Solar Decathlon India

FINAL DESIGN REPORT

Multifamily Housing

(April '22)

TEAM SUBZERO

School of Planning & Architecture,
New Delhi

Contents

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Team Subzero from School of Planning and Architecture, Delhi working on Multi Family housing. Our team comprises of 11 architecture students and 2 engineering students which focuses mainly on net-zero energy and recycling water, catered specifically to the cold climate zone prevalent in Kathmandu, Nepal. Design is developed with multidisciplinary team members and technical support from faculty lead.

Our site is located in Kirtipur in Kathmandu, Nepal, to demonstrate the applicability of our design. The developed prototype is a Seven-storey Building comprises of 24 apartments (1Bhk , 1 Bhk studio apartment, 1 Bhk with study room). The ground floor consists of various spaces for social, recreational, administrative and commercial use, as well as provisions for parking and services. With careful consideration to all the building science principles and affordability carrying out pre design comfort & energy simulation we developed an optimized building massing having a huge potential for obtaining thermal comfort through natural ventilation.

The client's main objective was to create an 1 Bhk housing solution designed for doctors and nurses. By deriving a typology specifically for these users, keeping in mind certain cultural and societal aspects, we aim at making the spaces less like “units” and more like a collective neighborhood. With a vision to contribute to this development, having net-zero energy & resource efficiency concepts at the core, we have designed & engineered a prototypical multifamily housing solution for the cold climate zone.

The aim was to not only reduce the energy consumption but also address to challenges of affordability and people’s lifestyle, market forces and people’s upgrading lifestyle. Our goal was to provide housing solutions that save, produce and store water and energy by implementing reliable and cost-effective measures that harness the natural potential of site, as well as improve the conditions of the local community and ecology of the area. We have incorporated rooftop Solar Photovoltaic system. We aimed at achieving self-sufficiency of the structure, in order to create housing solutions that will achieve a higher value than conventional ones, and is catered specifically to the cold climate of the region.

The envelope has been optimized by using hollow concrete blocks with XPS insulation for walls which has a U-value of 0.23W/m2K. Slate tiles are used as floor finish to increase solar gains.For glazing in windows, a clear double glazing of 6mm and 13mm with air filled, which has a U-value of 2.66 W/m2K.The shading devices are added based on this calculation and design also to add to the aesthetics of the the facade.

1.1 : Window Shading and planters

1. **Team Name** - **Subzero**
2. **Institution** - **School of Planning and Architecture, New Delhi**
3. **Division** - **Multi-Family Housing**

B.E.M PARTNERS

4. School of Planning and Architecture, New Delhi (Estd. 1941)

SPA Delhi is a specialized deemed University, only one of its kinds, which exclusively provides training at various levels, in different aspects of human habitat and environment. The School has taken lead in introducing academic programmes in specialized fields both at Bachelor's and Master's level, some of which are even today not available elsewhere in India.

5. Faculty Lead and Advisors

Dr. Shweta Manchanda

(Faculty Lead)- Dr Shweta Manchanda is an Associate Professor of Architecture at School of Planning and Architecture, Delhi. Following a B.Arch. from SPA Delhi, masters from University of Cambridge and specializes in environment design in architecture.

Dr. Khushal Matai

Dr Khushal Matai is an Associate Professor of Architecture it School of Planning and Architecture, Delhi. Following a B-Arch and M-arch from SPA Delhi.

Ashwani Kumar Datta

Visiting professor at department of architecture in School of Planning and Architecture, Delhi.Following B.Arch from Centre of Environmental Planning and Technology (CEPT), Ahmedabad and masters in Architectural Design from the University of Arizona, Tucson, USA.

Dr. Deepti Gupta

Visiting faculty at SPA Delhi for the last 16 years.architect and project manager having graduated from SPA. She is also a tensile engineer with a Master of engineering in membrane structures from Hochschule Anhalt university in Germany.

Kinshuk Aggarwal

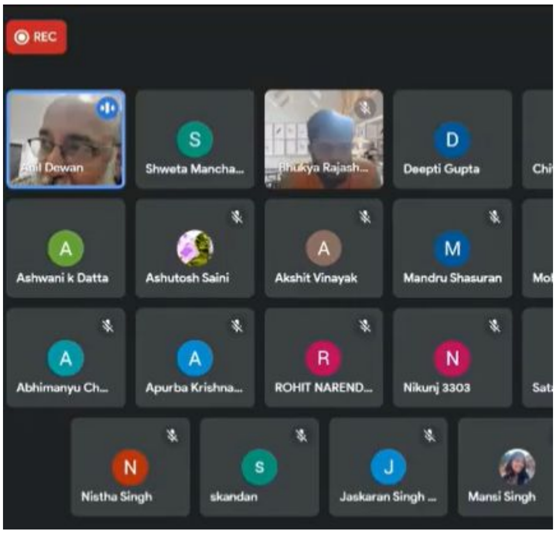
Visiting professor at the School of Planning and Architecture, Delhi. Following a B. Arch graduate from USAP, Delhi, he completed his masters from The Bartlett school of architecture, UCL,London, in Sustainable Urbanism.

Simulations and Tools Used

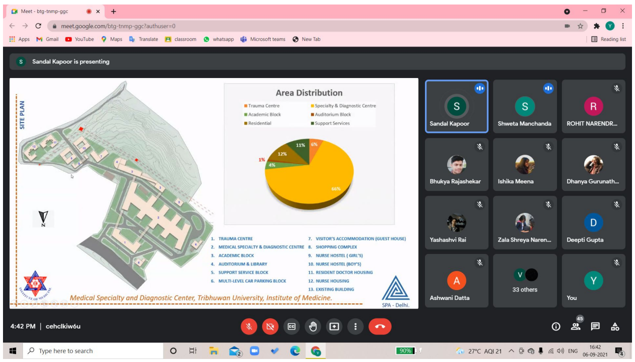
For more understanding approach to the design, simulations were done using various tools and many other tools were also used to help us with our design and report.

Design Management Process

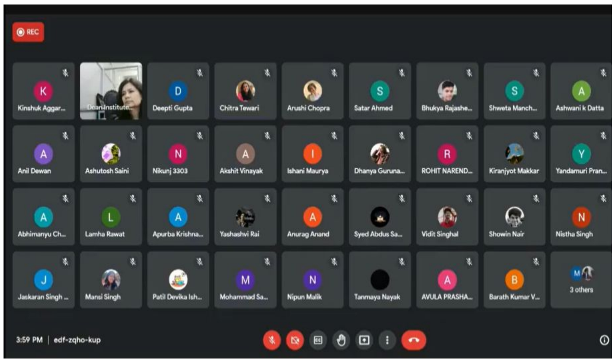
We Team Subzero has taken up this challenge and tried to make it sophisticated as much as possible. We had team meetings,analysis,reviews,industry partner inclusion ,project partner,discussions and various tools have been used for accurate data .



(Image 1)



(Image 2)



(Image 3)

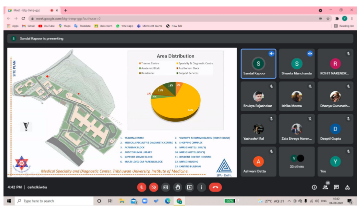
Meets with key individuals (image-1) ,project partner (image-2) and reviews (image-3) .

Challenges faced and approach taken to overcome them

Our team, Subzero aims to create a net-zero-energy, net-zero-water and waste, climate-resilient housing for the support staff of Tribhuvan University, Kathmandu, Nepal.

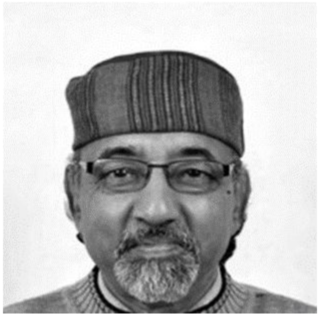
We have started this project in the period of pandemic. We have faced lots of challenges of in mode of communication with each other , we have taken up to conduct regular meetings on google meet , use multi interface software - slides,jamboards to stay connected regularly .

We have faced problems in creating design which is net zero, we have designed various layouts and we had done 5 various alternatives and reached out to the best case and resolved it even more into detail.



Project Name : Residential & Nursing Housing for Tribhuvan University, Kirtipur, Kathmandu, Nepal.

Project Partner : Dr. Dibya Singh Shah
Dean, Institute of Medicine
Tribhuvan University, Kathmandu, Nepal.



Key Individuals Involved

Dr. Anil Dewan
He is currently leading the team which is developing the Proposed Master Plan for the Tribhuvan University.

Dr. Dewan is also the HOD of Department of Architecture at SPA, New Delhi. And as a specialist in Hospital Design also is a faculty for Hospital stream teaching IV Year.

Brief Description of Project

The site is located adjacent to the Chakrapath (Ring Road) in Kirtipur, Kathmandu, Nepal. The residential housing is part of a larger plan to develop the site into a super speciality hospital under the Tribhuvan University. Currently, the proposed development is under the master plan stage.

3.1 : Project Location

Climatic Zone

The site lies in Kathmandu which falls in "**Temperate Climate with Dry Winter & Warm Summer**" according to the Koppen-Geiger Climate Classification.

- **Status of Project**
  - Currently under Master Plan Stage.
- **Profile of Occupants**
  - The housing is divided into two categories- Nurses Housing & Residents Housing. The Nurses Housing is for Nursing Staff who live along with their families, while Resident Housing is for the Doctors and some Faculty who want to reside within the campus along with their families.
- **Hours Of Operation**
  - As a residential building, the building will operate for **24 Hrs**. a day.

Special Requirements of Project Partner & Constraints

The project partner has a very low budget to accommodate 120 families (60 Nurse Families + 60 Resident Families). Hence, all the units are to be made as small **1BHK units.**

A high tension line is passing through the site which renders significant area of the site as **NO CONSTRUCTION ZONE.**

Total Built - Up Area

Site Area for the Housing - 8998.03 sq.m.
Permissible Built-Up Area - 26994.09 sq.m. with a F.A.R. of 3.
Permissible Ground Coverage - 30%
Estimated Built-Up Area - 8545.68 sq.m. ± 10%

Preliminary Construction Budget

The Preliminary Construction Estimate for project is calculated with rate of ₹ 28,000/ sq.m for built-up areas and ₹ 40,000,000 / acre of site development.

Hence, the preliminary construction budget is pegged at
28,000 x 8545.68 + 6000/4000 x 40,000,000 = ₹ 29.92 Cr.

Climate Zone

The site lies in Kathmandu which falls in "**Temperate Climate with Cold and Dry Winter & Warm Summer**" according to the Koppen-Geiger Climate Classification.

Appliance	Quantity (No's)	Capacity/ Size
Television	1	24"
Refrigerator	1	179 L
Washing Machine	1	6.5 kg
Exhaust Fan	2	150 m3/h
Ceiling Fan	2	1200 mm

5.2: Equipments: Capacity

Appliance	Wattage	Duration of use	No's	No. of days	Electricity used (kW)
Ceiling fan	26	5	54	200	1404
Lighting- A	12	4	270	365	4730
Lighting- B	25	4	64	365	2336
Lighting- C	16	4	48	365	1121
Refrigerator	130	8	24	365	9110
Washing Machine	462	1.5	24	104	1730
Television	60	2	24	365	1050
Heat Pump	14000	3	1	130	5460
Water Pump	750	1	4	365	1095
Lift	5600	1	1	365	2044
Others	NA	NA	NA	NA	3000
TOTAL					**32715**

5.3 : Electricity usage per floor per day

Energy Efficiency

AIM - To attain EPI less than 20.

Scheduling HVAC for winters at the time when building is in use.

Using Energy Efficient Appliances.

Inverter Technology Compressor made VRF HVAC more efficient.

Achieved EPI - 15.22.

Maximizing Groundwater Recharge

Aim is to have at least 50% area for groundwater recharge.

Road Area - 1720 sqm,   Built up Area - 1450 sqm.

Green Area - 5828 sqm.

Area Available for Ground Water Recharge - 4578 sqm (57.5%).

Thermal Comfort

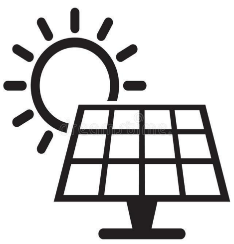
AIM - 100% Comfort Hours

Comfortable Hours- 7117/ 8760 hrs

Fan Forced Ventilation Cooling- 68 hrs

Dehumidification - 2685 hrs

Rest for 1643 hrs HVAC and Fan is used to attain 100% comfort.



Solar Power

AIM - To generate 100% power through Solar Power Plant.

Power required = 1,63,575 KWh.

Solar Devices Incorporation - Solar panels, Solar Heaters.

Solar power generated = 2,22,385 KWh/y.

Percentage generated = 135% approx. (Energy Positive Building)

Waste and Water management

AIM - Target per capita water consumption: 70 LPD.

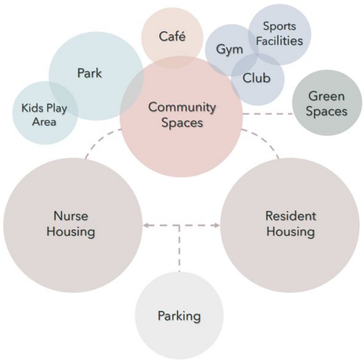
Base case usage : 135 LPD.

Achieved per Capita Water Consumption : 66.6 LPD.

Achieved 65% of Fresh Water Consumption through Rain Water Harvesting.

5. Architectural Design

The orientation of each block has been done in a way to increase the energy efficiency of the buildings. It affects the heating and cooling of the building and maintains an optimal temperature in the living environment. Orientating slightly east of south exposing the unit to morning and afternoon sun and enabling the building to heat during the day in the winters. Greater the perimeter to area ratio, greater is the heat gain of the building.



6.2 : Bubble Diagram site level

6.1 : Site plan

5. Architectural Design

There is a 12 meter wide non buildable area in our site due to the presence of an high tension electric line which passes from north to south west corner of the site, so to utilize the area we have used it as road and parking. Two wheeler parking is given in the stills which can be accessed through the hardscaping around the building.

6.3 : Outdoor spaces

The outdoor spaces are placed according to the needs of the users. Sports facilities are placed near the resident housing and kids play area is placed near the nursing housing. A gym is also placed in the north west block which has visual and spatial connection to the outdoor spaces throughout the site. The resident of this society are doctors and nurses who has a very hectic timetable, so to ease their house hold works we have designed few shop for daily needs close to the entrance of the society.

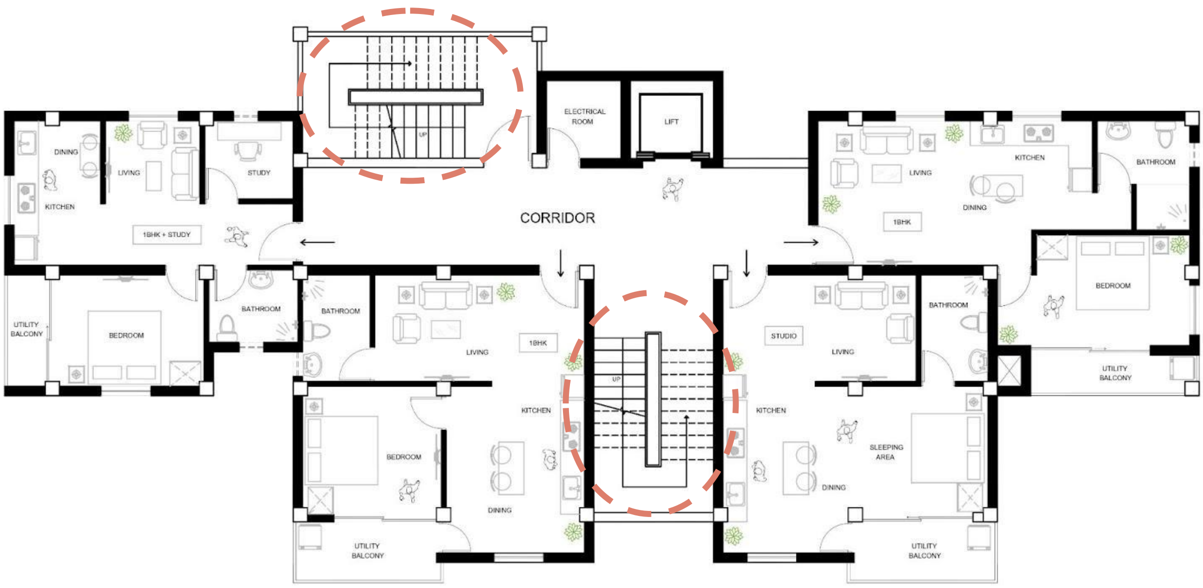
Four units per floor are arranged towards the south side of a central core with no openings towards the core and the units are arranged in such a way that we can provide openings on at least two sides of the units making them double and triple aspect for ventilation and day lighting purposes. These units are majorly oriented towards the south and the core towards the north.

6.4 : Floor Plan

Architectural Design

Air pollution is **a major environmental risk to health**, Breathing clean air can lessen the possibility of heart and respiratory diseases so to improve the indoor air quality we have designed the plan to the building in a way that every space have a opening to allow proper ventilation and also allow sunlight to enter the spaces.which can further enhance the health and wellbeing of the residents.

To maintain proper ventilation and ample amount of daylight to enter in the corridor area we have provided two open staircases which also helps in case of any emergency fire escape. The width of the corridors are kept to be 2.4 meter because it spacious enough to not create any cramped spaces especially in front of the staircase and lift (According to NBC Nepal)



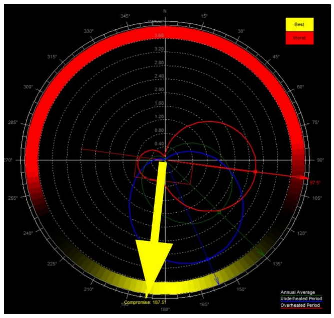
6.5 : Fire exit

1. Energy Performance

Orientation

The blocks are oriented towards South East and South West for a better climatic and site response. This angle would enable the sun to fall on the north part of the building at some point of the day increasing heat gains.

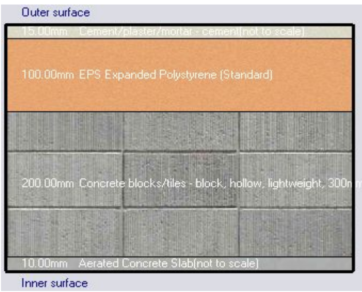
This simulations are performed on typical two floors without typical HVAC system to analyse the design changes.



6.6: Best Orientation

Envelope optimization

The envelope has been optimized by using hollow concrete blocks with XPS insulation for walls which has a U-value of 0.23W/m2K. Slate tiles are used as floor finish to increase solar gains. Underdeck polyurethane insulation is used for roof assembly along with brick bats for waterproofing. The U-value of the roof assembly is 0.22W/m2K.

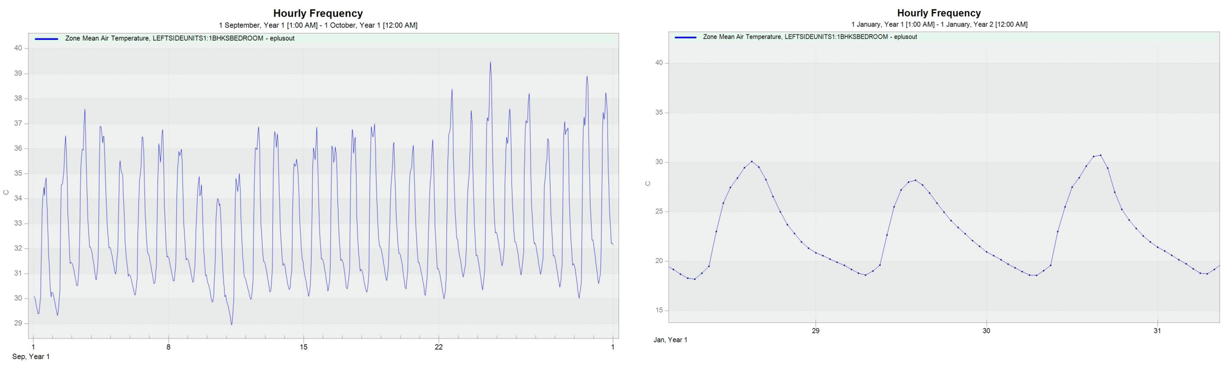


6.7 : Wall Assembly

6.8 : Internal Floor Assembly

6.9 : Roof Assembly

U Value of glass was optimized differently for both north and non north building elevations. It was taken in comparison with ECBC values for SHGC, VLT and U Value.

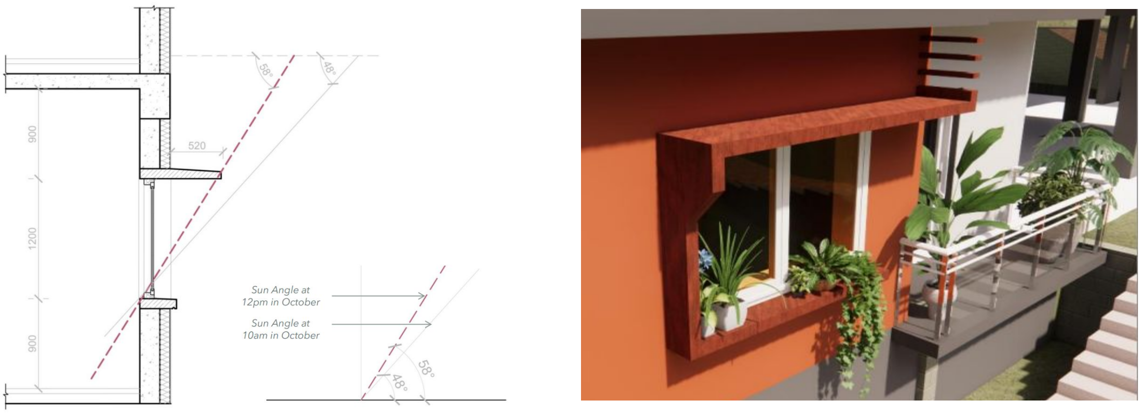


6.10: Graphs showing Temp Control because of Building Envelope

1. Energy Performance

Shading Optimization

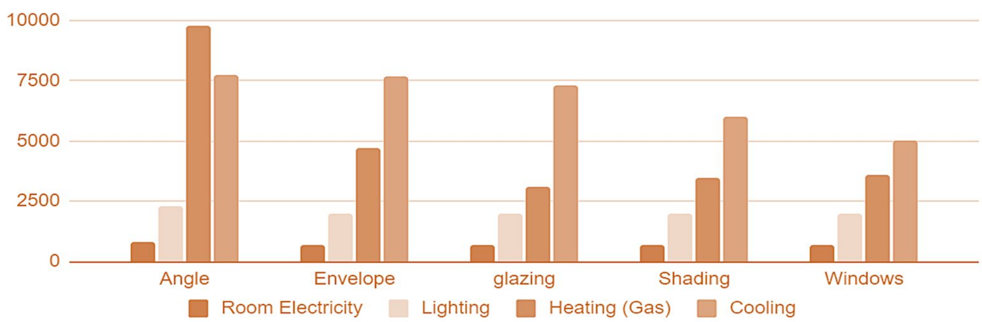
Shading is required in the summers and the cold season starts from the October, so the solar angle of October 1st is taken into consideration for the length of shading such that the summer sun is blocked for most of the time. The shading devices are added based on this calculation and design also to add to the aesthetics of the the facade.



6.11 : Shading

Windows

The windows on southwest and southeast facade are maintained at a window to wall ratio of 30% to increase the heat gains from direct sunlight and the windows on northeast and northwest are reduced to 20% to reduce heat losses.



6.12 : Comparison of different design changes on a typical two floor block

	Basecase	Optimized
Room Electricity (kWh)	808.55	680.08
Lighting (kWh)	2286.40	2002.26
Heating (Gas) (kWh)	9807.34	3598.40
Cooling (Electricity) (kWh)	7715.94	4994.25

The energy consumption has been reduced considerably by these measures. In this simulation we can see the EPI has been reduced from 81 kWh/m2 to almost 43 kWh/m2

1. Energy Performance

Glazing

This allows much daylight into the building without much heat losses. This glazing option lets optimum daylight into the building with a U-value that doesn't let much heat losses. From above table we can see considerable change in Solar Heat Gains through Externa Windows by **1,13,005 KWh.**

Glazing (Optimized)	
Dimension	6 x13 MM
U-Value	2.66 W/m2K
SHGC	0.7
VLT	0.78
Solar Transmission	0.6
Solar Gains / Year	129944 KWh

Glazing (Base Case)	
Dimension	6X13 MM
U-Value	5.894 W/m2K
SHGC	0.861
VLT	0.85
Solar Transmission	0.837
Solar Gains / Year	16939 KWh

Table 6.1 - Glazing optimized and base case

Target Energy Performance Index

Conditions as per GRIHA (Nationally Accepted Benchmark)

- ❖ Climate-Composite
- ❖ Building type- Residential building
- ❖ Operational for 12 hours and 7 days a week.
- ❖ Total number of working hours in a day = 12 hours
- ❖ Total number of working days = 7 days

The site lies in Kathmandu which falls in "**Temperate Climate with Cold and Dry Winter & Warm Summer**" according to the Koppen-Geiger Climate Classification. Our goal is to achieve less than or equal to 50% reduction in the EPI.

Target Energy Performance Index(EPI)< 40.75 kWh/sqm per year

EPI = Appliances load + Laptop load + Lighting load + HVAC component Electric Load + Miscellaneous load (Pump load + Others)

= 1.8 + 1.5 +2.69 + 7.23 + 2

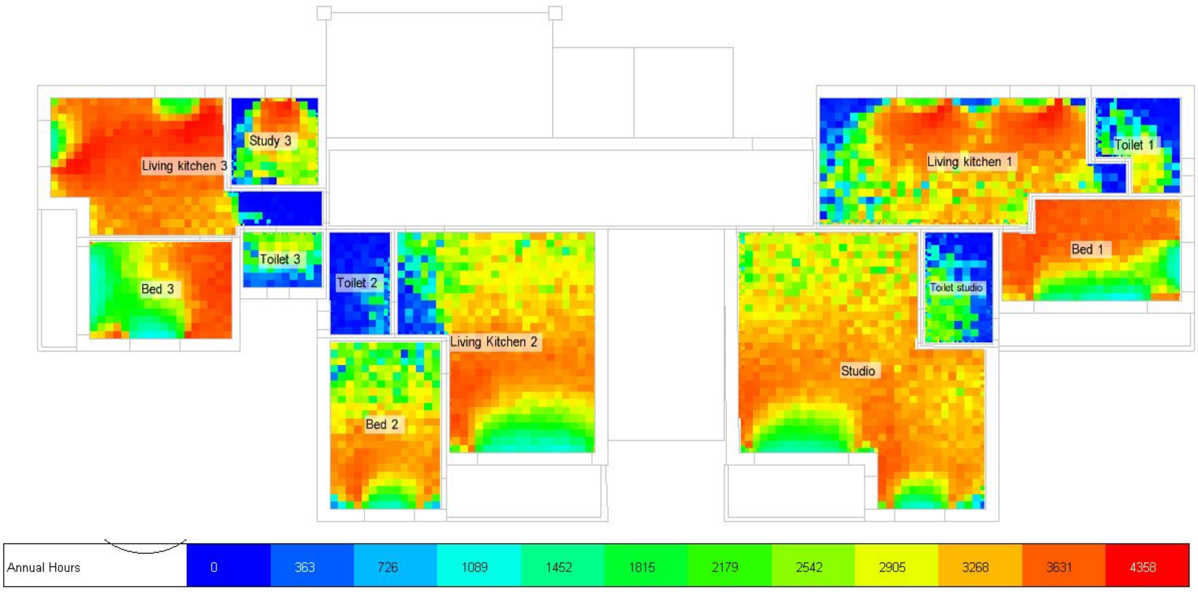
= 15.22 kwh/m²/year

Daylighting

The simulation shows the Useful Daylight Illuminance analysis of a typical floor which excludes any times when there is inadequate natural daylight or excessive direct sunlight which would give rise to a risk of glare. The thresholds are taken as 100 lux and 2000 lux based on GRIHA manual. Except for the toilets most spaces have a UDI area range above 70% which exceeds the daylighting requirements based on GRIHA.

Zone	UDI Area in Range (m2)	UDI Area in Range (%)
Living Kitchen 1	18.5	81.7
Toilet 1	1.9	42.1
Toilet Studio	1.8	36.2
Bed 1	9.9	86
Studio	33.6	94.8
Bed 3	7	74.9
Toilet 2	0.2	5.1
Living Kitchen 2	20.8	82.8
Toilet 3	1.7	57
Living Kitchen 3	15.1	86.8
Study 3	3.7	72.6
Bed 2	10.9	86.6
TOTAL	**125.6**	80.1

Table no 6.17 -UDI values per zone



6.22 : Daylighting assembly in Design Builder

1. Energy Performance

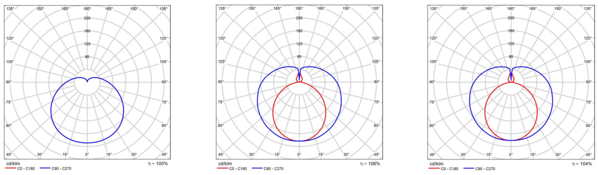
Artificial Lighting

Artificial lighting is an important segment to focus upon in order to design net-zero energy building. We have aimed to use artificial lighting to reach the optimum lux level for respective rooms as per IS 3646 standards and also to reduce the energy consumption as much as we can.

The number of luminaires used has been calculated using the formula:

$$E = (\Phi \times n \times N \times UF \times LLF) / A$$

P	12.0 W	16.0 W	25.0 W
Φ_{Lamp}	910 lm	2500 lm	3700 lm
$\Phi_{Luminaire}$	909 lm	2641 lm	3858 lm
η	99.91 %	105.65 %	104.27 %
Luminous efficacy	75.8 lm/W	165.1 lm/W	154.3 lm/W
CCT	3000 K	3000 K	3000 K
CRI	100	100	100



Polar LDC

table 6.2Product details

The simulations has been performed in the ***DIALUX EVO Software***

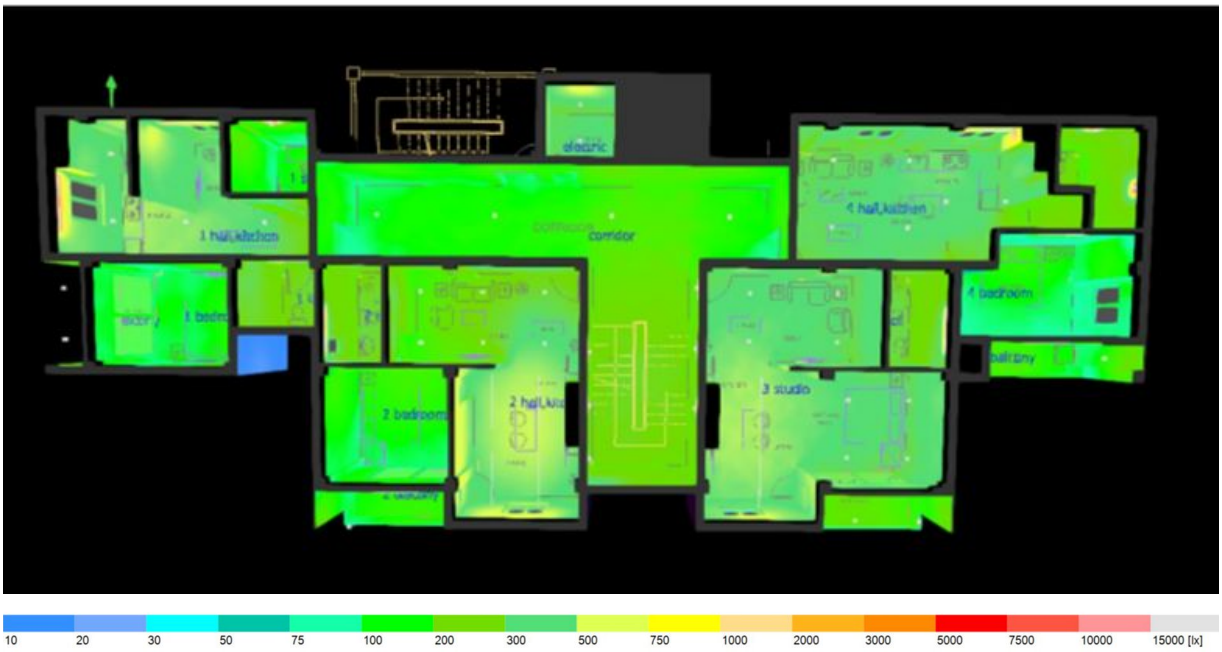


Fig 6.13: Artificial lighting simulations

Energy Performance

	Space	Area	Interior colour scheme	Led light	No. of bulbs	Lighting power density	Ē (Target)	Total Power (W)	Hours Used	Energy per day (KW/h)
1 BHK + STUDY	Living room, kitchen	19.55 m²	Light	12w 25w	4 2	5.01 W/m²	357 lx (≥ 300 lx)	98	8	0.784
	Toilet	3.87 m²	Light	16W	1	4.13 W/m²	123 lx (≥ 100 lx)	16	4	0.064
	Bedroom	10.29 m²	Light	16W	1	1.55 W/m²	123 lx (≥ 100 lx)	16	7	0.112
	Study room	4.18 m²	Light	12W	1	2.87 W/m²	123 lx (≥ 100 lx)	12	4	0.048
	Balcony	2.67 m²	Light	12W	2	9.00 W/m²	123 lx (≥ 100 lx)	24	1	0.024
STUDIO	Living room, kitchen, bedroom	36.26 m²	Light	12w 25w	8 2	4.03 W/m²	357 lx (≥ 300 lx)	146	8	1.168
	Toilet	4.34 m²	Light	16W	1	3.69 W/m²	263 lx (≥ 200 lx)	16	4	0.064
	Balcony	5.03 m²	Light	12W	2	4.77 W/m²	138 lx (≥ 100 lx)	24	1	0.024
1 BHK (Left unit)	Living room, kitchen	27.74 m²	Light	12w 25w	6 4	6.20 W/m²	364 lx (≥ 300 lx)	172	8	1.376
	Toilet	4.36 m²	Light	16W	1	3.67 W/m²	250 lx (≥ 200 lx)	16	4	0.064
	Bedroom	10.73 m²	Light	16W	1	1.49 W/m²	125 lx (≥ 100 lx)	16	7	0.112
	Balcony	5.03 m²	Light	12W 16W	1 1	5.57 W/m²	125 lx (≥ 100 lx)	28	1	0.028
1 BHK (Right unit)	Living room, kitchen	23.60 m²	Light	12W 25W	6 1	4.11 W/m²	131 lx (≥ 100 lx)	97	8	0.776
	Toilet	5.06 m²	Light	12W	2	4.75 W/m²	208 lx (≥ 200 lx)	24	4	0.096
	Bedroom	11.99 m²	Light	16W	1	1.33 W/m²	106 lx (≥ 100 lx)	16	7	0.112
	Balcony	3.94 m²	Light	12W 16W	1 1	7.11 W/m²	131 lx (≥ 100 lx)	28	1	0.028
CORRIDOR, STAIRCASE		47.97 m²	Light	12W	10	47.97 m²	125 lx (≥ 100 lx)	120	11	1.32
Total										**6.2**

Table 6.3 : Artificial lighting calculation

Φ_{total}	P_{total}	Luminous efficacy
96755 lm	893.0 W	108.3 lm/W

Reflection factors: Ceiling: 70.0 %, Walls: 90.0 %,
Floor: 75.6 %
Light loss factor: 0.80 (fixed)

Total lighting load per floor = 6.2*365 days/280 sqm = 8.08 kWh/m2/year

Energy Performance

Solar Potential

The site receives an ample amount of solar radiation throughout the year, making solar energy a viable option for energy generation. Roof-mounted solar panels are installed on the terrace with a 30° tilt, facing towards the south side. 646 panels have been arranged in building , Gymnasium , roof top of parking area .

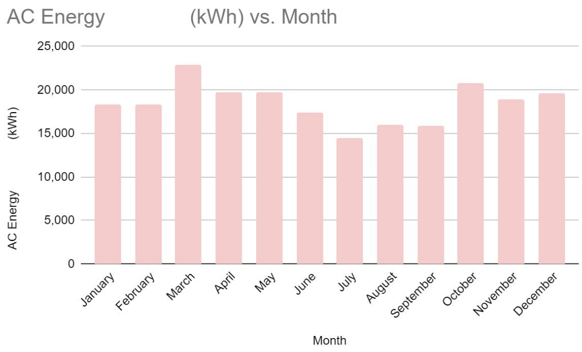


Fig 6.14 :On site solar energy generation graph

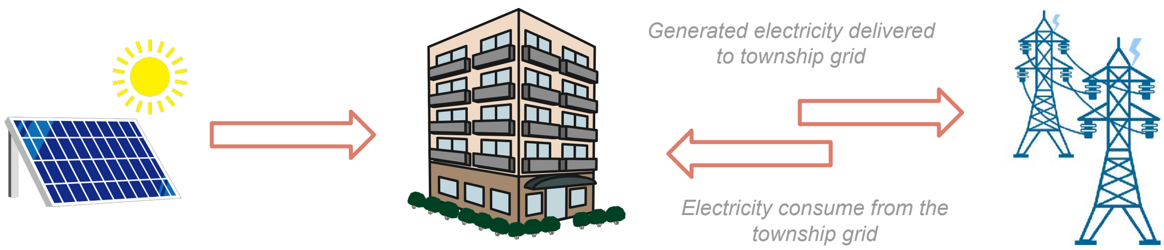
Total Energy Consumed (1,63,575 kWh/yr) < Total Energy Generated (2,22,385 kWh/yr)

The extra electricity(58,810) generated from the renewable panel is delivered to the township grid. Thus, making it a net-zero project.

The generated renewable energy is partially consumed at the cluster level, and the additional generation is fed to the grid. At the cluster level, the additional electricity consumed is directly taken from the township grid. The extra electricity generated from the renewable panel is delivered back to the township grid. Thus, making it a net-zero project.

PV generator capacity	220 kW
Area covered	1100 m2
Numbers of pv module	646
Dimension	1960 x 992 mm
Model efficiency	17.90%
Numbers of PV module	646
Total Yearly Generation	222385 kW/h

Table 6.4: System specifications



Total electricity consumed in a year	1,63,575 kWh/yr
Total electricity generated in a year	2,22,385 kWh/yr
cost of electricity	5.2 INR
cost saving per year	8,50,590 INR

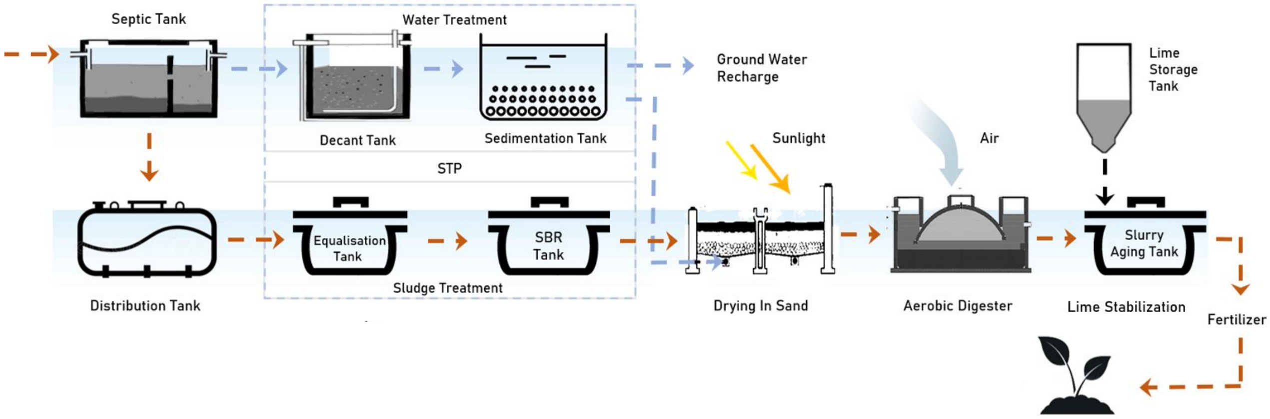
Table 6.5 Solar Photovoltaic modules cost

Cost of total panels	6679086
Maintenance cost of the system	66791
Total cost (INR)	6745877
Annual Energy Savings (kwh)	2,22,385 kWh/yr
Payback Period (in years)	4 year

Table 6.6 PayBack Period Calculation

Engineering and Operations

Solid Waste Management: Sludge Treatment



Waste Segregation

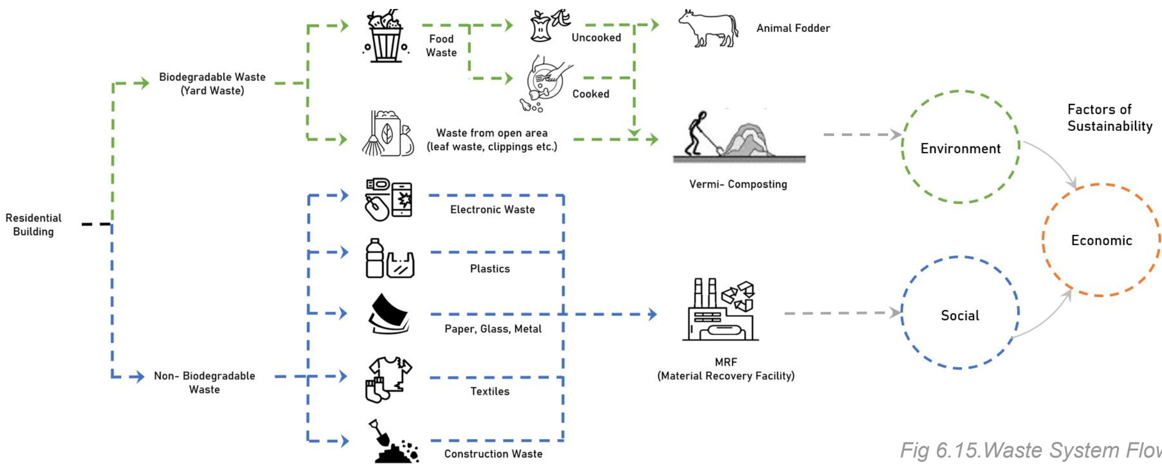
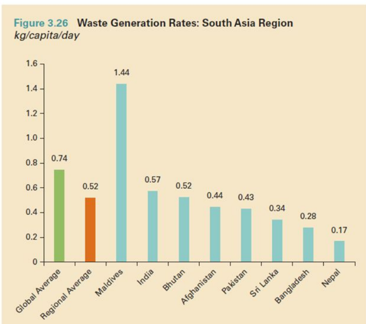
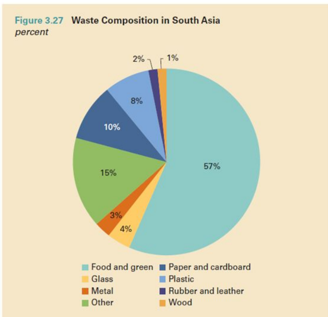


Fig 6.15.Waste System Flowchart





Category	% age	Tons/ Year
Food & Green	57	60.42
Paper & Cardboard	10	10.6
Plastics (HDPE etc.)	8	8
Rubber & Leather	2	2
Metal	3	3
Glass	4	4
Wood	1	1
Others	15	16
Total		**105**

Source: https://openknowledge.worldbank.org/handle/10986/30317

Table:6.7 Waste Generation as per World Bank Report

No. of Residential Units- 120

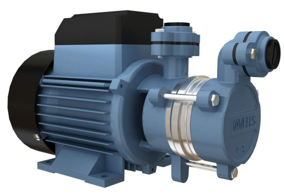
Average occupants per unit- 2

Anticipated Waste Generation- 106 Tons/ Year

Source: https://www.zerowastedesign.org/waste-calculator/

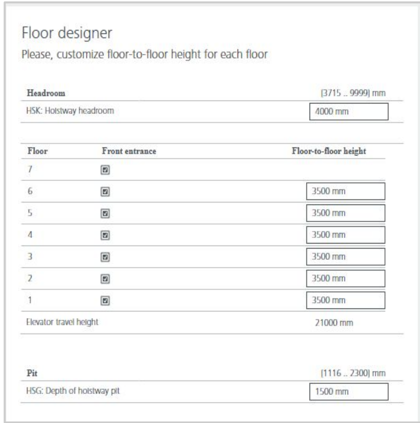
Engineering and Operations

Building Automated System



Product - Havells Self Priming Hi-Flow A-1 Monoblock Pump
Price - 7,250 rs
Power - 0.75 KW
Horse power - 1 HP
Item Dimensions LxWxH - 18.4 x 14 x 32.2 Centimeters

Product - Crompton Centrifugal Deep Well Jet Pumps
Price - 22,500 rs
Power - 0.75 KW
Horse power - 1 HP



Market Price of Schindler Lift is **Rs 5.25 Lakh/ Unit**.

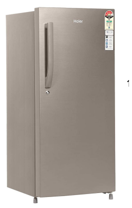
Model	Power		Pipe Size	Total Head in Metre												
				3	6	9	12	15	18	21	24	27	30	32	36	39
	kW	HP	mm	Discharge in Litre Per Hour												
AL2	0.37	0.5	13 x 13	1600	1500	1385	1235	1110	950	800	675	480	270			
A3	0.55	0.75	25 x 25		2000	1900	1750	1600	1425	1250	1050	820	600			
A1	0.75	1.0	25 x 25		2450	2330	2200	2080	1970	1840	1725	1550	1340	1120	825	535

Table 6.8 water pump calculation

Equipments

Type: Ceiling Fan
Motor Speed: 380 RPM
Power Consumption: 26 W
Blade Sweep Size: 1200 mm
Price -₹3,775

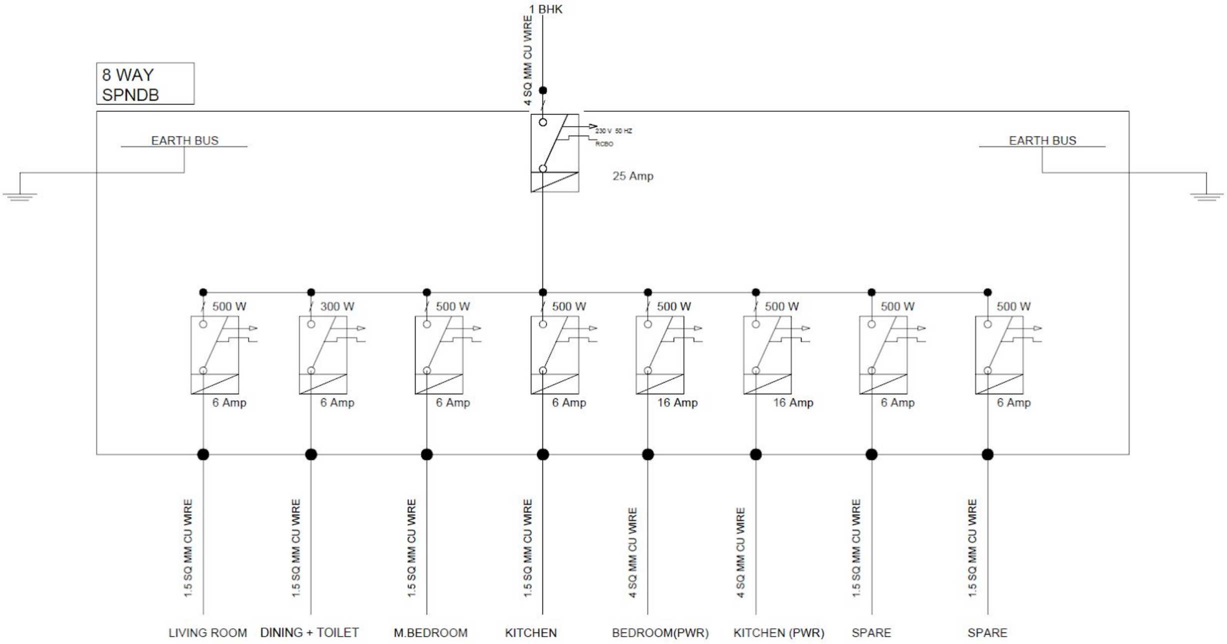
Power Consumption: 15 Watts,
25000 Hours Life,
150mm Cut Out Required
Price-₹1159



Haier 195 L 4 Star Direct Cool Single Door Refrigerator (HED- 20 CFDS, Brushline Silver)
₹18,200

AmazonBasics 81cm (32 inch) HD Ready Smart LED Fire TV AB32E10SS
Power Consumption -60 watts
Price:-₹14,999.00

4. Engineering and Operations

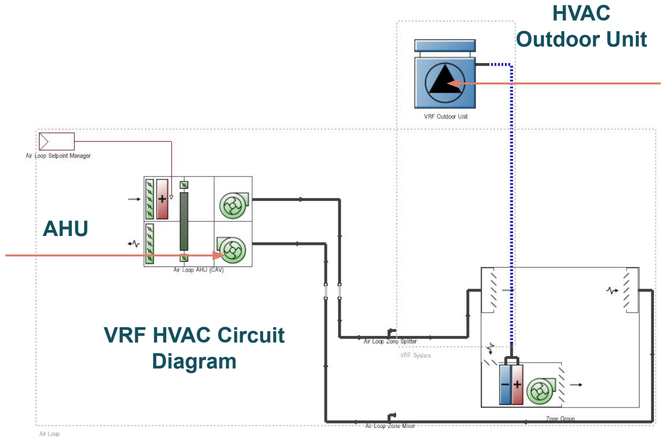


Equipment Optimization

Appliance	Wattage	Duration of use	No's	No. of days	Electricity used
Ceiling fan	26	5	54	200	1404
Lighting- A	12	4	270	365	4730
Lighting- B	25	4	64	365	2336
Lighting- C	16	4	48	365	1121
Refrigerator	130	8	24	365	9110
Washing machine	462	1.5	24	104	1730
Television	60	2	24	365	1050
HVAC	33990	8	1	130	9720
Water Pump	750	1	4	365	1095
Lift	5600	1	1	365	2044
Others	NA	NA	NA	NA	3000
Total					**37340**

Table 6.9 - Equipment Optimization

4. Engineering and Operations



VRF HVAC Circuit Diagram

VRF HVAC SYSTEM

Space Conditioning & Ventilation

Goals for the space cooling and ventilation:

1. Efficient Heating system.
2. Achieve thermal comfort
3. Reduce duct length by planning the space for device effectivity.

Greenheck **Dedicated Outdoor Air Systems (DOAS)** now feature inverter compressors on select RV and RVE models offering **5 to 30 tons PDX cooling capacity**. Inverter compressors provide precise temperature and humidity control and operate at reduced sound levels.

They also help save energy by improving part load efficiency. Inverter compressors typically achieve **15%-20% higher IEER** compared to digital scroll compressors.

Fig 6.16 Dedicated Outdoor Air Systems (DOAS)

HVAC Outdoor System Sizing

As per the ton of refrigeration required for the conditioned space, we compared different system based on efficiency of the system, initial capital cost, low maintenance cost. Finally cost benefit analysis was done for the final selection of the system.

Unit	Space	System Capacity (KW)	System Capacity (W/M2)
Type 1	Living + kitchen	0.92	38.98
	Bedroom	0.62	64.38
	Living + kitchen	0.61	33.03
	Bedroom	0.76	58.21
	Study	0.31	67.71
	Bathroom	0	0
Type 2	Living + kitchen	0.71	59.82
	Bathroom	0	0
	Studio Room	1.33	37.52
	Living + kitchen	0.8	33.95

Table 6.10 - system Capacity

No of Type 1 units = 6

From Design Builder Simulations Data,

Total of Type 1 units

= 3.220+2.860+2.880+2.860+2.90+3.280 **= 18 KW.**

No of Type 2 units = 6

Total of Type 2 units

= 2.840+2.520+2.510+2.510+2.540+2.930 **= 15.85 KW**

Sizing of Type 1 + Type 2 = 18 + 15.85 KW

= 33.85 KW = 9.62 Ton.

Engineering and Operations

HVAC Temperature Control + Ventilation

Summers

According to the adaptive thermal comfort model for mix conditioned area as per NBC

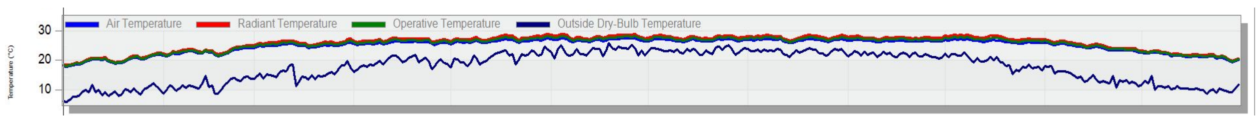
Indoor Operative Temperature
=(0.28*Outdoor Temperature) + 17.87
=(0.28*34)+17.87
=27.39 degree Celsius

Winters

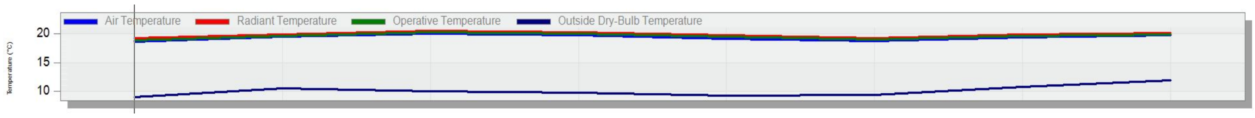
According to the adaptive thermal comfort model for mix conditioned area as per NBC

Indoor Operative Temperature
=(0.28*Outdoor Temperature) + 17.87
=(0.28*04)+17.87
=18.97 degree Celsius

Temperatures, Heat Gains and Energy Consumption - Sdi - Subzero, Building 1
1 Jan - 31 Dec, Daily



Temperatures, Heat Gains and Energy Consumption - Sdi - Subzero, Building 1
24 Dec - 31 Dec, Daily



The **solar gain, internal loads** (lighting and equipment loads) and the occupancy loads are high enough to put the winter in a temperature range of 18-22 degrees celsius.During the winter the operative temperatures in the naturally ventilated area come in the range of 18 to 24 degrees celsius which can easily be taken care of with **clothing factor of 1**.

As our Building is in cold climate zone, so looking at the coldest time of winters we can see that we are able to attain temp of **18-22 degree celsius**, which may not lie in comfort zone according to standards but as according to **Adaptive thermal comfort model** we can increase indoor temp by **6 degree** and achieve rest comfort through **clothing**.

End Uses	Electricity Consumption
Heating	8450 KWh
Fans	1270 KWh

Reduction due to Inverter Technology Compressor

Table 6.11 - HVAC consumption

Engineering and Operations

Electrical Layout

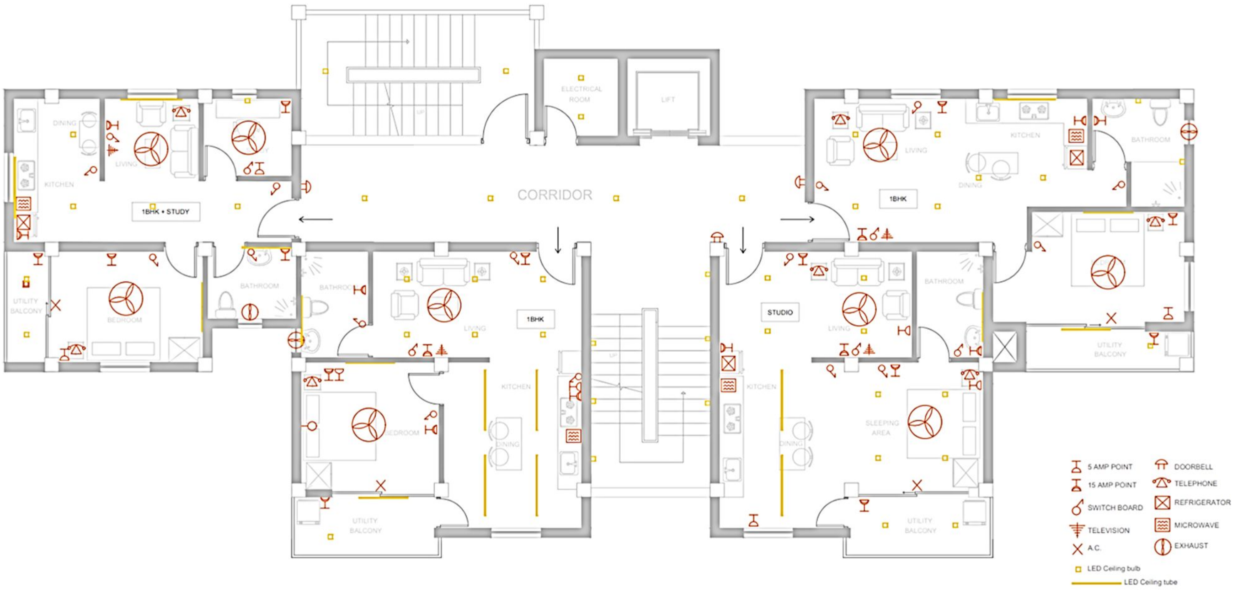


Fig 6.17 Electrical Layout

Plumbing Layout

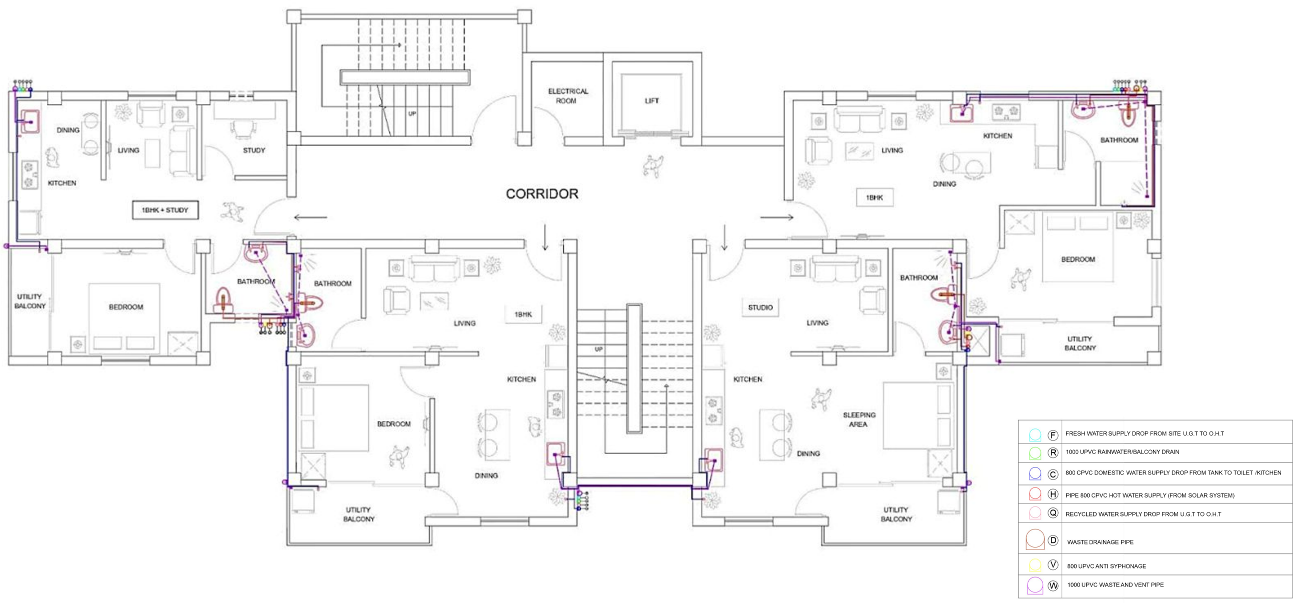


Fig 6.18 Plumbing Layout

Water Performance

Water is being used effectively on the site using the measures that are given below

Low flow fixtures

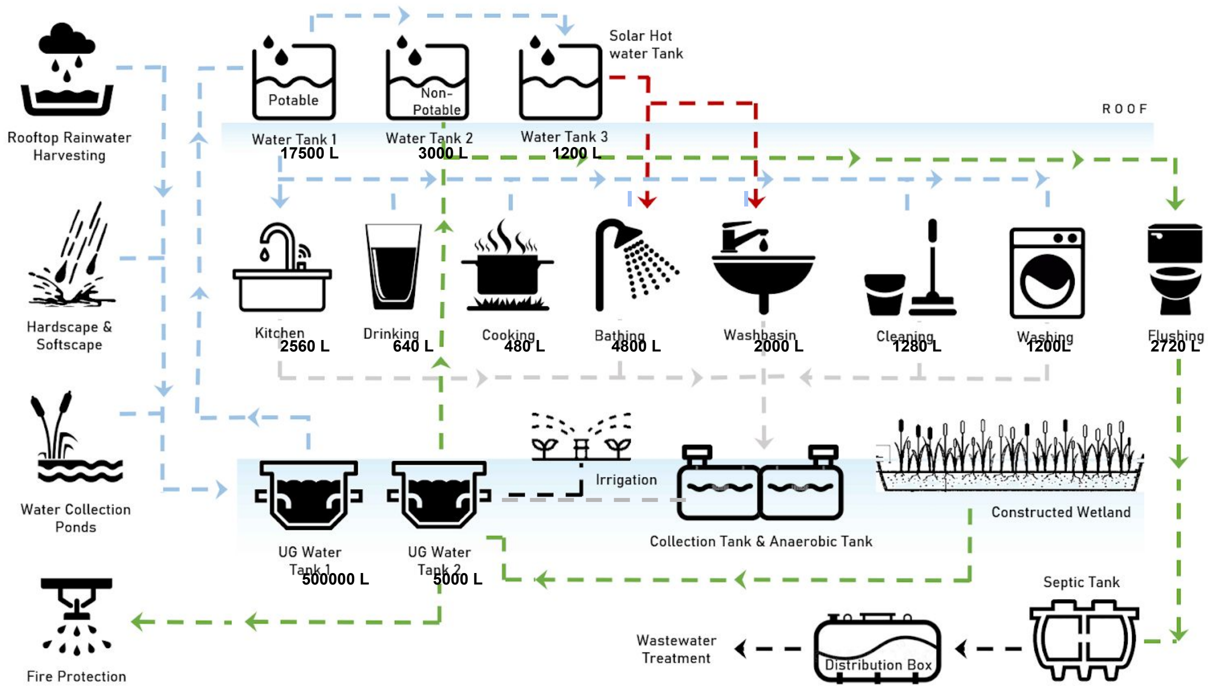
Low flow fixtures which uses the high pressure technique are used to create same water pressure and uses less water. These fixtures helped us to reduce the water requirement from 135 lit/person/day to 66.6 lit/person/day, which is a 50% reduction in usage.

Rain water harvesting

Water collected from rain is used majorly for the daily uses of the occupants.Rain water is filtered and then sent to the use.Rain water is also harvested from the hardscape and softscape areas.65% of the fresh water needs are covered by rain water harvesting.

Water treatment

Water treatment plants are equipped on the site to treat and reuse the wastewater generated on the site.Grey water is treated using a 20 Kld aerobic water treatment plant. This treatment helps us reduce the fresh water demand by 20%. Grey water is being used for toilet flushing and for irrigation needs on the site.



6.19 : Water Cycle

Water Performance

Category	Annual Water Consumption (in Litres)
LPD/ Person	66.6
No. of units	120
No. of occupants/ unit	2
No. of occupants	240
Total water required/day	16000
Total	**5840000**

Table 6.12- water calculation per annum

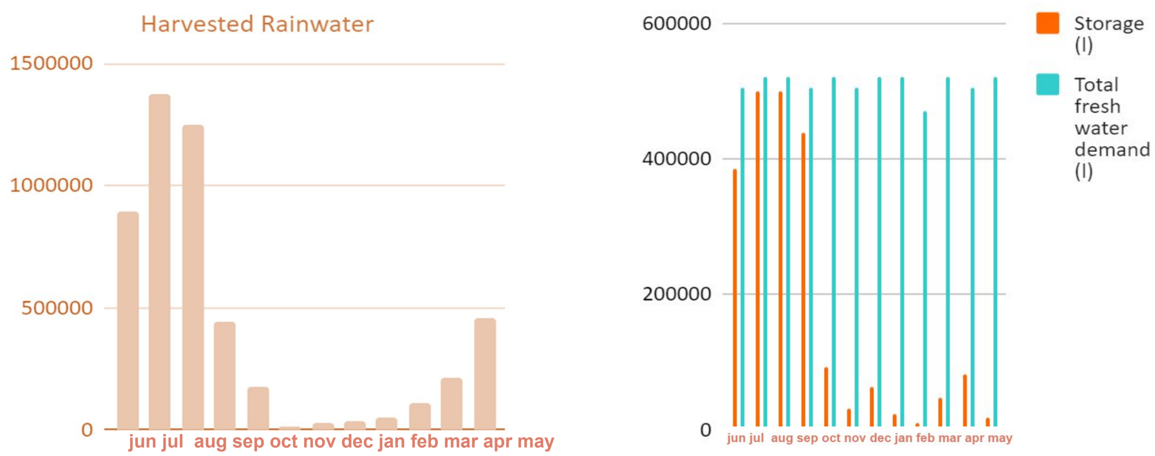
Total annual consumption : 5840 kl
Water harvested from rain : 3562 kl
Water taken from municipality : 2278 kl

Rain water harvesting

Water harvested from rain contributes to **65**% of the freshwater usage on the site. No other source of water is used in the site from may to october months.for the other six months water is taken from municipal water supply, that is only 35% of total freshwater demand.

Water harvesting Sources	Area(m2)	Runoff coeff
Roof Surfaces	1440	0.95
Hardscape areas	2228	0.7
Softscape areas	3032	0.3
Effective Catchment Area	**3837.2**	

6.13 : Catchment area calculations



6.20 : Water calculations for rainwater harvesting

Water Performance

Month	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Harvested Water (kl)	890	1374	1251	441	177	12	31	35	54	111	215	457
Municipality water Supply (kl)	0	0	0	0	0	150	380	380	315	315	175	0
Primary Demand (kl)	480	496	496	480	496	480	496	496	448	496	480	496
Grey water generated (kl)	300	310	310	300	310	300	310	310	280	310	300	310
Irrigation Water demand (kl)	36	38	38	91	94	182	188	188	170	188	91	94
Grey water flushing(kl)	82	84	84	82	84	82	84	84	76	84	82	84
Unused Grey Water (kl)	182	188	188	127	132	36	38	38	34	38	127	132
Total fresh water demand (kl)	398	412	412	398	412	398	412	412	372	412	398	412

Table 6.14- water calculation

Low flow fixture specifications

Fixtures with flow restrictors are used to reduce the water demand. These restrictors save upto 80% water without compromising on the flow. Air showers are used for showers. Air is mixed with water to make shower drops lighter but voluminous. This helps save 30% of water without compromising on the showering experience.Using these tech we have reduced the water demand by 50% when compared to standard case. Fixtures used in the project are shown below.

End Use	Percent use	Use in LPD	Greywater in LPD	Blackwater in LPD
Bathing	30%	4800	4,800	
Washing	20%	3200	3,200	
Cleaning house	8%	1280	1,280	
Washing Utensil	16%	2560	2,560	
Others	2%	320	160	160
Drinking	4%	640		640
Cooking	3%	480		480
Toilet Flushing	17%	2720		2,720
Total		16000	12,000	4,000

6.15: Water calculations as per activity

Water Performance

Water Tank Sizing

For rainwater harvesting one tank of 5 lakh litres is installed underground in the site. Water will enter the tanks after filtration of rainwater is completed later the water goes for daily use by the residents.

Overhead water tanks are sized to supply the water required for almost one and a half day. We are using one tank of 2000L and a tank of 1500L which makes to a total of 3500L of storage overhead.placement of these tanks in on mumty of the staircase.

Grey water tank of 3750L is provided to cater the needs of the whole site. The water enter into tank after the water treatment is completed and goes for the flushing and irrigation needs of the occupants.

Buildings	No of units	No of residents	Fresh water(LTRS)	Grey water(LTRS)
Per Block	24	48	2656	544

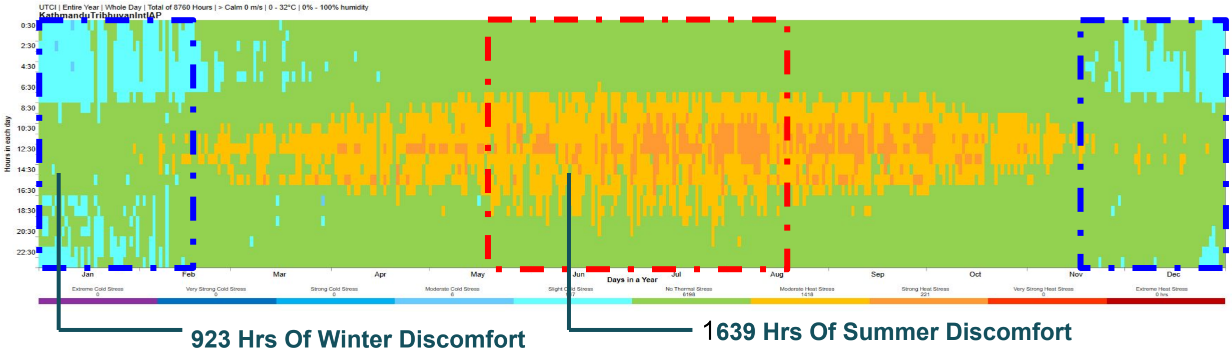
6.16:Rainwater calculations

Water Treatment Plants

Grey water is treated using aerobic treatment, in which the water is collected and initially insoluble material is separated from the wastewater then water flows to a biological treatment plant in which air is flown into the water so that the bacteria eats up the impurities in the water.This has a very high efficiency of 95%.

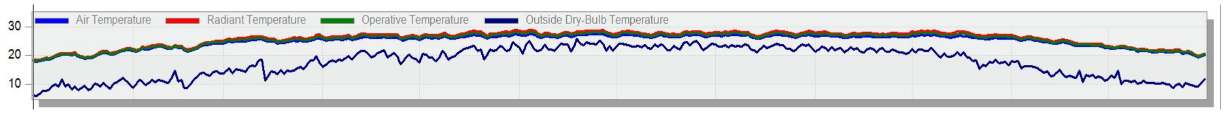
Then the ultrafiltration is done to the water with microscopic pores to prevent viruses.Ultraviolet lamps are used for extra protection against pathogens. Chlorination is done afterwards finally the water is sent into the storage tank. This plant reduces the freshwater demand by **20**%.

Health and Wellbeing



Yearly Comfort Hours

The above data shows that thermal comfort is achieved for 6196 Hrs (70%) out of 8760 Hrs without any thermal control measures. For, discomfort hours the VRF system gets activated.



Yearly Temperature Data

With the help of VRF system, thermal comfort is achieved for discomfort hours, the design conditions for heating and cooling are given in the adjoining table.

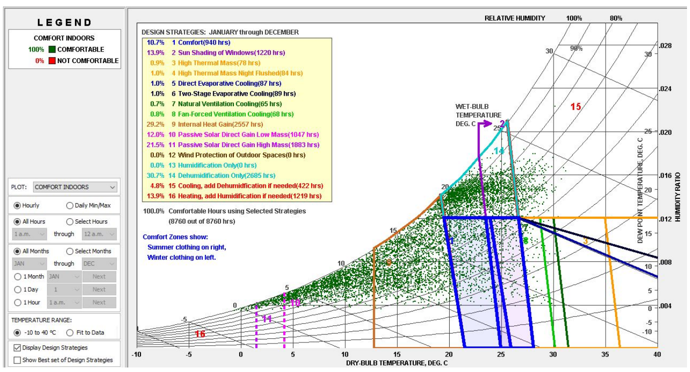


Fig 6.21 Psychrometric Chart

Heating Design Conditions

Coldest month:	January
Coldest week:	1/ 4 - 1/10
Typical winter week:	12/ 6 - 12/12
Annual HDD for 18 °C is:	727
Design temperature 0.04 %:	2.6 °C

Cooling Design Conditions

Hottest month:	July
Hottest week:	7/24 - 7/30
Typical summer week:	5/22 - 5/28
Annual CDD for 10 °C is:	3,099
Design temperature 99.6 %:	29.8 °C

Health and Wellbeing

Landscape Strategies

Functional Criteria: Block noise, clean the air, control wind and provide safety and shade to vehicles and pedestrians, and habitat for urban wildlife.

Ecological Criteria: Fitting for the soil and climate of the city, resistant to wind, pests, diseases and air pollution.

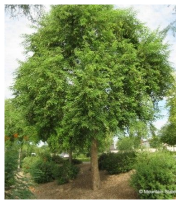
Socio-Economic Criteria: Cost, care, longevity, and reflection of urban identity.

Structural Criteria: Fast development, pruning-ability, strong root system, tree shadow, flowering and fruiting, future size, and diameter.


Rhododendrons


Jacaranda Mimosifolia

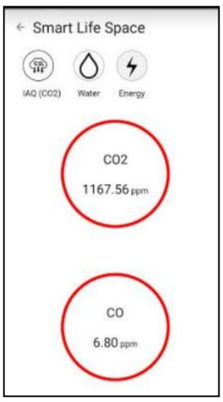

Deodar cedar

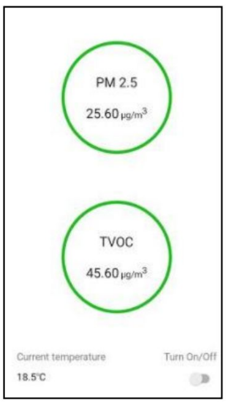

Dalbergia sissoo

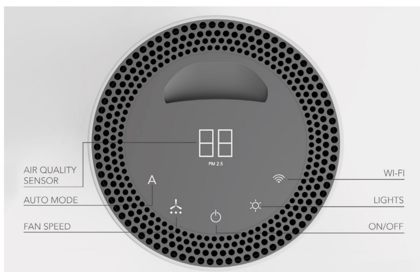
6.23 : Landscape Strategies

Air Quality

The air is purified and air quality is monitored with the help of air purifier, which gives feedback on an app regarding the PM 2.5, PM 10 values in the air.







Air Purifier

App UI for Air Quality Monitoring

Health and Wellbeing

For Water Storage instead of Plastic or Sintex Tanks, RCC tanks are chosen as this can also provide structural stability and protection against plastic deterioration. Also RCC Tanks perform better in case of earthquake.

Sintex Polyethylene Tank

Concrete tank

Encourage use of materials with low emissions so as to reduce adverse health impacts on building occupants. Low VOC paints are those that contain less “Volatile Organic Compounds” (VOC) or VOC Solvents than traditional coatings.

The VOC solvents act to slow the initial drying by maintaining a “wet-edge” which gives a longer time to work with the product. The Griha ratings give VOC content limits for amount of VOC which can be present in gm/ litre for coatings, paints and adhesives.

Technical Specifications (21°C (70°F))

Solids by Volume: 35% (± 1%)
Solids by Weight: 53% (± 1%)

Volatile Organic Compounds (VOCs)*
According to ASTM D3960-05: < 1 g/L
**No emission is detectable by the United States Environmental Protection Agency (USEPA) Test Method 24.*
Colorants added to base paints may increase the VOC significantly depending on colour choice. However PPG offers a low VOC line of colorants which, if used even at maximum tint load in any colour, contributes less than 8 g/L of VOC to the final tinted product.
Canadian regulation: < 100 g/L

Available Colours
97500 White
Can be tinted to light pastel colours, max 4 oz. of colourant per 3.78 L.

Gloss Level Flat finish
• Gloss @ 60°: 0 – 5%
• Sheen @ 85°: 0 – 5%

Practical Coverage
39.5 - 46.5 sq. metres (425 - 500 sq. ft.) per 3.78 litres
10 - 12 sq. metres per litre
Coverage figures do not include loss due to surface irregularities and porosity or material losses due to application method or mixing.

Resin Type
• Vinyl Acrylic

Viscosity Ready to use (98 ± 5 Krebs Units)
Manufacturing specification, working viscosity may vary

Flammability Non Flammable
Flash Point Not applicable

Film Thickness requirements
• Wet: 81 to 96 μm
3.2 to 3.8 mils
• Dry: 29 to 34 μm
1.1 to 1.3 mil

Drying Time @ 25°C/77°F - 50% Relative Humidity
Touch dry: 30 minutes
To recoat: Minimum 4 hours
Before cleaning: 14 days
Full curing: 14 days
When relative humidity is higher than 50%, double the required time.
Drying times listed may vary depending on temperature, humidity, film build, colour, and air movement.

Technical Data Source: 97500

ULTRA ZERO VOC* INTERIOR LATEX PAINT 97500

Paint applications	VOC limits (grams of VOC per litre)	
Interior coatings	Flat	<50
	Non-flat	<150
Exterior coatings	Flat	<200
	Non-flat	<100
Anti corrosive	Gloss/ semi gloss/ flat	<250

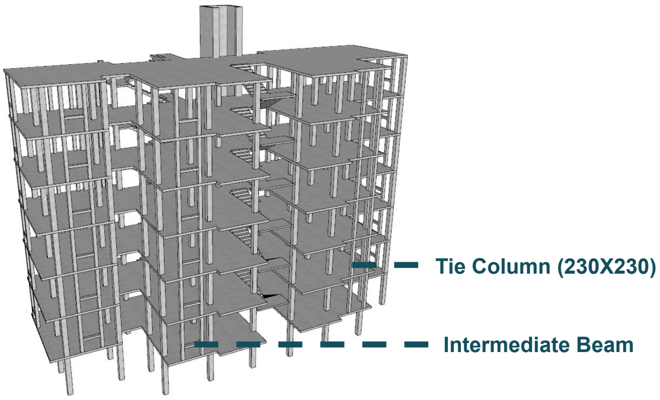
Architectural adhesive application	VOC content limit (g of VOC/litre)
Wood Flooring	100
Industrial/rubber flooring	60
Ceramic tile	65
Structural glazing	100
Multi-purpose construction	70
Sub-floor	50
Wall boards/panel	50
PVC welding	285
Adhesive primer for plastic	250
Structural wood member	140
Sub-specific use metal to metal	30
Wood	30
Fibre glass	80
Plastic foams/porous materials (except wood)	50

VOCs Content

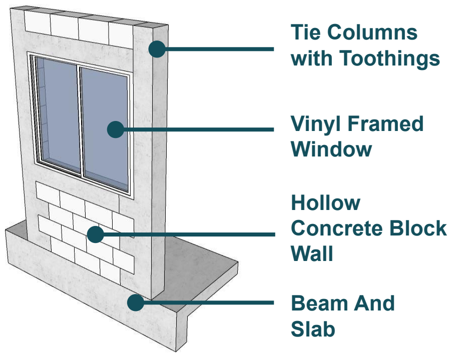
Resilience

Disaster Resiliency

A confined masonry structure consisting of tie columns and intermediate beams has been chosen to minimize the structural damage in case of earthquake as Kathmandu lies in a frequent earthquake zone.

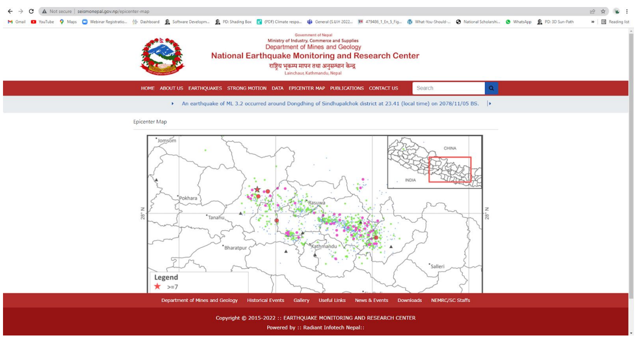


6.24 Structural model



6.25 Wall and structure assembly

Furthermore Reinforced Concrete Block Wall Masonry has been provided to minimize cosmetic damage to the building in case of an earthquake.



6.26 Interactive application

6.27 Reinforced hollow concrete wall

An interactive application interface will be designed which will be connected to the nepal seismological website and alert residents regarding a disaster before hand to minimize the accidents.

Resilience

Bioswales have been incorporated to add resiliency in Landscape, these help in channelizing rainwater as well as clean water by settling down the unwanted dust and particulate from the rain water.

Making use of multiple sources of water and hence not being dependent on only one single source of supply. In terms of uncertainty where one form of supply fails, such as the erratic grid supply provisions such as bio technological plants, filtration systems and rainwater harvesting can be used to maintain the smooth operation of the site.

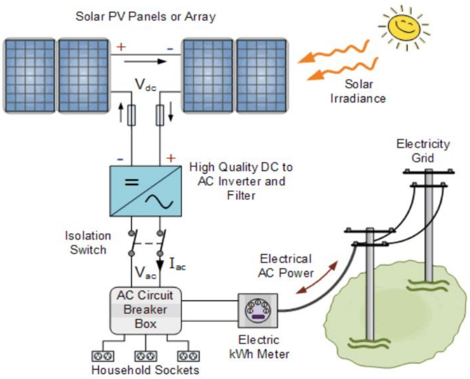
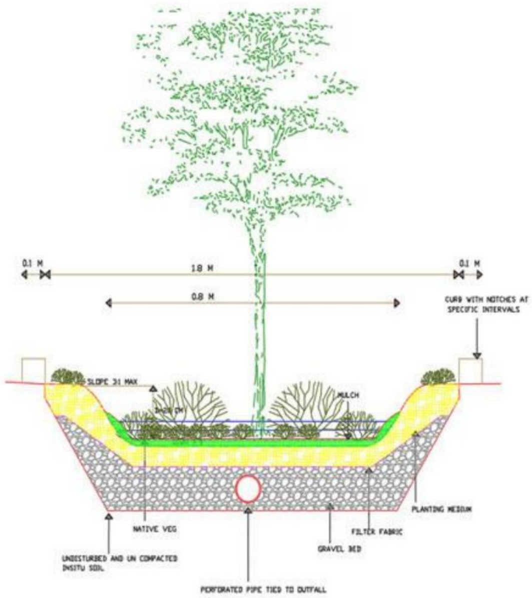
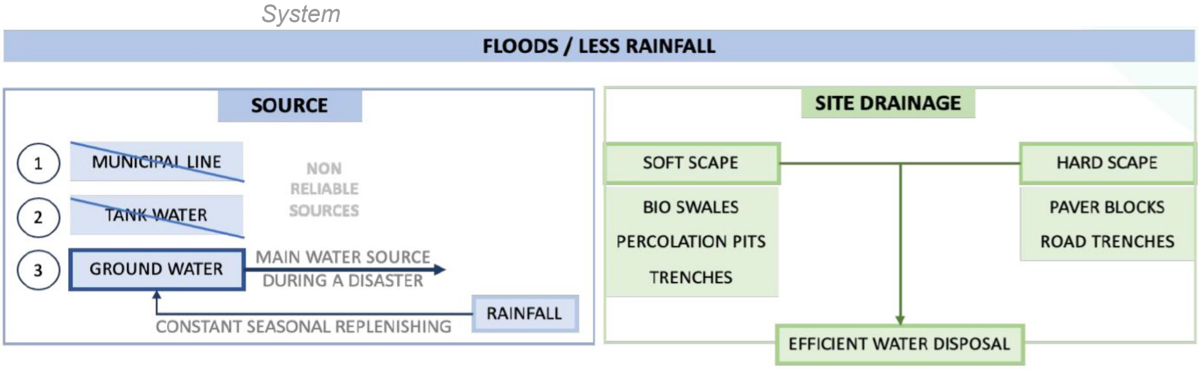


Fig 6.28 Hybrid Grid Connected Solar PV System



6.29 Bioswales



By using Solar PVS we have managed to create alternate sources of electricity during a power cut adding to the resilience of our structure.

Affordability

The main intent was to select the best material providing best value to its cost and is locally available .Hollow concrete block is easily available near our site. It is an energy efficient material and is very affordable as compared to clay bricks. They also provide good insulation to the building.

Item	Cost per CUM (INR)	Cost per Cu ft. (INR)
Concrete block	3514	99.5
9” Brick wall	5633	159.52

Table - Hollow Concrete blocks and clay bricks price comparison

6.30 : Hollow concrete Block

The energy consumption needs has been met by installing pv panels. There will be initial investment required for installing pv panels but it will generate enough energy to overcome the pv panel installation cost and it will also stop all future expenditures on electricity.

Total electricity consumed in a year	1,63,575 kWh/yr
Total electricity generated in a year	2,22,385 kWh/yr
cost of electricity	7.5
cost saving per year	1226812

Table 6.5- Annual electricity consumption and PV panel annual electricity generation

The water consumption has been minimised by installing low flow fixtures and rainwater harvesting plant has been installed on roof which is further stored in an underground storage for further use. Also the grey water treatment plant is installed to reuse for irrigation purpose and flushing.

Cost of total panels	6679086
Maintenance cost of the system	66791
Total cost (INR)	6745877
Annual Energy Savings (kwh)	2,22,385 kWh/yr
Payback Period (in years)	4 year

Table 6.6- Payback period Calculation

Affordability

The workers working on site are mostly local people and their shifts are scheduled properly. This will reduce the cost of travelling and accommodation of workers coming from outside areas. This will cut labour cost expenses greatly.

Every component of the house is prelanned and rationalization of the design procedure is done for reducing the size of the component in the building. This will avoid wastage of materials due to demolition of the unplanned components of the building.

Timber: Nepal is having lush green forests and hardwood trees so timber is easily available near the site. The skilled labour for timber is also locally available. Sal,devadar, pine, teak, Alder etc are some trees found in Nepal.

6.31 Timber

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Slate: As the most affordable natural stone flooring option, slate tile flooring is one of the ideal choices for your Bloomington or Minneapolis home if you're seeking a Floor Covering that is durable, beautiful, and unique .While slate is a very hard flooring material, it is also quite brittle, so if something heavy is dropped on it, the tile is likely to break.Slate is resistant to chemical attack.

6.32 : Slate

7. Scalability & Market Potential

Scalability

Scalability can be determined in terms of number of users, energy consumption, community spaces.

The scalability in no. of doctors and nurses living in the housing blocks can potentially increase in future. For this increase in number of residents new housing blocks can be constructed on site and also the floor levels of existing housing blocks can be increased. As the no. of occupants will increase the no. of vehicles will also and for that the existing parking can be increased around the periphery of the site.

The scalability in energy consumption can be solved by installing solar panels on the facade of the housing blocks receiving the maximum amount of sunlight throughout the day.

The scalability can be seen in community spaces like green spaces, gymnasium, commercial shops related. These can be initially resolved by constructing new levels on existing community spaces but on further increase in demand it should be taken care by authorities.

Market Potential

In housing block there are 120 one BHK with approximately 240 people staying in them .Due to more people in housing block we will set up a commercial complex including vegetable shops, grocery shops, restaurant and cafe, that people can easily access .The authorities can charge some percentage of revenue generated.

Also the market potential can be realised in the form of general public. There will be lot of patients, doctors and nurses,staff, students , security guards, commercial shops etc. This as a whole will help to increase business and employment opportunities. It will also increase transportation opportunities like auto, cabs, buses etc.

The doctors and nurses are usually very health conscious. So there is market potential in setting up gymnasium. This will create business opportunities in supply of gym equipments, supplements and also employment opportunities for gym trainers and other health related things like yoga, aerobics, zumba etc.

8. Innovation

Modular Construction

- Modular Construction is a newer member of the construction technology trends. It refers to the offsite prefabrication of 'modules' or structures.
- Modular Construction is time-saving as the site clearance and construction can be done at the same time. This also helps tackle construction delays arising from weather, geography, and other onsite factors.
- It reduces the carbon emissions as the number of onsite constructions is lowered.
- Also, the construction wastage is significantly reduced as the offsite subcontractors can sell the remaining modules to other clients.
- It is also worth remembering that offsite construction is highly suited for locations that prefer remote work. This is mainly due to various technical difficulties at the construction site.
- It does all these without compromising the quality of the structures. In fact, it can be as good as traditional buildings.

Advanced Window Control System

This energy efficient system makes use of microprocessors and sensors along with insulated windows. This helps to automatically adjust the shading based on the sunlight and the time of the day. This provides proper comfort, lighting, saves energy and money.

6.33 : Advanced window control system

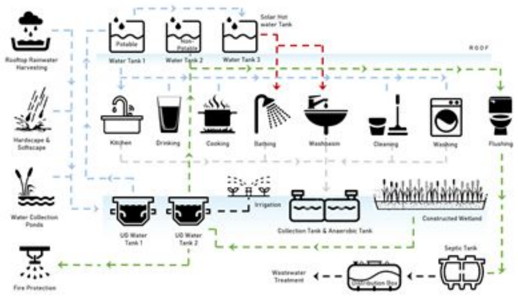
Self Healing Roads

- Self healing roads is a new and modern concept of roads which is started.
- Self healing roads are newest technology of building of roads , its efficient and long lasting.
- It cuts off the upto 50% damage repair costs as its self healing concrete and total maintenance cost .
- 16% lower emissions and 32% lower costs compared to a conventional road over the lifecycle.
- "Bio-based self-healing concrete is a very new material." says stanford.

9. Communication

All the information is of prescribed length and is according to the structure of deliverables. For the purpose of communication, all the information is mentioned in easy to understand way, and more importantly visuals are also added with them for better understanding.

- ❖ For the audience to understand the strategies we have used in our design, different photos, illustrative diagrams, graphs, bar charts, tables, etc has been used.
- ❖ In design documentation more focus is given on visuals, Plans have been rendered which would easily give the basic idea of materials used, in some plans shadow patterns are also mentioned, in section we have mentioned human figures which would be helpful in giving the experience of heights to the audience.
- ❖ Flow chart diagrams has been used for better understanding of the proper treatment of water and other resources.



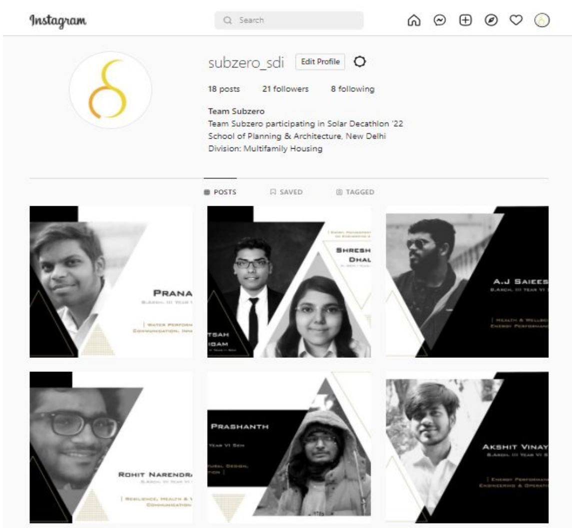
6.34 : Flow Charts

6.35 Rendered Plans

Engagement with the public using media such as print, digital, and social, is initiated through Instagram. With this we can be more engaged with the audience and about their views.

On the completion of final report, we can further proceed with printing of the research papers which would be available for the future reference.

In context of digital engagement, we can proceed with creating an mp4 file format, and uploading it on social media platform like youtube.



6.36 : Social Media