

NEARLY ZERO ENERGY SCHOOL

A THESIS

Submitted in partial fulfillment of the requirements for the award of
Master of Architecture degree in Sustainable Architecture

By

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SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)

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MAY 2024



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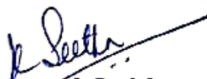
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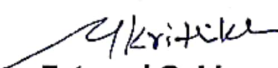
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This is to certify that Thesis Report is the bonafide work of **Valroshini K (42890007)** who carried out the Thesis entitled "**Nearly zero energy school**" under our supervision from January 2024 to May 2024.

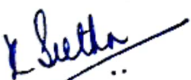

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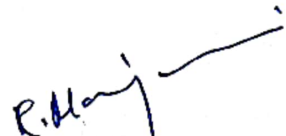

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DECLARATION

I, **VAIROSHINI K** hereby declare that the Thesis Report entitled "Nearly Zero Energy school " done by me under the guidance of **Ar.Seetha Visalakshi K** (Internal Guide), **Ar.Catherine Selvaraj** (Internal Review Member) and **Ar.Krithikha Muthukrishnan** (External Guide) Sathyabama Institute of Science and Technology is submitted in partial fulfillment of the requirements for the award of Master of Architecture degree in Sustainable Architecture.

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ACKNOWLEDGEMENT

I am pleased to acknowledge my sincere thanks to Board of Management of **Sathyabama Institute of Science and Technology** for their kind encouragement in doing this thesis and for completing it successfully. I am grateful to them.

I convey my thanks to **Dr. Devyani Gangopadhyay**, Dean and Head of the Department, School of Building and Environment, Our Design Chair **Ar. Sarath Chandra Kanth**, thesis Coordinator **Ar. Catherine Selvaraj** for providing me necessary support and details at the right time during the progressive reviews.

I would like to express my sincere and deep sense of gratitude to my thesis Internal guide **Ar. Seetha Visalakashi K**, Internal Review member **Ar. Catherine Selvaraj** and External Guide **Ar. Krithikha Muthukrishnan** for their guidance, suggestions, and constant encouragement which paved the way for the successful completion of my thesis work.

I wish to express my thanks to all Teaching and Non-teaching staff members of the **Department of Architecture**, all my family members and my friends who were helpful in many ways for the completion of this thesis.

VAIROSHINI K

THESIS SYNOPSIS

Chennai, a bustling metropolis with a warm and humid climate, faces significant power demands that surpass even those of the entire state of Kerala. This underscores the urgent need for energy-efficient infrastructure, particularly in educational institutions where energy consumption is consistently high. The concept of a Nearly Zero Energy school presents a viable solution to this challenge, aiming to drastically reduce energy consumption while promoting sustainability and environmental stewardship.

An NZE school in Chennai would leverage a combination of innovative design principles and renewable energy technologies to minimize its reliance on external power sources. The design would integrate passive cooling techniques, such as strategic orientation, shading devices, and high-performance building envelopes, to combat the region's intense heat and humidity. Natural ventilation, combined with energy-efficient HVAC systems, would ensure a comfortable indoor environment while reducing energy use.

Renewable energy generation, particularly through rooftop solar photovoltaic panels, would play a pivotal role in achieving near net-zero energy status. These solar installations would harness Chennai's abundant sunlight, providing a significant portion of the school's energy needs. Inside the school, energy-efficient lighting, appliances, and smart energy management systems would further optimize energy use. The integration of green spaces and water management systems, such as rainwater harvesting and greywater recycling, would enhance the school's sustainability.

By adopting these strategies, an NZE school in Chennai not only addresses the city's pressing power demand issues but also serves as a model for sustainable development. This project would educate students on the importance of energy efficiency and environmental responsibility, fostering a generation of eco-conscious individuals committed to sustainable living.

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CHAPTER 1

1. INTRODUCTION

1.1 INTRODUCTION

Net-zero buildings are crucial in the building sector as they represent a significant step toward addressing climate change, increasing energy efficiency, promoting sustainability, enhancing occupant well-being, and contributing to a more resilient and environmentally responsible built environment.

They are an important part of global efforts to reduce carbon emissions and create a more sustainable future. It's a way of taking responsibility and leadership in addressing a shared global challenge.

In essence, achieving net zero emissions is critical for safeguarding the planet, promoting sustainable development, and securing a better future for current and future generations. It's an essential step toward creating a more environmentally conscious and resilient world

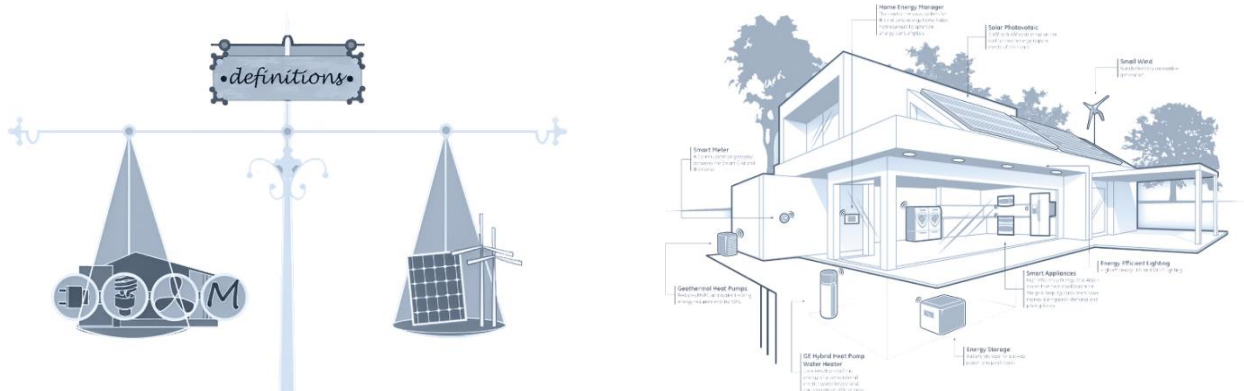


Figure 1.1 Net Zero Concept

1.2 WHY IT IS IMPORTANT?

As per global per capita energy consumption ranking, India ranks 7th but 579.1 million of the population do not have access to electricity. So, though India ranks 7th in consumption, more than a third of the population doesn't have proper access to electricity. To satisfy the energy requirement of this growing nation, a smarter alternative must be formulated.

1.3 GOVERNMENT FRAMEWORK AND INITIATIVES

The Prime Minister of India announced a net zero by 2070 target at COP26 in 2021 (Ministry of External Affairs, 2021). In December 2022, a “net zero emissions” bill was introduced in the upper house of the Indian parliament to provide a framework for achieving net zero emissions by the year 2070

1.4 WHY SCHOOL?

- Education can equip young people with the necessary skills to tackle the impact of climate change.
- A solid understanding of the factors contributing to global warming and problem-solving abilities are crucial.
- Student-led climate initiatives can enhance the quality of education and inspire efforts to combat climate change.
- Implementing these initiatives at scale across India's schools can help achieve net-zero emissions by 2070.



India is committed to achieve the Net Zero emissions target by 2070, says Minister Jitendra Singh



Green initiatives will be taken in the construction sector to make the country carbon neutral by 2070: Gadkari

Previous Story



Union Minister of State (Independent Charge) Science & Technology, Dr. Jitendra Singh said India is committed to achieve the Net Zero emission target by 2070, as announced by Prime Minister Narendra Modi. Minister said this while participating in the 'Green Ribbon Champions' programme in New Delhi on September 28.



Climate Change Should Be Taught At School Level

By IPS MAY 10, 2023

Carbon neutrality should be part of the curriculum to make the youth climate-ready, starting from schools: Prakash Javadekar



India has also allocated Rs 35,000 crore in the Union Budget for 2023-24 for priority capital investment towards energy transition and achieving the net-zero emission goal.

- 1 All educational institutions in India should make their campuses carbon neutral by 2030 to help the country achieve the target of net-zero emissions by 2070, former environment minister Prakash Javadekar said.
- 2 Addressing the launch of "U75: Net-Zero in the University Campus", a new initiative by environment NGO Green TERRE Foundation to make educational institutions in India carbon neutral by 2030, Javadekar said the initiative will create "required environmental sensitivity amongst students whose future depends upon our fight against climate change".

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Figure 1.2 Newspaper Articles

1.5 AIM:

To design a net zero school in Chennai's Warm and Humid Climate.

1.6 OBJECTIVE:

- To understand the fundamental principles of net-zero design, including energy efficiency, renewable energy integration, passive design strategies, and sustainable materials.
- To Investigate emerging technologies and architectural innovations that can be applied to net-zero school design.
- To develop a conceptual net-zero school design prototype that integrates cutting-edge sustainable technologies and practices.
- To Innovate strategies for engaging the school community, students, teachers, and local residents in the process operating a net-zero school.

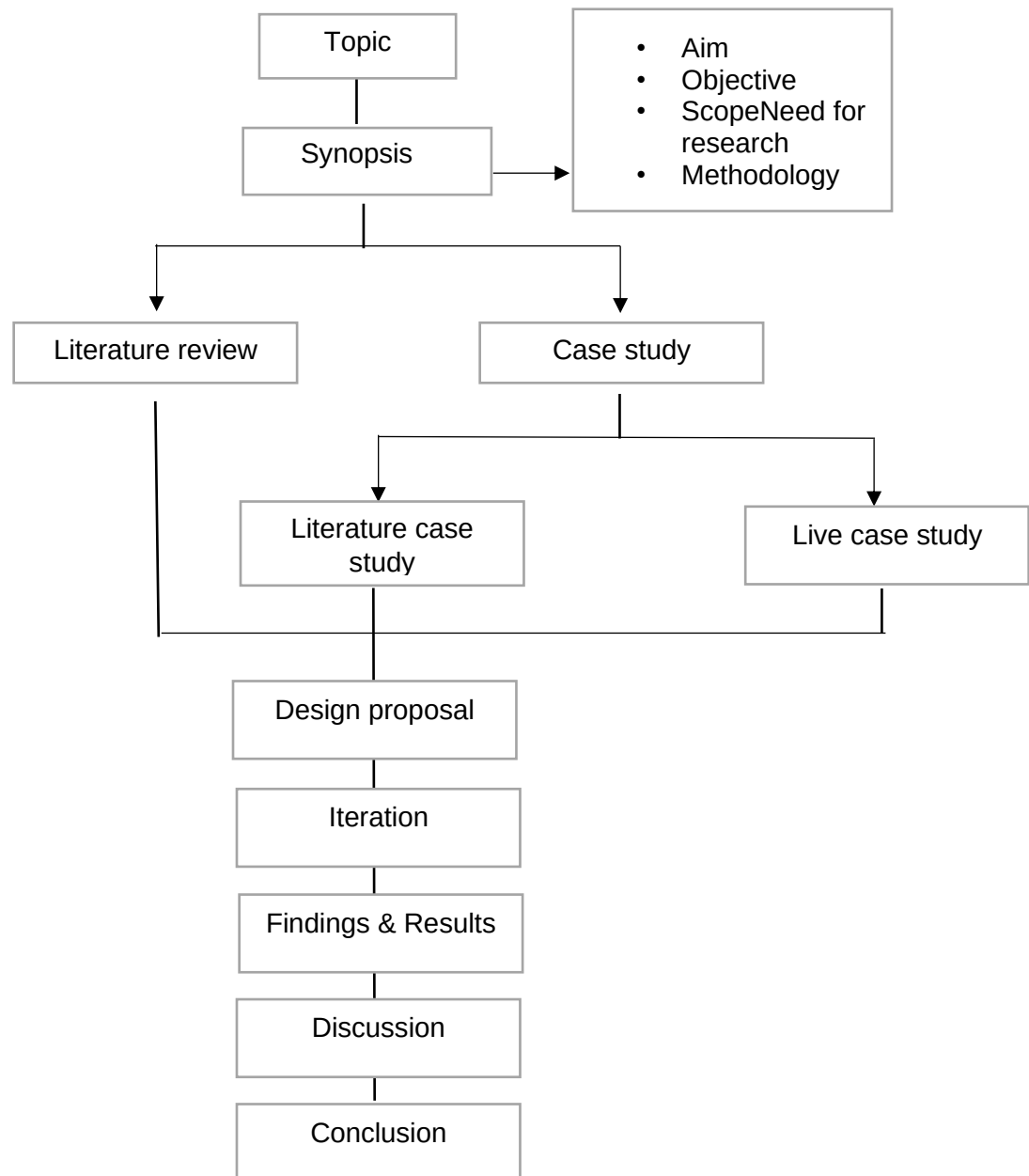
1.7 SCOPE:

- Implementing energy-efficient strategies and using renewable energy sources to reduce the building's carbon footprint.
- Increase in the reuse of waste resulting in a reduction of sending the waste to landfill
- Opportunity to convert waste to energy.
- Improvement in water efficiency and hence reduction in annual water consumption
- Reduce dependency on raw water. Reducing dependency on raw water consumption.

1.8 NEED FOR THE PROJECT:

- India faces significant environmental challenges, including air & water pollution and climate change.
- Net-zero schools generate their energy through renewable sources like solar panels, reducing reliance on fossil fuels and lowering carbon emissions, thus contributing positively to the environment.
- Building net-zero schools allows for hands-on learning experiences. Students, teachers, and the community learn about renewable energy, sustainable practices, and the importance of reducing their carbon footprint.
- India has committed to significant renewable energy targets and sustainability goals. Creating net-zero schools aligns with these national objectives.

1.9 METHODOLOGY:



CHAPTER 2

2. LITERATURE REVIEW

2.1 DESIGN GUIDELINES FOR NET ZERO ENERGY BUILDING (NZEB) IN WARM AND HUMID CLIMATE OF INDIA

Author: Dhruv Repuriya, Dr.Fahreen Bano

OBJECTIVE OF THE STUDY:

- This paper discusses active, passive strategies used to achieve net zero goal in high-performance commercial buildings followed by renewable energy generation.
- This paper concludes design recommendations and strategies for Net Zero Energy Building in the warm and humid climate of India

RESEARCH METHODOLOGY

First of all, net zero as a concept has been studied followed by different classifications and types of net zero buildings. Inferences are carried out, and after that design recommendations are concluded from the inferences for a NZEB in a warm and humid climate.

RESULT AND DISCUSSION

1.Orientation and Internal layout & planning:

- Building orientation is crucial for net zero energy buildings. N-S axis orientation is most beneficial as it reduces solar heat gain and maximizes use of daylight
- Compact plan to reduce solar heat gain & increase daylight penetration. Corridors & service cores on east or west to reduce heat gain from solar radiation.

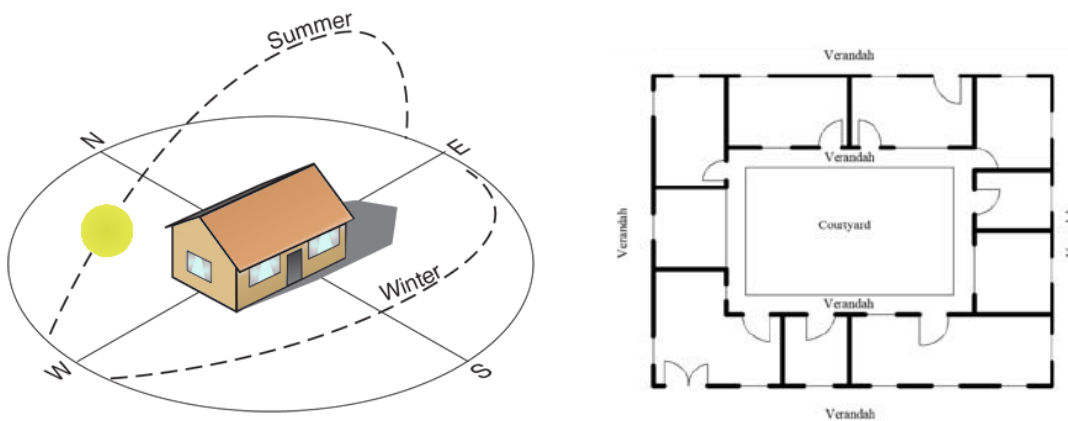


Figure 2.1 Orientation & Building Layout

Daylighting:

- Building orientation is crucial for side lighting, with south and north being ideal orientations.
- Top lighting is effective for spaces under roofs, and can also help lower floor levels through the use of atriums or light wells.

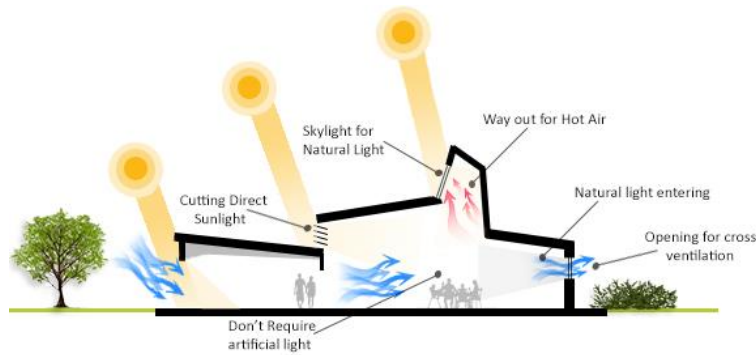


Figure 2-2 Daylighting Strategy

Ventilation:

- Operable windows can work with low-energy systems like radiant/desiccant cooling systems. Courtyard and stack effect are the most common strategies for natural ventilation.
- With the help of solar chimneys stack effect can be created inside the building spaces

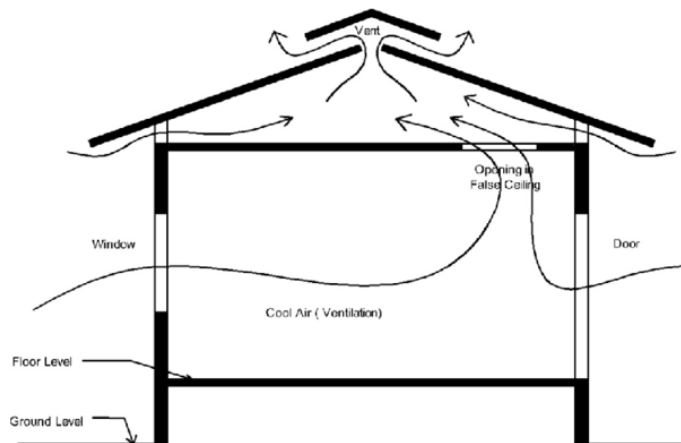


Figure 2-3 Wind flow Diagram

Building envelope:

- To reduce cooling load, use a low U-value envelope design with thick walls, insulated roof.
- High-performance windows, and U-value, SHGC, and VLT as per ECBC codes. Keep WWR within 40%.

Shading:

East and West façade windows need special type of horizontal and vertical shading devices. A horizontal overhang can provide effective shading on south facing windows.

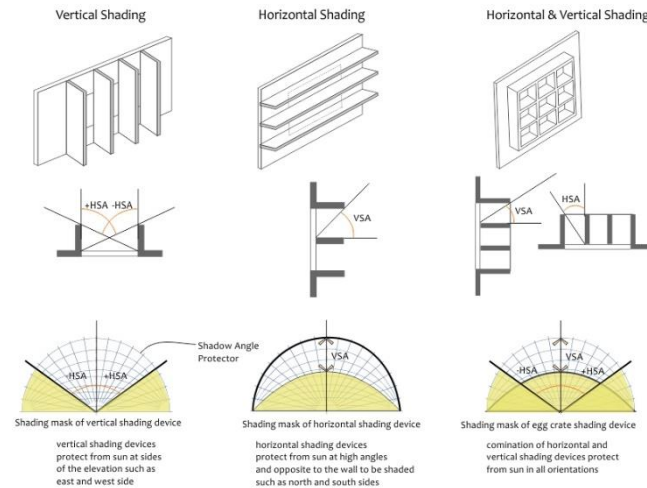


Figure 2-4 Types of shading device

Vegetation:

Landscaping vegetation provides shading & diffuse daylight into a building, as well as green roofs and walls, which can be used to shade external walls. However, maintenance costs for these systems can be high

ACTIVE STRATEGIES

Heating ventilation and air-conditioning:

Mixed mode and **low energy HVAC systems** can reduce energy consumption. **COP measures HVAC efficiency**. For net zero energy buildings, equipment should exceed ECBC requirements.

Lighting:

Use **low energy lighting fixtures like LEDs and luminaires**, implement occupancy sensors to reduce lighting usage. Use BEE star labelled to minimize energy consumption.

Energy efficient equipment:

Plug loads are a significant part of a building's energy consumption hence equipment should have BEE star label or equivalent performance

Renewable energy systems:

Warm and humid areas receive ample solar radiation, hence solar PV is a reliable option. The efficiency of PV depends on location, panel temperature, & climate conditions.



Figure 2-5 Types of Renewable Resources

2.2 JUDICIOUS DESIGN SOLUTIONS FOR ZERO ENERGY SCHOOL BUILDINGS IN HOT CLIMATES

Author: Amani Al-Saadi, Saleh Al-Saadi, Hayder Khan, Aliya Al-Hashim, Hanan Al-Khatiri

Objective of the study:

- This study examines the feasibility of net-zero energy schools in hot climates, offering practical design solutions.
- It begins by providing an overview of Oman's climate, the school building, and its systems.
- Oman has four climates: hot-humid, hot-dry, warm-humid, and high-altitude. Muscat represents the hot-humid climate, Nizwa the hot-dry, and Salalah the warm-humid.

Research methodology:

A school building was investigated and data was collected for model validation. Simulated strategies were evaluated, and an optimal design was recommended.

Walls typologies impact:

- For Muscat, which represents the hot-humid climate, WT #1 and WT #2 provided similar energy with maximum savings of 3.23 % and 3.31 % respectively
- Despite the fact that a 10 cm thickness of thermal insulation is used for WT #3, it provided more energy and operational cost savings when compared to the other two wall typologies.
- As noticed, the maximum savings in energy consumption of 3.72 % with WT #3 in the hot dry climate of Nizwa
- Considering Salalah, the potential for savings was comparatively low, with maximum savings of 1.99 % in the operational cost for WT #3.

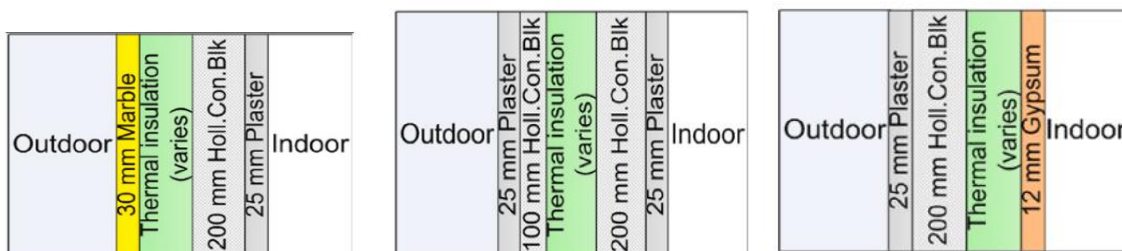


Figure 2-6 Wall U Value Section

Roof designs impact:

- In Oman, 7.5 cm of EPS thermal insulation is typically used on school roofs. However, increasing the insulation layer isn't effective in all climates, with energy savings being less than 0.5%. In some designs, insulation was reduced to 5 cm or removed altogether. As a result, energy consumption increased by 0.7% in hot climates (Muscat and Nizwa) and 0.4% in warm-humid climates (Salalah).

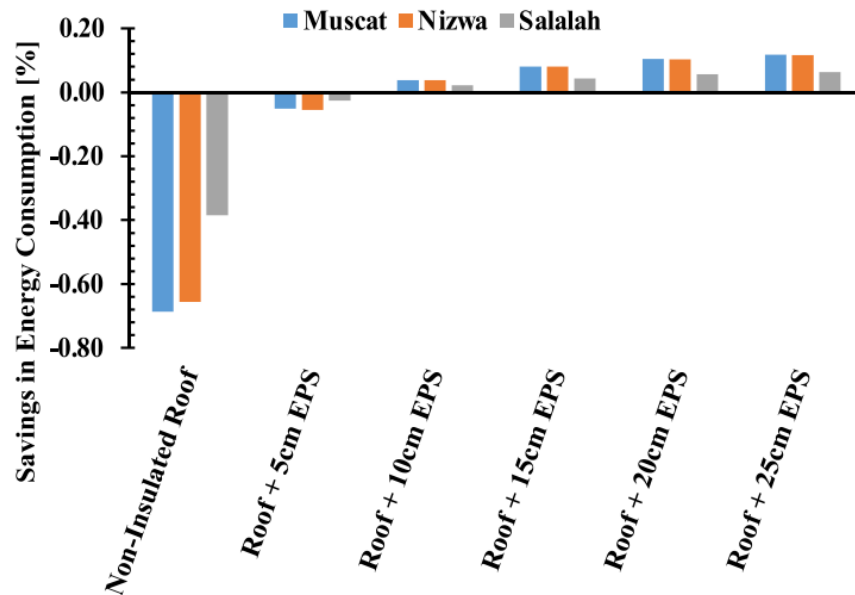


Figure 2-7 Roof Impact Graph

Windows designs impact:

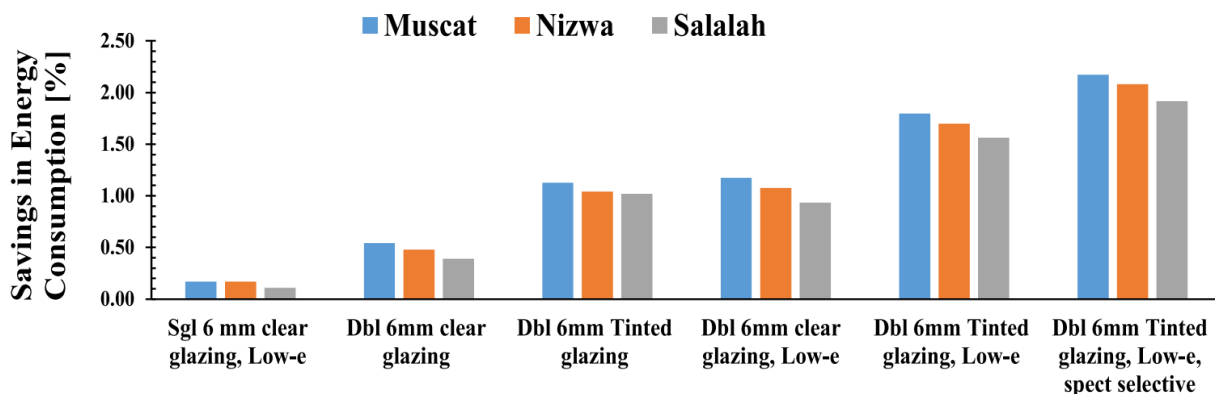


Figure 2-8 Window Impact Graph

Shading device impact:

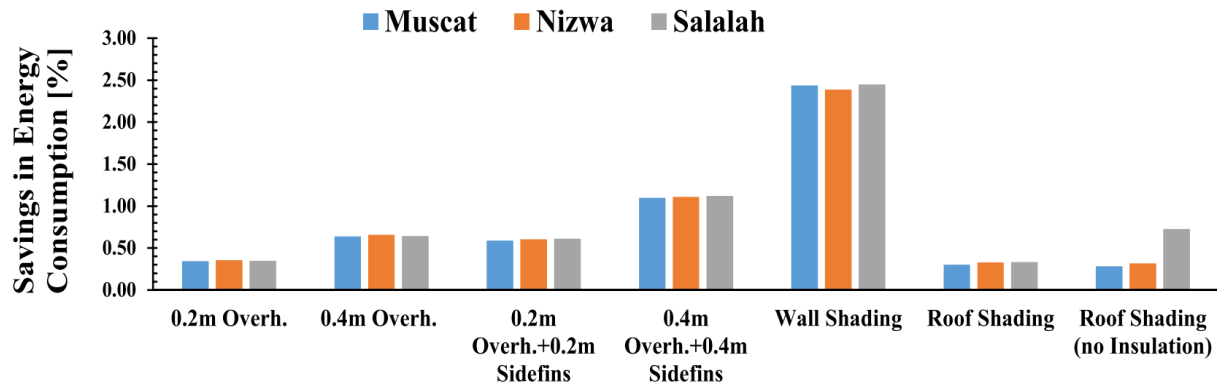


Figure 2-9 Shading Device Impact graph

Active design strategy:

- LED light with dimming capability resulted in 11.8% energy savings. AC systems' COP increased from 2.6 to 3.4, leading to 8.1% energy savings.
- When using VRF for the entire school building, energy consumption was affected. In an alternative design, standalone split systems were used for the server and patch panel rooms, while the rest of the school was cooled by VRF which resulted in up to 13% savings in energy consumption.

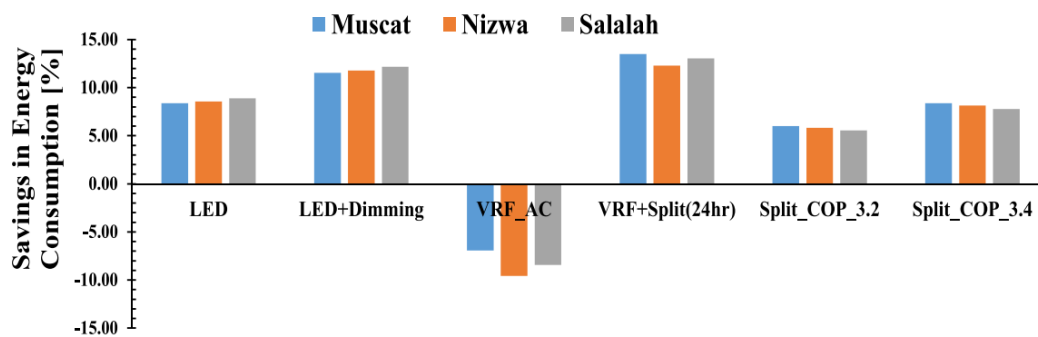


Figure 2-10 Active Design Impact graph

Renewable energy:

Muscat needs 567 PV panels for net-zero energy, Nizwa needs 520, and Salalah needs 588. Additional panels can be installed in the car park or backyard.

Conclusion:

- Considering the passive design strategies, integrating thermal insulation of at least 50 mm thickness in the walls and roof benefits the hot climates only.
- The **insulation should be located on the interior side of the wall and the exterior side of the roof**. Clear glass with Low-e for all climates when dimming lighting control is used.
- Besides, extensive solar shading should be avoided, especially when a dimming control system is used. For the active design strategies, it is suggested to use dimmable LED lights for all climates
- The use of a VRV/VRF air conditioning system is recommended, except for spaces that operate on a 24/7 basis.
- Integrating these strategies, the total reduction in the annual energy consumption reached **25.14 %, 27.9 %, and 28.53 % for the warm humid, hot-humid, and hot-dry zones, respectively**
- Aiming to reach the zero-energy status, the impact of integrating a PV system was simulated. The results revealed that the school consumed **56.47–57.22 % of the PV onsite generation**, exporting the remaining energy to the national grid in the **hot zones**.
- For the **warm-humid zone**, the school consumed **54.25 % of the PV generation**.

2.3 SOLID WASTE MANAGEMENT ON A CAMPUS IN A DEVELOPING COUNTRY: A STUDY OF THE INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

Author: Nikhat Parvez, Avlokita Agrawal and Akhilesh Kumar

Objective of the study:

- A dedicated SWM program on the campus will sensitize and build the consciousness of the campus occupants toward waste management;
- Higher education institute (HEI) campuses replicate a city's characteristics on a small level, producing similar environmental impacts. Therefore, they can be considered as small cities
- Thus, these campuses can demonstrate & influence local neighborhoods to adopt and successful waste management practices

Research methodology:

- For this study, primary surveys were conducted by the authors at the IITR campus over 2 months starting from November 2018 to December 2018.
- Data were collected through Personal observation, Interviews, and through recorded documents.
- Samples were collected from various bins qualitative (visual) and quantitative data were collected.

Issues identified:

- Organic and garden waste together constitute the most solid waste generated on campus
- Paper waste is the second largest solid waste generated on campus that has the scope of recycling.

Table 6. Types and quantity of solid waste.

Area	Quantity in kg/day										
	Paper	Garden	Organic	Inorganic	Plastic	Construction	Chemicals	Medical	E-waste	Metal	Glass
Overall IITR Campus	1580	569	1676	595	613	36	53	47	45	175	111
Bhawans	638	146	317	238	159	3	0	10	10	22	27
Bhawan Mess	10	25	456	15	17	0	0	0	0	0	0
Academics and Admin	519	140	189	67	58	19	47	0	11	127	33
Residential	292	160	553	225	337	11	6	30	24	26	47
Recreational and facilities	121	99	162	51	43	4	0	7	0	0	3

Figure 2-11 Types and Quality of waste

Table 10. Strategies used to treat different type of waste.

Waste Typology	Methods of Treatment and Recycling															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Paper and cardboard	✓	✓			✓	✓				✓					✓	✓
Food waste	✓							✓	✓	✓					✓	
Garden waste	✓							✓	✓	✓					✓	
Plastics	✓	✓			✓	✓				✓					✓	
Cloth/textile	✓	✓				✓				✓					✓	✓
Wood	✓	✓				✓				✓					✓	✓
Glass	✓	✓				✓				✓					✓	
Metals	✓	✓				✓							✓		✓	
Rubber	✓		✓	✓			✓			✓	✓	✓		✓	✓	
E-waste	✓	✓				✓				✓					✓	

Methods: 1—prevention; 2—preparation for re-use; 3—re-treading; 4—recovery, use at road surfaces; 5—close loop recycling; 6—recycling; 7—re-treading method; 8—anaerobic digestion; 9—composting; other energy recovery technologies; 10—energy recovery; 11—another recovery; 12—gasification/incineration; 13—recycling after energy recover; 14—microwave treatment; 15—final disposal; 16—low-grade fuel (briquetting).

Figure 2-12 Waste Processing Strategies

Suggestions:

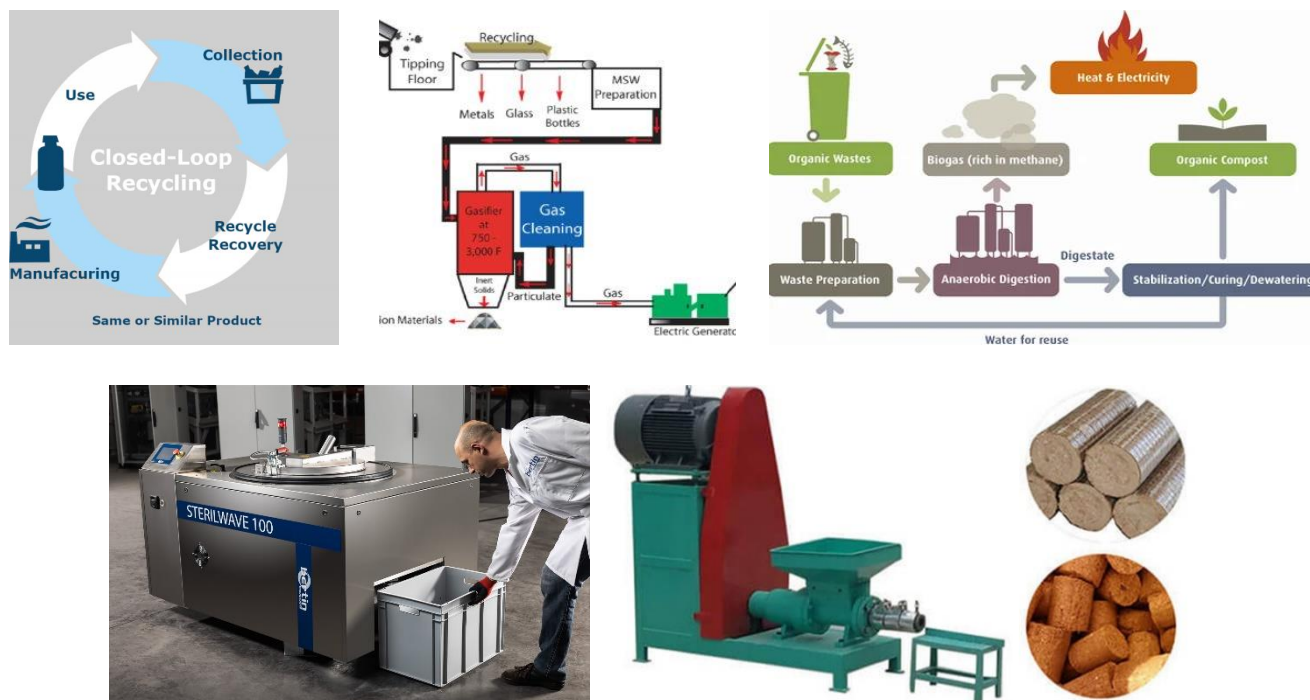


Figure 2-13 Waste Processing Strategies

2.4 SUSTAINABLE WASTE MANAGEMENT STRATEGY FOR A CAMPUS: A CASE STUDY OF JUET, GUNA

Author: Shiva Shankar Y. and Rachit Khandelwal

Objective of the study:

Higher educational institutions play a role in promoting sustainability and resource conservation. Improper waste management leads to environmental pollution. Campus sustainability is an important issue, as the waste generated on campus can be a valuable resource.

Research methodology:

The study area discussed in this paper is Jaypee University of Engineering and Technology, located at Raghogarh, on the Agra-Mumbai national highway, M.P., in an area of 125 acres, housing a population of more than 3,000 inside the campus.

Samples were collected separately from residential areas, academic buildings, shopping complexes, messes, and hostels. Food waste sample was analyzed for parameters such as moisture content, pH, volatile matter, fixed carbon and calorific value. Analysing through these parameters are important in assessing the feasibility for processing and managing waste.

Issues identified:

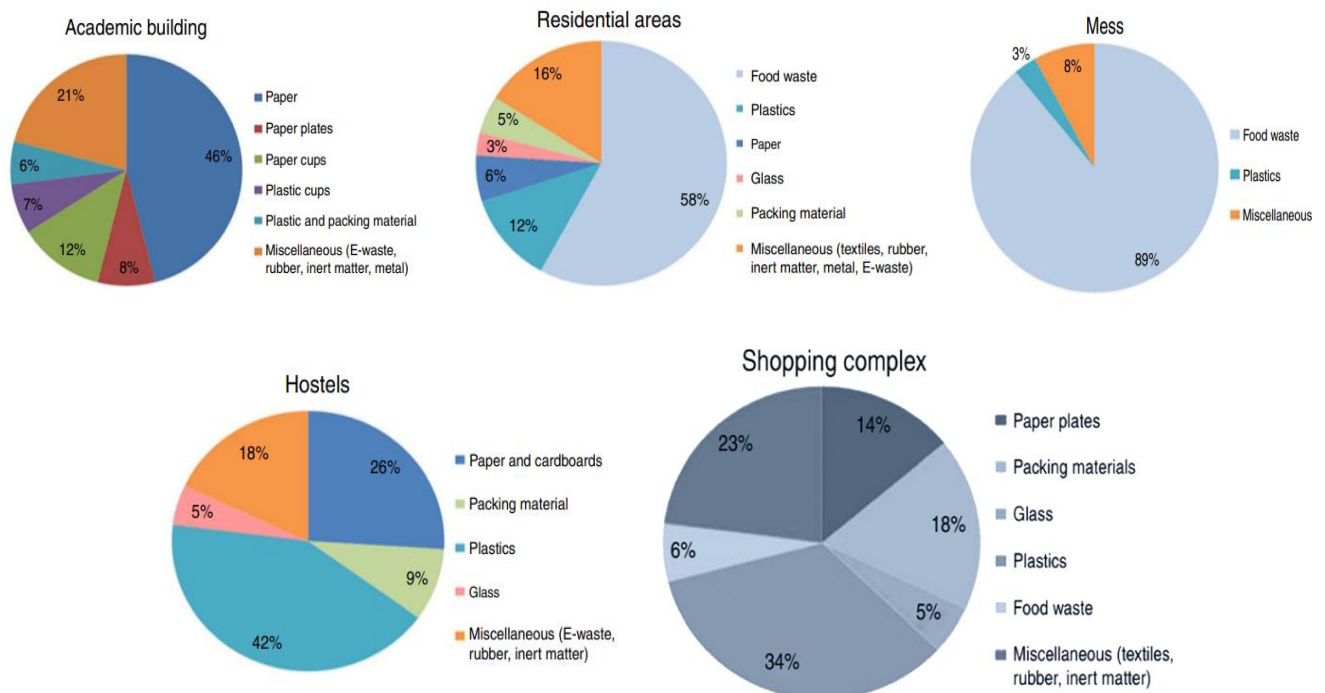


Figure 2-14 Issues Identified in Campus Buildings

Results and discussion:

Food waste:

- The experimental studies carried out concludes that biogas models developed under favorable conditions has good potential for methane gas generation
- The efficiency of the system could be further enhanced through the addition of sewage sludge, cow dung and pre-treatment of garden waste

Parameter	Obtained value	Desirable range (Ministry of Urban Development, 2000)
Moisture content (%)	58	< 45 (thermo chemical conversion) > 50 (bio chemical conversion)
Volatile matter (%)	43	> 40 (for both the processes)
Fixed carbon (%)	12	< 15 (thermo chemical conversion)
Calorific value (kcal/kg)	2,377.08	> 1,200 (thermo chemical conversion)
pH	7.1	

: **Source:** Author's own research

Figure 2-15 Chemical Properties of Waste

Plastics:

Plastic recycling units are increasing day by day. Identification of nearby dealer and supplying the used plastics after segregation and recovery provides economic benefits.



Figure 2-16 Plastic Recycling

Paper waste:

Used paper can be recycled on the campus through the paper recycling process. Adaptation of this process minimizes the paper waste and recycled paper can be recirculated among the faculty along

Paper cups:

aper cups were observed to be one of the major components of waste generated from the academic buildings. The total number accounts to more than 400 cups in a day. Prevention / minimization of this component and replacement with permanent cups.



Figure 2-17 Paper Cup waste

Conclusion:

Integrated solid waste management adopting waste hierarchy such as: prevention (paper cups), minimization (paper), reuse and recycle. Energy recovery (food waste and garden trimmings) provides economic and environmental benefits.

CHAPTER 3

3. CASE STUDY

3.1 NUS SCHOOL OF DESIGN & ENVIRONMENT 4 (NUS SDE4) SINGAPORE

Introduction

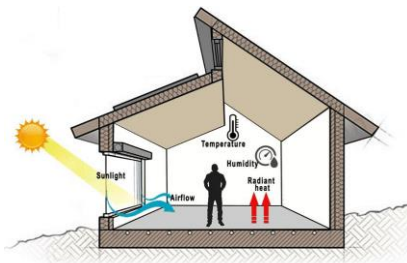
- Location: Singapore
- Area: 8,500m²
- Climate: Warm and humid
- Context: Institutional zone
- Architect: Serie + Multiply Architects, Surbana Jurong
- Connectivity: Grid-connected
- EPI: 58 kWh/m²/yr



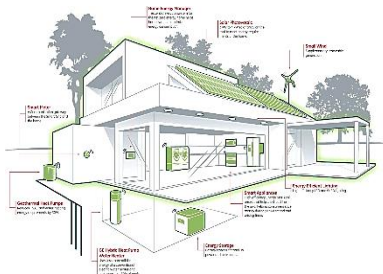
Figure 3-1 SDE4 Front Elevation

- Located within the School of Design and Environment of the National University of Singapore (NUS).
- The six-storey SDE4 is a new addition to the precinct and it is part of a larger campus redevelopment
- SDE4 is the first new-build net-zero energy building in Singapore

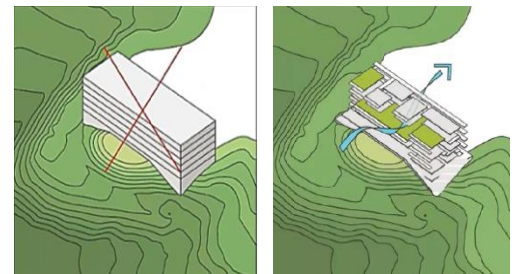
Design vision



High thermal comfort



Net zero energy



Porous architecture

Figure 3-2 Design vision strategies

Passive strategies:

Site layout & planning

Abundant mature trees are assimilated with the new building to bring the landscape to interior spaces



Figure 3-3 Plan and preserved tree inside building

Form & massing

- Floating box concept. Shallow plan and porous layout allow for cross-breezes.
- The optimal North-South openings let in natural light & provide outdoor views.

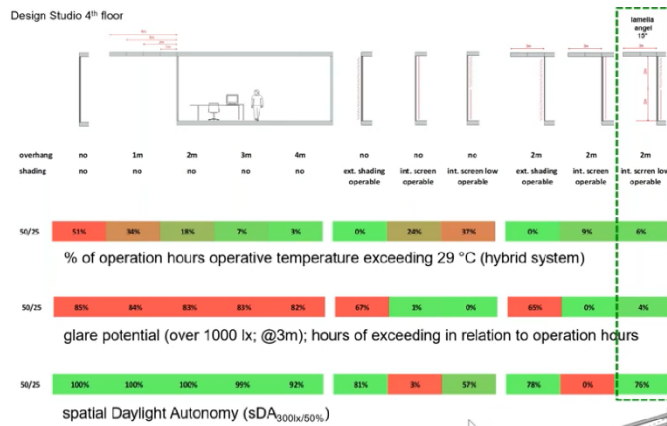
Biophilic design

Ambiguous boundaries between the indoors & outdoors, allows uninterrupted connection of occupants with the natural systems.



Figure 3-4 Section and biophilic interior

Façade



View from South-West



View from North-West

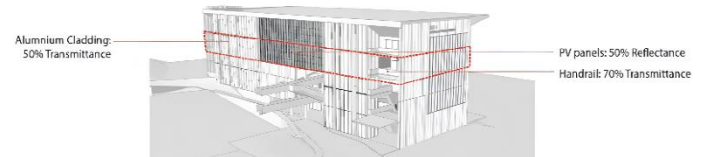


Figure 3-5 Façade design strategies

- South façade - lined columns (scaling the entire height of the structure) with a large over-sailing roof, shade the building from the tropical sun.
- East and west facades - covered in perforated corrugated aluminum panels acting as shading devices. The glass used for facades is a high-performance double-glazed unit (DGU) along with large overhangs and high louvers.

Daylight Design

The building is optimized to facilitate daylight with the help of open platforms, minimal walls & large window / glazed façade with overhangs. Spaces that depend less on daylighting are grouped together.



Figure 3-6 Simulation result and classroom view

ACTIVE STRATEGIES:

Ventilation design:

Only 17% of the building is fully air-conditioned, whereas 46% of the building is naturally ventilated and 26% of the building is hybrid tempered.



Figure 3-7 HVAC Design strategies

spaces adopt a hybrid cooling system (HC) that employs both AC and ceiling fans with a design zone setpoint temperature of 29 degrees Celsius and elevated air movement via ceiling fans. Ceiling fans provided thermal comfort with higher setpoint temperatures based on predicted mean vote (PMV) calculations and validated experiments

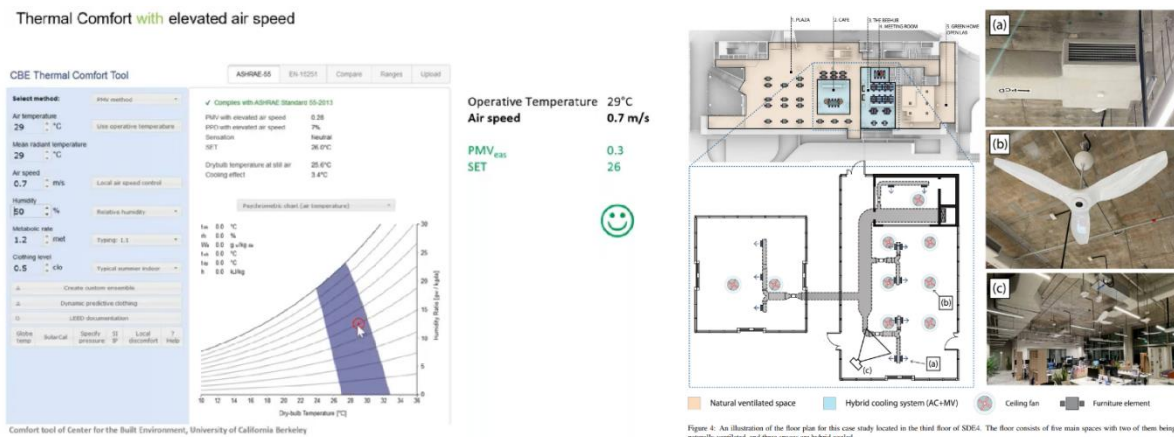


Figure 3-8 Thermal comfort and internal HVAC layout

Artificial lighting design

- 90% of the lighting requirement is met by LEDs.
- Artificial lights have been carefully selected to ensure high color rendering index (CRI) values, low glare and low flickering.
- All lights are controllable through dimmers.

Smart features

- The windows of hybrid tempered rooms are equipped with sensors that trigger the system to switch off the air conditioning when the windows are opened.
- Daylight utilization is enhanced through a network of photocells and occupancy sensors in addition to the architectural design.
- Demand control ventilation strategies are in place to ensure that indoor carbon dioxide levels do not exceed 750 ppm.
- Sensor's measure, track and optimize indoor air quality.

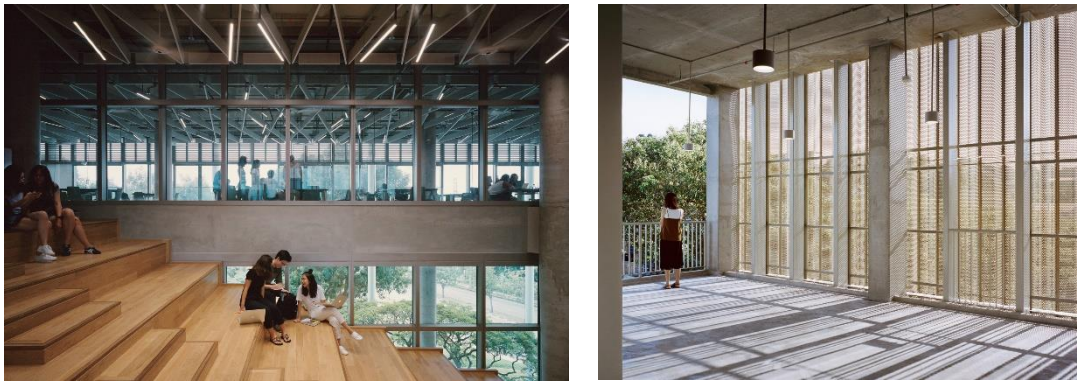


Figure 3-9 Daylight sensors

Net zero energy

- The building has more than 1,200 solar photovoltaic panels on its roof which generate around 500 MWh/yr of electricity, enough to power the entire building's estimated annual energy requirements.
- On days with insufficient insolation, the building draws energy from the power grid. Based on the performance data over a year, it is observed that SDE4 is operating at net positive.

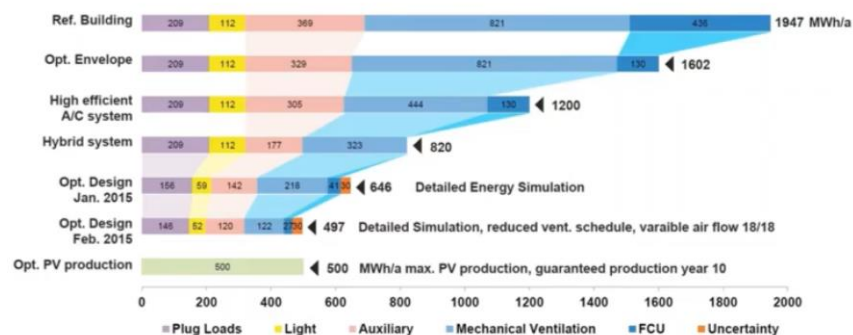


Figure 3-10 Net Zero Energy Reduction Strategies

3.2 AVASARA ACADEMY, PUNE

Introduction:

- Location: Lavale, Pune
- Area: 11,148 m²
- Climate: Warm and humid
- Context: Institutional zone
- Architect: Case Design
- Connectivity: Grid-connected
- Status: Nearly NZEB



Figure 3-11 Avasara Academy Front Elevation

- Settled into the valley slope above the village of Lavale, the 4.3-acre campus is located 10 km west of Pune. The school is located as a part of the growing township of Knowledge City
- The campus is a collection of simple structures arranged around an informal series of walkways, courtyards, gardens and terraces. The built environment of the campus was designed for economic efficiency as well as flexibility.

Design vision:

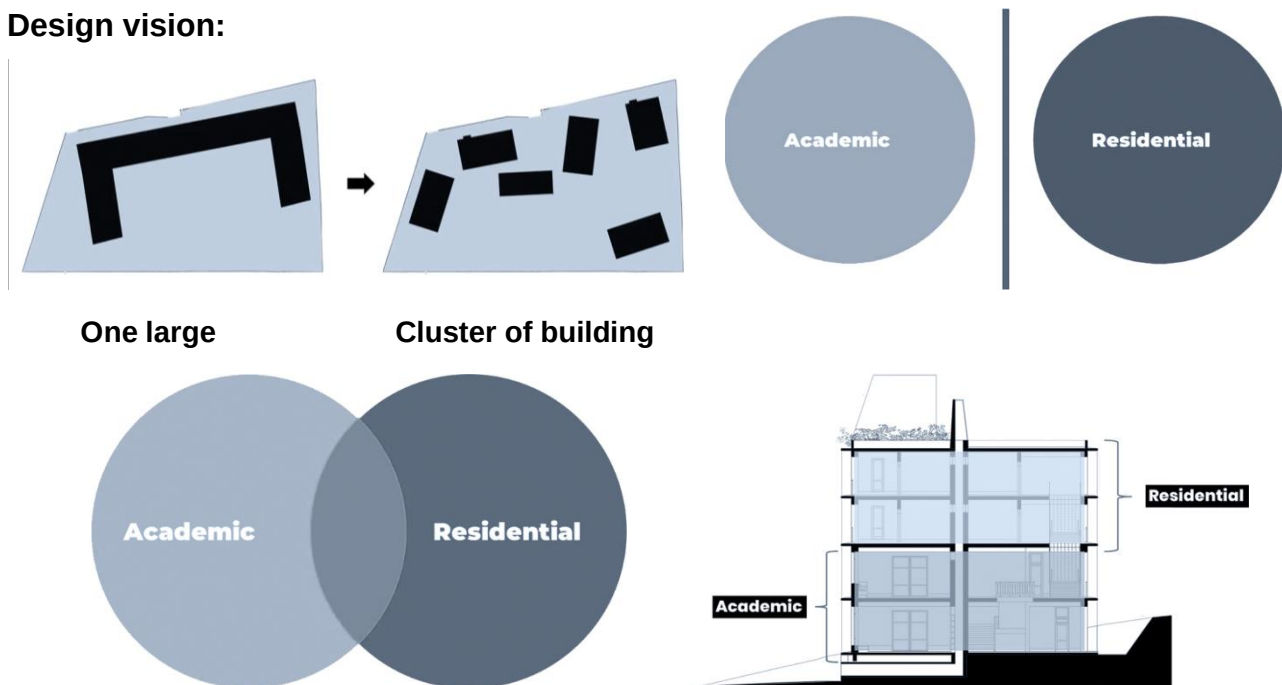


Figure 3-12 Design Concept

Passive strategies:

Site layout & planning:

- The 6 four-storeyed rectangular blocks are organized as per the most favourable orientation, acknowledging contours and seeking the best vistas.
- The campus is interconnected yet the blocks are informally arranged around pathways, courts, gardens & terrace



Figure 3-13 Site plan & Floor Plan

Façade:

- The reinforced concrete floors/ceilings project outwards a little, creating generous overhands that act as a form of brise soleil
- The façade is shrouded in bamboo screens. These locally sourced and skilfully designed screens serve as sun protection, thus preventing excessive heating of the interior from direct sunlight



Figure 3-14 Façade Design

Daylighting:

- The bamboo screen and the lightly woven blades placed on the overhangs deploy a second skin that provide privacy, reduce glare.



Figure 3-15 Classroom Interiors

Materials used:

- The majority of timber windows are recycled from demolished structures, blockwork partition walls are burned from fly ash.
- Floor mosaics are made from the remains of marble quarries, majority of doors are made of teak from demolition objects



Figure 3-16 Refurbished and Re-used material

Ventilation design:

- Passive heating-cooling systems are designed with earth ducts, structurally integrated vertical cavities, and solar chimneys to induce ventilation in each building, lowering interior temperatures by 5-9°C during uncomfortably hot summer months.
- Earth ducts are concrete pipes laid beneath buildings that are around 16-20m in length and have a diameter of 900mm.
- These ducts pre-cool fresh outdoor air, which is then circulated freely inside the spaces, providing ventilation to lower floor spaces along the facades.

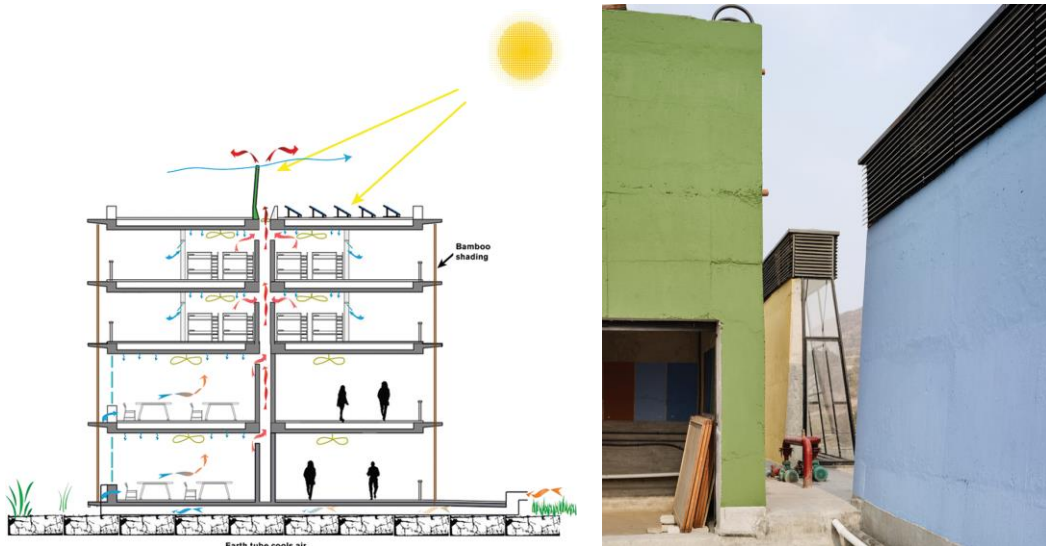


Figure 3-17 Ventilation Tower

Renewable energy:

- Photovoltaic solar panels on the building roof provide electricity for ceiling fans and electric lighting in the building, while solar water heaters provide hot water for showers. Together, this accounts for around 85% of the energy requirement of the building

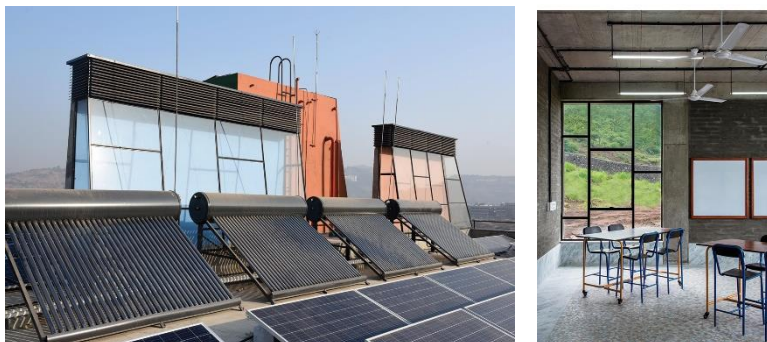


Figure 3-18 PV Panel system

3.3 INDIRA PARYAVARAN BHAWAN

Introduction:

- Location: New Delhi, India
- Area: 9,565 m²
- Climate: Composite climate
- Context: Office
- Grid Connectivity: Grid-connected
- EPI: 44 kWh/m²/ yr



Figure 3-19 IPB Front elevation

- Indira Parya varan Bhawan is a green-rated office building for the Ministry of Environment and Forest in India.
- It has a unique design that emphasizes the use of natural light, shading, and energy-efficient systems.
- It has been awarded GRIHA 5 Star and LEED Platinum certifications

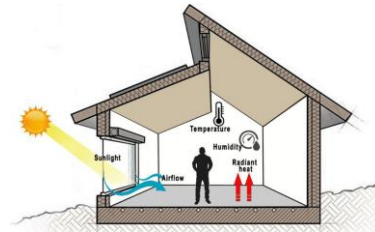
Design vision:



Preserving trees



Net zero energy



Thermal comfort

Passive strategies

Site layout & planning:

- The office building has 2 blocks facing north and south with a large central courtyard that provides natural light and air.
- The porous design allows for cross-ventilation.
- Circulation roads and pathways are soft paved to enable groundwater recharge.

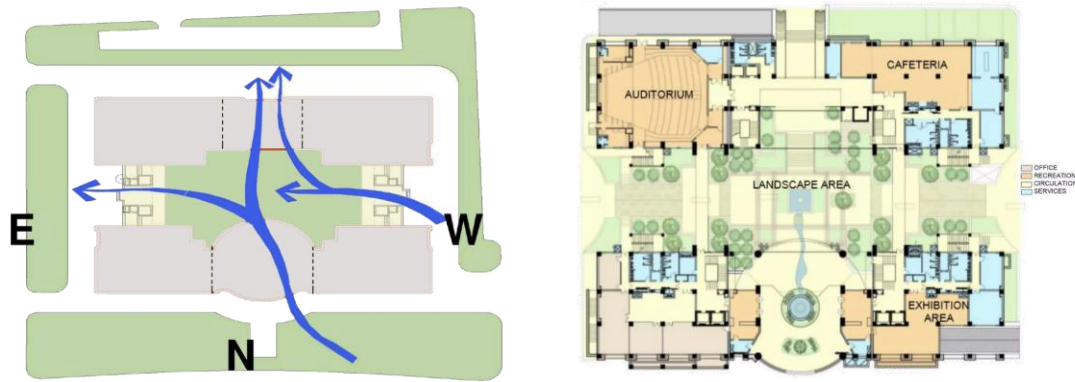


Figure 3-20 Site Plan & Floor Plan

Façade:

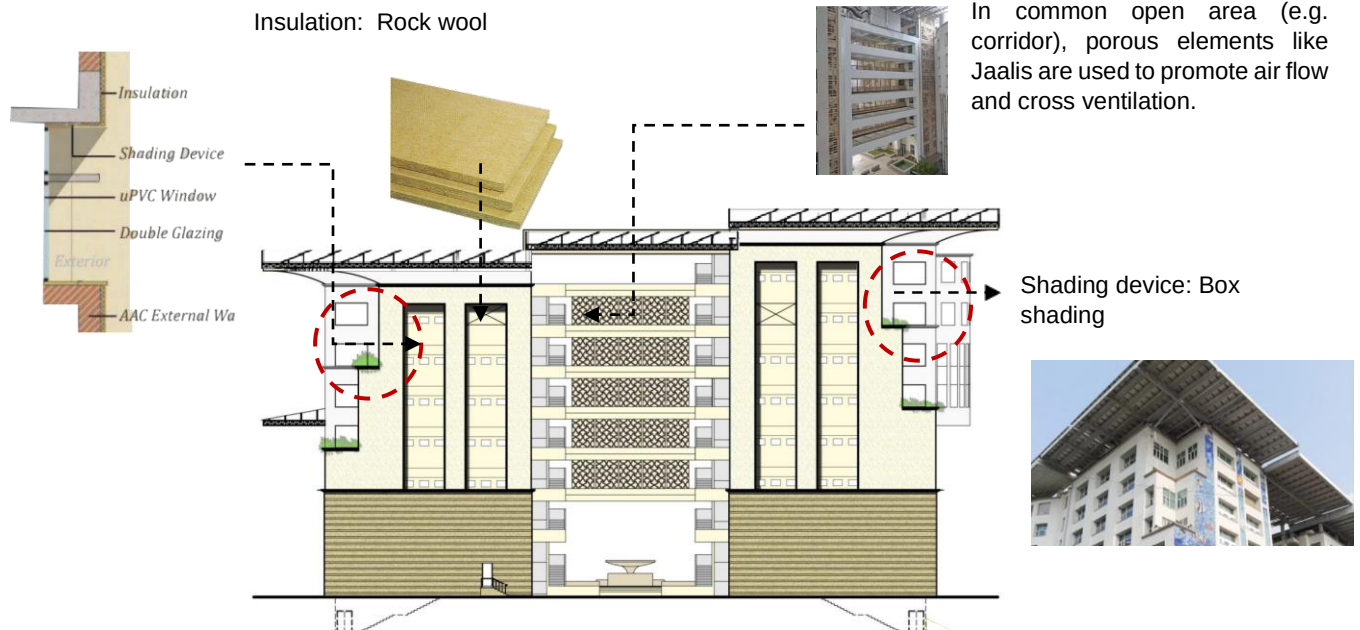


Figure 3-21 Façade Design

- Wall: AAC block wall and fly-ash-based plaster and mortar with a U-value as low as 0.34.
- Insulation: Rock wool is used for insulation for wall assembly.
- Window: UPVC window frames and double glazing makes with VLT of 0.6 & U-value of 1.8.

Lighting:

- The central courtyard acts as a lightwell, the offices receive daylight from both ends (from the front facade & lightwell). The daylight covers more than 75% of building floor space. Thus, dependence on artificial sources of lighting has been reduced to a minimum

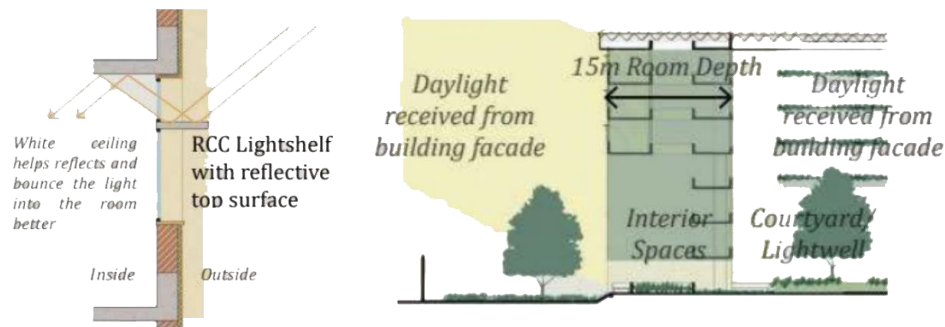


Figure 3-22 Light-Shelf

Lux level sensor:

The sensor helps control and minimize the usage of lighting automatically according to different situations.

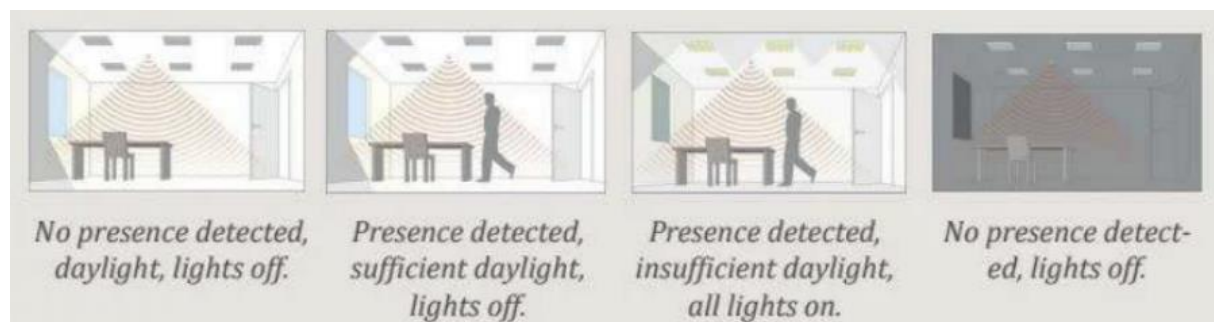


Figure 3-23 Lighting Sensor

Active lighting system:

- LED are used in office to reduce energy & TS5 are used in basement car parks which has no daylight. The lighting power density is maintained near to 5 W/m² which is 50% more efficient than ECBC (11 W/m²)



Figure 3-24 Lighting fixture used in IPB

Passive ventilation:

IPB'S block configuration is broken into 4 parts, connected via an open corridor and central courtyard. The porous setting directs airflows into the building. No end is blocked thus cross-ventilation can happen.

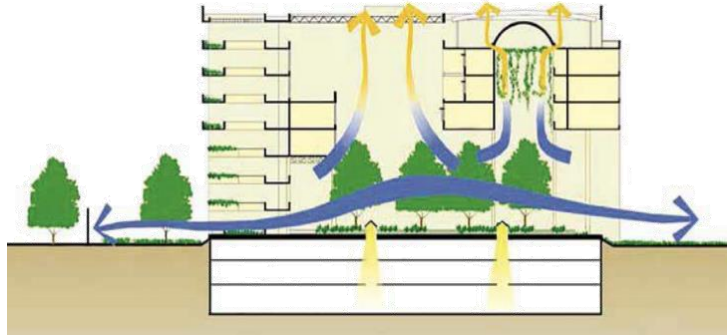


Figure 3-25 Air flow Between Blocks

HVAC:

- Functional zoning based on programs is done to reduce the energy demand. It is a more effective and efficient way of cooling the space.
- Air-conditioning of unused/unnecessary rooms can also be avoided
- Spaces like auditorium, exhibition space in IPB, takes up large space, hence the load are larger hence these spaces are zoned together.
- And small spaces like conference and offices are zoned together

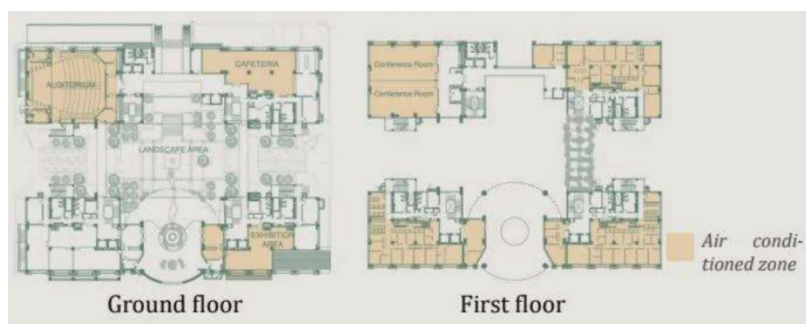


Figure 3-26 HVAC Layout

Other strategies:

Chilled beams were installed in all conditioned office spaces to reduce air-conditioning load. chilled water is supplied to rooms at 16°C and return with a temperature of 20 °C. Room temperature is maintained at 26 ±1 °C



Figure 3-27 Chilled Beam Layout

Geothermal:

- The building premises have 180 vertical bores, each 80 meters deep, with a minimum 3-meter distance between them. Each bore has a HDPE pipe U-loop and is grouted with Bentonite slurry.
- The U-Loops are connected to the central air conditioning plant room's pipe system. Together, they have a heat rejection capacity of 160 TR without a cooling tower

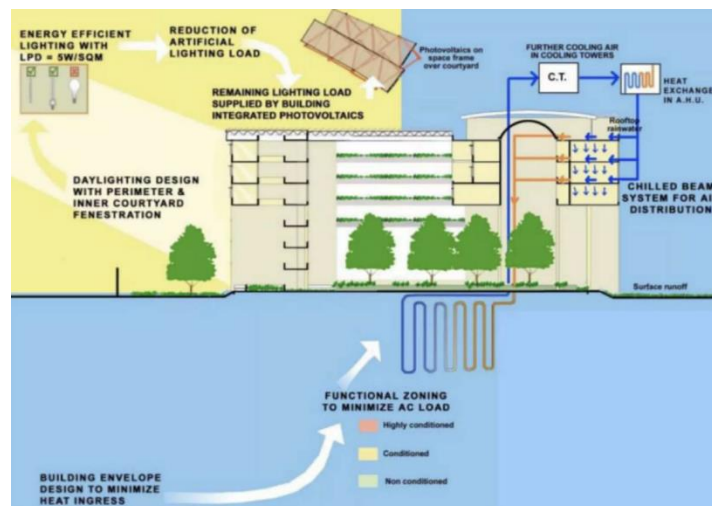


Figure 3-28 Geothermal strategies

Grey water treatment:

Greywater is recycled for zero discharge. 26,37,230 liters of water is been recycled on-site annually. 30 KLD sewage treatment Plant

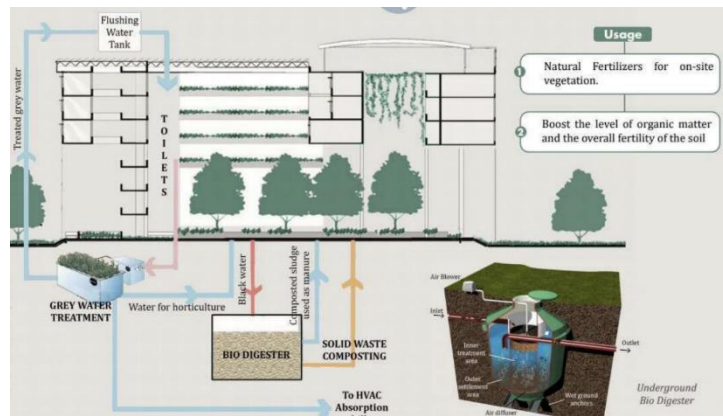


Figure 3-29 Grey water treatment

Renewable energy:

- Solar PV System of 930 kW capacity
- Total Area: 6,000 m²
- Total Area of panels: 4,650 m²
- No of panels: 2,844
- Annual Energy Generation: 14.3 lakh unit
- The panels are five-degree tilted to fully optimize it.
- It is grid-connected.
- The excess energy generated can be stored in battery and sell back to the municipal grid.

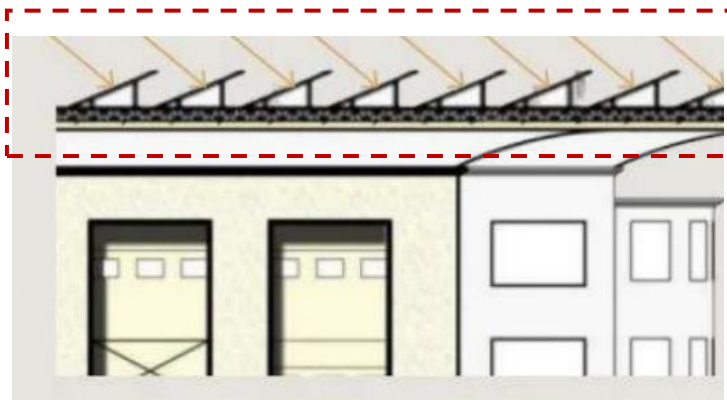


Figure 3-30 PV Panel Section

3.4 ELA GREEN SCHOOL

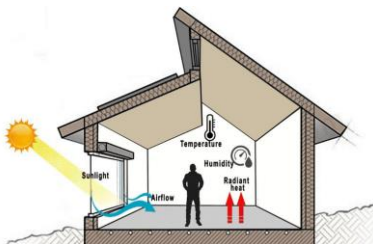
Introduction:

- ELA Green School is situated amidst a 7-acre landscaped campus.
- The campus and its buildings are designed to be sustainable in every aspect, be it the materials used or its operations.
- The building is IGBC, USGBC and LEED certified.
- Designed capacity: 768 students
- Current Capacity: 210
- Site area: 7 acres
- Built up area: 7902 sqm
- Climate: Warm humid

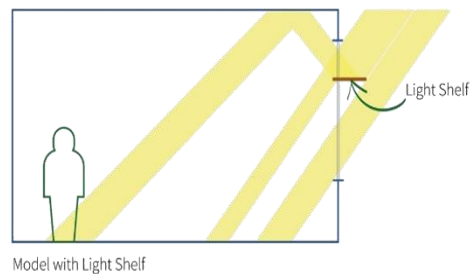


Figure 3-31 Ela green school Front elevation

Design vision:



Thermal comfort



Optimizing daylight



Health and well-being

Design strategies:

Site layout & planning:

- The school block is staggered to enhance the daylight, ventilation, and views
- To reduce the heat gains following strategies have been used
- Insulated walls are used in south southeast and northwest.
- Based on sun path analysis DGU are used on critical faces with high exposure to radiation
- Roof of 0.5 w/m²k u value with 60mm XPS insulation has been used.

Green Building

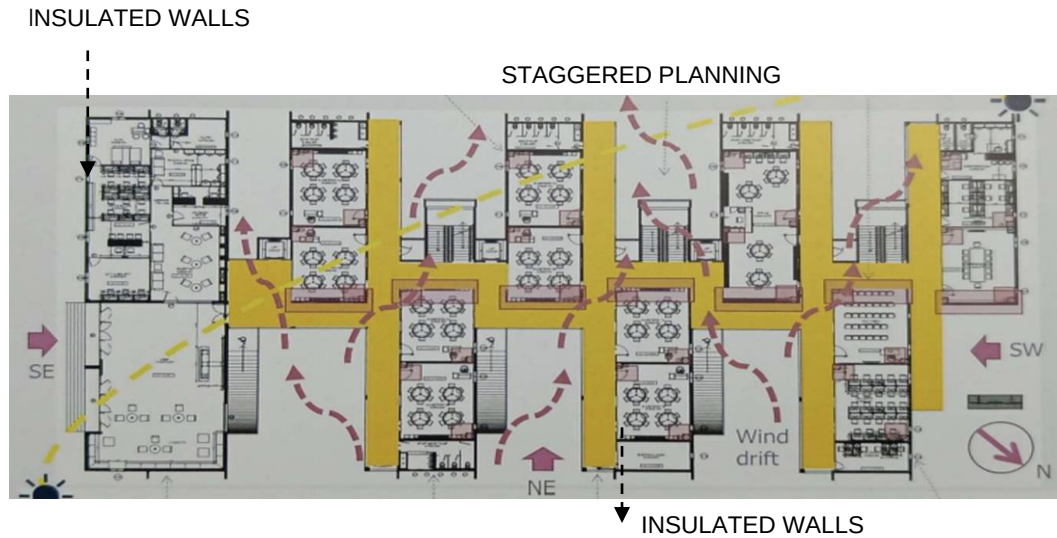


Figure 3-32 Floor Plan

Daylight:

- In order to improve the daylight performance inside the classroom light shelf, shafts, and sufficient WWR has been given in all the rooms.
- Average of 90% of the building receives 150 lux which is the required standard level for school. Thus reducing the dependency on artificial lighting as well as decreases the energy consumption

Thermal comfort:

- According to an analysis done Only 5 hours fall within the comfort range during operational hours. To improve the thermal comfort, the operable area of window design has been increased, and assisted ventilation through a ventilation shaft has been provided
- 2 vertical ventilation shafts will have openings in each classroom Turbo ventilators on top of each of these shafts will induce airflow

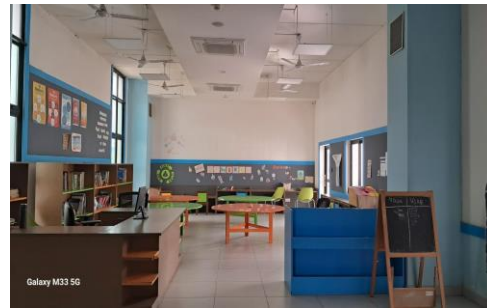
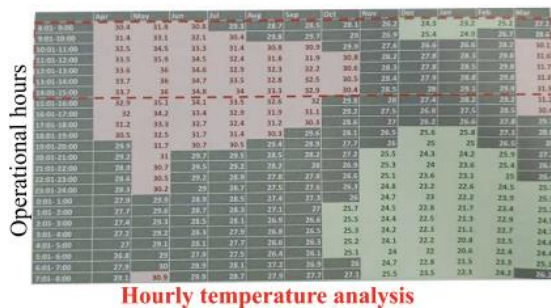


Figure 3-33 Simulation result and wind tower

- The revised window design and assisted ventilation has increased the comfort hours from 23% (base study) to 44%.

Month	No. of operating hours	Max. adaptive comfort temperature	Base Case		Case 1: Increase in operable window area + Shading + DGU clear glass		Case 2: Case 1 + Assisted Ventilation	
			No. of comfortable hrs	% comfortable	No. of comfortable hrs	% comfortable	No. of comfortable hrs	% comfortable
Jan	154	28.3	82	53	104	68	153	99
Feb	140	29.12	69	49	77	55	92	66
Mar	161	30.44	23	14	29	18	47	29
Apr	140	31.45	0	0	11	8	30	21
May	161	32.23	5	3	7	4	11	7
Jun	154	31.98	4	3	7	5	16	10
Jul	147	31.55	13	9	27	18	39	27
Aug	161	31.11	12	7	24	15	37	23
Sep	147	30.98	14	10	27	18	41	28
Oct	154	30.18	16	10	32	21	65	42
Nov	154	29.09	67	44	89	58	129	84
Dec	147	28.68	103	70	124	84	141	96
TOTAL	1820		408	23	558	31	801	44

Figure 3-34 Simulation result of base case and proposed case

Energy efficiency:

- Ela Green School consumes 96.4% of the building's electricity through the state utility grid with 3.6% from diesel generators.
- The school has achieved a score of 100 as per Energy Star building performance scorecard and is reaping the benefits of lower operational cost
- While the EPI benchmark as per BEE is 150 kWh/m2/year, the project consumes only 14.5 kWh/m2/year (90.4% increased performance)

Reducing ozone impact by enhanced refrigerant management:

- The air conditioning in the buildings are met by VRF systems and R-410a refrigerants are used
- Fresh air is being provided naturally in all the air-conditioned zones
- All HVAC and refrigeration equipments are CFC/Halon free, reducing the impact on Ozone

Waste management:

The waste generated is segregated into wet, dry and E-waste and collected by respective third-party vendor once the waste generated has reached a specific threshold

Water performance:

- Domestic water is consumed from groundwater borewells on-site in the project
- Water meter logs for the groundwater borewells are attached for the performance monitoring

- Water for domestic purposes is treated and used for handwash, kitchen dishwashing etc.
- In addition to this, the provision of ultra-low-flow fixtures reduces domestic water consumption.

Disadvantage:

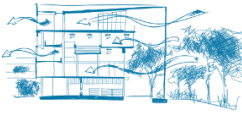
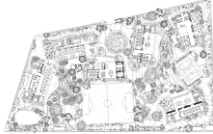
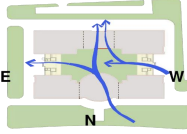
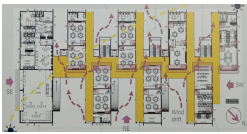
No light shelves were installed, contributing to insufficient daylight in the room. Additionally, posters placed on the windows obstructed natural light, further reducing brightness. The green wall had to be removed due to damp problems.

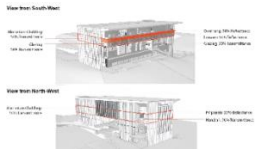
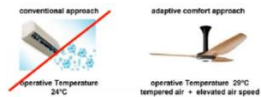
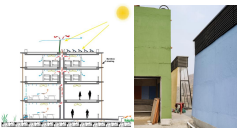
Improving the situation could involve installing light shelves to optimize daylight penetration, removing the posters from the windows to allow unrestricted light entry, and addressing the damp issue through proper ventilation or moisture control measures.

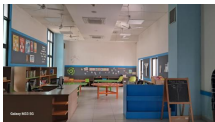


Figure 3-35 classroom interior and building exterior

3.5 COMPARATIVE ANALYSIS:

Case study name	NUS School of Design & Environment 4	Avasara Academy	Indira Paryavaran Bhawan	Ela green school
Location	Singapore	Pune, India	Delhi, India	Chengalpattu, India
Climate	Warm and humid	Warm & humid	Composite	Warm & humid
Typology	Institutional	Institutional	Office	Institutional
Design vision	1. High thermal comfort 2. Net zero energy 3. Porous architecture	1. Net zero energy 2. Residential and dormitories are zoned in same block	1. Preserving trees 2. Net zero energy 3. Thermal comfort	1. Thermal comfort & Health and well being 2. Optimizing daylight 3. Green Building
Site layout & planning	  • Mature trees blend with building, bringing the outdoors inside. • The design has floating boxes with cross-breezes and North-South openings for natural light and outdoor views • Biophilic design approach	  • The campus comprises of six four-storey rectangular blocks • The arrangement is informal yet interconnected through pathways, gardens, terraces, and courts.	 • The office building has 2 blocks facing north and south with a large central courtyard that provides natural light and air. • The porous design allows for cross-ventilation. • Circulation roads and pathways are soft paved to enable ground water recharge.	 • The school block is staggered so as to enhance the daylight, ventilation and views

Case study name	NUS School of Design & Environment 4	Avasara Academy	Indira Paryavaran Bhawan	Ela green school
Shading	 • south façade has lined columns with over-sailing roof for shade. • The east & west facades has corrugated aluminum panels acting as shading devices.	 • The façade has bamboo screens. These screens serve as sun protection, thus preventing excessive heating of the interior from direct sunlight	 Box shading 	No shading device
Ventilation design	 17% air-conditioned, 46% naturally ventilated, 26% hybrid tempered. Spaces use a hybrid cooling system with AC and ceiling fans. Temperature setpoint is 29°C with elevated air movement.	 Passive heating-cooling systems are designed with earth ducts, structurally integrated vertical cavities and solar chimneys to induce ventilation in each building, lowering interior temperatures by 5-9°C during uncomfortably hot summer months.	 • Functional zoning based on programmes is done to reduce the energy demand. • It is a more effective and efficient way of cooling the space	 The air conditioning in the buildings are met by VRF systems and R-410a refrigerants are used

Case study name	NUS School of Design & Environment 4	Avasara Academy	Indira Paryavaran Bhawan	Ela green school
Renewable energy	The building has 1,200 solar panels generating 500 MWh/yr, powering its energy needs. 	Solar panels and water heaters on the roof cover 85% of the building's energy needs. 	- Solar PV System of 930 kW capacity. No of panels: 2,844 - Annual Energy Generation: 14.3 lakh unit 	
Other strategs	- Hybrid tempered rooms have window sensors that turn off the AC when windows are opened. - Daylight utilization is enhanced through a network of photocells and occupancy sensors. - Demand control ventilation to ensure carbon dioxide levels do not exceed 750 ppm. - Sensors measure, track and optimize indoor air quality 	 - The majority of timber windows are recycled from demolished structures, walls are burned from fly ash. - Floor mosaics are made from the remains of marble quarries - Majority of doors are made of teak from demolition objects - Pastel hues use natural pigments, contributing towards less environmental impact choices	 - Chilled water is supplied to rooms at 16°C and return with temperature of 20° C. Room temperature is maintained at 26 ±1 ° C GEOTHERMAL: - They have a heat rejection capacity of 160 TR without a cooling tower. 	 2 vertical ventilation shafts will have openings in each classroom Turbo ventilators on top of each of these shafts will induce air flow. - Assisted ventilation has increased the comfort hours from 23% (base study) to 44%

CHAPTER 4

4. DATA COLLECTION

4.1 Net Zero Energy

ECBC 2017			
COMPONENTS	ECBC	ECBC +	SUPER ECBC
External Wall	ECBC	ECBC +	SUPER ECBC
	≤0.4 W/m ² k	≤0.34 W/m ² k	≤0.22 W/m ² k
	School <10,000 m²		
	≤0.85 W/m ² k	≤0.63 W/m ² k	≤0.22 W/m ² k
Roof	For unconditioned building U value - ≤0.8 W/m² k		
	For all building		
	≤0.33 W/m ² k	≤0.26 W/m ² k	≤0.20 W/m ² k
	School <10,000 m²		
Fenestration	For all building		
	U value		
	≤ 3 W/m ² k	≤ 2.2 W/m ² k	≤ 2.2 W/m ² k
	SHGC		
Skylight	≤ 0.27		
	VLT ≤ 0.27		
	U value ≤ 4.25 W/m ² k		
	SHGC ≤ 0.35		
Interior lighting measurement	SRR ≤ 5%		
	Building Area Method		
	school/university		
	11.2 W/m ²	9 W/m ²	6 W/m ²
	Library		
	12.2 W/m ²	9.8 W/m ²	6.1 W/m ²
	Dining/cafe/teria		
	11.5 W/m ²	9.2 W/m ²	5.8 W/m ²
	Workshop		
	14.1 W/m ²	11.3 W/m ²	7.1 W/m ²
	Space function Method		
	Lobby		
	9.1 W/m ²	7.3 W/m ²	4.6 W/m ²
	Classrooms		
	13.7 W/m ²	11 W/m ²	6.9 W/m ²
	Lab		
	15.1 W/m ²	12.1 W/m ²	7.5 W/m ²
	Library reading area		
	10 W/m ²	9.2 W/m ²	5.7 W/m ²
	Library book stack		
	18.3 W/m ²	14.6 W/m ²	9.2 W/m ²
	Stairway		
	5.5 W/m ²	4.4 W/m ²	2.7 W/m ²
	Restroom		
	7.7 W/m ²	6.1 W/m ²	3.8 W/m ²
	Storage		
	6.8 W/m ²	5.4 W/m ²	3.8 W/m ²
	Workshop		
	17.1 W/m ²	13.7 W/m ²	8.6 W/m ²
	Conference/Meeting		
	11.5 W/m ²	9.2 W/m ²	5.7 W/m ²

Table 5-3 Minimum Requirements for Unitary, Split, Packaged Air Conditioners in ECBC Building

Cooling Capacity (kW)	Water Cooled	Air Cooled
≤ 10.5	NA	BEE 3 Star
> 10.5	3.3 EER	2.8 EER

Table 5-4 Minimum Requirements for Unitary, Split, Packaged Air Conditioners in ECBC+ Building

Cooling Capacity (kW)	Water Cooled	Air Cooled
≤ 10.5	NA	BEE 4 Star
> 10.5	3.7 EER	3.2 EER

Table 5-5 Minimum Requirements for Unitary, Split, Packaged Air Conditioners in SuperECBC Building

Cooling Capacity (kW)	Water Cooled	Air Cooled
≤ 10.5	NA	BEE 5 Star
> 10.5	3.9 EER	3.4 EER

COMPONENTS	ECBC	ECBC +	SUPER ECBC
Interior lighting measurement	Corridor/Transition		
	7.1 W/m ²	3.6 W/m ²	2.3 W/m ²
	Dining		
	9.1 W/m ²	7.3 W/m ²	4.6 W/m ²
Exterior lighting measurement	Building entrance with canopy (m ² - canopied area)		
	10 W/m ²	8 W/m ²	5 W/m ²
	Building exit		
	60 W/ Linear m of door width	48 W/ Linear m of door width	30 W/ Linear m of door width
	Building façade		
	5 W/m ² vertical façade area	4 W/m ² vertical façade area	2.5 W/m ² vertical façade area
	Driveway, open parking		
	1.6 W/m ²	1.3 W/m ²	0.8 W/m ²
	Pedestrian walkways		
	2 W/m ²	1.6 W/m ²	1 W/m ²
	Stairway		
	10 W/m ²	8 W/m ²	5 W/m ²
Uninterruptible Power Supply	Landscaping		
	0.5 W/m ²	0.4 W/m ²	0.25 W/m ²
	UPS energy efficiency at 100% load		
	kVA ≤ 20 - 90.2% 20 ≤ kVA ≤ 100 - 91.9% kVA ≥ 100 - 93.8%		
Renewable energy	Renewable energy generation zone		
	Atleast 25% area either on roof or on-site		
	For university buildings > 20000m ² built up area		
	1% of total peak demand	3% of total peak demand	6% of total peak demand

Table 5-1 Minimum Energy Efficiency Requirements for water cooled Chillers

Chiller Capacity (kW)	ECBC Building		ECBC+ Building		SuperECBC Building	
	COP	IPLV	COP	IPLV	COP	IPLV
<260	4.7	5.8	5.2	6.9	5.8	7.1
≥260 & <530	4.9	5.9	5.8	7.1	6.0	7.9
≥530 & <1,050	5.4	6.5	5.8	7.5	6.3	8.4
≥1,050 & <1,580	5.8	6.8	6.2	8.1	6.5	8.8
≥1,580	6.3	7.0	6.5	8.9	6.7	9.1

Table 5-2 Minimum Energy Efficiency Requirements for air cooled Chillers

Chiller Capacity (kW)	ECBC Building		ECBC+ Building		SuperECBC Building	
	COP	IPLV	COP	IPLV	COP/ IPLV	
<260	2.8	3.5	3.0	4.0	NA	
≥260	3.0	3.7	3.2	5.0	NA	

Table 5-6 Minimum Efficiency Requirements for VRF Air conditioners for ECBC Building*

Type	Size category (kW)	For Heating or cooling or both	
		EER	IEER
VRF Air	< 40	3.28	4.36
Conditioners,	≥ 40 and < 70	3.26	4.34
Air cooled	≥ 70	3.02	4.07

* The revised EER and IEER values as per Indian Standard for VRF corresponding to values in this table will supersede as and when the revised standards are published.

Figure 4-1 ECBC Requirement

4.2 Water & waste – IGBC

1. Segregation of Waste

IGBC		
COMPONENTS	Daily water consumption = Fixture flow rate*duration of use *FTE* daily use per person	
Plumbing fixture	Fixture type	Max. flow rate & Estimated daily use per FTE
	WC	6L per flush (Full-flush) 1 each for male & female
		3L per flush (Half flush) 2 for female
	Urinals	4L per flush 2 times
	Faucets	6L per 15 seconds Mini 4 times
	Health faucets	6L per 15 seconds Mini 1 time
Rain water harvesting	Design to collect one-day rainfall volume obtained from average of peak rainfall of previous 5 years	
	Average peak month rainfall	one day rainfall
	Above 701mm	3%
	Water collection efficiency for sloping roofs	85%
	Run off volume = Surface area * run-off coefficient * peak coefficient	
RWH design guidelines	surface material	Runoff coefficient
	Cemented/tiled roof	0.95
	Roof garden	0.1 -0.5
	Turf	0.25 -0.45
	Vegetation	0.1 - 0.3
	Concrete pavement	0.95
	Gravel pavement	0.75
	Grass pavement	0.5
	Water bodies	0.95
Landscape design	Surface material	Run-off coefficient
	Drought - tolerant/ native/Adaptive/Species area	≤ 30%
	Turf area	≤ 30%
Waste water treatment and reuse	On-site system: Treat 100% generated wastewater 25% - 75% of wastewater has to be used for landscaping , flushing, cooling tower	
	Average no.of.watering days for landscaping	6L/m2/day for 300 days

Table :Types of Waste at Building Level

Color Bin	Name of the bin	Examples of Waste
	Paper Recycling	Office paper, clean cardboard, newspaper, milk & juice cartons, disposable coffee cup-lids only
	Organic Recycling	Food, pruning's, fruit & vegetables, plate scrapings including meat, fish & leftovers, coffee grounds, flowers
	Hazardous waste	Sanitary napkins, diapers, used syringes blades, bandages, expired medicine
	Mixed recycling	Glass bottles, aluminum cans
	Soft plastic recycling	Bread bags, pasta & rice bags, cling wrap, plastic bags, biscuit packets, frozen food bags, bubble wrap
	E-waste	CFL, tube light, printer cartridges, batteries

Figure 4-2 Waste Color-Code

2. Allocate a centralized facility to store, segregate and handover collected waste to the identified recycle vendors



Figure 4-3 Segregated Waste

3. Recycling of waste

Bio-degradable Waste:

1. Install on-site Waste Treatment System approved by Swachh Bharat Mission Urban to treat 100% of organic waste generated at building level and use as manure either on site or at any other site. (max. points - 5)
2. Demonstrate generation of energy from the organic waste generated and utilisation of the same within the premises. (max. points - 5)

Non-Biodegradable Waste:

1. Demonstrate recycling of non-bio-degradable waste through responsible handling and handing over of the same to the respective recyclers. (max. points - 3)
2. Any other innovation strategies to recycle, reuse of dry waste, wet waste and e-waste during post occupancy with long term contract agreement with vendors, thereby diverting from landfill (max. points -5)

4. Net zero waste

The percentage of quantity of waste sent to landfill	Quantity of waste sent to landfill Total quantity of waste generated
--	---

% of Waste going to Landfill	Credit points
25.0 – 22.0 %	1
22.5 – 20.5%	2
20.0 – 17.0 %	3
17.5 – 15.5 %	4
15.0 – 13.0 %	5
12.5 – 10.5 %	6
10.0 – 8.0 %	7
7.5 – 5.5 %	8
5.0 - 3.0 %	9
2.5 - 0 %	10

4.3 SCHOOL BY-LAWS

CBSE BY-LAWS

Minimum Land required	3200 sq.m
Class room size	8 X 6 M = 48 m ²
Science lab	9X6 M = 54 m ²
Library	14 X 8 M = 112 m ²
Computer lab	9 X 6 M = 54m ²
Maths lab	8 X 6 M = 54m ²
Play ground	200 m ²
Students	40 – Secondary school 45 – Senior secondary school

Environment education

The school must strive to promote conservation of environment of the campus through rainwater harvesting , segregation of waste , recycling of organic waste , proper disposal of waste including electronic waste , use of energy saving and energy efficient electrical equipment, greening of campus , use of solar energy education and awareness amongst children on environmental conservation and cleanliness , etc

Source : <https://www.cbse.gov.in/cbsenew/affbye//Chapter%203.pdf>

4.4 NBC & TNCDRBR

Lux level

				coverage
21	EDUCATION			
21.1	Assembly Halls			
21.1.1	General	200-300-500	3	
21.1.2	Platform and stage			Special lighting to provide emphasis and to facilitate the use of the platform/ stage is desirable
21.2	Teaching Spaces			
	General	200-300-500	1	
21.3	Lecture Theatres			
21.3.1	General	200-300-500	1	
21.3.2	Demonstration benches	300-500-750	1	Localized lighting may be appropriate
21.4	Seminar Rooms	300-500-750	1	
21.5	Art Rooms	300-500-750	1	
21.6	Needlework Rooms	300-500-750	1	
21.7	Laboratories	300-500-750	1	
21.8	Libraries	200-300-500	1	
21.9	Music Rooms	200-300-500	1	
21.10	Sports Halls	200-300-500	1	
21.11	Workshops	200-300-500	1	

Source: NBC

20.4.16.2	Waiting rooms	100-150-200		
20.4.17	Dental surgeries			
20.4.17.1	Chair	Special lighting		
20.4.17.2	Laboratories	300-500-750		
20.4.18	Consulting rooms			
20.4.18.1	General	200-300-500		
20.4.18.2	Desk	300-500-750		
20.4.18.3	Examination couch	300-500-750		
20.4.18.4	Ophthalmic wall and near-vision charts	300-500-750		
20.5	Hotels			
20.5.1	Entrance halls	50-100-150		
20.5.2	Reception, cashier's and porters' desks	200-300-500		Localized lighting may be appropriate.
20.5.3	Bars, coffee base, dining rooms, grill rooms, restaurants, lounges	50-200		The lighting should be designed to create an appropriate atmosphere
20.5.4	Cloak rooms, baggage rooms	50-100-150	3	
20.5.5	Bed rooms	30-50-100		Supplementary local lighting at the bed head, writing table should be provided
20.5.6	Bathroom	50-100-150		Supplementary local lighting near the mirror is desirable
20.5.7	Food preparation and stores, cellars, lifts and corridors			See 'General Building Areas'
20.6	Libraries			
20.6.1	Lending library			
20.6.1.1	General	200-300-500	1	
20.6.1.2	Counters	300-500-750	1	Localized lighting may be appropriate.
20.6.1.3	Bookshelves	100-150-200	2	The service illuminance should be provided on the vertical face at the bottom of the
17	COMMERCE			
17.1	Offices			
17.1.1	General offices	300-500-750	1	
17.1.2	Deep plan general offices	500-750-1000	1	
17.1.3	Computer work stations	300-500-750	1	
17.1.4	Conference rooms, executive offices	300-500-750	1	
17.1.5	Computer and data preparation rooms	300-500-750	1	
17.1.6	Filing rooms	200-300-500	1	
17.2	Drawing Offices			
17.2.1	General	300-500-750	1	
17.2.2	Drawing boards	500-750-1 000	1	
17.2.3	Computer aided design and drafting			Special lighting is required
17.2.4	Print rooms	200-300-500	1	
17.3	Banks and Building Societies			
17.3.1	Counter, office area	300-500-750	1	
17.3.2	Public area	200-300-500	1	
22.3.7	Loading areas	100-150-200	3	Localized lighting is appropriate
23	GENERAL BUILDING AREAS			
23.1	Entrance			
23.1.1	Entrance halls, lobbies, waiting rooms	150-200-300	2	Localized lighting may be appropriate
23.1.2	Enquiry desks	300-500-750	2	
23.1.3	Gatehouses	150-200-300	2	
23.2	Circulation Areas			
23.2.1	Lifts	50-100-150		
23.2.2	Corridors, passageways, stairs	50-100-150	2	
23.2.3	Escalators, revelators	100-150-200		
23.3	Medical and First Aid Centres			
23.3.1	Consulting rooms, treatment rooms	300-500-750	1	
23.3.2	Rest rooms	100-150-200	1	
23.3.3	Medical stores	100-150-200	2	
23.4	Staff Rooms			
23.4.1	Changing, locker and cleaners rooms, cloakrooms, lavatories	50-100-150		
23.4.2	Rest rooms	100-150-200	1	
23.5	Staff Restaurants			
23.5.1	Canteens, cafeterias, dining rooms, mess rooms	150-200-300	2	
23.5.2	Servery, vegetable preparation, washing-up area	200-300-500	2	

Figure 4-4: LUX level as per NBC

Max. heigh	Not exceeding 1.5 time of street width
Staircase width	1.5 m
Tread Riser	>0.3 m < 0.15 m
Corridor width	Minimum 1.5 m
Parking – car	1/70

Minimum Stair width	1.6m
Travel distance to staircase from any part of the space	22.6 m
Corridor width	1.8 m
Classroom minimum size	6 x 6

Circulation areas

Circulation areas such as corridors, entrance halls, staircases, etc, in the school buildings with double loaded and single loaded corridors shall not be more than 18 percent and 24 percent of the total covered area of the building respectively.

Noise level

Class A	Noise producing	a) Workshops b) Kitchens c) Dining rooms d) Gymnasiums e) Indoor swimming pools
Class B	Noise producing but needing quiet at times	a) Assembly halls b) Lecture halls c) Music rooms d) Typing rooms
Class C	Average	a) General class-rooms b) Practical rooms c) Laboratories d) Offices
Class D	Rooms needing quiet	a) Libraries b) Studies
Class E	Rooms needing privacy	a) Medical rooms b) Staff rooms

6.2.4.2 The recommended minimum sound reduction (D_w) between rooms of the same class is as follows:

- a) Class A : 25 dB
- b) Class C or D : 35 dB
- c) Class B or E : 45 dB

CHAPTER 5

5. SITE SELECTION AND SITE ANALYSIS

5.1 Site selection - Why Chennai

Chennai ranks second among big cities in power usage

While the state's average daily power demand is 15,000 MW, Chennai alone requires 2,750 MW.



Image used for representational purpose.

S Guruvanmikanathan

Updated on: 01 Sep 2023, 7:27 am · 1 min read



Chennai's Electricity Demand is Increasing, Close to Entire Kerala's. What's the Reason?

• Reported By: **B Sivakumar** • Edited By: **Shilpy Bisht** • **News18.com** • Last Updated: MAY 15, 2023, 10:12 IST • **Chennai, India**



Between 2013 and 2023, Chennai's electricity demand has increased by 25% and consumption by 60%. (Photo: Shutterstock)

Domestic demand in Chennai is on the increase every year because more and more people from other districts as well as from other states are settling in the city, said Tamil Nadu Electricity Board chairman

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Figure 5-1 ECBC Article Images

- According to the Central Electricity Authority (CEA), among major cities in the country, Hyderabad tops the chart with a power demand of 4,479 MW, followed by Chennai with 4,383 MW in the current fiscal year (2023-24).
- CEA also forecasts Chennai's power consumption climbing to 4,576 MW in the 2024-25 fiscal. Between 2013 and 2023, the city demand has increased by 25% and consumption by 60%.
- In 2013, the power demand in the city was 3,027 MW and on April 20 this year, the demand touched 3,778 MW, which is close to the entire Kerala demand which is close to 4,500 MW," said Tamil Nadu Electricity Board (TNEB) chairman Rajesh Lakhani

5.2 CLIMATE STUDY

- LOCATION: Chennai
- COORDINATES : 13.0827° N, 80.2707° E
- ALTITUDE : 7m
- CLIMATE : Warm and humid

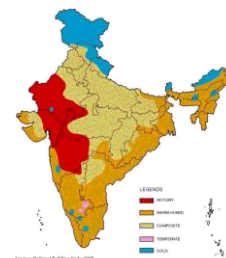
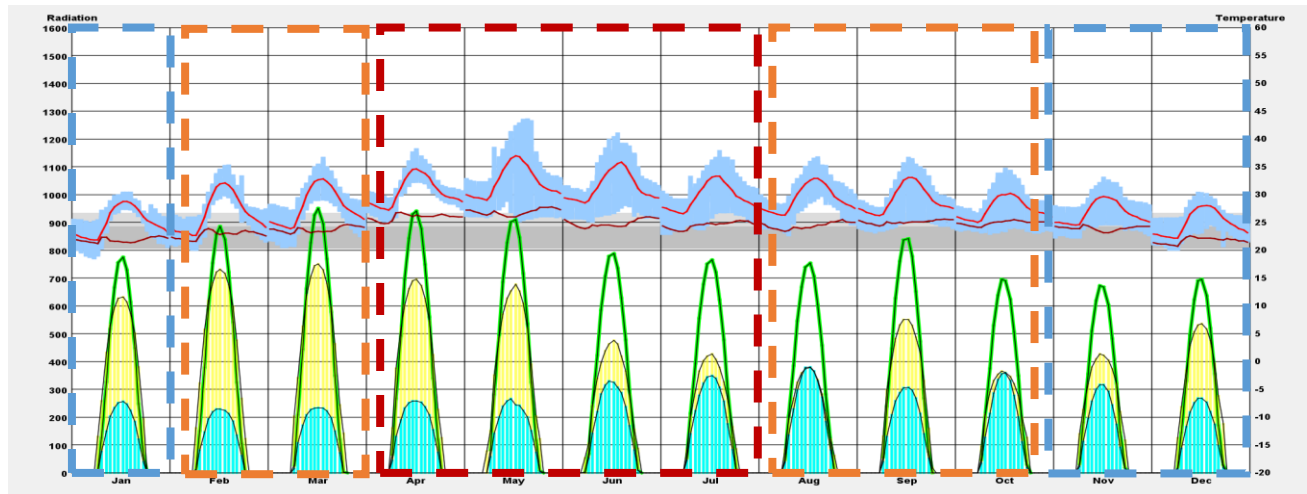


Figure 5-2 ECBC Climate map

Monthly Diurnal Averages



COMFORTABLE HOT HOTTEST HOT COMFORTABLE

Figure 5-3 Monthly Diurnal Graph

- The hottest season lasts from April to July, with an average daily high temperature above 35°C.
- The comfortable season lasts from November to January, with an average daily high temperature below 30°C.

Relative Humidity

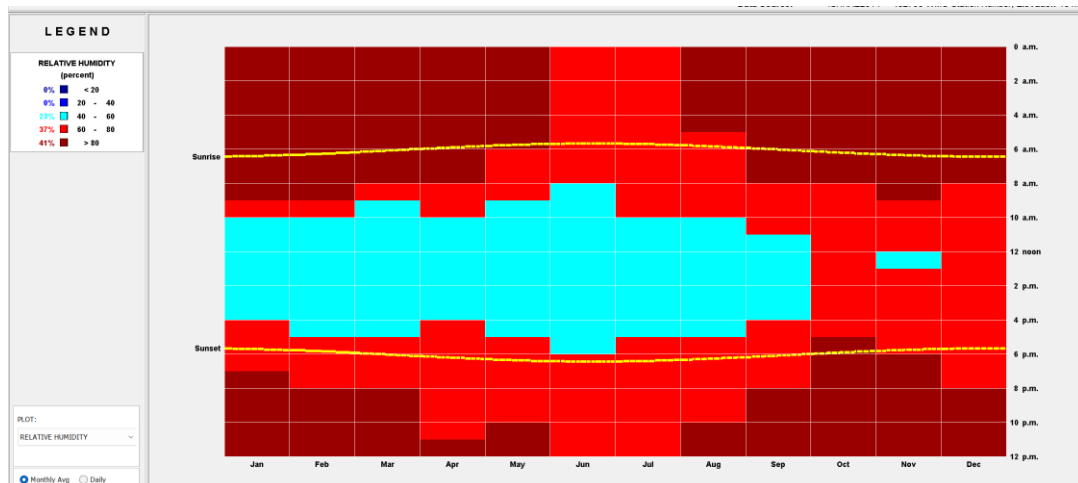


Figure 5-4 Relative Humidity Graph

Wind

The most prevailing winds in Chennai is the Southwesterly between the end of May to end of September and the Northeasterly during the rest of the year

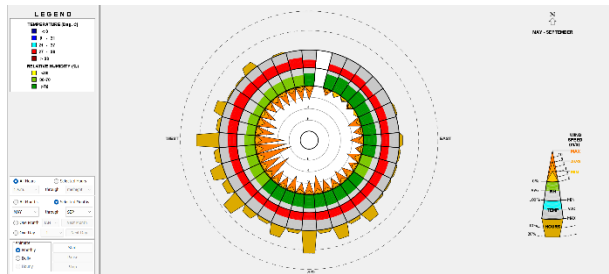


Figure 5-5 Wind Diagram 1

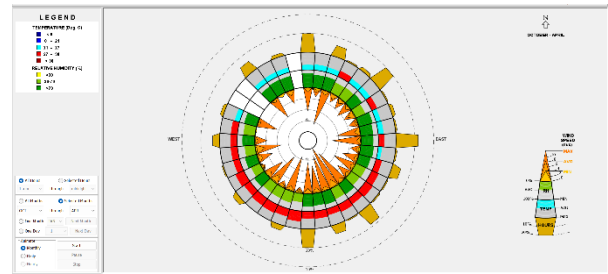


Figure 5-6 Wind Diagram 2

Sky Cover

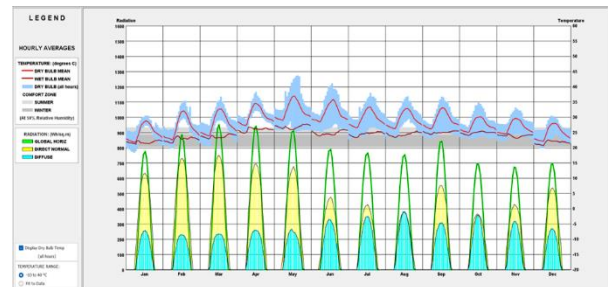
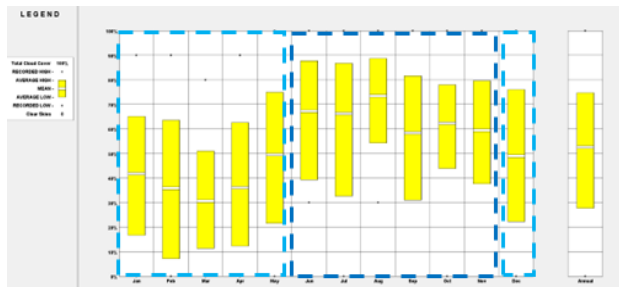


Figure 5-7 Sky cover and monthly Diurnal Graph

- December to May are the clearer part of the year while June to November are cloudier part of the year
- During clearer part of the year that is from December to may the radition is about 640 wh/sqm to 690 wh/sqm. During cloudier part the radition is about 420 to 470 wh/sqm

Rainfall

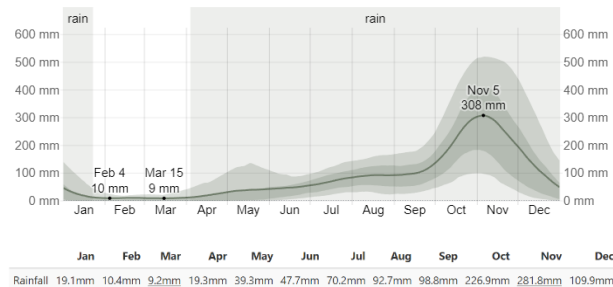


Figure 5-8 Rainfall graph

Psychometric Chart

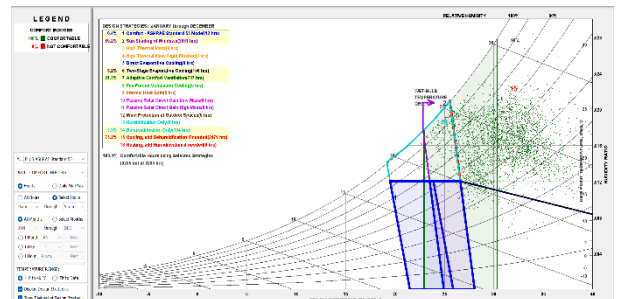


Figure 5-9 Psychometric graph

Design Guidelines:

1. Open spacing for breeze penetration

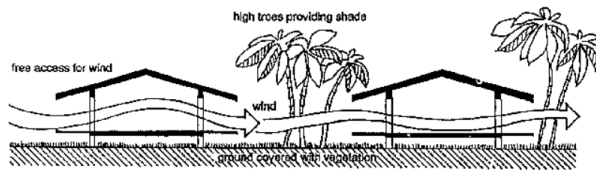
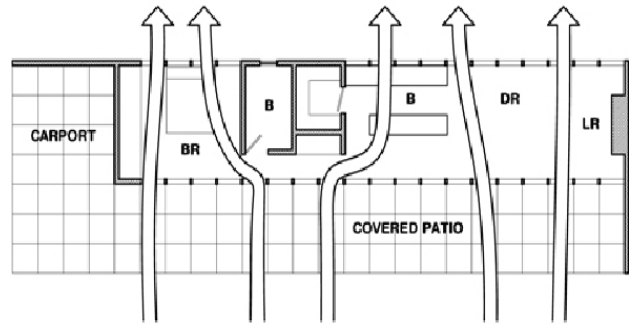
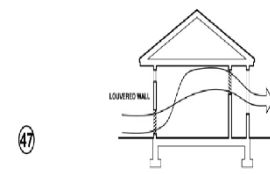
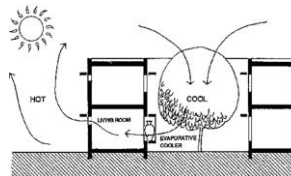
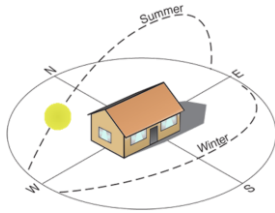


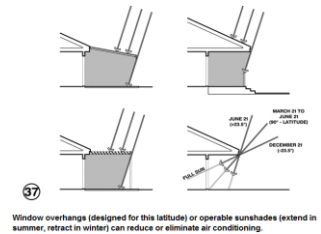
Figure 5-10



2. Layout: Buildings oriented on North & South with Courtyard



Use open plan interiors to promote natural cross ventilation, or use louvered doors, or instead use jump ducts if privacy is required



3. Exclude direct sunlight; provide indirect lighting

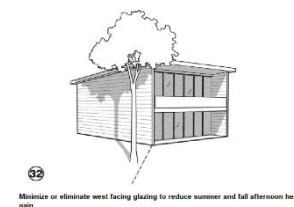
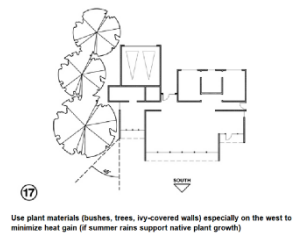
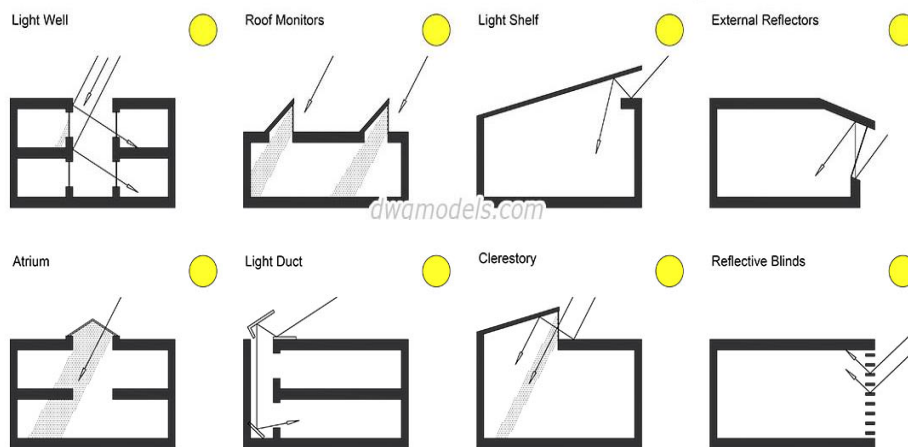


Figure 5-11 Design Guidelines

5.3 Site Analysis

5.4 Site Detail

- Site area – 30401 sq.m / 7.5 acre
- The site is located in Velacherry one of Prime location of Chennai with proper Transit connectivity
- The site is located in mixed use zone with Residence, school and other Commercial entity
- The site is situated near to velacherry Railway station



Figure 5-12 Site Location

Dimension and DCR

LEGEND					
	PRIMARY RESIDENTIAL		WATER BODY		INDUSTRIAL
	MIXED RESIDENTIAL		AGRICULTURAL		SPECIAL AND HAZARDOUS INDUSTRIAL
	COMMERCIAL		L.T. CORRIDOR		OPEN SPACE & RECREATIONAL
	INSTITUTIONAL		CONTINUOUS BUILDING AREA		URBANISABLE
			EWS AREA		NON URBAN

Land Use Map

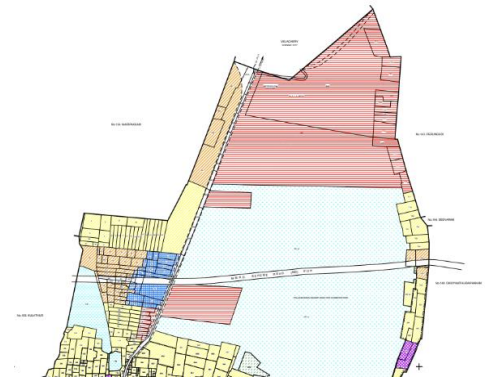


Figure 5-13 Land use Map

Minimum Road width	7.2 m
Max building height	18.3 m
Permissible FSI	2.0
Front setback	6 m
Side and rear setback	2 m
Allowable built up area	60802 Sqm
OSR	3100 sqm

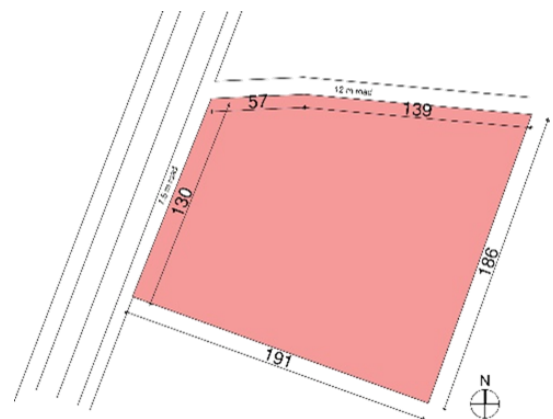


Figure 5-14 Site Dimension

Site and Surrounding

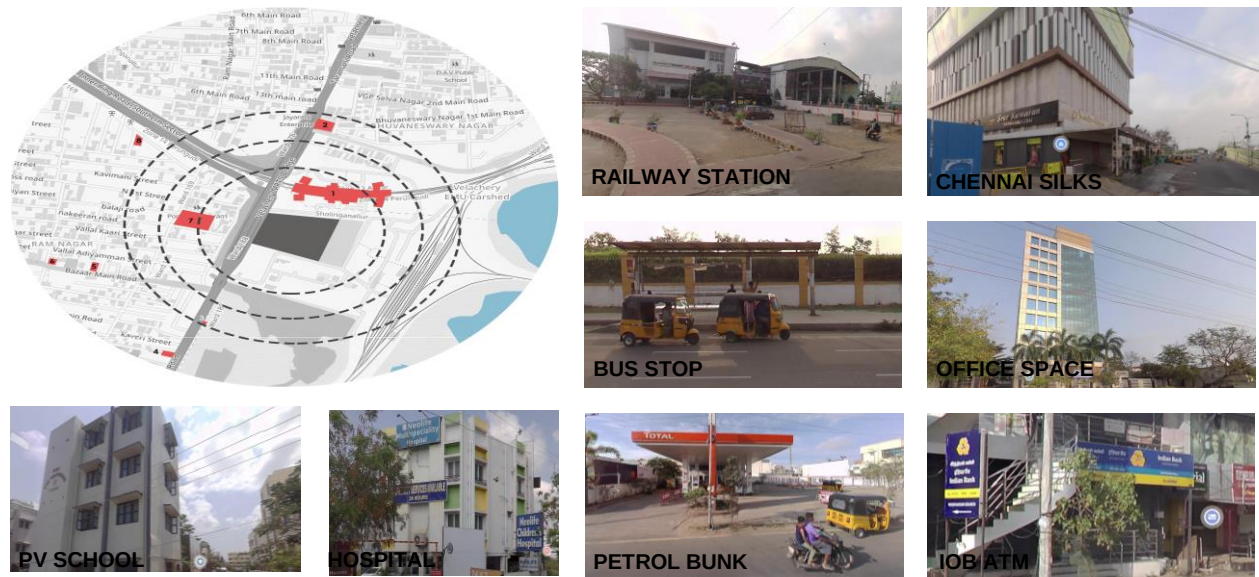


Figure 5-15 Site Surrounding

Swot analysis

- 1.Strength :** The site is surrounded by busy neighbourhoods creating a safe and secure environment for children . The abutting road doesn't have much traffic during the school hours
- 2.Weakness:** Sound related issues due to presence of railway station
- 3.Opportunity:** The site is situated next to velacherry railway station and bus stop which improves the last mile connectivity thus encouraging the users to use public transport
- 4.Threat :** Since the site is situated next to the railway station, noise will be a major threat to the site.

Site morphology



Figure 5-16 Morphology

Natural feature – Terrain (Site Photos)



Figure 5-17 On site Images

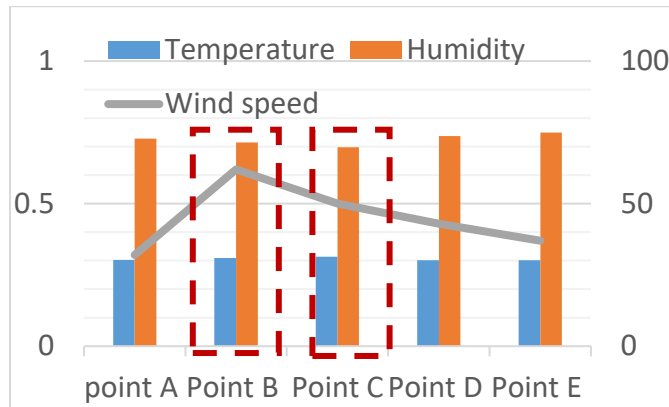
On site readings

Analysed on 05.02.24 & 06.02.24

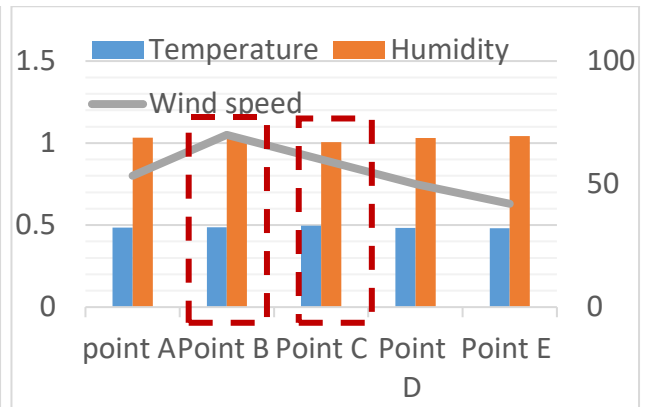


Figure 5-18 On Site Reading

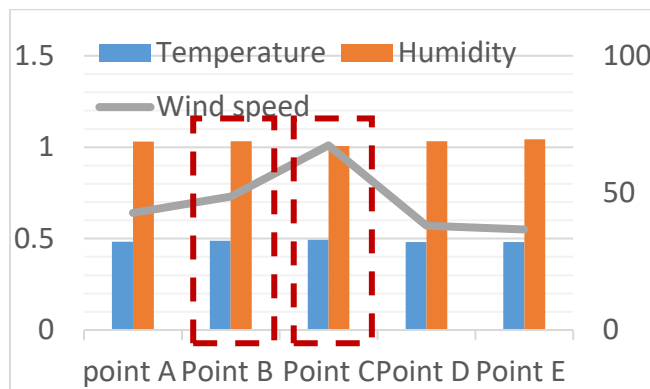
09: 00 am – 05/02/24



12:00 pm – 05/02/24



03: 00 pm – 05/02/24



05: 00 pm – 05/02/24

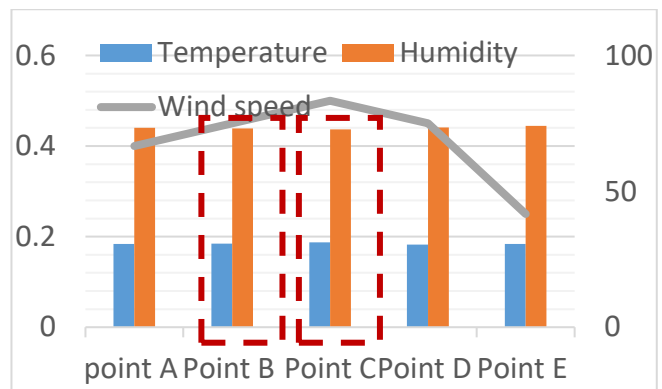
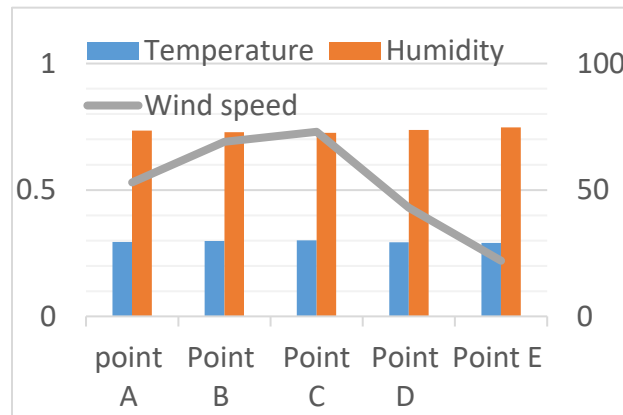


Figure 5-19 On Site Readings - Graph

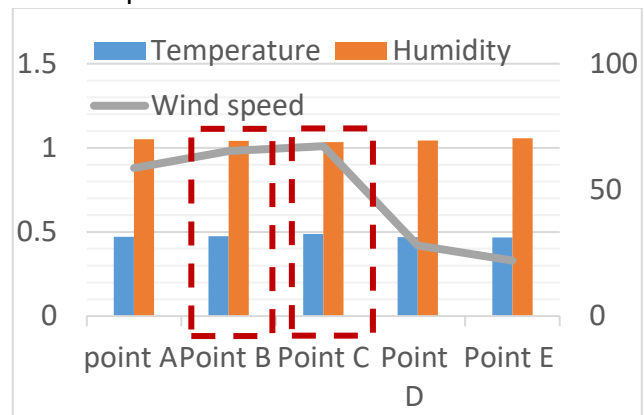
Inference

- The Temperature peaks at 12 pm (33.1) in point C. Throughout the day temperature at point C is higher compared to the other points
- After point C, point B records second highest temperature. This is mainly because both point B & C is not surrounded by any vegetation and doesn't receive any.
- And hence relative humidity is lower in these two points.
- Point E records lowest temperature throughout the day when compared to the other points it is because point E is being shaded by near plots tree and being surrounded by large shrubs. Even though the temperature is lower but humidity is higher in the point E. Wind speed is high at point B which is in east direction.
- After point B, point C records the second highest wind speed throughout the day
- While point E receives the lowest wind speed throughout the day.

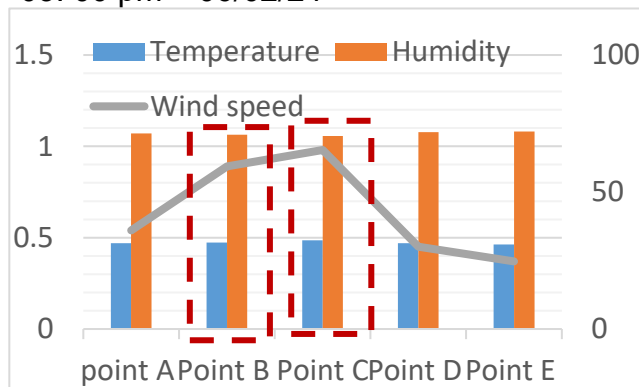
09: 00 am – 06/02/24



12: 00 pm – 06/02/24



03: 00 pm – 06/02/24



05: 00 pm – 06/02/24

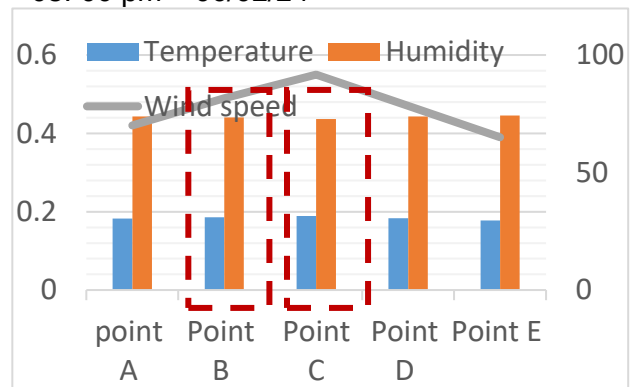


Figure 5-20 On site reading - Graph

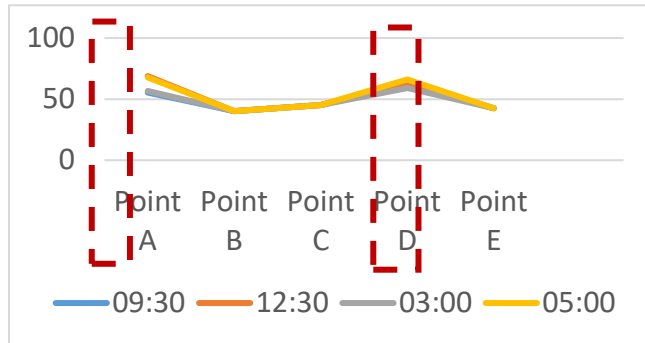
Inference

- The Temperature peaks at 12 pm (32.6) in point C. Throughout the day temperature at point C is higher compared to the other points
- After point C, point B records second highest temperature.
- This is mainly because both point B & C is not surrounded by any vegetation and doesn't receive any. And hence relative humidity is lower in these two points
- Point E records lowest temperature throughout the day when compared to the other points it is because point E is being shaded by near plots tree and being surrounded by large shrubs
- Even though the temperature is lower but humidity is higher in the point E
- Wind speed is high at point B which is in east direction.

- After point B, point C records the second highest wind speed throughout the day
- While point E receives the lowest wind speed throughout the day

On Site Readings

Sound - 05.02.24



Sound - 06.02.24

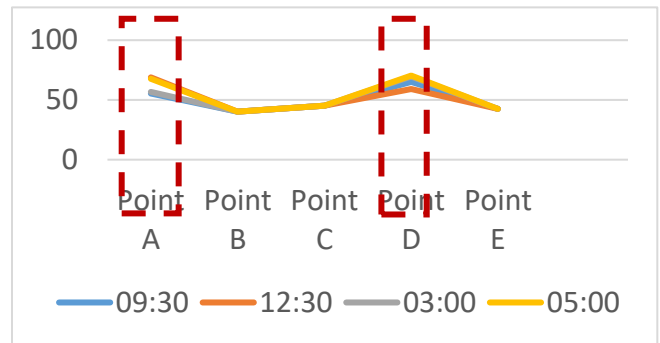


Figure 5-21 On site Noise reading - Graph

Inference

- Point A receives 68 – 55 dB of noise, the noise predominantly comes from railway station and moving vehicles
- Point B receives 70 – 59 dB of noise. The noise level peaks at 5pm due to traffic and lowest dB recorded during 12 pm.
- The noise at point B is mainly due to vehicles
- Other points receives an average of 40 dB throughout the day

Circulation



Traffic analysis – 12 pm



Traffic analysis – 5 pm



Traffic analysis – 9am



Traffic analysis – 3 pm



Fast Slow

MAN MADE FEATURES



Figure 5-22 Traffic Analysis

Sunpath and wind direction



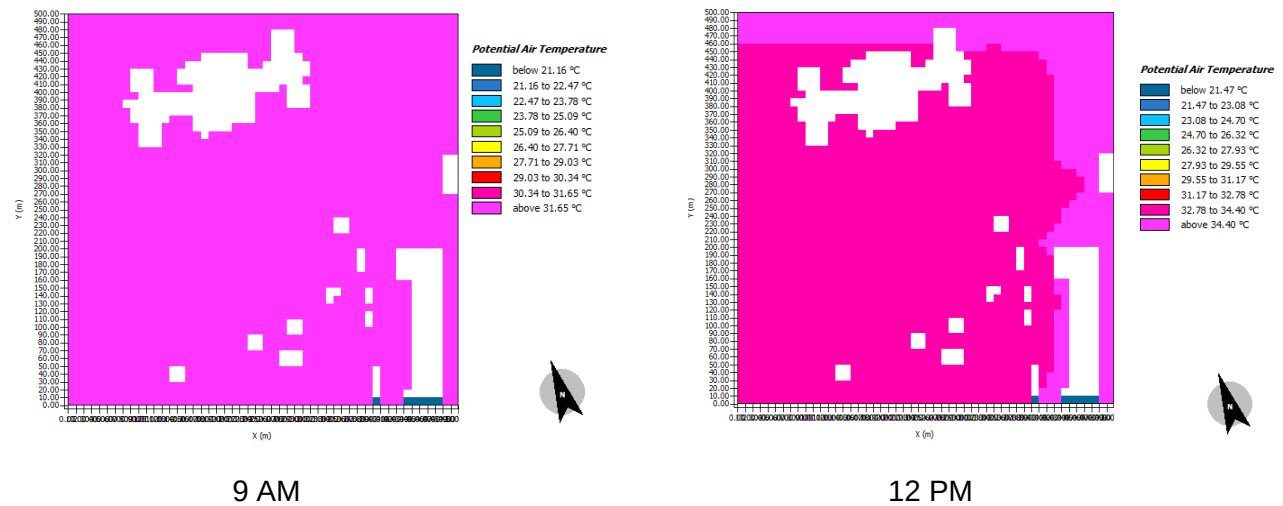
Figure 5-23 Sun path and wind Direction

Views



Figure 5-24 Site surrounding views

Temperature – Summer Solstice & Winter Solstice (MACRO CLIMATE ANALYSIS)



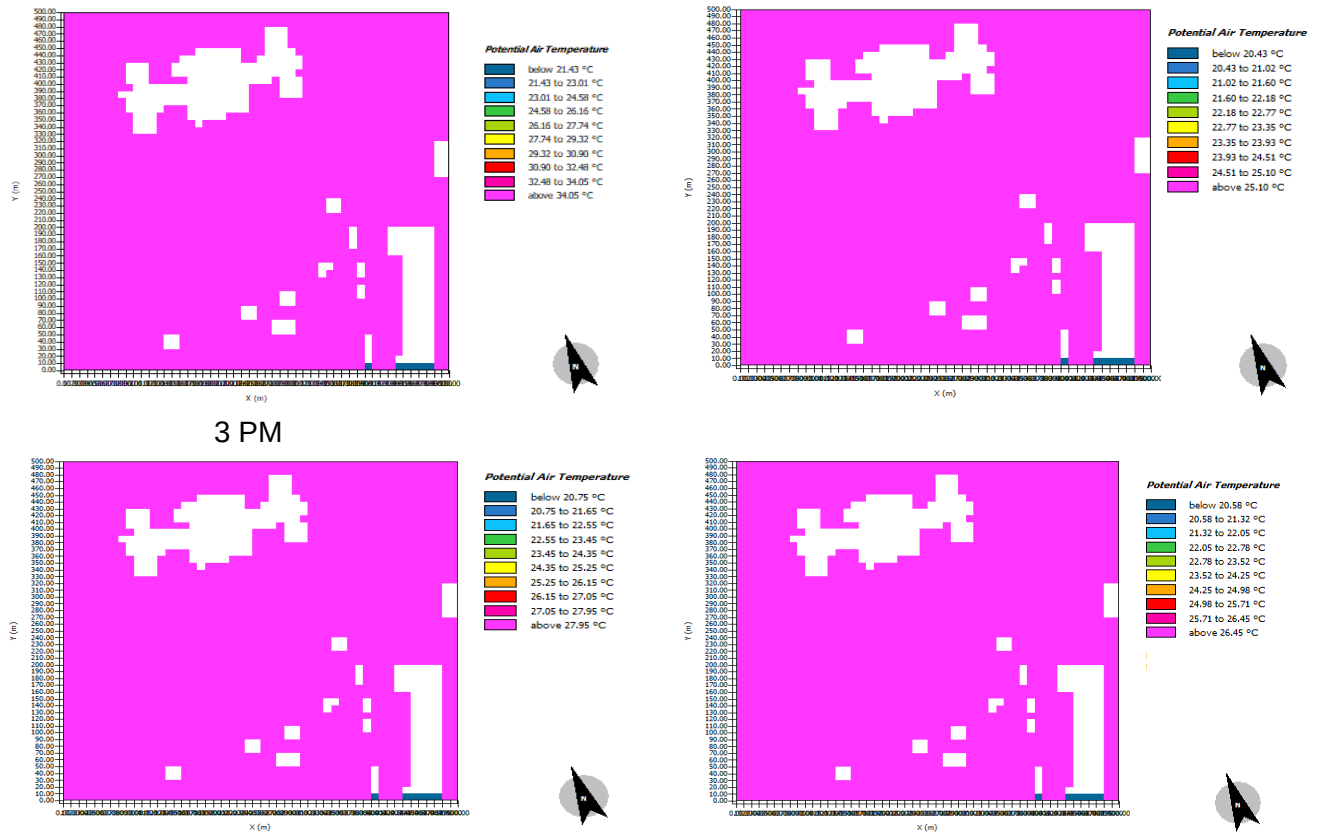
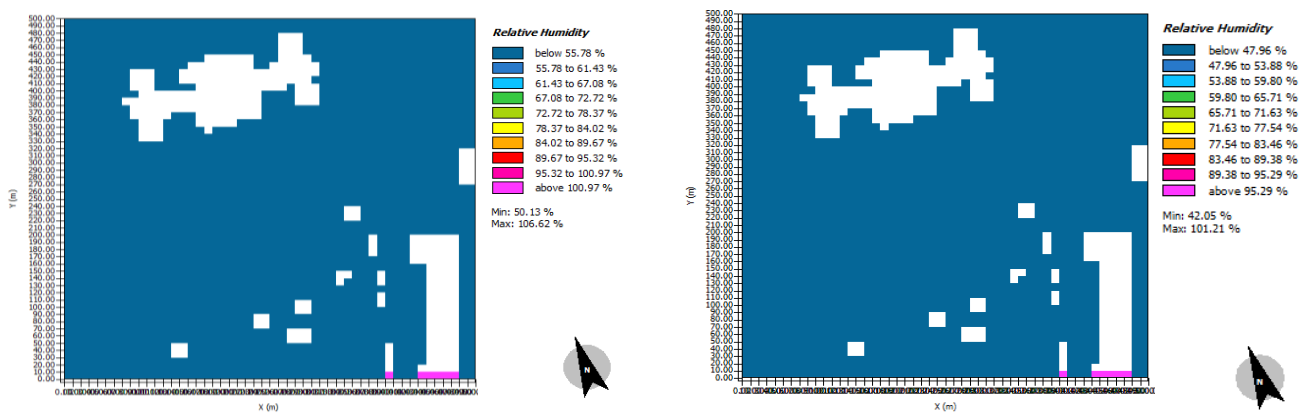


Figure 5-25 Temperature Simulation - ENVIMET

Inference

During summer solstice the maximum temperature 34.4°C and minimum of 27.5°C and during winter solstice maximum temperature in the site reaches up to 27.9°C and Minimum of 23

Humidity – Summer solstice & Winter solstice



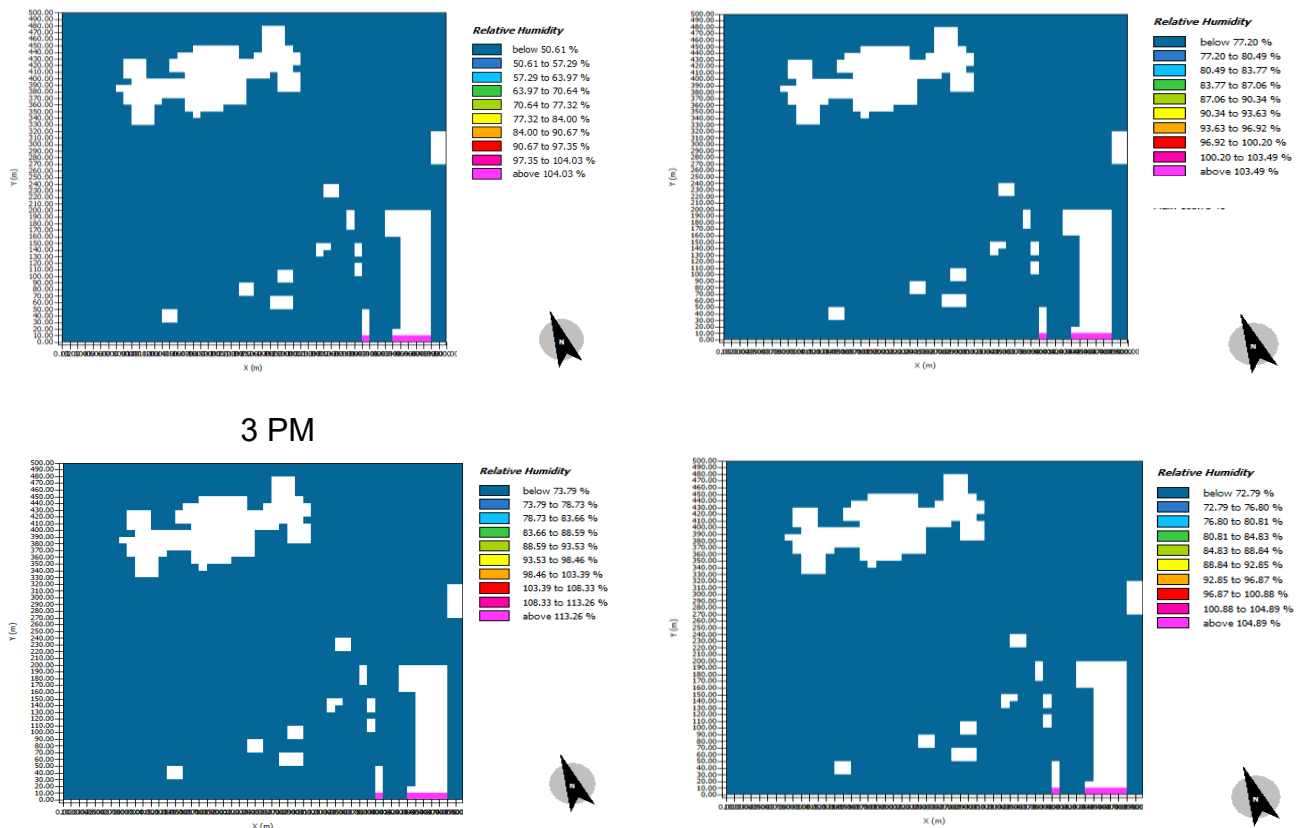
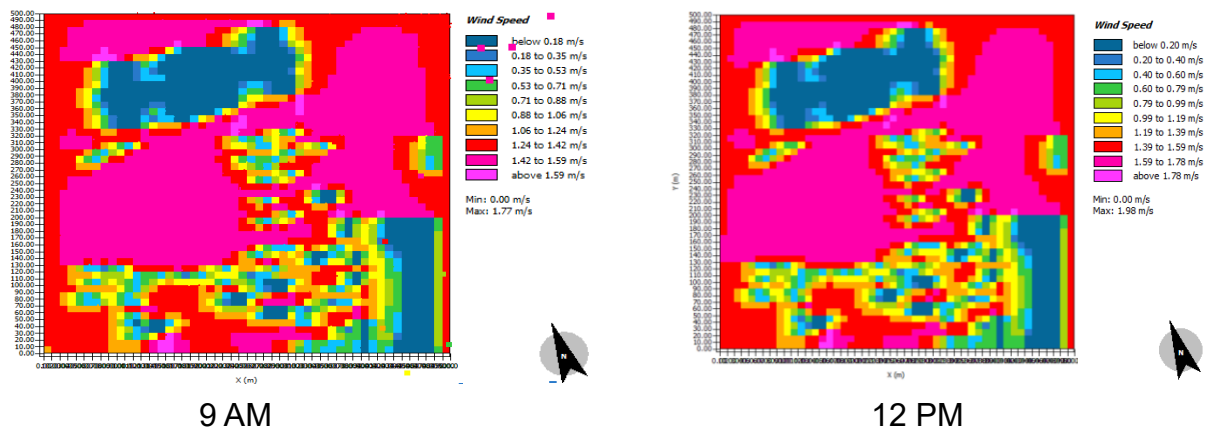


Figure 5-26 Humidity Simulation - ENVIMET

Inference

During summer solstice the maximum Humidity in the site is 74% and minimum of 42% and during winter solstice maximum Humidity in the site is 79% and minimum of 65%

Wind – Summer solstice & Winter solstice



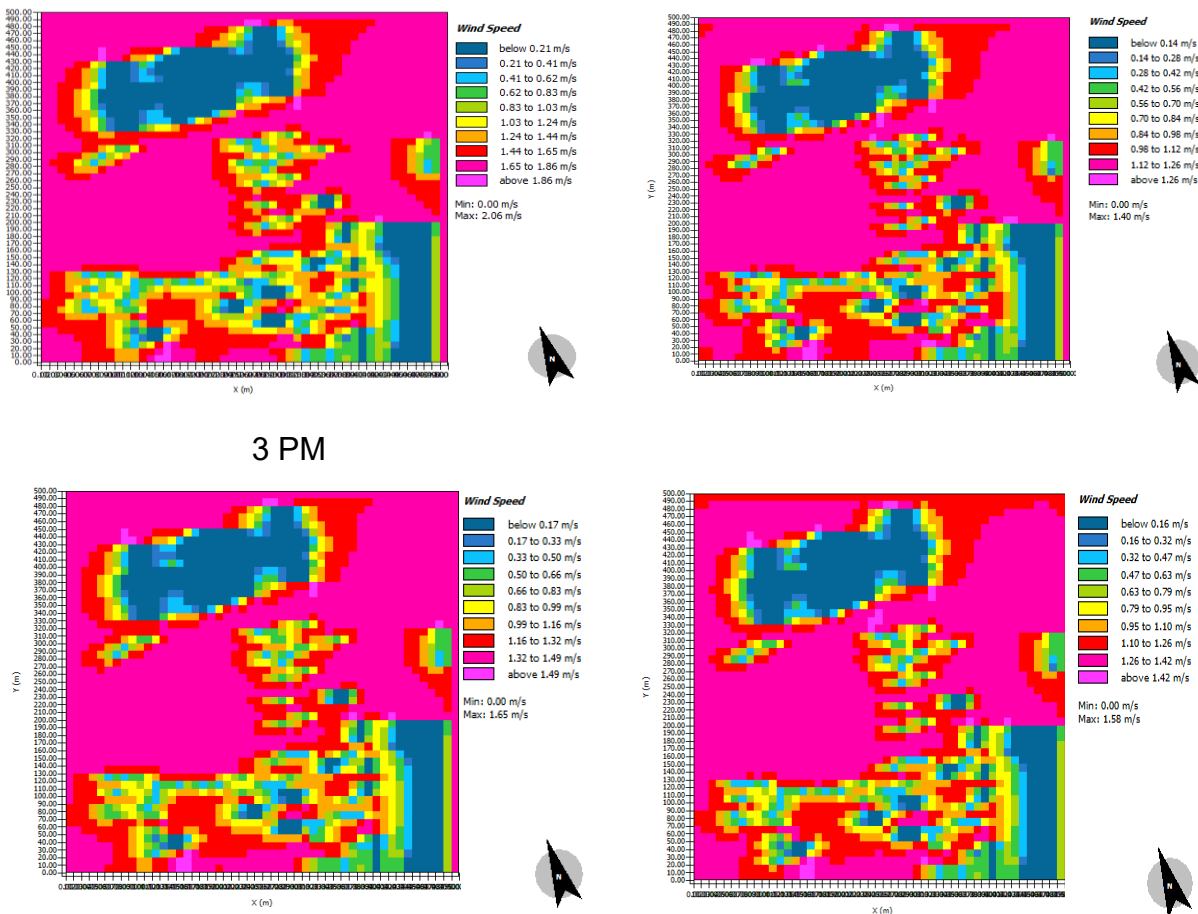


Figure 5-27 Wind Simulation - ENVIMET

Inference

During summer solstice the wind velocity reaches maximum of 1.86m/s and minimum of 1.59m/s and wind velocity reaches maximum of 1.42m/s and minimum of 1.26m/s in winter solstice considering the site context

CHAPTER 6

6. Area Statement

Administration					
S.no	Space name	Length (m)	Breadth (m)	Nos	Area (sq.m)
1	Admin Office	5	6	1	30
2	Principal room	5	4	1	20
3	Vice principal	5	4	1	20
4	correspondent room	5	4	1	20
5	conference room	5	4	1	20
6	Records room	4	4	1	16
7	Toilet	5	4	2	40
8	Electrical room	2	3	1	6
9	Reception	7	7	1	49
10	Accounts	5	6	1	30
Circulation space (24%)					50.5
Total area					301.5
Kinder garden					
S.no	Space name	Length (m)	Breadth (m)	Nos	Area (sq.m)
1	Classroom	8	6	12	576
2	Library	14	8	1	112
3	Activity room	12	8	1	96
4	Indoor play area	10	10	1	100
5	Staff room	7	8	3	168
6	First aid room	3	4	1	12
7	Maths lab	8	6	1	48
8	Toilet	5	5	2	50
9	Electrical room	2	3	1	6
Circulation space (24%)					292
Total area					1460
School block					
S.no	Space name	Length (m)	Breadth (m)	Nos	Area (sq.m)
1	Classroom	8	6	28	1344
2	Library	14	8	1	112
3	Staff room	7	8	6	336
4	Maths lab	8	6	1	48
5	Physics lab	9	6	1	54
6	Chemistry lab	9	6	1	54
7	Biology lab	9	6	1	54
8	Computer lab	9	6	1	54
9	Language lab	8	6	1	48
10	Activity room	10	10	1	100
11	Indoor play area	10	10	1	100
12	First aid room	3	4	1	12
13	Toilet	5	5	6	150
14	Electrical room	2	3	2	12
Circulation space (24%)					619.5
Total area					3097.5
Activity block					
S.no	Space name	Length (m)	Breadth (m)	Nos	Area (sq.m)
1	Dance room	10	8	1	80
2	Music room	10	8	1	80
3	Art and craft room	10	8	1	80
4	Activity room	5	8	5	200
5	Multipurpose room	10	10	1	100
6	Ncc room	5	6	1	30
7	Scouts and guides room	5	6	1	30
8	Students counsellor room	5	4	1	20
9	Staff room	7	8	1	56
10	Toilets	5	5	2	50
Circulation space (24%)					181
Total area					907
Overall area					5766
Play ground					300
Basketball court					420
Cricket					134

- Total no.of students : 1280
- Total no. of. staff: 43
- Car parking: 20
- Bike parking: 40.

CHAPTER 7

7. SITE ZONING

7.1 Zoning 01:

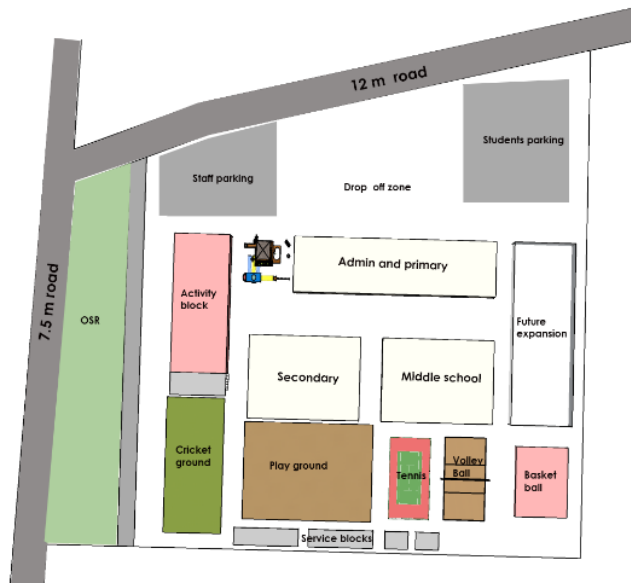


Figure 7-1 Zoning 1

Inference

- OSR is placed on the west side of the site Which acts as noise buffer zone
- Future road construction can be easily done Without disturbing the school
- Ground is placed at the rear end of the site that is south side the building provides the shade needed during the school hours
- Parking is placed at the front of the site which affects the user's navigation to the site
- Parking kept at the front side affects the view of the school

Wind

- Activity block orientation blocks the wind flow from the Leeward side.
- It reduces the wind speed from 3.85 to 1.28 and 0.86 around the other blocks

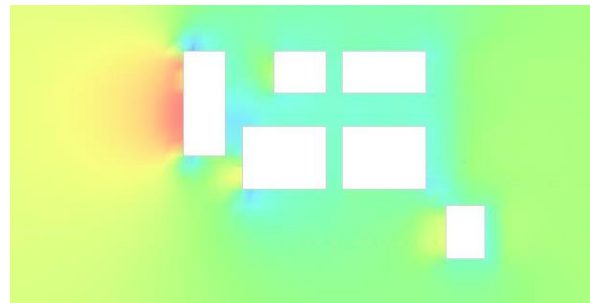
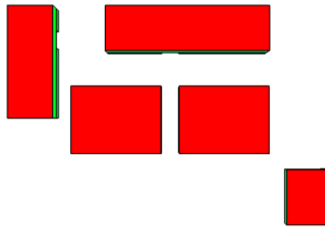


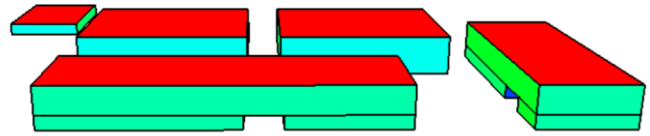
Figure 7-2 Zoning 1 CFD Analysis



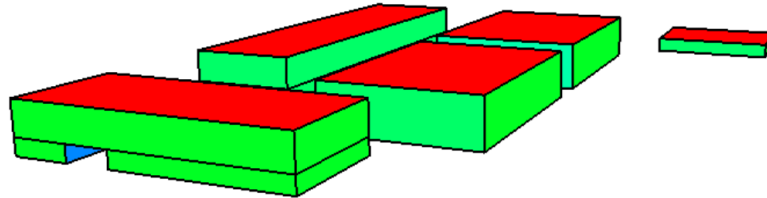
Top view



North



South west



North East

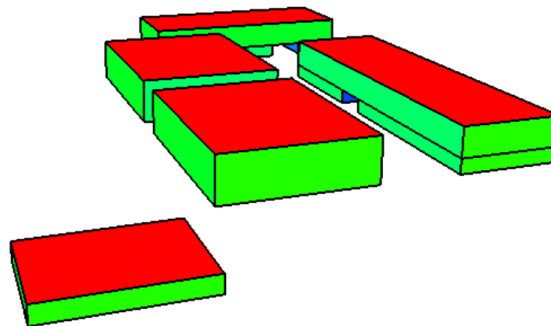


Figure 7-3 Zoning 1 Solar analysis

Source : Design builder



Inference

- The top surface of the building receives 1875 kwh of solar radiation per year
- Activity Primary and admin block façade on the **north** side receives **750 kwh** of solar radiation per year
- While the secondary and middle school block behind the primary blocks receives 625 kwh of solar radiation
- South, west and east side of the site receives around 1250 kwh of solar radiation

7.2 Zoning 2

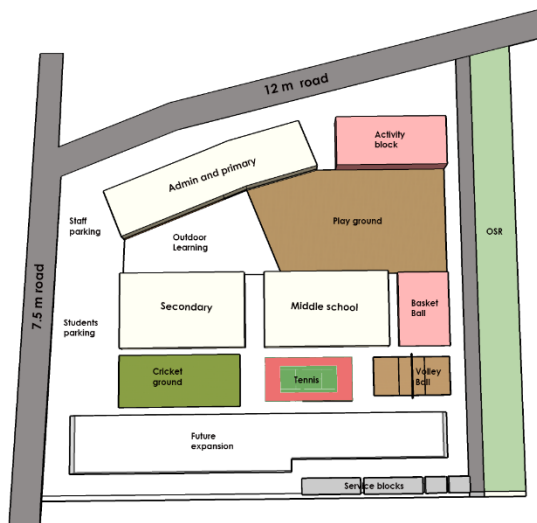


Figure 7-4 Zoning 2

Inference

- OSR is placed on the East side of the site, if incase a building comes in the adjacent open space the osr Width reduces the effect of the adjacent buildings
- Ground is placed between the building blocks which helps which creates shade needed during the day time
- The ground acts a central focal point which also creates a buffer space between blocks at the same it encourages interaction between the students creating a vibrant environment
- Parking is placed at the west side thus avoiding clutter in the front
- Since parking is placed at the side the view
- of the school doesn't get affecte

Wind

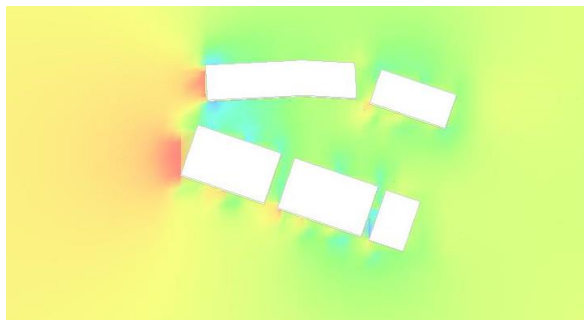
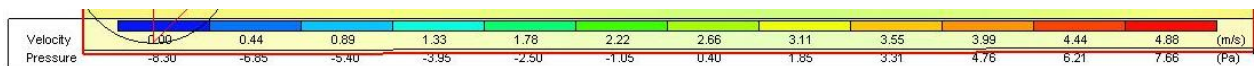
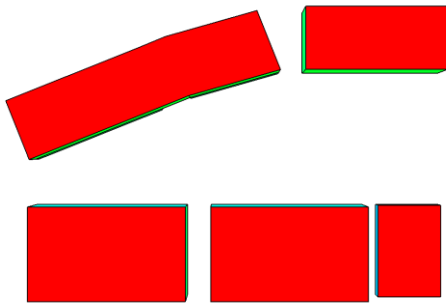


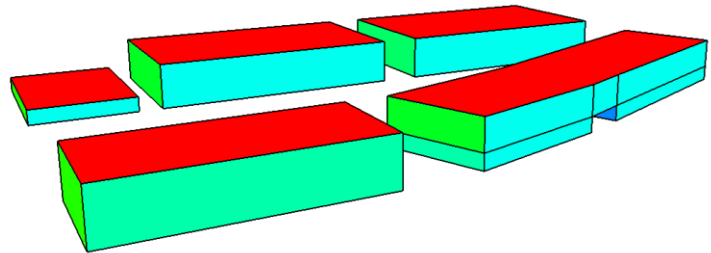
Figure 7-5 Zoning 2 CFD Analysis



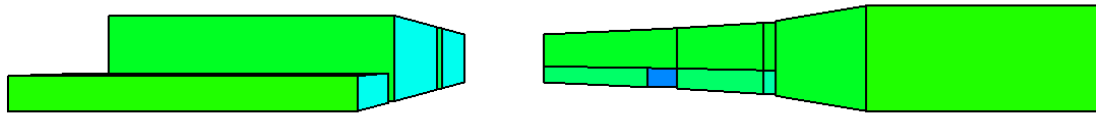
Top view



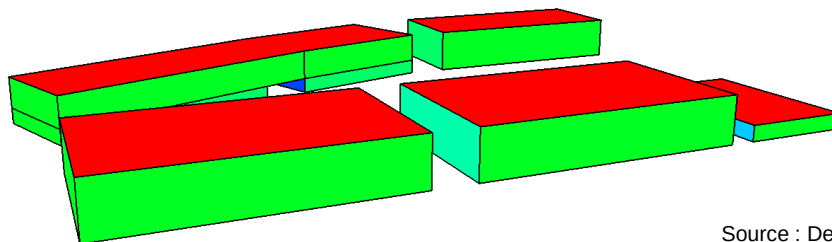
North



North East



South west



Source : Design builder

Figure 7-6 Zoning 2 Solar analysis



Inference

- The top surface of the building receives 1875 kWh of solar radiation per year
- Primary and admin block façade on the north side receives 500 kWh of solar radiation per year since it is oriented towards true north
- While activity blocks receive 625 kWh of solar radiation
- While the secondary and middle school block behind the primary blocks receives 500 kWh of solar radiation

- South, west and north east side of the site receives around 1250 kwh of solar radiation

7.3 Zoning 03:

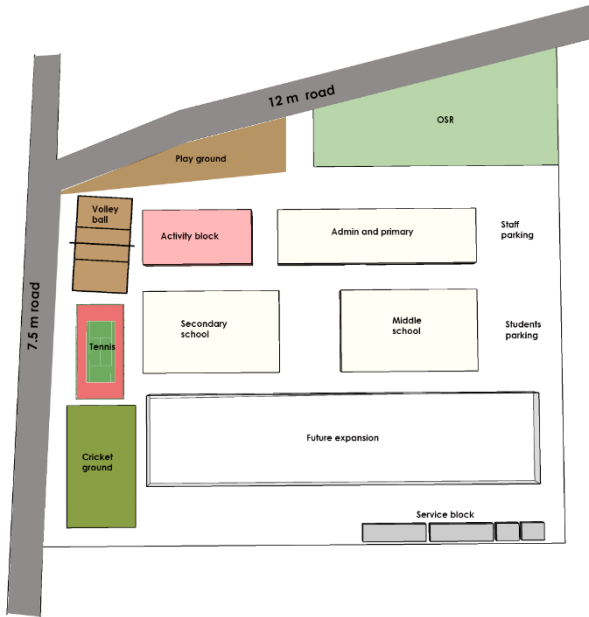


Figure 7-7 Zoning 3

- OSR is placed on the front of the site which will be used for road extension
- OSR takes the major road width
- Since OSR is placed at the front site it affects the front view of the school
- Ground is placed in the front side of the site creating a vibrant environment
- Parking is placed at the east side creating less clutter in the front end of the side

Wind

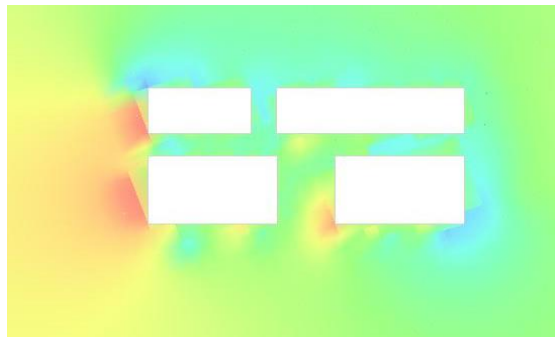
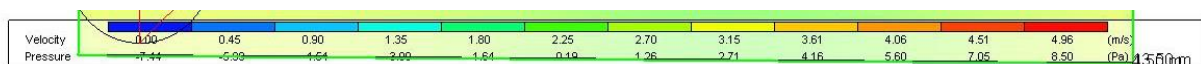
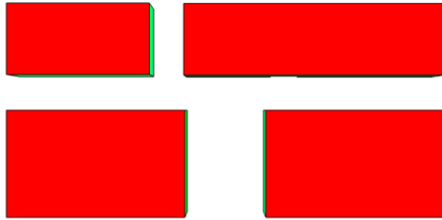


Figure 7-8 Zoning 3 CFD Analysis

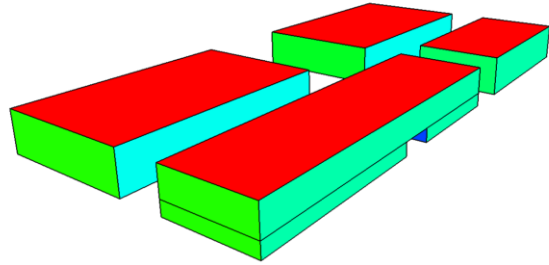
- The block arrangement reduces wind speed and also reduces the wind pressure around the building blocks.
- Even though the wind speed and pressure is higher at the activity block and secondary block. Both gets reduced due to its positioning around the central spline.



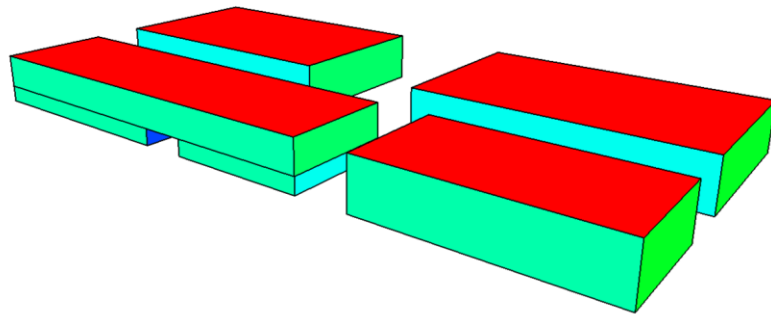
Top view



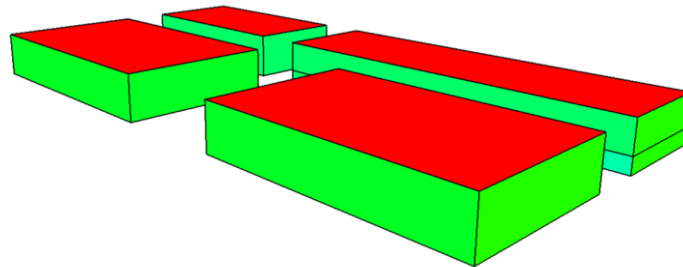
North east



North



South West



Source : Design builder

Figure 7-9 Zoning 3 Solar analysis



- The top surface of the building receives 1875 kwh of solar radiation per year
- Activity block, Primary and admin block façade on the north side receives 750 kwh of solar radiation per year since it is oriented towards true north.
- While the secondary and middle school block behind the primary blocks receives 500 kwh of solar radiation

- South west and north east side of the site receives around 1250 kwh of solar radiati

7.4 Zoning 4

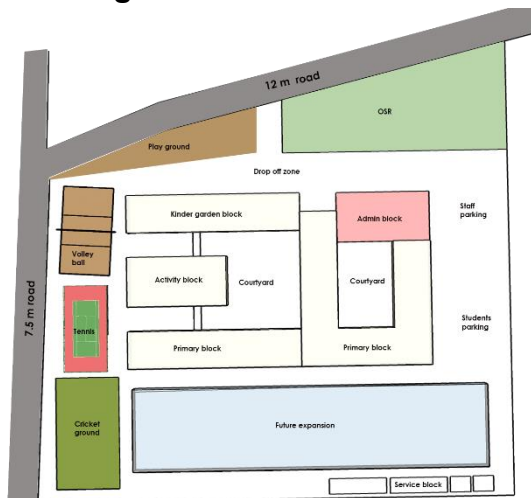


Figure 7-10 Zoning 4

Wind

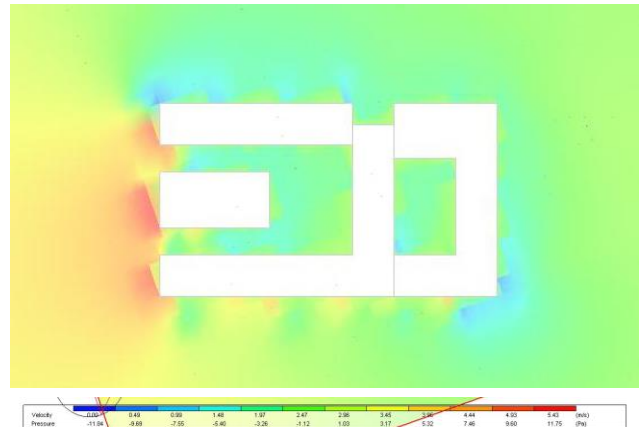
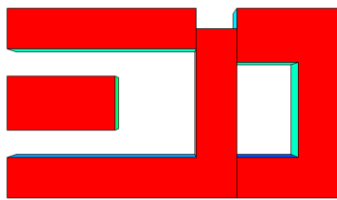
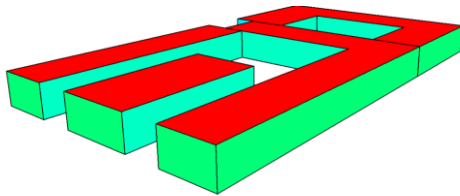


Figure 7-11 Zoning 4 CFD Analysis

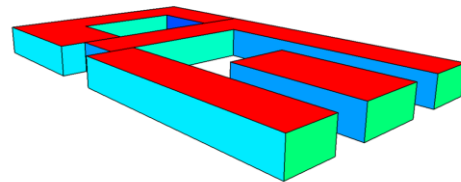
Top



South West



North west



South east

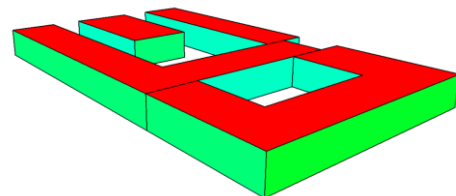


Figure 7-12 Zoning 4 Solar analysis



- The top surface of the building recives 1875 kwh of solar radition per year
- Activity block, Primary and admin block façade on the north side receives 625 kwh of solar radiation per year. While the school block behind the kindergarden blocks receives 250 kwh of solar radiation due to the shading

7.5 Zoning 5

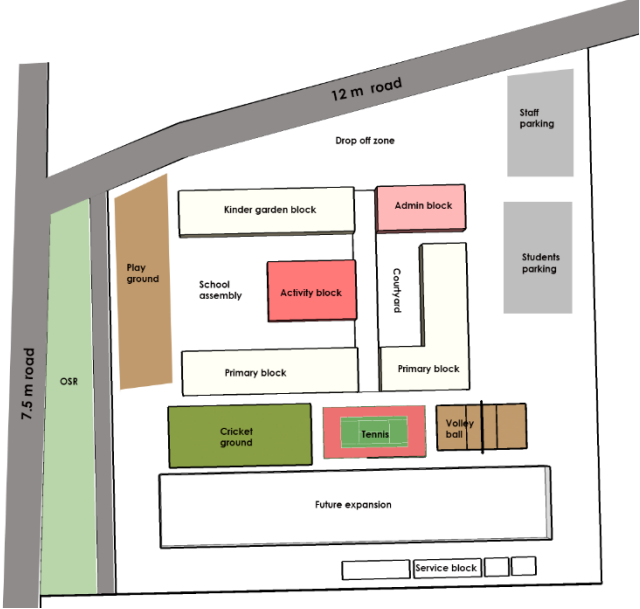


Figure 7-13 Zoning 5

Wind

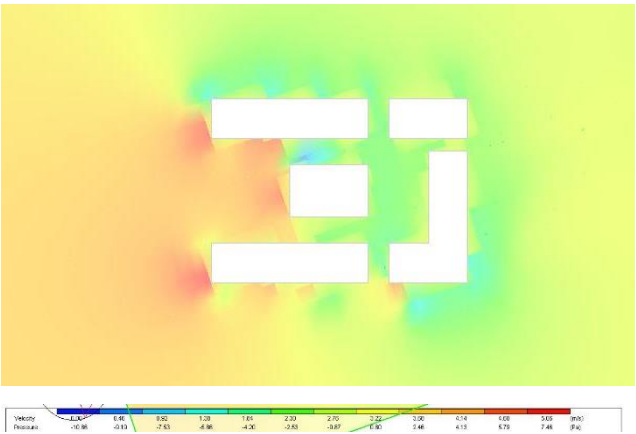
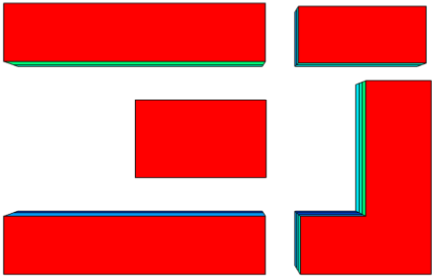
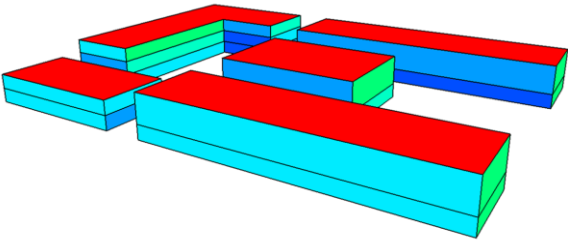


Figure 7-14 Zoning 5 CFD Analysis

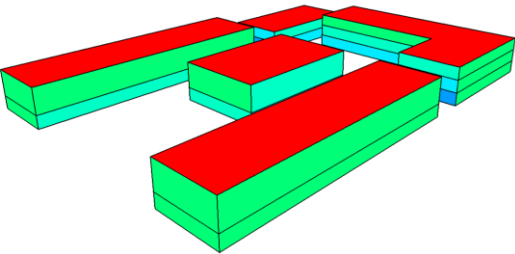
Top



North west



South West



South east

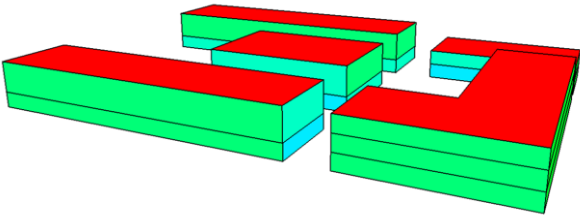


Figure 7-15 Zoning 5 Solar analysis

CHAPTER 8

8. DESIGN DEVELOPMENT

SITE PLAN

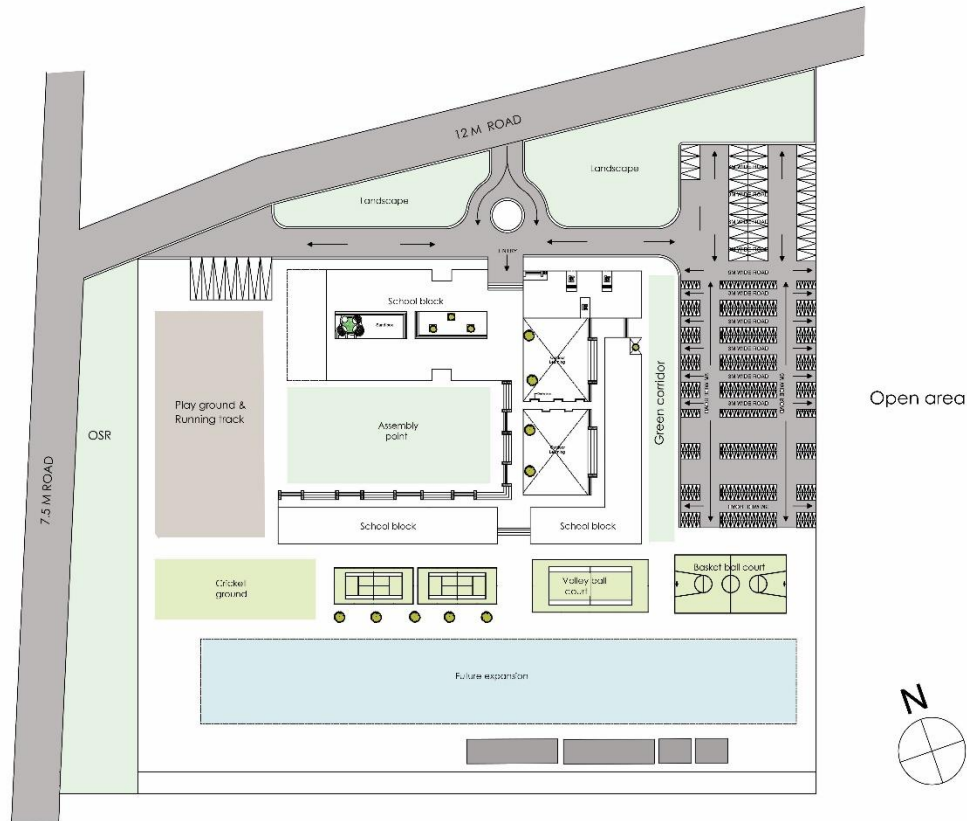


Figure 8-1 Site plan

Creating a site plan for a school involves considering various elements and features that are essential for an educational facility. While the specific design will depend on the school's requirements and available space, here are some common components to include in a school site plan. The school site plan design includes strategically positioned buildings and structures, such as classrooms oriented for optimal natural light, administration offices near the main entrance for accessibility and security, and libraries. Specialized facilities are placed to enhance educational and functional relationships.

Classrooms are oriented to maximize natural light and scenic views, often clustered by grade level to enhance interactions and accessibility. Administration offices are strategically placed near the main entrance for visitor convenience and enhanced security. Outdoor play and recreation areas are thoughtfully designed with playgrounds, basketball courts, seating areas, ensuring adequate space and safety. Outdoor amenities has adequate utility connections, with thoughtful consideration for water, electricity, and drainage.

SCHOOL BLOCK



Figure 8-2 Ground floor plan

SECTIONS



Figure 8-4 North Section

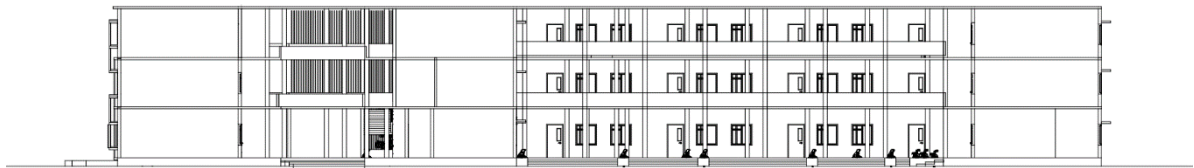


Figure 8-5 West Section



Figure 8-6 East Section

VIEWS - EXTERIOR





Figure 8-7 Exterior Views

VIEWS - INTERIOR



Figure 8-8 Interior Views

REFERENCE

1. <https://nzeb.in/>
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