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PUNAPUR POLICE STATION

Final Design Report - April 2023

Punapur Police Station for Nagpur Smart and Sustainable City Corporation Limited

Team V⁰ Office Building Division

Visvesvaraya National Institute Of Technology, Nagpur

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01 Executive Summary

Team V0 comprises a group of 15 students - 13 from the field of Architecture and 2 from Engineering - hailing from the esteemed Visvesvaraya National Institute of Technology (VNIT) in Nagpur. Traditionally, police stations have been perceived as intimidating and uninviting spaces that people hesitate to visit, rendering them inaccessible to the general public and severely limiting their usage.

The team's assignment was to work on the **Punapur Police Station** project, which is an integral part of the Pardi-Punapur TPS of Nagpur's Smart City initiative, and collaborate with the Nagpur Smart City Project as their project partner. The site is located in Pardi, Nagpur, India, and is rapidly developing.

The team was tasked with developing a new kind of police station that would align with the principles of the Smart City initiative, which includes making government buildings accessible and open to the public, designing sustainable buildings, and utilizing smart technologies to promote good governance.

To achieve energy efficiency, the team implemented various strategies such as grouping mechanically ventilated and conditioned spaces together, optimizing the window-to-wall ratio (WWR) to an average of 18%, incorporating twin courtyards to enhance natural light and ventilation while minimizing reliance on artificial lighting, and utilizing an external bamboo skin and shading device to achieve a remarkable **69%** reduction from the GRIHA benchmark and achieve an EPI of **78.8 kWh/m2/year**. The team also devised a peer-to-peer energy sharing mechanism to facilitate renewable energy sharing within the building, thus reducing dependence on carbon-heavy grid electricity.

The team also ensured that the building's water requirements were largely met through rainwater harvesting, which amounted to **2,456,215 liters**, thereby reducing dependence on municipal water sources. Additionally, **1,247,857 liters** of recycled water were utilized to create a net-zero water cycle, with any surplus water being used to replenish the groundwater table. The building's thermal comfort was also prioritized, with the team capping maximum temperatures at **32 degrees** Celsius and ensuring resilience during heatwaves. This was achieved through the development of an external bamboo skin and shading device to reduce electrical and cooling loads.

The team worked with Punarnava Ecological Services' partner, Ar Pradyumn Sahastrabhojanee, to design the external bamboo skin, and made sure to strike a balance between practicality, technology, cost, and performance at every step. The end result is a net-zero energy and water building that significantly enhances the quality and status of police station buildings.

02 Response to reviewer’s comments

Energy Performance:

Basecase was derived from GRIHA.
Solar calculation corrections were done.
Consumption Generation imbalance is solved using peer-to-peer energy sharing mechanism.

Water Performance

Headers were corrected and readability has been increased.
Graphs corrected.
Surplus water is stored in fire station’s tanks.

Embodied Carbon

All the calculations were done using the EDGE tool.
Additional required data has been added.

Resilient Design

Flood strategies elaborated and thermal comfort graphs enlarged.
Days and hours of autonomy added along with battery sizing.

Engineering and Operations

Solid waste management strategies added along with lighting layout.

Architectural Design

Additional required drawings added.

Affordability

Life Cycle Costing added.

Innovation

Further explaination regarding feasibility has been added.

Health and wellbeing

Simulations added for better understanding.

Value Proposition

Value additions for Smart City Project and larger community has been explained.

03 Team Introduction

Team Name: Team V⁰

Institution Name: **Visvesvaraya National Institute of Technology, Nagpur**

Division: **Office Building**

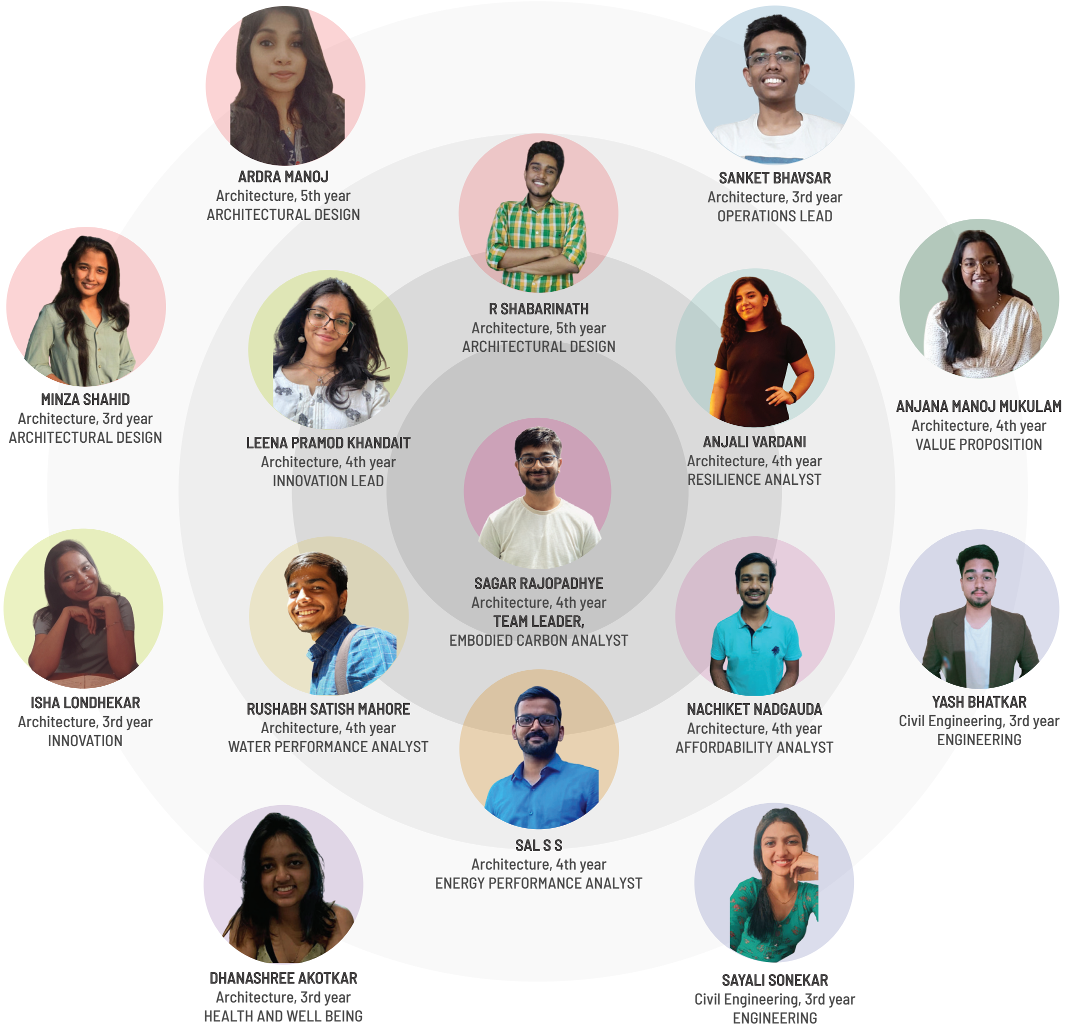


Fig. : Introduction to team members and their roles

About VNIT

Visvesvaraya National Institute of Technology (VNIT) is one of the 31 National Institutes of Technology in the country, and is an institute of national importance. The main degrees conferred to students are B.Arch, B.Tech & M.Tech.

The coursework relevant to the 10 contest areas are - Climate Responsive Architecture, Green Architecture, Environment Behavioral Studies, Estimation & Valuation, Appropriate Technology, Disaster Management, and Architectural Design.

About Team V⁰

Team V⁰ *(V- nought)* comprises fifteen students currently enrolled in architecture and engineering programs at Visvesvaraya National Institute of Technology in Nagpur. The team has a diverse composition, with members ranging from third to fifth year students in Architecture and Civil Engineering.

Faculty Lead

Meenal Surawar, Assistant Professor in the Department of Architecture & Planning at VNIT.

She is a researcher in UHI studies with core competencies in Urban Climate, Geographic Information Systems & Remote Sensing, Photogrammetry & Image Interpretation, Housing, Architectural Design, Landscape Design & Theory of Architecture.

Industry Partner

PUNARNAVA ECOLOGICAL SERVICES

Ar. Pradyumna Sahasrabhojanee, Partner

Punarnava is a team of ecologists and architects who specialize in environmental conservation. They consider all ecological factors, including water, land classification, soil, biodiversity, and people in their work. Their eco-friendly architecture uses non-polluting, earthy materials such as **bamboo**, found on the surface of the earth instead of extracting resources from underground.

Team Approach and Process

July '22
- Team V⁰ assemble
- Search for Project Partner

August '22
- Partnered with Smart city
- Nagpur
  - Discussion with project partner : Project & site introduction,
  - clients expectations and budget Site visits and analysis

September '22
- Assigning contest areas to team members
- Research and SLMs

October '22
- Case studies, context & site analysis,
- Pre-design analysis Preliminary Report

November
- Discussion with project partner; found requirements:
  - Water logging issue on site-need to raise plinth height
  - Strategies & design options discussed
- Predesign Analysis and Concept Report submission

December '22
- Change in Project Partner key individual
- Discussion with project partner
  - Idea of bamboo skin & shading device approved
  - Energy sharing mechanism innovation appreciated

January '23
- Industry partner for Bamboo found
- Site visit at a Bamboo workshop
- Prototype development

February '23
- Team Working on D3
- Detailing of individual contest areas
- Performing simulations Intermediate Design
- Development Report submission

March '23
- Team working on the reviewers' feedback and working on each contest area
- Preparing Architectural & Engineering Drawings
- Detailed Cost estimates & LCC

April '23
- Working on Final Report detailing
- Developing Bamboo Shading Device Prototype at Bamboo workshop
- Movie Making
- Final Report Submission

Finals Preparation...
- Making of final Presentations for the Division and Grand Juries
- Poster and shading device toolkit making
- Scaled physical model making of the project

Fig. : Team Approach and Process

04 Project Background

Project Name

Punapur Police Station, Pardi-Punapur TPS, Nagpur

Project Partner

Nagpur Smart and Sustainable City Corporation LTD, NSSCDCL

It is a government-owned company established with the aim of promoting sustainable urban development in the city of Nagpur, India.

It's primary goal is to improve the quality of life of Nagpur's citizens by providing them with better infrastructure, services, and opportunities while simultaneously promoting sustainable development practices. The corporation also places a strong emphasis on using innovative technology and data-driven solutions to enhance the efficiency of public services, reduce environmental impacts, and improve the overall livability of the city.

Key Individuals

Shri. Ajay Gulhane IAS, Chief Executive Officer, NSSCDCL

Shri. Rahul Pande, Chief Planner, NSSCDCL

Project Description

The proposed architecture design project involves creating a Smart Police Station at Punapur with the primary emphasis being on the convenience of police officers who will be the primary users of the facility.

NSSCDCL will make it to Build-own-operate, making it the first police station to be developed with smart city norms in the city. The project is necessary due to the expansion of the city commissionerate, which now includes 35 villages on the periphery of the city. The Kalamna police station, which previously covered this area, is now unwieldy, leading to the bifurcation and the creation of the Punapur police station.

Project Details

Location: Pardi-Punapur TPS, Nagpur

Climate Zone: Tropical wet and dry climate
(Aw in Köppen climate classification)

Project Stage: Design Development Stage
(Construction expected to start in October 2023)

Profile of Occupants:

1. Police Officers including Station House Officer (SHO) or Inspector, Sub-Inspectors, Assistant Sub-Inspectors, Head Constables, and Constables.
2. Suspects or Accused
3. Victims or Complainants
4. Witnesses
5. Support Staff

Fig. : Location and Site Context

Sanctioned Staff: 74 staff members with 7 officials, with a permanent requirement to have at least 23 staff present at all times.

Hours of Operation: 24 hours - 7 days a week

Proposed Budget: INR 12 Cr.

Site Details

Site Area : 12,152 Sqm

Permissible Builtup Area : 24,316 sqm

Ground Coverage : 13.1%

Proposed Builtup Area : 2927.2 sqm

FSI : 2

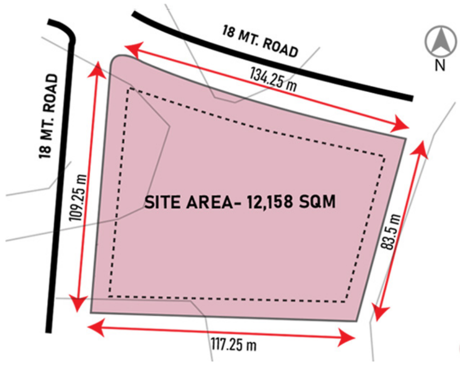
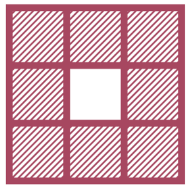


Fig. : Site Geometry

Special Requirements of Project Partner and Team V^0's Response

1. The inclusion of a courtyard in the structure is a crucial element that must be incorporated into the design.

   Our solution only does a courtyard provide a beautiful indoor-outdoor space, but it also helps to reduce the building's energy consumption and improve air quality.



2. The design could consider the needs of the surrounding community, such as creating public spaces or integrating greenery into the design.

   Our proposal includes the creation of a neighborhood pocket park and an art installation. These additions have the potential to improve the relationship between the police and local community by creating a welcoming and enjoyable space for both parties. Additionally, the park and art installation would enhance the quality of life for both police officers and community members.

3. Use of locally available materials to create an attractive building.

   As we developed our design, we explored innovative and eco-friendly materials and techniques that can help to reduce the building's carbon footprint and minimize its impact on the environment. We extensively worked on bamboo as an alternative building material.

4. The project partner has emphasized the need to develop the design with the Smart City mission and it's sustainability principles in mind.

   As a team, we were committed to creating designs that not only meet the project's requirements but also contribute to the larger vision of creating more sustainable, livable spaces.

05 Goals

Energy Performance

+ Target EPI : 90 Kwh/m2 per year.
+ Illumination of 100 - 2000 lux in an area more than 50% = 1792.5 sq m.
+ To achieve net zero energy

✓ EPI Achieved : **78.8 Kwh/m2** per year.
✓ Illumination of average of **658 lux** achieved in about 48.7% of the floor area and 100-500 lux in the remaining at all times in the day.
✓ Building achieves **net zero** through Solar PVs and peer-to-peer energy sharing mechanism.

Water Performance

+ Achieving the net-zero use of water by using the rainwater harvesting and by reuse of greywater.
+ Annual water reuse of 50% through water recycling.

✓ **Net-positive water cycle** achieved with the help of 57% reduction in potable water demand and water sharing to increase storage capacity.
✓ **75%** of the generated greywater recycled by low energy systems and reused.

Embodied Carbon

+ Reduction of estimated base case final embodied energy by 50% (2300 MJ/m2 to 1000 MJ/m2) and operational CO2 emissions (B6) by 60% (35 tCO2/month to 15 tCO2/month).
+ To substitute high carbon emission materials with alternatives that'd reduce the overall building carbon footprint.

✓ Embodied energy reduced by **40%** (with final embodied energy 1363 MJ/m2) & **8 tCO2** monthly operational carbon.
✓ Material substitution resulting in **3205 GJ** EE savings.

Resilience

+ To achieve thermal comfort for 50% of the uncomfortable hours annually and especially during heatwave period.
+ To achieve self-suffciency and autonomy for 5 days for water and for energy-24 hours for critical functions.

✓ Thermal comfort was achieved for 100% of the hours with 32.9 deg as maximum temperature.
✓ Water autonomy was achieved for 20 days and energy for 24 hours for functioning during power cuts and calamities.

Engineering & Operations

+ To use of construction systmes with at least 20% recycled content.
+ To achieve cost saving of about 50-60% in HVAC.

✓ Slabs use 30% pulverised fly ash as a cement substitute.
✓ By using VRF instead of VAV, 30% savings in OpEx are achieved. Moreover the need for false ceiling with a large plenum is eliminated.

Architectural Design

+ Optimum spatial planning, including transition spaces and buffer spill-out zones.
+ To minimise heat and create a comfortable indoor environment for occupants.

✓ By introducing double-heighted spaces and multiple courtyards, the design breaks away from the typical psychology of how such a facility works.
✓ Staggering of building form reduces heat gain and subsequent cooling loads.

Affordability

+ Reduce the CAPEX of overall structure by at least 5%
+ Reducing OPEX by 20%, so as to fund other aspects of modernization of police.

✓ CAPEX savings were re-invested in better systems, rendering the CapEX same as project partner's budget.
✓ OPEX reduced by 15.7% through various strategies and low energy systems also requiring less maintainance and replacement.

Value Proposition

+ A net zero energy proposal delivered within the project partners budget.
+ Extending the value of the building to the larger community.

✓ A GRIHA certified net-zero energy and water building delivered to project partner without increase in CapEx.
✓ Accomodating spaces for the community such as pocket park, art installation and community hall for a better police-people relationship.

Innovation

+ To solve the problem of imbalance between energy generation and consumptio
+ To develop a smart kiosk as a part of Smart City Mission's police station reforms.

✓ Imbalance is resolved using peer-to-peer energy sharing mechanism.
✓ A smart interface was developed where citizens can access police services and supply information.

Health & Well Being

+ To ensure thermal comfort (27-30 degrees) according to IMAC range.
+ To reduce glare, increase visual access and visual comfort.

✓ Therrmal comfort achieved in all spaces according to IMAC.
✓ Disturbing glare reduced to 2.1% spaces, 66.3% spaces with quality views, contributing to visual comfort.

06 Design Documentation

What is a police station?

The **modern interpretation** of a police station challenges traditional notions of law enforcement facilities by prioritizing community engagement, accessibility, and sustainability.

It recognizes that the police are an integral part of the community and that effective policing requires building trust and positive relationships with citizens. The facility includes spaces for community engagement, such as a community room and a child-friendly space, to build trust and promote positive interactions between police officers and citizens. The design also prioritizes accessibility and inclusivity for people with disabilities and provides separate spaces for women and children.

Energy Performance

Envelope Optimization

The aim is to optimize a wide range of building envelope variables in terms of energy, daylight, cost, and thermal comfort. For the same, various material palettes were analyzed and simulated for the optimum result.

Option	Wall Assemblies	U-Value (W/sqm.K)
1	25mm external wall plaster +100mm fly ash brick + 50mm air gap + 100mm fly ash brick + 15mm internal wall plaster	0.45
2	25mm external wall plaster + 100mm fly ash brick + 50mm air gap + 100mm fly ash brick + 15mm internal wall plaster	0.24
3	25mm external wall plaster + 100mm fly ash brick + 50mm air gap + 45mm XPS-extruded polysterene + 100mm fly ash brick + 15mm internal wall plaster	0.29

Table 01 : Wall Assembly Options & Selection

Option	Roof Assemblies	U-Value (W/sqm.K)
1	10mm Gloss white heat reflective ceramic tile + 110 mm concrete slab + 45mm polyurethane foam + 25mm gypsum board	0.43
2	10mm china mosaic tiling + 20mm mortar bedding + 75 mm inverted clay pots with mud phuska + 45mm polyurethane foam + 5mm waterprooofing + 75 mm concrete RCC slab + 25mm gypsum board	0.25
3	10mm china mosaic tiling + 25mm mortar bedding + 100mm brick bat coba + 45mm polyurethane foam + 75 mm concrete RCC slab + 20mm gypsum plaster	0.38

Table 02 : Roof Assembly Options & Selection

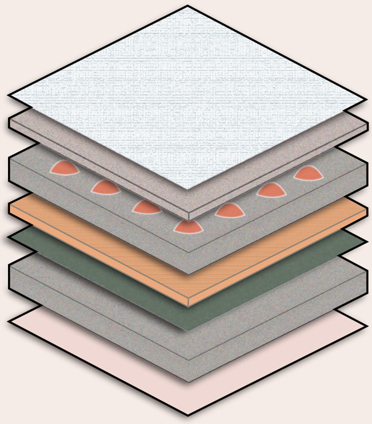


Fig. : Roof Assembly

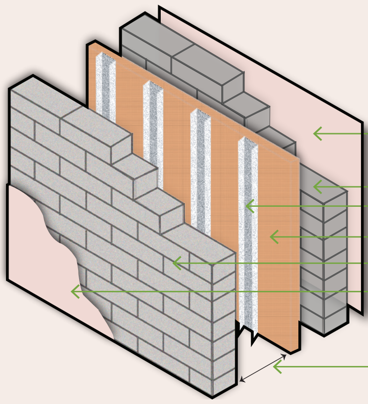


Fig. : Wall Assembly

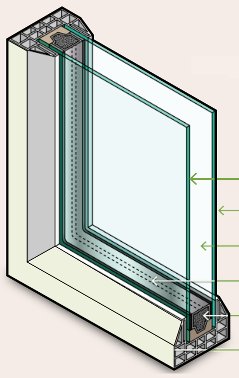


Fig. : Window Assembly

Selected Window Assembly	U-Value (W/sqm.K)	SHGC	VLT	Emissivity
6mm clear glass + 20mm argon filled- 80 per concentration + 8mm clear glass	1.79	0.23	0.2	0.3

Table 03 : Wall Assembly Selection

By assessing the three options, we observed that **coconut pith board** is a more environmentally friendly choice because it contains less carbon. Nonetheless, **XPS** was adopted as a last alternative because it is inexpensive, easily portable, durable, and more widely available.

Among the roof assembly options, **brick bat coba** offers less insulation and increases the overall assembly size. **Inverted clay pots** are therefore a more sustainable solution that is easily accessible, requires less technical effort, and doesn't increase the expense for water proofing.

Double glazed windows are utilised in window assembly because they retain heat and prevent it from escaping. Argon, as an inert gas, does not conduct heat as well as air, making it the ideal insulator.

HVAC Optimization

The HVAC System in use is **Variable Refrigerant Flow** (VRF) which consist of outdoor units connected to multiple indoor units via refrigerant piping to provide cooling and heating to individual zones.
Main advantage of VRF is its no-to-minimal ductwork eliminating any energy waste and allows individual zone cooling with temperature control as opposed to a centralised cooling system.

HVAC optimization has been performed with careful zoning and functionality in areas such as office spaces, server rooms, and labs.

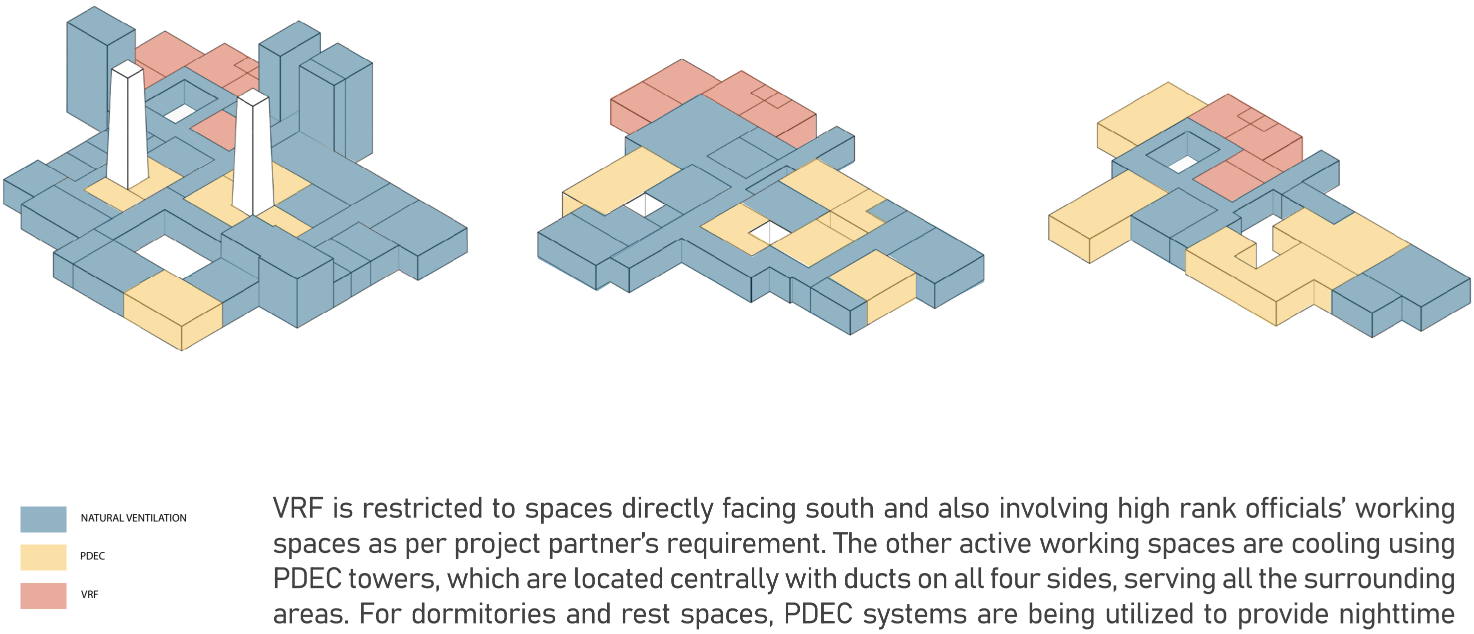


Fig. : HVAC zoning

VRF is restricted to spaces directly facing south and also involving high rank officials' working spaces as per project partner's requirement. The other active working spaces are cooling using PDEC towers, which are located centrally with ducts on all four sides, serving all the surrounding areas. For dormitories and rest spaces, PDEC systems are being utilized to provide nighttime thermal comfort.

EPI Optimization: Base Case Vs Proposed Case

Equipments : 46,388 kWh
Lighting : 1,02,069 kWh
Cooling : 95,111 kWh

$$\text{Target EPI} = \frac{\text{Total Target Energy Usage}}{\text{Total Built-up Area}} = \frac{243568}{3091}$$

= 78.8 kWh/sqm.yr

According to GRIHA guidelines, the EPI benchmark for a 24-hour occupancy office building is 225. However, through the strategic use of building orientation, with a 22.5-degree angle and staggering of the building form, the EPI can be reduced to 119.6. Further reduction is achieved through envelope optimization, HVAC sizing and scheduling, installation of an external bamboo skin, and use of efficient lighting fixtures. As a result of these measures, the final achieved EPI is **78.8 kWh/sqm.yr.**

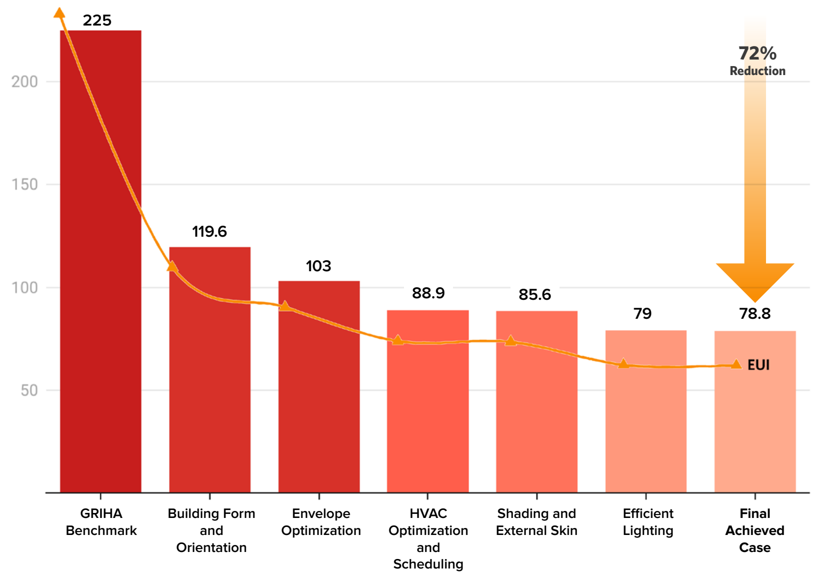


Fig. : EPI optimization graph

The cooling and lighting systems in the design were the main focus of the energy consumption iteration.

By adjusting the schedule and setting the setpoints in accordance with the IMAC comfort range, HVAC was optimised. Using a mixed-mode ventilation system, high energy systems were used only when unavoidable to achieve thermal comfort.

Using effective fixtures and scheduling helped to lower the lighting demand. LPD was decreased as a result, down from 9.9 to 7.9.

In order to make the building net-zero, 78.8 kWh/sqm.yr or more renewable energy needs to be produced on-site.

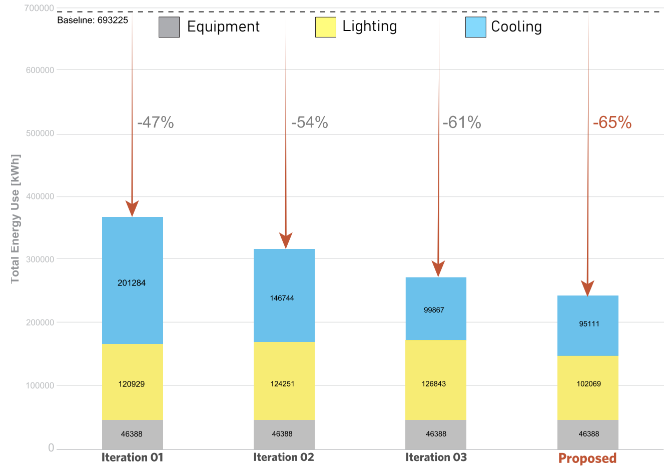


Fig. : Comparison of the energy consumption in various design iterations.

Energy Generation Potential

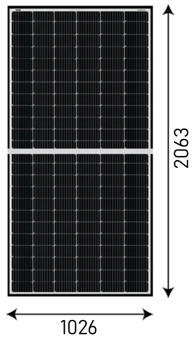
The site has an average solar irradiance of 5.02 Kwh/sqm per day, indicating a significant solar potential. To capitalize on this potential, we have proposed the installation of solar panels on the roof-level terrace and parking lot canopy. The panels will be angled at 21 degrees for maximum output.

Based on the assumption that direct sunlight is falling on the roof, a 1 kWh solar PV system requires 10 sq.m of space to generate 1500 kWh of energy per year.

The energy needed to be net zero = 2,43,478 KWh/year
Area required to produce 2,43,478 KWh/year = 1625 sqm

Area of rooftop = 1030 sq.m Parking Rooftop = 595 sq.m

Based on the available rooftop space, it is estimated that the building can generate a total of **1,54,500 kWh** of energy per year, while the parking lot rooftop can generate an additional **89,250 kWh** per year. Therefore, the combined solar PV potential of the building is **2,43,750 kWh** per year.



Module Specifications
Loom Solar Panel - Shark 445

Size: 2063 x 1026 x 35 mm
Area: 24 sq.ft / 2.22sq.m
Tilt angle: 21 deg
Number of panels: 366 panels
Solar panel Type: Mono PERC
Module Efficiency: 22%
Number of cells: 144
Output Power: 445 Watts

Fig. : PV module specifications

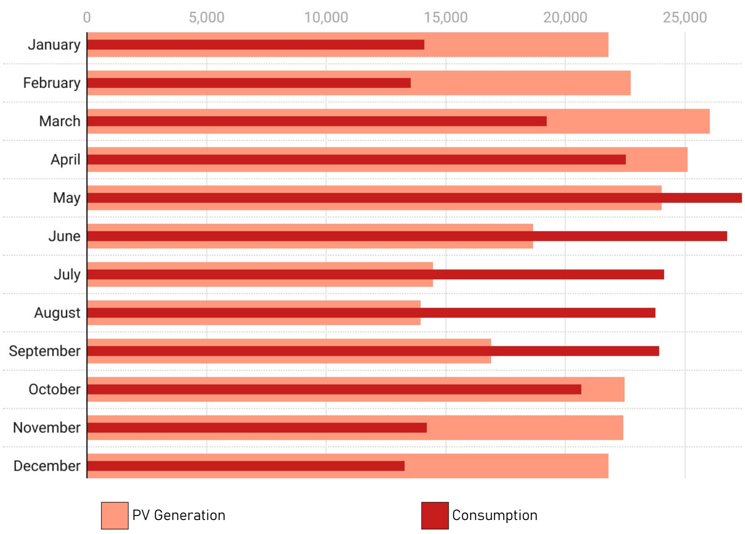


Fig. : Annual Generation Vs Consumption Graph

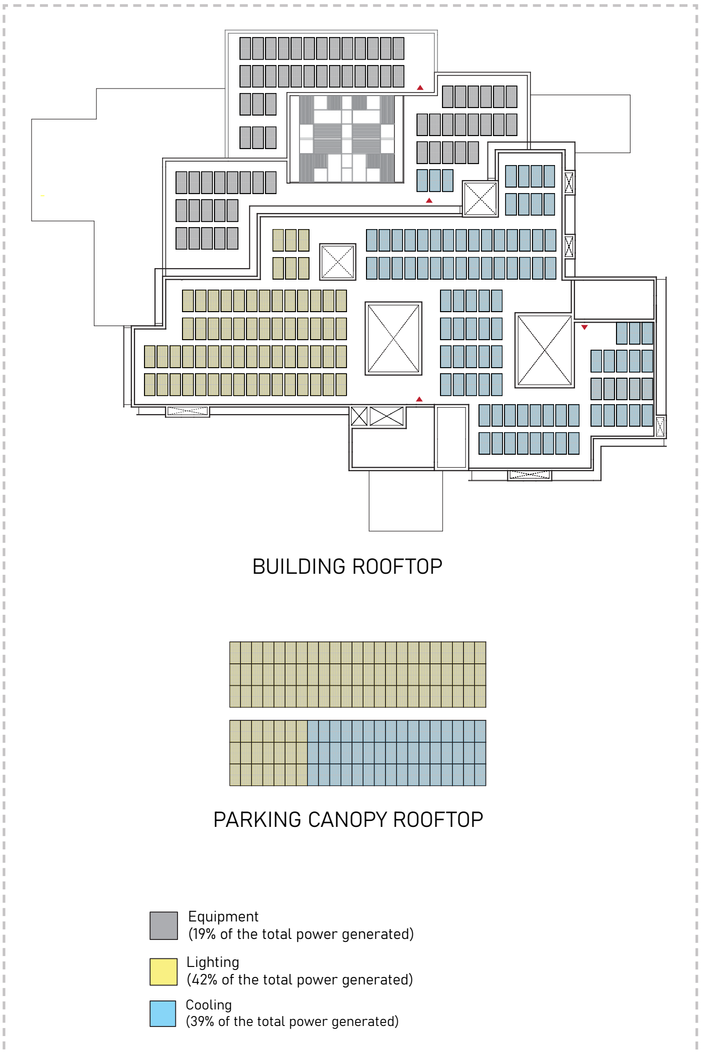
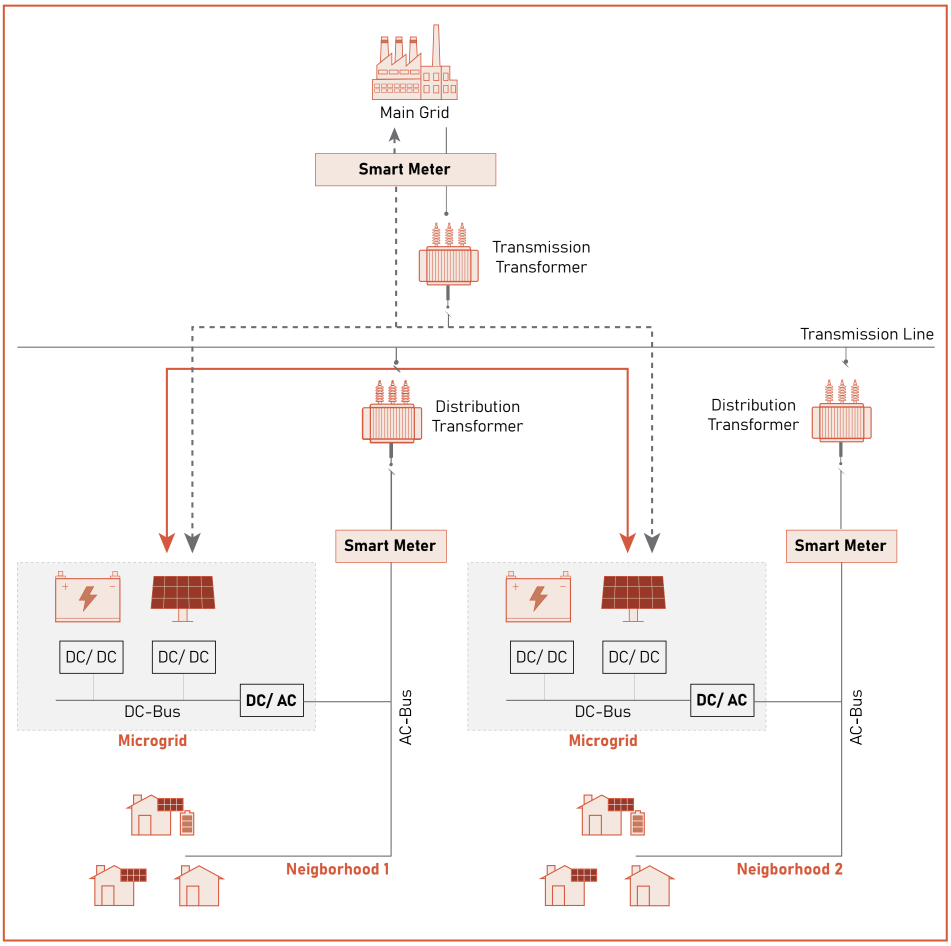


Fig. : PV layout on rooftop and on parking shading structure

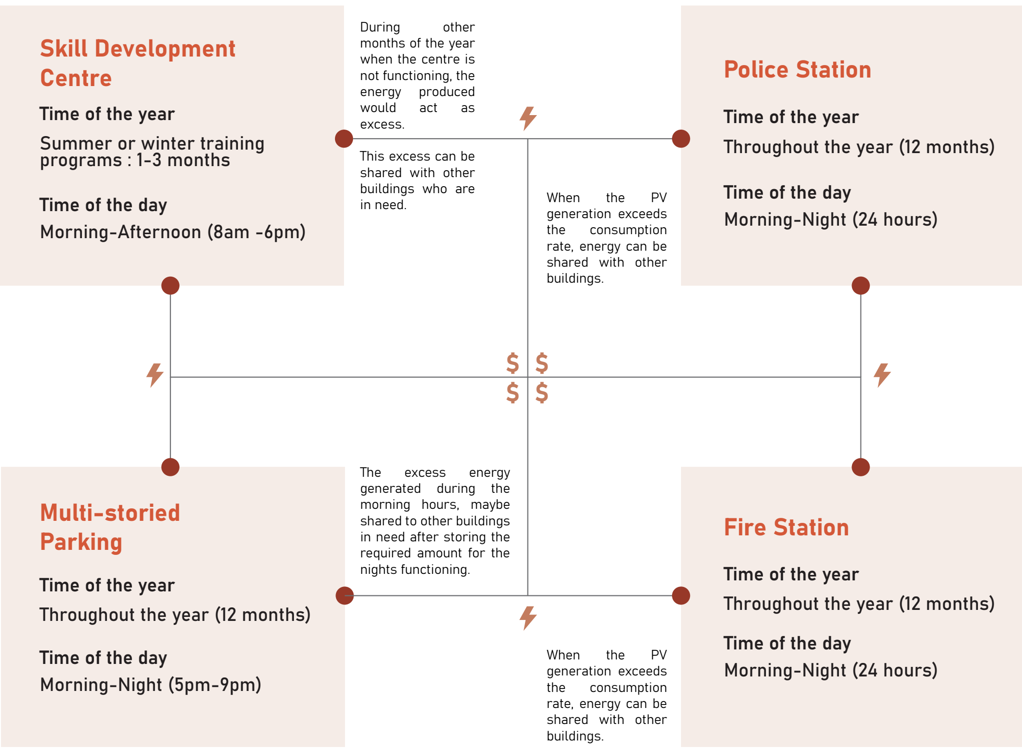
Energy Sharing Mechanism



This model proves to be **27% cost saving** compared to a non-coopera-tion case, when the harvested energy is not enough, the utility is the only option to meet the energy demands.

Fig. : Schematic diagram of the working of proposed peer-to-peer sharing and peer-to-grid with PV.

In the annual generation vs consumption graph we can observe that the building generations for the months of May, June, July, August and September is less than its consumption. In this case, 2 ways can be opted to fulfill the require-ment. First is dependency on the grid and decond is Peer-to-peer trade.



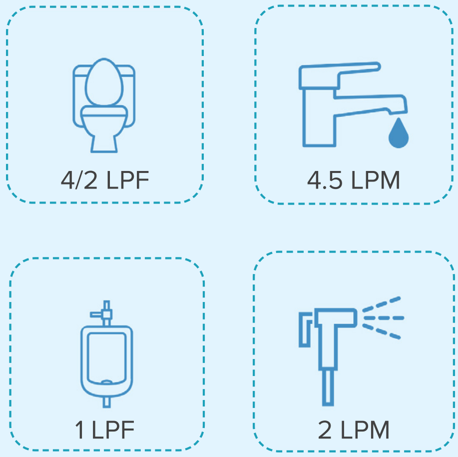
In times of energy shortage, the model depicts sharing between four buildings in around the site.

Fig. : Proposed energy sharing and exchange mechanism around the police station site.

Water Performance

The potable requirement of 45 lpcd for office buildings as per NBC, has been reduced to 25.6 lpcd, about 43% of the initial demand. This is done using:

1. Using water-efficient fixtures such as low-flow faucets; installing aerators, flow restrictors, and pressure regulators
2. Designing landscape for water efficiency, such as using native plants that are adapted to Nagpur's local climate and soil conditions, such as Neem and Palash, and using micro-sprinklers.
3. Balancing water and energy conservation strategies, such as using water and air-side economizers in VRF system.



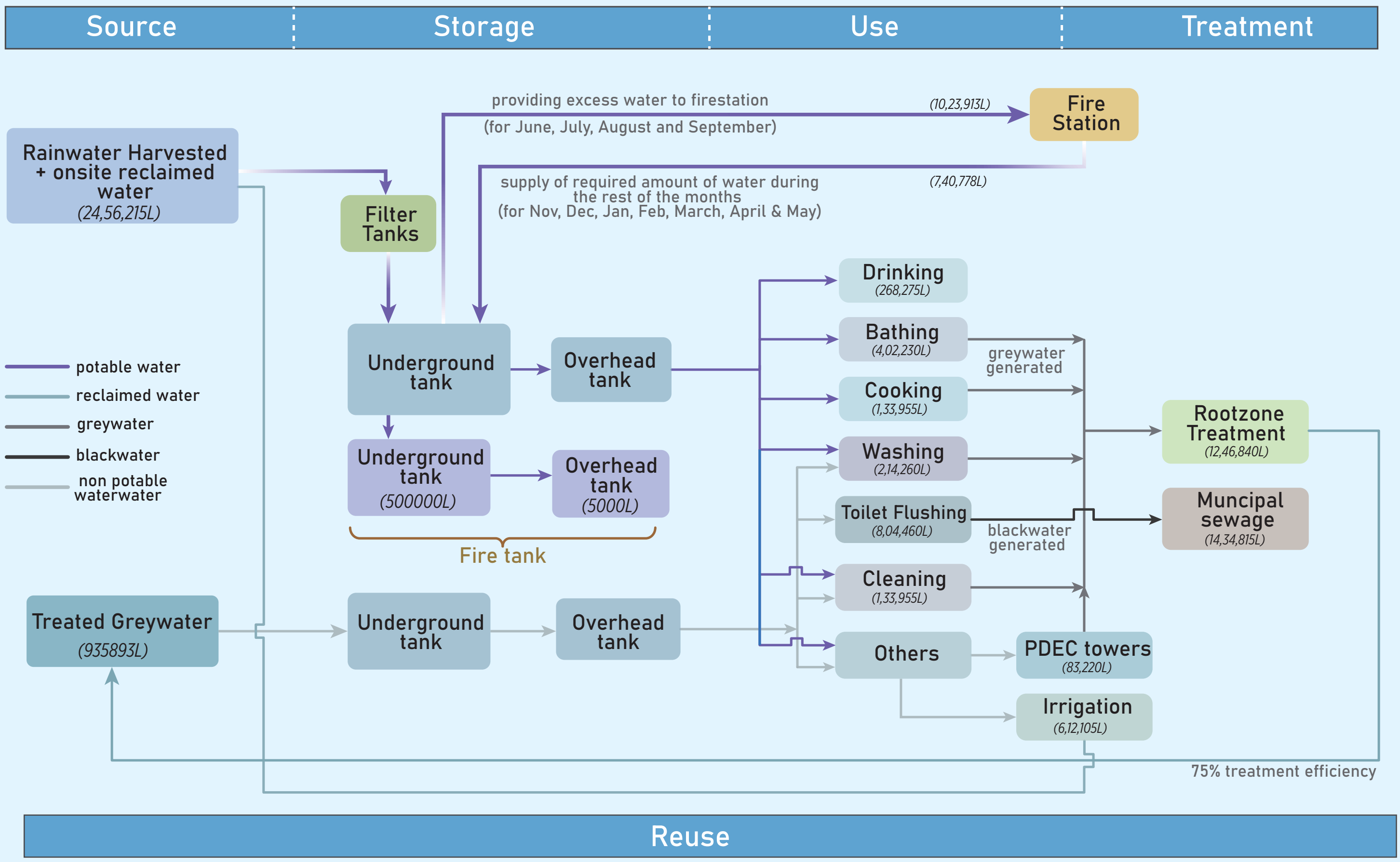


Fig. : Water Balance Diagram

A sustainable water management system has been designed to ensure ample water supply for daily consumption and irrigation needs. The system includes treating wastewater and reusing it to minimize the demand for potable water and achieve a **net-zero water cycle**.

To eliminate the need for large storage tanks and reduce the CapEx of the project, our team decided to utilize the already existing infrastructure of the fire station on the adjoining site. During the months of June, July, August, and September, the 1,00,000 L capacity onsite tank will be expanded, and excess water will be given to the fire tank for temporary storage. This excess water can be taken back during the summer months to meet the water demands of the proposed building. This solution not only eliminates the need for large storage tanks but also ensures a sustainable and efficient water cycle.

		CONSUMPTION						WATER SOURCES				SHARING	
Month	Days in month	Domestic Use (L)	Cooling Use %	Cooling Use (L)	Irrigation Use %	Irrigation Use (L)	Total Consumption (L)	Municipal Water (L)	Rainwater (L)	Greywater (L)	Blackwater (L)	Water given to Fire st. (L)	Water taken from Fire st.(L)
Jul	31	227,763	90%	3,176	5%	176	231,116	-	677,003	105,910	121,853	551,797	-
Aug	31	227,763	80%	2,823	5%	176	230,763	-	679,379	105,910	121,853	554,526	-
Sep	30	220,416	50%	1,708	50%	1,708	223,831	-	361,068	102,493	117,923	239,731	-
Oct	31	227,763	75%	2,647	30%	1,059	231,469	-	161,531	105,910	121,853	35,972	-
Nov	30	220,416	20%	683	90%	3,074	224,173	-	28,505	102,493	117,923	-	93,174
Dec	31	227,763	0%	-	90%	3,176	230,939	-	33,256	105,910	121,853	-	91,773
Jan	31	227,763	0%	-	90%	3,176	230,939	-	26,130	105,910	121,853	-	98,900
Feb	28	207,763	20%	643	90%	2,894	211,096	-	40,383	96,515	111,044	-	74,199
Mar	31	227,763	50%	1,765	90%	3,176	232,704	-	23,755	105,910	121,853	-	103,040
Apr	30	220,416	90%	3,074	90%	3,074	226,563	-	7,126	102,493	117,923	-	116,944
May	31	227,763	100%	3,529	90%	3,176	234,468	-	30,881	105,910	121,853	-	97,678
Jun	30	220,416	90%	3,074	90%	3,074	226,563	-	387,198	102,493	117,923	263,128	-

Table 04 : Water Balance Calculations

	Occupant load	Per capita daily comsumption (lpd)	Total Consumption (L)	Yearly Consumption (L)
BASE CASE	287	45	12,915	4,717,204
PROPOSED CASE	287	25.6	7,347.20	2,734,625

Irrigation Use	Litres per square metre	Area (sq M)	Total Use (L)
BASE CASE	1.7	1,377	2,304.90
PROPOSED CASE	1	1,377	1,377

Table 05 : Water Consumption Optimization

Factor	Base Value	Efficient Value	Unit
Faucets for all Bathrooms	6	2.5	L/min
Water Closets	6	4,2	L/flush
Heath faucet for all Bathrooms	5	2	L/min
Urinals	2.5	1	L/flush
Faucets for Kitchen Sink	5	3	L/min
Washing Machine	60	50	L/kg

Table 06 : Low Flow Fixtures Specifications

Catchment Surfaces	Area m2	Runoff Coeffecient	Effective Catchment Area (m2)
Roof Surfaces	1,677	0.85	1,45.45
Hardscape areas	500	0.7	350
Softscape areas	2000	0.3	600
Other			0
Total Effective Catchment Area			2,375.45

Table 07 : Rainwater Catchment Surfaces

In September, the surplus water obtained from the water cycle system can be used to meet the water requirements for the month of October. During the remaining months, the primary sources of water for the system are rainwater, treated greywater, and water obtained from the fire station.

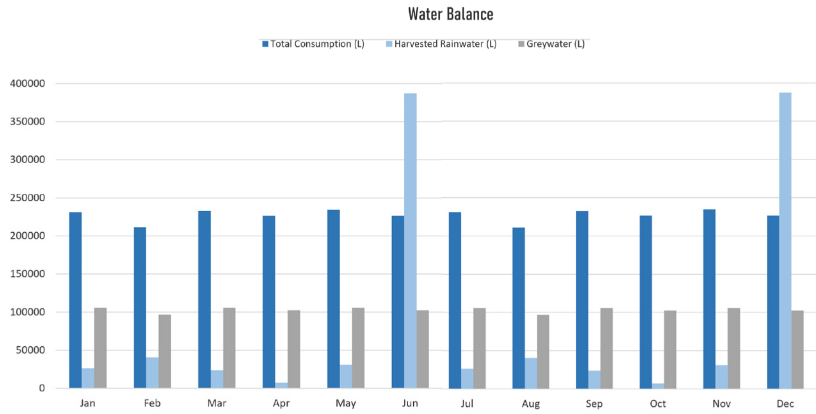


Fig. : Water Balance Annual Graph

Water Demand Breakdown

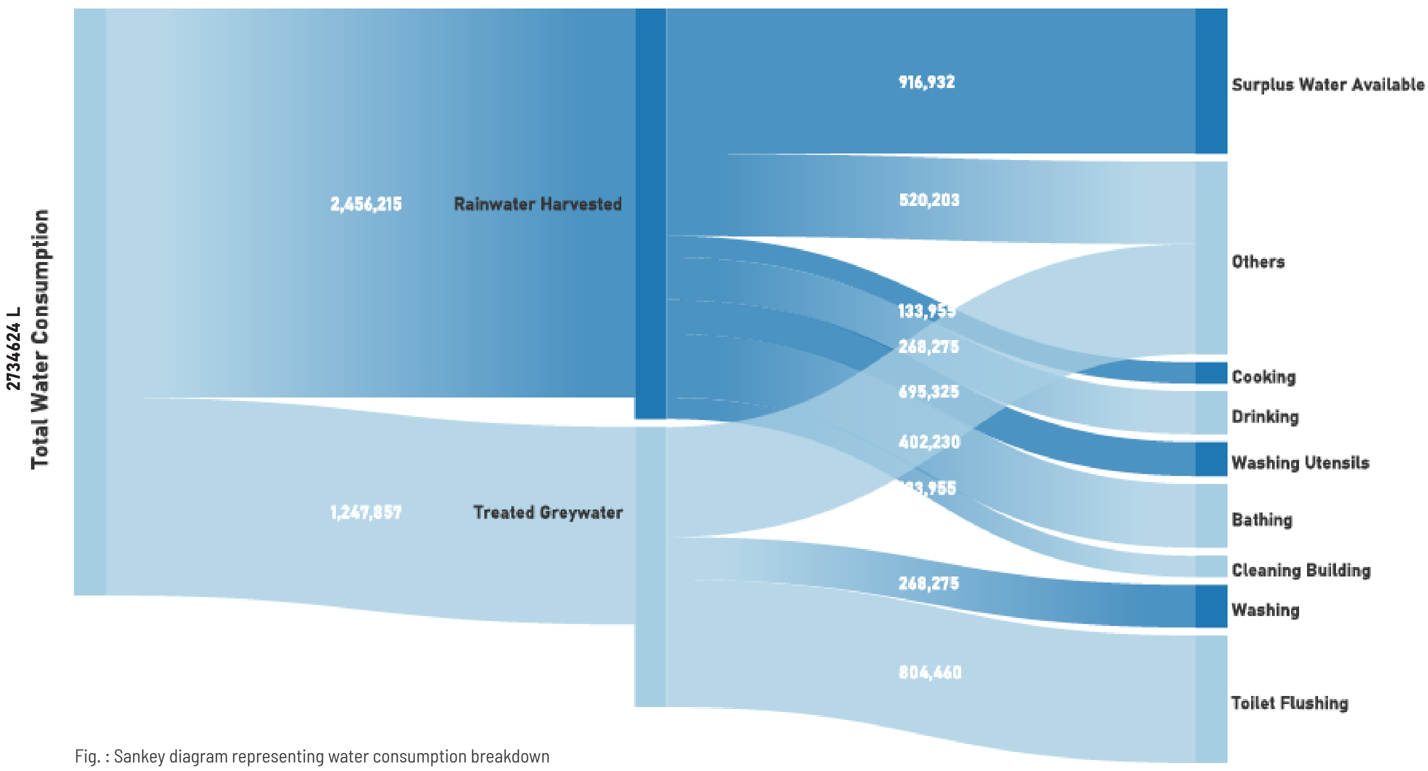


Fig. : Sankey diagram representing water consumption breakdown

Water Processing and Storage

The building's roof serves as a catchment area for rainwater, while the catchment area is expanded through the use of bioswales and landscaping.

The collected water from both hardscape and softscape is treated by a gravity sand filter for both potable and non-potable use. Despite the limited rainfall for most months, the collected water is stored and reserved for future use.

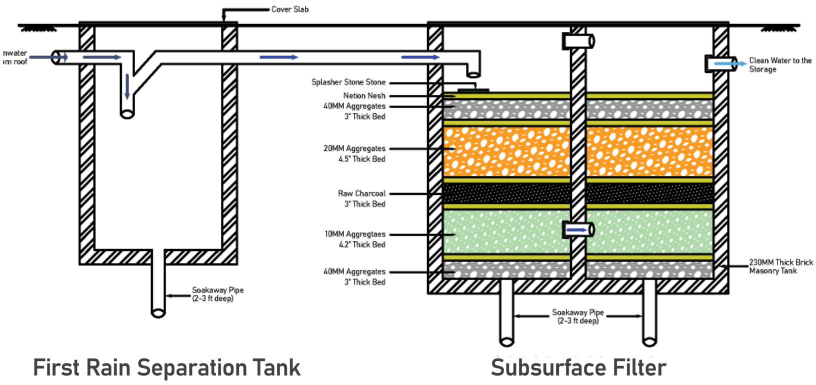


Fig. : Gravity Sand Filter

The building has a segregated tank system for different types of water usage. The main water source is collected and stored in underground tanks for rainwater and treated greywater. Additionally, a separate tank with a total capacity of **55kL** is designated for fire safety purposes.

To ensure easy access and supply of water in case of a fire emergency, the tank is positioned before a staircase located on the rear side of the building, taking advantage of the slight slope and proximity to the fire station.

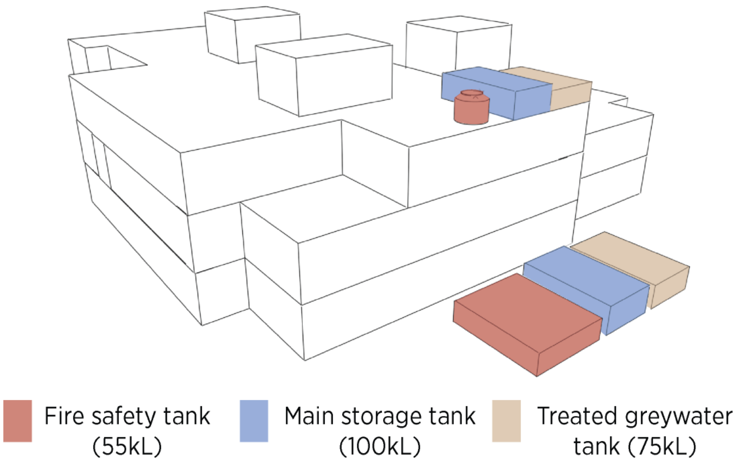


Fig. : Water Tank Configurations

Greywater Treatment

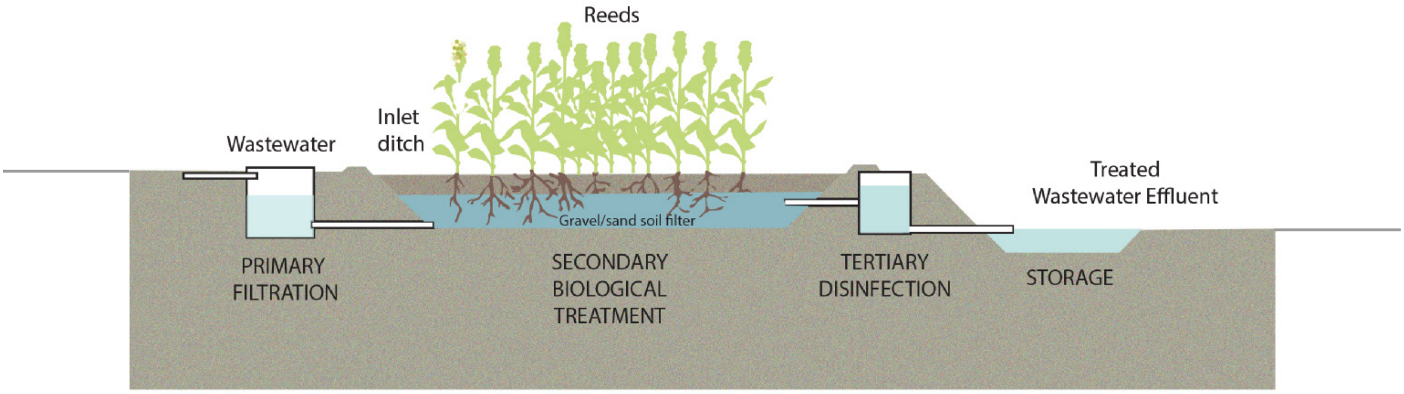


Fig. :System based on NEERI's phytoremediation technique

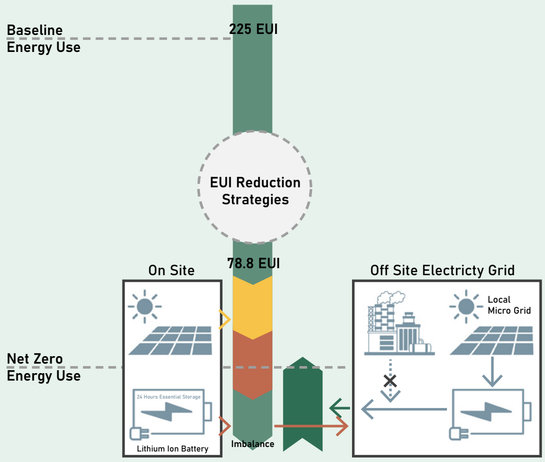
Onsite treatment of greywater is carried out using root zone treatment or **phytoremediation** techniques, achieving an efficiency of 75%. The total amount of greywater generated is 12,47,858 L, out of which 9,35,895 L is treated for use in activities such as toilet flushing, cooling, and irrigation.

Embodied Carbon

Towards Carbon Neutrality: Minimizing dependency on carbon-intensive grid electricity

The 163 kW on-site solar PV plant satisfies the complete annual energy demand of the building which theoratically saves **5012 tonnes of CO_2** annually and reduces **B6-7 emissions**.

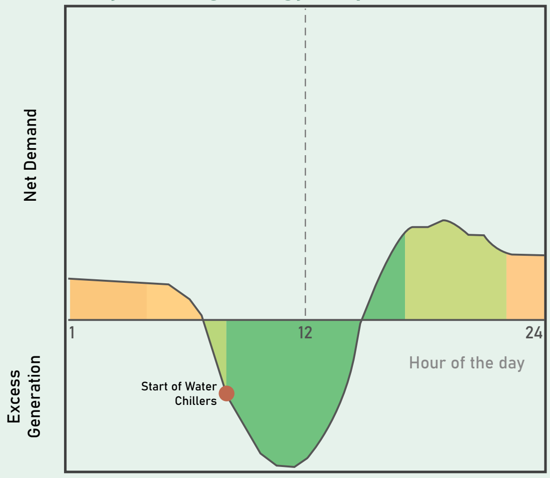
Nonetheless, as there exists a difference in energy utilization and production on a monthly basis, utilizing grid-connected PV systems may resolve the matter. However, this solution might not attain **carbon neutrality** since the use of fossil fuel-based energy and storage can result in an increase in carbon emissions.



net zero energy ≠ carbon neutrality

Using peer-to-peer energy exchange, the proposed mechanism relies on local PV based microgrids to reduce transmission losses, therby helping omit all possible emissions.

Daily Building Energy Graph

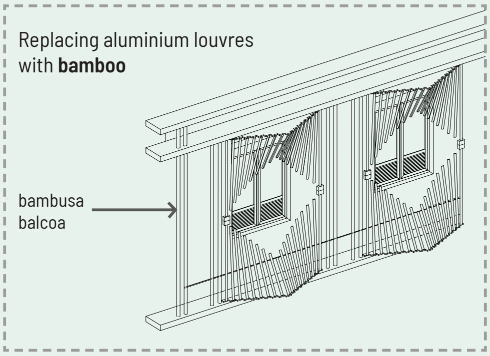


Chilled water storage: Low Carbon Scheduling

Chilled water for space cooling by VRF and refrigeration would be generated at times of day when electricity carbon is lowest.

Fenestration Optimization:

Use of bamboo external skin and limiting west WWR to 13% lowers peak cooling and avoid times when the electricity grid has high carbon emissions.



Carbon Sequestration ↑↑

Fly ash bricks: Low Carbon Envelope Alternatives

Embodied Energy: **628.7 MJ/m2**
CO2 Emission: **108 kgCO2/m2**

Since the bricks are sourced from Koradi and Khaparkheda power plants, waste utilization ranges from 22% to 70% fly ash plus possible 4-5% gypsum.

Additionally, fly ash is used as a supplementary cementitious material for a low-carbon concrete mix in floor and roof slabs.

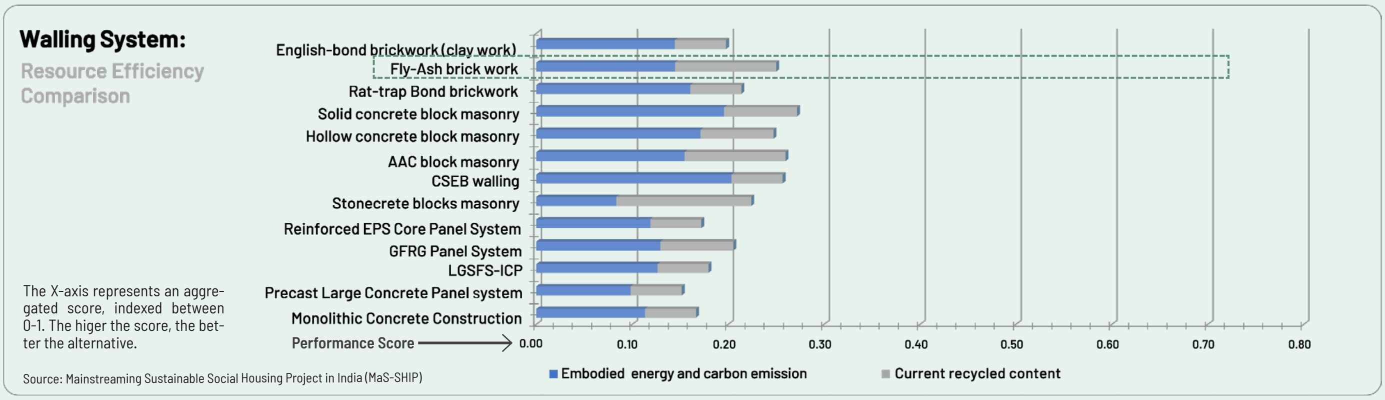
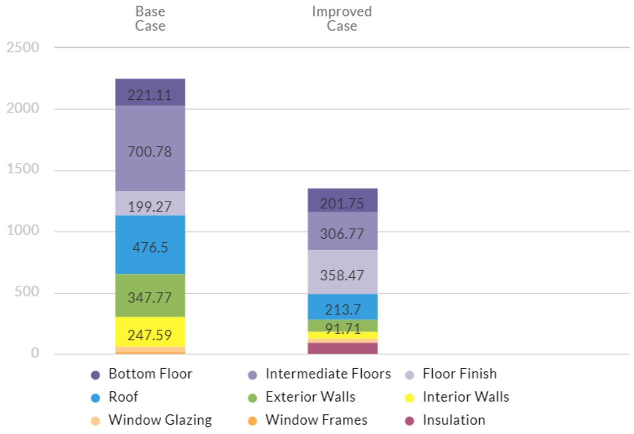


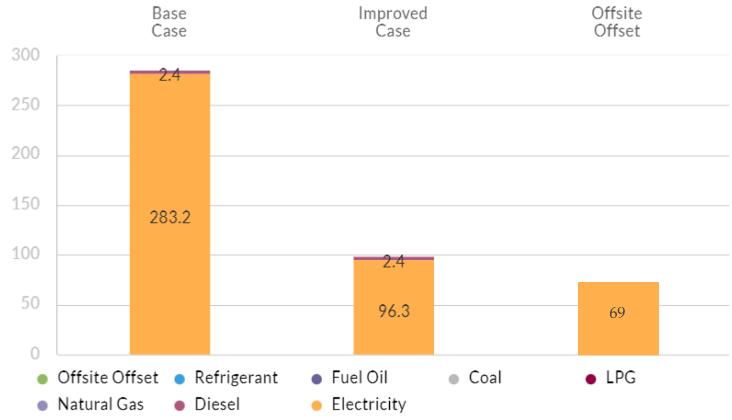
Fig. :Walling Systems Resource Energy Comparision

Fig. :Embodied Energy Reduction



EMBODIED ENERGY (MJ/M²)

Fig. :Carbon Emissions Reduction



CARBON EMISSIONS(tCO_2e/Year)

1363 MJ/m2 40% Reduction in EE through Material Substitution

3205 GJ EE Savings

8 tCO2 Monthly Operational C02

188.5 tCO2 Annual Operational CO2 Savings

Note: Results are based on data obtained by entering material and system specifcations in EDGE tool.

Resilience

Resilience against heatwaves

The city faces the threat of heat waves (especially in May), and to ensure comfort during such events is important.

Strategies such as Passive downdraft evaporative cooling (PDEC), building orientation optimization, self-shading of the structure and the mass using bamboo skin and shading devices, stack effect in courtyards, and using wall and roof assemblies with higher U-values than conventional configurations have been used for maximizing thermal comfort.

Thermal comfort during heatwaves

Simulations with values of thermal comfort acheived during Heatvawes have been shown here. Heatwave period in Nagpur: 148th to 155th day of the year (28th May to 4th June – “Navtapa”)

IMAC acceptability range during May :	Achieved maximum RT:
NV Zone: 28.5 deg to 33.2 deg	NV Zone: 32.9 deg
PDEC Zone: 23.7 deg to 30.6 deg	PDEC Zone: 28.8 deg
VRF Zone: 24.3 deg to 27.3 deg	VRF Zone: 28.2 deg

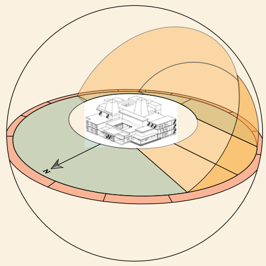


Fig. : Building orientation to minimize heat gain.

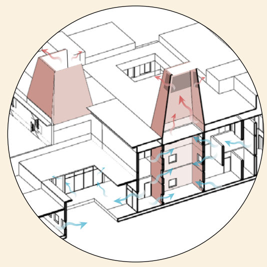


Fig. : PDEC tower working with courtyard.

Fig. :VRF zone temperature graph during heatwaves

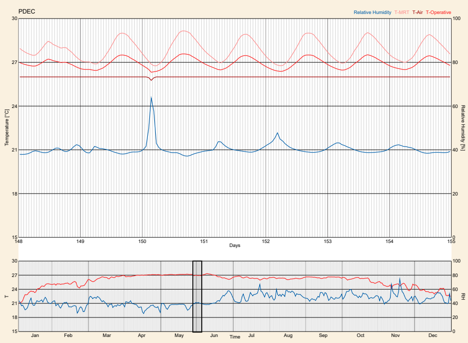


Fig. :NV zone temperature graph during heatwaves

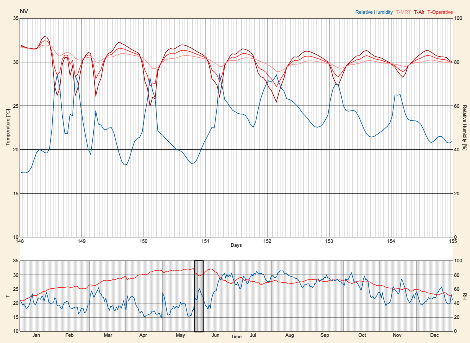


Fig. :PDEC zone temperature graph during heatwaves

Thermal comfort was achieved in all 3 zones during the critical heatwave period successfully.

Flood Resilience

With Nagpur experiencing an increase in extreme heavy rainfall-triggered floods and the site being located in a depressed area, the building needs to be resistant to localized flooding.

Elevated Plinth: The plinth of the buildings is raised to 1.1 m which prevents entry of water into the interiors. Fly-ash brick with cement plaster was selected as the primary material for the walls, as their characteristics such as drying time, durability, porosity, and amount of water absorbed, ensure a better Post-flood resistance strategy.

Bioretention swales: They are designed to capture and filter runoff from the parking areas, while also enhancing the aesthetics of the site by incorporating a variety of vegetation. The swales not only improve air quality, but also act as a cost-effective alternative to traditional stormwater management methods.

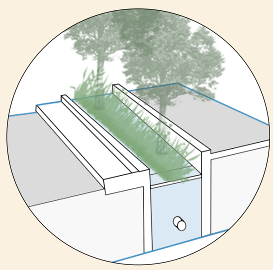


Fig. : Bioretention swales around the site perimeter.

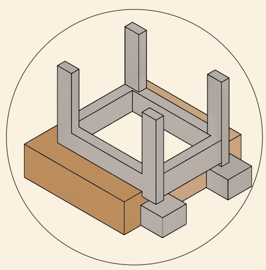


Fig. : Plinth elevated to 1100MM.

Fire Safety

The presence of ammunition and increased consumption of electrical equipment in the Police station leads to increased chances of fire.

Fire safety norms are adopted based on the NBC-Part 4 to make the building resilient during fire emergencies.

Sr no.	Types of Fire Protection	Description
1	Underground and overhead water tank	UGT- 50,000 liters OHT- 5,000 liters
2	Fire Extinguisher	2 per floor with travel distance, not more than 12 m.
3	Automatic detection and Alarm System	For the entire building
4	Automatic Sprinkler System	For the entire building
5	Emergency Lights	At escape routes and exits
6	Fire shaft	2 Fire-rated lifts and staircases

Table 08 : Fire safety building specifications

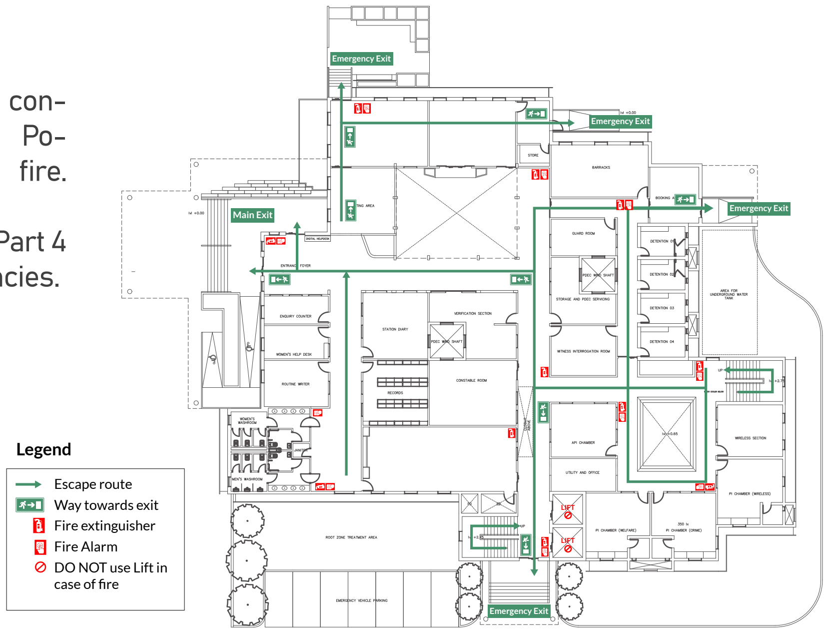


Fig. : Fire escape plan

Resilience against power outages

The site in Pardi, being in the outskirts of the city, is susceptible to frequent power cuts, particularly during summers. Therefore, it is crucial for the police station to have a backup power source in case of emergencies.

To address this issue, we propose the use of a lithium-ion solar battery that stores electricity generated from the rooftop solar panels. During blackouts, the stored energy can be used to power essential services such as server rooms, wireless and communication systems, life safety systems, including egress lighting, smoke evacuation, fire alarm systems, elevators, etc. Moreover, the radio systems will be on standby power, enabling the station to manage operations during emergencies.

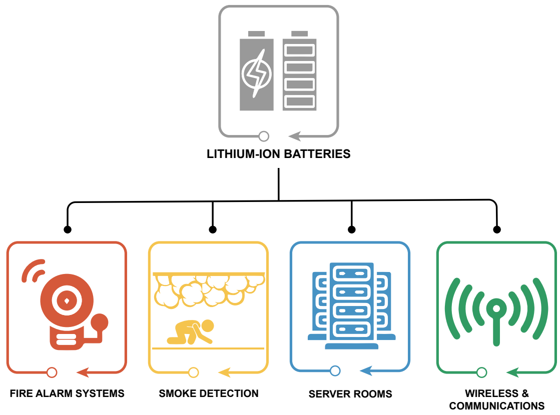


Fig. : Critical functions continue using lithium-ion batteries during power cuts.

Sufficiency and Autonomy for critical functions

Water facility:

Total water storage capacity (critical storage + main storage) at a given point is 1,50,000 L and daily water demand is 7346 L.
Total water storage capacity / Daily water demand = Days of Autonomy
i.e. 1.50,000/7346= **20.4 days of autonomy**

Energy Efficiency:

Annual energy consumption is 2,43,478 kWh which includes lighting, cooling, and equipment.
The total annual energy generated using solar PV (both rooftop and parking panels) is 2,43,750 kWh

In all the months (except May, June, July, August), excess energy is generated out of which energy to power essential services for **24 hrs** is stored in lithium-ion batteries on site, and the remaining is utilized in the energy sharing mechanism. In the months where energy generated is insufficient, it is taken from the local mini grid or the city grid and stored in the batteries for emergency uses.

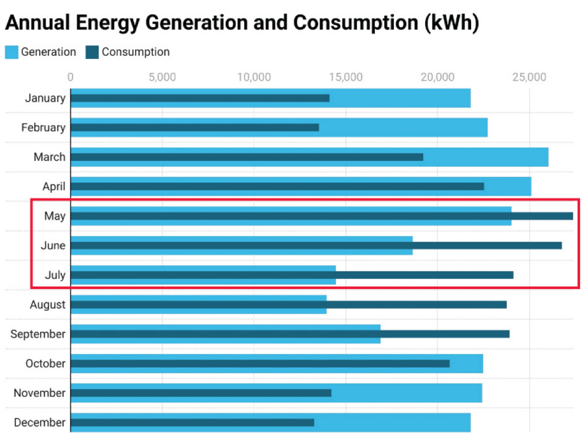


Fig. : Annual Energy Generation Vs Consumption

Engineering and Operations

Structural Design

The false slab provides a smooth, level surface for the finished flooring, which can enhance the aesthetic appeal of the building and create a more comfortable living or working environment. By using M30 grade concrete, we have ensured that the false slab will have the strength and durability necessary to support the weight of the finished flooring and any expected loads.

We designed strip footings for the shear walls of the lift shaft and wind shaft column. These footings provide a wide base of support to evenly distribute the weight and resist lateral forces during seismic activity and strong winds. Our efficient and functional design incorporates different types of footings to create a robust foundation for the building's structural elements, ensuring safety and longevity.

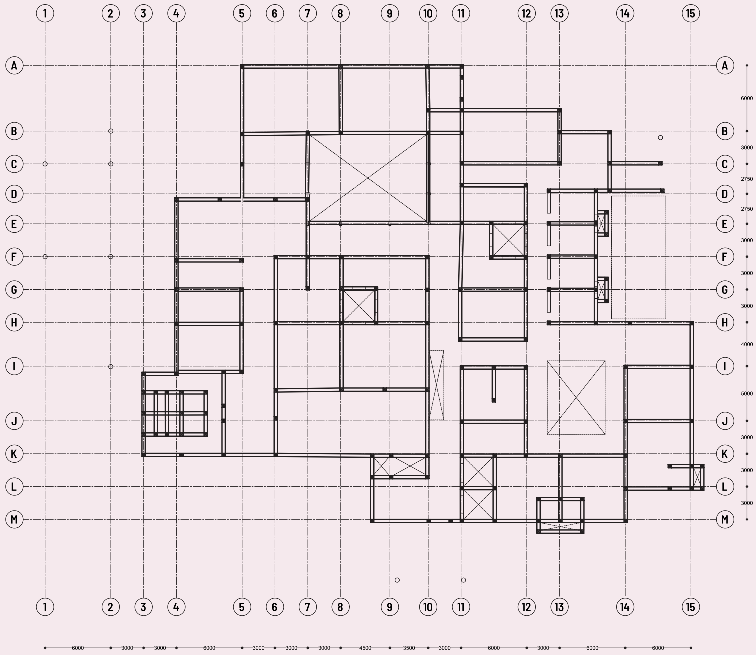


Fig. : Structural Column Layout

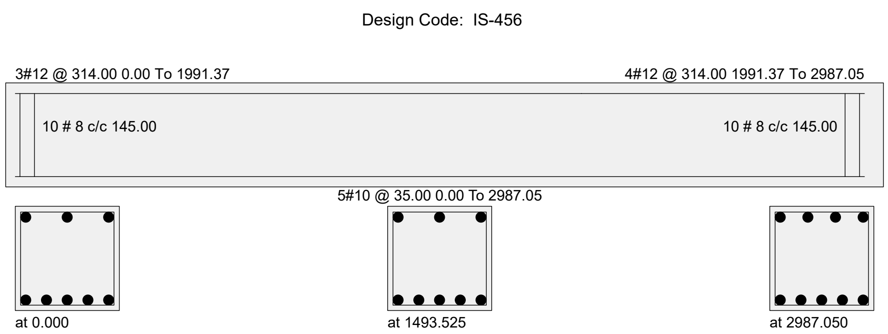


Fig. : Ground Floor Beam

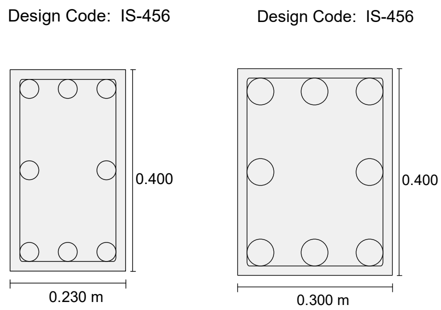


Fig. : Column Design

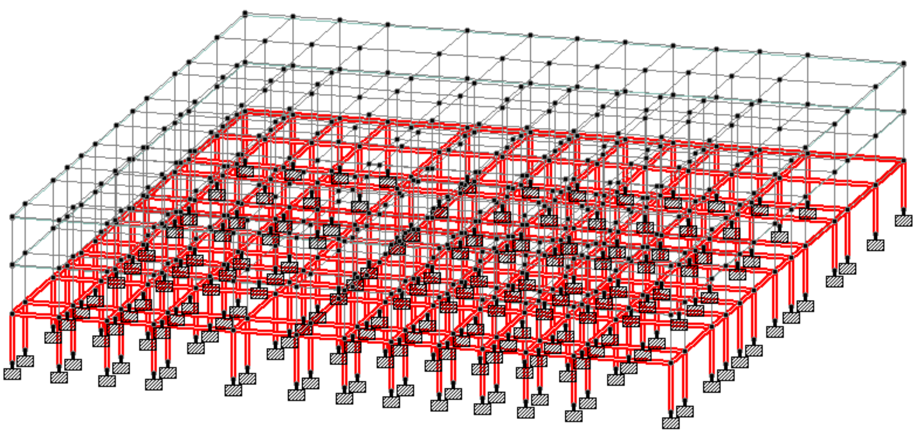


Fig. : Structural line diagram of the building using STTAD Pro

For the construction of the building, we used M30 and M25 grade concrete for various components such as the columns, beams, and foundation. We designed the building using **STAAD Pro** software and followed the guidelines outlined in IS 456 to ensure that it meets the necessary safety standards.

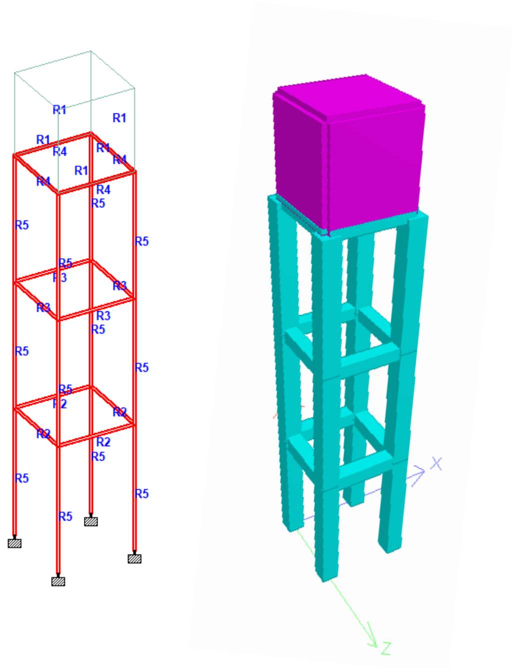
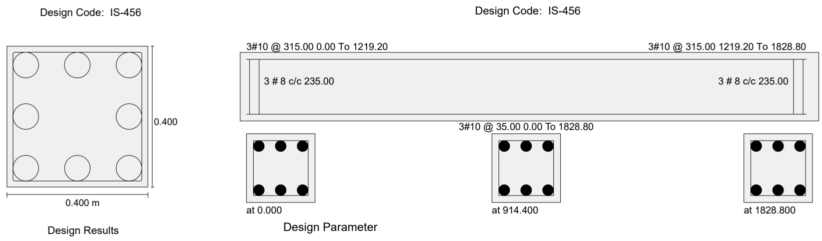


Fig. : Structural design of the wind tower

Structural design of wind tower

One of the key design features of the building is the water tank located at the top of the wind shaft. To ensure the tank's stability, we used a combination of reinforced concrete columns and beams, as well as high-strength steel to reinforce the tank walls. The tank's location also helps to reduce the building's overall footprint and maximize the use of vertical space.



Design Results

Fy(Mpa)	550
Fc(Mpa)	30
As Reqd(mm²)	49.000000
As (%)	0.565000
Bar Size	12
Bar No	8

Design Parameter

Fy(Mpa)	550.000000
Fc(Mpa)	30.000000
Depth(m)	0.349999
Width(m)	0.349999
Length(m)	1.828796

Fig. : Structural details of wind tower column and beam on ground floor

HVAC Design

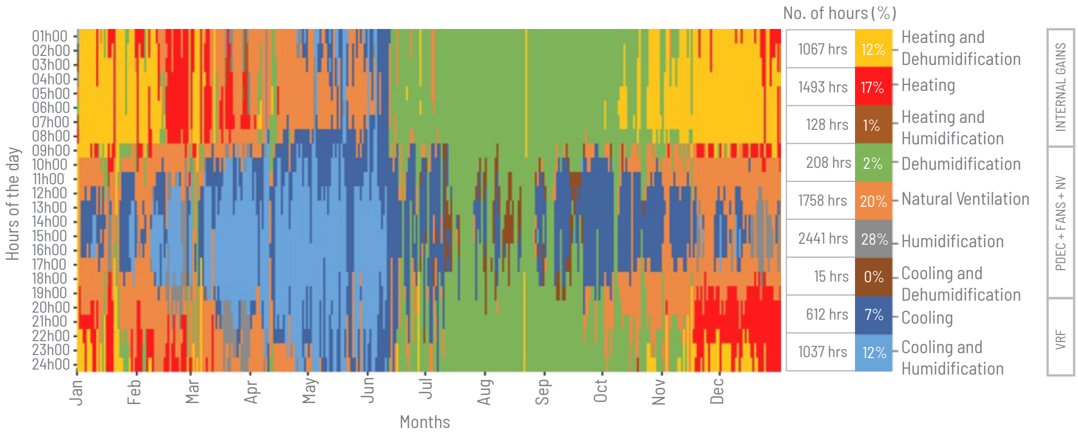


Fig. : Annual operation mode using mixed mode adaptive comfort model (IMAC)

To reduce energy consumption, the annual operation schedule of the building's HVAC system is based on the IMAC comfort range. Mixed mode operation of the building involves using a combination of NV, Fans, PDEC, and VRF to provide thermal comfort that is dependent on the occupancy and outdoor temperatures.

In order to minimize the energy consumption of our building, we conducted a comprehensive analysis of various systems available in the market. After careful consideration, we selected the VRF (variable refrigerant flow) system for **active cooling,** as it has been proven to reduce energy consumption by about **30%** in comparison to other available options.

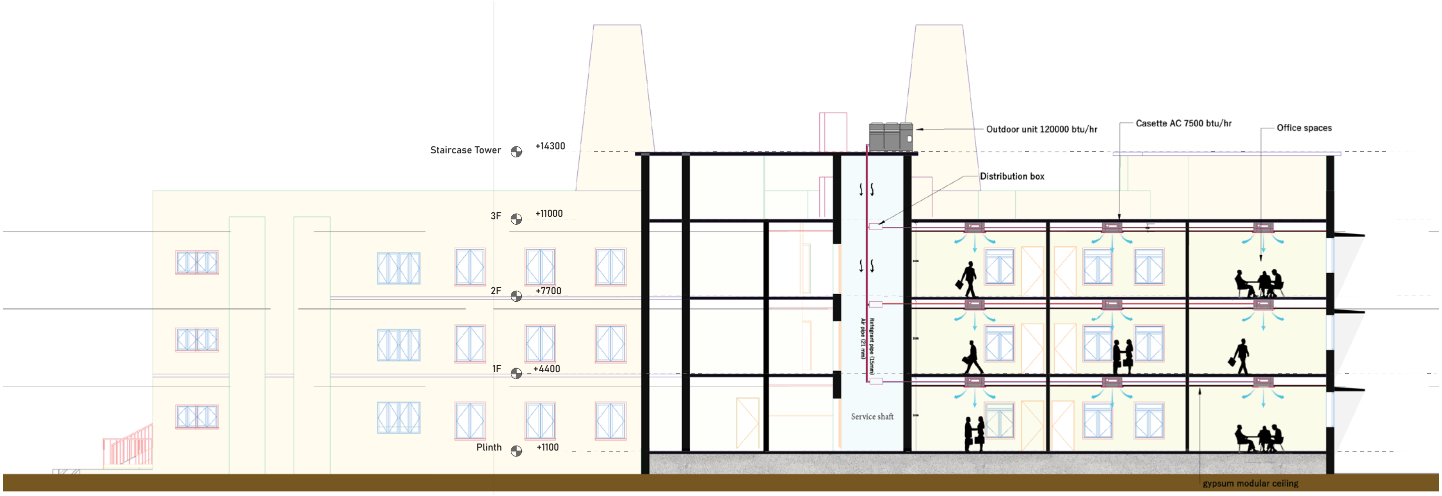


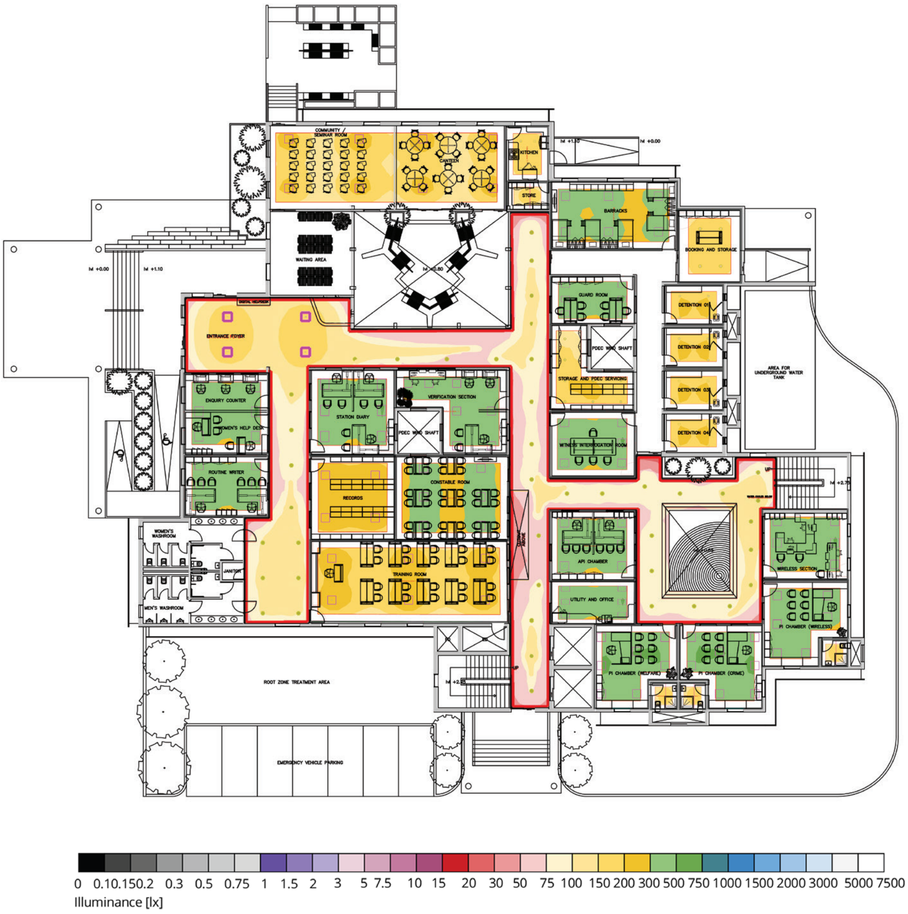
Fig. : Section showing HVAC systems

Moreover, we have incorporated **occupancy sensors** that are integrated with the VRF system. These sensors are capable of detecting whether a particular area is occupied or not, and then adjust the heating or cooling accordingly. This helps in ensuring that energy is not wasted on unoccupied areas and also enhances occupant comfort.

We have also installed **programmable thermostats** throughout the building. This allows us to set different temperature zones based on occupancy and time of day, which further reduces energy consumption and improves comfort.

Overall, our energy efficiency efforts have not only resulted in reduced operating costs, but also have a positive impact on the environment by **minimizing our carbon footprint**.

Lighting



General
Calculation algorithm used: Average indirect fraction
Height of luminaire plane: 3.10 m
Maintenance factor: 0.80

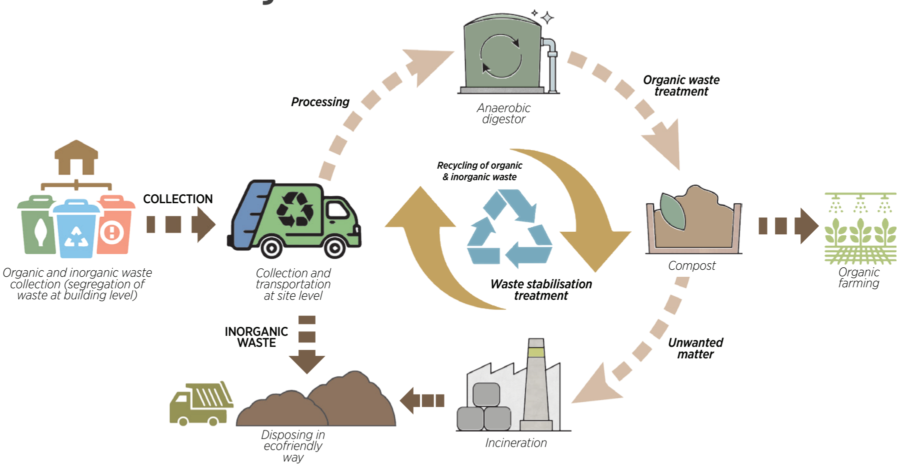
Total luminous flux: 13600.00 lm
Total power: 144.0 W
Total power per area (34.11 m²): 4.22 W/m² (1.83 W/m²/100lx)

SPACES	LUX LEVEL RANGE
CORRIDORS	75-150 lx
PI CHAMBER	350-400 lx
API CHAMBER	350-400 lx
WITNESS ROOM	350-400 lx
VERIFICATION ROOM	350-400 lx
GUARD ROOM	350-400 lx
ROUTINE WRITER	350-400 lx
STORAGE ROOM	150 lx
DETENTION ROOM	150 lx
RECORD ROOM	200 lx
TRAINING ROOM	200 lx

To ensure uniform lighting, energy efficient luminaires of 20W to 36W have been used. The average power used is 4.22W/m2 throughout the entire area. The False ceiling depth is 400mm and for office spaces the reference plane taken is 750mm above the ground. For corridors and common spaces, reference plane is on ground level.

Strip lighting of 21W has been used in Washrooms. The WC and storerooms have light sensors and require 150lx light to ensure proper vision in these spaces.

Soild Waste Management



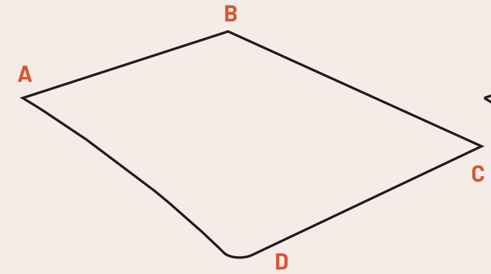
An efficient system has been developed for managing solid waste that involves segregation of organic and inorganic waste at the source. Organic waste is collected at the site level and is subsequently picked up by municipal garbage trucks. The collected organic waste is then composted locally to produce high-quality manure that can be used for landscaping purposes.

Architectural Design

Concept And Design Development

Law enforcement through a new lens.

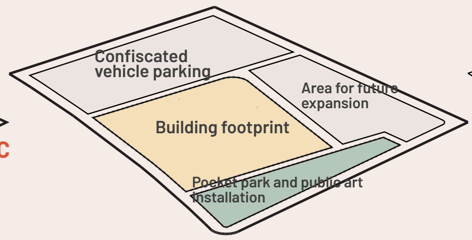
A new police station for the people of Pardi that responds to the complex operational needs of keeping law enforcement at work while standing as a symbol to how architecture can inspire a more sustainable future for police stations around India through deep connections with its place, culture and community.



00. SITE

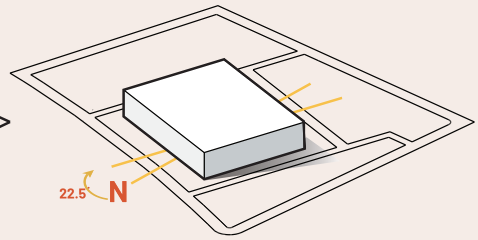
AB - 83.6m
BC -117.3m
CD -115.5m
DA -135m

Total plot area is 12152 sqm.



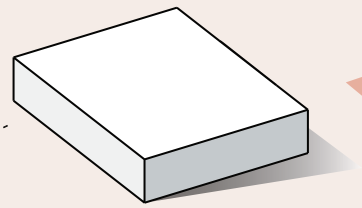
01. SITE ZONING

Site zoned with the building footprint dividing public and private uses on the site.



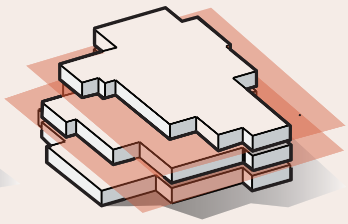
02. BUILDING ORIENTATION

Building oriented with longer side facing 22.5 deg from the north.



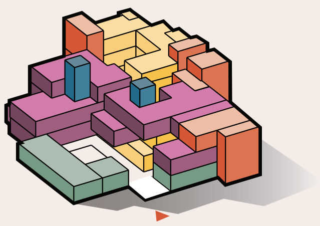
03. BUILDING MASS

Building plane is extruded to 9.6m height.



04. STAGGERING OF FORM

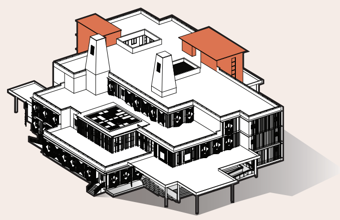
Inorder to form a self-shading structure whilst creating a dynamic and visually engaging exterior.



05. PROGRAMS

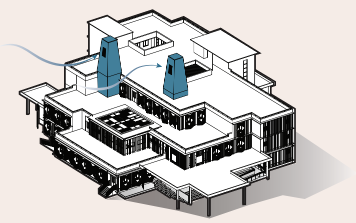
The different activity areas are stacked over one another with respect to the nature of activities.

Public Private High security



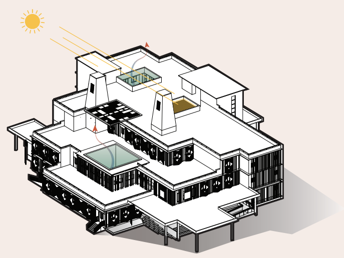
06. CIRCULATION CORES

Two staircases are provided accompanied with the lift core by one side.



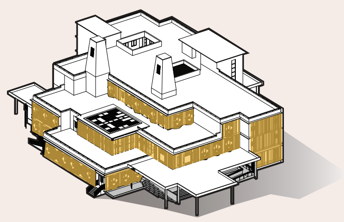
07. PDEC

Integration of PDEC system to cool the office spaces via the false ceiling.



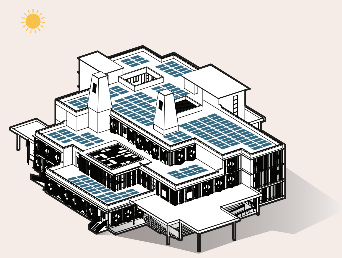
08. COURTYARD

Insertion of two courtyards, with one for public-centric usage and the second is surrounded by private activities.



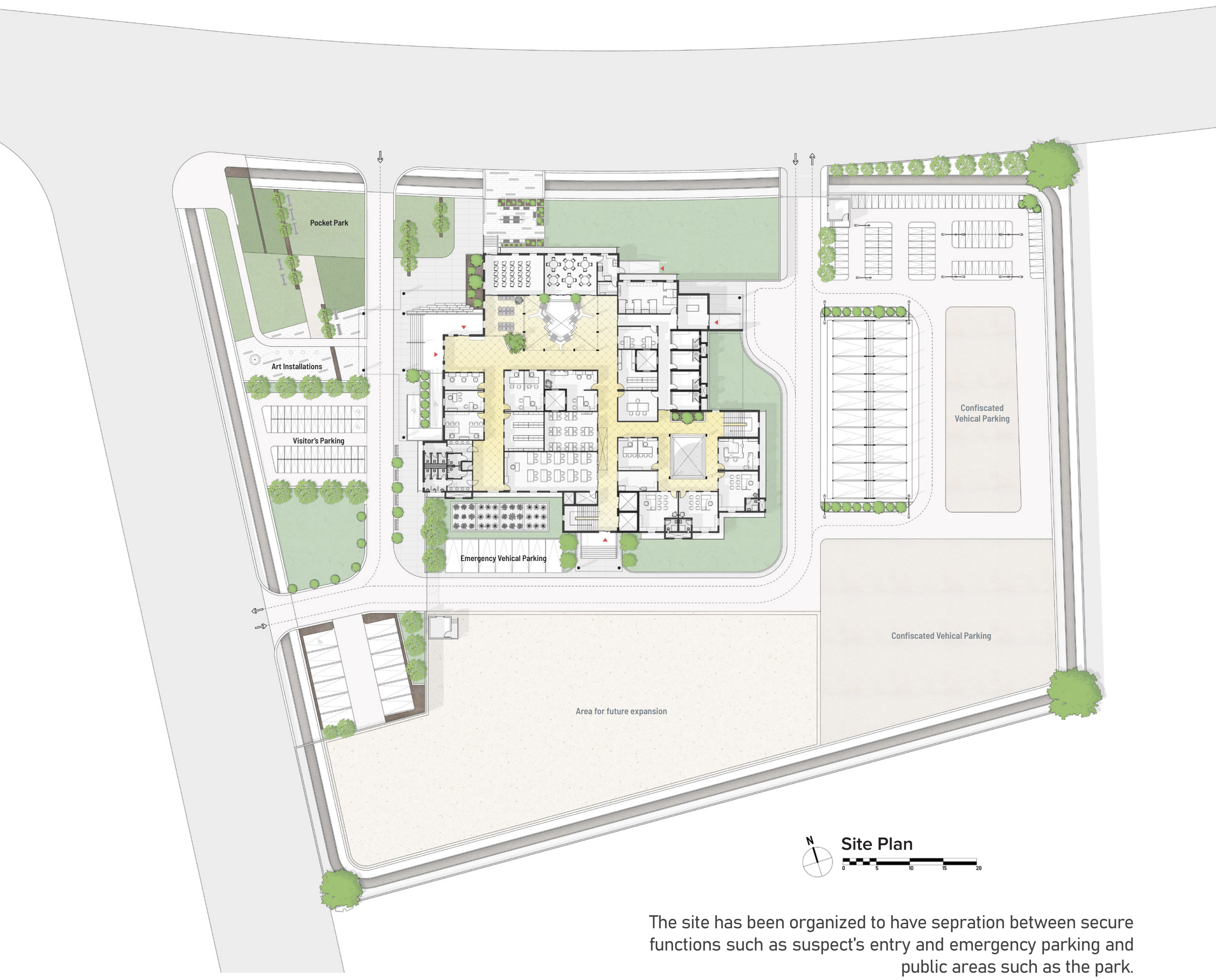
09. BAMBOO LOUVERS

Provide shading and ventilation, which helps regulate the temperature inside the building, at the same time, create a more comfortable and inviting environment for its occupants.



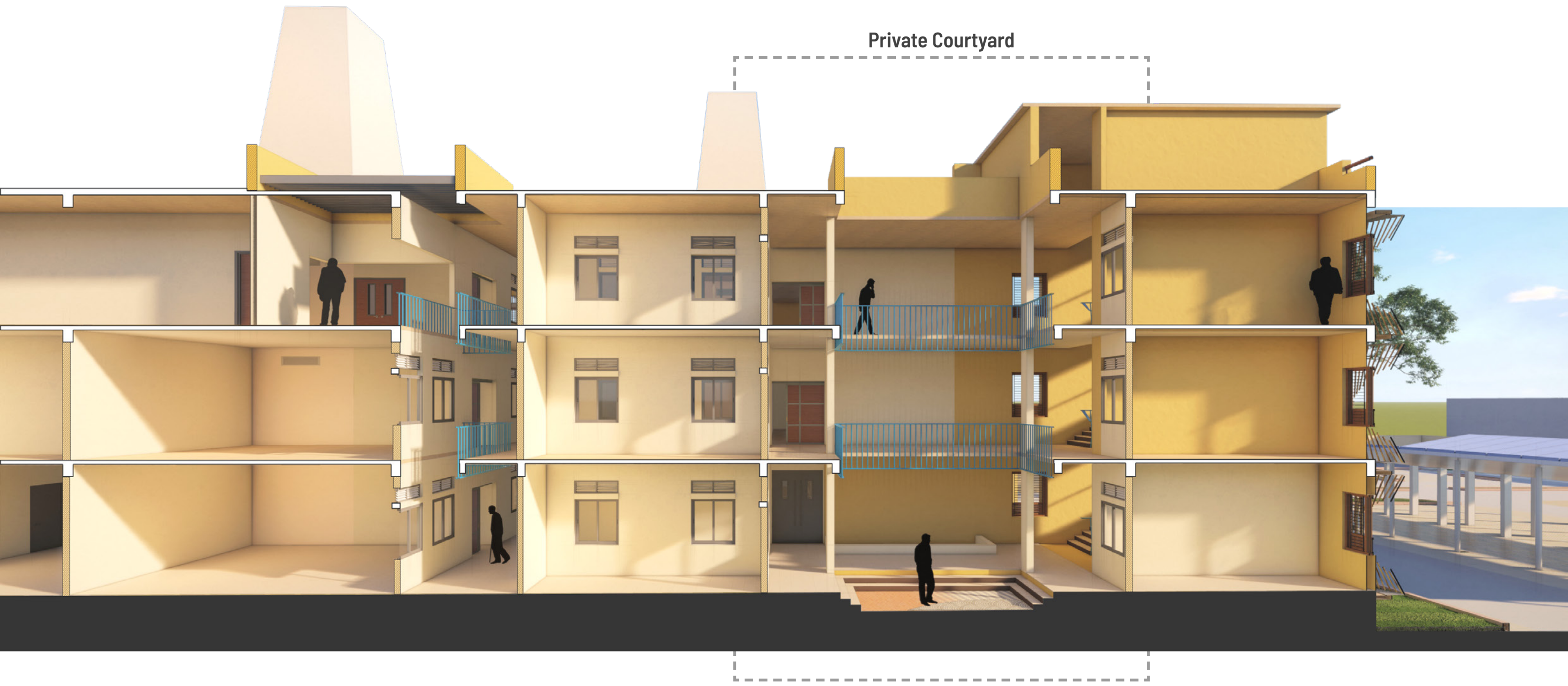
10. PV PANEL

Addition of PV panels on the roof top to meet the energy requirements of the building.



Site Plan

The site has been organized to have sepration between secure functions such as suspect's entry and emergency parking and public areas such as the park.



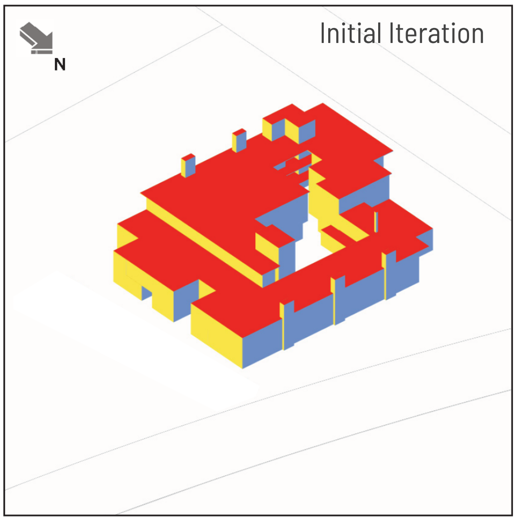
LEGEND

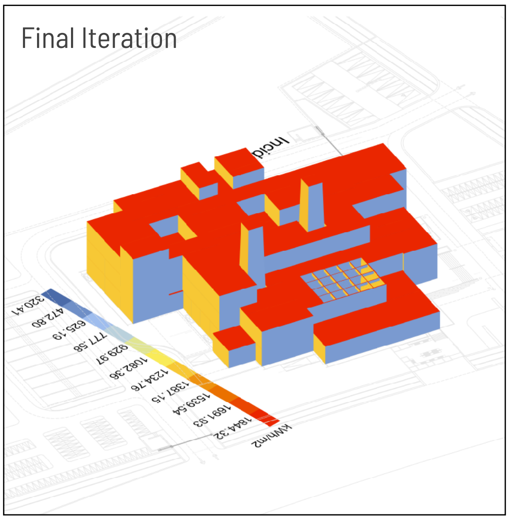
- 01 Entrance Foyer
- 02 Reception
- 03 Enquiry Counter
- 04 Waiting Area
- 05 Community Room
- 06 Cafeteria + Kitchen
- 07 Public Courtyard
- 08 Station Diary
- 09 Verification Section
- 10 Women's Help Desk
- 11 Routine Writer
- 12 Records
- 13 Constable Room
- 14 Training Room
- 15 Washrooms
- 16 Barracks
- 17 Booking and Storage
- 18 Guard Room
- 19 Detention
- 20 Storage and Services
- 21 Witness Interrogation
- 22 Private Courtyard
- 23 API Chamber
- 24 Utility and Office
- 25 PI Chamber (Welfare)
- 26 PI Chamber (Crime)
- 27 PI Chamber (Wireless)
- 28 Wireless Section

The floor plan is zoned as per security requirements. Most of the public functions are located near the entrance to restrict public access to sensitive areas. These areas are organized using a public court-yard.

A second courtyard is private to police officers and wraps all official working spaces around it. It ensures natural light in all spaces while also maintaining the required level of security, being separated from the public courtyard.

The PDEC tower works in conjuction with the two courtyard to ensure a free flow of breeze. The tower has micronizers which dampen and cool the outdoor air, which comes down, absorbs heat and escapes from courtyard through stack effect.





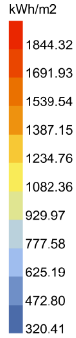


Fig. : Form Interations based on Incident Solar Radiation

Daylight and Illuminance

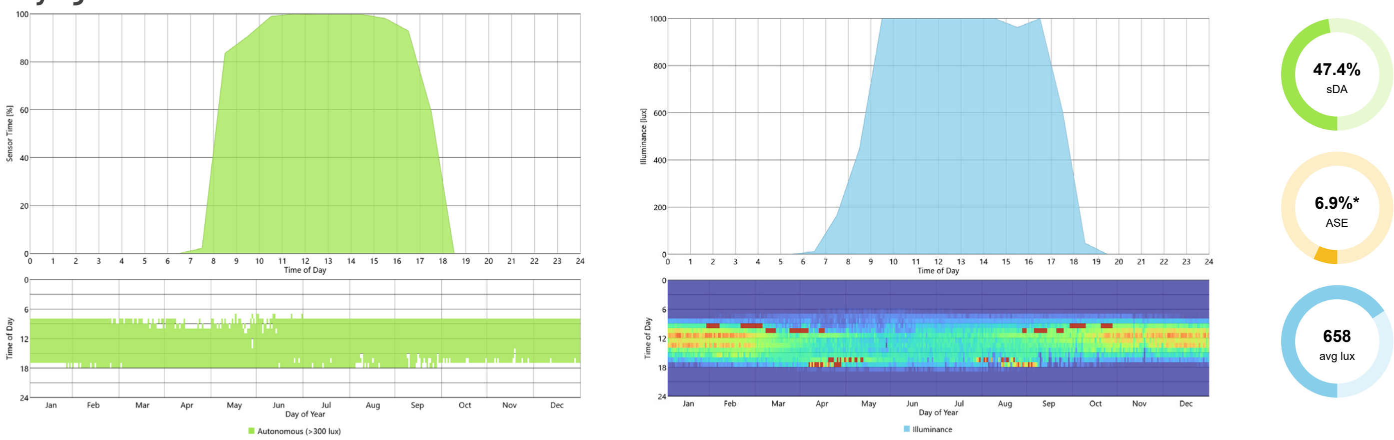


Fig. : Daylight Autonomy and Illuminance Graphs

The wall to window ratios (WWR) have been optimized (average 18%) to have spatial daylight autonomy in **47.4%** of the floor area. The sunlight exposure (>1000 lux) have been limited to **6.9%** of the area, mostly near the courtyards.

The average illuminance in the building is **658 lux**, above the minimum requirement of 200-500 lux recommened by BIS.

How effective is the operable shading device?

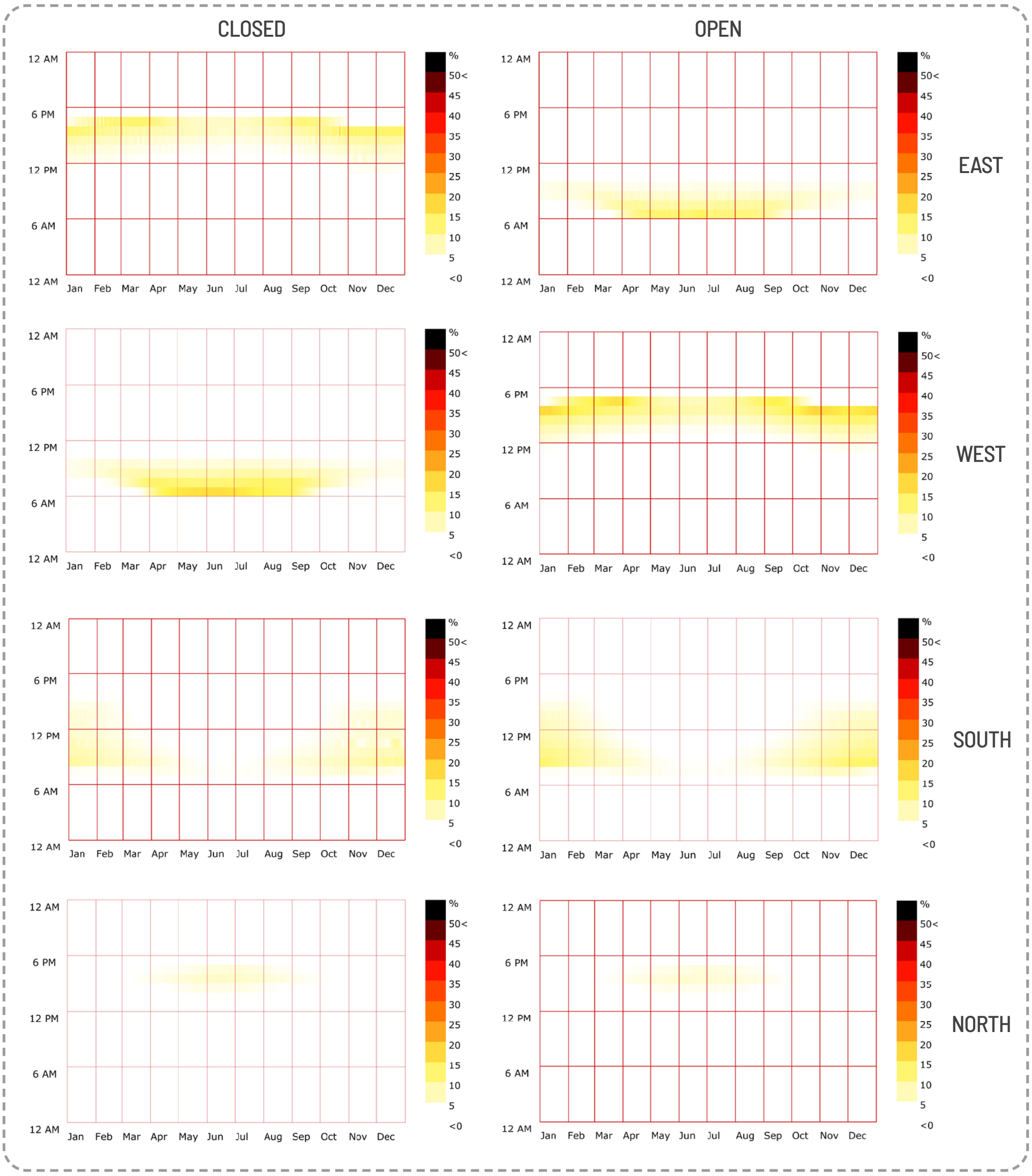


Fig. : Percentage of window exposed to direct sunlight when shading device is closed vs open.

Suggested mode of operation for maximum window shading, thermal comfort and energy performance:

Eastern windows closed during summers from 8-10AM.

West windows closed in the afternoons all year round atleast from 3:30PM till sunset.

Northern and Southern windows can be kept open or closed as per user requirement.

Summer months are shaded.

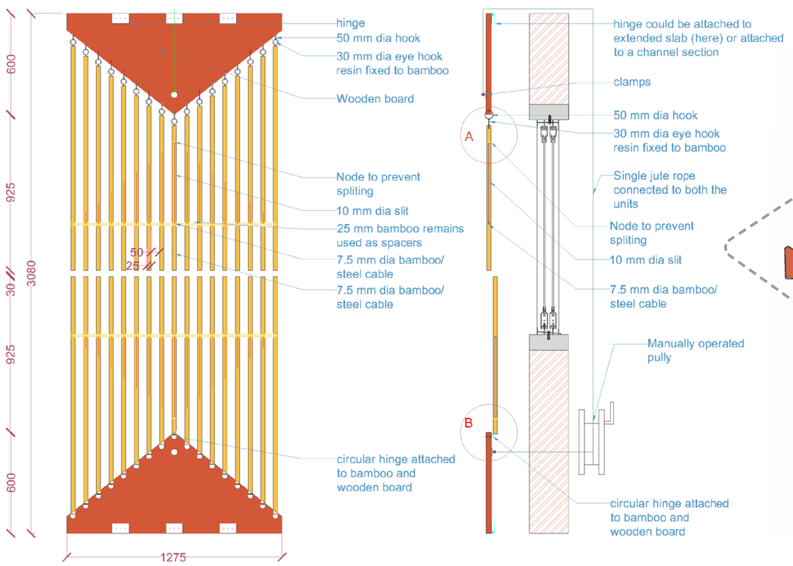


Fig. : Elevation and Section of Bamboo Shading Device

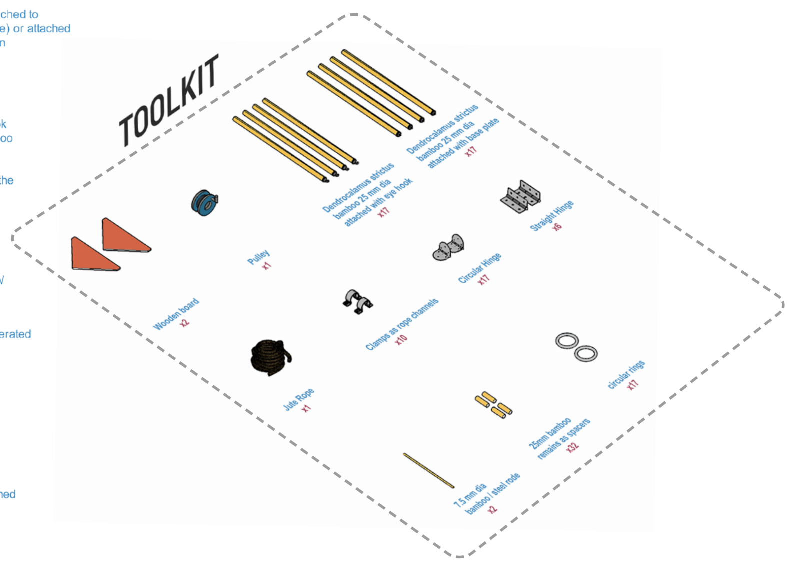


Fig. : Built-it-yourself Toolkit

Affordability

Construction Cost Estimation

S.No.	Particulars	Proposed Estimate (Project Partner/SOR Basis)		
		Amount (Million INR)	%	Amount (INR per sqm
1	Land	0.03	0.04	10.25
2	Civil Works	50.8	60.89	17354.47
3	Internal Works	11.1	13.30	3792.02
4	MEP Services	36.1	43.27	14781.86
5	Equipment & Furnishing	8.3	9.95	3398.60
6	Landscape & Site Development	5.4	6.47	2211.14
7	Contingency	1.02	1.22	417.66
	TOTAL HARD COST	112.75	97.55	33325.87
8	Pre Operative Expenses	0	0.00	0.00
9	Consultants	2.83	2.50%	8.54
10	Interest During Construction	0	0.00	0.00
	TOTAL SOFT COST	2.83	3.39	1158.80
	TOTAL PROJECT COST	115.58	100%	39484.83
		Total Project Cost =Rs.11,98,60,000		
		Project Cost per sqm =Rs.39484		

The construction estimate is within project partner's budget of 12 Crores.

The total project cost is Rs. 11,98,60,000.

The project cost per sqm is Rs. 39484.

Table 09 : Cost Estimation

Strategies to reduce CapEx

Economic Feasibility ↑↑

1. Management:

- Adoption of lean construction techniques such as prefabrication and modular construction techniques to reduce construction time and material waste, optimize resource allocation, and improve collaboration among project stakeholders.
- Use of Building Information Modelling (BIM) to optimize the design process, reduce rework, reduce construction time by 20% (about 2-3 months), and save 20% cost of construction.

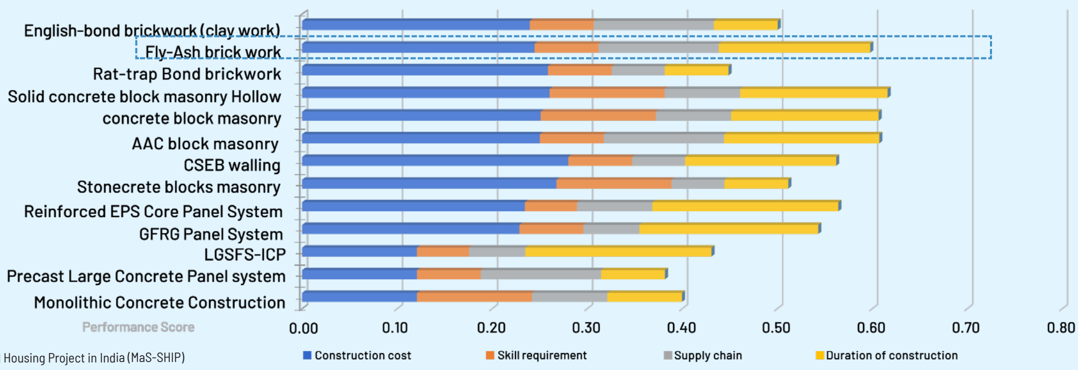
2. Financing:

- Financing of green elements through "Green Bonds" issued by the SGrB, reducing the cost by 7%.
- 12% savings from base case on property, sales, and income tax bills annually due to the implementation of green strategies overall.

3. Material:

- 22.5% less material cost required for fly ash bricks, inverted clay pots with mud phuska, and argon-filled windows.
- Use of high-performance glass, wall, and roof assemblies to reduce thermal loads and more reliance on natural ventilation.

Walling System:
Economic Impacts Comparison



The X-axis represents an aggregated score, indexed between 0-1. The higer the score, the better the alternative.

Source: Mainstreaming Sustainable Social Housing Project in India (MaS-SHIP)

4 Energy:

- 20% reduction in lighting power density and 10.8% lower electrical consumption with optimized daylighting design.
- Annual revenue of Rs. 17,3,065 generated from excess energy produced by PV panels, reducing OPEX by 41% and recovering excess capex in 5.5 years.
- Dimmed lighting fixture linked to sensors saves up to 30% of lighting cost and complete shutting down of appliances saves up to 50% energy and cost.
- Use of Lithium Ion Batteries reduces OPEX by 20% compared to the base case.

5 Cooling Systems:

- Reduction in OPEX cost by 34% annually.
- Sensors control the lighting and temperature of the utilizing area based on the system operating, saving 35% in OPEX annually.

6 Water Performance:

- Cost-cutting of Rs. 2,73,967.5 on water bills annually due to rainwater harvesting and greywater treatment.
- 43% water saved due to the use of low-flow faucets and fixtures, saving Rs. 1,17,806.025.

Life Cycle Cost and Benefit Comparision

The upfront cost being reduced, gives a direct picture that how green systems are helping to achieve net zero structure and saving cost at the same instance. Also, LCCA makes the decision making easier. The LCCA for various green building systems was done for a period of 25yrs and 60yrs, in comparison to the base case. There was an increase of 9% in CAPEX i.e. from 10.64 Cr to 11.70 Cr , due to the strategies and the systems used which in turn makes a reduction of 15.7% in OPEX compared to Base case

Variable Refrigerant Flow (VRF)

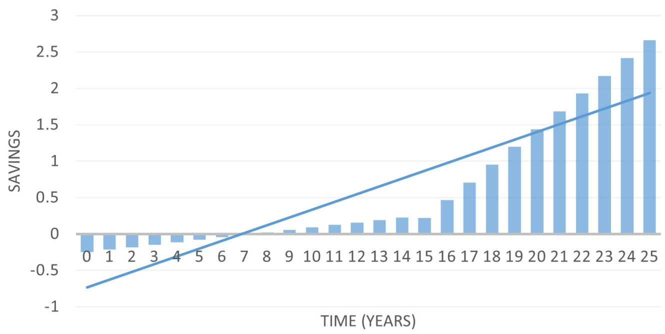


Fig. : Economic Feasility of VRF in 25 Years

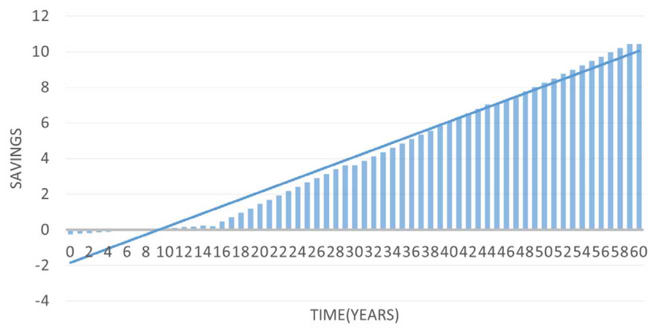


Fig. : Economic Feasility of VRF in 60 Years

Solar Photovoltaics

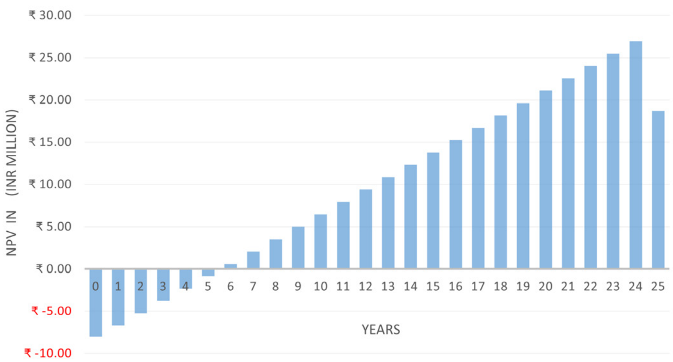


Fig. : Economic Feasility of Solar PV in 25 Years

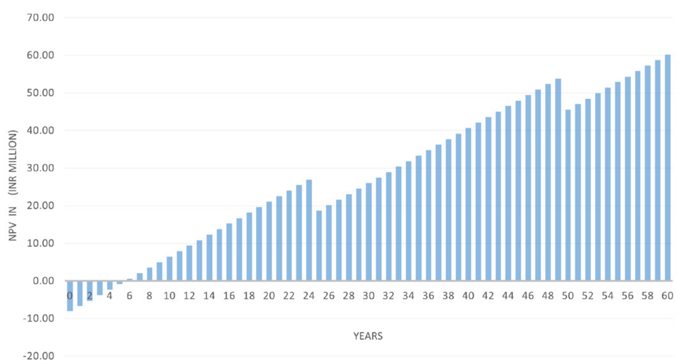


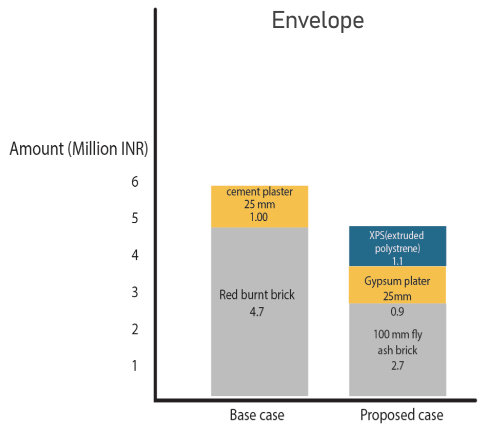
Fig. : Economic Feasility of Solar PV in 60 Years

	Scenario-1	Scenario-2	Scenario-3
CapEx (Year -0)	10.64	11.7	12.5
Incremental Capex		1.06	1.86
Addl. CapEx (Year -6)			
Annual OpEx	0.46	0.275	0.21
Annual OpEx Savings		40%	54%
Annual savings in Opex	0	0.185	0.25

CASH FLOWS (INR . Crores)	Scenario-1	Scenario-2	Scenario-3
Y0 (Incremental Capex)	0	-1.06	-1.86
Y1 (Savings in OpEx)	0	0.185	0.25
Y2 (Savings in OpEx)	0	0.185	0.25
Y3 (Savings in OpEx)	0	0.185	0.25
Y4 (Savings in OpEx)	0	0.185	0.25
Y5 (Savings in OpEx)	0	0.185	0.25
Y6 (Savings in OpEx - Addl Capex)	0	0.185	0.25
Y7 (Savings in OpEx)	0	0.185	0.25
Y8 (Savings in OpEx)	0	0.185	0.25
Y9 (Savings in OpEx)	0	0.185	0.25
Y10 (Savings in OpEx)	0	0.185	0.25

Discount Rate	10%		
Payback Period (Years)	0	5.73	7.44
IRR (Internal Rate of Return)		12%	6%
ROI (Return on Investment)		305%	134%
NPV (Net Present Value) of Cashflows		0.1	(0.3)
Life Cycle Cost (Cr)	28	18.6	20

Table 09 : Life Cycle Cost Analysis



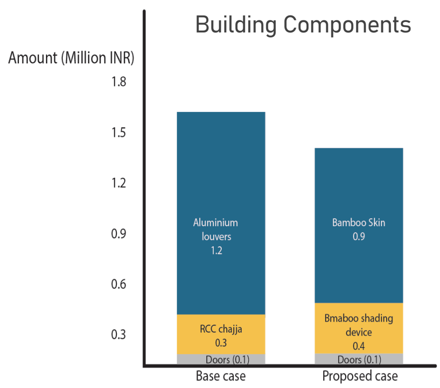


Fig. : Cost savings due to material substituiton

In **Scenario 2**, the incorporation of innovative wall assembly structures, such as those made from alternative materials like bamboo or composite panels, results in a 9% increase in capital costs compared to Scenario 1. Similarly, the replacement of centralized air conditioning systems with variable refrigerant flow (VRF) systems, use of PV panels for renewable energy generation, water treatment through root zoning, and the implementation of bamboo louvers and shading devices add to the capital cost. However, these features are designed to reduce the building's energy consumption and operating costs by up to 40% over its lifetime, making it more cost-effective and sustainable in the long run.

In contrast, **Scenario 3** involves even more advanced features such as electrochromic glass, smart appliances, and an advanced building automation system. While these technologies offer significant energy savings, they also result in a substantial 14.8% increase in capital costs compared to Scenario 2. Moreover, the reduction in operational costs is not as significant as in Scenario 2, with only a 54% decrease in OPEX. As a result, the payback period increases, ROI decreases, and the LCC becomes 11.5% greater than in the ideal Scenario 2.

Therefore, while it may seem tempting to implement the latest and most advanced technologies, it is important to carefully evaluate the costs and benefits of each option. By doing so, we can ensure that we create a building that is not only energy-efficient but also cost-effective and sustainable over its entire lifetime.

Innovation

#1 A peer-to-peer energy exchange

Based on the system implemented by Power Ledger in India

An electricity cooperation mechanism among neighboring buildings of Pardi with RES is proposed. It relies on adjusting the RES tariff with a mutual agreement between the neighboring buildings, with an aim to minimize operational costs.

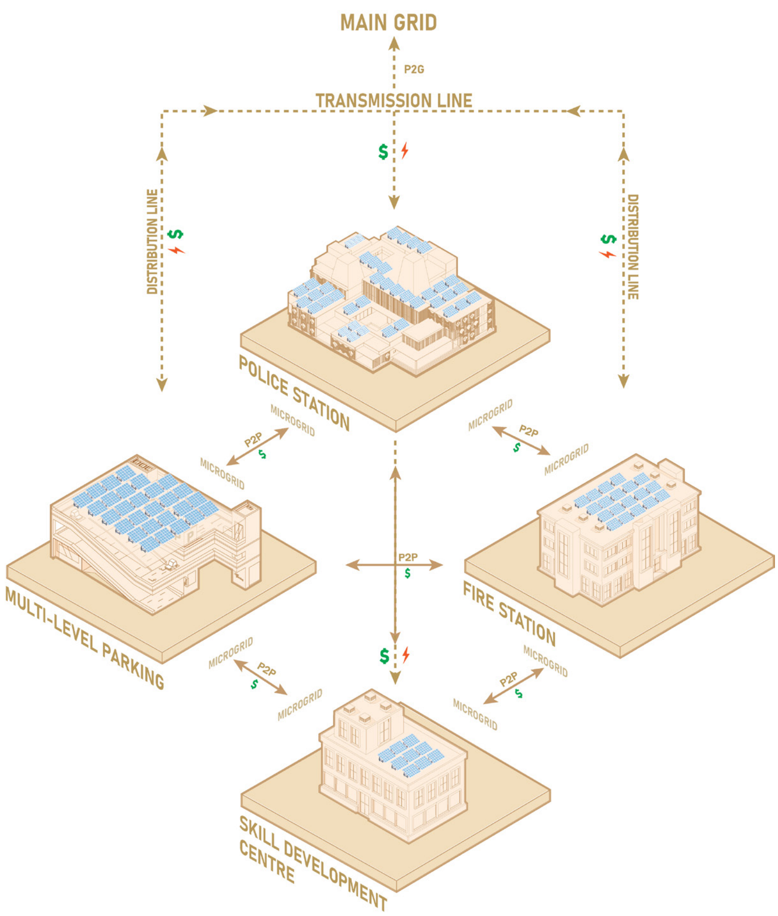
PROBLEM

Exporting generated electricity by on-site renewable energy systems from buildings to the grid is only slightly profitable in many countries. Therefore, it is required to investigate the benefits of sharing generated energy in a microgrid within a community of buildings in the Pardi locality.

OBJECTIVE

- Reducing dependency on the grid, Thereby helping to mitigate the per capita carbon dioxide emissions.
- Access to cheaper, renewable energy.
- Potential revenue stream for renewable energy generators.
- Encourages load shifting to deal with peak periods on the grid. In time improving grid resilience.

SCENARIO



There are N neighboring buildings (here we have considered 4 buildings: Skill development center, multi-level parking, fire station and police station) which are in close vicinity so that it is possible to have physical connections between them for energy transfer.

Each building is considered to be owned by the Smart city project of Nagpur and is connected to the national power grid through net metering.

Each building can share its surplus electricity, and can also buy and sell it to the grid using smart metering.

When a building is unable to meet its electricity demands from its RES, it purchases electricity from other buildings, if there is any.

In case other buildings also don't possess sufficient energy, they will be purchased from the utility.

Fig. : Energy and money flow for peer- to- peer and peer-to-grid trading among the 4 buildings

Fig. : Energy and money flow between different neighbourhoods of Pardi TPS demonstrating the innovation's scalability.

MARKET POTENTIAL

The peer-to-peer (P2P) energy-sharing market is a relatively new and rapidly growing market. The commercial segment is expected to grow as more and more businesses are looking to use P2P energy sharing to reduce their energy costs and carbon footprint. The driving factors would include increasing adoption of renewable energy, rising awareness about the benefits of P2P energy sharing, and supportive government policies.

#2 One Counter Solution Helpdesk

PROBLEM

- Need for a way for people to convey their concerns, tips or issues anonymously, making it easier for them to share sensitive information without fear of retribution.
- Efficient way for collecting information, allowing the police to gather data and intelligence on crime trends, suspicious activities or potential threats.

Scalability & Market Potential :

It can be easily implemented in all police stations across Nagpur, as well as nationwide. As the machine gains popularity and success, its demand is likely to increase even in smaller cities, ultimately reducing the cost of installation.

Health and Well Being

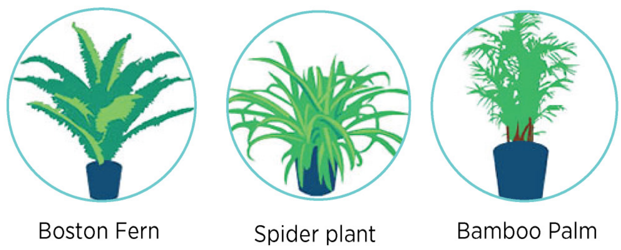
Achieving Optimum IAQ

In Nagpur, it has been noticed that public buildings lack indoor plants, and even if they have them, the upkeep is minimal. In addition to their air-purifying benefits, indoor plants can also have a positive impact on people's mental health and wellbeing. Incorporating indoor plants into public buildings such as the police station can create a more welcoming and calming environment for both visitors and staff.

A. **Bamboo** removes benzene, trichloroethylene and formaldehyde while also adding moisture to the air to act as a natural humidifier.

B. **The Spider Plant** is rated by NASA's Clean Air Study as one of the top 3 plants for removing formaldehyde and other toxins.

Some more plants are-
Peace lily, dracaena, Boston fern, English evy and Gerbera Daisy.



Achieving Thermal Comfort

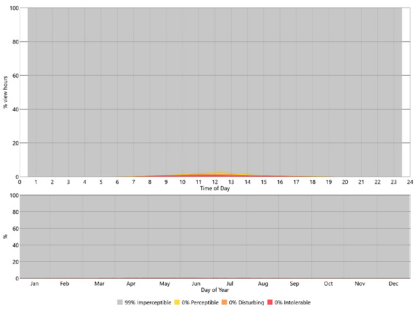
Achieving thermal comfort is crucial for ensuring maximum productivity within a building. To achieve this, the building's annual passive design strategies prioritize natural or fan-forced ventilation. When these methods are insufficient, low-energy systems such as Passive Downdraught Evaporative Cooling (PDEC) are utilized. In situations of extreme heat, Variable Refrigerant Flow (VRF) systems are employed. According to simulations, thermal comfort is achieved throughout the year with an 80% acceptability rating within the IMAC range.

MONTH	CLIMATE SEGMENT	COMFORTABLE HOURS	PASSIVE DESIGN STRATEGIES	% HOURS	OTHER STRATEGIES
January	Cold	28.1% 209 out of 744 hrs	Sun shading of windows	22.7	Dehumidification Cooling and Dehumidification Heating and Humidification
			High Thermal Mass	21.4	
			Internal Heat Gain	40.6	
			Passive Solar Direct Gain High Mass	26.6	
February		28.9% 194 out of 744 hrs	Sun shading of windows	31.4	Heating and Humidification
			High Thermal Mass Night Flushed	33.5	
			Internal Heat Gain	35.6	
			Passive Solar Direct Gain High Mass	25.3	
March	Mildly Comfortable	33.7% 251 out of 744 hrs	Sun shading of windows	35.6	Internal Heat Gain Passive Solar Direct Gain High Mass Dehumidification
			Two-stage Evaporative cooling	32	
			Cooling and Dehumidification	20.3	
April	Hot and dry	10.3% 74 out of 744 hrs	Sun shading of windows	37.4	Internal Heat Gain Passive Solar Direct Gain High Mass Dehumidification
			Two-stage Evaporative cooling	69.6	
			Cooling and Dehumidification	16	
May		1.7% 13 out of 744 hrs	Sun shading of windows	37.6	Fan-Forced Ventilation Cooling Dehumidification
			Two-stage Evaporative cooling	44.6	
			Cooling and Dehumidification	50.7	
June		0.0% 0 out of 744 hrs	Sun shading of windows	34.7	Two-stage Evaporative cooling Natural Ventilation Cooling
			Dehumidification	23.8	
			Cooling and Dehumidification	71.3	
July, August, September	Wet and Humid	0.0% 0 out of 744 hrs	Sun shading of windows	33.1	Not required
			Dehumidification	39.8	
			Cooling and Dehumidification	60.2	
October	Mildly cold	12.0% 89 out of 744 hrs	Sun shading of windows	28.5	High Thermal mass night flushed Internal Heat Gain
			Dehumidification	38.3	
			Cooling and Dehumidification	34.5	
November	Cold	27.6% 199 out of 744 hrs	Sun shading of windows	25.4	Dehumidification Cooling and Dehumidification Heating and Humidification
			High Thermal Mass Night Flushed	20.4	
			Internal Heat Gain	32.4	
			Passive Solar Direct Gain High Mass	19.4	
December		31.5% 234 out of 744 hrs	Sun shading of windows	20.4	High Thermal Mass Dehumidification Cooling and Dehumidification Heating and Humidification
			Internal Heat Gain	51.1	
			Passive Solar Direct Gain High Mass	27.1	

Table 10 : Monthly strategies for thermal comfort

Fig. : Prototyping for shading device

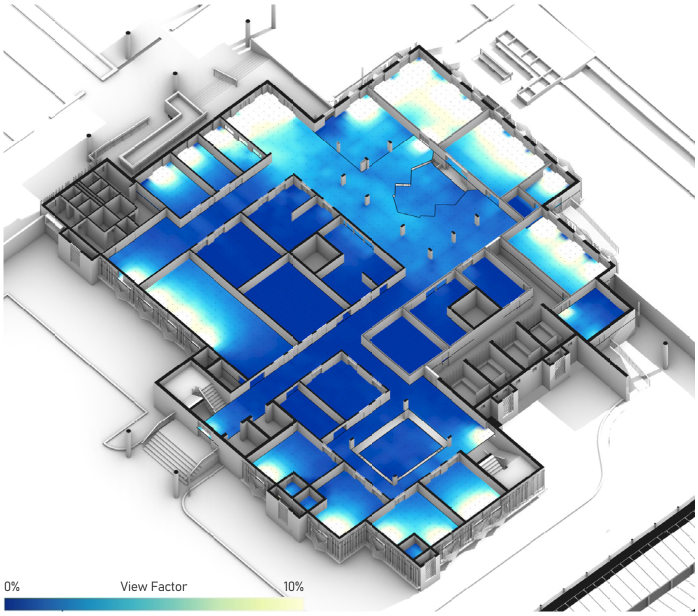
Window shading is crucial to ensure comfort for a significant number of hours. Our team has developed a shading device prototype that not only provides adequate shading but also eliminates unattractive chajjas.

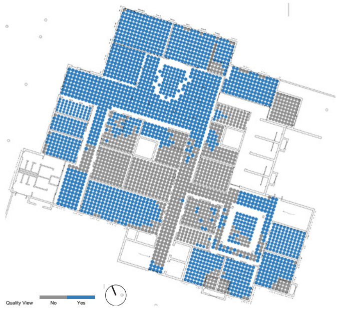


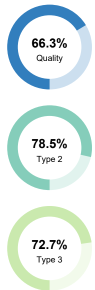
The external shading eliminates glare in most parts of the building, with only **2.1%** of the spaces with disturbing glare in >5% of the time.

Glare is concentrated in courtyards in summer.

Fig. : Glare analysis on ground floor plan







Average view factor: **3.14%**

Quality Views in **66.3%** of the floor area, primarily concentrated in public areas and working spaces.

Fig. : View analysis on ground floor plan

The nature of work of police officers involves high pressure and requires acute attention to detail, making clear and unobstructed visual access crucial. By providing quality views without glare, police officers can work more comfortably, reduce the risk of eye strain, and improve their overall physical and mental health.

Accessibility

The design of the police station has been thoughtfully executed to ensure that it is universally accessible and inclusive to all members of society. With the implementation of an **ADA ramp** featuring a gradient of 1:20, individuals using a wheelchair are able to access the ground floor with ease. In addition, an elevator has been installed to allow for access to the other floors. To further cater to individuals with disabilities, each floor of the police station features a **wheelchair accessible washroom**.

Addressing Neighbourhood Light Pollution

As a police station, it is essential that the building has outdoor lighting that must remain switched on throughout the year during the night. However, this may have adverse effects on nearby residential areas as it can cause light pollution and discomfort to the residents. To address this issue, **Glare Control shields** have been installed on the outdoor lights. These shields help to reduce the overflow of light beyond the site boundaries and prevent upward light emission into the sky.

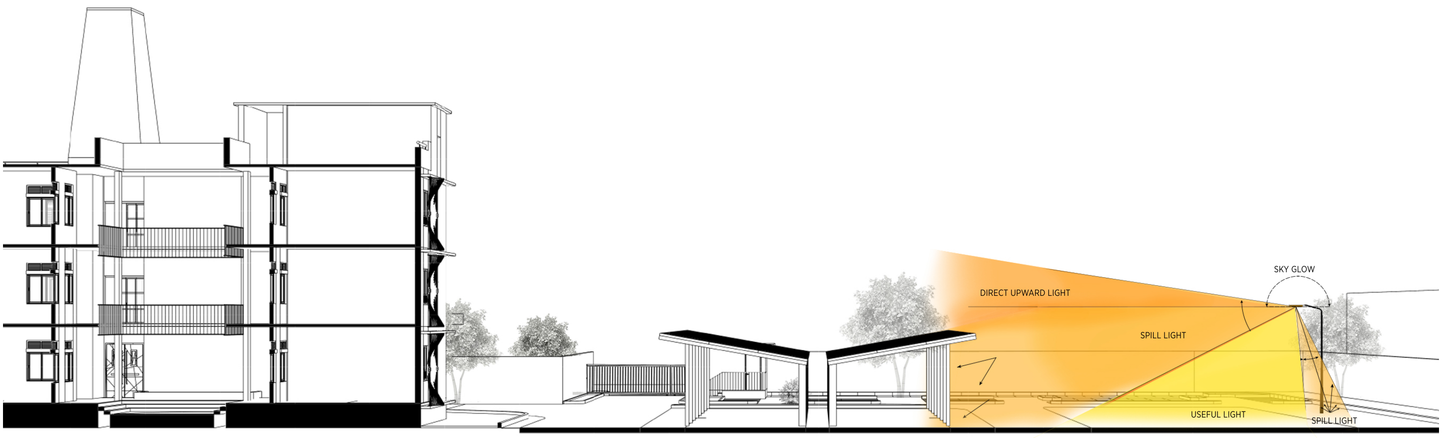


Fig. : Site section showing Glare Control

Value Proposition

Pardi Police Station: The beginning of a Ripple Effect

BRIEF

The Pardi Police Station is a project for the Nagpur Smart and Sustainable City Development Corporation that intends to set an example as a net-zero-energy water facility for the city while enhancing people's quality of life.

The building has a total built-up area of 3585.8 sq m and provides offices, resting areas, lockups, meeting spaces, and other recreational amenities to 23 police officers and the general public.

PROJECT PARTNER

Our proposal is an end result of various design iterations to optimize the building for energy efficiency, daylight access, electric lighting performance, water performance, security, visual, thermal, psychological comfort, and other measures of occupant health.

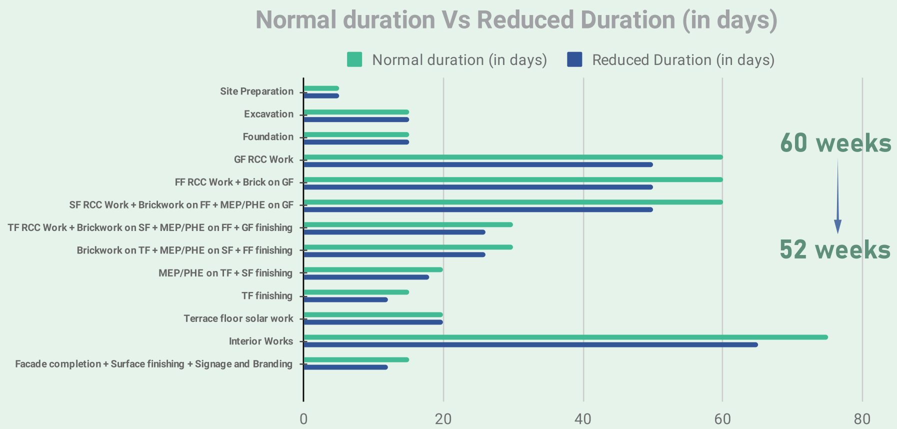
Reduced Energy consumption | High Performance Envelope | Appropriately Designed System | On-site Energy production | Reduced Water demand | Building simulations performed that are tuned for real-world need

The project's onset would serve as a focal point for future sustainable initiatives in the Pardi neigborhood, furthering the cause of the Smart City Mission. Currently our proposal meets 5 out of the 6 fundamental principles on which the concept of Smart Cities are based on.

P2P Energy Sharing | Bamboo technology | Bamboo technology

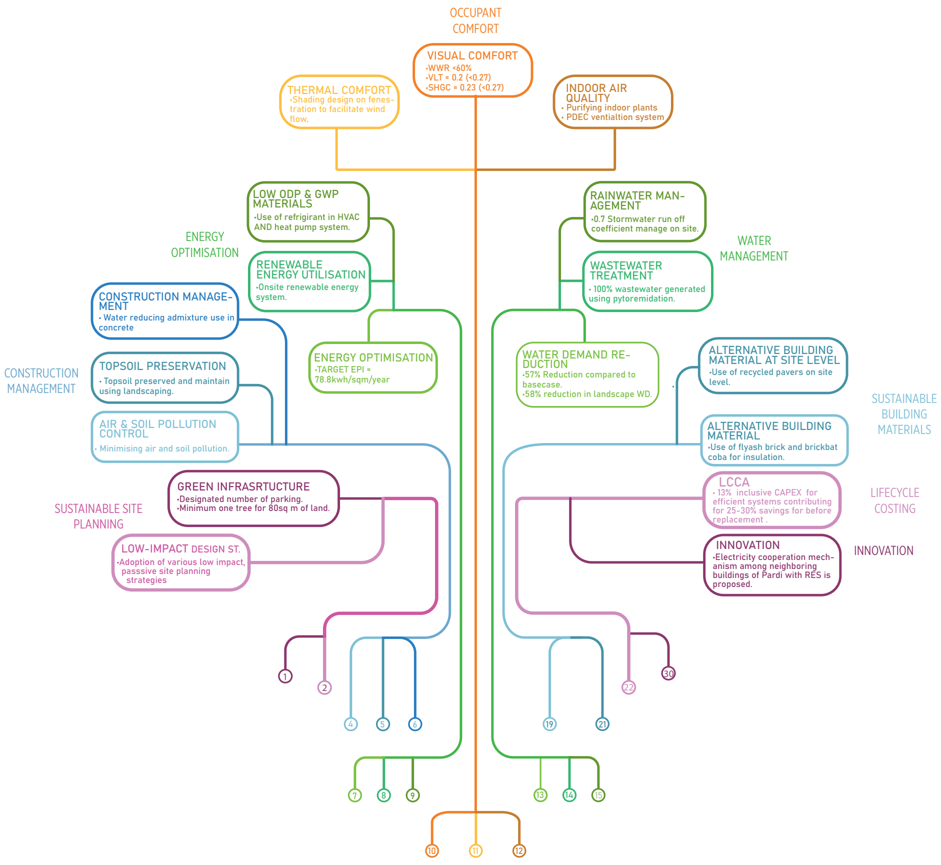
Construction time is shortened

Construction costs were **decreased by 20%** as a result of the building timeline being shortened from the basecase scenario of 14 months to 12 months.



Green Building Certification Compliant

Achieving net-zero status for a police station is a significant value addition in itself. However, for the project partner, having a recognized metric for measuring sustainable performance would further enhance the value of the project. Therefore, upon evaluation of compliance with GRIHA criteria, it has been confirmed that the project has achieved compliance. As a result, the Nagpur Smart City Project can have the distinction of having **India's first newly constructed GRIHA-compliant police station**.



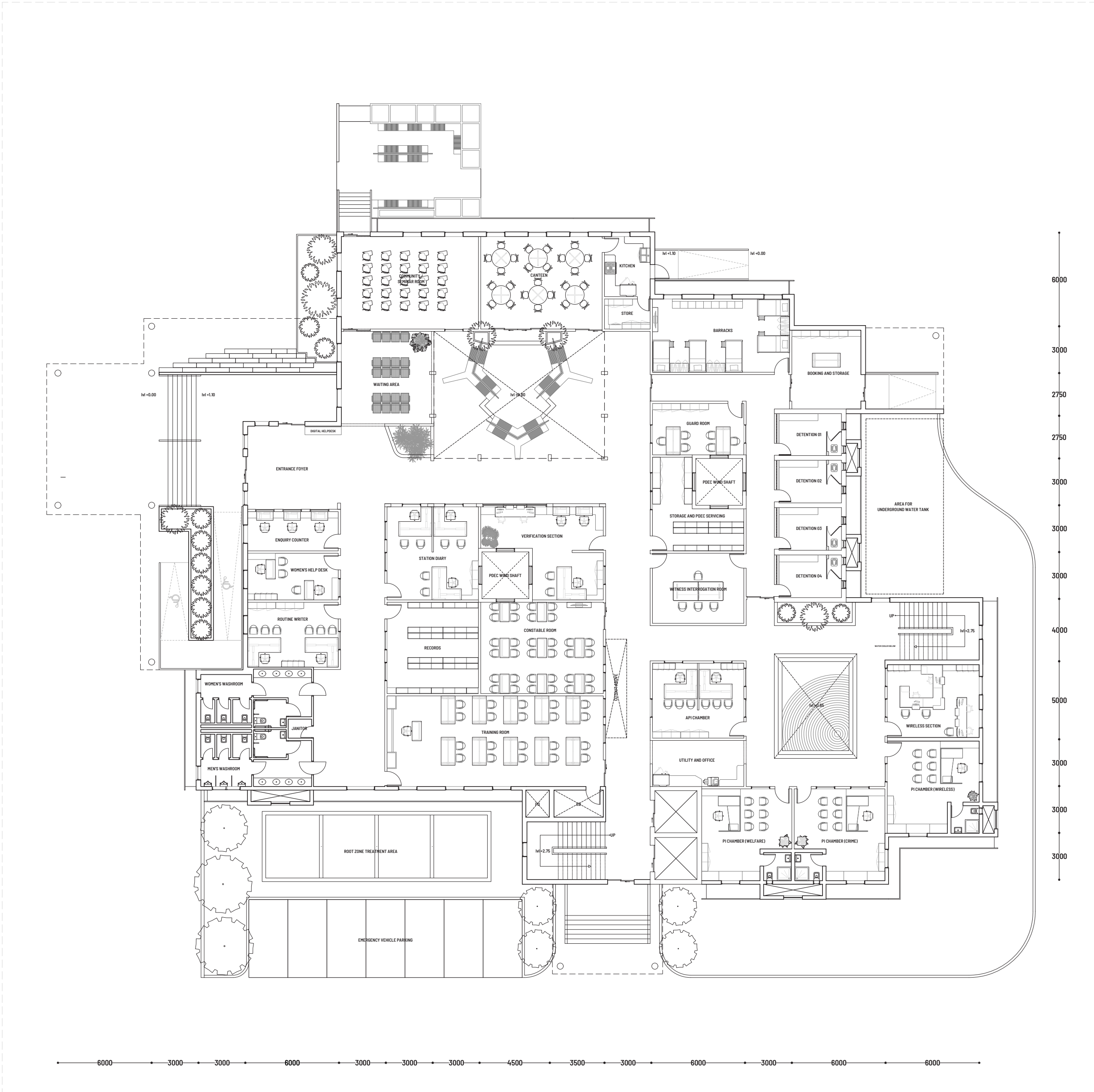
GRIHA CRITERIAS

07 Appendix

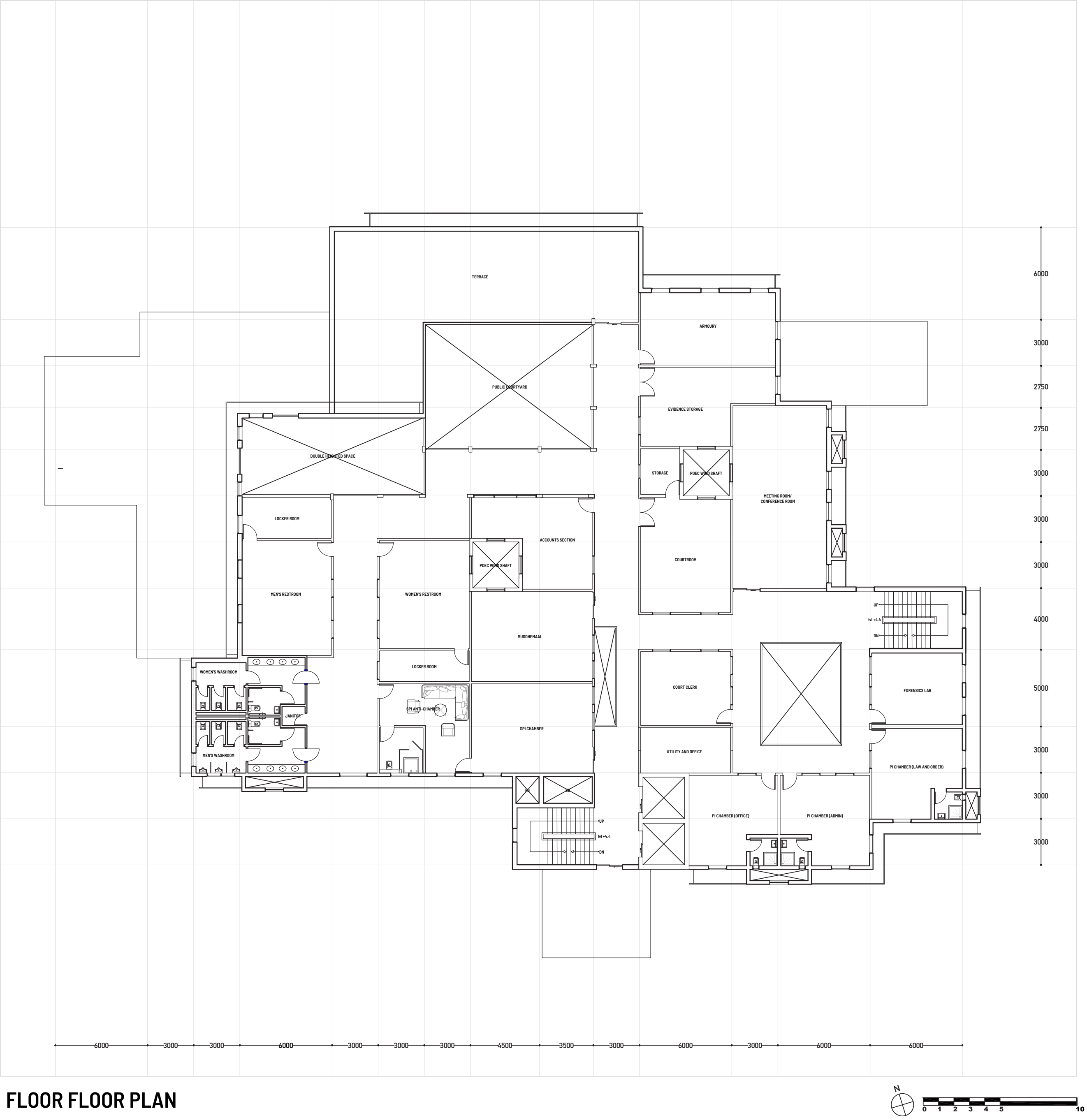
Building Area Programme

Sr. No.	Spaces	Typology	No. of units	AREA (sqm)	TOTAL AREA(sqm)	HVAC Provisions	TYPE OF HVAC
1	OFFICER'S CABIN (INCLUDING TOILET)	OFFICES	2	30+3.2	66.4	CONDITIONED	VRF
	SPI CHAMBER		1	46	46	CONDITIONED	VRF
	SPI ANTI CHAMBER		1	34	34	CONDITIONED	PDEC
	PI CHAMBER		1	30+3.2	33.2	CONDITIONED	VRF
	PI CHAMBER(ADMIN)		1	30+3.2	33.2	CONDITIONED	VRF
	PI CHAMBER WIRELESS		1	30+3.2	33.2	CONDITIONED	VRF
	PI CHMABER CRIME		1	30+3.2	33.2	CONDITIONED	VRF
	PI LAW & ORDER		1	30+3.2	33.2	CONDITIONED	VRF
	PI WELFARE		1	30+3.2	33.2	CONDITIONED	VRF
	CONSTABLE ROOM		1	46	46	CONDITIONED	PDEC
	API		1	28	28	CONDITIONED	VRF
2	ROUTINE WRITER	OTHER OFFICES	1	24.1	24.1	UNCONDITIONED	Naturally Ventilated
	VERIFICATION		1	36	36	CONDITIONED	PDEC
	COMMAND CONTROL		1	64	64	CONDITIONED	PDEC
	ACCOUNTS SECTION		1	36	36	CONDITIONED	PDEC
3	ENTRANCE/LOBBY	COMMON	1	32	32	UNCONDITIONED	Naturally Ventilated
	ENQUIRY COUNTER		1	14.6	14.6	UNCONDITIONED	Naturally Ventilated
	COMMUNITY ROOM		1	51.6	51.6	UNCONDITIONED	Naturally Ventilated
4	GENTS REST ROOM	RESTING FACILITIES	1	43.3	43.3	CONDITIONED	PDEC
	LADIES REST ROOM		1	41	41	CONDITIONED	PDEC
	GENTS LOCKER ROOM		1	15.4	15.4	UNCONITIONED	Naturally Ventilated
	LADIES LOCKER ROOM		1	12	12	UNCONITIONED	Naturally Ventilated
	GENTS DORMITORY		1	82+63(W/C+Bath)	145	CONDITIONED	PDEC
	LADIES DORMITORY		1	103+26.4(W/C+Bath)	129.4	CONDITIONED	PDEC
	GUARDS ROOM		1	19.3	19.3	CONDITIONED	PDEC
	BARRACKS		1	41.2	41.2	CONDITIONED	Naturally Ventilated
5	DETENTION ROOMS	DETENTION	4	9.2 + 1.5(toilet)	42.8	UNCONITIONED	Naturally Ventilated
6	MEETING ROOM	MEETING	1	72.4	72.4	CONDITIONED	PDEC
	STATION DIARY		1	35	35	CONDITIONED	PDEC
7	ELECTRICAL ROOM	SERVICES	1	22.7	22.7	UNCONITIONED	Naturally Ventilated
	SERVER ROOM		1	17.2	17.2	CONDITIONED	VRF
	STORAGE AND PDEC SERVICING		1	24	24	CONDITINOED	PDEC
	WIRELESS		1	28	28	CONDITIONED	VRF
8	COURT CLERK	COMMON WORKING	1	28	28	CONDITIONED	Naturally Ventilated
	TRAINING CENTRE		1	80.4	80.4	CONDITIONED	Naturally Ventilated
	WOMEN HELPDESK		2	17.4	17.4	UNCONITIONED	Naturally Ventilated
	LIBRARY		1	43	43	CONDITIONED	Naturally Ventilated
9	ARMORY	ISOLATED	1	41.2	41.2	CONDITINOED	Naturally Ventilated
	MUDEEMAAL		1	46	46	UNCONITIONED	Naturally Ventilated
	RECORD		1	34	34	CONDITINOED	Naturally Ventilated
	EVIDENCE STORAGE		1	37	37	CONDITIONED	Naturally Ventilated
10	GYM	RECREATIONAL	1	72.5	72.5	CONDITIONED	PDEC
	CANTEEN (+KITCHEN)		1	46+11.5(Kitchen)+5.5 (storage)	63	UNCONITIONED	Naturally Ventilated
11	GENTS WASHROOM	SANITARY AREA	2	(18.7+3.8(disabled man WC))	45	UNCONITIONED	Naturally Ventilated
	LADIES WASHROOM		2	(18.7+3.8(disabled woman WC))	45	UNCONITIONED	Naturally Ventilated
	JANITOR'S CLOSET		2	1.8	3.6	UNCONITIONED	Naturally Ventilated
	STORAGE		1	7.4	7.4	UNCONDITIONED	Naturally Ventilated
12	UTILITY AND OFFICE	OTHERS	2	17	34	UNCONDITIONED	Naturally Ventilated
	FORENISICS LAB		1	27.5	27.5	CONDITIONED	VRF
	BOOKING AND STORAGE		1	22.3	22.3	UNCONITIONED	Naturally Ventilated
	INTERROGATION ROOM		1	26.3	26.3	CONDITIONED	Naturally Ventilated
	CIRCULATION (40%)				887	MIXED	
	TOTAL BUILTUP AREA				**2927.2 SQM**		

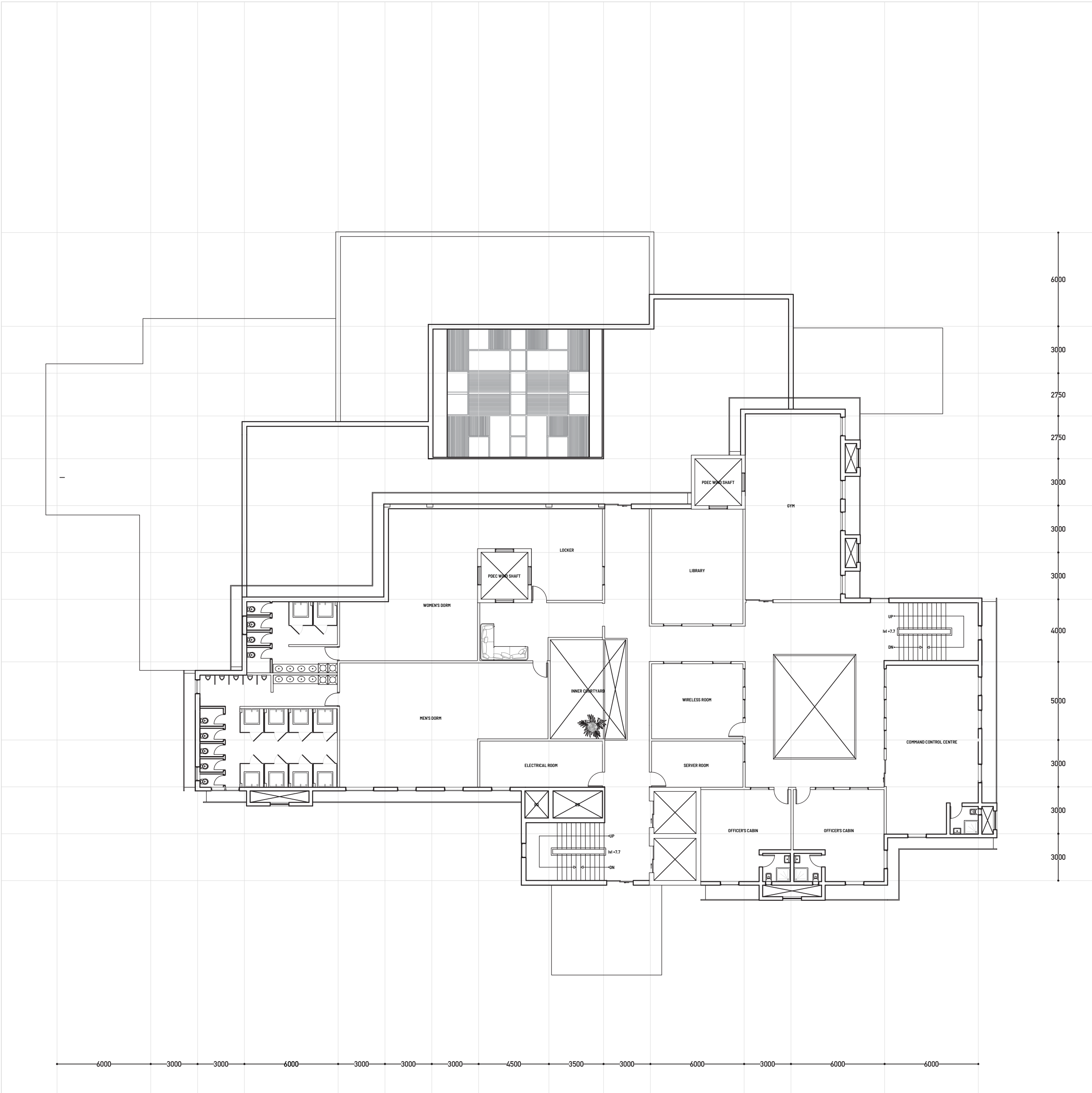
Architectural Drawings



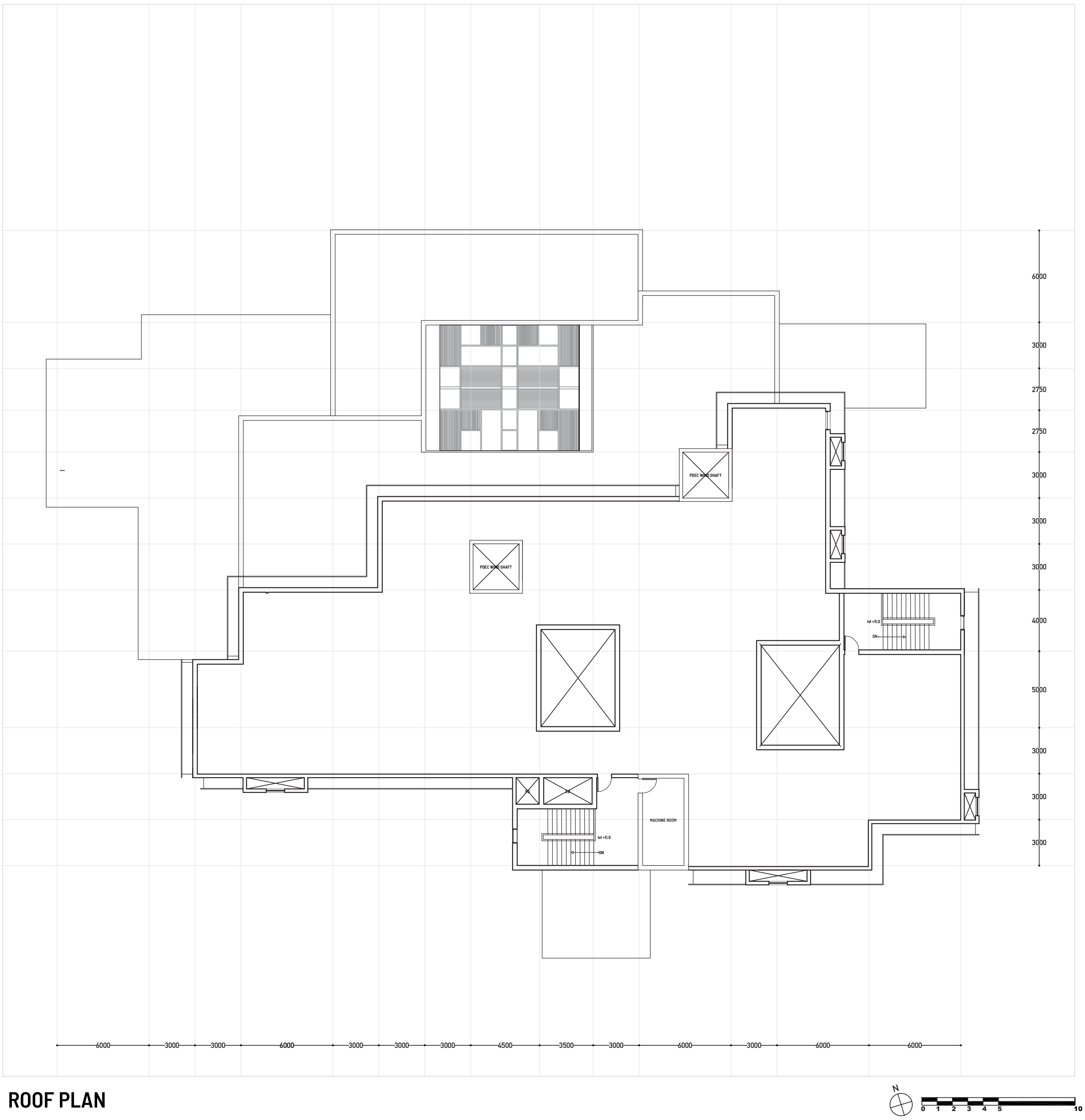
GROUND FLOOR PLAN



FLOOR FLOOR PLAN



SECOND FLOOR PLAN


6000
3000
2750
2750
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MACHINE ROOM
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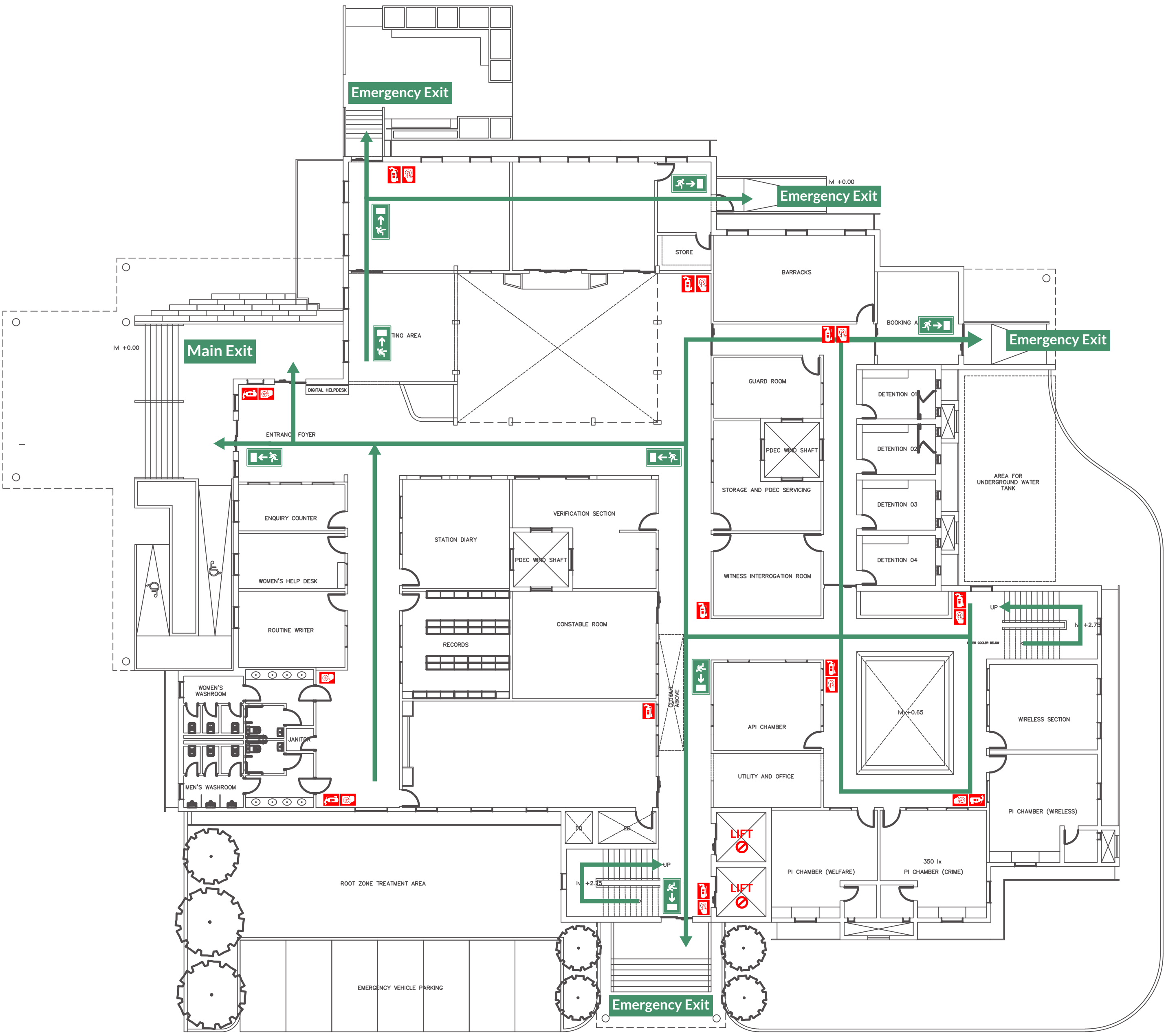
6000
6000

ROOF PLAN



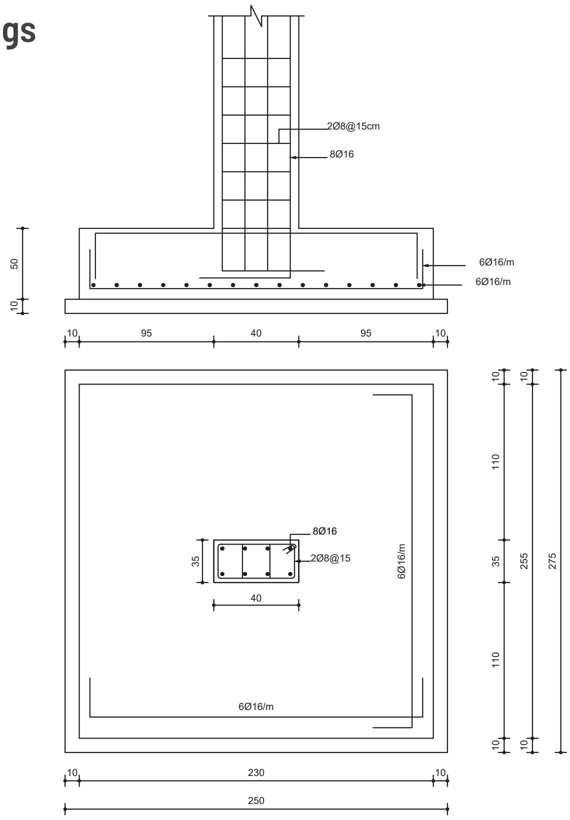
FIRE ESCAPE PLAN ON GROUND FLOOR

Legend

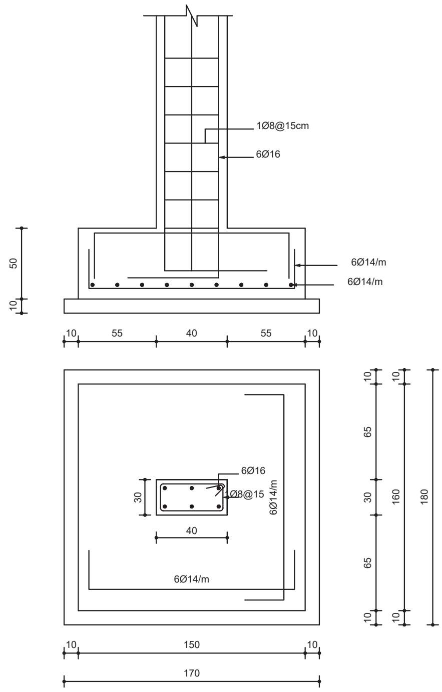
- Escape route
- Way towards exit
- Fire extinguisher
- Fire Alarm
- DO NOT use Lift in case of fire

Engineering Drawings

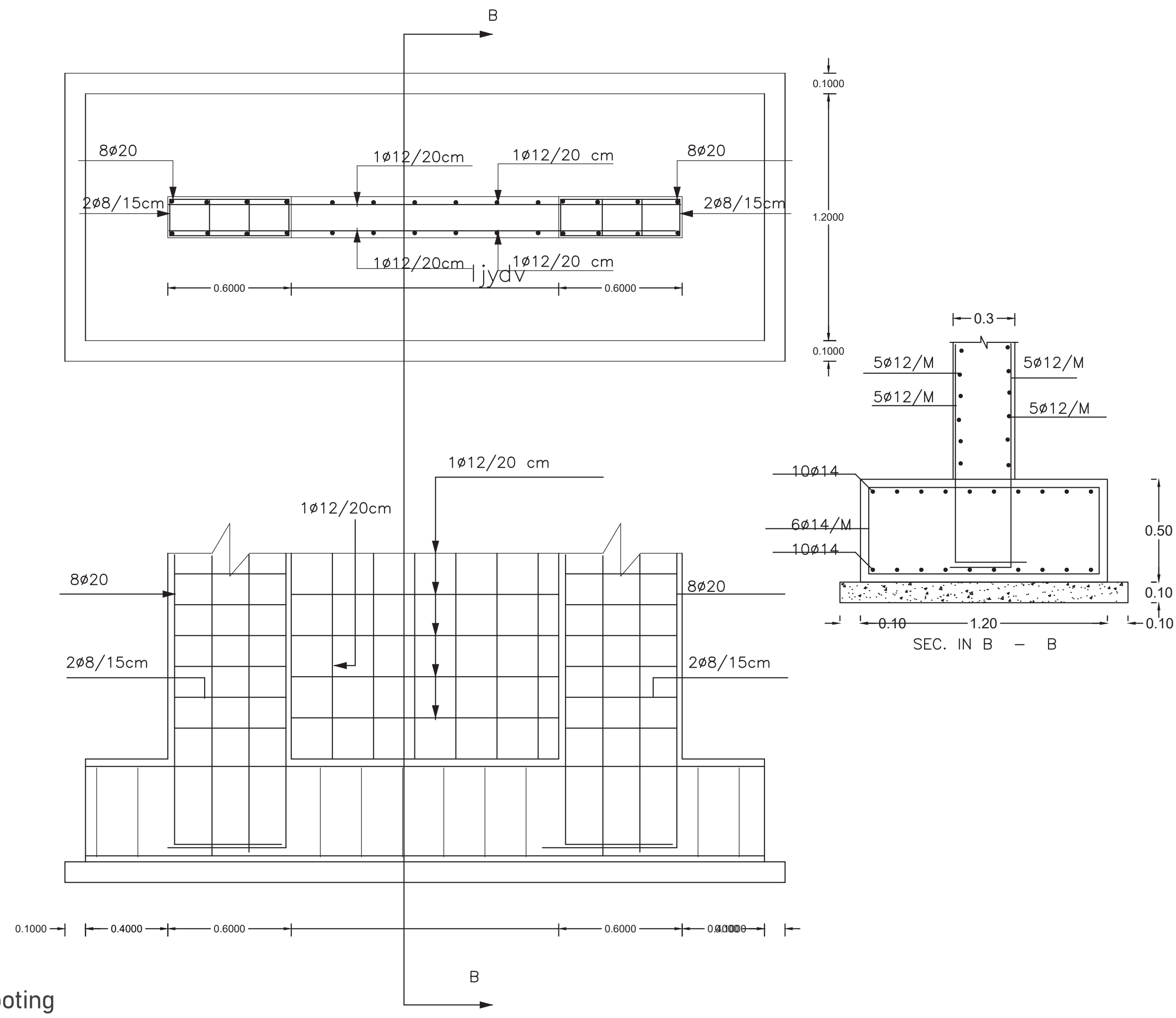
Footings



Pad Footing for Water Tank

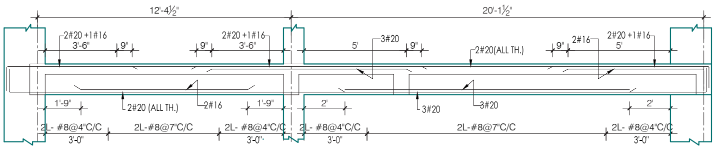


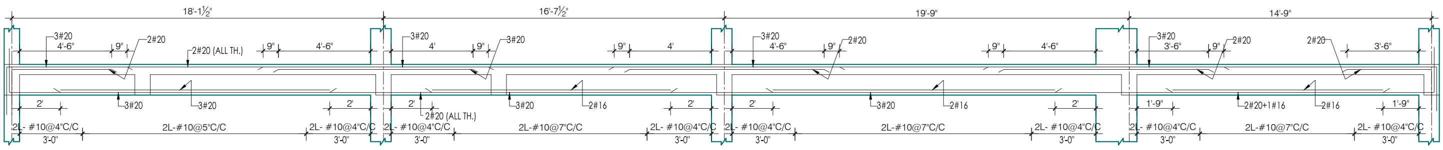
Normal Pad Footing



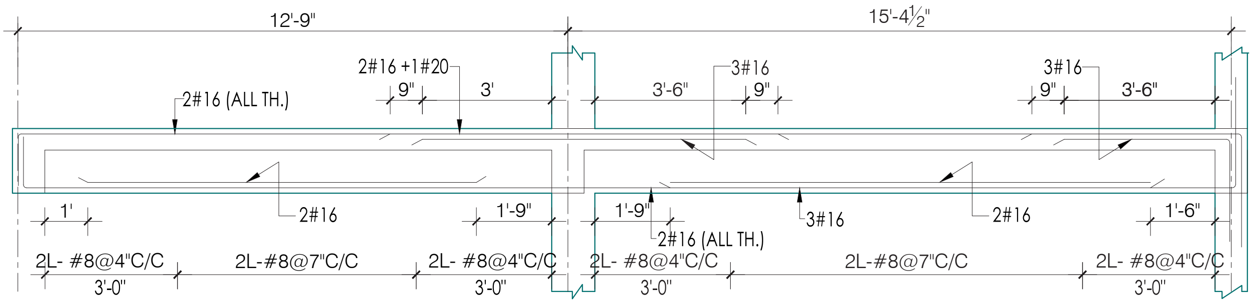
Strip Footing

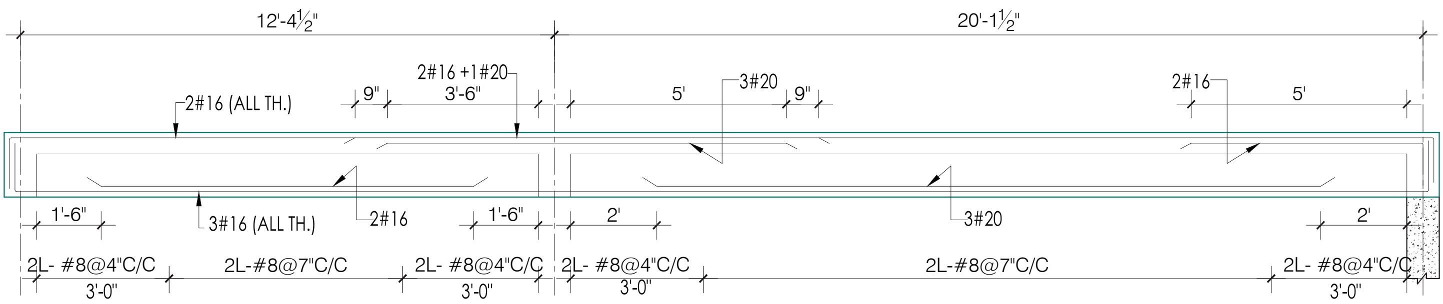
Slabs



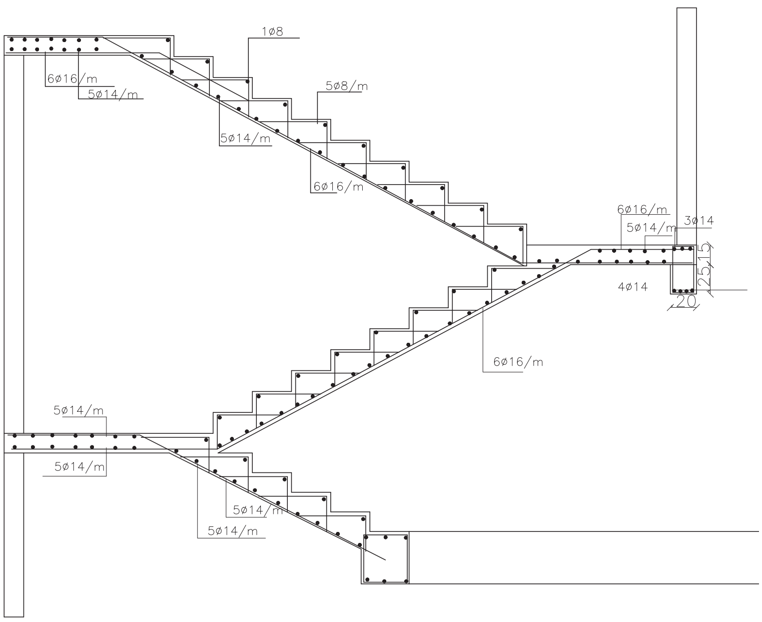


Combine Slabs





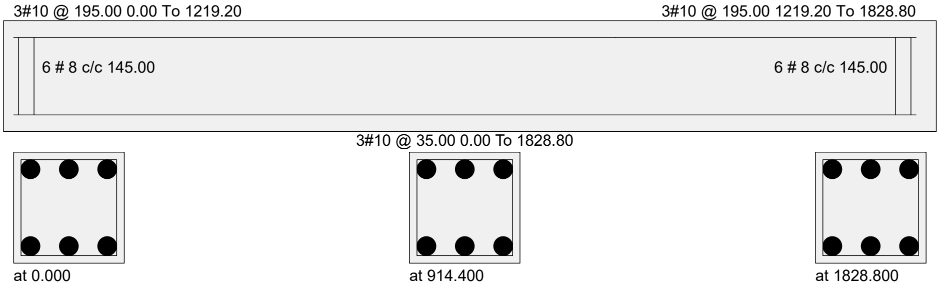
Cantilever Slabs



Staircase Details

Beams and Columns

Design Code: IS-456

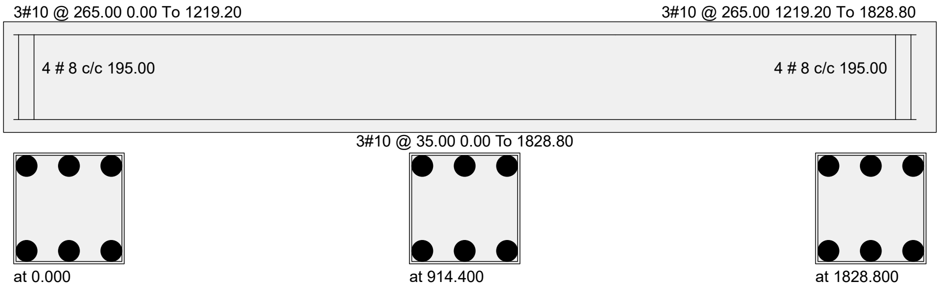


Design Parameter

Fy(Mpa)	550.000000
Fc(Mpa)	30.000000
Depth(m)	0.230000
Width(m)	0.230000
Length(m)	1.828796

Wind Tower 2nd Floor Beam

Design Code: IS-456

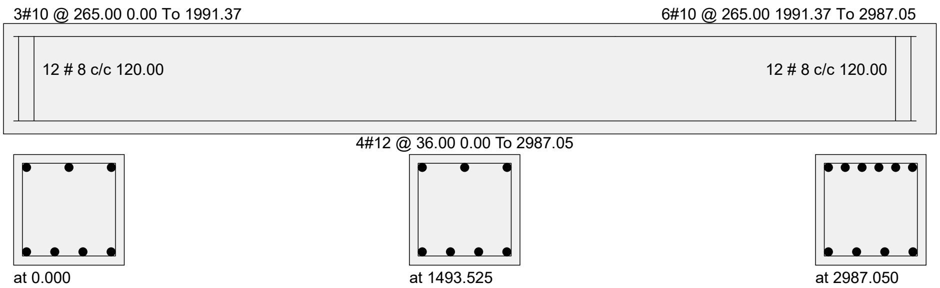


Design Parameter

Fy(Mpa)	550.000000
Fc(Mpa)	30.000000
Depth(m)	0.299999
Width(m)	0.299999
Length(m)	1.828796

Wind Tower 1st Floor Beam

Design Code: IS-456

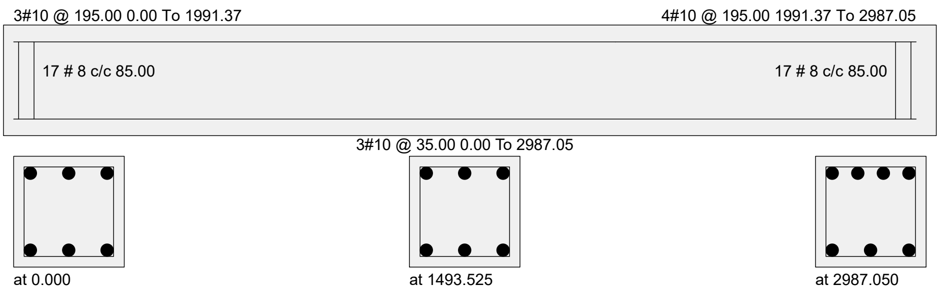


Design Parameter

Fy(Mpa)	550.000000
Fc(Mpa)	30.000000
Depth(m)	0.299999
Width(m)	0.299999
Length(m)	2.987044

First Floor Beam

Design Code: IS-456



Design Parameter

Fy(Mpa)	550.000000
Fc(Mpa)	30.000000
Depth(m)	0.230000
Width(m)	0.230000
Length(m)	2.987044

Second Floor Beam

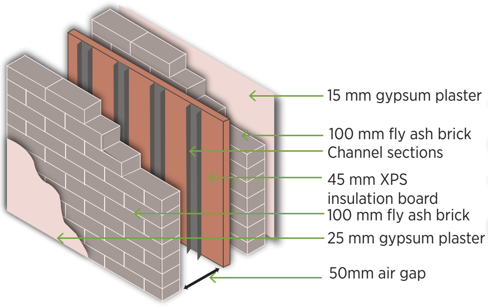
Building System Specifications

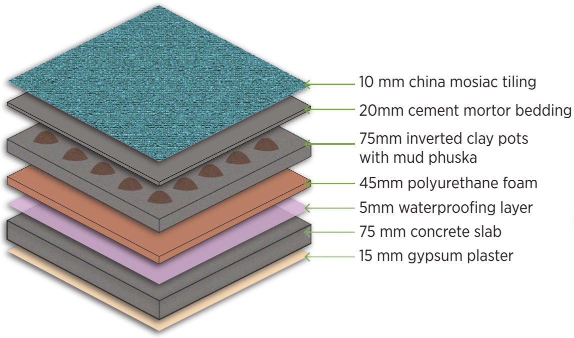
Envelope System

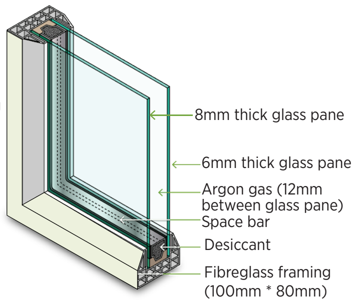
Wall Assembly			
	Trial 1	Trial 2	Final
Description	external wall plaster (25mm) +fly ash brick (100 mm) +air gap (50 mm)+ fly ash brick (100 mm)+ internal wall plaster(15mm)	external wall plaster (25mm) +fly ash brick (100 mm) +air gap (50 mm)+ coconut pith board (80mm)+ fly ash brick (100 mm)+ internal wall plaster(15mm)	external wall plaster (25mm) +fly ash brick (100mm) +air gap (50mm) +XPS - extruded polysterene (45mm) + fly ash brick (100 mm) + internal wall plaster (15mm)
U value	0.45 W/sqm.K	0.24 W/sqm.K	0.29 W/sqm.K

Roof Assembly			
	Trial 1	Trial 2	Final
Description	gloss white heat reflective ceramic tile (10mm) +concrete slab (110mm) +polyurethane foam (45mm)+ gypsum board (25mm)	china mosaic tiling (10mm) +cement mortor bedding(20mm) +100 mm brick bat coba + polyurethane foam (45mm) +concrete rcc slab(75mm) + gypsum plaster(20mm)	china mosaic tiling (10mm)+ cement mortar bedding (20mm)+ (inverted clay pots with mud phuska (75mm) + polyurethane foam (45mm) +water proofing (5mm) + concrete rcc slab (75mm) +gypsum plaster (25mm)
U value	0.43 W/sqm.K	0.38 W/sqm.K	0.25 W/sqm.K

Window Assembly	
Description	clear glass (6mm)+ argon filled- 80 per concentration (20mm) + clear glass (8mm)
U value	1.79 W/sqmK
SHGC	0.23
VLT	0.2
Emissivity	0.3

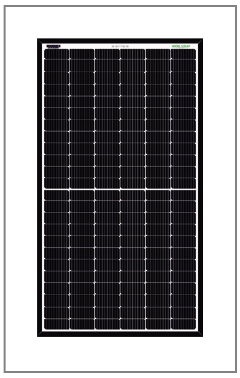


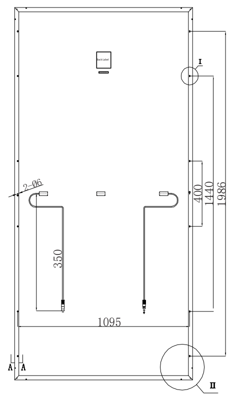




SOLAR ENERGY

System for generating 243750 kWh/hr og renewable energy anually on site	
Loom Solar Panel - Shark 445 - Mono Perc, 144 Cells, Half Cut	
Capacity	445 W, 24V
PV Panels Installed	366
Area per PV panel	2.22 sqm
Efficiency of Panel	22%
Solar Plant Capacity	162.5 kW





HVAC- VRF SYSTEM

Used in conditioned spaces	
Variable Refrigerant Flow (VRF)- heat pump system	
Outdoor unit	
System name	Thoshiba -VRF Heat pump , MMY-MAP1404FT8-E, 14HP, INVERTER
cooling capacity-Non ducted Indoors	40kW
Cooling power consumption	11.7kW
Annual power consumption	7800kWh
COP	4
EER	3.54
Indoor unit - for PI and station diary	
System Name	Thoshiba,VRF heat pump, MMK-AP0124MH- E, 1 phase, 50Hz, 230V
cooling capacity	4 kW
sensible cooling capacity	5640 Btu/h
Cooling power consumption	6.1kW
annual energy consumption	840kWh
EER	11
COP	3.3
indoor fan mortor - DC current	25 W

HVAC- VRF SYSTEM

Passive Drought Evaporative cooling- water is used for this system	
Water used per day	140 L
Tower dimensions	3m *3m
q cool (cube.m/hr)	391
ACH	2.2
PDEC diameter	0.47m
area of vent	0.17 sqm

WATER SYSTEMS

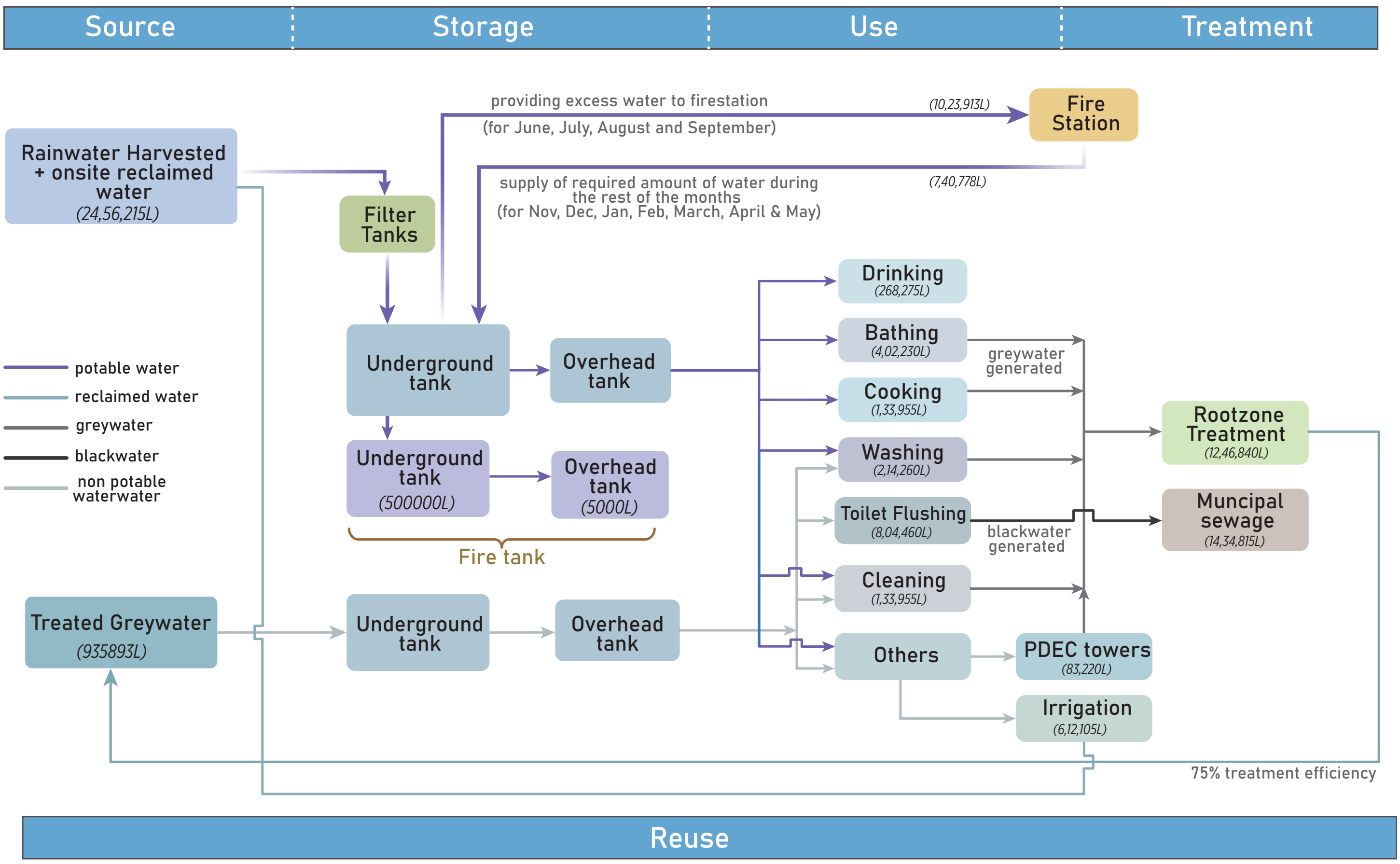
Passive Drought Evaporative cooling- water is used for this system	
Water used per day	140 L
Tower dimensions	3m *3m
q cool (cube.m/hr)	391
ACH	2.2
PDEC diameter	0.47m
area of vent	0.17 sqm

LIGHTING SYSTEM

LPD base case	9.9 W/sqm		
LPD proposed case	7.9 W/sqm		
Lighting needed for illuminating the interiors, mostly classrooms. For exteriors, solar powered lighting fixture was chosen so that it won't require additional energy.			
Activity	Lux Level		Lighting Equipment used
office spaces	500	Interior spaces	1. PHILIPS Astra Glow 15-watt Round LED Downlighter Recessed LED Downlight for False Ceiling LED Ceiling Light for Home and Hall | Cut Out: 6 inch 2. Phillips LED main fit baisc cro pro lamps 3. FlexFit (Hybrid UL Type A + B)Ballast Compatible & Ballast Bypass 4.CorePro Corn Cob Glass (120/277V) -
entrance lobies and circulation spaces	350		
resting facilities	200		
meeting rooms	350		
recreational spaces	500		
storage spaces	150		
service areas	300		
isolated spaces	200		
sanitory spaces	150		
exterior spaces	400	Exterior spaces	1. SOLAR STREET LIGHT - MODEL M2, 2. M4Boulder LED PAR IP65 Waterproof Outdoor 24x10W 3. Exteriors Philips Tango LED floodlight

*** Renewable Energy Source used- Solar Energy**
***Achieved EUI / EPI: 78.8 kWh/sqm/yr**
***Annual Energy Consumption: 2,43,478 kWh**
***Total annual Energy Generation on site: 2, 43, 750 kWh**

Net-zero water-cycle design and calculations



		CONSUMPTION						WATER SOURCES				SHARING	
Month	Days in month	Domestic Use (L)	Cooling Use %	Cooling Use (L)	Irrigation Use %	Irrigation Use (L)	Total Consumption (L)	Municipal Water (L)	Rainwater (L)	Greywater (L)	Blackwater (L)	Water given to Fire st. (L)	Water taken from Fire st.(L)
Jul	31	227,763	90%	3,176	5%	176	231,116	-	677,003	105,910	121,853	551,797	-
Aug	31	227,763	80%	2,823	5%	176	230,763	-	679,379	105,910	121,853	554,526	-
Sep	30	220,416	50%	1,708	50%	1,708	223,831	-	361,068	102,493	117,923	239,731	-
Oct	31	227,763	75%	2,647	30%	1,059	231,469	-	161,531	105,910	121,853	35,972	-
Nov	30	220,416	20%	683	90%	3,074	224,173	-	28,505	102,493	117,923	-	93,174
Dec	31	227,763	0%	-	90%	3,176	230,939	-	33,256	105,910	121,853	-	91,773
Jan	31	227,763	0%	-	90%	3,176	230,939	-	26,130	105,910	121,853	-	98,900
Feb	28	207,763	20%	643	90%	2,894	211,096	-	40,383	96,515	111,044	-	74,199
Mar	31	227,763	50%	1,765	90%	3,176	232,704	-	23,755	105,910	121,853	-	103,040
Apr	30	220,416	90%	3,074	90%	3,074	226,563	-	7,126	102,493	117,923	-	116,944
May	31	227,763	100%	3,529	90%	3,176	234,468	-	30,881	105,910	121,853	-	97,678
Jun	30	220,416	90%	3,074	90%	3,074	226,563	-	387,198	102,493	117,923	263,128	-

	Occupant load	Per capita daily comsumption (lpd)	Total Consumption (L)	Yearly Consumption (L)
BASE CASE	287	45	12,915	4,717,204
PROPOSED CASE	287	25.6	7,347.20	2,734,625

Irrigation Use	Litres per square metre	Area (sq M)	Total Use (L)
BASE CASE	1.7	1,377	2,304.90
PROPOSED CASE	1	1,377	1,377

Factor	Base Value	Efficient Value	Unit
Faucets for all Bathrooms	6	2.5	L/min
Water Closets	6	4,2	L/flush
Heath faucet for all Bathrooms	5	2	L/min
Urinals	2.5	1	L/flush
Faucets for Kitchen Sink	5	3	L/min
Washing Machine	60	50	L/kg

Catchment Surfaces	Area m2	Runoff Coeffecient	Effective Catchment Area (m2)
Roof Surfaces	1,677	0.85	1,45.45
Hardscape areas	500	0.7	350
Softscape areas	2000	0.3	600
Other			0
Total Effective Catchment Area			2,375.45

Summary of Cost Estimate

S.No.	Particulars	Proposed Estimate (Project Partner/SOR Basis)		
		Amount (Million INR)	%	Amount (INR per sqm
1	Land	0.03	0.04	10.25
2	Civil Works	50.8	60.89	17354.47
3	Internal Works	11.1	13.30	3792.02
4	MEP Services	36.1	43.27	14781.86
5	Equipment & Furnishing	8.3	9.95	3398.60
6	Landscape & Site Development	5.4	6.47	2211.14
7	Contingency	1.02	1.22	417.66
	TOTAL HARD COST	112.75	97.55	33325.87
8	Pre Operative Expenses	0	0.00	0.00
9	Consultants	2.83	2.50%	8.54
10	Interest During Construction	0	0.00	0.00
	TOTAL SOFT COST	2.83	3.39	1158.80
	TOTAL PROJECT COST	115.58	100%	39484.83
		Total Project Cost =Rs.11,98,60,000		
		Project Cost per sqm =Rs.39484		

Building Operation Narrative

Water Supply And Wastewater Treatment:

1. Summary of the building system installed.
The building's water supply and wastewater processing system includes a combination of traditional water supply, a rainwater harvesting system, low flow fixtures, and a rootzone treatment system for wastewater treatment. The rootzone treatment system is a natural wastewater treatment system that uses vegetation to treat wastewater.

2. Describe the automated operations.
The building's water supply system is partially automated and controlled by a pressure control system. This system maintains the water pressure within the building at a set level, to ensure a consistent supply of water to occupants. The rootzone treatment system is also partially automated and monitored by a control panel. This system uses sensors to monitor water flow and treatment processes and adjusts the flow rate and timing of the wastewater to optimize the treatment process.

3. Instructions for operating the building system.
To operate the water supply and wastewater processing system effectively:
- The pressure control system should be set to maintain a constant water pressure of 50-60 PSI throughout the building.
- Rainwater harvesting system should be used for non-potable water needs like irrigation, toilet flushing and cleaning.
- Low flow fixtures must be used in toilets, urinals, showerheads, and sinks to conserve water usage.
- The rootzone treatment system requires regular maintenance and monitoring to ensure optimal treatment efficiency. The flow rate and timing of wastewater should be adjusted based on the results of regular water quality testing.

4. Instructions for occupant interaction with the building system.
Occupants should interact with the water supply and wastewater processing system as follows:
- Use the low flow fixtures to reduce water usage.
- Avoid flushing non-degradable materials down the toilet.
- Report any water leaks or malfunctions to the building operations team immediately.
- Be aware of the rainwater harvesting system, and use non-potable water for irrigation, toilet flushing and cleaning.

5. Provide instructions for regular inspection and maintenance.
For optimal system performance, regular inspection and maintenance are essential. The following tasks should be performed:
- Inspect and test the pressure control system regularly to ensure it is functioning correctly.
- Inspect and clean low flow fixtures, aerators, and showerheads regularly to maintain water efficiency.
- Regularly test the water quality of the rootzone treatment system to ensure optimal treatment efficiency.

6. Describe the operation of the system in critical mode.
In case of a water shortage or contamination event, the rootzone treatment system will continue to function normally. However, the pressure control system will reduce the water pressure in the building to conserve water until the water supply is restored or the contamination issue is resolved. The rainwater harvesting system will be used as a backup water source until the water supply is restored.

Interior and exterior lighting system

1. Summary of the building system installed.
The lighting system in the building consists of a combination of LED and fluorescent fixtures controlled by a Digital Addressable Lighting Interface (DALI) system. The system is equipped with motion and occupancy sensors to automatically turn lights on and off as needed, which helps reduce energy consumption and prolong the life of the fixtures. The DALI system also allows for easy control and monitoring of the lighting system through a centralized management interface.

2. Describe the automated operations.

The DALI system is fully automated and can be programmed to turn lights on and off based on occupancy, time of day, or other criteria. The system uses motion and occupancy sensors to detect when someone enters a room and turns on the lights. When the room is empty, the lights are turned off automatically to save energy. The system also allows for dimming and zoning of the lighting system to provide the right level of light in each space.

3. Instructions for operating the building system.
To operate the lighting system effectively:
- Use the centralized management interface to program the DALI system to turn lights on and off based on occupancy, time of day, or other criteria.
- Encourage occupants to turn off lights when leaving a room, as this helps conserve energy and prolong the life of the fixtures.
- Use dimming and zoning capabilities to provide the right level of light in each space.

4. Instructions for occupant interaction with the building system.
- Occupants can use manual switches to turn lights on and off in a space if needed.
- Occupants can adjust the level of light in a space using dimming controls if available.

5. Provide instructions for regular inspection and maintenance.
- Inspect fixtures and sensors for damage and replace as needed.
- Regularly clean fixtures and lenses to ensure they are operating at maximum efficiency.
- Regularly calibrate and update the DALI system to ensure it is operating at peak performance.

6. Describe the operation of the system in critical mode.
- In the event of a power outage, the DALI system can switch to battery backup power to ensure that essential lighting remains on.
- In emergency situations, such as a fire alarm activation, the DALI system can automatically turn on all lights in the building to aid in evacuation.

Thermal comfort and ventilation system, including operable windows:

1. Summary of the building system installed:
The building's thermal comfort and ventilation system includes a combination of mechanical and natural ventilation. The mechanical ventilation is provided by a Variable Refrigerant Flow (VRF) system, which consists of a series of indoor fan coils connected to an outdoor unit. The natural ventilation system consists of operable windows and clerestory vents. To achieve cooling, the building incorporates a PDEC (Evaporative Cooling Method) system. The building also uses bamboo shading devices as dynamic facades that can be opened or closed to regulate daylight and solar heat gain.

2. Describe the automated operations:
The VRF system is fully automated and controlled by a Building Automation and Control System (BACS). The system controls the temperature and humidity levels throughout the building to ensure a comfortable environment for occupants. Local thermostats allow the occupants to further adjust the temperature to lower it by 2°C or raise it by 4°C beyond the BACS setting. The PDEC system is also automated and controlled by the BACS. It utilizes temperature and humidity sensors to regulate the operation of the system.

3. Instructions for operating the building system:
To operate the thermal comfort and ventilation system effectively:
- Set the BACS to control the temperature for air-conditioning at 25°C during the cooling season and 22°C during the heating season. Limit the indoor relative humidity to a maximum of 70%.
- If outdoor temperatures are lower than the indoor setpoint, notify the occupants to open the windows and vents for natural ventilation.
- Operate the PDEC system during the hot and dry season to achieve cooling.

4. Instructions for occupant interaction with the building system:
Occupants should interact with the thermal comfort and ventilation system as follows:
- Building users and occupants can operate the windows, ceiling fans, and adjust the thermostats to maintain comfort, health, and help reduce the environmental impact of the building.

- Occupants may open the windows when the building operations team notifies them that the outdoor temperature and humidity levels are appropriate for natural ventilation.
- Occupants may change temperature settings on the thermostat when the air-conditioning system is on. However, occupants can only change this to lower it by 2°C or raise it by 4°C from the default setting.

5. Provide instructions for regular inspection and maintenance:
- Inspect the VRF system for refrigerant leaks and perform preventative maintenance every 6 months.
- Inspect the PDEC system's water tank for algae buildup and clean every 3 months.
- Inspect and clean bamboo shading devices before and after the monsoon season every year.

6. Describe the operation of the system in critical mode:
During extreme events when grid power availability is restricted, the VRF system will function as long as grid power is available. However, cooling will be available only to the Office spaces, and the BACS system will change the cooling setpoint to 29°C. If grid power is not available, the thermal comfort and ventilation system will be shut off, and the occupants will rely on natural ventilation for cooling. All ceiling fans, emergency lights, and 5-ampere outlets will run on the on-site solar and battery storage.

Renewable energy and on-site energy storage system:

1. Summary of Renewable Energy and Energy Storage System:
The building is equipped with solar panels installed on the terrace, generating renewable energy to power the building. The solar panels are connected to a battery storage system, which stores excess energy generated during the day for use at night or during times of high energy demand. In addition, the building is also designed for energy sharing with nearby buildings, allowing the excess energy generated to be used by other buildings in the vicinity.

2. Description of Solar Panels and Battery Storage System:
The solar panels installed on the terrace of the building are a key component of the renewable energy system. They are designed to convert sunlight into electricity and produce clean, renewable energy to power the building. The energy produced by the solar panels is stored in a battery storage system, which provides backup power during periods of low sunlight or high energy demand. The battery storage system is capable of storing excess energy generated during the day, which can be used to power the building during the night or periods of high energy demand.

3. Energy Sharing with Nearby Buildings:
The building is designed for energy sharing with nearby buildings, allowing the excess energy generated to be shared with other buildings in the vicinity. This helps to reduce energy waste and increase the overall efficiency of the energy system in the community. The energy sharing system is designed to automatically detect excess energy generated by the building and make it available to other buildings in the area, helping to reduce the reliance on non-renewable energy sources.

4. Operating Instructions for Renewable Energy and Energy Storage System:
To effectively operate the renewable energy and energy storage system, the following instructions should be followed:

- Keep the solar panels clean and free from debris to ensure maximum efficiency.
- Regularly check the battery storage system to ensure it is functioning properly and is adequately charged.
- Monitor energy production and usage to identify areas of potential improvement and optimize energy consumption.
- Coordinate with nearby buildings for energy sharing, ensuring that excess energy is utilized effectively.

5. Maintenance Instructions for Renewable Energy and Energy Storage System:
To ensure the efficient and reliable operation of the renewable energy and energy storage system, regular maintenance is required. The following maintenance instructions should be followed:

- Schedule regular inspections of the solar panels and battery storage system to identify any issues and address them promptly.
- Perform routine cleaning of the solar panels to ensure maximum efficiency.
- Monitor battery charge levels and perform routine maintenance as needed.
- Regularly monitor the energy sharing system to ensure it is functioning properly and identify any potential issues.

Lifts :

1. Summary of Lift Systems:
The building is equipped with a lift system that provides vertical transportation for occupants and materials. The lift system is designed for optimal performance, safety, and energy efficiency. The lift system is equipped with state-of-the-art features such as energy-saving mechanisms and smart controls that help to reduce energy consumption and increase efficiency.

2. Description of Lift Components:
The lift system consists of several key components, including the elevator car, the hoistway, the traction mechanism, and the control system. The elevator car is the platform that moves up and down the hoistway. The hoistway is the shaft that contains the elevator car and its supporting components. The traction mechanism is the system of cables and pulleys that moves the elevator car up and down the hoistway. The control system is the electronic system that regulates the movement and operation of the elevator.

3. Energy Efficiency of Lift Systems:
The lift system is designed for energy efficiency, incorporating various features and technologies to reduce energy consumption. The lift system is equipped with energy-saving mechanisms such as regenerative braking, which recovers energy generated during braking and reuses it for future lifts. The lift system is also designed with smart controls that optimize elevator movement and reduce wait times, further reducing energy consumption.

4. Safety Features of Lift Systems:
The lift system is designed with several safety features to ensure the safety of occupants and materials during vertical transportation. The lift system is equipped with emergency brakes, backup power systems, and safety sensors that detect obstructions and prevent elevator movement if necessary. The lift system is also designed to meet all applicable safety standards and regulations.

5. Operating Instructions for Lift Systems:
To effectively operate the lift system, the following instructions should be followed:

- Follow all applicable safety guidelines and regulations when operating the lift system.
- Use the elevator controls properly, including the call buttons and the door open/close buttons.
- Do not exceed the weight limit of the elevator car.
- Do not block the elevator doors or obstruct the movement of the elevator car.
- In the event of an emergency, follow the emergency procedures outlined in the building's safety plan.

6. Maintenance Instructions for Lift Systems:
To ensure the efficient and reliable operation of the lift system, regular maintenance is required. The following maintenance instructions should be followed:

- Schedule regular inspections of the lift system to identify any issues and address them promptly.
- Perform routine cleaning of the elevator car and hoistway to ensure proper operation.
- Monitor the condition of the cables and pulleys and replace them as needed.
- Test the emergency brakes and backup power systems regularly to ensure they are functioning properly.

Key Parameters

INPUT PARAMETERS	UNITS	PROPOSED DESIGN VALUES	
General			
Building area	m²	2927.2	
Conditioned Area	m²	1317	
Electricity Rate	INR/kWh		
Natural Gas Rate	INR/GJ		
Building Occupancy Hours	Hrs	8	
Average occupant density	m² / person	9	
Interanal Loads			
Interior Average Lighting power density	W/m²	7.9	
List of lighting controls		1. PHILIPS Astra Glow 15-watt Round LED Downlighter Recessed LED Downlight for False Ceiling LED Ceiling Light for Home and Hall | Cut Out: 6 inch2. Phillips LED main fit baisc cro pro lamps 3. FlexFit (Hybrid UL Type A + B)Ballast Compatible & Ballast Bypass 4.CorePro Corn Cob Glass (120/277V) -	
Average euipment power density	W/m²		
Minimum OA ventilation	l/sec.m²		
Envelope			
Roof assembly U value	W/m².K	0.25	
Roof assembly SRI		0.36	
Average Wall assembly U value	W/m².K	0.29	
Window to Wall ratio (WWR)	%	18	
Windows U value	W/m².K	1.79	
Windows SHGC		0.23	
Windows VLT		0.2	
infiltartion rate	ac/h		
Describe exterior shading devices		Bamboo dynamic external skin based on the sun path The building is tilted at an angle of 22.5 deg. so the sunpath analysis gives the need to shade all four sides The dynamic facade is designed with the help of Bamboo corrugated sheets that acts as a chajja element that projects about 600 mm based on the sunangle , it is also taken so that cutting out into the zigzag shape is also possible smoothly The fasade is manually operated with the help of pulley system as shown to take up the dynamic shape.	
HVAC system			
HVAC sysytem type and description		(PDEC & VRF system (Daikin)), automated with Building Automation and Control System (BACS)	
Cooling source		VRF +PDEC + natural ventilation	
Cooling Capacity (outdoor unit)		120000 btu/hr	
Cooling Capacity (indoor unit)	kW	7500 btu/hr	
Cooling COP (indoor unit)		3.3	
Cooling COP (outdoor unit)		4	
Operation hours		1649	
Output Parameters			
Proposed EUI (Total)	kWh/m²/ yr	78.8	
Monthly energy performance		Geration	Consumption
January	kWh	22140	14346
February	kWh	23133	13580
March	kWh	26458	18100
April	kWh	25523	22520
May	kWh	24426	27563
June	kWh	18968	27102
July	kWh	14689	24207
August	kWh	14181	24052
September	kWh	17165	24200
October	kWh	22860	19523
November	kWh	22819	14300
December	kWh	22183	13985

LETTER OF CONFIRMATION: PROJECT PARTNER

NAGPUR SMART AND SUSTAINABLE CITY DEVELOPMENT CORPORATION LIMITED

CIN: U74999MH2016SGC283173

REGD OFF: NEW ADMINISTRATIVE BUILDING, NAGPUR MUNICIPAL CORPORATION,CIVIL LINES, NAGPUR-440001, Maharashtra, India

Landline: +91-712-2567037, Email: ceonsc.nmcngr@gov.in, ceonsscdcl@gmail.com, Website: www.nsscdcl.org

Smart City

.nagpur

No.1951 /OUT/NSSCDCL/2023

Date:09 /02/2023

To,

The Director,
Solar Decathlon India,
16th Cross road, Sadashiva Nagar,
Armane, Nagar, Bengaluru,
Karnataka - 560080

Subject: Letter for Project Partner with VNIT, Nagpur for the Solar Decathlon India 2022-23 competition.

Sir,

This is to inform you that our organization **Nagpur Smart and Sustainable City Development Corporation Limited (NSSCDCL)** has provided information about site and project details of ongoing **Police Station building at Punapur under Nagpur Smart City Project,** to the participating team led by **Visvesvaraya National Institute of Technology, Nagpur**, so that their team may use this information for their Solar Decathlon India 2022-23 Challenge entry.

As a Project Partner to this team for the Solar Decathlon India 2022-23 competition, we are interested in seeing the Net-Zero-Energy, Net-Zero-Water, resilient and affordable solution this student team proposes and the innovative outcomes from the same. We intend to have a representative from our organization attend the Design Challenge Finals event in April, if this team is selected for the finals. We would like our organization's logo to be displayed on the Solar Decathlon India website, recognizing us as one of the Project Partners for the 2022-23 Challenge.

With warm regards,

Ajay Gulhane (IAS)
Chief Executive Officer
NSSCDCL

Copy to:
Smt. Meenal Surawar,
Assistant Professor,
Department of Architecture & Planning,
Visvesvaraya National Institute of Technology, Nagpur

LETTER OF CONFIRMATION: INDUSTRY PARTNER

PUNARNAVA
Ecological Services & Eco-Design Solutions

PUNARNAVA ECOLOGICAL SERVICES, 35-B, HINDUSTAN COLONY, AMRAVATI ROAD, NAGPUR – 440033

13 January 2023

To,

The Director,

Solar Decathlon India

Dear Sir,

This is to inform you that our organization, Punarnava Ecological Services, is collaborating with the participating team led by Visvesvaraya National Institute of Technology on an Office Building project for their Solar Decathlon India 2022-23 competition entry.

As part of our cooperation, we would assist the group with designing a shading device made primarily of bamboo and testing it, if needed. In addition to exposing them to industry-standard bamboo design practices, we will offer guidance with the aim of making their design practical and ready to be implemented on the ground.

At present I am not able to commit to whether we would be able to have a representative from our organisation attend the Design Challenge Finals event in April/May, if this team is selected for the Finals.

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

With warm regards,

Pradyumna Sahasrabhojanee
Partner,
Punarnava Ecological Services

Email ID: sahasrabhojanee@gmail.com
Cell No.: +91 9422106238