ENGRIHA

On-site Construction Worker Housing

FINAL DESIGN REPORT - APRIL 2023

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RESPONSE TO REVIEWER'S COMMENTS

	REVIEWER'S COMMENTS	RESPONSE
REVIEWER 1		
ENERGY PERFORMANCE	Energy performance calculations appear to have been done only for the equipment and fixtures. What about any energy efficiency gains resulting from load reduction from passive design and building envelope measures? Please double check whether the costs of these super-efficient fans and panels have been correctly considered. What is the total installed capacity of the solar PV?	The energy calculations have been updated incorporating passive design measures and the costs of the fixtures and their respective wattages have been revised.
WATER PERFORMANCE	Good discussion on water consumption efficiency and reuse, you may want to see if there are any stones you've left unturned to get to net zero water.	With the introduction of hardscaping, we have achieved net-zero water system just with rainwater harvesting, low fixtures and modified practices.
EMBODIED CARBON	It's not clear from the report, apart from the Ricron products, what are the exact sources of embodied carbon reduction for roofs, floor, fenestration and structure. You'll do well to better articulate these reductions.	We have articulated all the emissions from all the elements of building and shown manufacturing process of materials.
RESILIENT DESIGN	Look at assessment of potential risks resulting from and strategies to address stressand disruptions to energy and water supply and waste disposal disruption.	We have taken care of all the necessary supplies under such situations , we have extra storage space for food, regular supply of water and electricity are also ensured
ENGINEERING AND OPERATIONS	This contest is not just about service drawings for different services. In order to do well in this contest, please think about right-sizing and integration, and constructability at scale.	We have made the drawings and details to support
ARCHITECTURAL DESIGN	It may be useful to compare options for different aspects in a table view (with the options in the columns, and the comparison criteria in rows) so as to facilitate conclusions about the likely directions.	We have added the design options in the design process on page no. 9
AFFORDABILITY	Double check costs corresponding to the items highlighted in the Energy Performance comments above.	All the product costs have been cross-checked and mentioned in the service fixtures table is in appendix
INNOVATION	Do pay attention to the 6 points in the documentation requirements in Appendix D of the competition guide for the criteria of this contest.	We have referred to appendix D and documented it according to the criteria.
HEALTH AND WELLBEING	Good discussion on thermal comfort and ventilation.	Thank you.
VALUE PROPOSITION	A compelling narrative for the Project Partner needs to be developed.	We have created a narrative in accordance with cost and comfort for both the user and the provider.

SECTION	REVIEWER'S COMMENTS	RESPONSE
REVIEWER 2		
ENERGY PERFORMANCE	The solar energy generation is on a little higher side and may not generate enough power as calculated. Although, the team has considered significant passive features in design, it is not clear how these features are effecting the energy consumption of units. The load calculation needs structure in order to make it readable and understandable. The EPI justification is not clear.	The passive design measures have been incorporated into the energy calculations and the EPI calculations have been revised with the necessary changes in order to make the calculations more readable.
WATER PERFORMANCE	Justification and supporting calculations for water consumption and efficiencies are not calculated in detail. Critical details are missing, such as water treatment plant which will be required in case rainwater is been intended, also, the additional softener plant along with their efficiencies will be required. STP efficiency and subsequent distribution is also not been considered.	The supporting calculations for water consumption and efficiencies have been included. The rainwater filter and softener have been included in the calculations. The biodigester tank is 100% efficient
EMBODIED CARBON	Please elaborate on the Engriha Panels as mentioned, there is no back up data supporting the material.	The process of manufacturing and emissions have been articulated.
RESILIENT DESIGN	Risks pertaining to the project site is not addressed, specifically in case of flooding and heat waves. Also, this area is subjected to intense cyclonic storms, the consideration for such an event is also not been addressed.	The space is more prone to cyclonic events hence we have run our structure through a cyclonic simulation and our footing and columns are safe under such situations, for flooding we have raised our plinth as per topography
ENGINEERING AND OPERATIONS	Critical details are missing from the drawings and narratives. Such as, location of STP, Biogas plant, their inter-relatedness, None of the services prepared have proper annotations or legends to explain the drawing and the respective sizing of equipment and systems.	All the annotations have been included, along with including the locations of necessary paraphernalia.
ARCHITECTURAL DESIGN	The drawings are not annotated to be able to understand the architectural features in the project.	We have included the necessary annotations in all the drawings in this report
AFFORDABILITY	There are few key items which are missing in the list, Rainwater harvesting system, motors, pipes, electrical cables etc. They'll have a significant impact on the cost. Do pay attention to the 6 points in the documentation requirements in Appendix D of the competition guide for the criteria of this contest. Also, the return on investment is not understood at all, how the income has been calculated. What is the basis?	All items have been considered and Appendix D requirements are on page .33. The ROI is explained under the affordability contest on page 26
INNOVATION	The considerations of the EnGriha panel does not include manufacturing, labor, site conditions, material availability, embodied carbon actual performance of the material.	We have looked in to all of those aspects and tested a prototype to prove the same. Details on page no.33
HEALTH AND WELLBEING	A detailed wind analysis is been done on the design however, the inferences of this intervention is not documented or seems to be integrated in design. Please elaborate more in case these inferences have been included in the design of units. Also, thermal comfort conditions inside the spaces are not considered, moreover apart from fans no other means of cooling is been proposed.	Achieved thermal comfort according to IMAC standards in all occupied hours considered using passive design strategies
VALUE PROPOSITION	The value proposition has been prepared around the EnGriha Panel, which still needs proof of concept on ground. Additionally, the turn around time, storage and maintenance of the structure has not been considered in the proposal.	We have considered and tested panels in our proposal.

1 . EXECUTIVE SUMMARY

Team **EnGriha** is focused on creating a net-zero construction worker housing colony that addresses the needs of this specific housing sector in India. The team is using a data-driven approach and includes students from architecture and engineering disciplines to ensure **sustainability, comfort, and quality living** standards for the workers.

Our team is working on a construction worker housing colony- **modular, affordable and compact** for lower income groups in **Rambilli** District near Vizag, Andhra Pradesh for **KEC International** who is developing residential quarters under INS Varsha for the Indian navy, challenging us to achieve sustainability. As the name of our team suggests, we aim to create an environmentally sustainable housing colony for **210 occupants**, predominantly men, who are subjected to long working hours and minimal amenities. The project is deliberated with a focus on using **sustainable and efficient techniques** and materials such as bamboo, ricron and PVC sheets.

The focus on modularity allows for quick and easy assembly and disassembly of the unit, making it a **rentable service** for the project partner with a significant **return on investment of 62.19 % per year**. The team initially aimed to reduce the cost of a module by **30%** but has managed to achieve a **26.81 % reduction in the investment cost per unit**. Apart from this, the team has also managed to reduce the **cost per sq. m to 61.38 % of the baseline cost** by the project partner.

Our primary objective was to minimise GHG emissions by reducing the embodied carbon in our construction materials. To achieve this, we selected materials that emit **lower amounts of carbon and have carbon-negative properties**. Additionally, since our construction process involves transportation, we focused on techniques that minimise the need for manufacturing and transportation, utilising local materials where possible. As a result of these efforts, our **total emissions are 81.8 % lower than the base case** while creating a minimum of up to **12 cycles** of assembly and disassembly.

As drilling a borehole and having a municipal water connection was not possible, **rainwater harvesting and greywater recycling** were essential to establish an efficient water cycle for 210 workers' housing. Through adaptable practices of workers, the team has achieved a **57.7% decrease in per capita water consumption** while **recycling 85%** of the water consumed. This in addition to rainwater harvesting has helped us achieve a **net-zero water model**.

Our aim for energy performance was to achieve net-zero status for the building. We have achieved this by using **energy-efficient equipment and fixtures**, which reduced the load on the system, and by harvesting energy from on-site renewable sources, such as solar panels and batteries. Our **generation EPI was 10.416 kWh/sqm/year** and the consumption EPI, which included efficient use of energy through fixtures, was **20.178 kWh/sqm/year**. We have reached our **energy goal of 9.762 kWh/sqm/year**, resulting in a **35 % EPI reduction** from base case.

We have undertaken the responsibility to devise strategies to ensure an overall benefit to both, the user and the provider by creating comfortable niches for the construction worker by creating an IEQ which pertains to the NBC and BOCW Act, 1996, by ensuring **humidity levels to 40-60%** and also have addressed **health care and overall well-being** of the occupants.

2. TEAM SUMMARY

2.1 TEAM NAME : EnGriha

2.2 INSTITUTIONS : R V College of Architecture, Bangalore
R V College of Engineering, Bangalore
R V University, Bangalore

2.3 DIVISION : On-Site Construction Workers Housing

2.4 TEAM MEMBERS

Anish Perumal
Architecture
(4th year)

Amogh J Acharya
Architecture
(4th year)

Chandana Kulkarni
Architecture
(4th year)

D Yashashri
Architecture
(4th year)

Nidhi Rai
Architecture
(4th year)

Nikita Biju Thomas
Architecture
(4th year)

Rajathashree M K
Architecture
(4th year)

Sanket Danolli
Architecture
(4th year)

Vachana Shreedhar
Architecture
(4th year)

Deepti Mishra
Architecture
(3rd year)

Jennis J Varghese
Architecture
(3rd year)

Akansha Belliappa
Architecture
(3rd year)

Rohan Chaturvedi
Architecture
(3rd year)

Ronan D Silva
Mech Engineering
(3rd year)

Yashika
B. Design
(2nd year)

2.5 TEAM ORGANISATION

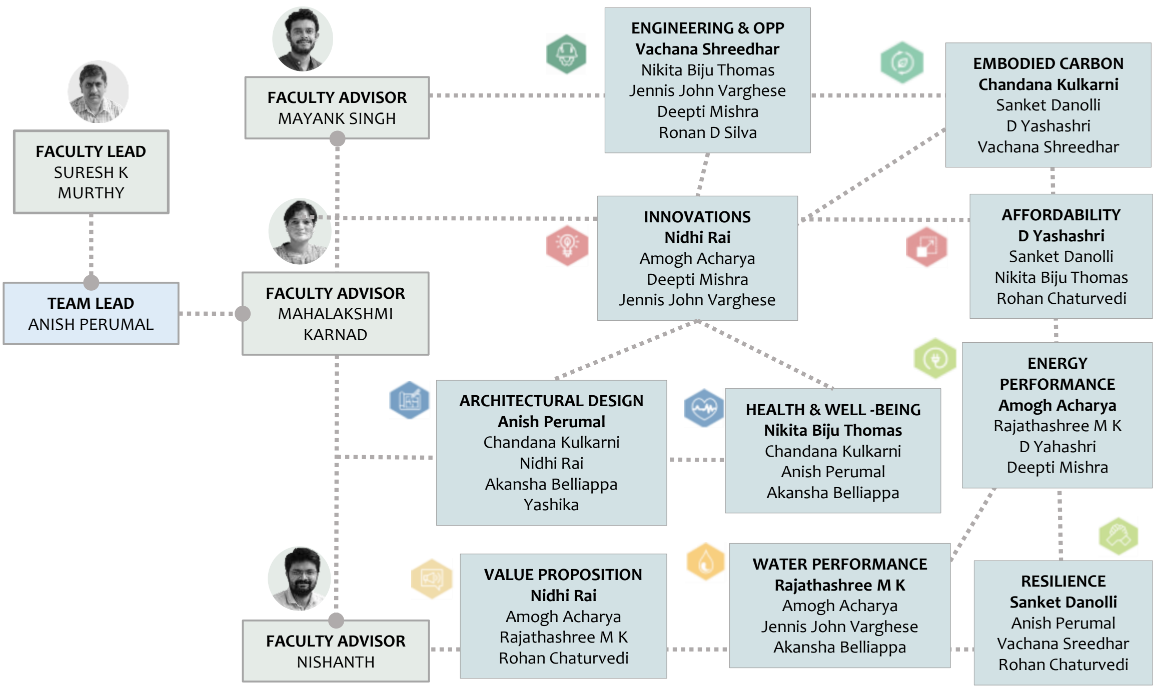
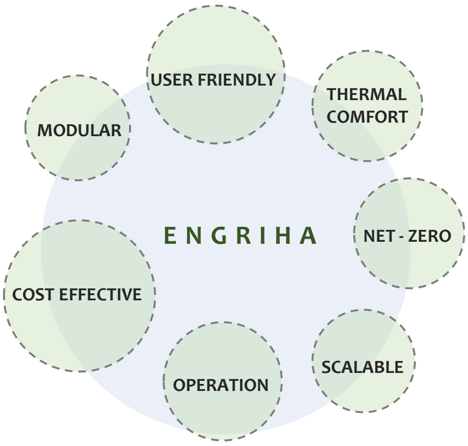


Table 1. Contest Allocation

2.6 APPROACH



- The team approach is to design an individual unit for thermal comfort and low maintenance for construction workers.
- Working under various verticals to fit into the competitive scope of choices and availability to make on-site construction worker housing.
- Individual teams are working at a market, base case and case study level to facilitate and optimise choices and make the project viable.

2.7 BACKGROUND OF LEAD INSTITUTE

R.V. College of Architecture (RVCA), established in 1992, as Department of Architecture in **R. V. College of Engineering (RVCE),** Bengaluru. In 2014 they shifted to a new campus and function independently with a vision of being a centre of excellence, nurturing academics, profession and research for a sustainable contemporary society. The courses offered include B.Arch. and M.Arch which deal with topics like architectural design, graphic design, interiors, structures and also the integration of modern digital means in the design process.

2.8 FACULTY LEAD

Suresh Krishna Murthy – Professor and Dean
B.Arch. from M.S. University of Baroda and M.Tech from IIT Delhi in Building Science and Construction Management. Experience of 15 years working at MIT and RVCA.

2.9 FACULTY ADVISORS

Mayank Singh – Assistant Professor
B.Arch. BIT, Mesra and M.Tech (Structural Engineering) from CEPT. His main subjects are building construction, large-span and high-rise structures. He is also a part-time freelance structural design consultant involved in various National and International projects of small to medium scale.

Dr. Mahalakshmi Karnad – Associate Professor
B.Arch. from Bengaluru University and M.Arch in Landscape Architecture from SPA, Delhi. She joined the RVCA team in 2009 and has work experience with several professional organisations in landscape architecture.

Nishant – Assistant Professor
B.Arch and M.Arch (Architectural Conservation) from SPA, Delhi. Has contributed to the renovation works of the existing Parliament Library, Parliament House and the Old Parliament Annex building.

2.10 INDUSTRY PARTNER

Ricron is a brand that is redefining the use of plastics. It creates a circular economy from plastic waste to sustainable building materials. It follows the steps: **make, use, dispose, recover, regenerate.** They are recipient of the Green Pro Certification Award, presented by Confederation of Indian Industry (CII).

RicronPanels

2.11 DESIGN PROCESS DOCUMENTATION

RESEARCH

- Project brief
- Case studies
- Self Learning Modules and webinars
- Meetings with project partner and industry partner

SITE ANALYSIS

- Climate analysis
- Understanding levels on site
- Context analysis using Google Earth

PRELIMINARY DESIGN

- Budget analysis
- Weekly in-person meetings
- Shortlisting goals and strategies
- Quantifying goals for each contest

DESIGN DEVELOPMENT

- Module development
- Formation of clusters
- Choosing appropriate materials
- Orientation
- Shading device Fenestration

RE-ITERATION BASED ON FEEDBACK

- Cost re-estimation
- Thermal comfort
- Justification of design
- Energy performance

PRESENTATION

- Process diagrams
- Technical drawings
- Joinery details
- Renders

2.12 TOOLS USED

3. PROJECT SUMMARY

3.1 PROJECT NAME : EnGriha
3.2 PROJECT PARTNER :
KAMANI ENGINEERING CORPORATION (KEC) INTERNATIONAL LTD

KEC INTERNATIONAL LIMITED

KEC International LTD is an Indian Multinational company headquartered in Mumbai, India. It is engaged in EPC works for Power Transmission and Distribution, Railways, Cables, Urban Infrastructure, Solar, Civil and smart Infrastructure. It has operations in the regions of India, SAARC, East Asia Pacific, Africa, Middle East and the Americas.

3.3 NAME AND DESIGNATION OF KEY INDIVIDUAL INVOLVED :
Mr. Praveer Khare (Project Manager)

3.4 BRIEF DESCRIPTION OF PROJECT :

LOCATION - Rambilli, Andhra Pradesh, India
LATITUDE - 17°27’04.9”N
LONGITUDE - 82° 54’38.4”E
CLIMATE ZONE - Warm and Humid
CURRENT STATUS OF THE PROJECT - Built for 210 people

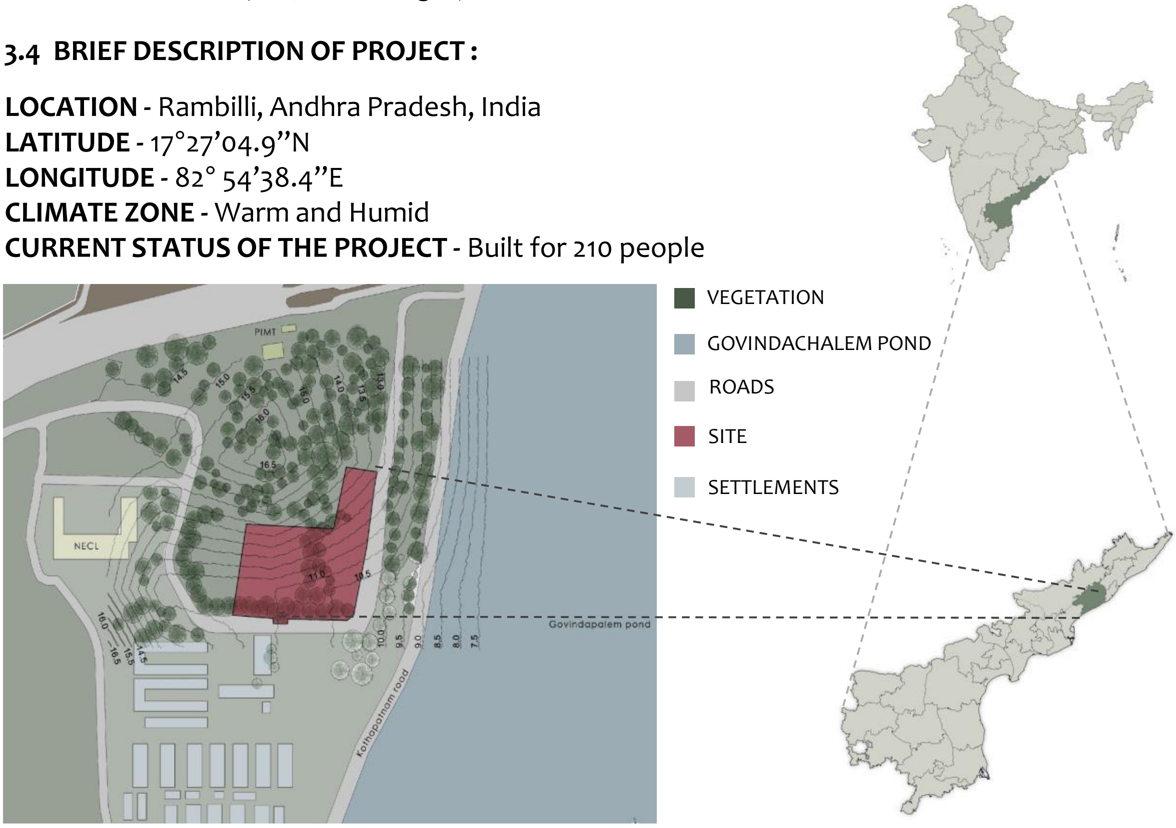


Fig. 1 : Site Map

KEC has undertaken a project **“INS VARSHA”** under Project Varsha for the Indian Navy.
This base will be the home of the Navy's new fleet of nuclear submarines and ships. It was planned to be located within a radius of approximately 200 kilometres (124.27 statute miles) from Visakhapatnam, the headquarters of the Navy's Eastern Naval Command. The base is being developed at Rambilli, which is **50 km** from **Visakhapatnam**.

The occupants include single laborers, and mandatorily **only men** are allowed, but a provision for **accommodating women in 10 percent** of the units has been made in the design.
The duration of the project is approximately **30 months**.
The effective working period of the workers is **12 hours** i.e., 6 AM to 6 PM with a break of 1 hour for lunch, hence the hours of operation of the building shall be from 6 PM to 6 AM, however the common spaces may be utilized during break hours and on other days.

3.5 AREA STATEMENT:

This indicates the area of built and unbuilt. Inferring to which design considerations are taken which allows easy circulation and living condition.

SITE AREA	8270 sqm
BUILT - UP AREA	2400 sqm
GROUND COVERAGE	1,824 sqm
ROOF AREA	2,350 sqm

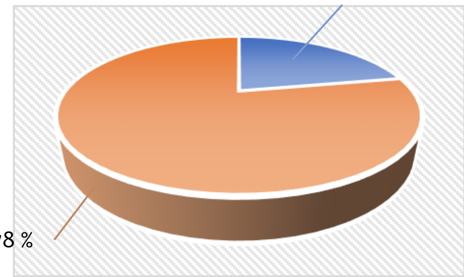


Fig. 2 : ground coverage vs open space

SL NO	PROGRAMME	REMARKS	NUMBER OF UNITS	NUMBER OF PEOPLE	TOTAL AREA (IN SQM)	CONDITIONING
1	**Living Unit**					
	Sleeping Unit	Triple Sharing	72	3 (Per Unit)	1152	Mechanical Ventilation with passive design strategies
	Toilets	1 WC=8 people 1 bathing cubicle=8 people	28	210	328	Unconditioned
2	**Common Kitchen**					
	Cooking	Half The Area For Dining	1	210	155	Mechanical Ventilation
	Dining		1	210	310	Unconditioned
	Washing		1	-	60	Unconditioned
	Storage		1	-	60	Unconditioned
3	**Common Zone**					
	First Aid Rooms		3	-	40	Mechanical Ventilation
	Common Room		1	-	120	Unconditioned
	Indoor Games Room		1	50	60	Partially Conditioned
	Tool Storage	One For Four Clusters	1	-	60	Unconditioned
4	**Community Space**	Outdoor	1	210	250	Open
				TOTAL AREA	**2400**	

Table 2. Program area statement

3.6 SPECIAL REQUIREMENTS:

On site construction worker housing changes location from time to time based on the project and clients needs. This requires the structure to be resilient and to change in times of climatic changes and natural disasters. This project has been planned with a vision to scale it to a multiple uses than limiting it. The project also provides a benchmark for the minimum standard requirements for future on site construction worker housing projects.

3.7 CONTINGENCIES IN PROJECT:

- Increase in Cost- not likely to occur since the fabrication process occurs only once.
- Damage - individual components are easily replaceable.
- Occupancy - easy expansion from 3 to 6 persons in case of dire need.
- Injuries- provision of medical emergency aid.
- Natural and manmade calamities- considered under resilience.

4. GOALS AND STRATEGIES

SL No.	CONTEST		GOALS	ACHIEVED
1		ENERGY PERFORMANCE	Increase energy generation which is 10.416 kWh/sq.m/year by a factor of 5% and achieve a target EPI of 8 kWh/Sq.m/year.	The consumption EPI reduction has been achieved by using more efficient fixtures and passive design measures, bringing it down to 20.178 kWh/sqm/year and our overall EPI to 9.762 kWh/sqm/year with solar PV generating 51.6% of the energy needs on-site. The electrical consumption has been reduced by a factor of 28.79 %.
2		WATER PERFORMANCE	Optimize on-site water consumption and grey water recycling for non potable usages and creating a sustainable water cycle.	Successfully achieved a net-zero water consumption model using various techniques by minimizing water consumption by 70% using aerators while recycling greywater for non potable usages through Biochar Portable Water Treatment System, rainwater harvesting through rooftop and hardscape area (3664470.6 L/year) to meet 100% of the total demand a year.
3		EMBODIED CARBON	Achieve Net - Zero Carbon building during all stages of building use and management by using low embodied energy materials and sourcing them from local regions	Achieved 81.8% Net-Zero Carbon Building by using materials with carbon emission ranging between -1.4 kgCO2e/kg to 0.91 kgCO2e/kg, and devising the 'EnGriha Panel' with Jute (natural material) and RICRON panels which is made up of recycled plastic, for walls.
4		RESILIENCE	We aimed to make the building resilient during natural and man-made hazards by ensuring workability, and comfort.	Footing and columns are stable under cyclones , tested with cyclonic simulation . The foundation are made with rubbles which gives extra support and plinths are raised by 450mm to avoid flooding, all the corners of the room are given with louvers for better air movement and the existing trees are not cut which help us in avoiding heat waves. Quick hospital service, extra storage of food supply has been taken care.
5		AFFORDABILITY	Minimize construction, operational and maintenance costs to attain affordability and reduce per sq. m cost by 60% as compared to the base case by Project Partner.	Achieved the 60% reduction in cost per sq.m and also 30% reduction in cost per unit as compared to market rates. The payback period for a module is achieved in 1.52 years with a return on investment of 65.93% per year. The reason for 60% cost reduction is that the Project Partner has built only 930 sq. m for the same cost of 1.5 crores and we have built 2400 sq.m for the same cost. Renting out of the clusters help with gaining back the initial investment which interests the Project Partner. The units are similar so wastage is less and bulk ordering of materials reduces costs.
6		INNOVATION	Flexible envelope to accommodate various weather conditions.	We have made a prototype of a modular panel which meets requirements of cost and U value
7		ENGINEERING AND OPERATIONS	Ensure quick and easy assembly and disassembly, and easy transportation with minimum wastage and ensure materials last for over 12 cycles of assembly and disassembly of the cluster	We have manufactured a wall panel which could be made in 2 hours which proves the quick assembly of the structure is feasible
8		ARCHITECTURAL DESIGN	Accommodating 210 people while maintaining the requirements pertaining to hostel accommodation in NBC 2016	The design stick to the NBC requirements for lighting, ventilation, toilets, fire protection, areas of accommodation per person and also the provisions of the Labor Laws of India.
9		HEALTH AND WELL-BEING	To provide 100% of occupied hours (5475 hours per annum / 15 hours per day) as comfort hours with temperature range between 21 - 27 deg C. and bring down indoor RH to 40 - 60%	Out of 5475 hours, 63% or 3687 hours are within the comfort band according to adaptive comfort model, By using effective ventilation and passive design strategies.
10		VALUE PROPOSITION	We wish to develop scalability, sustainability, modularity and minimizing the maintenance cost.	The units are made modular for easy scalability, and the materials such as recycled steel and recycled plastic sheets are low maintenance and sustainable, and these can be used for varied purposes as a business model

6. FINDINGS FROM PRE-DESIGN ANALYSIS

Fig. 3 : Site analysis map

Rambilli is a town in Visakhapatnam district of Andhra pradesh, along the coastline of Bay of Bengal.

Thus very high **relative humidity of 85-95%** and high temperature around **32-41 deg C** on site

- Use of local vernacular methods will help us overcome the problems of wind hazard and flooding.
- Using local materials and green material from plants will help us to maintain cooler atmosphere in and around the building.

- Fast blowing winds of the region can prove helpful in achieving comfort conditions indoors passively.
- Hence having adequate open spaces and permeable walls will be beneficial for the design.
- Further due to the warm and humid climate, having shaded open areas can also be helpful .

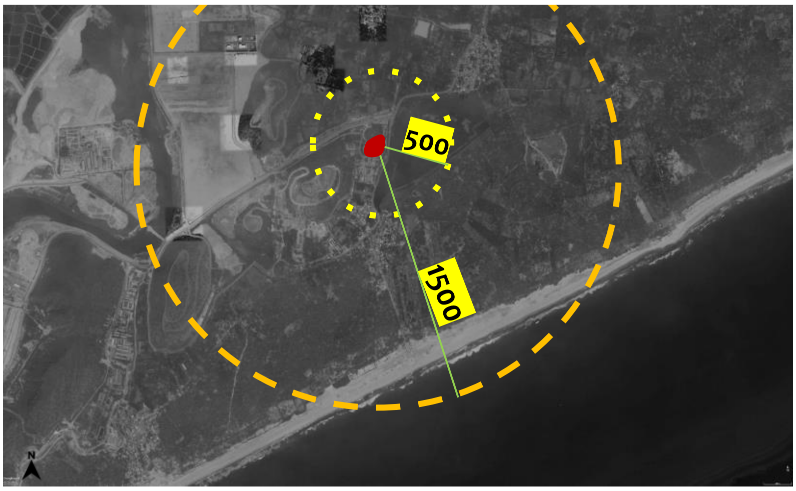


Fig. 4: Site- Context Proximity Map

In 500m proximity	In 1000m proximity	In 1500m proximity
Next to site (63m away) is the **GOVINDAPALEM** pond which is around 81 acres wide. Influences : Adds moisture to the soil thus adds on to the humidity by ground. Cools the wind prevailing from north-east , and south-east winds Sets up convection currents between itself and the hill towards the north west	In 700m to the site a small village settlement is **Vada Naraspuram** Influences : If any high rise structure might affect the wind flow Local construction techniques can be borrowed from the surrounding regions..	In 1200m south is the river **SARADA,** And 1100m east is the **Bay of Bengal** Influences : River might flood during monsoon seasons Sea accounts for continuous breeze And humidity High risk of hazards such as thunderstorm and cyclones.

Table 3. Context around site

7. DESIGN PROCESS

7.1 EVOLUTION OF THE CLUSTERS

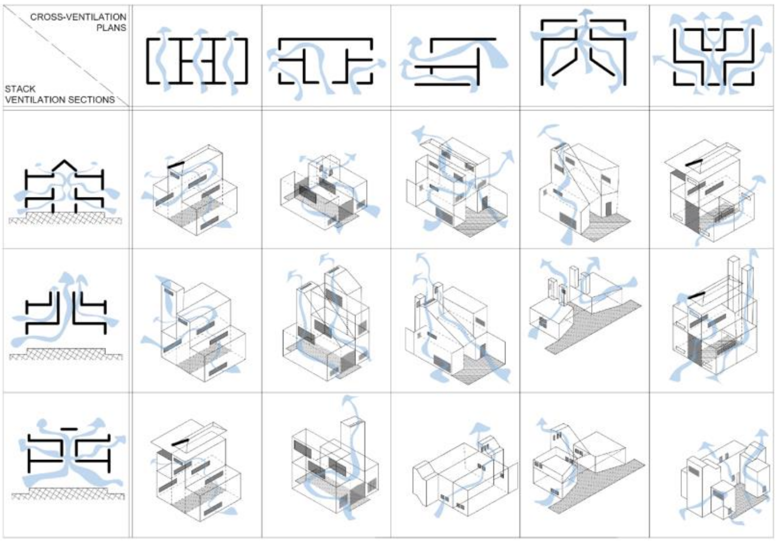


Fig. 5 : Clusters matrix based on ventilation

Starting with the clustering, we used **climatic resilience** as a starting point and tried to mitigate the effects of **high humidity** by using **cross ventilation and stack effect.**
Drawing from various arrangements to achieve cross and stack ventilations, for which we made a **matrix of the various arrangements**

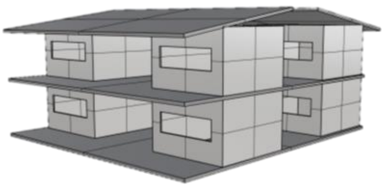


Fig. 6a : Iteration 1

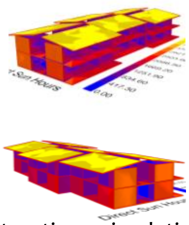


Fig. 6b : Iteration 1 simulation

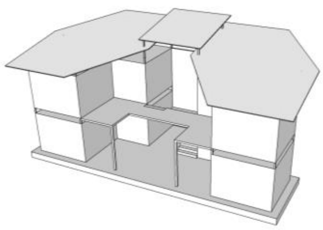


Fig. 7a : Iteration 2

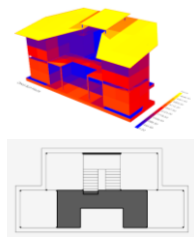


Fig. 7b : Iteration 2 simulation

PROS	CONS
Tried Achieved Open Spaces	Large Footprint – Cluttered Master Plan
Spill Out Between Units	No Common Walls
	Optimisation Of Materials Wasn't Achieved

PROS	CONS
Tried Achieved Open Spaces	Space Given Courtyards Has Become Too Much
Spill Out Between Units	Higher Amount Of Materials To Give Structural Stability
Courtyard And Interlinked Courtyards	

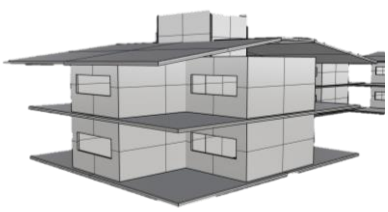


Fig. 8a : Iteration 3

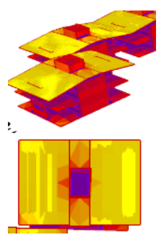


Fig. 8b : Iteration 3 simulation

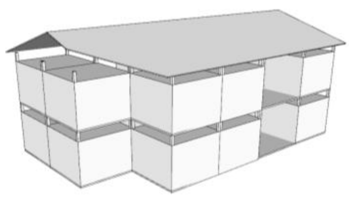


Fig. 9a : Iteration 4

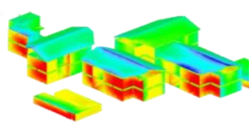


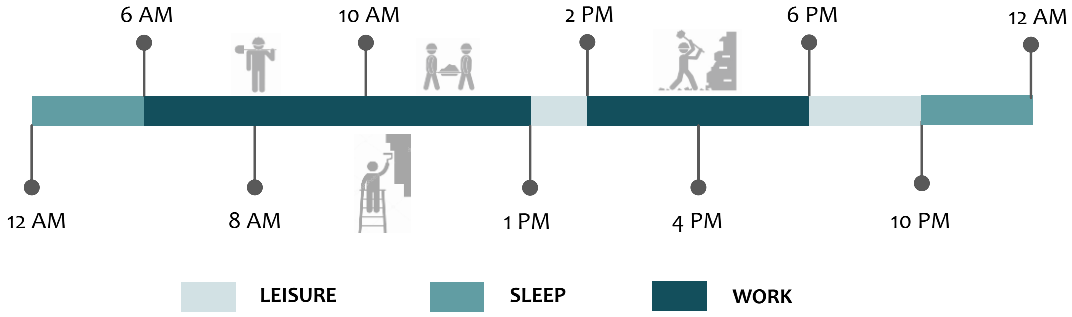
Fig. 9b : Iteration 4 simulation

PROS	CONS
Tried Achieving Common Wall	The Excessive Balconies Needed To Ensure Proper Circulation
Tried Keeping Stack Ventilation Active	More Materials
Central Core Which Acts As The Stack	Need Two More Staircase

PROS	CONS
Tried Achieving Common Structural Nodes	Larger Floor Area Covered
Reduced The Structure Costs	Wasted Space
Ventilation – Optimised Balcony Area	Introverted Corridor, No Outward Connect

8. ARCHITECTURAL DESIGN

ACTIVITY CHART OF CONSTRUCTION WORKERS



8.1 PRINCIPLES OF DESIGN

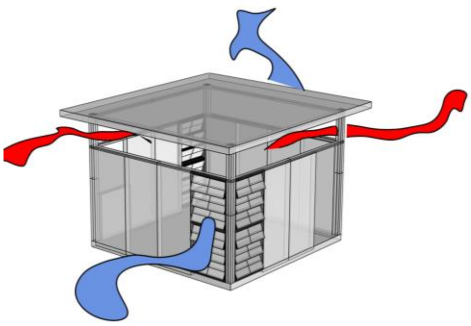


Fig. 10 : Permeable walls

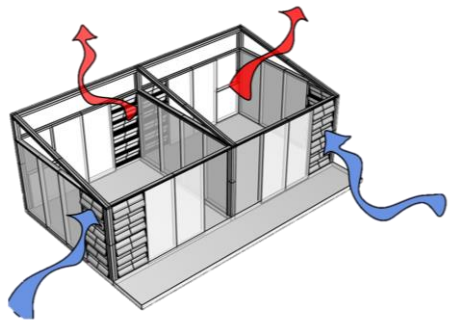


Fig. 11 : Air Circulation

Permeable walls for Cross Ventilation
Having permeable walls on at least two sides of the unit in order to ensure effective cross ventilation

Ensuring that there are no dead zones
Arranging the openings in order to ensure that there is proper mixing of air and no short circulation causing dead air zones.

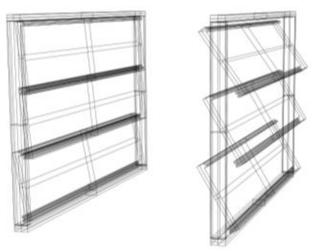


Fig. 12 : Idea of louvers

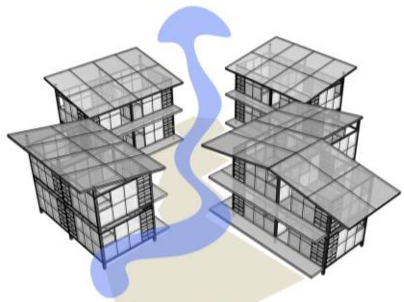


Fig. 13 : Buffer Spaces

Use of Louvers
Operable louvers ensure that ventilation can take place while still having sun shading and privacy in the units.

Buffer Zones around Clusters
Ensuring open spaces around the clusters to ensure effective air exchange and dissipation of heat

Courtyards and Interaction Spaces
Provision of spill outs, and courtyards and interaction spaces at multiple levels from cluster to masterplan to ensure interactions between the occupants.

Ricron Composite Panel
Use of Ricron Composite Panel panel with corrugated insulation material and air cavity to ensure light weight but thermally optimal wall structure.

8.2 DESIGN OF A SINGLE LIVING UNIT

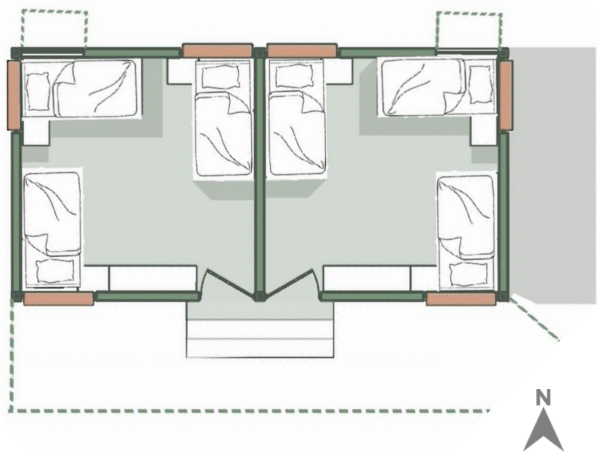


Fig. 15 a : Unit plan

Fig. 15 b : Unit Sectional Perspective

A single living unit is a **4m X 4m Squ**are in plan, where each unit functions as an **independent structural system** with columns on four corners and framing members holding the **EnGriha panels** as the wall system.

To ensure **cross ventilation** there are **louvered openings** on the two opposite corners and all the storage **furniture** has been maintained at **shoulder levels** to have unimpeded airflow in the unit. **Above lintel** level on one side of each unit, a **meshed opening** is used to ensure effective exhaust of stale air from the interiors.

8.3 STRUCTURAL DESIGN OF THE UNIT

The unit is made up of almost entirely of **recycled steel** and **rests on tyre foundation** raised from ground level by **450 mm.** The system comprises of T-angle and box sections within which **Ricron composite panels** fit. Windows, doors and louvres are provided in the panel cavities. Straw bale is sandwiched between corrugated and plain Ricron panel forming the flooring system. A mesh is provided at the top of each unit for ventilation. Corrugated Ricron panels are fit onto a **bamboo truss makes the inclined double roof over which the PV panel rest**.

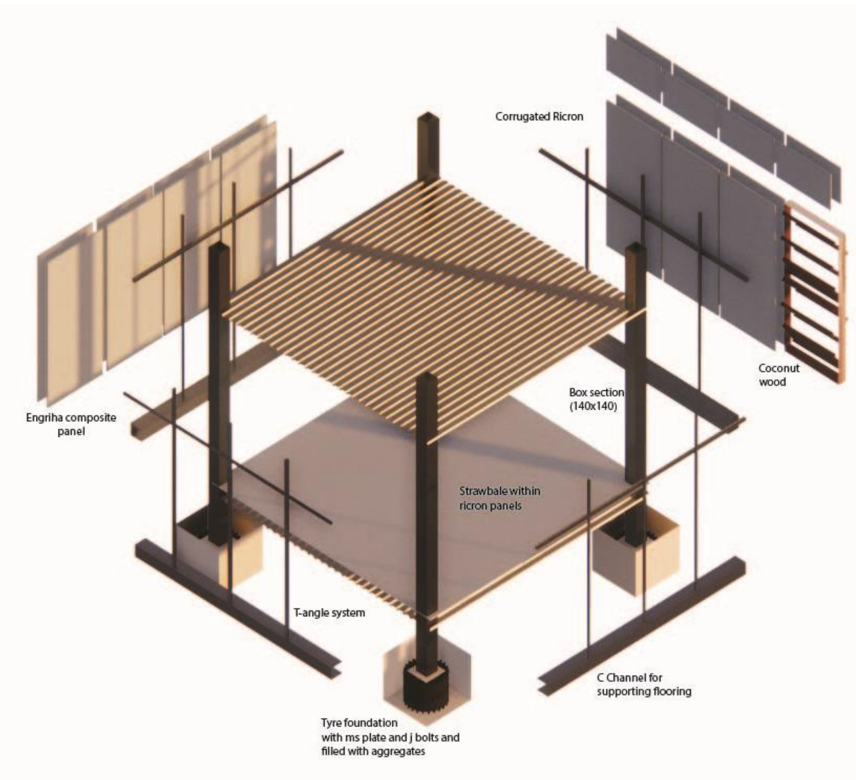


Fig. 16: Exploded Isometric of Structure

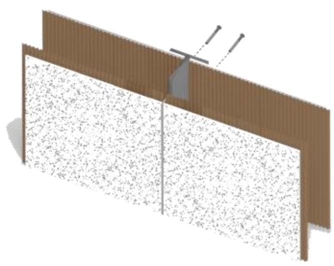


Fig. 17: Wall panel to Support Joinery

8.4 CLUSTERING OF UNITS

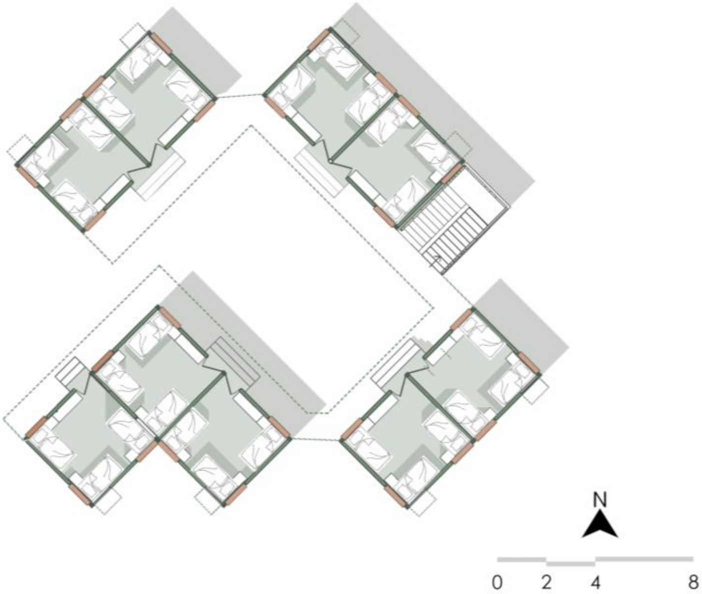


Fig. 18 : Cluster plan

Fig. 19 : View of Cluster

Fig. 21 : View of Cluster

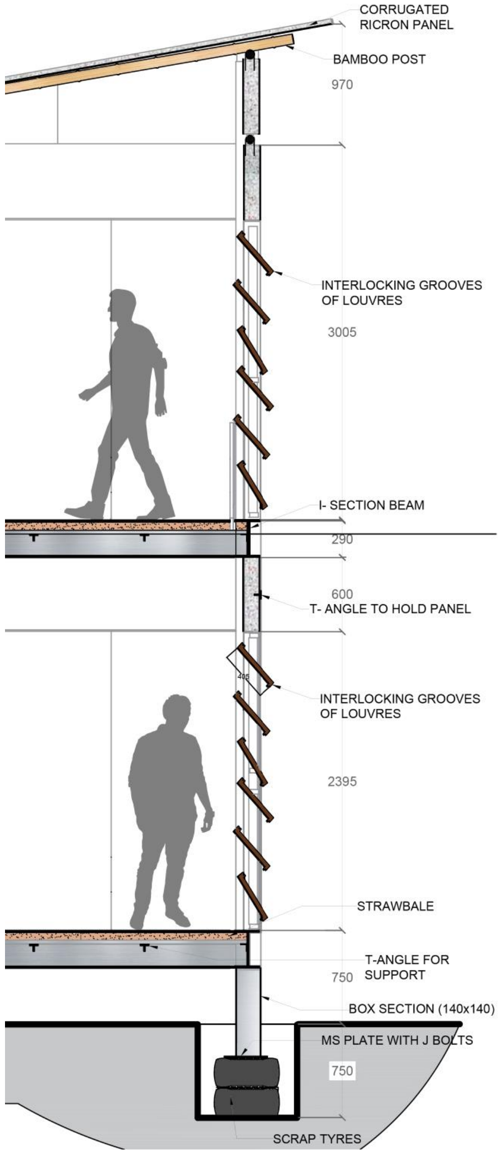


Fig. 20 : Typical Wall Section

- The cluster is based on **optimising the Structure** while still maintaining the **optimal ventilation** patterns.
- The structure is optimised by having **common columns** between units at multiple places as well as material optimisation is brought about by having **common walls** which reduces the number of panels requires.
- The **upper floor circulation** is based around a perforated sheet **balcony** which serves as the corridor.

8.5 ARRANGEMENT OF MULTIPLE CLUSTERS

Fig. 22.a : Super clustering

Each Cluster Contains **18** units, hence, to house 210 people with three per unit, **4 clusters** are required.
These four clusters have been arranged around a **open space** in the centre and the **toilet units** have been placed separately in the **corners**.
The zone is **approached** through a path from the common zone going along the first cluster in a 45 degree angle and leading into the central area, which acts as a **smaller community space**

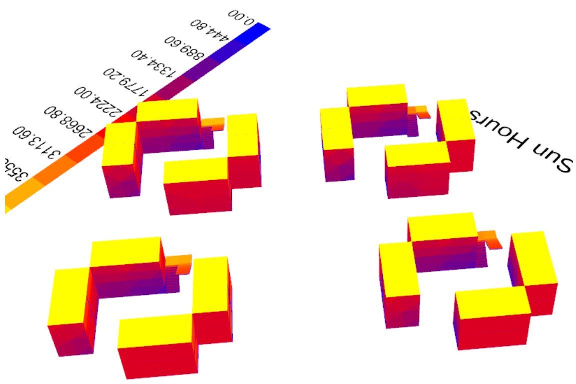


Fig. 22 B : Radiation Simulation Of Super Clustering

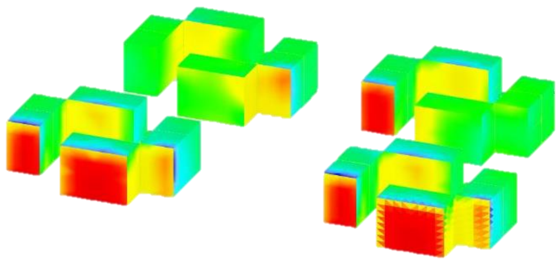


Fig. 22 C : Wind Simulation Of Super Clustering

8.6 ZONING DIAGRAM

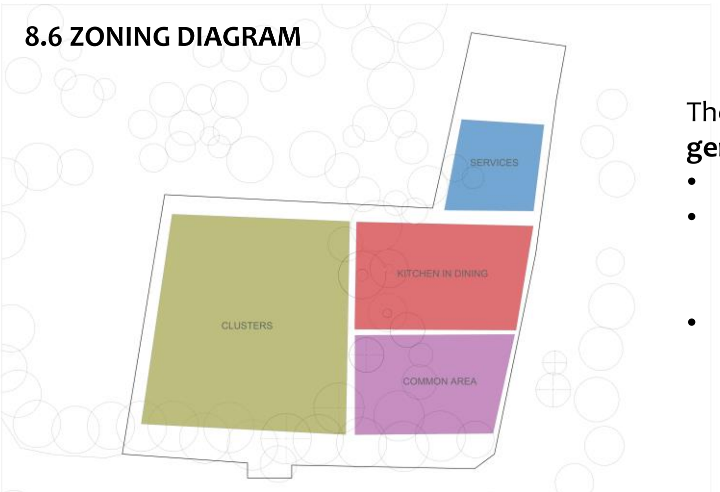


Fig. 23 : Zoning Diagram

The Site has been divided into **three general zones**,
- The **living zone** with the clusters,
- the **common zone** with the Kitchen, Dining and the common areas and the **service arm** to the north;
- The Common zone and the living zone is separated by a row of **pre-existing trees** on site.

8.7 COMMON AREAS

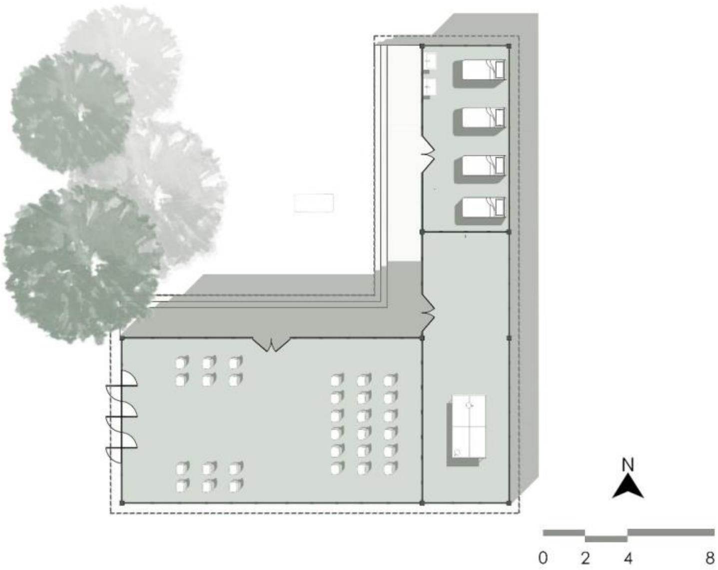


Fig. 24 : Plan of Common Areas

Fig. 25 : view of Common Areas

Fig. 28 : Elevation of Common Areas

8.8 KITCHEN AND DINING

Fig. 26 :sectional perspective of dining hall

Fig. 27 : section of Community kitchen

The Community Dining, Kitchen and common areas are the places where the residents interact with each other and build a community, it is separated from the units by a row of pre-existing trees and in terms of their character differ from the units.

These areas use **Mud compacted plinth** and **Bamboo wall panels** which give them a similar Character to the houses of the villages these construction workers hail from.

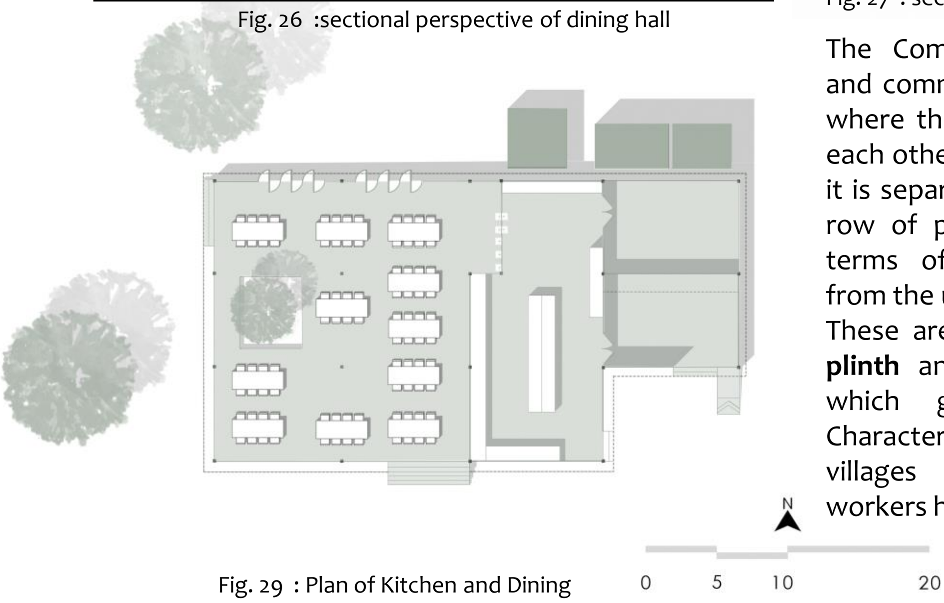


Fig. 29 : Plan of Kitchen and Dining

8.9 OUTDOOR RECREATIONAL SPACE

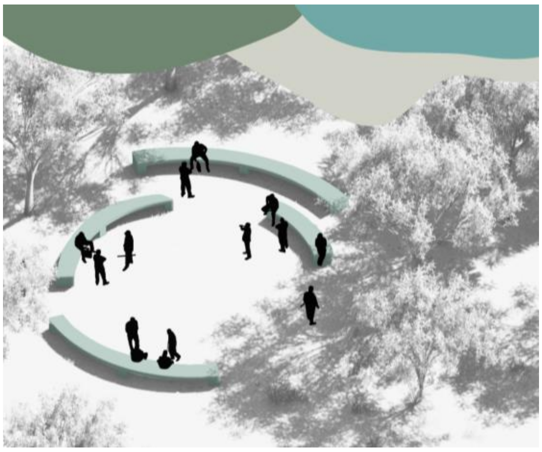


Fig. 30 : Outdoor Areas

Fig. 31 : Street Lighting

Designed in form of **benches** placed in between the trees and around the **common area courtyard**, this space acts as a place for the workers to engage in recreational and **cultural activities as a community**

8.10 MASTER PLAN

Fig. 32 : Master Plan at roof

The Master Plan has **three zones**, **the living zone** with the clusters, **the common zone** where the dining, kitchen and common areas are, and **the service zone** in the north arm.

9. ENGINEERING AND OPERATIONS

9.1 CLUSTER SERVICE DRAWING

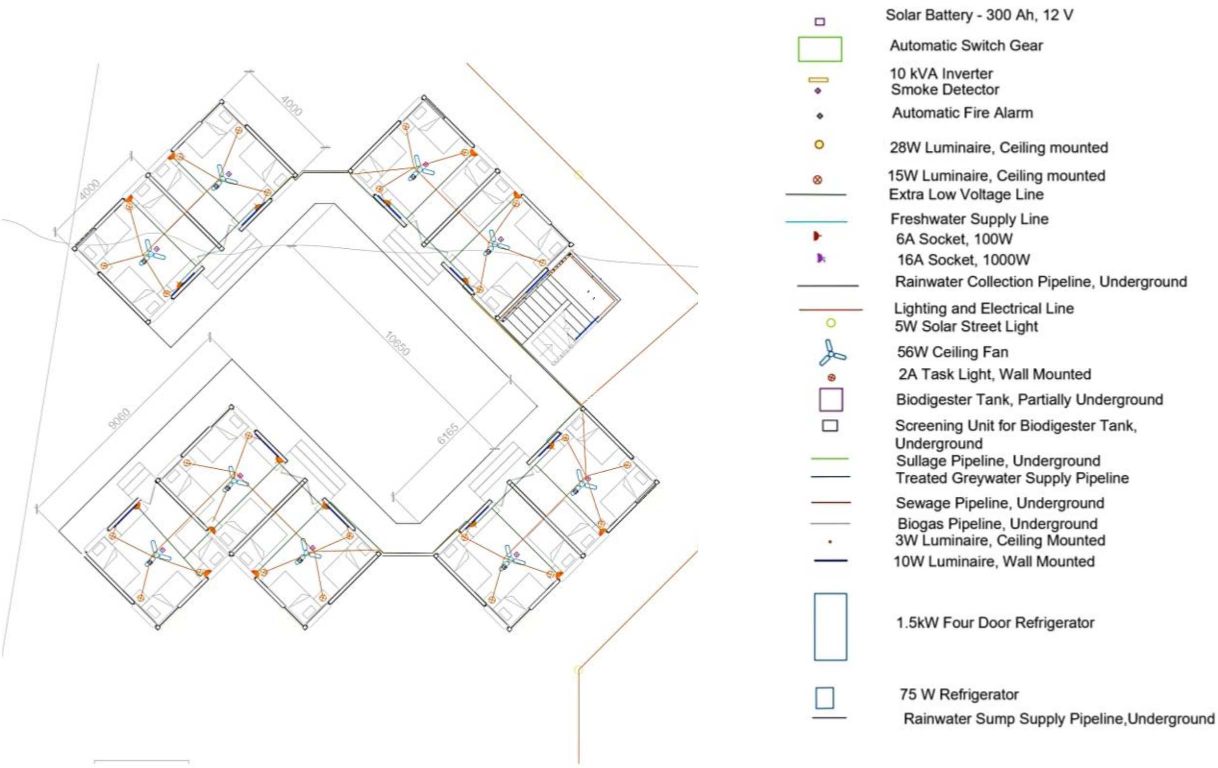
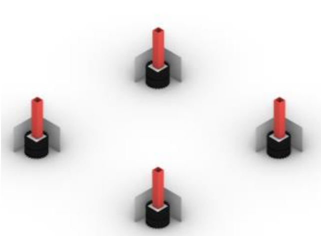


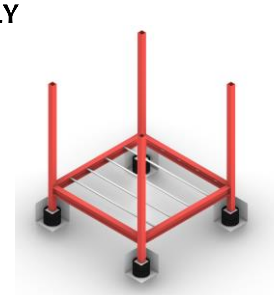
Fig. 33 : Services for Clusters

The Clusters have **two lines** of lighting circuits, one for the **internal lights** and ceiling fans, and one for the **external circulation lights**. Apart from that, there is also an ELV line for the smoke detectors and fire alarm

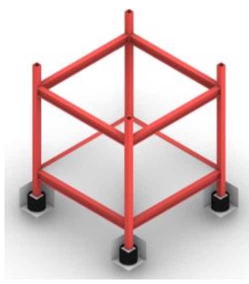
9.2 PROCESS OF ASSEMBLY



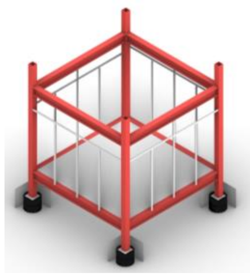
Tyre foundations with MS plate and J-bolts holding a box section of 140mm x 140 mm



I-beams having t-angles within to support the corrugated ricron forming the flooring.

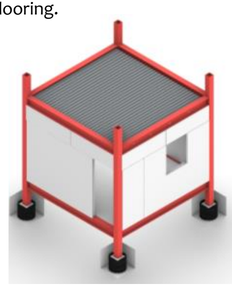


I-beam sections holding the plain ricron panels and forming frame for next floor



T-angle section frame is installed

Panels installed and t-angles put to support the flooring.



Corrugated ricron panel placed on t-angle to for flooring.

T-angle section frame installed for first floor.

Panels fitted into the t-section frame for first floor.

Fig. 34 : Process of Assembly

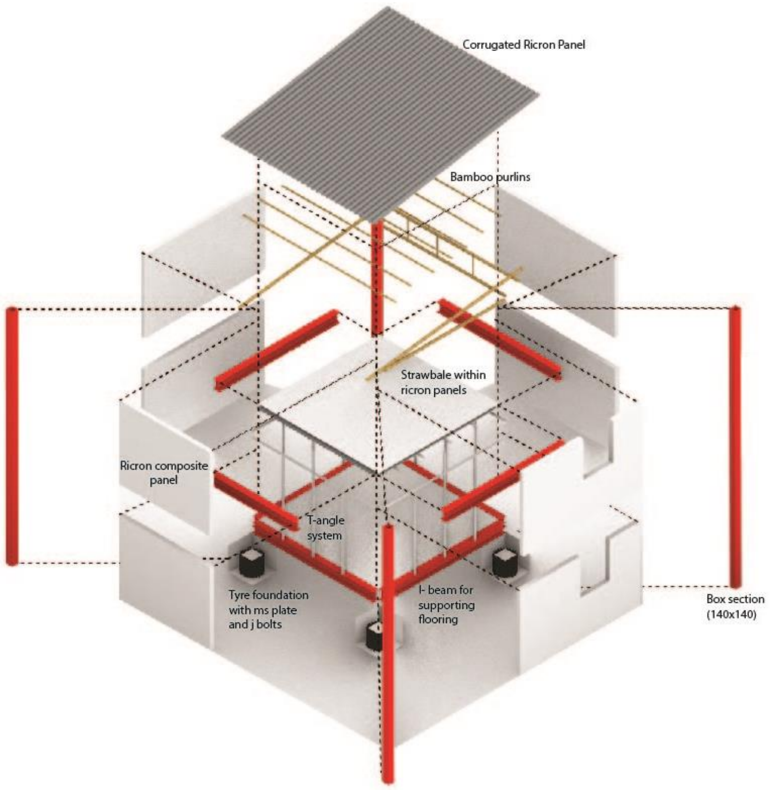


Fig. 35 :Exploded view of unit

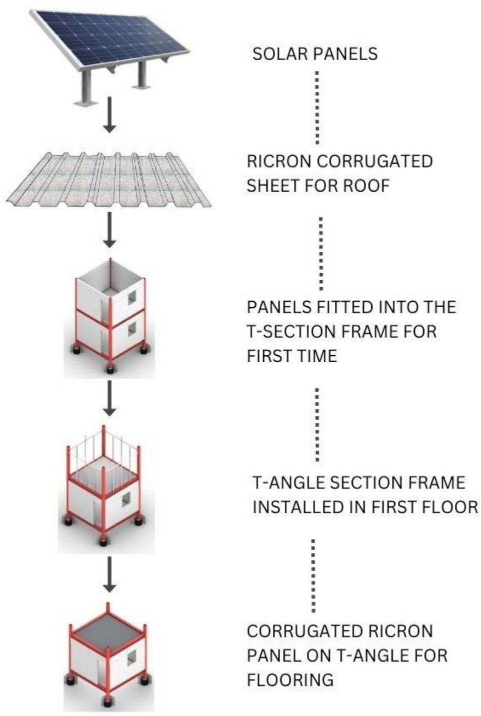
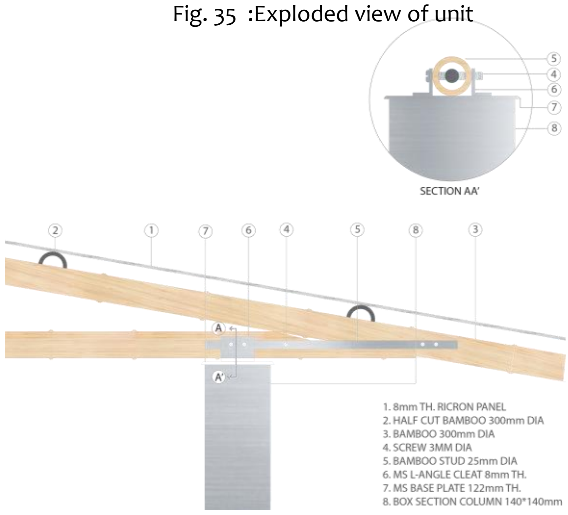
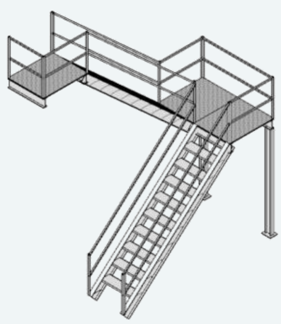


Fig. 36 : Fixing of solar panel

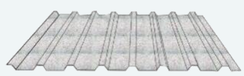


ROOF DETAIL



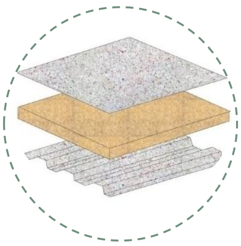
Steel staircase made with treads resting between two stringers

Solar panels attached to corrugated ricron and bamboo by an L-angle

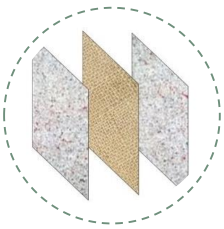


Ricron corrugated sheet for roof

MATERIALS

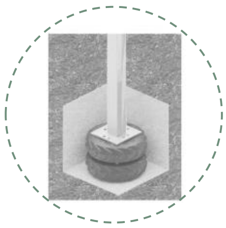


Ricron panels sandwiched with strawbale

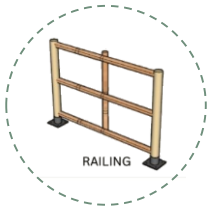


Ricron panels sandwiched with corrugated jute

Corrugated jute



Tyre foundation



Bamboo railing

9.3 DISTRIBUTION OF SERVICES IN THE MASTERPLAN

Fig. 37 a : Masterplan electrical services

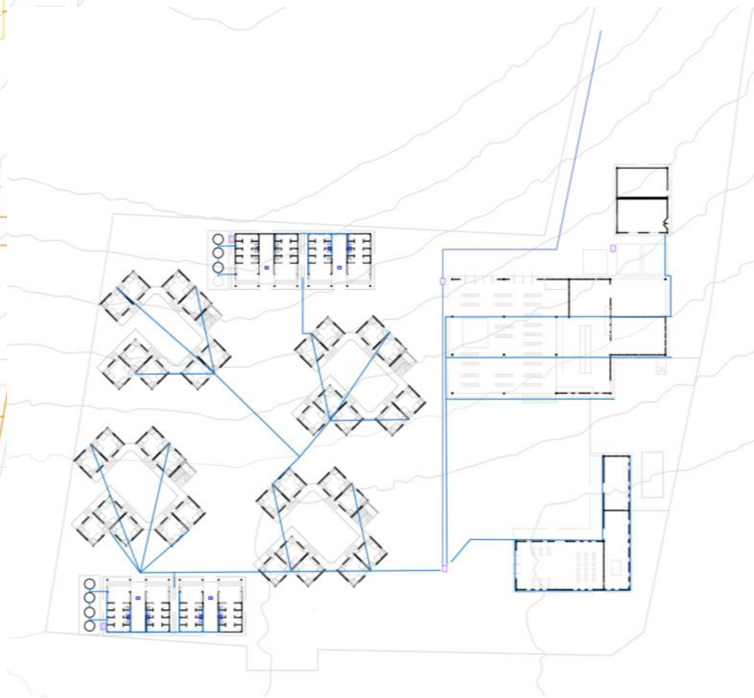
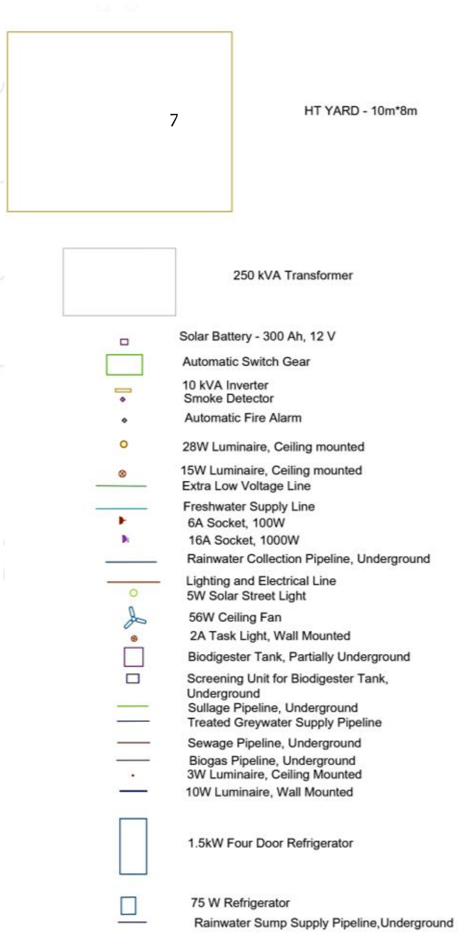


Fig. 37 b : Masterplan Water services

Fig. 37 c : Masterplan Sewage and biogas services



9.4 TOILET SERVICE DRAWINGS

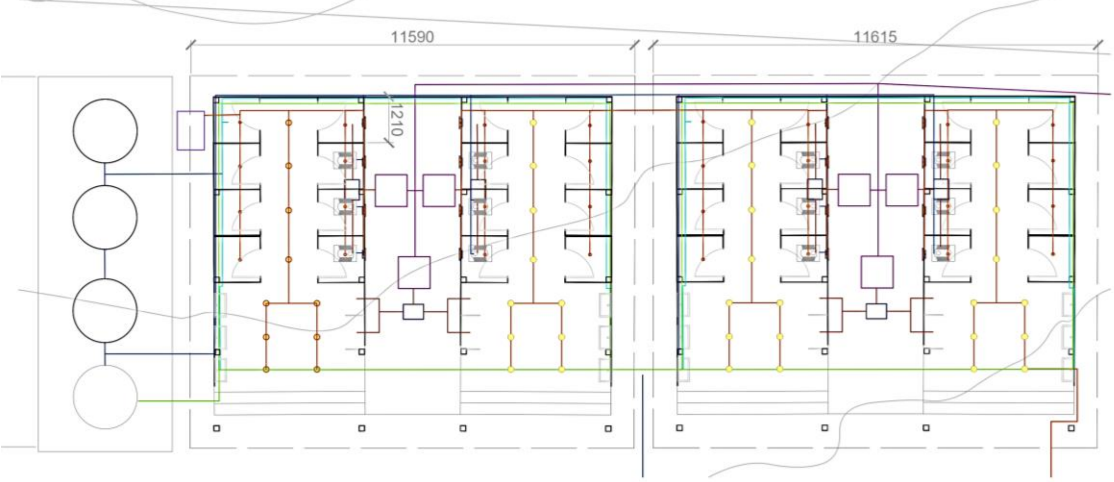
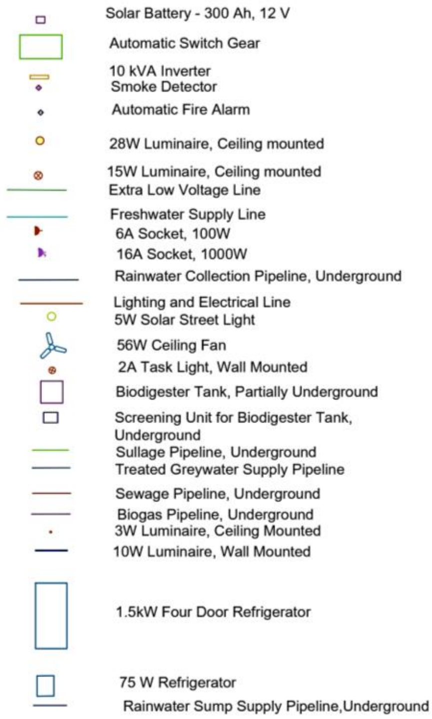


Fig. 38 : Services in toilets

There are **two layers** of service lines going in the toilets, one through the **ceiling** for **water supply**, both fresh water and treated grey water as well as the **lighting connections**.
Other one **under the floor** is for **sewage** and **sullage** lines, the sullage is taken to the grey water treatment plant while the sewage goes through a screening unit into the **biodigester unit**. The **biogas** that comes out of the biodigester is taken to the kitchen.

9.5 KITCHEN SERVICE DRAWINGS



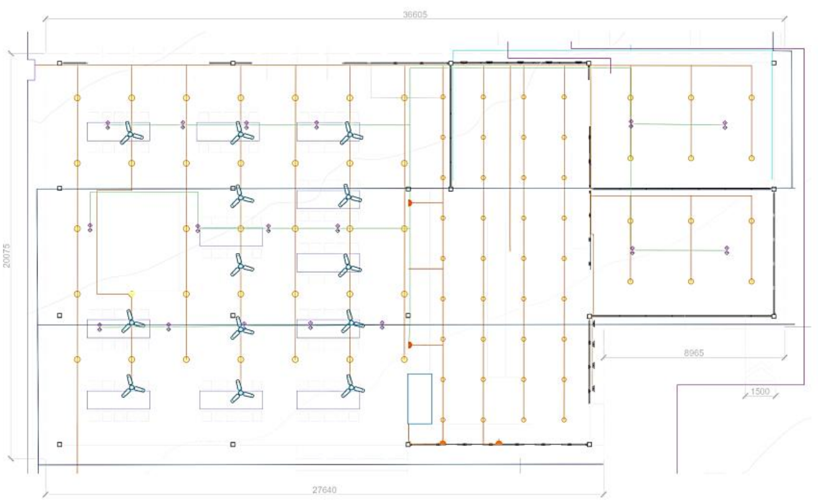


Fig. 39 : Services in Kitchen and Dining

The **Electrical services** for the kitchen and dining block include connections to **lights and ceiling fans** for the dining area as well as the **extractor fans** for the cooking area.
The **water supply** happens from the water tanks abutting the block and the **biogas** is supplied from the **holding tank** which is connected to the **biodigester toilets**

10. ENERGY PERFOMANCE

Our target goal for energy performance index is **9.762 kWh/sq.m/year.** We plan to achieve this using more efficient lighting and ventilation equipment, greater generation of on- site energy and reducing wastage of electrical power. We estimate that our on-site renewable energy generation through Solar power is approximately 10.416 kWh/Sqm/year.

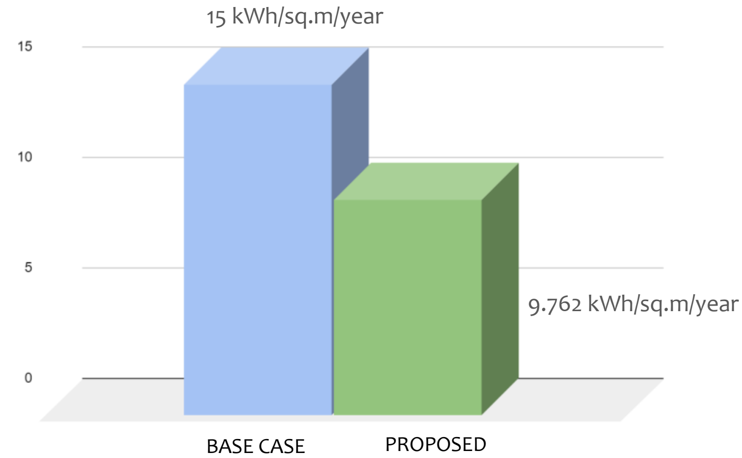


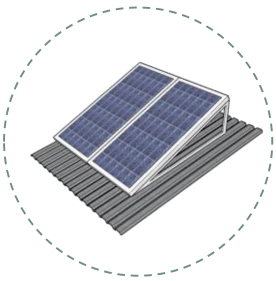
Fig. 40 : EPI Base case Vs Proposed Case

10.1 STRATEGIES

- Efficient fixtures
- Passive design
- Solar panels which have higher panel efficiency

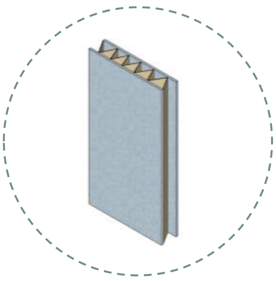
	BASE CASE	PROPOSED
CONSUMPTION PER DAY	81.6 KWH / day	139.6 KWH / day
GENERATION PER DAY	0	76.44 KWH / day

Table 4. Consumption and generation per day



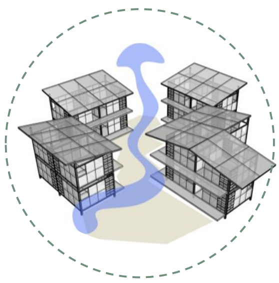
USING RENEWABLE TO CONSUME LESSER POWER FROM GRID

51.6% OF THE POWER GENERATED FROM ON-SITE SOLAR PV



WALL PANELS
INDOOR AND OUTDOOR TEMPERATURE THROUGH ENGRIHA WALL PANEL

COMFORT ANALYSIS REDUCED FAN USAGE BY 6.82% PER YEAR.



ORIENTATION OF CLUSTERS STRATEGIZED BY WIND DIRECTION

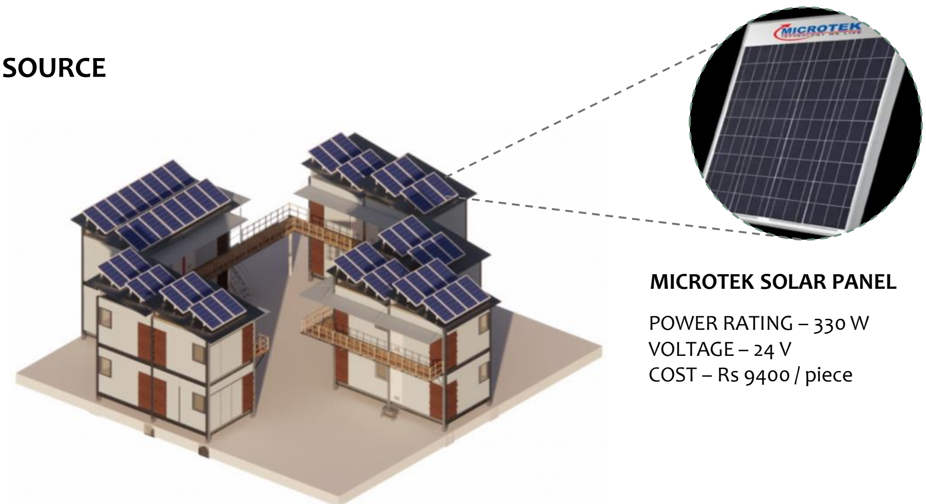
POSSIBLE REDUCTION OF 1.376 kWh/sqm/year IN EPI

EFFICIENT FIXTURES

REDUCTION OF 28.79% OF POWER CONSUMPTION BY FIXTURES

RENEWABLE ENERGY SOURCE

From the grid we are consuming **63.16 kWh per day.**
In the event of power outage, our solar battery array is equipped to run for an additional **2 days** autonomously.



MICROTEK SOLAR PANEL

POWER RATING – 330 W
VOLTAGE – 24 V
COST – Rs 9400 / piece

10.2 EPI CALCULATION TABLE

CONSUMPTION	LIGHTING	FANS	EXTRACTOR FANS	SOCKETS	PUMPS	HVAC	REFRIGERATOR	TOTAL (kWh/sq.m)
Per Unit	0.0735	0.504	0	0.45	0	0	0	1.0275
Total for 70 units	5.145	35.28	0	31.5	0	0	0	71.925
Per Toilet	1.194	0	0.84	0	0	0	0	2.034
Total for 2 units	2.388	0	5.88	0	0	0	0	8.268
Kitchen	4.725	0	1.5	4.125	0	0	1.8	12.15
Dining area	5.88	3.15	0	0	0	0	0	9.03
Indoor Games room	0.675	0.63	0	0.225	0	11.25	0	12.78
First Aid Room	0.45	0.63	0.15	0.45			1.92	3.6
Common room	1.8	1.05	0	0.675	0	0	0	3.525
Services	0	0	0	0	1.8	0	0	1.8
Total Consumption per day KWH								126.1395
Total consumption per year KWH								46040.9175
Considered area Sqm								2400
Consumption EPI KWH/Sqm/Year								20.178

Generation potentials							
Roof area	430						
Solar generation						Biogas	
Energy Generated Per Sqm	165.00	Efficiency	22%	Yearly Avg. Clear sky	0.65	Generated Amount Per day	10.92 Cu m
Running time	9	Diversity	0.75	Total Generation KWH	68.485	Net Generated Biogas	3985.8 Cu m

Consumption EPI	20.178	Generation EPI	10.416	NET EPI	9.762	KWH/SQM/YEAR

Possible Minimum Consumption EPI with Passive Design	18.8014425	kWh/sqm/year
Current Consumption EPI	20.178	kWh/sqm/year
Maximum Possible reduction in Consumption EPI with Passive Design	1.3765575	kWh/sqm/year

Table 5. EPI calculation table

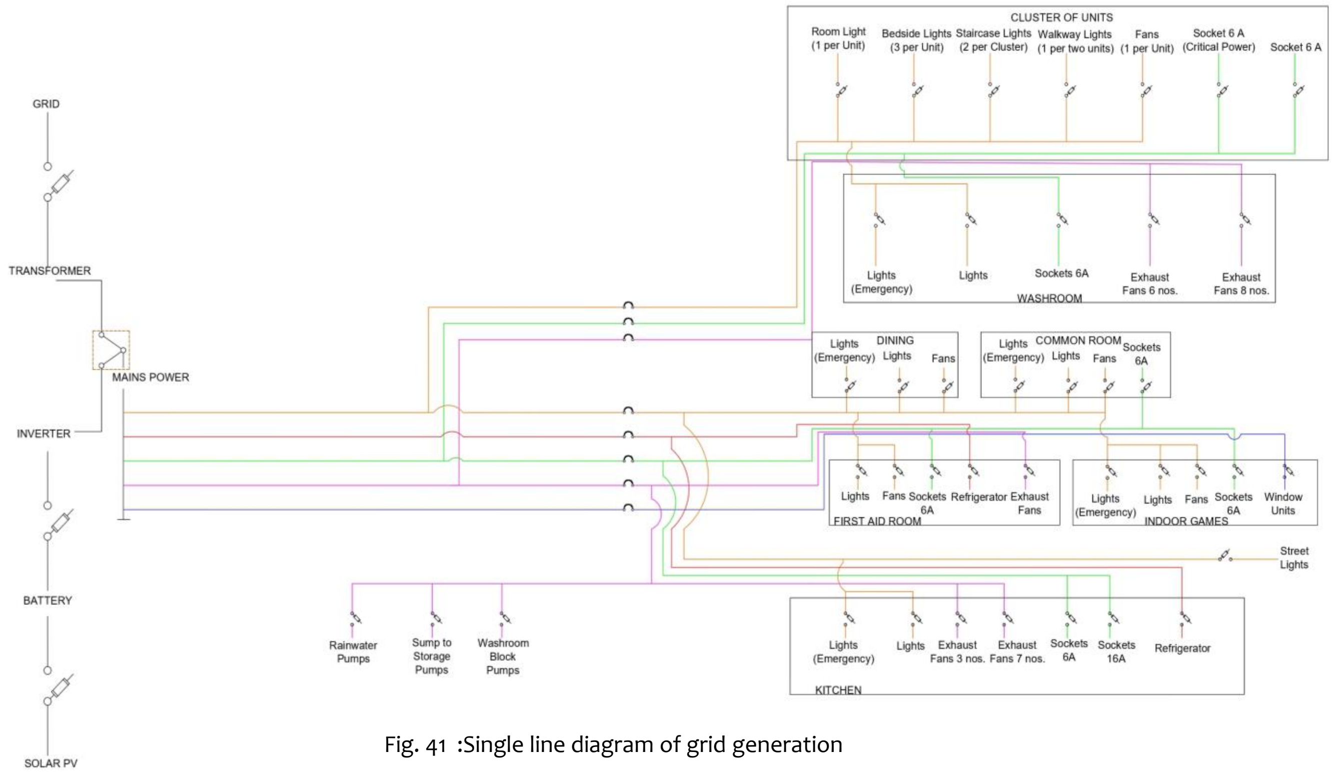


Fig. 41 :Single line diagram of grid generation

12. WATER PERFORMANCE

Obtaining a net-zero water cycle was a challenge for us since we neither have a municipal connection at the site nor we have permission to dig a borewell. Since the facility is intended to house 210 workers, effective water use through implementing strategies that reduce per capita demand and treating as much wastewater as possible were key considerations in making the facility water-efficient without compromising cost. **100% of the total freshwater demand is satisfied by rainwater harvesting and treated greywater for flushing in toilets.** The efficiency was achieved by the **reduction in per-capita consumption by 58.6%** and **recycling of 85% of the water consumed**.

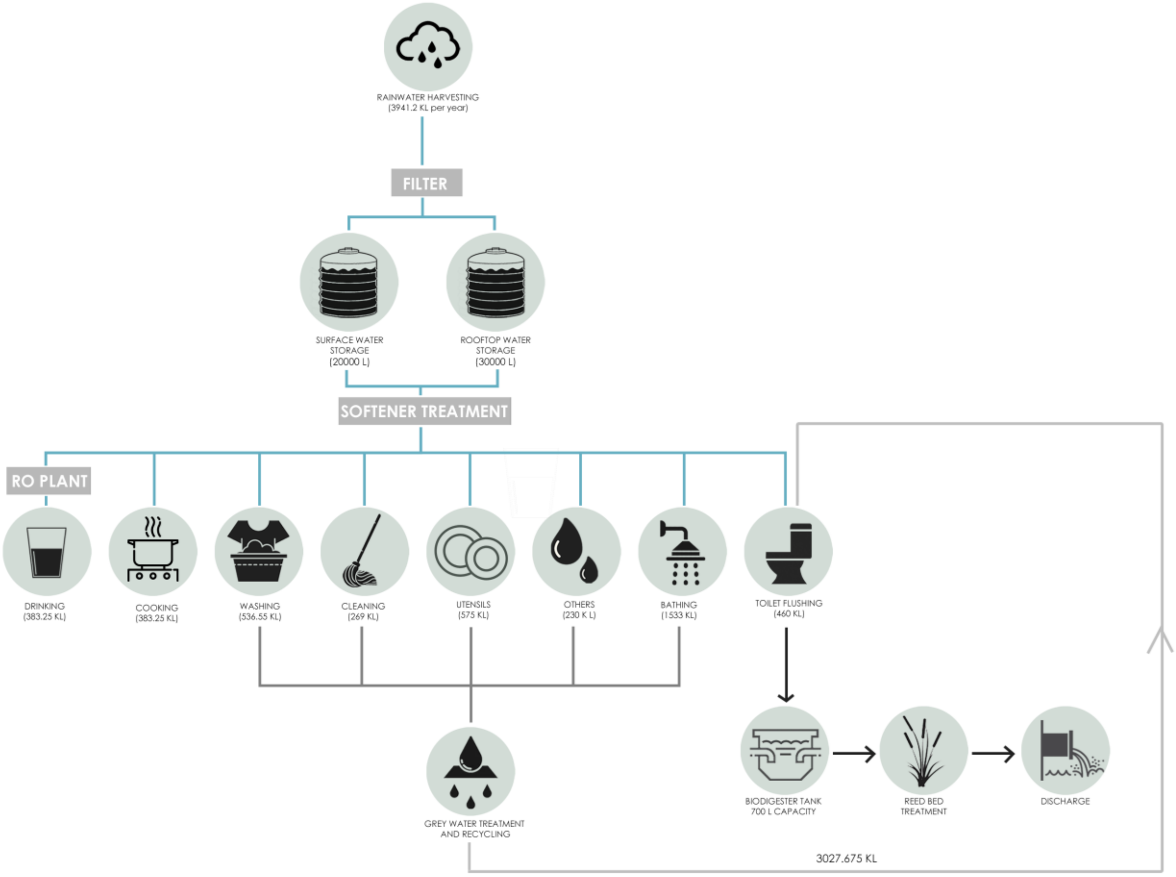


Fig. 42 :Water cycle diagram

The use of aerator fixtures taps reduces 65% of water consumption

50% reduction by using non-water urinals

Low-water closets use 75% less water per flush

50% reduction by Bucket Bath

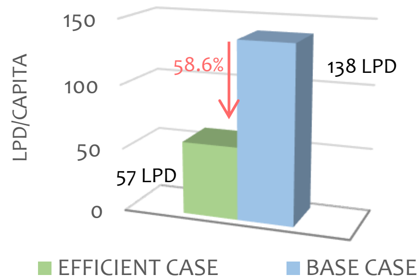


Fig. 43 : per capita consumption

USE	CONSUMPTION	BASE CASE	EFFICIENT CASE	QUANTITY/DAY	PERCENTAGE	GREY WATER (%)	GREY WATER (L)	BLACK WATER (%)	BLACK WATER (L)
Bathing	29.0%	40	20	4200	35.1%	100%	20	0%	0
Washing	19.6%	26	7	1470	12.3%	100%	7	0%	0
Drinking	4%	5	5	1050	9%	0%	0	100%	5
Cooking	3%	4	5	1050	9%	0%	0	100%	5
Toilet	17.0%	25	6	1260	10.5%	0%	0	100%	6
Cleaning house	8.0%	11	3.5	735	6.1%	100%	3.5	0%	0
Washing Utensils	16.4%	23	7.5	1575	13.2%	100%	7.5	0%	0
Others	3.00%	4	3	630	5.26%	50%	1.5	50%	1.5
TOTAL		**138**	**57**	**11970**			**39.5**		**17.5**

Table 6. per capita consumption table based on activity

		CONSUMPTION		WATER SOURCE			
MONTH	DAYS IN MONTH	FRESH WATER DEMAND (L)	TOTAL WATER DEMAND (L)	HARVESTED RAINWATER(L)	GENERATED GREYWATER (L)	FILTERED GREY WATER (L)	GENERATED BLACKWATER (L)
JUL	31	332010	371070	**709509**	257145	218573.25	113925
AUG	31	332010	371070	**779680**	257145	218573.25	113925
SEPT	30	321300	359100	**690017**	248850	211522.5	110250
OCT	31	332010	371070	**615947**	257145	218573.25	113925
NOV	30	321300	359100	319669	248850	211522.5	110250
DEC	31	332010	371070	89663	257145	218573.25	113925
JAN	31	332010	371070	23390	257145	218573.25	113925
FEB	28	299880	335160	27289	232260	197421	102900
MAR	31	332010	371070	19492	257145	218573.25	113925
APR	30	321300	359100	19492	248850	211522.5	110250
MAY	31	332010	371070	179326	257145	218573.25	113925
JUN	30	321300	359100	**467808**	248850	211522.5	110250
TOTAL	365	3909150	4369050	3941282	3027675	2573523.75	1341375
TOTAL WATER DEMAND = 4369050 L			WATER REUSED = 459900 L		TOTAL RAINWATER HARVESTED = 3664470.6 L		EFFICIENCY = 100%

Table 7. Detailed water calculation

RAINWATER HARVESTING

- Rainwater is stored from July to Oct and external water supply is taken to meet fresh water demand. The stored water will be more than the fresh water demand of the dry months.
- Collected rainwater is filtered by a pop up filter and stored in separate tanks. We have excess water in the months from June to October after meeting the fresh water demands. We store the water for 3 days to ensure continuous supply in case of no continuous rain, and then we **supply it to the construction site as a debt.** In the **months where the harvested rainwater isn't enough** to meet the fresh water demand, we take **the supply from the construction site as repayment of debt.**
- We will still have 32 KL which is used in the construction site for curing or other purposes.

Rainwater harvesting surfaces	Area m^2	Runoff coeffecient	Effective catchment area m^2
Roof Surfaces	2350	0.90	2115
Hardscape areas	392	0.70	274.4
Softscape areas	5030	0.30	1509
Other			0
			0
Total Effective catchment area			3898.4

Months	Rainfall (mm)	Effective rain (mm)	Harvested rainwater (l)
July	187	182	709509
August	205	200	779680
September	182	177	690017
October	163	158	615947
November	87	82	319669
December	28	23	89663
January	11	6	23390
February	12	7	27289
March	10	5	19492
April	10	5	19492
May	51	46	179326
June	125	120	467808

Rainwater collected in peak month	779680 L
	25150 L/DAY
Freshwater Demand of the month	332010 L
Therefore Storage	447670 L
	14440 L/DAY
Considering storage for 3 days	3 X 14440 L
Storage Capacity	43320 L
	50 cubic metre
Tank size	**5m X 2m X 2m - Rooftop harvested water**
	5m X 3m X 2m - Surface runoff water

Table 8. Effective catchment area and rain water harvesting

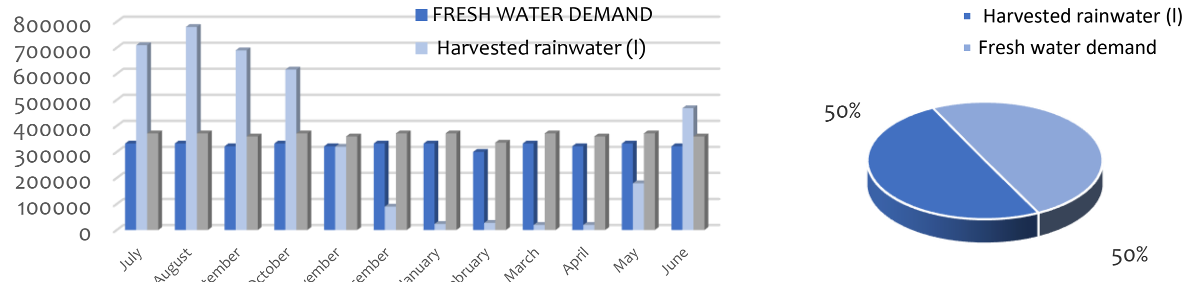


Fig. 44 : consumption vs generation

WASTEWATER TREATMENT

K.K.NAG Private Ltd. has developed a Biodigester Tank system in association with DRDO (Defence Research Development Organization) that uses anaerobic bacterial screens to degrade human waste into usable water and gases through an environment friendly 3 step process. The secondary effluent is fed to the reed bed and the gas released is used for cooking. This system doesn't not require any energy, is maintenance free, inexpensive and modular.

For greywater treatment, Biochar Treatment is used, the treated water is used for toilet flushing

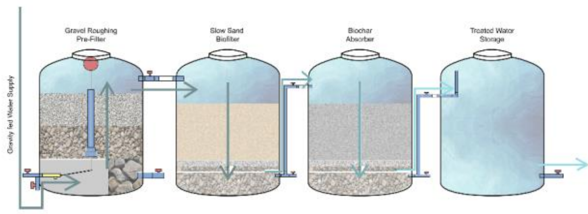


Fig. 45 : Biochar greywater treatment system

Greywater generated in a day = 8400 L
No. of day for the complete treatment = 1 day
No. of tanks required = 8 (4 tanks in 1 treatment system)
Therefore capacity of each tank = 4000 L

12. RESILIENCE

Threats are identified by BMTPC HAZARD MAPS OF INDIA and ANDHRA PRADESH hazard maps.

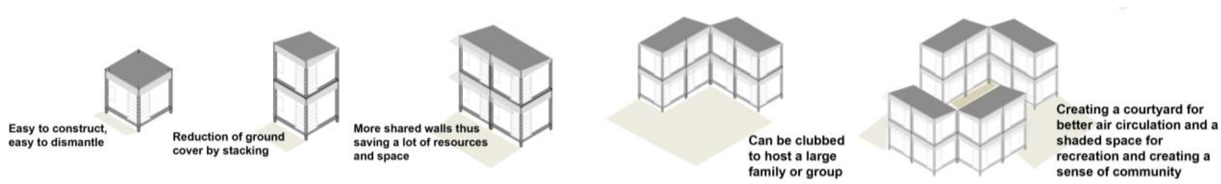
Steps included to achieve maximum resilience are :

1. Identify risks and Vulnerability
2. Reduce Vulnerability
3. Increase Preparedness

POTENTIAL THREATS

RISK / VULNERABILITY	FLOODING	CYCLONE AND WIND	FIRE
Structural Damage	Low	High	High
Catastrophic Failure	—	High	High
Failure of Building Elements	Moderate	High	High
Stagnant Water	High	—	—
Overflow or Backflow of Sewage	High	Low	—
Electric Supply Failure	Moderate	High	High
Water Supply Failure	High	Low	—
Communication Failure	Moderate	High	High
Food Supply Failure	High	Moderate	—
Physical Injuries	Low	Moderate	High
Adverse Effect on Health	Low	Low	High

Table 9. Potential threats



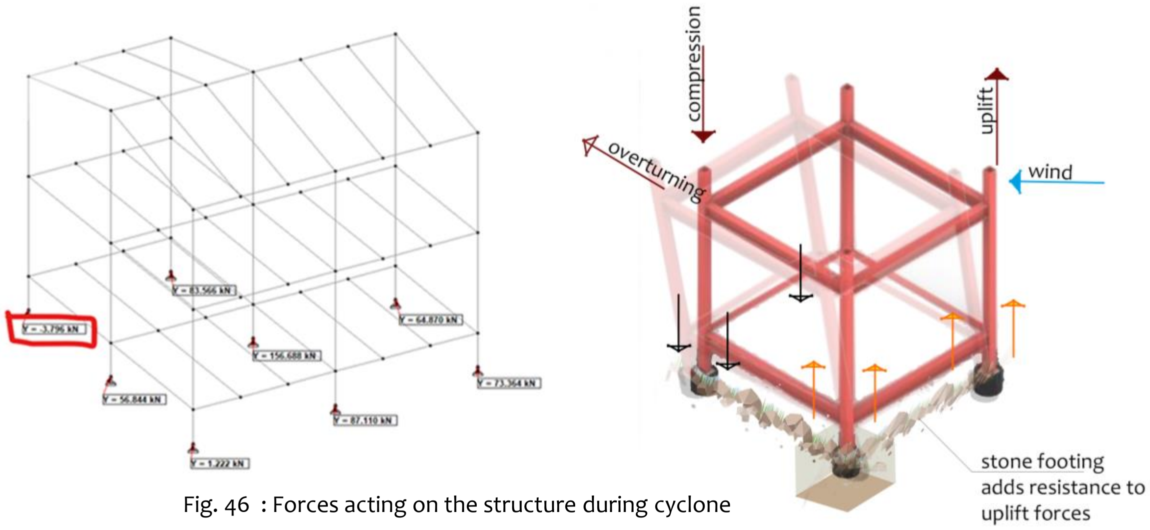


Fig. 46 : Forces acting on the structure during cyclone

Maximum uplift reaction is -3.796 kN
For a pit of 0.8m x 0.75m x 0.75m size the weight of the rubble fill (at 15 kN/cubic meter)
= 0.8 * 0.75 * 0.75 * 15 = 7.2kN
Which is greater than the uplift forces due to cyclones, Hence the footing is safer during cyclones.

RESILIENCE TO FLOODING

Since the site is closer to sea , there is a possibility of 1% increase in water level every year and there is a possibility of water stagnation due to heavy rains thus, 450mm rise of plinth is necessary to evacuate water at site level.

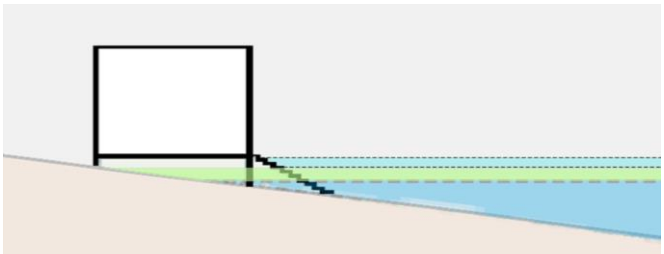


Fig. 47 :Flood level marking

INCREASED PREPAREDNESS

Quick dismantling of structure during cyclone and high wind situation.

Ample amount of water and food storage to supply during Critical situations.

24 x 7 availability of dispensary and rest space for injuries due to Natural or man made calamities.

Electrical Autonomy and Modes of Functioning

139.188 KWH/day

Normal Functioning
All Circuits live, Power deficit taken from grid

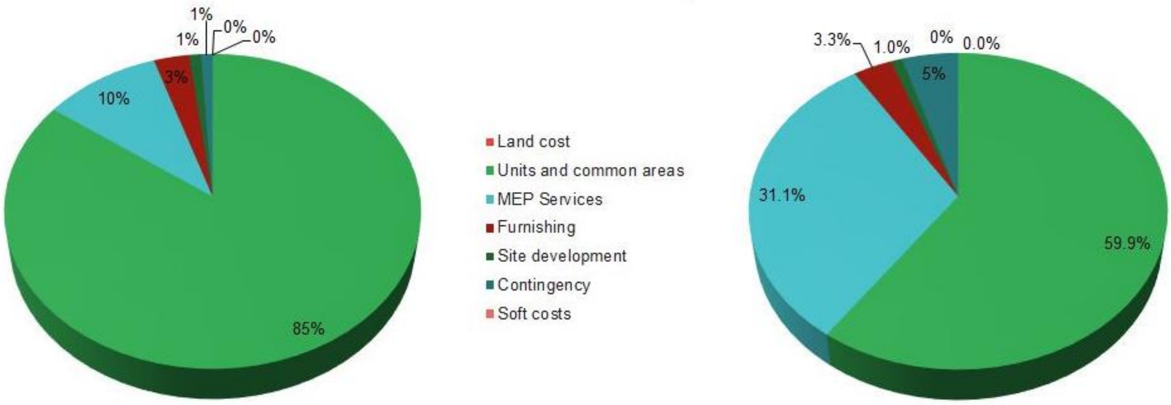
87.834 KWH/day

Critical Functioning
In case of failure of grid power, battery storage for the extra power required for two days

65.985 KWH/day

Autonomous Functioning
Post two days of Grid failure, no extra battery power, solely supported on PV generation

13. AFFORDABILITY



BASE CASE   Fig. 48 : percentage cost in each component   PROPOSAL

SL. NO	PARTICULARS	DEFINITION	BASELINE ESTIMATE BY PROJECT PARTNER			BASELINE ESTIMATE BY OUR TEAM		
			AMOUNT	PERCENTAGE (%)	AMOUNT (INR per sqm)	AMOUNT	PERCENTAGE (%)	AMOUNT (INR per sqm)
1	Land cost	Cost of land purchased or leased by the Project Partner (temporary usage of land only)	0	0%	0.0	0.0	0.0%	0.00
2	Units and common areas	Refer Item A- Units and common areas in Construction cost sheet	12,000,000	80%	12,903.2	8,981,254.6	59.9%	3,796.89
3	MEP Services	Refer Item B- MEP Services in Construction cost sheet	1,500,000	10%	1,612.9	4,665,712.4	31.1%	1,944.05
4	Furnishing	Refer Item C- Furnishing in Construction cost sheet	450,000	3%	483.9	493,000.0	3.3%	172.42
5	Site development	Refer Item D- Site development in Construction cost sheet	300,000	2%	322.6	144,116.0	1.0%	17.43
6	Contingency	Amount added to the total estimate for incidental and miscellaneous	750,000	5%	806.5	714,204.2	5%	297.59
7	Soft costs	Pre-operative expenses, consultants and interest during construction are nil because it is a temporary structure	0	0%	0.0	0.0	0%	0.00
	TOTAL PROJECT COST		**15,000,000**	**100%**	**16,129.0**	**14,998,287.2**	**100.0%**	**6,228.37**

Table 10. Total project cost

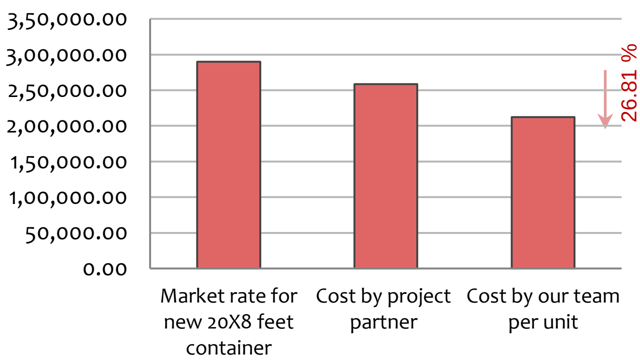


Fig. 49 : Comparison in cost

REDUCTION IN COST PER SQ.M= 61.89%

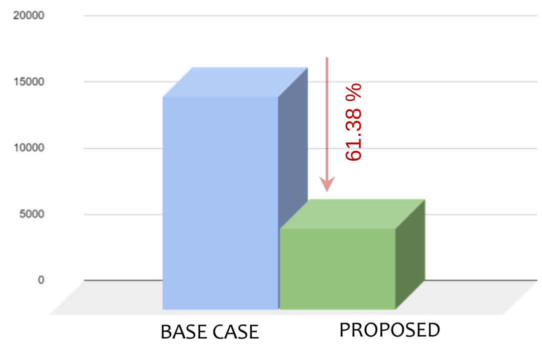


Fig. 50 : Reduction in cost per sqm

DESCRIPTION	AMOUNT (in INR)
Cost of investment per cluster	1,698,090.3
Net income per month per cluster	88,000.0
Net income per year per cluster	1,056,000.0
Cost of investment per unit	212,261.3
Net income per month per unit	11,000.0
Net income per year per unit	132,000.0
RETURN ON INVESTMENT (%)	**62.19%**
PAYBACK PERIOD (years)	**1.61**

Table 11. Return of investment and payback period

	NO.OF SOLAR PANELS	COST (INR in millions)	TOTAL EPI (kWh/ Sq.m per year)
CASE 1	108	1.02	14.95
CASE 2	215	2.02	9.76
CASE 3	323	3.04	4.53
CASE 4	430	4.04	-3.08

Table 12. Cost calculation of solar panels

The **market rate** for renting a steel container of 20X8 feet for one month is **Rs 12,500**. According to the market rates, the **rent for our unit** similarly would approximately be **Rs 13,500**. This size is chosen for a comparison because it is closest to our unit which measure 16 Sq. m.

The **investment cost for one cluster is Rs 16,98,090**. This cluster includes 4 units on the ground floor, 4 units on the first floor and also a washroom unit for **24 people**. This is an **optimal arrangement** which ensures the number of people per washroom pertains to the NBC recommendation for hostels.

One of the aims was to rent out a cluster which is **net-zero energy** and this is achieved from having **32 solar panels**. The **renting cost for one unit is Rs 11,000** which also **includes the solar panels and washrooms**.

The graph tells us the relation between cost of solar panels and total EPI. Due to budget constraints, 215 solar panels with an area of 2X1m each are considered.

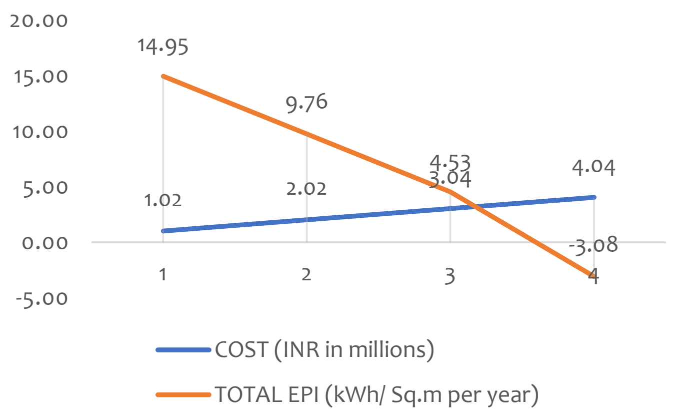


Fig. 52 : Cost analysis regarding energy

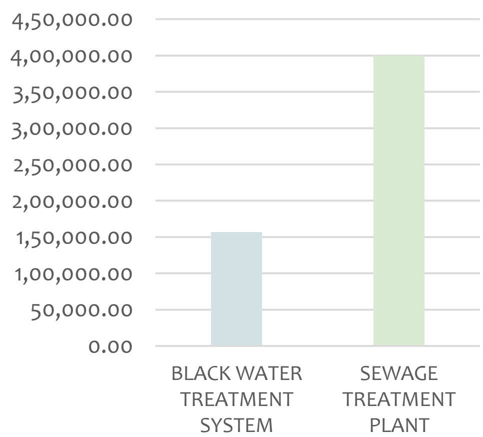


Fig. 51 : Cost analysis regarding water

Both these water treatment systems treat the same amount of black water but the cost of an STP is higher for the same capacity and will also involve running costs.

14. EMBODIED CARBON

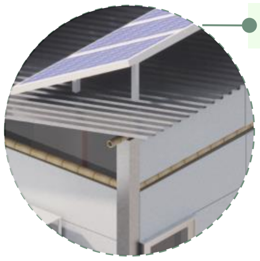
Carbon - negative materials are sourced from local regions which not only reduces material emission but also transport emission compared to the baseline case.
Construction techniques are strategized to lessen manufacturing emission by assembling and dismantling the structure and wall panels.

14.1 MANUFACTURING AND TRANSPORT EMISSION

ROOF ↓ 87.9 %

BASE CASE – 63.3 $kgCO_{2}e$
CORRUGATED STEEL
STEEL SECTIONS

PREFABRICATED ROOF PANELS



PROPOSED - 7.6 $kgCO_{2}e$

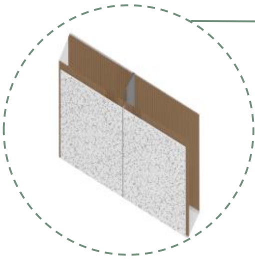
CORRUGATED RICRON PANEL
RECYCLED PLASTIC

BAMBOO
NATURAL MATERIAL – LOCALLY AVAILABLE

WALLS ↓ 73.07 %

BASE CASE – 63.5 $kgCO_{2}e$
PUF PANELS
STEEL SECTIONS

PREFABRICATED PUF PANELS MODULES



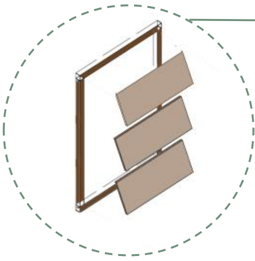
PROPOSED - 17.1 $kgCO_{2}e$

RICRON PANEL
RECYCLED PLASTIC

JUTE – INSULATION
NATURAL MATERIAL – LOCALLY AVAILABLE

FENESTRATION ↓ 90.89 %

BASE CASE – 64.8 $kgCO_{2}e$
CHICKEN WIRE MESH
STEEL SECTIONS

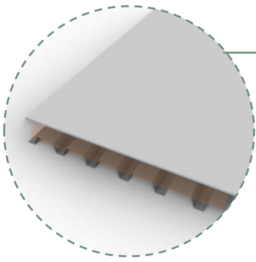


PROPOSED - 5.9 $kgCO_{2}e$

COCONUT TIMBER
NATURAL MATERIAL
LOCALLY AVAILABLE

FLOORS ↓ 75.74 %

BASE CASE – 63.5 $kgCO_{2}e$
CORRUGATED PUF PANELS
STEEL SECTIONS



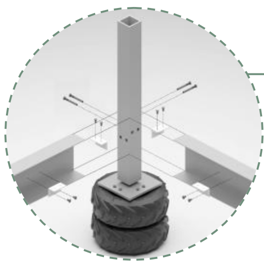
PROPOSED - 15.4 $kgCO_{2}e$

RICRON PANEL
RECYCLED PLASTIC

STRAWBALE
CARBON NEGATIVE MATERIAL
NATURAL MATERIAL

STRUCTURE ↓ 79.46 %

BASE CASE – 65 $kgCO_{2}e$
STEEL SECTIONS
MS FLASHING , MS BOLTS AND NUTS



PROPOSED - 11.8 $kgCO_{2}e$

STEEL SECTIONS
RECYCLED STEEL

TYRE FOUNDATION
REUSING RECYCLED TYRES

Variables	PUF PANEL	ENGRIHA PANEL	ACP
U - value (W/m²K)	0.38 (50MM)	0.25 (135MM)	9
Cost (Rs / m)	1100	1030	1500
Embodied Carbon (kgCOe/kg)	4.26	2.51	9.12

Table 13. PUF panel vs Engriha vs ACP comparison table

Comparing with the base case and ACP which are commonly used in constructing prefabricated modules, Engriha panel is sourced with lesser embodied carbon emission.

The total carbon emission of our design is **81.8 % lesser than base case.**

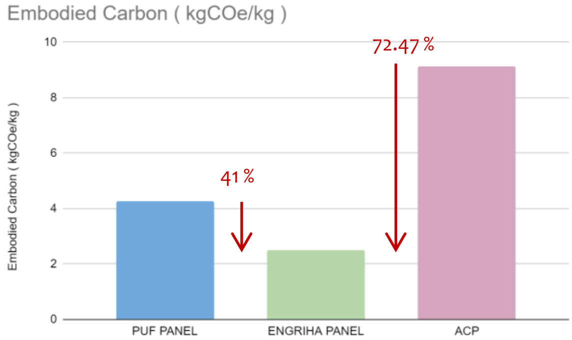


Fig. 53 : Comparison chart of Engriha with PUF panel and ACP

14.2 MANUFACTURING OF RICRON

1 Ton of Ricron Products used Eliminates 4 Tons of CO2 GHG Emissions.

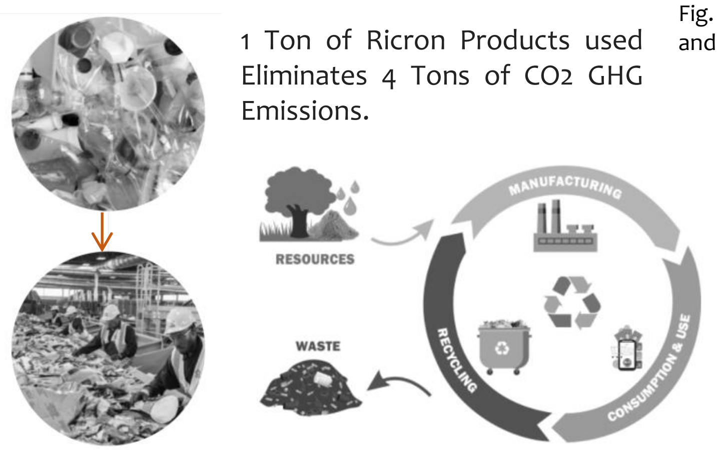


Fig. 54 : Manufacturing of ricron

Able to contribute to the problem of handling waste that has no means of recycling and converting them to useful products that can be used as a substitute to other products.

Using technology that allows us to convert this waste into forms of sheets that are used as a building material.

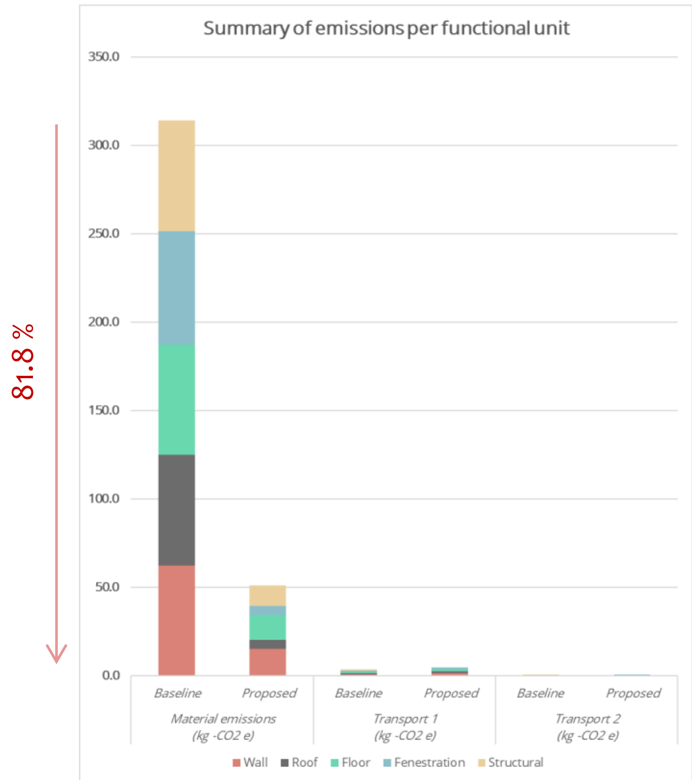
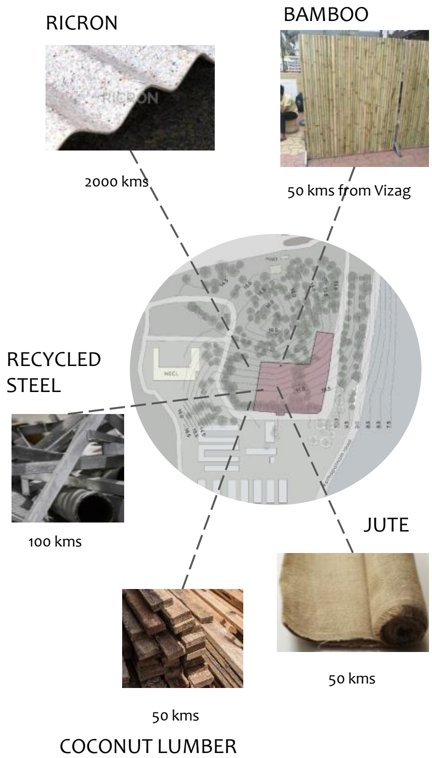


Fig. 55 : Summary of emissions per sqm unit

TRANSPORTATION EMISSION



15. HEALTH AND WELL BEING

The aim was to provide thermal comfort for 5475 hours using different strategies of passive design and ventilation.

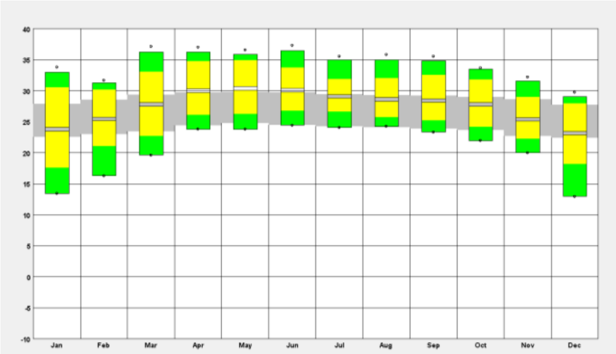


Fig 56. Graph showing temperature ranges and months that thermal comfort needs to be achieved .

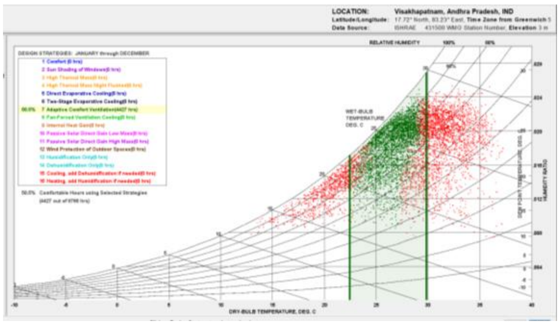


Fig 57. Graph depicts psychometric chart with strategies that ensure comfort year round.

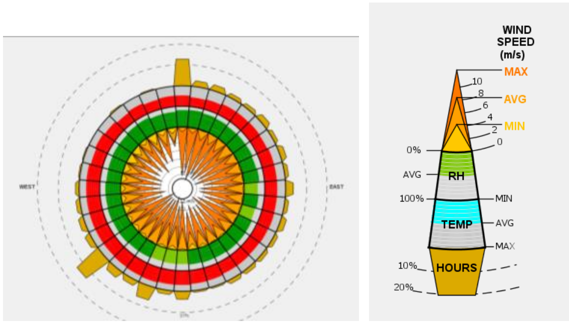


Fig 58. Windrose diagram shows max winds from SW and NE direction

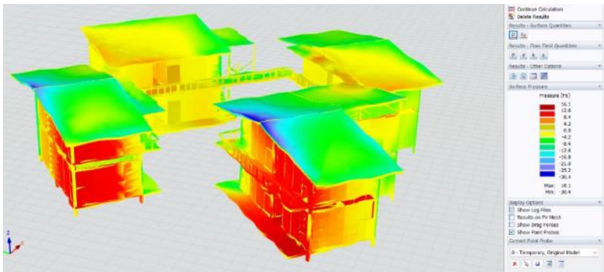
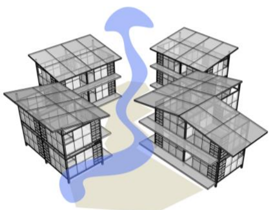


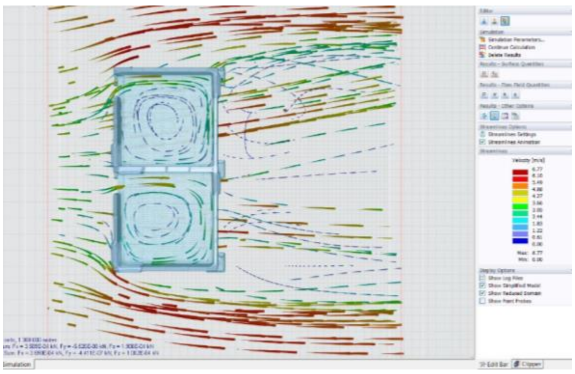
Fig 59. Wind analysis for a single cluster

The wind simulation demonstrates how the windows, as well as their size and placement, contribute to increased ventilation within the modules. Thus, using passive technologies and orienting the building maximum wind flows through the clusters



Having permeable walls on at least two sides of the unit in order to ensure effective cross ventilation

Fig 60. wind flow for a single cluster from SW direction



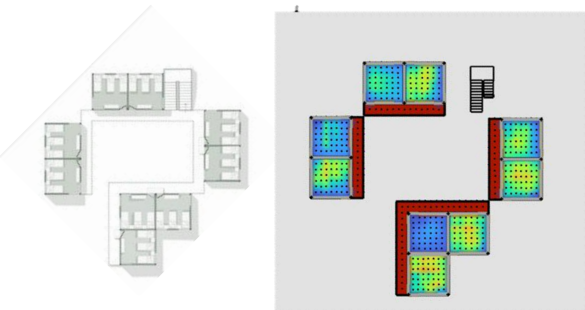


Fig 61. Daylight analysis for a single cluster

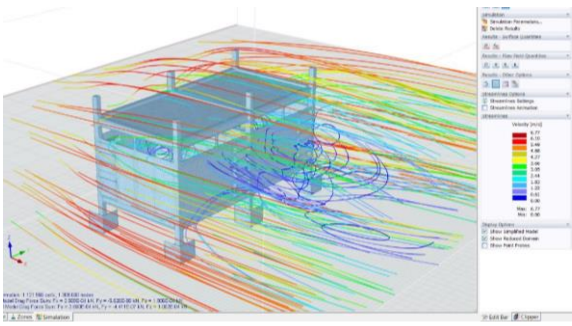


Fig 62. Wind analysis for a single unit

15.1 Thermal comfort hours:

Total daily operational hours for living units are **15 hours per day** (subtracting their 8am - 5pm work shift). In a year, 5475 hours would be operational hours.

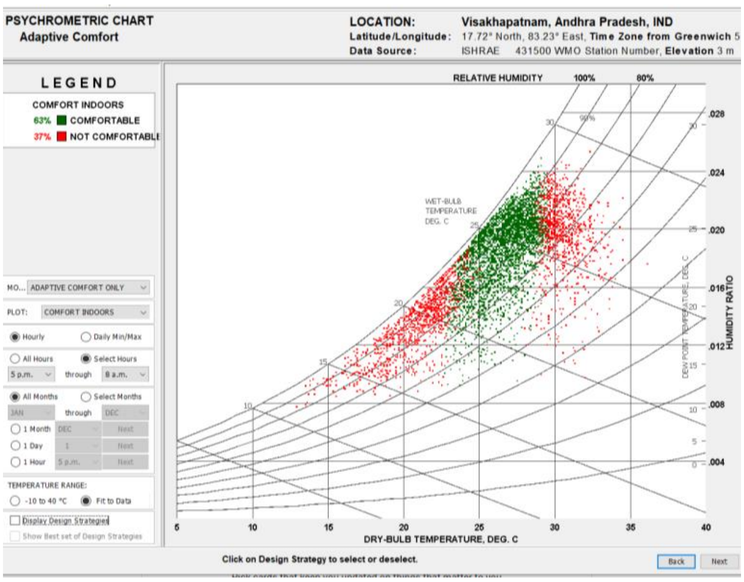


Fig 63. Psychrometric chart showing the comfort hours

Out of this, 63% or 3687 hours are within the comfort band according to adaptive comfort model.
Total discomfort hours is 1788 hours out of which 1029 hours are below 22 degrees. In a hot and humid climate, lower temperatures can be passively handled by wearing more and thicker layers of clothing.
Total hours with temperatures above 28 degree Celsius and outside comfort band are 759 hours.

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CEPT University, K.L.Campus, Navarangpura, Ahmedabad 380 009, INDIA
Phone: +91 79 2630 2470, Ext: 383, Email: ashajoshi@cept.ac.in, Website

Select city: Vishakhapatnam

Months	Acceptibility Range	Naturally ventilated	Mix Mode buildings	Air.cond. Based on air temp.	Air.cond. Based on std. effective. Temp
January	90%	27.90	27.91	26.58	25.86
		23.14	20.99	23.58	23.86
February	90%	28.60	28.27	26.68	25.88
		23.84	20.99	23.68	23.88
March	90%	29.67	28.83	26.84	25.91
		24.91	21.91	23.84	23.91
April	90%	30.95	29.49	27.02	25.94
		26.19	22.57	24.02	23.94
May	90%	31.75	29.91	27.14	25.96
		26.99	22.99	24.14	23.96
June	90%	31.67	29.86	27.13	25.96
		26.91	22.94	24.13	23.96
July	90%	31.20	29.62	27.06	25.94
		26.44	22.70	24.06	23.94
August	90%	30.87	29.45	27.01	25.94
		26.11	22.53	24.01	23.94
September	90%	30.81	29.42	27.00	25.93
		26.05	22.50	24.00	23.93
October	90%	30.55	29.28	26.97	25.93
		25.79	22.36	23.97	23.93
November	90%	29.68	28.83	26.84	25.91
		24.92	21.91	23.84	23.91
December	90%	28.31	28.12	26.64	25.87
		23.55	21.20	23.64	23.87

Fig 64. CEPT adaptive temperature for Vishakapatnam

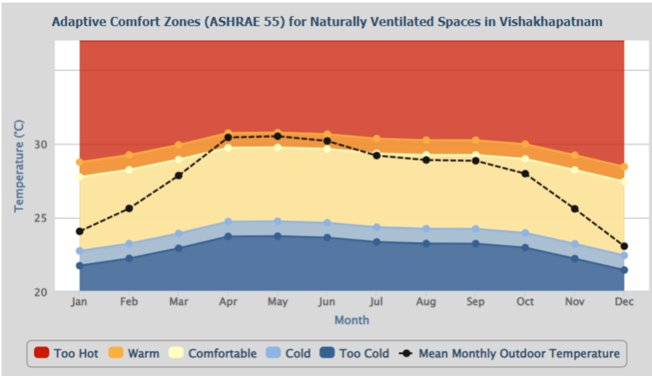


Fig 65. Adaptive comfort zones for NV spaces in Vishakapatnam

The months of April, May and June are the hottest summer months. The temperature goes up to 37 degrees Celsius.
While in the month of march, the unoccupied hours are out of the comfort zone but the occupied hours which are from 5pm - 8am are meets comfort band conditions.

The operative temperature at 30 degrees Celsius is compliant with the standards of ASHRAE - 55

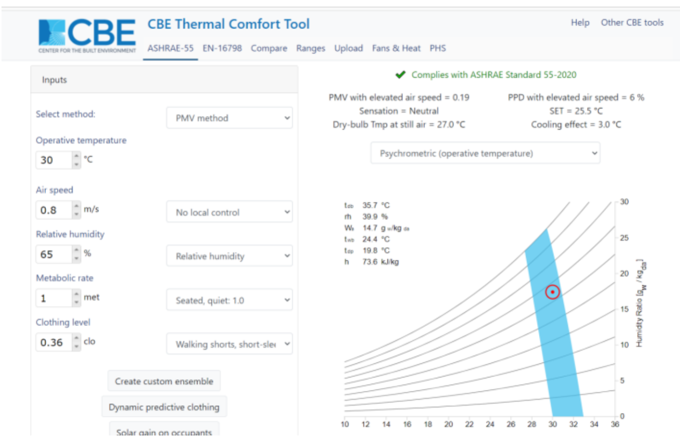


Fig 66. CBE Thermal Comfort tool

Fenestration design:
There are 3 types of openings in the living module to make the space as passively ventilated as possible (leaving x% open out of total wall area). The W.W.R for one module is 44%.

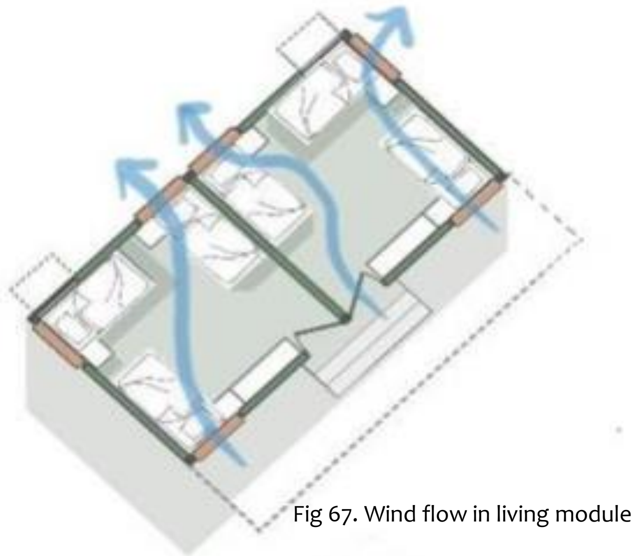


Fig 67. Wind flow in living module

15.2 DESIGN SPECIFICATIONS :

- **3 louvered screens** per room of dimension 1200 x 1000mm made out of coconut timber where each louver is 400 mm in length.
- **1 Glazed window** at the corner of the room for daylight with vertical and horizontal sun shading added to prevent heat gain from SW, NW and SE directions.
- **3 clerestory openings** with a mesh on the top helps evacuate the hot air.

The exterior porch is shaded by the projecting balcony 1.2m wide, which acts as a external thermal stress reducer in the transitional spaces.

15.3 Shading Device Design:

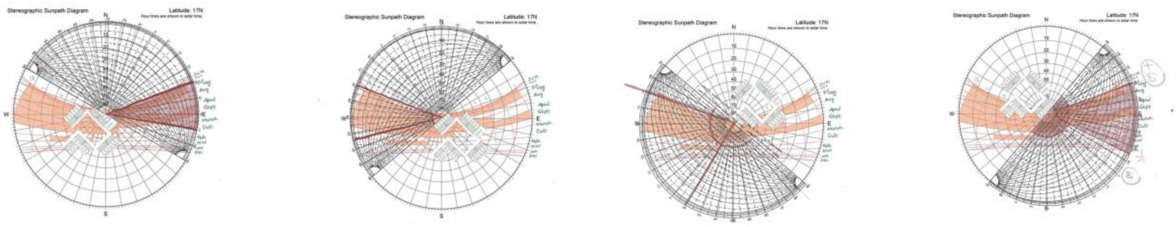


Fig 68. Shading masks for all 4 orientations

Out of this, 63% or **3687 hours are within the comfort band according to adaptive comfort model.**
Total discomfort hours is 1788 hours out of which 1029 hours are below 22 degrees. In a hot and humid climate, lower temperatures can be passively handled by wearing more and thicker layers of clothing.

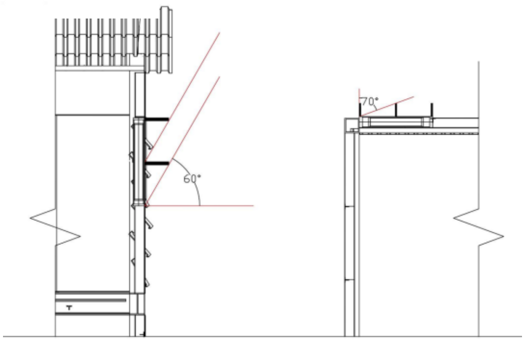


Fig 71. Sunshade from SW direction

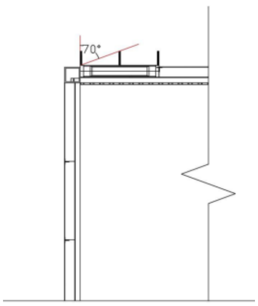


Fig 69. Sunshade for NE

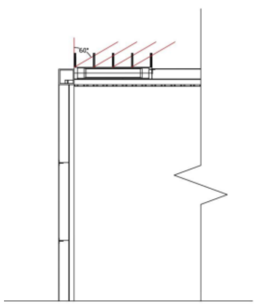


Fig 70. Sunshade for NW

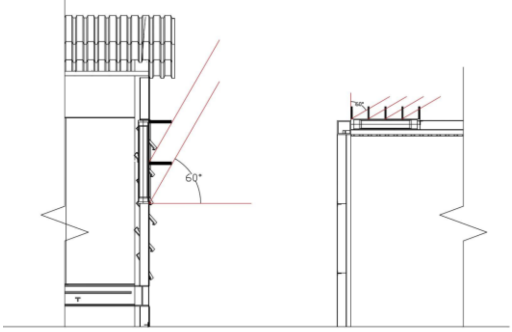


Fig 72. Sunshade from SE direction

SIMULATION RESULTS

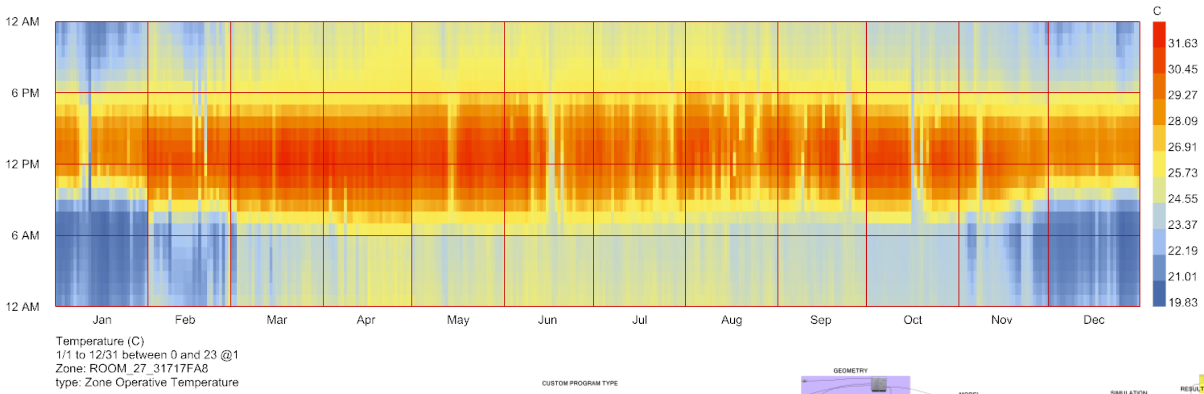
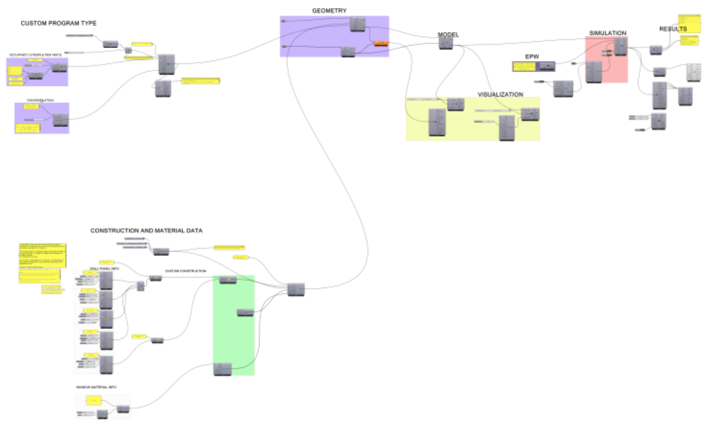


Fig 73. Operative temperature simulation



16.2 Coconut Wood Louvers

The use of louvers for the openings was decided to allow for **ventilation while keeping solar shading** in mind.

By the virtue of their upward angle, the louvers force the air flowing to move up along the surface, and by **using raked coconut wood**, the rough nature of the louvers induces turbulence which causes the particulate matter from the air to settle, acting as a filter without significantly slowing down the wind. The groove on top also has a bead of charcoal strip which further acts as an absorber of the particulate matter

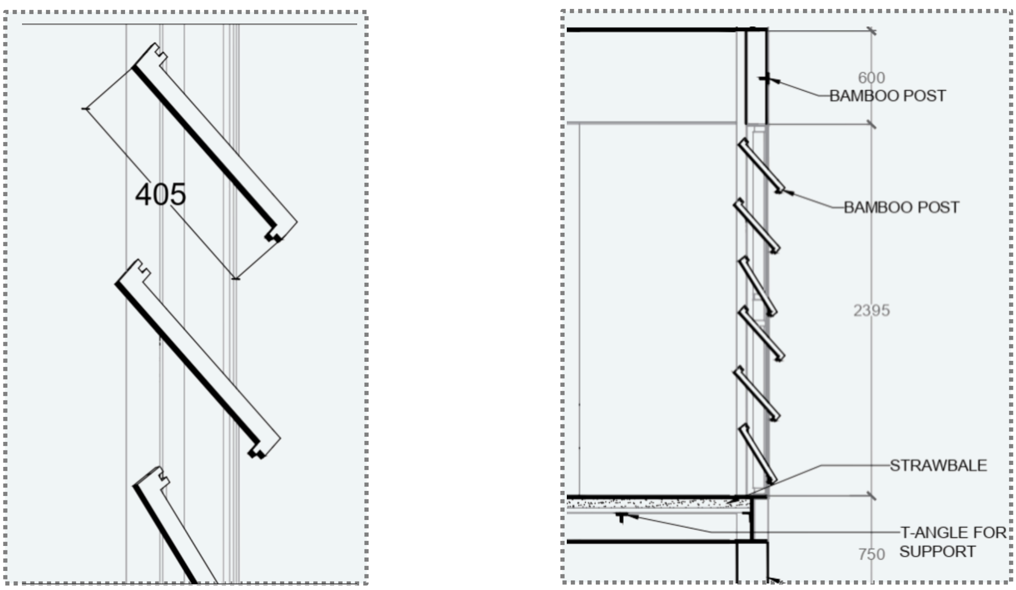


Fig 74. Coconut louvers

16. INNOVATION

EnGriha Panel

The EnGriha panel is a wall panel developed by our team which tries to balance considerations of affordability, embodied energy, and ease of construction to form an optimal solution which is easily assembled, Light in weight and optimally insulating.

Industry Partner: Ricron Panels Pvt. Ltd.

Intent

- One of the considerations while designing a construction worker housing was the fact that the building needed to be dismantlable
- We needed to use a structure and panel system of construction predominantly.
- The issue with the available panels like PUF panels was the high cost and embodied energy that they carried.
- Through this exploration, we found out about Ricron panels, which were economical, but the challenge was how to make it thermally insulating.
- So for thermal insulation we used jute in a corrugated manner.
- Hence the panel has Ricron panels as the Facia and corrugated jute as the core material.
- The theoretical development and deciding on the corrugation density was done through a grasshopper code which gave the equivalent thickness of Jute and the U value of the overall panel.

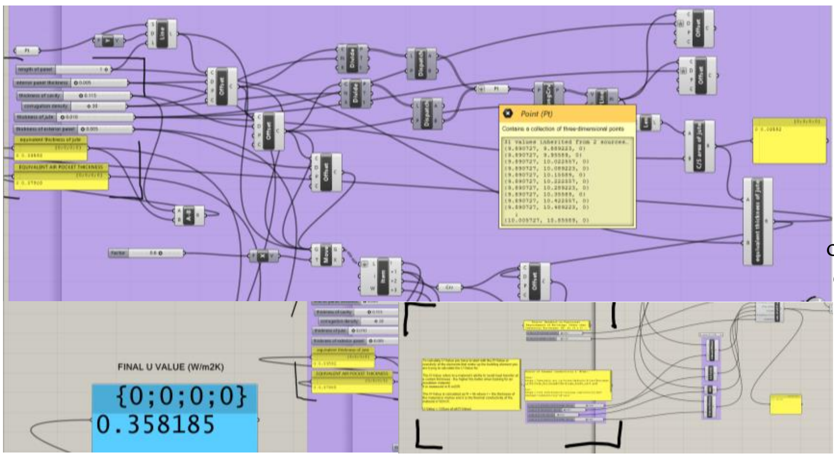


Fig 75. Snippets of grasshopper code

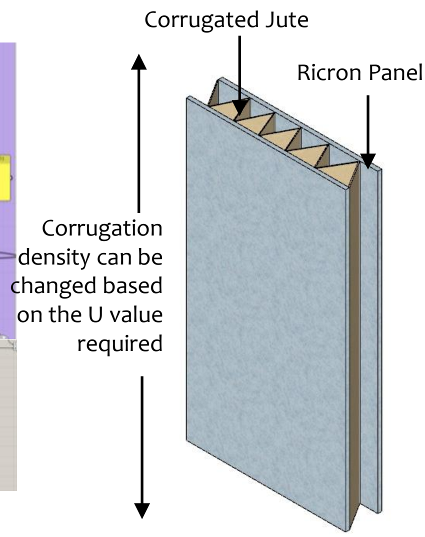


Fig 76. Schematic section of engriha panel

16.1 Physical Prototyping And Testing

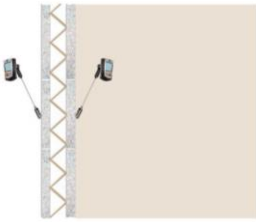
The wall panel of size 2mX 1m was manufactured and tested for various properties on campus and the results are the following. The only deviation was that we used Jute in form of rolls as opposed to corrugation, but we ensured that the amount of jute remained same.

Process of Manufacturing

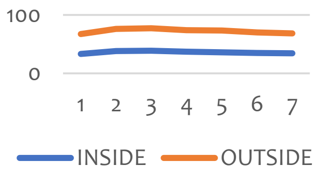
Process of Testing: Thermal Mass

A plywood enclosure is built and the manufactured panel is used as the front
This apparatus is then exposed to the sun and temperatures inside and outside are recorded every hour from 9 am to 6 pm.

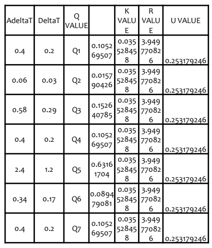
Making an Enclorue



Thermometers are placed inside and outside



Recording both temperatures at equal intervals



Calculating U Value

Observations

TIME OF DAY	INSIDE	OUTSIDE	DIFFERENCE IN TEMPERATURE
11:00 AM	33.5	33.7	0.2
12:00 AM	38.03	38.06	0.03
1:00 PM	38.6	38.89	0.29
2:00 PM	37	37.2	0.2
3:00 PM	36	37.2	1.2
4:00 PM	35	35.17	0.17
5:00 PM	34.1	34.3	0.2

Table 14. Panel testing observations

AdeltaT	DeltaT	Q VALUE		K VALUE	R VALUE	U VALUE
0.4	0.2	Q1	0.105269507	0.035528458	3.949770826	0.253179246
0.06	0.03	Q2	0.015790426	0.035528458	3.949770826	0.253179246
0.58	0.29	Q3	0.152640785	0.035528458	3.949770826	0.253179246
0.4	0.2	Q4	0.105269507	0.035528458	3.949770826	0.253179246
2.4	1.2	Q5	0.63161704	0.035528458	3.949770826	0.253179246
0.34	0.17	Q6	0.089479081	0.035528458	3.949770826	0.253179246
0.4	0.2	Q7	0.105269507	0.035528458	3.949770826	0.253179246

Table 15. Panel test report

The Tested U value comes to be 0.253 W/sqm K which is close to the predicted U value of 0.25 w/sqm K

Effect of Water Test

Initial Thickness: 5mm
Final Thickness after 24 Hours of Submersion: 5 mm
Hence the Sheet doesn't swell or warp when exposed to water

17. VALUE PROPOSITION

This proposal comes as an opportunity to scale our modular construction worker housing into something more than a temporary residence for workers.
We have achieved structural flexibility for these modular units in order to assemble and disassemble using a kit of parts method with minimal wastage, by using steel grids and composite materials consisting of jute, Ricron and other materials, which come together economically and ergonomically benefiting both, user and the provider.
It is important to understand the need of this designed housing unit since it provides us with:

User comfort	Achieved 63% of comfort hours
Easy assembly	4-5 hours/per unit
Easy disassembly	3 hours/per unit
Minimal wastage	10% per each site
Cost of one unit	212,261.3 Rs per unit
Resilience to	Weather and Climate
	Natural Calamities like flooding and earthquakes
	Man Made calamities like electric shocks, fire etc.
Water Performance	Net Zero Water

Fig. 77 : Kit of parts

- Team EnGriha has **prioritised cost and comfort** to benefit the workers and the project partner with an occupancy of 3 per unit and total 72 units.
- Sustainably **reducing carbon emissions to 56.4 kgCO2e**
- Used water reduction technologies like biodigester toilets and creating an on-site water cycle to manage water, we achieved **Net-Zero Water Model** thus not limiting to one single approach to benefit the provider.
- We ensured efficient cost values which however were a restraint to a net-zero energy model. Although, our unit is **21.81% cheaper than a 20x8 steel container**.
- **Cheaper and modular** than concrete construction
- **Fire resistance** of material provides a large spectrum of uses
- Use of **water proof** material like Ricron makes it efficient to be used as a building material in wet zones.

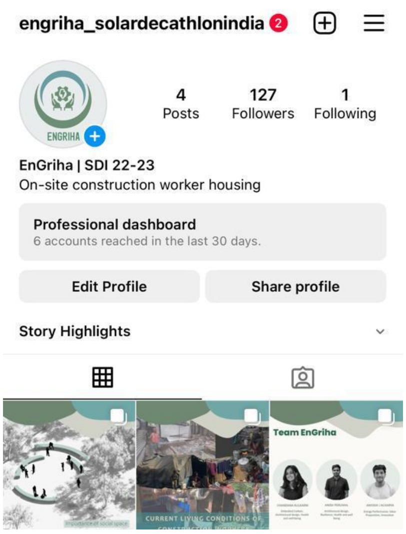


Fig. 78 : Social medial proposition

In view of the **ease of transport and assembly** of our units, we would like to scale this project and use these technologies and units for other purposes like:

1.Disaster Management
- Police Checkpoints
- Shelter houses
- Stock Houses

2.Archaeological Research
3.Healthcare
- Quarantine Units
- Storage

4.Entertainment Sector
- Sets
- Greenrooms

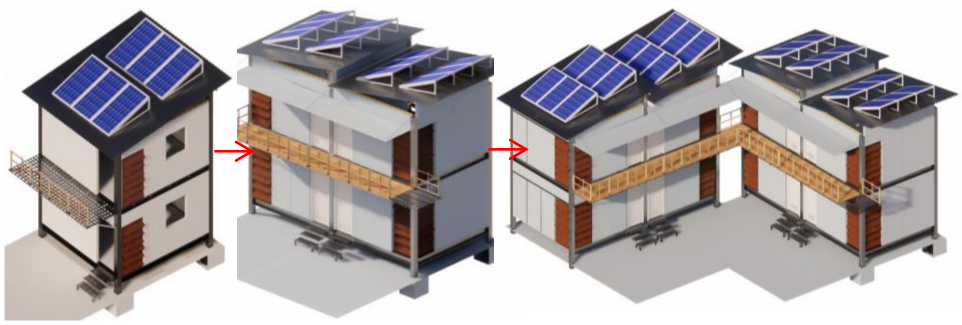


Fig. : Modularity and scalability

These purposes include a plethora of variety which increases our ability to generate a revenue model based on renting these units and bring about greater returns to a manufacturer

18. APPENDIX

18.1 ELECTRICAL AUTONOMY AND CRITICAL FUNCTIONING CHART

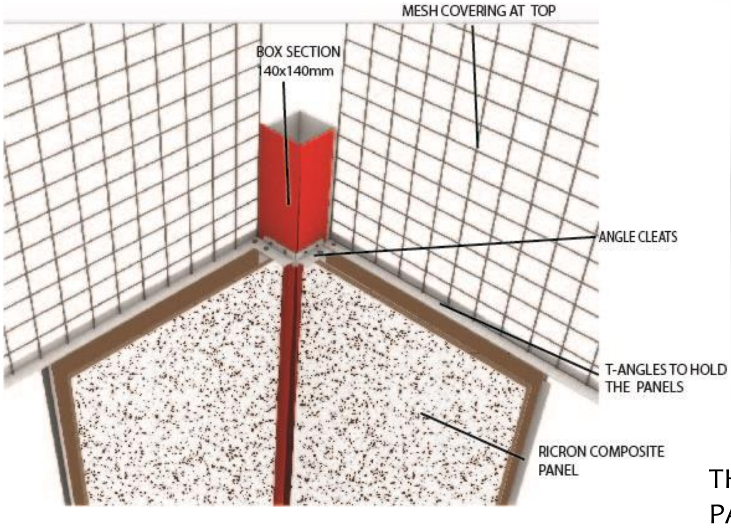
	PUMPS				KITCHEN							DINING		
	Rainwater	Washroom Block	Sump to OHT	**Street Lighting**	Extractor Fans (critical)	Extractor Fans	Refrigerator	Lights (emergency)	Lights	6A sockets	16 A sockets	Lights (Emergency)	Lights	Fans
Critical														
Autonomus	in case of rain													
Normal														

	COMMON ROOM				INDOOR GAMES ROOM					FIRST AID ROOM				
	Lights (Emergency)	Lights	Fans	6A sockets	Lights (Emergency)	Lights	Fans	Window unit	6 A socket	Lights	Fan	Refrigrator	Extractors	6A Sockets
Critical														
Autonomus								In case of high temperatures						
Normal														

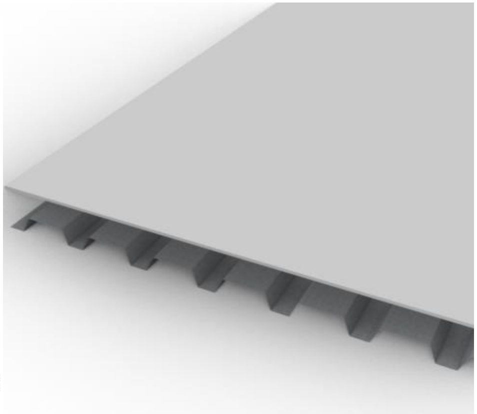
	WASHROOMS					CLUSTER							
	Extractor fans 6 nos.	Extractor fans 8 nos.	Lights (Emergency)	Lights 15 W	Lights 28 W	Room light (ambient)	Bedside light	Staircase lights	Walkway lights	Fans	6 A socket 1 nos.	6 A socket 1 nos.	Power Consumed per day (KWH)
Critical													65985
Autonomus													87834
Normal													139188

The electrical Fixtures in the building have been segregated in different circuits based on the three modes of operation, Namely Normal, Autonomous and Critical.

18.2 ENGINEERING DRAWINGS

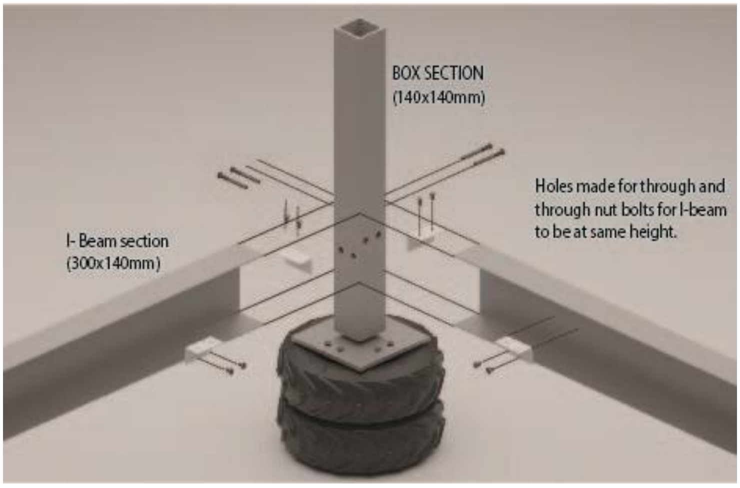


PANEL TO COLUMN JOINERY DETAIL

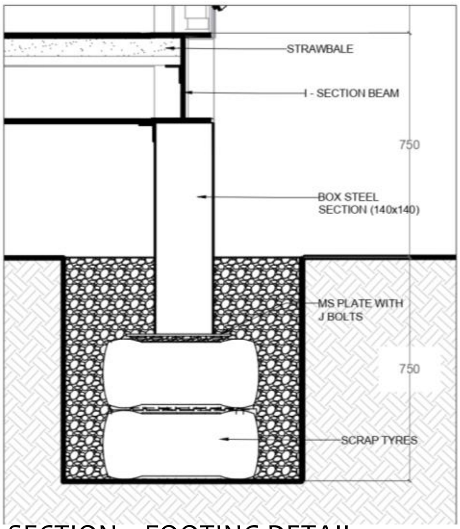


THE FILLING BETWEEN THE RICRON PANELS IS STRAWBALE WHICH FORMS THE FLOORING.

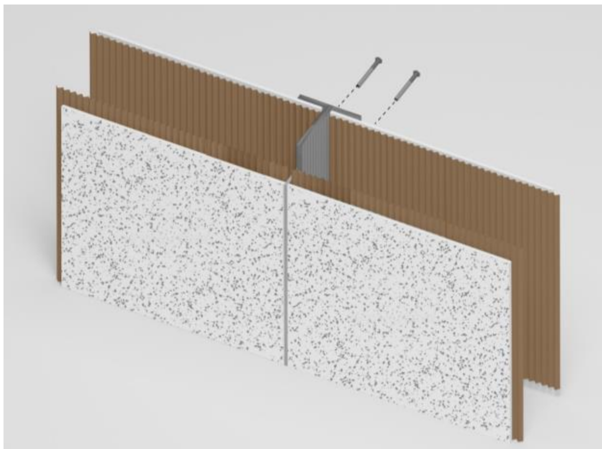
ISOMETRIC - FOOTING DETAIL



ISOMETRIC - I-BEAM TO COLUMN JOINERY

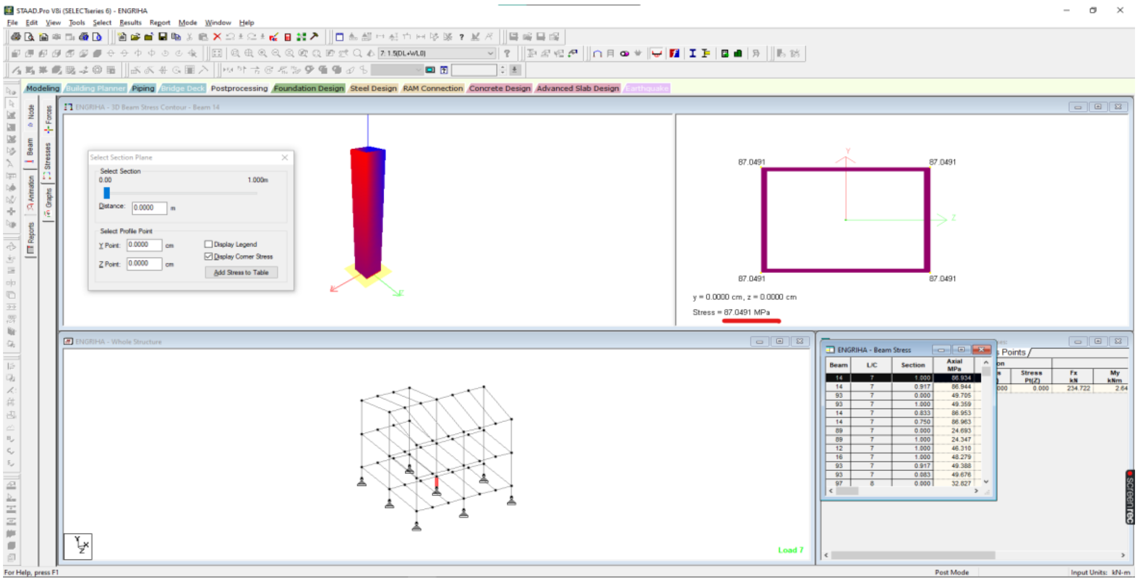


SECTION – FOOTING DETAIL



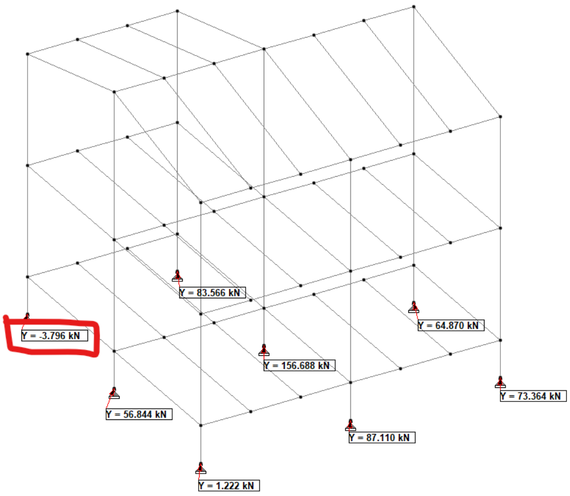
WALL PANEL TO SUPPORT JOINERY

18.3 CYCLONIC STABILITY ANALYSIS OF STRUCTURE



3	*Cyclone Wind Forces for Single Cluster*				
4					
5					
6	k1 =	1	*Probablity Factor*		
7	k2 =	1.05	*terrain roughness factor*		
8	k3 =	1	*topography factor*		
9	k4 =	1.3	*importance factor for cyclonic region*		
10	Vb =	55	*Basic Wind Speed (m/s)*		
11	Vz =	75.075	*Vb * k1 * k2 * k3 * k4 (m/s)*		
12					
13	pz =	3381.753	*0.6 Vz^2, wind pressure (N/m2)*		
14	Kd =	1	*wind directionality factor*		
15	Ka =	0.9	*area averaging factor*		
16	Kc =	0.9	*combination factor*		
17	pd =	2739.22	*Kd * Ka * Kc * pz, designn wind presure (N/m2)*		
18					
19	Cpe =		*External Pressure Coeff*		
20		A	B	C	D
21	0	0.7	-0.3	-0.7	-0.7
22	90	-0.5	-0.5	0.7	-0.1
23					
24					
25	Cpi =	0.5	*(+/-) Internal Pressure Coeff*		
26					
27	*pd x (Cpe + Cpi) (KN/m2)*				
28		A	B	C	D
29	0	3.29	0.55	-0.55	-0.55
30	90	0.00	0.00	3.29	1.10
31					
32	*pd x (Cpe - Cpi) (KN/m2)*				
33		A	B	C	D
34	0	0.55	-2.19	-3.29	-3.29
35	90	-2.74	-2.74	0.55	-1.64

Sheet1



Column Stress check under

Maximum Axial Stress under Wind Load = **87 Mpa**
Load Case = 1.5 (DL+WL at 0 degree)
Column: 140 x 140 box section 5mm thick, sub floor pedestal column
Effective Length = 1.5 m
For MS Column with Yield Strength 250 Mpa, this is well within limits.

Footing Uplift check under

Maximum Uplift Reaction is **-3.796 kN**
For a pit of 0.75 x 0.75 x 0.75 size
the weight of the rubble fill (@15 KN/m3) = 0.75*0.75*0.75*15 = **6.32 KN**
Which is greater than th uplift forces due to cyclones, hence footing is OK

18.4 ELABORATE ENERGY CALCULATIONS

CONSUMPTION					
HOUSING UNIT POWER CALCULATIONS		UNITS			
AREA PER UNIT	16	SQM			
NO OF UNITS	72				
NO OF PEOPLE PER UNIT	3				
TOTAL BUILT UP AREA OF UNITS	1152	M^2			
ELECTRICAL UNITS PER ROOM	NUMBER	POWER RATING	TOTAL POWER	UNITS	
CEILING FAN	1	56	56	W	
LED TASK LIGHTS	3	2	6	W	
AMBIENT LIGHTS	1	10	10	W	
6A SOCKETS	2	100	200	W	
POWER CONSUMPTION PER UNIT PER DAY	NUMBER	POWER RATING(WATTS)	TIME(HOURS)	DIVERSITY FACTOR	TOTAL PER DAY (KWH)
CEILING FAN	1	56	12	0.75	0.504
LED TASK LIGHTS	3	2	8	0.75	0.036
AMBIENT LIGHTS	1	10	5	0.75	0.0375
6A SOCKETS	2	100	3	0.75	0.45
TOTAL FOR ONE UNIT (KWH)	1.0275				
TOTAL FOR 72 UNITS PER DAY (KWH)	73.98				
WALKWAY AND STAIRCASE LIGHTS					
POWER CALCULATIONS	NUMBER	POWER RATING(WATTS)	TIME(HOURS)	DIVERSITY FACTOR	TOTAL PER DAY (KWH)
WALKWAY LIGHTS	36	15	5	0.75	2.025
STAIRCASE LIGHTS	8	15	5	0.75	0.45
TOTAL POWER CONSUMED PER DAY (KWH)	2.475	KWH			
COMMON ROOM					
COMMON ROOM POWER CALCULATIONS		UNITS			
AREA OF COMMON ROOM	115	SQM			
FAN COVERAGE	23.04	SQM			
NO OF FANS	5				
LUMINAIRE CALCULATION		UNITS			
NO OF LUMINAIRES REQUIRED	36				
WATTAGE OF EACH LUMINAIRE	23	W			
POWER CONSUMPTION	NUMBER	POWER RATING(WATTS)	TIME(HOURS)	DIVERSITY FACTOR	TOTAL PER DAY (KWH)
CEILING FAN	5	56	5	0.75	1.05
LIGHTS (15 W)	32	15	5	0.75	1.8
SOCKETS 6A	3	100	3	0.75	0.675
TOTAL PER DAY (KWH)	3.525				
TOILETS					
TOILETS POWER CALCULATIONS		UNITS			
TOTAL NUMBER IF TOILET UNITS	2				
AREA PER TOILET UNIT	130	SQM			
TOTAL TOILET AREA	260	SQM			
POWER CONSUMPTION PER UNIT	NUMBER	POWER RATING(WATTS)	TIME(HOURS)	DIVERSITY FACTOR	TOTAL PER DAY (KWH)
LIGHTS FOR CUBICLE	28	3	4	0.75	0.252
LIGHTS FOR HALLWAY (28W)	8	28	4	0.75	0.672
LIGHTS FOR HALLWAY (15W)	6	15	4	0.75	0.27
EXHAUST FANS	14	40	2	0.75	0.84
TOTAL PER UNIT PER DAY	2.034				
TOTAL FOR ALL UNITS PER DAY	4.068				
KITCHEN					
KITCHEN POWER CONSUMPTION		UNITS			
TOTAL KITCHEN AREA	276.2	SQM			
NO OF KITCHENS	1				
POWER CONSUMPTION PER KITCHEN	NUMBER	POWER RATING(WATTS)	TIME(HOURS)	DIVERSITY FACTOR	TOTAL PER DAY (KWH)
LIGHTS	45	28	5	0.75	4.725
6A PPOWER SOCKETS	5	100	3	0.75	1.125
16A POWER SOCKETS	2	1000	2	0.75	3
EXHAUST FANS	10	40	5	0.75	1.5
TOTAL PER KITCHEN PER DAY (KWH)	10.35				
TOTAL PER DAY OF ALL KITCHENS PER DAY(KWH)	10.35				

DINING ROOM					
DINING ROOM POWER CONSUMPTION		UNITS			
AREA OF DINING ROOM	337	SQM			
FAN COVERAGE AREA	23.04	SQM			
NO OF FANS	15				
POWER CONSUMPTION PER DINING ROOM	NUMBER	POWER RATING(WATTS)	TIME(HOURS)	DIVERSITY FACTOR	TOTAL PER DAY (KWH)
LIGHTS	56	28	5	0.75	5.88
CEILING FANS	15	56	5	0.75	3.15
TOTAL PER DINING ROOM PER DAY (KWH)	9.03				
TOTAL FOR ALL DINING ROOMS PER DAY(KWH)	9.03				

INDOOR GAMES ROOM					
FLOOR AREA	55				
FAN COVERAGE AREA	23.04	SQM			
NO OF FANS	3				
POWER COMSUMPTION FOR INDOOR ROOM	NUMBER	POWER RATING(WATTS)	TIME(HOURS)	DIVERSITY FACTOR	TOTAL PER DAY (KWH)
LIGHTS	12	15	5	0.75	0.675
CEILING FANS	3	56	5	0.75	0.63
SOCKETS 6A	1	100	3	0.75	0.225
TOTAL POWER PER DAY (KWH)	1.53				

INDOOR GAMES ROOM HVAC CALCULATIONS		
FLOOR AREA	55	SQM
FLOOR AREA IN SQFT	593	SQFT
EFFECTIVE ROOM AREA	890	
TOTAL A/C TONNAGE(TR)	2.225	
POWER RATING	1500	W
TOTAL NO OF WINDOW UNITS	2	
TOTAL WATTAGE	3000	W
DIVERSITY FACTOR	0.75	
1.5TR = 1.5KW		
TOTAL POWER CONSUMPTION FOR HVAC	TIME(HOURS)	POWER RATING(WATTS)
	5	3000
TOTAL (KWH)	11.25	

FIRST AID ROOM					
FLOOR AREA	38	SQM			
FAN COVERAGE AREA	23.04	SQM			
NO OF FANS	3				
POWER CALCULATIONS	NUMBER	POWER RATING(WATTS)	TIME(HOURS)	DIVERSITY FACTOR	TOTAL PER DAY (KWH)
LIGHTS	8	15	5	0.75	0.45
CEILING FANS	3	56	5	0.75	0.63
SOCKETS 6A	3	100	2	0.75	0.45
REFRIGERATOR FOR MEDICINES	1	80	24	1	1.92
EXHAUST FANS	1	40	5	0.75	0.15
TOTAL POWER PER DAY (KWH)	3.6				

REFRIGERATOR CALCULATIONS		
REFRIGERATOR POWER CALCULATIONS		UNITS
POWER CONSUMPTION IN W	1500	W
TIME(HOURS)	24	HOURS
TOTAL PER REFRIGERATOR (KWH)	1.5	
TOTAL NO OF REFRIGERATORS IN KITCHEN	1	
REFRIGERATOR DIVERSITY FACTOR	0.5	
TOTAL POWER CONSUMPTION PER DAY (KWH)	18	

PUMPS POWER CALCULATIONS		
POWER CONSUMPTION FOR PUMPS		UNITS
NUMBER OF PUMPS REQUIRED	8	
POWER RATING OF EACH PUMP	150	W
POWER RATING IN KW	0.15	KW
NO OF HOURS THE PUMPS ARE OPERATED PER DAY	2	HOURS
DIVERSITY FACTOR	0.75	
TOTAL POWER CONSUMED PER DAY (KWH)	1.8	

SOLAR		
GENERATION		UNITS
SOLAR GENERATION POTENTIAL		
AREA	430	SQM
ENERGY GENERATED PER SQM	165	W
RUNNING TIME	9	HOURS
PANEL EFFICIENCY	0.22	
DIVERSITY FACTOR	0.75	
CLEAR SKY FACTOR IN A YEAR	0.65	
GENERATED POWER(POTENTIAL)	68.485	KWH PER DAY
GENERATION EPI		
GENERATION EPI CALCULATION		
TOTAL AREA	2400	SQM
SOLAR GENERATION EPI	10.416	KWH/SQM/YEAR
TOTAL EPI	10.416	KWH/SQM/YEAR
MAXIMUM CONSUMPTION PER DAY (KWH)	139.608	KWH
TOTAL AREA (M^2)	2400	SQM
CONSUMPTION PER YEAR	48425.67	KWH
CONSUMPTION EPI	20.178	KWH/SQM/YEAR
TOTAL CONSUMPTION EPI	20.178	KWH/SQM/YEAR
ENERGY GOAL	**9.762**	**KWH/SQM/YEAR**
TRANSFORMER SIZING		
MAX DEMAND LOAD	139.608	KW
LOAD FACTOR	0.9	
TOTAL MAX DEMAND LOAD	125.6472	KW
PERFORMANCE FACTOR	0.8	
EFFICIENCY	0.85	
TRANSFORMER CAPACITY	184.776	
TOTAL CAPACITY CONSIDERING 20% FOR FUTURE	221.732	
FINAL TRANSFORMER SIZING	222	KVA
INVERTER SIZING		
TOTAL POWER IN W	37828	W
POWER FACTOR (EFFICIENCY)	0.8	
POWER IN VA	47285	VA
INVERTER SIZE	59.107	kVA
PER INVERTER CAPACITY	10	kVA
NO OF INVERTERS REQUIRED	6	
BATTERIES REQUIRED		
BATTERY SIZE	300	Ah
VOLTAGE	12	V
BATTERY CAPACITY IN KWH	3.6	KWH
NO OF BATTERIES REQUIRED	20	
BACKUP BATTERY STORAGE		
EXTRA STORAGE REQUIRED FOR AUTONOMY	38.698	KWH
NO OF BATTERIES REQUIRED EXTRA	11	
REDUCTION IN EPI DUE TO PASSIVE DESIGN STRATEGIES		
YEARLY POWER CONSUMPTION FOR FAN BEFORE	183.96	kWh/year
YEARLY POWER CONSUMPTION FOR FAN AFTER	138.096	kWh/year
YEARLY CONSUMPTION FOR ALL FANS	13245.12	kWh/year
REDUCTION IN CONSUMPTION	3302.208	kWh/year
TOTAL YEARLY CONSUMPTION BEFORE	48425.67	kWh/year
TOTAL YEARLY CONSUMPTION AFTER	45123.462	kWh/year
POSSIBLE CONSUMPTION EPI	18.8014425	kWh/sqm/year
CURRENT CONSUMTION EPI	20.178	kWh/sqm/year
POSSIBLE REDUCTION IN CONSUMPTION EPI	1.3765575	kWh/sqm/year

18.5 ELABORATE CONSTRUCTION COST ESTIMATE

NO.	ITEM DESCRIPTION	UNIT	QUANTITY	RATE	AMOUNT (in INR)	COST PER SQ.M
A. UNIT AND COMMON AREAS COST						
1	FOOTING					
1.1	Excavation in soil	Cu. m	91.20	266.00	24,259.20	10.11
1.2	Tyre used in foundation	Each	380.00	399.00	151,620.00	63.18
1.3	Backfill (coarse aggregate)	Cu. m	76.95	1,058.00	81,413.10	33.92
2	STRUCTURAL STEEL WORK					
2.1	Recycled steel columns (140X140mm)	Kg	26,040.60	35.00	911,421.07	379.76
2.2	Recycled steel beams (300x140mm)	Kg	33,484.96	35.00	1,171,973.60	488.32
2.3	Perforated steel walkway	Sq.m	220.99	591.80	130,783.07	54.49
2.4	Secondary beams for floor	Kg	5,601.80	35.00	196,063.06	81.69
2.5	Dog legged steel staircase (6 mm thick)	Kg	2,622.53	35.00	91,788.48	38.25
2.6	Plinth steps to the units	Kg	1,526.04	35.00	53,411.40	22.25
2.7	Railing for staircase	R m	79.60	400.00	31,840.00	13.27
2.8	Steel frame for glass in north light truss	Kg	480.98	35.00	16,834.16	7.01
2.9	Steel gutter	R m	478.94	200.00	95,787.40	39.91
2.10	J-bolts (30cm)	Each	760.00	45.00	34,200.00	14.25
2.11	Covering for staircase	Kg	427.04	35.00	14,946.40	6.23
	SUB-TOTAL COST FOR STEEL WORKS (A)			110.00%	3,023,953.49	1,259.98
3	WALLS					
3.1	Ricron panel (12 mm thick)	Sq. m	733.68	807.00	592,076.53	246.70
3.2	Ricron panel (5 mm thick)	Sq. m	2,863.21	408.00	1,168,189.68	486.75
3.2	Jute mat (10 mm thick)	Sq.m	5,139.46	60.00	308,367.72	128.49
3.3	Coconut wood louver (20 mm thick)	Cu.ft	432.00	600.00	259,200.00	108.00
3.4	Metal woven fabric mesh	Sq. m	51.60	276.00	14,241.60	5.93
3.5	Bamboo panel for kitchen	Sq. m	383.50	350.00	134,225.00	55.93
4	WINDOWS					
4.1	Units (10mm thick glass)	Sq.m	86.40	1,935.00	167,184.00	69.66
4.2	Common areas (5mm thick polycarbonate sheets)	Sq.m	9.30	800.00	7,440.00	3.10
4.3	External shading for window	Sq.m	78.56	408.00	32,052.48	13.36
4.4	North light truss (5mm thick polycarbonate sheets)	Sq.m	224.48	800.00	179,584.00	74.83
5	DOORS					
5.1	PVC 750mm wide door	Each	64.00	950.00	60,800.00	25.33
5.2	PVC 900mm wide door	Each	74.00	1,135.00	83,990.00	35.00
5.3	PVC 1500mm wide double door	Each	5.00	1,850.00	9,250.00	3.85
5.4	Bamboo 1500mm wide double door	Each	10.00	1,935.00	19,350.00	8.06

6	**FLOORING**					
6.1	Ricron (8mm thick)	Sq.m	2,556.08	602.00	1,538,760.16	641.15
6.2	Strawbale	Cu. m	201.60	540.00	108,864.00	45.36
6.3	Mud compacted flooring	Cu. m	488.54	162.00	79,143.23	32.98
7	**ROOFING**					
7.1	Ricron (5 mm thick corrugated)	Sq.m	2,246.95	408.00	916,756.42	381.98
8	**BAMBOO TRUSS**					
8.1	Bamboo railing	R m	892.78	23.00	20,534.03	8.56
8.2	Bamboo mats	Sq.m	200.82	236.72	47,537.16	19.81
8.3	Bamboo truss	R m	3,641.41	23.00	83,752.43	34.90
	SUB-TOTAL COST (B)				**8,981,254.64**	**3,796.89**
B. MEP SERVICES						
9	HVAC					
9.1	Window unit	Each	2.00	26,000.00	52,000.00	21.67
10	**ELECTRICAL SERVICES**					
10.1	Solar panels	Each	215.00	9,400.00	2,021,000.00	842.08
10.2	Ceiling fan	Each	98.00	1,400.00	137,200.00	57.17
10.3	LED Ceiling Light	Each	56.00	55.00	3,080.00	1.28
10.4	LED Panel Light	Each	144.00	148.00	21,312.00	8.88
10.5	LED Tube Light	Each	117.00	120.00	14,040.00	5.85
10.6	LED Batten	Each	144.00	229.00	32,976.00	13.74
10.7	Rechargable study lamp	Each	216.00	120.00	25,920.00	10.80
10.8	Exhaust fans	Each	39.00	999.00	38,961.00	16.23
10.9	Solar Battery Storage	Each	29.00	11,500.00	333,500.00	138.96
10.10	Water pump	Each	8.00	5,000.00	40,000.00	16.67
10.11	Transformer (250 kVA)	Each	1.00	160,000.00	160,000.00	66.67
10.12	Refrigerator	Each	1.00	160,200.00	160,200.00	66.75
10.13	Circuit breaker (MCB)	Each	9.00	399.00	3,591.00	1.50
10.14	Circuit breaker (RCCB)	Each	2.00	3,006.00	6,012.00	2.51
10.15	Inverter	Each	6.00	82,000.00	492,000.00	205.00
10.16	Solar street light	Each	36.00	1,250.00	45,000.00	18.75
10.17	Single door mini refrigerator	Each	1.00	7,900.00	7,900.00	3.29
10.18	Interior wiring	R m	980.00	35.00	34,300.00	14.29
10.19	Site level wirring	R m	215.00	65.00	13,975.00	5.82

11	**PLUMBING AND SANITATION**					
11.1	Ablution tap	Each	60.00	220.00	13,200.00	5.50
11.2	Jet spray	Each	28.00	250.00	7,000.00	2.92
11.3	Indian toilet	Each	24.00	8,500.00	204,000.00	85.00
11.4	Western toilet	Each	4.00	8,500.00	34,000.00	14.17
11.5	Nahani trap	Each	80.00	100.00	8,000.00	3.33
11.6	RO Plant	Each	1.00	35,000.00	35,000.00	14.58
11.7	Heating coil	Each	14.00	650.00	9,100.00	3.79
11.8	GRP Storage Tank	Per L	50,000.00	5.00	250,000.00	104.17
11.9	Grey water recycling syntax	Per L	28,000.00	3.95	110,600.00	46.08
11.10	Urinals	Each	10.00	4,000.00	40,000.00	16.67
11.11	Washbasins	Each	34.00	1,176.00	39,984.00	16.66
11.12	Kitchen sink	Each	2.00	2,750.00	5,500.00	2.29
11.13	Internal drainage	R m	142.31	75.00	10,673.40	4.45
11.14	External drainage	R m	173.00	125.00	21,625.00	9.01
11.15	Rainwater filter	Each	1.00	8,500.00	8,500.00	3.54
11.16	Water softner	Each	1.00	18,000.00	18,000.00	7.50
11.17	Bio-digester tanks	Each	8.00	19,600.00	156,800.00	65.33
12	**SECURITY SYSTEM**					
12.1	Fire Alarm System	Each	73.00	125.00	9,125.00	3.80
12.2	Smoke Detector System	Each	109.00	382.00	41,638.00	17.35
	SUB-TOTAL (C)				**4,665,712.40**	**1,944.05**
C. FURNISHING						
13	FURNISHING					
13.1	Foldable bed	Each	213.00	1,800.00	383,400.00	159.75
13.2	Chair	Each	110.00	200.00	22,000.00	9.17
13.3	Table	Each	12.00	700.00	8,400.00	3.50
13.4	Sorage space (cupboard)	Each	72.00	1,100.00	79,200.00	33.00
	SUB-TOTAL (D)				**493,000.00**	**172.42**
D. SITE DEVELOPMENT						
14	**SITE DEVELOPMENT**					
14.1	Clearing and levelling	Sq.m	8,270.00	2.80	23,156.00	9.65
14.2	Reed beds	Sq.m	105.00	200.00	21,000.00	8.75
14.3	Cement concrete paving tiles	Sq.m	392.00	255.00	99,960.00	41.65
	SUB-TOTAL (E)				**144,116.00**	**17.43**
	SUB-TOTAL (B+C+D+E)				**14,284,083.04**	**5,930.78**
15	**CONTIGENCY**					
15.1	Incidental and miscellanous cost			5.00%	714,204.15	297.59
	TOTAL				**14,998,287.19**	**6,228.37**

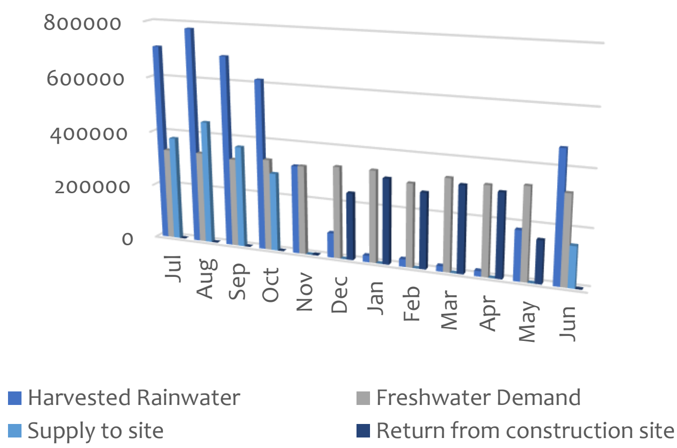
18.6 ELABORATE CONSTRUCTION COST ESTIMATE FOR ONE CLUSTER (8 UNITS)

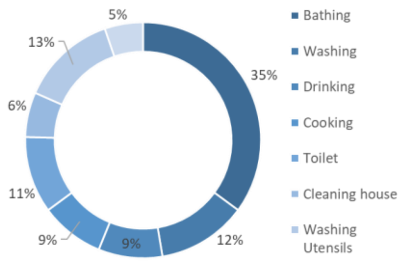
NO.	ITEM DESCRIPTION	UNIT	QUANTITY	RATE	AMOUNT (in INR)
1	Ricron (5mm thick)	Sq.m	441.6	408.0	180,172.8
2	Jute (10mm thick)	Sq.m	792.7	60.0	47,560.3
3	Coconut wood louver (20 mm thick)	Cu.ft	48.00	600.0	28,800.0
4	Metal woven fabric mesh	Sq.m	21.6	30.0	648.0
5	Ricron (8mm thick)	Sq.m	256.0	602.0	154,112.0
6	Strawbale	Cu.m	22.4	245.0	5,488.0
7	Recycled steel columns (140X140mm)	Kg	1,931.6	35.0	67,606.0
8	Recycled steel beams (300X140mm)	Kg	3,780.6	35.0	132,319.6
9	Secondary beams for floor	Kg	622.4	35.0	21,784.8
10	Dog legged steel staircase (6 mm thick)	Kg	655.6	35	22,947.1
11	Railing for staircase	R m	19.9	400	7,960.0
12	Perforated steel walkway	Sq.m	22.8	591.8	13,493.0
13	Bamboo mats	Sq.m	22.3128	236.72	5,281.9
14	Bamboo railing	R m	99.198	23.0	2,281.6
15	Ricron (5 mm thick corrugated)	Sq.m	100.0	408	40,783.7
16	Bamboo truss	R m	134.8	23	3,100.4
17	PVC 900mm wide door	Each	8.0	1,135.0	9,080.0
18	Window (10mm thick glass)	Sq.m	9.6	2,150.0	20,726.0
19	External shading for window	Sq.m	8.7	408.0	3,561.0
20	Ceiling fan	Each	8.0	1,400.0	11,200.0
21	Rechargable Study Lamp	Each	24.0	120.0	2,880.0
22	LED Batten	Each	8.0	229.0	1,832.0
23	Solar panels	Each	32.0	9,400.0	300,800.0
24	Foldable beds	Each	24.0	1,800.0	43,200.0
25	Storage space	Each	8.0	1,100.0	8,800.0
26	Ricron (12mm thick)	Sq.m	97.9	807.0	79,021.4
27	Ablution tap	Each	9.0	150.0	1,350.0
28	Jet spray	Each	3.0	160.0	480.0
29	Nahani trap	Each	8.0	100.0	800.0
30	Heating coil	Each	3.0	650.0	1,950.0
31	Urinals	Each	2.0	400.0	800.0
32	Toilet	Each	3.0	8,500.0	25,500.0
33	Exhaust fan	Each	3.0	999	2,997.0
34	Washbasin	Each	3.0	1,176.0	3,528.0
35	Water pump	Each	1.0	5,000.0	5,000.0
	SUB-TOTAL (A)				**1,257,844.6**
36	Fixing and labour costs			35.00%	440,245.6
	TOTAL COST OF INVESTMENT				**1,698,090.3**

18.7 ELABORATE WATER ESTIMATION CALCULATIONS

Per Capita daily consumption	Number of occupants	Total daily consumption	Grey water filter efficiency
57	210	11970	85%

Water use	Quantity	Liters/day
Occupants : {People x l/person}	210	57
Irrigation (max) : {m² x l/m²}	0	0
Cooling tower (max) : {Ton x l/Ton}	0	0
Other		





Month	Days in month	Generated black water	Generated Grey water	Filtered grey water	Month	Days in month	Occupant demand	Irrigation seasonal factor (%)	Irrigation demand	Cooling tower Usage factor (%)	Cooling tower water demand (l)	Total water demand (l)
Jul	31	113925	257145	218573.25	July	31	371070	20%	0	0%	0	371070
Aug	31	113925	257145	218573.25	August	31	371070	20%	0	0%	0	371070
Sep	30	110250	248850	211522.5	September	30	359100	20%	0	0%	0	359100
Oct	31	113925	257145	218573.25	October	31	371070	50%	0	0%	0	371070
Nov	30	110250	248850	211522.5	November	30	359100	50%	0	0%	0	359100
Dec	31	113925	257145	218573.25	December	31	371070	50%	0	0%	0	371070
Jan	31	113925	257145	218573.25	January	31	371070	100%	0	0%	0	371070
Feb	28	102900	232260	197421	February	28	335160	100%	0	0%	0	335160
Mar	31	113925	257145	218573.25	March	31	371070	100%	0	50%	0	371070
Apr	30	110250	248850	211522.5	April	30	359100	100%	0	100%	0	359100
May	31	113925	257145	218573.25	May	31	371070	50%	0	100%	0	371070
Jun	30	110250	248850	211522.5	June	30	359100	50%	0	50%	0	359100

FIXTURES

100LPH RO PLANT

MERINO WATERLESS URINALS

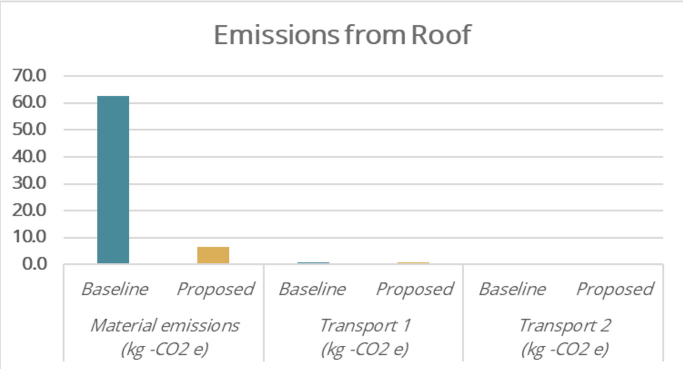
500LPH – 10000LPH WATER SOFTENER

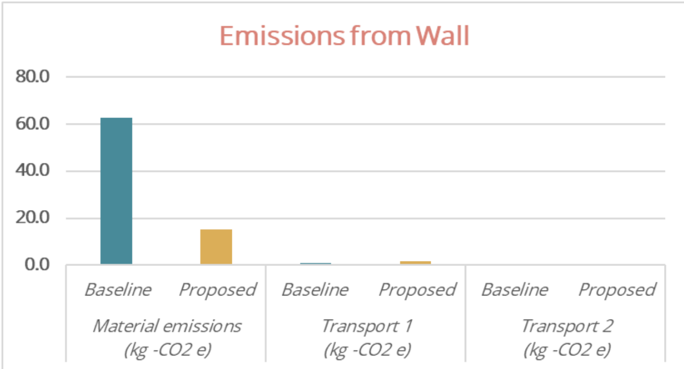
EASYPAL RAINWATER FILTER

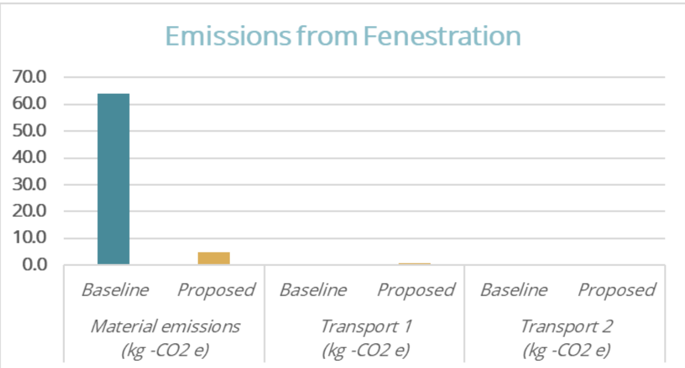
FRP WATER STORAGE TANK

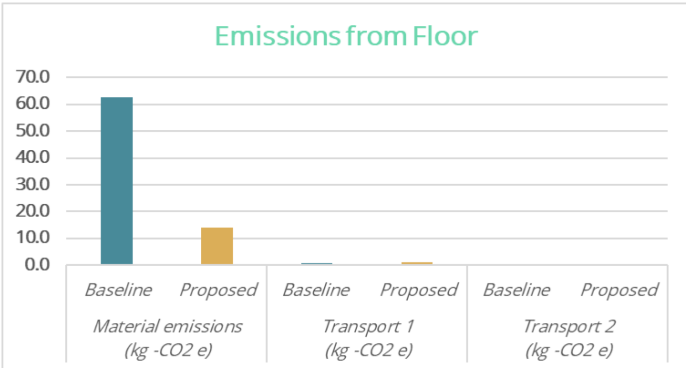
18.8 EMBODIED CARBON SUMMARY

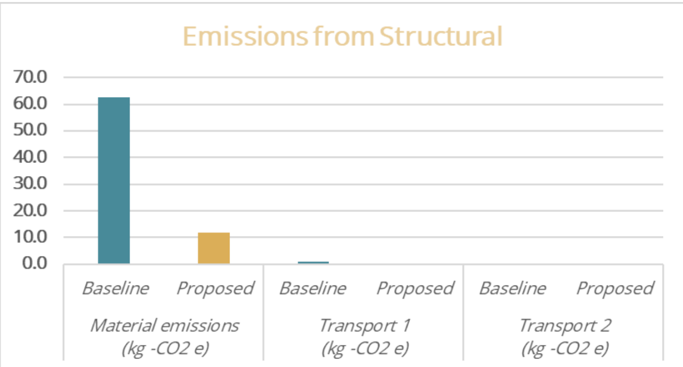
System Type	Baseline				Proposed			
	Material emissions (kg -CO_2 e)	Transport 1 (kg -CO_2 e)	Transport 2 (kg -CO_2 e)	Total (kg -CO_2 e)	Material emissions (kg -CO_2 e)	Transport 1 (kg -CO_2 e)	Transport 2 (kg -CO_2 e)	Total (kg -CO_2 e)
Wall	62.5	0.8	0.1	63.5	15.2	1.7	0.2	17.1
Roof	62.5	0.8	0.0	63.3	6.7	0.9	0.0	7.6
Floor	62.5	0.8	0.1	63.5	14.1	1.2	0.2	15.4
Fenestration	64.1	0.6	0.1	64.8	4.9	0.9	0.1	5.9
Structural	62.5	0.8	0.0	63.3	11.8	0.0	0.0	11.8
		Grand Total emissions per functional unit (kg -CO_2 e)		318.3		Grand Total emissions per functional unit (kg -CO_2 e)		57.8











SOURCES :
http://www.emccement.com/pdf/Full-BSRIA-ICE-guide.pdf

18.9 SERVICE FIXTURES

ITEM DESCRIPTION	RATE (in INR)	POWER RATING	QUANTITY REQUIRED
MECHANICAL VENTILATION			
Bajaj Frore 1200 mm Ceiling Fan	1400	56W	98
LIGHTING			
Round Ceramic 3W Deep LED Ceiling Light, Lighting Color: Cool White	55	3W	56
Plastic Cool White / Warm White 15 W Slim LED Panel Light	148	15W	144
LED Eveready T5 28W Tube Light	120	28W	117
wipro Garnet 10-Watt LED Batten (Warm White, 2 Feet)	229	10W	144
Plastic 2W Rechargeable LED Table Lamp, Cool White, Battery Type: Lithium Ion	120	2W	216
SOLAR PANEL			
EMMVEE SOLAR PANEL POLY 325Wp (crosscheck panel efficiency)	9,400	330W	215
EXHAUST FAN			
imee-Primo Ventilation Exhaust Fan-40W(10IN)	999	40W	39
FIRE ALARM			
FR Polymer Fully Automatic Fire Alarm	125	Built in battery	73
SMOKE DETECTOR			
Agni Hunt AHSD-650 Optical Smoke Detector White	382	-	109
SOLAR BATTERY STORAGE			
Exide Tubular Solar Battery 300Ah, 12V	11,500	3.6kWh	29
PUMPS			
Sunsun Submersible Pump | Hj 6000 6800l/h 150w	5,000	150W	8
TRANSFORMER			
Servokon, 250KV	1,60,000	250 kVA	1
REFRIGERATOR			
Gauge 16 steelfabs pvt ltd	1,60,200	1.5kW	1
CIRCUIT BREAKERS (MCB)			
Havells Euro-II 50A Single Pole C Curve MCB, DHMGCSPF050	399	50A	12
CIRCUIT BREAKERS (RCCB)			
AC 100A 4 Pole 30MA ELCB/RCCB HAGER CD484Y	3006	100A	2
INVERTER			
Luminous 10kVA	82,000	10 kVA	6
SOLAR STREET LIGHT			
Quace 18 LED Super Bright Waterproof 4 Mode PIR Motion Sensor Solar Security Wall Light (Cool White,ABS)	1250	5W	36
FIRST AID ROOM FRIDGE			
Midea Mini Bar 45 Litres 2 Star Direct Cool Single Door Mini Refrigerator	7900	75W	1

18.10. MATERIALS SPECIFICATION

SPECIFICATION	MATERIAL	U value (W/m2K)	EMBODIED CARBON (kgCOe/kg)
WALL			
LIVING UNITS	RICRON	0.404	0.8
	JUTE	0.427	0.61
	RECYCLED STEEL	0.12	0.47
COMMON AREA	BAMBOO PANELS	1.4	0.7
COMMUNITY KITCHEN AND DINING			
FLOOR			
LIVING UNITS	RICRON	0.404	0.8
	STRAWBALE	0.17	-1.4
	RECYCLED STEEL	0.12	0.47
COMMON AREA	MUD COMPACT	1.9	0.009
COMMUNITY KITCHEN AND DINING			
ROOF			
LIVING UNITS	RICRON	0.404	0.8
COMMON AREA	BAMBOO	1.4	0.7
COMMUNITY KITCHEN AND DINING			
FENESTRATION			
LIVING UNITS	COCONUT WOOD	0.077	0.7
COMMON AREA			
COMMUNITY KITCHEN AND DINING			
STRUCTURE			
LIVING UNITS	RECYCLED STEEL	0.12	0.47
COMMON AREA			

19. LETTER FROM PROJECT PARTNER

KEC

KEC INTERNATIONAL LTD.
RPG House
463, Dr. Annie Besant Road
Worli, Mumbai 400030, India
+91 22 66670200
www.kecrpg.com

Date: 29.08.2022

To,

The Director,
Solar Decathlon India.

Dear Sir,

This is to inform you that our organisation, KEC International, has provided information about our project to the participating team led by R V College of Architecture, so that their team 'EnGriha' may use this information for their Solar Decathlon India 2022-23 **ON SITE CONSTRUCTION WORKERS' HOUSING** competition entry.

As a Project partner to this team for Solar Decathlon India 2021-22 competition, we are interested in seeing the Net-Zero-Energy, Net-Zero-Water, Resilient and Affordable solutions that this student team proposes and the innovations that result from this.

We have no issues with our organisation logo being displayed on the Solar Decathlon India contest, recognising us as one of the Project partners for the 2021-22 competition.

With warm regards,

Srikanth Vardhan

Vice President-(Operations)

KEC International Ltd.

Registered Office: RPG House, 463, Dr. Annie Besant Road
Worli, Mumbai 400030, CIN: L45200MH2005PLC152061, India.

An RPG Company

20. LETTER FROM INDUSTRY PARTNER

RicronPanels

MANUFACTURERS OF REGENERATED PLASTIC SHEETS

Certified Green Product

22/02/2023

To,

The Director,

Solar Decathlon India

Dear Sir,

This is to inform you that our organization, Ricron Panels Private Limited (Formerly known as Deeya Panel Products Pvt. Ltd), is collaborating with the participating team led by R V College of Architecture on an On-site Construction Worker Housing Building project for their Solar Decathlon India 2022-23 competition entry.

The nature of our collaboration will be in form of us providing them with the technical details of the RICRON panels developed by us to use in the innovation for their wall panels.

We would like have a representative from our organization attend the Design Challenge Finals event in April/May, if this team is selected for the Finals.

We would like our organization's logo to be displayed on the Solar Decathlon India website, recognizing us as one of the Industry Partners for the 2022-23 competition.

With Warm Regards,

Ricron Panels Private Limited

Ms. Radhika Chaudhari

CFO

+91 95225 62258

RICRON PANELS PRIVATE LIMITED Ankleshwar

RICRON PANELS PRIVATE LIMITED

(Formerly known as "Deeya Panel Products Pvt Ltd")

6108/6109 G.I.D.C., Ankleshwar - 393002, Gujarat info@ricron.com www.ricron.com

21.1 BONAFIDE CERTIFICATES - RVCA

RV Educational Institutions ®
RV College of Architecture ®
Affiliated to Visvesvaraya Technological University, Belagavi | Approved by Council of Architecture (COA), New Delhi

Date: 21-02-2023

BONAFIDE CERTIFICATE

This is to certify that the bearers of this letter are bonafide students of R.V.College of Architecture (RVCA), Bengaluru currently studying in VI & VIII Semester B. Architecture course.

The B. Architecture course is of 5 Years duration affiliated to Visvesvaraya Technological University, Belagavi.

This certificate is issued only for the purpose to take part in "Solar Decathlon Competition", on request of the EnGriha Team.

Dr. O P Bawane
Principal
PRINCIPAL
R V COLLEGE OF ARCHITECTURE
BENGALURU - 560 109.

List of the Students:

1. Mr. Anish Perumal - 1RW19AT012
2. Ms. Chandana Kulkarni -1RW19AT026
3. Ms. Nidhi Rai - 1RW19AT062
4. Ms. Rajathashree M.K. - 1RW19AT076
5. Ms. Akansha Belliappa - 1RW20AT005
6. Ms. Deepti Mishra - 1RW20AT021
7. Mr. Rohan Chaturvedi - 1RW20AT077
8. Ms. Vachana S. - 1RW19AT111
9. Mr. Sanket Danolli - 1RW19AT089
10. Mr. Jennis John - 1RW20AT040
11. Mr. Amogh Acharya - 1RW19AT009
12. Ms. Nikita Biju Thomas - 1RW19AT065
13. Ms. D.Yashashri - 1RW19AT030

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21.2 BONAFIDE CERTIFICATES - RVCE

RV Educational Institutions
RV College of Engineering
Autonomous Institution Affiliated to Visvesvaraya Technological University, Belagavi
Approved by AICTE, New Delhi

DATE: 22-02-2023

BONAFIDE CERTIFICATE

This is to certify that the below-mentioned students are bonafide students of R V College of Engineering and currently studying in V-Semester B. E.

Bachelor of Engineering is a 4 Year duration course, and R V College of Engineering is affiliated with Visvesvaraya Technological University, Belagavi, Karnataka (India).

This certificate is issued only for the purpose to take part in "Solar Decathlon Competition", on request of the EnGriha Team.

Dr. K. N. Subramanya

Principal

Student:

Ronan D Silva - 1RV20ME090

(5th sem, Mechanical Engineering)

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21.3 BONAFIDE CERTIFICATES - RVU

RV UNIVERSITY
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an initiative of RV EDUCATIONAL INSTITUTIONS

RV Vidyaniketan, 8th Mile, Mysuru Road, Bengaluru, 560059, India
Ph : +91 80 68199900 | www.rvu.edu.in

Date: 23.02.2023

BONAFIDE CERTIFICATE

This is to certify that Ms. Yashika Bajaj, D/o Ms. Annu is a bonafide student at RV University. She has been admitted in academic year 2021-22 for Bachelor of Design (B.Des) in the School of Design & Innovation. Presently, She is pursuing her 2nd year IV Semester in Spatial and Interior Design Specialisation 4-year undergraduate programme (B.Des).

This Certificate is issued at the request of the Engriha team for the purpose of participating in the Solar Decathlon Indian Competition.

RV University Bengaluru-59.

Vinay Mundada
Dean – School of Design & Innovation