FINAL DESIGN REPORT

April 2023

Competition division: Office building

Team: Titans

Executive summary Team Introduction Project Background Goals Design documentation

National Institute of Technology,
Tiruchirappalli

Solar Decathlon India

Contents

List of Tables

List of Figures

Executive Summary

Titans is a multidisciplinary group of 12 students from various backgrounds in architecture, civil and energy engineering. The project was to design a Net Zero office building for Agrocorp with the project location as Bangalore. The design process was created using a data-driven, integrated design approach. The project is a Basement+4 story build-own-operate project. The aim of the design was to design a net zero building with various contests into considerations not limiting to energy, water, resilience, health and wellbeing, embodied carbon, engineering systems and affordability by involving various aspects of design, production and execution.

Considering all the building science principles, a pre design study was conducted on comfort, site studies and RE potential. An optimised building mass has been achieved in terms of the pre design analysis to achieve maximum thermal comfort, daylighting, operating the building in a mixed mode ventilation and by reducing the cost.

The built up area of the project is 4615 Sq.m. In terms of energy the achieved EPI is 43.69 kWh/ Sq.m, reaching the NetZero status by installing a renewable system of 145kWp panels producing 2,17,500 kWh/annum. The building also reached its net zero water by reducing its LPD usage to 15.3lpd. Water consumption has been reduced by 70% through fixtures. To further enhance the value of the project a water positive system has been designed by combining efficient rain water harvesting, Vortex DEWATS system.

The façade of the building is designed based on their cardinal axis as every side will have different requirements. The indoor comfort, embodied carbon, heat transfer and cost is being considered for an efficient design. Embodied carbon and Engineering and operations worked on reduction of embodied energy and quantity of materials resulting in a 2337.4 metric tonne of KgCO2-e emission, which is 40.2% reduction in carbon emission from the basecase.

The occupancy hour's drive energy and water use in office buildings, resulting in high effluent generation. Multiple sources were used to collect data for the offices from case studies about prospective building occupants for this project (e.g., Google search volume trends, publicly available demographic data and a bespoke survey especially designed for this project). The data provided us with insights into potential expectations from the personal comfort environment, facility usage, and guided the project's goals. For example, in our design proposal, we place a high value on the system installed, as well as the installation of a solar PV canopy array. This resulted in the creation of a highly efficient design in which the needs and comfort of the occupants are prioritized in relation to the Client.

Providing Aeroponics tower garden system in the rooftop increases the monthly profit for the client as the yield of an aeroponics system is three times that of a hydroponic system. Algae Bio-reactor panels have been used to increase the energy production while cleaning the air of pollution at the same time. To and fro discussions among the 10 contests converged into an effective design proposal which has followed the path set out by the initially proposed goals. The estimate of the project increased by 12%, but the payback period for the client is reduced to 3 to 5 years. In which the client will be able to get back his investment.

Response to Reviewer Comments

Section	Reviewer's Comment	Our Response
Reviewer 1		
Energy Performance	Your team demonstrated well about your strategies of energy conservation however simulation result header have no result. Also 84% reduction is unrealistic so check that.	Initially we took values from ASHRAE for baseline simulation. We have reiterated it with material specification from ECBC. The calculation has been updated in energy performance Energy Performance.
Water Performance	Impressive you are on the right track but rainwater harvesting capabilities from the mentioned catchment area needs reconsideration. As your team incorporates the DEWAT system area requirement, initial and maintenance cost needs to be added.	The catchment area for rain water harvesting has been updated as there has been a bit of change in the site plan. The cost of the system has been added in affordability contest while the area is mentioned in the site plan.
Embodied Carbon	Great work in reducing carbon footprint for wall material; do the same for overall project. The percentage will be changed and then you can claim overall reduction of your project. Transportation emission reduction needs justification.	Overall reduction of carbon footprint has been updated in Embodied Carbon. Transportation distance has been updated in the sheet provided in the appendix.
Resilient Design	Your team's findings in threats for the location is good. Fire exit plan is impressive. Your team missed a major threat that is power cut; explore how you will be handling electrical failure. For structural strength you can add some pictures of your interventions to improve physical strength.	Regarding structural interventions it is mentioned in Engineering and operations. We considered our battery backup for our days of autonomy. This helped us in avoiding the requirement of a generator.
Engineering and Operations	Good effort. You are using PTFE sheets which are having high embodied carbon value any particular reason behind using it in the east. West façade windows are mutually shaded by the adjacent buildings you mentioned so mention the distance between those two buildings. Did you check the cooling demand of your project? Without knowing the requirement how you are understanding	The distance between the two buildings in the west orientation is 7M. The cooling demand for the project is added in the appendix. For the East façade we have considered algae bioreactor panel as this will improve our design in terms of both energy production and converting CO2 into O2. Details regarding the HVAC system has been mentioned in Energy and engineering operations and all the calculation tables has been added in Appendix.

	VRF will a perfect fit or not and what will be the capacity and number?	
Architectural Design	Design is great; work on interior aesthetics and user experience.	It has been updated in Architectural Design contest
Affordability	Your cost estimation needs rectification. All your interventions need to be considered in cost estimation and also check ROI for the same.	We have updated the data in AFFORDABILITY.
Innovation	Kinetic façade is an interesting idea. Did you check the feasibility and cost effectiveness of it? How will you automate it? Are you working on the M&V application if yes then explain it elaborately with a demo.	The innovation part has been updated from the last submission Innovation.
Health and wellbeing	Excellent work	No comments
Reviewer 2		
Energy Performance	Please check RE generation potential. please clearly identify the envelope EE measures for the final proposed case. please check EPI again.	RE generation potential has been verified.
Water Performance	Please explain how is the surplus being returned to a public source. it is also not clear if the waste water from kitchen/ sink is being recycled or not (as per the water diagram).	Every outlet water from the building is getting treated in our proposed vortex DEWATS system with an addition of disinfection tank it converts the water potable which we use for landscaping and flushing.
Embodied Carbon	Please consider measures for roof, interior finishes and fenestration.	We have updated our work Embodied Carbon.
Resilient Design	The resilience measures are still very nascent. Please develop them further. eg: please specify how will the bioswale	The queries raised has been answered in the design documentation stage Resilience.

	be designed for storm water management? please share more data about the risks; historical patterns or data to support your assertion that these are critical risks.	
Engineering and Operations	Please add information about building systems such as the envelope, HVAC, water management etc.	The data has been added in Engineering and operations.
Architectural Design	The built form and facade treatment looks promising but needs further development. Please check the size of the vertical fins on the facade. if these are to be shading devices, the size may be inadequate.	For the East façade we have considered algae bioreactor panel as this will improve our design in terms of both energy production and converting CO2 into O2. Details regarding the HVAC system has been mentioned in Energy and engineering operations and all the calculation tables has been added in Appendix.
Affordability	Please revisit the costs. Consider operational costs also.	Affordability data has been updated in the design documentation. Also the calculation data has been updated in the excel file.
Innovation	Please describe in detail the kinetic facade. And it is not clear how this will be integrated in the building. Other solutions listed in this section are common in sustainable buildings.	Innovation design for this project has been reworked on by including some new parameters. Innovation.
Health and wellbeing	Thermal comfort and indoor air quality standards are not mentioned. Neither are the strategies for both described. it is also not clear if the indoor air quality and thermal comfort is sufficient.	The data has been updated in the design documentation stage.
Value Proposition	Measures for net zero water and energy are logical. The report has clarity and the information presented is easy to understand. Please highlight the economic returns over the lifetime, and physiological benefits to users.	It has been updated in the design documentation stage. Value Proposition.

Table 1: Response to Reviewers Comments

Team Summary

Team Name : Titans

Institution Name : National Institute of Technology, Tiruchirappalli

Division : Office building

Team Members

Figure 1: Team Members

Approach

Titans is a multidisciplinary team from the Departments of architecture, civil and energy engineering background. The team members were chosen after careful consideration and introspection of their strengths. The team consists of ten students pursuing a Master of Architecture specializing in Energy Efficient and Sustainable Architecture, one student pursuing a Master of Technology in Civil Engineering and one student pursuing a Master of Technology in Energy Engineering. Roles and responsibilities were divided based on each individual's strengths and areas of interest. Regular discussions with all the members of the team were held regularly to arrive at a design that is context-based, that goes along with the climatic parameters to arrive at design goals concluding in a better design and a high-performing building.

Background on Lead Institute

National Institute of Technology, Tiruchirappalli, comes under the Ministry of Human Resources Department (MHRD). It is a deemed university, having been declared an institution of national importance by the government of India in 2007. It offers ten undergraduate programs, 28 graduate programs and doctorate programs in Engineering, Architecture and Management.

Figure 2: NIT Trichy

Faculty Lead

Prof. Amalan Sigmund Kaushik S is an Assistant Professor at the Department of Architecture, NIT Trichy. He worked as a landscape architect in Dar Al-Handasah, Pune for three years after completing his master's in landscape architecture from School of Planning and Architecture, New Delhi and his bachelor's degree from School of Architecture and Planning, Anna University, Chennai. He is also a LEED AP specializing in Building Design and Construction.

Industry Partner

Ecofirst Services limited, a 100% subsidiary of Tata Consulting Engineers Limited is a leading multi-disciplinary Integrated Sustainable Design Consulting firm for the built environment with its headquarters located in Mumbai. They have a large portfolio of 350+ projects completed till date. The team works with Mr. Rakesh Bhatia a Senior Vice President in the firm to guide us to develop and discuss on the functionality of the proposed design, expert advice on project design and planning, Assistance with creating the Design Documents, Performance reports for competitions and building Certification Processes.

Design Process

Titans adopted a collaborative design strategy which helped the team to articulate the objectives and their correlations. The design process comprises nine stages, from the project introduction to the achievement of net zero targets. The constant meetings and design discussions enabled us to accomplish the project's goals. The design concept focuses more on bringing additional diversity when compared to monotonous office buildings.

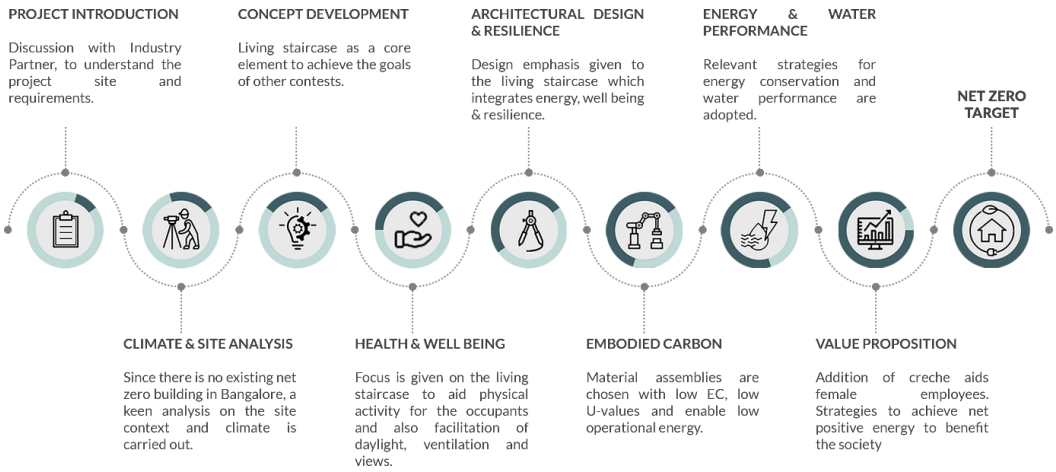


Figure 3: Design Process

Figure 4: Software's used

Project Summary

Project name: Agrocorp HQ Corporate office

Project partner

Agrocorp Land base (P) Limited is a premiere realty company headquartered in Bengaluru, the technology capital of India. Its focus has been to create a mark in the land investment and premium second homes segment. Paving the way for hassle free, effortless, and transparent land investments that will enable millions to transact with trust while they grow their dream homes and wealth.

Project description

The intent of the project is to construct a build-own-operate project by the project partner Agrocorp. The site in located in the Hebbal Region of Bengaluru, the site area is 4097 sqm.

Area statement

- Location : Hebbal, Bengaluru
- Site Area : 4097.67 m^2
- Permissible FAR (including premium FAR) : 3.2
- Permissible built-up area : 13112.544 m^2
- Permissible ground coverage : 1475.16 m^2
- Proposed ground coverage : 1334 m^2
- Proposed built-up area : 4615 m^2
- Proposed Height : 15 m (G+3)
- Mandatory Setback (as per height) : 4m

The maximum FAR has not been achieved due to the bye-laws and site restriction. The setback for a 15m high building is 4.5m and when the height increases, the setback increases to 9m.

Target EPI

With a built-up area of 4615 m^2, our building has been designed to achieve an EPI of 43.69 kWh/sqm-year, under mixed mode typology for best-in-class design, achieving its net-zero target through solar PV. ((Reshma Singh, 2018)

On – site renewable energy potential

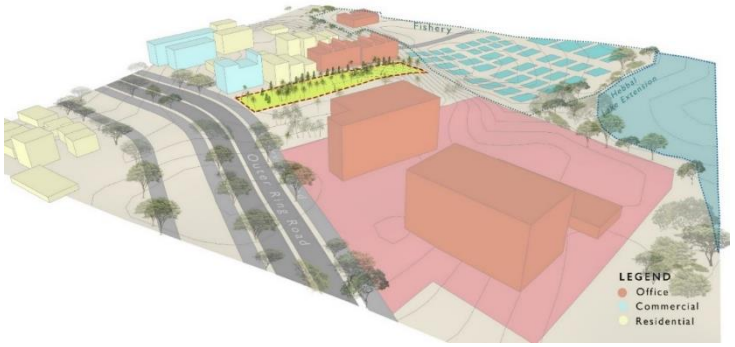
By maximising the roof area through an extended canopy to accommodate an expansive solar PV system we can achieve **2,17,500 kWh/year (145 kWp system).** The generated power can cater to the annual energy requirement of the building and its occupants and make it Net Zero via a net metered connection.

ON-SITE RENEWABLE ENERGY POTENTIAL	
Total Roof Area (With Solar Canopy)	1100 sqm
Roof Area excluding Services (20%)	926.2 sqm
PV system potential per hour	145 kW
Sun Hours in a day	9
Number of Sunny Days	251
Total Potential kWh/ annum (Potential*Hours*Days)	2,17,500

Table 2: On-Site renewable Energy potential

Site and Context

The site is in the Northern part of Bengaluru, near Hebbal Lake. It is in Residential Zone and is surrounded by Commercial and office spaces. One of the prominent residential markets of the city, Hebbal has gained prominence due to its advantage as a premium commercial centre hosting many MNCs & Information Technology firms, making the location attractive for potential clients. Daily use of the office space will happen majorly by the office staff, potential Ago-land buyers are the expected clients, which is expected to be around 30% of staff occupancy.



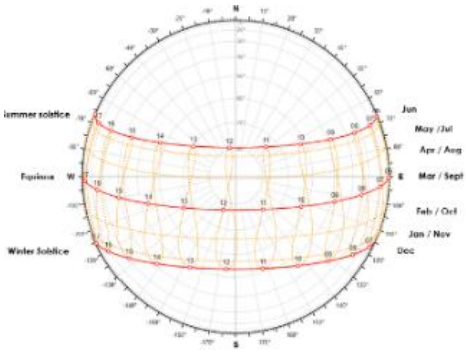


Figure 5: Sunpath

The site orients to northeast- southwest. The site abuts **a 30m** wide road which is the primary noise source to the site. Apart from it there is a **railway track** in the close vicinity (**65 m)** which also contributes to noise **pollution**. The natural pool existing on site would be used in water shed management. Vegetation – Site is **coconut grove**, along with **Ashoka Trees** lines on the west and South.

Terrain - The site slopes towards NE. A water catchment of 110 sq. m area is situated on the Northern end of the site. Surrounding massing – On the west, the Site is flanked **by 3-5 storeyed buildings**, offering shade in the evenings. The Eastern And Northern part of the Site overlooks the Hebbal lake

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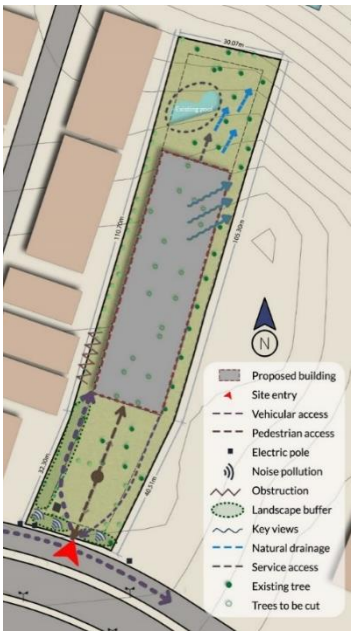


STRENGTH: Well-connected location with all major amenities in the

OPPORTUNITY: To develop an agro based office well coherent with the site context.

WEAKNESS: Site orientation is not in favor of flexible spatial planning.

THREAT: Flooding may occur as the site slope naturally flows towards lake.

Figure 6: Site Context Analysis

Goals

Energy Performance

To achieve an EPI for best-in-class design (below 50 kWh/Sq. M) under mixed mode typology	Through various passive strategies, active strategies to reduce the energy consumption in the building. Designing a Renewable energy of 145kWp to reach net zero status. An optimized EPI of 43.69kWh/ Sq.m is achieved.

Water Performance

To achieve a Net- Zero water cycle and reduce freshwater demand	A water performance ratio of 1.72 was achieved indicating Water Positive system by recycling up to 90% of on-site waste water and efficient rain water harvesting systems. The water demand was reduced from 45lpd to 15.3lpd.

Embodied Carbon

To reduce the embodied energy of structural and non-structural systems to achieve GRIHA standards	A 56.8% reduction in carbon emission is observed in non-structural components (Wall and fenestration). A 4.9% reduction in carbon emission is observed in non-structural components (columns, beams, foundation, floor and roof slabs). An overall Embodied carbon reduction of 40.23% is observed.

Resilience

To make the building functioning itself for a period of 5 days of autonomy.	This is achieved by Reli standard for resilient design + construction and NBC. Site planning and building design is based on foreseen threats.

Engineering and Operations

Minimize material waste, energy consumption during construction & operation.	Usage of 20% recycled aggregate concrete in order to use salvage materials. Usage of flat filler slabs to increase the efficiency and reduce the self-load of slab. Usage of Air based cooling system with airside economizer and energy recovery ventilation achieving an epi of 32 kWh/Sq.m cooling load.

Architectural Design

To design a net zero office building with effective space and functional needs.	An optimized design is achieved by taking into account the climate, context, occupancy, and user specific functions.

Affordability

To reduce unnecessary and operating costs, ensure value for materials,	The capital expense increased by 12% as the installation of algae panels, PV panels, aeroponics system, water saving fixtures and energy efficient equipment's are higher.

Innovation

Creating robust systems to increase the efficiency as well as income generating opportunity which increases to ROI	Using Algae Façade system for energy, Vortex DEWATS system for water and Aeroponic Tower garden for rooftop gardening to achieve Net Zero to Net Positive Generation in energy and high payback for affordability.

Health and Wellbeing

To provide better indoor environmental quality that benefits health and wellbeing of the occupants to meet WELL v2 guidelines.	Air quality, water quality and comfort have been achieved in accordance with WELL guidelines

Value Proposition

To communicate energy efficient and sustainable solutions for the benefits of project partner, stake holder, employees.	Social, financial and environmental benefits. Including market potentials are met through various strategies and technologies

Design documentation

Energy Performance

To achieve an **EPI for best-in-class design (below 50 kWh/Sq. M)** under mixed mode typology to achieve its net-zero target through solar PV Canopy of 145Kwp.

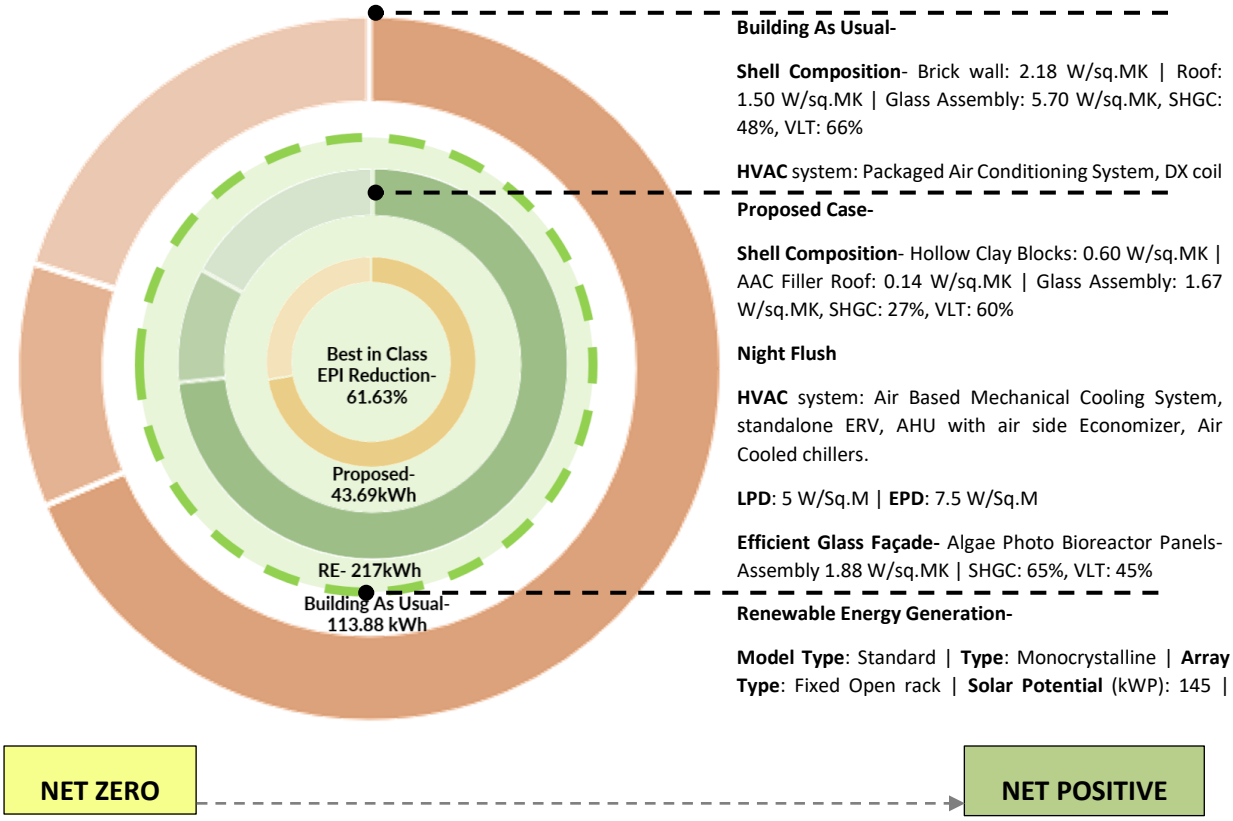


Figure 7: Energy Performance

As per the **Building as Usual Case** energy consumption of the particular office building is mostly due to cooling followed by equipment and lighting. To reduce the business-as-usual EPI with targeted EPI a certain set of Energy Conservation Measures were employed.

Passive Strategies:

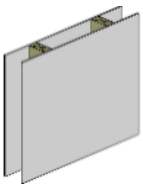
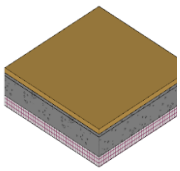
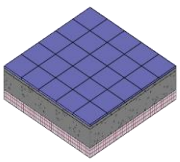
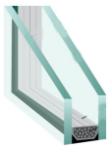
Optimizing building Envelope	Opaque Assembly				Glazed Assembly-(2)
Wall and roof selection to shield the building from external heat gains. Glazing to minimize solar heat gain and maximize visible transmission level.	Hollow Clay Blocks	Agri Bio panel assembly	AAC filler slab assembly	AAC filler roof + cool roof tiles	Double Glazed Unit
					

Table 3: Optimized building materials

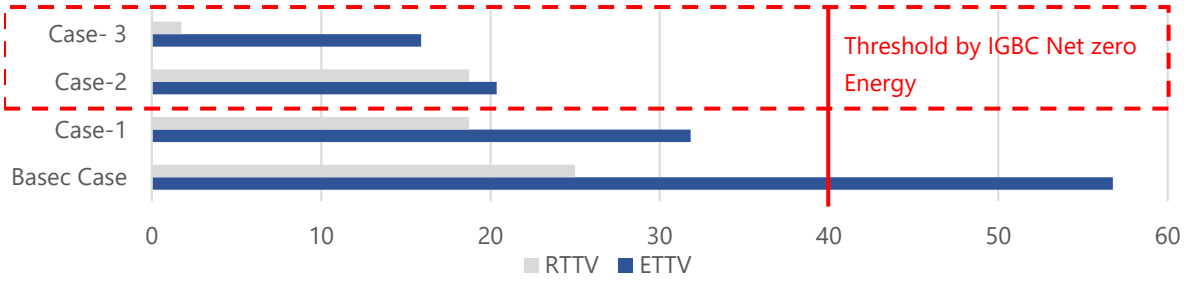


Figure 8: ETTV and RTTV Calculation

Optimizing Fenestration	Glazed Assembly-(2)	
Double glazing, higher visual light transmittance, SHGC (lower is better in cooling dominated climes), U-Value. Algae Photo Bioreactor Panels- Assembly was carefully chosen for cost and performance (depending on building orientation and as per radiation levels).	Double Glazed Unit  1.67 W/sq.MK SHGC: 27%, VLT: 60%	Algae Panels  1.88 W/sq.MK SHGC: 65% VLT: 45%

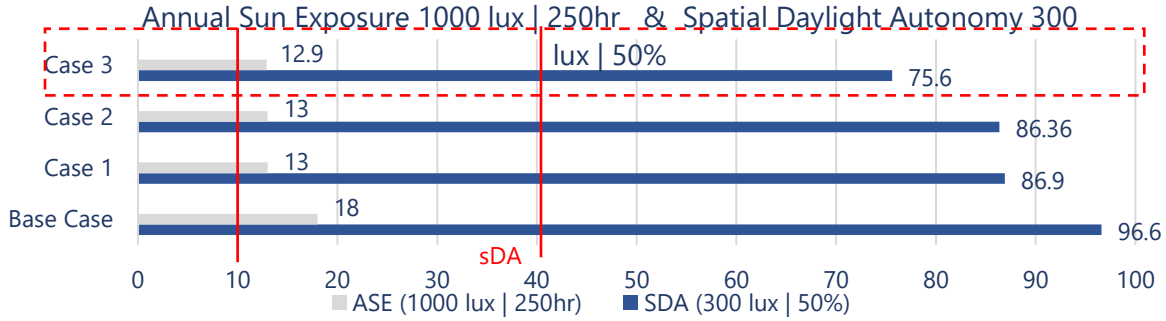


Figure 9: Fenestration Assembly

Active Strategies:

The building uses a hybrid HVAC system which is integrated with sensors to allow active as well as passive fair cooling for the uncomfortable hours. The system consists of **Air-Cooled Chiller, Air Handling Unit with Airside Economiser and Standalone Energy Recovery Ventilation.**

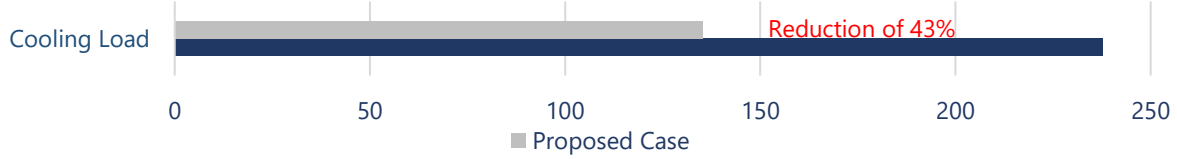


Figure 10: Base Case and Proposed Case for cooling load

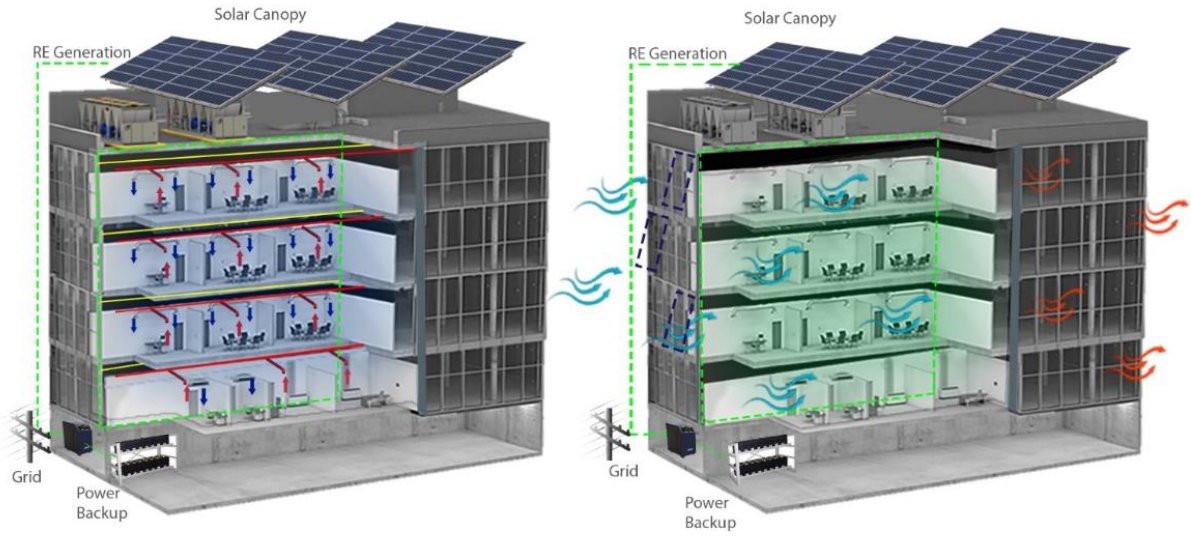


Figure 11: Ventilation Schematic

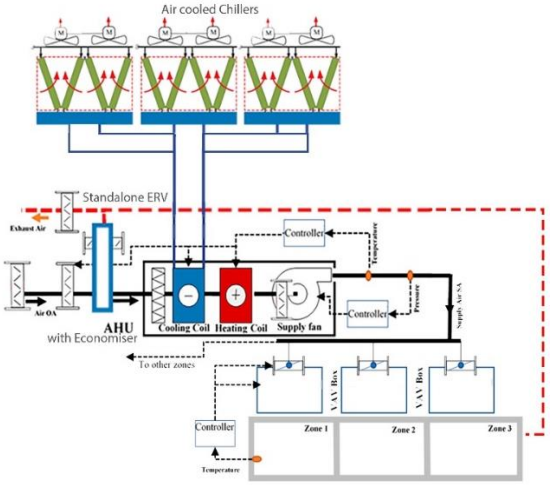


Figure 12: HVAC Schematic

Solar Canopy Details	
Model Type	Standard
Type	Monocrystalline
Array Type	Fixed Open rack
Array Tilt	20'
Inverter Efficiency	96%
Solar Canopy Area	1100
Solar Potential	145 (kWp)
Onsite Generation	217500
Excess Generation	33228.66
Solar Panel Size	79"*36"*1.4"

Figure 13: Solar Canopy Details

Renewable Strategies:

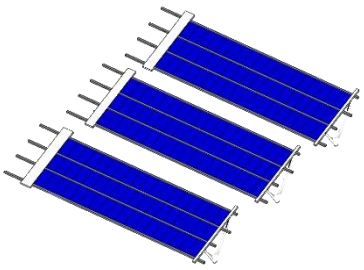


Figure 14: Solar Panel Array

The building is equipped with solar canopies. A Solar Canopy is an overhead roof or overhanging structure with a metal covering that provides shade.

Efficiency ratings of monocrystalline solar panels used for the project is 15%, earning them the title of the efficient solar panel type. The higher efficiency rating of monocrystalline panels makes them ideal with limited roof space, as it needs relatively fewer panels to generate electricity.

Solar Power Generation		
Months	**Solar Radiation**	**AC energy**
	(kWh/Sq.M/day)	**(kWh)**
January	6.77	**31,467**
February	6.86	28,256
March	7.08	**31,982**
April	6.64	**28,920**
May	**5.5**	**24,910**
June	4.67	**21,208**
July	4.27	20,146
August	4.22	19,868
September	4.66	**21,118**
October	5.46	25,336
November	5.26	**24,202**
December	5.6	26,608
Annual	5.58	**304,021**

Table 4: Monthly Solar Generation

Water Performance

The baseline consumption was 5,813kl/year, and harvested water + recycled grey water was 3,823kl/year; hence about 1,990kl/year was required from the municipality to meet the demand. To counteract this, we have designed a **Water Positive system** with the annual consumption being 1,845kl/year and harvested + treated grey and black water being 3,676kl/year. Hence a water positive balance of **1,796kl/year** is achieved after considering water storage for dry months, fire safety, 5 days of autonomy, landscape irrigation and aeroponics tower garden.

Proposed Water System		
Pattern	**Quantity**	**Unit**
Daily domestic requirement	4,401	lpd
Daily flushing requirement	2,015	lpd
Total daily domestic consumption	6,855	lpd
Total annual domestic consumption	18,43,909	l/yr
Aeroponics System - Treated Water	1,695	l/yr
Total annual consumption	**18,45,604**	**l/yr**
Total treated grey water	3,081	lpd
Total treated black water	1,813	lpd
Total daily domestic treated water	4,894	lpd
Total annual treated water	**12,07,546**	**l/yr**
Total rain water harvested	**24,68,196**	**l/yr**
5 Days of autonomy	34,273	ltrs
Annual Net Water Positive Balance	**17,95,865**	**ltrs**

Table 5: Proposed Water System

Baseline Water Consumption Pattern				
Baseline Consumption			45 lpd	
Use	**Pax**	**Flow Rate**	**Days**	**Consumption/Year**
Drinking	326	3	269	2,63,082
Kitchen Faucets	326	8	269	7,01,552
Fixtures	**Pax**	**Flow Rate**	**No.of Uses**	**Consumption/Year**
Toilets (Solid Flushing)	326	8	0.35	2,45,543
Toilets (Liquid Flushing)	326	4	3	10,52,328
Urinals	163	3.8	3	4,99,856
Health Faucets	326	8	0.35	2,45,543
Sink Faucets	326	8	3	21,04,656
Use	**Area**	**Ltr/Day**	**Days**	**Consumption/Year**
Landscaping	1532	1.7	269	7,00,584
Total Consumption per Year (ltr)				58,13,144

Proposed Water Consumption Pattern				
Proposed Consumption			15.3 lpd	
Use	**Pax**	**Flow Rate**	**Days**	**Consumption/Year**
Drinking	326	3	269	2,63,082
Kitchen Faucets	326	3	269	2,63,082
Fixtures	**Pax**	**Flow Rate**	**No.of Uses**	**Consumption/Year**
Toilets (Solid Flushing)	326	3	0.35	92,079
Toilets (Liquid Flushing)	326	1.5	3	3,94,623
Waterless Urinals	163	0	3	-
Health Faucets with aerator	326	1.8	0.35	55,247
Sensor Sink Faucets with aerator	326	2.5	3	6,57,705
Use	**Area**	**Ltr/Day**	**Days**	**Consumption/Year**
Landscaping	878	0.5	269	1,18,091
Total Consumption per Year (ltr)				18,43,909

Source: GRIHA v.2019

Table 6: Baseline vs Proposed Water consumption pattern

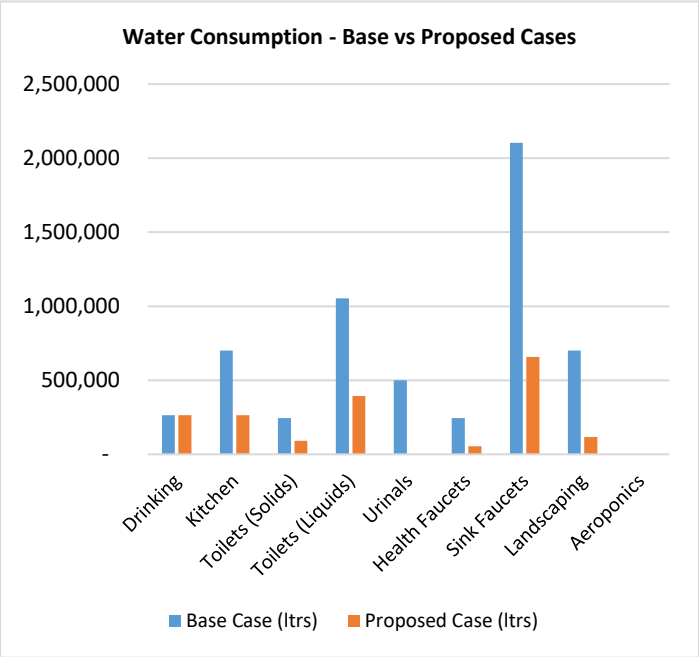


Figure 15: Base vs Proposed Case Graph

Rain Water Harvesting Sources		
Water harvesting Sources	**Area (sqm)**	**Runoff coeff**
Roof Surfaces	1161	0.95
Hardscape areas		
Internal Road & Parking Bays	1253	0.95
Pathways	150	0.8
Loose Aggregate	56	0.45
Softscape areas		
Vegetation on ground	878	0.3
Bio-swale	133.5	0.5
Effective catchment area	**2768.65**	

Muncipality & Borewell water supply (l/day)	**0**
Storage size (l) - UHT + Percolation Pond	**5,05,187**

Daily Water Consumption		
Water consumption point	**Quantity**	**Liters/day**
Occupants : {People x l/person}	326	**15.3**
Irrigation (max) : {m^2 x l/m^2}	878	**0.5**

The usage of **water-efficient fittings and fixtures** has resulted in a **68.3% reduction** from the base case.

The domestic sewage water is treated with a **90% efficient Vortex DEWATS** that allows us to reduce fresh water demand. The treated water is further disinfected on site to be made safe for human consumption following the **5-part sanitation system as per the WELL standards**.

There is no water taken from the municipality and bore wells. The total demand on site is being met with the rain water harvested and treated black and grey water using the Vortex DEWATS.

	New & Existing Buildings
Part 1: Organic Chemical Removal	O
Part 2: Sediment Filter	O
Part 3: Microbial Elimination	O
Part 4: Water Quality Maintenance	O
Part 5: Legionella Control	O

Due to the usage of the Hybrid aerothermal heat recovery system with VRF, water consumption would be minimal. Water required at the time of commissioning the system is 4000 Litres.

Water Performance - Water Balance Table										
Month	**Days In Month**	**Effective Rain (mm)**	**Harvested Water (l)**	**Muncipality Water Supply (l)**	**Total Fresh Water Demand (l)**	**Grey and Black Water Generated (l)**	**Irrigation Treated Water Demand (l)**	**Treated Water (l) for Flushing and Other Uses**	**Total Fresh Water Demand (l)**	**Storage (l) (*Water Balance*)**
September	22	200	5,53,176	-	1,09,732	98,758	966	97,793	1,09,732	4,43,445
October	23	158	4,38,333	-	1,14,719	1,03,247	1,010	1,02,238	1,14,719	5,05,187
November	22	22	60,633	-	1,09,732	98,758	4,829	93,929	1,09,732	4,56,089
December	23	18	48,894	-	1,14,719	1,03,247	5,049	98,199	1,14,719	3,90,264
January	23	0	-	-	1,14,719	1,03,247	10,097	93,150	1,14,719	2,75,545
February	20	2	5,703	-	99,756	89,780	8,780	81,000	99,756	1,81,492
March	23	16	43,080	-	1,14,719	1,03,247	5,049	98,199	1,14,719	1,09,853
April	22	33	91,310	-	1,09,732	98,758	4,829	93,929	1,09,732	91,431
May	23	148	4,10,812	-	1,14,719	1,03,247	2,019	1,01,228	1,14,719	3,87,524
June	22	87	2,41,592	-	1,09,732	98,758	1,932	96,827	1,09,732	5,05,187
July	23	97	2,68,891	-	1,14,719	1,03,247	2,019	1,01,228	1,14,719	5,05,187
August	23	110	3,05,770	-	1,14,719	1,03,247	2,019	1,01,228	1,14,719	5,05,187
Total			**24,68,196**	**-**	**13,41,718**	**12,07,546**	**48,597**	**11,58,949**	**13,41,718**	

Table: Showing Rain Water Harvesting Portential, Total Consumption, Grey water Generated and Water Balance

Table 7: Water Balance Table

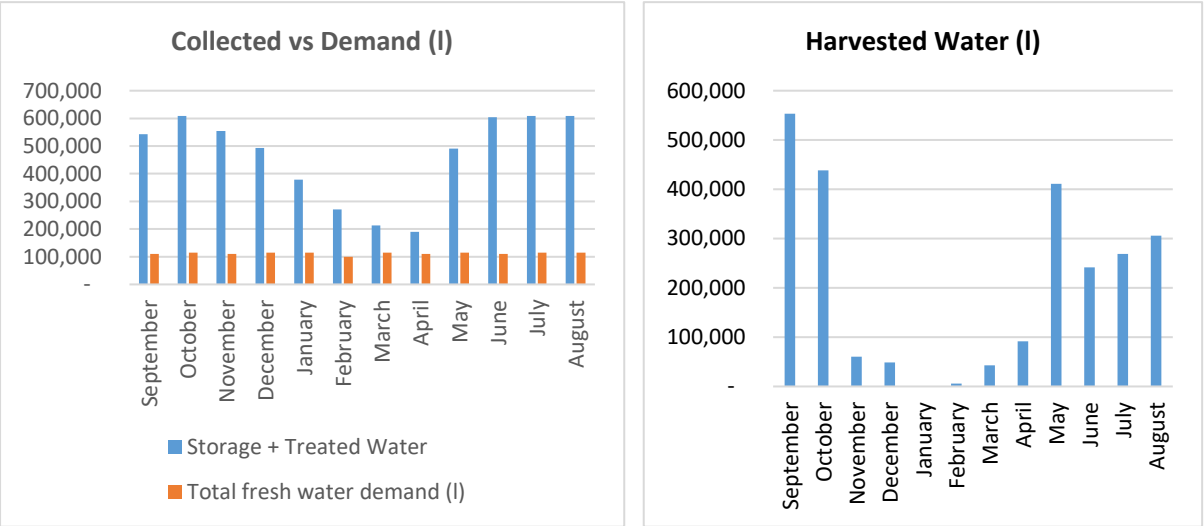


Figure 16: Graph showing water collected vs water demand

An effective closed loop water cycle with **sub-metering and monitoring** has been developed to minimize daily water demand. Harvested rainwater is **stored in oversized tanks to fulfil the water demand in the dry months** and reduces the freshwater demand completely. **Treated wastewater plus excess rainwater** is used as an **alternate source of water** for non-potable purposes. In the monsoon months, the **surplus rainwater is used for ground water recharge** through the **bio-swale and percolation pits.**

Water Performance - Sanitary Fixture Details								
FIXTURE			Flow Rates		No. of Fixtures	No. of Uses	Details	Note
			Proposed Case	Base Case				
1		Toilets (Solid Flushing)	3	8	37	0.35	Roca In Tank (Dual Flush)	At 3.0 Bar Pressure
		Toilets (Liquid Flushing)	1.5	4		3		
2		Waterless Urinals	0	3.8	9	3	Parryware C0586	
3		Health Faucets with aerator	1.8	8	37	0.35	Parryware G0202A1GF	
4		Sensor Sink Faucets with aerator	2.5	8	30	3	Jaguar	
5		Kitchen Faucets with aerator	3	8	4	3	Roca G0639A1GJ	

Table 8: Sanitary Fixture Details

Reduction of water in landscaping:

Native plants with high aesthetic value such as Amaltas (Cassia fistula), Gulmohar (Delonix regia), Semul (Bombax ceiba), Indian coral tree (Erythrina variegate), Champa (Magnolia champaca) have been used **for landscaping and in the bio-swale on the periphery** and **native shrubs** such as White orchid-tree (Bahunia acuminate), Bougainvillea (Bougainvillea glabra), Hibiscus (Hibiscus syriacus), Kaner (Nerium oleander), Chandini (Tabernaemontana divaricate) are planted throughout the site. **These require low maintenance and water.**

A **80% efficient drip irrigation system combined with the use of native flora, limited lawn area and the bio-swale** has **decreased** the water **consumption by 83%** and reduces water loss due to evaporation and wind.

Water Consumption - Proposed Water System				
S No.	System	Details	ltrs	cum
1	**Underground Tanks**			
a	Fresh Water Tank (Potable)	4 x daily water required	27,419	27
b	Treated Grey Water Tank	3 x daily treated water generated	14,682	15
c	Rain Water Tank	as per water balance table	5,00,000	500
d	Fire Tank	as per NBC 2016 (business buildings)	50,000	50
2	**Overhead Tanks**			
a	Fresh Water Tank	1.5 x daily domestic demand	6,602	7
b	Treated Grey Water Tank	1.5 x daily flushing demand	3,022	3
c	Fire Tank	as per NBC 2016 (business buildings)	5,000	5
3	**Natural Vortex DEWATS**			
a	DEWAT System (2 Phase)	0.2sqm per user for grey and 0.14sqm for black water	110 sqm	
b	Vortex Tubes	2 acrylic tubes of 50cm dia and 1.8m ht.		
c	Polishing Pond		4,894	5
4	**Composting Pits**		544	1
5	**Bio Swale**		133.5 sqm	
6	**Aeroponics Farming System**	75 towers each of 2*0.6m = 90sqm total consumes 6.3 l/day. This system required a water reservoir tank with a monthly capacity as stated.	138.6	0.1

Table 9: Proposed Water System

Schematics for water performance drawings has been added in the appendix

Embodied Carbon

The Embodied Carbon calculation is done for 5 building components- Walls, Roof, Floor, Fenestration, and Structures. The base and proposed cases specifications are mentioned in the table below.

Base Case	Proposed Case
Exterior and Internal wall – 230mm Burnt Brick wall + 20mm exterior cement plaster + 12.5mm interior cement plaster	**Exterior wall** - Hollow clay block(0.4mx0.2mx0.2m) + cement mortar
	Internal wall - AgriBio Panel board drywall – 12mm board+100mm studs (air gap) + 12mm board
Intermediate slabs - 150 mm thick filler slab + 15mm Vitrified tile flooring.	**Intermediate slabs -** 150 mm thick filler slab with 50mm thick AAC block fillers + 25mm Granite stone flooring
Windows – Aluminium framed openable windows with 6mm glass shutters.	**Windows** - uPVC frame openable windows with DGU on South, East, and North walls. The West façade is single-glazed 6mm glass shutters.

Curtain wall - Fully glazed façade with 6mm glass with spider fittings on South and East. aluminium casement with 6mm glass panels.	**Curtain wall** - Fully glazed façade with 6mm DGU with spider fittings on South and East + Algae panels. (**See innovation).** UPVC casement with 6mm DGU with an air gap.
Structural components – Reinforced Cement Concrete (Beams + Columns + Foundation)	**Structural components** - RCC with 20% recycled concrete aggregate (Beams + Columns + Foundation)
Roof - 150 mm thick filler slab + cement finish	**Roof** - 150 mm thick filler slab + Cool Roof tiles

Table 10: Material Palette for base and proposed case

Strategies applied for each of the five building components are as mentioned below-

Walls (Exterior walls + Interior walls):

Using **locally manufactured** Hollow clay block that requires no plastering reduces material quantity requirements and transport energy. For internal partition, a carbon sequestering material – AgriBio Panel is chosen. It reduces 3Kg of Co2 in the atmosphere for every 3 Sq.ft of board. These materials are also biodegradable after their use phase.



Figure 17: Agribio Panel, Hollow Concrete Block and AAC filler Slab

Fenestration (Curtain walls + Openable windows + Algae panel):

Usage of low-energy material. UPVC frames were chosen over metal frames as their initial carbon is relatively lower is relatively lower and requires much less maintenance over time. Energy generative Algae panels are incorporated into facades to utilize renewable resources on site (refer to Innovation contest for details).

Floors and Roof:

Load reduction- Incorporating filler blocks in the floor slabs to RCC slabs reduces the quantity of concrete used in the slabs. Use of AAC blocks as filler material, which has much lower Embodied energy in comparison with concrete. **Recyclability** – After the building's use phase, Granite stone tiles used for floor slab finish can be reused as tiles or recycled into aggregate/ sand without loss in compressive strength.

Structures (Beams + Columns + Foundation):

Load Reduction – Reduction in dead-load of the walls and floor slabs, leading to the reduced quantity of material used in structural components. Use of recycled material – 20% of aggregate material is replaced by Recycled aggregate Concrete, avoiding the use of fresh material and avoiding waste.

Embodied Energy - Base Vs Proposed Case			
Building Component	**Base case (kg -CO2 e)**	**Proposed case (kg -CO2 e)**	**Result**
Wall	643615.21	18393.12	Reduction in CO_2 by 97.1422%
Floor	1276509.7	1263769.2	Reduction in CO2 by 0.998%
Roof	71467.9	85728.56	Increase in CO2 by 16.6%
Fenestration	3312543.65	1691210.43	Reduction in CO2 by 48.7%
Structure	504952.73	412561.69	Reduction in CO2 by 18.3%
Total	5809089.234	3471663.043	**Overall reduction in carbon by 40.2374%**
Refer to Annexure xxxx or link https://shorturl.at/glpuM for details on transport energy			

Table 11: Embodied Energy Base vs Proposed Case

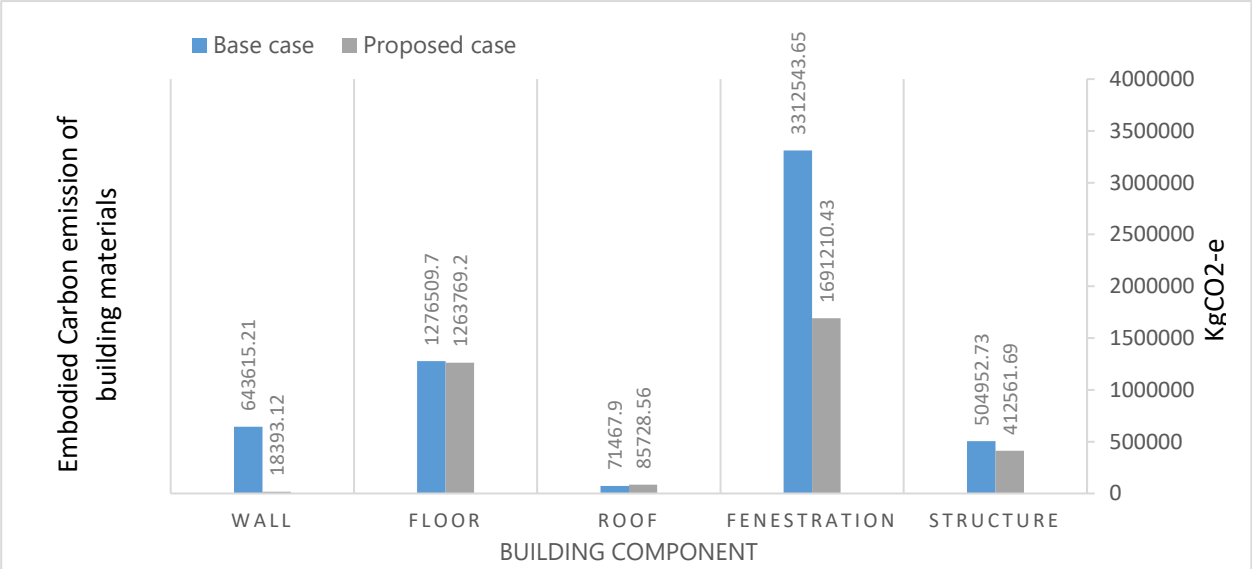


Figure 18: Comparative Carbon emission of Base vs Proposed Case

Embodied Carbon saving summary	
Non-structural Carbon reduction	2246.555315 Metric tonne
Structural Carbon reduction	90.870876 Metric tonne
Overall Carbon reduction	2337.426191 Metric tonne
2337.426191 Metric tonne of carbon emission reduction is equivalent to carbon sequestered by 2,787 acres of forest in a year.	

Table 12: Embodied Carbon Summary

Resilience

Bangalore is one of the fastest growing metropolises in India with a population of over 12M people. The ability of the building to mitigate short-term and long- term hazards is described here.

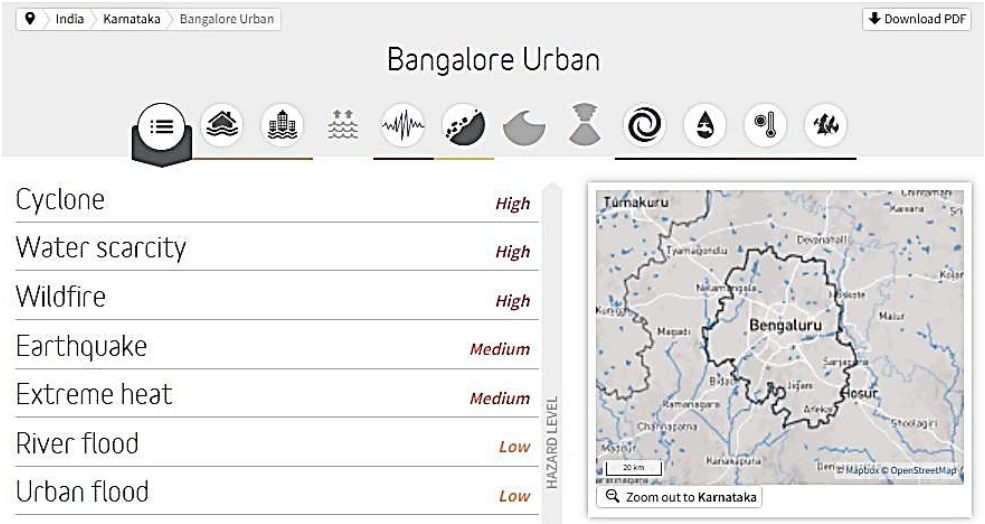


Figure 19: Bangalore Natural Disaster prone chart

Seismic zone:

According to the seismic classification of Karnataka provided by BMTPC, Bangalore lies in Zone II, which is a low damage risk zone. The structure is designed by taking into account the eathquake codes IS 4326 (1993) and IS 1893 (1984).

Wind hazard:

According to the Wind hazard map of Karnataka provided by BMTPC, Bangalore lies in low damage risk zone (V_b = 33 m/s). Suitable strong framed structure is provided in case of any future hazard.

Water scarcity:

Bangalore has a high risk of water scarcity and droughts are expected to occur on average of every 5 years. On site rainwater and recycled water storage to cover operations icluding toilet flushing for emergency stand alone operations for a period of atleast 120 hours is provided. UG sump of capacity 27 cu.m, 16 cu.m and 500 cu.m are provided for storing portable water, treated grey water and rainwater respectively. Overhead tank of capacities 7 cu.m and 3 cu.m are provided for storing portable water and treated grey water respectively.

Fire Hazard:

The living staircase acts as the fire stair and refuge area. Non – combustible structural materials are used. Buildings divided into blocks acts as fire breaks. UG sump of capacity 50 cu.m and overhead tank of capacity 5 cu.m is provided for firefighting.

Figure 20: Firefighting Plan

Electricity:

Bangalore in recent days is facing the issue of power cuts during the working hours. Considering 5 days of autonomy, the peak load requirement is 121 Wh. Hence, an 18150 VA inverter is provided in the electrical room to serve this purpose.

Cyclone:

Rectangular, square symmatric shapes are more efficient to withstand the wind forces. Structural strength is been taken care of in the foundation, wall and roof from lateral loads through wind actions. We have used deep foundations as the soil is clayey.

Air and Noise pollution:

Frontage provided as per the development control rules which itself creates a buffer between the road and the building. Materials with good Sound Transmission Class (above 40 dB) is used to ensure less transmission from outdoor to the indoor and inbetween the spaces in the indoor. The existing trees act as a barrier for air and noise pollution in the front.

Technological change:

The design includes adaptable spaces which adhere to change in future functionality and number of occupants. Parking facilities provided for electronic vehicle. Aeroponic system provided in the terrace addresses food resilience.

Engineering and operations

- Materials with low embodied carbon and low self-weight is used for construction.
- MEP systems has been rightly sized keeping in mind the potential increase in cooling demand due to climate change or increase in number of occupants.

Figure 21: Model of Structural Systems

The proposed construction materials are

- Foundation, Beams and Columns are constructed using 20% recycled aggregate concrete to increase the usage of salvage materials.
- The foundations have been custom sized in order to use only the required amount of concrete and reinforcement usage.
- Filler slabs have been used with Concrete blocks of 200*200*50mm to reduce the concrete usage.
- Agri Bio panels have been used as interior partition walls for cabin spaces to reduce the load on the framed structure.
- Hollow Clay blocks have been used as an exterior wall material. Hollow clay blocks have been selected because of its low embodied energy and low weight.
- Low emissivity double glazed glass for glazing.

Structural Sections

All the structural layouts has been attached in the appendix

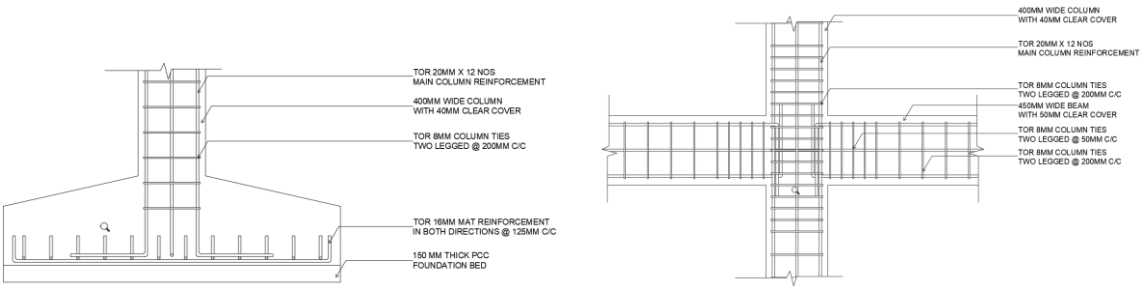


Figure 22: Foundation Section and Column, Beam Section with Reinforcement data

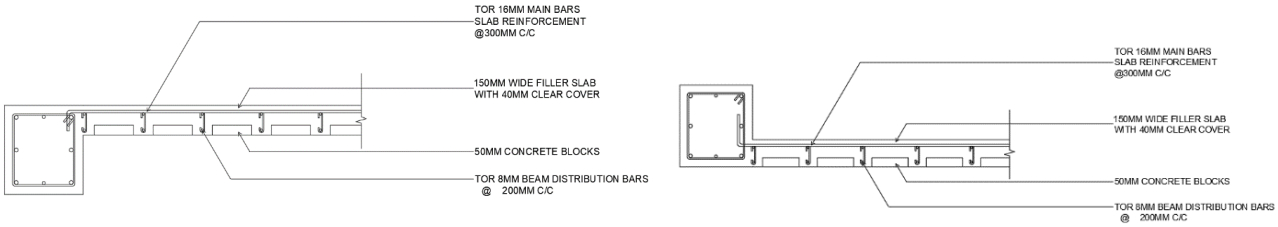


Figure 23: Slab Sections

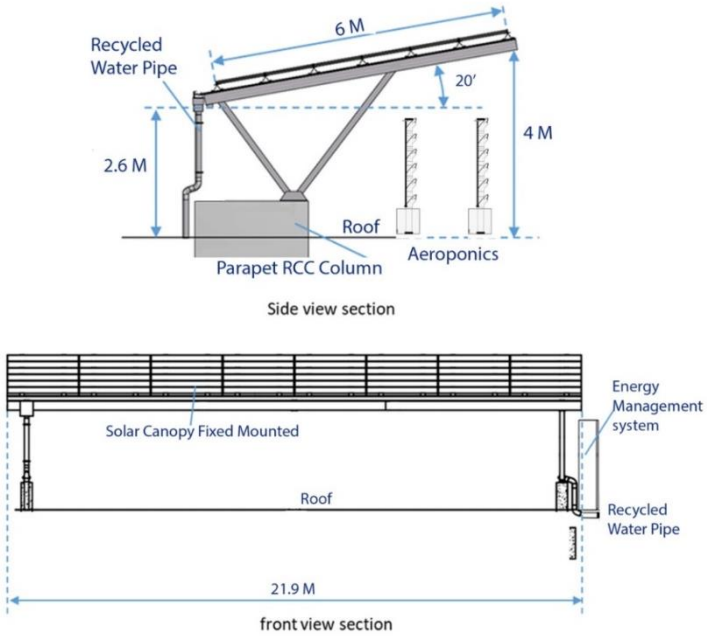


Figure 24; Solar Canopy Details

Waste Generation Details						
Waste Sources	**Colour of Bin**	**No. of Bins**	**Category**	**Composition**	**Quantity (kg/yr)**	**Treatment / Disposal Method**
Black Water Sludge	-	-	Bio-degradable	-	544	This is turned into compost through manual composting using pits. The stabilised material is used as fertiliser for the landscape on site.
Food & Organic Waste (Wet Waste)	Brown	14		40% of total solid waste generated	5261.6	
Domestic Hazard Waste - Toilets	Yellow	10	Incineration			Sent to municipality incineration plant
Dry Waste - Cardboard, Paper etc	Blue	35	Recyclable			Sent for recycling through approved recycler
Dry Waste - Plastic Waste	Red	35		60% of total solid waste generated	7892.5	
Metals - Cans, Tetrapacks etc	Green	4				
E-Waste	Black	4				
Total Yearly Waste Generation		*As per GRIHA v.19*		*As per NBC*	**13154.1**	

Table 13: Waste Generation Details

The air conditioning tonnage is calculated to be 157.76 tons. The calculation table has been attached in the appendix.

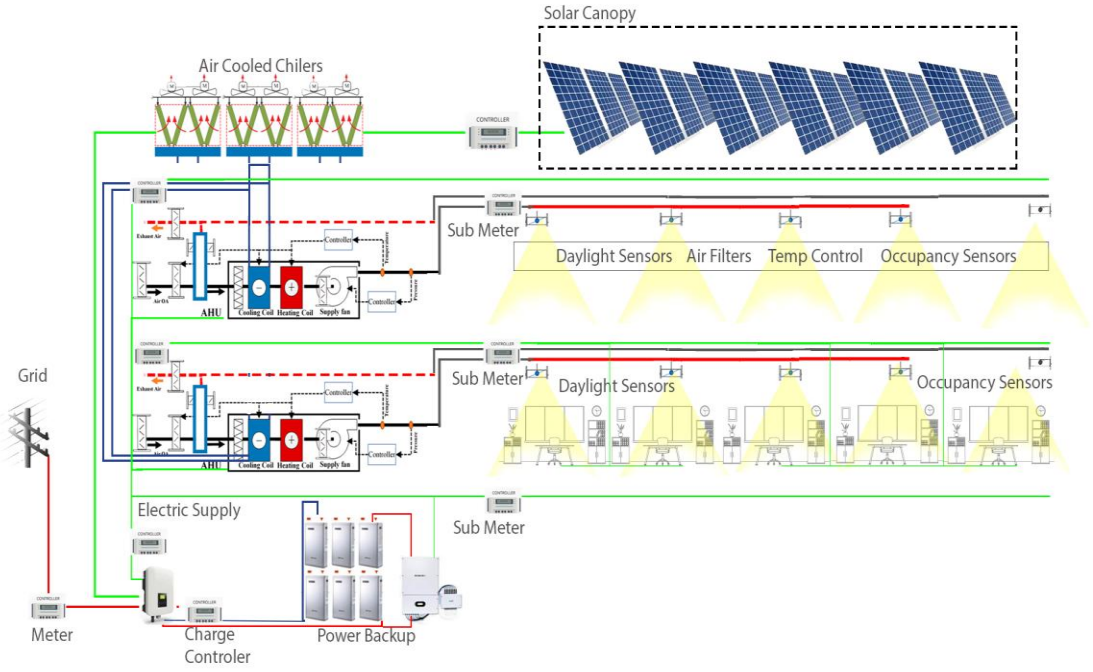


Figure 25: Schematic for HVAC and Building Automation systems

Architectural Design

Design concept with one stair element connecting all the floors enables pedestrian circulation. Staircase is organic which makes people use it rather than the lifts. Good ratio of solids and voids helps in daylighting, natural ventilation, and views.

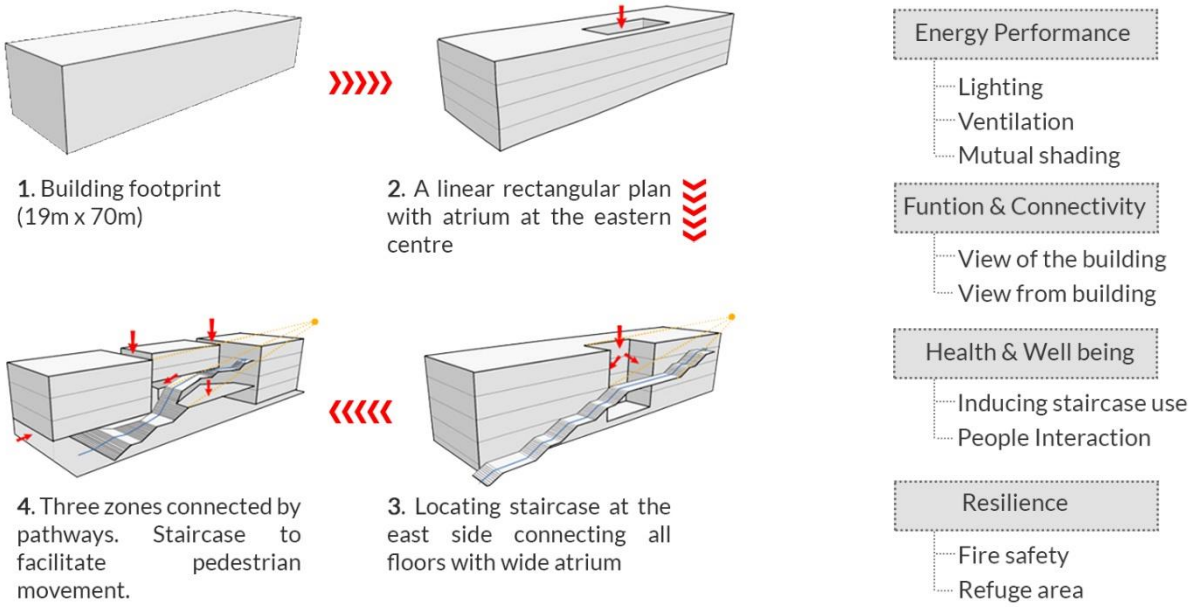


Figure 26: Building Form Development

The design began with the proximity mapping followed by zoning. The living stair will connect to all the floors. The living stairs will add to the aesthetics of the building, create on site views, enhance lighting, induce users to use the staircase, lower the solar radiation ingress and acts as emergency stair also.

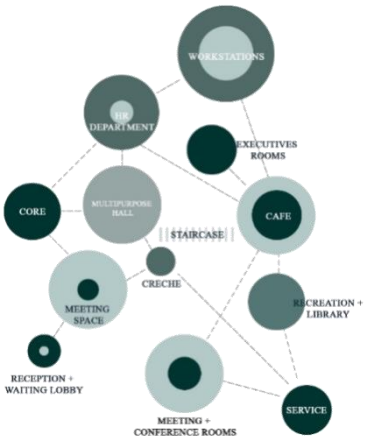


Figure 27: Proximity Chart

Conceptual views were made to bring in more clarity into the design. The backside of the site has the DEWAT system and the walkthrough pathway which has a very good onsite view. The northern side of the building is treated with slanting wall to facilitate the occupants have a view on site and view towards the lake.

The southern part of the site has the main entry. The façade is treated with glazing units as primary element. Expanded metal cladding is done to facilitate shading and daylighting together. The double floor high space at the South eastern side has landscape and it is open. The eastern side has the living staircase running through the periphery of the façade. It has the algae panels for improved energy efficiency and shading.

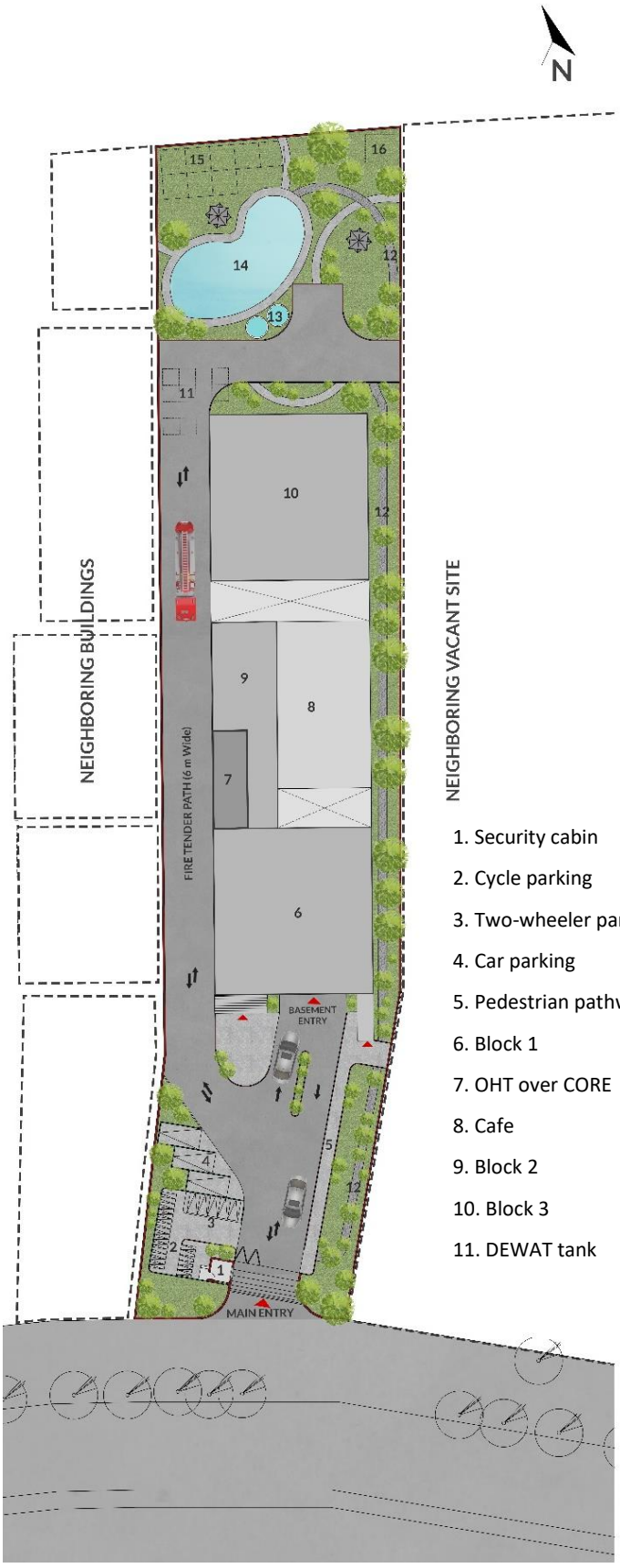
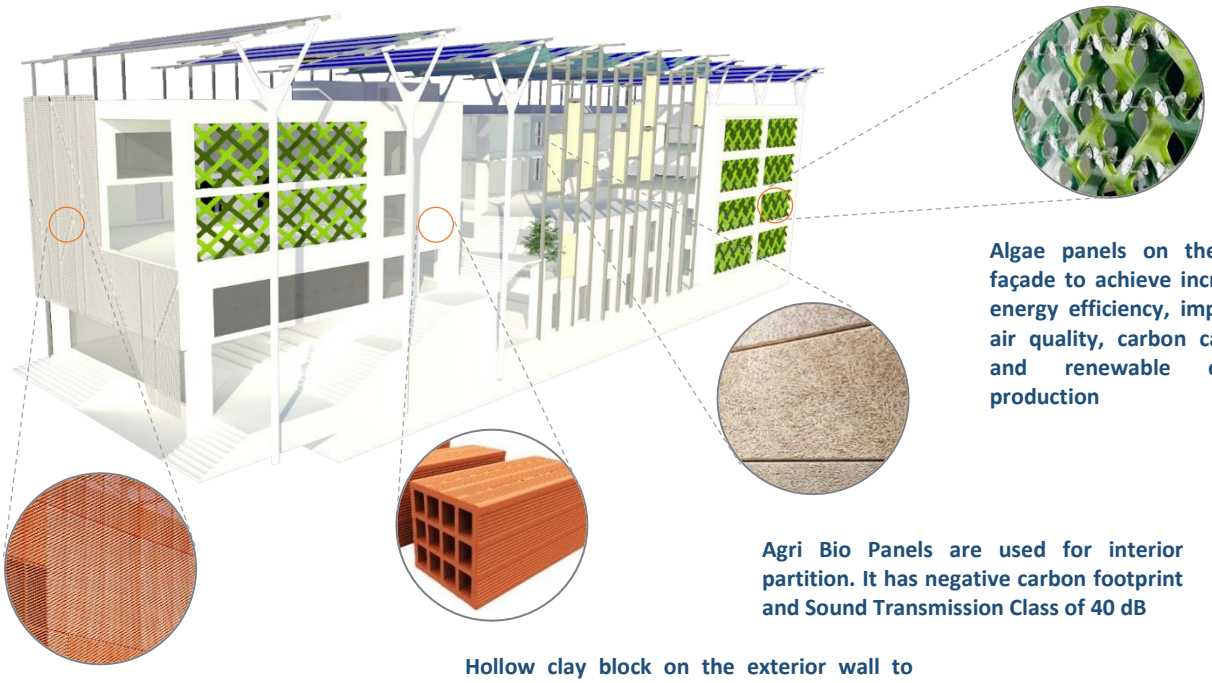


Figure 28: Building Site Plan

Ground floor First floor Second floor Third floor

1) Reception 2) Waiting lobby 3) Back office 4) IBMS room 5) Vendor discussion 6) Lift 7) Staircase 8) Hub room 9) Toilet 10) Creech 11) Multipurpose hall 12) Workstations 13) Meeting room 14) Conference room 14a) AV room 15) Manager room 16) Reprography 17) Library 18) Café 19) Recreation hall 20) Balcony 21) Board room 22) CEO room 23) Assistant room 24) Executives room 25) Living staircase



Algae panels on the east façade to achieve increased energy efficiency, improved air quality, carbon capture and renewable energy production

Agri Bio Panels are used for interior partition. It has negative carbon footprint and Sound Transmission Class of 40 dB

Expanded Metal sheet on the Front façade for the purpose of providing shade and light together

Hollow clay block on the exterior wall to reduce the dead load and increase the indoor thermal comfort.

AFFORDABILITY

Project cost data: Base case vs proposed case

The total estimate of proposed cased is higher than base case estimate due to addition of eco-friendly materials and interventions in design, energy and water.

S.No.	Particulars	Definition	Baseline Estimate (Project Partner / SOR basis)			Proposed Design Estimate		
			Amount (Million INR)	%	Amount (INR per sqm)	Amount (Million INR)	%	Amount (INR per sqm)
1	Land	Cost of land purchased or leased by the Project Partner	0.00	0.0%	-	0.00	0.0%	-
2	Civil Works	Refer Item A, Civil works in Cost of construction worksheet	6310.89	27.4%	78,88,607	5253.48	19.9%	65,66,854
3	Internal Works	Refer Item B, Civil works in Cost of construction worksheet	4589.21	19.9%	57,36,507	4696.57	17.8%	58,70,708
4	MEP Services	Refer Item C, Civil works in Cost of construction worksheet	312.67	1.4%	3,90,835	0.00	0.0%	-
5	Equipment & Furnishing	Refer Item D, Civil works in Cost of construction worksheet	5290.95	22.9%	66,13,683	5290.93	20.0%	66,13,657
6	Landscape & Site Development	Refer Item E, Civil works in Cost of construction worksheet	4420.09	19.2%	55,25,115	8676.90	32.8%	1,08,46,125
7	Contingency	Amount added to the total estimate for incidental and miscellaneous expenses.	2092.38	9.1%	26,15,475	2475.18	9.4%	30,93,972
	TOTAL HARD COST		**23,016.2**	**100%**	**2,87,70,222**	**26,393.1**	**100%**	**3,29,91,316**
8	Pre Operative Expenses	Cost of Permits, Licenses, Market research, Advertising etc	10.00	0.0%	12,500	10.00	0.0%	12,500
9	Consultants	Consultant fees on a typical Project	10.00	0.0%	12,500	10.00	0.0%	12,500
10	Interest During Construction	Interest paid on loans related to the project during construction	20.25	0.1%	25,318	11.72	0.1%	14,653
	TOTAL SOFT COST		**40.3**	**0%**	**50,318**	**31.7**	**0%**	**39,653**
	TOTAL PROJECT COST		**23,056.4**	**100%**	**2,88,20,539**	**26,424.8**	**100%**	**3,30,30,968**

Table 14: Basecase Vs Proposed Estimate

CAPEX:

The capital expenses for base case is less than proposed case as the installation of algae panels, PV panels , aeroponics system, water saving fixtures and energy efficient equipment's are higher.

OPEX:

The operational expenses for proposed case is less than base case as above mentioned interventions consistently reduces the post operational expenses and in turn adds revenue to the building that can balance the maintenance and replacement cost. The use of solar panels on the terrace and algae panels on the facade generates onsite renewable energy that reduces the operational cost further.

COST REDUCTION STRATEGIES:

- Use of porotherm bricks reduced the plastering, painting material and labour cost by 25% compared to that of conventional bricks.
- Using recycled concrete in place of conventional concrete reduces cost by 2%
- Installing fire hydrant system saves money on sprinkler system.
- Use of energy-efficient materials and strategies will achieve payback period within 3-5 years.
- Sending additional electricity to grid earns 5% of revenue.

LIFE CYCLE COST ANALYSIS:

LCC for the proposed case is less compared to base case as it is done for period of 10 years. As mentioned capex is high for a proposed case but the other expenses for annual maintenance, replacement is considerably reduced due to use of high efficiency equipment's recommended for the proposed case.

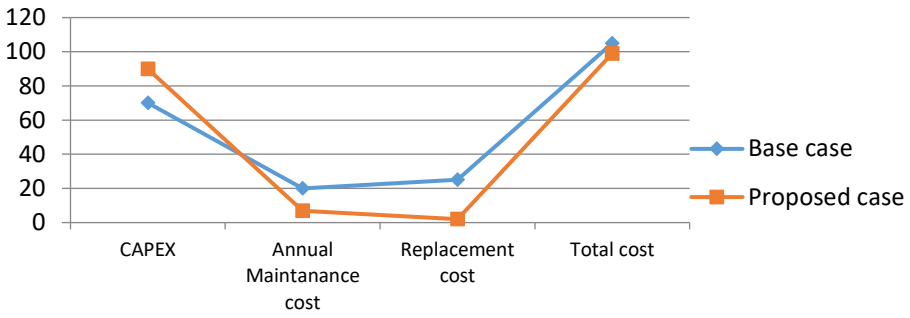


Figure 29: Life Cycle Cost Comparison

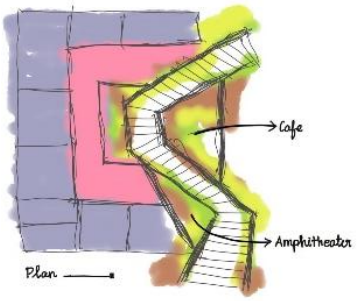
Health and Wellbeing

The health and comfort of the occupants have become an inevitable part of the building's design and construction. Currently, there are many standards and benchmarks available for health considerations in buildings from various organizations. WELL standards have emerged as one of the leading standards for the health and comfort of building users worldwide. WELL, v2, the updated version of standards that considers 10 different parameters to ensure the health and well-being of the occupants, was released in 2019. Factors like ventilation, lighting, and comfort become a basic need as all green certifications have them as prerequisites in their rating systems. So, we are getting a step ahead and focusing more on psychological comfort and productivity.

Role of design in health and well-being

Biophilic design:

The staircase design plays a major role in the health and well-being of the building's occupants. The staircase design encourages users to use it, increasing their fitness. This was achieved by making the stair appear more predominant and aesthetic (biophilic design), and recreational spaces like cafés were added in between and easily accessed through the stairs.



Vista: Workstations with a functional layout have access to outside views (view towards the lake on the east) and open planning, which allows the user to move freely. And the workstations have green zones to make the indoor space more alive.

Comfort

Barrier-free environment: The design of the building makes provision for elderly and differently abled people.(Refer to the floor plans)

- Ramp access (at entrance)
- Lift/Elevator (to access different floors)
- Handrail design (guiding rails)
- Toilet for the differently abled (with wheelchair access)

User comfort:

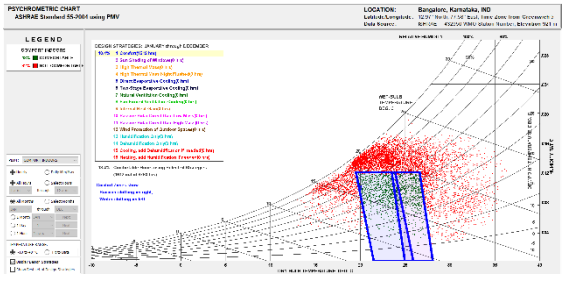
- Ergonomic furniture and layout
- Lighting: CRI > 90, reduced flicker rate
- Sound: 40m buffer for road (includes trees)
- Material: The materials used in the project are low VOC, mercury, and lead.

Social:

The staircase increases interaction space as it accesses all recreational and other spaces, and it has been designed with more width, which acts as a social corridor. And the design includes many recreational zones like a café, gym, library, etc. A creche area for workers kids and a feeding area for feeding mothers have been provided.

Thermal comfort:

The Bangalore comfort chart from CARBSE tools shows it has more comfort hours throughout the year except February, March, April, and May. An annual cooling load of 17.5% of hours is needed to achieve thermal comfort, and naturally ventilated spaces enjoy cross ventilation to regulate indoor temperature.



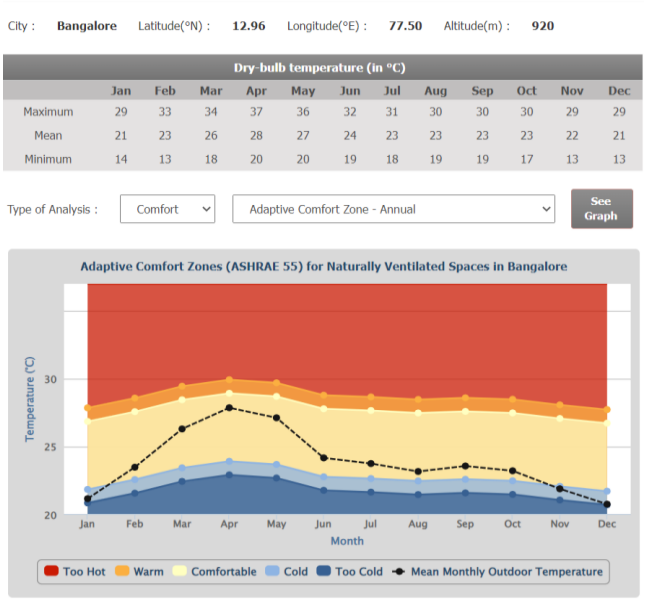


Figure 30: Thermal Comfort Data

Indoor air quality

Naturally ventilated spaces have been designed in such a way to achieve cross-ventilation. Algae panels used in the façade not only produce energy; they also absorb CO2 and purify the air. Mechanically ventilated HVAC systems were combined with filters like carbon, UVGI, HEPA, and MERV 13 (based on WELL v2). The building and site are smoke-free zones. Live monitoring of pollutants like

CO2, PM2.5, and PM10 will be constantly monitored and displayed in common areas. Air purifiers will be installed at the entrance.

Indoor plants: Plants like chrysanthemums, spathipyllum, ficus elastic, etc. have been added. These plants are known for their air-purifying capabilities.

Water

Drinking water: the occupants will be provided with UV-RO purified water, and dispensers have been provided at a rate of 1 per 100m.

Recycled water: The recycling of wastewater involves a DEWAT system with two vortices and additional UGVI and activated carbon. A sediment filter is provided, which makes the wastewater 90% pure compared to drinking water. Thus, using this recycled water for indoor plants doesn't affect the occupant's health.

Water-use spaces like toilets and potable water dispensers remain moisture-resistant, which resists microbial generation around them.

Innovation

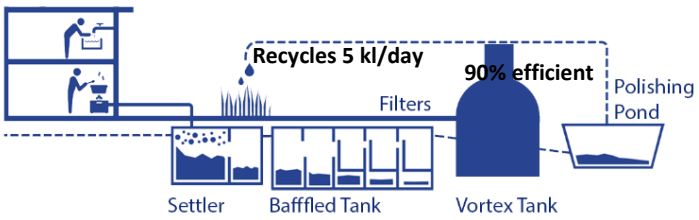
Agrocorp office building has been designed as an interactive system which takes micro to macro level variable into consideration. The team intends to focus on providing energy and water efficient system to its occupants and owner. Therefore, a system has been proposed which focuses on enhancing the efficiency as well as income generating opportunity which in turn benefits the ROI.

The algal facade system consists of two glazing systems and an algae bioreactor system. This cutting-edge algal facade offers sufficient thermal and structural performance, good daylight transmission, and shading capacity. It enhances indoor air quality by generating O2 and absorbing CO2 as a by-product of algae's photosynthesis.

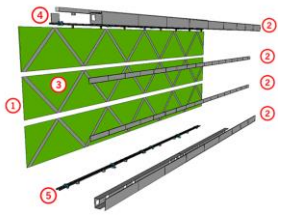
WATER

Vortex DEWATS & Aeroponic Tower Garden

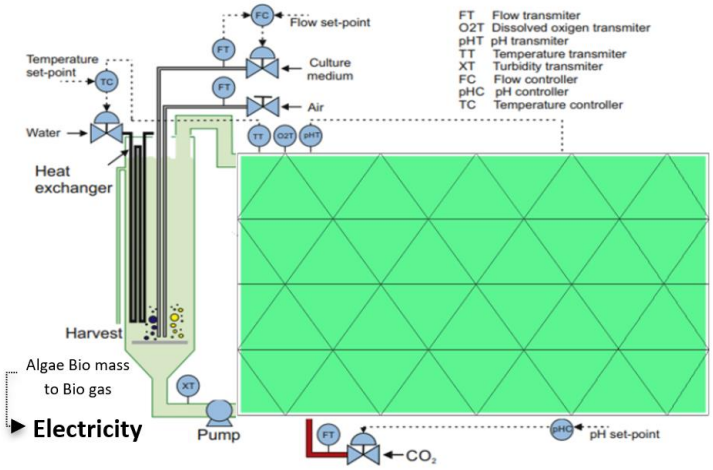
Vortex DEWATS. It uses minimal space, requires low energy input, and quickly provides oxygen saturation in the wastewater for complete odour control without any mechanical and chemical processes and no complex maintenance procedures.



Horizontal flow System- Wastewater is fed in at the inlet and flow slowly through the porous substrate under the surface of the bed in a more or less horizontal path until it reaches the outlet zone.



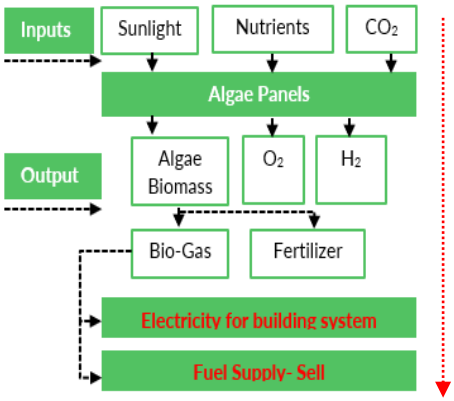
1. Flat Plate Photo Bio reactor (PBR)- 19.95 Sq.M with each triangular panel of 1.18 Sq.M.
2. Brackets with thermal Break to reduce interna; heat gain
3. Bio algae Media 4 liters in each panel producing
4. Supply of water with pH regulation
5. Supply of air, nutrients (waste water) and biomass collection

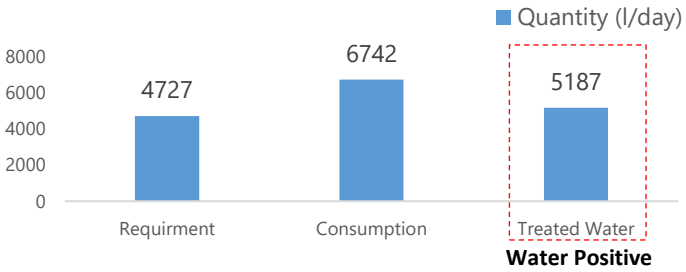


Flat-plate reactors are characterized by a high surface-to volume ratio, which leads to the best photosynthetic efficiencies observed for any photobioreactor.

Proposed System functioning and details-

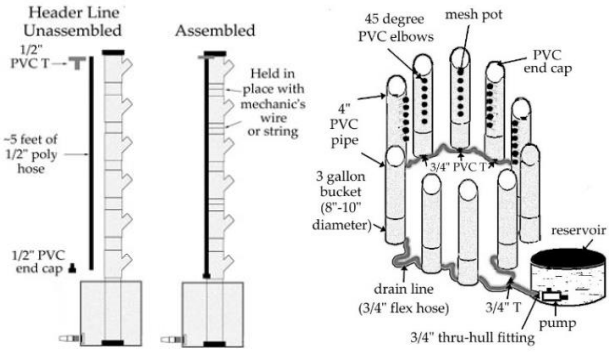
U-value	1.88
SHGC	0.08
VLT	0.6
Biomass Production/ Day	780 gm (7.5gm/panel)
Bio fuel Production/year	50,839.25 L
Chlorella Algae Price (Rs)	2500/kg





Water Positive

Aeroponics is the practice of growing plants in an air or mist environment without the use of any substrate. That is, the plant roots are suspended in the air and are misted or sprayed periodically with a nutrient solution or aerosol of nutrient solution. This system requires about 5 l/day for 60 towers covering a total area of 90 Sq.M. This demand is met by the on-site recycled grey water.



It is a farming technique that involves growing crops in layers that are piled vertically. It is carried out in a controlled environment utilizing soilless growing method.

Area covered	90 Sq.M
Nominal Yield (Tomato)	40 Tons/acre (8.9 kg/Sq.M)
Yield through hydroponics (30% more than nominal)	1035 kg (11.5 kg/Sq.M)

Value Proposition

Nourishing sustainable developments

Net -zero office building for Agro corp in Bangalore delivering the package of healthy environment, human well-being, productive economy. Functional efficiency, Effective utilization of spaces are ensured in the design. Sustainable design solutions are provided to achieve net-zero energy, best environmental quality, net zero water.

Project	Builders	Occupants
		
Building reflects company's moto through biophilic design will act as standout symbol. Reducing the operating cost throughout the lifetime.	Future to developing towards smart way of self-efficient development solutions coordinated with new ecofriendly products and technology to meet market value.	Experience and lifestyle are a key factor to increase the productivity and the wellbeing of the Employees and staffs.

Economic Benefits

- Building design (Orientation, WWR, Algae panels) evolved from climate analysis results utilize the daylight and solar radiation helps in energy efficiency. (Refer: Innovation and design sheets)
- Renewable energy generated (217500kwh) through solar panels are sufficient to meet the daily energy (184271.34kwh) requirement. (Refer: Energy performance sheets)
- Reducing construction cost (up to 20%) by using filler slab and hollow blocks and by reducing transportation cost.
- Operating costs are reduced by energy efficient Equipment and lighting fixture, efficient mechanical ventilation (HVAC)
- Our sustainable solutions do not compromise structural stability, hence increase the property value. (Source: https://ijcsm.springeropen.com/articles/10.1007/s40069-015-0100-0)
- Urban farming through Aeroponics, which will yield vegetation (81kg of tomato) and create a positive impact towards the environment. (Refer: Innovation).

Environmental Benefits

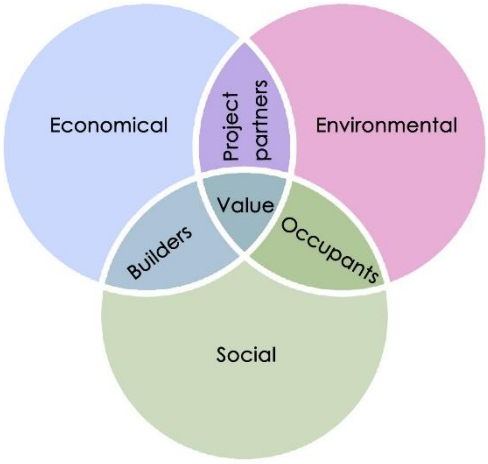
- Sustainable and locally available materials such as (Hollow clay blocks, AgriBio panels) reduce carbon emission up to 40%. (Refer: embodied carbon)
- Some of the existing trees are retained and for landscape areas native species for landscape areas.
- Around 1000kl of water is saved per year using efficient water treatment plants, and efficient plumbing fixtures. (Refer: Water Performance)
- Building Automation including sensors to reduce energy consumption and to maintain comfort and air quality.

Social Benefits

- Aesthetics of the enhanced with integrated biophilic design creates productive environment.
- Flexibility of spaces like open plan, multipurpose area adds to the utility value.
- Quality of life (fitness to the occupants) improves by creating active spaces such as stairways along the building and horizontal pathways. (Refer: Health and wellbeing)
- Physiological benefits for the employees including enhancing their productivity and mental health towards perceived wellbeing by creating the green and active spaces.

***Reach out to integrated solutions ***

1. Solar panels
2. Aerophonics
3. Algae panels



1. Local material
2. BMS
3. Water saving
4. Biophillic design

Building Renders

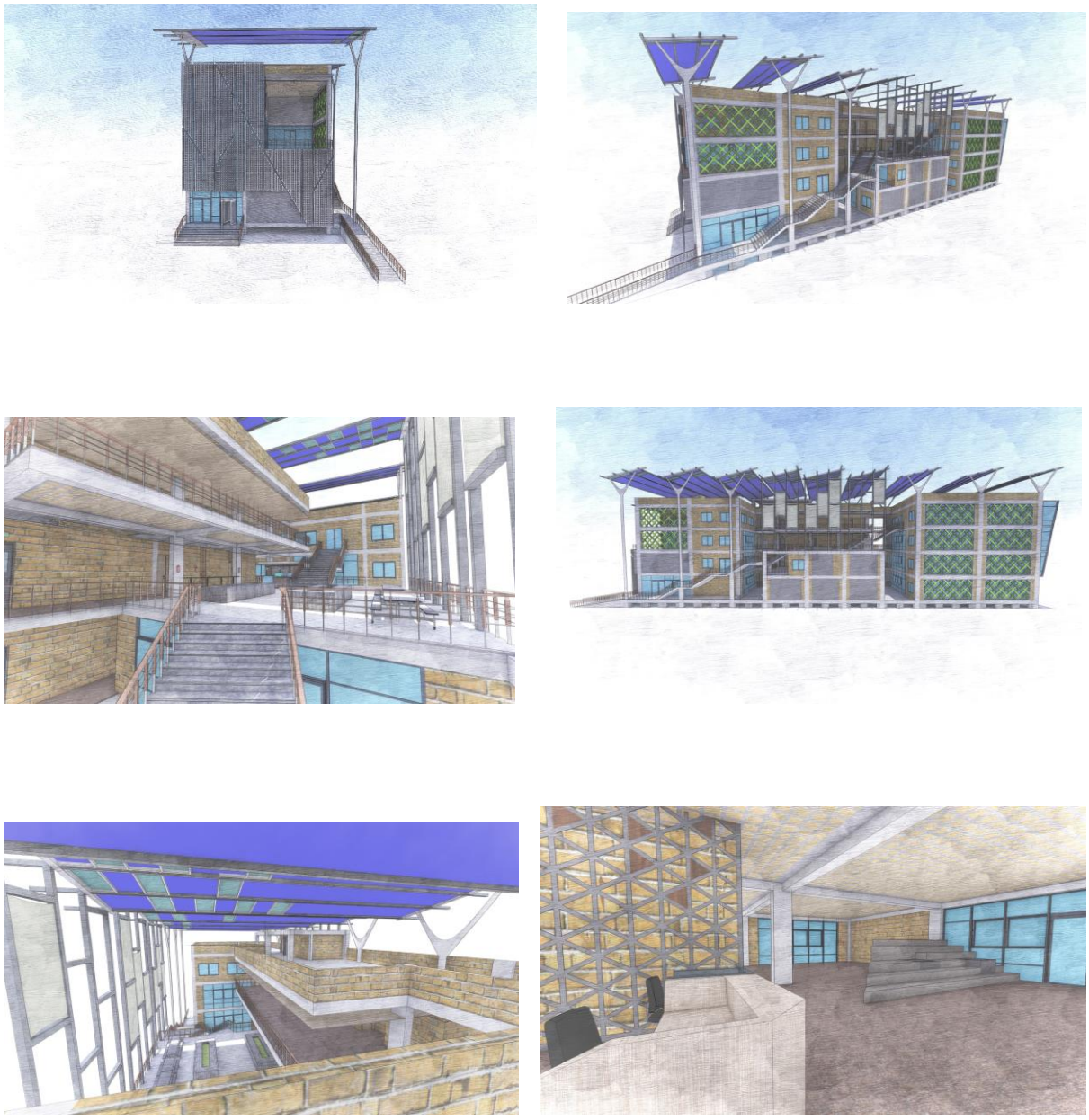
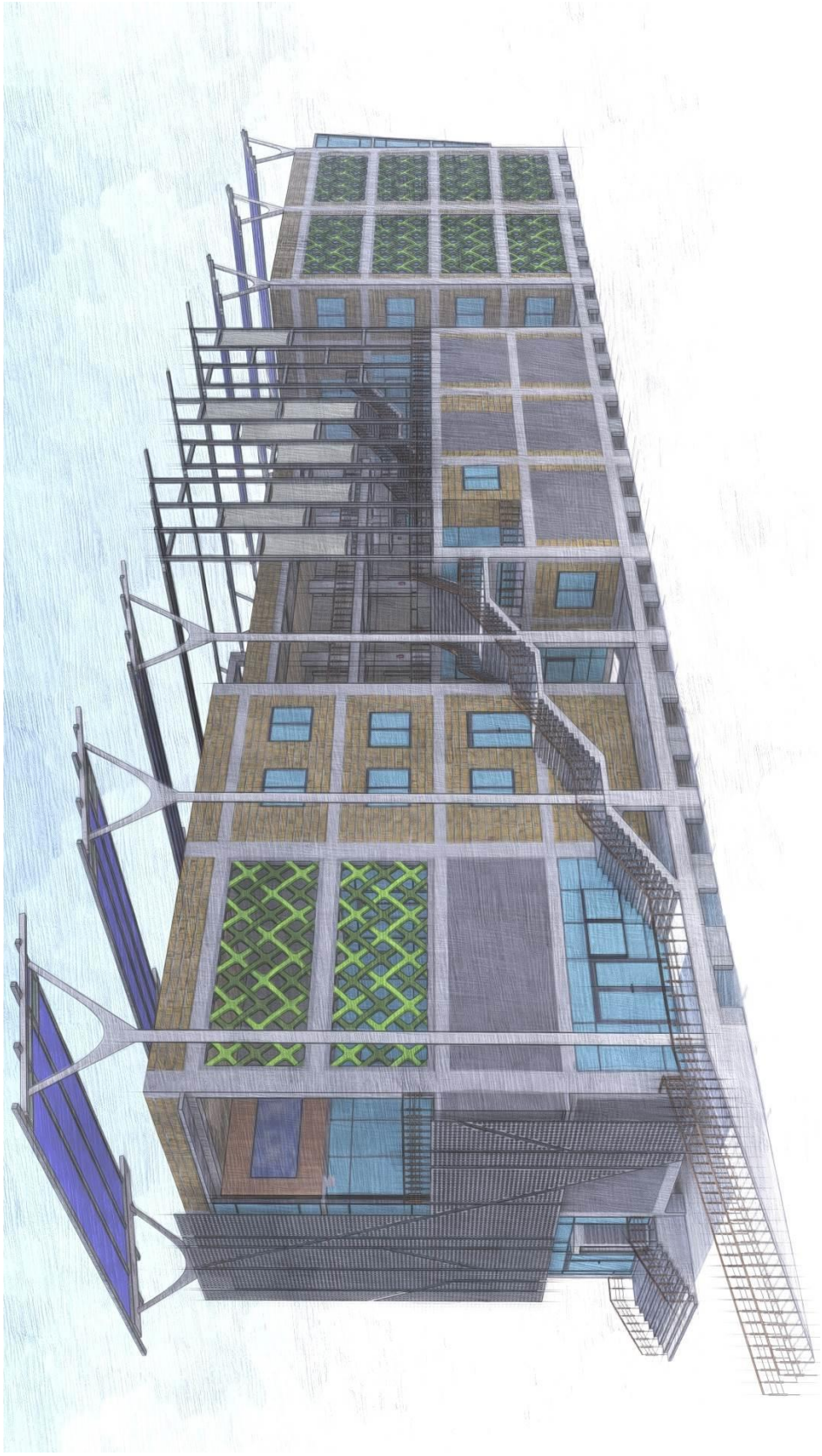


Figure 31: Building Renders



Appendix

Appendix 1 - Detailed building area program

No	Space	occupants	Area (sqm)
	BASEMENT FLOOR		**1334**
1	ELECTRICAL ROOM		45
2	PARKING AREA		1144
			1189
	GROUNDFLOOR		
1	RECEPTION	2	21.9
2	WAITING LOBBY	30	64
3	BACK OFFICE	4	14.82
4	IBMS & CONTROL ROOM	6	33.28
5	VENDOR DISCUSSION	10	101.5
6	LANDSCAPE 1		51.75
7	CRECHE		88
8	MULTIPURPOSE HALL		158.13
9	LANDSCAPE 2		96.5
10	MEETING ROOM 1	5	18.52
11	MEETING ROOM 2	5	18.52
12	AV ROOM		71.11
13	HR MANAGER		23.16
14	WORK STATION		230.97
			992.16

Table 15: Area Statement Ground Floor

No	Space	occupants	Area (sqm)
	FIRST FLOOR		
15	MANAGER ROOM 1	1	17.66
16	MANAGER ROOM 2	1	17.66
17	MANAGER ROOM 3	1	17.66
18	WORKSTATIONS		123
19	CONFERENCE ROOM 1		59.56
20	CONFERENCE ROOM 2		59.56
21	MEETING ROOM 1		23.13
22	MEETING ROOM 2		23.13
23	LANDSCAPE		50.8
24	WORKSTATION		322.66
25	MANAGER ROOM 1		17.66
26	MANAGER ROOM 2		17.66
27	MANAGER ROOM 3		17.66
			767.8

	SECOND FLOOR		
28	LANDSCAPE		77.75
29	LIBRARY		220
30	CAFÉ		194
31	RECREATION		387.46
			879.21
	THIRD FLOOR		
32	BOARD ROOM		42.32
33	CEO ROOM		30.8
34	ASST.ROOM		14.05
35	CFO ROOM		18
36	CFO ROOM		18
37	TOILET 1		6.54
38	TOILET 2		6.07
39	BALCONY		94.1
40	MANAGER ROOM 1		17.66
41	MANAGER ROOM 2		17.66
42	MANAGER ROOM 3		17.66
43	WORKSTATIONS		343.23
			626.09

Table 16: Area Statement First, Second, Third Floor

No	Space	No of Space	Area (sqm)
	SERVICE CORE		
44	M. TOILET	4*31	124
45	H. TOILET		
46	W. TOILET		
47	HUB ROOM	4*19	76
48	LIFT 1	5*11	55
49	LIFT 2		
50	SERVICE STAIR	5*26	130
51	CORRIDOR (ALL FLOORS INC)		332.35
52	OUTDOOR STAIRCASE		105.81
			823.16
	BASEMENT FLOOR AREA		1368
	GROUND FLOOR AREA		1368
	FIRST FLOOR AREA		1085
	SECOND FLOOR AREA		1140
	THIRD FLOOR AREA		1022

Table 17: Area Statement of Service Core

Appendix 2 - Architectural drawings

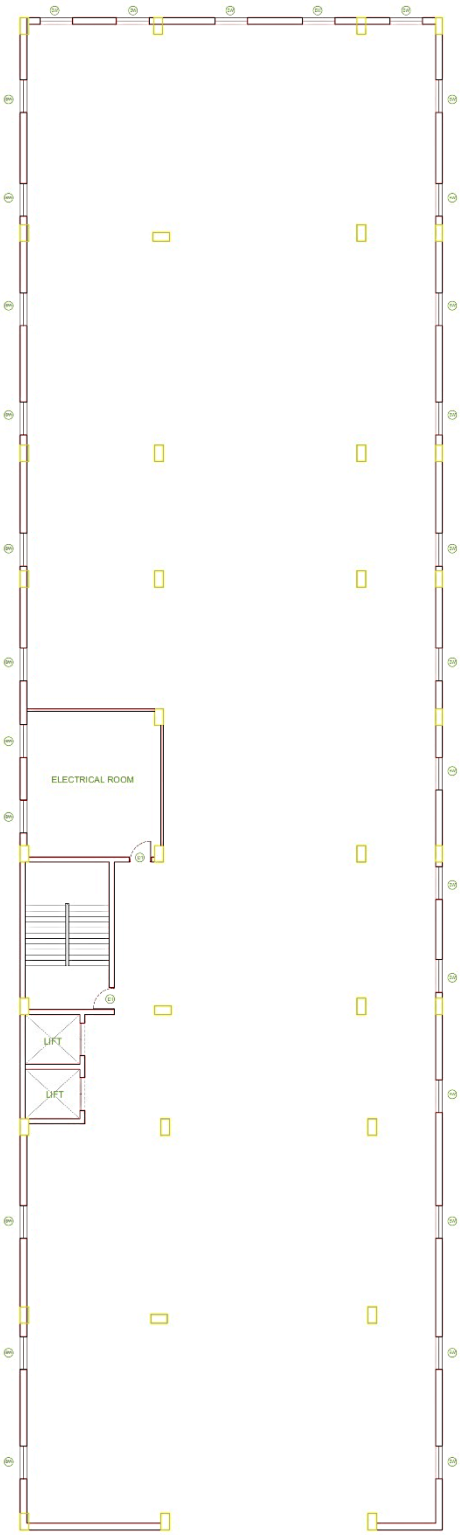


Figure 32: Basement Floor Plan

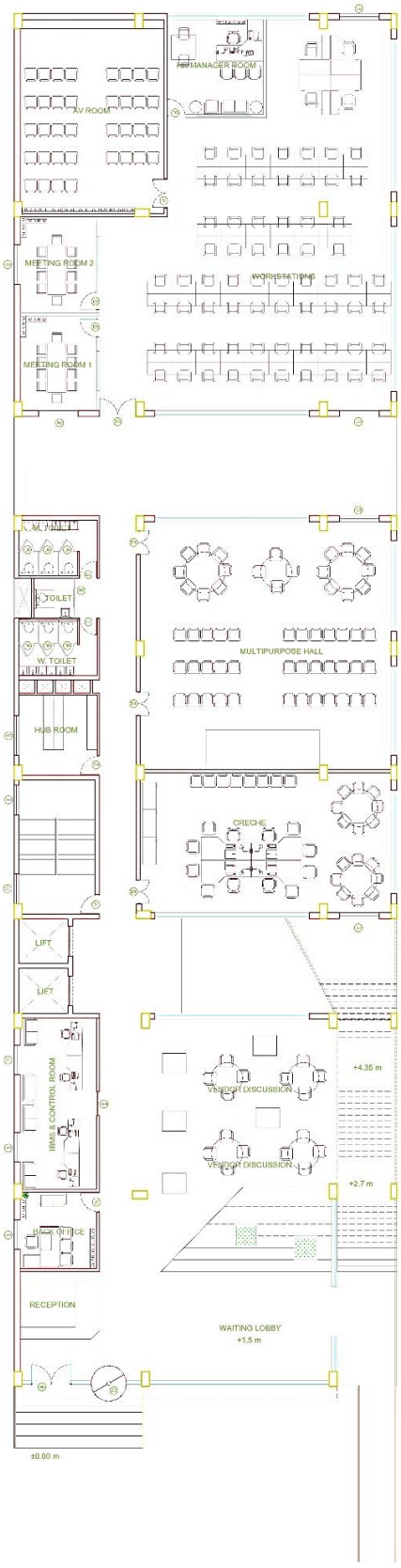


Figure 33: Ground Floor Plan

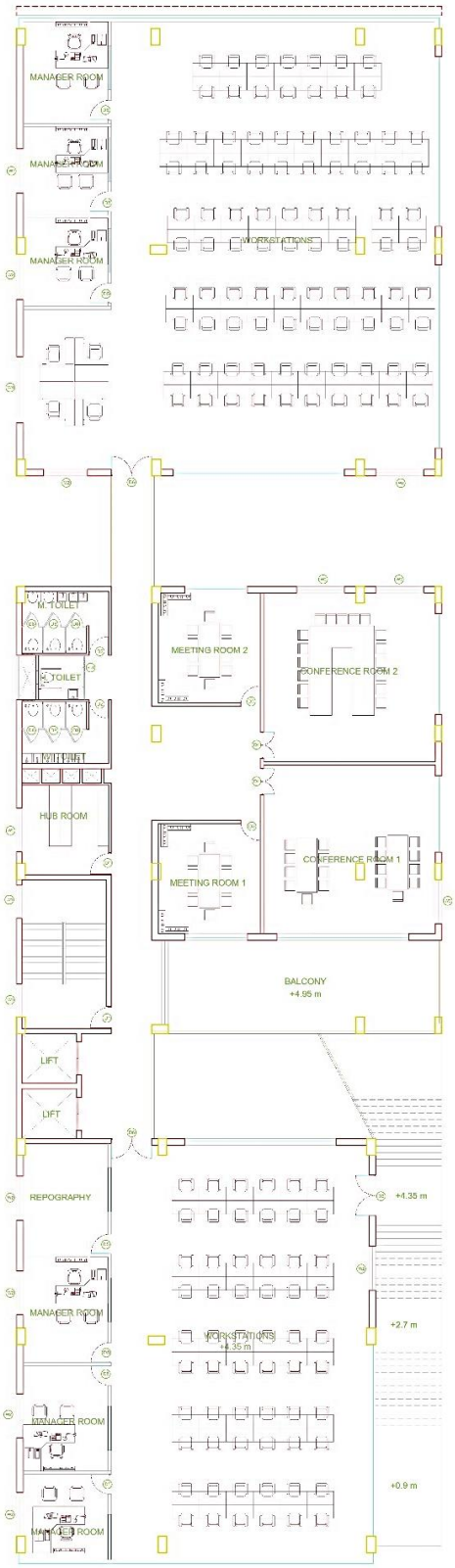


Figure 34: First Floor Plan

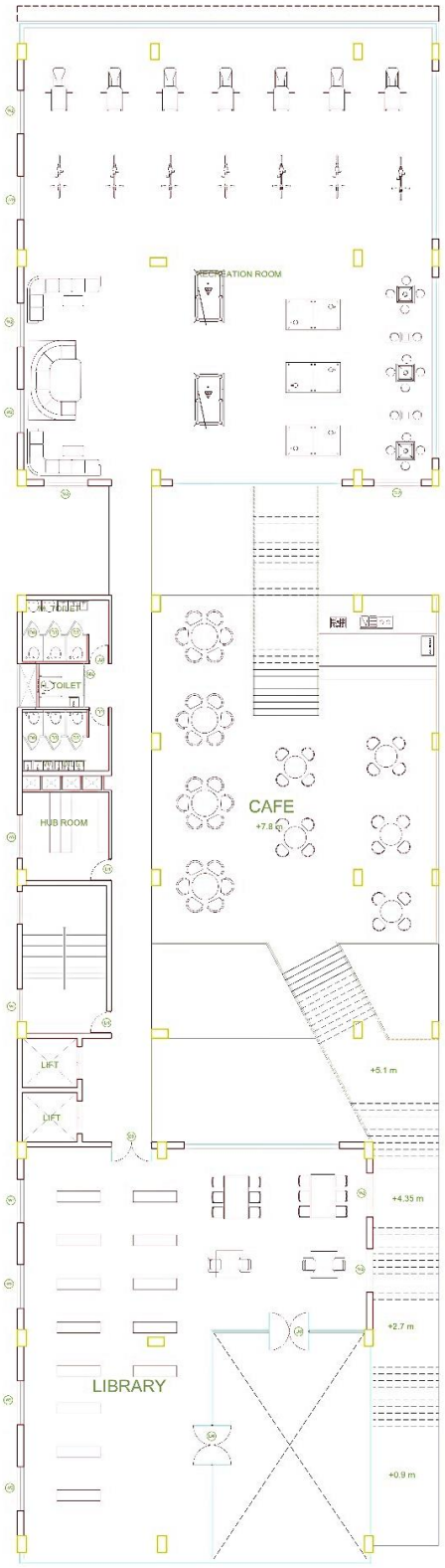


Figure 35: Second Floor Plan

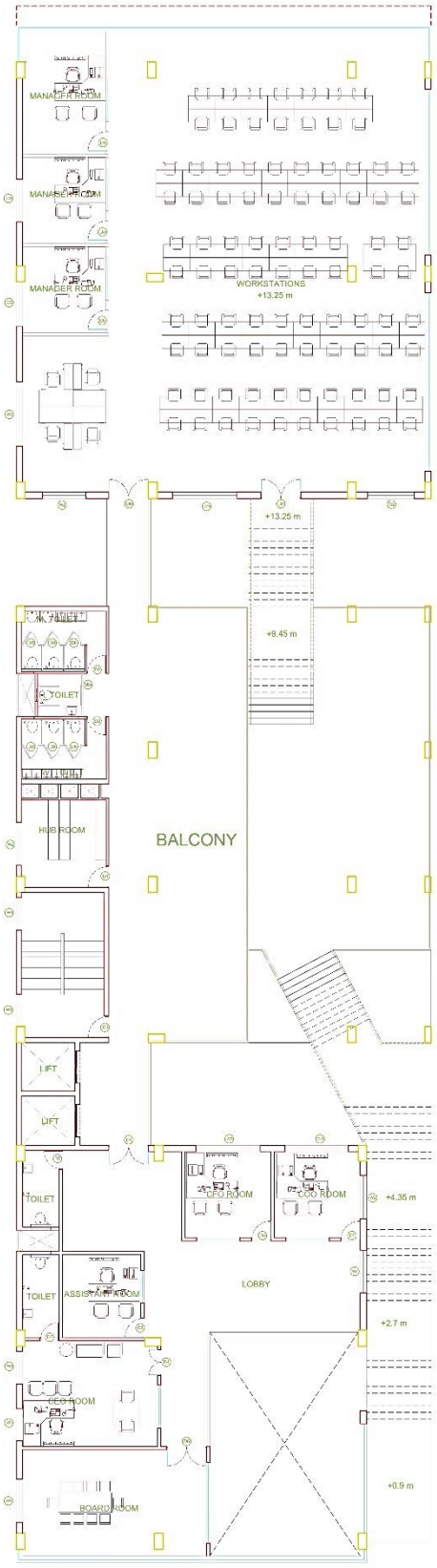


Figure 36: Third Floor Plan

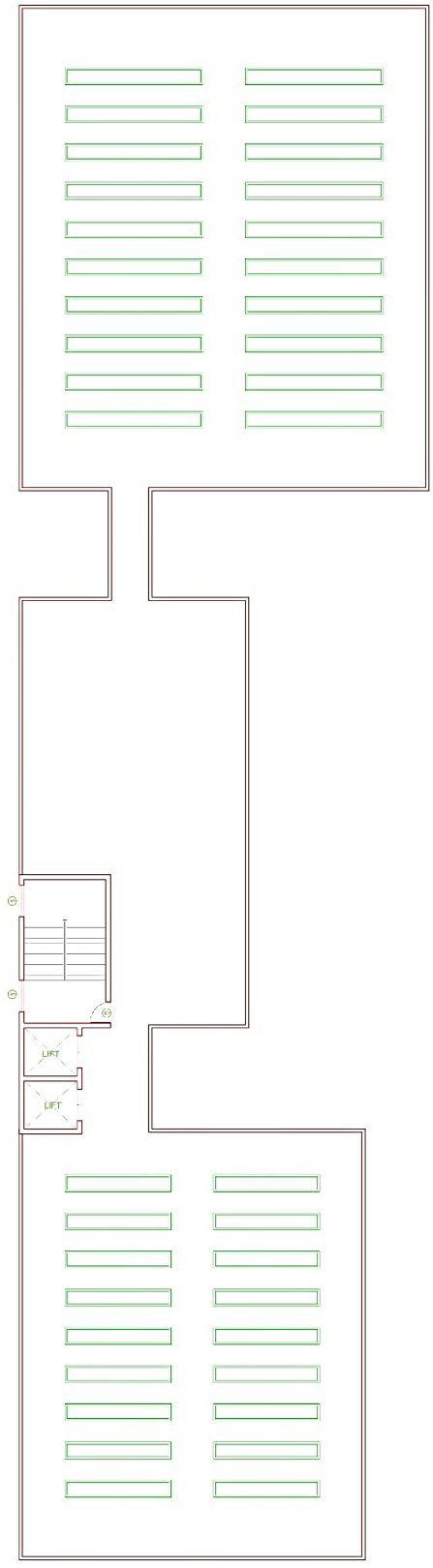


Figure 37: Terrace Floor Plan

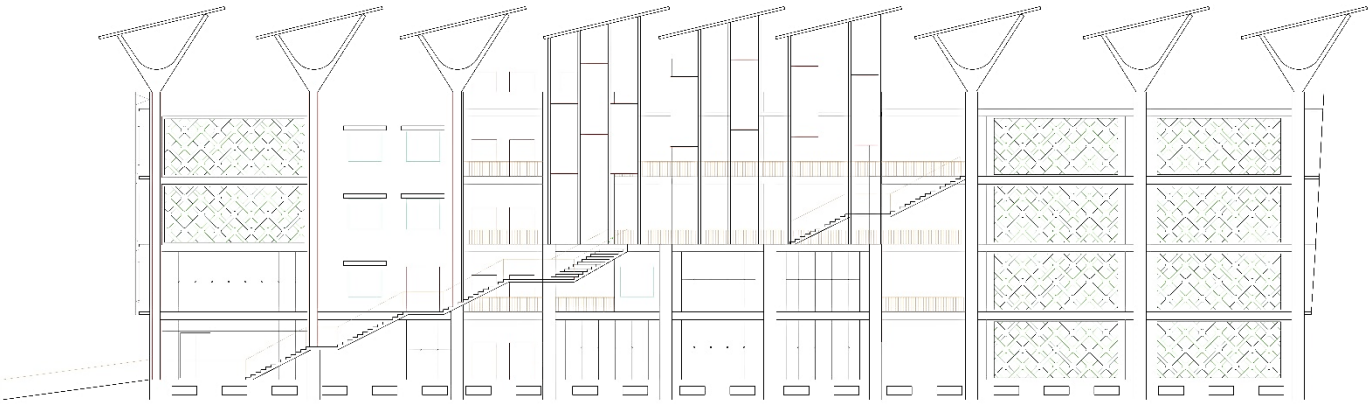


Figure 38: East Elevation

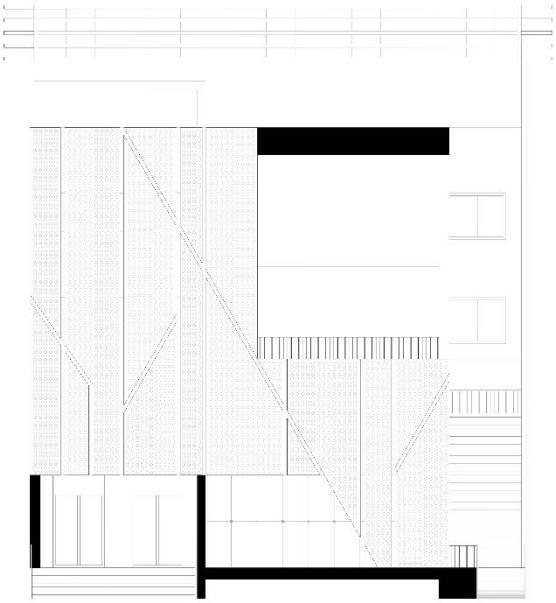
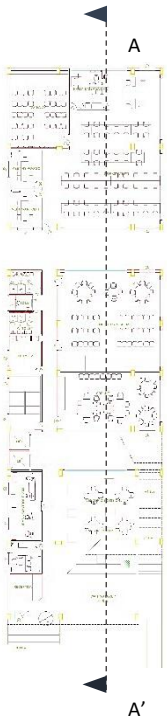


Figure 39:South Elevation



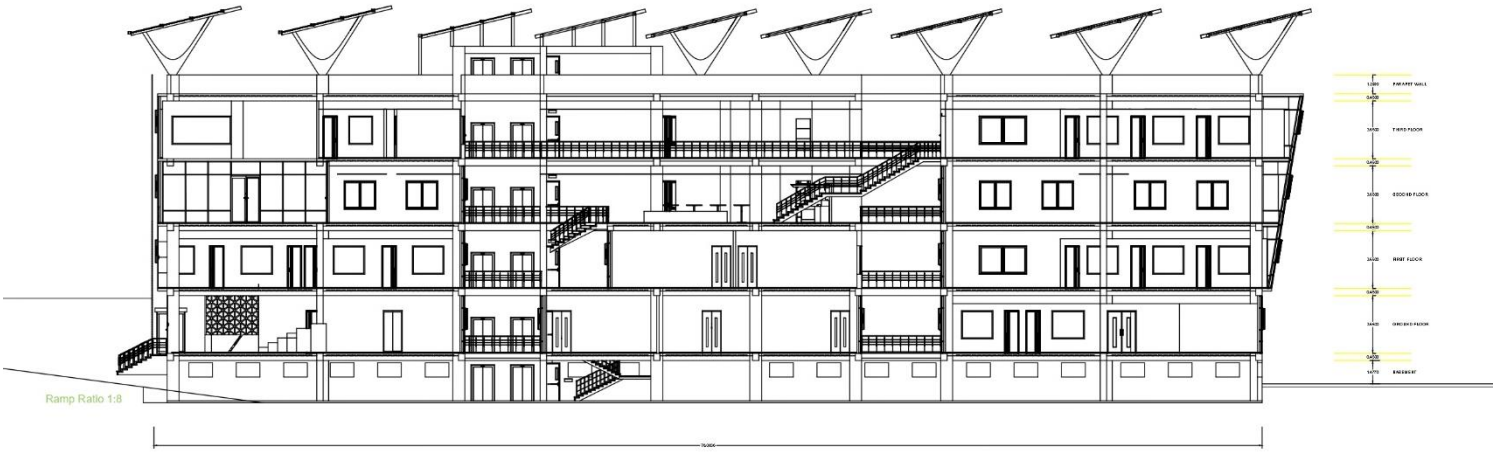


Figure 40: Section AA'

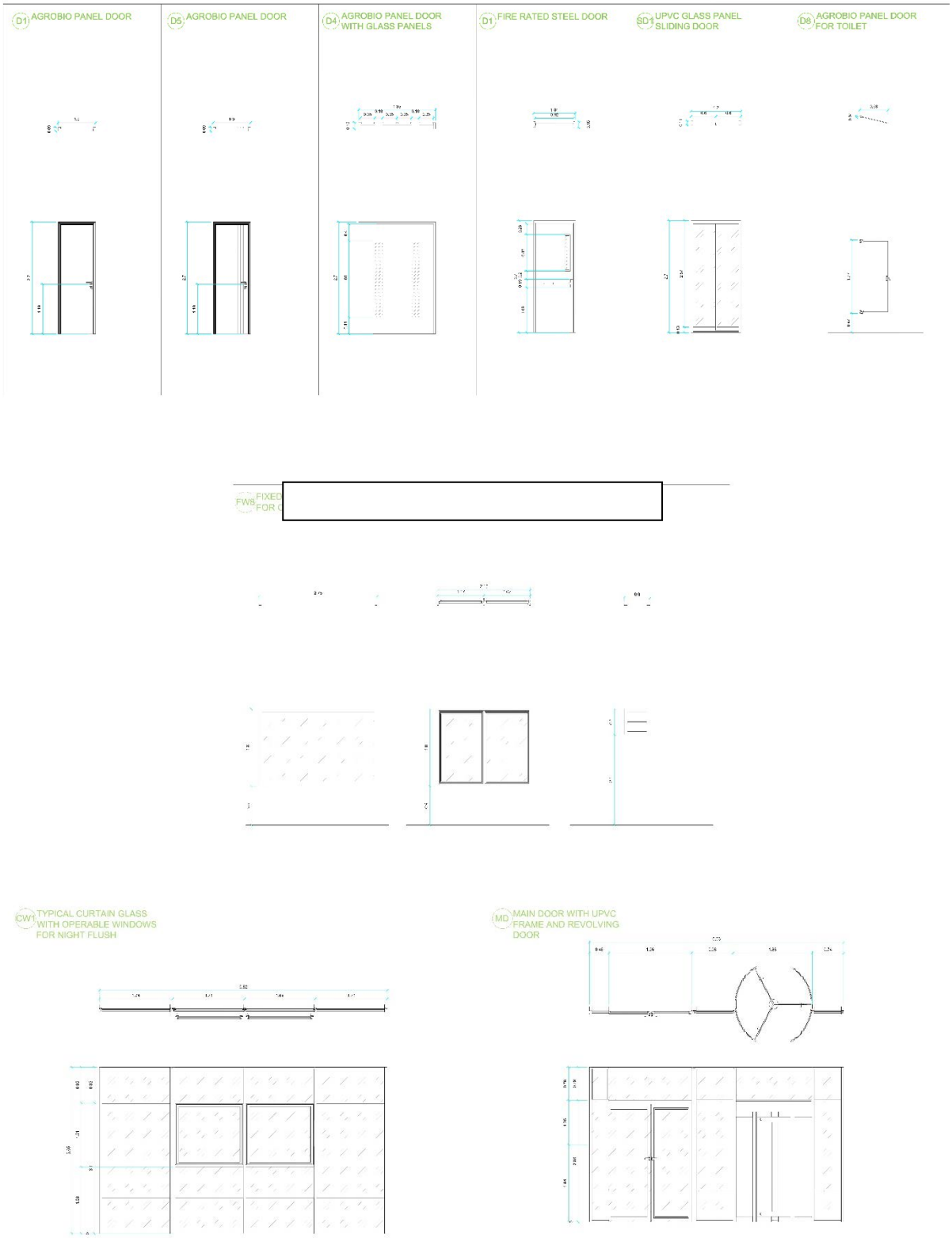


Figure 41:Section AA'

Figure 42: Measurement Drawing

Figure 43: Measurement Drawing

Figure 44: Measurement Drawing

Appendix 3 – Engineering drawings

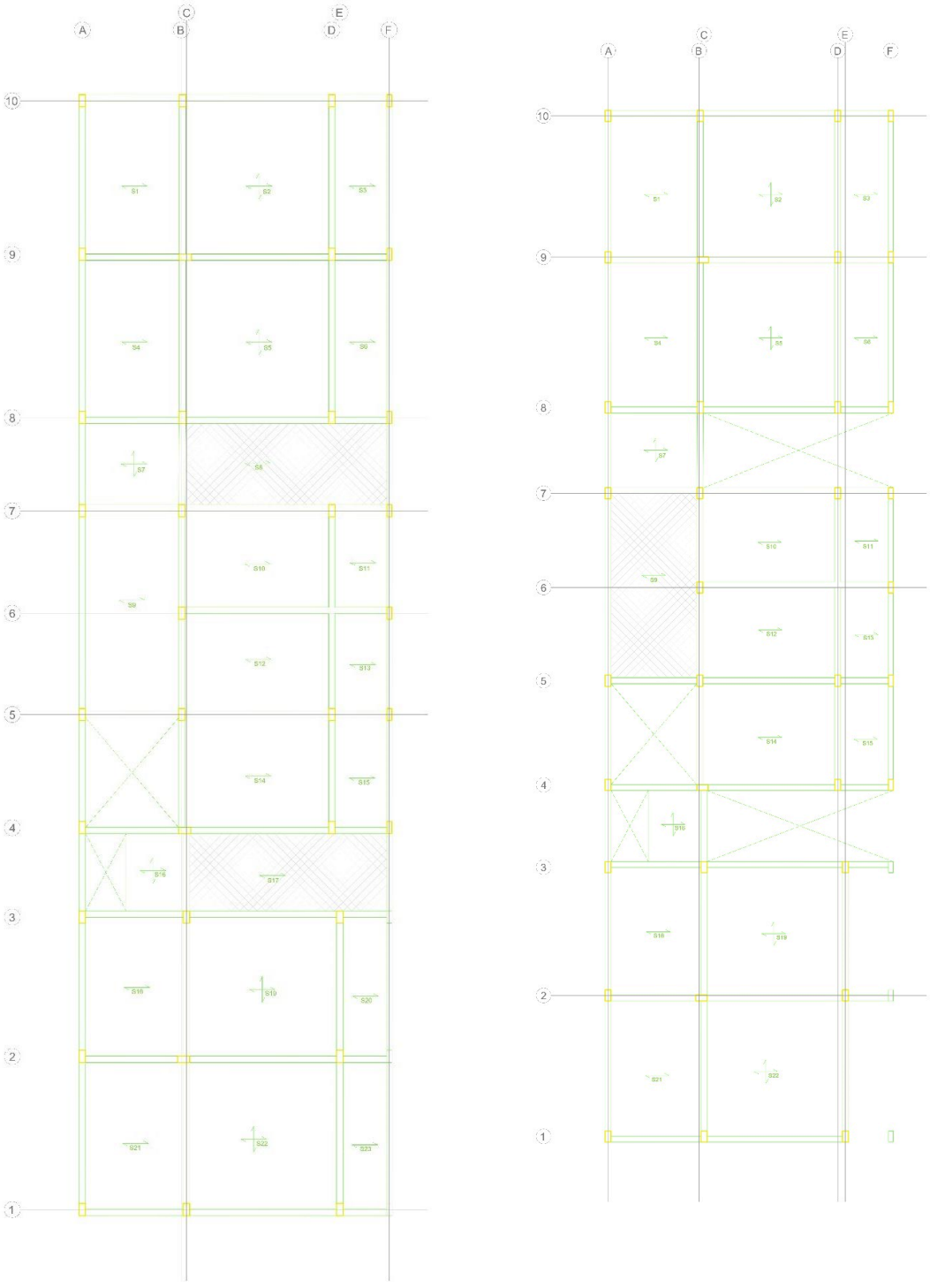


Figure 45: Slab and beam layout

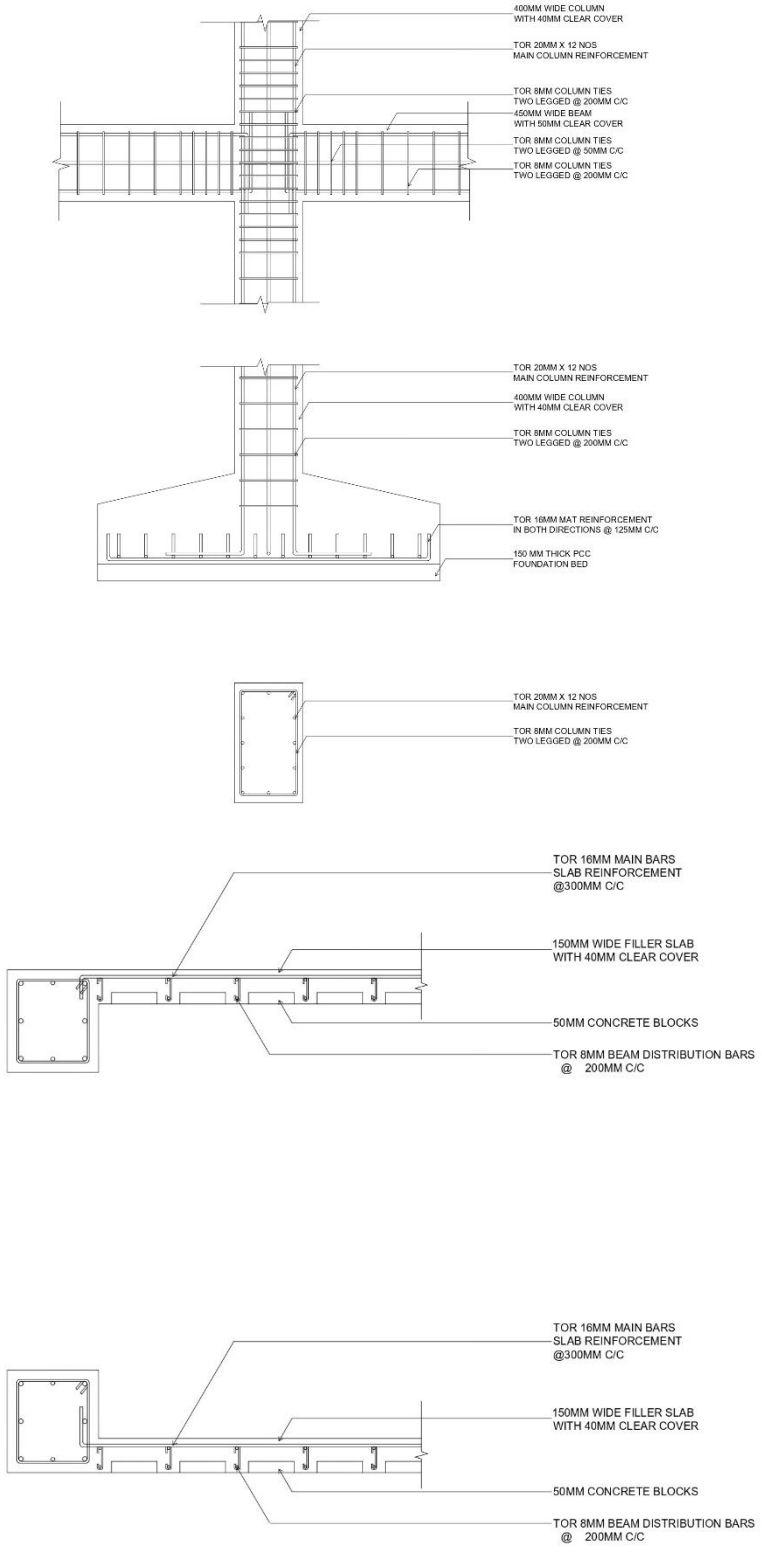


Figure 46: Structural Sections

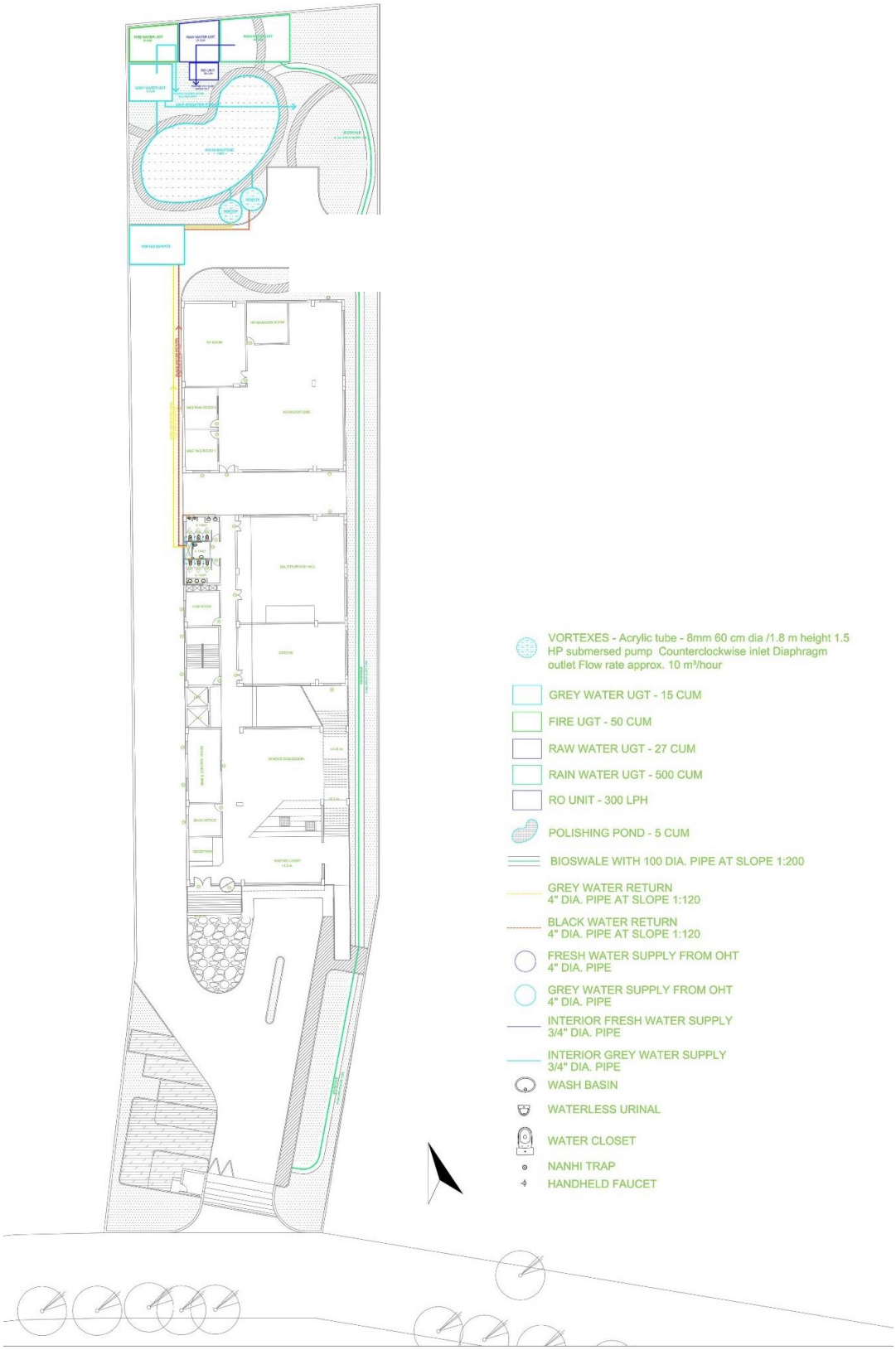
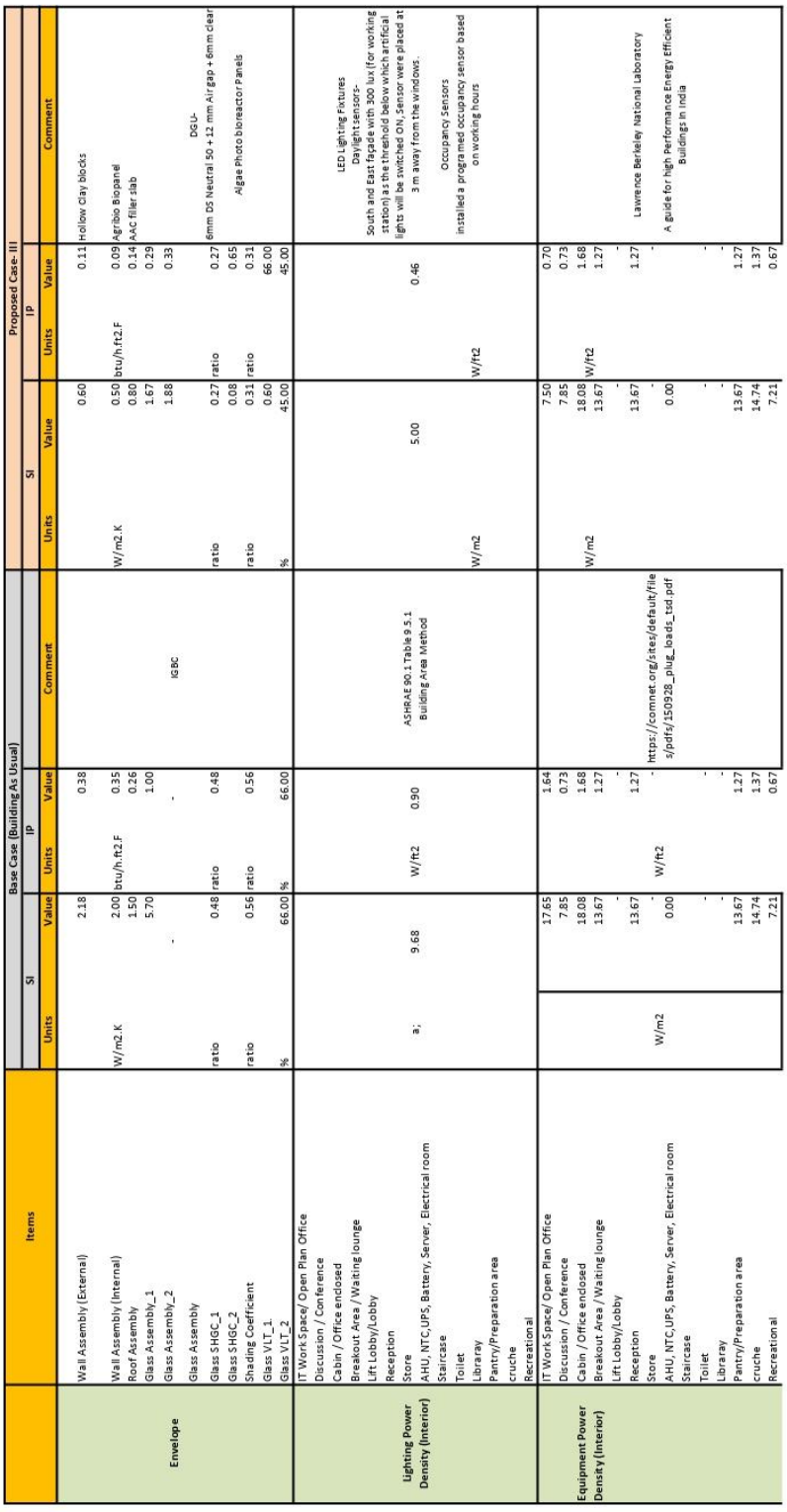
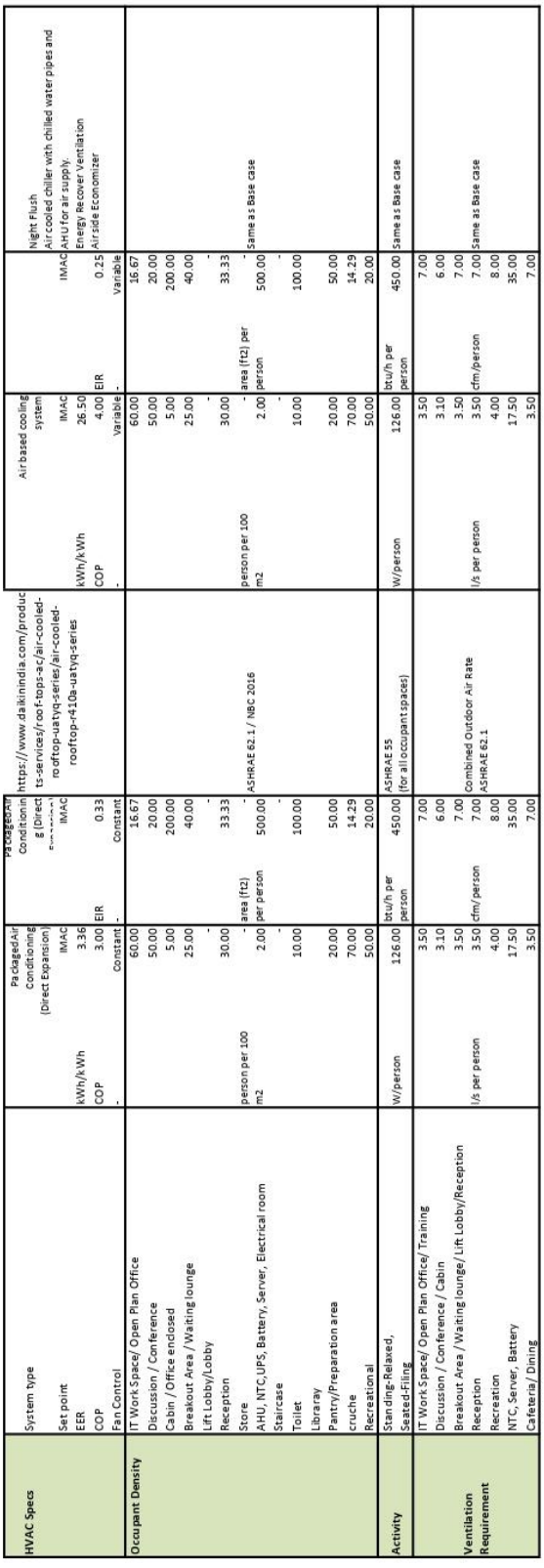


Figure 47: Plumbing Layout

Appendix 4 – Energy simulation inputs



	Items	Base Case (Building As Usual)					Proposed Case- III				
		SI		IP			SI		IP		
		Units	Value	Units	Value	Comment	Units	Value	Units	Value	Comment
Envelope	Wall Assembly (External)		2.18		0.38			0.60		0.11	Hollow Clay blocks
	Wall Assembly (Internal)	W/m2.K	2.00	btu/h.ft2.F	0.35		W/m2.K	0.50	btu/h.ft2.F	0.09	Agrobio Biopanel
	Roof Assembly		1.50		0.26			0.80		0.14	AAC filler slab
	Glass Assembly_1		5.70		1.00			1.67		0.29	
	Glass Assembly_2	-		-		IGBC		1.88		0.33	DGU-
	Glass Assembly										6mm DS Neutral 50 + 12 mm Air gap + 6mm clear
	Glass SHGC_1	ratio	0.48	ratio	0.48		ratio	0.27	ratio	0.27	
	Glass SHGC_2							0.08		0.65	Algae Photo bioreactor Panels
	Shading Coefficient	ratio	0.56	ratio	0.56		ratio	0.31	ratio	0.31	
	Glass VLT_1							0.60		66.00	
	Glass VLT_2	%	66.00	%	66.00		%	45.00		45.00	
Lighting Power Density (Interior)	IT Work Space/ Open Plan Office										LED Lighting Fixtures Daylight sensors- South and East façade with 300 lux (for working station) as the threshold below which artificial lights will be switched On, Sensor were placed at 3 m away from the windows. Occupancy Sensors installed a programed occupancy sensor based on working hours
	Discussion / Conference										
	Cabin / Office enclosed										
	Breakout Area / Waiting lounge										
	Lift Lobby/Lobby										
	Reception										
	Store					ASHRAE 90.1 Table 9.5.1 Building Area Method		5.00		0.46	
	AHU, NTC,UPS, Battery, Server, Electrical room	a;	9.68	W/ft2	0.90						
	Staircase										
	Toilet										
	Libraray						W/m2		W/ft2		
	Pantry/Preparation area										
	crucche										
	Recreational										
Equipment Power Density (Interior)	IT Work Space/ Open Plan Office		17.65		1.64			7.50		0.70	
	Discussion / Conference		7.85		0.73			7.85		0.73	
	Cabin / Office enclosed		18.08		1.68		W/m2	18.08	W/ft2	1.68	
	Breakout Area / Waiting lounge		13.67		1.27			13.67		1.27	
	Lift Lobby/Lobby		-		-			-		-	
	Reception		13.67		1.27			13.67		1.27	
	Store		-		-	https://comnet.org/sites/default/files/pdfs/150928_plug_loads_tsd.pdf		-		-	Lawrence Berkeley National Laboratory A guide for high Performance Energy Efficient Buildings in India
	AHU, NTC,UPS, Battery, Server, Electrical room	W/m2	0.00	W/ft2				0.00			
	Staircase										
	Toilet		-		-			-		-	
	Libraray		-		-			-		-	
	Pantry/Preparation area		13.67		1.27			13.67		1.27	
	crucche		14.74		1.37			14.74		1.37	
	Recreational		7.21		0.67			7.21		0.67	



HVAC Specs	System type		Packaged Air Conditioning (Direct Expansion)		Packaged Air Conditioning (Direct Expansion)		https://www.daikinindia.com/products-services/rooftops-ac/air-cooled-rooftop-uatyq-series/air-cooled-rooftop-r410a-uatyq-series	Air based cooling system		Night Flush Air cooled chiller with chilled water pipes and AHU for air supply; Energy Recover Ventilation Airside Economizer
	Set point		IMAC		IMAC			IMAC		IMAC
	EER	kWh/kWh	3.36					26.50		AHU for air supply;
	COP	COP	3.00	EIR	0.33			4.00	EIR	Energy Recover Ventilation
	Fan Control	-	Constant	-	Constant	-		Variable	-	Airside Economizer
Occupant Density	IT Work Space/ Open Plan Office		60.00		16.67			60.00		16.67
	Discussion / Conference		50.00		20.00			50.00		20.00
	Cabin / Office enclosed		5.00		200.00			5.00		200.00
	Breakout Area / Waiting lounge		25.00		40.00			25.00		40.00
	Lift Lobby/Lobby		-		-			-		-
	Reception		30.00		33.33			30.00		33.33
	Store	person per 100 m2	-	area (ft2) per person	-			-	area (ft2) per person	-
	AHU, NTC,UPS, Battery, Server, Electrical room		2.00		500.00		ASHRAE 62.1 / NBC 2016	2.00		500.00
	Staircase		-		-			-		-
	Toilet		10.00		100.00			10.00		100.00
	Library									
	Pantry/Preparation area		20.00		50.00			20.00		50.00
	cruche		70.00		14.29			70.00		14.29
	Recreational		50.00		20.00			50.00		20.00
Activity	Standing-Relaxed, Seated-Filing	W/person	126.00	btu/h per person	450.00		ASHRAE 55 (for all occupant spaces)	126.00	btu/h per person	450.00
Ventilation Requirement	IT Work Space/ Open Plan Office/ Training		3.50		7.00			3.50		7.00
	Discussion / Conference / Cabin		3.10		6.00			3.10		6.00
	Breakout Area / Waiting lounge/ Lift Lobby/Reception		3.50		7.00			3.50		7.00
	Reception	l/s per person	3.50	cfm/person	7.00		Combined Outdoor Air Rate	3.50	cfm/person	7.00
	Recreation		4.00		8.00		ASHRAE 62.1	4.00		8.00
	NTC, Server, Battery		17.50		35.00			17.50		35.00
	Cafeteria/ Dining		3.50		7.00			3.50		7.00

Figure 48: Energy Simulation Inputs

https://docs.google.com/spreadsheets/d/1b71DWn_FJRsKrZ3ZJ4xm3D5EaP4I41gL/edit?usp=sharing&ouid=108340848250037805143&rtpof=true&sd=true

Appendix 5: Energy Output table

File has been linked from drive:

https://drive.google.com/file/d/14izgAKHs4l5qez0aPcyoZw8Jy2sORxQT/view?usp=sharing

Appendix 6 – Net-zero water-cycle design and calculations

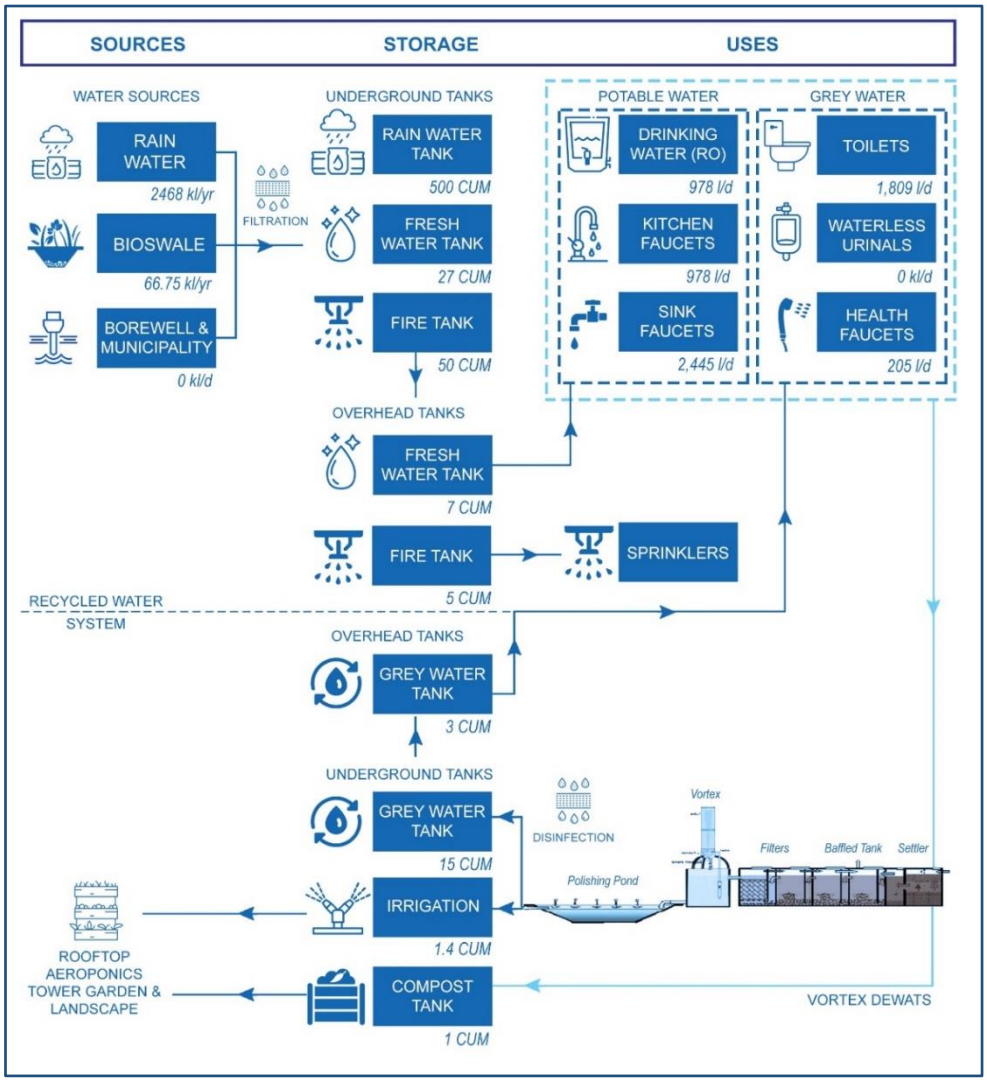


Figure 49: Water Schematic Drawings

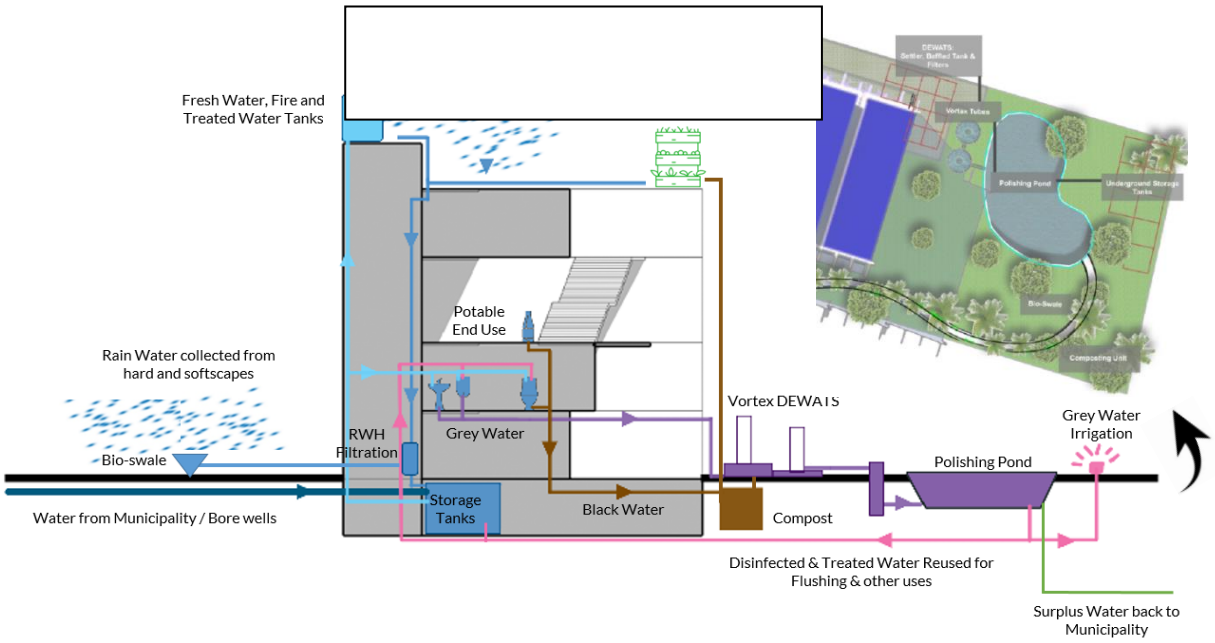


Figure 50: Schematic Drawing of water performance

Appendix 7 – Cost Estimate Summary

S.No.	Particulars	Definition	Baseline Estimate (Project Partner / SOR basis)			Proposed Design Estimate		
			Amount (Million INR)	%	Amount (INR per sqm)	Amount (Million INR)	%	Amount (INR per sqm)
1	Land	Cost of land purchased or leased by the Project Partner	0.00	0.0%	-	0.00	0.0%	-
2	Civil Works	Refer Item A, Civil works in Cost of construction worksheet	6464.51	27.8%	80,80,632	5253.48	19.9%	65,66,854
3	Internal Works	Refer Item B, Civil works in Cost of construction worksheet	4589.21	19.8%	57,36,507	4696.57	17.8%	58,70,708
4	MEP Services	Refer Item C, Civil works in Cost of construction worksheet	312.67	1.3%	3,90,835	0.00	0.0%	-
5	Equipment & Furnishing	Refer Item D, Civil works in Cost of construction worksheet	5290.95	22.8%	66,13,683	5290.93	20.0%	66,13,657
6	Landscape & Site Development	Refer Item E, Civil works in Cost of construction worksheet	4420.09	19.0%	55,25,115	8676.90	32.8%	1,08,46,125
7	Contingency	Amount added to the total estimate for incidental and miscellaneous expenses.	2107.74	9.1%	26,34,677	2475.18	9.4%	30,93,972
	TOTAL HARD COST		**23,185.2**	**100%**	**######**	**26,393.1**	**100%**	**3,29,91,316**
8	Pre Operative Expenses	Cost of Permits, Licenses, Market research, Advertising etc	10.00	0.0%	12,500	10.00	0.0%	12,500
9	Consultants	Consultant fees on a typical Project	10.00	0.0%	12,500	10.00	0.0%	12,500
10	Interest During Construction	Interest paid on loans related to the project during construction	20.25	0.1%	25,318	11.72	0.1%	14,653
	TOTAL SOFT COST		**40.3**	**0%**	**50,318**	**31.7**	**0%**	**39,653**
	TOTAL PROJECT COST		**23,225.4**	**100%**	**######**	**26,424.8**	**100%**	**3,30,30,968**

Table 18: Estimate Summary

Appendix 8 – Embodied Carbon calculations

ummary		Base Case					Proposed case				
				Manufacturer to supplie	Supplier to site				Manufacturer to supplie	Supplier to site	
	1	Structures	Material Emission (kg -CO2 e)	Transportation 1 Emission (kg -CO2 e)	Transportation 2 Emission (kg -CO2 e)	Overall Emission	Structures	Material Emission (kg -CO2 e)	Transportation 1 Emission (kg -CO2 e)	Transportation 2 Emission (kg -CO2 e)	Overall Emission
tures Summary		Steel reinforcement (stee	256819.8984	1145.482598	47.92325155		Steel reinforcement (stee	214016.582	954.5688318	39.93604296	
uction of 18.3% of		Cement (ordinary Portlar	234909.2944	195.8050714	43.37647447		Cement (ordinary Portlar	187927.74	156.6443109	34.7012358	
nission is seen in		M-sand	10890.14638	90.20671251	801.8374446		Aggregate (mixed gravel/	4.967605269	0.04114833	0.365762936	
roposed case		Aggregate (mixed gravel/	8.096763108	0.067068188	0.596161669		Recycled Aggregate Conc	0.3355	0	0.05955125	
			502627.4359	1431.56145	893.7333323	504952.7307	M-sand	8712.117104	72.16537001	641.4699557	
								410661.7422	1183.419661	716.5325486	412561.6944
	2	Floors	Material Emission (kg -CO2 e)	Transportation 1 Emission (kg -CO2 e)	Transportation 2 Emission (kg -CO2 e)	Overall Emission	Floors	Material Emission (kg -CO2 e)	Transportation 1 Emission (kg -CO2 e)	Transportation 2 Emission (kg -CO2 e)	Overall Emission
		Steel reinforcement (stee	113134.2358	504.6077003	21.11113848		Steel reinforcement (stee	94278.5298	420.5064169	17.5926154	
		Cement (ordinary Portlar	222246.985	184.9615933	41.03835352		Cement (ordinary Portlar	197249.5325	164.4143493	36.42252356	
ors Summary		Aggregate (mixed gravel/	4426.62264	36.66719087	325.9305855		Aggregate (mixed gravel/	5.4189432	0.044886913	0.398994781	
uction of 0.998%		M-sand	6.1056864	0.048167082	0.449559428		M-sand	3928.73382	32.54301181	289.2712161	
emission is seen		Vitrified ceramic floor til	63214.06752	363.0160789	28.60126682		AAC	13223.275	9.311570125	0	
proposed case		Cement (ordinary Portlar	820754.3635	683.0600417	683.0600417		Granite	84308.499	0	8.045569125	
		M-sand	49042.32804	406.2339506	406.2339506		Cement (ordinary Portlar	820754.3635	0	0	
			1272824.708	2178.594723	1506.424896	1276509.728	M-sand	49042.32804	0	0	
								1262790.681	626.8202351	351.7309189	1263769.232
	3	Roof	Material Emission (kg -CO2 e)	Transportation 1 Emission (kg -CO2 e)	Transportation 2 Emission (kg -CO2 e)	Overall Emission	Roof	Material Emission (kg -CO2 e)	Transportation 1 Emission (kg -CO2 e)	Transportation 2 Emission (kg -CO2 e)	Overall Emission
		Steel reinforcement (stee	23181.34878	336.0609734	39.92953035		Steel reinforcement (stee	23181.34878	103.3947595	4.325699122	
		Cement (ordinary Portlar	41490.40896	12.1583616	7.661287603		Cement (ordinary Portlar	36315.63936	30.2231255	6.705755971	
oof Summary		Aggregate (mixed gravel/	1.1398464	0.029226831	0.774705861		Aggregate (mixed gravel/	0.9976824	0.072651744	0.678082944	
rease of 16.6% of		M-sand	826.38864	21.18945231	561.6617492		M-sand	723.31974	5.70618906	53.25776456	
nission is seen in		Cement (ordinary Portlar	4827.993206	1.414796544	0.878942353		AAC	2737.375	1.101337208	0	
oposed case.		M-sand	144.2429289	4.006748025	10.62055343		Cool-roof tile	17565.40776	146.7228178	7.030468351	
			70471.52236	374.8595587	621.5267688	71467.90869	Cement (ordinary Portlar	4561.290115	3.796062689	3.321554853	
							M-sand	272.54961	2.15011359	2.15011359	
								85357.92805	293.167057	77.46943939	85728.56454
	4	Fenestration	Material Emission (kg -CO2 e)	Transportation 1 Emission (kg -CO2 e)	Transportation 2 Emission (kg -CO2 e)	Overall Emission	Fenestration	Material Emission (kg -CO2 e)	Transportation 1 Emission (kg -CO2 e)	Transportation 2 Emission (kg -CO2 e)	Overall Emission
		Toughened glass	40716.39	45.345144	4.1566382		u-PVC window frame	5523.258	8.429577477	0.234620447	
nerstration		Aluminum extruded profi	3243144.135	742.4513238	20.51704453		Toughened glass	306824.025	403.5564967	36.99267887	
Summary		u-PVC window frame	27842.8403	26.18892799	1.630471968		AgriBiopanel	-7791.6644	1.901117868	0	
uction of 48.7% of			3311703.366	813.9853958	26.3041547	3312543.655		304555.6186	413.8871921	37.22729931	305006.7331
nission is seen in											
proposed case							Toughened glass	11893.44	15.53759002	1.424279085	
							Aluminum extruded profi	1373970	314.5422475	8.754655	
								1385863.44	330.0798375	10.17893408	1386203.699
	5	Wall	Material Emission (kg -CO2 e)	Transportation 1 Emission (kg -CO2 e)	Transportation 2 Emission (kg -CO2 e)	Overall Emission	Wall	Material Emission (kg -CO2 e)	Transportation 1 Emission (kg -CO2 e)	Transportation 2 Emission (kg -CO2 e)	Overall Emission
lls Summary		Brick - High draught/zigz	517069.5987	320.2617865	301.0460793		Honeycomb brick	49717.5551	109.3685775	0	
reduction of		Cement (ordinary Portlar	119165.9156	99.32893742	22.00422639		AgriBiopanel	-57326.686	9.006525015	0	
1422% of CO2		M-sand	4254.417209	313.2511634	313.2511634		Fiber cement board	1252.1974	20.23876773	0	
ion is seen in the		Fiber cement board	1252.19904	20.23879424	0.72281408		BOF Steel	480.984	1.9920754	0	
roposed case		BOF Steel	480.984	1.9920754	0		Cement	23351.17075	18.52269607	4.251110573	
					0		M-sand	697.648302	5.503669938	51.36758609	
			642223.1145	755.0727569	637.0242831	643615.2115		18172.86955	164.6323117	55.61869666	18393.12056

Table 19: Embodied Carbon calculation summary

Material	T1 - Manufacturers to distributers		T2 - Distributers to site	
	Distace	Source	Distace	Source
Cement	64.1 Km	https://rb.gy/vpk8	14.2 Km	https://rb.gy/3rat
M-sand	6.3 Km	https://rb.gy/024pi	56 Km	https://rb.gy/9iqgh
Steel	980 Km	t.ly/iEBo	41 Km	t.ly/DMu0
Brick	20 Km	Assumed upper limit	18.8 Km	https://rb.gy/1j5x7
Hollow clay block	61.5 Km	https://rb.gy/3qfae	-	-
AgriBio Panel	666 Km	https://rb.gy/lq7ts	-	-
Fibre cement board	560 Km	t.ly/xknx	-	-
uPVC	310 Km	t.ly/CRUw	19.3 Km	t.ly/2ZDM
Aluminium	503 Km	https://rb.gy/qotb	13.9 Km	https://rb.gy/un3v
Glass	276 Km	https://rb.gy/nd6t	25.3 Km	https://rb.gy/yrzb
AAC block	560 Km	t.ly/xknx	-	-
Granite Tiles	58.6 Km	https://rb.gy/yfn84	2.5 Km	https://rb.gy/9dz6p
Vitrified tiles	330 Km	https://rb.gy/qohfl	42.6 Km	https://rb.gy/2b563
Recycled Aggregate Concrete	30 Km	Assumed radius of procurement from the city		
Cool Roof tiles	480km	https://rb.gy/l1ocz	23.5 Km	https://rb.gy/gjij7

Table 20: Material sources and their distance

Links to Working files -

Carbon calculation tool - https://drive.google.com/file/d/1gKY1MQgJWtKZrOGnbpeqb29sO3WBQqCd/view?usp=sharing

Material final weight - https://docs.google.com/spreadsheets/d/15IIo1NWvCUI5f4THv7VbdiPv9-8IU0fu/edit?usp=sharing&ouid=108340848250037805143&rtpof=true&sd=true

Material Volume calculation –

https://docs.google.com/spreadsheets/d/15IIo1NWvCUI5f4THv7VbdiPv9-8IU0fu/edit?usp=sharing&ouid=108340848250037805143&rtpof=true&sd=true

Appendix 9: Cooling Load Estimate

HEAT LOAD ESTIMATE		
TITLE		Standard design
LOCATION		BENGALURU
LATITUDE		12.58°N
SPACE		OFFICE
AREA - Sq.ft	Conditioned area	32538
HEIGHT - ft		13.0

SOLAR GAIN - GLASS						
Item	Direction	Area (ft^2)	ΔT (°F)	Correction fator	SHGC	BTU / Hour
Glass	N	4313	39	1.3	0.69	145297
Glass	NE		11	1.3	0.52	0
Glass	E	1786	11	1.3	0.27	6639
Glass	E	2701.001	11	1.3	0.6	22317
Glass	S	4337	11	1.3	0.27	16127
Glass	SW		66	1.3	0.52	0
Glass	W	1282	158	1.3	0.27	68453
Glass	NW		158	1.3	0.52	0
Skylight						0

SOLAR & TRANSMISSION GAIN - WALL & ROOF						
Item	Direction	Area (ft^2)	ΔT (°F)	Correction fator	U-value	BTU / Hour
Wall	N	1572	4	3	0.30	3301
Wall	NE		10	3	0.14	0
Wall	E	3146	18	3	0.11	7268
Wall	SE		18	3	0.14	0
Wall	S	1999	16	3	0.11	4178
Wall	SW		14	3	0.14	0
Wall	W	5273	12	3	0.11	8701
Wall	NW		6	3	0.14	0
Roof		10550	32	3	0.19	70159

TRANSMISSION GAIN EXCEPT WALLS & ROOF					
Item		Area (ft^2)	ΔT (°F)	U-value	BTU / Hour
All Glass		14419	19.5	0.15	43399
Door		1107	19.5	0.09	1943
Partition		12228	14.5	0.09	15957
Ceiling		33443	14.5	0.14	67889
Floor		33443	14.5	0.14	67889

INTERNAL SENSIBLE HEAT						
	Quantity	Unit rates				BTU / Hour
People	345	245				84525
Equip (W)	23410	3.41			1	79828
Lights (W)	18048	3.41			1	61544
Supply air fan gain	5%					38771

INTERNAL LATENT HEAT						
	Quantity	Unit rates				BTU / Hour
People	345	205				70725

OUT SIDE AIR HEAT						
	Flow rate (CFM)	ΔT(°F) & Δg/lb	Convesion factor			BTU / Hour
Sensible	41219	19.5	1.08			868072
Latent	41219	5.0	0.68			140145
					Total Room Sensible heat	1682259
					Total Room Latent heat	210870
					Grand total heat, BTU/hr	1893128
					AIR CONDITIONING TONNAGE	157.76

	Standard	Efficient	% reduction
Envelope	1352989	549519	59.4%
Equipment	273384	118599	56.6%
Lights	102634	61544	40.0%
People	155250	155250	0.0%
Fresh air	1008217	1008217	0.0%

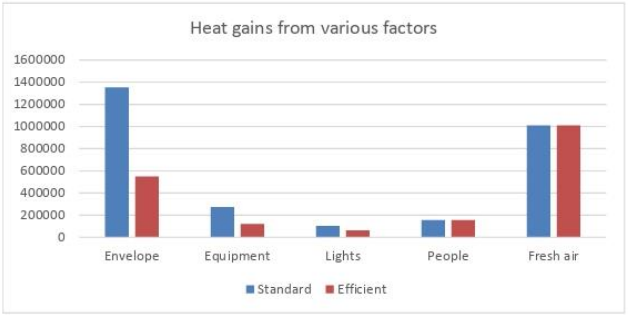
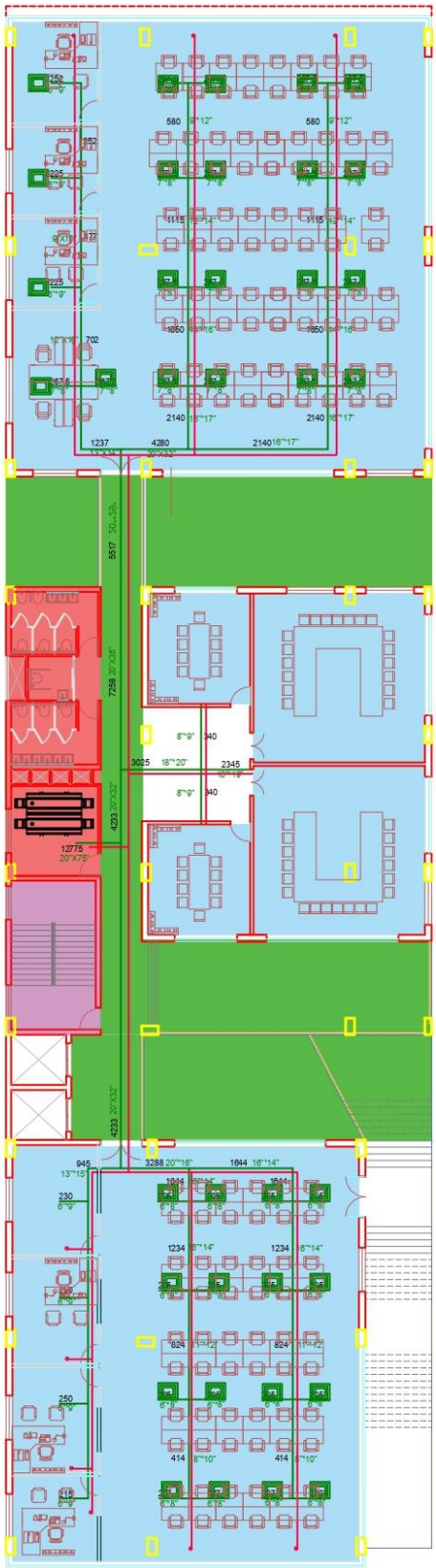
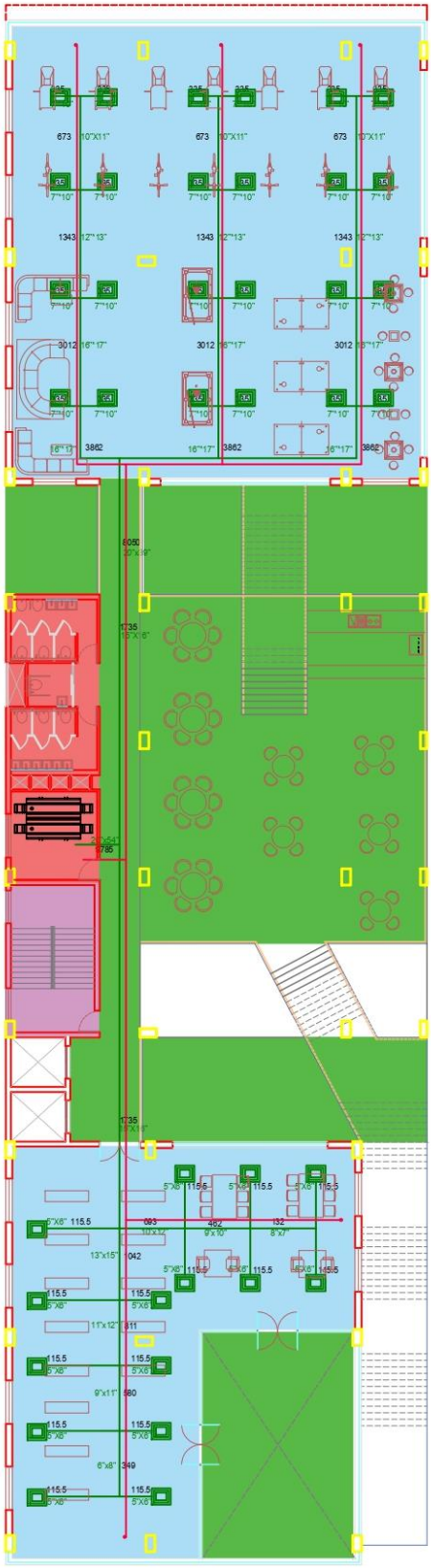


Figure 51: Cooling Load Calculations

Appendix 10: Mechanical and Electrical Layout





FAN FORCED VENTILATION
POSITIVE PRESSURISED ZONE
NEGETIVELY PRESSURIZED ZONE
AIR CONDITIONED ZONE
FRESH AIR
RETURN AIR DUCT
SUPPLY AIR DUCT