Net Zero Consideration

Designing a net-zero building requires careful consideration of various factors to achieve energy efficiency and minimize carbon emissions. The followings are the key factors that has been considered during the whole process of designing this modular building:

- **Energy Efficiency:** A thorough focus on maximizing energy efficiency is incorporated by employing insulation in the ceiling and outside wall, efficient natural ventilation systems, high-performance windows, and LED lighting. The total energy demand has been reduced through the effective building orientation, shading, and passive design strategies.
- **Renewable Energy:** A standard portion of the roof area has been used for Incorporating renewable energy sources - Solar panels to generate on-site renewable energy.
- **Building Envelope:** For the design of building envelope, elements are included such as - insulation, airtightness, and thermal bridging mitigation. Apart from extended shading structure Aluminum Screen is placed to enhance the envelope's performance that minimizes energy loss and reduces the heating and cooling loads.
- **Water Efficiency:** In the whole building water-efficient fixtures, such as low-flow faucets and toilets has been implemented and rainwater harvesting systems is also considered for non-potable water use. Opportunities for graywater recycling or on-site wastewater treatment is also proposed in design level.
- **Materials and Construction:** Sustainable and locally sourced materials with low embodied energy has been used while designing the building. Recycled or reclaimed materials and products with environmental certifications has been prioritized. Steel Construction systems is selected to reduce waste and minimize environmental impact.
- **Daylighting and Natural Ventilation:** Natural light penetration through thoughtful window placement and design is maximized. As RIA does not encourage mechanical ventilation systems, natural ventilation strategies is provided to reduce reliance on mechanical systems and enhance occupant comfort.
- **Life Cycle Assessment**: The life cycle impacts has been considered of building materials, systems, and operations. The embodied carbon emissions associated with construction is also assessed by the engineers, as well as the operational carbon footprint. Main target of the project was to Aim for low-carbon alternatives and explore offsetting strategies.
- **Occupant Behavior**: A proposal for regular session can be initiated to educate and engage building occupants to adopt energy-conscious behaviors . This sessions can be provided for promoting energy-efficient practices, such as turning off lights and equipment when not in use and encourage sustainable transportation options.
- **Performance Monitoring**: Implementation of routine monitoring and evaluation system to track energy consumption, indoor air quality, and other performance metrics can be reflected that can help analyzing the data to identify areas of improvement and ensure the building operates as intended.

Moreover, a net-zero building is a multidisciplinary effort that requires collaboration between architects, engineers, contractors, and other consultants. Additionally, local building codes, regulations, and climate conditions has been considered to ensure compliance and optimize performance.

Innovation in Design, Materiality and Technology

Innovation in design and materiality is essential for advancing sustainable architecture. It involves pushing boundaries, exploring new concepts, and integrating cutting-edge technologies to create buildings that are both environmentally responsible and aesthetically captivating. In this design, innovation is included in the use of sustainable materials such as recycled and low-carbon options, as well as the incorporation of smart systems for energy management and occupant comfort. Here are the key elements that explains innovation for the whole pedal and flipper building-

- **Innovation in modules:** The simpler approach for the reconfiguration of the modular section is the main goal of the entire project. Each module is independent by design and has free access to all sides of the building, which makes it easier for workers to install the module and gives the module plenty of breathing area for ventilation.
- **Innovation in materiality:** This project makes use of a variety of materials that, because of their distinctive qualities, serve the building as a whole in various ways. These include:

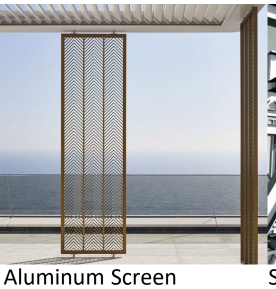
1. ***Cross Laminated Timber Flooring*** - CLT panels are engineered by cross-laminating layers of timber at right angles, resulting in a highly durable and strong material. It is a sustainable and environmentally friendly building material that has a low carbon footprint compared to other construction materials. CLT flooring can be prefabricated off-site, allowing for faster construction and reduced on-site labor requirements. It also provides excellent thermal insulation properties, contributing to energy efficiency in buildings. Finally, CLT offers design flexibility, enabling architects and designers to create unique and innovative spaces.
2. ***Linea™ Weatherboard- James Hardie for Exterior Cladding:*** The Linea Board is made with Sycon formulation which is an Innovative Scyon™ fibre cement. It is thicker, yet as durable and easy to nail, for aesthetic cladding. The speed for insulation is way faster as it is Pre-primed and ready for paint. This product is fire resistant and adheres to bushfire attack level requirements to BAL40. It Contains the charm of timber without the longevity issues of shrinking, swelling and warping to retain it's looks for longer.
3. ***Precast Concrete:*** Precast concrete accelerates construction timelines, improves quality control due to off-site fabrication, enhances durability, fire resistance, versatility in design, and reduces waste.
4. ***Aluminum Screening:*** This kind of screening is lightweight in nature. It is durable, corrosion resistant, easy of install, and requires low maintenance. The screening in the design is a customized CNC cut panel as aluminum can be highly customizable. These screens provides excellent visibility and allows adequate airflow in the building while acting as a shading material as well.
5. ***Steel Structure:*** Steel is the best option while considered for modular architecture. It adds high strength-to-weight ratio. Also, it is durable, flexible in design and construction, resistant to fire, pests, and natural disasters. Steel structures are also cost-effective, sustainable, and allow for faster construction, as well as easy reconfiguration in the future.
6. ***Natural Fiber Insulation:*** Natural fiber insulation includes high thermal performance, moisture regulation, sound absorption, non-toxicity, and low embodied energy. It is environmentally friendly, renewable, and recyclable. The insulation also improves indoor air quality, reduces energy consumption, and provides a comfortable and healthy living environment.

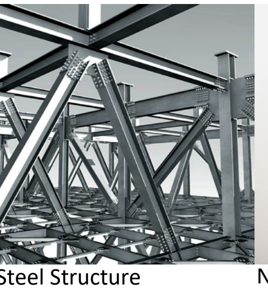
7. Structural Insulated Panel (SIP): SIP is provided for the interior walls to reduce waste. SIP are great in terms of thermal performance, energy efficiency. It also reduces construction time and labor cost. Besides, It improves airtightness, enhances durability and provides design flexibility. SIPs also offer superior strength and can contribute to the overall structural integrity of a building.

- **Innovation in Technology:** This project makes use of a variety of materials that, because of their distinctive qualities, serve the building in various ways. These include:

1. ***Robotics***- Robotic automation can be implemented in the off-site modular elements and Precast footing construction. This process offers huge potential to enhance productivity, efficiency and manufacturing flexibility throughout the construction industry. Along with making the industry safer and more cost effective, robots are improving sustainability and reducing environmental impact by enhancing quality and cutting waste.
2. ***The Internet of Things (IoT):*** As the design propose for regular session to educate and engage building occupants to adopt energy-conscious behaviors IoT can be associated to help enhancing the sessions with necessary data.
3. ***Building Information Modelling (BIM):*** For the performance monitoring purpose BIM can be introduced to track the life cycle of the project as well as simulate and analyze various building scenarios for optimal decision-making. The systems can easily help to identify areas of improvement and ensure the building operates as intended.


CLT


Aluminum Screen


Steel Structure


Natural Fiber Insulation


Exterior Cladding


SIP Panel


Pre-cast Concrete

Service Design and Coordination

Service design in modular house focuses on the efficient integration and planning of essential services such as plumbing, electrical, HVAC, and communication systems within the modular structure. In the design services involve careful consideration of routing, standardized connections, and accessibility for maintenance and repairs. By incorporating service design principles, the modular units can optimize space utilization, streamline installation processes, and ensure the smooth functioning of utilities. In the building service installation can commence which will utilize the designed area beneath each module which allows for ample area to conduct installations and ongoing maintenance to all services required for the structure including – Plumbing, Electrical, Internet routing connections etc. Mechanical ventilation has been avoided due to the prohibitions of RIA.

BCA Compliance (NCC)

Section A |A6 Building Classification: The building is designed as a **Class 6 building** (Bike shop) that is used for the sale of goods by retail or the supply of services direct to the public and a Class 2 Building (Apartment) that is a building containing two or more sole-occupancy units. The Pedal And Flipper service goes with the retail services and includes the following:

(a) A cafe at the reception area has been provided.
(b) A dining room is provided in the first-floor level.
(c) Public laundry is in the 2nd and 3rd floor for the residents.
(d) Pedal and Flipper bike hire facility will act as a sale room, showroom, including service stations.

Section B | B1 Structure Classification: The steel structure to be designed to AS4100 requirement or other as appropriate, Concrete footings designed to AS3600, Metal Roofing to AS1526.1, CLT flooring AS1720.1 or as appropriate and the external wall glazing to AS2047.

Section C | Fire Resistance: According to C1F1 and C1F2 the building provides to Vertical circulation detached from building to allow occupants time to evacuate safely, the site design allows fire bigrade to intervene and avoid damage to other property. The design provides structural stability in terms of height and fire load following C1P1. The stair placement fulfil the requirement for C1P2.

Section D |: Access and Egress: According to D1F1 and D1F2 the building circulation allows its occupants a safe entry to all services and functions and safe evacuation during emergency. With Ramp and Lift provision the building ensures access for people with disabilities, D1P1. Slip resistant material in ramp and stairs, handrails of 1m and landings are provided following D1P2, D1P3. Exits have been designed in every 6m incorporating D1P4-D1P7.

Section E | Fire fighting equipment: According to E1F1 the building comprises of the following design solutions-

- The outer staircase allows occupants to evacuate with enough time while not getting affected by fire.
- Keeps several entries with all the provisions to enter the fire bigrade team to the building easily.

Section F | Health and Amenity:

- F5 Rooms heights – The modular units has 3m clear height that is convenient for a residential use.
- F6 light and ventilation- The building is oriented north-south direction to allow maximum daylight to the building. An adequate number of windows and opening are provided to enhance internal space with proper light and ventilation. LED lights are used to function at night that satisfy F6F1-F6F3 and other appropriate clauses.
- F7 Sound transmission – Lightweight sound insulation are included in ceiling walls and floors using insulated material or independent insulation that completes F7P1-F7P4 requirements

BCA Compliance (NCC)

Section J |Energy Efficiency Performance Requirements: A thorough focus on maximizing energy efficiency is incorporated by employing insulation in the ceiling and outside wall, efficient natural ventilation systems, high-performance windows, and LED lighting. The total energy demand has been reduced through the effective building orientation, shading, and passive design strategies.

Construction Program (*from engineers*)

Construction Methodology

Considering the modularity of the project, the construction methodology will be adversed to most construction site methodologies. The modularity implies that each module must be constructed at an off-site location and must be transported to site and connected to adjacent modules. It also means that the repurposing of the modules must be a relatively simple task, from the dismantlement of the current structure, to the transportation, and to the reconstruction process.

Listed below is the construction methodology in chronological order:

1. Casting of concrete footings on-site. The casting of concrete footings should commence prior to any other task onsite including the lifting of the modules into place. Once the barge arrives at the jetty on Rottnest the trucks will be unloaded off the barge with the modules still loaded on them. The trucks then make their way to the construction site where the modules are to be unloaded and placed in a temporary sight next to the buildings location while the footings are being casted.

   Modules are to be unloaded using the 100t crane outlined in section 2.4.1

1. Construction of the Pedal and Flipper bike shop on top of precast concrete footing will then commence next. The construction of the modules will start from the ground level with each module to be stacked side by side according to the structural plans. A more in - depth assembly plan is included below in section 2.4.1. A 100t mobile crane is to be used for stacking the modules and is to move in between unloading modules and stacking them as needed.
2. After the modules are in place and connected according to design the installation of all non-modular and non-load bearing materials will take place. This includes some finishes and fittings as well as furniture placement in the modules.

Assembly Details:

Once the modules arrive on site there will be 6 main stages of assembly for the modules. The crane used for the module assembly will be based on the assembly of the top-level apartment modules as the apartment modules are the heaviest and the top level requires the greatest beam radius of the crane. To save the cost of transporting multiple cranes to Rottnest one 100t mobile crane is used for both unloading and stacking of each module.

Stage One: During the first stage the steel framing of the apartment modules will be placed and fixed with the connections designed in appendix 2 to the footings. As mentioned above the crane that will be used for placing the apartment modules will be used for the whole construction of the building. This crane will be a 100t mobile Crane. The 100t crane is chosen as the 7.5t critical module will need to be lifted a maximum boom length of 19m and a slew radius of 15m in order to place the 3rd floor apartment modules into place. Using the 100t load chart shown below in figure 1 at a boom length of 19.8m and a slew radius of 15m the crane is able to lift roughly a 15t load which allows for a factor of safety of 2 for the lifting of the 7.5t critical apartment module.

Only the ground floor, first floor and second floor apartment modules should be placed to begin with before the second floor has its walkway prefabrications attached.

Stage Two: Stage two will be attaching the balcony prefabrications onto the side of the apartment modules on the second floor. These prefabricated balconies will be attached via bolts that have been designed in appendix 2. The prefabricated walkways will be lifted in by the same 100t mobile crane onto the second floor before the third-floor apartment modules are assembled to allow easier access for the crane.

Stage Three: following on from the second-floor walkway prefabrications being attached, the third-floor apartment modules should be placed on top of the second floor. Once all third-floor modules are in place according to the structural drawings the third-floor walkways will be attached using the 100t mobile crane in the same process as the second floor.

Stage Four: The fourth assembly stage will see the roof modules attached to the third-floor apartment modules. Even though the roof modules have to be lifted the greatest height, the weight of these modules are less than the apartment modules so the 100t mobile crane will be sufficient in placing these modules safely in the correct position.

Stage Five: Once all steel-framed modules are lifted into place, and connected with outlined connections, all non-load bearing elements will be lifted into place and connected to the steel framing as per structural drawings in Appendix 6. This includes all Cross Laminated Timber, Structural insulated Panels and glass windows.

Stage Six: Finally, service installation can commence which will utilise the designed area beneath each module which allows for ample area to conduct installations and ongoing maintenance to all services required for the stricture. Such services include electricity, water, sewerage, gas etc.

Cost Planning (*from engineers*)

Works Preliminary Estimate

The preliminary estimate is a rough estimate that is completed from the initial design of the residential building on Rottnest Island which produces a ballpark figure for construction. A preliminary estimate breaks down the cost of the project into elements of construction and then determines the cost of each of these elements. The cost sum of all these elements will then be the ballpark estimated construction cost figure. The preliminary estimate is designed to provide the client with a more in-depth upfront cost estimate compared to the approximate estimate. The elements of work involved in the Rottnest Island project are:

- Preliminaries
- Substructure
- Superstructure
- Finishes
- Fittings
- Services
- Contingencies

Table 1 : Preliminary Estimate

Component Weight	Description	Unit	Qty	Rate ($ AUD)	Total ($ AUD)	Reference
Preliminaries						
11%	Preliminaries	sqm	2065	331.75	685,064	Rawlinsons Construction Cost Guide 2023
Substructure						
5%	Substructure	sqm	2065	143.75	296,844	Rawlinsons Construction Cost Guide 2023
Superstructure						
39%	Upper Floors	sqm	2065	338.75	699,519	Rawlinsons Construction Cost Guide 2023
	Staircase - Steel	m/rise	13	2675	34,775	Rawlinsons Construction Cost Guide 2023
	Roof	sqm	1197	157	187,929	Rawlinsons Construction Cost Guide 2023
	External Walls and Windows	sqm	2065	481.5	994,298	Rawlinsons Construction Cost Guide 2023
	External Doors	sqm	2065	44.25	91,376	Rawlinsons Construction Cost Guide 2023
	Internal Walls	sqm	2065	186.75	385,639	Rawlinsons Construction Cost Guide 2023
	Internal Screens	sqm	2065	12.25	25,296	Rawlinsons Construction Cost Guide 2023
	Internal Doors	sqm	2065	50.25	103,766	Rawlinsons Construction Cost Guide 2023
Finishes						
10%	Wall	sqm	2065	104.75	216,309	Rawlinsons Construction Cost Guide 2023
	Floors	sqm	2065	109.75	226,634	Rawlinsons Construction Cost Guide 2023
	Ceiling	sqm	2065	105.75	218,374	Rawlinsons Construction Cost Guide 2023
Fittings						
6%	Fitments	sqm	2065	180.5	372,733	Rawlinsons Construction Cost Guide 2023
Services						
27%	Plumbing	sqm	2065	478.5	988,103	Rawlinsons Construction Cost Guide 2023
	Mechanical	sqm	2065	56.5	116,673	Rawlinsons Construction Cost Guide 2023
	Fire	sqm	2065	15	30,975	Rawlinsons Construction Cost Guide 2023
	Electical	sqm	2065	147	303,555	Rawlinsons Construction Cost Guide 2023
	Transportation	no	2	141000	282,000	Rawlinsons Construction Cost Guide 2023
External Services						
0%	External Services	sqm	2065	11	22,715	Rawlinsons Construction Cost Guide 2023
Extras						
2%	Contingency	sqm	2065	58.25	120,286	Rawlinsons Construction Cost Guide 2023
TOTAL						
Total (excluding GST)					**$ 6,402,860.25**	

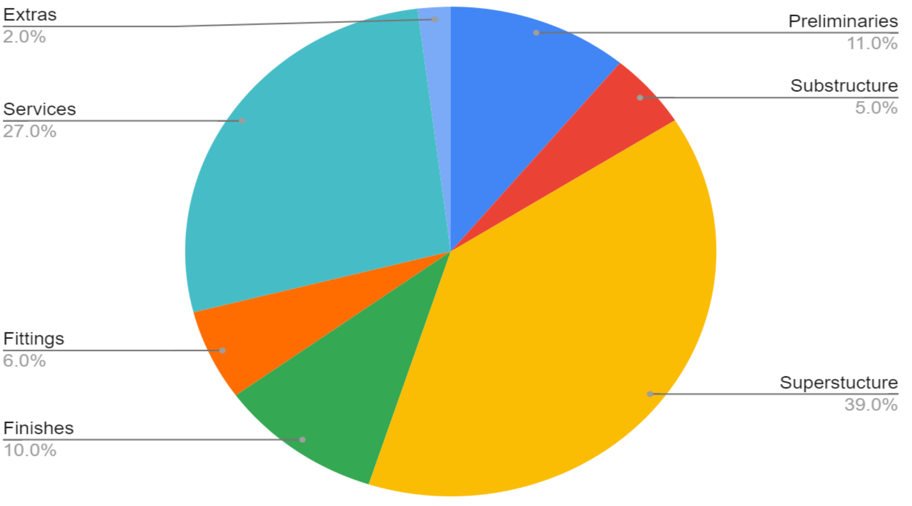


Figure 1: Preliminary Estimate Breakdown

Table 1 is a breakdown of the preliminary estimate with rates taken from Rawlinsons Construction Cost Guide 2023. The preliminary estimate is also simplified in Figure 1 showing the major elements of construction such as preliminaries, substructure superstructure etc. It can be seen that superstructure is the most expensive element taking roughly 39% of the final cost. External services in Table 1 is close to 0.35% of the final cost which compared to other elements is very small thus not being portrayed in Figure 1.

CESMM4 Class Item	Total (AUD)
CLASS A: GENERAL ITEMS	$3,085,7981.00
CLASS B: GROUND INVESTIGATION	$800.00
CLASS E: EARTHWORKS	$6739.40
CLASS F: IN SITU CONCRETE	$37,931.75
CLASS M: STRUCTURAL METALWORK	$3,945,463.60
CLASS N: MISCELLANEOUS METALWORK	$37,250.00
CLASS O: TIMBER	$220,513.35
CLASS W: WATERPROOFING	$29,133.15
CLASS Z: SIMPLE BUILDING WORKS INCIDENTAL TO CIVIL ENGINEERING WORKS	$24,138.00
TOTAL EXCL GST	$7,387,768.00
GST	$578,795.93
TOTAL TENDER	$7,966,563.93

Table 4: Bill of Quantities Summary

From Table 3 above, it can be seen that Class A and Class M take up the majority of the cost. Class A is relatively high due to the provisional sums required for tasks that are out of the Scope of Works, therefore estimated rates are used. The large amount of provisional sums questions the accuracy of the cost but a further detailed bill of quantities can be constructed that entails items outside the Scope of Works. Class A also includes costs for contingency, overheads and profit and insurance. The cost prior to these percentage add-ons is $5,787,959. This cost is lower than the approximate and preliminary estimate as expected but because the percentages stated before as well as GST are included, the total tender price is higher.

Class M can be seen as the most costly item, taking up to 50% of the cost and this is due to the vast tonnage of beams and columns required for the proposed design. Roughly 400 tonnes of steel is required for all modules and Rawlinsons 2023 costs a tonne of steel at $10,000. Rawlinsons Construction Cost Guide 2023 and other sources were used to find rates as seen in Appendix E.

Design Options

The flooring used in the pedal and flipper building has many design benefits. Cross laminated Timber (CLT) is used as the flooring option in the apartment building. It is often mistaken that CLT is more expensive and bad for the environment, but this is far from the truth, and it is in fact the opposite. This section will look at the cost and sustainability benefits of using CLT flooring over more traditional concrete flooring.

Cost

Cost of elements always plays a vital role in the success of a project. Since the flooring of the full construction is going to be all CLT, it is worth looking at the price differences between other conventional options. In table 5 below, it can be seen that the price of CLT flooring is near half the price per sqm compared to a concrete slab. This is assuming that the CLT panels are connected directly to the bearers and joists of the frame and the concrete slab is 20MPa with 20mm aggregate size.

	Cost ($AUD/sqm)	Reference
CLT	82.55	CRSI 2018
Concrete Slab	150	Rawlinsons 2023

Table 5: CLT vs Concrete Cost

Not only is the price of procurement cheaper, indirect costs of flooring are also cheaper. To pour a concrete slab, an agitator truck, formwork, reinforcements are also required which induces more costs. Concrete also requires to be cured which extends the project finish time. CLT flooring just requires the transportation of the panels and connections to beams which is much cheaper. If the concrete was to be precast, a crane that has greater lifting capacity will be needed because the weight of concrete is relatively high, thus inducing more indirect costs for just flooring.