FINAL DESIGN REPORT
APRIL 2021

SCRIBBLE

OFFICE BUILDING

SPA BHOPAL REVA UNIVERSITY

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EXECUTIVE SUMMARY

'Team Scribble' is composed of eleven students from two institutes (SPA Bhopal and Reva Institute), coming from diverse backgrounds and working on various aspects of design, production and execution. The journey started with an email invitation to participate in Solar Decathlon India and the rest of it is being covered online, via Zoom and Google Meets. All progress is tracked over shared drives spreadsheets.

The project is a Government Office Building for the National Health Mission Headquarters in Bhopal. ARCONS Architectural Consultancy Services, is responsible for its design and the execution is being managed by the Capital Project Administration.

Usually, government buildings, especially administrative and office ones are perceived to be monotonous and are not considered to be forerunners of innovation. We aspire to fundamentally change the perception of government offices from stagnant to dynamic and groundbreaking.

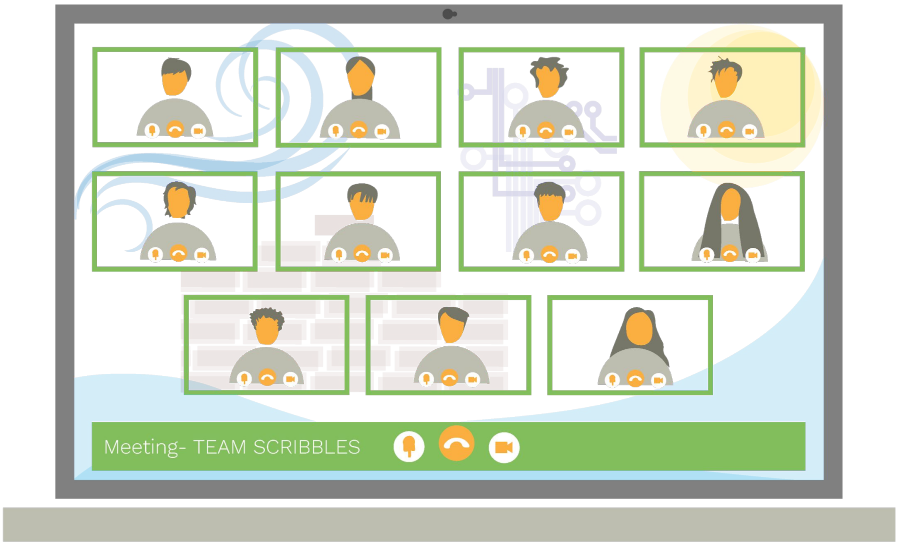
An Integrated building design process is at the heart of the project. The design is developed through extensive charrettes considering all the stakeholders- conducting research and experimenting design ideas in passive design, construction materials, HVAC, water, renewable resources etc.
Our design approach has 2 parallel concepts: creating a net zero energy building using vernacular spatial logics, and designing an office space that breaks away from the cage-like perception it is currently associated with.

The core strategy is to create a permeable building using thin plans and central open areas to establish an optimum microclimate. Passive design and daylighting strategy bundles, referenced from the book "Sun, Wind, Light", are developed for each level of building design from neighbourhood to elements. With careful consideration of all the building science principles and affordability parameters, we carried out our pre design comfort & energy simulations, We also developed an optimized building massing having a huge potential for obtaining thermal comfort through natural ventilation, courtyard design, buffer spaces and operating the building on mixed mode. Our final design outcome emerged out of an evolution of between three design options merging into one. We were able to reduce the Energy Use Intensity (EUI) from **91 KWh/m^2/a** in the base building to **24.3 KWh/m^2/a** in our proposed design.

The Solar Photovoltaic system, which shades the rooftop terrace generates **1,39,250 Kwh** annually for the office building against a calculated annual consumption of **1,30,015 Kwh,** successfully creating a Net-Positive energy building. Our building uses Net-metering to supply back the excessive energy produced to the city grid and we've made systems to cater to 2 autonomous days in case of a disaster. The design is also Net-zero water, combining water efficiency measures coupled with rain water harvesting and wastewater recycling system to reduce municipal water demand by **84%.** Climate based design strategies, building management systems and smart zoning design allows us to rightsize the chiller size to **84Tr**, scaling it down by **12%.** Phase Change Materials were added in the HVAC cycle to further reduce the chiller size to **42Tr.** A Life-Cycle Assessment of the building materials and systems indicates **38%** reduction in Embodied Energy from EDGE's base case. We've innovated in utilising Building Management Systems in a competitive spirit, modernising and developing vernacular design strategies and utilising PCMs in the false ceilings zoning to bank on the Night Ventilation strategies, bringing down requisite set-points by **2-3°C**. An affordable, (with a utility cost reduction of Rs 3.8 Cr) is achieved by utilising local materials and monetizing spatial resources to manage costs.

TEAM SCRIBBLE

Lead Institution: SPA Bhopal
Additional Institution: Reva University
Building division : Office building



Ar. Arvind Kumar Meel
Assistant Professor, BEM
Faculty Lead

Ar. Gaurav Singh
Assistant Professor
Senior Project Manager
Faculty Advisor

Figure 1. Team Scribble Illustration

The idea is to create innovative and energy-efficient solutions by engaging ourselves in an architectural design process, which accords to ample avenues for the incorporation of latest design ideologies and technologies; and their avant-grade applications.

LEAD INSTITUTION BACKGROUND

Figure 2. Pictures of SPA Bhopal

School of Planning and Architecture, Bhopal was established by Government of India in the year 2008. This school is committed to produce the best Architects and Planners of the Nation to take up the challenges of physical and socio-environmental development of global standards. It is being developed as a locus where a sense of enquiry prevails amongst all stakeholders- students, researchers, professors and society at large. The university strives for social, cultural as well as environmental sustenance.

INDUSTRY PARTNERS

PLUSS® | TECHNOLOGY FOR A BETTER WORLD

Pluss Advanced Technologies specialise in Phase Change Material technologies and related strategies. We intend to take advantage of the high diurnal temperature difference in Bhopal with help of PCM pouches in order to provide additional daytime cooling in summers.

avrio energy

Handling electricity consumption for commercial buildings is an area of expertise for Avrio Energy Pvt. Ltd. We aim to partner with them with regards to our approach towards building management systems.

NATIONAL HEALTH MISSION

HEADQUARTERS, BHOPAL

PROJECT PARTNERS

The construction of the National Health Mission Headquarters in Bhopal is being done for the Ministry of Health and Family Welfare. ARCONS, our project partner, is a commercial developer working in partnership with Capital Project Administration.

PROJECT DESCRIPTION

The headquarters of the National Health Mission for Madhya Pradesh is currently under construction in Patrakar Colony, Bhopal. As per Köppen climate classification, Bhopal is situated in 'Humid Subtropical' region of India. The headquarters will be used as the main office building to oversee various health policies and family planning initiatives undertaken by the Government of India. It is a **Build-Own-Operate** project.

MAXIMUM BUILT UP AREA : 9100 m^2

BUDGET : 30,000 INR/m^2(Construction)

PROJECT BUDGET : 28,00,00,000 INR (including MEP)

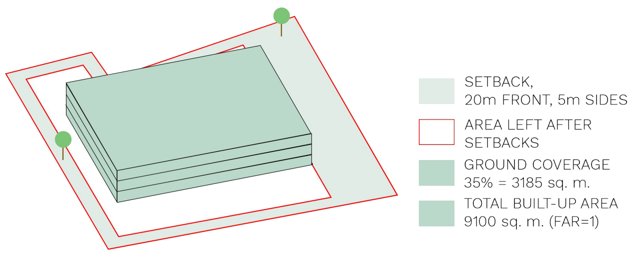


Figure 3. Site Details

Patrakar Colony, where the building is under construction, is a central and administratively important part of the city. The site sits amidst a lush distribution of natural vegetation. The link road in front of it connects the site to other major areas. Further, the residential areas are in front.

Figure 4. Views around the site

SPECIFIC COSTING TARGETS

We aim to meet the budget restrictions set by the Project partner, as the project was earmarked to be a sustainable building. We want to prove that a Net-Zero Energy Building can be achieved with the same resources. We also aim to bring down Operational costs while keeping a balanced ratio of hard and soft costs.

SPECIAL REQUIREMENTS

The special requirements for the building as asked by the client are-

Two entry points for the building

Meeting rooms to be provided in each floor

Conference hall to be placed near the main entrance

CONTEXT AND MARKET ANALYSIS

For the past few decades, Bhopal has worked hard to create an identity of a beautiful, green city. Designing the headquarters of a state-level government office provides an opportunity for the city to reinforce this identity, and advertise the many financial and environmental advantages of such buildings.
Bhopal is famously known as the city of lakes, and many of its lakeside palaces have several traditional passive design strategies. We have attempted to follow up on these architectural traditions with courtyards, jalis and water-edges.

SITE AND BUILDING PROGRAM

The site is fairly flat, with a gentle slope towards the South West edge (refer pg 12), the land is entirely buildable but the black clayey soil of Bhopal demands strong stump foundations. The program of the building is designed to weave a pattern of open and closed spaces, for example, the courtyard is surrounded by offices, which further contain office cabins surrounded by open-plan working spaces. A hierarchy of spatial development is keenly taken into consideration.

Spaces	Area (m^2)	No.	Total Area (m^2)
Director's Office	20	33	660
Officer's Room	11.5	11	126.5
PA Office/ Pantry	8	9	72
Open Plan Office 1	40	20	800
Open Plan Office 2	86	2	172
Open Plan Office 3	146	1	146
Waiting Area	30	2	60
Executive Office	35	4	140
Chief Engineer Office	25	1	25
VC Room/ Minister Room	49	2	98
Record Room	40	5	200
Meeting Room	48	4	192
Conference Room	180	1	180
Bathroom	40	4	160
Library	72	1	72
Recieve/Dispatch	66	1	66
Training Hall	88	1	88
Reception/Foyer	65	1	65
Circulation Core	84	1	84
Cafeteria/ Games Room	32	3	96
Toilet 1 / Janitor's Closet	4	6	24
Toilet 2	5	3	15
		TOTAL	3690.5

Table 1. Area Programme

PERFORMANCE SPECIFICATIONS

CLIMATE ZONE

Köppen–Geiger - **Csa** (hot summer Mediterranean climate)
Bansal-Minke - **Composite** climate zone

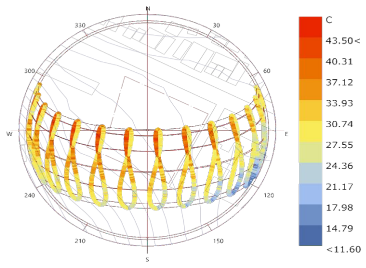


Figure 5. Sun Path Diagram

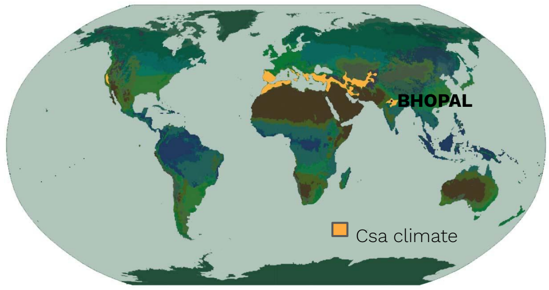


Figure 6. World map acc. To Koppen-Geiger classification

BUILDING ENVELOPE

Element	WWR	Wall	Roof	Window	EUI
Specifications	N - 33-35% S - 15-18% E - 18-20% W - 13-15%	200mm AAC + 50mm Rockwool + 50mm air gap + 25mm Sandstone	150 mm Filler Slab + Rockwool false ceiling	Double pane low-e glass	49.2
U-value (W/m²K)	-	0.23, 0.26	0.20	1.80	-

Table 2. Envelope configuration

HVAC

Units	Specifics	Area/volume	Power/ Energy stored	Number	*Tonnage*
Recirculation Chiller	F-308	400x500x550	1.2 kW	3	35 TR (each)
Water-cooled screw chiller	RFILO0695	400x500x550	169 kW	2	48 TR (each)
DOAS	62x	5029x2590x4724	50 kW	2	55 TR (each)
Make up air system / AHU	D-AHU Modular R	1750x5500x2100	2.99 kW	2 (per floor)	-
CRCP	-	1200x2400	-	-	-
Phase-Change Material	HS22 Hydrated Salts PCM Pouches	600x600(ceiling tile) 570x157(pouch)	543.15 Wh/sqm	3 pouches/tile	-

Table 3. HVAC specifications

ELECTRICITY AND LIGHTING

Power Density (W/sqm)	Open Office	Private Office	Meeting Rooms	Conference Hall	Circulation & Buffer
Electric Power Density	7.82	7.99	8.85	4.68	4.70
Lighting Power Density	7.47	2.26	8.05	30.18	8.50

Table 4. Lighting specifications

WATER SYSTEMS

Total water used - **1800 L/day**
Total greywater produced - **8766 L/day**
Total water tank size - **857600 L**
Effective Catchment Area for rainwater harvesting - **3792 sqm**
Reduction in annual municipal water demand - **87%**

RENEWABLE ENERGY

Solar PV potential - **1,72,500 kWh**,
Required Generation - **1,30,015 kWh/year**
Total Generation - **1,39,250 kWh/year**
Using PV Generator of Capacity 48 W/hr, No. of PV cells : **330**

GOALS

By incorporating a mix use of strategies we intend to achieve a cost efficient NZE Office Building.

4.1 ENERGY PERFORMANCE:

The aim is to decrease annual EPI upto 32.35 (as calculated) by incorporating passive design strategies and using Monocrystalline silicon cells (2m*1m) with efficiency 19.5% and 422 KWH annual energy generation and target AC usage of less than 50%

4.2 RESILIENCE:

The aim is to make the building withstand climate scenarios upto the year 2050, considering temperature variations, water shortages and biohazards by performing life cycle analysis on efficient materials and built form through simulations and introducing flexibility in design and construction.

4.3 SCALABILITY AND MARKET POTENTIAL:

The goal is to break the norms and misconception around user oriented and inviting government buildings and NZEBs being overly expensive by proper interior space planning and using landscape elements creating better work environment for users and staff.

4.4 ARCHITECTURAL DESIGN

Taking Neufert Architect's Data, CPWD, Building code of Ireland as a base for designing, we strive to create spaces that cater to functionality, optimum energy usage and make the building accessible.

4.5 INNOVATION:

We intend to improve indoor comfort and achieve positive user behavior by incorporating contemporary vernacular building techniques and using Building Management System (BMS) to develop an app and track consumption competitively.

4.6 AFFORDABILITY:

We aim to meet the Project Partner's budget of Rs. 24 Cr. for the overall design by weighing in more on the capital expenses while simultaneously bringing down operational costs utilizing locally available materials, system coordination and resource optimization.

4.7 COMFORT AND ENVIRONMENTAL QUALITY:

We are following Super ECBC guidelines and the Indian Model of Adaptive Comfort (IMAC) to develop Building Automation systems and design strategies to optimise efficiency and achieve comfort levels by using elements that bring in wind and block harsh sun.

4.8 ENGINEERING AND OPERATIONS:

LIGHTING AND EQUIPMENT SYSTEMS: We intend to achieve a target Lighting Power Density of 5.4 W/sqm for office areas and total Equipment Power Density of 12 W/sqm by selecting all appliances with at least BEE 4 Star rating.

HVAC SYSTEMS : We aim to use mixed mode cooling system with radiant cooling by reducing cooling loads and rightsizing chiller.

4.9 WATER:

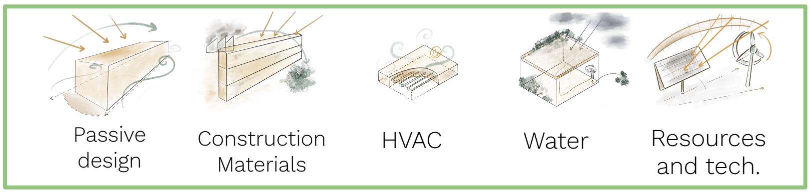
The goal is to achieve Net-Zero Water by reducing and tracking consumption and utilising harvested water, using water-efficient fixtures and planning root-zone treatment for sustainable re-use of greywater.

DESIGN PROCESS

The integrated design approach split all members in teams in two categories. With eleven members, we split the work the research work into 5 categories. Each one, containing two members. The group leader coordinates and helps all 5 teams, holding regular meetings and organizing data. The design process, momentarily, split the members into three teams to develop the initial options. As we progressed we assigned different tasks to each member, the likes of designing shading devices, internal layouts, developing structural details, running specific simulations etc.

INTEGRATED DESIGN APPROACH

RESEARCH AND INNOVATION

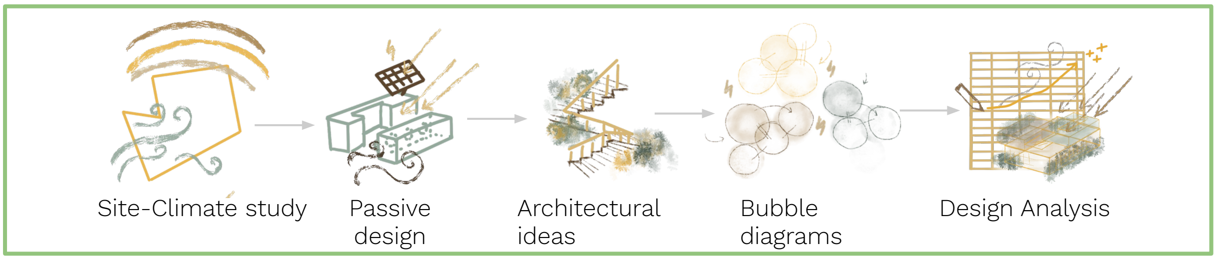


Weekly meetings are held to bring together developments of each category, and advance design in a cohesive direction.

DESIGN

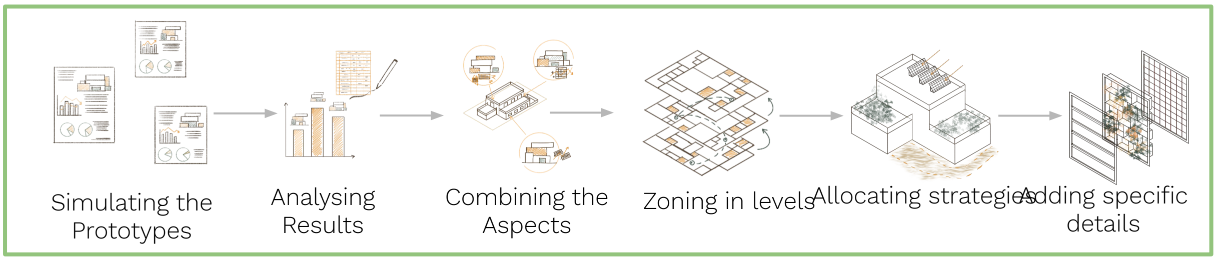
Phase 1- Base Models Analysis

11 of us split into 3 teams to develop 3 different iterations on the basis of passive strategies and architectural themes discussed.



Phase 2- Design Development

The base models were further developed to combine into one model which was consecutively simulated at all stages of design-zoning, interior detail, material conjecture and element detail etc.



Phase 3- Finalised Design-Planned

We further plan to enhance our elemental strategies, by mindfully incorporating innovative and cost efficient solutions resulting in an optimum building design.

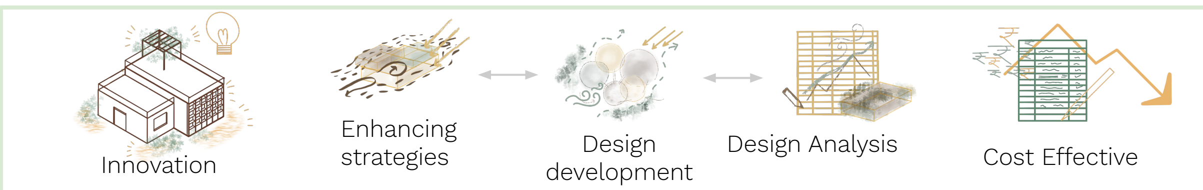


Figure 7. Design Approach Illustrations

DESIGN PROCESS DOCUMENTATION

DETAILS OF DESIGN CONCEPTION FLOW

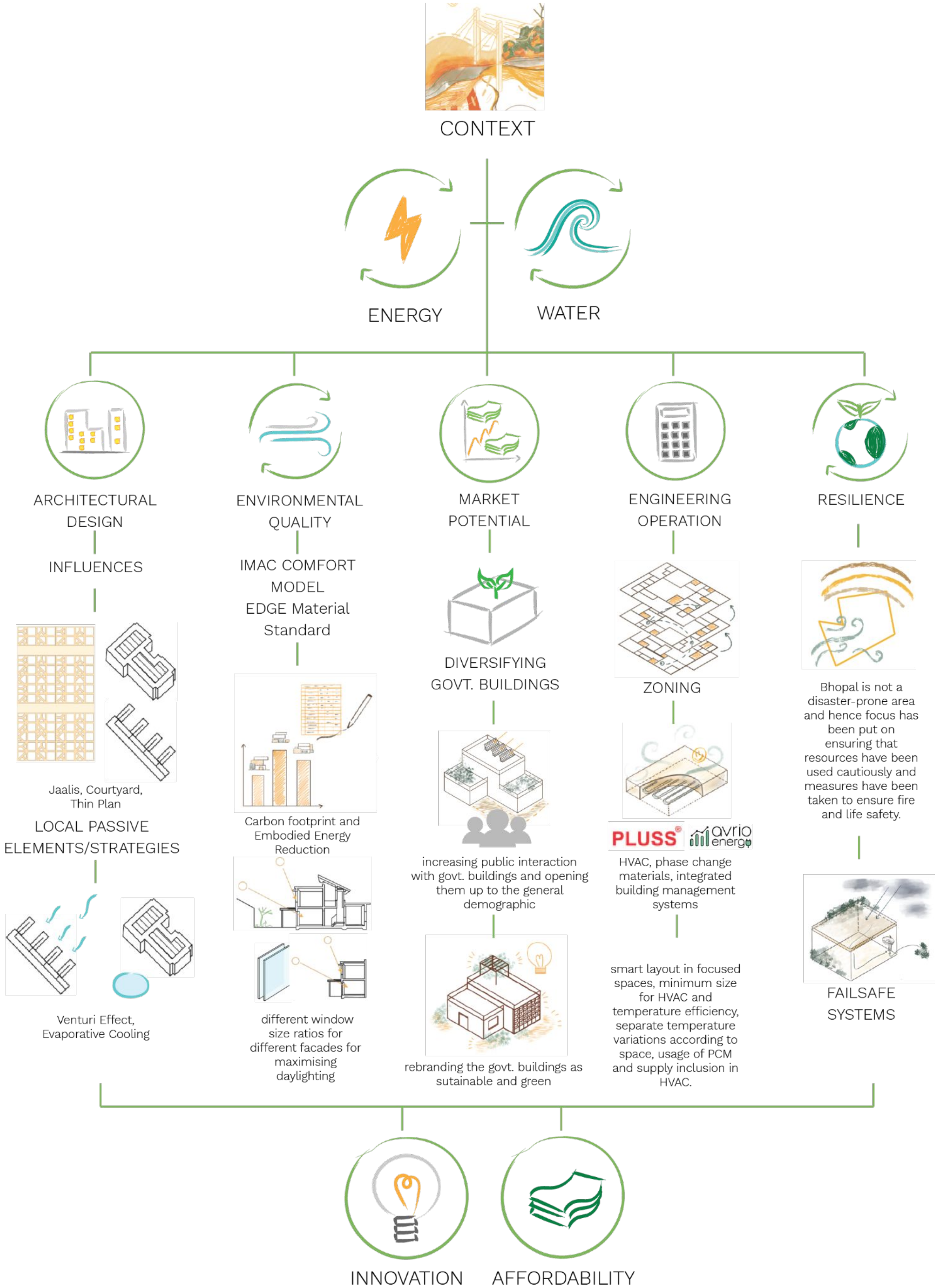


Figure 8. Design Documentation Flow

TEAM DISCUSSIONS AND CO-WORKING

The team interacts regularly and shares regular updates with mentors in whatsapp groups. Bi-weekly team meetings are organised on the G-meet platform. Files are shared on a common Google drive and it is updated after each meeting.

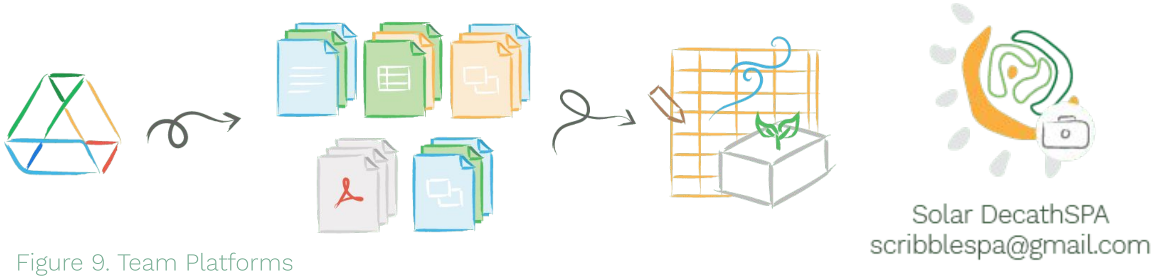


Figure 9. Team Platforms

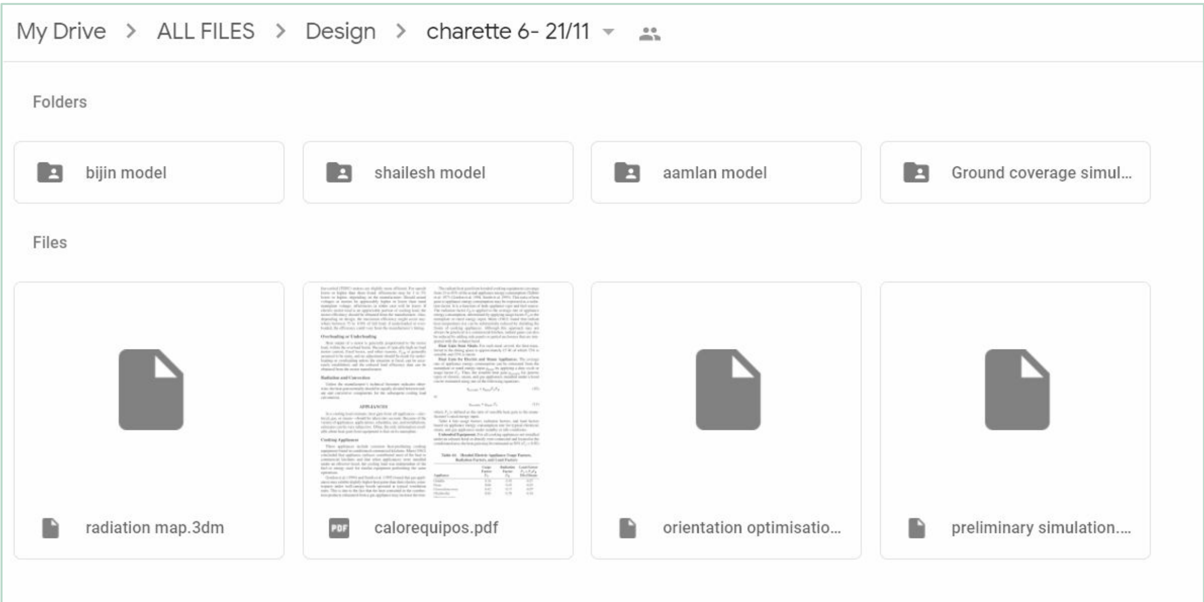


Figure 10. Data Sharing

Design charrettes hold design discussions, model developments, simulations, focussed readings and research to bring together a new version and strategy every week. All the reports are on google docs and each member of the team updates the document with their portion of work and progress.

SOFTWARES AND ANALYSIS

Different members run different simulations. Rhino and Revit is used for modelling. Grasshopper and its plugins are utilised for initial analysis and parametric interventions. Weather and energy simulations have been generated through multiple softwares and Plugins like Sefaira, Grasshopper, Ladybug, etc.

SOFTWARE UTILISED FOR DESIGN CONCEPTION

PURPOSE	SOFTWARE
Drafting	AutoCAD
Modelling	Revit
	Rhino
Parametric Interventions/ EUI Calculations	Grasshopper
Pre-design weather analysis	Lady Bug
Post-design daylight autonomy	Honeybee
Material selection analysis	Opaque
Post-design daylight autonomy, Glare, PV cells, Energy Usage, Cooling-Heating Loads, Equipment, Luminaries, Ventilation	Cimate Studio
Heat Balance, System Energy, Cooling Loads, Heating Loads, Solar Gains, Equipment Gains, Occupancy Gains	Design Builder
Daylighting, Energy Simulation	Sefaira
	Ansys
	Open FOAM
CFD Wind-flow Analysis	Butterfly
Structural Analysis	Staad.Pro

Table 5. Software used

PARTNER INTERACTIONS

Meetings with the project partner give an insight about their design approach and client's demands and limitations. We also learn more about the professional practice. Industry partners help us detail active strategies and encourage innovation.

Figure 11. Project Partner Meeting

CLIMATE STUDY

ALL YEAR TEMPERATURE-TIME TABLE PLOT

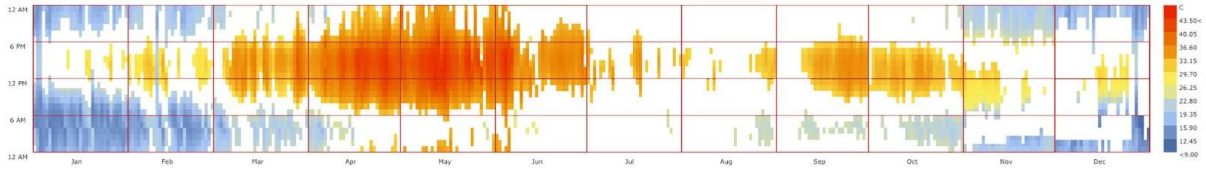


Figure 12. IMAC Temperature discomfort for mixed mode building

Discomfort ranges

Bhopal has a composite climate with a temperature range from 10°C to 43°C. The summers are hot and last from April to July with temperatures peaking at 43°C. The winter months from November to February are relatively cold, with the temperature dropping as low as 7°C. The monsoon months of August and September have comfortable temperatures falling between 20°C to 30°C.

ALL YEAR HUMIDITY PLOT

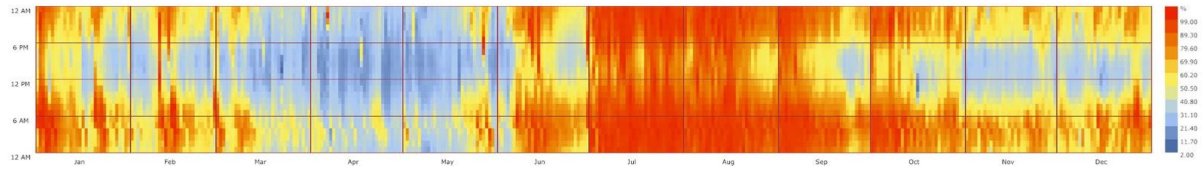


Figure 13. IMAC Humidity comfort band for mixed mode building

The months between November and March are very dry with the humidity levels ranging between 2% and 40%. The months between April and May are comfortable with humidity levels of 40% to 60%. The monsoon months of June to September are muggy with humidity levels from 70% to 100%

MONTHLY WIND ROSE

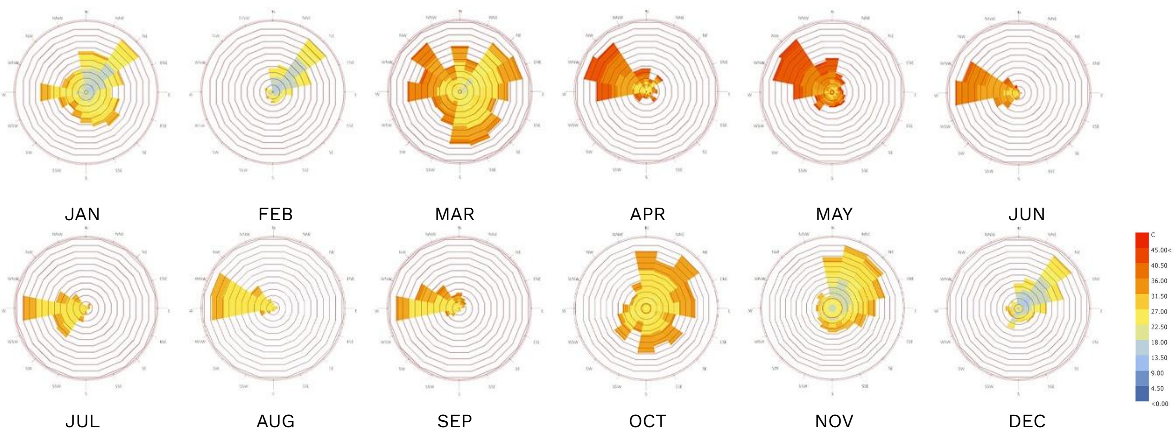


Figure 14. Monthly wind rose with temperatures showing hot, humid and cool winds

The winds in the months November to June are usually uncomfortable, carrying temperatures as low as 18°C and as high as 45°C. The hot winds are called loo. Comfortable winds blow from July to October, prominently from the West.

WIND ROSE INFERENCES

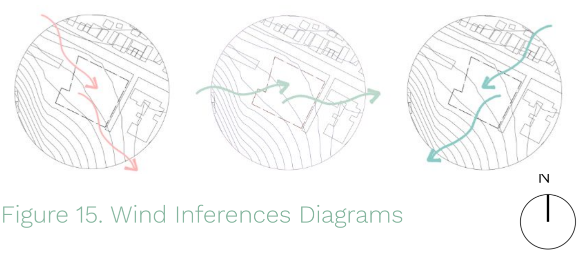


Figure 15. Wind Inferences Diagrams

a. The hot Summer winds are from the North-West need to be cooled down before entering the building mass.

b. Humid winds that blow from the West, carry moisture and dictate the direction of rainfall.

c. Cold winter winds hail from North and North East. They need to be blocked from entering the site.

SITE AND CLIMATE ANALYSIS

Climate in Bhopal is composite. The summers are hot and last from April to July, reaching upto 43°C. The winter months from November to February are relatively cold, with the temperature dropping as low as 7°C. The monsoon months of August and September have comfortable temperatures along IMAC standards.

PROXIMITY MAPPING

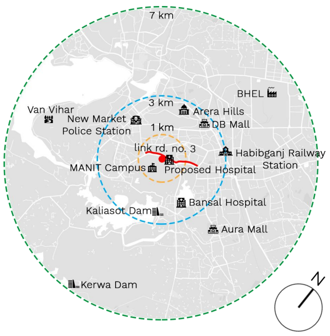


Figure 16. Proximity Mapping

Nearest railway station is 3.7 km.

SLOPE ANALYSIS

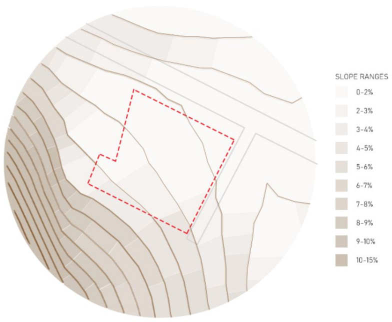


Figure 17. Slope Analysis

Since it is mostly flat, the whole site is buildable.

EXISTING VEGETATION

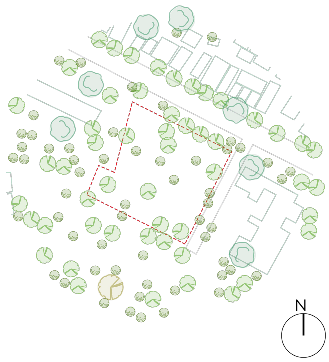


Figure 18. Vegetation Cover

Site is surrounded by dense vegetation.

SOIL ANALYSIS

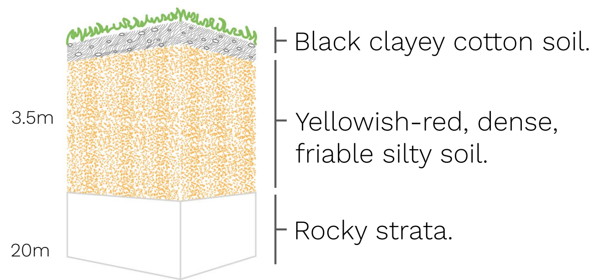


Figure 19. Soil Analysis

Name	Legend	Picture
NEEM Azadirachta Indica		
EUCALYPTUS Eucalyptus globulus		
GULMOHAR Delonix Regia		
BABOOL Vachellia Nilotica		

Bhopal has a predominantly rocky terrain. The foundation suitable for this type of terrain is shallow pad foundation.

RADIATION INFERENCE

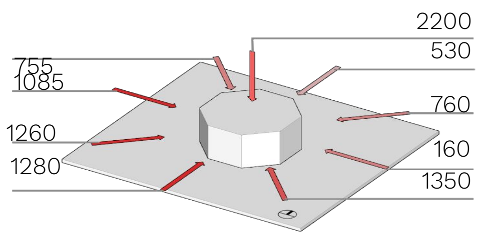


Figure 20. Radiation Inference

Considering the sum-total of solar radiation from opposite directions, it is optimal for the site to have the longer facade along the North and South direction. The best orientation is an East - West elongated building.

VOLUMETRIC INFERENCE

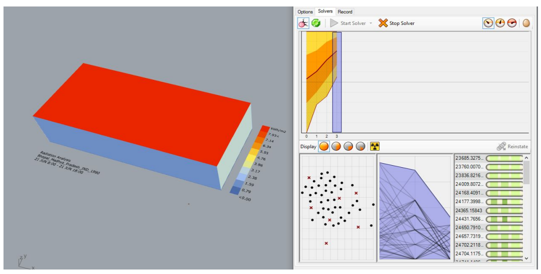


Figure 21. Best Orientation and Building Size on site

Optimal building size: 32 m x 72 m x 16m, 4 floors.
Orientation: E-W aligned

CONCEPT DEVELOPMENT

After analysing the site and climate data, we created design strategy bundles for each design stage using the method in the book “Sun, Wind and Light: Architectural Design Strategies” by Mark DeKay. The strategies cascade into different levels and were incorporated in each stage of design.

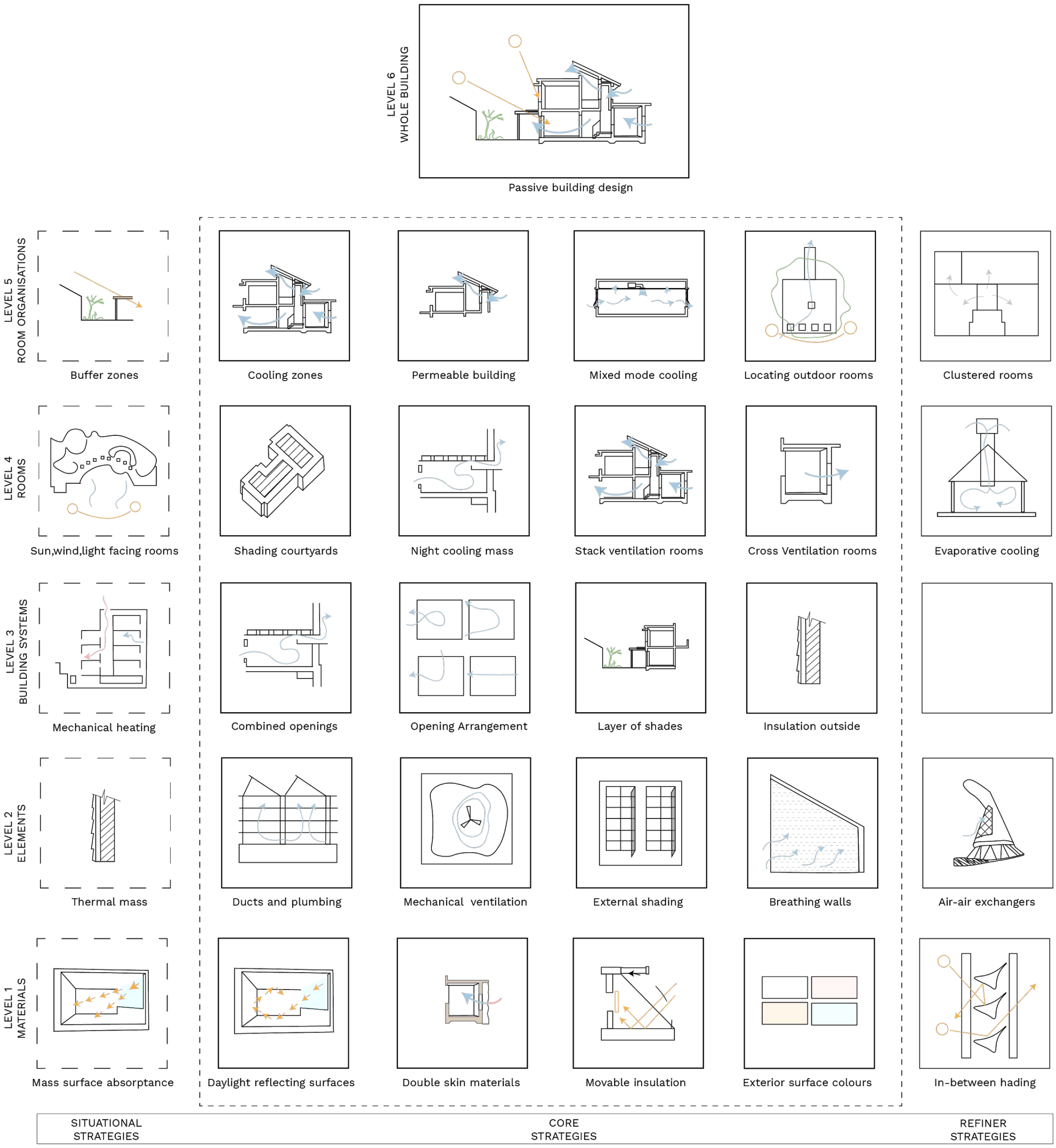


Figure 22. Passive Design Strategies

PASSIVE DESIGN BUNDLE

The main concept is to design a building form with thin plans around courtyards. An open layout emerges as a more comfortable work space allowing for the possibility of staggered roof heights. Semi-open buffer spaces emerge as an optimum technique to decrease heat gained by the workspaces while allowing more diffused light to enter. The interweaving of open and closed spaces, and small pockets of greenery help create a healthy microclimate within the site.

DESIGN DEVELOPMENT

From the three previous explored idea we have narrowed down to two options. Out of the two models, we chose the one that performed better. We continued to optimised this model till we achieved compliant EUI, daylighting and architectural design.

OPTION A	OPTION B	OPTIMISED

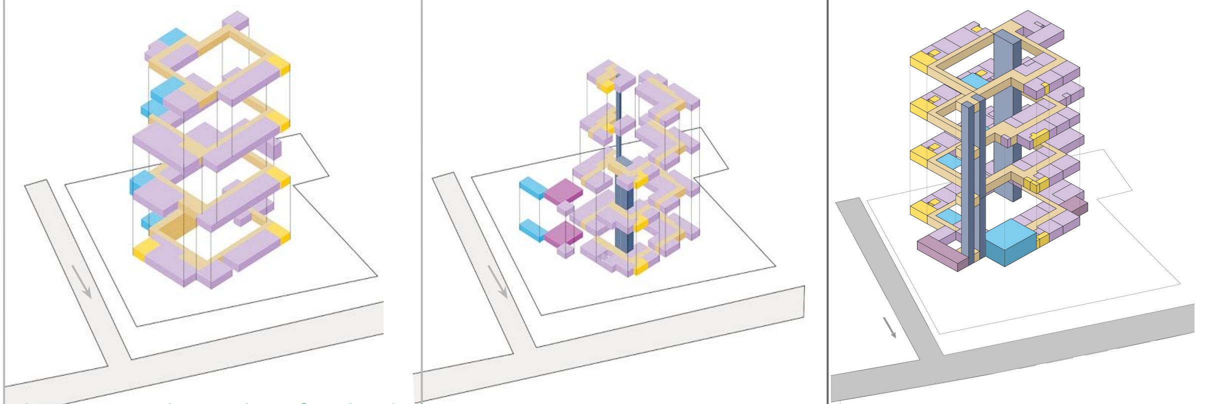


Figure 23. Design options for simulations

ENTRANCE DEPARTMENT CORE MEETING ROOM CORRIDOR SHADING JAALI WALL TOILET

Refinery strategy explored: A central connecting atrium.	Refinery strategy explored: Dispersed, staggered blocks.	Staggered blocks around connecting atriums, to create a hierarchy of courtyards.
The idea of a central courtyard was taken forward at account of good ventilation and daylighting. The electric loads were comparatively low. Buffer spaces such as record rooms, toilets and corridors are placed to face the south to minimize heat gain in the main offices	In the case of the dispersed building, daylighting proved to be the most efficient. In this step we brought the blocks closer to concise the building spread. This however came at a tradeoff as there was more heat gain which is evident in the generated EUI.	The final model was developed around the two-courtyard typology, minimally dispersing the office blocks around it. The resultant form was rearranged several times to achieve the low EUI values and good daylighting values as depicted.

EUI

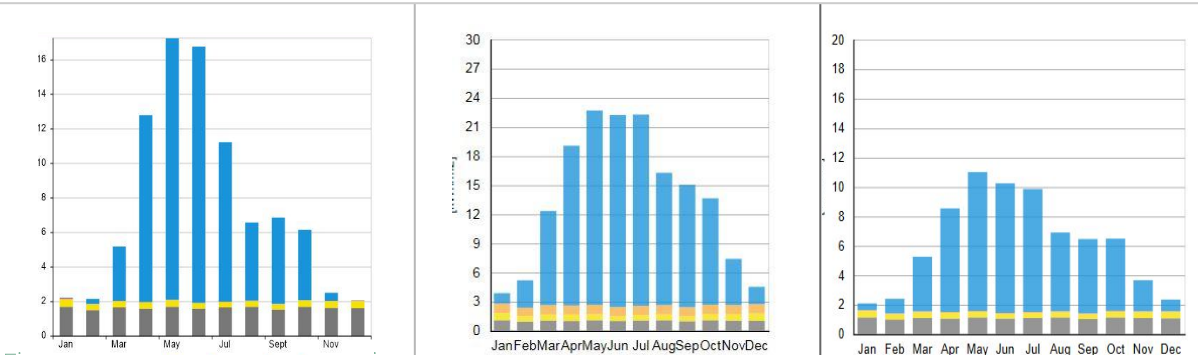


Figure 24. EUI Charts for all 3 options

Equipments Fans Light Hotwater Heat Cool

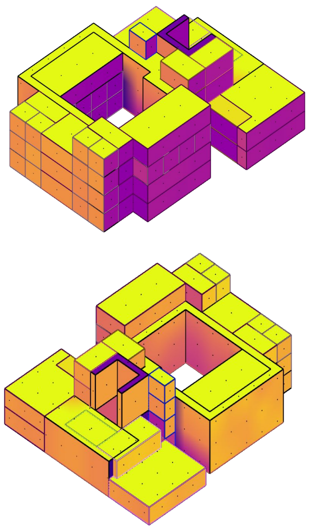
EUI Calculated = 91 KWh/m^2/a 50% reduction from baseline EUI of 182 KWh/m2/a for building with more than 50% HVAC.	EUI Calculated = 101 KWh/m^2/a 45% reduction from baseline EUI of 182 KWh/m2/a for building with more than 50% HVAC.	EUI Calculated = 27 KWh/m^2/a 85% reduction from baseline EUI of 182 KWh/m2/a for building with more than 50% HVAC.

DESIGN DEVELOPMENT

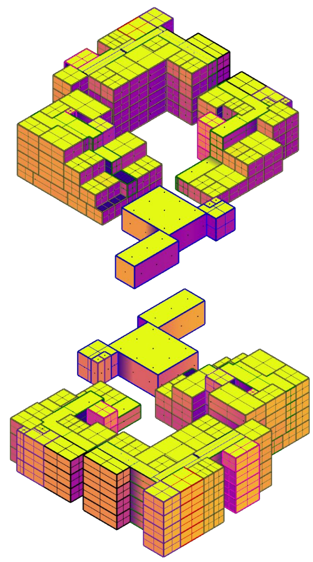
A combination was needed which had least solar radiation absorbed by the surface, but in the meantime allowing in optimal daylight. Staggering towards the North east allowed for this, as understood form model 1 and 2.

Solar Radiation

OPTION A



OPTION B



OPTIMISED

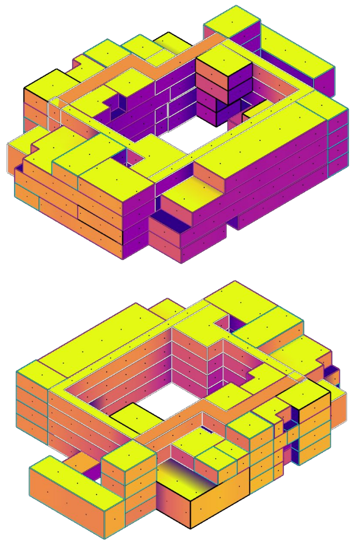
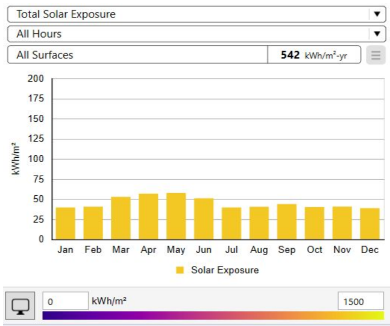
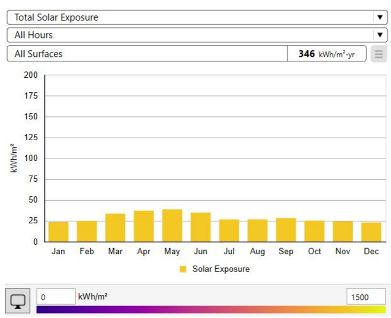


Figure 25. Solar Radiation Mapping





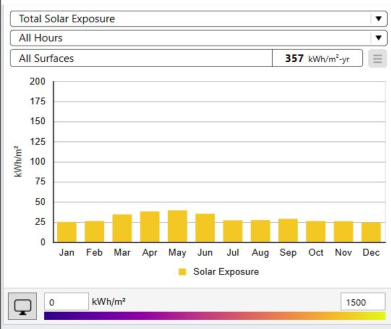
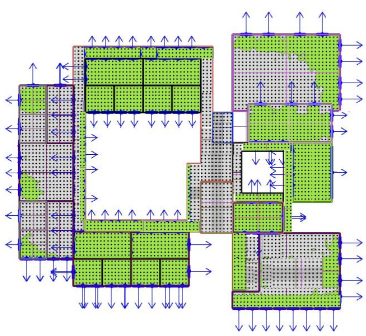


Figure 26. Solar exposure charts

Daylighting



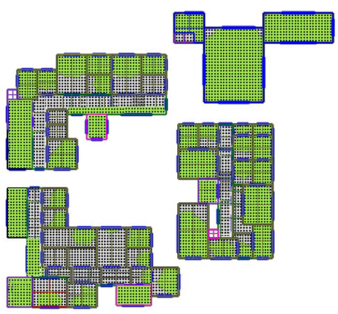


Figure 27. Daylight mapping

Option A:
Daylight (sDA 300/50%): 55%
Glare (ASE 1000.250): 26.4%
2 LEED daylight credits

Option B:
Daylight (sDA 300/50%): 57.2%
Glare (ASE 1000.250): 18.8%
2 LEED daylight credits

Optimised:
Daylight (sDA 300/50%): 65%
Glare (ASE 1000.250): 12%
2 LEED daylight credits

ENERGY PERFORMANCE

DESIGN OPTIMIZATION OF ENVELOP CONFIGURATION

After finalising the building form and zoning, the building envelope options were reviewed. Thin, open plans allowed us to arrange a multitude of options for wall layers, as per specific spatial requirements. The final material palette was selected based a cross analysis of the best energy performance and affordability.

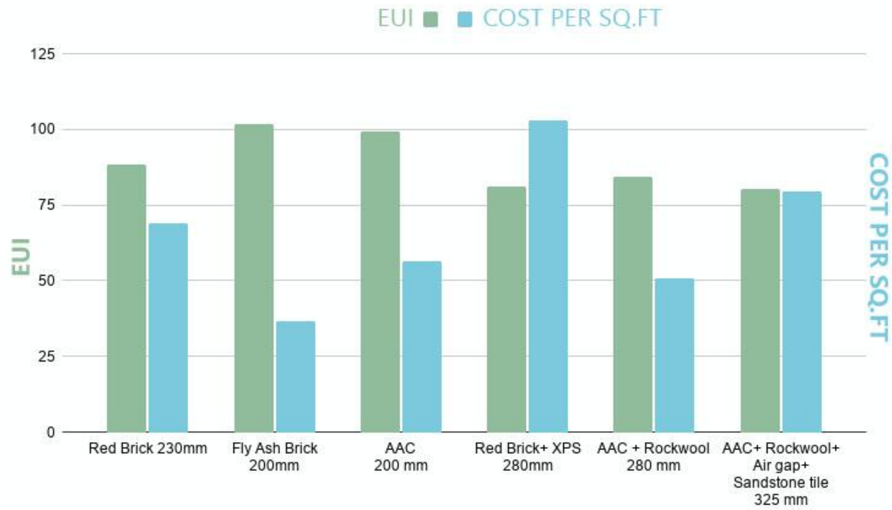


Fig 28. Wall assembly impact on EUI with cost

The Window-Wall ratio (WWR) was varied for each cardinal direction, as the building is oriented along the East-West direction and North light is favoured for office working spaces. The minimum WWRs are used in the West and South direction, to compensate the harsh sun on the sides. The ratios are simulated to make sure ample daylight peers in the spaces.

Combination	WWR	Wall	Roof	Window	EUI
Best	N - 30% S - 20% E - 15% W - 15%	200mm AAC + 50mm XPS + 200mm AAC	150mm Filler slab + 150mm XPS + 50mm Rockwool Foam	Triple pane Low-e glass	45.82
Selected	N - 33-35% S - 15-18% E - 18-20% (33-35% in buffer spaces) W- 13-15% (60-70% in buffer spaces)	200mm AAC + 50mm Rockwool + 50mm air Gap 25mm Sandstone	150mm Filler slab + Rockwool false ceiling	Double pane Low-e glass	49.2

Table 6. Envelope configuration

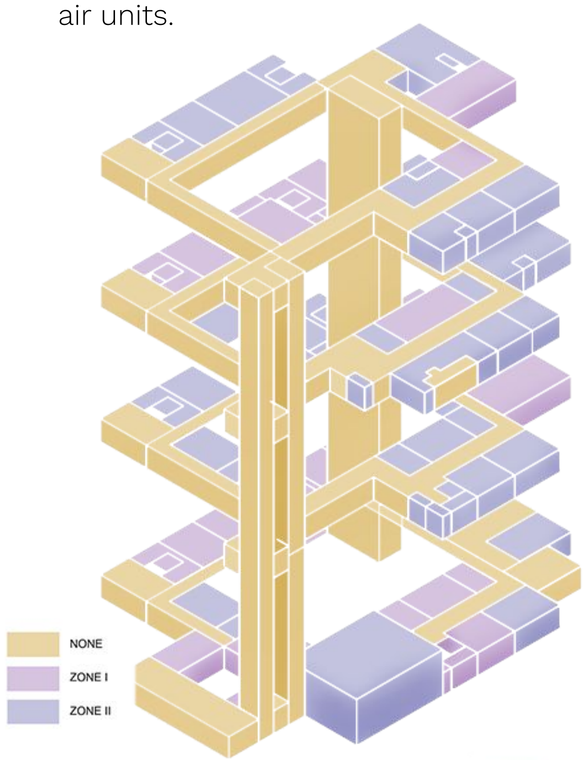
Fig 29. Embodied Energy Reduction

Fly ash based AAC is used as the major masonry material to utilise the large amounts of concrete construction by-product present in the city and Rockwool is used for insulation. It is made from naturally occurring basalt rock found within 100km of the site and recycled slag. It is efficient and durable. Thereby, embodied energy is reduced by 38% as compared to EDGE base case simulation of office building data.

HVAC OPTIMIZATION

Type of system

The HVAC System in use is a radiant cooling system with use of chilled roof panels that circulate water through the pipes cooled from a Recirculating chiller. The system incorporates a separate DOAS System to reduce the ducting and the amount of area required for separate FCU/AHU units by combining the CRCPs with floor wise Make-up air units.



OPTIMIZATION PLAN

The downsizing of the tonnage requirement of the whole system was done first with the set point temperatures remodelled according to the requirements of the building itself and zoning of the building. - done by understanding the adaptive thermal comfort of the people inside. The following band gives the ranges as preferred in IMAC.

Ranging from Naturally ventilated to Mixed-mode cooling, supplemented with passive design strategies the further downsizing to a 50% was achieved by PCM use with the radiant cooling system. The material used helped in reducing the total need for cooling and load per zone by increasing cooling capacity.

Fig 30. HVAC Optimized

	January	February	March	April	May	June	July	August	September	October	November	December
ZONE 1	23-28	23-28	21-28	21-27	21-26	21-26	21-27	21-28	21-28	21-28	21-28	23-28

	January	February	March	April	May	June	July	August	September	October	November	December
ZONE 2	23-28	23-28	21-28	21-28	21-28	21-28	21-28	21-28	21-28	21-28	21-28	23-28

Table 7. HVAC temperature setpoints following IMAC standards

In the morning, the heat recovery system along with the Radiant cooling system works to cool the building.

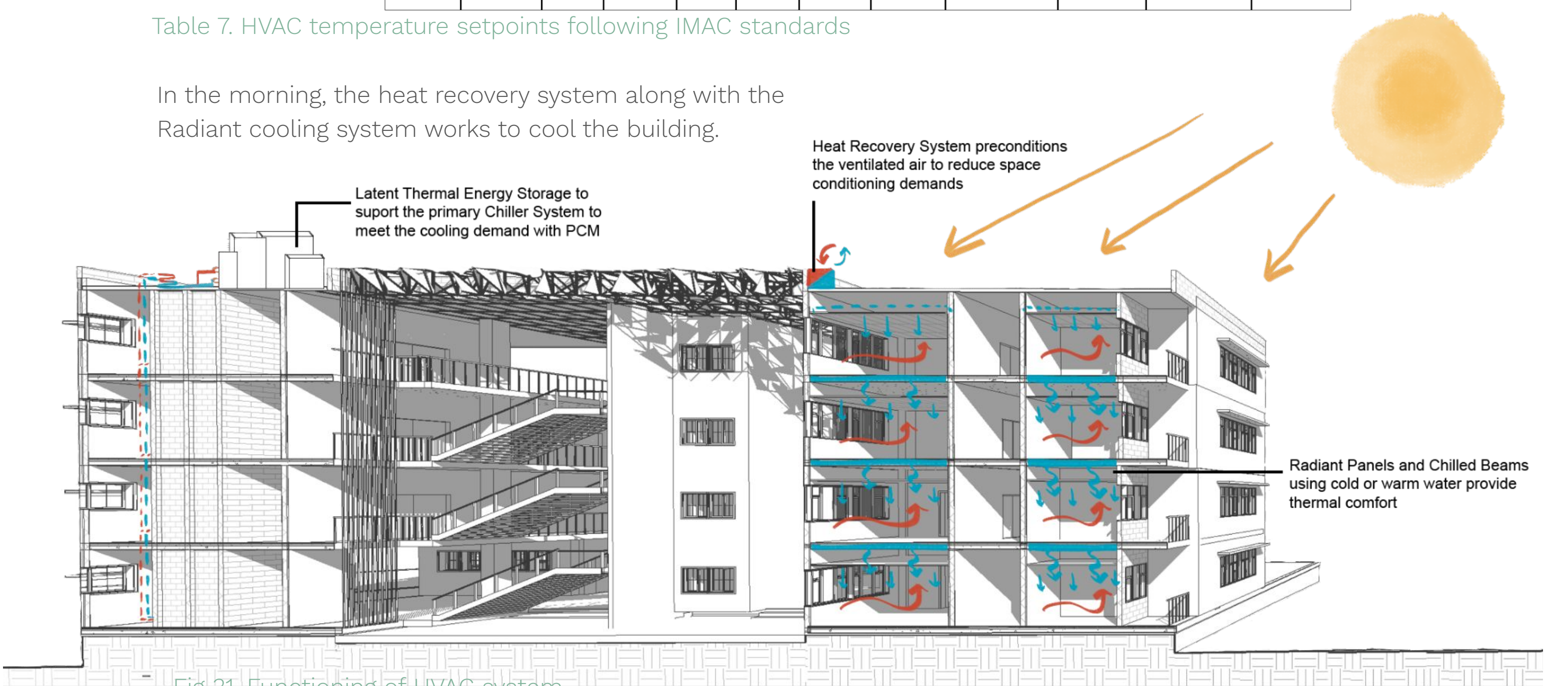


Fig 31. Functioning of HVAC system

HVAC OPTIMISATION RESULTS

HVAC optimisation has also been done with respect to functionality in spaces. It has been tailored to fit to Office spaces, meeting rooms, training hall, conference room and waiting areas. It has been reduced to mechanical ventilation only in areas which allow for easier flow of air, like corridors, core, bathrooms and storage areas. This allows for efficient use of energy while not compromising on comfort.

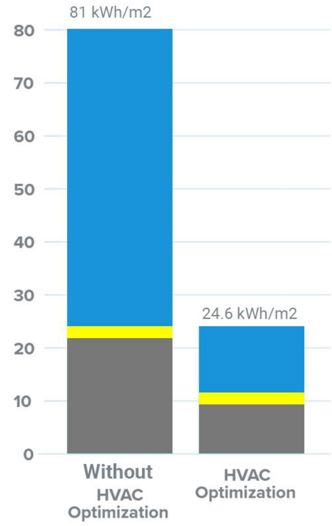


Fig 32. HVAC optimization results

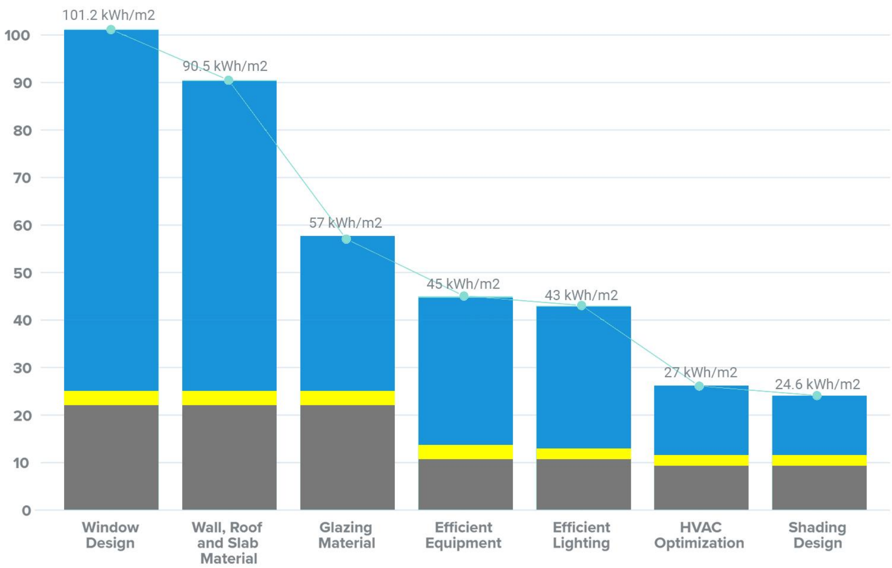
TARGET EPI

Following the Energy consumption break up, our annual energy targets following Super ECBC are as follows :
Equipments : 108000 kWh, Lighting : 9400 kWh, HVAC : 25,206 kWh and Hot water generation: 3000 kWh. (Refer to the Appendix for detail calculations)
Hence, the total target energy usage is

$$\text{Target EPI} = \frac{\text{Total Target Energy Usage}}{\text{Total Built-up Area}} = \frac{145606\ \text{kWh}}{4500}$$

Prelim Target EPI= 32.35 kWh/m^2 per year

OPTIMISATION RESULTS



EUI optimizations were done parametrically, against a default value defined earlier. After achieving a desirably low EUI value, elements were added to increase visual and thermal comfort, especially in non-HVAC areas.

Fig 33. EUI Optimization results

RATINGS ACHIEVED

We followed IGBC, LEED and EDGE standards while designing our building, and were able to achieve a GOLD IGBC rating by scoring 71 points (refer to Appendix, for detail break-up) and are compliant to Green Building Standards for Life Cycle Analysis of EDGE. We also were able to bring to Embodied Energy by 37%. The daylighting and comfort levels of our building adhere by LEED standards and we are compliant with ECBC+/Super ECBC in specific cases (refer to Appendix for detail break-up).

ENERGY POTENTIAL

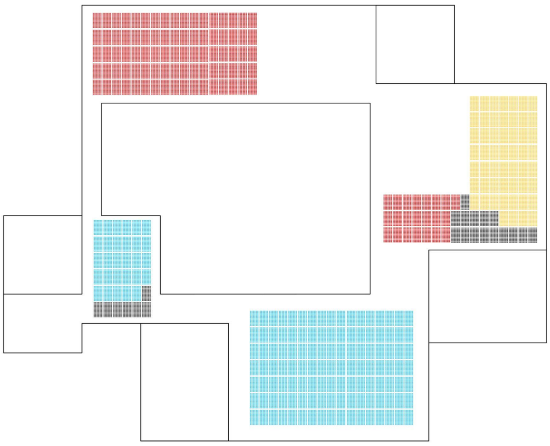
The site receives an average solar irradiance of 5.13 kwh/sqm per day which promises a positive solar potential. We have proposed the use of Solar panels which will be placed on the roof level terrace. The panels will have a provision of angle adjustment depending upon the time of the year for maximum output. The technical specifications and energy generation details are given below.

Assuming there is direct sunlight falling on the roof,
1 kwh capacity solar pv systems needs 10m^2 to generate 1500 kWh energy per year.
So,
Total energy generated by the building = $\frac{\text{Roof Area}}{10 \text{ m}^2}$ x 1500 kWh = $\frac{1150 \text{ m}^2}{10 \text{ m}^2}$ x 1500 kWh

Solar PV potential = 115 x 1500 kwh = 1,72,500 kWh,

Required Generation (for peak loads) : 1,30,015 Kwh/year
Using PV Generator of Capacity : 48W/hr, No. of PV cells : 330

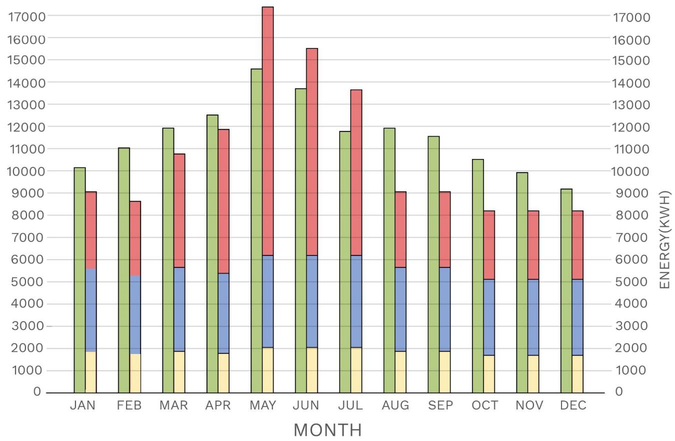
PV layout



Equipment (32% of the total power generated)
HVAC (45% of the total power generated)
Lighting (16% of the total power generated)
Buffer (7% of the total power generated)

Fig 34. PV Layout

Monthly generation vs consumption



Equipment Energy Use
Lighting Energy Use
HVAC Energy Use
Monthly PV Generation

Fig 35. Generation vs consumption graph

PV Specifications

330 Loom solar panels 2m*1m in size have been used to meet the energy demand of the building. Each panel generates 422 Kwh per year.

Module specifications

Weight: 23 KG
Capacity: 0.422 Kilowatt-peak(KWp)
Monocrystalline cells, 12x6 in series
Module Efficiency: 19.5%
Dimension: 1965mmx985mmx40mm

Schematic Working of PV

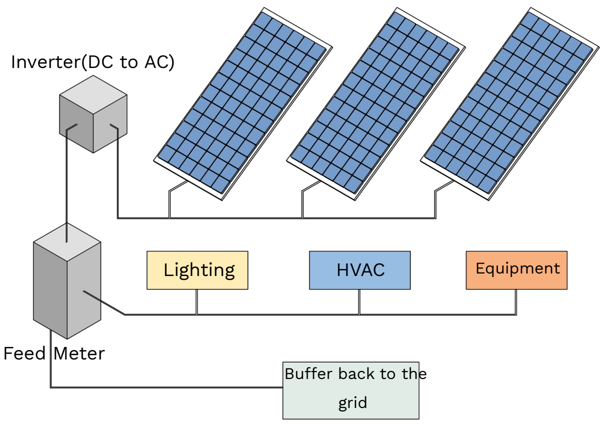


Fig 36. Schematic PV working diagram

All panels are connected to Delta solar inverters 100KW capacity and the converted power is distributed into the building and the buffer is fed to the grid.

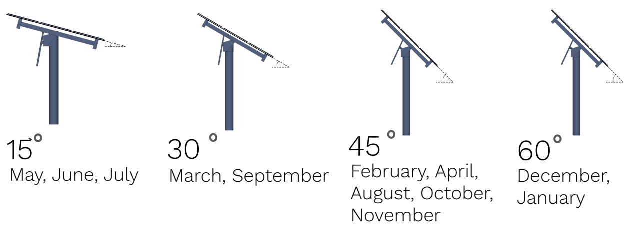


Fig 37. Operation angle of solar panels

WATER PERFORMANCE

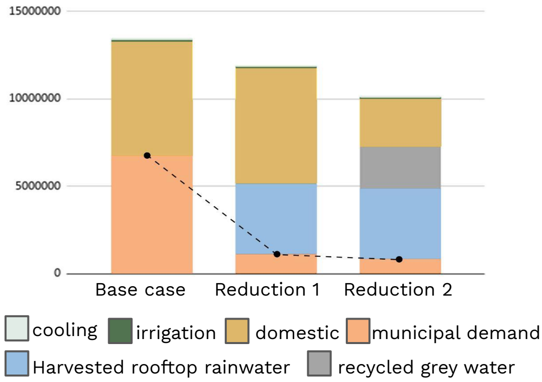


Figure 38. Baseline Water Calculation

The overall water performance was improved by explorations done in three phases.

1. **Base case:** A base water demand calculation was done for the required footfall.
2. **Reduction 1:** Rainwater harvesting was explored and implemented. This helped reduced the fresh water demand by more than 50%.
3. **Reduction 3**: A thorough research was done on the various available efficient fixtures with the proper flow rates. The right fixtures were chosen which helped reduced fresh water demand to 87%

WATER CYCLE

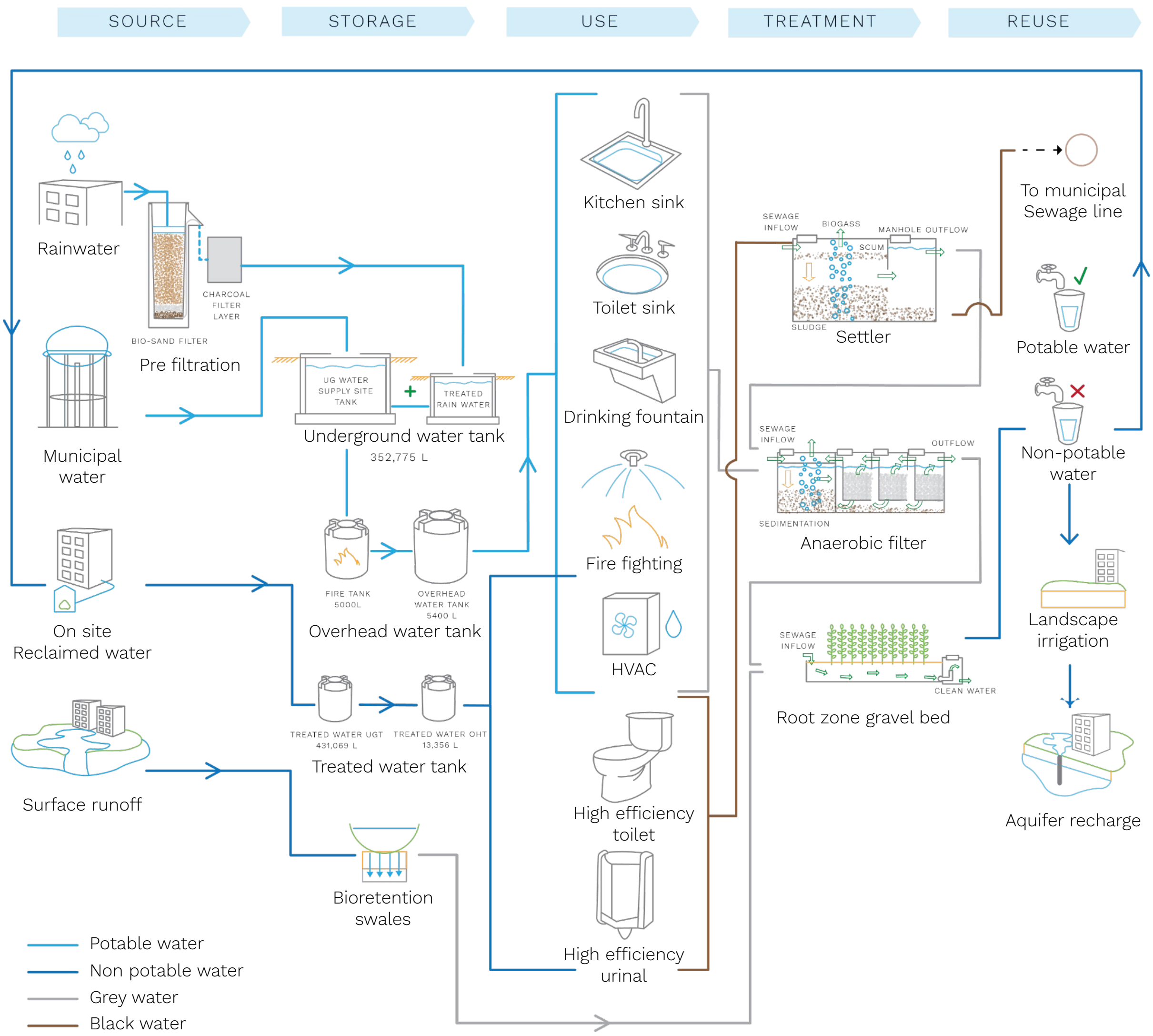


Figure 39. Schematic Water Use Cycle for the building

An effective water cycle has been developed to minimize daily fresh municipal demand. Rain water harvesting coupled with a root zone water treatment that treats surface runoff and grey water are used as alternate sources of water. Vegetated swales are designed around the site to help channel surface run-off to the storage tanks. Water from the swales are also used to irrigate the site. Local vegetation has been used to reduce turf area, thus, minimizing on landscaping requirements. In the monsoon months extra grey water is sent to Ground recharge.

BASELINE ESTIMATE

Water consumption point	Quantity	Baseline (lpd)	final (lpd)
Occupants : {People x l/person}	400	45	35
Irrigation (max) : {m2 x l/m2}	4140.5	3	2
Cooling tower (max) : {ton x l/ton}	84	4.5	3

Table 9. Baseline Estimates

END-USE ESTIMATE

End use	Percentage use	Use in LPD	Greywater in LPD	Blackwater in LPD
Cleaning house	14%	2520	2520	-
Washing Utencils	17%	3060	3060	-
Others	11%	1980	1980	1980
Drinking	10%	1800	1206	594
Cooking	03%	540	-	540
Toilet Flushing	45%	8100	-	8100
Total	100%	1800	-	11214

Table 10. End Water Usage Estimate

WATER HARVESTING SOURCES

Water harvesting sources	Area	Run-off coeff
Roof Surfaces	1400	0.85
Hardscape area	1600	0.85
Softscape area	4140	0.3
Effective catchment area	3792	

Table 11. Water harvesting sources

FLOW RATE OF FIXTURES

End Use Area	Baseline water use for fixtures	Benchmark water use for fixtures	No. of fixtures
Water Closet	6l per flush	3l per flush (dual)	65
Urinals	3.8l per flush	2.4l per flush	18
Restroom lavatory faucet	8l per minute	4.4l per minute	10
Public lavatory faucet	8l per minute	4.4l per minute	55
Health faucet	8l per minute	6l per minute	65
Kitchen faucet	8l per minute	6l per minute	4
RO Water Treatment	3l rejected for 1l produced	1l rejected for 1l produced	400 people

Table 12. Flow rates of fixtures

STORAGE SIZING

Sl no	Tanks	Size (L)
	Underground tank (UGT)	
1	fresh water UGT (municipal + treated rooftop rain water)	352,775
2	treated water UGT (recycled grey water + surface run-off rain water)	431,069
3	fire tank UGT	50,000
	Over Head Tank (OHT)	
4	fresh water OHT (municipal + treated rooftop rain water)	5,400
5	treated water UGT (recycled grey water + surface run-off rain water)	13,356
6	fire tank OHT	5,000
	Total Tank Size	857,600

Table 13. Storage size Estimate

RAINWATER HARVESTING AND MUNICIPAL DEMAND

Months	days in month	rainfall (mm)	effective rain water (mm)	rooftop rainwater (mm)	surface runoff (L)	total harvested water (L)	monthly potable fresh water demand (L)	remaining demand after using rooftop rain water (L)	fresh water demand after carrying over stored rooftop rainwater into next month (L)	municipal water demand (L)
July	31	355	350	416500	910700	1327200	167400	249100		0
August	31	359	354	421260	911208	1342368	167400	253860	335560	0
September	30	229	224	266560	582848	849468	162000	104560	196420	0
October	31	30	25	29750	65050	94800	167400	-137650	134310	0
November	30	9	4	4760	10408	15168	162000	-157240	-132890	132890
December	31	13	8	9520	20816	30336	167400	-157880	-147720	147720
January	31	13	8	9520	20816	30336	167400	-157880	-148360	148360
February	28	5	0	0	0	0	152550	-152550	-157880	157880
March	31	9	4	4760	10408	15168	167400	-162640	-147790	147790
April	30	2	0	0	0	0	162000	-162000	-162640	162640
May	31	8	3	3570	7806	11376	167400	-163830	-158430	158430
June	30	100	95	113050	247190	360240	162000	-48950	-50780	50780

Table 14. Rain water harvesting and municipal fresh water demand.

-ve means there is less rooftop rain water for that month and that same amount needs to be balanced with municipal supply

WATER BALANCE

		Consumption						Water Sources						
month	no. of days	domestic use (L)	cooling usage %	cooling usage (L)	irrigation usage %	irrigation usage (L)	total consumption	municipal water (L)	rainwater (L)	generated grey water	filtered grey water	generated black water	total sourced	total stored
Jul	31	558,000	50%	5,859	0%	0	563,859	0	1327200	271,746	203,810	347,637	1531010	967151
Aug	31	558,000	50%	5,859	0%	0	563,859	0	1342368	271,746	203,810	347,637	1546178	1949469
Sep	30	540,000	50%	5,670	5%	567	546,237	0	849468	262,980	197,235	336,420	1046643	2449875
Oct	31	558,000	50%	5,859	50%	5,859	563,718	0	94800	271,746	203,810	347,637	298610	2178767
Nov	30	540,000	20%	2,268	70%	7,938	550,206	132890	15168	262,980	197,235	336,420	212403	1973854
Dec	31	558,000	0%	0	70%	8,203	566,203	147720	30336	271,746	203,810	347,637	234146	1789516
Jan	31	558,000	0%	0	70%	8,203	566,203	148360	30336	271,746	203,810	347,637	234146	1605819
Feb	28	508,500	40%	4,271	80%	8,543	521,314	157880	0	247,640	185,730	316,796	185730	1428115
Mar	31	558,000	75%	8,789	90%	10,546	577,335	147790	15168	271,746	203,810	347,637	218978	1217548
Apr	30	540,000	90%	10,206	100%	11,340	561,546	162640	0	262,980	197,235	336,420	197235	1015877
May	31	558,000	100%	11,718	100%	11,718	581,436	158430	11376	271,746	203,810	347,637	215186	808056
Jun	30	540,000	90%	10,206	75%	8,505	558,711	50780	360240	262,980	197,235	336,420	557475	857600

Table 15. Water balance

SITE LEVEL WATER SLD

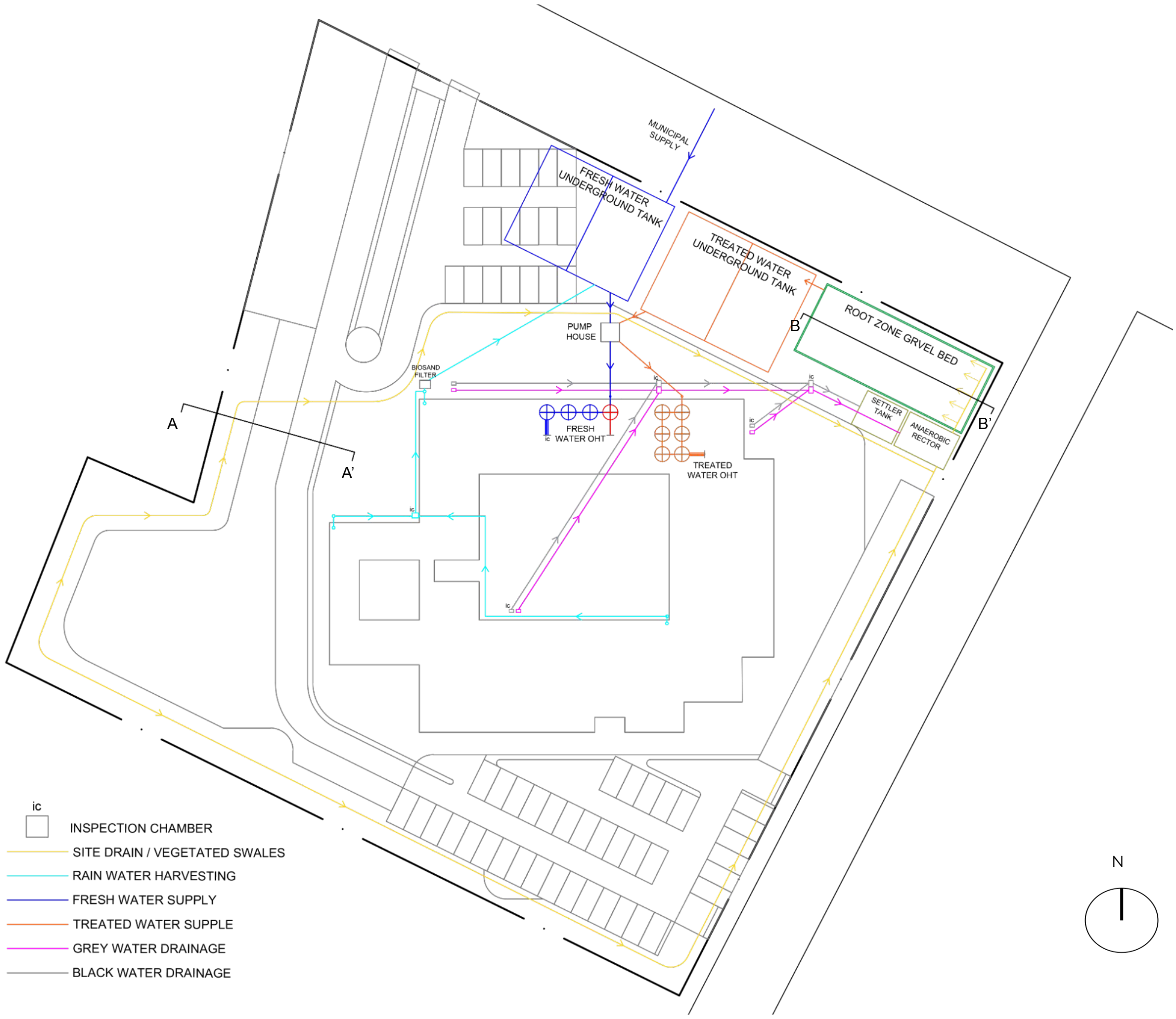


Figure 40. Site level plumbing SLD

SECTIONS

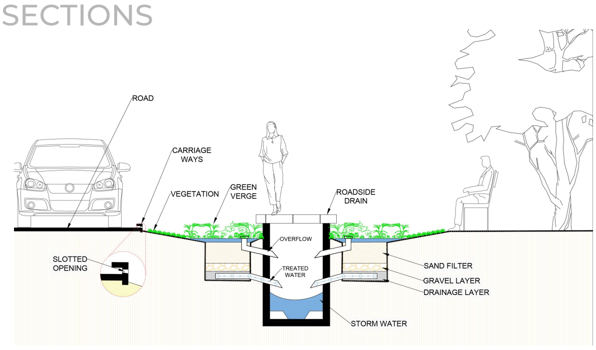


Figure 41. Vegetated swale section AA'

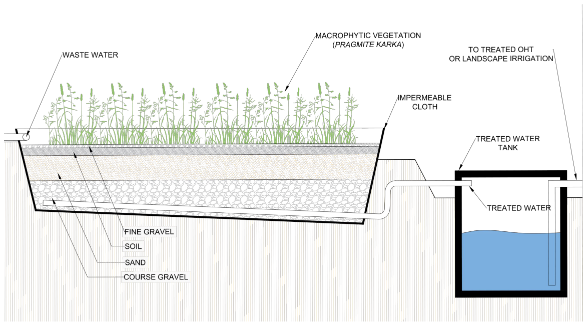


Figure 42. Gravel Bed Section Of The Root Zone Treatment BB'

SWALE DESIGN

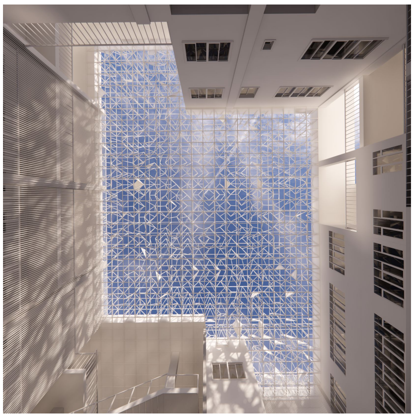
To maximize water harvesting from surface runoffs, vegetated swales are design along all the asphalt roads and pedestrian footpaths. A catchment drain, under the footpath, channels all the water to the root zone treatment. These swales double up as landscaping elements which help improve the quality of space around the site.

ROOT ZONE TREATMENT

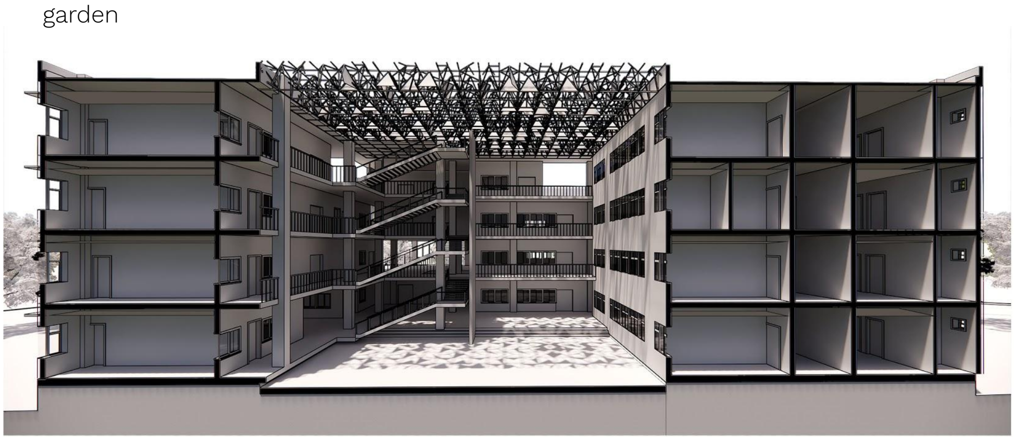
A three phase root zone treatment was chosen to treat and recycle water on site. First grey water is stored in a pre-settler tank to remove all suspended solids by sedimentation. It is then passed into an anaerobic filter to digest any microbial organisms. In the last step the water is passed into the gravel bed where the roots of the plant 'pragite karka' treat the water organically. The treated water is collected in a separate tank.

ARCHITECTURE

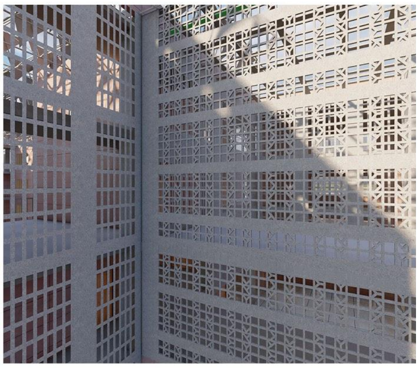
Irresistible staircase with vertical garden



Shaded courtyard



Section



Jaali Patterns

Singly loaded and shaded corridors

Figure 43. Architectural views and elements of the building

Comfort and energy have been prioritised and thus the design scores well in that aspect. Office blocks with higher occupancy have been placed on the north side for better comfort and daylighting. All the rooms are well from the exterior as well as from the courtyard. Shading devices and light shelves have been provided at adequate locations ensuring daylighting. The shaded courtyard in the centre acts as a recreational area. Single loaded corridors are open to the courtyard and become a liminal space connecting different departmental offices.

STRATEGIES TRANSLATED FROM THE BUNDLES

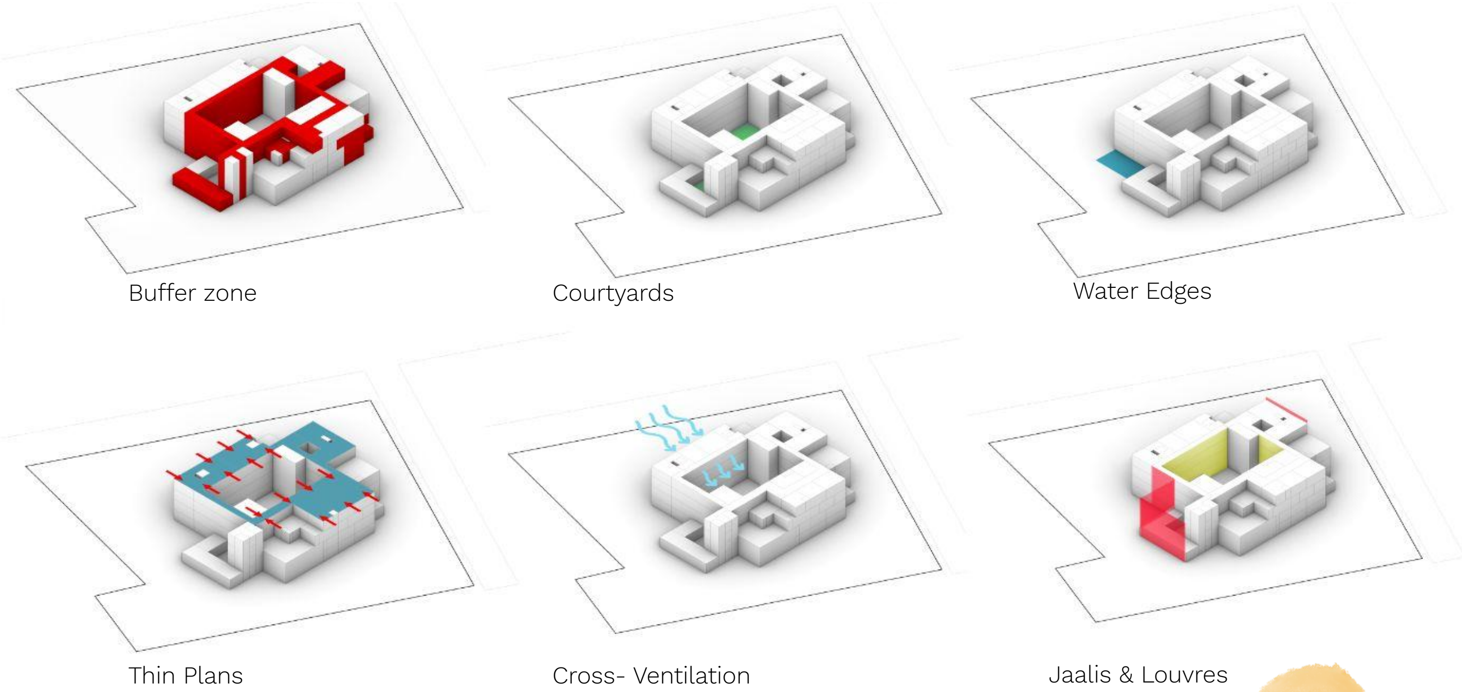


Figure 44. Passive strategies

INCORPORATING NIGHT VENTILATION VIA PCM

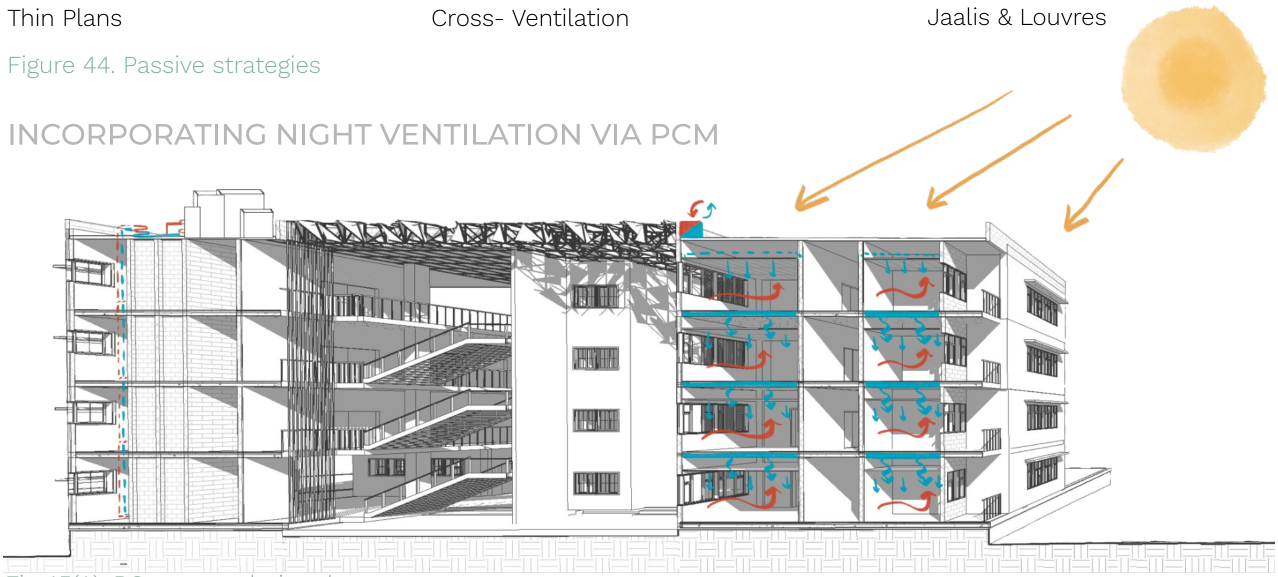


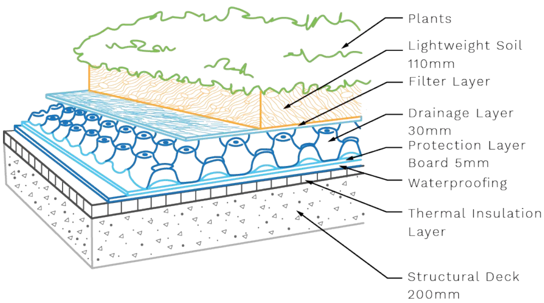
Fig 45(A). RC system during day

In the morning, the heat recovery system along with the Radiant cooling system works to cool the building. During the Night, the Latent thermal storage cools itself down for daytime use while the chiller runs to charge the PCM.

Fig 45(B). RC system during night

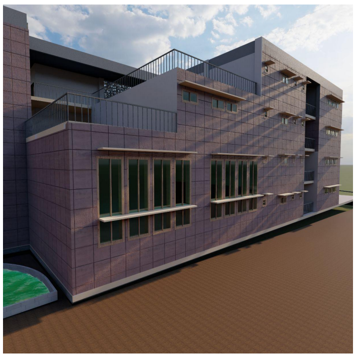
PROMINENT CLIMATE RESPONSIVE FEATURES

Figure 46. View of the courtyard and space frame

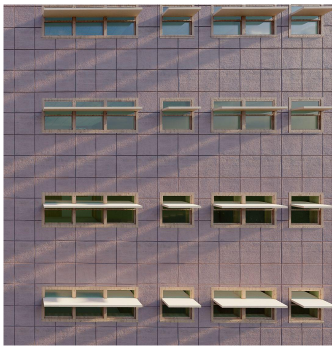


Green roof assembly

Figure 47. Green roof assembly



South Elevation



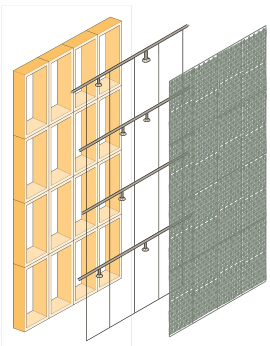
North Elevation

Figure 48. Shading designs

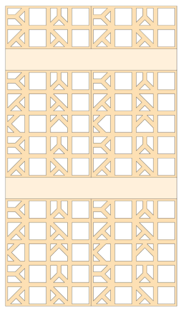
Windows have been optimized in both type and size based on how much solar radiation falls on that surface, and daylighting requirements based on functionality.

TAPERED PERFORATIONS WITH SPRINKLERS

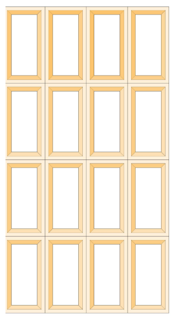
We have developed a cooling and humidification combination inspired by the vernacular Rathwa housing of Madhya Pradesh. In their homes, they utilise a bamboo mesh jaali with tapered openings to cool down the incoming air. In hot summer months, sprinkling water on the jaali to cool down the building further. We've used tapered fly-ash hollow blocks paired with an easy facade sprinkler system to incorporate the strategy.



Jaali assembly



Sandstone jaali



Tapered AAC blocks

Figure 49. Types of Jaali used

COMFORT AND ENVIRONMENTAL QUALITY

VENTILATION AND COMFORT

Optimising the zoning, layout and Window-wall ratios allowed us to create comfortable (less than 27°C) inner surface temperatures in more than 70% of our building. Some upper floors and blocks facing the West and South west directions exhibited temperatures greater than 27°C and were resolved by adding buffer spaces, setting lower HVAC setpoints and utilizing Phase Change Materials (PCMs) in the false ceilings.

INNER SURFACE TEMPERATURES

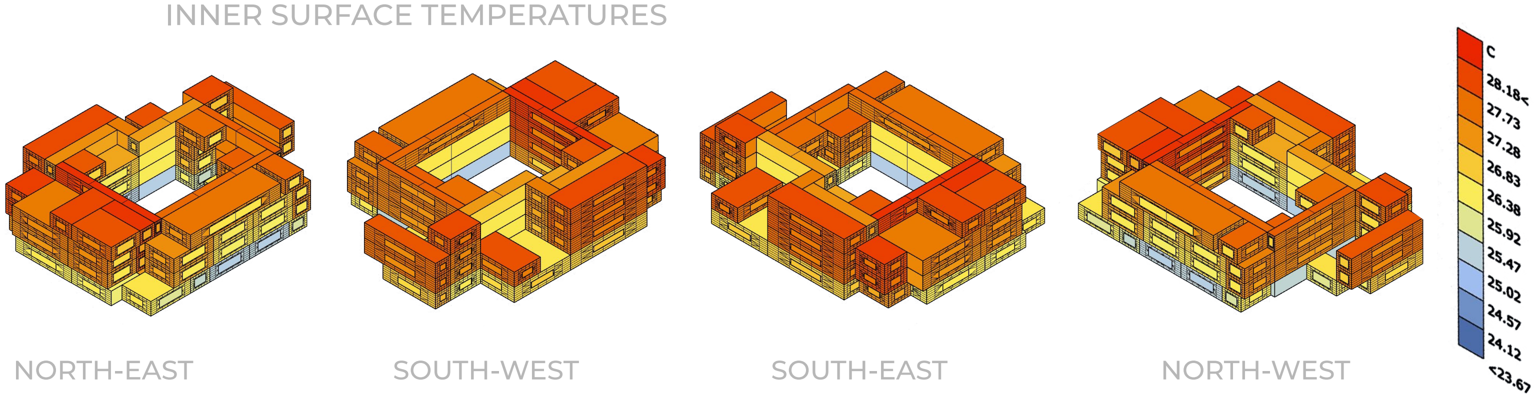


Figure 50. Surface temperatures simulations

NATURAL VENTILATION

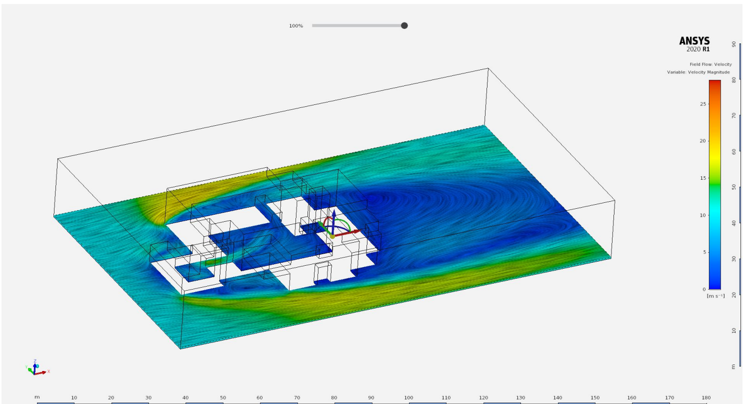


Figure 51: The path between the two courtyards implements the venturi effect

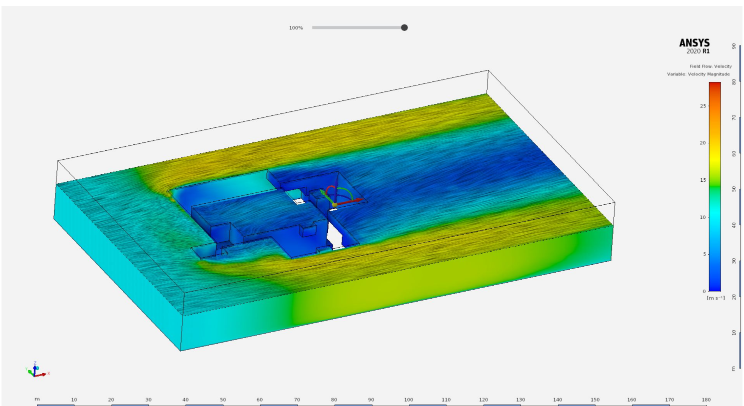


Figure 52: The two courtyards help in maintaining wind speed

We utilise cross ventilation, stack effect and venturi effect(jaalis) in our project to provide ample natural ventilation. Our design has used jaalis and breeze blocks to facilitate natural ventilation and provide additional comfort to occupants. Hollow breeze blocks of fly-ash have been provided on the Western facade with about 60% perforation percentage. Facades of entrances have been adorned with more elaborate sandstone jalis of about 70% perforation percentage. The jalis have been found to increase the wind speed and aid in the stack effect involving the courtyards.

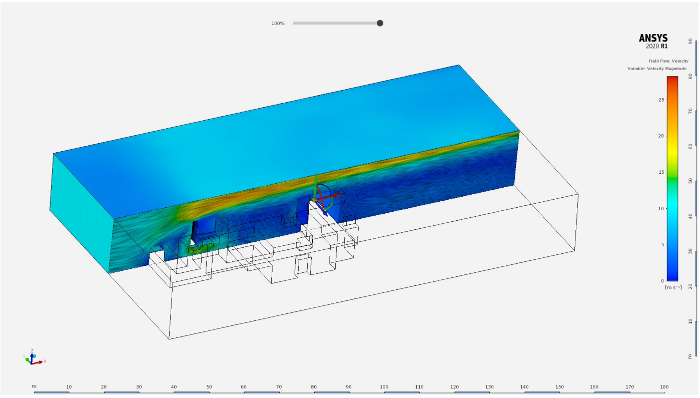


Figure 53: The building allows cross ventilation across its premises, accelerating the wind around it

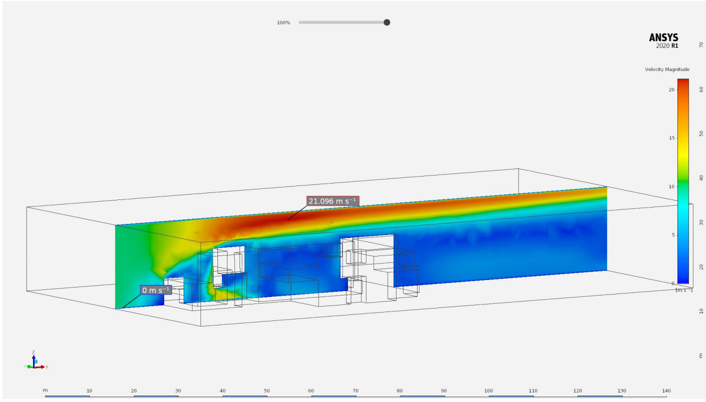


Figure 54: Junctions in the form are designed to accelerate the wind speed

The built form and building rooms have cross ventilation, using an interweaving of open spaces and locating windows on opposite sides of the rooms. The green partition wall (refer to pg22) allows circulation throughout the open plan office.

JAALI VENTURI EFFECT

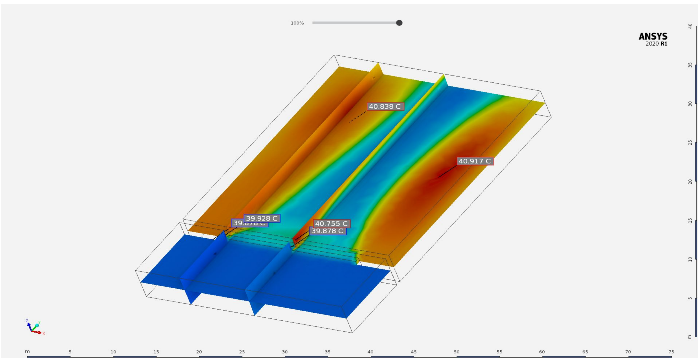


Figure 55: Jaali CFD simulations

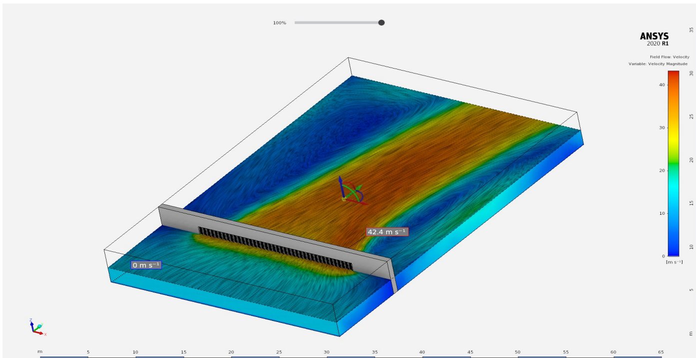


Figure 56: Jaali CFD simulations

The breathing wall (jaali) is used on the facade (refer to pg 21) to accelerate the summer air and cool it down, in the process. The accelerated wind carries through the corridors and courtyards to the office openings.

HVAC

The desiccant Radiant cooled system used for the building allows for a large range of adaptability throughout the year , taking into account the needs of the various departments. The CRCP in the ceiling panels allow for better ventilation and air flow which allows for a higher set point - thus saving on cooling loads while maintaining comfort. The System thus runs on peak for 4 months, while the rest of the year sees minimal cooling use.

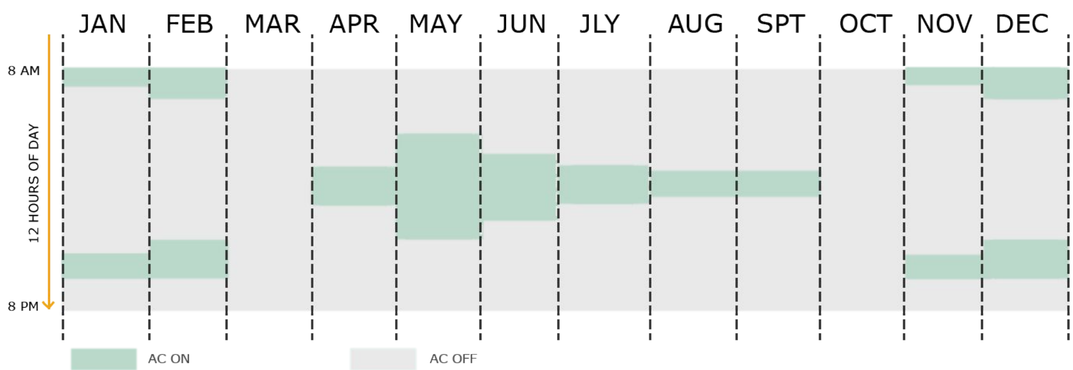
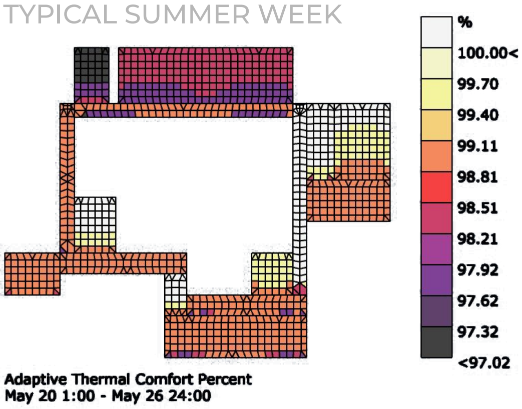


Figure 57: HVAC Switch Graph

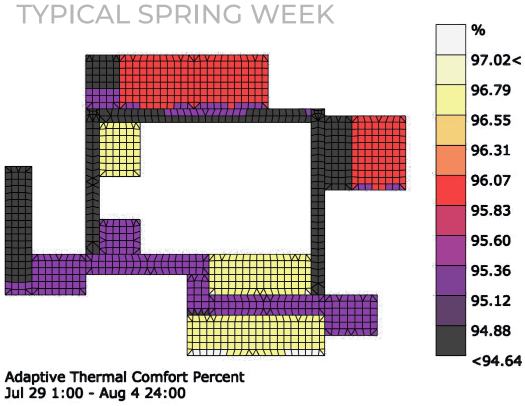
SEASONAL THERMAL COMFORT MAPPING

TYPICAL SUMMER WEEK



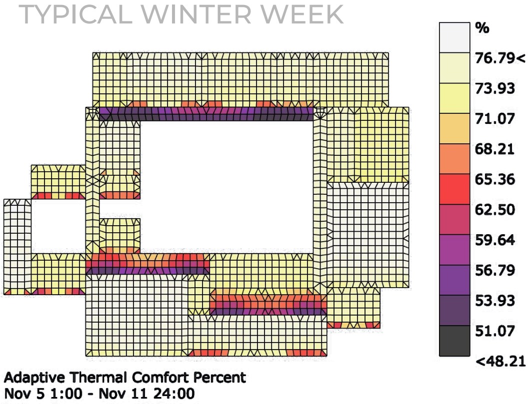
The top-most floor is observed to be more than 97% comfortable in all areas.

TYPICAL SPRING WEEK



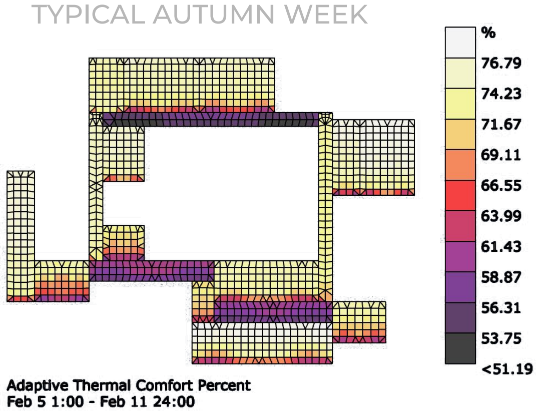
The second floor is observed to be more than 94% comfortable in all areas.

TYPICAL WINTER WEEK



The ground floor is observed to be more than 73% comfortable in all living areas.

TYPICAL AUTUMN WEEK



The second floor is observed to be more than 74% comfortable in all living areas.

Figure 58: Adaptive Thermal Comfort Simulations

Honeybee and Open Studio are used to read the EPW file to select typical weeks of each season and map Adaptive Comfort based on ASHRAE-55. The scales are varied according to the variation in comfort level to get accurate information. The initial results were also analysed on a daily basis to design HVAC schedule and set points. The mapping of Thermal Comfort shows that the building offers thermal comfort (above 70%) for more than 90% of the hours, as suggested by IMAC.

DAYLIGHTING

Daylighting was integrated in every step, to allow a naturally, comfortably lit space. Using the LEED v.4.1 system, we ensured each floor qualified for at least 2, if not 3 LEED Daylight credit points. This also meant reducing glare, which was minimized to an average of 20% through each space. The bulk of the glare is in non-working spaces like corridors, further optimizing visual comfort.

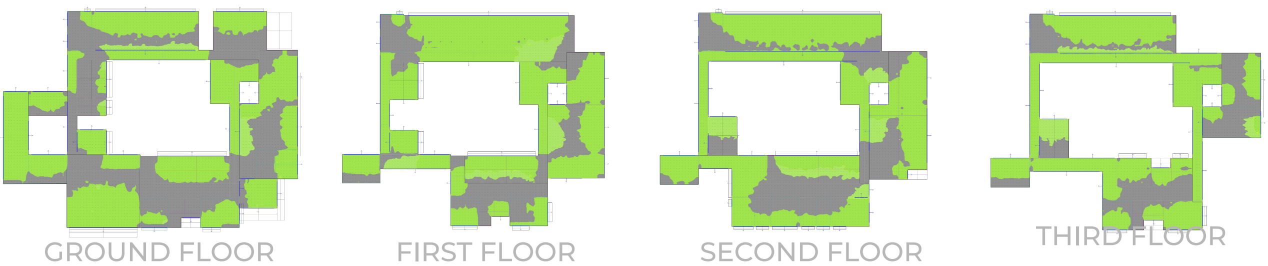
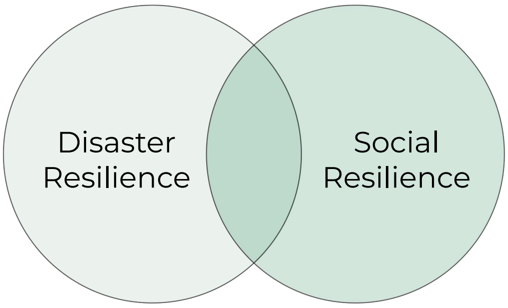


Figure 59: Daylight mapping

RESILIENCE

STRUCTURAL DESIGN
The Design is IS-456 Code complaint, which implies the building strength is evaluated to last a 100 years.



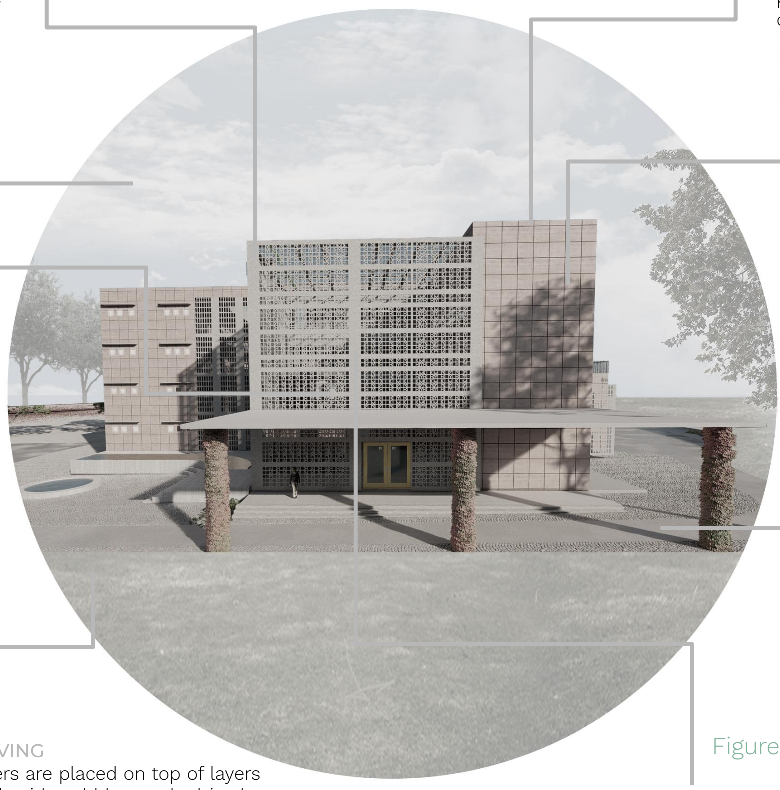
PHOTOVOLTAIC PANELS
Installation of local PV Roof panels help during grid disruptions and blackouts.

The building is designed to offer resilience to natural, man-made as well as social calamities and threats.

MICROCLIMATE
By utilising the existing trees, creating jali walls and water edges a cool microclimate is developed around the building.

DISASTER RESILIENCE

SANDSTONE TILES
The multilayered, non-porous tile acts as a heat resistant layer on the rooftop, vastly protecting the building during heat waves.



NATURAL LIGHTING AND VENTILATION
Jaalis, Light shelves and courtyard can provide ample lighting and comfort through natural ventilation to work and help in the functioning of the office during a longer power cut and if power backup needs to be saved for evening time and longer working hours.

BIOSWALE DESIGN
Bioswales concentrate and convey stormwater runoff while removing debris and pollution.It prevents flooding on site and recharges the depleting ground water.

Figure 60. Front Elevation Details

SEMI-PERMEABLE PAVING
Permeable cement pavers are placed on top of layers of gravel, and sand bed, with pebbles packed in the spaces between the pavers. This helps in percolation of rainwater through the hard surface. Additionally, the low SR value of Concrete (30-50% for new pavers and 20-35% for old) keeps the pavement surface cool.

WATER STORAGE
Excess availability of water and use of renewable water resources allows storage for minimum days which can be used during water shortage or a natural calamity.

BMS/FANS/EQUIPMENT
The building management system is designed to increase competitiveness among users and facilitate best practices. The system advices the users to prepare according to the conditions of next working day so that in case of failure of systems, the staff will be least affected. Further there is manual mode operation of each module with control at respective departments. There are provisions for staircases and fans in case of failure of Lifts and HVAC systems.

ELECTRICAL LAYOUT
All Circuit breakers have been provided with ample spares for immediate replacement in case of failure and high resilience of the building against natural disasters and power outages.

SEPARATION IN BLOCKS
All Work spaces have been designed and divided into blocks with individual lighting and equipment services so that in case a block fails, the other blocks can function normally and aid the failed block as well.

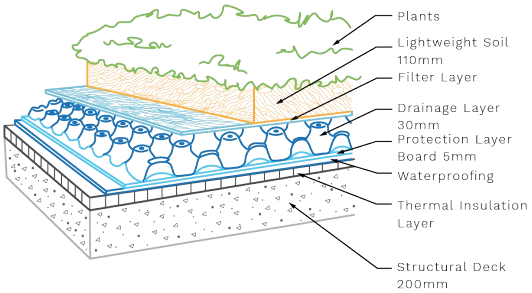


Figure 61. Green Roofs

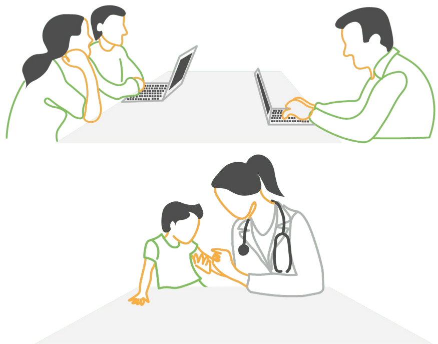


Figure 62. Temporal usage of open plan office

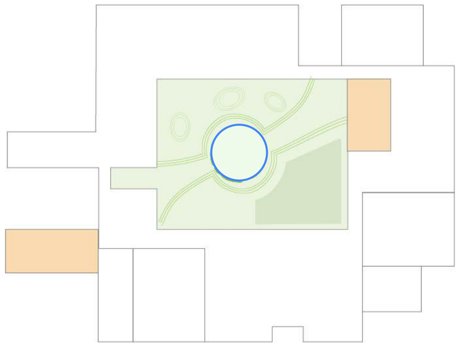


Figure 63. Building plan with circulation cores

The green roofs used in the building lower the temperature as shown in figure 61 and offer resilience to heat gains. The open plan offices have been designed in such a way that they can be used in case of calamities such as vaccination centres as shown in figure 62. Two circulation cores have been used as shown in figure 63 in the building block with one core following the fire safety norms and can be used as an escape route during fire hazards

SOCIAL RESILIENCE

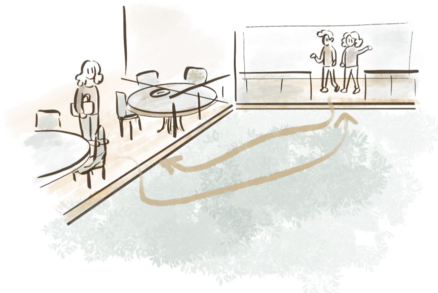


Figure 64. Break-out spaces

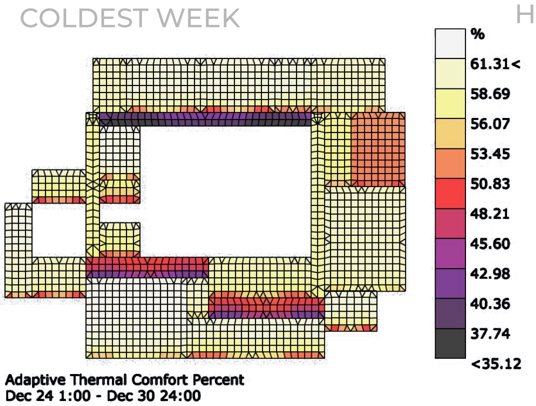
Figure 65. Open plan office

Figure 66. Landscape as sound barrier

Figure 64 shows a view of the break out spaces introduced in the design which helps in increasing the quality of work by providing relaxing spaces for the workers to take breaks. Open place office space as shown in the figure 65 helps in providing a comfortable work environment with more interaction among the co-workers. Figure 66 shows a schematic site plan of the design with enough landscaped spaces around the built-up which acts as a sound barrier for the nearby communities offering social resilience.

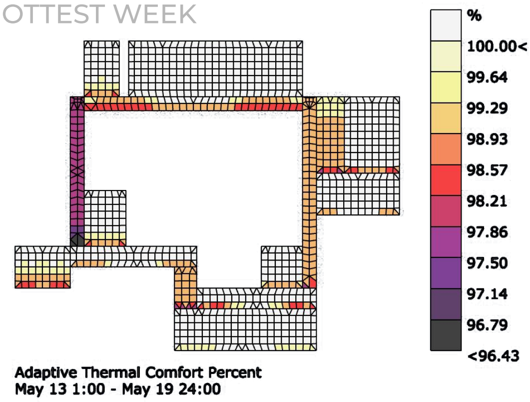
THERMAL COMFORT IN EXTREME CONDITIONS

COLDEST WEEK



The ground floor is observed to be more than 58% comfortable in all living areas.

HOTTEST WEEK



The top-most floor is observed to be more than 96% comfortable in all areas.

The EPW file was edited to include projected temperatures after 20 years and the spaces are comfortable even in the extreme conditions of the same.

SCALABILITY AND MARKET POTENTIAL

AT THE NATIONAL LEVEL

The documented land size owned by the Government of India is 13,505 sq km, nine times the size of New Delhi. Given the scale of monetary and geographical resources, the central body has the potential to be a pioneer for Net-Zero building design. Currently, the Sustainable Building Industry is dominated by Non-Government or Private organisations, all of the 15 Net-Zero Building projects fall under the said categories. The top Green buildings of India also have a similar suit.

The headquarters of the National Health Mission allows us to make use of the opportunity to design a green government building that can become the beacon of hope in the new era of sustainable development. The projects aims to highlight not only the resultant building design but the design process. The inclusion of new technologies with a focus on passive design and contemporary interpretations of the vernacular shows what an "Indian Net Zero Building" would be.

Kalpana Housing **Multi Residence cum Office** Auroville	Jaquar Headquarters **Office** Manesar	Humanscapes **Community Housing** Auroville
Unnati **Office** NOIDA	Residential School **Avasara Academy** Pune	Pocharam Campus **Infosys** Bangalore
Indian Green Building Council **IGBC** Hyderabad	Godrej Plant 13 **Annexe** Mumbai	A Living Laboratory **CEPT** Ahmedabad
Indira Paryavaran Bhawan **MoEF** New Delhi	Akshay Urja Bhawan **Hareda** Panchkula	Eco Commercial Building **Bayer Material Sciences** Greater NOIDA
Malankara **Tea Plantation** Kottayam	Office Complex **GRIDCO** Bhubaneswar	Net Zero Energy Building **SunCarrier Omega** Bhopal

Figure 68: LIst of NZEB India

Figure 69. Essence of Bhopal

Bhopal, often called the city of lakes, has worked hard to create an identity of a clean, green and beautiful city. But the recent five year plan completely disrespects the ecological balance and foliate of the city only focussing infrastructural development. Its implementation could cause large-scale flooding as the methodic supply-demand chain of the lakes around which Bhopal grew, is disturbed. The people of the city are unabashedly protesting against it.

Figure 70: Public space view

AT THE NEIGHBOURHOOD LEVEL

The project site is in an up-and-coming area along Link Road No. 3 where many contemporary public buildings are being proposed and constructed. Situated some distance away from the lakes in old centre of the city, it is one of the many recently developed urban areas around the city. It lies adjacent to the sprawling campus of Maulana Azad National Institute of Technology, and is sufficiently close to the commercial centre of the city. A medium density residential neighbourhood lies near the site. Thus, a wide variety of people cross by the site, from college students and localites navigating through their daily tasks, to the influx directed towards the bustling markets and tourists walking through the city. As well as, various officials and dignitaries visiting the NHM building itself. The building is highly influential. Further, the reduced operating costs of a Net Zero or Net Positive building make it a lucrative option for other key builders and contractors to invest in. Not only will it save energy on it's own, it will inspire the people working in it to do the same. We are confident that other similar projects will come up when they see the benefit of such a building.

We have also designed Public spaces in our campus, to intrigue and include the people. The OAT and sculpture grounds are used to create awareness about healthy living and health issues. The cafe and seating area provides a respite from extreme temperatures and helps people interact with the Government officials in the common, accessible space.

AFFORDABILITY

COMPARISON OF CURRENT AND PROPOSED

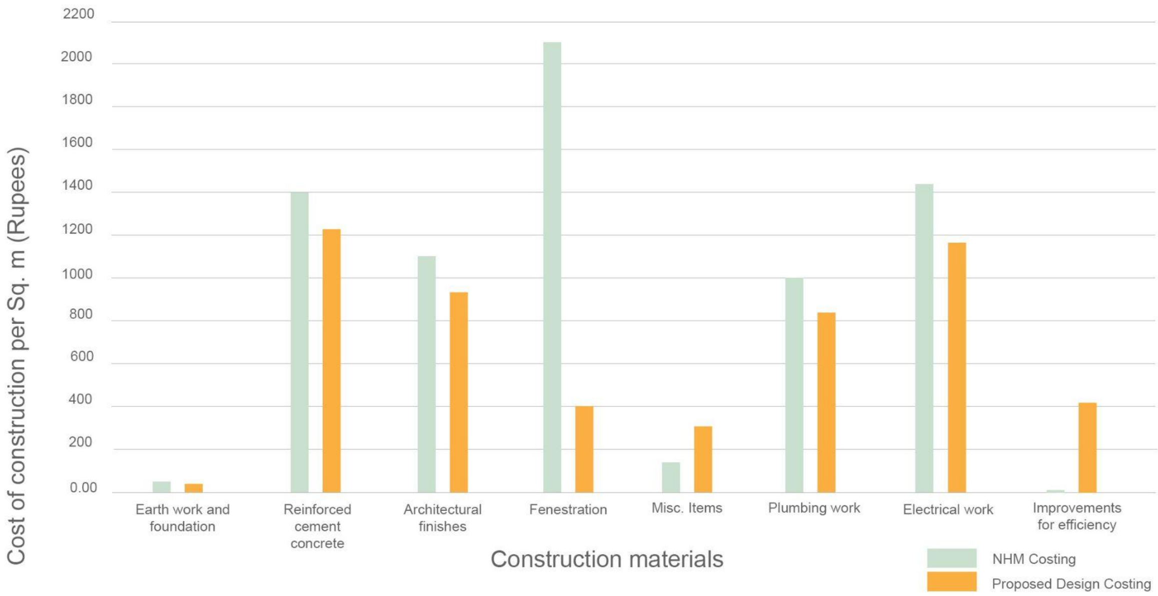


Figure 71. Comparison of current and proposed building

The overall costs of our project are 27.4% less than the proposed costs of the NMH building. We were able to reduce costs by optimising our building footprint and we have remarkable maximum in fenestrations by optimising their sizes according to heat and light requirements for each direction. Overall, the building design utilises proper zoning, passive strategies and smart IBMS technology to save costs.

PROJECT BUDGET BREAKDOWN AND PRICING

The land costs for our project were null, since this is a Government land and development project. Civil works take up the majority of costs, due to the black soil present on site and as our focus is on technological development, amenities take another prime slot from our budget. We are well within our budget (refer to Appendix for detail breakdown) and are able to even to get a lower cost of construction than the initial proposed design-by utlising layers of local material, and optimising fenestrations rather than making a fully glazed facade.

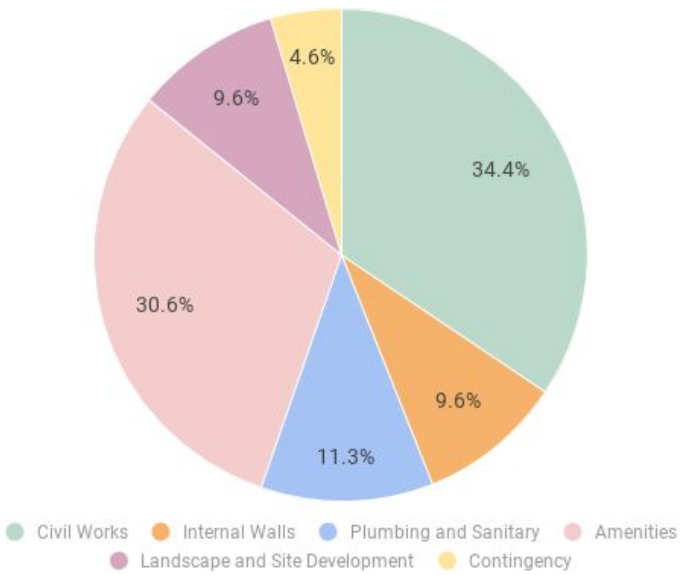


Figure 72. Operation costs and financial breakups

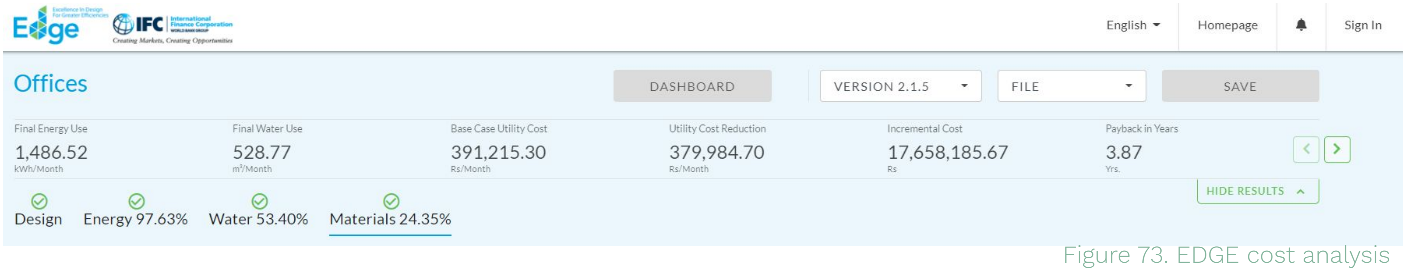


Figure 73. EDGE cost analysis

As the project is a government building, the most important factor to make it affordable was reducing operation costs. The multi-layered shading and facades is the first line of defence, bringing down cooling requirements. The loads of HVAC, equipments and lighting are reduced by using IMAC standards, replacing computer systems with laptops and using no maintenance LED lights offering 50% savings by providing an amplified lumen for the same wattage. The operating expenditure is also brought down by using an Intelligent Building System, using sensors to on/off appliances and lighting. Low flow water fixtures and utilising rainwater and grey water bring down water bill costs by reducing demand of municipal water by 87%. Apart from reducing building electrical demands, PV units also allow a 7% deduction in electrical bills. All this adds up to reduce utility costs by almost 95%.

MONETIZING SPATIAL CAPITAL

The site is zoned to hold public facilities around the office building. As the site was earlier a public ground, we've tried to give back to the people and also, earn revenue on the spaces to generate capital for operations and maintenance. The cafe is space is leased on an annual bases and the OAT is rented out to active groups to spread awareness about Health issues in the form on "Nukkad Nataks" and small skits. Visitors can pay a small fee for the sculpture and play area and enjoy the shaded seating overlooking swale design.

Figure 74. Site Zoning

We're also implementing Net-Metering, to supply our excess electric energy back to the grid and earn a concession in bills. The site also has potential to add more PV panels as the years progress and even supply energy to another small office, for a fee.

NET METERING

The Net Metering system by Store Edge is referenced and used to create a layer of load priorities and small back-up before the solar energy is sent to the grid. The current sent forth can be tracked by the user and monetized further as policies develop.

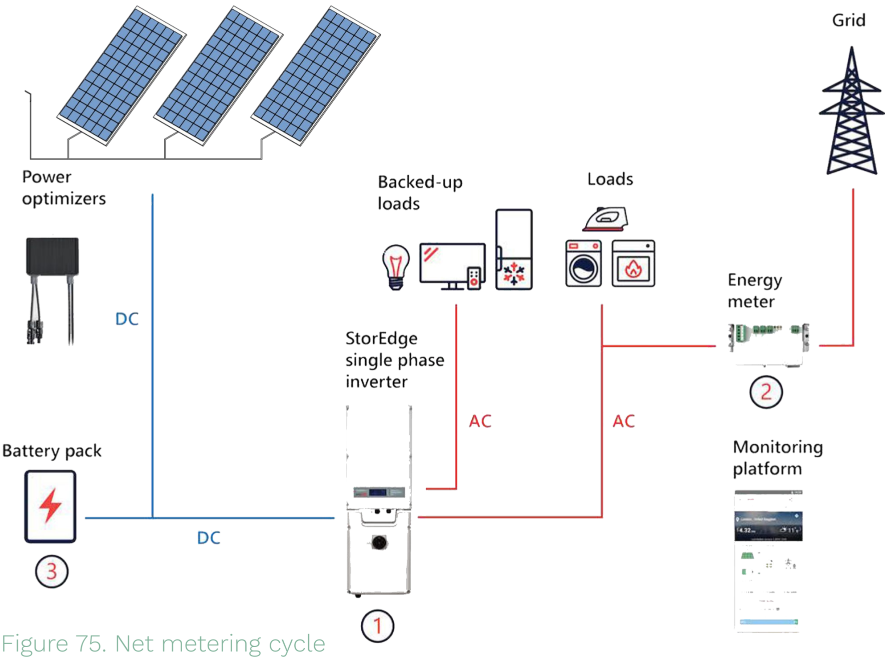


Figure 75. Net metering cycle

SCHEDULE, EQUIPMENT AND MAINTENANCE

OCCUPANCY SCHEDULE

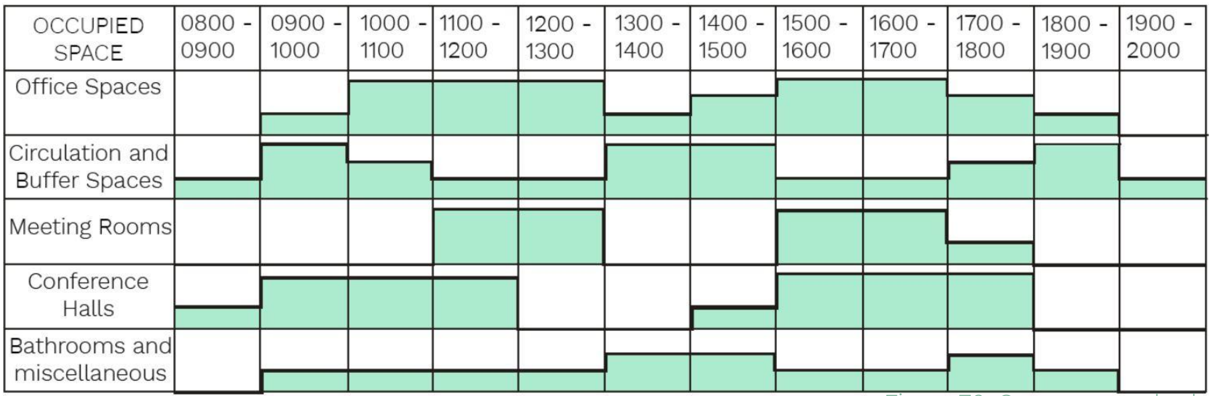


Figure 76. Occupancy schedule

APPLIANCE LIST

	Name	Model	Brand	Power	Cost (INR)			Name	Model	Brand	Power	Cost (INR)	
Lighting	Green Square	RC 140B	Philips	33 Watts	5,455		**Misc.**	Refrig-erator	GL-D201ASCY	LG	131 Watts	16,490	
	Smart Glow	RC 383B	Philips	28 Watts	5,309			Micro-wave	MAGICOOK PRO SOLO 25	Whirl-pool	50 Watts	6,740	
	Green Perform	DN 395B	Philips	22 Watts	3008			Excella Water Purifier	EX5BLAM01	Blue Star	25 Watts	13,900	
	Green Perform	DN 394B	Philips	15.5 Watts	2712			Mono Space® Elevator	U	Kone	470 Watts		
Misc.	Wall Mounted Fan	High Flo Cressida	Crompton	50 Watts	3,350			Deskjet Ink Advant-age 4178 Printer	7FT02B	Hewlett Packard	1 Watt & Off: 0.1 Watt	5,931	
	UPS	Nirantar UPS - 622	iBall	360 Watts	3,300			Corded Tele-phone	KX-TSC62SXB	Pana-sonic	5 Watts	1,800	
	Laptop	Inspiron 3505	Dell	50 Watts	37,250			Desktop	HP All-in-One 21-b01 01in PC	Dell	100 Watts	29,452	

Table 16. Appliances specifications

MAINTENANCE

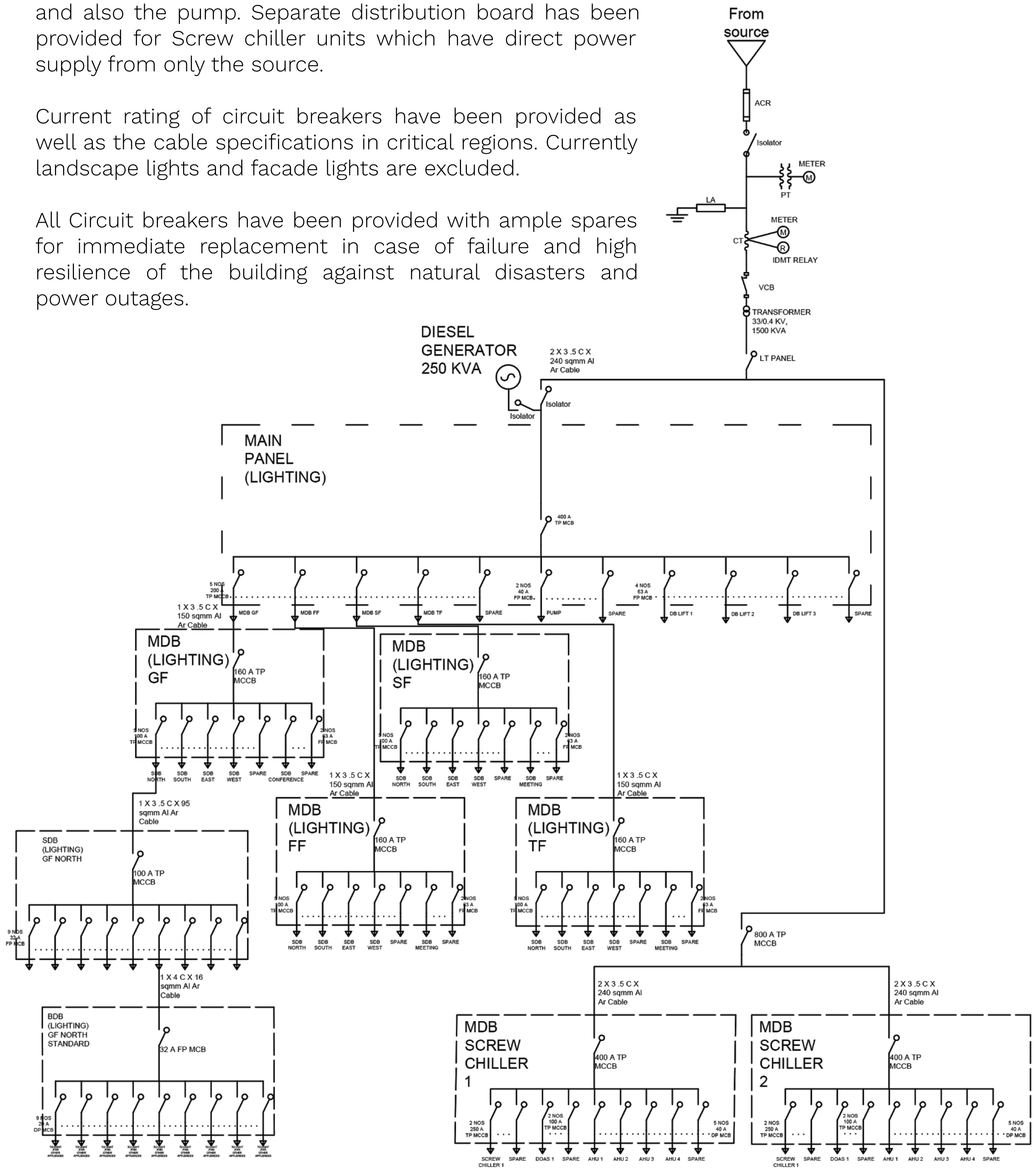
The office administration is responsible for maintenance systems above the Office-unit level. An Intelligent Building System (detail drawings in Appendix) has been established which is zoned to track overall consumption of each department, and will detect fail locations and overuse. Further, the maintenance of the building will be partially funded by the profits earned through cafeteria services and PV electricity generation.

ELECTRICAL SLD

The Electrical layout of the building has been designed (as in Appendix) and is explained through a single line diagram which shows details from the source to the Branch Distribution board level. A typical SDB and BDB has been described and the rest are assumed to be similar. There is a provision of a 250KVA Diesel generator that satisfies energy backup requirements of the lights, appliances, lift and also the pump. Separate distribution board has been provided for Screw chiller units which have direct power supply from only the source.

Current rating of circuit breakers have been provided as well as the cable specifications in critical regions. Currently landscape lights and facade lights are excluded.

All Circuit breakers have been provided with ample spares for immediate replacement in case of failure and high resilience of the building against natural disasters and power outages.



STRUCTURAL DESIGN

The Structural Design of the NHM office building has been done with Earthquake loads of Bhopal, using STAAD.Pro software. The Design is IS-456 Code complaint and has been done for M-30 Grade of concrete and Fe-550 Reinforcement Bars. A few screenshots have been attached as the following figures for showcasing the

The design employs 4 types of typical beams sections and 5 types of typical column sections in the entire project. Precast Concrete can be used as recommended material to reduce construction time of project. This enables Perfect casting and best fitting of components. Such a project can be made airtight easily and shall be affordable to implement.

The structure considers a water tank on top of primary toilet complex and green roofs with special structural care given to accessible rooftops and green roofs. A conventional rigid from structure has been proposed for easier implementation on site and if need be can be converted into an in-situ casted construction process.

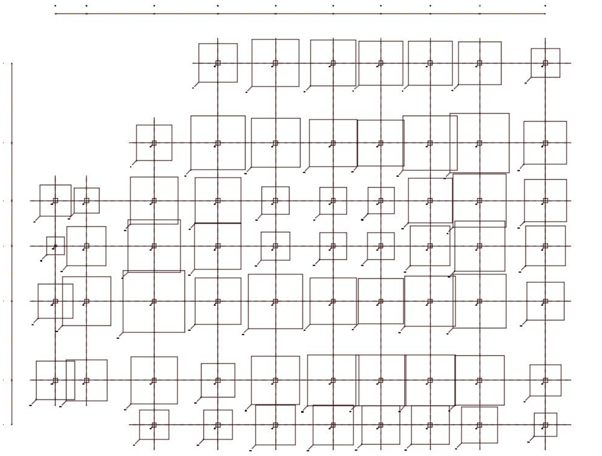


Figure 77. Foundation Footing and Column Layout

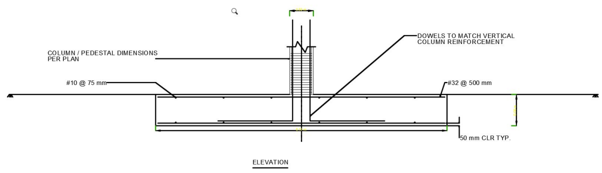


Figure 78. Typical footing Section

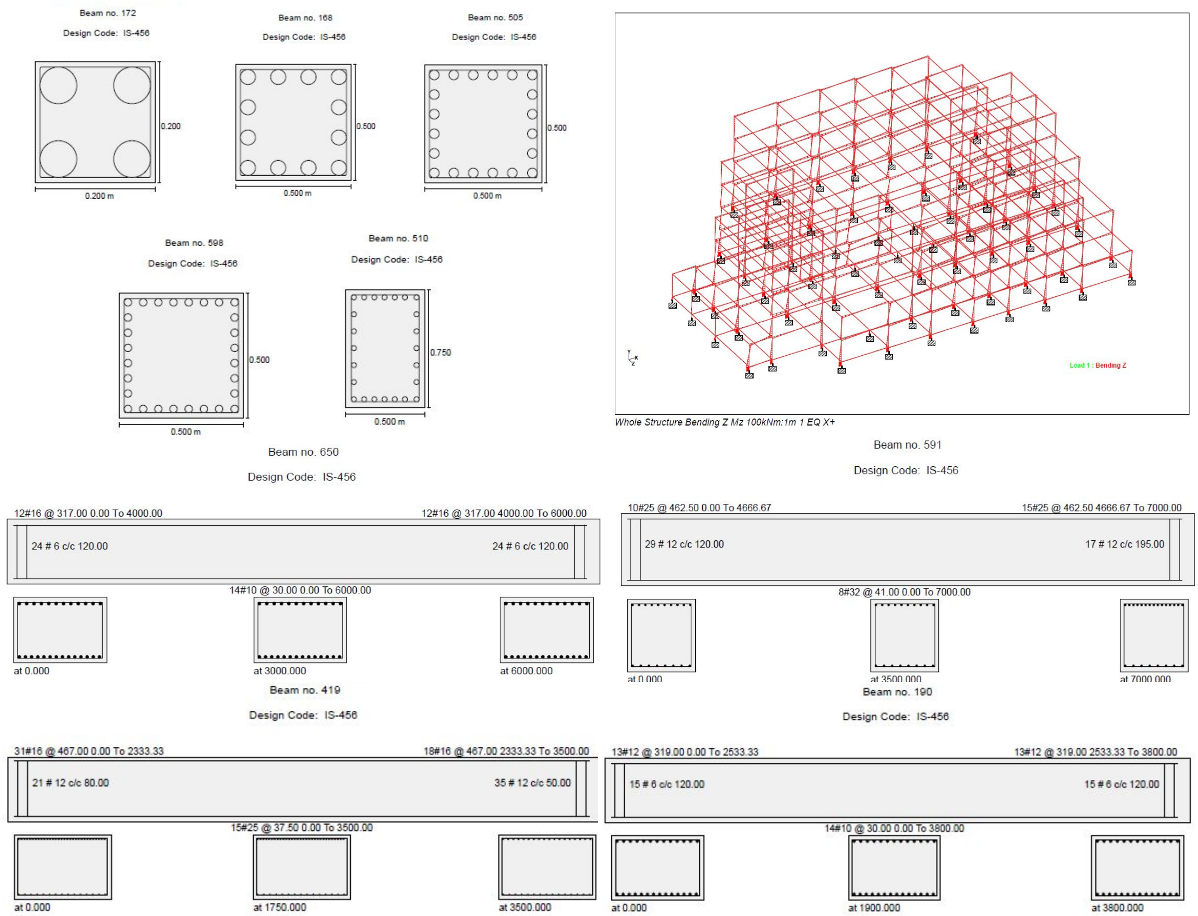


Figure 79. Columns and beams section

INNOVATION

COMPETITIVE ENERGY TRACKING INTERFACE

The Intelligent Building System is zoned to track overall consumption of each department allowing us to create an additional interface on the Management Tracking. An energy budget is allotted to each department and they can check their consumption on the app. The departments can also view the statistics of other departments and a healthy competition is promoted to encourage reduced energy consumption. The app will offer a point based reward system to gratify the winners and information about energy savings, the daily statistics, the leading team etc can also be depicted in the common rooms to boost morale.

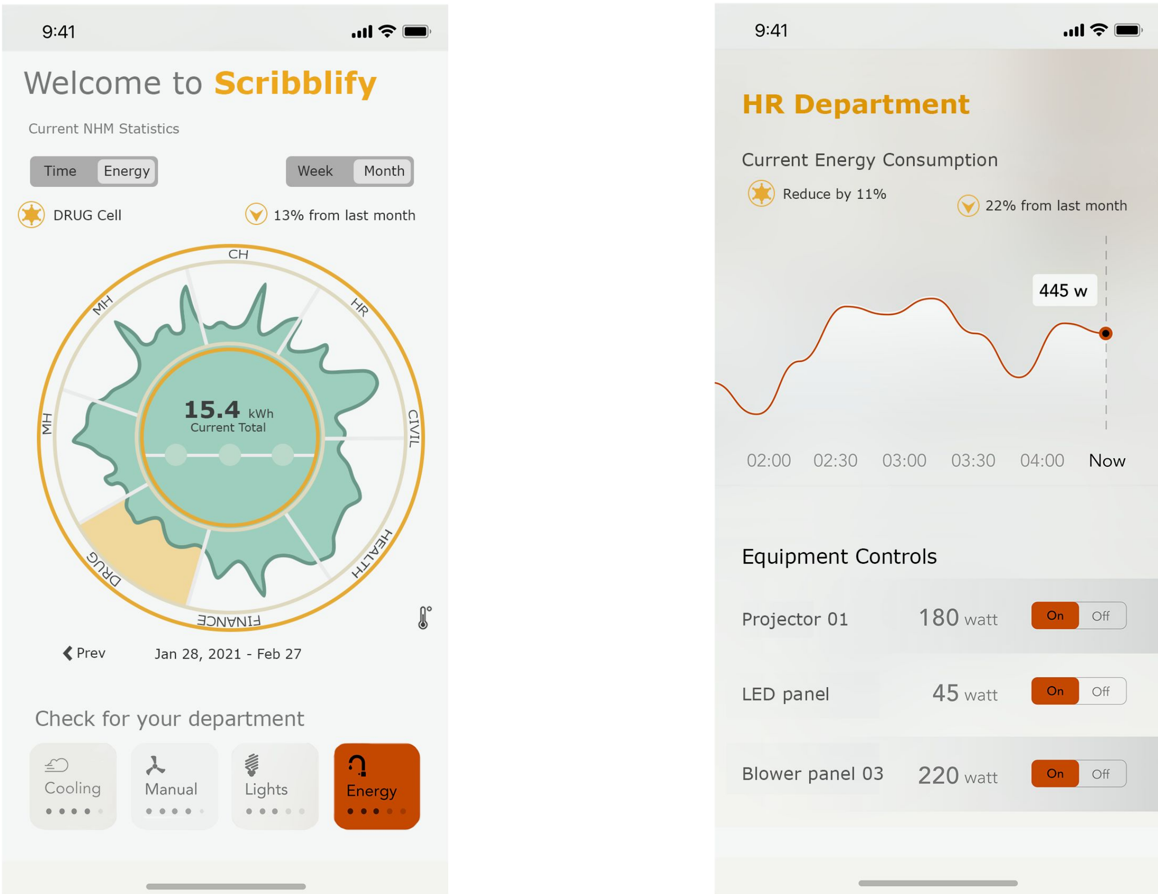


Figure 80. App Interface Design

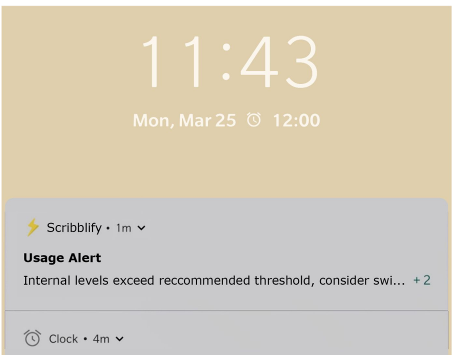
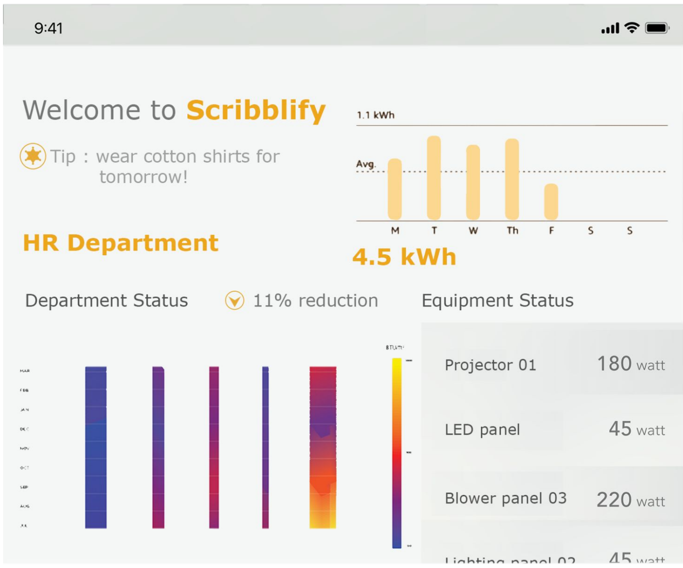


Figure 81. App Notification

The application works by taking data from different heads and departments according to modes of usages and compares the same with each other. The subsequent ratings given for appliance and wattage are given and can be compared for the same. This gives a detailed analysis for the departments for their usage and tells how one can improve the same.

Owing to site benefits and operant comfort models, the application can monitor comfort suggestions too.



Suggestions for appliance usage, number of appliances connected, the best operant settings for ventilation, HVAC, etc are given on a daily basis to reduce the dependency on resources further.

This helps reach higher savings and reduce dependency on active systems further - by giving the users tips on how to dress up, spaces to use and ways of conduct, this helps making better habits and take charge of a healthier carbon footprint at the core!

Figure 82. Website Design

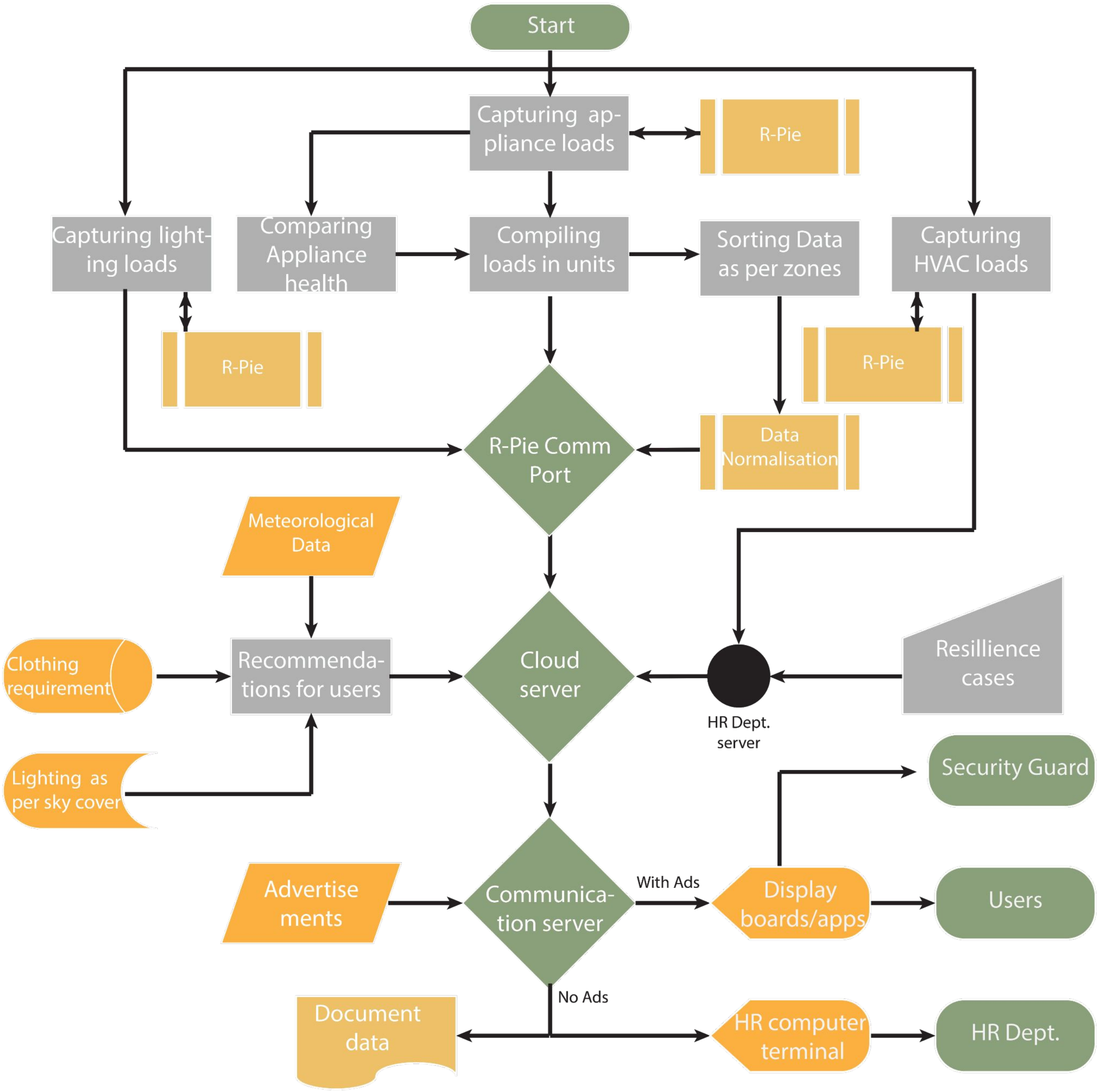
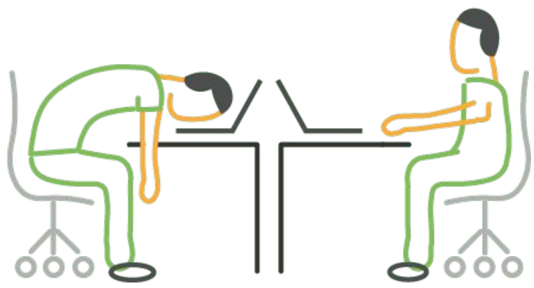


Figure 83. BMS Flow Chart

PITCH TO PROJECT PARTNER



Why are offices the way they are? Why are government offices so often associated with a 'boring' block, filled with dull employees who have lost all drive? Why do we, time and again, keep repeating a clearly unsustainable and unhealthy work environment?

We believe it's time for a change.
Government offices have the potential to impact hundred of people, not only its employees but the others who come into contact with it on a daily basis. They need to breakaway from their stereotype and become architectural trailblazers, sending home the message that we are a part of a more inclusive, more responsible future. They need to be resilient, both environmentally and socially.

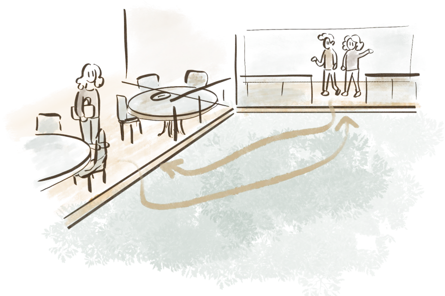


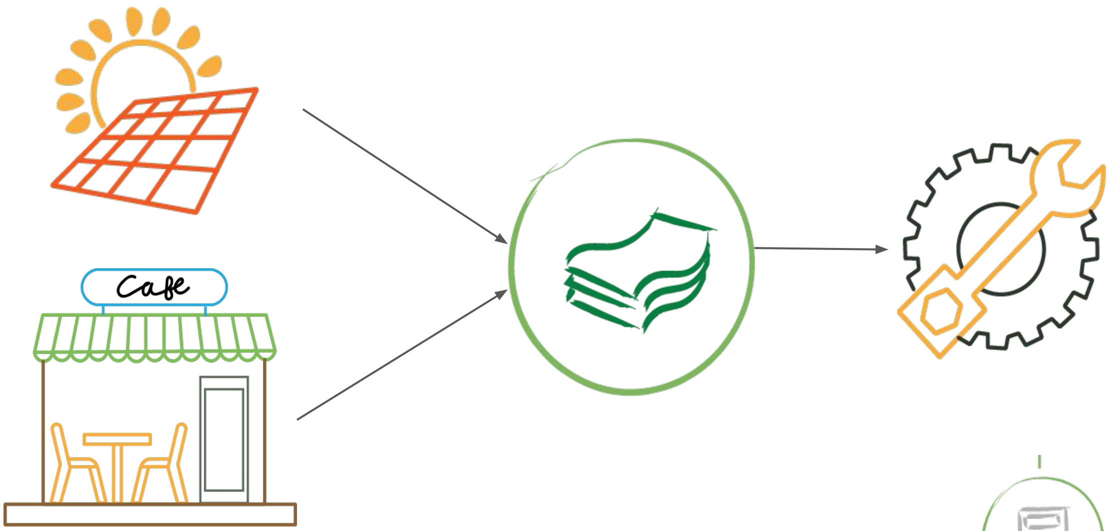
Figure 84. Break-out spaces

Figure 85. Open plan office

Figure 86. Landscape as sound barrier

So what all does this mean, spatially?
For starters, the functionality of the building needs to be expanded to welcome the people this building is supposed to serve- the public. The dichotomous thought process that separates the workers from who they are working for creates a chasm between the community and the government, and needs to be rethought. Secondly, it means creating better work environments for the staff themselves. This includes looking at greenscapes and 'pause' spaces, as well as restructuring the office layouts to make them more interactive and less hierarchical. Another component this encompasses is creating a possibility of multiplicity in use, depending on the situation. And finally, most importantly, this requires the building to be environmentally conscious, striving to be Net zero energy and water by reducing its energy use, and cutting down on water consumption through better architectural and system design. Further, the energy required would be self-producing by the building, using sustainable sources like rainwater and solar energy.

And here’s the best part- it saves you money!
There’s a common misconception that green buildings burn a hole in your pocket. But that’s just what that is, a misconception. Responsible design and construction not only cuts down the operating costs drastically, it also pays for its maintenance through the money earned by selling energy produced through PV cells, and the engagement of people with the on-site cafe and pop-up spaces. In fact, according to our analysis, various strategies like replacing computer systems with laptops and using no maintenance LED lights offers a 50% saving in electricity consumption, that directly translates into lower electricity bills. The operating expenditure is also brought down by using an Intelligent Building System, using sensors to on/off appliances and lighting. Low flow water fixtures and utilising rainwater and grey water brings down the water bill by reducing demand of municipal water by 87%. Apart from reducing building electrical demands, PV units also allow a 7% deduction in electrical bills. All this adds up to reduce utility costs by almost 95%.



Certain new-age technology is also incorporated into this design, like the use of Phase-Change Material. This marks the beginning of a technologically advanced way of functioning. Another often overlooked factor here, is the power of people. Not only will the building cut down it’s own energy consumption, it will also create a system for its workers to use energy responsibly. A mobile application will enable workers to see their energy consumption, and suggest ways to reduce it without sacrificing comfort.

Overall, rethinking the NHM building as a socially resilient and NZEB creates a path for governing bodies and citizens alike to embrace environmental consciousness as a way of life, necessary for our survival.

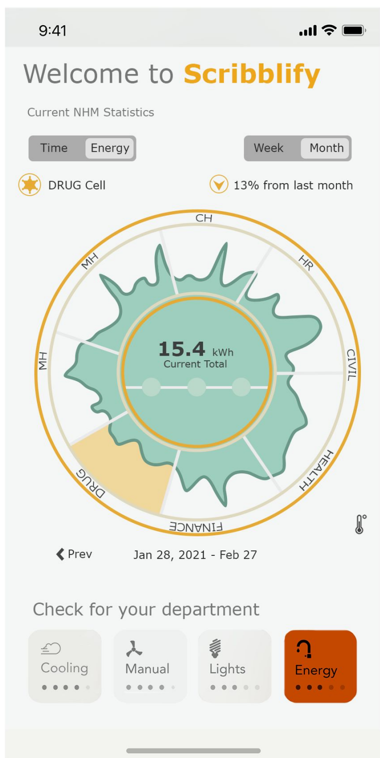
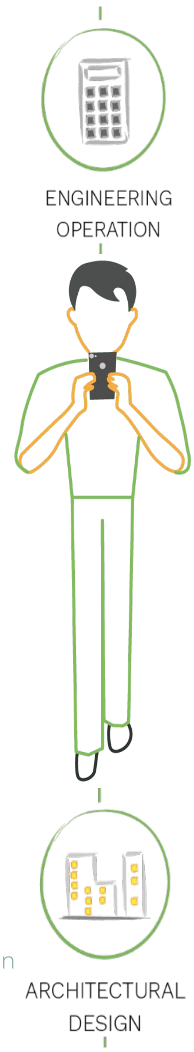


Figure 87. Screenshot of Application



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