Solar Decathlon India

ON-SITE CONSTRUCTION WORKERS HOUSING

FINAL DESIGN REPORT (APRIL- 2023)

sattva

SATTVA 2.0

PROJECT PARTNER:

Larsen and Toubro Construction

PARTICIPATING INSTITUTIONS:

University School of Architecture and Planning, GGSIPU
Indian Institue of Technology, Roorkee

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01 EXECUTIVE SUMMARY

Construction workers are a vital part of our society and are necessary to keep our society moving and growing. However, their housing needs are little understood, forcing them to live in dismal conditions. Team Sattva 2.0 from the University School of Architecture and Planning, GGSIPU has taken the opportunity provided by Solar Decathlon India to come up with a net zero solution for L&T Construction. The interdisciplinary team followed a systematic approach involving data collection, communication and execution.

The project set in Central Vista houses 2500 male construction workers belonging to varied socio-cultural backgrounds on site. This project, Nilaya, is a joint attempt to provide a dignified living space for the workers and become a model for worker housing and allied net-zero solutions across the country.

The team engaged in research, data collection and site visits to identify the problems of the workers and understand their behavioural patterns and needs. The solution was therefore intended to address, comfort, quality and experience for the user, efficient resource management and affordability, scalability and flexibility for the project partner.

An issue observed on site was the lack of social gathering spaces and restricted movement due to a high-security zone. Hence, the design aims to instill a sense of belonging among the workers by providing aangans with all units and collective open spaces that establishes an indoor-outdoor connection. A compact structure has been designed to minimize circulation and optimize the use of resources.

A total number of 210 dwelling units that have an achieved EPI of 18 kWh/m^2.year and WWR of 24% are provided. The partnership with Premier Energies enabled the provision of solar panels generating 2,77,400 kWh/yr of on-site energy and thus providing a net-positive solution. Further, passive strategies like recessed balconies, convective ventilation and sail shades for open spaces have been employed to maximize the user's thermal comfort.

Water wastage by 2500 workers was another major problem which led to water shortage on site. Thus, reduction in water consumption has been attained by efficient low-flow fixtures, behavioural measures, rainwater harvesting and wastewater treatment to achieve a net zero water cycle. The EcoTec process using innovative herbal product technology has been used for sewage water treatment.

Use of kit-of-parts construction system with materials like mild steel hollow box sections, fibre cement boards, ferro-cement panels, insulation and particle boards led to 102.68% more carbon efficiency than the base case. This modular structure with ease of assembly and dismantling allowed us to achieve resilience in the face of disaster while maintaining autonomy in energy and water for 48 hours.

To cater to the challenge of sanitation on site, Sattva 2.0 introduced another benchmark of Waste Disposal and Management to utilize the potential of biodegradable waste for energy generation.
The resulting design achieved full FSI with a cost of 102.2 million INR and savings in operational cost by 48%.

02 RESPONSE TO REVIEWERS' COMMENTS

SECTION	REVIEWER'S COMMENT	OUR RESPONSE
	REVIEWER 1	
ENERGY PERFORMANCE	Is there anything specific that you want to add on integration of low energy comfort systems?	We have installed low energy wall mounted fans near each bed in the housing unit paired with use of windows and balconies. This implies a mixed mode of passive and active cooling.
ENGINEERING AND OPERATIONS	Engineering systems can also include details on other systems and specs like STP, ETP, HVAC specs, solar PV, etc in addition to architectural/ structural/ building material related specs.	The specific issues have been identified and addressed under the Building Operations (Do's & Don'ts) division in the appendix on page number: 54 and 55
HEALTH AND WELL-BEING	What about annual thermal comfort analysis and unmet hours? Quantifiable data analysis is missing in this section for thermal comfort.	In the quantification assessment of our design, the housing units are left with 1452 hours out of 8760 hours annually. 840 hours: During night time. 366 hours: Peak afternoon. 246 hours: During humid days.
	REVIEWER 2	
ENGINEERING AND OPERATIONS	Team has done commendable analysis on structural stability, however, engineering innovation or intervention with respect to MEP services have been overlooked.	The MEP services have been catered to in the Engineering and Operations division on page number: 18
ARCHITECTURAL DESIGN	The dimensions in the drawing provides a clarity on spatial components and their inter-relatedness with other interacting spaces. As this site has many constraints, the spatial relationship of building areas with its surroundings are critical. In the drawings, that relationship understanding is not visible.	This has been addressed under the Architecture design section on page number: 14
	Specifically, the site or location drawing is not fully developed.	This has been addressed under the Architecture design section on page number: 14
AFFORDABILITY	The analysis is very well constructed, however, team should do a comparative analysis of existing design to proposed design in order to understand the difference in cost.	This has been addressed under the Affordability section of the Appendix on page number: 48 and 49

Table 01: Response to reviewers' comments

03 TEAM INTRODUCTION

Team Name : Sattva 2.0

Institution Name : University School of Architecture and Planning, GGSIPU

Indian Institute of Technology, Roorkee

Division : On-site construction worker housing

TEAM MEMBERS

Sonu Rathor, 4th-year Architecture student
ROLE: TEAM LEADER, Architectural design & Affordability

Muskan Gupta, 4th-year Architecture student
ROLE: Energy performance & Health and wellbeing

Shreya Singh, 4th-year Architecture student
ROLE: Health and wellbeing & Embodied carbon

Ashish Jain, 4th-year Architecture student
ROLE: Embodied carbon & Architectural design

Ansh Taneja, 3rd-year Architecture student
ROLE: Affordability & Energy performance

Deepshikha Panda, 3rd-year Architecture student
ROLE: Energy performance & Resilience

Soumitra Das, 3rd-year Architecture student
ROLE: Waste disposal and management & Water performance

Priya Singh, 3rd-year Architecture student
ROLE: Affordability & Waste disposal and management

Ishita Mittal, 4th-year Architecture student
ROLE: Value proposition & Water performance

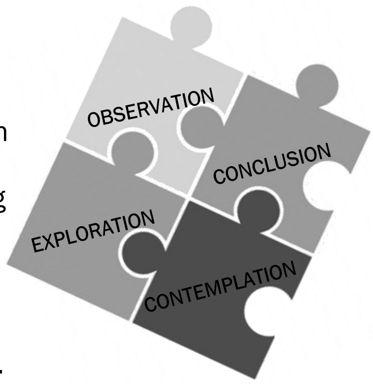
Priyanshi Gupta, 4th-year Architecture student
ROLE: Innovation & Energy performance

Jahnvi Aggarwal, 4th-year Architecture student
ROLE: Water performance & Engineering and operations

Ayush Diwang, 3rd-year Civil engineering student
ROLE: Engineering and operations

APPROACH

Our team consists of individuals who are passionate about the environment and have diverse academic backgrounds. Despite our differences, we work together cohesively to create a systematic approach to our objective. We engage in a variety of activities, including **observing, exploring, contemplating, and concluding.** Our process involves gathering data and considering multiple perspectives in order to arrive at well-informed conclusions.
Our team emphasizes the importance of exchanging information and maintaining strong communication. This involves sharing ideas, giving and receiving feedback, and working collaboratively to achieve our goals.



03 TEAM INTRODUCTION

INSTITUTIONS

LEAD INSTITUTE: UNIVERSITY SCHOOL OF ARCHITECTURE & PLANNING, GURU GOBIND SINGH INDRAPRASTHA UNIVERSITY

Established in 1998, USAP has a robust teaching pedagogy and offers courses in architecture, students are encouraged to look into environment-friendly, context-relevant solutions. Programs include a Bachelor of Architecture, a Master of Architecture (Urban Design) and a Master of Planning (Urban & Regional Planning).

INDIAN INSTITUTE OF TECHNOLOGY, ROORKEE

IIT Roorkee is the oldest engineering institution in India that offers over 10 undergraduate and more than 55 postgraduate degree courses in engineering, applied sciences, architecture, and planning.

FACULTY GUIDES

FACULTY LEAD: Ar. Priyanka Kochhar

Associate Professor, University School of Architecture and Planning, GGSIPU.

She has more than 18 years of experience in the field of sustainability, green buildings, policies, and implementation. She has worked with UNIDO, GRIHA council, TERI, and GBCI.

FACULTY ADVISOR: Prof. Dr. Neeraja Lugani Sethi

DEAN, University School of Architecture and Planning, GGSIPU.

With more than 28 years of experience in the field, she has been the general manager of HSCC India Ltd. and is a celebrated alumnus of IIT Delhi, SPA, and CCA.

INDUSTRY PARTNERS

Premier Energies

1. **Premier Energies** is the second-largest integrated solar cell and module manufacturer in India with 25+ years of influential presence in the solar industry. Premier Energies is known for its commitment to creating sustainable energy solutions.

Point of contact : Mr. Sudhir Reddy

Designation : Director, Premier Energies

2. **Ar. Gaurav Shorey** is one of the founding members of the GRIHA rating system and currently heads PSI, a sustainable design studio in Delhi and 5waraj an NGO. He has also been a part of UN-HABITAT, TERI, and an ECBC Master Trainer.

PSI PARTNERSHIPS FOR SUSTAINABLE INDIA

DESIGN MANAGEMENT PROCESS

Our design team has divided itself into groups based on individual strengths and interests to ensure efficient execution. Our team followed a design process which involved defining a design brief, conducting research, developing a design concept, refining the design, testing, and effective communication. The final execution involved the use of various tools such as AutoCAD, Sketchup, Climate Studio, Design Builder, Ecotect, STAAD Pro, MS Publisher, Adobe Photoshop, and MS Excel.

04 PROJECT INTRODUCTION

Project Name : *NILAYA* *(PEACEFUL HOME)*

PROJECT PARTNER

Larsen and Toubro Construction

L&T construction is a division of Larsen and Toubro, founded in 1934 and is a major Indian technology, engineering, construction, manufacturing and financial services conglomerate with global operations.

KEY INDIVIDUALS:

Dr S.Rajkumar
HEAD and DGM
Centre for Excellence and Futuristic Development
PAF - B&F IC
L&T Construction

He holds a PhD in Building and thermal comfort from IIT Delhi, a Mtech degree in energy technology from NIT Tiruchirapalli and has more than 20 years of experience in working with energy-efficient buildings and sustainability.

PROJECT BRIEF

Our project site lies in the newly renovated heart of Delhi- Central Vista, (28.61446159785467N, 77.2210946959912E). It is housed in the composite climate of Delhi. Our current site- the Indira Gandhi National Centre for the Arts (IGNCA) is among the three museums with a completion deadline in 2023.
The project site lies along the north of the Kartavya Path and east of the Janpath Road i.e right at the now-demolished IGNCA location.

Figure 01: Site plan

The materials available near the site area include fly ash bricks, foam expansion joint filler board, clay bricks, timber, bamboo, cement, aggregates, etc.

2500 male construction workers are housed in containers on site. These workers travel from Chhattisgarh, Jharkhand, Bihar and Orissa.

04 PROJECT INTRODUCTION

Geographical Profile of Site

The soil condition map depicts the characteristics of the soils- highlighting the conditions and problems along with soil and water use relation. The site falls in the soil type of Hamidpur - Palla Association.
The soil occurs on gently sloping land of 1-3% slope developed on the alluvial plains and has a low elevation range of 241 to 260.
The water holding capacity of soil is low thus making the percolation of water easier.
The soils of this association are coarse loamy, sandy loamy and calcareous with calcium carbonate of more than 1% in the upper 50 cm depth of the soil. This makes it easier to construct on soil and it can withstand large loads.

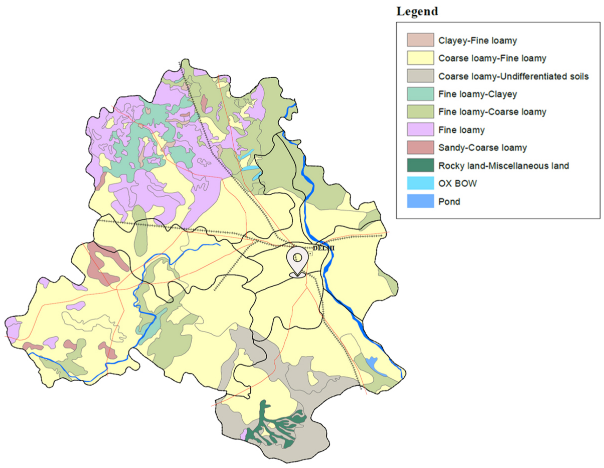


Figure 02: Soil condition map

Professional Profile

Occupation: Labour, Carpenter, Mason, Steel worker, Mechanical and Civil fitter

Skill: 80% unskilled

Working hours: 24 hours in shifts, 8:30 AM to 4:30 PM (8 hours), followed by a paid overtime of up to 4 hours.

Economic Profile

They work for 3-4 months and their salaries range from ₹15K to ₹30K per month. These workers are registered under the BOCW act. They fall in the age group of 18- 50 years.

Current Habitable Conditions

The construction worker housing on site has been fully operational for the past six months. It is a double-storey housing with 100 containers. Each container houses 24 workers and has double bunk beds, 4 lights, 24 wall-mounted fans and switchboards.
The current style of construction and the provision of amenities on the present site is beyond the present scenario of the usual construction workers' housing in Delhi.
However, there are still some inconveniences about the location of toilets, security concerns, wastage of water, lack of adequate thermal comfort etc. Therefore, we aim to reduce the energy, water, fuel consumption, cost and waste generated on-site.
The purpose of the design intervention will be a **build-own-lease and operate**.

Total Site Area: 20,900 m^2
Total Built-up Area for the existing CWH: 6,000 m^2
Total Built-up Area for the proposed CWH: 9,900 m^2

SPECIAL REQUIREMENTS

The land area constraints made it possible for the project partner to only provide washrooms, bathing and living facilities for the **male** construction workers. The scarcity of land would lead to an unsafe environment and security concerns, therefore, our project partner requires a net-zero solution for male construction workers' housing.

The financial targets for CAPEX and OPEX are as follows:

- **CAPEX: 102.2 Millions INR**
- **OPEX: 3.2 Millions INR**

05 GOALS

01 ENERGY PERFORMANCE

Goals:

Target EPI= 18 kWh/m^2.year. To minimize energy consumption by 43%. To provide a net positive solution by generating 55% surplus energy.

Achievements:

The targeted EPI and energy consumption has been achieved by minimizing solar heat gain by attaining 24% WWR, 0.3082 W/m2.K U value for wall, 0.35 W/m2.K and 1 W/m2.K for roof and glass respectively, and by integrating energy efficient appliances and generating on site solar energy.

02 WATER PERFORMANCE

Goals:

To reduce water demand by 63.35%. To recycle 95% of the grey water and 70% of the black water.

Achievements:

A net positive water cycle has been attained by using low flow fixtures, efficient rainwater harvesting and water recycling techniques. Additionally an annual groundwater recharge of 54,52,677.875 L was also achieved.

03 EMBODIED CARBON

Goals:

To assess carbon-efficient alternatives for functional requirements. To execute low-carbon techniques for assembly and disassembly.

Achievements:

102.68% reduction in carbon emissions using recycled/ locally sourced/low carbon materials, reduced transportation emissions, and a dismantlable design for easy assembly/disassembly has been achieved.

04 RESILIENCE

Goals:

Designing a structure capable of withstanding earthquakes, strong winds, thunderstorms and occasional heat waves. Protection, reduction, and preparation against man-made hazards. To maintain autonomy in energy and water performance for 48 hours in the face of disaster.

Achievements:

The design has been made resilient by strategically designing the building envelope and structure, and reducing the disruption to services.

05 ENGINEERING AND OPERATION

Goals:

Minimizing waste of materials, equipment and energy during construction and operational phase.

Achievements:

The design procedure reduces material and energy waste through modular construction and framework planning, which is also a structurally stable design system.

06 ARCHITECTURAL DESIGN

Goals:

Foster a sense of community and belonging by promoting interaction across all levels. Prioritize user comfort to enhance the quality of life through thoughtful design. Emphasize compact planning and efficient flow of spaces.

Achievements:

We created interacting spaces of varying sizes to encourage community interaction and engagement, with multiple central courtyards for cross-ventilation. Staircases are placed 15 meters apart for optimal movement efficiency.

07 AFFORDABILITY

Goals:

To reduce capital investments by 15% and operational costs by 48%.

Achievements:

The CAPEX and OPEX has been brought down judiciously and approximately 49% savings have been achieved in life cycle analysis by deliberate design solutions, use of energy replenishing techniques and effective choice of materials.

08 INNOVATION

Goals:

To provide creative solutions for problems related to the flexibility of the structure. To design for ease of assembling, dismantling and relocating. To achieve sustainability and mobility in systems of construction.

Achievements:

A modular and flexible design was achieved by the use of kit-of-parts system. Further, the Ecotec process was incorporated for water reusage.

09 HEALTH AND WELL BEING

Goals:

Achieving thermal comfort for occupants through natural ventilation for sleeping units through passive strategies and minimal mechanical intervention (I-MAC guided). Maximising acoustic, visual and odour comfort. Providing primary healthcare for a better standard of living.

Achievements:

An indoor operative temperature of 30°C and 27°C in the living and office zones has been achieved respectively with minimal mechanical intervention.

10 VALUE PROPOSITION

Goals:

To provide a socio-economic design for the welfare of the construction workers while keeping in mind the budget provided by the project partner. To enhance the wellbeing and productivity of the workers.

Achievements:

An ergonomic design free of social boundaries is achieved that complies with the health, well-being, and safety standards.

Waste is another aspect believed by Sattva to bring the net zero cycle to completion. Therefore, we introduce waste disposal and management as the 11th contest.

11 WASTE DISPOSAL

Goals:

To utilize the potential for energy generation from biodegradable waste. To recycle and reuse non-biodegradable waste. To achieve proper sanitation and prevention of outbreaks of diseases on-site.

Achievements:

The quantity of LPG used per month has been reduced by 15.27%. 70% of the waste generated from kitchen and human waste has also been converted into bio-energy.

06 DESIGN DOCUMENTATION

6.1 ARCHITECTURAL DESIGN

Design Process

UNDERSTANDING THE REQUIREMENTS

We set out to design a temporary structure that can be easily assembled at the site and disassembled after use, for that the structure needed to be lightweight and easily transportable from one site to another.

SITE ZONING AND PLANNING

For the form development and structural strength of the project, several teams including energy performance, architectural design, resilience, engineering and operations-all worked together to provide an iteration with optimum surface area-to-volume ratio, efficient planning with minimum circulation and optimum use of the structural system. To judge the livability of the design, several aspects were considered, including solar heat gain, useful daylighting index, shadow analysis and energy analysis.

FORM, STRUCTURE AND LIVABILITY CHECK

For the form development and structural strength of the project, several teams including energy performance, architectural design, resilience, engineering and operations-all worked together to provide an iteration with optimum surface area-to-volume ratio, efficient planning with minimum circulation and optimum use of the structural system. To judge the livability of the design, several aspects were considered, including solar heat gain, useful daylighting index, shadow analysis and energy analysis.

MATERIAL AND TECHNOLOGY

We innovated a kit of parts system to make the structure replicable. The joineries for the same were engineered. The reduction of GWP was emphasized by considering local and recycled materials. The acoustic, visual odour and thermal comfort were maintained. The VoC values were kept in mind along with the affordability, economic feasibility and U values of the materials. The design was made to use a minimal amount of material and avoid space wastage, keeping the structure lightweight and transportable.

THE OPERATIONAL PHASE

During the operational phase, we are committed to using renewable energy sources and reducing energy demand through the use of energy-efficient fixtures, greywater recycling, rainwater harvesting, and blackwater reuse and treatment. We are also incorporating innovative waste disposal solutions such as biodigesters to generate biogas from the kitchen and human waste.

FUTURE

Following a systematic approach and after considering multiple perspectives our team has been able to reduce the resource consumption and environmental impact of the design considerably while delivering a livable, durable and replicable structure. It has been kept affordable and provides value for money to the project partner.

06 DESIGN DOCUMENTATION

Site Planning

Figure 03: Construction worker housing

- The design complies with L&T and NBC standards regarding area requirements, living standards, and fire hazards.
- The use of a grillage foundation, mild steel box sections for columns and beams, and panel-type walls provide ease of assembly and disassembly while minimizing disturbance to site topography.
- Single-storey structures using thinner mild steel box sections are used for offices and medical centres, while the existing brick kitchen setup is maintained.
- Various combinations of the design are possible by removing internal wall panels as needed.

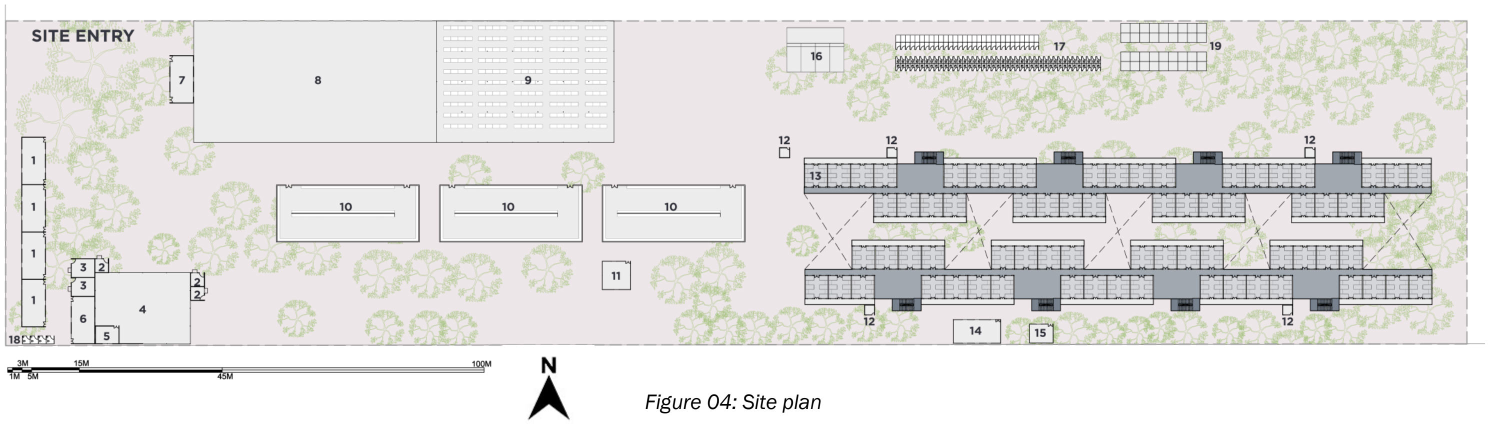


Figure 04: Site plan

1. Office Area (10000 x 5000)
2. Print & Vegetable Kiosks (3000 x 3000)
3. General Store (5000 x 4000)
4. Canteen & Dining (20000 x 15000)
5. Canteen Kitchen (4900 x 3600)
6. Incubation Unit (10000 x 5000)
7. Medical Centre (10000 x 5000)
8. Open Recreational Space (51000 x 25500)
9. Shaded Recreational Space (37250 x 25500)
10. Community Kitchen (30000 x 12000)
11. RO Plant (6000 x 6000)
12. Security Post (2200 x 2200)
13. Housing Units (5000 x 5000)
14. Warehouse (10000 x 5000)
15. Electrical Room (5000 x 4000)
16. Biodigester
17. Toilets (1000 x 1500)
18. Staff Toilets (1700 x 1700)
19. Open Washing Area (2000 x 2000)

- The existing trees on site are integrated into the landscape design of the project, providing better air quality and fostering community building among construction workers.
- Separate structures for washrooms, bathrooms, and washing areas provide a more affordable, easy-to-maintain, and efficient plumbing layout, enhancing the transportability of the complex.
- Structures such as a vegetable store, general store, and a minor cyber cafe are provided due to the lack of external movement restrictions around the site.

Figure 05: Courtyard between housing units

Figure 06: Solar panels on roof

06 DESIGN DOCUMENTATION

Housing Units

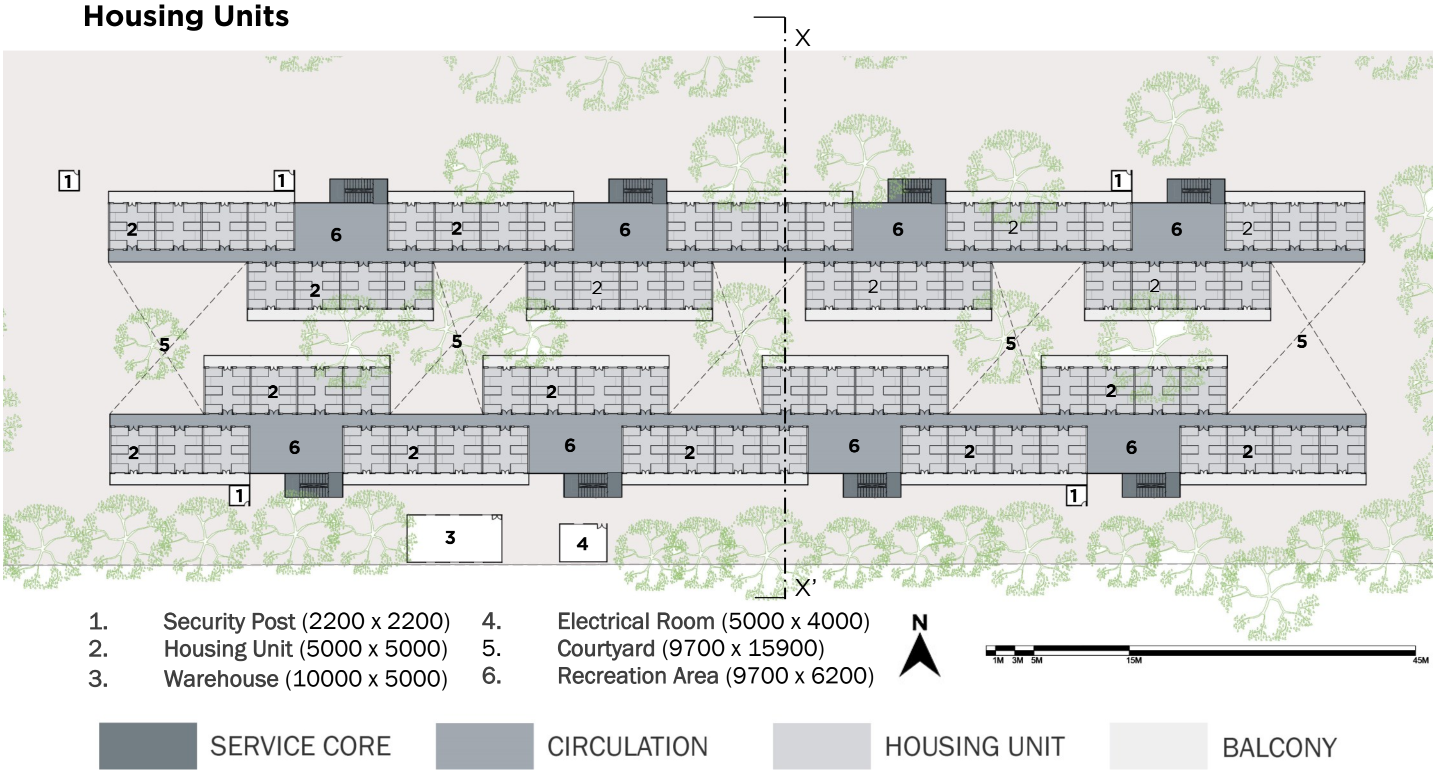


Figure 07: Typical floor plan

- The building includes multiple interaction spaces such as courtyards, corridors, and gathering spaces outside the units, creating pocket recreational areas that enhance social interaction and community building.
- ·Blocks are oriented to minimize solar heat gain and facilitate cross-ventilation, using balconies that act as sun breakers for the windows of the floor below.

Figure 08: Section XX'

A visual connection to nature is ensured in every unit, corridor, and collection space, providing a sense of openness and reducing feelings of claustrophobia.

06 DESIGN DOCUMENTATION

Single Unit Design

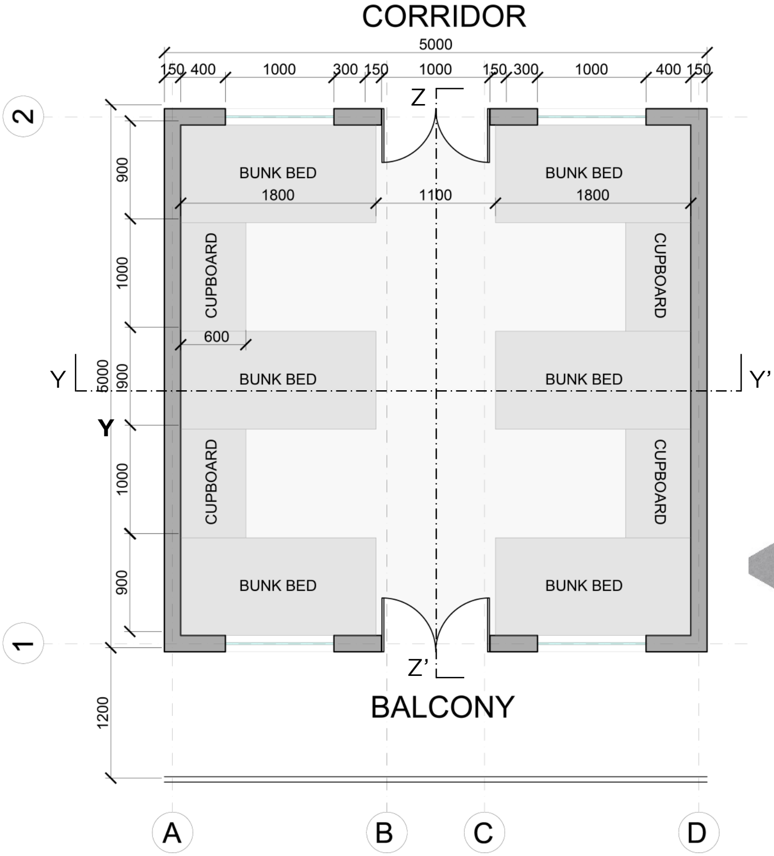


Figure 09: Single unit plan

Figure 10: Single unit of proposed CWH

- Every unit has its lightweight structural framework made of mild steel hollow box sections.
- 150mmX150mm sections are used for the main structure while 100mmX100mm sections are used as supporting members.
- Achieving a 3.6 m2/person floor area (as per NBC) in the housing cluster to ensure ample space for daily activities.
- A 5mX 5m module houses 12 people employing 6 bunk beds to provide 47% open floor space in the unit.

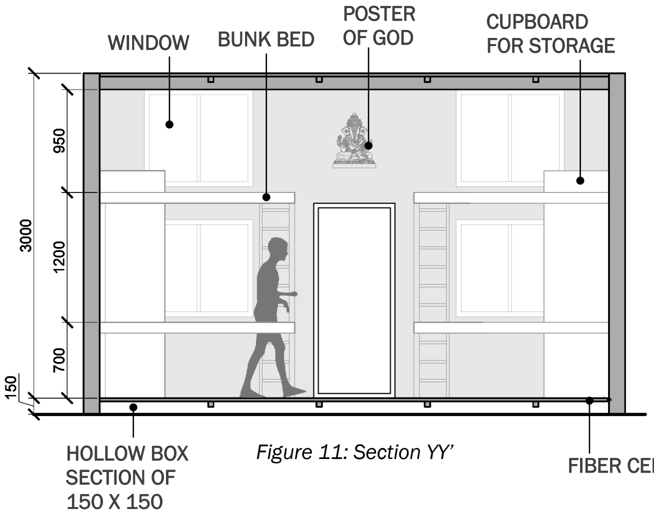


Figure 11: Section YY'

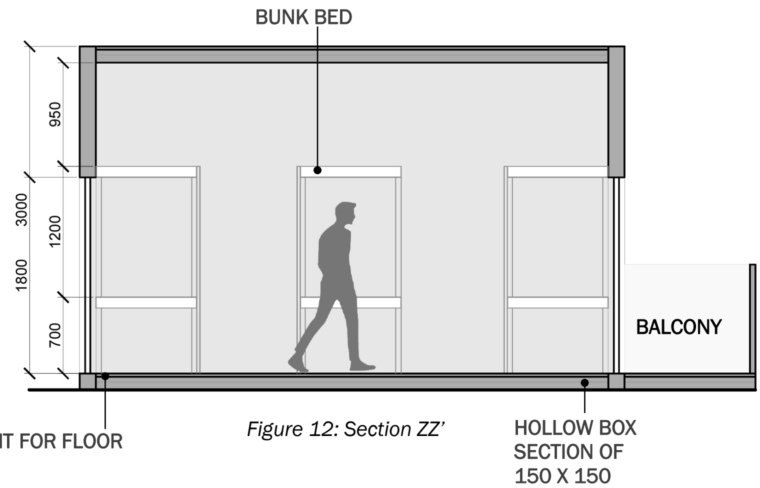


Figure 12: Section ZZ'

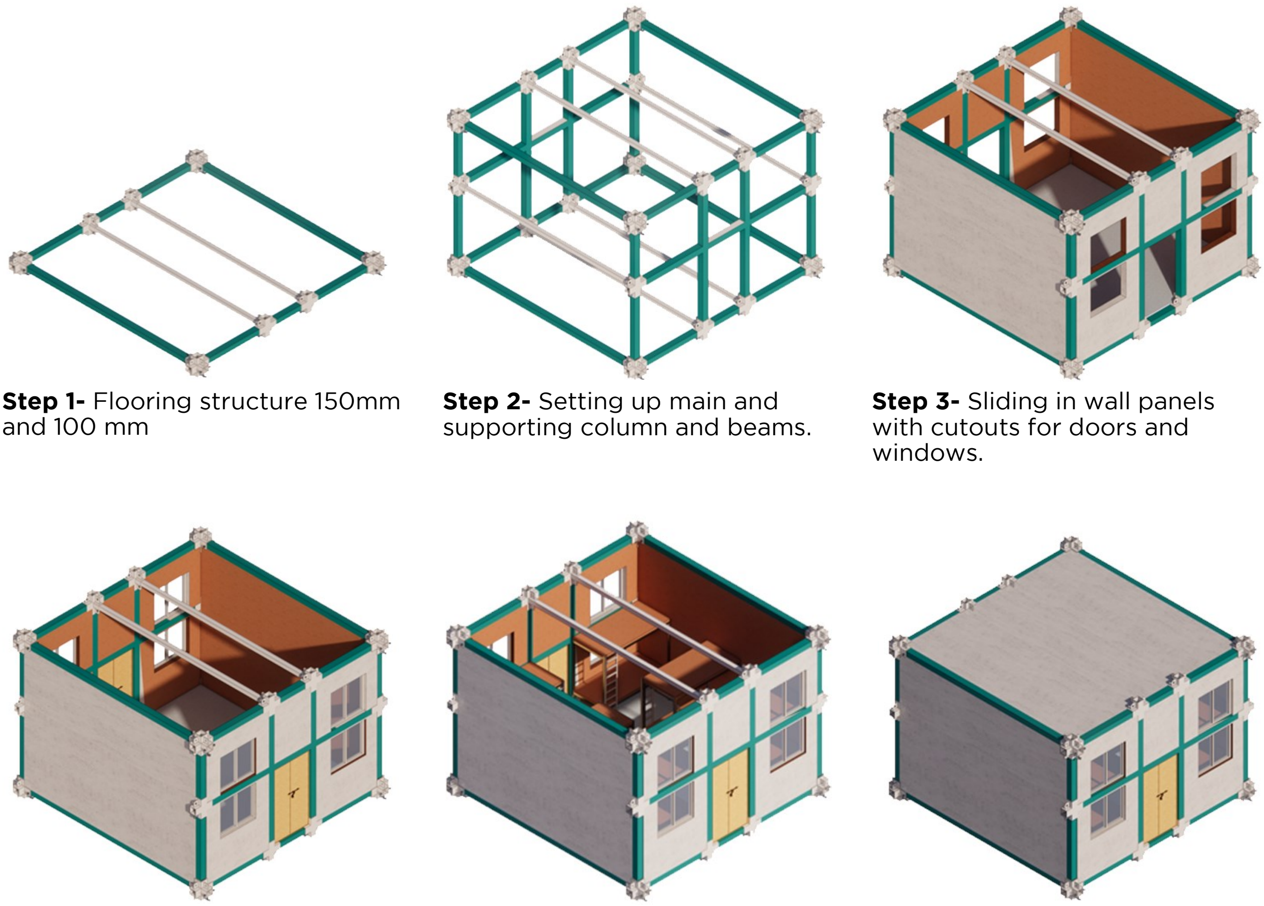
- ·Storage is provided below the bunk beds and as cupboards to ensure the orderliness of the rooms.
- ·Openings are provided on opposite sides of the unit at different levels to facilitate cross-ventilation and adequate daylight penetration.

Figure 13: Recreation area on all floor levels

Figure 14: View from the corridor

Assembly Process

The use of replicable modules made of high-quality, durable, and environmentally friendly materials ensures flexibility and adaptability to the changing needs of various user groups, as well as the efficient use of locally sourced/recycled resources.



Step 1- Flooring structure 150mm and 100 mm

Step 2- Setting up main and supporting column and beams.

Step 3- Sliding in wall panels with cutouts for doors and windows.

Step 4- Installing doors and windows in the cutouts.

Step 5- Adding furniture and fixtures.

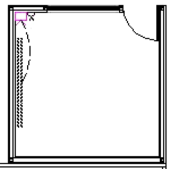
Step 6- Attaching the roof with the structure using main and support beams.

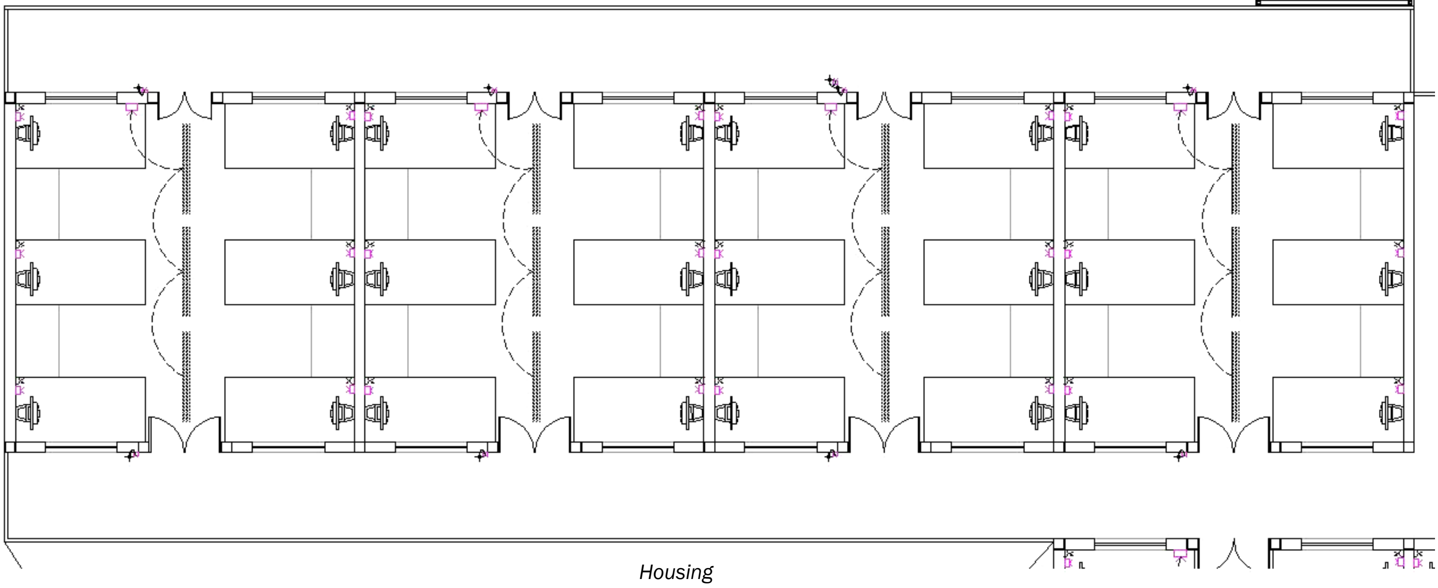
Figure 15: Assembly process

6.2 ENGINEERING AND OPERATIONS

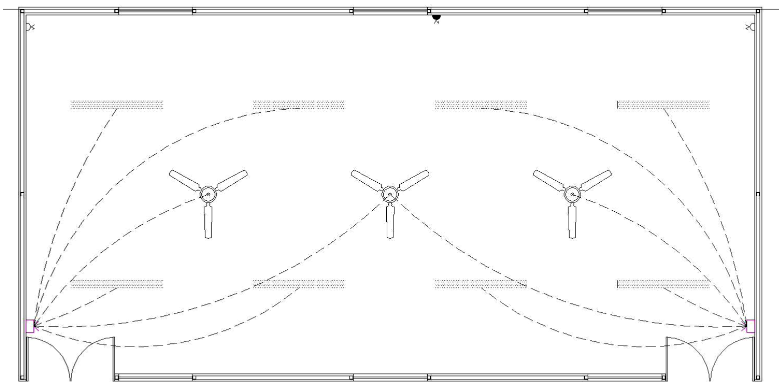
MEP Plan

The electrical plan has been thought of as an integrated approach. The lighting appliances have been placed with relation to window placements. The cooling appliances have been placed according to the space design.



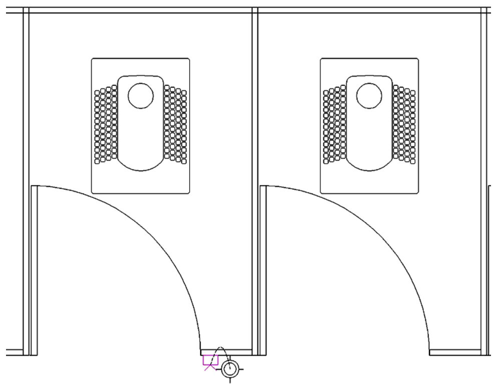


Housing

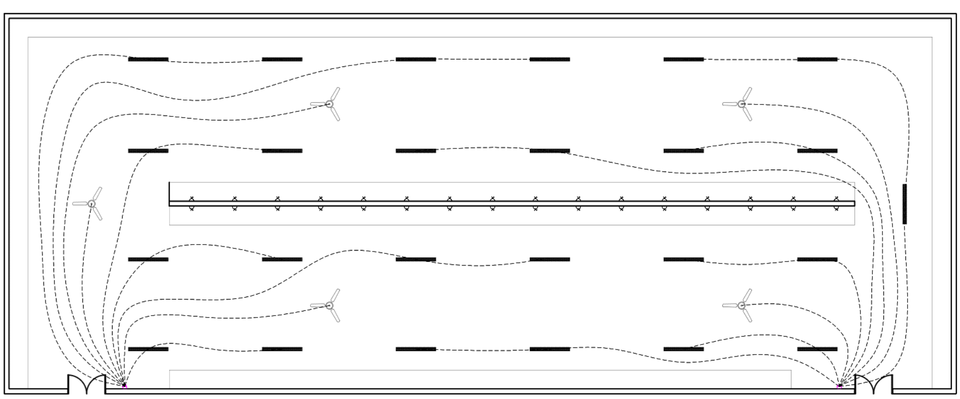


Office

There is one air conditioner installed in office area.



Toilet



Kitchen

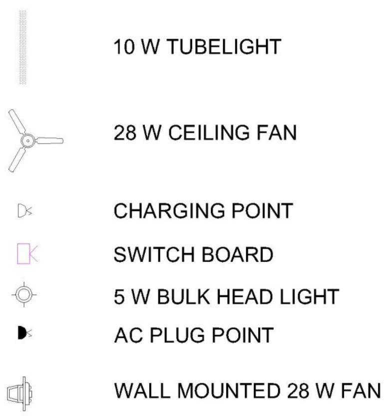


Figure 16: Electrical plan

06 DESIGN DOCUMENTATION

The plumbing plan depicts the piping layout and storage tanks placement on the site. The fresh water tanks are placed near the 3 kitchen for cooking and drinking water consumption. 8 tanks with treated grey water are placed near the bathing and washing area while 2 are placed near the kitchen for quick access. The 5 tanks containing treated black water are place around the toilets for flushing water demand. 3 tanks collect all the discharged water after treatment and sends it to the bio digester.

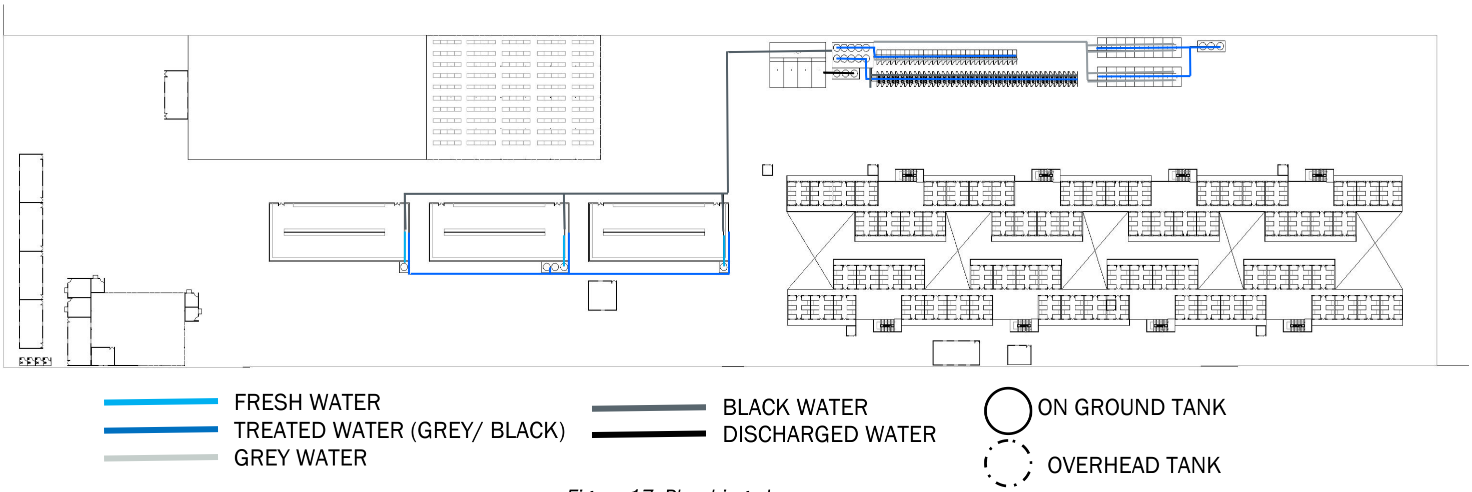


Figure 17: Plumbing plan

The solar panel system, HVAC and water treatment systems have been explained in energy and water performance sections respectively. Refer to the Appendix section for the DO's and DON'Ts of the building systems.

Structural System and joinery Design

12 persons are housed in a 5m X 5m module using stacked bunk beds. These units are then stacked to form a G+2 structure. By removing interior wall panels as needed, different configurations of the design are feasible. While the current kitchen layout is used because it is built in brick, single-story constructions for offices and medical facilities using thinner mild steel box sections.

The structural system is a temporary construction system made out of a hollow steel column grid system and panel types for the walls and floor. A modular unit is generated and repeated, keeping in mind the temporary and lightweight nature of the structure.

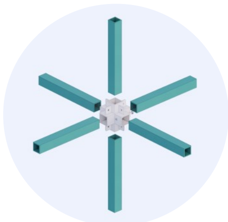


Figure 19 : Blowup detail A

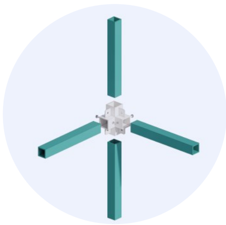


Figure 20 : Blowup detail B

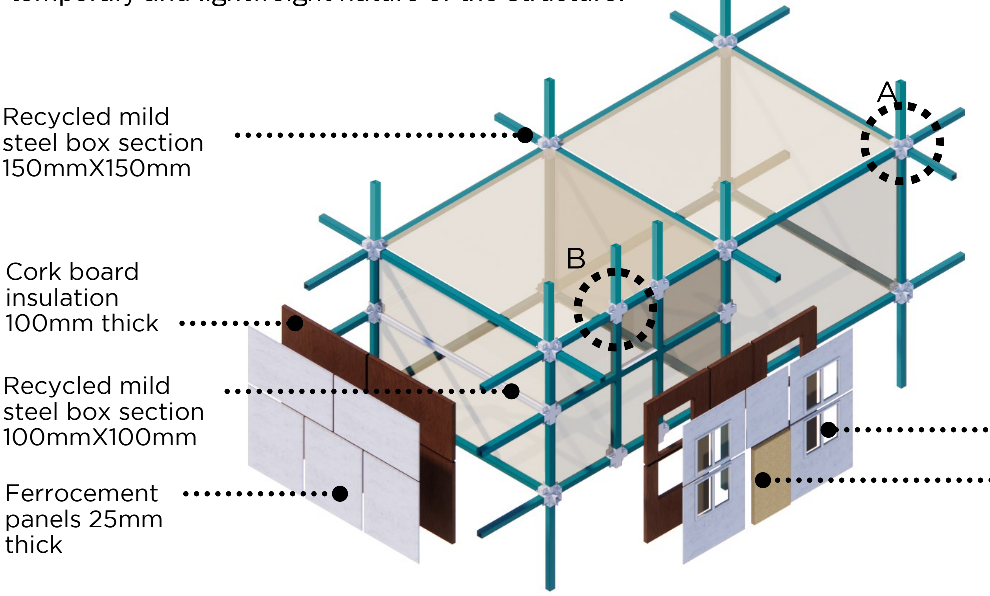


Figure 18: Exploded isometric of units

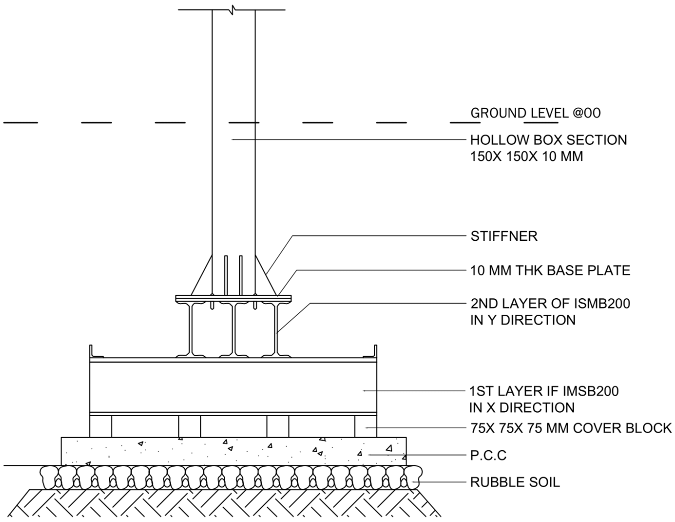


Figure 21 : Grillage foundation section

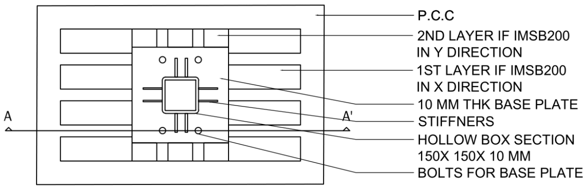


Figure 22: Grillage foundation plan

Ease of assembly and disassembly is ensured by the use of a grillage foundation. The load is distributed uniformly across a vast area using a two-tier grillage foundation with beams arranged at right angles. This also results in the least disturbance to site topography.

Mild steel box sections are used for the columns and beams, creating a grid system covered by panel-type walls. The structure consists of 150mm box sections, with a 25mm ferrocement exterior finish. It is insulated with 100mm cork and has a 25mm particle board interior finish.

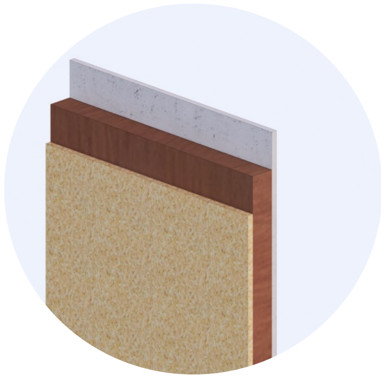


Figure 23: Wall joinery detail

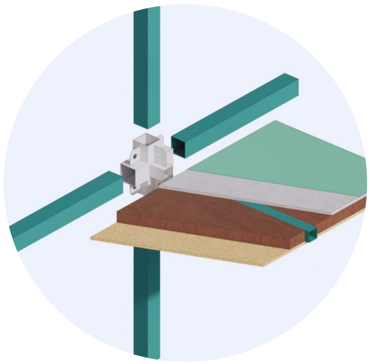


Figure 24: Floor joinery detail

The flooring system consists of a 100mm box section structure with a 3mm linoleum finish. The structure includes an 18mm fibre cement core and 100mm cork insulation for added thermal comfort. The underside of the flooring is finished with a 25mm particle board.

Structural Stability

Structural stability analysis on STAAD pro for the housing block was done to calculate the maximum allowable stress and displacement under stress. The occupancy load is 24 x 35 (user x unit) with value for live load is taken as 1 KN/m² and dead load 2.5 KN/m² according to material. Soil properties according to area were considered and proper wind load for Delhi taking wind speed 50m/s.

	A	B
1	<= 0	23.1067
2	23.1067	46.2133
3	46.2133	69.32
4	69.32	92.4266
5	92.4266	115.533
6	115.533	138.64
7	138.64	161.747
8	161.747	184.853
9	184.853	207.96
10	207.96	231.067
11	231.067	254.173
12	254.173	277.28
13	277.28	300.386
14	300.386	323.493
15	323.493	346.6
16	346.6	>= 369.706

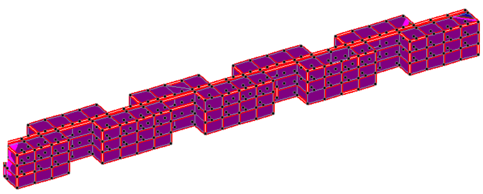


Figure 25: Structure under max absolute stress

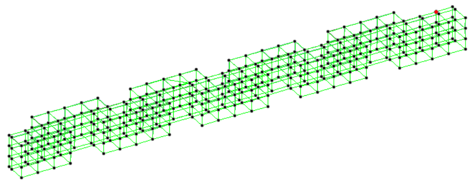


Figure 26: Structural nodal displacement under max absolute stress

On analysing we see that the structure is under the stress 46.2133 psi where as the ultimate permissible stress of steel is 348.091 psi .
Also the permissible displacement for hollow steel beam at nodes under max absolute stress is 20.84 mm and the system is displacing for 20.41 mm.
Hence , the system is stable under the current loading conditions.

Minimizing Waste of Material and Energy

Several strategies are employed in various ways, such as **using environmentally friendly materials that are readily available locally and have low VOC values,** to avoid and reduce material and energy waste. Steps such as **reducing construction errors** including improper panel cutting or **deformation during disassembly**, proper module storage to avoid **damage during storage or transportation**, and ordering the correct panel sizes after consulting the manufacturers to avoid receiving irregular shaped materials .By taking into account climatic factors while designing the envelope, HVAC, and lighting fixtures, it is possible to reduce energy waste and increase indoor comfort. To optimize the resources, manpower, equipment, and tools used in the process at a reasonable cost, steps including planning the material, transportation and labour were also done in the handling process.

	MATERIALS	TYPE	LENGTH (MM)	WIDTH (MM)	HEIGHT (MM)	THK. (MM)	DENSITY (KG/M3)	U VALUE (W/M^2K)	VOC (MG/M3)	EMBODIED CARBON (KGCO2.EQ)/KG	EFFECT ON WATER	COST (INR)
BASE	STEEL SHIPPING CONTAINER	-	52560	WRAPPED	3000	2 TO	7750	ASSEM-BLY U VALUE - 0.42	-	0.935	NONE	825/SQFT
	XPS - (INSULATION)		ALONG THE WALL			75-100	33		0	2.9	INTERIOR	51.4/SQFT
	PARTICLE BOARD - (WALL)		-	1830	2745	12	700		450	-1.3	INTERIOR	20/SQFT
	PARTICLE BOARD - (ROOF)		2440	1220	-	12	700		450		INTERIOR	20/SQFT
	LINOLIUM - (FLOORING)		500	500MM	-	3	1200		0	1.1	INTERIOR	19/SQFT
	BRICK WALL - (KITCHEN WALL)		-	-	-	115	1760	2	0	0.39	NONE	150/SQFT
	HDPE PANEL (WASHROOM PARTITION)		-	1220	2440	6	1000	44	0	-0.03	INTERIOR	110/SQFT
PROPOSED	FERROCEMENT PANEL - (WALL)	T1	-	2440	1220	25	1350	2.784	-	0.29	NONE	29/SQM
		T2	-	1830	1220	25	1350	2.784	-		INTERIOR	29/SQM
	PARTICLE BOARD - (WALL)	T1	-	2440	1220	25	700	2.6	450	-1.3	INTERIOR	20/SQFT
		T2	-	1830	1220	25	700	2.6	450		INTERIOR	20/SQFT
	PARTICLE BOARD - (ROOF)	-	2440	1220	-	25	80	2.6	450		INTERIOR	20/SQFT
	CORK BOARD - (INSULATION)	-	ALONG SURFACE			100	100	0.4	150	-1.4	INTERIOR	250/SQ FT
	STEEL SECTIONS (59% RECYCLED CONTENT)	T1	150	150	3000	10	7800	-	-	0.75	NONE	60/KG
		T2	50	50	3000	5	7800	-	-		NONE	60/KG
	FIBRE CEMENT BOARDS - (FLOORING)	-	2440	1220	-	18	1200	11.11	0	0.41	NONE	65/SQFT
	LINOLIUM - (FLOORING)	-	500	500	-	3	1200	100	0	1.1	INTERIOR	19/SQFT
	U-PVC FRAME - (WINDOW)	W1	-	1000	900	-	2.8	-	0	3.9	INTERIOR	500SQFT
		W2	-	1000	1200	-	2.8 KG/	-	0	3.9	INTERIOR	500SQFT
	LOW E GLASS (SHGC- 0.36 AND VLT- 71%) - (WINDOW)	G1	-	1000	900	4	2500	1	0	7/SQM	NONE	100/SQ FT
		G2	-	1000	1200	4	2500	1	0	7/SQM	NONE	100/SQ FT
	PARTICLE DOOR - (DOOR)	D1	-	750	1800	25	700	2.6	450	-1.3	INTERIOR	72/SQ
		D2	-	1000	1800	25	700	2.6		-1.3	INTERIOR	72/SQ
		D3	-	1200	1800	25	700	2.6		-1.3	INTERIOR	215/SQFT
	HDPE PANEL - (WASHROOM WALL)	-	-	1220	2440	6	1000	44	0	-0.03	INTERIOR	110/SQFT
	PUFF PANELS - (ROOF)	-	2440	1220	-	60	40	0.35	0	3	NONE	120/SQFT

Table 02: Comparison table of base case material to proposed case material

Material Scalability and Technology

Comparing the base case envelope and other materials to the proposed case ,these are substituted according to the resource availability along with an optimised assembly selection based on the heat transfer characteristics and cost proponent. The **climate-responsive integrated framework is used** as a tool to find the best way to reach net zero efficiency that are **adapted to the site's occupant capacity and prevailing context.** This allows the module the ability to be altered and used in a variety of settings, which is advantageous to the project partner.

6.3 EMBODIED CARBON

	MATERIALS	THK. (MM)	DENSITY (KG/ M3)	EC (KGCO2.EQ)/ KG	TOTAL AREA (M2)	TOTAL AMOUNT USED (KG)	TOTAL EC OF MATERIAL (KGCO2.EQ)	TOTAL EC OF ASSEMBLY (KGCO2.EQ)	EC OF FUNCTIONAL UNIT (KGCO2.EQ/SQM)
BASE	**WALL**								
	ASSEMBLY 1								
	STEEL SHIPPING CONTAINER	2.00	7,750.00	0.94	24,300.0	376,650.00	352,167.75	330,297.75	**20.00**
	XPS - (INSULATION)	100.0	33.00	2.90	16,200.0	53,460.00	155,034.00		
	PARTICLE BOARD	12.00	700.00	-1.30	16,200.0	136,080.00	-176,904.00		
	ASSEMBLY 2								
	HDPE PANEL - (WASHROOM PARTITION)	6.00	1,000.00	-0.03	461.00	2,766.00	-82.98	-82.98	**-0.18**
	ASSEMBLY 3								
	BRICK WALL - (KITCHEN WALL)	115.00	1,760.00	0.39	630.00	127,512.00	49,729.68	49,729.68	**78.94**
	FLOOR								
	STEEL SHIPPING CONTAINER	2.00	7,750.00	0.94	10,125.0	156,937.50	146,736.56	164,354.06	**24.30**
	XPS - (INSULATION)	100.00	33.00	2.90	6,750.00	22,275.00	64,597.50		
	PARTICLE BOARD	12.00	700.00	-1.30	6,750.00	56,700.00	-73,710.00		
	LINOLIUM	3.00	1,200.00	1.10	6,750.00	24,300.00	26,730.00		
	FENESTRATION								
	U-PVC FRAME (1200X1000)	-	2.8 KG/M	3.90	3780M	10,584.00	41,277.60	170,877.60	**50.20**
	GLASS	4.00	2,500.00	12.00	1,080.00	10,800.00	129,600.00		
	ROOF								
	STEEL SHIPPING CONTAINER	2.00	7,750.00	0.94	10,125.0	156,937.50	146,736.56	137,624.06	**20.40**
	XPS - (INSULATION)	100.00	33.00	2.90	6,750.00	22,275.00	64,597.50		
	PARTICLE BOARD	12.00	700.00	-1.30	6,750.00	56,700.00	-73,710.00		
	STRUCTURAL MATERIAL								
	STEEL SECTIONS (50X 50MM)	5.00	6 KG/M	2.50	1,863.00	11,178.00	27,945.00	27,945.00	**53.70**
TOTAL SUPERSTRUCTURE									**247.36**

Table 03: Embodied carbon calculations for base case

Shipping containers are used as structure and exterior finish, lined with XPS insulation. One-side laminated particle boards are used for internal finishing, with linoleum flooring and u-PVC window frames with float glass for fenestrations.

The goal was to create a durable, easily transportable, temporary net-zero embodied carbon structure using recycled and locally available materials.

Corkboard insulation was used instead of extruded polystyrene insulation to reduce the U-value of walls and act as a carbon sink, reducing overall GWP

The proposed design considers user comfort and uses Low E glass (SHGC- 0.36 and VLT- 71%). Initially, 24 workers resided in an area of 45 sq m with 6 windows only to fulfil ventilation and lighting demands. We have increased the window to 8 and decreased the area and users to 25 sq m and 12 users, respectively.

This not only increases the reflected daylight, air quality, and natural ventilation but the use of low E, Low carbon glass also reduces the embodied carbon/sqm of glass used.

Steel sections used in the proposal are made of 59% recycled steel, which has 70% less embodied carbon than virgin mild steel hollow sections. The kitchen present on-site was reused, resulting in 0 kg CO2 eq for kitchen walls and truss structure.

	MATERIALS	THK. (MM)	DENSITY (KG/ M3)	EC (KGCO2.EQ)/ KG	TOTAL AREA (M2)	TOTAL AMOUNT USED (KG)	TOTAL EC OF MATERIAL (KGCO2.EQ)	TOTAL EC OF ASSEMBLY (KGCO2.EQ)	EC OF FUNCTIONAL UNIT(KGCO2.EQ/ SQM)
PROPOSED	**WALL**								
	ASSEMBLY 1								
	FERROCEMENT PANEL	25.00	1,350.00	0.29	9,034.00	304,897.50	88,420.00	-243,580.00	**-27.00**
	PARTICLE BOARD	25.00	700.00	-1.30	9,034.00	158,095.00	-205,523.50		
	CORK BOARD	100.00	100.00	-1.40	9,034.00	90,340.00	-126,476.00		
	ASSEMBLY 2								
	HDPE PANEL - (WASHROOM WALL)	6.00	1,000.00	-0.03	946.00	5,676.00		-170.30	**-0.18**
	ASSEMBLY 3								
	BRICK WALL	STRUCTURE REUSED, HENCE **0.0** EMISSIONS FOR THIS INTERVENTION							**0.00**
	FLOOR								
	FIBRE CEMENT BOARDS	18.00	1,200.00	0.41	8,453.00	182,585.00	74,860.00	-202,314.00	**-23.90**
	PARTICLE BOARD	25.00	80.00	-1.30	8,453.00	147,927.50	-192,306.00		
	CORK BOARD	100.00	100.00	-1.40	8,453.00	84,530.00	-118,342.00		
	LINOLIUM	3.00	1,200.00	1.10	8,453.00	30,430.00	33,474.00		
	FENESTRATION								
	WINDOW TYPE 1								
	U-PVC FRAME (1200X1000)	-	2.8 KG/M	3.90	60.00	616.00	2,402.40	2,822.00	**47.00**
	LOW E GLASS	4.00	2,500.00	7/SQM	60.00	60SQM	420.00		
	WINDOW TYPE 2								
	U-PVC FRAME (900X1000)	-	2.8 KG/M	3.90	1,512.00	17,875.00	69,712.50	80,296.00	**53.00**
	LOW E GLASS	4.00	2,500.00	7/SQM	1,512.00	1512SQM	10,584.00		
	ROOF								
	PUFF PANELS	60.00	40.00	3.00	5,880.00	14,112.00	42,336.00	42,336.00	**7.20**
	STRUCTURAL MATERIAL								
	ASSEMBLY 1								
	STEEL SECTIONS (59% RECYCLED) (150X150)	10.00	34 KG/M	0.75	8560M	291,040.00	218,280.00	291,360.00	**34.47**
	STEELSECTION(59% RECYCLED) (100X100)	5.00	6 KG/M	0.75	8120M	97,440.00	73,080.00		
	ASSEMBLY 2								
	KITCHEN TRUSS STRUCTURE	STRUCTURE REUSED, HENCE **0.0** EMISSIONS FOR THIS INTERVENTION							**0.00**
	ASSEMBLY 3								
	STEELSECTIONS(59% RECYCLED) (50X50)	5.00	6 KG/M	0.75	1251M	7,506.00	5,629.50	5,629.50	**2.14**
	TOTAL SUPERSTRUCTURE								**92.73**

Table 04: Embodied carbon calculations for proposed case

This cycle is completed by reducing the net embodied carbon of proposed design to 102.68% from the baseline.

Reuse of existing materials and structures like that of kitchen.

Use of 59% recycled steel in the structural system.

Figure 27: 3R cycle in embodied carbon

Refer to the appendix section for embodied carbon tool summary and calculations.

6.4 INNOVATION

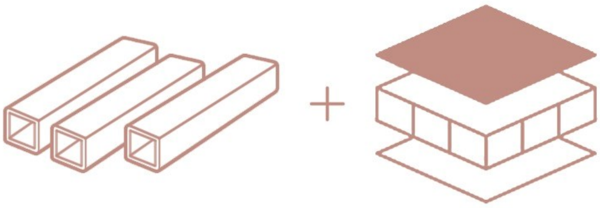
Two innovative measures have been taken to cater to the problems of modularity and water treatment. These will benefit the project partner (in terms of affordability, scalability and flexibility) and the workers (in terms of better living conditions, safety, and availability of good quality water).

Innovation 1: Kit-Of-Parts

Kit of Parts is an object-oriented construction approach which requires integration and coordination between architects, engineers, manufacturers and builders for the most efficient and cost-effective design. This can also be understood as a pool of different building elements where every element is optimized for production, assembly and disassembly.

Problem: To make the structure more modular and sustainable as compared to the present container system, which will allow for easy assembly, dismantling and transportation (in terms of cost, number of vehicles, material size etc).

Technology: The structural arrangement responds extremely efficiently for assembly, dismantling and transport. The details and logistics of the unit are worked out keeping in mind the material which is economically feasible and also durable. There are no complex joineries introduced to speed up construction. The corner joint in the structure is designed to cater to loads as well as to help in controlled future expansion.



The kit consists of mild steel hollow box sections, fibre cement boards, ferro-cement panels, insulation and particle boards.

Market: We have used standard materials for construction which are easily available in the Indian market and are suitable for all climatic conditions. The materials used are well-researched and produced by credible manufacturers and have their EPDs widely available.

Scalability: The usage of panels for walls and floors gives the liberty of designing according to the site all over the country making the project scalable. It is stackable, and hence can be used on sites having area constraints.

Cost, Benefits and Impacts: The use of a kit-of-parts system provides a low-waste, fast programme and cost-efficient approach. It allows for easy assembly, disassembly and transportation. Its benefits are:

Replicable design, the modules can be modified according to usability. Cluster or linear arrangements can be done as per the requirement.

It enables designing for maximum and better space utilization.
It ensures better product quality.

This system provides a cost-efficient approach.
Lower storage cost.

It saved the cost from the base case (container system) by 15.43%.

This system reduced total carbon emissions by 102.68%.
Materials used have lower emissions factor.

Parts can be reused with minimum environmental impact.
Steel with high recycled content is used.

06 DESIGN DOCUMENTATION

Innovation 2: EcoTec Process
The technology called the EcoTec Process basically consists of Herbicide Treatment Programmes like Ecoclean 2300 and the combination of Ecoclean 20 and Ecoclean 50 as systems are proposed on-site for black and grey water treatment respectively.

Problem: To treat the greywater and blackwater to desirable quality so that they can be reused for various purposes like flushing, cleaning, and groundwater recharge. It will help to reduce the problem of water shortage and achieve a net zero water cycle.

Technology: Major processes involved are flocculation and sedimentation, disinfection, and end-stage filtration using a sand carbon filter.

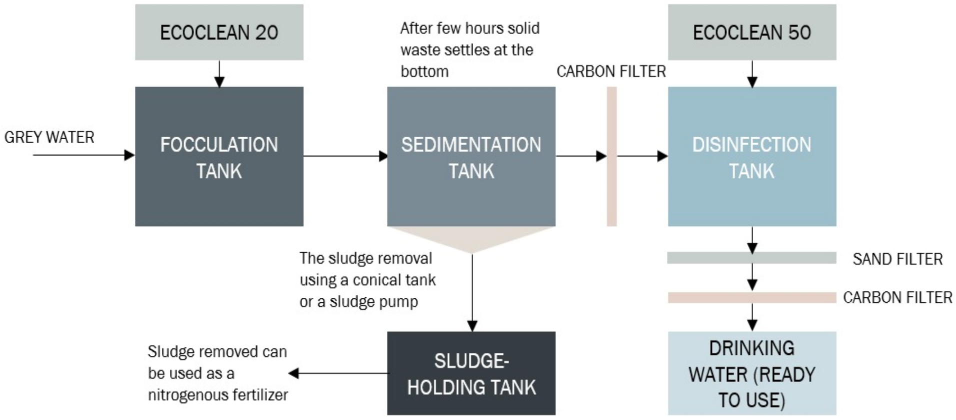


Figure 28: EcoTec treatment process for greywater

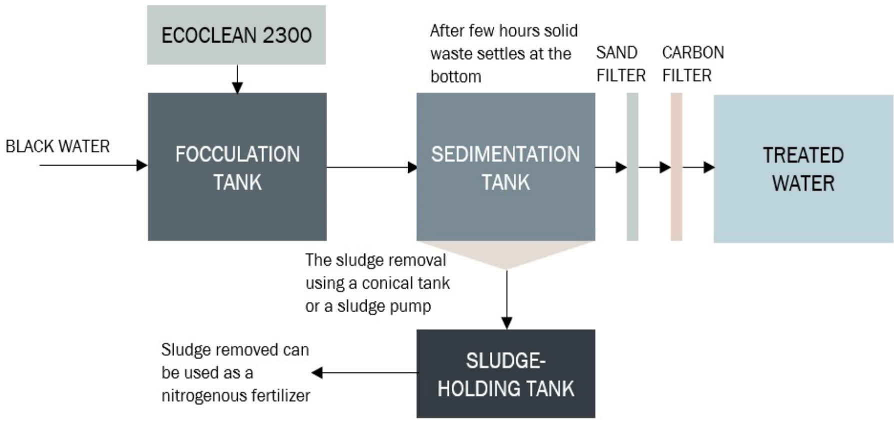


Figure 29: EcoTec treatment process for blackwater

Market: This technology has been developed by Ecohealth Products Pvt Ltd, Chennai, Tamil Nadu. Loyola College had taken the initiative to come up with this project and the EcoTec technology has been tested by recognized laboratories like the SGS Labs and ABC Techno Labs.
It targets wastewater treatment in various institutions, industries etc. The process is quite suitable to be used in an STP where bulk quantities of sewage water are collected, especially in urban areas. Further, Ecoclean-20 is effective across a wide range of pH and temperatures without modification. It is an ideal de-scaling and antiscalant for water used in boilers, cooling towers, chilling units and cold storage. On the other hand, Ecoclean-50 is a healthy, non-irritating disinfection option for swimming pools, water parks, ponds and tanks.

Scalability: The company has dealers in many different cities as well as international dealers. Further, cylindrical tanks and filters are also readily available in the market. However, the availability of conical tanks might pose a problem, but it can be compensated by a sludge pump. Thus, these herbal products and other materials are easily available in the market, enhancing the scalability of the technology and it is a modular and versatile solution.

06 DESIGN DOCUMENTATION

Cost, Benefits and Impacts: It is an eco-friendly and cost-effective sewage water treatment system.

Use of herbal, organic, food-grade, non-toxic products for sewage water treatment. As a result, check the greenhouse effect.

It is sympathetic to the existing biological flora.
It minimizes sludge and gives its alternative use.
It eliminates the need for chemicals like Polymers, Alum, PAC, Chlorine, etc.

Maximum time required by the process is 5-7 hours which increased capacity utilization.

The use of EcoTec process reduces the CAPEX and OPEX costs of WTP/ STP.

Product costs:
Ecoclean 20- ₹750/kg, Ecoclean 50- ₹950/l and Ecoclean 2300- ₹880/kg

Reduces the power requirements to the various equipment required for treatment and hence is a low power consumption process.

Progress Assessment Of Innovations

INNOVATION	KIT-OF-PARTS	ECOTEC PROCESS
TECHNOLOGY READINESS LEVEL		
The technology is in basic research		
Applied research begun and practical application has been identified	✓	✓
Preliminary testing done and feasibility established in a laboratory environment	✓	✓
Preliminary testing done and feasibility established in a field environment	✓	✓
INNOVATION READINESS		
The product or service has been integrated in design for the intended application	✓	✓
The cost estimates and ROI calculations have been done	✓	✓
Partnerships have been developed with the relevant industry		
The proposed innovation has been reviewed by the partner/s and their feedback has been incorporated		
The proposed innovation has been endorsed by the partner/s		
The product or service has been prototyped for the intended application		
The prototype has been tested in the field for the intended application		
COST AND BENEFITS		
The proposed innovation has potential to reduce greenhouse gas emissions	✓	✓
The greenhouse gas emissions reductions have been quantified	✓	
The other environmental impacts that can be reduced have been listed	✓	✓
The other environmental impacts that can be reduced have been quantified	✓	
Cost and benefits have been estimated to show an ROI		

Table 05: Progress Assessment of innovations

6.5 WATER PERFORMANCE

The base case for freshwater demand is 161 LPHD (*As justified in the Appendix*) for CWH buildings and 50 floating population of the office.
By implementing measures such as adopting water-efficient methods, the proposed case seeks to **reduce water demand by 63.35 %, resulting in a freshwater demand of 59 LPHD** (*Water consumption table compared to baseline in appendix).* Strategies like using 2 LPM flow fixtures, recycling grey and black water, collecting rainwater, and adopting behavioural changes were proposed and implemented.
The goal of net positive was achieved and annually 54,52,677.875 L of water was sent back to the source by groundwater recharge.

		CONSUMPTION	RAINFALL			WATER SOURCES					
MONTH	DAYS IN MONTH	DOMESTIC USE (L)	RAIN FALL IN MM	NO. OF RAINY DAYS	RAIN WATER POTENTIAL (L)	RAINWATER SEND TO THE GROUND (L)	RAIN WATER USED (L)	MUNICIPAL WATER(L)	TREATED GREY WATER(L)	TREATED BLACK WATER (L)	TREATED WATER FOR GROUND RECHARGE
Jul	31	45,72,500	471	14	5,17,49,600	5,50,000	6,45,203	0	27,60,938	11,66,375	6,12,928.125
Aug	31	45,72,500	265.6	14	2,91,81,880	5,50,000	6,45,203	0	27,60,938	11,66,375	6,12,928.125
Sep	30	44,25,000	528.2	7	2,90,17,170	5,50,000	6,24,390	0	26,71,875	11,28,750	5,93,156.25
Oct	31	45,72,500	123.9	2	19,44,720	5,50,000	6,45,203	0	27,60,938	11,66,375	6,12,928.125
Nov	30	44,25,000	0	1	0	0	0	6,24,390	26,71,875	11,28,750	5,93,156.25
Dec	31	45,72,500	0	1	0	0	0	6,45,203	27,60,938	11,66,375	6,12,928.125
Jan	31	45,72,500	31	3	7,32,210	93,804	6,45,203	0	27,60,938	11,66,375	6,12,928.125
Feb	28	41,30,000	0	3	0	0	0	5,82,764	24,93,750	10,53,500	5,53,612.5
Mar	31	45,72,500	0	3	0	0	0	6,45,203	27,60,938	11,66,375	6,12,928.125
Apr	30	44,25,000	0	1	0	0	0	6,24,390	26,71,875	11,28,750	5,93,156.25
May	31	45,72,500	0	3	0	0	0	6,45,203	27,60,938	11,66,375	6,12,928.125
Jun	30	44,25,000	9	5	3,33,500	3,33,500	0	6,24,390	26,71,875	11,28,750	5,93,156.25
Total	365	5,38,37,500				26,27,304	32,05,202	43,91,543	3,25,07,812.5	1,37,33,125	72,16,734.375

Table 06: Comparison of baseline to proposed water consumption table

Wastewater Treatment System

The freshwater demand was further reduced to **8.325 LPHD** to fulfil the drinking ,cooking and small amount of bathing water demands by using efficient grey and black water treatment systems. The grey water from bathing, cleaning utensils, cleaning cloths and others are collected and treated, whereas the water from drinking, cooking and flushing is collected as black water and reused to fulfil the flushing demands after treatment.

Ecoclean 2300 and the combination of Ecoclean 20 and Ecoclean 50 as systems are proposed on-site for black and grey water treatment respectively.
For the **grey water**, the combination of Ecoclean 20, and Ecoclean 50 provides an **efficiency of 95%** and takes around a capacity of 30 m3.The system provides a **Ph of 7.10, BOD of 12 mg/l, TSS of 23 mg/l** and also offers **the absence of bacterial suspended like E.COLI.** The water is supposed to go through a sand and carbon filter and is collected where Ecoclean 20 is added to remove suspended solids. Ecoclean 50 is then used to remove the bacterial suspends and then is again filtered and sent for daily use. For the rainwater and groundwater recharge treatment, the same system as that for grey water is used.
For the **black water**, the Ecoclean 2300 is used which provides an **efficiency of 70%.** The system provides a **Ph of 6.93, BOD of 26 mg/l, and TSS of 158 mg/l.** The water is supposed to go through a sand and carbon filter and is collected where Ecoclean 2300 is added to remove suspended solids and bacteria to some extend. This water is then filtered and send for flushing.

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Rainwater Harvesting

Due to space and budget restrictions, retaining that much rainwater is not feasible with the design's temporary, low-footprint facility. Hence it was decided to use a recharge pit all year and municipal water resource to fulfil fresh water demand of the non-monsoon months(Feb, Mar, Apr, May, Jun, Dec, Jan)

The roof, together with the hardscapes and softscapes, received the most rainwater of all the catchment zones. The rainwater collection filter used for this water automatically washes out dirt and debris.

Rainwater will be collected during the monsoon season, utilised as needed, and the remainder being refilled into the groundwater. Requirements for drinking, cooking and small amount of bathing is fulfilled by this water collected on the rainy day.

AREA	AREA COVERED (SQM.)	RUNOFF COEFF.	RUNOFF POTENTIAL
ROOF	5,880	1	5,880
SOFT PAVED	14,525	0.3	4357.50
HARD PAVED	495	0.7	346.50
TOTAL	15,000		10584
TOTAL POTENTIAL		50.64%	

Table 07: Runoff potential

Ground Water Recharged

To optimise on-site storage, groundwater was recharged. The ground is recharged in two steps, firstly during the rainy season **5,50,000 L** of surcharge is captured in the months of July, August, September and October and sent to recharge pits. For step two the untreated water from grey and black water is collected daily and is then treated to achieve **19,564.0625 LPD** that is again sent to recharge pits.
The discharge from treating this is used to fuel the bio digester, ending the cycle within the site.
This results in an **annually 54,52,677.875 L** of ground water recharge.
In the case of disaster, the current tank used for potable, treated grey and black water provides an **autonomy of 2 days.**

Refer to the appendix section for net zero cycle design & calculations and to the Resilience section for the autonomy calculation of water.

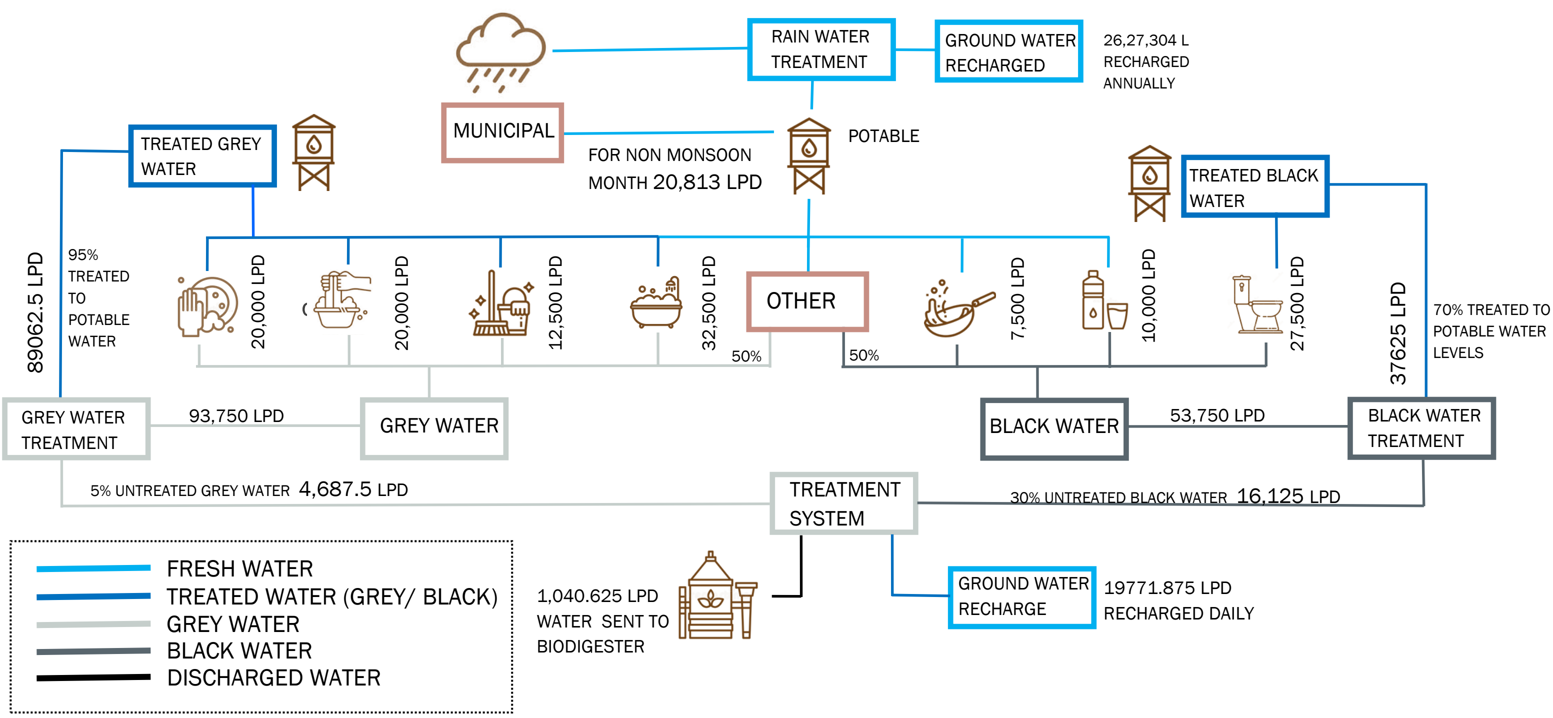


Figure 30: Water cycle diagram

6.6 WASTE DISPOSAL AND MANAGEMENT

The project aims to reduce waste entering landfills by reducing, reusing, and recovering waste streams.

We begin by determining the sources and types of waste. Both wet and dry waste will be treated on-site. Hazardous waste is dealt with at the occupant level. Waste will be collected from the separated dustbins envisaged for the site near the housing and kitchen.

Most of the biogas digesters we see are permanent construction and have very high operating and maintenance costs. 70% of the waste generated is biodegradable from Kitchen waste and human waste which can be converted into bio-energy. The Flexi biogas system is an inexpensive, portable and compact solution.

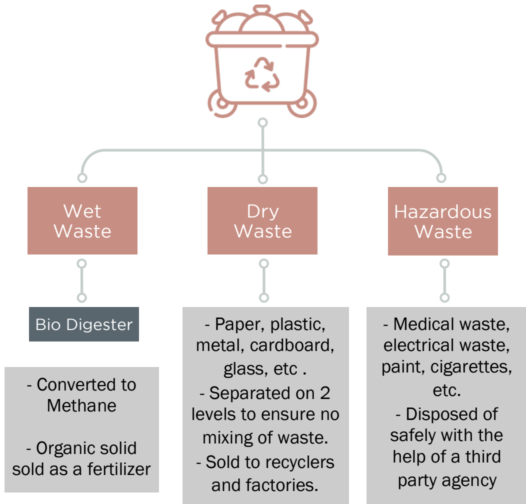
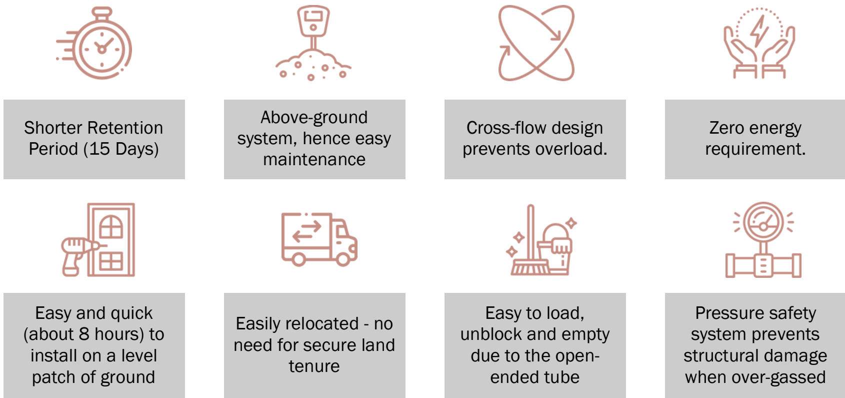


Figure 31: Typical Flexi biogas system



A typical FBS consists of four major components: plastic input and output pipes, a reinforced plastic digester bag, plastic piping to deliver biogas to storage, and a plastic greenhouse covering.

As per research, the average amount of human waste produced by individuals doing labour-intensive work and having a vegetarian diet is 330gm. Hence, 2500 people generate 837.5 kg of human waste per day. The waste is fed to the PVC tank, where the anaerobic process happens.

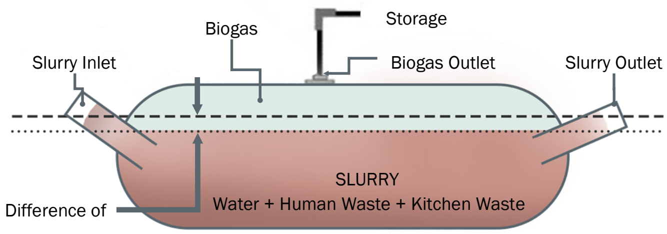


Figure 32: Typical section through a biodigester tank

The greenhouse tunnel is critical in maintaining a steady temperature of about 50C(approx) and accelerates methane extraction. The daily feedstock has additional kitchen waste; based on a 15-day retention time, a biodigester of volume 36m3 is appropriate. The feed can be divided into four 9m3 digester tanks. The tanks are cleaned every 2-3 weeks depending upon the usage.

The Buswell calculation approach yields 35.7 m3 of biogas each day. The biogas generated is stored in balloon tanks. The gas is kept safe by employing pressure valves and a separate container box to keep the tanks safe. We calculated the daily LPG requirement of 216L by considering the average energy utilised for everyday meals. If biogas is used instead of LPG, then we see a reduction of 15% in LPG usage.

Refer to the appendix section for the calculation of biodigester and LPG reduction.

6.7 ENERGY PERFORMANCE

S.NO.	APPLIANCES	NO.OF APPLIANCES	WATTAGE OF EACH APPLIANCE	AVERAGE WORKING HOURS (DAILY)	ENERGY CONSUMPTION (Wh/ day)
LIVING ZONE					
01	LED TUBELIGHT	630	10	4	25,200
02	WALL MOUNTED FAN	2520	28	6	4,23,360
03	LED BULKHEAD LIGHT	124	5	0.5	310
04	PHONE CHARGER	1260	5	2	12,600
KITCHEN					
05	LED TUBELIGHT	75	18	3	4,050
06	CEILING FAN	15	28	2	840
WASHROOMS AND BATHROOMS					
07	LED BULKHEAD LIGHT	78	5	0.5	195
OFFICIAL ZONE					
08	LED TUBELIGHT	48	10	2	960
09	CEILING FAN	18	28	6	3,024
10	PHONE CHARGER	12	5	1	60
11	DESKTOP	5	100	6	3,000
12	TV	2	45	1	90
13	AC	6	252	2	3,024
SECURITY POST					
14	LED TUBELIGHT	5	10	15	750
15	WALL MOUNTED FAN	5	32	8	1280
16	PHONE CHARGER	5	5	1.5	37.5
AMENITIES					
17	LED TUBELIGHT	17	10	2	340
18	CEILING FAN	5	32	6	960
19	PHONE CHARGER	5	5	1	25
20	DESKTOP	1	100	1	100
21	PRINTER	1	30	1	30
22	PUMPS	4	405	6	9,720
TOTAL DAILY ENERGY CONSUMPTION= 489.5 kWh/day					
ANNUAL ENERGY CONSUMPTION= 1,78,833.76 kWh/year					

Table 08: Proposed energy consumption
(The average working hours consider that cooling appliances won't get used during the winter months in Delhi)

PROPOSED EPI: **18 kWh/m^2.year**
Energy consumption reduced by **43.31%**

Refer to the Appendix for baseline energy consumption.

Energy Analysis

Maximum impact has been due to halving of energy consumption by passive cooling.

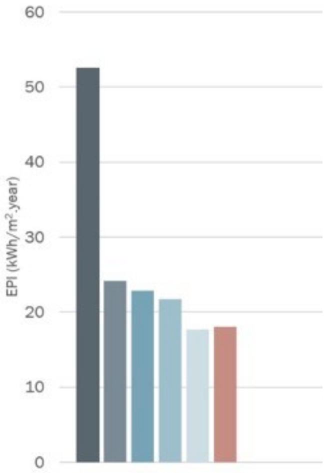


Figure 33: Energy analysis of proposed case

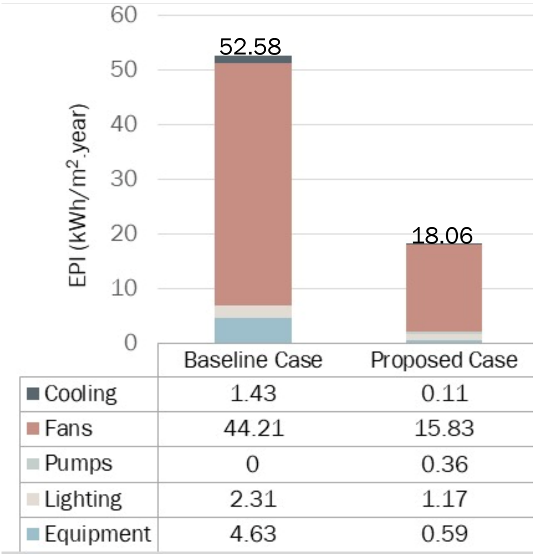


Figure 34: Comparison of breakdown of EPI between base and proposed case

Energy Demand Reduction

The energy performance of the structure can be improved by starting by reducing the energy demand itself. To do so, passive strategies for cooling and defining an efficient envelope are crucial.

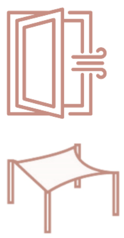
Energy efficient appliances

APPLIANCES	% ENERGY SAVING COMPARED TO BASE CASE
10W ORIENT LED TUBELIGHT	50
5W ORIENT ETERNAL LED BULKHEAD LIGHT	50
28W BRUSHLESS DIRECT CURRENT(BLDC) CEILING FAN	62.67
28W BLDC WALL MOUNTED FAN	44
18W SLEEKLINE LED TUBELIGHT LTSL	10
45W TCL HD LED 32" TV	35.71
DIAKIN SPLIT 5 STAR AC	74.30

Table 09: Energy efficient lightings and equipment

Energy efficient appliances have been used to reduce the energy consumption. Since lighting and cooling systems are used the maximum, their energy consumption reduction was crucial.

Passive Strategies for Cooling



- Maximising convective ventilation with windows and ventilators in the sleeping units.
- Sail shades for open spaces.
- Using recessed balconies as shading devices thus reducing direct heat gain through windows.

In Delhi, in the months from April to September, the hours between 10 am and 2 pm need shading. The maximum vertical shading angle in south direction is 60º, implying that a 1126 mm deep horizontal shade is enough. Thus, 1200 mm wide balcony acts as the shading device for window and the ventilator.

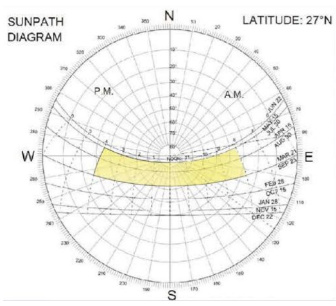


Figure 35: Sunpath diagram

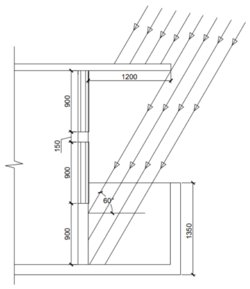


Figure 36: Horizontal Shade

06 DESIGN DOCUMENTATION

Envelope Efficiency

Reducing energy demand by reducing heat gain through the envelope by:

- Achieving 24% WWR.
- uPVC double-glazed window comprising of a 16 mm argon filled cavity sandwiched with 4mm Low-E glass.
- Using Ferrocement panels as external walls which have lower U-value compared to their conventional counterparts.

Figure 37: Wall assembly

ENVELOPE ELEMENTS	ASSEMBLY	U-VALUE ($W/m^2.K$)
WALL	25 mm Ferrocement panel+100 mm cork insulation+25 mm Particle board	0.3082
ROOF	60 mm Puff panel	0.35
GLASS	4 mm Low-E glass+16mm Argon gas+4 mm Low-E glass	1

Table 10: Assembly u-values of the envelope of proposed structure

Assembly U-Values achieved for the proposed structure are lower than the base case container system which have u-vale of 0.42 $W/m^2.K$.

On-site generation of electricity through Solar Energy

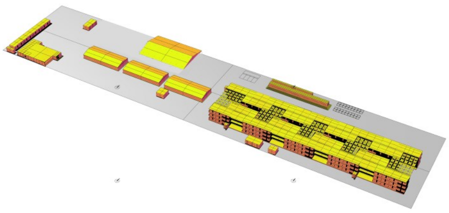


Figure 38: Solar insolation

Since the rooftop receives the maximum sun during the day, solar panels have been installed there. The trays shade the roof area too.

We are using the Half Cut Mono Facial Solar PV Cell.

MODULE TYPE	PE
Maximum Power (Pmp)	515
Open Circuit Voltage (Voc)	49.2
Short Circuit Current (Isc)	13.15
Maximum Power Voltage (Vmp)	41.72
Maximum Power Current (Imp)	12.34
Module Efficiency (nm)	19.93

Table 11: Solar panels

Keeping in mind the efficiency, carbon footprint and affordability of the product; the solar panels by Premier Energies with these specifications have been selected-

The number of hours Delhi receives sunlight per day is 7.4 hours,
Therefore,

$$\text{The energy generated by one panel per day} = \frac{\text{(Wattage of panel x Efficiency x hours of sunlight received)}}{(1000 \times 100)}$$

$$= \frac{(515 \times 19.93 \times 7.4)}{(1000 \times 100)}$$

$$= 0.76 \text{ kWh}$$

So, Annual electricity generated per panel= 277.4 kWh/year

Considering the dimensions of the panel i.e., (2279 x 1134) mm.
Area covered by one panel= 2.6 m^2
Roof area available= 2900 m^2
Space required for 1000 panels = 2600 m^2
Area for circulation= 300 m^2
Estimated Energy generated by 1000 panels per year=2,77,400 kWh/year

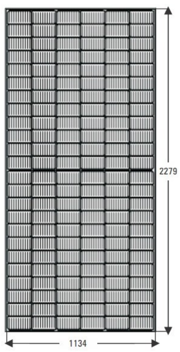


Figure 39: Dimensions of solar panels

Now, Since, expected energy consumption per year of proposed case= 1,78,834 kWh/year
Percentage of The surplus energy produced= (2,77,400-1,78,834)/ 1,78,834 = 55.11 %
We are producing 55.11% surplus energy. Thus, providing a net positive solution.

6.8 HEALTH AND WELLBEING

Indoor Air Quality and Odour Comfort

To address air pollution and promote comfort and well-being, the housing units have been separated from enclosed washing and toilet areas.
Wall panels with minimal or zero VOC, such as ferrocement panels and particle boards, have been used. Similarly, flooring and roof materials like linoleum and Puff panels have been selected to minimize VOC emissions.

Visual Comfort

A WWR of 24% with uPVC DGU with a glass of VLT 71% has been utilized in the living zone. The lighting used is placed in the unit according to the window and daylight penetration.

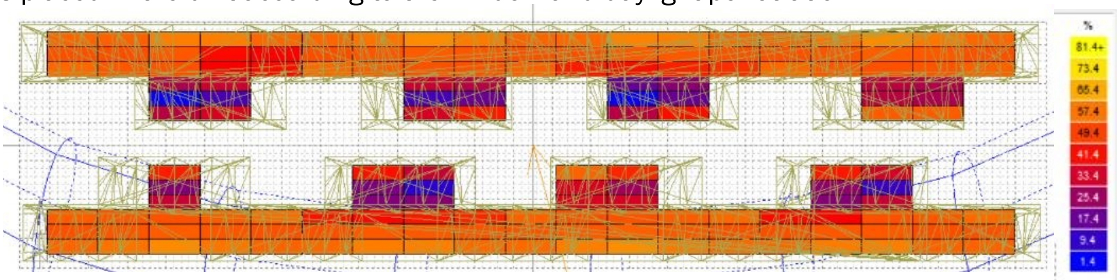


Figure 40: UDI simulations for living zone

Thermal Comfort

U-Value: To ensure comfortable living zones, our project focuses on low U-values for assemblies to minimize heat gain.
Clo Factor: We consider the Clo Factor by taking into account the light clothing worn by construction workers during Delhi's hot summer months.
Shading Devices: Balconies on upper floors serve as shading devices to reduce direct solar heat gain through the glass and provide added comfort for lower floors.

Living zone- Naturally ventilated spaces
Indoor Operative Temperature = (0.54 x outdoor temperature) + 12.83
Outdoor temperature= 30-day outdoor running mean air temperature= 33.35°C
Indoor Operative Temperature = (0.54 x 33.35) + 12.83 = 30.839°C
Office zone- Mixed Mode ventilation
Indoor Operative Temperature = (0.28 x outdoor temperature) + 17.87 Outdoor temperature= 30-day outdoor running mean air temperature= 33.35°C
Indoor Operative Temperature = (0.28 x 33.35) + 17.87 = 27.208°C
Thus, the design caters to their thermal comfort in the living zone and office zone accordingly.

Mental Well Being

The lack of green open spaces for recreational activities and interaction was amended with effective cluster planning. Aangans and courtyards were introduced to uplift their mental well-being.

Figure 41: Courtyard between housing units

Introduction to Government Schemes

Through our project partner, we aim to improve the standard of living and quality of life of the local community by introducing beneficial schemes.

- The Deendayal Antyodaya Yojana National Urban Livelihoods Mission will offer skill development and upskilling programs, training over 1 lakh construction workers and providing them with employment opportunities abroad.
- “Shramik Mitras" will inform workers about government programs, including an increased Dearness Allowance for Unskilled and Semi-Skilled Workers.

6.9 RESILIENCE

Our site can potentially face hazardous earthquakes, strong winds, thunderstorms, heat waves and pandemics/ epidemics following the BMTPC Hazard Maps.

S. No.	CALAMITY/ HAZARD	MAGNITUDE/ FREQUENCY	DISRUPTION CAUSED	DESIGN INTERVENTION
1	EARTHQUAKE	6.0-6.9 on the Richter scale, ZONE IV	Electricity supply, Water supply, Food security, Medical services and Waste disposal	Using sturdy connectors and maintaining structural integrity (through grillage foundation and steel sections) becomes primary, especially in temporary structures.
2	STRONG WINDS	Very High Damage Risk, velocity= 50m/s, ZONE B	Electricity supply and Medical services	Designing building envelope openings consciously, the orientation of the building and roof design (avoiding large overhangs) becomes crucial.
3	THUNDERSTORM	Frequency: 61-75 per year	Electricity supply	Lightning protection mast can be made foldable, constructible, or telescopic allowing the mast to be moved to other locations. It is a cost-effective solution.
4	HEAT WAVES	The average summer temperature is usually 36-38C. In mid-May, the temperature shot up to 49C in some parts of the city.	Water supply and Medical services	Thermal insulation through material selection, and passive cooling strategies like cross ventilation, and shading devices will help optimise occupant comfort and well-being.
5	EPIDEMIC/ PANDEMIC	-/-	Food security, Medical services and Waste disposal	Sanitation-related outbreaks of diseases and other communicable diseases ranging from the common cold to COVID-19 can occur if proper isolation wards and clusters are not effectively planned.

Table 12: Disaster risk reduction

Mitigation Measures

Awareness programs and campaigns can be further introduced to improve sanitation practices among workers.
Evacuation drills according to the evacuation plan should be conducted regularly. Training for the handling of fire extinguishing equipment etc. must be conducted as well.

Autonomy

Understanding the severity of the stresses and disruptions in the services, we are providing autonomy for **48 hours** in terms of electricity and water through on-site storage.

Calculation for Water Autonomy

The goal of the proposed water system is to have the ability to restore and continue the potable water supply as rapidly as possible in the case of any disaster.
In order to do so, existing potable water storage and two third of the grey and black treated water are stored that gives stored water to be **1,06,270.834 LPD**
The critical consumption (drinking, cooking, flushing) in case of disaster is **52,500 LPD.**
Storage / critical consumption = No. of days for autonomy
1,06,270.834 LPD /52,500 LPD = 2.024
Therefore at any time of day, in case of disasters, the present proposed tanks provide potable water for **2 days of autonomy.**

Calculation for Energy Autonomy

Energy generated by 1 panel per day= 1 KWH
Total number of solar panels =1000
Total energy generated per day for proposed design=1000 KWH
Total energy consumption per day =489.5 KWH
Excess energy (Total energy generated-Total energy consumed)=(1000-489.5)= 510.5 KWH
Total energy consumed in 2 days= (489.5x2)=979 KWH
Maximum capacity of storage of battery = 55 KWH
Therefore, the total number of batteries required = Total energy consumed in two days/Storage capacity of battery = (979/55) = 18
Hence, the design has an autonomy of 48 hours in terms of electricity through on-site storage of solar energy in 18 batteries.
The batteries would be restored to full capacity after generating electricity for two days consecutively.

Evacuation Plan

In case of a fire, various equipment like fire buckets, fire extinguishers and hose reels have been provided in alignment with the NBC.

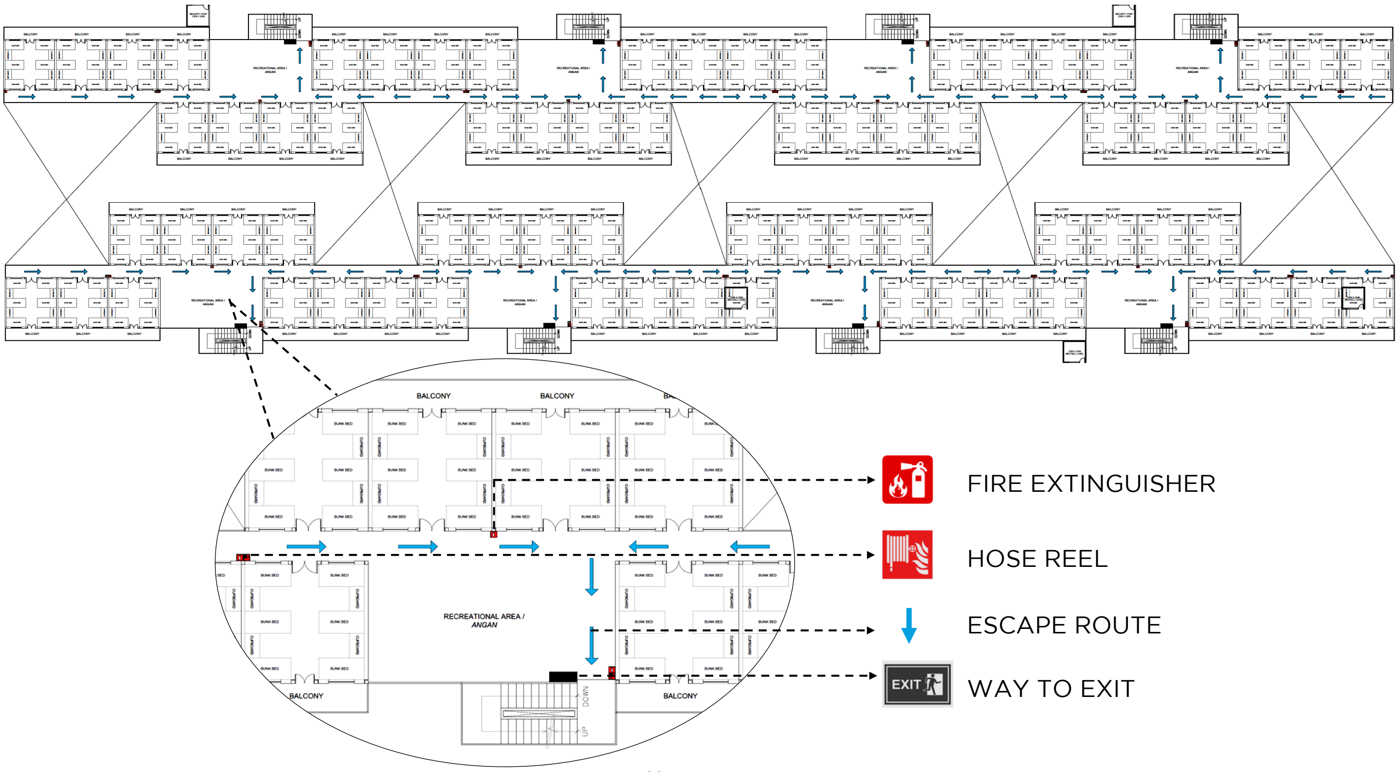


Figure 42: Evacuation plan

Recovery Plan

1. Provide immediate medical attention and launch a rescue operation for all personnel with assistance from emergency services.
2. Alert the authorities for any disruption in water and electrical supply.
3. Account for all damages and introduce a priority order.
4. Focus on the re-establishment of the normal functioning of all services and maintenance and repair of structures.
5. Procure clean water, electricity from power storage and food.

Epidemic/ Pandemic

In case of an epidemic/ pandemic breakout, the spacious courtyards of the design can be transformed into wards with temporary partitions in between them.

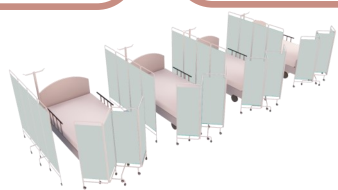


Figure 43: Temporary Isolation wards

6.10 AFFORDABILITY

The cost of the proposed case is lesser than the base case. The proposed design uses Hollow Steel Sections as the primary structural element compared to Steel Shipping Containers of the base case. The use of Steel Sections introduces modular construction which is highly efficient in time, resource, and cost management.

PARTICULARS	DEFINITION	BASELINE ESTIMATE (PROJECT PARTNER)			PROPOSED DESIGN ESTIMATE		
		AMOUNT (IN MILLION INR)	AMOUNT IN INR/ SQM.	PERCENTAGE	AMOUNT (IN MILLION INR)	AMOUNT IN INR/ SQM.	PERCENTAGE
LAND	Cost of land purchased or leased by the project partner	0.00	0.00	0.0%	0.00	0.00	0.0%
CIVIL WORKS	Refer item A, Civil works in Cost of construction worksheet	55.91	9,318	46.5%	23.92	2,658	23.4%
INTERNAL WORKS	Refer item B, Civil works in Cost of construction worksheet	50.06	8,343	41.7%	26.84	2,982	26.3%
MEP SERVICES	Refer item C, Civil works in Cost of construction worksheet	4.13	688	3.4%	41.74	4,638	40.8%
EQUIPMENT AND FURNISHING	Refer item D, Civil works in Cost of construction worksheet	0.42	69	0.3%	0.70	78	0.7%
LANDSCAPE AND SITE DEVELOPMENT	Refer item E, Civil works in Cost of construction worksheet	0.00	0.00	0.0%	0.29	32	0.3%
CONTINGENCY	Amount added to the total estimate for incidental and miscellaneous expenses.	6.07	1,011	5.0%	5.15	572	5.0%
TOTAL HARD COST		116.6	19,430	97%	98.6	10,960	97%
PRE OPERATIVE EXPENSES	Cost of Permits, Licenses, Market research, Advertising etc.	3.60	600	3.0%	3.59	399	3.0%
TOTAL SOFT COST		3.6	600	3.0%	3.6	399	3.0%
TOTAL PROJECT COST		**120.2**	**20,030**	**100%**	**102.2**	**11,359**	**100%**

Table 13: Project summary: base case vs proposed case

On comparing life cycle cost for both the cases, it was found that the proposed case design is expected to reduce the annual expenditure for maintenance, utility and replacement by 49%.
Proposed Design CAPEX: 11,359/sq.m
Proposed Design OPEX: 497.77/sq.m.year

Refer to Appendix for detailed LCC analysis.

06 DESIGN DOCUMENTATION

Cost Performance Review

Design Intervention:
Use of Modular construction aids for smooth assembly and disassembly flow. It is adaptable for different project sites. The materials used are durable with a life expectancy of at least 8 years.

Less Construction Time: Modular building projects can be completed 30-50% faster than traditional methods.

Less waste generation: Traditional construction generates more waste than modular construction.

Cost-effective: Modular design significantly reduces construction and labour costs. Modular building projects are 33% less expensive than the construction style in use.

Material Comparison and Contrast:

Steel Hollow Sections ***cost 34% less*** *than Steel Shipping Containers at cost/kg rate.*

Particle Boards used for walls and roofs have a ***life of 20 years****, once put to use and retail at affordable prices.*

Cork insulation panels ***costs 54.5% less*** *than the in-use XPS insulation panels with a life of 25 years.*

Linoleum flooring is ***more affordable*** *and pleasant with* ***low U-value****, as compared to in-use flooring.*

Figure 44: Materials used in construction

Energy Intervention:

- Solar Panels: The use of solar panels decreases the operational costs of electricity requirements by 65% which outweighs the cost of investment.
- Appliances: The use of energy-efficient and BEE- rated electrical appliances reduces energy demand and in turn decreases operational costs.

Water Management:

The project is net positive due to rainwater harvesting. The use of harvested rainwater helps to reduce municipal drinking water consumption and has the potential to save a significant amount of water each year. This, in turn, lowers the cost of procuring potable water daily.

Waste Management:

For maximum utilisation of on-site energy, a Flexi Biogas Digester System has been proposed. This biodigester system uses biodegradable wastes to produce Biogas which can be used as a fuel in kitchen activities. This reduces the additional costs of gas cylinders, as being used in the base case.

- Gravity-fed, above-the-ground pipelines are being used to omit the set-up costs.
- The digester system is fully transferable, therefore, it can be re-equipped at different sites for the Project Partner.
- It requires little to no maintenance and has a life of about 10 years.

Refer to the appendix section for breakdown of construction cost, CAPEX and OPEX.

6.11 VALUE PROPOSITION

The project, Nilaya, aims to alleviate the housing conditions of on-site construction workers along with assisting the various requirements of the project partner. The design caters to the comfort, quality and experience for the user, efficient resource-management for the community and affordability, scalability and modularity for the project partner.

Narrative for Project Partner

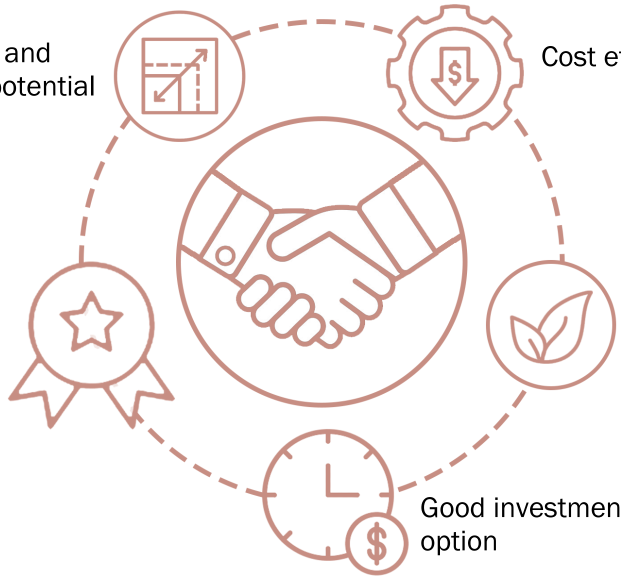


Figure 45: Benefits for project partner

The construction worker housing proposed by Team Sattva 2.0 is a sustainable and net zero solution having several socio-economic benefits. The various parameters have been worked upon to provide a flexible, scalable and affordable solution for the L&T Construction sites.
The proposed design uses an innovative approach of the kit-of-parts system which allows for modular structure with the ease of assembling, dismantling and transportation. Efficient handling of structure led to optimization of both construction costs (of the CWH) and transportation costs (of the materials and modules). Also, the materials used in construction are carbon efficient and are optimally utilized.
Further, the achievements in energy and water performance minimized the operational costs by significant amounts, thus making the project more economical. Energy consumption has been reduced from 3,15,451 kWh/yr to 1,78,834 kWh/yr by the integration of various passive design strategies, optimum envelope design and use of energy efficient equipment. The provision of solar panels generated 2,77,400 kWh/yr of on-site energy, thus attaining net positive energy performance. As a result, the operational costs were reduced by 65%.
Water consumption was reduced from 161 LPCD to 59 LPCD by using efficient low flow fixtures, rainwater harvesting and wastewater treatment. This helped to achieve a net zero water cycle, thus reducing the reliance on municipal water sources. Use of the EcoTec process for water treatment reduced the operational costs by 26%.
The biodegradable waste has been managed to generate energy in the form of LPG. To optimize the potential and biogas production, bioproducts have been employed. This provides various economic and environmental benefits.
These sustainable provisions will enable the project partner to gain star ratings from GRIHA. This will add to the brand value and economic benefits of the project partner. When choosing among similarly priced projects, the one with a green rating will tend to hold greater interest. Several government policies and codes focus on the sustainable aspects, thus the project is more viable from the point of view of approvals and legal formalities.
Last but not the least, the resilience of the design in the face of disaster, its modularity and mobility, enhances the scalability and market potential for the project.

06 DESIGN DOCUMENTATION

Narrative for End User– Construction Workers

Figure 46: Benefits for construction workers

The project, Nilaya, meaning a peaceful home is an initiative taken to address the needs of construction workers and dignify their living conditions on site. Construction workers are an integral part of the building sector, however their welfare is often neglected. Planning schemes tend to ignore the provisions for upliftment of the workers. Thus, this project emerges as the model for on-site worker housing across the country, catering to their problems, behavioural patterns and needs.
To accommodate diversity within the affordable sector and create a sense of belonging among the users, aangans and courtyards have been provided attached to the housing modules. These help to establish a link with the outdoors and build social relations. Inside the housing modules proper storage spaces have been given, which was a problem faced by the workers. The design provides security and acceptance to the workers.
This ergonomic design is free of social boundaries and comply with the health, well-being, and safety standards. Employing rainwater harvesting and herbal treatment of water provided sufficient and good quality water to the workers for various purposes.
The strategic design of structure using steel sections, tight connections and optimum envelope provides resilience against calamities like earthquakes, strong winds, etc. Moreover, the compact and modular structure makes it easy and safe for the users to handle.
Use of carbon efficient materials in construction of the housing leads to reduction in greenhouse gas emissions which ultimately creates a healthier living environment for the workers. On top of that, the module is designed to achieve optimal thermal comfort of the occupants throughout the year by using passive strategies to improve daylighting and indoor air quality. The visual, acoustic and odour comfort and mental well-being of the users have also been taken care of.
Conclusively, the proposed design addresses the socio-cultural needs of the workers and provides improved comfort, experience, sanitation, security and well-being for them. Overall it leads to the upliftment and improved productivity of the on-site construction workers.

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08 APPENDIX

BUILDING AREA PROGRAMME

TOTAL NUMBER OF WORKERS ON SITE = 2,550					
TOTAL SITE AREA = 20,900 m^2					
FUNCTIONS	AREA (SQM.)	NO. OF UNITS	TOTAL AREA (SQM.)	CONDITIONED / UNCONDITIONED	REMARKS
LIVING ZONE					
SLEEPING AREAS	25	210	5250	UNCONDITIONED	Use of bunk beds to reduce 40% of required floor area.
WASHROOMS	1.5	86	129		Designed separately for an efficient plumbing layout. No. of washrooms are as per NBC for one shift of workers.
BATHROOMS	1.5	30	45		Designed for 1:15 ratio as per NBC, for one shift of workers i,e. 840 people.
COMMON AREAS					
COMMUNITY KITCHEN	360	3	1080	UNCONDITIONED	Existing self-serve kitchens.
CANTEEN + DINING	300	1	300		Proximity to kitchen allows for use as dining and canteen.
SHADED RECREATIONAL AREA	950	1	950		
MEDICAL CENTRE	50	1	50	CONDITIONED	Includes examination, first-aid, and basic treatment.
AMENITIES					
WATER STORAGE	80	3	240	UNCONDITIONED	Water tanks as per calculations.
STP	25	3	75		As per calculations.
ELECTRICAL ROOM	20	3	60		As per calculations.
RO PLANT	36	1	36		Existing RO plant.
GENERAL STORE	18	2	36		Provided due to lack of external movement around site.
PRINT KIOSK/ CYBER CAFE	9	1	9		To help connect workers with hometowns.
VEGETABLE KIOSK	9	2	18		Provided due to lack of external movement around site.
WAREHOUSE	50	1	50		For food and resource security during calamities.
OFFICE ZONE					
OFFICE AREA	50	3	150	CONDITIONED	Office area for site engineers and architects.
INCUBATION UNIT	50	2	100		For training and spreading awareness among workers.
STAFF WASHROOM	3	4	12	UNCONDITIONED	
SECURITY POST	5	5	25		For monitoring and safety of occupants.
TOTAL			8615		
15% CIRCULATION			1285		
TOTAL BUILT-UP AREA			9900		
OPEN AIR RECREATIONAL AREA	1300	1	1300	OPEN SPACES	To be used for mass gathering of workers, workshops, and recreational activities.
BIO DIGESTER	81	6	486		
OPEN BATHING AREAS	1.5	30	45		Designed as per request from L&T, and workers to help them feel connected to their native places.
WASHING AREA	4	35	140		Self washing areas for clothes

Table 14: Building area programme

08 APPENDIX

CALCULATIONS FOR ENERGY PERFORMANCE

INPUT PARAMETERS	UNITS	PROPOSED DESIGN VALUES
GENERAL		
BUILDING AREA	m^2	9900
CONDITIONED AREA	m^2	300
ELECTRICITY RATE	INR/kWh	NA
NATURAL GAS RATE	INR/Gj	NA
BUILDING OCCUPANCY HOURS	-	Living zone: 24 hrs, Admin zone: 9 am-5 pm
AVERAGE OCCUPANT DENSITY	m^2/ person	3.5
INTERNAL LOADS		
INTERIOR AVERAGE LIGHTING POWER DENSITY	W/m^2	0.95
LIST OF LIGHTING CONTROLS	-	-
AVERAGE EQUIPMENT POWER DENSITY	W/m^2	8.29
MINIMUM OA VENTILATION (BUILDING AVERAGE)	$l/sec.m^2$	0.3
ENVELOPE		
ROOF ASSEMBLY U VALUE	$W/m^2.K$	0.35
AVERAGE WALL ASSEMBLY U VALUE	$W/m^2.K$	0.31
WALL TO WINDOW AREA RATIO (WWR)	%	24
WINDOWS U VALUE	$W/m^2.K$	1.0
WINDOWS SHGC		0.36
WINDOW VLT	%	7.1
DESCRIBE EXTERIOR SHADING DEVICE		The recessed balconies act as shading thus reducing direct heat gain.
HVAC SYSTEM		
HVAC SYSTEM TYPE AND DESCRIPTION	-	Split AC
DESCRIBE MIXED MODE STRATEGY IN OPERATION/ CONTROLS OF AC AND WINDOWS	-	Since the conditioned spaces are heavily shaded by trees around them, the demand for cooling reduces exponentially. The AC is required only for un-shaded hours of the day
HEATING SOURCE	-	-
HEATING CAPACITY	kW	-
HEATING COP		-
COOLING SOURCE	-	Electric
COOLING CAPACITY	kW	3.35 at 100% and 1.67 at 50%
COOLING EER		6.2
OPERATION HOURS		2
HEATING SET POINT	°C	-
COOLING SET POINT	°C	27

Table 15: Input parameters for energy simulations

08 APPENDIX

OUTPUT PARAMETERS	UNITS	PROPOSED DESIGN VALUES	
PROPOSED EUI (TOTAL)	kWh/m²/ yr	18.06	
HEATING	kWh/m²/ yr	-	
COOLING	kWh/m²/ yr	0.11	
FANS	kWh/m²/ yr	15.83	
PUMPS	kWh/m²/ yr	0.36	
HEAT REJECTION	kWh/m²/ yr	-	
SERVICE HOT WATER	kWh/m²/ yr	-	
LIGHTING	kWh/m²/ yr	1.17	
EQUIPMENT	kWh/m²/ yr	0.59	
ANNUAL OPERATING ENERGY COST	INR/m²	45.45	
COOLING CAPACITY	Tr	1	
MONTHLY ENERGY PERFORMANCE		**GENERATION**	**CONSUMPTION**
JAN	kWh	21,554	1,754
FEB	kWh	23,094	1,585
MAR	kWh	25,660	24,165
APR	kWh	28,226	23,385
MAY	kWh	28,226	24,165
JUN	kWh	23,094	23,385
JUL	kWh	17,449	19,646
AUG	kWh	16,935	19,646
SEP	kWh	21,554	19,013
OCT	kWh	25,660	19,646
NOV	kWh	25,660	1,698
DEC	kWh	21,554	1,754

Table 16: Output parameters for energy simulations

08 APPENDIX

Comparison of Base Case with Proposed Case

S.NO.	APPLIANCES	NO.OF APPLIANCES	WATTAGE OF EACH APPLIANCE	AVERAGE WORKING HOURS (DAILY)	ENERGY CONSUMPTION (Wh/ day)
LIVING ZONE					
01	LED TUBELIGHT	400	20	4	32,000
02	WALL MOUNTED FANS	2400	50	6	7,20,000
03	LED BULKHEAD LIGHT	130	10	0.5	650
04	PHONE CHARGER	2400	15	2	72,000
KITCHEN					
05	LED TUBELIGHT	75	20	3	4,500
06	CEILING FAN	15	75	2	2,250
OFFICIAL ZONE					
07	LED TUBELIGHT	20	20	2	800
08	WALL MOUNTED FAN	15	50	6	4,500
09	PHONE CHARGER	24	15	1	360
10	DESKTOP	6	100	6	3,600
11	TV	1	70	1	70
12	AC	12	980	2	23,520
TOTAL DAILY ENERGY CONSUMPTION= 864.25 kWh/day					
ANNUAL ENERGY CONSUMPTION= 3,15,451.25 kWh/year					

Table 17: Baseline energy consumption
(The average working hours consider that cooling appliances won't get used during the winter months in Delhi)

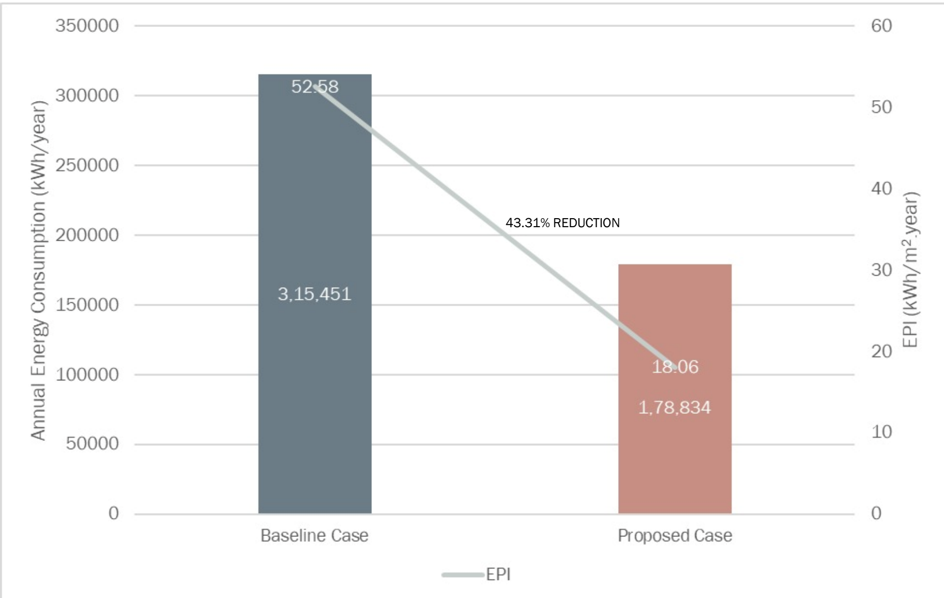

Figure 47: Comparison between baseline and target values.
Proposed annual energy consumption is 1,78,834 kWh/year, 43.31% less than base case.

08 APPENDIX

CALLCULATIONS FOR WATER PERFORMANCE

Justification for Baseline Table

The values for the baseline were gathered for interviews conducted as an SOP was not disclosed to us by the Project Partner. Surveys for the water consumed on daily bases were recorded and averages were written. It was observed that consumption for drinking, cooking and bathing was more than the average as utensils and clothes were washed individually by each worker which caused more consumption.
The table contains wastage and leakage as additional water because the water was provided by tanks and habitual wastage of water was observed the values were added to make it more accurate on our part. Also, the baseline and proposed design have additional water for drinking and cooking for the floating population of 50 people in the office.

WATER CONSUMPTION PER CAPITA PER DAY= 58.5L PER CAPITA PER DAY								
TOTAL NUMBER OF USERS = 2500 + 50 Staff / Visitors								
	BASE CASE		PROPOSED CASE					
ACTIVITY	CONSUMPTION (LITERS)	CONSUMPTION FOR 2500 (LITERS)	PERCENT	CONSUMPTION (LITERS)	CONSUMPTION FOR 2500 (LITERS)	GREY WATER L (2500)	BLACK WATER L (2500)	NOTE
LEAKAGE	9.8	24,500	3.4	2	5,000	2,500	2,500	Efficient tap and pipe system
WASTAGE	11.2	28,000	5.1	3	7,500	3750	3750	Promoting behavioural changes
WATER CONSUMPTION AFTER LEAKAGE AND WASTAGE								
DRINKING	5.46	13,650L	6.8	4	10,000	-	10,000	Water for both CWH and 50 visitors
COOKING	4.06	10,150	5.1	3	7,500	-	7,500	Water for both CWH and 50 visitors
FLUSHING	23.8	59,500	18.8	11	27,500	-	27,500	Low flow taps
BATHING	40.6	1,01,500	22.4	13	32,500	32,500	-	Low flow taps
HOUSE CLEANING	11.2	28,000	8.5	5	12,500	12,500	-	Low flow taps
WASHING UTENSILS	22.96	57,400L	13.7	8	20,000	20,000	-	Promoting community washing
WASHING CLOTHES	27.44	68,600	13.7	8	20,000	20,000	-	Promoting community washing
OTHERS	4.48	11,200	3.4	2	5,000	2500	2500	Indirect use
TOTAL	161	4,02,500	100	59	1,47,500	37.5 (93,750)	21.5 (53,750)	
TOTAL ANNUAL CONSUMPTION BASE CASE = 365 X 4,02,500 = 14,69,12,500 L								

Table 18: Comparison of baseline to proposed water consumption table

Calculations

Baseline water consumption per day per person = 161 L
Use of low-flow fixtures to reduce consumption considering drinking and cooking water as necessary water usage. The low-flow systems used have a flow rate of 2 lpm.

Consumption

Therefore reduced water consumption = 59 LPCD
Annually consumption for 2500 people = 59 x 2500 x 365 = 5,38,37,500 L
Water used from municipal to fulfil potable water demand annually (7 months)= 43,91,543 L
I.e. 63.35 % reduction in consumption

08 APPENDIX

Recycled Water
Grey water produced = 37.5 LPCD
Grey water produced by 2500 people daily = 37.5 x 2500 = 93,750 LPD
Efficiency of the system - 95%
Treated grey water recycled = 95% 37.5 = **35.625 LPCD**
Treated grey water recycled by 2500 people daily = 35.625 x 2500 = 89,062.5 LPD
Treated grey water recycled annually = 35.625 x 2500 x 365 = 3,25,07,812.5 L

Black water produced = 21.5 LPCD
Black water produced by 2500 people daily = 21.5 x 2500 = 53,750 LPD
Efficiency of the system - 70%
Treated black water recycled = 70% 21.5 = **15.05 LPCD**
Treated black water recycled by 2500 people daily =15.05 x 2500 = 37,625 LPD
Treated black water recycled annually = 35.625 x 2500 x 365 = 1,37,33,125 L

Total treated recycled water = 50.675 LPCD
Annually recycled water = 50.675 x 2500 x 365 = **4,62,40,937.5 L**
I.e. 85.9 % of water is recycled by treatment

Rainwater Harvested
As the water is either directly used or treated and sent to ground recharge
Fresh water demand daily for 2500 people = 20,812.5 LPD
Rain Water collected in tank for potable water demand in monsoon = 20,813 LPD
Rain water used annually (154 days) = **32,05,202 L**
Rain water recharged by recharge pit to ground water annually = **26,27,304 L**
I.e. 5.9% of water is harvested from rain

Ground water recharge
Untreated grey water = 5% 37.5 = 1.875 LPCD
Untreated grey water for 2500 people = 1.875 x 2500 = 4,687.5 LPD
Untreated black water = 30% 21.5 = 6.45 LPCD
Untreated black water for 2500 people = 6.45 x 2500 = 16,125 LPD
Treatment system efficiency = 95%
Treated water returned back to the source by ground water recharge
95%(4,687.5 + 16,125) = 95%(20,812.5) LPD = **19,771.875 LPD**
Annually groundwater recharge = 19,771.875 x 365 = **72,16,734.375 L**
Total water recharged = (rain + treated) = (26,27,304 L + 72,16,734.375 L)
= 98,44,038.375 L
Discharge = 5%(20,812.5) = 1,040.625 L
This water is send to the bio digester on site
Daily water demand of bio digester = 845LPD
Ie **18.28** % water was retired back to source by round water recharge

NET-ZERO CALCULATION
Water demand - recycled water - potable rainwater used - water returned back to source
5,38,37,500 - **4,62,40,937.5** - **32,05,202** - **98,44,038.375** = - 54,52,677.875 L
The negative sign show net positive water cycle.
The goal of net positive was achieved and annually 54,52,677.875 L of water was send back to the source by ground water recharge.

08 APPENDIX

CALCULATIONS FOR WASTE DISPOSAL AND MANAGEMENT

As per research, the average amount of human waste produced by individuals doing labour-intensive work and having a vegetarian diet is 330gm. Hence, **2500 people generate 837.5 kg of human waste per day.** The waste is fed to the PVC tank, where the anaerobic process happens. The greenhouse tunnel is critical in maintaining a steady temperature of about 50C(approx) and accelerates methane extraction. The daily feedstock has additional kitchen waste; based on a 15-day retention time, a biodigester of **volume 36m3** is appropriate. The feed can be divided into four 9m3 digester tanks. The tanks are cleaned every 2-3 weeks depending upon the usage.

The Buswell calculation approach **yields 35.7 m3 of biogas each day.** The biogas generated is stored in balloon tanks. The gas is kept safe by employing pressure valves and a separate container box to keep the tanks safe. We calculated the **daily LPG requirement of 216L** by considering the average energy utilized for everyday meals. If biogas is used instead of LPG, then we see a reduction of **15% in LPG usage.**

Calculation for Biodigester

Total number of people = 2500
Human waste generated per person = 330 gm
Total Waste produced per day = 825kg
Dry Matter present in waste = 30% (825) = 247.5kg
Amount of carbon present = 24% (Dry Matter) = 24% (247.5) = 59.4kg
Percentage of carbon biodegraded = 60% = 35.64kg

Using Buswell Equation,
Weight of Methane-Carbon = 53%(35.64) = 18.8892 kg
Weight of Methane = (18.8892 *16)/12 = 25.1856kg

16 G → 1 MOL
Moles of methane (CH_4) = 1574.1 MOLES

1 MOL → 22.4 L (@STP)
= 1574.1 *22.4 = 35259.84L = 35.259M3

1 M3 BIOGAS → 23.4 MJ
Total energy produced by 35.259 m3 biogas= 825.08 MJ
SInce, 1L LPG → 25 MJ heat
1 MJ given by 1/25 L LPG
Therefore the amount of Methane equivalent to LPG = 837.58/25 = 33 L LPG/ DAY

Cooking energy= Rice + Cabbage= 0.08 +0.09 = 0.17 KWH = 0.2 KWH (Approx.) = 0.72 MJ

Cooking energy required for 2500 people (breakfast+lunch+dinner) = 2500 * 0.72 * 3
= 5400 MJ / DAY

LPG required = 216 L LPG/DAY
Actual LPG used= 216-33= 183 L

Percentage of LPG required =(33/216) *100 = 15.27%.

08 APPENDIX

CALCULATIONS FOR AFFORDABILITY

Construction Cost Breakdown

On comparing the construction cost breakdown from the base case and proposed case, we see that the civil works costing has been significantly reduced from 77% to just 56%, which accounts the most of the costing in both the cases.
A steady and uniform distribution can be seen in the construction cost breakdown in the proposed case.

Project Summary								
Project Information								
	Team:	sattva 2.0						
	Division:	On site Construction Worker Housing		Land Cost:	0	Million INR		
		Site Area (sqm)	16,000	City:	new delhi			
		Built-up Area (BUA) (sqm)	6,000	State:	delhi			
		Ground Coverage (Plinth Area) (sqm)	4,000					
		Proposed design buildup area (sqm)	9,000					
S.No.	Particulars	Definition	Baseline Estimate (Project Partner / SOR basis)			Proposed Design Estimate		
			Amount (Million INR)	%	Amount (INR per sqm)	Amount (Million INR)	%	Amount (INR per sqm)
1	Land	Cost of land purchased or leased by the Project Partner	0.00	0.0%	-	0.00	0.0%	-
2	Civil Works	Refer Item A, Civil works in Cost of construction worksheet	55.91	46.5%	9,318	23.92	23.4%	2,658
3	Internal Works	Refer Item B, Civil works in Cost of construction worksheet	50.06	41.7%	8,343	26.84	26.3%	2,982
4	MEP Services	Refer Item C, Civil works in Cost of construction worksheet	4.13	3.4%	688	41.74	40.8%	4,638
5	Equipment & Furnishing	Refer Item D, Civil works in Cost of construction worksheet	0.42	0.3%	69	0.70	0.7%	78
6	Landscape & Site Development	Refer Item E, Civil works in Cost of construction worksheet	0.00	0.0%		0.29	0.3%	32
7	Contingency	Amount added to the total estimate for incidental and miscellaneous expenses.	6.07	5.0%	1,011	5.15	5.0%	572
	TOTAL HARD COST		**116.6**	**97%**	**19,430**	**98.6**	**96%**	**10,960**
8	Pre Operative Expenses	Cost of Permits, Licenses, Market research, Advertising etc	3.60	3.0%	600	3.59	3.0%	399
	TOTAL SOFT COST		**3.6**	**3%**	**600**	**3.6**	**3%**	**399**
	TOTAL PROJECT COST		**120.2**	**100%**	**20,030**	**102.2**	**100%**	**11,359**

Table 19: Project summary with hard costs and soft costs

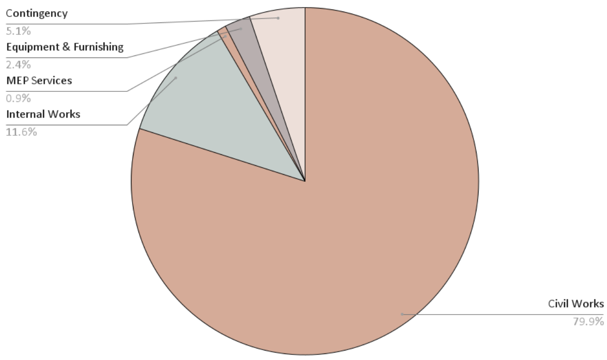

Figure 48: Construction cost breakdown for base case

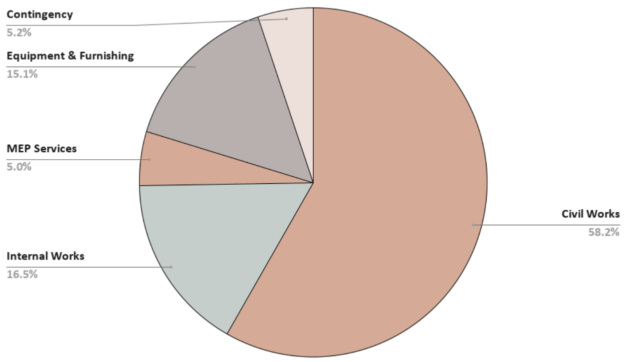

Figure 49: construction cost breakdown for proposed case

CAPEX and OPEX Breakdown

On comparing the CAPEX and OPEX, in the base case and the proposed case, it is evident that a decrease of CAPEX by 15.43% from 120.2 to 102.2 Million INR has reduced the OPEX by almost 48%. With the base case OPEX being 6.6 million and no net-zero initiatives, the proposed case puts forth a better solution that can be efficiently executed with OPEX of just 3.2 million.
NET DECREASE IN OPEX: 48%
NET DECREASE IN CAPEX: 15.43%

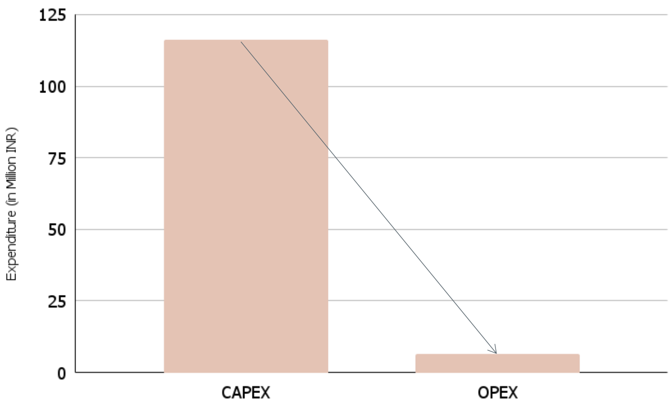

Figure 50: CAPEX & OPEX breakdown for base case

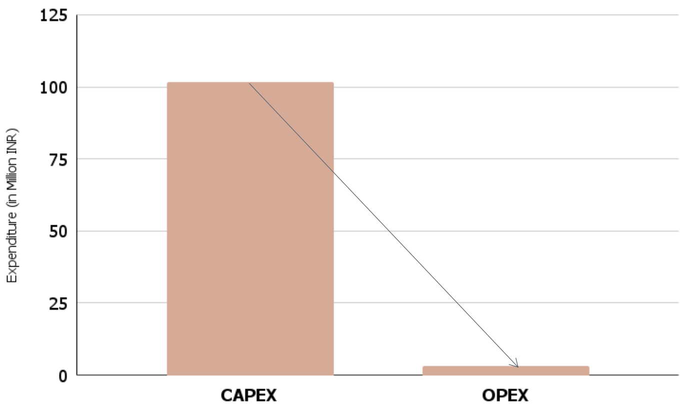

Figure 51: CAPEX & OPEX breakdown for proposed case

08 APPENDIX

LCC Analysis

Life cycle cost analysis has been done for 10 years for both the cases. On comparing the life cycle costing of the base case design and proposed case design we came to the conclusion that not only the capital investment is decreased, but also the total cost being used for annual upkeep has also decreased.

Life Cycle Cost (LCC)

BASE CASE DESIGN

Time (Year)	Capital Cost (INR Million)	Annual Maintanance (INR Million)	Utility Cost (INR Million)	Replacement Cost (INR Million)	Total Cost (INR Million)
0	120.1822653				120.1822653
1		3.4	3.2	0.5	7.1
2		3.4	3.2	1.2	7.8
3		3.4	3.2	2	8.6
4		3.4	3.2	1.2	7.8
5		3.4	3.2	10.6	17.2
6		3.4	3.2	1.2	7.8
7		3.4	3.2	1.4	8
8		3.4	3.2	2	8.6
9		3.4	3.2	1.4	8
10		3.4	3.2	1.6	8.2

Discount Rate	8%
Life Cycle Cost	**179.74**

Annual Average costing (INR Million):	8.91

PROPOSED CASE DESIGN

Time (Year)	Capital Cost (INR Million)	Annual Maintanance (INR Million)	Utility Cost (INR Million)	Replacement Cost (INR Million)	Total Cost (INR Million)
0	102.2314756				102.2314756
1		2.6	0.6	0.6	3.8
2		2.6	0.6	1	4.2
3		2.6	0.6	1.5	4.7
4		2.6	0.6	1.2	4.4
5		2.6	0.6	1.6	4.8
6		2.6	0.6	1	4.2
7		2.6	0.6	1.3	4.5
8		2.6	0.6	1.8	5
9		2.6	0.6	1.3	4.5
10		2.6	0.6	1.5	4.7

Discount Rate	8%
Life Cycle Cost	**131.98**

Annual Average costing (INR Million):	4.48
Savings %age (Base Case Design vs Proposed)	49.71941639

Table 20: LCC breakdown for base case and proposed case design

In the base case, every 5 years, the Steel Shipment Containers are replaced and bought again to sustain the dwelling units. However, in the proposed case, no replacement is required for over 25 years.
In proposed case, we have significantly reduced the cost requirements for Utility by introducing Solar energy, recycling of water and re-utilization of waste.

Annual Maintenance Cost includes expenditure for wear-tear, small repairs and labour cost for cleaning and sustentation.

Utility Cost includes expenditure for Electricity, Water, Waste disposal and likewise.

Replacement Cost includes expected expenditure margin for replacing utilities and building members like steel shipment containers in base case design.

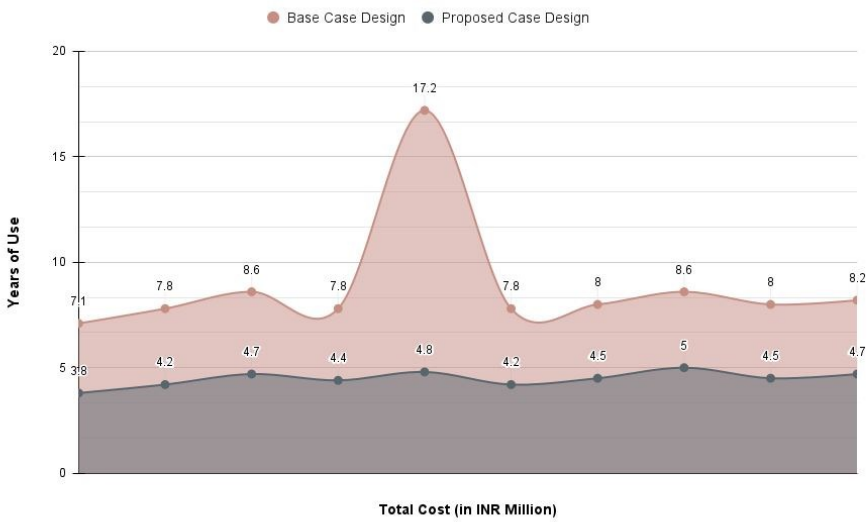

Figure 52: Total annual cost comparison for 10 years

Therefore, a total saving of 49% has been achieved in the proposed case design as compared to base case design.
Annual Project Operating Cost: 497.77/sq.m.year

08 APPENDIX

SUMMARY OF EMBODIED CARBON CALCULATIONS

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	99.1	1.1	0.1	100.4	-27.1	0.0	0.0	-27.1
ROOF	20.4	0.1	0.0	20.5	7.2	0.0	0.0	7.2
FLOOR	24.3	0.1	0.0	24.5	-23.9	0.0	0.0	-23.9
FENESTRATION	50.2	0.1	0.0	50.3	100.1	0.0	0.0	100.1
STRUCTURAL	53.7	0.0	0.0	53.7	36.6	0.0	0.0	36.6
GRAND TOTAL EMISSIONS PER FUNCTIONAL UNIT ($kg-CO_2$ e)				**247.8**	**GRAND TOTAL EMISSIONS PER FUNCTIONAL UNIT ($kg-CO_2$ e)**			**92.9**

Table 21: Summary of embodied carbon calculations

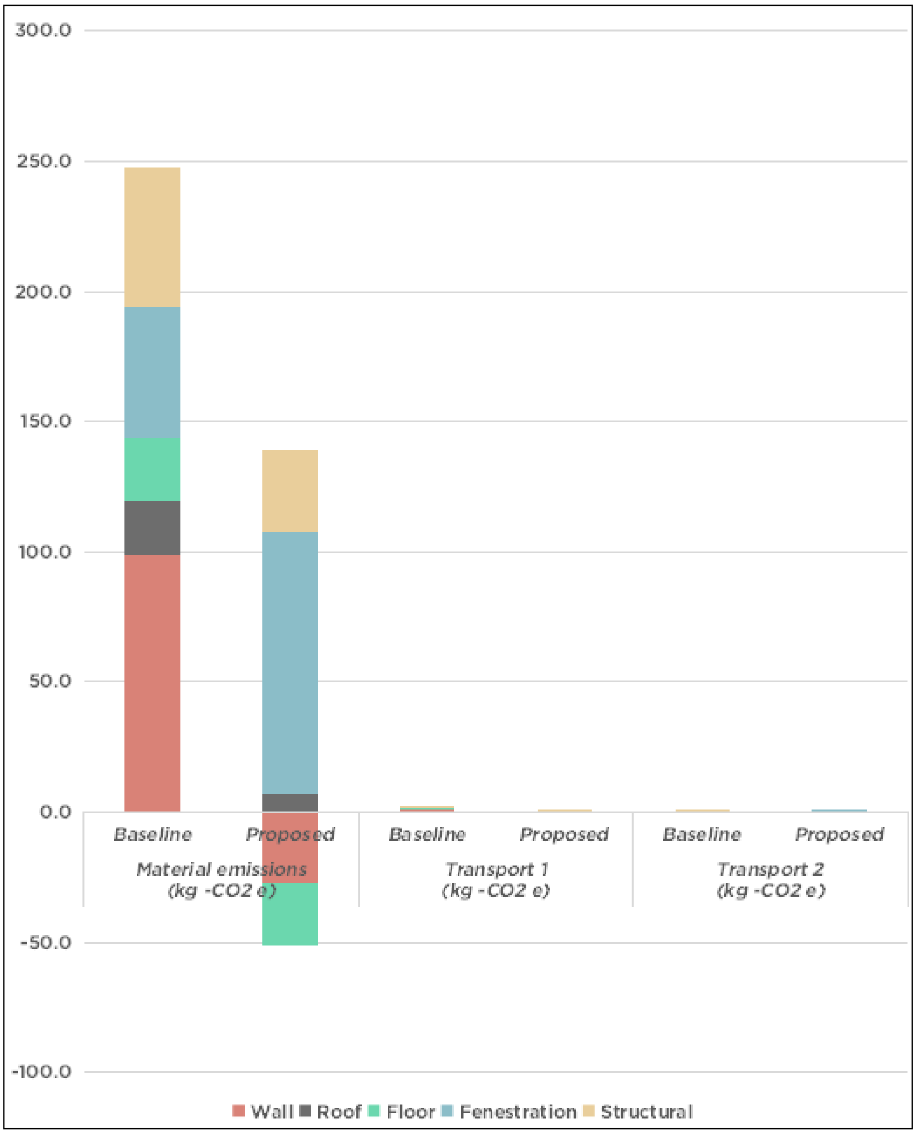

Figure 53: Summary of emissions per functional unit

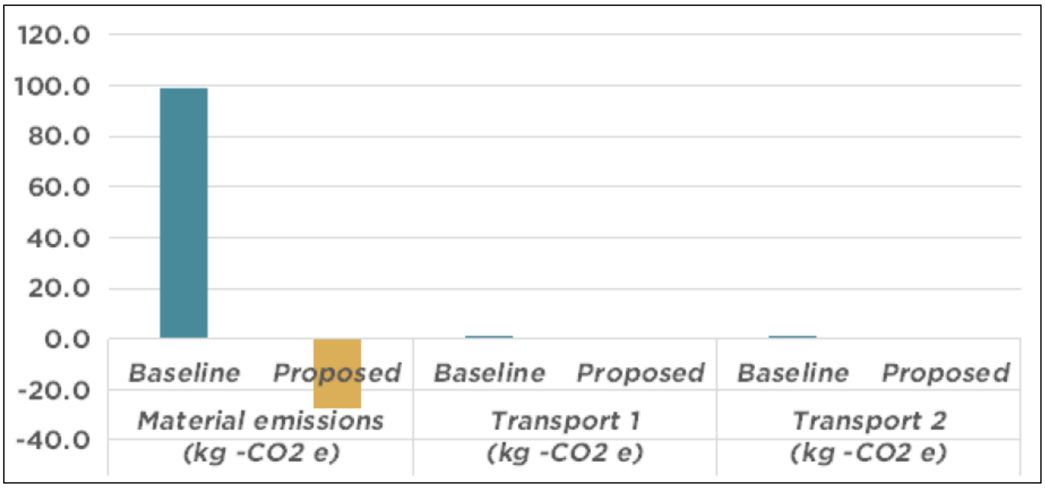

Figure 54: Emissions from wall

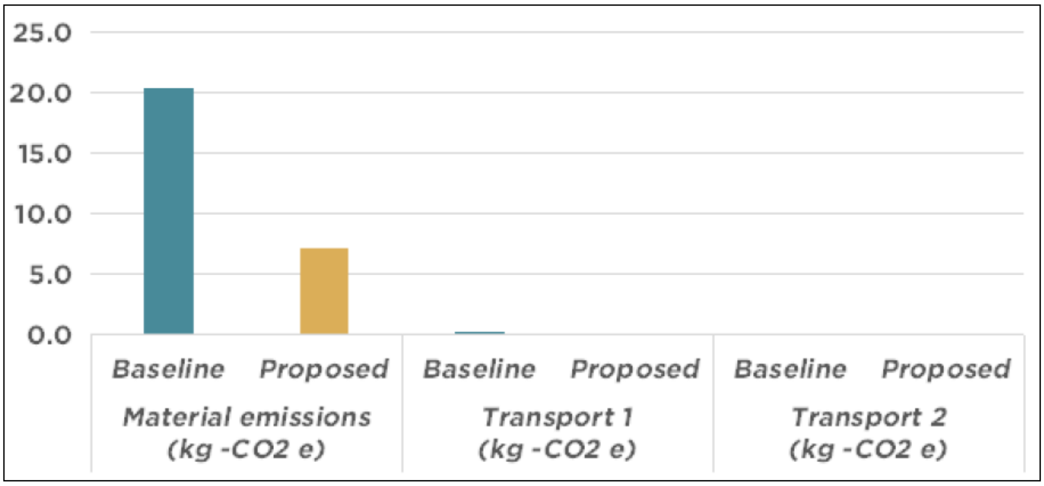

Figure 55: Emissions from roof

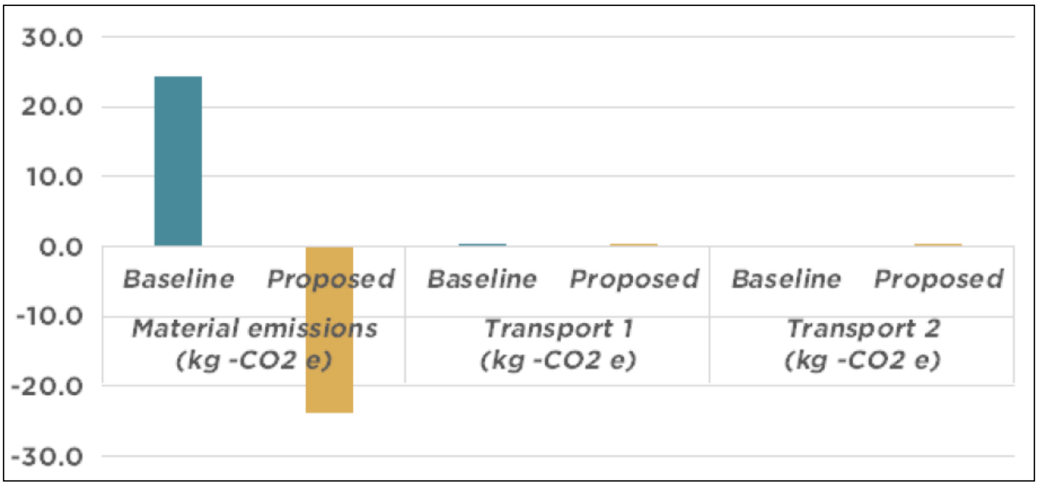

Figure 56: Emissions from floor

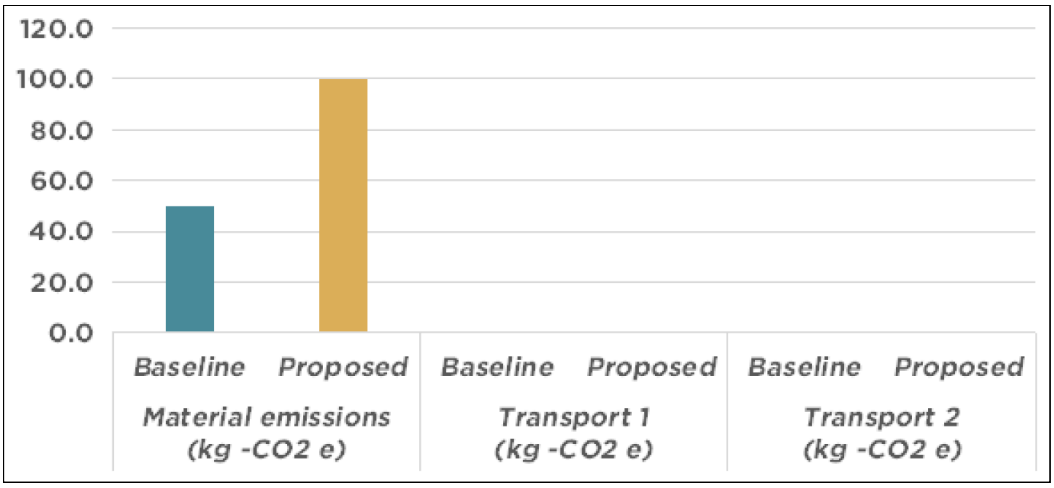

Figure 57: Emissions from fenestration

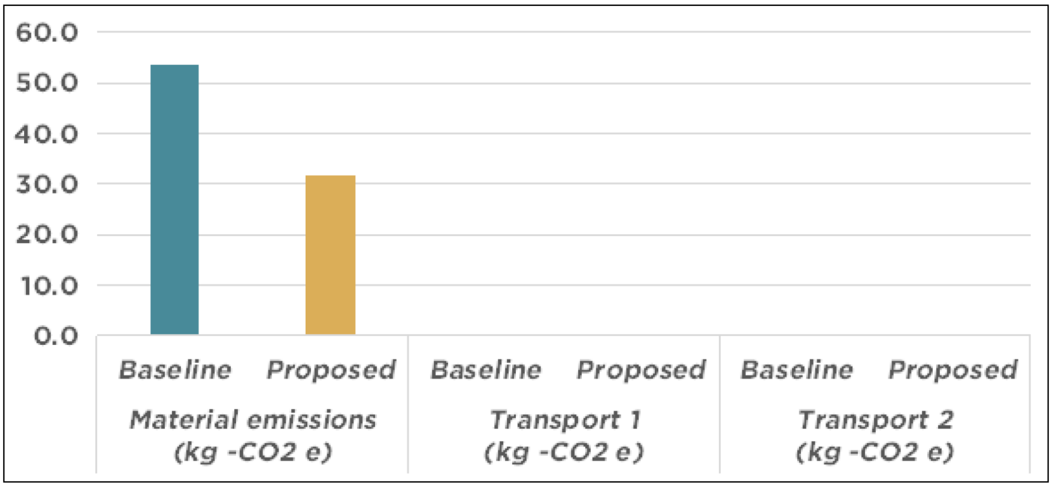

Figure 58: Emissions from structural

08 APPENDIX

Total Embodied Carbon Calculation

Base case-
Total embodied carbon of wall =A1(330,297.75)+A2(-82.98)+A3(49,729.68)= 379,944.45 KGCO2.eq
Total embodied carbon of floor=164,354.06KGCO2.eq
Total embodied carbon of roof =137,624.06KGCO2.eq
Total embodied carbon of window = 170,877.60 KGCO2.eq
Total embodied carbon of super-structure = 27,945KGCO2.eq
Total embodied carbon of structure =wall(379,944.45)+floor(164,354.06)+roof(137,624.06)+window (170,877.60)+superstructure(27,945)=880,745.18KGCO2.eq

Proposed case-
Total embodied carbon of wall =A1(-243580)+A2(-170.30)+A3(0)=-243,750.30 KGCO2.eq
Total embodied carbon of floor=-202,314KGCO2.eq
Total embodied carbon of roof =42,336KGCO2.eq
Total embodied carbon of window = W1(2,822)+W2(80,296)= 83,118 KGCO2.eq
Total embodied carbon of super-structure =A1(291,360)+A2(0)+A3(5,629.50)=296,989.50KGCO2.eq
Total embodied carbon of structure = Wall(-243,750.30)+Floor(-202,314)+Roof(42,336)+Window (83,118)+Superstructure(296,989.50)=-23,620.80KG CO2.eq

Although the proposed case has a positive carbon emission per square meter, the overall structure has negative carbon emissions due to the use of different assemblies, with carbon-negative assemblies such as floors and walls being used more frequently.
The transportation carbon of the existing structure as per EC tool= 1.6KgCO2eq/m2.
While transportation carbon of the proposed design as per EC tool= 0KgCO2eq./m2.

Therefore, the carbon efficiency of structure- [{880,745.18-(-23,620.80)}/880,745.18]x100
= 102.68%

08 APPENDIX

BUILDING OPERATIONS (DO'S AND DON'TS)

Thermal Comfort & Ventilation System

When designing a housing or office space, proper ventilation and temperature control are crucial factors to ensure a comfortable and healthy environment. In this regard, there are certain dos and don'ts that can be followed to achieve optimal results.

DO'S	DON'TS
Provide windows for natural cross ventilation in housing units to reduce the need for excessive use of fans.	Avoid relying solely on air conditioning for ventilation and temperature control.
Install wall-mounted fans in each bed space to allow focused cooling.	Do not install a single AC unit for multiple rooms with different use patterns.
Use balconies in upper units as heat buffers to eliminate direct solar insolation.	Do not set the AC temperature too low, as it may lead to health issues and energy wastage.
Install independent split air conditioners in office areas with different use duration and timings.	On-Site Renewable Energy Generation (Solar Energy) And Storage System
Set the ACs to 24 degrees Celsius during summer to maintain a comfortable environment.	Incorporating solar panels into a complex can be an effective way to reduce energy costs and promote sustainability. However, there are certain considerations to keep in mind to ensure the optimal functioning and maintenance of solar panels.
Provide windows for natural ventilation in office spaces that can be used during the mornings and evenings.	
Incorporate long openings between the wall edges and ceiling edges in kitchens and recreational areas to allow hot air to escape.	
Use ceiling fans to quicken the cooling effect on extremely hot summer days.	

Table 22: Ventilation system do's and don'ts

On-Site Renewable Energy Generation (Solar Energy) And Storage System

Incorporating solar panels into a complex can be an effective way to reduce energy costs and promote sustainability. However, there are certain considerations to keep in mind to ensure the optimal functioning and maintenance of solar panels.

DO'S	DON'TS
Install enough solar panels to generate sufficient electricity to power the entire complex without relying on energy from the grid.	Do not install an insufficient number of solar panels that may lead to energy shortages.
Consider the average solar hours per day in the area when determining the number of solar panels needed.	Avoid ignoring the average solar hours per day and weather patterns when determining the number of solar panels needed.
Store excess energy generated during the day to be utilized during unexpected cloudy or rainy days.	Do not overlook the need for energy storage systems to ensure energy availability during unexpected weather conditions.
Regularly check and maintain the solar panels at least once a year to ensure optimal efficiency.	Avoid neglecting regular maintenance and checks of the solar panels, as this can lead to decreased efficiency and potential damage.

Table 23: Solar energy do's and don'ts

08 APPENDIX

The Waste Treatment System

Effective waste management is crucial for reducing environmental impact and promoting sustainability. The waste treatment system plays a significant role in reducing, reusing, and recovering waste. The Flexi Biogas System (FBS) is a key component of the waste treatment system, which aims to handle both wet and dry waste on-site, while hazardous waste is dealt with at the occupant level.

DO'S	DON'TS
Use the Flexi Biogas System (FBS) to treat waste, as it is an effective way to reduce waste and generate biogas.	Do not ignore the importance of waste management and the role of the waste treatment system in promoting sustainability.
Ensure proper waste collection and sorting by trained personnel to prevent contamination.	Avoid improper waste collection and sorting, as it can lead to contamination and inefficiencies.
Regularly maintain and clean the waste treatment system to ensure optimal functioning.	Do not neglect regular maintenance and cleaning of the waste treatment system, as this can lead to decreased efficiency and potential damage.
Use biogas generated by the FBS as an alternative to LPG to reduce energy consumption and promote sustainability.	Avoid using LPG instead of biogas generated by the FBS, as this can lead to increased energy consumption and environmental impact.
Address any issues with the system immediately to prevent further damage or inefficiencies.	

Table 24: Waste treatment system do's and don'ts

Water Treatment System- Ecotec Process

The water treatment system proposed for the project utilizes the EcoTec Process technology, which is eco-friendly and cost-effective. It consists of two components, one for greywater and the other for blackwater. The system utilizes Ecoclean products to treat the water and provides an efficiency of 95% and 70% respectively.

DO'S	DON'TS
Regularly monitor the efficiency of the water treatment and replace sand and carbon filters when required.	Do not neglect the regular monitoring of the efficiency of the water treatment as it can affect the quality of treated water.
Add the required amount of Ecoclean products for efficient water treatment periodically.	Do not avoid replacing sand and carbon filters when required as it can impact the performance of the system.
Reuse pipes and tanks from the existing system and maintain them.	Do not overlook the periodic addition of the required amount of Ecoclean products as it can reduce the efficiency of the treatment system.

Table 25: Water treatment system do's and don'ts

Note: The treated water can be reused for purposes like flushing, cleaning, and groundwater recharge.

Water Pumps

DO'S	DON'TS
After the pump has been running for 3000 hours, suggest checking the wearing parts (such as bearings, seals, mechanical seals etc.), otherwise the damage to the mechanical parts will cause greater losses.	The solar water pump must be connected to its controller and not run without it, otherwise, the motor will be burned.
If the pump is not used for a long time, it should be cleaned and dried, and properly kept in a ventilated and dry place	It is strictly forbidden to connect wires when the power is on, otherwise, there will be a risk of electric shock.
Before use, check whether the pump is intact, and whether there is any looseness, seepage or oil leakage at each connection.	The water pump and controller must be properly grounded before use, otherwise, there will be a risk of electric shock.

Table 26: Water pumps do's and don'ts

08 APPENDIX

PERFORMANCE SPECIFICATIONS

INPUT PARAMETERS	UNITS	PROPOSED DESIGN VALUES
GENERAL		
BUILDING AREA	M^2	9900
CONDITIONED AREA	M^2	300
BUILDING OCCUPANCY HOURS	-	Living zone: 24 hrs, Admin zone: 9 am-5 pm
AVERAGE OCCUPANT DENSITY	M^2/ PERSON	3.5
ENVELOPE		
ROOF ASSEMBLY U VALUE	W/M^2.K	0.35
AVERAGE WALL ASSEMBLY U VALUE	W/M^2.K	0.31
WINDOWS U VALUE	W/M^2.K	1.0
WALL TO WINDOW AREA RATIO (WWR)	%	24
DESCRIBE EXTERIOR SHADING DEVICE	-	The recessed balconies act as shading thus reducing direct heat gain.
HVAC SYSTEM		
HVAC SYSTEM TYPE AND DESCRIPTION	-	SPLIT AC
DESCRIBE MIXED MODE STRATEGY IN OPERATION/ CONTROLS OF AC AND WINDOWS	-	Since the conditioned spaces are heavily shaded by trees around them, the demand for cooling reduces exponentially. The AC is required only for un-shaded hours of the day
COOLING CAPACITY	TR	1
OPERATION HOURS		2
EPI		
PROPOSED EUI (TOTAL)	KWH/M^2/ YR	18.06
COOLING	KWH/M^2/ YR	0.11
FANS	KWH/M^2/ YR	15.83
PUMPS	KWH/M^2/ YR	0.36
LIGHTING	KWH/M^2/ YR	1.17
EQUIPMENT	KWH/M^2/ YR	0.59
ANNUAL OPERATING ENERGY COST	INR/M^2	45.45
RENEWABLE ENERGY		
TYPE	-	Half Cut Mono Facial Solar PV Cell.
EFFICIENCY	%	19.93
GENERATION CAPACITY	KWH/YEAR	2,77,400
EMBODIED CARBON		
TOTAL CARBON EMMISION	KGCO2.EQ/ SQM	92.70
WATER SYSTEM		
ANNUAL CONSUMPTION	L	5,38,37,500 L
ANNUAL RECYCELD WATER	L	4,62,40,937.5
ANNUAL RAIN WATER HARVESTED WATER	L	32,05,202
ANNUAL WATER RETURENED BACK	L	98,44,038.375

Table 27: Performance specifications

Gmail Sonu Rathor <sonurathor1999@gmail.com>

Fwd: Project Partner Letter of Confirmation
3 messages

priyanka Kochhar <priyanka.k@ipu.ac.in> Tue, Sep 27, 2022 at 10:33 AM
To: "sonurathor1999@gmail.com" <sonurathor1999@gmail.com>

---------- Forwarded message ---------
From: **Dr.S.RAJKUMAR** <energyraj@lntecc.com>
Date: Tue, Sep 27, 2022 at 7:09 AM
Subject: Project Partner Letter of Confirmation
To: priyanka Kochhar <priyanka.k@ipu.ac.in>

15th September 2022

To,

The Director,

Solar Decathlon India

Dear Sir,

This is to inform you that our organization Larsen and Toubro has provided information about our Central Vista project to the participating team led by University School of Architecture and Planning, GGSIPU, so that their team Sattva 2.0 may use this information for their Solar Decathlon India 2022-23 Challenge entry.

As a Project Partner to this team for the Solar Decathlon India 2022-23 competition, we are interested in seeing the Net-Zero-Energy, Net-Zero-Water, resilient and affordable solution this student team proposes and the innovation that results from this. We intend to have a representative from our organization attend the Design Challenge Finals event in April, 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 Project Partners for the 2022-23 Challenge.

With warm regards,

08 APPENDIX

Dr.S.Rajkumar

HEAD and DGM

Centre for Excellence and Futuristic Development

PAF - B&F IC

L&T Construction

energyraj@lntecc.com

8754474018

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priyanka Kochhar <priyanka.k@ipu.ac.in> Tue, Sep 27, 2022 at 10:33 AM
To: "sonurathor1999@gmail.com" <sonurathor1999@gmail.com>

---------- Forwarded message ---------
From: **Dr.S.RAJKUMAR** <energyraj@lntecc.com>
Date: Tue, Sep 27, 2022 at 7:10 AM
Subject: Project Partner Letter of Confirmation
To: priyanka Kochhar <priyanka.k@ipu.ac.in>

26th September 2022

[Quoted text hidden]

Sonu Rathor <sonurathor1999@gmail.com> Tue, Sep 27, 2022 at 10:40 AM
To: Team Sattva <teamsattva2.0@gmail.com>

[Quoted text hidden]

PREMIER ENERGIES PHOTOVOLTAIC PVT. LTD.
Formerly known as Sakura Premier Solar Pvt. Ltd.

21st Feb 2023

To

The Director
Solar Decathlon India

Dear Sir,

This is to inform you that our organisation Premier Energies, is collaborating with the participating team led by University school of architecture and planning, GGSIPU, on a On-site Construction Worker Housing Building project for their Solar Decathlon India 2022-23 competition entry.

The nature of our collaboration will be to provide guidance on solar energy technologies, application and working and its application in the context of the project.

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

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

With warm regards,

Name: Sudhir M Reddy
Designation: Director
Name of the Organisation: Premier Energies Ltd
Email msudhir@premierenergies.com
Phone 9177014545

MFG. UNIT & REGD. OFFICE:
PLOT NO. 8/B/1&2, E-CITY (FAB CITY)
MAHESHWARAM MANDAL, RAVIRYALA VILLAGE
RANGA REDDY DISTRICT-501359
TELANGANA, INDIA

CORPORATE OFFICE:
SY. NO. 54 PART, KAKAGUDA
VIKRAMPURI COLONY
SECUNDERABAD-500009
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T +91 40 27744415/16
E PEPHOTOVOLTAIC@PREMIERENERGIES.COM
W PREMIERENERGIES.COM

GST 36AAXCS4996H1ZB | CIN U74999TG2016PTC111510

We provide cutting-edge services such as documentation & consultancy for green ratings, innovative passive design solutions for energy saving, building energy performance simulations for energy demand quantification, advanced natural and artificial lightings simulations for visual comfort and, water-saving studies including waste-recycling and management.
PSI members include GRIHA certified evaluators and trainers, ECBC certified master trainers,

- *(p)sī/ - noun - term derived from Greek, ψ psi, 23rd letter of the Greek alphabet; from Greek (ψυχή) psyche, "mind, soul"*
- *Pound per Square Inch or, more accurately, pound-force per square inch (symbol: psi) pressure per square inch - unit of pressure or stress*
- *In parapsychology, psi is the purported process of information transfer or energy transfer in extrasensory perception or psycho-kinesis that is unexplained in terms of known physical or biological mechanisms.*

PSI ENERGY PVT LTD
Partnerships for
Sustainable
India

21/02/2023

To,

The Director,
Solar Decathlon India

Subject: Industry Partner consent letter for collaboration with Team Sattva of USAP, New Delhi.

Dear Sir,

This is to inform you that our organization, Psi Energy Pvt. Ltd., is collaborating with the participating team led by University school of Architecture and Planning, GGSIPU, 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 Regarding passive & low-energy space cooling / HVAC systems, and green building systems & technologies.

We would not be able to 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,

For PSI Energy Private Limited
Director

Gaurav Shorey
Director - PSI Energy Pvt. Ltd.
B.Arch (SPA, New Delhi); DACM (NICMAR, Pune)
GRIHA trainer; ECBC Master Trainer (BEE, Government of India)
Member - Technical Advisory Committee - GRIHA, SVA-GRIHA, GRIHA-LD,
Visiting Faculty - School of Planning & Architecture, New Delhi
(Mobile) +91 9811 478 353

Psi Energy Pvt. Ltd. CIN: U74999DL2016PTC298555 H-6, South Extension Part 1 New Delhi-110049
Email: info@psienergy.in Website: www.psienergy.in Phone: +91 8800 214 774

Guru Gobind Singh Indraprastha University
University School of Architecture and Planning
Sec 16C, Dwarka, New Delhi – 110 078

GURU GOBIND SINGH INDRAPRASTHA UNIVERSITY

Ref. No.GGSIPU/STUDENTUSAP/2022-23/ 1080 Dated: 21/02/2023

This is to certify that the following students with mentioned enrolment numbers are the of (the year as mentioned in the table below) University School of Architecture and Planning, Guru Gobind Singh Indraprastha University, Dwarka, New Delhi.
They are participating in the Solar Decathlon India 2022-23.

S.no	Name	Enrolment no.	Batch	Year
1.	Sonu Rathor	04717301619	2019-2024	4th
2.	Muskan Gupta	00717301619	2019-2024	4th
3.	Jahnvi Aggarwal	00317301619	2019-2024	4th
4.	Ishita Mittal	00517301619	2019-2024	4th
5.	Priyanshi Gupta	01117301619	2019-2024	4th
6.	Shreya Singh	01917301619	2019-2024	4th
7.	Ashish Jain	03117301619	2019-2024	4th
8.	Ansh Taneja	00417301620	2020-2025	3rd
9.	Soumitra Das	07417301620	2020-2025	3rd
10.	Deepshikha Panda	01217301620	2020-2025	3rd
11.	Priya Singh	05017301620	2020-2025	3rd

N Lugani Sethi

Prof. (Dr.) Neeraja Lugani Sethi
Dean, USAP

08 APPENDIX

भारतीय प्रौद्योगिकी संस्थान रुड़की
रुड़की – 247 667, उत्तराखण्ड, भारत
Indian Institute of Technology Roorkee
ROORKEE -247667, UTTARAKHAND, INDIA

TEL : +91-1332-285246
: +91-1332-284274
FAX : +91-1332-273560
e-mail : dosw@iitr.ac.in

No. B-4807-2023

Date: February 15, 2023

e-CERTIFICATE

Certified that **Ayush Diwang** S/o Sri. Mr. Dilip Kumar and Smt. Smt. Baby Snehlata Singh is a bonafide student of B.Tech Civil Engineering 3rd year (Enrollment No. 20113038). This being a residential institute, it is obligatory for each student to reside in the institute hostel. He is residing in room No. AG-32 of Jawahar Bhawan.

M.K. Barua

Dean of Students' Welfare