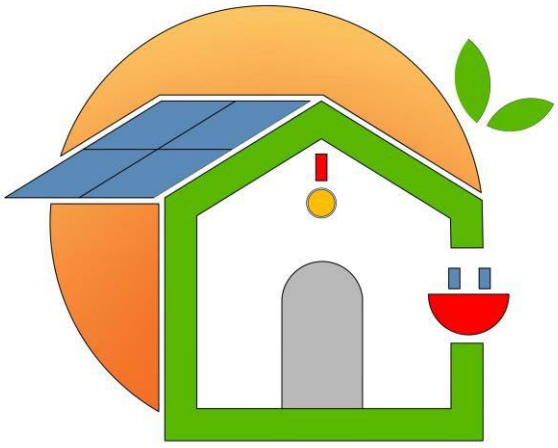
Solar Decathlon India™

ON SITE CONSTRUCTION WORKER HOUSING (CWH)



TEAM ECHO

Final Design Report

(Deliverable 04 – April 2023)

DIT UNIVERSITY
IMAGINE ASPIRE ACHIEVE

School of Architecture Planning and Design

DIT University, Dehradun (Uttarakhand)

1.0 Abbreviations

CWH	Construction Worker Housing
STP	Sewage Treatment Plant
WTP	Water Treatment Plant
BUA	Built up Area
RWH	Rainwater Harvesting
EPI	Energy Performance Index
PV	Photovoltaic
kWh	Kilo Watt Hour
DIT	Dehradun Institute of Technology
UX	User Experience
UI	User Interface
ID	Interior Design
IIT	Indian Institute of Technology
INR	Indian Rupees
NBC	National Building Code
CAPEX	Capital Expenditures
OPEX	Operational Expenditures
ICU	Intensive Care Unit
LPD	Liters Per Day
LED	Light Emitting Diode
CCTV	Closed Circuit Television
CSR	Corporate Social Responsibility
NGOs	Non-Governmental Organization
LPG	Liquefied Petroleum Gas
m	Meters
mm	Millimeters
L/l	Liters
PVC	Photovoltaic Cell
LPM	Liters Per Minute
UPCL	Uttarakhand Power Corporation Ltd.
BEE	Bureau of Energy Efficiency
EPS	Expanded Polystyrene Form
CSIR	Council of Scientific and Industrial Research
PU	Polyurethane
GI	Galvanized Iron
UPVC	Unplasticized Polyvinyl Chloride
VOC	Open Circuit Voltage
DCDB	Direct Current Distribution Board
ACDB	Alternating Current Distribution Board
MCB	Miniature Circuit Breaker
CEPT	Central for Environment Planning and Technology
CARBES	Central of Advanced Research in Building Science and Energy
CO_2	Carbon Dioxide
kg	Kilogram
UGT	Under Ground Tank
OHT	Over Head Tank
HFL	Highest Flood Level

2.0 Table of Contents

3.0 List of Tables

4.0 List of Figures

5.0 Reviewers Comments and Response (Action Taken Report)

Action Taken Report on Reviewer's Comments / Observations is attached

(Please Refer Appendix 12.16 at the end of this report).

6.0 Executive Summary

Building construction and infrastructural development depends on various aspects including the availability of funds, materials and skilled workers. Construction workers who put tireless efforts in the construction of dwellings, offices, hospitals and hotels for the quality life of the citizens; generally, live in challenging conditions on project site for the duration of the project which may vary from 12 months to 24 months. TEAM Echo Respect Human, Social and Environmental Values and has worked out a Model of CWH in order to contribute in uplifting the quality of life of millions of construction workers when they reside on the project sites.

A model of CWH has been worked out which can easily be fabricated in modules, can be stored, transported, assembled, maintained and dismantled on site conveniently. It is intended that CWH of up to 150 workers can be made ready on project site within 15 days of placing order with the promoter. Architectural design of the CWH dwelling unit has been proposed which is appropriate for the composite climatic zone of India.

Proposed model not only ensures the physical, mental and social wellbeing of the construction workers, but also facilitate the generation of onsite energy through renewable resources (roof top solar PV). Construction details and methods are considered which are simple to fabricate and easy in assembly and dismantling of the units. Safety, Comfort, Convenience, Maintenance and Affordability are some of the aspects which have been duly considered while working out the CWH model, which is commercially viable too. Environmental aspects like reduced water consumption, energy efficiency, embodied energy, carbon emissions, smokeless fuel, STP and RWH are duly addressed together with the consideration of minimum disturbance of flora and fauna on site and negligible residue leftover of project site after dismantling of the units.

Project site of CWH for the 200 Bedded Hospital at Haldwani (Uttarakhand) has been considered to work out the conceptual / prototype model, being Peyjal Nigam Uttarakhand as Project Partner. CWH for seventy-two workers is proposed on a site of 70 m x 30 m. Orientation and layout of the dwelling units is considered which is climate responsive and facilitate generation of on-site energy using roof top solar PV panels to achieve the stage of NET ZERO Energy and near to Carbon Neutral. EPI is estimated at 23.9 W/m^2. Customized sections of walls, roof and floor shall be worked out after carrying out exercises and analyzing the thermal performance of various concepts/option, which is cost effective, visually appealing, easy to fabricate, transport, install and dismantle after the completion of the project adaptable to be reused.

Proposed model of CWH Dwelling Unit is conceptualized to achieve the Goals, in view of parameters as required by the Solar Decathlon India. Sun Path and shadow studies are carried out using sketch Up-Pro software. Shadow patterns are studied for various seasons during the year, which confirm that the walls and windows of dwelling units will receive solar radiations during winter and will be shaded during summer season. Feasibility of harnessing solar energy was explored and confirmed by studying yearly sunshine hours and radiation for our site. A model of CWH is being proposed to create and ensure an ambience within the residential zone which is welcoming and convey the feeling of safety, comfort, convenience, belongingness and dignity to all construction workers / residents on site, as well as which helps in enhancing their productivity during working hours, at an affordable price of INR 60/- per construction worker per day.

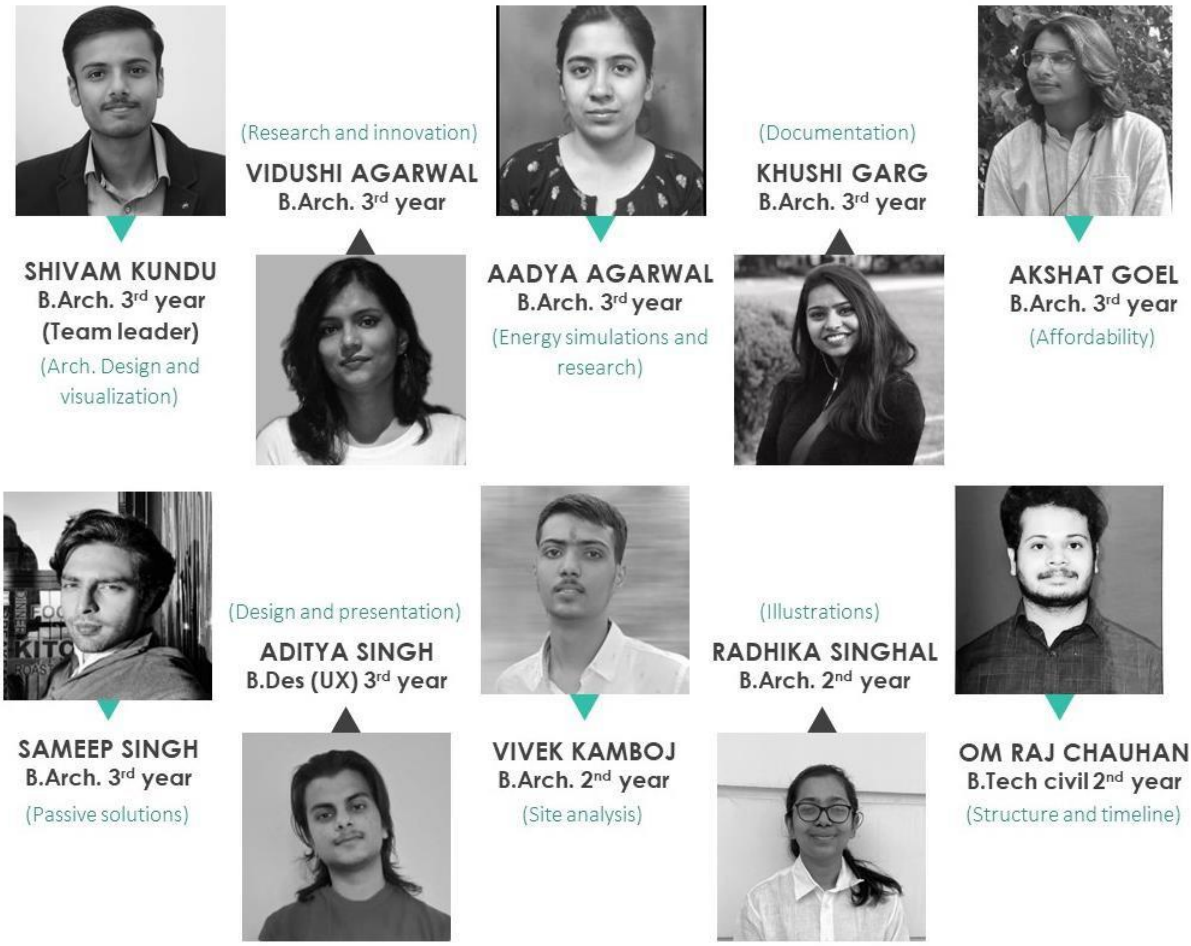
7.0 Team Introduction

7.1 Team Name: ECHO

7.2 Institution Name: School of Architecture Planning and Design, DIT University

7.3 Division: On Site Construction Worker Housing

7.4 Team Members:



7.5 Team Approach

A TEAM of budding professionals having varied skills and interest areas is formed for the purpose. Task is discussed at Macro and Micro Level and divided among TEAM members with mutual consent, in accordance with the skills and interests of the TEAM members. Members conducted a series of meetings, some during the day time and majority in the evening after the regular class hours. Work progress and challenges were discussed in the meetings and issues were resolved after seeking suggestions from all members and the faculty mentor. TEAM members have contributed with RIGHT spirit and delivered their part of work within stipulated time frame. Each one of the TEAM members are committed to further the task with the best of their skills and ability under the guidance of faculty mentor. TEAM is participating with fullest of potential and energy in order to learn as much as possible in this field.

7.6 Team Organization

Solar Decathlon Competition Guide was circulated among all the students by the institute faculty members. Matter was discussed among the students and self-nominations were asked by the interested students who can proactively carry out the task.

Architecture students have varied areas of interest and possess knowledge of varied technological fields. Students have discussed and self-nominated them in order to form the present TEAM of like-minded people having diversified interest areas and skill set. For structural aspects, student of Civil Eng. department was included in the TEAM. Also, student having visual graphics and presentation skills from B. Des. (UX) program was also included in the TEAM to advise the TEAM on such aspect. Each of the TEAM member is contributing relevant knowledge and inputs in the project.

E.g., Shivam- Solar Studies, Aadya-Thermal Performance, Vidushi-PHE, Khushi-Electrical Consumption, Aditya-User Experience, Akshat-Solid Waste Disposal and Logistics, Sameep- Illustrations, Vivek-Site Studies, Radhika-Social Studies, Om Raj-Cost Analysis.

7.7 Institution Background

DIT University has a legacy of 25 years in educational field. This University is known for Holistic Quality Education, Vibrant Curriculum, Industry Academic Collaboration, Excellent Placement Records, State of the Art Library and Infrastructure, Center of Excellences, Research and Consultancy, Outcome Based Education and Corporate Social Responsibility. The School of Architecture, Planning & Design, established in the year 2005, is a dynamic Department of DIT University offering professional degree programs like B. Arch., B-Design (ID) and B-Design (UX/UI) and M. Plan.

The program focuses on Globalization, Urbanization, Climate Change and Technology inculcating a culture in Design Thinking, Innovation and Digital Technology in order to nurture individual creativity and talent.

7.8 Faculty Lead

Dr. Rajeev Garg (Professor of Architecture)

B. Arch. from Lucknow University (1997), Ph.D. from IIT Roorkee (2008),
Dr Rajeev Garg is a Professor of Architecture having 15 years of teaching and 06 years of corporate experience in the field of architecture. Apart from serving at premier Govt and Private Universities, Dr Garg has served leading national and international corporates like TATA Consulting Engineers Limited and JACOBS Engineering.

7.9 Name of Project and Industry Partners

List of potential Industry partners are mentioned hereunder;

Name of Project Partner	LOGO	Purpose
Uttarakhand Peyjal Nigam Haldwani (Nainital) Uttarakhand		CWH is being proposed on the Site of 200 Bedded Hospital being constructed by Uttarakhand Peyjal Nigam
Name of Industry Partner	**LOGO**	**Purpose**
ALCOI		Providing Techno Commercial Information
Name of Potential Industry Partner	**Brand Name / LOGO**	**Purpose / Material**
TATA Steel (EzyNest)		For Sanitation Solution
TATA Solar Power		For Solar PV Panels
Energy Projects Limited		For Portable STP and Water Treatment Plant
Ken Brook Solar		For Solar Water Heater
Everest Industries Limited		For Wall and Roof Panels
SURYA Roshni		For Electrical Fittings

7.10 Design Management Process

Task is discussed at Macro and Micro Level and divided among TEAM members with mutual consent, in accordance with the skills and interests of the TEAM members. Members conducted a series of meetings, some during the daytime and majority in the evening after the regular class hours. Online meetings were also organized to discuss the issues and monitor the progress. Work progress and challenges were discussed in the meetings and issues were resolved after seeking suggestions from all members and the faculty mentor. TEAM members have contributed with RIGHT spirit and delivered their part of work within stipulated time frame. Each one of the TEAM members are committed to further the task with the best of their skills and ability under the guidance of faculty mentor. TEAM is participating with fullest of potential and energy to learn as much as possible in this field.

8.0 Project Introduction

8.1 Project Name: 200 Bedded Multispecialty Hospital

8.2 Project Partner

Uttarakhand Peyjal Nigam is a Governmental Organization which is responsible for supplying water in the state of Uttarakhand. The Nigam is responsible for planning, survey, design, and execution of urban as well as rural water supply and sewage schemes in the state of Uttarakhand. Nigam has also been authorized as a construction agency for construction / development works in the state.

Key individuals

Mr. Himanshu Verma (Project Manager, Construction Unit, Haldwani)

Kasana Builders Pvt. Ltd. (Contractors)

8.3 Brief description of Project:

8.3.1 The project is in Moti Nagar Hathi Khal area (Coordinates- 29°09'24" N,79°31'34" E) of Haldwani, Uttarakhand. The project is built under the Health Ministry of Central Government's National Rural Health Mission. The project is of construction worker housing for 200 Bedded Multispecialty Hospital in an area of 2.65 hectare which is under development phase.

8.3.2 Site has a gentle gradient of <1m towards the South (No water logging issue).

Figure 1:Photographs of CWH Site

User Profile

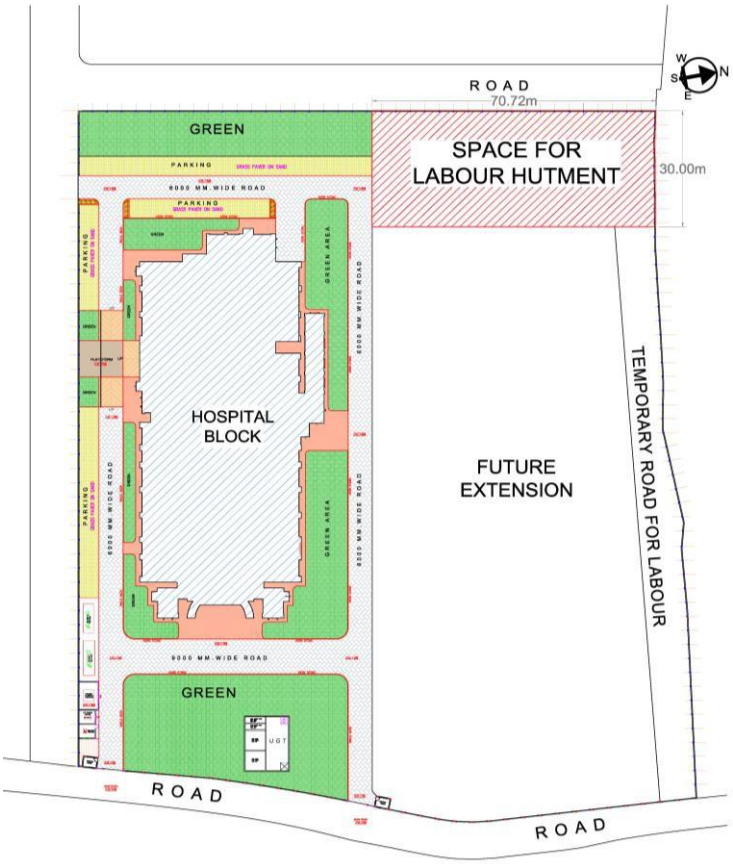
Occupation	Construction workers
Age group	18- 45 years
Working hours	9hrs (9 am – 6 pm)
Stay duration	12- 18 months on site
Lifestyle	Simple
Facilities	Essential furniture, sanitation, electricity, and water supply

Demographics

No of workers	Approx. 80
Female workers	30
Male workers	Approx. 50
Children (0 -5 years)	25
Average literacy	5 – 10 %
Wages (per day)	Labor – 500 INR Mason- 700 INR INR 1000 / family

8.4 Site Context and Estimated Built up Area (CWH):

Total estimated proposed built-up area of CWH project is 780 m^2. It includes the area of 36 Dwelling Units, Common Facilities and Services.



Location: Moti Nagar, Hathi Khal area
Climate: Composite
Temperature Range: 3°C to 38°C.
Total Site Area: 26514 sq m
(CWH) Site Area: 2117.10 sq m
Permissible built up (CWH): 846.84 sq m
Permissible ground coverage (CWH): 40 %
Estimated ground coverage (CWH): 36.78
Stage of project: Under Construction
A Model of CWH, which is commercially viable can be executed on Built-Own-Lease basis.

Figure 2: Site Plan of the Project (Space for Construction Workers Housing)

8.5 Regional Environmental Issues

- This is a wild animal prone area where wild animals like bear and fox / jackals can enter residential premises.
- Site is at an elevation of about 100m from the Highest Flood level of the region, thus there is no risk of flooding.
- The site has chances of experiencing Earthquake tremors being located in Seismic Zone – IV as per NBC.
- In view of locational and geographical aspects, there are no mountains or valleys in adjacency (no risk of land slide).
- Storms (Extreme weather conditions / windstorms) may occur occasionally.

8.6 Requirements of Project Partner

- Housing for about 75 people (construction workers and family)
- Compact modules with essential amenities
- In-situ assembly within limited time (15 days)
- No Site disturbance / Leftovers after project completion.

8.7 Special Targets and Constrains of Project Partner

- In view of the varied nature and varied magnitude of the ongoing and future projects, initially no limit of CAPEX and OPEX is fixed.
- However, the expected outcome or solution for CWH must be economically optimized/value for money solution.
- Project partner is the end user of the CWH design solution. It has to be built, owned and operated (leased out) by some investor external agency. Large construction companies may consider to build, owned and operate for themselves only.

8.8 Context (CWH and Project Site)

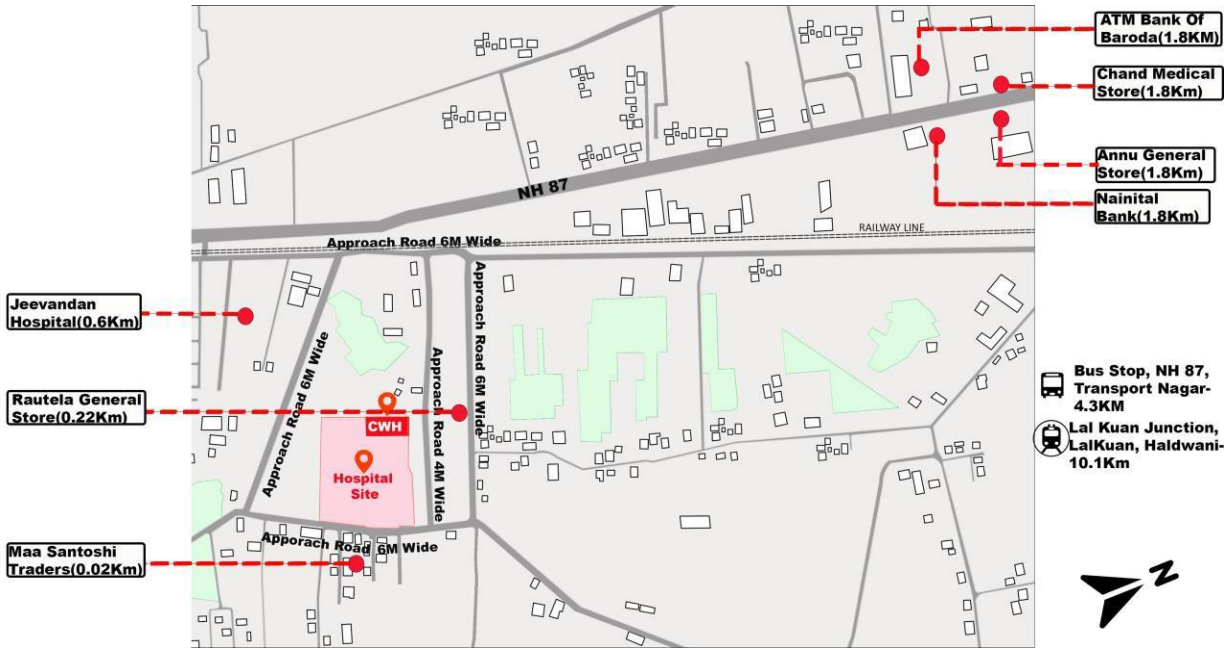


Figure 3: Master Plan Indicating Site and Surroundings

Practices in Nearby Localities	Facilities to be Provided / Considered
Dwelling Envelope is not adequate to protect Construction Workers from harsh weather conditions.	Proper dwelling units with fenestrations and verandah for proper thermal comfort / protection from extreme weather, adequate ventilation and daylight.
No dedicated cooking and washing facility on site.	Proper drainage and sanitation by providing separate cooking and washing area.
Lack of recreational and cultural aspects, belongingness and gathering space on site.	Providing Open spaces/ Children playground, Creche, Milk and Grocery booth
Water Logging on low lying areas on project sites.	Our site has a mild slope; we have to ensure that natural drainage of storm water is not obstructed.
Locality is prone to movement / attack by wild animals like bear and wolf.	We have to provide fencing / boundary wall around residential zone.
Lack of Comfort, Convenience and Social Cohesion.	Adequate electrical fixtures like Lighting, Fan, Mobile Charging Points etc. are to be considered in the dwelling units.

8.8.1 Case Study-01

Project:	College of Nursing, DIT University
Location:	Dehradun, India
No. of Dwellings:	105 (approx. 240 residents)
Climate:	Composite
Area of Each Units:	6.0 m^2 each
Material of Construction:	Non-Insulated GI Sheet and Roof fixed on frame of hollow Mild Steel rectangular and circular sections. Mud Flooring and Brick on Bat Flooring was provided in the units.
Toilets:	10 WC (Uni-gender facility) Portable type with Bio Digester, Common bathing area (Semi covered / Open to sky).
Kitchen:	Common Kitchen areas were provided. Some of the workers developed the facility inside their dwelling units.
Other Facilities:	One shop for daily needs items, One Temple, Common Area Lighting.

Figure 4: Images of CWH Facility of Case Study-01

8.8.2 Problems Identified in Case Study

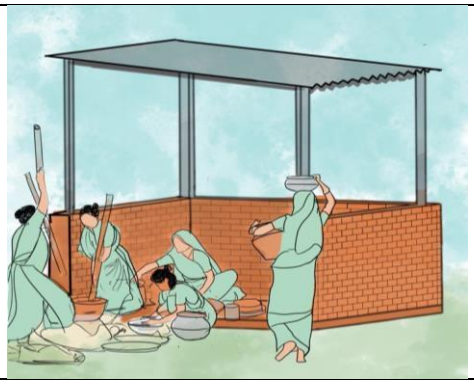
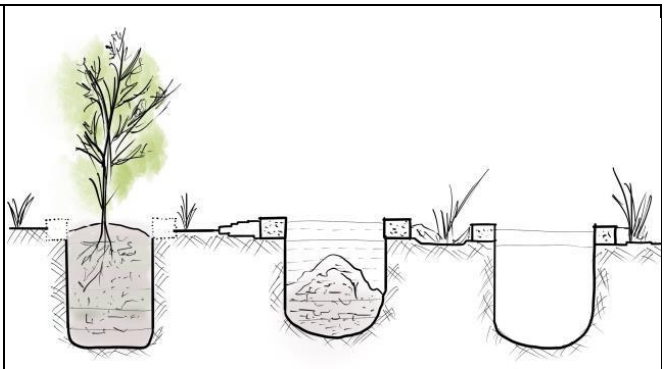
- No ventilation in sleeping units.
- Poor sanitation as common bathing region is near sewage.
- For sleeping, a temporary bed is built, which is quite uncomfortable.
- Not durable and weather resistant.
- Poor drainage.
- Structurally unstable units.
- No proper cooking and other essential facilities provided.

8.8.3 Inferences

A construction worker, who materializes the designs on construction sites and is an integral part of the construction industry often gets neglected. With evolution in buildings, the living conditions of workers has not evolved much. These are to be dealt with humanity and appropriate level of comfort, convenience and safety are to be considered for their residential facility on site. Some of the take-away are listed hereunder.

- Provision of community areas and facilities for CWH is necessary.
- Shuttering ply is a versatile material and being used for multiple purposes. It is easily available, durable and can be used multiple times.
- Use of mobile toilets which is easy to transport to other sites.

Table 1: Take Away of Good Practices from Case Studies

	
Common Kitchen Spaces (Sharing of Resources and Social Cohesiveness)	**Composting Pits for Organic Waste**

8.8.4 Case Study-02

	Tata Steel's Nest-In is a range of steel-based modular and prefabricated construction solutions.
Location:	Can be installed in any required location.
No. of Dwellings:	As per requirement
Climate:	Suitable for all weather type.
Area of Each Units:	customizable
Material of Construction	Insulated sandwich panel and stainless-steel sections for framework of the cabins.
Variety of usage and sizes.	• Guard huts/ Security Cabin: 1.8 x 1.2 x 2.4 m • Storage containers: 1.8 x 1.2 x 2.4 m • Portable Toilets/ Sanitation Blocks: 6.0 x 2.4 x 2.65 m • Facilities at mines, construction sites & manufacturing plants: 6.0x2.65x3.0 m • Quarantine Wards & ICU Cabins: 12.0 x 3.0 x 2.65 m • Residential Accommodation: 6.0 x 3.0 x 2.65 m • Conference Rooms: 6.0 x 3.0 x 2.65 m
Advantages:	• They are portable, easy-to-install and can be reused and repurposed. • These units also offer flexibility in terms of design and speed of installation. • They are also cost effective as compared to conventional, permanent construction.

Figure 5: Pre-Engineered Building Solutions by TATA Nest-In

9.0 Goals and Strategies

9.1 Energy Performance

Goals

- To achieve optimum thermal comfort
- To keep the LPD < 10 W/m^2.
- To meet the annual energy demand (approx. 31060 kWh).

Strategies to Achieve the Goal

- Dwelling units shall be suitably oriented with respect to cardinal directions (N, E, S and W) for optimum thermal performance. Also, sun shading / overhangs shall be designed so that these are warm during winter season and cool during summer season.
- Efficient light fixtures i.e., LED Lights shall be used for indoor and outdoor lighting.
- Generating 100% renewable energy on site i.e., Solar PV Modules shall be provided on rooftop of dwelling units.

9.2 Water Performance

Goals

- Reducing the freshwater consumption by 30% with respect to conventional demand i.e., 135 l/head/day.
- To recharge ground water table.

Strategies to Achieve the Goal

- Use of water efficient plumbing fittings and fixtures.
- Recycle and reuse greywater after treatment.
- Use of Rainwater as much as feasible
- Installing rainwater harvesting system for recharging Ground Water Table.

9.3 Embodied Carbon

Goals

- Reducing Embodied Carbon by 30% with respect to base case.

Strategies to Achieve the Goal

- Use of Low Embodied Energy Building Materials.
- Use of Building Materials with Multiple Use / Cycles.
- Use of Building Materials which do not harm the environment when disposed after life cycle.

9.4 Resilience

Goals

- To provide the construction workers with the built environment, which can protect them from natural disasters like earthquake, flooding and landslides.
- Life Safety shall be considered for all residents from all external threats like wild animals and theft.

Strategies to Achieve the Goal

- Judicious site planning to avoid any chance of accident during any disaster.
- Only one storied dwelling units are provided, which are structurally stable, and no damage is envisaged during moderate earthquake scenario.
- Providing sturdy fencing all-round, CCTV surveillance and controlled entry to CWH site to avoid any attack by the wild animals like Bear / Jackal.

9.5 Engineering and Operations

Goals

- To design a durable, easy to assemble and dismantle, convenient to transport and adaptable to be reused after a construction project is over.
- To avoid any wastage of building materials / resources during construction/fabrication, installation and dismantling of dwelling units.
- To optimize energy consumption in Operations and Maintenance.

Strategies to Achieve the Goal

- Building Materials shall be judiciously selected on the basis of their physical and thermal properties.
- Grid of modular system shall be considered so that the modules can be fabricated using the standard size of materials available in the market.
- Electrical, Water and Waste Management systems shall be judiciously designed for optimized functional use to avoid any wastage of electricity and materials.

9.6 Architectural Design

Goals

- To cater to gender specific needs of safety, privacy, and hygiene.
- To provide suitable spaces to socialize, creating a sense of dignity, pride and belongingness for workers and their families including children.
- To provide an ambience in the CWH / residential zone which convey feeling of safety, comfort & convenience to all residents on construction worker site.
- To ensure the well-being of all residents.

Strategies to Achieve the Goal

- Considering natural day light and ventilation in dwelling units.
- Spaces to be designed according to Climate and Vastu for well-being of all residents.
- Fulfil the NBC Fire and Life Safety Standards especially with respect to the area requirement and fire hazards.
- Considering provision of proper solid waste management and hazard free disposal.
- Facilitating CSR activities by the corporates / NGOs for under privileged community/children.
- Use of insulation material in walls and roof to achieve thermal comfort.
- Improve the wellbeing (saving time and energy) of residents by providing convenient shop making.

9.7 Affordability

Goals

- To keep the price per module optimum whilst improving the thermal comfort.
- To consider building materials with optimized performance (Low Embodied Energy and Low Life Cycle Cost).
- To design the module with the materials for multiple use (average 6 use cycles).

Strategies to Achieve the Goal

- Dwelling Units shall be designed on modular system considering standardization of elements and keeping the type of modules in limited numbers.
- Joinery and construction details shall be worked out those are simple and easy to practice.
- Appropriate materials shall be considered (based on their physical and thermal properties as well as the cost) for structural members, wall units, roofing system and the flooring.

- Construction cost shall be optimized in view of life cycle of material, with No compromise on structural stability.

9.8 Innovation

Goals

- To work out the solution of modular walls, roof and floor system for CWH, which is cost effective, visually appealing, easy to fabricate, transport, install and dismantle after the completion of the project adaptable to be reused.
- To integrate roof top solar PV panels in the architectural design.

Strategies to Achieve the Goal

- Customized sections of walls, roof and floor shall be worked out after carrying out exercises and analyzing the thermal performance of various concepts/options.
- Simple and easy to fabricate / practice joinery details shall be worked out for various joints of structural members and other paneling units.
- Roof top solar PV panels for optimized energy performance.

9.9 Health, Safety and Well Being

Goals

- To provide an overall ambience within the CWH residential zone which convey feeling of safety, comfort, convenience, and dignity to all residents on construction worker site.

Strategies to Achieve the Goal

- Dwelling Units of appropriate size shall be designed for convenient and comfortable living, which suits the lifestyle of the construction workers.
- Adequate toilet facilities shall be provided for the residents.
- Common semi covered kitchen workstations shall be provided with LPG connection for convenient and smokeless cooking.
- Adequate covered, semi covered, open spaces to facilitate individual, family and community activities.
- Composting Pits shall be provided for efficient and environmentally friendly disposal of solid waste.
- On site shop shall be provided to meet the daily needs of the residents

9.10 Value Proposition

Goals

- To work out a feasible and cost-effective solution for the CWH, which can be adopted by any project developer for their projects in composite climatic zone of India.
- To create and ensure an ambience within the residential zone which is welcoming and convey the feeling of safety, comfort, convenience, belongingness, and dignity to all residents on site, as well as which helps in their productivity during working hours as a byproduct.

Strategies to Achieve the Goal

- These goals shall be achieved by considering/integrating appropriate spaces, features, elements, systems and materials / finishes in the site layout and the architectural design of buildings.
- Majority of the strategies are already mentioned in various points from 9.1 to 9.9 above.

10.0 Design Process

Good Health and Well Being of Human Being has been the spirit of VASTU Principles and very much contextual in the modern times too. In Vedic Period too, scholars had given due emphasis on Covered, Semi-Covered and Open Spaces in any planning and development works in the composite climate of India.

Alinda (Verandah) is considered as ideal place for performing daily household activities in all seasons, as this is the space where we get natural daylight and breeze throughout the day in all seasons. **Shala** (Room) is considered a private living zone, for which adequate provisions of daylighting and thermal comfort are considered in the scheme. Size of the dwelling units is considered which suits the anthropometrics and facilitate routine family activities of the resident/family. Some of the other considerations are illustrated in the Figure below.

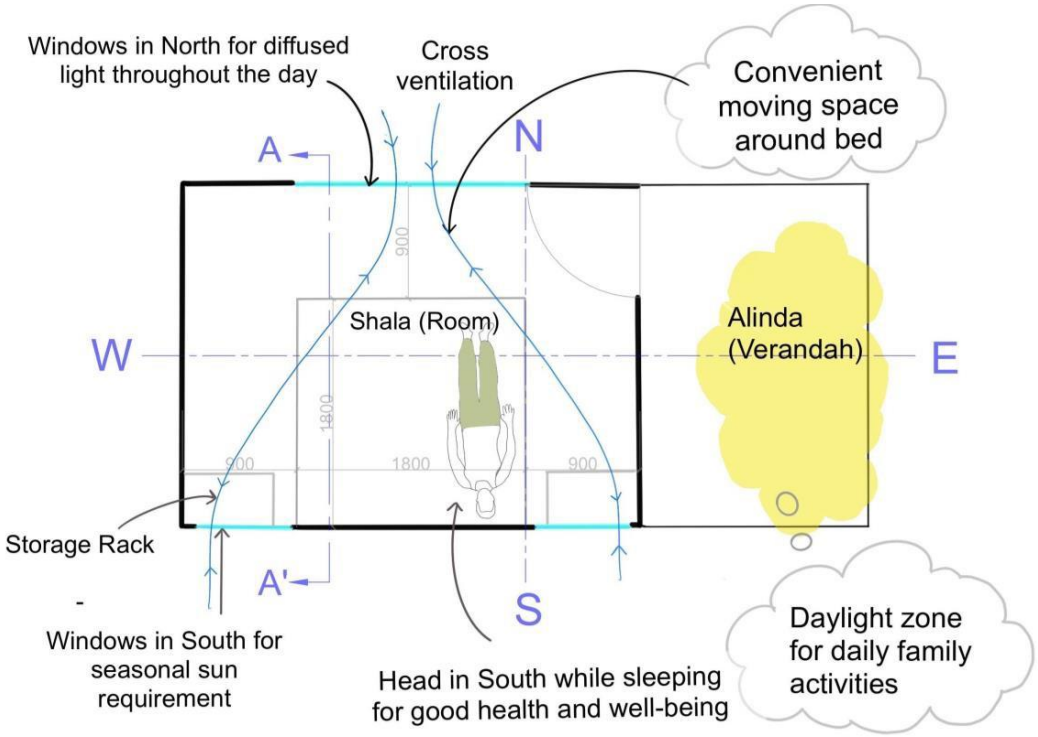


Figure 6:Conceptual Framework of Typical Dwelling Unit

(Source: Andrew Marsh Tool, Climate Consultant, Design Builder)

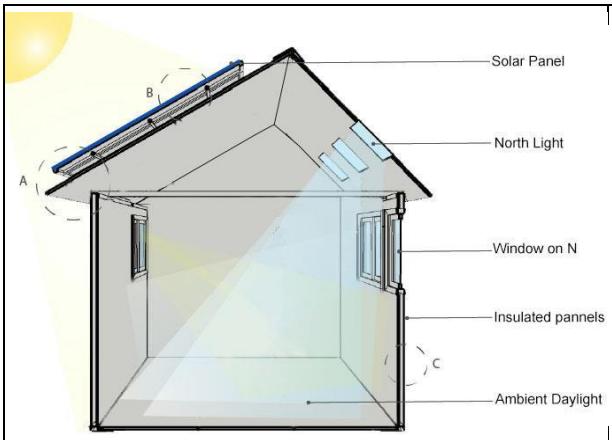


Figure 7: Cross Section of Typical Dwelling Unit indicating Fenestrations and Rooftop

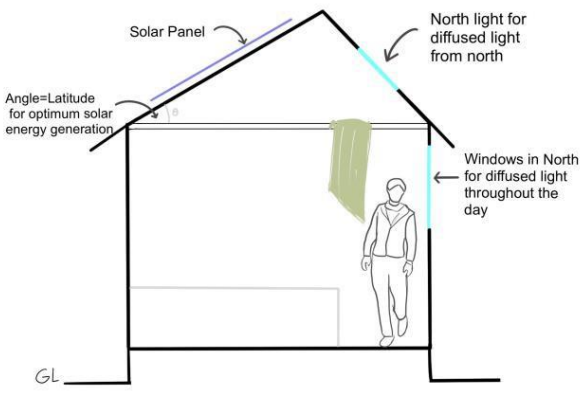


Figure 8:Conceptual Section of Typical Dwelling Unit

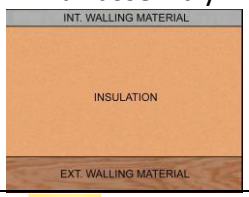
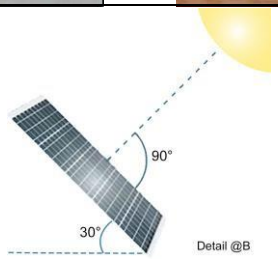
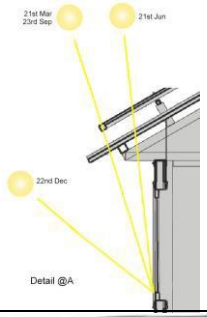
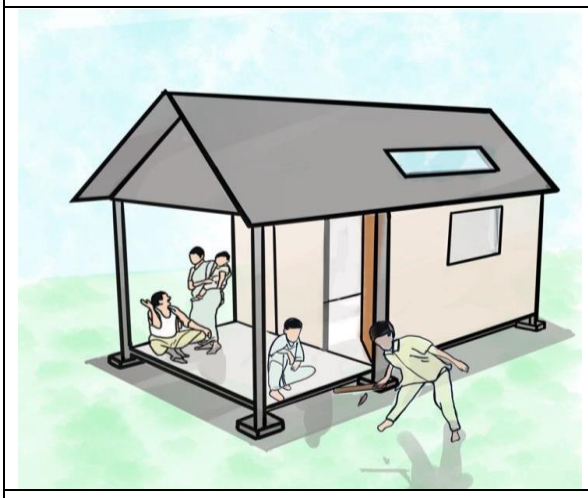
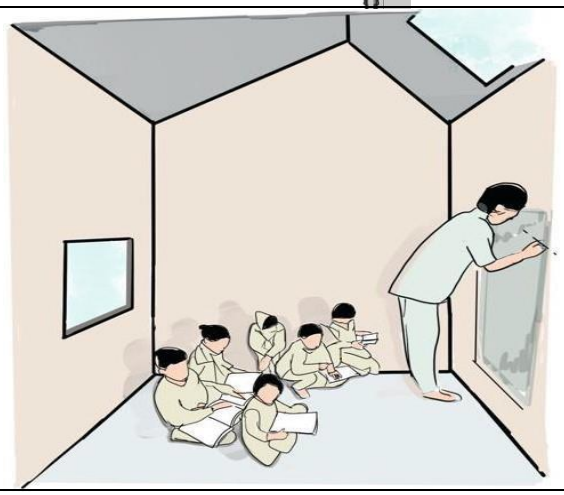
Insulated Walls and roofs	Roof assembly  Wall assembly 
Solar panel provided in the S at 30 ° inclination in accordance with the latitude to harness maximum solar radiation throughout the year.	
The extension of roof to act as a sunshade to avoid the entry of summer sun through the windows. The optimum length of extended roof is recommended 275mm as per the sun angles on the 21st of Jun 22nd Dec 23rd Mar and 22nd May	
	
	

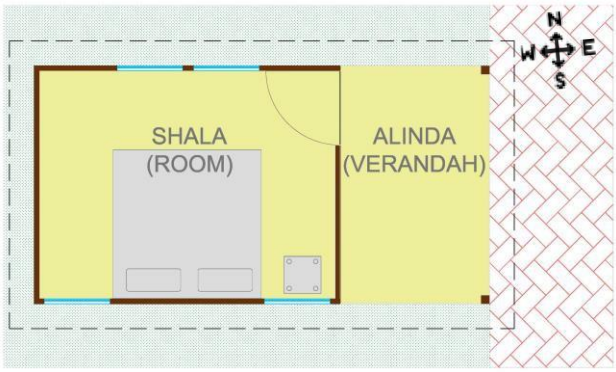
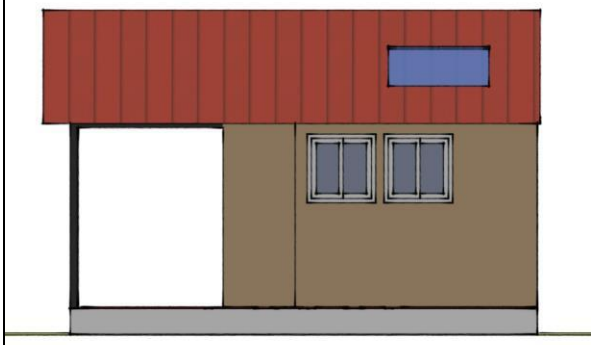
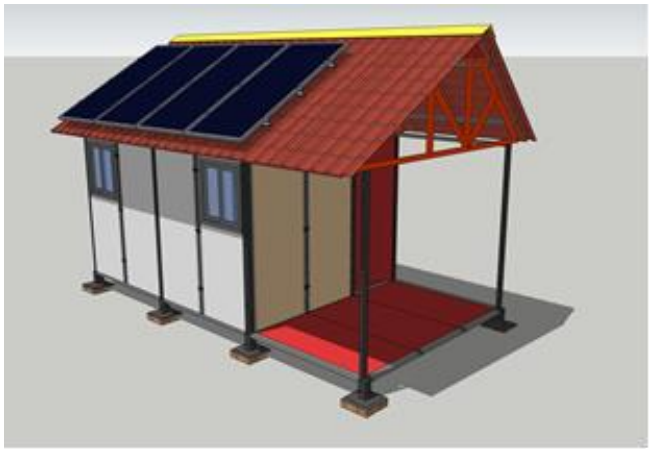
Figure 9:Conceptual Sketches of Dwelling Unit to Suit various Activities.

Verandahs to act as the center point social cohesion and a place for the families to carry out major day-to-day activities.

Creche, Convenient Shop and Infirmary and also depicted in the sketches.

Dwelling Unit is conceptualized to achieve the Goals. Sun Path and shadow studies are carried out using Sketch Up-Pro software. Shadow patterns are studied for 04 major dates in a year (21 March, 21 June, 22 September and 22 December) to analyze suitability of orientation and sun shading overhang width for various seasons. Satisfactory responses were frozen and output of shadow pattern is presented in composition below (for 12:00 hours on the mentioned dates).

Table 2: Conceptual Dwelling Units Responding to the Local Climate

	
PLAN of Dwelling Unit	North Elevation of Dwelling Unit
	
Shadow Pattern on 22 DEC (Winter Solstice)	Shadow Pattern on 21 MAR (Equinox)
	
Shadow Pattern on 22 SEP (Equinox)	Shadow Pattern on 21 JUN (Summer Solstice)

11.0 Design Documentation

11.1 Energy Performance

11.1.1 EPI Goal

Total Built up area (proposed): 780 m^2 (Number of Dwelling Units proposed: 36 Nos)
Total Energy Consumption (estimated for one year): 21158 kWh
EPI: 21158 / 780 = **23.98 kWh/ m^2`**

11.1.2 Energy Analysis

Electricity supply shall be initially provided through a temporary electric connection of Uttarakhand Power Corporation Limited (UPCL) for essential services. Further, it shall be generated on site through Renewable resources (Solar PV Panel), however supply through UPCL shall be continued only for essential services.

Relevant statistics is mentioned hereunder;

Number of Dwelling Units proposed: 36 Numbers (Total)
Total Built up area (proposed): 780 m^2
Total Energy Consumption (estimated for one year): 21158 kWh

Target EPI: 21158 / 780 = **23.98 kWh/ m^2**

Solar Panel Size considered: 992 x 1955 mm

Average solar radiation considered: 150 W/ m^2

Energy Generation per panel (average): 216 W

Sunshine hours during the year: 2578 h

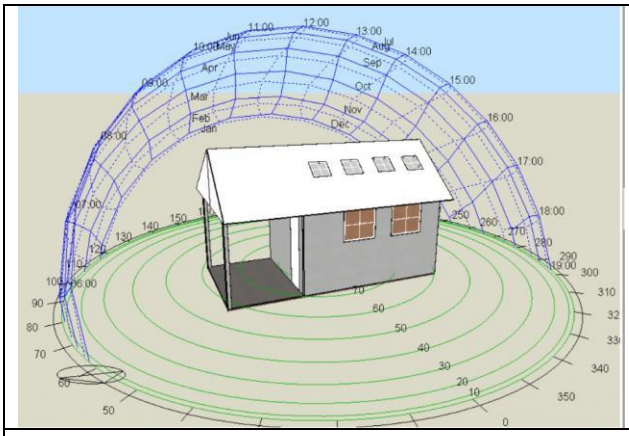
(Source of Information: Climate Studio and TATA Power Solar TP 300 series brochure)

Total number of Solar Panels (Rooftop) to be installed: 60

Total Renewable Energy Generated: 60 x 216 x 2578 = 33410.9 kWh

We can generate more than 100% energy required per year through renewable energy resources with the proposed configuration / architectural scheme.

EPI of proposed project is **23.98 kWh/ m^2**, which is less than 29.0 kWh/ m^2 (a bench mark of 5 Star Rating of Residential Building Energy Rating Program of BEE (Govt of India)



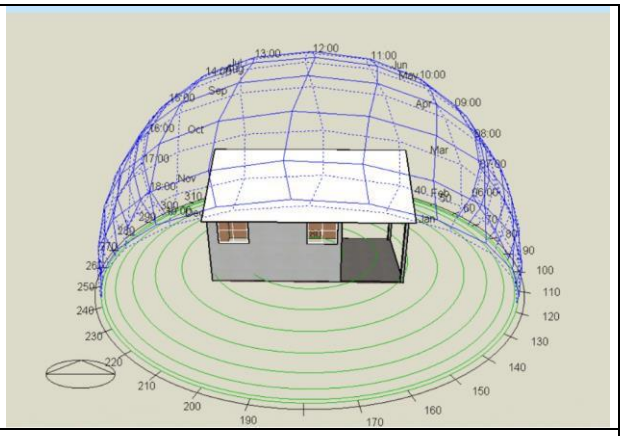


Figure 10: Indicative Images of Sun Path Analysis using Design Builder Software.

11.1.3 Energy Calculation

Table 3: Energy Calculation for Baseline Case

Energy Calculation - Baseline Case									
S.No.	**Space**	**Appliance**	**Wattage**	**No. of unit**	**Total Load (Watt)**	**Daily Hours of operation**	**Daily Consumption (kWh/day)**	**No.of days**	**Yearly consumption (kWh)**
1	**Workers Dwelling Units**	Fan	60	1	60	8	**0.48**	200	**96**
		LED tube	12	2	24	10	**0.24**	365	**87.6**
		6A Socket	60	1	60	6	**0.36**	365	**131.4**
	Total				-	-	**1.08**	-	**315**
	Total for 36 units				-	-	**38.88**	-	**11340**
2	**Common spaces**								
i	Bathing Space	LED bulb		12	144	8	**1.152**	365	**420.48**
ii	Toilets	LED bulb		20	240	8	**1.92**	365	**700.8**
iii	Common Kitchen	LED bulb		6	72	8	**0.576**	365	**210.24**
iv	Creche	LED bulb		2	24	10	**0.24**	365	**87.6**
		Fan		2	120	10	**1.2**	365	**438**
		6A Socket		2	300	10	**3**	365	**1095**
v	Infirmary	LED bulb		2	24	12	**0.288**	365	**105.12**
		6A Socket		2	300	13	**3.9**	365	**1423.5**
		Fan		1	60	12	**0.72**	200	**144**
3	**Services & Staff**								
i	Water supply + Pump Room	LED bulb		2	24	6	**0.144**	365	**52.56**
		Water Pump	1200	1	1200	3	**3.6**	365	**1314**
ii	Supervisor Office	LED bulb	12	2	24	10	**0.24**	365	**87.6**
		Fan	60	1	60	10	**0.6**	365	**219**
		Air Conditioning	3500	1	3500	12	**42**	90	**3780**
iii	Outdoor Lighting	LED Lights	18	30	540	13	**7.02**	365	**2562.3**
iv	Electricity + Battery room	LED bulb	12	2	24	3	**0.072**	365	**26.28**
vi	STP & Water Treatment	STP and Water Treatment	1500	1	1500	4	**6**	365	**2190**
vii	Miscellaneous	Miscellaneous	80	4	320	6	**1.92**	365	**700.8**
TOTAL ENERGY REQUIRED							**113.472**		**26897.28**
Daily Consumption				**113.47 kWh /780 sq.m. = 0.145 kWh/sq.m./day**					

Energy Performance Index (EPI): 26897.27/780 =34.48 KWH per sq. m/year
Preliminary estimate of onsite renewable energy generation potential = 42.83 KWH per sq.m/yea

Table 4: Energy Calculation for the Proposed Development

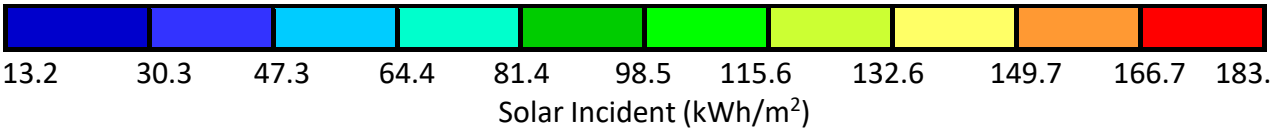
Energy Calculation - Our Case									
S.No.	**Space**	**Appliance**	**Wattage**	**No. of unit**	**Total Load (in Watt)**	**Daily Hours of operation**	**Daily Consumption (kWh/day)**	**No. of days**	**Yearly consumption (kWh)**
1	**Workers Dwelling Units**	Fan	60	1	60	8	**0.48**	200	**96**
		LED bulb	12	1	12	8	**0.096**	365	**35.04**
		6A Socket	60	1	60	6	**0.36**	365	**131.4**
	Total				-	-	**0.936**	-	**262.44**
	Total for 36 units				-	-	**33.696**	-	**9447.84**
2	**Common spaces**								
i	Bathing Space	LED bulb	6	8	48	6	**0.288**	365	**105.12**
ii	Toilets	LED bulb	6	20	120	6	**0.72**	365	**262.8**
iii	Common Kitchen	LED bulb	12	6	72	6	**0.432**	365	**157.68**
iv	Creche	LED bulb	12	2	24	8	**0.192**	365	**70.08**
		Fan	60	2	120	9	**1.08**	200	**216**
		6A Socket	150	2	300	8	**2.4**	365	**876**
v	Infirmary	LED bulb	12	2	24	12	**0.288**	365	**105.12**
		6A Socket	150	2	300	8	**2.4**	365	**876**
		Fan	60	1	60	12	**0.72**	200	**144**
3	**Services & Staff**								
i	Water supply + Pump Room	LED bulb	12	2	24	6	**0.144**	365	**52.56**
		Water Pump	1000	1	1000	3	**3**	365	**1095**
ii	Supervisor Office	LED bulb	12	2	24	10	**0.24**	365	**87.6**
		Fan	60	1	60	10	**0.6**	200	**120**
		Air Cooler	400	1	400	10	**4**	90	**360**
iii	Outdoor Lighting	LED Lights	18	30	540	12	**6.48**	365	**2365.2**
iv	Electricity + Battery room	LED bulb	12	2	24	3	**0.072**	365	**26.28**
vi	STP & Water Treatment	STP and Water Treatment	1500	1	1500	4	**6**	365	**2190**
vi	Miscellaneous	Miscellaneous	60	4	240	3	**0.72**	200	**144**
TOTAL ENERGY REQUIRED							**63.472**		**18701.28**
Daily Consumption				**69.72 kWh /780 sq.m. = 0.089 kWh/sq.m./day**					

Target Energy Performance Index (EPI): 21158/780 =23.98 KWH per sq. m/year
Preliminary estimate of onsite renewable energy generation potential = 42.83 KWH per sq.m/year
Site has the potential to generate energy through renewable resources (Solar PV Panels) 1.5 times than the annual energy consumption, however it is proposed that necessary Solar PV Panels should be installed to achieve a stage of NET ZERO Energy.

11.1.4 Solar Radiation Analysis

Thermal analysis of model unit has been carried out using Andrew Marsh Tool, Climate Consultant, Design Builder. Data from available Govt documents / publications and internet resources has been gathered. Output of simulation for some cases is being represented hereunder with the graphical scale.

Although, we had considered VASTU Principles and had oriented the layout of dwelling units with due respect to cardinal directions, however, its suitability is validated by the results of thermal simulations. Results are presented in the form of graphical illustration, which confirm that maximum solar radiation is received on south face, which suits the installation of roof top solar radiation. This configuration not only helps is generating on site energy through renewable resources, but rooftop solar PV panels provide shade to the roofing system, which controls the rise of indoor temperature inside dwelling during summer season. During winter season, solar radiation is received on south wall, which helps in warming the indoor air when it is desirable.



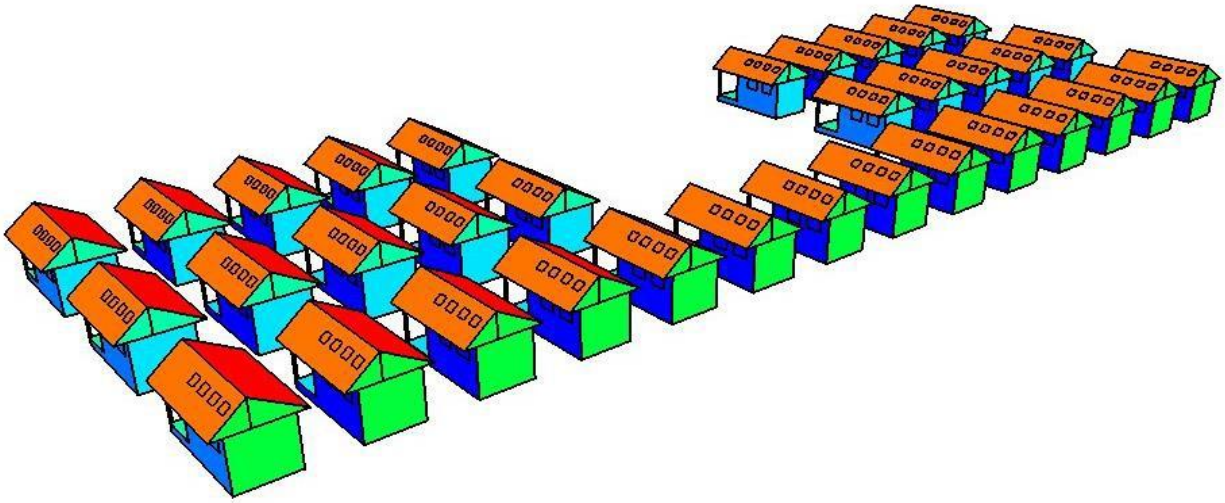


Figure 11: Solar Radiation values on North faces of the Roofing panels

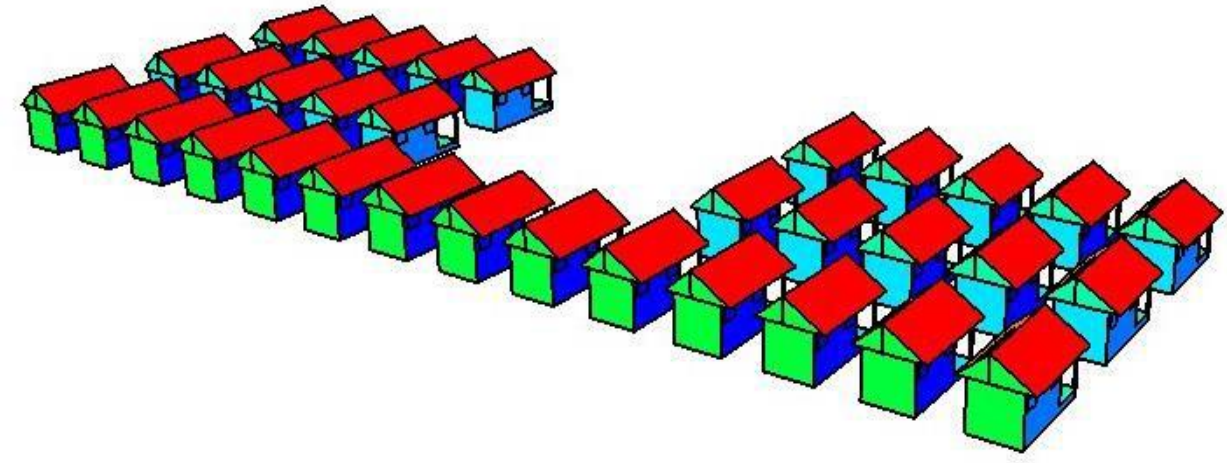


Figure 12: Solar Radiation values on South faces of the Roofing panels

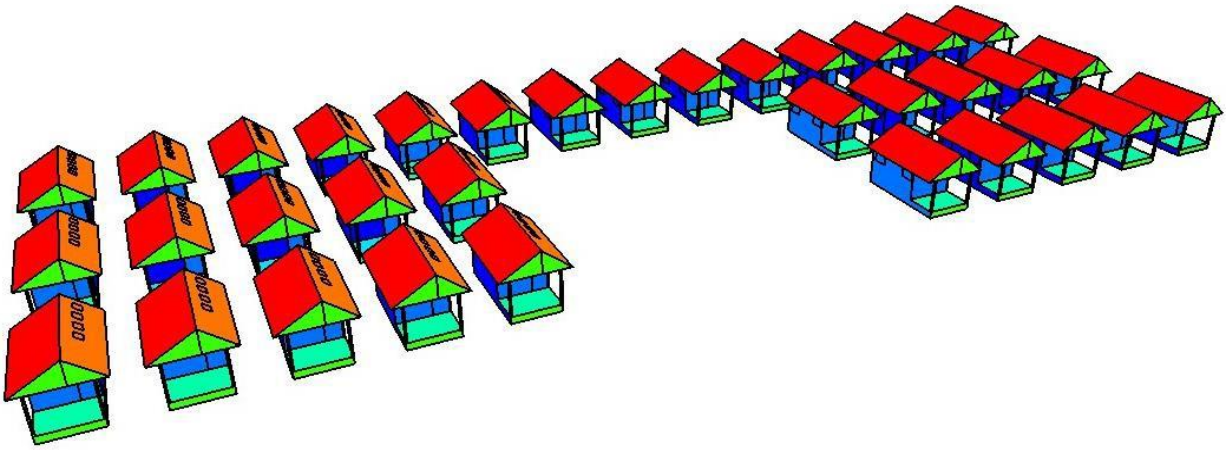


Figure 13: Solar Radiation values on Verandah faces of the Roofing panels

11.1.5 Daylight Analysis using Design Builder Software

Adequate provision of daylight is considered in architectural scheme of CWH unit. Four windows of 0.8x0.8 m each are provided, 02 on North wall and 02 on south wall. Total windows area is 25% of the floor area of unit, which is in line with guidelines of National Building Code of India.
Although, daylight levels fluctuate during different time periods of the day, also depends of sky conditions during various sessions, however, simulation results indicate that 50 to 100 lux level is achieved on floor level during day time under clear sky conditions in the month of December.

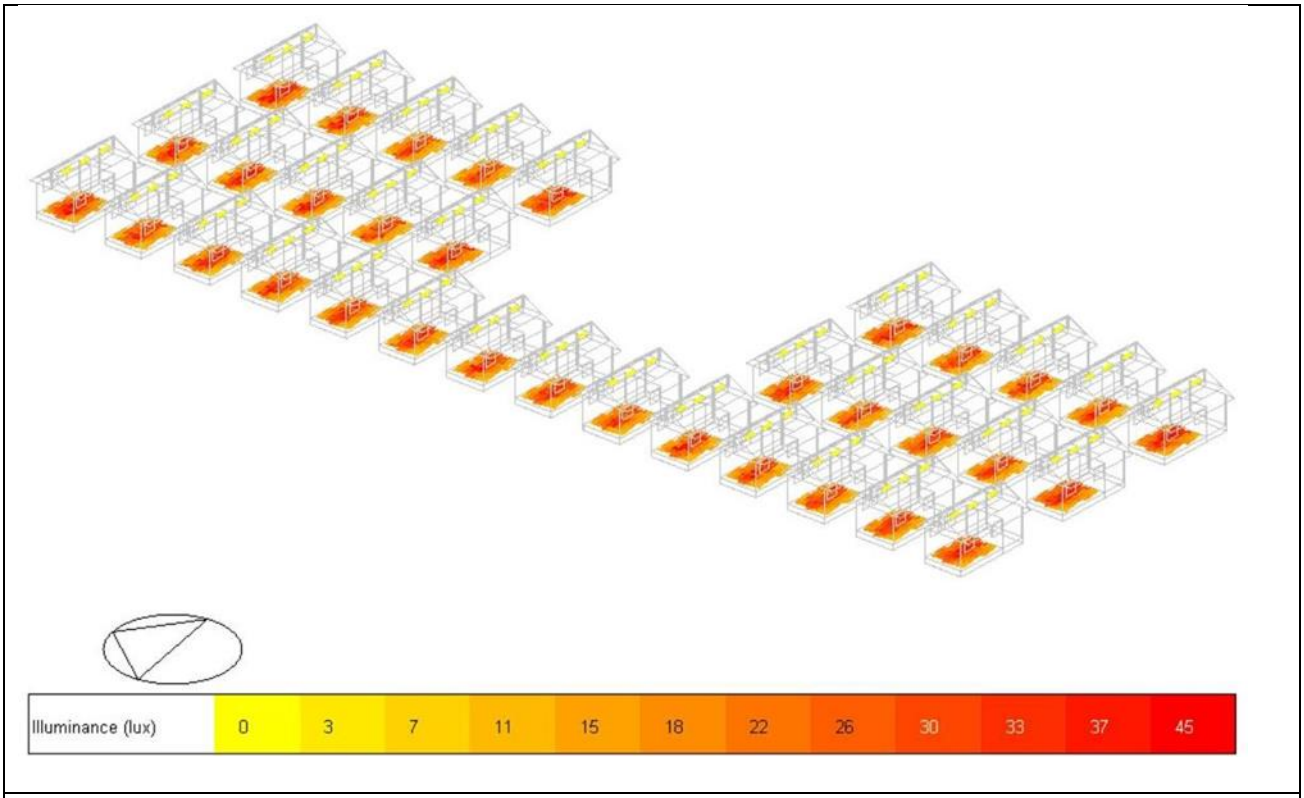


Figure 14: Daylight Simulation Indicating Illuminance level (02:00 PM in March)

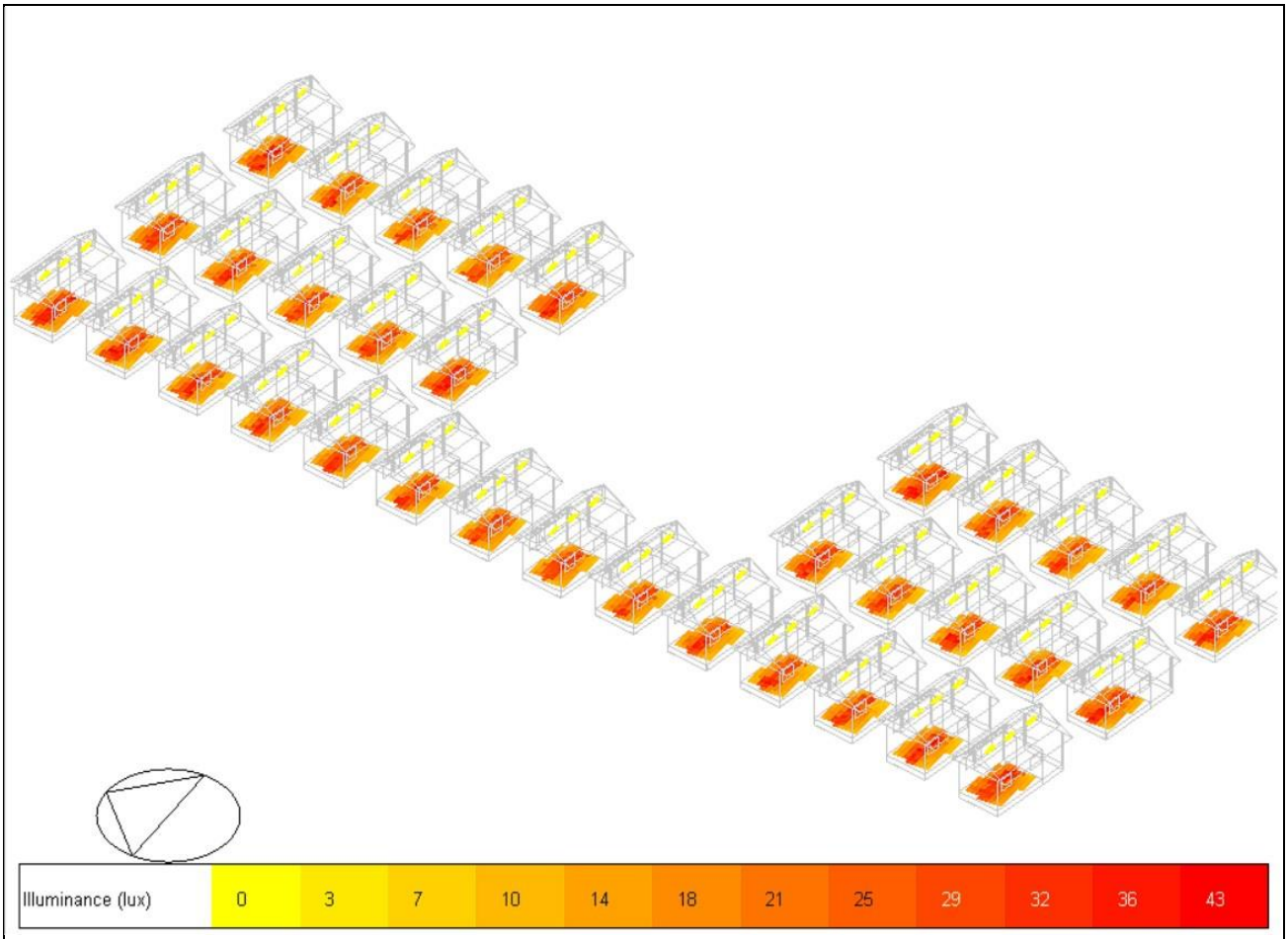


Figure 15: Daylight Simulation Indicating Illuminance level (02:00 PM in August)

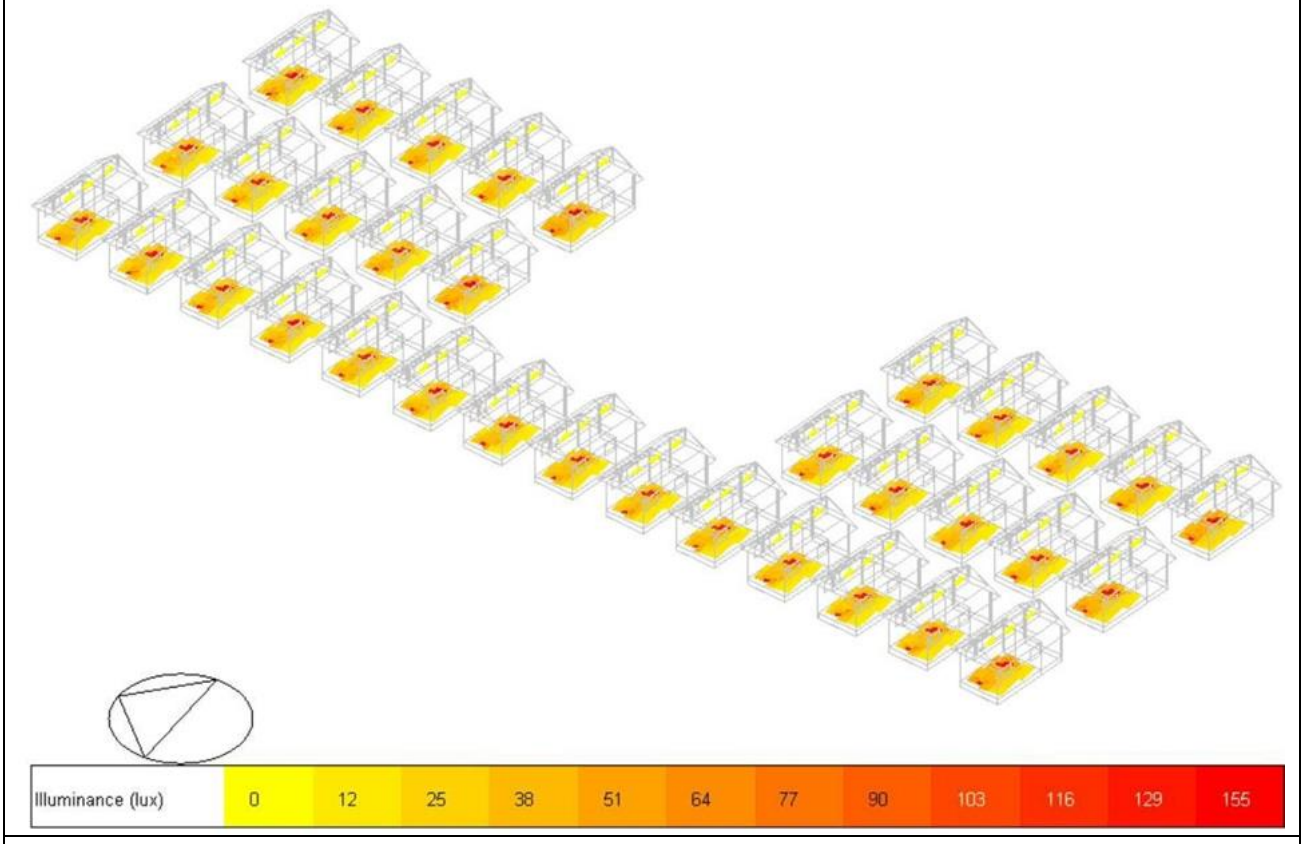


Figure 16:Daylight Simulation Indicating Illuminance level (02:00 PM in December)

11.2 Water Performance

11.2.1 Water Consumption

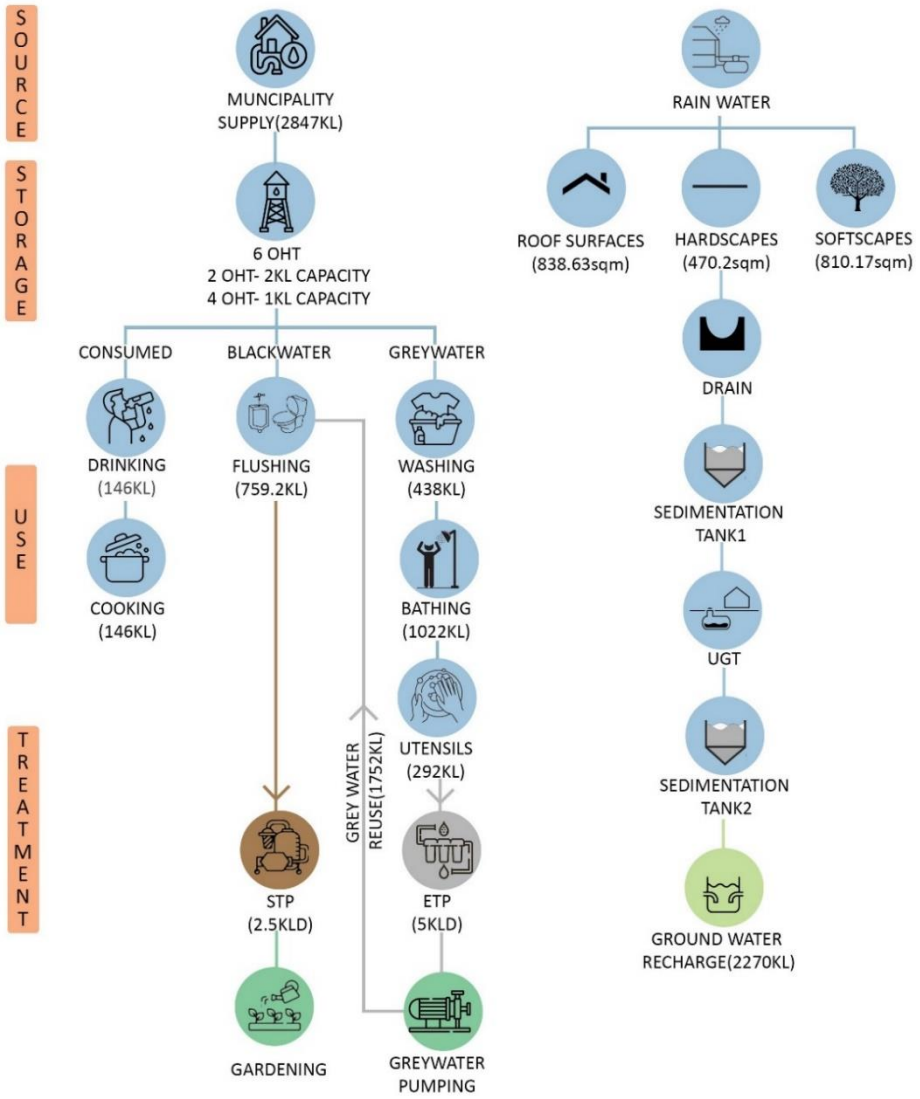


Figure 17: Water Cycle Diagram

Note: Water quantity is given in Kilo Liter (KL) per year. Water usage values listed here are as per our calculations following NBC guidelines. However, there is a slight difference in the calculation of grey & black water generation using the Water calculation tool provided in Survival Kit.

Table 5: Efficient Water Consumption

CASE	LPD/ PERSON	TOTAL LPD	ANNUAL CONSUMPTION
Base case	135L	10,800L	39,42,000 L
Our case	96L	7,680L	28,03,200 L

Note: Water consumption on site is considered 30% lesser than the Base Case consumption.
We intend to achieve it by certain measures like water efficient fixtures, limited use, recycling and avoiding any wastages

Table 6: Consumption and wastewater generation

TOTAL USE	END USE	GREY WATER GERENATED	BLACK WATER GEN.	CONSUMED
PER DAY	7,680 L	4,800L	2,080L	800 L
ANNUAL	2,803,200L	17,52,000L	7,59,200L	292000 L
Solution provided: Portable Sewage Treatment Plant (Capacity: 2500 liters/day)				

11.3 Embodied Carbon

Carbon footprint is an environmental indicator that represents the global warming potential (GWP) of greenhouse gases emitted in the process of developmental/ construction activities. CO_2 equivalent (CO2 e) of a residential building is estimated as 645 – 1059 kg Co_2 e/m^2 for new construction. However, specifications of CWH are considered moderate with respect to general resident buildings and hence it is expected that CO_2 equivalent of CWH shall be about 300 kg Co_2 e/m^2. We have estimated the material quantities of a baseline case of CWH and the proposed case. Accordingly, carbon footprint is calculated by multiplying CO_2 equivalent factors of respective materials to get the embodied carbon, summary of which is presented in the table below, together with graphical comparative illustrations:
Source: (DOI:10.3390/su10093229)

Table 7: Embodied Carbon Emission Analysis (Baseline and Proposed case)

System Type	Baseline Case				Proposed Case			
	Material Emission	Transport 1	Transport 2	Total	Material Emission	Transport 1	Transport 2	Total
Wall	162130	207.6	103.8	162441	12998.7	100	90	13188.7
Floor	10950	3.5	1.6	10955.1	3556.4	2.8	1.8	3561
Fenestration	7980	10.5	5.2	7995.7	6292.8	2.4	1.2	6296.4
Roof	6514	10.5	5.2	6529.7	23919	13.3	3.5	23935.8
Structural Elements	5018	2.5	1.6	5022.1	100685	11.5	6.2	100703
Grand Total Emissions per functional (kg CO2 e)				**192944**	**Grand Total Emissions per functional (kg CO2 e)**			**147685**

Source: https://learning.solardecathlonindia.in/mod/resource/view.php?id=1672

Table 8 below illustrates various building materials/elements used in the proposed CWH scheme. Weight of various building materials is determined and accordingly equivalent CO2 emissions are calculated.

Table 8:Embodied Carbon/ Emission Table

ITEM	Weight Per Module (kg)	Weight of 41 Modules (kg)	Carbon Emission Equivalent	Total Carbon Emission (kg CO2 e)
Solar Panel Mounting	60.00	2,460.00	2.5	6150.00
Purlins	80.00	3,280.00	2.5	8200.00
Trusses	194.72	7,983.52	2.5	19958.80
Windows	40.29	1,651.89	2.5	4129.72
T-Section Flooring	10.40	426.40	2.5	1066.00
Angle Section Flooring	09.42	386.22	2.5	965.55
C-Section Flooring	168.95	6926.95	2.5	17317.37
C-Section Roofing	121.28	4972.48	2.5	12431.20

C-Section Column	292.37	11987.17	2.5	29967.92
Angle Section Column	11.02	451.82	2.5	1129.55
Box Section Column	69.06	2831.46	2.5	7078.65
Box Section Footing 1	24.08	987.28	2.5	2468.20
Box Section Footing 2	11.40	467.40	2.5	1168.50
Base Plate	33.91	1390.31	2.5	3475.77
Gusset Plate + Other units in Trusses	8.00		2.5	
Main Gate	-		2.5	
Miscellaneous	21.00	861.00	2.5	2152.50
Corrugated GI Sheet	249.75	10239.75	3	30719.25
Plywood	366.83	15040.03	-0.31	-4662.40
Acrylic Sheet	15.36	629.76	1.7	1070.59
Rice Husk Board	98.18	4025.38	-1.3	-5232.99
Pu Foam	08.78	359.98	2.9	1043.94
EPS Sheet	24.05	986.05	2.9	2859.54
PCC	229.73	9418.93	0.14	1318.65
Bricks	120.00	4920.00	0.32	1574.40
Electric Wires	0.15	6.15	7.4	45.51
Chain Link Fencing	-	41.00	3	123.00
GI Edging	7.92	324.72	3	974.16
TOTAL	**2276.65**	**93,056**	**-**	**147493.40**

Source: IFC Database for Global Warming Potential

11.4 Resilience (Various Aspects)

It is the ability of a project/development to adapt to change and regain its original state when subject to shock, such as flooding, drought, pest attack and health hazards.

Following provisions are considered in architectural scheme for the purpose.

Geographical Hazard:

1. There are no chances of site being flooded during monsoon season, being HFL of the region is much below than the site level above mean sea (difference of more than 100 m).
2. In view of locational and geographical aspects, there is no chance of landslide etc. on site, being no mountains or valleys are in adjacency.
3. Site has mild topography and there are no chances of water logging on site, however, necessary drains shall be provided for smooth discharge of excess storm water from site.

Facilities:

4. Site shall be treated with necessary chemicals (Chlorpyriphos 5%) and other pest control measures for rodent control shall also be taken care. Building materials are chosen so that these are not affected by the termite and Fungai etc.
5. Pathways are provided for convenient pedestrian movement within site as well as to

protect the residents from moving in water logging during the raining season.

6. Entry to the premises is controlled and monitored. For the safety of the residents, Chain-link fencing (2400 mm high) is provided to protect the residents from attack by wild animals like bear and fox / jackals.
7. Only one storied dwelling units are provided, which are structurally stable, and no damage is envisaged during moderate earthquake scenario.
8. CCTV cameras shall be provided in common areas for general monitoring and to avoid any cases of theft and social misconduct.
9. Architectural finishes for floors are suitably considered so that there are no slip hazards.
10. Development shall happen in a way so that after completion of project, CWH units shall be dismantled and there will be negligible construction waste left on site, and dwelling units and joinery details shall be designed accordingly.

Disaster Hazards:

11. Storms (Extreme weather conditions / windstorms) may occur occasionally, and hence trees are not planted in East Direction to protect the life and property from any damage.
12. Lightning spike shall be provided with the conductor with onsite earthing for protection of the units from any lightening incidence.
13. Central assembly area is provided where people can be assembled in case of earthquake.

Health Hazards:

14. CWH shall be provided in a safe zone where construction works dust / noise do not impact adversely on the heath of the residents.
15. Electrical fixtures, fittings and wires etc. shall be provided in a way so that residents are safe and chances of any short circuiting / shocks are minimized.

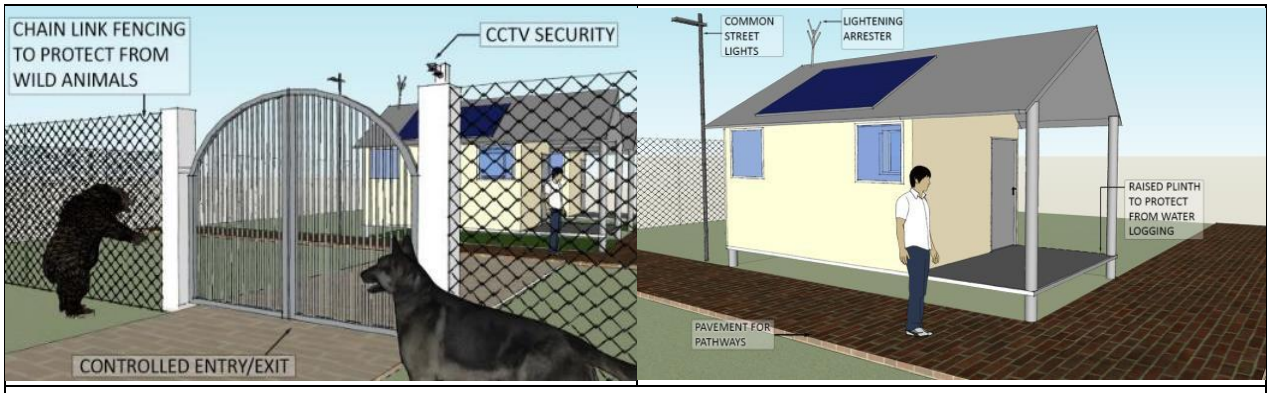
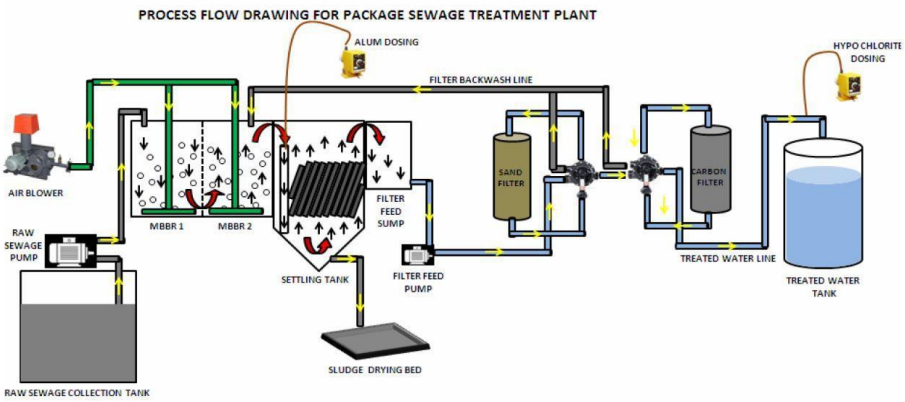


Figure 18: Sketches Illustrating Provisions for making the development Resilient.

11.5 Engineering and Operations

Table 9: Construction Steps/Features of various elements/equipment for CWH Project

Equipment Used	Details	Capacity	On Site Construction Steps
ETC Solar water heater	Evacuated Tube Collector (Standard) GI Powder Coated Tank of SS-304 	500L x 2 =1000L TOTAL = 1000L	1.Installation of water supply tank and pump 2.Installation of roof top solar water heaters 3.Connection of water supply, inlet and outlet pipes.
Portable STP	Membrane Bioreactor Sewage Treatment Plant	5000 l per day 0.5kWh pump	1. Layout markings on site. 2. Excavation of earth, PCC bed and levelling. 3.Installation of STP. 4.Laying of soil/sewer drain pipes and electrical connection. 5. Testing before operation.
			
Toilet	UPVC mobile bio clean toilets by Organica biotech Pvt. Ltd. 	(Trailer- 8-seater 17’ x 6’ 6”) x 2 =16 Nos.	1. This is a portable public toilet system, shall be located on designated place on site and necessary water supply, drainage and electrical connection shall be made.
Parabolic Solar Cooker 	Price-Rs 10,000 Brand-Jay Renewable Energy Private Limited Specifications- Fabricated Structure Easy to operate Available as a DIY Kit	Capacity-4 Jars Weight-17Kg Power-230W Voltage-220V	1. These are ready to use equipment’s, shall be placed on designated place on site. 2. Necessary training shall be given to all residents to use them appropriately. (Dos and Don’ts)

TP 300 - Solar Panel 	Price- Rs 8,700 Brand-Tata Power Specifications-72cell configurations with wattage 300watts. Torsion and corrosion resistant with anodized aluminum frame. High full factor for improved energy conversion efficiency	Power Output-300W Open Circuit Voltage (VOC)-44.8V Weight- 24 Kg Module Dimension-1955X992X38 mm	1. These are manufacturer Solar PV modules their installation commissioning / operation shall be dealt by the supplier, service provider. 2. No specific site work is required except electrical wire connection circuit. 3. No specific site work is required except electrical wire connection circuit. 4. Necessary space for battery is provided on site.
Plastic Underground Water Tank 	Price- Rs 10,000 Brand- Sintex Specifications- 47.2-inch diameter,46inch length.	Storage Capacity-	1. This will include on site works like marking on ground, excavation of earthwork and embedding readymade water storage tank imposition. 2. Necessary water supply inlet and outlet connections are to be made.
PVC White Ganga Water Storage Tank 	Price- Rs 5,000 Brand- Ganga Specifications- 44-inch diameter,46inch length	Storage Capacity-(2 x 2000) L + (4 x 1000) L =8000 L	1. This requires erection of stage by assembling mild steel members as per engineering drawings. 2. Water supply line are to be provided with necessary plumbing fitting like ball valve, union, float valve etc.
Street Lights	Price – Rs 1000 Brand – Surya	18-watt x 30 = 54 watt	1. Mild steel pipe section shall be maintained on the base plate with engineered attachment. 2. Lighting fixtures shall be mounted on top of the pipe and electrical connection shall be provided.

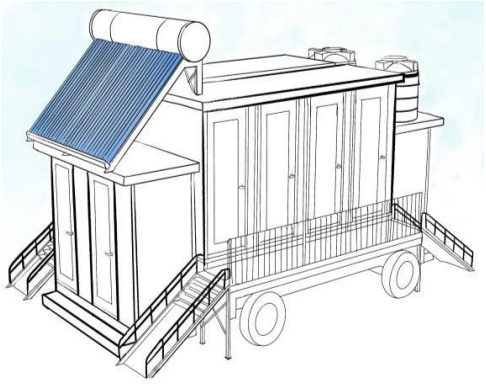


Figure 19: Solar Water Heater Diagram

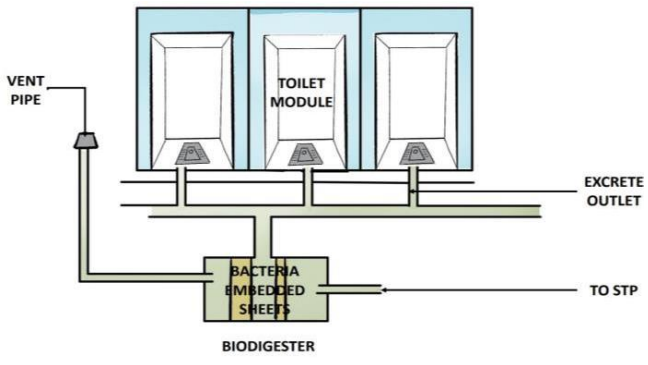


Figure 20: Bio Toilets fitted with Bio Digesters

Table 10: Construction Steps/Features of various elements for CWH Project

Services Provided	Material	On Site Construction Steps
Chain link Fencing	Galvanized Iron	• Hole is drilled in earth with auger at 4M center to center. • Base plate will be fixed to PCC bed • Three panels of chain link fencing shall be assembled on mild steel frame.
Main Gate	Chain linked panel Mild Steel Frame	• Earthwork, foundation work, support columns and fixing of gate shutters.
CCTV Camera	CP Plus	• No special element is to be considered • These shall be installed on under site of roof/electrical poles with necessary wiring connection with central storage and monitoring device.
Pavement	Clay bricks	• Levelling of ground • Laying of interlocking blocks/ bricks.
Drains	PVC Pipes	• 250 mm PVC pipe shall be cut longitudinally to obtain semicircular section which shall be laid on ground in slope 1:100 to facilitate drainage of storm water
Rainwater Recharge Pits	PCC	• Marking on ground • Excavation of earthwork • Installation of perforated PVC pipe in rainwater tank (plastered brick work covered with ferrocement lid) • After the project completing these can be used by the owner for Rainwater Harvesting in future for the project.

Note: We have studied various solutions available in the market, as offered by different manufactures/suppliers. We have selected an appropriate one which suits our requirements, capacity and lifecycle/warranty period on site service.

Table 11: Structural Load Calculation for one Unit

Building Element	Unit	Total wt. (kg)
Truss		
Main Beam	50x50x2.9	13.02
Rafters and joists and bracing struts	50x50x2.6	29.60
Total Weight =		42
Other welding and gusset plate		08
Total Weight of Truss		50
Purlins		
Weight of purlins	40x40x2.6	17
Total Weight of 5 Purlins		85
Roof Load		

Weight of trusses = 4x50		200
Weight of Purlins		85
Weight of roof sheet		297
Weight of Total roof assembly		582
Live Load on roof		150
Total Roof Load		732
Solar panel and Roofing sheet		
4 Rooftop Solar panel		88
Assembly of Solar panel		75
Roofing Sheet	2.6 x 5.8	15.08
	5.8 x 1.85	10.73
Total Weight of roofing sheet	25.81	296.80
Wall Panels		
Total Weight of all panels	14	635.04
Area of Unit	3.15x5.4	17.01
Load on Column		
732 kg load distributed to 8 columns		
Roofing assembly weight/sqm		30
Load on middle column due to roofing	2.87 x 1.8	155
Self-weight of 1 column		35
Sectional Area	9.1x2	18.20
Live Load on a column	1.5x1.8	675
Weight of roof		155
Weight of wall panel		90
Weight of perimeter channel (top & bottom)	4 units	23
Flooring & miscellaneous		75
Total		1053
Total Load with FoS @30%		**1350**

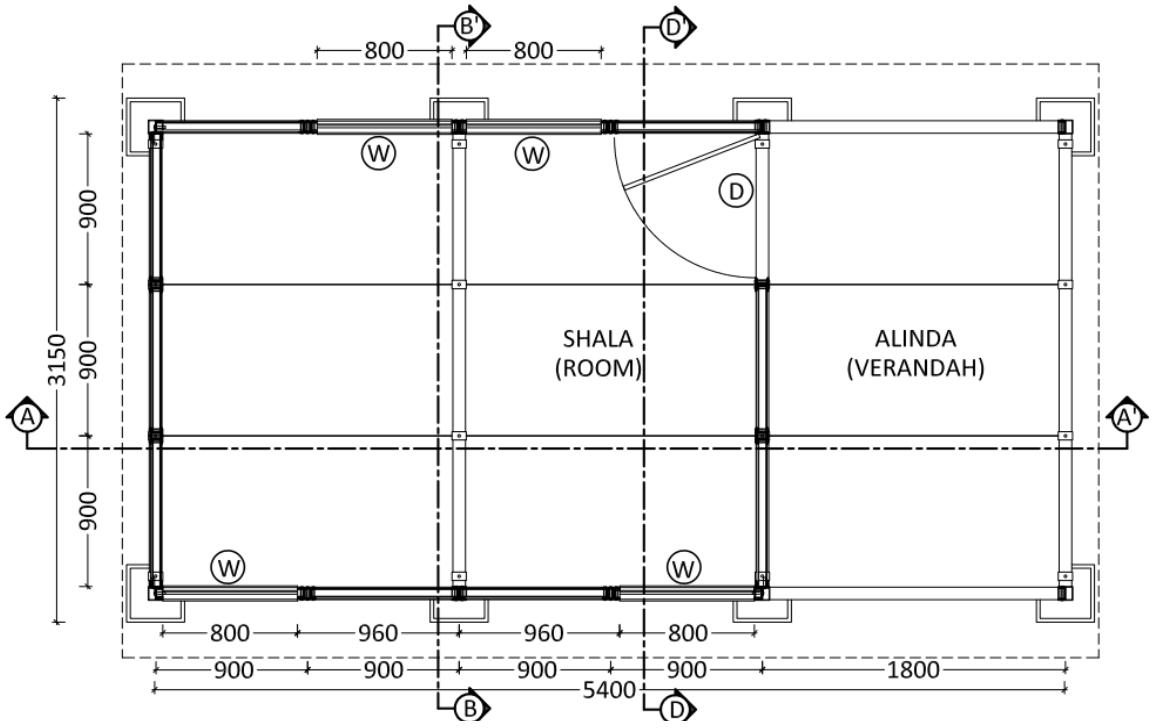
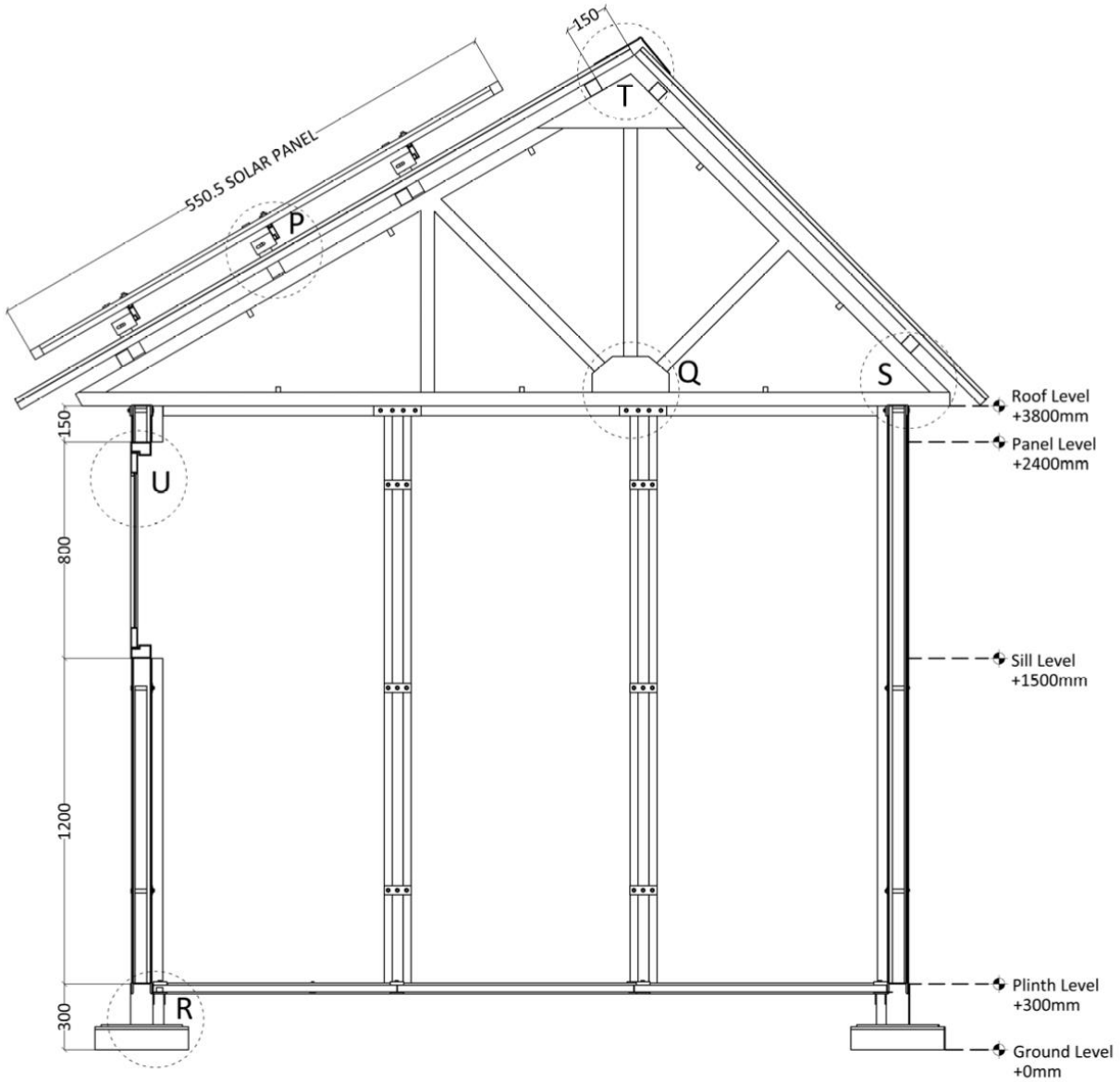


Figure 21: Module Plan of the CWH Housing



SECTION DD'

Figure 22: Section D-D' of the given Module of the CWH Housing

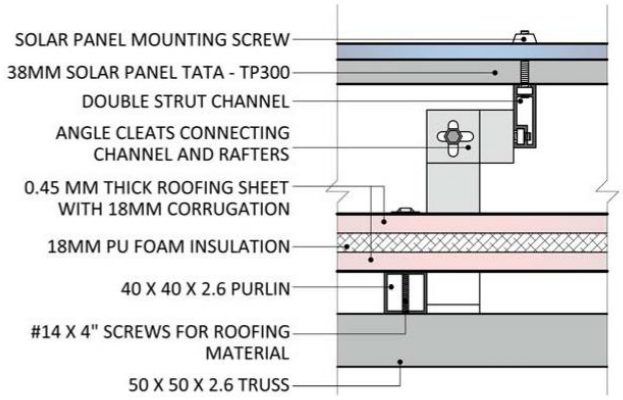


Figure 23: Detail 'P' - Solar panel mounting

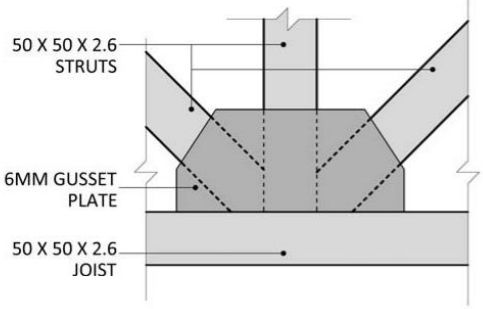


Figure 24: Detail 'Q' - Gusset plate joining struts

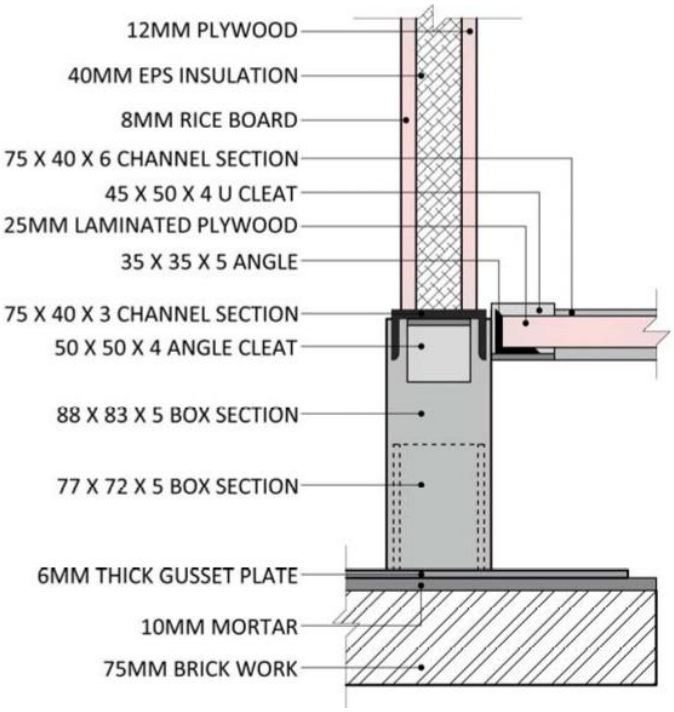


Figure 25: Detail R - Joinery of Baseplate to Column & floor joist

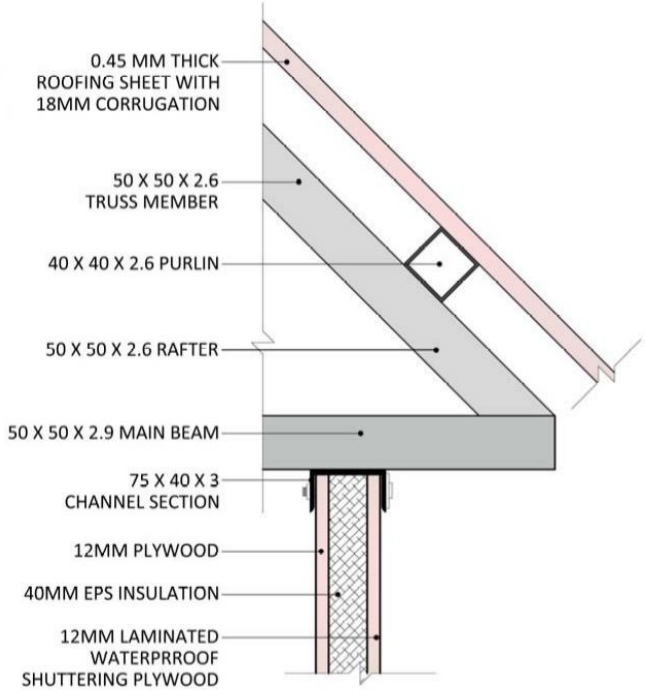


Figure 26: Detail S - Joinery of Truss, purlins & Roofing

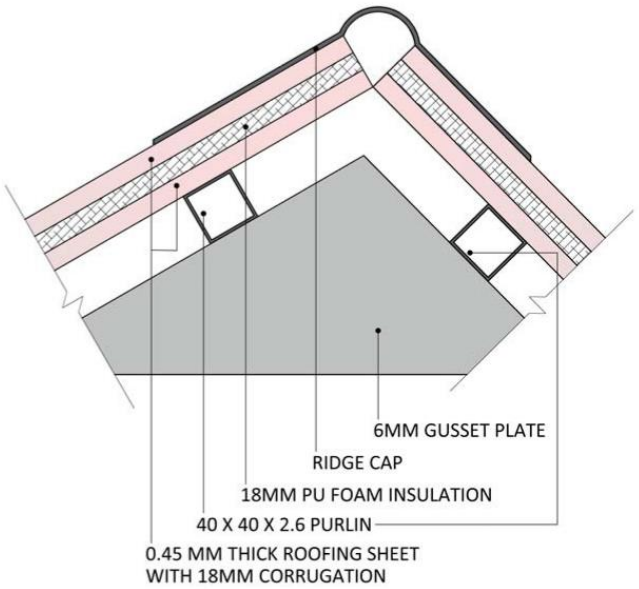


Figure 27: Detail T - Ridge detail

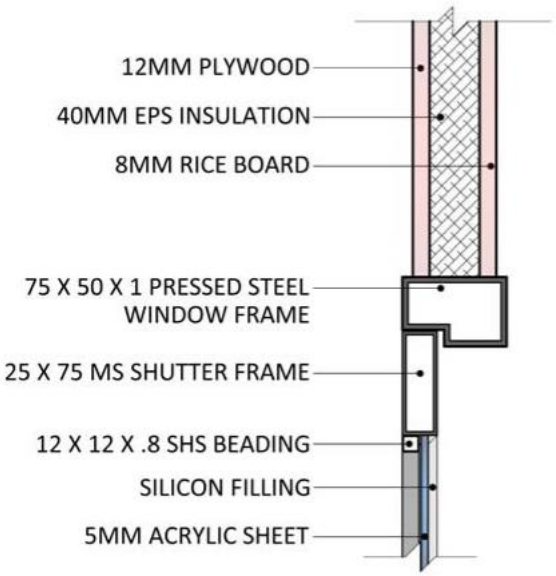


Figure 28: Detail U - Section of wall panel with window

11.6Architectural Design

Figure 29: Schematic Site Layout of CWH Project

Site for CWH is allocated as part of multi- specialty hospital project site. It has a gently slope topography (almost flat land) and is situated in composite climatic zone. It is surrounded by farms and forest and is connected to the city by Bilaspur-Haldwani highway (running parallel to a railway line) which is 200 m away from the site. It is approached by an internal road (6.0 m wide) temporarily developed for this purpose.

Total 34 Dwelling Units are placed on the allocated site to ensure an ambience within the residential zone which is welcoming and convey the feeling of safety, comfort, convenience, belongingness and dignity to all construction workers, and enhance their productivity during working hours. Common amenities like Creche, Infirmary, separate toilets for men and women, common kitchen, daily need shop, supervisor's office and community open space.

Figure 30: Site renders of CWH Project

11.7Affordability

11.7.1 Construction Budget and Timeline

Table 12: Project Construction Budget and Cost Estimate

S.No.	Particulars	Baseline Estimate (Project Partner / SOR basis)			Proposed Design Estimate		
		Amount in Million INR	%	Amount (INR per sqm)	Amount in Million INR	%	Amount (INR per sqm)
1	Land	0.00	0.0%	-	0.00	0.0%	-
2	Civil Works	8.47	64.6%	10,865	0.15	1.2%	198
3	Internal Works	0.04	0.3%	45	2.68	20.4%	3,436
4	MEP Services (Pumps, Solar PV & Batteries, Water Storage)	0.01	0.1%	17	2.76	21.1%	3,543
5	Equipment & Furnishing (CCTV, Toilets with Bio digester and STP etc.)	0.11	0.8%	138	0.11	0.8%	138
6	Landscape & Site Development including paving	0.01	0.1%	12	0.13	1.0%	170
7	Installation, Dismantling, Storage, Transportation and Contingency	0.43	5.0%	554	0.29	5.0%	374
	TOTAL HARD COST	**9.07**	**70.8%**	**11,631**	**6.13**	**49.5%**	**7,859**
8	Pre-Operative Expenses	-	0.0%	-	-	0.0%	-
9	Consultants	0.30	2.3%	385	0.30	2.3%	385
10	Interest During Construction	3.75	28.6%	4,806	2.21	16.8%	2,827
	TOTAL SOFT COST	**4.05**	**30.9%**	**5,191**	**2.51**	**19.1%**	**3,212**
	TOTAL PROJECT COST	**13.12**	**100.0%**	**16,822**	**8.63**	**65.8%**	**11,070**

NOTES: Land value has been considered NIL *(zero) because the land will be returned to the project owner.
Source: Delhi schedule of rates 2021, Estimation tool and currently prevailing market rates, as appropriate.

Table 13: Life Cycle Modalities and Offer Cost of Services to Project Partner and End User

PARTICULARS	AMOUNT (Million INR)
Number of Use Cycles of CWH Modules and Infra. Facilities	6
Per Cycle Cost (6.10/6)	1.02
Profit of Industry Partner / Lender / Service Provider (10%)	0.10
Offering Cost for the Services to Project Partner (for 12 months):	1.12
Additional Cost (for additional 06 Months): 20% of the yearly cost	0.22
TOTAL COST of CWH Facility for 18 Months to the Project Partner:	**2.46**
Scrap Value of Modules after Life Cycle (20% of Initial Investment) shall be considered additional profit / Bonus to the investor	1.22

11.7.2 Commercial Viability

Assuming a case where a Construction Worker utilizes 10% of his daily wages to be spent towards accommodation, which is an established standard / rate of HRA by Govt of India.
Daily income of CW varies from INR 600/ to 1000/- day.
Expenditure by Construction worker for 18 months: -

75 Workers X 60 (10% of 600) X 548 days = Rs. 24,66,000
Our Cost of providing the facility for 18 months = Rs. 24,60,000

As per our calculations above, it is estimated that CWH facility for 75 workers shall cost to the project partner INR 2.46 million for the duration of 18 months.
At this cost, an ambience can be provided which is welcoming and convey the feeling of safety, comfort, convenience, belongingness and dignity to all construction workers / residents on site, as well as which helps in enhancing their productivity during working hours, at **an affordable price of INR 60/- per construction worker per day**.

11.8 Innovation

Also please refer section 10 Design Process, in addition to the information provided here.

1. Name
    - **श्रमिक आश्रय**
2. Idea
    - Doorway of quality life for construction worker
3. Problem
    - Construction workers who put tireless efforts in the construction of dwellings, offices, hospitals and hotels for the quality life of the citizens. Generally, live in challenging conditions on project site for the duration of the project which may vary from 12 months to 24 months.
    - A model of CWH is being proposed to create and ensure an ambience within the residential zone which is welcoming and convey the feeling of safety, comfort, convenience, belongingness and dignity to all construction workers/residents on site, as well as which helps in enhancing their productivity during working hours, at an affordable price of INR 60/- per construction worker per day.

4. Technology or Solution
    - Yes, we have deviced a business module which promoter/ investor has to Built-Own-Lease basis.
    - Promoter has to invest in procurement of materials and fabrication of portable shelters for construction workers which can be leased out to construction agencies for on-site accommodation of these construction worker for a period of 12-24 months.

5. Market
    - India is a developing country and lot of infrastructure projects including housing, hospitals, engineering structure, highways are to be constructed at a phase higher than present.
    - It is envisaged that such a business model may prove to be revolutionary approach in facilitating many stakeholders in the construction industry.
    - Although pan India market requires such a solution, however in view of transportation and logistics associated, one promoter can cater to a specific reason may be from 150-300 km distant location from the warehouse.
    - Proposed model can be used in any location of composite climatic zone of India.

6. Costs, benefits and impacts
    - A model of CWH is being proposed to create and ensure an ambience within the residential zone which is welcoming and convey the feeling of safety, comfort, convenience, belongingness and dignity to all construction workers/residents on site, as well as which helps in enhancing their productivity during working hours, at an affordable price of INR 60/- per construction worker per day.
    - Such a solution also addresses sustainability goals of UN which are good health and well-being (SDG-03), gender equality (SDG-05), clean water and sanitation (SDG-06), affordable and clean energy (SDG-07), reduce inequality (SDG-10), and sustainable communities (SDG-11).

11.9 Health and Well-being

Following aspects are considered for health and well-being of CWH residents

- An overall ambience within the CWH residential zone which convey feeling of safety, comfort, convenience, and dignity to all residents on construction worker site.
- Dwelling Units of appropriate size shall be designed for convenient and comfortable living, which suits the lifestyle of the construction workers.
- It is estimated that about 450 hrs. during day time (from 12:00 -17:00) in the month of May, June and July only shall pose thermal discomfort (temperature beyond 27^0 C). We have considered wall and roof insulation and roof projections so that dwelling unit is unaffected from outside daily temperature variations.
- Units are naturally ventilated and for this purpose we have provided 2.56 m sq of window area. Two windows of 0.8 x 0.8 m each are provided on opposite long faces of the unit to facilitate cross natural ventilation round the clock. Rate of natural ventilation can be controlled by sliding the acrylic sheet over the wire mesh area to prevent the cold waves or heat waves during extreme weather conditions.
- We have provided windows and north skylight through which 50 to 100 lux level is achieved on floor level inside dwelling unit during day time under clear sky conditions.
- Adequate toilet facilities shall be provided for the residents.
- Common semi covered kitchen workstations shall be provided with LPG connection for convenient and smokeless cooking.
- Adequate covered, semi covered, open spaces to facilitate individual, family and community activities.
- Composting Pits shall be provided for efficient and environmentally friendly disposal of solid waste.
- Infirmary has been provided on site to address the routine medical checkup/requirements of the residents and family members
- Creche on site has been considered to facilitate day care of working women.
- On site shop shall be provided to meet the daily needs of the residents
- Pathways are provided for convenient pedestrian movement within site as well as to protect the residents from moving in water logging during the raining season.
- CCTV cameras shall be provided in common areas for general monitoring and to avoid any cases of theft and social misconduct.
- Storms (Extreme weather conditions / windstorms) may occur occasionally, and hence trees are not planted in East Direction.
- Solar Cooker for convenient and energy efficient healthy cooking.
- Ample daylight in the verandah to facilitate routine domestic activity.
- Building material and finishes are considered which do not impose and injury or health hazard to the occupant

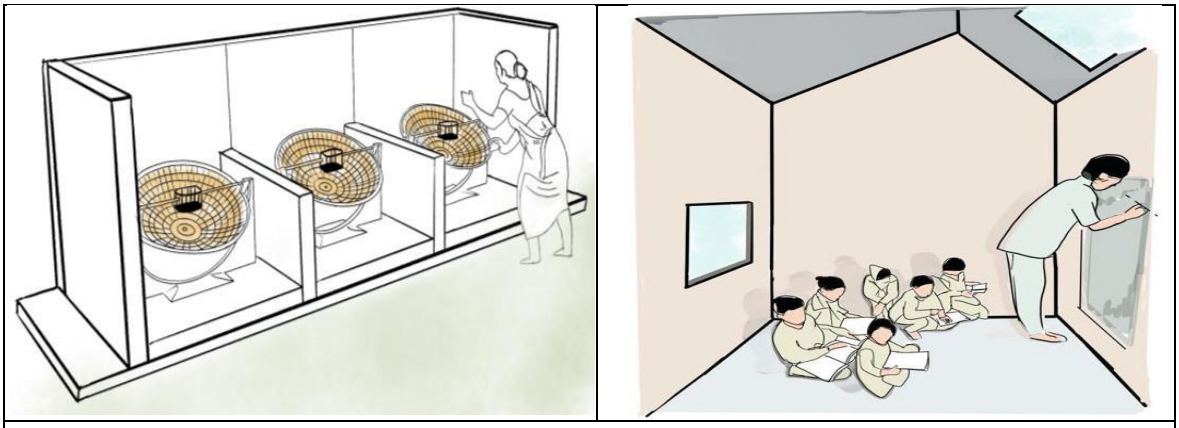


Figure 31: Provision of Solar Cooker and Creche on site

11.10 Value and Proposition

- Implementation of such a business model will benefit several stakeholders in the construction sector.

- This is not only a profitable business invention by the promoters/investors but also a much-needed solution/service which is required in the construction industry for construction worker. Such a solution also addresses sustainability goals of UN which are good health and well-being (SDG-03), gender equality (SDG-05), clean water and sanitation (SDG-06), affordable and clean energy (SDG-07), reduce inequality (SDG-10) and sustainable communities (SDG-11).

- To work out a feasible and cost-effective solution for the CWH, which can be adopted by any project developer for their projects in composite climatic zone of India.

- To create and ensure an ambience within the residential zone which is welcoming and convey the feeling of safety, comfort, convenience, belongingness, and dignity to all residents on site, as well as which helps in their productivity during working hours as a byproduct, at an affordable price of INR 60/- per construction worker per day.

- These goals shall be achieved by considering/integrating appropriate spaces, features, elements, systems and materials / finishes in the site layout and the architectural design of buildings.

- Majority of the strategies are already mentioned in various points from 9.1 to 9.9 above.

12.0 Appendix

12.1 Building Area Program

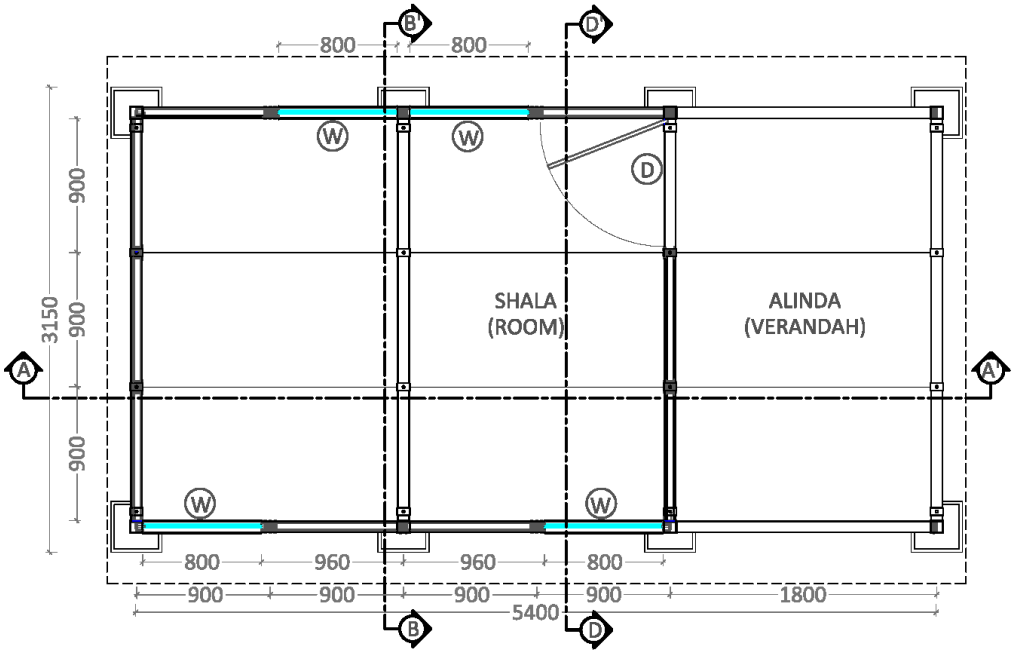
Table 14: Building Area Program for CWH Project

S.no.	Function	Size (m)		Area (in sq.m.)	No. of units	Total Area (in sq.m.)	Conditioned/ Unconditioned
		L	B				
	Living Space (Unit)						Unconditioned
1	Room	3.7	2.85	10.55	36	379.62	Air cooled by fans
2	Verandah	1.8	2.85	5.13	34	174.42	
	TOTAL for 36 Units			15.68	-	554.04	
	Common Zone						
1	Toilets	1.0	1.20	1.20	20	24.00	Unconditioned
2	Bathing						Unconditioned
	Male	1.0	1.50	1.50	4	6.00	
	Female	1.0	1.50	1.50	4	6.00	
3	Washing Area	1.2	1.20	1.44	3	4.32	Unconditioned
4	Common	2.0	2.00	4.00	3	30.00	Unconditioned
	Services						
1	Water supply +	3.7	2.85	10.55	1	10.55	Unconditioned
2	Supervisor	3.7	2.85	10.55	1	10.55	Conditioned
3	Electricity + Battery	3.7	2.85	10.55	1	10.55	Unconditioned
	Well-being Zone						
1	Cr	3.7	2.85	10.55	1	10.55	Unconditioned
2	Infirmary	3.7	2.85	10.55	1	10.55	Unconditioned
3	Sh	Provided in Verandah of Unit					Unconditioned
4	Open area	-	-	-	-	-	-
	TOTAL				**36 Units**	**677.09**	
	15% Miscellaneous					101.56	
	Total Area					778.65	For 72 workers
	Site area for CWH					**2117.10**	
	Ground coverage %					36.78	
	Open Area (Landscape)					1338.45	

Notes:

1. 'Condition' word (Services – Supervisor Office) is used for evaporative air cooler & not for Air Condition system.
2. Rooms are being cooled by passive design strategies & a wall mount/ceiling fan in each unit.

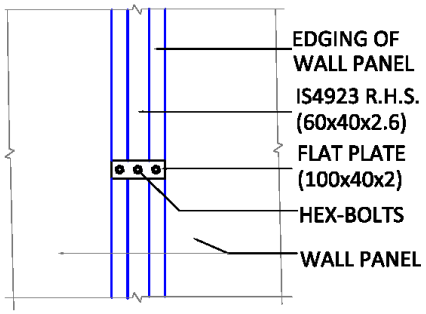
12.2 Architectural Drawings



MODULE PLAN

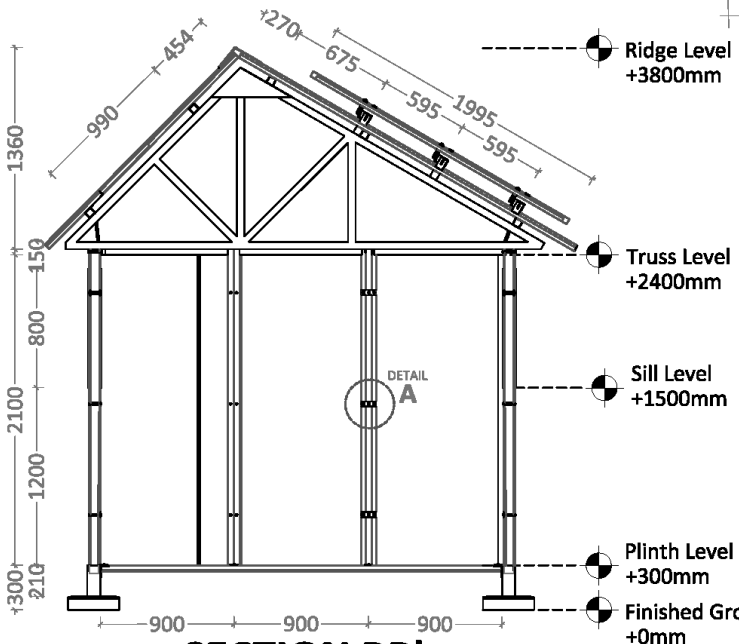
Figure 33: Architectural plan of module

Schedule Of Openings			
S.No.	Type	Size	Nos.
1.	Door	2100mmX855mm	1
2.	Window	800mmX785mm	4
3.	Skylight	455mmX450mm	4



DETAIL - 'A'

SCALE - 1:10

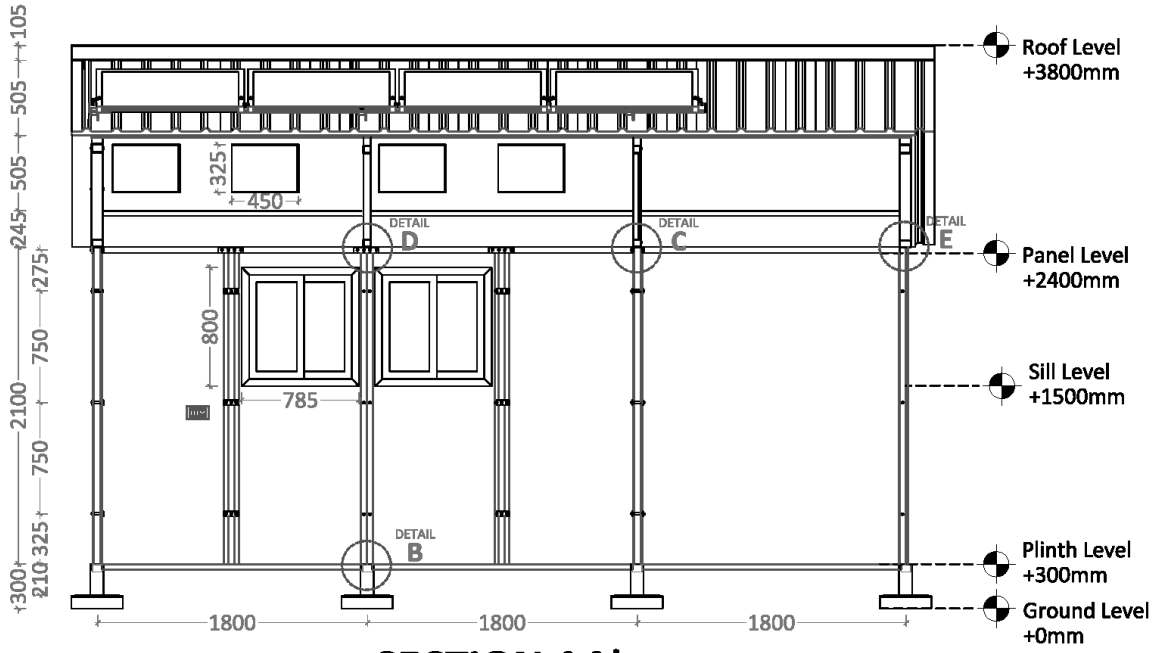


SECTION BB'

Scale- 1:40

NOTE: ALL DIMENSIONS ARE IN MM.

Figure 32: Section B-B' & Detail 'A'



SECTION AA'

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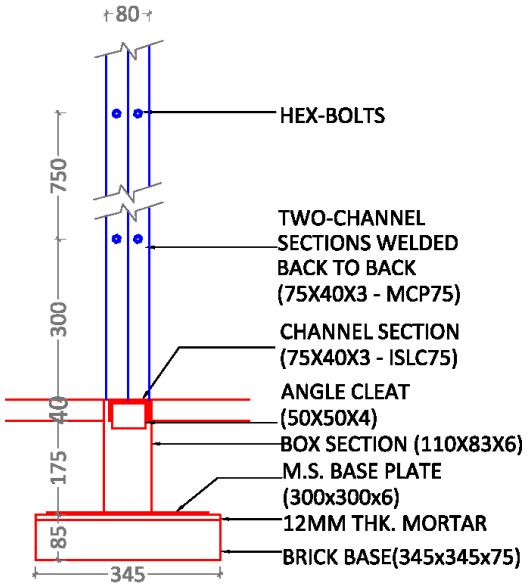
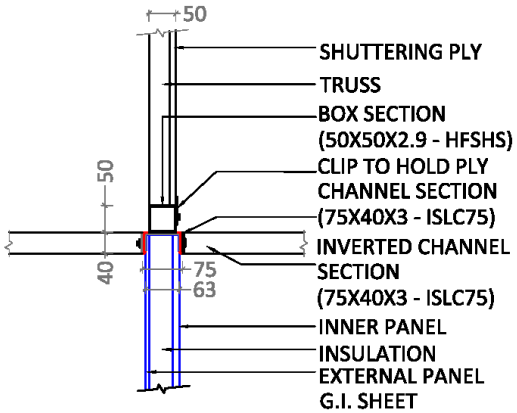


DETAIL - 'B'

SCALE - 1:10



DETAIL - 'C'

SCALE - 1:10

NOTE: ALL DIMENSIONS ARE IN MM.

Figure 34: Section A-A' & Details explaining joinery

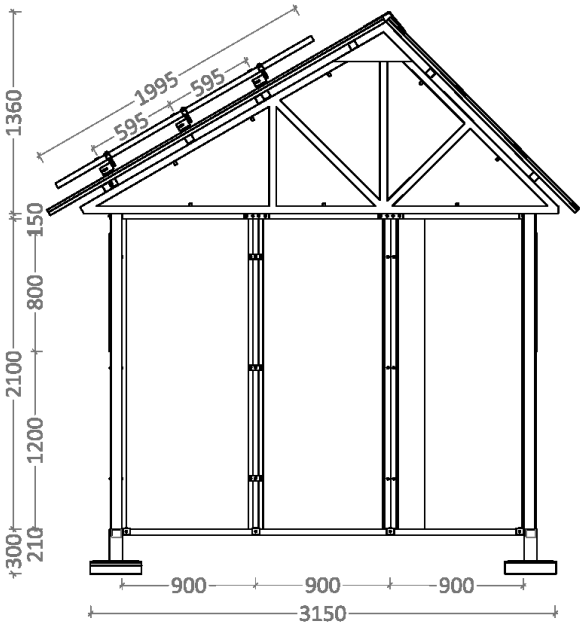


Figure 35: Front Elevation

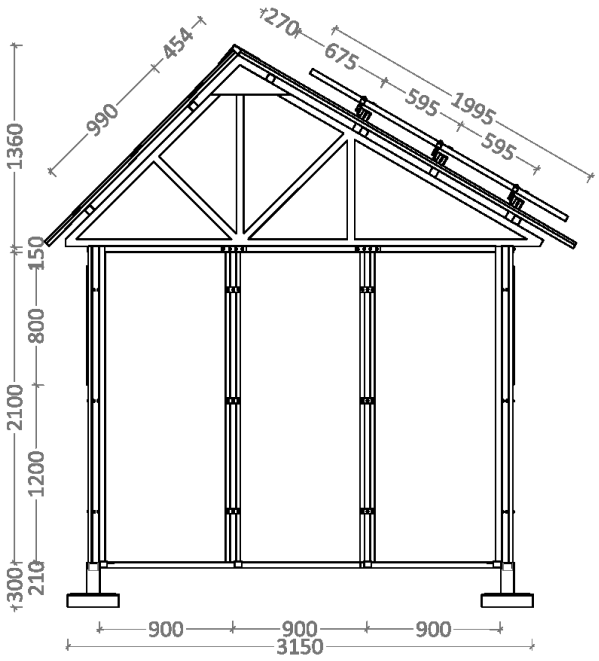


Figure 38: Rear Elevation

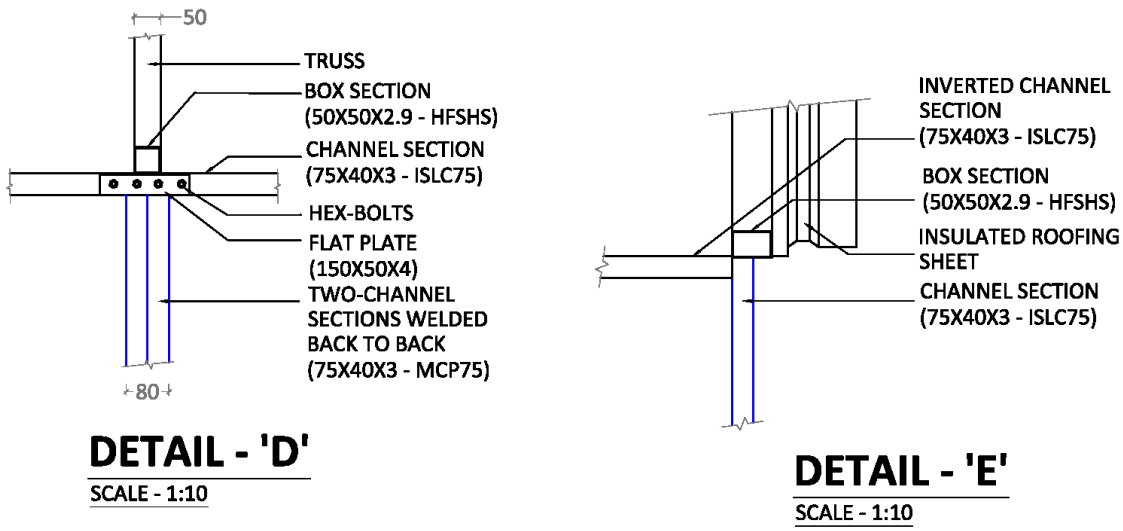
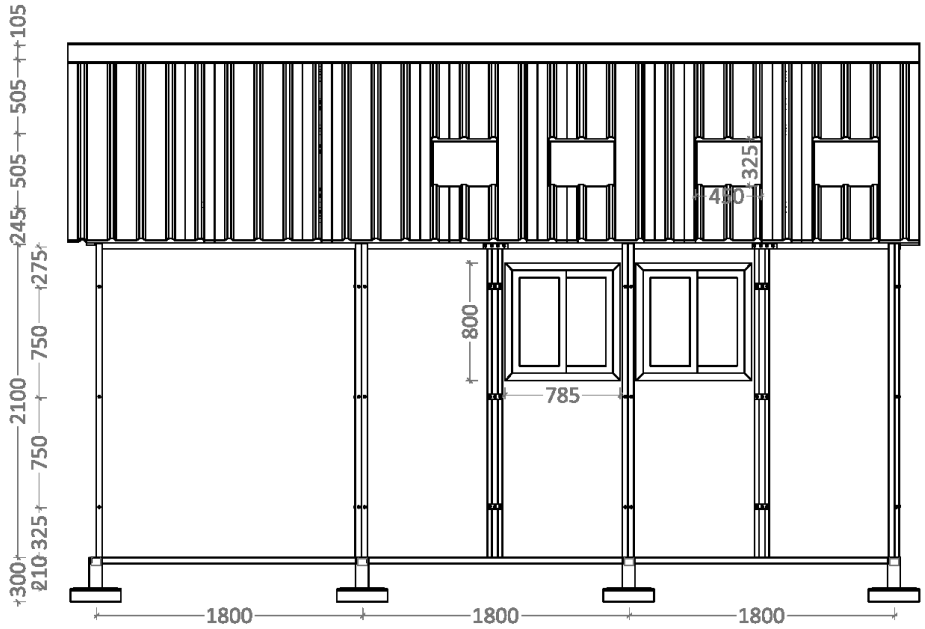


Figure 40: Joinery details of Section A-A'

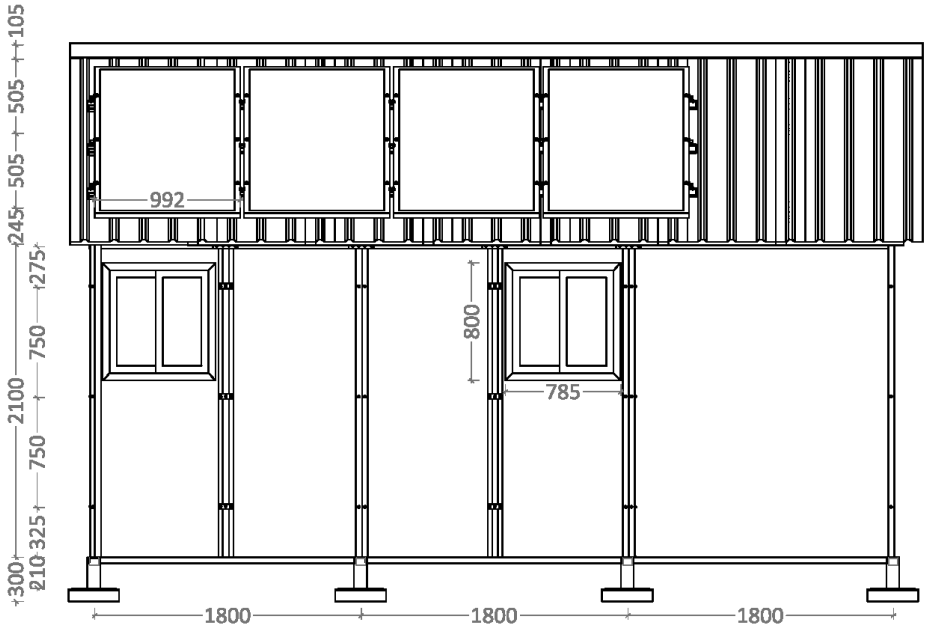
NOTE: For foundation and joinery details refer section engineering and operations under section 11.5.



RIGHT ELEVATION

Scale- 1:40

Figure 37: Right Elevation



LEFT ELEVATION

Scale- 1:40

Figure 36: Left Elevation

12.3 Engineering Drawings

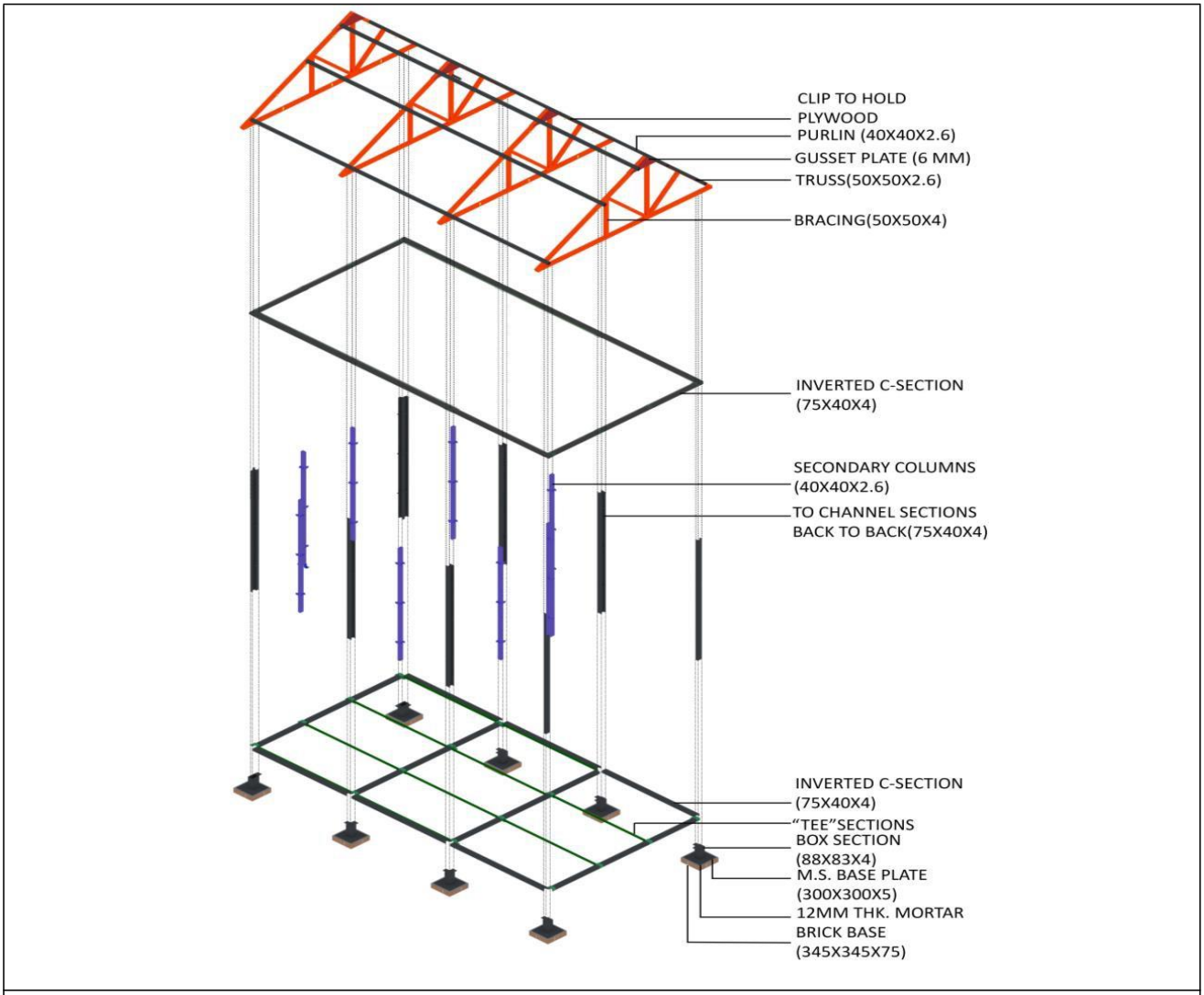
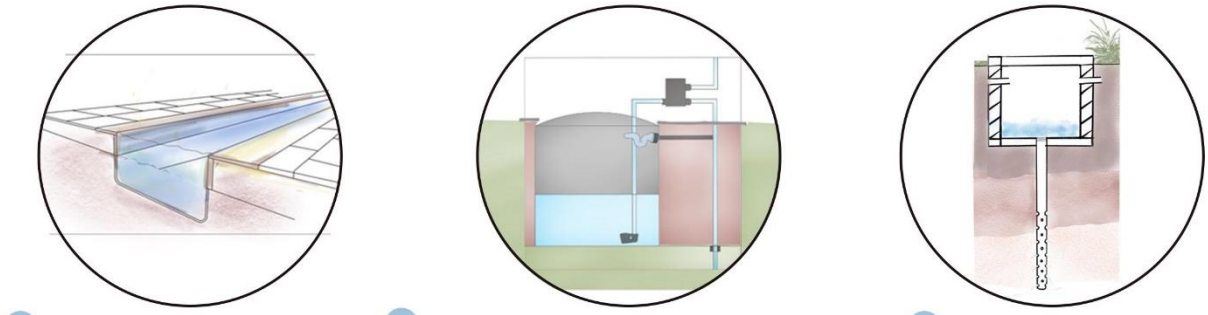


Figure 40: Exploded View for Module Structural System

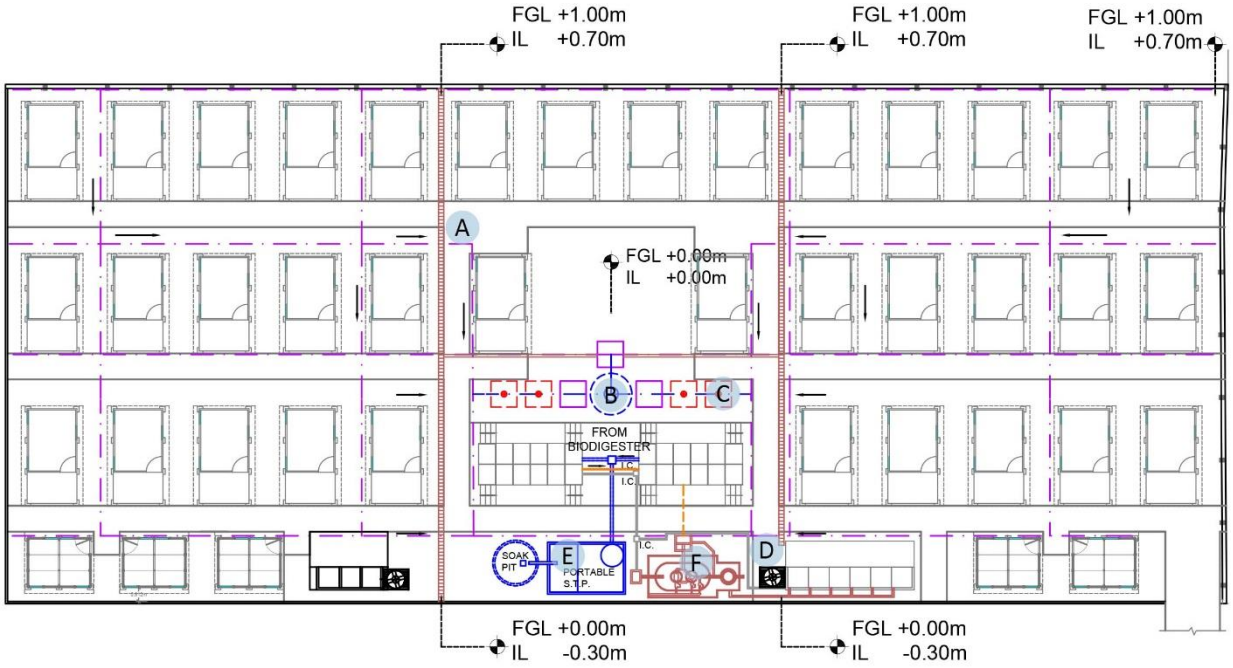
Table 15: Information sheet of engineering elements/members

S.no.	Structural Member	Technical Designation	Dimension(mm)	Units (Per module)
1	Base Plate	Flat Plate (8mm)	300 X 300 X 6	8
2	Box Section above base plate	SHS 100x100	110 HIGH, 6 THK	8
3	Primary Column (Two C-Sections welded back-to-back)	ISLC 75	2 X (75X40X3)	5
4	Secondary Column	RHS 6040	60 X 40 X 2.35	8
5	Rear Columns (C-Section welded to angle	ISLC 75 ISA 75756	75 X 40 X 3 75 X 75 X 3	2
6	Inverted C-Section Tie Beam	ISLC 75	75 X 40 X 3	12
7	Flooring Joist T-Beams	ISNT2540	40 X 25 X 3	6
8	Inverted C-Section Lintel Tie	ISLC 75	75 X 40 X 3	16
9	Truss – Main Beam Rafters & Joists	HFSHS5050	50 X 50 X 2.9 50 X 50 X 2.6 50 X 50 X 2.6	1 2 3
10	Purlins	SHS4040	40 X 40 X 2.6	5
11	Cleats	ISA50506	50 X 50 X 4	32
12	U-Cleats	MS Flat-4mm	50 X 50 X 4	16
13	Flat Plate strips	MS Flat-4mm	150 X 50 X 4	62
14	Nuts & Bolts	13mm dia	M8.8 13mm dia.	90

12.3.1 Drainage Layout



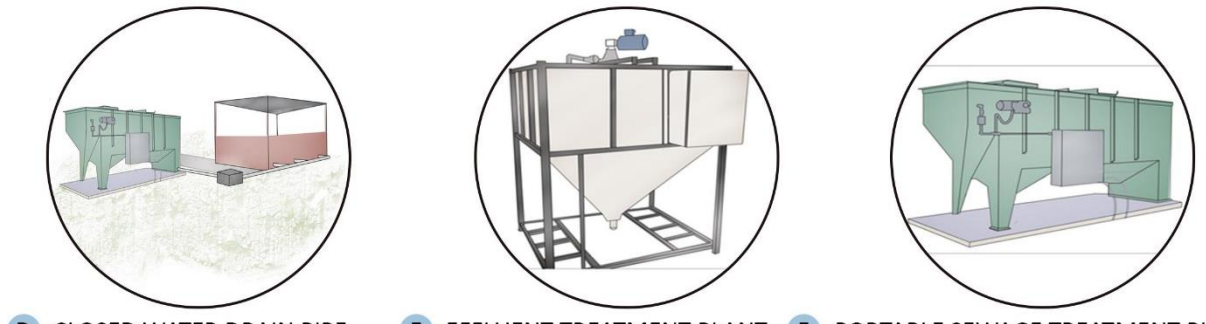
A OPEN STROM WATER DRAIN B UNDERGROUND RAINWATER HARVESTING C WATER RECHARGING PIT



SITE PLAN SHOWING WATER FLOW CYCLES

LEGEND

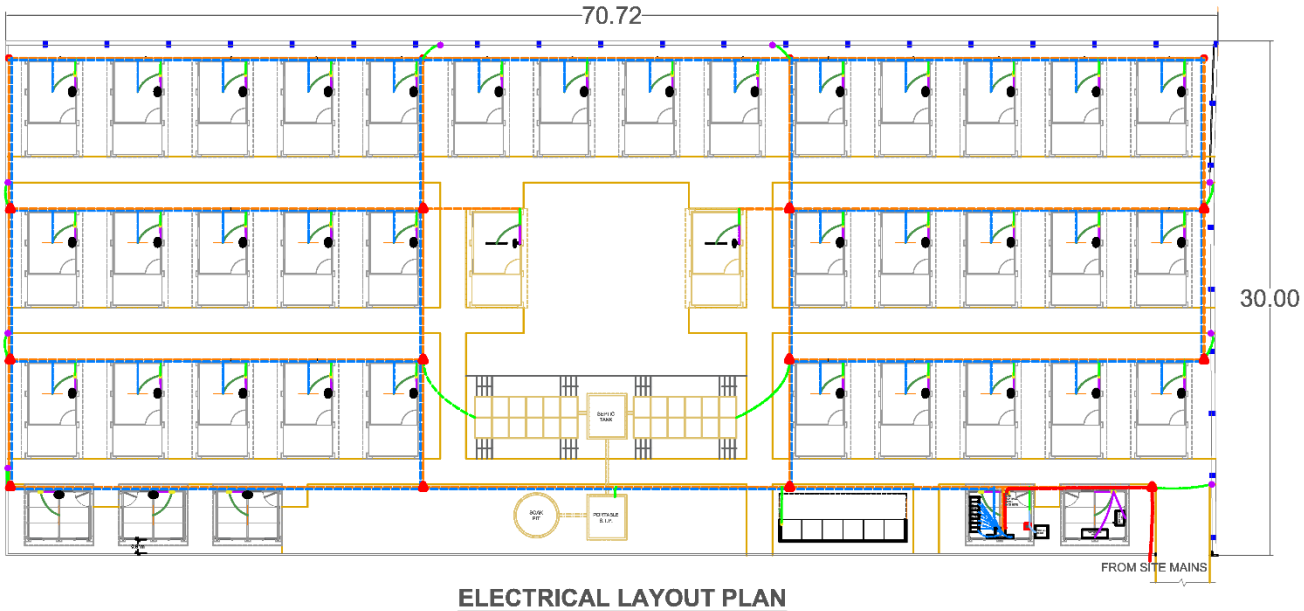
	UGT(RAINWATER HARVESTING) 6000L		GREY WATER INLET		OPEN PREMEABLE CHANNEL		SOAK PIT
	WATER RECHARGING PITS		OPEN DRAIN		DRAIN PIPE		EFFLUENT TREATMENT PLANT
	SEDIMENTATION TANK (1.5 X 1.5 X 1.5)METER		CLOSED DRAIN		TREATED WATER FOR FLUSHING		PORTABLE S.T.P.



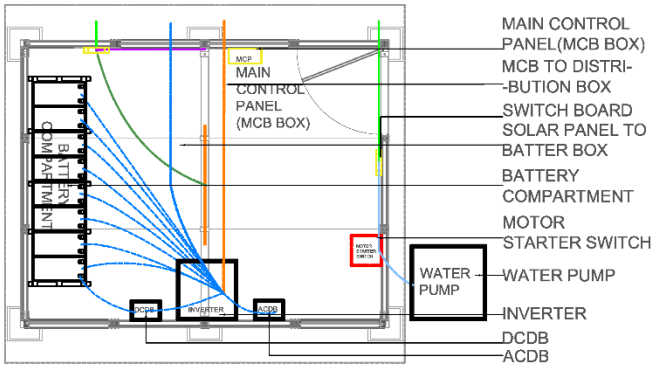
D CLOSED WATER DRAIN PIPE E EFFLUENT TREATMENT PLANT F PORTABLE SEWAGE TREATMENT PLANT

Figure 38: Sanitation Scheme for the Project

12.3.2 Electric Layout



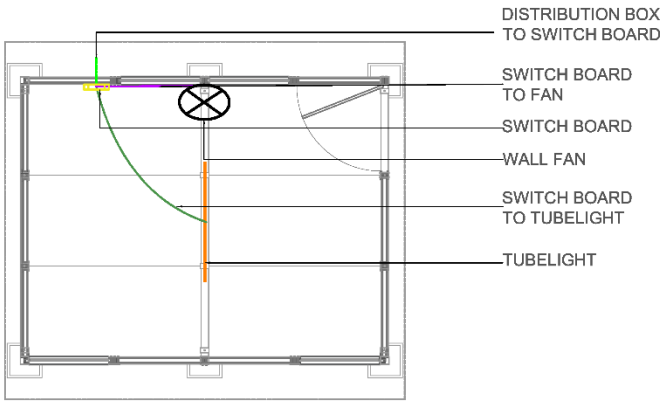
ELECTRICAL LAYOUT PLAN



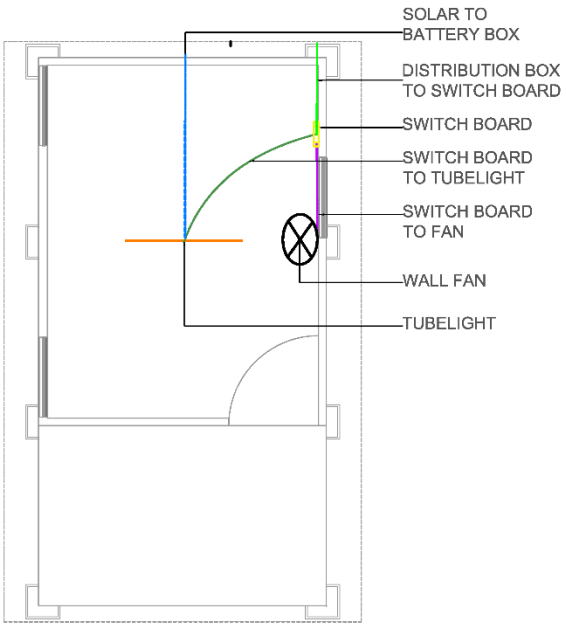
ELECTRIC AND WATER PUMP ROOM PLAN

	WALL FAN
	TUBELIGHT
	SWITCH BOARD
	STREET LIGHT
	CCTV CAMERA
MCP	MAIN CONTROL PANEL
DCDB	DCDB
ACDB	ACDB
	MOTOR STARTER SWITCH
	FROM SITE MAINS TO DISTRIBUTION BOX
	MCB TO DISTRIBUTION BOX
	DISTRIBUTION BOX TO SWITCH BOARD
	SWITCH BOARD TO FAN
	SWITCH BOARD TO TUBELIGHT
	SOLAR TO BATTERY BOX

LEGEND



DWELLING UNIT PLAN



DWELLING UNIT PLAN

Figure 39: Electrical layout and details

12.4 Specification of Building Systems

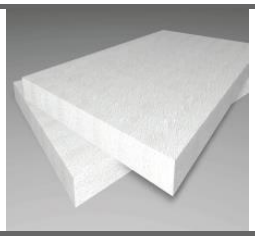
Table 16: Broad architectural specification sheet

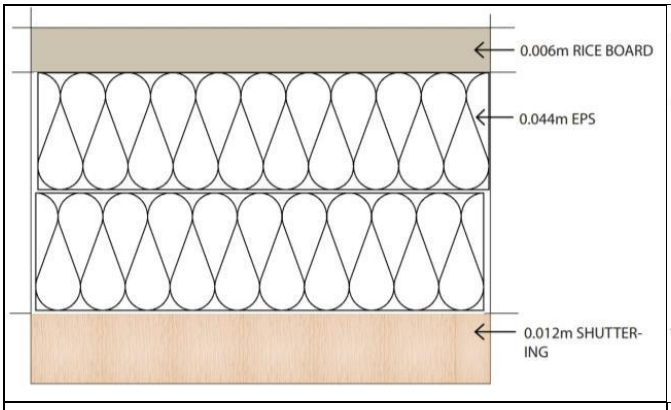
S.No.	Building Element	Proposed CWH model	Baseline Case
1.	**Dwelling Unit**		
	Foundation Base	Bricks Course (75 mm Thick) with Cement Mortar (1:6) at top for levelling	Stepped Footing Foundation of Brickwork in Cement Mortar (1:6)
	Plinth Level & DPS	300 mm High w.r.t. FGL, Inverted C Section (75x40x6)	450 mm High w.r.t. FGL, 40 Thick Cement Conc (1:1.5:3)
	Columns	Double C Sections welded back-to-back, 2 X (75x40x6)	RCC Columns or Load Bearing Brickwork Walls
	Walls	Insulated wall panel with GI edging, 63mm thick	230 mm thick Brick walls
	Flooring	Laminated Shuttering ply 25mm thick	Cement Conc. Flooring with PCC Base over earth filling
	Windows	MS Casement Window (800mm x 800mm)	MS Framed Casement Window (900 x 900 mm)
	Doors	Flush Door (850mm x 2100mm)	Flush Door (850mm x 2100mm)
	Roofing	Insulated GI Sheet	RCC Slab
	Glazing	3.0 mm Thick Acrylic Sheet	5 mm thick Float Glass
	External Paving	Brick / Interlocking Pavers	Cement Conc. / Brick on Edge
2.	**Common Toilets**		
	Floor	GI Flooring covered with PVC (in mobile toilet), P.C.C. in Bathroom floors (As provided in Mobile toilet module)	Ceramic Tiles over Cement Mortar Base
	Walls	PVC Panels	Brick walls with Ceramic Tiles inner dado.
	Roof	GI Sheet	RCC Slab
	Fixtures	PVC Taps, Ceramic WC and Washbasin	PVC Taps, Ceramic WC and Washbasin
3.	**Common Kitchen**		
	Floor	Brick on Bat over Levelled Earth	Cement Conc. Flooring
	Walls	Brick masonry	Brick walls with Ceramic Tiles inner dado.

	Roof	Insulated GI Sheet	RCC Slab
4.	**Electrical Works**		
	Lighting Fixture	LED Tube light	LED Tube light
	Wires / Cables	1.00mm dia. Triple-core wire	1.00mm dia. Triple-core wire
	Fans	Wall-mount fans	Ceiling and wall-mount fans
	Switch board	Distribution Board with 2 switches & 1 socket in each DU	Distribution Board with 2 switches & 1 socket
	Solar Panels	4 X (216-watt PV Panels) on each module (60 panels in our case)	Generally, not provided
	Batteries	20 Batteries – 150Ah each	Generally, not provided
	MCB Panel	MCBs, ACDB, DCDB and inverter	MCBs, ACDB, DCDB and inverter
	Outdoor Lighting	LED Street lights	LED Street lights
	CCTV	CCTV Surveillance for security	Generally, not provided
5.	**Water Supply and Sanitation Works**		
	Water Pump	Pump for lifting water to OHT of toilets	Pump for lifting water to OHT
	Sewage Treatment	Bio-digester (2X Included with Mobile toilets) & MBBR Sewage treatment plant	Generally, not provided
	Rain Water Harvesting	Sedimentation tank, recharging pits and underground storage tank.	Generally, not provided
	Solar water heater	2 X 500l = 1000l capacity	Generally, not provided
6.	**Site Development**		
	Fencing	Gate and GI Chain link fencing	Generally, not provided
	Internal Pathways	Brick pavement	Cement Conc. / Brick on Edge

12.5 Energy Simulation Inputs

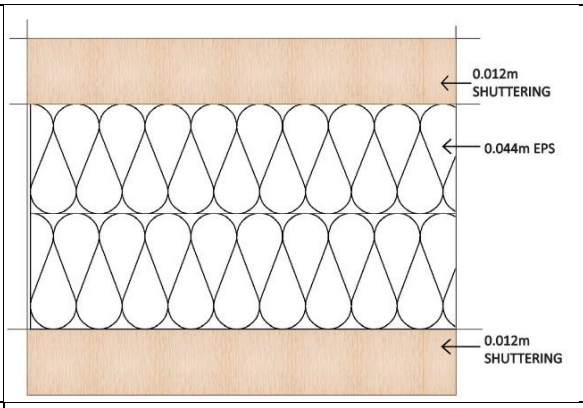
Table 17:Thermal Performance of Proposed Composite Wall Panel

WALL (Material)	PLYWOOD	INSULATION (EPS)	RICE BOARD
			
Thickness (m)	0.012	0.044	0.006
U- value(W/m^{2}K)	14.2	0.76	3.3
R-value	0.07	1.3	0.3
K-value (W/mK)	0.17	0.03	0.02
Cost (sq/m)	400	100	700
(Source: Data bank of Insulating materials.pdf CSIR, Roorkee) CARBES CEPT U value tool			



Thickness -0.63m
R Value – 1.67(W/K)
U Value – 0.59 W/m^{2}k

Figure 40: Wall Assembly 1



Thickness- 0.68 m
R Value- 1.44 (W/K)
U Value – 0.69 W/m^{2}k

Figure 41: Wall Assembly 2

Table 18: Thermal Performance of Proposed Composite Floor Panel

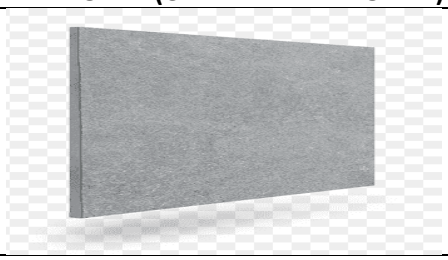
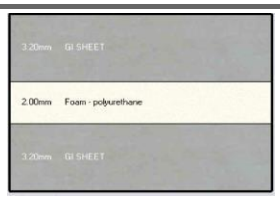
FLOOR	WATERPROOF PLYWOOD	TOILET (CEMENT FIBER BOARD)
		
U-value (W/m2K)	10	50
R-value	0.1	0.0
K-value	0.174	0.9
Thickness (m)	0.018	0.018
Cost (sq/m)	880	25

Table 19: Thermal Performance of Proposed Roof Panel

ROOF (Material)	GI sheet	PU Form	PU Sandwich panel
			
U-value (W/m2K)	0.13	1.	0.12
R-value	7.3	0.	0.905
K-value	61	0.02	-
Thickness (m)	0.00045	0.018	0.0189
Cost (sq/m)	1760	300	1200
(Source: Data bank of Insulating materials.pdf CSIR, Roorkee)			

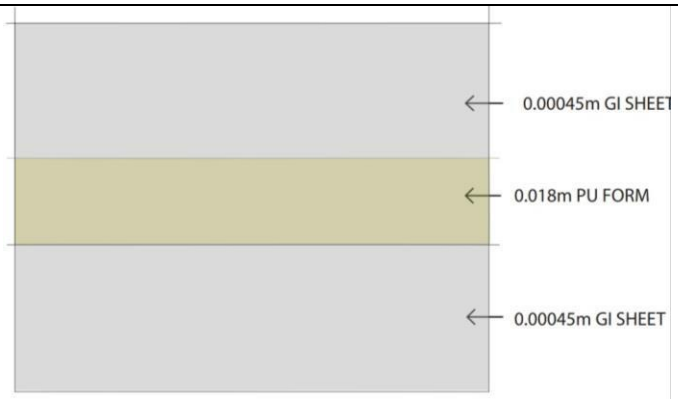


Figure 42:Roof Assembly Section

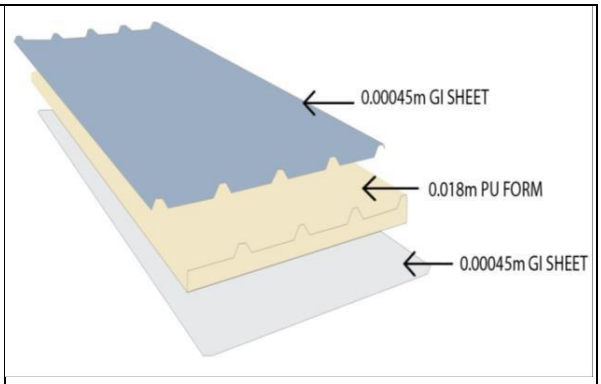


Figure 43: Roof Assembly Isometric

Table 20: Thermal Performance of Proposed Composite Fenestration Panel

FENESTRATION (Material)	WINDOW (CASEMENT)	DOOR
		
U-value (W/m2K)	12.5	10
R-value	0.08	0.1
K-value	13.56	0.22
Thickness (m)	0.63-0.68	0.022
Cost	900	400

12.6 Net-Zero Water Cycle Design and Calculations

Table 21: Water Usage according to Occupants Activities/ Behavior

Occupant's Activity	Percent usage	Quantity	Grey water	Black water
Bathing	36.5%	2520.11	100%	0%
Washing	15.6%	1079.65	100%	0%
Drinking	5%	359.42	0%	100%
Cooking	5%	359.42	0%	100%
Toilet	27.1%	1871.76	0%	100%
Cleaning house	0.0%	0	100%	0%
Washing Utensils	10.4%	718.84	100%	0%
Others	0.04%	2.76	50%	50%

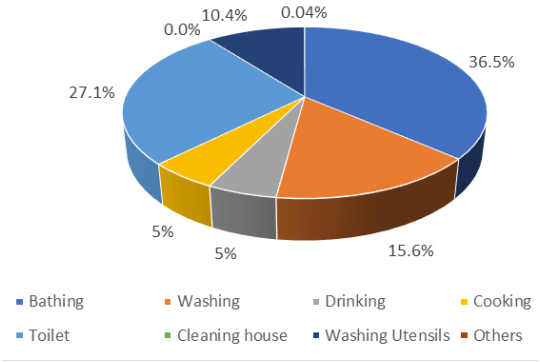


Figure 44: Occupant demand percentage

Table 22: Monthly Black and Grey Water Generation (In Liters)

Month	Days in Month	Generated Black Water	Generated Grey Water	Occupant Demand
Jul	31	80352	133920	214272
Aug	31	80352	133920	214272
Sep	30	77760	129600	207360
Oct	31	80352	133920	214272
Nov	30	77760	129600	207360
Dec	31	80352	133920	214272
Jan	31	80352	133920	214272
Feb	28	73224	122040	195264
Mar	31	80352	133920	214272
Apr	30	77760	129600	207360
May	31	80352	133920	214272
Jun	30	77760	129600	207360
Yearly		946728	1577880	2524608

Yearly water demand for CWH is 2803200 L.
Rainwater collected 2279498 L.
Greywater generated 1752000 L.
Treated greywater reused 1577880 L.
Surplus water = 2279498 + 1577880 – 2803200 = 1054178 L.
Hence, we are achieving net zero water stage.
Surplus water is discharged to recharging pits after necessary treatment.

Source: Water Calculation Tool provided in Survival Kit

12.6.1 Fixture Details

Table 23: Information Sheet of Sanitary Fixtures

Image of the Sanitary Fixtures			
Sanitary Fixture	Water Taps	Toilet Flush	Aqua Waterless Urinal
Baseline Water Usage (LPM)	4.31	6	2.2
Benchmark Water Usage (LPM)	2	1	0
Company	Supreme	Hindware	Hindware
Cost (each unit)	40	1200	5900
NOTE: Water used for flushing, washing (clothes, utensils) and bathing is reduced approximately			

12.6.2 Rainwater Harvesting

Table 24: Rainwater Harvesting Table

Months	Rainfall (mm)	Effective Rain (mm)	Harvested Rainwater (l)
July	649	644	721374
August	587	582	651925
September	301	296	331563
October	110	105	117615
November	5	0	0
December	14	9	10081
January	57	52	58248
February	33	28	31364
March	35	30	33604
April	8	3	3360
May	40	35	39205
June	256	251	281157
		Total	2279498

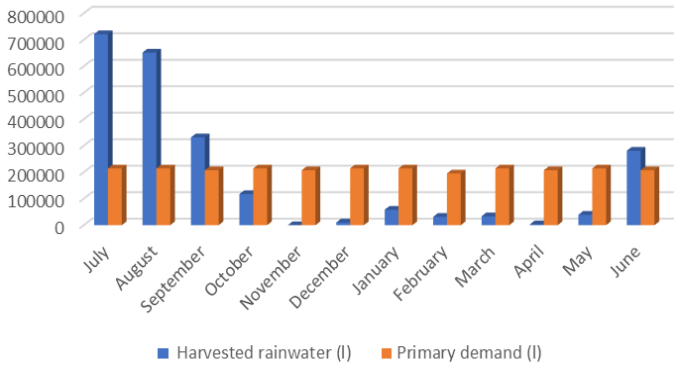


Figure 45: Rainwater Harvesting and Occupant Demand

Rainwater Harvesting Surfaces	Area (m^2)	Runoff Coefficient	Effective Catchment Area (m^2)
Roof Surfaces	838.6	0.75	628.97
Hardscape areas	470.2	0.70	329.14
Soft scape areas	810.2	0.20	162.03
Total Effective Catchment Area			1120.14

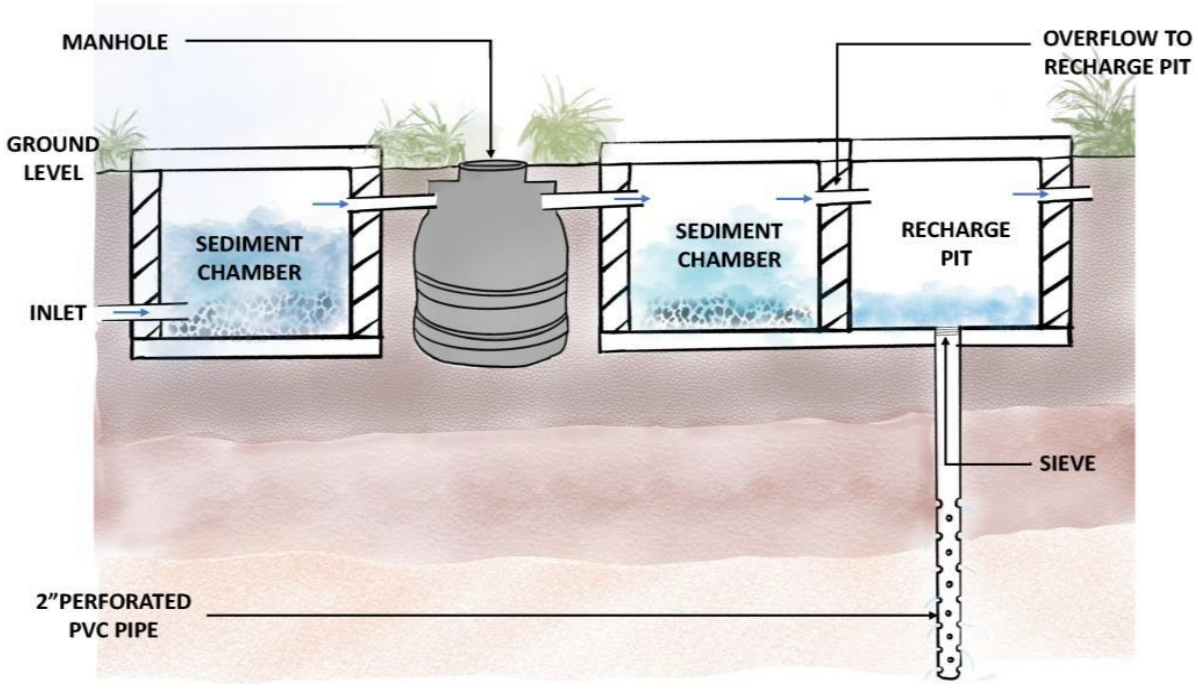


Figure 46: Illustration of Rainwater Harvesting and Water Recharging Pits.

(NOTE: Total Water Harvesting Capacity-6000 liters/per day)

12.7 Summary of Cost Estimate

Provided in Point 11.7.1 (Please refer Page: 40)

12.8 Packaging and Logistics

It is estimate that average 03 dwelling units of CWH can be transported in one standard Truck.

Table 25: Packaging and Logistics Calculations

PACKAGING and LOGISTICS				Actual Dimensions (m)			Packaged Dimensions (m)			
S.No.	Packet No.	Item Name/Description	Items	Length	Width	Height	Length	Width	Height	Volume
1	P1	Solar Panel	4	1.995	0.992	0.152	2.15	1.15	0.2	0.50
2	P2	Solar Panel Mounting	3	4.14	0.063	0.06	4.3	0.1	0.1	0.04
3	P3	Roofing Panels (North)	1	5.28	1.818	0.018	5.45	2	0.075	0.82
4	P4	Roofing Panel (South)	1	5.8	2.615	0.018	5.95	2.775	0.075	1.24
5	P5	Gable End Paneling	2	3.046	0.024	1.116	3.1	0.075	1.3	0.30
6	P6	Purlins	5	5.48	0.12	0.08	5.6	0.175	0.125	0.12
7	P7	Trusses	4	3.22	0.2	1.228	3.4	0.25	1.4	1.19
8	P8	Door Shutters	1	2.097	0.856	0.022	2.25	1	0.075	0.17
9	P9	Panels with Window	4	2.134	0.884	0.26	2.3	1	0.3	0.69
10	P10	Sandwich Panels	9	2.134	0.9	0.57	2.3	1.05	0.65	1.57
11	P11	Flooring Plywood	9	1.74	0.91	0.225	1.9	1.05	0.275	0.55
12	P12	T-Sections for Flooring	6	1.735	0.06	0.032	1.8	0.1	0.08	0.01
13	P13	Angle Section for Flooring	4	1.735	0.05	0.05	1.8	0.1	0.1	0.02
14	P14	C-Sections for Flooring	6	1.725	0.1	0.08	1.8	0.15	0.125	0.03
15	P15	C-Sections for Flooring 2	4	2.71	0.1	0.08	2.85	0.15	0.125	0.05
16	P16	C-Sections for Roofing	2	1.73	0.15	0.08	1.9	0.2	0.125	0.05
17	P17	C-Sections for Roofing 2	14	0.875	0.2	0.15	1	0.25	0.2	0.05
18	P18	SHS Columns	7	2.135	0.16	0.12	2.2	0.2	0.18	0.08
19	P19	Double C-Section Columns	5	2.35	0.25	0.08	2.5	0.3	0.15	0.11
20	P20	C-Section + L-Sections Columns	2	2.35	0.16	0.16	2.5	0.2	0.2	0.10
21	P21	C-Section Columns	2	2.35	0.1	0.08	2.5	0.15	0.15	0.06
22	P22	Base Plates + Box Sections	8	0.5	0.5	0.35	0.55	0.55	0.4	0.12
23	P23	Fan + Light	1	0.45	0.45	0.45	0.6	0.6	0.3	0.11
24	P24	Miscellaneous	-	0.6	0.6	0.6	0.6	0.6	0.6	0.22
-	-	**TOTAL**	-	-	-	-	-	-	-	**8.20**
		Volume in One Truck / Container					4.8	2.15	2.5	25.80
No. of CWH Dwelling Units transported in One Truck / Container:										3

It is estimated that about 03 dwelling units of Construction Worker Housing can be transported in one standard Truck. The housing module can be efficiently and safely transported to the construction site by packing them as per the following table in 24 packets.

12.9 Summary of Embodied Carbon Calculations

Figure 35, 36, 37 and 38 are illustrated graphically below to specify the material emission of roof, wall, fenestration and floor.
Further illustration demonstrates the material emission of roof, wall, fenestration and floor for the baseline and proposed case which is approximately 4000 kg CO_2 e, 120000 kg CO_2 e, 6000 kg CO_2 e, 3000 kg CO_2 e respectively.

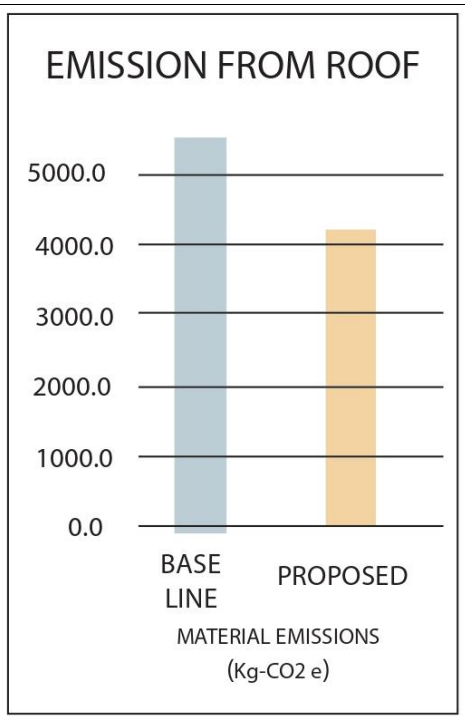


Figure 47: Embodied Carbon / Emission from Roof

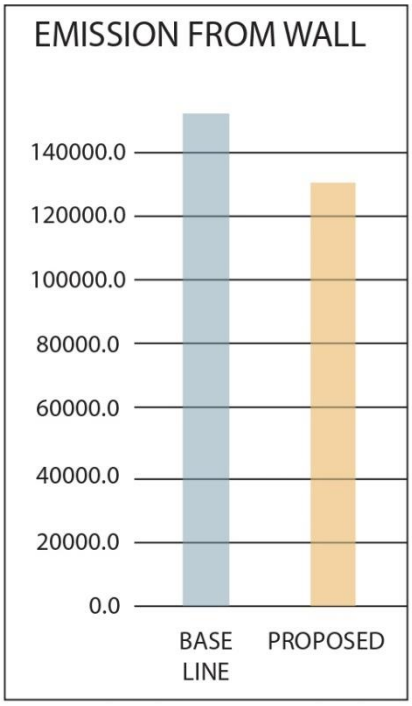


Figure 48: Embodied Carbon / Emission from Wall

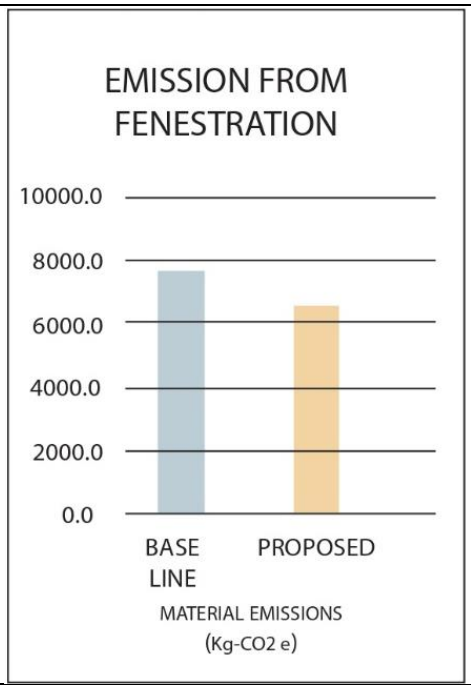


Figure 49:Embodied Carbon / Emission from Fenestration

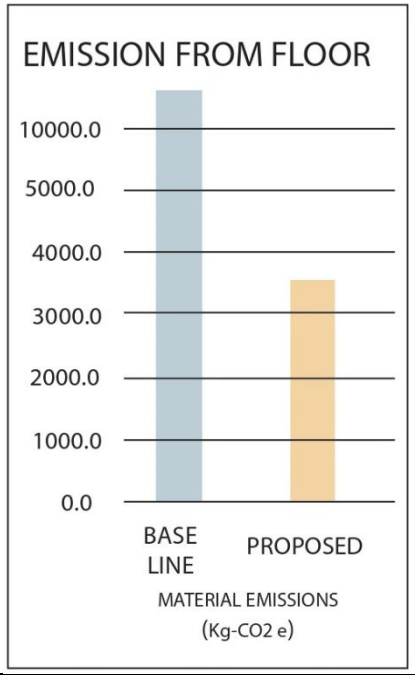


Figure 50:Embodied Carbon / Emission from Floor

12.10 Do's and Don'ts for Proposed Building Systems

Audience: On-Site Construction workers who will be assembling and residing in the modules.

The modules shall be assembled as explained in the Installation guide / Operation manual (*Annexure 13*). The operating and storage precautions have been explained in detail in the same.

Summary the building system installed: -

1. Interior and exterior lighting system

Each DU consists of a tube light and a wall fan connected to a distribution board with 2 switches & 1 socket. 1.00mm dia. Triple-core wires are used as connections.
MCBs, ACDB, DCDB and inverter are provided in the Electricity and Water Supply Room. LED Street lights and CCTV Surveillance for security provided for external spaces.

2. Thermal comfort and ventilation system

Each DU contains 4 MS Casement Windows (800mm x 800mm) with 3.0 mm thick acrylic sheet for natural ventilation (placement as per module layout) and 450x325mm north light window for ambient daylight. Insulated wall panels with GI edging, 63mm thick are provided for thermal comfort.

3. Water supply and wastewater processing system

Water supply from municipal line is pumped to OHTs using pump. Sedimentation tank, recharging pits and underground storage tank provided for rain water harvesting. A solar water heater of 2 X 500l = 1000l capacity for bathing. Bio-digester (2X Included with Mobile toilets) & MBBR Sewage treatment plant is provided for waste management.

4. Renewable energy and on-site energy storage system

On-site energy is generated from 4 X 216-watt PV Panels on each module (60 panels in our case) provided with 20 Batteries – 150Ah each for storage.

12.11 Key Parameters to Measure the Performance of the Building

- **DAYLIGHT**

Adequate provision of daylight is considered in architectural scheme of CWH unit. Simulation results indicate that 50 to 100 lux level is achieved on floor level during day time under clear sky conditions in the month of December.

- **THERMAL COMFORT**

VASTU Principles are being considered and had oriented the layout of dwelling units with due respect to cardinal directions. Configuration provide shade to the roofing system, which controls the rise of indoor temperature inside dwelling during summer season.

- **LIFE CYCLE/ DURABILITY**

CWH Housing units are to be used for more than one project. It is expected that Units shall work well for 06 cycles of 12 to 18 months each on various project sites. Building materials with optimized performance (Low Embodied Energy and Low Life Cycle Cost) are considered for the module. Durability of materials, joinery wear and tear, maintenance, assembly, storage, dismantling, and transportation aspects are duly considered for the module.

- **USABILITY/ FLEXIBILITY**

CWH Housing units are to be used for more than one project. It is expected that Units shall work well for 06 cycles of 12 to 18 months each on various project sites. Also, these can be used for some other purpose than residential e.g., office, shop, clinic/medical facility, store etc. Module is designed for the flexible use. Concept of Alina and Shala facilitates the flexible use of dwelling unit for residential or any other use.

- **EXTREME WEATHER CONDITIONS**

Storms may occur occasionally, and hence trees are not planted in East Direction to protect the life and property from any damage and a central assembly area is provided where people can be assembled in case of earthquake.

- **OPERATIONAL COST**

For an affordable price of INR 60 per construction worker per day, for a model of CWH is being proposed to create and ensure an atmosphere within the residential zone that is welcoming and conveys a sense of safety, comfort, convenience, belongingness, and dignity to all construction workers and residents on site.

- **ENVIRONMENTAL IMPACT**

The site must be treated with the required chemicals (5% chlorpyriphos), and further rodent control measures must also be done. The choice of building materials is made to prevent termite and other pest damage.

12.12 Pros and Cons of Architectural Elements

Table 26: Pros and Cons of various Design Elements

Aspect / Feature	PROS	CONS
Built Form	Gable roof helps to provide an appropriate angle for the installation of solar panels	Sloped roof limits the users to the ground floor.
Wall Material	Insulated walls and roofs can benefit the inmates in the term	Slightly high initial cost for the insulated walls and roofs
Roof Material	The assemblies can be easily dismantled and transported	
Floor Finish	Shuttering ply is a Low Embodied Energy Material. It can be reused multiple times and prevents moisture being pre-laminated.	Subject to warping / bending under moist conditions, after some uses.
Fenestrations on North and South Faces	Getting diffused daylight from North and direct sunlight from South faces.	No Cons.
Structural System and Elements	MS Angle, Channel and Hollow rectangular section have High strength and durability. Embodied Energy is 1/5 w.r.t. Aluminum.	No Cons.
Verandah	A well illuminated semi-covered area suitable for all seasons. Used for various routine domestic and social activities.	Extra Initial Cost.
Room Size	Room size of 3.5 x 2.7 m is considered. Optimum room size to facilitate convenient domestic living.	Appropriate Room Size. No Cons.
VASTU Considerations	Health and Well Being	No Cons.
Site Layout	Units are planned with due respect to the cardinal directions. Energy Efficiency and Thermal Comfort.	No Cons.
Common Toilets	Sanitation facilities at community level. Better Operation and Maintenance.	No Cons.
LED Lighting	Energy Efficiency / Low LPD	No Cons.
CCTV	Provides safety from various threats. Avoids Social Misconduct.	Higher initial project cost
Chain-link Fencing and controlled entry	Protection from wild animal's attack.	Higher initial project cost

12.13 Project Partner's Letter of Consent

कार्यालय परियोजना प्रबन्धक
निर्माण इकाई
उत्तराखण्ड पेयजल निगम
हल्द्वानी (नैनीताल)
उत्तराखण्ड
पिन– 263139

pmnwramnagar@gmail.com

Office of Project Manager
Construction Unit
Uttarakhand Peyjal Nigam
Haldwani (Nainital)
Uttarakhand
PIN - 263139

पत्रांक : 270 / Adhi-5 / 17 दिनांक: 16.02.2023

To,

The Director,
Solar Decathlon India

Dear Sir,

This is to inform you that our organization(Uttarakhand Peyjal Nigam),has provided necessary information about our 200 bedded hospital project (Site Plan etc) to the participating team led by DIT University, Dehradun, so that their team ECHO 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, without having any financial or otherwise liabilities towards us.

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 have No Objection, would like 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.

Regards,

(Himanshu Verma)
Project Manager

Copy to :-
1. Dr Rajeev Garg (Professor) Architecture, DIT University, Dehradun for Information Please

Project Manager

12.14 Industry Partner Letter

Date: 30.11.2022

To,

The Director,
Solar Decathlon India

Dear Sir,

This is to inform you that our organization, **ALCOI India Private Limited**, is collaborating with the participating team led by **DIT University (Team Echo)** 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 providing necessary support towards techno-commercial information related to Aluminum fenestration systems.

We **would like** 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,

Nitin Mehta
Executive Director
ALCOI India Private Limited
nitin@alcoi.in
+91 98154 45544

Office & Works
ALCOI India Private Limited
Plot No 427 - 430, Industrial Area 1
Panchkula 134 113, Haryana, India
Tel : +91 172 256 7649
Fax : +91 172 256 7650
info@alcoi.in
www.alcoi.in
Registered Office: 3870, Sector 32 D, Chandigarh 160 022, India

12.15 Bonafide letter

Mussoorie Diversion Road,
Dehra Dun - 248 009
Uttarakhand INDIA

Phone +91.135 7144000, 001
+91.135.7144300, 301
E-mail: dit@dituniversity.edu.in

DIT UNIVERSITY
IMAGINE ASPIRE ACHIEVE

Date: 15/02/2023

To,
Project Manager,
Construction Unit,
Peyjal Nigam UTTARAKHAND.
Haldwani.

It is to certify that following students of School of Architecture, Planning& Design and Department of Civil Engineering, DIT University Dehradun are participating in Solar Decathlon India 2022-23 competition organized by Indian Institute for Human Settlements and Alliance for Energy Efficiency Economy.
The team of students will have to prepare a design proposal for Construction Workers' Temporary Housing on 200 Bedded Hospital Site at Ghodapadav, Haldwani for the competition.

S.No	Name of Student	Program
1.	Shivam Kundu	B.Arch
2.	Khushi Garg	B.Arch
3.	Vidushi Agarwal	B.Arch
4.	Aadya Agarwal	B.Arch
5.	Akshat Goel	B.Arch
6.	Vivek Kamboj	B.Arch
7.	Sameep Singh	B.Arch
8.	Radhika Singhal	B.Arch
9.	Om Chauhan	B.Tech(Civil)
10.	Aditya Singh	UX

You are humbly requested to kindly facilitate the students by providing necessary information/ drawings/ NoC on the prescribed format. The information provided shall be used only for academic study purpose.

Thanking you in anticipation.

SCHOOL OF ARCHITECTURE PLANNING & DESIGN ★ DIT UNIVERSITY

Regards,

15/02/2023

Ar. Jitendra Kumar Sarohi
HoD: School of Architecture, Planning and Design
DIT University, Dehradun.

Er. Anil Joyal

PM

12.16 Action Taken Report (Response to Reviewer's Comments)

S. No.	Reviewer's Observation / Comments	CLARIFICATIONS/ ACTION TAKEN
1.0	REVIEWER-01	
	ENERGY PERFORMANCE	
1.1	Tables 3 and 4 are doing a fair comparison of baseline case and proposed case using electrical fixtures and efficient fixtures. However, the use of passive strategies and low energy strategies are not justified sufficiently. You need to convert your analysis to results. For example- you have done solar radiation analysis anyway. The result is "Orientation of dwelling units" which is a passive strategy. These are not coming out fully. Work more on passive and low energy technologies' integration.	Vastu principles are the major basis of architectural design of dwelling units and the layout. Orientation is a significant aspect which contributes in thermal comfort by avoiding solar radiation when it is not appropriate in summer season and inviting sun during winter season, with due consideration to sun shading devices/ overhangs. This is illustrated on page no 22. In CWH, we are not depending on HVAC system and hence there are limited opportunities for integration of low energy technologies, except lighting.
	WATER PERFORMANCE	
1.2	Good attempt at the water balance cycle. However more details on each source and the quantity of water needs to be mentioned right from the source. A similar comment was given in deliverable-2 also. Supporting data has been added in page 48 which is good. Also, add as much information in the water balance cycle itself. A short narrative on how the baseline case (135L) and proposed case (96L) differ in terms of strategy can add value. Although there has been back-thought, the articulation of necessary information can be better	Water balance diagram is updated and enriched with information on page no.29. Explanatory paragraph is also added on page no. 56.
	EMBOIDED CARBON	
1.3	This is 1 page as per the report you have provided. A short supporting narrative could have helped. Units are missing in table-7. Do the colors represent anything? What is the inference from table 7? It looks like a stand-alone table with no preface, no narrative and no inferences. Again, you have done good work, but you have not articulated it well. The "Why" is not being addressed. "Why" the table? What's the inference in terms of embodied carbon and its emissions?	Explanatory paragraph is added in section 11.3 on page no. 30. Table is suitably updated by removing any ambiguities. Answer to "Why this table" is also clarified on the same page.

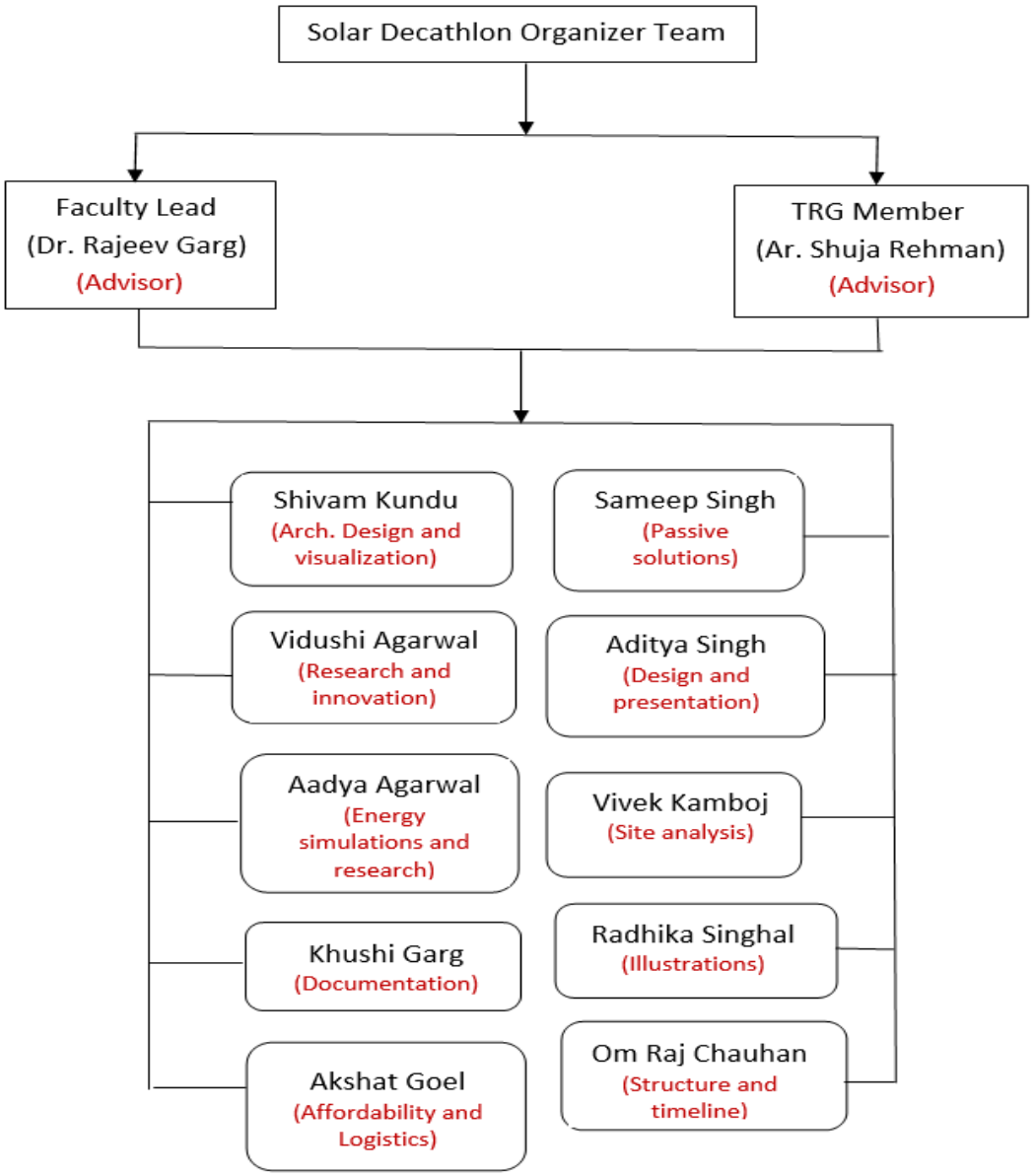
	RESILIENT DESIGN	
1.4	Good job. There are some comments from Deliverable 2 that you have addressed in page 61 but are not reflected in page 29 under this section. When you are assessing for risks, it is a good practice to mention the source of supporting document that helped you identify the risk. For eg- you have mentioned about wild animals. Which source has pin-pointed you to this risk? That kind of information can be added with these points to make it complete and robust	TEAM has visited site and had spoken to the people available there. Information about wild animals was provided by the local's residents, and hence no literary source is mentioned.
	ENGINEERING AND OPERATIONS	
1.5	Very good job on the engineering systems details and specifications. Capacity/ sizing has been mentioned. However, you need to justify how/ why you are calling it "Rightly sized" as per the requirement in the brief. Space provision and architectural integration can be explained consistently for all systems. Constructability at scale also needs to be talked about as a narrative. Some of the above two are available randomly but need to be consistent for all engineering systems	Initial size of structural members was considered after talking to the faculty advisor/structural engineering faculty/professionals. However, we have now revised the sizes to achieve economy after necessary load calculations and in view of capacity of structural members (as suggested by civil engineering team member). Constructability of unit is explained in Operation Manual (attached as annexure 13) and information about system/equipment's is updated in table 9 and 10 on page no.33, 34 and 35.
	ARCHITECTURAL DESIGN	
1.6	Great job! The narrative is good. Any creative process or ideas that you specifically have can be added in the narrative or shown as part of the visuals. Both the figures convey the same conclusion. - the site plan although one is technically a site plan and the other is a roof plan. This is already evident from images in your solar radiation analysis. Two images conveying the same features on site is redundant unless the design brief states it as a mandatory requirement. If not, you can use the space by replacing one of these images and adding something even more relevant that can address- evidence-based and creative process or aesthetics etc. See how you can address this	Comment is suitably incorporated in this document and information/images are introduced/ updated in section 11.6 on page no. 39.
	AFFORDABILITY	

1.7	Great job! The comparison and baseline and proposed case is good. However, you can mention what are the strategies that led to that difference in cost. You can add one more column for "Strategies" and link it to previous sections/ strategies as necessary. Without this, it is just numbers being reduced from baseline to proposed case without mapping the "How" part. Similarly in table -10, you can add the relevant sources of the information- of it is from a reference/ standard/ project partner etc.	Type of construction and specifications of various building elements form the major basis of difference in cost of baseline case and the proposed case. This is clearly mentioned in table no 15 In section 12.4, page 52 and 53. The cost of various items is considered as per Delhi schedule of rates 2021 and currently prevailing market rates, as appropriate.
	INNOVATION	
1.8	Good job! Try to distinguish between Innovation and strategies. Eg- Solar PV is a strategy, not an innovation unless you have very specifically worked on the technology or layout or specifications to suit your needs in an innovative way.	Relevant section 11.8 (on page no. 41) is updated in line with D4 requirements.
	HEALTH AND WELLBEING	
1.9	This section mentions or lists most of your "architectural features" in a way. You need to address health and well-being as per the brief in terms of thermal comfort annual simulations, operating modes, ventilation requirements, mechanical ventilation etc. This is not being addressed.	Relevant section 11.9 (on page no. 42) is updated in line with D4 requirements and reviewers' comments.
	VALUE PROPOSITION	
1.10	This section can be done better. Please read through the brief.	Relevant section 11.10 (on page no. 43) is updated in line with D4 requirements and reviewer's comments.
S.NO	**OBSERVATION**	**CLARIFICATIONS/ ACTION TAKEN**
2.0	**REVIEWER-02**	
	ENERGY PERFORMANCE	
2.1	Appreciate the thorough energy calculation with citation for all specifications given. The team could further design for energy efficiency by designing the modular skins and fenestration for thermal insulation with appropriate material and shading systems.	Relevant information is presented in section 12.5, table 16, 17, 18 and 19 on page no. 54 and 55.
	WATER PERFORMANCE	

2.2	Given the CWH typology, the water requirement for gardening will be negligible. Consider using treated water for flushing and incorporate the same in water calculations. The team could further detail this section by providing a site plan that illustrates water flow cycles.	Water cycle diagram is updated in line with D4 requirements and reviewers' comments on page no 29.
	EMBOIDED CARBON	
2.3	Comparative analysis with the baseline case is missing. Please cite sources for all embodied carbon specifications. Further illustrate the use of these different materials in construction detail drawings (sections)	Relevant information is incorporated in section 11.3, table 7 on page no.30. Use of materials is illustrated in detail P, R, S, T and U under section 11.5 on page no. 34 and 35.
	RESILIENT DESIGN	
2.4	In the CWH typology, waste disposal and sanitation is key. Illustrate design strategies for the same with detailed architectural drawings and specifications	Relevant information is incorporated in section 12.3.1, figure 33 on page no.43.
	ENGINEERING AND OPERATIONS	
2.5	Appreciate the sizing drawings, suggesting the team to calculate live and dead loads for the same to arrive at the required sizing of structural members. Foundation details are key (grade of pcc, dimensions and joinery details). Illustrate junction details in appropriate and legible scales.	A new table is introduced (table 11) under section 11.5 on page no 37 and 38. Engineering drawings are reproduced in section 12.3 to maintain consistency and legibility of scale.
	ARCHITECTURAL DESIGN	
2.6	The module is well thought out, on the masterplan level, consider deleting a few units to give breaks for better ventilation and to open recreational pockets of common spaces. Consider reversing the modules in the middle row of the site plan to make verandahs face each other to promote interaction between residents and community relations. The roof design will still remain as per direction required for solar PV panels in the south.	Layout and orientation of dwelling units can be customized depending on the area available on the project sites. A layout with verandahs facing each other may require customization of modules. Although verandah facing each other will facilitate community interaction which is required for shorter duration of the day, however, the resident will lose privacy which is very much required for longer durations of the day.
	AFFORDABILITY	

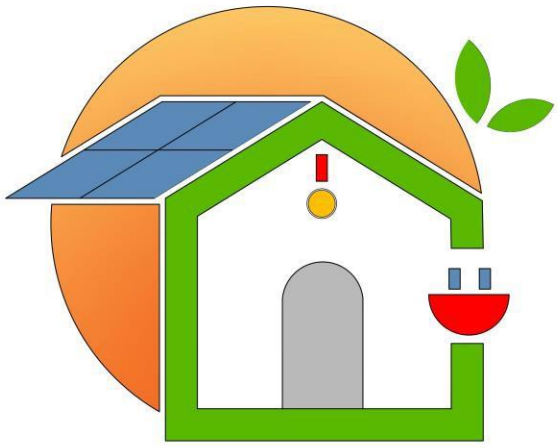
2.7	There seems to be no information about budgeting of common infrastructure. Where are the costs of the solar PV system, water tank, hardscape paving, furniture, kitchen, bio toilets and other common facilities? Please provide material specification for the baseline scenario versus the team's project. Add rates and quantities to arrive at the total costs.	Comment is suitably incorporated by introducing table 12 under section 11.7 to clarify the scenario of baseline and proposed case on page no 40.
	INNOVATION	
2.8	Appreciate the modular and packaging planning. The team can further illustrate the innovation in design through assembly - disassembly drawings and details in the form of a manual.	Innovation is illustrated in the form of very simple joinery details of various members of CWH modular unit. Operational manual is attached as annexure 13
	HEALTH AND WELLBEING	
2.9	This section focuses on design for achieving thermal comfort; which should be supported through a detailed analysis of annual simulations. Please provide calculations of the thermal comfort levels achieved through the design strategies used.	It is estimated that about 450 hrs. during day time (from 12:00 - 17:00) in the month of May, June and July only shall pose thermal discomfort (temperature beyond 27^0 C). We have considered wall and roof insulation and roof projections so that dwelling unit is unaffected from outside daily temperature variations.
	VALUE PROPOSITION	
2.10	Appreciate the points mentioned, though the module will have to be appropriately reconfigured to suit geographic/climatic conditions.	Yes, module is proposed in view of prevailing weather conditions under composite climatic zone of India, however, some of the building elements like wall sections and flooring can be reconsidered for other climatic zones like warm humid and hot dry.
	ADDITIONAL COMMENTS	
2.11	At this stage, one would have expected to see better illustrated and detailed architectural 2D and 3D drawings and visualizations.	Illustrations are improved in view of their contents, clarity, legibility and relevance in D4 document.

12.17 TEAM Organogram



Solar Decathlon India

ON SITE CONSTRUCTION WORKER HOUSING (CWH)



TEAM ECHO

Installation Guide/Manual
(Annexure - 13)

DIT UNIVERSITY
IMAGINE ASPIRE ACHIEVE

School of Architecture Planning and Design

DIT University, Dehradun (Uttarakhand)

1.0 Table of Contents

2.0 List of Tables

3.0 List of Figures

4.0 Structural Members

Table 1: Structural Members Storage Method

S.no.	Structural Member	Dimension(mm)	Units/ Module	Storage Method / Instructions
1	Base Plate	300 X 300 X 6	8	Shall be kept one above the other stacked upto 08 members in one column.
2	Box Section above base plate	110 HIGH, 8 THK	8	Shall be stored in plywood box (08 numbers in one box)
3	Primary Column (Two C-Sections welded back to back)	2 X (75X40X6)	5	These shall be stored in bundled form, can be kept horizontally or vertically inclined (max 15 deg angle).
4	Secondary Column	60 X 40 X 2.35	8	These shall be stored in bundled form, can be kept horizontally or vertically inclined (max 15 deg angle).
5	Rear Columns (C-Section welded to angle section)	75 X 40 X 6 75 X 75 X 6	2	These shall be stored in bundled form, together with primary and secondary columns.
6	Inverted C-Section Tie Beam	75 X 40 X 6	12	These shall be stored in bundled form, can be kept horizontally or vertically inclined (max 15 deg angle).
7	Flooring Joist T-Beams	40 X 25 X 3	6	These shall be stored in bundled form, can be kept horizontally or vertically inclined (max 15 deg angle).
8	Inverted C-Section Lintel Tie	75 X 40 X 6	16	These shall be stored in bundled form, can be kept horizontally or vertically inclined (max 15 deg angle).
9	Truss			These shall be kept vertically in MS stand. (Please refer Figure-1)
10	Purlins	40 X 40 X 2.6	5	These shall be stored in bundled form, can be kept horizontally or vertically inclined (max 15 deg angle).
11	Cleats	50 X 50 X 6	32	These shall be stored in Plywood Box (max 32 in one box).
12	U-Cleats	50 X 50 X 4	16	These shall be stored in Plywood Box (max 32 in one box).
13	Flat Plate strips	150 X 50 X 4	62	These shall be stored in Plywood Box (max 32 in one box).
14	Nuts & Bolts	M8.8 13mm dia.	90	These shall be stored in Plywood Box (max 32 in one box).

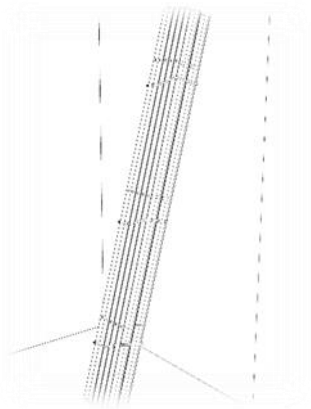


Figure 1: Storage Method of Columns.

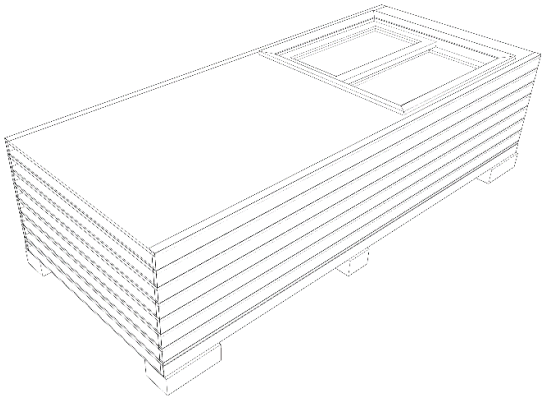


Figure 2: Stack the wall panels one above the other, stack shall be elevated from ground on angle sections, to prevent moisture sepage

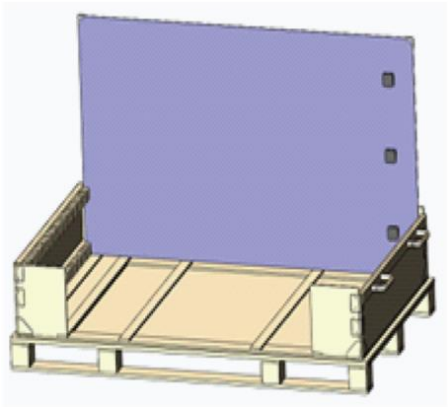


Figure 4: Store the PV modules, vertically in slots.

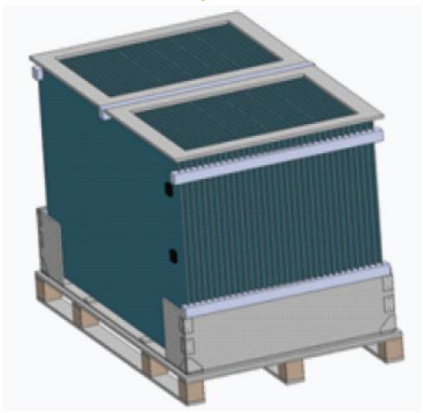


Figure 3: Place the packing belts on top and place protecting ridges on corners

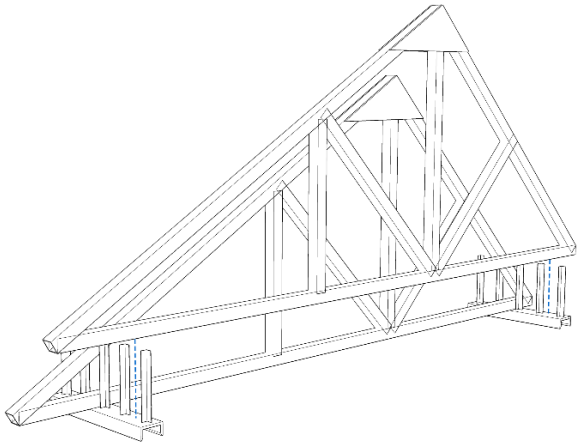


Figure 5: Storage technique of trusses

Vertically place the trusses on inverted channel sections, supported on angle sections

5.0 Assembly on Site

Table 2: Assembly Instructions of Module

1

Levelling of ground and marking the grid.

Ground should be levelled and any foreign objects / weeds should be thoroughly cleared to ensure a stable base to support the footing. Center Marks should be made prominent with clear center point denoted as crossing of two grids.

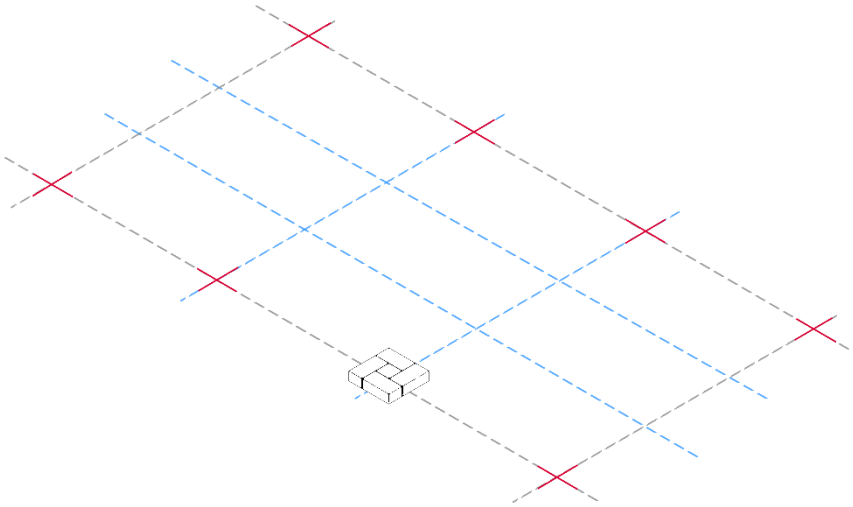


Figure 6: Layout on Levelled Ground and Marking of Grids.

2

Placement of base pedestal on the designated marks.

Place the base pedestal of bricks on designated marks on levelled ground for resting of base plate of columns

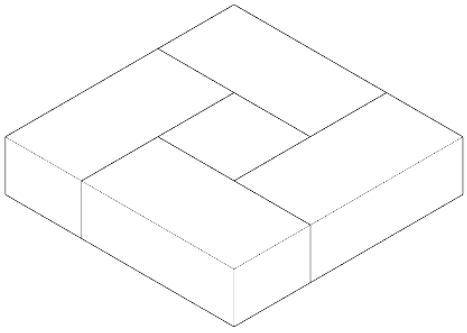


Figure 7:Base pedestal of Bricks for Resting Base Plate of Columns.

3

Placement of base plate welded with box section

Place the base plate (300x300mm, 6mm thk.) over the brick footing, welded with box section to support the column.

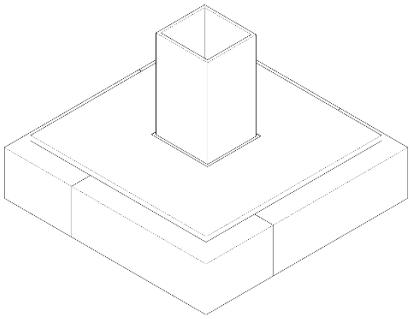


Figure 8:Placing of Base Plate over Brick Pedestal with Mortar

4

Insertion/Placement of columna

Insert the inverted box sections welded with columns, in the box section connected to footing, further connected to the base plate, placed over the brick footing. (Fig. 9)
Repeat the procedure for all 08 columns of a module ensuring the upright positions of the columns. (Fig. 10)

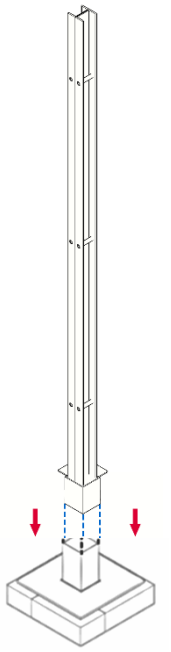


Figure 9: Fixing of MS Column to the Base Plate

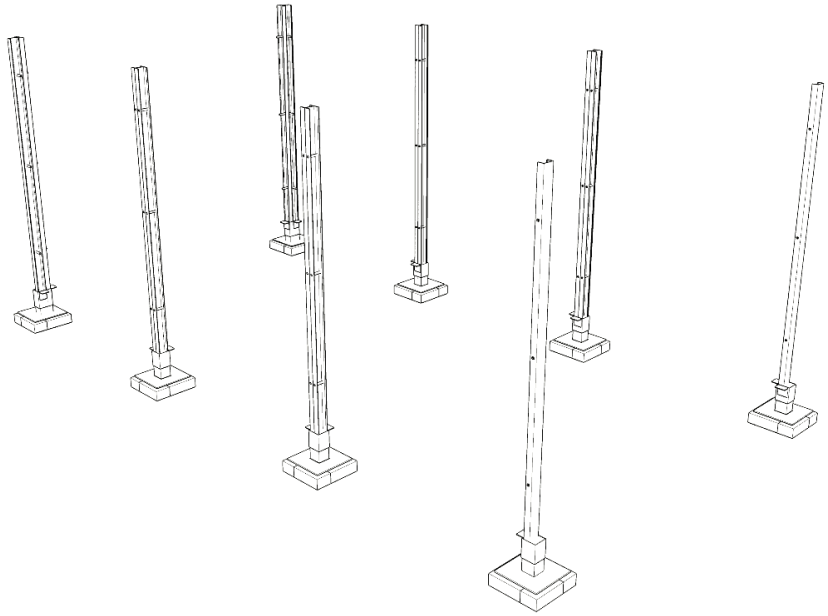


Figure 10: All columns are to be erected for one dwelling unit.

5

Connection of flooring joists.

Place the inverted channel sections on the angle cleats welded to the columns to support the load of flooring. Fix the T-sections & Angle-sections (on the periphery) on U-cleats.

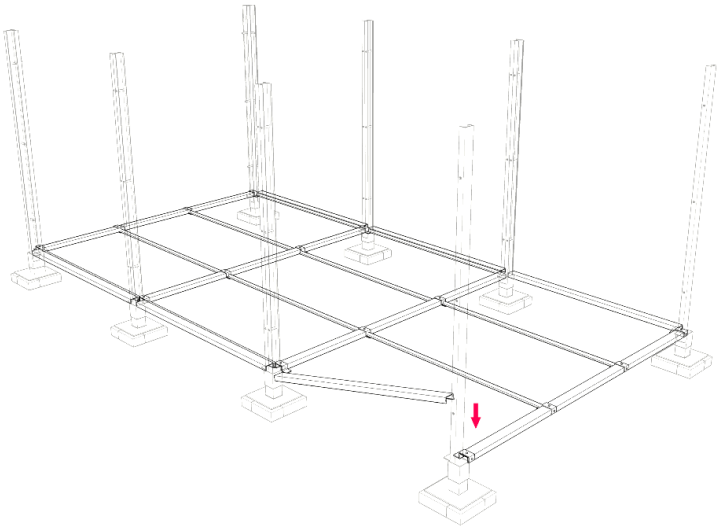


Figure 11 : Connections of flooring joists.

6

Placement of flooring boards

Insert laminated shuttering plyboards over the flooring joists (between Angle sections and T-sections).

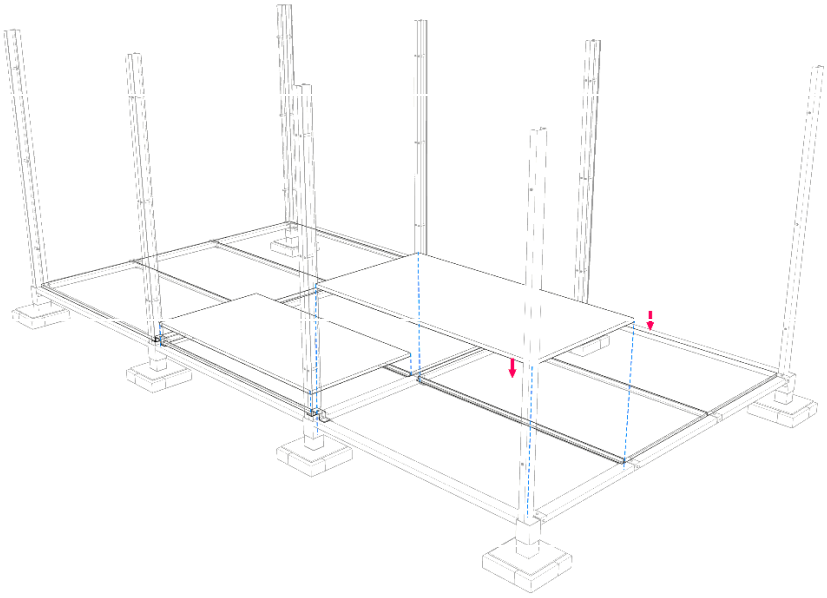


Figure 12 : Placement of flooring boards.

7

Insertion of wall panels

Insert the wall panels along the flanges of columns. Fix them with the column using 13mm nuts & bolts in C-section & 13mm bolts & nut to fix intermediate box section columns to the wall panel edging using M.S.Flat.

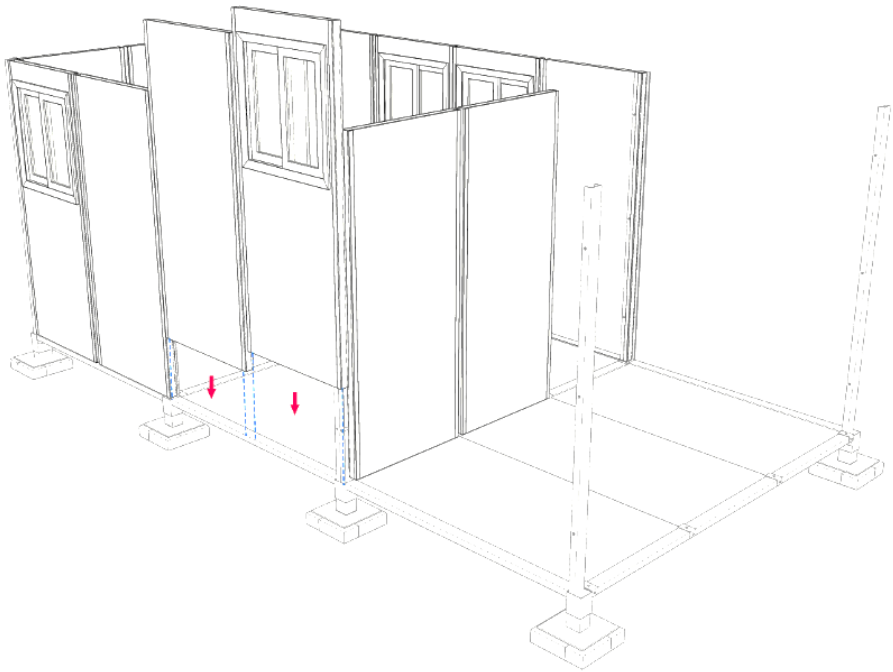


Figure 13: Insertion of wall panels.

8

Installation of top rail sections

Install the top rail to hold the columns and wall panels together.

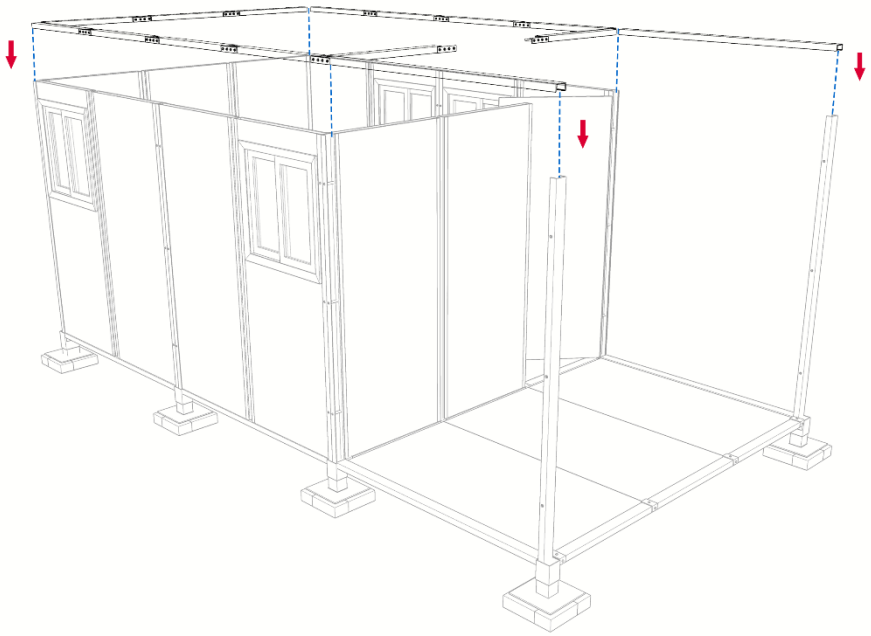


Figure 14: Insertion of top rail section.

9

STEP 10: Attachment of trusses to the top rail

Fix the trusses vertically above the columns.

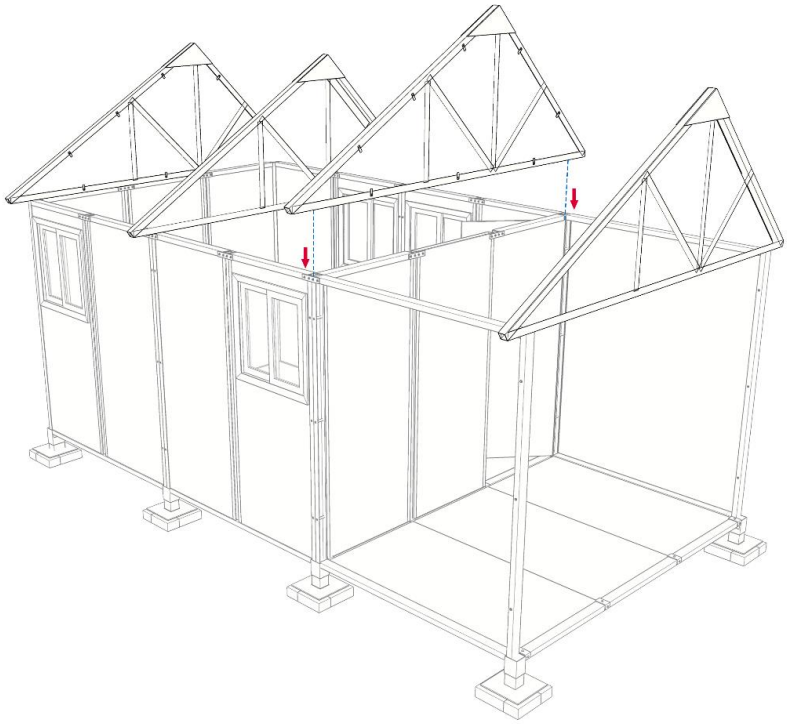


Figure 15: Attachment of trusses to the top rail.

10

Installation of purlins

Install the purlins by screwing them to the trusses.

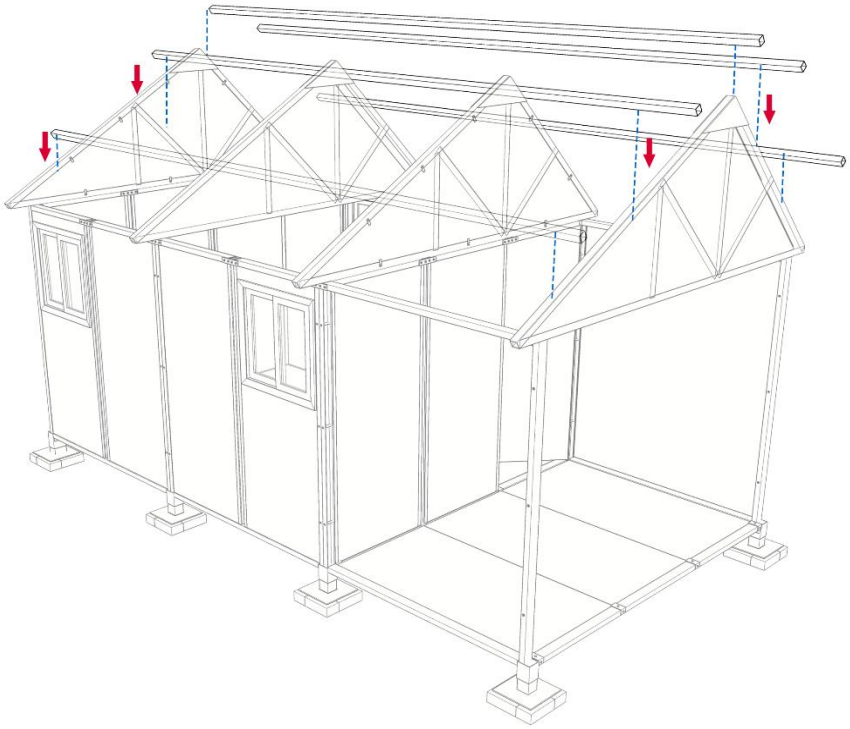


Figure 16: Insertion of purlins.

11

Installation of roof sheets

Install the roof sheets to purlins using bolts.

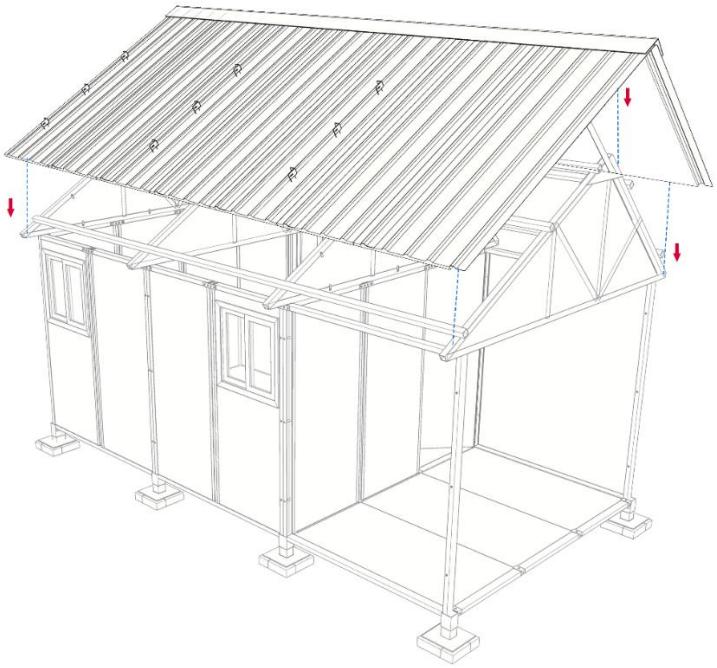


Figure 17: Installation of roof sheets.

12

Placement of solar panel mounts

Place the mounts on the hinges bulging out of the roof sheets.

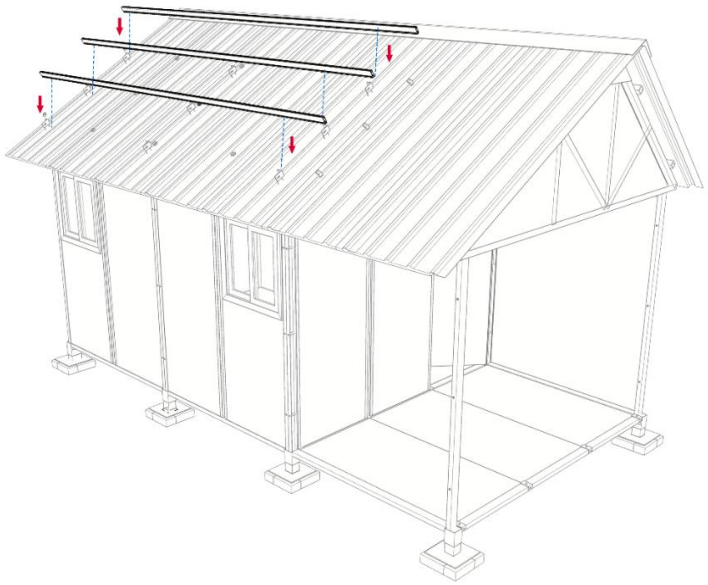


Figure 18: Placement of solar panels mount.

14

Mounting of Solar panels

Mount the solar panels on the roof mounts on the southern side of the module.

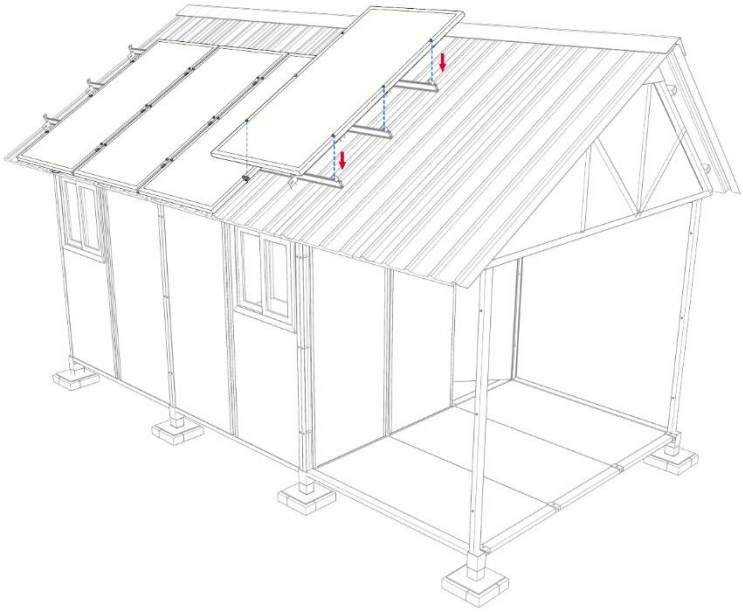


Figure 19: Mounting of solar panels.

Precautions

- Keep them dry
- Prevent moisture retention
- Do not keep them flat to prevent breakage

15

Installation of North lights

Install the north lights on the roofs where the voids have been left.

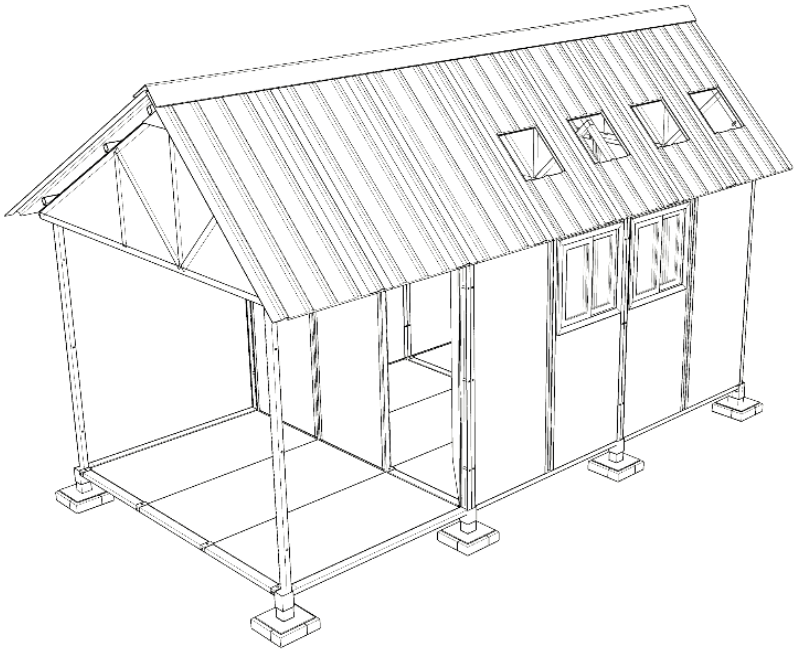


Figure 20: Installation of North lights.