TEAM AURUM BMSCE-CA

FInal Design Report

APRIL 2023

Educational Building

BMS College of Architecture | BMS College of Engineering

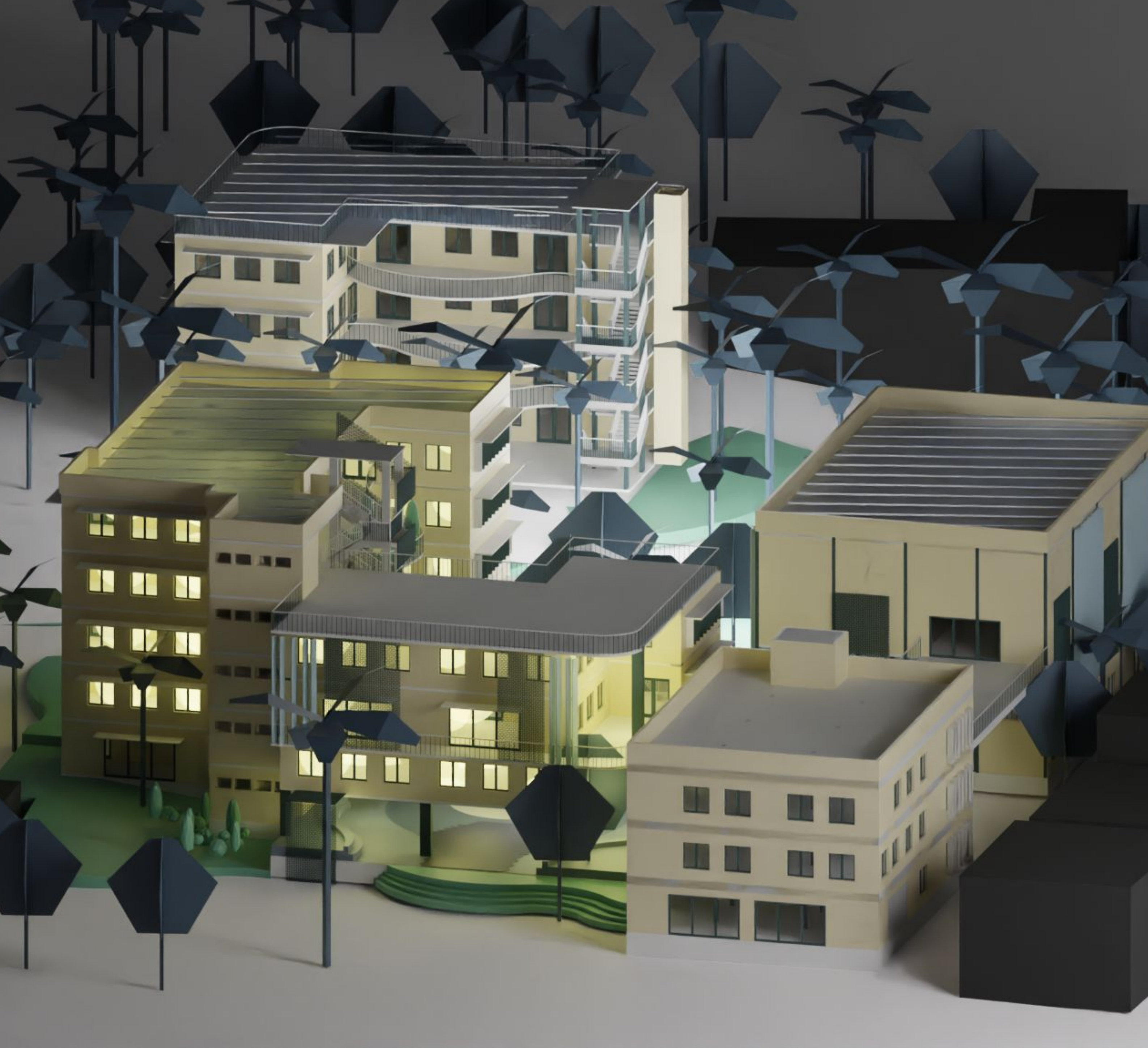


Table of Contents

List of Figures

List of Tables

Response to Reviewers' Comments

Section	Reviewers' Comment	Response
	Reviewer 1	
Energy Performance	The approach used is good and clearly presented. While the strategy to reduce U-value in envelope is a practical approach, it is advised that you also present details of structural strength/ integrity of components (for e.g., slabs with coconut shell) in the Engineering section. Your HVAC design requires rethinking as the comfort temperatures (presented in Health & well being section) is not meeting the set-point as per the comfort model, plus the operative and DBT is higher than the outside DBT for most times of the year. It shows that the choice of using natural ventilation only in the classrooms is not working. Further, provide cost calculations for the RE generation system (Solar PV panels, Pavegen tiles) in your affordability section and incorporate in overall cost of the project.	Details of the structure have been added. The graph showing inside operative dbt higher than outside dbt has been re looked inot and appropriate changes have been made to ensure comfort inside the classrooms. Cost calculations for RE systems were already added in the total cost of project but have also been added to affordability section now.
Water Performnace	Overall, good details provided. The approach is good. The idea of using coconut husk needs further detailing - what is the shell life of this (as they are biodegradable), how and when they will be replaced? Do you have any case studies which provides evidence that these are effective filters? The table on water consumption and sources require narrative description. Right now few things are not clear like why the values for building maintenance, irrigation usage, etc., are changing by months. The storage capacity and monthly water requirements are not matching. Look in to the net-zero calculation and present it more clearly.	Further detailing on coconut husk has been incorporated and reference links to the case study has been provided in the Water Performance Section. The values in the water table have been changed and explanation has been presented more clearly.
Embodied Carbon	The section requires more detailing in terms of construction technologies used in proposed design. The narrative provides some clarity on the use of CLC blocks and coconut shells. details on windows, floors, superstructure is missing. Also, it will be beneficial if you provide supporting narrative/ sources on how you arrived at the embodied carbon content of the selected materials in your proposed design.	Construction details and technologies have been further detailed and incorporated in this section. A narrative to explainhow we arrived at the embodied carbon values has been provided.
Resilience	You have reflected on the potential risks and presented in the report. It is quite clear. However, you should quantify the risks in terms of number of hours the building's usage/ essential supplies will be affected and then present your solution to mitigate those disrupted hours of operation while maintaining acceptable range of comfort and well being of the occupants	Addressed under Resilience Section
Engineering and Operation	The narrative provides some clarity on the proposed engineering systems. Table 11 does not provide clarity on what systems you have used for efficient design. Heat gain from fresh air could be reduced if you explore HVAC technologies.For the envelope, you have shown heat gain reduction by CLC blocks only, however, you should also include other components of envelope and present an overall reduction calculation.The section on HVAC system provides clarity on the type of system you are proposing however you should provide your cooling load demand and present calculation to show how your proposed system meeting that demand (annually/ peak monthly). Space provision and architectural integration is not clear/ presented. You have also not provided details on constructability (at scale).	Addressed under Engineering Operation Section.Changes have been made to Table 11 specifying the type of system being proposed. A narrative on how we are proposing reduction in heat gain from all components of the envelope has been incorporated.
Architectural Design	Good set of rendered images is present. However, the section does not meet the contest criteria as mentioned in the competition guide. Please refer to the requirements and provide the details.	We appreciate this comment. We have relooked at the competition guide requirements and we feel we have addressed the points mention. However, more narratives and details have been incorporated to further reinforce our design process and concepts.
Affordability	You have provided calculations and some narrative explanation about cost-effective strategies. The table presented shows that the cost for proposed design is higher than your baseline. How are you justifying this to the client? The table does not provide cost for RE systems or additional consultant you are proposing. How is the interest during construction reduces? Provide justification. There is some narrative points made on how the operation of the building could be cost-effective but no it should be backed by calculations, i.e., LCCA and ROI calculation.	We had added RE systems cost to our cost calculations already. Narratives on our justification for cost effectiveness to the client as well has ROI have been elaborated in the Value Proposition Section. Further calculations have been added.
Innovation	The narrative provides good clarity on your ideas. The use of AI in BMS requires justification and details on how it will improve the currently available advanced BMS system. Right now the benefit you have mentioned is something that can be achievedeven without the usage of the AI hence how will you convince your client to use this technology? What is the cost implication of this in your budget (it was not reflected in affordability section). The idea of using husk for paper making is a good idea but it seems this technology and usage is already available. What is the innovation you are bringing? Your proposal fits more under reuse of waste material (under waste management) however, do not entirely fits the criteria of innovation based on your current narrative.	Addressed under Innovation Section
Health Wellbeing	You have provided description of strategies. The strategies needs to be justified with calculation and analysis which is missing in the report. It is not clear which thermal comfort standard your are following (although it is noted that you have considered 20-27C as the comfort range). However, the graph on temperature does not matches with your claim that comfort is maintained all the occupied hours as there are several hours where the indoor temperature is higher than 27C (sometimes beyond 30C) and is above the outside temperature. Space by space analysis of comfort is also missing. The IAQ section needs more details such as details of hours for modes of operation, analysis showing the minimum requirement is met, airflow network diagram, operation schedule. It is also noted that in your simulation input, you have considered Relative Humidity as 10% which is very low. Recheck the input values for this and other variables.	The thermal comfort standard chosen has been presented more clearly. The graph showing inside operative dbt higher than outside dbt has been re looked inot and appropriate changes have been made to ensure comfort inside the classrooms. SPace by spae analysis has been added and airflow diagrams have been incorporated
Value Proposition	The descriptions are good. However, it is verbose and requires justification with quantifiable numbers. Although you have presented calculation for RE systems but it doesn't cover all aspects which you have listed. The initial cost for proposed design is also higher than the baseline and you should provide well rounded justification for this that will help your client to invest in your proposed idea. This section can be improved if you use compelling narrative to justify why your client should invest along with financial implications.	Addressed under Value Proposition Section
	Reviewer 2	
Energy Performance	Good detailed work is done in the energy analysis and achieving net energy positive building. You have wind turbines and pavegen as an additional source of energy generation. Furthermore, a deeper investigation is advised on the feasibility and maintenance of these sources. Please check if the capital cost of wind turbines will compensate to the energy generation on your particular site. Will the pavegen tiles bear the stress of children running and jumping over it? The cost of maintenance and replacement of it should be considered. The idea of ECO roof is innovative and appreciated. You have mentioned that the ECO roof is used for rainwater absorption,which will further create issues of reduced rainwater runoff, water seepage through the roof, and then mold growth if not maintained and checked timely. It is good that you prefer to keep classrooms naturally ventilated. However, you shouldcheck for the comfortable and uncomfortable hours experienced during the occupancy hours inside these spaces. Alternative ventilation should be thought of to achieve comfort during uncomfortable occupancy hours.	The details on the pavegen tile system have been added to address this comment. Further detailing of eco roof has been incorporated. The comfortable and uncomfortable hours experienced in the classrooms have been fully detailed out under the Health and Wellbeing Section.
Water Performnace	The water cycle needs to be detailed further. How are we reusing the treated water into the system? Also consumption quantities should be mentioned besides the usage to see the water balance. Right now the water balance is not seen in this diagram. The details of LPM/ LPF for the efficient fixtures considered should be mentioned. The materials considered for different surfaces should be reported as well. The idea of using coconut husk is innovative. Moreover, this will require regular monitoring and maintenance. Coconut husk is biodegradable material which will decompose and invite mould or other fungi. A deeper analysis is needed towards the practicality and functionality of the idea.	Reuse of treated water has been mentioned. Deeper study on the coconut husk innovation has been done and inferences have been incorporated in the report
Embodied Carbon	The narrative, detailed information, data presentation, and graphs are very well reported.	No comments.
Resilience	Your approach toward addressing the section is thoughtful. For unforeseen disasters, the days of autonomy should be considered for a quantitative assessment. The representative sketches are impressive. Additional drawings and calculations can also be provided.	Addressed under Resilience Section
Engineering and Operation	You have effectively addressed the requirements. The units should be mentioned in figures 51 and 52. If you have provided a fan inside the learning spaces to maintain the ACH, then it is not considered as naturally ventilated. It is highly appreciated that you have provided references in the foot notes.	Addressed Uunder Engineering and Operation Section
Architectural Design	The visual representation and renders are worth appreciating. The designing and modeling is intricate and well-planned.	No comments.
Affordability	The LCC calculations in the excel are not updated as per the project proposal, the proposed case is showing Radiant cooling which is not mentioned in the report. Please mention the parameters which contribute to reduced cost and affordability. It is unclear if the construction timeline of the project is taken into consideration here. Recheck the Cost estimation sheet for HVAC systems LCC.	Parameters contributing to reduced cost havebeen mentioned in Affordability as well as Value Proposition Section. Cost Estimation sheet has been updated.
Innovation	From the innovation narrative, it is understood that the software is the innovative output. More clarity is needed regarding the functioning and target audience of the software. The need for AI along with BMS is good but the necessity needs to be strongly convinced. How is innovation if you are outsourcing the recycling of paper? you might need an innovative plan to implement this waste management system. A detailed plan on an effective way of collecting paper and raw materials for recycling or educating students about the recycling of paper can be part of an innovative program.	Addressed under Innovation Section
Health Wellbeing	Figure 61 is nicely presented where you have observed the percentage when the temperature is in the comfort range. It will be best if you provide a comfort band behind the temperature graphs in figure 63. You should also assess the comfortable and uncomfortable hours experienced during the occupancy hours throughout the year. This will help you in right-sizing and scheduling the systems for the cooling requirements during those uncomfortable hours.	Comfort band provided. Comfortable and Uncomfortable hours have been assesed and detailed in the report.
Value Proposition	Good work on the compounding costs graph to explain the payback and profits in the future. You should also mention the units (INR) in the graph for the y-axis. It is appreciated that you have also given a SWOT analysis. The information provided under the value proposition is all through bullet points. Try to make it a narrative with complete sentences.	The comment is appreciated. However, we feel that expressing the main points via bullet points gives a more clear and crisp understanding of this particular section. We have made them complete sentences but the information has been formatted as bullet points to make it clear.

Executive Summary

Team Aurum is a multidisciplinary team of students of architecture, civil, mechanical and aeronautical engineering disciplines from BMS College of Architecture and BMS College of Engineering, Basavangudi, Bangalore. Our team has worked in collaboration with faculty advisors as well as technical advisors from the industry to propose a Net Zero Primary and High School Institute for Rays Academy for Learning (RAFL).

The project was envisaged by RAFL in Vasanthapura, Bangalore near Bikasipura on a site filled with coconut and mango trees. The aim was to design a net zero school that would not only incorporate the standard teaching curriculums but also rope in the importance of nature and integrate the spaces with the dense tree plantations present on site. Achieving a net zero status for this school not only benefits our project partner but will also educate its students on various strategies that contribute to an efficient net zero building. This school would set an example and show the scope for net zero status for other educational institutes.

The design was thus developed through multiple iterations that catered to the climate, context, vegetation on site, affordable techniques and the main user group which is primary and high school students (Class 1 - 12). Referring to case studies like The Krishna-Avanti Primary School and Energy-Plus Primary School located in similar temperate climatic zones guided us to give importance to building orientation for thermal comfort, appropriate material choice for envelope, utilizing renewable sources of energy and passive strategies like green roofs.

Along with these strategies, our design proposal advances from the standard 4 walled classrooms by provision of spill out balconies as informal learning spaces for the students to interact and connect with nature and one another. These balconies also played as a thermal comfort strategy to bring in more natural ventilation into the classrooms, thus achieving indoor comfort levels without the use of air conditioning.

A total number of 36 classrooms, library, labs and other extra-curricular spaces have been provided which all together have an EPI of 33 kWh/m^2-yr. All spaces are well ventilated and lit naturally and have also been provided with energy efficient LED lights. An energy efficient star rated AC system has been adopted for admin offices, auditorium and computer lab as per the client's request. The rooftop PV array helps attain net positive energy by generating 206,692 kWh/m^2-yr of energy. Net zero water is attained by wastewater treatment and rainwater harvesting.

Schools should ideally serve as optimal learning environments for students, but poor air quality in a school's building can have negative effects. The Co2 levels inside the classrooms are maintained below the recommended 1100 ppm by ensuring adequate air changes per hour (acph) per person through cross ventilation, ceiling fan and opening windows. Indoor air quality monitors have been installed to monitor the same.
The proposed design aims to achieve the break even period in the next 5 years followed by consequent profits (throughout its life cycle).

Team Introduction

Team Name : Aurum BMSCE - CA
Institution(s) : BMS College of Engineering, Basavangudi.
BMS College of Architecture, Basavangudi.
Division : Educational Building

Team Members

ARCHITECTURAL DESIGN

Shayna Kurian B. Arch Team Lead	Kiran S B. Arch Energy Performance, Model & Simulations	Badam Lokesh B. Arch Water Consumption & Innovation	Shadha Abusabah B. Arch Energy Performance & Simulations	Chandana Bala B. Arch Water Consumption & Simulations

Raksha Hemmige B. Arch Affordability & Goals	Sai Aditya B. Arch Value Proposition & Resilience	Rithika Ballal B. Arch Health - Wellbeing & Resilience	Niharika KC B. Arch Water Consumption & Innovation	Mohammad Azeez BE (Mech) Embodied Carbon & Operations

ENGINEERING AND OPERATIONS

Bishal Bhurtel BE (Civil) Operations & Affordability	Poojitha BE (Mech) Operations	Niranjan Hegde BE (Mech) Engineering & Embodied Carbon	Karthik D O BE (Mech) Embodied Carbon & HVAC Loads	Likhith Raj BE (Aeronautics) Innovation

Team Approach

The team was split up into smaller groups and each given responsibility of 1-2 of the 10 contests. The topics are all interrelated, thus resulting in good communication and cohesive working of the members of our team.

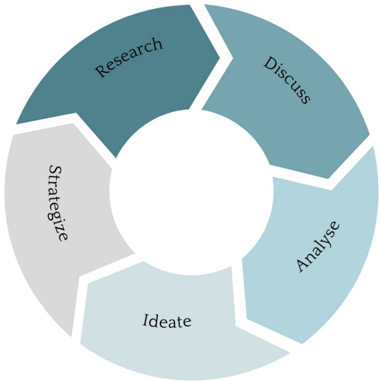


Fig 1 : Team Approach

Institution Background

BMS College of Architecture (BMSCA), Basavanagudi, Bengaluru, Karnataka
It has been a frontrunner in the field of architectural education for the past 40 years. BMSCA offers an environment ideal for stimulating discourse on art, architecture, technology and sustainability.

BMS College Engineering (BMSCE), Basavanagudi, Bengaluru, Karnataka,
BMSCE is the first private sector initiative in engineering education in India. It offers 13 undergraduate & 16 postgraduate courses both in conventional and emerging areas. 14 of its Departments are recognized as Research Centers offering PhD/M.Sc (Engineering by Research) degrees in Science, Engineering and Management.

Faculty Lead

Dr. Suhas B.G
Assistant Professor
Department of Mech. Engineering, BMSCE

Faculty Advisor

Shubhra Pande
Associate Professor, BMSCA

Industry Partners

STUDIO IKINSA

Studio IKINSA
Technical support, latest technologies, market techniques and industry related mentorship.

ECO SOCH Sunny Living

EcoSoch Solar
Advisors for solar power technology, assisted us with solar energy calculations.

Design Management Process

STEP 1 : Site Visit & Context Analysis
To start off, our team visited the site which gave us a better understanding of the accessibility, on site features like the dense tree plantations and the surrounding neighbourhood context. Site data was collected for further analysis.

STEP 2 : Program Formulation
The team came together to formulate a detailed Area Program by considering RAFL's vision for the school, referring Neuferts and NBC Code Books. Decisions regarding conditioned and unconditioned spaces were taken at this stage. *(Refer Appendix for Area Program*).

STEP 3 : Case Studies & Setting Goals
Other educational institutes with similar user group, design program and climatic zone were studied. The takeaways from these guided design decisions for our proposal. *(Refer Appendix for Case Studies*). With the help of SLM's, goals for the 10 contests were set and smaller teams were made, each taking responsibility of 1-2 of the contests

STEP 4 : Concept Development & Pre-design Analysis
Brainstorming, concept ideation and preliminary analysis was carried out simultaneously in meetings held in our college campus as well as online. The site data, climate data, SWOT and various materials and techniques were analysed. The goals set prior to this assisted us in taking decisions. Running energy and thermal simulations on shoe box models further strengthened our design choices.

STEP 5 : Initial Zoning, Form Development & Internal Planning
The team came up with 2 iterations for the school campus which broadly catered to climate, thermal comfort, circulation, visual connect and user group.
Areas were put to the roughly defined zones which further developed the massing and form of the iterations. Internal planning was done to more accurately define the circulation both horizontally and vertically in the blocks.

STEP 6 : Energy SImulations & Webinars
The team attended the webinars organised by SDI which gave more insight into various sustainable and efficient strategies that could be implemented to create a more well rounded design. Running simulations on Design Builder for the iterations helped to weigh out the pros and cons of each and gave us an understanding on the performance of our proposed building.

STEP 7 : Choosing Final Iterations
All this finally paved the path for us to come up with our final design proposal which aligned with all our goals and more importantly, catered to the clients specific request of preserving and integrating the on-site trees with our built for a more nature oriented design.

STEP 8 : Industry Partner Collaboration
Consulting our Industry Partners and getting advice from experts in the industry proved extremely helpful for the team to propose more efficient solutions.

STEP 9 : Report Compilation
With a lot of discussion and deliberation with all team members and faculty advisors, the report was compiled. Our solutions for the 10 contests have been detailed out in further sections.

Project Background

Project Name : RAYS Academy for Learning - Primary and High School

Project Partner : RAYS Academy for Learning - RAFL Organisation
RAYS Institutions supports ICSE & IGCSE Curriculums with a strong Indian Culture. They encourage communication and confident participation in academics and extracurriculars.
RAFL is a commercial developer organisation.

Key Members : Usha S. Ramgiri
Designation : Principal, Rays Academy for Learning - RAFL

RAFL
Empowering Excellence
Rays Academy For Learning

Project Description

Involvement of Project Partner post completion = Build-Own-Operate.

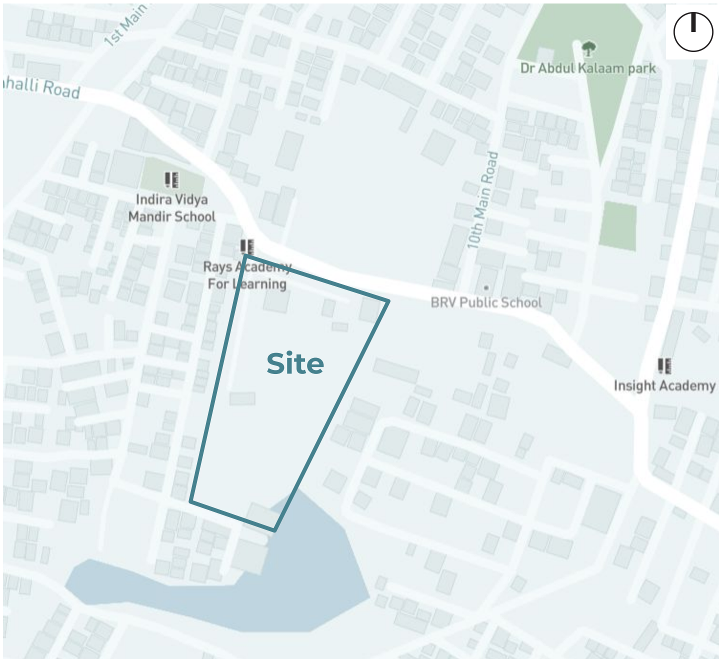


Fig 2 : Project Site Location

Specifics :
Project Site shown in Fig 2
Site Area : 6 Acres (24280 m²)
Existing Vegetation : Coconut and Mango Trees
Existing Built : RAFL Montessori (745 m² total, 4 floors), House, 3 Nos. Animal Shed, Other Built-Ups (silk mill), Tulsi Kattey.
Status of the project : Block 01 - Under Construction

Other relevant site info :
South East - Vasanthapura Lake.
Drainage Line along the Existing Mud Road.

Vasanthapura Main Rd, Sharada Nagar, Bikasipura, Bengaluru, Karnataka 560062

Profile of Occupants

(Total = 1150)

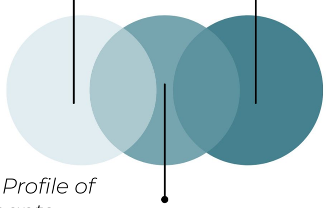


Fig 3 : Profile of Occupants

Montessori Kids 2-4yrs
School Children 5-16yrs
1080 students (grade 1-12)
Adults 21 above
54 Teachers, 16 admin + maintenance staff

Climate zone

Temperate

Hours of operation

School Working Hours : **8 am - 4 pm**
Faculty Working Hours : 8 am - 4 pm
Special Classes Working Hours : Weekends - 8 am - 12 pm

Special requirements of the Project Partner

The site was divided into parts - Phase 1 and Phase 2 as shown in Fig 5. The clients requirement was to build the school in Phase 1, leaving Phase 2 for future expansion. Requirement to leave 15m buffer from the lake on South East side.
Client requirement to cut least amount of trees and incorporate trees into the program - integrate nature with the learning spaces.
To have AC in the offices, computer lab and auditorium

Areas as per Zonal Regulations

Site Area	24280m²
Ground Cover	10926m² (45%)
FAR	2.25
Permissible Built	54630m²
Proposed Built	6170m²

Table 1 : Area Calculations

Our Proposed Built up : **6170 m²**
Proposed Total Project Cost =41.67 cr

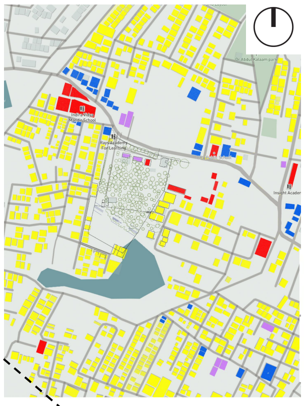
Context Analysis

Fig 4 : Site with context

Surrounding Context Map

1.Upper Middle Class 2.Middle Class 3.Lower Middle Class

People residing in Vasanthapura and Bikasipura areas mainly belong to the **middle class strata.**



Land Use Map

Road width : 13.5 m
Land Use : Agricultural
In vicinity to : Vasanthapura lake (South-East to site)

- Residential
- Commercial
- Industrial
- Public & Semi Public

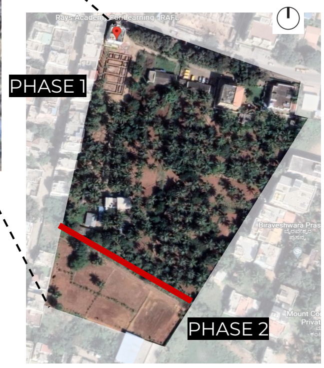


Fig 5 : Site

The site had been divided into Phase 1 and Phase 2 as shown in fig 5.

Fig 6 : Site picture showing vegetation

Site Pictures

Fig 6 depicts the site with its dense existing vegetation taken by the team during site visit.

About the region - Vasanthapura

One of the earliest settlements in South Bangalore and still a fast developing locality.

Area (2020)	1.02 km²
Population (2020)	12309
Population Density (people/km²)	12075
Male Population	6554
Female Population	5755

Population Tree

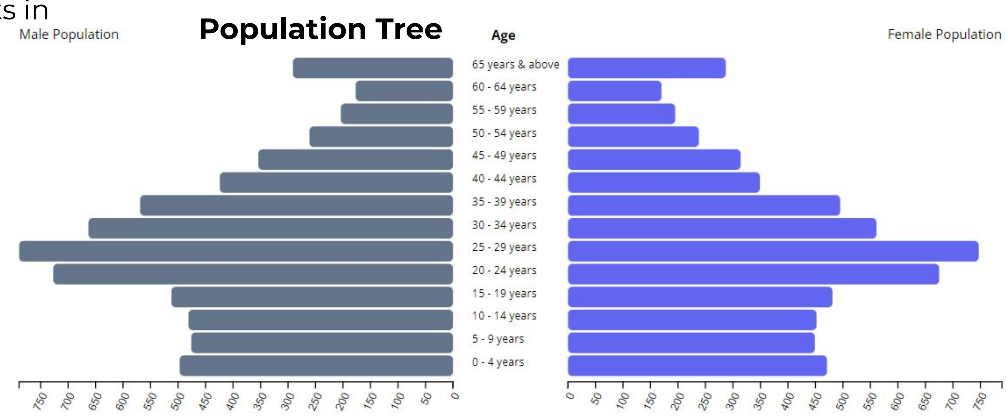


Fig 7 : Demography of Vasanthapura Source:https://geoiq.io/places/Vasanthapura/

Regional Issues :
Smaller roads in the area choke with heavy traffic. Road widening for Uttarahalli Main Road is being planned. Garbage clearance remains an issue in some inner areas of this locality. The local community residents have come together to bring up schemes for restoring and maintaining Vasanthapura Lake (which is abutting Phase 2 of our site).

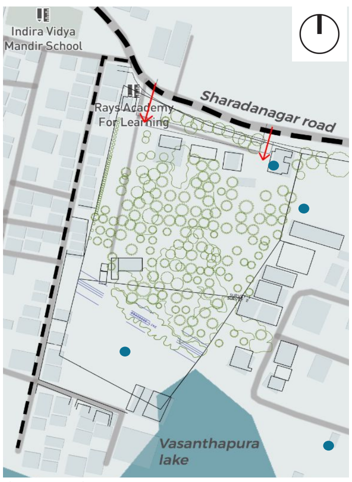


Fig 8 : Site access

Accessibility

Shown in Fig 8
Majestic bus stand : 11km (Location from CBD)
Lalbagh : 7.5km (Location from CBD)
Nearest bus stand: Pipeline bus stand - 3min walk from RAFL
Nearest metro stn : 1.5km (konankunte cross) 2km (yelachenahalli)

Goals and Strategies

ENERGY PERFORMANCE
To achieve a net-zero energy building, consuming least energy by achieving EPI goal of 33 kWh/m^2
Strategies:
Renewable Energy systems, efficient active and passive techniques, reduction in energy consumption.

WATER PERFORMANCE
To achieve net zero water design.
Strategies:
Rain-water harvesting and provision of Sewage Treatment Plant (STP). On-site water cycle processes monitored with a water meter. Gravity based toilets will be implemented which consumed 30% less water.

EMBODIED CARBON
To reduce carbon emissions by 45% than standard construction.
Strategies:
CLC blocks, Filler slab using on site coconut shells, double glazing windows

RESILIENCE
To make the building resilient to natural calamities and changing environmental condition and increase building lifespan.
Strategies:
Using RC frames and a strong foundation for structural stability, raised plinth to prevent flood, using fire resistant building material like CLC blocks.

INNOVATION
To implement new innovations in the design for an efficient and well-functioning structure.
Strategies:
Using coconut shells as filler material, coconut husk for water filtration, making paper out of coconut waste, and bms combined with AI system.

VALUE PROPOSITION
To establish a Net Zero Educational Building
Strategies:
Implementing energy efficient strategies that result in cost savings and greater profits over the building's life span.

ENGINEERING AND OPERATIONS
To implement efficient engineering techniques and reduce mechanical loads on the building.
Strategies:
Using energy efficient comfort systems like Inverter ducted AC which offers 25% power savings than conventional air conditioning systems.

ARCHITECTURAL DESIGN
To implement efficient, functional,, climate, context and user sensitive design.
Strategies:
Orientation, spatial planning and arrangements to cater to climate and the users. Achieving thermal comfort by introducing courtyards and integrating the on-site trees as a part of form generation, interacting with the built spaces and elements.

AFFORDABILITY
To design a cost-efficient building with a sustainable revenue system
Strategies:
Cost effective materials and construction, renewable energy production leading to cost savings

HEALTH AND WELLBEING
To achieve thermal comfort and appropriate indoor air quality for better learning spaces
Strategies:
Providing a comfortable environment to improve the learning and productivity of the students, quality space will be provided for playgrounds, the rooms are well planned made for co-curricular activities.

Design Documentation
Architectural Design - Process

Understanding the brief and requirements of project partner led to different explorations in the design. The primary factors that influenced the design were with regards to the goals set for the 10 contests, the site and user group as well as special requirements of the project partner.

1. Tree Mapping

The design process began with mapping out all trees on site to determine areas of least tree density and work towards integrating the trees with the built spaces. The placement of blocks on the site was determined by areas of least tree density and based on orientation according to prevailing wind direction.

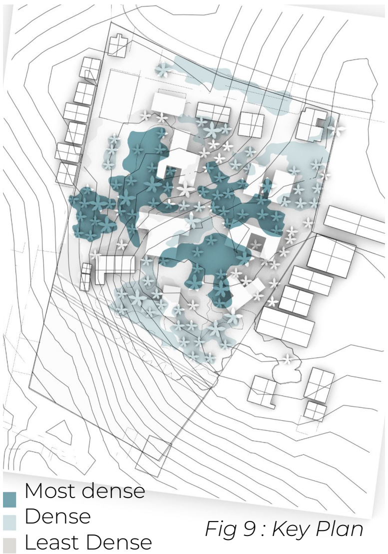


Fig 9 : Key Plan


Fig 10 : Tree detail

Marked in red, 2m radius around each tree's roots have been left undisturbed to ensure no tree is harmed or cut while placing the built masses.

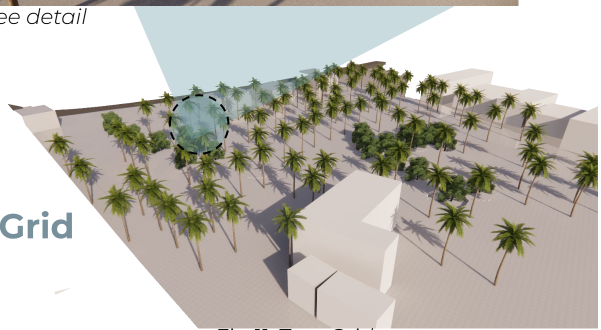


Fig 11 :Tree Grid

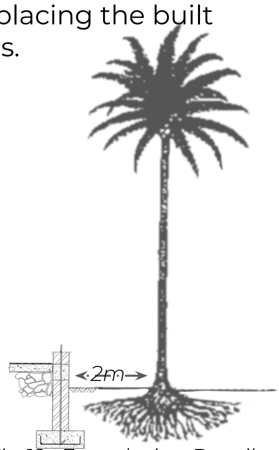


Fig 12 : Foundation Detail

2. Design Iterations

The design program was broken down into **mainly 3 zones** - Classroom blocks, Admin block, other learning and extracurricular spaces. **The main design challenges** to be tackled were incorporating trees, optimizing orientation and envelope for thermal comfort as well as efficient circulation for the students. This resulted in 2 iterations as shown in fig 13.

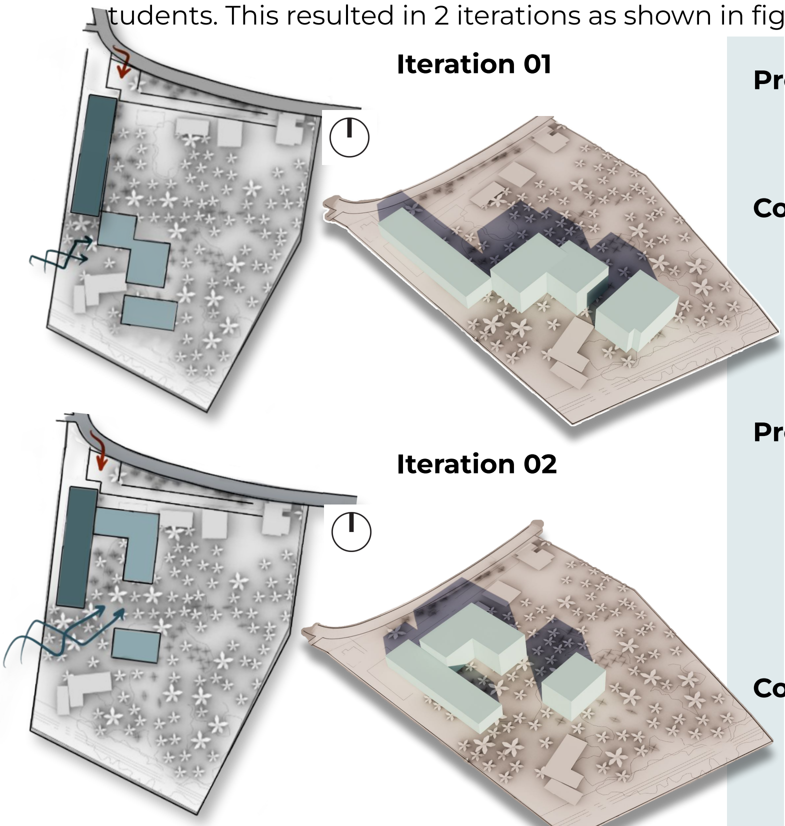


Fig 13 : Zoning Iterations

Comparison

Iteration 01

Pros
- Placement of blocks based on less density of trees, orientation to catch prevailing SW winds.
- Continuity in built mass

Cons
- Inefficient visual connect between blocks
- Increased cost of construction due to increased building footprint.
- Isolation of southern block from the rest of the blocks

Iteration 02

Pros
- Visual connection between blocks through an inward looking organization.
- Incorporating trees into the built, orientation for ventilation, daylighting
- Efficient circulation for students
- Central courtyard has sense of enclosure and brings in light and air movement

Cons
- Distance to Phase 2 of the site may be large

3. Choosing the final iteration

After weighing out the pros and cons, **Design Iteration 02** was carried forward and further detailed out.

Architectural Design
Form Development

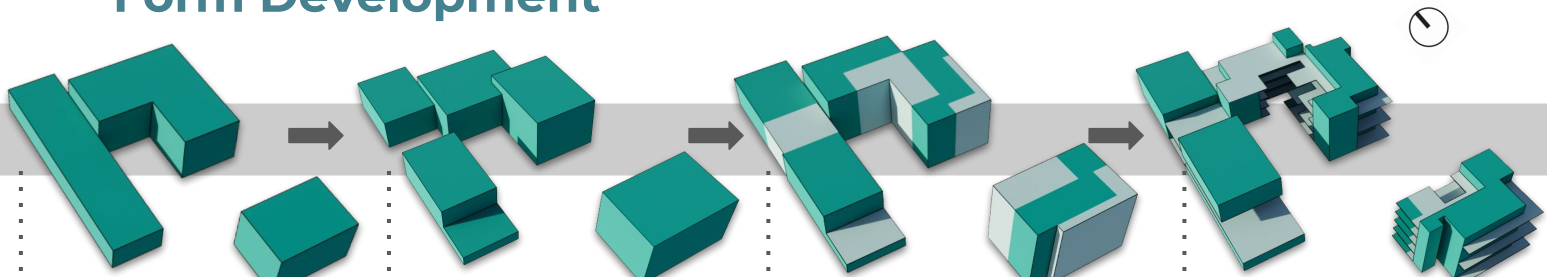


Fig 14 : Form development

Step 01 :
Block placement and orientation influenced by areas with least existing trees to avoid felling and climatic factors

Step 02 :
Splitting the masses according to function and introducing different levels which creates a gradual rise in section

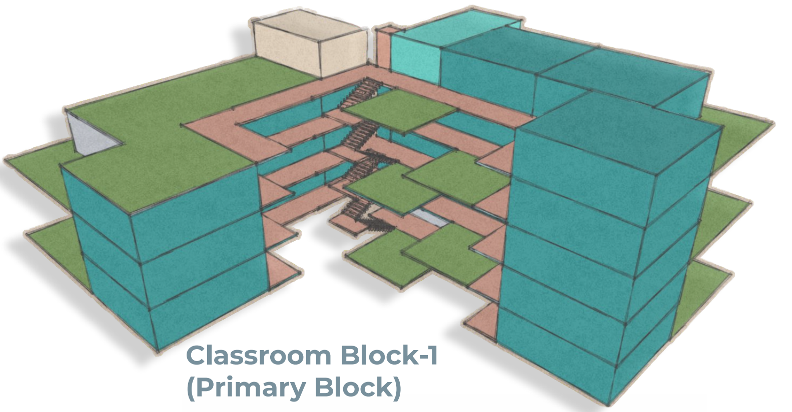
Step 03 :
Formation of built and unbuilt spaces to create cut-outs and courts which promote daylight and natural ventilation through the built.

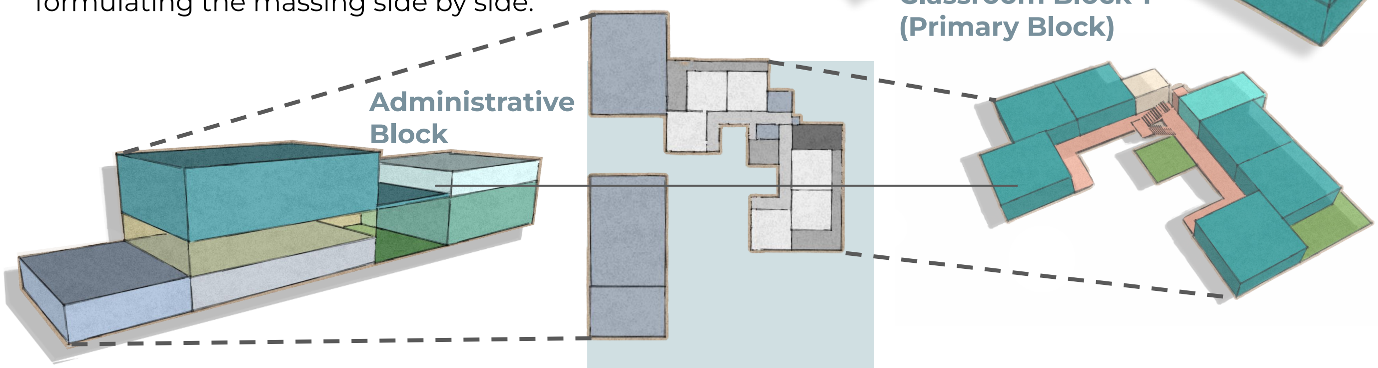
Final Form :
Inward looking corridors with alternating courts. Creating porous floor plates to allow passage of wind through the spaces

Zoning and Massing

The spaces are zoned according to the user groups where the younger students were allotted classrooms in closer proximity to the admin block and entrance while the senior students has their own block towards the south.

The program was divided between the various spaces and transferred to the higher floors, thus formulating the massing side by side.





- Reception/Waiting (25m²)
- Offices (75m²)
- Labs (480m²)
- Extra Curricular (370m²)
- Auditorium(300m²)
- Canteen (120m²)

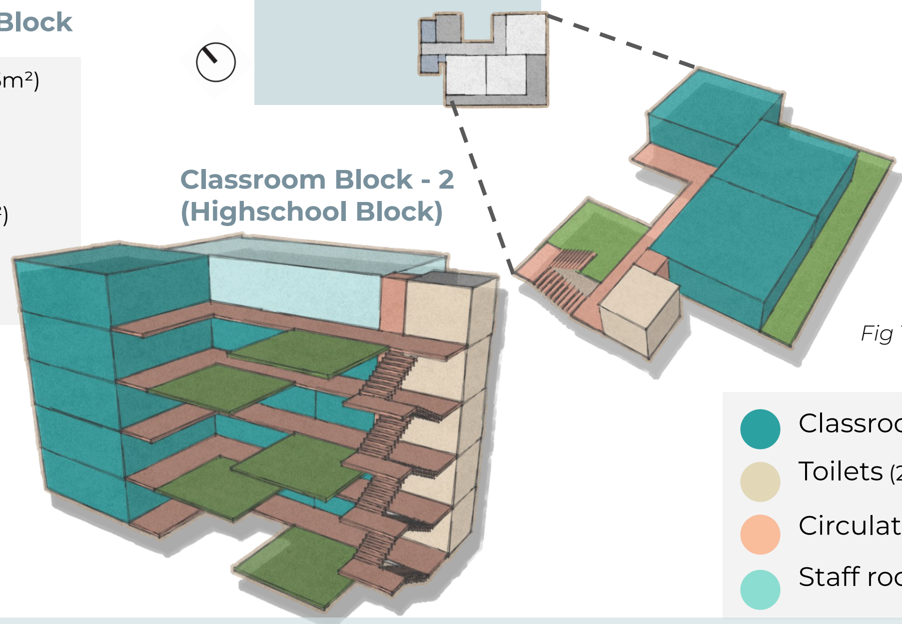


Fig 15 : Zoning and massing

- Classrooms (64m²)
- Toilets (20m²)
- Circulation spaces
- Staff room (40m²)

Architectural Design

Concept Sketches

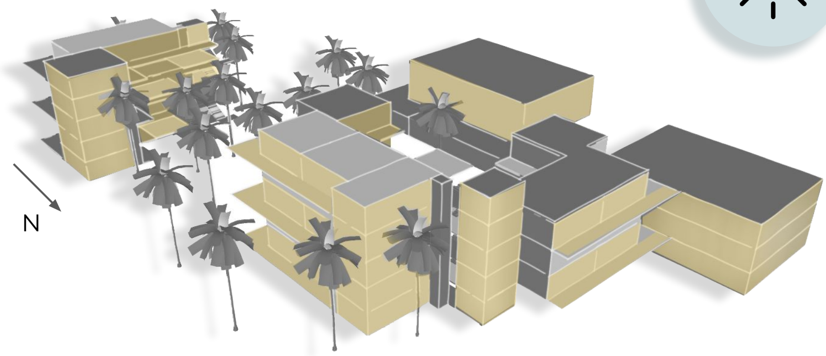


Fig 16 : Natural Light

Natural Light

Buildings are oriented to receive best North and East sunlight. Each function receives ample daylight into their spaces, reducing the dependency on artificial sources of light and energy.

- North and East light on the surfaces

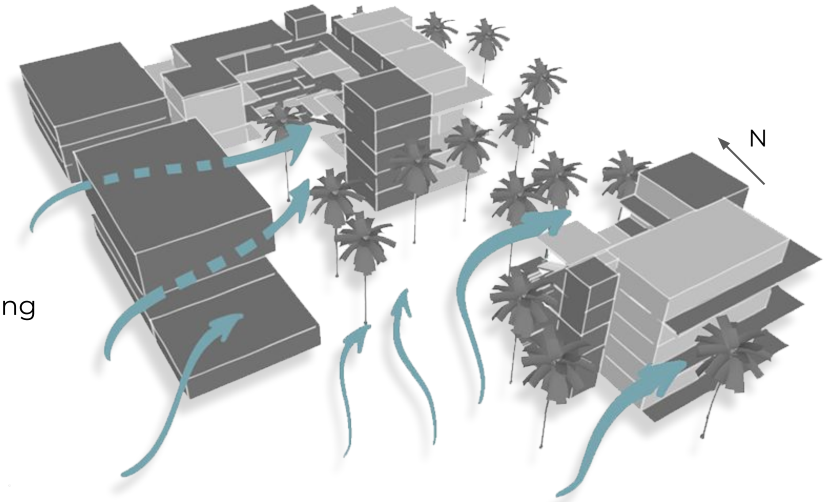
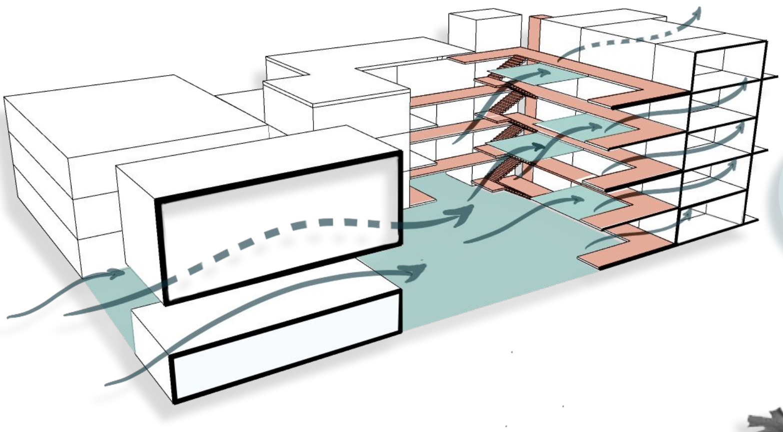


Fig 17 : Passive Ventilation

Passive Ventilation

Climate study reveals that prevailing wind direction of the locality is the South-West direction. The cutouts in mass and central courtyard draw in the breeze, thus ventilating the spaces efficiently.

- Wind flow through the design



Thermal Comfort

Proper passive ventilation through the built and unbuilt spaces helps to achieve thermal comfort

Circulation

Efficient horizontal and vertical circulation between the floors.

- Corridors and staircase + lift

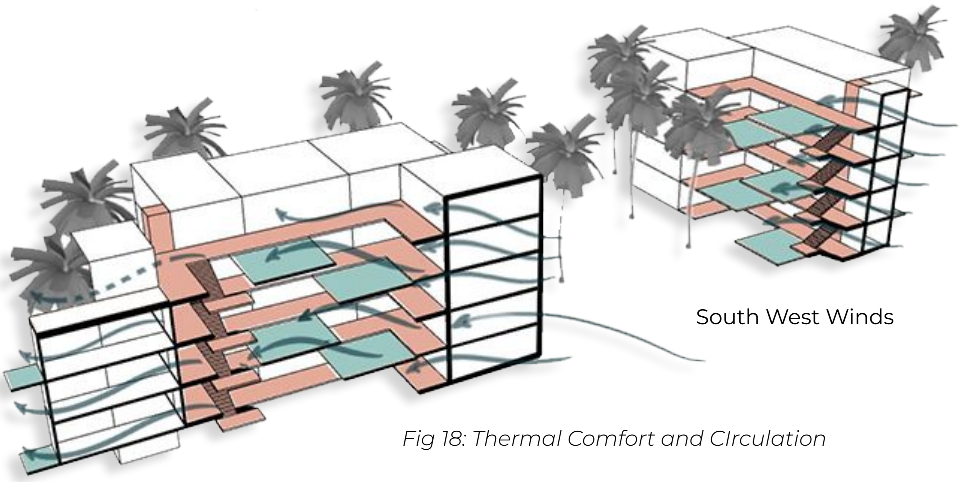


Fig 18: Thermal Comfort and CIrculation

Architectural Design

Master Plan

Fig 19 : Entrance View

Stilted semi-open Space

The main entrance leads to a shaded space consisting of seating areas for the parents.

It also has a pathway laid with **Piezo Tiles** that help in generating energy.

Central Lawn

This space acts as an interactive zone for students from various grades to socialize.

It also forms the center of circulation in the unbuilt spaces.

Classroom Block-2

The southern block has the common library and high school classrooms with common inward looking balconies as well as private outward looking balconies.

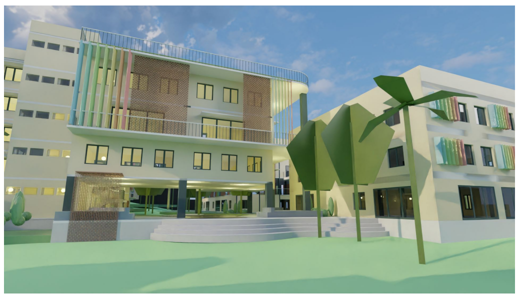
Fig 20 : Master Plan

Outdoor seating Area

This is a stepped informal seating area which is the spill out space from the indoor canteen.

Path at the center laid with Piezo tiles to generate energy as students walk over it.

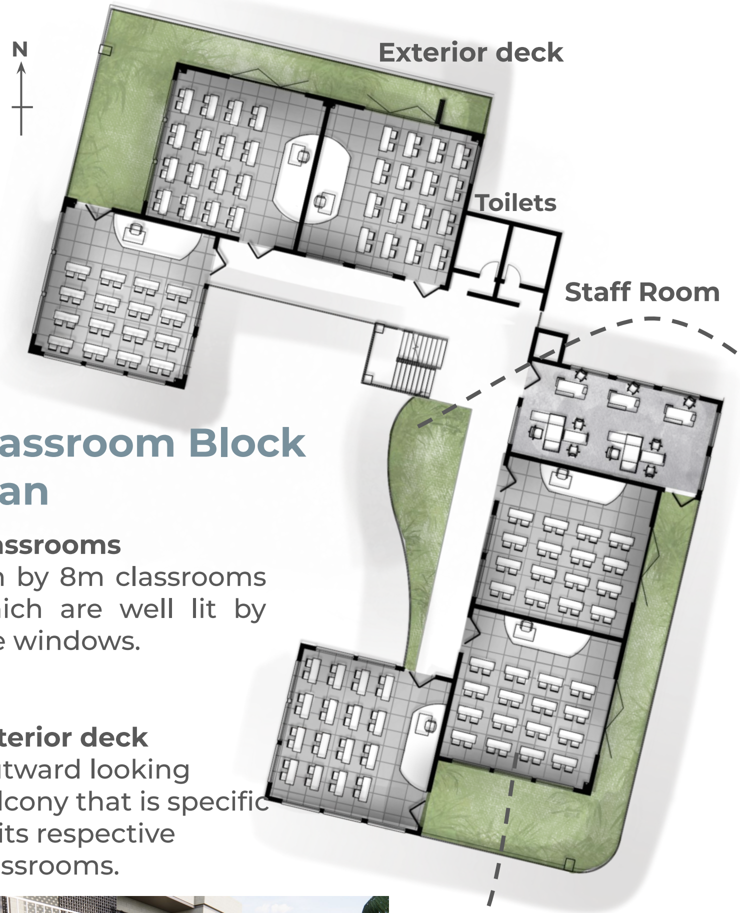
Canteen Block



Main Entrance

Fig 21 : views

Architectural Design

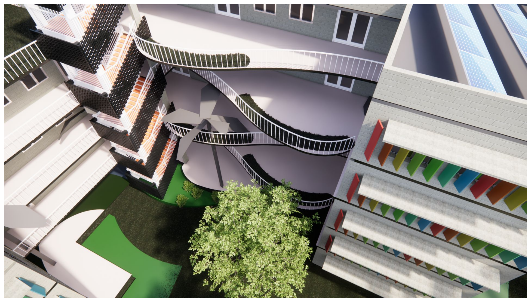


Classroom Block Plan

Classrooms
8m by 8m classrooms which are well lit by the windows.

Exterior deck
Outward looking balcony that is specific to its respective classrooms.

Fig 22 : Block A Plan



Central Balcony
Each floor has a common green balcony that overlooks the central courtyard.

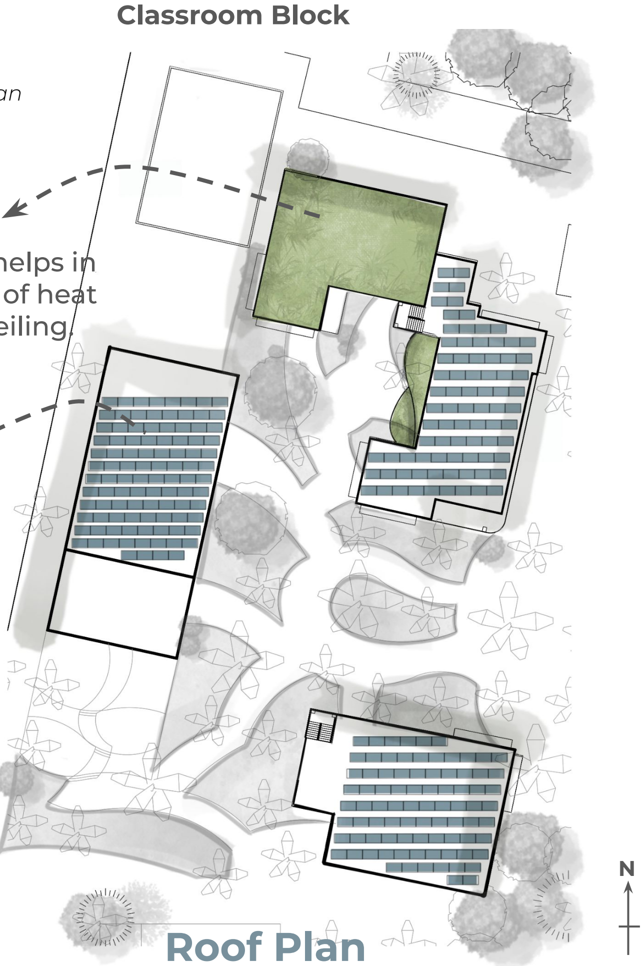
This area acts as an informal learning space for students.

Classroom Block

Green Roof
This passive strategy helps in reducing the amount of heat gained through the ceiling.

Terrace
The terraces have been dedicated to solar panels that are angles southwards to receive maximum amount of sunlight.

Staggered Balconies
The organic shaped balconies help in maintaining visual connection between the floors.



Roof Plan

Fig 23 : Roof Plan

Architectural Design

Design Elements

Staircase Detail
The staircase is enclosed within a terracotta jaali that acts as a porous screen and also creates a play of light and shadow.

Staircase Isometric

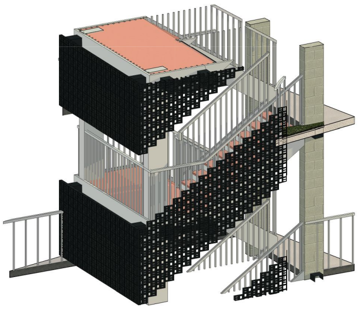
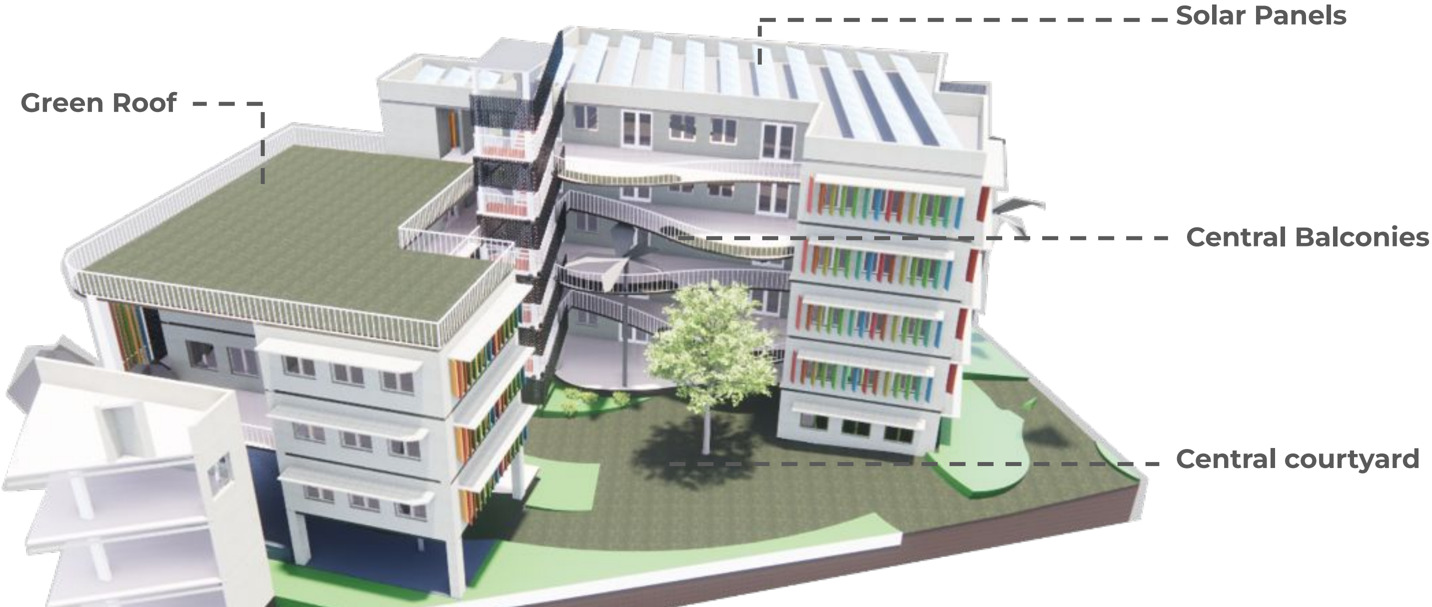


Fig 24: Staircase details

Louvered panels
The facade of the building is lined by colourful louvred panels that controls daylighting and livens up the place.

Terracotta jaali screens
in the balconies promote cool air movement within the building while creating shadow and light effect.



Classroom Block Isometric

Fig 24 : views of classroom block

Architectural Design

Sections

Key Plan

SECTION AA'

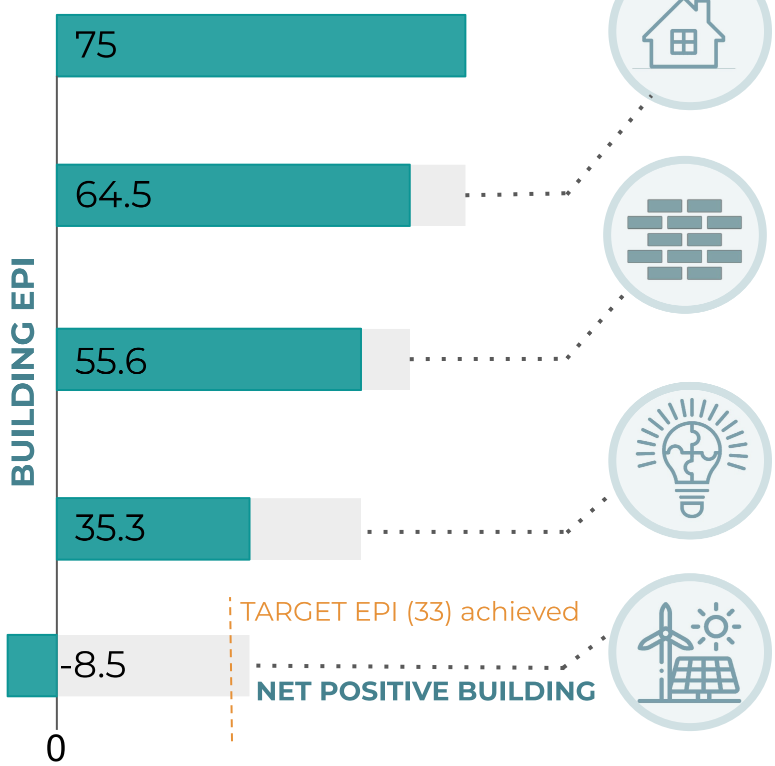
SECTION BB'

SECTION CC'

Fig 25 : Detailed Sections

Energy Performance

GRIHA BENCHMARK: 75 kwh/m² per year
Target EPI : 33 kwh/m²



Passive design
1.Massing and block orientation
2.Incorporation of existing trees
3.Optimised natural ventilation
4.Staggered courts and balconies
5. Shading

Envelope optimisation and construction
1. Wall, Roof and Window optimisation
2.Jaali screens
3.Vegetative roof

Efficiency and operation
1.Efficient HVAC system
2.Efficient lighting fixtures - LED
3.Efficient equipment

Renewable energy
1.Solar panels
2.Wind turbines
3.Pavegen

The building was designed using various passive design strategies, envelope optimisation techniques, construction methods, efficient HVAC systems,lighting fixtures, and equipments by running multiple simulations to achieve the target EPI of 33 kWh/m² . The use of renewable energy through solar panels,pavegen tiles, and wind turbines reduces the EPI to create a net positive energy building, allowing us to give back to the grid.

Passive design Strategies

Heat gain through the building is controlled by the building massing,orientation, and the choice of materials in the design.
The massing and zoning of the building is done to accommodate the existing trees which are responsible for reducing the glare and increasing the thermal comfort.
The window to wall ratio has been optimised to 30% to obtain the required levels of daylight for classrooms and to obtain AC/H between 5 and 6 as recommended by ASHRAE 2016 6.2 .
The staggered courts and balconies increases the air exchange rate which promotes heat loss during the summers.
Shading through overhangs and balconies are provided to prevent direct solar radiation on the walls.

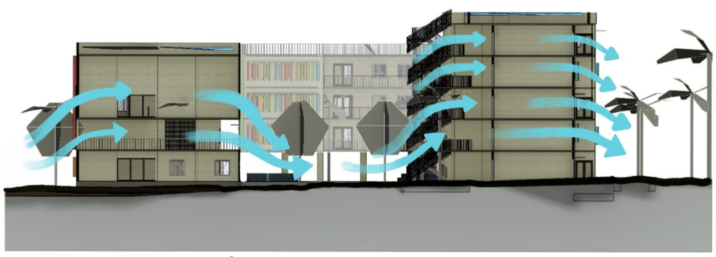


Fig 26a : Section of site

Section of the site showing natural ventilation through the trees

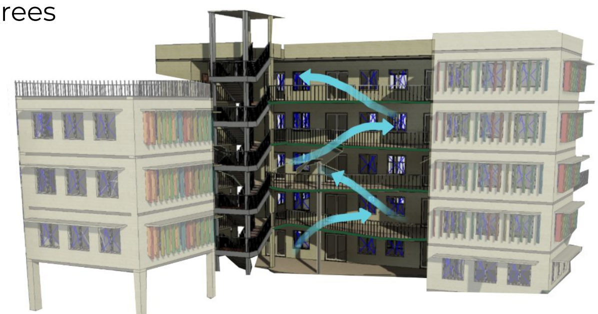


Fig 26b : View of courts

View showing the air flow through the staggered courts

Envelope Optimisation and Construction

	WALL	ROOF	WINDOW
STANDARD DESIGN	brick + 12mm cement plaster on either sides **U Value = 2.63**	RCC slab + cement plaster (12mm) +screed + tiles + waterproof layer **U Value= 1.75**	Single glazed U Value = 5, **SHGC = 1**
PROPOSED DESIGN	CLC block+ 12mm cement plaster **U Value= 0.38**	1.RCC slab +underdeck PUF sheet insulation +cement plaster (12mm) +screed +tiles + waterproof layer **U Value=0.337** 2. RCC slab+ 12mm cement plaster + screed + coconut shells(filler material)+ waterproof layer **U Value = 0.259** 3. Green roof	Vertical sealed Double glazed window + 20 mm air gap, **SHGC= 0.25**

Table 2 : Envelop Optimisation and Constructions

Comparison of Construction U Values

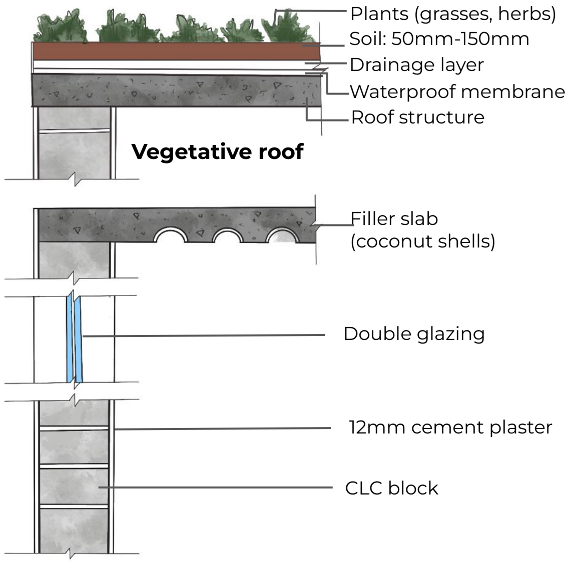


Fig 27 : Detailed Section of envelope

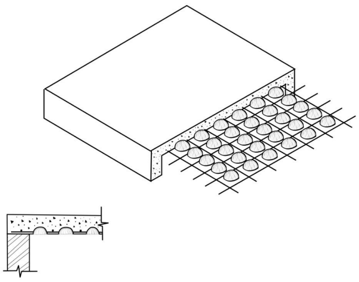


Fig 27a : Filler slab detail

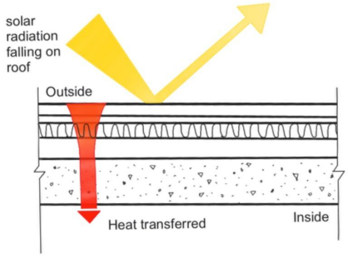


Fig 27b : Puf insulation roof detail

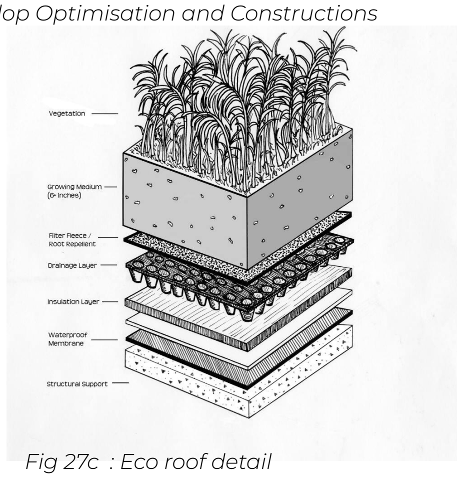


Fig 27c : Eco roof detail

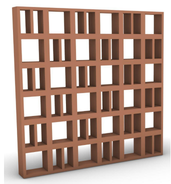


Fig 28 : view of jaali

Terracotta Jaali screens on the north and east facades regulate and conditions the air flowing through the balconies into the classrooms.

The materials for the walls, roof and glazing are chosen by comparing the U - Values to regulate the thermal gain inside the building.
The ECO Roof is used to increase rainwater absorption, provide insulation, help to lower urban air temperatures and combat the heat island effect.
This allows us to passively maintain comfort levels without using mechanical cooling in the classrooms.

HVAC

The auditorium, office rooms and computer lab, all have the inverter Ducted HVAC systems, optimised according to their respective functionality and appliances. HVAC systems have been completely eliminated in the classrooms as the natural ventilation is sufficient to maintain 5 acph.
Comparisons of simulations of the Baseline(VRF) along with the proposed Inverter Ducted HVAC assisted in implementing energy saving strategies.

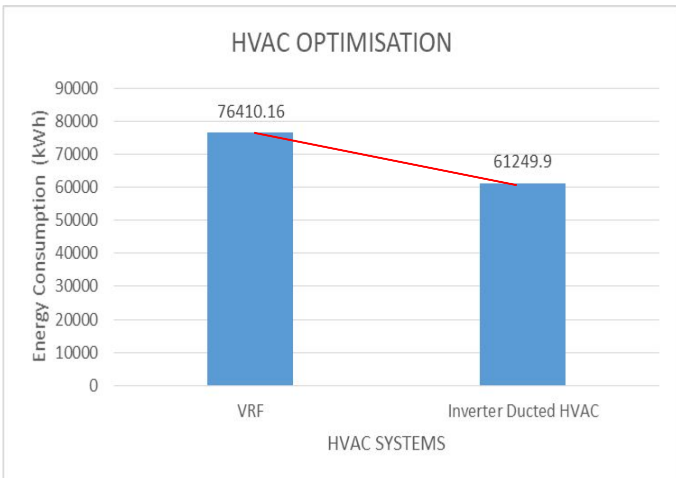


Fig 29 : Comparison of VRF HVAC system with Inverter Ducted HVAC

Solar Potential

The site offers a promising solar potential according to its daily average solar radiation of 5.5kWh/m². In comparison to the building facade, the horizontal terrace receives the most solar radiation. To meet the demands of energy requirements, solar panels are installed on the terrace. The amount of solar energy produced at the location was calculated using PVWatts. The panels have the ability to generate 2,06,690 kWh per year .

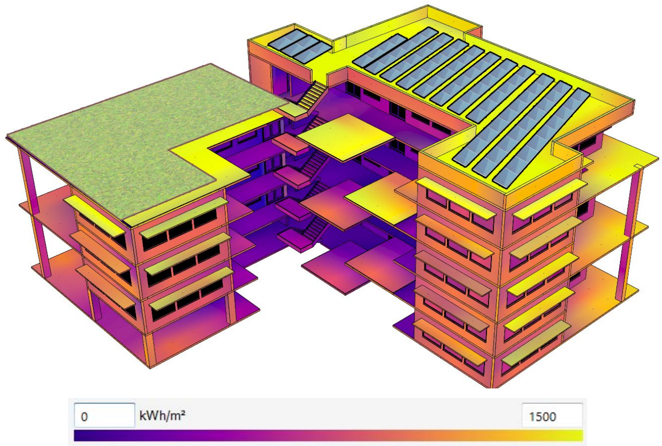


Fig 30 : Solar radiation mapping of classroom block

Month	Solar Radiation	AC energy(kWh)
jan	6.42	20414
feb	7.28	20574
mar	7.25	22015
apr	6.84	20343
may	4.71	14687
jun	4.78	14901
jul	4.74	15260
aug	4.25	13734
sept	4.82	14975
oct	5.01	16048
nov	5.15	16197
dec	5.4	17542
Annual	5.55	206690

Table 3 : Solar radiation and electricity generation

Solar energy generated per year in kWh

2,06,690
kWh

module specifications :
monocrystalline panel
System type: on grid
panel size: 2.27m * 1.11m
output power : 540 Watts
Series: (12*6) * 2 of 144 cells
Tilt angle : 13°
no. of panels: 260

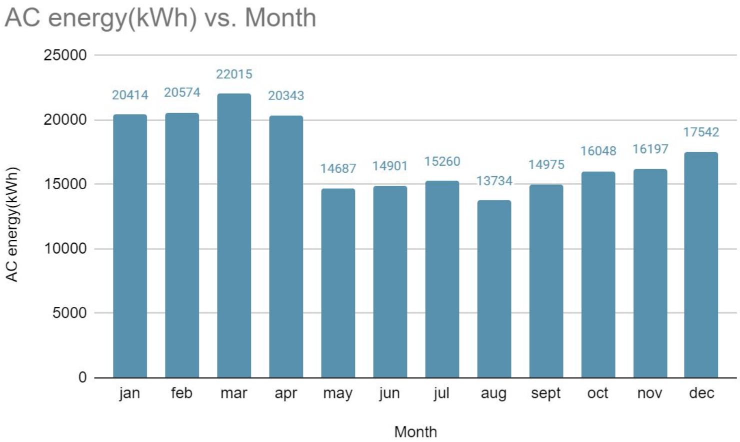


Fig 31 :AC Energy Table : Envelope Details energy vs. Months

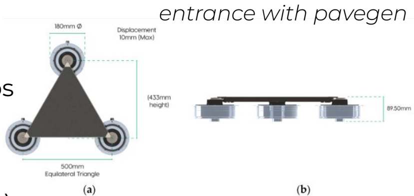
Pavegen tiles

Pavegen is a device that transduces kinetic energy from trampling into electrical energy.It consists of a triangular basement with an electromagnetic generator at each corner. These tiles are placed at the entrance to maximise usage through steps.

Fig 32 : rendered view of entrance with pavegen tiles

Energy calculations

1 pedestrian/student = 18 steps approx to cover tiled area
Total no. of students= 1100
Frequency of walk across tiles= 2x span of tiled area(9m)
1 step generates= 5W*



V3 version of Pavegen's tile [68]; top view (**a**), side view (**b**)**

Energy generated in 1 day= 18 x 1100 x 2 x 5 (W)

198
kW/day

For 220 working days in a year

43,560
kWh/year

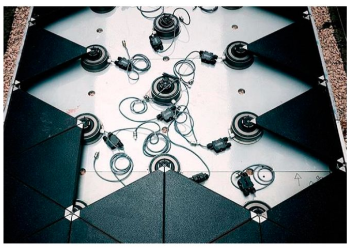


Fig 33 : pavegen details

Detail of installation of tiles**

Wind Energy

The site's location and climatic conditions provide a great potential for the generation of wind energy on site. There is a future potential to explore wind turbines which will generate more energy and further advance the energy returns to the grid.

Summary

As a conclusion,the energy generated on-site is higher than the energy consumed by the building, making it a net positive building.

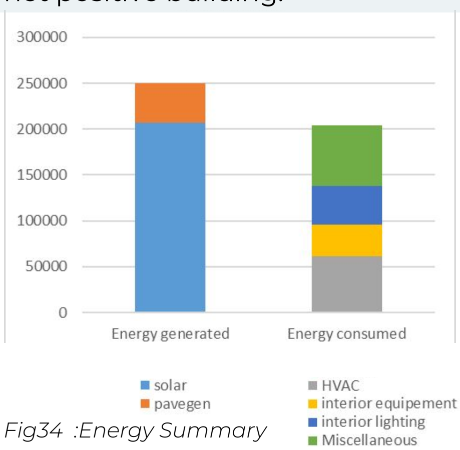


Fig34 :Energy Summary

*https://www.wevolver.com/specs/pavegen.v3

**https://www.mdpi.com/1996-1073/15/2/432

Water Consumption

To ensure a water sufficient educational building with no dependency on the municipal water supply various techniques were employed Emphasis was placed on reducing per capita consumption by employing efficient fixtures, while site responsive landscaping reduced irrigation water loads. Water from the domestic uses was further recycled for non-potable uses in the campus. Sufficient rainfall allowed utilization of rainwater for domestic use.

		CONSUMPTION						WATER SOURCES			
Month	Days in month	Domestic Use (L)	Building maintenance	Irrigation seasonal factor %	Irrigation water demand (L)	water used for Irrigation (L)	Total Consumption (L)	Municipal Water (L)	Rainwater harvested (L)	Greywater (L)	Blackwater (L)
Jul	31	4,59,083	25,000	5%	71,300	3,565	4,87,648	42,200	388845	3,21,207	1,85,380
Aug	31	4,59,083	25,000	5%	71,300	3,565	4,87,648	42,200	397888	3,21,207	1,85,380
Sep	30	4,44,274	25,000	50%	69,000	34,500	5,03,774	42,200	551617	3,10,845	1,79,400
Oct	31	4,59,083	25,000	30%	71,300	21,390	5,05,473	42,200	428031	3,21,207	1,85,380
Nov	30	4,44,274	25,000	90%	69,000	62,100	5,31,374	42,200	250187	3,10,845	1,79,400
Dec	31	4,59,083	25,000	90%	71,300	64,170	5,48,253	42,200	54257	3,21,207	1,85,380
Jan	31	4,59,083	25,000	90%	71,300	64,170	5,48,253	42,200	0	3,21,207	1,85,380
Feb	28	4,18,358	25,000	90%	64,975	58,478	5,01,835	42,200	6029	2,92,712	1,68,935
Mar	31	4,59,083	0	90%	71,300	64,170	5,23,253	42,200	33157	3,21,207	1,85,380
Apr	30	4,44,274	0	90%	69,000	62,100	5,06,374	42,200	120572	3,10,845	1,79,400
May	31	4,59,083	0	90%	71,300	64,170	5,23,253	42,200	379802	3,21,207	1,85,380
Jun	30	4,44,274	25,000	90%	69,000	62,100	5,31,374	42,200	364730	3,10,845	1,79,400
Total					8,40,075	5,64,478	61,98,510	5,06,400	29,75,114	37,84,538	21,84,195

Table 4 : Water Consumption and Sources

- The water generated on site (rainwater harvesting + treated grey water) = **67,59,652 L** annually
- The water consumption = **61,98,510 L** annually
- Since, the **on site generation of water is greater than the demand supply from municipal corporation, our building meets net zero water conditions.**
- **The generated grey water is used in two parts, 50% for irrigation and other 50% for flushing and non- potable uses.**

IRRIGATION WATER

(The link for the '**irrigation water calculator**' is provided at the bottom)

Water used for irrigation per day = 2300 l

Water **used** for irrigation **=** Water **required X** Irrigation **seasonal factor**

***Note**

1. **Water required for irrigation** has a variation in different months is due to the number of days present in that month
2. **Water used for irrigation** has a variation in different months is due to the change in seasonal factor every month

Daily water consumption calculation

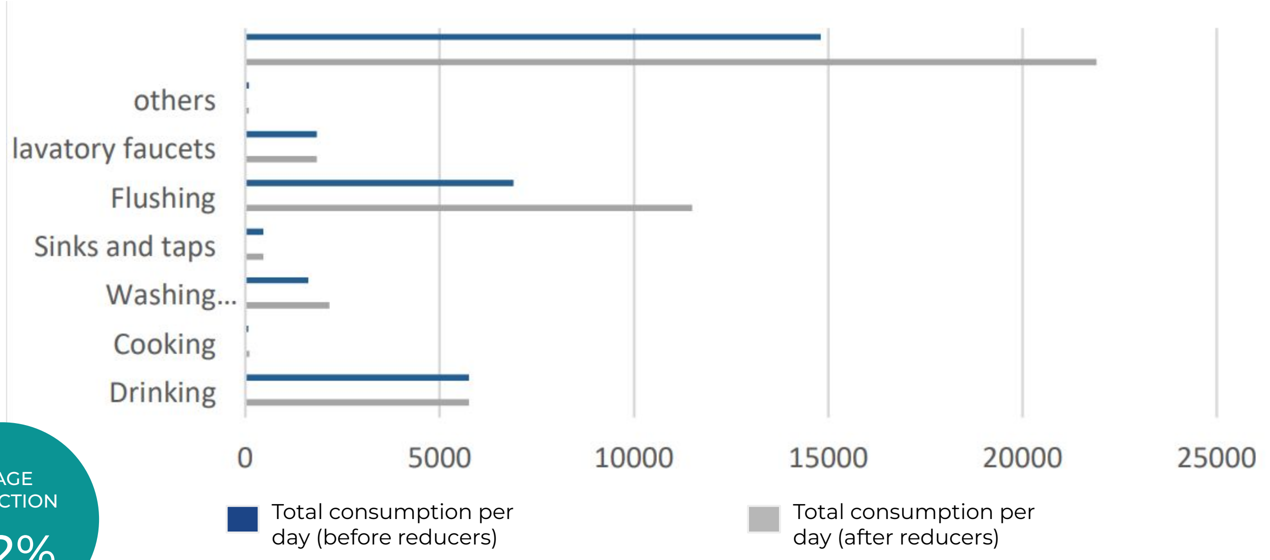
No of occupants = **1150**
Water consumption per head per day = **14.5 l**
Water consumption per day = **16675 l**

Capacity of storage tanks

For rainwater harvesting OHT = **10000 l** (~ 2 days of water)
(per day potable water = 5750 l)
For grey water treatment OHT = **10000 l**
For UGT ~ 2 days capacity = **30000 l** (potable water)
For UGT ~ 2 days capacity = **30000 l** (grey water)
Total tanks capacity = 3 days capacity

https://ucanr.edu/sites/UrbanHort/Water_Use_of_Turfgrass_and_Landscape_Plant_Materials/Water_Demand_Calculators/Water_Demand_Calculators/index.cfm

Water Consumption



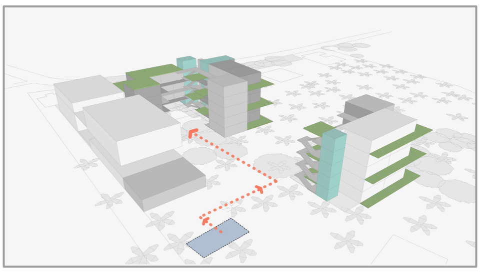
USAGE REDUCTION

32%

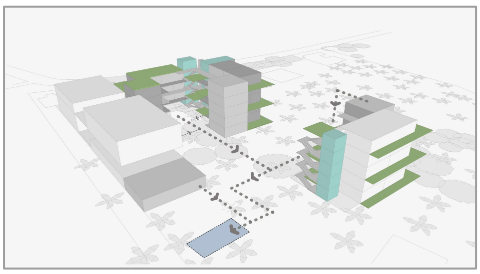
Purpose	Per head usage per day	Occupants	Total consumption per day (without reducers)	Percentage use	Reduction by	Reduction percentage	Total consumption per day (after reducers)
Drinking	5	1150	5750	14%	NA	0	5750
Cooking	3	1150	103.5	3%	low flow fixtures	25%	77.625
Washing utensils	10	1150	2162	19%	Pressure regulator	25%	1621.5
Sinks and taps	8	1150	460	5%	Pressure regulator	25%	460
Flushing	25	1150	11500	40%	Dual flush systems	40%	6900
lavatory faucets	10	1150	1840	16%	low flow fixtures	25%	1840
others	4	1150	92	2%	NA	0%	92
			21907.5				14809.125

Base case　　Efficient case

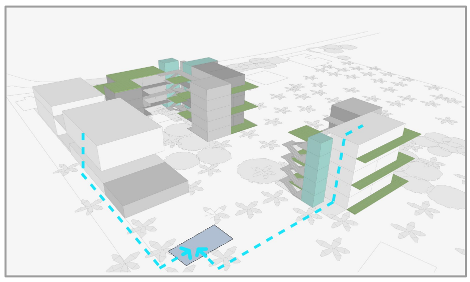
Table 5 : Comparison of water usage before and after the efficient strategies



IRRIGATION WATER



GREY WATER



RAIN WATER

Fig 35 a: Water connections

All the grey water from the blocks is collected and passed through a natural filter and sent back for irrigation and flushing.

Using sprinkler system for irrigation reduces our water demand by 50%

Rainwater collected from the rooftops will be collected in tanks at a level below the terrace and supplied to the levels below by gravity

Water Consumption

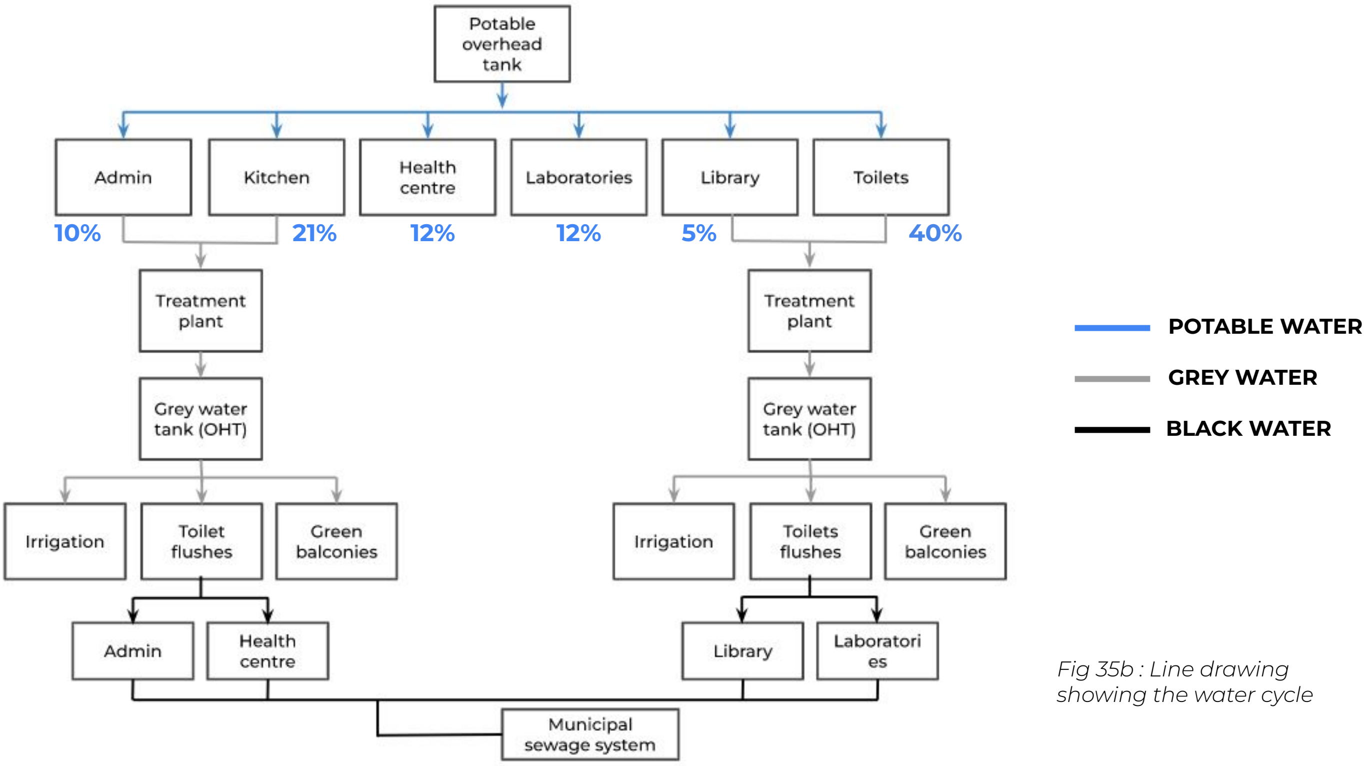


Fig 35b : Line drawing showing the water cycle

Rainwater harvesting

Out of all catchment areas i.e roof, hardscapes and softscapes, the roof receives the maximum rainwater. This water goes through a rainwater harvesting filter which automatically flushes out dirt and debris. The harvested water is stored in a tank at a lower level and excess is stored underground. This water is used in drinking fountains, kitchen sinks, and washbasins

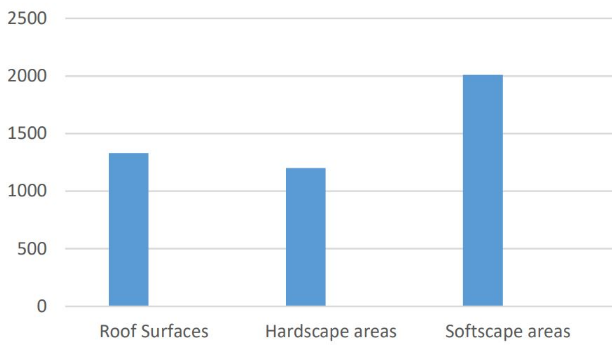


Fig 35 c : Rainwater Harvesting Surfaces

Indoor water use reduction

To reduce indoor water consumption , we are using

- Treated grey water in cleaning , water faucets , water closets & urinals.
- Using efficient fixtures like low flow fixtures we are reducing the water demand from 21 lcpd to 16 lcpd.
- Dual flush systems reduces water usage by 40 % .

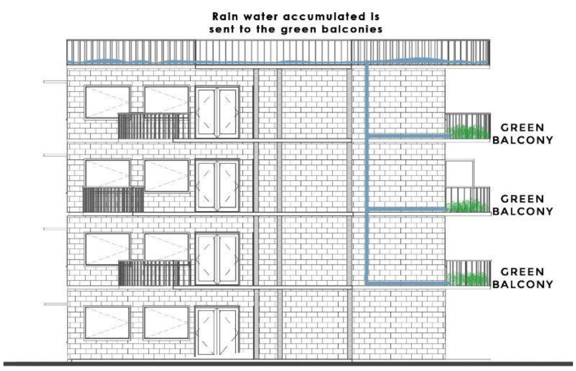


Fig 36 : Accumulated rain water is sent to the green balconies

Outdoor water use reduction

- To reduce outdoor water use in irrigation we are using effective irrigation system like sprinkler system to avoid unnecessary waste of water.
- Using Tall Fescue grass, which need water only once a week.

Water Consumption

Grey water treatment procedure: (Innovation)

Idea : Coconut husk as a filter

Coconut husk can be used along with gravel, coarse sand, fine sand, and activated carbon to prepare a filter. Coconut husk can be braided or made into thin layers and sandwiched between any fibrous fabric material.

Problem: Various chemicals are used to treat water which if not monitored will lead to hazards. In addition, The husk from the coconuts will be discarded and to carry out the waste product, we need to pay for transportation and labor.

Cost and impact: Cost-efficient and use natural material for filtration. It helps in minimizing waste from the coconut trees on the site.

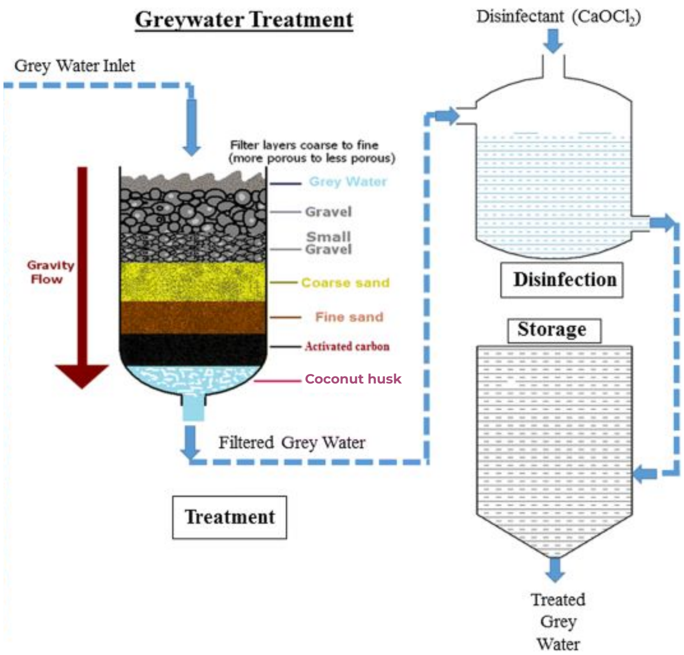


Fig 37 : Multi - grade filter bed

Months	Rainfall (mm)	Effective rain (mm)	Harvested rainwater (l)
July	134	129	388845
August	137	132	397888
September	188	183	551617
October	147	142	428031
November	88	83	250187
December	23	18	54257
January	4	0	0
February	7	2	6029
March	16	11	33157
April	45	40	120572
May	131	126	379802
June	126	121	364730
Total			2975114

Table 6 : Harvested rainwater

HARVESTED WATER

95%

TANK	CAPACITY	VOLUME
Rain water harvesting (OHT)	10000 L	10 Cubic m
Grey water storage (OHT)	10000 L	10 Cubic m
Underground water tank (UGT)	30000 L	30 Cubic m
Grey water tank (UGT)	30000 L	30 Cubic m

Table 7 : Tank sizes and volumes

Coconut husk fibres function is to screen out large solids such encountered through various sources of greywater (.sinks,dishwashers,etc) This material can withstand suspended solids due to the physical characteristics of the fibre .
The fibers are weaved to create a tight mesh pattern and several layers are added to ensure efficient filtration
The filters are generally replaced after every 12 months, but to ensure less accumulation of solids due to large scale of greywater produced compared to smaller programs like housings or smaller modules, **layers can be replaced every 6 months**.

Embodied Carbon

Embodied carbon is the carbon dioxide (CO_2) emissions associated with materials and construction processes throughout the whole lifecycle of a building or infrastructure.
It includes any CO_2 created during the manufacturing of building materials (material extraction, transport to manufacturer, manufacturing), the transport of those materials to the job site, and the construction practices used.

Materials

System Type	Material		Advantage over Standard Case
	Standard	Proposed	
Wall	Bricks	CLC BLocks	Bricks have an emission factor of 0.39 while CLC blocks have 0.37. CLC blocks emit very low Co2 while manufacturing as compared to Bricks. CLC blocks are made of material such as fly ash and other industrial wastes. The production process of CLC blocks don't release any harmful effluents that affects ground, water or air. In CLC Block there is no soil utilization and it produces low Carbon dioxide in contrast to Standard Bricks while fabricating.
Roof	Rcc	Rcc filler slab with coconut shells	On site coconut shells as filler material - this reduces the amount of cement and steel used and makes use of the shells present on site. It is both low in carbon emission and aesthetically pleasing to the eye. Transport cost of filler material = 0 which contributes to lower emissions.
Windows	Aluminium Frame	uPVC Frame	Carbon emissions factor of Aluminium is 26 while uPVC is 3.9 which is a drastic decrease. uPVC has excellent properties, for a lesser cost than aluminium.

Table 8 : Embodied Carbon Material Comparison

Fig 38 : Materials
CLC Blocks , Filler Slab (coconut shell), uPVC windows double glazed

Embodied Carbon Content:

There are two main factors that make up the Carbon Emissions content in a particular system (wall / roof / floor, etc.) These are :

- Material Emissions

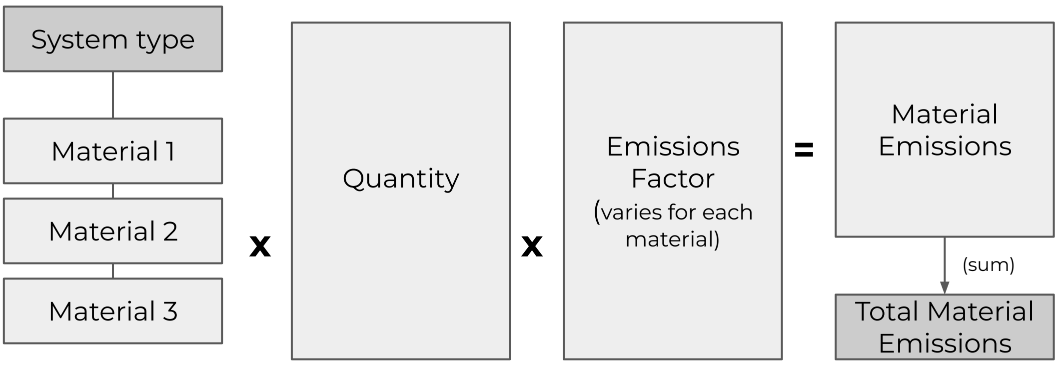


Fig 39 : Carbon Calculation Process

- Transport Emissions

This takes into consideration the type of vehicle used for transportation, distance from source to site and number trips, and amount of fuel consumed for the same. This gives the transport emissions for each material which, when summed up gives the Total Transport Emissions of the system.

Total Material Emissions + Total Transport Emissions = Total Carbon Emissions per functional unit of system

Embodied Carbon

Using the Embodied Carbon Excel Tool*, comparisons were drawn for a **functional unit of 1 m²** of area between a base case and our proposed case. The base case had standard brick wall construction, rcc slab roof and floors, vitrified tiles and aluminium window frames. Our proposed case uses CLC block construction, filler slab roof, rcc floors with PUF Insulation, stone and ceramic tiles and uPVC window frames. Fig40-43 shows the comparison of carbon emissions from 4 main categories - Walls, Roof, Floor and Fenestration.

Choosing appropriate materials and construction techniques makes a big difference in the overall carbon emissions of the building, as depicted in the graphs here.

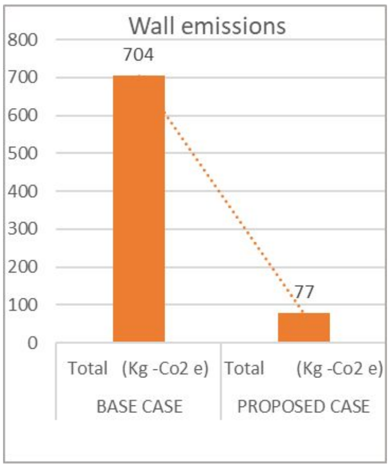


Fig 40 : Wall emission

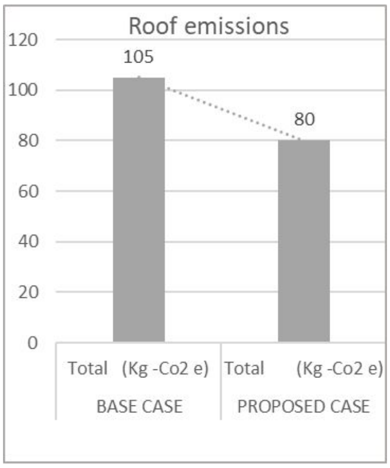


Fig 41 : Roof emission

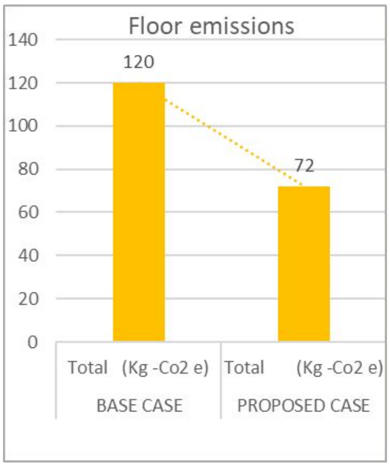


Fig 42 : Floor emission

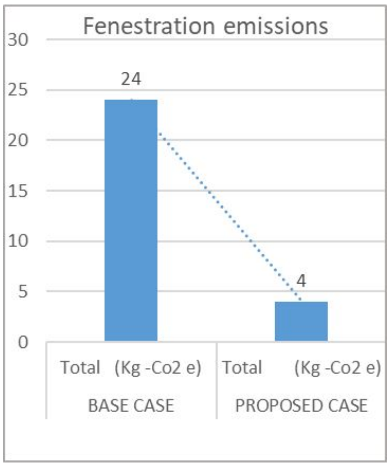


Fig 43 : Fenestration emission

Embodied Carbon Reduction % from baseline to proposed design case :

Walls = 89% reduction due to CLC block walls
Roof = 23.8% reduction due to filler slab roof technique
Floor = 40% reduction due to insulation and tile type
Windows = 83.3% reduction due to uPVC frames.

The transport distances from manufacturer to supplier (transport 1) and supplier to site (transport 2) also impacts the carbon emissions. This further shows benefits of using on site coconut shells and lesser rcc in slabs.

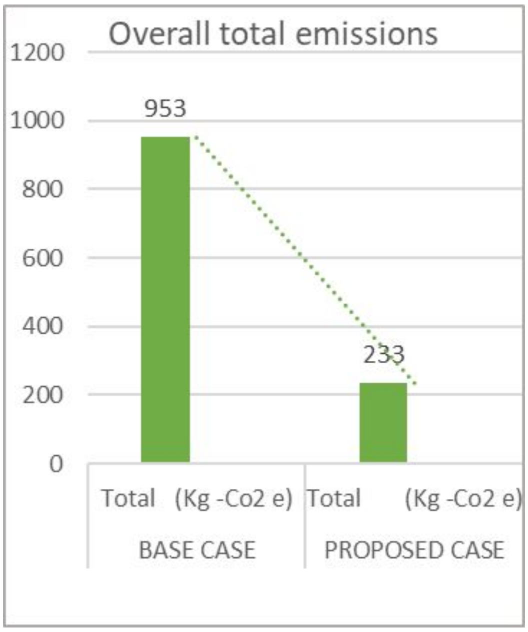


Fig 44 : Overall Total emission

System Type	BASE CASE				PROPOSED CASE			
	Material Emissions (Kg -Co2 e)	Transport 1 (Kg -Co2 e)	Transport 2 (Kg -Co2 e)	m	Material Emissions (Kg -Co2 e)	Transport 1 (Kg -Co2 e)	Transport 2 (Kg -Co2 e)	Total (Kg -Co2 e)
Wall	702	1	1	704	75	1	1	77
Roof	103	1	1	105	79	1	0	80
Floor	119	1	0	120	72	0	0	72
Fenestration	24	0	0	24	4	0	0	4
	Grand Total emissions per functional unit (Kg -Co2 e)			**953**	**Grand Total emissions per functional unit (Kg -Co2 e)**			**233**

Table 9 : Embodied Carbon Comparison

*The Excel tool for Embodied Carbon did not calculate the tables or graphs on Summary sheet. Graphs and tables were made manually with data from the tables in baseline and proposed case tabs.

Resilience

The topic- Resilience, was further divided into three categories to find context based issues and their solutions.

Natural calamities

- **Floods**
  - Prevent backflow of drains by providing valves
  - Elevated plinth
  - Maintenance of nala for smooth flow of stormwater
- **High wind speeds /cyclone**
  - RCC frame structure provides optimum support against cyclone winds. Flat slabs are preferred.
  - Roof slab is cast homogeneously with moment frame.

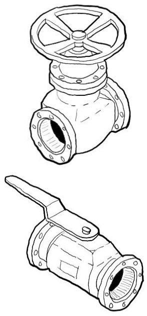


Fig 45 (a-b): Backflow prevention valves

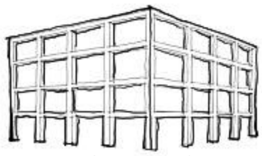


Fig 45 c : RC Frame Structure

Fig 45 d : Uplifting of roof

Building performance

- **Climate response** - appropriate passive cooling techniques employed to result in least dependency on mechanical support for ventilation to achieve thermal comfort
  - **Winters** - Insulating properties of CLC blocks.
  - **Summers** - Passive cooling methods.
    - Cooling effect of trees
    - Incorporating voids and courtyards in the mass
    - Orientation of openings
    - Mutual shading of blocks and trees
- **Grey water** shall be treated and used for landscaping and manure if sludge is healthy.
- Waste from all zones of the school (dry, wet, medicinal, electrical,lab) shall be segregated and either used to generate energy or disposed efficiently.
- **Proposed materials** aid in thermal comfort as follows:
  - CLC Block -Thermal conductivity of CLC

    Thermal conductivity of foam concrete achieved is **0.36 watt/m/k** which is comparatively better than generic construction materials.
    - Brick - 0.5-1 watt/m/k
    - Rcc - 2 -3.2 watt/m/k
    - Cement blocks - 1.95 watt/m/k

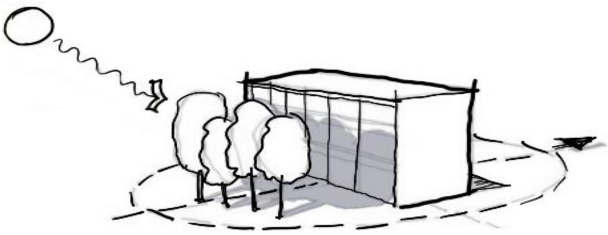


Fig 48 : Shading from trees

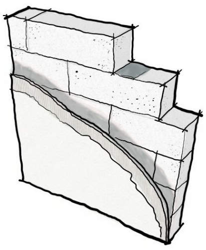


Fig 46 : CLC Block - Insulation

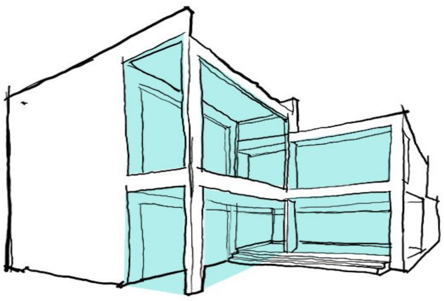


Fig 47 : Voids in the mass for cooling

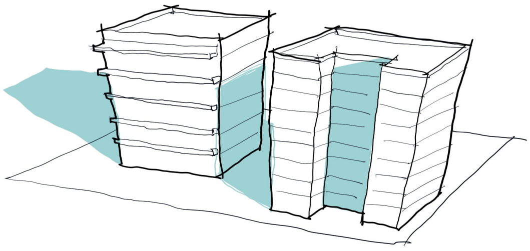
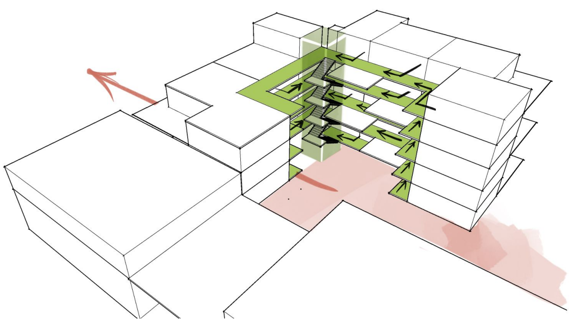


Fig 49 : Mutual shading of buildings

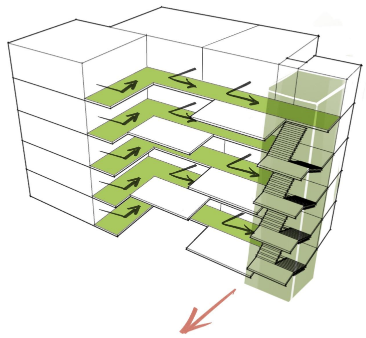
Resilience

Unforeseen disasters

- **Electricity cut** shall be handled by the 4000kW DG on site
- **Water supply interruption** we can survive longer than normal buildings due to the water conservation technologies and reuse of water as explained in water performance
- **Firefighting strategies**
  - Fire pumps, fire sprinkler systems and fire alarm system
  - Exit signage and emergency lighting
  - **Materials:** CLC blocks of 100mm thickness - wall density 1000 kg/m^3 with a fire rating of 4 hours without releasing any toxic fumes during the fire



From Classroom Block - 1



From Classroom Block - 2

Fig 50 (a-b): Fire escape routes

Days of Autonomy - Water

Daily water consumption calculation

No of occupants = **1150**
Water consumption per head per day = **14.5 l**
Water consumption per day = **16675 l**

Capacity of storage tanks

For rainwater harvesting OHT = **10000 l**
For grey water treatment OHT = **10000 l**
For UGT ~ 2 days capacity = **30000 l** (potable water)
For UGT ~ 2 days capacity = **30000 l** (grey water)

Assuming only potable water usage

-Potable water consumption a day - 5750 l
-Assuming total potable water stored in facility is 30,000 l and OHT of 10,000 l - 40,000 l

Days of autonomy are **- 6.95 days**

Assuming overall water usage

-Water consumption a day - 16675 l
-Assuming total water stored in facility is 2* 30,000 l and 2 * OHT of 10,000 l - 80,000 l

Days of autonomy are **- 4.75 days**

Days of Autonomy - Electricity

Considering the urban context of Bangalore and its history of reliable electricity supply, we arrived at the conclusion it was unnecessary to invest additional capital on an extensive UPS system for continued electrical supply and proceeded with an **"on grid solar system"**, which allows for ease of returning electricity back to the grid.
The different passive cooling strategies employed to reduce dependency on mechanical cooling, increase natural ventilation and interior comfort allow for lack of electricity back up.
However, the presence of **2 diesel generators** allows for continued usage of minimal electricity in the computer labs and auditoriums in special cases based on availability of fuel, therefore assuming days of autonomy as **1 day**.

Engineering and Operations

Heat Load Calculations

Various factors contribute to the heat gain in a building. A comparison was drawn between both cases to arrive at the amount of heat load reduction our proposal would achieve. *(Refer Appendix for full calculation tables).*

The total heat produced in BTU/hr for our efficient case drops down and a reduction of **70.6%** in internal heat gains is observed from basecase.

Strategies

Optimizing envelope by using **CLC blocks** which have excellent thermal insulation and much lower U Value to reduce internal heat gains, efficient **WWR of 30%** to keep out unnecessary heat, **double glazing uPVC windows** that keep out heat during summers and retain heat during winters, roof typologies like **green roof** as well as **PUF insulated roofs with solar panels** that provide shading to the roof and keeps it cool, thus reducing heat gain to the interiors.Using energy saving or **star rated equipment** and efficient LED lights than the conventional constructions. The comparison shows a major reduction in heat gain from standard to efficient case.

Refer Table 3 for Envelope U values

Factor	Standard (Btu/Hr) VRF System	Efficient (Btu/Hr) Inverter ducted Ac	% Reduction
Envelope	728016	119604	83.6%
Equipment	48152	14024	70.9%
Lights	25510	10094	60.4%
People	123750	123750	0.0%
Fresh air	7644	7644	0.0%
Total	933072	275116	70.6%

Table 10 : Load Reduction for different elements

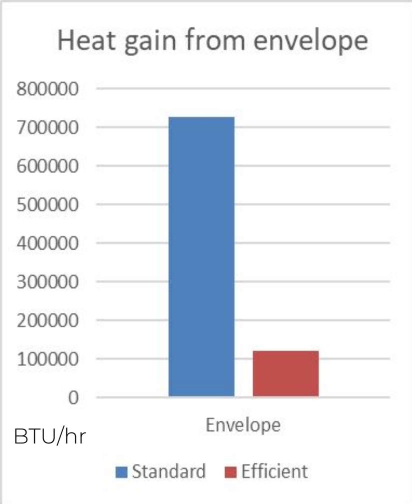


Fig 51 : Heat gain comparison 1

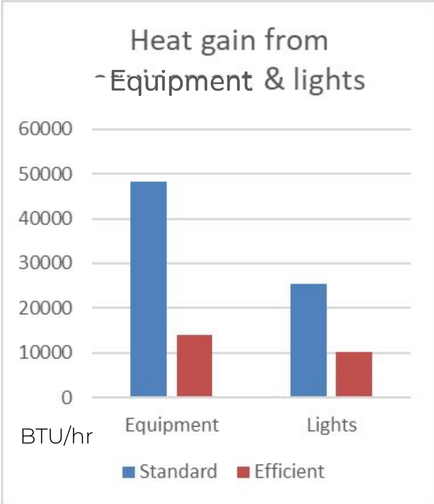


Fig 52 : Heat gain comparison 2

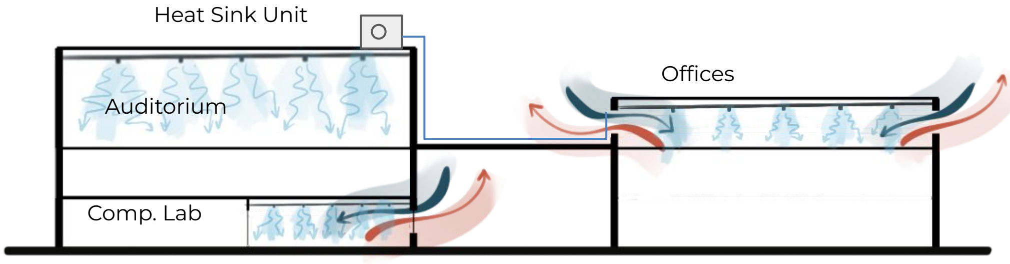
Comfort Optimization

Months	Min. Set Point Temp	Max. Set Point Temp
Summer (March - Sept)	20 °C	23 °C
Winter (Oct - Feb)	23 °C	26 °C

Table 11 : Set Point Temperature Range

Comfort Setpoint Temperature Range has been set according to comfort temperature analysis as recommended by ASHRAE 2019. The Inverter Ducted AC system connect to the BMS x AI system which is automatically control the temperatures in the conditioned spaces within this range.

Basecase vs Proposed Case of heat loads shows that out Peak Cooling Load is **275116 BTU /hr**



The placement of windows allow the hot air from the interiors to escape bringing in cool, fresh air from the exterior.

Fig 53 : Section showing heat escape

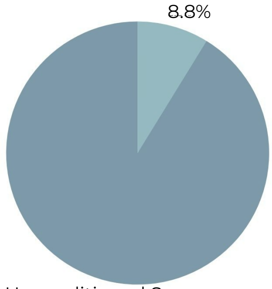
* Product Specs - https://www.bluestarindia.com/media/324792/inv-ducted-catalogue.pdf

**https://www.multitanks.com/en/refrigerant-gases-substitute-to-r410a-and-r32/2715-350grs-multicool-refrigerant-can-hc32-replaces-r32-and-r410a-3760317881354.html

HVAC

The classrooms and other learning spaces of the institute are naturally ventilated. As per the client's request, 3 spaces are air conditioned, namely - admin offices, computer lab and auditorium. The proposed HVAC system is a ducted central air conditioning system. Blue Star has recently developed a New Generation Inverter Ducted System.* The First Generation Inverter Ducted System was widely accepted in the market, especially by educational institutes. The New Generation model offers advanced energy - efficient inverter compressor technology and unique logic control which modulates the capacity of the system precisely to meet the actual load requirement inside the conditioned space.

The Inverter PCBs are refrigerant cooled with a unique heat sink. The refrigerant used is R410A which is set to be phased out by the end of 2023. **Multicool HC32**** is a refrigerant with a reduced global warming potential (GWP). It is designed to replace R410A in the upcoming air conditioning systems.
This AC system is highly efficient and has been given a **5 star rating by BEE.** This AC system is also compatible with BMS Control software and hence the operating hours can be optimized to a need-only basis. Spaces like auditorium will not have daily usage. This type of AC has 25% power savings compared to conventional type.
The conditioned spaces comprise only 8.8% of the total building area.
There are 3 spaces that are provided with air conditioning - Computer Lab, Auditorium and Admin Offices
Fig 53a shows the supply and return network from to each of these spaces.



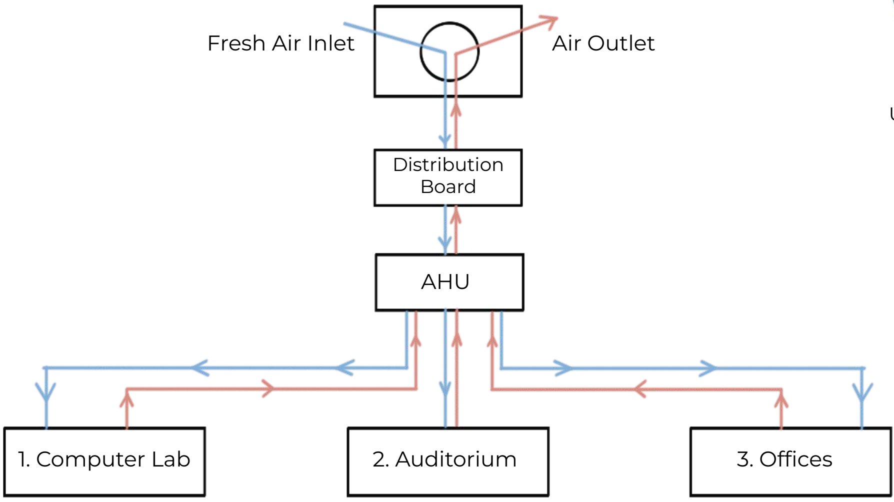


Fig 53a : HVAC Network

The cooling load requirement of these spaces is met by our proposed Inverter Ducted AC System that has a nominal cooling capacity of 264000 BTU/hr.

Space	Area (m^2)	Height (m)	Occupancy	Timings
Computer Lab	100	3	Daily	8am - 4pm
Auditorium	300	6	On occasion	Varies with event
Offices	100	3	Daily	8am - 4pm

Table 12 : Occupancy of conditioned spaces

The room area and height of offices and computer lab is much smaller than the auditorium, hence cooling load for these spaces will be much lesser. That can be satisfied by the proposed system.

As the auditorium will be used only on occasion for a smaller duration of time, the requirement for air-conditioning in the space is not daily as it is in the offices and computer lab.

Building Structure

Column Type	Dimension(mm)
C1	600*450
C2	450*200
C3	200*200

Spans (m)

Classroom blocks = 8*8

Extracurricular block = 4*5

Beam Type	Dimension(mm)
B1	300*800
B2	300*450

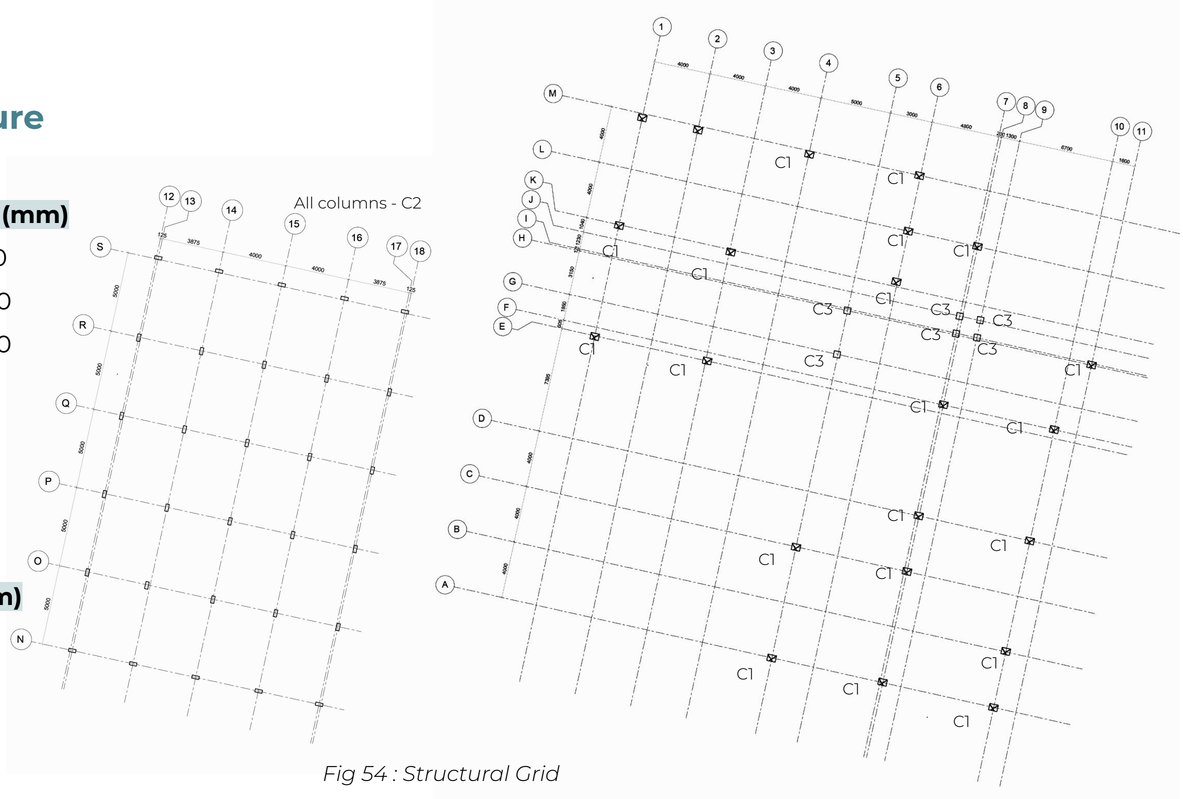


Fig 54 : Structural Grid

Fig 54 a: Extra-Curriculars Block   *Fig 54 b: Classroom 1 Block*

Solid Waste Management

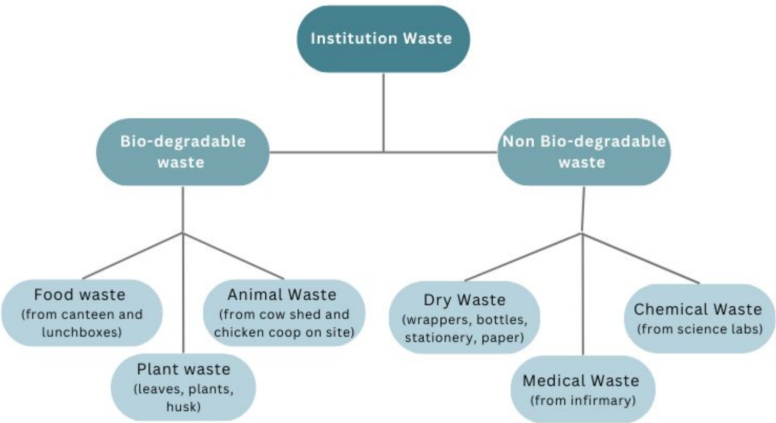


Fig 55 : Flowchart of Solid waste management

The different sources of Solid Waste in our institution are shown in fig xx. The biodegradable waste. BBMP* in Bangalore has developed a running functional solid waste management system that caters to 8 broad zones of the city, over 1 cr population and 27 building divisions including educational institutes. One of the 8 major zones is South Bangalore where our project site comes in. Segregation of waste is extremely important for proper treatment of the different types of waste. This will be followed in the school to ensure efficient waste management.

Solutions

Biodegradable waste is used for vermicomposting to produce manure. This manure will be used for organic farming purposes on site wherein the students of the school get involved and learn from nature. (Nature integrated in the curriculum).

Due to the abundance of coconut trees on site, a significant quantity of coconut husk waste is produced. This husk is being used for our greywater treatment mechanism, and the remaining husks and coconut coir can be incorporated into a paper making mechanism. Coconut coir contains cellulose, it can be used in pulp manufacturing to convert these into books, journals, greeting cards and art supplies. As per a case study**, 50g of coconut husk can produce 1 handmade paper, and the process of converting husk to paper is relatively simple. Using this method, we can produce ample amount of paper that can be used by this school as well as sold outside.

The Non Biodegradable waste is segregated further into recyclable and non-recyclable waste.

The recyclable wastes likes paper, cardboard, plastics will be sold to recycling companies. Chemical and medical wastes will be sent to BBMP facilities for treatment.

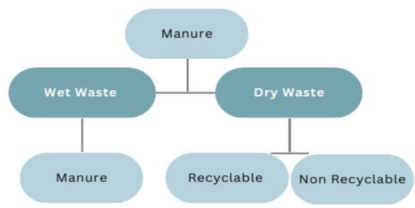


Fig 56 : Waste management flowchart

* BBMP - Bruhat Bengaluru Mahanagar Pallike
** http://www.ijarse.com/images/fullpdf/1523555657_369IJARSE.pdf

Affordability

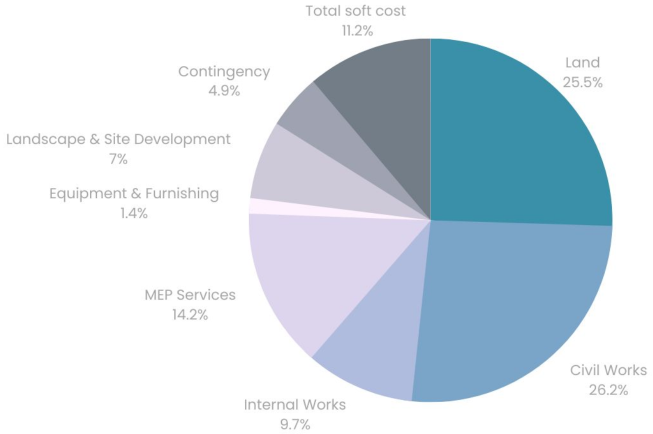
Program Formulation

The team came together to formulate a detailed Area Program by considering RAFL's vision for the school, referring Neuferts and NBC Code Books. Decisions regarding conditioned and unconditioned spaces were taken at this stage.

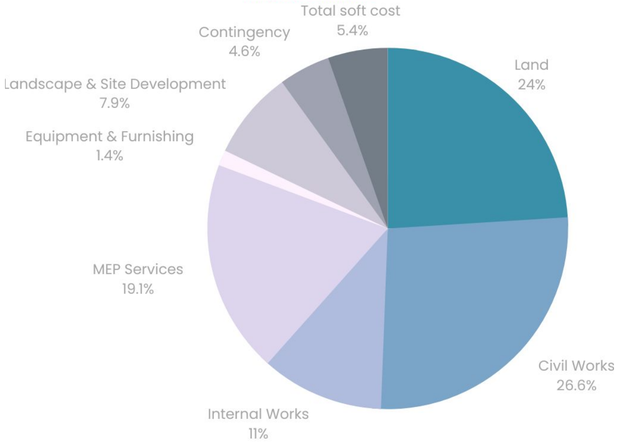
NOTE: For the comparison of the baseline and proposed design estimate, the baseline estimate is calculated in proportion to the proposed design built up area (6170 sq.m)

S.No.	Particulars	Baseline Estimate (Project Partner / SOR basis)			Proposed Design Estimate		
		Amount in Million INR	%	Amount (INR per sqm)	Amount in Million INR	%	Amount (INR per sqm)
1	Land	100	26.00%	2,059	100	26.00%	2,059
2	Civil Works	102.81	26.70%	2,117	111	28.80%	2,286
3	Internal Works	37.92	9.90%	781	45.76	11.90%	942
4	MEP Services	55.78	14.50%	1,149	79.62	20.70%	1,640
5	Equipment & Furnishing	5.58	1.40%	115	5.72	1.50%	118
6	Landscape & Site Development	27.5	7.10%	566	33.2	8.60%	684
7	Contingency	11.48	5.00%	236	13.76	5.00%	283
	TOTAL HARD COST	**341.07**	**90.60%**	**7,024**	**389.06**	**102.50%**	**8,012**
8	Pre Operative Expenses	10	2.60%	206	10	2.60%	206
9	Consultants	10	2.60%	206	10	2.60%	206
10	Interest During Construction	23.77	6.20%	490	2.21	0.60%	45
	TOTAL SOFT COST	**43.77**	**11.40%**	**901**	**22.21**	**5.80%**	**457**
	TOTAL PROJECT COST	**384.84**	**100.00%**	**7,925**	**411.26**	**106.90%**	**8,469**

Table 13 : Project Summary Cost



Baseline estimate



Proposed design estimate

Fig 57 : Pie chart comparison of baseline and proposed design estimate

- Cost effective construction by replacing BBM with CLC blocks which consist of additives like fly-ash are recycled in their composition.
- Usage of passive strategies and site features to minimize on the mechanical cooling and operational costs.
- The generation of electricity through efficient and green rated equipment- solar and piezoelectric media to achieve a resultant return of 45000 kW of electricity per year to the main grid resulting in a revenue returns every year.
- Additional consultation for new technology and expenditure on the energy generating equipment is met by constant revenue generation throughout life cycle soon after the break-even period (graphically quantified in value proposition)
- The proposed design aims to achieve the break even period in the next 5 years followed by consequent profits (throughout its life cycle).

Affordability

Construction Timeline

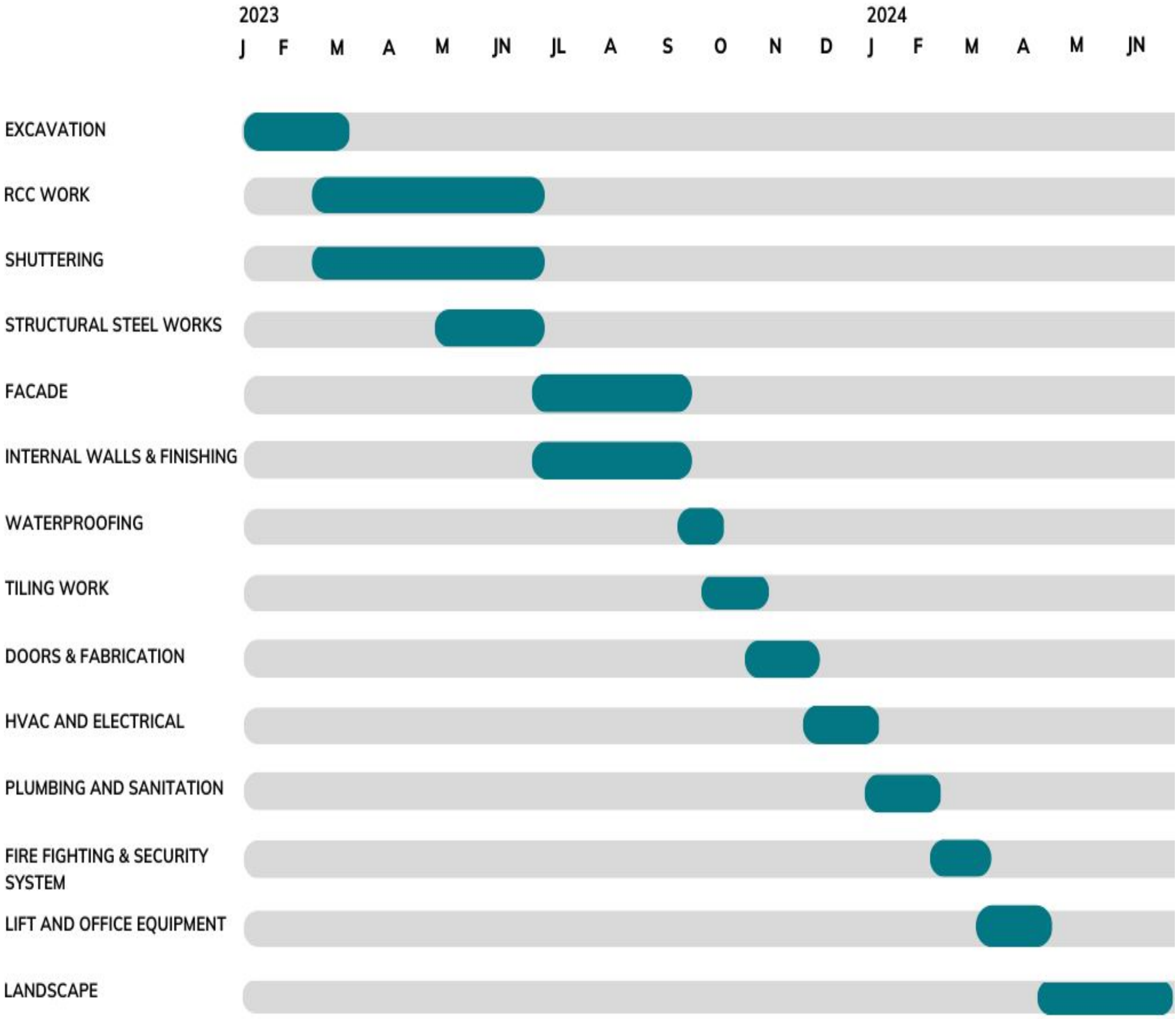


Table 14: Project construction timeline

Innovation

Name: AI x BMS. (Artificial Intelligence x Building Management Systems)
Idea:
With the advent of smart buildings and critical dependency on technology for everyday activities and functioning of buildings, we are proposing the integration of one of the most up and coming technologies, **Artificial Intelligence** along with existing technologies related to **Building Management Systems**.

Problem:
Inadequate monitoring of electrical appliance usage in semi public spaces like schools , colleges etc, contributes a lot of **unnecessary wastage** of electricity and funds. To counter this advanced Building Management Systems have been under development over the last few years, however taking this to the highest efficiency and responding in a **"tailor made "** fashion **based on subjective needs is a need of the hour**.
The growing concerns of sustainable building combined with the need of making sustainability affordable during the service period of a building are the key problems being addressed here.
Additional problems like **reduction of human dependency**, **reduction of risk, human errors and maintenance** of these existing softwares and **centralised data collection and digitisation of spaces** are auxiliary issues/benefits addressed here.

Technology:
A Building management system (BMS) is a control system that can be used to monitor and manage the mechanical, electrical and electromechanical services in a facility. The most common functions under the bracket of BMSs' functions are -
Electric power control—control and monitor core electrical and mechanical equipment.
Heating—schedule the system on and off; maintain a set temperature point.
Ventilation—adjust based on occupancy controls(HVAC, Blinds, openings, jaalis etc.)
Security and observation—access control; surveillance and intrusion detection
WORKING-
In our suggested model the different sensors employed will be namely - **Light sensors**, **cameras** equipped with **facial recognition** and **infrared detection**, **temperature sensors** (the infrared detection and temperature sensors double up as fire sensors also), **IAQ sensors etc.**
With respect to ventilation several standalone softwares are developed for performative screens and jaalis with movable portions and with wet systems, we also propose an integration and control over these systems in our software which would enable the most **efficient usage of power** and response to occupancy.
The necessity of integration of **artificial intelligence -**
with the existing BMS software is noticed when multiple security roles, managerial works, logistic record and supply maintenance tasks are essentially reduced to mere software processed as opposed to the current systems where manpower in involved in nearly all processes.

- For example - the cameras installed and the buildings system can track the movements and paths of children thereby reducing the manpower in the security field, also helpful during examination processes.
- The automatic updation and sourcing of logistic and maintenance related goods is done by the computer reducing on the manual help required.
- Integration of personalized lesson plans for students and administrative guidance to the parents via this interface, scheduling meetings, pickups, emergency schedules and protocols all reducing admin manpower required and a centralized database keeping track of students records and also allowing for understanding staff performances and areas of improvement as an institution.

Innovation

Market:
The recent discovery and usage of AI bots like ChatGPT etc have shown the possible potential of integration of AI into various services. The resultant market is very much in trend and is receiving great funds.With the increasing adoption of AI and related technologies, the funding of enterprises in India providing such services has seen an uptick over the years. In 2022, there has been a increase in funding for AI startups. Funding has been stable from $1,108 Million in 2021 to $1,109.62 Million in 2022. Successful products and promotion of the efficiency of products would help in scaling up.

Costs, benefits and impacts:
Generic BMS softwares cost around 20L in commercial scenarios in our scale, but the intricacy of the network and integration of AI along with greater no. of systems results in a higher cost.
The greater initial investment would reduce running costs and greater efficiency for the clients and direct purchasers of products, the AI in the system can also help w security and managerial aspects in the different school systems which have extensive databases for every student.
The school catching up with the rapid digitisation of the educational processes and increased efficiency of the students, institution and the building, would be the immediate impacts of the product.

Name: Producing paper with coconut husk and recycled paper

Idea:
Coconut husk can be used along with other materials like used paper,cotton rags, linen rags, coffee husk, banana fiber, recycled paper etc to make paper of varied colour and texture.These can be utilized by the students and used for revenue generation also.

Problem:
A typical school will use an average of 2,000 sheets per day, meaning that during a full school year of 160 days, a school will use up 3,20,000 sheets of paper per year. This will lead to huge amount of wastage per year. The paper industry consumes 42% of all the wood felled industrially every year and its share of the world's cleared forest is an area of about three million hectares annually. Implying 50,000 trees are cut at one go.

Cost and impact:
The price for raw materials is zero as we are providing the company with the material. Capital that is generated by selling these handmade papers is invested in boiling and blending equipment. So recycling paper along with coconut husk and other rags will be an effective waste management system and also help in saving the trees from felling.
The process of recycling paper consists of

- Collection of raw materials(used paper, coconut husk, leaves,)
- Shredding of used paper
- Soaking
- Blending and heating of fibers
- Mashing of soaked paper
- Moulding
- Drying

All of these processes are intended to be done by students that will sow seeds of lessons in their minds about recycling, waste management, teamwork, etc. All of these processes are conducted behind classroom block 2 with a small sheltered space for boiling and blending.

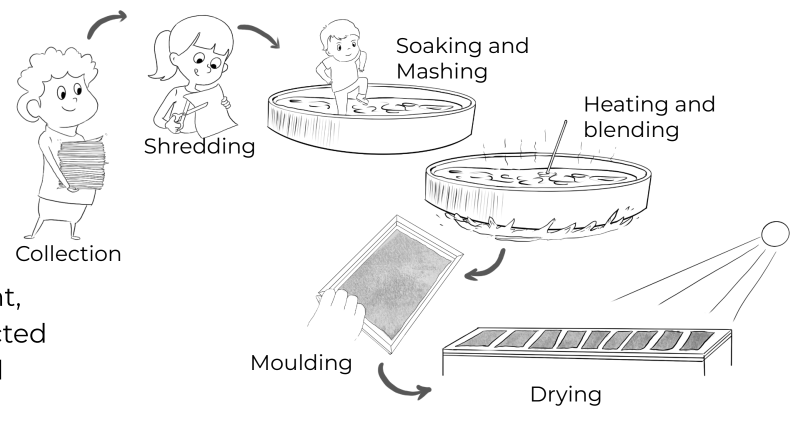


Fig 58 : Paper production from coconut husk

Health and Wellbeing

To start with comfort analysis, we studied the standards given in **ASHRAE and BEE** and tried to achieve the optimum values with respect to all the comfort factors such as temperature, ventilation and natural light, without any extra mechanical support.

We analyzed the outdoor temperature of Bangalore and through this study 47% of the year falls under the comfortable temperature range and to provide during the remaining 53% of the year various passive strategies are adopted.

Monthly Temperature Graphs

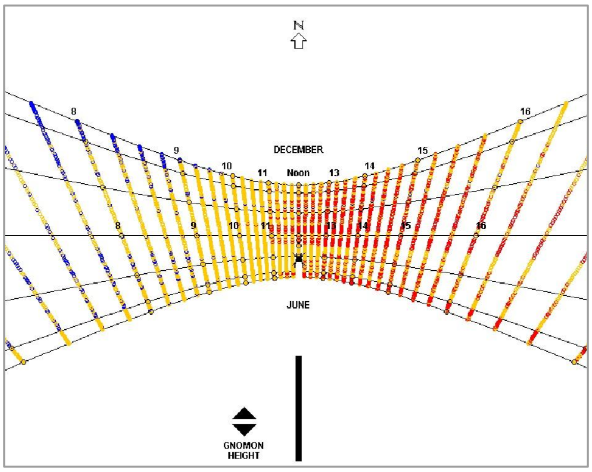


Fig 59 : Temperature from June 21 to December 21

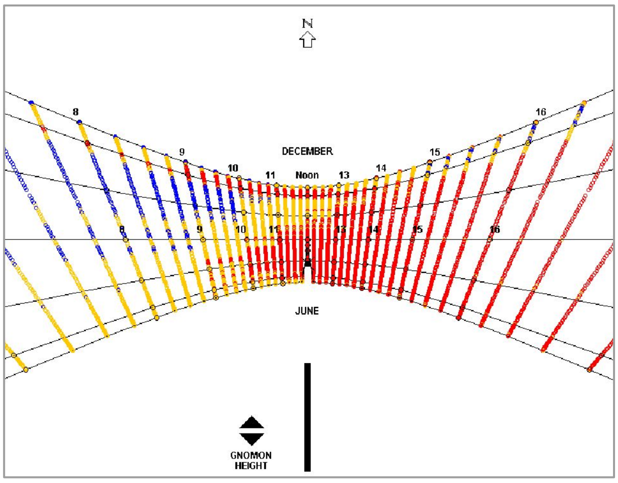


Fig 60 : Temperature from December 21 to June 21

Fig 59,60 denotes outdoor temperature for school working day through the year (8am-4pm)

Legend

Comfort Analysis throughout the year

Fig 61 compares the temperature trends from 8am-4pm for different months through the year.
(Refer above legend)

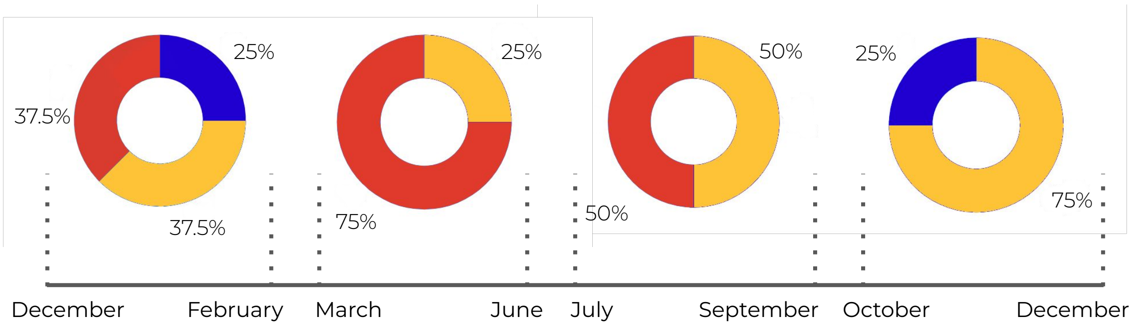


Fig 61 : Comfort Analysis throughout the year

From the above analysis, we derive the overall comfort for the operation of our school.

- **47%** of the operative hours is in the **comfort range** and can function by passive ventilation of opening windows as well as turning on ceiling fans.
- 12.5% of operative hours fall under cool temperature range and this can be can tackled by containing the warmth inside classrooms via double glazing windows during winter.
- 40.5% of operative hours are in the warm range. As our site has a **dense tree plantation** and the built is organised around a central court, this cools down the microclimate and pulls in fresh cool air through the **terracotta jalis and windows**. **CLC Blocks** having excellent thermal insulation keeps out heat in the summers, double glazing units and optimum shading devices reduces the amount of internal heat gains.

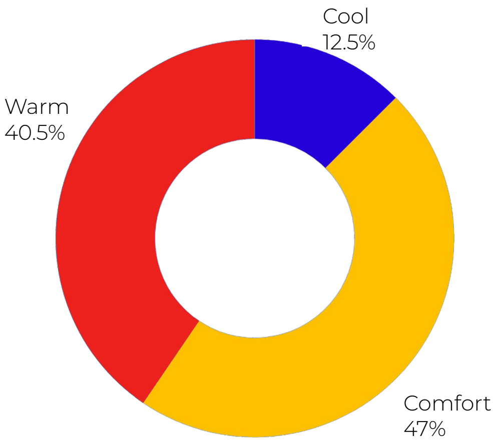


Fig 61 a : Yearly average analysis of comfort hours
(average of the operative hours of the school for all the months in a year)

Light and Ventilation

Studies strongly suggest there are physical and psychological health benefits from increased daylighting in schools. The aim is to bring in ample natural light through fenestrations and achieve the recommended lighting lux levels in a classroom of 250-500 lux for bright learning spaces for students. ***(Recommended by BEE and ASHRAE)***. This is being achieved by providing optimum window - wall ratio of ≤ 40% of wall area as per ECBC for temperate climates.

Recommended ventilation rate **according to ASHRAE** is 5 L/s per person or 15-20 cfm/person in schools. Our classrooms are naturally ventilated and surrounded by trees and courts that bring in fresh air to cool down the spaces. Fig 62 shows the light and ventilation in the classroom blocks.

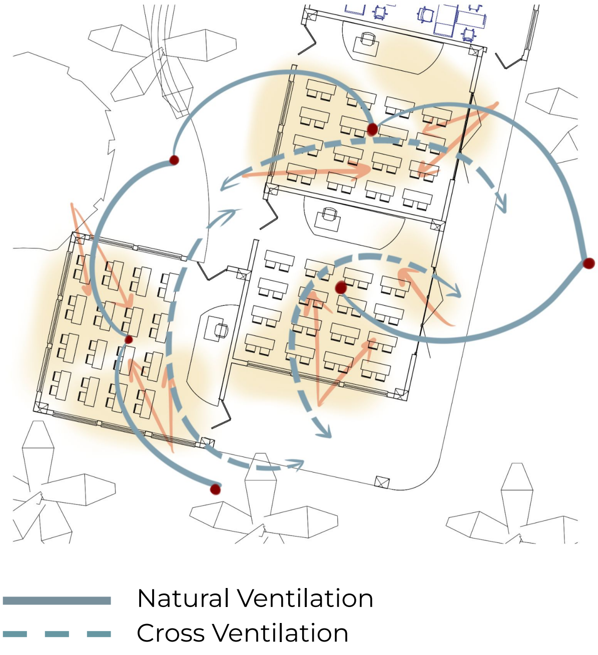


Fig 62 : Light and ventilation in classrooms

Indoor Air Quality

Schools should ideally serve as optimal learning environments for students, but poor air quality in a school's building can have negative effects. **According to ASHRAE**, the recommended CO2 level in buildings should be no more than 1100 parts per million (ppm) above outdoor air. Since outdoor air is approximately 400ppm, indoor CO2 levels should be no more than 1,100 ppm.

Our goal is to maintain the level at 700ppm. CO2 and other VOCs in the air can be harmful and have adverse health effects on children. It inhibits their learning capability. Proper indoor air quality must be maintained for students to function and learn efficiently. Table 13 shows IAQ index of VOCs and CO2 levels.

Strategies for good IAQ :

Proper ventilation naturally and by ceiling fans helps in achieving the recommended acph for students thus regularly replacing toxic air with fresh air. Using eco friendly paints which have less VOCs released in the air. Installing IAQ monitors in classrooms to continuously monitor CO2 and VOC levels and detect potential ventilation problems.

IAQ Index			
PM2.5	VOC	CO2	
μg/m^3	μg/m^3	ppm	Hazard Level
<12	100	700	Good
35	200	800	Moderate
56	300	1100	Poor
150	400	1500	Unhealthy
250	500	2000	Very Unhealthy
300	600	3000	Hazardous
500	700	5000	Extreme

Table 15 : IAQ Index

Operation :

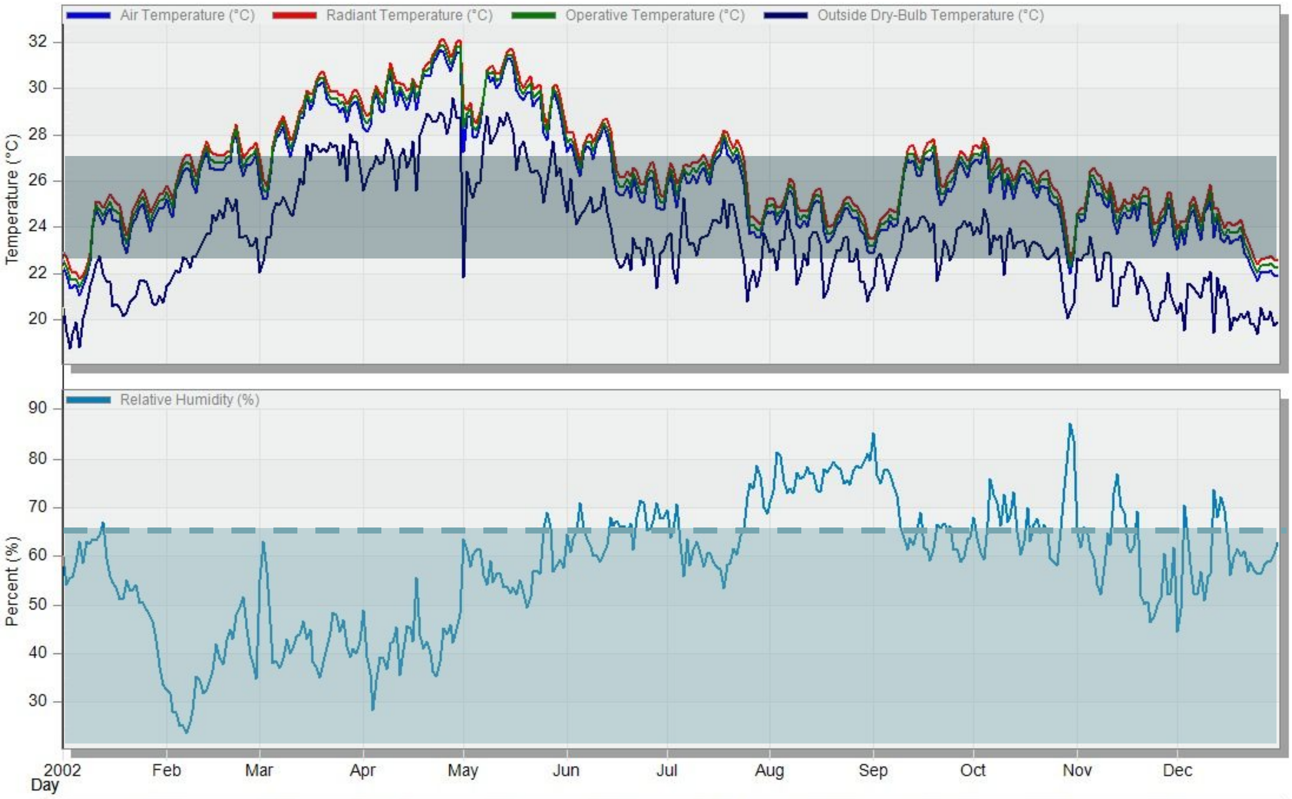
The IAQ monitor will be linked and managed by the BMS x AI system. The acceptable levels as mentioned in table 14 will be pre-set in the system. The system will thus make sure that appropriate Co2 levels are maintained in the classrooms.

- If indoor CO2 levels are above 1000 ppm, occupants will be notified to open the windows and vents for natural ventilation.
- Occupants may open the windows when the IAQ monitors notifies them that CO2 levels are 1000 ppm.

Comfort Optimization

The main goal to was to optimize our design and use efficient strategies like optimizing wwr at 30, providing windows with shading devices to avoid excess heat gain, terracotta jaali screen with further cool the air that passes through it, double glazing units which keep out warm summer heat from entering and retain warmth in the interiors during winter, the use of CLC blocks which has excellent thermal insulation properties, etc which would ensure that the classrooms and other learning spaces would fall between the defined comfort range of 21 - 27c, without the use of HVAC system. i.e through natural ventilation and ceiling fans.

Fig 63 shows the temperatures achieved in the classroom blocks throughout the year.
Shows the comfort band which is 23-27 C as per ASHRAE standards
Shows that the humidity % remains below 65% for most of the year which is the comfort standard according to ASHRAE.



Air Temperature (°C)	24.65	28.05	30.66	30.22	27.25	27.15	23.44	24.97	25.19	24.15
Radiant Temperature (°C)	25.53	28.55	31.09	30.68	28.18	27.72	24.02	25.86	26.00	24.66
Operative Temperature (°C)	25.09	28.30	30.87	30.45	27.72	27.43	23.73	25.42	25.60	24.41
Outside Dry-Bulb Temperature (°C)	21.61	24.94	27.44	28.76	24.03	24.18	21.84	22.36	22.71	20.75
Relative Humidity (%)	31.81	37.02	42.20	56.60	67.99	57.29	78.21	65.69	59.55	51.40

Fig 63 : Temperatures achieved in classroom blocks throughout the year. Source : Design Builder

The graphs prove that most of the operative hours throughout the year fall within the comfort band of temperature and humidity.
During the summer months of April and May, the temperatures exceed the comfort band. Due to the dense tree cover present on site, the **microclimate of the site** is affected as the trees cool the site greatly.
The **thermal comfort** in the interiors of the school is maintained through **passive techniques** and by taking advantage of the **site's features** such as dense tree cover.

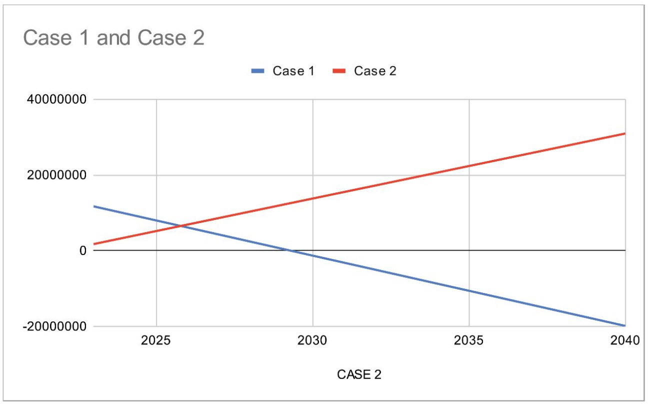
Value Proposition

Intangible aspects

- Achieving clients requirements by involving student activities in nature.
- High air quality because of integrating design with trees.
- Encouraging outdoor learning and providing spaces for the same
- Inward looking design encourages interaction

Expenditure and ROI for clients

- Generating electricity through 3 different media
- Proposing BMS x AI new tech innovation to improve efficiency of equipment running in the building



X axis - the years of project under use.
Y axis - amount spent/saved in maintenance (INR)

Fig 64 : Comparison of compounding costs and returns over 17y

This graph shows us how Case 1 intersects the compounding costs of Case 2 in 2026 and achieves breakeven and profits post 2028.

Case 1 - AURUM proposal
Case 2 - Initial proposal without . energy measures

Factors considered -
Solar power generated with 540 kW panels per year - 206690kW
Piezoelectric electricity generated per year
. - 43560 kW
Total generated - 250250 kW produced per year
Consumption of power by the project per year
. - 203610 kw
Return - 250250-203610
= 46640 kW returned to grid

Case 1

The generation of electricity through solar and piezoelectric media shows a resultant return of 46640 kW per year to the main grid resulting in a **return of 1.4L per year** through govt. schemes. Creating savings of **1.7 L per year** (from electricity expenses saved)
Therefore **break even** of investment occurs **in 2029**

Sustainability

- Using coconut husks - as a water filter
- Filler slabs utilised with local on site coconut shells
- Providing natural thermal cooling and shading via passive design elements
- Promoting gardening and farming activities, keeping land fertile and healthier environment, and is also a constant source of revenue.
- EPI value was set at 33 and it was met and exceeded as well

Market potential and scalability is dependant on the analysis of the design and its success as a business proposition.
SWOT analysis post design
S - Integrating nature into design is attractive for customers.
- Lesser trees disturbed, greater sustainability.
- Passive design encourages natural cooling and greater thermal comfort.
- Inward looking encourages interaction and successful, usable spaces for children.
- Vertical stacking gives more scope for future expansion & more outdoor areas.

W - Higher initial capital costs
- Lower scope of intriguing design for children owing to the restriction of minimal cutting of trees
- Isolated playground

O- Saving costs over maintenance and electricity over time
- Revenue generation through 3 different sources of energy production
- Treated greywater and harvested rainwater can be utilised for flushing, landscaping and maintenance

T- Coconuts hazard for children
- multiple open spaces may create slippery spaces for children.

Appendix

1. Project Partner Letter
2. Industry Partners Letters
3. Bonafide Letter from BMSCE
4. Bonafide Letter from BMSCA
5. Performance Specifications
6. Building Area Program, Material Analysis
7. Case Studies
8. Energy simulation input and outputs
9. Water Tables
10. Cooling Load Estimate - Standard vs Proposed Case
11. Embodied Carbon Content
12. Architectural drawings
13. Building Operation Narrative

Project Partner Confirmation Letter

25 Nov 2022

To,

The Director,

Solar Decathlon India

Dear Sir/Ma'am,

This is to inform you that our organization **RAYS ACADEMY FOR LEARNING (RAFL)** has provided information about our **RAFL - MASTER PLAN DESIGN** project to the participating team led by **BMS College Of Architecture and BMS College Of Engineering**, so that their team **AURUM BMSCE - CA** may use this information for their Solar Decathlon India 2022-23 Challenge entry.

As a Project Partner to this team for the Solar Decathlon India 2022-23 competition, we are interested in seeing the Net-Zero-Energy, Net-Zero-Water, resilient and affordable solution this student team proposes and the innovation that results from this. We intend to have a representative from our organization attend the Design Challenge Finals event in April, if this team is selected for the finals.

We would like our organization's logo to be displayed on the Solar Decathlon India website, recognizing us as one of the Project Partners for the 2022-23 Challenge.

With warm regards,

Name of Representative: Usha S. Rangiri.
Designation: Principal
Email: raflprincipal@raysinstitutions.com
Phone: 9606009562

Head Mistress
Rays Academy For Learning - RAFL

Industry Partner Confirmation Letter

25 Nov 2022

To,

The Director,

Solar Decathlon India

Dear Sir/Ma'am,

This is to inform you that our organization, **STUDIO IKINSA**, is collaborating with the participating team led by **BMS College of Architecture and BMS College of Engineering** on a **Educational** Building project for their Solar Decathlon India 2022-23 competition entry.

The nature of our collaboration will be in terms of technical support (latest technology and market techniques) and industry related mentorship with the team; Intention being to interact and assimilate the above stated approaches into new design innovations.

We would like have a representative from our organization attend the Design Challenge Finals event in April/May, if this team is selected for the Finals.

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

With warm regards,

Name : Afrin Banu
Designation : Junior Architect - Design Team Lead
Name of the Organisation : Studio Ikinsa
Email : afrin.studioikinsa@gmail.com
Phone : +917358438478

Industry Partner Confirmation Letter

ECO SOCH
Sunny Living

EcoSoch Solar Pvt. Ltd.
www.ecosoch.com / info@ecosoch.com
: +91 8123410101 / 8123420202
GSTIN: 29AADCE8640G1ZH

Date 21/02/23

To,

The Director,
Solar Decathlon India

Dear Sir,

This is to inform you that our organization, EcoSoch Solar is collaborating with the participating team led by BMS College of Architecture and BMS College of Engineering on an Educational Building project for their Solar Decathlon India 2022-23 competition entry.

The nature of our collaboration will be in terms of technical support and industry related mentorship for the team. The main aim is to guide and assist the team in their SOLAR POWER related strategies.

We would like to have a representative from our organization attend the Design Challenge Finals event in April/May if this team is selected for the Finals.

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

With warm regards,

Hemant Sharma

Hemant

ECOSOCH SOLAR PVT. LTD
Estd
2015

CEO,

EcoSoch® Solar Pvt. Ltd.
hemant@ecosoch.com
+91 8971865219
"Sha Arcade", 2nd Phase,
NTI Layout, Rajiv Gandhi Nagar,
Kodigehalli, Bengaluru – 560097
Web: EcoSoch || Blog || Map || Twitter

Bonafide Letter - BMSCE

Phone : +91-80-2662 2130-35
Fax : +91-80-2661 4357
e-mail : principal@bmsce.ac.in
URL : www.bmsce.ac.in

B.M.S. COLLEGE OF ENGINEERING
ESTD. 1946
Autonomous College under VTU | Aided by GOK | Approved by AICTE | Accredited by NBA

BMSCE/ACA/UG/CERT/2022-23 Date:20.02.2023

BONAFIDE CERTIFICATE

This is to certify that following students studying in V semester B.E. during the academic year 2022-23. This College is an Autonomous Institution, approved by AICTE, New Delhi and affiliated to Visvesvaraya Technological University (VTU), Belagavi. The duration of the course is four years (eight semesters). The medium of instruction is English. This certificate is issued for the purpose participating in solar Decathlon for designing "Net Zero energy Educational Building"

His & Her character and conduct are good.

Sl No	Name of the student	USN	Department
1	Likhith Raj	1BM20AS021	Aerospace Engineering
2	Bishal Bhurtel	1BM20CV193	Civil Engineering
3	Niranjan S Hegde	1BM20ME098	Mechanical Engineering
4	Karthik D O	1BM20ME066	Mechanical Engineering
5	Mohammed Azeez Chikkabbar	1BM20ME087	Mechanical Engineering
6	Poojitha P	1BM20ME109	Mechanical Engineering

PRINCIPAL

P.B. No. 1908, Bull Temple Road, Bengaluru - 560 019 Karnataka. INDIA

Bonafide Letter - BMSCA

BMS College of Architecture

COA Approved | VTU Affiliated

BMSCA
BMS COLLEGE OF ARCHITECTURE

Tel: (O) 080-26622126-127
e-mail: info@bmsca.org
website: www.bmsca.org

Ref/BMSCA/BC/001/UG/2022-23/766

Date: 20.02.2023

WHOMSOEVER IT MAY CONCERN

I certify that the following students are bonafide students of BMS College of Architecture and allowed as a participants in SOLAR DECATHLON, India 2021-22 competition by team "Aurum".

This certificate is issued for the purpose of participation in SOLAR DECATHLON competition only.

Sl.No	Name of the student/participants	USN
1	Shayna Kurian	1CF19AT106
2	Badam Lokesh	1CF19AT016
3	Niharika K C	1CF19AT044
4	Rithika Ballal	1CF19AT086
5	Shadha Abusabah	1CF19AT102
6	Sai Aditya	1CF19AT093
7	Kiran S	1CF19AT048
8	Chandana V Bala	1CF19AT020
9	Raksha S Hemmige	1CF19AT079

Thanking You,

Regards

Mamatha P Raj 20/2/23

Dr. Mamatha P Raj
Director & Professor

Bull Temple Road, Bengaluru – 560 019, Karnataka, INDIA

Performance Specifications

Parameter		Values
Envelope Specification	Window-wall Ratio	30%
	Wall U Value	0.38
	Roof U Value	0.33 (Rcc with PUF insulation) 0.25 (Filler Slab)
Glazing Specification	U value	3
	SHGC	0.25
HVAC System	System Type	Inverter Ducted AC
	Cooling Capacity	264000 Btu/Hr
	Conditioned Area	500 m^2
	Unconditioned Area	5670 m^2
Lighting	LPD	6-7.5 W/m^2
On-Site Consumption	EPI	33 kWh/m^2-yr
On-Site Generation	Type 1	PV Panels
	Installed Capacity	139.5 kWp
	Panel Rating	540 W Monocrystalline
	Total Energy Generation	206,692 kWh/m^2-yr
	Type 2	Pavegen Piezoelectric Tiles
	Total Energy Generation	43,560 kWh/m^2- (for 220 working days)
Water System	Total Water Consumption	8.85 kL per day
	Recycled Water	14532.7 L per week
	Water for maintenance	225 m^3
	Rainwater storage tank	30 m^3

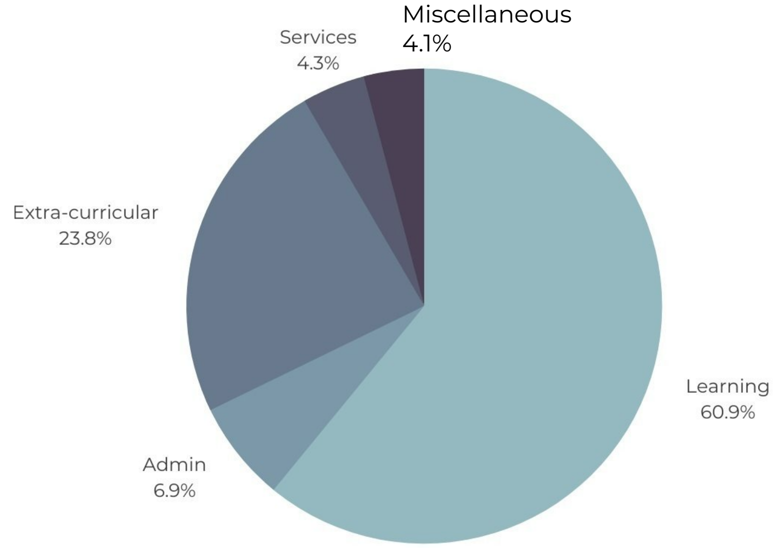
Building Area Program

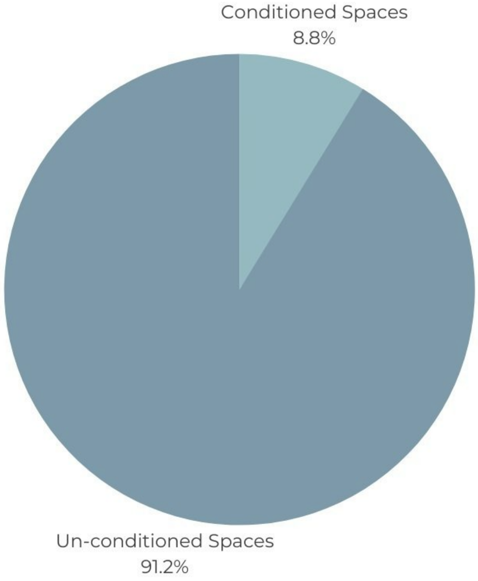
BUILDING AREA PROGRAM							
Sn.	Space	Function	Built Area / Unit (m^2)	Users / Unit	No. of Units	Total Area (m^2)	Conditioning
1	Academic Spaces					2640	
		Classrooms	65	30	36	2340	Unconditioned
		Library	300	90	1	300	
2	Laboratories					480	
		Physics Lab	100	30	1	100	Unconditioned
		Chemistry Lab	100	30	1	100	
		Biology Lab	100	30	1	100	
		Home Science Lab	80	30	1	80	
		Computer Lab	100	60	1	100	Conditioned
3	Admin					100	
		Accounts office	100		1	100	Conditioned
		Administrator Office			1		
		Reception			1		Unconditioned
		Principal's Office			1		Conditioned
		Waiting Lobby			1		Unconditioned
4	Faculty Spaces					252	
		Staff Rooms	36	8	7	252	Unconditioned
5	School Facilities					210	
		School Supply Store	30		1	30	Unconditioned
		Uniform Store	30		1	30	
		Infirmary Room	30		1	30	
		Cafeteria & Kitchen	120		1	120	
6	Toilets					220	
		Girls		1 per 25 pupils		130	Unconditioned
		Boys		1 per 40 pupils		90	
6	Extra Curricular Spaces					670	
		Dance Studio	60	30	1 of each	60	Unconditioned
		Music Studio	60	30		60	
		Theatre Studio	60	30		60	
		Yoga and Meditation	60	30		60	
		Workshop	65	30		65	
		Art Studio	65	30		65	
		Auditorium	300	200		300	Conditioned
8	Outdoor Sports					450	
		Football					
		Basketball	450		1 space for all these	450	Unconditioned
		Volleyball					
		Badminton					
		KOKO					
		Kabbadi					
		Throw ball					
		Running Track(100m)					
9	Indoor sports					100	
		Table tennis	100		1 space for all these		Unconditioned
		Carrom					
		Chess					
		Foosball					
10	Event area						
		Short put					
		Javelin throw					
		High jump					
		Long jump					
	Area of Spaces				Built Area	5122	
	Circulation		18% of Covered Area			1045	
	Total Conditioned Area						450
	TOTAL BUILT AREA					**6167**	**m^2**

Building Area Program

Site Area = 6 Acres = 24280 m² Total Built Area = 6167 m² Estimated no. of Users = 1150

AREA DISTRIBUTION





Construction Cost

NOTE: For the budget comparison of the baseline and proposed design estimate, the baseline estimate is calculated in proportion to the proposed design built up area (6170 sq.m)

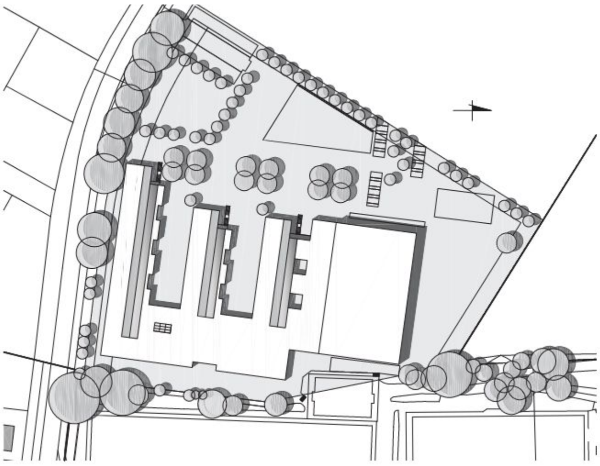
Material Analysis

U value analysis for project materials

Wall Materials			
Material Specification	Thickness (l)	Conductivity (λ)	R Value (l/λ)
	(m)	(W/mK)	(m²K/W)
CLC Block	0.2	0.084	2.381
Cement Plaster (12mm each side)	0.024	0.72	0.033
Surface Conductance (inside)			0.107
Surface Conductance (outside)			0.05
Total R Value			2.571
U Value (W/m²K)			**0.389**

Roof Materials			
Material Specification	Thickness (l)	Conductivity (λ)	R Value (l/λ)
	(m)	(W/mK)	(m²K/W)
RCC Slab	0.15	1.58	0.095
Underdeck PUF sheet insulation	0.06	0.025	2.4
Cement Plaster (12mm)	0.012	0.72	0.017
Screed	0.075	0.3	0.25
Tiles	0.02	0.84	0.024
Waterproof Layer	0.001	0.039	0.026
Surface Conductance (inside)			0.107
Surface Conductance (outside)			0.05
Total R Value			2.969
U Value (W/m²K)			**0.337**

Roof Materials			
Material Specification	Thickness (l)	Conductivity (λ)	R Value (l/λ)
	(m)	(W/mK)	(m²K/W)
RCC Slab	0.112	1.58	0.071
Cement Plaster (12mm)	0.012	0.72	0.017
Screed	0.075	0.3	0.25
Coconut Shells (Filler Material)	0.1	0.03	3.333
Waterproof Layer	0.001	0.039	0.026
Surface Conductance (inside)			0.107
Surface Conductance (outside)			0.05
Total R Value			3.854
U Value (W/m²K)			**0.259**



Case Studies

Energy-Plus Primary School

Germany

Occupancy Type -School
Climate Type - Temperate Seasonal Climate
Project Area - 7,414 m2
Grid Connectivity - Off-Grid
EPI - 23 kWh/m2/yr

Niederheide Primary School in Hohen Neuendorf near Berlin is the first school in Germany to be awarded the **Gold Medal for Sustainable Construction** by the German Federal Building Ministry.

Passive Design Strategies

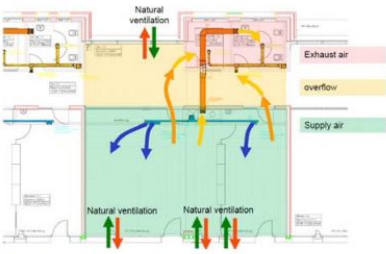
Orientation
The classrooms are oriented to the south. This enables efficient solar shading, natural lighting und passive solar heating.

Building envelope and fenestration
The main structure of the school building comprises of concrete walls, slabs and roof. Sports hall has a timber roof. The building has a very good thermal insulation level that achieves the passive house standard

Facade designed:
It is designed to provide efficient solar control, natural lighting und pa
energy gain.

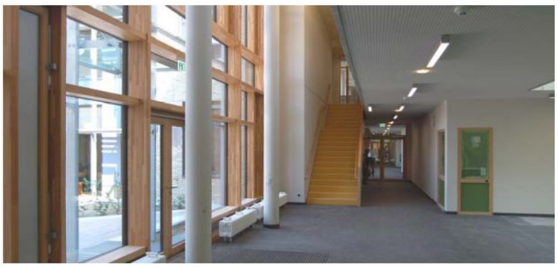
U- value of envelope	
Exterior wall 1	0.15 W/m2K
Exterior wall 2	0.13 W/m2K
Windows	0.80 W/m2K
Roof	0.11 W/m2K
Slab	0.10 W/m2K

Acoustics and thermal storage mass
The concrete ceilings are left uncovered for good thermal contact and large parts of wall surfaces is covered by highly efficient broadband acoustic absorbers.

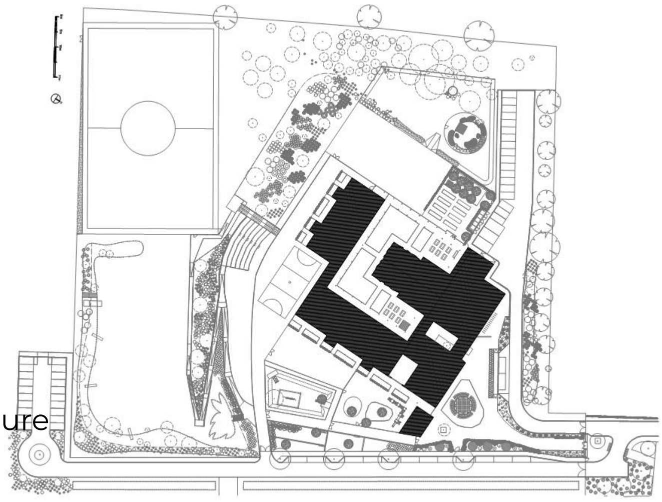


Home area for one class daylighting natural ventilation mechanical ventilation

A hybrid ventilation strategy using mechanically opened windows for natural ventilation during the teaching breaks supported by a mechanical ventilation system



Use of **renewable energy** resources such as wood pellets for heating, an integrated photovoltaic plant for solar power generation and wood pellet driven combined heat and power generation.



Case Studies

The Krishna-Avanti Primary School / Cottrell & Vermeulen Architecture

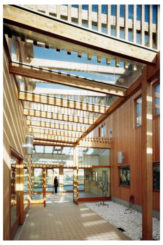
Floor Area - 1907 m2
Sector - Education
Total Cost - 7M euros
CO_2 Emissions - 14.1kg/m2/yr
Architects - Cottrell & Vermeulen Architecture
Year - 2009
Occupancy type - School

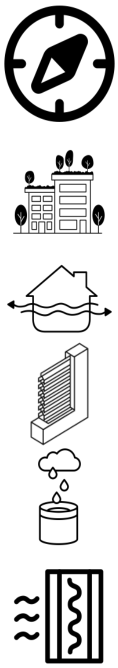
INTRODUCTION -

Krishna-Avanti Primary School is a state of the art educational environment and a sustainable building with an integrated engineering approach that provides a low impact, energy efficient solution. The school has one of the **highest BREEAM scores** for a school in the UK and is fully accessible and inclusive.

PLANNING -

From the outset, the design team and client set up consultations and strategies to define the **material palette**, **low/renewable energy technologies**, **community involvement**, and **future adaptability** in order to ensure a sustainable and future proofed design (for example the foundations have been designed to allow the walls to be opened up if open-plan teaching is required in the future).
The entire space is designed to reduce energy consumption and minimise carbon production in a number of fully integrated ways:

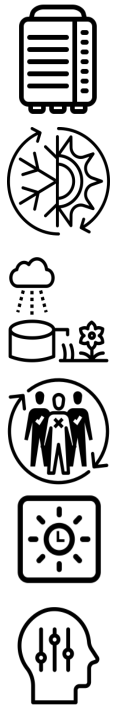


Passive strategies

- **Orientation** of building enables usage of natural daylight to largest extent
- **Green roofs**, planted with sedum to insulate and provide ecological benefits
- **Natural ventilation** with automatic controls
- External **solar louvres** to reduce solar gain and direct glare
- **Stormwater detention pond** and **rain water harvesting** to tackle poor on site drainage
- Thermal Insulation - **LOW u value** materials used

Active strategies

- **Ground source heat pumps** have to been installed to provide upto 68% of the heating demand of the space
- Local **thermostatic controls** have been specified for control of maximum hot water temperature at taps
- Use of **recycled water** for landscaping
- **Absence detection**, low energy artificial lighting controls
- **Daylight sensing** and time clock control of external lighting
- **Fully automatic and self learning, BMS control system** for higher efficiency in primary energy usage



Energy efficient construction procedures were employed -
Contractors practiced reduced waste on site; co-ordinated deliveries; used recycling skips; water use on site was monitored; earth excavations were re-used; hoardings were recycled; recycled crushed concrete shingle and sand were used.

Energy Simulation Input - Output Parameters

Input Parameters	Units	Proposed Design Values
General		
Building Area	m²	6170
Conditioned Area	m²	500
Electricity Rate	INR/kWh	
Building Occupancy Hours	-	Example: 7am - 6pm
Average Occupant Density	m² / person	0.4680
Internal Loads		
Interior Average Lighting Power Density	W/m²	2.5
Average Equipment Power Density	W/m²	6
Envelope		
Roof Assembly U value	W/m².K	0.25
Average Wall Assembly U value	W/m².K	0.35
Window to Wall Area Ratio (WWR)	%	30%
Windows U value	W/m².K	0.38
Windows SHGC		0.25
Infiltration Rate	ac/h	5
Describe Exterior Shading Devices		1m overhang with vertical louvres
HVAC System		
HVAC System Type and Description	-	Inverter Ducted HVAC System
Describe Mixed mode strategy in operation/controls of AC and windows	-	Windows open whenoutdoor temperature below 23C, AC switches off automatically.
Cooling Source	-	Multi cool HC32 Refrigerant
Cooling Capacity	kW	
Operation Hours		
Heating Set Point	°C	20
Cooling Set Point	°C	28
Relative Humidity Set point		50

Output Parameters	Units	Proposed Design Values
Proposed EUI (Total)	kWh/m²/ yr	33.6
EUI Breakdown by End Use		
Cooling	kWh/m²/ yr	14.5
Fans	kWh/m²/ yr	1
Lighting	kWh/m²/ yr	10
Equipment	kWh/m²/ yr	8.12
Total Envelope Heat Gain (Peak)	Btu/h	119604

Water Tables

		CONSUMPTION						WATER SOURCES			
Month	Days in month	Domestic Use (L)	Building maintenance	Irrigation seasonal factor %	Irrigation water demand (L)	water used for Irrigation (L)	Total Consumption (L)	Municipal Water (L)	Rainwater harvested (L)	Greywater (L)	Blackwater (L)
Jul	31	4,59,083	25,000	5%	71,300	3,565	4,87,648	42,200	388845	3,21,207	1,85,380
Aug	31	4,59,083	25,000	5%	71,300	3,565	4,87,648	42,200	397888	3,21,207	1,85,380
Sep	30	4,44,274	25,000	50%	69,000	34,500	5,03,774	42,200	551617	3,10,845	1,79,400
Oct	31	4,59,083	25,000	30%	71,300	21,390	5,05,473	42,200	428031	3,21,207	1,85,380
Nov	30	4,44,274	25,000	90%	69,000	62,100	5,31,374	42,200	250187	3,10,845	1,79,400
Dec	31	4,59,083	25,000	90%	71,300	64,170	5,48,253	42,200	54257	3,21,207	1,85,380
Jan	31	4,59,083	25,000	90%	71,300	64,170	5,48,253	42,200	0	3,21,207	1,85,380
Feb	28	4,18,358	25,000	90%	64,975	58,478	5,01,835	42,200	6029	2,92,712	1,68,935
Mar	31	4,59,083	0	90%	71,300	64,170	5,23,253	42,200	33157	3,21,207	1,85,380
Apr	30	4,44,274	0	90%	69,000	62,100	5,06,374	42,200	120572	3,10,845	1,79,400
May	31	4,59,083	0	90%	71,300	64,170	5,23,253	42,200	379802	3,21,207	1,85,380
Jun	30	4,44,274	25,000	90%	69,000	62,100	5,31,374	42,200	364730	3,10,845	1,79,400
Total					8,40,075	5,64,478	61,98,510	5,06,400	29,75,114	37,84,538	21,84,195

Water Consumption and Sources

Purpose	Per head usage per day	Occupants	Total consumption per day (without reducers)	Percentage use	Reduction by	Reduction percentage	Total consumption per day (after reducers)
Drinking	5	1150	5750	14%	NA	0	5750
Cooking	3	1150	103.5	3%	low flow fixtures	25%	77.625
Washing utensils	10	1150	2162	19%	Pressure regulator	25%	1621.5
Sinks and taps	8	1150	460	5%	Pressure regulator	25%	460
Flushing	25	1150	11500	40%	Dual flush systems	40%	6900
lavatory faucets	10	1150	1840	16%	low flow fixtures	25%	1840
others	4	1150	92	2%	NA	0%	92
			21907.5				14809.125

Comparison of water usage before and after the efficient strategies

Months	Rainfall (mm)	Effective rain (mm)	Harvested rainwater (l)
July	134	129	383827
August	137	132	392753
September	125	120	357048
October	147	142	422507
November	65	60	178524
December	23	18	53557
January	4	0	0
February	7	2	5951
March	16	11	32729
April	45	40	119016
May	131	126	374900
June	126	121	360023
Total			2680835

Harvested rainwater

TANK	CAPACITY	VOLUME
Rain water harvesting (OHT)	10000 L	10 Cubic m
Grey water storage (OHT)	10000 L	10 Cubic m
Underground water tank (UGT)	30000 L	30 Cubic m
Grey water tank (UGT)	30000 L	30 Cubic m

Tank sizes and volumes

Cooling Load Estimate

STANDARD COOLING LOAD ESTIMATE

COOLING LOAD ESTIMATE

TITLE	Standard design
LOCATION	BENGALURU
LATITUDE	12.58°N
SPACE	TOTAL
AREA (ft^2)	5382
HEIGHT (ft)	10.0

CONDITIONS	DB (°F)	WB (°F)	RH (%)	Humidity Ratio (g/lb)
Outside Air	94.5	70.1	31	85.0
Room	75	63.5	55	80.0
Difference	19.5	6.6		5.00
Outdoor design data from table 1.2				
Daily range for May: 24F. Refer table 1.3.				

SOLAR GAIN - GLASS

Item	Direction	Area (ft^2)	ΔT (°F)	Correction fator	Glass Factor	BTU / Hour
Glass	N	27	20	1.3	1	676
Glass	NE		20	1.3	1	0
Glass	E	260	20	1.3	1	6510
Glass	SE		20	1.3	1	0
Glass	S	145	20	1.3	1	3631
Glass	SW		20	1.3	1	0
Glass	W	260	20	1.3	1	6510
Glass	NW		20	1.3	1	0
Skylight			20	1.3	1	0

REMARKS: For Solar Gain refer Table -1.10. Sun gain considered for May 21, 4pm. Correction factors applied: 1.17 for steel sash and 1.07 for dew point correction.

SOLAR & TRANSMISSION GAIN - WALL & ROOF

Item	Direction	Area (ft^2)	ΔT (°F)	Correction fator	U-value (BTU/h.ft^2)	BTU / Hour
Wall	N	1938	20	3	2.60	115892
Wall	NE		20	3	2.60	0
Wall	E	2162	20	3	2.60	129288
Wall	SE		20	3	2.60	0
Wall	S	1938	20	3	2.60	115892
Wall	SW		20	3	2.60	0
Wall	W	2162	20	3	2.60	129288
Wall	NW		20	3	2.60	0
Roof		5382	20	3	1.75	216626

REMARKS:
For Temp difference(wall) refer Table -1.21. Wall weight considered as 100 lb/sq.ft.
For Temp difference(roof) refer Table -1.22. Wall weight considered as 80 lb/sq.ft.
For correction factors
For U-value refer

TRANSMISSION GAIN EXCEPT WALLS & ROOF

Item		Area (ft^2)	ΔT (°F)		U-value (BTU/h.ft^2)	BTU / Hour
All Glass		665	19.5		0.25	3242
Door		21	19.5		1.13	463
Partition			14.5			0
Ceiling			14.5			0
Floor			14.5			0

REMARKS:
For U-value refer Table - 1.9
For U-value refer Table - 1.9

INTERNAL SENSIBLE HEAT

	Quantity	Unit rates		Conversion fator	Diversity factor	BTU / Hour
People	275	215		1		59125
Equip (W)	2100			3.41	1	7161
Lights (W)	7481			3.41	1	25510
Supply fan gain	5%					40991

REMARKS: For heat gain from people refer table-1.24

INTERNAL LATENT HEAT

	Quantity	Unit rates				BTU / Hour
People	275	235				64625

REMARKS: For heat gain from people refer table-1.24

OUT SIDE AIR HEAT

	Flow rate (CFM)	ΔT(°F) & Δg/lb	Convesion factor			BTU / Hour
Sensible	215	19.5	1.08			4528
Latent	235	19.5	0.68			3116

REMARKS: For outside air quantity refer NBC 2016

Total Room Sensible heat	865331
Total Room Latent heat	67741
Grand total heat, BTU/hr	933072
AIR CONDITIONING TONNAGE	77.76

PROPOSED COOLING LOAD ESTIMATE

COOLING LOAD ESTIMATE

TITLE	Standard design
LOCATION	BENGALURU
LATITUDE	12.58°N
SPACE	total
AREA - Sq.ft	5382
HEIGHT - ft	10.0

CONDITIONS	DB	WB	%RH	g/lb
Outside Air	94.5	70.1	31	85.0
Room	75	63.5	55	80.0
Difference	19.5	6.6		5.00
Outdoor design data from table 1.2				
Daily range for May: 24F. Refer table 1.3.				

SOLAR GAIN - GLASS

Item	Direction	Area (ft^2)	ΔT (°F)	Correction fator	SHGC	BTU / Hour
Glass	N	290	20	1.3	0.25	1770
Glass	NE		20	1.3	0.25	0
Glass	E	260	20	1.3	0.25	1587
Glass	SE		20	1.3	0.25	0
Glass	S	145	20	1.3	0.25	885
Glass	SW		20	1.3	0.25	0
Glass	W	260	20	1.3	0.25	1587
Glass	NW		20	1.3	0.25	0
Skylight			20	1.3	0.25	0

REMARKS: For Sun Gain refer Table -1.10. Sun gain considered for May 21, 4pm. Correction factors applied; 1.17 for steel sash and 1.07 for dew point correction.

SOLAR & TRANSMISSION GAIN - WALL & ROOF

Item	Direction	Area (ft^2)	ΔT (°F)	Correction fator	U-value	BTU / Hour
Wall	N	1938	20	3	0.38	16570
Wall	NE		20	3	0.38	0
Wall	E	2162	20	3	0.38	18485
Wall	SE		20	3	0.38	0
Wall	S	1938	20	3	0.38	16570
Wall	SW		20	3	0.38	0
Wall	W	2162	20	3	0.38	18485
Wall	NW		20	3	0.38	0
Roof		5382	20	3	0.33	39961

REMARKS:
For Temp difference(wall) refer Table -1.21. Wall weight considered as 100 lb/sq.ft.
For Temp difference(roof) refer Table -1.22. Wall weight considered as 80 lb/sq.ft.
For correction factors refer table 1.23
For U- Factors refer CARBSE tool

TRANSMISSION GAIN EXCEPT WALLS & ROOF

Item		Area (ft^2)	ΔT (°F)		U-value	BTU / Hour
All Glass		665	19.5		0.25	3242
Door		21	19.5		1.13	463
Partition			14.5			0
Ceiling			14.5			0
Floor			14.5			0

REMARKS:
For Factor refer Table - 1.9
For Factor refer Table - 1.9

INTERNAL SENSIBLE HEAT

	Quantity	Unit rates				BTU / Hour
People	275	215				59125
Equip (W)	1280	3.41			1	4365
Lights (W)	2960	3.41			1	10094
Supply air fan gain	5%					9659

REMARKS: For heat gain from people refer table-1.24

INTERNAL LATENT HEAT

	Quantity	Unit rates				BTU / Hour
People	275	235				64625

REMARKS: For heat gain from people refer table-1.24

OUT SIDE AIR HEAT

	Flow rate (CFM)	ΔT(°F) & Δg/lb	Convesion factor			BTU / Hour
Sensible	215	19.5	1.08			4528
Latent	235	19.5	0.68			3116

REMARKS: For outside air quantity refer NBC 2016

Total Room Sensible heat	207375
Total Room Latent heat	67741
Grand total heat, BTU/hr	275116
AIR CONDITIONING TONNAGE	22.93

Embodied Carbon Content

BASE CASE

1. ROOF

Standard Rcc Slab

Material	Unit	Material manufacturing emissions		
		Quantity	Emissions Factor	Material Emissions (kg $-CO_2$ e)
Cement (ordinary Portlar	kg	66528	0.91	60540
M-sand	kg	100485	0.009	904
Aggregate (mixed grave	cu. m	138.6	0.009	1
Steel reinforcement (ste	kg	13200	2.6	34320
Cement floor screed (co	kg	99000	0.18	17820
<select material>		0	0	0
<select material>		0	0	0
<select material>		0	0	0
<select material>		0	0	0
<select material>		0	0	0
<select material>		0	0	0
<select material>		0	0	0
<select material>		0	0	0
<select material>		0	0	0
<select material>		0	0	0
			Total material emissions per functional unit (kg $-CO_2$ e)	103

PROPOSED CASE

Filler Slab with coconut shells

Material	Unit	Material manufacturing emissions		
		Quantity	Emissions Factor	Material Emissions (kg $-CO_2$ e)
Cement (ordinary Portlan	kg	48240	0.91	43898
M-sand	kg	97150	0.009	874
Aggregate (mixed gravel/	cu. m	134	0.009	1
Steel reinforcement (stee	kg	12320	2.6	32032
Cement floor screed (con	kg	99000	0.18	17820
<select material>		0	0	0
<select material>		0	0	0
<select material>		0	0	0
<select material>		0	0	0
<select material>		0	0	0
<select material>		0	0	0
<select material>		0	0	0
<select material>		0	0	0
<select material>		0	0	0
<select material>		0	0	0
			Total material emissions per functional unit (kg $-CO_2$ e)	86

Note : The roof type assessed here was filler slab, since the coconut shells reduce the amount of concrete used. Emission factor of coconut shell was considered zero.

2. WALL

Standard Brick wall

Material	Unit	Material manufacturing emissions		
		Quantity	Emissions Factor	Material Emissions (kg $-CO_2$ e)
Lightweight concrete bloc	kg	635400	0.37	235098
Cement (ordinary Portlan	kg	35438.5	0.91	32249
M-sand	kg	214136	0.009	1927
Paint	l	718	0.659	473
Water	l	154370	0	0
<select material>		0	0	0
<select material>		0	0	0
<select material>		0	0	0
<select material>		0	0	0
<select material>		0	0	0
<select material>		0	0	0
<select material>		0	0	0
<select material>		0	0	0
<select material>		0	0	0
<select material>		0	0	0
			Total material emissions per functional unit (kg $-CO_2$ e)	75

CLC Block Wall

Material	Unit	Material manufacturing emissions		
		Quantity	Emissions Factor	Material Emissions (kg $-CO_2$ e)
Lightweight concrete blo	kg	635400	0.37	235098
Cement (ordinary Portla	kg	35438.5	0.91	32249
M-sand	kg	214136	0.009	1927
Paint	l	718	0.659	473
Water	l	154370	0	0
<select material>		0	0	0
<select material>		0	0	0
<select material>		0	0	0
<select material>		0	0	0
<select material>		0	0	0
<select material>		0	0	0
<select material>		0	0	0
<select material>		0	0	0
<select material>		0	0	0
<select material>		0	0	0
			Total material emissions per functional unit (kg $-CO_2$ e)	75

3. FLOOR

RC floor with XPS insulation

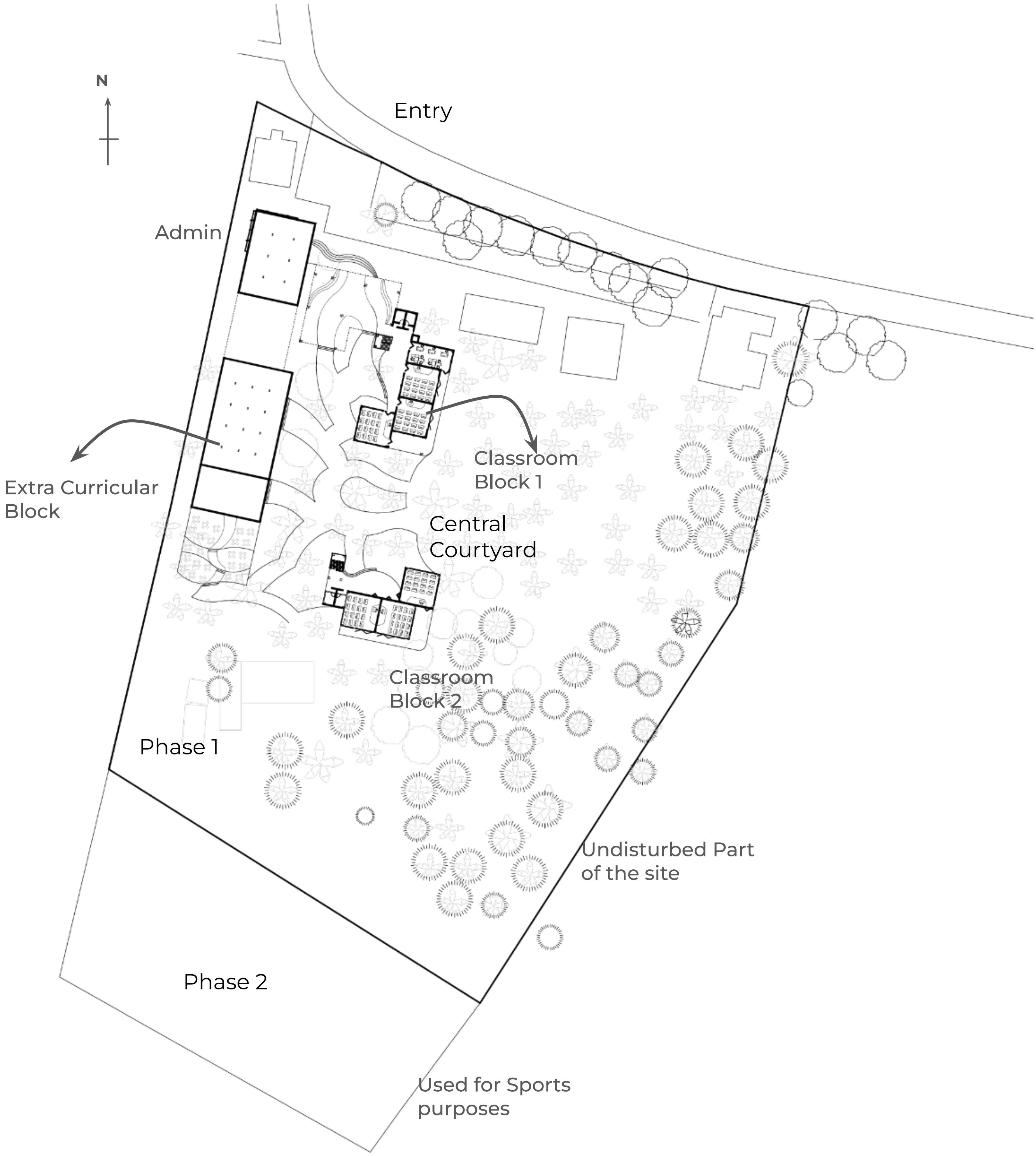
Material	Unit	Material manufacturing emissions		
		Quantity	Emissions Factor	Material Emissions (kg $-CO_2$ e)
Cement (ordinary Portlar	kg	66528	0.91	60540
M-sand	kg	100485	0.009	904
Aggregate (mixed grave	cu. m	138.6	0.009	1
Steel reinforcement (ste	kg	13200	2.6	34320
Cement floor screed (co	kg	99000	0.18	17820
XPS	kg	1100	2.9	3190
Vitrified ceramic floor til	kg	21389	0.68	14545
<select material>		0	0	0
<select material>		0	0	0
<select material>		0	0	0
<select material>		0	0	0
<select material>		0	0	0
<select material>		0	0	0
<select material>		0	0	0
<select material>		0	0	0
			Total material emissions per functional unit (kg $-CO_2$ e)	119

RC Floor

Material	Unit	Material manufacturing emissions		
		Quantity	Emissions Factor	Material Emissions (kg $-CO_2$ e)
Cement (ordinary Portla	kg	66528	0.91	60540
M-sand	kg	100485	0.009	904
Aggregate (mixed gravel	cu. m	138.6	0.009	1
			0	0
Cement floor screed (co	kg	99000	0.18	17820
Stone floor tile	kg	768	0.056	43
Vitrified ceramic floor til	kg	332	0.68	226
<select material>		0	0	0
<select material>		0	0	0
<select material>		0	0	0
<select material>		0	0	0
<select material>		0	0	0
<select material>		0	0	0
<select material>		0	0	0
<select material>		0	0	0
			Total material emissions per functional unit (kg $-CO_2$ e)	72

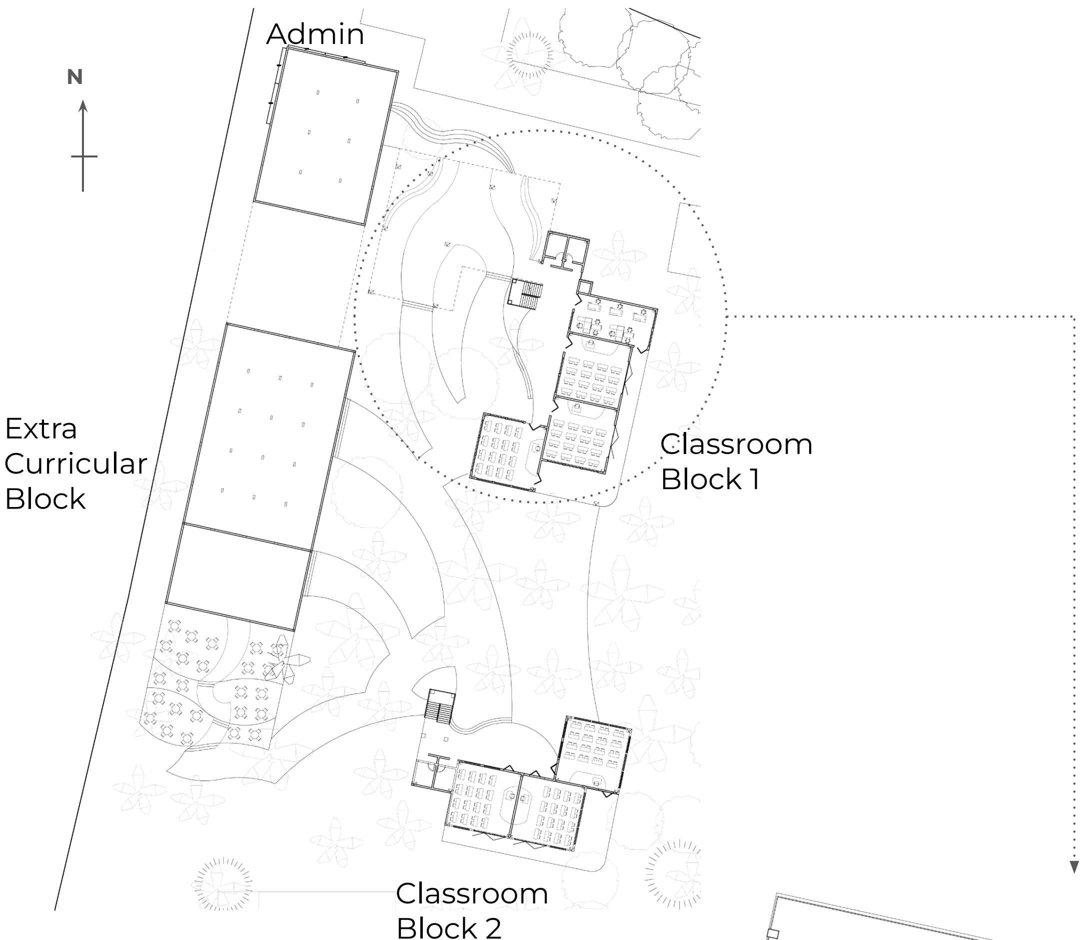
Architectural Drawings

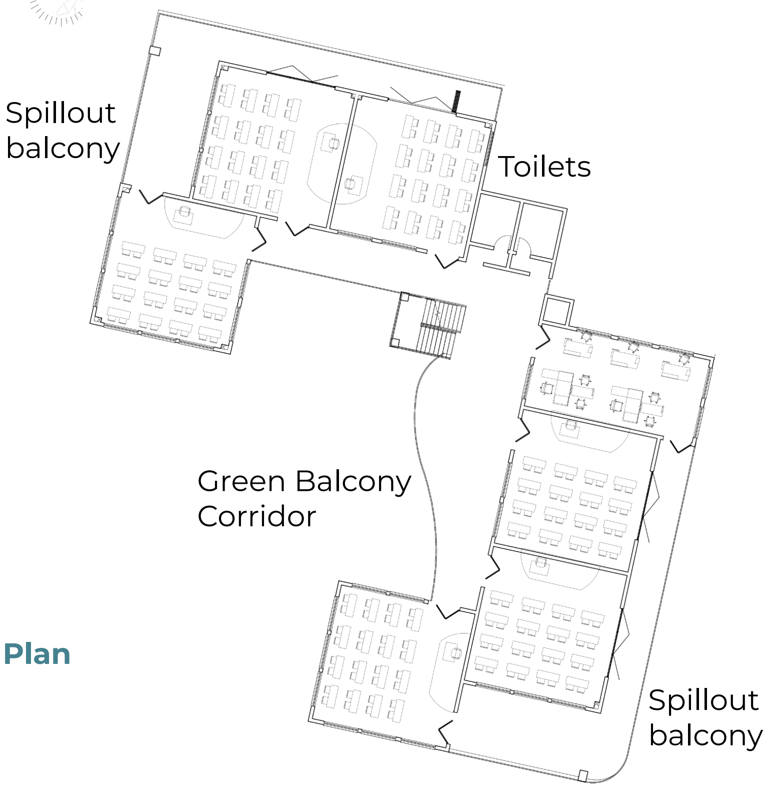
Site Master Plan



Architectural Drawings

Master Plan





Classroom Block1 Plan

Building Operation Narrative

Thermal Comfort and Ventilation Systems

1. Building system installed
The building's heating, cooling and ventilation (HVAC) system consists of a combination of mechanical and natural ventilation. The classroom and extracurricular spaces are provided with openable windows and ceiling fans. Natural ventilation is achieved with windows and spill out balconies that draw in fresh air. Mechanical ventilation is provided only in offices, computer lab and auditorium by an inverter ducted HVAC system, which includes air handling unit kit, heat sink unit, and ductwork.
Indoor air quality (Vocs and Co2 levels) and ventilation needs are monitored by an IAQ monitor installed in the learning spaces and labs.

2. Automated operations
The Inverted ducted HVAC system is automated and controlled by the BMS x AI system. This system controls of temperature and humidity levels in office spaces, computer lab and auditorium (as requested by client), to ensure a comfortable environment for occupants. This AC system comes with a touch screen controller which also allows the occupants to manually set timers, room temperature display and error indication, and further tune the temperature by 2 -4 °C beyond the BMS setting if needed. The overall control and monitoring of the BMS system is taken care of by integrated AI system.

3. Instructions for operating the building system
To operate the HVAC system effectively:
● Setup the BMS to control temperatures for air-conditioning (according to chosen thermal comfort standard of ASHRAE) at minimum setpoint of 23°C and maximum setpoint at 25°C during summers, and minimum setpoint of 20°C and maximum setpoint of 23°C during winters. Limit the indoor relative humidity to a maximum of 65%.
● In the cooling season, when the outdoor temperatures are lower than the indoor setpoint, notify the occupants to open the windows and vents for natural ventilation.
● If indoor CO_2 levels are above 1000 ppm, notify the occupants to open the windows and vents for natural ventilation.

4. Instructions for occupant interaction with the building system
Occupants should interact with the HVAC system as follows:
● Building users and occupants can operate the windows, ceiling fans and adjust the thermostats if needed to maintain comfort, health, and help reduce the environmental impact of the building.
● Occupants may open the windows when the IAQ monitors notifies them that CO_2 levels are 1000 ppm.

5. Instructions for regular inspection and maintenance
Inspect air-filters every 3 months. Check the refrigerant coils for leaks every year. Inspect and maintain ductwork and drainage lines. Check the windows for smooth operation and leaks before and after the monsoon season every year.

6. Operation of the system in critical mode
During extreme events when grid power availability is restricted, the HVAC systems will function as long as grid power is available. However, cooling will be available only to the office spaces, and the BMS system will change the cooling setpoint to 29°C. If grid power is not available, the HVAC system will be shut off, and the occupants will rely on natural ventilation for cooling. All ceiling fans will run on the on-site solar power generation. During summer months, the On-grid solar system generates more power than the building consumes, hence returning back excess power to the grid. During monsoon and winter months when the sun is not as strong in the sky, the building will get the required excess energy back from the grid. Incase of power outage, 2 nos 4000 kVA Diesel Generators present on site will sustain the building for upto 1 day

Building Operation Narrative

Renewable Energy and On-site Storage Systems

1. Renewable Energy Systems installed

Solar Energy

Solar PV panels have been installed on the terraces of the educational building to capitalize on the strong solar radiation received on site. There are 260 panels distributed across the terraces of the buildings. The system type is an On-grid solar system where in the energy gets sent to the grid from which the school makes use of it.

Piezoelectric Tiles - Pavegen Tiles

Pavegen is a device that converts kinetic energy into electrical energy. The device generates energy as people step on the tiles. The tiles have been placed at the entrance as this is where most number of people will walk through, multiple times in the day.

2. Instructions for use of Pavegen Tiles

Occupants should interact with the system as follows:

- The tiles are designed to carry 9 kN or 917 kgs of load over it, making it durable for children and adults to walk, jump and run over it.
- The tiles are placed in the entrance as this is where most number of people will walk through, multiple times in the day.
- Occupants just have to make sure to walk over these tiles at least twice a day while entering and leaving the school, and at any other time to generate more energy. All they have to do is walk as they would normally, no extra effort!

3. Instructions for regular inspection and maintenance

Solar PV Panels -

- Keep the surface of the panels (glass) free from dust.
- Occasional inspection (2-4 times a year) and checks of the solar module to ensure the performance efficiency

Pavegen Tiles -

- The tiles are waterproof and can be mopped during regular daily floor maintenance procedures
- The tiles should be cleaned regularly and electricity lines to the power management plant should be checked once or twice a year.

4. Operation of the system in critical mode

Solar Energy

During summer months, the On-grid solar system generates more power than the building consumes, hence returning back excess power to the grid. During monsoon and winter months when the sun is not as strong in the sky, the building will get the required excess energy back from the grid.

Incase of power outage, 2 nos 4000 kVA Diesel Generators present on site will sustain the building for upto 1 day

https://4baltic.lv/docs/pavegen.pdf

Building Operation Narrative

Water Supply and Wastewater Systems

1. Water Supply System

The building's water supply is catered to by rainwater harvesting and treated grey water which eliminates the need to depend on municipal water supply. Use of recycled greywater in the flush systems and irrigation reduces potable water use. Rainwater runoff is collected from various surfaces, treated and reused in landscaping as well as flushing purposes. The building is water self sufficient. Coconut husk is being used as a filter to treat the greywater. Gravity toilets that use less water are being used.

2. Instructions for water conservation and reuse on site

- The treated greywater is to be used to irrigate the landscape on site.
- Taps in washrooms must be closed after use.
- Dispose tissues and sanitary napkins in the dustbins and do not flush them down the toilet as this will cause a clog.

3. Instructions for regular inspection and maintenance

- All washrooms must be checked regularly for leaks
- Regular maintenance and cleaning of tanks, filters etc in the rainwater harvesting system
- Ensuring collected water gets treated and reused efficiently.
- Coconut husk filter layer to be replaced every 6 months

4. Operation of the system in critical mode

- Our building is water self sufficient. Even during water cuts at the main municipal source, our building will be able to function for upto 3 days given our storage capacity and reuse systems.