THE INNOVATION HUB
HUB
FOR AFFORDABLE HEATING AND COOLING

The Innovation Hub
for Affordable Heating and Cooling

Design Studio Outcomes Report (100% Milestone)

IDS-01 NEXTDC Data Centres I

Project IDS01

23 October 2020

The University of Melbourne

About i-Hub

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

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

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

Primary Project Partner

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

The IDS-01 NEXTDC 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 students work jointly with Engineering consultants and academics to develop Data centre designs. This type of facility is known to have high operational energy requirements and produce significant excess heat requiring HVAC dissipation/cooling.

Based on a dedicated project brief by NEXTDC, students explore novel approaches to develop a data-centre on an inner-urban site. Particular focus is given to introducing auxiliary public functions to the site and to integrating novel technologies that provide synergies with the programmatic requirements of the data-centre, thereby significantly reducing its carbon footprint.

Lead organisation	The University of Melbourne		
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1. SUMMARY

1.1 Purpose

This report summarises all findings taken from IDS-01, 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-01, and they will further be disseminated under the IDS Knowledge Sharing strategy associated to the program.

1.2 Executive summary

The IDS-01 NEXTDC Data Centre has been initiated early March after substantial stakeholder engagement that commenced in Q4 of 2019. The studio ran for 15 weeks until the end of June.

Work undertaken as part of IDS-01, resulted in a number of key findings that can be summarised under two main categories:

1) Analysis of the integrated design process, its opportunities, and challenges. A team of UoM academics has diligently been observing and analysing the integrated design process as it unfolded and addressed all stakeholders with a series of questions about their experience in applying integrated design in a dedicated study after the semester.

2) Integrated design exploration of data centres. Fifteen individual design proposals were developed by architecture students, who advanced their ideas for a Data Centre over the course of a semester. These proposals reflect in-depth analysis of 'Net Zero' design approaches for Data-Centres, and they offer an array of solutions, tackling environmental design in different ways. Recognising the speculative and highly experimental nature of the design explorations the design process was coupled with a 6-8-week feasibility vetting process that took place after the studio's completion. Here, the collaborating consultants examined the students' proposals to scrutinise certain 'Net Zero' related technologies and their application in the context of a Data Centre. The consultants analysed bespoke technology solutions in greater detail and compare 'Business As Usual' approaches in Data-Centre design, with the outcome of the IDS. The findings of the vetting process have been incorporated into this report, and the full consultant vetting report has been appended.

Key observations:

Integrated Design Process

- Good integrated design requires a 'design co-author' mindset in all participant designers.
- To achieve truly integrated design, the definition of common goals is a key priority. Common tasks set at a detailed level (as well as aspirational level), assist in facilitating co-authorship.
- Achieving integrated design requires active curation: Engineers potentially struggle, when asked to become involved in ideation processes, and architects often lack the skills of interpreting how engineering data can advance their design thinking. Opinions differ on where this curation role sits (internal or external to the design team), this will be interrogated in future studios.
- Integrated design happens over a limited time window, once initial fact-gathering is complete, and delivery-focused design has not yet commenced. The timing of this was found to vary across studios depending on the strength of the guidance from the design curator (also to be further interrogated in future studios).
- Design innovation often emerges from consolidating competing interests, not (just) from gradual improvements.
- Academic education plays a key role in introducing integrated design principles to aspiring professionals

Data Centre design Exploration

- The fifteen design solutions by students highlight the breadth of opportunities in the design of Data Centres, in particular when stepping away from a purely functional, and construction-cost optimised design. Selected key ideas that emerged were:
    - Incorporation of renewable energy.
    - Capture and recycling of waste energy through adjacent symbiotic uses (Aquatic centres and greenhouses for example).
    - Incorporation of modular construction
    - Incorporation of self-building/updating mechanisms (gantry cranes etc that when combined with modular philosophies facilitate expansion or updating of technologies).
- Due to the extensive (80+ MW) site power usage of a large Data Centre, 'Net Zero' targets are impossible to achieve via technology interventions and building envelope improvements. The main opportunities for improvement sat with the introduction of adjacent symbiotic programs.
- As much as the renewable energy sources and the adjacent programs represented only a minor percentage of the overall energy involved in running data centres (less than 1.0-2.5%), they were significant in terms of the adjacent uses considered. Significantly reducing the operating energy bills of an aquatic centre or community greenhouse would be seen to solve what is often a major burden for local councils and therefore presents opportunities for the Data Centre industry to better engage with councils and local community. Importantly by adopting such an approach, data centre providers may find themselves able to better position themselves as preferred partners with councils in competing for sites, while at the same time providing real, tangible community benefits.

2. PROJECT CONTEXT AND INCEPTION

2.1 Context to the NEXTDC 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. Two IDS projects were chosen to run in parallel during Semester 1 2020, which spans over 13-15 weeks from early March until late July.

NEXTDC is one of these two 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 internal *Human 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

A number of meetings with project-participants pre-semester revealed that an intensive full-day workshop at the point of studio inception (week one of the semester) would represent the best possible start to kick off the project. All project participants signed off to this idea and assisted in programming the workshop which took place on March 5th, 2020. It represented a day packed with introductory presentations, discussion rounds, and QnA sessions that involved the students, tutors, clients, consultants, and all academics involved in both studios. The workshop was partially run across both IDS, and partly in isolation to allow project participants to get exposed to overarching issues, while also focusing on their bespoke program. Next to the benefits for information exchange, the initial kick-off workshop also fulfilled the essential task to introduce all key IDS participants to each other and facilitate social bonding.

Figure 1: Solid discussions during the initiation workshop Figure 2: IDS introduction during the initiation workshop

2.3 Client Engagement

With NEXTDC, the project found an open-minded client, keen to consider unprecedented and novel design ideas while involving a team of trusted consultants, both on the architecture, as well as the engineering side. This mix between willingness to experiment and risk-taking, paired with a high degree of expertise in data-centre design, is greatly benefitting the conversations and design approaches in the studio. The client is keen to remain involved intermittently over the entire duration of the semester and provide comments and feedback, in particular at mid-semester and end-of semester milestones.

2.4 Site Visit

Due to commercial confidentiality the client on the NEXTDC project is not in the position to reveal the exact address of the project site. In order to compensate for the lack of geographic specificity, the client provided an in-depth introduction to the site context, in terms of its geographic and orientation characteristics, planning restrictions, as well as its socio-economic environment. Students were provided with this information at the inception workshop and were able to ask the client further site-specific questions in the weeks to follow.

3. DESIGN STUDIO PROGRESSION

3.1 Setup for Collaborative Design Integration

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

General

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

- Facilitate an environment that prioritises working on **common goals** over **individual goals**
- Establish **trust** among participants (open/non-judgmental/sensitized/willing/etc.)
- Allow every participant to understand what's **important to the others**.
- Explain the **process** each participant (group) typically goes through, in order to derive their desired **output**.
- Understand **why** we often see things **differently**, 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,** 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 and apply end-use performance metrics
    - What are the mechanisms to address them in **early**-stage design?
    - What are the mechanisms to address them in the **advanced** design stages?
- Develop an iterative 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 as design studio leader within a 13-15-week semester, as well as preparatory conversations held with the industry consultants, the client, and the academic participants. The schedule addresses 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 maps out the intensity and duration of engagement between the architecture students and the engineering consultants.

3.3 Weekly interaction between Design Studio Participants

After the initial kick-off workshop, the NEXTDC IDS moved into the phase of weekly 6-hour design review sessions.

The initial two to three weeks were marked by additional presentations by the Engineering Consultants and the introduction of reference projects by the architectural studio Tutor. Students were then asked to start presenting first preliminary responses to the site context and the articulation of various programmatic features (in particular of 'public' nature) to complement the data-centre function.

In a 13-15-week design programme much of the front end is taken up with briefing and bringing design parties up to speed with each other's discipline (in general knowledge terms). Concepts were explored, dismissed and re-evaluated in rapid fashion and first concrete ideas start to emerge. The first public presentation of preliminary design concepts occurred at the IDS Mid-semester presentations in the last week of April. These presentations offered students a first 'check' on their progress in front of a public jury, they set the scene for a more focused exploration in the second half of semester. The back end is conversely dominated by design development and documentation type activities.

With the purpose of increase the interaction between students and engineering consultants, and allocating more time for in-depth discussions, one-on-one sessions were organised during weeks 9 and 10 of the semester. The students publicly presented their final design in the last week of June to a 'crit-panel' consisting of UoM-external design professionals, academics, the client, and the collaborating consultants.

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

The COVID-19 pandemic has impacted on student availability (a number of engineering students were unable to travel to Australia to commence the studio in person) – combined with issues in advertising to engineering students resulted in low numbers and a decision being taken to proceed with architecture students only, concentrating on their interaction with engineering consultants and academics. As distancing restrictions tightened the studios were forced to transition to remote (on-line) delivery. This transition has proved successful and in fact has some advantages in terms of design interaction observation. 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. At this point, it is not expected that the online delivery method will severely alter either the nature or quality of project outcomes. Due to the extra week required to transfer all teaching online, the University of Melbourne extended the duration of the semester by one week.

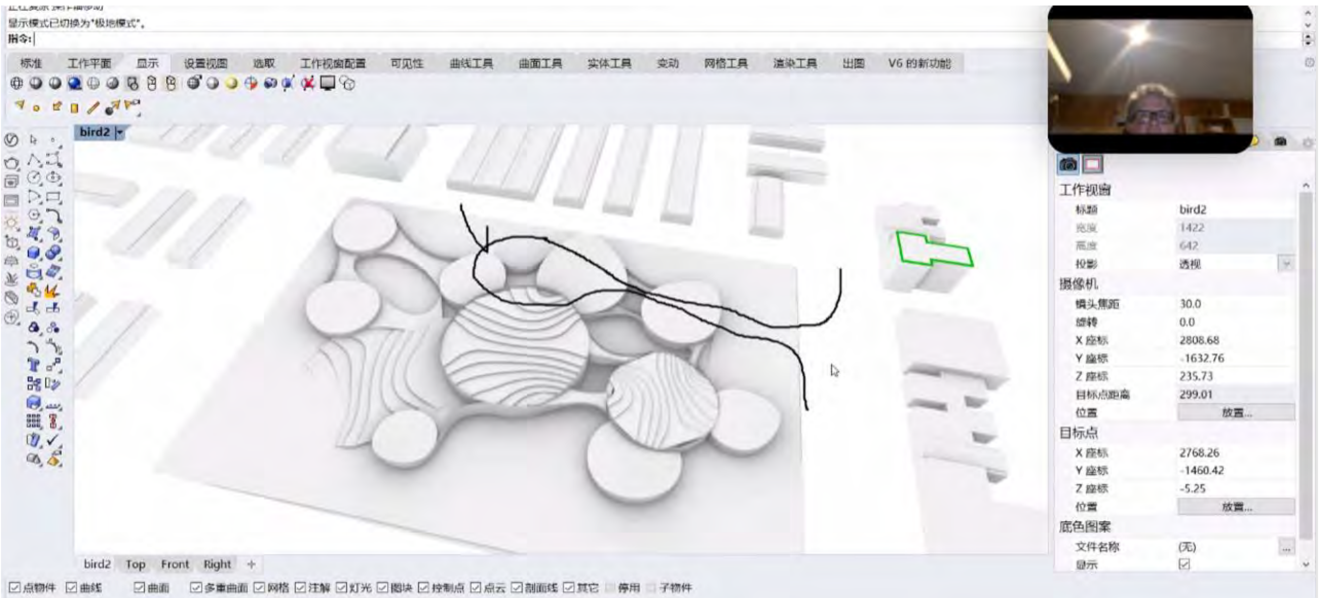


Figure 3: Screenshot of online design reviews using annotations in Zoom

4. DESIGN STUDIO FINDINGS

The findings from the IDS-01 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 Working toward Common Goals

One key element requiring further investigation during the second half of semester is a more targeted articulation of common goals that address zero carbon in the joint architect/engineer effort. As much as the engineering consultants are used to following the architect's lead in the articulation of a design direction, it appeared that they at times do not yet have enough confidence 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.

One aspect that appears highly bespoke in the context of IDS-01, is the openness of the brief, that by nature asks the designers to introduce unexpected and (possibly even contradictive) programmatic functions, to test out the effects of their juxtaposition with an otherwise highly determined and structured program of a data centre.

4.1.2 Establishing a co-author mindset

Integrated design is the coming together of multiple disciplines to produce design solutions that meet 'whole of project' visions. Observations during the IDS-01 reveal, that not all designers are used to working in this way.

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

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

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

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.

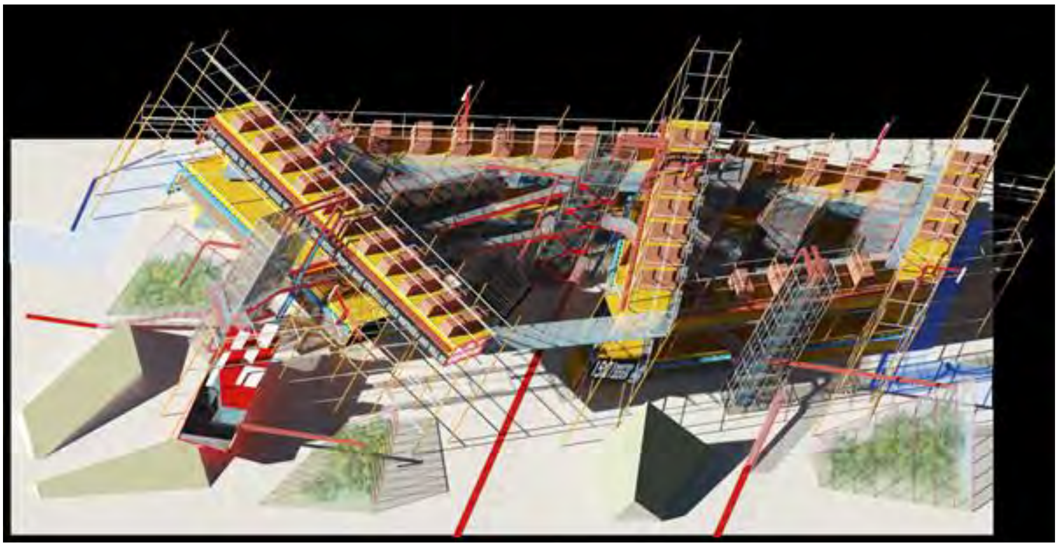


Figure 4: 'A.R.T. Centre' by Pan Shi: Expandable and updateable modular data units in self-building gantry framework.

4.1.3 Active Curation

Striking a balance between architecture and engineering requires active curation. Throughout the design studios, all the activities related to design development were conducted by the architecture students (The engineering students were not enrolled in IDS-01 due to enrolment issues partly caused by COVID-19 travel restrictions). With the absence of engineering students, 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. However, the **engineering consultants preferred to provide comments and guidance, rather than proposing design solutions** or actively engaging in design activities.

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, how they operate within the data centres and the spatial/functional issues to be resolved. 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 engineers 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 brief as the requirements to be met while 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, was the primary point of contact and the person who the students spent most time with and received most guidance from. 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.

4.1.4 Grasping the window of opportunity

In-between the early fact-gathering period, and the start of the phase focusing on the delivery of captivating graphic output for the end of semester (weeks 5-8), there was a **very brief period, when core design ideas were generated and formed**. Once design ideas are formed, it was difficult to materially change direction due to the momentum involved. Designers hold preconceptions after this initial ideation and the natural tendency is to adjust direction rather than to discard totally to start again. This means it is important to recognise when this ideation period is happening ensuring everything and everyone is in place to make it as successful as it can be.

It was observed, that initially - within this period - most students' primary focus was to create interesting forms without providing strong functional logic behind the forms. Therefore, the consultants had a rightful concern about engineering services design not being resolved. The client also raised the point after mid-semester presentation about the brief's requirements not being met by most of the developed designs. After receiving those comments, the students changed their focuses and attempted to modify their forms to meet those requirements. Instances of redoing the design due to neglecting the brief and functional requirements were observed. To avoid the reworks at later stages, upfront focus on brief and spatial/functional requirements can be effective.

In several instances within this phase, the **students appeared to be struggling with lack of understanding of the technical aspects of designing a data centre**. They seemed to be more familiar with the human interface (e.g. community spaces). This also led to more effort on (and therefore more physical space allocated to) community areas and less areas to data centre itself. This was not preferred by the client since the data centre area is the revenue bringing side of the facility.

Figure 5: 'Zero-C Data Centre 'by Weixiang Zhang: Street view

One-on-one sessions were found to be an effective method for design collaboration which led to better implementation of the ideas discussed. As a result of one-on-one sessions students not only learned better, but also started to realise the importance of the technical aspects and show interest in those topics. In general, the students implemented the recommendations by the consulting engineers after one-on-one sessions. Therefore, in the following sessions, the discussions went one level deeper on functionality of the mechanical/electrical service plants, as well as strategies for zero carbon emissions.

The final designs by the students reflected creativity in use of forms and creating beautiful spaces. By the end of semester, the student could manage to resolve the majority of functional and spatial issues, while remaining focused on innovative strategies to tackle zero-carbon criteria. One lasting 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. Some highly innovative sustainable design features were employed within the final design solutions, 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.

Figure 6: 'The Loop' by Bowen Liu: Solar roads designed in the form of running tracks on roof.

Communication:

Although the face-to-face interactions were not possible due to COVID-19 restrictions, the use of virtual collaboration platforms introduced new interaction methods including close access to the presentations on individual audience's screen. One key feature was the ability to use annotation tools to mark on the presentation. These features were found effective to overcome the limitations of remote communication and increase the effectiveness of interactions between consulting engineers and architectural students on a virtual platform.

At the initial stages of the studio, some of the engineering comments seemed to be too specialised for architectural students who didn't have in depth knowledge of the engineering concepts. They seemed to find them complicated and difficult to deal with. As the studio progressed, mutual effort by both parties to find a common language was a successful step that improved the effectiveness of their communication.

The individual approaches affect the process of integrated design. Each consultant may have their own interest areas or perceived topics of importance. Those individual approaches if not managed well can skew the approach taken by architectural students. Given this fact, a clear brief statement to communicate the common goals can lead to consistent approach by all design parties.

The method of presentations by students directly affect the consultant's understanding of the design and the quality of their feedback. Presenting the sections, plan drawings and diagrams were useful ways of presentation that resulted in more in-depth discussions and effective feedback by consultants.

Recommendations for future iterations:

For an effective integrated design process, it is important that each architecture student interacts with an engineering consultant (and/or an engineering student), on a weekly basis - and ideally even each session. The studio tutor needs to actively curate these points of engagement, to assist in streamlining the dialogue, and foster the notion of co-authorship, with shared responsibilities. If this does not occur, the engineers are likely limit their engagement in the collaborative co-designing process to a reactive 'consulting' activity.

The use of brief document as a reference is an effective way to incorporating the key project requirements while setting out the common goals and assuring a consistent approach among the involved parties.

More educational sessions at the initial weeks of studio to raise the students' understanding of the brief and their knowledge on spatial, functional and operational requirements can help them incorporate those requirements from the early stages.

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

The feedback from the key contributors of IDS-01 were captured via an online face-to-face interview process. Two 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.

The interviewees outlined the important steps to achieving a truly integrated design. Particularly for data centre projects, understanding of engineering systems' operation, scales and spatial requirements, and the co-relations between those systems, are among important drivers. For achieving an environmentally sustainable design outcome, it is important to understand the mechanics behind the energy consumption and transfer. Integrating the mechanical, electrical and architectural design, utilises right proportions of systems and parts, and brings them into context with the facility as a whole. Minimizing the energy consumption is another important step towards truly integrated design.

The participating industry consultants highlighted that creating a peer-to-peer discussion atmosphere, where the design team could freely exchange ideas and debate various aspects of design, is an important enabler of the integrated design in studio settings. The fact, that engineering students were not enrolled was a hurdle to accomplish this kind of collaborative environment. The industry consultants outlined that, although they provided guidance to students, the nature of their contribution could not be the same as engineering students due to differences in level of experience and knowledge. As such, the absence of engineering students led to challenges with lack of sufficient exploration of the brief, lack of sufficient understanding of the technical concepts, and measures of performance indicators of their proposed solutions. For the same reason, the architectural students focused more on creating community spaces (which they were more familiar with), and less on scrutinising the detailed technical specification of data centre spaces.

Figure 7: 'New Eden" by Shaun Lim: Community gardens used as human interface and community engagement features

The industry consultants indicated that the nature of their contribution was mostly through providing guidance and raise students' understanding on the technical side of the design activities such as meeting brief's requirements, resolving the issues related to operation of the engineering systems, their scales and spatial requirements. The consultants indicated that they consciously did not take an active role as designers since they wanted to allow experimentations and help students evolve their own design thinking to generate unique and creative solutions. According to the consultants their weekly sessions with students were undoubtedly effective since they covered the areas of struggle and helped students understand and resolve the functional and operational aspects of the design:

“Students actually got a lot out of it. They all eventually were able to comprehend the spatial aspects and had more time for the more creative aspects of the design rather than necessarily just the understanding of the bits of the building”. Gerard Page- Industry consultant

The design outcomes were deemed to not entirely reflect creativity in developing effective environmental solutions with real impact. According to the industry consultants and the client representative this outcome could be avoided by involving engineering students:

“There was a lot of very similar solutions in terms of the environmental aspects. Maybe that was driven to a degree by the consultants because they were the obvious answers. What happened, there wasn't enough exploration of other alternative solutions. again, if there were young engineering students there, there would be more dialogue and more discussion and different fresher ideas would be proposed”. Gerard Page- Industry consultant

*“**In reality, if we're doing 60 MW to 100 MW of capacity, a swimming pool will use 40 kW. It's not making any real difference**. We need engineering and science people involved with that type of technical project to integrate the design with the architecture”. Jeff Van Zetten- Client representative*

It was outlined that the brief has an important role in setting out comment goals for the integrated design team. According to the industry consultants and the studio tutor, the brief provided by NEXTDC for IDS-01, was very technically oriented with an engineering-focused language and therefore not easy to comprehend by architects. The industry participants suggested that the brief should be improved to embed more directions on spatial, functional and operational requirements of parts and systems and more emphasis on the value-bringing targets such as retaining client’s priorities and environmentally sustainable design goals. the client representative indicated that the brief should highlight the importance of maximising the outcomes for the client rather than focusing on just meeting the minimum requirements.

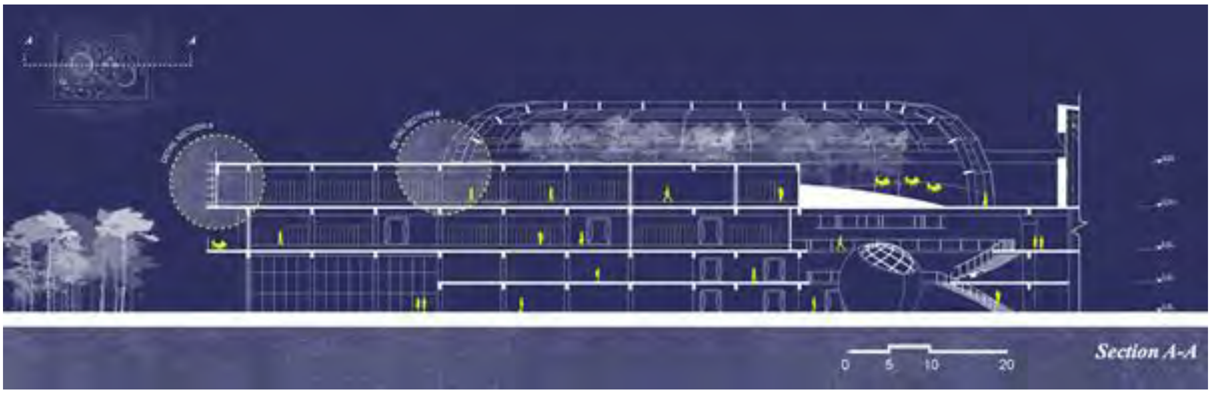


Figure 8: ‘Invaded” by Fan Wei: Incorporation of public greenhouse heated from waste data centre heat.

All the interviewees agreed on the fact that both, the aesthetic, as well as the functional aspects of the design were compromised. According to the studio tutor, in IDS-01 there was more emphasis on the real-world requirements and engineering aspects than the usual studios and therefore, the stylistics of the design were slightly compromised. On the contrary, the client representative believed that the students prioritised the architectural and aesthetics over the core capacity and functionality. The engineering consultants indicated that while some compromises are inevitable it is possible to achieve a design that can be both functional and aesthetic.

The above observations should not be seen in a negative light. Instead, they highlight the potential inherent to embracing conflicting views: During certain instances within the design process, students and consultants started to realise that elements of their design, that made a lot of sense from an environmental sustainability perspective, were in opposition to social engagement or potentially also safety and security. **The most interesting solutions did not emerge from avoiding such conflicts, but by embracing them and confronting them full-frontal in order to find innovative outcomes.**

The desired integrated design process would be to understand and accept the functional requirements and still being able to create a visually interesting design. Good understanding of the project components and their mechanisms and seeing those mechanisms an opportunity rather than a constraint can help with reducing the level of compromises of aesthetic and functional aspects:

"For me if it's functional, it's also quite aesthetic ... there were students that were trying to put the chillers in basements and trying to put roofs over to hide them away. That may be a good architectural strategy. But we need to recognize how these technical systems operate and the spatial requirements they need which also impacts scale and shape". Bill Giannikos- Industry Consultant

"It is about them understanding the bits and pieces of the building and the outputs of the systems but also what those components could fit in their design. For example, we talked about generators. They take air in at one side and blow out the other side. Once they understood this, they could actually use the air movement from the generators to create some interesting visual effects e.g. bits of metal, which could kind of wave in the wind". Gerard Page- Industry Consultant

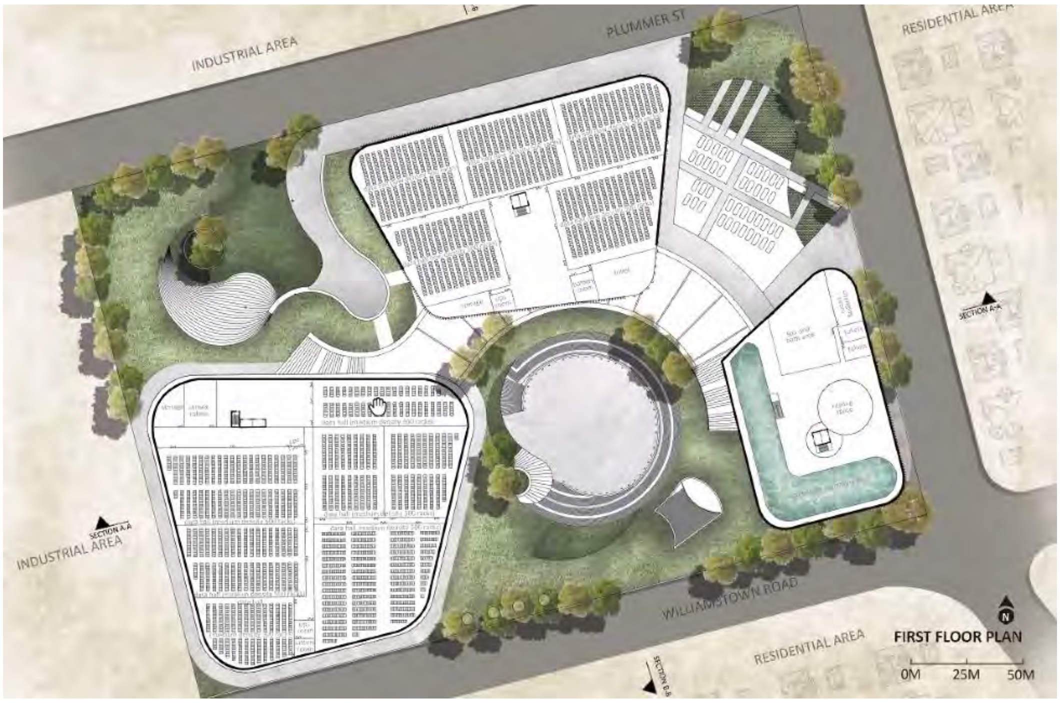


Figure 9: 'Zero C Data Loop' by Katrina Su: The data centre spaces and functions designed while created visually appealing forms

The process of integrated design as described by the interviewees is the close cooperation of all design parties who understand each other and respect each other's perspectives and work together towards achieving a common goal. Client leadership and stakeholder engagement were outlined as the key elements of integrated design process. It is very important for all parties to have appetite for integrated design. Being open-minded to learn about other disciplines' requirements and allowing everyone to contribute is an important part of the creative process. The industry consultant recommended that the curator should be a neutral party whose role is to steer toward desirable design outcomes without being involved in the actual design activities. The studio tutor on the other hand believed that the architect should be the key person to manage the process and curate the inputs by all other parties.

"It is like a film making where the film director is responsible for overseeing everyone but allowing everyone to be creative within that process. they would discuss with costume designer, but not design the costumes. You know, they would discuss framing with the cameraman. But if they've got a better way of doing something, then be open to that, and realize that, they're not the best person at lighting". Toby Reed- Studio Tutor

The constraints to integrated design outside the actual design process were outlined as time, fees, a willingness to sit in a room for a couple of days, engaging stakeholders who are not open to different ideas outside what they practice and are used to or the stakeholders who are not open to cultural changes.

Finally, all the interviewees agreed that experiencing integrated design process, as a part of higher degree education, is useful for the students. **The industry participants believed that IDS prepare them for dealing with compromises in real world and experience real-life situations**, problems and processes while it hones their powers of negotiation. According to studio tutor, one out of four studios in master's degree should be IDS. He indicated that while IDS help them experience real-life situations and constraints, other studios will allow them to practice the extremes of experimentation which is also a necessary part of their education. The client representative highlighted that the integrated design should in fact be a mandatory part of undergraduate degrees rather than being a part of master's degree:

"It is a huge running problem in the industry that the architects and engineers are different types of people and they're often arguing. So, if the architects and engineers have to work on a project, in reality like this, then the courses should be the same. They need to get to know each other and their way of thinking and if they did that, from the start that have a better understanding". Jeff Van Zetten- Client representative

Figure 10: 'Zero C Data Loop" by Kun Feng: Section view displaying data hall spaces & community spaces

4.3 Feedback from the participating students

After the completion of the semester, students participating in the IDS-01 were asked to respond to a 15-point online survey. The purpose of the survey was to extract key qualitative and quantitative data from students to establish how they perceived the integrated design process, and how it assisted them in addressing environmental design issues. Questions asked, cover the adequacy of the design brief to enable integrated design, the benefits and challenges of the integrated design process, as well as the perceived impact of engineering feedback on their design process.

There was a mixed level of environmental design experience among students who attended this class (median score 2 out of 5). The majority of respondents highlighted they either had little-to-no environmental design experience; a few had come across it in other classes.

Students listed: *Imagination and creativity*, *In-depth knowledge of technology for collaboration*, and *time assigned to the dialogue between architects & engineers* as the key design-drivers affecting successful environmental design to achieve renewable energy utilisations/zero carbon goals.

Figure 11: Key design-drivers affecting successful environmental design

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, one student responded:

Overall, it was well communicated and complimented with the verbal presentation in class, but it could have provided clearer direction on the architectural design side.

The above critique can be seen in the context of NEXTDC not being able to share the exact address of the site due to confidentiality constraints. One respondent did highlight that engineering terminology in the brief could be explained clearer to save the time of communication. This touches on the importance to introduce the architects to some of the technical engineering terminology early on.

Prompted about the most critical decision-making points when balancing arch/eng input for generating environmentally optimised design solutions, students listed: '*finding a double solution, that respond to both domains, as well as efficiency and innovation'*. In addition, students pointed towards the need to consider a data centre be a civil space for the wider community.

The inspiration for the Data-centre design solutions were broad and varied, some students listed the surrounding site analysis and natural environmental impacts, others referred to the idea of natural ventilation, that can translate into an architectural language. Other students again, pointed towards precedence design references, as well as, modular design and the contrast between function and architecture style.

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

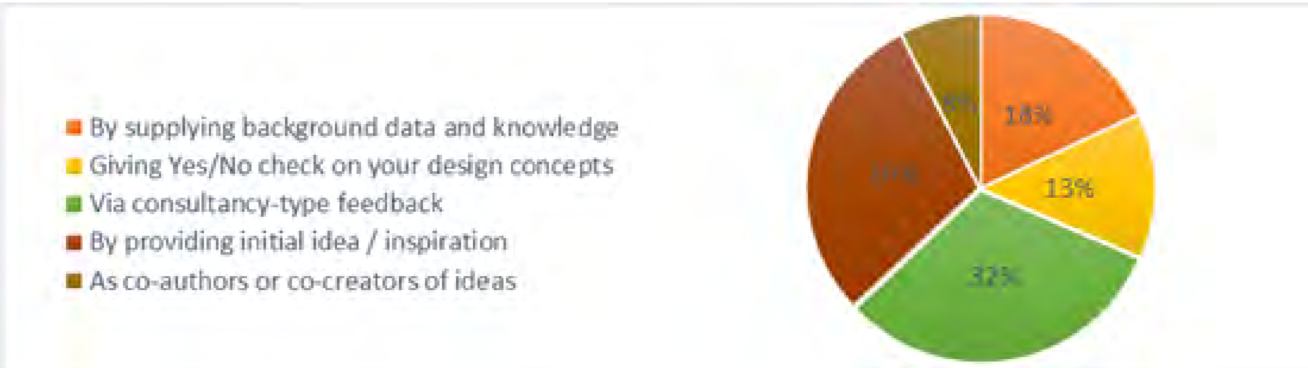


Figure 12: Inputs provided by the Engineering Consultants

Asked about the most useful guidance by the consultants, students highlighted: *how each type of equipment operates, how to place it, and how to use it efficiently*. Students referred to specifically to the location and placement of *chillers, generators, switch rooms* and their associated circulation / access requirements for operation & maintenance. One key response did highlight that the architecture students were unfamiliar with the kind of input engineers provide into the design process in the first place, providing correct guidance and offering more appropriate solutions.

With a median score of 4.6 (out of 5), most students argued that the input by consultants strongly increased their *'level of understanding of'* environmental issues and associated solutions

Students expressed their desire for more individual feedback sessions and more interaction *while* designing than consultation *after* designing, as well as ways to help them benchmark certain engineering solutions. Feedback: should provide relevant and convenient ways for us to learn and try to calculate some engineering data.

In IDS-01, students did feel that they had to compromise aesthetics and functional design aspects when balancing architectural and engineering concerns (median score 3.7). 70% responded that it was *'quite a bit'*, with 30% feeling ambivalent about it. When asked how compromising aesthetics could be avoided, students felt that extra time and closer cooperation with consultants to raise solutions via mutual discussions should allow for this.

Despite the overall positive feedback about the IDS, students also reported a number of challenges when advancing their design-thinking with environmental/engineering constraints in mind. Consolidating strong *ideas-driven design* with *cost and technical constraints*, while *meeting environmental requirements*, was listed as a key item, as well as meeting engineering requirements of arrangement and spatial configurations. The sizing and positioning of HVAC equipment, and the distribution of different energy needs (and associated heat loads), had often not been considered by the students, who were exposed to this side of design for the first time. Other barriers and constraints in architects/engineer collaboration related predominantly to knowledge-gaps and time constraints on projects.

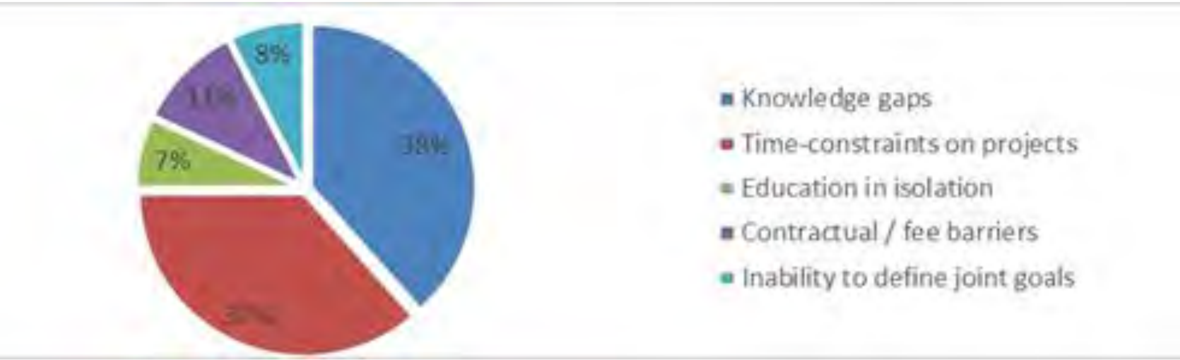


Figure 13: Challenges reported by the students

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

- *It is reality. I think it should be the emphasis of university teaching.*
- *It is more difficult to come through a design that respond to both disciplines, however, the solution is more comprehensive and practical.*
- *A balanced soup, with perfect spices*
- *It is the trend in the future design process*
- *It is the real design process, actually.*
- *It is a wonderful direction that allows people to think more comprehensively and consider more challenging projects at every stage of the design.*

The question about the usefulness of learning about integrated design processes as part of their university education, elicited a predominantly positive response, with 40% of students saying it was 'extremely useful' and 60% attesting it to be 'quite useful' (median score: 4.4 out of 5).

5. STUDIO DESIGN OUTPUT - Select Examples

A select number of student projects have been taken further by the Engineering Consultants AURECON in order to consolidate feedback and extract some key data. The following two sections contain AURECON's consolidation of 2 initiatives they saw emerging from the most promising student work; they relate to electricity generation and recycling of generated heat for auxiliary programs. These initiatives identified have the intent to reduce the carbon footprint of an 80 MW Data Centre facility. Three projects were selected to examine these initiatives in greater detail. The full 12-page document can be found as an appendix to this document.

5.1 Project 1: New Eden

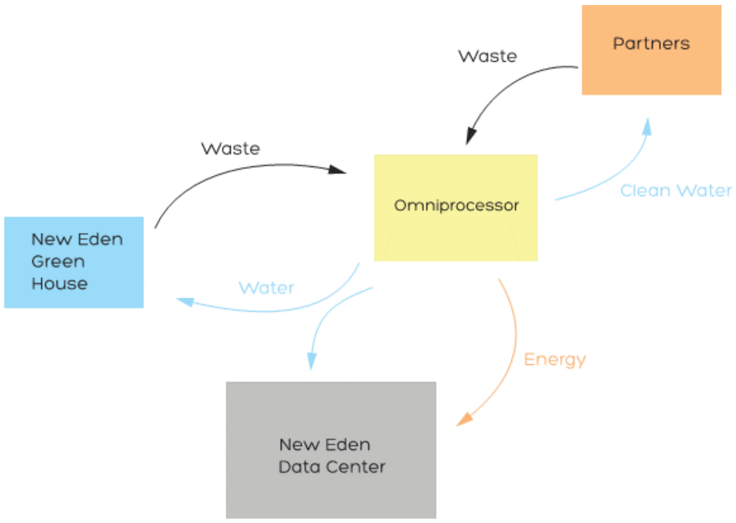


Figure 14: Achieving Zero Carbon Cycle Concept Diagram

Initiatives proposed on site:

The New Eden project proposed three main initiatives to address energy, water, and waste cycles on site. This includes an Omniprocessor, Greenhouse spaces, and a Pool/Bathhouse that interact with the main Data-centre function. As described in the summary below, the impact of proposed initiatives relating to generation of energy through renewables, and recycling of waste energy was not found to be significant for an 80 MW data centre facility. While the proposed Omniprocessor can only produce 0.24% of the electricity demanded on site, the cumulative heat that can be recovered by greenhouse and heated pool is only 0.035% of the waste heat produced on site.

Summary of Key Figures:

Electricity Generation		
PV Cells	0	MWh
OmniProcessor	2,190	MWh
% of Site Consumption of Electricity per Annum	0.24	%
Heat Exchanged/Reduction of Chiller Load		
Heating Greenhouse (Space) Annual	700,000	MJ
Heating Pool/Bathhouse (Water) Annual	190,000	MJ
% of total heat rejection per Annum	0.035	%
Water Produced		
OmniProcessor	86,000	L

5.2 Project 2: Zero C Data Loop "Babylonia"

Solar Road, Green Houses, and Heated Swimming pool are proposed as the strategies toward Zero-Carbon targets in Zero C Data Loop "Babylonia" project. The proposed strategies are found to have minor impact in addressing the energy and water waste issues on site. In an 80 MW data centre facility, the proposed amount PV cells is able to compensate for only 0.08% of the site electricity consumption while the Greenhouse and pool can only reuse 0.041% of the waste heat rejected from the facility.

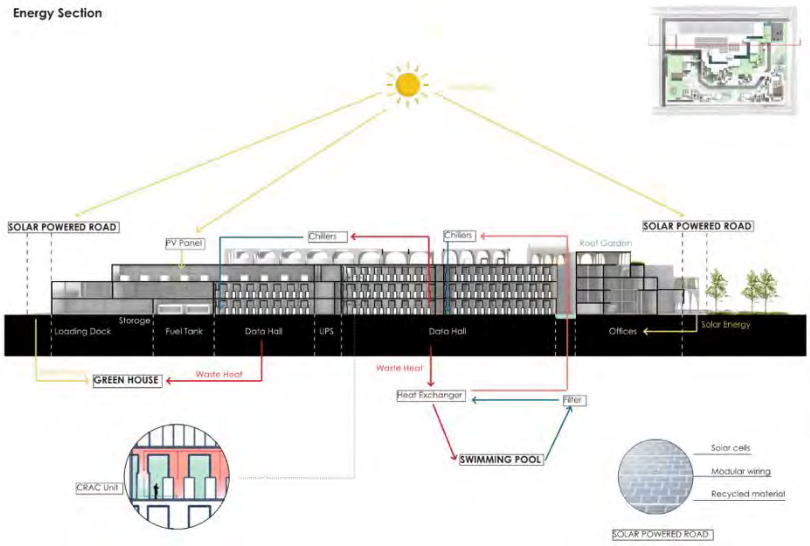


Figure 15: Energy Cycle

Electricity Generation		
PV Cells	757	MWh
OmniProcessor	N/A	MWh
% of Site Consumption of Electricity per Annum	0.08	%
Heat Exchanged/Reduction of Chiller Load		
Heating Green House (Space) Annual	800,000	MJ
Heating Pool/Bathhouse (Water) Annual	242,000	MJ
% of total heat rejection per Annum	0.041	%
Water Produced		
OmniProcessor	N/A	L

5.3 Project 3: Zero C Data Loop

In Zero C Data Loop project, Solar Cell Roof Canopy, Greenhouse and Heated Swimming Pool are the initiatives used to address the Zero-Carbon goals. While the proposed amount of PV cells can produce around 0.33% of the annual electricity requirement, the greenhouse and pool together can reuse 0.28% of the waste heat rejected by the facility.

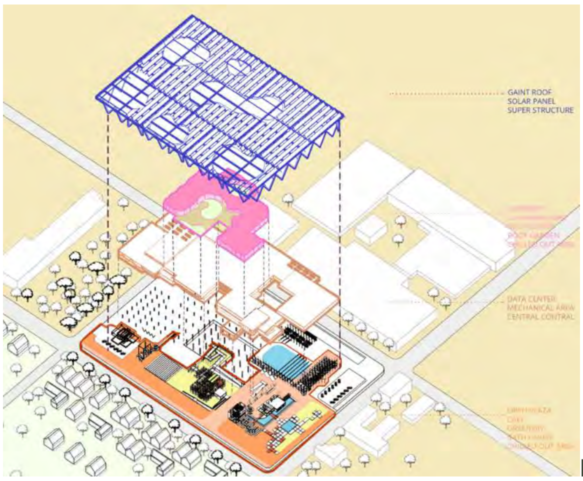


Figure 16: Concept Layout (Solar Cell Canopy)

Electricity Generation		
PV Cells	3,008	MWh
OmniProcessor	N/A	MWh
% of Site Consumption of Electricity per Annum	0.33	%
Heat Exchanged/Reduction of Chiller Load		
Heating Green House (Space) Annual	6,400,000	MJ
Heating Pool/Bathhouse (Water) Annual	702,000	MJ
% of total heat rejection per Annum	0.282	%
Water Produced		
OmniProcessor	N/A	L

6. SUMMARY OF CONSULTANT VETTING – Performance relative to BAU

6.1 Carbon neutral power generation from renewable sources (PV cells) & recycled waste (OmniProcessor)

Approaches taken by the IDS-01 students to generate clean energy were through introducing renewable resources (PV cells) and recycled waste (OmniProcessor). Solar PV panel is a system component that generates DC electricity when exposed to photons/solar radiation. The projects have seen both the application of solar roof panels and solar road cells. OmniProcessor plant takes human waste and converts it into drinking water and electricity.

By taking some general assumptions, the impact of carbon neural power generation strategies in an 80 MW data centre have been assessed. The total renewable power generated is <1% of the total site power usage, which seems small when compared to a mega facility of 80 MW. However, in the context of a typical 10-20 MW facility these figures start to show significant contributions (in excess of 2.5%). Further, the biproduct of waste heat from the facility can lead to community spaces run almost for free, from a community perspective these are significant returns.

6.2 Recycling of generated heat to serve public spaces such as swimming pools and greenhouse

The application of swimming pool heat exchangers for salt and low chlorine swimming pool heating has been applied to IDS-01 projects. A heat exchanger is used to transfer heat energy from one medium to another without the two media being mixed. In this application, CHWR (Chilled Water Return) would pass through the heat exchangers before either passing through the chillers or returning as CHW to the cooling system associated with the data centre. Chillers use a significant amount of power to maintain data centre internal temperatures, this method of heat exchange would reduce the load across the chillers and in turn provide direct energy savings.

Glass Greenhouse is another heat recovery strategy applied on IDS-01 projects. On average greenhouses consume 0.50–0.60 kg of CO_2/hr/100 m^2 and require 8-16 L/m^2 of water per day. The intent of the greenhouse in the site cycle is to utilise water produced through the OmniProcessor, plant waste is recycled back to the OmniProcessor. Secondly, waste heat from data halls is exchanged with the greenhouse to maintain 25 °C climate throughout the year. This heat exchange could be done via hydronic radiant heating (directly using CHWR for this process). This process would reduce the load across the Chillers. Using IES modelling, the heat gain required for heating the 1200 m^3 Glass Greenhouse was used to extrapolate the approximate heat gain for various sized Greenhouses presented in the three projects.

6.3 Baseline vs Best Practice

An Industry Standard Comparison has been carried out to evaluate the effectiveness of the solutions taken by the projects during IDS-01. As evident in the table, while the percentage of renewables are higher than current industry benchmark, the percentages of energy savings in the project is significantly lower that industry norm and industry benchmark. The reason is the size of the facility which would not be considered typical commercial building, and at 80 MW this facility would become one the largest in Australia to date. It should be noted that data centre capacity per unit floor area of the building (MW per m^2) for this project is significantly higher than the other Industry Norm or Benchmark building. (i.e. The absolute values of percent contributed by the renewable energy system are not comparable, need to normalise by per unit area of the building site footprint or roof area for meaningful comparison.)

	Industry Norm	Industry Benchmark	Project Benchmark (80MW)
NABERS	4 Star	5 Star	5 Star
PUE	1.45	1.3	1.3*
% Renewables	<0.2%	0.28%**	0.33%
Energy Savings (Initiatives)	5-10%	20%***	<1%*****
Industrialised Construction	Yes	Yes	No
Carbon Savings (Tonnes)	100	452.25****	3,250
Community Engagement	None	Minimal	High

*Assumed value for purposes of project evaluation (Note: an ideal PUE is 1.0)
**Typically, Solar Roof Panels or Wind turbines are installed.
***Sites utilised free cooling via economy cycle, modular approach to installing mechanical plant, enhanced building tuning via machine learning, BMS to control equipment, optimising plant performance.
****Notably NEXTDC M1 project installed largest privately owned Solar Array 2013, data from NEXTDC website
*****Value reported does not include “free cooling via economy cycle, modular approach to installing mechanical plant, enhanced building tuning via machine learning”.

6.4 Key Feasibility Vetting Findings

For an 80 MW Data Centre the percentage figures in the ballpark of 1% savings are not interpreted as of significant energy/electricity savings from a PUE (Power usage effectiveness) perspective. But this size facility PUE is a ratio of total Facility Power usage to energy delivered to equipment. This ratio is a measure of a facilities operation’s overall efficiency. All power generated on site (even renewables) would not substantially reduce the PUE as the equivalent power is still being delivered to the site. An energy saving method such as heat exchangers would significantly reduce the heat load across high power equipment (such as chillers) and in turn reduce the facilities usage of power, thus reducing PUE.

These savings estimated for the students’ Studio project may not be considered significant from a hyperscale Data Centre perspective, but the biproduct of waste heat from the facility can lead to community spaces run almost for free; from a community perspective, these are significant returns.

For a high-power density data facility, these initiatives when applied, mean:

- Community Garden heated for almost nothing
- Community Pool has 100% reduction in heating cost.

When compared to a mega facility of 80 MW, these energy savings are proportionally small, when in the context of a typical 10-20 MW facility, these figures start to show significant savings (in excess of 2.5%)

7. CONCLUSIONS

7.1 Conclusions and integration into the wider IDS programme

The NEXT-DC Data Centre IDS has received highly positive feedback from all involved, in particular the client. Against the backdrop of a difficult start to the semester, with engineering students unable to join, and the sudden move to online teaching, the IDS managed to create an environment of architect/engineer collaboration (with net zero carbon targets as a focus), in which to study how integrated design occurs.

The trial IDS teaching framework, paired with experienced educational experts, and equally proficient engineering and architecture consultants, supported students to challenge the existing dogma of (often sequential) design collaboration, to come up with unprecedented solutions that took the client 'out of his comfort zone'. Via the integrated design approach, over a dozen of environmentally optimised, and architecturally challenging proposals were developed by students over the course of the semester.

The studio progress was logged by the IDS team via detailed observations. They noted the particularities of the integrated design process, and the nature of the architect-engineer dialogue from beginning of the semester, all the way to the final presentations and beyond. At the completion of the studio, the IDS research team managed to extract key qualitative, as well as quantitative information from all studio participants to allow them to scrutinise the advantages and challenges of integrated design processes. The observations reflect some of the conditions met by professionals in everyday practice, but they also offer ample suggestions for process-improvement, change in attitude, and suggestions on how to set up integrated design processes to maximise the output of all involved. At the same time, the reflections from those involved, also offer constructive criticism on how to improve the IDS program for future iterations.

The design output generated by the students represents a dense array of solutions, that address the functional and operational requirements of the client, whilst challenging existing conventions. Inspired by the consultants and the studio tutor, the students included and tested a range of highly innovative technologies, both for the existing building stock as well as the new additions. Beyond this quality, some key solutions have been taken further by the consulting engineers, in order to produce an in-depth investigation about the energy performance of schools, with a detailed comparative study on zero Carbon interventions vs BAU.

The studied projects will achieve a 5 Star rating in NABERS which is compliant with the current industry benchmarks. Please note NABERS for data centres is based on a facility's actual operational data, not design. The design by the students were successful in achieving high level of industry engagement and carbon savings additional to the industry benchmarks' options. The students did not consider using industrialised construction methods in their designs unlike the current trend in the industry.

Summary findings have been presented in the executive summary section of this report.

APPENDIX A – SELECTED STUDENT WORK

APPENDIX B – TRANSCRIPT OF INDUSTRY/TUTOR INTERVIEWS

APPENDIX C – TRANSCRIPTS OF STUDENT FEEDBACK

APPENDIX D – ENGINEERING CONSULTANT VETTING REPORT

Design Studio Outcomes

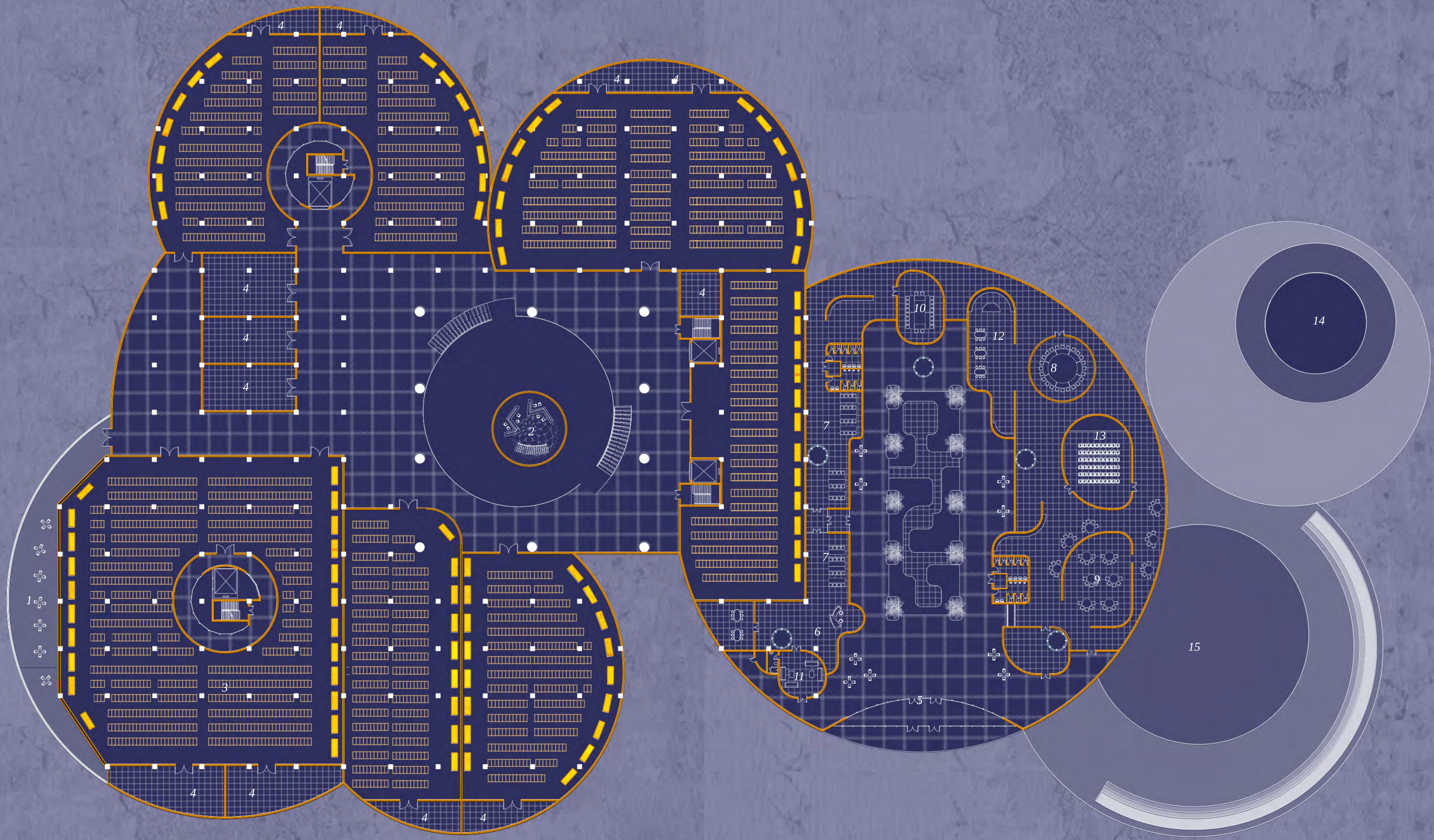
IDS-01

APPENDIX A

SELECTED STUDENT WORK

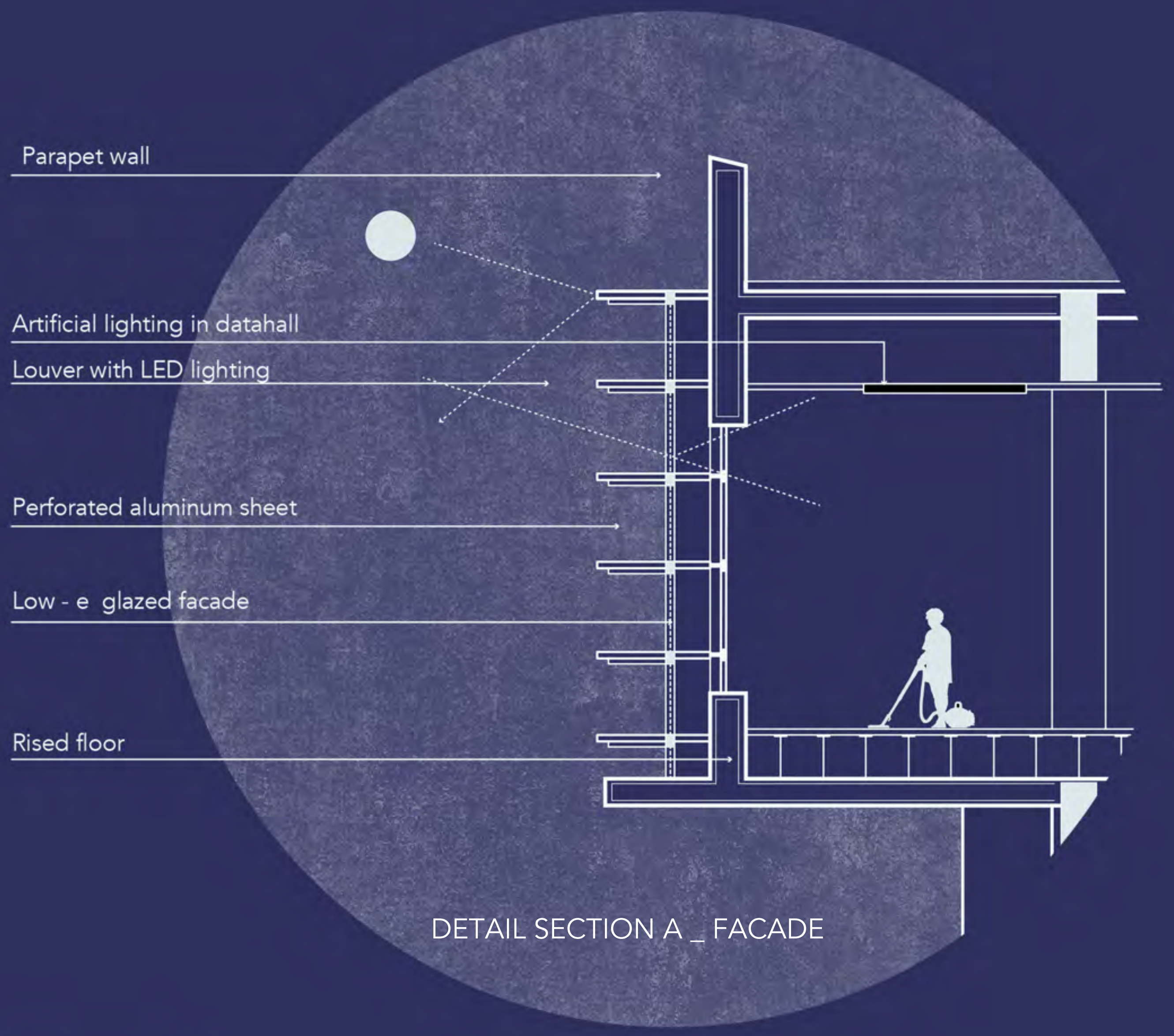
INVADED

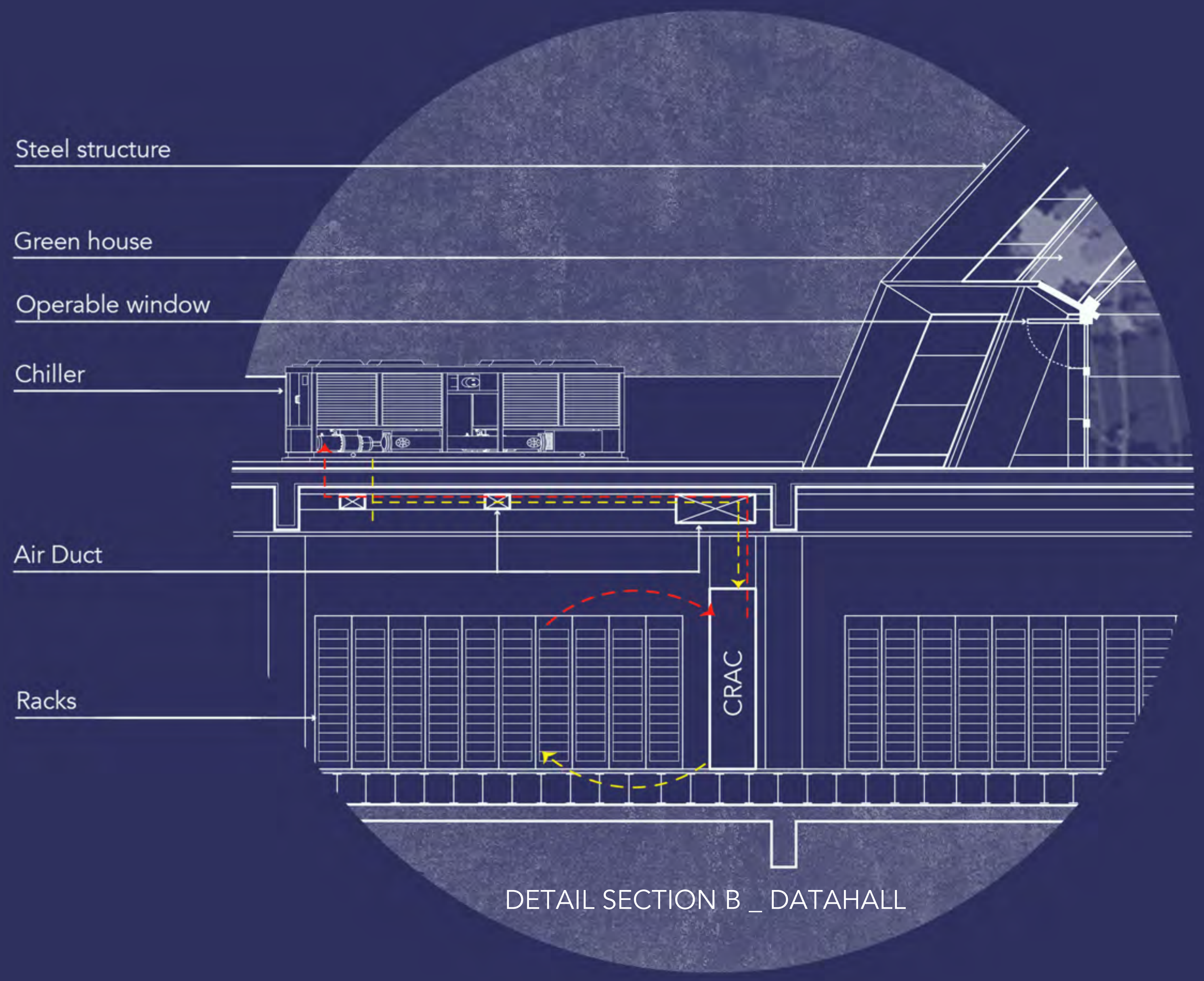
By Wei Fan

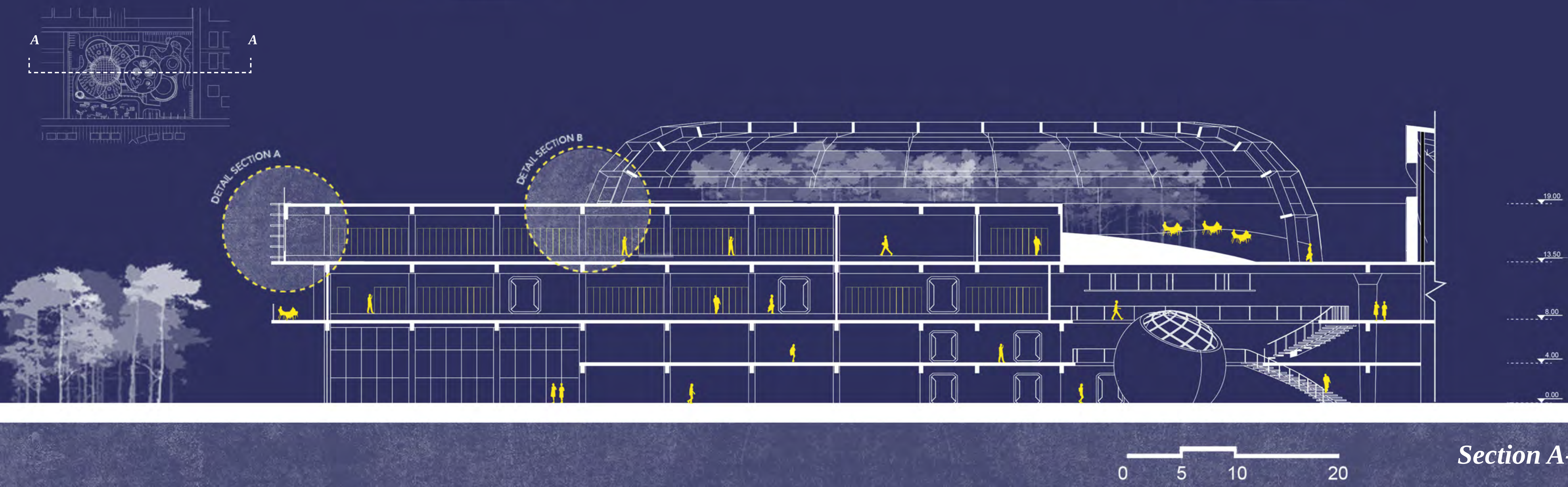


1 staff rest
2 control cente
3 datahalls
4 interconnect room
5 client entry
6 reception
7 office
8 meeting
9 cafe
10 board room
11 waiting room
12 brainstorming
13 water landscape
14 swimming pool
15 plaza

First Floor


Parapet wall
Artificial lighting in datahall
Louver with LED lighting
Perforated aluminum sheet
Low - e glazed facade
Rised floor
DETAIL SECTION A _ FACADE


Steel structure
Green house
Operable window
Chiller
Air Duct
Racks
CRAC
DETAIL SECTION B _ DATAHALL


A
A
DETAIL SECTION A
DETAIL SECTION B
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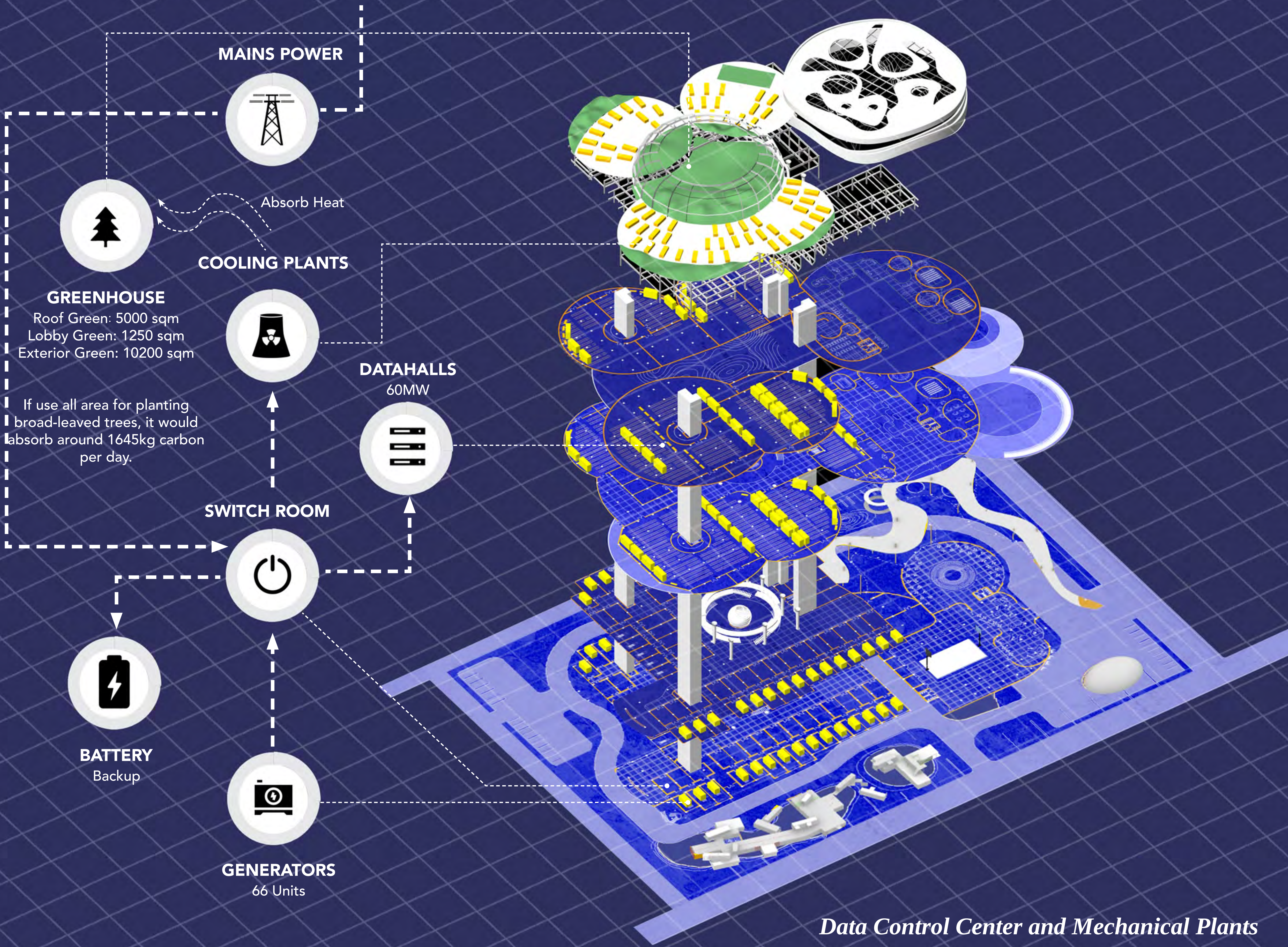
Section A-A



Data Control Center and Mechanical Plants

Aerial View from Graham St. &Plummer St.

THE LOOP

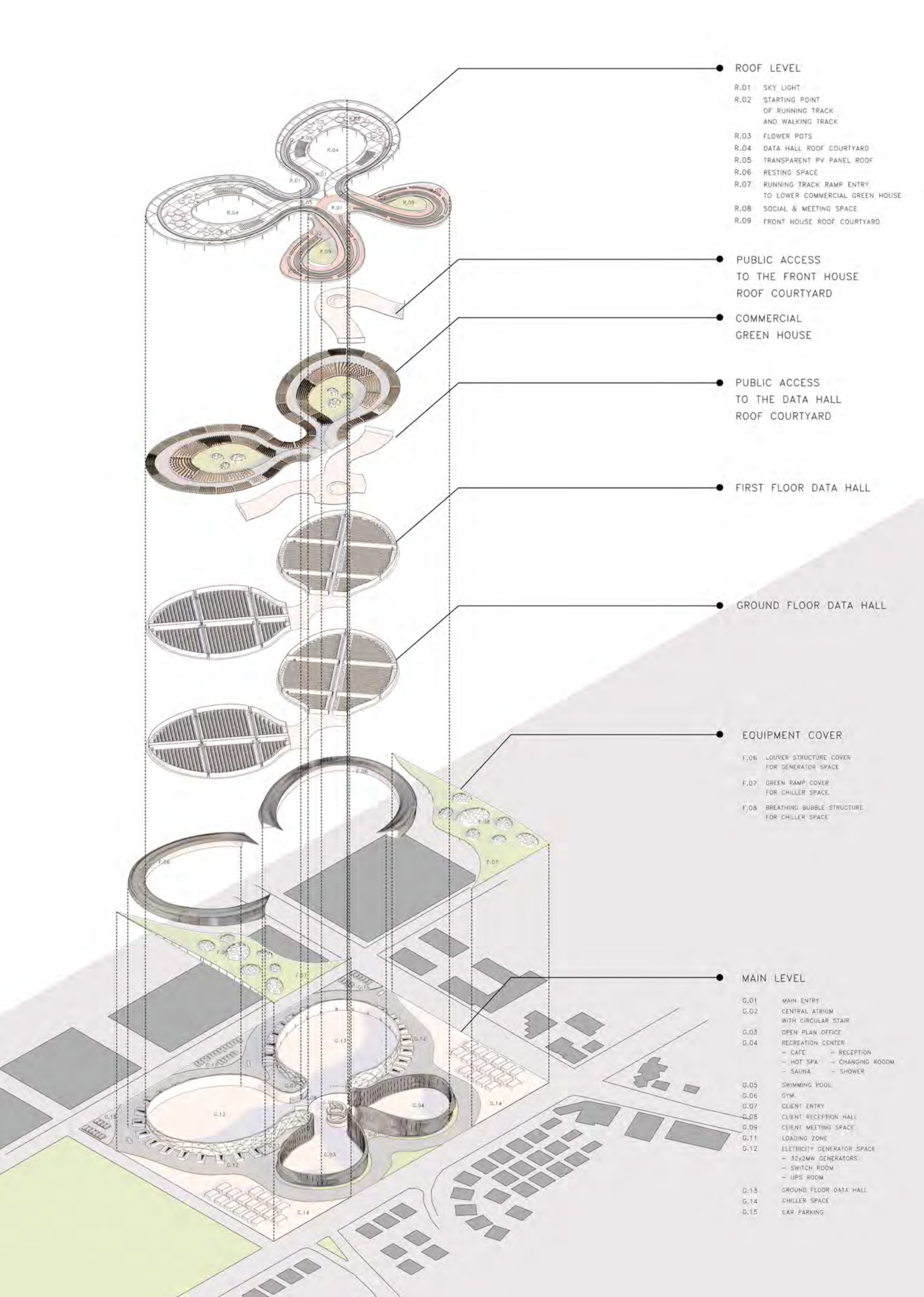
By Bowen Liu

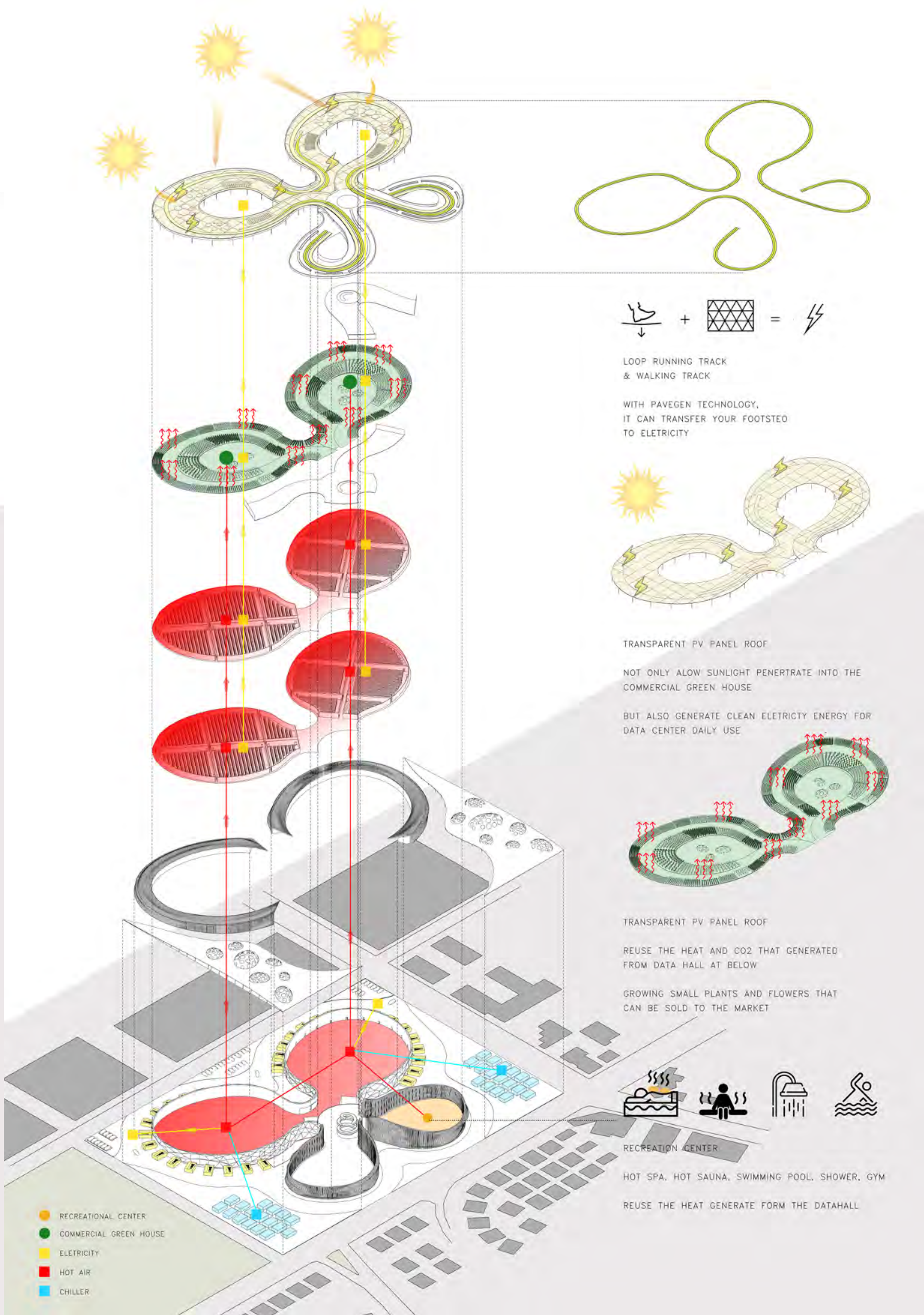
CONCEPT

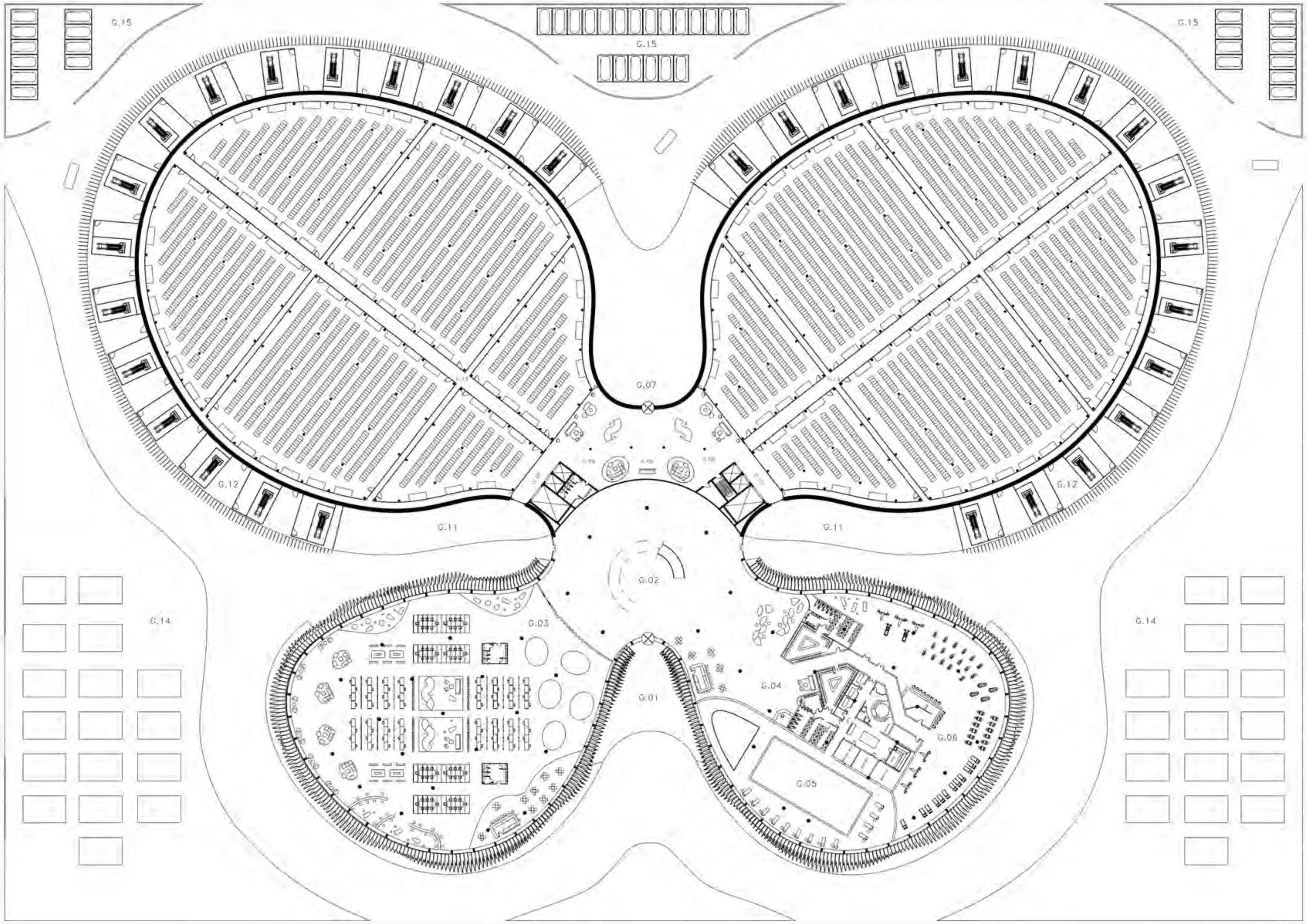
- PROVIDING SPORTS SPACE FOR THE LOCAL COMMUNITY
- PROVIDING GREEN SPACE FOR THE LOCAL COMMUNITY

- SATISFYING THE NEED OF THE DATA CENTER
- RENEWABLE CLEAN ENNERGY AND ZERO CARBON LOOP
- ENCORAGE LOCAL COMMUNITY GERNERATE CLEAN ENERGY BY RUNNING

AERIAL PHOTOMONTAGE


ROOF LEVEL
R.01 SKY LIGHT
R.02 STARTING POINT OF RUNNING TRACK AND WALKING TRACK
R.03 FLOWER POTS
R.04 DATA HALL ROOF COURTYARD
R.05 TRANSPARENT PV PANEL ROOF
R.06 RESTING SPACE
R.07 RUNNING TRACK RAMP ENTRY TO LOWER COMMERCIAL GREEN HOUSE
R.08 SOCIAL & MEETING SPACE
R.09 FRONT HOUSE ROOF COURTYARD
PUBLIC ACCESS TO THE FRONT HOUSE ROOF COURTYARD
COMMERCIAL GREEN HOUSE
PUBLIC ACCESS TO THE DATA HALL ROOF COURTYARD
FIRST FLOOR DATA HALL
GROUND FLOOR DATA HALL
EQUIPMENT COVER
F.06 LOUVER STRUCTURE COVER FOR GENERATOR SPACE
F.07 GREEN RAMP COVER FOR CHILLER SPACE
F.08 BREATHING BUBBLE STRUCTURE FOR CHILLER SPACE
MAIN LEVEL
G.01 MAIN ENTRY
G.02 CENTRAL ATRIUM WITH CIRCULAR STAIR
G.03 OPEN PLAN OFFICE
G.04 RECREATION CENTER
- CAFE - RECEPTION
- HOT SPA - CHANGING ROOOM
- SAUNA - SHOWER
G.05 SWIMMING POOL
G.06 GYM
G.07 CLIENT ENTRY
G.08 CLIENT RECEPTION HALL
G.09 CLIENT MEETING SPACE
G.11 LOADING ZONE
G.12 ELETRICITY GENERATOR SPACE
- 32x2MW GENERATORS
- SWITCH ROOM
- UPS ROOM
G.13 GROUND FLOOR DATA HALL
G.14 CHILLER SPACE
G.15 CAR PARKING


LOOP RUNNING TRACK & WALKING TRACK
WITH PAVEGEN TECHNOLOGY, IT CAN TRANSFER YOUR FOOTSTEO TO ELETRICITY
TRANSPARENT PV PANEL ROOF
NOT ONLY ALOW SUNLIGHT PENERTRATE INTO THE COMMERCIAL GREEN HOUSE
BUT ALSO GENERATE CLEAN ELETRICTY ENERGY FOR DATA CENTER DAILY USE
TRANSPARENT PV PANEL ROOF
REUSE THE HEAT AND CO2 THAT GENERATED FROM DATA HALL AT BELOW
GROWING SMALL PLANTS AND FLOWERS THAT CAN BE SOLD TO THE MARKET
RECREATION CENTER
HOT SPA, HOT SAUNA, SWIMMING POOL, SHOWER, GYM
REUSE THE HEAT GENERATE FORM THE DATAHALL
RECREATIONAL CENTER
COMMERCIAL GREEN HOUSE
ELETRICITY
HOT AIR
CHILLER

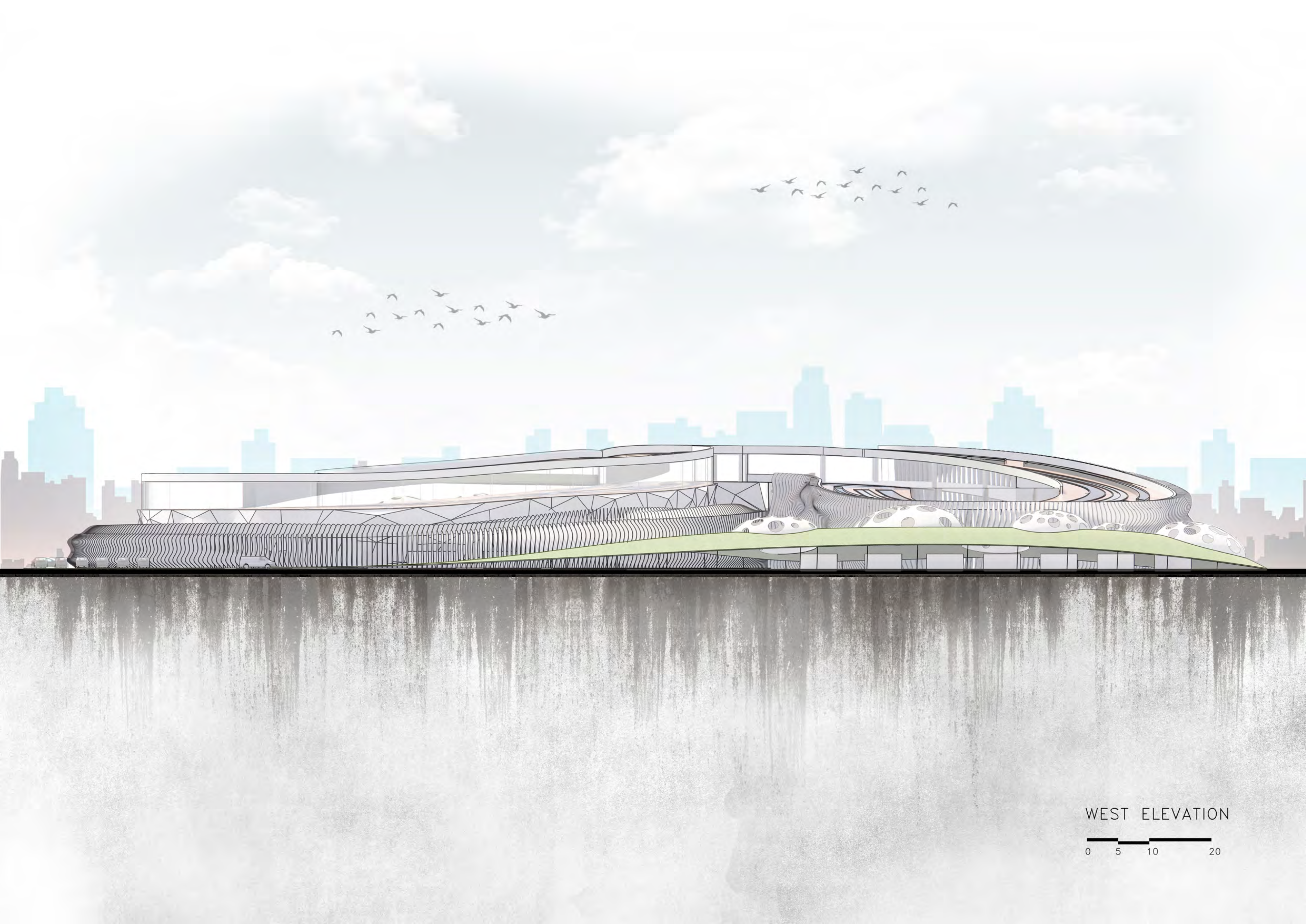


LEGEND

G.01	MAIN ENTRY
G.02	CENTRAL ATRIUM WITH CIRCULAR STAIR
G.03	OPEN PLAN OFFICE
G.04	RECREATION CENTER – CAFE – RECEPTION – HOT SPA – CHANGING ROOOM – SAUNA – SHOWER
G.05	SWIMMING POOL
G.06	GYM
G.07	CLIENT ENTRY
G.08	CLIENT RECEPTION HALL
G.09	CLIENT MEETING SPACE
G.10	BUILDING CORE – 1x GOODS LIFT – 2x Passenger LIFT – TOILLET – STORAGE ROOM – FIRE ESCAPE STAIRCASE
G.11	LOADING ZONE
G.12	ELETRICITY GENERATOR SPACE – 32x2MW GENERATORS – SWITCH ROOM – UPS ROOM
G.13	GROUND FLOOR DATA HALL
G.14	CHILLER SPACE
G.15	CAR PARKING

GROUND FLOOR PLAN

0 10 20 40



WEST ELEVATION

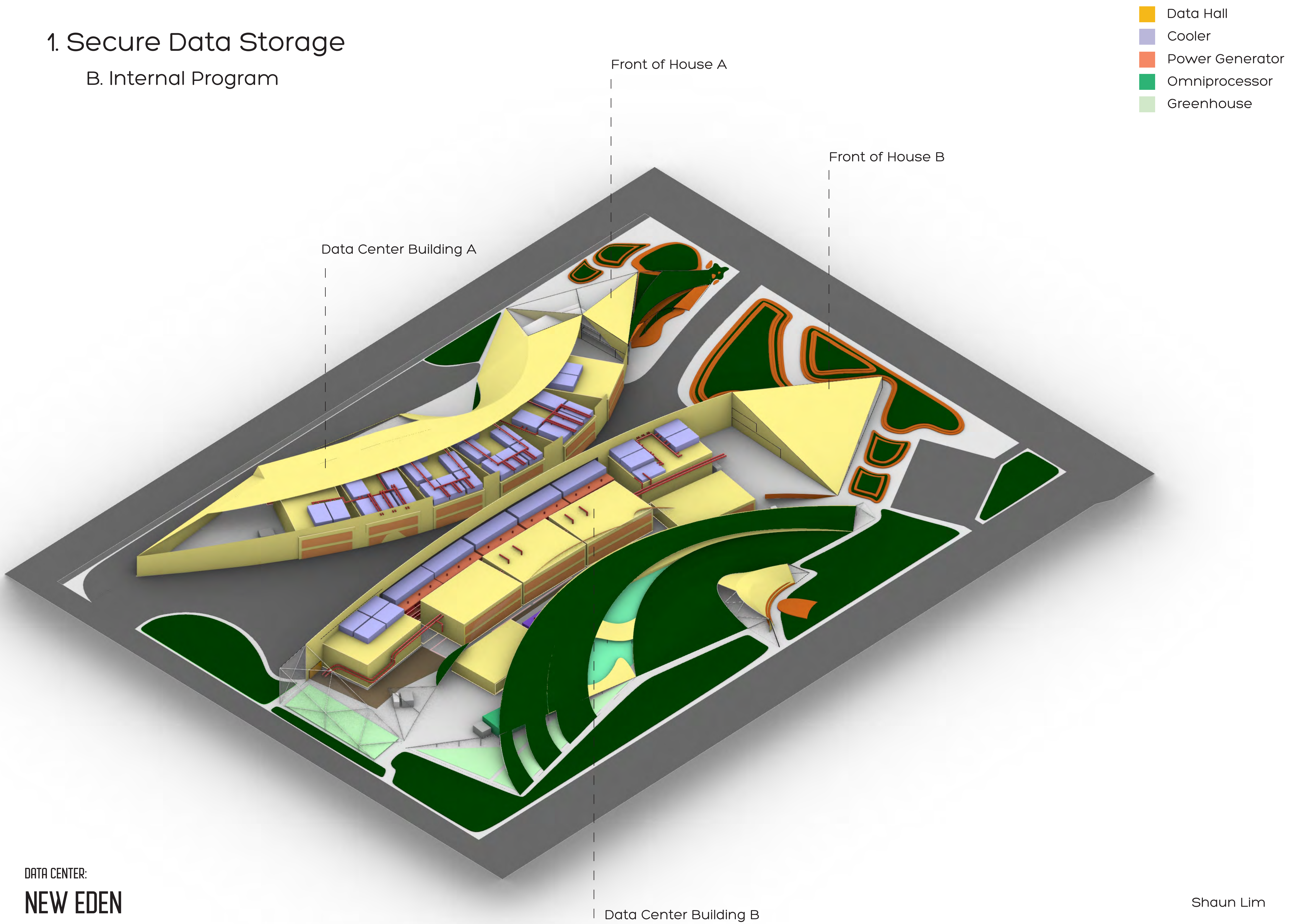
0 5 10 20

NEW EDEN

By Shaun Lim

1. Secure Data Storage

B. Internal Program



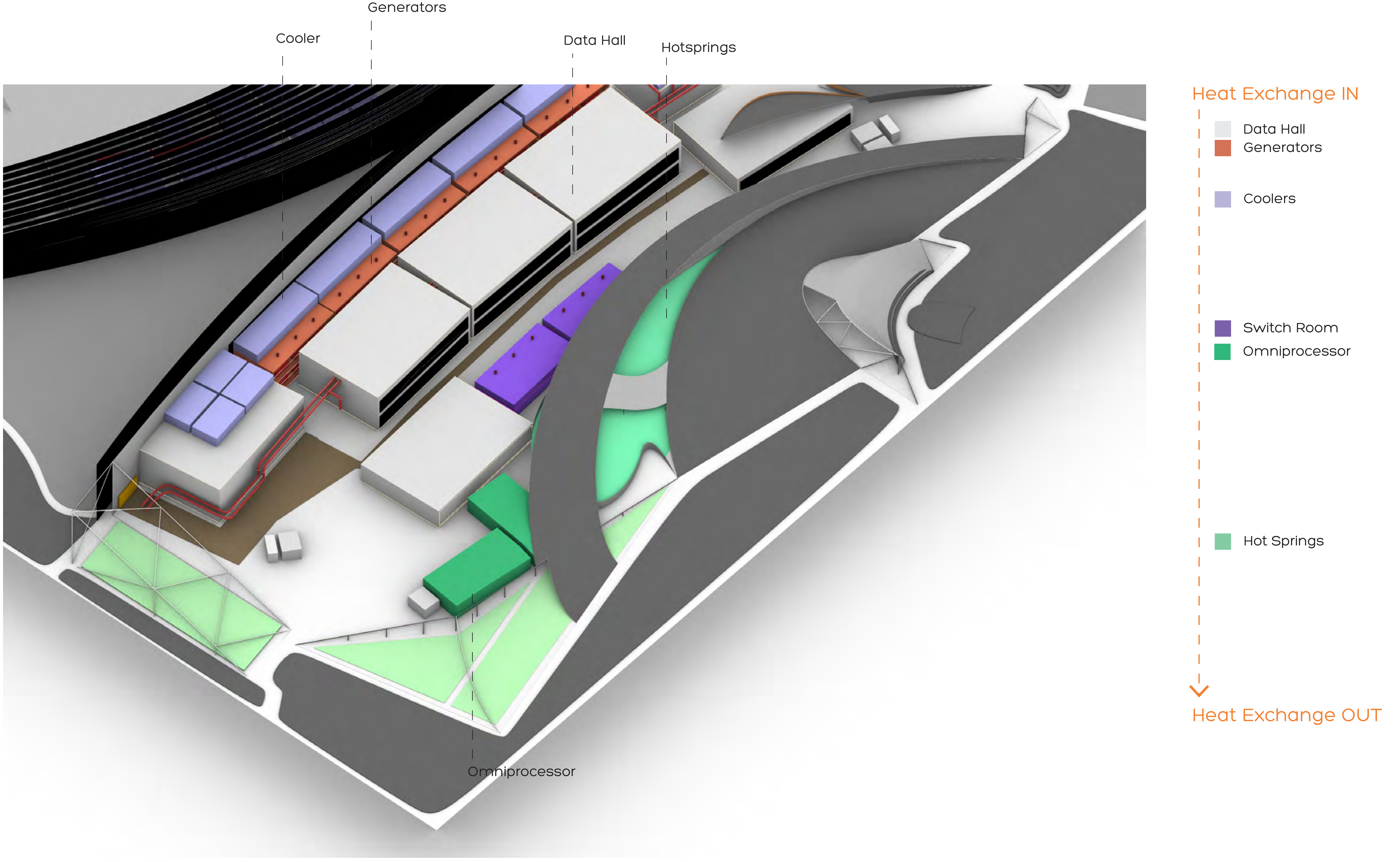
DATA CENTER:

NEW EDEN

Shaun Lim

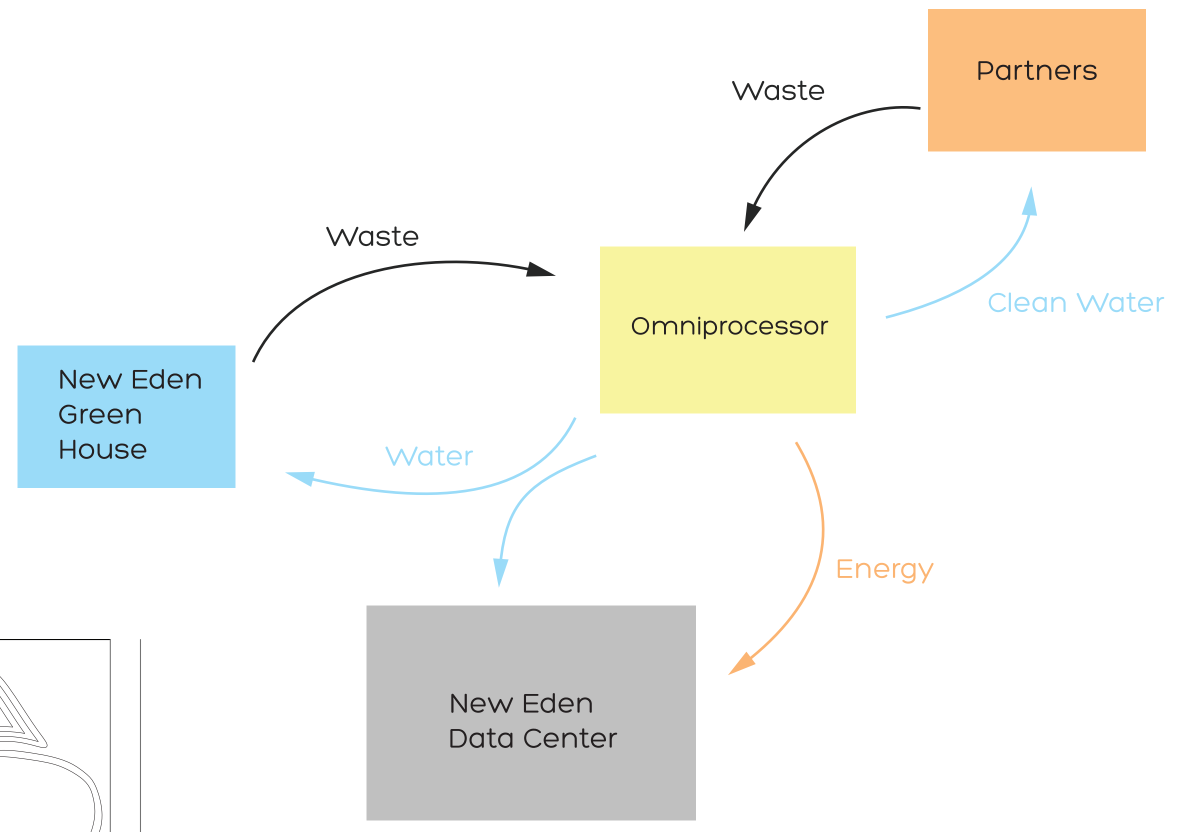
2. Reliable Cooling Systems

B. Heat Exchange System

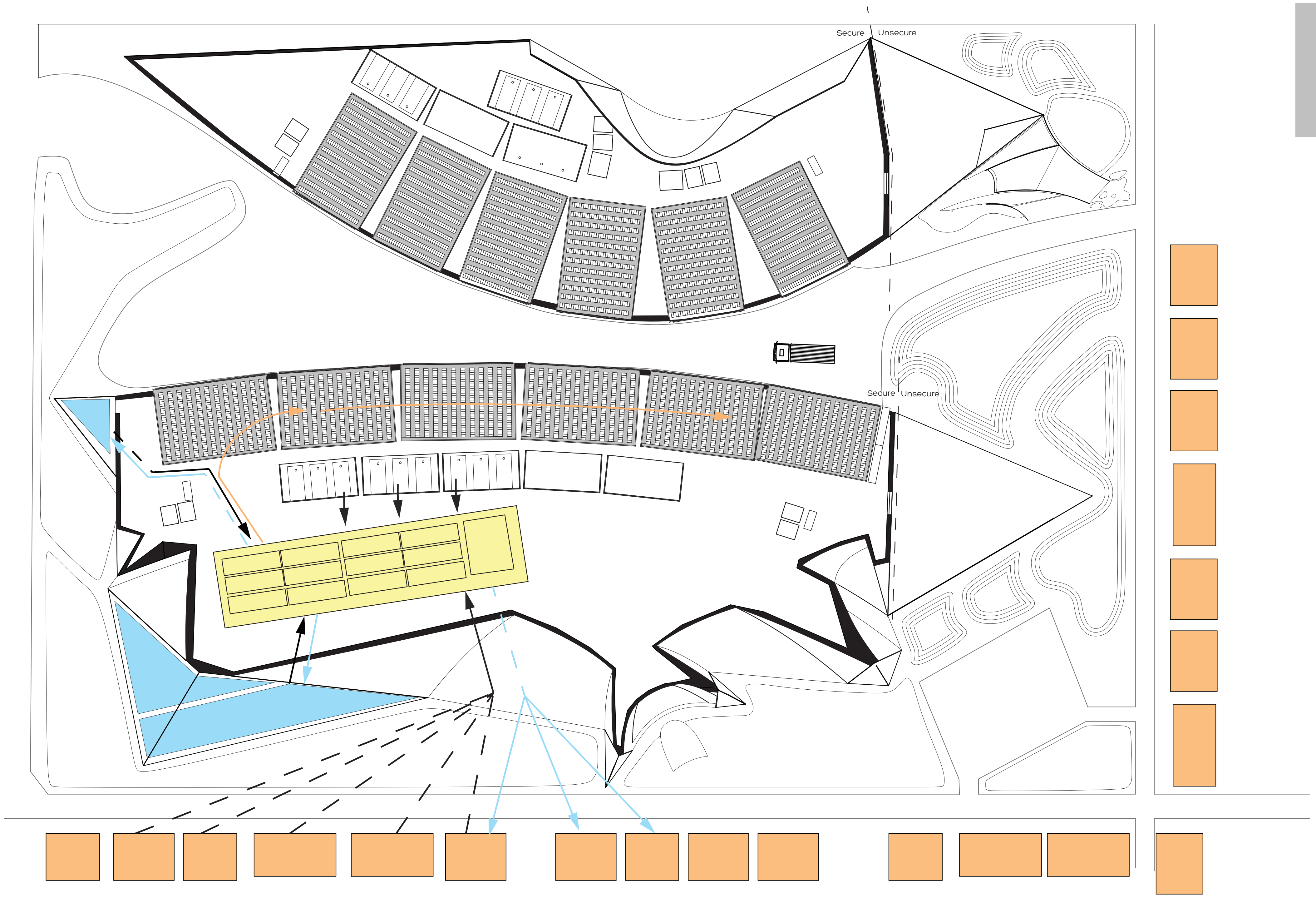


3. Achieving Zero Carbon

A. Reducing carbon emissions with the use of an Omni processor System.



Diagramatic Concept:

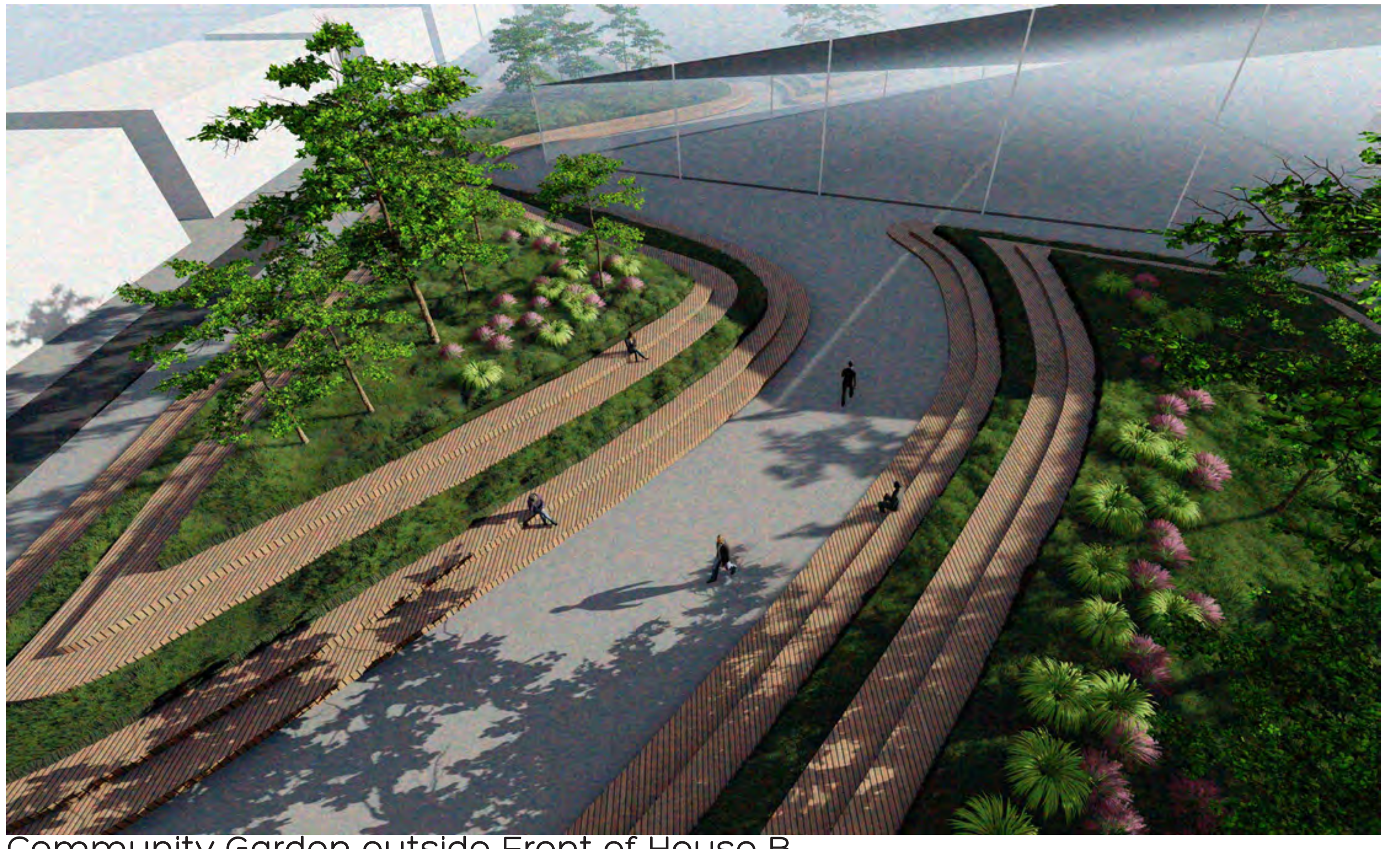


DATA CENTER:

NEW EDEN

Shaun Lim

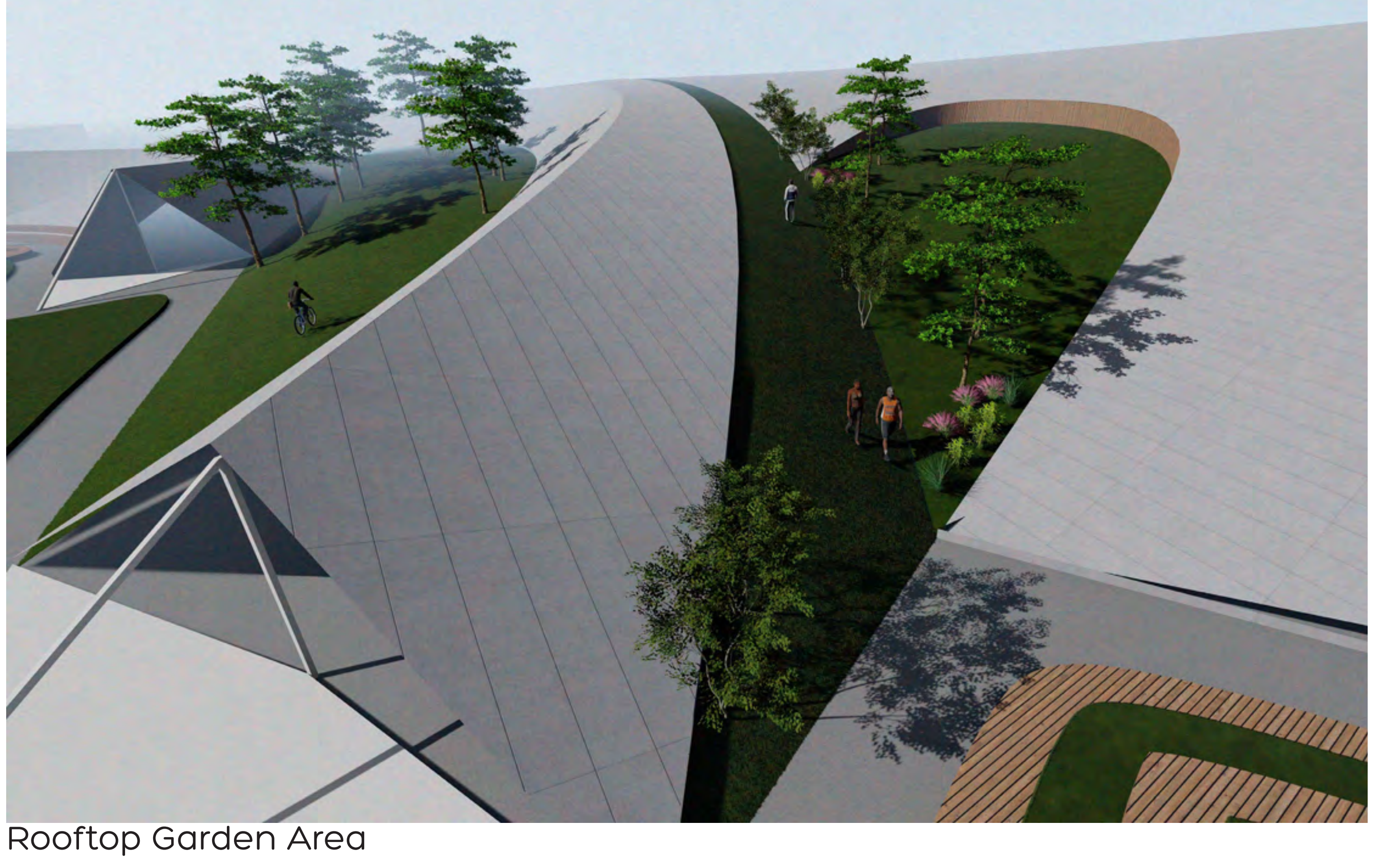
4. The Human Aesthetic



Community Garden outside Front of House B

Garden Space Above Front of House A

Performance Amphitheatre outside Swimming Pool complex

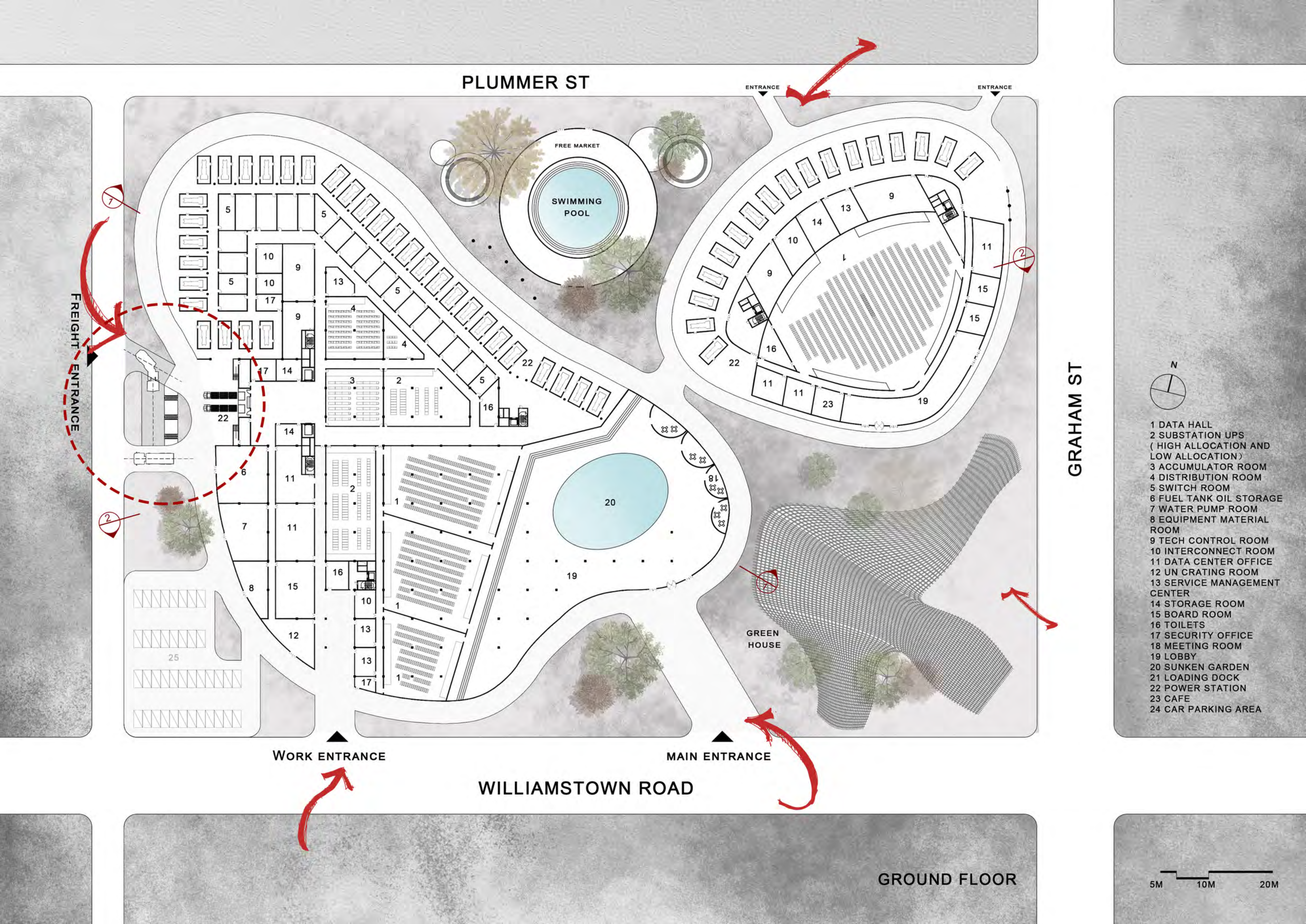


Rooftop Garden Area

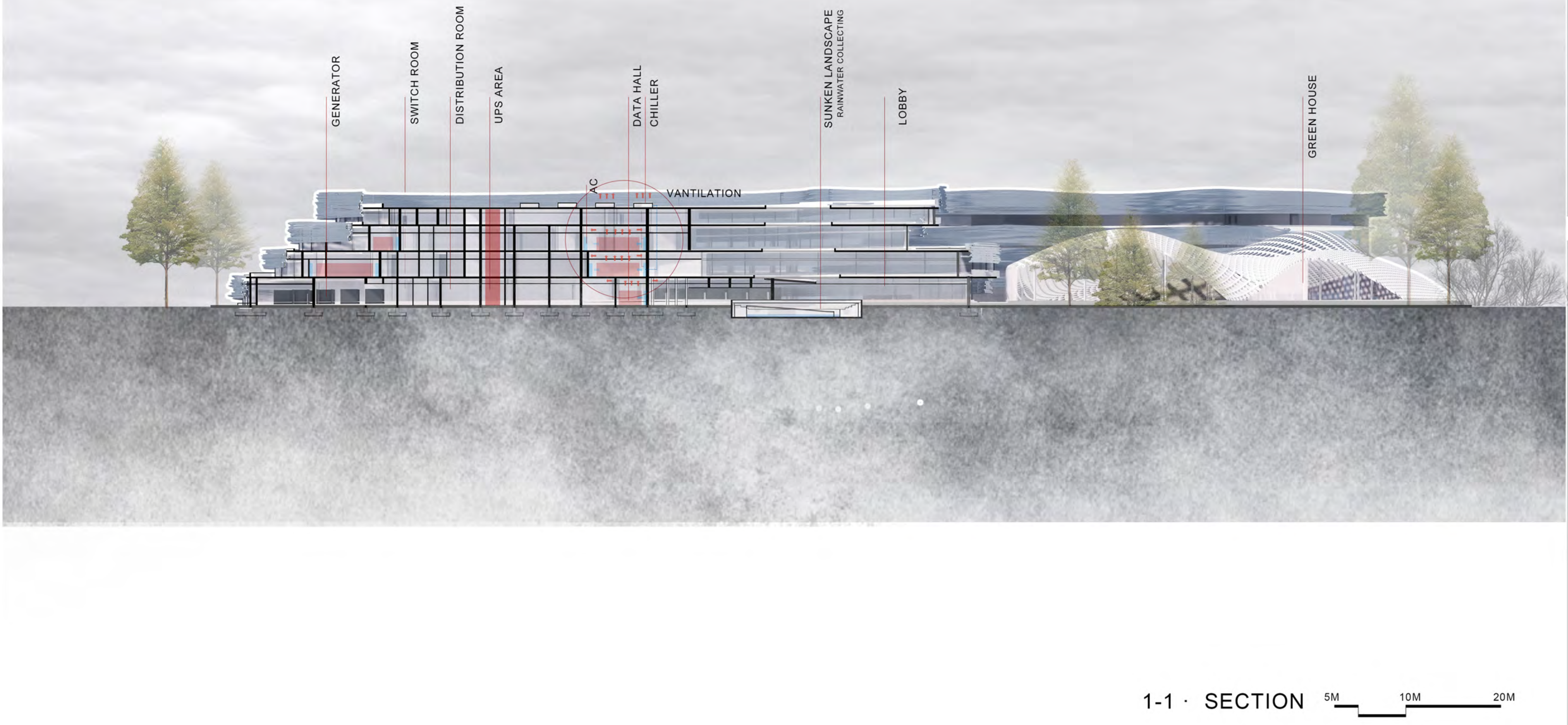
4.1 - New Eden develops community by using the landscape across the data center's aesthetic as multi-purpose spaces. New Eden is filled with exciting spaces and personal experiences for the curious individual to discover.

ZERO C LOOP

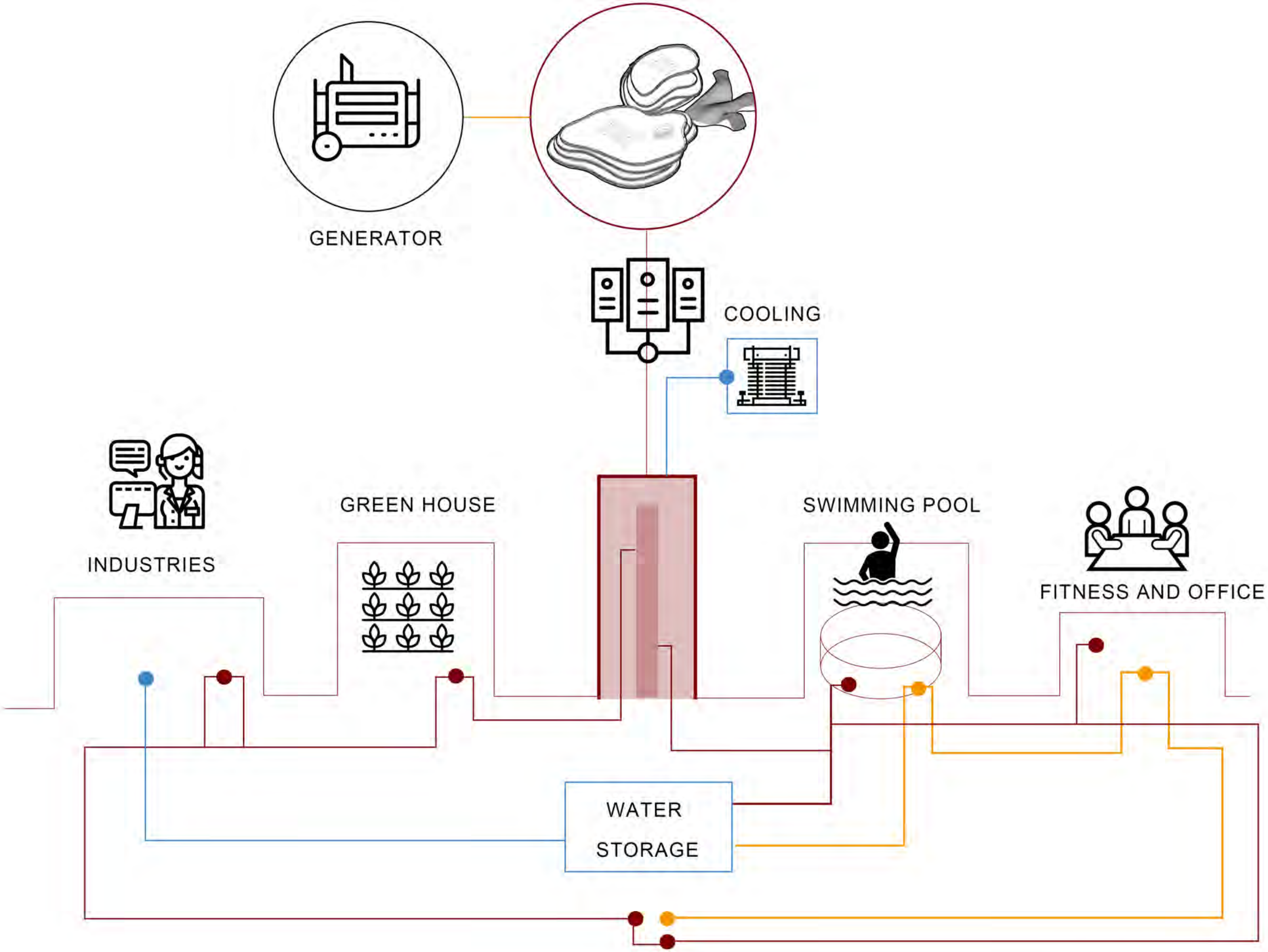
By Jun Wang



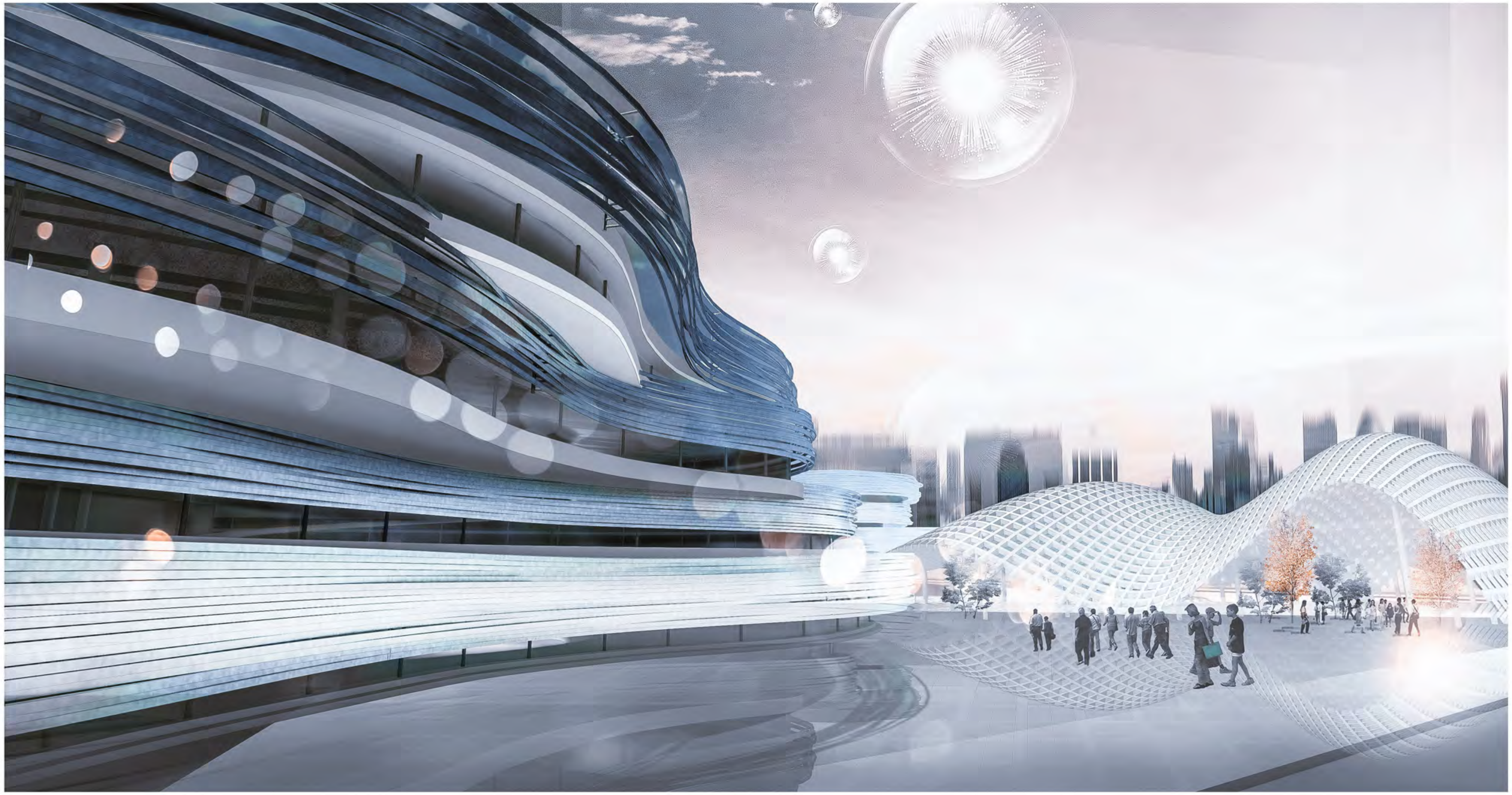
GROUND FLOOR


GENERATOR
SWITCH ROOM
DISTRIBUTION ROOM
UPS AREA
AC
DATA HALL
CHILLER
VANTILATION
SUNKEN LANDSCAPE
RAINWATER COLLECTING
LOBBY
GREEN HOUSE
5M
10M
20M

1-1 · SECTION



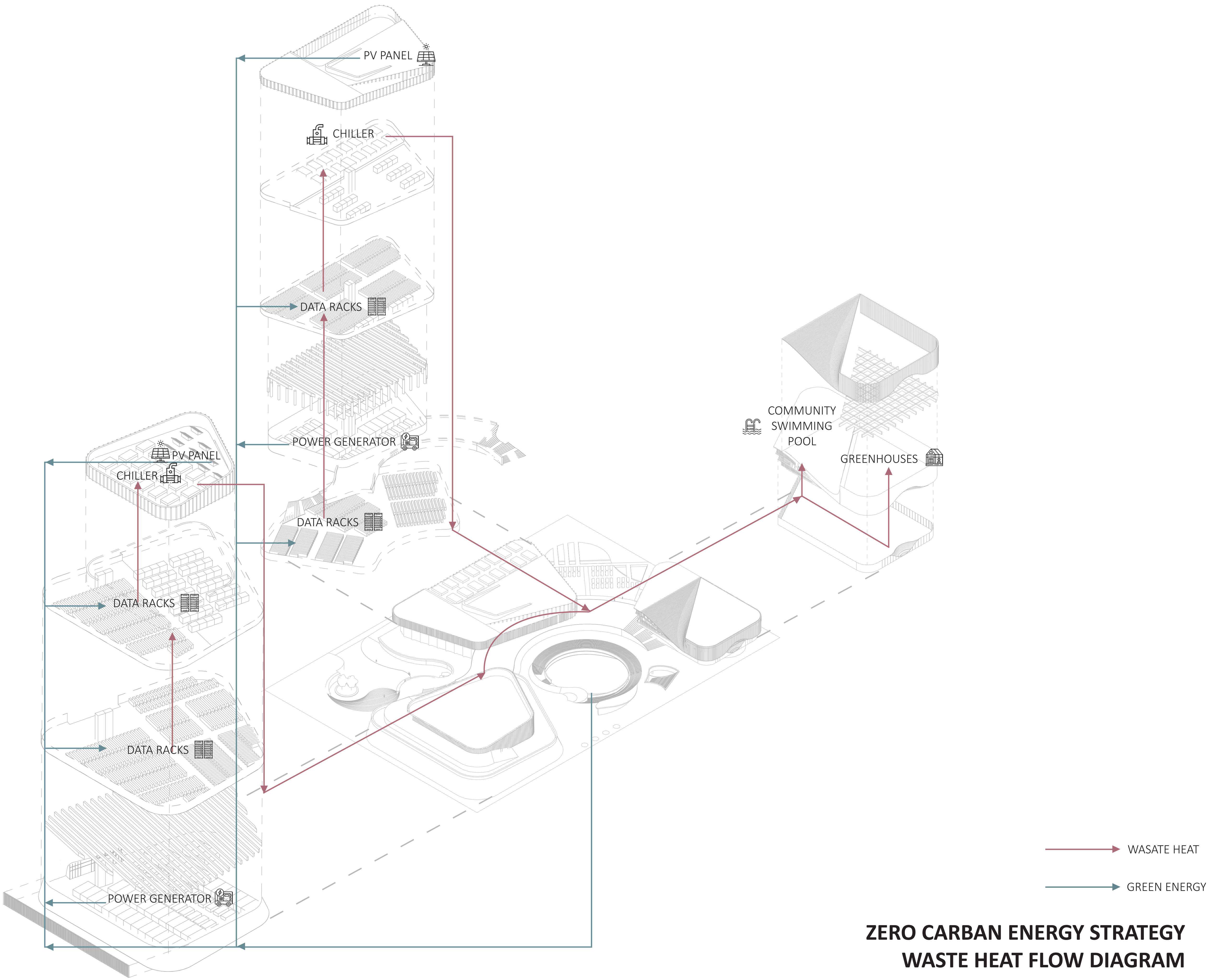
ZREO C LOOP IN DATA CENTER



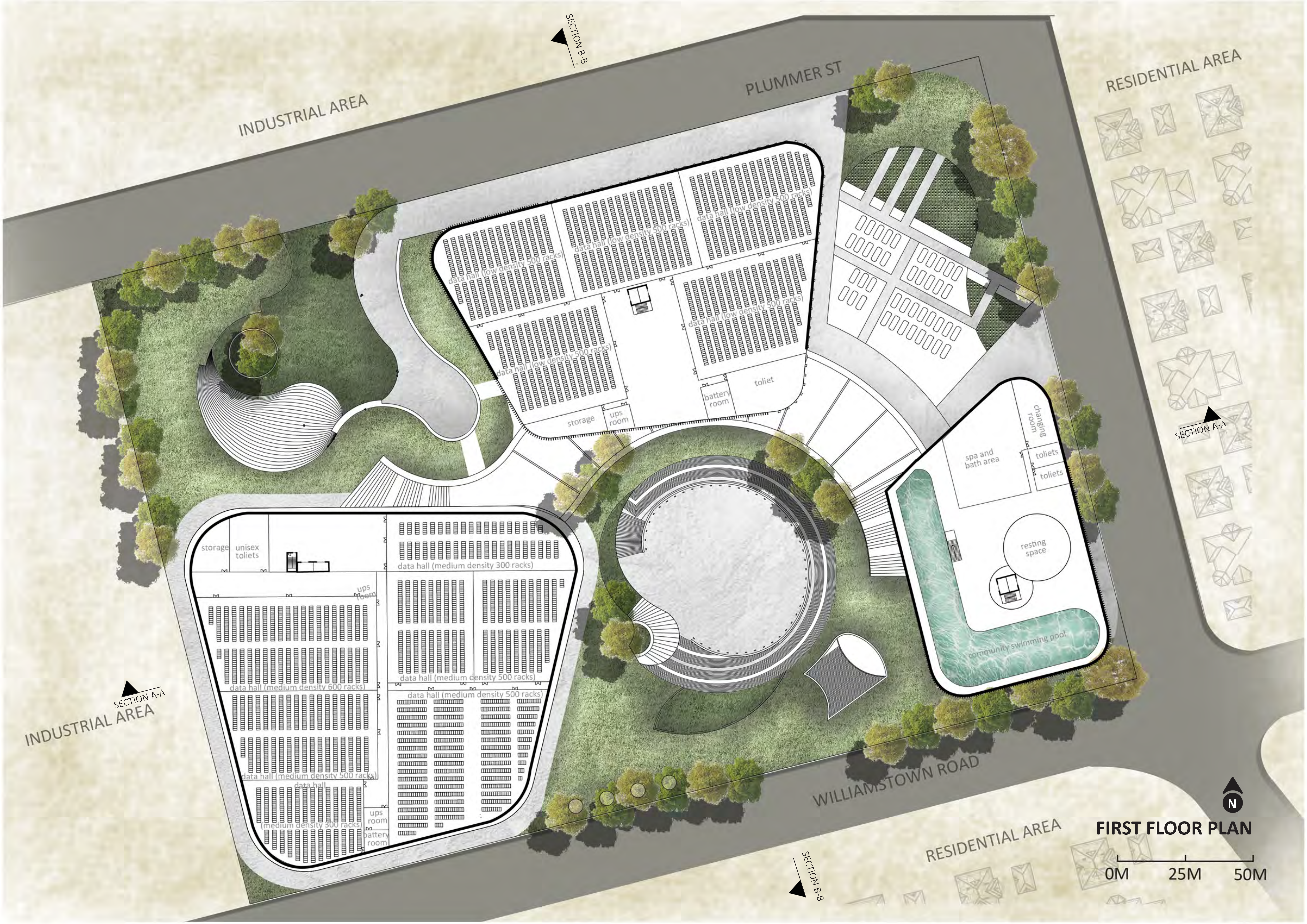
MAIN ENTRANCE VIEW

ZERO DATA LOOP

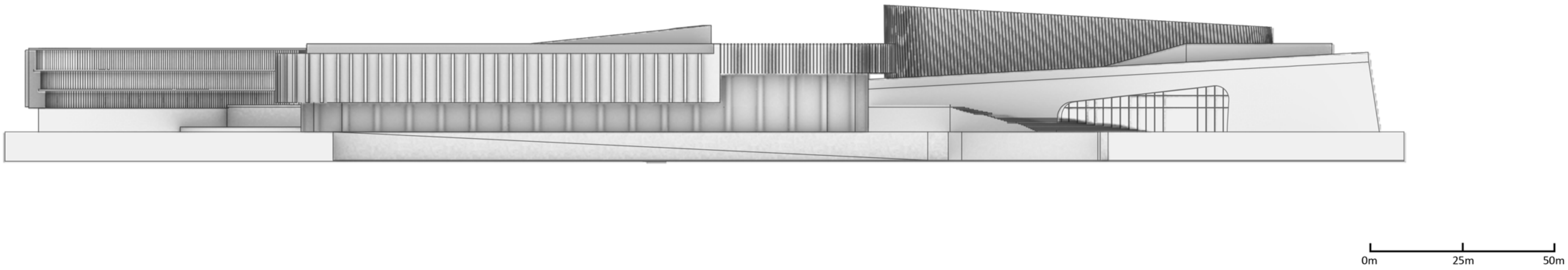
By Katrina Su



ZERO CARBAN ENERGY STRATEGY
WASTE HEAT FLOW DIAGRAM



FIRST FLOOR PLAN



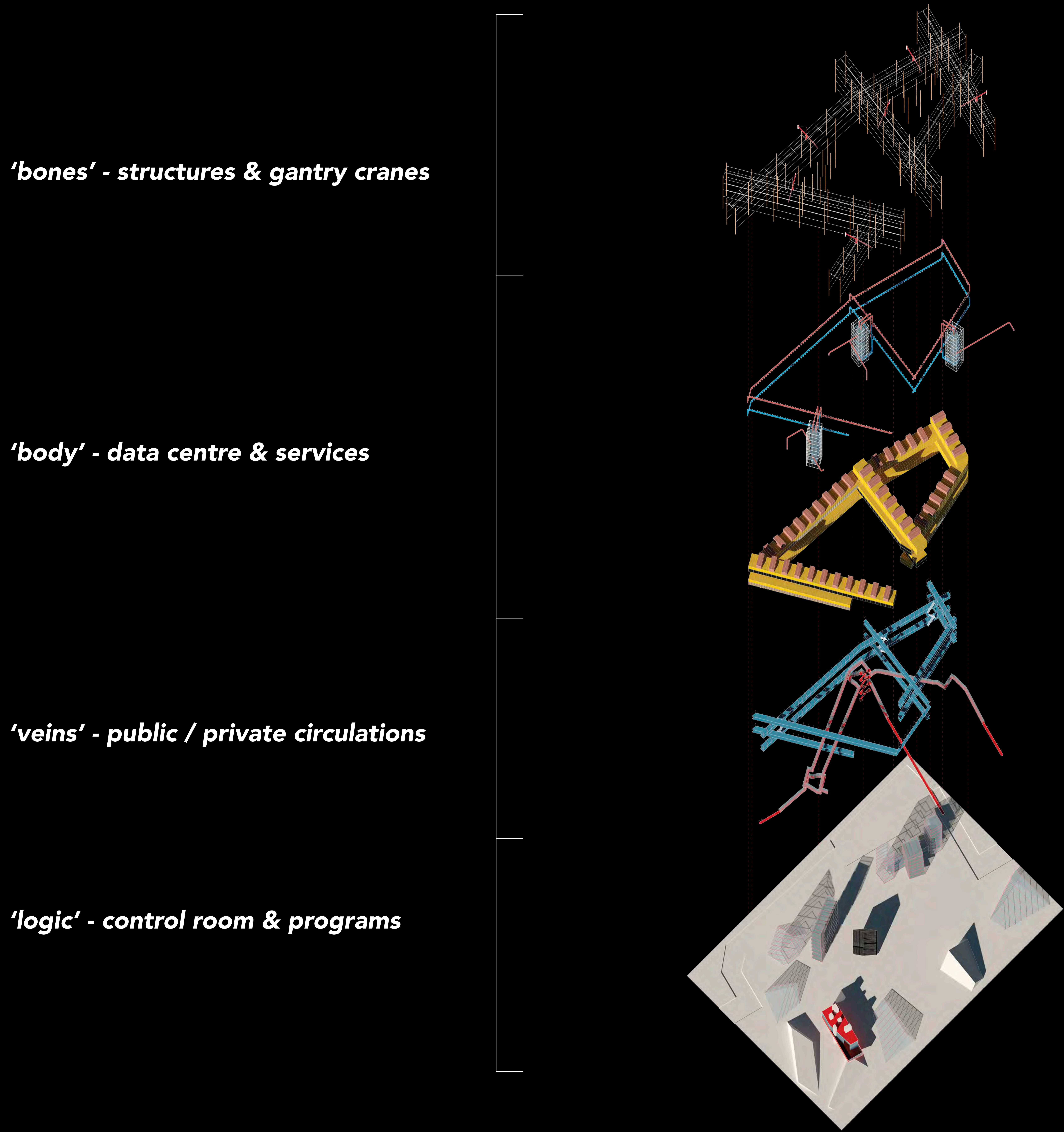
NORTH ELEVATION

SOUTH ELEVATION

SUNKEN PLAZA ENTRANCE

A.R.T CENTRE

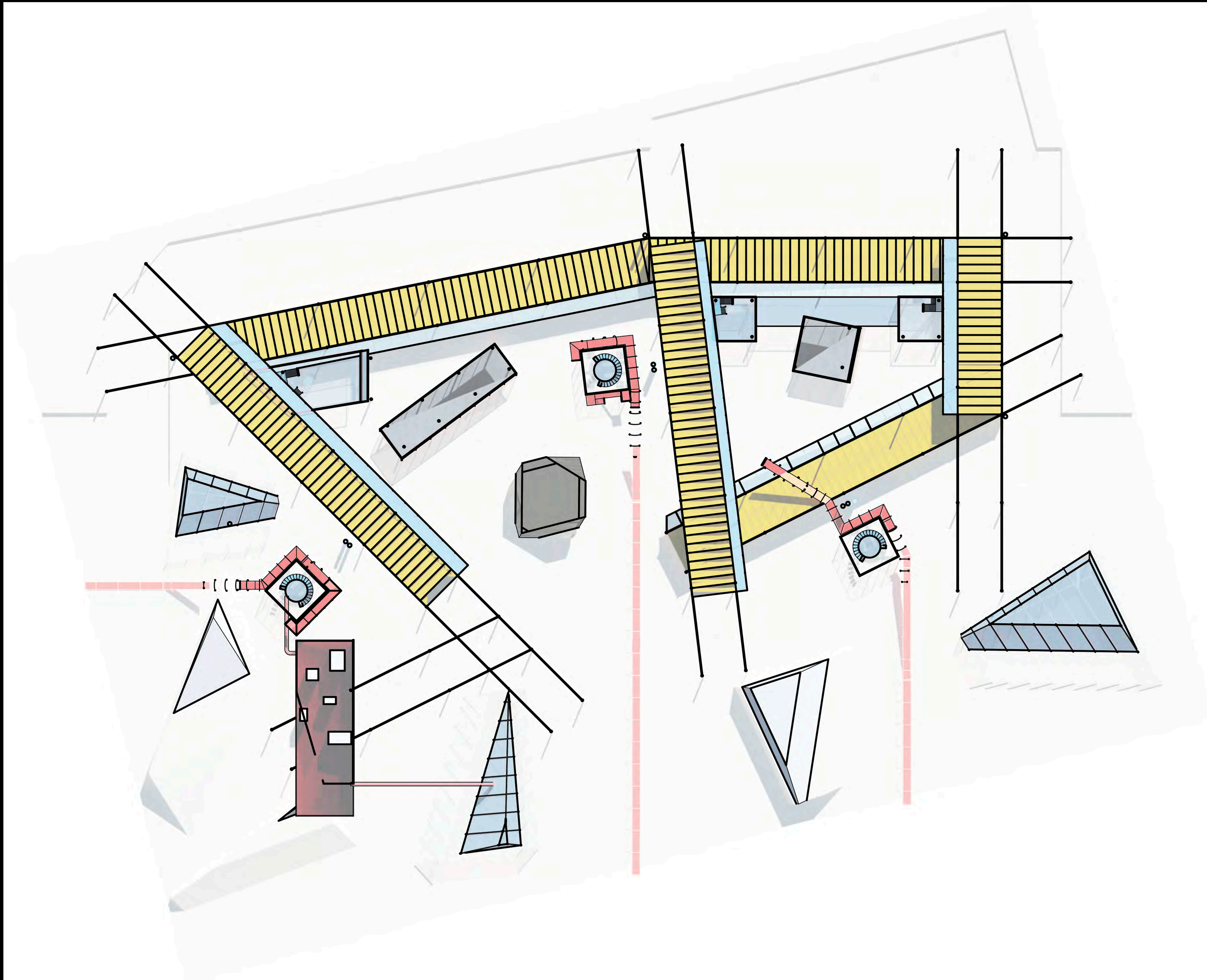
By Pan Shi

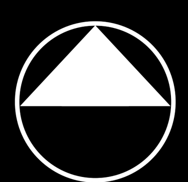


'bones' - structures & gantry cranes
'body' - data centre & services
'veins' - public / private circulations
'logic' - control room & programs

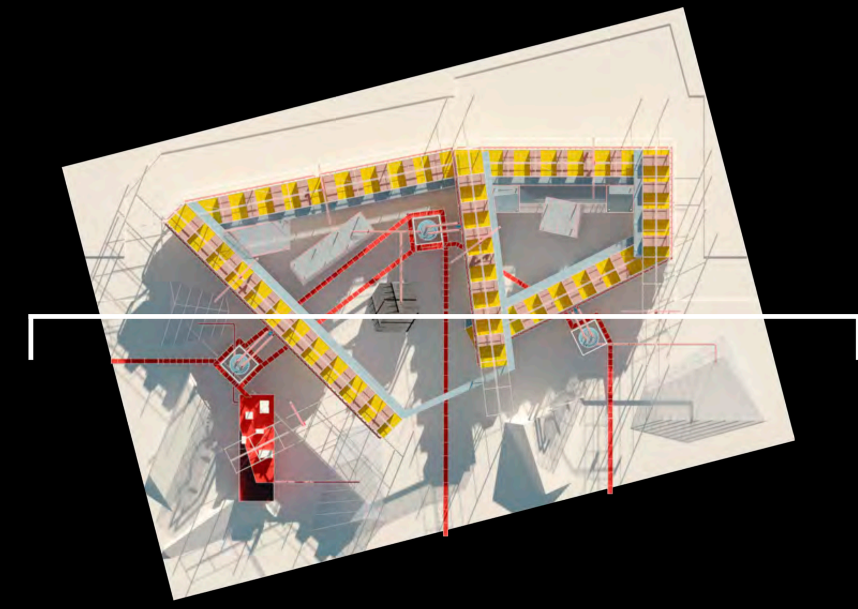
first floor

1:500 @ a1





energy / water loop



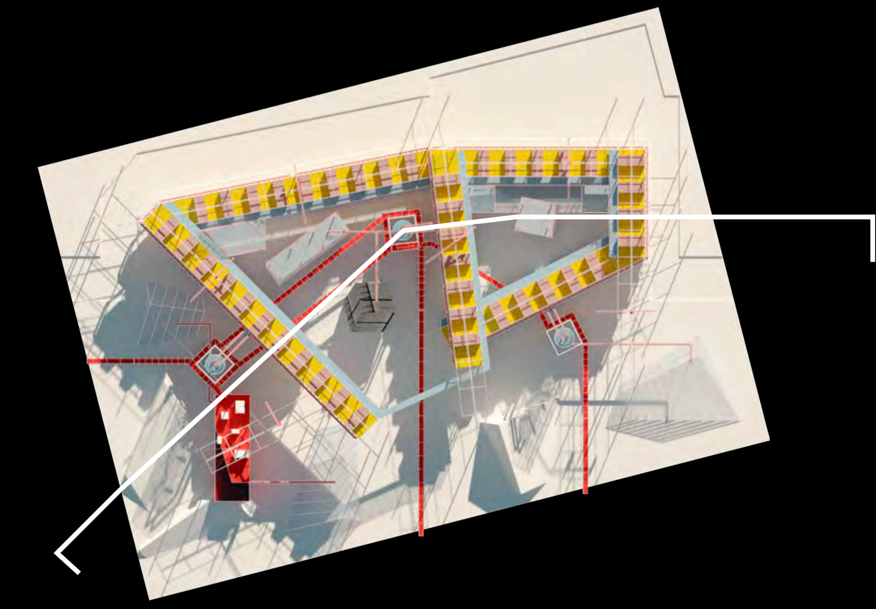
heated water

cold water

hot water (for VPP)

section cut

perspective section



film roll 2

Design Studio Outcomes

IDS-01

APPENDIX B

TRANSCRIPT OF INDUSTRY/TUTOR INTERVIEWS

Integrated Design Studio 01 Interview with Gerard Page (Greenbox Architecture)

Q1: What are the key factors/drivers that enable successful Integrated Design in the studio setting?

Having engineering students is a key to make the integrated design studios successful. Architectural students needed engineers who were at a similar level to them so they wouldn't feel intimidated and therefore the ideas would have flowed more freely. Also, with having engineering students, the outcomes may have been more creative and maybe less plausible to a degree (which is not a negative quality in the studio setting). By having the engineering student rather than the consulting engineers we could see unconventional and creative ideas that may not necessarily be the best ideas, but different ideas which the consulting engineers may have not thought of. On the other hand, the consulting engineers tempered the ideas down to make them workable and sensible which did not stifle the creativity. Instead, the architects possibly would have been inclined to think more creatively when trying to see the project as a real-world experience.

Q2: Please tell us about the studio brief's impact on achieving integrated design solutions (considering the way it was written & communicated). Please reflect on the level of detail and the language of the brief. Was it adequate? (if not, what could be changed?)

The brief was a very real-world brief. The Next DC's briefs are engineering briefs not architectural. They're very technically orientated. The language was very engineering focused.
If the engineering students were present in studios from the start, there would be more discussion and more questions going backwards and forwards to understand the brief. Although the consulting engineers were present, there were not the right questions asked because maybe the students felt slightly intimidated or felt as though it would be a stupid question. The students early in the semester did not thoroughly investigate and interrogate the brief as they were expected to.
Inside the brief, there should have been a bit more description about the spaces themselves and what the brief for those spaces were. Although the consulting engineers provided a lot of pre-assumed knowledge about what some of those spaces would be, it still took a few weeks until it the students finally could comprehend about the scale of the spaces and the size of the facility.
Very few people have any experience with data centres. Therefore, a site visit could have been beneficial for them to understand the components of a data centre, especially in relation to some of the plant spaces, sizes of generators, the sizes of cooling towers, space required around them and how that will actually relate back to the overall size of the site.

Q3: What were the most critical decision-making points/questions to answer when balancing architectural and engineering input for generating environmentally optimised design solutions? Where did the inspiration for the students' solutions come from? How did the engineers contribute to the authorship of those solutions?

One important point is to develop an understanding of the fundamental components of the facility. Once they understand how the building components function, then they can ask questions such as 'I've got all these generators here, which are generating a lot of waste heat. What can I do with that? What are the outputs from the systems which aren't currently used? And how can we try and use those'?
The equipment is not something that students design or change. They just need to understand it and all the parameters around it. where they can or can't put it. That is where the boundaries can be pushed in terms of where things are located or doesn't have to be there. Could it be over here? Do we have to have them all in a line? Can we space them out? Once they understand all the parameters around services, they will know how that is actually going to fit on site.
It's getting that balance right between it being interesting and engaging for the students and meet the brief requirements, which is the function of what the building is. It took the students quite a while to grasp how big the building needed to be. Because what we saw about the first third of the semester were

quite small data centres, then all the rest of the site was filled up with the community spaces. Whereas if they actually understood how much data centre space they needed, they'd realize that actually wasn't a lot of room for all the other stuff.
There was a lot of very similar solutions in terms of the environmental aspects. Maybe that was driven to a degree by the consultants because they were the obvious answers. What happened, there wasn't enough exploration of other alternative solutions. Again, if there was young engineering students there, there would maybe have been more dialogue and more discussion and different fresher ideas proposed. They may put 10 ideas out there, but nine of them may not work and one may be a really good, very different idea that nobody's thought of before.
Another problem was because the engineering students weren't involved, the consultant engineers were at the forefront although they had more knowledge and experience as students. The role of the consultants should have been to sit back and watch and then checking and questioning some of the decisions, again stepping back and let them all discuss it. So, it's more about discussing with their peers rather than discussing with a consultant.

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

Getting them to think about spatial aspects of data centres in terms of getting to grips with the size and the components of the facility relative to the size of this site. I tried to accelerate that process of understanding. Students actually got a lot out of it. They all eventually were able to comprehend the spatial aspects and had more time for the more creative aspects of the design rather than necessarily just the understanding of the bits of the building.
Some students struggled with having some preconceived ideas about data centres whereas the whole point was to actually think outside the box and which the consultants tried to encourage them to. They had one idea and they thought of it as the final idea. Instead they should have explored more ideas and generate various iterations and scenarios of design. I helped the students to take up a less rigid approach and think slightly freer.
It would have been beneficial to spend more time physically with the students in the studio rather than via zoom. Also, some more one to one sessions rather than actually just being there for the presentation could be beneficial. And I think a lot of the students were warmed up a lot at the end. In the first instance, there were quite shy and maybe slightly timid in a group, but if you actually talk to them one to one, it probably would have been more beneficial for them.

Q5: Were aesthetic and functional design aspects compromised when balancing architectural and engineering concerns? If yes, please explain why and how. Could this be avoided?

They possibly were. It is going back to the point I made about them understanding the bits and pieces of the building and the outputs of the systems but also what those components could fit in their design. For example, we talked about generators. They take air in at one side and blow out the other side. Once they understood this, they could actually use the air movement from the generators to create some interesting visual effects e.g. bits of metal, which could kind of wave in the wind. They thought that was the be all end all rather than they could actually start questioning whether it needs to be like that. Again, the presence of engineering students could be helpful in this matter.

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

They didn't really struggle. Maybe some of them did. The struggle was actually with understanding the technical engineering aspects. For instance, with the heating of the swimming pool they may have struggled with how to get the waste heat from the data hall to swimming pool. Again, if there was student engineers, they probably would have had more discussion and dialogue around those aspects.

So maybe some of those fundamental aspects were missing. Not in all the schemes but just in some of them.

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

There was a lot of fantastic ideas, but maybe the question was raised whether they were realistic in terms of budget. So in in real life budgets got a key role to play. But in my opinion the budget should not stifle creativity. Next DC wanted more creative ideas. So, having a cost constraint may have stifled that and I think there's probably enough time within the real world to be working around cost constraints. Maybe it would have been interesting once the ideas have been firmed up to have some cost estimator or construction students come in just for one session to analyse and provide the architects and engineers with degree of input, but not necessarily let it stifle them.

Q8: How would you describe integrated design?

It's about everybody understanding what the other people do and being respectful of what the other people do. And foreseeing that a person may have a problem with my idea/action so that the they would come together a lot quicker. Rather than wasting time, effort and fee by pushing for their individual ideas.

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

I think really useful. It prepares them for how they deal with people in the real world, and it hones their powers of negotiation in terms of compromise. And I suppose all those skills that as architectural student, you don't necessarily get to experience but as an architect in the real world you would.

Additional remarks on the role of engineering students:
The plan originally was to have the engineer students just come in to contribute a bit and then go away. They need to be part of that process. They need to be producing outputs as well. When doing a project architects produce drawing while actually the engineers should also produce some drawings or a report. They need to be a part of the project.
Getting some the engineers to work together with the architects in pairs or in groups or somehow is good for both sides. It just encourages people to share ideas, which I think as architects sometimes we don't like doing because we think they're my ideas, and they belong to me rather than sharing the idea, and having somebody else contribute and get a better outcome.

Integrated Design Studio 01 Interview with Bill Giannikos (Aurecon)

Q1: What are the key factors/drivers that enable successful Integrated Design in the studio setting?

One important factor is students' understanding of the brief and brief's scale and the scale of the facility. There were some challenges towards the start of the studio in the first few weeks in terms of understanding the brief, but once the students started to understand the brief, the integrated design started evolving.
Another important factor is the student's understanding of the inputs from all the design disciplines. Lack of engineering students left the design team (architects) without somewhere to go to discuss the engineering aspect. The consulting engineers covered that through weekly meetings which no doubt was useful.

Q2: Please tell us about the studio brief's impact on achieving integrated design solutions (considering the way it was written & communicated). Please reflect on the level of detail and the language of the brief. Was it adequate? (if not, what could be changed?)

From an engineering technical perspective, brief was adequate. Possibly from a sustainability and community engagement perspective, not as detailed as it probably could have been. It could have also included energy efficiency targets. The brief was left a bit open to allow different ideas to come through. Certain design responses to energy efficiency targets, truly did integrate e.g. large photovoltaic systems while others didn't. In the students' designs there was a special focus on making the facility an open, inviting environment, which is part of the brief in terms of bringing a community focus to the site.
The brief was very engineering written and very structured. The level of detail was pretty clear in terms of technical requirements. However, it didn't have the right language in terms of how to connect the facility with community and to really understand the security elements and some of the risk elements in that regard. The sustainability aspects required more direction and more reflection on some smart ways of improving energy efficiency on site. Directions on security element could have been included since the student were struggling with a lot of security questions.

Q3: What were the most critical decision-making points/questions to answer when balancing architectural and engineering input for generating environmentally optimised design solutions? Where did the inspiration for the students' solutions come from? How did the engineers contribute to the authorship of those solutions?

The initial design iterations did not reflect spatial awareness and understanding of the scale of the facility (for instance what a 60-megawatt data centre looks like). These elements need to be resolved upfront. Another point is appreciating how the engineering systems operate. For instance, the location of the chillers (there were students that were trying to put them in basements and trying to put roofs over to hide them away.) That may be a good architectural strategy. But we need to recognize that how these technical systems operate, the spatial requirements they need which also impacts scale and shape. Another important point is maintenance and access. A live data centre requires safe and accessible roadway and access points for heavy machines which are brought in and removed, replaced and maintained frequently without the need to shutting down for that to happen. The architectural students did quite well once they understood the parameters.
At the beginning, most students considered the project as a community landscape, and primarily thought of hiding away the facility. But once it was apparent that the facility was actually quite enormous, everyone turned the mindset around and started developing a workable building that also somehow incorporates community and environment spaces. In a couple of months, the students could find the right balance where they started to realize they can focus on both facility and community requirements.

The consulting engineers kept providing the advice on how the technical solutions work and question some of the decisions they have been making and without telling them that they're right or wrong explaining to them some of the limitations of what they're seeking and some potential food for thought on strategizing. Moving chillers to the roof is a good example, where a lot of students adopted. The consultants basically helped them understand some of the pathway and operational challenges and how technology works and where it needs to sit within the built form.

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

Giving them an appreciation of the systems, generators, chillers, how the data hall works and operates. I think that's where they got the most benefit. We consciously wanted to let them experiment and evolve their own thinking. We just provided, some information and some of the limitations on the very specific pieces of equipment and let them respond and most did. I think the design evolution was very much by the students. We just helped them with the isolated input that made them think about some of the ancillary challenges.
I would like to do a couple more engineering specific workshops. At the start of the studios, we had a full day session with the students in which we spent a couple of hours with them. I believe those sessions were very useful. And we were able to sketch up some ideas. But maybe we could have done two or three of those types of sessions. Because the engineering systems of a data centre are very specific, more time could be spent to further continue on process and get them to understand the basics around those specific systems. If I was to do this again, I would probably recommend more interaction and opportunity for us to speak not just answer questions. The opportunity for us to paint a picture of how the systems operate might help them position things in a slightly different way from day one.

Q5: Were aesthetic and functional design aspects compromised when balancing architectural and engineering concerns? If yes, please explain why and how. Could this be avoided?

For me if it's functional, it's also quite aesthetic. There definitely was a little bit of a compromise but it's not a negative thing. And there always will be particularly in a data centre project, because it is very technical. It can't be avoided. At times, there are some critical aspects to respond to. For instance, for the pretty onerous security requirements of data centres, there is going to be an aesthetic penalty because there will be pretty rigid physical barriers somewhere. A lot of the designers made the inviting side of the site where they were able to eliminate any aesthetic issues and the back of house with more industrial setting which is perfectly acceptable in a data center to have. Coming back to the example where someone wants to hide something in a basement or behind a roof e.g. the chillers. They want them out of view. So aesthetically, that's nice. Functionally though, that doesn't work. The chiller may not need to be seen from the street, but it definitely needs to be in an open environment.

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

They struggled a bit with the technology and technical aspects, which is absolutely reasonable to expect. They struggled with mechanics behind the energy transfer. Some students were very convincing in the way they sketched up their schematic diagrams to show how the energy transfer works through the site, others probably didn't quite get to that level. They also struggled with appreciating the energy consumption. That's not what we tasked them to do since we were after design responses. However, they did struggle with appreciating what 80 megawatts means?

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

Time definitely is the big constraint that we face every day. It's not to say that they're always the problem but they can be the problem. So for clients that require establishing a design by a certain date, obviously we would explore the path of least resistance, which might be more expensive and less integrated design.
I feel less constrained by fees. Ultimately, we run businesses and we eventually make profit. However, that conversation can quickly turn to a value conversation. How we communicate that value is another constraint in the industry. One constraint is a willingness to sit in a room for a couple of days and throw some crazy ideas. However, that loop can never end if we are not careful. In a right integrated design setting, there should be someone navigating the conversation and being a bit neutral and steering to an outcome. Engaging all the stakeholders is another barrier that could slow down the process of integrated design. Some stakeholders do not like the idea of doing something differently since they've learned the bad lessons and landed on something that works. They don't want to see a big cultural shift.

Q8: How would you describe integrated design?

Everyone coming together as early as possible, sharing ideas, collaborate and work through the challenges together. The client leadership and stakeholder engagement are key to integrated design. Also everyone including the client, architects and engineers needs to have an appetite for it.

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

I'd like to think that they got a lot out of this process. Whether they appreciate it or not, they have been facing real life brief, real-life situation, real life problems and real life process to experience. There was a lot of value there for students. If they were to look at month one compared to the end, they would see where they started and how their ideas evolved and integrated with engineers, client and others. That is a positive outcome for them.

Integrated Design Studio 01 Interview with Jeff Van Zatten (Next DC)

Q1: What are the key factors/drivers that enable successful Integrated Design in the studio setting?

We need far more engineering input and engineering students for integrated design of data centres, because the design is primarily driven by engineering, not architecture and the architecture wraps around the engineering requirements. Generally the ratio of engineers to architects is about five to one, with dedicated mechanical, electrical, structural, fire and hydraulic engineers who are specialists at those trades and all have quite significant spatial requirements and with an architect and ideally a town planner as part of that for our true integrated design. Therefore, it was difficult when only architects were trying to do integrated design. It was a good experience and I think the architects learned but it put a lot of strain on the external engineering consultants who have daytime jobs to try to fill the missing participation. It was very difficult for the engineers from an external consultancy, donating their time for free. And to do that for so many students on so many fronts was a problem. I couldn't give as much time as I thought I would.

Q2: Please tell us about the studio brief's impact on achieving integrated design solutions (considering the way it was written & communicated). Please reflect on the level of detail and the language of the brief. Was it adequate? (if not, what could be changed?)

We (Next DC) are improving our brief as it is. At present is very much focused on the technical engineering requirements for data centre-because it's a technical project and it probably didn't have a lot of content for the architects, as such. The second point is that the brief set minimum requirements for the project. But obviously, as a company, we want to maximize our return on investment and exceed those minimums. The brief stated a minimum capacity of 60 megawatts IT load which is very important because that is what we sell as a business. And what I found was the students would achieve that minimum and then dedicate the rest of the site for community services. Whereas we're a private organization, and unfortunately, it's not a parkland. And to put it in perspective, we're doing the design right now for that same site in reality and we're going to push that site to 100 megawatts of IT load. So, I felt that the brief maybe should have emphasized that the goal to not just to achieve the minimum IT load, but to maximize the capacity of the site. And I also think it could have emphasized-this is what architects do need to learn, that this is a business and they have to be thinking about how to maximize the return. So that's the brutal truth. We did actually state that in some of the studios, but it didn't really get taken on board. I couldn't say it during the studio because we didn't want to hurt the youngsters feeling. There were some great ideas and we asked them to come up with new ideas so we can use some of those. I also didn't want to stifle the creativity and we deliberately let them proceed to see what would happen as it is a studio for research purposes. But I would have preferred to receive of some designs that would push the limits of what we can feed on the site, it would have been more useful. We were hoping for engineering ideas, that design of how to save energy and we didn't get anything of real substance. I think the architects attempted to show some nice theoretical diagrams about trying to reuse heat and they had this idea of zero carbon. But in reality, if we're doing 60 megawatts to 100 megawatts of capacity, a swimming pool will use 40 kilowatts. It's not making any real difference. We need engineering and science people involved with that type of technical project to integrate the design with the architecture. So as an example, right now we are trying to incorporate a lot of free air economization, which affects the facade. This is this is true integrated design because mechanical engineers work with the architects to how to do the filtration working out the facades and the louvers in the rain. It is engineers and architects integrating together. And that didn't quite happen, because we didn't have enough engineering.

Q3: What were the most critical decision-making points/questions to answer when balancing architectural and engineering input for generating environmentally optimised design solutions? Where did the inspiration for the students' solutions come from? How did the engineers contribute to the authorship of those solutions?

The most critical one for me is how much capacity could we fit on site in excess of the minimum. And I don't think the question was properly addressed. They just stuck with 60 megawatts. When we even during the studio specifically said, we'd like to see how much more you can fit on the site. The second question is, how do we integrate the mechanical, electrical and architecture to get the right proportions and to minimize the energy consumption through free cooling economization? I'd say that wasn't really addressed at all. So we tried to lead them to it, but it was difficult for them. Consultants just had to give the bare minimum for them or some rough spatiales. I think most of the inspiration for the architects was coming from the desire to create a community involvement, which was part of the brief. We do need to integrate at this live industrial zone with the residential. But there was very little from the technical engineering.

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

In the early stages, there was a lot of very nice high-level ideas however the students didn't understand anything about the engineering requirements at all. And that was a neglect for the fact that we need generators and cooling units and computer room cooling, etc which are the core of the data centre. Myself, Greenbox and Aurecon tried to provide the guidance they needed. Probably the most important input was to say, 'please look at the technical requirements of the brief which you need to achieve that'. Certainly, they learned something. I think most architects are used to dealing mainly with the human aspects of buildings only. And they spend most of their time thinking about the human interface. And I hope that having a highly technical project made them realize that sometimes you're designing not just for people but for quite complex processes and equipment, etc and the industry needs that. We had hoped to bring them to a data centre at some point, so that they could get a better understanding of what a data centre is. I think if they had seen, a real data centre earlier, they would have got a better context and understand the requirements. Travel restrictions and COVID didn't help.

Q5: Were aesthetic and functional design aspects compromised when balancing architectural and engineering concerns? If yes, please explain why and how. Could this be avoided?

Most certainly. They definitely prioritized the architectural and aesthetics over the core capacity and functionality. That was pretty significant, but we allowed that to happen.

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

I think they simply did not have a grasp of the true magnitude of the energy consumption and what is required to make a meaningful impact. Most of it was token gesture greenwash, not really significant energy recycling or energy saving. There was no real maths behind it at all. I think that'd be quite shocked to find out how insignificant a lot of those solutions would have been. That's not their fault. They are architecture students, and that needs some serious science and engineering.

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

For me, it's always time. It's a very fast-moving industry and where we want everything yesterday. So sometimes you cannot spend as much time tinkering with designs or analysing designs as much as you would like because you have to deliver and maximize return as soon as possible.

Q8: How would you describe integrated design?

The close cooperation of all engineering disciplines, together with architecture and town planning, to optimize returns for the business and benefits for society.

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

I personally think it should be mandatory as part of undergrad. It shouldn't be a master's requirement or something for master students. It should be happening year one to year four of your course. I think engineering and architecture students are too siloed during their education undergrad and that makes them to be even more divergent. It is a huge running problem in the industry that the architects and engineers are different types of people and they're often arguing. So, if the architects and engineers have to work on a project, in reality like this, then the courses should be the same. They need to get to know each other and their way of thinking and if they did that, from the start they would have a better understanding. You know, they come out of high school as kind of similar creatures. And then they take a path, and then they diverge. Whereas they should be growing together, like a forest.

Integrated Design Studio 01 Interview with Toby Reed (Studio Leader)

Q1: What are the key factors/drivers that enable successful Integrated Design in the studio setting?

The students have got to learn to see things from not just a single fixed point of view, but they've got to be open to looking at things from multiple angles, imagining they're an engineer and mashing their pedestrian and imagining they're also an interesting architect. They have to flip around their mindset to many different ways of looking at the design and then somehow learn how to bring them all together into one unified work.
It's good to be very open minded and to not just assume there's a kind of master slave relationship with consultants. It's good to assume that you do not know everything. And that part of the creative process is seeing what is out there. And what can other people give you? In that way, you could be open to the ideas for the project. You can be more like a curator who curates all the ideas and brings them together by getting the best out of everyone else. Even if they talk to a mechanical engineer, they can quiz them and find out their attitudes, ideas and knowledge about any particular subject that might be vaguely related to the project and then absorb that information and try to think about it in a new way that maybe they hadn't even thought of before. But it's the interaction between the two.
I think there shouldn't be equal collaboration in the integrated design. Because that doesn't often work. It is a bit like a film making where the film director is responsible for overseeing everyone but allowing everyone to be creative within that process. they would discuss with costume designer, but not design the costumes. They would discuss framing with the cameraman, and the person who lays the tracks to the dolly. But if they've got a better way of doing something, then be open to that, and realize that, they're not the best person at lighting. That's very much how Rem Koolhaas and his engineer Cecil Balmond worked together by understanding each other's creativity. A part of Rim's process is the organization of other people's creativity and acknowledge that there's going to be elements of chance that come in because of the way they're allowing everyone to contribute. And that can help a project generally.

Q2: Please tell us about the studio brief's impact on achieving integrated design solutions (considering the way it was written & communicated). Please reflect on the level of detail and the language of the brief. Was it adequate? (if not, what could be changed?)

The brief was more of a brief for an engineer than what an architect is used to. But in that way, it was fantastic because there was a bit of reality here and the students needed to take that and inject some life into it. It was a very one-sided brief and reflected the whole issue about data centres and, and problems that they have. Architecture students don't like to read 50 pages of brief. And I imagine engineers be pretty similar. But the fact that it was so detailed about the square meter for various components was a comfort to the architects because they could always go back and find the answer. So it was good in that respect. But the architects had to invent all the other components on for example how to make a good social space? Even, all green and ESD related issues were probably not really in the brief. It was really just about number of racks, and ventilation and spacing of racks etc. It was really very much a commercial brief. So it was interesting artefacts for students to encounter but it didn't really help the ideas to process.
The consultants quite often told students that if they don't meet the brief, they would fail. I know for a fact that they can do the brief and get into moderation and still fail, because they're not doing all the other stuff which the department requires, which is about learning how to be a good architect. So they got in quite a full on one sided architect client experience with Next DC. Next DC in particular was really good at responding to that, once he saw that we can do so much more with the design of a data centre. He wasn't annoyed about that. I think this process made him question how they would think about a brief in the future.

Q3: What were the most critical decision-making points/questions to answer when balancing architectural and engineering input for generating environmentally optimised design solutions? Where did the inspiration for the students' solutions come from? How did the engineers contribute to the authorship of those solutions?

We talked about the kind of zero energy loop idea and putting other functions with the data centre, that was kind of a big issue, like, how can we use all this waste energy that's being produced by this building, and without just dumping into the environment. So that automatically entailed some idea about cross programming, about adding other functions that could then form an energy loop of some kind.
It is important to understand contradictory forces. There was a big issue around the technical aspects such as air flow and putting all the different rooms in relation to each other, to optimize ventilation and to minimize the length of pipes that were needed and so on. So, these are all sort of hard engineering decisions which are needed for creating a good environmental solution, but they don't necessarily create a good social environment. They had to counterbalance almost like the urban planning design of public space with what makes a good engineering solution for the environment. That was what I think was the two opposing forces and trying to work out how to bring them together slowly. And so, I would actually try get the students to design from one point of view and then design from the other point of view and slowly bring them together as much as they could and then try to optimise and see what ideas can go together and what don't. That meant being brainstorming lots of creative ideas and see what fitted best.
There was a lot more focus on reality and engineering than usual studios. So we probably didn't interrogate the stylistics of the designs as much as I would usually do. Because it was more a matter of trying to make something that satisfied the engineering and also satisfied architecture to some degree, but maybe not as much as usual. So, the architects rely very heavily on what knowledge they have of architectural history and the last 30 years of architectural trends. I try get them to get a wider variety of sources and guide them towards more original solutions. When dealing with so many engineering factors, and a client is on your back you don't always manage to be so obscure and find something different. The consultants and the client really helped make workable buildings.

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

I really pushed this idea of the zero-energy loop and the cross-programming idea that if they put different things together, they can counteract one the other. The other thing is my methodology of trying to see things and design projects from different points of view and slowly bring it together and see what happens next and then you rework it and do it again. I suppose it comes down to multiple design methodologies, which, we experiment ourselves, and then teach the students. I might say to a student your work really looks like this person, you got to research the methodology there may be something in it for you. It just seems like this person should be looking at architect or that engineer, because their work is in that realm.
Also, right from the start, I guided students to accept the reality of all they will deal with in real world and work out how to manipulate them in the right way, so you get an interesting result. Trying to get, the best kind of result working with all the real issues and requirements, and still trying to make it creative like it's from another planet.

Q5: Were aesthetic and functional design aspects compromised when balancing architectural and engineering concerns? If yes, please explain why and how. Could this be avoided?

It would seem the work was slightly compromised. Because generally within the architecture faculty there's a big emphasis on creativity, and a combination of creativity and theory and experimentation. there's a lot of fantastic work there, which is purely theoretical and unbuildable, which I think is great thing because it helps create ideas and push the discipline further. But we also need to do integrated studios where we can learn how to make them work in the real world. It's a little bit harder to get a good grade student project because we are juggling a lot of practicalities, which the other studios are not dealing with at all. So, it will make the project more like they are from the real world and less inspirational, but they're still good projects. It takes architects a long time to learn how to design anything. I'm always amazed every year I teach nothing. They have been studying five years and they still don't know how to design a really good form with a good space. So, when you put them together with the real world of engineering, it's a hard thing.

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

I think the biggest struggle for the students is not taking the clients and engineers advice and trying to manipulate that to achieve a design they want. Quite often their first reaction is 'we are in a real situation so I'm going to design something boring'. That's a real challenge for them to realize how far they can push something and make a work of art that still satisfies everything that everyone else wants. Probably the biggest lesson they can learn in the studio is that all these factors shouldn't diminish their art they should just help you make it stronger. But there's a hurdle they need to overcome and absorb and then it will turn into something better. Quite often, we do a beautiful design for client, and they say, no and give you constraints, which are horrible. And then we redesign it and it still works out.

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

The biggest barrier probably is the one of people falling into their normal roles of consultant-architect. You want everyone to suggest from their discipline, what they think would be a great solution. Then the architect experiment with it. That's a big barrier, because the consultants and client are waiting for the architect to come up with a design and they may just put some more constraints. From the architect's point of view, they used to do something and then having engineers solve it. And they are also used to the client saying 'no that's crazy' or 'that is too expensive', 'too artistic'. The architects need to make the good bits of design indispensable, so that the client is going to love it because it's somehow solves some of their issues. They have to make it integral to everything that happens with the building so that they see a logic to it.

Q8: How would you describe integrated design?

Understanding design from a holistic, multi perspectival point of view, not as one unified thing with just one mindset, but actually understanding how multiple viewpoints can help form of space and object and work that into the design process. Also understand the complexity of all the other viewpoints and somehow bring them all together.

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

I think it's particularly good for them to do the extremes. I think they sometimes need to do design projects where they're just learning about amazing ideas of space form and drawing and other times they should do an integrated design studio. So out of four studios in master's degree one of those should be integrated/ I wouldn't say all of them because then we don't get the extremes of experimentation that is necessary. I think it is a matter of getting each student to do different types of studios. In integrated design studios we're trying to get to see projects from multiple points of view and in other studio they can experiment other types of approaches and so they come out with four different experiences at the end.

Design Studio Outcomes

IDS-01

APPENDIX C

TRANSCRIPTS OF STUDENT FEEDBACK

Design Studio Outcomes – IDS-01 APPENDIX C

QUESTIONNAIRE Students Responses

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

   There was a mixed level of environmental design experience among students who attended this class (median score 2). The majority of respondents highlighted they either had little-to-no Environmental Design experience; a few had come across it in other classes.

2. What are the key design-drivers that affect the success of environmental design to achieve renewables/zero carbon goals on a Date Centre project?

Level of existing expertise of individual contributors	**1.5**
Imagination and creativity	**3.9**
In-depth knowledge of technology for collaboration	**2.4**
Time assigned to the dialogue betw. Architects & Engineers	**1.8**
Software skills to simulate and analyse building performance	**0.5**

3. Did the client's brief support you in achieving a balance between architectural and engineering design?

   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

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

   - *yes*
   - *Absolutely, it helped me to communicated with my design.*
   - *It was well communicated and complimented with the verbal presentation in class.*
   - *It lists items required in the project with comments on size and quantity. However, some terms maybe not a bit difficult to understand its function and connection with the others.*
   - *The brief did help in designing but, it can be more architectural with sizes of spaces specified.*
   - *The brief helps understanding the project very well! Just some details in the brief may cause misunderstanding*
   - *The brief has an important impact, helping the designer to control the overall project*
   - *the brief indicates a reality building while the studio final work ask us to do creative building. the brief could give more clear direction in architecture design side*

- *For the entire design process, Integrated Design is like a bold attempt. In every aspect, we need to consider more and make bolder imaginations. At the same time, it also seems to give an opportunity to make people more motivated to find more precedent*
- *In general the brief plays an important role in guiding the design, but engineering terminology in the brief could be explained clearer to save the time of communication*

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

- *Is it gonna work in the real life?*
- *The gaps between the actual and ideal need to be balanced*
- *Efficiency of the design.*
- *The critical point is finding a double solution, the reason behind the design should not only focus on architecture nor engineering, but respond to both.*
- *Spaces for machinery and their airflow*
- *What solution works best with your concept*
- *Whether the project conforms to natural conditions and uses natural energy*
- *Is it possible to make a data centre be a civil space for community? How to deal with the security and insecurity space and balance the functions and form .*
- *The most critical point should be high efficiency and innovation!*

6. Where did the inspiration for your solutions come from?
   - *It's from the basis of how data centre works.*
   - *A amount of precedents and theoretical architecture*
   - *Online research.*
   - *It comes from the idea of ventilation, which is very important in data centre project. Ventilation frames can also translate into an architectural language.*
   - *Indian heritage architecture.*
   - *suggestions from consultants*
   - *Surrounding site analysis and natural environmental impact*
   - *In early stage I doing form iteration to find a good relationship between building and site environment. For a data centre the truck access is an important issue and I use the circulation to make decisions of my building form as well as that the building itself could be a loop*
   - *Some very attractive precedents, such as Zaha and Kengo Kuma.*
   - *the idea of modular design and the contrast between function and architecture style*

7. How did the engineers contribute to the authorship of those solutions?

By supplying background data and knowledge	**1.8**
Giving Yes/No check on your design concepts	**1.4**
Via consultancy-type feedback	**3.2**
By providing initial idea / inspiration	**3.0**

As co-authors or co-creators of ideas	**0.8**

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

    - *The suggestion about how to locates professional machines like generators and chillers.*
    - *The consultants provided a series of knowledge of engineering science i was not familiar with these*
    - *The advice on engineering portions of the projects and on energy saving measures.*
    - *They help me with the relationships between items such as backup generators and switch rooms, how should they arrange, and the requirement for arrangement.*
    - *Circulation spaces for both machines and humans*
    - *guidance about energetics*
    - *Point out my problem, give me the correct guidance and give me a more appropriate solution*
    - *The explanation of engineering plants replacement and maintenance. It inspires me how to deal with the main entrance and also the route for different users to access building*
    - *For various engineering aspects, how each equipment and equipment operate, how to place them, and how to use them efficiently, these possibilities are the key points of the joint design concept.*
    - *feedback on plan was most useful*

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

    - *I will consider more about the facade.*
    - *More time with consultation, more individual feedback sessions.*
    - *Maybe more one-to-one consultation sessions would be really helpful.*
    - *more interaction when designing than consultation after designing.*
    - *Building layout, shape, structure*
    - *I divide the building into two part to have a good loading space for large mechanical plants*
    - *Can provide more cases and data support. For example, we do not know how to calculate some specific numerical calculations this time. It should provide relevant and convenient ways for us to learn and try to calculate some engineering data*

10. Did the input by the consultants increase your 'level of understanding of' environmental issues and associated solutions?

    With a median score of 4.6 (out of 5), most students argued that the input by consultants strongly increased their 'level of understanding of' environmental issues and associated solutions

11. Were aesthetic and functional design aspects compromised when balancing architectural and engineering concerns?

In studio 21, students did feel that they had to compromise aesthetics and functional design aspects when balancing architectural and engineering concerns (median score 3.7). 70% responded that it was ‘quite a bit’, with 30% feeling ambivalent about it.

a. Do you think this can be avoided? If so, please explain how!

- Yes, more time with the engineers will be good.
- It may be constrained when it comes to practical and economic considerations, but it still gets potentials to be aesthetically pleasing.
- The compromise can de reduced by closely cooperate with consultants. Rising solutions to discuss rather than rising only demand then receiving requirement.
- I think this is unavoidable, but this is also the direction for mutual discussion and study in the future. In the future, they can complement each other,

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

- *Some design ideas are not suitable when constructing it.*
- *Building construction, cost issues*
- *Implementing engineering concepts as an architecture student.*
- *Struggle to meet engineering requirements of arrangement and space.*
- *Spaces for Machines*
- *idea conflict with constraints?*
- *How to better achieve my concept while meeting environmental requirements*
- *I was confusing what we were pursuing after the midterm. At this time many things are blurring . When we were asked to do more crazy proposal, I believe everyone will be a little worried about how to deal with the structure side in the future. Some good ideas maybe be killed in the very early stage*
- *The design inspiration will be restrained, and it will be difficult to deepen the plan due to restrictions.*
- *struggle most with how energy travels and distributed because it relates to plans*

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

Knowledge gaps	**3.9**
Time-constraints on projects	**3.7**
Education in isolation	**0.7**
Contractual / fee barriers	**1.1**
Inability to define joint goals	**0.8**

14. "How would you describe integrated design?

It is reality. I think it should be the emphasis of university teaching.

- *Tricky but interesting.*
- *It is more difficult to come through a design that respond to both disciplines, however, the solution is more comprehensive and practical.*
- *A balanced soup, with perfect spices*
- *practical design with consultants*
- *I think integrated design is very important and it is the trend in the future design process*
- *Integrated design is the real design process actually. For students we don't have enough knowledge and communication skill to express our idea totally but it still make much sense for us.*
- *It is a wonderful direction that allows people to think more comprehensively and consider more challenging projects at every stage of the design.*
- *very informative*

15. How useful was it for you to learn about integrated design processes as part of your university education?
    The question about the usefulness of learning about integrated design processes as part of their university education, elicited a predominantly positive response, with 40% saying it was 'extremely useful' and 60% attesting it to be 'quite useful'. (median score: 4.4 out of 5).

Design Studio Outcomes

IDS-01

APPENDIX D

ENGINEERING CONSULTANT VETTING REPORT

iHub Design Studio

Data Centres – Energy &
Renewables Strategies Review

University of Melbourne

2020-08-07

Bringing ideas to life

Contents

1 Executive Summary

The purpose of this report is to identify and assess the performance of sustainability initiatives from three Integrated Design Studio projects.

Two types of sustainability initiatives have been identified:

- Carbon neutral power generation from renewable sources (PV cells) and recycled waste (OmniProcessor)
- Recycling of generated heat to serve public spaces such as swimming pools and greenhouses.

A numerical measure was needed to assess each initiative and compare performance of each.

Analysis

A numerical assessment was undertaken to validate each initiative and calculate its positive impact on the facility.

This was done through the following:

- PV cells assessed through simulation software (Helioscope) and extrapolation of data from commercially available products.
- OmniProcessor units produce electricity at a fixed rate and has a biproduct of water. Associated rates have been assessed through research data from pilot projects.
- Total heat required per year for a community pool has been calculated through two steps:
  - Thermal Energy for mains water (10°C) to be raised to temperature of 28°C (typical heated pool temperature)
  - Then the additional heat required to maintain this temperature throughout the year.
- For Green Houses, the additional heat supplied to the space to maintain a min temperature of 25°C was used as a measure for reducing the load of the cooling plant.

Results of Analysis

- A single OmniProcessor could conceivably produce 2,190 MWh of electricity annually.
- A Solar Cell roof canopy (Area = 21,000 m^2) produces 3,008 MWh of electricity annually.
- A Solar Road (Road length = 950m, width = 7.7m) produces 757 MWh of electricity annually.
- Thermal Energy exchanged with Green Houses and Swimming pools approximates to 7,000,000 MJ of heat per annum, this is equivalent to 0.3% of total heat rejected from the subject Data Centre facility per year.

Conclusions

The total renewable power generated is <1% of the total site power usage, which seems small when compared to a mega facility of 80 MW. However, in the context of a typical 10-20 MW facility these figures start to show significant savings (in excess of 2.5%).

The biproduct of thermal energy from the facility can lead to community spaces run almost for free, from a community perspective these are significant returns.

2 Introduction

Students forming part of the design studio have been tasked with the design of an 80MW IT rated data centre and to seek opportunities for reducing the energy and carbon footprint of these facilities through on-site renewables and associated initiatives.

The submitted designs have been reviewed and the essence of carbon neutral sustainability initiatives have been extracted from these. These initiatives identified have the intent to reduce the carbon footprint of an 80MW Data Centre facility. Three projects were selected from the cohort, with these particular projects being selected for their diverse approaches only, with no other particular selection criteria applied. From these sustainability initiatives, a numerical assessment has been undertaken to validate each initiative and calculate its impact on the facility. These initiatives either generated clean energy or utilised the biproduct of heat energy for another purpose.

The emphasis on community engagement through design was prevalent with initiatives focused on recycling of energy associated with running community facilities.

3 Initiatives

The numerical improvement associated with the following carbon neutral sustainability initiates to reduce the carbon footprint has been assessed:

1. On site carbon neutral power generation either from renewable sources (PV Cells) or via recycled waste (OmniProcessor).
2. The offset of heat generated to then be exchanged to serve public spaces (Swimming Pool or Bath House).

3.1 PV Cells

A Photovoltaic cell, also known as a solar cell, is an electronic component that generates DC power when exposed to photons/particles of light. Multiple PV cells are connected to form a module or solar panel. Strings of PV modules are wired in series, then fed to a string inverter (DC to AC converter) to produce AC power.

The projects have seen both the application of solar roof panels and solar road cells.

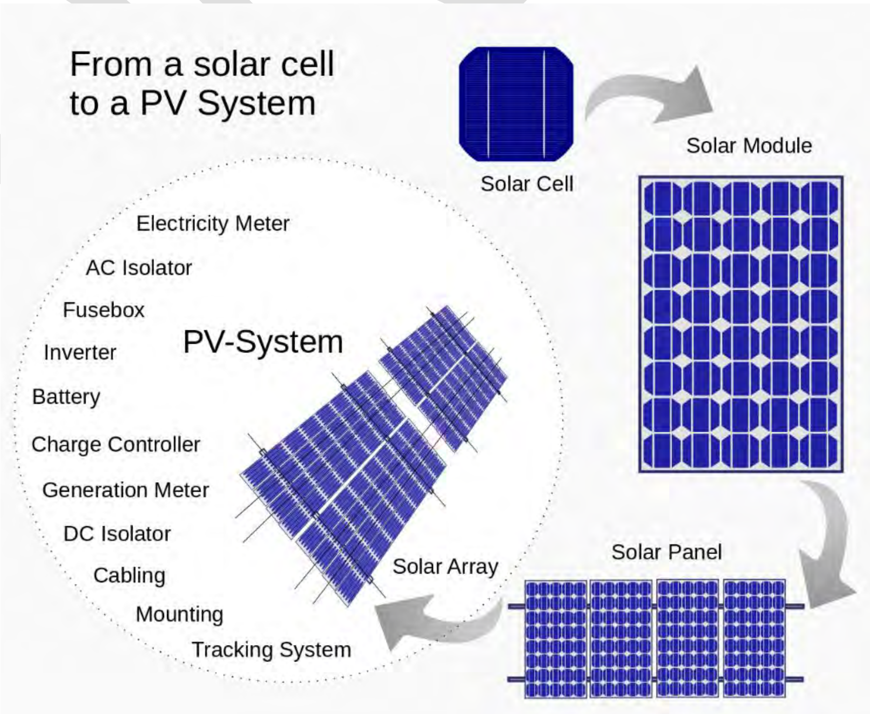


Figure 1: PV system overview. Source: https://en.wikipedia.org/wiki/Photovoltaic_system

General Assumptions:

- The site is located within Melbourne. The 'Melbourne, RMY (epw)' weather dataset has been used for the calculation of Global Horizontal Irradiance. An Annual Global Horizontal Irradiance of 1369.4 kWh/m^2 has been used for this assessment
- Total annual operating hours is 4,526 hours based on Melbourne sunrise/sunset data.
- The PV systems use Monocrystalline Silicon PV modules, which have higher conversion efficiency.

Rooftop PV System:

Solar Panel Data:

Type	Monocrystalline Silicon (492 Cells)	
Model	Sunpower P3-415-COM	
Panel Height	0.998	m
Panel Width	2.066	m
Power	415	W
Efficiency	20.10	%

- Solar panels are installed on the roof with 10° tilt and 600 mm spacing for access and maintenance.
- Calculations are based on Total Roof Area 21,000 m^2, and approximately 6,231 solar panels.
- Loss factors in calculations are based on simulation results from Helioscope.

Solar Road System:

Solar Panel Data:

Type	Monocrystalline Silicon	
Model	Wattway	
Panel Height	1.257	m
Panel Width	0.69	m
Power	125	W
Efficiency	18.20	%

- Wattway has manufactured solar panels designed for use on solar roads and pathways.
- Solar panels are installed flat with no spacing to form a road.
- Calculations are based on Total Road Surface Area 7345.8m^2, and approximately 8,338 solar panels.
- Loss factors used in calculations are based on worst case scenario for shading (10%) and soiling (5%)].
- Cost, maintenance and road safety have not been studied as a part of this report.

Figure 2: Wattway Road solar panels installed in Bobigny, France. Source: Wattway Website

3.2 OmniProcessor

Developed by Seattle-based engineering group Janicki Industries, Gates Foundation-funded OmniProcessor plant takes human waste and converts it into drinking water and electricity. The multi-stage process takes wet biosolid (raw sewage) through a boiling process that separates into dry solids and water vapour. Dry solids are then fired to turn water vapour into steam to power a steam engine. The steam is condensed back to water that is safe to drink.

A diesel genset and auxiliary fuel source is required to start the dry solid combustion process. Once the processor reaches steady state, the auxiliary fuel source is turned off, and the generated power is sufficient to keep the plant running. The excess power output can be used to power IT loads or general lighting and power.
The generated water can be used for the greenhouse or chiller system.

Water produced through the OmniProcessor could be supplied to the mechanical plant for use. A single water cooled chiller can use in excess of 2600 L/hr of water as part of an adiabatic system. A single OmniProcessor can provide 33 hrs worth of water a day to an adiabatic system, this could accommodate multiple chillers, but not to the extent of serving the entirety of an 80 MW cooling plant. On a full load day with chillers running for 6 hrs each, there is sufficient water produced to serve 5.5 chillers running at 75% capacity.

Figure 3: Janicki OmniProcessor (J-OP) Source: Sedron Technologies Website

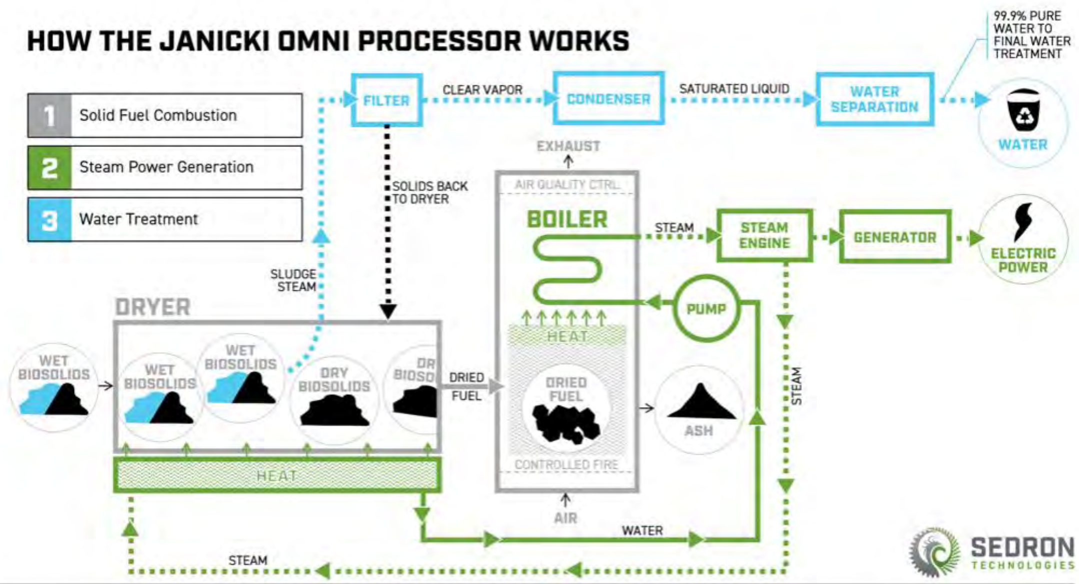


Figure 4: How the Janicki OmniProcessor works Source: Sedron Technologies Website

Assumptions:

- There is sufficient wet biosolid input to run the OmniProcessor for 24 hours per day.
- For optimal power production, there is 50% solids content (Minimum 20% solids content is required for the OmniProcessor combustion process)

Numerical Assumptions:

Footprint	21x26	m
Occupancy	100,000 to 200,000	people
Maximum Wet Biosolid Input	92.3	m^2 per day
Maximum Water Output	86,000	L per day
Maximum Power produced	300	kW
Operation Power Consumption	50	kW
Excess Power Output	250	kW
Running Hours (per day)	24	h
Estimated Annual Power Production	2,190	MWh

3.3 Swimming Pool/Bath House

The application of swimming pool heat exchangers for salt and low chlorine swimming pool heating has been applied to these projects. A heat exchanger is used to transfer heat energy from one medium to another without the two media being mixed. In this application, CHWR (Chilled Water Return) would pass through the heat exchangers before either passing through the chillers or returning as CHW to the cooling system associated with the data centre. Chillers use a significant amount of power to maintain data centre internal temperatures, this method of heat exchange would reduce the load across the chillers and in turn provide direct energy savings.

Assumptions:

- Pool shall be inlayed in concrete below Finished Floor Level (fully insulated) and surface water is exposed to convective heat losses.
- Total heat required per year for a single pool assumes two processes:
  - the mains water is brought up to the required temperature of 28°C (typical heated pool temperature)
  - additional heat required to maintain this temperature throughout the year.
- Temperature of water cannot exceed CHWR temperature (through heat exchange process), this reduces the temperature of normal bathhouse water from 45°C to 30 °C for calculation purposes, assuming no heat losses through pipework prior to heat exchange.

Numerical Assumptions made for calculation of heat exchanged:		
Pool depth	2000	mm
AVERAGE mains MELB water TEMP	10	°C
AVERAGE DB MELB TEMP (BOM 2017 data)	16	°C
Heat Capacity of Water	4200	J/kg°C
Convective losses Equation to maintain temperature of water	dQ/dt = hA(Twater-Tair)	
Thermal Conductivity of Water (h)	0.6	$W/m^2.K$

3.4 Green House

Glass Green houses or “hot houses” (when additional heat is supplied to the space to maintain a temperature) have been applied on these projects. On average green houses consume 0.50–0.60 kg of $CO2/hr/100\ m^2$ and require 8-16 L/m^2 of water per day. The intent of the green house in the site cycle is to utilise water produced through the OmniProcessor, plant waste is recycled back to the OmniProcessor. Secondly, heat from data halls is exchanged with the hot house to maintain 25 °C climate throughout the year. This heating exchange could be done via hydronic radiant heating (directly using CHWR for this process). This process would reduce the load across the Chillers.

IES modelling on 1200 m^3 Glass Green house:

Assumptions for modelling purposes:

- The Green house modelled is of rectangular prism of fixed height (4000 mm), no irregular prisms modelled
- The composition of the green house is assumed to be typical Glass of 3 mm thickness

- The heat gain required for heating the 1200 m^3 Glass Green House was used to extrapolate the approximate heat gain for various sized Green Houses presented in the three projects.

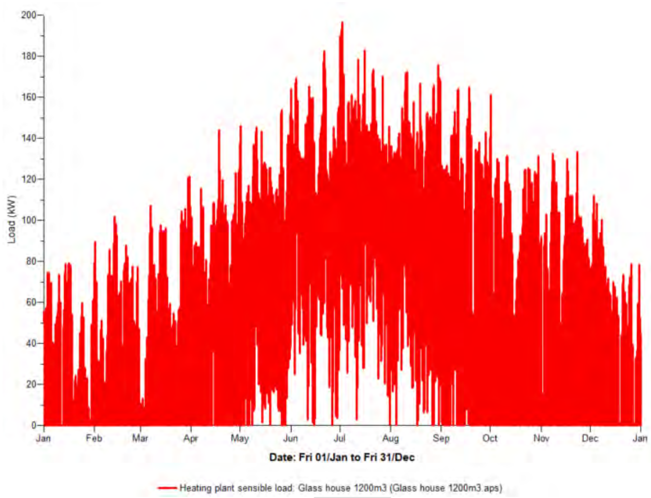


Figure 1: Heating Sensible Gain of Hot House (Heating only, no Cooling, IES Simulation)

Var. Name	Location	Filename	Type	Min. Time	Max. Val.	Max. Time	Mean
Heating plant	Glass house	Glass house	Load (kW)	09:30,01/Jan	196.531	07:30,02/Jul	62.860

Figure 2: Heat load to maintain min 25 °C internal Temperature of Hot House (Total Heat Load, IES Simulation)

3.5 Industry Standard Comparison

	Industry Norm	Industry Benchmark	Project Benchmark (80MW)
NABERS	4 Star	5 Star	5 Star
PUE	1.45	1.3	1.3*
% Renewables	<0.2%	0.28%**	0.33%
Energy Savings (Initiatives)	5-10%	20%***	<1%
Industrialised Construction	Yes	Yes	No
Carbon Savings (Tonnes)	100	452.25****	3,250
Community Engagement	None	Minimal	High

*Assumed value for purposes of project evaluation
**Typically, Solar Roof Panels or Wind turbines are installed.
***Sites utilised free cooling via economy cycle, modular approach to installing mechanical plant, enhanced building tuning via machine learning, BMS to control equipment, optimising plant performance.
****Notably NEXTDC M1 project installed largest privately owned Solar Array 2013, data from NEXTDC website

4 Project Initiative Summary

Key Assumptions used to numerically evaluate initiatives (in addition to those listed in Section 2 Initiatives):

IT Load = Heat load output	80	MW
Total Power to run facility if PUE 1.3 (estimated case)	104	MW
Assume total heat rejection (that could be exchanged) in line with IT load	80	MW
Annual estimated heat rejection at site of 80MW IT load	2,522,880,000	MJ
Annual estimated total facility energy consumption	911,040	MWh

4.1 Project 1: New Eden

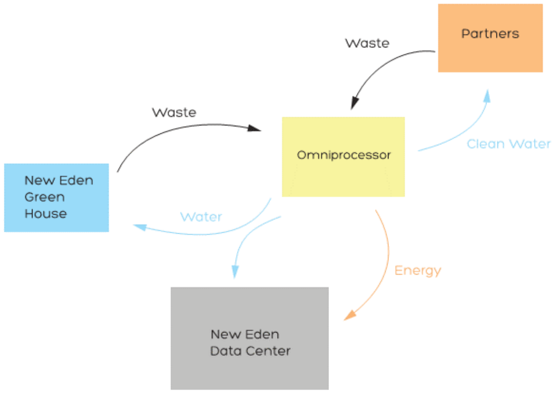


Figure 3: Achieving Zero Carbon Cycle Concept Diagram

Initiatives proposed on site:

- OmniProcessor (1 off)
- Green House A & B (2 off)
- Heated Swimming Pool (1) and Outdoor Bathhouse (1)

Summary of Key Figures:

Electricity Generation		
PV Cells	0	MWh
OmniProcessor	2,190.00	MWh
% of Site Consumption of Electricity per Annum	0.24	%
Heat Exchanged/Reduction of Chiller Load		
Heating Green House (Space) Annual	700000	MJ
Heating Pool/Bathhouse (Water) Annual	190000	MJ
% of total heat rejection per Annum	0.035	%
Water Produced		
OmniProcessor	86,000	L

4.2 Project 2: Zero C Data Loop "Babylonia"

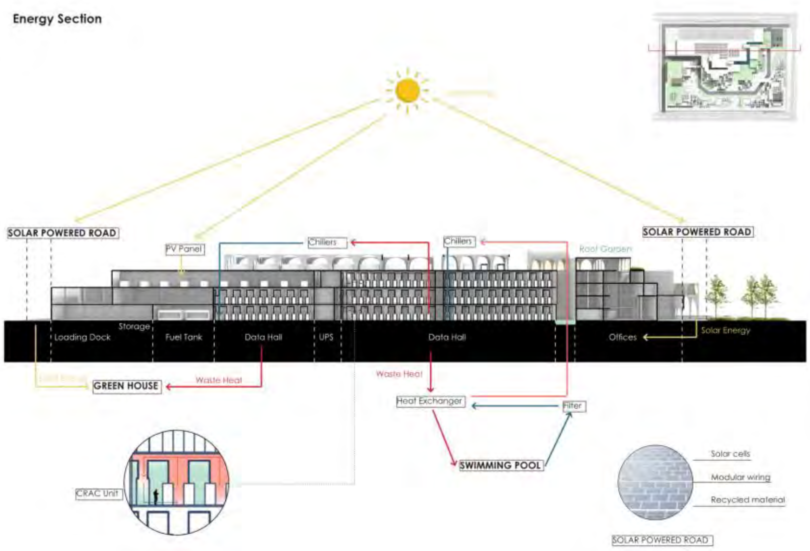


Figure 4: Energy Cycle

Initiatives proposed on site:

- Solar Road (Road Length = 950m, Width = 7.7m, Road Surface Area = 7,300 m^2, PV System Nameplate Rating 1.04MW)
- Green Houses (3 off)
- Heated Swimming Pool (1)

Summary of Key Figures:

Electricity Generation		
PV Cells	757	MWh
OmniProcessor	N/A	MWh
% of Site Consumption of Electricity per Annum	0.08	%
Heat Exchanged/Reduction of Chiller Load		
Heating Green House (Space) Annual	800000	MJ
Heating Pool/Bathhouse (Water) Annual	242000	MJ
% of total heat rejection per Annum	0.041	%
Water Produced		
OmniProcessor	N/A	L

4.3 Project 3: Zero C Data Loop

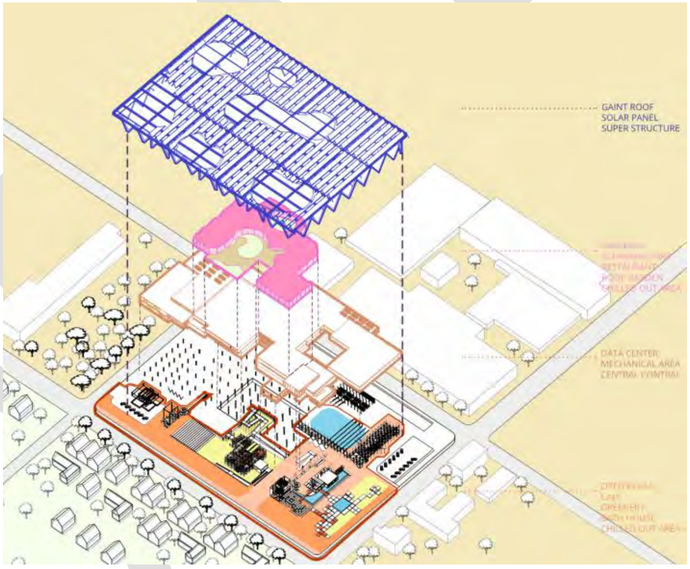


Figure 5: Concept Layout (Solar Cell Canopy)

Initiatives proposed on site:

- Solar Cell Roof Canopy (Roof Area = 21,000 m^2, PV System Nameplate Rating 2.57MW)
- Green House Space (2 Levels)
- Heated Swimming Pool (1)

Summary of Key Figures:

Electricity Generation		
PV Cells	3,008	MWh
OmniProcessor	N/A	MWh
% of Site Consumption of Electricity per Annum	0.33	%
Heat Exchanged/Reduction of Chiller Load		

Heating Green House (Space) Annual	6400000	MJ
Heating Pool/Bathhouse (Water) Annual	702000	MJ
% of total heat rejection per Annum	0.282	%
Water Produced		
OmniProcessor	N/A	L

5 Conclusion

- For an 80 MW Data Centre the percentage figures in the ballpark of 10^{-2} savings are not interpreted as of significant energy/electricity savings from a PUE (Power usage effectiveness) perspective. But this size facility would not be considered typical, and at 80 MW this facility would become one the largest in Australia to date.
- PUE is a ratio of total Facility Power usage to energy delivered to equipment. This ratio is a measure of a facilities operation's overall efficiency. All power generated on site (even renewables) would not reduce the PUE as the equivalent power is still being delivered to the site. An energy saving method such as heat exchangers would reduce the heat load across high power equipment (such as chillers) and in turn reduce the facilities usage of power, thus reducing PUE.
- These savings may not be considered significant from a hyperscale Data Centre perspective, but the biproduct of thermal energy from the facility can lead to community spaces run almost for free, from a community perspective these are significant returns.

  For a high power density data facility these initiatives when applied mean:

  - Community Garden is heated for almost nothing
  - Community Pool has 100% reduction in heating costs
- When compared to a mega facility of 80MW these energy savings are proportionately small, when in the context of a typical 10 - 20 MW facility these figures start to show significant savings (in excess of 2.5%).

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