The Innovation Hub

for Affordable Heating and Cooling

Design Studio Outcomes Report (100% Milestone)

IDS-03 ACT Schools II

Project IDS03

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)

On the back of the successful delivery of a similar studio in Semester 1 2020, the IDS-03 ACT Schools 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 worked jointly with Engineering experts to respond to environmental challenges faced by two existing schools located in the ACT. This type of facility is known to have specific energy requirements due to high variation of use throughout the day and the schoolyear. In addition, the geographic location (ACT) is associated with a need for both heating in winter, as well as cooling in summer.

Based on a dedicated environmental agenda that was informed by representatives from the ACT government, students explore novel approaches to address Net Carbon principles across both school sites (located in suburban settings in Canberra). Particular focus is given to understanding the energy needs of the existing facilities, and the way environmental concerns impact on their function as teaching spaces for primary and high school (7-10) students.

Lead organisation	The University of Melbourne		
Sub-Project number	IDS-03		
Sub-Project commencement date	01 July 2020	Completion date	30th May 2021
Report date	30 May 2021		
Contact name	Dr Dominik Holzer		
Position in organisation	Associate Professor in Digital Architectural Design		
Phone	0416 214 165	Email	dominik.holzer@unimelb.edu.au

Table of contents

List of tables and figures

1. SUMMARY

1.1 Purpose

This report summarises all findings taken from IDS-03 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-03 and they will be further disseminated under the IDS Knowledge Sharing strategy associated to the program.

1.2 Executive summary

The IDS-03 ACT Schools II was initiated in early July after the successful delivery of the ACT Schools I project in S1 2020. Early consultations for IDS-03 ACT Schools II had commenced in Q1 of 2020. 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; due to COVID-19, 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 for this IDS.

Over the course of the semester, work progressed on approximately a dozen individual design proposals by architecture and engineering students who interacted with the student tutor and the industry consultants on a weekly basis. A dedicated 'Catalyst for Integrated Design' guideline underpinned the collaborative effort and helped in the joint development of common goals toward 'Net Zero' design. Due to COVID-19, the two weekly sessions had to take place entirely online for the duration of the semester.

Findings from this semester indicate that the impact of COVID-19 was manageable IDS-03 project and individual projects by students advanced well. Participation of industry consultants occurred in regular intervals throughout the semesters. A combination of Zoom, 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.

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

- Importance to establish a level playing field that each participant group benefits from,
- Definition of more closely aligned definable goals as a key priority, ideally translating into clear assessment criteria,
- Engineering students struggle with a '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),
- Increase in the initial familiarisation time is required before the 'sweet spot' of design integration can productively occur,

- Integrated design happens over a limited time window - this semester shifting towards second half,
- Balance between architecture and engineering requires active curation.
- Introducing smaller task specific activities with common goals helped in bringing individuals (architects and engineers), together.
- Try achieving similar time allocations between students through the formation or adjustment of subjects between the faculties.

2. PROJECT CONTEXT AND INCEPTION

2.1 Context to the ACT Schools II Integrated Design Studio

In the lead-up to University of Melbourne's start of semester, Prof Brendon McNiven from the Faculty of Architecture, Building and Planning, and Prof Lu Aye from the Melbourne School of Engineering had engaged in intensive industry consultation in order to search for compelling case-studies to investigate new technologies under the Integrated Design Studio banner. 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.

ACT Schools II is one of these three projects as its programmatic and functional specificity promise a fertile testing ground for design exploration, in particular when considering Zero Carbon constraints. 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 selected the industry consultants to join 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, in order to fit with the online format. As a 6-hour-online event was deemed to 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, in particular between architecture and engineering students.

2.3 Client Engagement

With the involvement of ACT Government representatives, the IDS-03 project is building up on, and expanding on the relationship with a client who oversees a great number of school programs across the territory. With some of the existing building-stock dating back to the 1960s or before, environmental issues did not take centre-stage and many facilities perform poorly from an energy performance perspective. The cost of energy consumption, building maintenance, as well as the productivity of students and teaching staff all leave room for improvement.

The ACT Schools IDS therefore offers the ACT Government a fertile testing-ground to evaluate how existing assets in their portfolio can/should be refurbished in order to address the above points. The client is keen to hear about new technologies, but also to explore alternative modes of design via integrated approaches that combine architectural sensitives with engineering expertise. ACT government/client representatives have taken an active role to remain engaged in the IDS discussions, starting from their participation in the kick-off workshop and the facilitation of a virtual site-visit to both schools that occurred in mid-July. The client remained involved regularly over the entire duration of the semester to provide progressive guidance and feedback on the students' work. The client also participated as a panel member in the mid-semester and end-of semester milestone presentations.

2.4 Site Visit

Due to COVID-19 restrictions, it has not been possible for IDS participants to physically visit either of the Canberra schools as a studio cohort. This contrasts with the previous IDS iteration, where the students, studio tutors and consultants travelled to Canberra for the purpose of gathering key information about the existing architectural condition and the functional aspects of the schools as educational buildings.

Figure 1: Site context/Precedence

The studio was fortunate that one of the students was currently residing in Canberra, where COVID-19 restrictions were not as constrained. As a compromise, the client and this single student arranged to attend the sites to inspect the facilities, talk to student members of the schools and to relay this information back to the main studio cohort via a zoom link. The same student attended the sites on multiple occasions in order to undertake specific site measurements that were missing from or had been altered from the detailed documentation provided by the client.

This workaround allowed students to assess the existing climatic conditions, the outdoor areas, the building fabric, and the technical and non-technical systems currently installed to provide adequate human comfort levels within the schools. A certain level of data could be collected and, in conjunction with the information received from the operators, provided students with essential feedback with which to develop energy-masterplans for the two sites and integrate their design proposals with real-world references to work with. Still, the lack of an actual site-visit was not seen as ideal by the participating students. With no experience of the site environment, many students focused more on the Teaching and Learning pedagogy elements of the brief to the detriment of addressing the environmental side. This was a noticeable shift from S1 despite ½ the architecture students having already completed and ESD focussed studio prior to commencing this one.

3. DESIGN STUDIO PROGRESSION

3.1 Setup for Collaborative Design Integration

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

General

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

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

Focus on Performative design

- Address **environmental** building **performance** systemically across Arch and Eng
- Establish joint environmental **targets** per relevant building type à apply end-use performance metrics
  - 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 tutors proposed a detailed IDS schedule, based on their experience from the last iteration and their colletive experiences as design studio leaders within a 13-15-week semester. The proposed schedule was also informed by preparatory conversations held with the industry consultants, the client, and the academic participants. The schedule addresses both the output requirements typically inherent in Masters-level design studios at the Melbourne School of Design, as well as addressing the specific IDS output requirements for exploring novel technologies. In particular, the schedule maps out the intensity and duration of engagement between the architecture students, the engineering students and the engineering consultants.

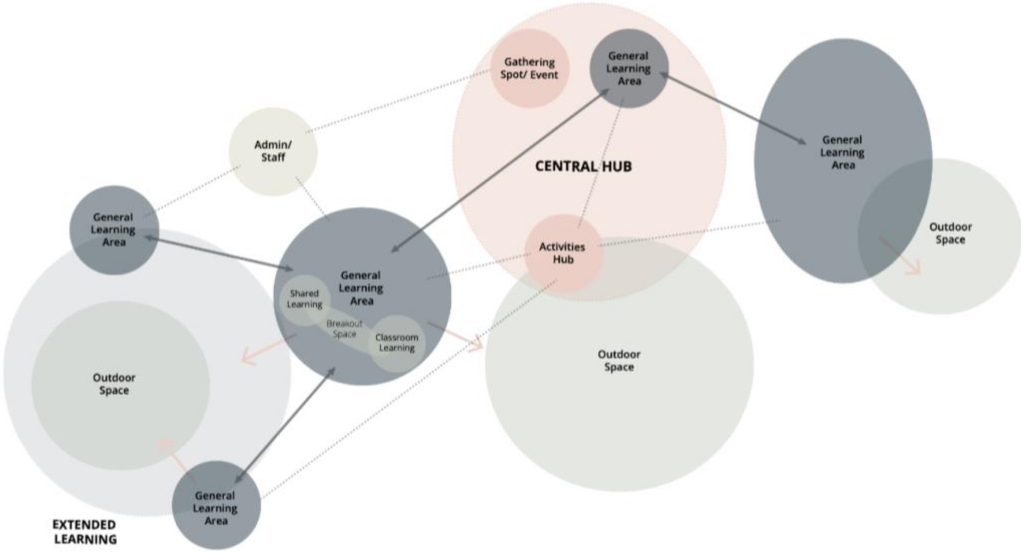


Figure 2: Layout development WIP

3.3 Weekly interaction between Design Studio Participants

After the initial online joint IDS workshops held in weeks one and two, the ACT Schools II IDS moved into the phase of weekly 6-hour design studio sessions. The 6 contact hours were divided equally between Monday and Thursday afternoons, to provide opportunities for bi-weekly feedback on student progress. Engineering students were scheduled to participate in 2 of the 3 hours of the Monday sessions and 1 hour of the Thursday sessions.

The studio tutors alternated lead responsibilities between the two sessions. The engineering consultants were generally in attendance for the Monday sessions. Supplementary sessions were added according to studio tutor and consultant availability and student demand.

The initial two to three weeks were marked by additional presentations by the engineering consultants and the introduction of reference projects by the architectural studio tutors. As part of this phase students were also tasked with researching various engineering seed ideas to present a series of relevant case studies. The students worked in mixed discipline groups for this exercise with one engineering student integrated with 3 architecture students. A key aspect of this task was for the architecture students to engage with the technical engineering aspects of the selected case studies, while the engineering students were asked to focus on the architectural aesthetic of the same case study projects, effectively kicking off the opportunity for integrated thinking within the studio.

Students were then asked to present their first preliminary responses to the site context of the two schools in the form of an Energy Masterplan and other location-specific observations in the form of a detailed site analysis. As part of the energy master-planning, the students were asked to jointly create a 3D model of each school for use in Sefaira, an energy analysis software tool. Additional engineering expertise was added to the studio to assist with this task and to help the students establish appropriate inputs for the program. This ensures that each student is working from a consistent base model and will allow them to more effectively analyse the energy impact of their integrated design and engineering interventions throughout the semester.

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 is a very brief period when core design ideas are generated and formed. Once design ideas are formed, it is difficult to materially change direction due to the momentum involved. Designers hold preconceptions after this initial ideation and the natural tendency is to adjust direction rather than to discard totally to start again. This means 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.

Mid-semester presentations of IDS projects occurred in late September, and project participants were then advancing their designs up until mid-November. At that point, a joint panel consisting of industry and academic guests joined the studio tutor, the consultants and the client during the final crit where the student work got assessed. After the final project submission/presentation, the industry consultants engaged in a vetting process to extract the essence of the most innovative concepts to then add 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.

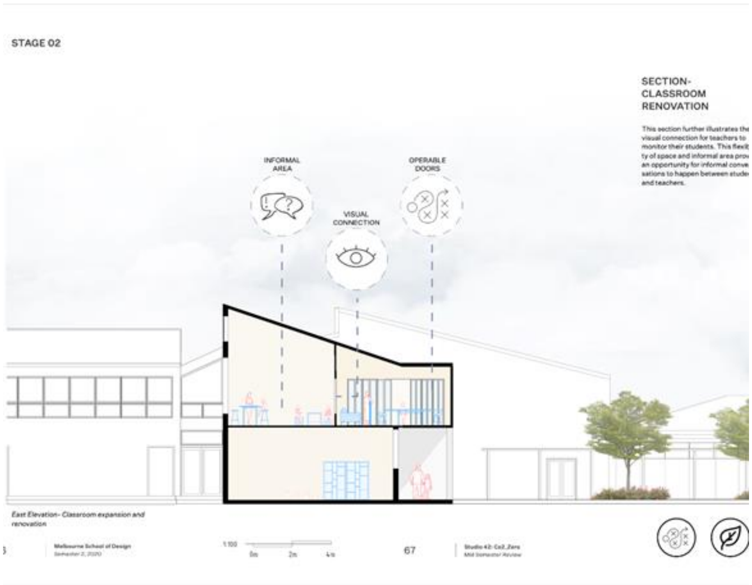


Figure 3: First concepts at Mid-semester

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

As a stage 4 lockdown was in place across Victoria at the start of the semester, the studios were forced to continue with the remote (on-line) delivery established during the first IDS. This online format is proving successful overall, but it is not without its challenges related to the desired bonding between architecture and engineering students. From an observation perspective the online delivery has some advantages in terms of design interaction observation. Students, the studio tutors, and the industry consultants 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 reviews also occurred online with the inclusion of a panel of experts. At this point, it is not expected that the online delivery method will severely alter either the nature or quality of project outcomes.

4. DESIGN STUDIO FINDINGS

The findings from the IDS-02 Design studio are drawn from three main sources:

- Firstly, observations during the studio that were logged and consolidated
- Secondly, feedback from the participating industry consultants, the studio tutor, and the client, and
- Thirdly, feedback from the participating students via an in-depth questionnaire.

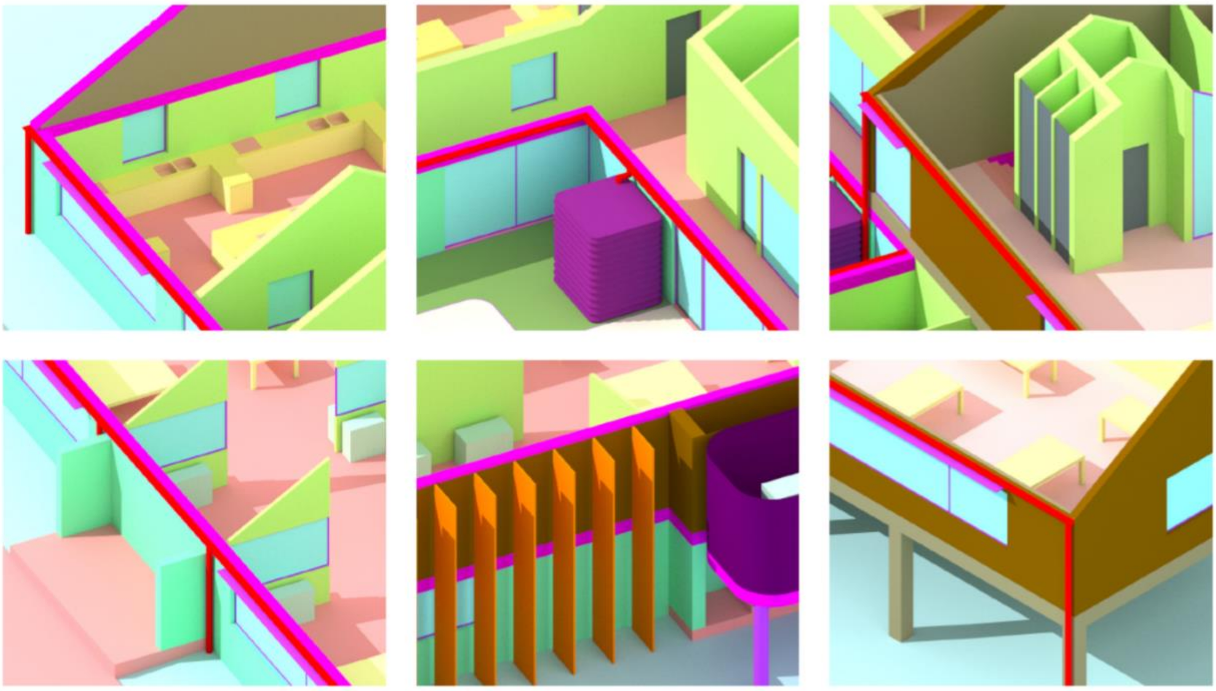


Figure 4: Concept study by Ashwin Gunawardana

4.1 Observations during the studio

The activities within the studio were observed throughout the semester by the IDS research team. The following sub-sections of this report represent the main observations regarding the process of integrated design and the contributing factors.

4.1.1 Understanding Professional Specificity (and how to overcome it)

Striking a balance between architecture and engineering requires active curation, particularly at the start of the design process, or in this case the early stages of the design studios, where threshold levels of team members' knowledge may be unknown. To enable effective opportunities for integrated design, sufficient understanding of the combined disciplines must be acquired so that a mutual understanding of the typical constraints of the other discipline is developed. This then allows each discipline to work independently for periods and to maximisation of opportunities for working together to jointly progress the project at regular intervals. Therefore, the early weeks of IDS-03 focussed on building technical capacity of the students via technical engineering presentations encompassing environmental, mechanical and electrical aspects of projects.

Of particular interest in this IDS is that approximately 50% of the architecture students have acquired significant background technical knowledge in relation to assessing passive building performance prior to entering this studio. This will provide the research team with an opportunity to assess the benefits of prior technical experience on the ability to engage effectively with the integrated design process and more technological solutions.

In the early stages of the studio, the engineering consultants were able to engage with the student research on seed ideas and case studies to help them evaluate the relevancy of the proposed systems for the Canberra school context and climate. This feedback enabled students to re-evaluate the options under consideration for their designs and to understand that not every option is an appropriate solution for every context.

The engineering primer sessions also enabled students to understand basic size and locational requirements of key mechanical and electrical componentry. Understanding these aspects early in their design journey allows students to evaluate options and make critical decisions about how they will engage with the complexities of provision of services in school campus context and that this may open up options for design opportunities, they may not have otherwise considered. Students are enabled to use their newly acquired tools.

Despite these advances, it could still be observed how Basic understanding of passive solar and HVAC was at times still lacking among architecture students, or they lacked the ability to apply their prior knowledge sufficiently. For future IDS iterations it could be suggested to produce a series of brief 'cheat sheets' with environmental data. Alternatively, pre-modules with technical information could be recorded to communicate knowledge required without spending valuable studio time on this information.

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 observations in the Integrated Design Studios (IDS's) currently underway is that not all designers are used to working in this way.

This was identified as highly relevant to the participation of the first cohort of engineering students within the studio this semester. The engineering students were challenged by working within the context of a more open brief, where the problems often first need to be uncovered before progress towards outcomes can commence. This was very different to the engineering students' usual approach of solving a series of clearly problems. Meanwhile the architecture students are more proficient in working with open ended problems but may not have the technical ability to resolve the architecture.

In this iteration of the IDS, one of the challenges faced is to integrate the architecture and engineering students within the studio as they progress towards differing assessment tasks. Therefore, identifying increased opportunities for students of different disciplines to work together will be a something that needs to be explored going forward.

Forward loading participation of engineering students (in tasks associated with the early part of the semester) was discussed, as there was not sufficient engineering student contribution to or impact on the studio outcomes (final proposals). The factors that contributed to this, include:

- Timing / structure of assessment for the engineering students not being part of the studio and the reluctance of students to engage / participate beyond basic delegated tasks.
- 'observational participation' appeared to be a complete failure based on what was observed by the studio leaders and consultants. Unable to actually determine if the engineering students benefitted for or learnt from this experience as the studio leaders and consultants were not involved in reviewing the engineering students' observations submissions.

This was highlighted in the interviews when the three consultants and 2 main client representatives indicated they were not even aware that there were any engineering students in the group.

4.1.3 Perspective and Process

Observations during the studio suggest that processes for more efficient group discussions and early co-design opportunities would have assisted students to progress faster in the earlier stages and allow better synthesis of the engineering information. This may have been a factor of the online studio format this semester. Many of the consultants reported repeated discussions with individual students appeared to limit progress on developing additional iterations.

Timing of studio tasks could be improved to allow greater opportunities for multiple iterations of their proposals. Master-planning was noted to be a valued step and it uncovered key areas that informed student proposals (as expected) but the consensus was that the masterplan was resolved too late. This may have been a factor of not getting an opportunity to visit the site and that students took longer to understand the site with the tools available. The engineering tech-heavy front end of semester (weeks 2 & 3) also contributed to pushing out the masterplan. Many of the consultants saw the need to better balance the engineering and architecture in the early weeks.

4.1.4 Working toward Common Goals

One key element requiring further investigation during the semester was a more targeted articulation of common goals that address Zero Carbon in the joint architect/engineer effort. In the previous semester, it was identified that the first step required was to formulate a brief that adequately sets out the common goals of the project and clearly identifies how they will be measured. As a step in that direction, for IDS-03, each student project is using the Sefaira energy analysis tool to track improvements in performance for the project. As the semester unfolds, additional information about the success of the designs, and the appropriateness of this proposed methodology will be reviewed and recommendations for any adjustments / changes can then be made.

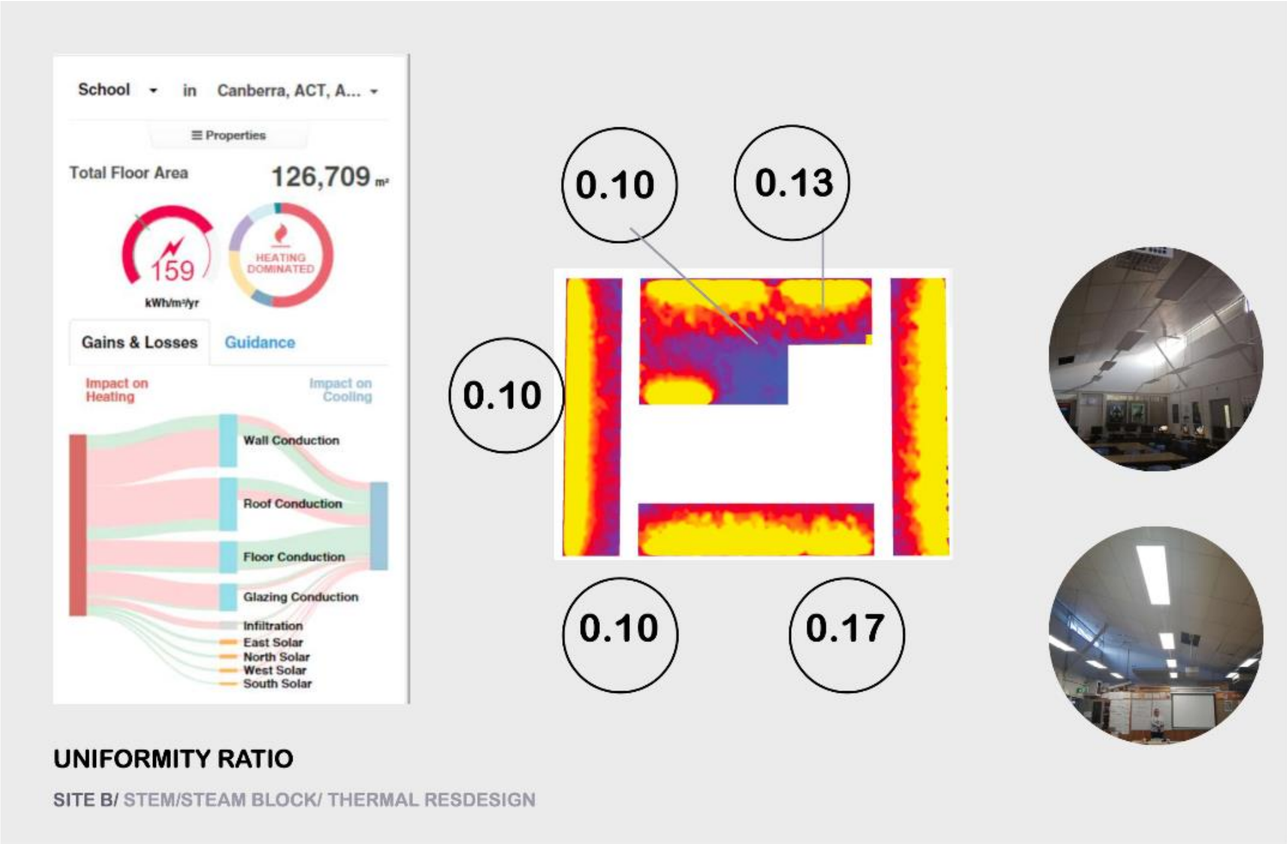


Figure 5: Sefaira software output

The architecture students in this cohort demonstrated a strong capability for working in teams and a number have also demonstrated that they are able to step up and assist with the curation of the team. This was evidenced in breakout spaces where students were actively engaging with each other as peer designers in the absence of a more experienced consultant in the space. Next, students implemented these skills in a cross-discipline environment (or in the presence of more senior designers / engineers) to further enhance their integrated thinking processes.

Feedback from class points towards the desire of participants to receive better explanations about the definitions of Net Zero Carbon / Carbon neutral etc. at the start of the studio and the definitions reinforced with appropriate precents to show what industry is doing now and what opportunities there are for pushing beyond the basics. Students could be assisted to develop their own definition.

4.1.5. Peer-to-peer Collaborations

The interaction between students participating in IDS-03 was affected by having to work remotely using online interfaces only. Use of a common virtual base model for the schools was a good tool for students to use in refining their designs and monitor the impact of changes they made. At the same time, some of the complexities meant that it was time consuming to get the model working correctly.

This included students needed extensive help in shifting from their 3D generated virtual models to a simplified model that would work in the analysis software. Mostly as a result of students not differentiating between the software models requiring a model that was a series of joined 2D planes and their models having thicknesses in their floors, walls and roofs.

The Whatsapp group proved beneficial for the students working on the combined group base energy model, allowing then to rapidly exchange information, have queries answered briefly by consultants within the chat or as an indication for the consultants of what the students were struggling with between the studio sessions and what they might need to assist with in the up-coming sessions.

The flip side of the energy model was that some students remained stuck on tweaking the model and became very focussed on the energy modelling, leaving their architectural vision behind.

Energy consultants identified that the energy analysis was skewed by 'plug-in' loads and recommended that these be excluded next time in favour of assumptions about loads.

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

Feedback from each of the key professional participants in the studio was obtained by conducting a series of interviews. This included the architectural consultant, the engineering industry consultant, the studio tutor, and the project client. The scope of the interviews included consideration of factors that enable or constrain integrated design in both studio settings and the industry context, as well as seeking opinions on the impact of the studio brief and the nature of individual professional contributions to the studio and the integrated design process. The value of tertiary level integrated design education was also canvassed along with identification of potential areas for improvement in the practise and teaching of integrated design processes.

4.2.1 Integrated design drivers

The interviewees provided input on the enablers of integrated design in studio settings. According to the client representative, one important enabler is clear understanding of the project's needs and requirements through high level of interaction with client which could translate into the designs that reflect the client aspirations. In addition to that, early consultations with the end users could facilitate the design ideation and incorporate operational requirements. Site visit was also mentioned as a useful step to facilitates better understanding of the site context, existing building and surroundings.

Other factors that were mentioned among the drivers of integrated design were appreciation of the solar passive design as well as the spatial and functional needs of building services. High percentage of students in the studio had undertook previous subjects with environmentally sustainable design focus. Having the background knowledge on ESD principles was an enabler of integration of those concepts in the design in a more organic manner.

According to the interviewees another enabler of integrated design was the fact that architectural students spent the initial sessions doing research on concepts of net Zero Carbon solutions which although were not necessarily best fit in terms of practicality and feasibility led to conception of ideas which were then translated into design solutions by incorporating input from consultants on the practicality and efficiency aspects.

Effective collaboration and coordination among multiple disciplines was mentioned as another important driver of integrated design.

4.2.2 The brief

According to the client representative the brief represented clear definition of the desired outcomes for both client and student learning. One reason for successful preparation of brief is the fact that this studio is the second iteration of IDS with the same client and project definitions leading to better understanding of the effective ways of communicating brief and incorporating lessons learnt from the first iteration (IDS-02). The client representative pointed out that while the brief provided in DS-02 was generic, the brief in IDS-04 was improved with more details and guidance on the client's desired design outcomes. The key to the successful brief is however to find the right balance between being too generic (resulting in designs that do not capture client aspirations) and too prescriptive (which could stifle creativity). According to the studio tutor one other improvement over the IDS-02 brief was the wording around the requirement for a design model and a baseline model to compare with.

The industry consultants believed that although the brief was clear, the students spend longer than expected to comprehend the brief's requirements. They believed the reason for this was the time constraints due to studio timeline and the fact that the students were not able to visit the site because of COVID travel restrictions. The industry consultants also pointed out that that expansion of some definitions e.g. net Zero Carbon in the brief could be useful for the students.

4.2.3 Nature of studio tutor and consultant contributions

The studio tutors describe their role as guiding the students and giving directions on the important steps of the design including site analysis and diverse aspects of sustainable building design such as microclimate, soil and plants, local climatic conditions, occupation schedules, embodied energy, renewable energy and reducing energy consumption. The studio tutor also suggested that it is better to provide students leading questions and encourage them to come up with solutions rather than giving them the answers.

The consultants contributed through providing the contemporary approaches, spatial and system requirements, available systems and products in market, and bridging the gap between the architect architecture and engineering. At the same time an important role of the engineering consultants was to bring the pure engineering focus in certain technical aspects of the design. Another contribution of the industry consultants was the ability to provide industry perspectives and practical examples which were well-received by the students. Although this approach by engineering consultants was a restrain architect's freedom, the interviewees believed that the students showed great respect to the consultant's views.

> *"They brought this pure engineering focus that just said, this is the reality of an engineering solution. And there are some areas that just you can't not do." Client Representative*

> *"I guess we were there to advise on if it was a good solution, or maybe there was something else to consider, or I'd look at more technical things and how that would relate in a real-life project... From my particular point of view, it was the energy modeling training. I think it was useful to them, because they could see how the changes that they would make on building performance, whether it be U-values or insulation, glazing, they could see how that had a wider effect on the building's energy" Sustainability Consultant*

The engineering consultants also pointed out that running a survey at the beginning of studio to understand the student's level of knowledge on certain aspects of engineering could help them figure out the level of detail on the engineering input throughout the studios.

The client representative described the client's contribution as providing input operational needs of the school buildings and how the design solutions would or would not work in from a day-to-day school operation mindset while also overseeing the design process to ensure the sustainability outcomes would be realised after the actual building is built.

4.2.4 Critical decision-making when balancing architectural and engineering input

The interviewees pointed out that one important decision-making point for students was when they realised how energy inefficient their particular design was and took that knowledge in the master planning decisions and design development. Further critical point was during modelling and simulation stage when the students could witness the impact of their design decisions on the performance of the building.

> *"That's where I saw the change in the thought process from architectural to understand that the heart of the problem is that both of these disciplines need to unite to resolve that energy equation." Client Representative*

According to the consultants the decision-making process taken by the students was to first consider sole architectural intent while the engineering aspects were incorporated later on in the design. The engineering consultant described this approach as "probably the most logical way of approaching the solution", since the otherwise concurrent interdisciplinary considerations could lead to more frequent change of design iterations and rework for both engineers and architects. They also touched on some key questions to answer as "what is the building? What is it designed to do? Who are the users? And how are they going to use the building?"

> *"The reason I say that is because whether from an architectural point of view, or an engineering services point of view, knowing and understanding who the user is, is going to affect design decisions whether it's the space design, from an architectural point of view, if there's specific requirements on thermal comfort, that might be services related, but also architecture related. And then services, which is the most suitable mechanical*

system or electrical system for that space, I think it a lot of it boils down to who is using it, how are they using it? And then you can tailor specific solutions around that." Sustainability Consultant

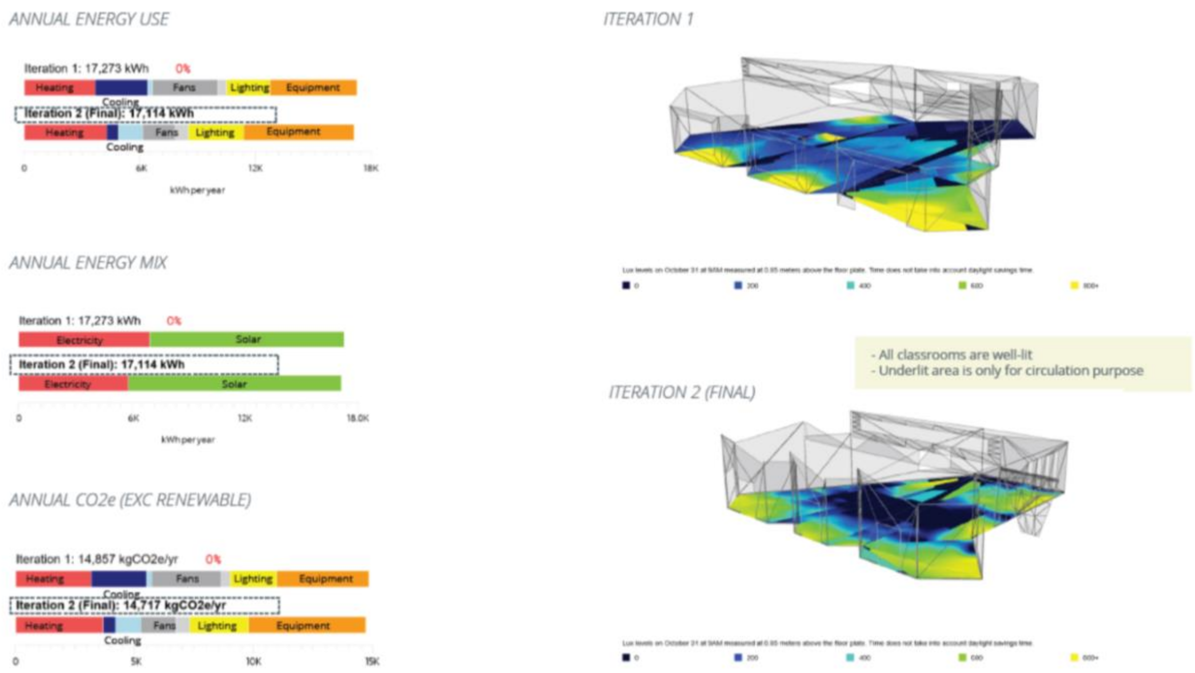


Figure 6: Energy Modelling and Daylight analysis by Yi Jie Lam

4.2.5 Aesthetic and functional compromises

According to the client representative, individual student's attitude to the integrated design studio experience affected their ability to balance the aesthetic and functional aspects of the design. The students who were more open to the guidance by studio tutors and consultants were more successful in achieving a balanced solution. On the other hand, the students who were 'welded to aesthetics of design' and were less flexible in making compromises struggled to unite the functional and the engineering in a seamless and synergistic way.

> *"I think a lesson moving forward in their careers is that sometimes our initial ideas and hopes for what we wish a project to be can't come to fruition, and you need to be able to just say, okay, it felt great to design that. But that's just not going to work here. That's a really mature approach. Understanding that, recognizing it and moving on. It is where I think they'll succeed" Client Representative*

The studio tutor believed that the students had varying level of imaginations which affected their ability to balance the architectural and engineering aspects in an innovative way. The ones that are naturally imaginative would easily come up with unique ideas to cope with those counteracting forces while others experience struggle in achieving a balanced solution.

The engineering consultant believed that the students did a good job in incorporating the engineering and systems requirements of the design such as assigning plant spaces, the detailing of ceiling height, ductwork, cable trays, etc. On the other hand, the consultants stated that there were areas that the students could advance their design further in terms of lighting distribution and air conditioning.

The sustainability consultant pointed out that there were times during studio that the focus was completely on engineering and sustainable design aspects and there was a risk of aesthetic considerations being overlooked. Being conscious of those situations they tried to guide students to get back on the track and maintain a holistic approach to design throughout.

4.2.6 Integrated design definitions

One description of integrated design provided by the interviewees was ‘collaborative dance of raising the questions and answering the questions together’. Integrated design was also described as ‘having the right designers with good understanding of the other discipline coming together to perfect their design’.

> *“The key is a collaborative approach, with designers or experts from a range of fields coming together to get an optimised solution.” Sustainability Consultant*

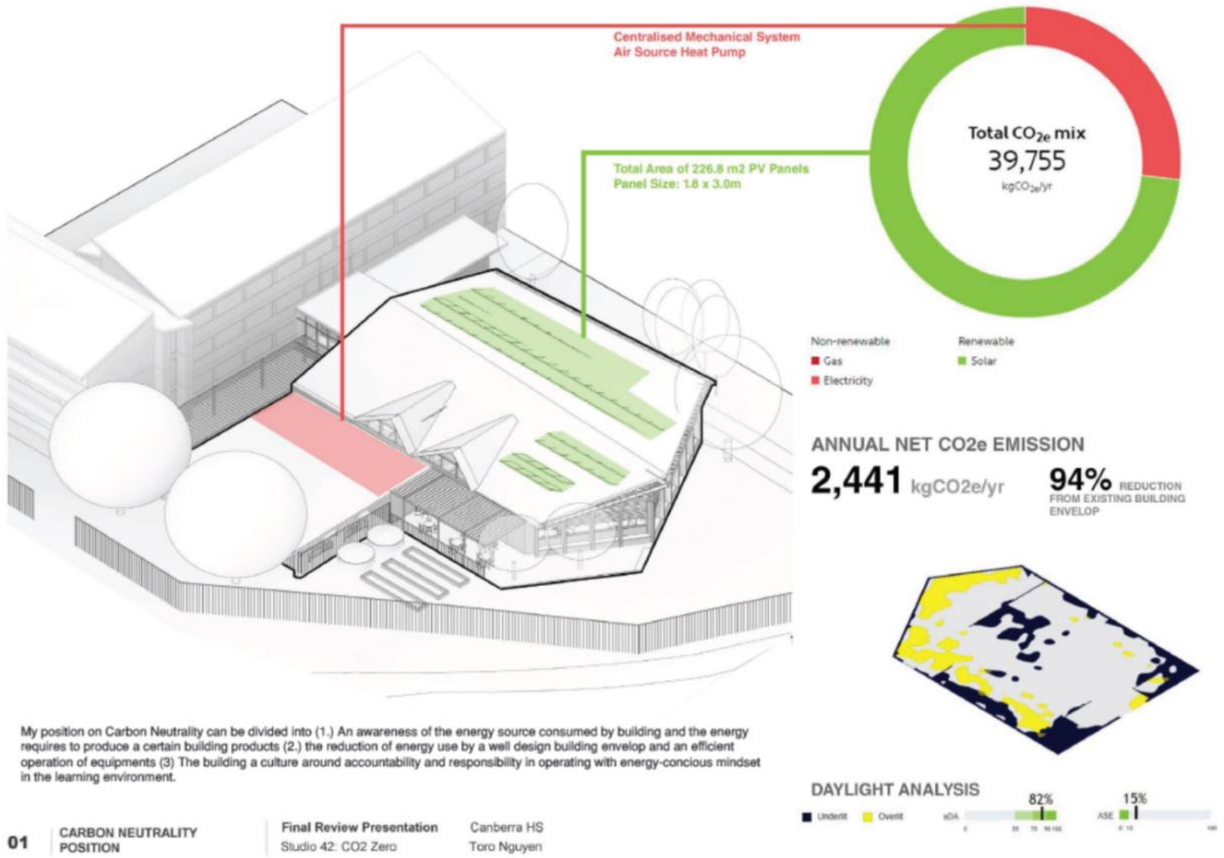


Figure 7: Carbon Neutrality check and Daylight analysis by Toro Nguyen

4.2.7 Constraints impacting on ability to engage in integrated design and architect/engineer collaboration

One area of struggle for the students was the ability to ask the consultants the right questions at the right time. The interviewees pointed out that this struggle was because the students were new to the concept of integrated design, and they will develop those skills as they progress in this journey. Another area of struggle identified by the consultants was the lack of enough understanding of basics of building fabric as well as mechanical systems and their spatial and functional requirements.

The engagement of engineering students was another area of struggle mentioned during the interviews. According to the client representative, engineering students were not able to break out of the mindset of being just engineers. The fact that the engineering students did not have previous exposure to ESD concepts and principles was a barrier to their contribution. Also, the differences in the way engineering and architectural students approach a problem was identified as another barrier to their collaboration. According to the studio tutor, the engineering students were used to having a far more clearly defined problem and understanding what their final solution needed to be while the architects are comfortable with some level of ambiguity in the problem statement.

"...it was very interesting, I felt that it really made the engineering students move out of their comfort zone, learn a different skill set about how to present to a varied audience of both lay people as well as technical experts. And I felt that that was good in helping each discipline understand what the other did." Studio Tutor

A general constraint to architect and engineer collaboration is ego and a perception that architects want to design a landmark building and the engineers get left behind in the journey to make that building operate well. Also the client's lack of understanding and clarity on the desired outcomes was mentioned among the constraints:

"I think a base understanding from the client as to what the benefits are of integrated design, is perhaps the single greatest missing link. If a client doesn't understand what the lifecycle benefits of the design approach are, then it's going to be very difficult to get the appropriate budgets allocated up front to achieve the long-term vision of zero emission buildings." Client Representative

The industry consultants identified lack of empathy as another constraint to architect and engineer's collaboration.

"It is about not spending the time to understand why something is important to someone. With both ways, whether it's an engineer, not understanding why the architect wants to paint that wall blue. And one architect not understanding why we need a four by five room." Engineering Consultant

Other external constraints to integrated design include time and cost as well as ability to assembling a good team with good mixture of skills and personalities to facilitate integrated design process.

4.2.8 Value of experience of integrated design at university

The studio tutor pointed out that the IDS's are very useful for students since not all studios take the students through the design process in such a systematic and multi-faceted way.

According to the industry consultants, integrated design should be pre-requisite to the actual design courses. They highlighted that integrated design process is a skill that needs to be learnt either academically or in industry, the former brings value quicker while latter takes a long time to be fulfilled. They also mentioned that the IDS is useful in bridging the gap between theory and practice as well as facilitating interdisciplinary collaboration experience.

"There are two aspects to it: the integrated design piece where they're collaborating with other disciplines to develop the project which is certainly a good thing. But then some of the things that the consultants brought from the industry side, would be very beneficial for when they come to be heading out into industry." Sustainability Consultant

The client representative's view was that in the tertiary sector there is a need for a shared unit for engineering and architectural students to educate them on common understanding of basic ecological principles around sustainable infrastructure.

4.3 Feedback from the participating students

There was a mixed level of environmental design experience among students who attended this class (median score 2.5). The majority of respondents highlighted they either had little-to-no Environmental Design experience, or simply had come across it in other classes.

Students listed: *In-depth knowledge of technology for collaboration, Imagination and creativity,* and *Time assigned to the dialogue between Architects & Engineers,* as the key design-drivers affecting successful environmental design to achieve renewables/Zero Carbon goals.

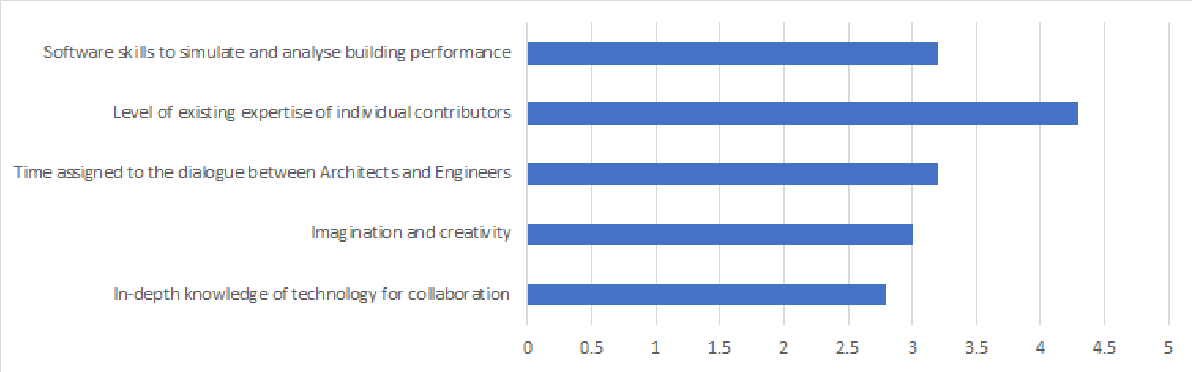


Figure 8: Key design-drivers affecting successful environmental design (with smaller numbers ranking higher)

With a median score of 4.5 (out of 5), the vast 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, some students seemed to appreciate its configuration saying: *It allowed us to develop our own ideas about the spaces required to transform the school whilst still highlighting the necessary features that were outdated or underperforming*, whereas others struggled with elements of it, as they state: *It was more related to the architecture aspect, while for Eng students, there are very few materials for reference.* Students appreciated the fact that the brief was not too constraining and allowed for personal adjustments.

Prompted about the most critical decision-making points when balancing architect/engineer input for generating environmentally optimised design solutions, students listed: *having a clear benchmark of engineering without sacrificing the design concept,* and to: *first, explore on the creative ways that are not bounded by the existing engineering solutions, only then, to acknowledge and research on the engineered products in the market that can be beneficial towards the creative design. Overall, students struggled to determine what the (spatial and otherwise) requirements were for the engineering components.*

The inspiration for School refurbishments were broad and varied. Overall, students listed *presentations by, and conversations with the engineers, external research, readings, and project precedents* as key elements. Others referred to the specific site context, and its uniqueness, with the ACT Government as the client.

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

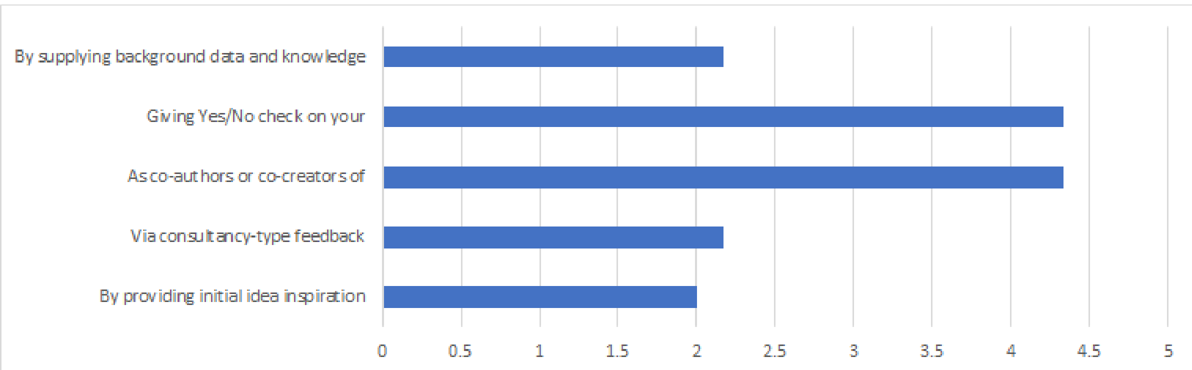


Figure 9: Reflection on input provided by the Engineering Consultants (with smaller numbers ranking higher)

Asked about the most useful guidance by the consultants, students referred to *the lectures in class in the early weeks, where Engineers outlined the nature of Energy Systems,* thereby assisting students to generate a *baseline-level of understanding*. One student summarised the most useful feedback as follows: *The main lessons that helped me and the progress of my project was being informed of how my design ideas may impact certain things like HVAC/structure, this allowed me to revisit and tweak ideas to optimise them to ensure that my end-product was an optimal, realistic and viable outcome.*

With a median score of 4.7 (out of 5), nearly all students argued that the input by consultants strongly increased their 'level of understanding of' environmental issues and associated solutions.

Students expressed their desire to spend more time with the consultants via face-to-face meetings (not possible due to COVID-19 restrictions), and they suggested a group approach where a consultant talks to 3 students at a time. *In addition, students were hoping for more specificity on the weekly agenda to segregate different aspect of learning.*

A critical voice commented that too much engineer input could constraint and misdirect the design intention, illustrating that not all students found it easy to accommodate the consultants' feedback as part of their design thinking.

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 3.5 points out of 5 (with 1 being best and 5 being worst). Students alluded to the fact that the deliverables and assessment tasks differed among the two groups, and that the engineering students were not always present class.

One respondent asked for: *More prepared discussions between the engineering students and architectural students on a specific topics rather than just assigning and splitting assignments within the group with no means of discussing integration of designs.* It emerged, that students from one discipline did not know what to expect from the other as one respondent explains: *The engineering students could exhibit the areas they know about, so that the arch students can gauge where they can get advice on. We didn't learn what skills they have, and they were present before our design stage began, so we couldn't apply any knowledge to the localised brainstorming of ideas.*

In IDS-03, students did not feel that they had to compromise aesthetics and functional design aspects when balancing architectural and engineering concerns (median score 2.8 - with 2.5 meaning 'neither-nor'). One half responded that it was totally, or rather not the case, the others felt ambivalent about it. In particular the architecture students learned how to orient their design towards Net Zero constraints, without necessarily getting bogged down by too stringent goals. One student explains: *Don't try to be too perfect with the engineer aspect, especially for arch students.*

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. The *inability to define joint goals*, was listed as a key challenge, as well as '*Education in isolation'* and more generally: *knowledge gaps*.

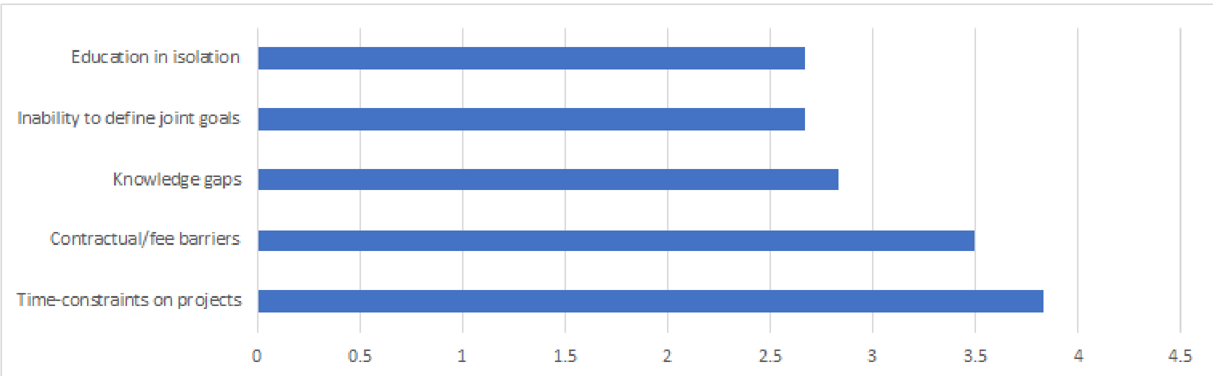


Figure 10: Challenges reported by the students (with smaller numbers ranking higher)

The additional struggles reported by the students and they can be summarised as follows: *The knowledge of how to adapt the energy modelling systems to systems other than gas, as in how to optimise solar and electric systems within the finer parts of the* (software) *program Sefaira;* working *...on both the architectural and engineering components in parallel;* as well as ... *not to getting too hung up on the engineering aspects of things on the initial phase, but rather focus on what design concepts can be explored first.*

This valuable feedback points towards the need for more continuous engagement with engineering collaborators throughout the semester. It will be crucial in fine-tuning the nature of involvement with engineering students to the program in future IDS iterations.

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

- Integrated design is the collaboration between designers, engineers, educators and ESD consultants from the very beginning of the design process.
- Making decisions with input and consideration from all disciplines to achieve a collaborative, optimal and innovate design outcome.
- Design that is critical to the improvement of environment in both functional and aesthetic aspects.
- A parallel design process between architecture and engineering.
- A deep-thinking approach to design where ESD is integrated successfully and not post-design.

The question about the usefulness of learning about integrated design processes as part of their university education, elicited a positive response, with one third saying it was ‘extremely useful’ and the rest attesting it to be ‘quite useful’. (median score: 4.33 out of 5).

5. STUDIO DESIGN OUTPUT - Select Examples

A select number of student projects have been taken further by the Engineering Consultants (**Jacobs)** in order to consolidate feedback and extract some key data. The following two sections summarise information contained in Jacob’s consolidation/vetting document. The full 36-page document can be found as an appendix to this document.

5.1 Passive Measures

Students were encouraged to consider passive design measures as a key priority. An introduction to the existing site-conditions made the students realise that the building fabric of the existing buildings was not currently suitable for a carbon neutral development, with clear impacts on energy consumption, thermal comfort and general indoor environment quality.

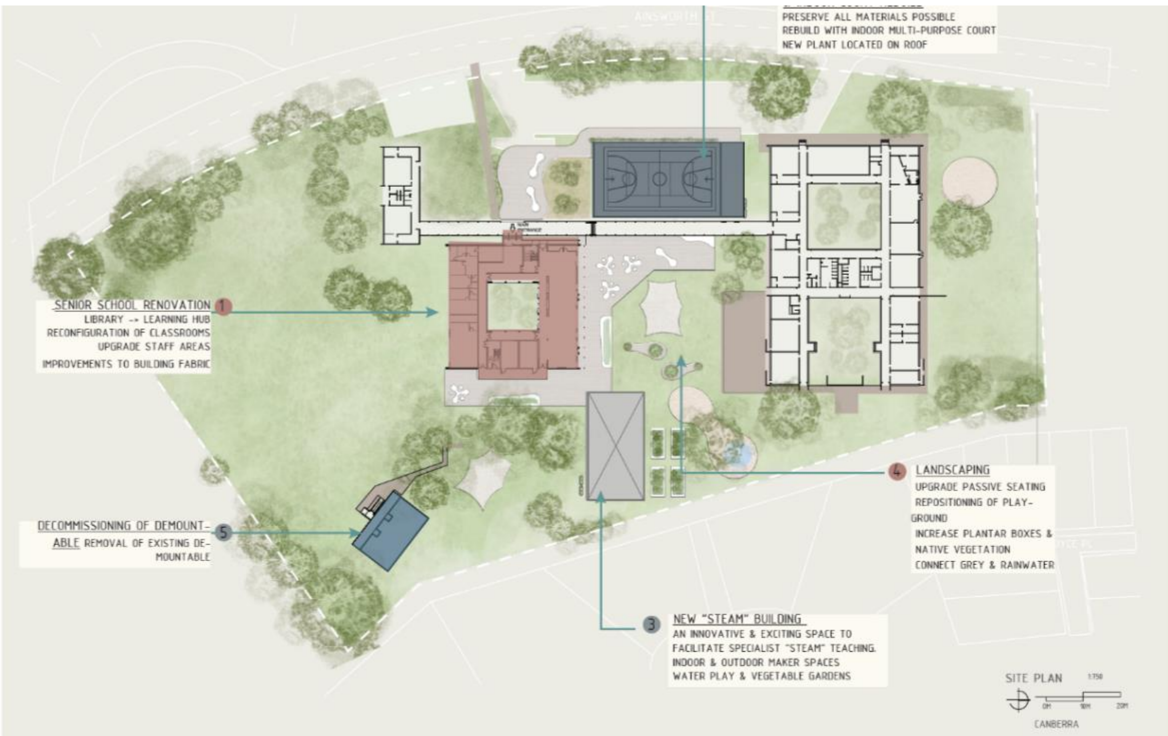


Figure 11: Masterplan Maddie Gundry (Mawson Primary)

The following initiatives were proposed (among others):

- Replacement of existing glazing with improved performance glazing.
- Improving the building fabric performance of the building walls, roof, and floor by adding or replacing insulation.
- Improved building fabric and the removal of thermal bridging.
- Introduction of natural ventilation, where possible.
- Replacing existing windows and doors with timber framed double glazing.
- Adding external shading to reduce cooling demand in problematic north facing spaces.
- Reuse of existing construction material (bricks) to establish a sustainable approach to materiality.

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 12: Masterplan Sarah McConville (Canberra High School)

The following initiatives were proposed (among others):

- Replacing existing gas-fired building services with efficient electric heat pumps.
- Improved internal lighting efficiency.
- Addition of new PV array.
- Increasing the size of the existing PV array.
- Adding battery storage for the PV array

6. SUMMARY OF CONSULTANT VETTING – Performance relative to BAU

6.1 Present: Existing Opportunities

Mawson Primary: The Mawson Primary School site comprises of school buildings ranging in lifespan from (1960's - 2010). They include the main two storey building block with teaching spaces for the Senior students, Staff Amenities and the Library. The Preschool Kinder building, the Hall directly linking to the Kitchen and Cafeteria, the Demountable across the oval.

A key infrastructure challenge for the school buildings are summer heat-loads and meeting thermal comfort requirements in a changing climate, combined with the changing expectations and standards for a building's thermal performance in the education context.

The school has undertaken progressive internal upgrades of the teaching and learning environments over the past

18 months, including some minor sustainable infrastructure projects such as:

• lighting efficiency program – LED tubes to existing fittings; and

• installation of a 10kW solar array.

To capitalise on the internal improvements, significant building envelope work to align with the asset renewal requirements of the school, including replacement of end-of-life building elements such as all windows and doors and the school roof.

The school also currently uses the original gas boiler and although still operational, the unit has had many repairs and is well beyond its expected life span and is to be replaced. Cooling is provided only in selected spaces by split system type air conditioners and is generally not provided in classrooms.

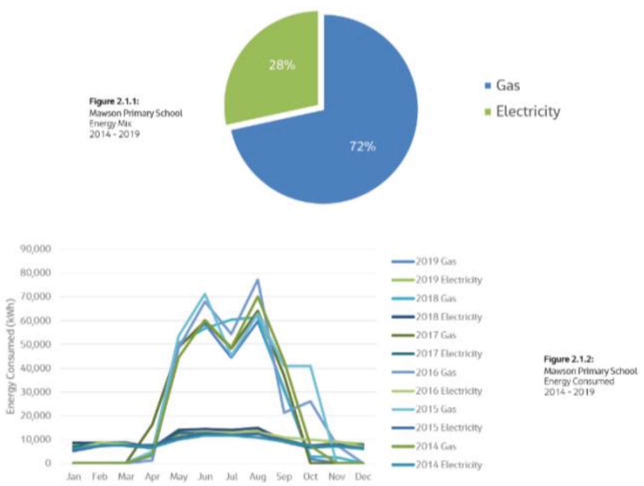


Figure 13: Mawson Primary Vetting report extract

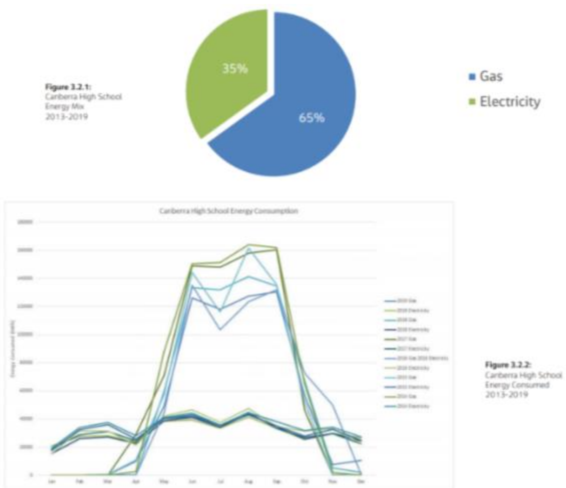


Figure 14: Canberra High School Vetting report extract

Canberra High: The Canberra High School site comprises of school buildings ranging in lifespan from the 1930's. They include the Main Entrance three storey building block and connected Library building, the Science and Technology blocks and the Assembly Hall and Gymnasium buildings.

Canberra High School was nominated to be the ACT's first carbon neutral school in 2012. Significant infrastructure improvements were undertaken at this time, and comprise:

• upgrade of lighting to LED lighting;

• installation of a 10kW solar array;

• installation of solar tubes to provide natural light to top story classrooms; and small scale wall insulation trials (on one west facing wall).

Currently, heating is provided on site by two large gas boilers (approx. 2 MW installed capacity). Cooling is provided to some spaces either by spilt system type air conditioners or evaporative coolers.

6.2 Future: New Build

Mawson Primary: Students reviewed the spatial planning of the main two storey building block, keeping in mind the structure of the building and how the adaptive reuse of this main skillion roof structural form can be renovated to allow for a minimum of two additional separate homerooms/classrooms and to be a more energy efficient building with visually engaging teaching spaces.

Consideration for an energy reduction strategy was investigated through existing materials and construction types with an emphasis on retaining as much as the built fabric as possible and only demolishing the existing conditions, if a renovation or enhancement is not possible.

Canberra High: Students undertook a review of the Master Planning of the site as a whole and devise a plan for a renovation to the existing Library and Technology Wing and the main multi-storey building's classrooms with a view to improving the quality and flexibility of the layout of teaching spaces while considering lines of sight and student and staff accountability and engagement. They also considered incidental spaces between buildings and the opportunities provided for socialisation and a sense of belonging, which is critical for adolescents to engage and thrive academically.

General:

In most spaces, indoor environmental control at both Mawson Primary School and Canberra High School is currently provided with heating only via heating hot water systems. Heated hot water is supplied by large, natural gas fired boilers located in a plant room and circulated with the use of electric pumps to radiators or small fan coil units in or adjacent to occupied spaces. In some instances, spaces are also cooled by direct expansion type (split unit) air conditioning units, however this is the exception rather than the rule and limited to smaller areas of the schools. In general, ventilation appears to be provided by openable doors and windows, rather than by mechanical systems.

The students recognised that heating is a principal contributor to energy consumption and carbon emissions at both schools. Student proposals for electric heating and cooling systems included air cooled heat pumps serving the whole of each campus or localised, direct expansion air conditioning systems installed on a building-by-building basis.

Ground source heat pumps were discussed in studio, however this option was not proposed in final student submissions, likely due to spatial considerations.

In our opinion, both air source heat pumps providing district chilled and heating hot water and smaller direct expansion systems serving individual buildings are feasible systems for schools. Both types of system offer similar efficiency: Air source heat pumps typically have a coefficient of performance of approximately 3 at full load, with improved performance at part load. A direct expansion system capable of serving a school building (for example a variable refrigerant volume system) typically has a coefficient of performance between 3 and 4. Other factors including spatial, acoustic, financial and sequencing considerations, as well as more detailed energy modelling would inform a decision between these two options

6.3 Baseline vs Best Practice

Students developed a base case model of the existing building and conditions to give an indication of the performance of the existing building and to calculate the level of improvement of the proposed design response.

The base case model was developed using information gathered by the students through site investigations and supplemented by typical existing building parameters representative of the building age and the time of construction.

The base case models included the following building specific information.

	Canberra High School			Mawson Primary School	
	Tech Block	Science Block	Library	Senior Block	Stem Hub
External Wall R-Value	0.5	0.5	0.48	0.314	0.24
Roof R-Value	1.8	1.8	0.55	2.3	2.3
Floor R-Value	0.75	0.24	0.79	0.07	0.29
Window U-Value	5.8	5.8	5.8	5.8	5.8
Shading	As Existing				
Air Tightness	Leaky				
Lighting	10 W/m²				
Heating System	Gas Boiler				
Cooling System	None				

Figure 15: JACOBS Vetting report extract – Comparative data on school environmental performance

Other fixed inputs were used in all models:

- Weather file: Canberra, ACT
- Occupancy: 2m²/person
- Equipment Load: 15W/m²

The graph below, details a range of iteratives and buildings and the exact level of improvement will depend on specific building characteristics and the level of improvement under each initiative. However, using the graph clear trends can be seen. For example, by improving building fabric the improvement in EUI can potentially be in the range from 4% to as high as 40% if using a combination of improvements.

Similarly, the reduction in EUI offered by improved HVAC and efficient lighting and control fell in a range between 14% and 35% excluding allowance for PV. Nate that an outlier that occurred during the modelling of Mawson Primary Senior Block indicating that using electric heat pumps will increase the building's EUI. This is likely spurious due to a low floor R value being used in the student's model (0.07 compared with 0.24 to 0.79 for other floors) and should be discounted.

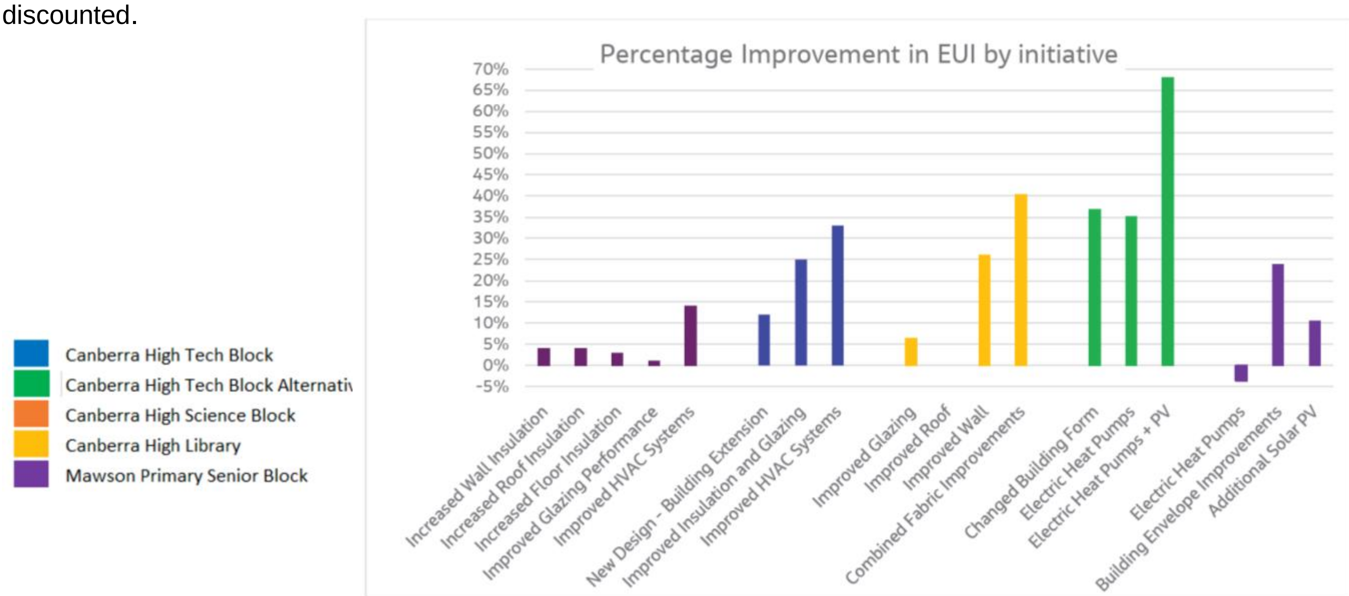


Figure 16: JACOBS Vetting report extract – Overall Improvement of proposed initiatives against BAU

6.4 Key findings

The energy modelling analysis was used to inform the design process as part of the design studio. The results of the modelling indicate that by using a combination of building fabric improvements through increased insulation and improved performance glazing as well as updated efficient electric HVAC services and internal lighting the building energy use intensity can be reduced significantly.

The following strategy is recommended:

• Reduce the energy being used by improving building fabric performance and services.

• Switch the energy fuel source by removing gas appliances and switching to electricity.

• Add on-site renewables to offset the electrical energy demand.

• Use carbon off sets or off-site renewables to offset the remaining energy demand.

The proposed building improvements (against ACT Smart Schools program and Sustainability Victoria benchmarks) for both Canberra High, as well as Mawson Primary are illustrated in the graphs below.

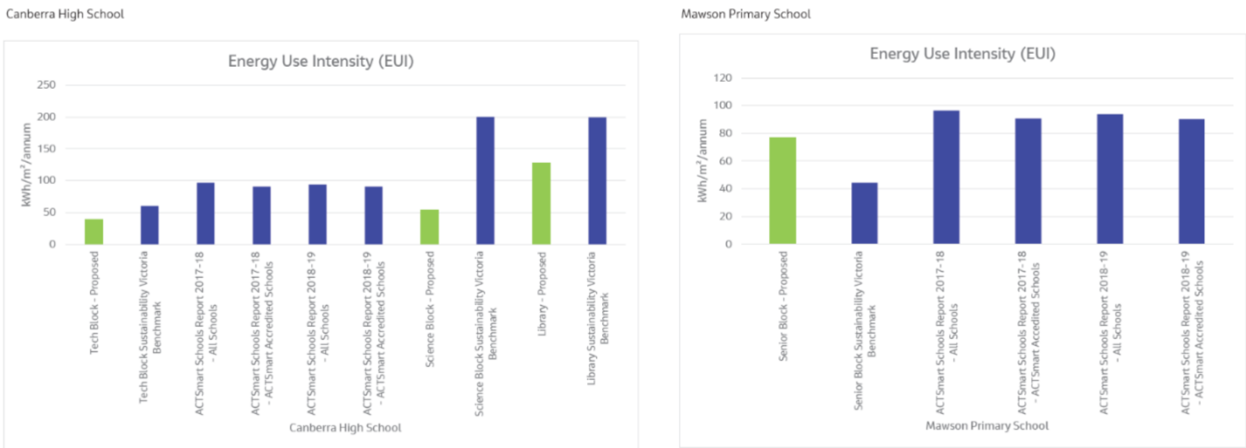


Figure 17: JACOBS Vetting report extract – Improvement of proposed initiatives against BAU per school

7. CONCLUSIONS

7.1 Conclusions

Approximately one dozen individual School refurbishment projects split across two different sites were worked on as part of IDS-03. Each project investigated novel concepts to complement the brief (which remained under development for large portions of the semester) and to consider additional design features that benefit the public and environment. Students from both architecture and engineering background enjoyed expert input from both the industry consultants, but also the client representatives who all combine extensive knowledge in the design of such centres. Each design response tackled the environmental conditions on site and a joint designedly/engineering response in a different way, providing a rich tapestry of ideas. A small number of those were then carried forward by the participating engineering consultants as part of their vetting process.

Common goals were tested in relation to consistently capturing energy improvement with the uniform use of the digital environmental analysis software 'Sefaira', in particualr for energy modelling across the studio.

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-03 outcomes report.

The results of the modelling (vetted by the engineering consultants after the end of semester) indicate that by using a combination of building fabric improvements through increased insulation and improved performance glazing as well as updated efficient electric HVAC services and internal lighting the building energy use intensity can be reduced significantly. The engineering consultants assess that additional improvements are possible through the use of optimised controls for building services and the use of daylight and occupancy sensors.

APPENDIX A – Engineering Consultant Vetting Report

APPENDIX B – Student Work

Design Studio Outcomes

IDS-03

APPENDIX A

ENGINEERING CONSULTANT VETTING REPORT

iHub IDS-03
ACT Schools

AIRAH | ARENA

Summary Report

Rev 01
May 2021

Jacobs

Photographer Mark Baker/AP, *Canberra chokes on world's worst air quality as city all but shut down,* January 3 2020, Photograph, Canberra ACT.

Document Verification

iHub Summary Report

Description	Revision	Date
Draft issue for review	Rev A	11th May 2021
Final issue to client	Rev 01	13th May 2021

Prepared by	Authored by	Reviewed by	Approved by
Bridget Hall	Jo Lettieri / Billy Ong Seng / Lachlan Blake / William Lumb	Chris Walker	Huai Lim

iHub Sponsors

ACT Government

THE UNIVERSITY OF MELBOURNE

msd Melbourne School of Design

Jacobs

AIRAH

ARENA

Australian Government

Australian Renewable Energy Agency

THE INNOVATION HUB

iHUB

FOR AFFORDABLE HEATING AND COOLING

Contents

1.0 Executive Summary

This section provides an overview of the summary report background and the key findings based on the energy modelling undertaken.

Clare Foran and National Journal, *Should Climate Change Come With a Warning Label?,* June 17 2014, The Atlantic, https://www.theatlantic.com/politics/archive/2014/06/should-climate-change-come-with-a-warning-label/445212/

Studio Overview

The iHub Integrated Design Studio 3 took place at the University of Melbourne during Semester 2, 2020. Students were asked to adopt an integrated design approach when responding to a brief from the ACT Education Directorate to address shortcomings in two existing ACT schools.

As part of the integrated design response students investigated initiatives to reduce operational energy use and integrate on-site power generation in their proposals with the aim of achieving net zero carbon emissions from buildings in use.

Energy Modelling

Energy modelling and analysis undertaken during the studio indicated that energy use intensity (EUI) reductions in the order of 20% - 40% are achievable through a combination of building design and fabric improvements together with installation of energy efficient equipment.

Modelling Findings

Modelling showed proposed buildings meeting or exceeding relevant Victorian and ACT benchmarks for their type, with EUIs as low as 40 kWh/m^2.annum for some buildings. Students also demonstrated that energy consumption in buildings with low EUIs could be completely offset on an annual basis by on-site generation from photovoltaic panels, achieving net zero energy use in operation.

Bristol Prefabricated Aluminium Classroom, c. 1951, Image, Public Records Office of Victoria

2.0 Studio Summary

This section summarises the integrated design studio IDS- 03 Schools offered by the University of Melbourne to students who are interested in carbon zero buildings.

"A truly integrated design approach dismantles traditional hierarchy between engineering and architecture to achieve sustainable design outcomes."

From left: Buckminster Fuller, Michael Hopkins, Tony Hunt, John Walker, Norman Foster, James Meller. © Tim Street-Porter.

Author Sam Wilkinson, Josh Mason and Photographer Tim Street Porter, A Journey to Digital Manufacture, April 27 2020, Photograph, https://www.fosterandpartners.com/plus/a-journey-to-digital-manufacture/

2

Overview

iHub IDS-03 Schools is the continuation of research undertaken by the Melbourne University Design Studios offered at MSD in 2020. The studios explored how schools could reduce energy usage in the built environment to reach carbon neutrality with a focus on renewable technologies.

iHub is an initiative led by the Australian Institute of Refrigeration, Air Conditioning and Heating (AIRAH) in conjunction with University of Melbourne and supported by the Australian Renewable Energy Agency (ARENA). It aims to facilitate the HVAC industry's transition to a low emissions future, stimulate jobs growth and showcase HVAC innovation within buildings.

In addition to industry input students were exposed to state-of-the-art research from the LEARN research hub as well as other specialists in education design. They also engaged with a real Client (ACT government) using existing school building stock in the ACT as a case study.

Integrated Design

Through the education program lens, students learnt to adapt, reuse and explore new spatial configurations to synthesis existing and new building fabric over a full building life cycle. They investigated how building performance can assist Australia's response to the 2015 Paris Climate Accord. At COP 21 in Paris, on 12 December 2015, Parties to the UNFCCC reached a landmark agreement to combat climate change and to accelerate and intensify the actions and investments needed for a sustainable low carbon future. The studio tested ideas of how education learning environments need to adapt to meet emerging challenges around pedagogy, technology and the climate.

More broadly, the studio emphasised advancing renewable energy technologies toward zero energy buildings and included a research agenda that aimed at changing current paradigms around how architecture and engineering disciplines interact.

Students

The students were guided by the studio leaders and multidisciplinary industry design consultants to challenge conventional interdisciplinary thinking between engineering and architecture to promote integrated design outcomes. A collaborative approach to innovation and sustainability dismantles traditional hierarchy between engineering and architecture as both disciplines are reliant on each other and technology to foster integrated design led thinking.

The studio began with a number of students from Melbourne School of Engineering (MSE) to further explore design across faculties and how an integrated studio might approach problem solving to achieve integrated design outcomes. Weekly studios were held over the semester with industry advice from Jacobs Group for architecture, engineering and sustainability.

3.0 Existing Conditions of Sites

This section introduces the two ACT school sites used as case studies for IDS-03 Schools namely, Mawson Primary School and Canberra High School and introduces the school background, site building fabric and energy use for each site.

3

Architects Kirsch Architecture and Photographer Hertha Hurnaus, *Elementary School Baslergasse / KIRSCH Architecture*, 2014, Wein Austria, https://www.archdaily.com/781412/elementary-school-baslergasse-kirsch-architecture?ad_medium=gallery

3.1 Mawson Primary School

Background

Mawson Primary School is one of three bilingual schools in the ACT. It is the only school offering a Mandarin immersion program, with 50% of the curriculum being taught in Mandarin and 50% in English. There is also a mainstream class in every year level that learns Mandarin for one hour each week.

The Site comprises of school buildings ranging in lifespan from (1960's - 2010). They include the main two storey building block with teaching spaces for the Senior students, Staff Amenities and the Library. The Preschool Kinder building, the Hall directly linking to the Kitchen and Cafeteria, the Demountable across the oval.

The school has undertaken progressive internal upgrades of the teaching and learning environments over the past 18 months, including some minor sustainable infrastructure projects such as:

- lighting efficiency program - LED tubes to existing fittings; and
- installation of a 10kW solar array.

Mawson Primary School
Site Plan

Building Fabric

To capitalise on the internal improvements, significant building envelope work to align with the asset renewal requirements of the school, including replacement of end of life building elements such as all windows and doors and the school roof.

The school also currently uses the original gas boiler and although still operational, the unit has had many repairs and is well beyond its expected life span and is to be replaced. Cooling is provided only in selected spaces by split system type air conditioners and is generally not provided in classrooms.

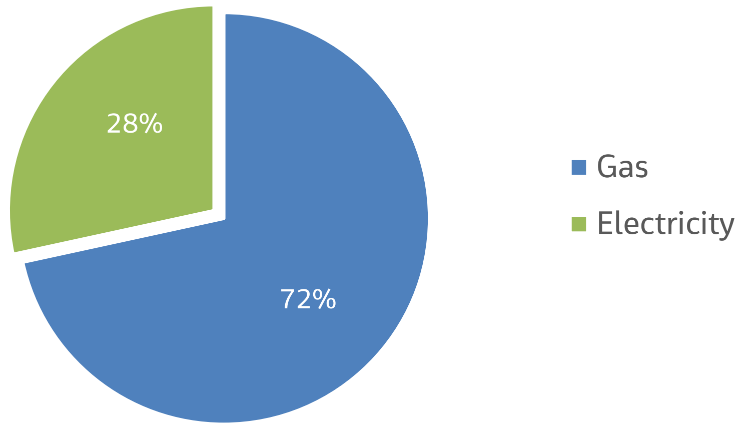
A key infrastructure challenge for the school buildings are summer heat loads and meeting thermal comfort requirements in a changing climate, combined with the changing expectations and standards for a building's thermal performance in the education context.

Energy Use

Electricity and gas usage data provided by the ACT Education Directorate for the years 2014 – 2019 indicates that natural gas accounts for approximately 72% of the energy consumed at the site (Figure 3.1.1).

Monthly use patterns show that electricity consumption is relatively constant throughout the year, while natural gas consumption peaks in winter (Figure 3.1.2). Although sub-metering data to accurately quantify energy used for particular purposes was not available, usage patterns and the equipment known to be installed on site suggest that the principal driver of energy consumption is space heating.

Figure 3.1.1: Mawson Primary School Energy Mix 2014-2019



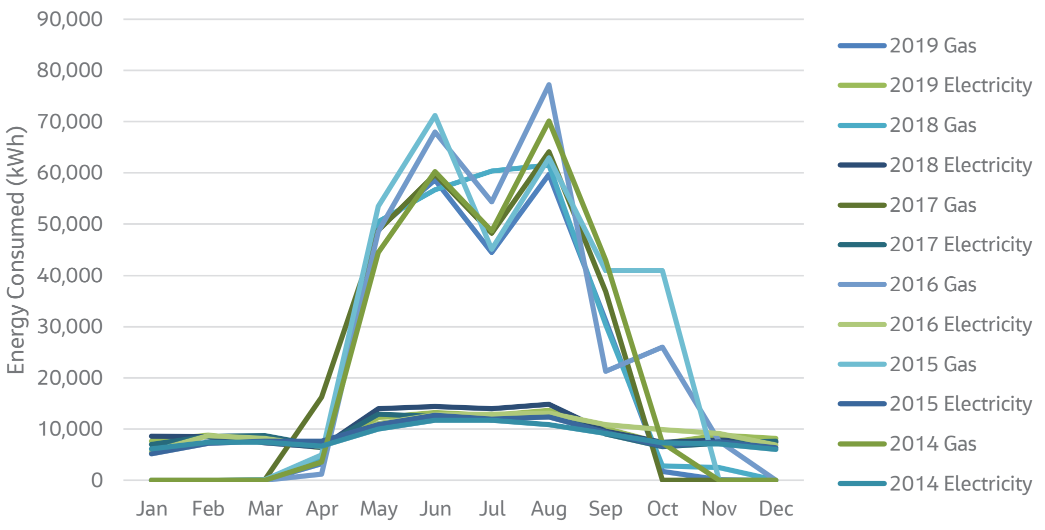


Figure 3.1.2: Mawson Primary School Energy Consumed 2014-2019

3.2 Canberra High School

Background

Canberra High School was originally based at the current School of Art at the Australian National University and moved to the current site in Macquarie on 21 August 1969. There have been many changes since 1938 providing a relevant curriculum and contemporary learning environment for students of the 21st century.

The Site comprises of school buildings ranging in lifespan from the 1930's. They include the main two storey building block with teaching spaces, Staff Amenities and the Library, the Hall, Gymnasium and Science and Technology Blocks.

The 21st century also presents key infrastructure challenges for existing school buildings as older buildings struggle to meet thermal comfort requirements of a changing climate and changing expectations for infrastructure performance in the education context.

Canberra High School
Site Plan

Building Fabric

Canberra High School was nominated to be the ACT's first carbon neutral in 2012. Significant infrastructure improvements were undertaken at this time, and comprise:

- upgrade of lighting to LED lighting;
- installation of a 10kW solar array;
- installation of solar tubes to provide natural light to top story classrooms; and small scale wall insulation trials (on one west facing wall).

Currently, heating is provided on site by two large gas boilers (approx. 2 MW installed capacity). Cooling is provided to some spaces either by spilt system type air conditioners or evaporative coolers.

Energy Use

Electricity and gas usage data provided by the ACT Education Directorate for the years 2013 – 2019 indicates that natural gas consumption makes up approximately two thirds of the energy consumed at this site (Figure 3.2.1).

Like Mawson Primary School, there is a large increase in natural gas consumption during winter while electricity consumption is less seasonal. (Figure 3.2.2). Again, usage patterns and equipment known to be installed on site suggest that the main driver of energy consumption at Canberra High School is space heating.

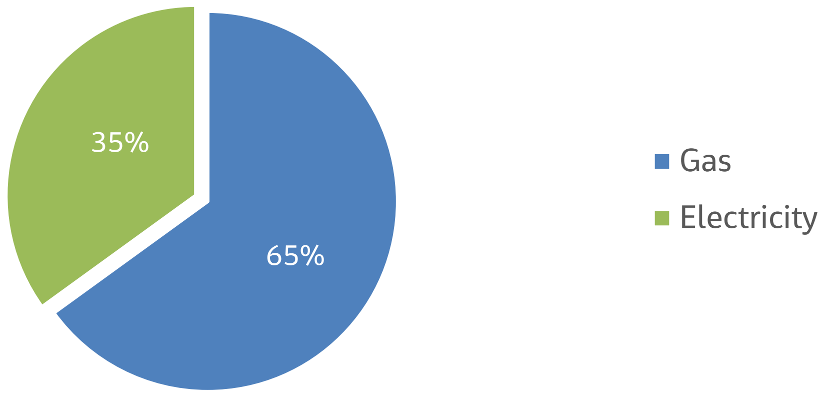


Figure 3.2.1:
Canberra High School
Energy Mix
2013-2019

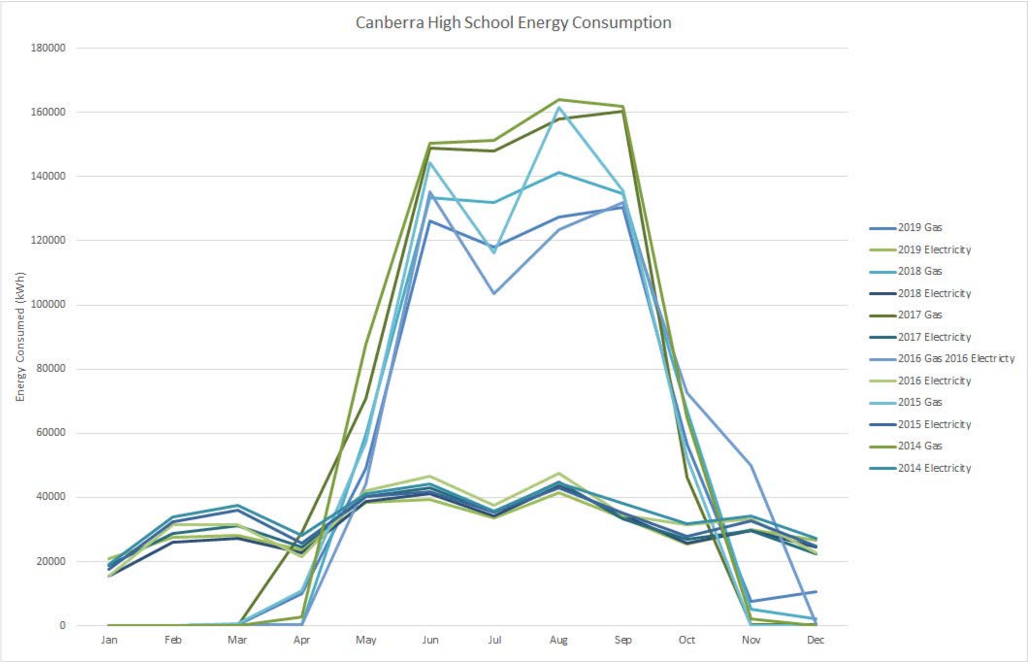


Figure 3.2.2:
Canberra High School
Energy Consumed
2013-2019

4.0 Design Brief

This section provides an overview of the school policy, ACT Climate Change Strategy and School community as part of a broader brief for students to respond to.

Architecture Firm SOM and Photographer James Ewing/OTTO, *SOM designs first net-zero energy school in New York City on Staten Island,* December 29 2015, New York City,https://www.dezeen.com/2015/12/29/som-designs-first-net-zero-energy-school-new-york-city/

4

4.1 ACT Education (EDU) Strategic Plan 2018-2021

Policy Context

Policy and strategic directions are key drivers for the modernisation and enhanced sustainability performance of ACT Public Schools.

ACT Climate Change Strategy

The ACT is considered a world leading jurisdiction in mapping the pathway to a zero- emission future and proudly has one of the most ambitions zero emission targets with 2045 the target year to achieve zero emissions across the territory's operations.

An interim target to reduce emissions in government operations by 33% by 2025 sets the scene for cross-industry collaboration and partnerships to envision how the target will be achieved and to explore opportunities for innovation an creative input. Additional to this target is the requirement for all government lease vehicles to transition to electric vehicles by 2021 (to take effect as each lease expires) and the increased focus on sustainable and active forms of transport, notable for the commute to work and school.

The broad randing iniatives under the Strategy provide a wealth of challenges and opportinities for school facilities to explore and implement as leaders in the ACT community and life of future generations.

The mission of the ACT Education Strategic Plan is (2018- 2021) is to

"..develop and deliver educational services to empower each child and young person in the ACT to learn for life."

From an infrastructure perspective the key priority of the plan is to deliver **"schools were students love to learn"** through the provision of 21st Century learning environments.

Contemporary research shows that learning occurs best when internal building temperatures are maintained between 19 -26 degrees Celsius; without mechanical intervention, most schools built prior to the implementation of energy efficiency standards in the 1990's are unable to deliver this comfort range without significant cost impost, owing to a combination of poor orientation, lack of insulation and unsealed building envelopes.

Photographer Peter Clarke, *Albert Park College Liberal Arts Centre,* South Melbourne, 2018. https://www.jcba.com.au/projects/albert-park-college-liberal-arts-centre

Crosier Scott Architects, *Eastwood Primary School,* 2017, https://croscott.com.au/portfolio/items/eastwood-primary-school/

4.2 Mawson Primary School

School Community

The school currently has approximately 500 students and has been the fastest growing primary school in the past few years, whereby all rooms are now used as homerooms and there are no rooms allocated to specialist teaching subjects such as Art/Drama/PE/Environmental Studies (Science). The school is located close to the Embassy zone and has students from diverse cultural and socio-economic backgrounds, with the majority speaking more than one language when at home.

School Brief

The Site comprises of school buildings ranging in lifespan from (1960's - 2010). They include the main two storey building block with teaching spaces for the Senior students, Staff Amenities and the Library. The Preschool Kinder building, the Hall directly linking to the Kitchen and Cafeteria, the Demountable across the oval.

Students reviewed the spatial planning of the main two storey building block, keeping in mind the structure of the building and how the adaptive reuse of this main skillion roof structural form can be renovated to allow for a minimum of two additional separate homerooms/classrooms and to be a more energy efficient building with visually engaging teaching spaces. Each homeroom/classroom is to be 50 sq m min. if it has access to a shared teaching space of 20 sq m or be 65 sq m if there is no access to a shared teaching space.

They also explored options to create more flexible, 21st century learning spaces, where staff can collaborate with the adjacent homeroom in a team teaching approach, or have access to shared areas, to allow for smaller teaching groups.

Mawson Primary School, Canberra, ACT. Digital Image. Google Image.

4.2 Mawson Primary School

Design Considerations

Consideration for an energy reduction strategy was investigated through existing materials and construction types with an emphasis on retaining as much as the built fabric as possible and only demolishing the existing conditions if a renovation or enhancement is not possible. so as to make best use of valuable resources and limit building materials needlessly going to land fill. A review of the Master Planning of the site as a whole and to devise a plan for a renovation to the existing Hall and the location of a new dedicated Art Room facility to best engage with and enhance the school's specialist subject curriculum was undertaken to improve connectivity of the following buildings:

- This Art space needed to accommodate two separate classes (each of 30 students max.) per teaching period, and allow for pottery/3-D construction, painting/ textural play, textiles and wood craft.
- The multipurpose hall to allow for a whole school assembly with sitting room for 70% of parents and carers and standing room for the remaining 30%.
- The existing direct link of the hall to the kitchen/canteen, for the serving of light refreshments and as a way of fund raising during larger school events.
- The Library space as a flexible learning hub that caters for both independent and collaborative learning, with access to technology so that some scheduled class times per year level can be run from this "learning hub".

1.

2.

3.

1. Suspended ceiling with openable windows above.

2. Gaps in wall thermal envelope.

3. Thermal bridging. Consider realigning window line so that the internal steel post is separate from external window frame.

4.3 Canberra High School

School Community

The school currently has approximately 800 students enrolled in Years 7 to 10 with over 40 different nations represented within the student population resulting in a multicultural school community.

Social and mental wellbeing are key factors in allowing the junior high school cohort to engage in their learning. Students come from diverse backgrounds and have diverse interests and space requirements during breaks from learning. Evidence from a recently modernised school, indicates that catering for these diverse needs in the playground and spaces used during breaks, can allow individual and group expression while minimising peer to peer friction. Connection of spaces and external environments should have a logical flow to destinations that are both passive and active and maximise the potential for diverse activities to be enjoyed, for example, passive meeting spaces are best located away from active ball sports.

School Brief

The school's vision is to create a sustainable 21st century high school campus, with a focus on the role of the technology building, a multi-purpose school library and various social interaction spaces.

- Current weaknesses – old space that do not enable flexibility or flow.
- Current strengths –excellent equipment and a broad curriculum which would be enhanced with more appropriate learning spaces.

The evolution of learning environments is at the heart of this brief as the school looks to explore the integration of technology while also preserving opportunities to learn and socialise in its absence.

Canberra High School, Canberra, ACT. Digital Image. Google Image.

Billrider2013, 'Old New School, New Canberra High School 2', *About my travels on a bike and related thoughts* (blog), April 6, 2013, https://billrider2013.com/2013/04/06/old-new-school/

4.3 Canberra High School

Design Considerations

Students undertook a review of the Master Planning of the site as a whole and devise a plan for a renovation to the existing Library and Technology Wing and the main multi-storey building's classrooms with a view to improving the quality and flexibility of the layout of teaching spaces while considering lines of sight and student and staff accountability and engagement. They also considered incidental spaces between buildings and the opportunities provided for socialisation and a sense of belonging, which is critical for adolescents to engage and thrive academically. Canberra High School whilst traditional in structure and function prides itself on innovative learning.

To compliment this, their STEM/STEAM offering, which is growing each year in popularity, requires a larger dedicated space within the Technology wing of the school. This space needs to provide for whole class and smaller focus group learning where the class configuration can vary, depending of the task at hand (e.g. software learning, coding, robotics, explanation of mathematics theory, group science experiments, presentations to peers access to various shared electronic materials).

The main building contains many classrooms across three storeys. Students reconfigured to provide for greater flexibility for staff and students to participate in a variety of teaching styles. The current classroom sizes are small and constrained and only allow for ridged furniture placement. Students studied space planning to create better linkages and team-teaching opportunities.

Students considered the following to address the broad ideas of a Master Plan, including opportunities of the Technology wing to better deliver STEAM/STEAM, the Library as a multi-faceted learning space and improve the classroom experience for both staff and students alike.

- Master Plan in the context of the strengths and weaknesses and to align to the school vision.
- Reimagined STEM/STEAM are that aligns with the school's innovating learning.
- 21st Century Library.
- Reconfiguration of classrooms for
- expansion.

1.

2.

3.

1. Bike enclosure highly used.

2. Outdoor Area, students built the pizza oven surrounded by lush green vegetation helps with heat load.

3. Hot water re-circulating fan coil unit fed from existing boiler.

5.0 Design Response

Architects HIBINOSEKKEI, Kids Design Labo, Youji no Shiro and Photographer Toshinari Soga | studio BAUHAUS, *KB Primary and Secondary School / HIBINOSEKKEI + Youji no Shiro + Kids Design Labo*, 2019, Sasebo Japan,https://www.archdaily.com/924188/kb-primary-and-secondary-school-hibinosekkei-plus-youji-no-shiro-plus-kids-design-labo-gasse-kirsch-architecture?ad_medium=gallery

5.1 Building Services Overview

In most spaces, indoor environmental control at both Mawson Primary School and Canberra High School is currently provided with heating only via heating hot water systems. Heated hot water is supplied by large, natural gas fired boilers located in a plant room and circulated with the use of electric pumps to radiators or small fan coil units in or adjacent to occupied spaces. In some instances, spaces are also cooled by direct expansion type (split unit) air conditioning units, however this is the exception rather than the rule and limited to smaller areas of the schools. In general, ventilation appears to be provided by openable doors and windows, rather than by mechanical systems. The students recognised that heating is a principal contributor to energy consumption and carbon emissions at both schools.

Student proposals for electric heating and cooling systems included air cooled heat pumps serving the whole of each campus or localised, direct expansion air conditioning systems installed on a building-by-building basis. Ground source heat pumps were discussed in studio, however this option was not proposed in final student submissions, likely due to spatial considerations.

In our opinion, both air source heat pumps providing district chilled and heating hot water and smaller direct expansion systems serving individual buildings are feasible systems for schools. Both types of system offer similar efficiency: Air source heat pumps typically have a coefficient of performance of approximately 3 at full load, with improved performance at part load. A direct expansion system capable of serving a school building (for example a variable refrigerant volume system) typically has a coefficient of performance between 3 and 4. Other factors including spatial, acoustic, financial and sequencing considerations, as well as more detailed energy modelling would inform a decision between these two options (Figure 1).

	Central heat pumps	VRF system
Capital requirements	Large initial upfont cost	Staggered per building
Overall installation cost	Likely to be higher	Likely to be lower
Expected economic life	20 - 25 years	10 - 15 years
Energy efficiency	Generally good, better performance at part loads.	Generally good, better than central plant in some configurations
Spatial requirements	Large outdoor acoustically treated enclosure. Can be remote from existing buildings	Small enclosure / roof space adjacent to building served.
Maintenance requirements	Lower (small number of large units)	Higher (large number of small units)

Figure 1.

5.1 Building Services Overview

It should also be noted that it is likely that a transition to all electric heating and cooling would entail upgrading the school's electrical infrastructure (substation, main switchboard, sub-boards and wiring).
The large area required and the expensive and disruptive nature of earthworks associated with installation of ground source heat pumps (numerous bore holes or large-scale excavation) in our opinion make these systems unlikely to be suitable for this application.

The students have demonstrated their appreciation of the various systems impacting energy consumption and included the following in their integrated design response:

- Orientation and building design elements to maximise daylight harvesting.
- Offsetting electricity consumption with increased onsite generation by photovoltaic solar panels.
- Use of energy efficient LED lighting combined occupancy detection control and creating smaller lighting zones.

The students have included daylight modelling as part of their analysis to optimise their integrated design by adjusting the building orientation to minimise solar heat gain and maximise daylighting to create better spaces while reducing the amount of artificial lighting.

The site investigations undertaken at Mawson Primary School and Canberra High School indicate limited onsite renewable power generation. The students have included photovoltaic solar panels on the roof in their proposals ranging from an effective of 350m² to 450m² area of panels equating to approx. 70kW to 90kW peak system size.

Whilst the inclusion of onsite PV generation is an ideal use of the roof space of the proposed development, further detailed investigation of the electrical infrastructure and discussion with the supply authority will be required to validate the capacity of the existing system to accommodate the PV system and approval to connect the PV system to the supply authority network. Further detailed analysis of the onsite generation will need to be undertaken as the peak onsite power generation will be in summer months coinciding when the electrical demand is relatively lower due to school holidays and heating systems not in service.

5.2 Students Proposal

Maddie Gundry

This project was bold in its design response to demolish the existing school gymnasium to meet the design brief however it was sympathetic in its reuse of bricks to establish a sustainable approach to materiality and a new language across the site.

Opportunities to explore Carbon Neutrality were investigated through improving building fabric., optimising daylight and improving natural ventilation.

Sarah McConville

This project below was a thought provoking response to reducing the carbon footprint and energy consumption through creating a micro climate within the site.

This was achievable through the softening of landscape as the key design element of the proposal supported by architecture as subordinate to the swale drain meandering through the school in between existing and new buildings working with the site topography fall from to create new zones for habitat.

Ashwin Gunawardana

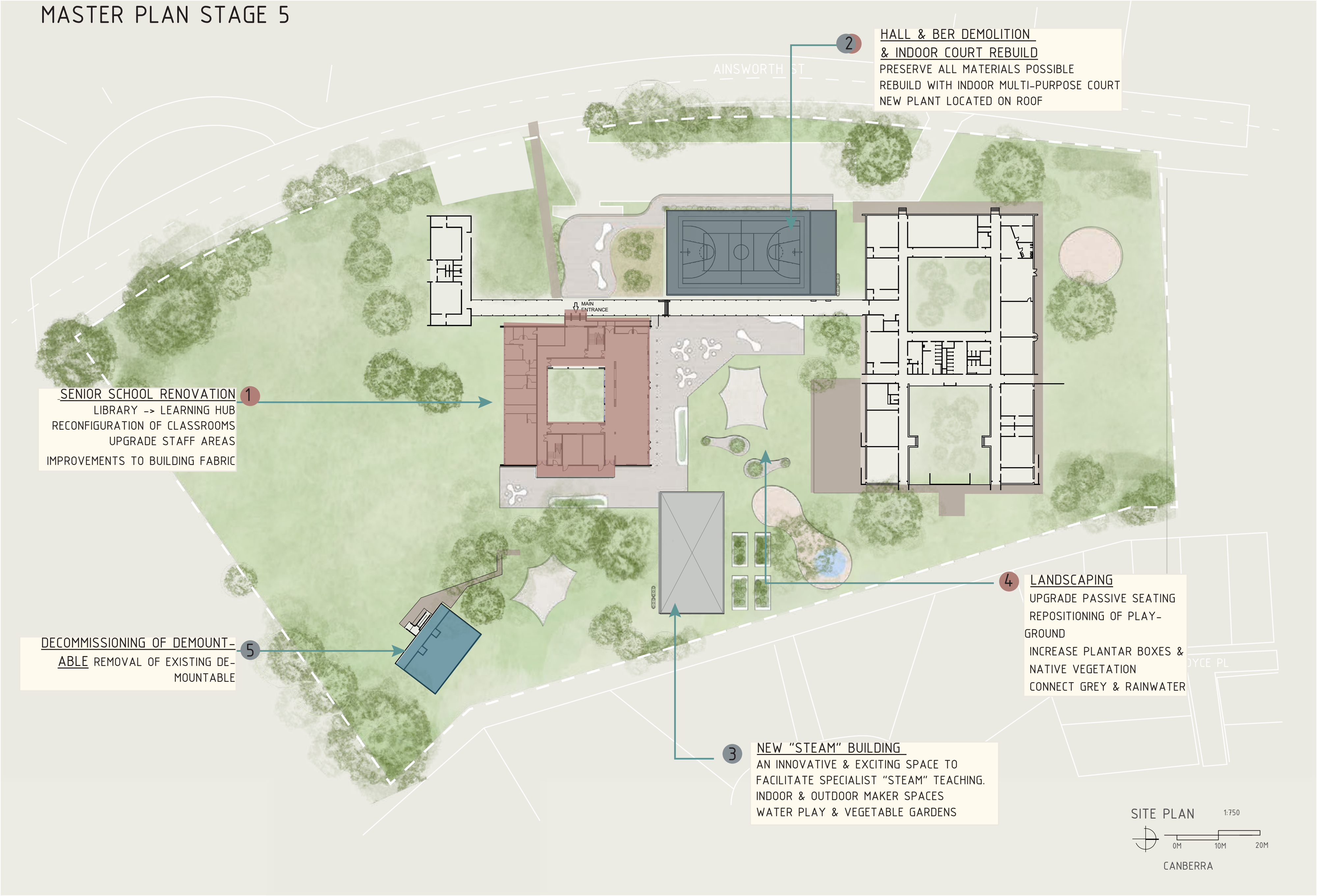
This project was elegant in its design response in meeting the requirements of the studio brief to achieved carbon neutrality through exploration of solar panels.

Optimisation of the roof design to create a set of design parameters that informed the roof pitch to support the solar panels provided an architectural language that was entwined with building performance and demonstrated integrated design thinking without compromising architecture.

Maddie Gundry

The design response included the following proposed initiatives:

- Improved building fabric and the removal of thermal bridging.
- Replacing existing windows and doors with timber framed double glazing.
- Replacing all gas-fired HVAC with electric heat pumps.
- Add external shading to reduce cooling demand in problematic north facing spaces.
- Improved internal lighting efficiency
- Increase the size of the existing PV array and add battery storage.

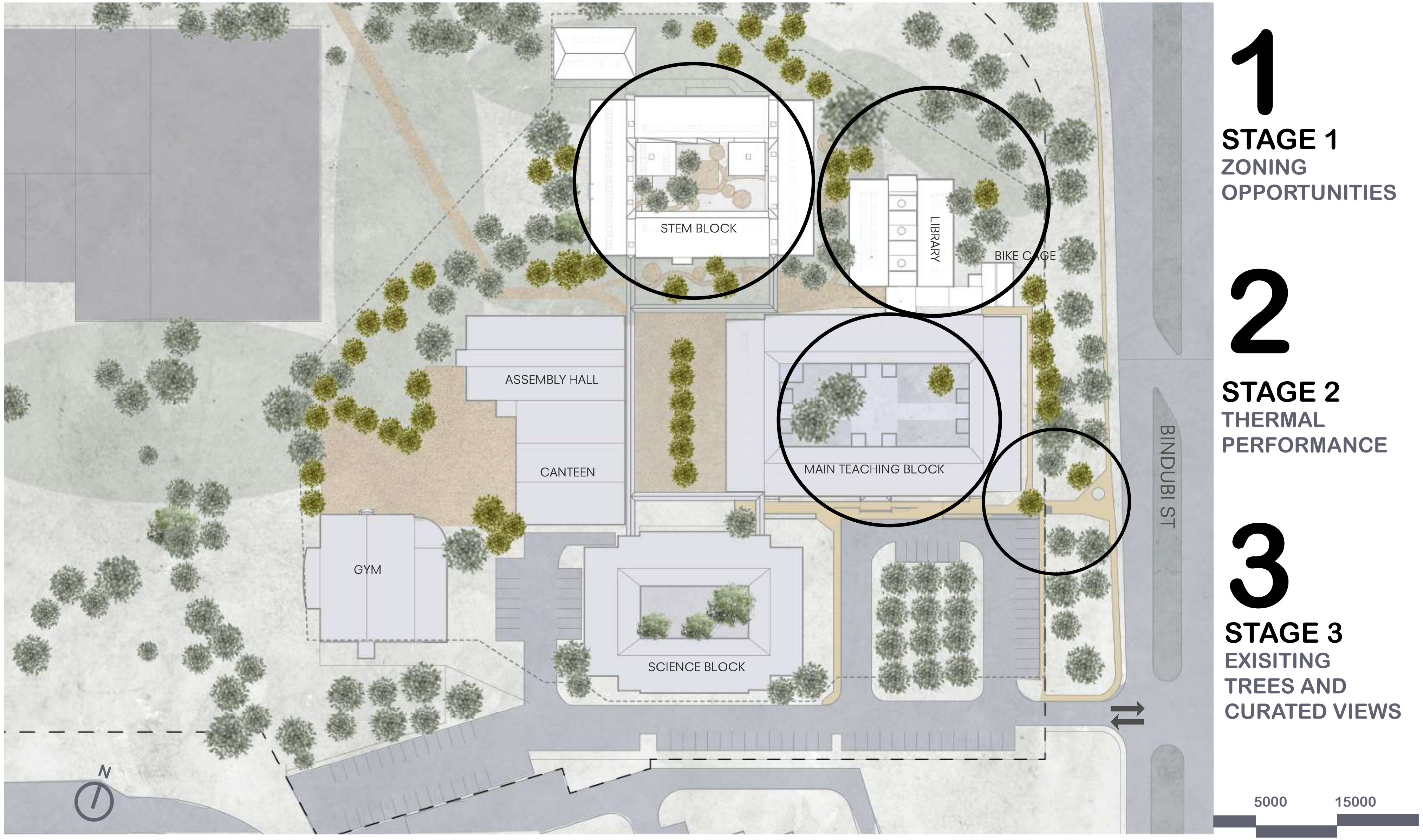


Maddie Gundry
Mawson Primary

Sarah McConville

The design response included the following proposed initiatives:

- Replacement of existing glazing with improved performance glazing.
- Improve the thermal performance of walls, roofs and floors by adding insulation.
- Replacing existing gas-fired building services with efficient electric heat pumps.
- Improved internal lighting efficiency
- Addition of new PV array.



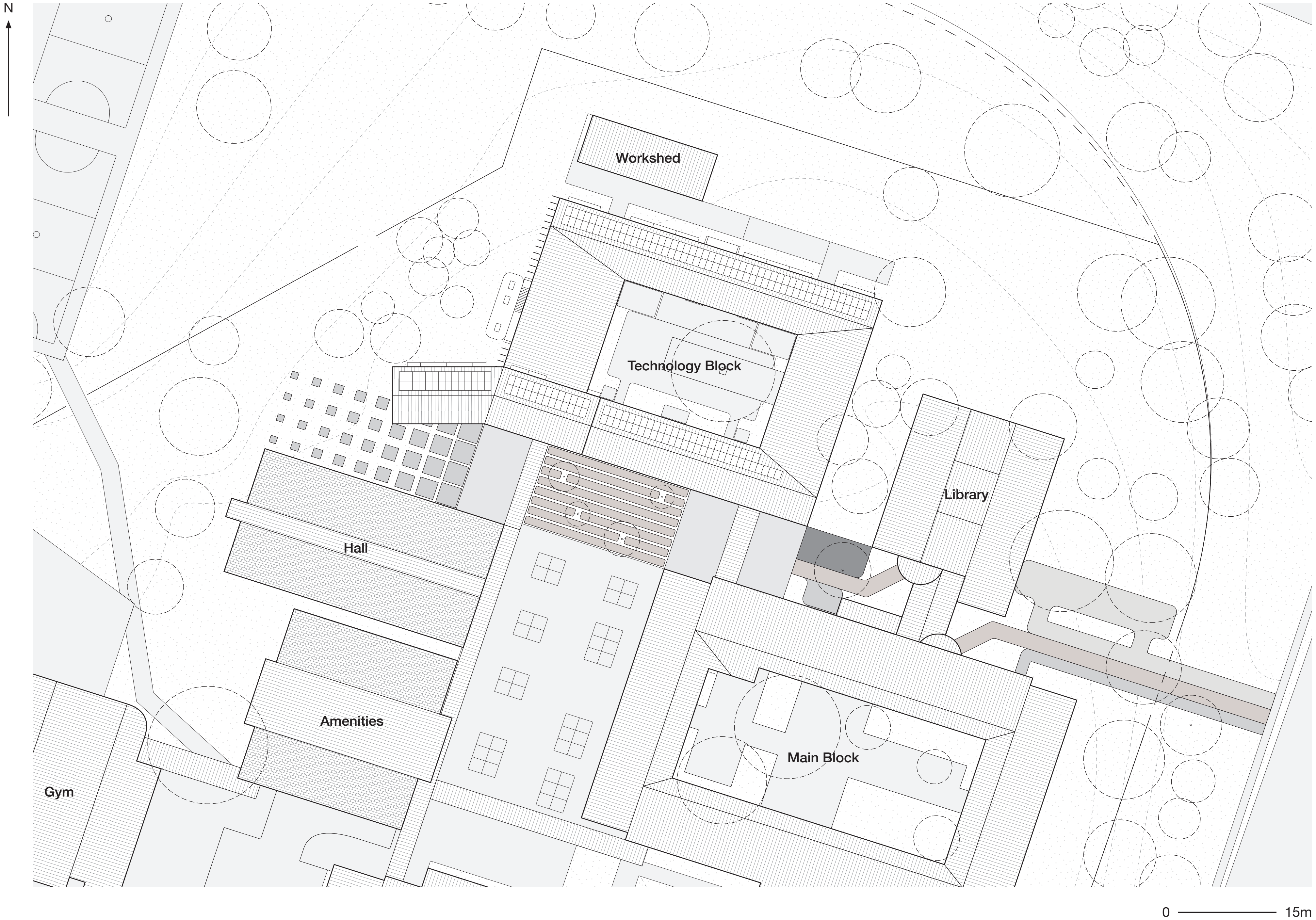
SITE A/ LIBRARY AND ENTRANCE
SITE B/ TECHNOLOGY BLOCK
SITE C/ MAIN TEACHING BLOCK

Sarah McConville
Canberra High School

Ashwin Gunawardana

The design response included the following initiatives:

- Improving the building fabric performance of the building walls, roof, and floor by adding or replacing insulation.
- Improving glazing performance by replacing existing with double glazing.
- Replacing the existing gas fired boiler with efficient electric heat pump systems.
- Improved internal lighting efficiency.
- Addition of new PV array.



Ashwin Gunawardana
Canberra High School

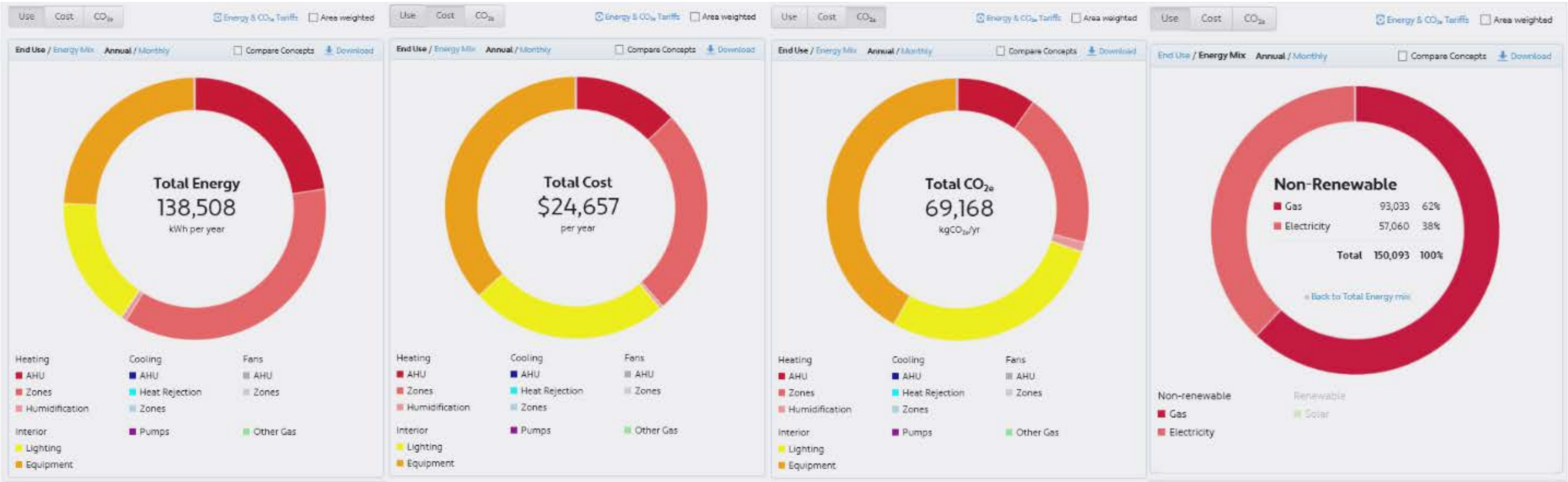
5.3 Analysis

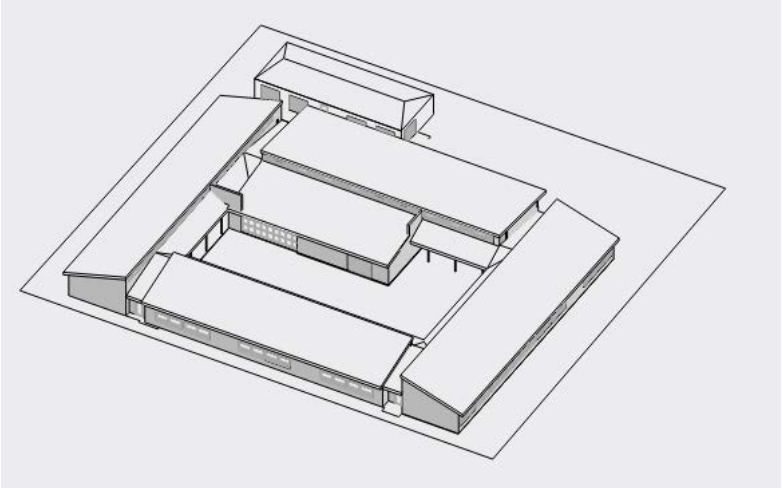
Students were tasked with producing a 3D digital twin of the building for analysis.

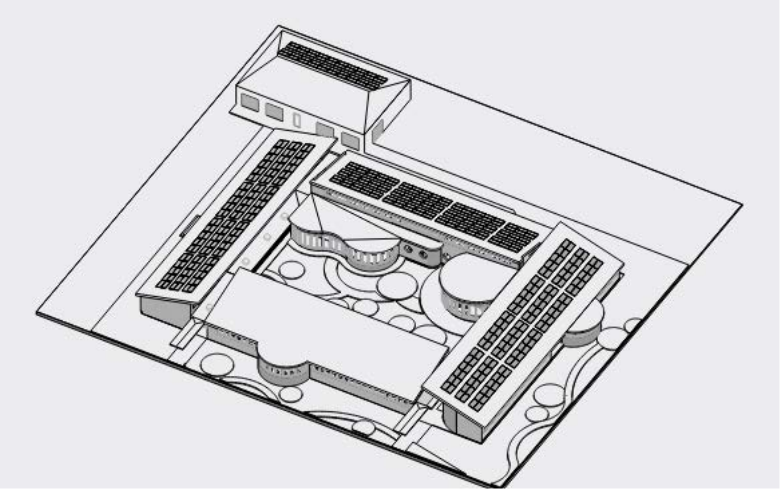
Each building was modelled in either Rhino or Revit and imported to the Sefaira platform for analysis.

The site location was identified and used to select an appropriate weather file along with building use properties and data produced from industry standards and guidance.

The results were analysed within the Sefaira platform to identify the effect of each initiative as well as a preferred combination. Energy end-uses included heating, cooling, pumps, fans, internal lighting, and equipment.







5.3.1 Base Case Model

Students developed a base case model of the existing building and conditions to give an indication of the performance of the existing building and to calculate the level of improvement of the proposed design response.

The base case model was developed using information gathered by the students through site investigations and supplemented by typical existing building parameters representative of the building age and the time of construction.

The base case models included the following building specific information.

Other fixed inputs were used in all models:
Weather file: Canberra, ACT
Occupancy: $2m^2$/person
Equipment Load: $15W/m^2$

	Canberra High School			Mawson Primary School	
	Tech Block	Science Block	Library	Senior Block	Stem Hub
External Wall R-Value	0.5	0.5	0.48	0.314	0.24
Roof R-Value	1.8	1.8	0.55	2.3	2.3
Floor R-Value	0.75	0.24	0.79	0.07	0.29
Window U-Value	5.8	5.8	5.8	5.8	5.8
Shading	As Existing				
Air Tightness	Leaky				
Lighting	$10 W/m^2$				
Heating System	Gas Boiler				
Cooling System	None				

Figure 2.

5.3.2 Design Model

Each project building was modelled with several improvements to investigate the effect on the buildings energy performance and CO2 emissions. These varied from building to building however the most common improvements investigated were:

- Increased external wall insulation
- Increased roof insulation
- Increased floor insulation
- Improved glazing performance (typically replace single glazing with double glazing)
- Efficient HVAC services (replacement of gas-fired equipment with efficient heat pump systems)
- Improved internal lighting efficiency (replacement of existing lighting with LED's)
- Addition of solar PV to offset some or all of the building's electrical energy.

The existing buildings do not currently have cooling systems installed. The proposed heat pump solutions would add this benefit and improve occupant comfort. It is noted that this however would increase the overall buildings energy usage. By switching to all electric systems, this increased energy can be offset though the use of solar PV systems therefore avoiding any additional CO2 emissions.

Some buildings have also been extended as part of a zoning and use analysis. This would also show an increase in annual energy usage when compared to the current baseline building. The designs demonstrate that the increased energy usage can be offset by the selected initiatives.

5.3.3 Individual Initiative Analysis

The analysis carried out focused on individual initiatives prior to arriving at a proposed combination for each site. The following graph shows the percentage saving in energy against the base case model for a range of proposed initiatives.

The graph adjacent, details a range of iteratives and buildings and the exact level of improvement will depend on specific building characteristics and the level of improvement under each initiative. However, using the graph clear trends can be seen. For example, by improving building fabric the improvement in EUI can potentially be in the range from 4% to as high as 40% if using a combination of improvements.

Similarly, the reduction in EUI offered by improved HVAC and efficient lighting and control fell in a range between 14% and 35% excluding allowance for PV. There is an outlier that occurred during the modelling of Mawson Primary Senior Block and it indicates that using electric heat pumps will increase the building's EUI.

This is due to the availability and use of cooling within the model. However by incorporating other measures this can be overcome.

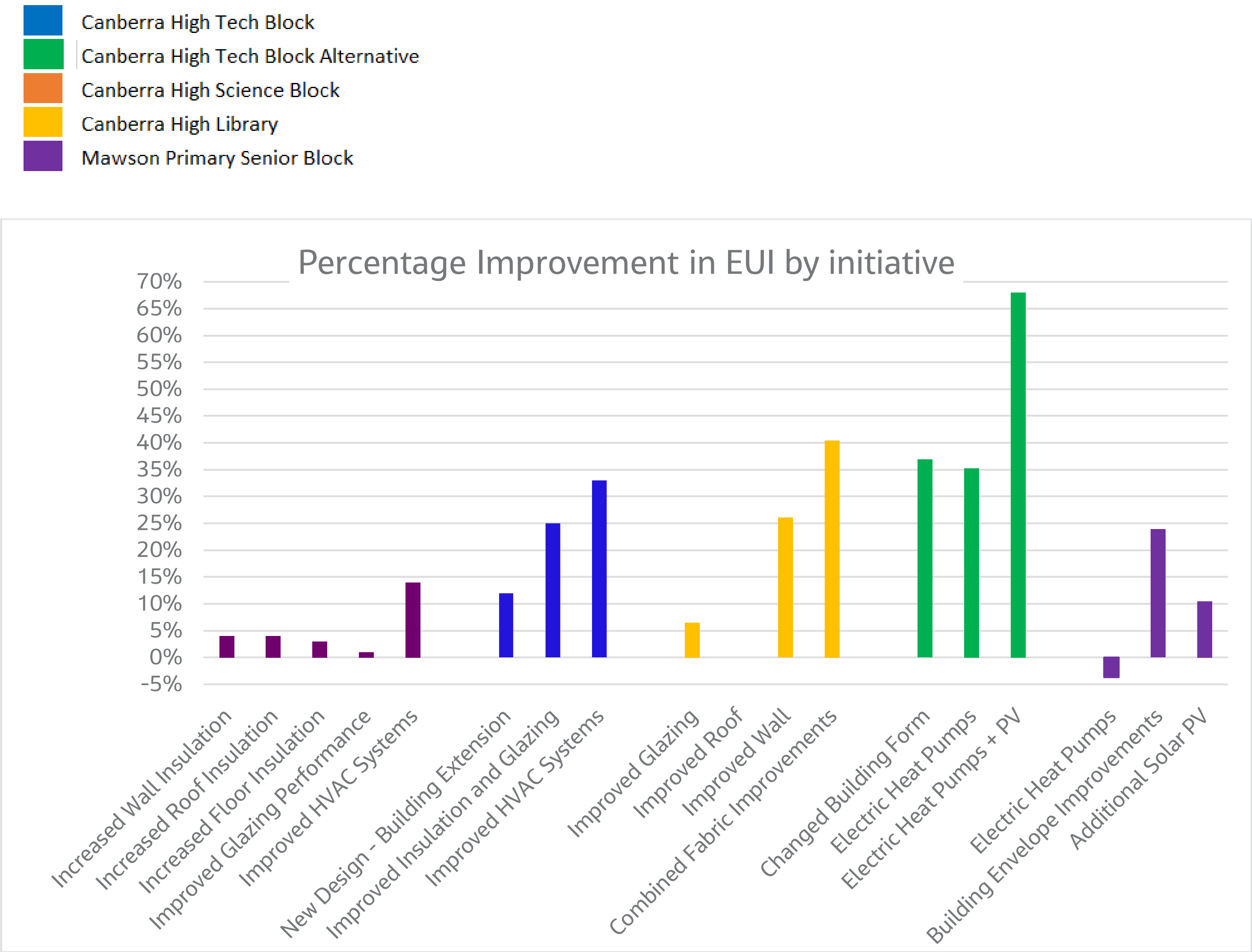


Figure 3.

6.0 Engineering Analysis & Benchmarking

This section summarises the research work undertaken to outline typical best practice and leading practice in school design, and identify typical energy benchmarks for schools.

6

Architects Kaminsky Arkitektur and Photographer Mikael Olsson, *Kollaskolan School / Kjellgren Kaminsky Architecture*, 2014, Kungsbacka Sweden,https://www.archdaily.com/572189/kollaskolan-school-kjellgren-kaminsky-architecture

6.1 Benchmarks

An analysis of benchmarking data allows the proposed design solutions to be evaluated against existing buildings and best practice targets. The benchmarks presented are taken from the Australian Capital Territory ACTSmart Schools program annual reports as well as targets from Sustainability Victoria.

The proposed project buildings are indicated including all chosen building improvements.

Note that the Sustainability Victoria benchmarks are provided in kWh/annum/student. These have been adjusted based on the proposed occupancy of the specific building and therefore there is a separate benchmark for each project building

Canberra High School

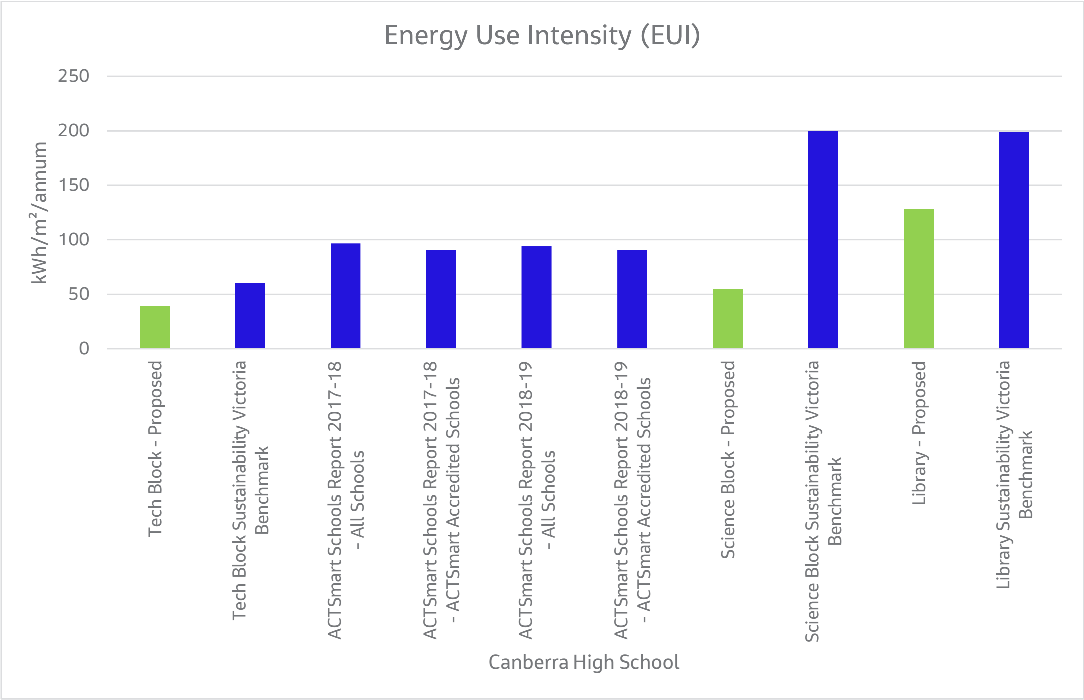


Figure 4.

Mawson Primary School

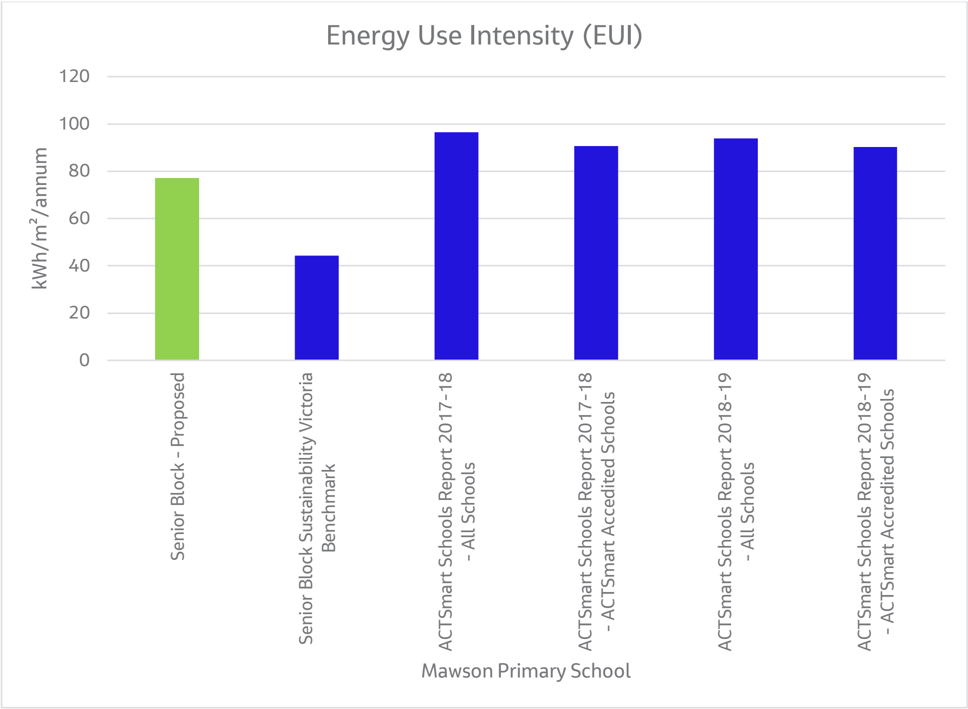


Figure 5.

7.0 Conclusion

This section summarises the results of the analysis and discusses the recommendations for existing and new schools for achieving net zero carbon in operation.

7

Architects Cottrell & Vermeulen Architecture Ltd. and Photographer Anthony Coleman, Westborough Primary School / Cottrell & Vermeulen Architecture Ltd., https://www.archdaily.com/193201/westborough-primary-school-cottrell-vermeulen-architecture

7.1 Summary

Overview

The energy modelling analysis was used to inform the design process as part of the design studio. The results of the modelling indicate that by using a combination of building fabric improvements through increased insulation and improved performance glazing as well as updated efficient electric HVAC services and internal lighting the building energy use intensity can be reduced significantly.

Findings

The following strategy is recommended:

- Reduce the energy being used by improving building fabric performance and services.
- Switch the energy fuel source by removing gas appliances and switching to electricity.
- Add on-site renewables to offset the electrical energy demand.
- Use carbon off sets or off-site renewables to offset the remaining energy demand.

Further Considerations

Further improvements are likely possible through the use of optimised controls for building services and the use of daylight and occupancy sensors should also be considered as part of the strategy.

It should also be noted that whilst a major focus of the modelling was to target net zero carbon, a holistic approach was taken and included consideration of improved occupant amenity, thermal comfort and glare and daylight. Some of these improvements have a negative impact on the buildings energy usage however, through careful choices such as using all electric HVAC systems and on-site generation these call all be overcome whilst still achieving net zero.

Onsite power generation has been taken into account by the students other benefit such as on selling of generated power during summer months could be investigated for further financial and carbon offset.

About Us

Huai Lim

As Director of Operations for Jacobs Built Environment, Huai's expertise is in the project delivery of small to large complex projects within tight timelines and budgets from inception of the design brief to project completion. She has a sound understanding of the processes involved in the facilitation of user groups, project funding, consultancy contracts and the technical/construction knowledge required for successful project delivery that is delivered on time and budget.

Chris Walker

Chris is the appointed Global Technical Lead for Integrated Urban Sustainability at Jacobs.Chris has spent the past twelve years working in various facets of the environmental and sustainability sectors. With a background and training in environmental science, Chris has added to these skills with an extensive career in building and infrastructure design, construction and operation, with a focus on sustainable materials, energy and water efficiency, and user health and wellbeing. This experience has enabled him to build a unique set of skills that complement and enhance the delivery of his holistic and innovative sustainable design solutions.

Josephine Lettieri

Josephine Lettieri is a Principle Architect at Jacobs with a qualified background in Civil Engineering. Her approach is design led with over 20 years' experience in integrated design projects including education and transport.

Billy Ong Seng

Billy is Technical Director with over 16 years' experience in the building services across a variety of government sectors. Billy is well versed in electronic security access control and CCTV design and experience in ICT infrastructure design, critical power supply and distribution system and lightning protection design.

Lachlan Blake

Lachlan Blake is a Mechanical Engineer with over 15 years' professional experience. During his time as a building services engineer at Jacobs he has completed projects in a variety of sectors including higher education, defence, water and transport.

William Lumb

William Lumb is a Sustainability Consultant at Jacobs. William's background is in Mechanical Engineering and Building Thermal Modelling. He has over 10 years' experience in building energy modelling and the use of analysis software including Sefaira.

References + Standards

To complete the analysis and reporting, a series of standards and documents were reviewed and considered as part of the process.

The following standards and documents were referred to:

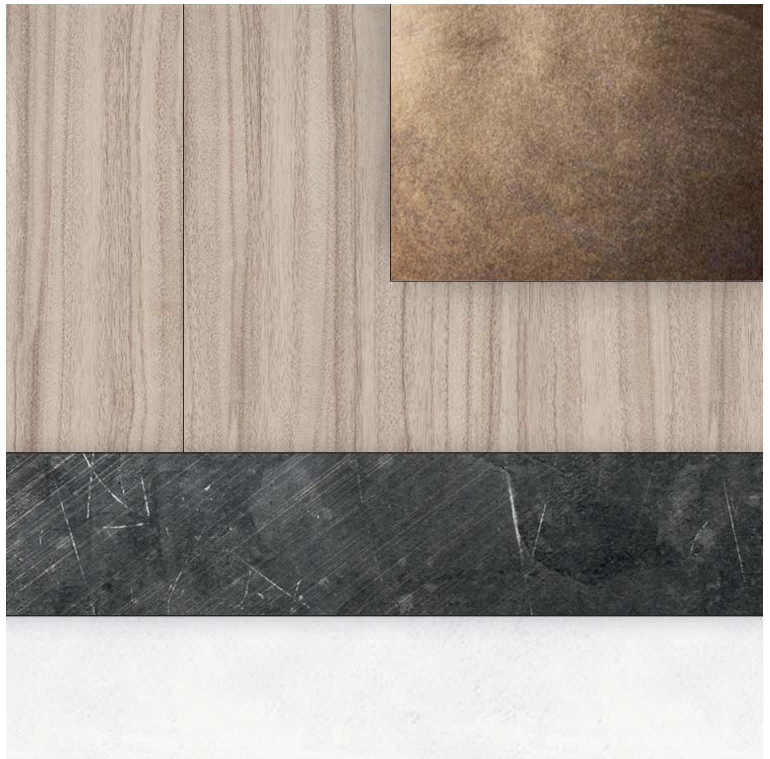
- National Construction Code 2019 Section J
- CIBSE Energy Benchmarks
- AIRAH Technical Handbook
- Carbon Trust
- Building Bulletin 101, 2018
- School Energy Star rating
- Sustainability Victoria, Resource Smart Schools
- Unsplash.com

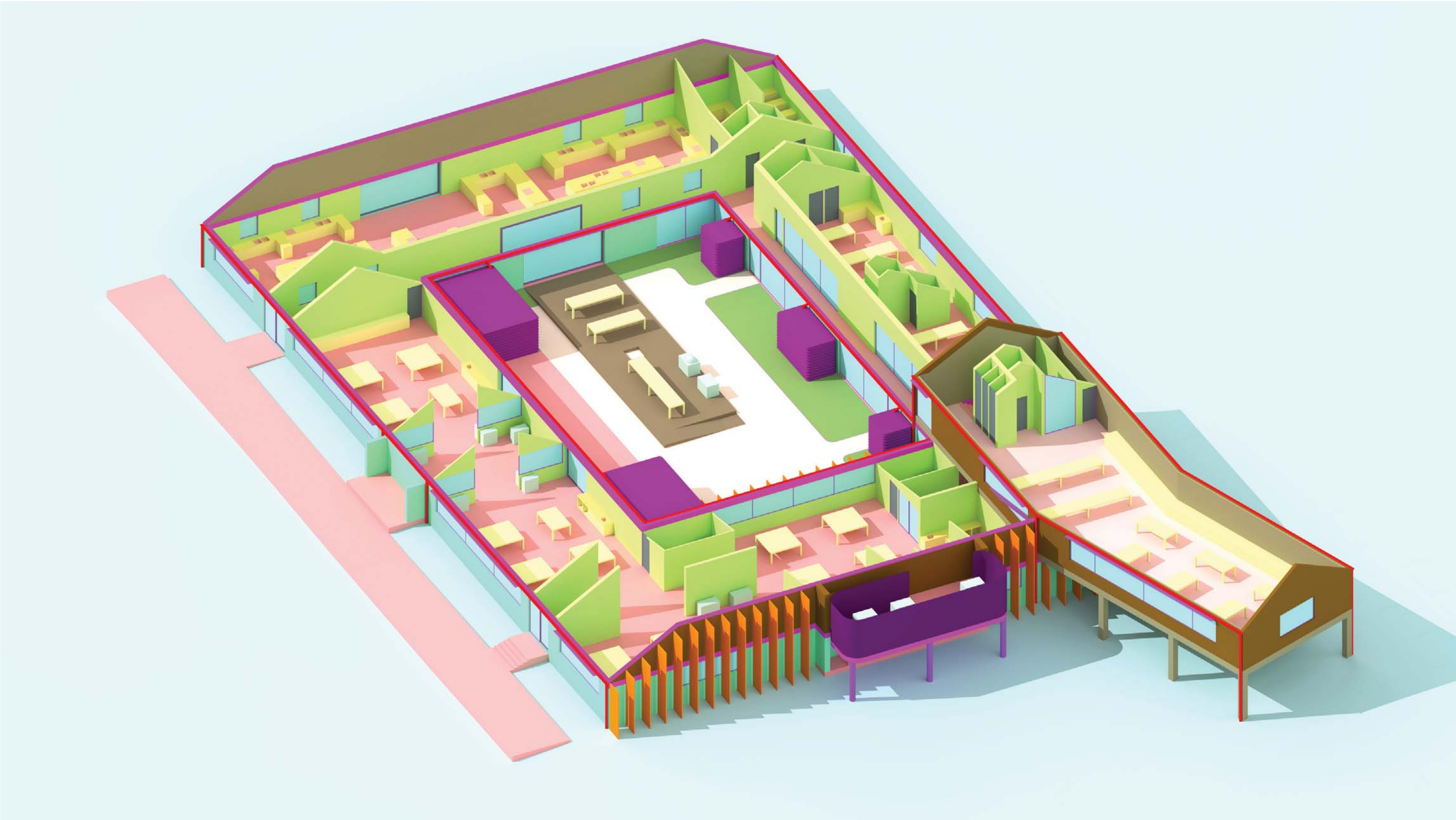
Design Studio Outcomes

IDS-03

APPENDIX B

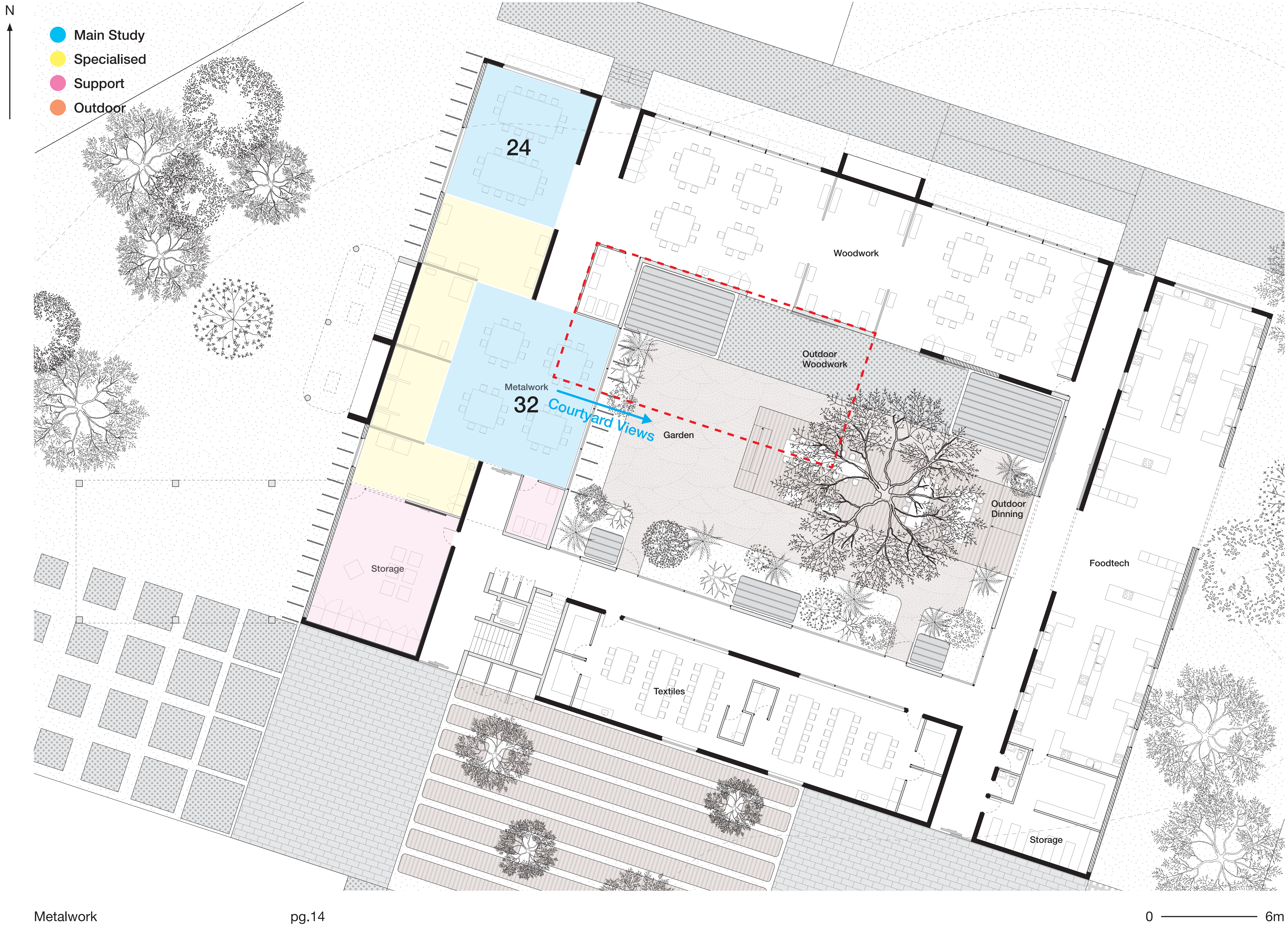
STUDENT WORK

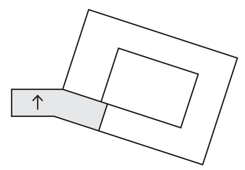




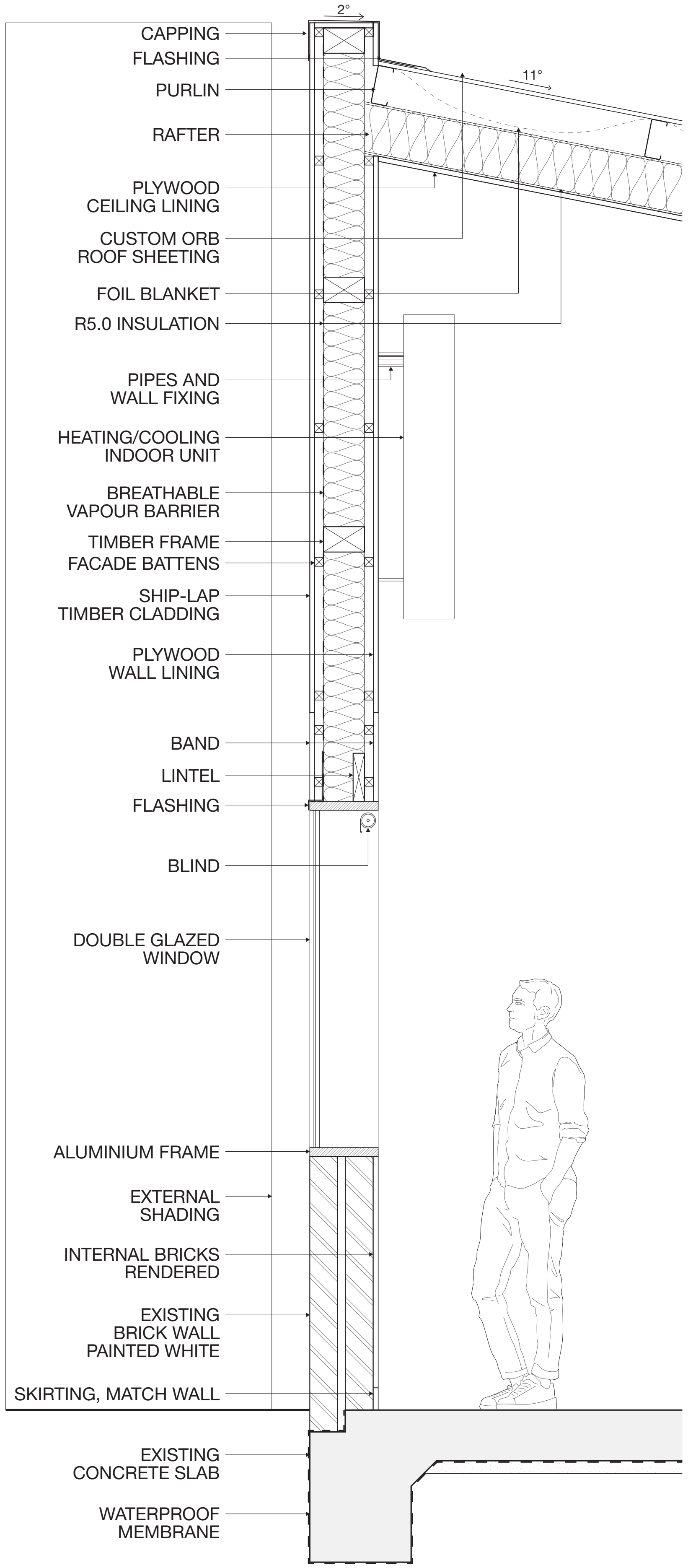
North-West Isometric

0 ——— 6m

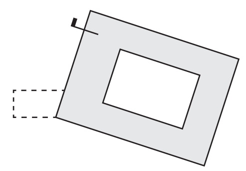

N
Main Study
Specialised
Support
Outdoor
24
Woodwork
Outdoor
Woodwork
Metalwork
32
Courtyard Views
Garden
Outdoor
Dinning
Foodtech
Storage
Textiles
Storage
0
6m



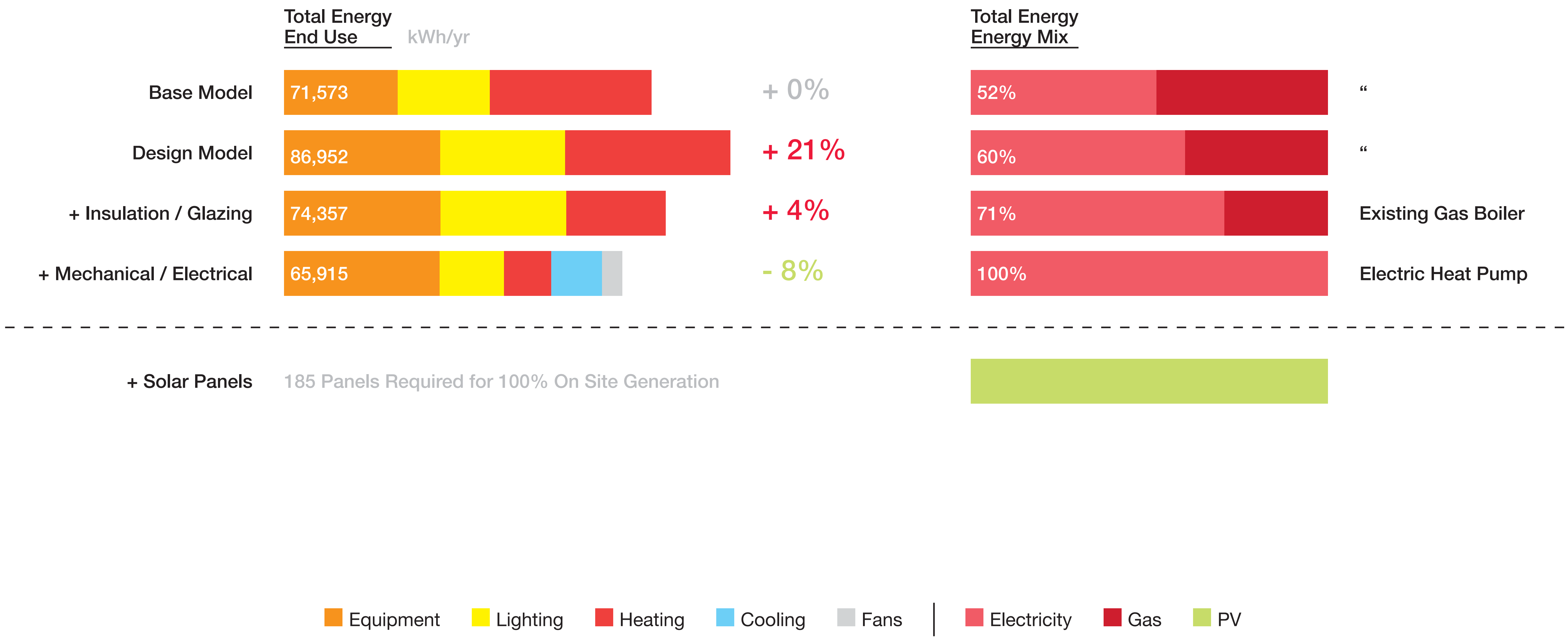
STEM Room

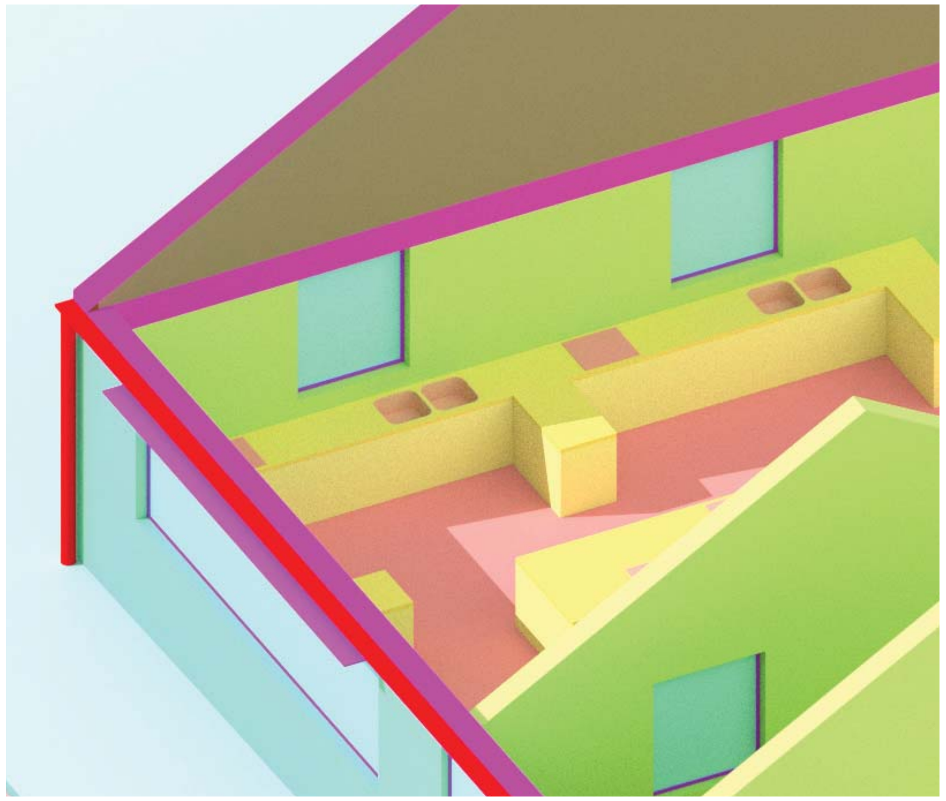
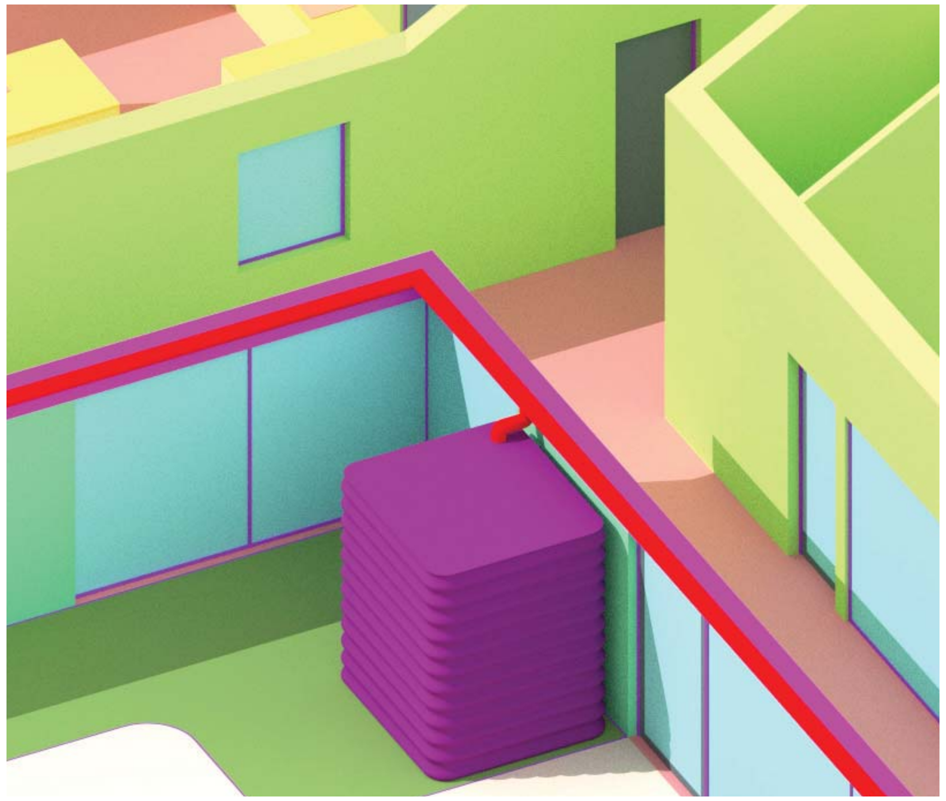
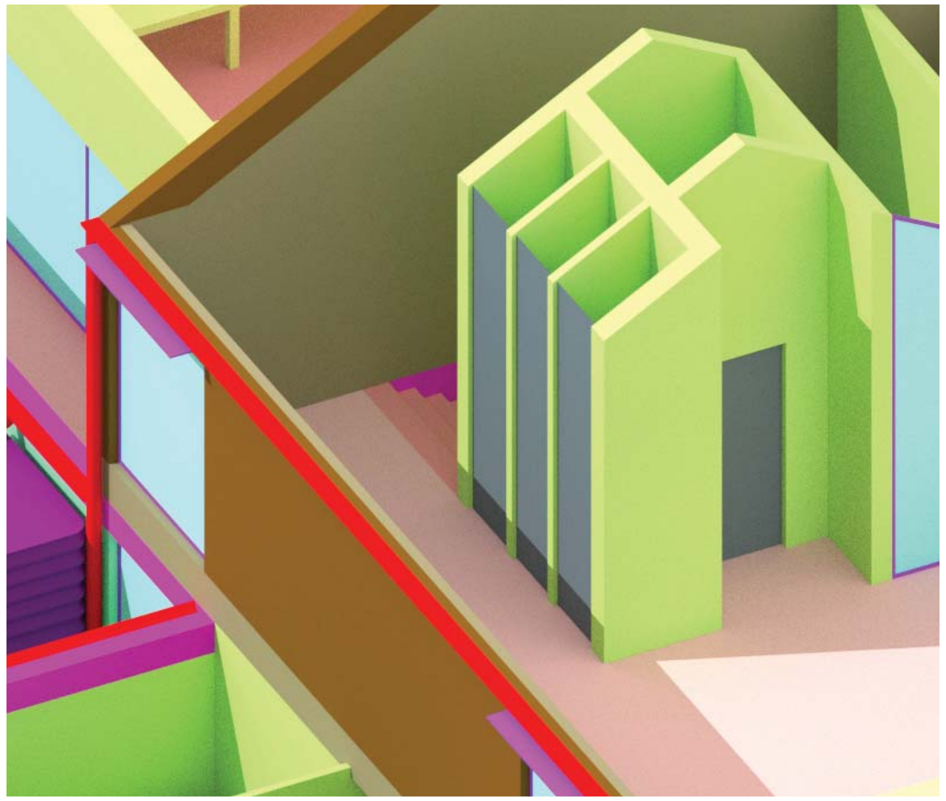
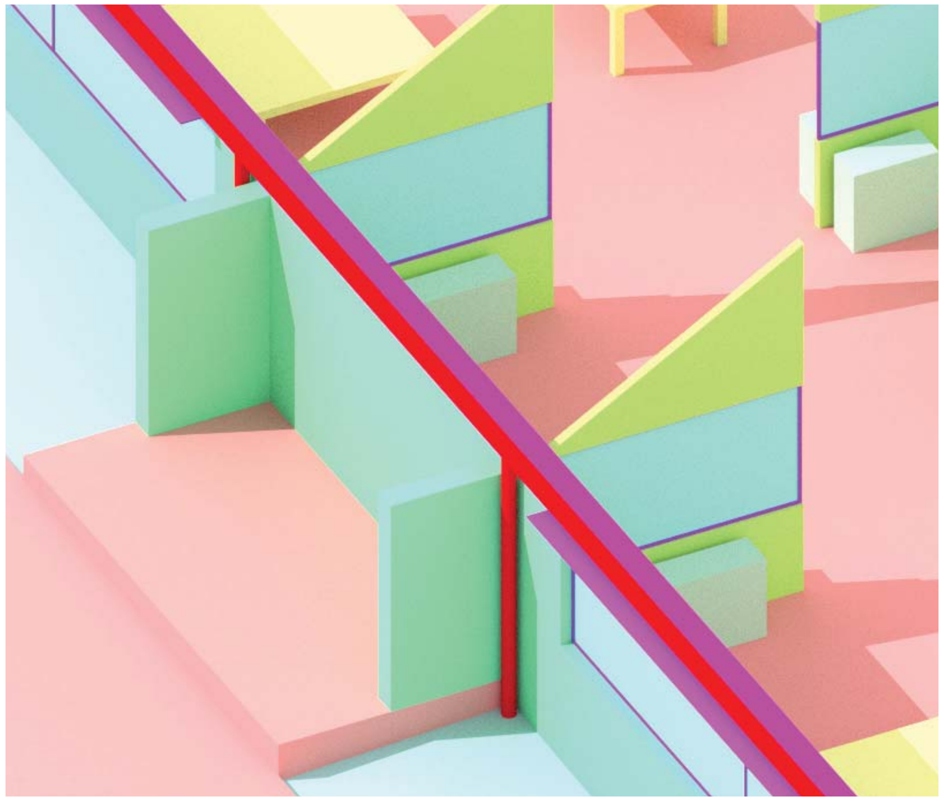
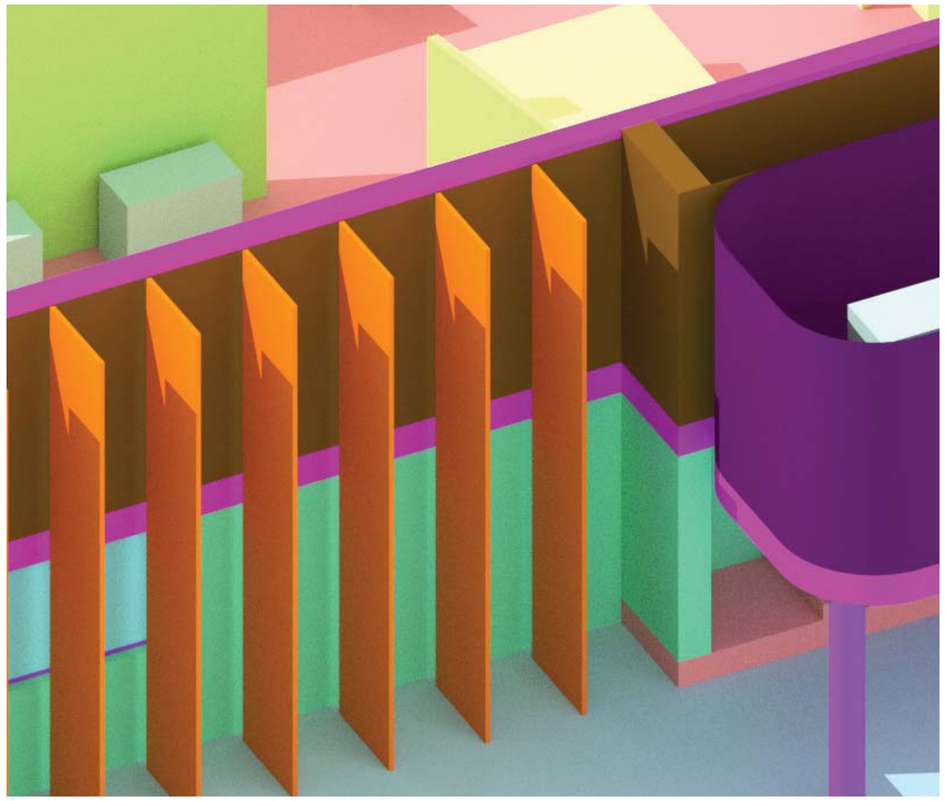
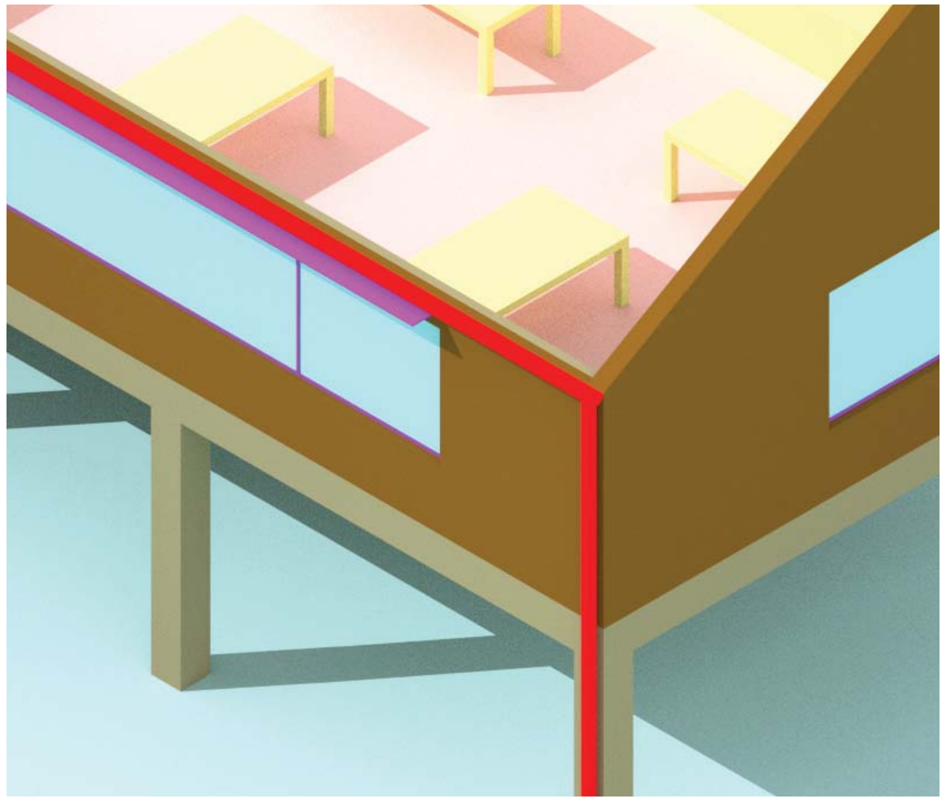


2°
11°
CAPPING
FLASHING
PURLIN
RAFTER
PLYWOOD
CEILING LINING
CUSTOM ORB
ROOF SHEETING
FOIL BLANKET
R5.0 INSULATION
PIPES AND
WALL FIXING
HEATING/COOLING
INDOOR UNIT
BREATHABLE
VAPOUR BARRIER
TIMBER FRAME
FACADE BATTENS
SHIP-LAP
TIMBER CLADDING
PLYWOOD
WALL LINING
BAND
LINTEL
FLASHING
BLIND
DOUBLE GLAZED
WINDOW
ALUMINIUM FRAME
EXTERNAL
SHADING
INTERNAL BRICKS
RENDERED
EXISTING
BRICK WALL
PAINTED WHITE
SKIRTING, MATCH WALL
EXISTING
CONCRETE SLAB
WATERPROOF
MEMBRANE



0 1m


Total Energy
End Use
kWh/yr
Total Energy
Energy Mix
Base Model
71,573
+ 0%
52%
“
Design Model
86,952
+ 21%
60%
“
+ Insulation / Glazing
74,357
+ 4%
71%
Existing Gas Boiler
+ Mechanical / Electrical
65,915
- 8%
100%
Electric Heat Pump
+ Solar Panels
185 Panels Required for 100% On Site Generation
Equipment
Lighting
Heating
Cooling
Fans
Electricity
Gas
PV

JOURNAL

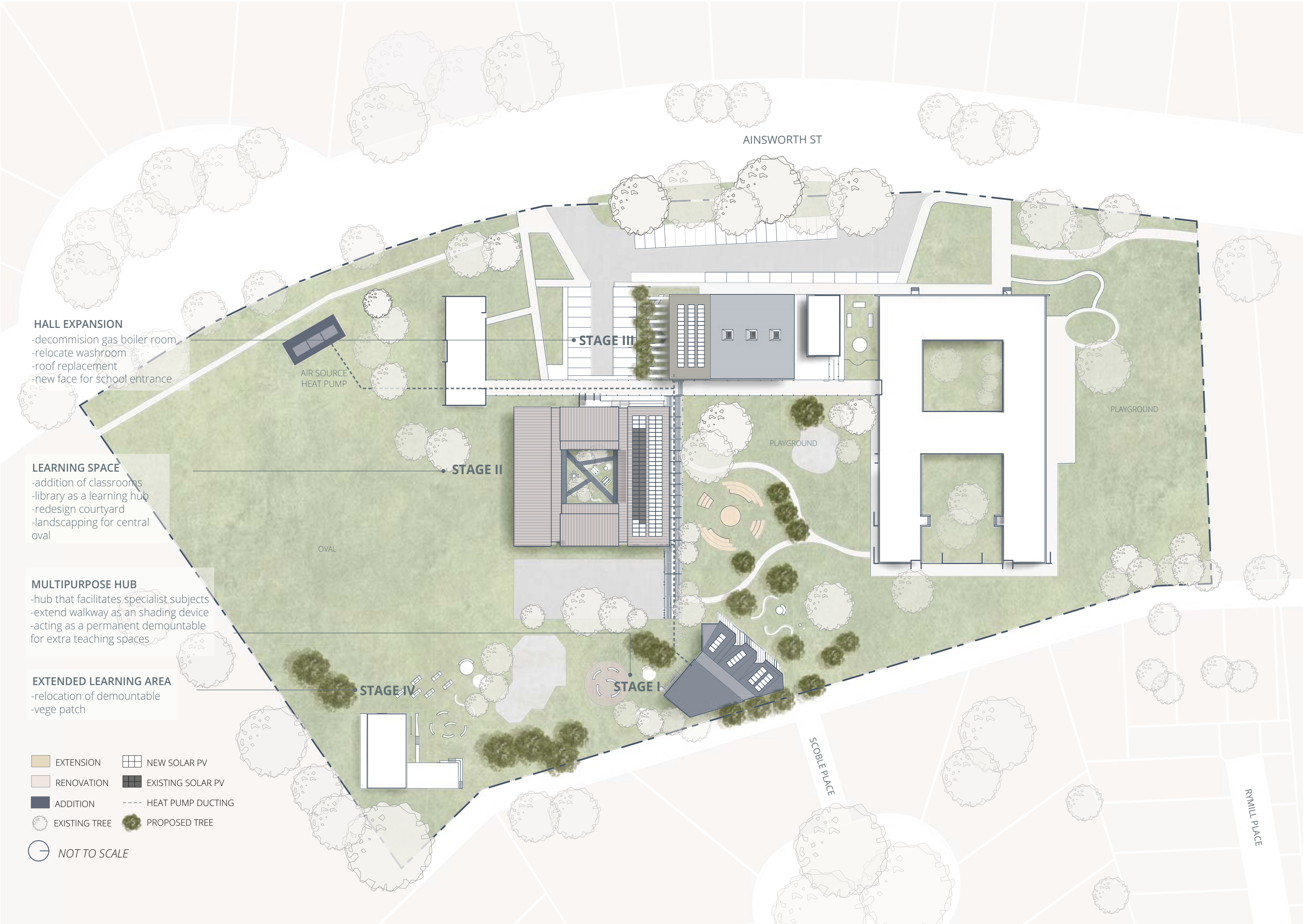
ABPL 90143 Design Studio D

Studio 42 CO_2 Zero

Yi Jie Lam 875783

Semester 2, 2020

MASTER PLAN (FINAL)



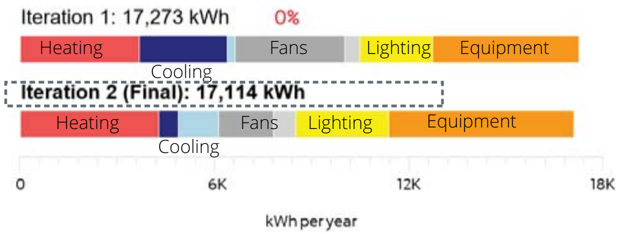
New Main Entrance

Central Oval

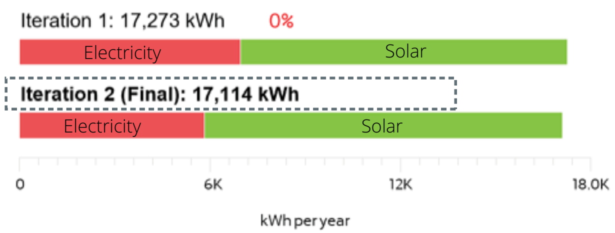

ROOF
R-VALUE - 6.3 m²K/W
17mm COLOURBOND DOUBLE SIDED TRIMDEK
PURLINS
BRADFORD ANTICON SARKING
90mm R2.0 BULK INSULATION
ROOF TRUSS
ROOF CAPPING
DRIP EDGE
ROLLER BLIND WITH PELMET
WINDOW LINTEL
ARGON GAS FILLED LOW-E COATING DOUBLE GLAZED WINDOW
LINE OF REVEAL BEYOND
RONDO KEYLOCK CONCEALED SUSPENDED CEILING
BRADFORD ANTICON R4.0 INSULATION BLANKET
9mm PLYWOOD CEILING PANEL
DOUBLE-GLAZED WINDOW
R-VALUE - 3.1 m²K/W
WALL TO ROOF CONNECTION
SCALE 1:20
9mm PLYWOOD PANEL
PRIMARY AIRTIGHT MEMBRANE
SERVICE CAVITY
50mm AIR CAVITY
90mm R3.86 KINGSPAN KOOLTHERM K17 RIGID THERMOSET PHENOLIC INSULATION
BREATHABLE MEMBRANE
19mm SHIPLAP CLADDING
CONCRETE PAD FOOTING
EXPOSED POLISHED CONCRETE
EPS INSULATION UNDER
DAMP PROOFING MEMBRANE
GRAVEL DRAINAGE LAYER
DOUBLE STUD WALL
R-VALUE - 7.0 m²K/W
FLOOR
R-VALUE - 3.4 m²K/W
GROUND TO WALL CONNECTION
SCALE 1:20
SHADING
GLAZING
SOLAR PV
DAYLIGHTING
CROSS VENTILATION
THERMAL MASS
RAINWATER HARVESTING
ART ROOM
MIX MEDIA LAB
STORE
NOT TO SCALE

ENERGY MODELLING

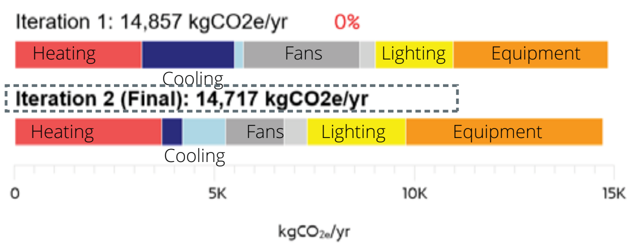
ANNUAL ENERGY USE



ANNUAL ENERGY MIX

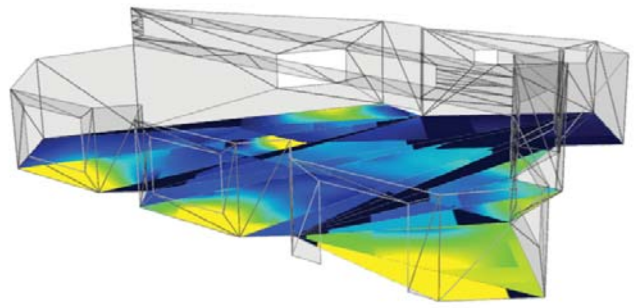


ANNUAL CO2e (EXC RENEWABLE)



DAYLIGHT ANALYSIS

ITERATION 1

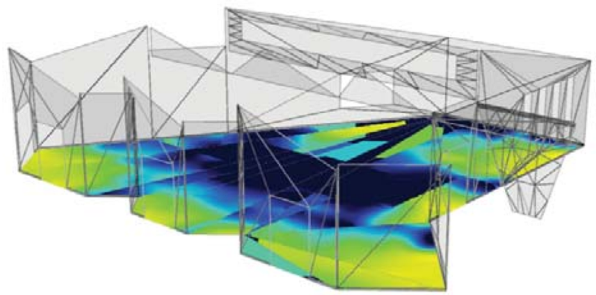


Lux levels on October 31 at 9AM measured at 0.85 meters above the floor plate. Time does not take into account daylight savings time.

0 200 400 600 800+

- All classrooms are well-lit
- Underlit area is only for circulation purpose

ITERATION 2 (FINAL)

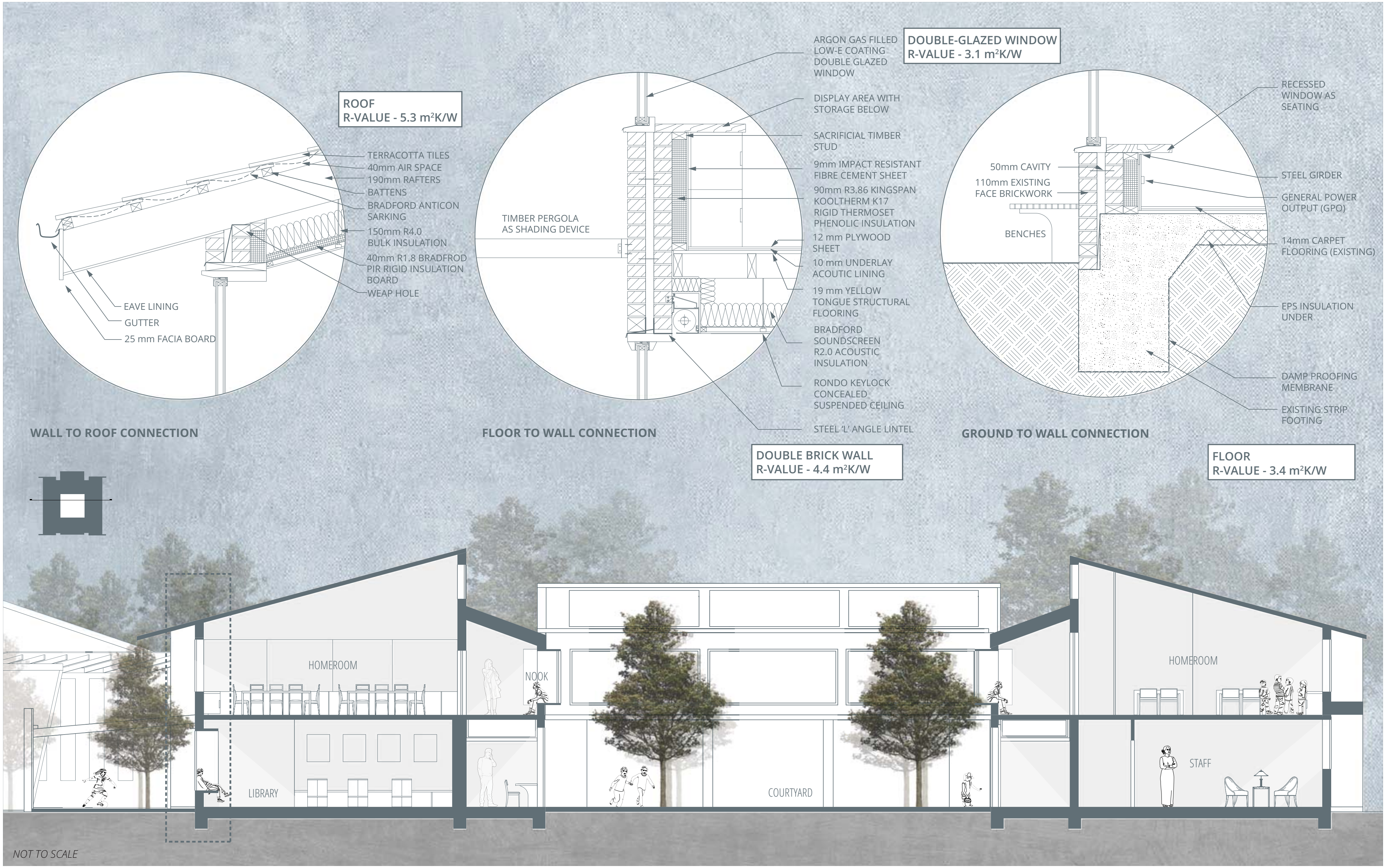


Lux levels on October 31 at 9AM measured at 0.85 meters above the floor plate. Time does not take into account daylight savings time.

0 200 400 600 800+

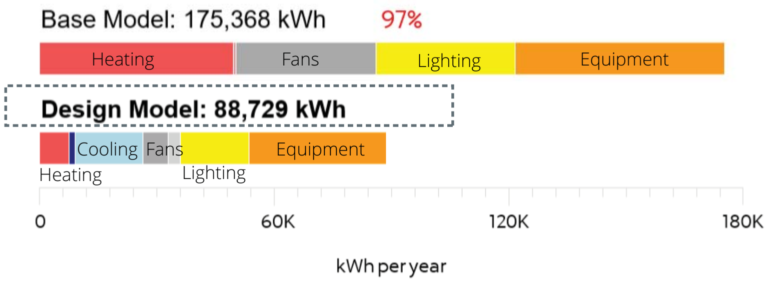
Ground Floor Courtyard

First Floor Learning Street

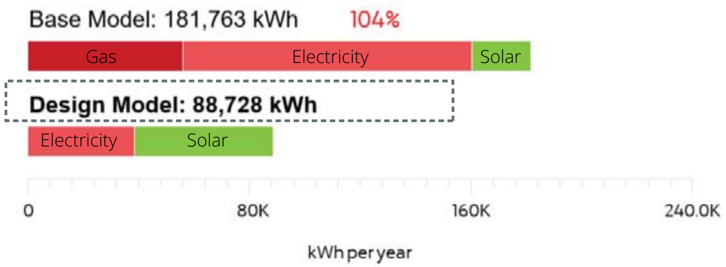

ROOF
R-VALUE - 5.3 m²K/W
TERRACOTTA TILES
40mm AIR SPACE
190mm RAFTERS
BATTENS
BRADFORD ANTICON SARKING
150mm R4.0 BULK INSULATION
40mm R1.8 BRADFROD PIR RIGID INSULATION BOARD
WEAP HOLE
EAVE LINING
GUTTER
25 mm FACIA BOARD
WALL TO ROOF CONNECTION
TIMBER PERGOLA AS SHADING DEVICE
ARGON GAS FILLED LOW-E COATING DOUBLE GLAZED WINDOW
DOUBLE-GLAZED WINDOW
R-VALUE - 3.1 m²K/W
DISPLAY AREA WITH STORAGE BELOW
SACRIFICIAL TIMBER STUD
9mm IMPACT RESISTANT FIBRE CEMENT SHEET
90mm R3.86 KINGSPAN KOOLTHERM K17 RIGID THERMOSET PHENOLIC INSULATION
12 mm PLYWOOD SHEET
10 mm UNDERLAY ACOUTIC LINING
19 mm YELLOW TONGUE STRUCTURAL FLOORING
BRADFORD SOUNDSCREEN R2.0 ACOUSTIC INSULATION
RONDO KEYLOCK CONCEALED SUSPENDED CEILING
STEEL 'L' ANGLE LINTEL
FLOOR TO WALL CONNECTION
DOUBLE BRICK WALL
R-VALUE - 4.4 m²K/W
50mm CAVITY
110mm EXISTING FACE BRICKWORK
BENCHES
RECESSED WINDOW AS SEATING
STEEL GIRDER
GENERAL POWER OUTPUT (GPO)
14mm CARPET FLOORING (EXISTING)
EPS INSULATION UNDER
DAMP PROOFING MEMBRANE
EXISTING STRIP FOOTING
GROUND TO WALL CONNECTION
FLOOR
R-VALUE - 3.4 m²K/W
HOMEROOM
NOOK
LIBRARY
COURTYARD
HOMEROOM
STAFF
NOT TO SCALE

ENERGY MODELLING

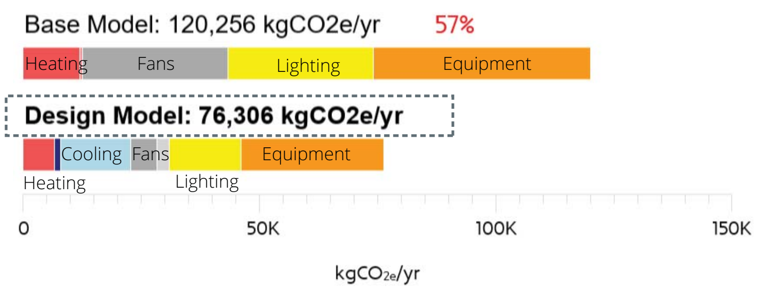
ANNUAL ENERGY USE



ANNUAL ENERGY MIX

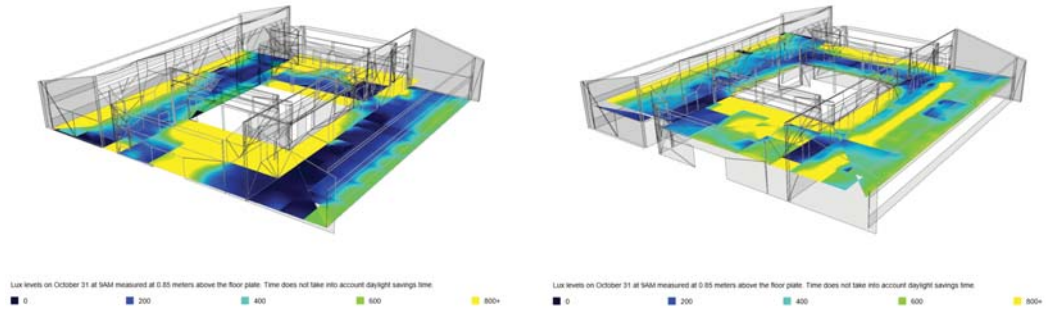


ANNUAL CO2e (EXC RENEWABLE)



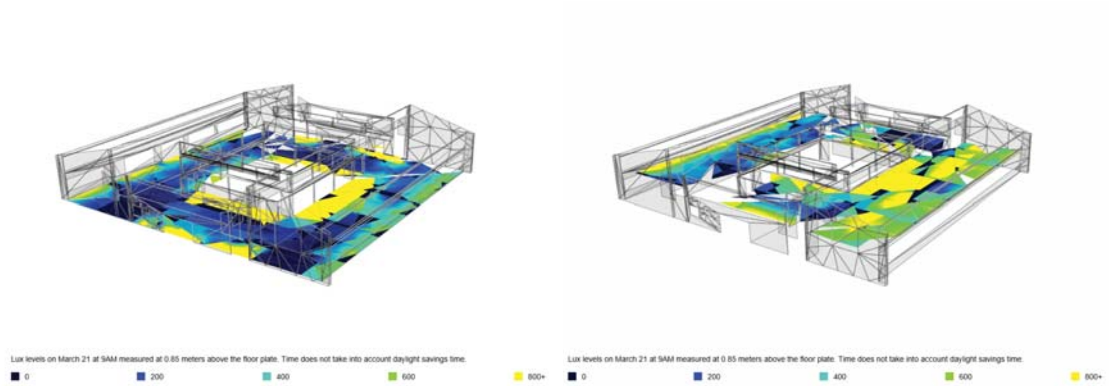
DAYLIGHT ANALYSIS

BASE MODEL



DESIGN MODEL

- Area of overlit on ground floor has been reduced
- Both North and South facing classroom are lit more evenly



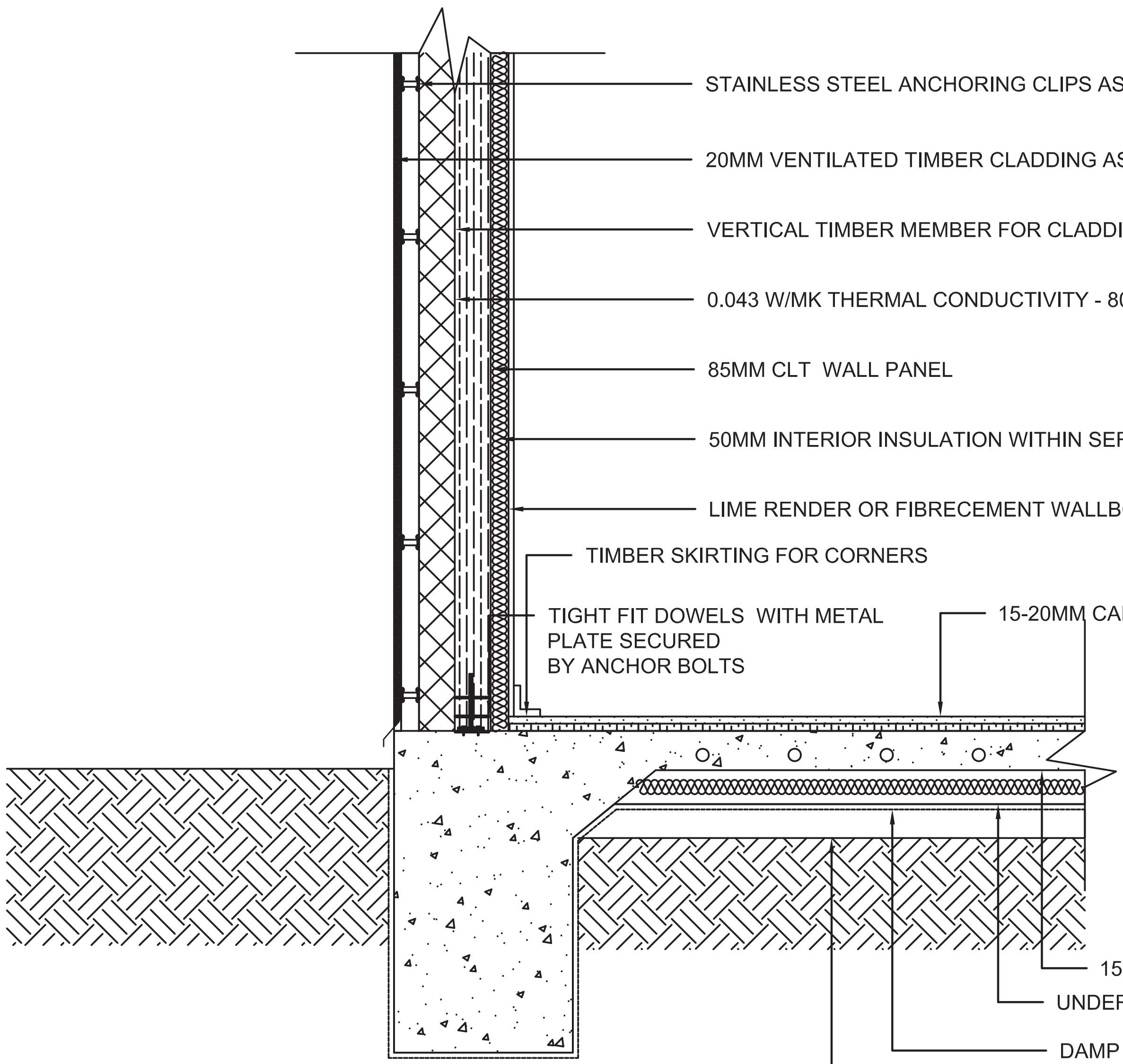
Studio 42 : CO2Zero

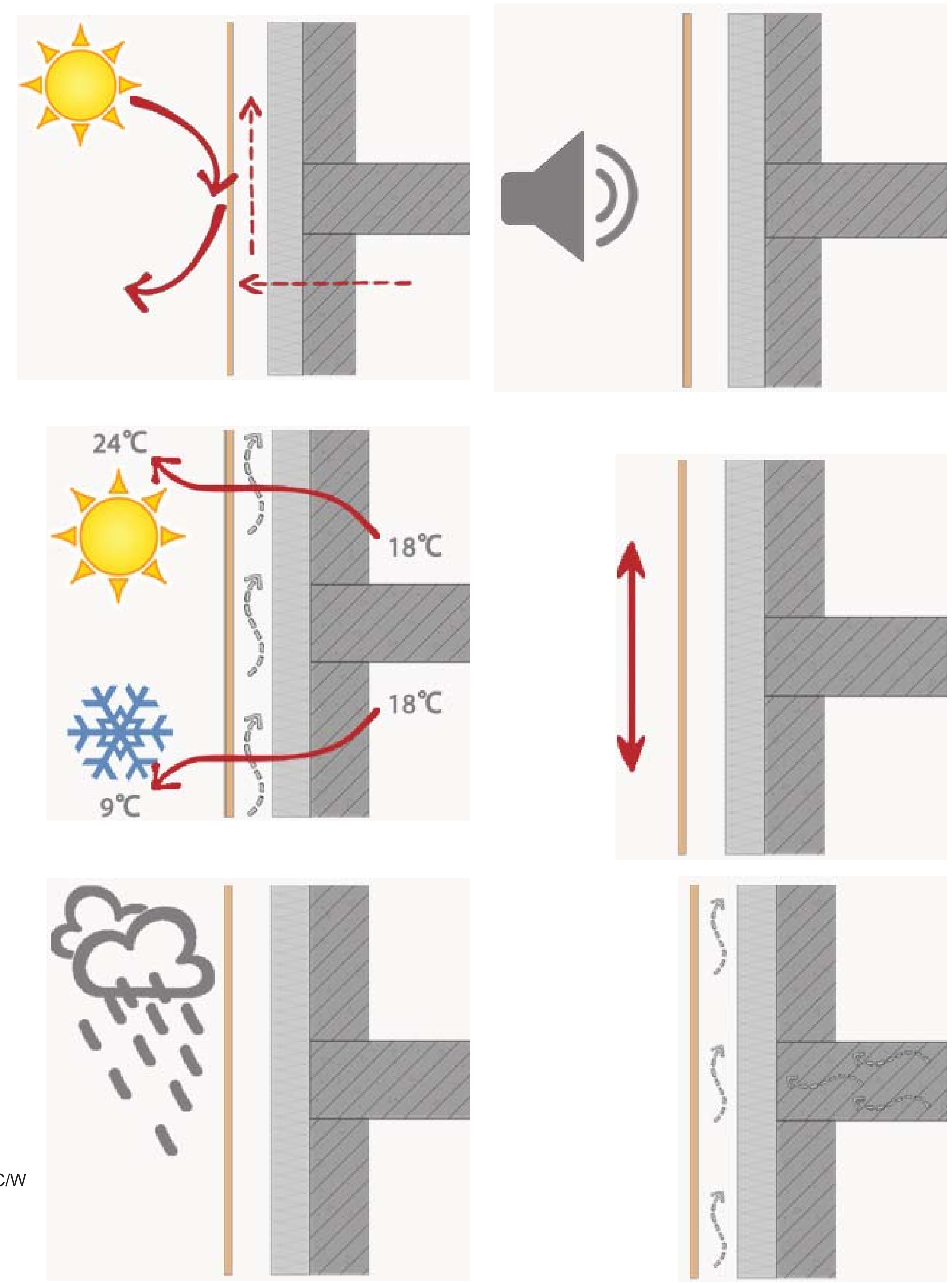
Presentation

Mawson Primary School

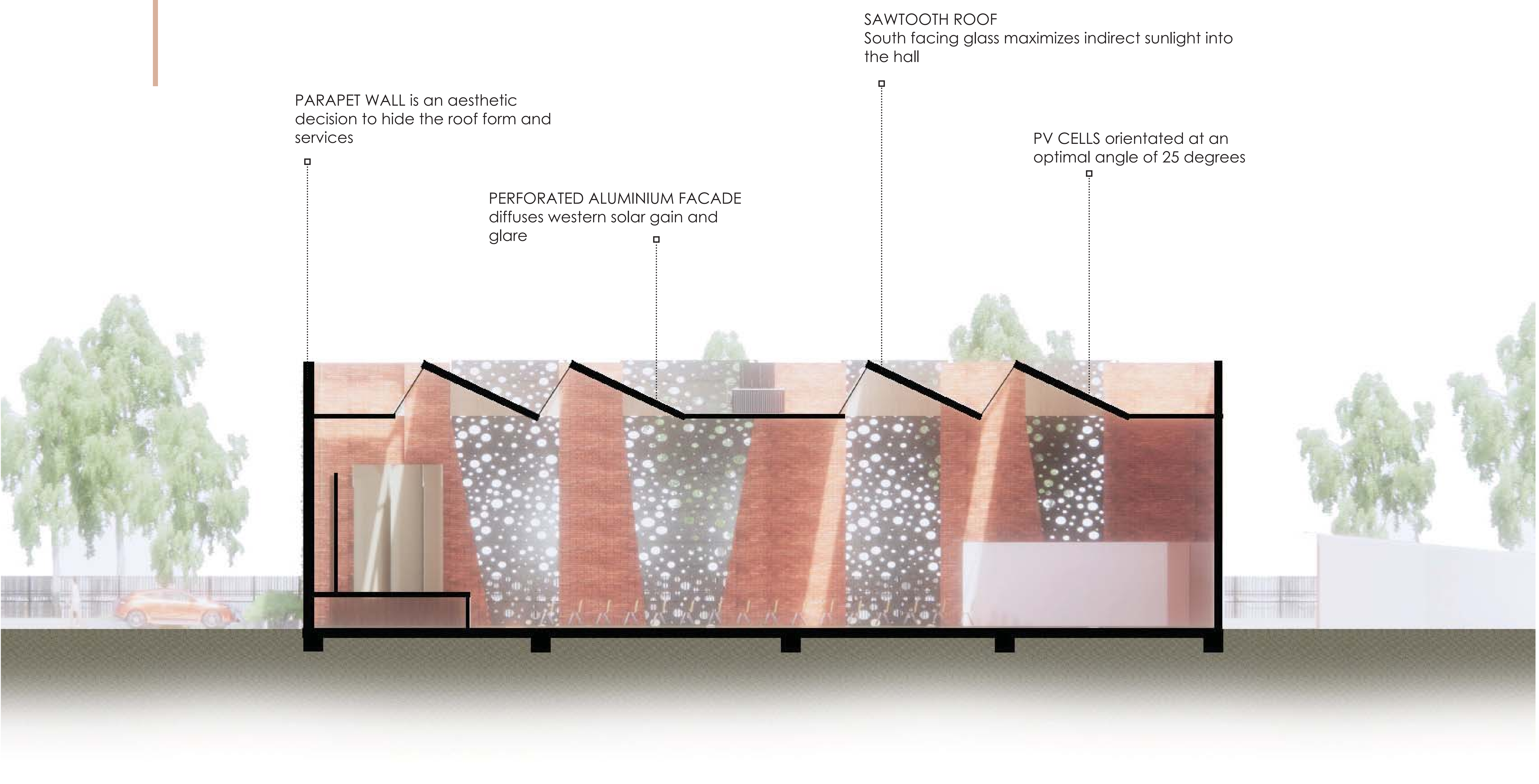
Lee Wen Jie
705009

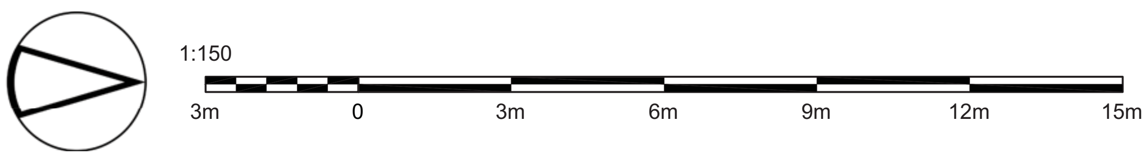
C-C 1:20 Wall Detail - Ventilated Facade





A-A Long Section





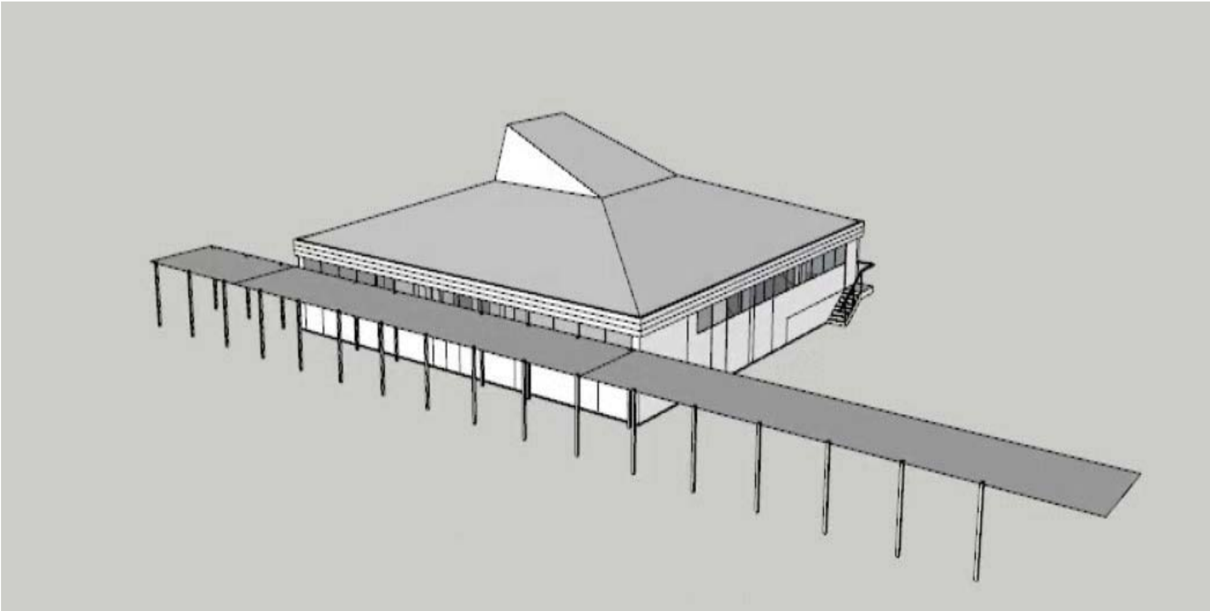
Interior Perspective

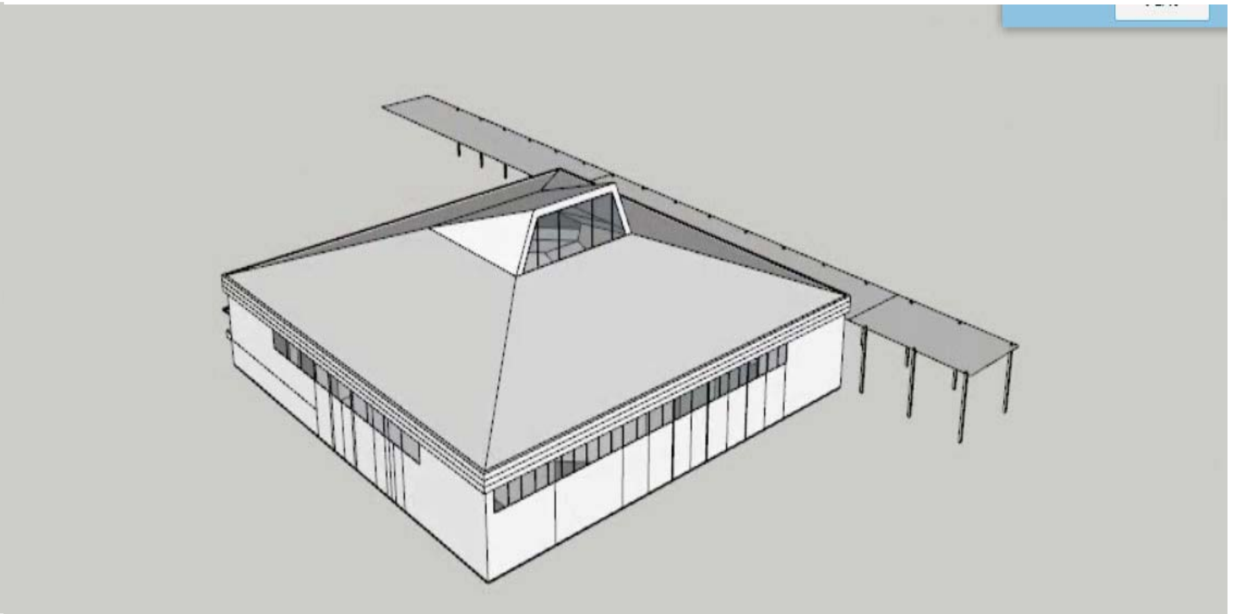
Studio 42: CO2Zero
Mawson Primary School

Wen Jie Lee
705009

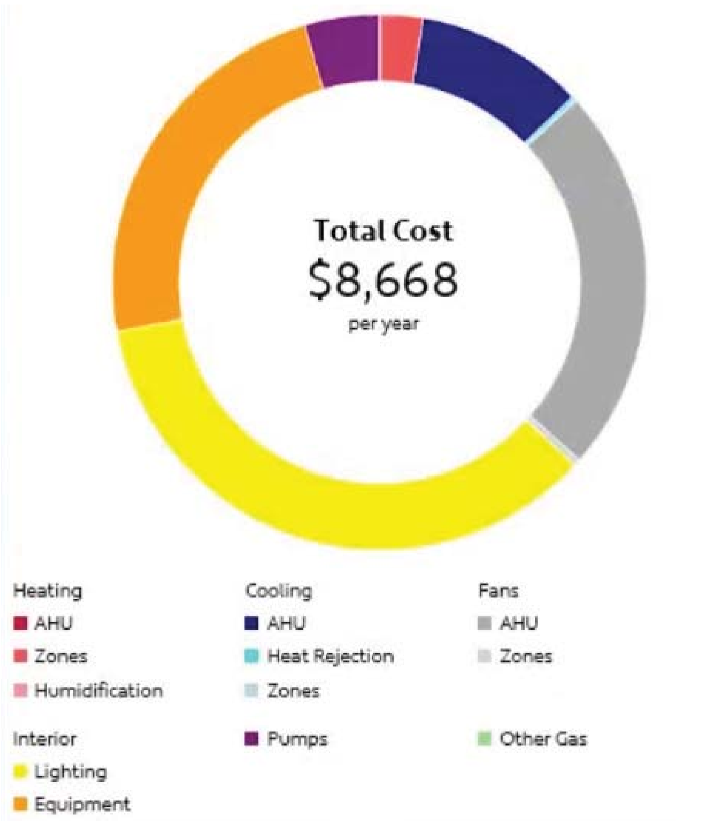
JOURNAL

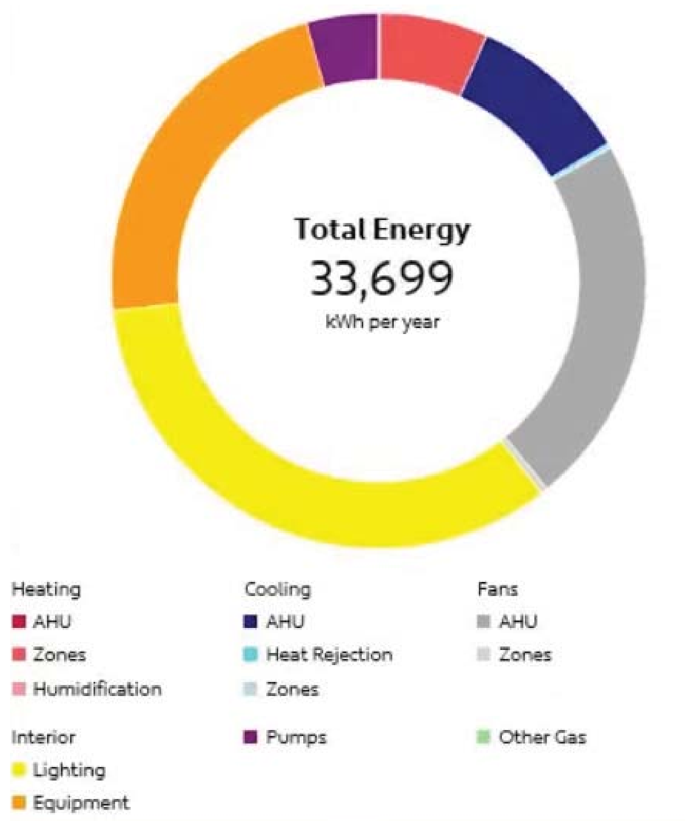
SHIN QIN LIM
905494
STUDIO D
DESIGN STUDIO 42 | CO2 ZERO |
SEMESTER 2 2020

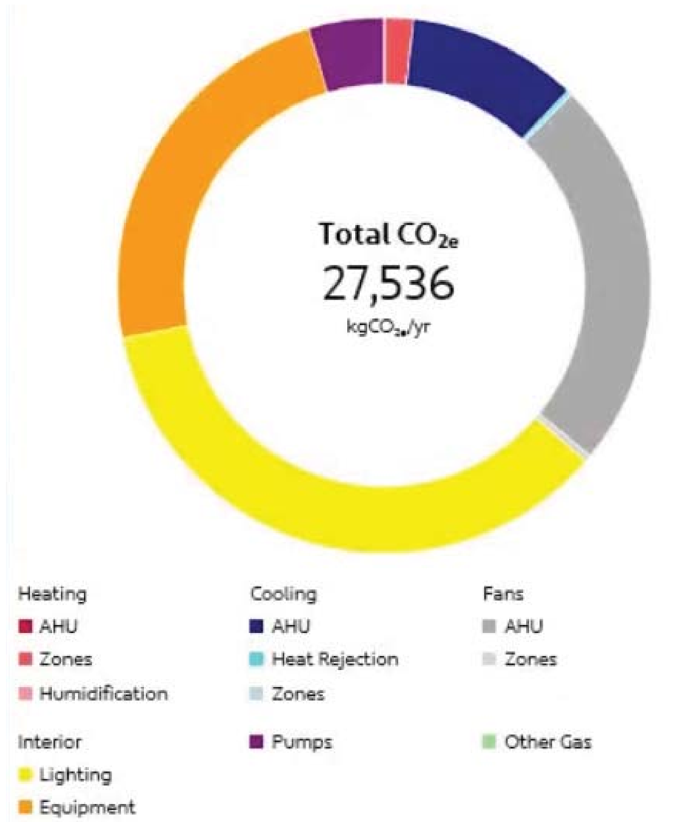


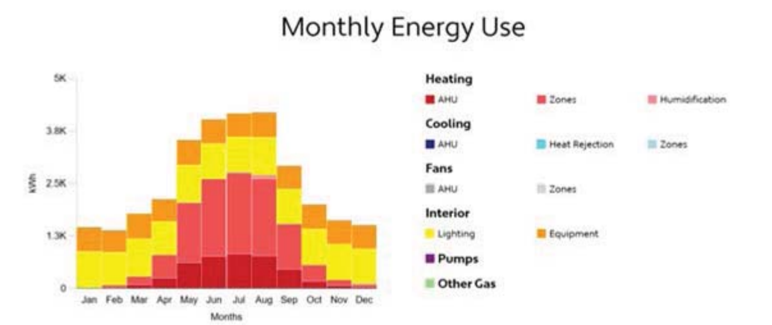


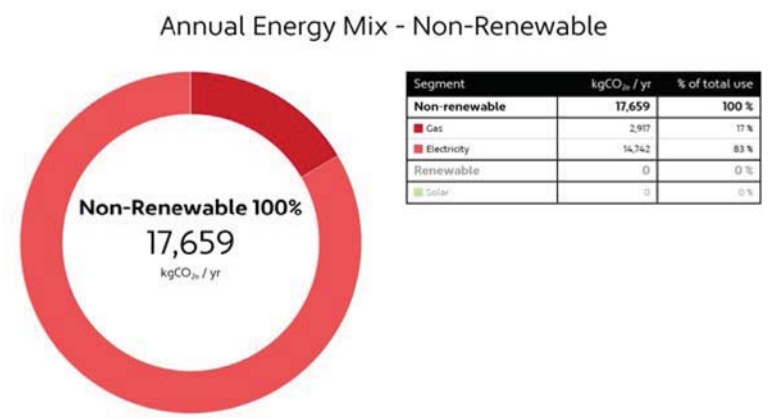
Energy: 33, 699 kWh/Year
Gas: 27, 536 kgCO2e/Year







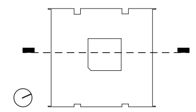


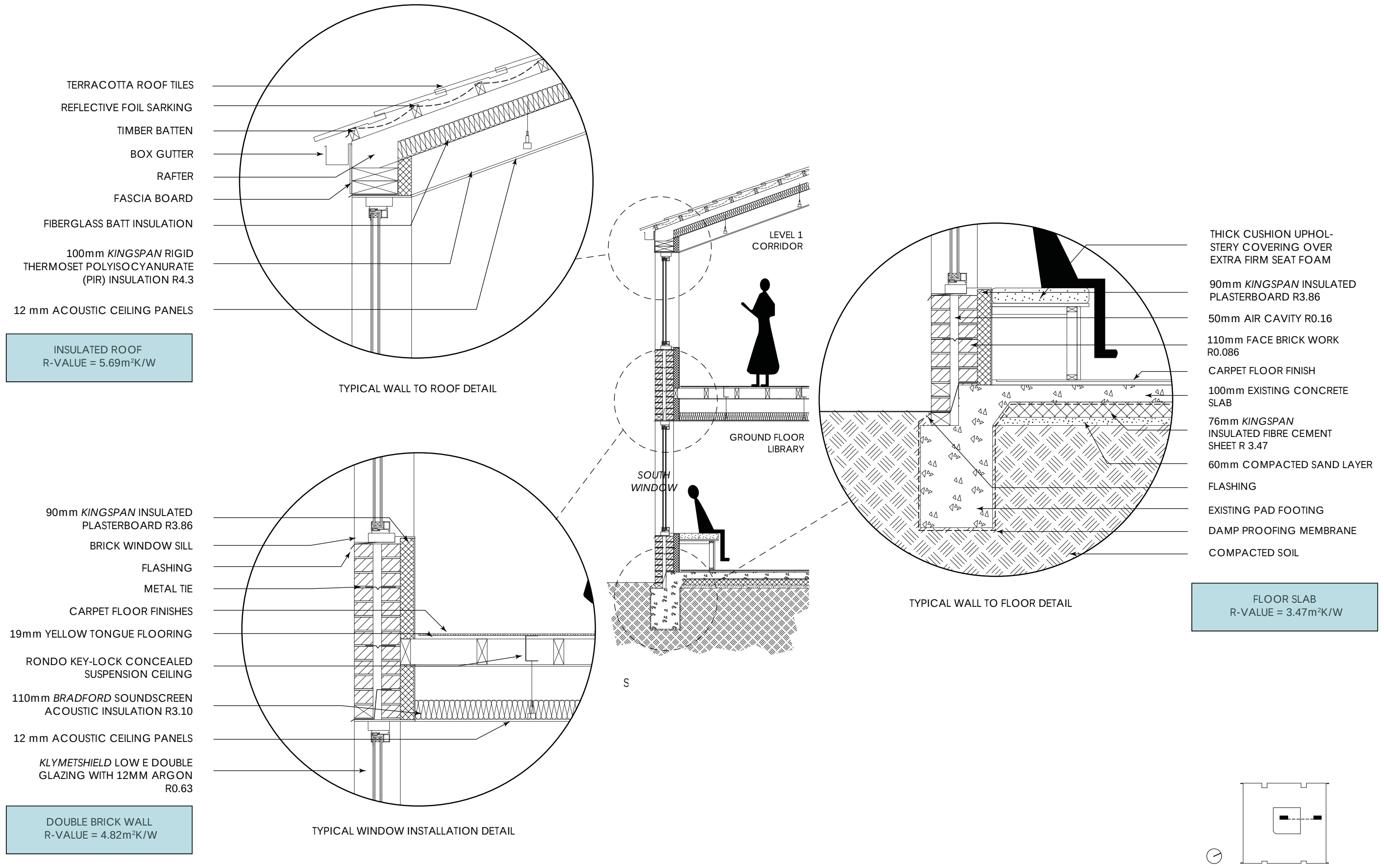


| GROUND FLOOR PLAN |

| FIRST FLOOR PLAN |

| SECTION |



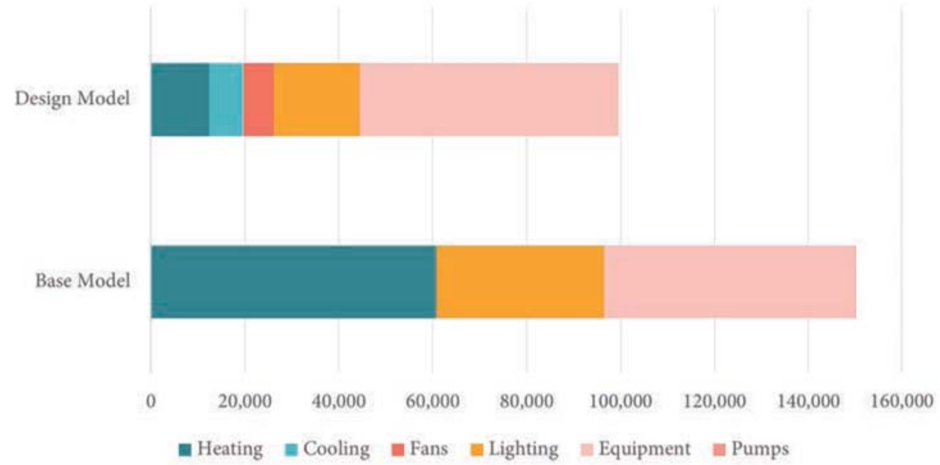


| DETAIL SECTION |

NOT TO SCALE

BASE MODEL **DESIGN MODEL**

ANNUAL ENERGY USE (kWh/year)

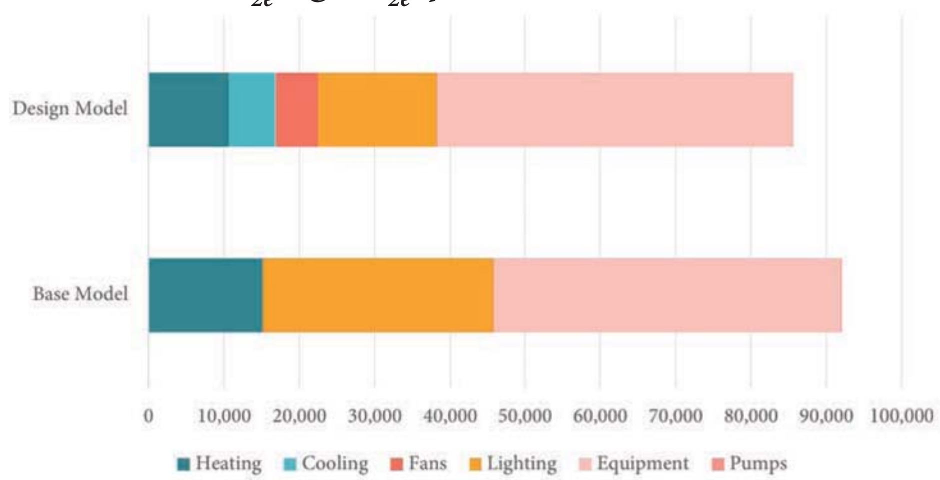


Total Energy Use:

150, 205 kWh

99, 636 kWh

ANNUAL CO_{2e} ($kgCO_{2e}$/year)

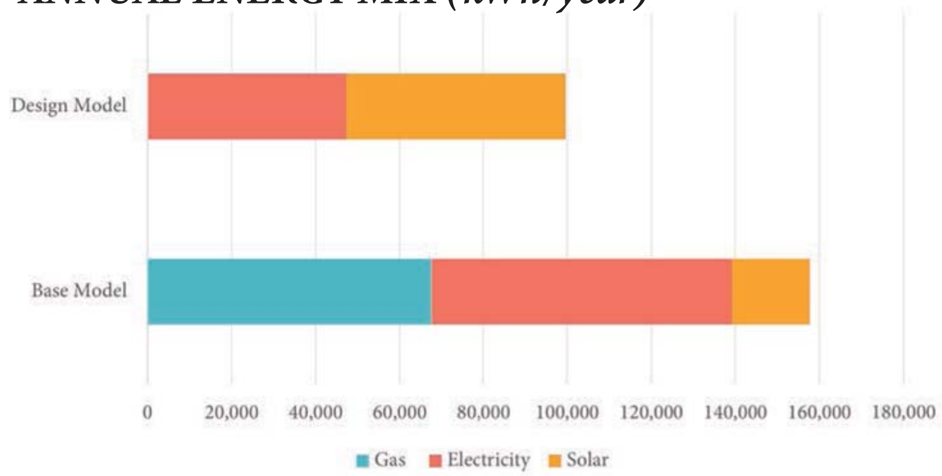


Total CO_2:

92, 041 kWh

85, 686 kWh

ANNUAL ENERGY MIX (kWh/year)

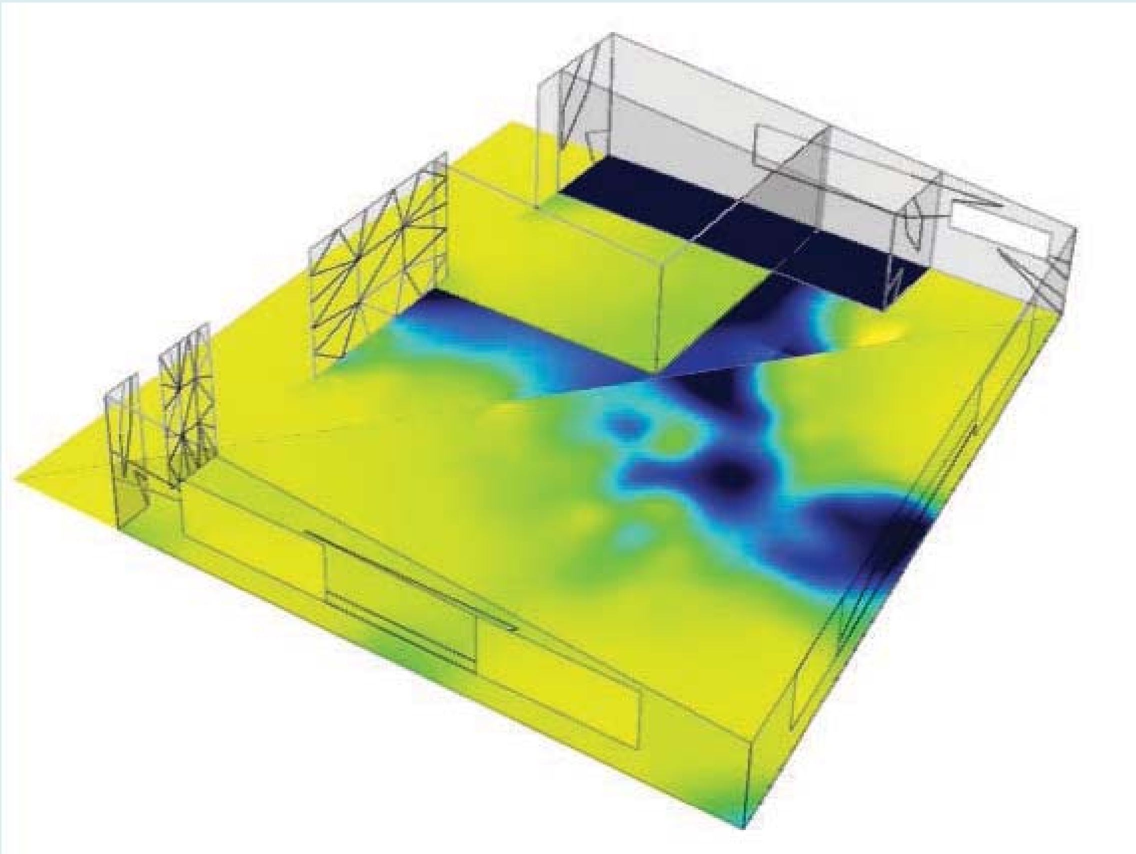


Total Non-renewable Energy:

139, 236 kWh

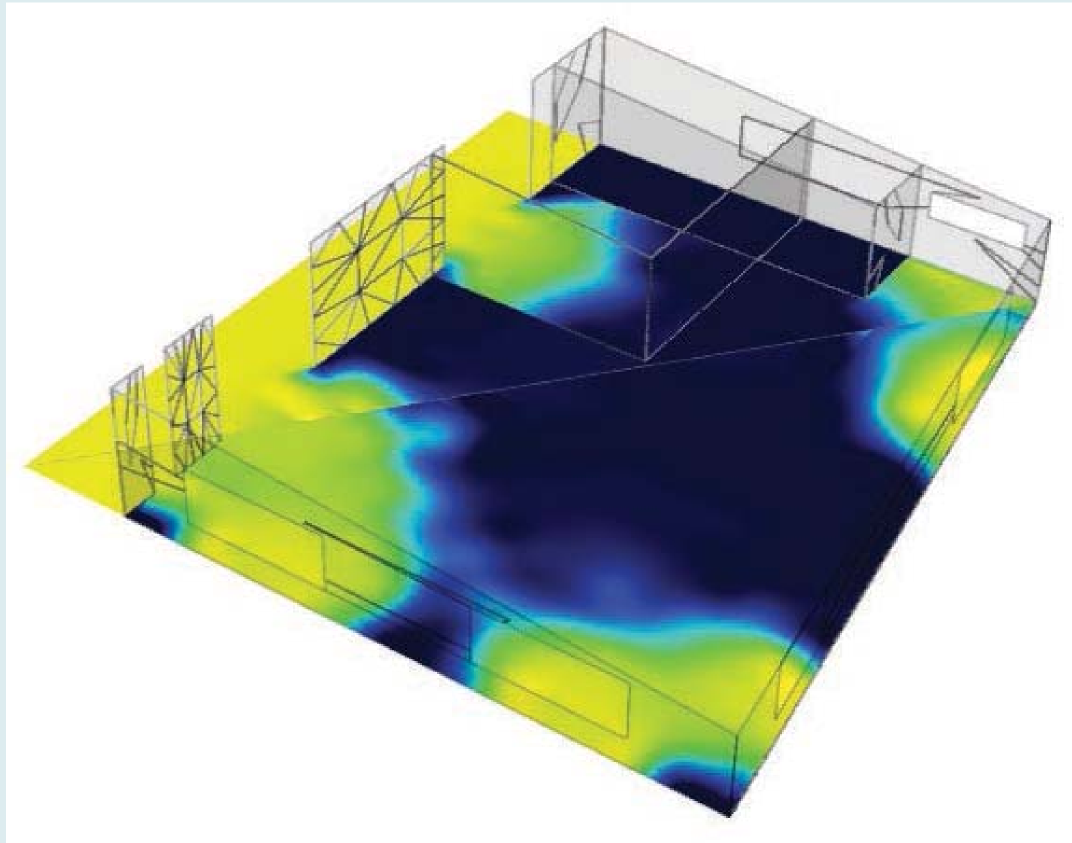
47, 343 kWh

BASE MODEL



Glazing: Single-glazed Clear Glass
VLT: 0.5
SHGC: 0.55

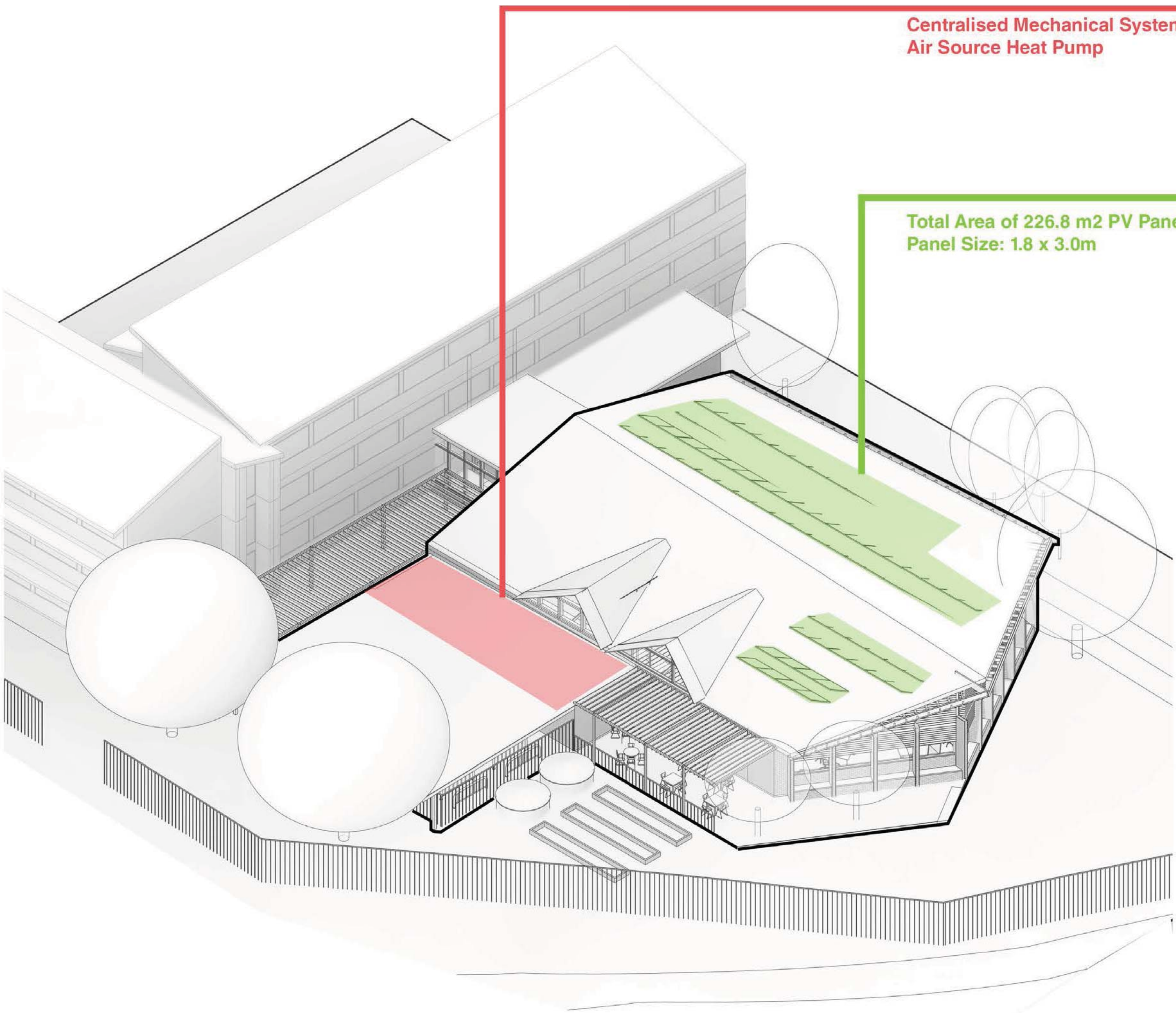
DESIGN MODEL

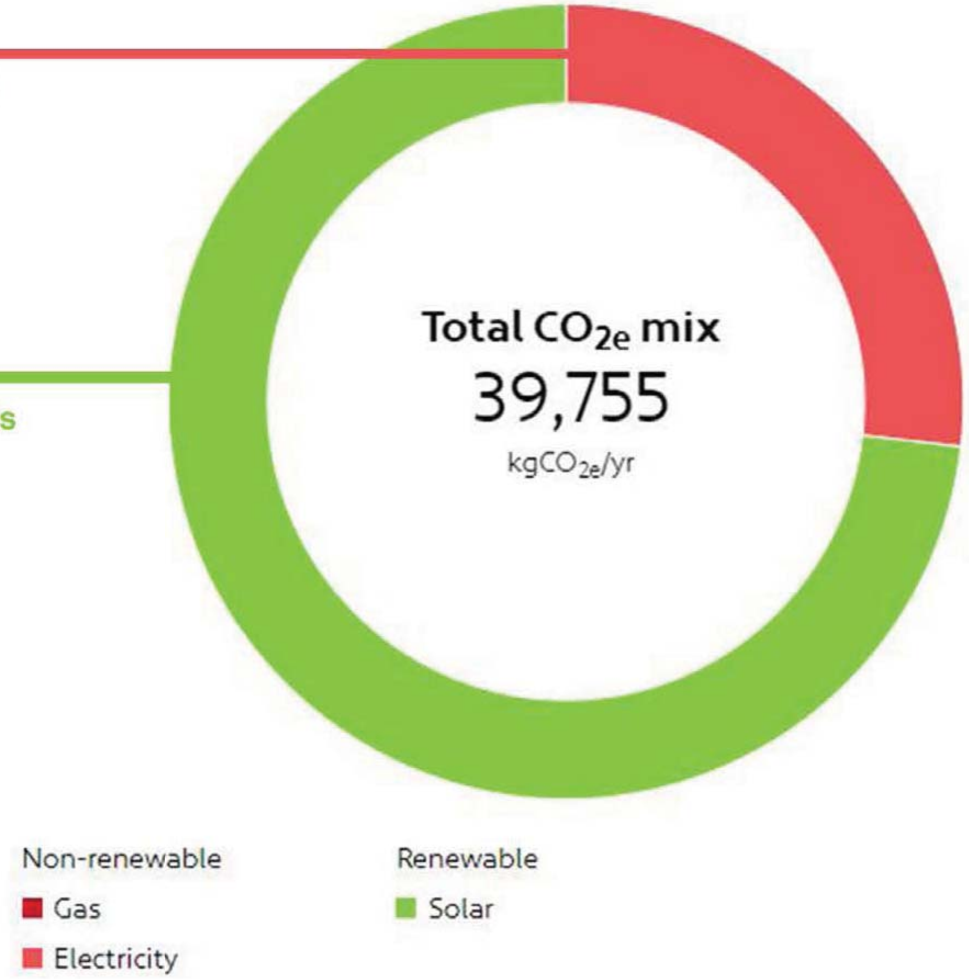


Glazing: Low-e Double glazed with Argon
VLT: 0.4
SHGC: 0.3

Percentage of occupied hours where illuminance is at least 300 lux, measured at 0.85 meters above the floor plate.

0% 25% 50% 75% 100%

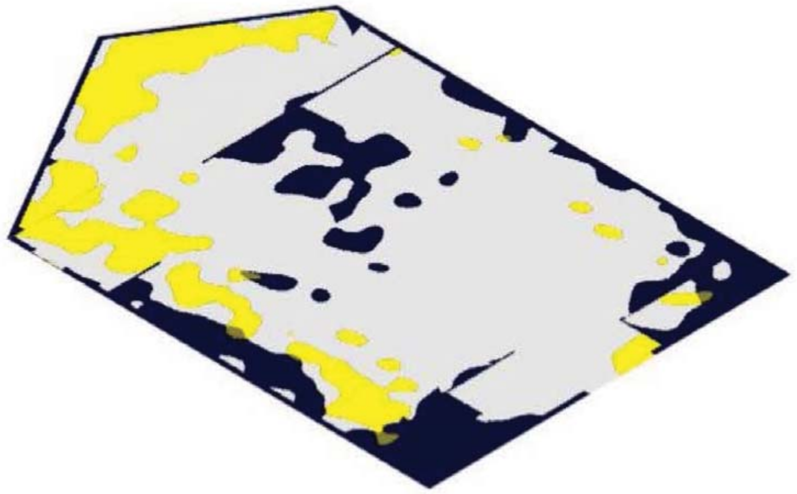




ANNUAL NET CO2e EMISSION

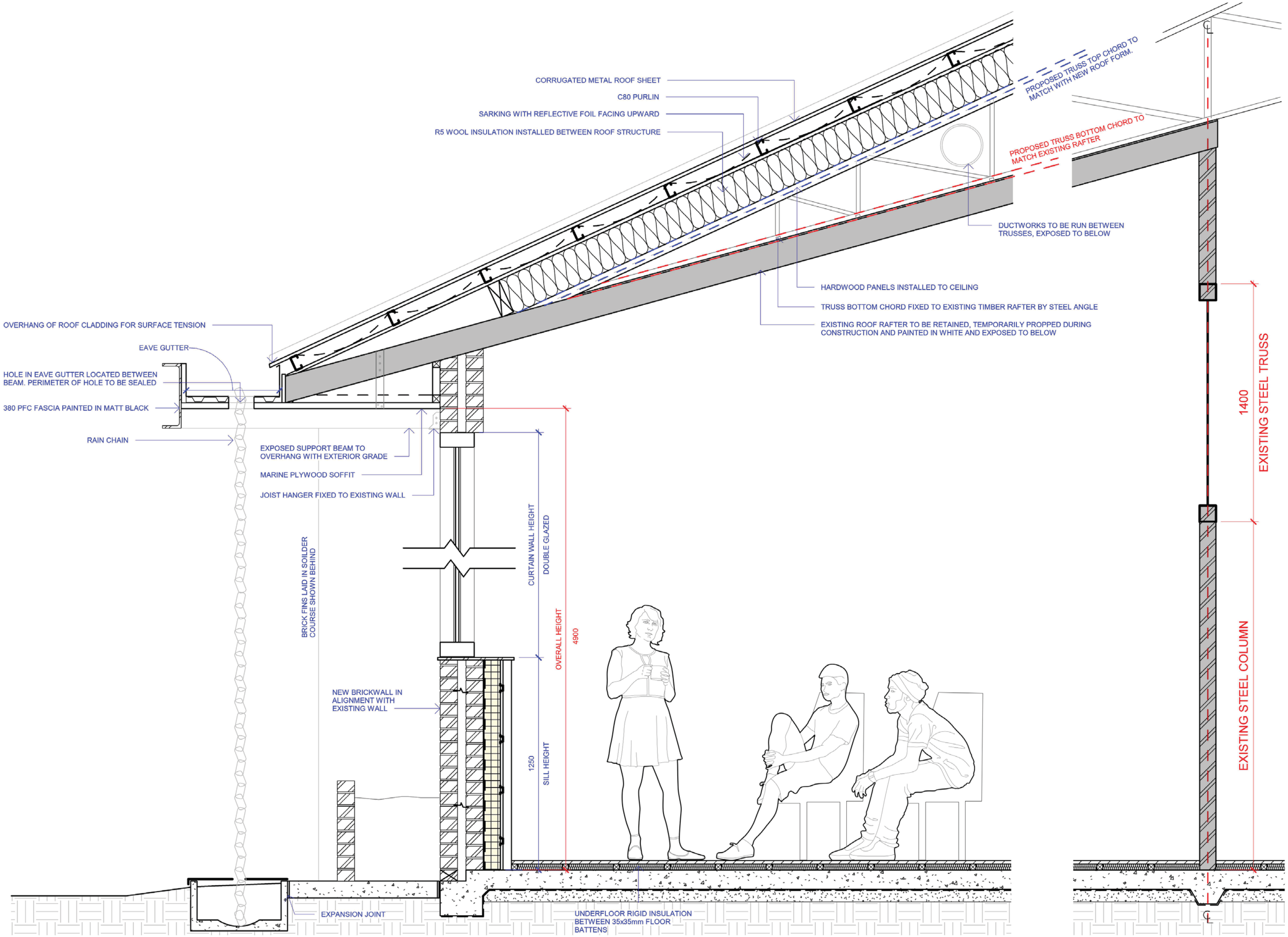
2,441 kgCO2e/yr

94% REDUCTION FROM EXISTING BUILDING ENVELOP



My position on Carbon Neutrality can be divided into (1.) An awareness of the energy source consumed by building and the energy requires to produce a certain building products (2.) the reduction of energy use by a well design building envelop and an efficient operation of equipments (3) The building a culture around accountability and responsibility in operating with energy-concious mindset in the learning environment.

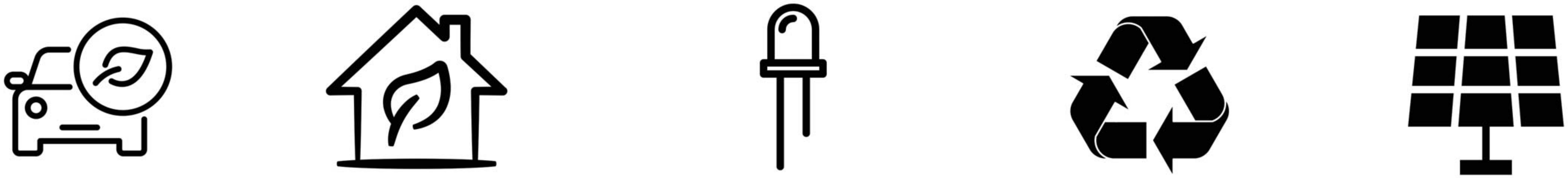
DAYLIGHT ANALYSIS



08 **Section B-B New Built**
Scale

Final Review Presentation
Studio 42: CO2 Zero

Canberra HS
Toro Nguyen



FUEL EFFICIENT VEHICLES

ENERGY EFFICIENT BUILDINGS

ENERGY EFFICIENT LED ALTERNATIVES

PASSIVE STRATEGY

SOLAR PV SYSTEM

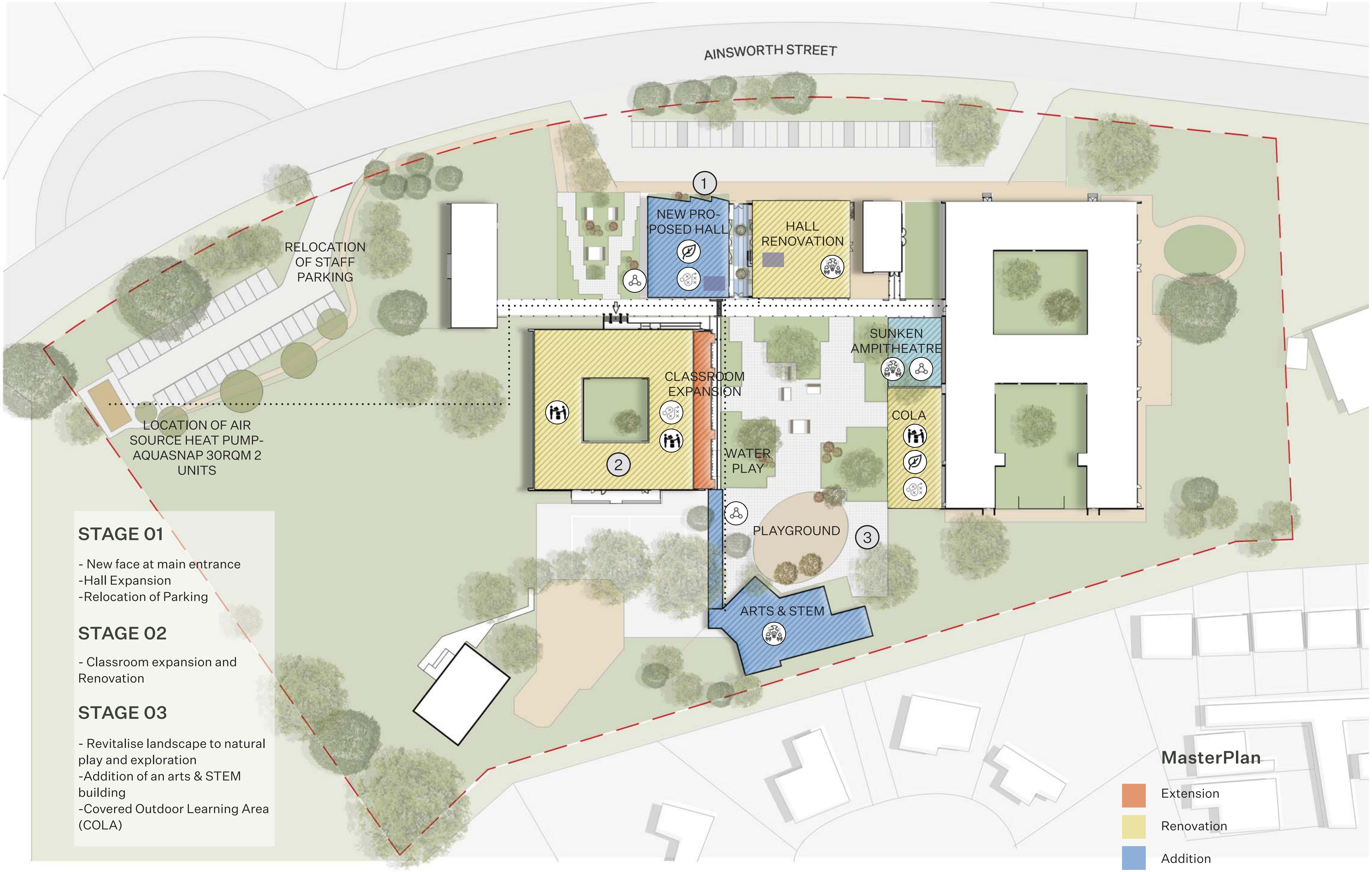
3 Steps:

Reduce energy use through more efficient user behaviour

Improve energy efficiency with more efficient buildings and HVAC systems

Incorporate renewable energy and GreenPower

ZERO CARBON EMISSION



STAGE 01

- New face at main entrance
-Hall Expansion
-Relocation of Parking

STAGE 02

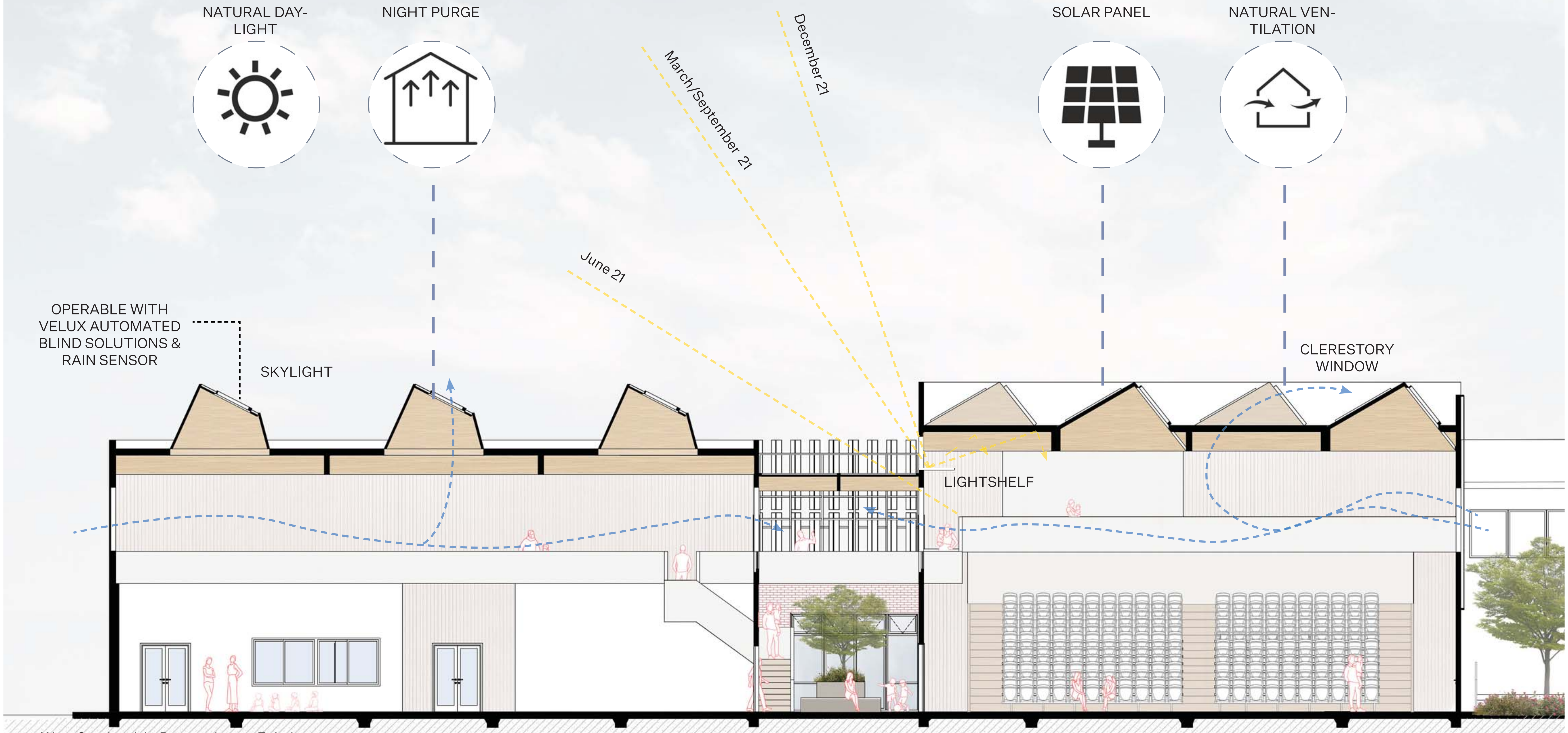
- Classroom expansion and Renovation

STAGE 03

- Revitalise landscape to natural play and exploration
-Addition of an arts & STEM building
-Covered Outdoor Learning Area (COLA)

1:750
0m 10m 20m

STAGE 01

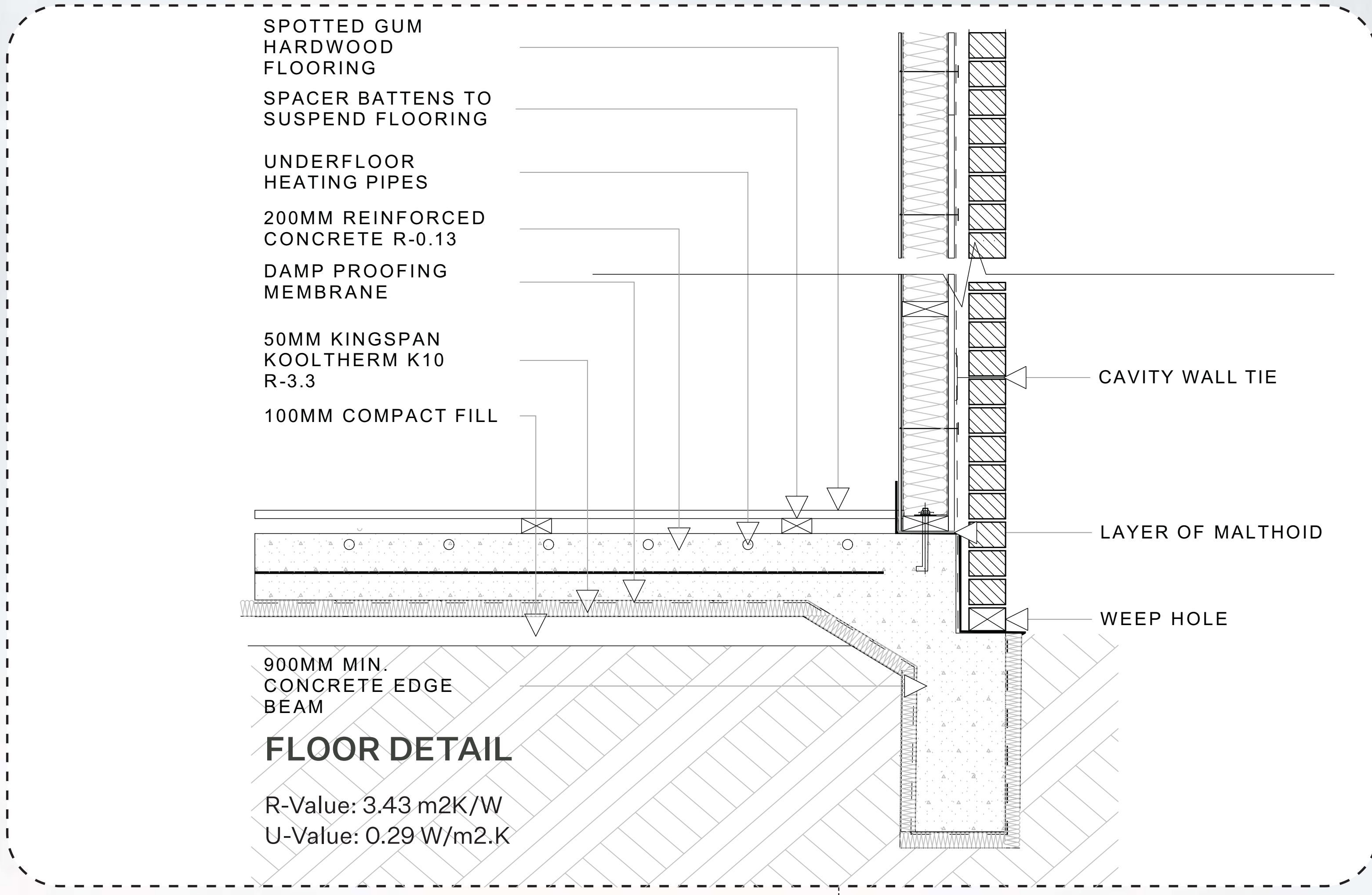


West Section AA- Renovation on Existing Hall and New Proposed Hall

1:125

0m 1m 2m 3m 4m

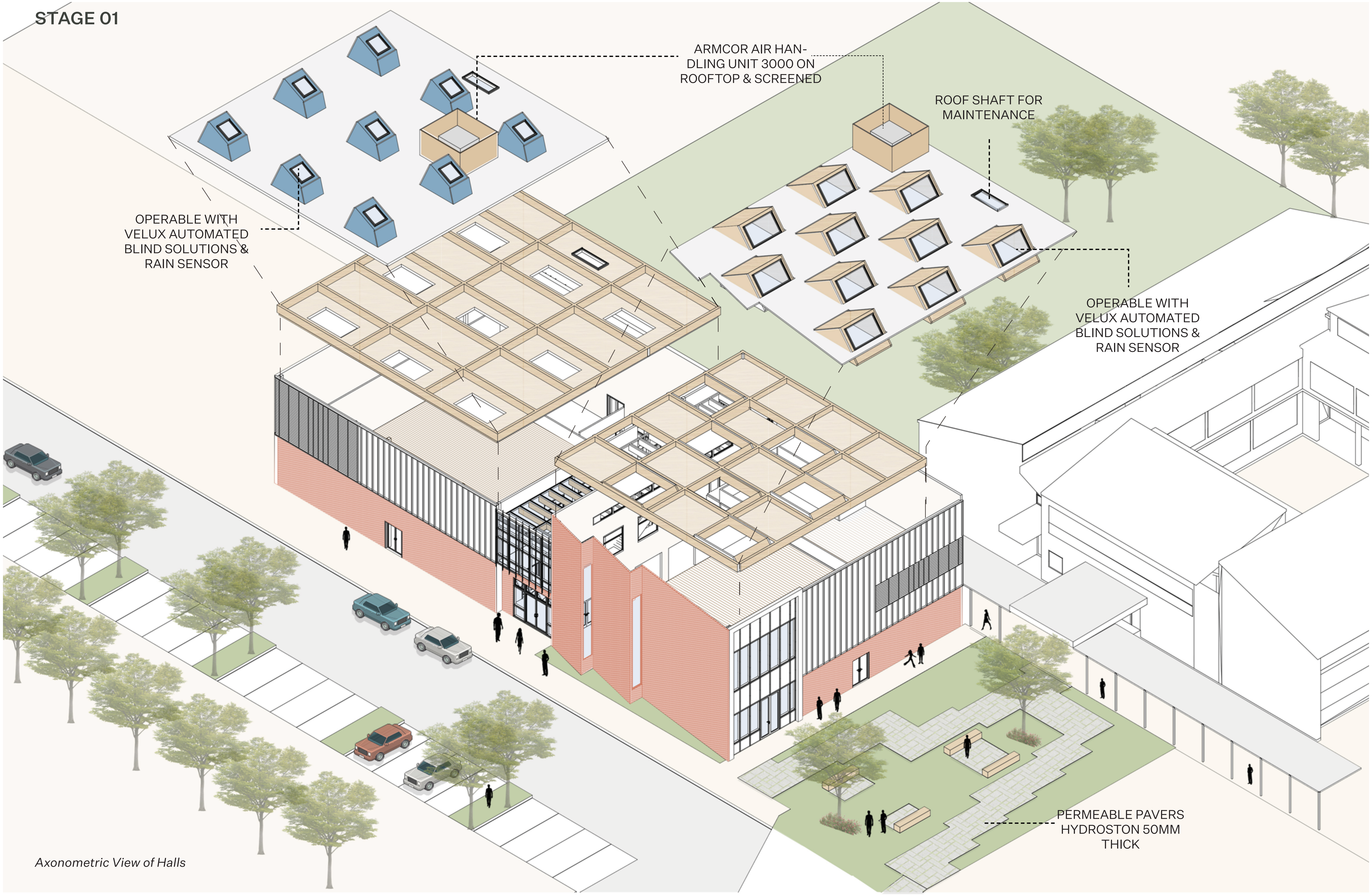
STAGE 01



New Proposed Hall Detail

1:20
0m 0.5m 1m

STAGE 01



Axonometric View of Halls

Internal atrium as new connectivity

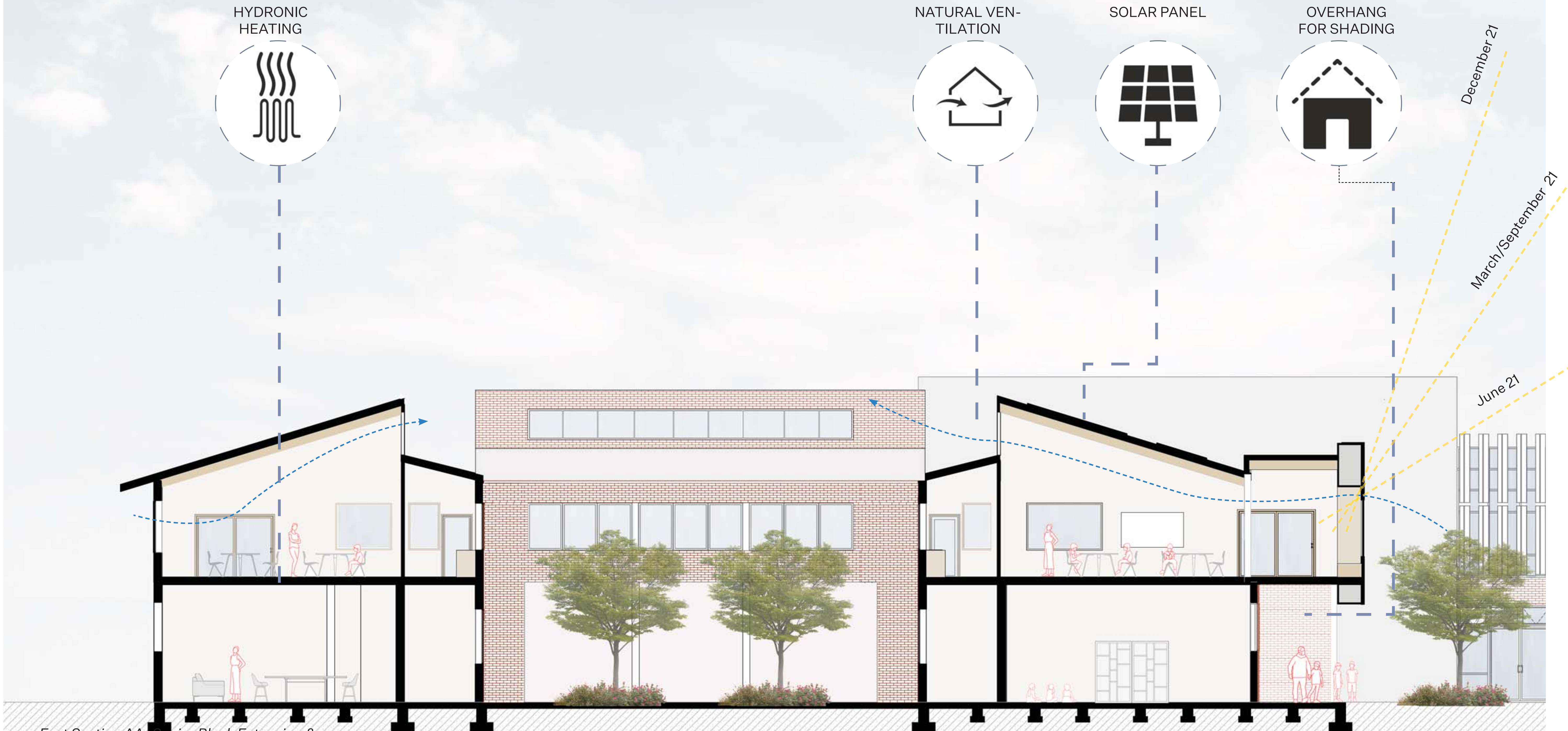
Artist's Impression

STAGE 02

- Renovate internal spatial arrangement for primary block
- Classrooms expansion

STAGE 02

22 December 2020 12.00PM



East Section AA- Senior Block Extension & Retrofit

1:125
0m 1m 2m 3m 4m

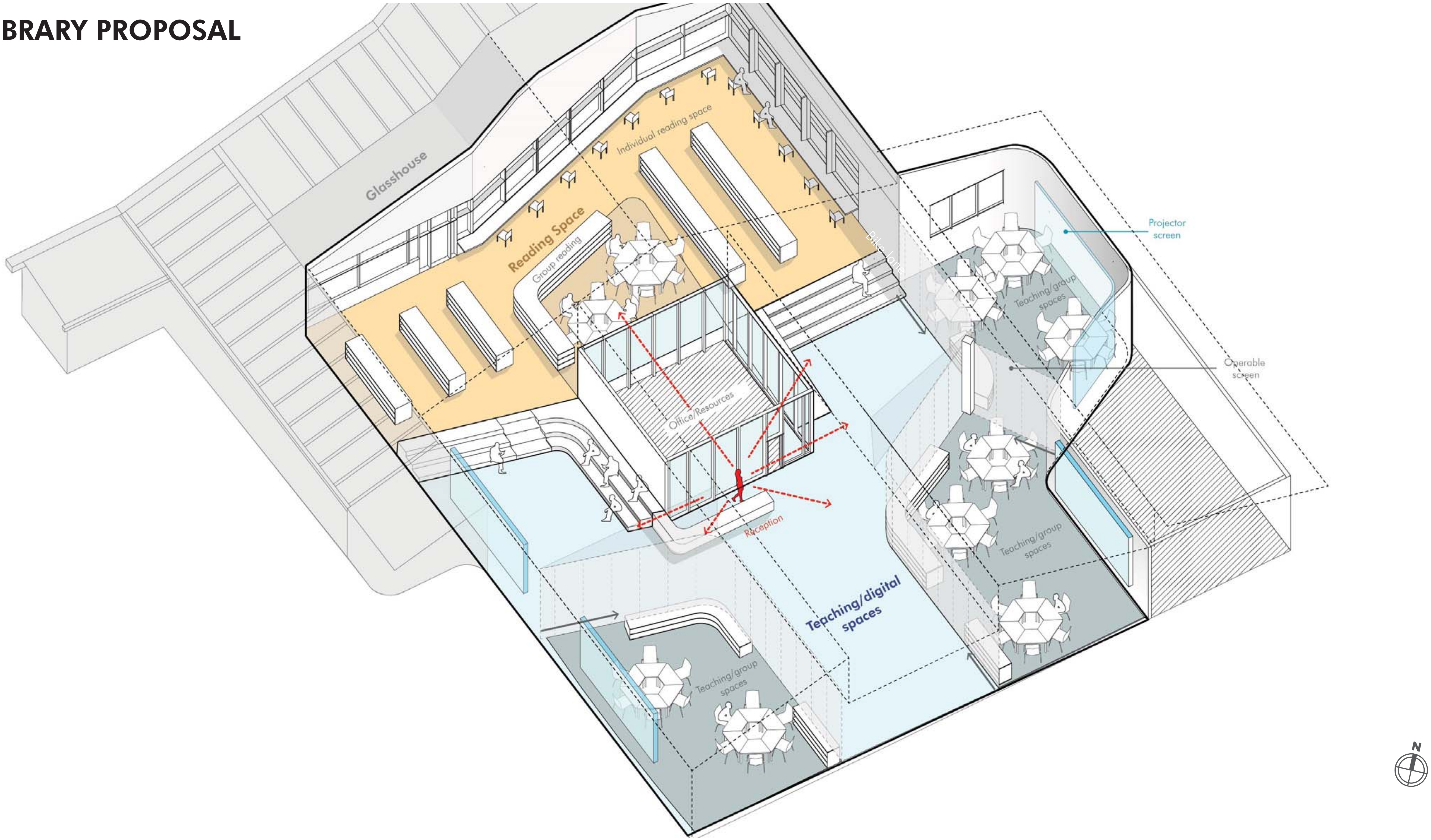
Senior Block Extension

Artist's Impression

Studio 42:CO2Zero_Canberra High School

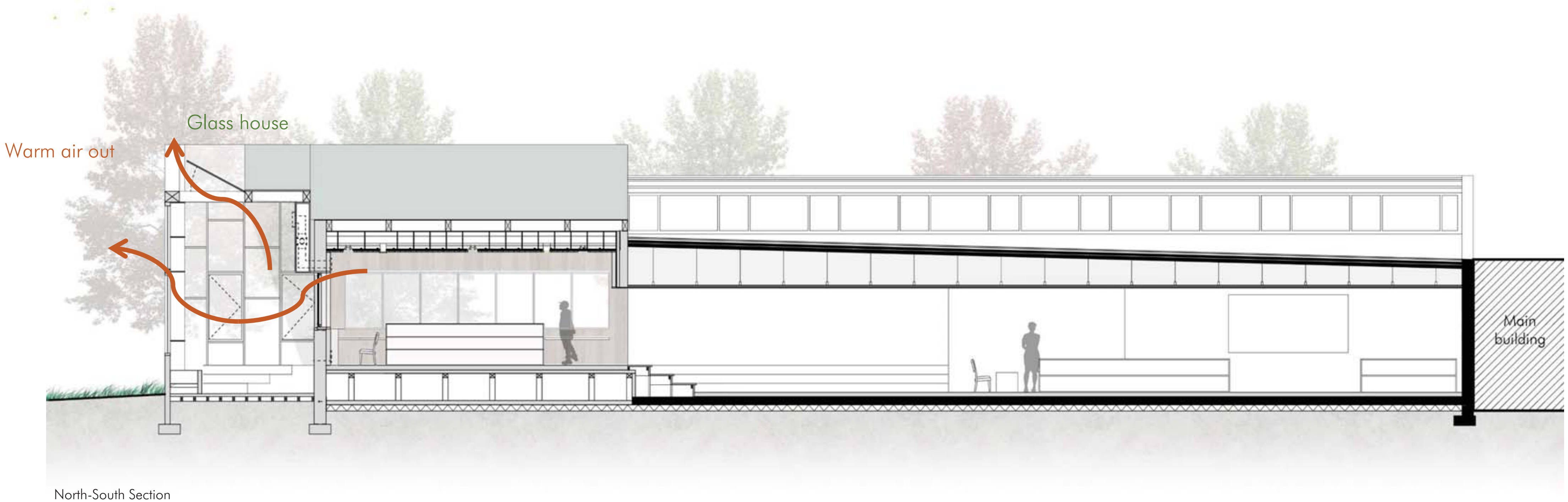
Wing Yiu Wan 1137412

LIBRARY PROPOSAL

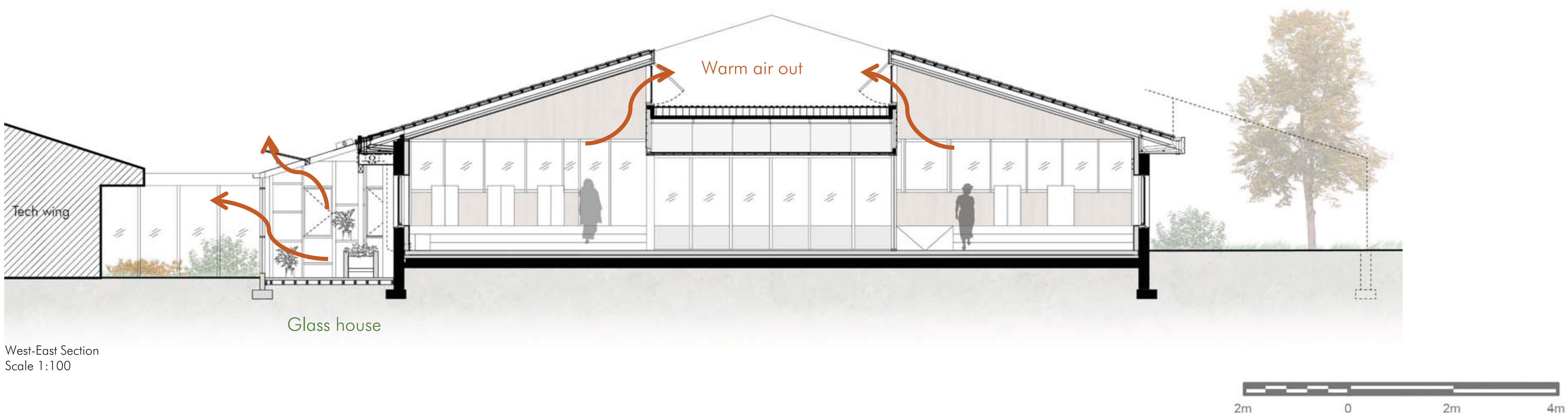


LIBRARY PROPOSAL

LIBRARY PROPOSAL_SUMMER



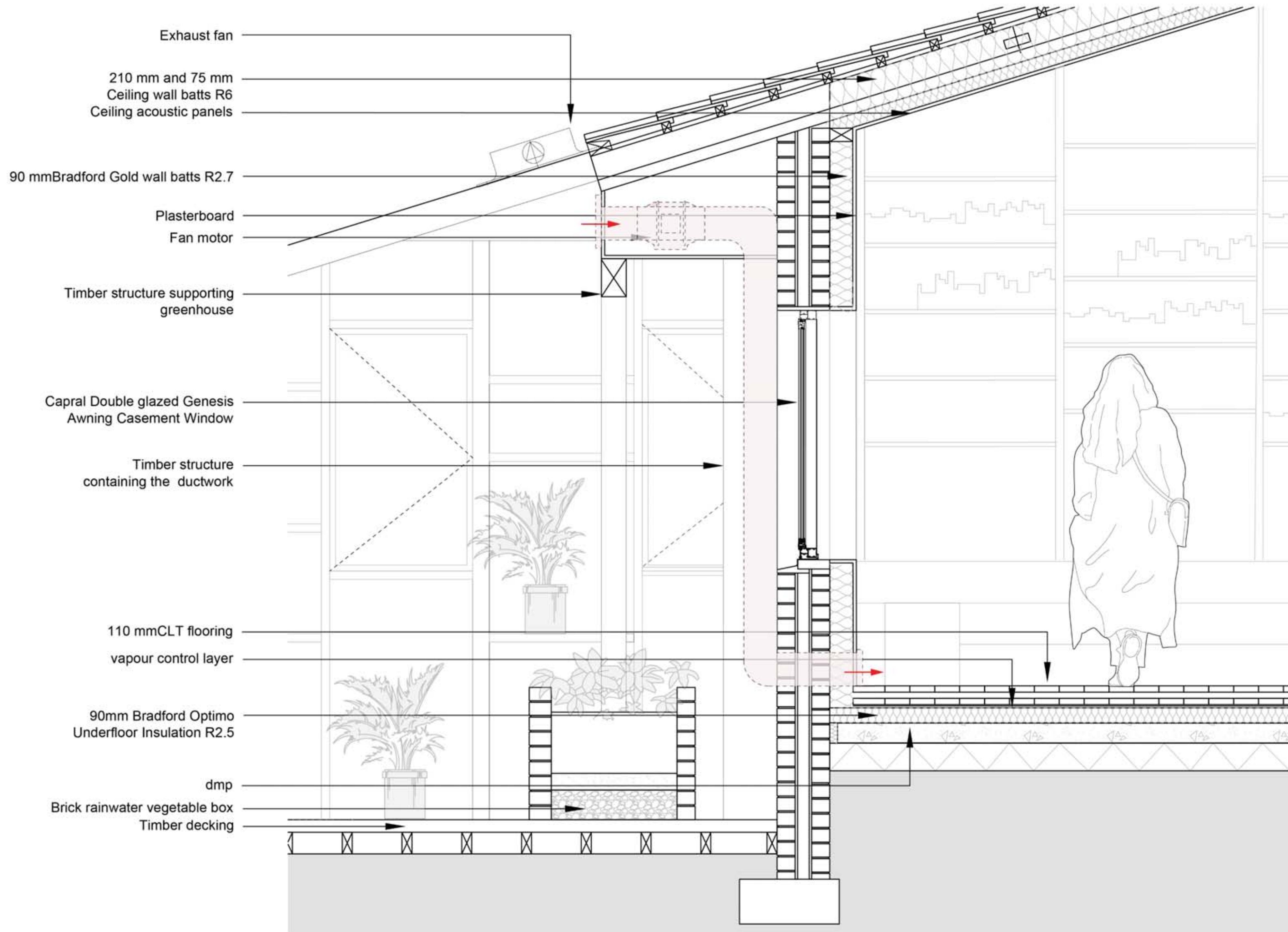
North-South Section
Scale 1:100

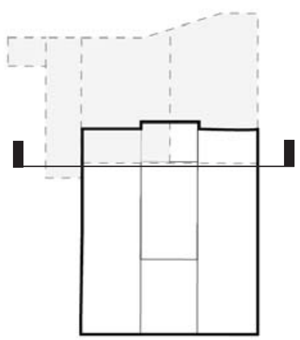


West-East Section
Scale 1:100

LIBRARY PROPOSAL

LIBRARY SECTION DETAIL



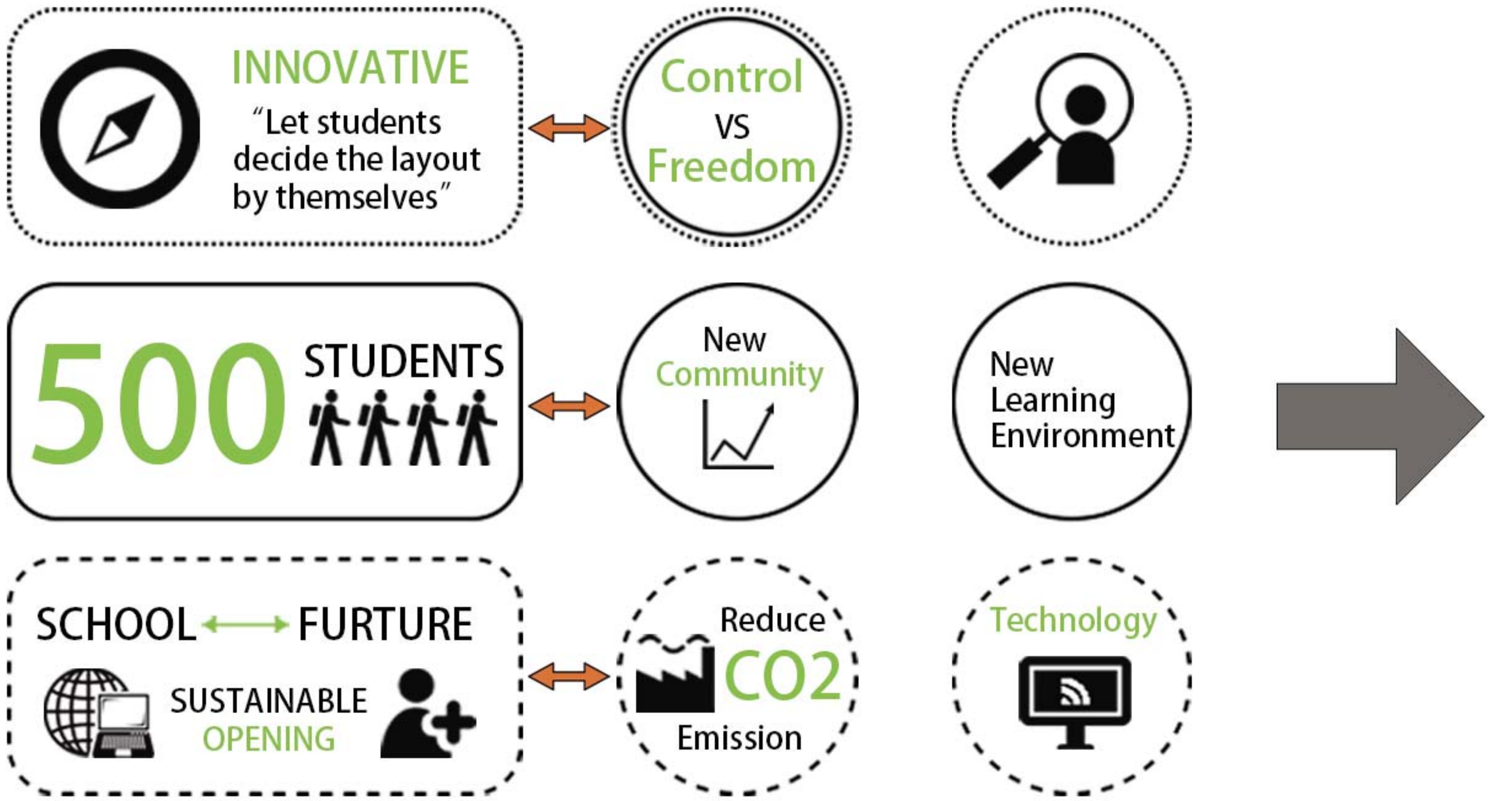


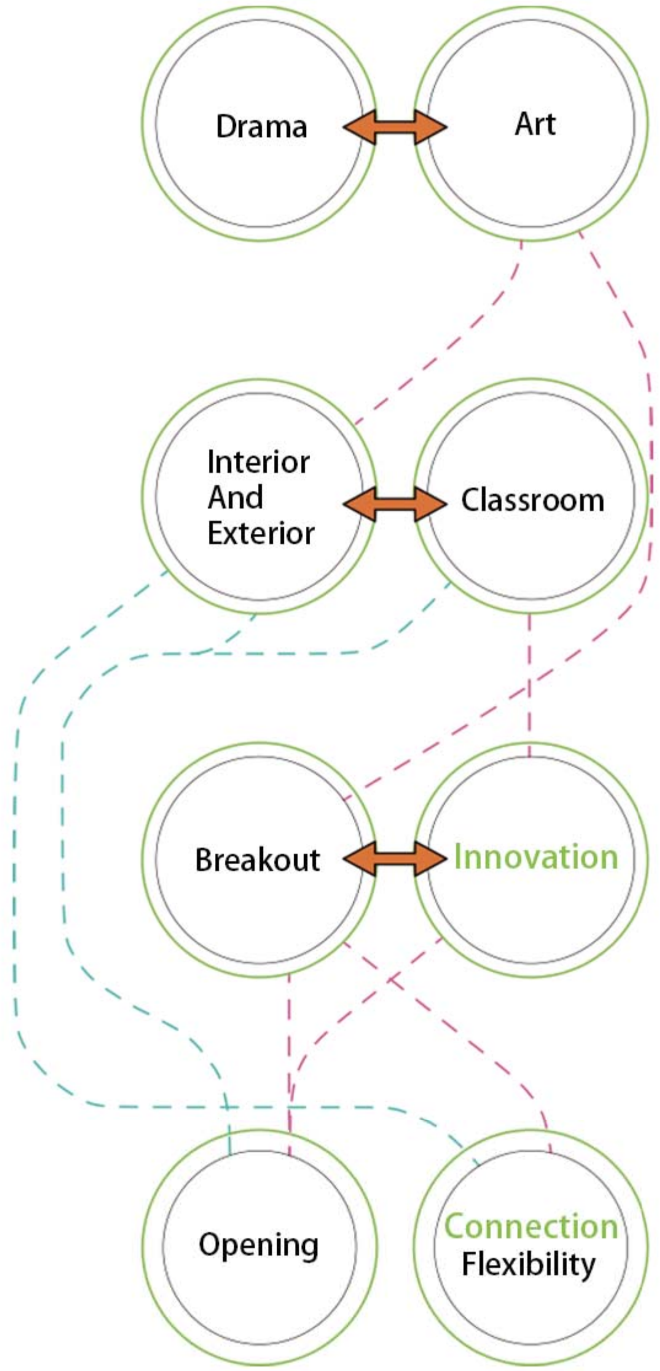
Scale 1:20

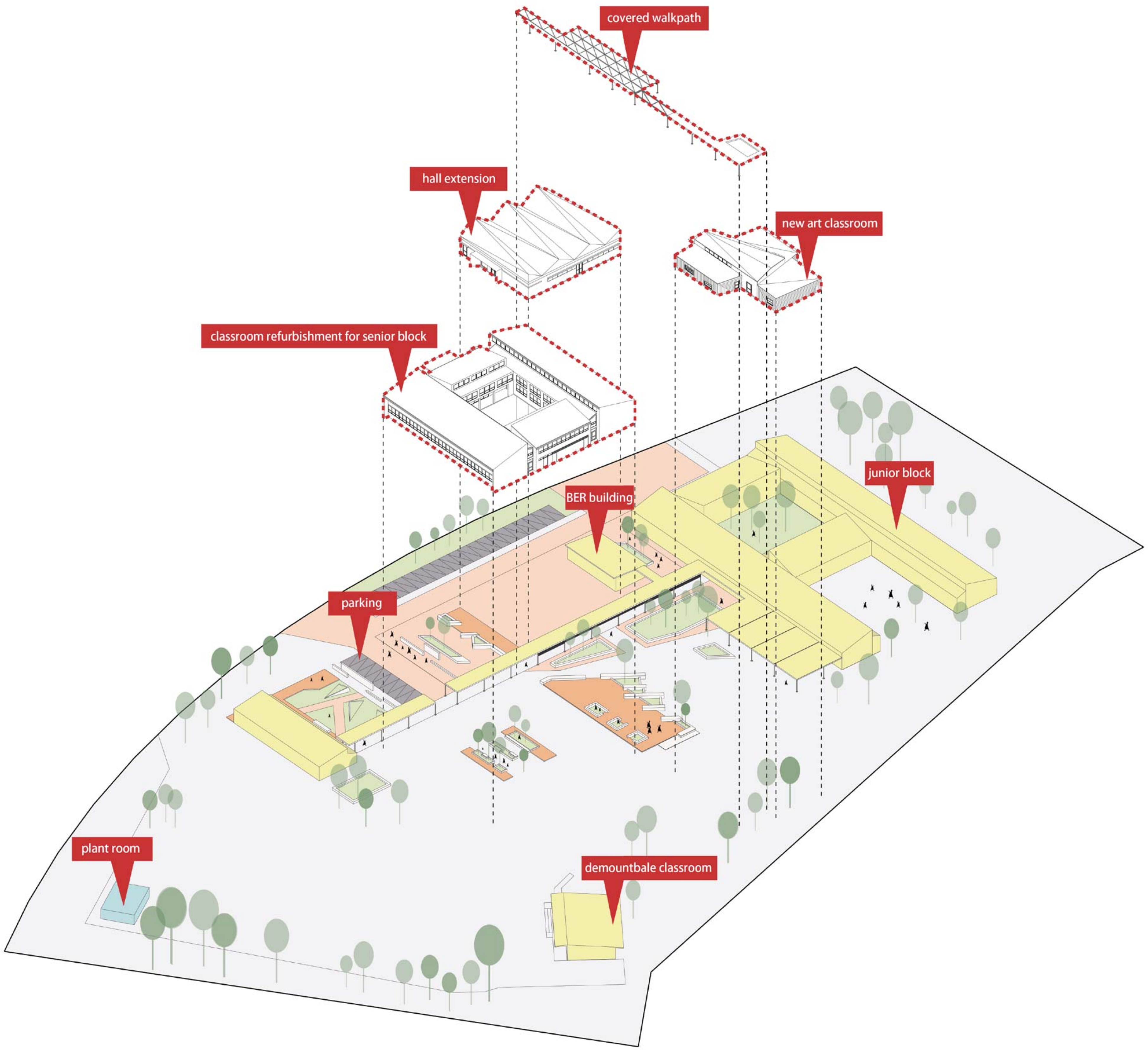
SOCIAL AND DISPLAY SPACES EXTERIOR

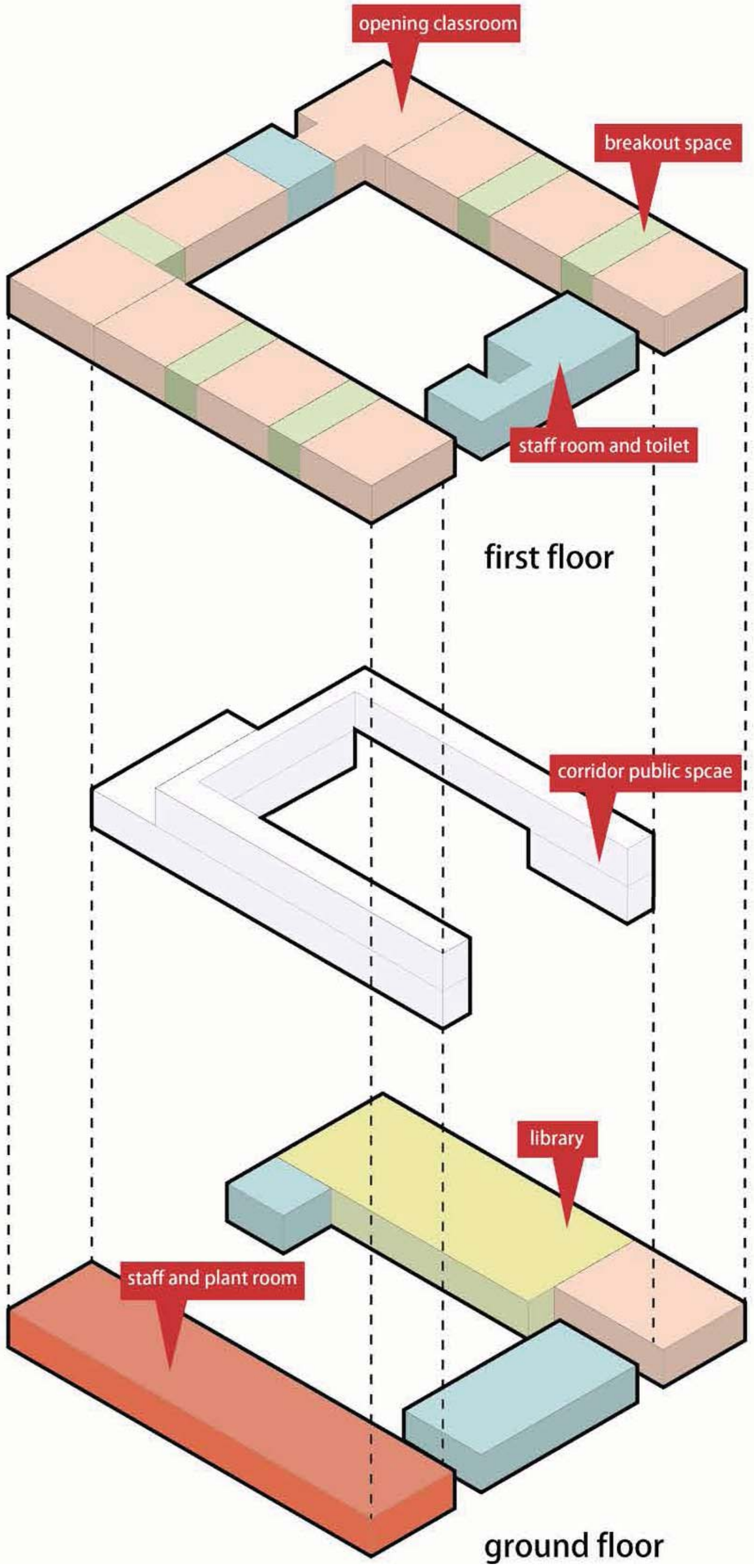
FINAL REVIEW

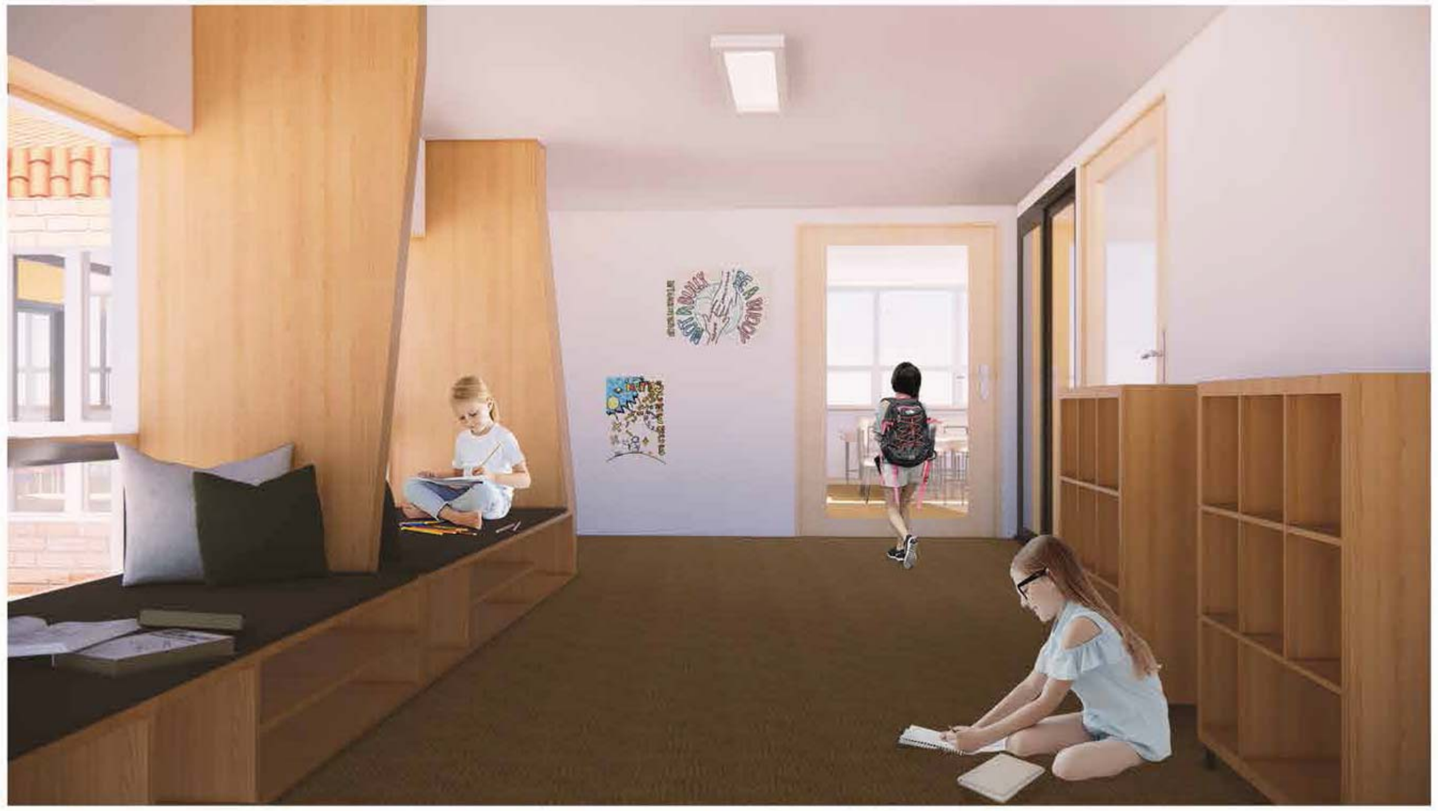
Mawson primary school

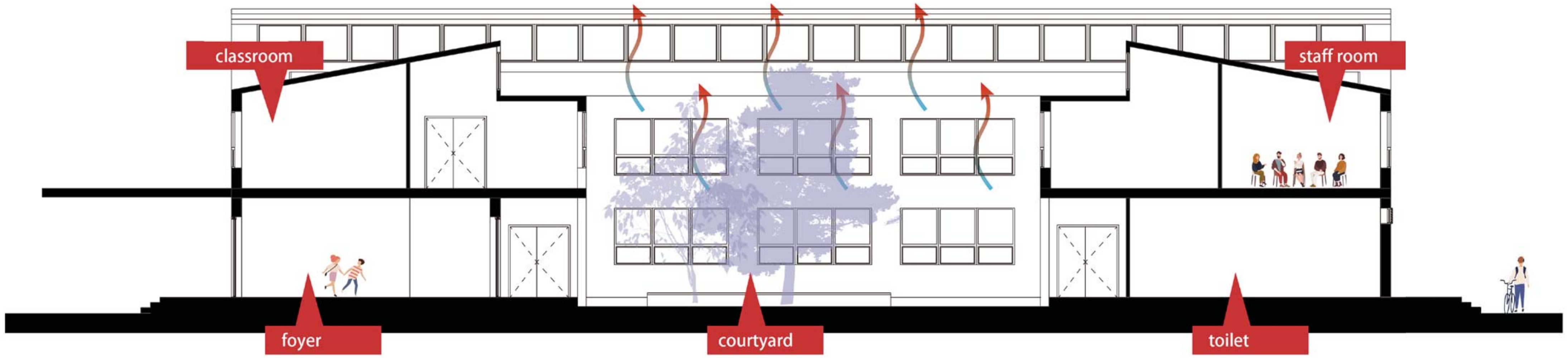

INNOVATIVE
"Let students decide the layout by themselves"
Control
VS
Freedom
500 STUDENTS
New
Community
New
Learning
Environment
SCHOOL FURTURE
SUSTAINABLE
OPENING
Reduce
CO2
Emission
Technology


Drama
Art
Interior
And
Exterior
Classroom
Breakout
Innovation
Opening
Connection
Flexibility

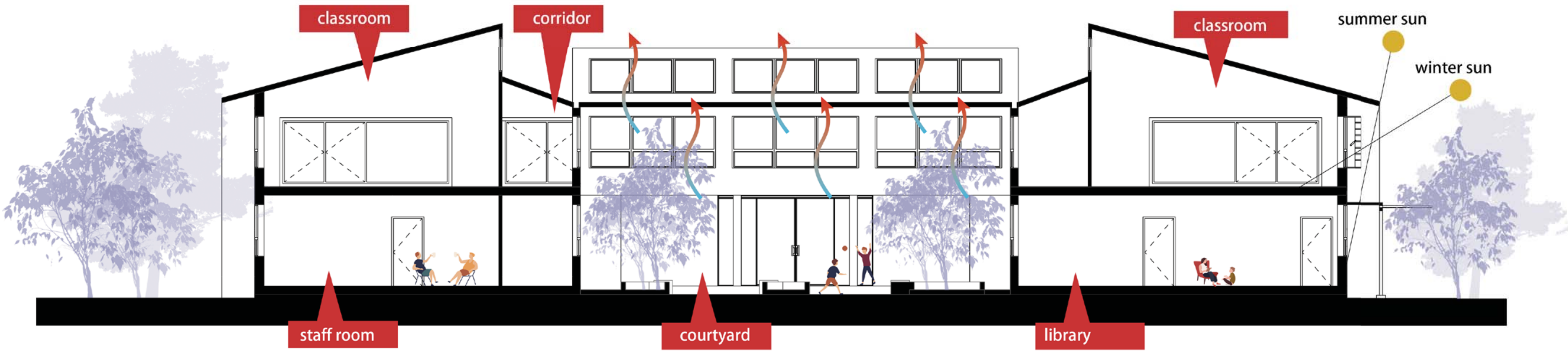

covered walkpath
hall extension
new art classroom
classroom refurbishment for senior block
junior block
BER building
parking
plant room
demountbale classroom


opening classroom
breakout space
staff room and toilet
first floor
corridor public spcae
library
staff and plant room
ground floor

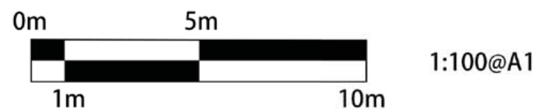


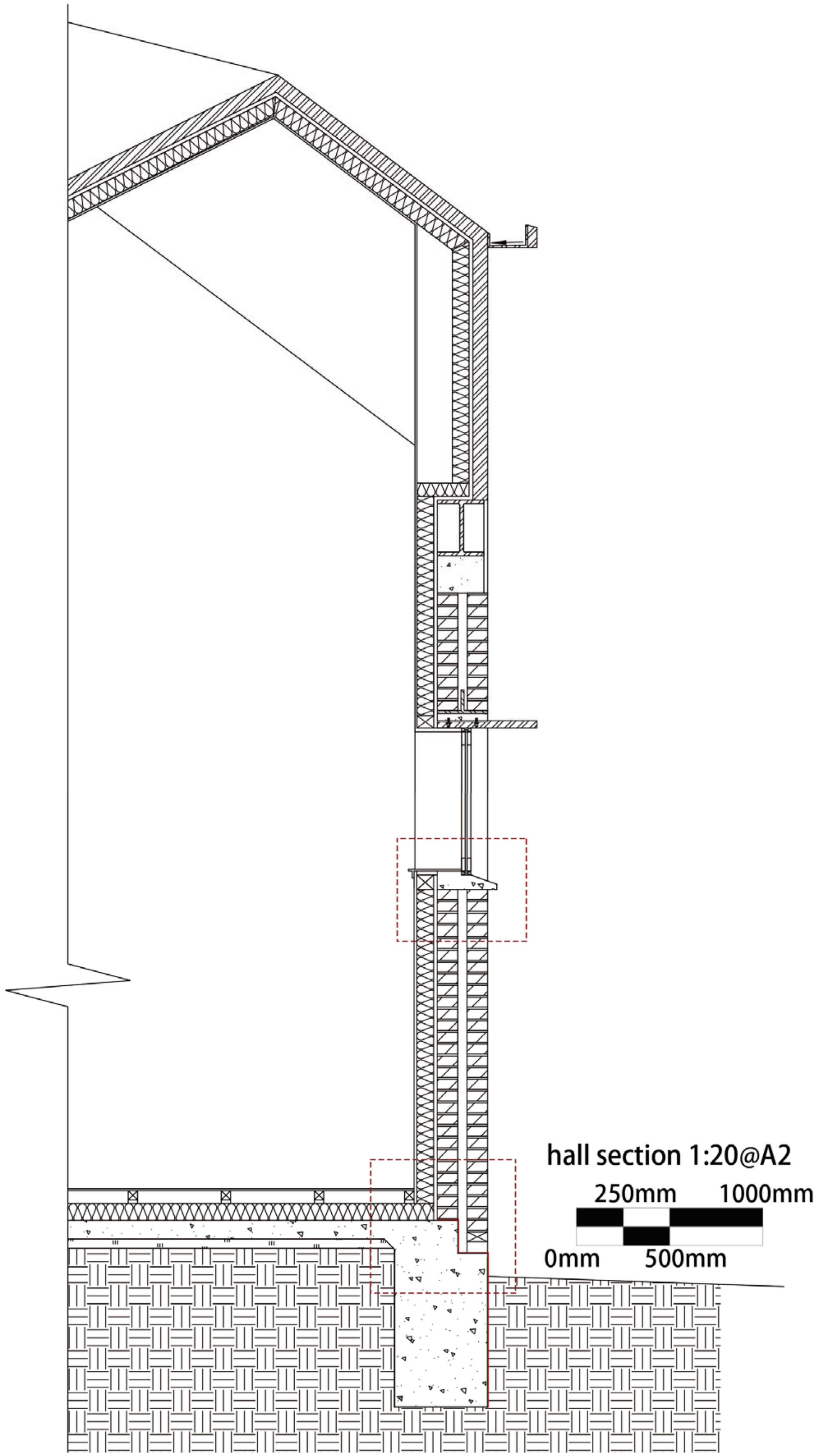


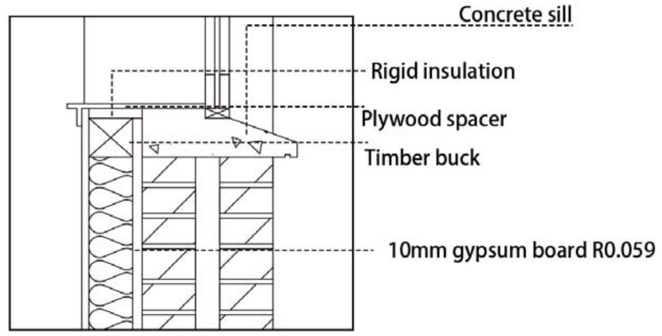
senior block A-A section 1:200@A3



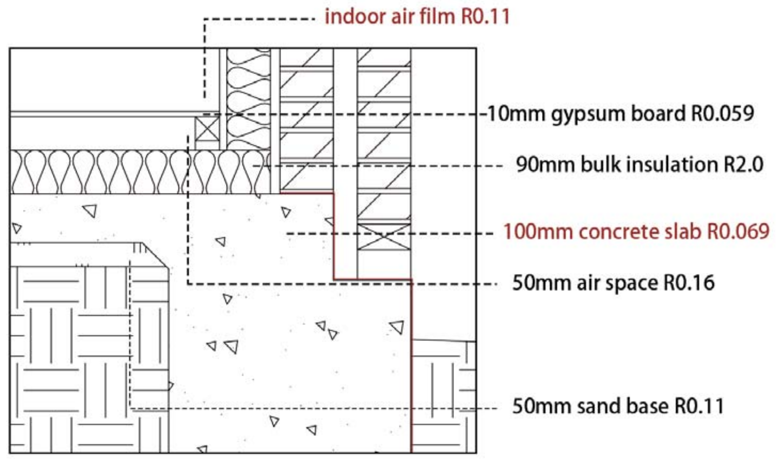
senior block B-B section 1:200@A3

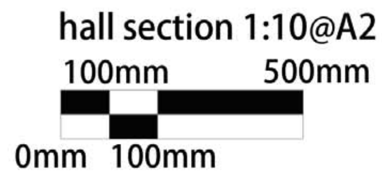




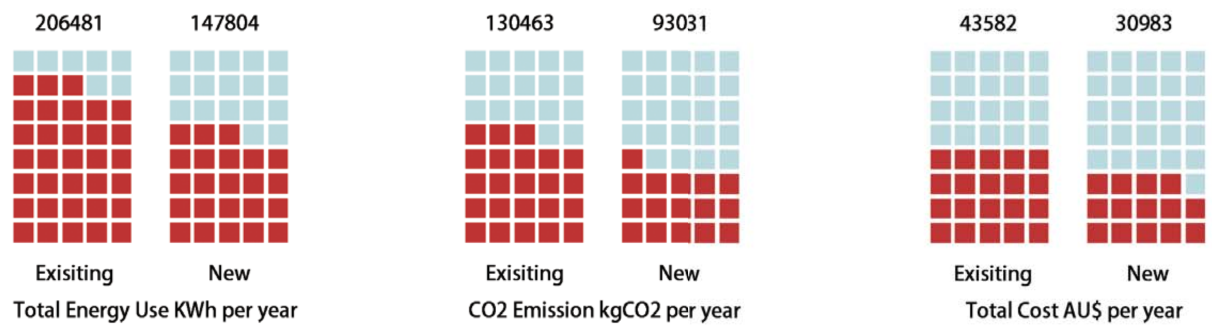


Total R value of floor:2.508㎡・k/w





Energy using difference



Key Principle for reducing CO2 emission

1.Reduce energy loss by thermal bridge

	Existing	New
Facada glazing	U value 1.99W/㎡・K	U value 1.6W/㎡・K
Wall(Double brick)	U value 1.7W/㎡・K	U value 0.59W/㎡・K
Roofs	U value 3.37W/㎡・K	U value 0.38W/㎡・K

2.Benefit from the renewables

The use of solar panels can effectively reduce energy use.

The use of air source heat pump replaces the original gas heater.

Thank You!