renouveau

Division - Educational Building

Final Design Report - April 2022

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5. EXECUTIVE SUMMARY

Renouveau is a multidisciplinary team of ten architecture and two BEM students from School of Planning & Architecture, New Delhi. Our team is guided by professionals and advisors from diverse backgrounds. Our team has worked together harmoniously, with everybody providing their unique inputs throughout the process.

We began by coming together as a team and working on different iterations, which were later consolidated to create a single comprehensive design reflective of each individual's ideologies. The final iteration was then developed further according to the contest goals. After finalising the design we divided the team roles based on the ten contests of SDI. Every individual was responsible for one of the ten contests.

The project we are working on is a medical institute which is a part of Tribhuvan University, Kathmandu, Nepal. Our goal was to design a modern building that belonged to the valley.

Our design process focused on working on different aspects each week and achieving our sustainable goals. We started with the building's water performance, for which we referred to the NBC to understand the standard demand of water for a building like ours. We used rainwater harvesting and water treatment systems (DEWATS and constructed wetlands) to reach our net zero water goal for the building.

To make our building sustainable, and respond to the climate of Kathmandu, we started working on the specifications of the building envelope, referring to the ECBC guidelines while doing market surveys. Comfort was our utmost priority while designing the building. We established a comfort range for indoor spaces keeping Kathmandu's heavy humidity and cold temperatures in mind. Accordingly, we developed passive strategies to aid in achieving these comfort levels.

Our goal was to make our building a net-zero-energy building. In order to do that we focused on using energy efficient fixtures and systems to minimise the energy consumption of the building. After running several energy simulations on DesignBuilder, our total calculated energy consumption was 47.44 kWh/sqm/year. This consumption was fulfilled by our solar energy generation capacity which produced 51.4 kWh/sqm/year. This process has led us to a solution that has achieved not just net-zero, but net-positive energy status.

6. TEAM INTRODUCTION

a. Team Name : Renouveau

b. Institution : School of Planning and Architecture, New Delhi

c. Division : Educational Building

d. Team Members :

e. Approach :

In order to produce a design reflecting the ideologies of each individual, it is crucial that each member of the team is fully able to express and communicate with each other during the design process without any hesitations. Consequently, the group has further divided into smaller disciplines where each individual takes lead for a discipline in which they showcase proficiency. In addition, overlaps and intersections between these disciplines ensures that communication is never an issue, and everybody is in the loop in each stage of design.

f. Background of the team institution :

School of Planning and Architecture, New Delhi, is a premier higher education federal institute, specializing in education and research, in the fields of planning and architecture, providing training at various levels and different aspects of the human environment. The institute primarily offers Undergraduate Degree in Architecture and Planning, Postgraduate Programs, Doctoral Programs and Executive Education Programs

g. Faculty Lead and Faculty Advisors

Shweta Manchanda

She is an architecture faculty at the SPA, New Delhi, specialized in Urban Design and Sustainability. She did her B. Arch from the SPA New Delhi, and her M. Phil and PhD. from the University of Cambridge.

Deepti Gupta

She is a visiting faculty at SPA, New Delhi. She did her B.Arch. from SPA, in 1990. Masters in Engineering from Anhalt Hochschule, Germany. PhD, Singhania University, Rajasthan.

Ashwani Dutta

He did his undergrad in Architecture from the Centre of Environmental Planning and Technology, Ahmedabad in 1986 and masters in Architectural Design from University of Arizona, USA. He teaches at the SPA as a visiting professor

Kinshuk Aggarwal

Kinshuk Aggarwal of SSSA Architects, did his B. Arch from USAP, Delhi, following which he completed his masters from The Bartlett, UCL, London, in 'Sustainable Urbanism'.

h. Industry Partners

Shah Hemp Inno-Ventures

With SHIV, we envision creating a sustainable socio-economic model with Cannabis as a main tool and developing the ecosystem around it.

Archeva Technologies

Specialisation in building automation which includes lighting, security, smart controls, etc. Helped in incorporating these in our building.

i. Design management process :

01 **Pre Design Analysis**
To start off the design, the team focused on familiarising themselves with the site. This included studying the climate and analysing the strength and weakness of the site.

02 **Concept Development**
After familiarising ourselves with the site, we decided on how we would treat the site and our general response towards it.

03 **Iterations**
The team worked on five design iterations handled the terrain in unique ways. We also focused on passive strategies to maximise natural comfort within the building.

04 **Incooperating Codes**
We researched about all of the necessary guidelines which included NBCs, ECBC etc.

05 **Energy Simulations and Webinars**
As we progressed further, we started attending the SDI Webinars, which made us aware of sustainable practices, and the measures taken to achieve a more wholistic design.

06 **Choosing Iterations**
From the five iterations created, the one which aligned with the goals we had envisioned for the project, was chosen.

07 **Guidance and Consultation**
Useful insights on how we can improve our design and use the site better were given by jury members Biresh Shah & Rajesh Dongre.

08 **Design Builder Simulation**
A back and forth process of edits and changes occured to improve upon the design according to the simulation results as well as right sizing of HVAC systems.

09 **Collaboration with Industry Partner**
Polishing up of ideas and techniques in collaboration with our industry partners, helped us create more accurate and workable innovations.

10 **Final Report**
After various edits and additions, the team came up with the final design, with each part detailed and thought out.

7. PROJECT BACKGROUND

a. Project Name : Academic Block, Institute of Medicine, Tribhuvan University

b. Project Partner : Tribhuvan University, Kirtipur, Nepal

Description

Tribhuvan University (TU) is a public university located in Kirtipur, Kathmandu, Nepal. Established in 1959, TU is the oldest of the six universities in Nepal. Tribhuvan University is a non-profit autonomous institution funded by the Government of Nepal. There are four research centres in TU. Being one of the largest universities in the world in terms of its size, it offers a wide variety of programmes and practices.

Key Individuals

Dr. Dibya Singh Shah
Dean, Institute of Medicine, Tribhuvan University

Prof. Anil Deewan
HOD, SPA Delhi & Master Planner for the Project.

c. Brief Description of Project

Location : TU Rd, Kirtipur 44618, Kirtipur, Kathmandu Valley, Nepal

Climate Zone :	Temperate	**Annual Rainfall** :	185 mm
Altitude :	1284m to 1524m	**Humidity Level** :	71%

Site and Context

The site is located South West of Kathmandu city in Kirtipur District - one of the five municipalities in the valley. Tribhuvan University's surrounding district has become a popular area for out-station students and teachers to settle and live in. The site is approximately 0.33 Km away from the ring road, which acts as the major link to the rest of Kirtipur.

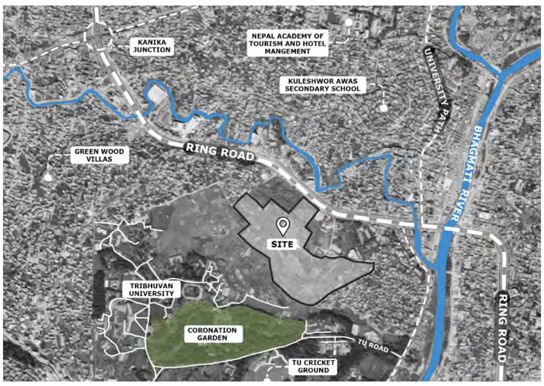


Figure 1 : The site

Status of the project : Master planning complete

Profile of occupants : 300 Students & 80 Faculty
Hours of operation- 9 hours per day, 6 days per week

Ownership : This institute is a government-funded project which will be built under a Build-Own-Operate clause. It is handed over to a private party for the entire construction process.

Occupation : The involvement of the Project Partner is the building's self-occupation. This institute is part of the Tribhuvan University Campus. Tribhuvan University is an institute of national importance in Nepal and the entire construction is funded by the Government of Nepal.

d. Site Areas

Site Area	8,115 sqm
FAR for Educational Building Type	2
Permissible Built-up Area	16,230 sqm
Permissible Ground Coverage	25%
Total Built-up Area	12000 sqm

e. Project Timeline

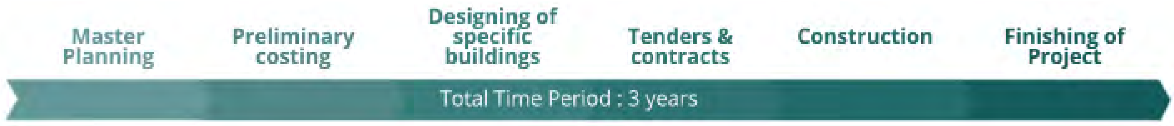


Figure 2 : Timeline of the Project

f. Construction budget & cost :

Preliminary construction budget (INR/sqm) = INR 35,000/sqm as per market survey.

Proposed construction cost (INR/sqm) = INR 18,691/sqm as per calculations

g. EPI - Energy Performace Index

Benchmark EPI for Educational Building	90 kWh/m2/yr*
EPI from Formit and Insight Analysis	95 kWh/m2/yr
Targetted EPI for Building	63 kWh/m2/yr (from edge app)
Achieved EPI for Building	37.5 kWh/m2/yr**

h. Special requirements of the Project Partner

- The project partner is desiring to have both net-zero energy and net-zero water facility for the academic block for creating an eco-friendly structure which is energy efficient but also replenishes the natural resources.
- As the site is in high earthquake expectancy zone so, the project partner desires a resilient building for withstanding any unfortunate conditions in the future.
- The client encourages to have affordable solutions for the mentioned requirements and future maintenance if any.

Notes :
**Referred from Griha Manual 2019*
***From Design Builder Simulation*

8. PERFORMANCE SPECIFICATIONS

Envelope Specifications			
Window Wall Ratio (WWR)	Wall	Roof	Window
28.5%	U-Value = 0.16	U-Value = 0.18	U - Value : 1.6, SHGC: 0.43 VLT: 0.66

Table 02 : Envelope Specifications

HVAC

System type : Heating Pump- Climatemaster TW340
Heating Capacity : 102kW
CoP : 5.1
ISEER/EER : 23.3

Number of System for Building : 8
Star-Rating Certified : Yes

LIGHTING

LPD : 3.1 W/sq.m
Fixtures :

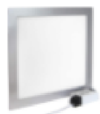
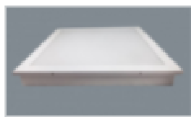
Name	Fixture Type	Specs	Wattage	Fixtures	Lumen
[Energy Class G] Panel Light	Type 1	LED 300x300	24		1900
HX9545-40	Type 2	LED 600x600	40		3400
EVO PANEL 1200X600	Type 3	LED 600x1200	50		5000
72w Cool White LED Ceiling Panel Light 1200 X 600	Type 4	LED 600x1200	72		5600

Table 03 : Lighting Fixtures

Controls - Smart Lighting Control system which controls the lighting of different spaces based on a given scheduling.

ELECTRICAL

Refer to Table in Annexure for detailed equipment load calcs
EPD : 10.25 W/sq.m
Renewable Energy System - Solar Energy system
with a capacity of **4,60,528 kWh/year/sqm**

9. GOALS AND STRATEGIES

CLIMATE RESPONSIVE
To offer climatic comfort throughout the year.

Strategy

To attain a climate responsive building, the analysis of the sun orientation, WWR, energy simulation, study of different materials was done. Considering the climate of Nepal, strategies focusing on dehumidification, thermal heat gain, minimization of heat loss, are considered.

PRESERVING THE NATURAL TERRAIN
Preserving the natural terrain-slope of 1300m-1325 m above sea level.

Strategy

Cut and Fill- This is one of the most cost effective solutions to building on a slope because it does not waste any soil. Everything is reused in one way or the other.

EARTHQUAKE PROOF STRUCTURE

Strategy

Structural considerations; Safety and evacuation techniques

ENERGY PERFORMANCE

Strategy

An EPI of 37.5 kWh/sqm/year achieved using energy efficient strategies.

ACOUSTIC DESIGN
Acoustic Resilience throughout the building

Strategy

To improve the acoustic quality of spaces like lecture halls, seminar halls etc. Wall panels, acoustic ceilings, are used for reducing noise.

SAFETY AND SECURITY
To create an environment where students and staff feel comfortable enough to navigate throughout the site.

Strategy

The use of the principles of CPTED to address issues of safety and security within the campus of the university.

ARCHITECTURAL DESIGN
The institute should foster healthy relations between the faculty and students, creating unique spaces.

Strategy

The building in itself should offers multiple public and semi-public spaces; different functions arranged in a way that there is flexibility.

WATER PERFORMANCE
Water Self Sufficient

Strategy

Rainwater harvesting eliminates the need for municipal water supply; low flow fixtures and user controlled automated systems reduce the water requirement; use of recycled greywater in the mechanical cooling systems and irrigation reduces potable water use.

10. DESIGN DOCUMENTATION

ARCHITECTURAL DESIGN

The design of the academic block was fundamentally centered on the segregation of occupants based on their profession on their arrival to the building block whilst also having a common space to make them feel connected. To do so, an arrival plaza was designed by creating an insertion into built form. Different entry points were given at this plaza guiding occupants into their designated spaces in the academic block with a proper drop-off zone.

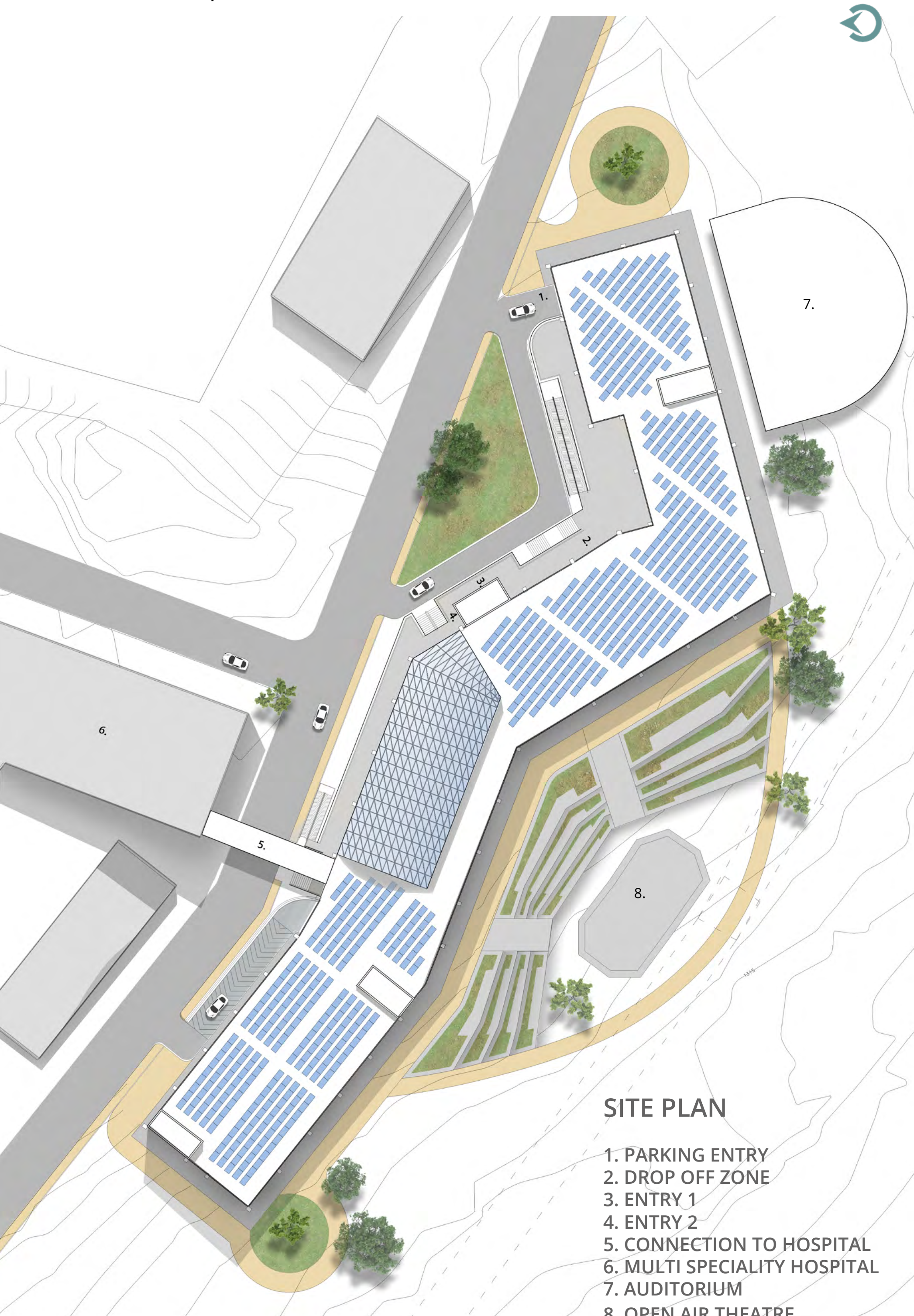


Figure 03 : Site Plan

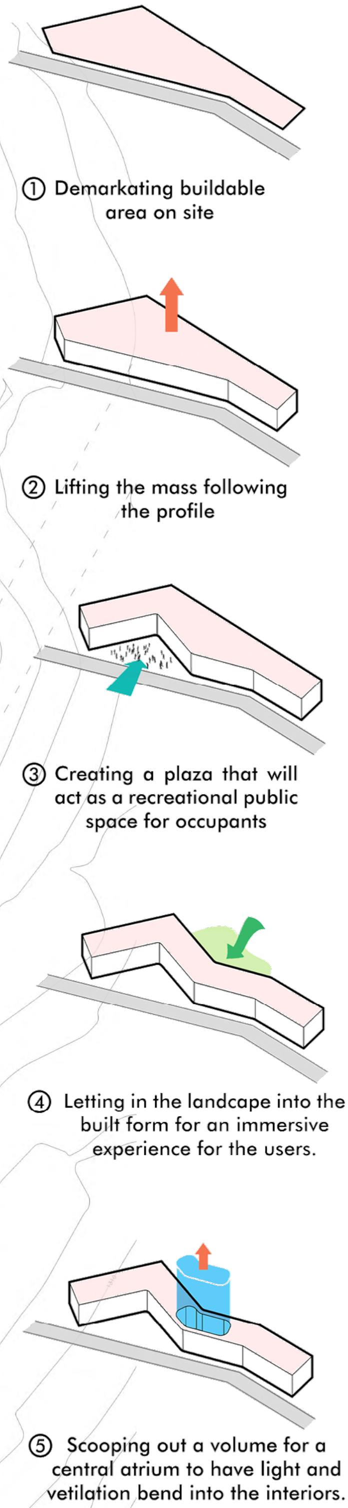


Figure 04 : Form Development

ARCHITECTURAL DESIGN

DESIGN CHARACTERISTICS

Spatially the building is divided into two zones - Academic Zone and Administrative Zone with an atrium dividing both. This Seating staircase will be the primary way of circulation for the students to commute to their classes and examination rooms as well as act as a space where they can hang out in their break time making the atrium space full of life and energy.
The atrium will also connect students to the library and cafe. Breakout spaces among classrooms and examination rooms are given to break the linearity of corridors, adding to the overall experience. The labs are strategically placed at the top floor to cut-off crowds and a direct connection to the main hospital block is given for the doctors and faculty to commute to and fro.

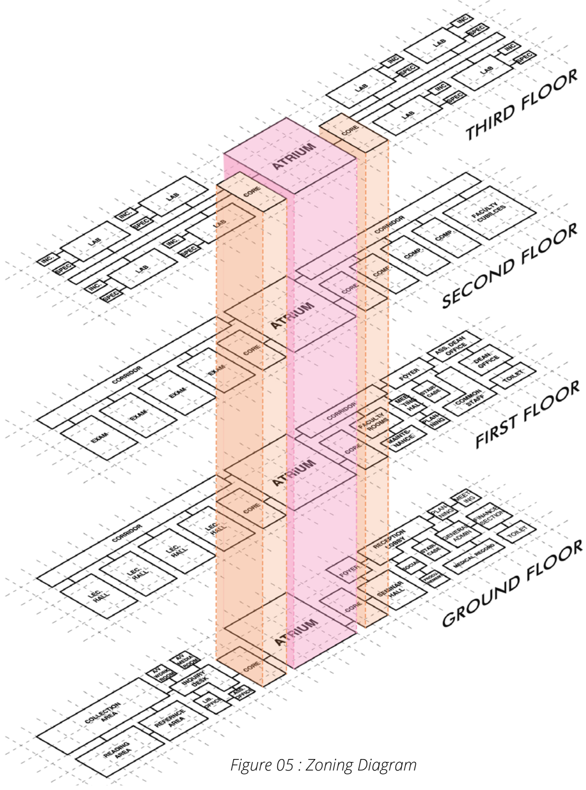
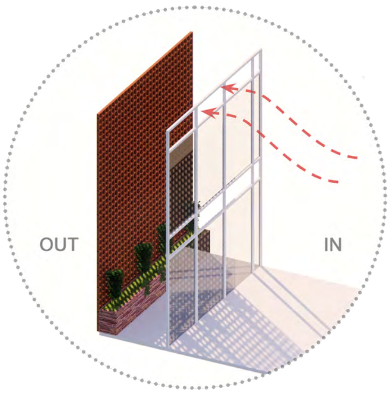


Figure 05 : Zoning Diagram



TERACOTTA JAALI

ATRIUM

INTERACTIVE STAIRCASE

GROUND PLAN

1. Library
2. Staircase
3. Restroom
4. Lift Lobby
5. Entry & Exit
6. Atrium
7. Cafeteria
8. Conference Room
9. Planning & Evaluation room
10. Procurement Section
11. Medical Record Room
12. Finance Section
13. Reception
14. Seminar Hall
15. General Admin
16. Social And Welfare Section

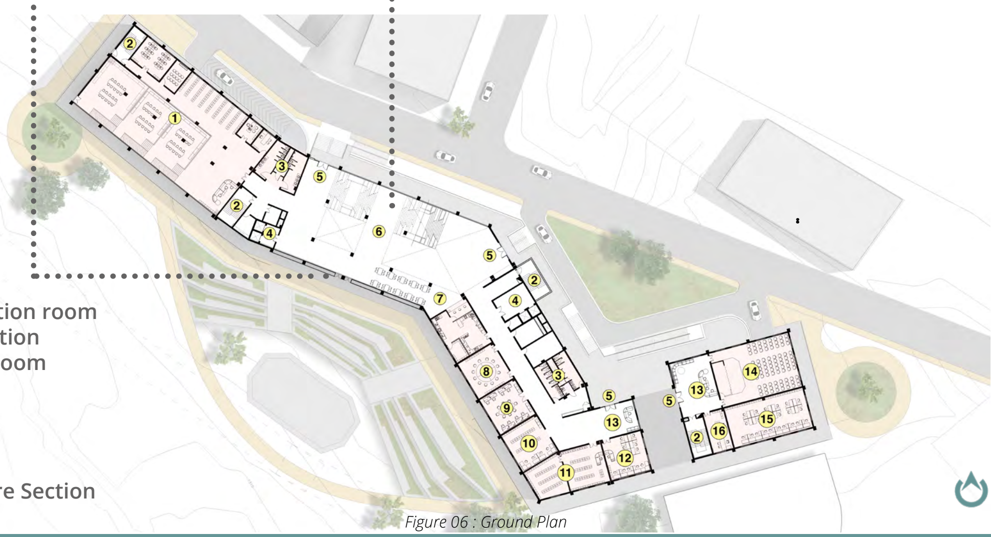


Figure 06 : Ground Plan

ARCHITECTURAL DESIGN

DESIGN OF SPACES

The atrium in the middle of the building is a primary source of natural lighting for central recreational space, as well as an important source of solar heating within the building. Apart from lighting and heating strategies, natural ventilation is also utilized through the atrium.

Considering Nepal's humid climate, terracotta ventilated facade system is used. During summers, terracotta being porous in nature absorbs moisture encouraging cooling in building whereas in winters, facade retains the heat in the air cavity, trapping the accumulated heat inside the building.

Central Atrium and Staircase

Cycling Track

Exterior Render showing plaza

Exterior Render showing connection to the Hospital

Figure 07 : Renders

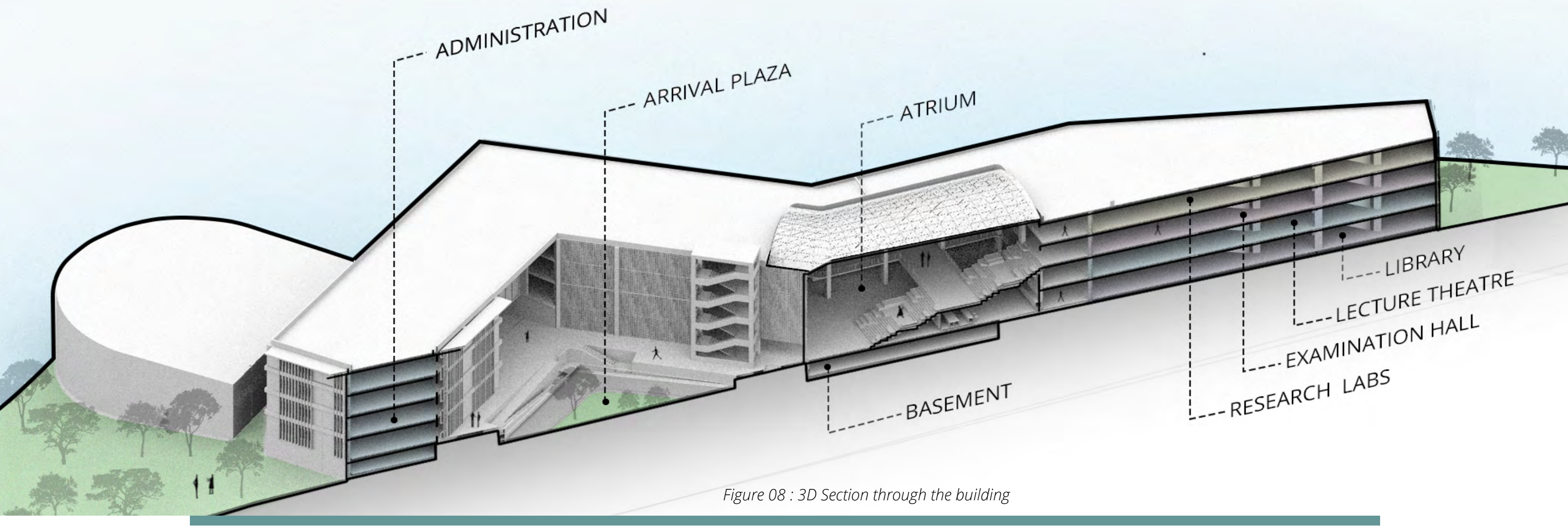


Figure 08 : 3D Section through the building

PASSIVE DESIGN

Hempcrete

Hempcrete is a bio-aggregate concrete, where the hemp shives - small pieces of wood from the stalk of the plant - are mixed with either a lime or mud cement to create a durable, eco-friendly building material. Like concrete , hempcrete can be either be cast in-place or prefabricated but since it is light weight, its non structural.

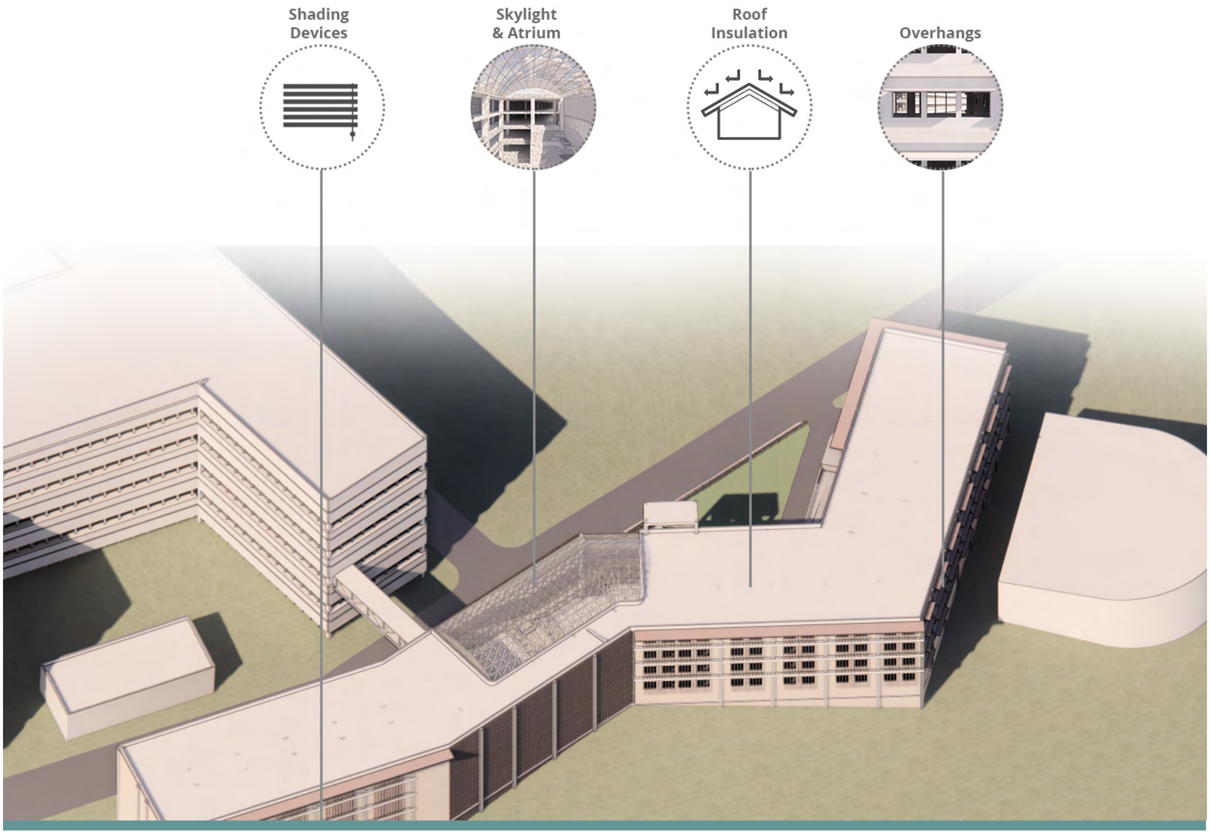
Advantages :

- Provides high resistivity, thereby a lower U-Value suitable for construction in compliance to ECBC guidelines.
- The air pockets created among the particles in hempcrete, make it both earthquake resistant and an efficient thermal insulator.

Strategies Used

The Skylight and Atrium acts as a key source for solar heating within the building during the winter months and decrease heating loads of the building. Other passive strategies like proper insulation for roofing and walls, overhangs, shading devices have also been incorporated in the building.

Figure 09 : Rendered View of Facade



ARCHITECTURAL DESIGN

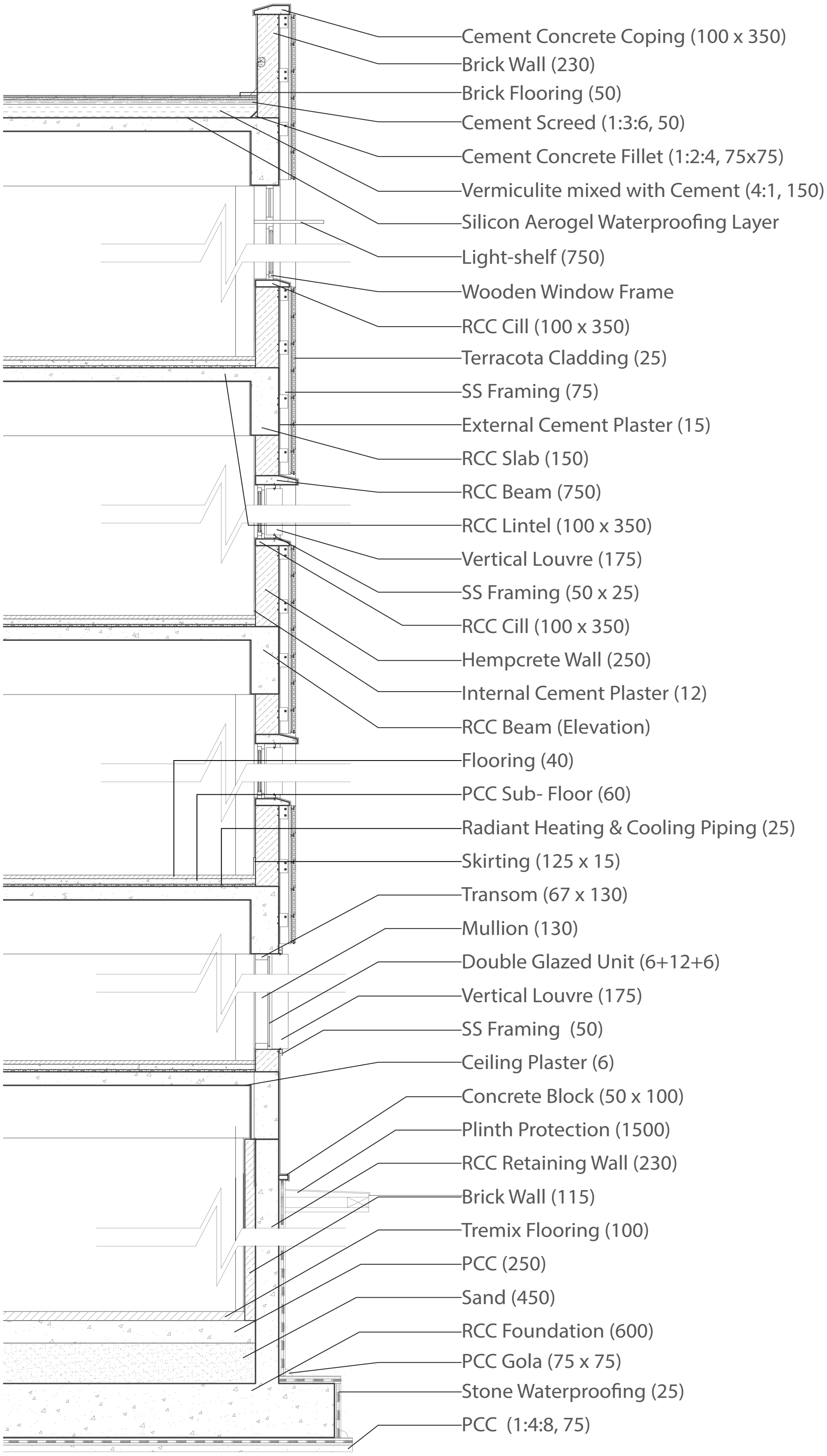
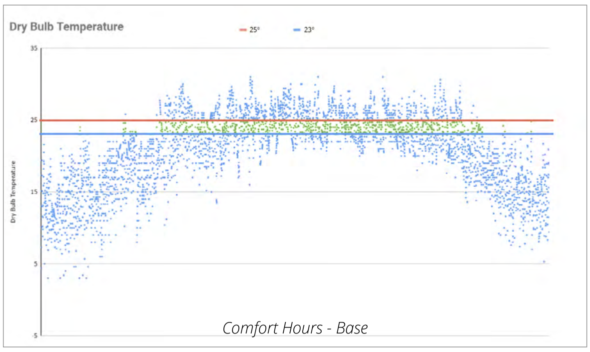


Figure 10: External Wall Section

HEALTH AND WELLBEING
COMFORT AND ENVIRONMENTAL QUALITY

To start the comfort analysis of our given site, we did a study using a 7 day running mean temperature to define the comfort band which recognised the daily changes in outdoor environmental condition and its effect on the building which we plotted against the number of operational hours throughout the year. Through this study around 30% of the operational hours fell into the comfort range and for the remaining 70% we decided to introduce various strategies to bring in comfort.



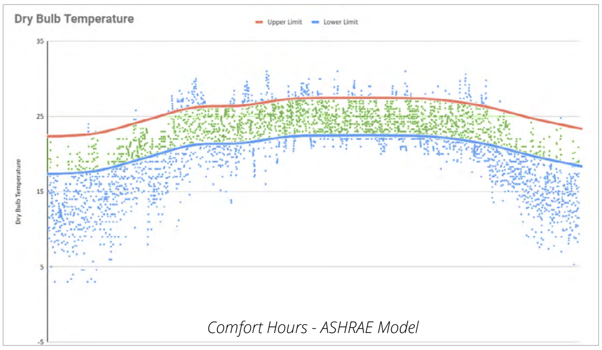


Figure 11 : Comfort analysis- Base case & ASHRAE Model

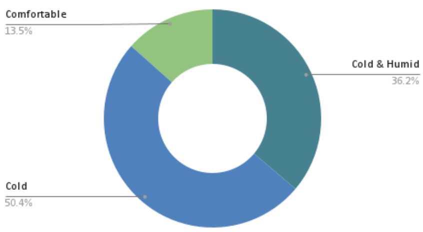
The climate is influenced by two factors i.e the humidity and the dry bulb temperature. To establish the comfort band, if the relative humidity falls either below 30% or above 70% it is deemed as uncomfortable. The same was done with temperature which defined the upper limit of comfort and the lower limit of comfort for each month, temperatures going beyond or below this band were classified as hot and cold respectively using the formulas :

$$\text{Upper 90\% acceptable limit} = 0.31T_{MOT} + 20.3$$
$$\text{Lower 90\% acceptable limit} = 0.31T_{MOT} + 15.3$$

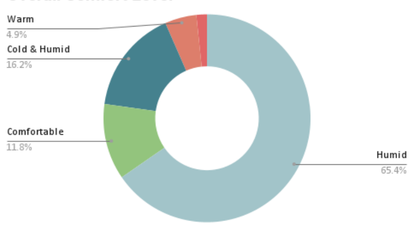
$$T_{MOT} = 0.33T_{(DAY)} + 0.23\,T_{(DAY-1)} + 0.16T_{(DAY-2)} + 0.11T_{(DAY-3)} + 0.08T_{(DAY-4)} + 0.05T_{(DAY-5)} + 0.04T_{(DAY-6)}$$

Combining these two cases we derived our overall comfort for the operation of the institute and did a monthly analysis. Around 26.7% of the operative hours the climate is comfortable and can function sans the use of any conditioning system besides the use of ceiling fans or opening of windows (March, April, May, October) . 18.4% of the hours are cold and 24.5% hours are cold and humid indicating the need for both heating and dehumidification (November, December, January and February) . 22.8% falls under extreme humid conditions indicating need for ventilation and dehumidification (June, July, August, September).

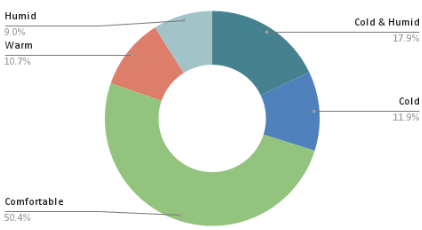
Figure 12 : Comfort analysis throughout the year



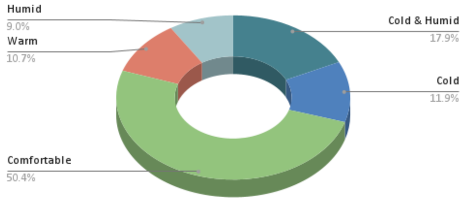
Comfort in November, December, January, February



Comfort in June, July, August, September



Comfort in March, April, May, Octoober



Comfort throughout the year

HEALTH AND WELLBEING
COMFORT OPTIMISATION

	Jan - Feb	March	April - May	June - Sept	October	November	December
Comfort Set Point	20	21	21	22	21	21	20
Comfort Set Back	17	18	24	25	24	18	17

Figure 13 : Setpoint and Setback temperatures

Comfort setpoint and setback temperatures have been set according to Comfort Temperatures Analysis according to ASHRAE 2019.Based on our study , we derived an hourly thermal comfort band for the entire year. This band gives a range of acceptable indoor operative temperatures thus allowing us to change the set point of the air conditioning system to match adaptive comfort. The derived set points are listed below. We also calculated the set back temperature for times, when the spaces will not experience peak occupancy, and can operate at a lower or higher temperature than what is suggested by comfort.

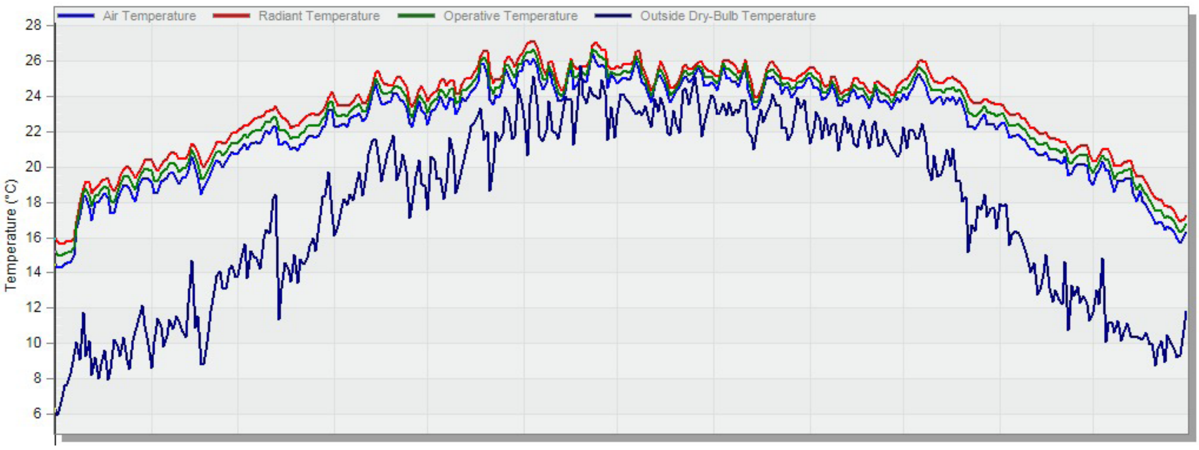


Figure 14 : Temperatures achieved in the Building throughout the year (Source : Design Builder)

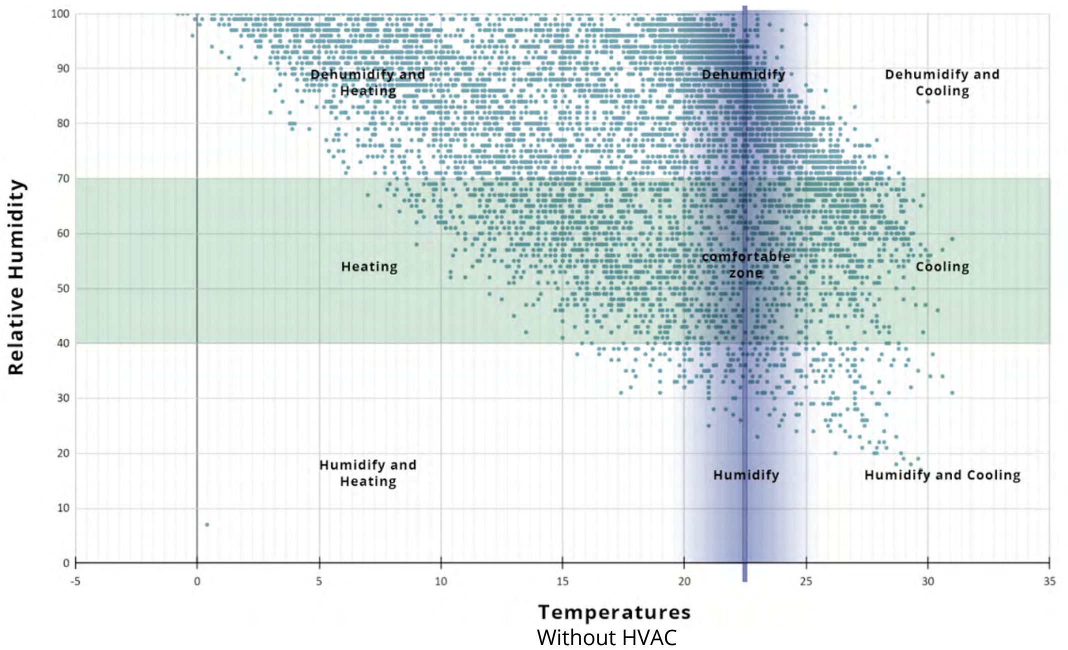


Figure 15 a.: Psychometric Chart

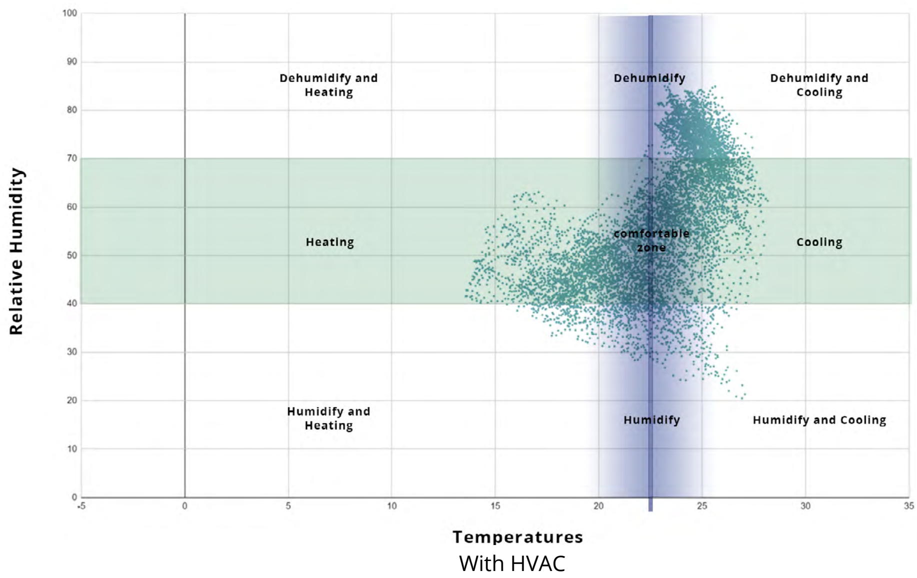


Figure 15 b.: Psychometric Chart

Furthermore, the system is operated an hour prior to the starting of the university, with the temperature set back to ease the load on the system to directly condition the space and help achieve comfort. All these strategies combine to help us achieve comfort throughout the year in our institution.

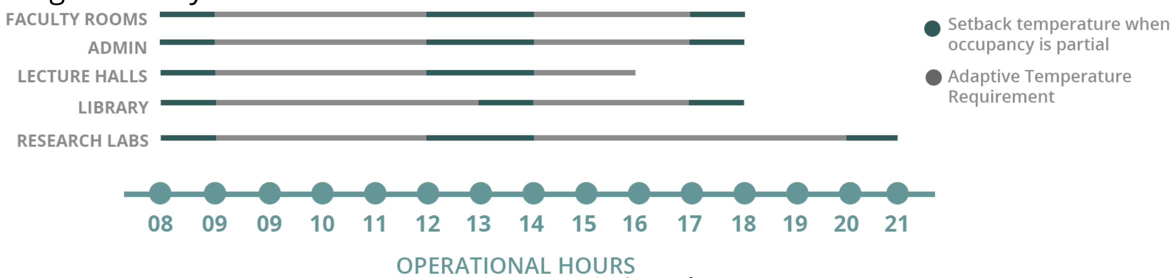


Figure 16: Operational Hours of HVAC

ENGINEERING DESIGN AND OPERATIONS

HVAC

The proposed system for our institutional building is a combination of a ground source heat pump along with a Dedicated Outdoor Air System. While the ground source heat pump takes care of the latent heat load, the DOAS takes care of the sensible heat load. Two systems have been deployed for the institute, where they work parallelly instead of letting one system take on the load of Kathmandu's cold and humid climate.

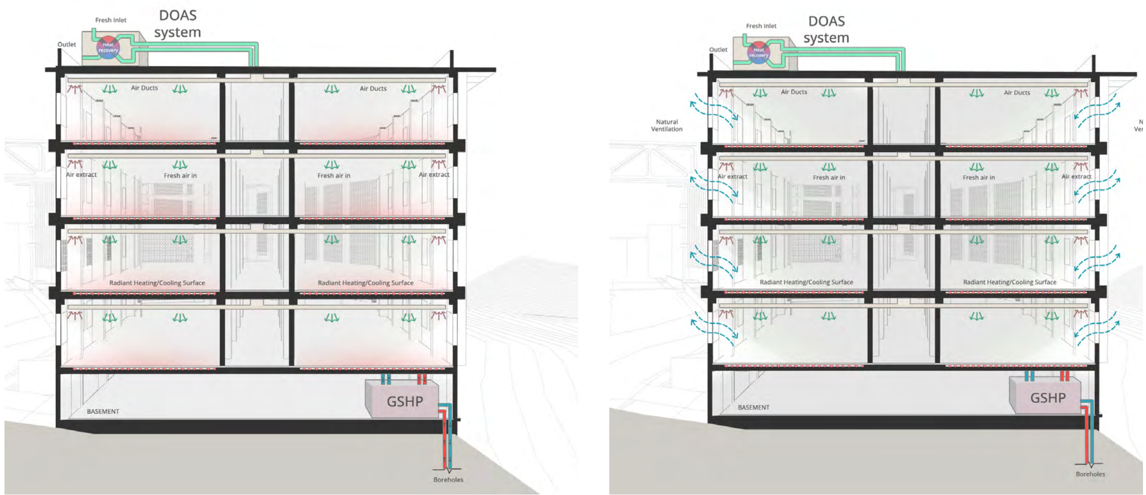


Figure 17 : Working modes of the proposed HVAC System

The ground source heat pump uses earth and a groundwater reservoir as a source of heat in winters and as a reservoir to reject heat in summers.The 6 piped heat pump takes on both heating and cooling loads throughout the year. The DOAS provides clean, filtered air to the space and helps bring down the loading of the conditioning system. It conditions the incoming air using energy recovery methods, in our case, a desiccant wheel which dehumidifies the air to extract heating or cooling from airstream going outside. The wheel senses temperature and humidity and transfers this onto the incoming air, however the air is not reused.

After treating the fresh air using the DOAS, the heating load is reduced by 50% and hence, reduces the sensible load for the building.

NO DOAS
Cooling : 747.6 kW
Heating : 1162 kW

WITH DOAS
Cooling : 332.27
Heating : 634.6

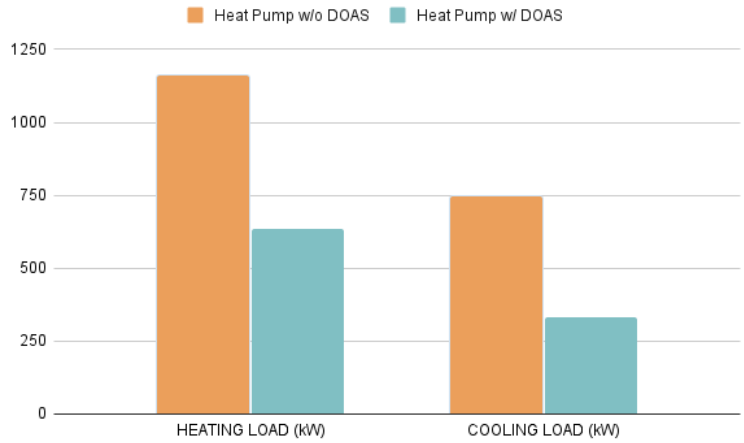


Figure 18 : Heating and cooling with and without HVAC

The primary conditioning of the institute is done through radiant floor heating and cooling, in combination with the ground source heat pump, using a 4 pipe system, which is done using radiant floor panels. Atop these floor panels is a layer of concrete slabs as the flooring so as to ensure proper energy transfer. To condition the area, chilled or heated water can be cycled through radiant floor panels, depending on the space load.

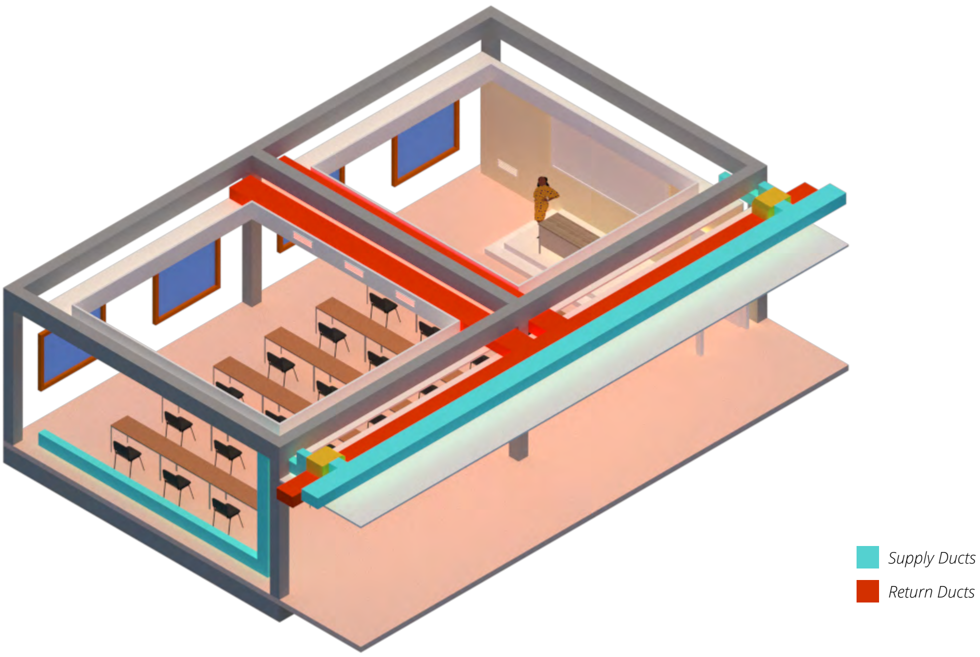


Figure 19 : HVAC Ducting

The system has been laid out in a way to provide suitable air pressure, velocity and temperatures in the spaces. For the same, the fresh air supply ducts have been placed in the lower end of the walls and the exhausts have been placed on the ceiling level to aid in air circulation and maintain thermal comfort.

The institute has been divided into two broad zones which require conditioning separated by a central atrium. These zones have been further subdivided into smaller zones with similar functions, schedules and activities for efficient system operation.

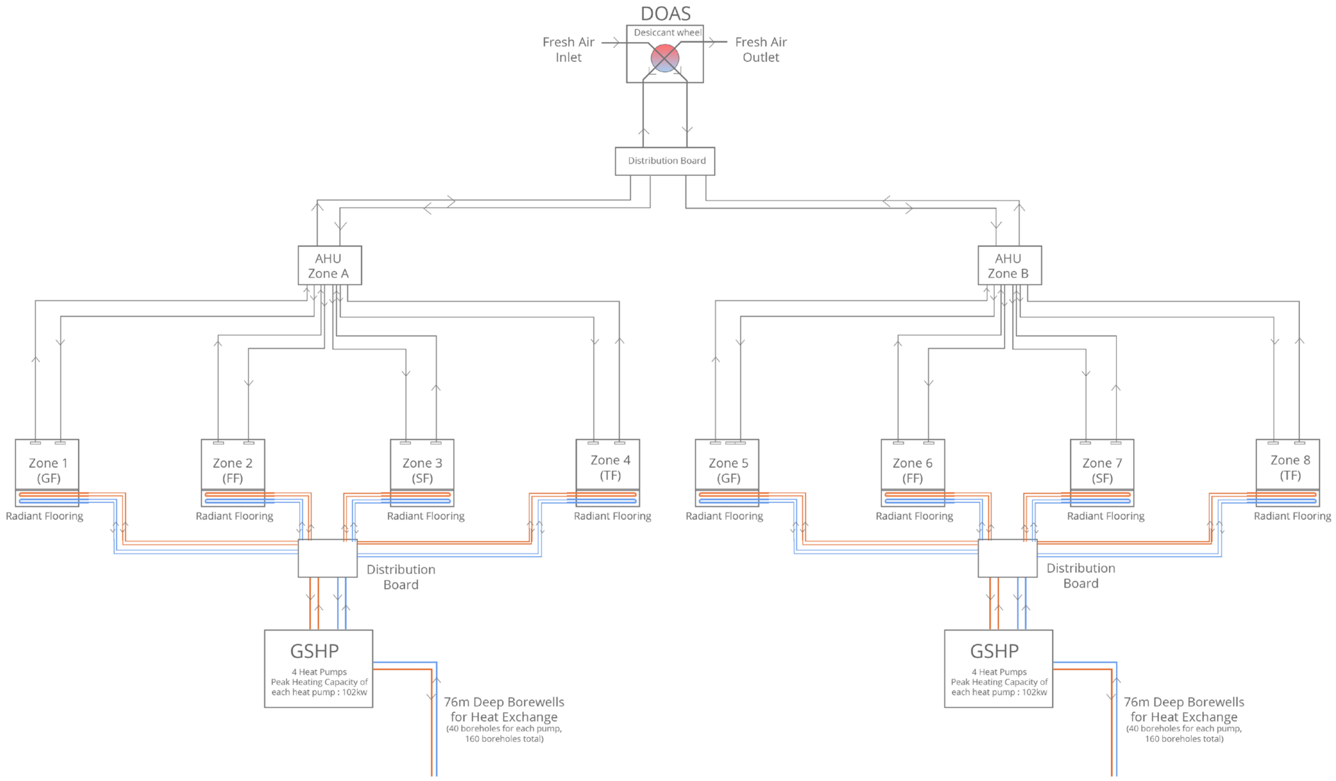


Figure 20 : HVAC SLD

On testing the heating load, our base case was around 2000kW (around 570tr) which is around 8.8 sq m/tr, whereas for our proposed case the heating load was 620 kW (around 176 tr) which is 28.7 sq m/ tr. For this load we have proposed 8 Ground Source Heat Pumps having a peak load capacity of 111kw, with each heat pump having boreholes going 76m deep and 40 in number. At this distance below the Earth, the temperatures are constant throughout the year, boreholes run throughout this distance forming a loop, circulating water to condition the building. As the temperatures are constant the heat pump does not have to expend as much energy into cooling or heating the water running through the pipes as the ground brings the water to a constant temperature.

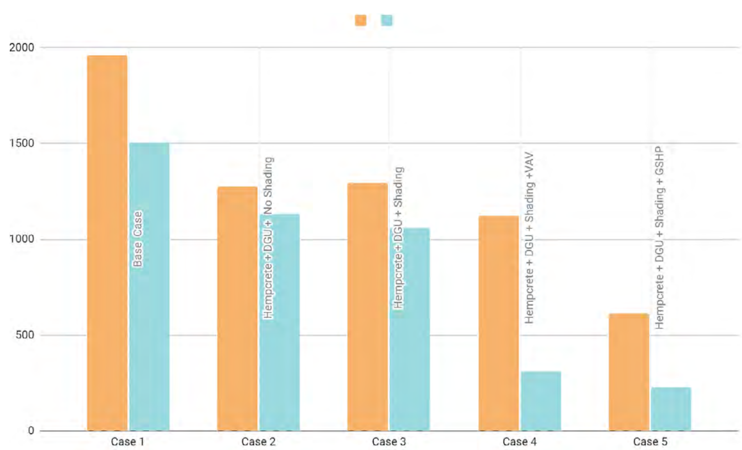


Figure 21 : Heating and Cooling Load Comparison

After incoporating pasive strategies ,building envelope and our proposed HVAC System we see a reduction of **68% in heating loads and 84% in cooling loads** of the building.

Proposed case

Cooling Load : 332.27 kW

Heating Load : 634.14 kW

ENGINEERING DESIGN AND OPERATIONS

SOLID WASTE MANAGEMENT

The current status of solid waste disposal in the Kirtipur Municipality is severely underdeveloped. Kirtipur Municipality does not have any section or unit for solid waste management and it is not directly involved in waste management related activities such as street sweeping, waste collection, transfer, recycling and disposal. This results in the need for development of an infrastructure that will deal our solid waste onsite and achieve a net-zero waste status.

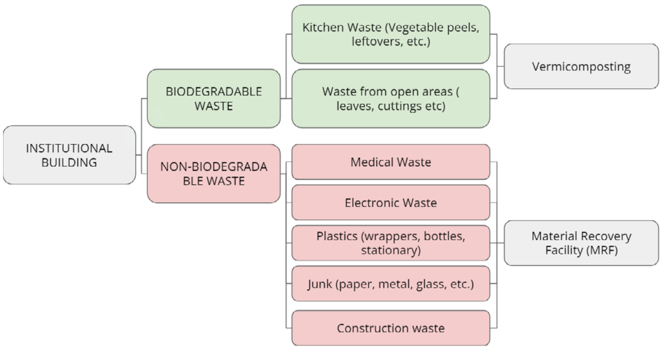


Figure 22 : Sources of Solid Waste

The different sources of waste from the institution are supposed to be treated in a specific manner. There are no set guidelines developed for solid waste management for institutions. We have devised a system that deals with all the different types of waste.
The biodegradable waste is used for vermicomposting to produce manure. This manure can be used within the Tribhuvan campus, or it can be sold outside the campus to generate extra funds.

The non-biodegradable waste comprises of a lot of different types of waste including the construction waste and the medical waste. Majority of this waste is dealt with at the Material Recovery Facility (MRF). A materials recovery facility (MRF). This MRF is a Manual facility where people will be employed to work. These employees are responsible for segregation of the waste, storing them efficiently, and their delivery outside the facility.

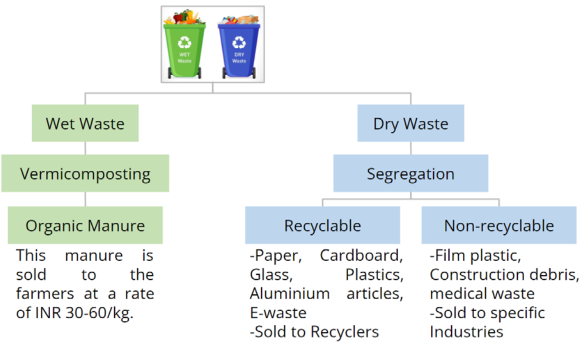


Figure 23 : Waste Segregation

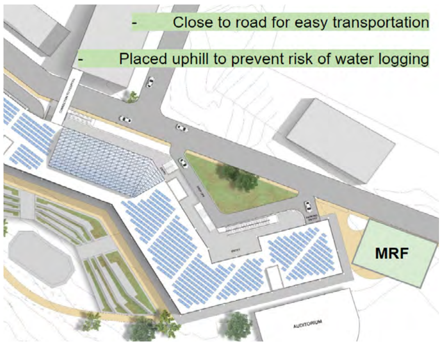


Figure 24 : Location of MRF

As per a research* based on Municipal Solid waste generation in Kathmandu, Nepal, we devised that for institutional buildings waste generation is 0.66 kg/capita/day. Out of this 55% (0.363 kg/capita/day) is organic waste and the rest (0.297 kg/capita/day) is dry waste. The number of occupants for the building is 450. This gives us an estimate of the total waste generated by the building i.e. 163.35 kg/day of organic waste and 133.65 kg/day of dry waste.
As a rule of thumb 1 kg of organic waste would produce 225g of organic manure. If we take into account a week's waste generation - 1143 kg, then we can produce 257 kg of organic manure in a week. This organic manure will be sold to farmers at a reasonable price of INR 30-60/kg, depending on the quality of the manure.
The dry waste produced by the building in 2 days is 267.3 kg. As per norms a 150 sqm MRF is sufficient in handling this capacity of waste. The MRF Facility is placed closer to the road to allow easy transportation, loading and unloading of the units.

** B. Degi Mohan, R. Pretz Christopher, A. Urynowicz Michael; "Municipal solid waste generation in Kathmandu, Nepal"- 2010; Published in Journal of Environmental Management,- California State University*

ENGINEERING DESIGN AND OPERATIONS

STRUCTURE

Column	Beam
Span = 8500 mm	
Depth: span/10 12000 / 10 = 1200 mm	**Depth:** span/10 8500/10=850mm **Width:** 1/3 of depth 850/3=283.3mm But, minimum width = 300 mm
Final Column Size = 1200mm x 1200mm	Final Beam Size = 300mm x 850mm

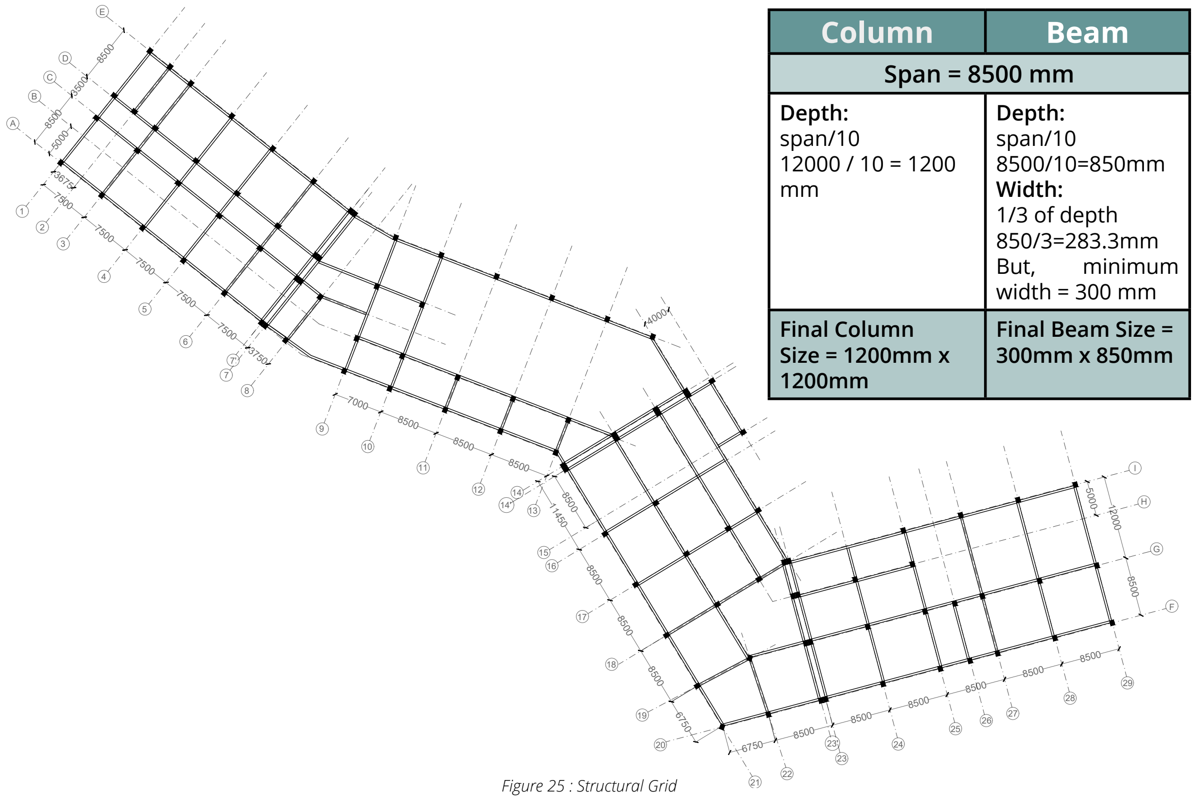


Figure 25 : Structural Grid

HEALTH & WELL-BEING

ECO-FRIENDLY COW DUNG PAINT

- An innovative, eco-friendly and cost-effective product inspired from the age-old Indian tradition of coating the walls and floor of the houses with cow dung.
- The ancient practice is redesigned into a modern product - Emulsion Paint by scientifically treating cow dung, the main raw material of this paint. The eight natural benefits i.e. the Ashta Laabh of the paint make it unique and an ideal protection for the walls.
- The paint is washable, waterproof, durable and dries quickly in just 4 hours. It conforms to BIS standards. Khadi Prakritik emulsion paint comes in white color base with matt finish.
- It can be developed into any color of choice by mixing colorants suitably.
- Khadi Commission has developed this innovative paint with the objective of increasing farmers income, creating sustainable livelihood through technology transfer and providing high quality paint to the general public at a reasonable price.
- Khadi Prakritik Paint contains negligible Volatile Organic Compounds (VOC). This causes extremely low vaporization of VOCs and prevents irritation to eyes.

INDOOR AIR QUALITY

The atrium is a naturally ventilated space inside our institute. It is the central gathering space used by the occupants throughout the day, therefore maintaining its indoor air quality was important. Plants encouraging dehumidification and producing oxygen were planted throughout the atrium. These help in keeping CO2 levels below 1000 ppm in schools as per ASHRAE standards.

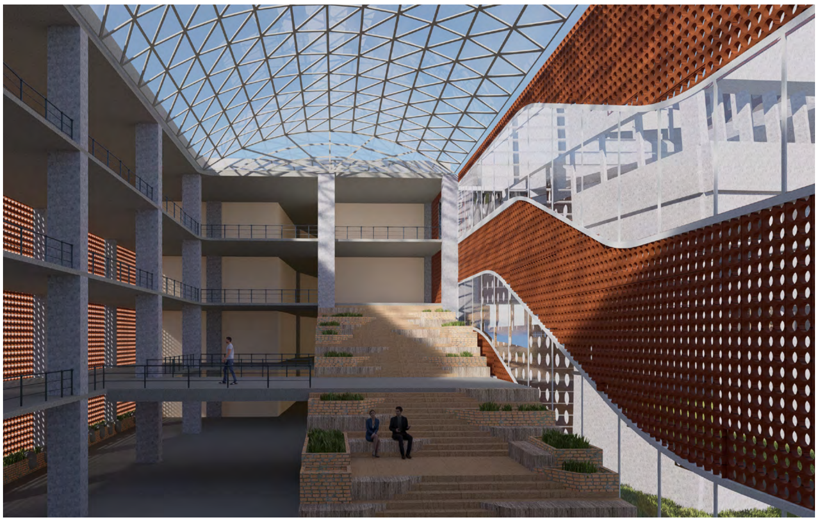


Figure 26 : Indoor Air Quality Strategies

DOAS AND GREEN ROOF CONFIGURATION

For our mechanically ventilated spaces, occupying around 50% of the total built up area, we proposed a DOAS to ventilate the spaces and bring about the necessary air changes. This fresh air is directly being let into indoor spaces, therefore, its treatment is important. Our site has unhealthy levels of PM 2.5 and PM10 and also high humidity levels, this increases the potential of air to hold the particles emitted, potentially triggering negative respiratory responses. Therefore, we have designed a system to treat the air before it enters the space itself. The DOAS unit placed on top of the roof takes in fresh air directly after it goes through a terrace garden surrounding the unit. The chosen vegetation for this terrace garden should have complex, waxy and/or hairy surfaces, as these features assist in the deposition and removal of particulate pollutants as the air passes through the leaves. This is estimated to result in a 60% reduction in the PM matter in the air.

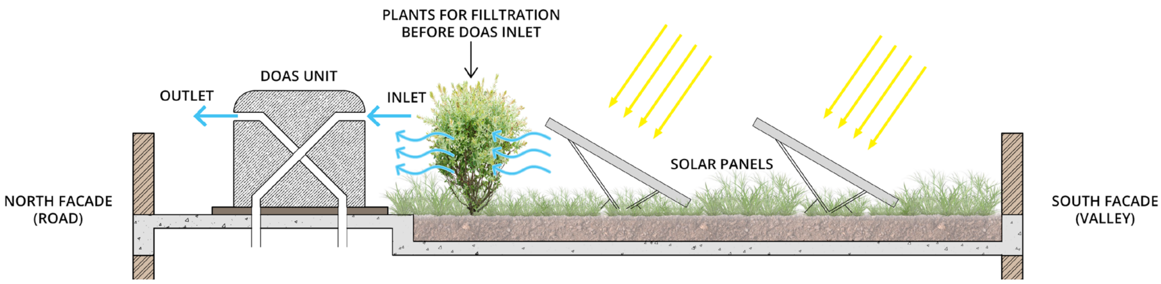


Figure 27 : Biosolar Roof System with DOAS

FILTERATION

Furthermore, media filters have been placed in the ducts as they are good for filtering out bacteria and fungus as well as the remaining fine particulate matter. These filters are low maintenance as changing is only required twice or thrice a year and provide the same level of filtration as a high-MERV filter, but they do it without the negative consequences of airflow or static pressure making sure to maintain 6 ACH, meeting ASHRAE's standards for the same.

GREEN BARRIERS

Based on the earlier principle, we planned on creating a physical barrier on the North Eastern wall facing the atrium. This physical barrier cuts down the sun and provides PM filtration on the north eastern facade, which receives high levels of solar radiation and is exposed to pollution due to the presence of an access road on this side. The green barrier on the north eastern facade consists of climbers like Tinospora cordifolia (Gurjo Plant), and the Ampelocissus barbata (Wall) with a waxy surface and wide leaf span. This green barrier helps reduce and disperse the PM matter so that occupants do not bear the direct consequences of it and remain protected.

Figure 28: Green Barriers

ENERGY PERFORMANCE

NATURAL LIGHTING

In order to reach our energy performance goals for the building, we developed detailed models and schemes in design builder. In addition, we optimized the envelope to reduce heat loads on building and increase natural lighting. We began by optimising our WWR keeping in mind the climatic conditions and solar radiation on site. The goal was to achieve enough daylight to minimise our lighting load, while simultaneously not compromising thermal comfort.

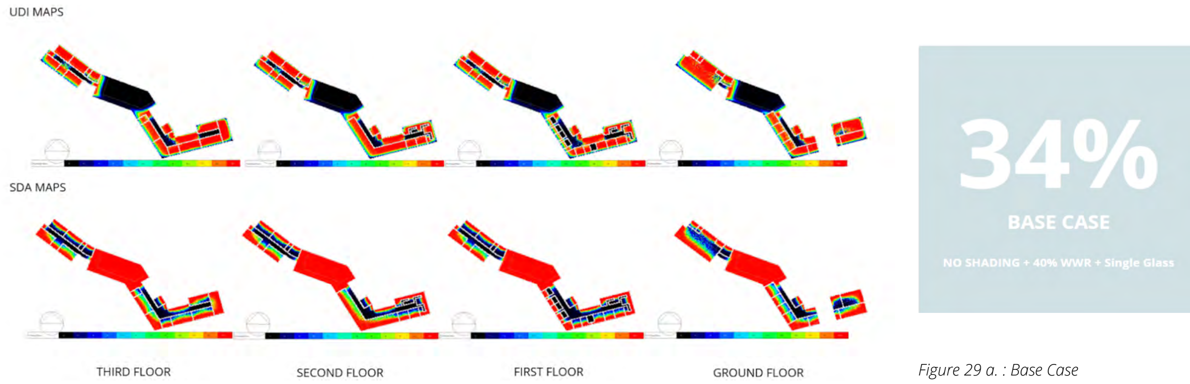


Figure 29 a. : Base Case

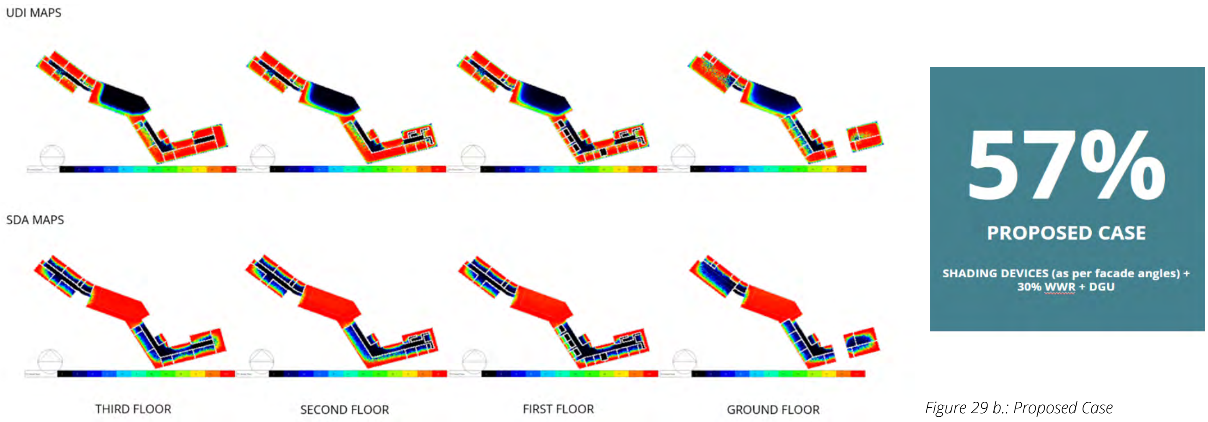
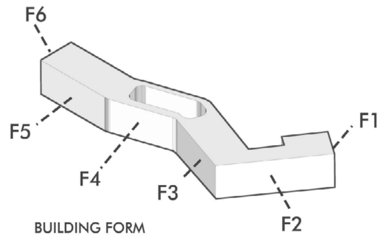


Figure 29 b.: Proposed Case

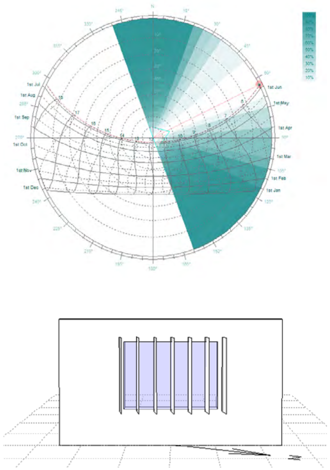
SHADING DESIGN

Facade	Orientation	Angle (degree)	Vertical Shading (mm)	Vertical Louvre Angle	Horizontal Shading Depth (mm)
F1	North East	70	300	-15	300
F2	South East	160	NA	NA	1000
F3	South West	235	500	0	750
F4	South East	200	300	30	1000
F5	South West	215	300	30	750
F6	North West	310	300	-60	600

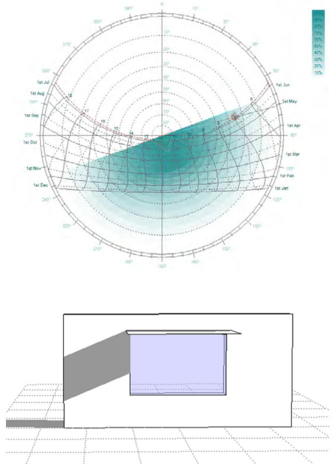
Table 03 : Solar Radiation analysis



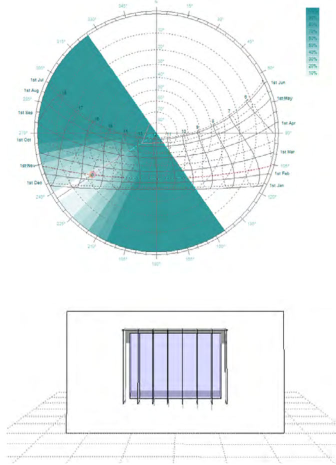
Facades of Building



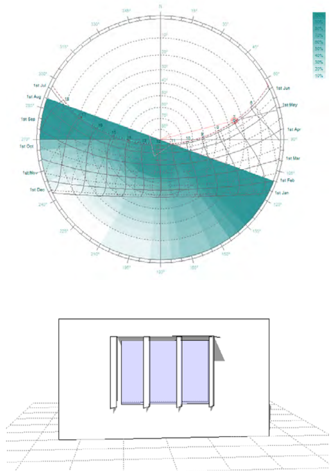
F1 Louvre Count : 8



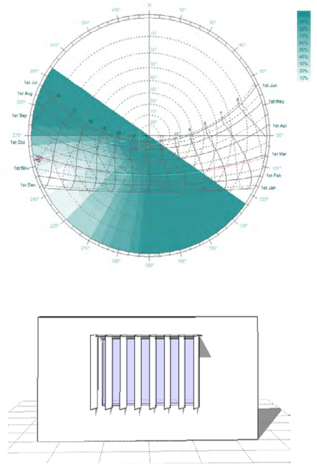
F2 Louvre Count : 0



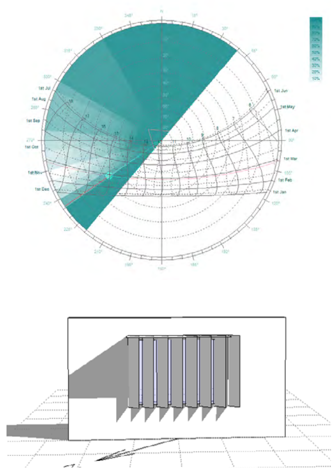
F3 Louvre Count : 8



F4 Louvre Count : 4



F5 Louvre Count : 8



F6 Louvre Count : 8

Source : Solar Tool

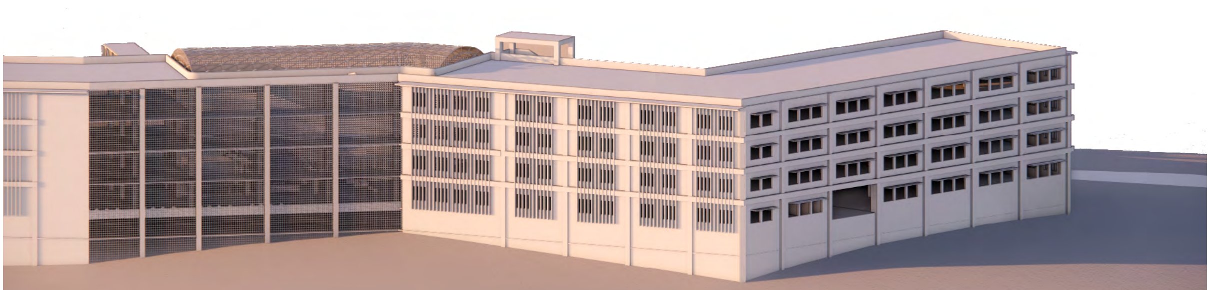


Figure 30 : Shading Design for different facades

BUILDING ENEVELOPE

	BASELINE		IMPROVED	
External Wall	Material	Thickness (mm)	Material	Thickness (mm)
	OUTSIDE		OUTSIDE	
			Terracotta Facade	30
	Cement Plaster	15	Air Gap	75
	Brick Wall	230	Lime Plaster	15
	Cement Plaster	12	Hempcrete	250
			Lime Plaster	12
	INSIDE		INSIDE	
	Total Thickness (mm)	**257**	**Total Thickness (mm)**	**382**
	U-Value (W/m2.K)	**1.765**	**U-Value (W/m2.K)**	**0.159**
Roof	Material	Thickness (mm)	Material	Thickness (mm)
	OUTSIDE		OUTSIDE	
			Clay Tiles (Terracotta)	75
	Asphalt	10	Screed	50
	Screed	50	Vermiculite	150
	RCC Slab	150	Silicon Aerogel Insulation	25
	Cement Plaster	12	RCC Slab	150
			Plaster	12
	INSIDE		INSIDE	
	Total Thickness (mm)	**222**	**Total Thickness (mm)**	**462**
	U-Value (W/m2.K)	**0.861**	**U-Value (W/m2.K)**	**0.18**

Table 04 : Roof and Wall assembly specifications

For the wall and roof assembly of the building we referred to ECBC Guidelines to maximise the building's efficiency.

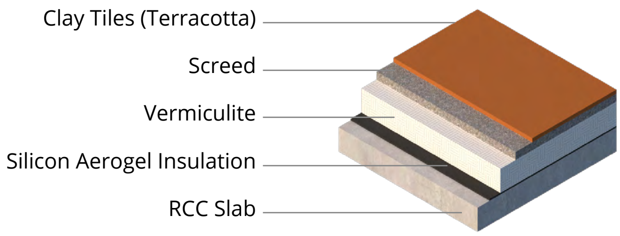


Figure 31 : Roof Assembly

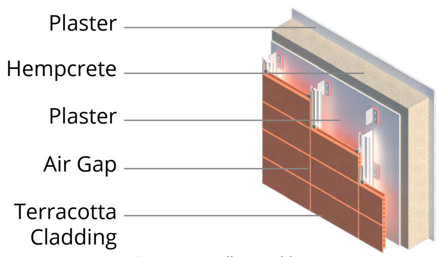


Figure 32 : Wall Assembly

TERRACOTTA VENTILATE FACADE

Nepal has a humid climate for 50% of the year and heavy rainfall during the monsoon months. Considering these climatic factors, we opted for a terracotta ventilated facade system. Due to terracotta's high water absorption capacity it acts as a rainscreen, and draws moisture away from the structure and protects the hempcrete wall while preventing rise in humidity indoors and maintaining a steady temperature inside. Further, a flashing will be provided at joints between teracotta tiles to allow drainage of water from the cavity between the rainscreen and the wall.

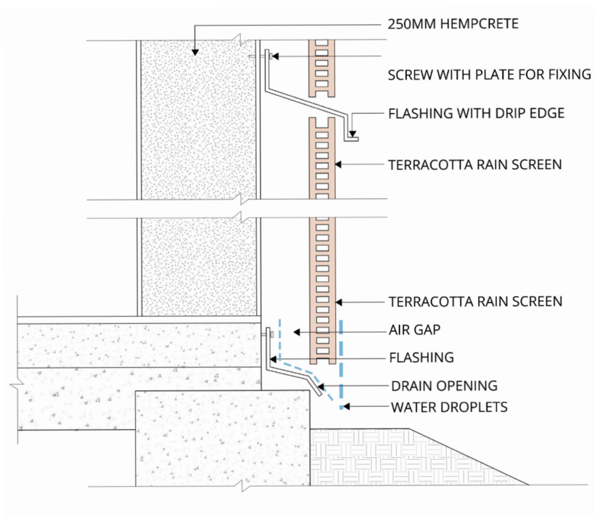


Figure 33 : Terracotta Ventilated Facade : Detailed Section

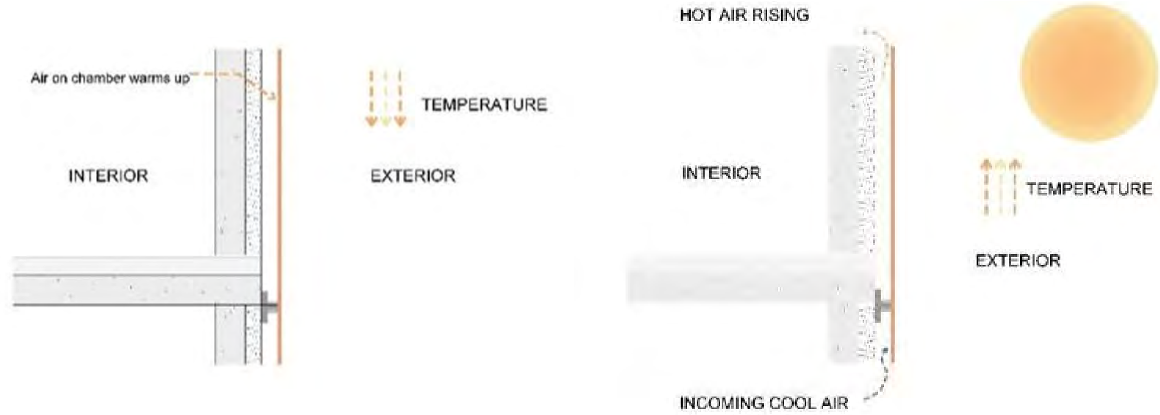


Figure 34 : Terracotta Ventilated Facade : Functioning

As terracotta is a porous material, after the point of saturation; i.e. when the screen absorbs humidity to the point it cannot hold in any more water, condensation occurs on the surface of these tiles. However, due to the presence of air gaps between the structure and the screen along with the gaps in between these tiles, a pressure difference is created, making the cool air from the bottom rise as hot air to the top, encouraging evaporation, and hence, preventing any sort of water damage to the structure. During Summers, where it tends to get uncomfortably humid, the terracotta facade (which is porous in nature) can absorb the moisture and help encourage evaporative cooling. During months of winter the facade retains heat due to the air cavity, while not letting the accumulated heat out.
Further, a flashing will be provided at these joints to allow drainage of water from the cavity between the rainscreen and the wall.

ENERGY CONSUMPTION

The building consumes energy in four major ways:

- Heating
- Cooling
- Lighting
- Equipments

For the base case and the proposed case, the equipment load remained the same but alterations were made in the heating, cooling, and lighting loads to minimise the building's energy consumption.

	BASE CASE - Energy Consumption (kWh/year)	PROPOSED CASE - Energy Consumption (kWh/year)
HVAC	3,41,606	1,28,131.39
Lighting	84,030	37,606
Equipments	1,74,657	1,74,657
Total Energy Use (kWh/year)	**6,00,293**	**3,40,394**

Table 05 : Annual Energy Consumption

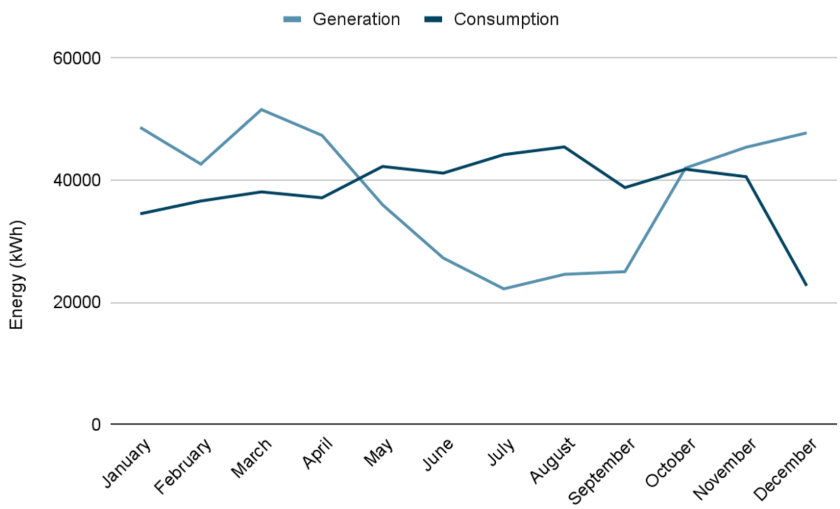


Figure 35 : Generation vs Consumption Statistics

The consumption pattern of the building does not match the generation pattern of the renewable energy system. This called for a strategy wherein the building was connected to the local grid for times of the year when solar energy generation is not enough.

RENEWABLE ENERGY ON SITE

Our site receives 0.2 kWh/sqm/year solar irradiation which gives potential for energy generation. The total roof area exposed to sun is 3500 sqm, out of which 3000 sqm is used for Solar power generation. The PV system array has been tilted at an angle of 30° to optimize the solar plant performance and for easy maintenance. The technical details for the same are as follows :

Area of roof exposed to the sun	3000 sqm
Panel Dimensions	1580×1062×40mm
Area of Panel	1.68 sqm
No. of Panels	655
Weight	20 kg
Array Tilt Angle	30 degrees

Brand	Energy NP
Model Name	96×5 Monocrys-talline Series 240Wp~265Wp 240Wp~265Wp
Peak Power Watts (W)	375
Panel Efficiency	18.4 %

Table 06 : Solar panel specifications

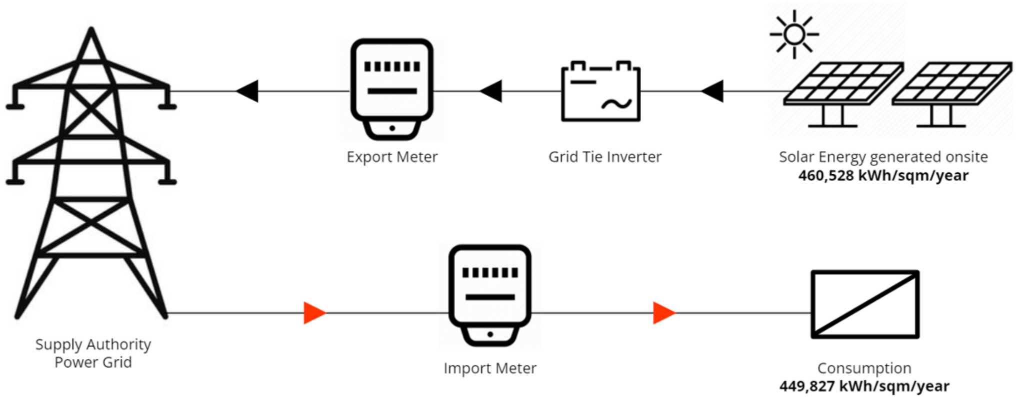


Figure 36 : Power Grid connection

The 290 kW plant size mandates gross metering in accordance with local regulations. The energy consumption is changed depending on the readings of the metres installed by the Nepal Electrical Authority (NEA) over a one-year period.
Solar panel energy production is uneven and fluctuating. As a result, we can employ a Grid Tie Inverter, which synchronises and converts the solar panel array's changing unregulated DC voltage to AC synced with the mains.

Energy Consumption (kWh/year)	(kWh/sqm/year)	Energy Generation (kWh/year)	(kWh/sqm/year)	Net-site energy (kWh/sqm/year)
4,49,827	37.5	4,60,528	38.4	+0.9 (net zero)

Table 07 : Energy performance of the building

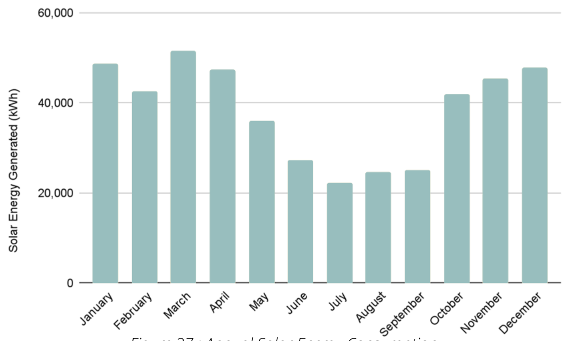


Figure 37 : Annual Solar Energy Consumption

REQUIREMENT

37.5 kWh/sqm/year

GENERATION

38.4 kWh/sqm/year

Net Zero energy status of the building = 38.4 - 37.5
= **0.9 kWh/sqm/year (Net Zero achieved)**

WATER PERFORMANCE

Various techniques were employed to ensure a water sufficient educational building with no dependency on the municipal water supply. Emphasis was placed on reducing per capita consumption by employing efficient fixtures, while site & climate responsive landscaping reduced irrigation water loads. Water from the domestic uses was further recycled for non-potable uses in the campus. Ample rainfall in Kathmandu allowed utilization of rainwater for domestic use. An artificial pond was proposed to the south of the site to store the rainwater.

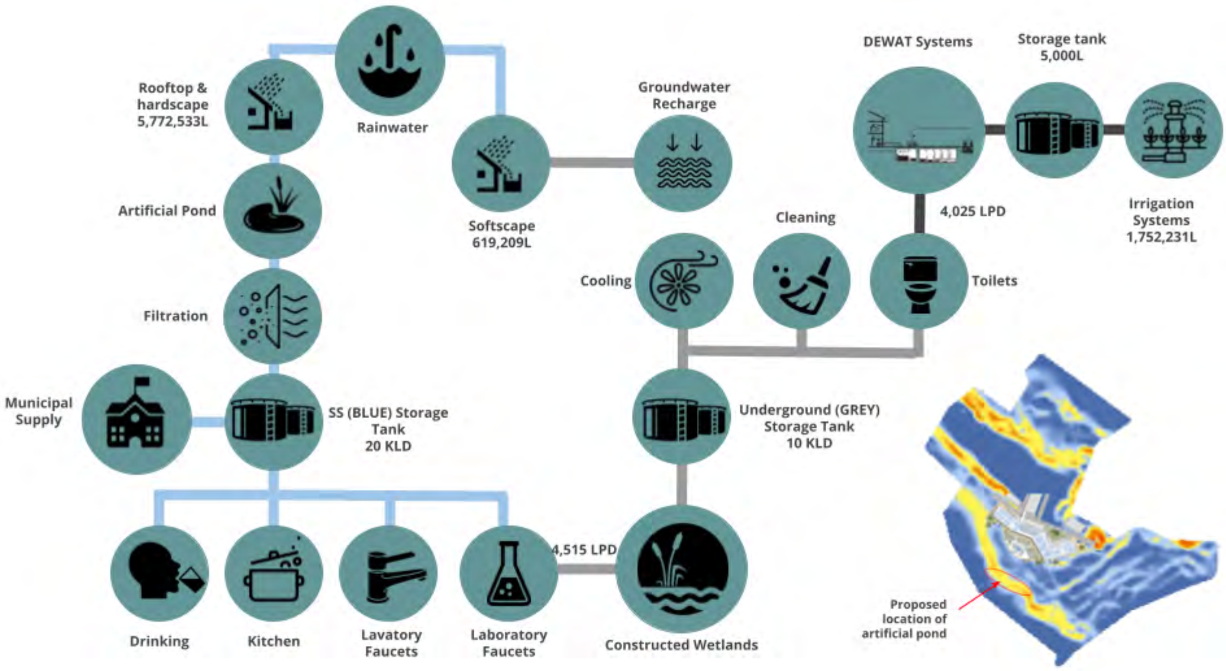


Figure 38 : Water Cycle Diagram

			Consumption								Water Sources				
Month	Days in Month	Working Days	Domestic Use Blue (L)	Domestic Use Grey (L)	Lab Use Blue (L)	Irrigation Use (L)	Cons. Blue (L)	Cons.Grey (L)	Total Cons. (L)	Municipal Water (L)	Rain Water (L)	Grey Water (L)	Black Water (L)	Total Stored (L)	Total stored after losses (assuming 1000 m.sq. surface area)
Jul	31	23	186,079	122,544	10,350	165,683	196,429	288,227	484,657	-	1,844,923	107,129	124,769	1,296,776	1,188,276
Aug	31	23	186,079	122,544	10,350	155,328	196,429	277,872	474,301	-	1,681,700	107,129	124,769	2,455,778	2,254,278
Sept	30	22	177,989	117,216	9,900	150,318	187,889	267,534	455,422	-	806,227	103,673	120,744	2,835,694	2,544,194
Oct	31	23	186,079	122,544	10,350	134,618	196,429	257,162	453,591	-	158,278	107,129	124,769	2,632,872	2,260,772
Nov	30	22	177,989	117,216	9,900	98,375	187,889	215,591	403,479	-	0	103,673	120,744	2,333,065	1,903,965
Dec	31	23	186,079	122,544	10,350	77,664	196,429	200,208	396,637	-	0	107,129	124,769	2,043,557	1,567,957
Jan	31	23	186,079	122,544	10,350	92,390	196,429	214,934	411,363	-	9,892	107,129	124,769	1,748,300	1,223,100
Feb	28	20	163,831	107,892	9,113	102,884	172,943	210,776	383,719	-	54,408	97,625	113,701	1,511,582	924,232
March	31	23	186,079	122,544	10,350	165,683	196,429	288,227	484,657	-	153,331	107,129	124,769	1,273,205	586,655
April	30	22	177,989	117,216	9,900	205,434	187,889	322,650	510,539	-	232,470	103,673	120,744	1,077,310	267,760
May	31	23	186,079	122,544	10,350	222,637	196,429	345,181	541,610	-	464,940	107,129	124,769	1,064,771	121,921
Jun	30	22	177,989	117,216	9,900	181,216	187,889	298,432	486,321	-	954,612	103,673	120,744	1,548,452	500,602
Total			2,178,340	1,434,564	121,163	1752230.6	2,299,503	3,186,795	5,486,297	-	5,772,532	1,262,216			1,548,452

Table 08 : Water consumption of the building

WATER PERFORMANCE

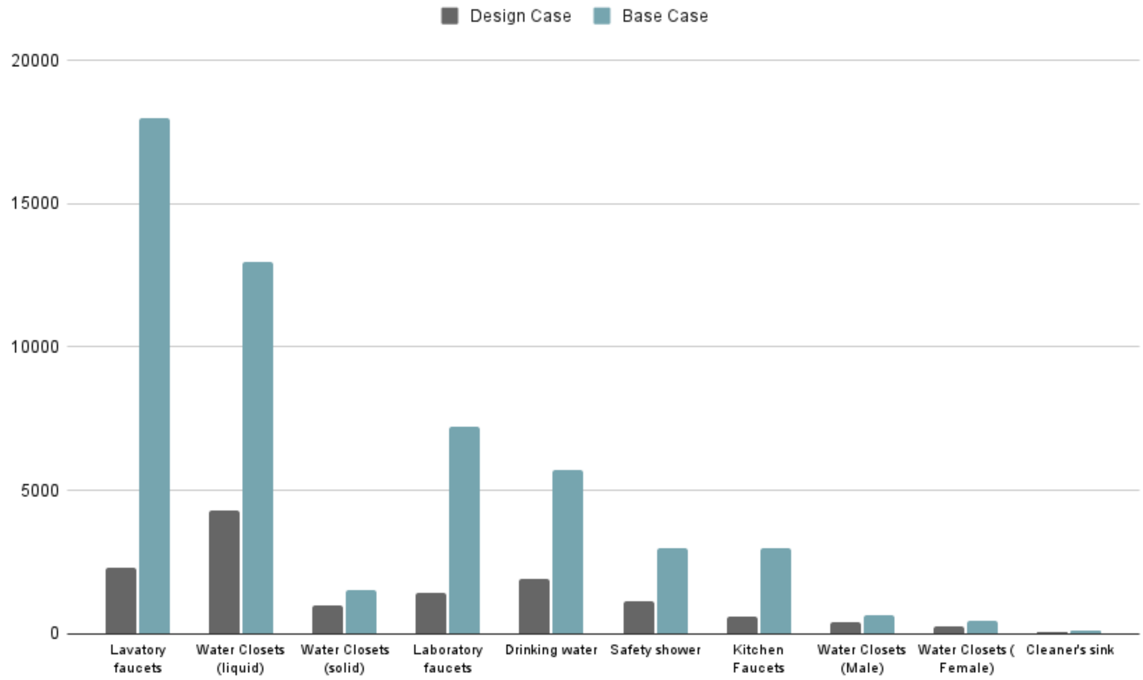


Figure 39 : Domestic Water Use Comparison

End Use	Percent use	Use in LPD (grey)	Use in LPD (blue)	Greywater in LPD (generated)	Blackwater in LPD (generated)
WC flush	40%	5,328.00		0.00	5,328.00
Kitchen Faucets	4%	-	600.00	600.00	0.00
WC bidet/taps	5%	-	684.00	0.00	684.00
Drinking	14%	-	1,900.80	0.00	1,900.80
Lavatory faucet	17%	-	2,280.00	2,280.00	0.00
Laboratory faucet	11%	-	1,440.00	0.00	1,440.00
Safety shower	8%	-	1,140.00	1,140.00	0.00
Cleaner's sink	0%	-	45.60	45.60	0.00
Total	**100%**	**5,328.00**	**8,090.40**	**4,065.60**	**4,024.80**

Table 09 : Domestic use of water and generation

Total Annual Water Reduction (using efficient fixtures) = 74.48%

RAINWATER HARVESTING

Out of all catchment areas i.e roof, hardscapes and softscapes, the roof receives the maximum rainwater. This water goes through a rainwater harvesting filter which automatically flushes out dirt and debris.
The harvested water is stored in two underground storage tanks each of
108 cum. This water is used in drinking fountains, kitchen sinks, and washbasins.

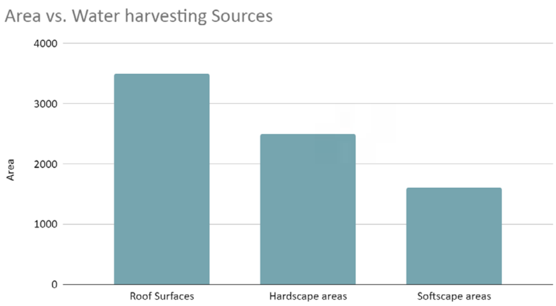


Figure 40 : Rainwater Harvesting Sources

WATER PERFORMANCE

ON-SITE WATER TREATMENT

For on-site wastewater treatment, we used DEWAT Systems and Constructed Wetlands as a cost effective, natural and sustainable treatment system for wastewater.

DEWATS is a technical approach to decentralized wastewater treatment. This system uses physical and biological treatment mechanisms such as sedimentation, floatation, aerobic and anaerobic treatment, to treat both, domestic and industrial wastewater sources. It is affordable, low maintenance, uses local materials, and meets environmental laws and regulations.

Considering the treatment efficiency, we used different treatment plants for grey water treatment and black water treatment so that the treated grey water can be used in cooling and cleaning after disinfection by UV treatment, whereas the treated black water can be used for irrigation.

LANDSCAPING STRATEGIES

S.No.	Month	Total water requirement (L)
1	January	83,436.60
2	February	103,622.88
3	March	166,873.20
4	April	206,909.31
5	May	224,235.87
6	June	176,629.90
7	July	166,873.20
8	August	156,443.63
9	September	151,397.06
10	October	135,584.48
11	November	95,884.80
12	December	78,221.81
Total Annual Water Requirement		**1,746,112.75**

Table 10 : Landscaping water demand

We have used a combination of systems (mechanical + natural) in order to achieve greater reduction in landscape water demand. In addition, we have used native trees, grass, shrubs and fruit trees to reduce the water demand and increase bird diversity.

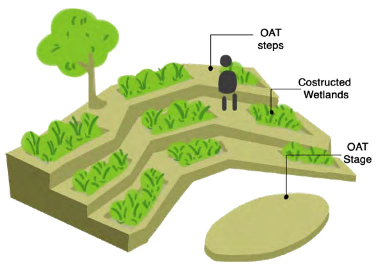


Figure 41 : Water system proposed for design

Total Annual Water Reduction = 21.39 %

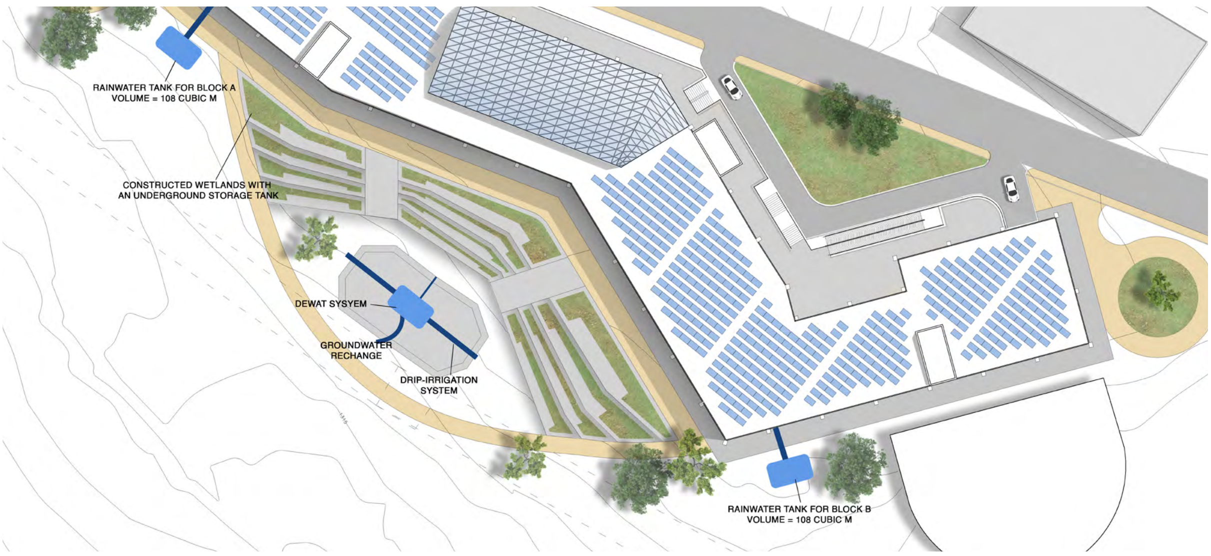


Figure 42 : Landscaping onsite

RESILLIENCE

Earthquake Resilience

Kathmandu lies in the zone 4 category of earthquake zones as per the Nepal National Building code NBC 105 : 1994. Steps have been taken to make the building earthquake resistant by designing in compliance with earthquake code of the Nepal Standard. The building frame system used in our design is Reinforced concrete with expansion joints provided at an interval of 30 metres (IS code 3414 of 1968,table 2 Clause 4.4). The building has been reinforced with shear walls at different places and all columns have reinforcement as per the NBC code for earthquake resilience.

Cyclone/ Heavy Rainfall Resilience

Strong connections between foundations and the roof make the building wind-resilient. Introduction of the central atrium reduces wind force and pressure to the roof by sucking in air from outside. Facade treatment involves the use of a terracotta rainscreen which acts as a weather-resistant barrier. A well planned and maintained gutter system to ensure proper no clogging takes place leading to flooding onsite. Rainwater collection system throughout the site to ensure no water gathers onsite and it also helps in achieving a net zero water status for the building.

Fire Resilience

Our building is designed in accordance with the fire safety norms of the Nepal NBC 107 : 1994. Water sprinklers have been provided at appropriate distances. All the staircases are compliant to fire safety and the code for egress. Automatic fire detection system has been installed as per NBC. Fire extinguishers at regular intervals are placed. There is pressurization in the staircase and lift shaft. The basement has fire exits and sprinkler systems installed and the fire staircases lead to outside. All the emergency fire equipment such as fire pumps, ventilation and smoke dampers, emergency lighting, fire exit signage etc. are connected with a backup generator and they would function even in case of electrical failure. Safety protocols are expected to be followed and will be taught to the students as part of fire safety training.

Figure 43 : Fire Safety Plan

Public Health Hazard

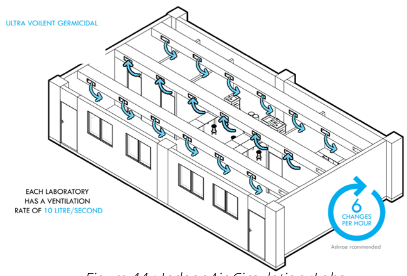
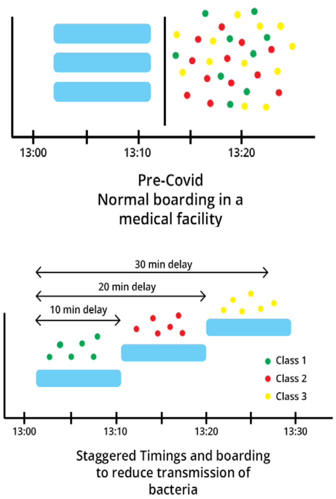


Figure 44 : Indoor Air Circulation :Labs

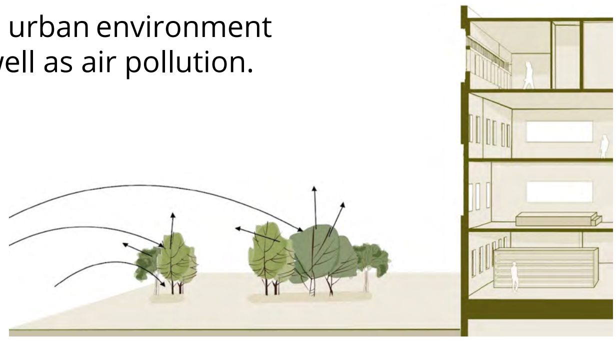
Buildings have recently had to adjust to the prospect of operating during pandemics.
Indoor air recirculation shall be prevented or reduced to the greatest extent practicable. One of the initiatives we took to achieve this in ourinterior areas was to install a DOAS (Dedicated Outdoor Air System).



Touchless technology for hand soap, hand sanitizer, and paper towel dispensers have been introduced to reduce transmission of any infection.
Arrival and departure timings, class transitions, are all staggered to prevent people from entering or exiting the building at the same time. Even a 5-10 minute time difference between tenants will considerably reduce the number of individuals in the corridor heading to the door at the same moment for dismissal.
Using pressure differentials to manage airflow across zones is a prevalent technique in healthcare settings. Negative pressure would be applied to areas such as the administrative office, procurement rooms, record rooms, and building cores.

Pollution Resilience

Due to the site's location in a densely packed urban environment there is always a risk of noise pollution as well as air pollution.



This building is an educational institution so having proper acoustic control is a priority. Wall panels, acoustic ceilings, building materials, and other ways for decreasing mechanical ventilation and street noise are all taken into consideration to increase the acoustic quality of the lecture rooms, seminar halls and other similar spaces. With outside noise levels going above 88Db , we aim to maintain the indoor noise levels in between (30dB - 45dB).There is a lot of pollution from vehicles, as well as emissions from household fuels, and brick manufacture. The use of appropriate materials on the exterior façade, as well as enough flora around the structure, aids in the reduction of air and noise pollution within the structure to a greater extent.

Thermal Comfort

The buildings' spaces are intended to be utilized in a variety of ways for various occasions. Our strategy was to build areas that could both produce a wonderful environment and serve as a replacement for another purpose.
The use of an atrium inside the building, an open interactive space on the south west side of the building, with effective landscaping helps create a cooler site atmosphere. These strategies create a comfortable environment in and around the building, and remove the heat from air using evapotranspiration, i.e., decreasing the surrounding and surface temperatures.

Lab Resilience

Since our building has special laboratories, we need to protect these areas keeping in mind the kind of equipment and chemicals used there. We have tried to incorporate lab standards as per the Neufert 4th edition.

Work Station:

- The benches are fixed and movable, in the workstation module; standard workbench: 120cm width for practicals, 80cm depth of work surface are taken for our lab room.
- Benches are made of steel tubing, with work-surfaces of stoneware panels without joints, less frequently tiles, or chemical-resistant plastic panels.
- Low cupboards are of wood or chipboard with plastic laminate. Supply services are from above from the ceiling void, or from below through the floor structure.

Water Sufficiency

On an average our yearly fresh water consumption is around 5,486,297L. Recycled gray (4,515 LPD) and Black water(4,025 LPD) is used to meet the rest of the water demand. We need fresh water for 5 days to keep the school running, therefore we erected two water tanks, one for storing blue water with a capacity of 20 KLD and the other is an underground grey water storage tank with a capacity of 10 KLD .

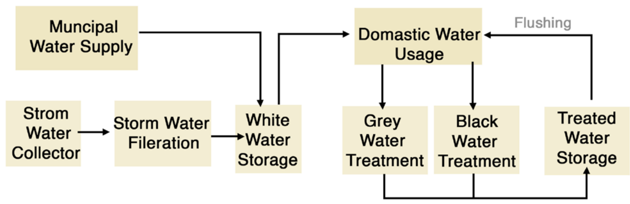


Figure 45 : Schematic Water Cycle

We have verified that the irrigation and toilet water requirements are satisfied by the treated black water from the DEWATS treatment plant, and the washing and cleaning requirements are covered by the treated greywater by precise water calculations.

Energy Sufficiency

Grid-interactive inverters produce AC power that matches the existing power presented on the grid. In particular, a grid-interactive inverter must match the voltage, frequency and phase of the power line it connects to.

For a building of this size, the battery backup would be large. The solution that we are using is to integrate inverters with a smart digital controller. This technology will be helpful whenever the connection with the grid is interrupted and we need a stable supply of electricity to the building.

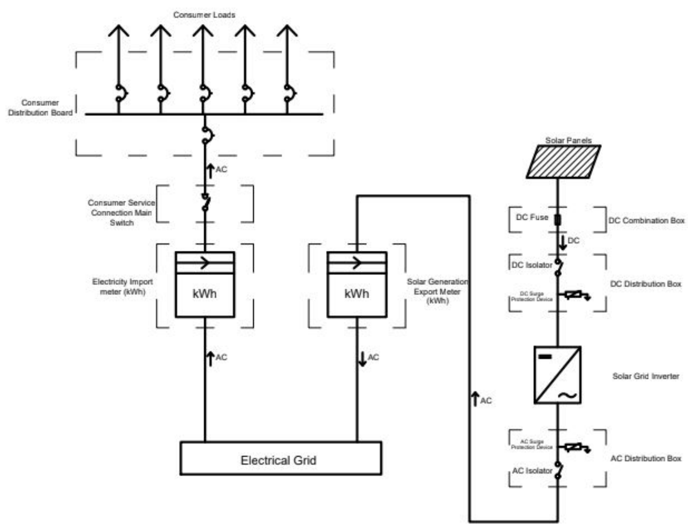


Figure 46 : Solar Panel System SLD

Safety and Security

Crime Prevention Through Environmental Design (CPTED) is a strategy that focuses on enhancing the built environment's design .The site's perimeter has been well marked and a visual barrier has been created by the use of proper landscaping. Pedestrian walking zones have been isolated from automobile pathways. The public and private sections are distinguished vertically from one another by the space zoning provided by us . Parking is available on-campus. People can keep an eye on who is entering and when from the administrative area, which faces the front.

INNOVATION

Material Recovery Facility (MRF)

A materials recovery facility (MRF), sometimes called a materials reclamation facility or materials recycling facility, is a plant that separates and prepares single-stream recycling materials to be sold to end buyers.

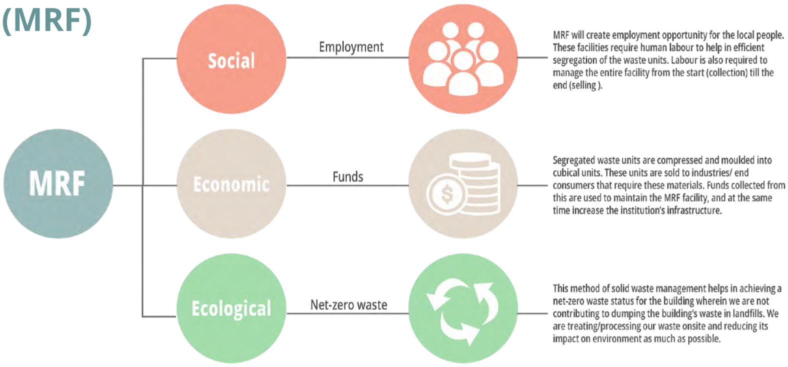


Figure 47 : Material Recovery Facility

Materials recovery facilities sort a wide array of recyclable materials, including, but not limited to: plastics, cardboard (OCC), paper, glass, metal, etc.
This method of waste management helps us in achieving a net-zero waste status for the building, while simultaneously providing the opportunity to collect funds to improve the institution's infrastructure and create employment opportunities for the society. (Details as part of Engineering and Operations)

Biosolar Roof System

Biosolar roof system primarily works by combining the two technologies - solar power and green roofs. It acts as smart green infrastructure which is multi-functional where both these systems benefit each other. The microclimate around the panels is important for the functioning of the panels. If it is too hot, the panels can lose efficiency. High temperature can decrease PV panel productivity by 25% and a value of -0.45% per degree Celsius (Peck & van der Linde, 2010). Another factor that contributes to decreased efficiency of panels is the pollution around which decreases it by 1.5%. The green roof element have a cooling effect from evapotranspiration and reduced pollution around, which enables a higher efficiency of PV panels. Year round, green roofs can help to keep ambient temperatures around the panels at or near 250C. This is the best temperature for solar panels to work most efficiently.

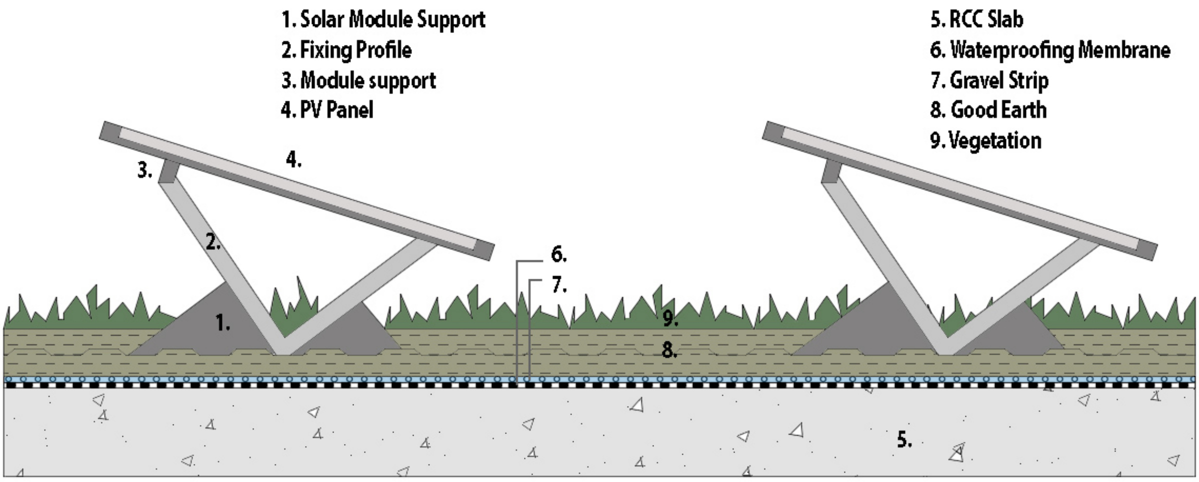


Figure 48 : Biosolar Roof System

The panels can create shaded areas underneath, with rain run-off making damper areas to the front and drier areas behind. This leads to flourishing of the green cover nearby. The panels also shade the plants from excessive sun exposure and evaporation which leads to more plant growth. The green roof helps in increasing the thermal comfort of the interiors and at the same time we are able to produce enough energy for the building. This system increases the electricity generation by 10% (Sam C M Hui, 2011).

Lab Monitoring System

Since this is a super speciality institution we wanted to maximise the comfort of the place where the students will spend the majority of their time - the laboratories. In order to do so we are proposing a lab monitoring system which will work towards monitoring the conditions of the lab and then providing a 24x7 feedback to the management (or whoever is in-charge).

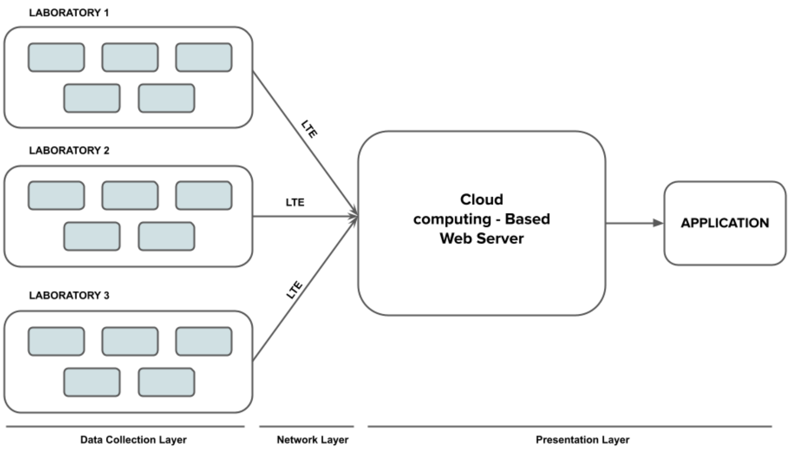


Figure 49 : LMS Database

The LMS is designed to issue alert mobile application users or facility managers of undesirable lab conditions such as unsuitable temperature, unsuitable air pressure, fumes, etc., so that responsible parties can take immediate action. This device has an expandable interface such that multiple sensors have been installed in a single device and these sensors vary from lab to lab depending upon the nature of the lab and the type of research being carried out.

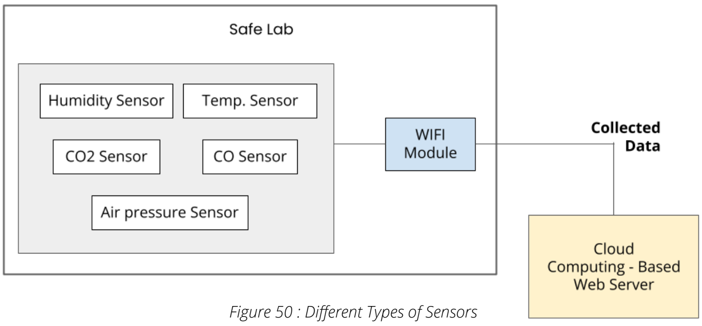


Figure 50 : Different Types of Sensors

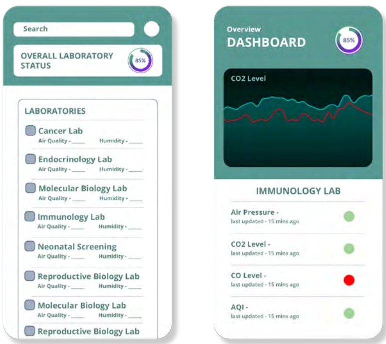


Figure 51 : Mobile Application Interface

This app will be developed in the following steps :

- Use of the Sensors for the precise monitoring of temperature, air pressure, humidity levels, Fume levels (CO2,CO etc.)
- Utilization of an IoT for efficient monitoring of real-time data
- Adoption of cloud computing for real-time analysis of indoor air quality
- Developing a mobile application- SafeLab to make the proposed IoT system with features of anytime, anywhere.

The main benefits of the cloud computing-based web server are faster speed, flexibility, and greater accessibility. The platform is designed based on an architecture of IoT platform that is mainly comprised of three components:

- Data collection layer, Network layer, Presentation layer
- The data collection layer is the sensing component to collect data using sensors or any measuring devices. The network layer is responsible for transmitting the detected data using a wireless network module. Finally, the presentation layer allows data visualization and storage for efficient monitoring.
- Use of alarms to indicate undesirable conditions within the labs

This monitoring system will be created in partnership with our Industry Partner Archeva Technologies. They specialise in building automation and smart controls, and this monitoring system will be integrated with the entire automation system of the building.

MARKET POTENTIAL

Tribhuvan University is the oldest and largest university in Nepal and is ranked in the top 800-1000 universities in the world. Adding a medical facility along with an academic block dedicated to the same will help in uplifting the name of the university more. It is the only location in the whole area allocated for a medical institution, making our facility the designated university for not just all medical students in the area, but also outstation students aged 22 to 30, with instructors and staff ranging in age from 40 to 60. The university offers master's and doctorate courses.

The location is in a growing region with a variety of housing, educational, and office projects in the works. A huge number of individuals work in both the public and commercial sectors in this area. A premium medical institute would be perfect for meeting the academic demands of students in this category since it allows them to have a more realistic understanding of how a medical facility operates. As a result, our design will be among the first buildings in Nepal to be built with this hempcrete, providing people with an example of how it works.

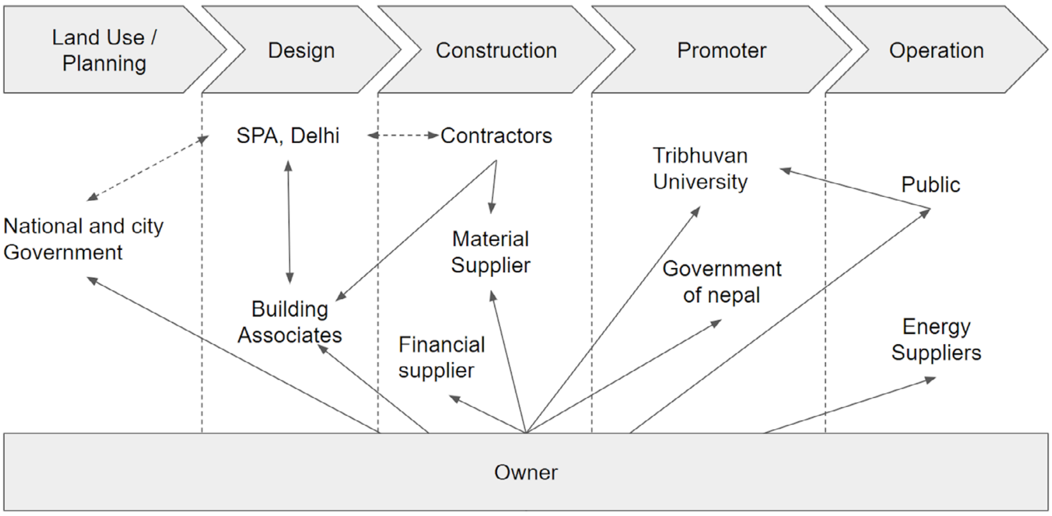


Figure 52 : Business Model for the Building

Our local environment is still growing in terms of infrastructure and currently lacks basic facilities. The area's planned growth, combined with the fact that our college caters to the demands of the target population, will entice the intended market.

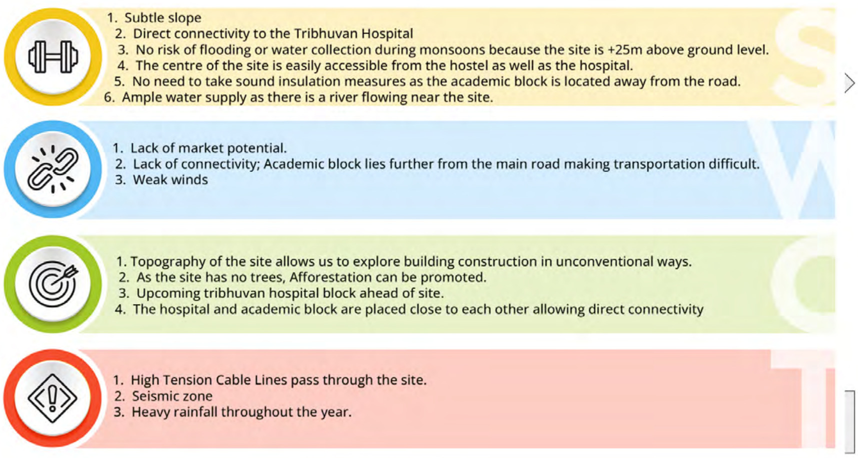


Figure 53 : SWOT Analysis

The project was created with the goal of becoming a net-zero energy, self-sufficient water facility. Tribhuvan University and the Nepalese government are the project's promoters. The user group includes the general population.

The construction of a hospital and a residential complex for employees, physicians, and students is expected to commence in the near future.

SCALABILITY

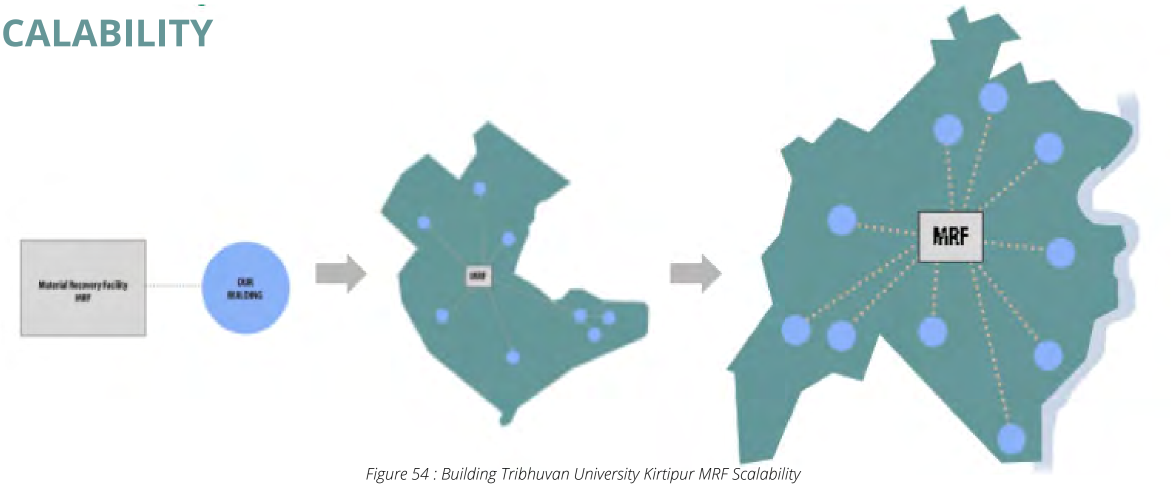


Figure 54 : Building Tribhuvan University Kirtipur MRF Scalability

We saw the lack of efficient waste disposal system around our site as an opportunity to venture into the world of waste management to create a waste management facility. Using this approach,we set up a Material Recovery Facility (MRF) onsite which is used to segregate the waste and create clean waste from the mixed waste. This clean waste is used to earn profit by selling it to the respective end consumers. The recyclable materials are sold to the recyclers and some industries, whereas the non-recyclables are sold to specific industries interested in buying this clean waste. This method can be adopted by any facility lacking an efficient waste disposal system to not only earn profits, increase employment but also to become a net-zero waste facility. This approach creates a net-zero waste structure with minimum generation and dumping of waste in landfills, providing a clever solution for a realistic problem faced by many high-density projects. We can set up an MRF at the Tribhuvan University Campus level and in future a community-level expansion is also possible. Kirtipur does not have a proper waste management system so this approach reduces the pressure on the landfills by 80%. Apart from the landfills the waste is currently also dumped on the banks of river Bagmati and setting up a community-level MRF will also protect this major water source from further pollution.

Lab Monitoring System

We have also developed a LMS (Lab Monitoring System) in order to monitor the environment of the labs 24*7. Labs are the most vital feature of our institute and the students will be spending a lot of time here. This led to the special attention being paid to the labs, but in future as the pollution level rises and as the budget for infrastructure development increases we can expand this monitoring system to a building scale or a campus scale.

A monitoring system can be useful in other spaces within the building. These systems can be used to assess the Carbon dioxide levels, temperature, air pressure, humidity levels, AQI, IAQI etc. Spaces like Lecture halls will need specific type of sensors. Service areas will need other kinds of sensors. With the changing climate and rise in pollution everywhere such monitoring will be necessary.

Figure 55 : Scalability of Monitoring System

AFFORDABILITY

Comparison of total project cost :

PROPOSED CASE vs BASE CASE

The cost of the proposed case is higher than the baseline estimates due to added cost of installations to reduce the embodied energy, such as, PV panels, alternative materials and hybrid construction. Since hemcrete is a relatively new material, the cost of sourcing it is slightly higher than its alternatives, however, its contribution to energy optimization outweighs the cost.

Project Summary								
S.No.	Particulars	Definition	Baseline Estimate (Project Partner / SOR basis)			Proposed Design Estimate		
			Amount (Rs Millions)	Cost in INR1Rs = 1.61NPR	%	Amount (Rs Millions)	Cost in INR1Rs = 1.61NPR	%
1	Land	Cost of land purchased or leased by the Project Partner	0.00	0	0.0%	0.00		0.0%
2	Civil Works	Refer Item A, Civil works in Cost of construction worksheet	147.94	238.1834	50.7%	158.62	255.37	54.3%
3	Internal Works	Refer Item B, Civil works in Cost of construction worksheet	57.94	93.2834	19.9%	56.38	90.77	19.3%
4	MEP Services	Refer Item C, Civil works in Cost of construction worksheet	70.08	112.8288	24.0%	86.69	139.5	29.7%
5	Equipment & Furnishing	Refer Item D, Civil works in Cost of construction worksheet	0.00	0	0.0%	0.00		0.0%
6	Landscape & Site Development	Refer Item E, Civil works in Cost of construction worksheet	2.01	3.2392234	0.7%	2.04	3.28	0.7%
7	Contingency	Amount added to the total estimate for incidental and miscellaneous expenses.	13.90	22.37618082	5.0%	15.17		5.0%
	TOTAL HARD COST		**291.87**	469.9110042	**100.2%**	**318.90**	**513.42**	**109.1%**
8	Pre Operative Expenses	Cost of Permits, Licenses, Market research, Advertising etc	-	0	0.0%	-		0.0%
9	Consultants	Consultant fees on a typical Project	-	0	0.0%	-		0.0%
10	Interest During Construction	Interest paid on loans related to the project during construction	-	0	0.0%	-		0.0%
	TOTAL SOFT COST		**0.00**	0	**0.0%**	**0.00**		**0.0%**
	TOTAL PROJECT COST		**291.87**	469.9110042	**100.0%**	**318.90**	**513.42**	**109.3%**
	Total Project Cost per Sq.m of Built-up Area		**17,961**	28917.60026		**19,624**	31,594.64	

Table 11 : Cost Summary of Project

CONSTRUCTION COST BREAKDOWN

- The right sizing of the various elements in the MEP services by various Design strategies lead to reduction in expenses for installation and maintenance .
- The use of radiant cooling with vapor absorption chillers due to availability of steam in the site, along with ventilation fans, has proved to be more efficient than conventional systems in terms of energy efficiency.
- No insulation is used in the wall which reduces the internal work cost by a considerable amount.

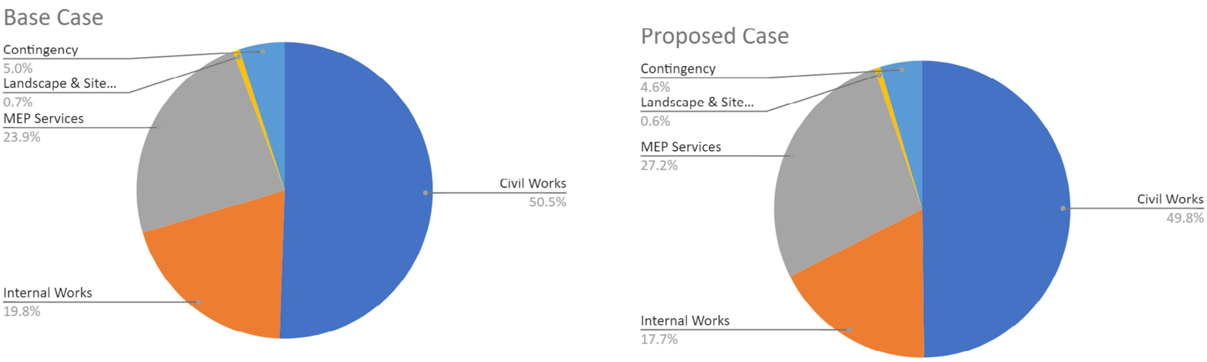


Figure 56 : Construction Cost Breakdown- Base Case vs Proposed Case

Cost Performance Review :

Design Intervention

- Continual design concept ensures faster tenant occupancy increasing the internal rate of returns which will be higher than the base case.
- The post modernist style of architecture increases the cost of finishes.

Cost Performance Review :

Energy Interventions

- Solar PV Panels- The solar PV panels give us 3.1 million Rs. savings per year, with payback period of 9 years.
- Optimized daylight reduces the need for electrical lighting which converts to 5.6% reduction in lighting power density.
- Electrical Appliances- The electrical appliances are energy efficient, which are generally costlier, but this in turn reduced our energy demand.
- HVAC- The ground source heat pump and radiant flooring system comes up to 24.31% in savings in 20 years when compared to a VAV System.

Water management

- Rain water harvesting makes the project net water zero. The use of harvested rainwater contributes to the reduction of municipal drinking water use and has the potential to save a significant amount of water per year.
- Water- Using efficient fixtures, to reduce water demand; reducing overhead tank sizes.
- Overhead tank supply to reduce the energy consumption utilizing gravity-fed plumbing.

Renewable Energy Cost Evaluation :

Before the proposal to install the solar PV array, the feasibility of investment is assessed by accounting for the costs of the hardware, equipment, installation costs and indirect labor costs for each of the orientations individually. The array of 660 panels was installed on the rooftop with capital cost of 8.5 million NPR and payback period of 9 years.
Over a period of 20 years life of the solar PV, the operation and maintenance are estimated at 1% of the capital expenditure. Over a 20 years life of the solar PV, the operation and maintenance are estimated at 1% of the capital expenditure and degradation of generation of 1% annually is considered for the solar panels.

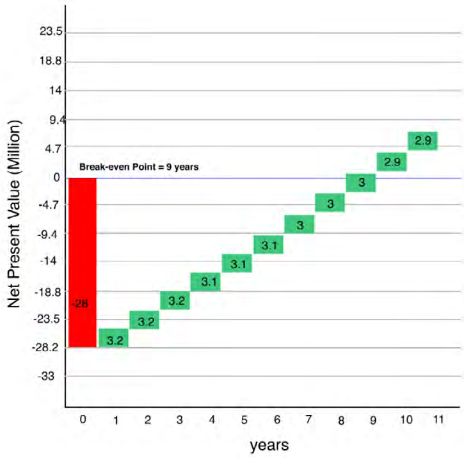


Figure 57 : Economic Feasibility of Solar PV Array

LCC cost breakdown :

Calculation of returns, mostly based on upfront costs, at times might not be able to obtain a clear picture of the total benefits of green initiatives and net-zero buildings.

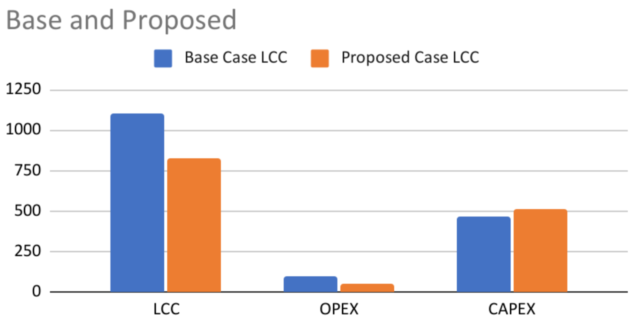


Figure 58 : LCC Base Case vs Proposed Case

Life cycle cost analysis is hence used to enable decision-making that is beneficial to the developer and the tenants/owner.
Life cycle cost analysis for a period of 10 years, for base case, compared to proposed case incurred incremental cost of 275 million NPR for energy conservation measures, to improve the occupant environment. The life cycle cost decreased by 25% i.e., from 1101 million to 826 million.