Solar Decathlon India

Final design Report April 2022

MULTI - FAMILY HOUSING

TEAM

SUKHIBHAVA

JAWAHARLAL NEHRU ARCHITECTURE AND FINE ARTS UNIVERSITY

SCHOOL OF PLANNING AND ARCHITECTURE, HYDERABAD

PROJECT PARTNER: SAVVY GROUP

TEAM SUKHIBHAVA

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1.0 EXECUTIVE SUMMARY

Team Sukhibhava is a group of 14 students from Jawaharlal Nehru Architecture & Fine Arts University with skills required for working towards achieving the goals of Solar Decathlon India competition. Our major goal is to design a net-zero-energy multi-family housing complex with 80 dwelling units for a specified income group, primarily those in the higher middle and upper income groups. Sukhibhava, as the name implies, represents happiness and a good life for the occupants.

Our renowned project partner Savvy group has given us the opportunity to work on the 'Pragya II' project, a 20-story high rise residential apartment with 80 housing dwellings located in Block 16-E, GIFT city, Gujarat, with a total area of 4790m²(1.18 acres). Our journey of the competition began with the establishment of goals for each of the ten contests. In the early stages of the project, a detailed climatic analysis was used to help with massing, block orientation, and block placement on site. Located in a hot and dry climatic zone, Pragya-II is designed to meet the problems such as higher temperature range than comfort zone needed as well as significant wind velocities from the southwest. At several stages of the design, both at the site and module levels, the site's potential for comfort through natural ventilation and daylighting was analysed. This aided in promoting cross ventilation and 87% of Useful Daylight Index(UDI $_{300\text{-}3000}$) in the indoors. The form of the block is staggered and self-shading after numerous iterations, reducing excess heat gain while optimising views for every unit towards the city on the north and the water body on the south, giving the occupants a villa-like experience. Following that, we assessed the operation modes for a 24 hour period in Ahmedabad using the IMAC tool (as the weather data for GIFT city is not available). The base design achieved a value of 56.64 Kh/yr/m² when the EPI was calculated. We used a variety of software to iterate our building design to get a final EPI of 26.11 KWh/yr/m². The final design is the result of optimized energy performance, thermal comfort, energy efficient equipments, privacy through passive techniques, star rated equipments, materials, and innovations based on the initial iterations. As a result, we have an EPI ratio of 0.46, which is in the top tier of the IGBC's net zero building grading system (that is less than 0.75).
Project Pragya II uses solar PV on the roof top and ground areas to attain net zero energy target by generating 28.28 KWh/yr/m² of EPI.

2.0 TEAM SUMMARY

Team Name Sukhibhava

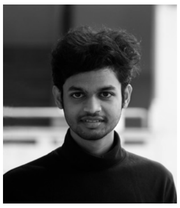
Institution Jawaharlal Nehru Architecture and Fine Arts University

Division Multi-family housing

TEAM SUKHIBHAVA

2.1 Team Members

M. MOJESH
(ARCHITECTURE)
TEAM LEAD
Architectural and Landscape Design, Affordability, Graphics



ABHINAV. D
(ARCHITECTURE)
CO-LEAD
Architectural Design, Modelling, Thermal Comfort, Engineering, Innovation

SHEKAR. A
(ARCHITECTURE)
Architectural Design, Energy Simulations, Affordability, Resilience

D.MONIKA
(ARCHITECTURE)
Design Development

V.S.S.HIMA BINDU
(ARCHITECTURE)
Water Performance

M.SASI VARUN
(ARCHITECTURE)
Research

P.R.KEERTHI
(ARCHITECTURE)
HVAC systems

B. MADHUSUDHAN
(ARCHITECTURE)
Electrical Systems

A. BHAVITHA
(ARCHITECTURE)
Market Potential

B. ROOP SINGH
(ARCHITECTURE)
Communication

D. RAM CHARAN
(ARCHITECTURE)
Material Specification, plumbing

M. INDHU
(ARCHITECTURE)
Research

C. LAKSHMI PRASANNA
(ARCHITECTURE)
Research

DINDI RAJESH
(FSP ENGINEERING)
Lighting

2.2 Institution

Jawaharlal Nehru Architecture and Fine arts university is one of the foremost institutions of Art in India and has the unique distinction of completing more than 70 years of useful and yeoman academic service in the field of education in general, and Architecture & Fine Arts in particular. Established in the erstwhile Nizam State in the year 1940, it is one of the premier institutions of Art and Architecture which has been rendering continuous service for more than seven decades. With the establishment of Jawaharlal Nehru Technological University in Oct. 1972, the College merged with the university and became a Constituent College of the JNT University.

2.3 Faculty Lead And Faculty Advisors

LEAD FACULTY

Ar. Ch. Srinivas
(B. Arch, M.U.R.P)
Associate Professor and HOD
JNAFAU

FACULTY ADVISORS

Ar. P. Uday Shankar
(PhD)
Assistant Professor
JNAFAU

Ar. Srishti Srivastava
(PhD)
Assistant Professor
JNAFAU

Meghna Mallick
(B.Arch, M.Arch)
(Sustainable Architecture)
Assistant Professor
JNAFAU

2.4 Industry Partner

Akshay Tiwari bachelor's from CSIIT, master's degree in environmental design from JNAFAU. Started work as a BIM modeler in 2013, moved to teaching later currently working as HOD interior design at Hamstech college of creative education and visiting faculty at JNIAS and Woxsen school of design.

2.5 Software and Tools Used

Various software and tools were used to run the simulations and help us with the design process and report making.

2.6 Approach

From the start we tried to understand and get a clear idea of what exactly the solar decathlon India 2021 - 2022 wanted us to accomplish. We continued to work on our teammates' varied capabilities and sensibilities in order to efficiently complete the tasks and 10 contests, as well as their requirements. We divided the work based on our teammates' areas of interest and ability in order to advance further in the competition. We are confident in our ability to meet the obstacles with the help of our project partners, faculty lead, and faculty advisors. We are able to understand all the sectors related to net zero approach, energy efficiency solutions, and latest trends and technologies based on the educational sessions organised by the solar decathlon India (SLMs, Webinars). For the goal of guidance, unofficial meetings with various industry partners were organised.

2.7 Design Process

2.7.1. Introduction To The Competition

As a part of our fourth year design studio, we participated in the Solar Decathlon India competition by forming into a group.

2.7.2. Research Work And Project Partner Introduction

Various topics related to multi-family housing and net-zero buildings have been identified and shared among the group members for a proper research. Solar Decathlon India has provided us with a project partner for the competition. The project proposal and site information were given by the project partner. And the SLMs provided by SDI helped in understanding the ten contests.

2.7.3 Case Studies

In the same climatic conditions as the project site, a case study was done. There have been a number of green features identified that could be implemented.

2.7.4 Industry Partner

We have approached the Industry partner who helped us with the understanding of water performance.

2.7.5 Site Analysis

A detailed site and climate analysis has been done. Different massing options have been explored.

2.7.6 Design Concept

From the start, a design concept was developed based on basic concepts, and passive measures were implemented. Various schematic drawings and zoning possibilities were tested. From the simulations that were run, a final iteration was chosen.

2.7.6 METAMORPHOSIS

By consulting industry specialists in the areas of structure, plumbing, HVAC, and landscaping, conceptual designs have been transformed into final architectural and engineering drawings using various tools.

Timeline

3.0 PROJECT SUMMARY

3.1 Project Name : Pragya II

3.2 Project Partner : Savvy group

Savvy is a progressive construction company that believes in changing the paradigm of the construction business by adopting innovative technologies.
It is with this approach that it is ISO 9001:2008 certified and will be the first construction company to have CRISIL rating in Gujarat.
Savvy endeavours to provide value for money to its customers. With a strong belief in safety, hygiene, efficiency and technological advancement, the company builds complete and exclusive structures.

- Provision of alive and kicking constructions and the comfort of clients forms the backbone of all the functions of the Savvy.
- Latest utility systems, aesthetically superior façades and explicit building maintenance form special features of all the Savvy constructions.

3.3 Project Description :

- **Location :** GIFT (Gujarat International Finance Technology) City, Gujrat.
- **Climate :** Hot and Dry climate with marginally less rain than required for a tropical Savanna climate.
- **Project Context :** GIFT City is an integrated development on 886 acres of land with 62 mn sq. ft. of Built Up area which includes Office spaces, Residential,Apartments, Schools, Hospital, Hotels, Clubs, Retail and various Recreational facilities, which makes this City a truly “Walk to Work” City. Samruddhi sarovar provides 15 days of drinking water supply to the entire city.
- **Project Status:** The current site is levelled site and is looking for private investors.
- **Type of Project:** Build-sell
- **Stage of Project:** Proposal of 80 flat apartment
- **Site area :** 1.18 acres (4790 m^2)
- **Permissible Build-able area :** 17,483 m^2 (FSI = 3.65)
- **Build-able area:** 16,870 m^2 (FSI = 3.52)
- **Permissible Ground Coverage :** 75%
- **Ground coverage :** 1060 m^2 (22%, excluding basement)
- **Building Occupancy Hours :** 24/7
- **Baseline Esitimate :** 19,000 per sq.m in INR

3.4 Energy Performance Index(EPI) Achieved : 26.11 KWh/m^2 per year

3.5 On Site Renewable Energy Generation :

- Onsite renewable energy of 5,05,187 kwh/year through PV panels.
- EPI attained with generation = 28.28 KWh/yr/m^2

4.0 GOALS AND STRATEGIES

Architecture: To design spaces that enhances the user experience.
The flats are arranged such that every unit feels like an independent villa. Open floor plates ensuring privacy. Minimal yet dynamic facade.

Market Potential & Scalability: Targeted user groups are upper MIG and HIG. To achieve adaptability as per spatial requirements.
We chose the most happening construction technique around GIFT city and Ahmedabad, which is RCC plus block work structure.
A design which could be replicated to the similar climatic context along with some modifications as per the module (1,2,3,4 bhk's) requirements.

Thermal Comfort: To achieve a thermal comfort using IMAC tool.
Maximum use of Natural ventilation. Fan forced ventilation for cooling. Use of mixed mode ventilation following the IMAC model to achieve comfortable temperatures during the winters (21-25 C) and summers (26-28 °C).

Resilience: Withstand the earthquakes and heat waves with passive strategies.
Although earth quake occurrence is not very severe(site falls under Zone III, in case of a high rise building, we aim to work on designing an earthquake resistant structure.
Wind Speeds: The site receives maximum wind velocity of up to 26 m/s. In case of high-rise, wind loads to be considered while designing.
To withstand the heat waves, the recreational activities are planned at the shaded region.

Water performance: To achieve reduced water consumption by 44%. Recharge groundwater for domestic use.
The site being in hot and dry climate, rain water harvesting can be done with systems like micro WH. Through water fixture optimisation 75 lpd is achieved. Sewage treatment plants have been placed which recycle 75% of the grey water, which is reused for landscape and flushing requirements.

Energy performance: EPI reduction of 40 -50% from the base case.
Achieved a final case EPI of 26.11 KWh/yr/m^2 *which is of 53% reduction from the base case by optimised orientation,passive strategies, shading, envelope optimisation, star rated equipment and on site renewable energy generation.*

Affordability:
Usage of local materials helps with transportation and budget, recycled materials like bricks, glass, wood, asphalt etc. can cover a some of construction part. Also we are considering low maintenance and efficient materials for floorings and windows etc.

Engineering And Operations: To make the functionally more effective.
An App interface design has been created to provide for the effective management.

Waste management: To collect, segregate and recycle the waste generated on site.
Taking advantage of the GIFT city's Automated solid waste management through chute system, waste is ejected from the site.

Innovation:
To create a canopy to protect the areas affected by the solar radiation. Use of dual mechanism water equalization system to maintain fixed water pressure across entire building.

4.1 SUMMARY OF CASE STUDY

4.1.1 PROJECT DETAILS

Project name : Savvy Solaris
Location : Motera, Ahmedabad, INDIA
Coordinates : N23.1, E72.5
Climate (as per NBC) : Hot & Dry
Site area : 11,235 sq.m
Architect : Mr Apoorva Amin
Total Built up Area : 2943 sq.m
No of dwelling units : 348 Units

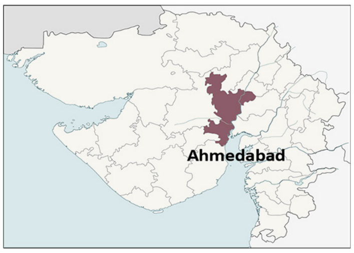


Figure 1a: Gujarat Map

Figure 1b: Location

Comprehensive analysis of all that factors that define and effect a net zero housing project, based on the location, climate, user, purpose, strategies, context, etc helped us in profound understanding to move forward.

4.1.2 FEATURES

1. Sustainable site planning

Top soil preservation

Preserves the natural top soil and natural biome.
Helps in saving cost of bringing top soil from a nursery post construction.


Figure 2a: Overall view


Figure 2b: Top view

2. Energy Performance

Passive Solar features

Building plan is rectangular in form. All external and internal walls are composed of AAC block masonry, which reduces heat transmission and keeps the interior space cooler than the outside. High SRI roof tiles is Heat reflective and recycled content.

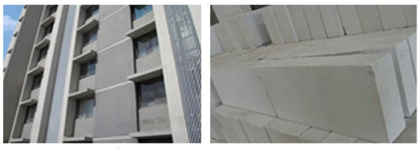


Fig. 2c: AAC masonry wall for external wall


Fig. 2d: SRI roof tiles

3.Water Performance

Rain water harvesting system, Ground water percolation, Waste water treatment, Sewage treatment plant water which will be used for toilet flushing and landscape irrigation.


Fig. 2e: Storm water drain


Fig. 2f: Waste water treatment

4.Landscape paving materials

Impervious paving, High SRI concrete pavement, concrete paver and grass lawns reduces heat island and reduces evaporation, helps in percolation.


Fig. 2g: Soft paving with grass


Fig. 2h: Hard paving with concrete paver

The above case study helped us to understand the various practices and strategies that could be applied to achieve a net zero sustainable green building. The inclusion of practices like solar systems , green roofs , usage of local materials and courtyard systems would have been beneficial for hot and dry climate zone buildings.

SOURCE : Info from : [2014BG02 HUDCO.pdf]
Images from : Magic bricks & 99 Acres.com

4.2 SUMMARY OF HOT AND DRY CLIMATE ZONE GREEN BUILDING FEATURES

GREEN FEATURES	IMPLEMENTED IN PRAGYA II
Citing And Climate Responsiveness	
Orientation	Longer Walls Orienting Towards North And South Side
Zoning	Shading Verandas And Living Spaces On Critical Orientations, Courtyards
Street design	Shaded Streets, Narrow Width
Roof Treatment, Roof Garden	Reflective Tiles, Vegetated Roofs/Terrace Gardens, Insulation
Shaded Windows	Shaded Windows on South - west
Walls To Respond To Outside Climate	Low Thermal Mass, hollow AAC Blocks with thermal insulation
Local Materials To Reduce Embodied Energy	Lime, Jikki, AAC Blocks, Nimaj Stone
Construction Technologies To Reduce Time And Volume Of Construction	Recycled Materials - Brick Waste, Thermocol Waste
Natural Ventilation	Through North And South Windows, High Ceiling For Air Circulation, Water Bodies For Moisture
Daylight Integration	Through Windows, balconies
Efficient Outdoor And Indoor Lighting By Use Of T5 Lamps, CFL, LED Etc.	LED For Lighting
Efficient Fans Or Other Heating/Cooling Technologies	Ceiling Fans
Solar Based Outdoor Lighting	Solar Power Street Light
Solar Based Water Heating	Solar Hot Water System For Individual House
Renewable Energy	Solar Photovoltaic Panels
Pervious Paving	Lower Hard Paving
Sedimentation Control Measures In The Landscape Design	Soft Drainage Using Aggregates Filters, Mulching
Use Of Native Species	Vegetation Around Habitat (landscaping)
Source Of Landscape Water From Recycled Water	Waste Water treated From Bathrooms And Kitchen
Water Body	Natural water body (Available on South side of site)
Rain Water Harvesting	Ground Recharge, Collection Pits For Reuse
Segregation Of Waste	Mandatory Waste Segregation, Dry And Wet Waste Segregation Of Kitchen

Table 1: Summary of hot and dry climate zone green building features

5.0 PERFORMANCE SPECIFICATIONS

5.1 CLIMATE

GIFT city (Gujarat International Finance Tech - City), Gujarat falls under hot and dry climate classification as per ECBC 2017. To understand the impact of climate on the building performance, a climate study has been done which is thoroughly explained in Annexure.

The weather data for Ahmedabad(27 km away from GIFT city) is taken from IWEC (International Weather for Energy Calculation) for the climate analysis since the epw file for GIFT city is not available.

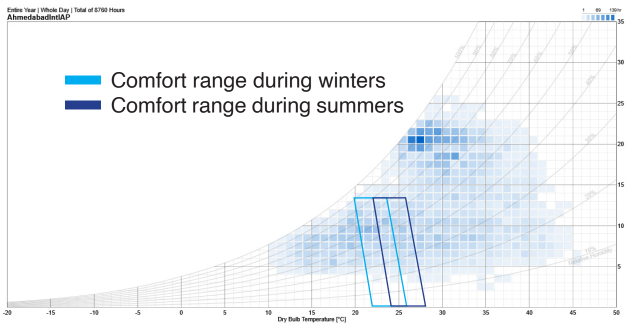


Fig.3: Psychometric Chart showcasing comfort range

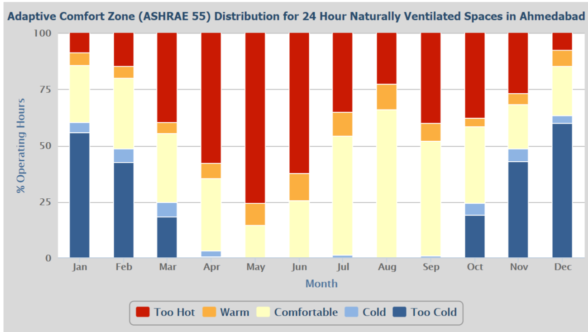


Fig.4: Further breakdown of Comfort zone using IMAC tool

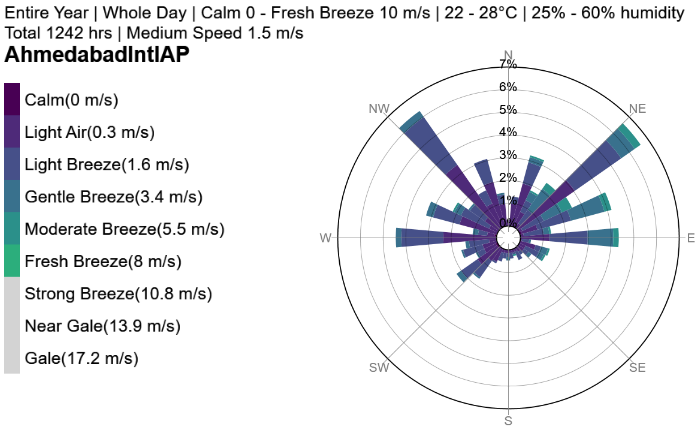


Fig.5: Wind-rose diagram showcasing the Comfortable winds

- To better comprehend the comfort range during different seasons, a psychometric chart was created. During the winter, the comfort range is 22-26°C, while in the summer, the comfort range is 24-27°C.
- An IMAC tool has been used to breakdown the % of comfortable hours, which helped to analyse the number of hours required for cooling.
- A wind rose diagram has been generated which helped in spatial zoning by giving the inputs such as temperature range between 22-28°C and Humidity between 25-60% to maintain the thermal comfort.

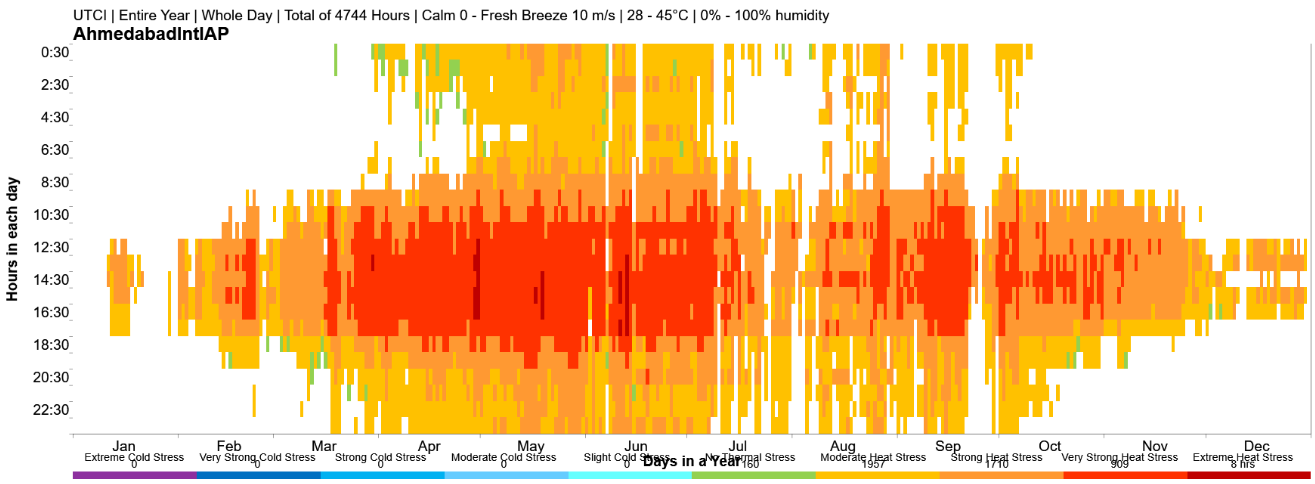


Fig.6: Heat map showcasing the uncomfortable hours annually

5.2 ENVELOPE SYSTEMS

5.2.1 EXTERNAL WALL

Composition : 15 mm plaster + 200 mm AAC Hollow brick + 15 mm plaster

Plaster [15mm] : A protective coating for walls.

AAC Hollow brick [200mm] : The concrete block wall provides for a greater flow of heat into the structures. To take use of air gap thermal insulation, hollow concrete blocks are used. It was discovered through ASHRAE (1981) study on getting the best possible thermal insulation value for the air gap.

5.2.1 ROOF

Composition : 60 mm concrete + 30 mm air gap + 60 mm concrete

Concrete [60mm] : Concrete roof tiles are made from a cellulose base material, which is placed into a mould that's injected with concrete. Then, the tile hardens and is removed.

5.2.3 WINDOW

Composition : 6 mm clear glass + 12 mm argon EN673 + 6 mm clear glass

The window glass units comprises of argon EN673 gas sandwiched between two 6 mm clear glass. The U - value is 1.63 W/m² with an SHGC of 0.53.

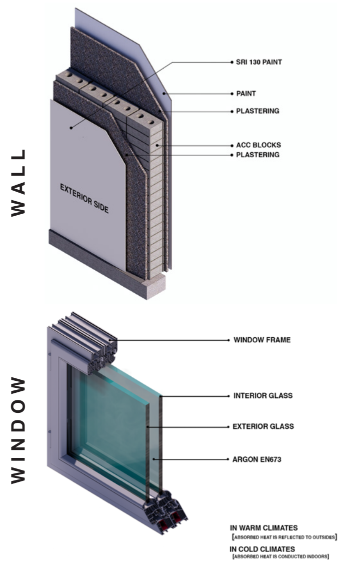


Fig.7: Envelope Specifications

5.3 HVAC SYSTEM

HVAC System Type: 2 ton Split Ac for each bedroom

Cooling Capacity (50%): 3050 W

Cooling Capacity (100%): 6100 W

ISEER rating: 4.66

BEE Star rating: 5 star

5.4 LIGHTING

Average Interior Lighting Power:

1.62 W/m²

5.4 EQUIPMENT

Average Equipment Power Density:

42.39 W/m²

5.5 SRI PAINT

Both the roof and the walls are painted with a high SRI value of 130 to reflect solar heat and maintain cooler indoor ambient air temperatures without the use of ACs.

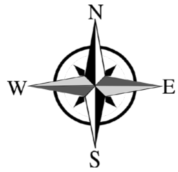
5.6 ON - SITE RENEWABLE ENERGY GENERATION

Annual Generation of RE = 5,05,197 KWh/year
EPI attained with generation = **28.28 KWh/year/m²**
EPI of the project = **26.11 KWh/year/m²**
Installed capacity = **322 KWp**
Efficiency = 20.4%
Area required for the generation of RE = 1772 m²

SITE PLAN

DESIGN DOCUMENTATION

6.0 CONCEPTUAL EVOLUTION



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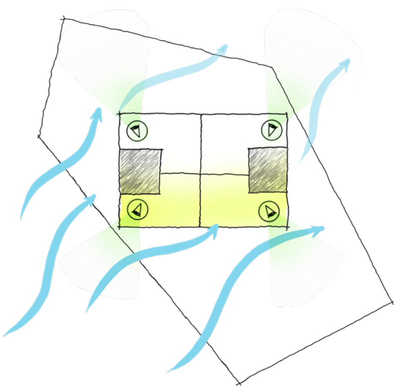
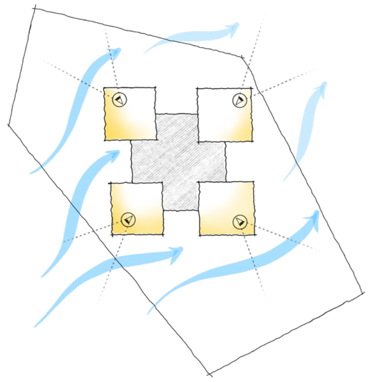


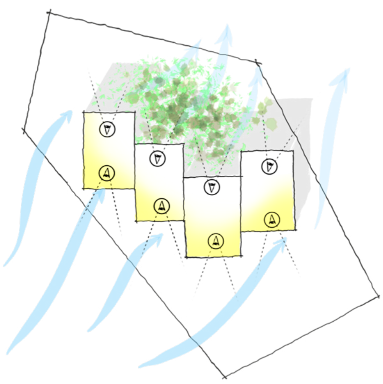
- Has common walls
- Two lobbies
- Limited views
- Less natural ventilation
- No privacy

2



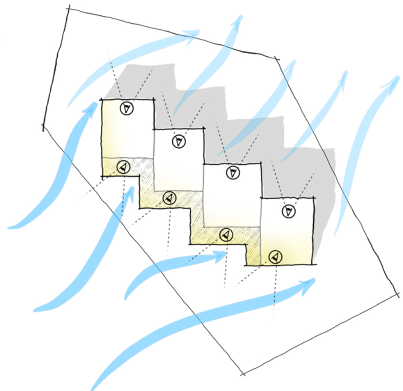
- No common walls
- Privacy
- Common lobby
- Limited views
- Cross Ventilation not feasible for all units.

3



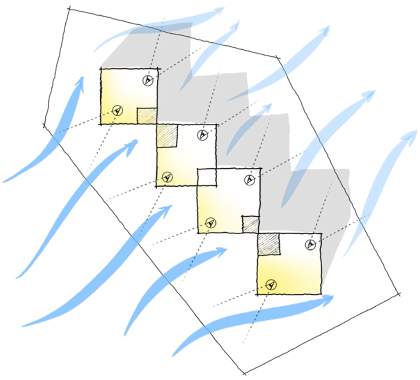
- Self shading
- Better scope for views
- Impact on site
- Shades recreational areas
- Possible Cross ventilation

4



- Staggered
- Self shading
- Better scope for views
- Cross ventilation
- South corridor (buffer to solar heat gain)
- Views onto north
- Lesser privacy

5. FINAL ITERATION



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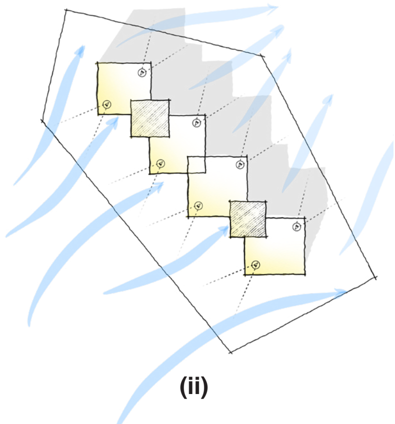


(ii)

- No Common walls
- 2 vertical circulation cores created by subtraction and addition.
- Maximum privacy (villa like experience)
- Maximized views both towards the water body and the city.
- Self shading blocks
- The garden onto the north is shaded throughout the day.
- Cross ventilation enhanced

Circulation Core/Lobby
Wind movement
Tentative solar heat gains

Figure 8: Key points under design evolution

Note: All the architectural drawings, circulation layouts, electrical drawings, etc. are provided in the Annexure. The block arrangement, zoning concepts are explained in 7.2 Architectural Design.

7.0 DESIGN DOCUMENTATION

TEN CONTESTS

7.1 ENERGY PERFORMANCE

7.1.1 PASSIVE STRATEGIES

The primary step to designing a net zero building is to use passive strategies. The sun, wind, light and the micro-climatic conditions need to taken into account from the climate study. Building form, orientation, and the shading decisions made early in the design process have the most impact on the building's energy consumption. The project Pragya is located in a hot and dry climate zone in which Air conditioning will always be required. But our goal is to reduced the use of air conditioning by minimizing the overheating using passive strategies.

- An open floor plan is designed to promote natural cross ventilation by positioning the windows to the prevailing breezes.
- The west facing glazing is minimized to reduce summer and fall afternoon heat gain.

DESIGN FOR CROSS VENTILATION

- Most of the glass and the balconies are oriented to the north and are self shaded by the blocks.
- On hot days ceiling fans or indoor air motion makes the indoors cooler by 5 degrees F (2.8C) or more, thus less air conditioning is needed.
- Light colored building materials and cool roofs(with high emissivity) are used to conduct heat gain.

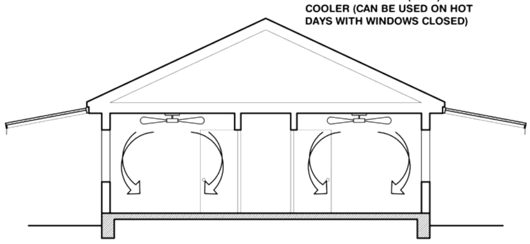
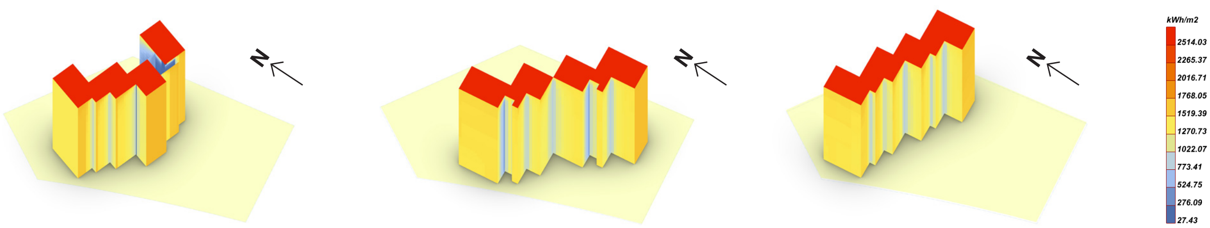


Figure 9: Passive design strategies

7.1.2 BLOCK OPTIMISATION

For the block model we referred the gift city standards for the maximum ground coverage. Number of floors were fixed by the project partner which has to be constant. So, each flat was made into a block(discussed in 6.2 Architecture) and possible arrangements were worked out.

Because of the sun's high altitude in summers, the blocks are staggered and arranged in such a way that they self shade themselves from sun's direct radiation. During winters, due to the azimuth angle of sun, the required warmth penetrates into the habitable areas.



Iteration 1 | Iteration 2 | Iteration 3

Figure 10: Solar Radiation Analysis for initial Iterations

These stimulations opened up our view to create the shading devices that not only optimise the thermal performance but also adds up to the character and beautification to the form.

- A preliminary idea at the design development stage was to design a canopy to protect the thermally exposed segment of the building, which is documented under 6.5 Innovation.

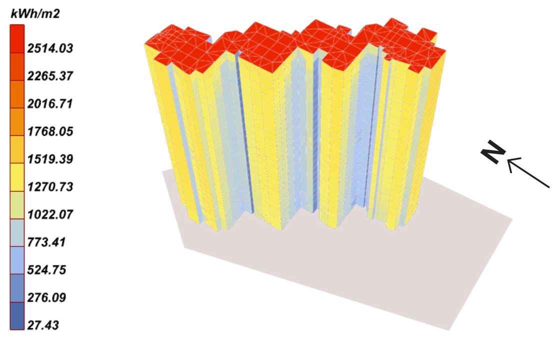


Figure 11: Solar Radiation Analysis for Final Iteration

7.1.3 FLOOR PLATE OPTIMISATION

SOLAR IRRADIANCE

- As the first phase, a floor plan was developed after the best potential block arrangement has been determined. Then it was modelled in Rhino software, where it could be tweaked based on the results of subsequent simulations. The floor plate has been optimised after the software model has been processed in several analysis plugins. On correctly oriented surfaces, the average yearly solar irradiation is around 60 kWh/m².

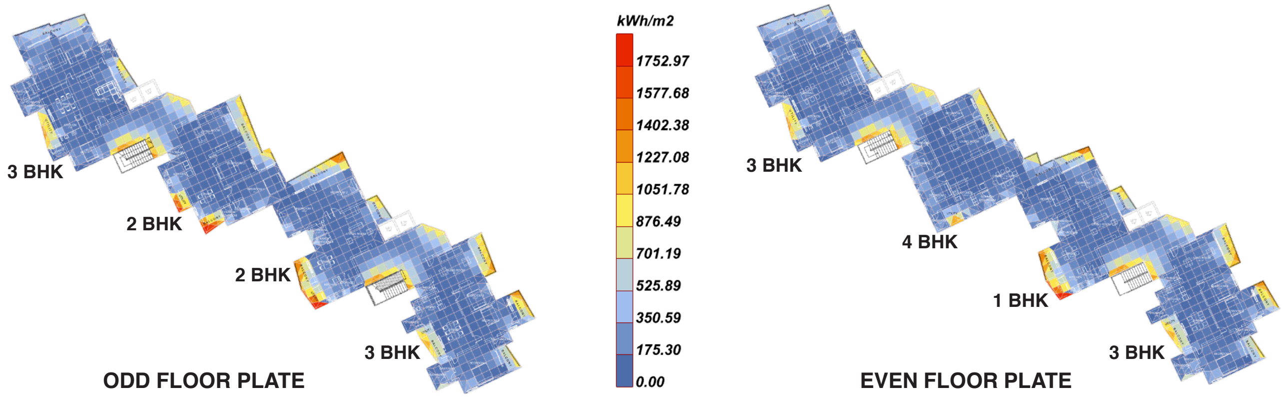


Figure 12: Annual Incident Radiation on the final floor plates

DAYLIGHTING

- One of the most effective strategies to save energy is to use natural light. Daylighting helps in saving money by reducing the quantity of artificial light needed. So, optimal daylighting has been considered from the beginning of the building design process.
- Not only is daylighting necessary for reducing the energy consumption, but it is also necessary for human health and well-being.
- In a clear sky scenario, the IGBC Green Home Rating System suggests that 75 percent of the regularly inhabited places in the building reach daylight illuminance levels of 110 lux to 2,200 lux. And as per IS 3646: 1992, the daylight illuminance levels range between 100 to 300 lux levels, which is not revised since 1992. So, the requirements for the IGBC green homes is taken as a proxy.

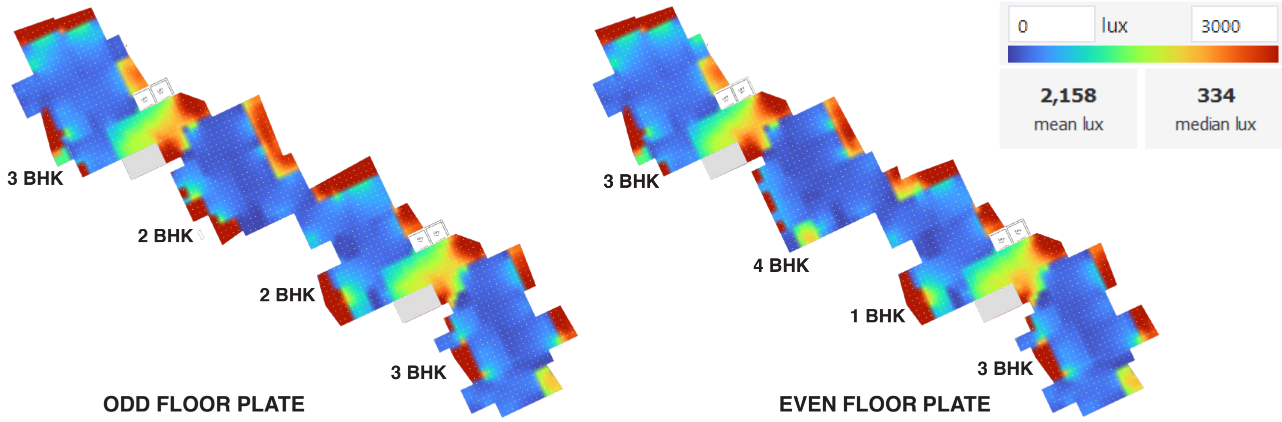


Figure 13: Point in time Illuminance during afternoon

- The building on simulating, has achieved **87.5% Spatial Daylight Autonomy** (sDA300/50%), which is the floor area that receives over 300 lux for a percentage of 3650 annual hours, and an **Annual Sunlight Exposure** (ASE1000,250%) of **15.4%.**

- Though the ASE exceeds 10%, majority of the floor plate which resulted in high sunlight exposure falls under balcony spaces. Hence, these conditions can be termed as 'favourable'.

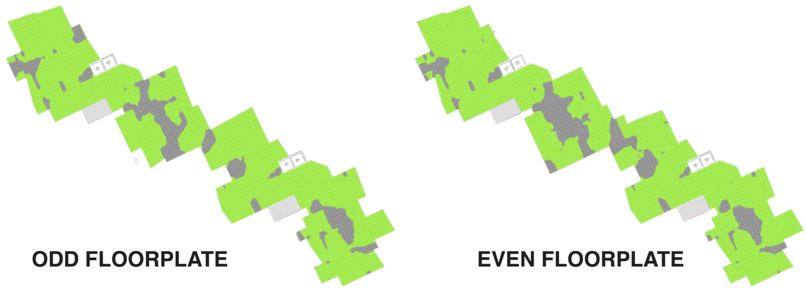


Figure 14: Daylight availability

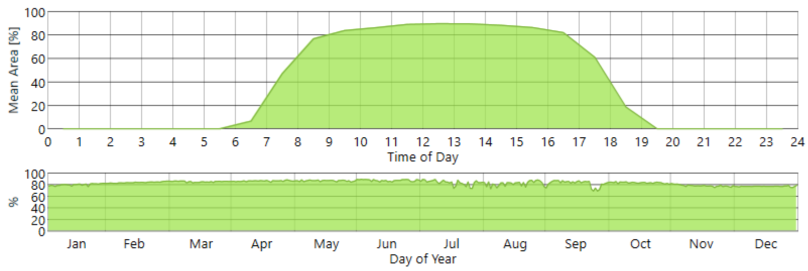


Figure 15 : Annual daylight availability

GLARE

- The floor plate is designed in such a way that the majority of the habitable zones are glare-free. The openings to the west have been reduced or completely eliminated. In sections where the windows are exposed, balconies rise to provide a buffer, reducing glare into the interiors. The figures 13, 14 below displays the annual percentage of areas that are overlit.

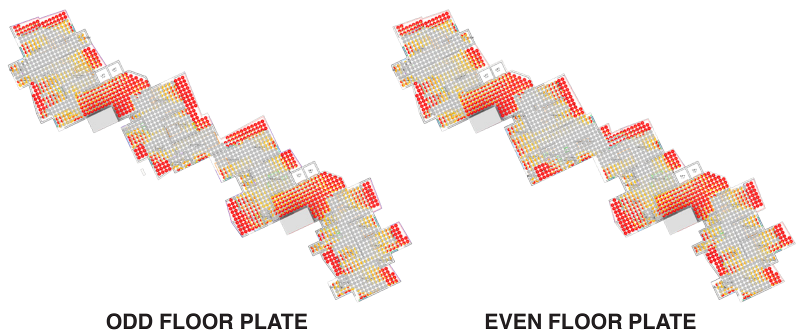


Figure 16: Annual Glare

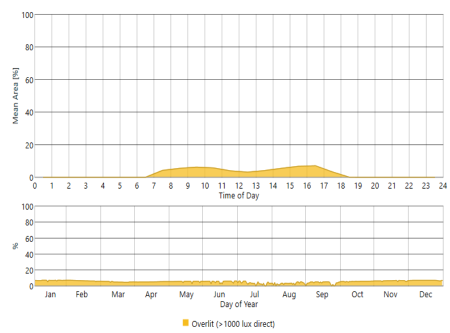


Figure 17: ASE chart

7.1.4 ENVELOPE OPTIMISATION

Envelope optimisation helps to create comfortable spaces by actively responding to the building's external environment, and substantially reducing the building's energy consumption. U-value measures the rate at which a product transfers heat. That means that the lower the U-value, the better the material is at insulating and the tighter your building envelope will be.

BUILDING ELEMENT	COMPONENT	U value (W/m²C)
Roof	60 mm concrete + 30 mm air gap + 60 mm concrete	0.84
Wall	15 mm plaster + 200 mm AAC Hollow block + 15 mm plaster	0.78
Window	6 mm clear glass + 12 mm argon EN673 + 6 mm clear glass	1.63 **SHGC** - 0.28

Table 2: Materials and their U - values

7.1.5 CHAJJA ORIENTATION

Using the sun shading chart in climate consultant, the size and orientation of the chajjas have been determined. So, they are oriented towards the S,SSW,SW and WSW at angles of 70°,60°,56° and 44°(VSA) for optimum shading performance. It was made sure that at least 50% of shading requirements are met during the extreme conditions.

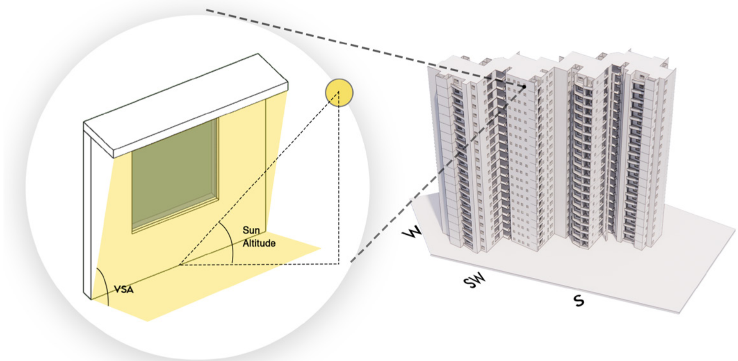
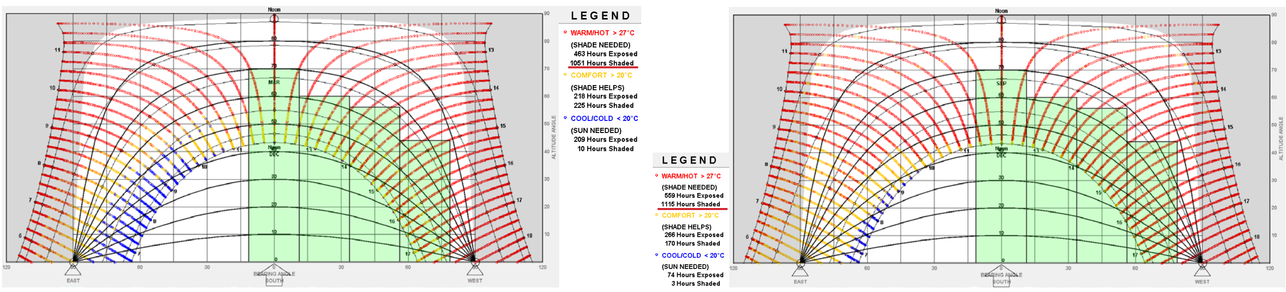


Figure 18: Chajja Placement on block



DURING DEC 21 to JUNE 21 **DURING JUNE 21 to DEC 21**

Figure 19: Sun chart showcasing chajja shading

7.1.6 AIRFLOW THROUGH BUILDING

Based on the weather data, the majority winds are from the south west region. To cut down the harshness in the winds, the staggered form helped in breaking the wind flow. These breaks helped in creating barriers reducing air pressures.

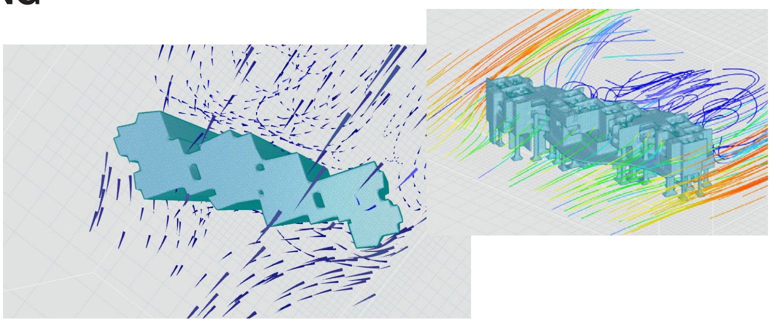


Figure 20: Air flow through the building

7.1.7 ENERGY PERFORMANCE INDEX (EPI)

Energy performance index (EPI) is the total energy consumed in a building over a year divided by total built up area in kWh/m²/year. A base case is developed for the block model optimised in terms of orientation, massing, shading, and building envelope insulation. The occupancy is 24 hours as it is a residential building and the use of cooling, lighting, heating are established with the help of IMAC tool using the weather of data of Ahmedabad as the weather file for GIFT city is not available. This **base case** of design attained an EPI of **56.64 KWh/yr/m².**

NOTE: *Detailed breakdown of hourly energy consumption of every month as per the required operation hours to provide thermal comfort is provided in Annexure.*

Energy consumption details

Common Amenities = 22,186 KWh/ year

Common Equipment(Elevators and Pumps): Elevators= 89001.6 KWh/year

Pump = 292 KWh/year

Total Annual Consumption of Common areas = 1,11,480 KWh/year

EVEN, ODD FLOORS combined (1 each)

S.No	Appliance	Rating (W)	Units	Annual Consumption of 2 floors(in KWh/ year)	Annual Consumption of 20 floors (KWh/ year)
1	Air conditioner	2000	17	41582	**415820**
2	Ceiling Fan	45	37	5303.35	**53033.5**
3	TV	148	10	2701	**27010**
4	Wifi Modem	5	10	438	**4380**
5	Tv setup box	18	10	1576.8	**15768**
6	Microwave Oven	750	8	2190	**21900**
7	Coffee maker	1500	8	876	**8760**
8	Toaster	700	8	408.8	**4088**
9	Refrigerator	105	8	7358.4	**73584**
10	Washing Machine	500	8	1460	**14600**
11	Electric Iron	1500	8	2190	**21900**
12	Laptop	90	10	985.5	**9855**
13	Chimney	150	8	876	**8760**
14	Exhaust fan	40	21	613.2	**6132**
15	LEDs bulbs	12	20	262.8	**2628**
16	LED ceiling lights	15	178	6736.41	**67364.1**
17	Geyser	2000	13	14625	**146250**

Table 3: Annual energy Consumption of housing units

Total Annual consumption of 20 floors = 9,01,832.68 KWh/year

Total Annual Energy consumption = Common areas + Housing units = 10,11,735 KWh/year

Energy Performance Index of base case (**EPI**) = 10,11,735/ 17,860 = **56.64 KWh/year/m²**

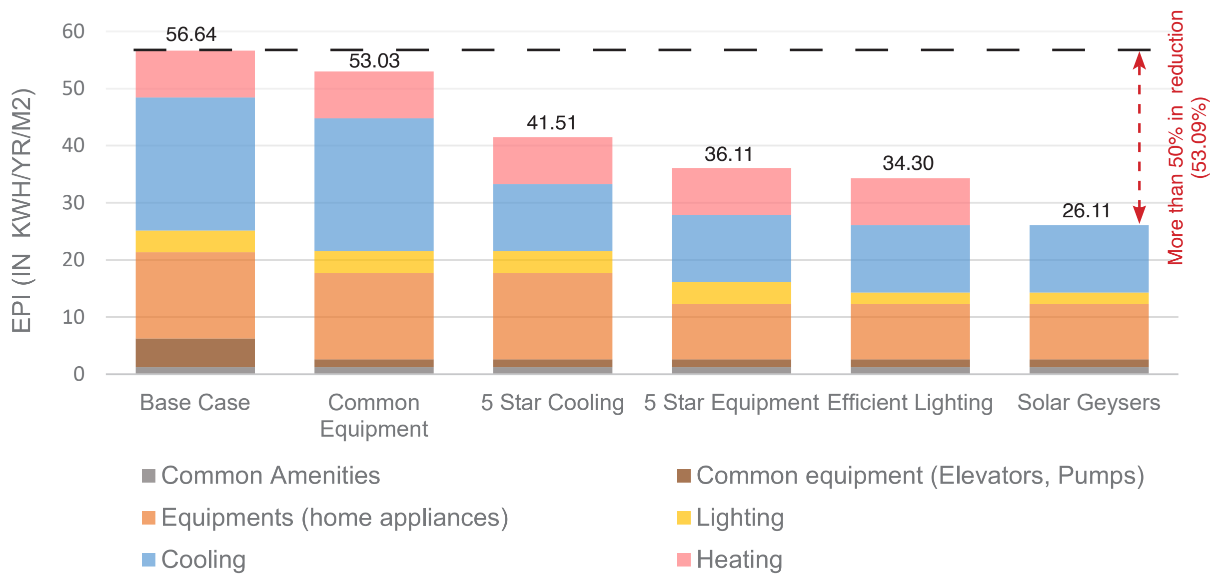


Figure 21: Reduction in EPI (in KWh/m²)

After achieving an EPI of 56.64 KWh/yr/m² for the base case, our main goal is to reduce the EPI by at least 50%. For doing that, first the common areas are equipped with energy efficient equipment reducing the EPI by 3%. Then for cooling, the HVAC systems have been changed to Panasonic 5 star Inverter split AC from the 3 star AC reducing the EPI to 41.51 KWh/yr/m². Next the use of efficient 5 star equipment and lighting further reduced the EPI to 34.30 KWh/yr/m². And as a final step, instead of using electric geysers which consume a lot of energy, Solar water heaters are installed which helped to achieve in the final **EPI value of 26.11 KWh/yr/m²**. Solar water heaters are used as there is abundant of thermal energy of sun throughout the year.

7.1.8 ON-SITE RENEWABLE ENERGY - SOLAR PHOTOVOLTAIC

A solar PV plant is proposed to set up on 90% of roof of the building. The PV power generation potential is estimated on the System Advisor Model (SAM) developed by NREL and Insight for Revit. 3.7 KW solar panel with 20.4% efficiency are considered. Using only the roof area, the energy generation of solar PV is **2,24,798 KWh/yr** which is clearly not sufficient to meet the energy requirement of **4,67,465 KWh/yr**(Energy generation potential is 48%). So, in order to maximize renewable energy generation, the Solar panels are set up on the landscape areas which are exposed while the shaded regions are used for recreational activities.

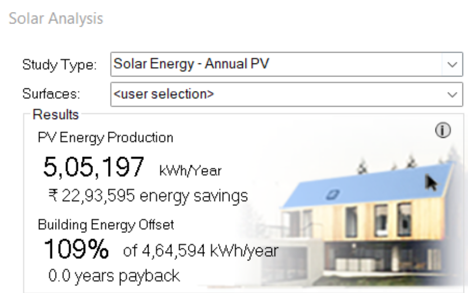


Figure 22: Statistic data

Annual Generation of RE = 5,05,197 KWh/year

EPI attained with generation = **28.28 KWh/year/m²**

EPI of the project = **26.11 KWh/year/m²**

Installed capacity = **322 KWp**

Efficiency = 20.4%

Area required for the generation of RE = 1772 m²

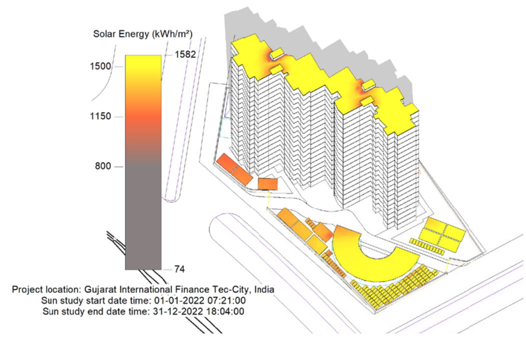
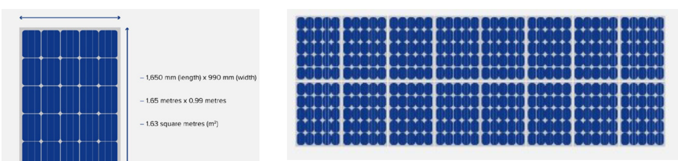


Figure 23: Solar PV placement for on-site RE



One Panel

3.7 KW System Sixteen solar panels, typically takes up around 28 m² space

Figure 24: Solar PV sizes

PRAGYA - II

RECREATIONAL SPACES

7.2 ARCHITECTURAL DESIGN

7.2.1 SELF SHADING ARRANGEMENT OF BLOCKS ON SITE

As the site is located in the GIFT city. And the city is yet to be developed, hence the future here is unpredictable about the contextual buildings. As there were no structures around the site as of now, the site is clearly exposed to the solar radiation through out the year. So, the initial idea is to make the building self-protecting before even thinking about the envelope and the innovation. So, after the from development, we came to a conclusion that the building should be staggered.

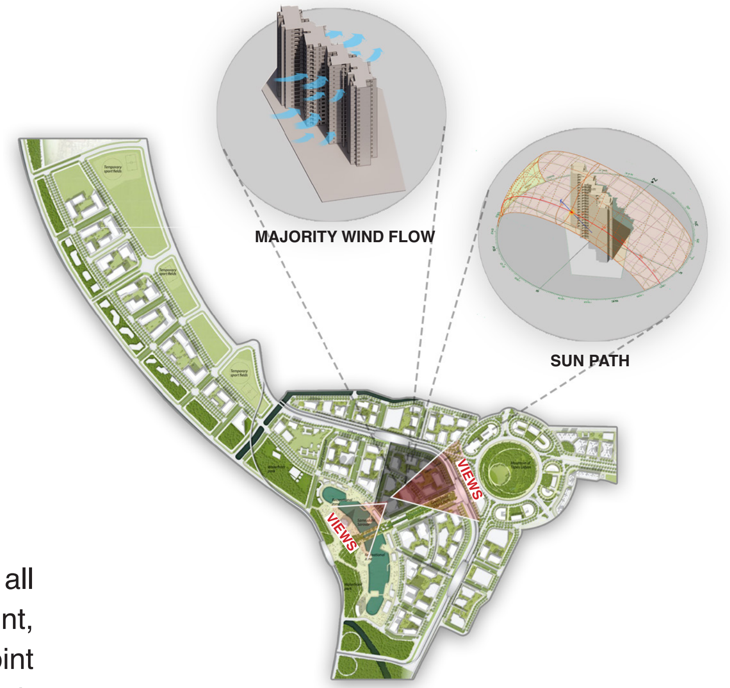


Figure 25: Site location in GIFT city

7.2.2 VILLAS

Even after achieving the net zero building in all aspects, if it fails to have a pleasing environment, the building will fail automatically in user point of view. The individual flats are arranged such that it does not feel as an apartment, but as a private villa in individual perspective. And the longitudinal axis is arranged along east west to attain maximum views. Hence, both city and river views are provided for every individual block, which was possible due to the staggering of the blocks. Various iterations were worked out to come to a conclusion of the staggered placement out of which few are presented below.

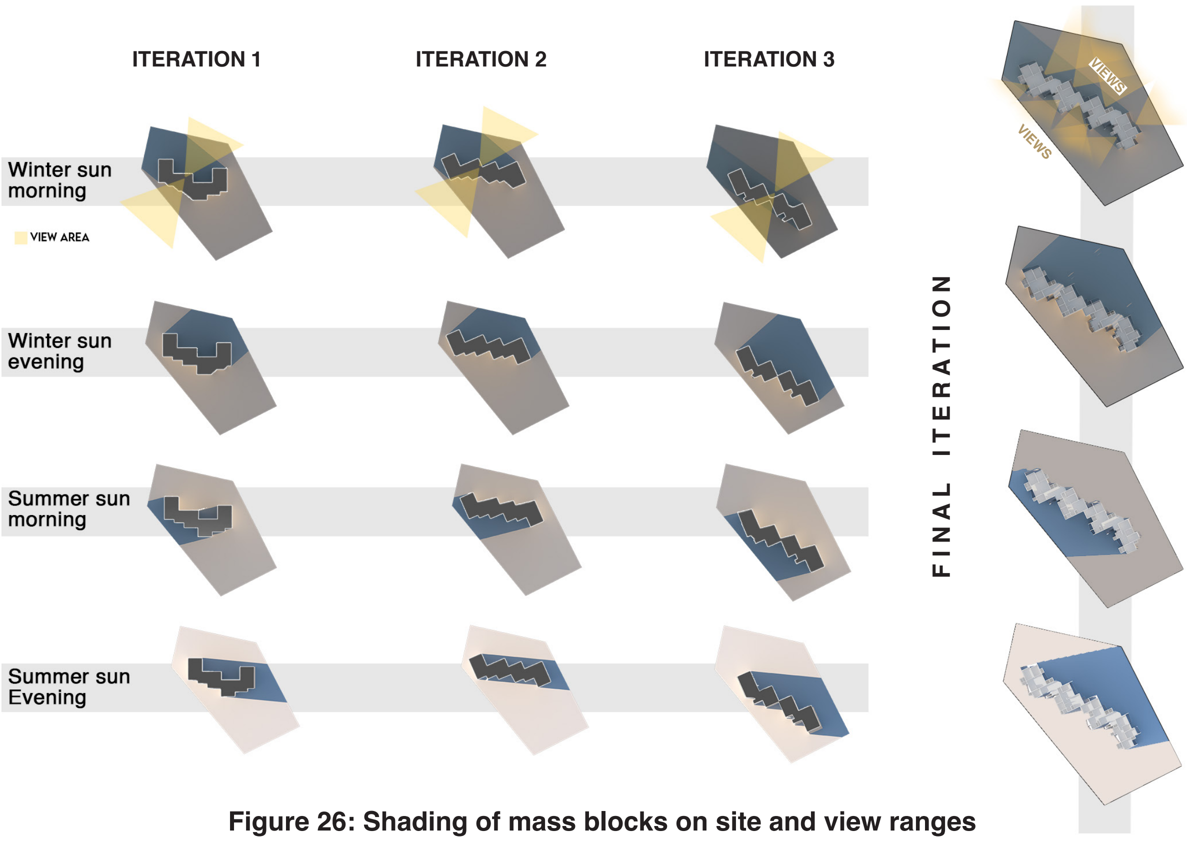


Figure 26: Shading of mass blocks on site and view ranges

7.2.3 ZONING

- The zoning of the flats is done such that there is a sense of openness in the plan, while enclosing the private spaces such as bedrooms, bathrooms to promote ease of movement, better communication, increased lighting and natural ventilation.
- The living areas are oriented to the north receiving natural daylight throughout the day where the users spend their mornings and other leisure time.
- The spaces that are typically occupied for less number of hours such as dining, kitchen, bathrooms are mostly placed towards the south – west orientation as there is a lot of solar radiation.

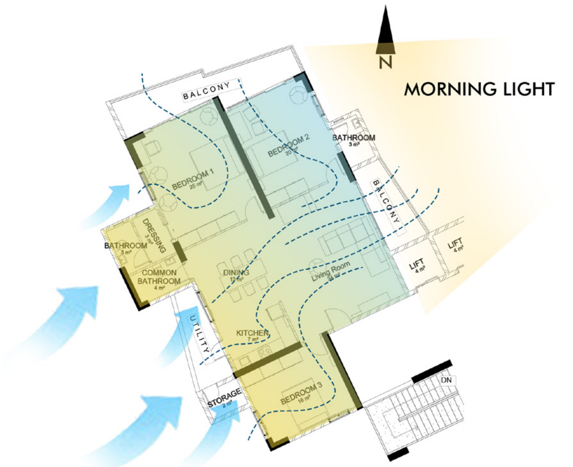


Figure 27: Floor plan of a 3bhk Unit

- Each flat is provided with the views towards the river on the south from the dining room and the city view onto the north from the living room. So, that it is not limited to the family itself but also for the guests.
- For instance, Figure 24 showcases the floor plan of a 3bhk unit which could be related to the above statements.

7.2.4 THE FACADE

- The facade is intentionally designed in an aesthetically pleasing way with breaking the normal rigid geometry. And the balconies pull and push themselves forward and back in order to attain dynamic character to the form. All these features are implemented to attract vide range of users to invest in the building.

Figure 28: The Facade of Pragya II

7.2.5 CORES

- Public movement in the building is reduced in order to offer privacy to the users. Two cores are planned strategically so that each core serves two flats on each floor. These cores are fitted in place such that they create openness and privacy. And in cases of emergency, the evacuation process happens quicker and easier as the travel distance to the exits are not much and the walls around the core has a high thermal resistance to buy enough time for safe evacuation.

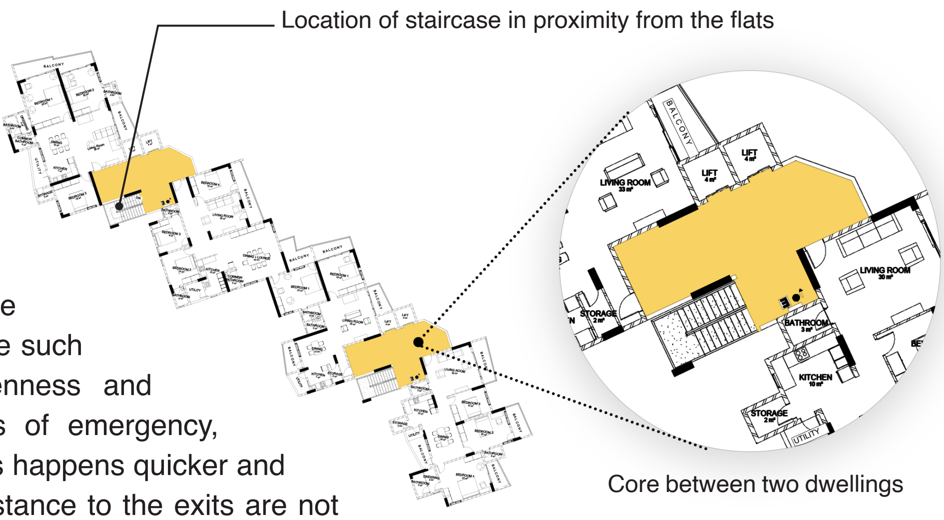


Figure 29: The Two Cores

7.2.6 WORKSPACES

It may be more difficult to separate work and personal life when working from home. Having a separate workstation, on the other hand, can help you be a more effective employee and maintain healthy connections with your co-workers and family. The workplaces are set up in the bedrooms to ensure privacy to make calls, access to natural light, and that other people's activities in the house are not disrupted.

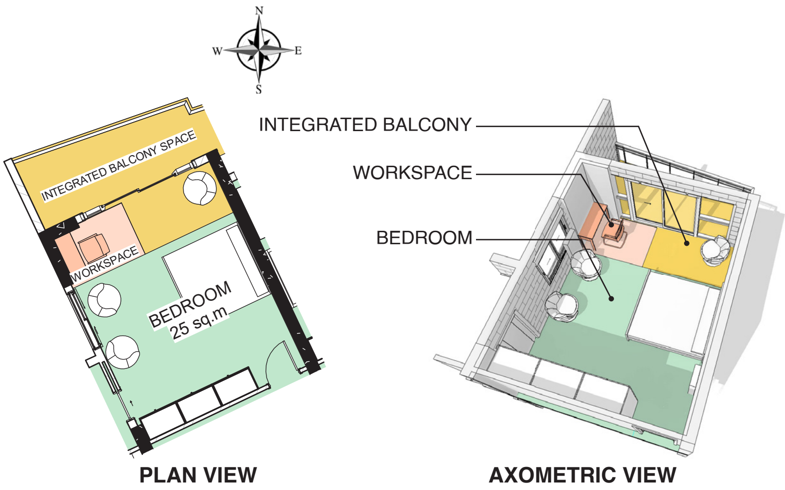


Figure 30: Workspace in Bedroom

7.2.7 SOCIALIZING

The apartment is stretched and arranged along the site in such a way that it gives a large shaded area on the site's northern side. This shaded area is used for recreational activities, green spaces that encourage people to socialise, and user health and well-being, as detailed in **6.6 Health and well-being.**

Figure 31: Socializing

7.3 WATER PERFORMANCE

As per National building code 2016, Standard fresh water demand for one person is 135 LPD (litres per day) for residential buildings. We have proposed to reduce about 44% water demand.

REDUCE	RECHARGE	REUSE
135 lpd to 75 lpd (44% reduction in consumption)	4702 KL/year (Rainwater harvesting + treated waste water ground recharge)	75% of grey water is filtered

7.3.1 REDUCE

The water consumption was brought down from the base case of 135 lpd to 75 lpd by efficient use of water saving fixtures, front load washing machines. The total occupant Water demand is estimated to be 33,750 lpd, consisting 450 people(30 guests).

	Per capita daily consumption(L)	Number of occupants	Total consumption Daily (L)	Total water requirement in a year (L)	Grey water efficiency
BASE CASE	135	450	60750	221,73,750	75%
DESIGNED CASE	75	450	33750	123,18,750	75%

Table 4: Water consumption

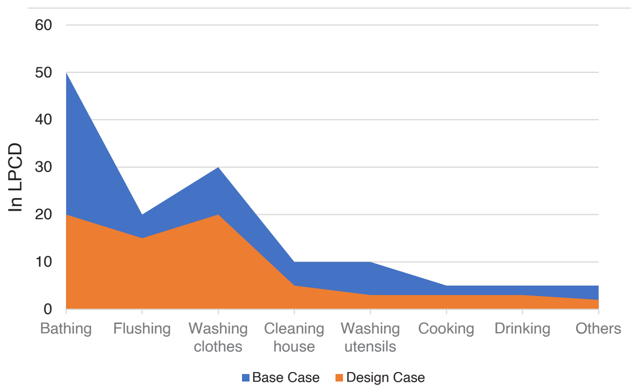


Figure 32: Water consumption breakdown LPCD

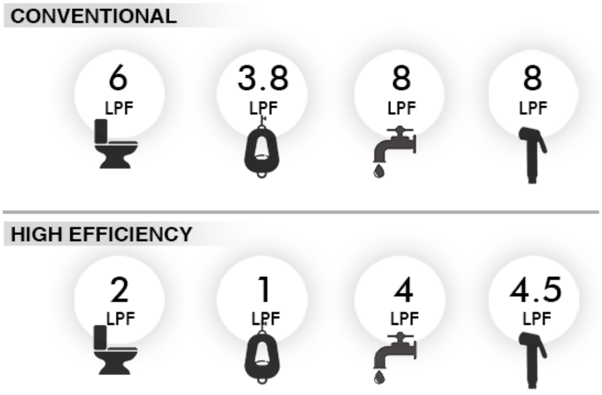


Figure 33: Flow and Flush rate of fixtures

7.3.4 REUSE

It is projected that the building generates **25.3125 KL of grey water** and **8.37 KL of black water** every day. For flushing, irrigation, and PV maintenance, grey water is recycled, filtered, and reused. The extra treated waste water is used to recharge the groundwater.

The grey water is collected in an underground storage tank, where it is sedimented and anaerobically treated before being filtered by the ROOT ZONE SYSTEM.

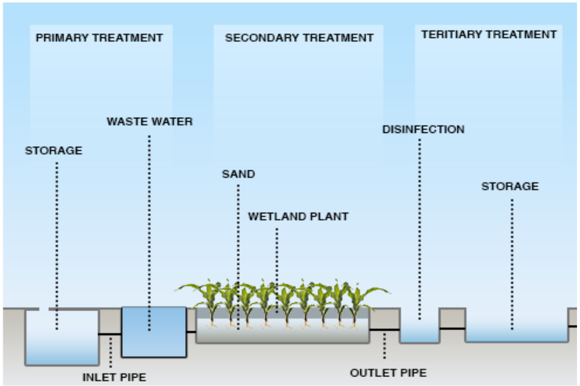


Figure 34: Grey Water treatment

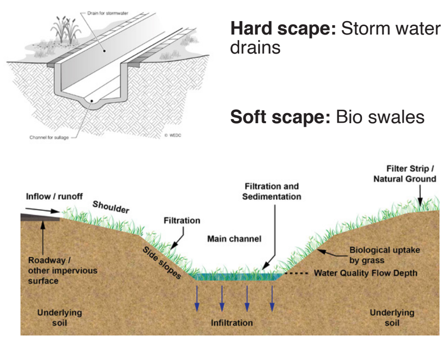
OCCUPANT'S ACTIVITY	USAGE (%)	QUANTITY (L)	GREY WATER (%)	BLACK WATER (%)
Bathing	30	10125	100	0
Washing clothes	20	6750	100	0
Drinking	4	1316.25	0	100
Cooking	3	978.75	0	100
Toilet	17	5737.5	0	100
Cleaning house	8	2700	100	0
Washing Utensils	16	5400	100	0
Others	2	675	50	50
TOTAL (in Litres)		**39082.5**	**25312.5**	**8370**

Table 5: Grey and Black water Generation

7.3.3 RECHARGE

- The roof of the building is utilized as a catchment area for the rainwater.
- Rainy FL-500 filtration system is used to remove the dirt and impurities with more than 90% efficiency, is later deposited in underground water tank (UGT) .

RWF filter
Rainy FL-500



Hard scape: Storm water drains

Soft scape: Bio swales

Figure 35: Rainwater treatment and collection methods

Source: WEDC Loughborough University
https://content.ces.ncsu.edu/

RAINWATER HARVESTING SURFACES	Area (m²)	Runoff Coefficient	Effective catchment area (m²)	Annual rainfall of site (m²)	Annual Rainfall (m³)	Annual Rainfall (litres)
Roof surfaces	1000	0.77	770	0.769	592.13	392130
Hardscape	1553	0.70	1087.1	0.769	835.9799	835979.9
Softscape	950	0.3	285	0.769	219.165	219165

Table 6: Rain water harvesting Calculations

Total Effective catchment area (m²) = 1479.9 m²

Total Rainfall harvested in a year (litres) = 16,47,274.9 litres

= 1,647 KL

TOTAL WATER REQUIREMENT (KL/year)	HARVESTED RAINWATER (KL/year)	RECYCLED GREY WATER (KL/year)	MUNICIPAL WATER (KL/year)
12318.75	1647.27	9239.0625	1432.3875

Table 7: Annual water consumption and generation

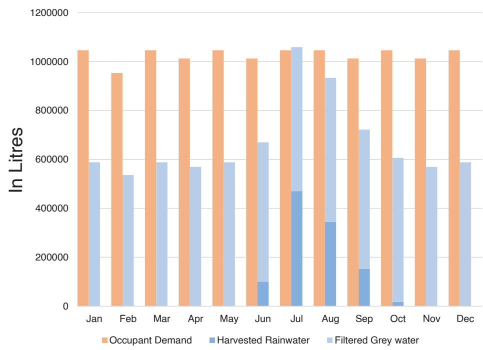


Figure 36: Water usage Vs Generation

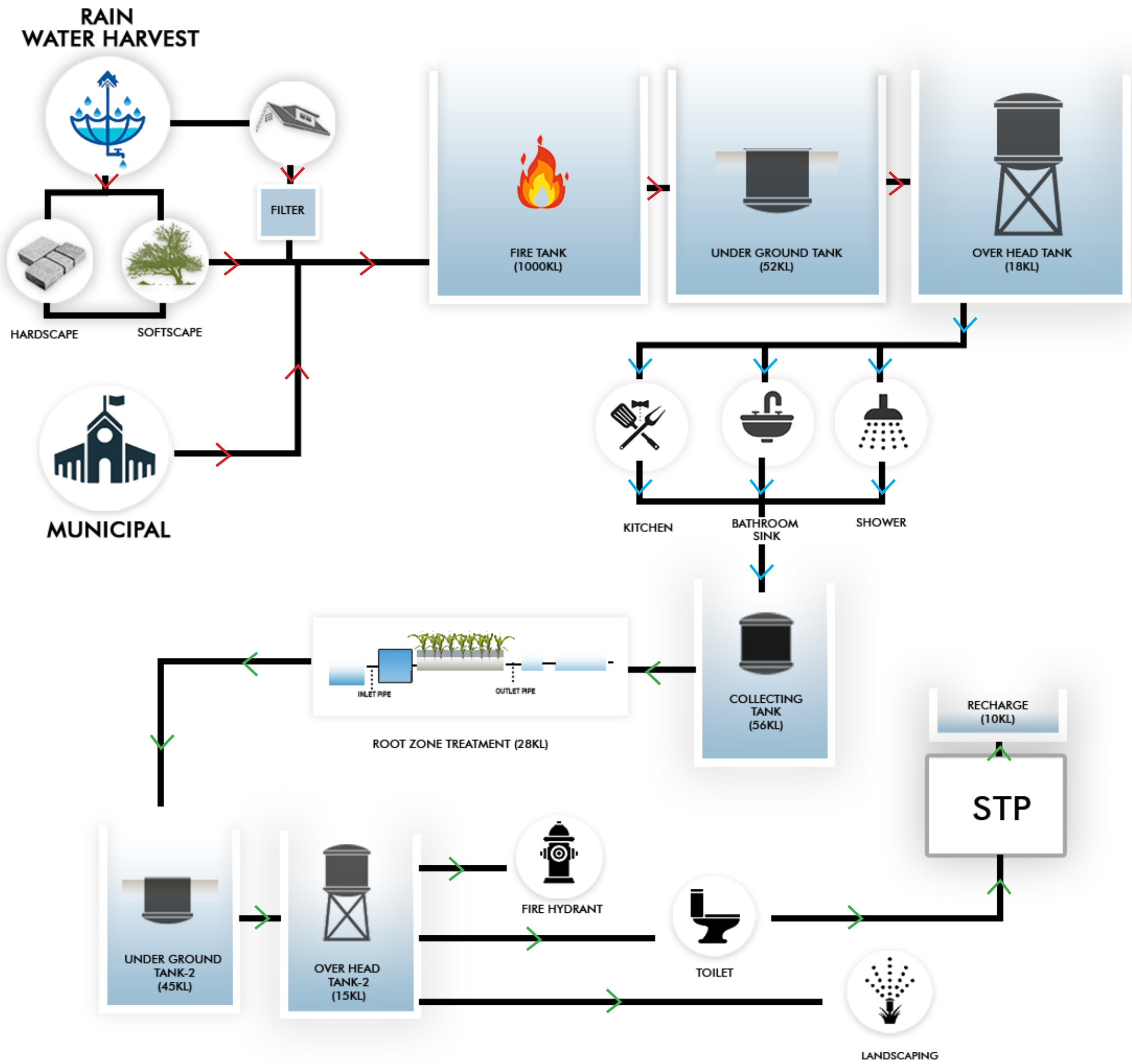


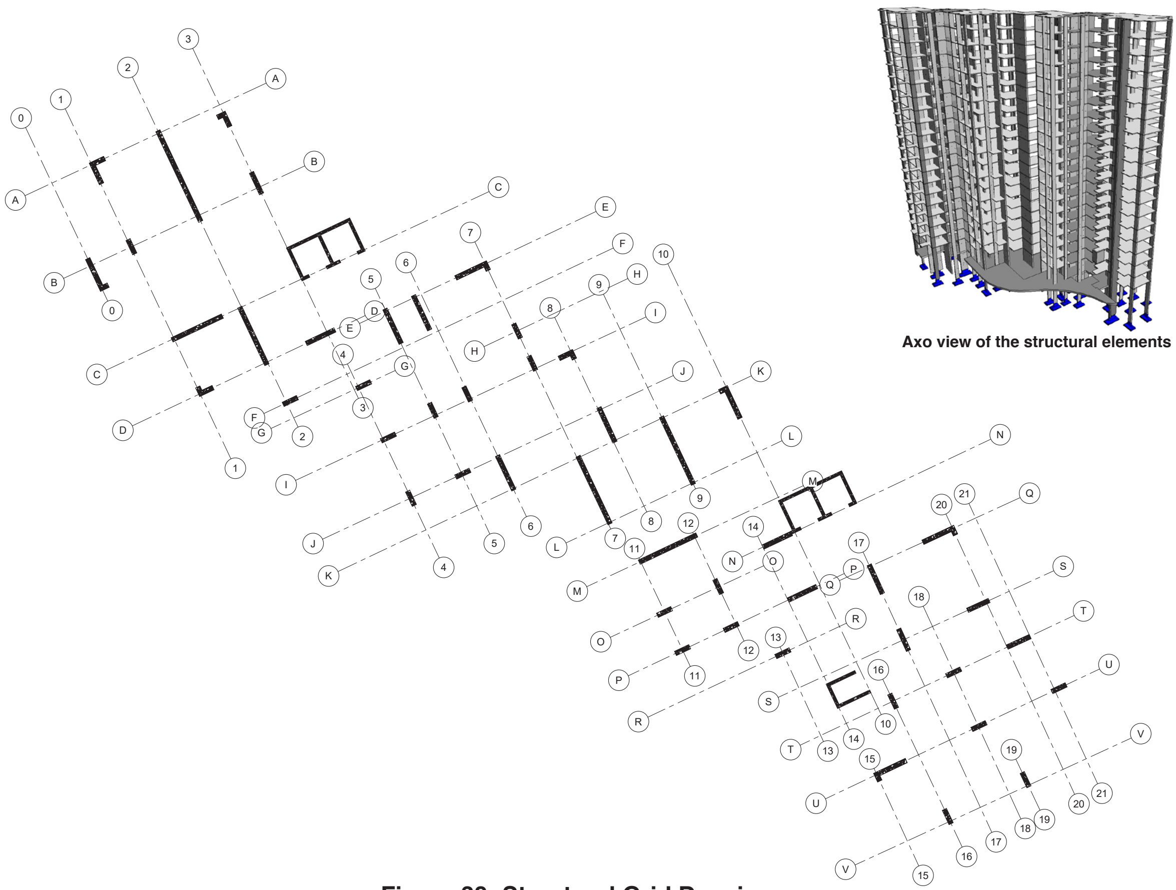
Figure 37: Water cycle Diagram

7.4 RESILIENCE

7.4.1 STRUCTURAL RESILIENCE

Gandhinagar City (the Capital of Gujarat, India) falls under Zone III on the seismic zoning map of India where an earthquake of magnitude 6 can be expected. So, the risk of having earthquake is considered to be moderate.

- Hence, the structure is included with shear wall system as this system provides adequate stiffness to the structure.
- To resist from lateral loads from earthquakes and winds, even the soft-story such as basements, parking, ground floor this system is continued.
- The core wall system is supplied at the heart of every two flats, each of which comprises of vertical circulation systems, due to the building's high rise typology. Shear wall is used to construct the lift core walls. This allows the structure to be built rapidly using the same frame work and at a lower cost.
- Long columns which act as shear walls are used in between the floor plate without intrusion to maintain the lateral stability.
- Locations where the angular momentum is more due to wind loads, L shaped columns are used to tackle wind force.



Axo view of the structural elements

Figure 38: Structural Grid Drawing

7.4.2 RESILIENCE FOR WATER OUTRAGE

The GIFT city is designed for 15 days of drinking water storage. In case of emergency lockout, the water storage has been made for 2 consecutive days for the essential uses of Pragya II occupants such as cooking, drinking, and washing. Detailed calculations are provided in water performance.

7.4.3 FIRE SAFETY

Fire Protection Systems are an integral, essential aspect of residential habitat design. The intricacy of these systems in a high rise building is exponentially more complex than regular dwellings. The fire safety systems are designed and installed as per the 'National Building Code (NBC) of India, Part – 4, Fire and Life Safety'.

- In accordance with regulatory norms, **Multi Detectors** are placed in every room across the floor plate barring kitchens. It consists of a Photoelectric Smoke Detector as well as a Heat Detector.

Figure 39: Multi detector

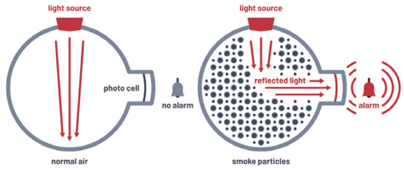


Figure 40: Functioning of photoelectric smoke detector

  The **photoelectric smoke detectors** work by projecting a continuous focused beam of light on to a mirror. If nothing interferes with the beam en route and back, the sensor perceives no obstruction. But when a small amount of smoke enters the chamber, the light is refracted slightly, this triggers an alert.

  The **Heat Detector** in a multi detector functions with the use of a thermistor. A thermistor is a type of resistor that can detect changes in temperature. These heat detectors have two triggering criteria; a fixed rate trigger and a rate of rise trigger. The detector will trigger when its sensor detects a temperature of 59° Celsius (fixed rate) or when the change in temperature exceeds the rate of rise of 11° Celsius per minute.

  Note: *The kitchens are installed with only heat detectors and not smoke detectors.*

- The core of every floor is provided with early warning fire measures like hand-held **fire extinguishers and water horse reels**. These extinguishers are recycled every year and the pressure is checked regularly to ensure effective functioning.

Figure 41: Fire extinguisher and horse reel

- The **Automated Sprinkler System** is a very important early measure mechanism that can quash a potentially devastating fire. They are provided in every room which are fed through the pressurized network of pipes.

  Every fire sprinkler has a temperature activated glass bulb that melts at 68° Celsius. Only the fire sprinklers in the region of the fire will activate when a fire melts the glass bulbs.

Figure 42: Sprinkler

DEDICATED WATER TANKS

Water is first pumped into dedicated Fire Tanks. When these tanks are at full capacity the water only then overflows into the daily use Domestic Tanks that supply water to your apartment. This way water is first prioritized to the Fire Tanks. All the pumping systems are provided in the basement. These water pumps activate in sequence when they sense a drop in water pressure. This ensures the sprinklers are fed with a constant water pressure.

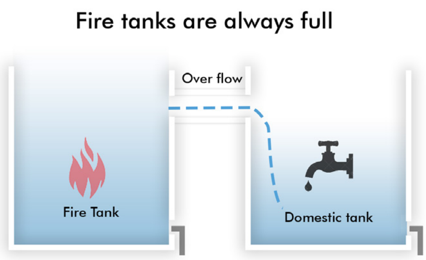


Figure 43: Diagram showcasing Water distribution

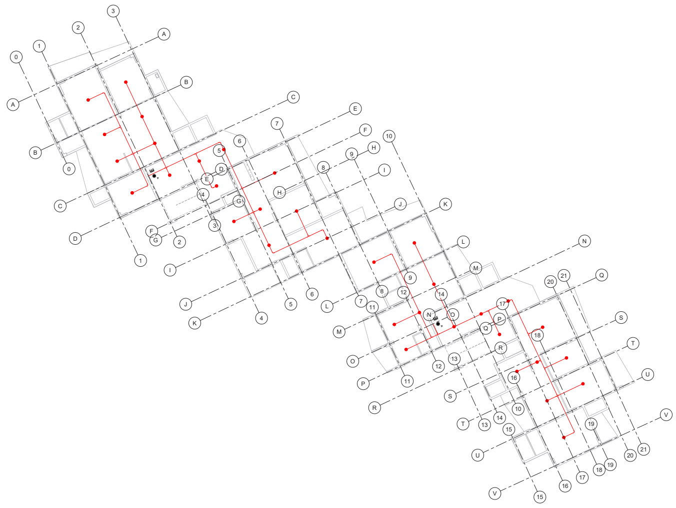


Figure 44: Fire sprinkler - odd floor plan

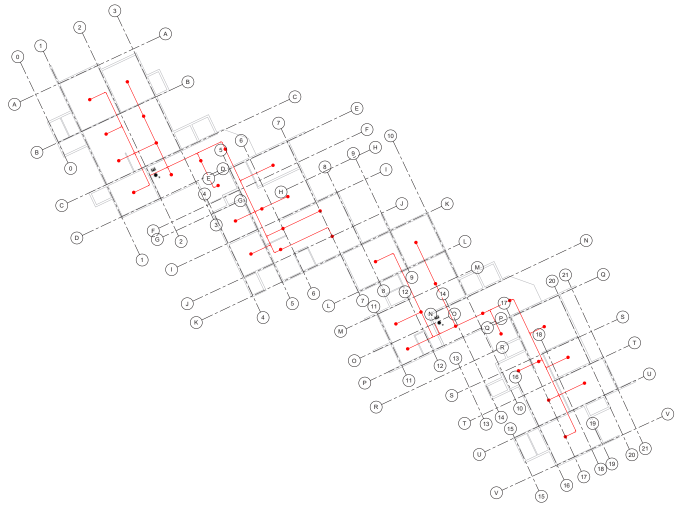
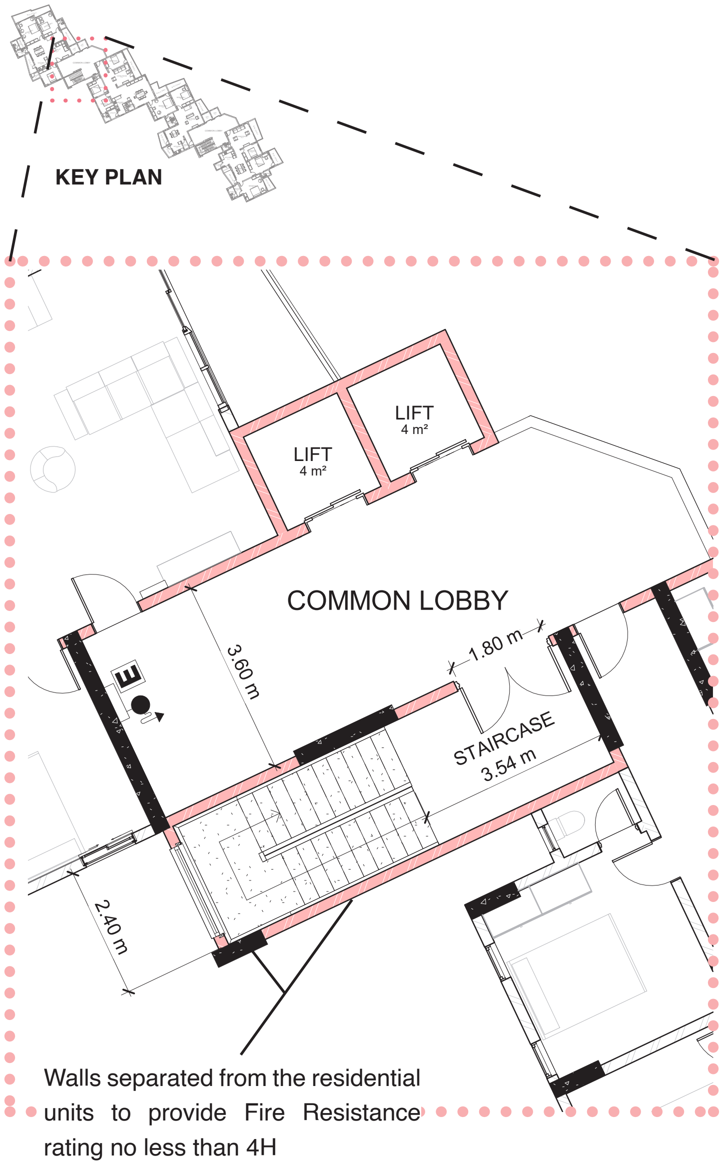
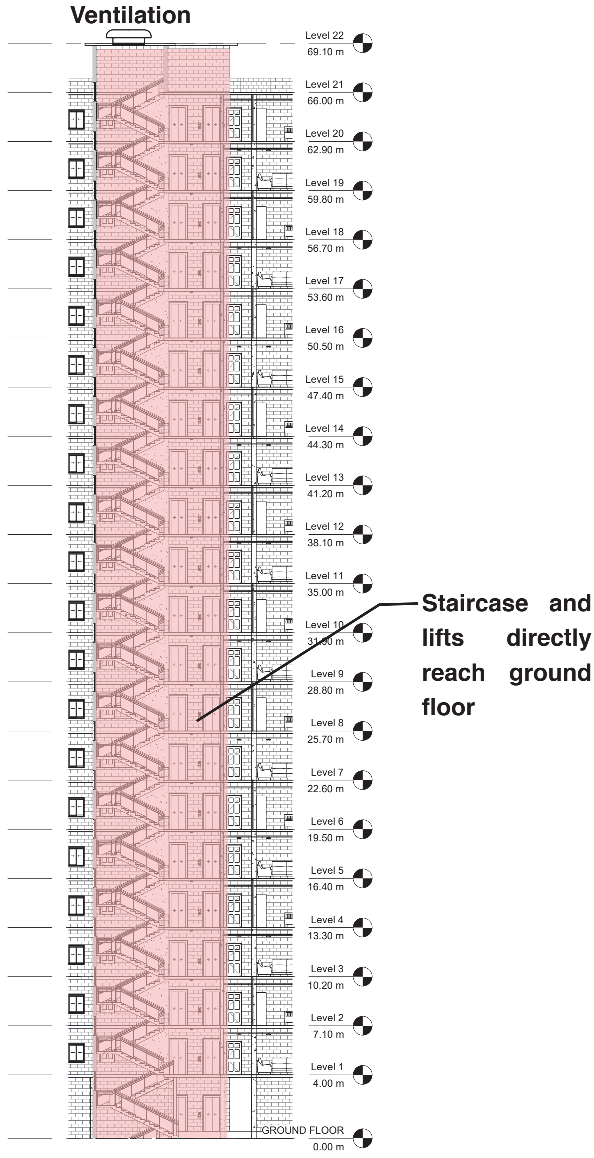


Figure 45: Fire sprinkler - even floor plan



PLAN - core with staircase and lifts



Section through circulation core

Figure 46: Fire staircase

7.4.4 CLIMATE RESILIENCE

- Future climate change scenarios in the hot and dry climate of GIFT city, Gujarat, have been anticipated using the LARS-WG model developed by Jayanta Sarkar and J R Chicholikar of IMD, Ahmedabad.
- For near, medium, and long term projections, we used three time periods: 2011-2030, 2046-2065, and 2080-2099. The maximum summer temperature is expected to rise by 0.5, 1.7, and 3.3 degrees, respectively. During the same time period, rainfall will increase by 2%, 11%, and 14%, respectively.
- As stated in 7.5.1 under Innovation, a tensile canopy has been designed. During the peak summer months, regardless of future temperature rise, this canopy helps to protect the north facade of the Pragya - II, which has a lot of glazing elements and balconies and the blocks self-shade the rest of the year. Every 20 years, this canopy will be replaced for optimum performance.
- Because passive design tactics and strategic block staggering have been adopted, Pragya - II can withstand future climate changes.

TIME PERIOD	INCREASE IN		RAIN
	Summer max temp.	Winter min temp.	
2011-2030	0.5 C	0.8 C	2%
2046-2065	1.7 C	2.2 C	11%
2080-2099	3.3 C	4.5 C	14%

Table 8: Predicted Future Climate

7.4.5 HEAT WAVES

Heat waves begin when high pressure in the atmosphere moves in and pushes warm air towards the ground.
Majority of the recreational spaces are protected from these heat waves by the building shade through out the day creating low pressure in the landscaped area. And the urban heat island effect in the future is reduced by the shaded vegetation area.

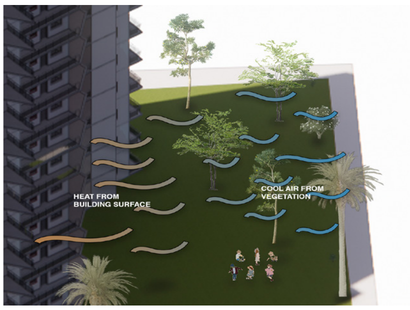


Fig. 47: Reduced Urban Heat Island effect

7.4.6 SHOCKS AND STRESSES

i) POWER FAILURE

To meet the Pragya - II consumers' electricity needs, a solar PV plant has been installed on site. Annually, 9% of the surplus energy produced is returned to the GIFT city electricity grid.

- In the event that the GIFT municipal electric grid fails, the users' demands can be met using the on-site renewable energy producing system.
- In the event that the PV system fails, power can be drawn from the power grid until it is re-established and functional.

ii) WATER OUTRAGE

Can be referred at 7.4.2.

iii) WASTE DISPOSAL

The garbage is gathered. Because every household's waste collection requires human intervention, failure can only occur in the GIFT city's chute system. If this occurs, the material can be delivered to a waste treatment plant by truck.

7.5 INNOVATION

7.5.1 CANOPY

- During the peak summer months, the sun rises in the north east, peaks slightly north of overhead point, i.e, it is higher in altitude but less inclined towards south and then sets in the north west. A simple latitude-dependent equator-side overhang can help to block 100% of the direct solar gain from entering the indoors on the hottest days of the year.
- Thermal simulations have been made while designing the tensile canopy to analyse the radiation during April - July at the time periods between 11 am to 4 pm.
- As stated in 6.2.3 Architecture - zoning, the living rooms are placed towards the north receiving daylight throughout the year. However, during the summers, these living areas will be affected by the solar radiation due to the change in sun's altitude.
- Taking advantage of the staggered block form, a tensile canopy is designed and is installed on the top floor to protect these living areas from the solar heat gain improving the user comfort. This tensile canopy is installed on the roof with the help of steel structural members that are welded.

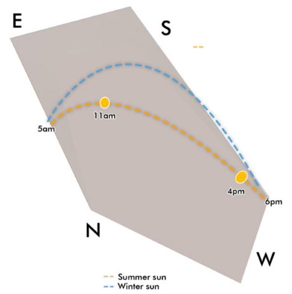


Fig. 48: Sun path between 11 am to 4 pm during summers

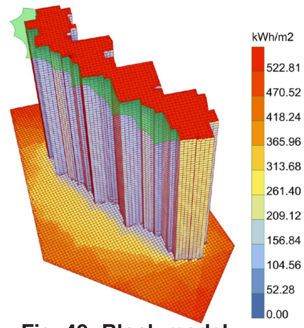


Fig. 49: Block model showcasing thermal analysis post canopy installation

Figure 50: Canopy view at Human eye level

7.5.2 WATER PRESSURE SYSTEMS

One significant issue that deserves consideration in the high rise structure is the water supply within the building, and how its transferred from floor to floor. For every 3m of vertical pipe, the water pressure increases by a factor of approximately 4.3 to 4.4 psi. So, the water pressure in the ground floor of a 20 story structure would roughly be about 87 psi more than the topmost floor, which is a huge difference. So, the Upper floors will suffer from very low water pressure levels, resulting in trickling water sources at all outlets and the lower floors will suffer from excess water pressure that leads to incessant damage to Faucet, geysers, and pipes. To mitigate this gravity-induced issue, a **Dual Mechanism Water Equalization System** is used that maintains a fixed water pressure across the entire building

i) To **reduce the water pressure levels at the lower floors**.

ii) To **increase the water pressure levels at the higher floors**.

i. **To reduce the pressures**, a series of **Pressure Reducing Valves(PRV's)** are placed at strategic intervals that are set at varied pressure settings. These Pressure Reducing Valves are passive mechanisms, meaning they don't require electricity or a motor to function. The valve's spring-loaded diaphragm opens and shuts at the preset position, allowing water to flow at the specified pressure. This network of PRV's effectively **maintains** a consistent water pressure in the **range of 21 to 29 psi**. The fixtures that are used are designed to effectively function between 7 to 58 psi.

ii. **To increase the pressures,** Pneumatic Booster Pumps are used. These pumps consist of two mechanisms, a motorized pump, and a pneumatically pressurized tank. The tank contains a water bladder that fills up to a certain capacity. This bladder within the tank is pressurized by compressed air to a specific pressure that matches the desired water pressure. When the water pressure in the tank starts to fall, the pumps switch on and refill water into the tank to maintain pressure.

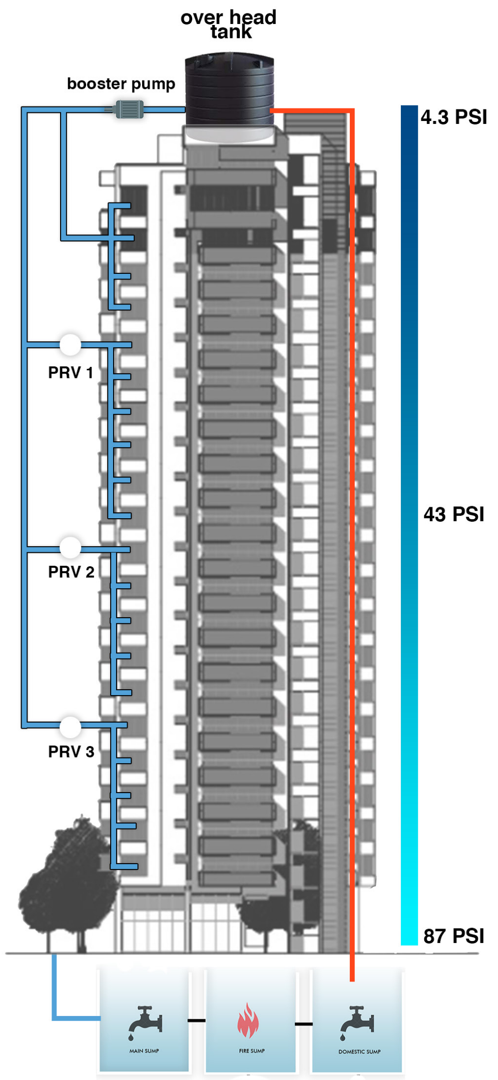


Figure 51: Water Pressure Systems

7.6 HEALTH AND WELL BEING

7.6.1 AIR QUALITY AND HEALTH

Considering the wind rose diagram obtained using the weather file, the windows are planned to obtain good indoor air quality.

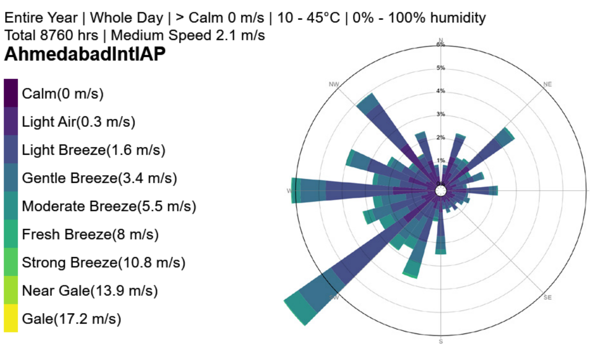


Figure 52: Wind rose Diagram

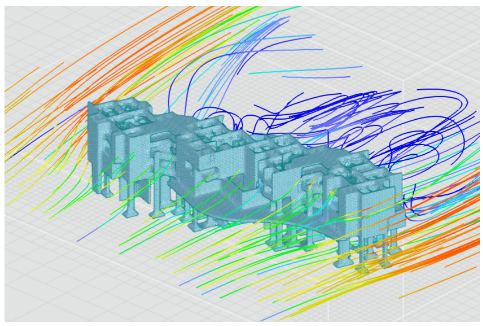


Figure 53: Wind pattern on block

Research suggests green spaces helps health in various ways. The World Health Organization funded a meta-analysis published in Lancet Public Health in November 2019 that pooled data from nine studies involving more than 8 million people from seven countries. People who lived close or in green places lived longer than those who were exposed to less green space, according to the study.

In a study designed to evaluate whether exposure to nature could help counter some of the negative effects of time indoors and under lock down because of the global COVID-19 pandemic, data showed that indeed, even a view outside can be helpful if nature is involved. And another research, published in November 2020 in Ecological Applications, looked at about 3,000 people in Tokyo and found that both seeing greenery from a window and going outside helped improve major mental health measures like depression, subjective happiness, self-esteem, and loneliness.

Hence, all the apartment units are planned in an order so that each unit gets a view towards water body and shaded green spaces to promote the health and well being of the inhabitants.

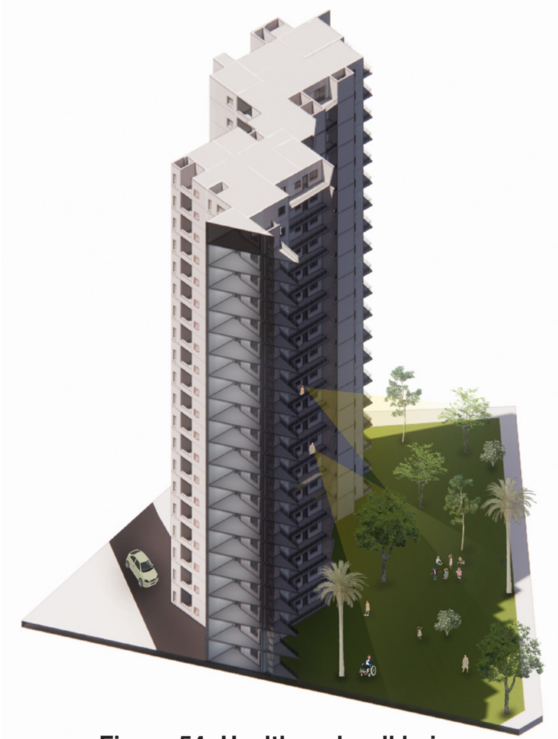


Figure 54: Health and well being

7.6.2 SOLID WASTE DISPOSAL

As a residential complex building produces huge amount of solid waste. Which not treated properly can produce a lot of landfills and can indirectly affect the community health. As the project site is located in GIFT smart city there is an existing solid waste treatment plant located at a distance of 2km from the site. The waste at the individual block stage is separated by the occupant himself in to dry, wet and medical waste. Then the apartment management transfers the waste to the vacuum suction pipes which transport then at the speed of 90 km per hour through a network of underground pipes. The organic waste will be sent to a Vermi compost where it will be used to make the manure which in will be used for the project's plantations and vegetation. The inorganic waste will be incinerated using plasma technology. This treatment plant treats the waste following the chute system.

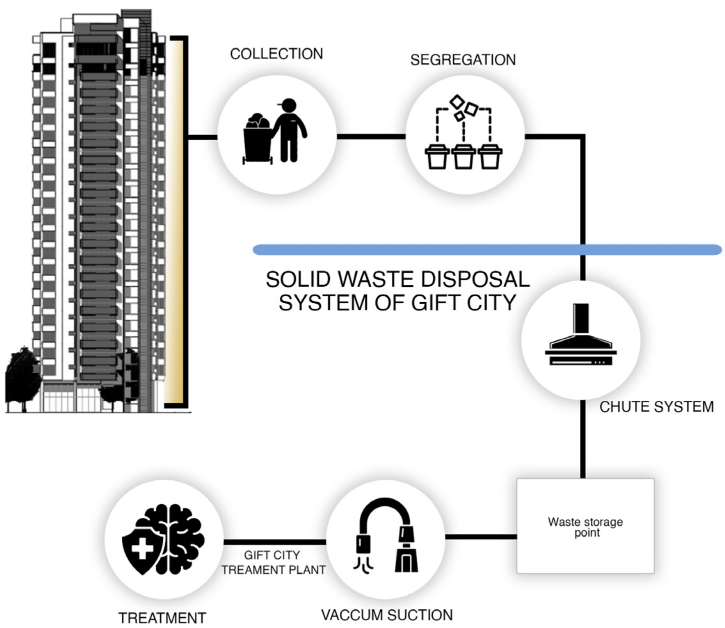


Figure 55: Solid waste Disposal Diagram

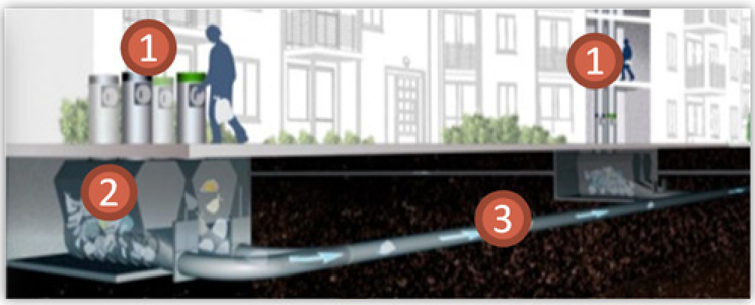


Figure 56: Automatic Collection and Transportation System

SOURCE: http://www.giftgujarat.in/solid-waste-management

7.6.3 INDOOR THERMAL COMFORT

As per ISHRAE, ‘Thermal comfort is that condition of mind, which expresses satisfaction with the thermal environonment, and it is assessed by subjective evaluation”. The most important aspect in overall human satisfaction when indoors is thermal comfort, which is linked to our health, wellbeing, and productivity.

The constant increase in cooling demand in India, particularly in residential and commercial structures, puts enormous burden on the power grids and the environment. This ever-increasing cooling demand in India should be addressed wisely, balancing active air conditioning with passive measures in order to reduce cooling demand in the first place. The requirement for active air conditioning equipment is minimized in Pragya - II thanks to passive measures and block arrangement, thoughtfully considered from the conceptual stage. The first line of defence is to reduce heat intake throughout the day by assessing orientation, buffer spaces, shade, and the building envelope - thermal mass, reflective surface treatment, and insulation.

Throughout the year, the indoor air temperature ranges from 21 to 27°C, which is within the thermal comfort range of 22 to 27°C. Despite the fact that the indoor air temperature is within a comfortable range, the relative humidity is not. Mechanical ventilation systems will be utilised for dehumidification to keep the relative humidity between 40% and 60% on days with higher relative humidity.

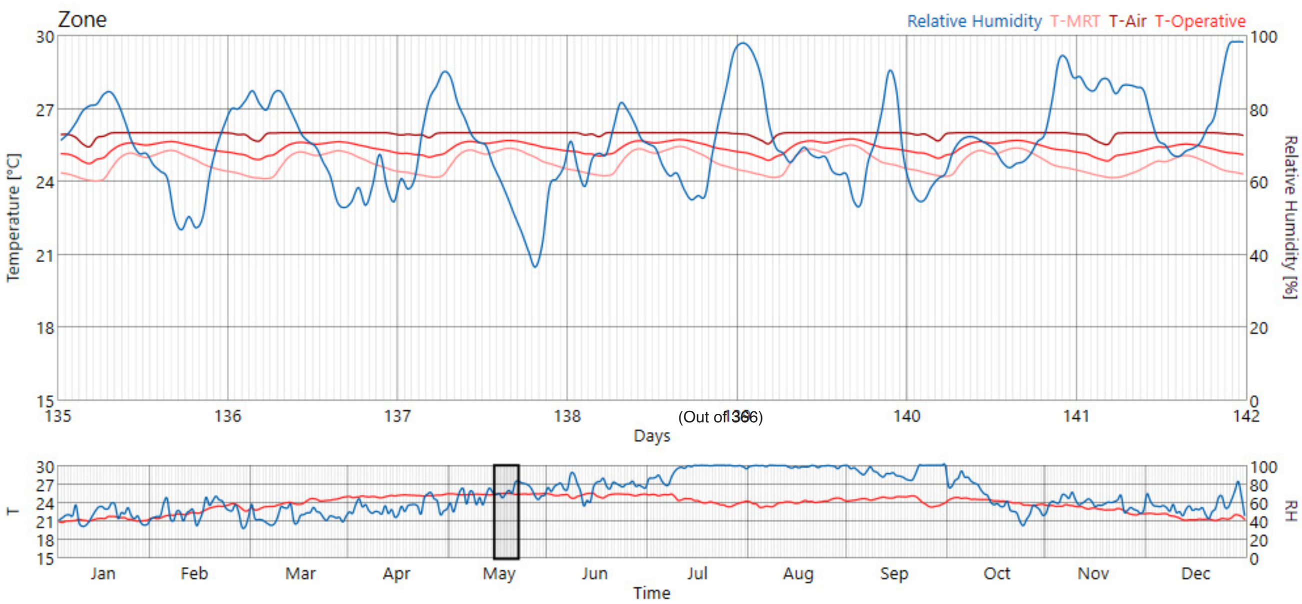


Figure 57: Line graph showcasing the indoor room temperatures and Relative Humidity

7.6.4 INVISIBLE GRILLS

All of the units have been designed to be the most innovative and luxurious, with safety invisible grills installed on the balconies. They safeguard the safety of individuals, particularly children, in addition to providing unobstructed panoramic views. They’re composed of high-quality stainless steel cable (316L GRADE) that’s been covered with a nano-technology membrane for added wear and tear resistance.

Figure 58: Invisible grills

7.7 ENGINEERING AND OPERATIONS

7.7.1 SELECTION OF 5 - STAR EQUIPMENT

Because the project is intended to be a net zero building, using energy-saving equipment will aid in lowering energy consumption. A comprehensive summary of all the equipment's calculations is provided in the Annexure.

		Base Wattage	5 star Wattage
EPD (Equipment Power Density) in W/m² for 1 unit	Wattage (W)	5811	4927
	EPD (W/m²)	61.31	42.39
LPD (Lighting Power Density) in W/m² for 1 unit	Wattage (W)	411	211.85
	LPD (W/m²)	3.16	1.62

Table 9: Summary of Equipment and Lighting Power Densities

Note: *Equipment includes Air conditioning, Fans, TV, wi-fi modem, set-up box, oven, coffee maker, toaster, refrigerator, washing machine, electric iron, laptop, chimney, exhaust fans.*

The use of inefficient equipment results in higher consumption, which leads to higher electricity bills. In a residential unit, majority energy consumers are the air conditioners, refrigerators, geysers, television, fans, washing machines etc. According to the energy calculations, energy efficient appliances are essential to attain net-zero energy use. Also some of these energy efficient home appliances will only need a lesser replacement and maintenance. They not only help to save money, but they can also help to reduce the carbon footprint and other greenhouse gases as they have lower emissions of harmful gases into the environment. The occupants can be briefed on energy efficient equipment and recommendations can be given at the time of occupation to guarantee that energy efficient appliances and lighting are used.

7.7.2 MOTION SENSOR LIGHTING

The motion sensors are a brilliant invention that can help us save energy. They work by turning on lights when they detect movement and turning them off when the movement stops. As a result, in the right environment, these lights can save money. Most motion sensors have an automatic cut-off time of 20 or 30 seconds. As a result, motion detector lights are ideal for medium-to-low movement rooms such as storage rooms and bathrooms, because it is easy to forget to turn off lights in low-traffic areas of the house. These fixtures consume 0.1W to 0.3W of energy on stand by, but can help in saving at least 60% than the CFL bulbs.

7.7.3 SOLAR WATER HEATER

Solar water heaters are best suited for the type of climate GIFT city has. The solar heater works based on the principle of heat transfer through water. The solar energy is transferred to the water by means of solar radiation. It is a passive strategy which can reduce a significant amount of energy consumption as it eliminates the requirement of electric water geysers. Hence, Solar water heater of capacity 100 litres is provided for one, two bedroom units, and 200 litres capacity is provided for three and four bedroom units. These solar heaters are to be pre-installed before occupation of the flats.

Figure 59: Solar water Heater

7.7.4 USE OF SPLIT ACs

Since most habitable spaces face north, artificial cooling systems are not required in all the spaces. The living rooms are comfortable and not as thermally exposed as the bedrooms, so there is no need for air conditioning in the living rooms. And there is no need for central air conditioning. The required number of hours for cooling was achieved using the IMAC tool to achieve thermal comfort in the bedrooms.

7.7.5 OPERATIONS

Nowadays, practically everyone has a smart phone. The creation of a mobile app, which will be managed by the community management, is recommended. This app will be required for all residents, mostly for security and operational reasons. This software will assist the occupant in gaining a better understanding of his or her impact on the environment so that he or she may act more thoughtfully.

- **ELECTRICITY :** The user/occupant can see his daily energy use in real time on this tab of the app. Individual data will be transferred over the app's connection to the server room. The occupant can see his/her consumption and the cost that he/she needs to pay for the electricity used.
- **WATER :** Every resident can examine the amount of water consumed on a given day from this tab, making him responsible for his carbon footprint. As It takes lots of energy to pump, treat, and heat water. Individual water consumption metering can improve a person's concern for water and have an impact on how he uses it. As a result, he must pay for his use.
- **EV status :** The electric vehicle revolution can overtake our country at any time. As a result, EV charging stations are available at parking lots, and the amount of energy utilised is tracked. In addition, the resident can view his battery charge percentage and vehicle location in real time from this tab.
- **SUPERMARKET :** A super market is located on the ground floor of the project partner's building program. The tab of the app can also be used to order groceries from this super market.
- **SECURITY :** Food delivery and e-commerce delivery have become a way of life for us. When a delivery person arrives , the security person will verify him at the security cabin using a one-time password method via this app between the user and the delivery person.

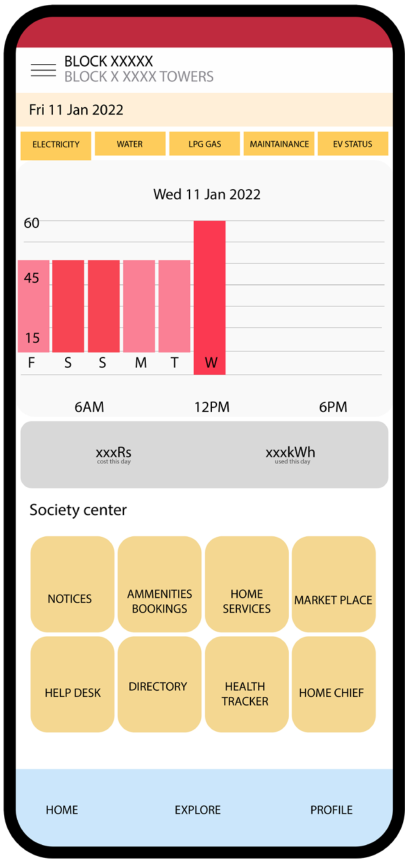


Figure 60: App Interface

7.7.6 WINDOW OPERATIONAL HOURS

Window operational hours have been stimulated throughout the year to ensure maximum thermal comfort in a variety of situations, and users will be advised when they can open and close their windows.

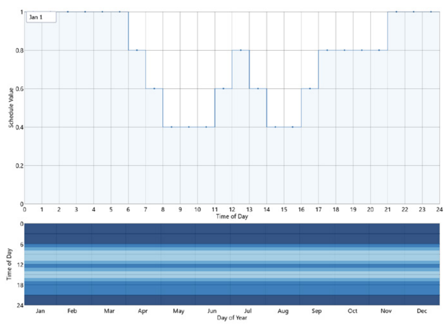


Figure 61: Window Operational Hours

7.8 AFFORDABILITY

7.8.1 SAVINGS ON CONSTRUCTION

- Slender beams and columns are used in the chosen structural system. This function expands the flat's carpet area. All of the electric fixtures are concealed into the slab thus making the ceiling unnecessary for functional purpose. This gives the occupant the option of lowering the ceiling cost while commissioning the interiors of the flat. In addition, because these columns are hidden in the wall, the brick work is reduced which results in 30% saving.

- Cost reduction achieved through steel. The load on the base structure will be very great due to the above floors acting on it, 32mm dia bars are used in the lower structure's columns. As the structure progresses to higher floors, the load to be transferred will be lower, hence the concept of column reduction will be used. This is a low-cost and low-material approach. The diameter of steel bars on progressive floors reduces while the column size remains constant. In the top stories, 16mm dia bars are employed. This method helped us to reduce steel cost exponentially.

7.8.2 SAVINGS ON OPEX

- LED fixtures with motion sensors are installed, which save over 5% energy, and all cooling equipment used in the dwellings is 5 star rated, which will save a lot of energy in the future.

- Every room in the house is designed and laid out in such a way that there is cross ventilation. This will assist in maintaining the occupant's thermal comfort while reducing reliance on artificial cooling systems.

- Installing low-flow shower heads and toilets will reduce water waste while also lowering the building's operational costs.

- Solar water heaters, despite their high initial installation costs, resulted in a nearly 20% reduction in annual electricity use.

- The shade created by the building on the landscaped area has reduced the use of heavy landscaping costs in the north part of the site. Having an indirect impact on the seller's price.

- The installation cost of tensile canopy may be high, but helps in significantly reducing the cooling loads by cutting the sun's incident radiation.

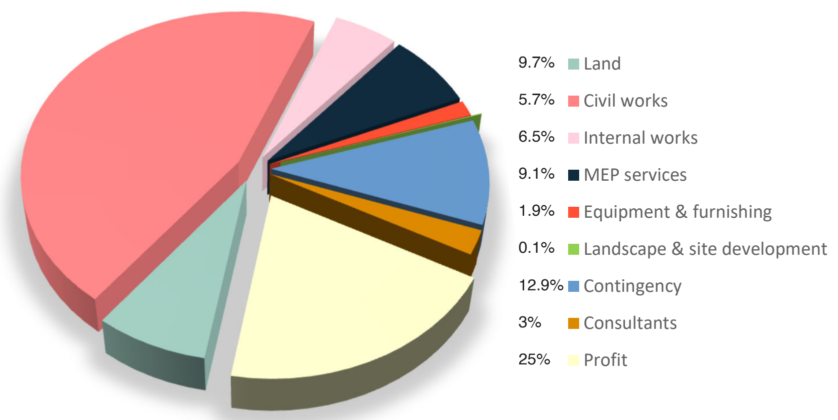


Figure 62: Percentage breakdown of Seller price

7.9 SCALABILITY AND MARKET POTENTIAL

7.9.1 SCALABILITY

- Each module was designed and various combinations of the required units were tried out vertically according to the project partner's programme specification. The ultimate practicable solution, which took into account many performance aspects, consisted of 3bhk receiving two distinct types of modules, 2bhk receiving two types, 4bhk and 1bhk receiving one type each. On the two corners of the floor plate, 3bhk modules are arranged on both even and odd floors, while in the central position, two 2bhk modules are arranged on even floors and one 1bhk and one 4bhk are arranged on the odd floor without disrupting the structural system, resulting in a quick and efficient construction process. As a result, the centre modules change every alternate floor, resulting in a consistent construction pattern.
- Another advantage is that, because the structural grid remains constant, if the program requirements change after the project is started (for example, if the demand for 2bhk units exceeds 1 & 4bhk), the even floors program can be reduced and the odd floors program can be increased during the primary construction stage based on market conditions with minor design changes.

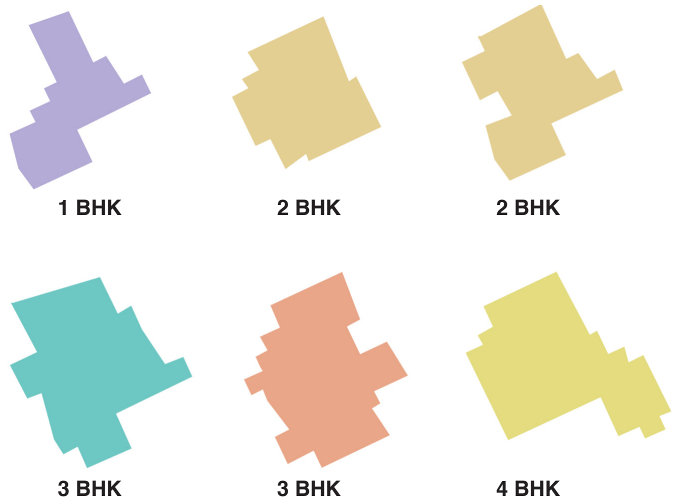


Figure 63: Modules in plan view

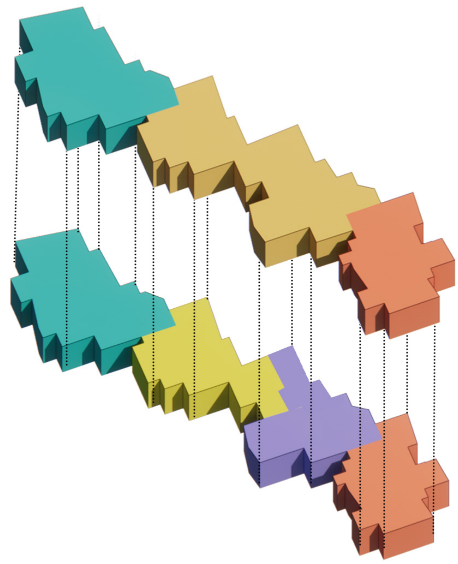


Figure 64: Module arrangement as per the Architectural program

The type of construction chosen for the project is a RCC framed wall with block work, which is a standard construction method for residential towers in Ahmedabad. It is also a fast construction system with easy construction and implementation. Another major benefit of this system is that the columns are only 30mm wide, which means they do not intrude into the indoor environment.

7.9.2 MARKET POTENTIAL

- The projects site is fortunately located in GIFT city which has immense scope to become one of the remarkable cities in India. It is India's first operational greenfield smart city and international financial services centre, which the Government of Gujarat promoted as a greenfield project.
- The city is designed so residents can walk to work, and includes commercial, financial and residential complexes.
- The city is connected though 4-6 lane State and National Highways. A double corridor metro system is being constructed to connect GIFT City to the nearby airport and various parts of Ahmedabad.

- Ahmedabad is currently India's most affordable market, with an affordability ratio of 24%, followed by Pune and Chennai, with affordability ratios of 26% for both cities (Knight Frank, 2020).
- The city's features itself are major selling points for this project.
- To analyse the current cost trend in the area, projects like SOBHA dream heights, SOBHA AVALON, and others in Ahmedabad with similar programmes were studied. Based on our research, the current range is between ₹6500 to ₹9000 per square foot, therefore we set a goal to finish the project below this budget range.

7.9.3 FINDINGS

- From all the responses received, 57% of customers prefer to buy a high-rise property between 10 - 20 storeys.
- The current era requires a housing unit to meet imperative requirements of maintaining healthy, comfortable, and safe living environments. The conventional design solutions and practices need to be altered to reduce the environmental impacts.
- Major part of it can be housing for the workers from existing office building and will attract many people from around the city for greater experience of future developed GIFT city with all amenities.

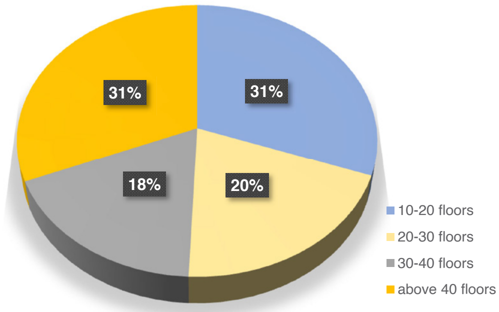


Figure 65: Floor Preference

S. No	Age group	Floors			
		10 - 20	20 - 30	30 - 40	above 40
1	20-30	5	5	12	18
2	30-40	11	13	6	11
3	40-50	9	9	1	6
4	50-60	16	2	7	8
5	60-70	3	0	0	2

Table 10: Bifurcation with respect to the age group willing to buy property

SOURCE: IRJET

7.9.4 SALIENT FEATURES OF PRAGYA - II

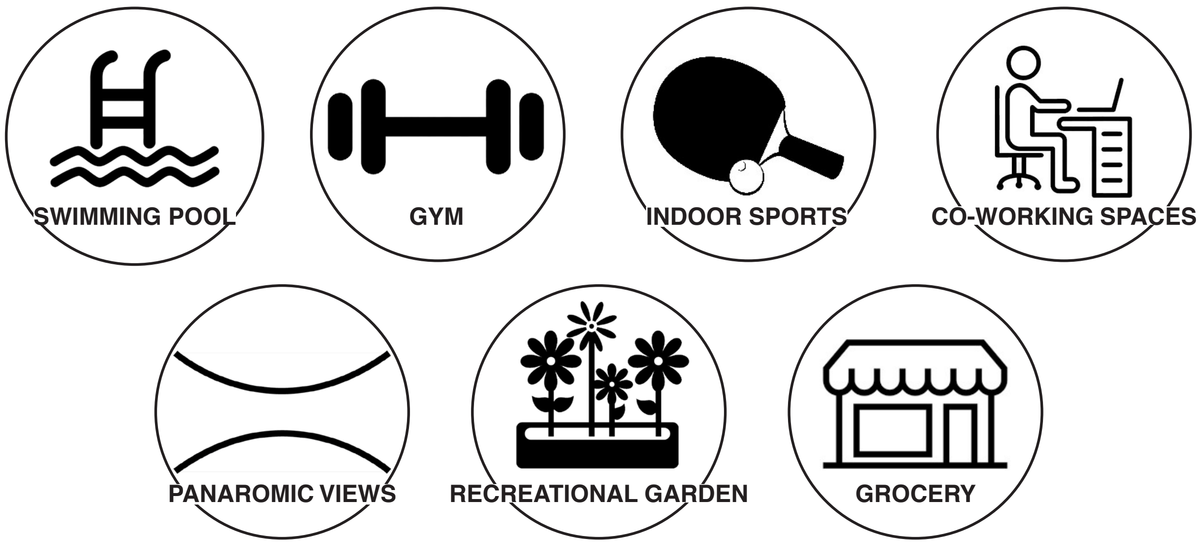


Figure 66: Salient Features of Pragya - II

7.10 COMMUNICATION

7.10.1 INTERACTIVE EVENT

A public interactive event has been initiated by the respective faculty leads. In which, team Sukhibhava has presented the work to the audience in the public region of understanding on the net zero buildings and the project Pragya - II. Various sustainable and green fefatures have been expressed and the design process alongside the simulations.

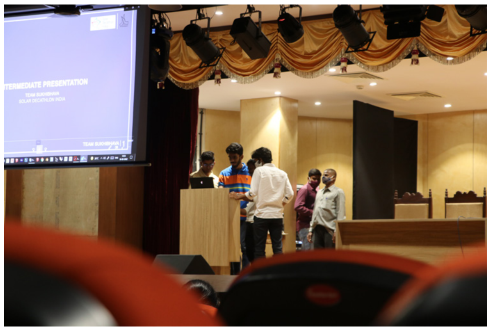


Figure 67: Interactive event

7.10.2 SOCIAL MEDIA

- A business account on Instagram has been created. In addition, posts introducing the agenda and goals of the team have been created. A few other posts have been made to explain the features of our net zero building in an easy-to-understand manner. On the basis of location and intended audience, the business account will be promoted. If a person searches for an apartment related topic, he will see an advertisement of our page (but at a cost). When the project begins to attract diverse targeted audiences, this can be done.
- We are also looking at the possibilities to arrange a virtual tour in meta verse for the interested audience via applications such as spatial.

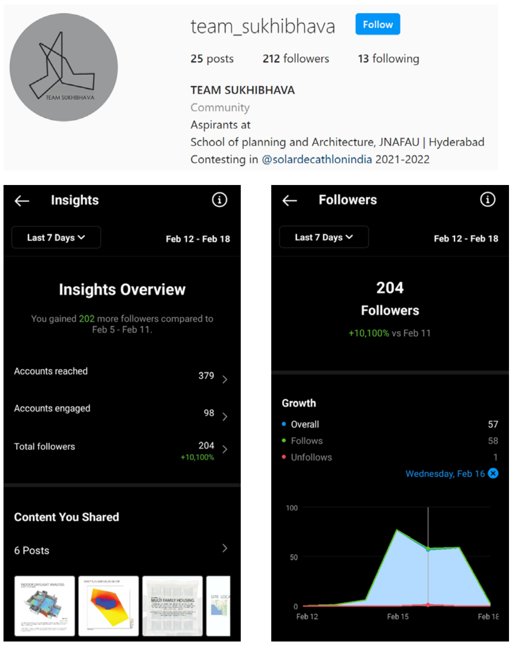


Figure 67: Instagram Activity

INSTAGRAM: https://www.instagram.com/team_sukhibhava/

8.0 REFERENCES

- NBC - National Building Code - Volume 1 and Volume 2
- ECBC - Energy Conservation Building Code 2017
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- IGBC Green Homes Rating System - Version 3.0 2019
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