The Innovation Hub

for Affordable Heating and Cooling

Lesson Learnt (Summary) Report

IDS-KS Integrated Design Studios – Cross Programme Knowledge Sharing

Project IDS-KS v3.0
27th May 2022

The University of Melbourne

About i-Hub

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

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

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i-Hub Lessons Learnt Report

Guidance notes for completion of the Lessons Learnt Report:

- This report is intended to be made public.
- Please use plain English, minimise jargon or unnecessary technical terms.
- Please use your organisation's branding for the report.
- The report should meet your organisation's publishing standards.
- Please use one template per each major lesson learnt and include as many as are relevant for your sub-Project. If what you learnt is more technical, this is the section to include technical information.
- The content of these Lessons Learnt Reports can be compiled (and updated, where necessary) for inclusion in the (public) Project Knowledge Sharing Report, for submission at the completion of your sub-Project.

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IDS-KS Lessons learnt – place holder report

The lessons learnt in the IDS activities have been presented in the individual studio reporting throughout the IDS activity

This report represents a conglomeration of the lessons from individual studios. They lessons have also been incorporated into the two main guidance documents coming from the IDS activity work.

- The Catalyst for Integrated Design (lessons and guidance on setting up integrated design on projects).
- The Carbon Catalogue (Technical lessons and guidance on net zero design across different building typologies).

These documents are encapsulated in the main summary reporting for the IDS activity under the knowledge sharing activity: IDS-KS.

Lessons on Integrated Design taken from the IDS activity stream.

The lessons reproduced below present the cumulative learnings built across subsequent studios. They relate to generalist learnings on 'Integrated Design' and are applicable to all studios.

These lessons have been derived from the testing (in studio environments) of the theoretical integrated design principles found in literature. They provide additional guidance assisting in the practical application of the theory.

Category	Technical – Integrated Design

#1
(IDS-01 #1)

Good integrated design requires a 'design co-author' mindset in all participant designers.

Current design paradigms often place engineering as following architecture in the design process. This encourages a consulting type approach to the engineering where engineers are asked to comment on preformed ideas. Design integration can occur in this model however to a reduced potential with the initial ideation missing ideas founded in engineering aspects of the project. The studios found this consulting model to be difficult to break free from. Attention needs to be paid to create a mindset of 'design co-authorship' in all participants (engineers and architects alike). The reasons for this are not immediately clear however we believe may be related to:

- Potential deficiencies in creative thinking education in degree content.
- Established practices in industry (i.e. accepted established role as consultants).
- Early career stage (more experienced engineers were found to be better at ideation that younger engineers).
- Disparity in time available to be dedicated to studio ideation.

Lessons to be incorporated into future studios:

- Emphasise the concept of co-authorship in ideation more heavily.
- Aim for a better balance in numbers between architects and engineers.
- Aim for a better balance of seniority between architects and engineers (to encourage approachability and reduce fear of failure in putting ideas forward).
- Introduce common tasks at a detailed analysis level as well as the high aspirations level to encourage interaction between architects and engineers with common goals. This is anticipated to foster more detailed generation of ideas between the two disciplines.

#2
IDS-01 #2, IDS-03 #2 & #5, IDS-10 #1.

Integrated design ideation happens in a limited time window after designers reach a level of base understanding of the disciplines to be integrated.

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 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. It is important to recognised when this ideation period is happening ensuring everything and everyone is in place to make it as successful as it can be.

Lessons to be incorporated into future studios:

In future studios more attention will be placed on this important ideation time. We may even give it a name so that the participants are aware of it and treat it with the degree of importance and priority it requires.

> ***Additional Learnings from IDS-03 #2 & #5***
>
> Base level of understanding required in disciplines to be integrated before integration can happen effectively. Student designer's solutions at mid semester were found to be pedestrian reflecting upskilling to understand what BAU is in each discipline. It was after this point that design integration and innovation was able to be productively pushed. This reflects research on polymath creativity across knowledge domains by Kaufman et al., 2010, Creativity polymathy: What Benjamin Franklin can teach your kindergartener. Likely for the same reason more experienced designers are quicker to commence, and more effective at integrated design ideation.

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Additional Learnings from IDS-10 #1 – Timing should be prior to significant structural bounds are placed on the design.
Timing of integrated design best occurs after an initial period of designers establishing a base understanding of others disciplines however it needs not to be so late that the opportunity if lost. When integrated design is sought following design completion, many project parameters have already been set, limiting potential opportunities. Adjustments to the façade are possible, with superficial shading being integrated within the existing structure, but any substantial changes require evaluation by a structural engineer, which undermines the preliminary work already completed at great cost. Similarly, any engineered solutions must work around the existing structure, resulting in changes primarily being made to envelope materials or active systems (e.g. HVAC, lighting etc.). These solutions have very little overlap, resulting in minimal integrated design opportunities. While these are opportunities that can be explored at a later stage of the design process, integrated design has more potential opportunities available at earlier stages of the design process, particularly at project inception.

#3 (IDS-01 #3)	Balance between architecture and engineering requires active curation.

IDS-01 took the approach of asking designers to approach the design from the two disciplinary extremes (architecture and engineering), from the beginning producing designs they felt represented each (ignoring the other). This approach emphasised the differences in the two approaches in designer's minds and articulated the prospects of needing to navigate the spectrum in-between the extremes in future design. Once equipped with this perspective it was easier for designers to understand that it is a balance between the two. Observations in the other IDS observed found that designers tended to follow the information in front of them without necessarily understanding the extents of the design spectrum.

This learning is a subset of the larger learning that active curation of the process is beneficial. There were conflicting opinions coming out of the interviews as to where this curation should sit. Some believed this should be the job of the architect, others believed a third party.

Additional Learnings from IDS-03 #3
The importance of the design curation was found to be even more important than first thought in IDS-03 to IDS-05 as relayed by stakeholders interviewed (Refer Lesson IDS-03 #03). Further investigation is required to establish if this is heightened due to the studio leader's joint role as 'teacher' in the studios. Differing opinions on where this design curation role best sits were also evident. Some believed this role should in the architect's remit, others believe it should be a third party independent to the architect and engineer.

Lessons to be incorporated into future studios:
In future studios we will consider adjusting the integrated design process to encourage this exploration of the extremes between the two disciplines views of the project and also discuss where this curation role bests sits.

#4
(IDS-01 #4)

There is a high level of excitement and buy in to the concept of integrated design.

A high level of excitement and buy in to the concept of integration was observed in all involved (demonstrated by studio popularity with students and keenness to be involved by participants). It is clear that the benefits are recognised. This may suggest that existing failures to follow a design integration path in industry occur as it is simply not an up-front agenda item.

Lessons to be incorporated into future studios:
Further work identifying the gap between practitioners and clients buy in, and the failure to see integrated design realised more in industry is worthy of further research.

#5
(IDS-KS #1)

Integrated Design Process - one size does not fit all

In taking the integrated design process consolidated from the literature search and applying it to the first two integrated design studios (IDS's) in practice, it was clear that the process needed a high degree of customisation. Variations between the studios included tailoring for:

- Studio Leaders style/preferences. While the studio leader is an IDS specific role and will not exist per se in practice, the individual styles and preferences of the players involved in leading design will. We felt it important to let the leaders dictate aspects related to their style of working to get buy in and maximise chances of success. We expect this will be an element that needs to be considered in implementing successful integrated design teams and environments in practice.
- Technical content. The high level of technical content involved in data centre design and achieving efficiency meant that addit. measures had to be taken to ensure architecture received adequate air time.
- Willingness and available time to be involved. All parties were keen however subject to various constraints. It was important to consider this in the input (frequency and duration).
- Ability to see the forest for the trees. The presence of a third party design leader or curator was important in providing perspective to the designers, someone outside and removed from the design who could provide feedback if the design was straying too far towards one discipline or the other.

#6
(IDS-KS #2)

Establishing Integrated Design extremes (or discipline goal posts) helps.

One of the preliminary observations in relation to process was that the curation of balance between architecture and engineering looks like it will be more successful when there is an element of inherent way finding. One of the studios asked designers to produce two designs, one from an architect's view ignoring engineering, and vice versa.

This appears to have offered some benefits in assisting the designers to set the goal posts – i.e. what might pure architecture look like, and what might pure engineering look like and how do we balance and achieve the best outcomes from there. Designers who did not do this tended to be taken along a narrower path following their noses in design development rather than knowing the possible bounds.

#7
(IDS-03 #1)

Precedent disparities exist in the working frameworks architects and engineers bring to projects.

Disparities exist in the frameworks architects and engineers work within when involved in design.

Lessons to be incorporated into future studios:

- Introducing smaller task specific activities with common goals helped in bringing individuals (architects and engineers), together. An example of this were tasks set to work with a common software tool to analyse performance of a small manageable part of the building.
- More closely aligned definable goals. Efforts were made to establish common goals in design however these were usually general in nature, i.e. zero net energy, better sustainability, more renewable energy etc. Design under these 'loose' aspirational goals often strayed whereas design in more defined tasks such as teams researching specific solutions (say labyrinth's or heat pumps etc), provided better focus. A part of this will be pre-semester efforts to try and more closely align assessment criteria between disciplines.
- Straight out reductions in disparities establishing as level a playing field as possible. Efforts will also be made in this front, i.e. achieving similar time allocations between students through the formation or adjustment of subjects between the faculties.

#8
(IDS-03 #2)

Experience levels of designers is an important consideration in integrated design.

Experience levels were found to impact on integrated design capability. Student (and early career consultants) were found to be capable in analysis but not necessarily design. This learning came from observing the nature of design development. Designs were found to be 'pedestrian' or Business as usual' (BAU) in nature up until the mid-semester critiques. We feel this is because the first half of semester is the time students required to become 'familiar' or 'comfortable' with the problem definition and the new cross discipline skills/appreciation they are acquiring. It is only after this point designers felt more at ease experimenting and pushing boundaries. The more experienced consultants in the design team were observed to be much better at integrated design in this respect (although not exclusively).

The learning from this is an increase in the initial familiarisation time required before the 'sweet spot' of design integration is able to productively occur.

Lessons to be incorporated into future studios:
Educate designers about the process of developing an understanding of the fundamentals before experimentation and productive design integration can effectively occur. Note that this does not mean that thinking about potential creative ideation and design integration should be ignored or not happen early on, just that it is unlikely to be productive until a sound understanding of the fundamentals is gained.

Additional Learnings from IDS-10 #4 – Design Frameworks are of benefit to inexperienced designers

It was commonly identified inexperienced designers were largely reliant on the experiences of the consultants to assist in guiding them through the design process. A design framework was established which directs students from one objective to another, building on their knowledge of previous work before undertaking more detailed designs. This framework was presented to the students in the form of assessments, with each subsequent assessment built on the work completed previously. This progression assuaged the overwhelming nature that design can have improving outcomes.

This design framework is not dissimilar industry, with return briefs and sign off stages established to ensure all parties are happy before a finalised design is arrived at.

#9 (IDS-03 #4)	Architects and engineers have different preferences in communicating and engaging.

Difference in personalities and preferred methods of communicating and engaging is becoming evident. Students from the two faculties engage differently on a number of fronts:

- Engineering students prefer more defined problems and better defined problem solving frameworks in which to work on them than architects.
- Engineers tend to be less communicative in open studio forums (more likely to have video switched off etc.).
- Engineers tend to be more comfortable with analytical tasks involving and metrics and specific outcomes.

It was felt that these differences hindered collaborations. The differences reduced over time in the studios. Further investigation as to the reasons underlying the differences and potential amelioration is required including exploring the benefits of introducing socialising activities external to the design process. It was noted that engineers in one studio (IDS-04), were highly engaged and this may have been due to the presence of one or two individuals with 'more collaborative and energetic attitude' acting to encourage others.

#10 (IDS-03 #5, IDS-14 #2)	Base level of understanding required in disciplines to be integrated before integration can happen effectively.

A base level of understanding was found to be required in the disciplines to be integrated before integration can happen effectively. Student designer's solutions at mid semester were found to be pedestrian (average) in quality reflecting student's upskilling to understand what business as usual (BAU) is in each discipline. It was only after this point in the studio that design integration and innovation was able to be productively pushed.

This reflects research on polymath creativity across knowledge domains by Kaufman et al., 2010, Creativity polymathy: What Benjamin Franklin can teach your kindergartener. Likely for the same reason more experienced designers are quicker to commence, and more effective at integrated design ideation.

Additional Learnings from IDS-14 #2 – Integrated thinking is difficult for all participants at the early stage where no building form is yet determined

Both architecture and non-architecture participants experienced difficulty in approaching energy efficiency, renewable energy, HVAC and sustainability (ESD) considerations and options at the initial phase of the project (prior to the emergence of any building form). It may be that engineering and ESD professions typically provided input at a later stage of design development, and that architects first want to consider building form (before function). This presents a challenge to the IDS goal. This challenge was also exacerbated by the very different levels of technical knowledge between architecture, engineering and construction management students; and between students and academic/industry professionals.

For future IDS projects within a university setting, it would be beneficial to first address the knowledge gap in architectural science and building services, by providing units/subjects that could be undertaken by students in architecture, engineering or construction management degree programs.
It would also help to break the IDS 'whole of project' concept into discrete segments, so that inexperienced (early career) professionals can focus on one aspect at a time, rather than trying to integrate all requirements into a single project. For professional practice, there may be a need for some interdisciplinary workshops to determine ways in which design concept can emerge collectively prior to building form being established.

#11
(IDS-06 #1)

Visual communication is the best universal language and is useful both for communication and as an analysis/collaborative thinking tool.

A valuable insight taken from IDS studios is that the power of visual communication is understood universally across disciplines.

An important moment of visual communication was the use of diagrams to explain logical design processes. For example the impact of structural layout on circulation or sightlines. This universal visual communication develops progressively over time, first, the team shared respect and understanding for the specialised knowledge and language. This was an early focus in the IDS through presentations and feedback on industry standard drawing convention but is not sufficient by itself. The most effective integrated designs then create a unique shared diagrammatic language which supersedes any one discipline, allowing emergent ideation to occur.

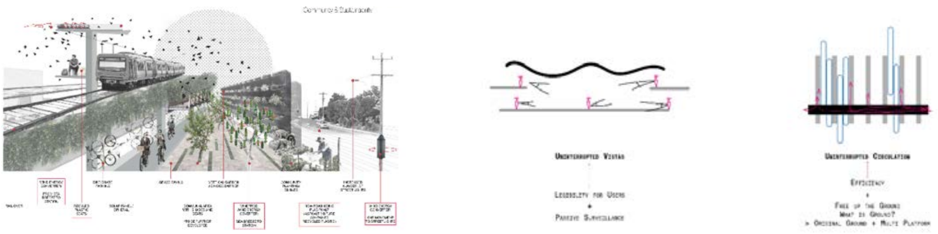


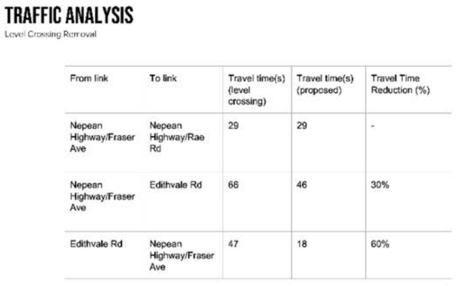
Figure: Examples of visual language, (a) annotated perspective with integrated technology, (b) diagrams of architectural and engineering design implications.

The process of drawing, presenting, and understanding became a form of problem interrogation (or analysis) that then facilitated integrated responses by allowing all disciplines to be involved in the critiquing and authoring of the refined solutions.

#12
(IDS-06 #2, IDS-10 #3)

An informed process of interrogation and iteration can assist in the process of integration

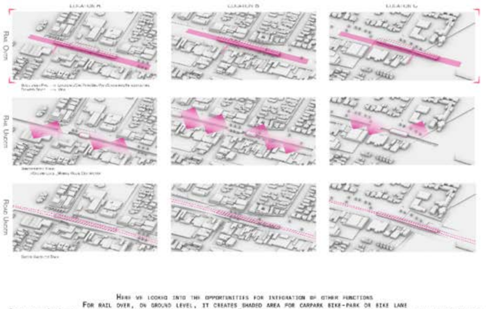
An informed and intentional process can make a significant difference to the level of 'integratedness' of a project or team. In the conventional design process, the role of any engineering designer is to validate architectural design. It was observed that the most valuable shared attribute of all engineering specialties is the practice of systematic analysis. The process of rigorously defining criteria, simulating potential scenarios and exploring the results with some level of objectivity can lead to optimized and unexpected results. This was observed in early geometry development, where traffic analysis drove different iterations of road alignment and consequential master planning:



TRAFFIC ANALYSIS

Level Crossing Removal

From link	To link	Travel time(s) (level crossing)	Travel time(s) (proposed)	Travel Time Reduction (%)
Nepean Highway/Fraser Ave	Nepean Highway/Rae Rd	29	29	-
Nepean Highway/Fraser Ave	Edithvale Rd	66	46	30%
Edithvale Rd	Nepean Highway/Fraser Ave	47	18	60%



Here we looked into the opportunities for integration of other functions
For rail over, on ground level, it creates shaded area for carpark bike-park or bike lane
Rail over Also provides opportunities for planting on ground, Rainwater can be harvested through viaducts, and distributed to rain garden beds. This contributes to the long term, sustainability of the development.
Also being a local highest point, views towards the sea would be nice

Examples of analysis driving design, (a) traffic simulation, (b) rail alignment.

This concept was developed further when the criteria against which scenarios were being tested included architectural logic, achieving particularly engaging integrated results. The idea of engineering practice as a process rather than a library of knowledge continues to be explored and can be applied at multiple points through the IDS so long as the conceptual strategy is clear and flexible.

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Additional Learnings from IDS-10 #3 – Evaluation matrices allow for simplified interdisciplinary design comparisons

Students across multiple disciplines do not always completely understand the technical aspects associated with other disciplines, with them finding it difficult to compare design solutions. The difficulty associated with this is that students understand design solutions relevant to their field and their associated positive and negative aspects. Through suggesting the use of an evaluation framework, students are able to break their design solutions down into relatable statistics (e.g. cost, feasibility, certification scheme ratings, etc.) so that an associated metric may be assigned. The associated metric gives students a manner in which to compare interdisciplinary design solutions. While further assessment is required following this process, it provides students with a tool to provide quantifiable justification for design decisions, with reasoning as to why other alternatives were discarded. Methods like this provide students with a method of communicating with other disciplines, which is not solely related to architecture and engineering.

#13
(IDS-06 #3)

Time pressures on delivery often negatively impact integration.

A limiting feature of the integrated design process was observed to be the time for documentation in the final four weeks. Due to the requirements of the studio as an architectural subject with conventional assessments, design iterations had to be finalised at the 75% milestone so that there was sufficient time for design teams to produce industry-level technical drawings and supporting presentations.

This is a critical skill for all designers to have, regardless of architecture or engineering backgrounds, as if you cannot communicate the design to a client, it will never be implemented. However, the architectural focus of this communication, constrained by the assessment requirements, limited the level of integration able to be achieved and, in some cases, disregarded the sustainability outcomes as superfluous.

#14
(IDS-06 #4)

An integrated design team is most effective in a comfortable space, encouraging innovation and experiment, built on strong social connections.

It is paramount that an integrated design team is a safe space where innovation and experimentation may occur in collaboration, built on strong social connections.

Without these foundations the convention of design team hierarchy results in a serial structure, where engineering follows architectural design, validating and documenting but not sculpting or motivating a scheme. For this reason, most engineers shy away from open-ended design problems and experimental ideation for fear of critique or negative feedback and want the security of clearly outlined problems.

This established hierarchy can make integration through inversion challenging, demanding a large shift in paradigm. One observed alternative to inversion is iteration, explicitly introduced by the studio leader in the project brief. Iteration initially appears to follow the serial relationship of convention, however, rather than validating a fully detailed design, iteration creates a feedback loop of analysis and experimentation. The engineering contribution to early-stage iteration has worked effectively using simple “rules of thumb” for example load flow, column spacing and construction impacts.

This is a known integrated design principle however this studio emphasised the importance of the social foundation aspect, something made possible by the face to face nature of delivery.

#15

(IDS-06 #5)

Materiality is a nexus of integration, drawing together architecture, structure/ construction, and sustainability.

This studio highlighted the importance of materiality as a nexus for design integration as it has direct and generally easily understandable impacts on all disciplines

An example of materiality as a nexus occurred when a team explored changing material from steel to timber as a way-finding tool and in compliance with fire safety and structural requirements for train stations, reducing the embodied carbon of the scheme where possible.

As the user moved from the beach-side park with canopied market stalls (CLT structure) to the urban context of the train station building (steel structure) materiality influenced the architectural language as well as the construction and sustainability of the infrastructure. In contrast, a team that only considered materiality through an architectural lens had poor sustainability outcomes, using a large volume of concrete with aluminium cladding.

This demonstrated how material selection is an opportunity but also, if sustainability concerns are overlooked, a high-impact decision in terms of outcomes.

#16

(IDS-07 #1)

Face-Face interaction is an important factor in facilitating integrated design.

A notable increase in the engagement and interaction between student designers (particularly engineers), was observed in IDS-07. This is thought to be attributable primarily to the face-face mode of delivery. ‘In studio’ interactions were far stronger due to communication mode and sense of commitment in a physical environment. The number and nature of conversations increased (i.e. formal and informal).

Anecdotal evidence from consultants on projects requiring remote delivery (i.e. international design teams or teams removed from project location) supported this. The practice of ensuring initial face to face interactions with a degree of social interaction between project members prior to them continuing to work together remotely on a project was noted as a method of strengthening communication and collaboration.

A secondary influencing factor was the changed nature of recruitment in IDS-07 for the engineers. Greater detail was provided on the purpose of the studios. This it was felt resulted in a degree of self-selection as students with particular interests in sustainability and integrated design were attracted.

Quote from RA observations: “Face-to-face contact of students allowed for social bonding and the establishment of a proper ‘group mentality’ among architecture and engineering students”.

#17

(IDS-07 #2)

Easily accessible software tools for interrogating technical performance is important to early design/integration process.

IDS-07 demonstrated the importance of designers having access to decision making tools in the form of software that enabled them to assess outcome. This both provided a common language that designers could use to interact and enabled quantifiable prioritisation of various solutions (options).

RA direct observation: “Students were found to be most likely to engage with and understand the impact of environmentally focused design decisions through the process of iteration. With the introduction of the Ladybug Tools platform to the students, tangible environmental impacts were able to be discovered within the student’s design tool of choice. Significant uplift in comparison with previous semesters regarding the student’s excitement and engagement were found as they developed their skills within this parametric software, which is easily translated into other aspects of their design skills. Further development of the base tools and strategies involved with the introduction of these tools are recommended for further studios, as it’s relevance to the students’ growth is recognised both within the studio and beyond. …These activities allowed designers to better understand the relationship between good design and performance and inform their understanding of how buildings work together”.

Atelier 10 (sustainability consultant) direct observation: “hands-on experience of testing the performance of their designs gave students a heightened awareness of the full impact of their design decisions”

#18

(IDS-08 #1, IDS-10 #2)

Reminders of how the common goals established at the start of the process translate to outcomes throughout the design was beneficial.

Reminding participants of how the common goals established at the start of the design translate to outcomes at progressive design moments was found to be beneficial in this IDS through the hands-on guidance of the studio tutor and industry consultants to maintain designers' focus.

Although this was felt to be particularly beneficial in the IDS environment where relatively inexperienced student designers navigated an unfamiliar design process, it was felt it would still be beneficial in industry as integrated design requires designers thinking and contribute to disciplines not in their traditional core areas of experience/expertise.

Additional Learnings from IDS-010 #2 – Importance and nature of feedback generally.
Feedback in any regard was found to be beneficial to student designers at most stages of the design. Feedback reassures confidence in designers and confidence in design direction. It was found greater discussions were facilitated in groups of 8 designers, 2 consultants and one academic. Larger group feedback sessions facilitated awareness of others disciplines and processes and methods.

#19

(IDS-08 #2)

Multi-discipline design critiquing found to be important in facilitating integrated collaborative outcomes

The process of bringing multiple perspectives into focus, via collaboration and critiquing, as designs develop was felt to be important. The process of design critiquing was discussed and observed to be more common in architectural design environments that in engineering.

It was felt that an environment that encouraged a constructive critique process involving all disciplines through the design was beneficial to the integrated design process as it assisted with communication and upskilling of disciplines in each other's areas of expertise.

#20

(IDS-11 #1)

Existing structural form restricts integrated design opportunities

Architects and engineers are willing and very much capable of working collaboratively to produce integrated design solutions for clients who are cognisant of the benefits of efficient building design. This fact holds for both new and retrofitted structures. While both engineers and architects can work collaboratively to achieve this goal, the scope of possible opportunities is narrowed in existing structures due to the restrictions imposed by the prevailing structural form and can be further compounded by the client brief. This is especially true if the client is resistant to any structural alterations.

Having a predetermined structure limits to potential opportunities primarily for architects, who focus predominantly on form and function. While there is opportunity for examination of architectural improvement, this is governed by an underlying structural restraint. These same restrictions are relevant to engineers, who are unable to make significant changes to the pre-existing structural form, limiting potential strategic possibilities. These limitations placed on both specialisations, while not preventing integrated design completely, to impose restrictions that can be challenging to overcome, especially where overlapping opportunities are being sought where architects and engineers can work collaboratively.

#21 (IDS-14 #1)	Co-design is a terminology that needs clarification

The term ‘co-design’ appears to be understood differently by different professions. Architectural students appeared to interpret it as ‘others’ contributing to ‘their’ design, i.e. the architect being in charge of the design, and inviting input from other parties. The architect can then choose to incorporate this input or not.
Non-architecture participants (students and consultants) also appeared to reinforce this idea, by seeing themselves as technical advisors or contributors to specific aspects requested by architects.

These views / roles may be reflective of common practice.

In future IDS activities we would include, at the initial stage, ‘co-design’ as a terminology that needs to be discussed by participants. Participants in an IDS project would need to collectively determine how co-design will be interpreted and implemented for that particular project.
Some questions that need to be resolved within an IDS team include:

- Are all participants considered equal contributors to the design, albeit with different inputs? Or is there a hierarchy of designers?
- Who, within the multidisciplinary team, should be the ‘manager’ of the design process?
- How will decisions about inclusion/exclusion of design ideas into the overall design be made?

This learning supports the theory from literature that the design team must be made aware that they are designing in ways that are not business as usual. It is imperative that the tendency to do things the way they have been done before is combatted and terminology and language is a key part of this.

#22 (IDS-14 #2)	Procurement methods can inhibit or support integrated design

All building projects are subject to a procurement contract of some sort (e.g. fixed price contracts such as lump sum or Design and Construct; or collaborative contracting such as early contractor involvement or managing contractor). Integrated Project Delivery (IDP) contracts appear to be best aligned with the integrated design objectives and process, particularly an Alliance Contract.

For IDS projects within a university setting, we would advise that the participant team establish an IDP Alliance Contract – both as a means of agreeing to roles, responsibilities, values and shared risks; and as a means of emulating what could be industry ‘best practice’.
For industry application: it would be helpful for professional bodies (e.g. Australian Institute of Architects; Engineers Australia and Australian Institute of Builders) to examine some emerging Alliance Contract forms (from the UK) and collectively develop Australian appropriate contract templates that can be used to enable integrated design to occur from a commercial and legal perspective.

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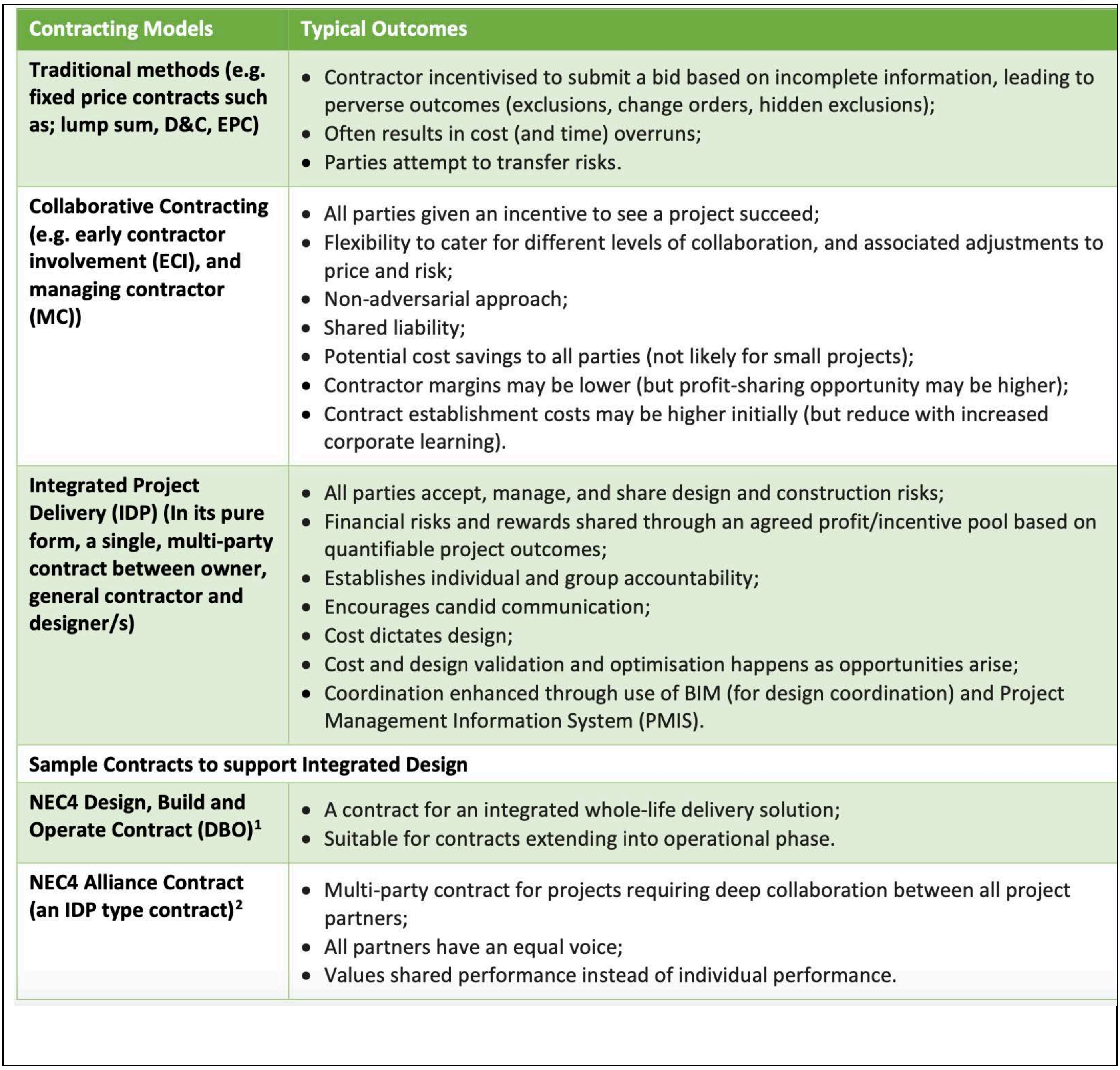


Contracting Models	Typical Outcomes
Traditional methods (e.g. fixed price contracts such as; lump sum, D&C, EPC)	• Contractor incentivised to submit a bid based on incomplete information, leading to perverse outcomes (exclusions, change orders, hidden exclusions); • Often results in cost (and time) overruns; • Parties attempt to transfer risks.
Collaborative Contracting (e.g. early contractor involvement (ECI), and managing contractor (MC))	• All parties given an incentive to see a project succeed; • Flexibility to cater for different levels of collaboration, and associated adjustments to price and risk; • Non-adversarial approach; • Shared liability; • Potential cost savings to all parties (not likely for small projects); • Contractor margins may be lower (but profit-sharing opportunity may be higher); • Contract establishment costs may be higher initially (but reduce with increased corporate learning).
Integrated Project Delivery (IDP) (In its pure form, a single, multi-party contract between owner, general contractor and designer/s)	• All parties accept, manage, and share design and construction risks; • Financial risks and rewards shared through an agreed profit/incentive pool based on quantifiable project outcomes; • Establishes individual and group accountability; • Encourages candid communication; • Cost dictates design; • Cost and design validation and optimisation happens as opportunities arise; • Coordination enhanced through use of BIM (for design coordination) and Project Management Information System (PMIS).
Sample Contracts to support Integrated Design	
NEC4 Design, Build and Operate Contract (DBO)[1]	• A contract for an integrated whole-life delivery solution; • Suitable for contracts extending into operational phase.
NEC4 Alliance Contract (an IDP type contract)[2]	• Multi-party contract for projects requiring deep collaboration between all project partners; • All partners have an equal voice; • Values shared performance instead of individual performance.

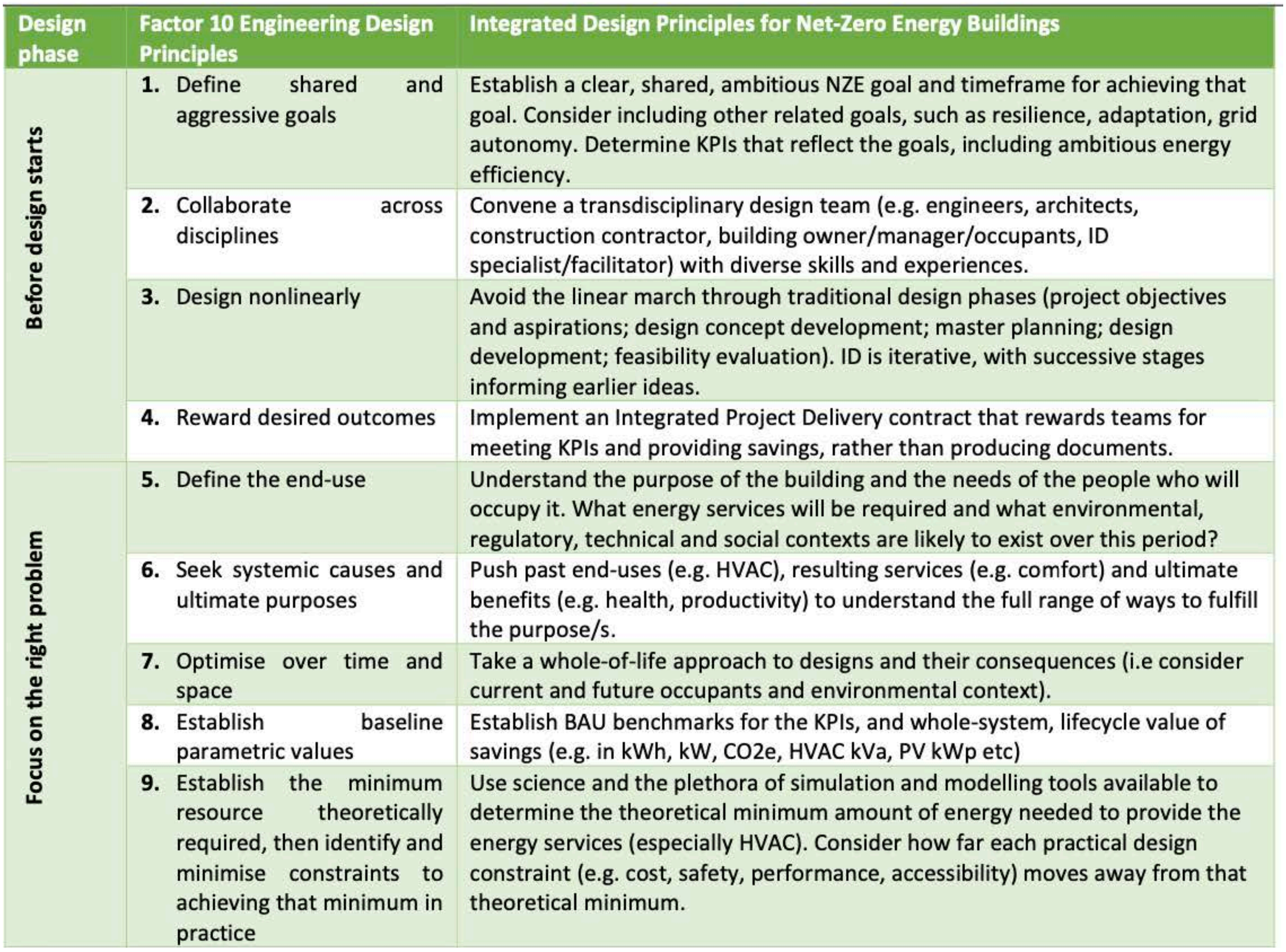
#23
(IDS-14 #5)

Adopting integrated design principles from literature important.

The basis of the IDSs was to test theoretical best practice knowledge on integrated design principles from literature. IDS-14 examined some of these principles (the Factor Ten Engineering Design Principles) in studio IDS-14.

Mixed-use building typologies is complex; designing for net zero energy or net zero carbon goals is complex; and the integrated design process can be considered complex. A set of guiding principles was found to be helpful in fleshing out the process while keeping focus on the core goal/s. A good starting point is the Factor Ten Engineering Design Principles, developed by the Rocky Mountain Institute over a decade ago. Factor Ten Engineering demonstrated that very large energy resources savings (a factor of 10) could be profitable through transforming design and engineering practice via whole-system thinking and integrative design. These principles were used as a basis for proposing design principles for net zero carbon buildings.

Future integrated design studios / projects could start with an examination of the proposed principles, and modification to suit the specific context. This could help to focus the attention of the collaborative design team on the core objective, and to assist in the ID process.



Design phase	Factor 10 Engineering Design Principles	Integrated Design Principles for Net-Zero Energy Buildings
Before design starts	**1.** Define shared and aggressive goals	Establish a clear, shared, ambitious NZE goal and timeframe for achieving that goal. Consider including other related goals, such as resilience, adaptation, grid autonomy. Determine KPIs that reflect the goals, including ambitious energy efficiency.
	2. Collaborate across disciplines	Convene a transdisciplinary design team (e.g. engineers, architects, construction contractor, building owner/manager/occupants, ID specialist/facilitator) with diverse skills and experiences.
	3. Design nonlinearly	Avoid the linear march through traditional design phases (project objectives and aspirations; design concept development; master planning; design development; feasibility evaluation). ID is iterative, with successive stages informing earlier ideas.
	4. Reward desired outcomes	Implement an Integrated Project Delivery contract that rewards teams for meeting KPIs and providing savings, rather than producing documents.
Focus on the right problem	**5.** Define the end-use	Understand the purpose of the building and the needs of the people who will occupy it. What energy services will be required and what environmental, regulatory, technical and social contexts are likely to exist over this period?
	6. Seek systemic causes and ultimate purposes	Push past end-uses (e.g. HVAC), resulting services (e.g. comfort) and ultimate benefits (e.g. health, productivity) to understand the full range of ways to fulfill the purpose/s.
	7. Optimise over time and space	Take a whole-of-life approach to designs and their consequences (i.e consider current and future occupants and environmental context).
	8. Establish baseline parametric values	Establish BAU benchmarks for the KPIs, and whole-system, lifecycle value of savings (e.g. in kWh, kW, CO2e, HVAC kVa, PV kWp etc)
	9. Establish the minimum resource theoretically required, then identify and minimise constraints to achieving that minimum in practice	Use science and the plethora of simulation and modelling tools available to determine the theoretical minimum amount of energy needed to provide the energy services (especially HVAC). Consider how far each practical design constraint (e.g. cost, safety, performance, accessibility) moves away from that theoretical minimum.

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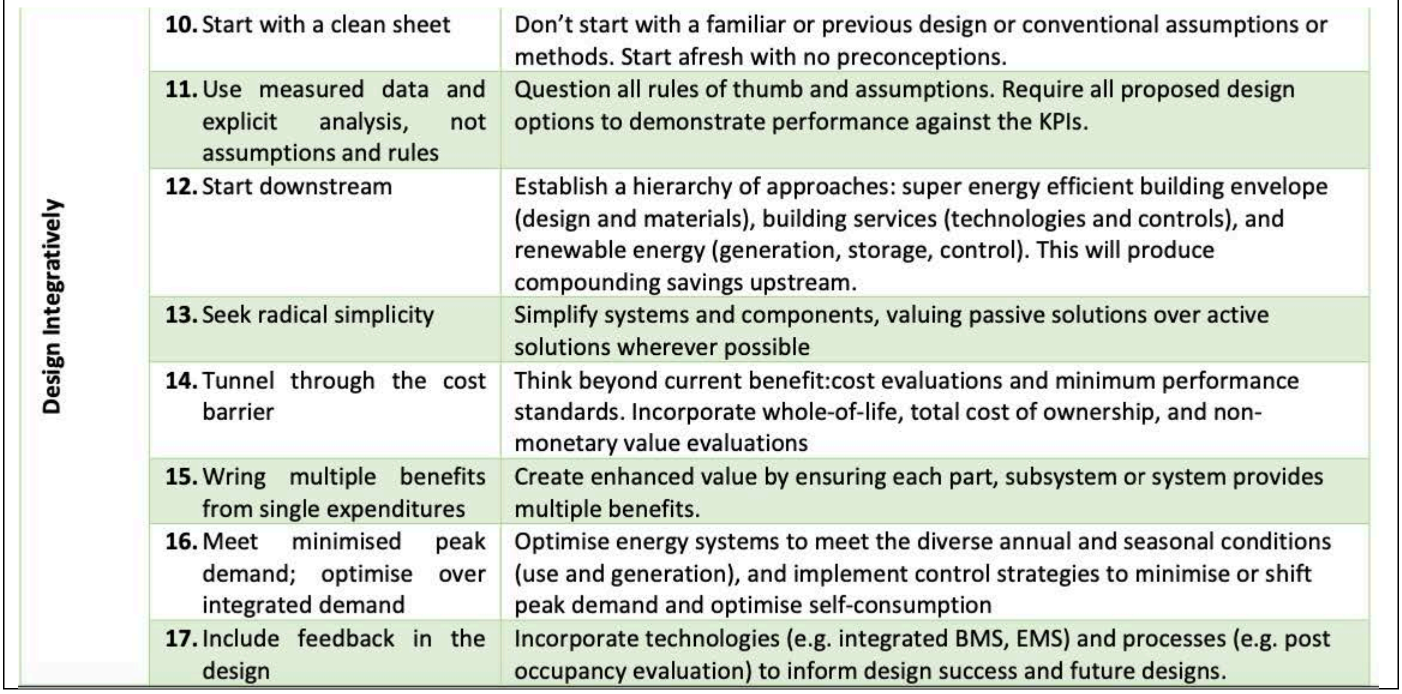

Design Integratively	**10.** Start with a clean sheet	Don't start with a familiar or previous design or conventional assumptions or methods. Start afresh with no preconceptions.
	11. Use measured data and explicit analysis, not assumptions and rules	Question all rules of thumb and assumptions. Require all proposed design options to demonstrate performance against the KPIs.
	12. Start downstream	Establish a hierarchy of approaches: super energy efficient building envelope (design and materials), building services (technologies and controls), and renewable energy (generation, storage, control). This will produce compounding savings upstream.
	13. Seek radical simplicity	Simplify systems and components, valuing passive solutions over active solutions wherever possible
	14. Tunnel through the cost barrier	Think beyond current benefit:cost evaluations and minimum performance standards. Incorporate whole-of-life, total cost of ownership, and non-monetary value evaluations
	15. Wring multiple benefits from single expenditures	Create enhanced value by ensuring each part, subsystem or system provides multiple benefits.
	16. Meet minimised peak demand; optimise over integrated demand	Optimise energy systems to meet the diverse annual and seasonal conditions (use and generation), and implement control strategies to minimise or shift peak demand and optimise self-consumption
	17. Include feedback in the design	Incorporate technologies (e.g. integrated BMS, EMS) and processes (e.g. post occupancy evaluation) to inform design success and future designs.

#24+ (IDS-09, 12)	Additional learnings from IDS-09, 10.

Additional learnings from IDS-09 & 12 will be added in the week ensuing milestone 7 (27th May 2022) for logistics reasons.

Technical Lessons on Net Zero Design taken from the IDS activity stream.

The lessons below on net zero design have been taken from the individual design studios undertaken across the IDS activity stream.

These lessons have been mapped and compared across both individual building typologies, and also three building typology groupings (simple, complex and specialist buildings) in the Carbon Catalogue section encapsulated in the summary reporting for IDS-KS.

The information provided below is in summary form, reference should be made to the 100% studio reports for each studio for more detail.

Net Zero Lessons learnt IDS-01	**Data Centres:** Net Zero Technical Learnings Summary

As a part of the studio fifteen individual design proposals were developed by architecture students, who advanced their ideas for analysis of 'Net Zero' design approaches for data centres offering an array of solutions, tackling environmental design in different ways. Recognising the speculative and highly experimental nature of the design explorations the design process was coupled with a 6-8-week feasibility vetting process that took place after the studio's completion (carried out by the consultants involved). Bespoke technology solutions were examined in greater detail and compared to 'Business As Usual' approaches. The findings of this vetting process were incorporated into a report, the summary findings are presented below:

- The fifteen design solutions by students highlight the breadth of opportunities in the design of Data Centres, in particular when stepping away from a purely functional, and construction-cost optimised design. Selected key ideas that emerged were:
- Incorporation of renewable energy.
- Capture and recycling of waste heat through adjacent symbiotic uses (Aquatic centres and greenhouses for example).
- Incorporation of modular construction.
- Incorporation of self-building/updating mechanisms (gantry cranes etc that when combined with modular philosophies facilitate expansion or updating of technologies).

Due to the extensive (80+ MW) site power usage of a large Data Centre, 'Net Zero' targets are impossible to achieve via technology interventions and building envelope improvements. The main opportunities for improvement sat with the introduction of adjacent symbiotic programs.As much as the renewable energy sources and the adjacent programs represented only a minor percentage of the overall energy involved in running data centres (less than 1.0-2.5%), they were significant in terms of the adjacent uses considered. Significantly reducing the operating energy bills of an aquatic centre or community greenhouse would be seen to solve what is often a major burden for local councils and therefore presents opportunities for the Data Centre industry to better engage with councils and local community. Importantly by adopting such an approach, data centre providers may find themselves able to better position themselves as preferred partners with councils in competing for sites, while at the same time providing real, tangible community benefits.

More detail is provided in the studio 100% reports which are intended to be made public through the knowledge sharing sub-project IDS-KS.

Further discussions with consultants in other studios, IDS-05 Aquatic Centres in particular highlighted the possibility for provision of cooling to the data centre through excess chilled water that is often available from aquatic centre facilities. This would be worthy of further exploration if a future data centres studio or a combined data centre/aquatic centre studio were to be undertaken.

Implications for future data centre projects are an increased focus on adjacent symbiotic relationships and potential partnering or consortium development models with third parties including councils.

Net Zero Lessons Learnt IDS-02	**Schools I:** Net Zero Technical Learnings Summary

As a part of the studio eleven individual design proposals were developed by architecture students, who advanced their ideas for two different ACT School refurbishment sites, over the course of a semester. These proposals reflect in-depth analysis of 'Net Zero' design approaches for School Refurbishments, and offered an array of solutions, tackling environmental design in different ways. Recognising the speculative and highly experimental nature of the design explorations the design process was coupled with a 6-8-week feasibility vetting process that took place after the studio's completion. Here, the collaborating consultants examined the students' proposals to scrutinise certain 'Net Zero' related technologies analysing bespoke solutions in greater detail and comparing with 'Business As Usual' approaches in School design. The findings of the vetting process have been incorporated into this report, and the full consultant vetting report has been appended.

Summary learnings School Design and Refurbishment Exploration

The eleven design solutions by students highlight the breadth of opportunities in the design and refurbishment of School projects in the ACT climate. Students embraced different aspects of environmental design both indoor, as well as outdoor, and they addressed these on refurbishment elements, as well as newly built components of their design. Selected key ideas that emerged were:

- Passive design measures as a key priority
    - Optimising the building envelope
    - Fixed and dynamic shading
    - Operable façade elements
    - Wintergardens and Green Roofs
- Active design measures as a key priority
    - Introduction of Rooftop Solar Panels
    - LED light fittings
    - Mechanical ventilation with heat recovery
    - Introduction of Heat Pumps (air source/ground coupled)
    - Shift from natural gas consumption to all-electric services strategies.

Consultant vetting of student projects, showed major opportunities for achieving Net Zero Carbon targets. Moving from a standard practice existing building to incorporating best practice initiatives results in Energy Use Intensities less than 40kWh/m^2.yr, with reductions in energy demand ~58% and energy consumption >52%. Further reductions expected to be realised through more effective control strategies such as daylight linking. Electricity generation from **onsite roof-top solar panels** would be predicted to exceed more than four times this amount. This indicates that there is a significant opportunity for the school to not only be net zero carbon in operation, but to be net positive energy in operation, with annual electricity generation exceeding annual consumption.

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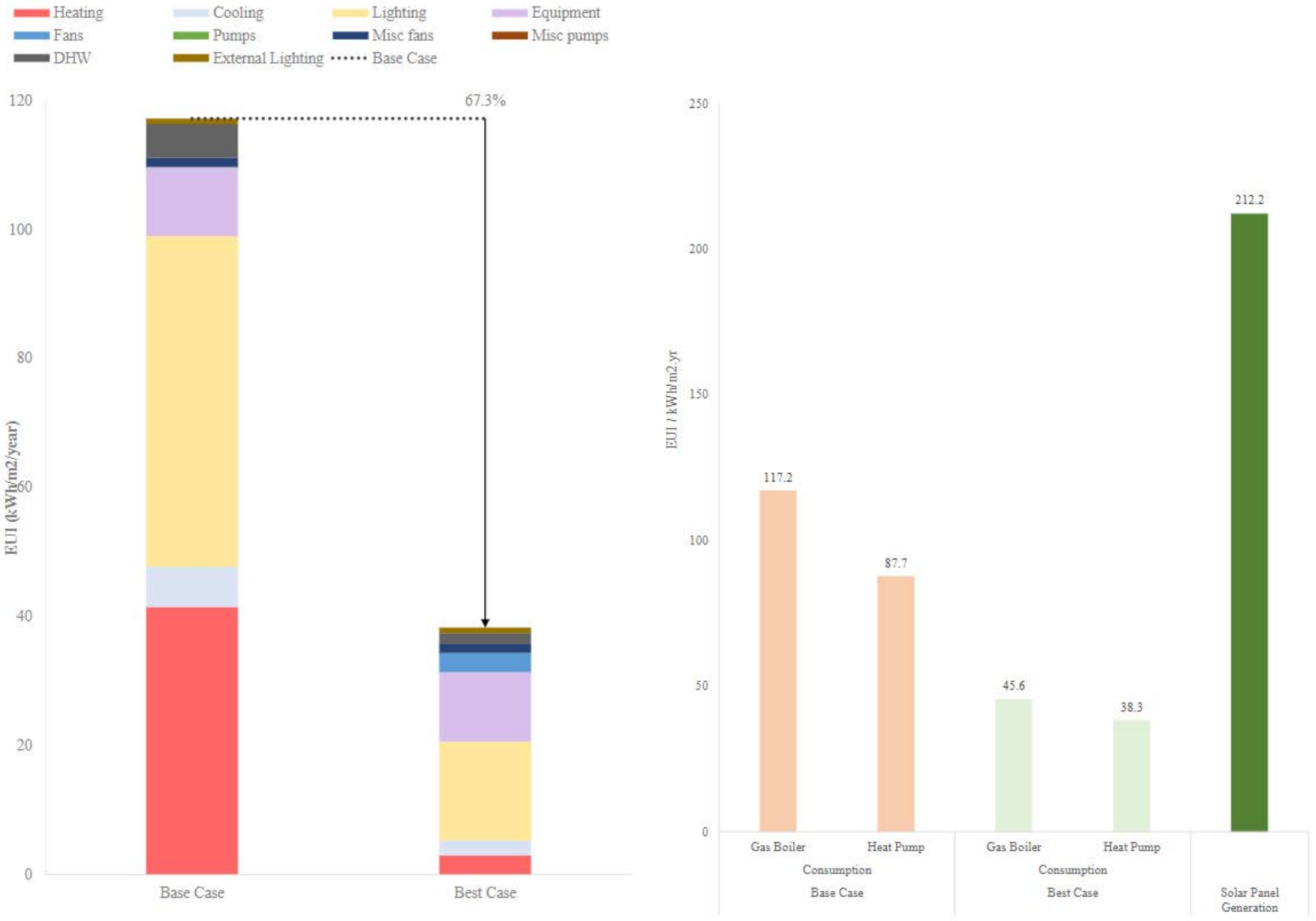


Figure 15 from Studio ‘100%’ report: Energy Usage Intensities (Arup)

Net Zero Lessons learnt IDS-03	**Schools II:** Net Zero Technical Learnings Summary

Similar to IDS-02 zero carbon design was found to be possible for schools. 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. Full offset of the reduced energy requirements can be offset through solar PV's depending on the roof area available.

The following strategies were 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 that could considered are:

- Improvements 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.
- Improved occupant amenity and thermal comfort (whilst not researched this was a premise of the holistic solutions developed in the studio).
- 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.

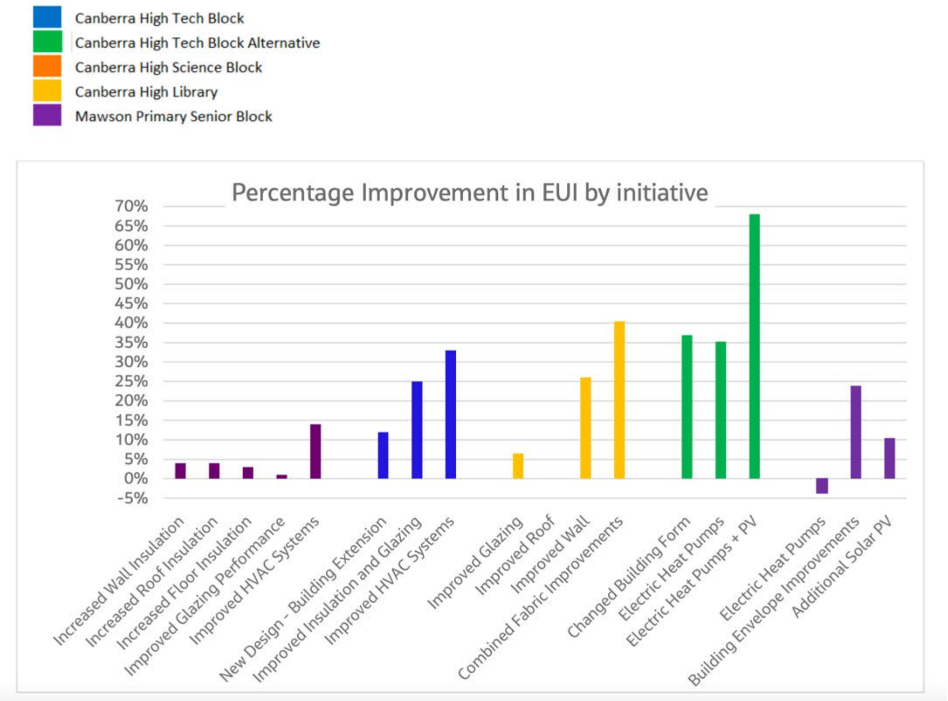


Figure extracted from the consultant vetting report (Jacobs).

Net Zero Lessons learnt IDS-04	**Emergency Response Facilities:** Net Zero Technical Learnings Summary

Reference should be made to the 100% Studio Outcomes Reports which summarise the Feasibility Vetting carried out by consultants (and include a copy of the vetting reports in the appendices) for detail of building typology specific technical learnings.

Zero carbon design was found to be possible for emergency response facilities along similar lines to the schools building typology. This was achieved through a combination of energy consumption (EUI) reduction (envelope, orientation, use of heat pumps etc.), and provision of locally generated renewable energy (typically solar PVs).

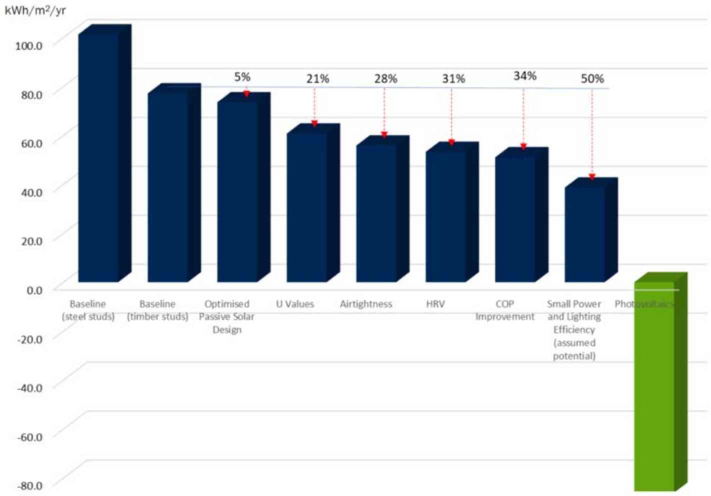
Differences with the schools typology centred around different building and programme planning. Emergency response facilities have a higher diversity of use requirements including garages, sleeping facilities, and respite areas. The specific technical requirements of each of these uses (acoustics, light, proximity to response etc.) were all considered in the architectural planning.

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

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

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

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



Extract (Figure 24) from vetting report (Atelier 10) – Benchmarking Student Proposals.

Net Zero Lessons learnt IDS-05	**Aquatic Centres:** Net Zero Technical Learnings Summary.

Aquatic centres are complex buildings with entrenched expectations from users such as large areas of glass facades or roof that don't align with energy efficiency. Achieving Integrated design from a standing start was found to be challenging for students.

Key energy initiatives explored included thermal zoning, passive heating envelop efficiency and various on-site renewables generation. Landscaped roofs were a popular initiative adopted yielding dual benefits of improved energy performance as well as providing additional public use space integrated within the building program.

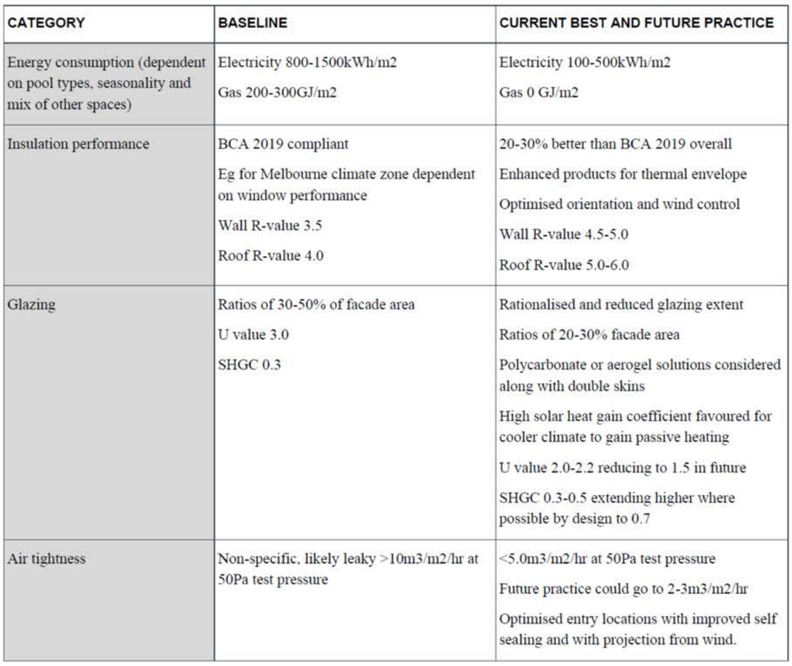
Timber structure solutions as used more commonly overseas in aquatic centres were another popular choice bringing significant embodied carbon benefits.

The consultants (WSP) prepared a useful table of 'opportunities for net zero energy' which presented 'current best' and 'future' practices which will be a useful resource for designers.

Key future focus areas identified by the IDS to progress towards zero carbon were:

- Building Thermal Fabric
- Electrification of building services
- Smarter and more precise control strategies
- Design to performance metrics (benchmarking)

Extract from consultant vetting report (WSP): Baseline vs Industry Best Practice Study.



CATEGORY	BASELINE	CURRENT BEST AND FUTURE PRACTICE
Energy consumption (dependent on pool types, seasonality and mix of other spaces)	Electricity 800-1500kWh/m2 Gas 200-300GJ/m2	Electricity 100-500kWh/m2 Gas 0 GJ/m2
Insulation performance	BCA 2019 compliant Eg for Melbourne climate zone dependent on window performance Wall R-value 3.5 Roof R-value 4.0	20-30% better than BCA 2019 overall Enhanced products for thermal envelope Optimised orientation and wind control Wall R-value 4.5-5.0 Roof R-value 5.0-6.0
Glazing	Ratios of 30-50% of facade area U value 3.0 SHGC 0.3	Rationalised and reduced glazing extent Ratios of 20-30% facade area Polycarbonate or aerogel solutions considered along with double skins High solar heat gain coefficient favoured for cooler climate to gain passive heating U value 2.0-2.2 reducing to 1.5 in future SHGC 0.3-0.5 extending higher where possible by design to 0.7
Air tightness	Non-specific, likely leaky >10m3/m2/hr at 50Pa test pressure	<5.0m3/m2/hr at 50Pa test pressure Future practice could go to 2-3m3/m2/hr Optimised entry locations with improved self sealing and with projection from wind.

The following key criteria were considered by WSP and their colleagues to compare baseline date to future best practice:

- Energy Consumption
- Insulation Performance
- Glazing
- Air Tightness
- Materia and Monitoring
- Control
- Heating Source
- Solar PV
- Mechanical Fresh Air supply
- Thermal Storage
- Landscaping
- Water Capture
- Water Filtration, and
- Structure/ Materials

Possible adjacent usage benefits were identified in IDS-01 which examined data centres and the large amounts of excess heat/energy that could be harvested. Opportunities for future research or in project development exist with colocation with data centres.

Net Zero Lessons learnt IDS-06	**Transport Buildings (Stations):** Net Zero Technical Learnings Summary.

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

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

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

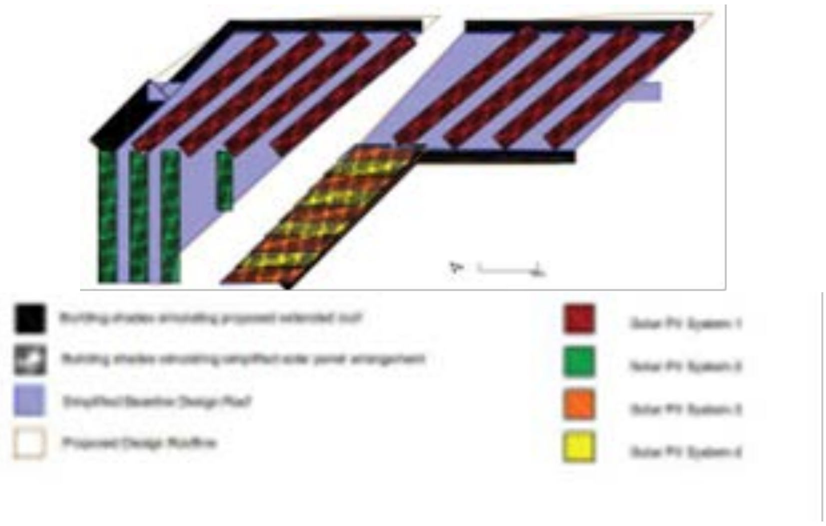


Figure: Simplified roof layout for eQuest simulation

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

Passive Measures

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

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

Active Measures

Next to addressing passive measures, a number of active measures were proposed by the two groups selected from this studio. Large roof areas of the stations with up to 2500m2 of surface area did provide opportunity for students to investigate the use of photovoltaics, next to other active measures such as ground source heat pumps, wind farming, and Piezo-electricity generation.

Key initiatives can be summarised as follows:

- Photovoltaics (rooftop)

- Ground source heat pump
- Wind harvesting
- Piezo-electricity generation
- Battery Systems

The feasibility vetting of designs produced for two case study stations (Chelsea and Edithvale), found that the schemes developed by students resulted in credible solutions using market-ready technologies for the design stations.

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

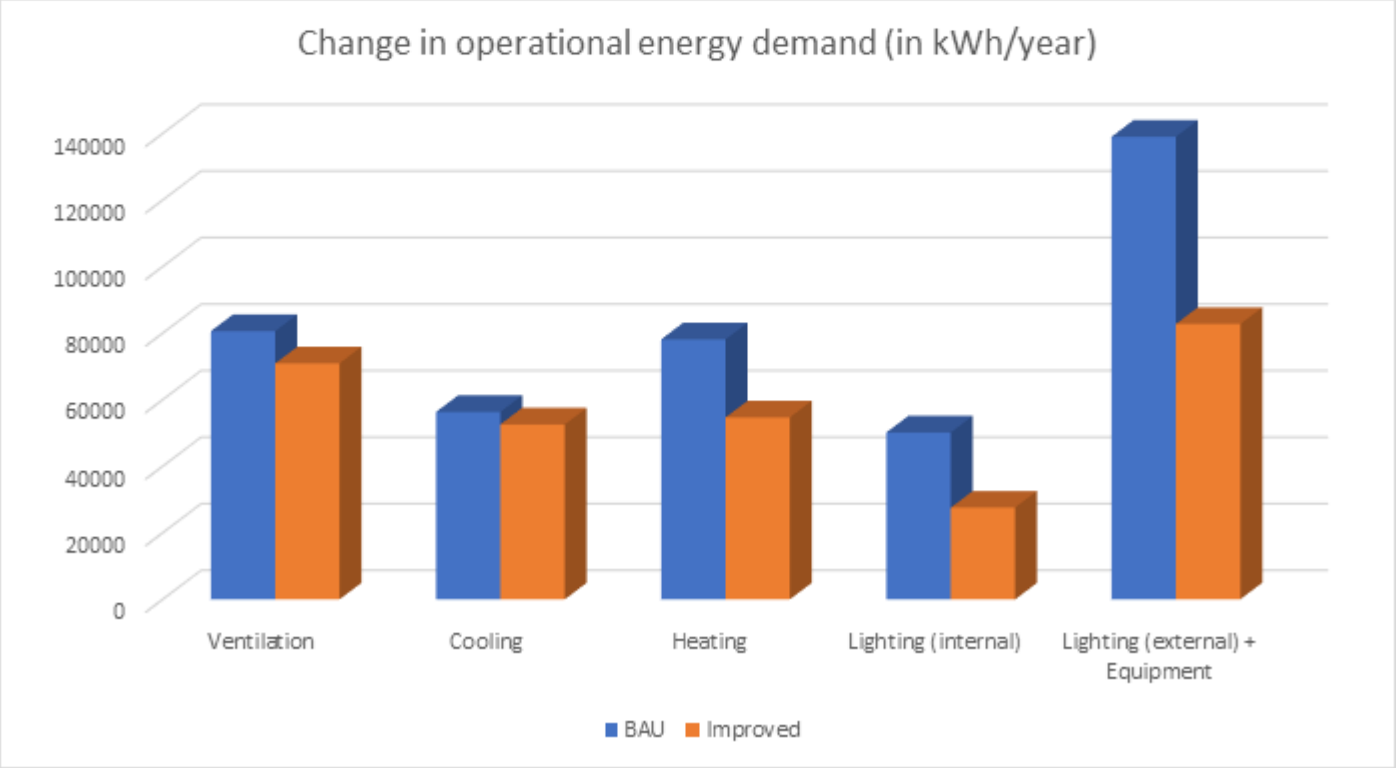
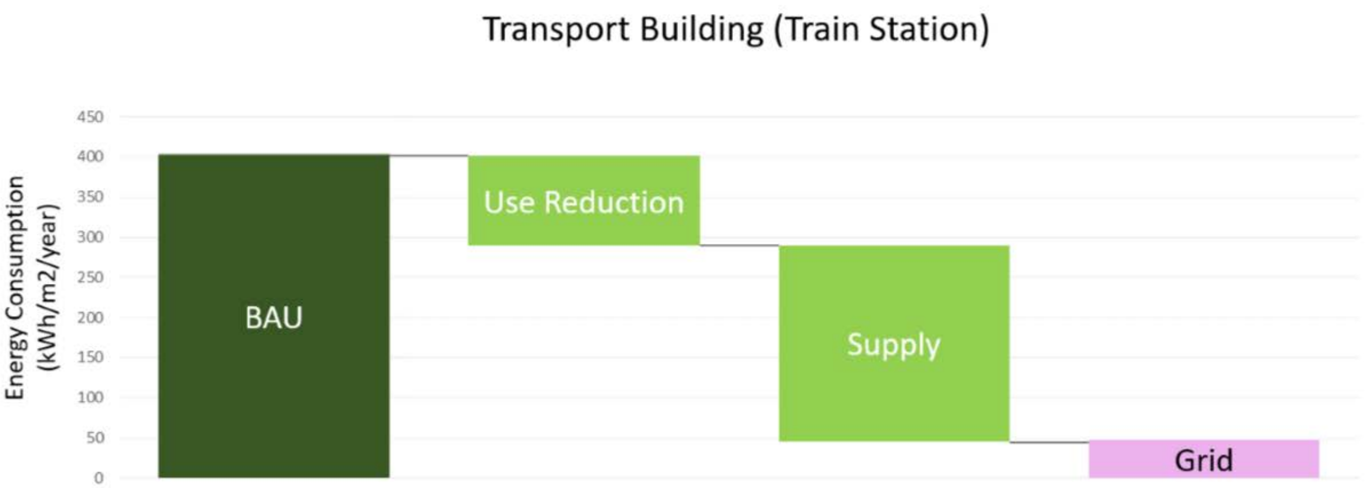


Figure 19: Project Vetting – Operational Energy Demand Reduction Strategies

In addition to the above reduction in operational energy demand, other opportunities were investigated to provide additional onsite generation. Several options were investigated, such as wind farms, Piezo-electricity generation, and photovoltaic (PV) cells. Existing efforts around the world[1,2] highlight in particular the benefits of solar rooftop (or other) PV cells. For the student project vetting, the large roof areas of the stations with up to 2500m2 of surface area did provide a major opportunity to investigate the use of photovoltaics in conjunction with battery usage. Analysis of the roof shape and orientation resulted in the proposition of four different solar array subsystems with panels tilted at 30 degrees of each orientation. Approximately 1200m2 of rooftop area could be covered by the PV cells, whilst still allowing natural daylight to penetrate the building via south-facing glazing in the roof. Combined, these subsystems have a capacity to provide 243,800 kWh/a of energy supply, thereby offering approximately 60% of energy supply when compared to BAU.



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

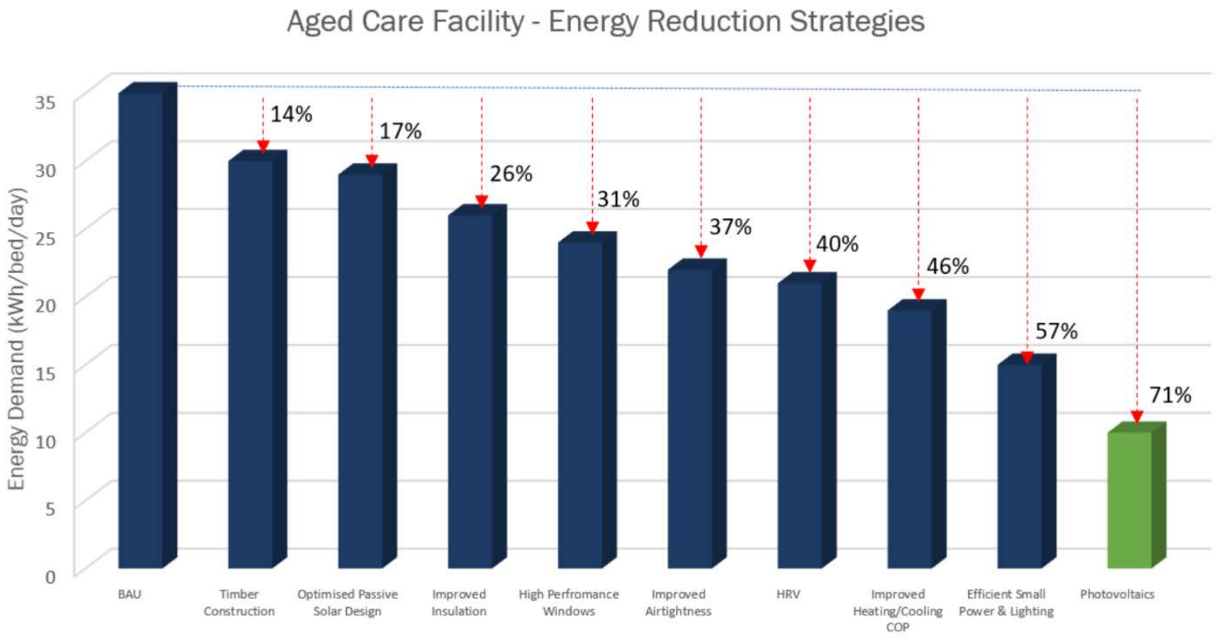
The project highlighted materials as an essential consideration in reducing carbon. Emerging concerns around the mercury (Hg) levels in fly ash used to replace cement present a potential threat to its continued use. The whole sustainability industry would benefit from further research in this area. As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

Net Zero Lessons learnt IDS-07	**Aged Care I**: Net Zero Technical Learnings Summary.

Work in the studio was able to show that energy savings of up to 60-70% could be achieved. This is especially significant considering the energy intensive typology which is inherent to aged-care homes. To cover the remaining energy which was to be drawn from the grid in the months which solar power could not meet the entirety of the demand, offsets and selecting green energy sources was identified as a pathway towards carbon neutrality in operations.

Key systems which were common across the studio which held the greatest benefits include:

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



In addition to the clearly demonstrated carbon reduction benefits, significant improvement to the health and well-being of occupants is associated with some of the strategies put forth. Health and well-being are of the highest priority when considering the use-case of the development, ensuring that the elderly occupants have access the best indoor environment quality possible. Implementations such as considered daylight access, thermal comfort control, airtightness and well-designed ventilation systems can be leveraged to improve the quality of life within the facility.

Detailed solutions deemed appropriate and achievable included:

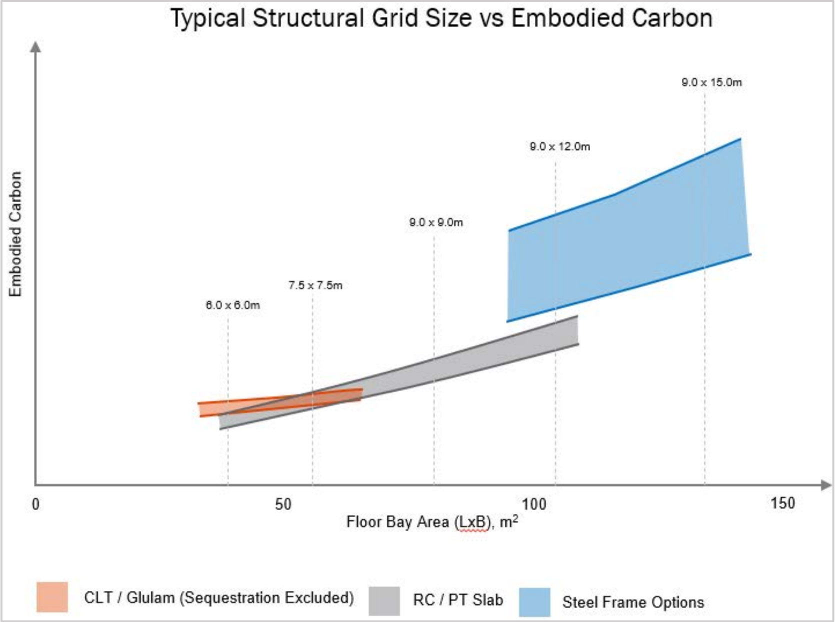
- Cross Laminated Timber (CLT), and Glulam structural materials
- 30% fly ash concrete slabs
- Prefabrication of units
- Appropriate floor depths for passive natural ventilation (<20m)
- Double / Triple Glazing

- Photovoltaics and battery systems
- Ground source heat pumps
- Recycled water-cooling towers
- Hydronic underfloor heating
- Onsite food growth
- Organic material recycling

Solutions which were found to be less appropriate in terms performance and cost include:

- Greenhouse style building for heat control
- Biodigesters

A study on structural material and grid size was carried out. at grid sizes larger than 6x6m, the benefit of CLT, without considering carbon sequestration, quickly falls in line with concrete structure. As such, whilst the student uptake of low-carbon construction methods was to be commended, further consideration of the results impacts in each of their proposals could be recommended for further studies.



Note: Images / technical findings extracted from consultant vetting report

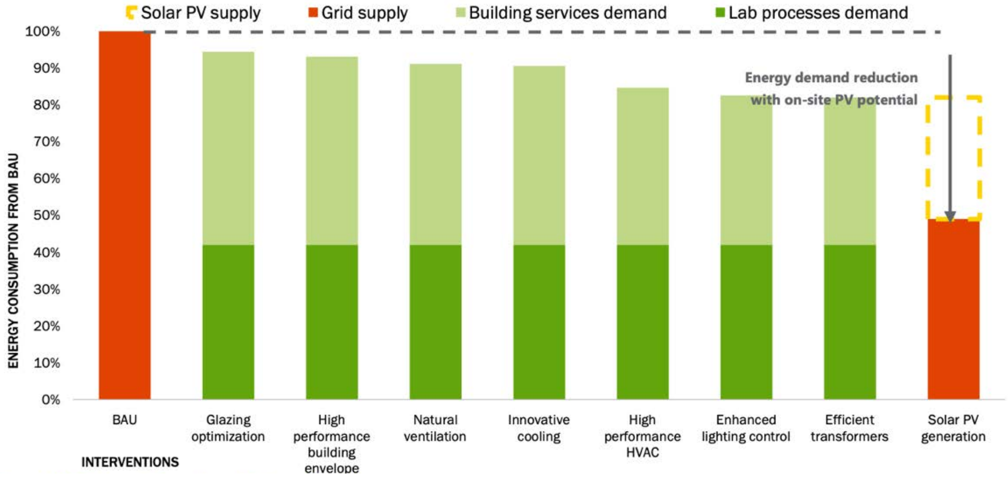
As well as improvements in energy, integrated design initiatives will likely improve IEQ bringing related health benefits to staff.

Net Zero Lessons learnt IDS-08	**Laboratories:** Net Zero Technical Learnings Summary.

Significant potential energy reductions over BAU were identified (approx 50% of grid energy requirements) however 'net zero' laboratories were found to be a feasible prospect only through the use of additional sustainable power purchase agreements or similar.

Operational Energy/Carbon

The studio demonstrated the potential for overall operational energy savings of up to 18% when compared with business as usual. This figure relates to the benchmarked energy use of a PC2 laboratory including laboratory process use. The laboratory process use (approximately 40% of the overall energy use) was not included in the energy savings explorations.



Reduced Operational Carbon Breakdown (extract fromn Atelier Ten Feasibility Vetting Report).

Commensurate with a laboratory of this size was a potential for on-site generation through solar PV equating to a further 33% reduction resulting in an overall potential reduction of 50%.

Further reductions in operational carbon would need to be countered through sustainable power purchase agreements or similar.

Savings identified were achieved through a mix of the following measures:

- Glazing optimization
- High performing building envelope
- Natural ventilation (non-laboratory areas)
- Innovative cooling solutions (including ground source heat pump air conditioning, earth insulation and evaporative cooling)
- Solar panels
- Mass timber structural system for office zones
- Low carbon concrete structural system and foundation

Embodied Energy/Carb

Extending the scope of 'net-zero' further, the students' schemes were interrogated against BAU structural systems, demonstrating their schemes achieve approximately a 35% reduction in upfront embodied carbon. With further detailed consideration of structural systems, construction methods and carbon offsets, the potential to achieve net zero life cycle carbon could be determined.

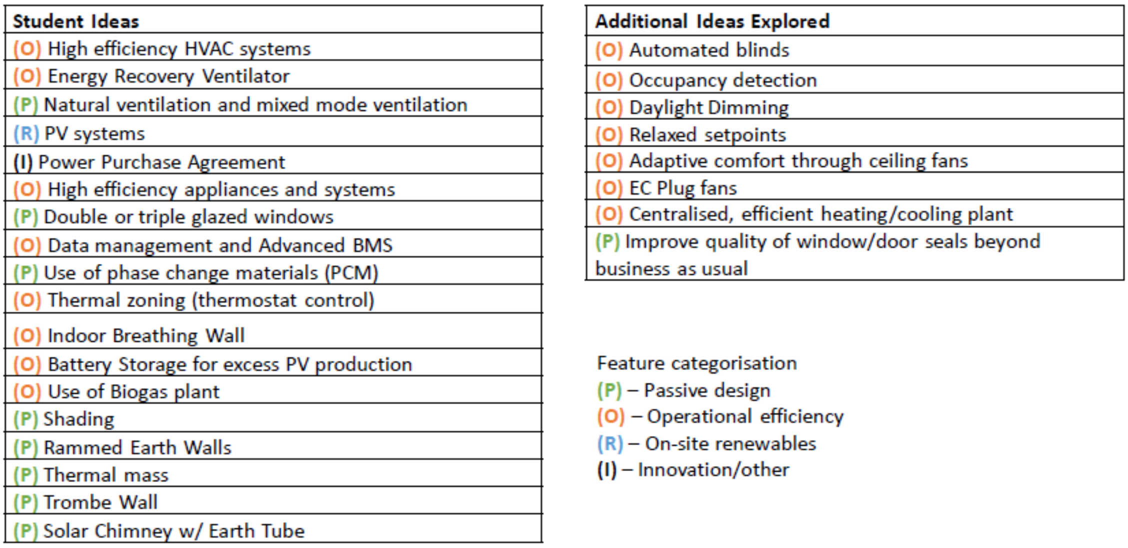
Well Being & Productivity

In addition to the energy and carbon savings identified, it was found that such a laboratory building would have a high impact on occupant health, well-being and productivity.

Net Zero Lessons learnt IDS-09	**Multi-Purpose Building Buildings:** Net Zero Case Study Technical Learnings summary

Existing Opportunities

As the design undertaken through the design studio utilised a *greensite*, many possibilities were available to be explored, with the primary limiting factors being the isolated nature of the site and the overall capital expenditure. This resulted in participants exploring many different potential technologies and strategies. The strategies identified by both parties can be seen (below) in Figure.



Student Ideas
(O) High efficiency HVAC systems
(O) Energy Recovery Ventilator
(P) Natural ventilation and mixed mode ventilation
(R) PV systems
(I) Power Purchase Agreement
(O) High efficiency appliances and systems
(P) Double or triple glazed windows
(O) Data management and Advanced BMS
(P) Use of phase change materials (PCM)
(O) Thermal zoning (thermostat control)
(O) Indoor Breathing Wall
(O) Battery Storage for excess PV production
(O) Use of Biogas plant
(P) Shading
(P) Rammed Earth Walls
(P) Thermal mass
(P) Trombe Wall
(P) Solar Chimney w/ Earth Tube

Additional Ideas Explored
(O) Automated blinds
(O) Occupancy detection
(O) Daylight Dimming
(O) Relaxed setpoints
(O) Adaptive comfort through ceiling fans
(O) EC Plug fans
(O) Centralised, efficient heating/cooling plant
(P) Improve quality of window/door seals beyond business as usual

Feature categorisation
(P) – Passive design
(O) – Operational efficiency
(R) – On-site renewables
(I) – Innovation/other

Figure: Student and consultant design solutions – Excerpt from vetting report

The consultants featured five strategies which would likely be of the greatest benefit to the project, having been tested commercially on existing structures with a proven performance history. These strategies are further detailed in Section 0 of the 100% studio report, and have been classified under the headings of:

- Embodied carbon
- Passive design solutions
- Operational improvements
- Renewable energy generation
- Designed for end of life considerations

Improvements vs. Business as Usual (BAU)

Embodied carbon (locally sourced culturally significant materials)

The client (and end user) has a focus on their environmental impact, with a desire to minimise their overall impact on the surrounding region. To achieve this, it is desirable to utilise *low-process and low carbon materials* such as timber, muds/clays, and repurposed/recycled/upcycled products. It is recommended that the design utilise materials that are locally sourced, minimising transportation requirements. Locally sourced timbers would not only achieve this low-processed desire, but are culturally significant to the local indigenous population, meaning that their implementation would achieve multiple design outcomes. Additionally, the incorporation of local mining tailings (a waste stream) could be used to create mudbricks or rammed earth walls, offering both structural and massing solutions for the building.

Passive design solutions

Passive systems such as thermal mass, building layout and orientation, and materials with good thermal properties were highly recommended to assist in regulating the internal thermal environment, which also assists in reducing the requirements of active systems. Thermal chimneys could also be included within the design to assist in ventilating the building's interior and maintain comfort conditions. Air infiltration also needs to be considered, to minimise undesired air changes when comfort conditions have been achieved.

Operational improvements

A series of operational improvements were outlined. These included:

- HVLS (High-Volume Low-Speed) fans to offset air conditioning

- Daylight dimming to reduce artificial lighting demands
- Occupancy sensors for lighting management
- Installation of Energy Recovery Ventilators (ERV's)
- Relaxation of temperature set point control
- Energy Management Systems

Renewable energy generation

Maximisation of PV systems should be considered due to their high return on investment and low payback periods. Due to this being a *greensite*, roof orientation can be designed to maximise solar gains, with building integrated PV systems highly suggested due to the simplification of their installation during construction, rather than being later retrofitted.

End of life

No building is expected to last forever, so the best time to plan for its eventual deconstruction is during the design phase. Design for end of life can maximise the potential reuse/recycling opportunities for materials once the end of life phase has been reached, especially given the remoteness of Lightning Ridge. Designing for disassembly is one method of maximising the potential reuse of materials, while modular assembly is also recommended. Modular design will simplify the assembly process, while also minimising potential waste during assembly/construction.

Key Findings

The strategies outlined by the consultants show that through implementation of commercially available solutions, a reduction of over 25% of operational carbon is possible given the various strategies being implemented. Depending on the design improvements implemented in addition to the onsite/offsite renewables, the consultants suggest that net-zero operational carbon is possible for the Lightning Ridge multi-purpose building.

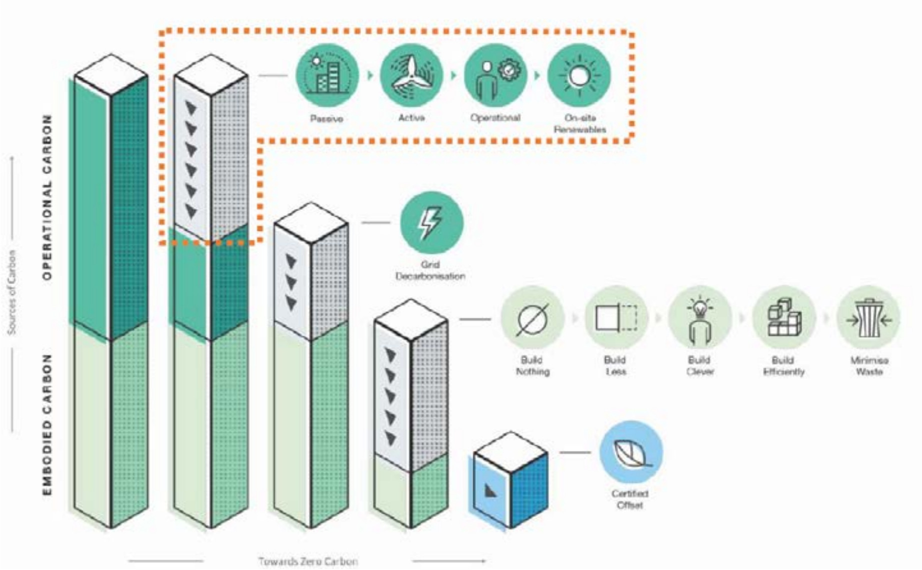


Figure: Net zero carbon buildings: Three steps to take now (ARUP 2020)

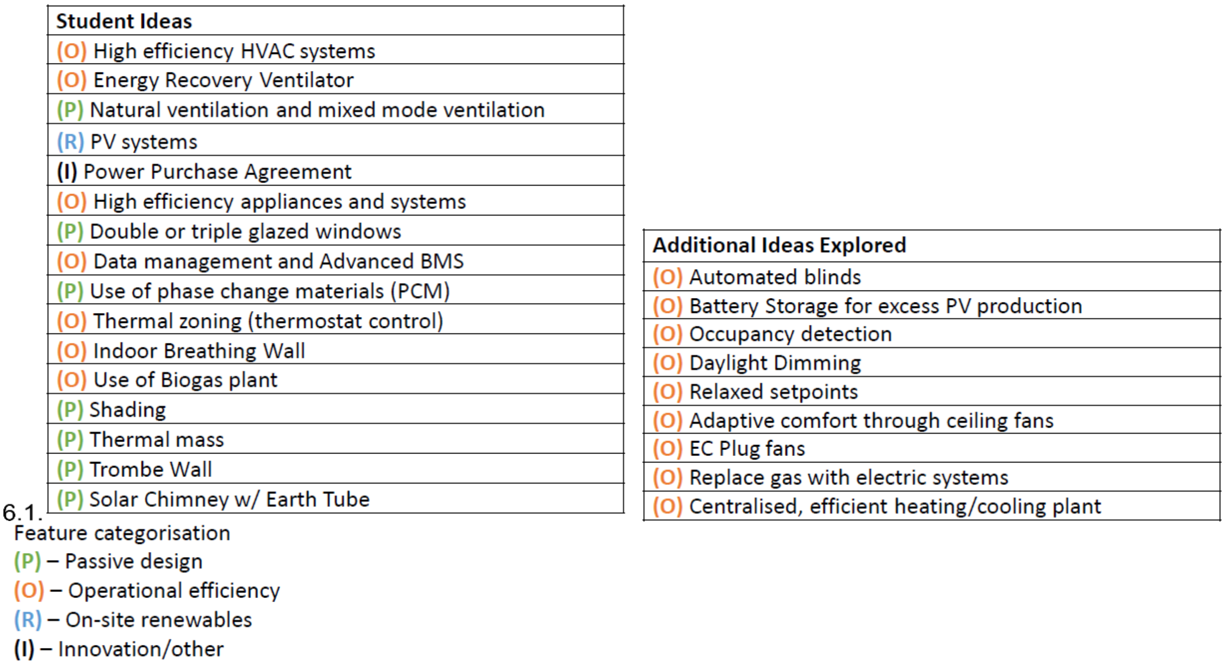
Net Zero Lessons learnt IDS-10	**Aged Care II:** Net Zero Technical Learnings summary

Existing Opportunities

As the design was finalised, it proved difficult to make structural changes without incurring significant financial penalties. As such, a majority of the design solutions explored by students focus on non-structural passive design solutions or active solutions, with consultants focusing solely on active operational solutions.

Of the potential ideas explored by both students a consultant, the consultants highlighted five key aspects, outlining the strategies considered most critical for each. These decisions have been made based on the strategies having been implemented on previous projects to great effect, and given they are commercially available. These aspects are:

- Design for Wellbeing
- Passive design solutions
- Operational improvements
- Additional renewable energy generation
- Embodied Carbon



Student Ideas
(O) High efficiency HVAC systems
(O) Energy Recovery Ventilator
(P) Natural ventilation and mixed mode ventilation
(R) PV systems
(I) Power Purchase Agreement
(O) High efficiency appliances and systems
(P) Double or triple glazed windows
(O) Data management and Advanced BMS
(P) Use of phase change materials (PCM)
(O) Thermal zoning (thermostat control)
(O) Indoor Breathing Wall
(O) Use of Biogas plant
(P) Shading
(P) Thermal mass
(P) Trombe Wall
(P) Solar Chimney w/ Earth Tube

Additional Ideas Explored
(O) Automated blinds
(O) Battery Storage for excess PV production
(O) Occupancy detection
(O) Daylight Dimming
(O) Relaxed setpoints
(O) Adaptive comfort through ceiling fans
(O) EC Plug fans
(O) Replace gas with electric systems
(O) Centralised, efficient heating/cooling plant

6.1.

Feature categorisation
(P) – Passive design
(O) – Operational efficiency
(R) – On-site renewables
(I) – Innovation/other

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

Improvements vs. Business as Usual (BAU)

Design for Wellbeing

The client has a focus on health, being that the project is an aged care facility, meaning that occupant wellbeing is a primary concern when considering design solutions. To accommodate these wellbeing principles, it is recommended that that design connect with nature and natural elements, whilst maximizing natural light and accommodating natural ventilation to provide fresh air to the residents. To improve occupant health, maximising thermal comfort is greatly recommended.

Passive Design Solutions

Passive systems such as thermal mass and trombe walls are highly recommended to assist in regulating the internal thermal environment, which also assists in reducing the requirements of active systems. Solar chimneys could also be included in the design to assist in naturally ventilating the buildings interior. Air infiltration will also need to be considered to reduce the requirements of the HVAC system while also maintaining a moisture barrier between internal and external environments.

Operational Improvements

Consultants outlined a series of operational improvements which could be implemented. These included (but are not limited to):

- HVLS fans to offset air conditioning
- Installation of Energy Recovery Ventilators (ERV's)
- Relaxation of temperature set point control
- Automated lighting control

Additional Renewable Energy Generation

Maximisation of PV systems should be considered due to their high return on investment and low payback periods. Roof layout can be adjusted to maximise this strategy, though PV can also be integrated within facades or smaller shading elements.

Embodied Carbon

Use of natural resources (e.g. timber, clay, recycled/repurposed/upcycled) reduces the overall embodied carbon of the structure, and lessons the environmental impact due the decrease in material processing. While this may not necessarily have a direct impact on the efficiency of the structure or its operational performance, it is nonetheless an important factor for the client who has net-zero target ambitions.

Key Findings

The strategies outlined by the consultants show that through implementation of commercially available solutions, energy reductions of 25% are possible for passive solutions alone (given a temperate local climate), with active services likely not being as significant. It is specified that the suggested active operational strategies, while reducing overall energy consumption, do not have the same potential as passive systems. However, in combination, the consultants outline that a 25% reduction in operational carbon is achievable.

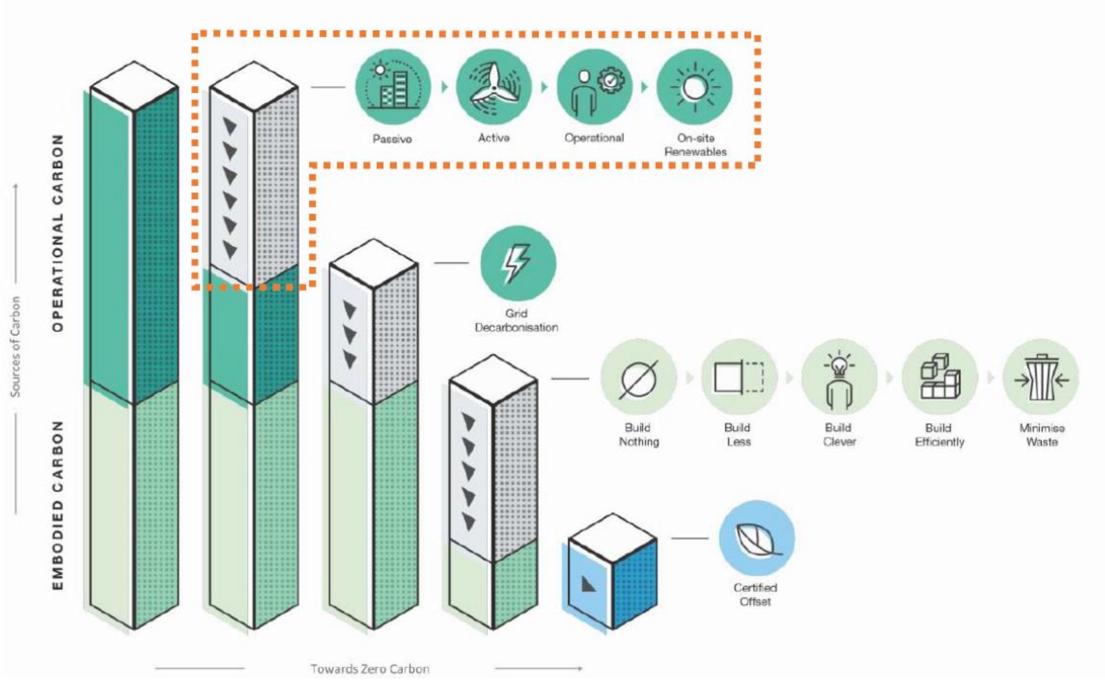


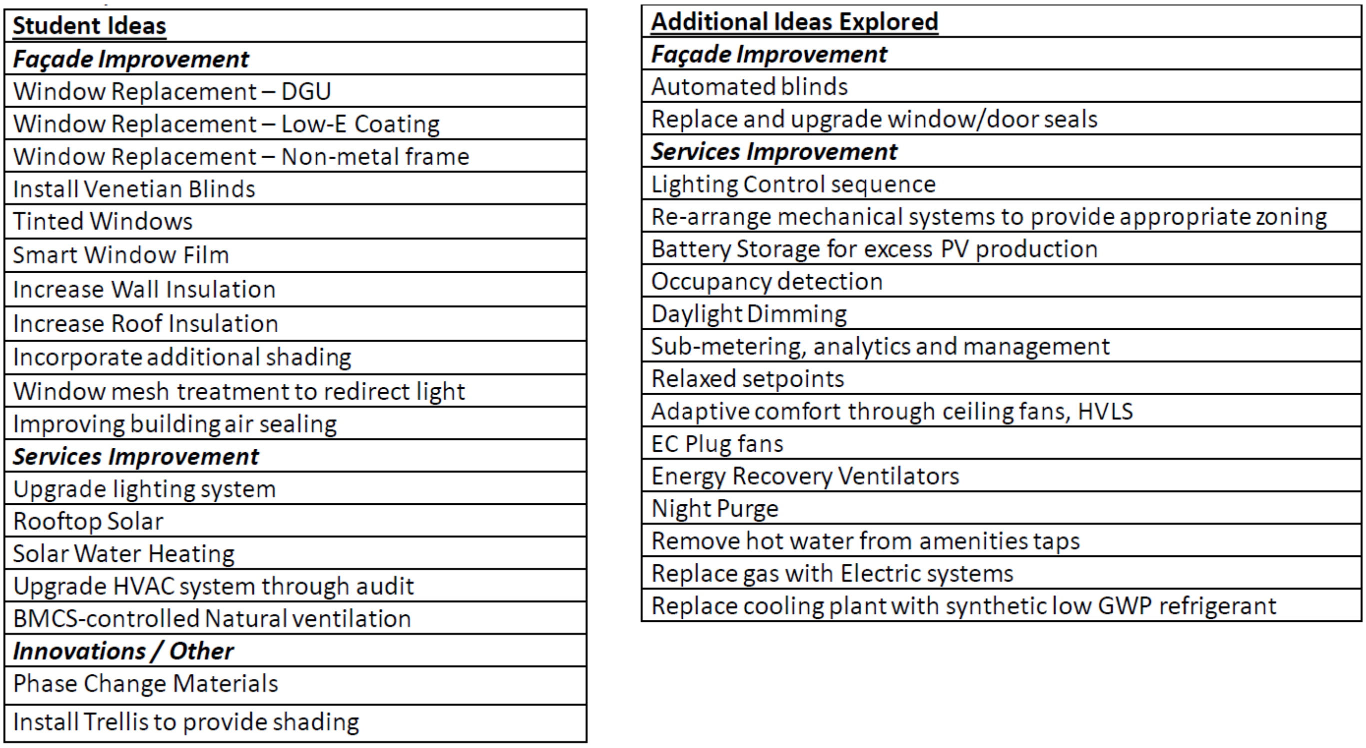
Figure: Net zero carbon buildings: three steps to take now (ARUP 2020) - Excerpt from vetting report

If a 25% reduction in operational carbon is possible in a design which is yet to be constructed, then it is a distinct possibility that improvements are possible to aged care facilities in general to make them more efficient. While these strategies will differ, improvements are possible.

Existing Opportunities

Due to the building in question already existing, the number of potential opportunities is more limited than for a new building. Nevertheless, a large number of potential opportunities still exist which are able to be explored. Of these potential solutions, the consultants highlighted five systems which would likely offer the greatest benefit, having been implemented within numerous past projects, and given they are readily available commercial solutions. These solutions were:

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



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

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

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

Improvements vs. Business As Usual (BAU)

Passive Solar Principles

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

High-Performance Façade

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

Heat Recovery

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

Operational Improvements

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

- Relaxing temperature set points while maintaining internal comfort conditions
- Reducing hot water usage through restricting hot water flow, or through eliminating hot water to public areas.
- Adaptive light diming throughout the day
- Occupancy detection to disable systems in zones not currently in use
  Additionally, maintenance, commissioning, and cleaning of existing HVAC systems will improve operational efficiency and reduce overall energy usage.
  Additional PV
  Through adapting student designed shade structures for car parks and accessible ramps, there can be an increase in shaded footprint, allowing for an increased number of PV systems to be installed. These additional PV systems allow for energy to be offset from existing active systems.

Key Findings

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

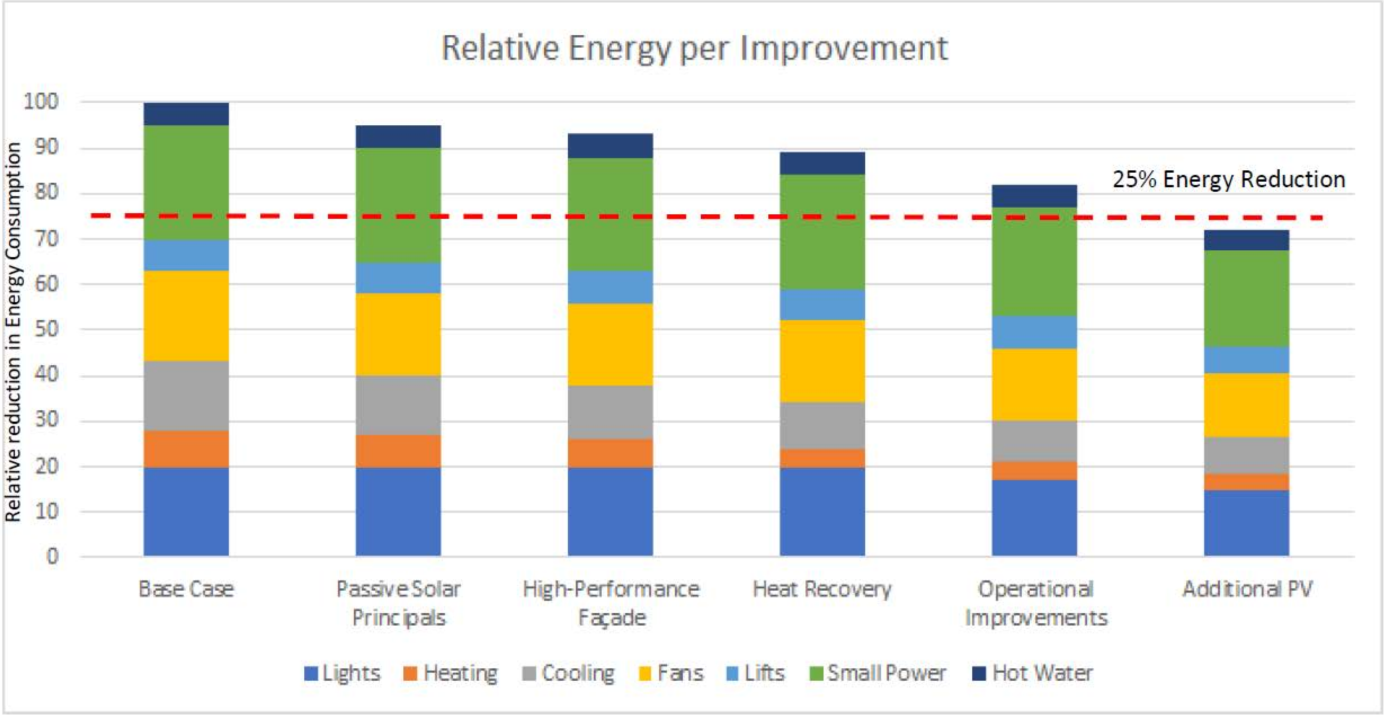


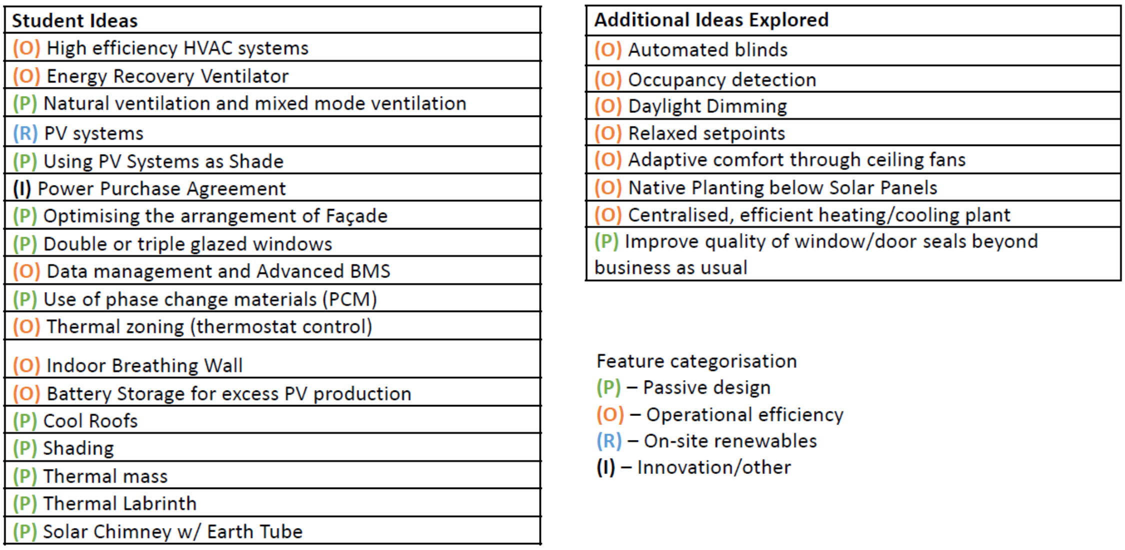
Figure 12: Relative energy improvement per strategy - Excerpt from vetting report

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

Net Zero Lessons learnt IDS-12 | **Mixed Use Buildings I:** First Net Zero case study Technical Learnings summary

Existing Opportunities

Similar to IDS-09 the design studio utilised a (mostly) greenfield site affording many potential technological and strategic possibilities. A summary of the identified strategies can be seen below.



Student Ideas
(O) High efficiency HVAC systems
(O) Energy Recovery Ventilator
(P) Natural ventilation and mixed mode ventilation
(R) PV systems
(P) Using PV Systems as Shade
(I) Power Purchase Agreement
(P) Optimising the arrangement of Façade
(P) Double or triple glazed windows
(O) Data management and Advanced BMS
(P) Use of phase change materials (PCM)
(O) Thermal zoning (thermostat control)
(O) Indoor Breathing Wall
(O) Battery Storage for excess PV production
(P) Cool Roofs
(P) Shading
(P) Thermal mass
(P) Thermal Labrinth
(P) Solar Chimney w/ Earth Tube

Additional Ideas Explored
(O) Automated blinds
(O) Occupancy detection
(O) Daylight Dimming
(O) Relaxed setpoints
(O) Adaptive comfort through ceiling fans
(O) Native Planting below Solar Panels
(O) Centralised, efficient heating/cooling plant
(P) Improve quality of window/door seals beyond business as usual

Feature categorisation
(P) – Passive design
(O) – Operational efficiency
(R) – On-site renewables
(I) – Innovation/other

Figure : Student and consultant design solutions – Excerpt from vetting report

The consultants, while mentioning many of these strategies outlined above, highlighted five systems/technologies specifically which could contribute to energy savings and embodied carbon reductions to better meet the desires of the client brief. These systems were:

- Relaxed temperature set-points
- Two-tone lighting
- On-site renewable energy generation
- Modular design and construction
- Recycled/sustainable ductwork

Improvements vs. Business as Usual (BAU)

Based on the building typology chosen by the student designers (i.e. multi-purpose building, commercial/retail spaces, residential development, etc.) a BAU baseline was developed, incorporating case studies for buildings of similar operation requirements which exist within similar climatic zones. These baseline values (developed by the student designers) varied depending on the operation of the buildings which were chosen by each design team. The calculated values ranged from an Energy Use Intensity (EUI) of 44.77kWh/m^2/year to 247.42kWh/m^2/year, with an assumption being made (by the students) as to what the 'typical' operating requirements would be.

Passive design solutions

Passive systems such as thermal mass, building layout and orientation, and material were highly recommended to assist in regulating the internal thermal environment, which also assists in reducing the requirements of active systems. Air infiltration also needs to be considered, to maximise the performance of any active cooling/heating systems and minimise undesired air changes when comfort conditions have been achieved.

Operational improvements

HVAC was a primary active technology outlined as being a necessity to assist in regulate internal comfort conditions, particularly during peak seasons (i.e. summer and winter), with various other systems included to support this primary technology (i.e. ceiling fans, HRV/ERV, building management system, etc.). Other minor improvements were also included (efficient appliances, occupancy sensors, daylight dimming, etc.) to assist in reducing typical daily energy usage profiles.

Relaxed temperature set-points

Typical temperature set-points are outdated (according to the consultants), assuming clothing styles and a workforce that is currently antiquated. Through relaxing set-point levels, a more comfortable environment can be created for all occupants (potentially improving work related outcomes) while simultaneously reducing the cooling requirements of the building by approximately 10%.

Two-tone lighting

It was identified that lighting requirements for the building/s could exceed 40% of the total energy requirements. In light of this, consultants recommend the use of a two-tone lighting scheme. While Australian Standards (AS1680.1) mandate 320 Lux within an office environment, this degree of lighting is excessive, resulting in 4.5-5W/m^2 (even with upgraded lighting systems). Ambient lighting within 'simple' task areas (i.e. away from desks and benches) only requires 160 Lux, which can substantially reduce the overall energy requirements of the building if implemented correctly.

On-site renewable energy generation

Maximisation of PV systems should be considered due to their high return on investment and low payback periods. Roof orientation can be designed to maximise solar gains, with building integrated PV systems highly suggested due to the simplification of their installation during construction, rather than being later retrofitted. PV installation can also exceed the typical implementation (i.e. rooftop solar), with shade structures and neighbouring buildings also being explorable as locations capable of generating additional solar energy.

Modular design and construction

Prefabricated building techniques are advantageous and are capable of saving time, and reducing waste and embodied carbon. These aspects are in keeping with the aspirations of the client, and also provide potential flexibility in the building layout, allowing for alterations to the floor space as required. Given that the functionality of the spaces may alter over time, modular and flexible design strategies would be an ideal inclusion.

Recycled/sustainable ductwork

Conventional rigid ductwork is a highly processed material, with a high embodied carbon content. To abate these additional embodied carbon values within the structure, the consultant has suggested the use of either recycled 3D-printed ducting or Cardboard ducting. 3D-printing is becoming more sustainable, with the material being recyclable once the product has reached its end-of-life. Additionally, 3D-priting this components allows for more bespoke designs, tailored specifically for the project. Alternately, cardboard ducting (such as Gatorduct) can be flat-packed and cut-to-shape on site, meaning the material is low-process, fully recyclable and completely customizable, with the exterior able to feature customised branding and artwork. This option will diminish embodied carbon values, and minimise potential waste materials. While similar results may be achieved with existing steel ducting, alternative solutions are mor in keeping with the aspirations of the client.

Key Findings

The strategies outlined by the consultants show that through implementation of commercially available solutions, a reduction of over 25% of building services loads is possible given the various strategies being implemented within a temperate climatic zone. Given the site, it is possible to introduce a sufficient level of PV to achieve a net-zero energy outcome, though this would still require the site to be connected to the grid to allow for energy draw/supply for peak periods and periods of lower than anticipated irradiance. Further savings are possible with additional financial investment, though this would require further investigation.

Many of the suggested technologies and strategies are sympathetic, working in tandem to achieve greater results than they would alone. These synergetic properties may allow for the removal or reduction in of other technologies completely, further reducing energy demands. Given these outcomes, the consultants hypothesise that not only is net zero-energy a possibility, but the building/s may also achieve net-zero operational carbon as well.

Net Zero Lessons learnt IDS-13 & 14	**Mixed Use Buildings II**: Second Net Zero Case Study Technical Learnings summary continued

IDS-13 & 14 studied the mixed use typology further (at QUT)

Mixed-Use Buildings present design challenges

Mixed use building typologies present a number of challenges for achieving net zero energy, such as:

- There is no ‘business as usual’ (BAU) energy use intensity (EUI) data for this building typology. BAU estimation requires obtaining average EUI data for each of the building classes expected to be incorporated into the mixed-use building. Current and relevant data can be difficult to obtain.
- Spaces within a mixed-use building can be used for different purposes, and b different classes of buildings, over time. This means that measurement of energy performance against BAU becomes even more problematic
- There is no clear methodology for allocating energy consumption and generation data (whole and parts) for mixed-use buildings, making it difficult to assign energy consumption costs, renewable energy benefits and demand response capability (who pays, who benefits, who decides?). This presents challenges for setting and meeting net zero carbon or net zero energy goals.
- Mixed-use buildings that incorporate residential services present a unique problem in that the building is both a home and a workplace, creating additional challenges relating to HVAC technology selection, system sizing, design and operation

It would be helpful to gather data on EUI of all building classes. Some helpful data may include

- EUI for office tenancies from NABERS FY2020 ratings (excluding outliers), as reported in Determining office
- tenancies energy end use. Final Report June 2021. Energy Efficiency Council. www.eec.org.au
- average energy intensity of retail tenancies (2012) as reported in Baseline Energy Consumption and Greenhouse Gas Emissions in Commercial Buildings in Australia. Part 1 – Report. November 2012. Council
- of Australian Governments (COAG) National Strategy on Energy Efficiency
- However the currency of the data is also important. For example, if using the 2012 report mentioned above, a discount (percentage improvement in efficiency) may be feasible to apply, reflecting changes to the market and regulations and technology availability. The EUI for each class needs to be agree by ID participants, and applied to each relevant area of the proposed design, to obtain a more accurate estimation of site energy consumption.