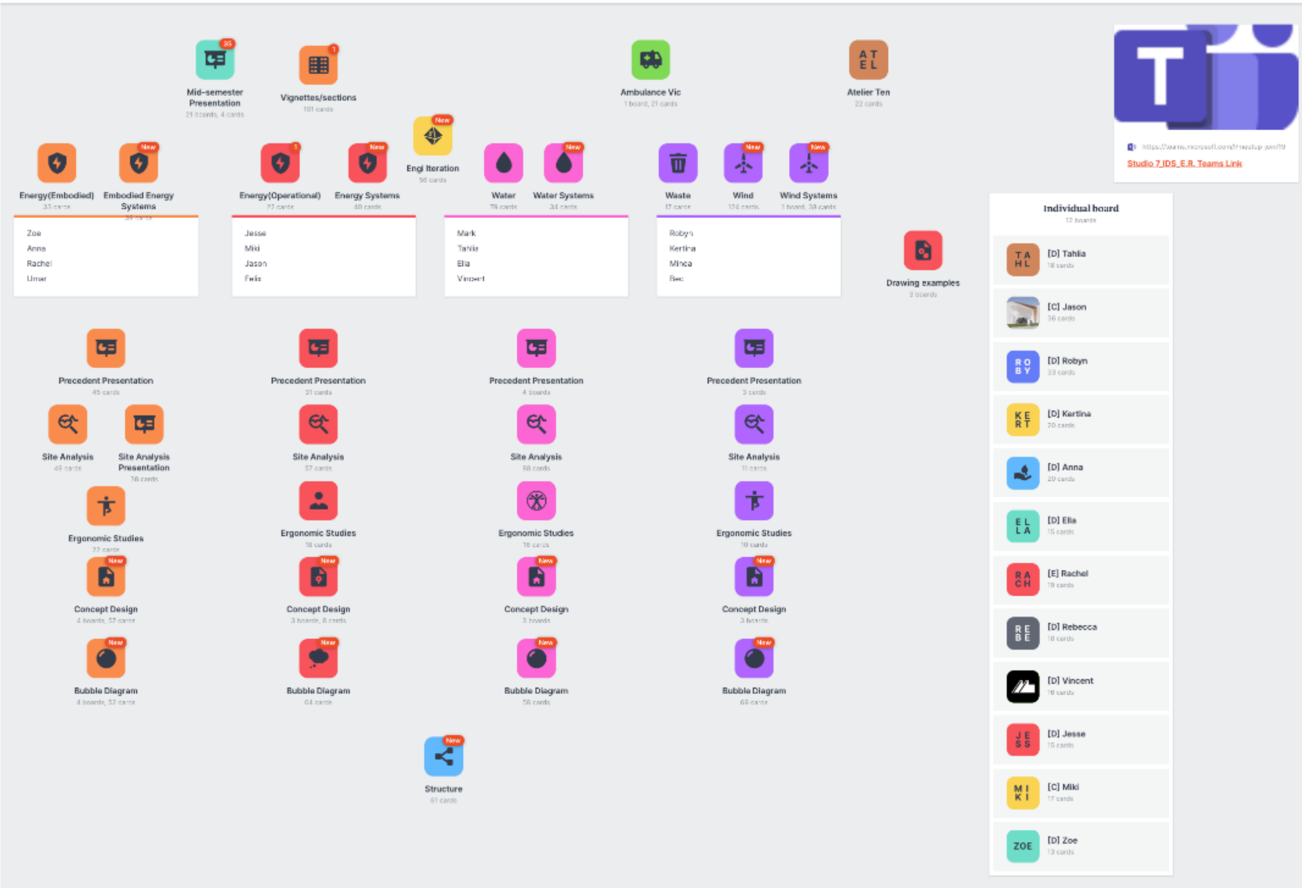

Figure 1: Milanote online interface for student participation and visual information storage.

Operating within these four overarching categories, each of the 16 students (comprising architecture and engineering students) advanced their ideas individually. First working on smaller group research, design exploration exercises and design proposals, architecture and engineering students interacted with the student tutor twice a week, and with the industry consultant, on a weekly basis. A dedicated 'Catalyst for Integrated Design' guideline underpins the collaborative effort and helps in the joint development of common goals toward 'Net Zero' design. Due to COVID-19, the two weekly sessions took place entirely online for the duration of the semester. It is clearly not the ideal context for teaching design studio, but it allows the team of UoM academics to diligently observe and analyse the integrated design process as it unfolds.

Findings from this semester indicate that the impact of COVID-19 was manageable IDS-04 project and individual projects by students advanced well. Participation of industry consultants occurred in regular intervals throughout the semesters. A combination of Zoom, Teams and Milanote online platforms provided the digital interface for engagement. It should be noted though, that the online delivery made bonding and more continuous exchange between architecture and engineering students a challenging task. Whilst different technologies were being tested and the dialogue in achieving integrated outcomes was still being tweaked by participants, first innovative solutions started to emerge by mid-semester.

Further work on the Integrated Design Studios occurred then during the remaining 4 weeks of the semester, once all students had completed their work, solutions were vetted by the engineering consultants, and in-depth interviews with project participants were carried out in the 4-6 weeks following marking of student work. Student responses to the online questionnaire also occurred within this period.

Studio observations through to the end of semester affirmed preliminary findings and overall pointed to key lessons which include (but are not limited to):

- Importance to establish a level playing field from which each participant group benefits, characterised by the replacement of professional specificity with mutual respect, and ideally realised through integration in shared decision making and work efforts.
- Clear articulation of common goals as a key priority, ideally translating into clear assessment criteria and being upheld in an intelligible way through the integrated design development process.
- Architecture students can struggle with an unfamiliar process, unable to 'join the dots' and can lose the way; reminders of how the common goal translates at progressive design moments can potentially re-focus designers to navigate unfamiliar territory.
- Engineering students struggle with 'brief under development', expect clearly defined problems instead.
- Managing collaboration is not easy with architects' frequent design changes, engineering students might feel alienated by this process (in particular, if not involved in the design decision-making process).
- Balance between architecture and engineering requires active curation, exemplified in this studio by actively encouraging designers to think holistically about the aesthetic and the functional design together so, compromise was minimised, and a balance achieved.
- Integrated design happens over a limited time window and, this semester shifting towards second half, potentially reflecting the encouragement of designers to adopt an approach rather than a solution compared with earlier IDSs.
- A 'whole of project' context and vision is key to developing innovative designs in the integrated setting, and its absence became a stumbling block for many designers trying to move forward with different or experimental design ideas, despite their strong start. The development of a relevant 'whole of project vision,' informed by the cross-disciplinary group and their collective understanding of the design challenge, should happen early in the project, and would assist in mitigating bias towards a strong client brief and encouraging innovative ideas.

2. PROJECT CONTEXT AND INCEPTION

2.1 Context to the Ambulance Victoria Integrated Design Studio

In the lead-up to University of Melbourne's start of semester, Prof Brendon McNiven from the Faculty of Architecture, Building and Planning, and Prof Lu Aye from the Melbourne School of Engineering had engaged in intensive industry consultation to search for compelling case-studies to investigate new technologies under the Integrated Design Studio banner. Three IDS projects were chosen to run in parallel during Semester 2 2020, which spans over 13-15 weeks from early August until late November.

Ambulance Victoria is one of these three projects as its programmatic and functional specificity promise a fertile testing ground for design exploration, particularly when considering Zero Carbon constraints. The brief and detailed program for the Ambulance Victoria (AV) remained under development in the first weeks of semesters. AV is looking for both, ideas related to the design of one of a 'Zero Carbon Branch' - a new standard for a local ambulance station, but also asks students to consider ways to develop modular components that can be used as a flexible kit-of-parts. In the weeks leading up to the start of semester, the Melbourne University team went on to gain University of Melbourne internal *Ethics Approval*, select the Design Studio tutor, establish the context for the IDS to integrate seamlessly with the existing curriculum, and chose the industry consultants to join in on the project.

2.2 Studio Inception

As in Semester 1, start-up workshops were to take place in Semester 2, to introduce all studio participants to the IDS principles, as well as providing a platform for stakeholders to get to know each other. Due to the COVID-19 context, these workshops needed to be reconfigured, to fit with the online format. As a 6-hour-online event was deemed too tiring for a cohort of students (and others involved), it was decided to split the initial workshops over 2 days in early August (one in the first, and one in the second week). The online workshop sessions ran across all three IDS and included presentations from the IDS research team, University of Melbourne academics, AIRAH, the clients, and the participating consultants. At certain points, the Zoom meetings were split, to allow the studio leaders to address their students separately and set the studio-specific goals and constraints of the integrated design process.

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

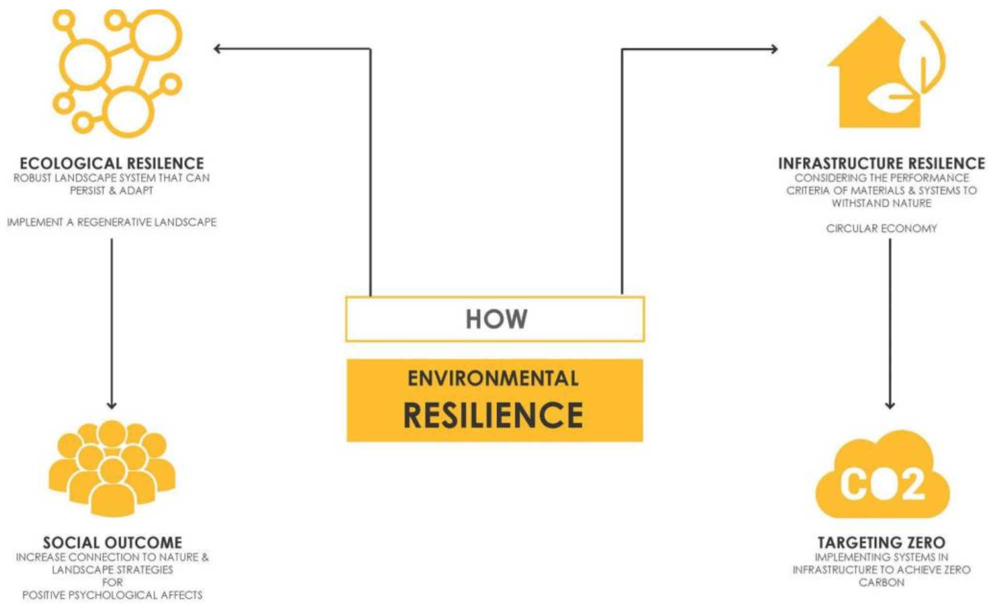

Figure 2: Environmental Resilience Diagram

2.3 Client Engagement

With representatives from Ambulance Victoria, this IDS worked with open-minded clients, whose aim is to redefine the design of their 200+ regional stations with a more conscious approach towards Zero Carbon goals. AV welcomes the opportunity to test unprecedented and novel technologies, brought into context with innovative design ideas. The IDS-04 Ambulance Victoria project was joined by industry experts and consultants, with a proven track record in the design, delivery and operation of these bespoke assets. This mix between willingness to experiment, paired with a high degree of expertise in ambulance station design, benefitted the conversations and design approaches in the studio. AV remained involved intermittently through the entire semester, providing guidance and feedback, particularly at mid-semester and the end-of semester milestones.

2.4 Site Visit

A site in regional Victoria was chosen by AV in Clyde North. Due to COVID-19 restrictions, it was not possible for IDS participants to physically visit any site.

In the absence of a site visit and delay in confirming the test site location AV, together with a Victorian Health and Human Services Building Authority (VHHSAB) representative, early in week 3 presented students with a thoroughly detailed account of the site selection process and expanded it to highlight AV's key future proofing and environmental strategies. This provided an opportunity for students to directly engage with AV's overarching environmental goals in the context of a test site and triggered a lively Q&A session in which architecture and engineering students were actively involved. It was observed during this engagement that the delay in site selection may have created an opportunity for students to assimilate generic environmental goals via precedent project analysis prior to application to the test site. Additionally, AV's site selection talk identified key features common to all AV sites to align with the briefed request for design concepts that were not site specific.

An interesting observation is that the collaborative nature of integrated design in this instance accelerated information processing, leading to a more adaptable process where a delay in receiving typically key information such as site selection, had no noticeable impact on outcomes and could be described as levelling the critical path.

3. DESIGN STUDIO PROGRESSION

3.1 Setup for Collaborative Design Integration

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

General

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

- Facilitate an environment that prioritises working on **common goals** over **individual goals**
- Establish **trust** among participants (open/non-judgmental/sensitized/willing/etc.)
- Allow every participant to understand what's **important to the others**.
- Explain the **process** each participant (group) typically goes through, to derive their desired **output**.
- Understand **why** we often see things **different**ly, and

- develop a **common language** that cuts across discipline silos (metaphors/analogies/co-experience)
- Call students '**designers**' **rather than architects** and **engineers**. Engineering should empower architecture and vice versa
- Set **common targets** à instill a sense of joint ownership … and
- introduce a sense of **shared responsibility** across group participants.
- **Knowing in action/heuristics**: discuss and advance integrated design solutions on the fly…
- **start with** educated guesses/**rule of thumb**, **then verify** validity of assumptions for preferred solutions.

Focus on Performative design

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

3.2 Schedule for Interdisciplinary Engagement

The studio tutor proposed a detailed IDS schedule in week two of the semester, based on her experience as design studio leader within a 13-15-week semester, as well as preparatory conversations held with the industry consultants, Ambulance Victoria (AV) and the academic participants. The schedule addressed the output requirements typically inherent to Masters-level design Studio teaching at the Melbourne School of Design, and the specific IDS output requirements for exploring novel technologies to support AV's Net Zero Carbon design goal. In particular, the schedule mapped out the intensity and duration of engagement between the architecture students, engineering students, the regular architectural and engineering design consultants and guest consultants.

3.3 Weekly interaction between Design Studio Participants

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

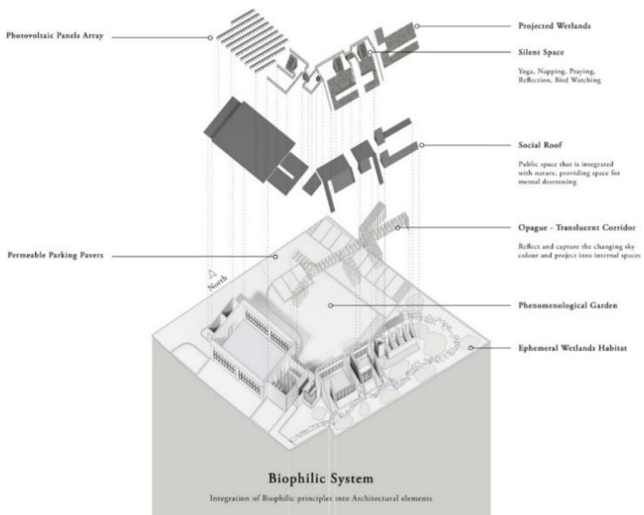

Figure 3: Biophilic System Proposal

The first half of the semester was divided into phases (motivation, speculation and review) giving context to guide studio interaction as they moved towards the final proposition phase in the second half of semester. The initial three weeks motivation phase was marked by additional presentations by Ambulance Victoria's architect and the Sustainable Design Consultant together with presentations from a guest consultant and students' return presentations of selected precedent projects. Students were then asked to start presenting first preliminary responses to the site context and the articulation/visualisation of various programmatic features (in particular of a social and environmental nature) to complement the community function and social responsibilities of an Ambulance Victoria branch. This led activity into the speculation phase, concluding group research activities and translating the brief into what it means for design.

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

In-between these two general phases, was a very brief period (typically around weeks 7-8) when core design ideas were generated and formed. Once that had occurred, it was observed how difficult it was for students to materially change direction due to the momentum involved. Designers held preconceptions after this initial ideation and the natural tendency was to adjust direction rather than to discard totally to start again. This meant that it is important to recognise when this ideation period is happening, ensuring everything and everyone is in place to make it as successful as it can be.

A first public presentation of preliminary design concepts occurred at the IDS Mid-semester presentations in late September and project participants advanced their designs through the 7-week proposition phase up until mid-November. The proposition phase was occupied with detailed development of designs and performance testing of individual designs in preparation for final presentations.

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

With the stage 4 lockdown in place across Victoria, the studios were forced to move entirely to remote (on-line) delivery. This online format proved successful overall, but not without some challenges related to the desired bonding between architecture and engineering students. From an observation perspective, it has some advantages as UoM researchers can act as a silent witness in the online chatrooms. Students, the tutor, and the industry consultants can take advantage of interactive online communication features to review and discuss design ideas both verbally, as well as by annotating sketches, plans/sections, and 3D models. Mid-semester and end-semester reviews occurred online with the inclusion of a panel of experts. It was observed that the online delivery method did not severely alter either the nature or quality of project outcomes.

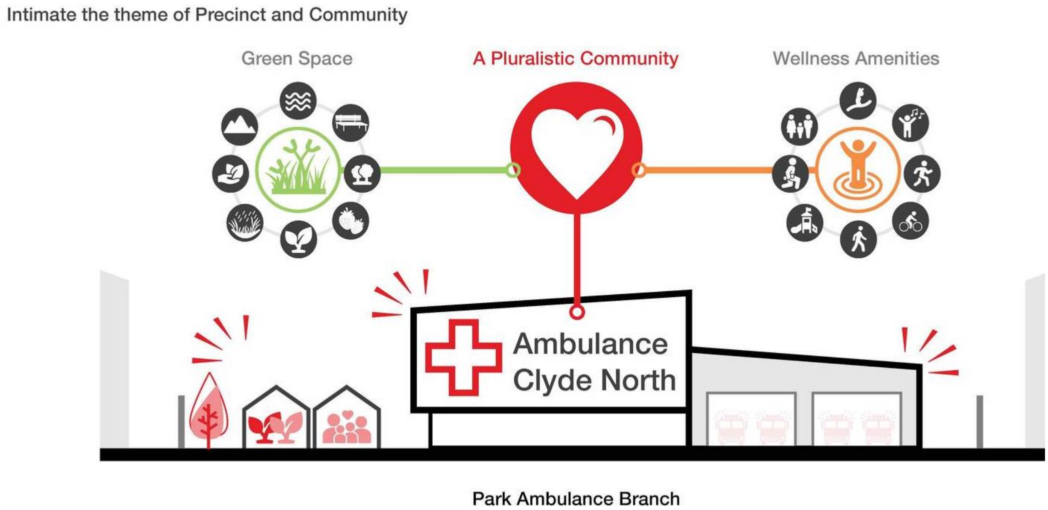

Figure 4: Ambulance/Community Diagram

4. DESIGN STUDIO FINDINGS

4.1 Observations in Studio Sessions

The activities within the studio were observed through the semester by the IDS research team. These observations focused on those aspects of the IDS that contributed to, or had a noticeable impact on, the integrated design process and outcomes.

4.1.1 Understanding Professional Specificity (and how to overcome it)

Striking a balance between architecture and engineering requires active curation. The Ambulance Victoria IDS took the approach of asking designers to work in four groups, each with 3 architects and 1 engineer and each responsible for key deliverables that would inform the concurrent development of individual design work.

This method offered the opportunity for architects and engineers to work closely together on common tasks to create key outputs that would influence individual designs. This gave each discipline the opportunity to gain familiarity with different design thinking during early project phases whilst engaged in activities for common benefit. Observations of discussions and presentations throughout the semester showed interdisciplinary familiarity initially developed slowly within groups, but an increased level of confidence emerged to an extent that individual architecture and engineering students began to reach outside their own discipline to communicate and propose alternative ideas. Engineering students were positively influenced by the architects' approach to framing questions and problem solving in some specific instances and vice versa. The content of the conversations stimulated inquiry and collaboration.

Earlier IDSs have adopted the opposite approach where designers were asked to tackle the project from the two disciplinary extremes (architecture and engineering), from the beginning producing designs they felt represented each (ignoring the other). This method emphasised the differences in the two approaches in designers' minds and articulated the prospects of needing to navigate the spectrum in-between the extremes in future design. Once equipped with this perspective it was easier for designers to understand that it is a balance between the two.

Observations in other IDSs had found that designers tended to follow the information in front of them without necessarily understanding the full extent of the design spectrum. It Is common for students to want to 'just get the assignment done' and fall back on familiar approaches, and it is common in industry, for efficiency and risk mitigation, to stick with what you know.

The cross-disciplinary familiarity that was observed in this IDS was fertile ground for the emergence of collaborative ways of working to achieve more integrated outcomes. Interviewees offered insight into how this unfolded through the semester, a key observation being that students displayed a maturity of understanding and a mutual respect for one another's disciplines, evidenced by students' reaching out to understand what the other disciplines could contribute. Although the structure of this IDS actively encouraged ongoing sharing and exchange of information and design ideas, the challenge of integrating themselves in shared decision making and being useful in the ongoing design development work efforts, was met by most students with noticeable hesitation.

4.1.2 Aligning the Dialogue

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

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

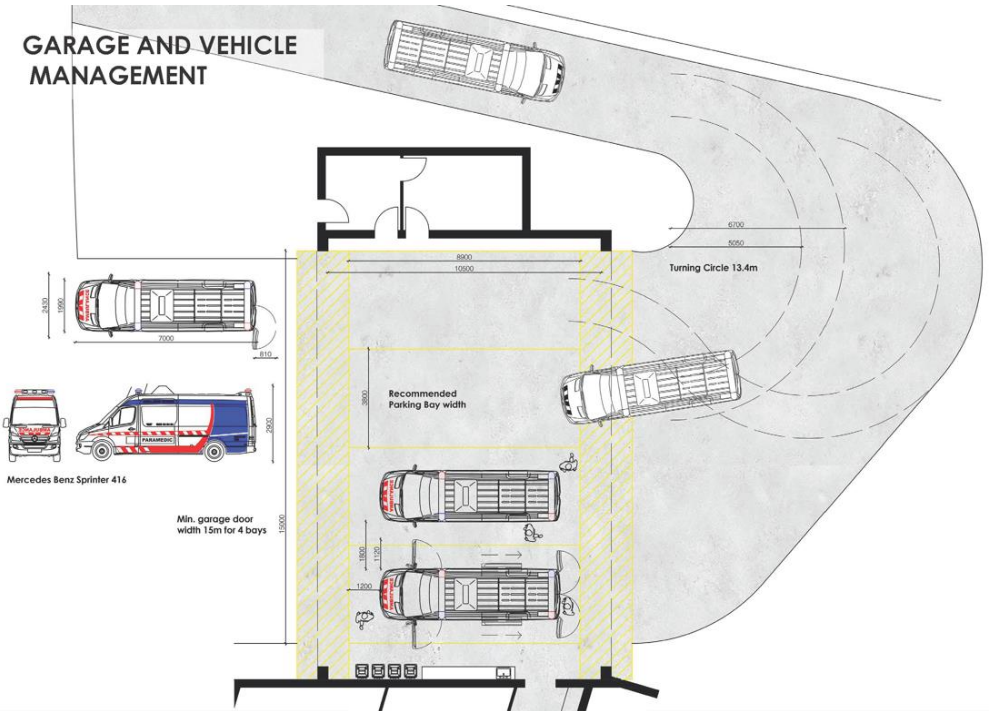

Figure 5: Garage and Vehicle Management – Ambulance Station

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

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

Notwithstanding the unchartered relationship between the disciplines, the IDS-04 Ambulance Victoria bridged the discipline gap by encouraging the creation of good working relationships within small groups, where both disciplines worked together in a move towards alignment of thinking and design co-author mindset.

Early observation of the AV IDS groups at work had found communication between participants showed a preference for words that represent familiar thinking for their own discipline but not necessarily for the other; architects were observed to use inspirational language around non-infrastructure aspects of the project such as human interactions and a sense of well-being, whilst engineers preferred factual/concrete topics and language. In some groups, communication whilst working on common tasks was intuitive without the use of words! Some of these common tasks are readily found in practice, so it is not surprising to observe a sense of common ownership.

It was previously reported that the AV IDS approach of offering early opportunity for group communication around foundational aspects of projects – client, site context / analysis, reference projects etc. offered value in founding a productive cross-disciplinary working relationship around common goals. These foundational aspects do not typically fall into an engineer's domain and despite initial awkward communications, the group setting, and sense of common ownership quickly matured into a successful common work effort with each group producing a collaborative research booklet to share across the studio. The maturity of the collaborative output impressed in the mid-semester critiques.

The common ownership that gave rise to this outcome may have reflected mutual agreement in the work effort - an important foundation for aligning the dialogue and leading to Design Co-authorship.

As the semester progressed students were observed to be "… keen to experiment with the architecture and integrating technological solutions into their buildings …" (*David Ritter*) and create something from their learnings. It was hoped that the common ownership of early outputs would translate to sharing the challenge of resolving design dilemmas during the design development phase. Unfortunately for many designers, and despite their notable understanding of the separate design elements, they struggled to adopt a Design Co-author mindset. Observations suggested that the absence of a clearly articulated 'whole of project' vision, informed by the collective skills and insight of the collaborative group, may have been a stumbling block and the collaborative work effort stalled. Some bolder designers pushed forward with their own vision and continued to individually workshop solutions, but hesitant designers settled on familiar solutions and stopped the workshop process altogether.

Upholding the sense of common ownership/shared challenge throughout the semester, encouraging mutual agreement around the work effort and actively encouraging the articulation of a 'whole of project' vision will be addressed in future IDSs.

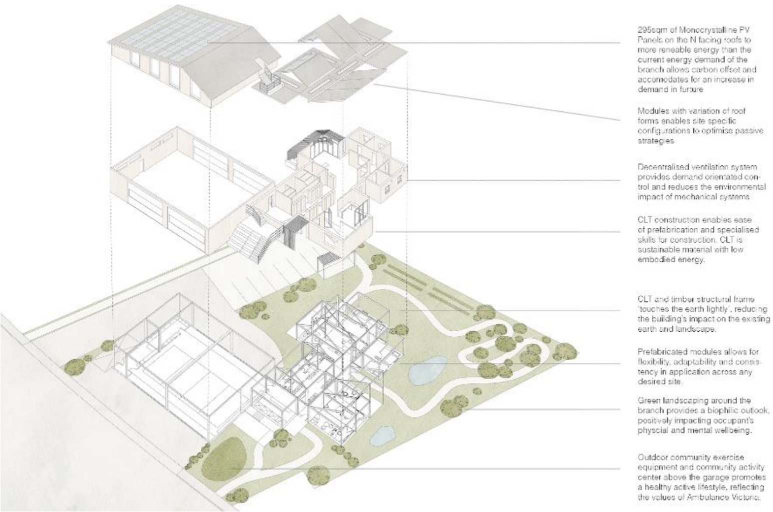

Figure 6a: Kertina Liu – Module #AV - Towards Net Zero Carbon - is it Achievable?

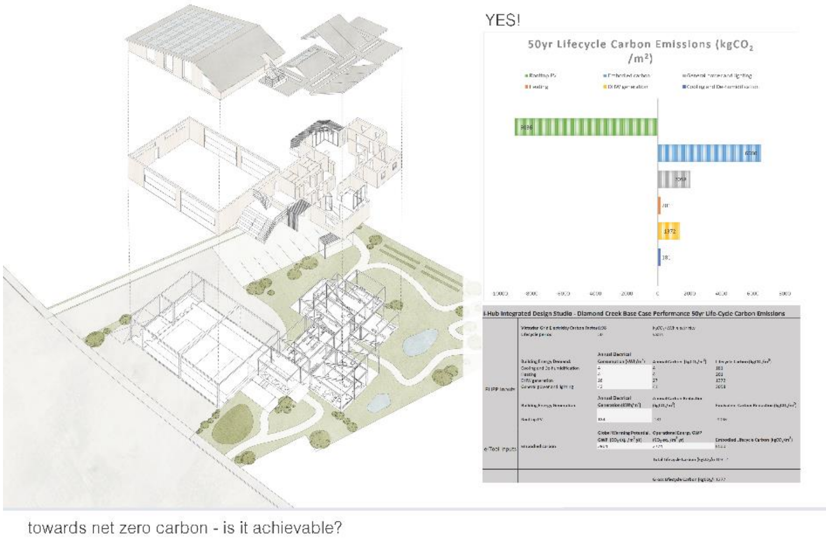

Figure 6b: Kertina Liu – Module #AV - Towards Net Zero Carbon - is it Achievable? YES!

4.1.3 Context and Client

The project foundation was built from the very detailed AV brief and the considerable AV input that included paramedics, project managers, strategic orientation, high-level net zero carbon and renewable energy commitments and more. The well-structured studio setting and encouragement of design inspiration via a range of presentations and engagements with industry consultants and guests together with students' collaborative group research ensured a strong foundational project context.

Observations of designers in studio sessions through to the end of semester confirms the early observation that creation of a solid foundational project context is critical for developing integrated designs.

AV presentations in the early phases of the project were observed to be well received. They triggered a wide range of questions that seemed random at the time, but later review uncovered a pattern of interrogation from the group. Individual's questions gravitated to the group's bias and fed off each other to build what appeared to be a solid early context of project understanding across client, function and infrastructure. The nature, structure and scope of the client presentation drove the interrogation bias to an extent and reveals the high value of client involvement at project start-up in creating an intelligible project context.

It had been reported that interrogation of AV constraints and different approaches to balancing priorities, observed in early student presentations, was interpreted as intuitive recognition of opportunities and constraints as being key to developing a relevant project context and guiding the formation of relevant solutions.

Ongoing observations affirmed that the 'whole of project' context unpacked in the AV brief was found to be complex and challenging for designers to navigate. With hindsight, it seems that designers may have simply adopted the client's detailed and well-structured context and expressed priorities without really understanding them or how they were arrived at. Designers appeared to be quite challenged by building on this foundation and struggled to add their own interpretation to the strong beginning. They did not demonstrate an understanding of how to build their own 'whole of project' context from which to develop a unique vision. These struggles were evidenced in designers' ability, or not, to balance competing priorities or acknowledge a hierarchy in emerging project information, and their seeming ambivalence around what aspects to build on in their own design.

Early observations had noted a tendency for some designers to gravitate to familiarity when on their own but in the well-defined context of the AV presentations these designers intuitively displayed group/shared interests, through the adoption of AV's detailed context and expressed priorities. These observations were earlier reported as encouraging steps towards an integrated design goal. However, in trying to create their own project vision, many designers were indeed observed to gravitate to the familiar and work independently of the group and without much reference to the group. Their tactics may have been flawed but may be interpreted as demonstrating an inadequate understanding of how to develop an integrated design context beyond what they were given - the AV brief.

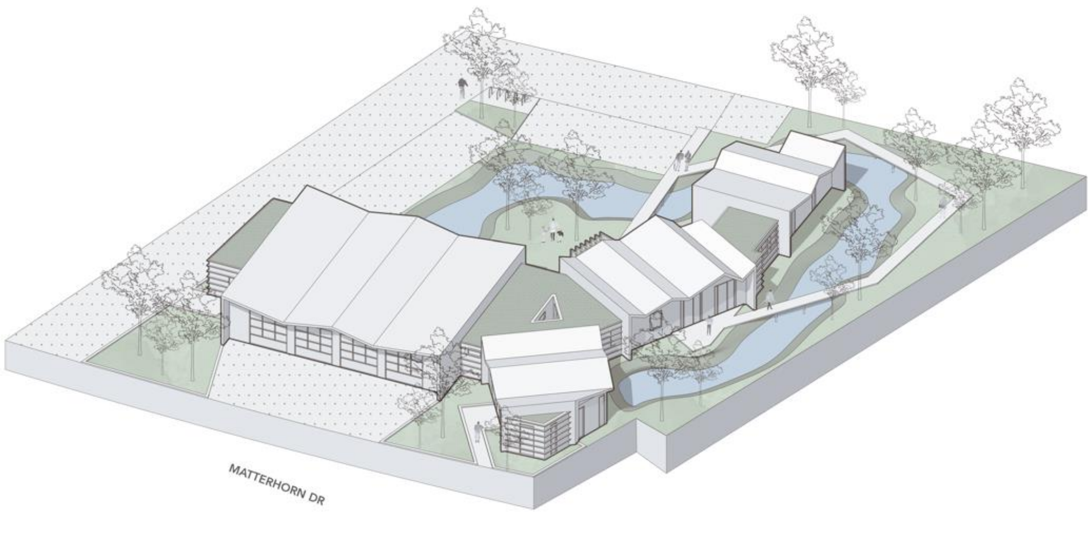

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Figure 7: Robyn Mackenzie – Post Pandemic - Impact on Landscape

4.1.4 Perspective and Process

Early observation of group selections of reference/precedent projects highlighted the challenges of 'seeing' buildings in an integrated way with several precedent projects illustrating few parallels to the AV project. An interesting correlation was observed to exist between the selection criteria for the precedent project and 'seeing' projects in an integrated way e.g., taking ESD principles outside of the context of a relevant completed project may have contributed to later prioritising challenges that occurred with some early design solutions. The value of precedent projects to strengthen understanding of the integrated nature of projects is worthy of note.

It was observed early (and unsurprisingly) that the engineers were uncomfortable without clearly defined scenarios and without clear outcomes. Observing engineers seeking specific site information not yet available, before moving forward, potentially illustrated intuitive understanding of the significance of permanent unchangeable project constraints. This perspective contrasted with the architects' observed desire to transcend reality and seek unconstrained inspiration to find solutions!

Observations indicated a slow grasp by designers that design evolves naturally out of key design drivers and can't be forced. Individual perspectives are not necessarily helpful in building, for example, a solid understanding of project priorities. Some projects were observed to be locked to an early idea that had arisen from an individual and early perspective on the design challenge. Some projects displayed compartmentalised understanding of the total building, expressing ideas through some limited but, to them, intelligible aspects. All designers will benefit from the perspective and knowledge of other disciplines when trying to prioritise key design information and achieve a relevant 'whole of project vision'.

The observed struggle with managing individual perspective in an integrated design process highlights the challenges in the paradigm shift from traditional to integrated design, emerging as it does through the shared perspectives of a collaborative group. Individual perspective has high value in informing that process and, as one interviewee described integrated design: *"… informed design i.e., designing with information at your fingertips... (is) still a design process but you've got more information to inform your design…"* (Cath O'Shea, AV)

Observations of the bumpy development of many designs led interviewees to suggest structured peer-to-peer feedback/critiques of designers' work in progress, bringing a group perspective to poorly supported individual design notions and assisting individual designers to navigate an unfamiliar process.

The dilemma of balancing architecture and engineering design components was managed well by individual designers however, some designers were observed to grab things that aligned with their own perspective and run with them. For example, the inclusion of new technology because it had value from the perspective of their own discipline, though the engineering perspective may not place the same value on this inclusion and would ask 'why?'

It was observed that the use of e-tools such as PHPP – Passive House Planning Package energy modelling software, introduced by the sustainability consultant can enhance and underpin designers' understanding of how buildings interact with their environment at multiple levels and that all aspects must work together as an integrated design response. Such activities allow designers to better understand the relationship between good design and performance, inform their understanding of how buildings work together and help broaden their own perspective

Observations in this studio of the range of opportunities of working in groups, with designers observing each other's outputs, participating in group presentations, receiving training in the use of energy modelling and benchmarking software/e-tools underpinned a growing sense of confidence across the group to a level that prompted such questions as "how can we better engage with each other" and prompted the engineers to come up with their own design proposition for a prototype ambulance station.

The engineering student group design arose from an engineering perspective and was appreciated by all designers as an interesting take on the shared design dilemma. However, successful solutions/outcomes can become an end in themselves absent of an understanding of the pivotal process by which they were achieved. There were missed opportunities for the architects and engineers to collaborate and use their different perspectives to advantage in prioritising the value of design components and deliver a more effective outcome. Interviewees unanimously suggested that specific guidance may better support students through this process.

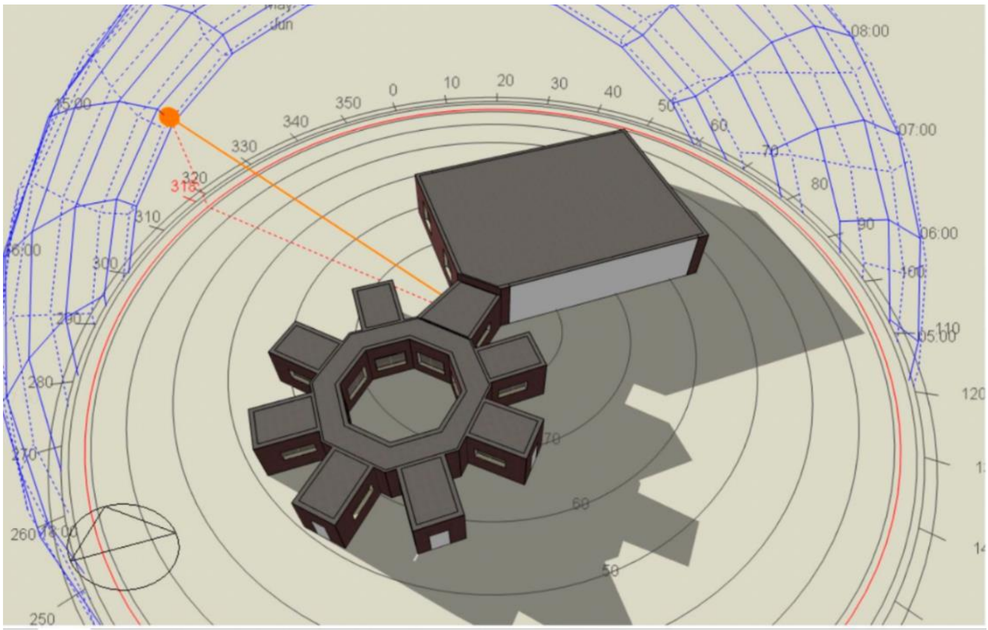

Figure 8: Engineers' group design proposition for a prototype ambulance station

4.1.5 Critical Thinking and Confidence

Observations of design proposals on display at the mid-semester review where novel technologies were explored, demonstrated how apparently straightforward novel technologies are more complex than they seem.

One project was observed to focus entirely on one novel technology as the central design concept with ESD featured as add-ons. The designer adopted an intelligible idea that may offer potential to meet key AV design parameters. It seemed that no critical analysis/review had been undertaken (individually or within a group) to view its merits from different perspectives.

Creative innovation in design requires critical thinking to include problem solving and critical analysis. Approaching design from an integrated perspective can create opportunities to test the merits of novel technologies for specific applications. Time spent understanding the problem from alternative perspectives before 'solving' it may greatly improve designers' creative confidence.

Providing more support for students through this process can enhance their confidence in taking a critical view of their own work. On their own, students were observed to struggle to take full advantage of the collaborative opportunities offered by the studio. This was interpreted as the same dilemma evidenced at other points in the process and noted herein, which is that students were not confident of their next step in the design process; they were not entirely sure where it would lead or how it could be integrated. They were observed to 'wax and wane' and many strayed from the collaborative approach and reverted to the familiar individual path that comes with its own inherent confidence in what they already know but, may not answer the question posed by the client brief.

The suggestion herein of peer-to-peer feedback/critiques during the design development phase may also highlight the impact, relevance and/or value of various aspects of individual design proposals and give designers confidence in evolving their concepts through the yet unfamiliar, integrated design development phase. Such inter-disciplinary discussion around design challenges offers learnings for all participants, building confidence both ways within the group sufficient to inspire even further creative exploration and insights to new ideas.

4.1.6 Working toward Common Goals

One key element addressed in more detail during the second half of semester, was a more targetted articulation of common goals towards net zero carbon in the joint architect/engineer effort. A team from Atelier 10 provided one-on-one engineering feedback to the architecture students in dedicated TEAMS channels and, following the post-mid-semester review the dialogue was continued on the Zoom platform, using breakout rooms to allow for direct annotation of drawings online and direct assistance with individual and shared challenges. That way, engineering feedback was provided more directly and in a more targetted fashion. Early in the semester one of the engineers led much of the engineering students' communication but the transition to the breakout room environment encouraged dialogue from all engineers.

During the second half of semester the Atelier 10 team ran workshops for students to use two software tools developed for assessment of buildings in terms of operational and embodied energy. This was particularly helpful for the engineering group who quickly grasped the analytical tools, spurring the engineers on to produce their own design for analysis with these tools. The architectural cohort displayed a great enthusiasm for the tools that was matched by a more holistic understanding of the energy consumption and carbon footprint of their designs.

The Passive House Planning Package or PHPP software program, determined their designs' operational energy performance based on its individual elements. When used as a design tool it gives immediate feedback on the operational energy impact of alternative design scenarios.

The eToolL website describes their software as 'a web-based, collaborative, performance optimisation tool for the whole building lifecycle'. It measures embodied energy and allows performance impacts to be captured at different time intervals over the lifecycle of the building e.g., construction phase, operational phase and end of life phases such as disassembly and disposal. Designers can model different design scenarios using a wide range of building components and systems and understand the costs and environmental benefits of potential design strategies.

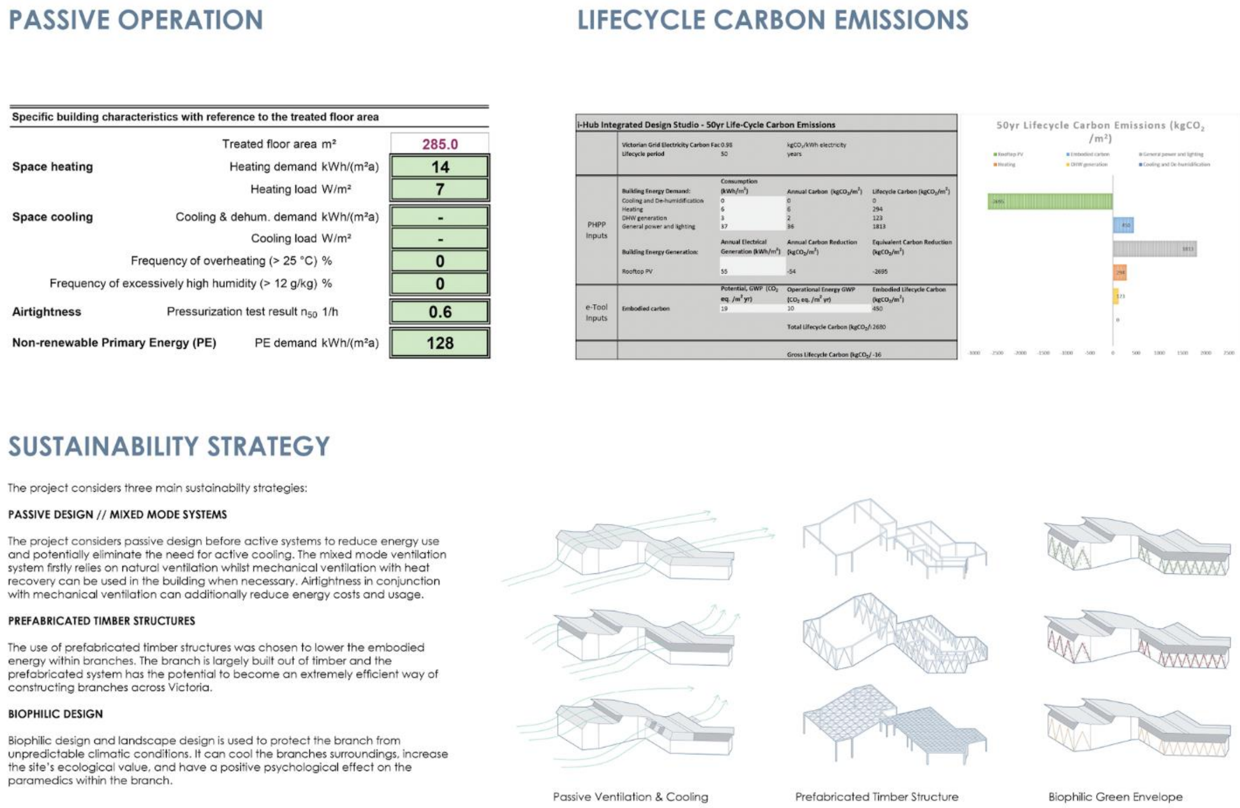

Figure 9: Rebecca Pike - Environmental Resilience – Sustainability Strategy

Both tools allowed designers to test the multiple scenarios that can contribute to achieving the common goal of net zero carbon. The tools gave targetted insight into their proposed building's performance under different design/construct scenarios and, the full lifecycle eToolL was especially valuable for designers who proposed modular assemblies that could be disassembled and re-used in other AV sites. Designers were observed to better understand the steps they needed to take towards achieving the common goal. The improved understanding that the goal could be reached through many small and effective design decisions, was a highly valuable learning outcome in the context of integrated design as it illustrated an alternative approach to the typical search for 'the big idea'.

This experience with its resulting improved awareness by students of the high value in taking collaborative cross-disciplinary steps towards the common goal, highlights some key aspects of the studio experience that will be considered for adoption in future studios. It was interpreted that this learning is likely to have improved the sense of confidence for designers in experiencing that a collaborative approach can lead to better design outcomes, despite having to walk an unfamiliar path to get there.

This iterative nature in the research, refining the findings and adjustments over multiple studios is one of the reasons multiple IDSs were planned. Future studios will help refine the findings and close the gap that currently exists.

Figure 10: Robyn Mackenzie – Post Pandemic - North Landscape

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

The feedback from the key contributors to IDS-04, was captured via online face-to-face interviews. Two industry consultants, the client representative and the studio tutor participated in these interviews. The interviewees were asked about the key drivers and barriers to achieving integrated design, their opinion on the studio brief, the nature of their contribution and their general feedback on the overall performance of the AV integrated design studio, its usefulness and areas for potential improvement. The interviewees' feedback Is summarised below and highlights a range of aspects of the IDS that interviewees perceived had influenced design integration, team integration and design outcomes.

The Ambulance Victoria Brief proposed an ambitious but clearly expressed challenge that designers could all understand and grapple with, without it prescribing a particular approach. The challenges of the brief forced the disciplines to think carefully about their responsibilities and how their actions/decisions may affect other disciplines. A positive perception was that designers were all able to absorb and mentally navigate the design challenge, via the brief, a range of client and industry presentations, and their own group research in early semester. This facilitated a clarity of purpose as a strong starting point on the path to a more integrated understanding and potential solutions.

A health facility brief contains prescriptive constraints that interviewees perceived may have dampened development of some design opportunities, but it did represent a real-world challenge. Some designers did not fully grasp the imperatives of the brief, and in these instances, it was found to be extremely difficult to guide them towards a change in thinking.

Most interviewees felt that the clarity of the brief assisted designers to engage with the challenge in a meaningful way and that the level of ambition of the brief was key to a successful integrated design outcome. All interviewees saw an opportunity for the brief to articulate a design development pathway to “harness direction” in the evolution of the project and were positive about the notion of prescribing a hierarchy of key design milestones in the integrated design journey.

Design Inspiration for students appeared to come from talks and exemplar projects of seasoned architects and to a great extent the consultant presentations. Interviewees noted that designers were, nonetheless, still attracted to technologies that could be utilised as a significant design element but were not necessarily applicable. They suggested that more support could be given to aid designers in rationalising use of available technologies and steer them away from the tendency to produce solutions before understanding the problem. A bias towards the strong AV brief was perceived in the middle band, but this resulted in few new ideas nor was any ‘rule breaking’ evident in this group of designs. The stronger designers were more confident in allowing designs to evolve along with their increasingly detailed understanding of the design challenge.

Figure 11: Zoe Ross – LightHouse – View from street

One interviewee expressed the thought that designers needed to have started their design before they could find meaningful inspiration and, went on to note that “… there's at least five areas that are about practicality in design and engineering that could be mud-mapped …” and interrogated earlier in the design development process. In the context of supporting designers’ sometimes fleeting ideation moments, this may better illuminate the context from which they derive inspiration and ignite a more targetted curiosity.

Design Co-authorship was perceived to play out in a positive way. Interviewees felt that designers overall displayed maturity in their collaboration that was quite successful, perceiving a direct link between the nature of their collaboration and design outcomes and specifically, the structuring of the studio to prioritise group work. Interviewees agreed that the interdisciplinary collaboration improved designers’ early research and presentations and provided a solid foundation for individual design development.

Given the positive nature of designers’ collaborative discussions, the further challenge of navigating how each discipline could integrate themselves in shared decision making and be useful in a common work effort, was met with noticeable hesitation. It was perceived that most designers did the engineering and architecture independently. Their natural reaction was to… *“Go about your own business, talk to the others, but keep going about your own business, and then* *try and merge them. Rather than… say, well, we've all got something up front (to share) if we do it a little bit differently and a bit more inclusively* ". (Ed Ewers, specialist industry architect).

Interviewees remarked on how well individual designers balanced the engineering requirements with the functional and aesthetic imperatives. Taking an alternative path to typical design studios, this studio prioritised consideration of the functional and systems aspects together with the design aesthetic, so *"… the balancing act … became a simple process because they were thinking about it… (and that) came through in the proposed aesthetics."* (Gumji Kang, Studio Leader).

"They were all keen to experiment with the architecture and integrating technological solutions into their buildings… Some students tried to celebrate certain technologies and brought them into their scheme such that they influenced say, the shape or construction of a wall… (and) one had a water treatment system integrated into their building." (David Ritter, Industry Consultant). One interviewee commented on the skill displayed by designers in turning *"the design features they were playing with, into a scenario of real outcomes - whether they're a good idea, whether they improve the outcomes or even change outcomes at all,"* (Cath O'Shea, client representative).

Designers lacked the confidence outside their own skillset to move forward in an integrated manner beyond doing well *"… on the challenges, on specific things, and on benchmarking the overall project."* (Cath O'Shea, client representative). Innovative design ideas could have been critiqued by other designers/disciplines to test whether the idea is worth pursuing. In a collaborative environment, going through the *"… rationale of explaining why you're choosing that approach is really valuable for the student experience, and their professional development; to explain to the client that, even if you don't like it, it's a good idea… on a technical or performance basis."* (Cath O'Shea)

The upskilling of designers by the industry consultant in the use of software to measure energy performance, highlighted how design aspects impacted building performance, and designers could ask a simple question: "If they're not impacting measurable outcomes, can they be retained for their beauty or aesthetic nature?" (Cath O'Shea).

Despite the stumbling blocks, all students were perceived to have performed well and made positive contributions to the common discourse. "They are coming from different experience and capability… They are different to each other and have different roles. But at the same time, they are the same, they're equal and can equally contribute to the design process." (David Ritter, industry consultant).

Figure 12: Kertina Liu – Module #AV - North Exterior View

Inter-Disciplinary Collaboration was seen by interviewees as a driver of positive engagement around agreed common goals. In the words of Gumji Kang, studio leader, it was *"...refreshing to see how architecture and engineering...*

approached design thinking; ...seeing engineering students' capabilities and how they work... had a positive impact on architecture students re how they approach questions and some particular problems; ...the engineering students were quite influenced by architects (approach to) questions… presenting and discussing a problem; …and see changes emerge… (through semester) in how they discussed or presented their materials in class…".* Interviewees shared the view that more guidance during the design development phase would help maintain effective collaborative engagement for the duration of the project; for example, identifying points of mutual agreement/common goals.

Timing of the Collaboration was perceived to have a noticeable impact on project momentum through design development. The engagement of industry consultants from beginning to end of the project *"…created an early sense of integration…"* (GK) as well as confidence among designers that their efforts to achieve integrated solutions would be supported through the project. This is a change from a typical design studio and from industry where, for multiple reasons, specialist consultants are brought in as necessity demands, for 'shooting technical solutions' or providing the technical specifics for a preconceived design notion.

It was perceived very positively that the engineering students did contribute ideas, as a group, to master planning/passive design and building forms by coming up with their own design proposition. This collaborative group outcome was presented many weeks into the process although it is unclear how much learning was absorbed into the architects' projects at this late stage. Project evolution occurs at a different pace for each designer, but it is of note that the engineering students absorbed a huge amount of project familiarity and learning along with a noticeable growth in confidence via their collaboration with the architects and during the development of the architects' designs. This confidence enabled them to think about, and come up with their own design quite rapidly, after spending most of their time thinking about the problem, apropos of Albert Einstein's thoughts about problem solving… *"If I had an hour to solve a problem, I'd spend 55 minutes thinking about the problem and 5 minutes thinking about solutions."*

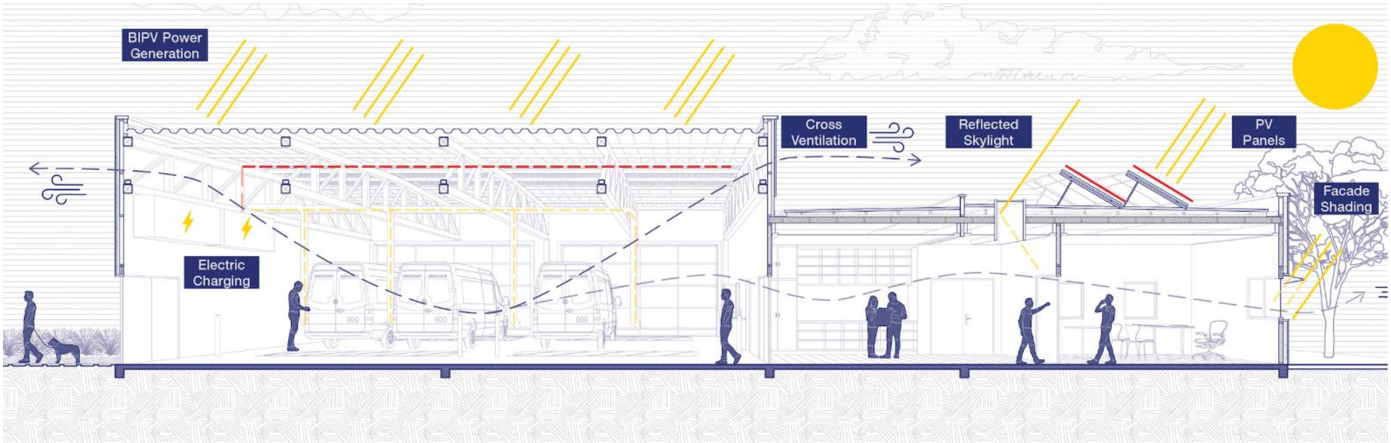

Figure 13: Jason Leung – Agile Vivacity – Section of the Operation

Designers' Struggles with time challenges were experienced in diverse ways through the integrated design development journey and all interviewees acknowledged the need to create milestones that can identify key moments of integrated project understanding that would assist designers to navigate this process in a timely way.

Other struggles with the design process were observed by all interviewees. Some designers "jumped straight into conventional solutions", as they could identify a familiar pathway to the solution. However, the pathway to a goal of a net zero carbon ambulance branch or environmentally sustainable design solutions was unfamiliar. Though the technologies that may comprise such an outcome were well understood by designers, how to apply the technologies to get to an outcome, were not well understood. Designers were observed to discuss, absorb and share quite complex technical and other researched information, but not how to prioritise it. Solution-oriented designers were observed to struggle with thinking about approaches different to their familiar / obvious solutions; they lacked the confidence to move beyond existing knowledge. There were missed opportunities observed in the application of some environmental solutions with a tendency toward 'overkill' and 'complexity for technology's sake' appearing in some designs and sacrificing well understood, simpler and potentially more beneficial environmental approaches.

The industry consultant suggested offering *"...some good, easy rules of thumb they can apply to their projects... (to) give them confidence in how their passive systems are performing."* (David Ritter)

> *"The biggest struggle was for the students to depart from what's already being done and … make that step forward … even though they can't see how to resolve all the details… The middle band settled on a solution, and then stopped the workshop process." (Gumji Kang).*
>
> *"Some did really well in one area but perhaps overdeveloped in another area or made too many presumptions that had to be wound back in some areas, developed in other areas or made no sense in some… and that's where they struggled… It's all about the process. It's difficult to just get to one stage, keeping a really clear goalpost in your mind, not to progress one area too much too soon, so you can build something on that engineering architecture relationship." (Cath O'Shea)*

Overall, *"they all demonstrated buildings that were quite advanced in their thinking around environmental or engineering systems and they managed that aspect really well. (However) …the challenge goes back to the …key steps in the process where engineering principles are really integrated into the architecture."* (David Ritter)

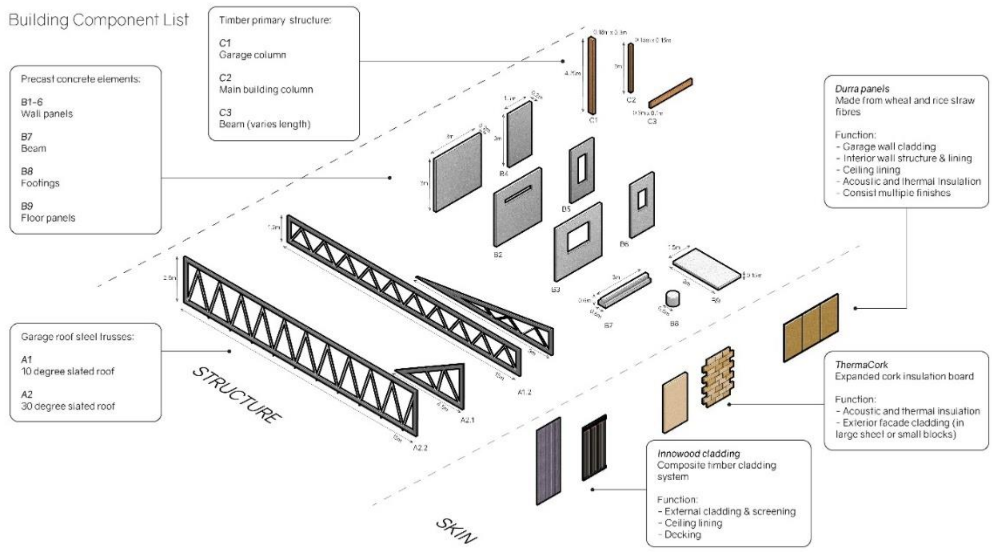

Figure 14: Rachel Koh – Healthy Ambulance Station - Building Components

The Industry Consultant offered four steps as key to an integrated design development pathway i.e., site master planning, façade, systems and testing. The feedback from all interviewees was unanimous on the need for students to be briefed up front on project milestones that aligned or were compatible with those key steps that mark the Integrated Design Development process or pathway. Having this information up front should, for example, *"… help them to then question what they can and can't push in their design considering its impact on other areas of the project…*" (Cath O'Shea), give clarity to the way ahead and uphold designers' confidence as they develop their design.

The Industry Consultant team engaged with all groups in the studio, including engineering students, weekly or twice weekly and participated in discussion-based exercises. The use of breakout groups in both the Teams and Zoom platforms was noted as allowing better opportunities for one-on-one discussions with consultants. After about 4 – 5 weeks designers displayed emerging confidence in this working environment as more cross disciplinary discussions began to happen quite naturally.

The industry consultant's early presentations soon began to emerge as themes and technologies in the developing designs. The industry consultant felt that designers could have been helped by more handholding through the (design development) thought process that may lead to a more holistic understanding of different technologies in application. Through the design development process, the industry consultant offered validating support of individual designer's efforts and curiosities without *"influencing too heavily"*.

The Studio Guidance provided by all interviewees was varied. In general, the nature of the guidance encouraged students to focus away from the concept of problems with correct/incorrect answers and towards dilemmas to be assessed and weighed up. The industry presentations were of significant benefit in particular the inclusion by the industry consultant, of some "*grounding principles of environmental design… (helping students) build a firm foundation on how to approach their project."* (Ritter). Designers were guided in organising their thoughts to manage different perspectives, focusing away from ideas and towards critical assessment of the outputs from their group research. They were introduced to the use of digital tools to measure and assess the performance of design elements/systems and, theoretically, benchmark this to the quality of aesthetic elements. Points of overlap in the design development process were identified by the industry consultant and designers were encouraged in 'cross-fertilising' one another's work to mutual benefit.

The client provided significant input via paramedics, project managers, (AV's) strategic orientation, high-level net zero carbon commitments and renewable energy, but remarked on their own heavy reliance on net zero carbon as a motherhood goal without explaining to students how AV got there.

Maximising input was something that all participants felt could be improved, with suggestions ranging from closer tracking of students' design progress and reviewing the nature and timing of studio activities, to steering students away from typical industry constraints that, in the studio environment, may discourage the pursuit of unconventional design approaches. Some interviewees felt the need to bring more structure to their own contribution, leading to observations that more structuring of the integrated design process itself may bring some clarity to the ongoing dilemma of process vs design. Interviewees all saw a need for structured thinking around engineering engagement in the studio and how they might optimise engineer/architect collaboration. The AV representative noted their new awareness of the performance measuring tools that can underpin future inclusion by this client of more specific/prescriptive energy performance targets in the brief.

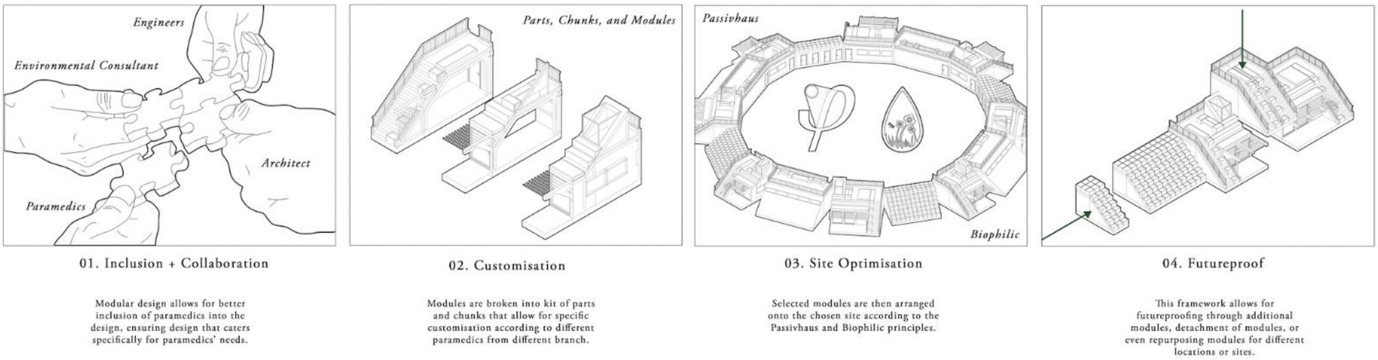

Figure 15: Vincent Heru – Modular Concordia - Design Framework Diagram

Enablers and Barriers to Integrated Design exist in the studio just as they do in industry. Interviewees commented variously that integrated approaches level the playing field by enabling mutual respect and active commitment to one another's disciplines. Integrated design is enabled by, "*passing on the pen"* and placing information at each other's fingertips. A key enabler is recognising and working with the hierarchy of information and prioritising it to mark out a clear pathway towards achieving project goals and, *"…harnessing or tailoring a series of expert disciplines through the work and workshopping (process)... It comes down to the presentation of the brief and each discipline defining their role within that brief…".* (Ed Ewers). An ambitious brief is a key enabler as, without ambition *"...disciplines can tend to go along their own merry way and not really interact with each other, not really having to synthesise anything, just doing compliance work."* (David Ritter). The Ambulance Victoria design requirements seemed to enforce synthesis of the disciplines through the ambitious brief where *"… all disciplines involved in the project are challenged and made to work hard, such that anything they do affects the other, so they have to work together."* (David Ritter)

In the studio setting *"… it's an educational environment, and the students need to be led a little bit, but… having multidisciplinary aspiration is really important to ensuring it's going in the right direction"* (David Ritter). The *"safe environment to share thoughts and ideas in a non-judgmental / open manner* " (Gumji Kang) that was enabled by the studio setting, encouraged group-based interactions inside and outside the studio, and a growing confidence in one's own and others' contributions in an unfamiliar design paradigm. *"The IDS setting (enabled) ... early introduction of a functional design approach and robust input from engineering students and consultants."* (Gumji Kang).

Barriers in industry arise, interviewees felt, when disciplines think in isolation about their own requirements, usually related to their discipline's performance, time and fee imperatives. Communication is a significant challenge and the architect's role is the only one that demands a multi-disciplinary approach; changing an existing hierarchy that puts the multi-disciplinary architect at the top of the communication triangle, is extremely challenging. Built solutions frequently ignore the negative impact that their solution has on other people by favouring business imperatives; they don't comprehend the lost opportunity to achieve a common goal.

The need to take an integrated perspective before the project even starts is a big challenge in industry but, "…from the client perspective, Ambulance Victoria has a growing understanding, at a beginner level, how much can be achieved by good design. Some of the outcomes of the studio showed that good design can reduce an energy demand by 50% or so, which is amazing… So why aren't we looking for the sites that give us... (good passive solar design)?" (Cath O'Shea)

The specialist architect's own experience is that *"…when project teams work very well together... (more integration happens) ...and there's also trust and, more than anything, the best projects are ones where the consultants are involved from very early concepts."* (Ed Ewers)

From the perspective of the Studio lead: "It's much better to have open discussions at the very beginning and so avoid multiple issues that will inevitably emerge in later design stages." In industry, the consultant model typically brings engineers in as necessary and the ability for consultants to gain a perspective on the project is curtailed. At the same time, the experience of Covid-19's enforced use of online collaboration platforms, showed these to be a time efficient way for industry consultants to engage with a project from the outset via regular online sessions to maintain the level of project knowledge needed for collaborative outcomes.

> *"Integrated design goals written into the brief can unite teams by a common, ambitious goal under a shared vision and shared goals and targets that unite. …(Creating) opportunities for dialogue where they can problem solve together to jointly meet project aims, goals and objectives would be good for them and help them think about how their proposals impact others and contributes towards the common goal." (David Ritter).*

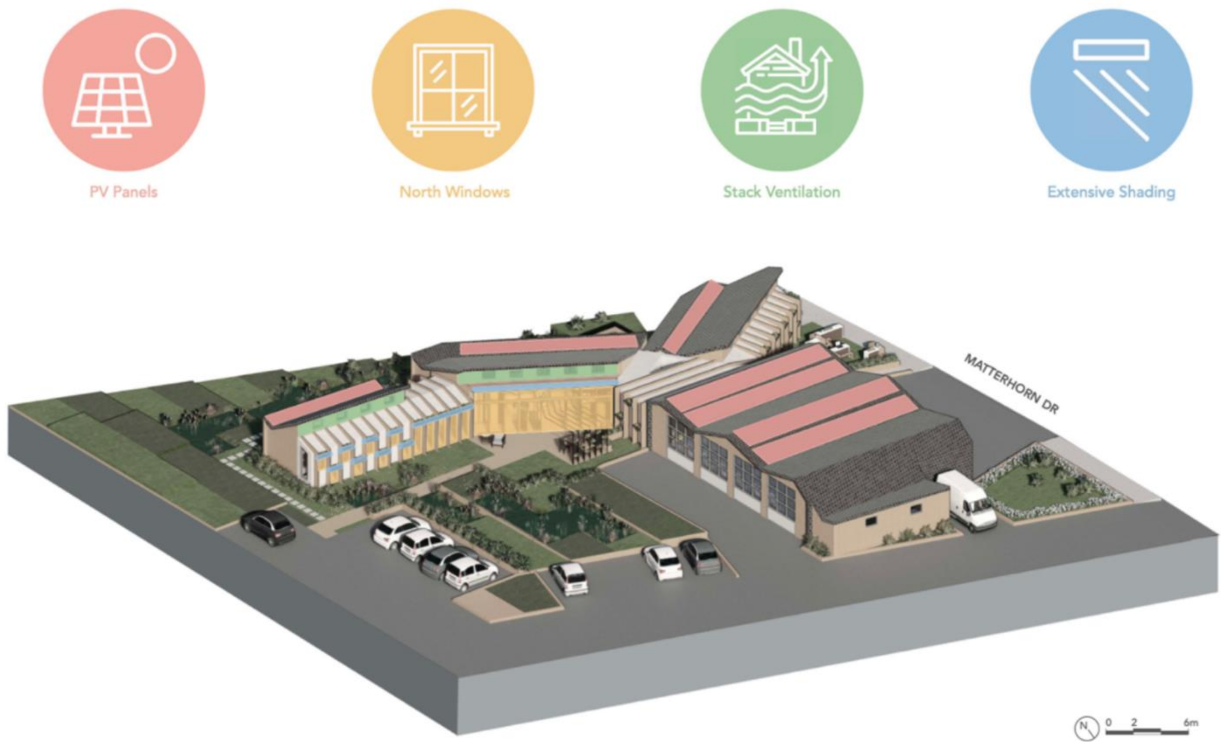

Figure 16: Robyn Mackenzie – Post Pandemic - ESD Strategies Isometric

Learning Outcomes for Students were significant in terms of environmentally sustainable design as they were exposed to a variety of perspectives via the speaker series and a range of consultants presenting on environmental engineering, structural engineering and, architects with alternative design perspectives to mainstream. Students were challenged to model their projects, albeit imperfectly, and pushed into technical methodologies that delivered some good outputs and highlighted, for students, the key design parameters that can impact energy performance. This hands-on learning experience is a stronger foundation for future learning vs a reference spreadsheet. One interviewee reflected that… *"if you set finite tasks regularly, you get better quality by keeping them working, and steered in a direction… (with) better learning outcomes."* (Ed Ewers)

It was expressed that the level of collaboration encouraged and experienced in this IDS is quite unfamiliar in industry, so the opportunity to design a project in a collaborative environment is something new that will make them better and more useful architects in practice.

Usefulness of Studios, posed as a question to interviewees, was responded to with unanimity. The IDS was considered an invaluable component in the structure of a curriculum that offers Master of Architecture or Engineering. It was observed that outside academia, opportunities for students to engage with the practising industry and engage with people outside architecture are becoming increasingly limited. It helps to see a much bigger picture in a world of increasing specialty. It was seen as essential for architecture and engineering students to experience how the other approached design thinking, how they work and approach questions and problem solving, how their skills are used and how they can influence one's own perspective. Observations of the design presentations and discussions through the semester reflected an increasing maturity in students' approaches.

> "*Students at higher levels of education start to develop real expertise and hone their knowledge. Key to this is to understand how to communicate, understand other disciplines' expertise, engage in a meaningful way ... and experience the value that everyone can bring into the design process rather than being tunnel visioned into a single architecture design approach*." (Gumji Kang)

> "*It helps to understand the requirements for team-working, shared responsibility and vision... It exposes students to the more technological side of architectural design… which can be inspiring and offer plenty of richness for students... At the very least, they've developed a much better appreciation of the technical requirements for making buildings work and a better appreciation of how to collaborate with others to get the best results… (and) getting their head around the fact that it's a team process where they spark off each other and different practitioners working together are greater than the sum of their parts and real inspiration comes about through those collaborations*." (David Ritter)

Typical practice of architecture was noted as not always practical nor grounded enough, and sometimes bordering on too "artistic and indulgent". The integrated design outcomes in this studio were seen as environmentally and functionally responsible outcomes that went much further than aesthetics because of the collaboration with engineering disciplines. The product of that working relationship is increased practical understanding, which is key to better design and better architecture. These students have learned the invaluable lesson that, in a project of any reasonable complexity, early consultant involvement leads to better architectural outcomes.

> "*I think it's… imperative… a really important part of the learning process... It's more important than ever that we design better buildings, that are heat and thermally (focused) … We're facing a much more important challenge in our time, that we get these things right. It's part of a responsible education that we're making sure that our buildings are going to function better for us over time, particularly for energy and efficiency*." (Cath O'Shea)

> "*All of those things mentioned …, being time poor or fees or contractual limitations, all counteract the potential for architects and engineers to work well together in that way. But if they have experience of that, and they know that's the objective, that they are part of a bigger team, and they've got bigger goals, then that's how they will become successful practitioners. To rise above the rest, because clients and architects and engineers will say "that person is really great to work with. They really helped me problem-solve and we got a better outcome".*" (David Ritter)

4.3 Feedback from the participating students

There was slightly advanced level of environmental design experience among students who attended this class (median score 3.2). An equal number of respondents highlighted they either had regularly applied Environmental Design principles on previous projects, or simply had come across it in other classes.

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

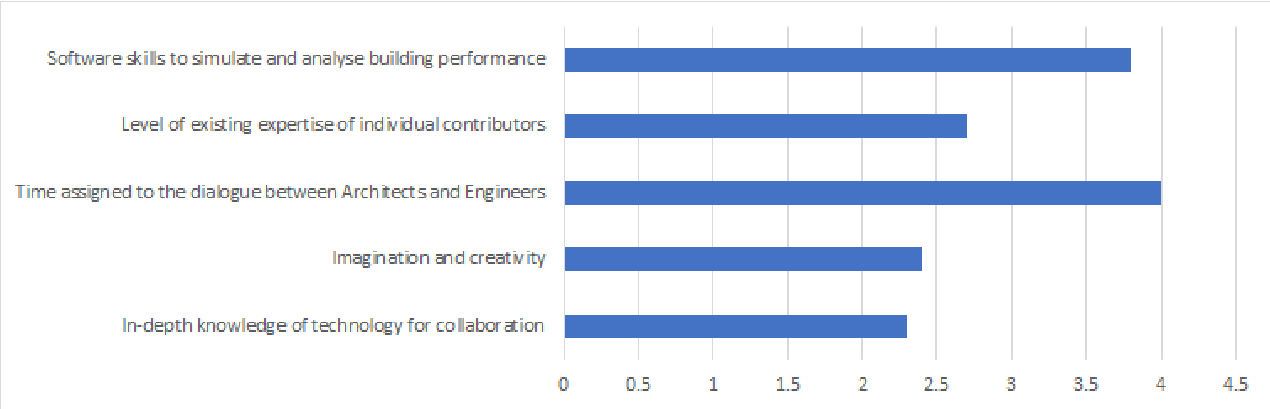

Figure 17: Key design-drivers affecting successful environmental design (with smaller numbers ranking higher)

With a median score of 4 (out of 5), the majority of participants felt that the client's brief supported them in achieving a balance between architectural and engineering design. Asked about the impact the brief had, and the way it was written/communicated, students appeared to have different views. Whereas practically all participating students appreciated its clarity and the freedom it would offer them in their design exploration, one student argued that: *the brief was clearly written and understood, but very restrictive.* Another student added: *There was some confusion in the class about how bold and/or risky our responses were encouraged to be, given we didn't have the scientific tools to test out truly revolutionary methods.* Others again, questioned the level of ambition associated with the size of the (single story) project as one student explains: *there are only so many passive designs that could be applied on the building of this scale.*

Prompted about the most critical decision-making points when balancing architect/engineer input for generating environmentally optimised design solutions, students listed: *maintaining the beauty of the architecture with the power of the engineering systems, achievability of the proposal / design decisions - gaining realistic feedback on whether it would actually work or not,* and how to: *...make it an interesting and radical project while balancing the interests of the client that is too practical.* Site specificity was one other aspect listed by respondents, with one student arguing: *It is critical to understand how appropriate an environmental design solution is compatible to the program on site.* Overall, architecture students seemed to struggle with the way engineering students approached design concepts. One student summed his/her experience up as follows: *To be honest, the engineering student I worked with has his own system that he wanted to explore, but is not to my interest or not relevant to my design my design concept.*

The inspiration for the design of an Ambulance Station differed from student to student. Some listed *precedents and, and conversations with the client,* others drew from *material research, suggestions from consultants,* as well as their *interviewing processes and live branch tours*. Others again named *biophilia,* and a *balance between all aspects of resilience, sustainability, human and non-human.*

According to the students, the engineers contribute to the authorship of design solutions primarily *by supplying background data and knowledge, via consultancy-type feedback,* and by *providing initial idea inspiration*.

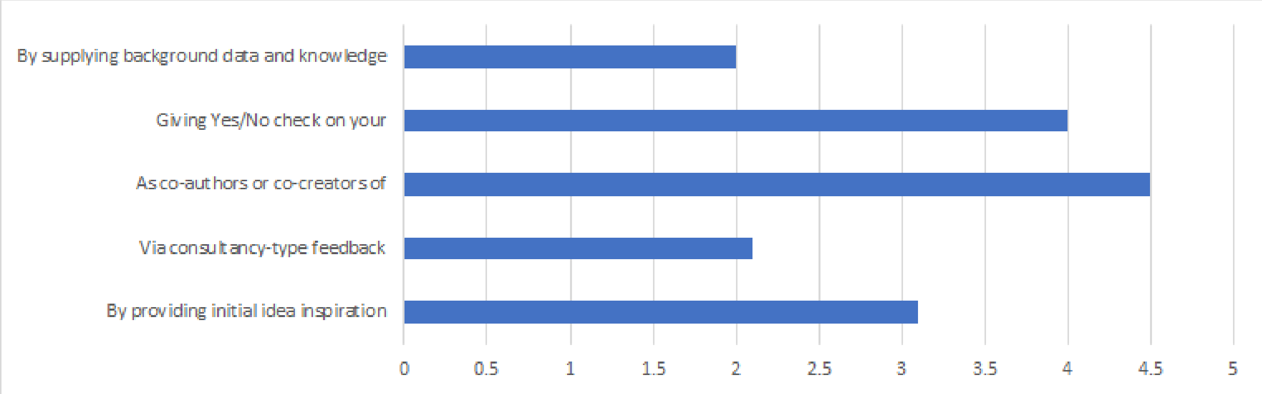

Figure 18: Reflection on input provided by the Engineering Consultants (with smaller numbers ranking higher)

Asked about the most useful guidance by the consultants, students referred to u*nderstanding how to integrate engineering systems seamlessly with the architecture,* as well as explaining *… basic principles of ventilation, temperature regulation and energy sources.* Consultants thereby assisted students to generate a *baseline-level of understanding*. As one student explains: *Speaking to the Atelier 10 team about their experiences with past projects and understanding how they make decisions was definitely eye-opening as it gave an insight about how they balance aesthetics and engineering.* Not all students saw the input from consultants in a solemnly positive way, and one respondent went as far as to state: *The consultants were great at teaching content and helping understand the base ideas, but I felt there was a lack of support in translating these ideas to my project.* This response illustrates that not all designers automatically realise the best way to maximise their design output in collaboration with other consultants. Being able to purposefully weave their input into one's own design process requires a learning process.

With a median score of 4.1 (out of 5), the majority of students argued that the input by consultants strongly increased their 'level of understanding of' environmental issues, with about one quarter still remaining sceptical.

Some students expressed their views that input from the consultants would have been more impactful if delivered face to face (not possible due to COVID-19), others suggested making their input more integral to the learning outcomes of the studio.

Critical voice commented that the engineers did not always provide them with a clear direction/response, with one student asking: *Make them less afraid to comment on our work and talk to us,* and another adding*: I felt consultants were nervous to give definitive answers because it was impossible to know with 100% certainty if innovative methods would work.*

For this iteration of the IDS, students clearly pointed towards the need for further fine-tuning the collaboration between architecture and engineering students. They rated the quality of collaboration 3.4 points out of 5 (with 1 being best and 5 being worst). Students alluded to the fact that engineering students were not attending classes frequently enough (particularly in the later stages of semester) and that the deliverables and assessment tasks differed among the two groups. As one architecture students sums up: *It would be helpful to further understand what objectives the engineering students had, ...that would have helped me to engage with them more.* Another architecture student added: *The engineering students also expressed resistance to making recommendations if they couldn't give us the information with complete certainty, which limited risk taking. None of us were sure how "risky" or bold our choices should be.*

In IDS-04, students did not feel that they had to compromise aesthetics and functional design aspects when balancing architectural and engineering concerns (median score 2.5 - with 2.5 meaning 'neither-nor'). One comment by a participating student sums it up as follows: *I do think we spent more time thinking about engineering than design at the beginning, but by the end of the semester I didn't feel that architectural qualities had been compromised at all.*

Despite the overall positive feedback about the IDS, students also reported a number of challenges when advancing their design-thinking with environmental/engineering constraints in mind. *'Time-constraints on projects'* ranked highest, followed by *'Knowledge gaps*' and '*Education in isolation'.*

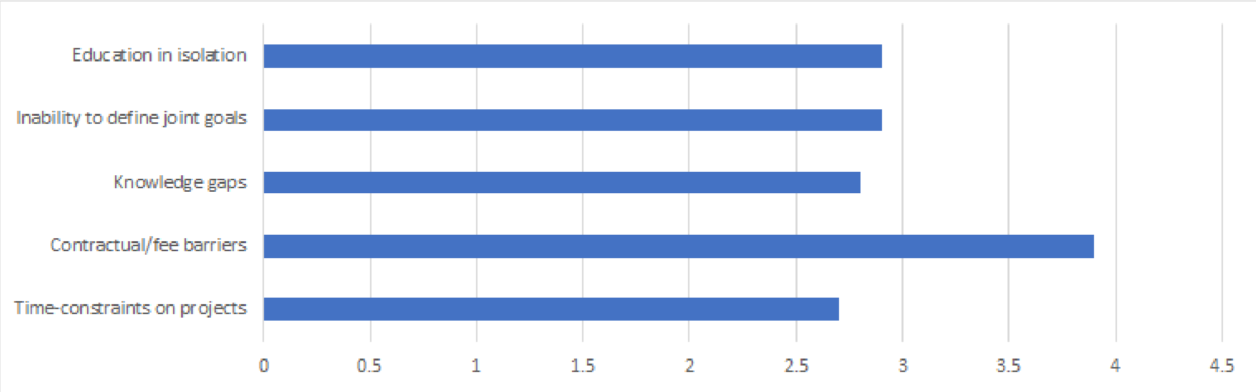

Figure 19: Challenges reported by the students (with smaller numbers ranking higher)

The additional struggles reported by the students can be summarised as follows: '*balancing aesthetics and building performance efficiency', 'design not being a big focus and becoming more of an afterthought determined by the performance decisions',* as well as '... *navigating a cost/benefit analysis, especially when specifying methods and materials.* One student adds: *It wasn't always clear how to make decisions, we were given a bunch of tools but after that I felt lost when different tools brought about conflicting potential directions for a project'.*

This valuable feedback points towards the struggle of students to interpret the results offered by the engineering analysis solutions, hand in hand with questioning their usefulness for decision support.

Asked about their definition of 'Integrated Design', students responded in many different ways: (responses include, but are not limited to)

- A seamless birthing of architecture and engineering
- The collaboration between architects and other professions starting as early in the design phase as possible to create a holistic design informed on architecture/aesthetics, function and performance, structure, sustainability.
- Integrated design occurs when architects, engineers, and others working on a project collaborate in early stages to avoid compromising design or environmental concerns at the expense of the other.
- Integrated design explores a holistic approach to architecture where all systems become part of the design process.
- It is design that combines facets of many fields as early as possible to facilitate efficient design processes

The question about the usefulness of learning about integrated design processes as part of their university education, elicited a positive response, with nearly half saying it was 'extremely useful' and the rest attesting it to be 'quite useful'. (median score: 4.4 out of 5).

5. STUDIO DESIGN OUTPUT - Select Examples

A select number of student projects (4) have been taken further by the Engineering Consultants (Atelier 10) in order to consolidate feedback and extract some key data. The following two sections summarise information contained in Atelier 10's consolidation/vetting document. The full 21-page document can be found as an appendix to this document.

The scope of the students' proposition has largely related to energy efficiency and carbon reduction, since the zero carbon target had been introduced to them as a key part of their brief that they had to investigate. It should be noted that all students have also taken on the challenge of designing for lower embodied carbon, and with consideration of circular economy principles.

5.1 Passive Measures

Students were encouraged to consider passive design measures as a key priority. A key aspect of the integrative design process that was presented to students was the use of energy and environmental performance modelling to inform design iteration.

It was expected that each student would carry out modelling analysis of their proposals using PHPP or e-Tool, or preferably both, gain feedback from the exercise and run further iterative design development and testing in order to refine their design concepts towards meeting the ambitious brief targets.

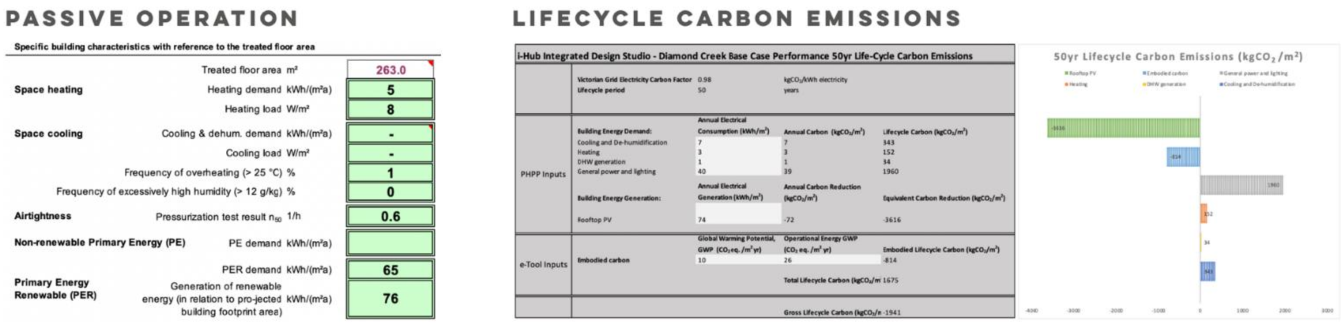

Figure 20: Robyn McKenzie – PPHP output and Lifecycle Carbon Emissions study

<u>The following initiatives were proposed (among others):</u>

- Passive solar orientation
- Stack / cross ventilation
- Introducing Green Roof strategies
- Passive House building fabric
- Maximising good daylight access
- Introducing double skin façade
- Introducing innovative thermal mass

5.2 Active Measures

The active measures proposed by the students ranged more widely. Although for many this studio was their first exposure to building services systems, they were inspired by a number of innovative ideas, complemented by widely accepted best practice initiatives.

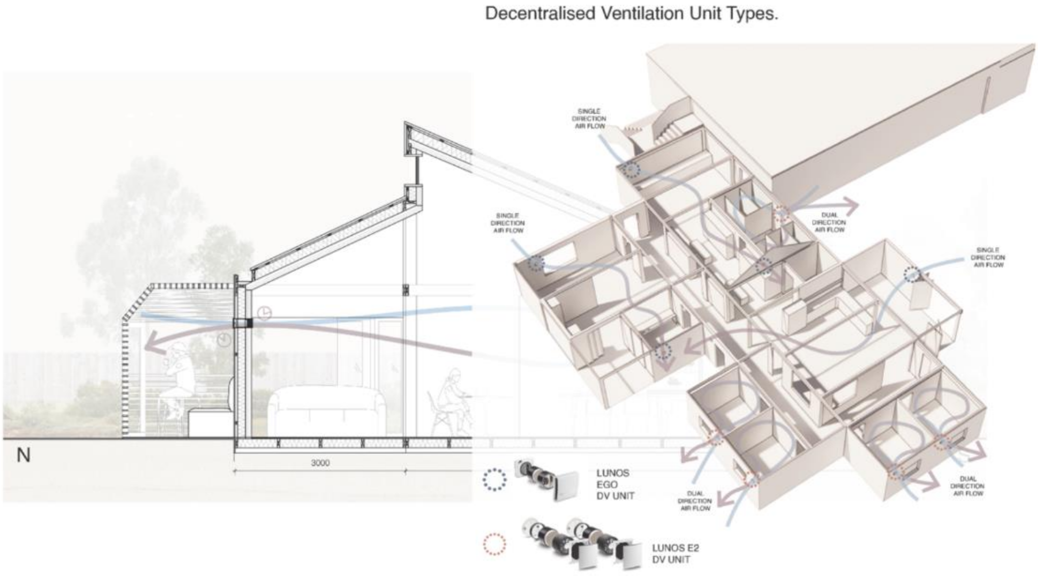

Figure 21: Kertina Liu – Mechanical Heat Recovery System

The following initiatives were proposed (among others):

- Photovoltaics (+batteries)
- Decentralised through-the-wall heat recovery systems
- Mechanical ventilation with heat recovery
- Displacement ventilation
- Ground source heat pumps
- BIPV (Building Integrated Photovoltaics)
- Underfloor heating
- Air-source heat pumps

6. SUMMARY OF CONSULTANT VETTING – Performance relative to BAU

6.1 Present: Existing Opportunities

Students were encouraged to consider the design outcomes to maximise the indoor environmental quality of the space. Best practice benchmarking can be considered to include elements such as:

- Provision of natural daylighting
- Elimination of direct glare and contrast glare especially off water surfaces
- Reduction in dark spaces throughout the building
- Best practice use of electric lighting to create both uniformity and interest in the lighting outcome
- Design to reduce noise and reverberation
- Design for adequate fresh air to eliminate odour

6.2 Future: New Build

Within this project the term net zero carbon is intended to focus on both operational carbon emissions and embodied carbon emissions within the construction, maintenance and demolition of the building works. through the course of the centre's lifetime. Hence from construction to operation, the overall emissions that are released must be reduced and offset by key reduction initiatives. This means students must consider low carbon alternatives such as timber construction and onsite solar PV.

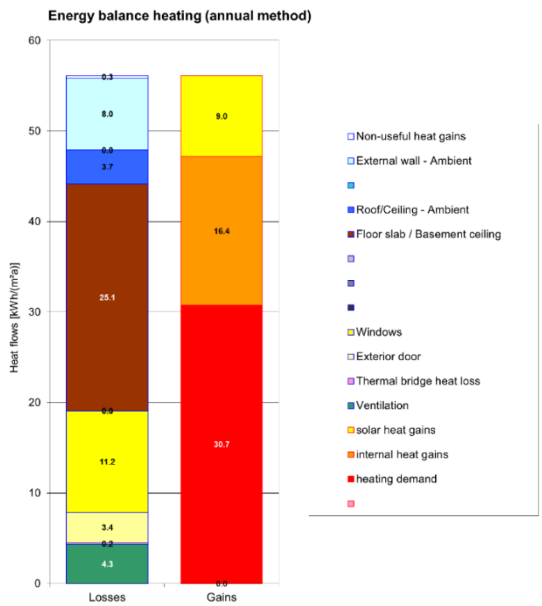

Figure 22: Jason Leung – Annual Heating Energy Balance

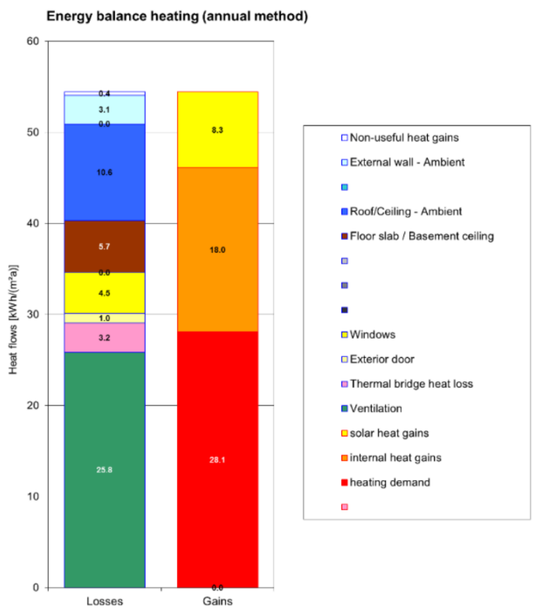

Figure 23: Rachel Huiyuan Koh – Annual Heating Energy Balance

6.3 Baseline vs Best Practice

In order to enable the benchmarking exercise Atelier Ten undertook modelling analysis to establish a base case for the business-as-usual approach. This was achieved by modelling a typical Ambulance Station based upon documentation provided by Ambulance Victoria for the recently built Diamond Creek Ambulance Branch.

A model of this business-as-usual base case was built using PHPP and eTool to calculate an accurate operational energy consumption and carbon emissions baseline as well as providing an appraisal of the 60-year life-cycle emissions taking into consideration the embodied carbon of the building.

The business-as-usual model was calibrated against actual monitored energy data from 16 Ambulance Stations provided by Ambulance Victoria. Annual energy performance varies from approximately 40 -120 kWh/m^{2}annum with an average of 75kWh/m^{2}annum. It can be seen that up to 50% energy saving compared to business-as-usual could be achieved through a cumulative combination of high-performance passive design measures, optimisation of HVAC systems, and consideration of on-going operational energy management.

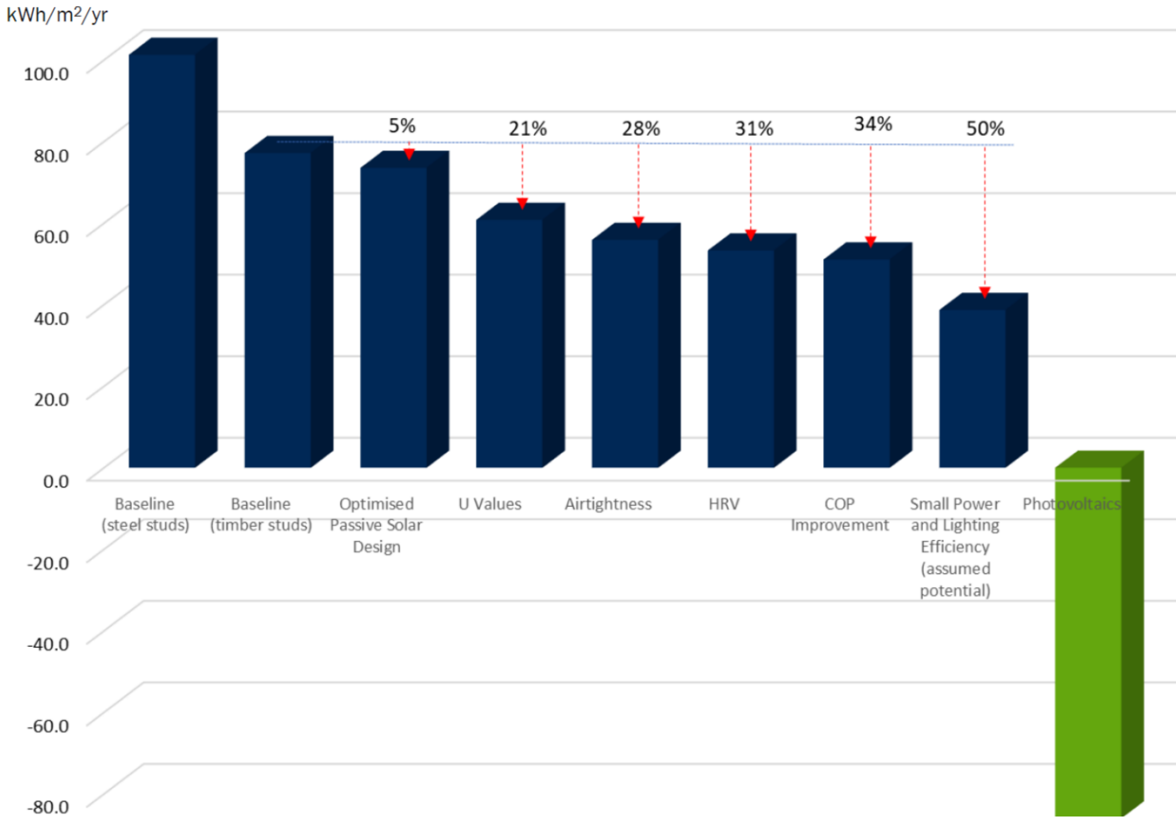

Figure 24: Benchmarking Student Proposals - Summary

6.4 Key findings

The results of vetting process demonstrate that the students have been successful in selecting solutions that are on a credible pathway toward net zero carbon performance as shown in the graph below of annual energy (electricity) consumption. It can be seen that up to 50% energy saving compared to business-as-usual could be achieved through a cumulative combination of high-performance passive design measures, optimisation of HVAC systems, and consideration of on-going operational energy management.

Across the student body of work, a number of strategies and technologies were consistent in recommendation. Their prevalence across a wide variety of different design proposals indicates their suitability and achievability within the scope of a typical Ambulance Station. Key systems which were common across the studio and which offered the greatest benefits include:

- Optimised Passive Solar principles for winter heating and summer control.
- High-performance building fabric through enhanced U-values of the building fabric
- Reduction in thermal bridging and airtightness construction quality Assurance
- Mechanical ventilation with heat recovery for energy saving benefit in addition to other indoor environmental quality and health benefits.
- Photovoltaic panels were consistently applied across projects for on-site renewable energy generation.
- Selection of materials which minimise the impact of embodied carbon across the development.

With such implementations, it was found that energy usage across the site could be reduced by up to 50% when compared against current business as usual statistics. Furthermore, when tied in with a photovoltaic system, the students have shown that energy production potential can entirely meet and exceed the demands on site. As such, the student body of work has shown that with current and existing technologies, a net-zero carbon approach is possible.

7. CONCLUSIONS

7.1 Conclusions and Next Steps

In all one dozen individual projects were developed to completion and explored a wide variety of technologies and innovations to achieve the net zero carbon goals of Ambulance Victoria. Approaches to each design were quite different but illuminating to observe that most proposals tried to push the boundaries whilst meeting the functional and operational needs of an ambulance branch that is essentially residential in scale. Each project was unique, yet some of the issues faced for design integration cut across all: questions of shared design authorship, the varying emphasis/benefits of the integrated effort across different ideation phases, the curation of an integrated workflow, and the definition of common goals.

As the semester progressed it became clearer how integrated design outcomes evolve from the multiple threads of a collaborative team working through a design process that ideally enables multiple, potentially competing, design considerations and components to be integrated to achieve high performance targets and innovative design outcomes. Unpacking these multiple threads has revealed key discussion points that will inform future IDSs.

Discussion points that appeared in the first half of semester included, but were not limited to, navigating the 'whole of project' context, the benefits of teamwork, common goals and the need for creative confidence when exploring novel technologies. Further discussion points, arising from observations through to end of semester, gave greater insight to the many ways that different approaches and inputs affected design outcomes. In particular, greater clarity is needed around the integrated design development process with more support indicated, to guide students and help them stay on the collaborative path.

Mid-semester presentations of IDS projects occurred in late September following which, project participants advanced their designs up until mid-November. During this time, the focus turned more closely to 'Net Zero' principles and their impact on design morphology/performance. The hands-on experience of testing the performance of their designs gave students a heightened awareness of the value in taking informed, collaborative steps, towards the common goal of 'Net Zero' carbon. It highlighted a key aspect of the studio experience that will inform future studios, and for future IDS students, the confidence generated will ideally translate into growing trust in a yet unfamiliar design development path towards integrated outcomes.

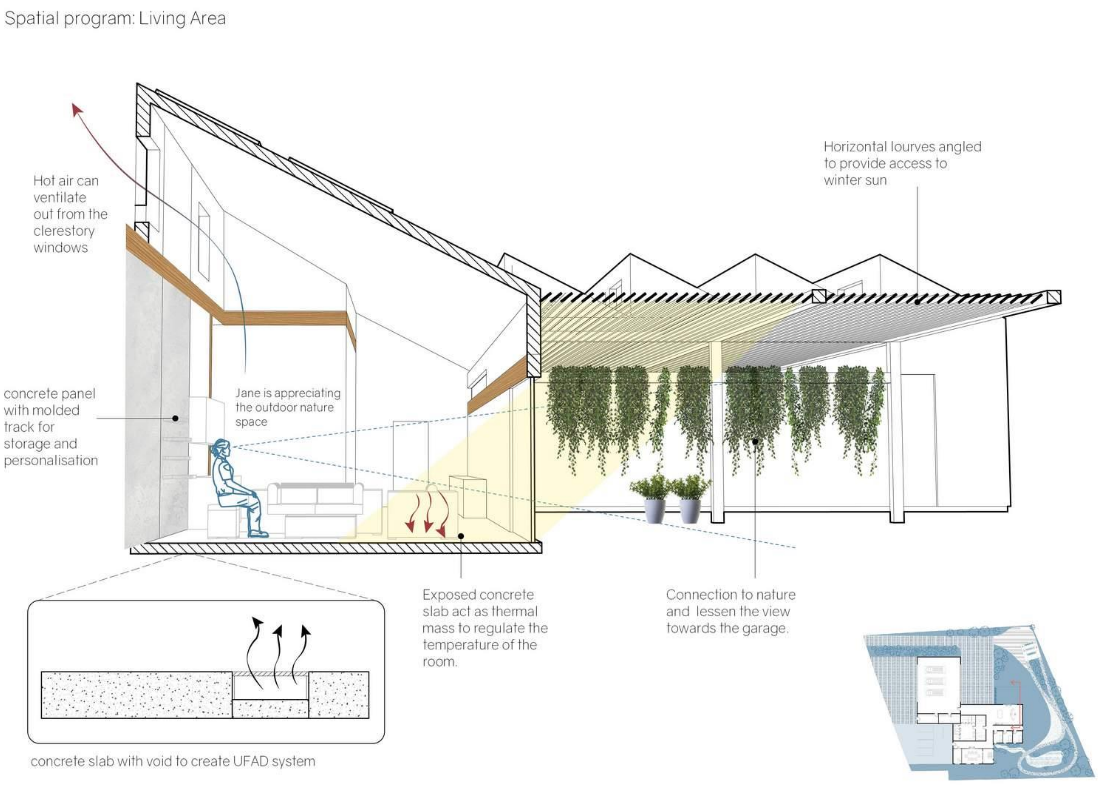

Figure 25: Mid-Semester Concept, exploring Spatial Program and Passive principles

After the final project submission/presentation, the industry consultants engaged in a vetting process to extract the essence of the most innovative concepts and added more articulation around those. In parallel, the UoM academics gathered feedback from all project participants about the effectiveness and quality of the integrated design process, to feed back this information into this 100% complete IDS-04 outcomes report.

APPENDIX A – Engineering Consultant Vetting Report

APPENDIX B – Student Work

Design Studio Outcomes

IDS-04

APPENDIX A

ENGINEERING CONSULTANT VETTING REPORT

i-Hub IDS Student Proposals Vetting Report

Ambulance Victoria Emergency Response Stations

Revision 02, 2021

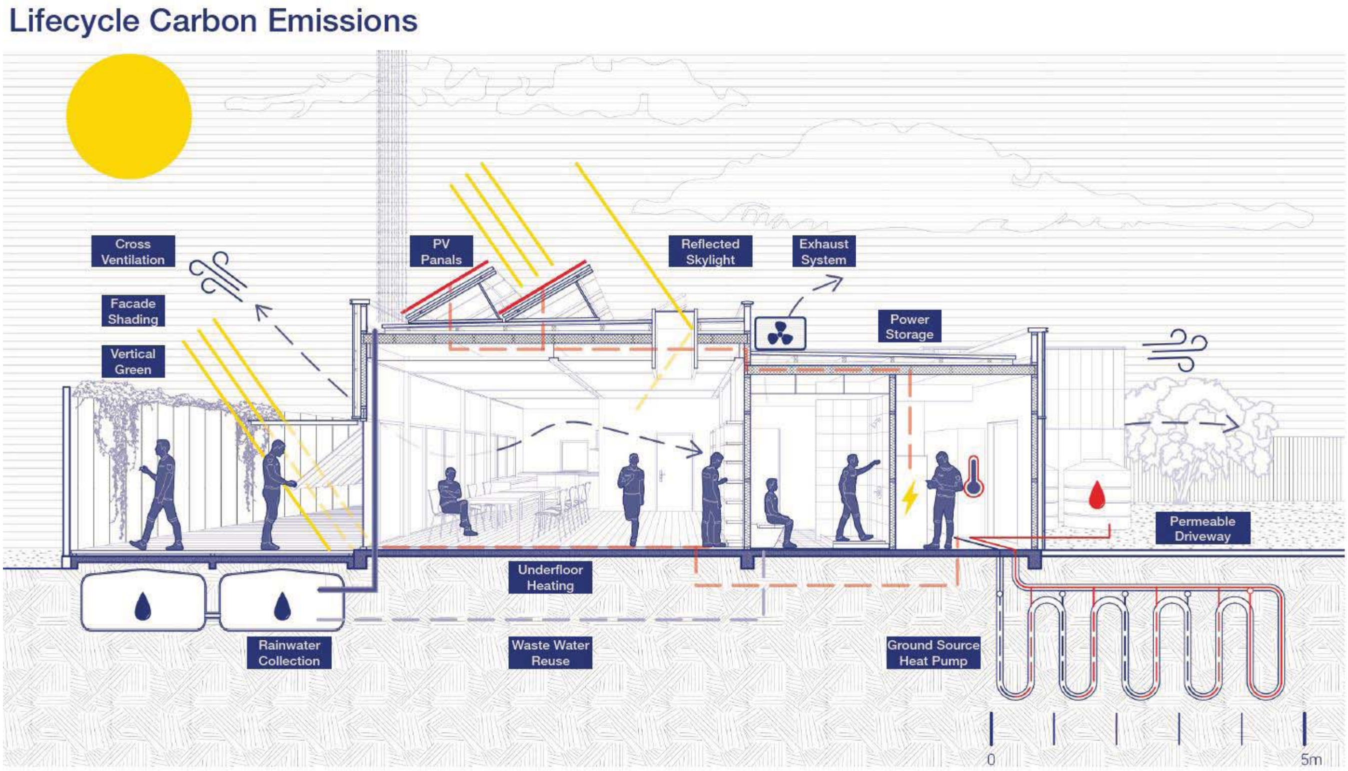

Image credit: Jason Leung

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Contents

Executive summary

The student design work has been successful in demonstrating that the pathway towards a net zero carbon ambulance station performance can be achieved using high-performance passive design, energy efficient systems and on-site photovoltaic energy generation.
The solutions presented by the student group are all readily available, known technologies that are relatively simple-to-construct which offer enhanced whole life cost performance over the life cycle of the project

Readily Achievable Solutions

The body of student work has demonstrated that a set of sustainability measures can be applied to achieve a cumulative energy saving of up to 50% compared to business as usual and that there is 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 technologies and systems proposed are all tried and tested solutions here in Australia and can be readily adopted for 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
- Reduction in thermal bridging and airtightness construction quality Assurance
- Mechanical ventilation with heat recovery for energy saving benefit in addition to other indoor environmental quality and health benefits
- Photovoltaic panels were consistently applied across projects for on-site renewable energy generation.

Enhanced Life-Cycle Benefits

All of the above technologies have a beneficial economic payback over the life of the asset due to the energy and running cost savings making a sound business case for their implementation.

Enhanced Health Outcomes

The above solutions also offer health and wellness benefits that are a significant value-add to end-users of the ambulance station. Good daylight, access to sunlight, thermal comfort and well-designed ventilation systems are key indoor environmental amenity outcomes that benefit the core health service provision through staff well-being and reduced sickness rates. Whilst natural ventilation is applicable for a large part of the year on most sites, the use of heat recovery ventilation in winter is of particular note as a means of achieving healthy internal air quality and minimising energy use.

1 Project Overview and Introduction

Ambulance Victoria's challenge to the IDS-04 students was to consider holistic sustainability principles: that being socially and environmentally responsible with the design, construction and operation of its Emergency Response Stations should align with enhanced delivery of Best Care. The key design challenge within this was to meet the objective of achieving a net zero carbon emissions facility in line with international Paris Agreement targets.

1.1 Project Overview

1.1.1 Emergency Response Station Brief

The students were provided with a comprehensive briefing pack by Ambulance Victoria (AV) including the following information:

- Ambulance Victoria Design Specification Sept 2019
- Presentation and slides by Ed Ewers Architecture on the key functional design requirements for AV Emergency Response Stations
- Typical tender package design documentation provided from a recent Emergency Response Station project at Diamond Creek, Victoria, 3809.

The students were also provided with site context information for the studio design project. A vacant plot, located at 69 Matterhorn Drive, Clyde North, the site is in a new housing growth area with the proposed new Emergency Response Station to act as a hub to this burgeoning community. Being a greenfield growth area, it is not subject to many constraints that would be expected for a more established urban setting, having good solar and daylight access from all sides with a neighbouring parkland and projected low-level housing development in the future.

1.2 Studio Introduction

1.2.1 Sustainable Design Brief

The sustainable design brief set for the students of this studio was to re-imagine a typical Ambulance Victoria Emergency Response Station with consideration of a broader set of briefing objectives:

- Consideration of AV's ambitious Environmentally Sustainability Design (ESD) policies including net zero carbon by 2050 target
- Passive Design
- Sustainable Materials and Waste Management
- Fleet and equipment management
- User comfort and workplace well-being
- Auditing: Establishing a benchmark to determine capital cost adjustments and life-cycle savings (payback)
- Operations: Adaptations to reduced energy consumption
- Opportunities: Community engagement, staff well-being, demonstration, and leadership in sustainability
- Determining an achievable emissions reduction target.

The 'real-world' challenges for the delivery of step-change innovation in line with the above ambition were principally determined to be the following factors that students were asked to consider in their research and design proposition:

- Cost
- Operational step-change and end-user buy-in
- Leadership
- Vigilance and accountability

1.2.2 Integrative Design Tools

As an experimental approach to this studio's teaching and learning experience, Atelier Ten decided to introduce 2no. performance analysis tools intended to enable the students to test their design proposals against net zero carbon objectives. The tools that were selected were:

- The Passive House Planning Package (PHPP). An excel spreadsheet energy model containing architectural building fabric and engineering systems intended for assessment of building design and construction energy performance in pursuit of the German Passivhaus standard.
- eToolLCD - Whole Building Life Cycle Assessment Software. This tool enabled the students access to a database of detailed embodied energy and carbon data for a wide range of common building materials and constructions, with an additional function for simplistic building operational carbon estimation.

Both tools were selected for their ease of access, and transparency in presenting the whole range of inputs and design variables that must be considered when undertaking a holistic energy and carbon performance assessment of any given design.

The PHPP tool was deemed particularly appropriate to the Emergency Response Station project because of the similarity of the building program and engineering systems to those of a residential building upon which the Passive House model was originally developed.

The students were given a basic introduction and 3no. tutorial sessions covering the use of the tools with the expectation that they would use self-learning to develop their skills and understanding further.

It was hoped that by giving the students to test their own architectural and engineering proposals it might provide a framework for learning through direct application, encourage collaboration between engineering and architectural students and encourage inter-disciplinary, integrative design thinking.

2 Studio Summary

2.1 Atelier Ten Input

1.1.1 Environmental Design and Engineering Systems Analysis Overlay

In addition to the architectural teaching program and engineering assignments that the students had been tasked with as part of their course, Atelier Ten provided an overlay of environmental design lectures and a series of tutorials to enable the students to carry out their own energy and carbon performance analyses to test their design proposals against the ambitious zero carbon brief set for the project. The structure of this overlay was generally set out to support the fast-track design process within the 12-week design term as they quickly move in their thinking from masterplan to built form as follows:

- Introduction to the ambitious performance targets, precedents, and pathways to achieving them.
- Design exploration and testing of masterplan (form and massing) concept ideas against environmental engineering performance requirements
- Introduction to detailed operational energy and embodied carbon analysis tools to allow refinement within the proposed built form.
- Tutoring and support to allow the students to freely produce their own outcomes using the learnt tools and techniques.

2.2 Submission Expectations

2.2.1 Expectations for Design Testing using Modelling Tools

A key aspect of the integrative design process that was presented to students was the use of energy and environmental performance modelling to inform design iteration. This is counter to the prevailing culture in industry where modelling and analysis tools tend to be primarily used for compliance checking after design has evolved.

It was expected that each student would carry out modelling analysis of their proposals using PHPP or e-Tool, or preferably both, gain feedback from the exercise and run further iterative design development and testing in order to refine their design concepts towards meeting the ambitious brief targets.

2.2.2 Expectations for Final Submission

For the final submission, the students were provided with an A3 single page template for completion with the following contents:

- A short text description of the sustainability strategy for their project
- A sustainability strategy diagram (either a section or axonometric drawing) which explains the proposals
- A summary of the operational energy performance of their project taken from PHPP
- A summary of the 50-year life-cycle carbon emissions calculated using e-Tool software

The format of the submission was kept deliberately succinct in order not to overburden the students with additional reporting requirements but provide a framework that challenged them to demonstrate integrated design working methods and successful refinement.

2.3 Working Methods

2.3.1 Encouragement for engineers and architecture students to collaborate

The studio was split into four groups, each allocated one engineering student. These groups worked collaboratively through the site analysis phase of the project and generally continued to collaborate as the studio program moved into individual project proposition.

At all stages of the process the architecture and engineering students were encouraged to collaborate. They were not necessarily encouraged to play the role of 'architect' and 'consultant' but rather work together as equals, exploring aspects of the design process that were of interest to them, rather than to be confined by preconceived roles. The key opportunities in this collaboration process were:

- Site analysis: with engineering students naturally supporting a summary of technical constraints and opportunities and architects contributing their understanding of urban planning and other softer constraints such as history, culture etc. An area of good crossover in their skillsets naturally seemed to be in the area of environmental design and sustainability.
- The process of modelling and testing design proposition to allow optimisation of form; the use of the PHPP tool provided an excellent framework for accessing this process for all students since it requires simple building geometry inputs as well as technical inputs related to engineering systems. It afforded all students the opportunity to be playing the role of both architect and engineer, whilst also encouraging them to have dialogue and assist each other with the data inputs.
- All students including the engineering students were encouraged to propose an architectural design concept and test its performance using the tools available or any other environmental design or energy modelling software that they were familiar with.

2.4 Programme

2.4.1 Atelier Ten teaching overlay

The following teaching overlay was added to the studio by Atelier Ten, with the intention of introducing some key concepts during the early part of the term and spending some time with the students in tutorial sessions to cover the key aspects of passive design integration.

Following the student presentation of their design concepts at mid-semester we focused on providing some tutorials to enable the students to run PHPP and eTool modelling of their projects, with the final part of the term devoted to students having tutorial time where they could discuss their design iteration and emerging outputs.

Table 2.1: Teaching Schedule

WEEK	Atelier Ten Teaching Activity
WEEK 1	N/A
WEEK 2	Introduction to Integrated Design Presentation + Individual Environmental Design Tutorials
WEEK 3	Climate Responsive Design Presentation + Individual Environmental Design Tutorials
WEEK 4	Introduction to Zero Carbon brief + Individual Environmental Design Tutorials
WEEK 5	Introduction to Principles of High Performance Facades - Passive House + Individual Environmental Design Tutorials
NON-TEACHING WEEK	
WEEK 6	MID-SEMESTER REVIEWS
WEEK 7	PHPP Tutorial 1
WEEK 8	PHPP Tutorial 2
WEEK 9	eTool Tutorial
WEEK 10	Individual Environmental Design Tutorials
WEEK 11	Individual Environmental Design Tutorials
WEEK 12	Individual Environmental Design Tutorials
WEEK 13	FINAL REVIEWS

2.5 Student Outputs

2.5.1 Engagement with the Ambitious Brief

The outputs from the architecture students only have been submitted for Atelier Ten review and vetting. These have been reviewed and summarised in the following pages.

In general, it can be reported that all students enthusiastically engaged with the zero carbon brief that was set for their design research and proposition. All of the architecture students engaged in dialogue and collaboration with their engineering colleagues and it was generally felt that the introduction of analysis tools that they could both access and utilise provided them with a common framework to discuss the design challenge set before them.

2.5.2 Uptake of Analysis Tools

The student outputs from the architecture students only have been submitted for Atelier Ten review and vetting. These have been reviewed and summarised in the following pages.

- All of the eleven architecture students were successful in submitting a PHPP excel model of their project demonstrating that they had engaged with the engineering and building physics concepts underpinning their design concepts to varying levels of accuracy and success.
- All of the eleven architecture students (bar one) were successful in providing an A3 submission summarising their projects sustainability strategy including calculation of operational and embodied carbon emissions.
- Four of the architecture students submitted an e-Tool model with a 50-year life-cycle carbon performance assessment of their project. Success in the submission of these models may however have been hampered by some challenges in using the tool's web interface for exporting a model for review

2.6 Student Outputs Summary

2.6.1 Scope of Student Proposition

The scope of the students' proposition has largely related to energy efficiency and carbon reduction, since the zero carbon target had been introduced to them as a key part of their brief that they had to investigate. It should be noted that all students have also taken on the challenge of designing for lower embodied carbon, and with consideration of circular economy principles. A number of students were also interested in water sensitive urban design, water efficiency, urban food production, and health and wellness considerations as part of their sustainability strategy. The following table 2.1 summarises their work, including their success in using the modelling tools and presenting a project with realistic net zero carbon potential.

2.6.2 Scope of Vetting Exercise

For the purposes of this report we have focused our vetting review of student proposals on the embodied carbon, energy efficiency and carbon reduction strategies as these are the aspects where the students have gone into some depth within their work and have utilised the modelling tools PHPP and eTool, to better enable a review and testing of their proposition.

Key: Achieved ✓ Insufficient Resolution ? Not submitted –

Table 2.1 Summary of Student Outputs

Student #	Low Carbon Construction Measures	Passive Design Measures	Energy Efficiency and Renewable Energy Technologies	Other Sustainability Initiatives	PHPP model	e-Tool model	Net Zero Carbon Potential
699090	• Timber structure • 100% timber cladding and interiors • Rammed earth walls	• Passive solar orientation • Stack / cross ventilation	• Photovoltaics • BIPV • Ground source heat pump • Underfloor heating	• Food growing	Achieved	Not submitted	Insufficient Resolution
756583	• Durra (straw) wall panels • Rammed earth walls	• Passive solar orientation • Stack / cross ventilation • Green roof • Passive House building fabric • Good daylight	• Air-source heat pump • Photovoltaics	• Rainwater harvesting • Indigenous species green roof • Food growing	Achieved	Not submitted	Achieved
779237	• Timber structure • Recycled brick	• Stack / cross ventilation • Good daylight	• Photovoltaics	• Food growing	Achieved	Not submitted	Insufficient Resolution
794491	• Timber structure; SIPS, prefab timber frame, LVL structure • Recycled cork insulation	• Passive solar orientation • Stack / cross ventilation • Passive House building fabric • Good daylight • Double skin facade	• Ground source heat pump • PV + batteries	• Rainwater harvesting • Waste water recycling	Achieved	Not submitted	Achieved
799168	• Timber structure • Durra (straw) wall panels • Prefab concrete panels with SCMs	• Passive solar orientation • Stack / cross ventilation • Good daylight	• Mechanical ventilation with heat recovery • Displacement ventilation • Photovoltaics	• Design for Disassembly	Achieved	Not submitted	Achieved
914559	• Timber construction	• Passive solar orientation • Stack / cross ventilation • Passive House building fabric • Good daylight	• Mechanical ventilation with heat recovery • Photovoltaics	• Health and hygiene strategy	Achieved	Not submitted	Achieved

Table 2.2 cont……Summary of Student Outputs

Student #	Low Carbon Construction Measures	Passive Design Measures	Energy Efficiency and Renewable Energy Technologies	Other Sustainability Initiatives	PHPP model	e-Tool model	Net Zero Carbon Potential
1061797	• Prefabricated timber structure	• Passive solar orientation • Stack / cross ventilation • Passive House building fabric • Good daylight	• Photovoltaics	• Biophilic design principles	✓	✓	✓
1062080	• ETFE cushion glazed areas • Timber construction	• Passive solar orientation • Stack / cross ventilation • Passive House building fabric • Good daylight • Innovative thermal mass	• Photovoltaics	• Growing food	✓	✓	✓
1069532	• Modular timber construction	• Stack / cross ventilation •	• Photovoltaics • BIPV	• Rainwater harvesting • Grey water treatment and irrigation	✓	✓	✓
1069729	• Timber structure • CLT wall panels	• Passive solar orientation • Stack / cross ventilation • Passive House building fabric • Good daylight	• Photovoltaics • Decentralised through-the-wall heat recovery system	• Rainwater harvesting	✓	✓	✓
1154520	• Modular panelised timber system • CLT wall panels	• Passive solar orientation • Stack / cross ventilation • Green roof	• Photovoltaics • BIPV	• Rainwater treatment and harvesting • Green roof • Growing food	✓	–	✓

3 Exemplar Project Feasibility

3.1 Introduction

3.1.1 Selection of Student Projects for Further Analysis

A range of the best student projects has been selected for further vetting analysis of their proposals and the validity of their technical analysis and application. The vetting analysis covers the application of the following systems and is primarily related to the energy and carbon performance of the projects:

- Passive operation measures (e.g. design of natural ventilation or building fabric improvement)
- Active systems proposals including building services systems
- On-site renewable energy generation systems

These projects have been selected for the quality of their engineering design integration and the range of systems and technologies that are representative of the group as a whole.

It is clearly evident that there are common systems and technological approaches that have been applied across the body of student work that merit further investigation and these can be summarised as follows:

- Use of timber construction systems as a means of meeting embodied carbon reduction goals
- Passive principles for solar heating and summer control, natural ventilation and daylight are readily incorporated into this building typology, so what are the common rules that can be applied on any given site?
- High-performance Passive House principles and Construction Quality Assurance are proposed to meet ambitious operational carbon reduction targets.
- Innovative heat pump solutions are explored for enhanced energy performance - are they worth pursuing?
- Mechanical ventilation with heat recovery is proposed for energy saving benefit in addition to other indoor environmental quality and health benefits
- Photovoltaic panels were consistently applied across projects for on-site renewable energy generation. Some students also investigated Building Integrated Photovoltaic opportunities (BIPV)

Table 3.1 Exemplar Student Proposal Measures

Student #	Low Carbon Construction Measures	Key Passive Measures	Key Systems Measures	Renewable Energy Systems Measures
794491	• Timber structure; SIPS, prefab timber frame, LVL structure • Recycled cork insulation	• Passive solar orientation • Stack / cross ventilation • Passive House building fabric • Good daylight • Double skin façade	• Ground source heat pump	• PV + batteries
799168	• Timber structure • Durra (straw) wall panels • Prefab concrete panels with SCMs	• Passive solar orientation • Stack / cross ventilation • Good daylight	• Mechanical ventilation with heat recovery • Displacement ventilation	• Photovoltaics
914559	• Timber construction	• Passive solar orientation • Stack / cross ventilation • Passive House building fabric • Good daylight	• Mechanical ventilation with heat recovery	• Photovoltaics
1069729	• Timber structure • CLT wall panels	• Passive solar orientation • Stack / cross ventilation • Passive House building fabric • Good daylight	• Decentralised through-the-wall heat recovery system	• Photovoltaics

3.2 Exemplar Project 794491

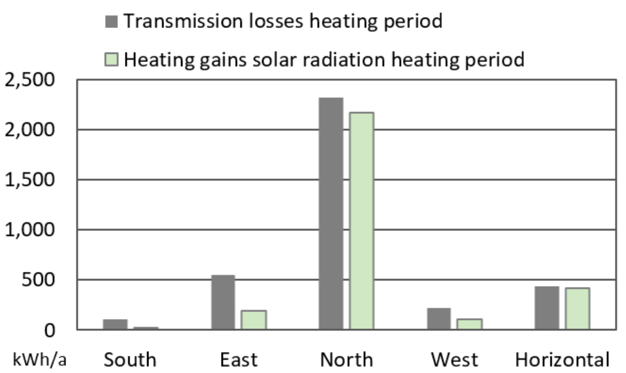
3.2.1 Passive Design Features:

Table 3.2 Building Information: Project 794491

Passive Design Criteria:	
Basic Building Parameters:	
Treated Floor Area (m²):	326
External Envelope Area (m²):	924
Form Factor (envelope area : treated floor area ratio)	2.83
Window : External Wall Ratio	11%
Building Fabric U-Values (W/m²K):	
Ground Floor	3.5
Walls	0.33
Windows (dbl glazed, Alu frame, non-thermally broken)	3.7
Roof	0.11
Natural Ventilation and Daylight:	
Typical Room Depth : Height Ratio	1.7 - 2.0
Openable Window Area (m²):	19.2

3.2.2 Passive Solar Performance

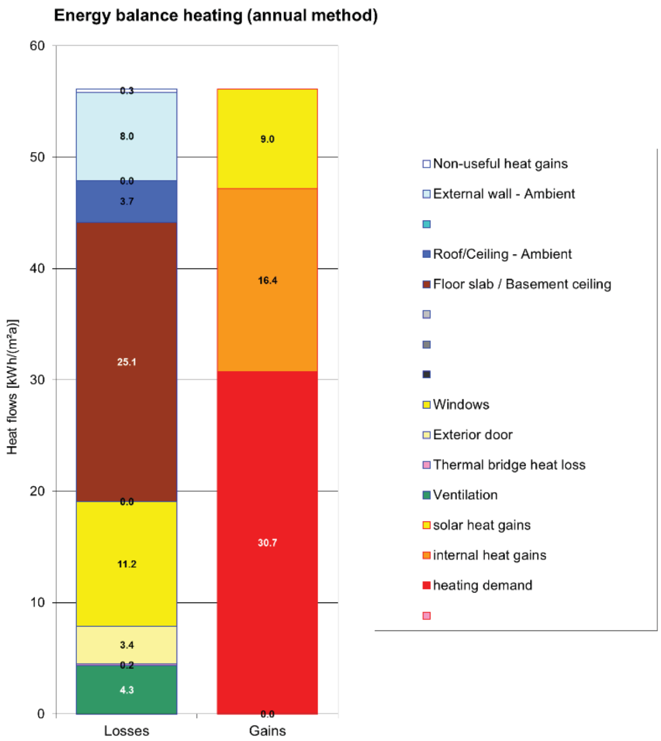
An ideal passive solar configuration should result in a net heat gain through the windows during the heating season. According to the PHPP analysis carried out by this particular student the proposals result in a net -725kWh/annum (i.e. net heat loss) during the heating season.



Although the student has strategically oriented the building for highest northern aspect exposure, this is due to the relatively high U-value and associated heat loss of the double-glazed window system with non-thermally broken frames selected for this project

3.2.3 Annual Heating Energy Balance

The annual heating energy balance for this project was submitted as being able to achieve the Passive House certification standard, however on review it was noted that the student did not account for the heat losses through the ground floor slab which we have subsequently added into the model.



3.2.4 Building Energy Performance Results

The following building performance summary data has been taken from the student's PHPP model for their project:

Table 3.3 PHPP Outputs: Project 794491

Summary Results from PHPP Model	
Basic Building Parameters:	
Annual Heating Thermal Demand (kWh/m²yr):	37.9
Annual Cooling Thermal Demand (kWh/m2yr):	1.7
% hrs Overheating Without Cooling	0.1
Energy Demand Breakdown (electricity) kWh/m²yr:	
Heating:	12.9
Cooling:	0.6
Domestic Hot Water:	2.4
Lighting & Power	32.6
Aux. (fans, pumps etc)	4.2
Renewable Energy Contribution kWh/m²yr:	
Photovoltaics (electricity):	20.5
Solar thermal (thermal energy):	3.8

3.3 Exemplar Project 799168

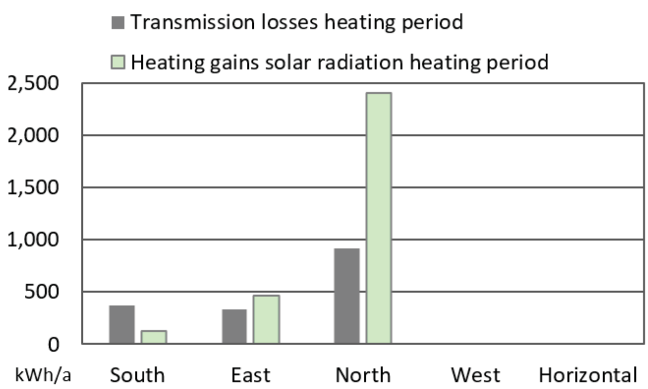
3.3.1 Passive Design Features:

Table 3.4 Building Information: Project 799168

Passive Design Criteria:	
Basic Building Parameters:	
Treated Floor Area (m²):	359
External Envelope Area (m²):	869
Form Factor (envelope area : treated floor area ratio)	2.42
Window : External Wall Ratio	19%
Building Fabric U-Values (W/m²K):	
Ground Floor	0.85
Walls	0.21
Windows (dbl glazed, low-E, argon fill, thermally broken frames)	1.3
Roof	0.33
Natural Ventilation and Daylight:	
Typical Room Depth : Height Ratio	1.5 – 1.7
Openable Window Area (m²):	14.9

3.3.2 Passive Solar Performance

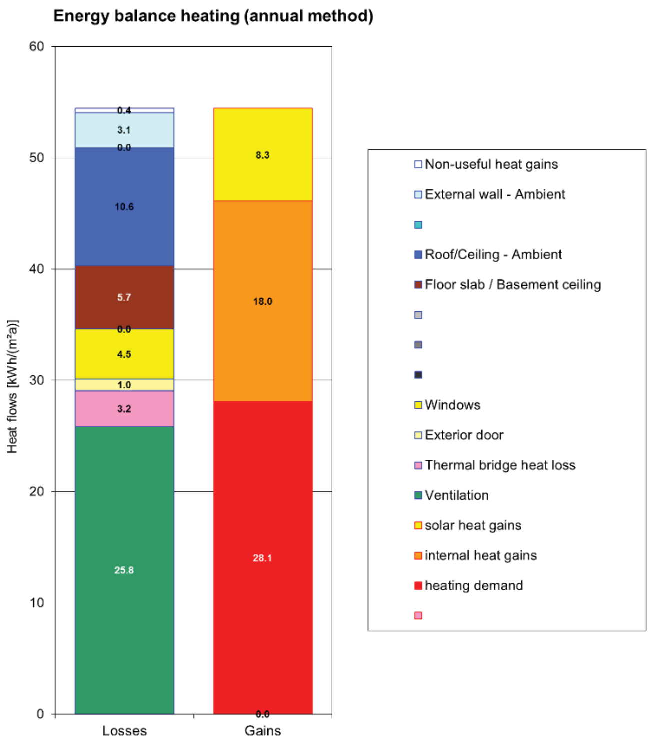
An ideal passive solar configuration should result in a net heat gain through the windows during the heating season. According to the PHPP analysis carried out by this particular student the proposals result in a net 1373 kWh/annum heat gain during the heating season.



The student has oriented the building for highest northern aspect to achieve a successful (net positive) passive solar heating strategy.

3.3.3 Annual Heating Energy Balance

The annual heating energy balance for this project demonstrates a reasonably low energy demand and is close to meeting the Passive House Low-Energy Building threshold for <30kWh/m²yr.



3.3.4 Building Energy Performance Results

The following building performance summary data has been taken from the student's PHPP model for their project:

Table 3.5 PHPP Outputs: Project 799168

Summary Results from PHPP Model	
Basic Building Parameters:	
Annual Heating Thermal Demand (kWh/m²yr):	31.9
Annual Cooling Thermal Demand (kWh/m2yr):	4.4
% hrs Overheating Without Cooling	2
Energy Demand Breakdown (electricity) kWh/m²yr:	
Heating:	10.8
Cooling:	1.5
Domestic Hot Water:	0.6
Lighting & Power	29.6
Aux. (fans, pumps etc)	2.7
Renewable Energy Contribution kWh/m²yr:	
Photovoltaics (electricity):	108.7
Solar thermal (thermal energy):	5.7

3.4 Exemplar Project 914559

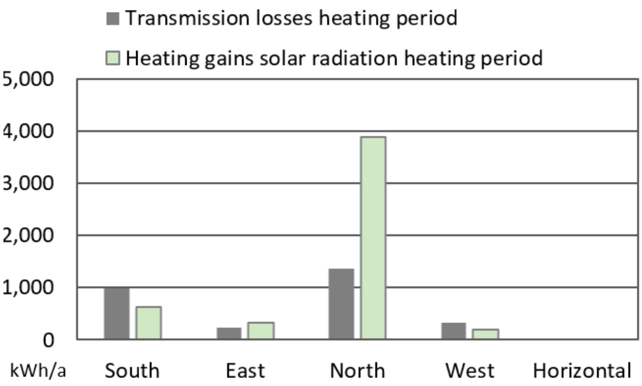
3.4.1 Passive Design Features:

Table 3.6 Building Information: Project 914559

Passive Design Criteria:	
Basic Building Parameters:	
Treated Floor Area (m²):	263
External Envelope Area (m²):	924
Form Factor (envelope area : treated floor area ratio)	3.51
Window : External Wall Ratio	23%
Building Fabric U-Values (W/m²K):	
Ground Floor	0.28
Walls	0.32
Windows (dbl glazed, low-E, argon fill, thermally broken frames)	1.3
Roof	0.27
Natural Ventilation and Daylight:	
Typical Room Depth : Height Ratio	1.5 - 2.4
Openable Window Area (m²):	69.7

3.4.2 Passive Solar Performance

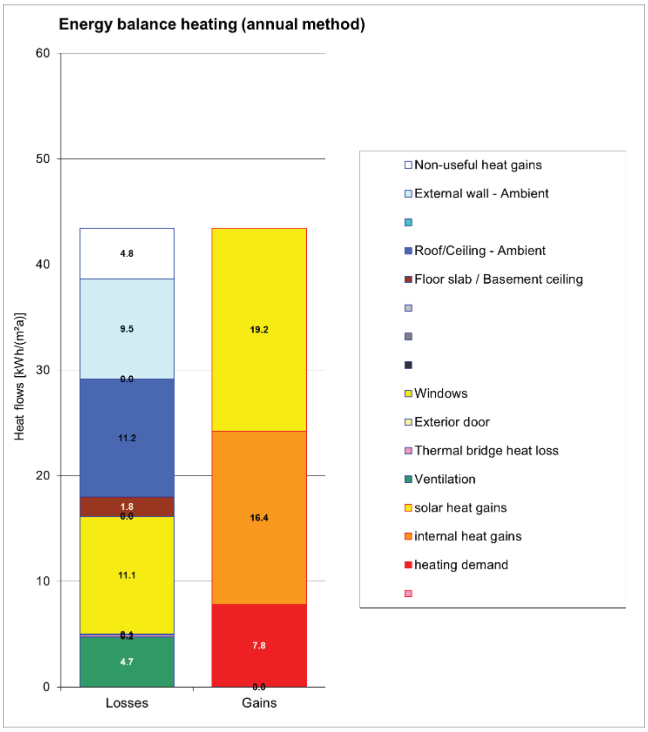
An ideal passive solar configuration should result in a net heat gain through the windows during the heating season. According to the PHPP analysis carried out by this particular student the proposals result in a net 2122 kWh/annum heat gain during the heating season.



The student has oriented the building for highest northern aspect to achieve a successful (net positive) passive solar heating strategy.

3.4.3 Annual Heating Energy Balance

The annual heating energy balance for this project was submitted as being able to achieve the Passive House certification standard, with a heating energy balance breakdown as follows:



3.4.4 Building Energy Performance Results

The following building performance summary data has been taken from the student's PHPP model for their project:

Table 3.7 PHPP Outputs: Project 914559

Summary Results from PHPP Model	
Basic Building Parameters:	
Annual Heating Thermal Demand (kWh/m²yr):	4
Annual Cooling Thermal Demand (kWh/m2yr):	3
% hrs Overheating Without Cooling	2
Energy Demand Breakdown (electricity) kWh/m²yr:	
Heating:	3.6
Cooling:	6.9
Domestic Hot Water:	1
Lighting & Power	40.4
Aux. (fans, pumps etc)	3.5
Renewable Energy Contribution kWh/m²yr:	
Photovoltaics (electricity):	73.8
Solar thermal (thermal energy):	6.6

3.5 Exemplar Project 1069729

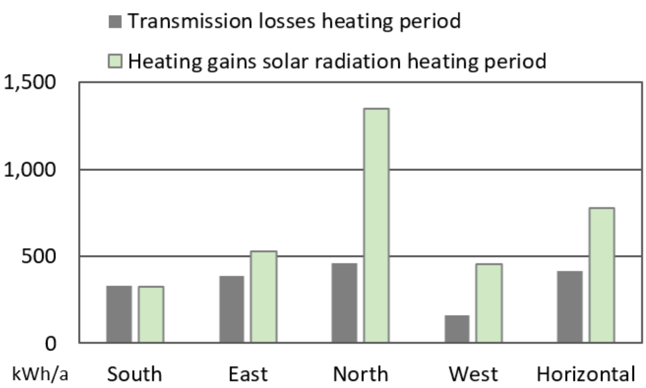
3.5.1 Passive Design Features:

Table 3.8 Building Information: Project 1069729

Passive Design Criteria:	
Basic Building Parameters:	
Treated Floor Area (m²):	280
External Envelope Area (m²):	1083
Form Factor (envelope area : treated floor area ratio)	3.86
Window : External Wall Ratio	12.6%
Building Fabric U-Values (W/m²K):	
Ground Floor	0.22
Walls	0.21
Windows (triple glazed, low-E, argon fill, thermally broken frames)	0.9
Roof	0.21
Natural Ventilation and Daylight:	
Typical Room Depth : Height Ratio	1.0 – 1.5
Openable Window Area (m²):	19.2

3.5.2 Passive Solar Performance

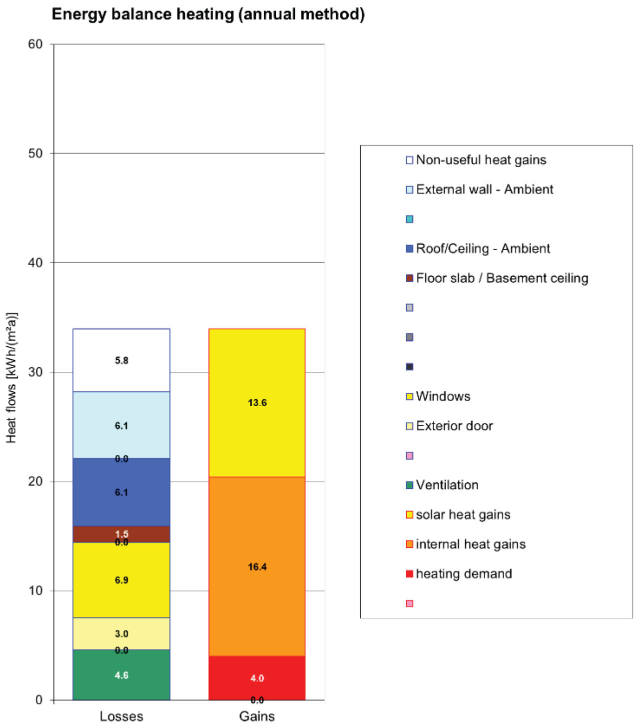
An ideal passive solar configuration should result in a net heat gain through the windows during the heating season. According to the PHPP analysis carried out by this particular student the proposals result in a net 1681 kWh/annum heat gain during the heating season.



The student has oriented the building for highest northern aspect to achieve a successful (net positive) passive solar heating strategy.

3.5.3 Annual Heating Energy Balance

The annual heating energy balance for this project was submitted as being able to achieve the Passive House certification standard, with a heating energy balance breakdown as follows:



3.5.4 Building Energy Performance Results

The following building performance summary data has been taken from the student's PHPP model for their project

Table 3.9 PHPP Outputs: Project 1069729

Summary Results from PHPP Model	
Basic Building Parameters:	
Annual Heating Thermal Demand (kWh/m²yr):	4
Annual Cooling Thermal Demand (kWh/m2yr):	15
% hrs Overheating Without Cooling	11
Energy Demand Breakdown (electricity) kWh/m²yr:	
Heating:	4.7
Cooling:	4.9
Domestic Hot Water:	0.9
Lighting & Power	42
Aux. (fans, pumps etc)	4.7
Renewable Energy Contribution kWh/m²yr:	
Photovoltaics (electricity):	184.4
Solar thermal (thermal energy):	7.3

4 Benchmarking Study

4.1 Benchmarking against Business-As-Usual

4.1.1 Atelier Ten Modelling of the Base Case

In order to enable the benchmarking exercise Atelier Ten undertook modelling analysis to establish a base case for the business-as-usual approach. This was achieved by modelling a typical Ambulance Station based upon documentation provided by Ambulance Victoria for the recently built Diamond Creek Ambulance Branch. The information for this exercise included:

- A stamped town planning drawing package by Ed Ewers Architecture dated February 2018
- BCA Part J report by energyraters.com.au dated February 2018

A model of this business-as-usual base case was built using PHPP and eTool to calculate an accurate operational energy consumption and carbon emissions baseline as well as providing an appraisal of the 60-year life-cycle emissions taking into consideration the embodied carbon of the building.

For simplicity of modelling, it has been assumed that the Ambulance Station is an all-electric building, without the use of gas for cooking or hot water generation. This is not deemed to be a significant factor in the modelling outcomes as cooking and hot water usage are a relatively low proportion of overall energy demand and since space heating is specified to be electric reverse cycle type.

4.1.2 Calibration against Ambulance Victoria Energy Monitoring Data

The business-as-usual model was calibrated against actual monitored energy data from 16no. Ambulance Stations provided by Ambulance Victoria.

Based upon the data provided it is apparent that there is a wide variation in energy performance across different stations, presumably linked to differing age of building, systems and occupancy patterns. Overall, annual energy performance varies from approximately 40 -120 kWh/m^{2}annum with an average of 75kWh/m^{2}annum

Two baseline buildings were modelled based upon alternative wall build-ups which are common in the construction market:

- Steel stud wall construction
- Timber stud wall (understood to be the most common system type used in AV buildings)

These two variations are significant due to the large increase in heat loss that is presented by the thermal bridging of the steel stud elements that bridge the insulation layer in the external walls. This is demonstrated by the difference in energy performance between the two options:

- The baseline building with steel studs was modelled with an annual energy demand of approximately 100 kWh/m^{2}annum
- The baseline building with timber stud construction demonstrated an annual energy demand of approximately 75 kWh/m^{2}annum

From the above results it was deemed appropriate that the timber stud construction option should be assumed as the baseline as it is more closely aligned to the average energy demand from real data taken from the sample of 16no. ambulance stations.

1.1.2 Scope of Student Design and Construction Technology Proposals

Common themes were evident in the students design propositions for solutions that meet the net zero carbon goal. These have been identified as follows:

- Optimised passive solar design through allocation of higher proportion of north facing, horizontal shaded glazing to better capture the winter suns heating energy
- High-performances building fabric U-values including enhanced glazing U-value performance
- Enhanced airtightness in line with the Passive House standard, achieving 0.6 air changes per hour during a blower door test at 50Pa pressure
- The use of heat recovery ventilation for enhanced indoor air quality and significant reduction in heating energy demand
- Improvement in heating and cooling efficiency through the use of higher efficiency heat pump systems, such as ground source heat pumps
- The use of renewable energy systems including rooftop solar thermal and photovoltaic panels.

All of the above steps have been evaluated against the baseline, aside from the solar thermal hot water system. This has not been modelled due to the uncertainty around the hot water load in the building and the accuracy that would be achieved from this exercise (no monitored data exists and anecdotally from AV staff we understand and the level of hot water usage to be low).

In addition, we have proposed a further step not explored in the students design proposals as it relates to operation and management efficiency. This final energy efficiency step assumes that it would be possible to achieve approximately a 30% reduction in small power and lighting energy usage through specification of highest efficiency fittings and optimum energy management control.

This final step is inserted as it helps to put the energy generation potential of rooftop PV panels into perspective relative to a high-performance Ambulance Station with consideration to design, construction and operation.

1.1.3 Performance Relative to Business-as-Usual

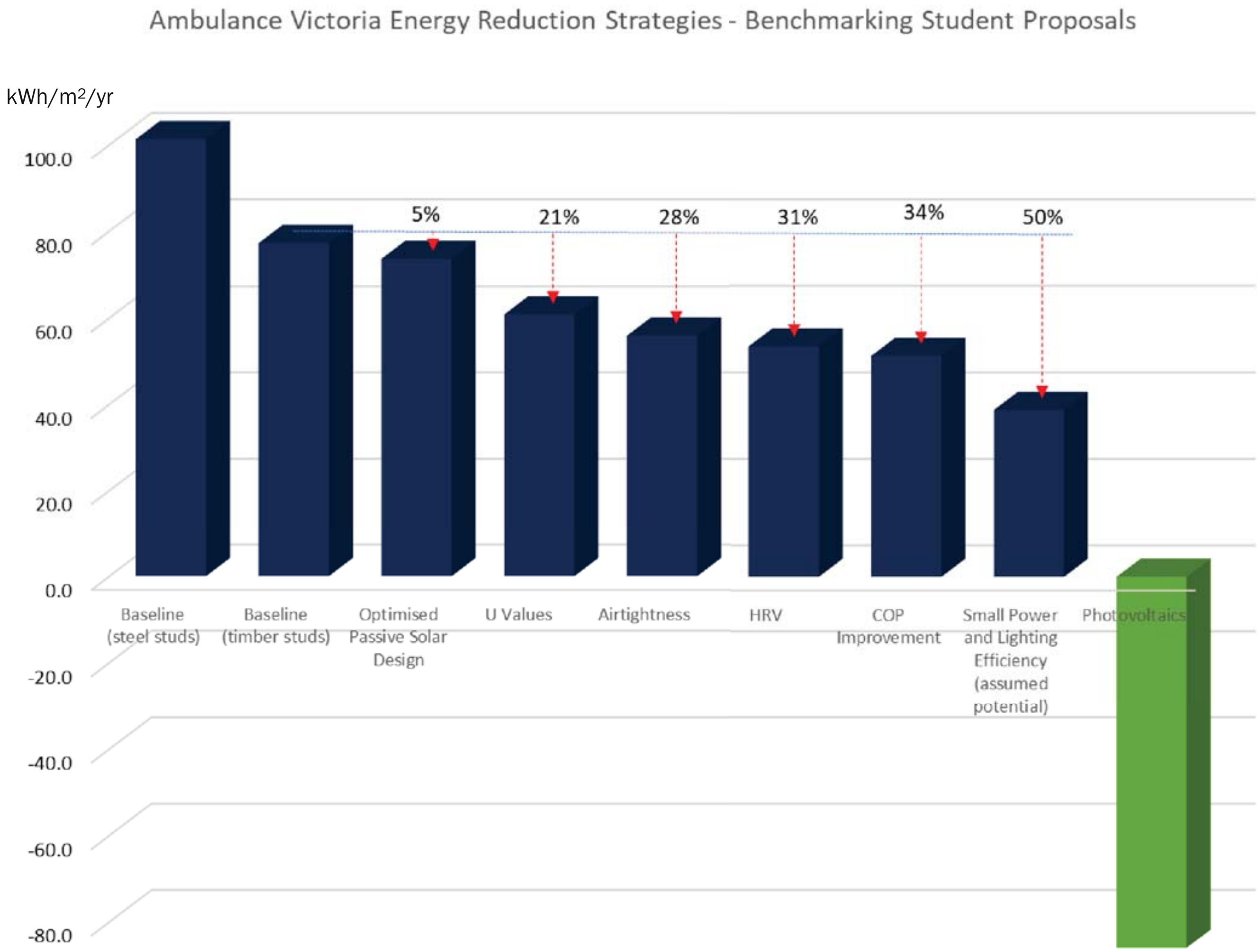
The results of vetting process demonstrate that the students have been successful in selecting solutions that are on a credible pathway toward net zero carbon performance as shown in the graph below of annual energy (electricity) consumption. It can be seen that up to 50% energy saving compared to business-as-usual could be achieved through a cumulative combination of high-performance passive design measures, optimisation of HVAC systems, and consideration of on-going operational energy management.

- Of the combination of measures within the scope of the student proposals, the most significant benefit is achieved through passive solar design, high performance building fabric and airtightness measures resulting in a 28% energy saving from the baseline.

1.1.4 Potential to achieve Net Zero Carbon Performance

Accompanying this radical reduction in energy demand that the proposed measures would achieve, the students had also provided on-site renewable electricity generation through the use of rooftop photovoltaic panels. As part of our vetting process we reviewed all the student propositions and determined an average number of solar panels across the studio that had been applied to their projects. The performance in energy generation that is achieved from this average 70 solar PV module array is show below on the same graph as a kWh/m^{2}annum energy generation capacity.

The results below clearly show that there is potential to generate 2-3 times the amount of energy consumed on site once all the energy efficiency measures are cumulatively applied



5 Strategy Comparison Matrix

5.1 Matrix

The following matrix has been compiled to compare the most common strategies employed by the students in greater detail.

Table 5.1 Strategy Comparison Matrix

Strategy	Description	Approx. Energy Reduction Potential	Benefit	Risk	Estimated Payback Period	Recommended?
Timber Stud Walls	• Use of timber stud framing for building structure in lieu of a steel stud framing system	• 25%	• Avoids significant thermal bridging and consequential energy losses caused by steel frames. • Reduced environmental impact in building materials	• More susceptible to fire damage • Lower longevity that steel frames	Instant	✓
Passive Solar Design	• Building design with consideration of site surroundings and orientation	• 5-10% (depends on how poorly performing the non-passively optimised comparator is performing)	• Optimised building design can maximise passive solar gains from the sun over winter periods and reduce energy losses throughout summer • Significant psychological benefit of winter sunlight	• None	Instant	✓
U Values Walls, Floors, Roof and Glazing specifications	• Selection of higher-performance insulation materials throughout the building envelope (relative to 2019 code)	• 15%	• Can significantly reduce the thermal conductivity of the building envelope which will help minimise the required heating and cooling loads required within	• Actual performance can vary based on quality of installation.	<10 years (Varies with level of insulation installed)	✓
Airtightness	• Sealed building envelope which minimises airflow between in the interior and exterior of the building	• 5-10%	• Reducing unintentional air leakage in / out of the building will significantly improve the buildings' ability to maintain its temperature. • Reduces the intake of exterior pollutants from traffic etc.	• Airtightness is dependent on stringent building specifications and installation. • Extremely airtight buildings will require MHRV	<5 years	✓
Heat Recovery Ventilation	• Heat recovery ventilation units cycle fresh air past pre heated / cooled air as it is expelled from the building	• 5%	• Maintains a constant supply of clean air within the building reducing the need to have windows open. • Energy is transferred from the outgoing air, reducing the energy required to cool / heat incoming air. • Reduced mould and interior condensation – general improvement in health and wellbeing	• Require regular maintenance. • More specialised than typical ventilation systems	<10 years	✓
High Efficiency HVAC and improved COP's	• Improved efficiencies in HVAC systems throughout building.	• 5%	• Reduction in building energy use	• Manufacturer specified efficiencies will vary across seasons and different climates	<15 years	?
Improved Small Power and Lighting Efficiencies	• Higher efficiency LED lighting and small goods	• 15%	• Reduction in building energy use	• None	<5 years	✓
Solar Thermal	• Solar thermal installation which harnesses solar energy to heat water	• 5%	• Reduces heating demand for hot water. • Reduces the demand for direct electric water heating (current AV default solution)	• Requires pumps and other equipment which can require higher levels of maintenance. • Energy reductions can be made redundant by solar panels which may often be cheaper.	<10 years	–
Photovoltaics	• Solar panels installed across roof and elsewhere on site where appropriate	• Scalable to net-zero and beyond	• Flexible levels of installation and costs to suit energy requirements. • Can be scaled to meet annual energy requirements but batteries should be considered for storage of power	• Roof design may need consideration to maximise benefits.	<5 years	✓

6 Embodied Energy

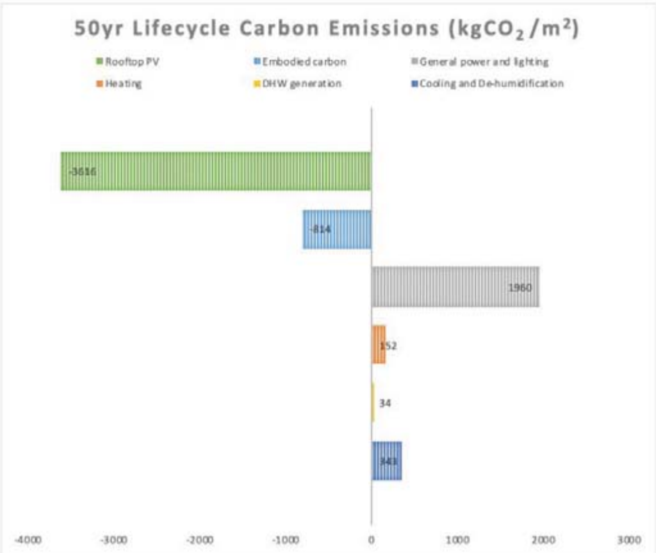
6.1 Implementation of Embodied Energy Analysis

6.1.1 eTool Implementation

In accompaniment to the energy focused design tool; PHPP, students were also introduced to a web-based life cycle analysis software, eTool. eTool provides a holistic platform which can be utilised to assess both the embodied carbon associated with a building design. By integrating this alternative scope of analysis into the studio, students were provided the tools to look past just the operational energy consumption related to their designs and consider the whole of life factors contributing to the overall environmental impact. Examples of some of the studies undertaken by students using the eTool platform include:

- Analysis of the embodied carbon associated in material choices across the design.
- Impact analysis of possible reduction strategies through alternative material choices, recycled materials and designing for disassembly.
- Impact reporting across a range of measures such as: CO_2e, Energy, Water, Land Use, Ozone Depletion, Human Toxicity and more over a building's entire life span.

Through such studies, students were able to graphs such as below which quantify the 50-year lifecycle carbon emissions of their designs.



In doing so, it was possible to understand the relationship between embodied and operational carbon and understand the potential for on-site PV generation as a generator of clean energy to 'offset' these emissions.

Students also widely experimented with the use of timber construction solutions such as traditional stud frame construction or mass timber solutions such as CLT. This highlighted the significant reduction in embodied carbon emissions that is possible compared to steel or concrete frame solutions..

6.1.2 Effectiveness of the study within the scope of the studio

Whilst the lifecycle analysis of their designs provided students with an optional alternative metric with which to consider their designs; the uptake and usage of the tool within the studio was considerably smaller than that of the PHPP (only 4 students made a final submission of their eTool model)

There are several factors which may have contributed to this, though the major considerations as identified by Atelier Ten are as follows:

- The web-based platform of eTool is not as intuitive nor as fast to use as the excel based PHPP and as such students may have faced some difficulties in exporting the relevant data for submission or design integration.
- Many of the inputs required by eTool are focused on less tangible elements when compared to the geometric and fabric-based assessment of PHPP. Inputs such as material volumes, or construction equipment requirements are typically outside the scope of a design-based studio and so students may not have had the time or knowledge to effectively populate the inputs in great detail.
- The feedback and outputs as provided by eTool are largely non-tangible in terms of the iterative process which students were hoping to undertake. For example, results such as the reduction in embodied carbon from recycled materials provided students with valuable information to consider but bore little weight in the spatial development of their designs.

Whilst the listed factors may have resulted in smaller impact on students realised design outcomes when compared to the PHPP, the process of studying the embodied and operational carbon opened an important and potent conversation in relation to how early-stage design choices can be leveraged to significantly reduce the buildings impact over its entire life. Evaluation of material choices was shown to be easily accessible within the scope of the design project, and offered valuable and tangible considerations for the students to carry on with them in their future design careers.

7 Conclusions

The multidisciplinary process across the course of the semester saw students successfully investigate and incorporate a range of environmental solutions into their designs. Outcomes indicated that with a considered approach, existing technologies and materials could be harnessed to significantly reduce energy usage, alongside the embodied and operational carbon impacts of their proposals.

7.1 Path to Net-Zero

7.1.1 Strategies Identified

Across the student body of work, a number of strategies and technologies were consistent in recommendation. Their prevalence across a wide variety of different design proposals indicates their suitability and achievability within the scope of a typical Ambulance Station. Key systems which were common across the studio and which offered the greatest benefits include:

- Optimised Passive Solar principles for winter heating and summer control.
- High-performance building fabric through enhanced U-values of the building fabric
- Reduction in thermal bridging and airtightness construction quality Assurance
- Mechanical ventilation with heat recovery for energy saving benefit in addition to other indoor environmental quality and health benefits.
- Photovoltaic panels were consistently applied across projects for on-site renewable energy generation.
- Selection of materials which minimise the impact of embodied carbon across the development.

7.1.2 Student Outcomes

With such implementations, it was found that energy usage across the site could be reduced by up to 50% when compared against current business as usual statistics. Furthermore, when tied in with a photovoltaic system, the students have shown that energy production potential can entirely meet and exceed the demands on site. As such, the student body of work has shown that with current and existing technologies, a net-zero carbon approach is possible. Outside the scope of this project it is recommended for Ambulance Victoria to investigate the feasibility of a net-zero carbon branch implementing the energy saving measures recommended by the students, and with further development of a renewable energy generation and storage strategy utilising batteries.

In addition to the clearly demonstrated carbon reduction benefits, significant improvement to the health and well-being of occupants is associated with some of the strategies put forth. Implementations such as considered daylight access, thermal comfort control, airtightness and well-designed ventilation systems can be leveraged to improve the quality of life within the station.

7.2 Recommendations

7.2.1 Studio Success in Big-Picture Learning

The integrative approach across the course of the studio contributed to a potent learning experience for all involved. Many of the students were successfully able to show that their designs could follow a net-zero pathway. This is a valuable exercise and one which they will hopefully continue to consider as they progress further into their design careers. The key value appeared to come from posing the big picture question asking them to discover whether they can design a zero carbon ambulance station and view this not only from an operational perspective but over the whole life of the project. This big-picture learning is recommended for future studios as it helps students' critical thinking and engagement with the key issues of our time.

7.2.2 Iterative Design Approach

Students were found to be most likely to engage with and understand the impact of environmentally focused design decisions through the process of iteration. Design iteration when considered through the lens of environmental performance metrics, provided students with a tangible way to engage the results and understand how their design decisions could reduce the impact of their buildings. As such, further encouragement of this iterative approach is recommended for future studios.

7.2.3 Software Choices

Two different analysis software's were introduced to the students over the course of the semester. Whilst the Passive House PHPP software was able to offer students direct and tangible results regarding the impact of design choices, the life-cycle analysis platform; eTool, was less successful in this venture. It was however valuable in quantifying embodied and operational carbon in student work and in doing so; opened an important conversation in fields such as material, equipment, and design for disassembly choices. Nonetheless, it did not offer the same level of integration nor potential for iterative design work. Hence, this points towards other software choices which might be more familiar and better suited to the student's current toolset, such as analysis tools built into the Grasshopper platform, which operates natively within the architectural software Rhinoceros which would enable direct feedback on the emerging 3D form.

Design Studio Outcomes

IDS-04

APPENDIX B

STUDENT WORK

MODULE NO.#AV

Studio 07
Emergency Response
Final Review

Kertina Qi Liu

design statement.

adaptable

flexible

resilient

modular

Ambulance Victoria strives to achieve net zero branches by 2050. They aim to develop an environmentally sustainable design for their branches with the emphasis towards thermal performance, response to climate zone, energy reduction and collection being the top priorities of the design. This lead me to reflect deeply on what strategies could be implemented to enable a site responsive design at any location an Ambulance Victoria branch needs to be placed.

As a result, my design proposal explores how the use of a modular system may facilitate an environmentally sustainable ambulance branch anywhere across Victoria, with a focus on the concepts of adaptability, flexibility, and resilience.

construction

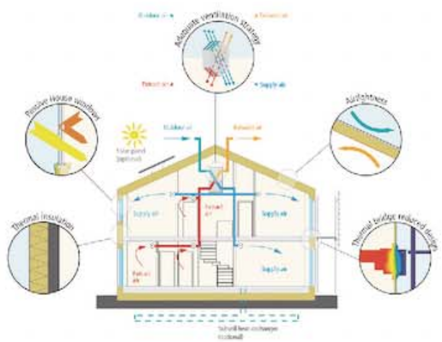
prefabricated modules

ease of installation and dismantle

minimise material waste

minimise permanant fixings for ease of interchanging components according to usuage as well as reducing impact to the land

systems & operations



passivhaus principles

optimises building performance

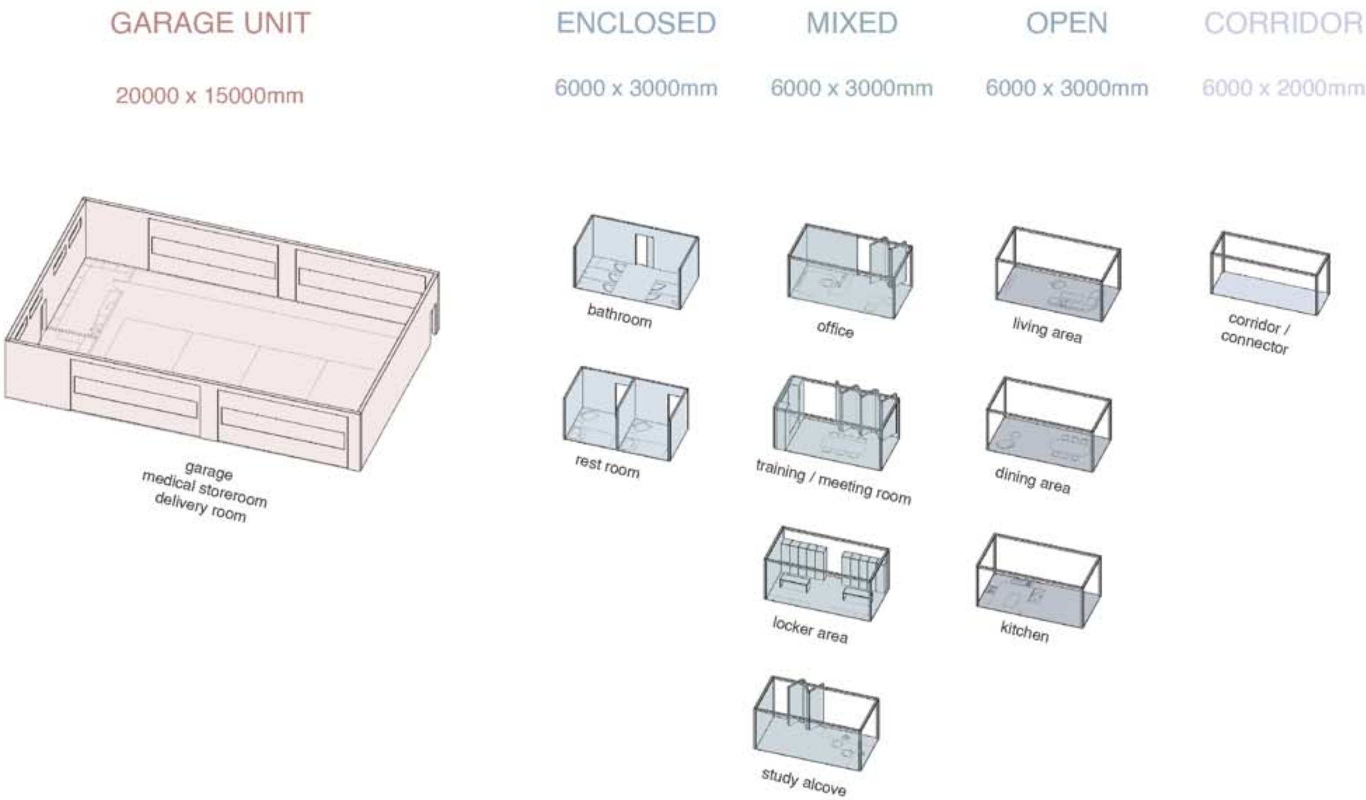
minimise demand for active energy con-sumption

occupant wellbeing

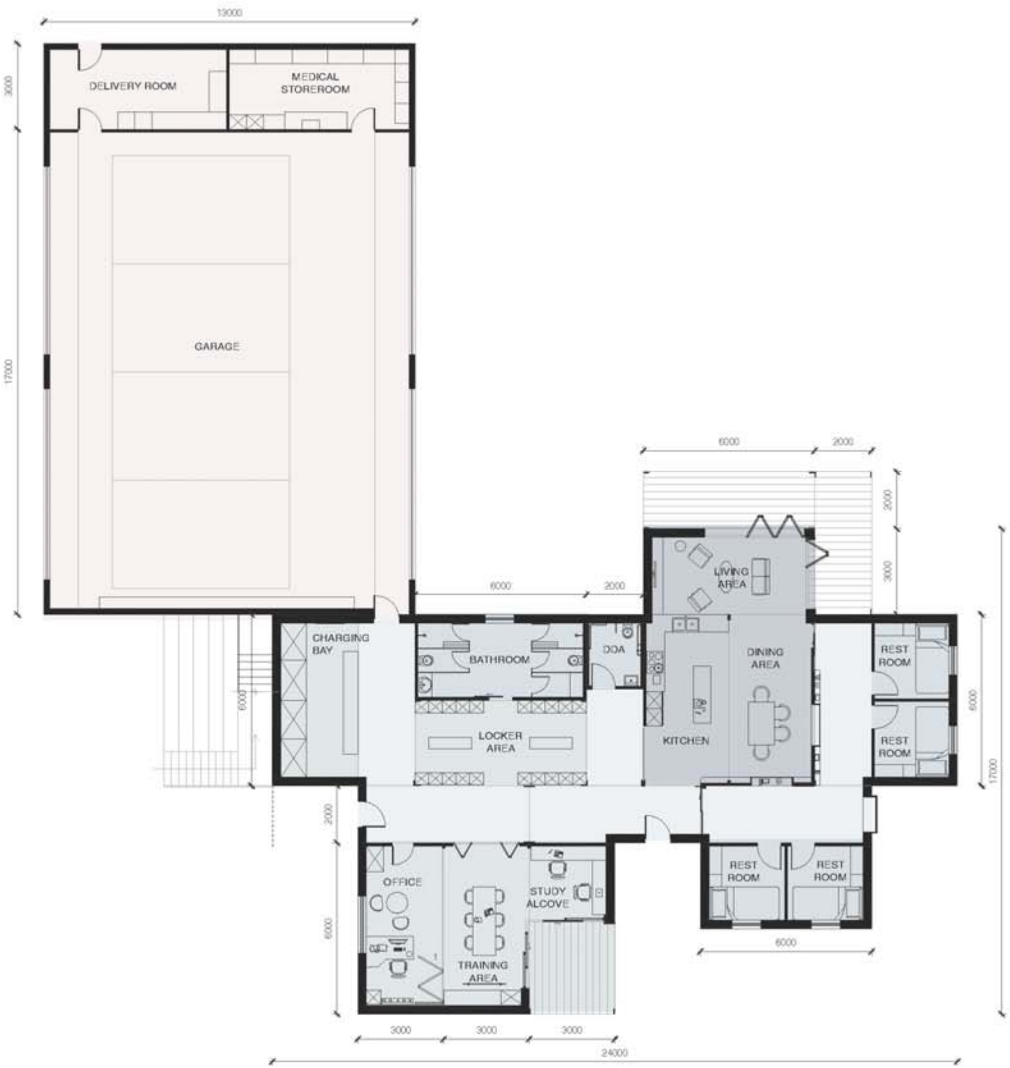
biophilic deisgn

increase occupant connectivity to the natural environment

positive impact on human health (both physical and mental) and productivity



types of spaces.



GARAGE UNIT

20000 x 15000mm

ENCLOSED

6000 x 3000mm

MIXED

6000 x 3000mm

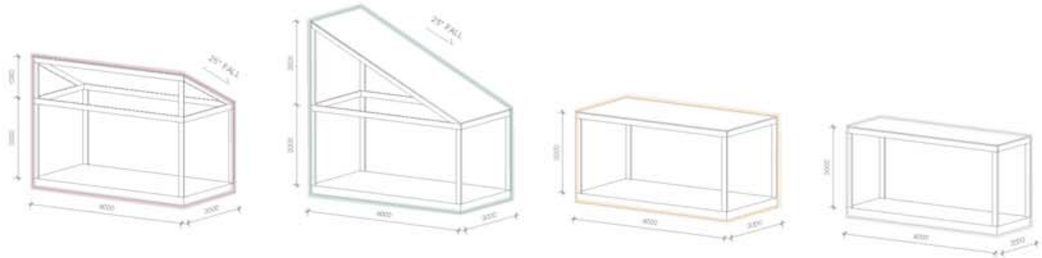
OPEN

6000 x 3000mm

CORRIDOR

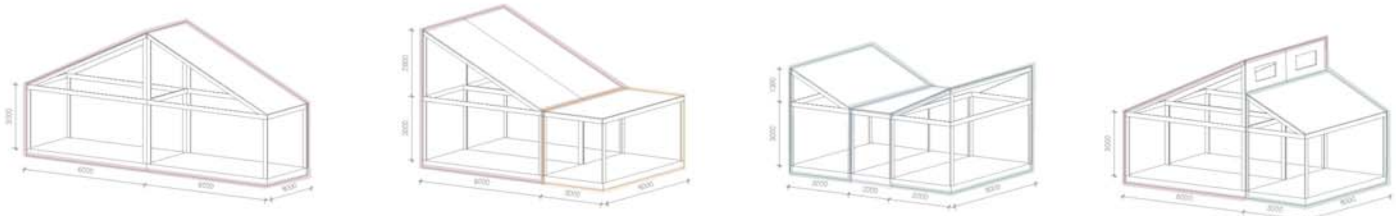
6000 x 2000mm

ground plan.



MODULE A MODULE B MODULE C MODULE D

Possible Configurations



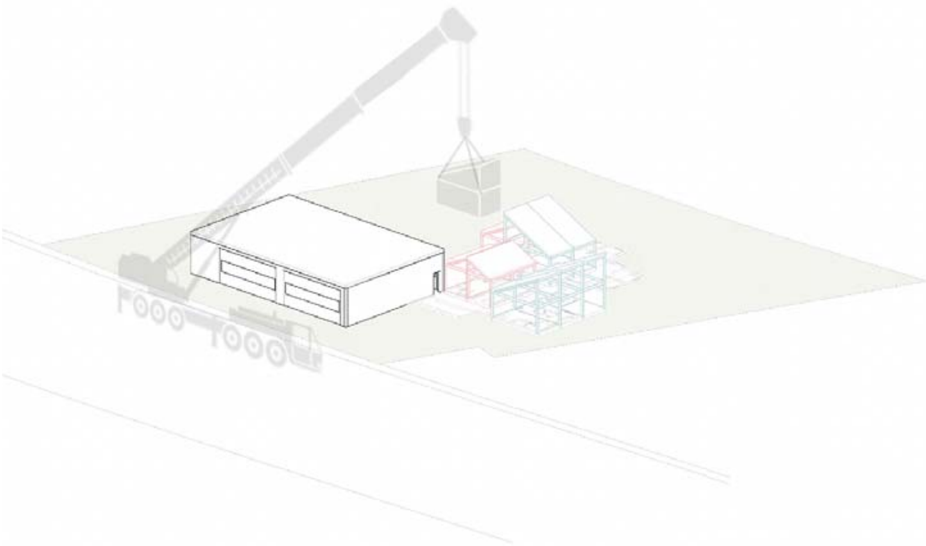
Pitched Roof
Module A x2

Slanted Roof
Module A x2
Module C x1

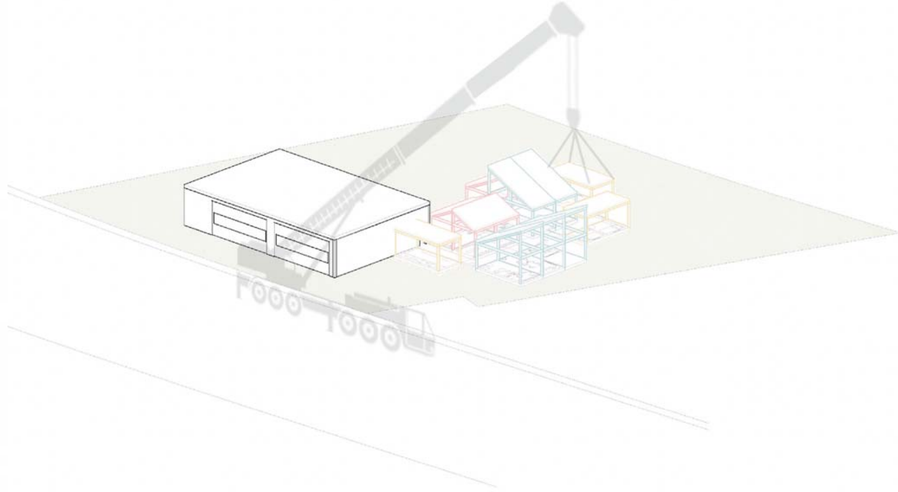
Butterly Roof
Module B x2
Module D x1

High-Low Roof
Module A x2
Module B x1

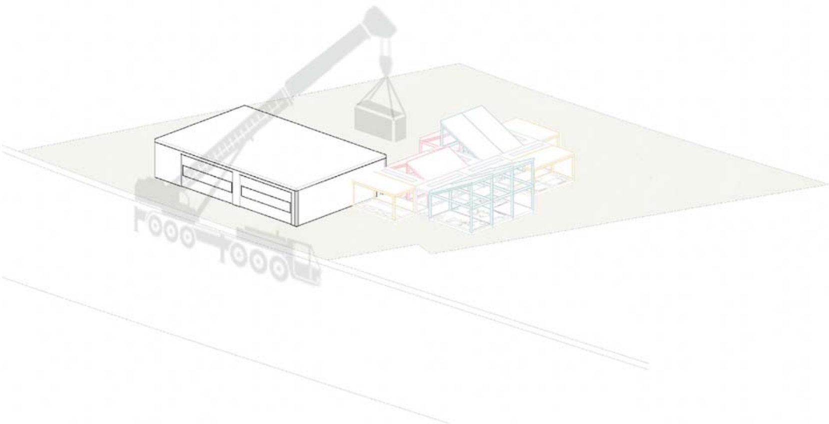
modules.



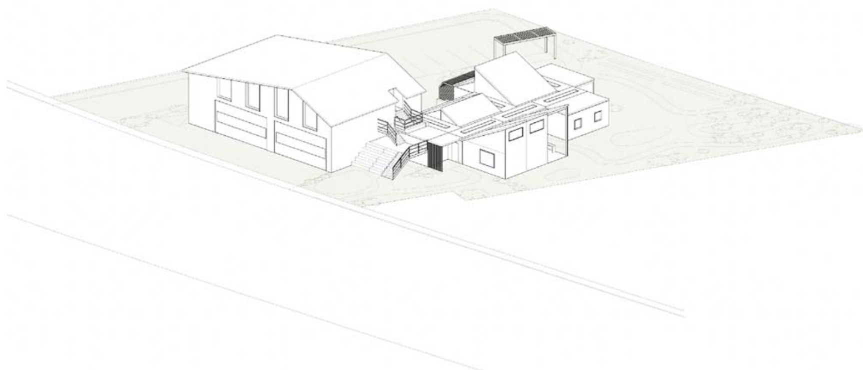
Module B - encourages wind entering the building



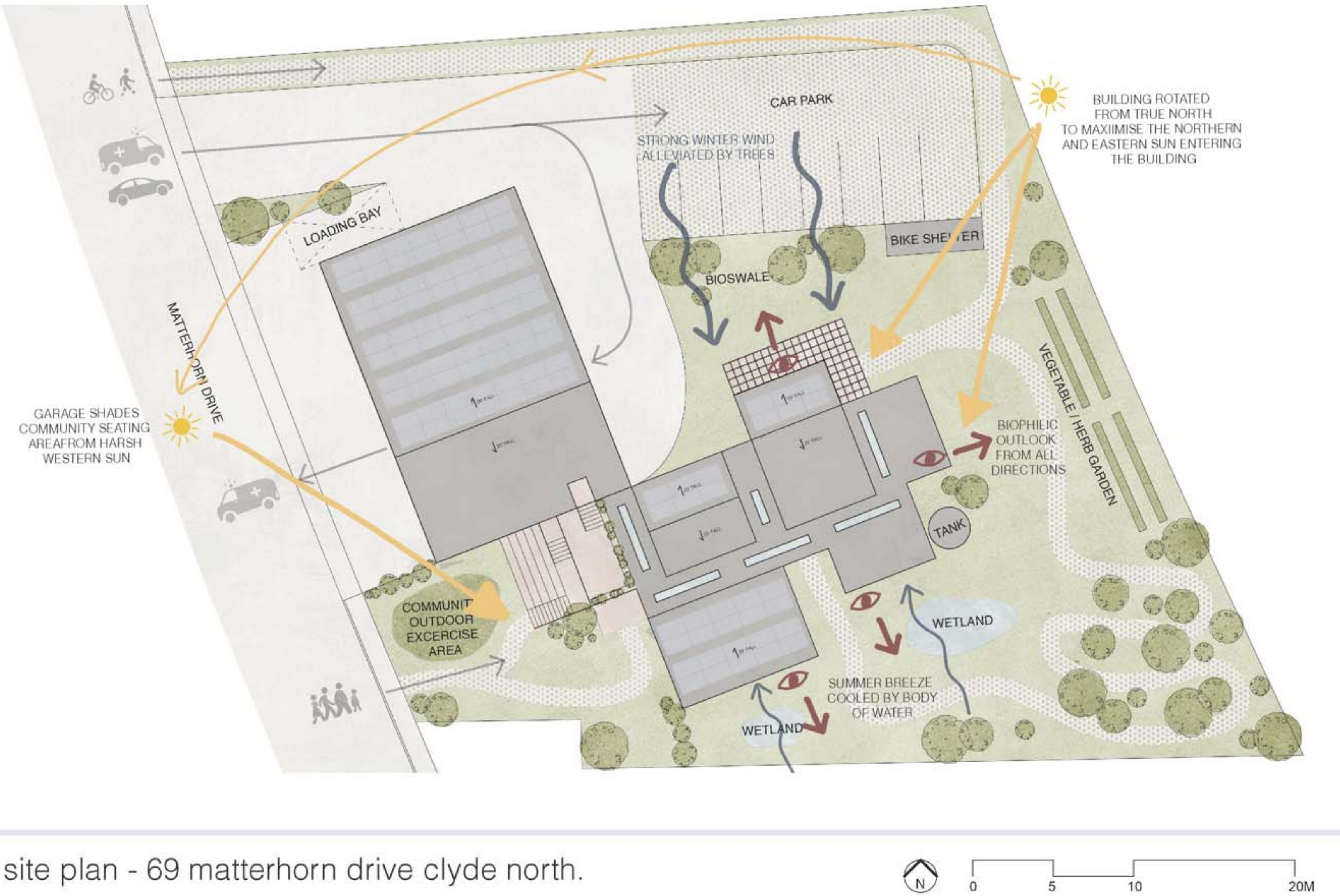
Module C - flat roof, for more intimate spaces



Module D - corridor / connection spaces



Site specific finishes applied, such as landscaping, secondary program etc.



site plan - 69 matterhorn drive clyde north.

Temporary Emergency Shelter
Generic parkland / oval / open sports field...
6000 x 3000mm module x6
6000 x 2000mm module x1

Smaller Urban Site
1000sqm
6000 x 3000mm module x11
6000 x 2000mm module x4

possible applications on other site.

street view.

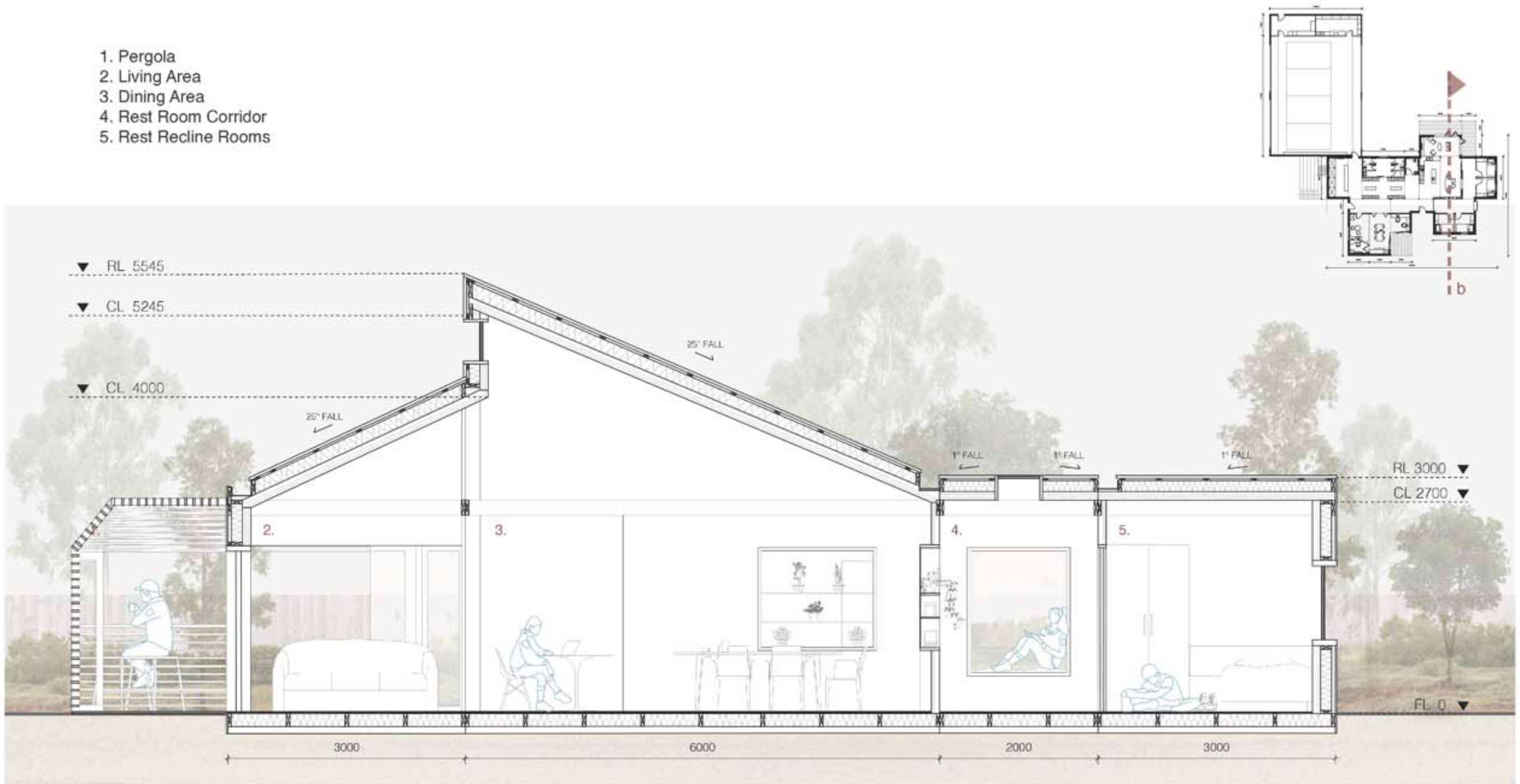
1. Medical Storeroom
2. 4 Bay Garage
3. Locker Area
4. Corridor
5. Office
6. Community Activity Center

section a-a.

entrance.

south exterior.

1. Pergola
2. Living Area
3. Dining Area
4. Rest Room Corridor
5. Rest Recline Rooms

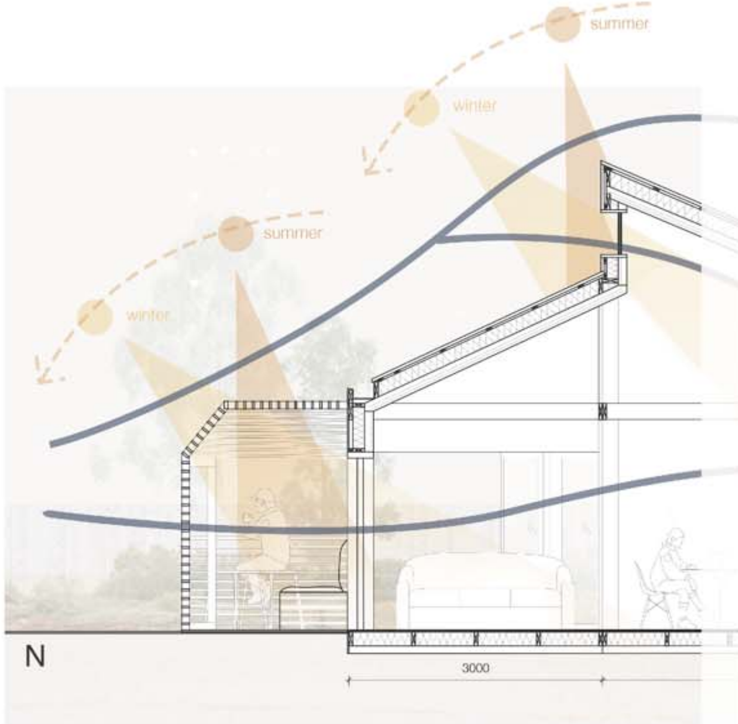


section b-b.

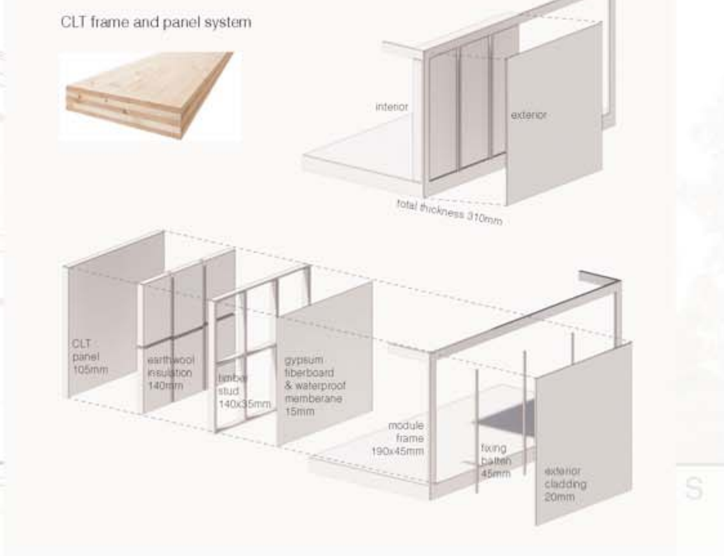
0 2 5M

kitchen / dining area.

north exterior.

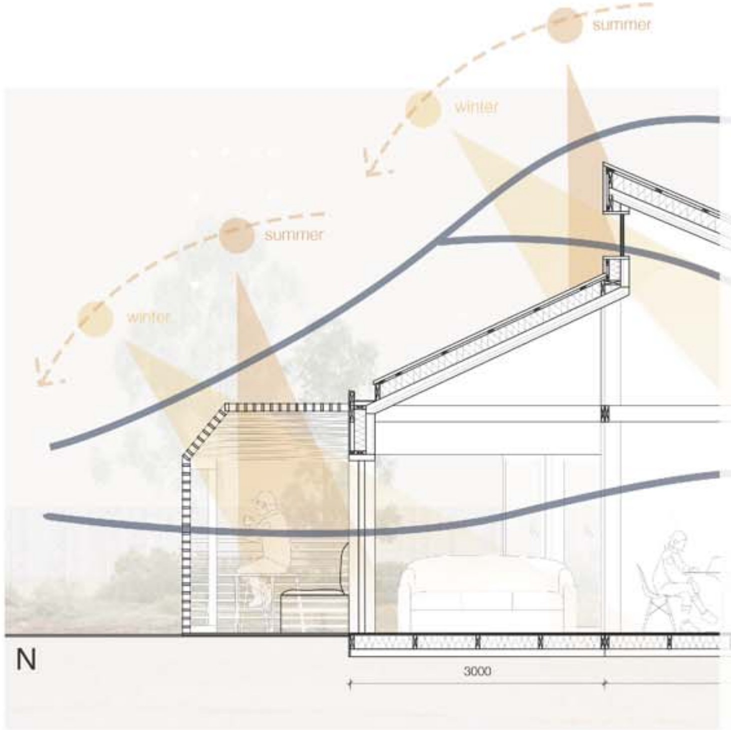


wall components - air barrier.



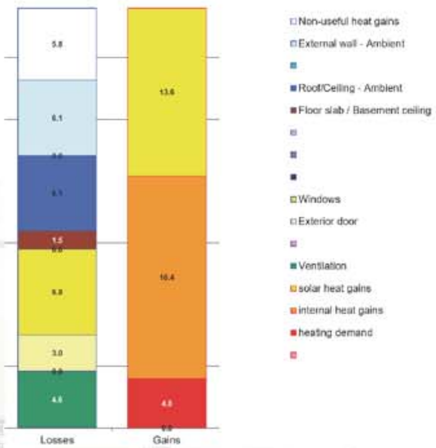
passive performance.

0 2 5M



PHPP
(Passive House
Planning Package)
output

without mechanical cooling



Specific building characteristics with reference to the treated floor area — The PHPP has not been filled completely; it is not valid as verification

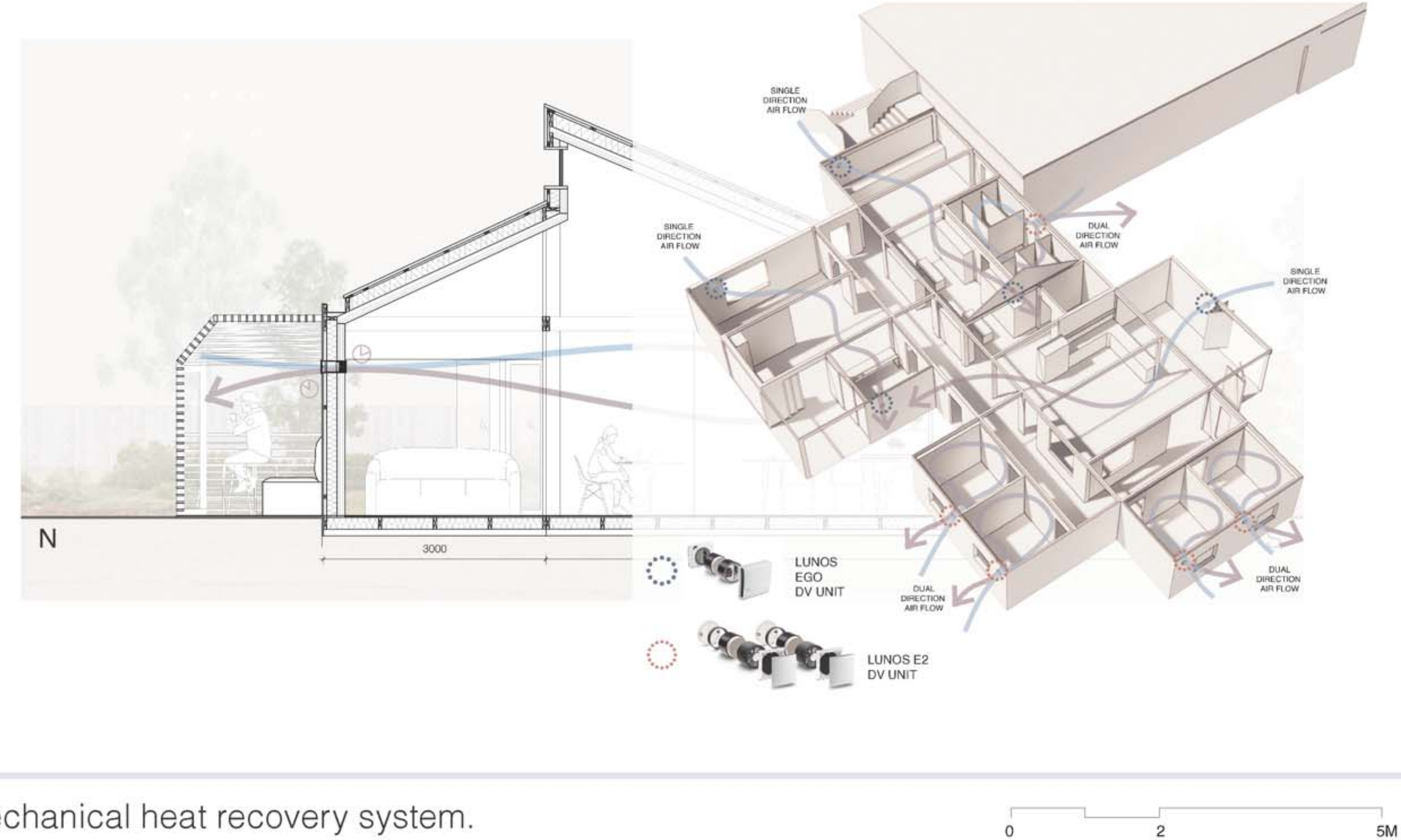
				Criteria	Alternative criteria	Fullfilled?[2]
	Treated floor area m²	252.8				
Space heating	Heating demand kWh/(m²a)	4	≤	15	-	yes
	Heating load W/m²	3	≤	-	10	
Space cooling	Cooling & dehum. demand kWh/(m²a)	-	≤	-	-	-
	Cooling load W/m²	-	≤	-	-	
	Frequency of overheating (> 25 °C) %	10	≤	10		yes
	Frequency of excessively high humidity (> 12 g/kg) %	0	≤	20		yes
Airtightness	Pressurization test result n_{50} 1/h	0.6	≤	0.6		yes
Non-renewable Primary Energy (PE)	PE demand kWh/(m²a)		≤	120		
Primary Energy Renewable (PER)	PER demand kWh/(m²a)	63	≤	-	-	-
	Generation of renewable energy (in relation to pro-jected building footprint area) kWh/(m²a)	186	≥	-	-	

[1] Empty field: Data missing; '-': No requirement

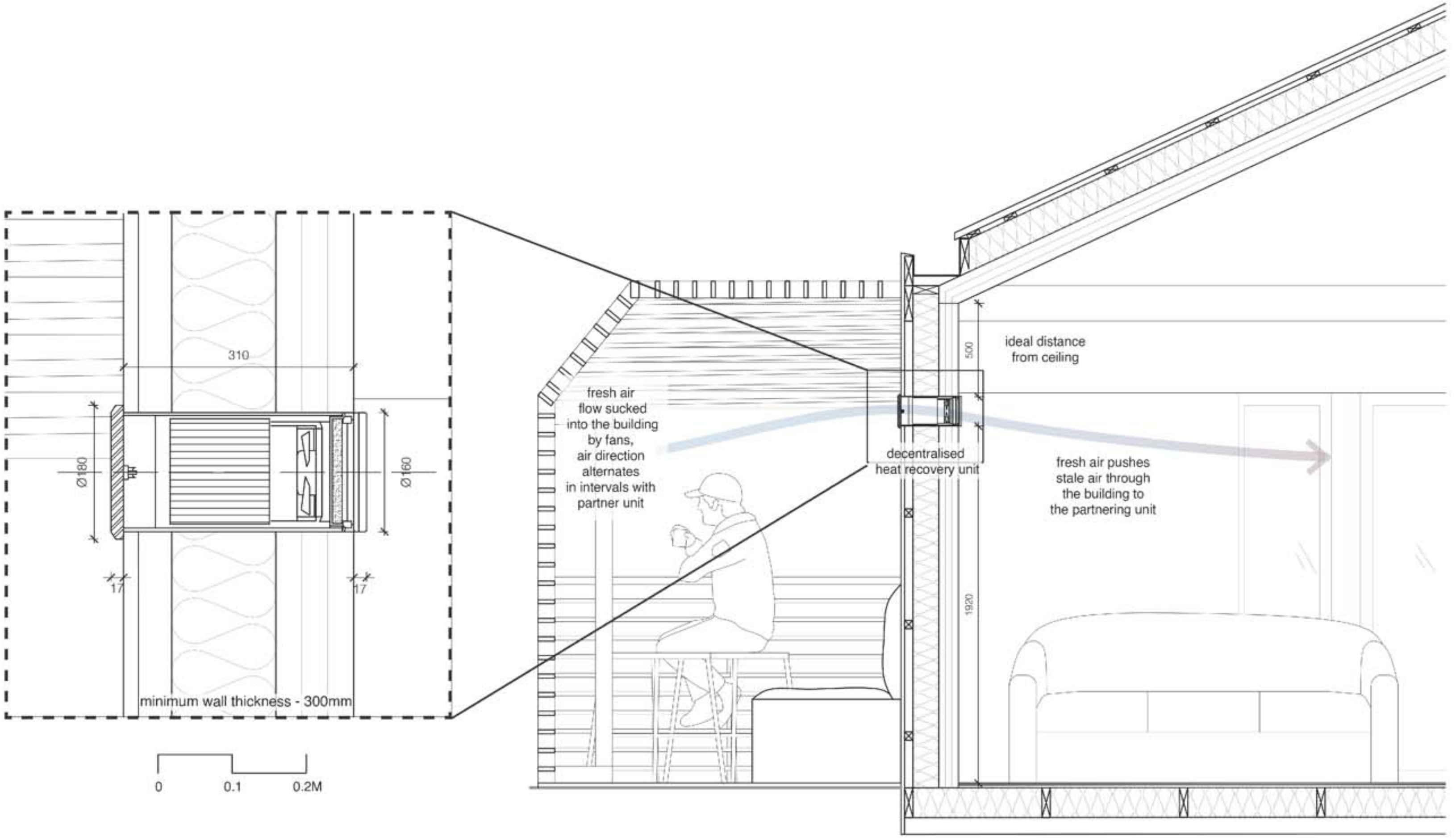
passive performance.

0 2 5M

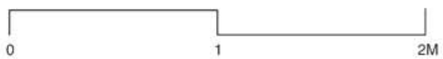
Decentralised Ventilation Unit Types.

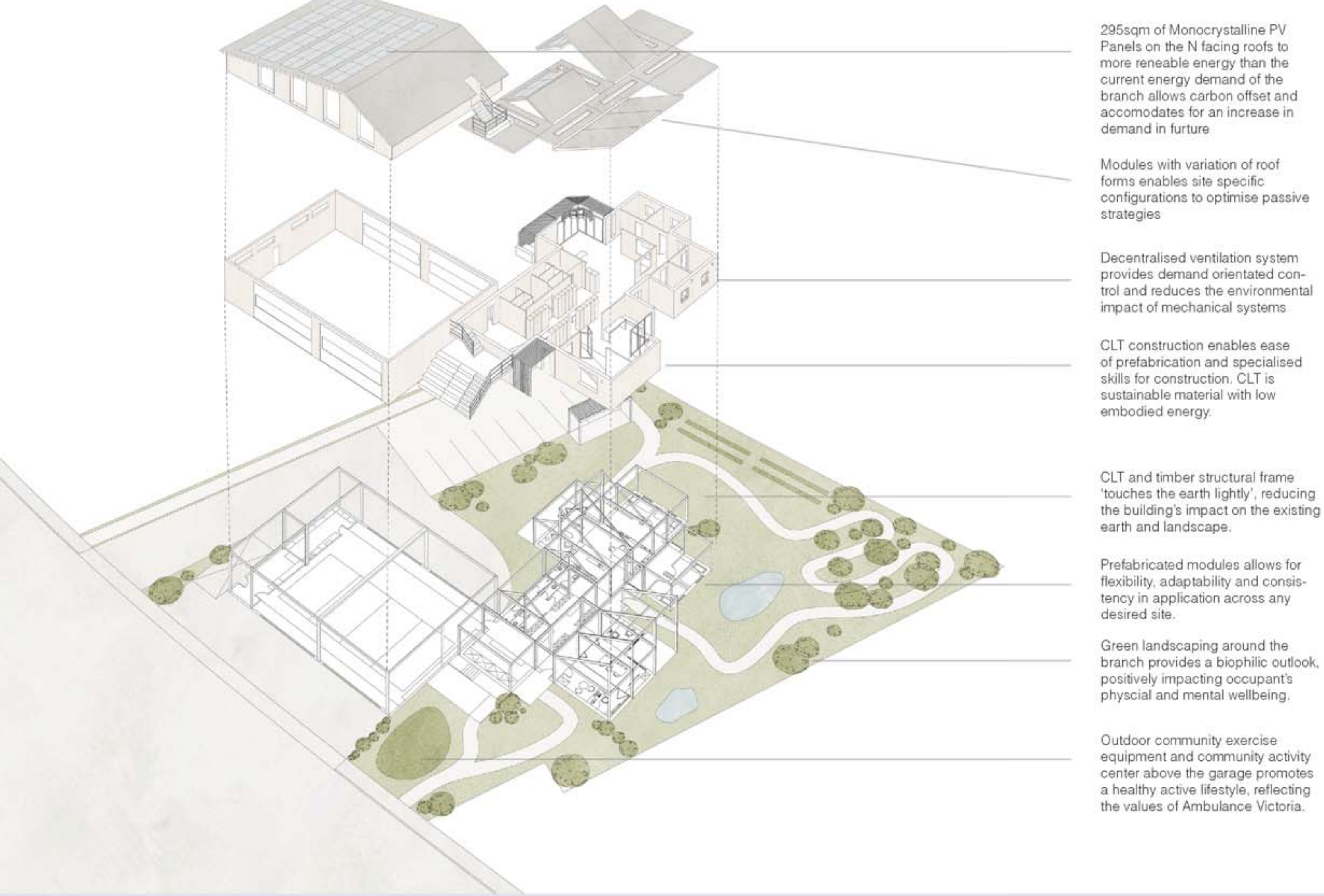


mechanical heat recovery system.

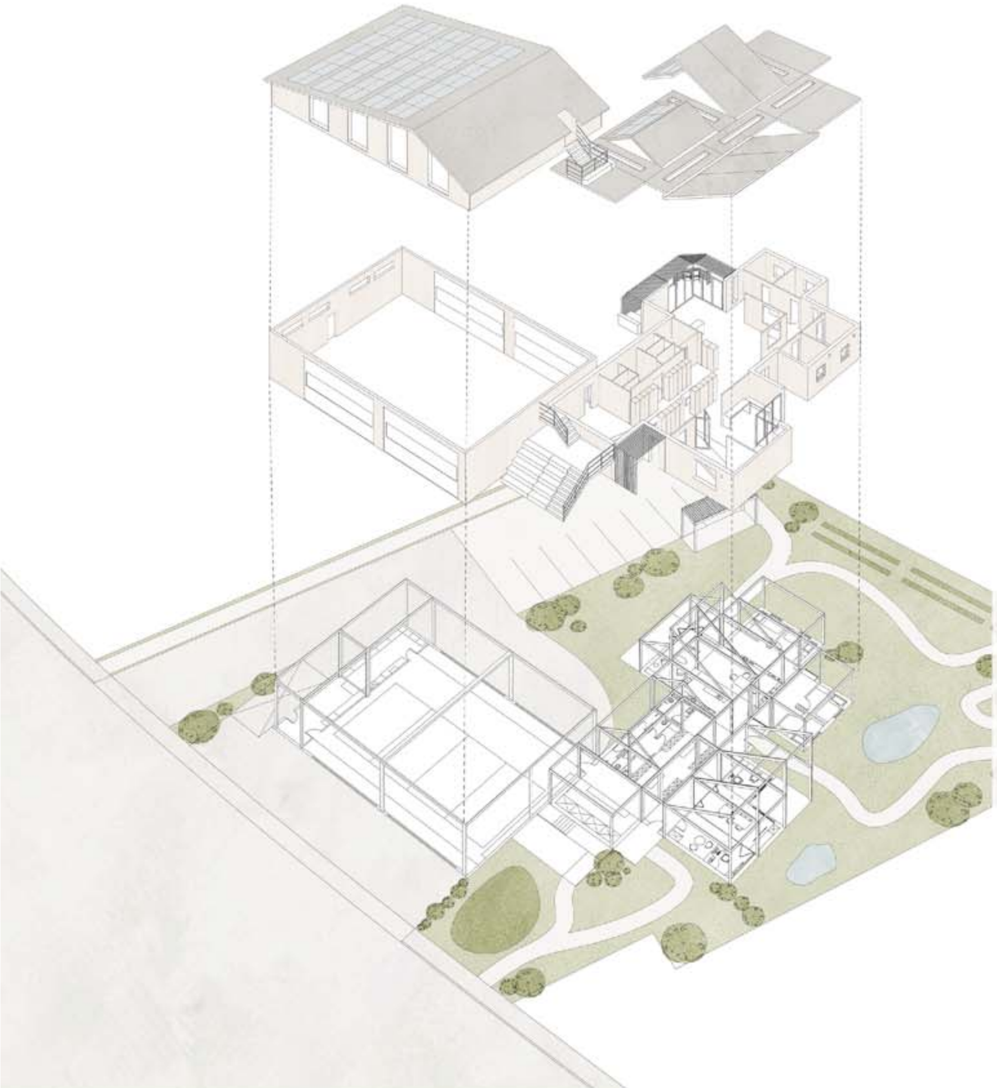


mechanical heat recovery system.

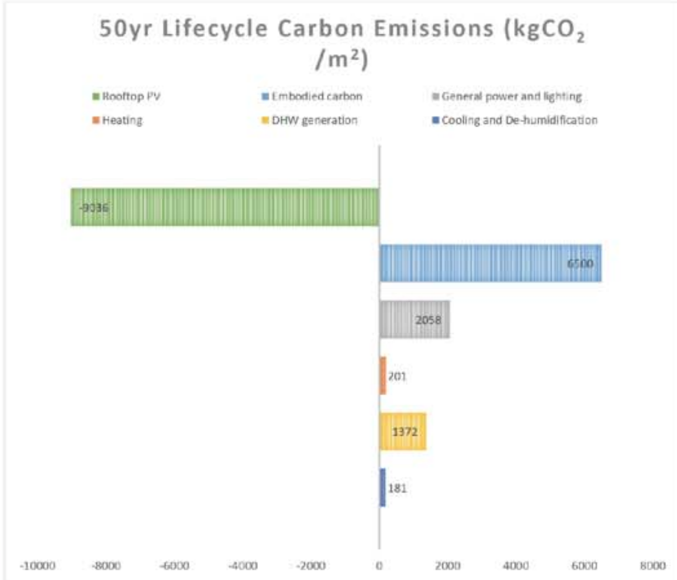




towards net zero carbon - is it achievable?



YES!



i-Hub Integrated Design Studio - Diamond Creek Base Case Performance 50yr Life-Cycle Carbon Emissions

	Victorian Grid Electricity Carbon Factor	0.98	$kgCO_2$/kWh electricity	
	Lifecycle period	50	years	
	Building Energy Demand:	**Annual Electrical Consumption (kWh/m²)**	**Annual Carbon ($kgCO_2/m^2$)**	**Lifecycle Carbon ($kgCO_2/m^2$)**
	Cooling and De-humidification	4	4	181
	Heating	4	4	201
	DHW generation	28	27	1372
PHPP Inputs	General power and lighting	42	41	2058
	Building Energy Generation:	**Annual Electrical Generation (kWh/m²)**	**Annual Carbon Reduction ($kgCO_2/m^2$)**	**Equivalent Carbon Reduction ($kgCO_2/m^2$)**
	Rooftop PV	184	-181	-9036
		Global Warming Potential, GWP (CO_2 eq. /m² yr)	**Operational Energy GWP (CO_2 eq. /m² yr)**	**Embodied Lifecycle Carbon ($kgCO_2/m^2$)**
e-Tool Inputs	**Embodied carbon**	3904	3774	6500
			Total Lifecycle Carbon ($kgCO_2$/n	10312
			Gross Lifecycle Carbon ($kgCO_2$/r	1277

towards net zero carbon - is it achievable?

Healthy Ambulance Station

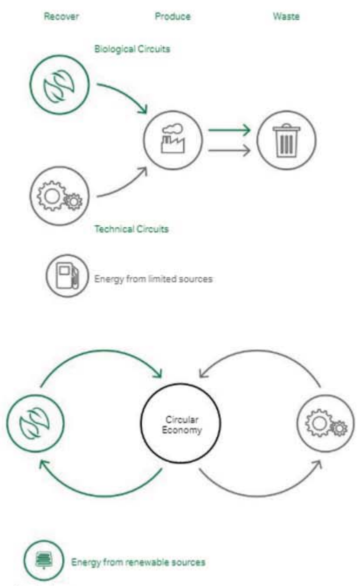
Ambulance branch(es) that can bring positive impact to both the environment and paramedics.

Issues:
Building wastage at the end of life cycle

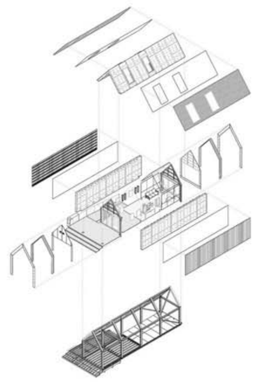
Typical ambulance branches have a life span of 50 years. What happen then?

It will be renovated or demolished which produce large amount of waste, this is the so called linear economy model widely use today. To reduce wastage from the demolition context, the next step is to shift into circular economy.

Part of the solution for that is the concept of Design for Disassembly (DfD) and it will be the main concept used to achieve zero carbon target ambulance branch.



Circular House,
Source: https://www.buildingacircularfuture.com/house



Construction diagram of Circular building by Arup
Source: Archdaily 'A Guide to Design for Disassembly'

Circular House Demonstrator interior,
Source: https://www.buildingacircularfuture.com/house

5 DfD principles

Material

Choose materials with properties that ensure they can be reused.

Quality
Use materials of a high quality that can handle several llife cycles.

Healthy
Use non-toxic materials to provide a healthy environment - now and in the future

Material
Use as pure materials as possible, which can recycled with ease.

Service Life

Design the building with the whole lifetime of the building in mind.

Layers
Make the long lasting building elements allow for flexibility, so other elements are easily changed.

Flexibility
Make a flexible building design that allows the functions to adapt and change in the future.

Interim
Think of the building as a temporary composition of materials and design with the preservation of material value in mind.

Standards

Design a simple building that fits into a 'larger context' system.

Modularity
Use modular systems where elements easily can be replaced.

Prefabrication
Use prefabricated elements for a quicker and more secure assembly and disassembly.

Components
Create a component when the composition of elements becomes too complex to handle.

Connections

Choose reversible connections that tolerate repeated assembly and disassembly.

Accessible
Make the connection accessible in order to minimize assembly and disassebly time.

Mechanical
Use mechanical joints for easy assembly and disassembly without damaging the materials.

Dissolvable
Avoid binders, but if necessary, use binders that are dissolvable.

Deconstruction

As well as creating a plan for construction, design the building for deconstruction.

Strategy
Create a simple plan for deconstruction, to ensure a quick and easy disassembly process.

Stability
Make sure that stability in the building is maintained during deconstruction.

Environment
Ensure the deconstruction plan is respectful to the nearby buildings, people and nature

Issues:
Paramedic's wellbeing

In smaller human scale, the project will focus on creating space that could improve the paramedic's well-being as their job could be stressful and demanding.

This is addressed by implementing biophilic design strategies into the project.

Nature in the Space

Visual Connection

Presence of water

Dynamic and Diffuse Light

Natural Analogues

Biomorphic Forms & Patterns

Material Connection with Nature

Complexity and Order

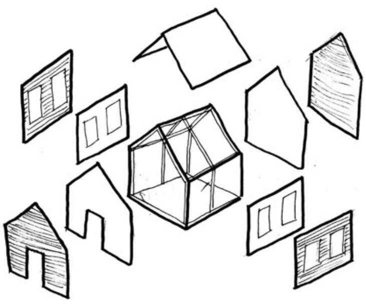
Nature of The Space

Prospect

Refuge

Mystery

Macro



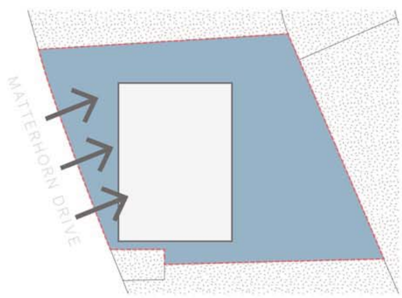
Design for Disassembly

Healthy Ambulance Station

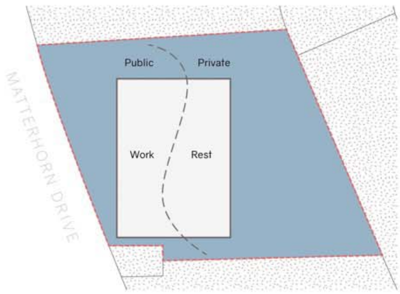
Micro

Biophilia

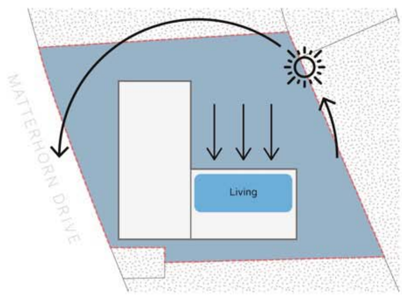
Plan Development



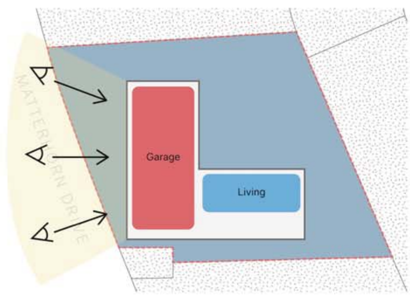
Site Access



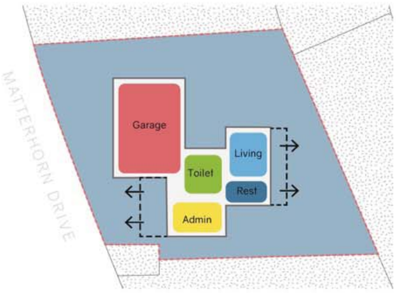
Work / Rest



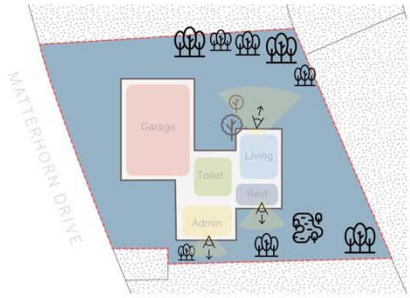
Sunlight access



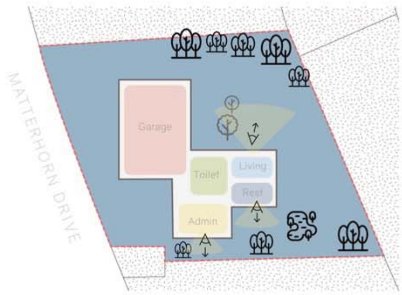
Ambulance garage as represent



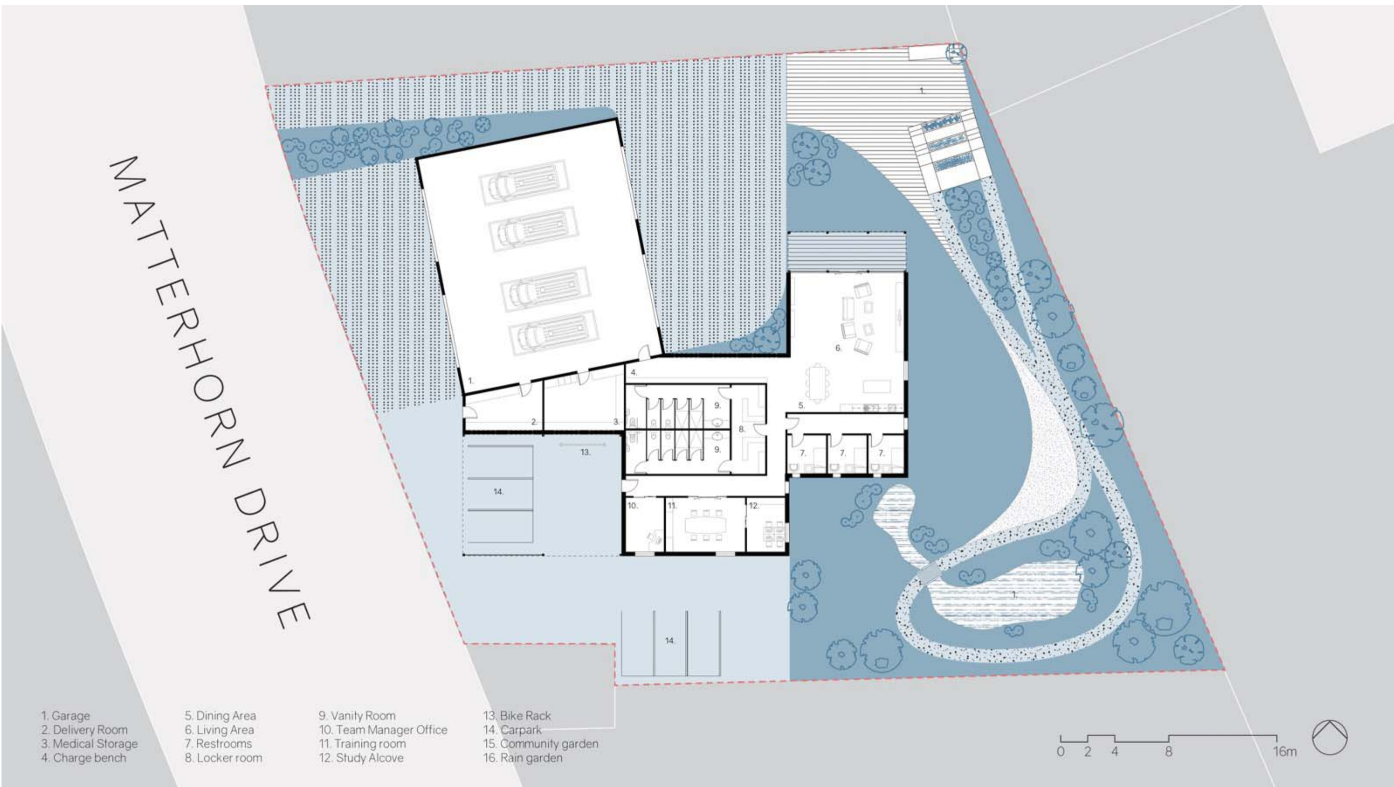
Efficiency

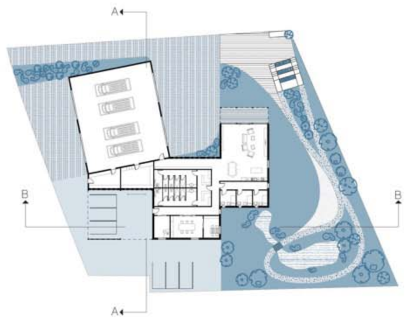


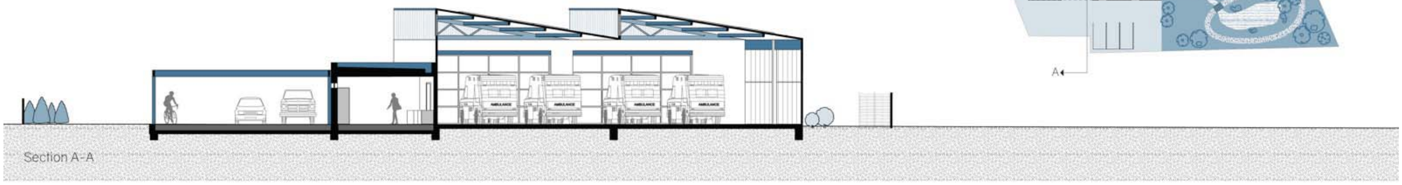
Future expansion

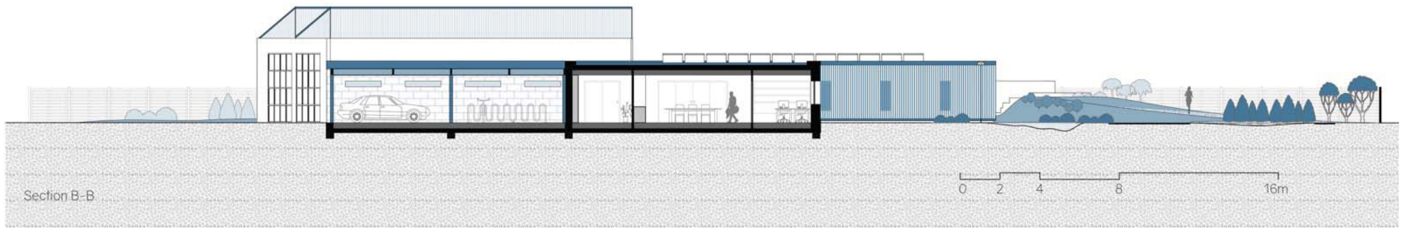


Connection to nature

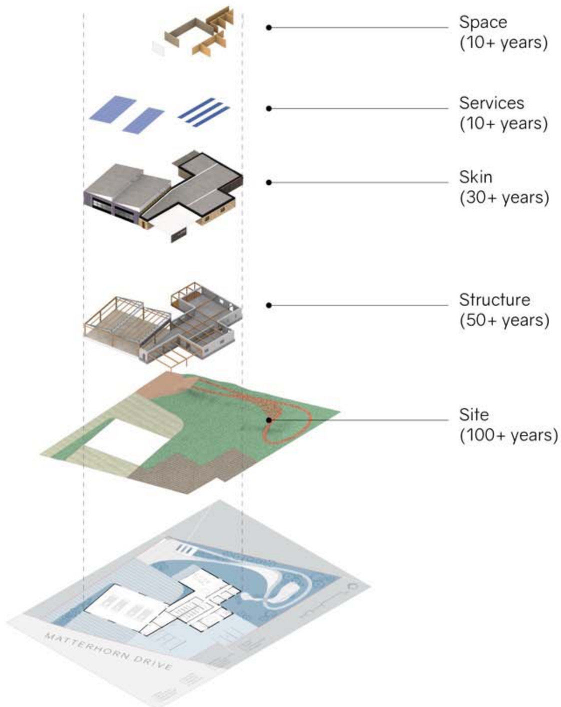




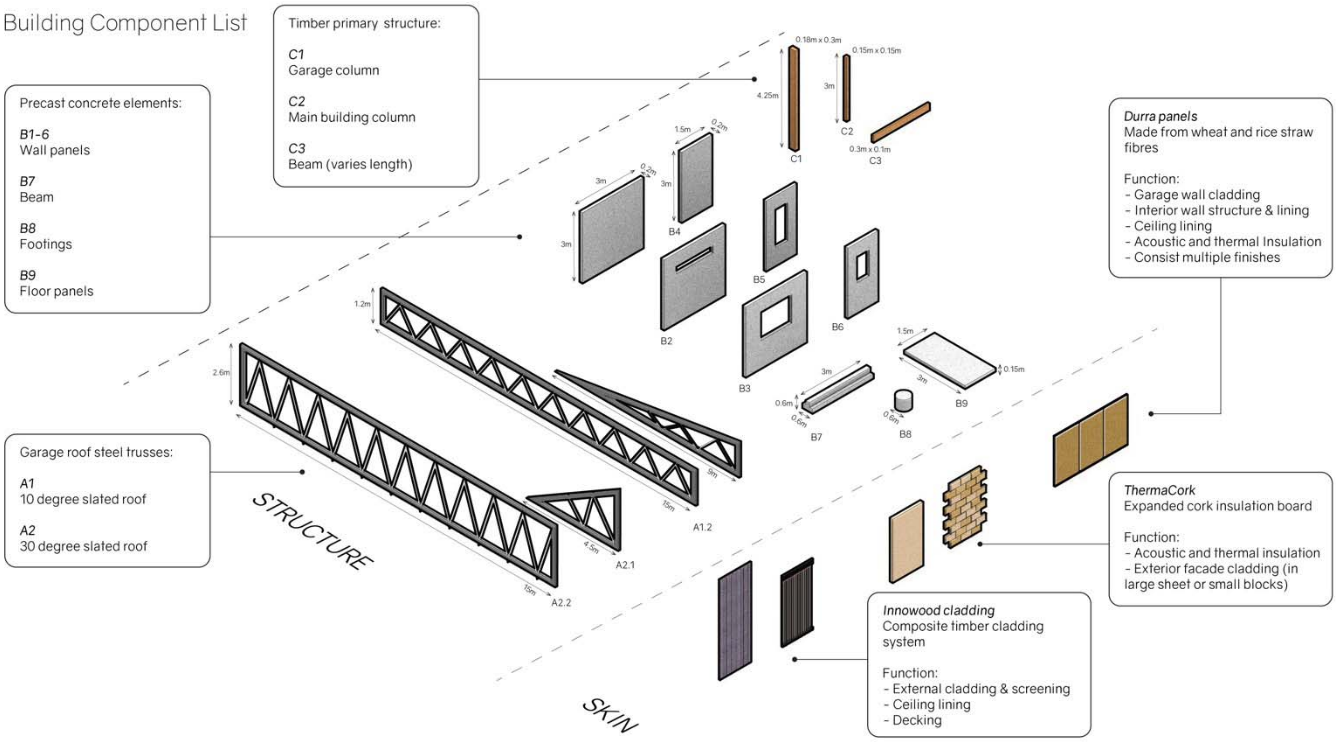


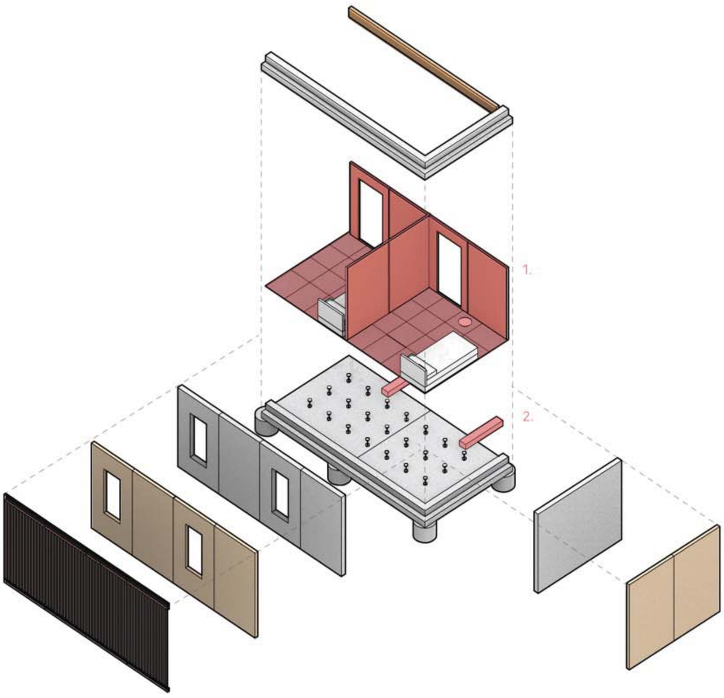


6 Building layers



Building Component List



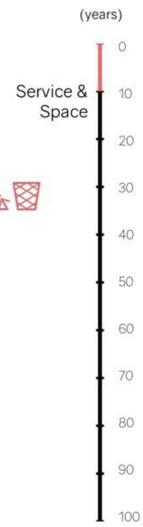


1. Durra panel

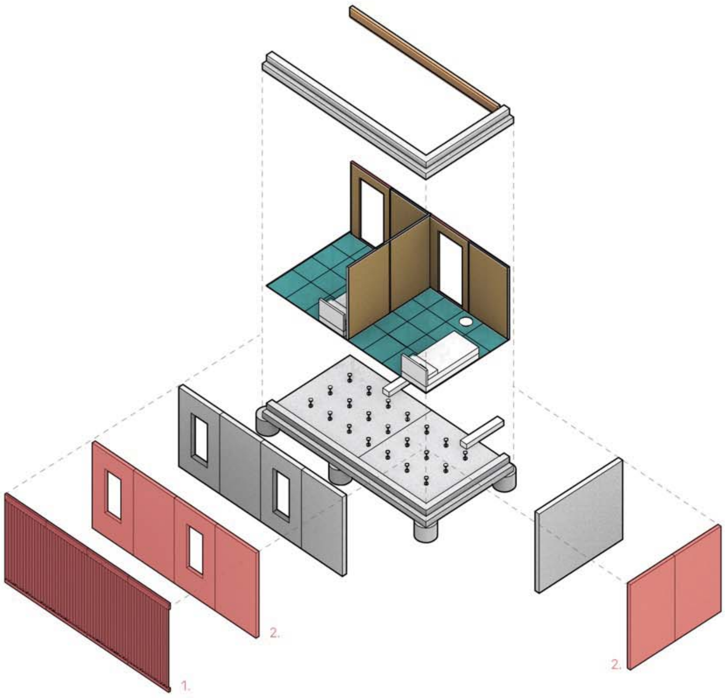
Durra panel is very durable and could be easily disassemble and reuse. At the end of the panels' life cycle, it could be further downcycle into mulch.

2. Underfoor Air Distribution system

Some component of the HVAC system can be recycled but some not.



Recycle · Reuse · Energy Recovery · Landfill

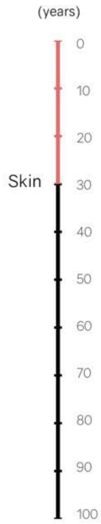


1. Innowood cladding

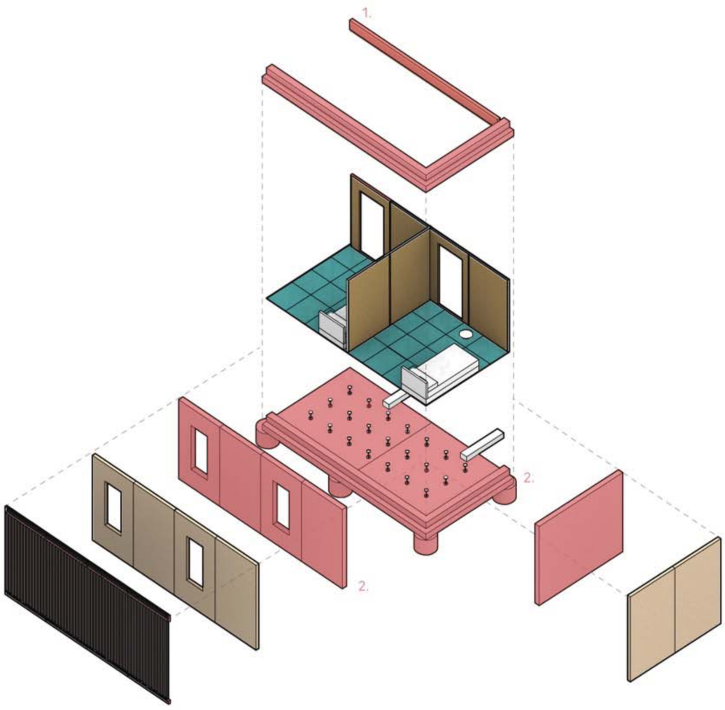
Innowood company has Recycling and Replacement Service where used Innowood product could be recycled back to create new Innowood profiles.

2. Thermacork cladding and insulation

Used expanded cork board could be used as biomass to produce energy.



Recycle Reuse Energy Recovery Landfill

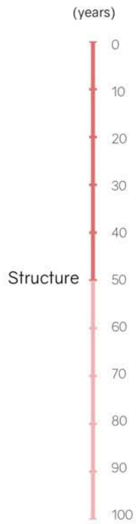


1. Glulam

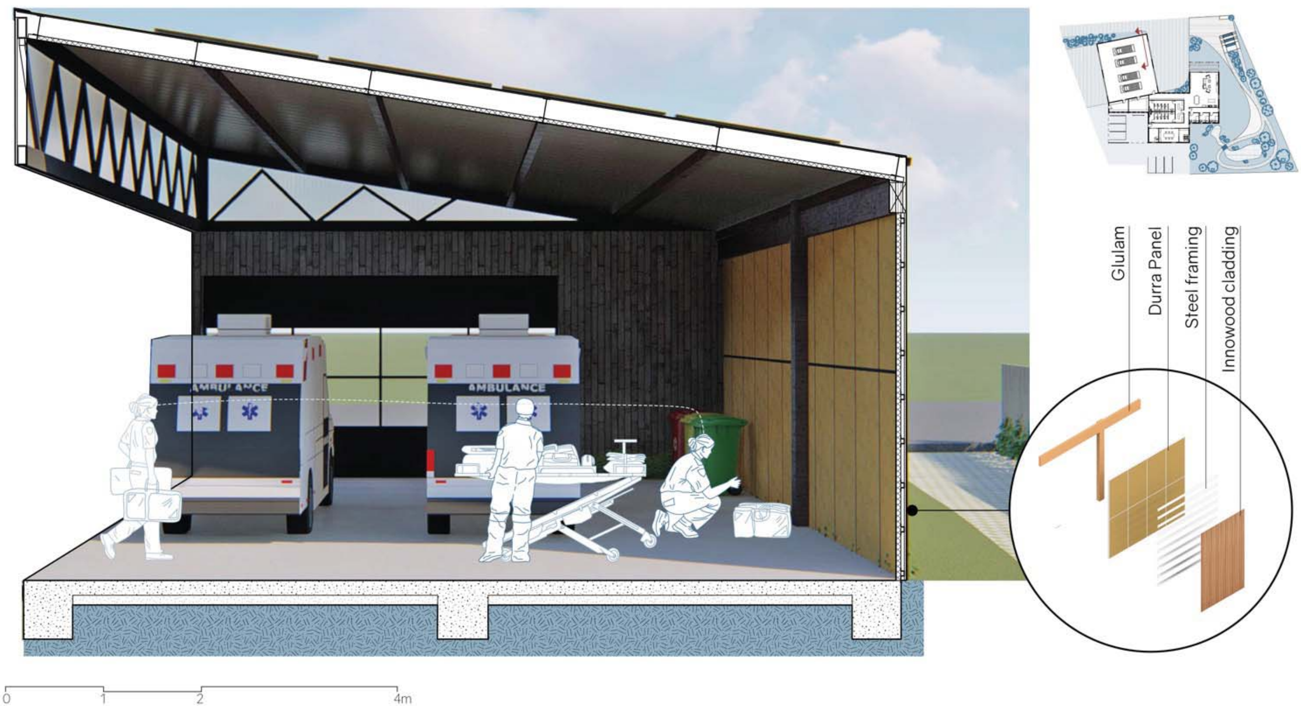
It is possible to direct reuse glulam for a second life which means it could glulam structure could be in use for 100 years. It could also be downcycled into wood chips and use as combustion to produce energy.

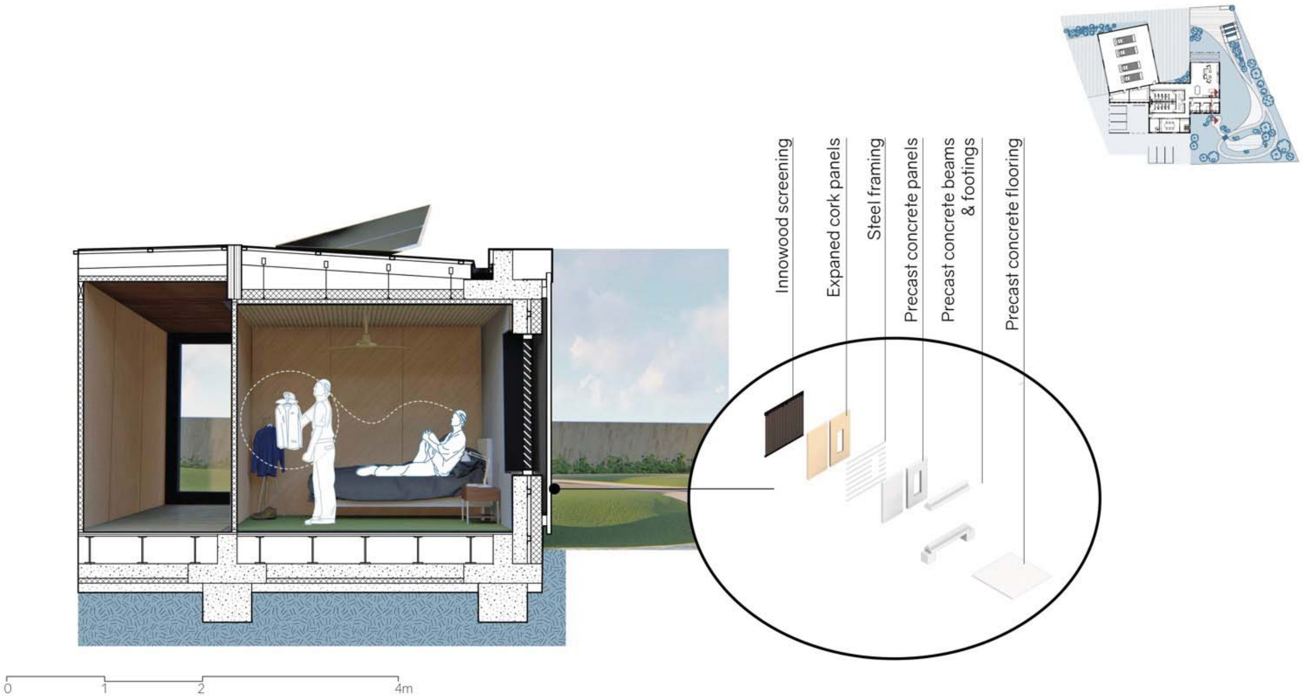
2. Precast concrete

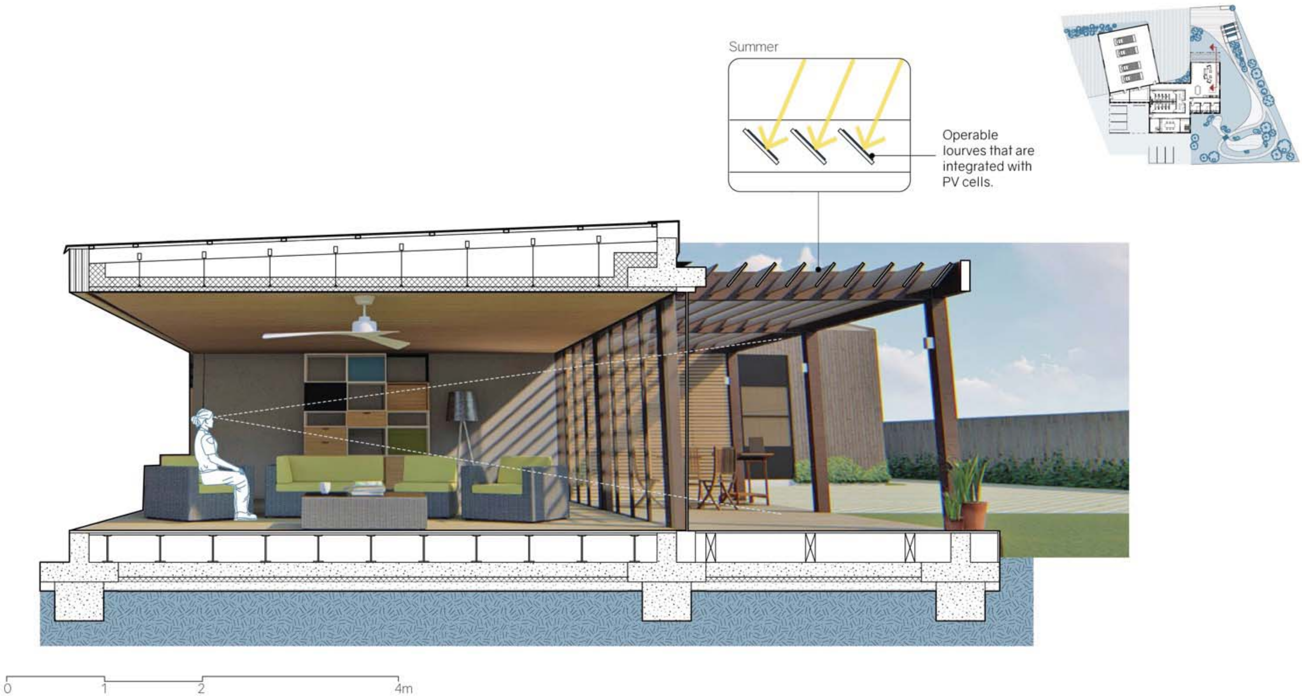
Concrete could last for 150 years, hence the best case scenario is to re-using all precast concrete panels and beams for 2 reuse cycle. Then be downcycled into aggregates.



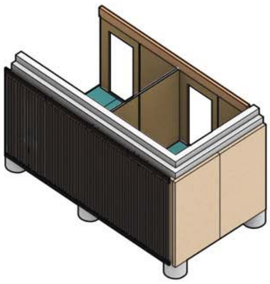
Recycle Reuse Energy Recovery Landfill


AMBULANCE
AMBULANCE
Glulam
Durra Panel
Steel framing
Innowood cladding
0
1
2
4m

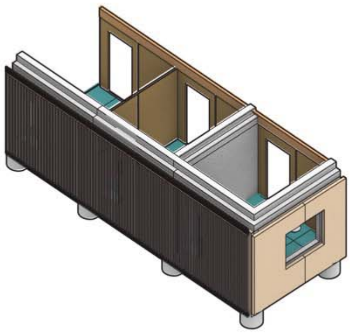

Innowood screening
Expaned cork panels
Steel framing
Precast concrete panels
Precast concrete beams & footings
Precast concrete flooring
0
1
2
4m



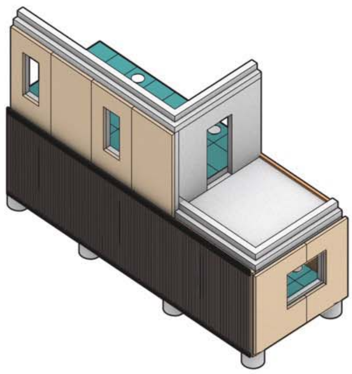
Future expansion



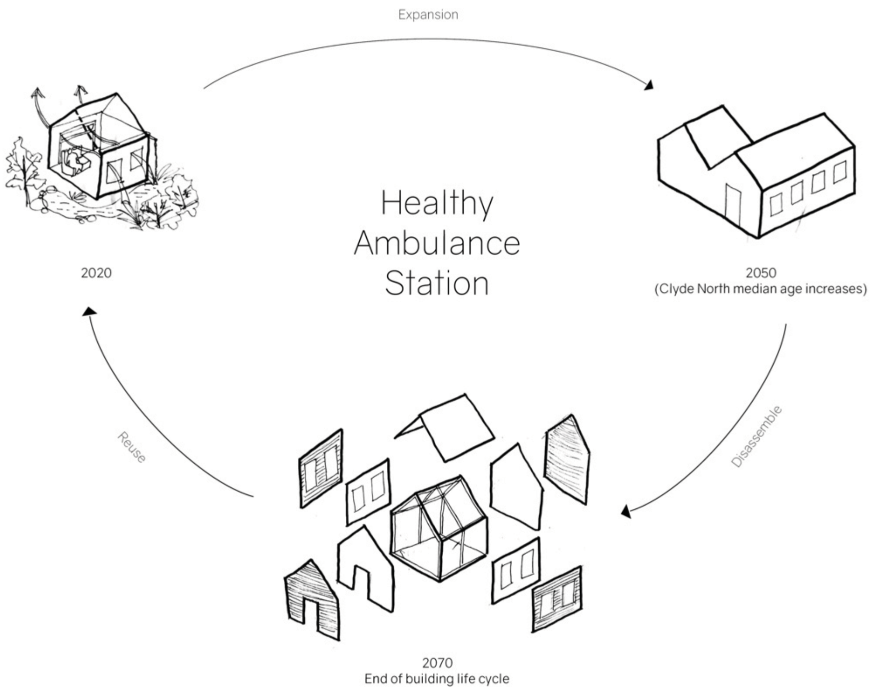
Initial design



Horizontal expansion

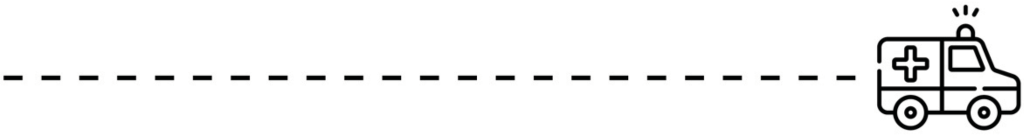


Vertical expansion



Next Steps:

- Optimising building components and their mechanical connections.
- Better understand embodied energy of less conventional building materials eg. cork insulation and Innowood products.
- Design and develop a building disassembly instruction.
- Develop a system of material passport.



2020.11.14

Agile Vivacity

Studio 7 E.R. Final Presentation

By Jason Leung

1.1 Project Key Issues

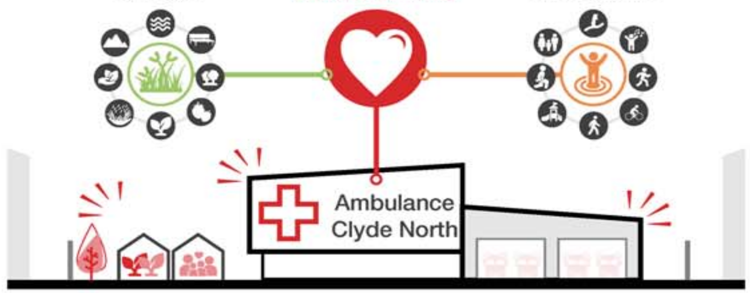
Agile Vivacity

Design Statement

This project is about enabling AV branches to adapt to the ever-changing world by designing with agility. A compact design is implemented which has put more emphasis on catering paramedics needs and the operation of the ambulance station. By using an agile and adaptive design strategy, it minimises the resources and energy consumption to fulfil paramedics routine requirement. In a long term, an open plan is designed to allow reconfiguration of spaces for respective functions which makes the internal layout highly flexible to meet the needs of users. This system can be easily replicated in all the Victorian Ambulance Branches.

Address 3 Focuses with 1 Design Concept

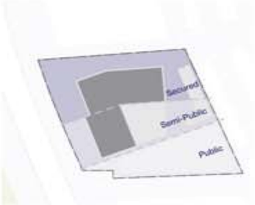
Design for Agility



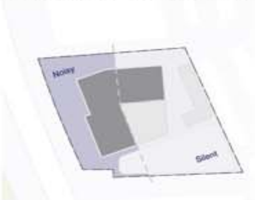
Park Ambulance Branch

1.2 Entrance Perspective

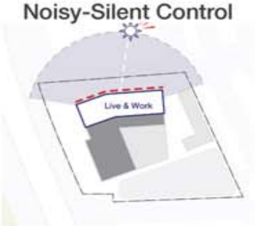
1.3 Master Planning



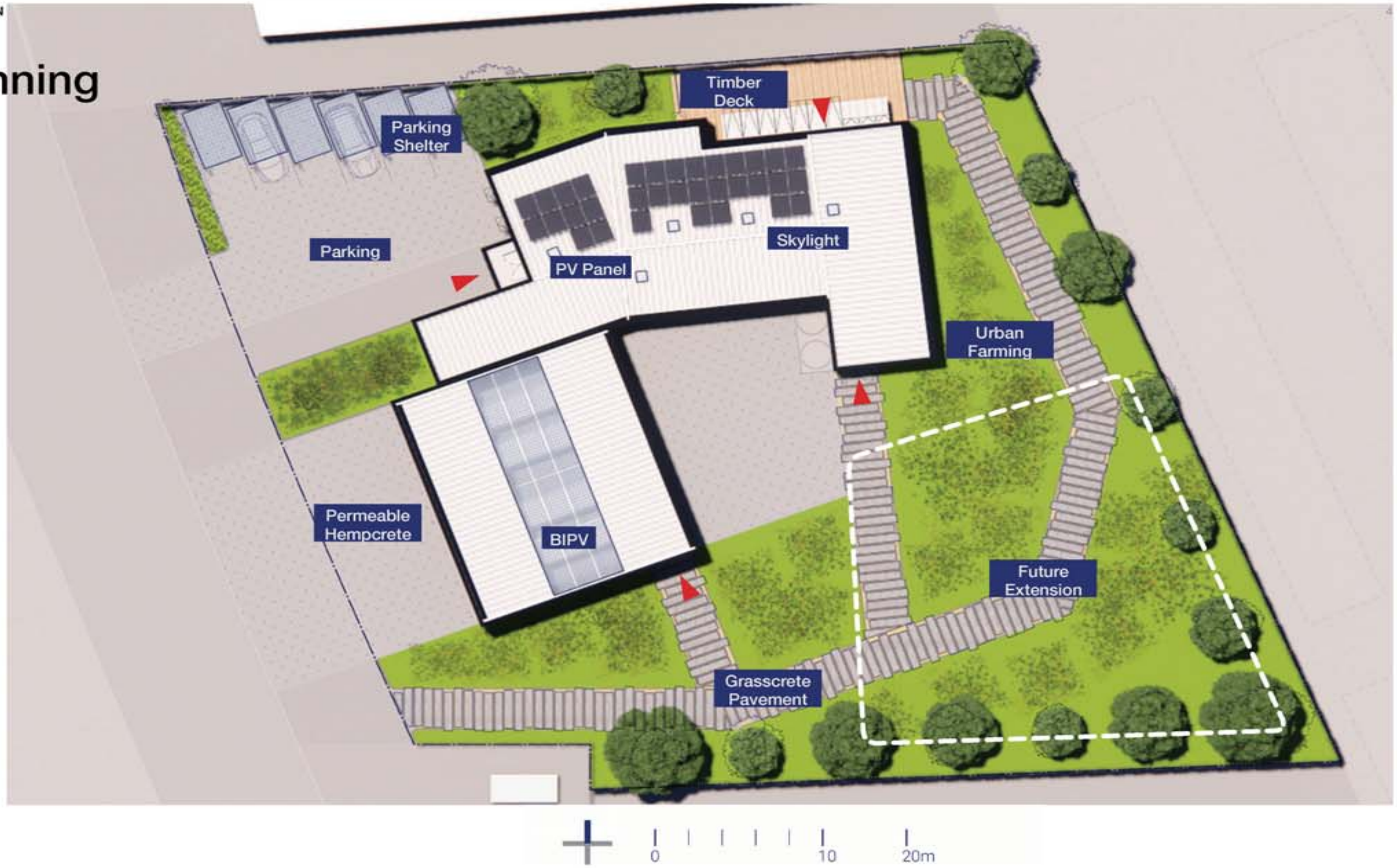
Public-Secured Control



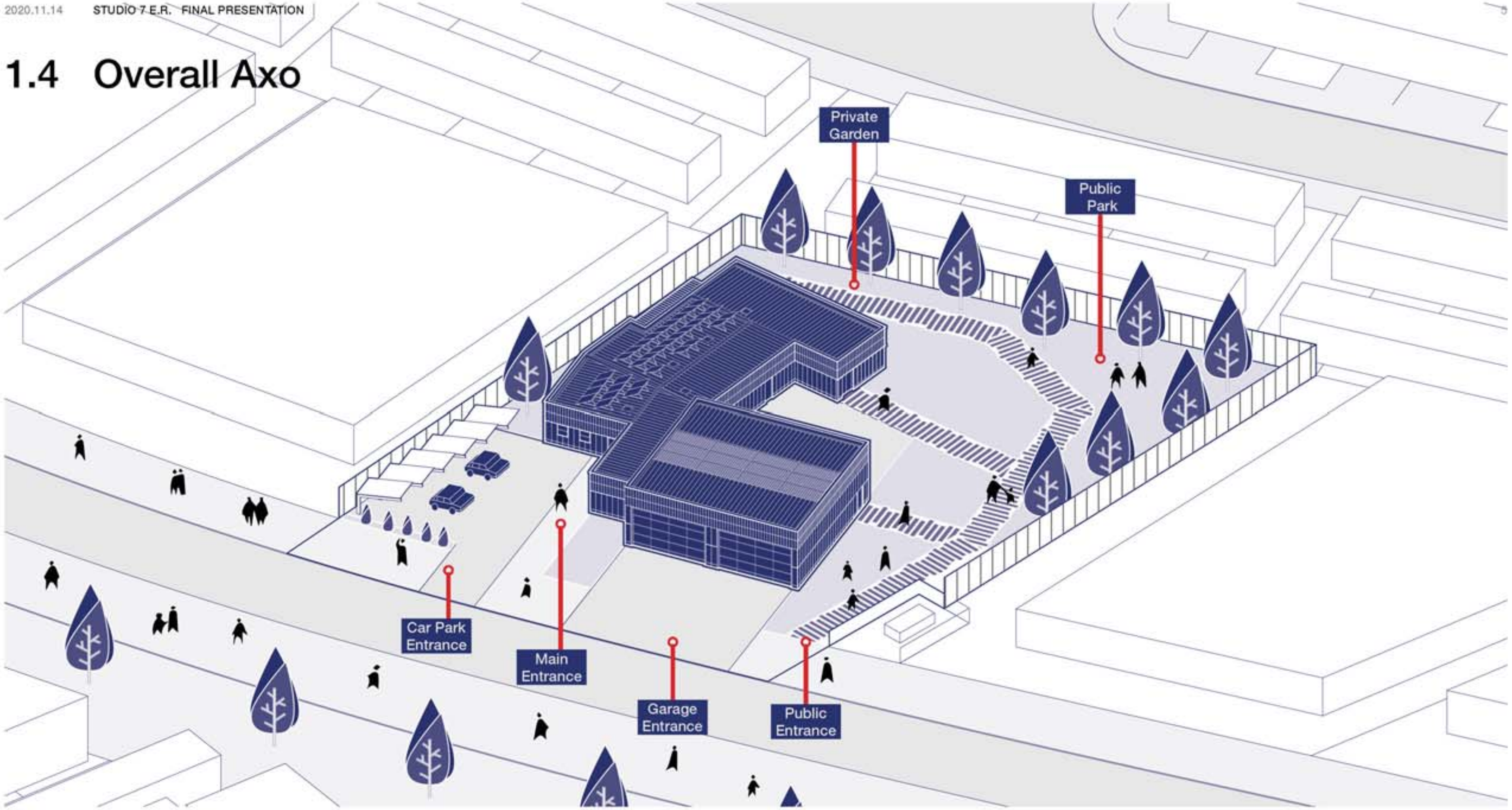
Noisy-Silent Control



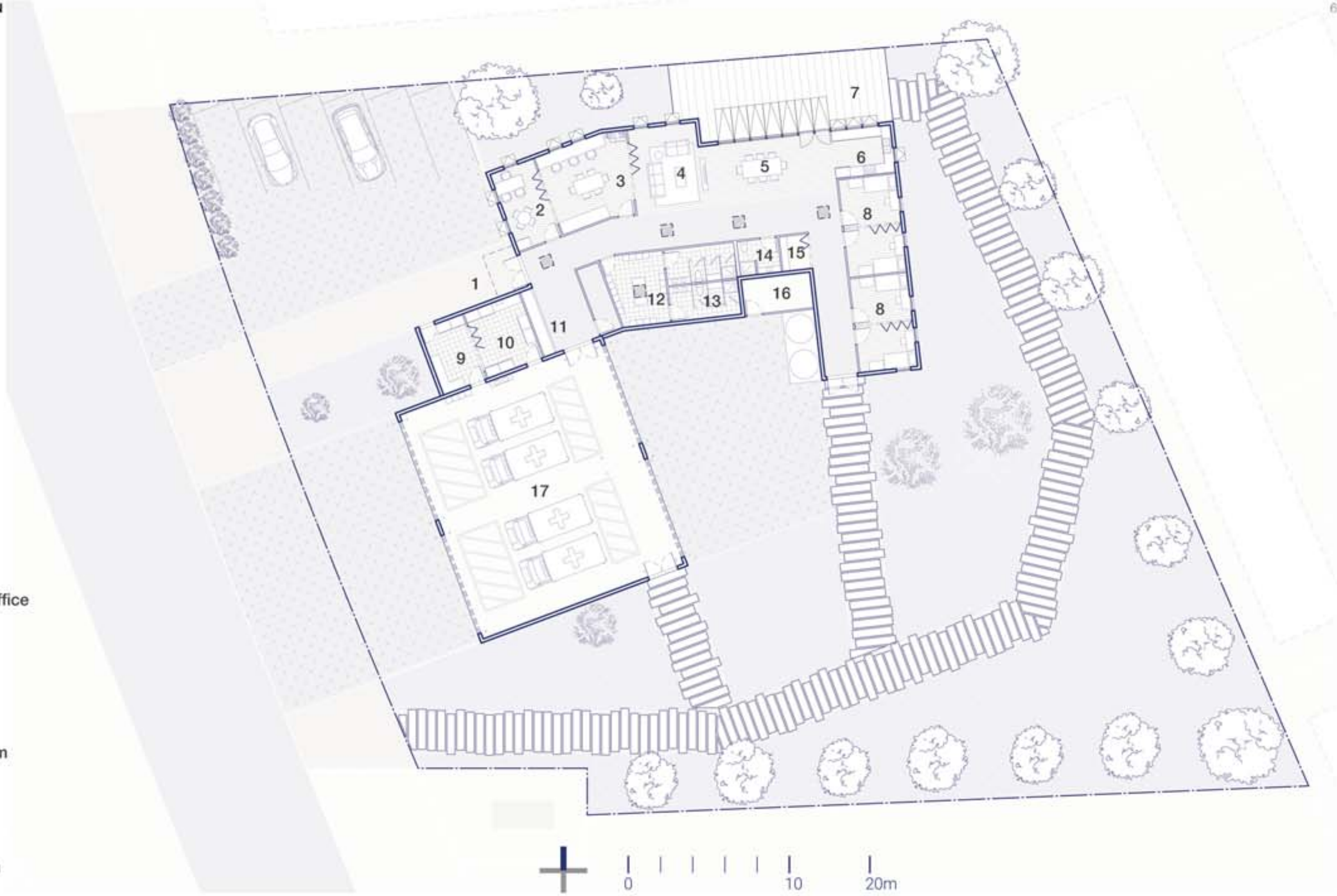
Sunlight Access



1.4 Overall Axo

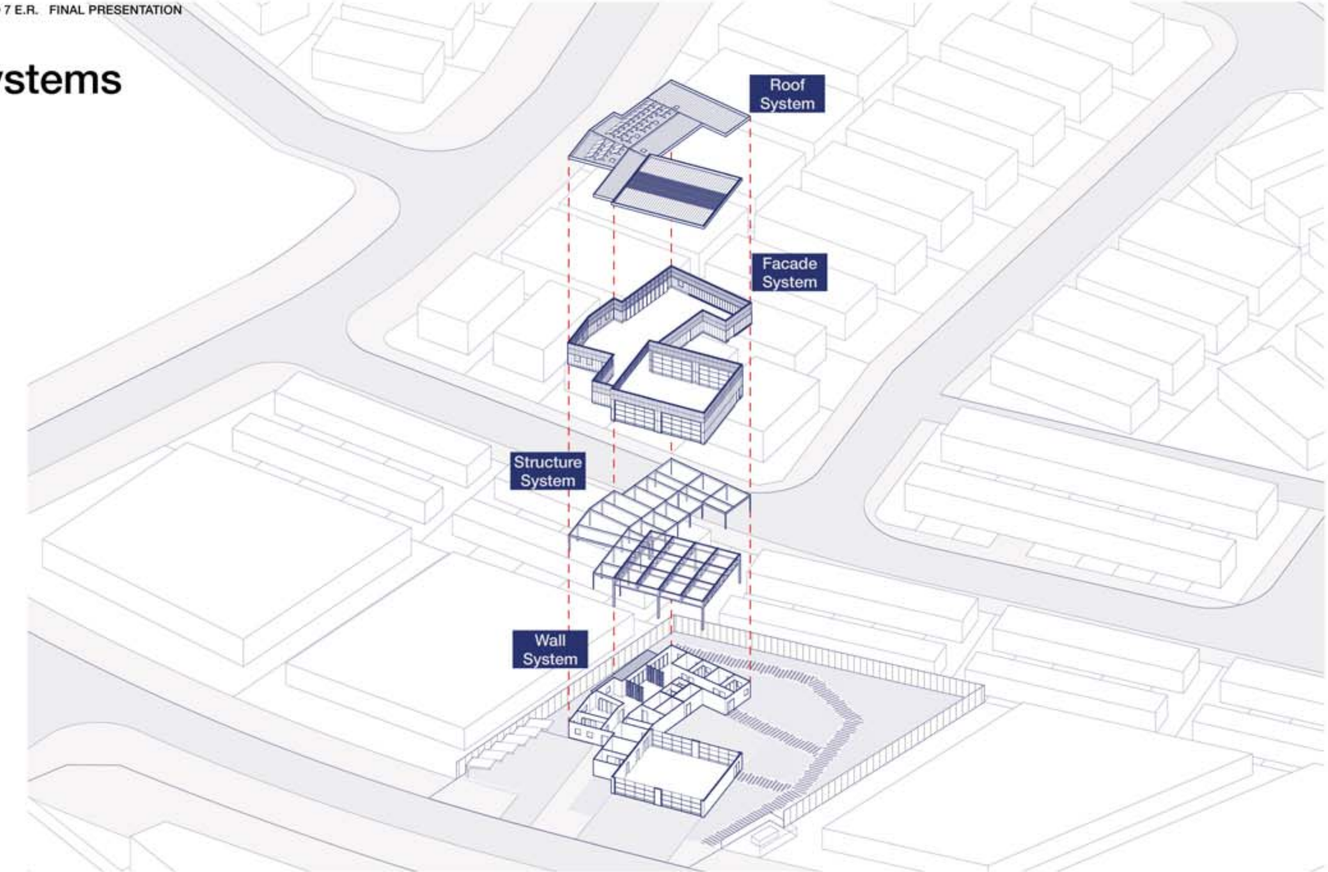


2.1 Floor Plan



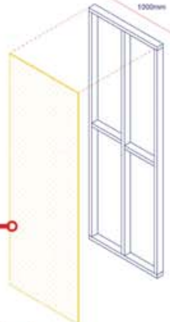
1. Entry
2. Team Manager's Office
3. Training Room
4. Living Space
5. Dining Space
6. Kitchen
7. Outdoor Deck
8. Rest Rooms
9. Delivery Room
10. Medical Storeroom
11. Charging Station
12. Lockers
13. Vanity Room
14. DDA Toilet
15. Store Room
16. Mechanical Room
17. Garage

2.2 Systems



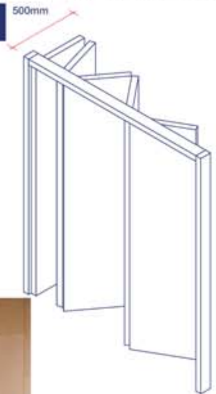
2.3 Wall & Facade System

Panel & Stud Wall



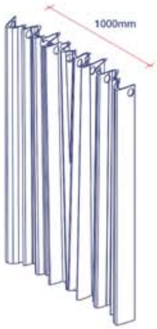
Recycled Cork

Operable Panel

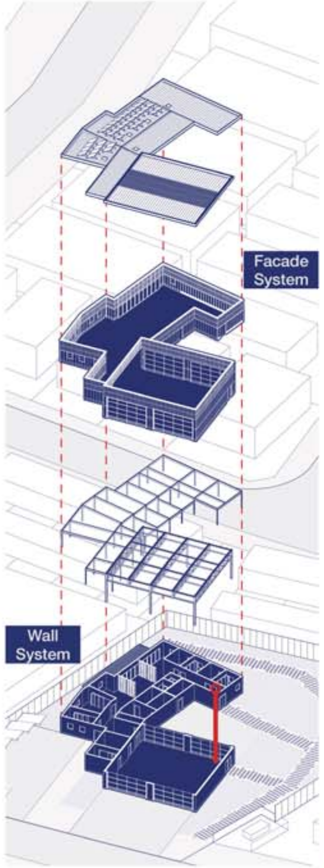


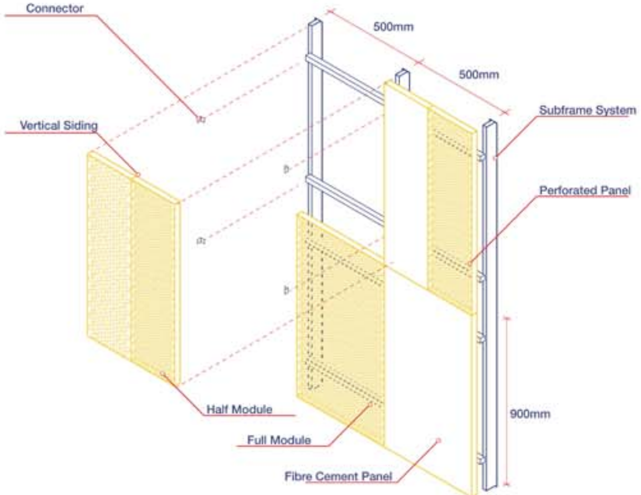
Birch Plywood

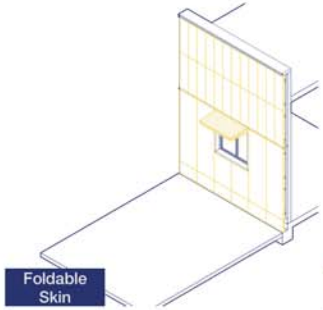
Curtain Partition



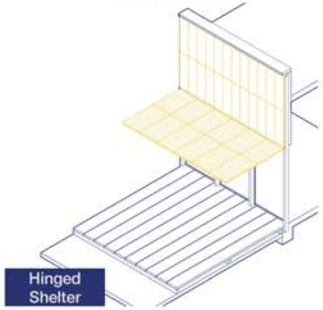
Fiberglass Cloth





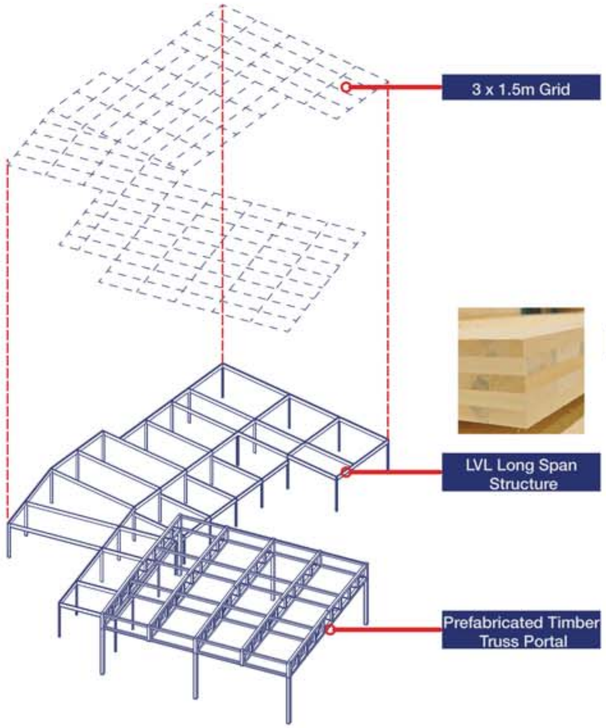


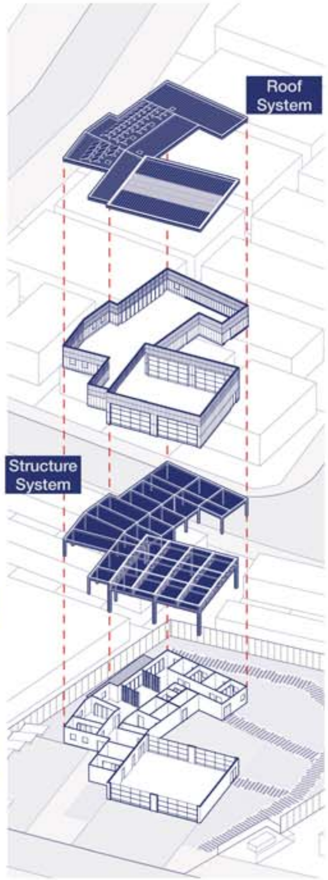
Foldable Skin

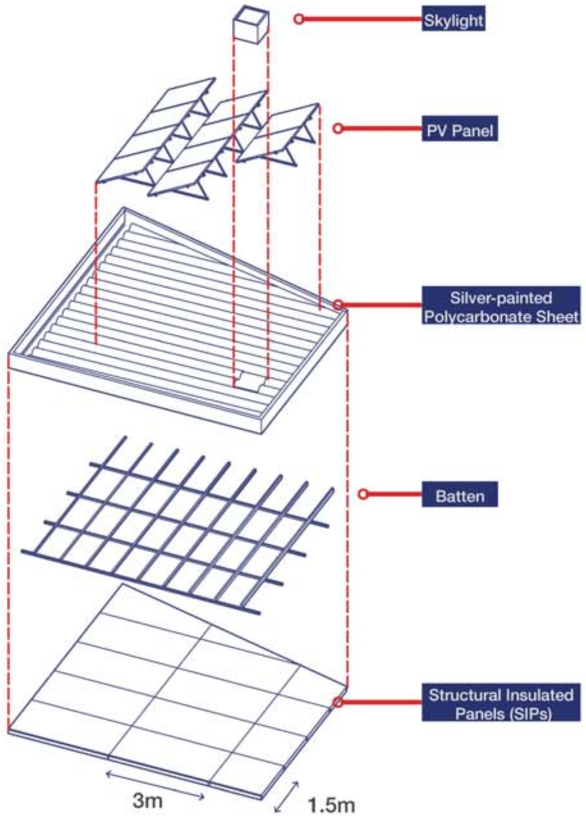


Hinged Shelter

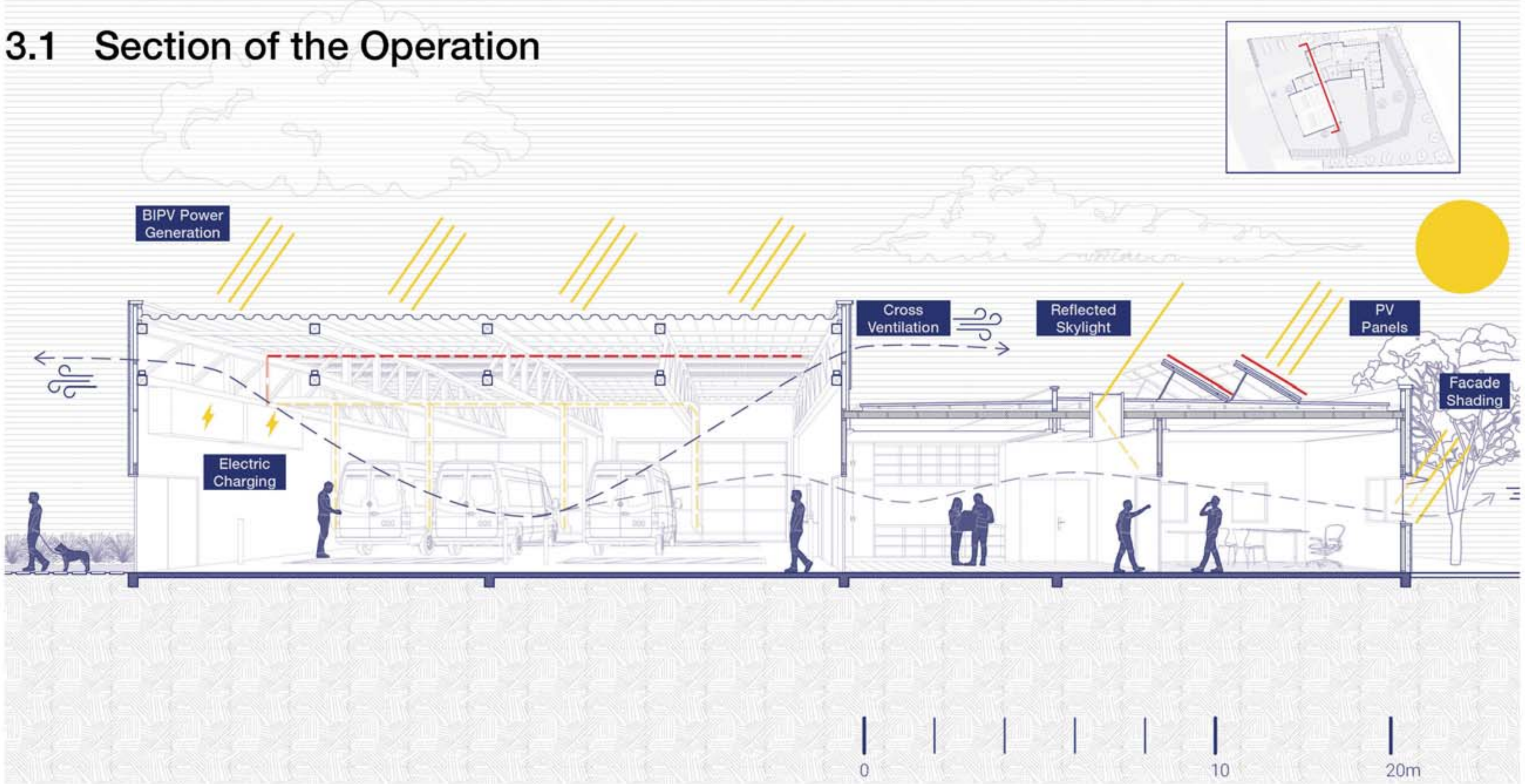
2.3 Structure & Roof System



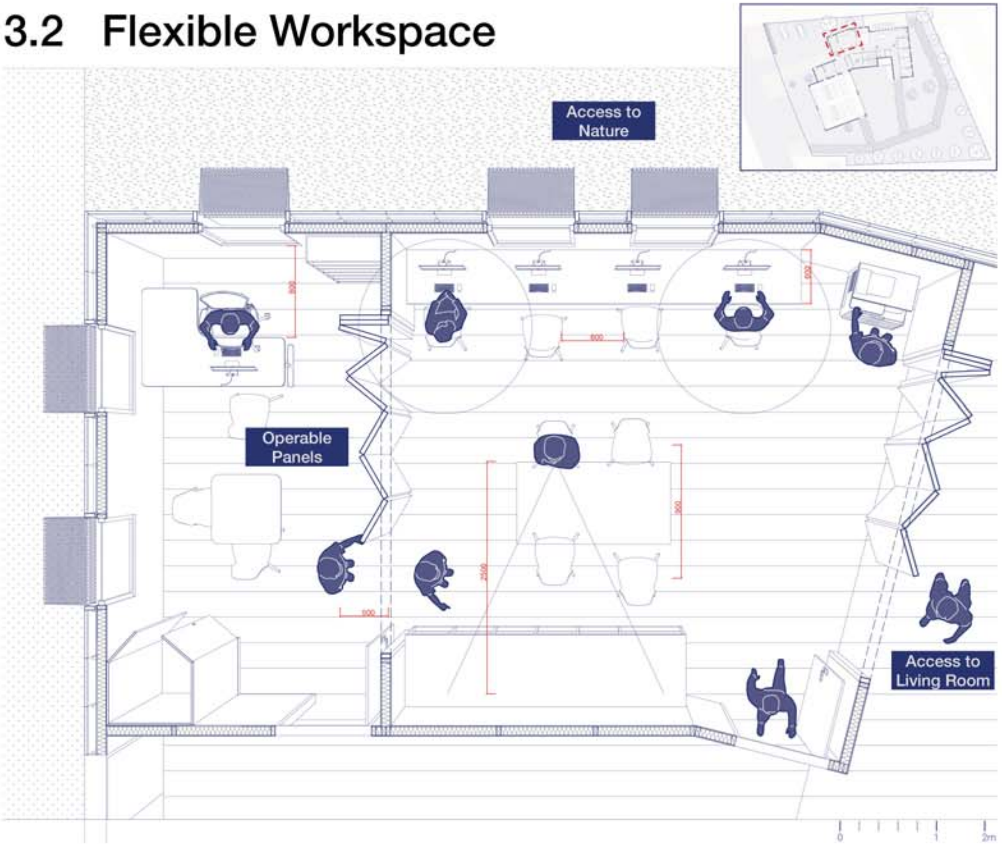




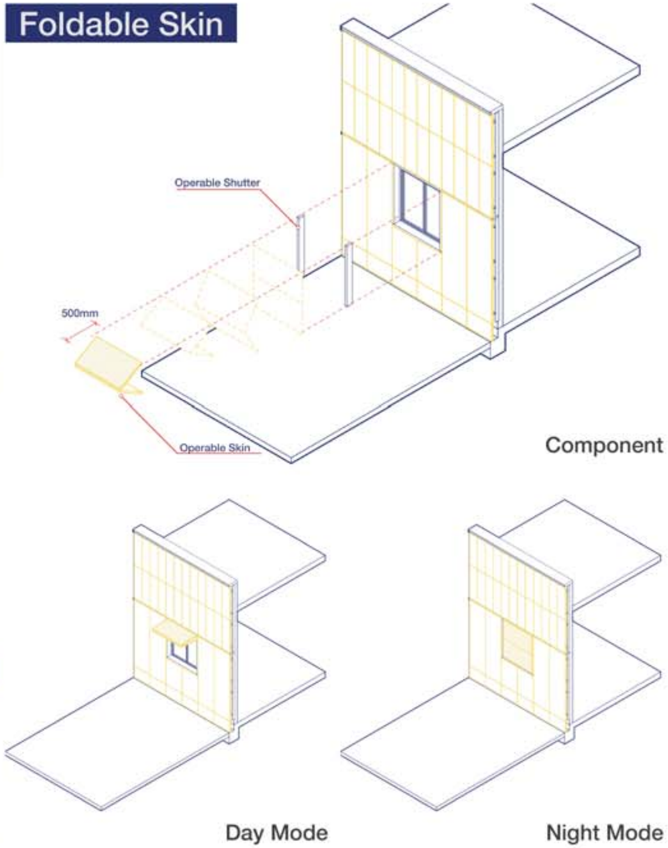
3.1 Section of the Operation



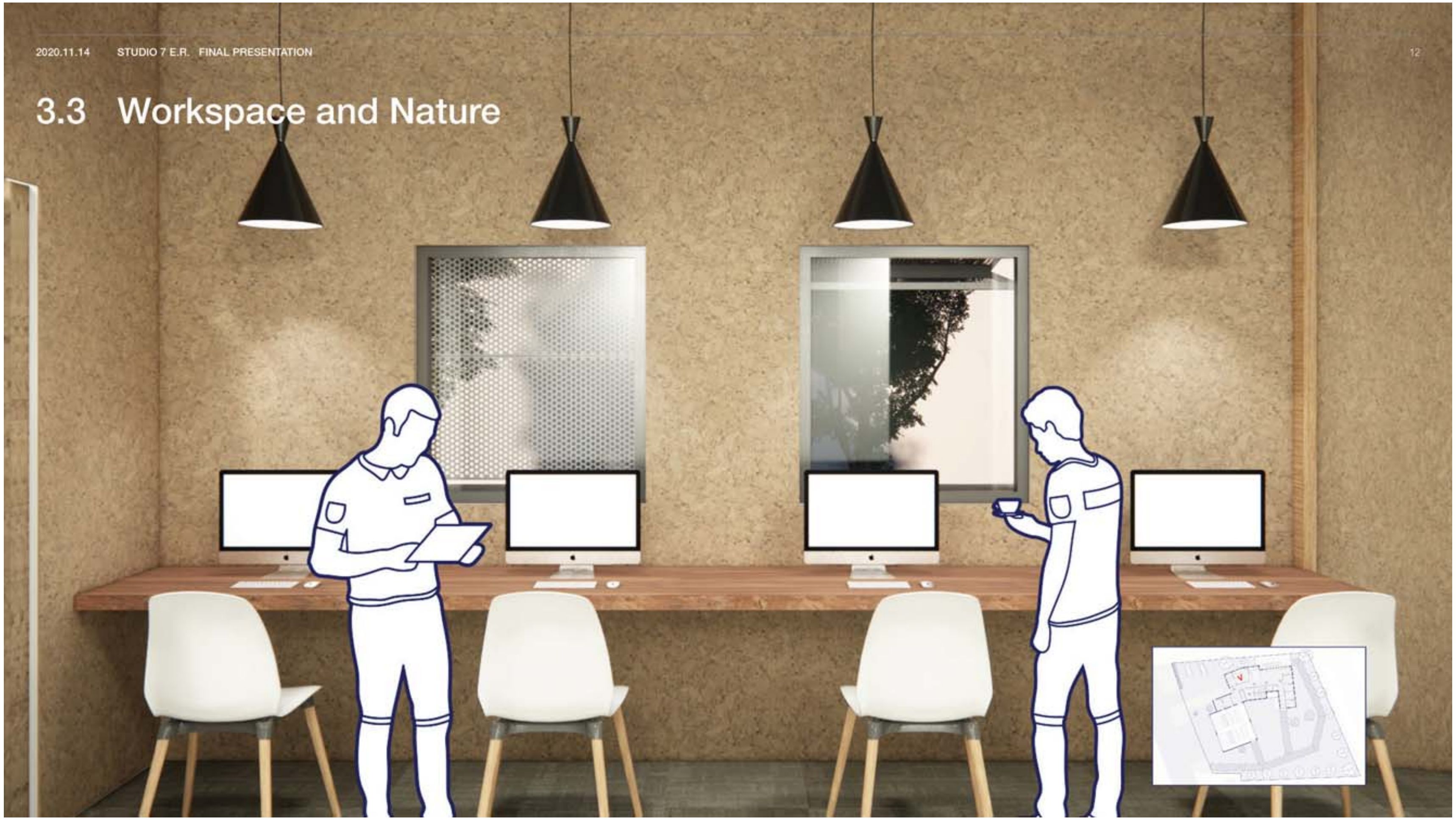
3.2 Flexible Workspace



Foldable Skin

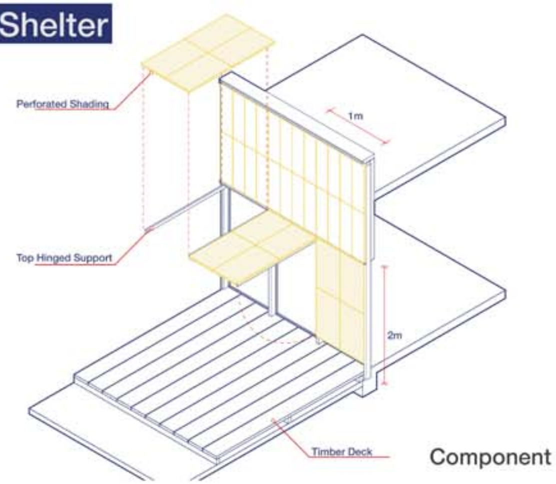


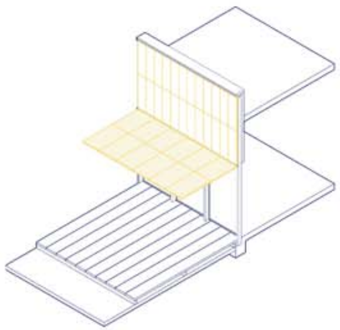
3.3 Workspace and Nature



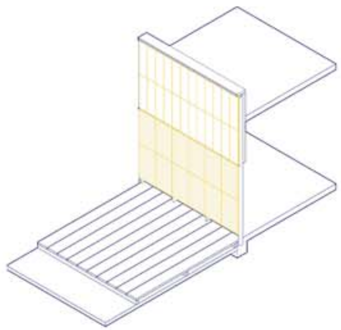
3.5 Outdoor & Indoor

Hinged Shelter





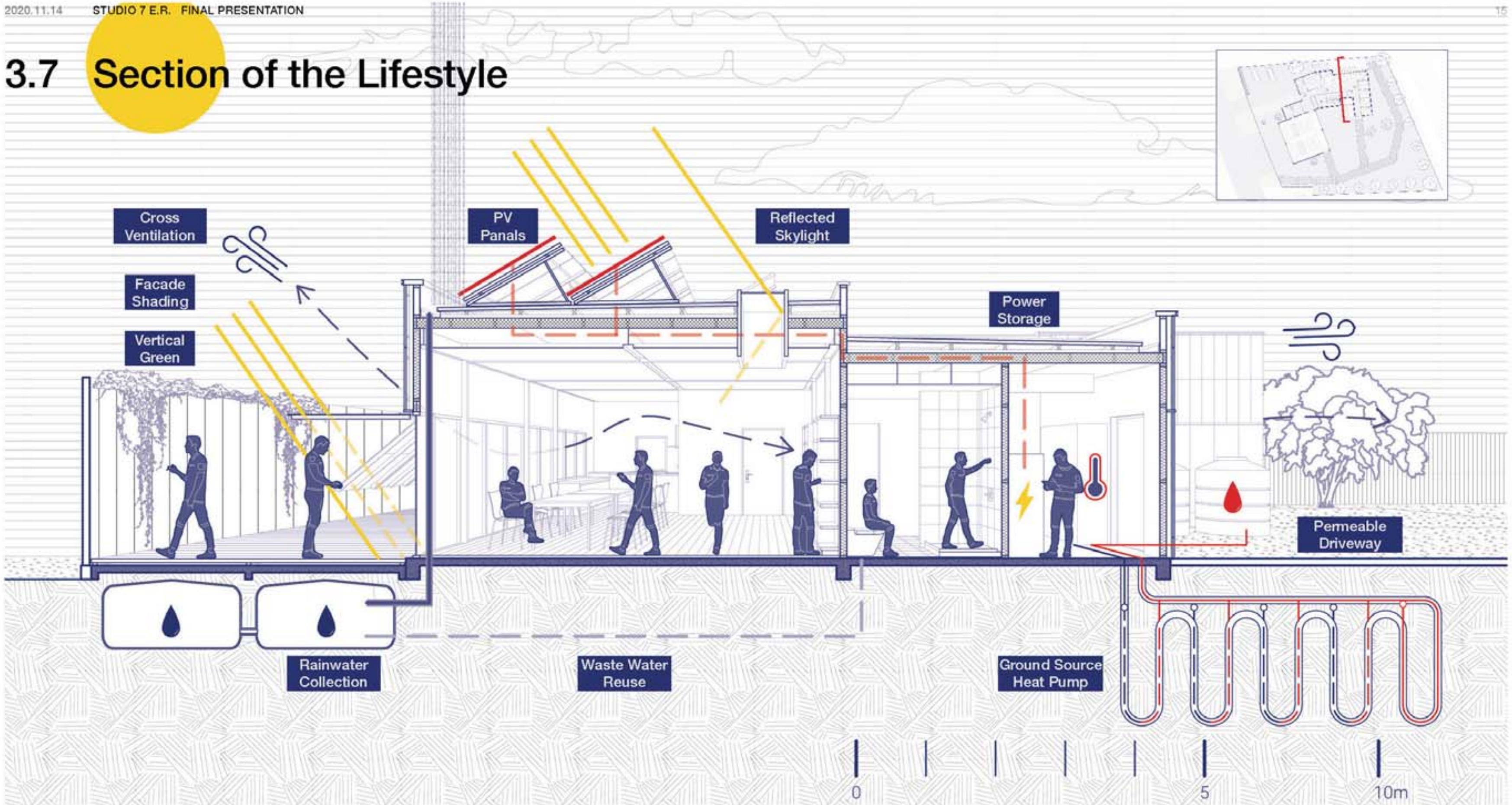
Summer Mode



Winter Mode

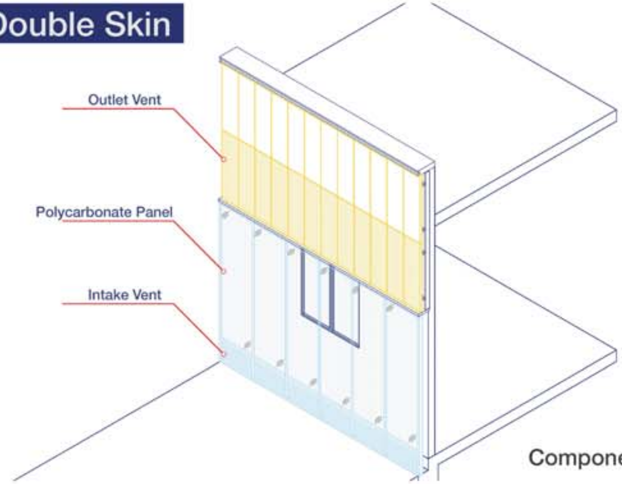
3.6 Outdoor Lifestyle

3.7 Section of the Lifestyle

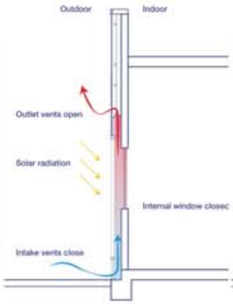


3.8 Rehabilitation & Fitness

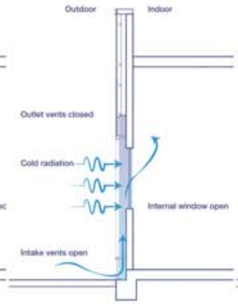
Double Skin



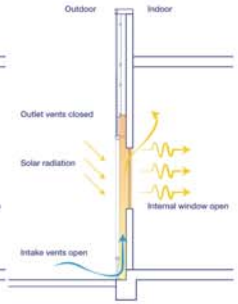
Component



Summer Daytime



Summer Nighttime



Winter Daytime

3.9 Garden Living

POST PANDEMIC:

THE FUTURE OF THE AMBULANCE BRANCH AFTER COVID-19

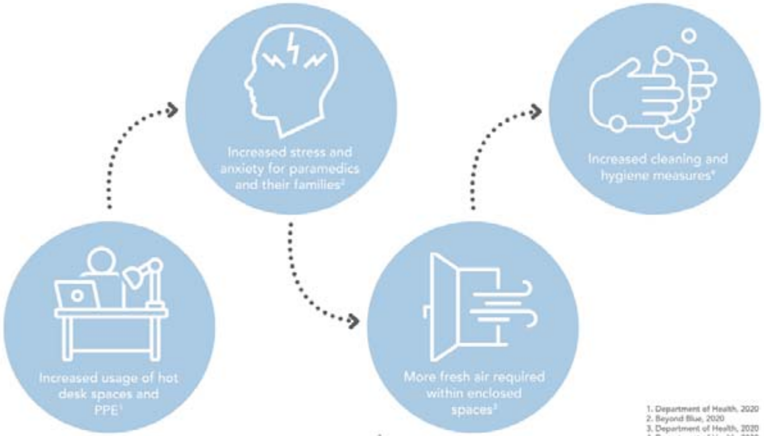
ROBYN MACKENZIE - 914559
STUDIO D - SEM 2, 2020
STUDIO 7
ASSIGNMENT 2

CONCEPT

What will a zero carbon ambulance branch look like post Covid-19?

Currently the pandemic is impacting both the functional requirements of the ambulance branch and the mental health of paramedics. In addition to these initial struggles, post-pandemic architecture will change to reflect learned behaviors about cleanliness and virus mitigation. My design aims to facilitate a dialogue between post-pandemic design and carbon zero strategies to create a healthy and sustainable ambulance branch. The design includes automatic ventilation strategies that create safer internal environments and reduces operational energy usage. In addition, several spatial changes will be implemented such as larger rooms for social distancing, disinfecting stations, and better quality outdoor spaces to encourage paramedics to spend time outside.

CURRENT IMPACT OF COVID-19

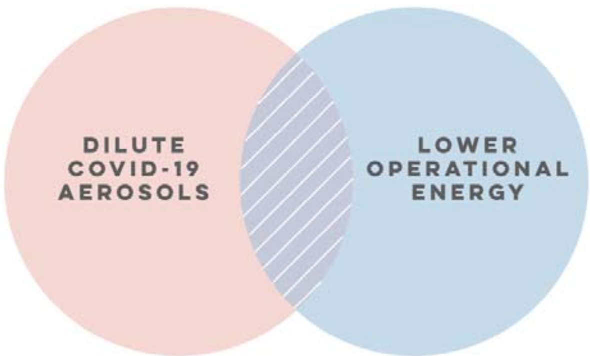


1. Department of Health, 2020
2. Beyond Blue, 2020
3. Department of Health, 2020
4. Department of Health, 2020

FUTURE IMPACT OF COVID-19

5. Vitra International, 2020

NATURAL VENTILATION OVERLAP

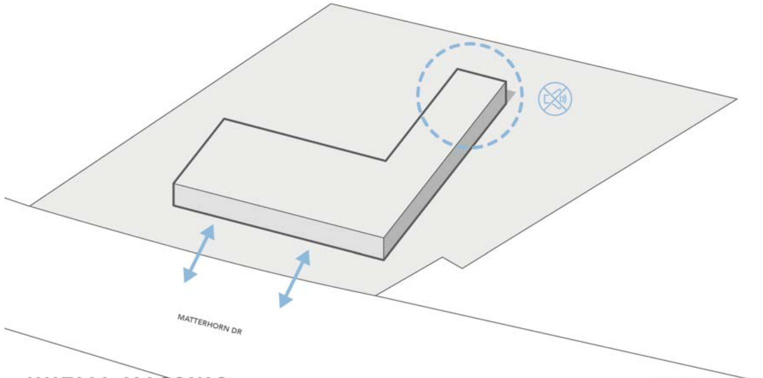


DESIGN SOLUTIONS

01 Spatial changes to allow for social distancing, disinfecting stations, and outdoor decks

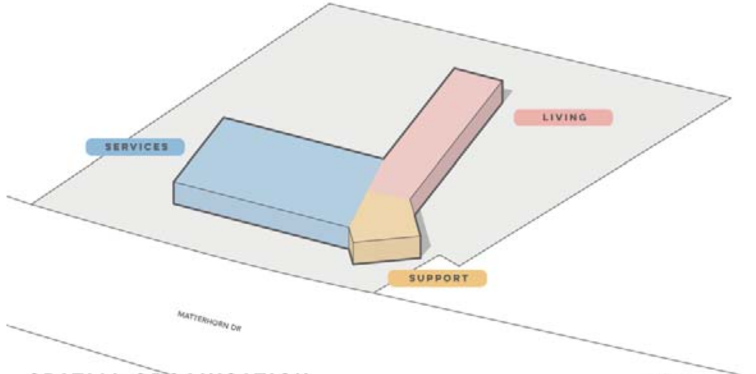
02 Mental health facilities for paramedics and the community

03 Increased reliance on natural ventilation systems



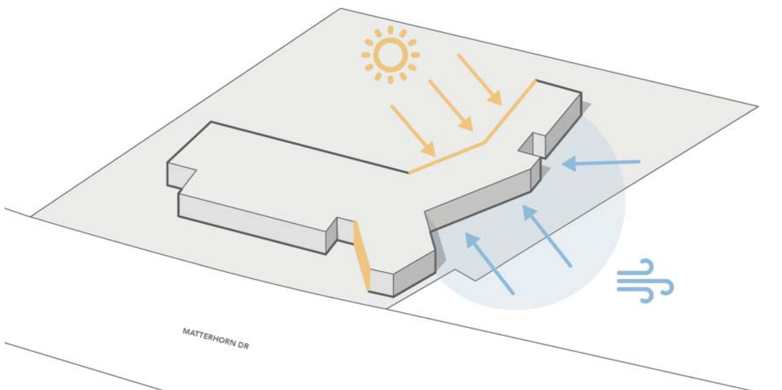
INITIAL MASSING

7



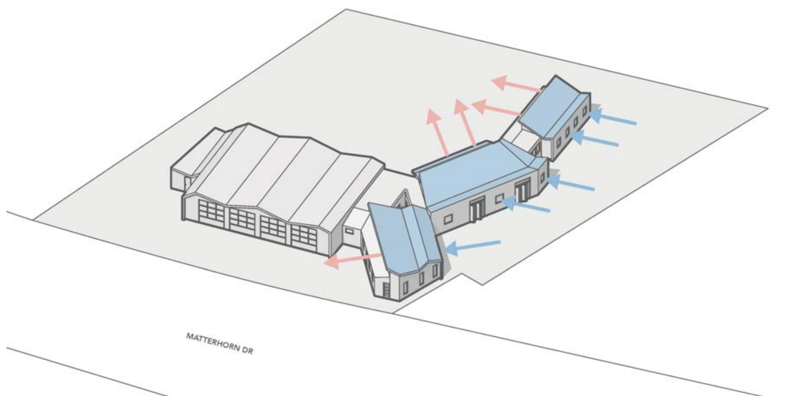
SPATIAL ORGANISATION

8



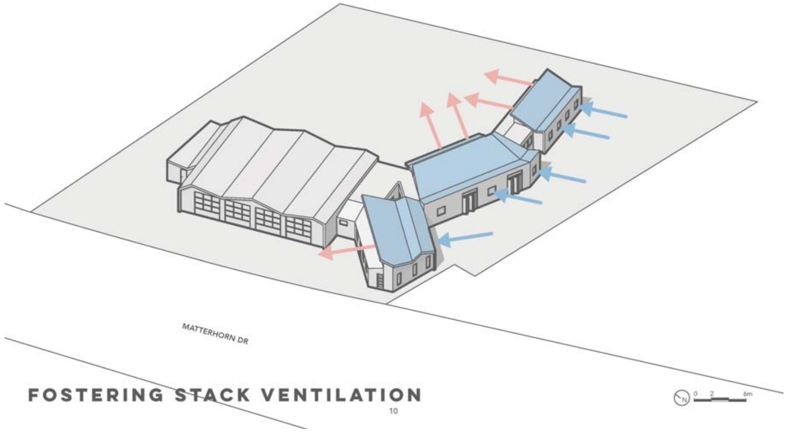
OPTIMISATION FOR SUN AND WIND

9



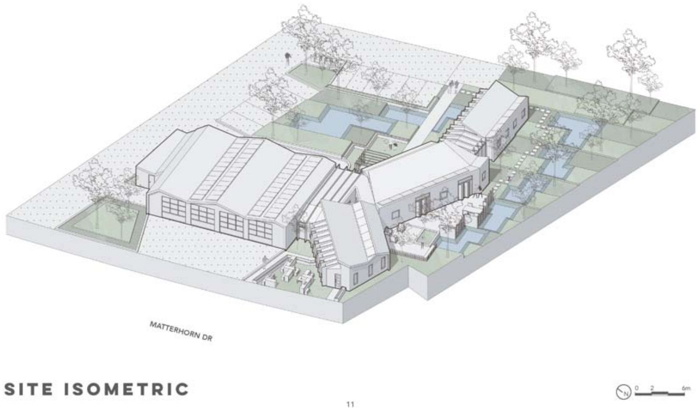
FOSTERING STACK VENTILATION

10



FOSTERING STACK VENTILATION

10



SITE ISOMETRIC

11

SITE PLAN

12

GROUND FLOOR PLAN

16

CROSS VENTILATION

0 0.75 2.25m

PASSIVE OPERATION

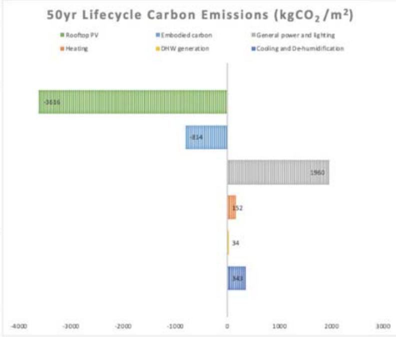
Specific building characteristics with reference to the treated floor area

	Treated floor area	m²	263.0
Space heating	Heating demand	kWh/(m²a)	5
	Heating load	W/m²	8
Space cooling	Cooling & dehum. demand	kWh/(m²a)	-
	Cooling load	W/m²	-
	Frequency of overheating (> 25 °C)	%	1
	Frequency of excessively high humidity (> 12 g/kg)	%	0
Airtightness	Pressurization test result n_{50}	1/h	0.6
Non-renewable Primary Energy (PE)	PE demand	kWh/(m²a)	
Primary Energy Renewable (PER)	PER demand	kWh/(m²a)	65
	Generation of renewable energy (in relation to pro-jected building footprint area)	kWh/(m²a)	76

LIFECYCLE CARBON EMISSIONS

i-Hub Integrated Design Studio - Diamond Creek Base Case Performance 50yr Life-Cycle Carbon Emissions

	Victorian Grid Electricity Carbon Factor	0.98	$kgCO_2$/kWh electricity	
	Lifecycle period	50	years	
PHPP Inputs	**Building Energy Demand:**	**Annual Electrical Consumption (kWh/m²)**	**Annual Carbon ($kgCO_2/m^2$)**	**Lifecycle Carbon ($kgCO_2/m^2$)**
	Cooling and De-humidification	7	7	343
	Heating	3	3	152
	DHW generation	1	1	34
	General power and lighting	40	39	1960
	Building Energy Generation:	**Annual Electrical Generation (kWh/m²)**	**Annual Carbon Reduction ($kgCO_2/m^2$)**	**Equivalent Carbon Reduction ($kgCO_2/m^2$)**
	Rooftop PV	74	-72	-3616
e-Tool Inputs		**Global Warming Potential, GWP (CO_2 eq. /m² yr)**	**Operational Energy GWP (CO_2 eq. /m² yr)**	**Embodied Lifecycle Carbon ($kgCO_2/m^2$)**
	Embodied carbon	10	26	-814
			Total Lifecycle Carbon ($kgCO_2$/m	1675
			Gross Lifecycle Carbon ($kgCO_2$/n	-1941



SUSTAINABILITY STRATEGY

To achieve low heating and cooling demands the building is angled to maximise the area of north facing windows. Above these windows 500mm shading is installed which allows for passive heating in winter and shading in summer. The building has polished concrete flooring as thermal mass which helps to keep the internal temperature comfortable year round. A continuous line of high-performance insulation is included in the building to prevent heat loss through the roof, walls, and slab. In addition, double glazed low-e windows provide good thermal properties and help to regulate heat loss through the building. Clerestory windows are installed along the northern facade to help facilitate stack ventilation thus helping to move warm air out of the building in summer. The clerestory windows are connected to the automatic natural ventilation system.

Automatic natural ventilation is employed to passively regulate the internal temperature of the building. Sensors are located inside and outside the building which monitor air temperature, wind strength and direction, rain, humidity, and CO_2 levels. These sensors connect to the building management system (BMS) which processes the inputs and outputs a solution such as activating motors on windows or turning on the heat recovery ventilation (HRV) units. This system is beneficial as windows are only opened and HRV systems are only turned on when necessary. This creates greater efficiency and lowers the operational energy usage of the building. In addition, this system is automatic so paramedics do not need to worry about manually turning systems off or on as they are called out to jobs. As security can be an issue, louvers are utilized as they reduce the risk of break-ins and therefore can be operated at night or when the branch is empty.

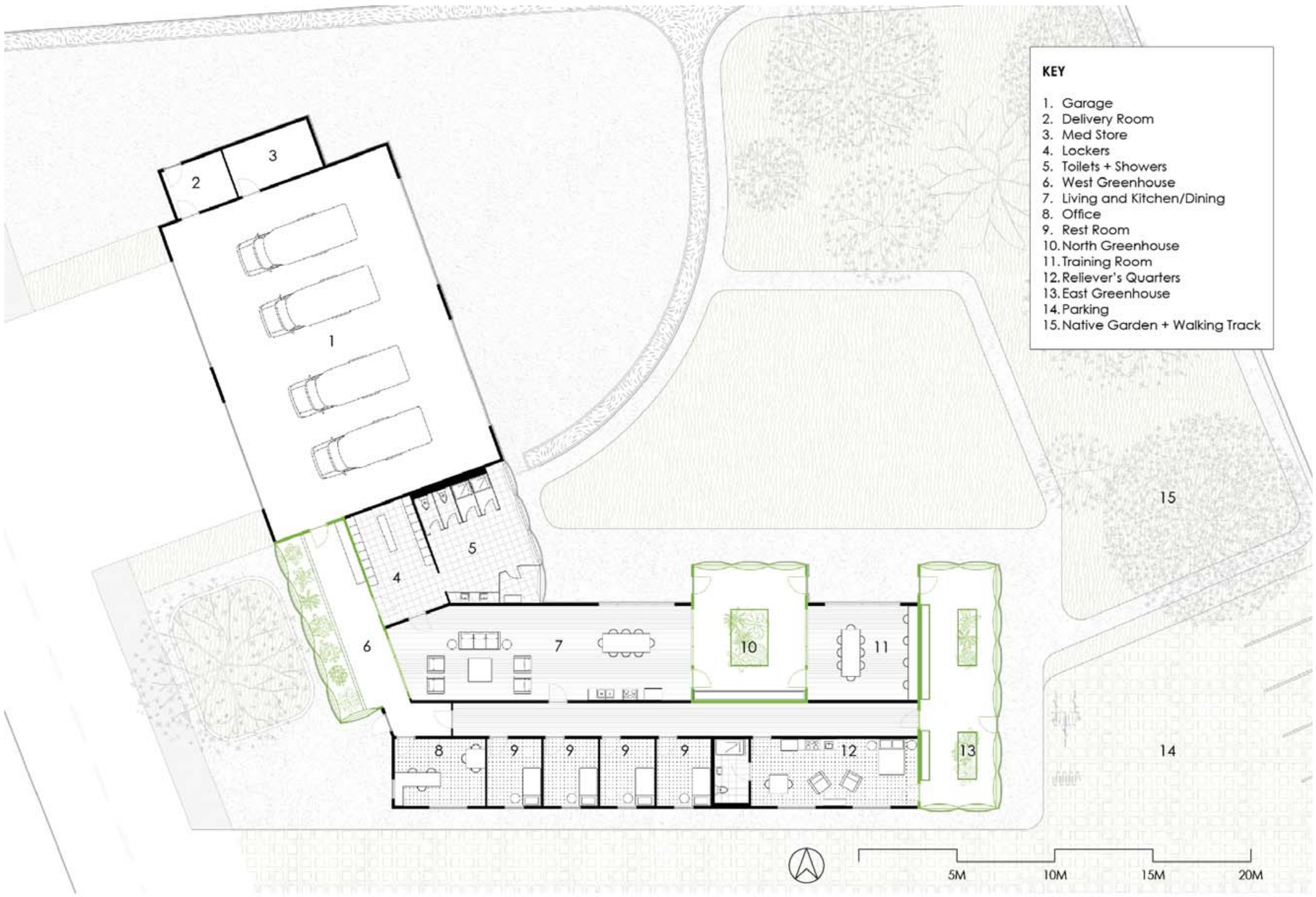
ESD ISOMETRIC


LIVING ROOM


SOUTH LANDSCAPE

Design proposal for Ambulance Victoria, for a net-zero carbon branch prioritizing passive solar principles, biophilia, and paramedic wellbeing given a semi-nocturnal lifestyle.

View from Street



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15
KEY
1. Garage
2. Delivery Room
3. Med Store
4. Lockers
5. Toilets + Showers
6. West Greenhouse
7. Living and Kitchen/Dining
8. Office
9. Rest Room
10. North Greenhouse
11. Training Room
12. Reliever's Quarters
13. East Greenhouse
14. Parking
15. Native Garden + Walking Track
5M
10M
15M
20M

Axonometric View

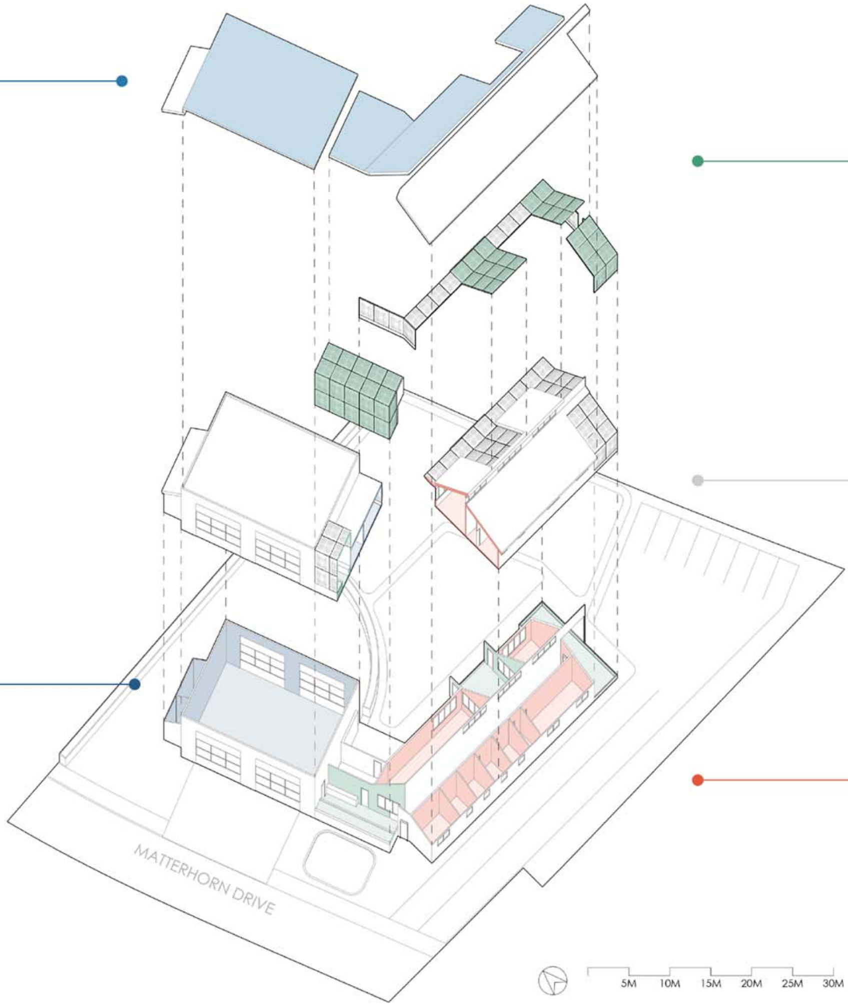
North facing Roof
380 m2 available area for PVs

Tighter thermal envelope in "Home Base" Zone could help reduce heating and cooling demands.

All external doors open onto a greenhouse space, which can act as airlocks for thermal retention.

These zones also carry a symbolic connotation, marking the transition between the active "work zone" and "home base".

"Work" Zone
Includes Garage, Delivery Room, and Medical Storage.

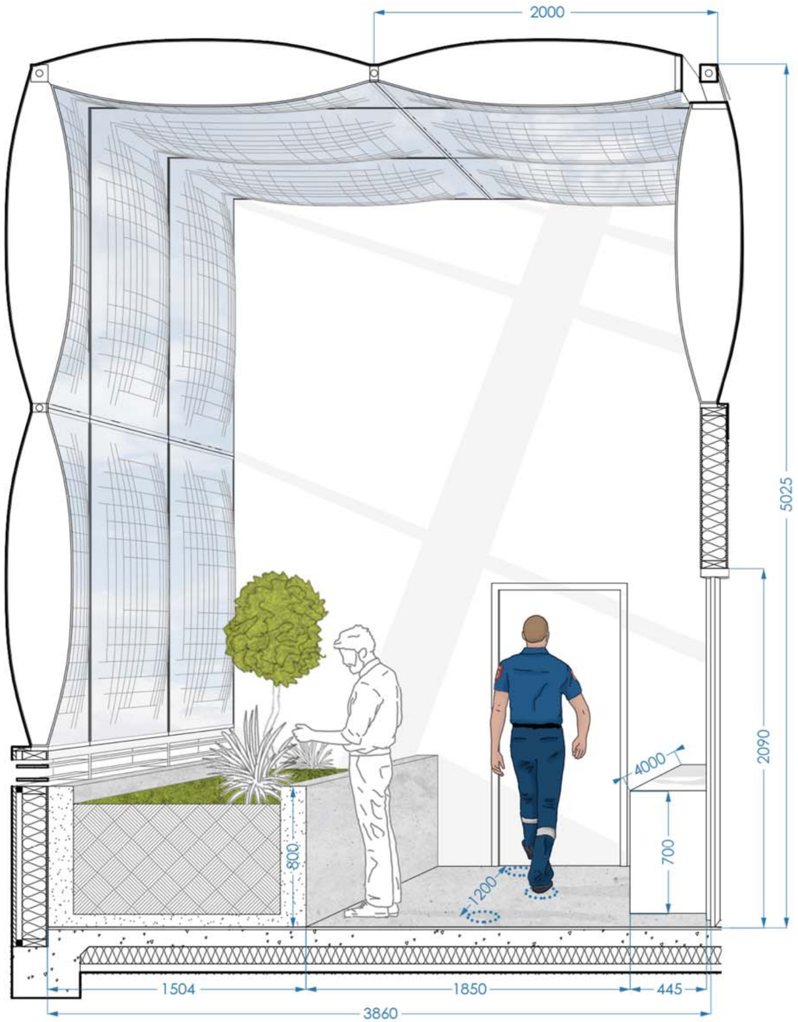


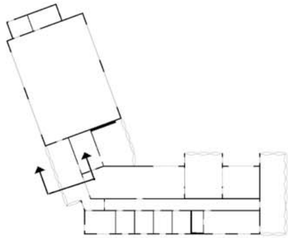
ETFE Polymer Roof
Lightweight inflated plastic material composing the greenhouse with performance equivalent of triple pane glass

Lightweight Timber Construction
Materials were selected to reduce embodied energy where possible.

"Home Base" Zone
Includes Living, Kitchen, Rest, Greenhouse, Office, Reliever's Quarters and Training Room.

Passage to Garage - Section Detail





Passage to Garage

Paramedics responding to a call grab necessities from charging station.

Those returning to the branch pass through metaphoric "front yard" on the way to the domestic portion of the building , such that they experience entering the branch as though through the front entrance rather than a back door.

Connection to the Street

The semi-transparent layering of ETFE with internal and external landscaping creates connection with the street while maintaining privacy and a distraction-free environment.

This "Drive-by engagement" gives locals a brief insight into the goings-on at the branch.