Solar™ Decathlon India

STUDENTS ISHRAE TEAM NIVAS

IEM
INSTITUTE OF ENGINEERING & MANAGEMENT
Good Education, Good Jobs

INSTITUTE OF ENGINEERING & MANAGEMENT ,KOLKATA

Team Nivas

Competition Division:Multi-family Housing

Project Partner:

MAHINDRA LIFESPACES

Mahindra Lifespaces

Final Design Report -April 2021

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Executive Summary:

Team NIVAS from IEM Kolkata, India has come up with a reform in the multi-family housing sectors with a net-zero energy building solution in Bangalore with a temperate climate. Our multidisciplinary team of fifteen members from different backgrounds along with the technical support from faculty advisor and industry partners identified the team differences as strength and directed the project towards a net-zero energy efficient and affordable building.

About project-Mahindra Lifespaces (MLDL) intends to develop an area of 7.88 Acres, bearing Survey No.49 & 50/2, Vajrahalli Village, Uttarahalli Hobli, Bangalore South Taluk, Bangalore Metropolitan Area as a Premium segment residential development.

Building Category- Residential Building	Specific Targets- Platinum Rating (IGBC GREEN HOMES)
Total built Up area- 31889.23 SQM(7.88Acre)	FAR -2.25(Achieved 2.243)
Project Timeline-36 months	Estimated Project cost- Rs 275 Cr
Target EPI- 50 KW-h/m2	Number of Towers- 4 (A, B, C, D)
Renewable energy Estimation- 40 to 75 kWh	Phase of Development- Phase 1 & 2

Contests	**Description**
Energy Performance	• In proposed design case overall EPI reduction achieved is 44.67% (tower A) & 50.99% (Tower B) with overall intervention and High performance SGU glass (Natura Plus) with 1m shading meets both the requirements of daylight and EPI reduction. • Optimistic Scenario of Roof top generation achieved is 26.02%.
Water performance	• Using low flow rate plumbing fixtures and the various water conservation measures, overall water reduction achieved is around 32%, 40% & 50% for three scenarios and project is Water Positive Site.
Resilience	• Strong Wi-Fi network through Network resilience analysis assurance and Structural resilience for wind pressure and seismic effect analysis.
Affordability	• Cost effective material selection like affordable glass and other energy and water saving measures to make the project affordable with saving in energy annually 5745878 INR for Two Tower only.
Innovation	• Developed Smart Lifespace app for IAQ, water & energy real time monitoring and Web based energy predictor. Turbo Wind catchers concept have been integrated.
Scalability and market potential	• Kanakapura has easy connectivity to the electronic city, basic amenities and good social infrastructure (Kanakapura range- INR 4,800-5,200/-/sq ft)
Comfort and environmental quality	• 100% comfort;4915 hours is in comfort without aid and balance with aid. • PMV analysis, Internal and External CFD, Natural ventilation analysis were performed.

Architectural design	• ECO NIWAS SAMHITA CODE COMPLIANCE building with RETV<15
Engineering design and operation	• Electrical load estimation, HVAC designing for clubhouse, Solid waste management sustainable option explored.

TEAM INTRODUCTION:

Our Team

Team NIVASis a multidisciplinary team of 15 dynamic Students skilled in various core engineering domains(Architecture, Civil, Mechanical, Electrical and Electronics) from Institute of Engineering & Management,Kolkata(lead institution), OmDayal Group of Institutions, West Bengal India, Jalpaiguri Government EngineeringCollege, West Bengal, India (Partner member institutes) registered in the competition division **Multi-family Housing.**

TEAM MEMBERS:

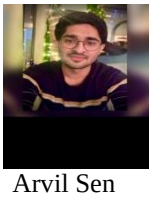
Vaishanavi Prasad (Team lead), V.Aditya, Debjit Guha,OindrilaDasgupta, Mahasweta Das, SrijaniDas, Agnibha Ghosh,Shweta Bharti, HadeeqaNishat, Aditya Pratyush,SrijitGanguly,RaubinsKumar,Akshay Kumar,Arijit Ganguly, Aman Kumar.

Extended Team Support:

Tina Soni
NIT RAIPUR

Homesh Nagpure
NIT RAIPUR

Noyonika Mukherjee
IEM, KOLKATA



Arvil Sen
IEM, KOLKATA

Riya Kumari
IEM, Kolkata

Priyanshu Banerjee
IEM, KOLKATA

Institution Profile:

Institute of Engineering & Management (IEM), Kolkata is the first and the oldest private engineering college in the West Bengal state. It is the 3rd best engineering college in the state as per initial given MHRD ranking and also with latest ranking; holding position within top 200. It is a NAAC 'A' grade college having 30+ years of academics. It offers both Undergraduate and Postgraduate Engineering and Management courses under AICTE, Govt. of India & affiliated to MAKAUT.

Faculty lead

Dr. S.C. Murmu

Mr.Pinaki Mukherjee

Dr. Rahul Baidya

Mr.Debashish Ghosh

Industry Partner	Point of Contact	Segment
Cype	Mr. Jahn Paul	Resilience
Design2occupancy	Mr.Anuj Gupta	Energy management
Inner Engineering	Miss Anjali Kulkarni	Insulation
Asahi India Glass Ltd. (AIS)	Mrs Garima Kamra	Glass selection
Arosia (Hydrotec Solutions)	Mr. Navin Gupta	Water
WEGoT Utility Solutions	Mr. AbilashHaridass	Water
Tech-mech	Mr. SpandanHeera	Solar
Avrio Energy	Mr. Puneet Batra	Energy management

Inoviea Consulting & Services	Mr. Suchin Jain from	Roof top solar system
Retas	Mr. Ankit Magan	Rain water harvesting
HVAC consultant	Pk Sen Sir	Thermal comfort.

Mr. Gunjan Kumar

Table1: Our Industrial Partners-

PROJECT BACKGROUND:

Project Name: Prakriti GreenSpace

Project Partner: Mahindra Lifespace Developers Limited, Dr. Sunita Purushottam- Head of Sustainability, Ar. Janhavi Parab- DGM Sustainability.

Description of the Project Partner:

Mahindra Life spaces is one of the leading real estate development companies in India. They espouse responsible, green design and development, and are driven by our mission of Sustainable Urbanization. Some of the Notable Achievements are listed below:

17.47 million sq. ft. of completed residential projects.

7.9 million sq. ft. of ongoing and forthcoming residential projects.

Over 5000 acres of ongoing and forthcoming integrated cities and industrial clusters in three cities.

Brief description of the Project:

Mahindra Life spaces (MLDL) intends to develop an area of 7.88 Acres, bearing Survey No.49 & 50/2, Vajrahalli Village, Uttarahalli Hobli, Bangalore South Taluk, Bangalore Metropolitan Area as a Premium segment residential development.

Table2:Brief description of the Project

Building Category- Residential Building	Specific Targets- Platinum Rating (IGBC GREEN HOMES
Total built Up area- 31889.23 SQM(7.88Acre)	FAR -2.25(Achieved 2.243)
Project Timeline-36 months	Total number of units- 527
Target EPI- 50 KW-h/m2	Estimated Project Cost- 276 Cr.
Renewable energy Estimation- 40 to 75 KWh	Study Scope- Phase 1 (Tower A & Tower B)

Acknowledgement:

Nikunj Verma, Samarpan Deb Majumder, Avinish Kumar, R.K.Karthick, Debdut Bose, Mayank Shekhar, Subhajyoti Manjhi, Ashish Bhuwaniya, Kunal Saha and Rounik Roy.

Project Site Information:

The property is a single land parcel admeasuring 7.88 Acres, bearing Survey No.49 & 50/2, Vajrahalli Village, Uttarahalli Hobli, Bangalore South Taluk, Bangalore. Kanakapura road is one of the developing hubs & preferred residential / commercial micro markets in South Bangalore with a well-developed social infrastructure.

Context and Market Analysis: The identified target customers include a mixture of people belonging to the varied income groups i.e. LIG (Low Income Groups), MIG (Medium Income Group) & HIG (High Income Group) which we have majorly categorized into two sections “BUYERS” & “INTENDERS”.In a

quantitative survey using a structured questionnaire conducted it was seen that, out of the 292 people participating in the survey, 243 belonged to the Intenders category and 49 rest were the recent buyers.

Specific Targets for the Project: Platinum rating, IGBC Green Homes.

Project Partner Target EPI (requirement)- 50 KW-h/m2.

Details about site & building program.

No. of Towers-4(Each tower having 527 units)
No of units in phase 1(tower A + tower B) = 277
No of units in phase 2(tower C + tower D) = 250

Towers	No. of Units	Carpet Area	RERA Carpet Area	Balcony and Utility area	Verandah Area	Sale Area
Tower A	107	3414	3025	407	79	4779
Tower B	170	2420	2824	348	50	4473
Tower C	107	3414	3025	407	79	4779
Tower D	143	5432	4873	590	50	7605

Table 3: Detailed Description of Areas in all the Towers:

Total Site Area	31,929.43 Sqm
Total Built Up Area:	98,770.46 Sqm
Green Built Area:	10,536.71 Sqm (33% of the Total Site Area)
Total Conditioned Area	18410.41 m^2(Tower A&B)
Total Unconditioned Area	11034.82 m^2(Tower A&B)
Permissible FAR	2.25
Achieved FAR	2.243
Usable Carpet Area	5,67,742
Total RERA Area	5,09,769
Car parking Area	343.55
Sale Area	7,94,838
Usable Carpet Area	79.07%

Common Area	19.90%
Window Area	23.60%

Table 4: Area Distribution

PERFORMANCE SPECIFICATIONS:

Bangalore has a Tropical Savanna Climate with distinct wet and dry seasons. Since Bangalore has a high elevation (920m above sea level) it enjoys more or less moderate climatic conditions. Although, during summers, it experiences occasional heat waves which becomes an uncomfortable condition.Bangalore experiences a varying length of day over the course of year. The length of the day on an average is about 53 minutes of 12 hours.

LATITUDE	12.8549
LONGITUDE	77.5243
ALTITUDE	34.50°
AZIMUTH	232.34°
DAYLIGHT DURATION	11h27m2s
SHADOW LENGTH [m]	1.45
CLIMATE ZONE	Temperate

Parameters	Specification	
	Client base case	**Proposed case with best possible EPI**
Walls	U value=3.831 W/m2 K	U value=0.608 W/m2 K
Roof	U value=0.584 W/m2 K	U value=0.259 W/m2 K
Fenestration	VLT= 67% U-Value= 5.6 W/m2K SHGC=0.68	VLT= 45% U-Value= 4.6 W/m2K SHGC=0.42
Lighting(LPD)	5.38 W/sq.m	4.42 W/sq.m
HVAC systems	System type-Split System Single Zone (DX- BEE) COP- 3.1 Star-rating-3 star	System type-Split System Single Zone (DX- BEE) COP- 3.5 Star-rating-5 star
Electrical(EPD)	8.07W/sq.m	3.23W/sq.m

Others	
Clubhouse	HVAC system type- VRV IV X AIR COOLED COP- 12 ISEER/EER- 3.75

Parameters	Specification			
	Base case	**Proposal 1**	**Proposal 2**	**Proposal 3**
Water systems	14670080 Litres/year	99137650 Litres/year(32% water saved)	88106437.5 Litres/year(40% water saved)	60170250 Litres/year(59% water saved)
	Rainwater and stormwater calculations: Average of annual 5 years rainfall-935.18 mm Average of annual 5 years rainfall rain water collection- 1,69,50,137.50 Litres Total site area- 31929.43 sq.m Total runoff from the site- 331.17365 cu. m			
	Holding capacity of 25 pits- 286.1325 cu. m Excess water to municipal drain in worst rainfall- 45.04 cu.m			
Renewable energy	**Scenario 1**	**Scenario 2**	**Scenario 3**	
	System type- Vikram Solar manufactured 325 Wp, 32V Si-poly Eldora.		System type- Open Market Power Purchase	
	Generation capacity- 178.29 KWp	Generation capacity- 602 KWp	Generation capacity- N/A	

Table5. Performance Specification

GOALS & STRATEGIES

Integration of building components like envelope, lighting, HVAC and allied services for net zero building performance.

Envelop design goals:

- Orientation of the building will be such that west-wall exposure to direct sunlight can be minimized along with the reduction of Urban Heat Island Effect.
- Envelop designing strategy will reduce heat gain without compromising carpet area.

Comfort goals:

- Thermal Comfort analysis with reference to ASHRAE Standard 55, adaptive comfort investigation by using local climate conditions for 2 deg. C set point.
- and Maintain 150-300 lux by artificial lighting design.Visual comfort validation with Daylight simulation for Green Building Code Compliance

Energy goals:

- EPI reduction 40-50% with reference to base case design.
- Meeting project Partner target EPI of 50KWh/m2.

Architecture Goals:

- We are checking our building design to comply with ECBC Residential Building Code Compliance as per Eco Niwas Samhita 2018 Part -1 Building Envelope also focused on integrated design approach with maximization of passive design strategies
- Enhance adaptive thermal comfort, Visual comfort and eco comfort.

Ventilation & IAQ goals:

- Passive design Strategies for IAQ monitoring for WHO standard compliance and low VOC material selection.
- Mixed mode ventilation strategies through positive pressure filtration.
- Internal and External CFD for velocity, pressure and temperature profile.

Water Performance:

- With low flow-rate plumbing fixtures water usage reduction is expected to around 30% in line with IGBC standard. Rain water harvesting estimation for net zero water design.
- Waste water reuse should be utilized up to 75%.

Innovation:

- App for real time CO2, CO, water & energy consumption monitoring also Web-based energy forecasting.
- Use of wind catcher to maximise ventilation potential in general indoor spaces along with basement areas.
- Residential Building Management System (BMS)

Resilience goals:

- Strong Wi-Fi signal assurance and Drinking water recharge facility via app.
- Ensure back up diesel generator set availability in the time of power disruption.
- Biogas generation implementing waste management system and providing a sustainable solution without affecting the biodiversity of the site.

DOCUMENTATION OF DESIGN PROCESS:

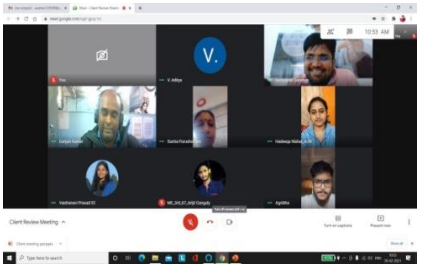
The design documentation of the project takes us through all the meetings with project partner, 12 industry partners, and own team NIVAS meetings explaining the discussions of the various segments, suggestions and guidance of the industry partners as well as progress of the project.

Sl. no.	Industry/Project Partner	No. of meetings	Tool used	Agenda point
1.	Mahindra Lifespace Developers Limited	16	Google meet/via mail	Project input data, work review, Project rectification
2.	Cype	8	Google meet + mail + whatsapp	Wi-Fi modulation and structural building design
3.	Design 2 Occupancy	6	Google meet	Energy simulations, water performance, daylighting
4.	Avrio energy	2	Google meet	Energy
5.	Hydrotech solutions	4	Google meet	Calculation of drinking water and stp
7.	P.K. Sen	3	Google meet	Ventilation and indoor conditions
8.	Asahi India glass Limited	8	Via Google meet + email	Glass properties for residential buildings
9.	WeGot	3	Via Google meet + email	Smart water management
10.	Innovia	1	Via email + google meet	Description of solar panels and calculation of solar energy
11.	Inner Engineering	3	Via email	Material selection
	Project partner & Industry partner joint meeting	3	Google meet	Brief discussion on the project
	Tech mech services	5	Google meet	Increasing solar power generation
12.	Retas	2	Google meet	Rainwater harvesting
13.	Applex	10	Google meet+ whatsapp	App development for monitoring IAQ, water and energy consumption
14.	Faculty Review	25	Google meet + whatsapp	project segment review
15.	Team Nivas meetings	150+	Google meet	10 contests, design approach, strategies, sub committee work coordination

Table 6: Meetings Description

BRIEF OF THE MEETINGS:

1. **Mahindra Lifespace Developers** Limited**:** The main highlights of the meeting were the current status of the project in different segments like water (data and calculations), energy simulations, renewable energy generated on site, materials selection, daylighting simulations and the glass properties, and market analysis approach. Important project related documents and slides were also shared with the team for proper guidance and help.

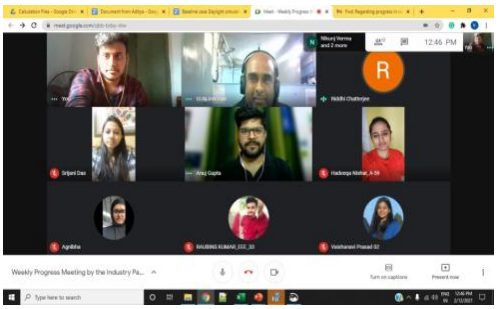


2. CYPE: Its honorable to have an International industry collaboration for the solar decathlon India project. It is a software provider company which added value to our project through their following suggestions:

- As wi-fi has become a need for smart homes so CYPE came up with a simulation process by which we created a very strong strength wi-fi zone in the entire building.
- Helped in doing better structural design of the building through their own software.

3. **Team Nivas Meeting:** The team had their weekly own review meeting in the presence of all the members and faculty members and their respective segment mentors where the loop holes were highlighted and the further roadmap to proceed with the project was discussed. Once in a month the team also managed to have physical meeting for important discussions.

4. Design 2 Occupancy: We had regular meetings with our D2O industry partner as it always stood out to guide in various segments, rectified the inaccuracy and miscalculations at every stage, suggested different approaches and cases which helped the project to divert in the correct direction with rectified outcome and improved design.



We procured guidance under

- energy management and simulations.
- construction materials like selection of the right material of walls and roof with preferred u-values
- in water segment like different means of water conservation methods
- also generation of renewable energy
- in daylighting the simulations were rectified and were suggested with additional 4 cases that further improved the design.

5. Avrioenergy: The team was recommended with the following:

- use of smart meter with net metering solution, Arduino or Rpi in pump & lights for automation.
- To do life cycle cost analysis and listing out the segments where it can be implemented.
- Also, an idea of a user-friendly energy predictor was proposed by us where
- some guidance was required.

6. Hydrotechsolutions:

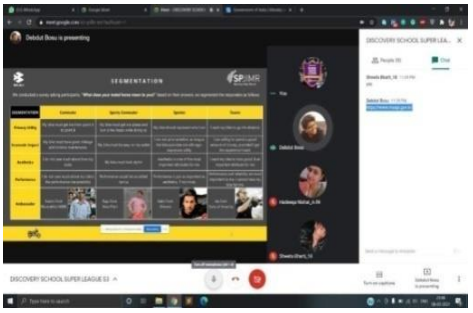
- Total water requirement and various methods for harvesting rain water.
- how to design a net zero energy/water cycle design and key technologies which are prevailing outside for the implementation of net zero energy in the upcoming residential buildings.
- Plumbing layout of both roof top plan and sectional layout.

7.P.K. Sen: We procured guidance in the ventilation part which is also one of the key segments. We were suggested as the project site is surrounded with much natural vegetation and lake so natural ventilation would be a boon to the project. The things used for natural ventilation were also highlighted.

Major light was thrown on the indoor conditions of the buildings at proper set point tempand further use of solar energy for thermal comfort and basic idea of improving IAQ in the residential buildings was discussed.

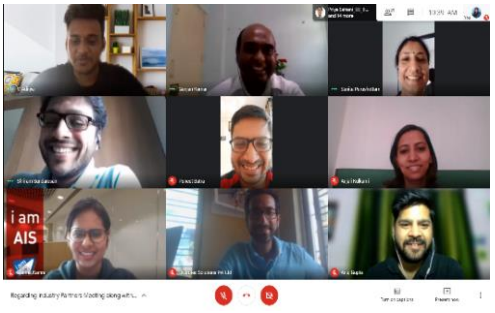
8. Asahi India glass Limited: We got to know about the different glasses, their properties and the cost ranges of various glasses used in various residential projects. With their guidance in the field of glass industry we have selected single glaze high efficient glass which is energy efficient as well as cost effective.

9. **DebdutBosu:** The following key points regarding market analysis was discussed and explained.



- Identifying our target (potential investors/buyers/tenants)
- understanding their aspirations, unique lifestyle, economic demographic characteristics, what is affordable to them, what is affordable in that area, etc.
- analysis should also inform how marketable or scalable our solution will bebeyond our specific project

11. PROJECT PARTNER AND INDUSTRY PARTNER JOINT MEETING:

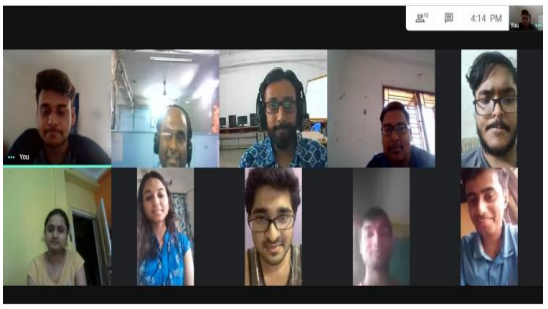


A joint meeting with all the industry partners and Project partner were conducted for a brief discussion on all the segments of the project. They had a mutual comprehensive discussion among themselves for further collaborations and discussions. Each industry partner came up with their own solution and validation as per the requirement of project.

12. TECH MECHSERVICES: We got to enhance our results in the solar segment with their help and guidance. The following key points were suggested by them:

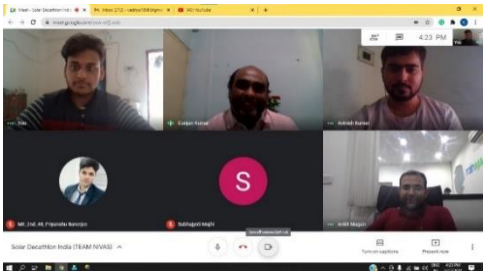
- Usage of south façade for greater solar power generation.
- Effective utilization of the areas above sports rooms for solar panel installations.
- Taking tilt angle to be 10 degrees so that the FAR can be increased.

13. APPLEX: In order to make the building digitalized along with NZE we had a collaboration with an app development company. The main agenda of this meeting was to develop an app so that the occupants can easily monitor the CO2 level and other pollutants in order to keep a track over IAQ. The app would also help the house owner to keep a track over energy consumption monitoring and prediction as well as water level monitoring.



14. RETAS: We had a meeting with Ankit Magan sir solely to get guidance in the rainwater harvesting segment.

They helped us in doing the rainwater calculations and tank sizing details for rainwater storage.



CHALLENGES AND HURDLES FACED:

1. The project Solar Decathlon India (multifamily housing) was itself a big challenge for us until the support of Project partner, industry partners and of course the entire Solar decathlon India team.
2. At the initial stage we were unable to get a suitable project partner which was a great demotivation for us but thankfully solar decathlon India team helped through this stage.
3. One of the biggest hurdles we faced was overcoming the insufficient availability of architect in the team, but we never let this insufficiency turn into weakness rather made the engineering and innovation part as our strength.
4. Software constraints also led to delayed simulations and results. More students were unable to access the software because of the virtual interaction among the team members.

ENERGY:

- We were unable to use wall insulation as the wall thickness cannot be increased much keeping in mind the importance of carpet area in a residential building.
- Change in occupancy might alter the energy requirements respectively.

SOLAR:

- The total area for solar installation was not sufficient to produce desired amount of solar energy but nevertheless we came up with brilliant solutions like using the south façade and other utility areas like sports room, etc. for more solar panel installation and generation.
- Also, on-site generation was not possible due to huge natural vegetation at the site

WATER:

- The challenge faced here is the change in occupancy in future which might alter the water requirements.
- Unexpected environmental stress might lead to reduction in groundwater levels and water quality.

DESIGN DOCUMENTATION

ENERGY PERFORMANCE:

DESIGN CONSTRAINTS

Bangalore has a Tropical Savanna Climate with distinct wet and dry seasons. Since Bangalore has a high elevation (920m above sea level) it enjoys more or less moderate climatic conditions.

Parameters	Bangalore
Latitude & Longitude	12.9716° N, 77.5946° E
Mean monthly sunshine hours	2360.9
Maximum and Minimum Temperatures	35.8 °C & 26.2 °C
Average RH (%) – values annually	65.2%
Solar Radiation- average annually	5.5 to 6.5 kWh/m^2/day
Average Monthly wind speed	10.5 miles per hour.
Average rainfall	986.9 mm(38.85 inches)
Average ground water level	Depth range 33-287 mbgl(as on March 2013)

Table7: About Bangalore

Site & Context

Bangalore is known as the Garden City of India. It is rich in greenery and culture both ethnic and modern. Bangalore has been divided into 3 belts, namely the development belt, the metropolitan corporate area, and the green belt. Our project site is located in the metropolitan belt. The property is a single land parcel admeasuring 7.88 Acres, bearing Survey No.49 & 50/2, Vajrahalli Village, Uttarahalli Hobli, Bangalore South Taluk, Bangalore. Kanakapura road is one of the developing hub& preferred residential / commercial micro markets in South Bangalore with a well-developed social infrastructure.

Fig1: Site images

ENERGY ANALYSIS

The property consists of 4 tower development (A,B,C & D) in two phase construction. At this stage our project partner is in process to develop phase one tower A and B along with common facilities. Orientation of tower A is North faced and Tower B is South faced.

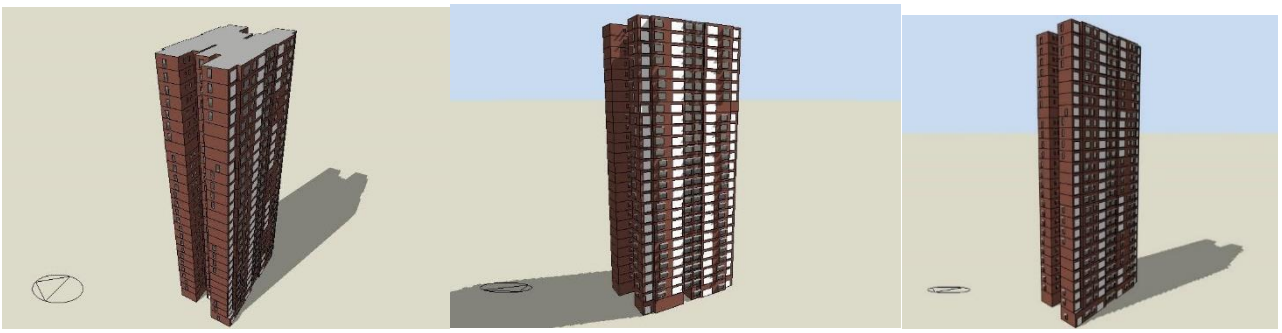
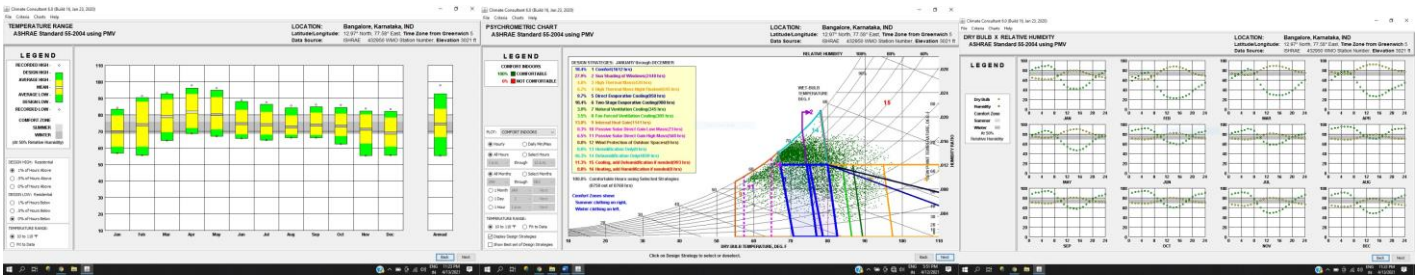


Fig 2: Design of the Model Building in design Builder

Bangalore outdoor condition for summer:



Dry-bulb temp 95°F Wet-bulb temp 75°F RH 45%

Assumption

We have taken Bangalore weather file and ASHRAE 90.1 2010 reference for simulation and kept Cooling set point at24°C & set back temp at 28°C (for conditioned spaces only), for thermal comfort 50% Relative humidity (for indoor spaces),lighting illuminance of 150 lux and for Fresh Air calculation 5cfm/person & 0.06cfm/sq ft. (For conditioned area) are being taken.

To begin with the energy analysis and optimization, various parametric simulations were performed by changing different construction materials and building loads. This was done to understand the effect of each component individually. We have used the Design Builder for our energy simulation with different diffeent parameters.
The inputs for the baseline case model were given by the client. For walls Client case was given with RCC wall having overall U value of 3.831 W/m2K. To neutralize the heat gains from wall surface and its impact on cooling load and energy use we have analyzed a proposed case with AAC blocks having overall U value of 0.608 W/m2K. Also Porotherm block was evaluated for energy performance.
For Roof, Client case was given with RCC slab with 50 mm XPS insulation having an overall U value of 0.584 W/m2K. To neutralize the heat gains from the roof surface we have increased insulation to 75mm with an overall U value of 0.259 W/m2K. Similarly to control conductive and radiative heat gain from fenestration various options of glasses were evaluated for cost effective and energy efficient solution.

Energy Conservation Measures	Description		Measure levels
	Client case	RCC wall 160 mm with 5 mm external plaster(cement) and primer and 5 mm internal plaster(gypsum)	U value=3.831 W/m2 K
	Proposed	AAC block wall 160 mm with 5 mm external plaster(cement) and primer and 5 mm internal	U value=0.608 W/m2 K

Walls	case	plaster(gypsum)	
Roof	Client case	RCC slab 175 mm with 50 mm XPS insulation and 25 mm sloping screen(PCC)	U value=0.584 W/m2 K
	Proposed case	RCC slab 165 mm with 75 mm XPS insulation, 3 mm internal plaster and 25 mm sloping screen(PCC)	U value=0.411 W/m2 K
Fenestration	Initial Base Case	Single Glazing Unit (ST- 167)	VLT= 67% U-Value= 5.6 W/m2K SHGC=0.68
	Client Existing Revised Glass Case	Double Glazing Unit	VLT= 60% U-Value= 2.8 W/m2K SHGC=0.6
	Conventional design case (Proposed case 1)	6mm clear glass SGU	VLT= 88% U-Value= 5.8 W/m2K SHGC=0.82
	Proposed Case 2	Single Glazing Unit (solar control glass) [Aura]	VLT= 53% U-Value= 5.7 W/m2K SHGC=0.69
	Proposed Case 3	Single Glazing Unit (solar control glass) [Spring]	VLT= 65% U-Value= 5.7 W/m2K SHGC=0.69
	Proposed Case 4	Single Glazing Unit (solar control glass & thermal insulation glass) [Natura Plus]	VLT= 45% U-Value= 4.6 W/m2K SHGC=0.42
	Proposed Case 5	24mm clear glass DGU	VLT= 78% U-Value= 2.8 W/m2K SHGC=0.72
	Proposed Case 6	Double Glazing Unit (Solar control & thermal insulation) [Spring]	VLT= 59%

			U-Value= 2.8 W/m2K SHGC=0.6
	Proposed case 7	Double Glazing Unit (Solar control & thermal insulation) [Aura]	VLT= 48% U-Value= 2.8 W/m2K SHGC=0.46
Window to wall ratio	Proposed case same as Client case	North	34.88%
		South	7.52%
		East	40.8%
		West	8.65%

Table 8-Energy Conservation Measures

For further EPI reduction and to restraint the sensible heat gain from lighting and various equipment we have further assessed our simulation with economical as well as less energy consuming efficient HVAC systems, LPD and EPD.

Lighting Design	Client case	Lighting Power Density	5.38 W/sq.m
	Proposed case	Lighting Power Density	4.42 W/sq.m
HVAC systems	Client case	Split System Single Zone Client case: DX- BEE 3 Star	COP- 3.1
	Proposed case	Split System Single Zone(DX- BEE 5 Star)	COP- 3.5
Equipment's	Client case	Equipment Power Density	8.07W/sq.m
	Proposed case	Equipment Power Density	3.23W/sq.m

Variation in EPI by doing interventions in client construction cases:

Sl no	Design Case	EPI Value (KWh/m2/year)	Overall EPI Reduction
		Tower A	Tower A
1	Base Case 1-Client construction case	48.27	NA
2	Base Case 2-Client construction case with revised Double Glazing Unit	47.36	1.88%
3	Client construction case with revised Natura plus glass	45.28	6.19%
4	Client construction case with revised 75 mm XPS insulation of roof	48.25	0.04%
5	Client construction case with revised Porotherm block wall	47.96	0.64%
6	Client construction case with revised Porotherm block wall and Natura Plus Glass	45.18	6.40%

Impact on energy savings

From the above simulation result we can see we are not achieving much less reduction in EPI by using client construction with doing some small interventions in constructions. Only 0.04% energy is saved when we alter the roof insulation and maximum 6.40% energy is saved when we are altering both the wall and glass construction. So to achieve maximum energy and cost savings as per net zero energy building requirement we have to change more in the simulation inputs for client cases.

Table 10: EPI SUMMARY SHEET

Sl no	Design Case		EPI Value (KWh/m2/year)		Overall EPI Reduction	
			Tower A	Tower B	Tower A	Tower B
1	RCC wall + Roof 50 mm XPS insulation including SRI paint +Single Glazing Unit (ST-167)	LPD-5.38 W/sq.m EPD-8.07W/sq.m HVAC system: 3.1 COP split system	48.27	42.73	NA	NA
2	RCC wall + Roof 50 mm XPS insulation including SRI paint+Double Glazing Unit		47.36	41.61	1.88%	2.62%
3	Acc block + Roof 75 mm XPS Insulation including SRI paint + 6mm clear glass SGU+4.42 W/sq.m LPD	LPD-4.42 W/sq.m EPD-3.23 W/sq.m HVAC system: 3.5 COP split system	31.08	26.55	35.61%	37.87 %
4	Acc block + Roof 75 mm XPS Insulation including SRI paint + Single Glazing Unit (solar control glass) [Aura]		28.66	23.49	40.63%	45.03 %
5	Acc block + Roof 75 mm XPS Insulation including SRI paint + Single Glazing Unit (solar control glass) [Spring]		29.74	24.85	38.39%	41.84 %
6	**Acc block + Roof 75 mm XPS Insulation including SRI paint +Single Glazing Unit (solar control glass & thermal insulation glass) [Natura Plus]**		**26.71**	**20.94**	**44.67%**	**50.99 %**
7	Acc block + Roof 75 mm XPS Insulation including SRI paint +24mm clear glass DGU+4.42 W/sq.m LPD		30.71	26.13	36.38%	38.85 %
8	Acc block + Roof 75 mm XPS Insulation including SRI paint +Double Glazing Unit (Solar control & thermal insulation) [Spring]		28.94	23.79	40.05%	44.32 %
9	Acc block + Roof 75 mm XPS Insulation including SRI paint +Double Glazing Unit (Solar control & thermal insulation) [Aura]		27.26	21.6	43.53%	49.45 %

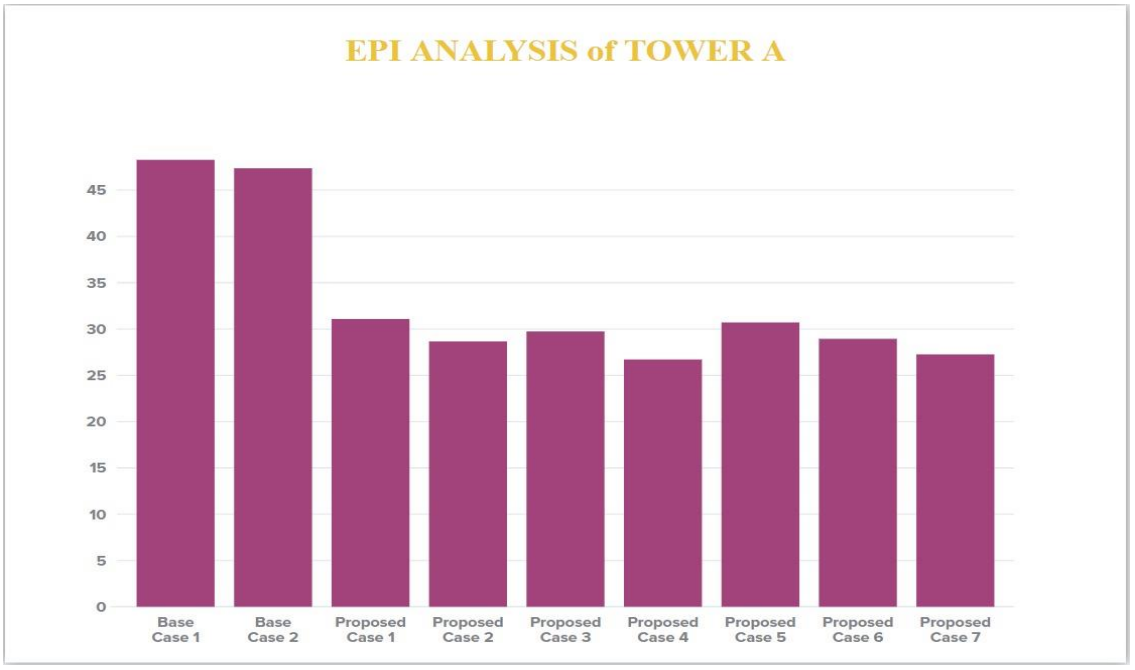
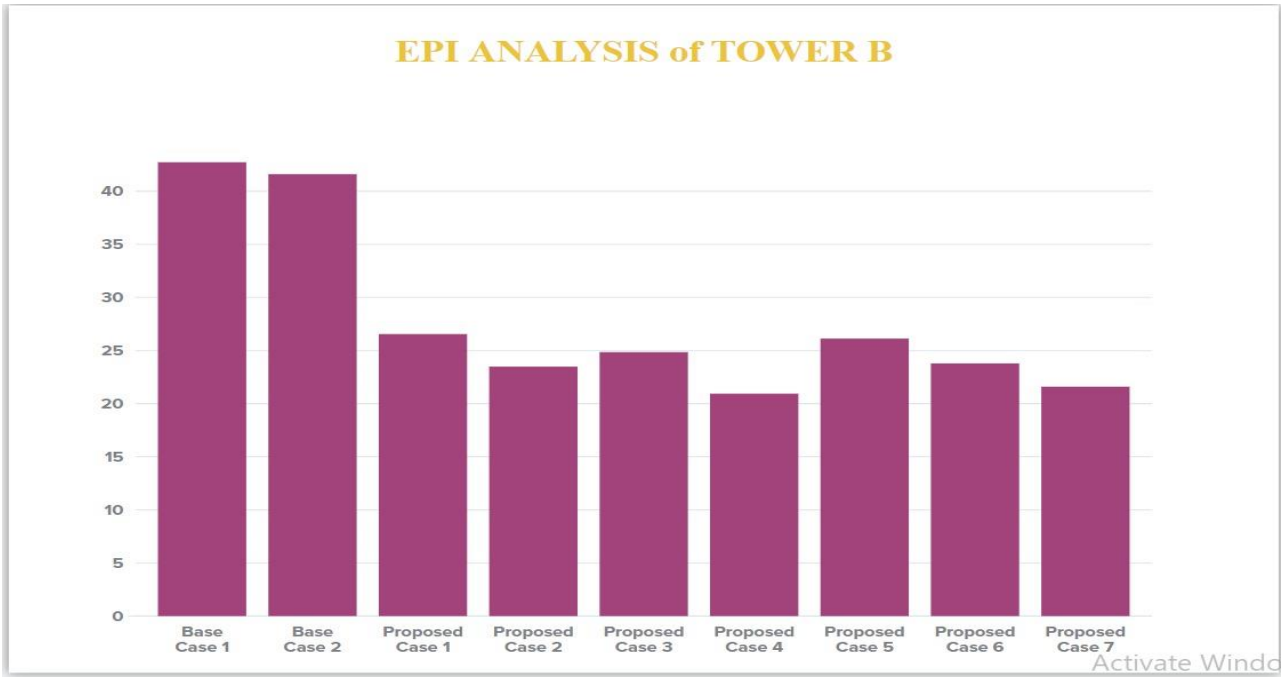


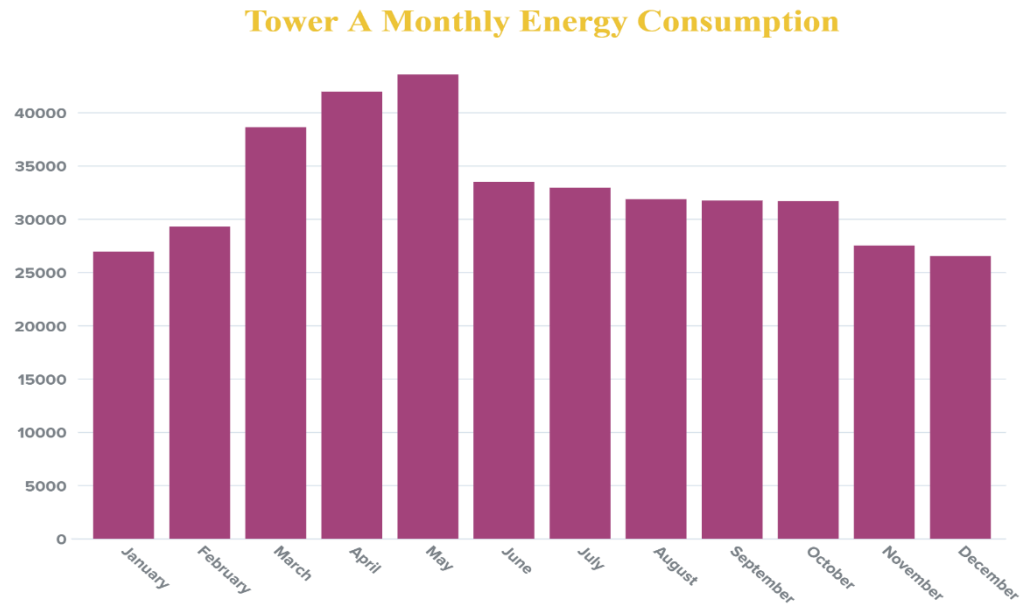
Figure 6: EPI Analysis Tower A & B

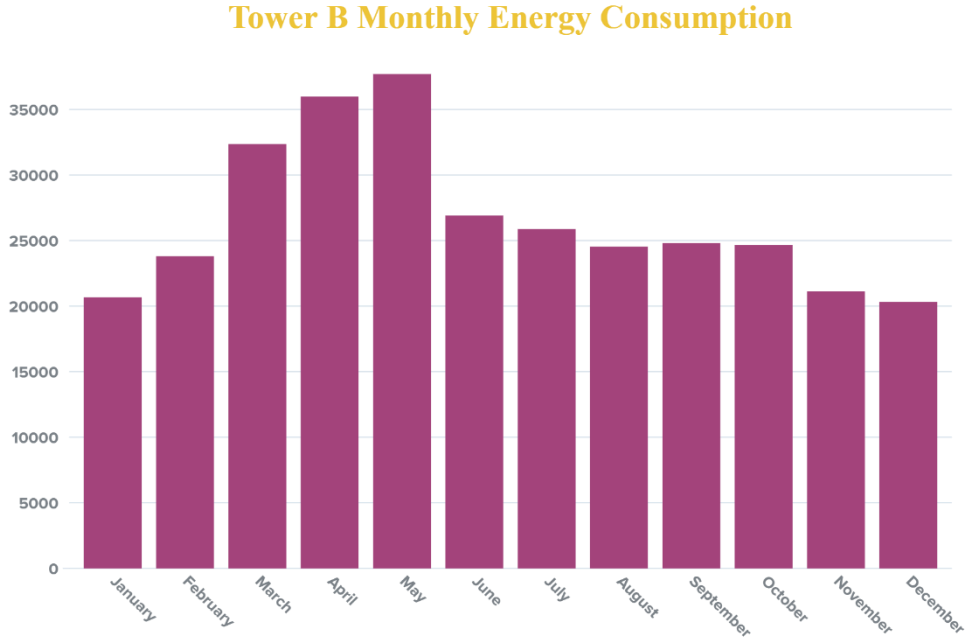


Impact on energy and cost savings:

- Maximum energy is saved by using the proposed case of walls, roof and natura plus glass and EPI is reduced by 44.67% for tower A and 50.99% for tower B from the client base case.
- Minimum energy is saved by using revised client base case construction materials of roof, wall and revised glass case and EPI is reduced by 1.88% for tower A and 2.62% for tower B the client base case.
- In the proposed case 4 simulation 45% energy and 45% cost for tower A and 51% energy and 51% cost for tower B are optimised from the client case.

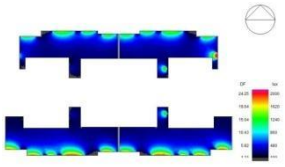
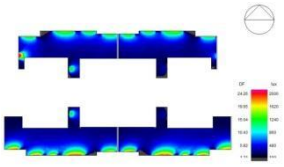
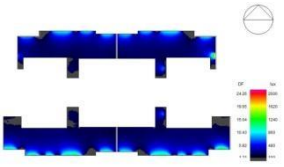
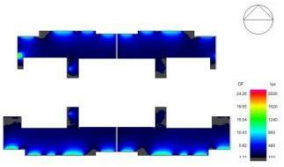
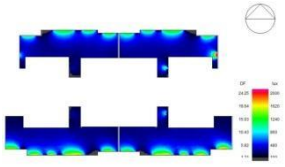
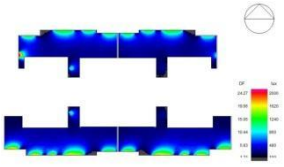
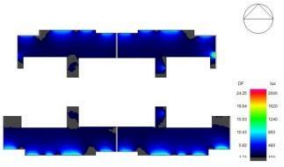
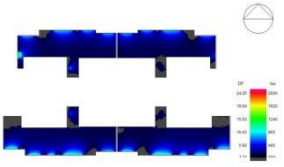
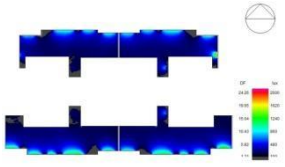
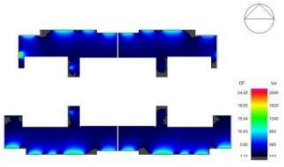
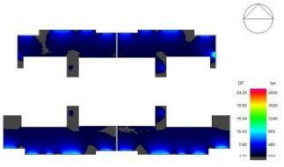
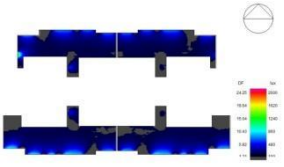
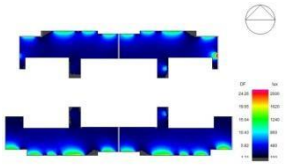
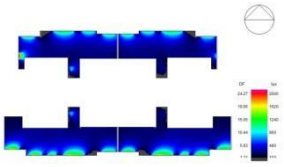
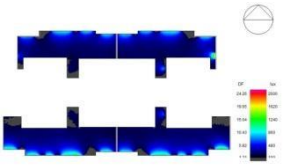
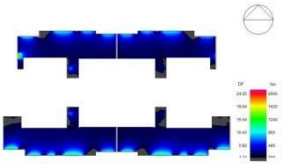
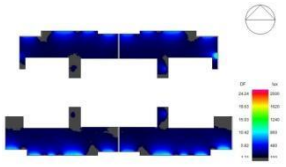
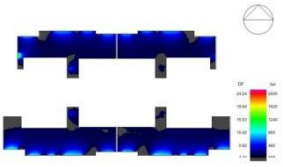
Monthly Consumption of Tower A and Tower B





Yearly consumption for Tower A is 396491.19 KWh and for Tower B is 318797.96 KWh

DAYLIGHT SIMULATION (TOWER A)

 Base Case 1-Client construction case (9:00am)	 Base Case 1-Client construction case (3:00pm)	 Base Case 2-Client construction case with revised glass (9:00am)	 Base Case 2-Client construction case with revised glass (3:00pm)
 Proposed case 1 (9:00am)	 Proposed case 1 (3:00pm)	 Proposed case 2 (9:00am)	 Proposed case 2 (3:00pm)
 Proposed case 3 (9:00am)	 Proposed case 3 (3:00pm)	 Proposed case 4 (9:00am)	 Proposed case 4 (3:00pm)
 Proposed case 5 (9:00am)	 Proposed case 5 (3:00pm)	 Proposed case 6 (9:00am)	 Proposed case 6 (3:00pm)
 Proposed case 7 (9:00am)		 Proposed case 7 (3:00pm)	

Choosing high performance glass will reduce EPI values but at the same time if total daylight area is not sufficient lighting load will be higher. Natural daylight is very important for a healthy physical and psychological condition of the residents.

Table 11: WFR Calculation

WFR Calculation	
Minimum required (ECO-NIWAS SAMHITA)	12.50%

Proposed Case(Tower A)	17.21%
Proposed Case(Tower B)	16.03%

As per ECO-NIWAS SAMHITA the openable window-to-floor area ratio (WFR) shall not be less than 12.50% for temperate regions. So our proposed cases are compatible for Bangalore area as per ECO-NIWAS SAMHITA.

Simulation results [100 to 2000lux]

Sky Model	1-Standard Sky, 2-CIE Clear Day
Time 1	9:00, 21 Sep
Time 2	15:00, 21 Sep
Location	BANGALORE
Working Plane Height (m)	0.750
Illuminance Lower Threshold (Lux)	110.000
Illuminance Upper Threshold (Lux)	2000.000

Table 12: Daylight Data

Good daylighting design in buildings not only provides a comfortable luminous environment, but also delivers energy savings and comfortable and healthy environments for building occupants. So to provide the best surroundings and cost effective result we have run simulations with glasses with varying properties. As per the data for obtaining the same indoor comfort result, by using Natura Plus glasses we are saving 53.27% cost than DGU glasses and 7.71% reduction in EPI. So Observing all these cases we finalize the natura glass where we are getting lower EPI value with sufficient daylight area and glare is controlled automatically and also cost efficacious.

ARTIFICIAL LIGHTING:

Artificial lighting is an important segment to focus upon in order to design net-zero energy building. We have aimed to use artificial lighting to reach the optimum lux level for respective rooms as per IS 3646 standards and also to reduce the energy consumption as much as we can.

The number of luminaires used has been calculated using the formula $E= (\Phi \times n \times N \times UF \times LLF)/A$ and the simulations has been performed in the DIALUX EVO software for 1,2,3 and 3.5 BHK flats for both the towers A and B to get desired lux levels and LPD.

Table13: PHILIPS product data sheet

PHILIPS Luminaire Properties	DN125B D187 1xLED10S/830	DN125B D234 1xLED20S/840
P	13.0W	24W
ΦLamp	1000 lm	2000 lm
ΦLuminaire	1000 lm	1999 lm
η	100%	99.96%
Luminous efficacy	76.9 lm/W	83.3 lm/W
CCT	3000k	3000k
CRI	100	100

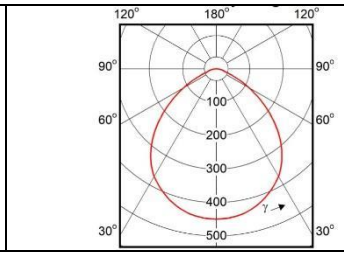
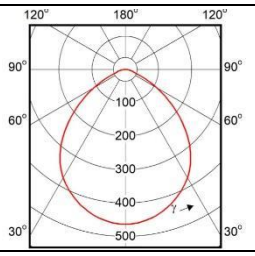
Lighting distribution of the luminaire		

Table14: Artificial lighting simulation result

From the simulations we can conclude that the annual energy consumption (say in a 2BHK flat) with the regular fluorescent tube lights is more than our proposed case.

Fluorescent tube light – 36 watts	Philips coreline downlight – 24 watts, 13 watts
Annual unit consumption= 841	Annual unit consumption= 767

Hence we can say that meeting the optimum lux level with lesser energy consumption and hence lesser electricity bill can be achieved with the above design.

Also the LPD values achieved give better energy simulation results. Better the EPI better the performance.

LPD for Tower A = 4.48W/m2	LPD for Tower B = 4.52W/m2

Solar Potential Generation:

Bangalore has a huge potential for solar power harvesting. It receives **5.77 KWh/sq.m/day** of direct solar radiation annually on an average. As the project is approaching Net Zero so in order to align the requirements the onsite generation of Solar Potential is estimated. This setup is not only cost effective but also consistent in the long run.

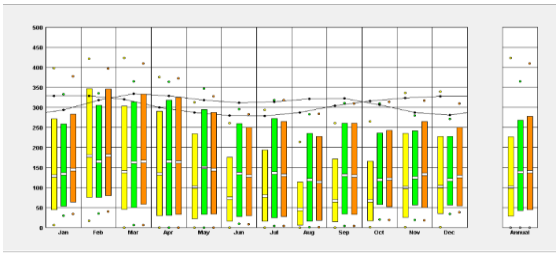


Figure7: Radiation Range in Bangalore

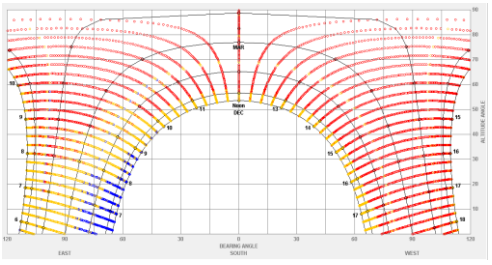


Figure8: Sun Shading Chart at Bangalore

The yield from the Rooftop alone was observed was less than that of expectation. In order to increase the generation, south façades are also used for PV installation. PV modules are installed at a height of 6.3m with 21^0 tilt angles at the South Facade.

Orientation
Tilt = 10.24 degrees **(Latitude*0.98 - 2.3)**
Azimuth = 0 degree (Northern part)
Support - Fixed, no Axis tracking provided.

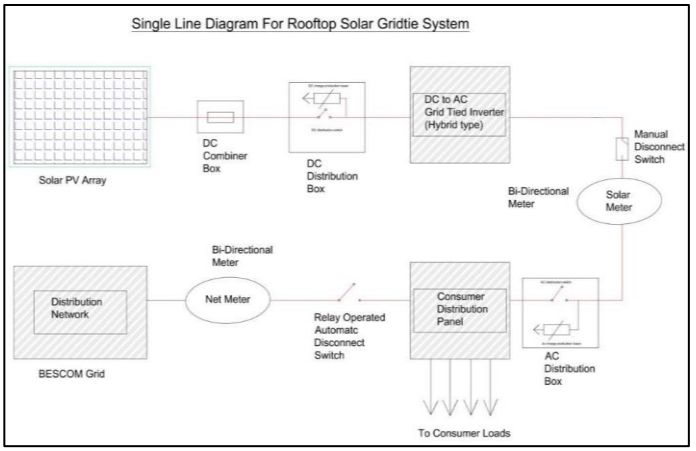


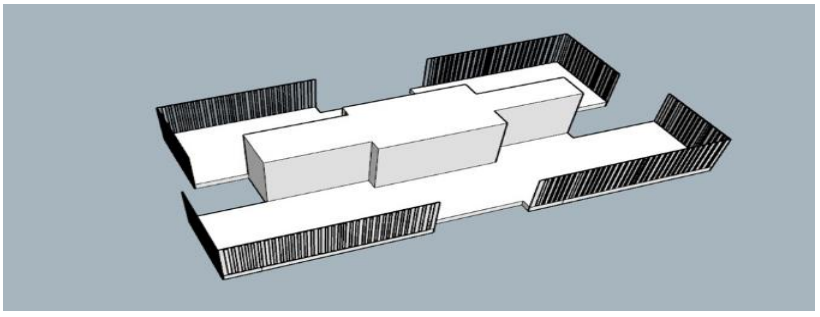
Figure9: SLD of rooftop Solar on Grid System

Energy Consumption detail as per client input including all site load:

Sl No.	Description	Maximum Demand (KW)	Total energy Consumption in KWh per day
1	Apartment loads	1689.00	17903.40
2	Basement loads	14.00	168.00
3	Common area	10.00	136.00
4	Ventilation & exhaust load	38.80	403.52
5	Club House	46.00	588.80
6	PHE load	33.30	279.72
7	STP load	21.00	84.00
8	Fire Pumps Load	0.00	0.00
9	Passengers Elevators Lift	120.00	1632.00
10	External lighting	3.75	33.38
11	Misc. Loads	5.20	49.92
	Total no of units consumed per day		21,278.74
	Total energy consumed per Annum		**7,766,738.28**

Hence the total energy consumed per Annum in KWh is **7766738.28 KW**

Scenario 1 as per client expectation RE generation potential without both Roof Superstructure and South Façade utilization:

Space available for generation	Area in Sq.m	Generation (KWp)	Annual Production (x1000 KWh)	Specific Production (KWh/KWp/year)
Roof Top				

Tower A	589.94	45.21	62.47	1381.8
Tower B	568.47	43.56	60.19	1331.51
Tower C	582.05	44.60	61.62	1363.31
Tower D	586.21	44.92	62.07	1373.06
South elevation railing Tower A		163.8 KWp	133.8	817
Tower B South Façade	1053	151 KWp	123 MWh	818
Tower C south façade	948	118 KWp	96.8 MWh	821
Tower D south façade	1045	115 KWp	94.3 MWh	820
Lift room and OH part Tower ABCD		26.40 KWp	40.1	1516.2
Club House	605	58.41 KWp	88.23	1510.5
Total		851.49 KWp	882.58	
RE generation percentage generation with respect to client case KWh site requirement			**11.36%**	

Table 15 Scenario 1 RE generation

Utilization of limited roof space of Towers and clubhouse and only the S façade of towers have generation of 882580 units per year. As per the energy requirement data, the remaining value is

7766738-882580 = 6884158 units annually

To reach the above, we need to install 6884158 / 1516.2 = 4540 KWp (4.5MW solar power plant)

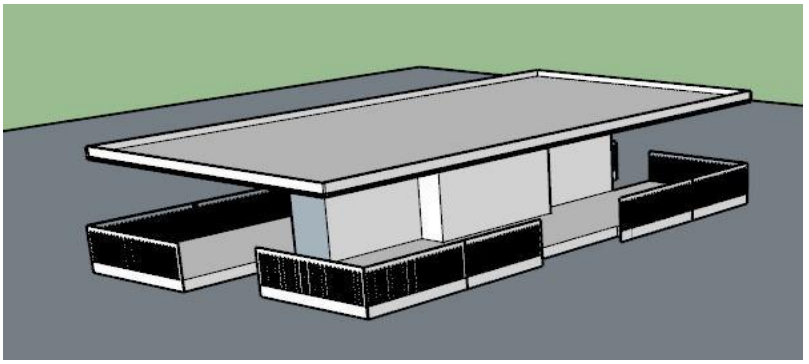
(Total annual units required / specific production of the location)

Ground area required for 4.5MWp SPV power plant = 72,000 SQM

Cost of the 4.5MWp project = Rs. 17.1 CR (@ Rs. 38000 / KWp)

Scenario 2 for Net Zero Approach RE generation potential with Roof Superstructure and South Façade utilization:

Table 16. Scenario2 RE generation

Space available for generation	**Area in Sq.m**	**Generation (KWp)**	**Annual Production (x1000 KWh)**	**Specific Production (KWh/KWp/year)**
Roof Top area with Super Structure Proposal				

Tower A	980	602	912.7 MWh	1516.2
Tower B	980			
Tower C	980			
Tower D	980			
South elevation railing Tower A		163.8 KWp	133.8	817
Lift room and OH part Tower ABCD		26.4 KWp	40.1	1516.2
Club House	**605**	58.41 KWp	88.23	1510.5
Tower B South Facade	1053	151 KWp	123 MWh	818
Tower C south façade	948	118 KWp	96.8 MWh	821
Tower D south façade	1045	115 KWp	94.3 MWh	820
Total		**1234.61KWp**	**1488.93 MWh**	
RE generation percentage generation with respect to client case KWh site requirement			**19.17%**	

Utilization of roof space of Towers and clubhouse and only the S façade of towers have generation of 1488930 units per year. As per the energy requirement data, the remaining value is

7766738-1488930 = 6277808 units annually

To reach the above, we need to install 6277808 / 1516.2 = 4140 KWp (4.1MW solar power plant)

(Total annual units required / specific production of the location)

Ground area required for 4MWp SPV power plant = 64,000 SQM

Cost of the 4.1MWp project = Rs. 15.6 CR (@ Rs. 38000 / KWp)

Scenario 3: Offsite generation and Open market Power purchase agreement

In our multifamily housing, project partner limitation of FAR, the roof area available is not sufficient for RE generation for the towers. From scenario 1, its very obvious that by accommodating site constraint RE Generation potential is 7.11%. In order to maximize the RE Generation, Team NIVAS explored scenario 2 with super structure and South Façade Utilization as our longer axis of the building is oriented towards North-South direction.

In order to counterfeit this situation, we need to set up the Solar panels on the landscape area or the other way is to buy from offsite generation. In scenario 2 generation achieved is 26.07%. So from Scenario 1 and 2 its very clear in order to achieve net zero energy for multi housing residential project, we have to explore Offsite generation or Open Market Power Purchase Agreement.

Open Market Power Purchase Agreement is another way that can be explored for achieving Net zero energy of multi-housing residential building. In this if a developer not find a way out due to site constraint to meet the requirements of RE Generation from their own site, they purchase the energy from where the sites are being located for RE generation through third party open market purchase agreement. Due to the cross subsidy end user power costs will be higher but still expected to lower than the State Electricity Board of Karnataka power tariff.

Specification of PV Modules used.

For RE Generation simulation and calculation we have considered the Vikram Solar manufactured 325 Wp, 32V Si-poly Eldora**.**

Table17 PV Model Specification

Modules Used	VIKRAM SOLAR 325Wp, 32V supply Si-poly Eldora VSP.72.325.03.04
Rated Power	325 Wp
Inverter Used	50 KW 200-800V tl 50/60Hz Delta Energy RPI M50A
Efficiency	20.2 %
Power Tolerance	0/+2.5%
Output Warranty term	25 year, linear

Simulation was performed on all scenarios in both PVsyst and Tata Solar Power Calculator. The detailed simulation outcome results are shown in the appendix.

ENERGY CONSERVATION MEASURES FOR NET ZERO COMPLIANCE

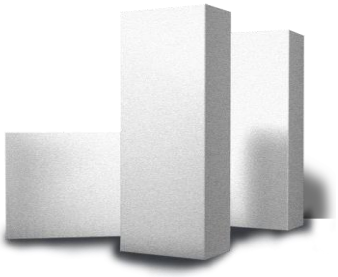
The building sector in India consumes over 30% of the total electricity consumed in the country annually and out of those residential buildings consumes 75% of the total electricity used by building sector. So residential building has a huge potential to bring down the demand of power in generation end which in terms will cut down the unnecessary billing of the residents. For this purpose we adapted some strategies in our project.

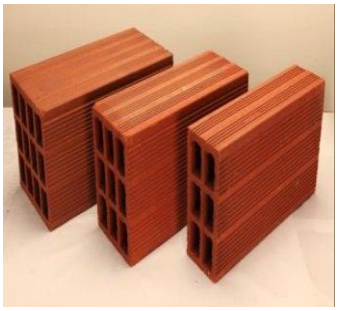
- Demand reduction through energy efficient envelope as per ECO-NIWAS Samhita Code Compliance.
- Internal Lighting and Equipment load reduction through tenant behavioural awareness and housing purchase agreement with energy awareness guidance.
- Mixed mode ventilation for cooling load reduction
- By using Team NIVAS developed app named Smart lifespace app for real time monitoring of Energy performance customised for residential occupant.
- Maximizing RE generation potential. .

Demand reduction through Energy Efficiency measures:

With integrated design approach by putting intervention on wall, roof, glass, energy efficient lighting fixtures and BEE 5 Star rated appliances the overall EPI reduction was achieved 44.67 % for Tower A and 50.99% for Tower B.

Table 18 Building material description

Material	Description	Images
AAC BLOCK	Autoclaved aerated concrete (AAC) is a lightweight, precast, foam concrete building material suitable for producing concrete masonry unit (CMU) like blocks. AAC offers incredible opportunities to increase building quality and at the same time reduce costs at the construction site. Composed of quartz sand, calcined gypsum, lime, cement, water and aluminum powder, AAC products are cured under heat and pressure in an autoclave. Depending on its density, up to 80% of the volume of an AAC block is air. AAC's low density also accounts for its low structural compression strength. It can carry loads of up to 8 MPa (1,160 PSI), approximately 50% of the	

	compressive strength of regular concrete. Thermal conductivity of AAC BLOCK is 0.25 w/Km.	
POROTHERM BLOCK	Porotherm Clay Brick is an innovative product especially developed for the changing climatic conditions, assisting in keeping indoors comfortable and pleasant always. The product innovation takes into account essential, positive deliverables for walling material: 1) A natural product providing quality construction 2) Lighter than traditional solid concrete block by 60 percent and high fire resistance 3) Excellent thermal and sound insulation 4) Ease of handling 5) High strength 6) Easy installation of appliances & fixtures. Porotherm HP 150 is having a U-value of 1.2 W/m2K. The compressive strength is greater than 3.5MPa, Density ranges from 694 to 783 kg/m3 and Water absorption is around 15.	
XPS	Extruded Polystyrene (XPS) Insulation is a closed cell, moisture-resistant rigid foam board well suited to meet the needs for a wide variety of building applications and play an important role to achieving “green” or “sustainable” goals. It is manufactured through an extrusion process. It provides a CFC & HCFC Free Environmentally Friendly Insulation product with Zero ODP & very low GWP. Advantages of XPS insulation are,1)High compressive strength,2)Protect waterproofing membrane,3)Minimal water absorption,4)Compatible with green roof system,5)Easy to handle and install,6)Reduces AC power consumption,7)High performance rigid extruded polystyrene insulation-thermal conductivity as low as 0.028 W/mk	
SRI	The SRI is a calculation method using solar reflectance and thermal emittance values to determine the roof's overall capacity to refuse solar heat. Solar reflectance is the amount of solar energy or UV rays that is reflected away from the building, back into the atmosphere. The higher the SRI value is, the greater ability the coating has to reject solar heat absorption, maintaining a cooler indoor ambient air temperature without the use of an air conditioning. The Solar Reflectance Index is used for compliance with LEED requirements . According to CRRC’s Rated Product Directory National Coatings AcryShield A590 High Reflectance white roof coating provides the highest aged (or 3-year) reflectivity capabilities available to the roof coating market.	

NATURA PLUS	Natura plus has a very neutral appearance. It maximizes natural light, creating a fresh feel for rooms and Improves the aesthetics of the suroundings. It also 1)Absorbs 30% to 45% of solar heat (depending on tint and thickness), thus reducing air-conditioning usage and energy costs 2) Solar control glass reduces uncomfortable glare 3)Reduces the bleaching effect of the sun by blocking sun's UV rays 4) It has U value= 4.6 and VLT= 45%.	

Mixed mode ventilation for cooling load reduction:

Mixed mode ventilation strategy is used in which fresh air passes through positive pressure filtration to increase amount of oxygen level & provide better indoor air quality in room by expelling hot & stale gases through slits. The focus was to use natural ventilation in most efficient manner & reduce the cost & load on air conditioners without compromising comfort of people. For assuring good ventilation turbo wind catcher strategy is implemented which will be used for basement parking area also.

With adaptive comfort and temperate climate condition of the site already offered of our 2/3rd of our comfort range and further two degree higher set point from 24°C to 26°C indoor air temperature with 55% relative humidity will improve energy performance.

Developing an App for changing the lifestyle of occupants:

Team NIVAS has developed an application Smart LifeSpace App for residential buildings in order to give the meter and monitor the Energy, IAQ, and water consumption of individual occupants through his/her mobile application. The visibility of data not only help occupant to save energy but also it will change the behavioral attitude. As app alert system will provide any abnormal utilization.

Renewable Energy Generation:

As reported above with developer constraint in Scenario 1, renewable energy generation was 11.36% and optimistic scenario 2 was 19.17%. With demand reduction achieved site power requirement was reduced up to 31.18 Lakhs units (approx. 31 lakhs KWh). With optimistic Scenario 2 approach we will get a generation of 14.88 Lakhs(14 lakhs KWh). Hence, we have to opt renewable energy Scenario 3 for Net zero multifamily residential building.

WATER PERFORMANCE:

Water is an essential commodity required for proper thriving of a society. Often, the choice of buying a property is greatly influenced by the quality and quantity of water in the region. As a result, "zero-waste" strategies have been developed to cater to the water requirements and efficient wastewater treatment plants have been proposed to maintain the optimal quality of the water available for different purposes such as drinking, household chores, building maintenance, gardening, and many more. According to BIS standards, the average per capita consumption per day has been considered as 135 for domestic communities with a population of 20,000. Out of this, around 20 L/day is

used for drinking and cooking, 45 L/day for flushing and the rest, around 50 L/person/day is used for other secondary purposes which mainly include washing clothes, utensils, etc.

1. Rainwater calculations

As the average rainfall in Bangalore is on the higher side, therefore, rainwater harvesting has been proposed. The storm water mainly includes the rainwater collected on roof, the softscape and the hardscape water.

Table 19: Annual rainwater collection of Bangalore

Annual rainwater collection from roof and non-roof area													
YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Total rainwater
2014	-	5.44	841.00	587.25	1,609.50	1,649.38	589.06	2,019.13	3,376.69	3,429.25	487.56	92.44	14,686.69
2015	27.19	-	311.75	2,528.44	2,923.56	1,453.63	522.00	2,465.00	4,110.75	1,469.94	3,561.56	52.56	19,426.38
2016	39.88	-	3.63	68.88	2,055.38	1,321.31	3,345.88	1,281.44	529.25	904.44	137.75	1,042.19	10,730.00
2017	34.44	-	549.19	706.88	5,145.69	589.06	433.19	3,857.00	7,340.63	4,157.88	447.69	235.63	23,497.25
2018	-	152.25	556.44	797.50	4,775.94	1,687.44	663.38	2,010.06	3,806.25	1,475.38	398.75	87.00	16,410.38
Average Of annual 5 year rain water collection in cubic meter													16,950.14
Average Of annual 5 year rain water collection in Litres													1,69,50,137.50

Type of person	Annual total water need	Daily total water need	Total Water need	Potable Water	Secondary usage water	flushing water	Number	Days
Resident	96177500	263500	85	20	50	15	3100	365
Care taker full time	1241000	3400	85	20	50	15	40	365
Care taker	680000	3400	85	20	50	15	40	200
Guest	3952500	26350	85	20	50	15	310	150

Table 20:Water requirement calculation (Part 1)

Type of person	Daily			Annually		
	TP	TG	TF	TP	TG	TF
Resident	62000	155000	46500	22630000	56575000	16972500
Care taker full time	800	2000	600	292000	730000	219000
Care taker	800	2000	600	160000	400000	120000
Guest	6200	15500	4650	930000	2325000	697500

Table 21: Water requirement calculation (Part 2)

Detailed Rain Water and Total Storm Water Runoff from the site Calculation are being shown in the Appendix.

2. Water balance

This section entails the proposed water distribution channels through municipal source and various wastewater treatment plants. Figure 5 also shows the various quantities of water at various uptake points. An additional aerobic digester has been added with the black water STP so as to remove sufficient amount of water from sludge which can be re-treated to increase the treated water quantity. Finally, the end uses of the water have been demonstrated. It is estimated that a total capacity of 170 KLD Grey water STP and 50 KLD Black water STP would be installed. The values have been taken to the nearest highest multiple of 5 so as to cater to any further increase in water demand in the near future.

Table 22: Fixture calculations

Low Flow Fixtures				Baseline Case		New Case 1 (Waterless Urinals +		New Case 2 (Waterless Urinals +		New Case 3 (Waterless Urinals + New	
Fixture Type	Duration per use (in minutes)	Daily uses (per person/ day)	Occupants	Flow Rate / Capacity (in LPF/ LPM)	Daily Water Use (litres)	Flow Rate / Capacity (in LPF/ LPM)	Daily Water Use (litres)	Flow Rate / Capacity (in LPF/ LPM)	Daily Water Use (litres)	Flow Rate / Capacity (in LPF/ LPM)	Daily Water Use (litres)
Water Closets	1 Flush	1	3140	6	18,840	4	12,560	4	12,560	4	12,560
	1 Flush	4	3140	3	37,680	3	37,680	2	25,120	2	25,120
Health Faucet/Bidet, Hand-held spray*	0.25	1	3140	8	6,280	6	4,710	4.5	3,533	1.2	942
Faucet*	0.25	8	3140	8	50,240	6	37,680	4.5	28,260	1.2	7,536
Kitchen Sink*	0.25	6	3140	8	37,680	6	28,260	4.5	21,195	1.2	5,652
Showerhead* /Hand-held Spray*	8	1	3140	10	2,51,200	6	1,50,720	6	1,50,720	4.5	1,13,040
Total Daily Volume (litres per day)					4,01,920	2,71,610		2,41,388		1,64,850	
Annual Usuage (litres per year)					146700800	99137650		88106437.5		60170250	
Percentage water savings annually (%)						32%		40%		59%	

Table 23: Water balance calculations

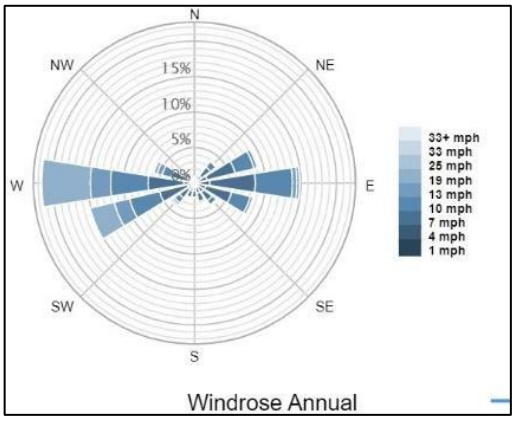
% Net zero Water approach	Value
With potable water	90%
Operation case with all recovery without potable water	117%

After a given point, when saturation will be achieved, i.e. when STP's treated water and rain water will be available for use, only potable water will be collected from the municipality water distribution lines and the rest of the water requirement will be satisfied by the re-circulated water (treated). So, removing the potable water requirement, the net zero approach shows 117% water positive which indicates that 17% water will be available in excess for future or auxiliary use

.

ARCHITECTURE:

Bangalore is known as the Garden City of India. It is rich in greenery and culture both ethnic and modern. Bangalore has been divided into 3 belts, namely the development belt, the metropolitan corporate area, and the green belt.
Climate Analysis
Wind rose diagram- Window rose Diagram was plotted for our Bangalore location and is shown in the figure. The wind rose diagram of Bangalore show that wind blow predominantly from the West about 20.45% of all wind directions.
Sun path-Sun path diagram is the one which helps us to know the position of sun at different parts of the day in a year. It is highly useful in studying the analysis for any site. This diagram helps in calculation of shadow analysis of a building in different parts of the day. This would help us in selecting the right size of the glass and optimizing the window wall ratio for maximum daylight catchment. is fromeast to west through south. **The mean monthly sunshine** ho**urs are 2,360.** The average Temperature ranges from **29.6 deg C. to 19.2 degc**



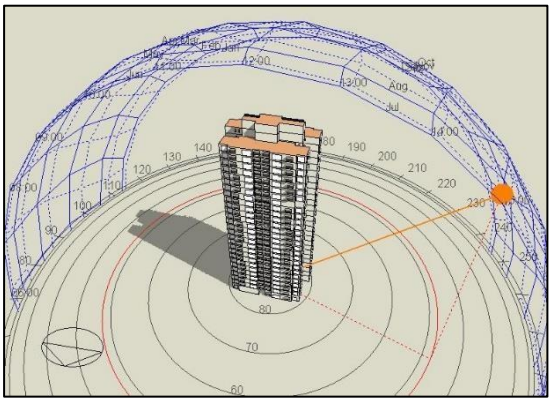


Figure 10– Wind Rose Diagram

Figure11 - Sun Path Diagram

Division of Area:

The architectural language of the building resembles the Modern & Minimalistic local architecture and historical elements. The homes are being constructed on the basis of Vaastu. With our design effort we have tried to give the connect with local architectural aspect and Vaastu Compliance from the home.

The total site area is 7.88 acres. The maximum ground coverage considered is 20 to 25% (2acres approx.) The Green cover is 75%(6acresapprox..,conservingthenaturalgreenscapeofthesite).The number of occupants and the division of the number of occupants in different towers are given below:

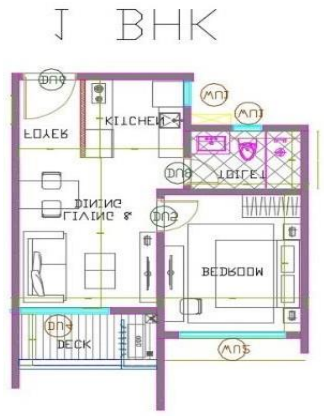
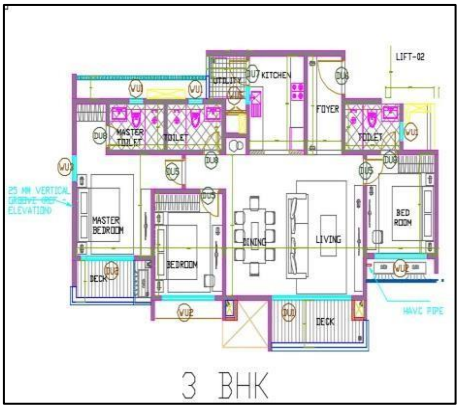
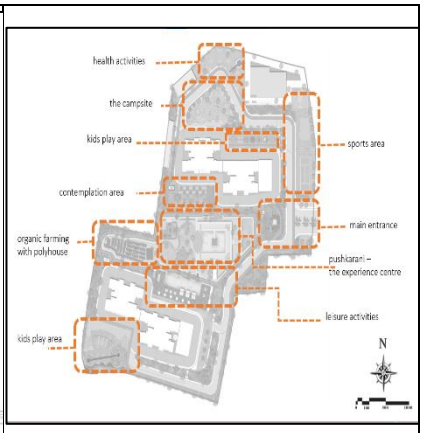
		
1 BHK- 107, Number of Occupants- 533, Area- 1 BHK- 43.08,1BHKL-75.78	2 BHK- 170, Number of Occupants- 628, Area- 2 BHK- 88.03, 2BHK L -115.72, 2BHK COM - 90.61	3 BHK- 107, Number of Occupants- 533, Area- 3 BHK L- 127.68, 3 BHK C- 119.48

Fig12: Different Types of Flat Layout.

		
3.5 BHK Flat Layout.	**3D model of Tower A**	**Site Area Zoning**

The detailed building program is given in Appendix Table no.

Validation for ECO_NIWAS Samhita 2018 Code Compilation for Tower A & B:

Eco-NIWAS Samhita 2018 sets the minimum standard of parameters for its code compliance for Residential Buildings. The code differs for each climatic zone. The main parameters are Residential Envelope Transmittance Value (RETV), Visible Light Transmittance (VLT), Thermal Transmittance of the Roof (U_{roof}). As our project location is in Bangalore, which lies in the Temperate Climatic zone, the code has set minimum and maximum values which are listed in the table below.

RETV is the net heat gain rate through the building envelope (excluding roof) of the dwelling units. It characterizes the thermal performance of the envelope. Limiting its value leads to reduction in heat gains and thereby improving thermal comfort and reducing the energy consumption.

VLT is the potential for estimating the use of daylight in buildings. It is the ratio of the transmitted light to the total incident light on the surface. Ensuring its minimum value improves the visible comfort as well as in daylighting and reduces the electricity consumption for artificial lighting.

Thermal Transmittance of the Roof indicates the thermal performance of the roof and the minimum value helps in reducing the cooling loads of the building.

Openable Window to Floor ratio indicates the potential of using the maximum possible limit of air and daylighting. Ensuring the minimum WWR helps in ventilation, improvement in thermal and visual comfort and helps in reducing the cooling energy.

The Table No. reflectclient case best possible RETV for Towers A & B was 21.07 and 22.59 was more than the required code compliance value 15 W/m2. We have checked the code compliance with client case wall intervention option as porotherm block, Team NIVAS proposed building envelope case with final selected Glass Natura Plus, and combination of porotherm block and Natura Plus Glass. For all these cases RETV is the range of 7.4 W/m2- 9.77 W/m2 for Tower A and 9.24 W/m2- 12.11 W/m2 for Tower B. WFR_{op} value for Tower A & B is considered construction is 17.21 and 16.03 respectively. VLT for Natura plus glass is 45% and cumulative value of U roof is 0.259. All parameter of proposed building envelope complying the BEE recommended Eco -NIWAS code requirement. Hence, we can conclude that building is ECO-NIWAS Samhita Code Complied.

Table 24. ECO_NIWAS SAMHITA 2018 Building code compliance

	ECO_NIWAS SAMHITA 2018 RESIDENTIAL BUILDING CODE COMPLAINCE					
	RETV		**WFR_{op}**		**VLT**	**U roof**
	Max 15 W/m2		**Temperate Min. 12.50%**		**>27%**	**Max 1.2 W/m2**
Building	Tower A	Tower B	Tower A	Tower B	Tower A & B	Tower A & B
Client base Case 1	25.62	28.26	17.21	16.03	67%	0.584
Client Base Case 2 with Revised glass	21.07	22.59	17.21	16.03	60%	0.584
Client base case construction with Porotherm Block and Client DGU	9.77	12.11	17.21	16.03	60%	0.584
Proposed Case 4 with Revised Construction and Natura plus glass	7.4	9.24	17.21	16.03	45%	0.259
Client construction case with Porotherm Block and Natura Plus glass	8.34	10.12	17.21	16.03	45%	0.259

Table25: Reinforcement Quantity

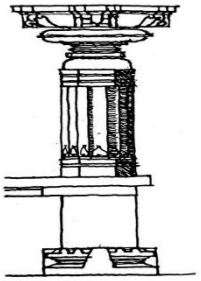
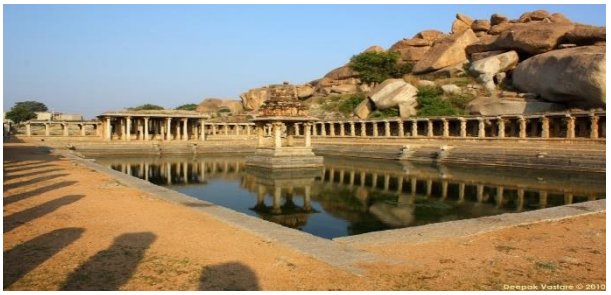
	Reference	Length(m)	Weight(kg)
Flat Slabs	Ø8	83023.72	36038
	Ø10	38283.18	25964
	Ø12	29628.52	28938
	Ø16	19499.62	33855
	Ø20	432851.55	1174232
	Ø25	9932.37	42100
		Total + 10%	**1341127**
Reinforced concrete walls	Ø6	15561.22	3804
	Ø8	209952.25	91136
	Ø10	83981.97	56955
	Ø12	59779.45	58381
	Ø16	50414.46	87526
	Ø20	17572.67	47671
	Ø25	85161.63	360979
		Total + 10%	**706452**
Summary	Ø6	15561.22	3804
	Ø8	292975.97	127174
	Ø10	122265.15	82919
	Ø12	89407.97	87319
	Ø16	69914.08	121381
	Ø20	450424.22	1221903

	Ø25	95094.00	403079
		Total + 10%	**2047579**

With the help of CYPE software solutions, we estimated the reinforcement quantitates per diameter.

LANDSCAPE DETAILS:

Our Project aims to promise the customers to live a life that is Modern & Minimalistic yet Rootedin culture, heritage and traditions. The design is inspired by the Bengaluru landscape, historical elements like the columns of Hampi architectural style and made in natural material providing a connect with the local architecture.

Our design includes outdoor community areas integrated with nicely designed landscape gardens. This creates large green open spaces, with a Vintage charmproviding the residents a place to spend their leisure time in the shadow of nature.The proposed design is a calm and peaceful environment which is suitable for all the age groups.




Present condition

Proposed landscape

Proposed Major Trees	Proposed Shrubbery
Areca Katechu	PyrostigaVenusta
Bismarkea Palm	PetreaVolublis
Coconucifera	Thumbergea
Jacaranda	Pandanus Dwarf
Cassia Javanica	Aurum Lily
Delonix Regia	Nephrolephis
Cassia Fistula	Spathiphyllum
Jacaranda	Spider Lily
Cassia Javanica	Heliconias


Our site has various highlights like Heritage forest, spaces for get togethers, sports activities, community spaces, a state-of-the art club, kids play area, yoga area, quiet seating plazas, camp sites, contemplation areas, tree house, Vehicle-free Podium, a cycling and jogging track which provides an attractive facade, spacious place to live.

RESELIENCE

Resilience is the ability to anticipate, withstand, respond to, and recover from disruptions. In this report the resilience has been discussed briefly in three parts - resilience for (a) power disruptions, (b) fire hazards, and (c) environmental disasters and its after-effects of any scale.

- **Power Disruptions:** With the help of solar PV modules, our system is capable of producing an ample amount of energy required to deal with power disruptions through Hybrid Grid-connected solar systems with Battery storage (8 KWh Li-Fe-PO4 Batteries). We provided Solar Battery backup for two days watersupply.

- **Fire Hazards:** In scenarios of fire outbreak of any intensity, our on-site water reserve is self-sufficient for fire extinguishing purposes. The fire extinguishing systems in the buildings are fed with the pond water (which also acts as the reserve for harvested rainwater) through pumps andpipelines.

- **Environmental Stress:** In order to deal with the tectonic shocks during an earthquake, the building's foundation will be supported with lead-rubber bearings which will help to retain its original rectangular shape. The elastic bearings would decrease the magnitude of inertial forces due to which the period of vibration will be increased, thereby reducing the chances of high damage to the buildingitself.

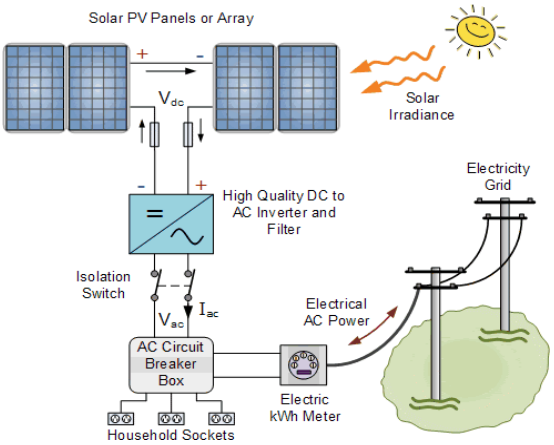


Fig13.(a) Hybrid Grid Connected Solar PV System

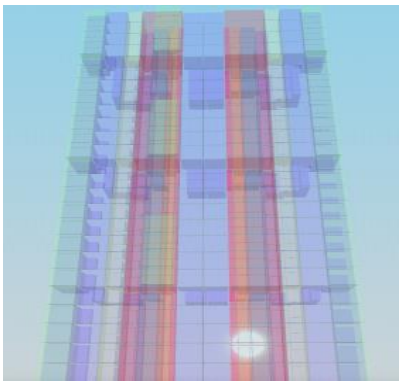
Fig14. (b) Water Reserve for Fire Extinguishing Purpose

Safety and security: The mobile of individual occupant (flat owner) will be integrated with central CCTV footage for digital security surveillance.

Diesel Generator (DG) Power Estimation

As the solar power production can be inconsistent throughout the day due to many climatic conditions, a diesel generator can be used which will fill the gap between the connected load requirement and power generated by the PV modules. This will therefore, suffice the energy requirement during long periods of power-cuts or insufficient PV power generation. The table here shows the estimation of the DG set for both phases of 4 towers.

Structural resilience: The structural Resilience is being evaluated for wind pressure and seismic effect . Wind flow pattern and the response of the building to it is being analyzed and shown below. Moreover, the seismic response for the building is also shown.



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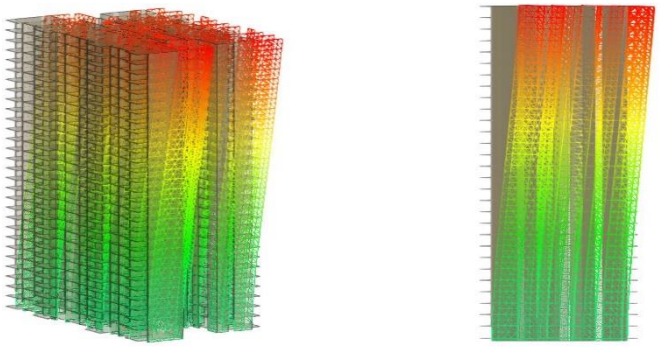
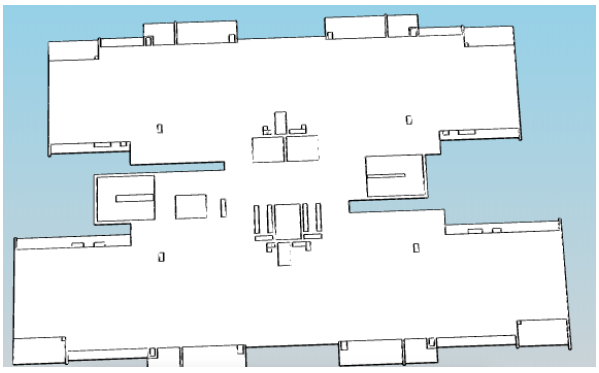


Figure15: Structural View

Figure16: Wind response of the building at different floors



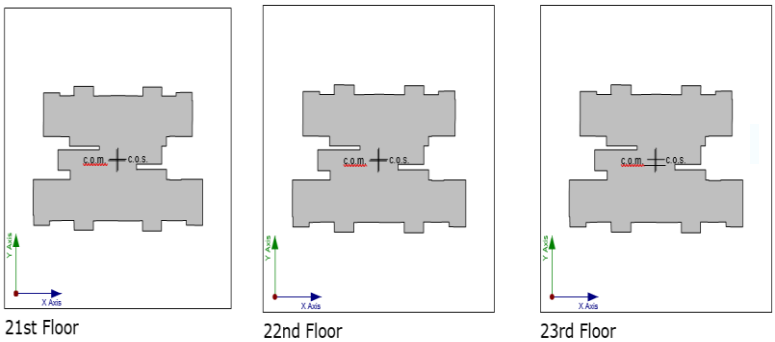


Figure17: Layout of the Floor Plan and Centre of mass and center of gravity at different floors.

Network Resilience: In this modern digital era, internet is the need of the hour. As the near future is the automation of each and every device developing to a smart era, WIFI installed homes are more resilient than the rest. The calculations are being shown along with the simulation results given in appendix..

Table 26: Network Resilience

Type of room	Height of the workplane (m)	Space	Power received (dB)			
			2400.0 MHz		2483.5 MHz	
			Min.	Max.	Min.	Max.
Living Rooms	0.8	Living Room	-40.5	-20.2	-40.8	-20.5
		Living Room	-40.5	-20.2	-40.8	-20.5
		Living Room	-40.5	-20.2	-40.8	-20.5
Decks	0.8	Deck	-44.2	-41.9	-44.5	-42.2
		Space_056	-37.4	-33.9	-37.7	-34.2
		Space_058	-44.2	-42.0	-44.5	-42.3
		Space_059	-42.8	-40.8	-43.1	-41.1
		Space_060	-37.3	-33.6	-37.6	-33.9
		Space_061	-37.3	-33.7	-37.6	-34.0
		Space_062	-42.8	-40.8	-43.1	-41.1

AFFORDABILTY:

Affordability Ratio:

Affordability of a house is referred to as the cost of housing services and shelter to a given individual's or household's disposable income who will be residing there. In simple words housing affordability refers to the rent-to-income ratio or house-price-to-income ratio. The value of these factors in (Kanakapura) Bangalore along with its comparison with the top 3 affordable cities of India i.e. Indore, Jaipur and Ahmedabad are listed below.

Table27. Price to income ratio

Index	Bangalore	Indore	Jaipur	Ahmedabad
Price to Income Ratio:	**7.88**	**12.10**	**7.49**	**10.68**

Source: **https://www.numbeo.com/property-investment/in/Bangalore**

Target Groups

Price to income ratio is the ratio between the price of a median home to that of the median annual household income in a particular city. For Bangalore the Price to Income Ratio is 7.88 which means that the costing of the house will be around 7.88 times the annual income of the households.

For our project we have divided our Target group in three categories. LIR (Low Income Range), MIR (Mid Income Range) & HIR (High Income Range). To make the homes affordable for all ranges, we have put a limit on the selling price of the homes to 5, even less than the Price to Income ratio of Bangalore. The income group has been categorized as per the PMAY Scheme.

Table 28. Income group Distribution

Income Group	Annual Income (As per PMAY)	Selling Price	Construction Cost (45% of the Selling Price)
LIG (Low Income Group)	**Rs. 6 lakhs**	**Rs. 30 Lakhs**	**Rs. 13,50,000**

MIG (Mid Income Group)	**Rs. 9 Lakhs**	**Rs. 45 Lakhs**	**Rs. 20,25,000**
HIG (High Income Group)	**Rs. 12 Lakhs**	**Rs. 60 Lakhs**	**Rs. 27,00,000**

Selling Price has been decided as per the income group defined by PMAY.

PRADHAN MANTRI AWAS YOJANA (PMAY) IN KANAKAPURA – FEATURES

1. This scheme is valid in urban India (towns, cities, metros) for urban poor of income below 6,00,000/ year and age between 21 years to 58 years.

2. Women play vital role in this scheme. A family comprising of husband, wife and unmarried children. Beneficiary should not own a pucca house either in their name or in the name of any member of their family in any part of India to receive central assistance under the Mission Meeting income criteria defined under the scheme.

3. Credit Linked Subsidy is available for housing loans availed for new construction and addition of rooms, kitchen, toilet etc., to existing dwelling as incremental housing. The carpet area* of house should be constructed or enhanced under this scheme should be upto 30 sq.meters for EWS(Economically Weaker Section) category and upto 60 square meters for LIG(Lower Income Group) category.

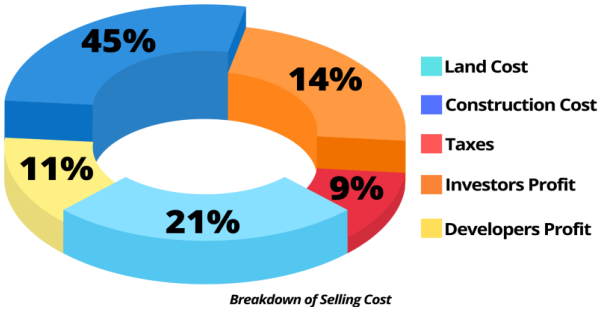
4. For identification as EWS/LIG beneficiary under the scheme, an individual loan applicant should submit self-attested certificate/affidavit as proof of income.

CLSS Scheme Type	Eligibility Household Income (Rs.)	Carpet Area-Max (sqm)	Interest Subsidy (%)	Subsidy calculated on a max loan of	Loan Purpose	Validity of scheme	Max Subsidy (Rs.)	Woman Ownership
EWS and LIG	Upto Rs. 6,00,000	30/60 sqm (322.917/645.835 sqft)	6.50 %	Rs. 6,00,000	Purchase/Self Construction/Extension	31 March 2022	2.67 Lacs	Yes *
MIG 1 **	Rs. 6,00,001 to Rs. 12,00,000	160 sqm (1722.23 sqft)	4.00 %	Rs. 9,00,000	Purchase/Self Construction	31 March 2020	2.35 Lacs	Not Mandatory
MIG 2 **	Rs. 12,00,001 to Rs. 18,00,000	200 sqm (2152.78 sqft)	3.00 %	Rs. 12,00,000	Purchase/Self Construction	31 March 2020	2.30 Lacs	Not Mandatory

Source: Pradhan Mantri Awas Yojana (https://loanyantra.com/CLSS/PradhanMantriAwasYojana-in-Kanakapura.aspx)

Calculation of Selling Price:

To correctly calculate the selling price, we had taken our data from several housing projects around Bangalore in Kanakapura (Prestige Group Housing Project, Sobha Developers, Godrej Ananda Properties and Vajram Group Bangalore) which has provided us with average figures for each segment. The segments that we have considered while calculating our selling price are as follows:



Breakdown of Selling Cost

Land cost: 21% Construction Cost: 45% Taxes: 9% Investors Profit: 14% Developers Profit: 11%

Affordability check of the project:

We aim to build a house which is affordable for a larger section of the market without compromising the comfort of the residents. So, to increase the affordability of this project we have implemented the following strategies.

Energy efficient solution: A survey was performed with 15 residential buildings and from there we have taken the equipments they are using along with their rated wattage of those eipments. Placing the same equipments in our building we were able to calculate the total energy consumption for the base case. As we are approaching towards net zero building, we increased the ratings of those equipments and used only energy efficient fixtures for our best case simulation to show the buyers/residents that using higher rating equipments may cost a little in the beginning but in the long run it saves a lot of energy and money. By changing the construction material we have reduce the u value by 84%. We are able to reduce the LPD(Lighting Power Density) of the building by around 17.84% and hence reduces the lighting load. Oue design proposes to reduce the Equipment Power Density of the building (EPD) is reduced from

by 59.9%. All these solutions are made while keeping the comfortability of the occupants intact. i.e, Humidity = 50%, Conditioned space Temperature maintained at 24-28 degree C. Lighting Illuminance = 150-500 LUX

Overall Reduction in energy consumption of Tower A using energy efficient strategy = 44.04%

Overall Reduction in energy consumption of Tower B using energy efficient strategy = 50.99%

In a long run, this design will save upto 2,082,304.8 kwh of energy in the next five years of span from each tower along with a better thermal comfort, visual comfort, resiliency, water and energy efficiency.

Water efficient solution: Keeping water tariff hike in mind we provide a solution where we are able to make the building a net positive building. We are harvesting rain water along with storm water and the black and grey water is recycled after treatment to reduce water demand in households. This all and all saves an extra 17% of the total water per year making the building a net water positive building. Using low flowrate plumping fixtures we are providing 65% reduction in water demand which in terms will save water bill.

Cost Effective Glass selection: In order to reduce heat gain through glass, generally DGU is used for its excellent resistive property. But its cost is a major concern. Cost of DGU glass 6508510.61 INR. In our project we are using high performance single glazing glass (cost 3041360.1 INR) where we can save up to **53.27%** of the total cost of glass which in terms will save the money of the buyers too.

Efficient Floor Plan: The biggest way to reduce cost is to have an efficient floor plan as it will always be more cost-effective than one that has underutilized space. This strategy will have the biggest impact on our budget as an efficient floor plan results in less excavation, site work, foundations, floor framing & finish, wall framing & finish, ceiling framing & finish, insulation, roofing, waterproofing, trim work, and MEP coverage, not to mention savings in energy usage when you live in the space.

Reduce complexity: Another strategy for reducing construction costs is to reduce the complexity of the design. We have tried to reduce the complexity of this project by having utmost number of similar design flats with similar features which saves time and money. Labor costs can be expensive so any way we can simplify our design to reduce the amount of time it takes to build will help.

Type	Flat Count Tower A	Flat Count Tower B	Flat Count Tower C	Flat Count Tower D
1 BHK		56		2
2 BHK	2	57	2	84
3 BHK	51	58	51	58
3.5 BHK	54		54	
4 BHK				

Cost Effective materials: In order to reduce the cost of construction, we have used the strategy of switching to different cost-effective materials in our project.

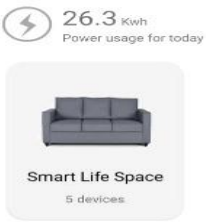
INNOVATION:

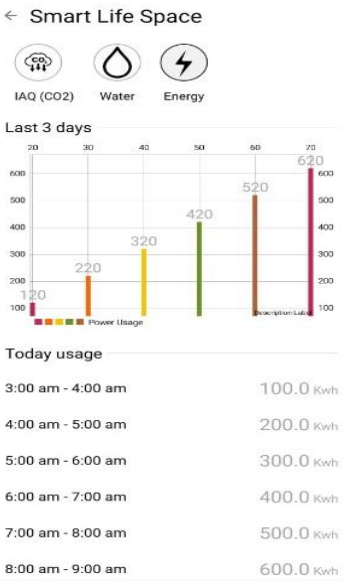
Introduction of a new idea in the design solution is very important to increase its efficiency and hence its market potential. Therefore, Team NIVAS has developed an application**SmartLifeSpace App** for residential buildings in order to map the IAQ, energy and water consumption The team has also developed a **web-based energy predictor** and introduced **wind catcher** technology for better ventilation (details of which is mentioned below).

These are the following innovative technologies listed below that are incorporated in the design.

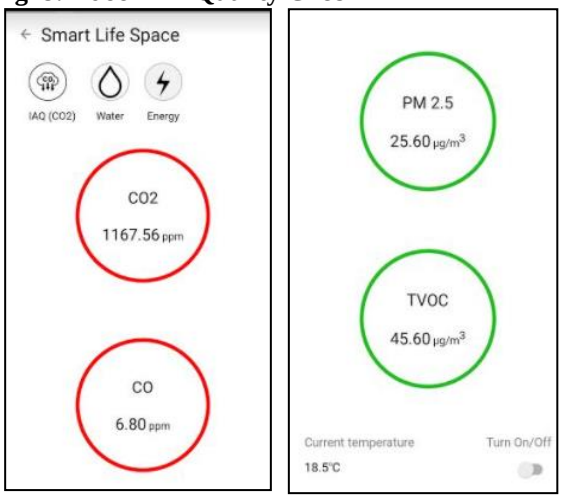
Smart Lifespace App:

- An android app is developed which can measure factors that affect human health, budget & environment.
- This app shows energy usage, indoor air quality and water.
- Download link: [nivas-app.apk - Google Drive]





Quick Glance at the app:

Features	Description
(1) Indoor Air Quality **Fig18:Indoor Air Quality Check** 	• Indoor air quality measures the CO, CO2, PM2.5, TVOC content of the air inside the room. Archived data can be reproduced to see variations in air quality. • Sensor is placed in each room & the data transferred to the app through the cloud interface. The app monitors the threshold level and if it goes above, then it will alert the user by a signal.

(2) Water Level Monitoring

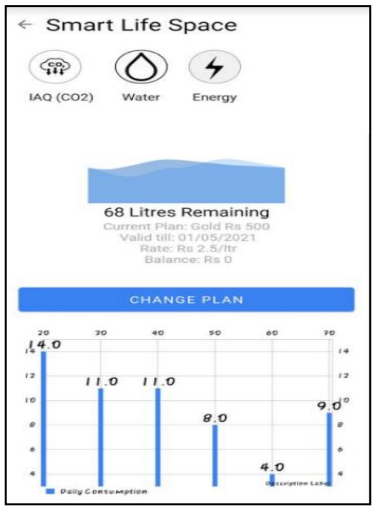
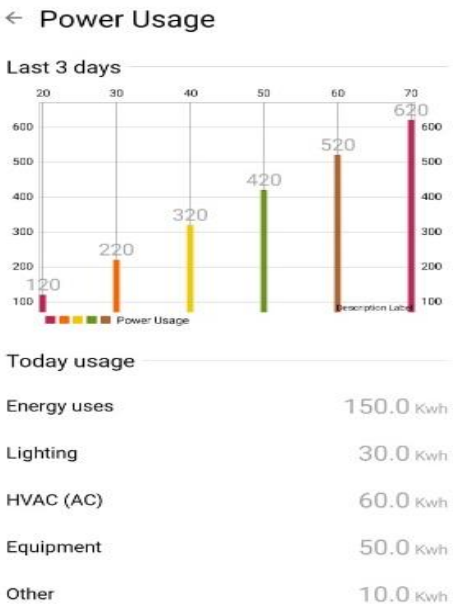


Fig19: Water Level Monitoring

- Water tab gives an information about the activated plan, water consumed in a month, remaining amount and an option to recharge the plan.
- This will also be recording the water usage and will show the water usage pattern and if there is an unnecessary wastage of water or not.

(3) Energy Monitoring

Fig20: Energy Monitoring



- The app will be retrieving data from the smart meters in each room via a cloud interface and will be displaying the data in real-time.
- It has further breakup into Lighting, HVAC, Equipment & others. This helps to analyze major areas of consumption and hence provides scope for intervention into energy savings.

User interface & processing:

- Front end: Native Android using java
- Layout: Xml
- Backend server: Google Cloud
- Architecture Used: MVVM (Model view view Model)

Energy Predictor:

- Web based energy predictor to foretell the energy bill based upon equipment to be used.

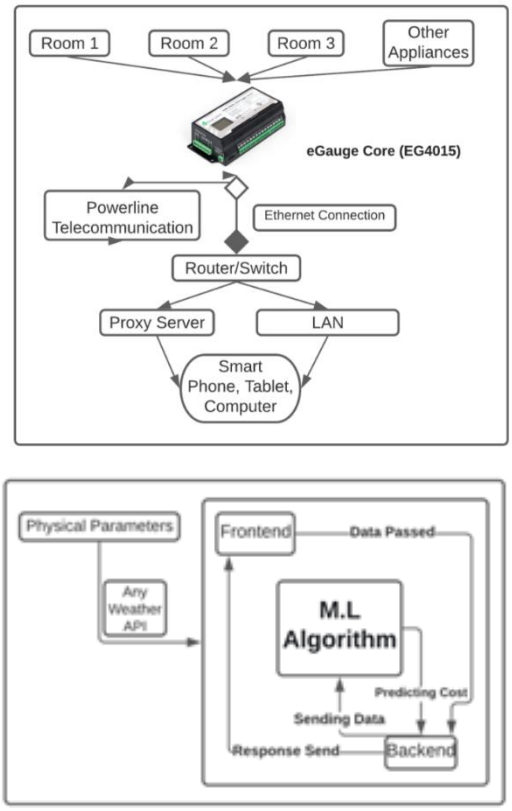


Fig21 :Energy Predictor

An energy predictor has been proposed on the basis of the consideration of both physical parameters (Temperature, humidity, cloud cover etc) and energy consumption of each household/dwelling units.

-Datasets are made from energy consumption details via smart meters and electric bill of 12 residents of 12 months' worth.

- Physical data's will be collected from online APIs (during an input) automatically.

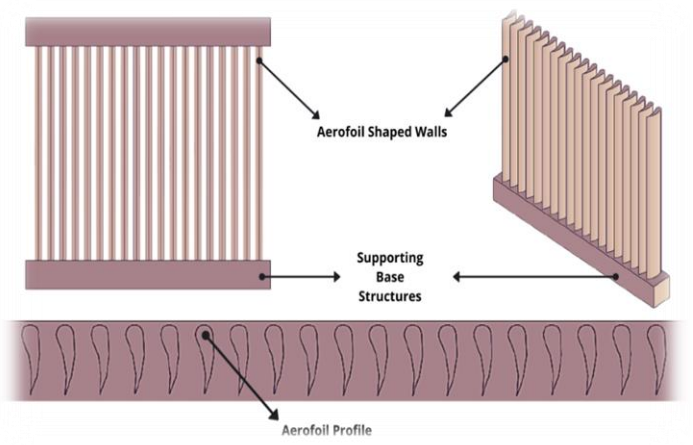
- Users are to input their energy consumption data's for mentioned types.

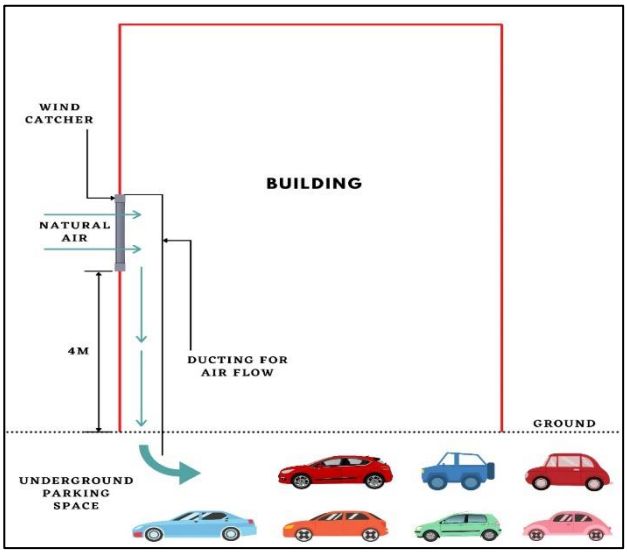
- Machine Learning algorithm used in the backend will predict the total energy consumption.

Link - https://predict-bill.herokuapp.com/

Wind Catchers:

Fig 22 Wind catchers





Wind catchers are innovative structures made from standard building materials to improve the ventilation or air circulation inside a room or in closed spaces.

- These devices are generally cylindrical or cubical in shape depending upon the requirements of the end-users.
- They are generally installed at a height above the ground (typically 5-10 m) so as to ensure that only good quality of air enters the building for ventilation.
- Here, the inlet walls of the wind catcher have been uniquely designed in the shape of an aero foil, thereby naming it as **"turbo-wind catchers".**

SCALIBILITY AND MARKET POTENTIAL:

Target Customers:

The identified target customers include a mixture of people belonging to the varied income groups i.e. LIG (Low Income Groups), MIG (Medium Income Group) & HIG (High Income Group) which we have majorly categorized into two sections "BUYERS" & "INTENDERS".

In a quantitative survey using a structured questionnaire conducted it was seen that, out of the 292 people participating in the survey, 243 belonged to the Intenders category and 49 rest were the recent buyers. Out of those 292 people, those 243 people who were intending to buy a property in Kanakapura are our main Target Groups.

The main reasons (needs and desires of the intenders) why they are considering to buy properties in Kanakapura are:

- To set up their first house / home
- A house near to their place of Work / Business
- Want to move close to places of daily interest such as School, College & Office
- Looking for better amenities
- Need to shift from rented to owned properties
- Looking for house in better localities
- Thinking about future family growth
- More space because of Family expansion

Source: Hansa Research Group and Mahindra Lifespaces

Design solution for the Intenders and Buyers:

We have followed an integrated approach of design where we preliminary set the goals that are to be achieved. After setting up the goals, research and analysis is done in order to solve the design problems with a number of options and select the design direction within each stage.

We varied the building envelope details and the setting up the right value of LPD and EPD to study the impact on overall energy performance of the building and calculation of Energy Performance Index. The potential daylight is also pre-assumed with the help of simulations. In addition to it the airflow pattern outside the building architecture is also found to set up innovations for energy efficiency measures. The comfort of the occupants being an important parameter. In

order to improve the same a smart application is being made where in the energy consumption, water consumption and the basic parameters for maintaining the Indoor Air Quality is being monitored and viewed.

Climate Responsive Design: Due to the global warming and the rapid climate change, the temperature is drastically rising everywhere. And it becomes difficult for the occupants because of the changes arising in the temperature comfort zone. So to provide thermal comfort to the occupants we are proposing an AAC/Porotherm Block as a building material for its low thermal conductivity property and high strength. Also, we are providing proper ventilation in all the spaces of the building. This all together reduces the heat load providing a great solution for the thermal comfort and which in a long run reduces energy consumption in a building and allows to save money. Addition to the, for the people who will be staying in the top floors we have used XPS Insulation so that the heat load is reduced and they can also live comfortably.

Centralized wifi connectivity: In this digital age Wifi becomes a basic need now a days for all the occupants irrespective of their ages. As our project is located near IT hub so we are assuming most of the occupants are IT engineers so keeping work from home culture in mind we have provided a centralized wifi connectivity for the residents with strong signal strength in each corner of the building. Wifi simulation justifies our case. Even for real time app monitoring this net connection will be used.

Smart LifeSpace App: Our team has developed an android application for the buyers through which they can measure factors that affect human health, budget & environment. The key features of the application are Indoor Air Quality, Water Level Monitoring, Energy Monitoring and Energy bill predictor.

Sustainable solutions: We are installing PV modules for on grid solar generation so that it becomes capable of supply power to some extend to our building while power supply disruption occurs. During natural calamity one of the major point of concern is water so in our solution we design our storage in such a way that it can back up 2 days of water supply.

Better Indoor air quality: In last 15 years 80% rise in respiratory disease is observed in Bangalore. So keeping that in mind we tried to provide the best indoor air quality with proper ventilation using wind catchers. Since our parking area is situated in the basement which is underground so use of wind catcher will help to maintain proper ventilation in the basement also.

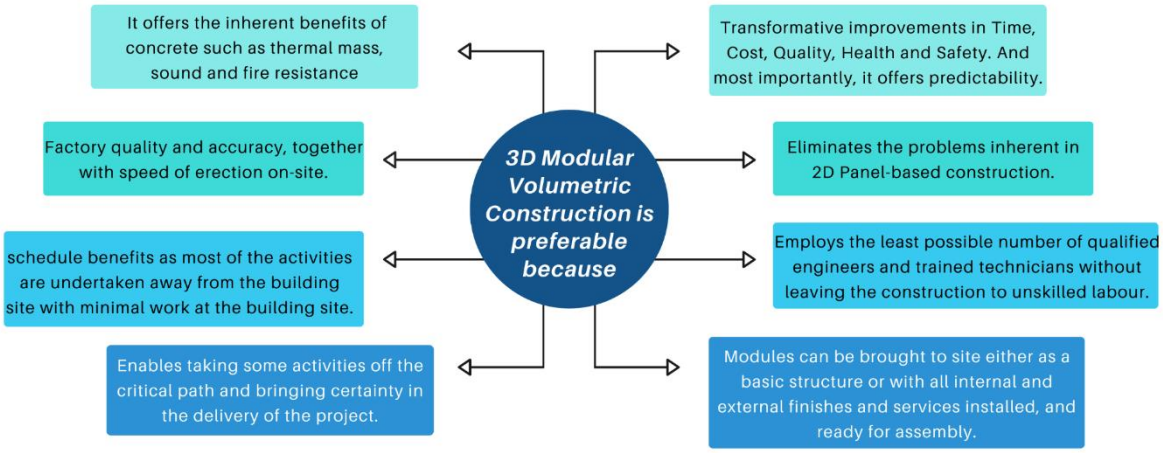
Connect with nature: In this busy schedule of our life, we all want to spend our spare time in between green in nature and as the high rise building construction is expanding the green area is getting reduced. So, we tried to keep our project design in such a way that it doesn't affect biodiversity. Our project site is full of different trees and having a pond and a farming area. As most of the site area is covered with plants and trees, residents can spend their spare time in close with the nature.

Construction Strategies / Techniques

In our Project, we are implementing **3D Modular Volumetric Construction** as it serves the purpose in all required aspects. We also have done the simulations in each segment keeping in mind all the probable cases.

Fig 23.

3D Modular Volumetric Construction is preferable because:



Benefits of 3D Modular Volumetric Technique

Fig24.

Construction Timeline with simulation-based design approach

The most beneficial point about implementing 3D Volumetric Construction is that it saves a lot of construction time. We have put forward the duration that will be taken by 3D Volumetric Construction to complete the Project and the time taken is also very less (20-35% less) compared to the traditional process of Construction. The time that is saved by our construction strategy also cut shorts on construction, labor, on-site and equipment rental costs which surpasses the transportation costs required in our Construction Strategy and it also gives the developers an upper hand on the capital costs.

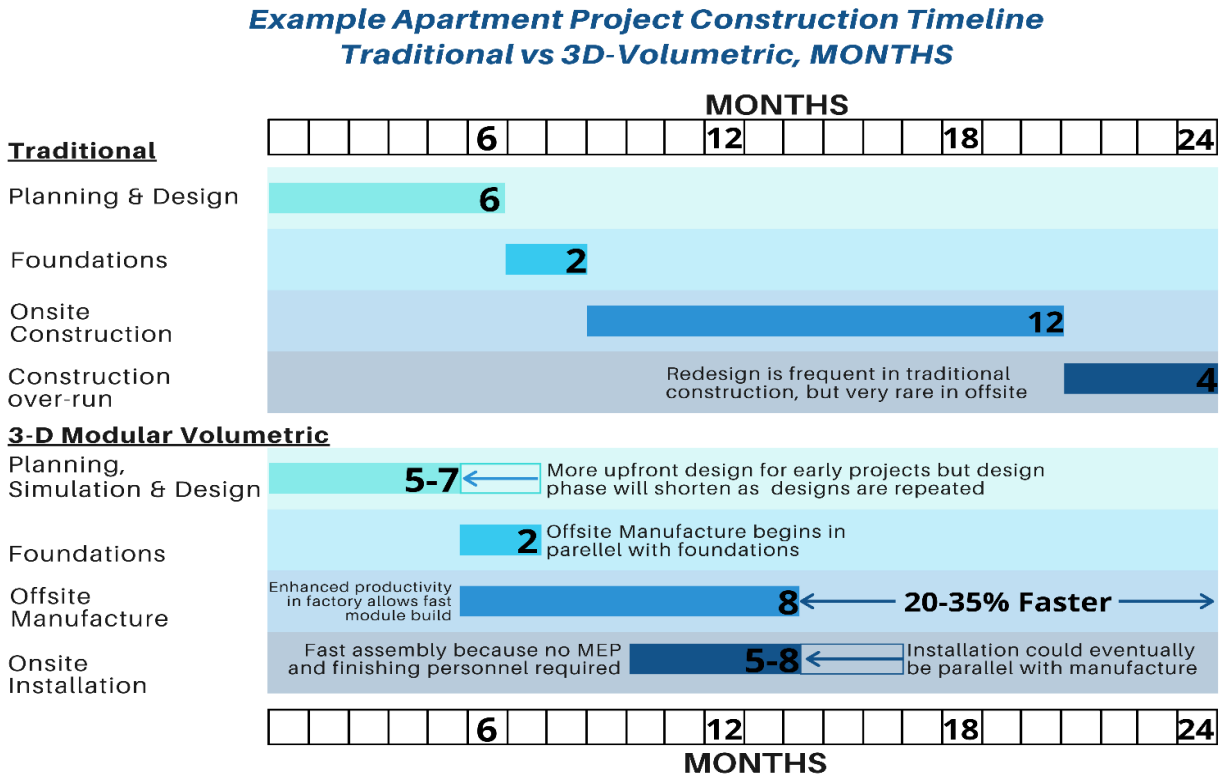
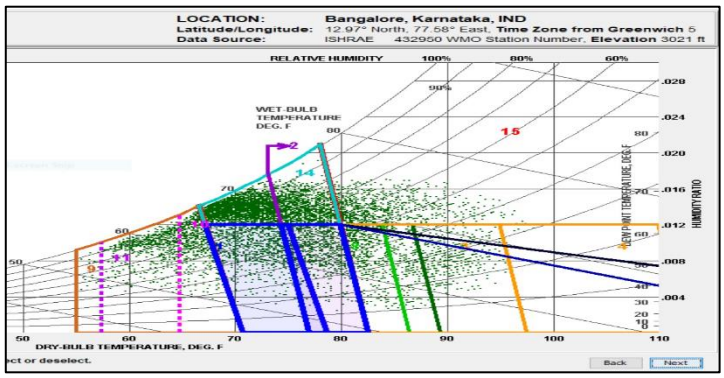


Fig25.

COMFORT AND ENVIROMENTAL QUALITY:

Thermal comfort Analysis

As we started designing the ventilation and fresh air units to work along side air conditioning, we felt the need to analyse the time during which the measures taken for better thermal comfort would be effective, also this would help us in avoiding any over-designing in the project and reducing cost upto an extent. We used simulation to find the actual hours for which the measures need to be taken to ensure comfort.



Software used- Climate Consultant 6.0

Standard Used- ASHRAE 55-2004 using PMV

The results obtained for Bangalore, Karnataka are shown in the analysis the details in depth we found the exact hours of comfort with and without aid. Using this data we can design the ventilation system and fresh air unit based on the following table:

Table 29. Thermal comfort techniques deployed

Thermal comfort	Hours	Remarks

Techniques Deployed		
Comfort without Aid	1612	The site won't need any aid for 18.6% of the time and will be comfortable
Sun shading of windows	2448	Providing shading on windows will increase the comfort hours upto 46.8% of yearly hours.
Direct Evaporative cooling	850	The **fountain present on the site** will increase the comfort hours cumulatively upto 57% of yearly hours.
	4910	Comfort Without Aid. Cumulative percentage : 64%
Natural ventilation & Fan forced Ventilation	650	Measures such as **wind catcher** in basement and **over-head windows** in corridor and passages boosts the thermal comfort hours.
Comfort with Aid	**3110**	For remaining **36% of time, Mechanical aid is required** for better thermal comfort. However, over a 24 HR period, as the temperature drops overnight, the coolness is absorbed and stored by the thermal mass in concrete and masonry.

PMV & PPD Analysis

Internal CFD for a flat 3 BHK Tower A(PMV & PPD Profiles)

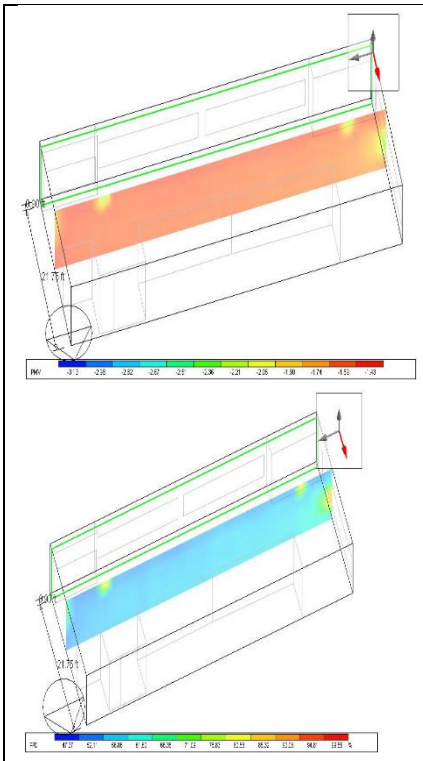
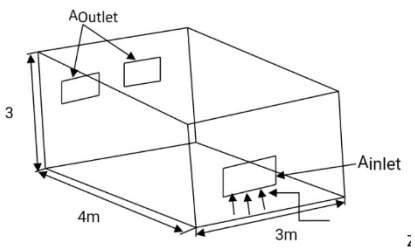
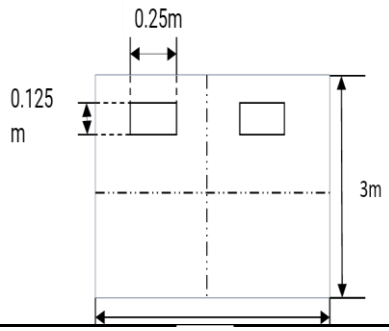
	Thermal comfort is the condition of mind that expresses satisfaction with the thermal environment and is assessed by subjective evaluation (ANSI/ASHRAE STANDARD 55).The predicted mean vote (PMV) and predicted percentage of dissatisfied (PPD) are the most widely used thermal comfort indices. ● PMV is an index that aims to predict the mean value of votes of a group of occupants on a seven-point thermal sensation scale. The heat balance of an individual can be influenced by levels of physical activity, clothing insulation, as well as the parameters of the thermal environment. ● Once the PMV is calculated, the PPD, or index that establishes a quantitative prediction of the percentage of thermally dissatisfied occupants (i.e., too warm or too cold), can be determined. PPD essentially gives the percentage of people predicted to experience local discomfort. From the figure we can see that PMV and PPD are in comfort range

Table30. Internal CFD for 3BHK

Numerical simulation of Natural Ventilation system of a residential building

For the feasible ventilation, natural circulation is the main concern here, which is highly dependent on a factor, related to wind speed. If the natural wind speed is increase, then natural ventilation and hence thermal comfort will be improved. Here we are considering Bengaluru's condition at night time. Thereby our main objectives here to find out the effect of air purifier and effect of wind speed through the air purifier and how energy consumption can be saved from the natural ventilation system. For the numerical simulation of building, commercial software ANSYS FLUENT was used. Air flow pattern inside the building, related heat transfer, turbulence, path lines of air flow, velocity and temperature profile inside the building has been observed.

- **Software used -** Gambit 2.4.6. & ANSYS FLUENT 16.2
- **Model and EquationsUsed- TransitionShear Stress Transport (SST) turbulence model,** Reynolds Averaged Navier-Stokes (RANS) equations, Reynolds averaged conservation equations for mass, momentum and energy.

Steps	Procedure	Relevant Diagram	Remarks
01.	Modelling the geometry of building		

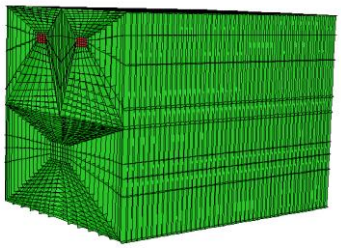
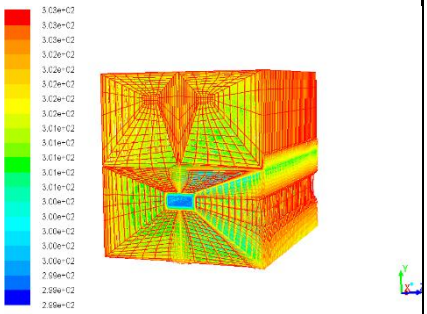
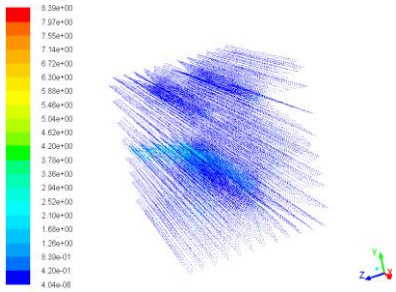
02.	Mesh generation		**Nodes- 157,368** The transition SST model has been used for present simulation which provides excellent results in predicting heat transfer under all situation i.e., laminar, transition and turbulent conditions suggested by "Abraham et. al. (2009)".
03.	Results obtained		No wall motion and no-slip conditions have been used on the wall. At the walls: u= 0, v= 0, T= 1, At the inlet: u= 1, v= 0, T= 1, At the outlet: Neumann conditions have been set for fluid variables i.e.$\partial\phi/\partial n$= 0 Where n is the direction normal to the outflow boundary. Considered, for room Rh= 40% at inlet.
04.	Post processing		The flow was mostly laminar as shown in the figure, this velocity is good for the ventilation application in our project. The optimum velocity was found to be **0.83 m/s.** **(AVG Nussetl number- 32.24)**

Table 31. Natural ventilation simulation procedure

Detailed Simulation Results for Natural Ventilation with various speed consideration is attached in Appendix.***

Hybrid system Proposed

Hybrid (mixed- mode) ventilation strategy has been used to cool the space in the most efficient manner by incorporating both usage of mechanical ventilation and natural ventilation method. BLDC fan and air conditioner work as part of mechanical ventilation and for natural ventilation, this filtration system can be used which brings fresh cool air from outside and induces it into the room so that the indoor air quality is improved. The noise level of this filtration unit is only 18 dB which is well below the standards for noise comfort.

Positive pressure ventilation system

The Positive pressure ventilation system can be connected to any compact IQAir air cleaning system. It enables the system to draw in polluted and contaminated air from outdoors or adjacent rooms. The IQAir system filters the airborne pollutants and pathogens and expels the cleaned air to the indoor environment. Thus this system can be used to provide clean air ventilation, positive pressure isolation or negative pressure containment of harmful airborne microorganisms and particulates.

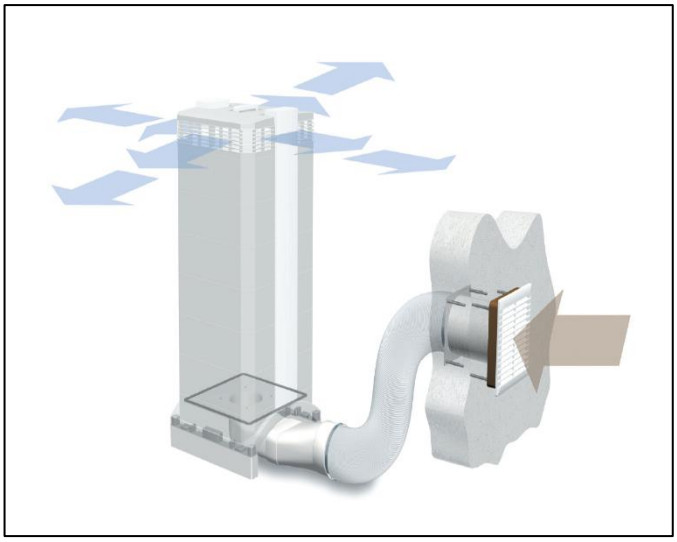


Fig26. Positive pressure ventilation system

Technical Specifications

• Required wall aperture: Diameter 130 mm (5.1")

• Length of wall duct: 100 mm (4") and 150 mm (6")

• Diameter of duct: 125 mm (5")

• Length: 250 mm (10") to 1000 mm (40")

Introduction of Wind Catcher

In Areas where the thermal comfort can be achieved directly by having an optimal velocity of air, we would like to introduce the concept of wind catcher in those areas. Environmental quality influences the living conditions outdoors as well as indoors. For meeting the optimal quality requirements, the proposed wind catchers have been simulated to develop a better understanding of the circulated air circulated indoors inside a room and as well as in the parking spaces. The incoming air velocity has been taken as 1.67 m/s, 3.56 m/s and 6.94 m/s (average air velocity of Vajrahalli, Kanakpura road, Bangalore) during the day, noon and night respectively.

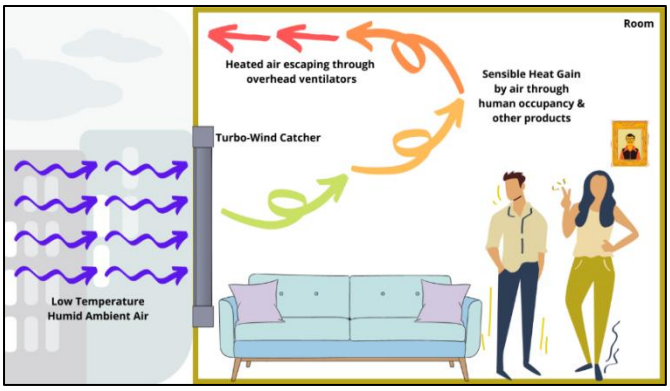


Figure 27 shows a typical ventilation process in a room with the help of the designed turbo-wind catcher. Additionally, as maintaining an optimum IAQ is of prime importance, the temperature and humidity of the incoming air can also be altered by installing fountains in the periphery of the plot, thereby allowing the air to carry moisture as it passes by. As a result, a lower temperature of incoming air is inherently expected in the region with a relative humidity of around 40-60%.

WASTE MANAGEMENT:

Solid Waste Management

Solid waste generation of all the towers along with the total population and its further breakdown into inorganic and organic waste generation is detailed below. Further, possible options are explored to use this waste to make a net zero waste system by comparing both biogas plant and a bio-composter.

Table32 Solid waste generation and segregation into Organic and Inorganic wastes.

Sl. No.	Description of Block/Wing	Total No. of unit	Number of Persons	Total Quantity of solid waste generated is 0.45 in Kg.	Organic (Wet) waste is around	Inorganic Waste is around 60% of total waste in Kg.

					40% of total waste in Kg.	
1.0	Building	528	4142	1863.9 ≈1864	745.48≈745	1118.22 ≈ 1118

Segregation:

- Segregation of wastes into wet, dry/ recyclables and household hazardous waste.
- Familiarizing users about the solid waste management system and organizing training programs.

Primary Collection & secondary storage:

- Door to door waste collection system will be carried out, and waste will be collected in two bins, one for Organic biodegradable waste & other for Inorganic one.

Processing & disposal:

- All the segregated Organic biodegradables are segregated and then will go to organic composter/biogas plant.
- All the Inorganic and hazardous wastes will go to Municipal Corporation, for proper disposal.

For further decomposition of organic waste, client has considered an organic composter; however, we are exploring and trying to access the feasibility of a biogas plant however we will compare both.

Specifications for a Biogas Plant

Area required for biogas plant = 2000 sq. ft. (Approx.)

Table33 Budget quotation for biogas plant

Capacity of the plant & waste input (max.) Approx. (kg/day)	Biogas produced Approx. (kg/day)	LPG equivalent Approx. (kg/day)	Electric power generated (Estimated) (kW/day)	Process Fresh Water Req/Day Approx.(lits)	Manure Production approx. (kg/day)	Budgetary Price approx. (for cooking purpose) (INR)	Budgetary Price approx. (for power production) (INR)
750	33	33	93	1500	270	19.55 Lakh	24.35 Lakh

- Waste will be fed in the digester after homogenizing with water in ration of 1:2.
- The biogas and manure generation is proportional to the quantity & quality of input waste loaded in the anaerobic digester.
- Waste has to be carefully segregated before proceeding to further decomposition
- By-product from the biogas plant can be used as liquid fertilizer.
- Conversion ratio of the genset will be in range 1.25 (Will produce 1.25kWh from 1cum raw biogas).
- The proposed plant will provide the clean cooking gas.

Return of Investment: -

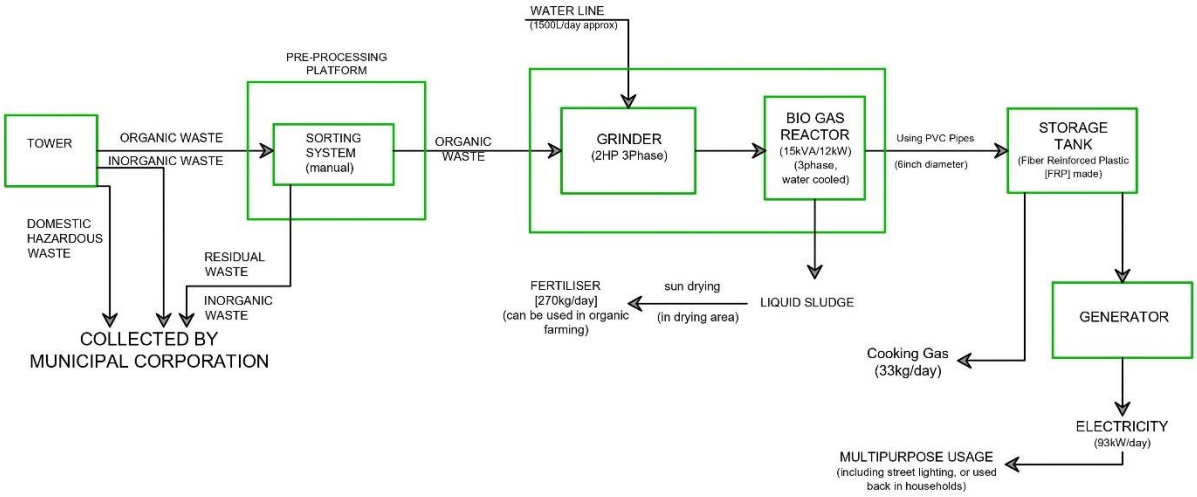
Case I: -

- Biogas savings per month ≈ 33 x 30 x ₹ 57.2 = ₹ 56,628
- Manure savings per month ≈ 270 x 30 x ₹10 = ₹ 81,000
  Total savings per month ≈ ₹ 1,37,628
  Return of Investment (ROI) ≈ 1 year 3 months

Case II: -

- Manure savings per month ≈ 270 x 30 x ₹10 = ₹ 81,000
- Electricity savings per month ≈ 93 x 30 x ₹ 8.05 ≈ ₹ 22,459.50
  Total savings per month ≈ ₹ 1,03,459.50
  Return of Investment (ROI) ≈2 years

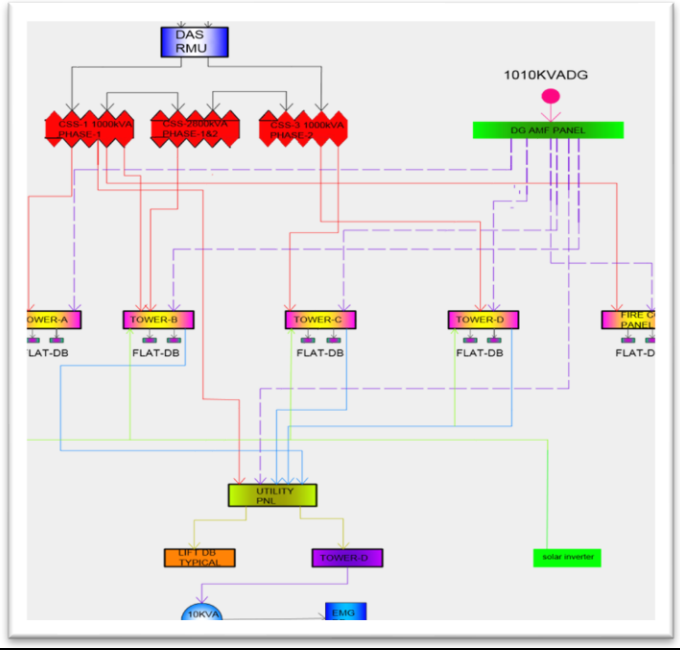
<u>Fig 28. Block Diagram</u> for whole waste generation and biogas formation (including inorganic and hazardous wastes): -



ENGINEERING DESIGN AND OPERATION:

Electrical Segment

Block Diagram of Overall Power Distribution



- This is the full block diagram of the overall distribution of electricity in the Towers: A, B, C, D. Phase-1 and Phase-2supply 1000KVA each to the Towers A,B& Towers C,D. The combination of Phase-1&Phase-2 supply 2800KVA.There is a solar inverter connected to the Towers where it supplies electricity for some specific appliances.
- Maximum Demand for Phase 1: 1878 KVA
- Total Demand (Phase 1 & 2): 3768 KVA
- Transforming sizing: 3768 KVA

Figure 29. Block Diagram of Overall Power Distribution	

From the SLD(Single Line Diagram) given in Appendix A, 2 12kV 630 A LBS(Load Break Switch) are connected to the 11kV supply bus. Then this supply charges the 2 11kV RMU(Ring Main Unit), one unit is in 1000kVA Phase 1 and the other is in 630kVA Phases 1 & 2. The Phase 1 and Phase 2 RMUs are connected to 1000Kva , Oil Type, 11kV/433kV and 800Kva, Oil type, 11Kv/433kV step up transformers respectively.

This stepped up voltage then supplies the buses which comprise the MCCB(Molded Case Circuit Breakers) that are eventually connected to the various metering panels. There are 4 metering panels, each of the first 2 consist of TOWER A and TOWER B and the other 2 consist of TOWER B only. All the metering panels are provided with CBCT(Core Balance Current Transformers) connected to ELR(Earth Leakage Relay) and the MCCBs connected consecutively are also of the same rating and supplied with 0-500V 3-φ A.C. Then followed by the Current Transformers with required ratings the EB bus and DG buses are interconnected with 3-φ direct operated energy meter, sealable fuse cutout, 40A TP MCB(Miniature Circuit Breaker)(10kA), ACCL(Automatic Source Changeover with Current Limiter) supplied from a 0.75kW 1-φ Diesel Generator and typical 10A SP MCB(10kA). From the ACCL the supply reaches connector box and thus, the distribution boxes of the corresponding flats. All the bus bars are of Aluminium with the phase and neutral current ratings at 100A.

Important keywords used:

LBS: A load break switch is a disconnect switch that has been designed to provide making or breaking of specified currents. ... These switches are used to de-energize or energize a circuit that possesses some limited amount of magnetic or capacitive current, such as transformer exciting current or line charging currents.

RMU: A Ring Main Unit (RMU) is a totally sealed, gas-insulated compact switchgear unit. The primary switching devices can be either switch disconnectors or fused switch disconnectors or circuit breakers, used at the load connection points of a ring type distribution network.
MCCB: The Molded Case Circuit Breaker basically utilizes a temperature-sensitive device which is also known as the thermal element with a current sensitive device are the magnetic elements to provide the protection and isolation which enables the MCCB device to provide overload protection along with electrical fault protection from any type of short circuit situations and also electrical switch for immediate disconnection.
CBCT with ELR: CBCT(Core balance current transformer) or the zero sequence current transformer are used to detect the leakage current in an Electrical Power System. Earth Leakage Relay (ELR) transmits a signal to activate the trip coil of the MCCB/ACB/OCB CONTACTOR in the event of Earth leakage, resulting in automatic isolation of the electrical power system.
ACCL: Automatic source changeover with current limiter is a high precision device which has a current limiting function. ACCL is used for efficient distribution of generator power in high rise apartments, townships, commercial buildings, etc without overloading the generator. The ACCL will switch the load to generator supply during failure of mains supply. It also acts as a current limiter when load on generator exceeds the pre-set limit thus avoiding any overload on the generator.

PITCH TO YOUR PROJECT PARTNER:

1. ENERGY EFFICIENT COST EFFECTIVE GLASS (Natura Plus)

Selection of a double glaze glass would be more efficient for less heat gain but the cost factor gets compromised. So in our project we have successfully reduced 6.19% EPI with sufficient daylight area using our proposed single glazed high performance glass, Natura Plus with client convention. So both the comfort of

the occupants and the cost factor is not compromised. Proposed glass is capable of saving 53.27% cost compared to the Double Glazed Unit. Moreover specially for this project we are successful in customizing the cost as in discussion with our Glass Industry partner (ASAHI glass India Ltd.) which turns out to be a plus point in the project budget.

2. ENERGY EFFIECIENT ENEVELOP MATERIAL

Even without compromising with the carpet area we are successful in reducing the U value of the building envelope by proposing usage of AAC/porotherm block instead of RCC. Only changing the construction material can reduce up to 6.40% of the overall EPI of our project.

Benefits:

- AAC and porotherm block both are a light weight building material (60% less weight than conventional building material).
- Both have better thermal and acoustic insulation properties.
- Both can be used in load bearing walls as well as non load bearing walls.
- The flyash used in AAC block production is eco-friendly and it also gives a solution of better utilization of waste material.
- Transportation cost for the material can be reduced as major authorised dealers of porotherm are Karnataka based.

3. ROOF INSULATION INTERVENTION

As the booking of the top most flats in any tower is not often assured because of maximum heat gain through roof which in turn increases the overall energy consumption. Hence in our design the thickness of the XPS material used for the roof insulation has been changed from 50mm (as mentioned by our client) to 75mm in order to give a better EPI.

4. LOW FLOW RATE PLUMBING FIXTURE FOR WATER CONSERVATION

Keeping water tariff hike in mind we provide a solution where we have come up with three different cases with different strategies to conserve water. In our first case we have changed all our plumbing fixtures with low flow rate fixtures and waterless urinals are installed which brings a reduction of 32% in overall water consumption. Using 4.5 LPM aerators with the previous case has a potential to bring down the consumption by 40% and as we are approaching towards net zero water building so we propose to use 1.2 LPM aerator with the proposed low flow-rate fixtures which conserve 59% of the total water. Additionally we are harvesting rainwater and storm water with black and grey water recycling which eventually reduces municipal water demand. An extra 5mins of storm water harvesting is considered than client case which gives up to 74890 litres of extra water.

5. APP BASED DRINKING WATER SERVICE & MONITORING

Team NIVAS developed app based solution for residential building occupants to get safe drinking water without any service liabilities. This IOT integrated app solution will take care of water refilling, system maintenance and water consumption monitoring with update to individual customers through his mobile phone.

6. DIGITAL AND SMART HOMES

As we are living in the digital era so upcoming building design must have integration of latest technology which measure and monitor the individual home performance with added values for customer delight. For this purpose Team NIVAS has developed app and web based solution for occupant’s use.

Team NIVAS automation app:

Monitoring comes prior to saving. So the main objective of the Smart Lifespace App is to retrieve data from smart meters and display the data in real time. This will help to monitor the amount of energy consumed on a daily or monthly basis. Similarly water levels and water usage pattern can also be monitored.CO2 levels for a better IAQ can also be monitored and if the threshold value gets crossed the users will get an alert signal.

Energy predictor:

This predicts the overall energy consumed by the resident annually as per the power ratings of the equipments used.

Wi-Fi modulation:

The project site is in close proximity to IT hub which shows that the majority of the residents are IT sector employees. And also to comply with the digital era and Work From Home culture we have done a Wi-Fi simulation to provide a good signal strength over all the space.

7. TURBO WIND CATCHER FOR VENTILATION

Mixed mode ventilation strategy is used Wind Catchers for proper ventilation throughout the building including the basement parking area.

8. SOLID WASTE MANAGEMENT

The biogas system is much more sustainable and techno economically feasible as the product of the system will either produce fuel or electricity, both of which can substitute complex traditional fuel or electricity requirements. Further the system is having almost negative carbon footprint when compare to composter. The energy or fuel will be utilized in the complex itself where the compost will be market driven also there will be production of compost in the case of biogas reactor. The ROI figure although looks better for composting but the variable or users for the compost is higher leading to risk and challenges.

9. HVAC SYSTEM SELECTION FOR CLUBHOUSE

Facility like Club house always face variable occupancy load pattern so we strongly recommend VRF systems for clubhouses cooling application with multiple cassette indoor unit have been chosen to give better airflow patterns and avoid blind spots.

FXFQ series (a round flow sensing cassette) is also selected to give a 360 degree air conditioning which provides an excellent comfort level, energy efficiency and flexibility due to advanced control functions.

CODE AND STANDARDS:

IS3646	CODE OF PRACTICE FOR INTERIOR ILLUMINATION
NBC 2016 VOL 1 AND VOL 2	NATIONAL BUILDING CODE OF INDIA
IGBC GREEN HOMES	INDIAN GREEN BUILDING COUNCIL
ECBC 2017	ENERGY CONSERVATION BUILDING CODE
UPC 2008	**Uniform Plumbing Code**
BEE	**Bureau of Energy Efficiency**
ASHRAE	American Society of Heating Refrigerating and Air-conditioning Engineers
ISHRAE	**Indian Society of Heating refrigeration and Air Conditioning Engineers**

BIS	Bureau of Indian Standards

REFERENCES:

1. Koshish Sustainable Solutions Pvt. Ltd.2021,*Biogas and BioManure Production Plant*. Available from: <https://koshishindia.in/>.[March 28, 2021].
2. Ministry of Urban development - Centre of excellence in urban development in the area solid waste and waste water management2011, *SWM Technology Manual.*[Feb 21, 2021]
3. Indiamart. Available from: <https://my.indiamart.com/>[March-April, 2021] (For quotation only)
4. Amazon. Available from: <https://www.amazon.in/>[April, 2021] (For quotation only)
5. **Council, I.G.B., 2015. IGBC green new buildings rating system—Version 3.0. India, April.**
6. de León, A.E.D., 2010. National building code of India and the international building code: an introduction. Indo-US Forensic Practices: Investigation Techniques and Technology, pp.111-120.
7. Hydro.imd.gov.in.2021.*Customized Rainfall Information System (CRIS). [online]*Available at: <http://hydro.imd.gov.in/hydrometweb/landing.aspx>.
8. B. Qolomany, A. Al-Fuqaha, A. Gupta, D. Benhaddou, S. Alwajidi, J. Qadir and A. C. Fong, Leveraging Machine Learning and Big Data for Smart Buildings: A Comprehensive Survey, IEEE Access 7 (2019) 90316-90356.
9. NagarajuKaja, A review of energy consumption in residential sector in india; possibilities for energy conservation, IMPACT: International Journal of Research in Humanities, Arts and Literature (IMPACT: IJRHAL) ISSN (P): 2347-4564; ISSN (E): 2321-8878
10. Guo, Gongde& Wang, Hui & Bell, David & Bi, Yaxin. (2004). KNN Model-Based Approach in Classification.
11. Pecan Street Dataport. [online] Available: https://dataport. pecanstreet.org/
12. Shapi, M.K.M, Ramli, N.A., Awalin, L.J., Energy Consumption Prediction by using Machine Learning for Smart Building: Case Study in Malaysia, Developments in the Built Environment

*

Joyful Homecomings

Mahindra LIFESPACES

12.10.2020

To,

The Director,

Solar Decathlon India

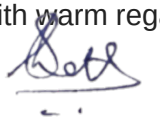
Dear Sir,

This is to inform you that our organisation, Mahindra Lifespaces, has provided information about our Residential Building project to the participating team led by **Institute of Engineering & Management, Kolkata** so that their team **Team NIVAS** may use this information for their Solar Decathlon India 2020-21 competition entry.

As a Project Partner to this team for the Solar Decathlon India 2020-21 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 organisation attend the Design Challenge Finals event in April, if this team is selected for the finals.

We would like our organisation's logo to be displayed on the Solar Decathlon India website, recognising us as one of the Project Partners for the 2020-21 competition.

With warm regards,



Name : Dr. Sunita Purushottam

Designation: Head of Sustainability

Name of Organisation: Mahindra Lifespaces

Email: purushottam.sunita@mahindra.com

Phone: 8600134626

Software for Architecture, Engineering and Construction

Avda. Eusebio Sempere, 5
03003 Alicante - SPAIN
Tel. (+34) 965 922 550
www.cype.com

To,

The Director,
Solar Decathlon India

28th January 2021

Dear Sir,

This is to inform you that our organization, CYPE, is collaborating with the participating team (team NIVAS) led by **Institute of Engineering & Management**, **Kolkata and OmDayal College of Engineering & Architecture** and **Jalpaiguri Government Engineering College** on a Residential Building project for their Solar Decathlon India 2020-21 competition entry.

The nature of our collaboration will be provide software for Architecture, Engineering and Construction and organize training sessions.

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 2020-21 competition.

With warm regards,

cype
Eusebio Sempere, 5 • 03003 ALICANTE
Tel. 965 922 550 • Fax 965 124 950
www.cype.es

Benjamin Gonzalez
Corporate Development Director
CYPE
benjamin.gonzalez@cype.com
+34965922550

D2O Learning Private Limited

CIN No. U80904RJ2020PTC071831

30/11/2020

To,

The Director,

Solar Decathlon India

Dear Sir,

This is to inform you that our organisation, **D2O Learning** is collaborating with the participating team led by **Institute of Engineering and Management, Kolkata** on a Residential Building project for their Solar Decathlon India 2020-21 competition entry.

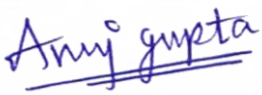
As an industry partner to **Team NIVAS** for the Solar Decathlon India 2020-21 competition, we are supporting them to make their best submission with various analysis. Our D2O team is supporting Team Nivas in all the technical work of the project.

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

We would like our organisation's logo to be displayed on the Solar Decathlon India website, recognising us as one of the Industry Partners for the 2020-21 competition.

With warm regards,

Name: Anuj Gupta



Designation: Co-Founder

Name of the Organisation: D2O Learning Private Limited

Email: anuj@d2olearning.com

Phone: +91-9509314499

INNER ENGINEERING
DESIGN • COMFORT • INSULATION

Date: 30-01-2021

To,

The Director,

Solar Decathlon India.

Dear Sir,

This is to inform you that our organization, Inner Engineering Products and Systems Pvt Ltd., Ahmedabad, is collaborating with the participating team led by Institute of Engineering & Management, Kolkata on a Residential Building Project for their Solar Decathlon India 2020-21 competition entry.

The nature of our collaboration will be purely on providing all kind of technical inputs required to team from insulation domain.

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

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 2020-21 Competition.

With Warm Regards,

Anjali Kulkarni,

Research & Development Coordinator,

Inner Engineering Products & Systems Pvt. Ltd.,

Ahmedabad, Gujrat-380015.

ie.research@innereng.com

+91 635000248.

22.01.2021

To,

The Director,
Solar Decathlon India

Dear Sir,

This is to inform you that our organization, Asahi India Glass Ltd., is collaborating with the participating team led by **Institute of Engineering & Management**, Kolkata and **Om Dayal College of Engineering & Architecture** and **Jalpaiguri Government Engineering College** on a Residential Building project for their Solar Decathlon India 2020-21 competition entry.

The nature of our collaboration will be to inform and educate the students about high performance glazing and guide in right product selection.

We would like to have a representative from our organization attend the Design Challenge Finals event in April/May, if this team (Team NIVAS) 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 2020-21 competition.

With warm regards,

Garima Kamra
Technical Manager
Asahi India Glass Ltd.
garima.kamra@aisglass.com
+91 7428389687

HYDROTEC
Solutions Private Limited

MS CERT
ISO 9001 : 2015 Certified

16-Feb-2021

To,

The Director,
Solar Decathlon India

Dear Sir,

This is to inform you that our organization Hydrotec Solutions Pvt Ltd (known for Arosia Water ATM) , is collaborating with the participating team (team NIVAS) led by **Institute of Engineering & Management**, Kolkata and **OmDayal College of Engineering & Architecture** and **Jalpaiguri Government Engineering College**on a Residential Building project for their Solar Decathlon India 2020-21 competition entry.

The nature of our collaboration will be guiding the team to design best industrial practice related to Water Management in the ongoing project.

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 2020-21 competition.

With warm regards,

Navin Gupta

Founder &CEO
Hydrotec Solutions Pvt Ltd
navin@hydroteclimited.com
8697702088

Date – 08-02-2021

To,

The Director,

Solar Decathlon India

Dear Sir,

This is to inform you that our organisation, WEGoT Utility Solutions, is collaborating with the participating team led by Vellore Institute of Technology, Vellore on an Educational Building project for their Solar Decathlon India 2020-21 competition entry.

The nature of our collaboration will be to assist the students/team engaged in the program, design water efficient buildings leading to net zero water infrastructures.

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

We would like our organisation's logo to be displayed on the Solar Decathlon India website, recognising us as one of the Industry Partners for the 2020-21 competition.

With warm regards,

Name – ABILASH HARIDASS
Designation – CO-FOUNDER, CHIEF OF GROWTH & STRATEGY
Name of the Organisation – WEGOT UTILITY SOLUTIONS
Email – abilash@wegot.in
Phone - 9884332714

GSTIN- 19ABDPH5517M1ZF
tm Services
Tech-Mech Services
An Unit of Small Scale Industries
Developer of Science & Archeological Museum, Energy & Amusement Park, Solar Power Plant
25/2, Thakur Pukur, Badu Road,
Kathor More, Kolkata - 700 128, West Bengal.
e-mail : admin@techmech.net, services@techmech.net
visit us : www.techmech.net
Dial : (033) 2526 0020, 09073389333, Fax : 033-2562-3909, Mobile : (+91) 9830055262, 9073389335
Branch Office : B-2,Mudrika Apartment, Bhavya Park, Bopal, Ahmedabad, Gujarat, PIN - 380058.

Date : 24-03-2021

To,
The Director,
Solar Decathlon India

Dear Sir,
This is to inform you that our organization, Tech Mech Services, 25/2 Thakurpukur, Badu Road, Barasat, Kolkata 700127, is collaborating with the participating team (team NIVAS) led by **Institute of Engineering & Management**, **Kolkata** on a Residential Building project for their Solar Decathlon India 2020-21 competition entry.

The nature of our collaboration will be to provide clarity on the approach of designing the installation of PV power plants, cost calculation of the project, and assist in procurement of materials as well as supervision of the work to achieve the goal.

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 2020-21 competition.

With warm regards,

Spandan Hira
Chief Operating Officer
Tech Mech Services
spandan.hira@techmech.net
+91 9830 659 083

Date 19 Jan 2021

To,

The Director,

Solar Decathlon India

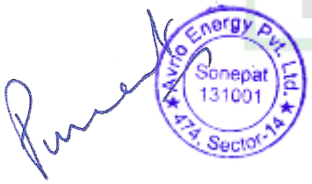
Dear Sir,

This is to inform you that our organization, **Avrio Energy Private Limited**, is collaborating with the participating team led by **Institute of Engineering & Management, Kolkata and Om Dayal College of Engineering & Architecture and Jalpaiguri Government Engineering College** on a Residential Building project for their Solar Decathlon India 2020-21 competition entry.

The nature of our collaboration will be Technology / Consultancy partnership where Avrio Energy will provide guidance to team on incorporating IOT solutions in their design proposal to increase comfort and reduce energy consumption. We will provide them solutions ranging from energy monitoring, temperature monitoring to control solutions.

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 2020-21 competition.



With warm regards,

Puneet Batra

Director

Avrio Energy Private Limited

puneet@avrioenergy.in

+91 8168956878

Date: 29 Jan 2021

To,

The Director,
Solar Decathlon India

Dear Sir,

This is to inform you that our organisation, (Inoviea Ventures Private Limited), is collaborating with the participating team led by Team NIVAS, SDI IEM, Kolkata on a Office / Educational / Residential / Community Resilience Shelter Building project for their Solar Decathlon India 2020-21 competition entry.

The nature of our collaboration will be Technology provider for solar plant with ipanelKlean.

We ~~would like~~/ would not be able to have a representative from our organisation attend the Design Challenge Finals event in April/May, if this team is selected for the Finals.

We would like / ~~do not want~~ our organisation's logo to be displayed on the Solar Decathlon India website, recognising us as one of the Industry Partners for the 2020-21 competition.

With warm regards,
-s/d-

Name: Suchin Jain
Designation: Director
Name of the Organisation: Inoviea Ventures Private Limited
Email: suchin@inoviea.com
Phone: 9910228861
(Does not require physical signature)

19.03.2021

To,

The Director,
Solar Decathlon India

Dear Sir,

This is to inform you that Retas Enviro Solutions Pvt. Ltd., is collaborating with the participating team (team NIVAS) led by **Institute of Engineering & Management**, Kolkata and **OmDayal College of Engineering & Architecture** and **Jalpaiguri Government Engineering College** on a Residential Building project for their Solar Decathlon India 2020-21 competition entry.

The nature of our collaboration will be in guidance related to innovative Rainwater Harvesting.

We would be able 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 2020-21 competition.

With warm regards,

RETAS ENVIRO SOLUTIONS PVT. LTD. Authorised Signatory

Ankit Magan
Director (Retas Enviro Solutions Pvt. Ltd.)
ankit.magan@resplindia.com
+91-9711074119

Prabir Kumar Sen, BE (Mech.), M.Tech
Consulting Engineer – HVAC

To
The Director,
Solar Decathlon India

Date 15.02.2021

Dear Sir,

This is to inform you that I, PRABIR KUMAR SEN, a freelance HVAC consultant, am collaborating with the participating team (team NIVAS) led by **Institute of Engineering & Management**, Kolkata and **OmDayal College of Engineering & Architecture** and **Jalpaiguri Government Engineering College** on the Residential Building project for their Solar Decathlon India 2020-21 competition entry.

The nature of our collaboration will be giving the team engineering guidance on ventilation (and air conditioning, if used), indoor air quality and usage of renewable energy in the project.

I shall confirm my attendance in the Design Challenge Finals event in April/May, 2021 (if this team is selected for the Finals) at a later date.

I have no objection in your mentioning my name on the Solar Decathlon India website, recognizing me as one of the Industry Partners for the 2020-21 competition.

With warm regards,

PRABIR KUMAR SEN
Consulting Engineer, HVAC
Email : prabirkumarsen@yahoo.co.in
Phone : +91 9830664806

applex.in

Date : 14/03/2021

To,
The Director,
Solar Decathlon India

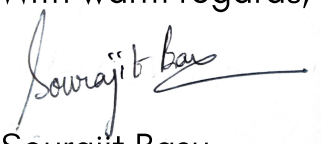
Dear Sir,
This is to inform you that our organization, applex.in, is collaborating with the participating team (Team NIVAS) led by **Institute of Engineering & Management**, Kolkata on a Residential Building project for their Solar Decathlon India 2020-21 competition entry.

The nature of our collaboration will be as technical partners and consultants for NIVAS's IT services.

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 2020-21 competition.

With warm regards,



Sourajit Basu
Co-Founder
applex.in
sourajit.basu99@gmail.com
+91 6290438875