Solar™ Decathlon India

THE ARCHONS

DIVISION - EDUCATIONAL BUILDING

Final Design Report
April 2021

School of Planning and Architecture, New Delhi

Table of Contents

Executive Summary 6
Team Introduction 7
Project Background 8
  Brief Description of Project: 8
  Special Requirements of the Client: 9
Performance Specification 10
  Envelope 10
Goals 11
Documentation of Design Process 12
Design Documentation 16
  Architectural Design 16
  Passive Performance: 19
Comfort and Environment Quality 20
Energy 23
  Envelope Optimisation 23
  Comfort Optimisation 24
  Final Result 25
  Solar Energy Generation 25
  Net Site Energy 26
Water Performance 27
  Water cycle diagram 27
  Black Water Treatment 28
  Grey Water Treatment 28
  Indoor water use reduction 28
  Outdoor water use reduction 29
  Rainwater harvesting: 29
  Stormwater 30
  Waste Management 30
Resilience 31
  Earthquake Resilient 31
  Fire Resilient 31
  Adaptive Utilisation: 32
  Future Extension 32
  Approach to Renewable Energy: 33
  Safety and Security 34
  Certifications 34
Innovation 35
Scalability 37
Market Potential 38
Affordability 39
  Finance and management: 39
Engineering Design and Operations 40
  Structural Design 40
  HVAC Design 40
  Building Operating System 42
Pitch to the Project Partner 43
References 45

List of Figures

Figure 1: Team Details 7
Figure 2: Site Context 8
Figure 3: Site Plan 16
Figure 4: Typical Spatial Layouts 17
Figure 5: Ground Floor Plan 17
Figure 6: Schematic Section through Building 18
Figure 7: Section through Primary Classroom 18
Figure 8: External Wall 19
Figure 9: Courtyard Details 19
Figure 10: Section through Building 19
Figure 11: Displacement Ventilation Schematic 21
Figure 12: Shadow Mask 22
Figure 13: Section through Courtyard 22
Figure 14: External Wall Composition 23
Figure 15: Solar and Electrical SLD 25
Figure 16: Water Cycle Diagram 27
Figure 17: Phytorid Plant Schematic 28
Figure 18: Grey Water Treatment Schematic 28
Figure 19: Landscaping Plan 29
Figure 20: Fire Exit Plan 31
Figure 21: Adaptive Utilisation of Space 32
Figure 22: Heat Island Effect 32
Figure 23: Grid Interaction Schematic 33
Figure 24: Natural Surveillance 34
Figure 25: Optical Lamp in Building Section 35
Figure 26: Optical Lamp Ray Diagram 35
Figure 27: Optical Lamp Specifications 35
Figure 28: Adaptive POD 36
Figure 29: Adaptive POD Module Specifications 36
Figure 30: Adaptive POD Scalability 37
Figure 31: Stakeholders 38
Figure 32: Strap Footing 40
Figure 33: WInd Tower Schematics 41
Figure 34: HVAC System Schematic 42
Figure 35: Building Management System 42
Figure 36: Application UI 42
Figure 37: Software Script 42

List of Tables

Table 1: Envelope Details 10
Table 2: Daylight Results 21
Table 3: Temperature Setpoints Schedule 24
Table 4: Proposed Specifications 25
Table 5: Solar PV Specifications 25
Table 6: Net Site Energy Results 26
Table 7: Water Calculations 27
Table 9: Grey-Water Treatment Details 28
Table 8: Phytorid Plant Details 28
Table 10: Rainwater Treatment Details 29
Table 11: Business Model Overview 39

List of Graphs

Graph 1: Comfort Analysis Mapping 20
Graph 3: U-Value and EPI 23
Graph 2: Envelope Optimisation Parameters 23
Graph 4: Reduction in EPI based on ECM's 24
Graph 6: Consumption Breakup 26
Graph 5: Generation vs Consumption 26
Graph 7: Consumption Breakup Comparision 26
Graph 10: Outdoor Water use Reduction 29
Graph 8: Indoor Water Use Reduction 29
Graph 9: Indoor Water Use Distribution 29
Graph 11: Sources of Water 29
Graph 12: Cost Comparision 39
Graph 13: Proposed Design Estimate 39
Graph 14: Cooling Load Calculation 40

Abbreviations

AHU................................Air Handling Unit
BEEP India .... Indo-Swiss Building Energy Efficiency Project
BEM .... Building Engineering Management
CoP .... Co-efficient of Performance
CSIR .... Council of Scientific & Industrial Research
DG set............................ Diesel Generator set
EAT .... Earth Air Tunnel
ECBC .... Energy Conservation Building Code
EPI .... Energy Performance Index
FCU .... Fan Coil Unit
GRIHA .... Green Rating for Integrated Habitat Assessment
HEPA.............................. High Efficiency Particulate Air
IB .... International Baccalaureate
IMAC .... Indian Model for Adaptive Thermal Comfort
IOT .... Indoor Operative Temperature
IPCC............................... Intergovernmental Panel on Climate Change
LECAVIR......................... Low Energy Cooling and Ventilation for Indian Residences
LEED.............................. Leadership in Energy and Environmental Design
NBC............................... National Building Code of India
NCR .... National Capital Region
NEERI............................ National Environmental Engineering Research Institute
PM2.5............................ Particulate Matter 2.5
PV System .... Photovoltaic System
sDA .... Spatial Daylight Autonomy
UDI................................. Useful Daylight Index
USP .... Unique Selling Price
VRF .... Variable Refrigerant Flow
WPI .... Water Performance Index
WWR............................. Window Wall Ratio
CPTED.............................Crime Prevention Through Environmental Design
RFID................................Radio-frequency identification
CCTV...............................Closed-circuit television
IS Code...........................Indian Standards Code
RWH................................Rainwater Harvesting
LED..................................Light Emmitting Diode
VOC.................................Volatile Organice Compounds
NRC.................................Noise Reduction Coefficient
PET...................................Polyethylene Terephthalate
PP.....................................Polypropylene
PVC..................................Polyvinyl chloride
LPD..................................Liters per Day

Executive Summary

Team Archons from the School of Planning and Architecture, New Delhi, India, includes **twelve 3rd year architecture students** and **one 2nd year BEM student**, eager to pave the way for future schools to be responsibly designed and managed to have a minimum negative impact on the environment. Taking up the challenge of designing a **net-zero energy and water IB school on a limited site area**, we hope to encourage future users of the school experience and learn to be more sensitive towards their environment.

The school is a part of the **Jaypee Wish Town in Noida,** which is being developed as an upscale town for multinational occupants, working for the various branches of Multinational Companies being established in the vicinity of the site. All basic amenities are provided in each part of the township, making the neighbourhood suitable for a reliable school affiliated to **International Baccalaureate (IB) board**.

The school aims to provide holistic development for the students, and we intend to design it to complement the school's intent by providing a platform to the students for actively contributing to sustainability, experiencing how a net-zero building can be a success with joint effort.

Water demands of the building were calculated with reference to **GRIHA**. Furthermore, by using the most efficient plumbing fixtures, irrigation methods, rainwater harvesting and on-site treatment of wastewater, we reduced the building water demand from a base case of **123.65 lpd to 45 lpd** compared to the **GRIHA base case of 80 lpd and NBC base case of 45 lpd**.

The building envelope was chosen after studying the **ECBC design guide** and looking into innovative materials with our industry partners. We adopted the **Indian Model for Adaptive thermal comfort for mixed-mode buildings** as specified in NBC, which takes occupant context into account. The corridors are not cooled, but the integrated passive strategies creating a cool microclimate allows them to act as buffer zones between the comparatively hotter exteriors and cooler interiors.

Further, by using a **combination of wind towers and VRF system** to cater to the comfort temperatures derived from IMAC, we **reduced the building's total energy consumption by over 60%**. Energy consumption was reduced to **3,21,291.36 kWh/yr (21.06 EPI) from a base case of 7,87,057.04 kWh/yr (51.59 EPI)** where the corridors were not cooled. Harnessing a total of **4,91,656.48 kWh of solar energy from the site**, which is equivalent to **32.21kWh/sqm/year**, the school is currently proposed as a **Net-Positive Energy Building**.

Developing and designing **fibre optic daylighting systems and modular multi-function pavilions** add up to the school design, making it a more pleasant, engaging, and innovative space. These are designed as scalable systems for different situations, keeping the cost to a minimum.

The school is designed to comply with **LEED and WELL certifications** as per the client's requirements.

The project as a whole is designed and planned by carefully weighing between cost and performance at every step. The outcome is a **net-zero energy and water building** with a healthy learning environment for students and an impressive affordability status compared to similar schools with the same facilities.

Team Introduction

THE ARCHONS

School of Planning and Architecture New Delhi

Division: EDUCATIONAL BUILDING

Team Members:

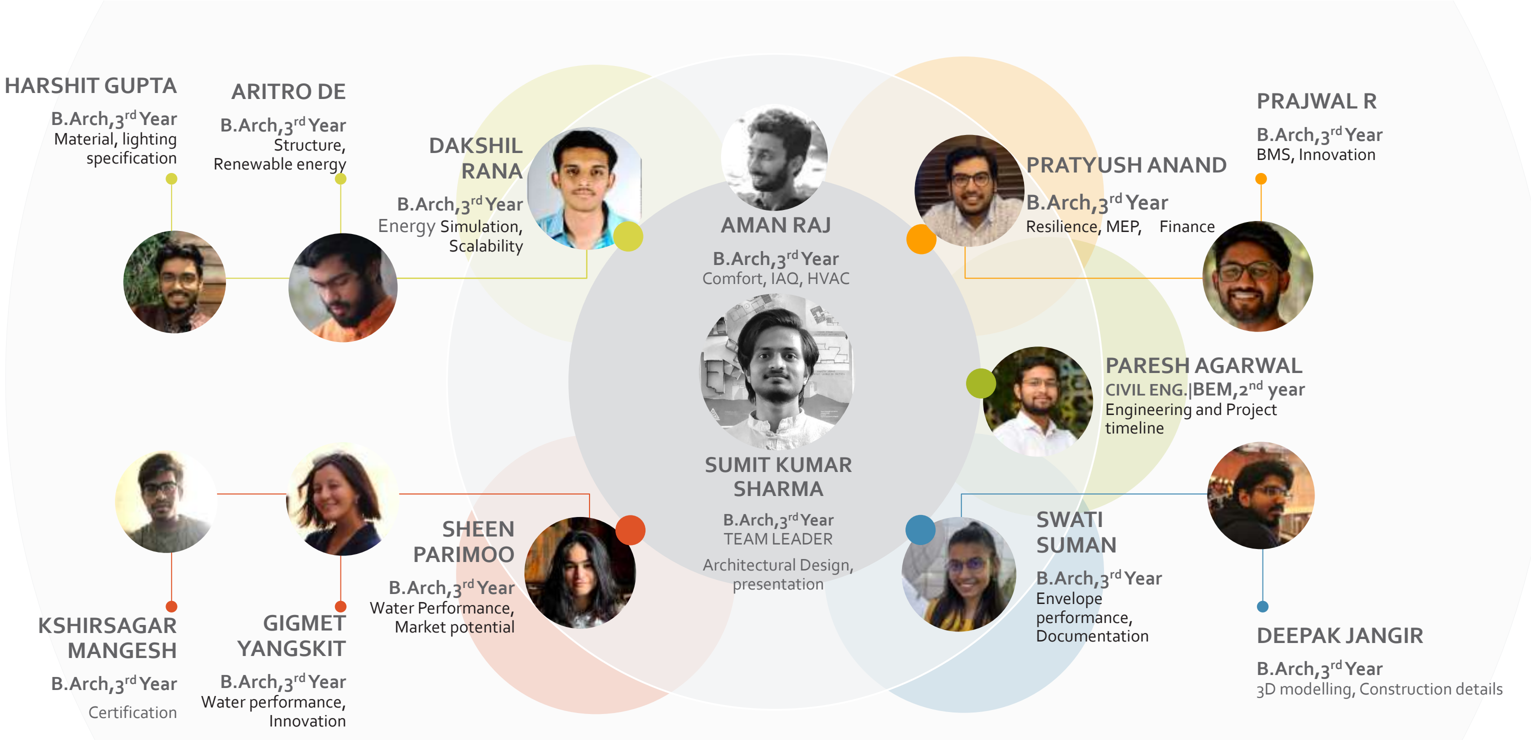


Figure 1: Team Details

Approach:

To develop the design, we split our group into **six teams of 2 people each** that came up with a design iteration of their own, focusing on passive strategies to enhance the quality of space with **massing, orientation, optimum daylighting and natural ventilation**, eventually selecting one design to go ahead with and do the detailed calculations and simulations on. As students, we constantly explored new systems and learning throughout the design development process as we had no prior experience designing net-zero energy and water buildings.

Institute Profile and Faculty advisors:

The **School of Planning and Architecture, New Delhi** is a specialized University, only one of its kinds, which exclusively provides training at various levels, in different aspects of human habitat and environment. The institute offers the courses of Bachelor of Architecture and Planning and Masters of Urban Planning, Housing, Environment Planning and Architectural Conservation, Landscape.

Dr. Shweta Manchanda – Environment Planning specialist – Faculty lead
Ashwani kumar Datta – expertise in Architectural Design and Construction – Visiting Faculty
Dr. Deepti Gupta – Tensile Engineer – Visiting Faculty
Kinshuk Aggarwal – expertise Sustainable Design – Visiting Faculty

INDUSTRY PARTNERS:

Project Background

Project Partner

ORD Towers

ORD towers are in the business of 'Build to lease' mostly commercial spaces, sometimes venturing into building other typologies. Their goal is to deliver green, LEED-certified workspaces in the most cost-efficient way possible. They are dedicated to bringing technology into Real Estate Sector to bridge that gap between the IT and Real Estate sectors.

Mr. Rajesh Gupta (Director)	Mr. Deepanshu Gupta (CEO)

Brief Description of Project:

1. Name: **ORD International school**
2. Building type: **Educational building**
3. Location: **Sector 134, Wish Town Noida, Greater Noida Expressway, Noida-201304(UP)**
4. No. of occupants: **2200 students + 200 staff**
5. Working hours: **8 am - 2 pm as school hours**
   7 am - 3 pm as staff hours
6. Climatic conditions: **Composite climate**
7. Size of the land: **3.77 acres ~ 15256 sqm.**
8. Neighbourhood: **JAYPEE Wish-town**
9. Applicable building regulations: **NOIDA bye-laws**
10. Allowed FAR: **1**
11. Permissible Ground coverage: **40%**
12. Height restrictions: **24 meters**

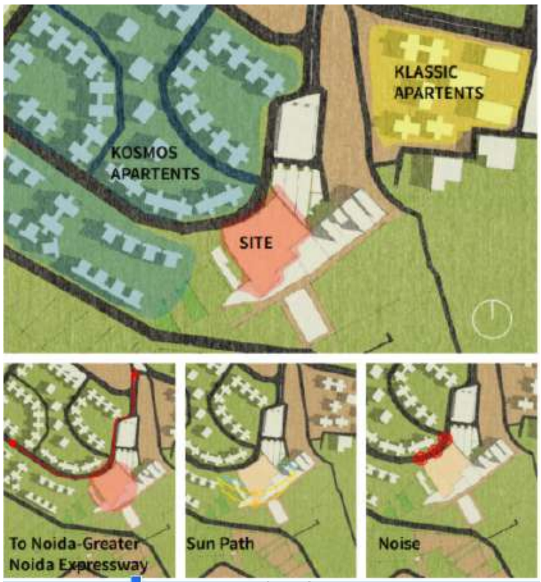


Figure 2: Site Context

The project partner intends to build the school and lease it to experienced school management for the best operation of the school.

Context and Market Analysis:

ORD International School is to be designed to cater the educational needs of Sector 134, Noida, JAYPEE wish town which is being developed in stages, having basic amenities such as primary schools, parks, nurseries, etc..

The image attached gives some basic information about the site and its immediate surroundings. The site is surrounded by 22-25 storeyed residential buildings on two of its sides and the other two having open lands. These residential buildings are mainly occupied by families coming from various countries, especially Korea and China, working for the several multinational companies opening up in the vicinity of the site. This neighbourhood with residents from different cultures turns out to be just perfect for a school affiliated to the International Baccalaureate (IB), aiming to provide holistic education to students.

Access to the site is from the North-Western curved edge of the site. This internal road of Jaypee Wishtown connects the site to the Noida-Greater Noida expressway.

Special Requirements of the Client:

The client is keen on taking inspiration from Japanese and Korean schools which focus on the holistic development of students emphasizing on the growth of every student's intellectual, emotional, social, physical, artistic, creative and spiritual potentials. Specific requirements that the client wishes to be looked after are:

- Visually engaging spaces to meet the psychological needs of students and to inspire them to be creative and to learn.
- Adequate storage spaces to store the records of 2200 students.
- Multipurpose spaces to be provided for adaptive re-use.
- Universal accessibility and special facilities for differently-abled students.
- The client is insistent on the building being LEED Platinum and WELL certified.

Project Highlights:

- The project is developed considering the comfort and well being of its users and its response to the environment, keeping its negative impact on the environment to a minimum. We have tried our best to achieve these mainly through design strategies and passive means as much as possible.
- Thermal comfort - We used a combination of strategies like a two-stage cooling system which includes a set of Wind Towers and VRF based air cooled system, air filled double glazed units on openings, etc. in order to meet the hourly comfort band derived from the IMAC comfort for mixed mode buildings.
- Resilience- The school is carefully designed to be resilient to earthquakes and breakage of fire, while complying to the respective IS codes. The spaces in the school are also designed to be adaptive to possible changes of requirements in the future, such as the current pandemic. Further, the water management of the building is designed to be resilient to a cut in water supply for a week. We have also made sure to keep space for future extension of the solar PV panels.
- Modular Spaces- We have designed modular kits for enhancing various kinds of spaces that can be used for several different functions. Easy to install modular components that can be used as play spaces, kiosks, exhibition spaces, etc. can also be rented out for other uses in indoor as well as outdoor spaces.
- Safety- Safety and security of students being a very important aspect in a school, we have integrated Crime Prevention Through Environmental Design (CPTED) strategies in the design of the school in order to avoid disputes and violence within the campus as well as security from unwanted and disturbing elements from outside of the school.
- Certifications- With various strategies and thoughtful design, the school is eligible for a LEED platinum certification for environmental responsibility as well as the WELL certification for the wellbeing and health of the occupants.

Performance Specification

Climate zone: Composite Climate
Temperature Range: 7°C – 44°C
Average Humidity: 25-35%

Latitude: 28.77 N
Longitude: 77.2 E
Average Annual Rainfall: 610 mm

Envelope

	Administration Block	Multipurpose Hall
Structure	RCC Framed M25 Design mix, Fe 500 re-bars	RCC Framed M25 Design mix, Fe 500 re-bars
Roof	80 mm overdeck Earthen pot insulation, Reflective China Mosaic Tile FInish U-Value = 0.263 kWh/m2-K	Insulated Corrugated GI Decking on steel truss - PV Panel Cover
External Walls	200 mm Agrocrete Hollow block Wall, Terracotta tile cladding, green facade Armstrong Acoustic Panels inside	200 mm Agrocrete Hollow block Wall + Terracotta tile cladding Armstrong Acoustic Panels inside
Internal Walls	Dry Partition Wall (Gypsum) Armstrong Acoustic Panels	-
Windows	NORTH FACE: ST167 Clear Toughened (6+12+6) U-Value: 1.4 (air), SHGC: 0.47, VLT: 59% uPVC frame - WWR: 35% SOUTH, SE, SW FACE: SKN154 Clear Toughened (6+12+6) U-Value: 1.3 (air), SHGC: 0.28, VLT: 52% uPVC frame - WWR: 35%	AIS Ecosense Edge 6mm blue tinted glass U-Value: 3.7, SHGC: 0.38, VLT: 47% uPVC frame - clerestory windows, WWR: 15%

LIGHTING POWER DENSITY (LPD)
Classrooms: 4.8 W/sqm. (daylight, occ. controls) Labs & Activity: 7 W/sqm. (occ. controls) Admin: 4.8 W/sqm. (occ. controls) Core & Corridors: 2 W/sqm. (scheduled) Multipurpose Hall: 4.9 W/sqm. (scheduled) Canteen: 7 W/sqm. (daylight, occ. controls)

ELECTRICAL POWER DENSITY (EPD)
Classrooms: 7 W/sqm. Labs & Activity: 7 W/sqm. Admin: 12 W/sqm. Canteen: 2 W/sqm.

Table 1: Envelope Details

HVAC:
Two-stage cooling system – Wind Tower and VRF based Air cooled system

- Six Wind Towers to pre-cool the air (operated by fans)
- Complete mechanical ventilation, 5 ach,
- Fresh air filtered using AHU, displacement ventilation using diffusers

VRF Capacity: 270 tonne
Academic block: 227 tonne
Multipurpose hall: 43 tonne
VRF System Cop: 4.47
Star Rating: 5 Star

Water systems:
Pumps: 3 hp centrifugal pump - 1050 lpm
Grey Water
Treatment: Sand Filtration
Pump: 3 hp centrifugal pump - 1050 lpm
Black Water
Treatment: Phytorid System
Pump: 1.5 hp centrifugal pump - 500 lpm

Renewable Energy: 290 kWp solar plant
Module Peak Power: 390W
Module Efficiency: 19.2%
No. of modules: 721

Building Management System: Smart Sol by Avrio Energy

Goals

Architectural Design
- To design a building which achieves a balance between form and function.
- To have optimum massing and orientation which would impact our energy consumption.

Comfort and Environment Quality
Good indoor environments inspire students to learn while boosting their productivity as well.
- To achieve 60% of the operational hours in the comfort range without the use of refrigerant cooling.
  (Annual comfort hours without AC = 78%)
- Maintaining adequate air quality indoors as well as outdoors.

Energy Performance
- Net Zero Energy Design. (Net site energy = -11.16 kwh/sqm/year)
- Target EPI: 40 kWh/sqm/year. (EPI = 21.06 kwh/sqm/year)
- Optimise the use of Renewable Energy.

Water Performance
- To design a Net-zero water building. (Achieved)
- To have zero water discharge. (Achieved)
- To treat 100% waste water on site Independently. (Achieved)
- Target Water Performance Index (WPI) < 40 lpd. (WPI = 45 lpd)

Resilience
- To create pandemic proof design.
- To include strategies that can keep the building performance stable for atleast next 25 years.
- Capacity of power backup, rainwater storage and wastewater treatment for the building to sustain itself independently for 7 days. (Achieved)

Saftey and Security
- To create a safe and secure environment.
- To prevent common crime through environment design.
- Designing for natural surveillance inside the building.

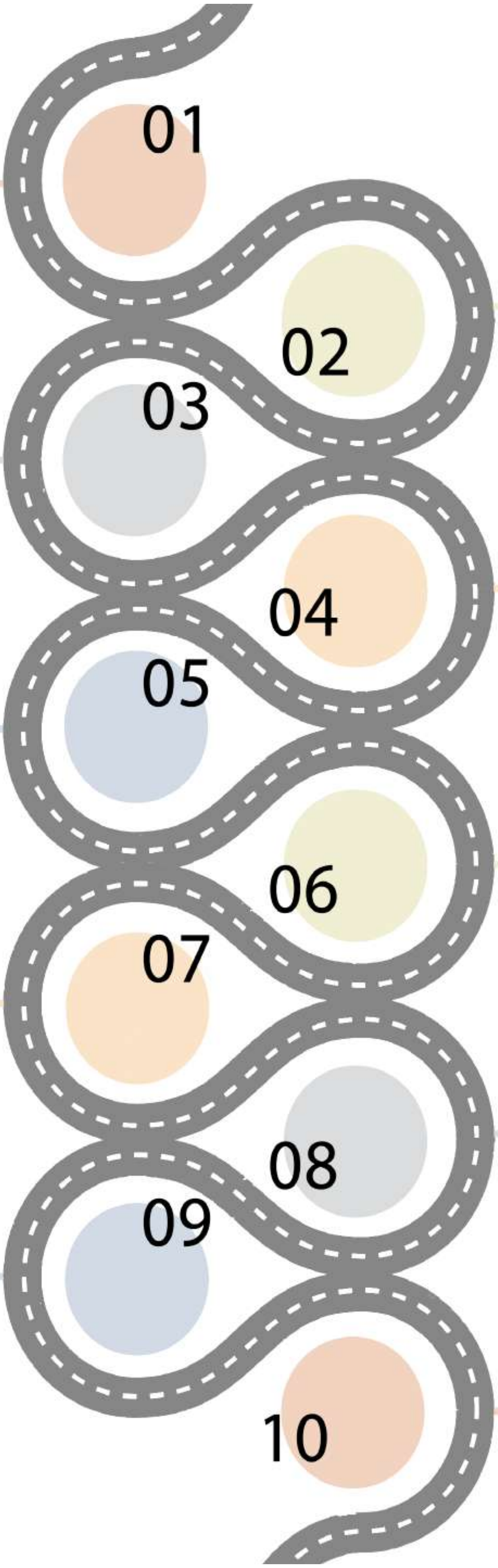
Waste Reduction
- Potential reuse of waste materials for construction.
- Zero waste water discharge. (Achieved)

Modularity of Spaces
- To design spaces which are similar in shape and size, so they can be linked to each other for efficient and effective reuse.
- To design the modular systems which can be used adaptively

Affordability
- Low Operational Cost at desired performance.
- Low Incremental Cost to get less Payback period.

Certifications
- LEED Platinum rating. (Achieved)
- Well Certification. (Achieved)

Documentation of Design Process



Preparatory Work
Getting familiar with the competition brief, making a team and setting performance goals.

Finding a Project Partner
Deciding on the building typology and finding the ideal project.

Pre-design Analysis & Design Development
Splitting into smaller groups and experimenting with design; performing simulations and analysis; developing 6 different designs.

Acquiring New Knowledge and Skills
Attending webinars, completing self-learning modules and exploring new softwares.

Identifying the Most Suitable Design
Performing a SWOT analysis to assess the 6 designs and choosing one to move forward with.

Allocation of Work
Division of work among the group members with respect to the ten contests; defining everyone's role in the team

Consultation
Conducting meetings with industry partners; consulting TRG members.

Qualifying as Finalists
Studying the technical aspects while preparing the deliverable for elimination round.

Conclusion of Final Report
Continuing our progress on the ten contests keeping in mind the feedback received from the jury and polishing the final report.

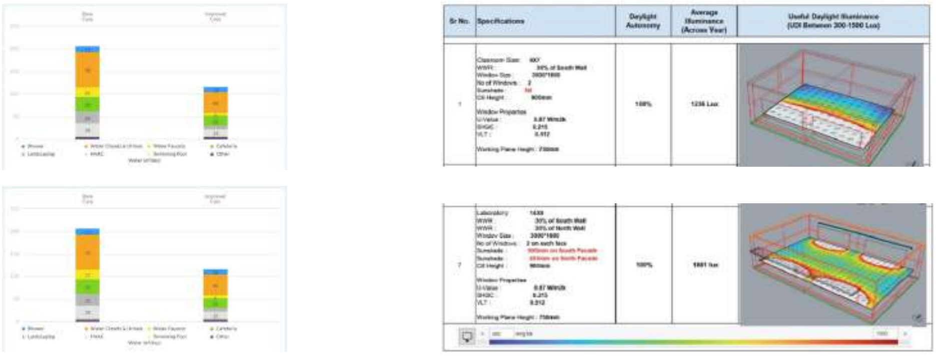
Preparation for the Final Jury
Working towards the presentation and video required for the final jury event.

01

Solar Decathlon India was part of our curriculum for college and was introduced to us by the faculty so the first step for us after making teams was to analyze the competition brief together over virtual meetings and decide on a typology. With everyone working remotely from their own homes, team coordination was difficult in the beginning and we did regular team meetings so we could learn to do collaborative work online in time and discussed our performance goals for the project.

02

Looking for a project partner was a challenge since we were a team comprising mostly 3rd-year college students with no prior experience in making green buildings. It took some time, but our faculty was able to procure a few projects for us and made the decision themselves on which would be most suitable for our situation given that we were doing this kind of a project for the first time and had a lot to learn along the way. Our project partner was in constant touch with us throughout different stages of the project and was very agreeable and comfortable to work with since his personal ideals and hence, requirements for the building aligned well with the competition brief.



03

To develop the design we split our group into 6 teams of 2 people each that came up with a design iteration of their own. Each team followed the same design methodology starting with case studies, site study, and pre-design analysis before proposing a concept and then working on developing it further. The goal was to have 6 designs, in the end, each of which would have different virtues and strengths.

1. Singly loaded corridor for natural light and ventilation and space to simulate experience.

2. Large courtyard surrounded by the singly loaded corridor to create a volume for the building.

3. Staggered cantilever flooring to create shading in the floors below and central open space for leisure

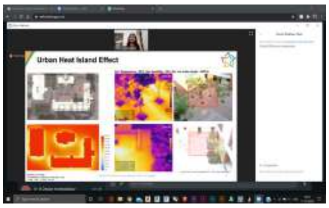
4. Division of zones comprising of the space that it is being used for and orientation.

5. Optimum orientation and use of singly loaded as well as doubly loaded where-ever required and utilization of atrium and colors.

6. Well thought of circulation spaces and efficient placement of cores, connecting all the parts of the building.

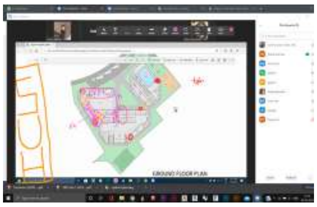
04

While working on the design, we were simultaneously attending webinars and doing self-learning modules to learn about the technical topics that were relevant for the competition and about skills required to be competing in the challenge. These proved to be very helpful as they were in line with report deliverables. We also took this time to learn new softwares which was needed for simulations like design-builder and climate studio.



05

At the end of the semester at college we had an external jury which reviewed all the different designs. Keeping their critiques in mind along with everything we had learnt over the semester we analysed and reviewed all 6 designs as a group. Pros, cons and scope for improvement for each design were discussed during multiple online meetings amongst the group. In the end, we selected one design to move forward with and intended to integrate assets from other designs into it as well.

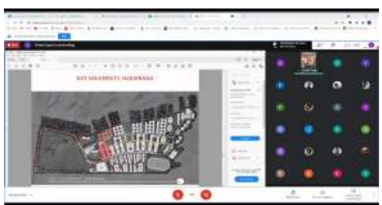

06

Work was divided according to the 10 contests of the competition, one person was handed the responsibility of each of the contests and others worked under their lead. At each step, the work was reviewed by the design faculty and necessary changes were made.

07

The competition gave us the opportunity to work on a real life project for the first time so we had to learn how things worked in the field. We didn't know much about the technical aspects either and needed to study and understand the functioning of a net-zero building. To help us with this we consulted our industry partners who had experience working on real-life projects. We also got help from the technical resource group members who clarified various doubts that arose while working on the technical aspects. Another issue that we faced during this stage was with our site which was proving to be quite unfavourable for a net zero building. It was located in Noida which has extreme temperatures and excessively polluted air. Furthermore the small size of our site with high occupant density did not help as it meant higher cooling loads but less area for solar panels.



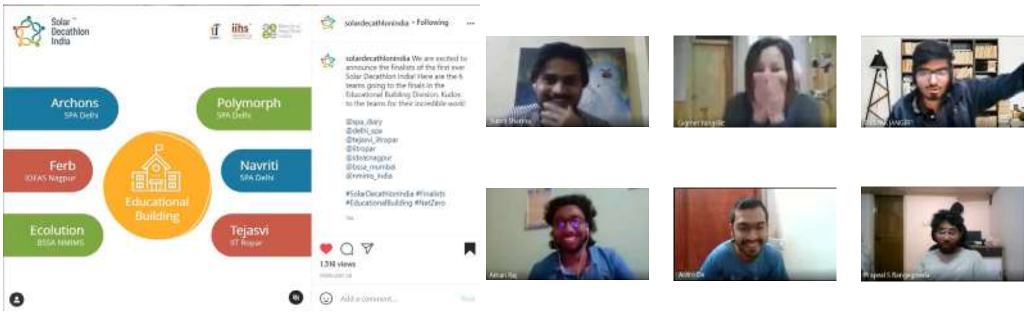



08

After getting a hang of how different systems in the building work, we studied the technical aspects, did detailed calculations and simulations, and compiled the work that we had into a report required as the deliverable for the elimination round.

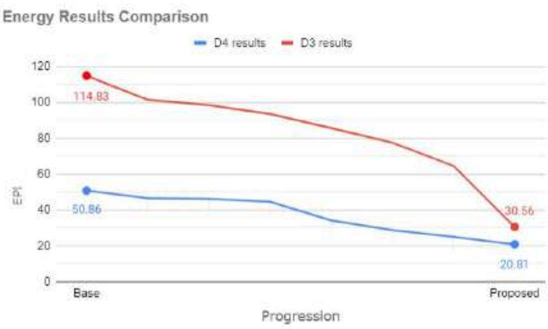
09

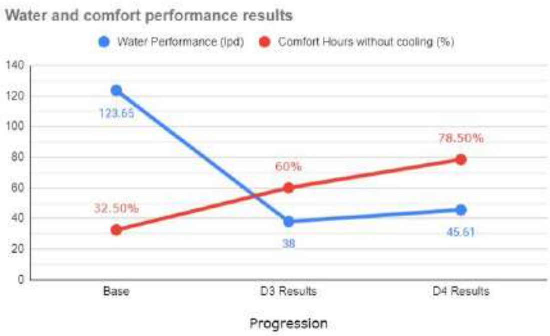
The entire team avidly awaited the results together on an online meet. We were elated upon learning that our team qualified for the finals.



Once our team qualified for the design finals, we got detailed feedback from the jury on all aspects of our report and we continued our progress on each of the ten contests according to the comments that we had received on the previous deliverable.

As students we were constantly exploring new systems and learning to do more detailed simulations and calculations. We were persistently trying out new systems as we learned about them because of which our simulation results were continually getting changed. After the third deliverable, we learnt about more innovative cooling strategies and to incorporate them we had to redo our energy and comfort calculations.





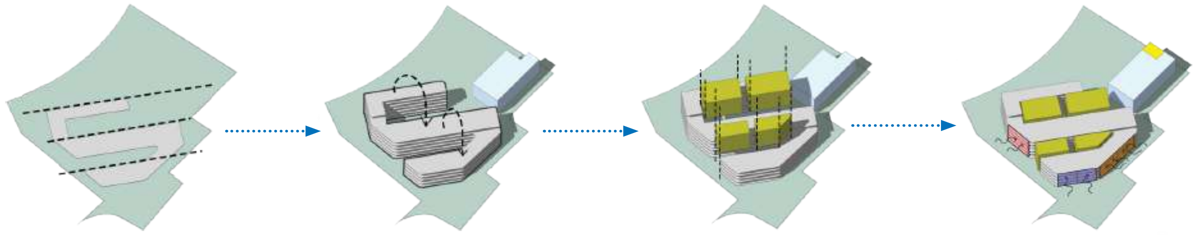
We focused on improving the facets which had scope for further improvement and completing the parts which we did not have much progress on earlier . The goal was to compile the final project report in time.

10

After submitting the final report we plan to start preparing for the final jury event. Some work has been going on towards the short movie and presentation required for the jury event but once report submission is done, the entire team will work on that together.We also intend on practicing our presentation and pitch as a team online before presenting at the jury event.

Design Documentation

Architectural Design



STEP 1
North-South orientation increases access to natural light, creating day-lit spaces

STEP 2
Building Blocks stepping down towards the south allow the entry of low angled winter sun inside.

STEP 3
Creating open courtyard spaces amidst building blocks

STEP 4
Placing rooms with the largest volumes on south and south-east side to reduce heat gain.

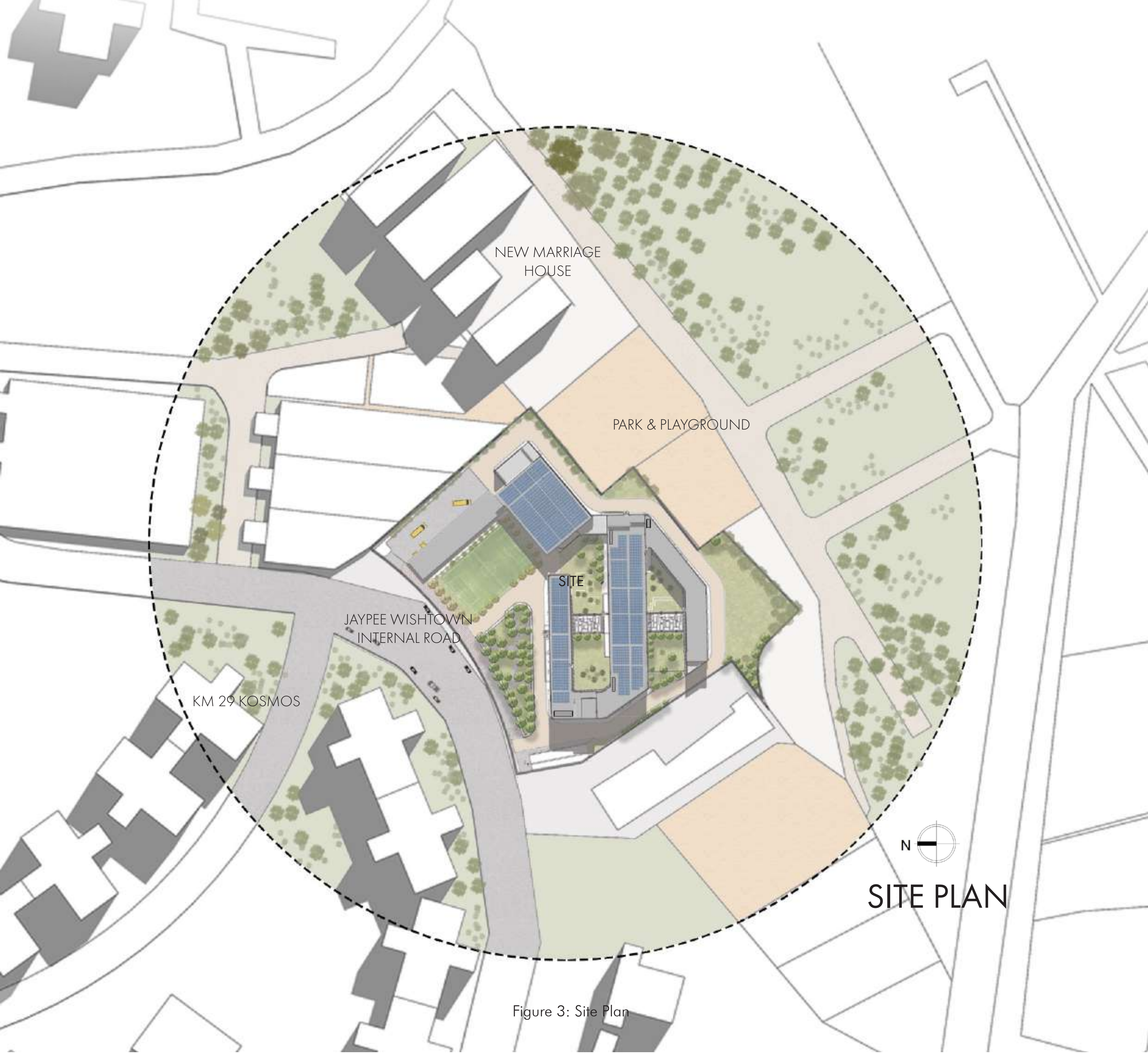
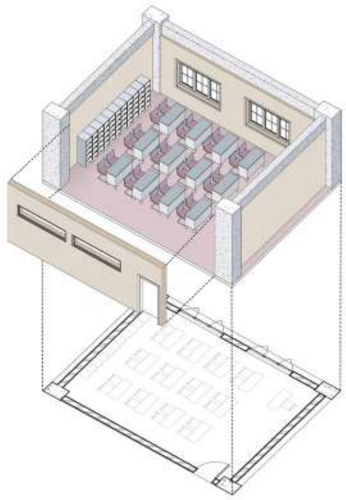


Figure 3: Site Plan

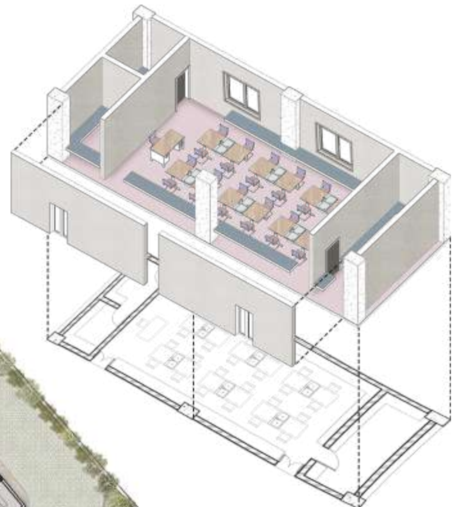
Design characteristics:

The school's optimum orientation and massing, along with thoughtfully designed shading devices, create the optimal conditions for daylit interiors and the placement of photovoltaic panels. We planned the building so that all classrooms and learning spaces are placed on either the north or south side to provide maximum access to natural light while ensuring that the associated heat gain and glare are easy to control. Spaces that will not be occupied throughout the day or where heat gain is not a problem, like circulation cores, service shafts, toilets, audio-visual rooms, and the canteen, are placed towards the east and west sides of the building. These strategically placed spaces effectively buffer unwanted radiation and help reduce the cooling load of the building.

Green courtyards have been incorporated between the building blocks to naturally bring down the surrounding space's temperatures and create a cool microclimate. These courtyards also act as breakout spaces for students and give them the chance to interact with nature in the dense urban context of Noida. All these strategies add up to provide a healthy environment for students which would promote their physical and mental health and also boost their productivity.

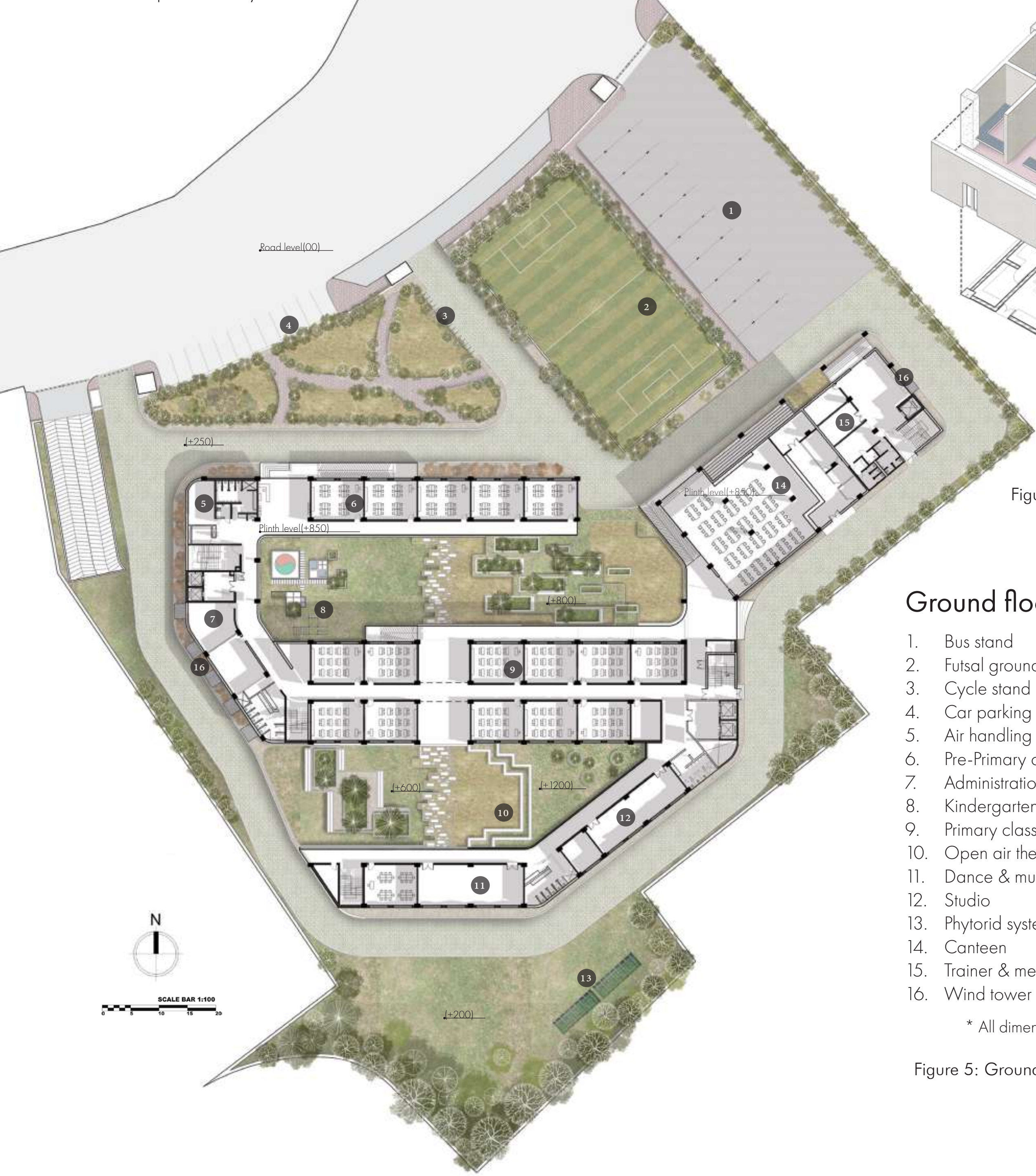


CLASSROOM
(50 sqm)



LABORATORY
(100 sqm)

Figure 4: Typical Spatial Layouts



Ground floor plan

1. Bus stand
2. Futsal ground
3. Cycle stand
4. Car parking
5. Air handling unit room
6. Pre-Primary classroom
7. Administration office
8. Kindergarten
9. Primary classroom
10. Open air theatre
11. Dance & music room
12. Studio
13. Phytorid system
14. Canteen
15. Trainer & medical room
16. Wind tower

* All dimensions are in mm

Figure 5: Ground Floor Plan

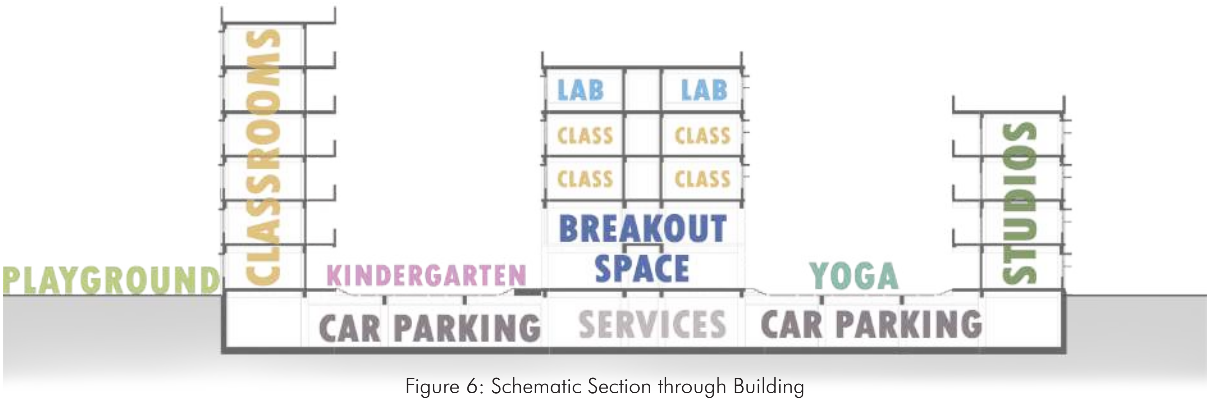


Figure 6: Schematic Section through Building

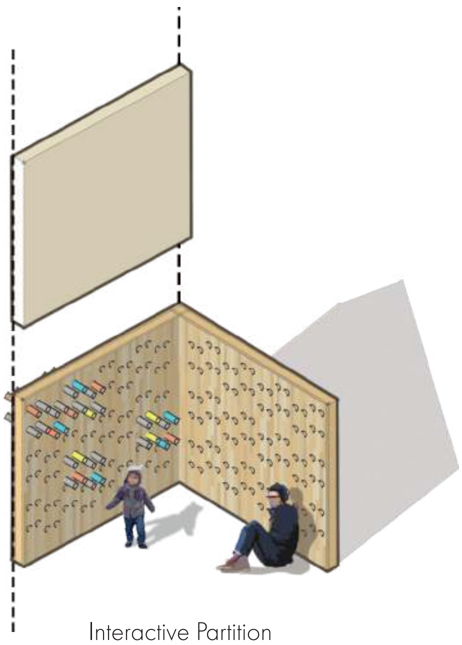
Interactive partition wall

Architectural elements as simple as partition walls are designed as interactive and interesting mini mazes to double up as play areas for students to enhance their curiosity and help improve their physical activity, while also adding to the quality of these spaces. These walls utilize oriented strand board (OSB) as both its structure and finish. The transparent, colored tubes which can be moved into different positions encourage the students to interact with each other as well as with teachers. The variations in tube adjacencies create unique combinations of light, color, texture, and pattern. These partition walls are placed in the play areas as well as between the pre-primary classes.

We also intend to include the use of various interesting cardboard designed furnitures in the campus, which could trigger the students to open up their minds to the numerous possibilities around them with respect to reuse of materials in innovative ways. Since young minds are curious and readily grasp their surroundings, all they need is a little push in order to enhance their ability to think rationally and responsibly. The use of the interactive partition walls and cardboard furnitures could act as that boosting factor for the students.

Sitting bench

Table & Chair



Interactive Partition

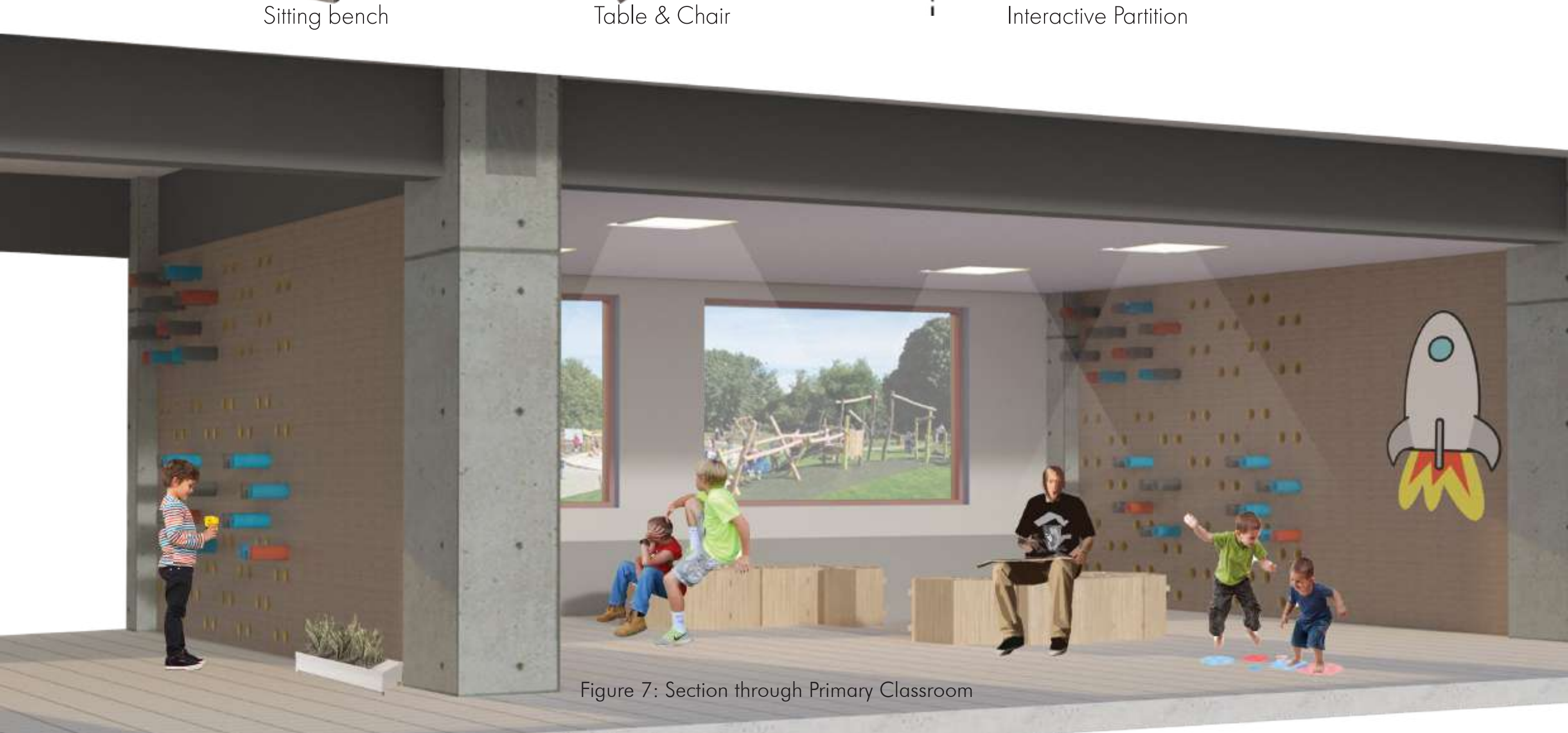


Figure 7: Section through Primary Classroom

Passive Performance:

For the school to require as little energy as possible for cooling, we used a combination of tightly integrated passive strategies. We started by orienting the longer axis of our building along the north-south direction, amplifying the amount of daylight entering the classrooms while minimizing the associated heat gain. The incorporation of shaded courtyards amid the built mass and the effective landscaping throughout the site help improve the airflow patterns (*figure 10*) and reduce the overall site temperature. The external walls are clad with terracotta tiles which have good thermal and acoustic insulation properties. We found terracotta ideal for the facade as apart from insulating the building's interior spaces, it also reduces the surface temperature of walls. Moreover, it is 100% natural, recyclable, durable, and requires no maintenance.

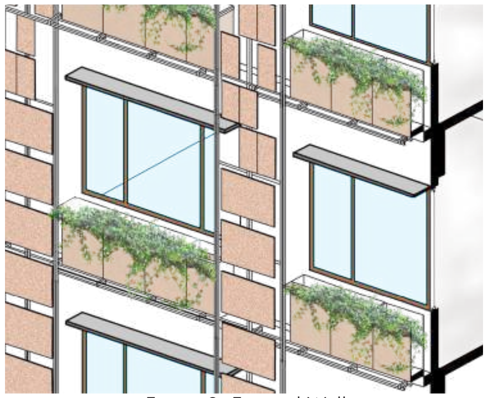
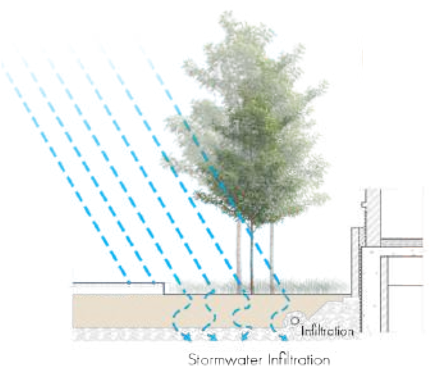


Figure 8: External Wall



We integrated plants into the facade as biophilic design can help with students' mental and psychological well-being. The addition of planters outside the classrooms on window level simulates an association with the outdoors providing true comfort. Windows enrich the rooms with natural light and further help in improving the quality of space.

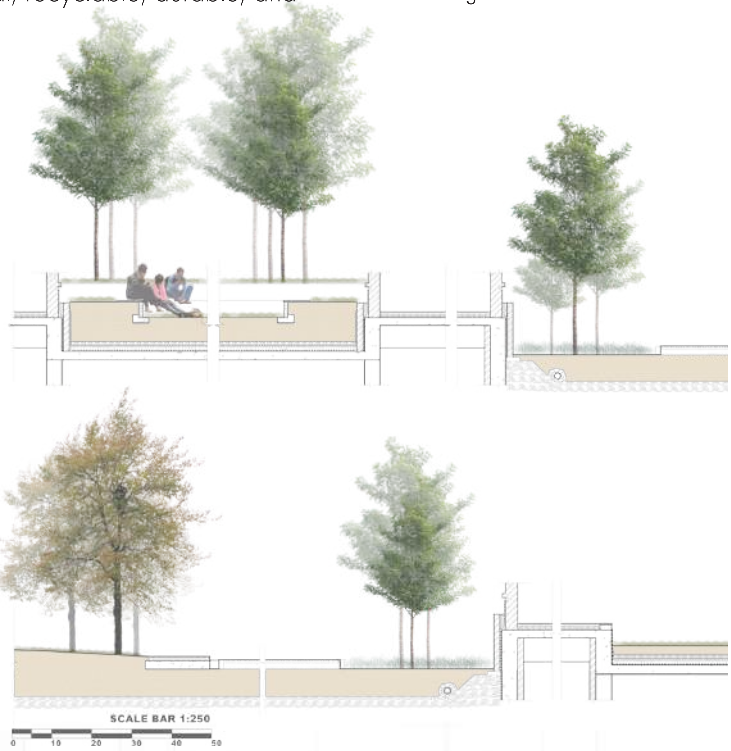


Figure 9: Courtyard Details

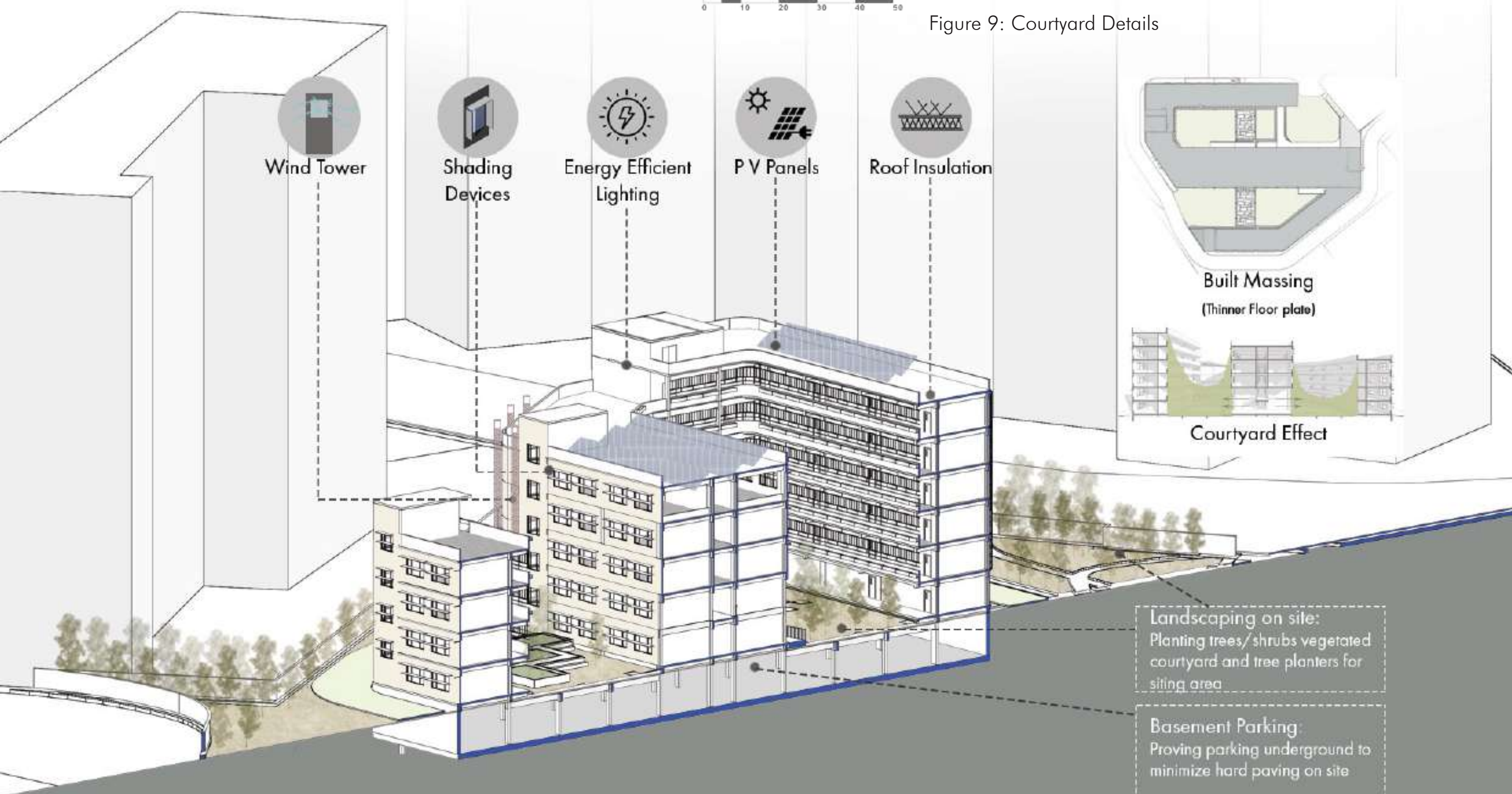
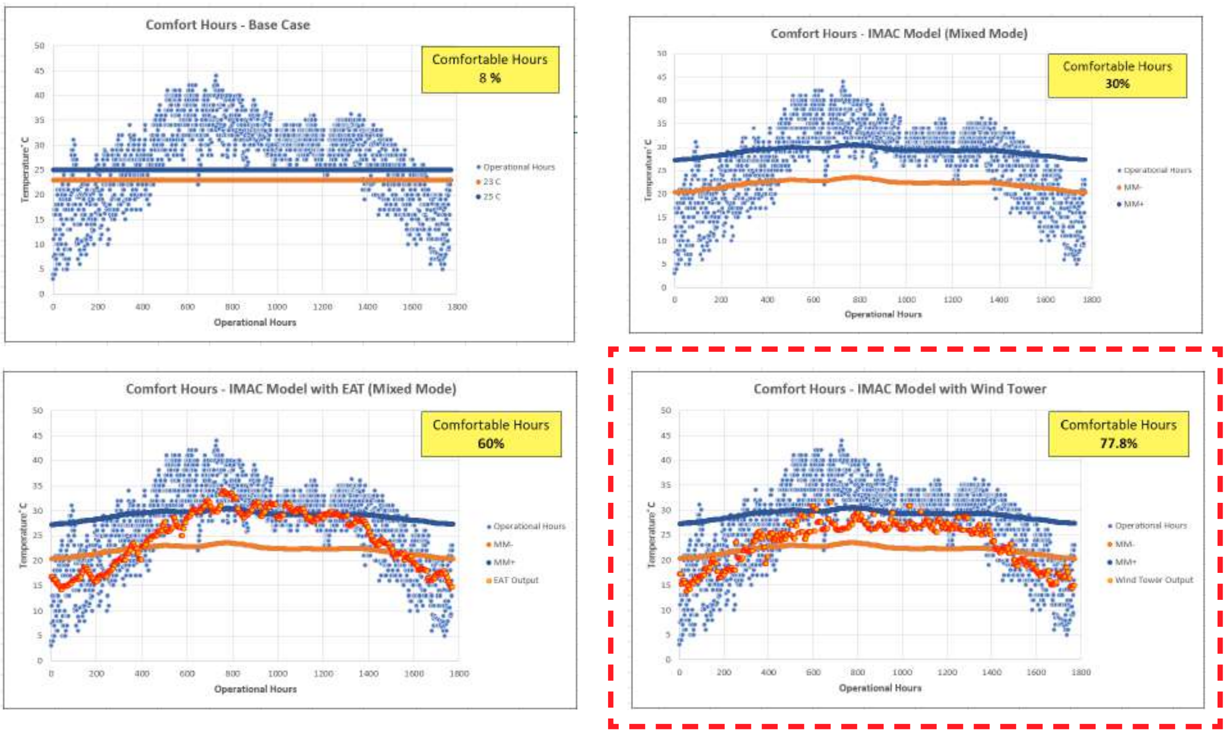


Figure 10: Section through Building

Comfort and Environment Quality



Graph 1: Comfort Analysis Mapping

For our design, we have adopted the IMAC comfort model specified in the NBC. This model recognises that thermal comfort depends on the occupants' context and varies with local outdoor environment conditions.

The **IMAC model** considers the above factors and recommends the range in which **Indoor Operative Temperature (IOT)** should lie for achieving thermal comfort. **IOT is considered the most suitable index** for assessing the comfort range as it encompasses the heat gains due to the surface and the occupants and also the heat dissipated by various equipment.

IOT is calculated using the formula,
Indoor operative temperature = (0.28 x outdoor temperature) + 17.87.
Here, **IOT** is the **neutral temperature**, the **outdoor temperature is the 30-day outdoor running mean air temperature**. The 90% acceptability range for the India specific adaptive models for mixed-mode buildings from the neutral temperature is **+-3.46 °C.** The **IMAC band** was thus plotted against the operational hours and the humidity between 40%-70% as established in the report **LECaVIR**. The total number of **comfortable hours satisfying** the above criteria was **16%**. The total number of hours whose temperature lies in the IMAC band but humidity is not in the comfortable range accounts for 16.5%, meaning that either humidification or de-humidification is required in these hours. Summing up, **32.5% of the total operational hours** lies in the comfortable band as specified by IMAC, with 16.5% of hours required to maintain humidity level.

However, there are still 67.5% of hours that are uncomfortable and require conditioning which adds a tremendous amount of cooling load in the building. Hence, to reduce the cooling load, **Earth Air Tunnel and Evaporative Wind Tower were analysed**, and **Wind Tower was finally proposed** in all of the conditioned areas during the operational hours. Superimposing on the IMAC band **78.5% of the total number of operational hours was found to be in comfortable range**, with 30% of the hours required to maintain humidity level.

Evaporative Cooling is based on the principle in which the air makes intimate contact with a flowing stream of water, either in a wet pad or a spray. Here, while the temperature comes down, its total energy content remains the same, as the latent heat of water vapor is added. Thus while this air will cool a warm object such as a human body or some stonework, it will not reduce the air conditioning load. To cater to that, at first, **evaporative cooling of stones at night and dries them using the dry and cool air at dawn**. The cold stones then directly cool the hot outside air during the daytime. This reduces the cooling load of the fresh air using natural processes only and further, the **output air is treated via AHU** and then passed into the **Heat Reclaim Ventilation system** which does the DX Cooling further and brings the temperature and moisture to the comfortable range based on occupancy of the zones.

Daylight

	Total Floor Area	Area in Range (m2)	Area in Range (%)
sDA	7285.9	4890.6	67.12
ASE	7285.9	6632.2	91.03

Table 2: Daylight Results

The building achieves **Spatial Daylight autonomy of >300 lux for >55% of the total floor area for 50% of the operating hours**, and achieves **2 out of 3 points of LEEDv4**, satisfying the reuired condition of ASE that no more than 10% of a space has direct sunlight more than 1000 lux for a maximum period of 250 hours per year. (90% of the area should be in Range). (Refer: Appendix 7)

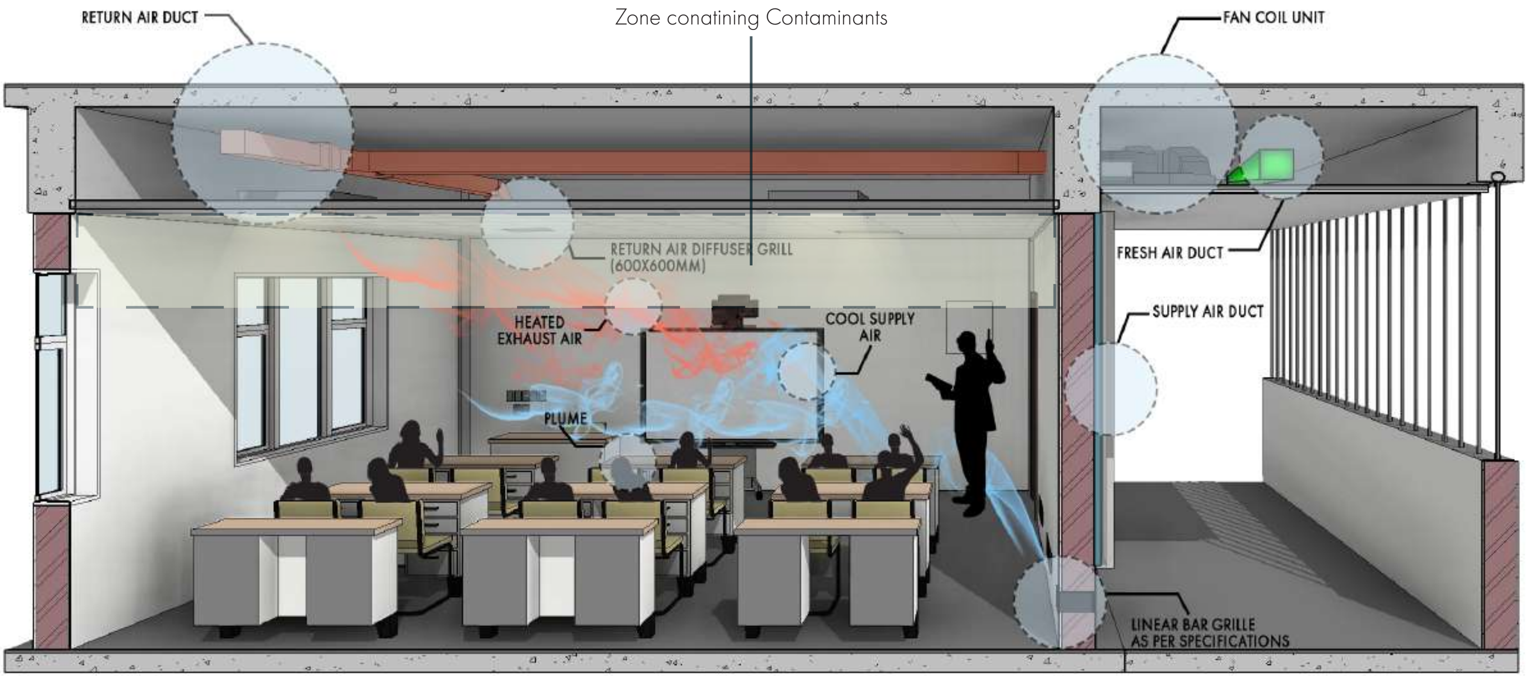
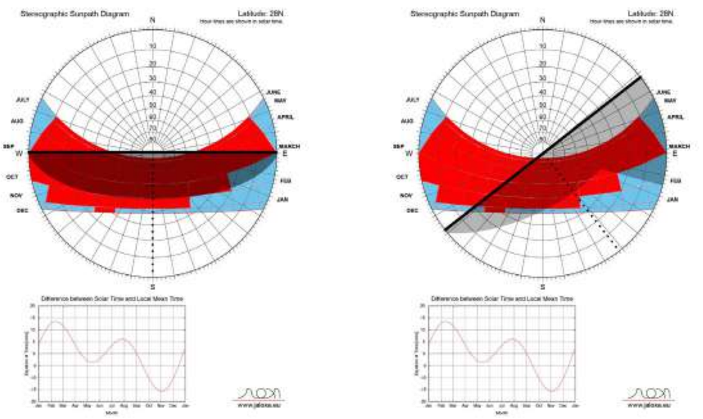


Figure 11: Displacement Ventilation Schematic

Shading Design

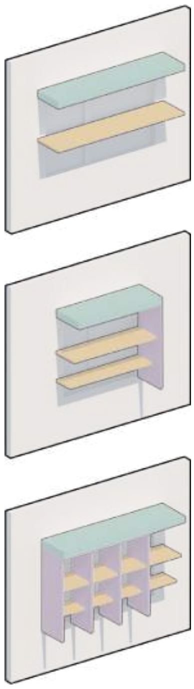
In terms of Passive strategies, **Courtyards** are provided in between the building blocks to reduce the thermal stress on the environment and have a cooler microclimate, acting as a place for interaction as well. This reduces the outside air temperature and acts as a buffer zone between various spaces in the school premises. To support this effect, plantation is done all throughout the site meeting the specifications as per **GRIHA guidelines**. The windows in the classroom are designed keeping in mind, not to restrict the views from the window for different age groups while managing the sun shading required as per the **shadow mask**.



Side - South
vertical shading angle - 50°
no horizontal shading

Side - South East
vertical shading angle - 45-48°
horizontal shading angle - 35°
east side

Figure 12: Shadow Mask



Horizontal fin 675mm each

Horizontal fin 750,600, 450mm. Vertical fin 750mm deep.

Horizontal fin 750,600, 450mm. Vertical fin 675mm deep.

The building being **mixed mode**, the intake of treated fresh air to the spaces is from the AHU. Considering the **bad Air Quality in Delhi NCR**, the air has to be treated for **CO_2 levels and different particulate matters**. Hence High Efficiency Air filter is utilised to serve this purpose which is infused in AHU itself. Air filters will reduce the concentration of **PM2.5 to be under 15ug/m^3**, and **PM10 to be under 50ug/m^3**. The **CO_2 levels have to be maintained below 1000ppm as per ASHRAE guidelines**, to cater this, fresh air is let inside the classroom maintained at **5 ach as specified by NBC**. The materials used for construction is also environment friendly and have **low VOC content**.

Contaminant distribution due to the occupancy of spaces within the rooms is also to be counted. This is influenced by several factors such as **supply air method**, contaminant source type, location within the space, heat sources, and space height. To cater to this, **Displacement Ventilation is proposed** inside the spaces, as the occupied zone in a classroom is generally within **1.5 m (considering the average heights of the students varying with the age groups)**, while the ceiling height being 2.8 m, so the rest of the space is not required to have the conditioned air. Displacement ventilation helps in improving occupant air quality by **reducing the contaminants in the occupied zone of the rooms**, and due to the general upward movement of air causes contaminants to **concentrate within the upper zone, and hence is extracted out from the return air duc**t. The **diffusers are mounted on walls** acting as an aesthetic element in the space and are also designed in consideration by controlling the stratification of temperature in the occupied zone based on the levels mentioned in ASHRAE (the temperature difference between the head and the foot level should not exceed 3°C for a standing person and 2°C for a seated person) for maintaining occupant comfort. This also produces low noise.

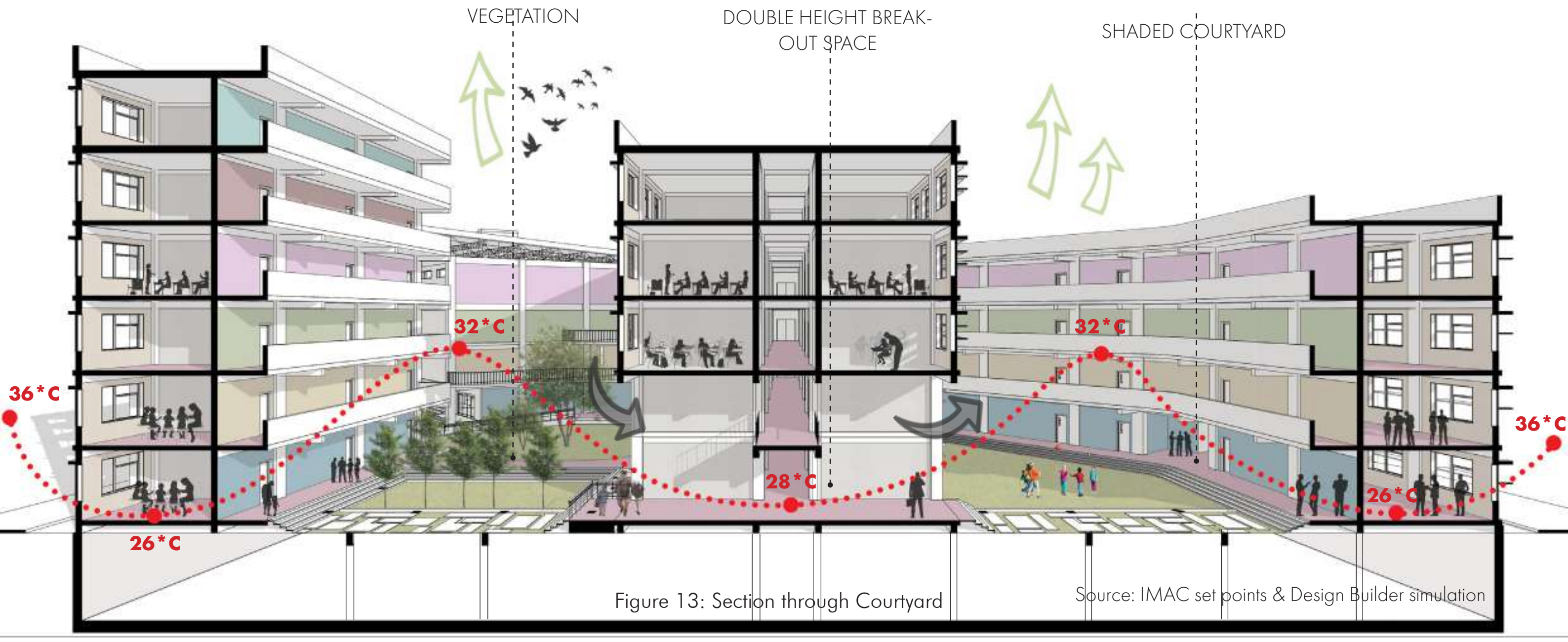


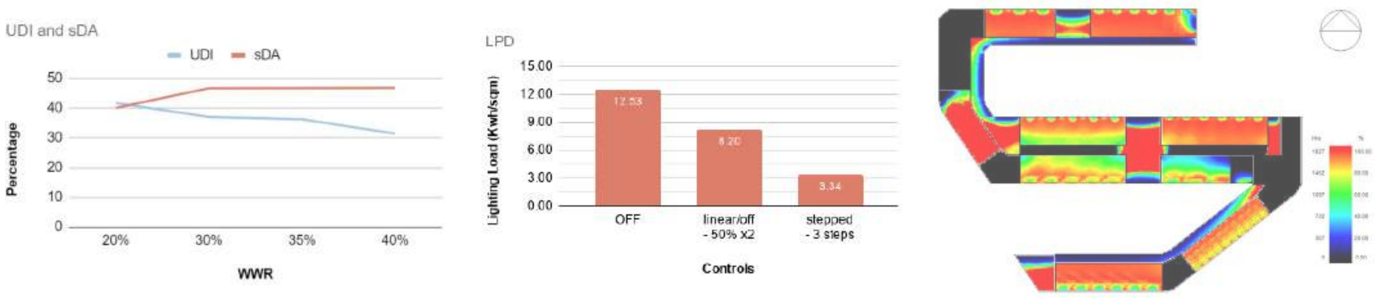
Figure 13: Section through Courtyard

Energy

The approach for the energy efficiency goal is two-fold. From the results of the pre-design simulations and the design oriented approach, the first step to reduce the energy consumption by passive means was covered by effective zoning, orientation and building configuration (Refer: Passive Performance). The next steps were to optimise the specific details.

Envelope Optimisation

The approach to optimise the building envelope begun with setting the Window Wall Ratio as providing enough daylight to minimise the lighting load as it is one of our design goals. We simulated and analysed the **UDI and sDA** for different WWR's to select the optimum result.

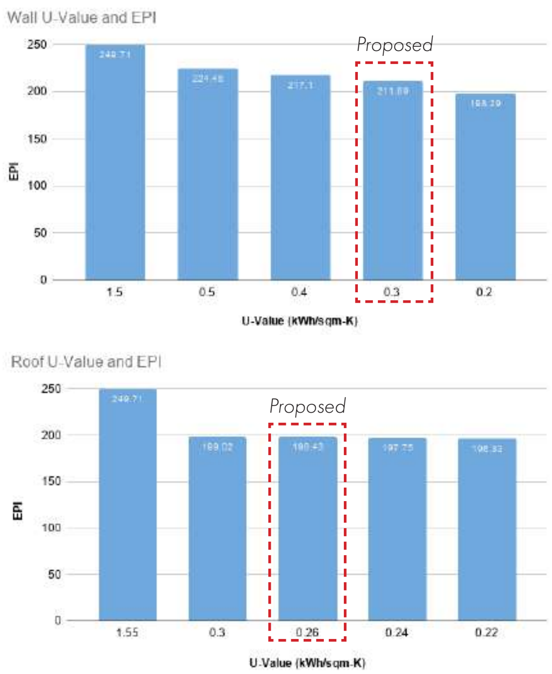


Graph 2: Envelope Optimisation Parameters

The nearly constant Daylight Autonomy (Graph 2) for all cases leaves the selection basis as UDI. We selected 35% WWR as it will more bring natural light and sunshade derived from the shadow mask is optimised in terms of construction and affordability. This system when combined with lighting controls saves around 60% of the total lighting loads.

We referred to the **ECBC design guide** for wall and roof constructions and simulated various combinations to analyze the impact different U-values had on the building's energy performance.

We selected the **AgroCrete** – the Carbon-negative material innovation walls by Green Jams (industry partner) – with terracotta tile cladding **(Wall Assembly U-Value = 0.312 kWh/sqm-K)** for external walls as it provided the required U-value without increasing the **width (260 mm)**.



Graph 3: U-Value and EPI

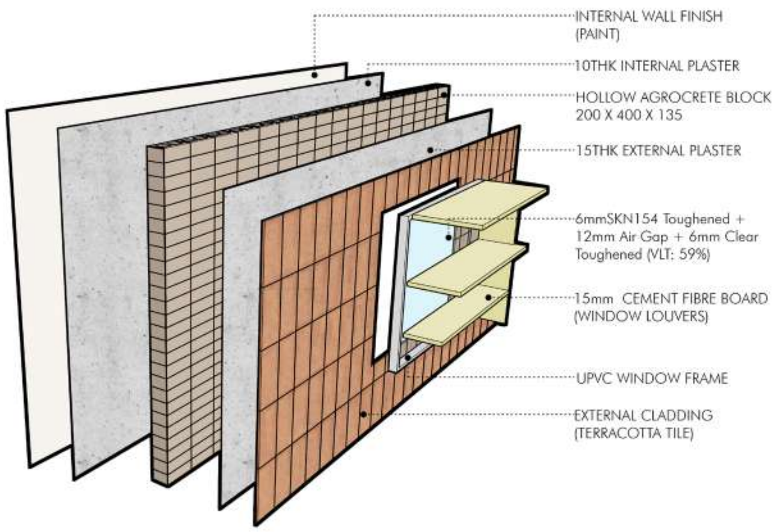


Figure 14: External Wall Composition

U-Value = 0.312 kWh/sqm-K
width = 260 mm

These results of the simulation run gave us the choices for the combination of materials and parameters for optimum envelope favouring the major impact on the lighting loads.

We are using the LED lights considering the overall cost factor (Refer Affordability). Further, the use of **stepped lighting controls** reduced the **vampire loads** during the break times. The star rated equipment and application of effective schedules for all the admin and classroom areas reduces the equipment loads by almost 50%. (Refer Building Operations)

Comfort Optimisation

As the major part of heat gain from the openings was catered by the shading design, we focused more on getting the daylight in and so used Air-filled Double glazed unit with high VLT and low U-value (Refer Comfort for details).

The optimization for the people's adaptive thermal comfort leads us to operate the air conditioners at floating set points. Based on our study of the Indian Model for Adaptive thermal comfort for mixed mode buildings, we derived an hourly thermal comfort band for the entire year. This band gives a range of acceptable indoor operative temperatures for the specific context of Noida. The derived setpoints monthly are listed below.

Jan - Feb	March	April	May - Sept	October	November	December
25° C	26° C	28° C	30° C	29° C	27° C	25° C

Table 3: Temperature Setpoints Schedule

The derived setpoints reduces the cooling load by almost 45%. To further reduce these loads, we looked at **two stage cooling systems** and ran simulations for two options –

Earth Air Tunnel and Wind Tower

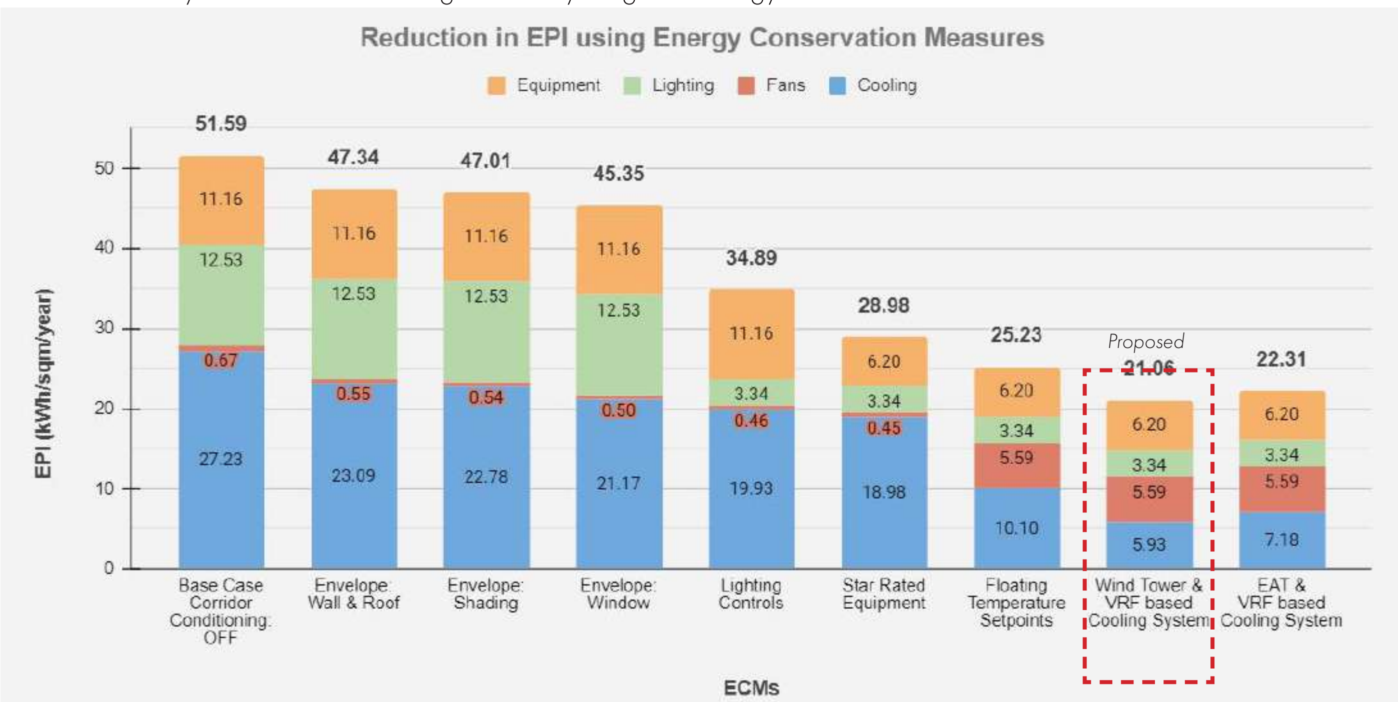
After analysing the results, we chose the wind tower because,

- The results of output temperature were in its favour (Refer Comfort)
- It was more feasible option when compared to Earth Air tunnel (Refer Operations)

By these results, we are proposing the two-stage cooling system which includes a set of Wind Towers to pre-cool the air and then use the VRF based air cooled system to bring down the air temperature at comfort levels. The Wind Towers, when operated at these setpoints, cuts down the conditioning loads by almost 50%. The use of VRF having system **Co-efficient of Performance 4.47** further brings down the electricity load. (Refer HVAC for details)

The approach to use mechanical ventilation for fresh air is elevated by the integration of the Wind Tower as it impacts the cooling as well. The Air Handling unit will filter the air before circulating is to the respective classrooms using displacement ventilation. (Refer: Comfort)

We simulated all the results from the base case again using the detailed specifications from our study. Here is the summary of the results after using seamlessly integrated energy conservation measures.



Graph 4: Reduction in EPI based on ECM's

Final Result

WWR	Walls	Roof	Window	Lighting & Equipment	Cooling	EPI
BASE CASE						
35%	230 mm Red brick Wall U-value: 1.52 W/m2-K	200 RCC slab, screed finish U-value: 1.51 W/m2-K	6mm + 12mm Air Gap + 6mm Clear Toughened Glass U-value: 2.7 W/m2-K SHGC: 0.87, VLT: 47%	Lighting: 11 W/sqm Equipment: 16 W/sqm	PTAC system 1900 kW (550 TR)	**51.59 kWh/sqm**
PROPOSED CASE						
35%	**External Walls:** 200 mm Agrocrete Hollow block Wall + Terracotta tile cladding **Internal Walls:** Dry Partition Wall (Gypsum) Acoustic Panels both sides	80 mm overdeck Earthen pot insulation, Reflective China Mosaic Tile FInish	**NORTH FACE:** ST167 6mm + 12mm Air Gap + 6mm Clear Toughened **SOUTH, SW, SE FACE:** SKN154 6mm + 12mm Air Gap + 6mm Clear Toughened	**LIGHTING POWER DENSITY:** Classrooms: 4.8 W/sqm. Labs & Activity: 7 W/sqm. Admin: 4.8 W/sqm. Corridors: 2 W/sqm. Multipurpose Hall: 4.9 W/sqm. Canteen: 7 W/sqm.	**Classroom Block:** Wind Tower to pre-cool air, 800 kW VRF System **Multipurpose Block:** Wind Tower to pre-cool air, 150 kW VRF Cooling	**21.06 kWh/sqm.**
	U-Value: External :0.312 W/m2-K	**U-Value:** 0.263 W/m2-K	**NORTH FACE:** U-Value: 1.4 W/m2-K (air) SHGC: 0.47, VLT: 59% **SOUTH, SE, SW FACE:** U-Value: 1.3 W/m2-K (air) SHGC: 0.28, VLT: 52%	**EQUIPMENT DENSITY:** Classrooms: 7 W/sqm. Labs & Activity: 7 W/sqm. Admin: 12 W/sqm. Canteen: 2 W/sqm.		

Table 4: Proposed Specifications

Solar Energy Generation

The site receives an **average direct solar irradiation of 1.15 kWh/m²**; providing a huge potential for solar power generation. We have utilised only 54% of the available roof area fulfilling our consumption needs. The PV array is tilted at an angle of **22° on the administration block** and at the roof tilt of **5° for multipurpose block.** The technical details for the PV system are as follows;

Area of Roof exposed to solar (Sqm)	
Multipurpose	Main Block
850	800
Panel Dimensions	2176 ×1098× 35 mm
Area of Panel (Sqm)	2.289

No. of Panels	
371	349
46 panels each in series	**21** panels each in series
8 such series in parallel	**17** such series in parallel
Total Panels	
721	

Brand	TRINA Solar
Model Name	Framed 144 Half-Cell Multi-Busbar Module
Authorised Dealer India	Loop Solar
Peak Power Watts-PMAX (Wp)* STC: Irradiance 1000W/m2, Cell Temperature 25°C, Air Mass AM1.5.	390
Module Effciency η m (%)	19.2

Solar Cells	Monocrystalline
Cell Orientation	144 cells
Module Dimensions	2176 ×1098× 35 mm
Weight	22.8kg
Glass	3.2 mm
Frame	35 mm Anodized Aluminium Alloy

Table 5: Solar PV Specifications

The **plant size of 290 kW** leads us towards gross metering as per the laws. In gross metering, we have two meters, Import meter and Export meter. The energy usage is adjusted on the difference of readings in these meters at the settlement period of one year (March - March).

The total energy generation takes place at two different places:

- On School Terrace & Multipurpose Hall Roof

These series will be connected to the inverters and the generated energy will be utilised as shown in the single line representation drawing (figure 15).

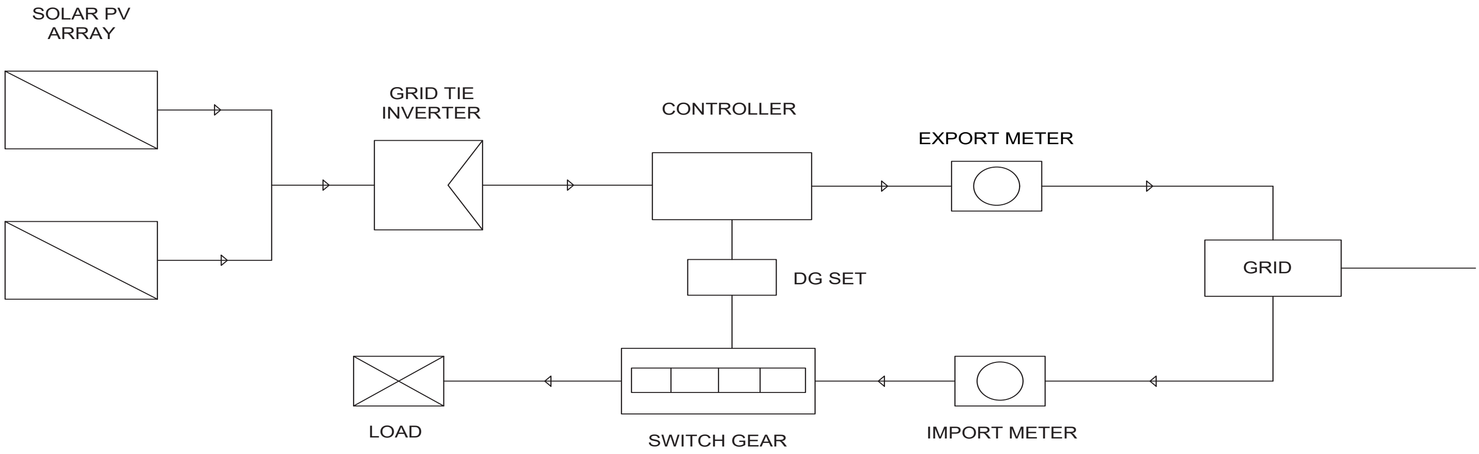
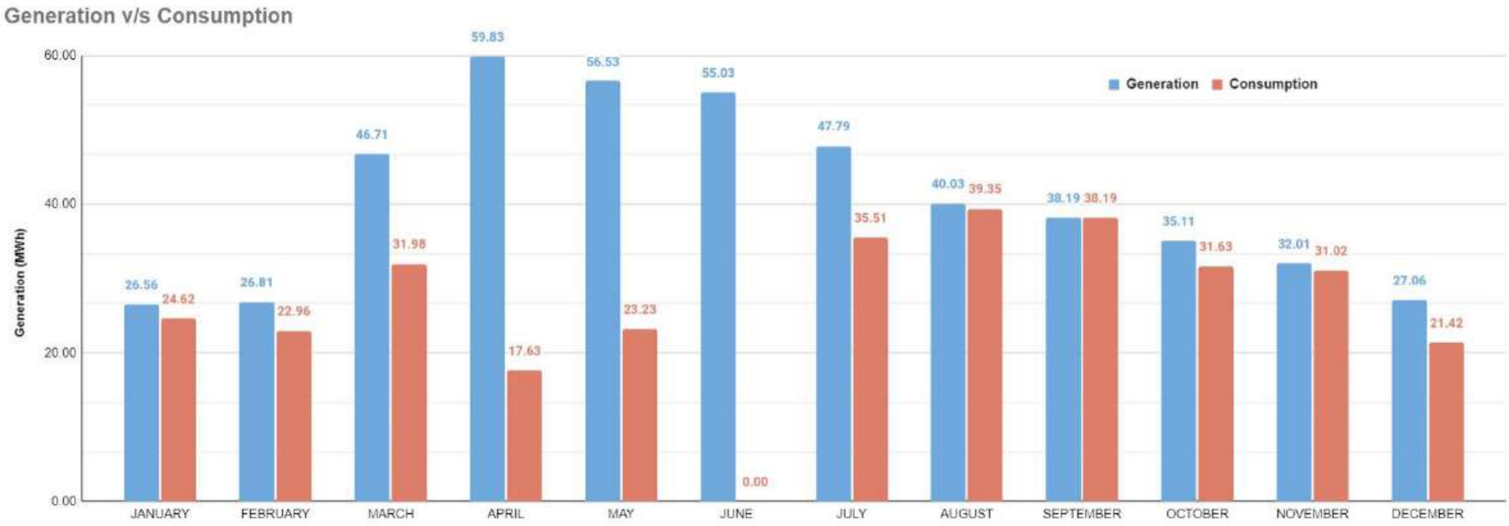


Figure 15: Solar and Electrical SLD

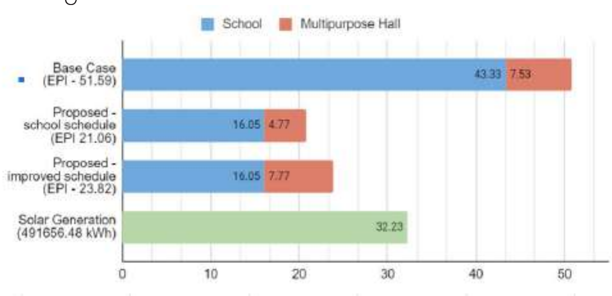
We are using the **Grid Tie Invertor**, which synchronize and converts the variable unregulated DC voltage from the solar panel array to AC synchronized with the mains. The energy production from solar panel is irregular and fluctuating. The Grid Tie inverter regulates this and averts the stress on grids and enhances the grid reliability.
When there is power failure, the Grid Tie Inverter automatically stops supplying electricity to the power lines, to create an islanding effect.
The Grid Tie inverter can also work with the DG set to supply the power in case of a power failure, to provide reference voltage. We could have used a battery bank, but for a school of this size, the battery bank size would be very large and hence not feasible. So we have used a hybrid system of grid as well as DG set to provide energy for the building (Refer Resilience for details).

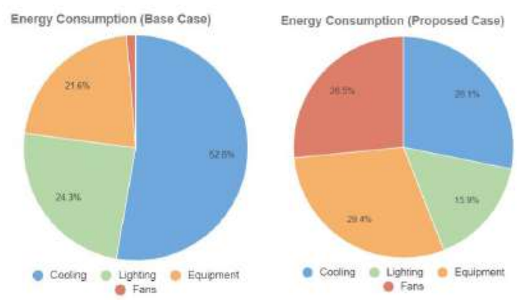
The following infographic demonstrates a monthly comparison between total energy generation and building total energy consumption.



Graph 5: Generation vs Consumption

We have proposed to utilise the Multipurpose Hall for the extra-curricular activities even on holidays (Refer: Business Model). This tends to increase the energy usage, but the two stage cooling method limits it. Graph 6 shows the comparison of energy consumption as per different schedules of multipurpose hall to the annual generation.





Graph 6: Consumption Breakup

Graph 7: Consumption Breakup Comparision

The total energy consumption by different means has been mapped in the pie chart (Graph 7). We can see the changes in the components of cooling and fans because of the mechanical ventilation and two-stage cooling. The drastic reduction in lighting loads due to naturally day lit areas helped the most in achieving the target.

Net Site Energy

	Generation (kWh)	Total Generation (kWh)	Total Consumption (kWh)	Net Site Energy (kWh)
Multipurpose Hall	268,436.86	491,656.48	321,291.36	-170,365.12
School Block	223,219.62			
	kWh/sqm.	32.21	21.06	-11.16

Table 6: Net Site Energy Results

Water Performance

We have created a closed net-zero water cycle on our site where the sum of water used from alternate sources and water recharged to the ground is equal to the total water demand. We have also achieved zero water discharge and ensured that 100% of the wastewater is segregated (into gray and black water) and treated independently on site. We accomplished this by implementing to the following strategies-

- Rainwater harvesting, including strategies for potable and non-potable uses
- On-site water treatment
- Wastewater reclamation and reuse
- Using efficient plumbing fixtures

Month	Days in month	No. of working days	Generated black water	Filtered black water	Generated Grey water	Filtered grey water	Harvested rainwater	Occupant demand	Irrigation demand (l)	Total water demand (l)	Municipal water demand (l)
Jul	31	23	840181	838506	1128067	1015260	937767.6	2107444	263348.65	2370793	0
Aug	31	23	840181	838687	1128067	1015260	933031.4	2107444	234,988.02	2342432	0
Sep	30	22	803651	802124	1079021	971119	629914.6	2015816	243,091.06	2258907	0
Oct	31	23	840181	838506	1128067	1015260	80515.4	2107444	263,348.65	2370793	436510
Nov	30	22	803651	802247	1079021	971119	0	2015816	229,246.94	2245063	471698
Dec	31	18	657533	656605	882835	794552	14208.6	1649304	186,369.81	1835674	370308
Jan	31	18	657533	657040	490464	441418	71043	1649304	178,266.78	1827571	658070
Feb	28	20	730592	729427	980928	882835	73411.1	1832560	197,086.73	2029647	343973
Mar	31	20	730592	729534	735696	662126	37889.6	1832560	264,196.86	2096757	667207
Apr	30	23	840181	839220	539510	485559	14208.6	2107444	305,824.24	2413268	1074280
May	31	13	474885	473647	637603	573843	33153.4	1191164	344,379.00	1535543	454900
Jun	30	0	0	0	0	0	269963.4	0	313,665.88	313666	0
Total water consumption (l)=				**23640113**	**Water used from alternate sources (l)=**			**20129002**	**Water recharged into the ground (l) =**		**3511111**

Table 7: Net Zero Water Calculations

Water cycle diagram

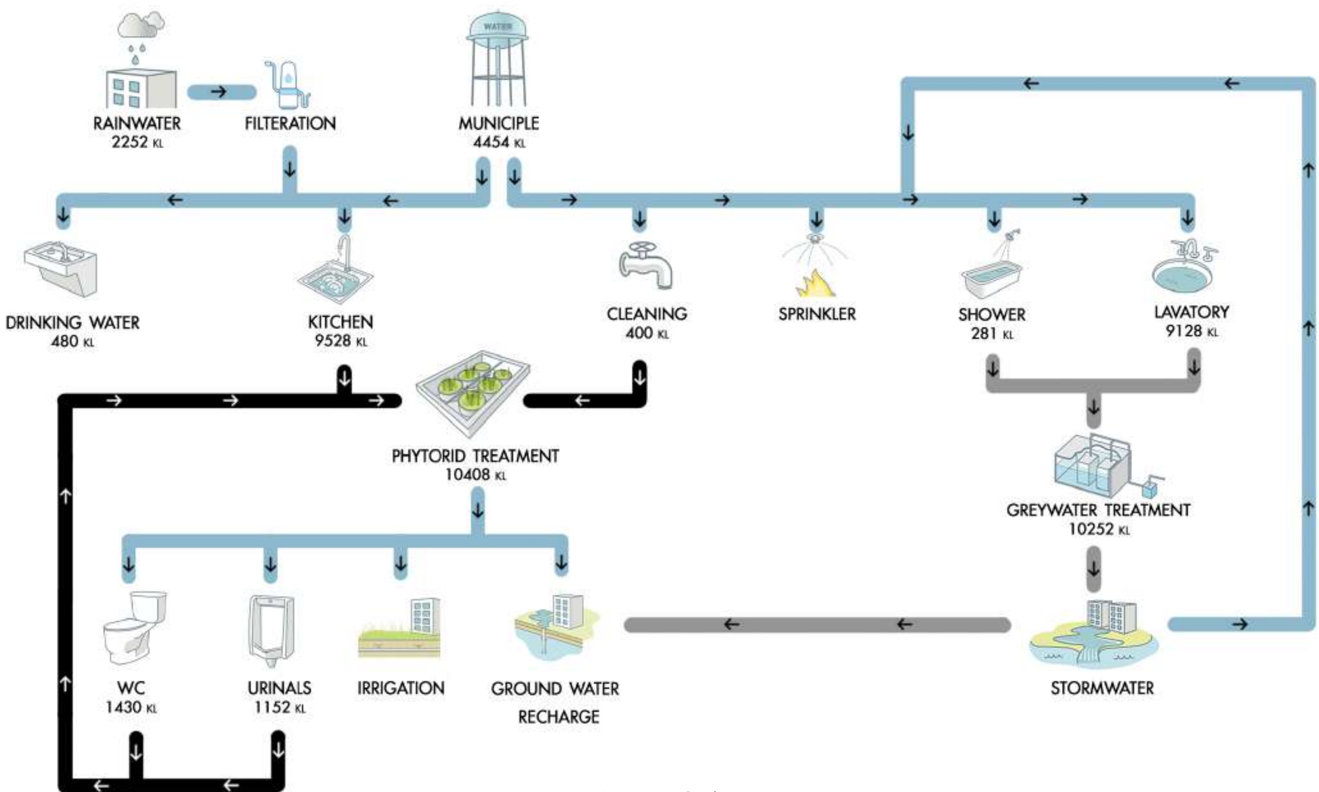


Figure 16: Water Cycle Diagram

Black Water Treatment

For on-site black water treatment, we used Phytorid wastewater treatment technology developed by CSIR-NEERI as a cost effective, natural and sustainable treatment system for wastewater. The Phytorid Technology is a combination of the physical, chemical and biological processes and works without electricity, minimum maintenance, less manpower and is self sustainable.

The reduction in the treated effluent for the total suspended solids (TSS) varies from 70% to 80%, BOD from 78% to 84%, nitrogen from 70% to 75%, phosphorus from 52% to 64% and fecal coliform from 90% to 97%.

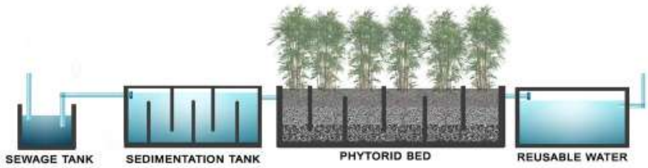


Figure 17: Phytorid Plant Schematic

The system uses natural vegetation and the plant specific associated microbiota, as leads to eco friendly sewage treatment technology. The subsurface flow treatment is totally free of mosquitoes and unpleasant odour. The treated water is used for irrigation, gardening and toilet flushing. The treated water from the phytorid plant also achieves the permissible limit for sewage discharge in the fresh and marine water bodies.

Size of Phytorid Treatment Plant	
Qty. of wastewater	48.7cum/day (max. flow)
Gross area of screen	0.0064sqm.
Sedimentation tank	2.8m x 8m x 2.25m
Phytorid bed	2.8m x 8m x 2.4m
Storage tank	36cum.

Plants used in Phytorid Bed
Elephant grass (Pennisetumpurpurem)
Cattails (Typha sp.)
Reeds (Phragmitessp.)
Cannaindica (Indian Shot)
Yellow flag iris (Iris pseudocorus)

Table 8: Phytorid Plant Details

Grey Water Treatment

Grey water is treated using a sand filter designed according to the daily volume of water to be treated on our site. Sand filtration is a combination of physical, chemical and biological processes as it removes turbidity, organic matter and microorganisms. Coarse particles help to remove suspended solids, whereas fine particles remove ions by adsorption and ion exchange mechanism. Optimal dosage of activated carbon increases the efficiency of treatment, the positive electric-charge of activated carbon attracts negatively charged organic anions on the surface and decreases the pH of treated greywater .It also removes the color of greywater which is identified by the colorless nature of the treated greywater. This is followed by UV treatment to kill any virus present and make the water fit for potable use.

S. No.	Filtering media (from top to bottom)	Volume of material used (cubic m)
1	sieve	-
2	Big gravel	17.36
3	Small gravel	14.45
4	Coarse sand	8.68
5	Fine sand	8.68
6	Activated carbon	3.86

Table 9: Grey-Water Treatment Details

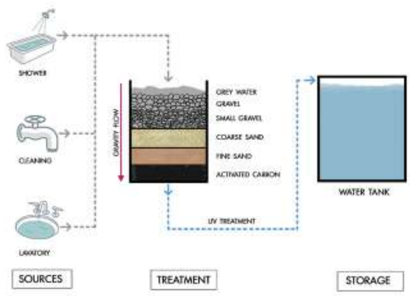


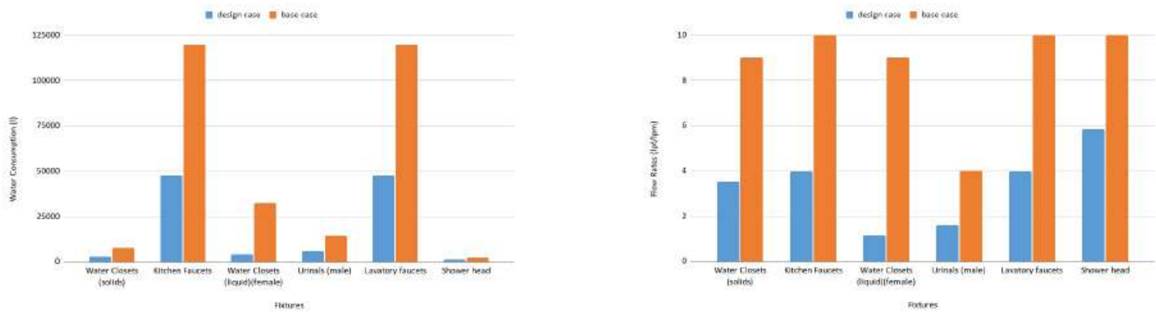
Figure 18: Grey Water Treatment Schematic

Indoor Water use reduction

Using efficient water management strategies we have brought down the **indoor water consumption of 45 litres per person per day**, achieving a **reduction of 63% from the base case** for this building. We also achieved a **43% reduction from the GRIHA base case of 80 lpd** for institutional buildings. (Refer: Appendix 5)

While most of our building's water demand is reduced by using the mentioned strategies, the other part of it would depend on the habits of the students using the space, which we hope to enhance with the help of interactive visual displays installed throughout the building. The displays would make the students aware of the water consumption and encourage them to not waste or over consume water, resulting in reduced usage.This way, we also actively involve the students in our efforts towards a more sustainable future.

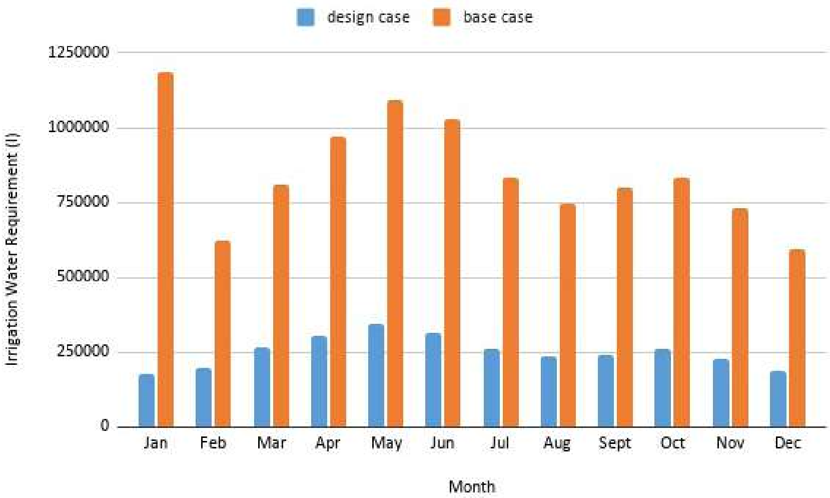
(Refer: Building management System)



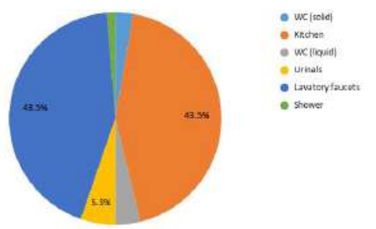
Graph 8: Indoor Water Use Reduction

Outdoor water use reduction

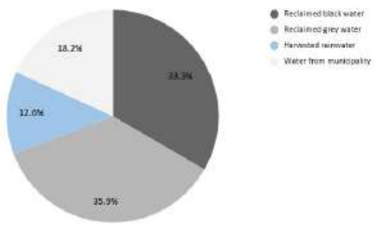
We have reduced the **outdoor water demand for irrigation to 3kL from the base case demand of 10.2kL per annum**. This amounts to a reduction of **irrigation water demand by 70.52%**. The strategies used for this reduction include the use of efficient irrigation systems like drip irrigation and sprinklers, planting only native trees and plants and use of xeriscaping in order to avoid unnecessary demand of water as much as possible.



Graph 10: Outdoor Water use Reduction



Graph 9: Indoor Water Use Distribution



Graph 11: Sources of Water

Rainwater harvesting:

Catchment area on the roof receives the rainwater. This water goes through a rainwater harvesting filter which automatically flushes out dirt and debris.The harvested water is stored in storage tanks for immediate usage. This water is used in drinking fountains, kitchen sinks, and washbasins. Stormwater falling on the ground is collected in a recharge pit from different channels on the ground and is filtered. Filtered water gets pumped up and is stored in an overhead tank.

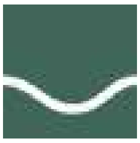
Figure 19: Landscaping Plan

Rainwater harvesting surfaces	Area (sqm)	Runoff coeffecient	Effective catchment area (sqm)
Roof Surfaces (Kota stone)	3628	0.95	3446.6
Stormwater harvesting surfaces	Area (sqm)	Runoff coeffecient	Effective catchment area (sqm)
Playground	880	0.35	308
Vegetation on ground	3444	0.25	861
Loose interlocking pavers	201	0.60	120.6
Total Effective catchment area			4736.2
Groundwater Recharge	Area (sqm)	Permeability	
Permeable pavers	6828	100%	6828

Months	Rainfall (mm)	Effective rain (mm)	Rainwater collected for use (l)	Rainwater recharged (l)
July	203	198	23879	1351944
August	202	197	23758	1345116
September	138	133	16040	908124
October	22	17	2050	116076
November	3	0	0	0
December	8	3	362	20484
January	20	15	1809	102420
February	21	16	1869	105834
March	13	8	965	54624
April	8	3	362	20484
May	12	7	844	47796
June	62	57	6874	389196

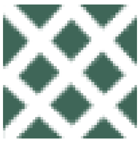
Table 10: Rainwater Treatment Details

Stormwater



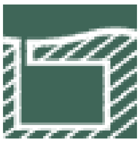
Bioswales

Bioswales are vegetated channels designed to treat and attenuate stormwater runoff. As stormwater runoff flows through the channels, it is treated through filtering by the vegetation in the channel, a subsoil matrix, and infilters into the underlying soils, recharging the ground aquifers.We are creating bioswales on both sides of paved surfaces, so any water running off from the plane surface travels into the low lying channels on either side.



Pervious pavement

We are using true grid pavers on the site which is a permeable pavement surface made of 100 % post-consumer recycled high density polyethylene with a stone reservoir underneath. The reservoir temporarily stores surface runoff before infiltrating it into the subsoil or sub-surface drainage and in the process improves the water quality. It is designed to allow percolation or infiltration of stormwater into the soil below where the water is naturally filtered and pollutants are removed. This material with gravel filling has been used for constructing the fire tender path, walkways and bus parking.



Underground storage

Stormwater falling on impervious or partially pervious materials on-site will be collected and stored in underground water tanks. The tanks were designed considering peak annual rainfall data and the area and run-off coefficients of landscaping materials. Pipes and sloping curb cuts lead surface storm water to subsurface tanks after which it is filtered and treated for use.

Waste Management

The school's waste management program has the potential to transform the school environment into a laboratory for learning about waste management. It also provides numerous opportunities for the students to understand this issue and its implications on the local environment. The primary waste generated in schools includes paper waste, accessories (pen, pencil, etc.), food waste from the canteen, plastic wastes such as wrappers from the packaged foods, cardboard waste, dead leaves on-site, etc. The main issue regarding waste generation in schools is the lack of awareness among the students about the enormous negative impact of their careless habits. One of our leading waste management strategies is to include waste management as a part of the school curriculum with awareness training for children and teachers. Other strategies used for the same are :

- Provision of dedicated waste bins for different types of waste at various locations on campus.
- Provision of donation bins for the students to help underprivileged children with their old clothes, books, etc.
- Administrative interventions
    1. Encouraging students to use sustainable fountain pens and reusable stationery to reduce the consumption of plastic.
    2. Encouraging students to pass on their academic books to their juniors in good condition to avoid unnecessary demand for new books.
- Making sure to supply the segregated waste to respective authorized recycling plants.
- Encouraging students to reduce waste generation as a group by awarding the least waste generating classroom.

Resilience

Earthquake Resilient

Noida/New Delhi lies in the zone 4 category of earthquake zones as per the **IS 1893, 2000 code**. Noida is quite prone to earthquakes. The design has taken into consideration the possibility of an event of earthquake and we have tried made the building earthquake resistant. The school has been designed in compliance with earthquake code of the Indian Standard. The building frame system used in our design is Special Reinforced concrete moment resisting frame. The building has been reinforced with shear walls at different places and . All columns have reinforcement as per the IS code for earthquake resilience. Ductile detailing has been considered for the design. Separation joint of 0.75 cm (building with shear wall in zone 4) has been given for giving space for vibration during an earthquake.

Fire Resilient

Our building is designed in accordance with the fire safety norms of the National Building code, Part 4. The building has down comer with **sprinklers installed on all floors with pipe diameter of 150mm** with valves on each floor. The **construction type is of Type 1** and the **walls have 2 hours fire rating against fire**. All the staircases are compliant to fire safety and comply with the code for egress. There is pressurization in the staircase and lift shaft. The staircases are placed at a maximum distance of 45m from the farthest point as per the code. Individual AHU system is installed for each floor so that the fire smoke does not spread from one floor to another.

The basement has fire exits and sprinkler systems installed and the fire staircases lead to outside. The ventilation system in basement works to remove the smoke from basement in case of a fire. All the emergency fire equipment such as fire pumps, ventilation and smoke dampers, emergency lighting, fire exit signage etc. are connected with a backup generator and they would function even in case of electrical failure. A **water pump of 900L/min capacity** has been installed in the pump room.

The building has a fire water sprinkler system installed in all the habitable spaces. **Automatic fire detection system** has been installed as per code **IS 2189:2008**. The building has a **6m wide fire tender path** all around, which gives access to fire tender to all sides of the building. The path is paved to be used in all seasons. There are assembly spaces near the exits so that people can assemble in case of a fire.

Figure 20: Fire Exit Plan

Adaptive Utilisation:

The spaces designed for the school are to be used in multiple ways in case of different occasions. But, to create alternate places for the same purpose in different situations, is quite a task. Our approach was to design the spaces which can create good quality atmosphere and can also be used as an alternative for some other function. Fig 21 shows some iterations. (Refer: Appendix 1c)

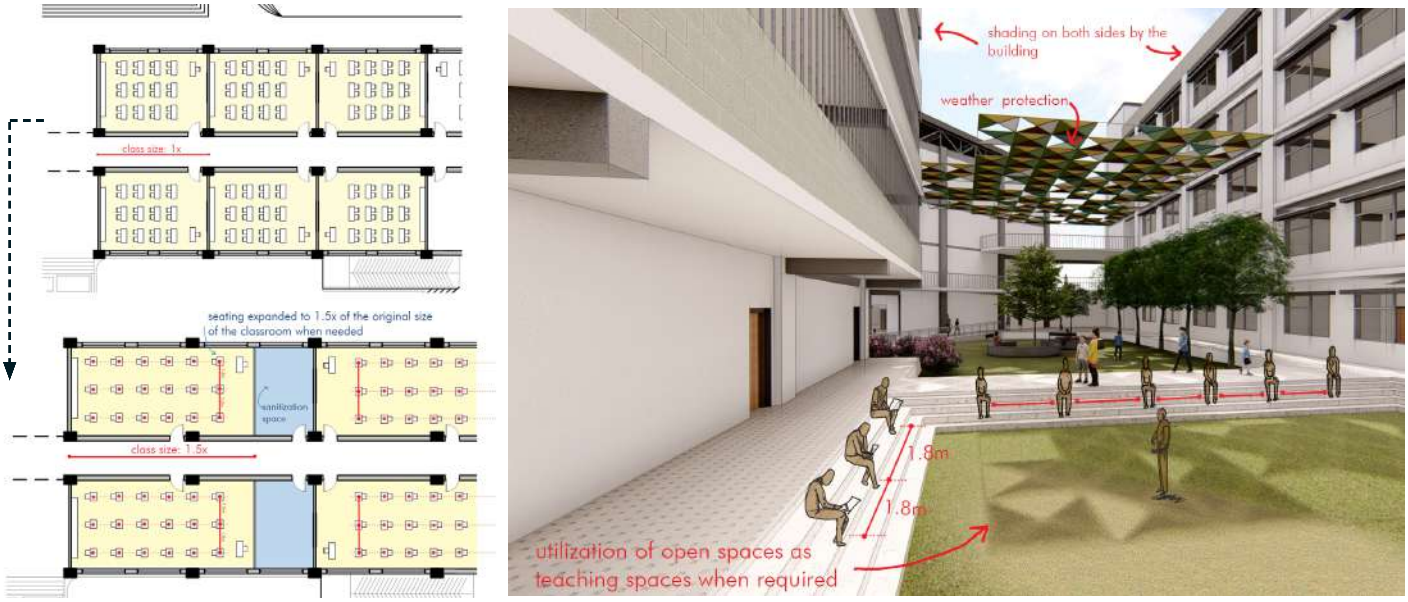


Figure 21: Adaptive Utilisation of Space

In these pictures, we can see how the purpose as well as the experience of the space changes just as we want. By just providing a temporary canopy, the courtyard space can now also be used as teaching space. We are able to make these alterations possible due to our innovative approach to design the spaces (Refer: *Design Documentation*). The use of courtyard systems, effective landscaping and the integration of Biophilia in the design helps create a cooler site atmosphere. These greens provide shade and remove the heat from air using evapotranspiration decreasing the surrounding and surface temperatures.

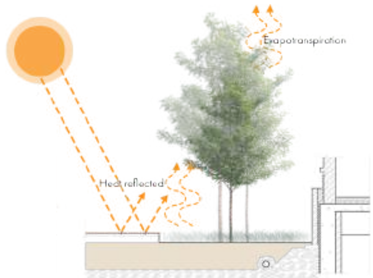


Figure 22: Heat Island Effect

Further, by the current pandemic situation, we know that the direct usage of the space may change anytime. And we are set to fulfill the needs of them in any case. The steps taken for resilience in energy and water are explained in the following sections. Further, one of the steps we took for this is the VRF (Variable Refrigerant Flow) based cooling system. The dynamic system allowing variable flow rates can cater the setpoint changes better than other systems. This system is used for all the typologies and can cater the needs dynamically when needed. This system is able to fulfill whichever requirements the project may need.

Future Extension

The Solar PV system is designed based on current electrical demand of the building. It may happen that in the future, the electrical demand increases, due to

1. Increase in electrical equipment connected to the system,
2. Decrease in efficiency of the solar PV system over time
3. Decrease in efficiency of HVAC system installed in the building
4. Due to increase in cooling load due to increase in the average temperature in next 50 years (as per report of IPCC)

Thus, if we limit the solar PV area, then in future we might not be able to expand our Solar PV capacity. To cater to the future demands, we are leaving some area on the roof where more Solar PV panels can be installed on the roof.

The total roof top area for the roof on the main building is **2200 m^2**. Currently, we are using **800 m^2** of the total rooftop area. The rest **1400 m^2** is left empty. This area can be used to install solar panels in the future.

Approach to Renewable Energy:

A rooftop solar PV that generates AC power will always need another source of power (whether the grid or diesel generator or batteries) to provide a reference voltage to function. If the inverter is using only grid power as a reference voltage, the plant will not generate power in a power outage, even if there is ample sunlight and the solar panel stops working. This effect is known as the islanding effect. In this case, we can either use a battery stored power bank or use a diesel generator set. For a school of this size, the battery pack would be large. The other solution that we are using is to be integrated solar-diesel inverters with a smart digital controller. Since the solar panel inverters need consistent reference voltage to operate, we use a Diesel generator at low RPM to provide a steady reference current.

The solar PV system can be connected to a serial bus bar, which is also connected to the DG set and the grid. Whenever there is a power failure, the inverter would trip, sensing a loss of reference voltage. Then the DG set will start automatically and will provide into the same serial bus bar. The inverter is tricked into perceiving this as grid voltage and starts energy production.

Thus, the energy is provided by both the DG set (at low RPM) and the Solar PV system. ELUM Hybrid Fuel Saver and Smart controller is a power controller dedicated to solar and diesel hybrid power plants. It allows the integration of solar panels on diesel generator installation to reduce their fuel consumption. It is connected to solar and diesel installations and it manages the overall power distribution of the system. It allows the maximum utilization of both the systems, eliminating the need for storage capacity. This way we can have a power backup with maximum fuel efficiency in case of a power outage

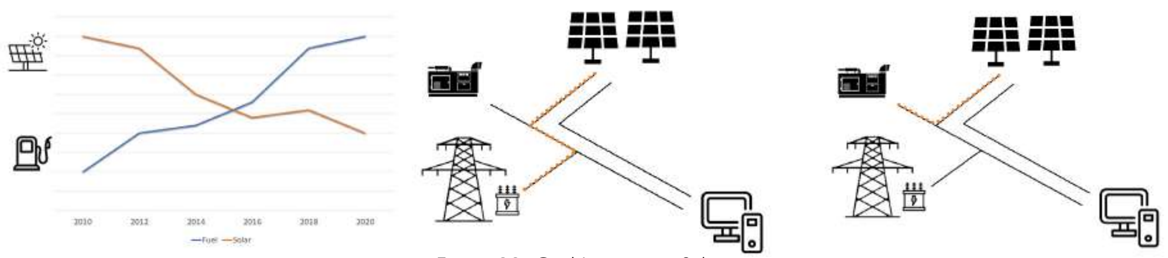


Figure 23: Grid Interaction Schematic

Resilience to cut in water supply

Water is an essential requirement for any building to function. In an event of water supply failure due to unexpected reasons, the building should have enough storage of water to manage the essential services in the building. Water management in the school building is designed such that the building will have enough water for all its needs for a week in case of a cut in supply of water from the municipality. The daily demand of the building is met through fresh water and with recycled water. The total fresh water requirement for a day is 47650L. Rest of the water demand is met through recycled grey and black water. For keeping the school functional, we need the fresh water supply for 5 days and so we have installed a water tank of capacity 238KL. This water tank will store water for everyday use and water for one day will be used from it and then restored from the supplied water.

As for the non-potable water requirements, we have ensured through detailed water calculations that the irrigation and toilet water requirements are met by the treated black water from the phytorid treatment plant whereas the washing and cleaning requirements are met by the treated grey water. Since these treatment plants have a retaining period of 24 hours, they provide the daily water requirements as long as the input of fresh is consistent, which is ensured for 5 days. If we include the 2 weekends, when the water demand is reduced to just irrigation use, we can conclude that we have water capacity for at least 7 days, which was our goal.

Safety and Security

The success or failure of any school is predisposed on how well it integrates security and crime prevention through environmental design. Crime Prevention Through Environmental Design (CPTED) is an approach that focuses on improving the design of the built environment to help reduce opportunities for disputes and violence and promote positive behavior. CPTED aims to ascertain the safety of three assets- people, information and property. CPTED involves building a safer environment to reduce the opportunities for crime incidents. Proper site planning and building planning plays an important role in this.

CPTED strategies include three major methods- the electronic method, the architectural methods and the organizational method. In the design method, we have designed the school in a way that provides maximum natural surveillance and deter any intruder from coming in. The boundaries of the site have been well demarcated and fenced. Pedestrian walking areas and vehicular walkways have been separated. The public and private areas are separated from one another and they are marked by change in pavers and fences. Bus parking is inside the campus. The administration area faces the front so that people can keep an eye on who is entering and when. The electronic method includes the use of CCTV cameras to keep a surveillance on the students and intruders, RFID tag is used for cars to be parked in the basement. Organizational method includes positioning of guard rooms at the entrance.

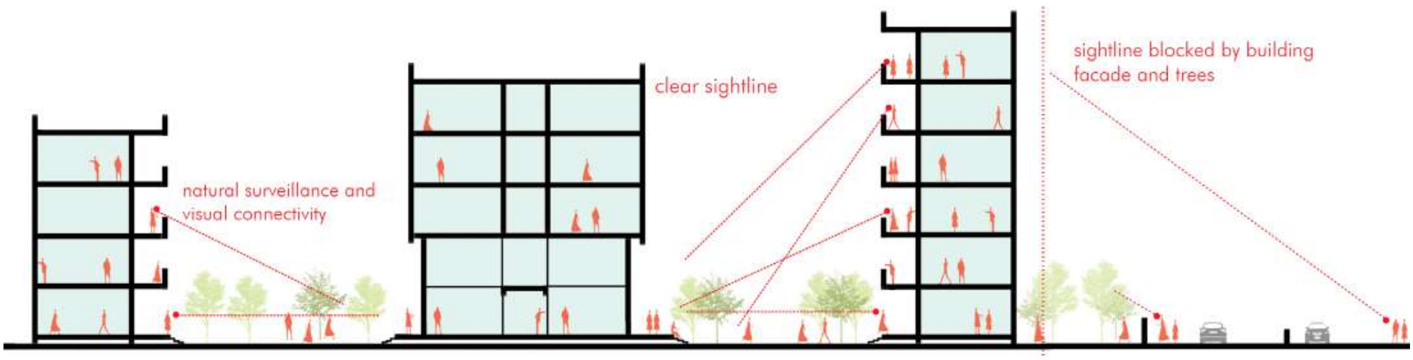


Figure 24: Natural Surveillance

Certifications

As per the client's special requirements, we have to propose the building design which can get LEED platinum and WELL certification.

LEED is a green building certification program used worldwide. It includes a set of rating systems for the design, construction, operation, and maintenance of green buildings, homes, and neighborhoods which aims to help building owners and operators be environmentally responsible and use resources efficiently.

We have to target LEED Platinum rating as per the client, which requires at least 80 points out of a maximum of 110. We have worked for 97 points, and are confirmed about 81 points which fulfils our goal of LEED Platinum rating.

The WELL rating is a performance-based system for measuring, certifying and monitoring features of the built environment that impact human health and wellbeing. It aims to prevent chronic diseases by improving the nutrition, fitness, mood, sleep patterns and performance of its occupants.

In order to get WELL certification, we have to fulfil 10 pre-conditions. Then the improvements count for certification levels. We have worked on all 10 pre-conditions but we lacked the needed assistance to fill the scorecard.

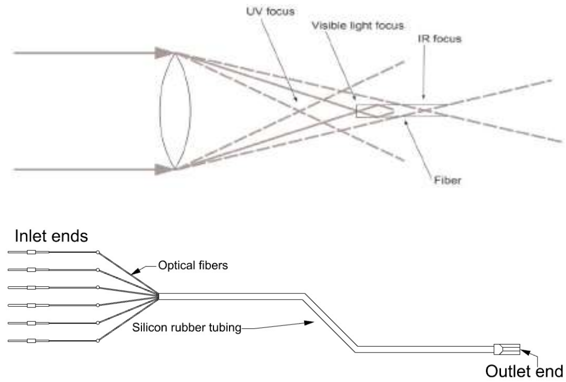
The filled scorecard for LEED checked by our faculty lead Dr. Shweta Manchanda, LEED AP, is attached in Appendix 10.

Innovation

1. Optical lamp

Globally electrical lighting accounts for almost 20% of the electricity consumption . We can reduce half of this electric consumption with the help of natural sunlight by using a system which collects sunlight and distributes it to indoor spaces lacking natural daylight . Replacing artificial lighting with natural sunlight reduces the energy cost on the production of greenhouse gasses , moreover sunlight is also proven to increase productivity by up to 16% .

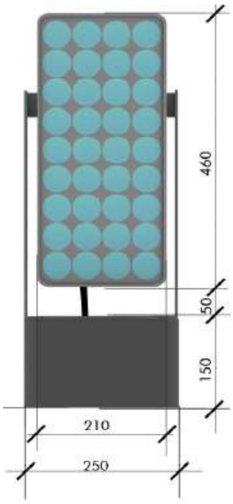
Figure 25: Optical Lamp in Building Section



Reference - This method was first invented by Dr.Kei Mori , [La Foret Engineering Co.,Ltd]

Figure 26: Optical Lamp Ray Diagram

We developed a system that delivers sunlight to dark spaces with the help of fiber optic cables in the most cost effective way possible. Receiving units capture sunlight from the outside of a building. Convex lenses installed on the receivers concentrate the sunlight into flexible fiber optic cables (avoiding UV and IR rays) which transport the sunlight to spaces which lack windows and are dark. The receiving units are equipped with sun tracking sensors and rotate with the movement of the sun in order to collect direct incident rays throughout the day. The receiving unit measures 250mm X 250mm X 670mm.



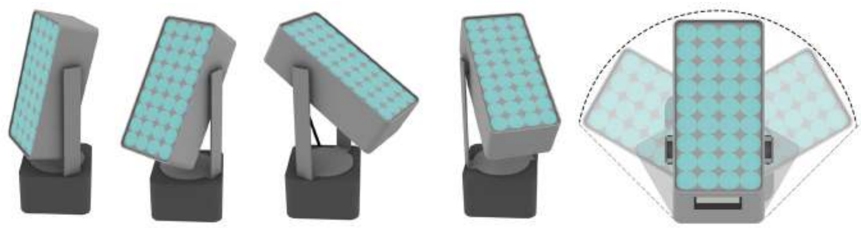
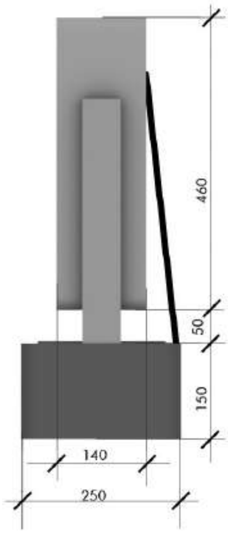


Figure 27: Optical Lamp Specifications



These sunlight receiving units can be installed on the roof,terrace,south facade,etc. where there is unobstructed sunlight.

The two axis tracking system follows the path of the sun during the day, while also adjusting horizontal angle throughout the year in response to the position of the sun in the sky from season to season. This system returns at night to the sun rise position , ready to immediately start tracking when the sun rises.

Light converged from six convex lenses lead to one distributing outlet where light is emitted at a spread angle of 58 from the edge of the optical cable. At two meters from the end of the optical cable, and approximately 2.2m diameter circle region (an area of 3.8m2) is illuminated at approximately 500 lux on average, taking the intensity of incident rays in the region.

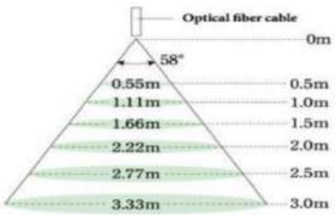
*In the case of direct illuminance from the sun of 98,000 lux

Illumination distance [m]	Average illuminance [lux]	Illuminance (center) [lux]	Illuminant diameter [m]	Illuminant area [m²]
0.5	7,967	11,154	0.554	0.241
1.0	1,990	2,786	1.109	0.966
1.5	884	1,238	1.663	2.172
2.0	497	696	2.217	3.860
2.5	318	445	2.772	6.035
3.0	221	309	3.326	8.688

Core size	1.0mmϕ
Number of cores	6 cores
Fiber length	15m
Luminous flux per cable	1,920 lumen * (lm)
Illumination angle	58°

*The unit of measurement for quantity of light= Lumen: One lumen is defined as the quantity of light that illuminates an area of 1 m² at a illuminance of 1 lux.

[Reference- Laforet Engineering co. Ltd., 2001]



Coverage of light at the outlet point.
[Reference- Laforet Engineering co. Ltd., 2001]

This light brings a feeling of skylights in these spaces where skylights are not actually possible. Since natural sunlight is transported into spaces in real time, the light shows beautiful variations in intensity during the length of the day, bringing a natural feel to the space.

2. Adaptive POD

Whether it is the courtyards, the open gardens, the playground or the huge multipurpose hall, all these space need to be designed and changed from time to time according to the different functions and purposed they are used for. With fast-changing trends in design of spaces and the need of sustainable and reusable solutions, modularity has gained a lot of popularity in the product industry. The use of units that can function individually eases manufacturing. It speeds up the assembling process of the system, and also increases the flexibility of the use of the system or product.

Keeping in mind the range of different activities that are carried out in a school campus, we designed a simple and easy-to-install kit for creating modular pavilions. The kit includes 2.4 meter long bamboo sticks, metal joints for corners, light-weight bamboo board louvers, stretched fabric louvers and stretched fabric sheets. These bamboo sticks can be joined together with the help of the metal joints in any desired combination to create a range of different kinds of spaces catering to different needs and functions. This range of reusability is further increased by the variety of partial and full covering of sides of the module, as shown in the illustrations.

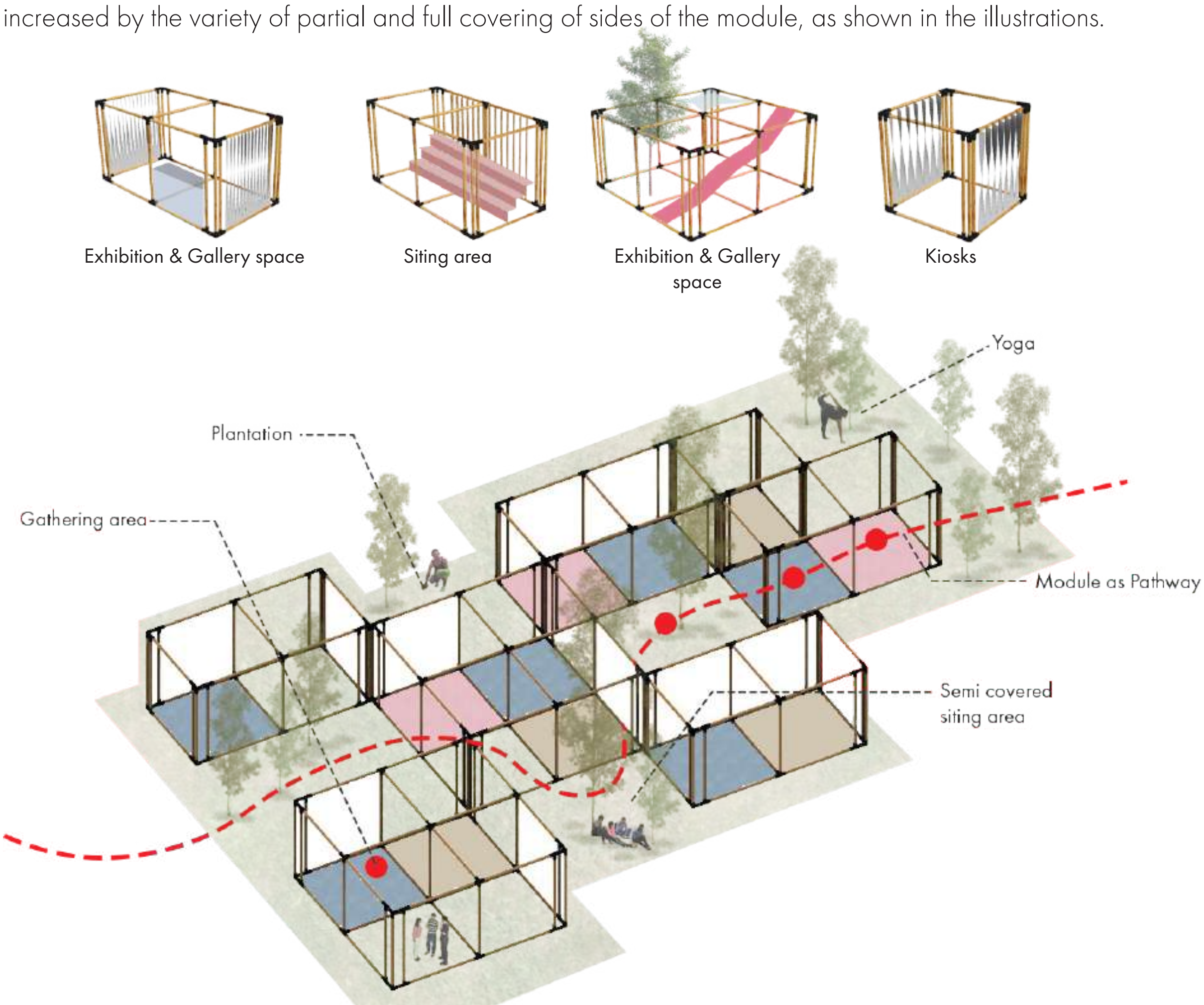


Figure 28: Adaptive POD

Building small parts that can be put together later is much easier than building one complex piece. The modules become increasingly complex and customizable, changing to fit the situation. These modules can be used as relaxing spots for students in the courtyards, or kiosks for the school fete, exhibitions in the multipurpose hall, and can even be rented out for any other possible use.

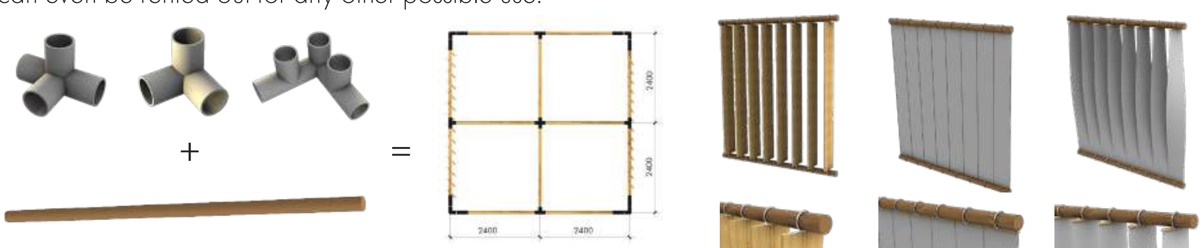


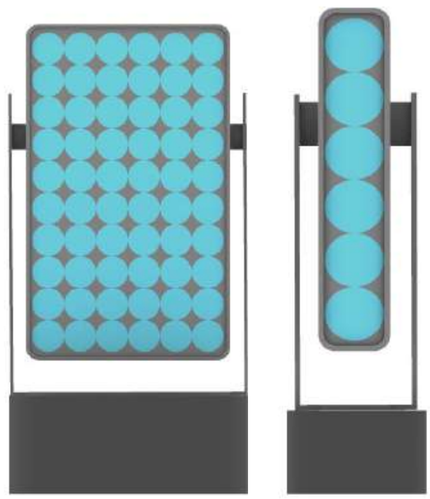
Figure 29: Adaptive POD Module Specifications

Scalability

We received a relatively small site of 15256 square metres to design a school campus catering to a manifold of functions for 2200 students. We saw the lack of space as an opportunity to venture into the world of modularity to create adaptable and multifunctional spaces. Due to this approach, we reduced our occupant density substantially compared to other IB schools in the area offering the same amenities. Modular spaces, similar in shape and size, can be linked to each other with retractable walls so rooms can be expanded or contracted as per need at the time of use. We proposed a multipurpose hall as our sports block that doubles as a gym and auditorium space with multisports courts instead of allocating separate areas for all functions. This approach creates a multifunctional structure with maximum flexibility, providing a clever solution for a realistic problem faced by many high-density projects. To go along with it, we used a dynamic HVAC system using variable refrigerant flow to cater to the needs of adaptable spaces.

The rapidly growing population of the NCR region would bring up many practical challenges in the near future, including an overall shortage of schools. Our approach to school design based on adaptability would present a desirable and scalable solution. This strategy is fit for large-scale implementation as it reduces construction time while also being environmentally friendly as the flexibility to change with the changing needs of time without the need for demolition or new construction uses less resources and energy.

Scalability might mean different for different types of products. It can be the endurance or the adaptability of the design depending on situations. For our modular systems, it is the flexibility to use the system.

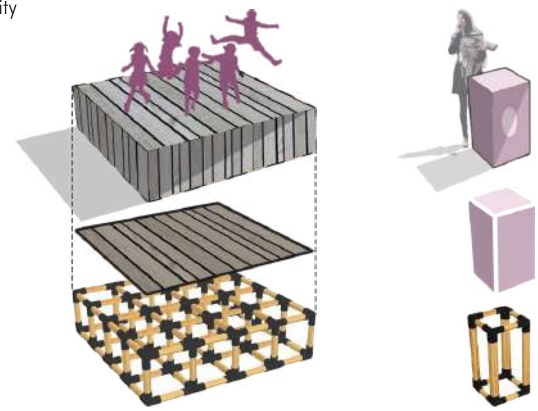


Talking about the Optical lamp system, it uses a number of convex lenses in an assembly. The designed modular lamp system uses six units of a 6-lens system to provide light needed for our room size, i.e. 60 sqm. The number of 6-lens system units can be increased or decreased as per the area requirement. We have tried till 10-unit system which can light up around 100 sqm area.

The smaller modules (1-unit - 3-unit) might get expensive as compared to bigger ones. While the assembly becomes heavy to rotate if we go beyond a 10-unit system (figure 30). But this can still be scaled and used as a pv panel system if used as fixed. The cost factor is unknown at this stage but we have certainty about the reduction in electricity

Figure 30: Adaptive POD Scalability

The similar system works for the adaptive pod. The size of the module itself can change by providing different sizes of bamboo and fabric. Same joints as long as we are providing the same diameter for the bamboo. We have proposed this big module as per our need, but the different sizes can be used even in public (figure 30). The sizes like 600 X 1200 can be used as an exhibition podium (figure 30). Changing the whole module opens up a whole new world to be explored and just leaving them with the kids is the best solution for it.



Market Potential

According to the Noida master plan, our site is allocated for an educational facility. It is the only site in the entire sector allocated for this purpose which would make our building the designated school for all children in the area who are between the ages of 3 to 18.

The target market of ORD International School would be families with children residing in Noida Sector 134. This area has a large population of people working in the business and service sector belonging to the high-income groups and also includes some expatriate workers from South Korea and China. A premium IB school would be ideal to cater to the academic needs of children belonging to this specific group since it offers prime amenities and enables students to join institutions outside the country for further education.

The immediate context of our site is still developing in terms of infrastructure and lacks basic amenities at the moment. It also does not hold the population for which it is planned. Across the street from our site lies the JAYPEE Wish Town, a developing township which ensures new people moving into the area (Refer to Project Summary) and gives our school the opportunity to attract all the children. Planned development of the area paired along with the fact that our school caters to the needs of the target demographic would make it enticing for the intended market.

Other educational facilities in the 5-10 km radius surrounding our site are- Step by Step School and Genesis Global School; the boarding schools of the area offering CBSE, IGCSE, and IB curriculums. After studying the Fee Structure for the schools offering IB curriculum, we can conclude that the fee range is ₹1-5 lakhs per term (quarterly) depending on the facilities they provide. The schools mentioned above-made use of their large sites to provide dedicated spaces for different uses, i.e. separate open fields for sports, theatres, activity rooms, separate facilities for different sports, etc, and hence have higher occupant density.

Lower Occupancy Density in our school gives us an inherent advantage over the other schools in our area in terms of market potential. Most IB schools provide 10-15 sqm for each child studying by allocating separate spaces for all the different functions. We capped this to 8 sqm, increasing the total carrying capacity of our school. We have designed spaces that can be adapted for multiple uses as per the need (Refer: Appendix 1c)

Modular spaces are designed for classrooms and labs which are similar in shape and size, linked to each other with retractable walls so rooms can be expanded or contracted for efficient reuse. We have also provided a multipurpose hall which doubles as a gym and auditorium space instead of allocating two separate areas for both functions.

We have discussed with IB School Authorities about the school & curriculum requirements to get know about the stakeholders and their role in this project. The following graphic (figure 31) gives an overview of the same.

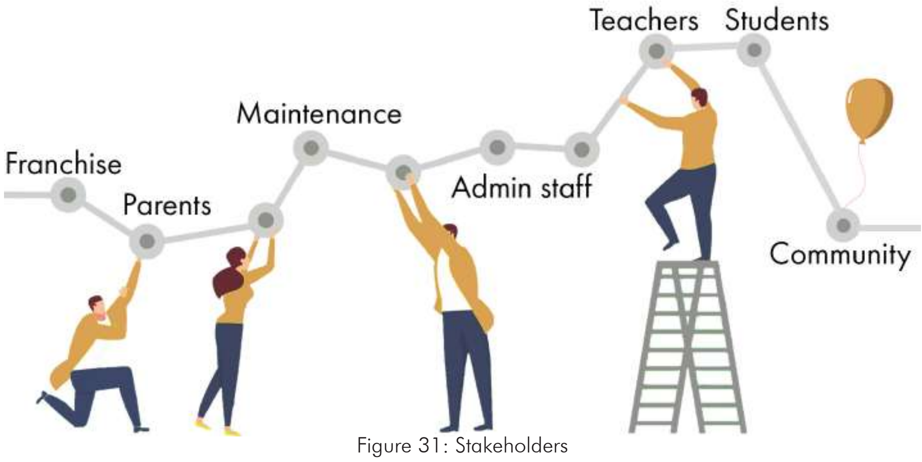


Figure 31: Stakeholders

The multi-utility spaces with the increased carrying capacity will eventually decrease the individual expenses. This will make more profits even with less student fees (Refer: Affordability). Our focus on biophilia and sustainability along with the achievements of our building with respect to energy and water performance would also attract an audience.

The Building Management system, using interactive visual displays which aims at educating students about sustainability and would imbibe them with energy saving habits would distinguish our school from others that focus solely on academics (Refer: Operations) would further increase our market potential. All this would add up to parents getting maximum benefits in terms of holistic development of their children at the least cost.

Affordability

The concept of affordability is subjective depending on the users and providers. For our project, the direct users are the students and staff, whereas the other stakeholders include the client and the parents (figure 31.). Affordability in this case is defined as giving the best service in least possible expenditure. And so, we went through the approach to cater the students targeting the parents, and provide indirect value for the owner.

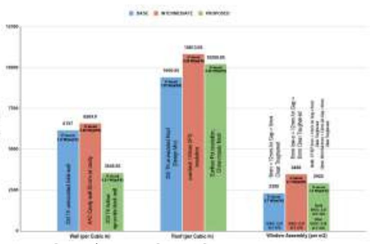
The approach was to plan and design the aesthetics and infrastructure of the building which can also help in optimising the performance at energy, water and comfort criteria. This includes the selection of materials for building envelopes and interiors, choosing and right sizing the HVAC system and selection of the components to generate electricity and improve water performance.

Starting with the building envelope, we tried using materials available in the vicinity to cut the transportation costs and hence provide the best prices. The roof and window assemblies are chosen from the local market and the wall assembly will be transported from the firm based on Roorkee as the chosen one is the company innovation providing high performance at prices better than conventional ones. LED lights and star rated equipment are our choices to get the value for money..

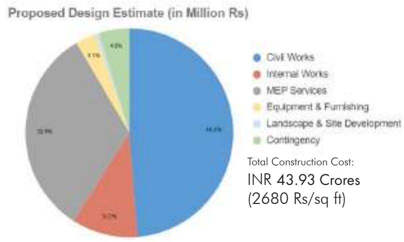
For Water Systems, we are using efficient plumbing fixtures with low flow rates. Although these fixtures are more expensive, we save money on the monthly utility bill as this uses less water. The black water treatment is done by Phytorid technology and grey water is treated by sand filtration. Compared to the conventional processes, these natural systems are zero energy and zero operation & require less maintenance.

With regards to interior spaces, we used gypsum partition walls as a cost-effective alternative to masonry walls or wooden partitions. For the classrooms we designed cardboard furniture which would be made out of discarded cardboard packaging and cost immensely lower than regular store bought furniture. The interior floor finishes and paints were decided on after doing a rigorous market survey and and cost analysis of all materials that were of a certain quality befitting a premium IB school.

The adjoining graph shows the cost comparison and selection criteria for the wall, window and roof assemblies. The proposed product details and specifications are provided in Appendix 8. (Refer Appendix 8)



Graph 12: Cost Comparision



Graph 13: Proposed Design Estimate

The attached excel sheet for costing includes the detailed Bill of Quantities for the project based on the prices from the prevailing market. The same sheet includes the Business model and detailed Life Cycle costs for the system wherever applicable. (Refer: Cost Estimation Excel and Appendix 11a)

Finance and management:

The property has to be leased to the school authorities to run and manage. This should make our task easier in this field. But, the building being in an educational typology, we need to look at the financial model at some extent. By studying the Business Model for a typical school, we know that the only source of income for the school is the fees collected from the students. But the expenditure includes the staff salaries, franchise fee, maintenance, marketing, catering, equipment, electricity and transportation (if provided). We are proposing to use the multipurpose hall on holidays for various camps which will generate income. The building performance and the lower occupancy density reduces the overall cost per student. Hence, we have proposed lesser school fees when compared to similar schools (Table 11). Refer Excel - Business Model assumptions for more details.

	Cost / yr	Remarks
Total Operational Cost	₹ 190,813,720.15	Refer Business Model
Expected minimum profit	₹ 70,000,000.00	school + client (30% margin)
Income Required	₹ 260,813,720.15	opex + profit
minimum Student fees required / term	**₹ 118,551.69**	2200 students

School	Avg. yearly fees (INR)
Pathways, Aravalli	₹ 680,000.00
British School, Chanakyapuri, New Delhi	₹ 800,000.00
Genesis Global School, Noida	₹ 454,000.00
Our proposed fees	**₹ 120,000.00**

Table 11: Business Model Overview

Engineering Design and Operations

Structural Design

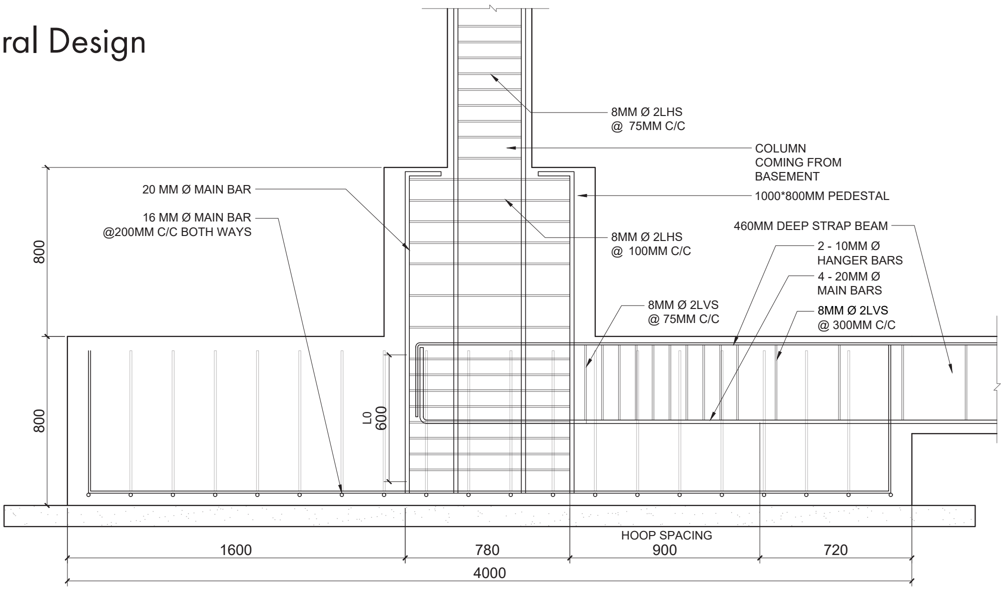
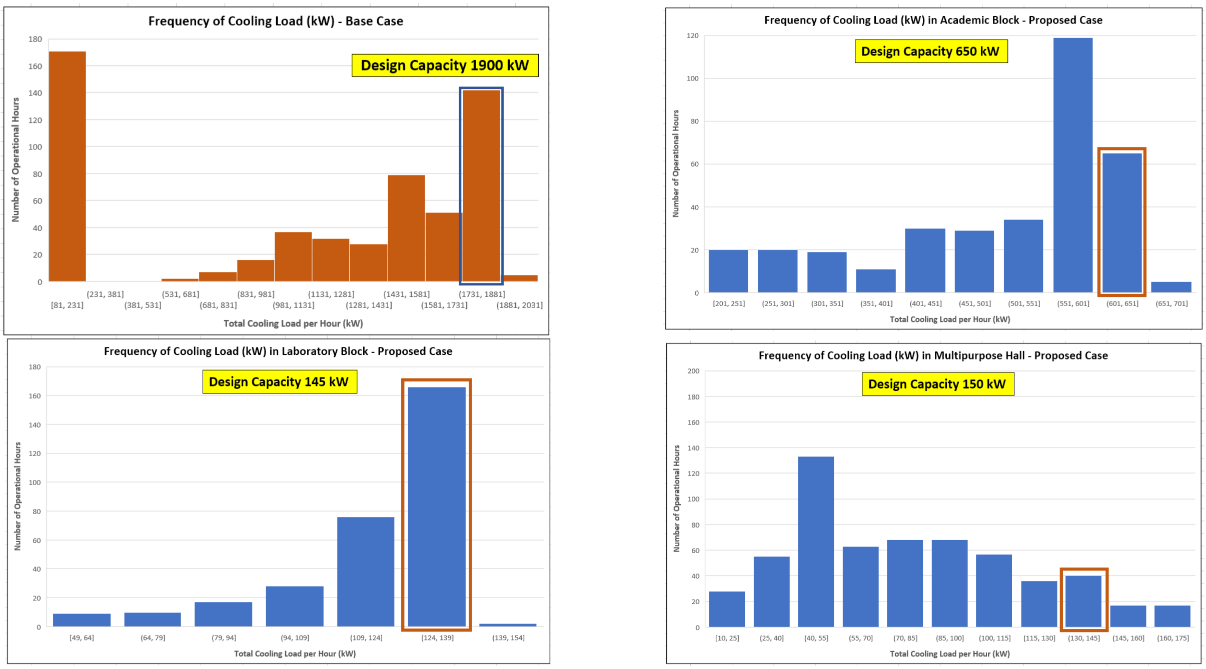


Figure 32: Strap Footing

There was no need for special structures for our building because of the typology. So, we chose the conventional RCC framed structure for the school. The effective grid of 6.5m X 8.5m made it possible to have one-way slabs much easily. For the large span of the multipurpose hall, we have designed the steel truss which will provide nominal slope for the solar panel accommodation Refer: Appendix 3 for all calculations and details. The structure has been designed in accordance with following codes: IS456:2000, IS 13920:2016, IS 800:2007, IS 2502:1963 (Reaffirmed 2004), IS 816:1969 (Reaffirmed 1996)
We have integrated strip foundations (figure 32) which is immensely effective in terms of shear forces and bending moments. Strip footings are least expensive and perform well against the earthquake forces also. The ductile detailing and separation joints are provided for the earthquake resilient design as per IS 1893:2000.

HVAC Design



Graph 14: Cooling Load Calculation

Considering the Design, the Peak Load for the Base case came out to be 1900kW (~550 tr),which turns out to be 150 sqft/tr for the conditioned areas.

For the proposed case, the Peak Load came out to be **950kW (~270 tr)**, which turns out to be **368 sqft/tr** for the conditioned areas. Out of the total peak load, **700kW is the required load for 88% of the conditioned areas** for the academic block in which **5 Wind Towers** are installed, and for the remaining 12% which constitutes of Multipurpose hall and Dining area, **150kW** is the required load which is connected to 1 Wind Tower. After pre-treating the air the cooling load is **reduced by 50%** and hence VRF systems are installed for better part load Efficiency.

Catering the above cooling Load, total 17 VRF Air Cooled Outdoor units (Coefficient of Performance 4.47) are proposed each of the Capacity of 16kW. Out of 17 systems, 3 Outdoor Units are installed on the South block, while 3 Outdoor Units on the middle block and 2 Outdoor Units on the north Block.

For 100% of the conditioned areas, the air would first pass through the **Evaporative wind tower** which draw in air through mechanical fans. This reduces the outdoor air temp, hence pre-cooling the atmospheric air, then the air is passed through the Air Handling Unit (AHU) on each floor, wherein the AHU treats the air for impurities and humidity, and then the air is passed on to Heat Reclaim Ventilation in each zone, where the refrigerant coming from the Outdoor Unit helps to cool down the air further to the comfortable range, which is monitored by the Building Management Systems installed. The air is then supplied to the zones by using Displacement Ventilation System.

Operations of Wind Tower

In the Academic block, there are 5 Evaporative Wind Towers installed each with the maximum capacity of 12,000 cfm having the dimensions of 3mX3m with the height of the tower being 18m. The air is drawn through the mechanical fans. Similarly, in the Multipurpose hall and the canteen, there is 1 Wind Tower installed.

The wind tower is divided into 4 sections:

1. **Spray Chamber:** The top portion in the tower which has air inlets. A pipe header with nozzles that spray water evenly to next section is also there. The size is based on the quantity of water required for evaporative cooling.
2. **Solid Fill:** The second section is filled with waste cement blocks collected during the construction (Approximately 100 Ton) arranged in a way so that the air and water should pass through easily.
3. **Air Outlet Chamber:** This chamber contains two air outlets, a fan and gravity dampers.
4. **Sump:** Bottom portion is a water sump with submerged pump.

The operation of the wind tower is divided into 2 Cycles, namely, Night cycle and Day cycle.

Night Cycle:

During night cycle, the cool dry night air is drawn in at the top (with the help of a fan at bottom of the tower) and is further cooled by evaporation in sprinkler chamber. The cement mass gives away heat to passing air and water and in the process cools down substantially. Saturated air is exhausted out; the water drops into the basin for re-circulation.

- After the routine for the night starts, say at 2200 HRS, the solenoid valve (Timer) remains `ON´ for 25 min.
- During this period, the tank is filled up to its maximum required capacity.
- After that, the pump remains ON for 2 min. and OFF for 10 min. until the level of water in the tank drops to the desired level (determined by the Flow Switch). The system functions as per this cycle the whole night depending on the water level.

Fan remains ON continuously during night operation

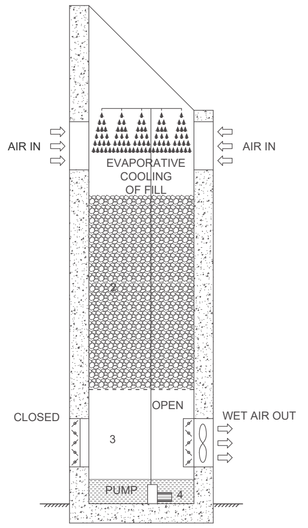
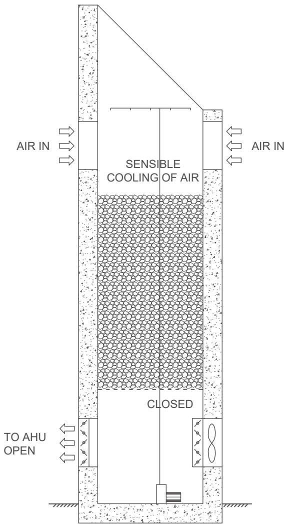


Figure 33: WInd Tower Schematics



Day Cycle:

During the day cycle, the pump is off, and the large mass of cool cement blocks remove heat from the hot air going to the AHU, thus saving energy by reducing the cooling load.

- The Pump & Fan system of the Wind tower is shut OFF.
- The Drain valve is operated to drain off all the water in the tank for 4 hours.

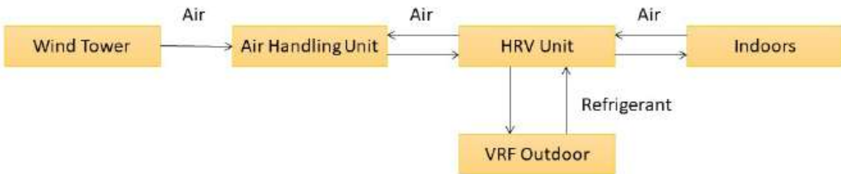


Figure 34: HVAC System Schematic

Building Operating System

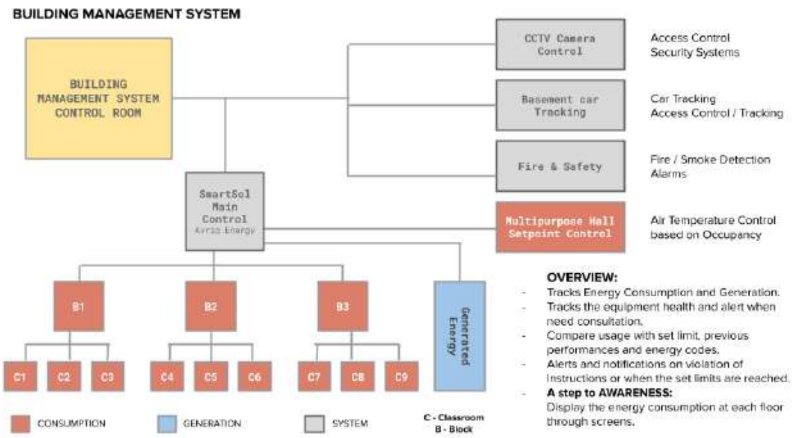


Figure 35: Building Management System

Energy saving is more crucial even though we are generating energy from renewable resources. In the household level energy consumption can be reduced thoughtfully but in the case of large occupant areas like schools it is very challenging. In case of school majority of the occupants are students and they are monitored by the faculties . We can use this system for the advantage in decreasing the consumption of energy. The games are the most important aspects in children's life as they help in their mental and physical development. We designed an app which is educating students about sustainability and environmental impacts by gamifying the way they use the energy in the campus and Imparting competitive behavior to save energy among the class by rewarding them for best performing class in terms of energy use. This system will create the habit of saving energy in their daily life.

Figure 36: Application UI

How is it done ?

We have implemented an in class energy load, A/c usage monitoring system, Which will record the consumption of electricity, usage hours by class wise from their activity like equipment, leaving lights on during inactive hours, Charging their devices even if it is fully charged. Which will increase the consumption. The device will record the results and Project the comparison report on the dashboard in front of the class. The class performance will be recorded by the faculty in their mobile app. Along with this waste generation will also be recorded. All this data is compared with 1 day and 30 period of time. Energy performance can be improved by indulging in saving energy habits in children if we increase the priority as other performance measures in the school.

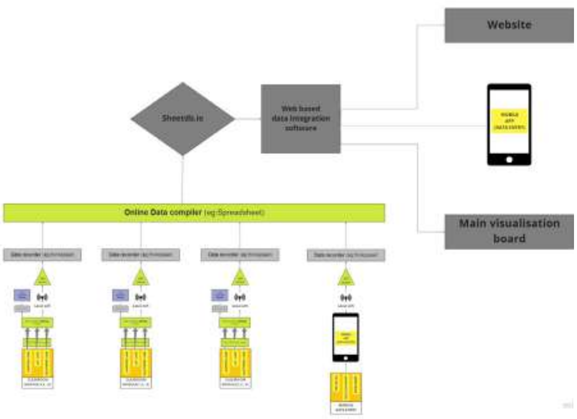
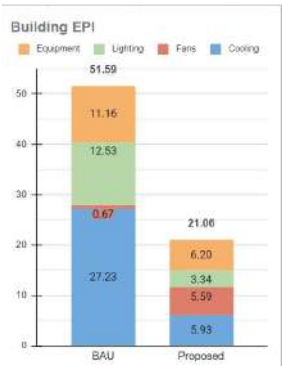


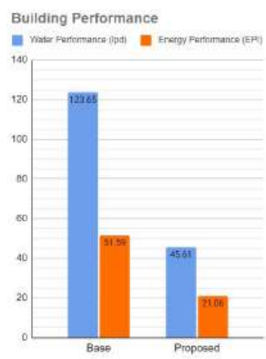
Figure 37: Software Script

Pitch to the Project Partner

ORD International School as designed by us is a 15131m² , six storeys high building and serves 2200 kindergarten through twelfth grade students.The building with an EPI of 21.06 offers an energy use reduction of 60% over a standard school in Noida and harvests more energy from renewable on-site sources than it uses on an annual basis.

1650 square-metres of photovoltaic array on the 3650 roof area generates solar energy equal to 32.21 EPI , making the building net positive and more than able to meet all its renewable energy demands.





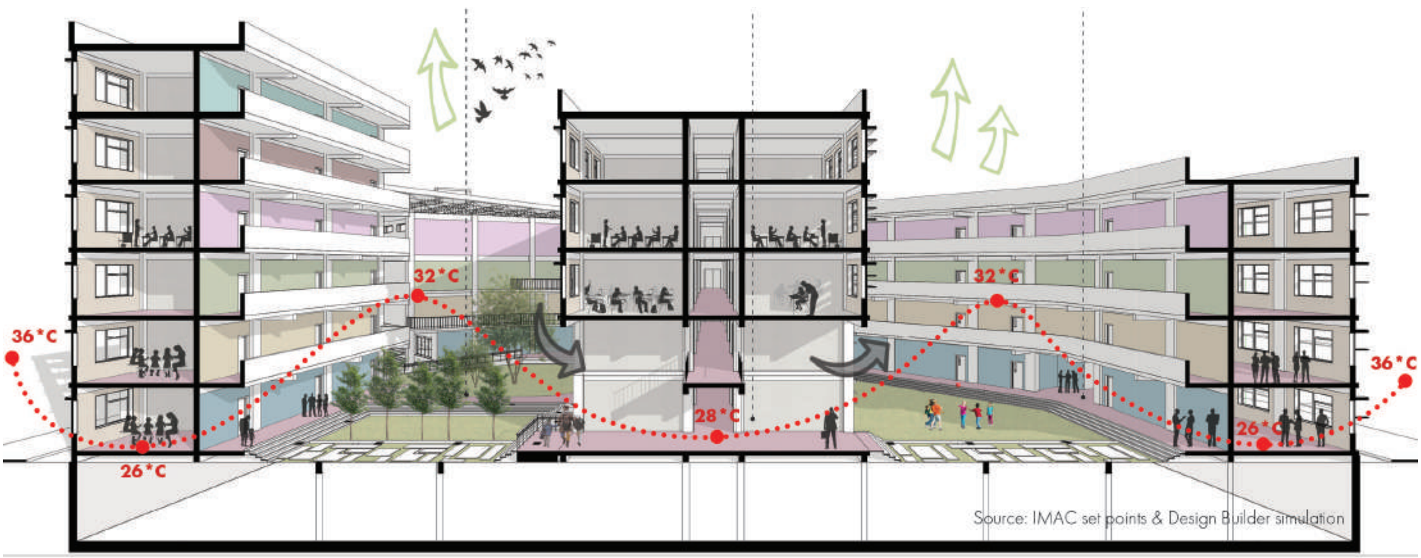
The team has worked out a net zero water cycle on site with zero wastewater discharge. Through tightly integrated water management strategies, the water consumption of the building is reduced to 45 litres per person per day as compared to our base case of 123 litres per person per day .

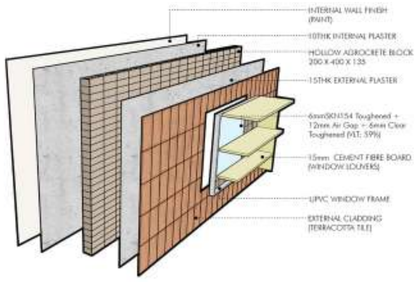
Daylighting

- Passive tecniques used yield classrooms that have as much as 80% daylight autonomy— a metric that defines the portion of normal school hours for which artificial lighting is unnecessary
- Building-wide, the average daylight autonomy is 67%
- Any lighting fixtures are only supplementary and have daylight harvesting capabilities.
- Daylighting isn't only about energy saving. In combination with biophilic design it simulates an association with the outdoors. This is proven to help with improving the mental, physical and psychological well-being of students.

Passive Strategies

- Optimum orientation and massing of the building along with integrated courtyards create a cool microclimate.
- Thoughtfully designed shading devices create the optimal conditions for daylit interiors.
- The passive strategies used result in making 78% of the annual operational hours comfortable without any need for air conditioning.



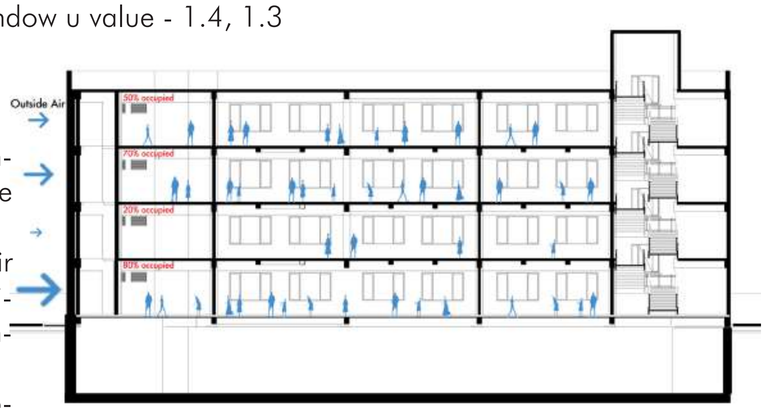


Building Envelope

- For the school to require as little energy as possible for heating and cooling, we designed a heavily insulated building envelope with low U-values.
- Walls u value- 0.312
- Roof u value- 0.263
- Window u value - 1.4, 1.3

Indoor Climate Control and Air Quality

- The building has two-stage cooling combining wind towers and VRF system to cater to the comfort temperatures derived from IMAC.
- To tackle health concerns related to poor air quality in the NCR region we went for a dedicated outdoor air system with heat reclaim ventilation.
- Perimeter displacement induction units supply conditioned air at a low velocity, which makes the devices both efficient and quiet.
- These units use occupancy sensors to supply fresh air in the occupied zones only, preventing unnecessary fresh air supply.



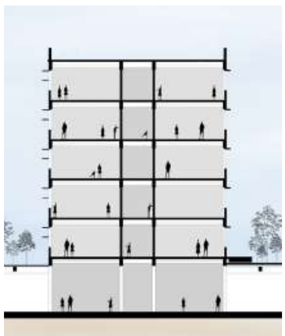
Adjust fresh air intake based on occupancy
Ventilation demand is determined by CO2 level (ppm)

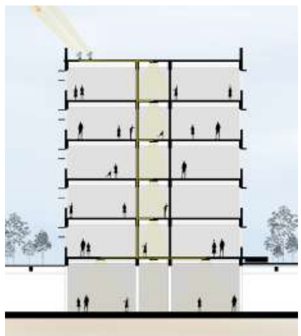
Interactive Dash Board for Engagement

- Interactive dashboards mounted throughout the building offer an opportunity for students to have a part in helping the school reduce its energy and water consumption.
- The kid-friendly graphics will display information like weather conditions, the amount of electricity generated by the PVs, and the amount of energy and water used in each space.
- This creates an opportunity to hold energy-conservation competitions between classrooms as a fun way to motivate children and help them gain environmental literacy.

Optical Lamps

- We developed a system that delivers sunlight to dark spaces with the help of fiber optic cables in the most cost effective way possible.
- Replacing artificial lighting with natural sunlight reduces the energy cost on the production of greenhouse gases
- sunlight is proven to increase productivity by up to 16%.
- These sunlight receiving units can be installed on the roof,terrace,south facade,etc wherever there is unobstructed sunlight.





Certifications

- The building is designed to comply with **IGBC LEED Platinum** as well as **WELL Certifiction** certification.

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