The Innovation Hub

for Affordable Heating and Cooling

Design Studio Outcomes Report (100% Milestone)

IDS-05 Aquatic Centres

Project IDS05

30 May 2021

The University of Melbourne

About i-Hub

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

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

This Project received funding from ARENA as part of ARENA's Advancing Renewables Program.
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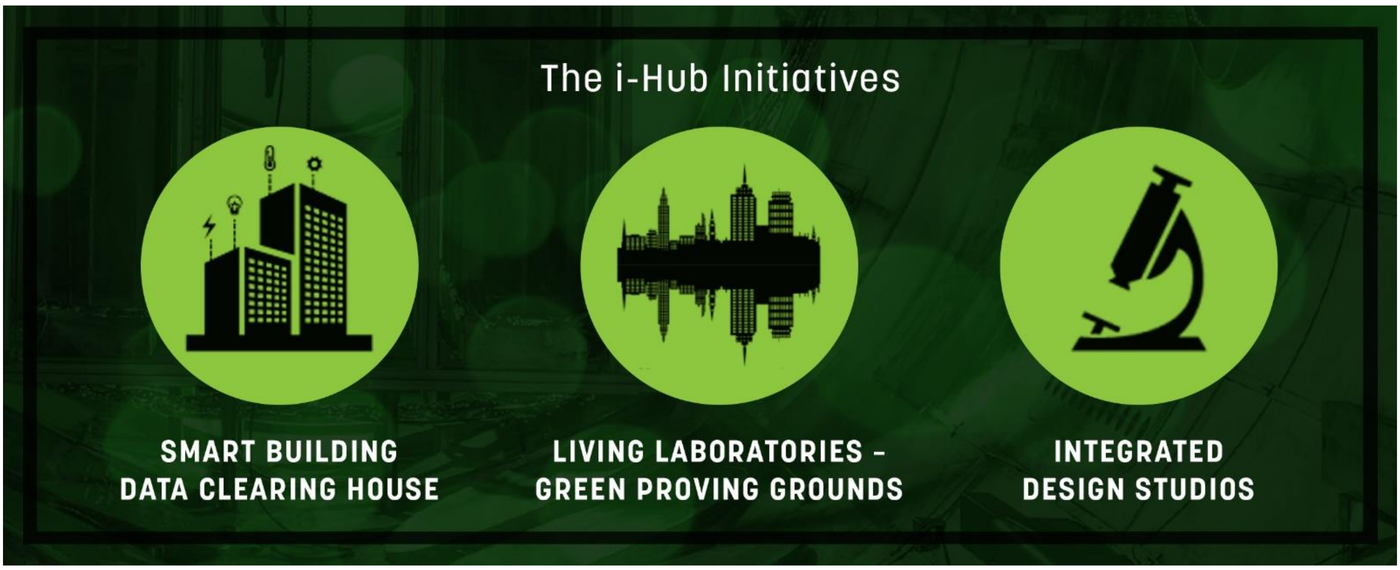

i-Hub Design Studio Outcomes Report (100% Milestone)

The IDS-05 Aquatic Centres Integrated Design Studio, investigates design innovation to reduce net energy consumption through the use of renewables and other energy technologies. Over a 14-week period, a group of architecture and Engineering students work jointly with Engineering experts to develop an Aquatic Centre. This type of facility is known to have high operational energy requirements.

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

Lead organisation	The University of Melbourne		
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Report date	14 October 2020		
Contact name	Dr Dominik Holzer		
Position in organisation	Associate Professor in Digital Architectural Design		
Phone	0416 214 165	Email	dominik.holzer@unimelb.edu.au

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1. SUMMARY

1.1 Purpose

This report summarises all findings taken from IDS-05, and thereby marks the 100% completion milestone at the end of the project. Information inherent to this report will flow directly into the 'Lessons Learned' from IDS-05, and they will further be disseminated under the IDS Knowledge Sharing strategy associated to the program.

1.2 Executive Summary

The IDS-05 Aquatic Centres has been initiated in early July after substantial stakeholder engagement with client representatives from the City of Yarra, Banyule City Council, Moreland Council, and Brimbank Council. Early consultations had commenced in Q1 of 2020. In contrast to the IDS run in Semester 1 2020, it was clear from that start that this IDS had to be run entirely online due to COVID-19 access restrictions to Melbourne University campus; due to COVID-19, semester start was postponed by one week. All classes were conducted online using Zoom as the main interface for presentations, as well as online repositories for file exchange among students and with the tutor.

One other main difference to the IDS undertaken in Semester 1, is the fact that the IDS organising team at the University of Melbourne, was able to secure the participation of four students from the Melbourne School of Engineering in this IDS.

Over the course of semester, work progressed on approximately a dozen individual design proposals by architecture and engineering students who interacted with the student tutor, and the industry consultants on a weekly basis. A mix of engineering and architectural students were split into groups in which they could interact and collaborate. The engineering students contributed to the design development by conducting analysis on structural, geotechnical and energy related requirements, and by cross programming the functions for individual designs. Additionally, they provided general engineering input on potential strategies to develop 'Net Zero' solutions. A dedicated 'Catalyst for Integrated Design' guideline underpinned the collaborative effort and helped in the joint development of common goals toward 'Net Zero' design. Due to COVID-19, the two weekly sessions had to take place entirely online for the duration of the semester.

Findings at the end of semester indicate that the IDS has only peripherally been impacted by COVID-19. The most challenging aspect has been the task to facilitate continuous exchange between architecture and engineering students until the end of semester. Despite this obstacle, the IDS resulted in 12 highly innovative noteworthy projects where both passive and active solutions were applied to address Net Zero goals. Studio observations through to the end of semester overall pointed to key lessons which include (but are not limited to):

- A base level of understanding required in disciplines to be integrated before integration can happen effectively.
- Student design solutions at mid semester were found to be pedestrian in regard to how they'd address Zero Carbon goals.
- Upskilling and the introduction of background material is required to understand what BAU is for each discipline and project type.
- It was after this point that design integration and innovation was able to be productively pushed.
- Clear articulation of common goals as a key priority, ideally translating into clear assessment criteria and being upheld in an intelligible way through the integrated design development process.
- Architecture students can struggle with an unfamiliar process, unable to 'join the dots' and can lose the way.
- Engineering students struggle with 'brief under development', expect clearly defined problems instead.
- Managing collaboration is not easy with architects' frequent design changes, engineering students might feel alienated by this process (in particular, if not involved in the design decision-making process).
- Balance between architecture and engineering requires active curation, exemplified in this studio by actively encouraging designers to think holistically about the aesthetic and the functional design together.

2. PROJECT CONTEXT AND INCEPTION

2.1 Context to the Aquatic Centres Integrated Design Studio

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

Aquatic Centres was one of these three projects as its programmatic and functional specificity promise a fertile testing ground for design exploration, in particular when considering Zero Carbon constraints. In the weeks leading up to the start of semester, the Melbourne University team went on to gain University of Melbourne internal *Ethics Approval*, select the Design Studio tutor, establish the context for the IDS to integrate seamlessly with the existing curriculum, and chose the Industry consultants to join in on the project.

2.2 Studio Inception

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

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

2.3 Client Engagement

With representatives of the City of Yarra, Banyule City Council, Moreland Council, and Brimbank Council, the project has found a group of open-minded clients, who are all managing or planning similar facilities that require a conscious approach to Zero Carbon. They all welcome the opportunity to test unprecedented and novel technologies, brought into context with innovative design ideas. The IDS-05 Aquatic Centres project is joined by industry experts and consultants, with a proven track record in the design, delivery, and operation of these bespoke assets. This mix between willingness to experiment, paired with a high degree of expertise in Aquatic Centre design, is greatly benefitting the conversations and design approaches in the studio. The client group has remained involved intermittently over the first half of the semester, providing guidance and feedback, in particular at mid-semester and the projected end-of semester milestone.

2.4 Site Visit

Due to COVID-19 restrictions, it has not been possible for IDS participants to physically visit any site. The studio has compensated for this limitation by providing 3D Rhino model as well as aerial, panoramic and street view images of the selected site from various angles. Also, the studio tutor allocated some time during initial studio sessions to analyse the site and discuss its characteristics.

3. DESIGN STUDIO PROGRESSION

3.1 Setup for Collaborative Design Integration

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

General

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

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

Focus on Performative design

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

3.2 Schedule for Interdisciplinary Engagement

The studio tutor proposed a detailed IDS schedule in week two of the semester, based on his experience in running such studios within a 13-15-week semester, and in consideration of feedback from industry consultants, the client, and the academic participants. The schedule addressed both the output requirements typically inherent to Masters-level Design Studio teaching at the Melbourne School of Design, as well as the specific IDS output requirements for exploring novel technologies. In particular, the schedule mapped out the intensity and duration of engagement between the architecture students, the engineering students, and the engineering consultants.

3.3 Weekly interaction between Design Studio Participants

After the initial online kick-off workshops, the Aquatic Centres IDS moved into the phase of weekly 6-hour design review sessions with three hours spent with studio tutor and three hours with engineering consultants. Due to the clash of schedule with another subject, the majority of engineering students could not attend the sessions where the engineering consultants were present. This dramatically reduced the level of interaction between the consultants and engineering students.

The initial two to three weeks were marked by additional presentations by the engineering consultants and the introduction of site and reference projects by the consultants and architectural studio tutor. Students were then asked to start presenting first preliminary responses to the site context, conducting research on the potential solutions to integrate structural, mechanical and architectural design domains, developing understanding of the strategies towards Net-Zero Carbon' targets and the articulation of various programmatic features to complement the aquatic centre functions.

In a 13-15-week design programme much of the front end is taken up with briefing, experimentation of general form, concept definitions and bringing design parties up to speed with each other's discipline (in general knowledge terms), while the back end is conversely dominated by detailed design development and documentation type activities. In-between these two general phases, is a very brief period when core design ideas are generated and formed. Once design ideas are formed, it is difficult to materially change direction due to the momentum involved. Therefore, it is important to align and integrate the directions among all design disciplines before generating the core design ideas. Not considering priorities of certain parties or disciplines during ideation will lead to unresolved issues in the developed design ideas. Designers hold preconceptions after the initial ideation and a natural tendency to adjust the existing design rather than to start a new design Therefore those concepts if tackled with at later stages, may not be completely integrate with the main generated form and core ideas. This means it is important to recognise when this ideation period is happening ensuring everything and everyone is in place to make it as successful as it can be.

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

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

As a stage 4 lockdown is in place across Victoria, the studios were forced to move entirely to remote (on-line) delivery. This online format is proving successful overall, but it is not without its challenges related to the desired bonding between architecture and engineering students. From an observation perspective, it has some advantages as UoM researchers can act as a silent witness in the online meeting rooms. Students, the tutor, and the industry consultants take advantage of interactive online communication features to review and discuss design ideas both verbally, as well as by annotating sketches, plans/sections, and 3D models. Mid-semester and final reviews occurred online with the inclusion of a panel of experts.

To facilitate communication and collaboration among studio participants, a common data environment was created by studio tutor on an online platform where all the information related to studio including the site information, site drawings, references for reading, and studio recordings were stored. This online folder was proved useful throughout online delivery acting as the single point of truth where all participants could refer to at any time to keep informed about recent updates and prevent miscommunications and loss of information.

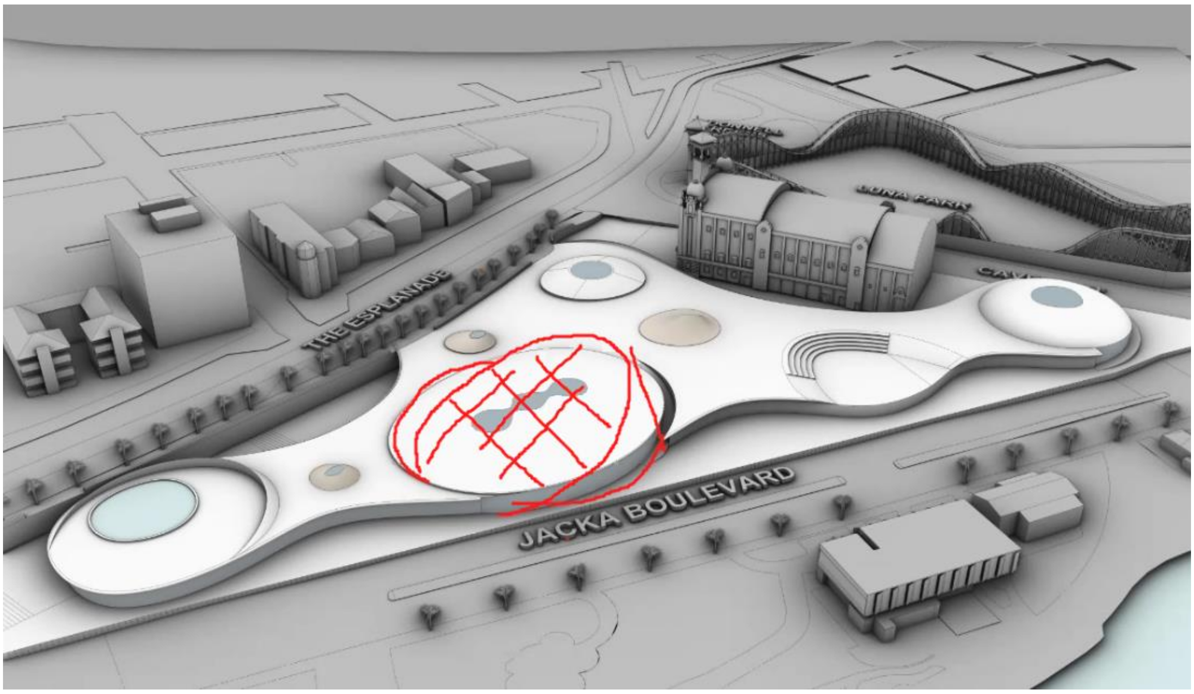


Figure 1: Use of annotation tools on Zoom to increase interaction during studio sessions

4. DESIGN STUDIO FINDINGS

The findings from the IDS-05 Design studio are drawn from three main sources:

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

4.1 Observations during the studio

The activities within the studio were observed throughout the semester by the IDS research team. The following are the main observations regarding the process of integrated design and the contributing factors.

4.1.1 Understanding Professional Specificity (and how to overcome it)

Understanding the project from various perspectives and appreciating the requirements and design directions by all involved parties is an important enabler of integrated design. Therefore, at the initial stages of the studio, the design team need to spend a generous amount of time to interrogate the brief and understand each-other's perspectives, language, expectations and priorities. This is not to develop a deep knowledge on other specialties but only to have a general understanding of the concepts and appreciate the potential counteracting forces and the need for regular synchronisation of design iterations across all disciplines.

A useful strategy to apply multi-disciplinary design approach during IDS-05 was to ask architecture students to look at the project from two different perspectives. The first perspective was to develop the forms by considering functions, circulations, site context and topography. The second approach was to collaborate with engineering students on the main concepts, rules or features for achieving Net-Zero Carbon goals followed by translating those concepts to a design idea for aquatic centre. The designers then analysed the two generated design and incorporated their findings into a third design that could represent both approaches. This methodology was useful in developing a design thinking method that could consider the projects from multiple angles.

Furthermore as an attempt to facilitate the incorporation of sustainable design strategies, one of the consultants developed a simple preliminary model that could estimate heating loads and sizing of the heat pumps while also could provide insights on thermal performance evaluation if the aquatic centres. The inputs for the tool were simple spatial and operational information, so that both engineering and architecture students could easily use it. This tool despite its useful features and user friendliness, was not used by any of the students to evaluate the performance of their buildings. One reason for this could be the very same reluctance by architecture students for conducting any kind of quantitative analysis to evaluate performance. While the engineering students could be a great asset in assisting with those quantified analysis, they failed make any meaningful contribution. This is likely due to the lack of enough motivation and the absence of a well-written brief or target statement which could mandate certain performance requirements and urge the designers to evaluate the performance of their buildings.

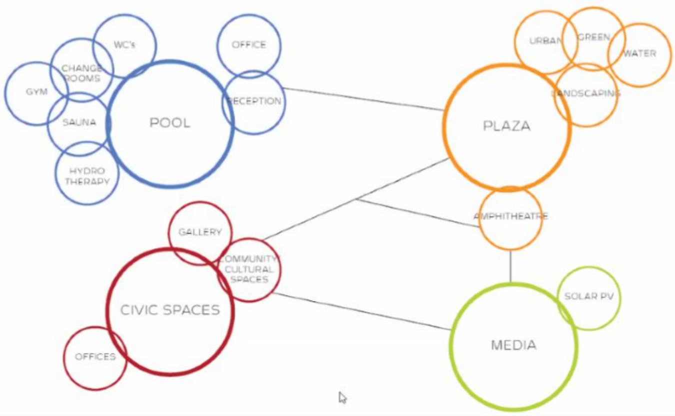
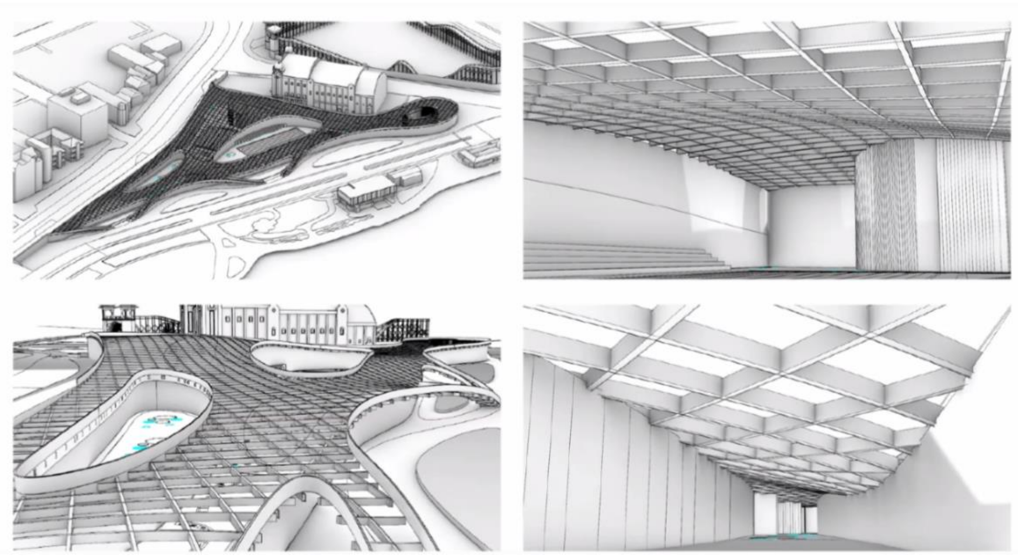


Figure 2: In search for a detailed brief, bubble diagrams are used to explore functions and spaces

4.1.2. Communicating Core Priorities

One important step to facilitate this was communication of the desired design outcomes and potential useful strategies by the engineering consultants during the few weeks of the IDS-05. As a part of the same process, the consultants also provided both engineering and architectural students with basic knowledge on the useful concepts of their engineering disciplines that could be useful during design development. They also educated the students on the methods and tools that can be used to quantify energy consumption and energy production on site. This process was proved useful in the sense that architecture students could grasp some of those ideas and explore potential solutions. For instance, the use of timber structures was encouraged by ESD consultants as well and structural engineering consultant as low-carbon structural solution. This concept became a theme for further research by students to explore different options of timber structures for aquatic centres and working with engineering consultants toward optimising the structure. Another example is the presentations on the advantages and functionality of heat pumps in Aquatic Centres, which was taken further by the architecture students during first few weeks of IDS-05 through research and exploration of heat pumps' applicability in their design.



Figures 3-6: Structural solutions, discussed on regular basis with structural engineering consultant

Although the fundamentals of design and requirements within other disciplines were continuously outlined by the engineering consultants, the architectural students failed to seamlessly integrate those requirements in their design. One area of struggle for the students was the lack of quantification of the design performance, and the mechanics behind the energy demand and supply. The students showed reluctance/saw it difficult to carry out any type of quantitative analysis to evaluate or back-up their design, although they were asked to do so. To facilitate the communication of sustainability and engineering requirements and incorporation of those in the design, the consultants came up with simplified ways to translate the performance metrics to a language that could be easily comprehended by the architects. For instance, the square meter of the solar panel that would likely be required for a aquatic centre facility or the likely thickness of the roof when various types of green roofs are applied. This method proved to be useful in increasing uptake of those strategies by the architecture students.

The language in which the core priorities are communication is a key to success of the integrated design. Setting performance targets (or minimum performance requirements) as the 'must meet' criteria is a useful step that defines vision, aim and meaning to the design process. In IDS-05 since the design vision and aim was not completely defined, the architecture students struggled with identifying missions for their design. While they were experimenting with forms to create an attractive architectural solution, the created forms seemed to be dis-integrated with the considerations of sustainability requirements communicated by the consultants. This is not due to insufficient engineering expertise or lack of architectural creativity, but because of lack of clear identification of tangible target sets from very beginning, which could function as the starting point for the design driving a more systematic and target-driven design process.

At the final presentations innovative sustainable design features were employed within the students' presentation, yet the lack of quantitative reasoning behind those solutions resulted in designs that either were not completely feasible or could not demonstrate/prove a meaningful impact in terms of achieving the zero-carbon targets. As much as non-feasibility was an accepted characteristic of a 15-week design process by students, their struggle in improving technology and sustainability performance highlights the difficulties of architectural designers to complement their creative exploration with analytical feedback concurrently. A higher base-level of understanding of 'Net Zero' principles would likely result in higher confidence and ability of (young) designers to do so.

4.1.3 Definition of Roles and Responsibilities

In an integrated design process, the definition of roles and responsibilities of each party is of great importance. The roles and responsibilities if not resolved, can lead to lack of design coordination and imbalance in level of contribution by various parties. At the early stages, after identification of core priorities, the roles by each design party should be clarified and documented. This definition of roles even if vague at the beginning, can bring a sense of responsibility and accountability to all design parties while also setting the design co-authorship mindset from early ideation stages.

During IDS-05 the absence of definition around roles and responsibilities especially with engineering students, led to several challenges in terms of design development as well as balancing the contribution and enabling collaboration between architecture and engineering students. For instance, despite the demonstrated interest by architecture students to the application on engineering solutions, they seemed to struggle with adopting those solutions to their design and balancing the aesthetic, functional and technical components of the design. This was due to the fact that the architecture students from the very beginning took the role of main party accountable for the design ideas (both architectural and engineering aspects) while the engineering students were unsure about their roles in the studio. Therefore, the design ideas came from architecture students leaving the engineering students in the background without the feeling of accountability or real contribution to the design. If the engineering students' role as co-designers could be defined at early stages, the engineering perspectives could be better incorporated in the concept stage leading to more rationalised creation of design solutions.

Throughout the design studios, all the activities related to design development were conducted by the architecture students. With the scarce of engineering students' active contribution, the consultants' role and their interaction with the students became more important, since they had to bridge the gap caused by lack of engineering input in the design team. Although the **engineering consultants mostly provided comments and guidance, rather than proposing design solutions, several instances of consultant's attempts to actively engage in design and providing tangible generalised design solutions were observed during IDS-05.**

The Consultants, through weekly sessions, reviewed the design progress and provided comments on the practicality of the proposed solutions and areas for further considerations. The consultants also provided explanations on the mechanics behind the engineering systems and provided some tangible solution to implement environmentally sustainable design strategies. Their feedback helped them evolve their designs to address the functional and spatial aspects. The consultants also participated in one-on-one consultation sessions. The one-on-one discussions were the closest instance of teamwork environment between architects and engineering consultants during which the consultants' role was shifted towards being 'co-designers'. They took a proactive approach and contributed to some design solutions.

The client representative provided directions to students about the important features of the aquatic centres awhile also providing feedback on the design and whether they fulfill the client's preferences.

The studio tutor, while leading the studio activities and coordinating the consultation sessions, while providing feedback from aesthetics and architectural point of view. The studio tutor was the primary point of contact and the person who the students spent most time with and received most guidance from while also acted as the person who would assess their final design. As such, the tutor's approach to integrated design shaped the student's thoughts and reflected on their design thinking and outcomes. It appeared that the tutor was inclined to emphasis on aesthetics and form as the primary design problem while the functional and engineering aspects were the secondary considerations that could be resolved at later stages. This mindset was reflected in the design approach taken by the students.

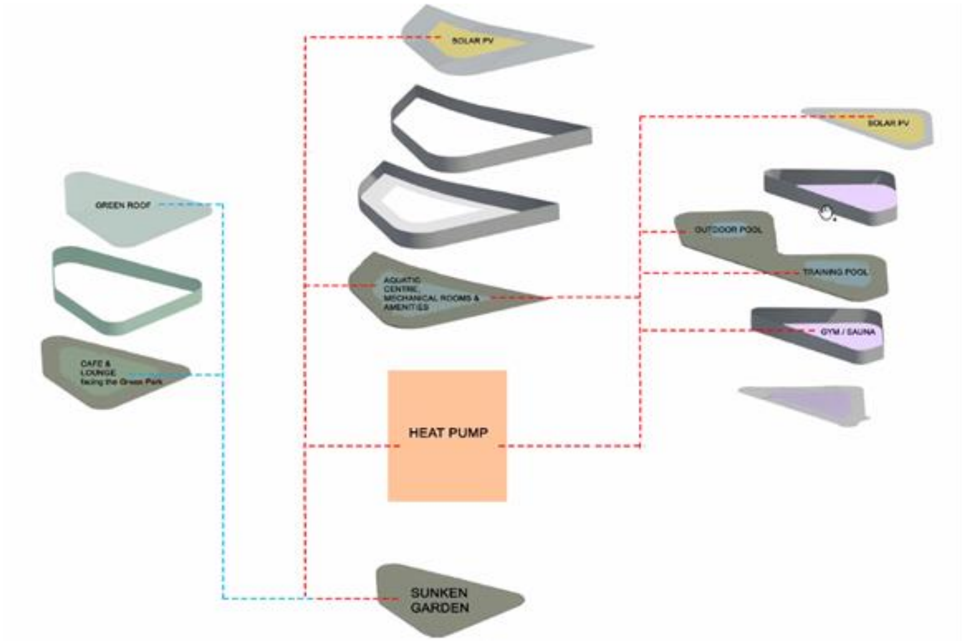


Figure 7: Preliminary ideas on the effective strategies to achieve Net-Zero Carbon solutions

4.1.4. Aligning the Dialogue

Integrated design is the coming together of multiple disciplines to produce design solutions that meet 'whole of project' visions. Observations throughout IDS-05 revealed that not all designers could adapt themselves to working in this way.

Current design paradigms often place engineering as following architecture in the design process. This encourages a consulting type approach to the engineering where engineers are asked to comment on preformed ideas. Design integration can occur in this model however to a reduced potential with the initial ideation missing ideas founded in engineering aspects of the project. The studios found this consulting model to be difficult (but not impossible) to break free from. Attention needs to be paid to create a mindset of 'design co-authorship' in all participants (engineers and architects alike). Design Co-author mindset is sensitive to the relationship of individual designers which can be complex. One positive example of individual's impact on the approach is witnessed during IDS-05 where some engineering consultants takes a more proactive roles in design while others follow the pattern of the existing consulting model. The presence of engineering students in IDS-05 provided opportunities to observe the extent of creation of a peer-to-peer discussion atmosphere and design co-authorship among student cohorts from two disciplines. However even between architecture and engineering students, the same pattern of designer-consultant relationship was witnessed.

Although important points on aligning the dialogue have been uncovered it will take some iteration in adjustments of the studio mix and nature of the integrated design process being trialled. This iterative nature in the research, refining the findings and adjustments over multiple studios is one of the reasons multiple IDS's were planned. Future studios will help refine the findings and close the gap that currently exists.

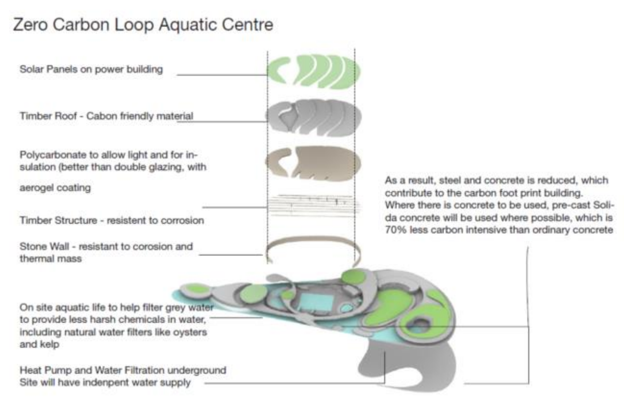
4.1.5. Peer-to-peer Collaborations

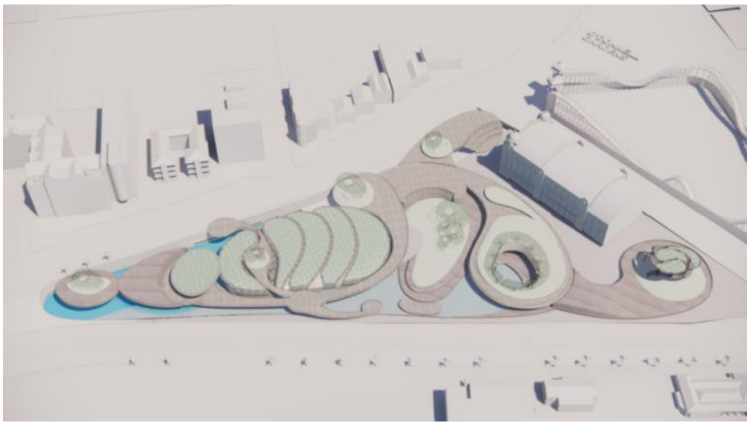
Although, engineering students' involvement in IDS-05 was an step towards providing grounds for pee-to-peer design collaboration, several factors caused challenges in their effective contribution to integrated design. The first and most important factor was lack of definition around the nature of involvement by the engineering students. Another issue around the involvement of engineering students was the fact that they were enrolled in a two-semester research based subject in which the timing and the nature of the assessments did not align with those of architecture students. Furthermore, the initial weeks of the studios when the engineering students' roles and contribution areas should have been defined, were mostly targeted at architectural students' briefing, education and project initiation. As such, the role of engineering students gradually faded such that no real impact of their engagement could be witnessed throughout the IDS-05. Another hurdle to collaboration of architectural and engineering students was the differences in the ways they approach a problem. While the architecture students are able to comprehend the wide yet vague image of the design problem and adapt to a brief under development, the engineering students were only comfortable with more narrowly focused and accurately defined problems to solve. Lack of problem definition at the initial stages lead to lack of clarity around the areas of contribution by engineering students. As a result, the engineering students spent the first few weeks of the studio sessions just as observers while also not being proactive within the groups they were allocated to (a mix of architecture and engineering students were grouped to collaborate). As the studio tutor encouraged and while the studio progressed, both architecture and engineering students attempted to tweak their approaches and adopt their languages to move towards discovering more effective ways of communicating ideas. The architectural students started to ask engineering-specific questions in their private groups while the engineering students tried to find the solutions for the questions raised. After mid-semester, some engineering students prepared presentations on the potential areas of their contribution such material choice and soil properties. Despite all the efforts, sadly no visible impacts of engineering-architectural peer-to-peer collaboration could be identified in the final design solutions.

4.1.6. Working toward Common Goals

A well-written brief document is a useful way of setting out common goals and motivate design parties to collaborate toward achieving those. In IDS-05 due to lack of a detailed brief, the client's priorities and functional goals of aquatic centre did not seem to be clearly communicated with the design team. The concept of 'brief under development' was used throughout IDS-05 in which a very high-level initial brief in the form of dot points was provided for the students while the students were asked to develop their own brief together with their design concepts. While some would argue that the 'brief under development' provides the grounds for creative design thinking, where free forms can be explores without any defined boundaries, it was found that some level of target definition in initial stages could be beneficial. The lack of a more focused brief left the designers without definitions around any social, environmental, functional, spatial or operational goals which at times lead to aimless fashioning of forms without exploring their functionality.

As a result of 'brief under development' the general goal of IDSs (environmental sustainability and Net-Zero Carbon goals) became the only concept used as the only common goal for design collaboration while the architectural students remained the sole party responsible of making decisions in terms of other design requirements. This factor also contributed to the way architectural students approached and uptake the feedback by engineering students and consultants, i.e. perceived the comments and feedback as secondary considerations that eventually were overlooked because the majority of design time and efforts were spent on experimenting with the free forms (again as a result of absence of design goal). The frequent changes of design ideas by the architects seemed to startle the engineering students and make them take a more passive role in the studio sessions.





Figures 8-9: Construction material analysis in a Zero Carbon context. Final result of project

The assessment criteria are another factor that affects the general approach in the studio settings and the contribution toward approach common goals. The designers are university students who are looking to be successful in the subject. Therefore, the assessment criteria have a major impact on their behaviour as designers. The design collaboration, integrated solutions and Net-Zero principles if included in assessment for both engineering and architecture students would make a positive impact towards achieving integrated design solutions in studio settings.

The engineering students' approach toward common design goals was not very different from engineering consultants as they also are not actively involved in design activities while their contribution is limited to solving specific problems or answering the questions that are raised by architects. Aligning the assessment criteria across both subjects that engineering and architectural students are enrolled, would define a common purpose for both cohorts and a strong incentive to collaborate to achieve those.

As much as the engineering consultants were used to following the architect's lead in the articulation of a design direction, it appeared that they at times they do not yet trust their ability to actively work on common design goals that go beyond the articulation of specific technologies. Whereas architects tend to thrive in an environment that still has undetermined outcomes, engineers tend to focus on pragmatic responses to solution findings that – at times – may limit the potential for achieving novel, and truly integrated design outcomes. In order to overcome this obstacle, each profession needs to challenge the others' way of thinking and approaching a potential solution-space. Instances of overcoming this obstacle was witnessed in IDS-05 in where innovative solutions are being developed as a result of design solutions being challenged by the structural engineering consultant.

The most interesting part of integrated design is the **realisation** of counteracting forces while trying to achieve the common goals and developing solutions that do not emerge from avoiding such conflicts, but by embracing them and confronting them full-frontal in order to find innovative outcomes. The IDS-05 process during first half of the semester has focused on aesthetic features and structural solutions for developed forms as two counteracting forces while also exploring the use of renewable energy and passive design strategies to complement Net-Zero solutions. The second half of the semester was concentrated on finalisation of core ideas, details of design and 'Net-Zero' principles during which more information on the approaches against conflicting forces were emerged. Due to the form-focused design process in which the creation of attractive forms was the primary focus in the first half of the semester, the incorporation of the required functions and service needs led to alterations in forms during the second half of the semester. While some students only had to apply minor tweaks in the existing design and achieve a somehow subtle transition, other students had to incorporate those functions as add-on features without being able to seamlessly integrate them with existing forms.

One case (see Figure 8) highlights the tension between functional/aesthetics and environmental solutions: The architect believed that the marked area could be a plaza while the ESD consultants indicated that the area would be a great position for solar panels. They negotiated on whether they can combine those tow ideas to create an innovative solution.

Figure 10: Live marking-up of drawings online, to negotiate environmental and functional design input

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

The feedback from the key contributors of IDS-05 were captured via an online face-to-face interview process. Four industry consultants, the client representative and the studio tutor participated in the interviews. The interviewees were asked about the key drivers, as well as barriers to achieve integrated design, their opinion on the studio brief, the nature of their contribution, and their general feedback on the usefulness of integrated design studios and the areas for improvement.

Enablers of integrated design:

The interviewees outlined the important steps to achieving a truly integrated design in studio settings. It was pointed out that a **structured process** in an important enabler of integrated design. This process should start with an established brief to which the designers should go back at various intervals in the process. Identifying gates or intervals with checklists acting as milestones can facilitate a more structured process with better visibility of the design progress as well as performance. Consultants also raised the point that having a more **performance focused brief with target sets** (or set points) can help with a clearer communication of design requirements, which as a result would lead to a more purposeful and target-driven design approach. One other enabler outlined by the interviewees is the **early briefing sessions to provide details to both engineering and architecture students about what is required from each cohort.** This could lead to better definition of roles and responsibilities in the studio and balance the contribution loads by both groups.

Figure 11: Gordon Hon Chun Hin – Final project exterior

Process of design collaboration:

On the other hand, the interviewees highlighted the issue about engagement of engineering students and the fact that the structure to involve the engineering students was not optimal. They believed engineering students could have offered a lot of help on structural design issues, selection of materials and low carbon structural design. If involved in the initial design conversations, they would come up with some suggestions and ideas that could be discussed and negotiated with architects. Some consultants suggested that a session directly with engineering students early on, would be beneficial to identify potential areas of contribution as well as providing guidance.

To improve peer-to peer collaboration, it was raised that workshop sessions with a mix of engineering and architectural students in which they were tasked with investigating a certain topic such a sustainability rating tool could be helpful:

‘We've got to give them something to talk about something tangible enough to focus their minds on. Because they are coming from two very different cultural perspectives. If we’d had a good workshopping process, in small groups, the architecture students may have not gone down so many rabbit holes. And the same time the engineering students might have been pushed, because they might have had to think about the engineering structural dimensions of innovative different shapes and structures and materials that would have been their job to find out about some of those sorts of things to inform how you could do the impossible’. Alan Pears-Sustainability Consultant

The interviewees commented on the nature of their contribution throughout the studios. Some consultants described their contribution as review, correct and challenge their designs while also providing advice on structure, spatial allowances, economics, and operation as well as technical aspects. Others outlined that they attempted to uplift the student’s knowledge by educating them on the mechanics behind heat pumps and energy transfer while also providing them with practical tools to calculate the energy demand and size of heat pumps. They also pointed out that while some aspects of their inputs were proved effective, the students did not use or implement some other inputs provided by the consultants.

“design was dominated by the students architectural inputs, rather than listening to client requirements and sustainability requirements and structural requirements, that was done by review, rather than collaborative design, which you might expect in an integrated design studio”. Damon Moloney – Sustainability Consultant

“*I did struggle to work out how I was going to be useful. I did produce a spreadsheet tool, which was meant to help them. I suspect none of them used that tool. ...There were two or three of the architecture students who did pick up on materials that I suggested and concepts that I was floating in response...I did actually find it quite difficult to feel like I was making much of a contribution”*. *Alan Pears - Sustainability Consultant*

The consultants outlined that being more prescriptive about the metrics of performance e.g. energy performance, window-to-wall ratio, etc. to be met by design, could help with better incorporation of the engineering and sustainability aspects in the designs. This could be linked to the idea of having a performance-focused brief to communicate the target sets from the front end.

The studio leader described that is contribution was through making students rethink the process of design and enable them to look at the design from various perspectives. He recommended to consider various requirements or elements of the design on in a time “*maybe look at it from a timber structure point of view one day, maybe from heat pumps another day*“ and see how they can create interesting architectural design by using those elements.

“I think I was hoping just to get through this idea that we can do these things and still be creative about it. It doesn't mean that we all have make everything depressed with boring spaces. It's trying to get them to realize that we can work with most of those set of relations and still do something that is inspiring.” Toby Reed – Studio Leader

Design development experience:

The interviewees also provided feedback on the important decision-making points in the process of integrated design. They pointed out that due to the energy-extensiveness of the Aquatic centre facilities, the energy use and onsite energy production through both active and passive strategies was an important criterion for decision-making. Also, the spatial requirements and structural solutions to cover the large span were other important considerations.

In terms of the process of balancing aesthetic and functional aspects to drive sustainable outcomes the interviewees opinions were controversary. A number of interviewees believed that the design tended to be dominated by architectural and aesthetic priorities and the designers either shoehorned the engineering requirements into their preconceived architectural plan through making minor adjustments or ignored the recommendations.

"We came up with that broad range of PV areas and I reckon at least half of the students didn't meet that basic criterion”. Alan Pears - Sustainability Consultant

Figure 12: Gordon Hon Chun Hin – Final project interior

According to studio leader in response to the consultant's comments on incorporate certain sustainable design features in design, different approaches were taken by different students. For instance, one student had designed the building in the form of large flower shapes and was planning to place solar panel on the roof. Although studio leader suggested to use grids to assure solar panels would look good on those shapes. However, the student resisted to do so.

> *'Architecture students take a long time to learn some very basic ideas. It's quite complex learning this whole 3d spatial design. Yet, especially when we integrate architecture structure, planning and urban design, all these different factors and also stylistic result, they find it quite complex takes a long time to learn. And so usually you tell them something like, you're gonna have three and a half 1000 square meters minimum of solar panels. And they'll think, yes, okay, but I'll deal with that later because everything else is so hard. You know, because there's so many things they're trying to juggle at once.' Toby Reed – Studio Leader*

Another student on the other hand, took the basic element of solar panel, and explored to make architecture out of that. He used the idea of solar farm, as an urban gesture, created skylights with spaces with them.

> *'And so I think they're two different responses. One is where you try to design that kind of accommodates the technology. Or the other one is where you get the technology and you mold it in a way that actually you don't have to mutate, or change the technology you just use it already made, but you actually use it in really artistic way, And I think I think that's a better system' Toby Reed – Studio Leader*

Other interviewees advocated that the design drivers were not merely aesthetic, and the students did successfully take on board the recommendations by the consulting engineers for example in regard to low-emission structural system by using timber, onsite energy production and green facades. As for the inspiration sources example international architectural designs and aesthetically appealing forms were mentioned as the main source driving the design decisions while other sources such as landscape and nature were also mentioned by the consultants. The engineering and sustainability requirements were not found to be inspiration sources for the students during IDS-05. Some consultants pointed out that certain students were quite proactive in integrating various perspectives of design while others struggled with this integration.

The consultants were unanimous in the idea that the timing of collaboration and providing individual guidance was sufficient. Some consultants pointed out that having certain intervals throughout the semester to set milestones for design outcomes could enable a more structured process. They also highlighted the importance of spending more time on workshop type activities as well as one-on-one sessions early on in the semester. Also, the consultants pointed out on the importance of equal time and quality of input provided to all students:

> *“I think it (timing) worked reasonably well. They got plenty of input from some quite experienced people every week. There were a couple of architecture students whose somewhat hogged the attention and a couple who didn't put themselves forward as much and get as much time. So maybe we could have better balanced some of that and make sure that it didn't go in the same order every week”. Barry Roben – Structural Engineering Consultant*

Areas of struggle:

As outlined by the consultants, the architectural students struggled with basic knowledge around building physics. As such they pointed out that educating architectural students on some essentials of building physics would positively affect their design decision-making. According to the consultants, the architects’ creativity in developing forms would not be constrained by this education but rather be nurtured. Developing some level of understanding of those principles would also equip the architects with the insight on what questions to ask or what information to demand from the engineers.

> *‘I'm not sure that the architecture students were very clear about what they wanted from the engineering students, or what the engineering students could even offer them’. Alan Pears*

The consultants also provided comments on the optimal methods of conveying the knowledge to students:

> *‘I think next time we need to work out what everyone understands and make the information general enough for people to understand, otherwise, you've lost them in the first hour... And then once we get them to that level, we let them loose on to designing elements and all the rest’. Derek Harbison – Sustainability Consultant*

Another struggle area identified by the consultants was the ability to integrate the architectural components in a seamless of subtle manner. They described some of the designs as ‘*fairly brutal*’ or ‘*kind of overdone*’. Another struggle area was the fact that the design considerations in the initial stages did not reflect clarity on the engineering sustainability requirements. This led to development of the forms before incorporation of the engineering systems and sustainable design strategies. As a result, those features were retrofitted later on as the add-on components that did not always agree seamlessly integrate with the existing forms.

Design outcomes:

The interviewees also provided feedback on the design outcomes. The interviewees believed that most of the students were successful in advancing their design thinking and evolve the design (some even to high standards) to incorporate the requirements from multiple disciplines. They were also impressed by the fact that the students applied various engineering systems such as solar panels, hydropower, rooftop gardens, etc. Part of interviewees believed that some final solutions did not completely demonstrate the proof of carbon neutrality and future-readiness, while also outlining the lack of quantitative analysis as an issue in IDS-05. Lack of enough focus on user experience was also raised as an issue in some final design solutions.

> *“some students had a PV contribution, but there was never really any verification that this was an actual kind of carbon neutral or net zero energy design. No one really did a good analysis of those energy balances. So, I felt like when the end goal was to look at future concepts for aquatic centers it didn't quite achieve that.”*

The consultants also expressed their positive thoughts on the ability of the new generation of designers to develop creative design ideas not only in developing beautiful forms but also innovative solutions to improve performance.

> *‘’Some of the ideas some of those people bought into the pool design was inspiring’ Derek Harbison - Sustainability consultant*

> *‘it's amazing for me to see, what these designers can produce. And the ideas that they come up with is really inspiring. The students should feel that they're, doing extremely well, and producing work that can't be produced by just anyone, or that although we as engineers, and consultants have experience in design inputs they're still doing things that we can't do.’ Damon Moloney – Sustainability consultant*

Definition of integrated design:

The interviewees were asked to provide their definition of integrated design. Some defined integrated design as a '*structured process to jointly explore the dimensions of the project, and map out their potential roles, and how they fit together and then implemented as a team*'. It was also described as '*A multi-dimensional and multi criteria approach which is not necessarily about being incremental'.* Integrated design also was defined as reprioritizing sustainability and energy flow in the building as your primary design criteria. Collaboration, open-mindedness, creativity and common goals were among the keywords used by interviewees for describing integrated design:

> *'Open minded creative designers in all disciplines coming together with the sole aim of ensuring that the client gets the best solution, not ensuring that their ego gets memorialized in a building that wins awards. Not to ensure that they make the most possible profit on delivering the simplest possible solution. But they come together to properly in an open mind and holistic way to properly consider what is the best way to spend the client's money.' Barry Roben – Structural Engineering Consultant*

Barriers:

The interviewees provided input on what they thought are barries to integrated design both in the context of IDS-05 and in general. Different course structure between engineering and architecture students was pointed out as a barrier to collaboration within studios. Online delivery and the inability to meet in person was identified as an important barrier to collaboration.

> *'I think we were quite limited by not being able to sit and sketch and draw and illustrate. Just trying to describe things across zoom was less helpful than it would have been if I'd had a shade of yellow trace and a big fat marker.' Barry Roben – Structural Engineering Consultant*

According to interviewees, outside the actual design process, the constraints identified included time, fees and being spread thin on multiple projects. The interviewees also reported the issue of difference in culture and way of thinking among architectures and engineers. They pointed out that the engineers looked for a fairly specific brief to respond to in a narrow practical way while they also tend to provide solutions that are familiar to them rather than exploring innovative ways of tackling with design problems. Another cultural issue identifies was around the separation of architectural and engineering zones or phases in in common design processes, in which the engineers are normally not involved in early design conversations and join later once certain design aspects are established.

> 'That's *what's happening in the industry. So we're actually seeing that divergence. And this is what happens, the designers start the process, and the engineers get it get board in about the second or third stage. we watched what happens in a normal build process. And how do I overcome that is not simple.' Derek Harbison-Sustainability Consultant*

Furthermore, the attitude of architects and engineers was identified as a cultural issue which constraints collaboration:

> *'There is a bad attitude among some architects and a bad attitude among some engineers. There are engineers who can't be bothered trying to innovate and make hard things work. So, they just want to show that the same solution every time. And also on the other side, there are architects who just have absolutely no interest, pay lip service to the whole idea. And at end of the day, it comes down to just whatever they want it to look like which is going to get built. Doesn't matter what it costs to the client, how it could be done better'. Barry Roben – Structural Engineering Consultant*

Usefulness of the studios:

The interviewees outlined the studios has raised the level of understanding in students on the requirements of environmentally sustainable design features and various design elements that contribute to sustainability-focused outcomes. Also, the studios were helpful in providing the opportunity to students to look at the projects from an outcome and performance-oriented point of view. They also raise the idea some positive impacts of the studio may not be visible immediately, but will affect the understanding and behaviour of the young designers.

'even the people we perceive as not understanding or getting benefit from it, you just don't know the effect that it has on them. I mean, you put Alan Pears is and Barry and a few of these other people in the room, Toby, with these students, good things happen, because you know, they know their stuff'. Derek Harbison – Sustainability Consultant

'the benefit of it is that if we're really trying to change the industry and change the way projects are delivered in the future, this is where it needs to start'. Amna Abdalla – Client Representative

All interviewees were unanimous in the idea that the integrated design studios are useful for students and should be an integral part of higher education degrees for both engineering and architectural students. They outlined that the studios provide the students with a real-life experience and an environment that they may come across later on in their careers.

The interviewees also pointed out that the studios were useful for them personally:

> *I'm very grateful, even at this stage of my career to be involved in that project, because I did learn a lot. And it did open my eyes to, a lot of areas where we were blinded to before... it's also informing the client, on the importance of including the engineers from early stages' Amna Abdalla – Client Representative*
>
> *'Professionally, I've learned. I apply so much from what I was hearing from those students. As when I'm talking to engineers as what not to do, and designers and what not to do.' Derek Harbison – Sustainability Consultant*

4.3 Feedback from the participating students

There was a mixed level of environmental design experience among students who attended this class (median score 2.75). There was no particular trend detectable in terms of prior knowledge, but rather an indication that everyone's experience seemed to differ.

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

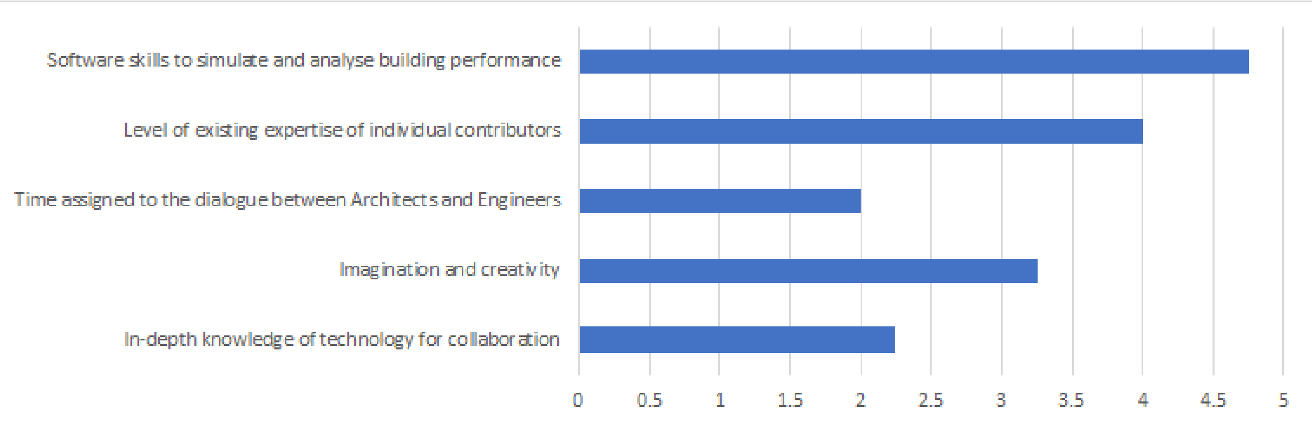


Figure 13: Key design-drivers affecting successful environmental design (with smaller numbers ranking higher)

With a median score of 4.5 (out of 5), the vast majority of participants felt that the client's brief supported them in achieving a balance between architectural and engineering design. Asked about the impact the brief had, and the way it was written/communicated, most students seemed to appreciate its configuration as one student sums up: *The brief was well written and benefitted my project. It was communicated in a consistent and thorough way throughout the semester - it was made clear the aspects we should focus on eg. the Zero-carbon loop as a concept*

Prompted about the most critical decision-making points when balancing architect/engineer input for generating environmentally optimised design solutions, students listed using: *existing technology to improve the performance of buildings,* as well as *the use of glazing, environmentally conscious material selection, floor-to-floor heights to control the pool room temperature, and devising various energy inputs and their relationship to the Zero-carbon loop in the building.*

The inspiration for School refurbishments were broad and varied. Overall, students listed *precedent studies, expertise from consultants and own research as key factors.* One student argued: *the engineer consultants were extremely gracious and helpful in giving their time and interest into our projects. They provided us with a level of consultancy that is not seen traditionally in our university studies. The consultants, consistently gave us personalised feedback with which we could edge our projects closer to reality, which was an invaluable experience*.

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

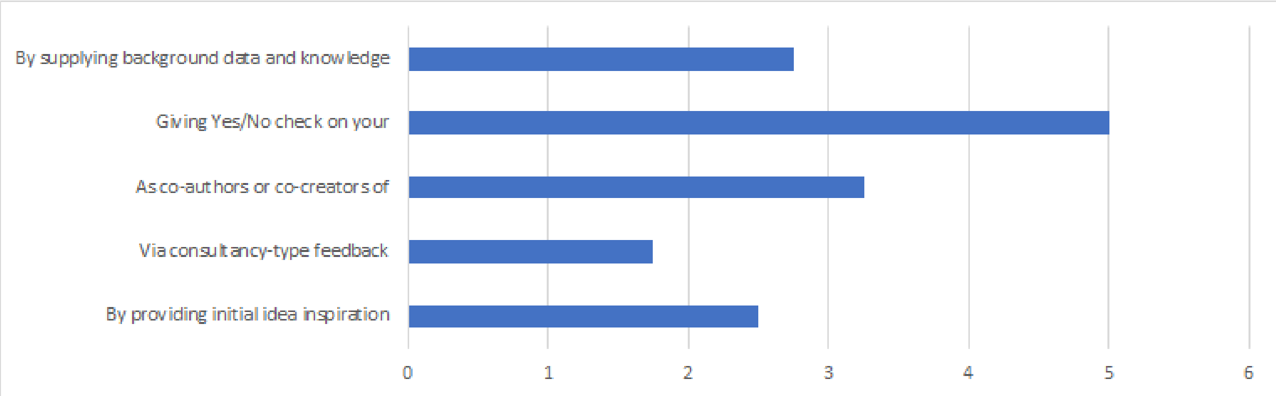


Figure 14: Reflection on input provided by the Engineering Consultants (with smaller numbers ranking higher)

Asked about the most useful guidance by the consultants, students referred to professional technical guidance by: *grounding the design to ensure that the outcome was more realistic, and providing expertise on materials and energy.* In consideration of guidance received specific to Aquatic Centre design, one student explains: *maintaining pool temperatures but doing various things with the space (eg, materials, lack of glazing, ceiling heights, room sizes, programming according to function to reduce temperature differentials). This guidance was most useful to me as it gave my project a realistic dimension - I was able to see the path from design concept into more of the 'negotiation' process that is involved with the various consultants getting a real project made.*

With a median score of 4.75 (out of 5), nearly all students argued that the input by consultants strongly increased their 'level of understanding of' environmental issues and associated solutions.

Students expressed their desire to spend more time with the consultants via face-to-face meetings (not possible due to COVID-19 restrictions), and they suggested adopting clearer guidelines for students on *how to use consultants and integrate their advice into our projects.*

A critical voice commented that the client feedback at times seemed to aim too much to achieving highly practical solutions that – at the same time – would not include strong design ideas and innovation.

For this iteration of the IDS, students pointed towards the potential for further fine-tuning the collaboration between architecture and engineering students. They rated the quality of collaboration 3 points out of 5 (with 1 being best and 5 being worst).

One student reported: *for my group, my engineering student was unavailable to meet when we needed to do our task. Possibly there could be a longer group project with an engineering student, although I'm not sure how this would work. The engineering students' presentation to us eagerly in the semester about the sites bearing capacities etc. was quite informative and useful. However, I think their involvement was phased out a bit as the semester progressed.*

In IDS-05, students did feel that they had to compromise aesthetics and functional design aspects when balancing architectural and engineering concerns (median score 3.5 - with 2.5 meaning '*neither-nor*'). Hence, in this IDS, we see a strong bias of students feeling that the performance focus impacted the design aesthetics of their project outcome. Three quarter of the respondents said it did so *'quite a bit'*, with one quarter responding: *'rather not'*. One student argued this could be avoided: *through the communication between architects and engineers at the beginning of the project.*

Another student put this into perspective by saying: *Often there was not enough friction between the designers and engineers to create more viable solutions.*

Despite the overall positive feedback about the IDS, students also reported several challenges when advancing their design-thinking with environmental/engineering constraints in mind, listing: '*Time-constraints on projects*', '*Education in isolation'*, and their *'Inability to define joint goals'* as the main obstacles.

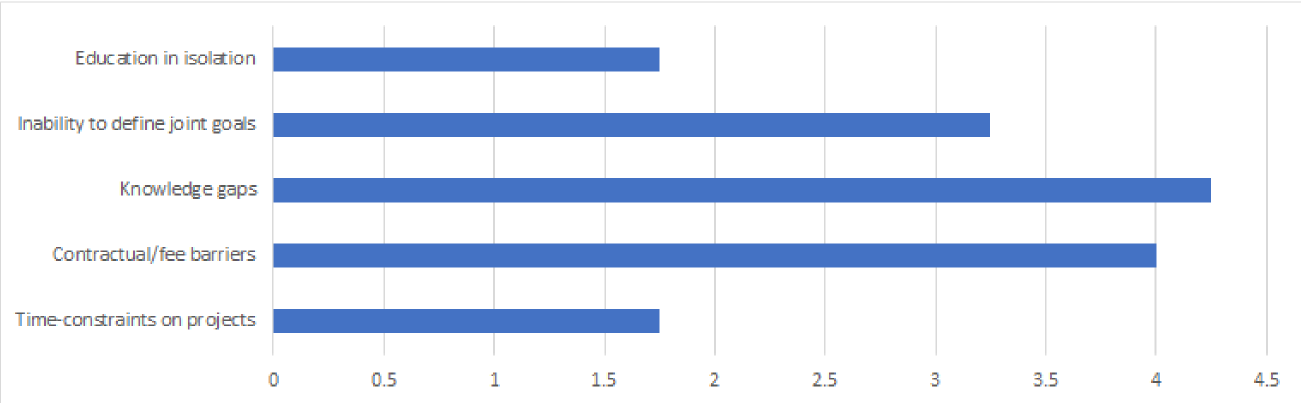


Figure 15: Challenges reported by the students. (with smaller numbers ranking higher)

Some of the additional struggles reported by the students related to balancing t*he performance of the building with the comfort of the building*, *how to refine the work*, or the choices to make based on the ideas presented by the consultants.

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

- An opportunity to have class with experienced consultants on board,
- A great multidisciplinary communication platform, or
- A more realistic representation of an interdisciplinary mode of thinking in regard to environmental design.

The question about the usefulness of learning about integrated design processes as part of their university education, elicited a highly positive response, with one three quarters saying was 'extremely useful' and the rest attesting it to be 'quite useful'. (median score: 4.75 out of 5).

5. STUDIO DESIGN OUTPUT - Select Examples

A select number of student projects (3) have been taken further by the Engineering Consultants (WSP & a group of Aquatic Centre specialist) in order to consolidate feedback and extract some key data. The following two sections summarise information contained in WSP's consolidation/vetting document. The full 27-page document can be found as an appendix to this document.

The scope of the students' proposition has largely related to energy efficiency and carbon reduction, since the Zero carbon target had been introduced to them as a key part of their brief that they had to investigate.

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

- Part naturally heated outdoor pool
- Solar PV Panels.
- Hydro botanic filter pond.
- Piezoelectric Pad
- Timber Structure (more rapidly renewable)
- Polycarbonate Façade with a weaving texture of 60% opaque and 40% opaque sheets. This has improved qualities than glass, such as improved heat retention and enabling more daylighting.

5.1 Passive Measures

Some of the initiatives introduced by the students were progressive or innovative and provided some new ways of thinking about and designing aquatic centres. Next to common approaches to introducing passive design measures, students also went down innovative paths by (for example):

- Introducing new activities to and features to complement the aquatics facility including ice-cream parlour, outdoor cinema, speciality shopping.
- Incorporation of green spaces including green roofs and pocket parks. These allow visitors to relax and enjoy an outdoor experience.

Figure 16: Phoebe Maguire – Final Project exterior

The following initiatives were proposed (among others):

- Orientation to capture passive solar radiation while excluding peak summer sun,
- Exposed external pools to capture solar radiation,
- Insulation within the building envelope, for the floors, walls and roof,
- Judicious rationalisation of glazing extent to balance natural daylighting while minimising heat transfer,
- The use of green roofs and planting elements to provide natural insulation,
- Thermal mass inside the building to help stabilise and moderate internal temperatures.

5.2 Active Measures

The active measures proposed were more varied across the board, as more broad opportunities exist. Many of the students encapsulated best practice initiatives. Solar PV was incorporated into the designs in interesting ways and other alternatives were explored including hydro power, geothermal technologies and piezoelectric systems.

Figure 17: Tingjun Bai - Solar PV shades

The following initiatives were proposed (among others):

- LED lighting.
- Rooftop Solar PV.
- Rainwater Harvesting.
- Electric heat Pump.
- Hydro-botanic filter pond.
- Microinverter technology to harvest energy from gym equipment.
- Piezoelectric energy system harvesting energy from foot traffic.
- Solar PV as shade structures

6. SUMMARY OF CONSULTANT VETTING – Performance relative to BAU

6.1 Present: Existing Opportunities

It is common to carefully consider thermal zoning within an Aquatic Centre and to ensure separation of wet zones and dry zones as well as those that require 24/7 operation and air conditioning. Typically, there is significant design work undertaken to option the thermal envelope including:

- Rationalisation of vision glazing to balance natural daylighting without compromising energy losses which are much greater from glazed elements than from insulated wall elements.
- Orientation of vision glazing is particularly crucial as this can lead to opportunities for natural solar heat gains.
- Building sealing is also crucial to the performance of the building envelope in order to minimise heat loses associated with air infiltration. Sealing works can include architectural detailing verified through performance testing.

6.2 Future: New Build

Students within the design studio were given the task of designing a sustainable Net zero Aquatic Centre in the St Kilda Triangle project site in Melbourne. All feasible opportunities for minimising the project carbon footprint and energy usage had to be analysed, encompassing all possible on-site and off-site active and passive solutions.

This site would then serve as a prototype for experimentation into Zero carbon projects in other suburban areas. The design had to be an attraction not just for one singular end use as a swimming pool, but as a community hub. It had to include an indoor and outdoor swimming pool, a diving pool, café and gym, a park and rentable offices or shops to diversify the social and economic potential of the site.

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

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

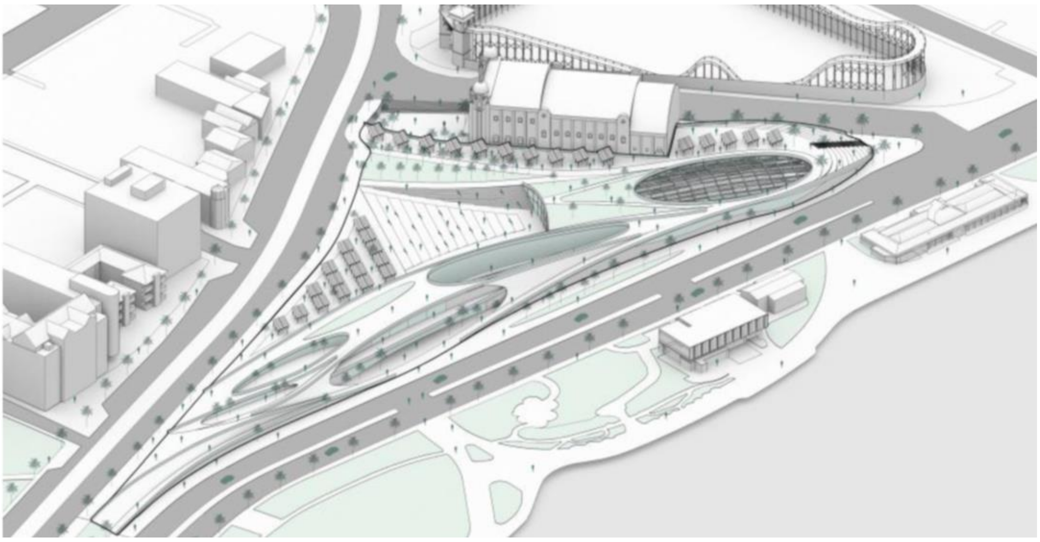


Figure 18: Gordon Hon Chun Hin, Aquatic Centre Proposal

6.3 Baseline vs Best Practice

Industry best practice varies between Australian states, this is reflective of the types of climate that aquatic facilities are designed for. Through further review of the student work, some key indicators were determined to compare a baseline design to a likely best practice outcome.

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.

Figure 19: Extract from WSP Baseline vs Industry Best Practice Study

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

6.4 Key findings

While much of the student work focused on form and building character there was also some work undertaken to develop solutions for solar photovoltaic systems and in some cases to showcase these as part the building form and aesthetics.

In vetting the student results and looking at alternatives to BAU, WSP and their colleagues assess that with an extensive solar PV array on an Aquatic Centre, along with a very efficient building envelope and carefully designed low-energy systems for mechanical services and pool filtration, it is possible to at least set a budget for annual energy consumption based on the contribution of solar PV on site.

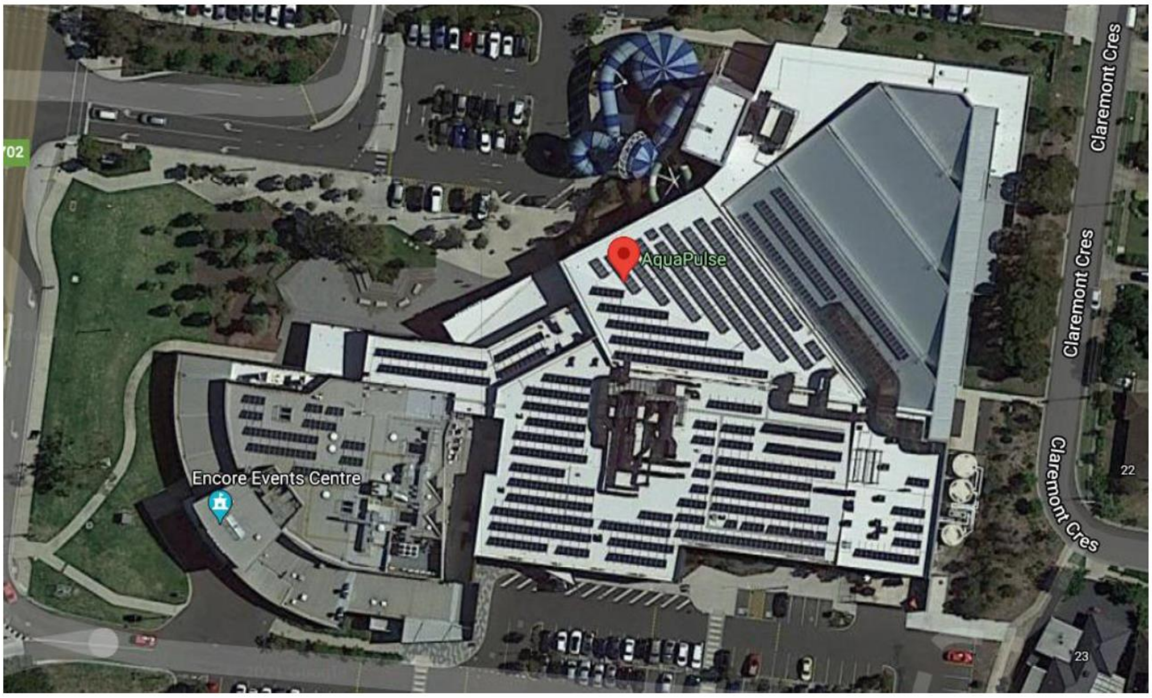


Figure 20: Example of rooftop solar PV array on Wyndham Aqua Pulse

An array of high-performance solar panels at 400-440W per panel with a roof spatial utilisation of around 65% allowing for panel access space, offsets from edges and miscellaneous obstructions, the total system output is likely to be of the order of 175-200 kWh/m2 pa of gross roof area.

7. CONCLUSIONS

7.1 Conclusions and Next Steps

Approximately one dozen individual Aquatic Centre projects were worked on as part of IDS-05, with each investigating novel concepts to complement the brief under development and the additional exciting features that benefit the public and environment. Students from both architecture and engineering background enjoyed expert input from both the industry consultants, but also the client representatives who all combine extensive knowledge in the design of such centres.

As part of their design process, students investigated low carbon design solutions, such as solar-efficient building forms and they developed their projects with thermal zoning in mind. On one hand projects explored opportunities for passive heating as well as the application of renewable energy supplies.

Most of the solutions investigated by the students focused on passive measures (e.g. orientation, material selection, insulation) to reach Net Carbon, but some mechanical/electrical systems (such as electric heat pumps. Hydro-botanic filter ponds, or solar PV) and managed to consolidate the inclusion of these measures with the aesthetics of their design.

The integrated design process was seen by students as a revelation in terms of how their design thinking can be influenced by environmental performance constraints. With the absence of the use of a dedicated tool for ESD analysis, most designs tackled environmental issues from a high-level/ master-planning view. The collaboration between architecture and engineering students worked well at the outset of the semester, but lost momentum towards its end. This likely has to do with the requirements to teach classes online, as well as a mismatch in expectations between architecture and engineering output and assessment. These are lessons learned to weave into any future IDS.

After the final project submission/presentation, the industry consultants engaged in a vetting process to extract the essence of the most innovative concepts to then add more articulation around those. In parallel, the UoM academics gathered feedback from all project participants about the effectiveness and quality of the integrated design process, in order to feed back this information into this 100% complete IDS-05 outcomes report.

APPENDIX A – Engineering Consultant Vetting Report

APPENDIX B – Student Work

Design Studio Outcomes

IDS-05

APPENDIX A

ENGINEERING CONSULTANT VETTING REPORT

UNIVERSITY OF MELBOURNE

I-HUB DESIGN STUDIO

ZERO CARBON AQUATIC CENTRES

APRIL2021

Question today

Imagine tomorrow

Create for the future

I-Hub IDS
Zero Carbon Aquatic Centres

University of Melbourne

WSP
Level 15, 28 Freshwater Place
Southbank, VIC, 3006

REV	DATE	DETAILS
0	Mar 2021	Issue for review
1	Apr 2021	Revisions and inputs from other consultants

	NAME	DATE
Prepared by:	Damon Moloney	Apr 2021
Reviewed by:	Barry Roben	Apr 2021
Approved by:	Barry Roben	Apr 2021

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TABLE OF CONTENTS

1 OVERVIEW

The I-Hub Integrated Design Studio (IDS) tests an integrated design approach to examine zero carbon strategies for a sustainable aquatic centre in St Kilda, Melbourne. This ideation approach created a selection of sustainable solutions, both passive and active as well as on-site renewables, to enable a net zero carbon operation.

This report summarises the vetting process that has been done after the conclusion of the studios, to come to informed conclusions for the optimal sustainability strategy of the construction of carbon zero aquatic centres around Melbourne.

Cover page image by Gordon Hon Chun Hin, University of Melbourne.

Opening page image by Tingjun Bai, University of Melbourne

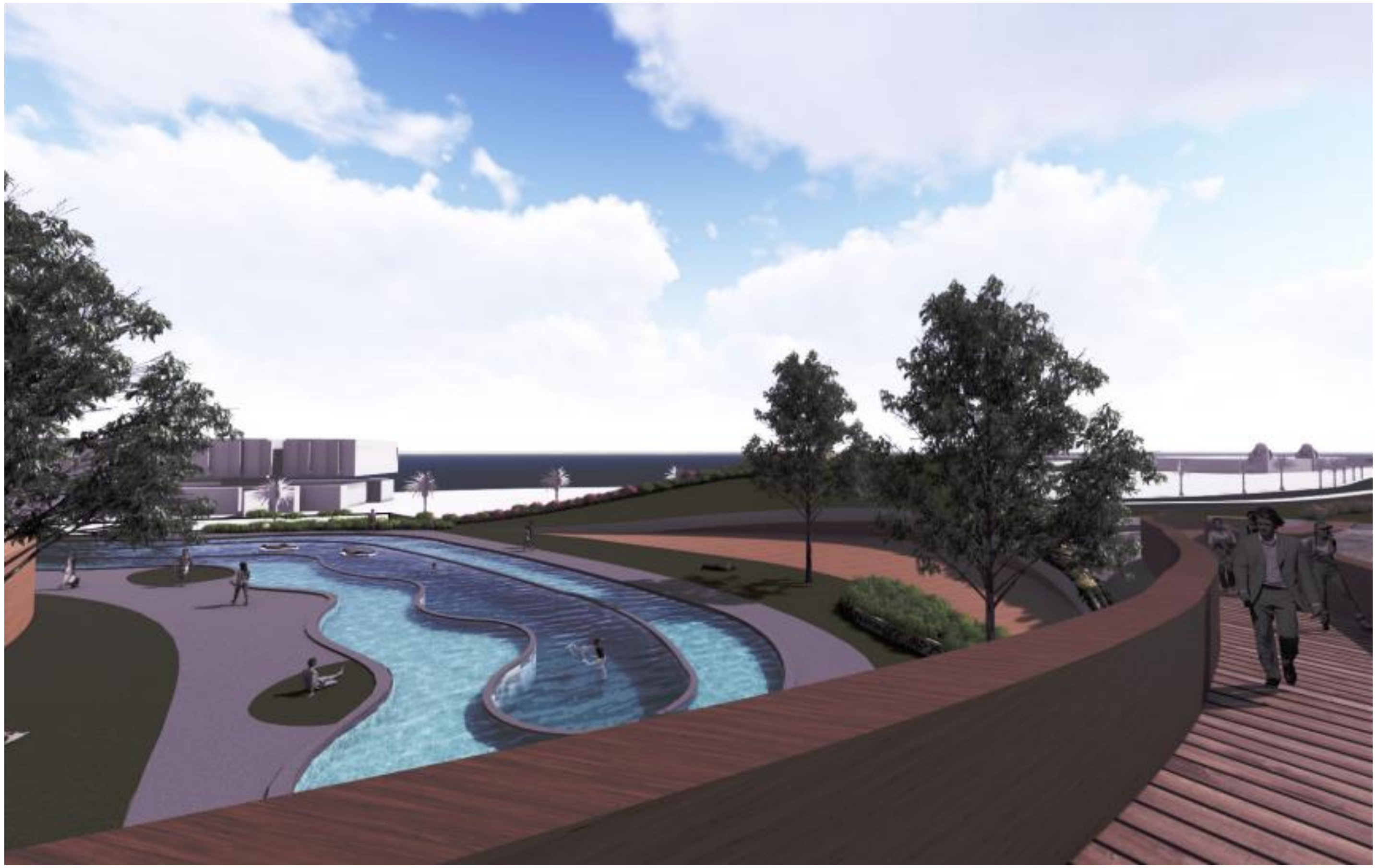
Image by Phoebe Maguire, University of Melbourne

2 INTRODUCTION

2.1 NET ZERO AQUATIC CENTRES

I-Hub is a program run by the Australian Institute of Refrigeration, Air Conditioning and Heating (AIRAH) alongside the University of Melbourne and supported by the Australian Renewable Energy Agency (ARENA). The Integrated Design Studios are a part of this initiative, producing innovative solutions to achieving net zero carbon on complex design projects.

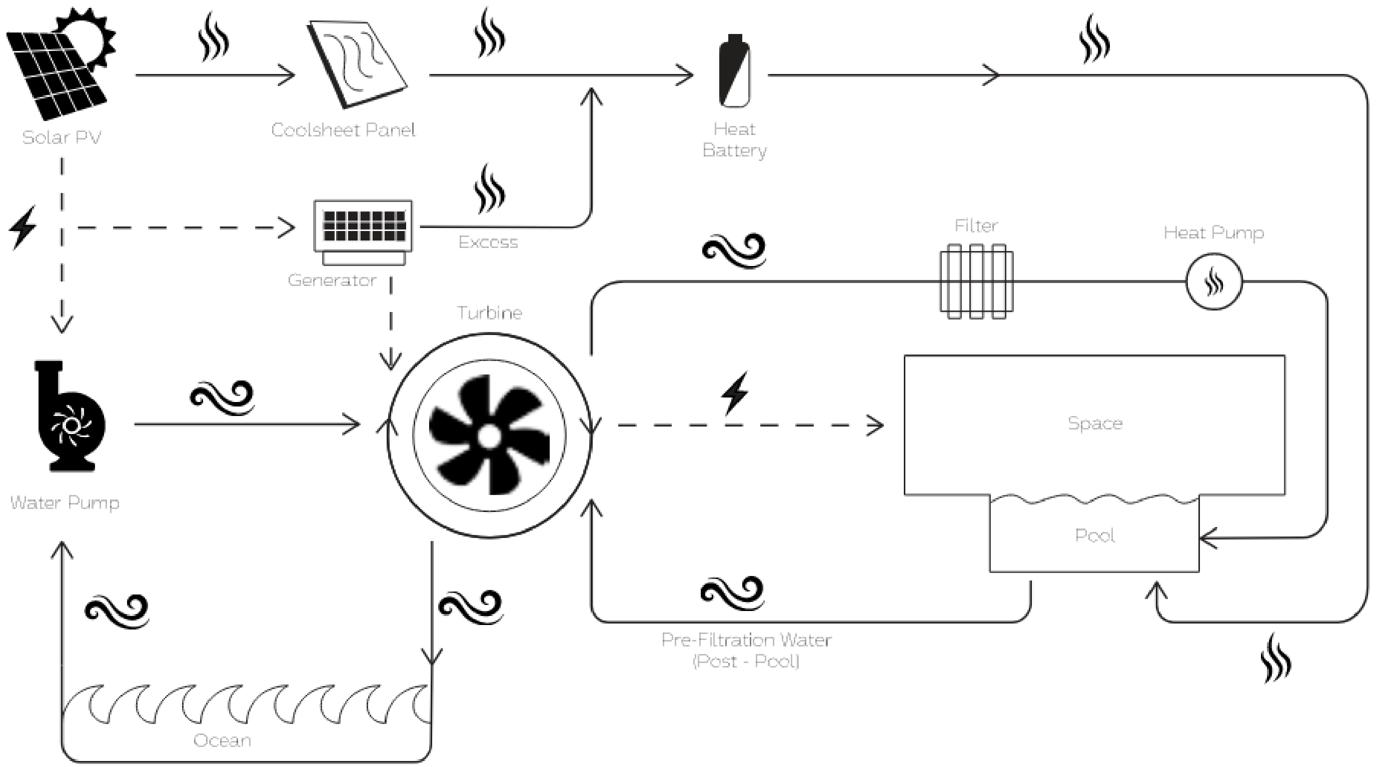
Students within the Melbourne University design studio were given the task of designing a sustainable net zero aquatic centre in the St Kilda Triangle project site in Melbourne. All feasible opportunities for minimising the project carbon footprint and energy usage had to be analysed, encompassing all possible on-site and off-site active and passive



solutions. This site would then serve as a prototype for experimentation into zero carbon projects in other suburban areas. The design had to be an attraction not just for one singular end use as a swimming pool, but as a community hub. It had to include an indoor and outdoor swimming pool, a diving pool, café and gym, a park and rentable offices or shops to diversify the social and economic potential of the site.

2.1.1 NET ZERO CARBON

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



3 STUDIO SUMMARY

This section provides a summary of the Integrated Design Studios completed by University of Melbourne students. It includes a closer review of three of the student IDS for the proposed St Kilda Triangle aquatic centre.

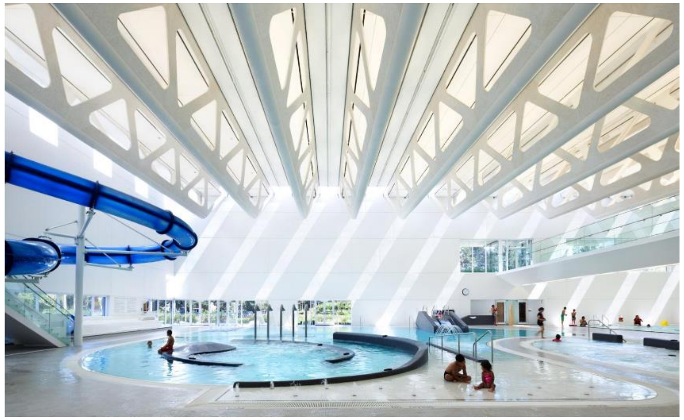
Overview of step by step process that students went through:

○ Each week, the students were given a brief to work on to guide their ideas and consequently their evolving design through to a finished concept.

○ Early parts of the design studio included inputs from the consultant panel on energy consumption, water consumption, typical efficiency measures, maintenance issues and construction techniques for aquatic centres.

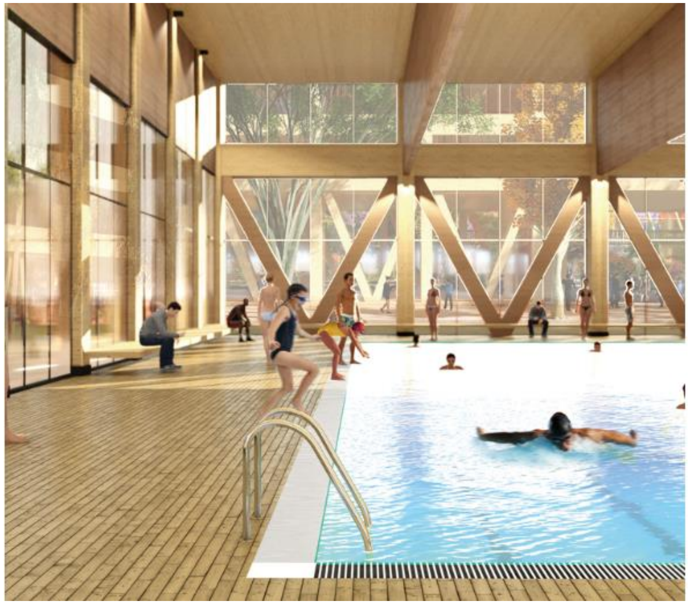
○ Further development continued to include considerations of structure and choice of materials as well as some calculation of the potential contribution from solar PV to the expected site loads

○ Along the way students reviewed precedent projects including exemplar aquatic centres and timber shell building forms

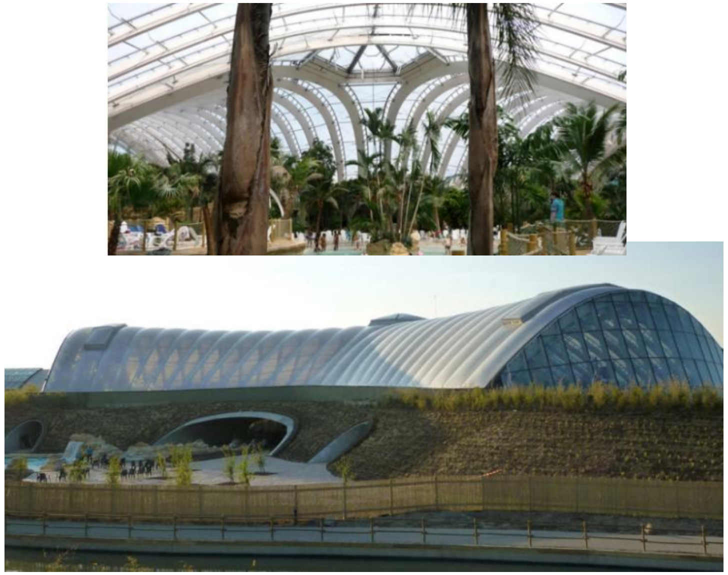


Students citing precedent of Guildford aquatic centre

Students citing precedent of Italian Convention Centre



Students citing precedent of Xiong An Community Centre



Students citing precedent of Aquamundo, Centre Parcs Moselle

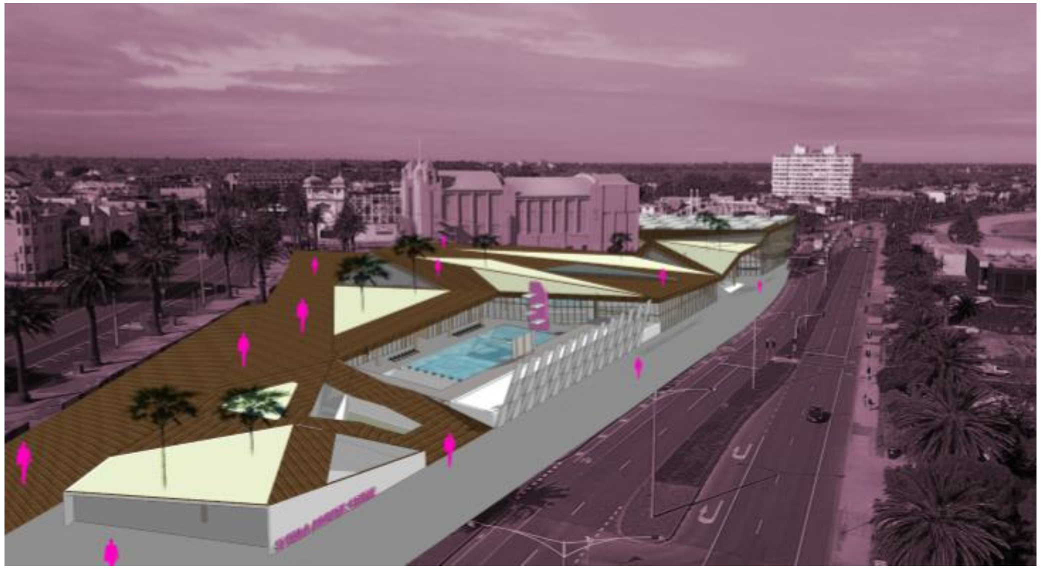
4 STUDENT PROPOSALS

4.1 PROJECT PROPOSAL: HAZIQ AZIZUL RAHMAN

Discussion and description

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

- Part naturally heated outdoor pool
- Solar PV Panels.
- Hydro botanic filter pond.
- Piezoelectric Pad
- Timber Structure (more rapidly renewable)
- Polycarbonate Façade with a weaving texture of 60% opaque and 40% opaque sheets. This has improved qualities than glass, such as improved heat retention and enabling more daylighting.



Design by: Haziq Azul Rahman, Melbourne University

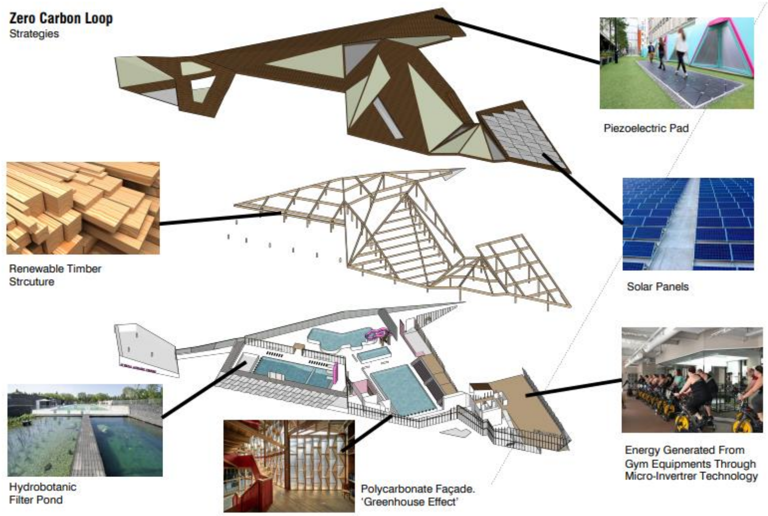


Image by: Haziq Azul Rahman, Melbourne University

4.2 PROJECT PROPOSAL: BILLY DONG

To achieve a zero-carbon outcome, this design proposal includes carefully selected features:

- Solar PV Panels.
- Carbon neutral timber roof to decrease the amount of steel and concrete used. Concrete used onsite is also selected as pre-cast “Solidia concrete” or equivalent which is 70% less carbon intensive than ordinary concrete. This is achieved through reduced energy in the kiln firing process and through sequestration using Co2 in the curing process.
- Polycarbonate is used to increase daylighting and insulation as an enhanced alternative to double glazing.
- Onsite aquatic life used to filter grey water to provide less harsh chemicals in water, including natural water filters like oysters.
- Kelp forests grown onsite for carbon sequestration.
- Heat pump to draw heat from buildings on site and aid in cooling underground storage facilities without creating a high demand for energy.

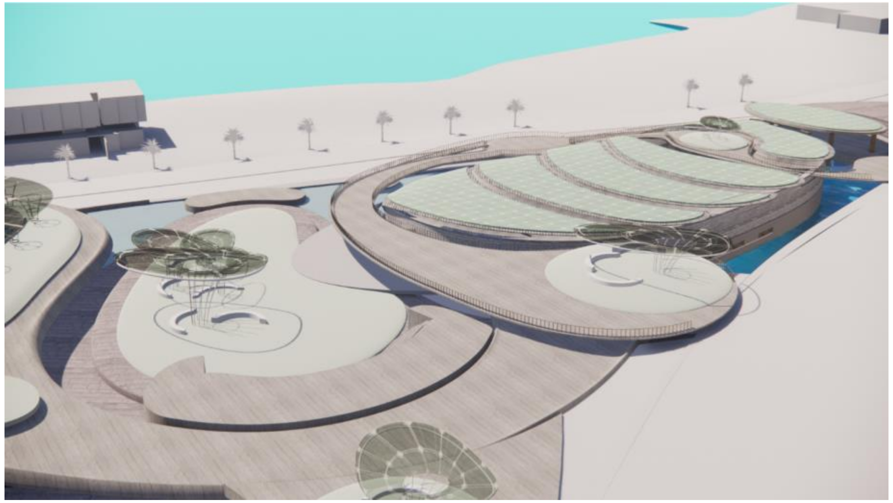


Image by Billy Dong, Melbourne University

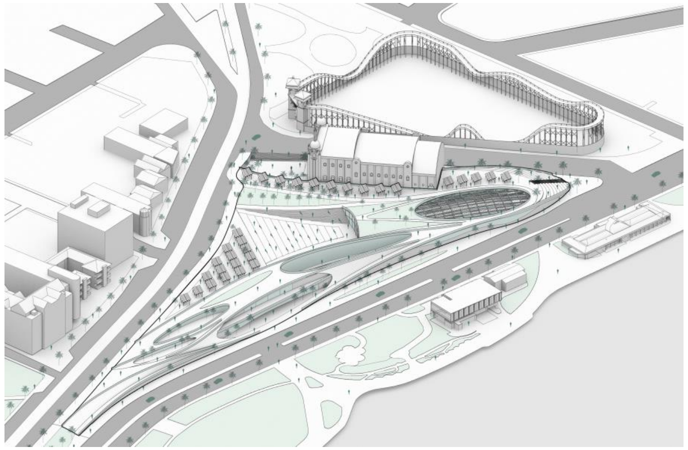
Image by Billy Dong, Melbourne University

4.3 PROJECT PROPOSAL GORDON HON CHUN HIN

This specific IDS project encapsulated the common initiatives across most of the student portfolios such as Solar PV Panels, a green roof and various landscaped zones, as well as a focus on utilising sustainable materials during construction such as engineered timber and sustainable concrete mixes.

Some interesting design features include:

- Piezoelectric energy derived from pedestrian foot traffic
- Diffuse natural daylight to decrease need for internal lighting.
- Abundant rainwater harvesting.
- Architectural shading provided for all rooftop areas and the use of both fixed and dynamic shading
- Air source heat pump.
- High performance glazed windows and/or polycarbonate.
- Low embodied carbon materials.
- Onsite vegetation both marine and land based.



Images by Gordon Hon Chun Hin, Melbourne University

Image by Gordon Hon Chun Hin, Melbourne University

5 PASSIVE SOLUTIONS

Passive measures were a key solution of focus for many of the students, as this area has a large impact on the carbon footprint of a building. Passive designs for buildings who are striving for a carbon neutral operation are extremely valuable, impacting on thermal comfort and indoor environmental quality immensely.

Initiatives integrated into many of the designs were:

- Orientation to capture passive solar radiation while excluding peak summer sun
- Exposed external pools to capture solar radiation
- Insulation within the building envelope, for the floors, walls and roof.
- Judicious rationalisation of glazing extent to balance natural daylighting while minimising heat transfer
- The use of green roofs and planting elements to provide natural insulation
- Thermal mass inside the building to help stabilise and moderate internal temperatures

Image by: Phoebe Maguire, University of Melbourne

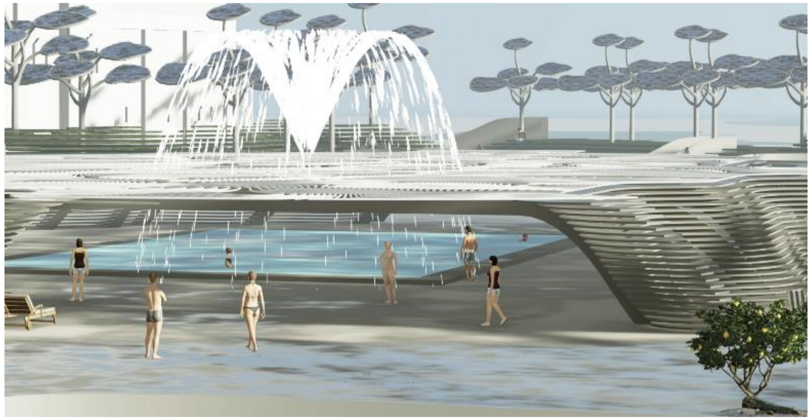


Image by: Tingjun Bai, University of Melbourne

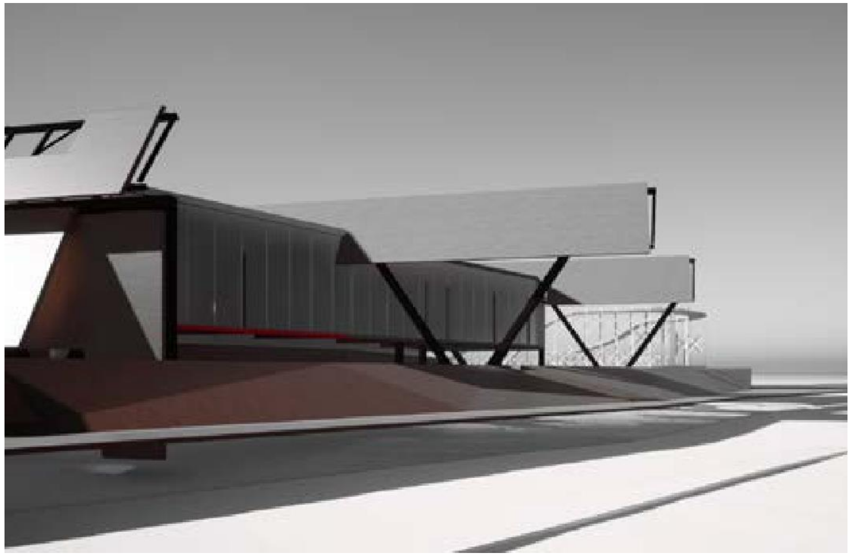


Image by George Rowlands Myers, University of Melbourne

Image by: Qiyu Tang, University of Melbourne

6 ACTIVE SOLUTIONS

The active measures proposed were more varied across the board, as more broad opportunities exist. Many of the students encapsulated best practice initiatives, including:

- LED lighting.
- Rooftop Solar PV.
- Rainwater Harvesting.
- Electric heat Pump.

And some more innovative active solutions such as:

- Hydro-botanic filter pond.
- Microinverter technology to harvest energy from gym equipment
- Piezoelectric energy system harvesting energy from foot traffic.
- External public theatre systems
- Solar PV as shade structures

Hydro-botanic filter pond, image sourced by Haziq Azul Rahman, University of Melbourne

Piezoelectric walking mats, image sourced by Haziq Azul Rahmam, Uni Melbourne

Solar PV shades, image by Tingjun Bai, University of Melbourne

Public theatre, image by Gordon Hon Chun Hin, University of Melbourne

7 PROGRESSIVE STUDENT INITIATIVES

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

Some of the interesting and progressive design solutions introduced by the students include:

- Introducing new activities to and features to complement the aquatics facility including ice-cream parlour, outdoor cinema, speciality shopping.
- Incorporation of green spaces including green roofs and pocket parks. These allow visitors to relax and enjoy an outdoor experience. Many of the green elements were incorporated into the designs in unique and interesting ways to incorporate terraces, water features and filtration strategies.
- Solar PV was incorporated into the designs in interesting ways and other alternatives were explored including hydro power, geothermal technologies and piezoelectric systems.

Outdoor cinema offering, Xuewei He, University of Melbourne

Green space and interesting public laneways blended through the design, Yifei Qiu, University of Melbourne

8 BENCHMARKING ANALYSIS

8.1 BUILDING THERMAL ENVELOPE

It is common to carefully consider **thermal zoning** within an aquatic centre and to ensure separation of wet zones and dry zones as well as those that require 24/7 operation and air conditioning.

Typically, there is significant design work undertaken to option the **thermal envelope** including:

Rationalisation of vision glazing to balance natural daylighting without compromising energy losses which are much greater from glazed elements than from **insulated wall elements**.

Orientation of vision glazing is particularly crucial as this can lead to opportunities for **natural solar heat gains.**

Building sealing is also crucial to the performance of the building envelope in order to minimise heat loses associated with air infiltration. Sealing works can include architectural detailing verified through performance testing.

Passivhaus public pool under design in Exeter UK

BUILDING FABRIC ELEMENT	BEST PRACTICE BENCHMARK CENTRE OF ELEMENT THERMAL PERFORMANCE IN MELBOURNE
Roof	R5.0
Walls	R4.5
Under slab	R2.0
Vision glazing	U 2.2 SHGC 0.55

UTS Sydney by DCM, 6 Star Green Star showing one large glazed wall but also rationalised slivers of glazing on slivers of glazing on other facades

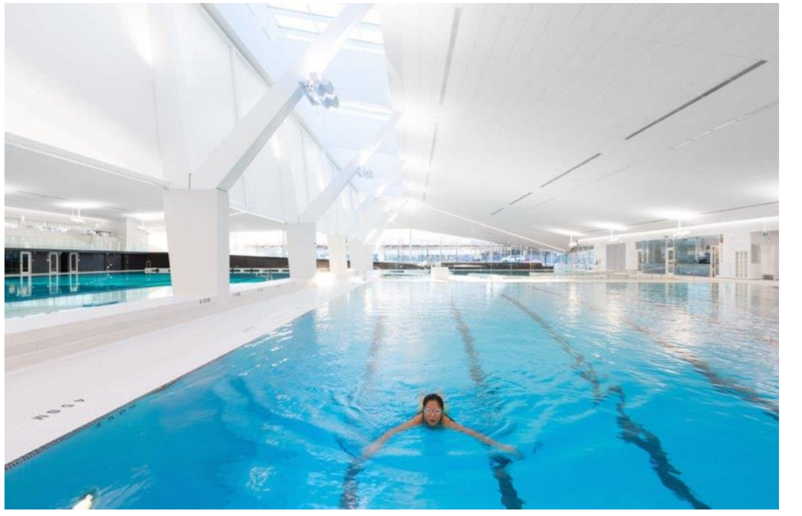
UBC aquatic centre by Ostroy Architects, Vancouver. Showing roof structure used to provide shading and to moderate the extent of façade glazing

8.2 INDOOR ENVIRONMENT QUALITY

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

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

Public pool showing potential surface glare hazard



The LEED Gold rated UBC aquatic centre showing mix of natural light, electric light and light diffusion. Acton Ostroy Architects and MJMA

Ian Thorpe Aquatic Centre, Harry Seidler - Finishes and form used to control light quality and noise quality

8.3 WATER SENSITIVE DESIGN

Best practice industry standards for water sensitive building design in aquatic centres include the following:

- Water efficient fixtures for showers, toilets and taps
- Rainwater capture and storage for reuse in toilet flushing, irrigation
- Water efficient filtration systems and smart backwash systems to reduce the extent of filtration backwash
- Precleaning of bathers to improve water quality and reduce the need for filtration
- Native landscaping with reduced water demands
- Water collection off hardstand surfaces for irrigation
- Potential for capture, treatment and reuse of grey water
- Heat recovery from wastewater
- Extensive water sub-metering and monitoring
- Resilient design to suit climate change scenarios


Pre-entry cleaning of patrons


Gunyama Park aquatic centre showing mix of landscaping, built form with solar and shade structures

WATER FIXTURE	BEST PRACTICE FLOW RATES
Showers	< 7.5litres/min with smart timer control
Taps	5-6 l/min non-touch with presence sensors
Toilets	4.5/3 litres/flush
Urinals	0.8 litres/flush

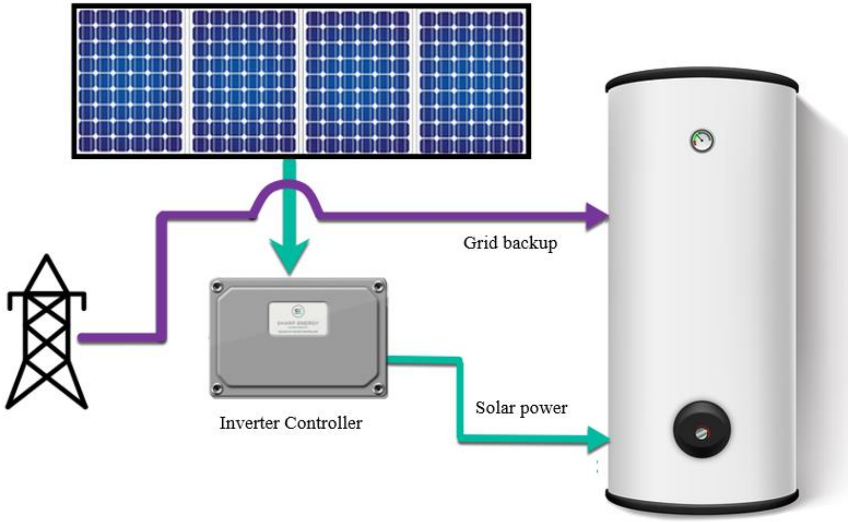
8.4 ALL ELECTRIC DESIGN

There is increasing recognition of the need to design buildings to operate entirely on systems supplied by electricity and to transition away from natural gas, as gas is a fossil fuel which cannot easily be replaced with renewable alternatives.

Electric heat pumps are therefore an increasingly common and well proven technology for many buildings. For aquatic centres these systems pose potential but with the challenge of having to design for supply of large amounts of heat to multiple pools and air systems during conditions of low ambient air temperatures.

Electric heat pumps can harvest heat from the air, ground or water bodies. These can also operate from renewable supplies such as onsite or off-site solar.

Other key design implications in incorporating electric heat pumps include increased noise from the units, increased spatial requirements and the need to resize electrical infrastructure to cope with the increased use of electricity.



8.5 ONSITE RENEWABLE ENERGY

8.5.1 SOLAR PV

Large arrays of solar PV are already being retrofitted to many existing aquatic centres and new facilities are being designed to incorporate systems of 200-600kW depending on the available roof space. Typically, is it possible to saturate the roof with solar PV without risk of excessive export, as the energy demands within an aquatic centre often outweigh the potential supply from onsite renewable energy.

8.5.2 OTHER RENEWABLES

Solar is currently the most cost-effective renewable energy source for most buildings, but designers remain vigilante to the viability of alternatives such as small wind energy, waste to energy or piezoelectric based systems. These alternatives can provide modest contributions to a site, but they also enable suer education around energy consumption and can help form part of a more circular economy solution.

Image sourced by Gordon Hon Chun Hin, University of Melbourne


Manly Aquatic Centre retrofit showing saturation with solar PV


Example of solar built into shade structures around an outdoor pool

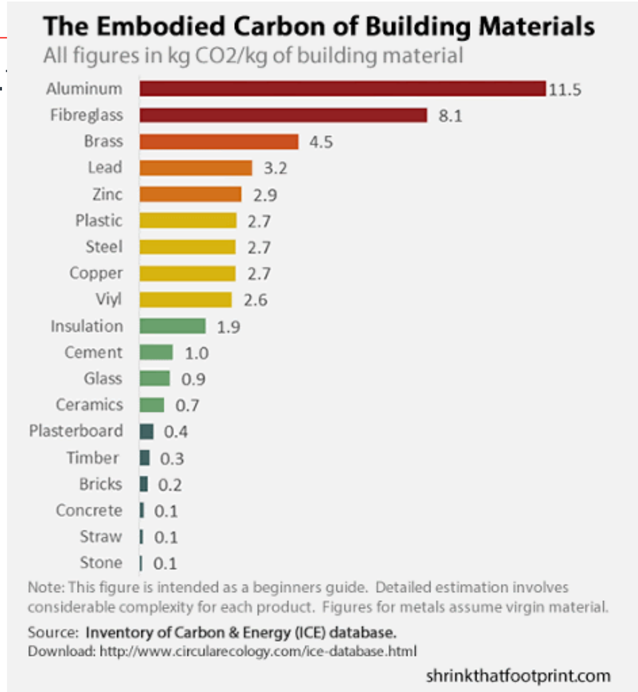
8.6 LOW CARBON MATERIALS

Concrete and steel are the biggest forms of embodied carbon within an aquatic centre construction due to both their relative carbon intensity and the volume with which these materials are used in construction.

Timber is an increasingly viable method of offsetting the need for steel and concrete in construction. This is suitable for aquatic centres as long as these materials are treated appropriately for longevity in an aqueous environment.

Through the studio many students adopted the use of timber as part of their design, developing tension member roof structures.

Aquatic Centre De Paris – Venhoven and Atelier



Toronto Regent Park Aquatic Centre, MacLennan Jaunkalns Miller Architekten

8.8 ENERGY INTENSITY

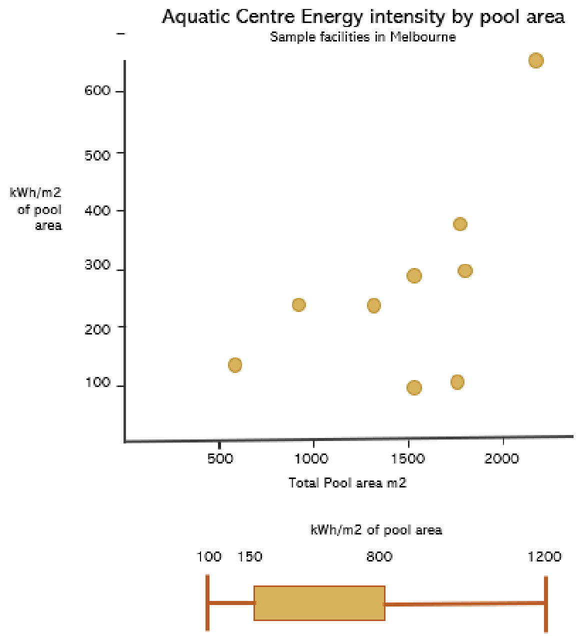
Energy utilisation and intensity varies widely amongst aquatic centres in the Melbourne Climate and there are a myriad of factors which influence the intensity \of existing facilities in Melbourne. These include:

- Seasonal factors and seasonal operation
- The mix of indoor and outdoor pools
- Additional facilities such as gyms and café
- Annual visitor numbers
- Water slides
- The presence of cogeneration

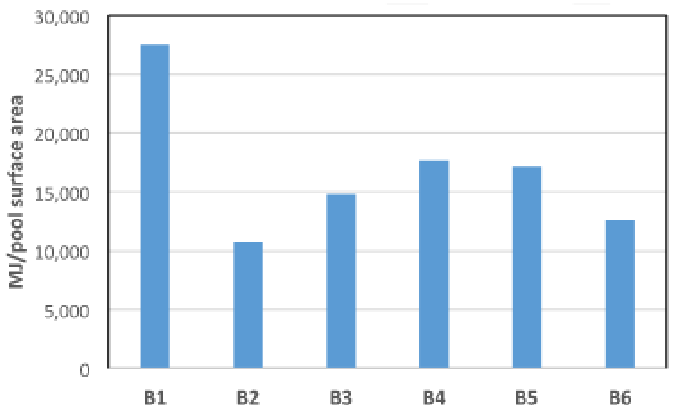
The consultant team has gathered some data for aquatic centres within Melbourne over the last several years with the intent to review benchmarking opportunities. Some of this data is also published by other researchers including Aquatics and Recreation Victoria in collaboration with Dakin university.

These energy intensity metrics require substantially more research and data analysis.

There are no widely accepted standards for energy intensity in aquatic centres.



Aquatic data intensity review by WSP, 2020



Gas and electricity (combined) energy intensity by pool area – from ARV Report 2016

9 OPPORTUNITIES FOR NET ZERO ENERGY

9.1 BASELINE VS INDUSTRY BEST PRACTICE

Industry best practice varies between Australian states, this is reflective of the types of climate that aquatic facilities are designed for. Through further review of the student work, some key indicators were determined to compare a baseline design to a likely best practice outcome. We have identified some of the key initiatives necessary on the pathway towards net zero energy or carbon neutrality.

9.2 IMPROVEMENTS

Further development and research can still be made in relation to the following:

- Cement replacement in concrete in aqueous environments
- Treatment of timber in aqueous environments and the use of timber structures

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.

Further development can still be made in relation to the following:

- Focus on health and well-being within building design including using features from the well building standard applicable to aquatic and community centres
- Air source heat pumps from aquatic centres is a relatively new approach to pools in cooler climates and needs further study through implementation
- Compliance with Passiv Haus for aquatic centres in cool climates such as Melbourne requires some further design research and verification
- Development of standards and benchmarks in aquatic facility performance, these vary widely between cities and facilities. NABERS for aquatic centres could be developed.

CATEGORY	BASELINE	CURRENT BEST AND FUTURE PRACTICE
Metering and monitoring	Basic sub metering of light and power and as per code requirements	Extensive metering of all major uses especially to enable auditing, tuning and ongoing improvement. Dedicated real-time energy management system.
Control	Standard mechanical control against temperature and lighting control against occupancy and daylighting	Control using temperature, relative humidity and system pressure. More optimised mechanical systems sized to suit the design without over design or compensating for poor thermal envelope.
Heating source	Gas heating combined with electric mechanical systems	All electric facility with electric heat pumps for heating. Can also utilise waste heat from nearby industry or district-based systems. Utilise the design for passive solar gains
Setting performance benchmarks	No performance benchmark set due to uncertainty and performance variability in the market.	Strong benchmarking to be established in the future using a metrics-based design approach. Using energy density as a metric based on wider market data analysis and more detailed modelling. Establishing the density metrics requires some further research. Aquatic centres to be certified using sustainability benchmarking tools such as Green Star.

CATEGORY	BASELINE	CURRENT BEST AND FUTURE PRACTICE
Solar PV contribution	Basic contribution or retrofit to existing facility of up to 100kW. This may achieve 5-10% contribution.	Design for maximum coverage of the roof form and carpark in some instances. In excess of 500kW per site will be more common. Target for net zero energy when combined with storage and highly efficient fabric and systems.
Mechanical fresh air supply	100% outside air	Reduced outside air with improved heat recovery and efficient humidity control. Highly efficient European centres use much less outside air proportions.
Thermal storage	None	Allowance for thermal and electrical storage to manage peaks and troughs especially for electric heat pump systems.
Landscaping	Not included	Option to include green roofs and/or with diverse native, hard wearing and water tolerant landscape designs.
Water capture, efficiency and reuse	Rainwater systems are standard practice Standard fixtures	Rainwater and greywater capture and reuse. Blackwater reuse subject to detailed analysis and evaluated against energy demands. Very efficient fixtures with timer control and sensor control
Water Filtration and water management	Sand filters on programmed timer control. Rainwater tanks	Sand or diatomaceous earth filtration on smart demand-based control and water quality control. Reuse of black water. Larger more resilient rainwater systems.
Structure and materials	Concrete and steel Embodied energy not considered	Concrete and steel is current best practice Future practice would need to use timber, tensile structures, composites or much lower embodied carbon in concrete. Full embodied energy calculation. Life-cycle approach to materials. Adaptable structure designed for longevity.

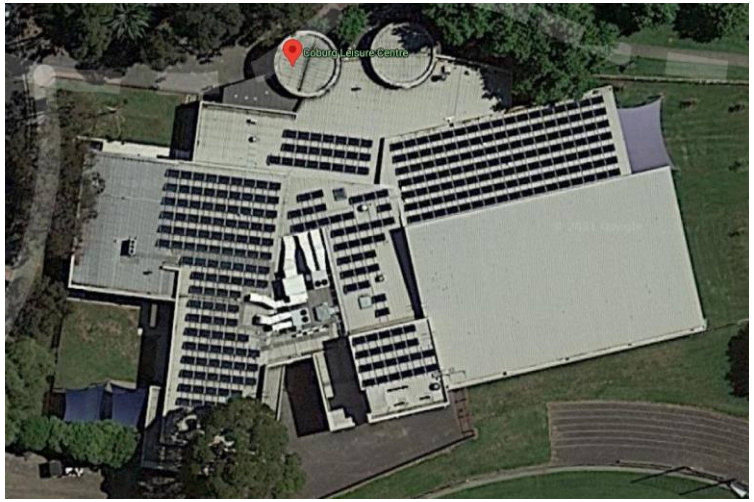
9.3 ENERGY INTENSITY FOR NET ZERO ENERGY

With an extensive solar PV array on an aquatic centre along with a very efficient building envelope and carefully designed low-energy systems for mechanical services and pool filtration it is possible to at least set a budget for annual energy consumption based on the contribution of solar PV on site.

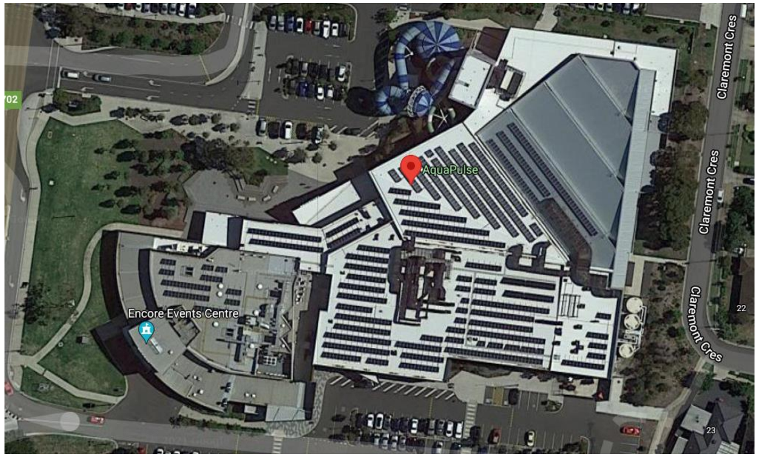
An array of high-performance solar panels at 400-440W per panel with a roof spatial utilisation of around 65% allowing for panel access space, offsets from edges and miscellaneous obstructions, the total system output is likely to be of the order of 175-200 kWh/m2 pa of gross roof area.

This sets an ambitious energy budget for an aquatic centre to ensure the facility generates as much energy as it consumes.

The existing range of energy consumption (gas and electricity) for aquatic facilities in Melbourne is of the order of 300-500kWh per m2 of covered area for indoor pools with a moderate mix of dry uses.



Coburg leisure centre has a moderate amount of solar PV



Wyndham Aqua pulse has a large roof-mounted solar PV installation

10 KEY FUTURE FOCUS AREAS

To progress the development of aquatic centres towards net zero energy, this IDS study process has identified a short-list of design measures that require additional focus and attention and further development from industry design teams.

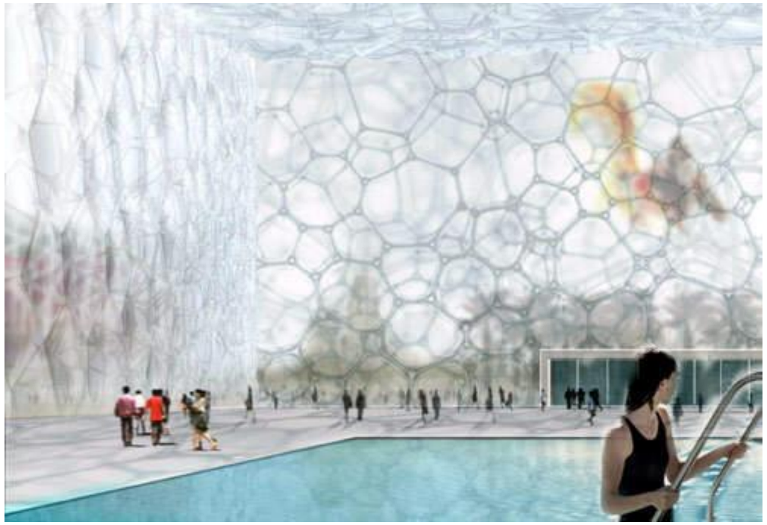
The following are the key focus areas identified through the IDS process:

Building thermal fabric performance development including more advanced insulation solutions, construction techniques, high performance vision glazing and higher standards in air tightness.

Electrification of aquatic centres including further development on electric heat pumps systems and controls suitable for aquatic water heating and air-side heating. This may also include storage.

Smarter and more precise control strategies for air distribution, temperature and humidity control, water filtration and backwash initiation

Design to performance metrics using benchmarked data and detailed modelling to more accurately set the performance expectations. This will also help drive design outcomes such as heat recovery.



Thermal fabric design and development (Water Cube, Beijing)

Aquatic centre electrification and extensive integration of solar PV

Setting metrics for Performance based design

Smarter and more precise control against a range of metrics

11 CONCLUSIONS

Through the IDS students explored a range of low carbon design solutions including solar-efficient building forms incorporating well-considered thermal zoning, opportunities for passive heating as well as the application of renewable energy supplies to a building with large electrical demands.

While much of the student work focused on form and building character there was also some work undertaken to develop solutions for solar photovoltaic systems and in some cases to showcase these as part the building form and aesthetics.

Students grappled with concepts for all electric building solutions however further detailed engineering of the solutions could be developed further. The studio work largely remained at concept master-planning stage but nonetheless highlighted some areas of industry focus.

Students also developed concepts for timber construction and considered opportunities to reduce the embodied carbon of materials. An important emerging area of design.

Landscaping and green roofs were a popular concept with many of the student designs, largely to soften the public realm.

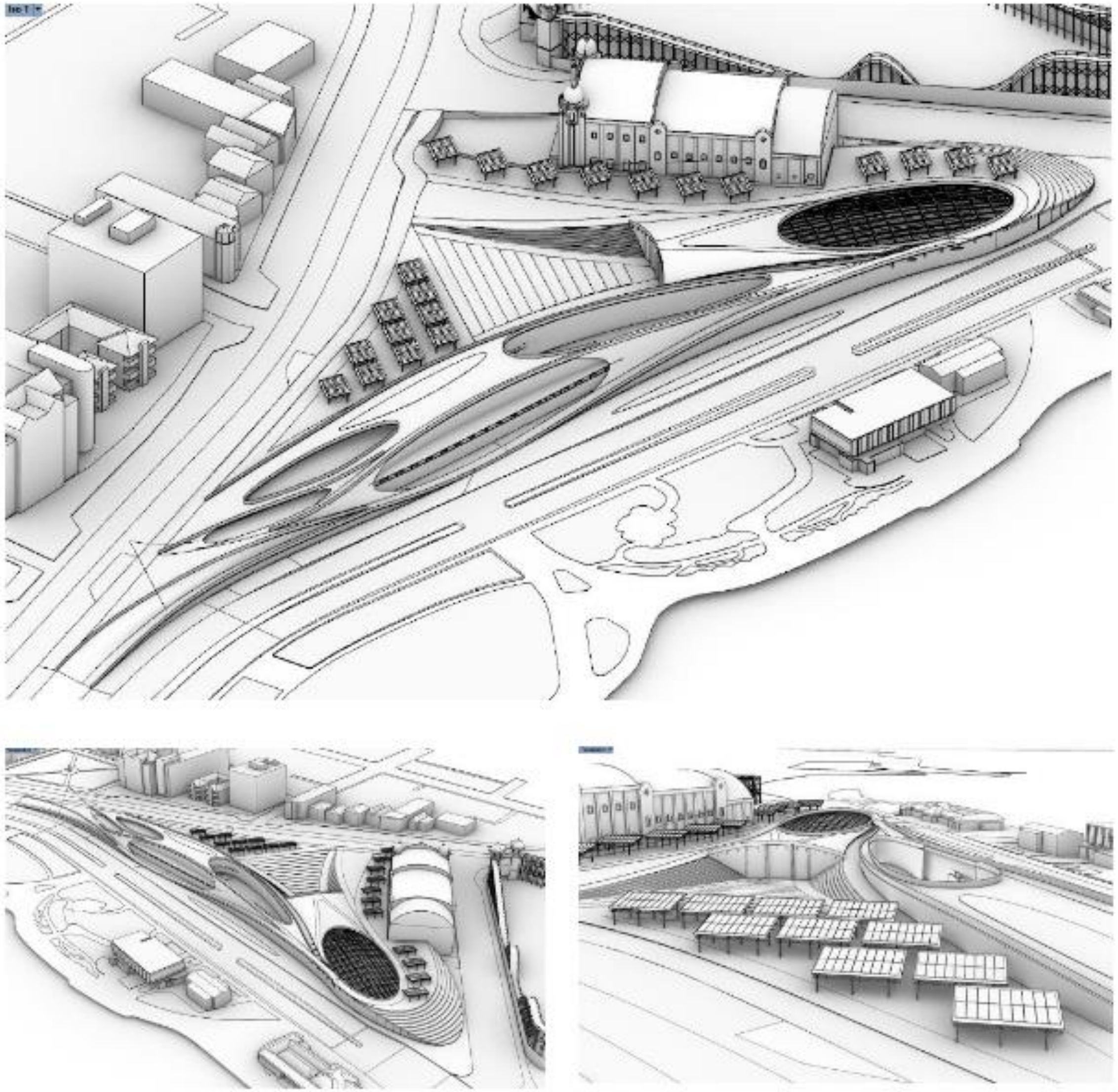


Image by Gordon Hon Chun Hin, University of Melbourne

Design Studio Outcomes

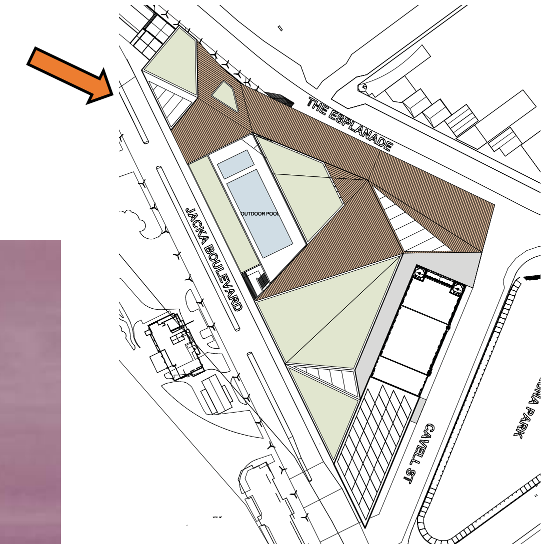
IDS-05

APPENDIX B

STUDENT WORK

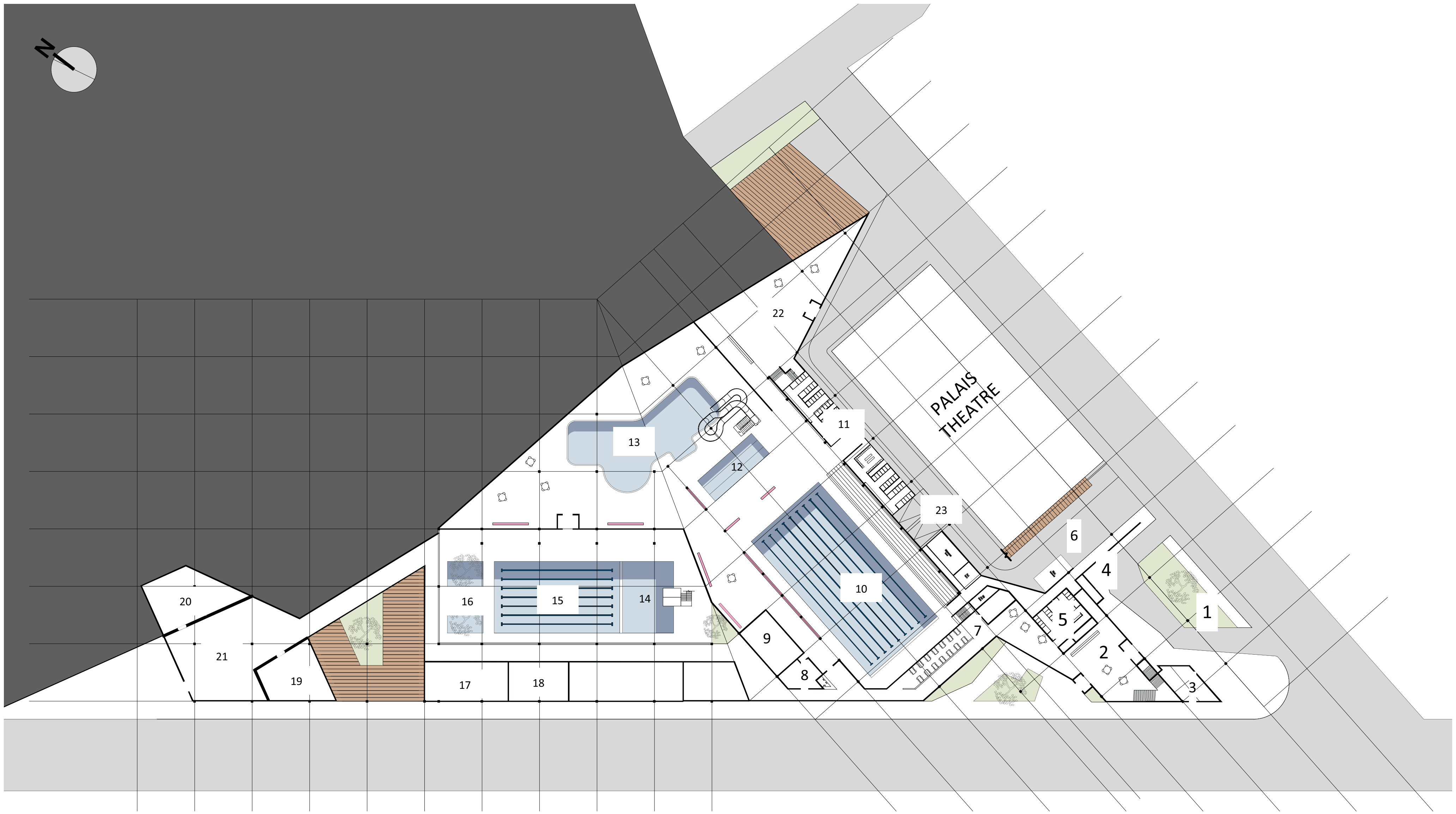
St Kilda Aquatic Centre

By Haziq Azizul Rahman



Aerial View

N.T.S @A3

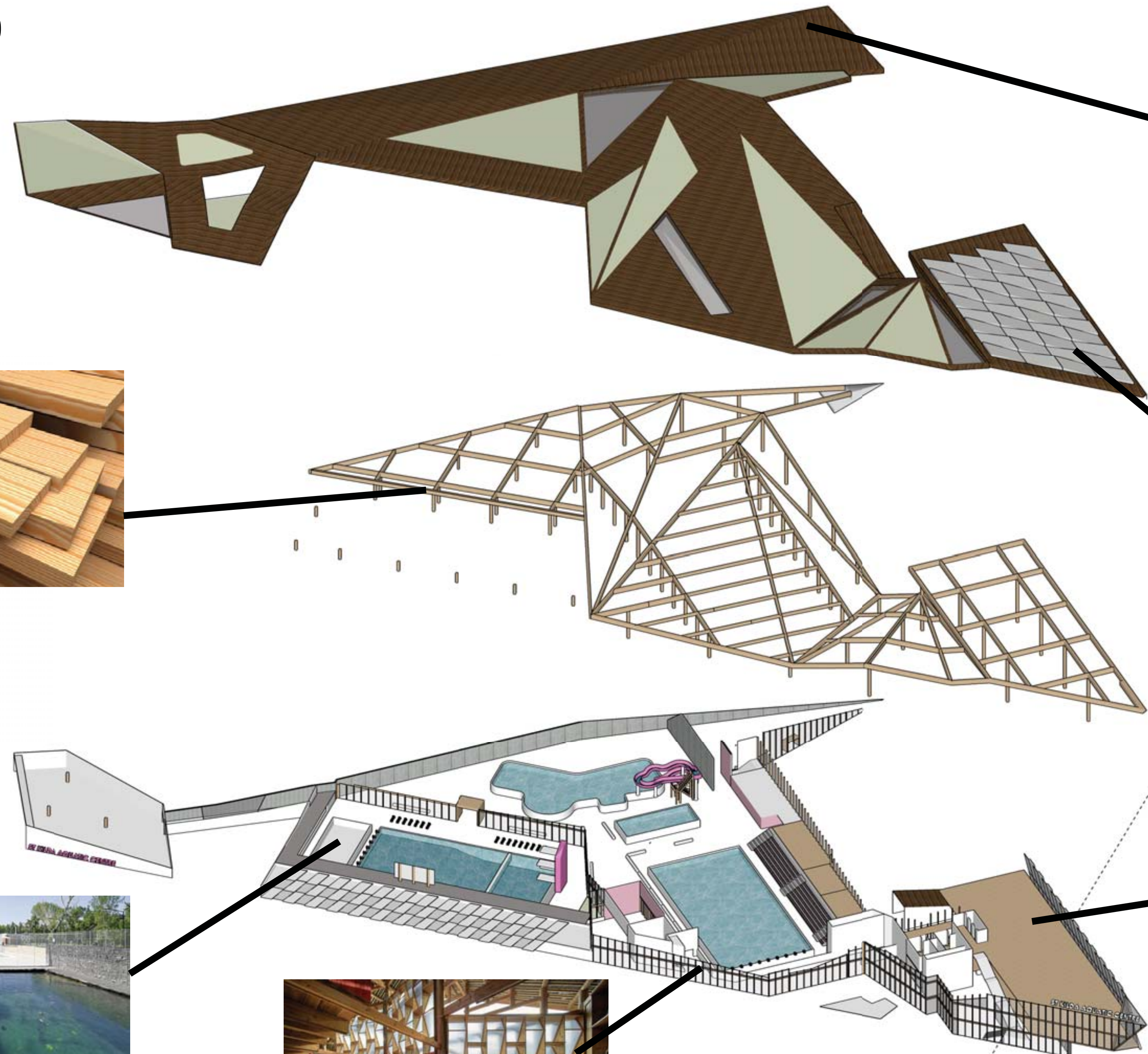


1. Drop Off
2. Lobby
3. Café
4. Lift Lobby
5. Toilet
6. Loading Area
7. Café
8. Indoor Pool Office
9. Retail
10. Oympic Indoor Pool
11. Changing Room + Toilet
12. Lesson Pool
13. Leisure Pool
14. Diving Pool
15. Outdoor Pool
16. Hydrobotanic Filter Pond
17. Gravel Filter Bed Room
18. Control Room
19. Aquatic Gallery 2
20. Aquatic Gallery 1
21. Gallery Lobby
22. Entrance from Esplanade
23. Entrance to Basement Parking

Ground Floor Plan

Scale 1:1000 @A3

Zero Carbon Loop
Strategies



Piezoelectric Pad

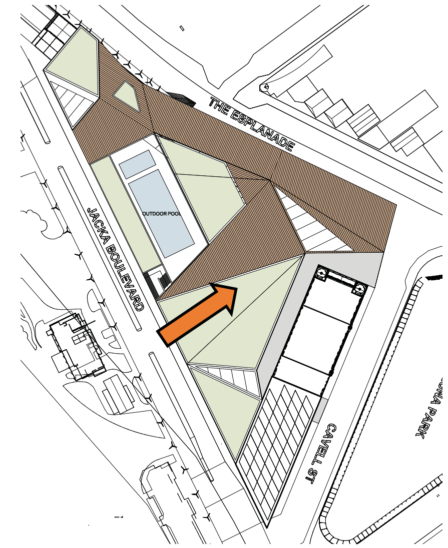
Renewable Timber
Strcuture

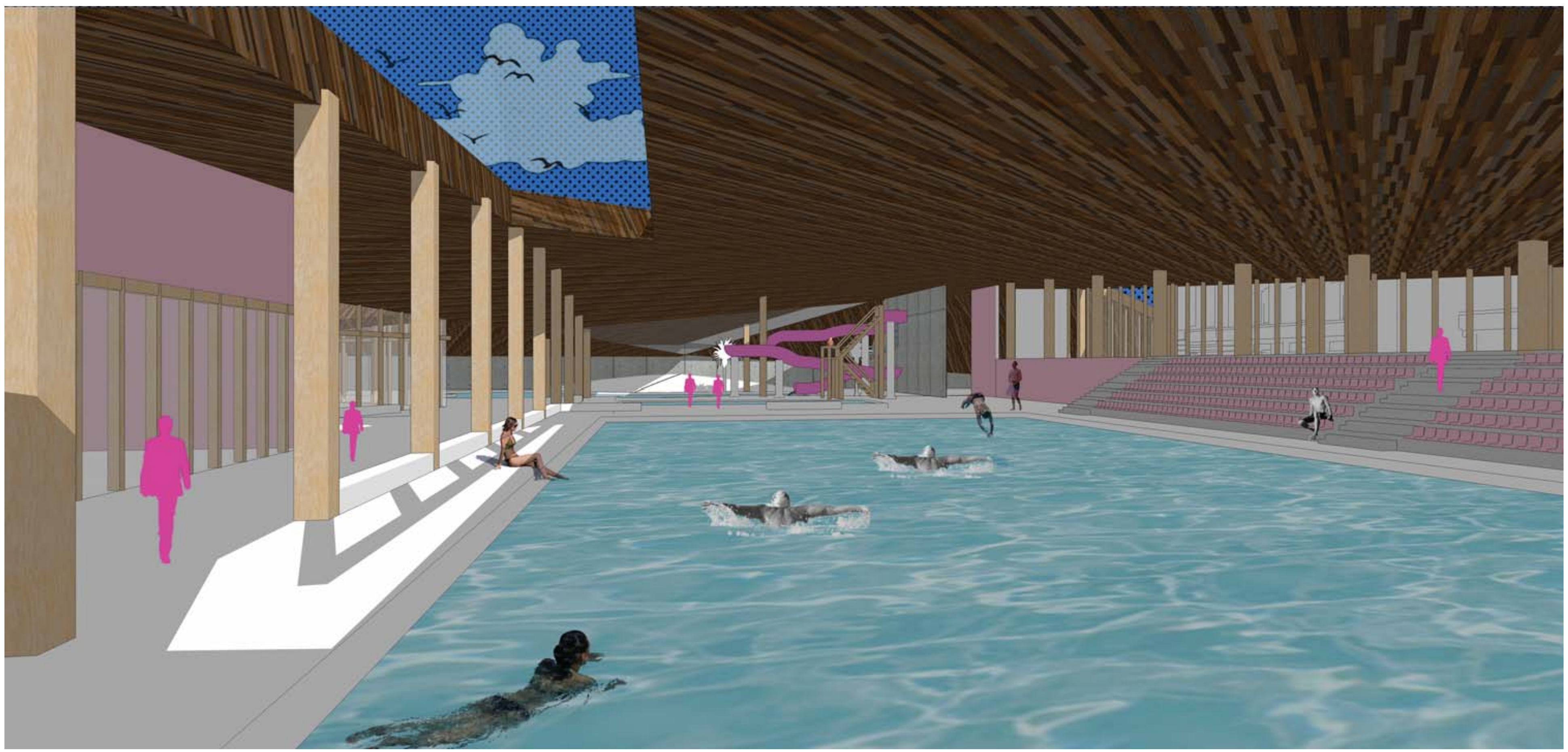
Solar Panels

Energy Generated From
Gym Equipments Through
Micro-Invertrer Technology

Hydrobotanic
Filter Pond

Polycarbonate Façade.
'Greenhouse Effect'



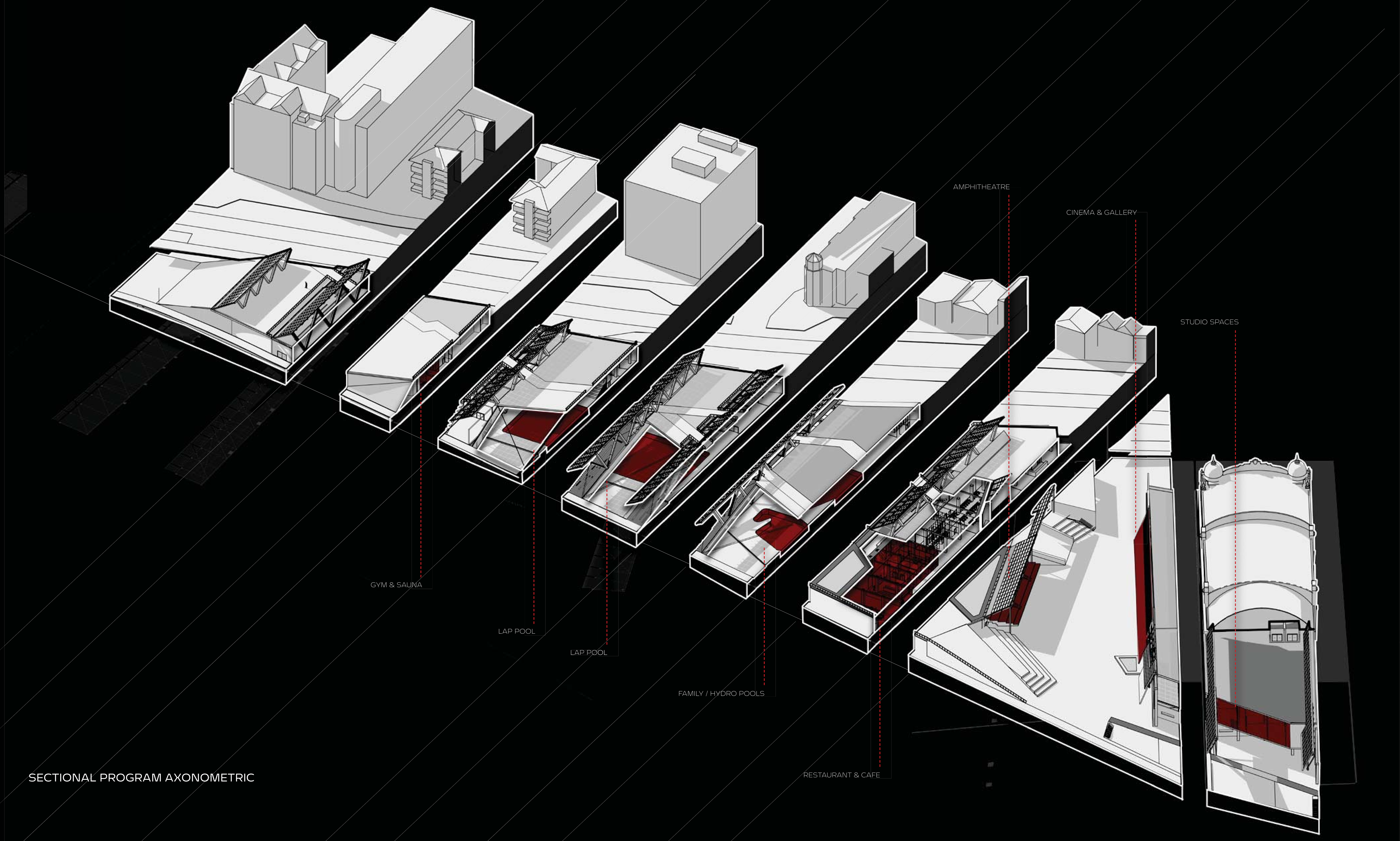


External View 02

N.T.S @A3

THE POOL LOOP

By GEORGE ROWLANDS-MYERS

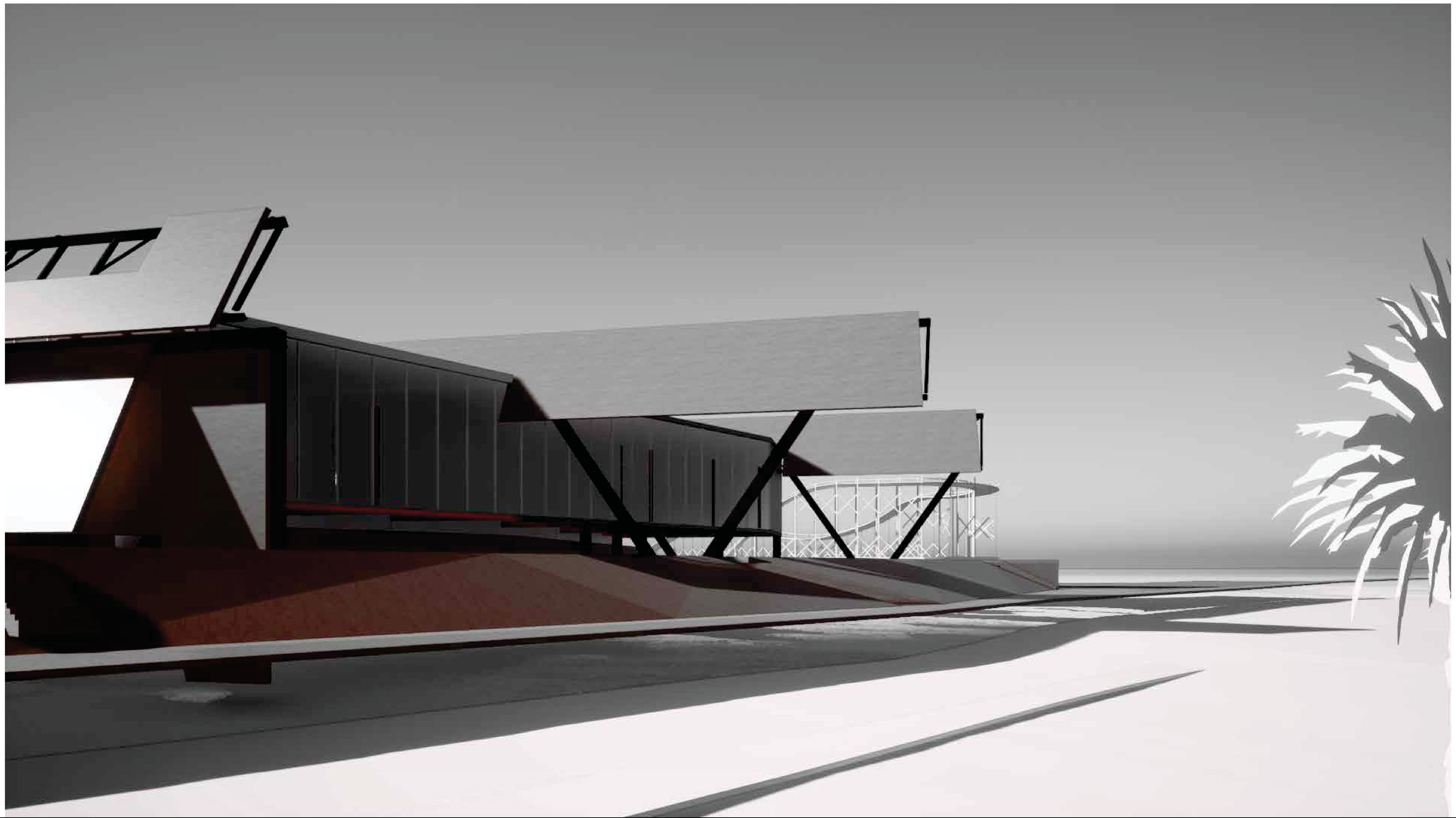


SECTIONAL PROGRAM AXONOMETRIC

1:500 @ A1

GROUND FLOOR PLAN

PERSPECTIVE - WALKWAYS WITHIN PV PANELS

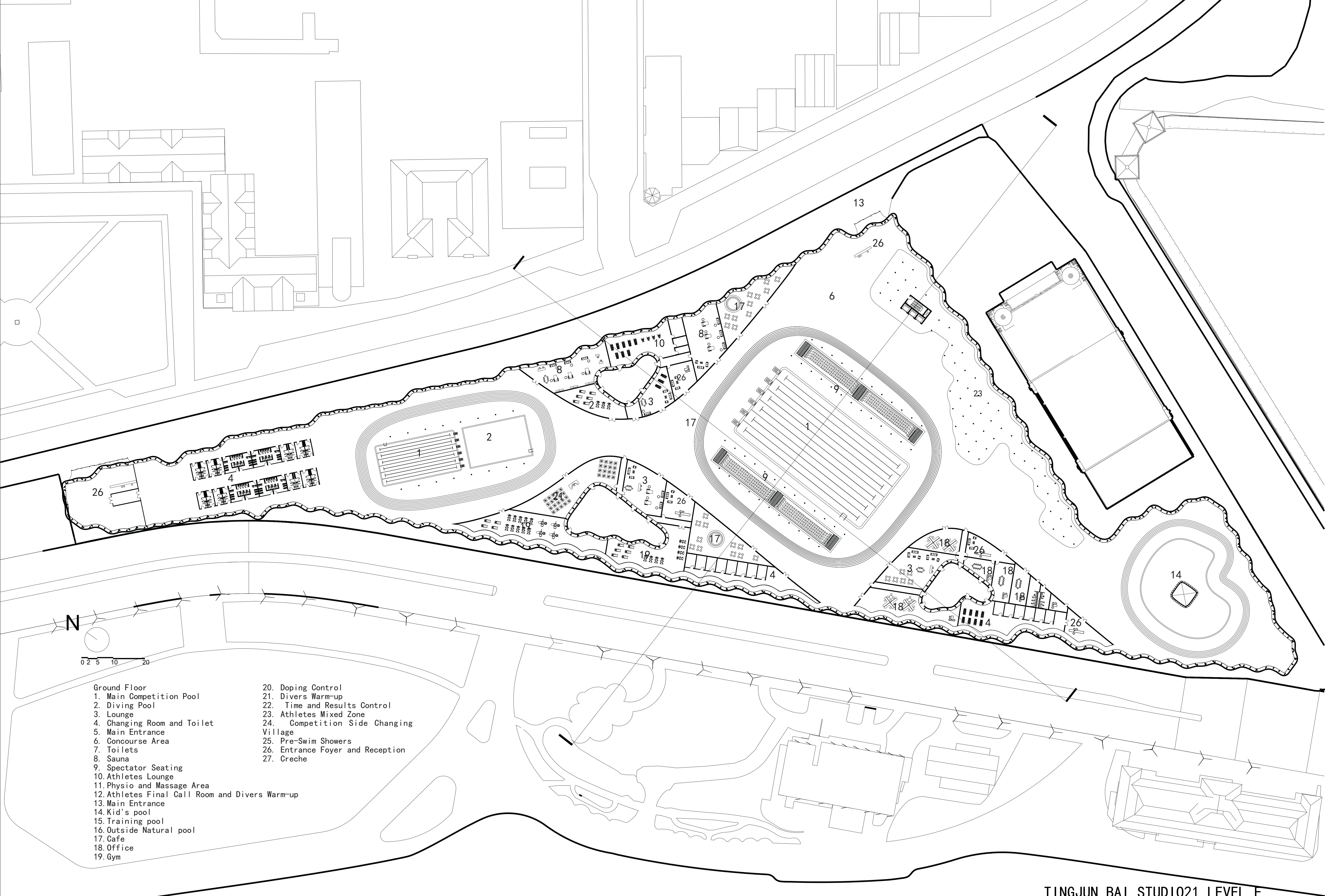


PERSPECTIVE - STREET VIEW OR
LANDSCAPE PATHWAYS OR WATER
AREA

THE POOL LOOP

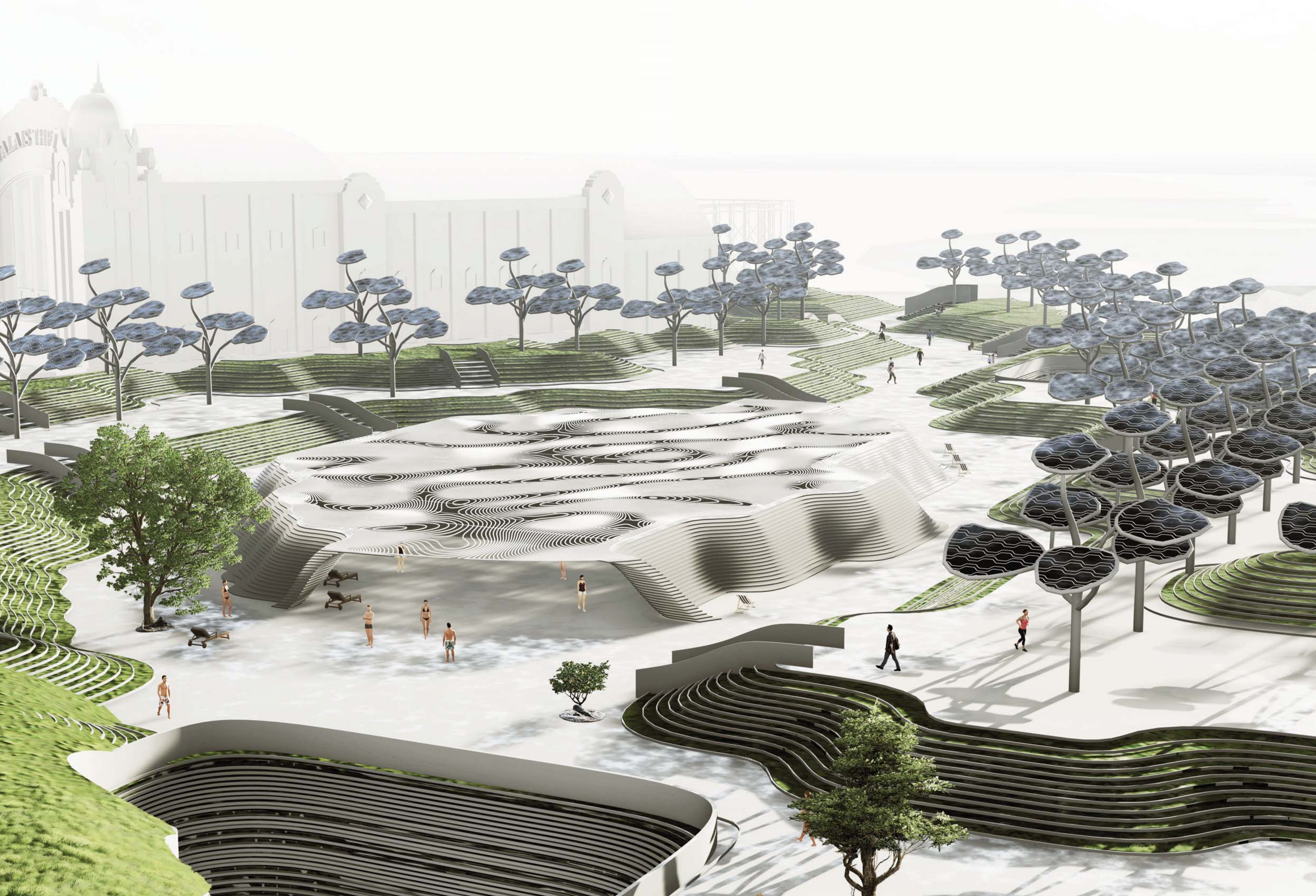
By Tingjun Bai

Ground Floor

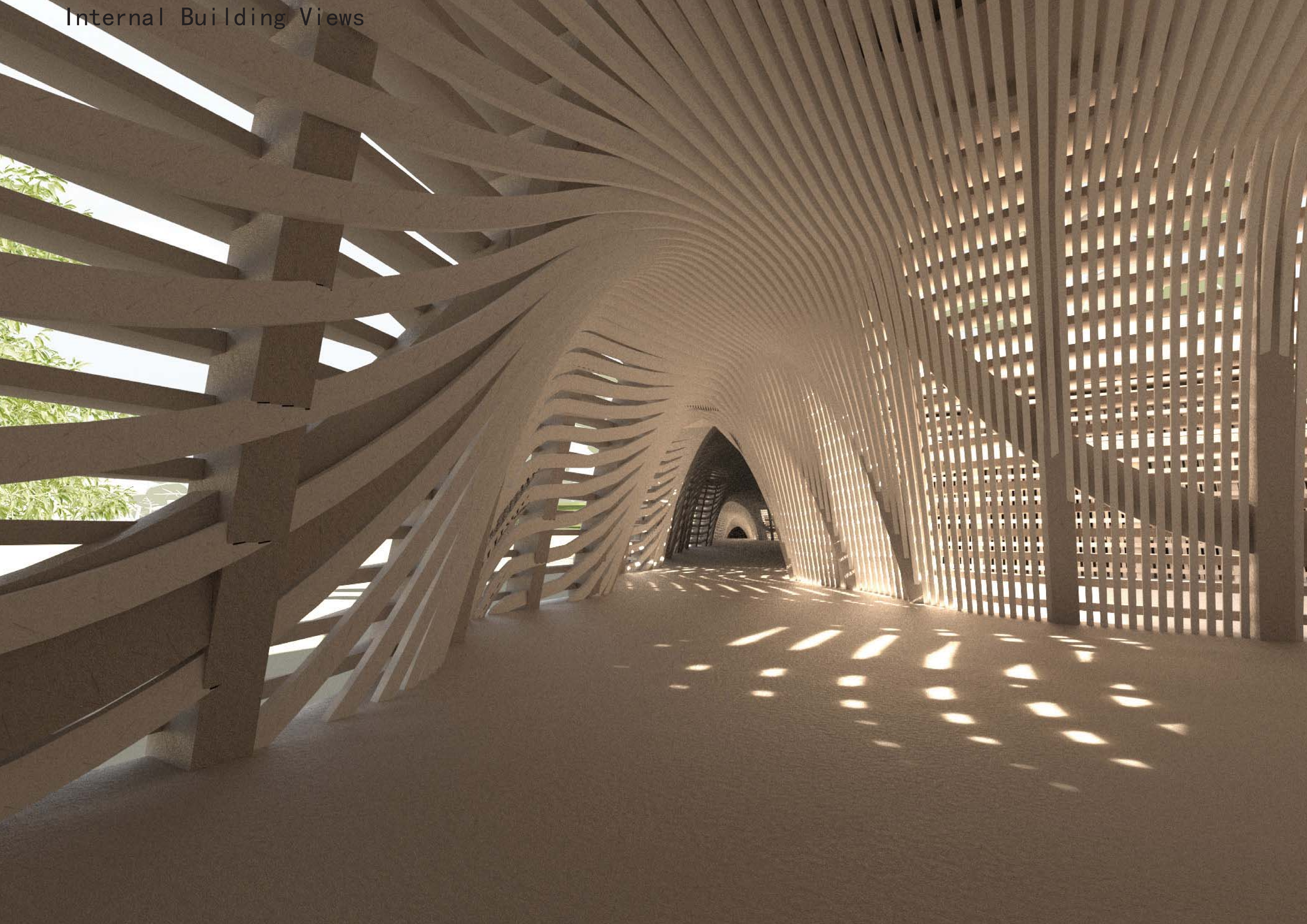


Ground Floor
1. Main Competition Pool
2. Diving Pool
3. Lounge
4. Changing Room and Toilet
5. Main Entrance
6. Concourse Area
7. Toilets
8. Sauna
9. Spectator Seating
10. Athletes Lounge
11. Physio and Massage Area
12. Athletes Final Call Room and Divers Warm-up
13. Main Entrance
14. Kid's pool
15. Training pool
16. Outside Natural pool
17. Cafe
18. Office
19. Gym
20. Doping Control
21. Divers Warm-up
22. Time and Results Control
23. Athletes Mixed Zone
24. Competition Side Changing Village
25. Pre-Swim Showers
26. Entrance Foyer and Reception
27. Creche

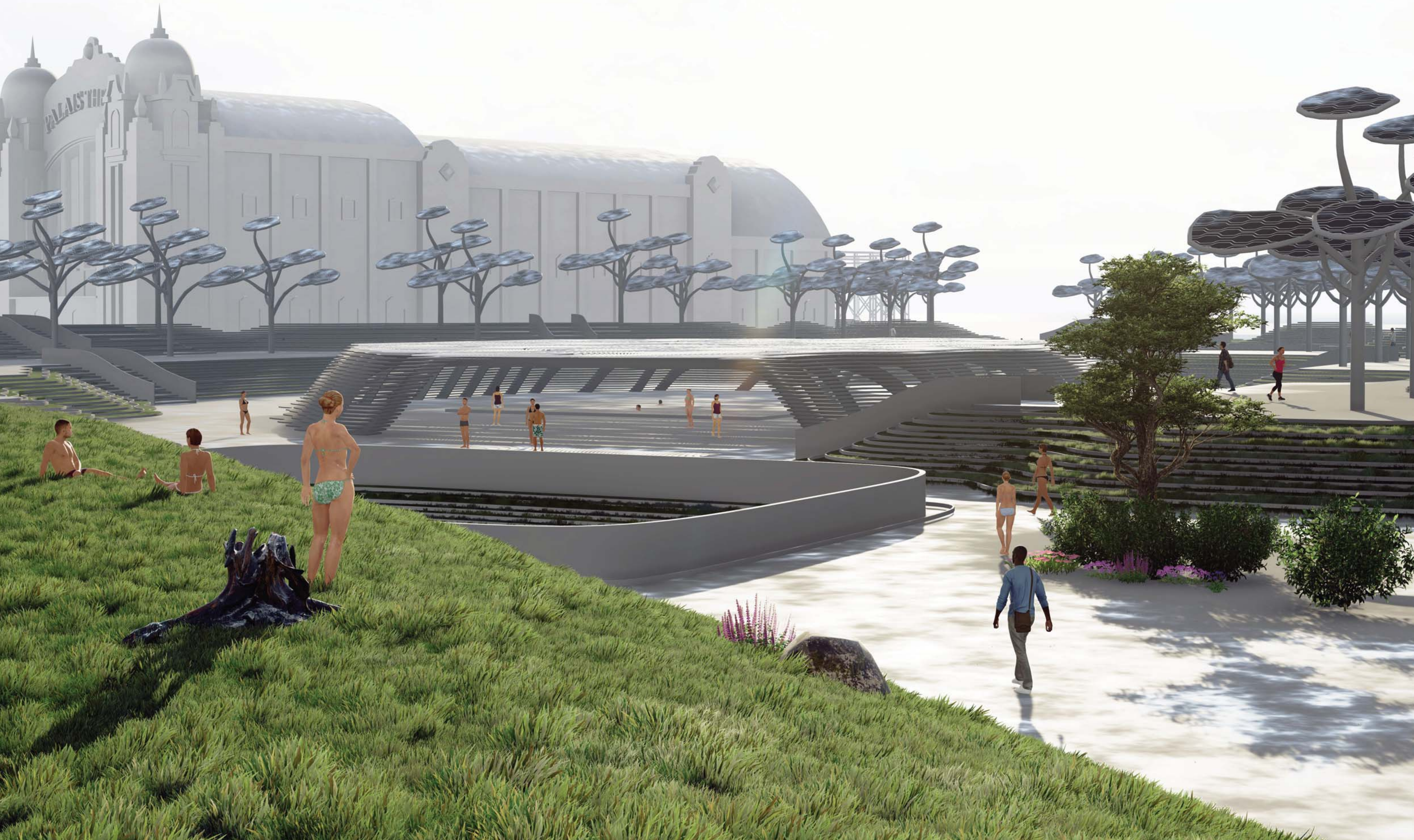
Aerial photomontages



Internal Building Views

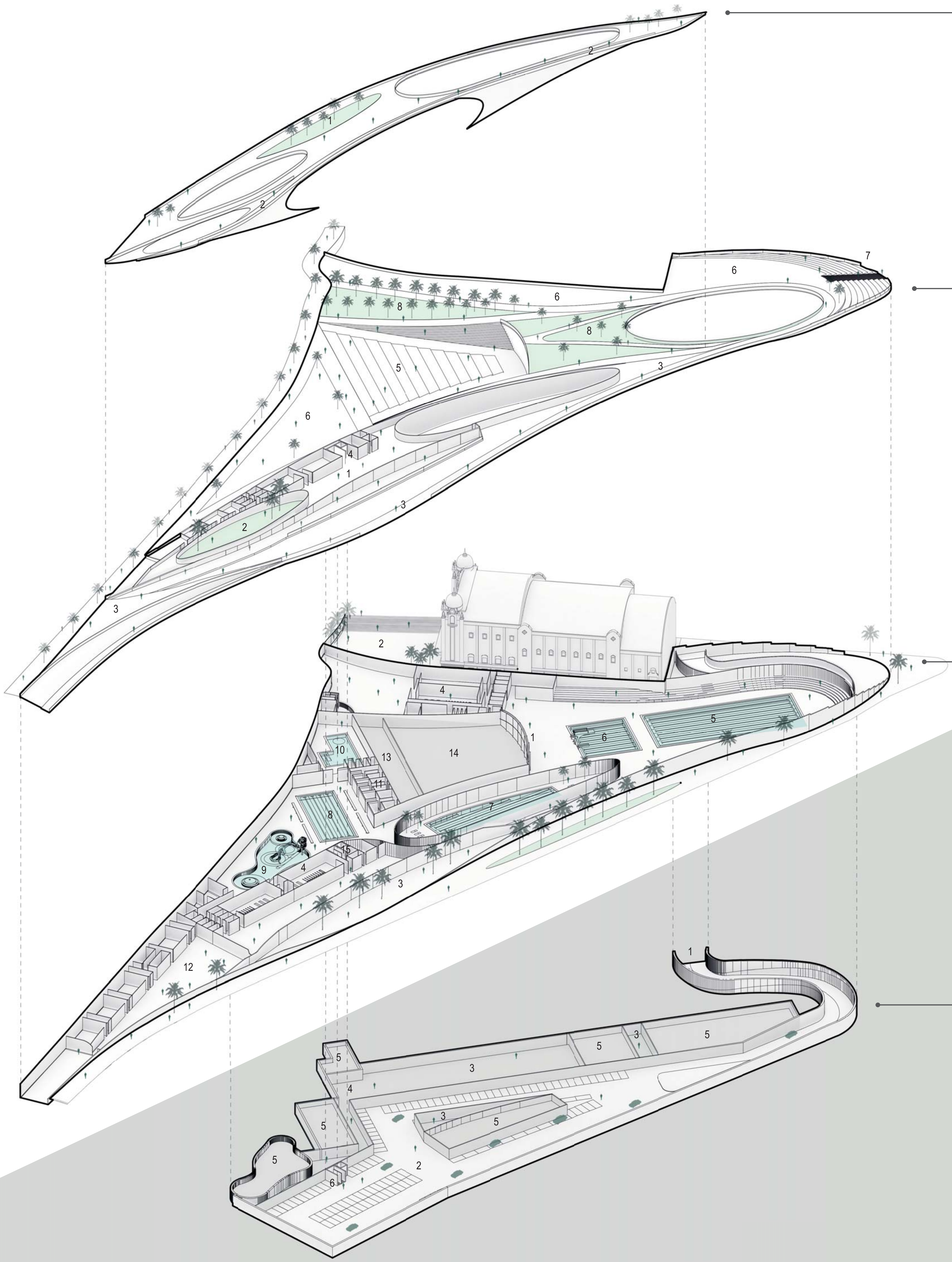


External views



ZERO CARBON AQUATIC CENTRE

By GORDON HON CHUN HIN



ROOF LEVEL

1 GREEN ROOF
2 PEDESTRIAN RAMP

PLAZA & 2ND LEVEL

1 GYM
2 OUTDOOR YOGA AREA
3 PEDESTRIAN RAMP
4 LIFT AND STAIRWELL
5 AMPHITHEATER
6 SOLAR PANEL & SUNDAY MARKET ZONE
7 PLAZA SEATING & PLAZA ACCESS
8 GREEN AREA

GROUND FLOOR LEVEL

1 PLAZA ENTRANCE
2 THEATRE ENTRANCE
3 JACKA BLVD ENTRANCE
4 CHANGE ROOM ZONE
5 OLYMPIC POOL
6 DIVING POOL
7 OUTDOOR LEISURE POOL
8 PROGRAM POOL
9 CHILDREN POOL
10 HYDROTHERAPY POOL
11 SPA & SANNA ZONE
12 FOOD COURT
13 STORE ROOM
14 VOID
15 LIFT AND STAIRWELL

BASEMENT LEVEL

1 CARPARK ACCESS
2 CARPARK ZONE
3 POOL PLANT
4 HEAT PUMP PLANT ROOM
5 BOTTOM POOL
6 LIFT AND STAIRWELL

EXPLODED AXONOMETRIC
PROGRAM CATEGORISATION

EXTERIOR PERSPECTIVE

OVERALL VIEW FROM JACKA BLVD

INTERIOR PERSPECTIVE
MAIN POOL