Final Design Report April 2021

Office Building

CEPT University

KillBill 4.0

Project Partner: ATS Savvy Developers LLP

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1.0 Executive Summary

Ensuring that skyscrapers provide an energy-neutral comfortable indoor environment is challenging. Limited roof space is a major hurdle in achieving Net-Zero energy solutions in high-rise building projects. Team KillBill 4.O from CEPT University has taken up this challenge and has tried to develop innovative solutions to achieve a Net- Zero 24 storey commercial complex.

Team KillBill 4.O is a combination of architects and engineers with varied backgrounds and experience. The team has partnered with ATS Savvy Developers LLP, whose mission is to strive for quality construction, architectural designs, and conscientious attention to detail. Our project, Pragya, is a 24 storied (commercial/ office with multi-level car park) complex located in GIFT city, Gandhinagar in Gujarat. We aim to provide the most cost-effective net-zero energy-water solution by integrating the various infrastructural needs of our project with centralized systems provided by the GIFT City while maintaining the individuality of the project.

In a high-rise project, the facade is the largest external surface. We have tried to create to produce a facade design that appeals to its target market in terms of appearance and aesthetics but also is utilized effectively as potential surface area to host carbon positive elements. The focus has been to reduce not only energy consumption but also address the challenges of affordability and marketability in a core and shell project that suffers from the classic problems of split incentives and the need for universal appeal to ensure continuous tenancy. The team tested the feasibility of a wide set of design solutions such as solar absorbers to develop a Hybrid Solar Thermal HVAC System to identify viable solutions that work from multiple points of view. In the particular case of the cooling plant type all tested technologies (low/lower-carbon) failed to complete with high-performance district chilled-water system in terms of energy efficiency and cost. The team proceeded with roof and façade solar PV systems.

With a built-up area of 37000 m^2, our building has been designed to achieve an EPI of 45 kWh/m^{2}yr, achieving its net-zero target through solar PV generation with a safety fact of 10%. The GIFT city chilled water supply system makes a large contribution to the exceptionally low EUI due to the high diversity factor in the operation of the district system (COP = 6.65). In addition, in most core and shell projects, most tenant guidelines are limited to efficient fixtures (lighting and terminal units). Our proposal shows that to achieve net-zero status in core and shell buildings, it is necessary to expand the scope of the tenant guidelines to operations as well. A 16% reduction in the potable water supply is attained by reducing water usage by efficient fixtures, drip irrigation for landscape, 100% on-site rainwater and stormwater management, and sewage treatment. By using a radiant cooling system, achieved a reduction of 70% in HVAC energy consumption.

Green buildings create a long-term value to all the stakeholders in a project, but due to a lack of awareness about the green component, investors have not paid much attention to core and shell office projects in India. A Build Own Operate and Transfer (BOOT) business model for a large-scale replicable building-integrated Solar Photovoltaic array is proposed by allocating the installation, operation, and maintenance to an energy service company (ESCo.). The Solar PV array of 1081 kWp capacity with an upfront cost of 5.14 Cr has an annual ROI of 11%, which breaks even within 11 years. This proposal interests the investors as the net present value for the solar PV is 2.84 Cr.

The resulting design achieved total FSI with an incremental construction cost of 3% (4.2 Cr.) to the developer yielding an internal rate of return at 20.75% and saving an average of Rs. 2.0 Cr. on the operational expenditure of building for occupants every year. The life-cycle cost is reduced by 6% for a calculated period of 25 years, at a discount rate of 10% after implementing the design solutions.

2.0 Team Summary

Team Name: KillBill 4.O

We draw inspiration from the perseverance and strength of the iconic female samurai warrior to come for a fourth time to kill the electricity shortage in India.

Institution Name: CEPT University, Ahmedabad, Gujarat.

Division: Office Building.

2.1 Team Members

Abraham Philip
(Architect)
Designer/ Team Lead

Amanda Santiago
(Architect)
Designer/ Co-Lead

Het Modi
(Civil Engineer)
Engineer

Irene Shaji
(Architect)
Facilities Manager

Macha Bhargav
(Architect)
Facilities Manager

Nikita Khatri
(Architect)
Energy Analyst

GVS Raghavendra Rao
(Architect)
Energy Analyst

Sejal Sanjay Shanbhag
(Architect)
Financial Analyst

Snowy S
(Energy & Envir. Engineer)
Engineer

Stuti Goyal
(Architect)
Designer

2.2 Approach

KillBill 4.0 comprises of student members with a diverse skillset. The team has selected strengths in areas of the ten contests and each on the team has a list of targets to chase. We planned on approaching the design head-on by establishing a robust understanding of the financially viable design proposed by the developer, along with the site context and climatic parameters to arrive at the design goals that conform to our aim of creating comfortable, high-performance buildings

Establishing our design goals was one of the main outcomes in defining the opportunities. As this project is a part of a district energy system, there is extensive infrastructure available on site that is plug-and-play in nature. A potential study was done with assistance from the developer and discussions with the industrial partners to understand the technical specifications since they have an impact on the financial, operational and space planning of the project. KillBill 4.0 relied on the fundamental understanding of human comfort (thermal and visual), workplace organization and organizational behaviour to improvise building systems that optimize comfort and energy use. The building and system optimization are done along with appropriate robustness checks to ensure that design decisions are not made based on simplistic representations of the environment.

2.3 About CEPT University

CEPT University (Centre for Environmental Planning and Technology) is recognized as a Scientific and Industrial Research Organization (SIRO) by the Department of Scientific and Industrial Research Organization (DSIR) of the Government of India. Its teaching programs deepen the understanding of human habitat and comprise five faculties; Architecture, Planning, Design, Management and Technology. Master of Technology in Building Energy Performance at the Faculty of Technology aims to nurture specialized professionals in climate-responsive building design and low-energy building operations. The students acquire hands-on experience and have access to state-of-the-art tools, more importantly- CARBSE the net-zero building on campus which enriches the students learning experience.

Figure 1: CEPT University

2.4 Faculty Lead

An Adjunct Assistant Professor in Faculty of Technology, CEPT University. She is a researcher in the field of performance-driven building design and worked for several years with consulting firms such as Buro Happold and Integrated Environmental Solutions Ltd. in the US. She is an experienced LEED consultant who has worked through 3 generations of the LEED rating system interfacing with developers, architects and mechanical engineers to guide them through the LEED certification process.

Prof. Minu Agarwal, PhD

2.5 Industry Partners

Aqua Utility Designs and Management Pvt. Ltd. provide lucrative solutions in utility services designs. They are amongst the top sought-after design firm working on a large number of diverse projects throughout the country. The KillBill 4.O team worked with Mr. Dipen Mehta the managing director of Aqua to achieve the water target and also to develop the MEP drawings.

CoLEAD LLP designs and assists architects, urban designers & planners, and policymakers to create high-performance design solutions across varied typologies & scales from single-family homes, factories, IT parks to townships. Mr. Vardan Soi from Colead worked with the KillBill 4.O team by guiding and advising on various energy-efficient measures throughout the project.

Gangotree Energy Projects Pvt. Ltd concentrates on energy resource development. They provide decentralized, sustainable & replicable energy solutions with Bio-Energy as a base. KillBill 4.O worked with Mr. Ashish Vaishnav the director and CEO of Gangotree on understanding and designing absorption chillers and vacuum flat plate collectors.

Technogas Systems Pvt. Ltd. is one of the fastest-growing companies in India which has expertise in manufacturing a wide range of Water Heating Systems and Water Treatment Plants. Mr. Naimish Mehta the director of Techno gas worked with the KillBill 4.O team about understanding the possible Sewage treatment systems that can be incorporated into the project.

The team is also thankful to experts for helping with various aspects of the design process:

- Prof. Rajan Rawal (Executive Director, CARBSE) for his support and guidance to the team throughout this project.
- Prof. Rashmin Damle (Faculty of Technology, CEPT University) for sharing his expertise.
- Prof. Aanal Shah (Faculty of Technology, CEPT University) for guiding the team in structural design
- Prof. Prashant Das (Real Estate Finance, Indian Institute of Management, Ahmedabad) discussed and informed the team about affordability and market potential.
- Gautam Bhasin (Inhabit, Regional Director (Mumbai)) for discussing and providing in-depth feedback on the architectural design and façade treatment.
- Omkar Jani (Director, Research & Culture at Kanoda Energy Systems Pvt Ltd) for discussing the renewable energy approach taken.
- Devang Khambhati (General Manager, Giocomini engineering consulting) for discussing the design and potential of the Radiant Low Cooling System.
- Gaurang Patel (Chief designer – GIFT City Central District Chilled Water Plant) for taking the team through what GIFT city has to offer and for discussing the District Cooling System in GIFT.

3.0 Project Introduction

Project Name: Pragya

3.1 Project Partner

Team 'KillBill 4.0' has partnered with **ATS Savvy Developers LLP** which is a progressive construction company that believes in changing the paradigm of the construction business by adopting innovative technologies. Savvy's mission is to strive for quality of construction, architectural designs, and conscientious attention to details of the building process in every project that is taken up.

KillBill 4.O has been working closely with Mr. Sameer Sinha, MD of Savvy group and Chairman, CII-Indian Green Building Council (IGBC) and Ms. Ruchi Gandhi, Project Manager of Savvy group, who has been managing project Pragya right from the initial planning stages.

3.2 Brief description of the project:

The commercial tower is situated in Gandhinagar, Gujarat which comprises a hot and dry climate. It is located in Gujarat International Finance Tec-City (GIFT) City. GIFT City is integrated with city level district cooling system, solid waste management and a plasma gasification system. The project is conceptualized to offer cutting-edge features and a world-class business environment to house the offices in the promising and finest commercial and retail space. The project, Pragya, is estimated to be completed in 2021.

The project is modelled to be built-own with 50% of the floor plate to leased and remaining sold with the builder retaining operation of the common services.

Figure 2: Site for Pragya (Commercial Block & MLCP); Gujrat International Financial tech-City

3.3 Context and Market Analysis

As the world strives for sustainable living, so do our cities and buildings. India is among the top 10 fastest growing economies which demands a world-class business environment to redefine the nature of business and global trade. GIFT city employs over 3 million people, and for the people to compete with international financial hubs, there is a need to provide the cities with infrastructure and work environment of global standards. IT/ITES sectors development potential promises opportunity for the construction industry. The infrastructural development cannot be undertaken with ignorance towards the alarming climate changes and the shortage of non-renewable energy resources. A planned business district such as GIFT city in Gujarat poses the essentiality for sustainable and energy-efficient design and not just an option of space planning.

Encouraging global trade and targeting the business of banking, Insurance, and capital market activities, the Government of Gujarat policy incentives, extend exemptions and subsidy under Special Economic Zone Act, 2005 (SEZ Act 2005). This project, within GIFT city which provides single-window clearance, competitive operation costs with a tax regime, relaxed company law provisions, and an international arbitration centre to facilitate businesses. Since the project is part of the shared benefits in terms of road, water supply, uninterrupted power supply, solid waste management, world-class Information and Communication Technology, etc., a unique commercial and retail space can be developed in the commercial tower to nurture and foster the financial services sector.

India is the only country among G-20 nations that is on track to meet its climate change mitigation commitments of 2°C under the 2015 Paris Agreement. The current era requires office spaces to meet imperative requirements of maintaining healthy, comfortable, and safe working environments. The conventional design solutions and practices need to be altered to reduce the environmental impacts. The interventions are required to be cost-effective and scalable, with the utilization of the existing policies and the state-of-the-art technologies, so that they can be employed by the masses.

3.4 Special requirements of the Project Partner

- Estimated Total Built-Up Area: – 37000 m^2 (excluding Shopping Area)
- The project needs to follow GIFT SEZ Development Control Regulations, which supersedes any other local by-laws.
- The project does not have the typical site plan with FAR, instead is assigned a building outline with permissible Built-Up Area.
- The project must incorporate the district cooling systems, centralized solid waste management system and sewage treatment system.

3.5 Building Area Program

As per gift city guidelines, the building footprint is provided to building owners, whereas no boundary walls exist for individual buildings. For our site, the existing above-grade building footprint has been considered as the ground coverage and the basement outline has been considered as the total site area, including the landscape area.

Site Area : 10360 m^2 (Approx.; as GIFT assigns building outline)

Building Floor Plate Area (Plot allotment as per GIFT SEZ)
Commercial Block : 2100 m^2
Multi-Level Cark Park : 2800 m^2

Permissible Built-Up Area
Commercial Block : 40100 m^2 (including Retail Area)
Multi-Level Cark Park : 17000 m^2

Table 1: Space Area Distribution for Commercial Block

Area Type	Area (m^2)
Site area	3422
Landscape area	1322
Ground coverage	61%
Space Type	**Area (m^2)**
Office Area	28000
Break Area	1500
Core and Services	3800
Transition spaces	2200
Restrooms	1500
Total	**37000**
Refuge Area	510
Commercial (Retail)*	3100
Basement (Parking)	3400

*energy and water performance calculations not in-scope

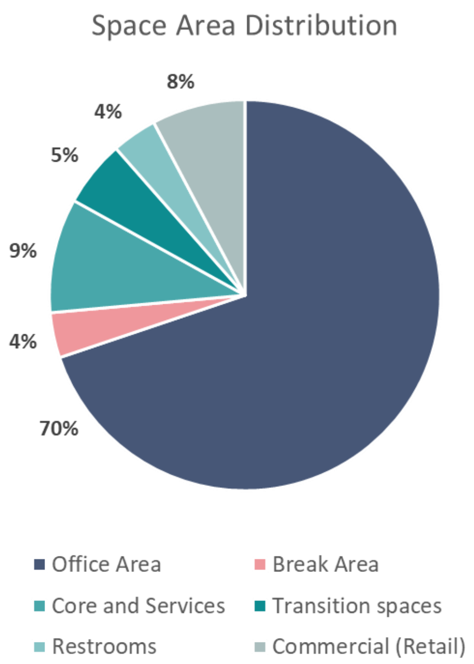


Figure 3: Space Area Distribution

4.0 Performance specifications

Climate Zone: Hot and Dry
Mean Monthly maximum temperature (°C) > 30 °C
Relative Humidity (%) < 55%
for a minimum of 6 months (NBC, 2016)

Table 2: Performance specification of the project

Envelope		
Wall	0.40	$W/m^2.K$
Roof	0.33	$W/m^2.K$
Window	3.00	$W/m^2.K$
SHGC	0.50	
SHGC	0.27	
VLT	70	%
HVAC		
System Type	Radiant Cooling System (RCP - Panel type) with Dedicated Outdoor Air System (DOAS)	
Cooling Source	District Cooling System (DCS)	
COP	Chiller COP - 6.65/ Overall COP - 3.90	
Lighting		
LPD	5	W/m2
Controls	Stepped	
Electrical		
LPD	10.8	W/m2
Renewable Energy		
Type	Monocrystalline Photovoltaic Panels	
Efficiency	19	%
Generation Capacity	1548146	kWh per annum
Water System		
Domestic Requirement	85,000	lpd
Flushing Requirement	64,000	lpd
PV maintenance and irrigation	13,200	lpd
Sewage Treatment Plant Capacity	1,29,500	lpd
Treated Water Quality (BOD, TSS)	10	mg/l
Rainwater Treatment		
System Type	RAINY FL-500 dual intensity RWH filters. (Cohesive and centrifugal force)	
Filter Element	SS-304 Screen	

5.0 Goals

Architecture

- Optimize the architectural design to **maximize daylighting and visual comfort with natural ventilation** (night purge ventilation for common areas) and minimize thermal load from environmental parameters by **limiting annual sun exposure in office areas to under 3%**.
- To exploit the daylighting to **achieve a minimum of 95% daylight spaces**, with an electric lighting system to have **lighting power density reduced by 30% over the ECBC standard case**.
- To create a **connection between the intense work environment and nature through vertical gardening**. Ensure access to outdoor views (under CEN European Daylight Standard EN17037) or views to indoor green space to all permanent building occupants.

Engineering design and operation

- **Building materials to be based on 20% recycled content** and optimized quantity of building materials to ensure minimum carbon cost and to reduce dependence on materials that have associated negative environmental impacts.
- Optimize structural design **to reduce steel and cement usage by at least 5%** in comparison with Building As-Usual case, while maintaining the structural design quality.
- **The hybrid Absorption chiller is driven by solar thermal energy for baseload** and District Cooling System for the seasonal load to improve the overall HVAC and renewable system efficiency.

Comfort and environmental quality

- Ventilation system **to ensure minimum fresh air required for indoor air quality and occupant well-being**.
- Formulate thermal comfort requirements through **holistic consideration of parameters of human thermal comfort** and not just based on space air temperature setpoints.

Energy performance

- **High-performance envelope materials** decrease the cooling design load, with the incremental cost to be offset by the lower cost of the HVAC system.
- **Performance-related robustness checks** to be performed during the selection of all HVAC systems, to maximize utility for the building owner and for reducing the risk of sub-par energy performance.

Water performance

- To **reduce the potable water demand by a minimum of 30%** from the baseline criteria (as per NBC 2016)
- **To reduce the landscape water demand by 75%** from the baseline criteria.
- **To manage and store 100% of the rainwater and stormwater runoff** on-site.
- **Treatment of 100% of the wastewater** generated, to the quality standards suitable for reuse

Affordability & Scalability

- Cost analysis to **identify cost-effective solutions**. Our cost analysis shall include the cost of construction, land costs and cost of capital. Payback analysis shall be done from the point of view of the developer and tenants as some of the systems shall be installed by the tenants.
- **To develop an efficient construction timeline and systems** to ensure scalability and construction productivity.

Resilience

- Designing the building and its infrastructure to have a minimum impact during calamities like earthquakes, cyclones, heatwaves and floods.
- **Flexible spaces** that could transform and adapt to various scenarios and changing times.
- Building performance to be **optimized for future climate**.

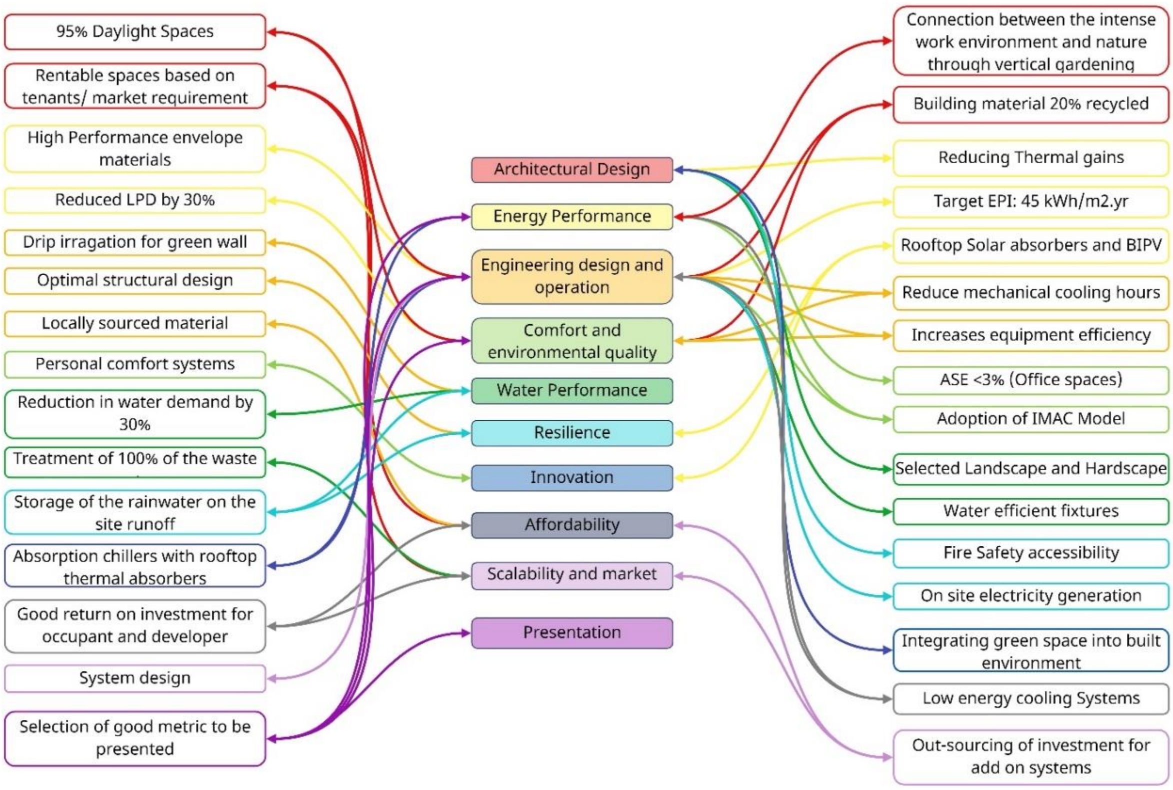


Figure 4: Goals for the project

KillBill 4.O has set its performance goals based on the ten contests of the competition. The goals were analysed through a matrix, in which the ten contests have been interlinked to established a common goal targeted and achieved during the design process. These helped ensure the design is robust and caters to multiple goals.

6.0 Documentation of Design Process

KillBill 4.O followed an integrated design approach in which the team established the goals and their interrelations with each other. This helped formulate a more concrete understanding of the targets that were to be achieved. The design process started with understanding the site and its strengths through SWOT analysis. This was further integrated with a climate analysis to understand the climate of Gandhinagar, Gujarat and what it has to offer. The constant interacting with the builder and industrial partners helped formulate a robust integrated design.

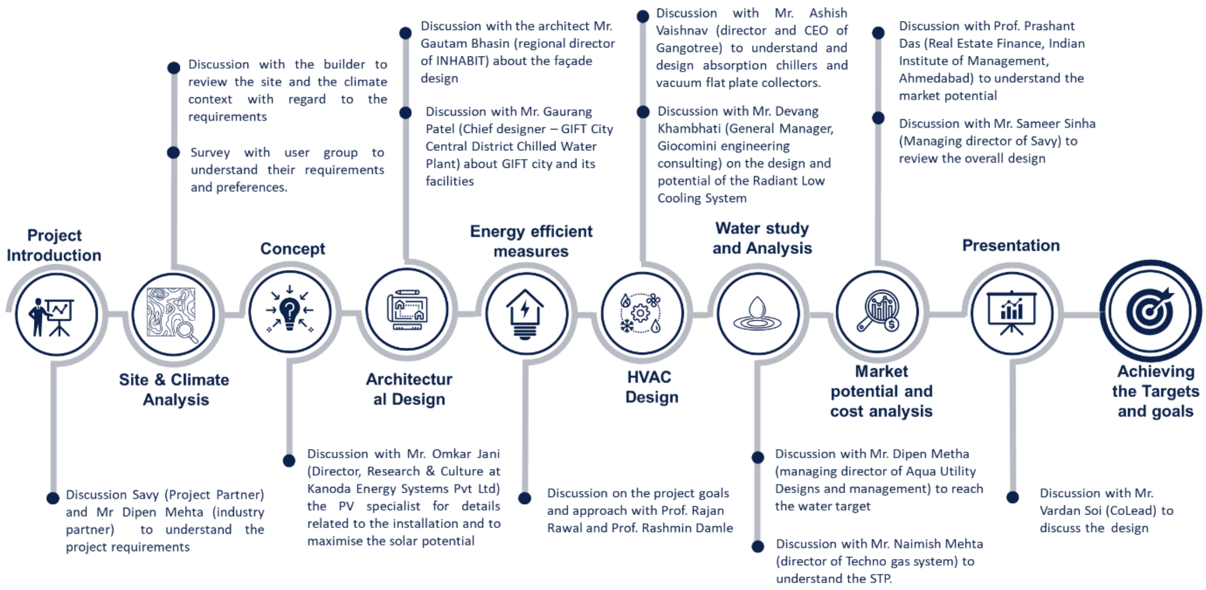


Figure 5: Design Process

The constant weekly meetings with the team strengthened the process and helped attain the goals of the project. The concept was developed with the idea of breaking the monotony of the regular office building, KillBill 4.O focused on trying to integrate green spaces in the office to help break the monotony of the complete concrete façade. This green space acts as a breather to both the occupant and the onlooker. The design was tastefully combined to ensure the occupants attainted both thermal and visual comfort. Mixed-Mode spaces were designated to ensure an even distribution for the occupants. An optimized and right-sized HVAC system is designed and integrated with a building management system to ensure the operation of the HVAC system at its peak efficiency while maintaining occupant comfort level. This was followed by ensuring that we met the water requirement of the project. On completion of the project, the market potential and cost analysis were conducted to ensure the project is on the right track.

Figure 6: Simulation and Analysis Tools used

6.1 Pre-Design Analysis

Site Context

The site Pragya is located in GIFT city in Gandhinagar, Gujarat, India. It lies under the SEZ-PA category with a site area of 3422 m^2. The site is strategically located, it is 12 km away from Sardar Vallabhbhai Patel International Airport and 12 km away from the Sabarmati railway station. The closest metro station is 500 meters from the site.

Figure 7: Site and location

Under the GIFT city master plan, currently, there is one building within 100 m of the site with potential for future building complex with the nearest being 40 m from the project site boundary. The North, South and East have adjacent open areas. The current nearest building is the Brigade International Financial Centre (BIFC). It is 98 m away from the Pragya tower and has two basements, G+ 14 floor, with a height of 60 m.

GIFT SEZ Ltd grants the building plot outline and built-up area granted as per its master plan. The Commercial Block is granted a building floor plate of an area of 2100m^2 and Multi-Level Car Park, a floor plate of 2800 m^2.

The project as per the GIFT SEZ Development Control Regulations needs to incorporate the district cooling system, centralized solid waste management system and sewage treatment system.

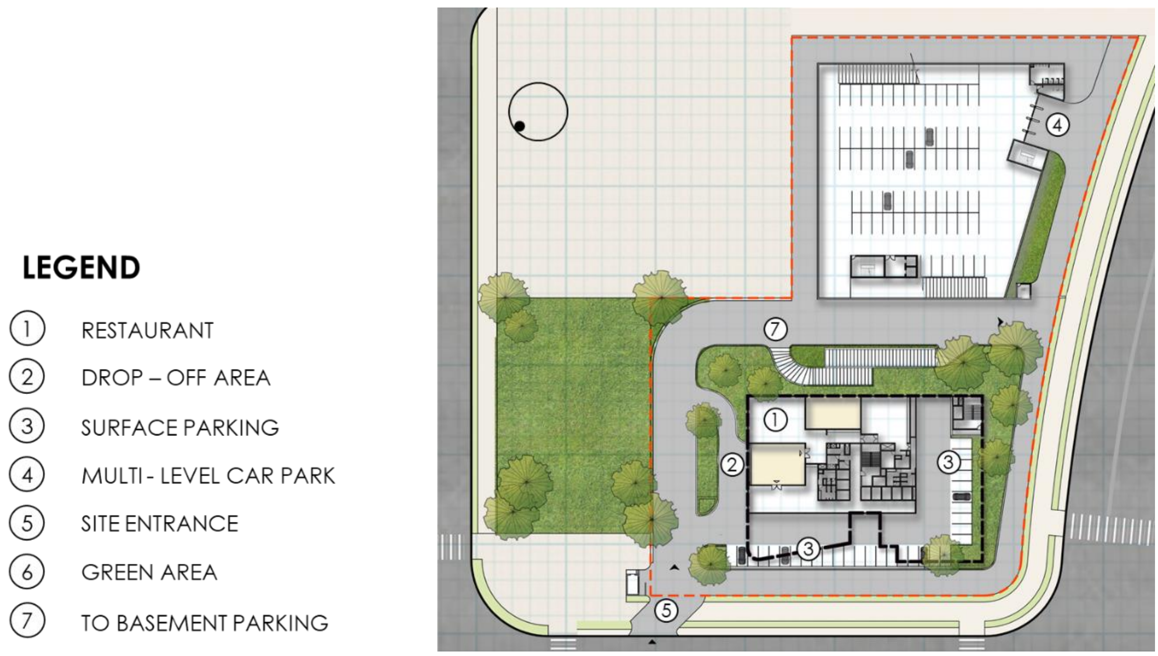


Figure 8: Site Plan

Climate Study

The project is located in Gandhinagar, Gujarat, which falls under the hot and dry climate classification as per ECBC 2017. A climate study was done of the environmental parameters to understand its impact on occupant comfort and building performance. The Typical Meteorological Year (TMY) weather data for Ahmedabad (30km from Gandhinagar) is taken for the entire analysis and energy simulation since the same is not available for Gandhinagar.

The Cooling Degree Days (CDD) for Ahmedabad is 3497 (40%) annual hours when the baseline temperature is 18.3°C. Hence, cooling is required predominantly for this climate.

Cooling design day conditions based on outdoor conditions:
0.4 % Dry-Bulb Cooling Design Temperature
DBT : 42.1 °C
MCWB : 23.0 °C

1 % Dry-Bulb Cooling Design Temperature
DBT : 41.0 °C
MCWB : 22.8 °C

DBT - Dry-Bulb Temperature
MCWB - Mean Coincidental Wet-Bulb Temperature

Source: NBC 2016

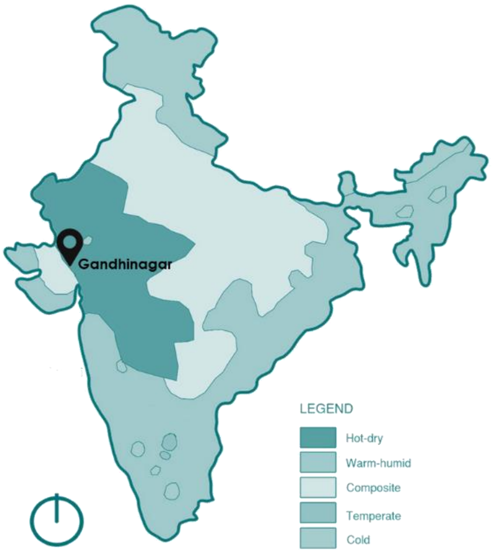


Figure 9: Climate Zone Map of India

The IMAC (Indian Model for Adaptive Comfort) model defines the daily operative temperature and its 90% acceptability thermal comfort limit (3.46°C from the neutral temperature). The operative (neutral) temperature for the IMAC model was generated from the Outdoor Running Mean Temperature of Ahmedabad 's TMY file to study environmental conditions

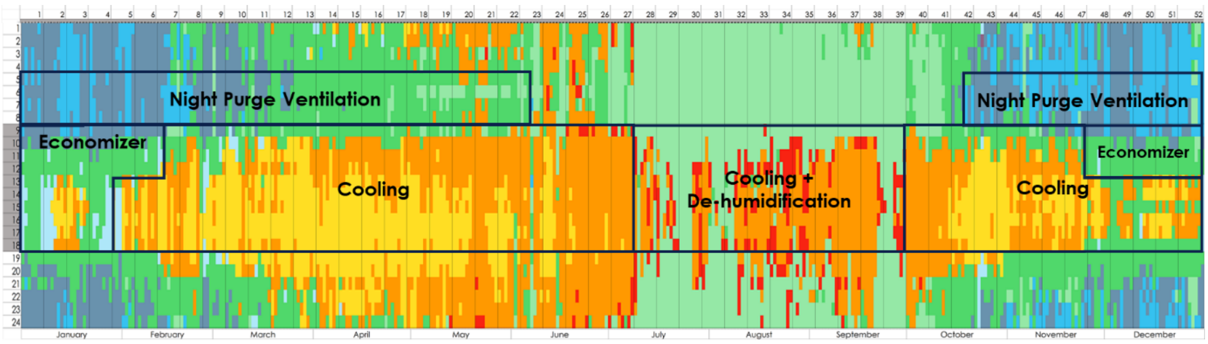


Figure 10: Categorization of annual hourly data based on temperature and relative humidity

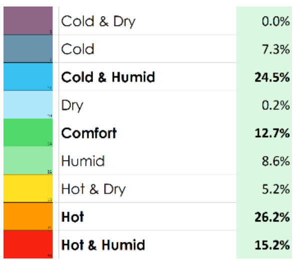


Figure 10 is the heatmap that charts the type of strategies and their schedule that can be adopted to achieve thermal comfort. Corresponding passive or active strategies can be adopted based on the mode of air treatment that is required.

6.2 Zoning

The design was conceived as a core and shell project with building services and transition happening at the centre while the regularly occupied spaces were placed at the periphery. The office spaces were envisioned as naturally lit areas with expansive views and a variety of formal and informal spaces for greater flexibility. All tenants were provided with separate refuge areas and spill-out spaces. The ancillary functions of waste disposal, firefighting, public convenience and electrical room were provided in the centre of the building. The core was planned as a mixed mode space acting as a buffer between indoor and outdoor environment for a gradual thermal transition.

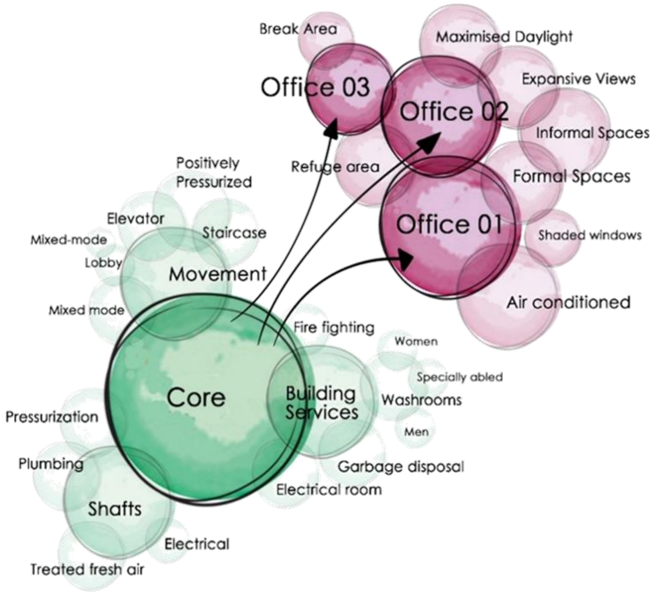


Figure 11: Zoning

6.3 Design Challenge and Approach

At the very onset of this project, the challenge was clear - the roof area required by the currently available technology to meet the on-site energy generation target was just not there. Large reduction in EUI were also insufficient to meet energy neutrality target. We thus tested BIPV and solar cooling as two possible solutions.

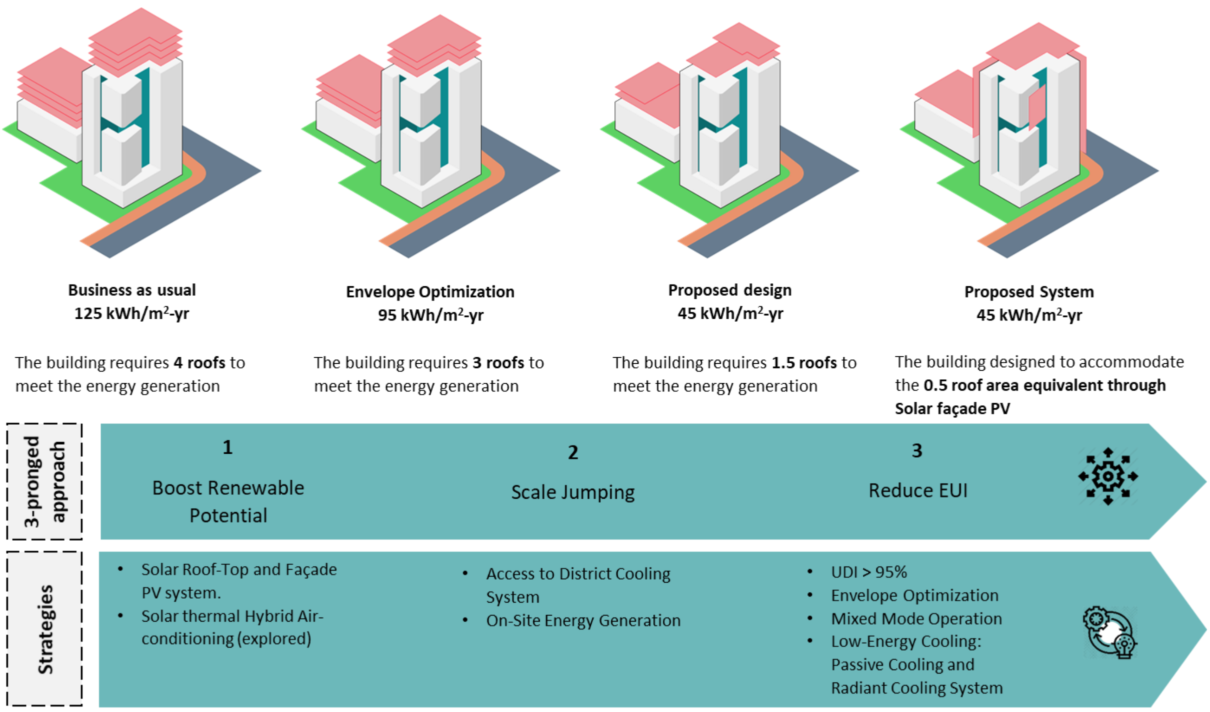


Figure 12: Design challenge and approach

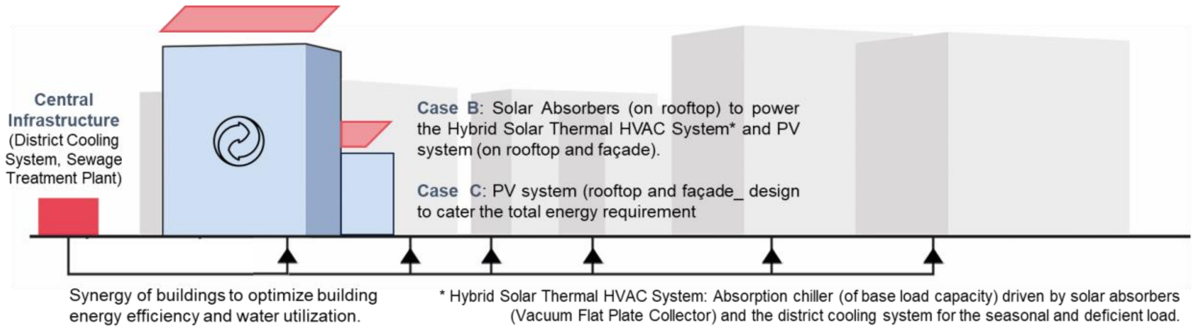


Figure 13: District level diagram

The next big design decision to be taken was regarding the choices available in the cooling plant as this decision was seen to have a far-reaching impact on detailed design decisions and had to be taken early. GIFT city by-laws insist that all buildings must use the district chilled water system. We still explored other alternate, low-energy methods for cooling such as solar-cooling and evaporative cooling. Solar cooling implied directing some area dedicated for PV to be diverted towards solar thermal arrays. Simple calculations showed that (see Figure 14) the district chilled water yielded the least energy intense cooling. However, solar-cooling delivers low carbon and refrigerant cooling. So, we compared these systems for cost as well, early on in the design process. Figure 15 shows the cost to the developer for the three options at hand.

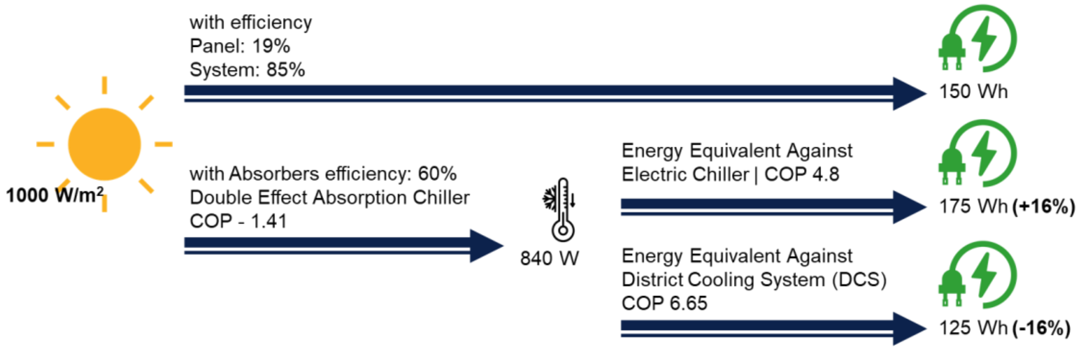


Figure 14: Renewable Energy system evaluation - PV x Solar Absorbers

Case A: Electric Chiller COP 4.8
Capacity 1700kW

Case B: Electric Chiller COP 4.8
Capacity 1000kW
Absorption Chiller COP 1.41
Capacity 700kW
with Solar Absorbers; η= 60

Case C: District Cooling System COP 6.65
Capacity 1700kW

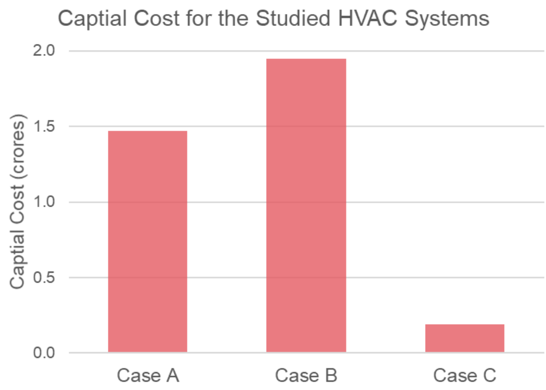


Figure 15: Capital Cost of the Studied HVAC System

7.0 Design documentation

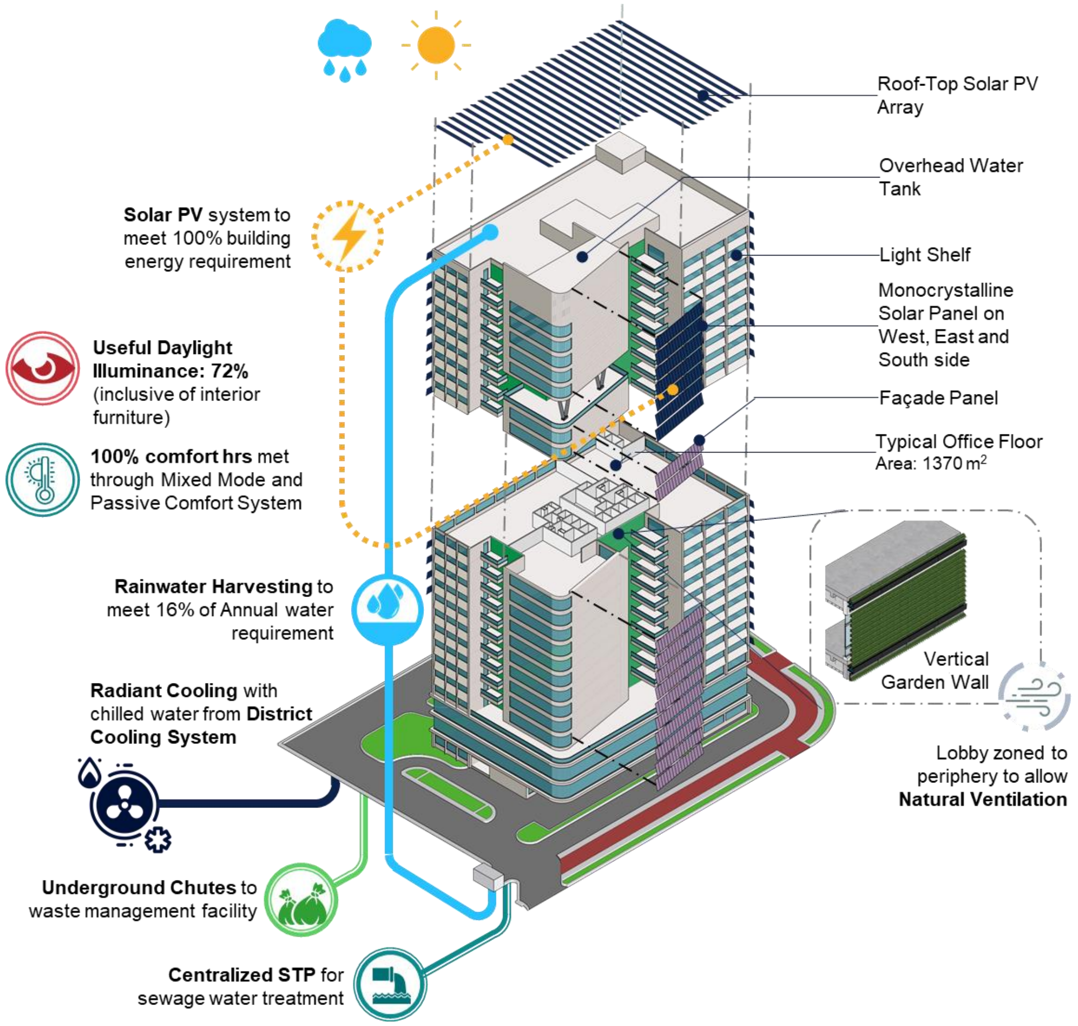


Figure 16: Integrated Design Integration of Building Elements

Kill Bill 4.0 aims to provide the most cost-effective net-zero energy - water solution by integrating the various infrastructural needs of our project with centralized systems provided by the GIFT City while maintaining our individuality. Underground chutes are provided to connect to the central waste management facility along with centralized STP for sewage water treatment. Catering to a resilient design, a rainwater harvesting system has been integrated in the building to meet 16% of the annual water requirement. Monocrystalline solar photovoltaic panels have been integrated on the roof as well as on the South, West and East façades of the building at a tilt angle of 81^{o} to maximise the solar radiation falling on them and cater to 100% building energy requirement. The panels have been fixed away from the wall to allow the movement of ambient air in between and prevent heat build-up.

Our building façade has been developed as a minimalistic amalgamation of materials to emphasize the vertical living wall which aims to provide visual comfort for the occupants and visitors alike while also acting as a buffer between indoor and outdoor environment. The North façade has the highest WWR to maximise the diffused daylight inside the workspaces. A UDI of 72% (inclusive of furniture) is achieved with effective window and shading strategies.

7.1 Architectural Design

The core principle guiding our design decisions was to minimise the energy use of the building and maximise the possibilities for energy generation while providing the occupants with a comfortable and aesthetically pleasing built environment.

Our building aims to redefine the usual glass boxes we have come to associate as office buildings, with our distinct efforts targeted at creating a contextual façade which performs well on aesthetics, occupant views, energy, as well as thermal aspects of the building. The living walls were introduced onto the building to break the monotony of built structures and as areas for people to interact and get closer to nature. They have been designed to become an unhindered and bold feature of the building. The PV panels are a striking feature of our building that have been displayed as a symbol of sustainability and resilience and an inspiration towards a greener future.

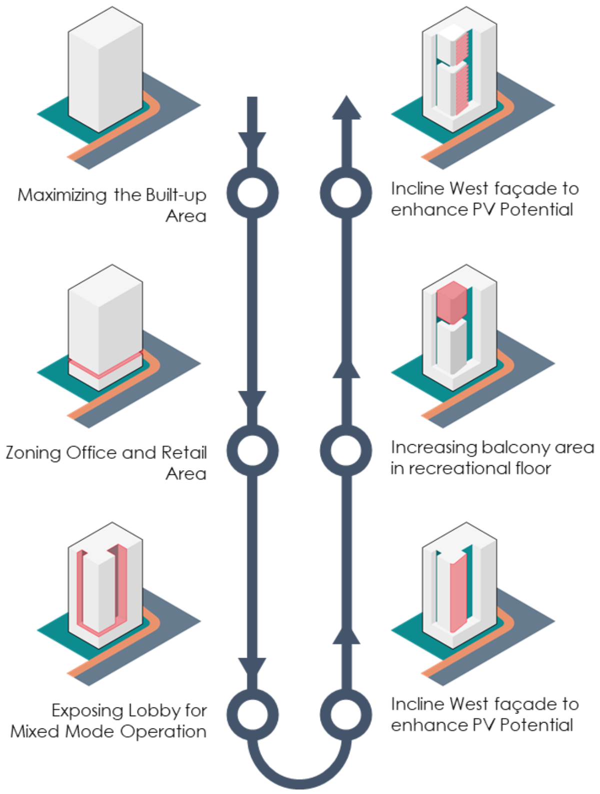


Figure 17: Form Development

Figure 18: Architectural Visualization of North-West Facade of the tower

Typical Floor Plans

Figure 20: Typical floor plan - Cafeteria and banquet hall

Figure 19: Typical floor plan - 3 tenant layout

The floor layouts ensure a comfortable environment for the employees and incorporate the flexibility of working styles. The preference to work in formal and informal settings has been considered as an important factor governing the efficiency of the occupants and the organization. The space has been divided into three sections, one for each tenant. Tenant space A is for larger tenants with a carpet area of 595 sqm, tenant space B with a carpet area of 470 sqm and tenant space C with 305 sqm.

All tenants have their own entrances and spill-out areas along with separate washrooms. It has been ensured that all occupants have access to adequate daylight and views which has been discussed in detail under the daylight section. The 16th floor of the building has been developed as a collective breakout space for all employees of the building with semi-open and indoor seating spaces along with a cafeteria and a banquet hall.

Living Wall

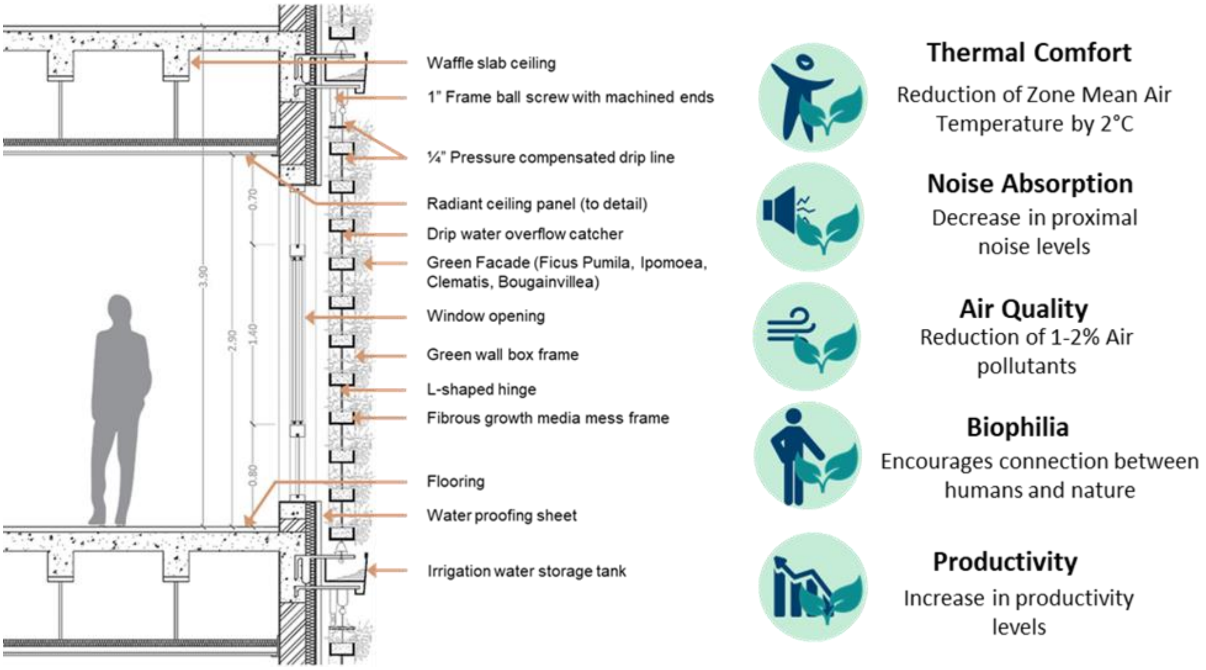


Figure 21: Typical Section of the Living Wall

Bringing nature into our cities is a vital component for a sustainable future. Our connection to the natural world is often overlooked in this increasingly urban world. The incorporation of a green wall in our design has multiple benefits, some of these include the increase in thermal comfort by reduction of the zone mean temperature by 2°C (Djedjig, Belarbi, & Bozonnet, 2017). The green wall also leads to a decrease in proximal noise levels (Paull, Krix, Torpy, & Irga, 2020) thus allowing for a discreet office environment. It also reduces the air pollutants by 1-2% (Abhijith et al., 2017) and finally allows for the increase in productivity of the occupants due to their interaction with the green wall. This creates a connection between the occupants and nature which in turn increases the occupant productivity.

The green wall runs along the North and West façade of the building. It is anchored by 150 mm into the tie beam at every floor to ensure stability. The planter is held in place by a metal frame with a 100 mm trough that contains a multitude of native species that thrive well in the hot and dry climate of Gandhinagar. The plants are selected to ensure minimum water requirements. This is met through the drip irrigation system. The green wall is designed for both the public and its occupants.

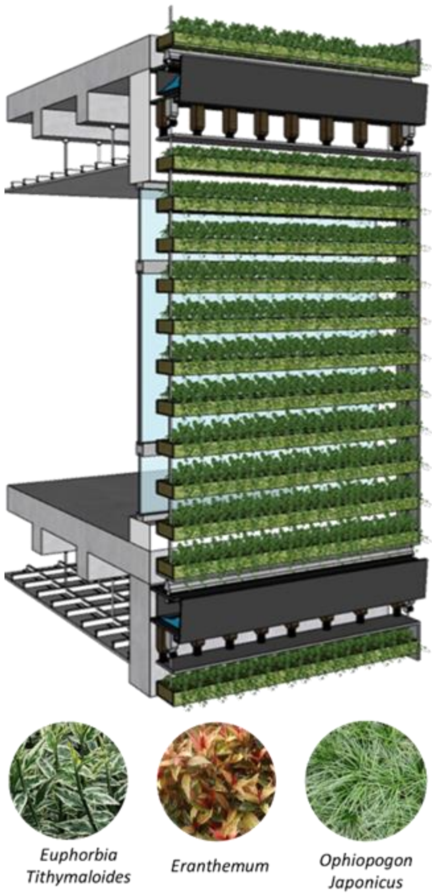


Figure 22: Living Wall 3D detail

7.2 Energy Performance

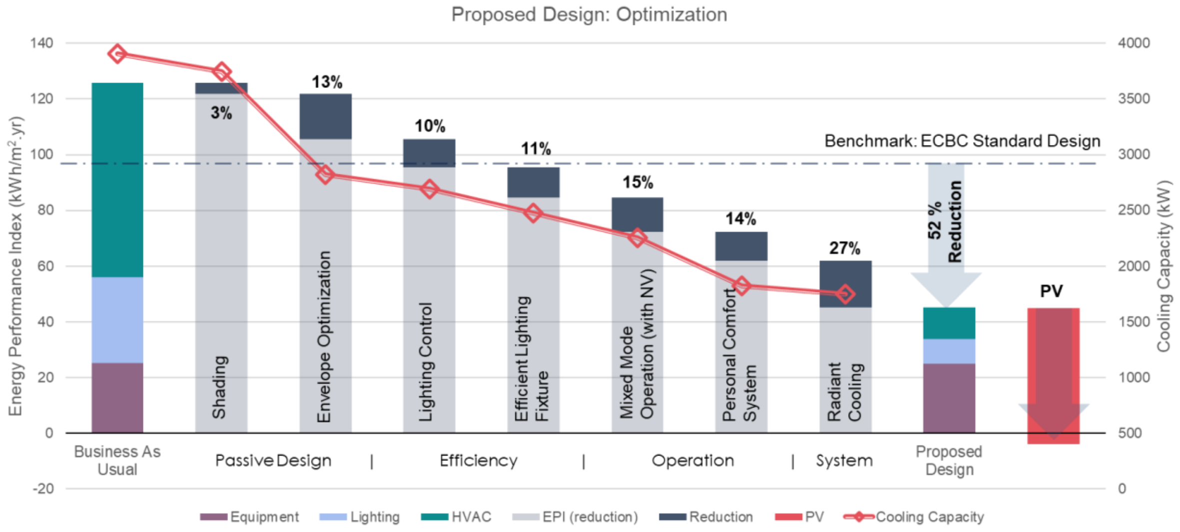


Figure 23: Optimization of the Proposed Design

Net-zero energy building is the goal for the proposed design. The workflow includes making a Building as usual (BAU) case simulation model in Design Builder software. This BAU case is done by using BAU envelope with occupancy, usage schedules, HVAC system taken from ECBC resulting with an EPI of 124 kWh/m^2.yr.

The Energy conservative measures (ECM's) were identified as per climate analysis & BAU case's end-use load profiles, starting with:

Passive design strategies

- Shading – Provided as per sun-path analysis and to reduce solar radiation and optimize visual comfort
- Envelope Optimization – To analyse and arrive at an efficient envelope configuration by looking at multiple options and their end-use energy demand.

Efficiency

- Lighting controls - To utilise daylight and minimum artificial lighting
- Efficient Lighting Fixtures - To provide lighting with high CRI & luminous efficacy.

Operational strategies

- Mixed-mode Operation (with NV) – This strategy is used in some selective spaces to enhance the use of available comfort hours from the outside environment.
- Personal comfort systems - Occupants have access to the ventilation-based personal control system. This increases the threshold of thermal comfort, allowing the increase of thermostat set point (which decrease the cooling load)

System selection

- Radiant Cooling – Radiant cooling system to target sensible load and DOAS for latent load and fresh air requirement.

The proposed design thus consists of all the ECM's mentioned above and has a resultant EPI of 45 kWh/m^2.yr. with a solar PV system design to cater to 110 % of the current energy demand of the building.

Parametric Envelope optimization

As a part of Passive energy strategies, envelope optimization analysis is being conducted. Energy plus v8.9 and jEPlus v2.1 were used to conduct parametric simulations to optimize the envelope configuration. There are a total of 300 combinations focused on four envelope parameters: window to wall area ratio on the north facade (3 options), wall insulation (5 options), window-type (5 options), roof insulation (5 options). The below graph contains 300 strings and presents one combination at a time with their EPI values respectively.

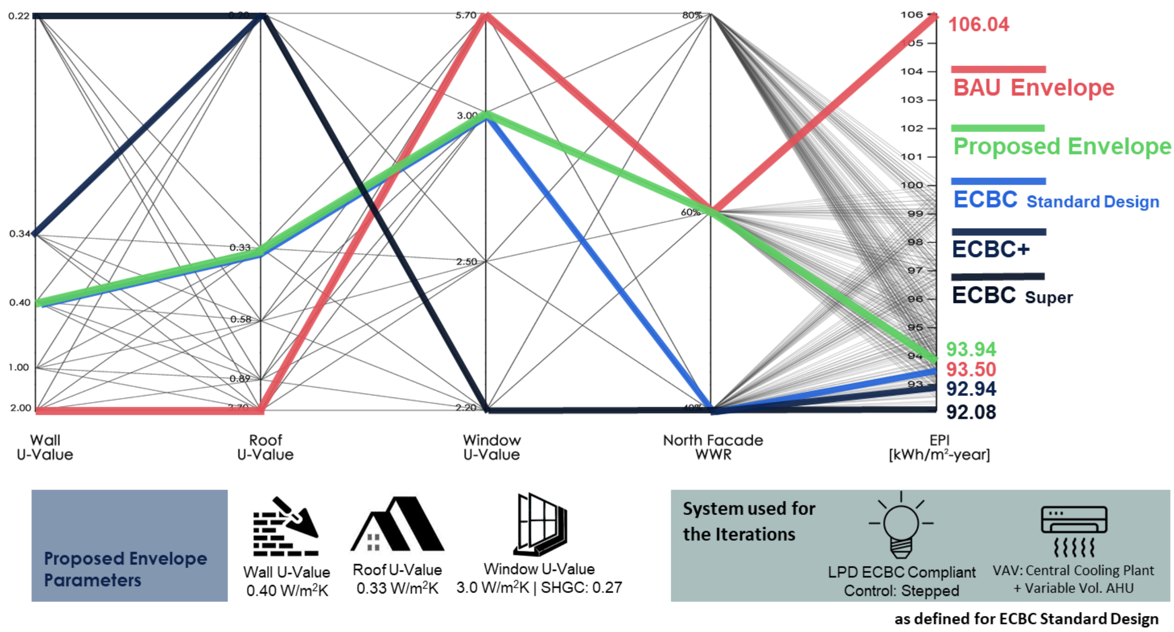


Figure 24: Parametric study of envelope specifications

The EPI values vary between 93.50 to 92.08 kWh/m^2-yr. With the help of the simulation runs four main combinations were recognized and highlighted in the graph. The combinations are ECBC standard case, ECBC+, ECBC Super & proposed case. The proposed case (best envelope configuration - highlighted in green) is selected after considering constraints like affordability, constructability, financial feasibility.

Table 3 - Design Assemblies

	Wall Assembly	Roof Assembly	Window Assembly	WWR (North Facade)
Standard Design	U-value: 0.40 (Outer cement Plaster 0.01m + XPS 0.07m + Brickwork 0.2m + Inner Cement 0.01m)	U-value: 0.33 (Cement Plaster 0.01m + XPS 0.09m + RCC Slab 0.15m + Cement 0.01m)	U-value: 3.00 6 mm (Solar Control Glass) - 12 mm (Air Gap) - 6 mm (Clear Glass)	40%
Proposed Design	U-value: 0.40 (Outer cement Plaster 0.01m + XPS 0.07m + Brickwork 0.2m + Inner Cement 0.01m)	U-value: 0.20 (Cement Plaster 0.01m + XPS 0.16m + RCC Slab 0.15m + Cement 0.01m)	U-value: 3.00 6 mm (Solar Control Glass) - 12 mm (Air Gap) - 6 mm (Clear Glass)	60%

Solar Radiation Analysis for PV potential

The solar radiation analysis for the building site along with the built context is modelled using the Rhino 3D tool to get the optimized surface area for the installation of solar panels on the roof and façade. The South, East and West façade of Pragya covers 2600 m² of module area, followed by the PV panel installation on Pragya tower (1520 m²) and MLCP (2810 m²) with a Ground Coverage Ratio of 0.75 to avoid inter-row shading of panels.

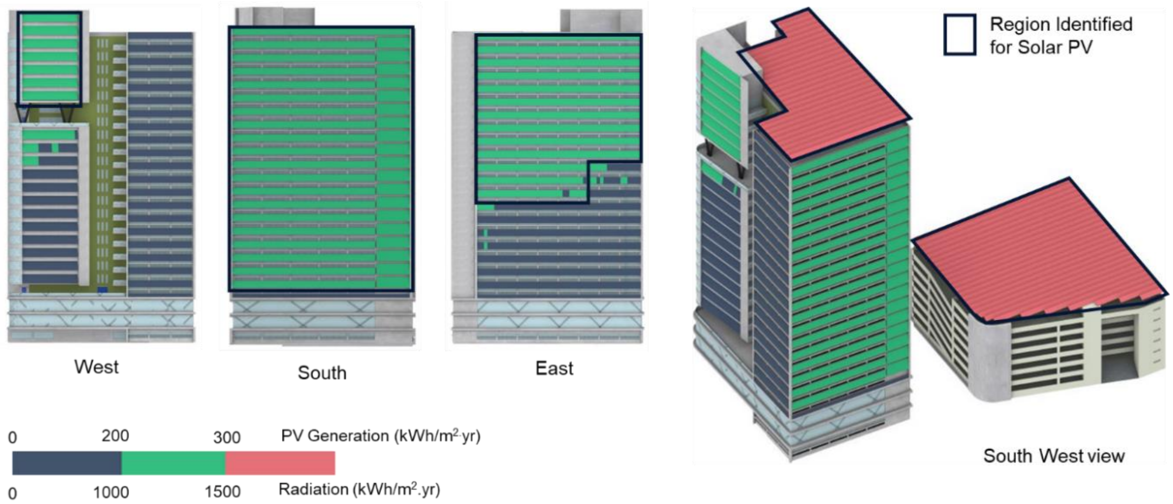


Figure 25: Annual Irradiance

The target energy performance index is 45 kWh/m².year with an annual energy consumption of 14,08,050 kWh for a total built-up area of 31,290 m². The PV generation for the façade and roof is calculated from the direct solar radiation data based on Ahmedabad TMY file using Solar Adviser Model software by NREL and the panel efficiency 19% Mono-crystalline cell is considered. The proposed system has the potential to cater up to 49 kWh/m². yr, 10% safety factor achieving net-positive energy target.

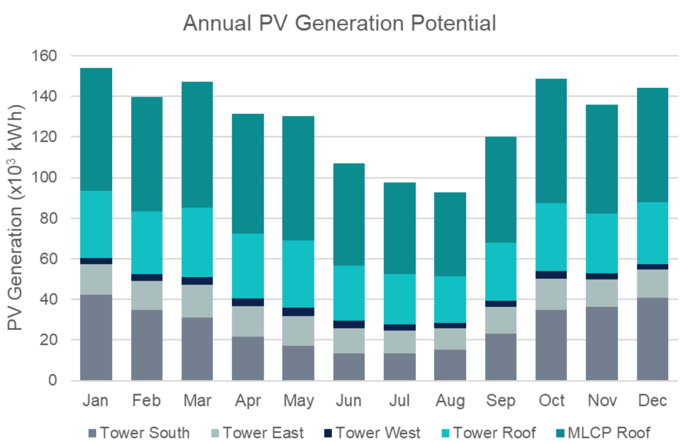


Figure 26: PV Monthly generation data for facades

*Table 4: Properties of Anti-Reflective PV**

	Regular (A)	Anti-Reflective (B)
	A	B
Average Reflective Luminance: cd/m²	13000	4390
DGI Daylight Glare Index	>22	<15
Discomfort Glare Criterion	Unacceptable	Perceptible

Source: Talesun: Anti-Glare Module

*the anti-reflective coating reduces the glare and improves the light transmittance, thus increasing the efficiency of the PV module

7.3 Comfort and Environmental Quality

Thermal Comfort

The IMAC (India Model for Adaptive Comfort) is a thermal comfort model developed for Indian conditions based on thermal comfort surveys of office buildings across India. Climate analysis shows that there is a potential for utilizing favourable outdoor environmental conditions for about 10% of the operational period. Hence the building is chosen to be a mixed-mode building. The IMAC model defines the daily operative temperature and its 90% acceptability thermal comfort limit (3.46°C from the neutral temperature).

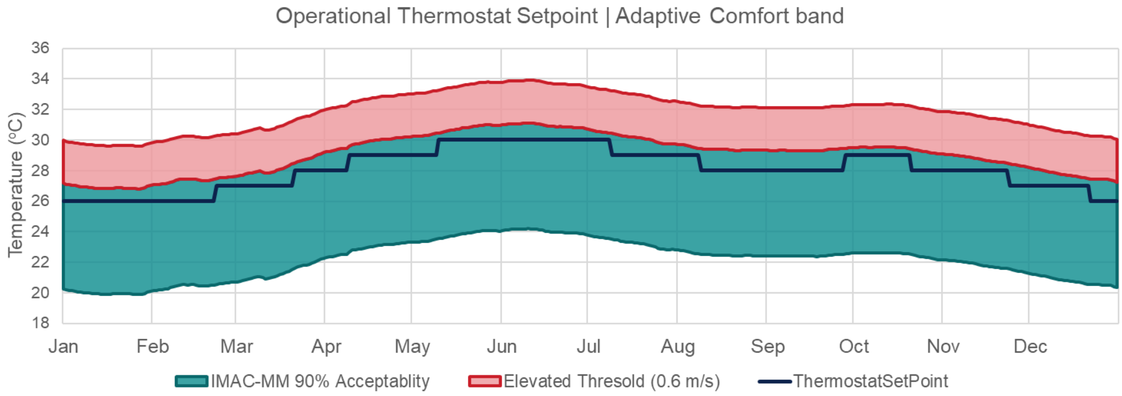


Figure 27: Thermostat setpoint based of Adaptive Comfort Band IMAC MM and elevated range

Operative temperature = (0.28 x DBT $_{\text{30 Day running mean}}$) + 17.87

The upper comfort threshold is further increased by 2.8°C by introducing elevated airspeed of 0.6m/s as defined by ASHRAE 55-2017. This is achieved by introducing a ventilation-based personal comfort system for each occupant, enabling them to adjust their operative temperature threshold by 2.8 to ensure thermal comfort. The resultant neutral temperature is used to derive the operational thermostat setpoint for the HVAC schedule and the comfort limits for the operational schedule.

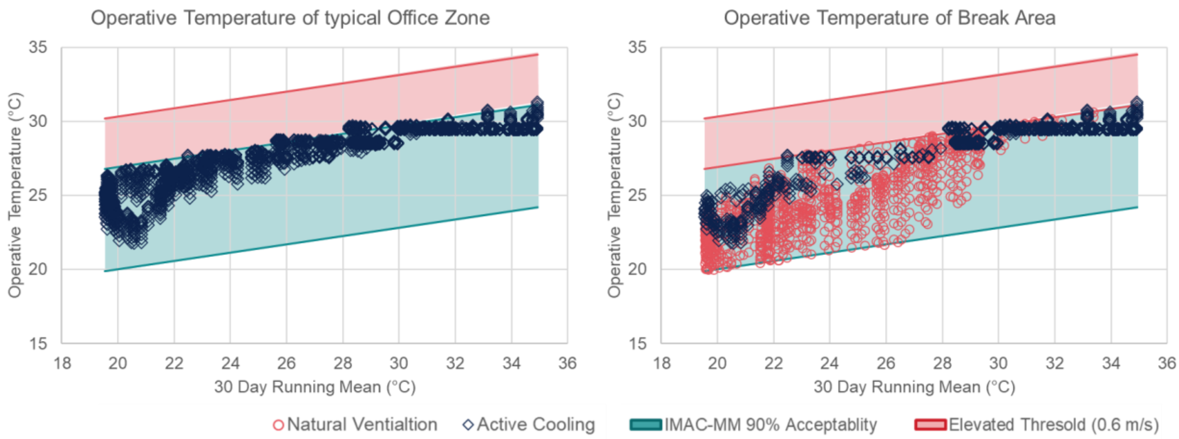


Figure 28: Resultant Operative Temperature of typical office zone and break area for the proposed design (based of the system and operation)

Visual Comfort

Visual comfort is important for the health, well-being and productivity of occupants. It is a subjective response to the quality and quantity of light. It comprises various aspects like illuminance, quality, views and glare. Amongst the stated aspects, the illuminance levels should adhere to lighting standards to assure neither high nor low levels. The use of daylight can prove to be energy efficient as well as have psychological and physiological benefits. Therefore, it becomes a primary reason to use daylighting to meet the targets of daylighting metrics of any architectural space.

For the building, the area of analysis is the 15th floor. It has 40% WWR on all sides. The building is modelled in SketchUp and imported to LightStanza. The preliminary design's input parameters required for the simulation are derived from ECBC 2017. It is modelled with no external shading devices. The work plane height is 0.80m and the sky condition is climate sky. Glass has a visual transmittance of 65% and is modelled with transmission shade as when required. The time of analysis was from 8 am to 4 pm as per ECBC 2017. The target was to limit annual sun exposure in open plan office areas under 3% and achieve a minimum of 95% daylight spaces. As per WELL standards, Annual Sunlight Exposure (ASE) should be no more than 10% of the area which can receive more than 1,000 lux for 250 hours each year. As per ECBC 2017, Useful Daylight Illuminance (UDI) of 60% with a threshold of 100 to 2000 lux levels for 90% time of the year qualifies for the mandatory requirement of daylight for Super-ECBC compliant buildings.

With the simulation results of the preliminary design, iterations were done to optimise the result and shading devices were proposed. The shading devices were devised from sun path analysis and shading masks. The details of the shading devices can be seen in Figure 29.

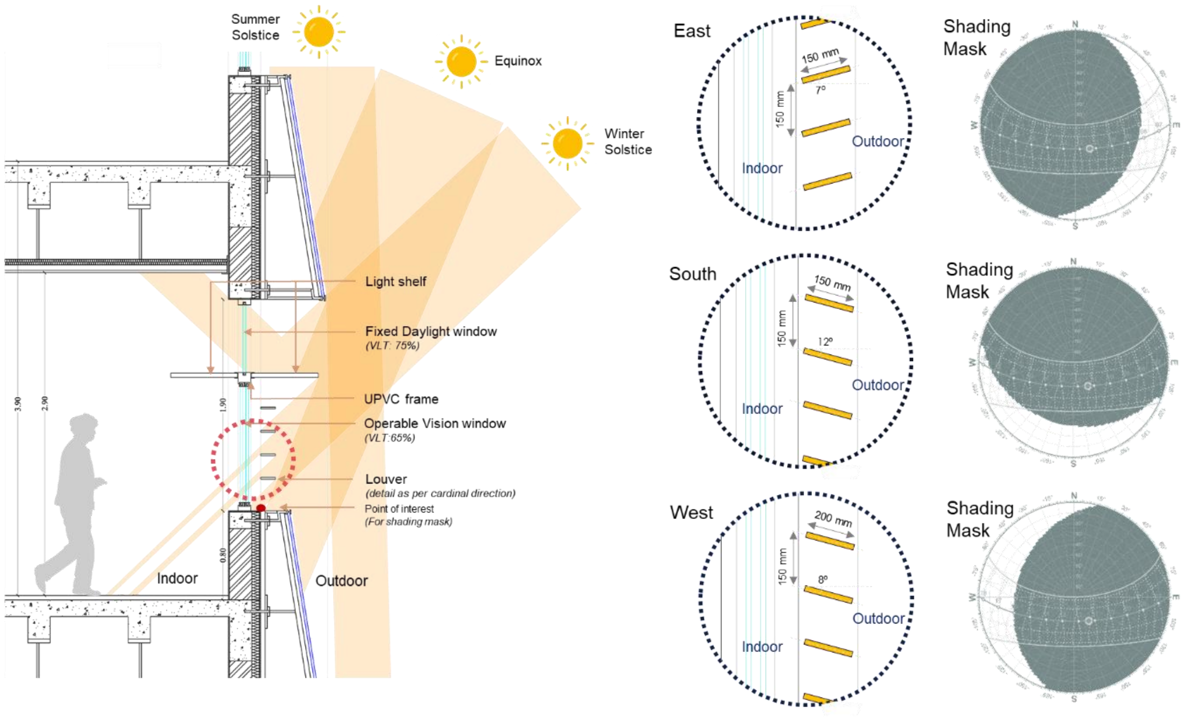


Figure 29: Optimizing the shading device to minimize Annual Sunlight Exposure

The intent of introducing external lights shelves of 0.60m depth was to cut down solar exposure in the east, west and south façade. It also helped to improve the UDI results as above 2000 lux levels were reduced. The internal light shelves of 0.60m depth were introduced to improve penetration of light into deeper levels of the space. Louvers at an angle were added to reduce the direct sun exposure. Hence, the proposed design simulation results meet all the set targets as shown in Figure 30. From preliminary to the proposed design, ASE has reduced to 0% and UDI has been optimised by 28%. Simulation results of the proposed design with furniture layout show a 26% reduction from the proposed design. This can be attributed to the hindrance created by internal partitions, workstations and other fixed furniture. Hence, tenant guidelines should be referred to in order to achieve these results.

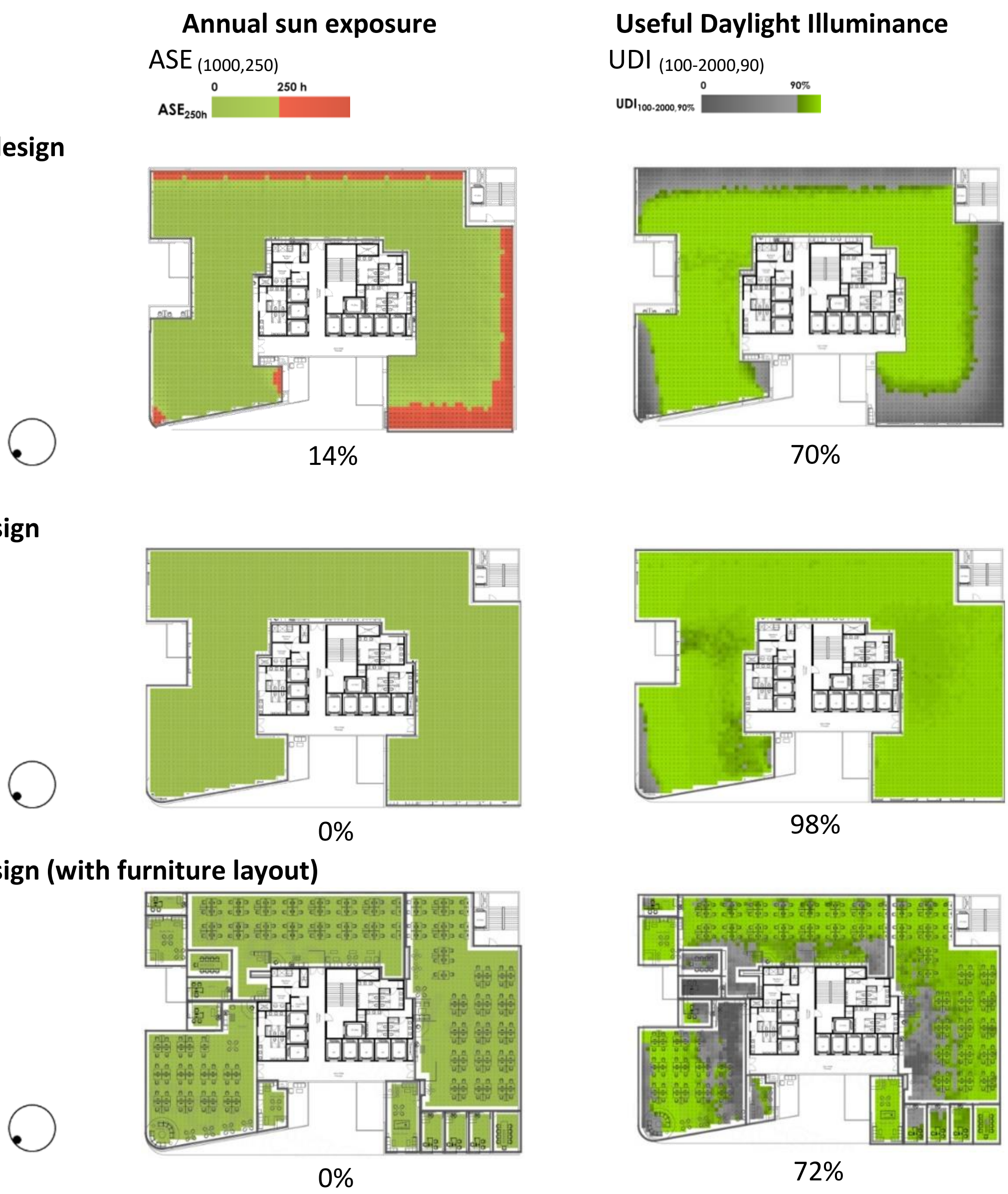


Figure 30: Preliminary and proposed design simulation results for daylight metrics

Another aspect of visual comfort was the view analysis of occupants. It was based on the European daylight standard (EN17037) and was reported only for horizontal sight angle. As seen from Figure 31, open plan office occupants' which are within 3m from the periphery have a 'high' level of recommendation for view out. Even to a depth of 9m from the periphery, the occupants have a 'medium' level of recommendation for a view out. For private office occupants, the level of recommendation for a view out is 'high'. View plays an important role in an occupant's appraisal of the interior environment and to establish contact with the exterior environment.

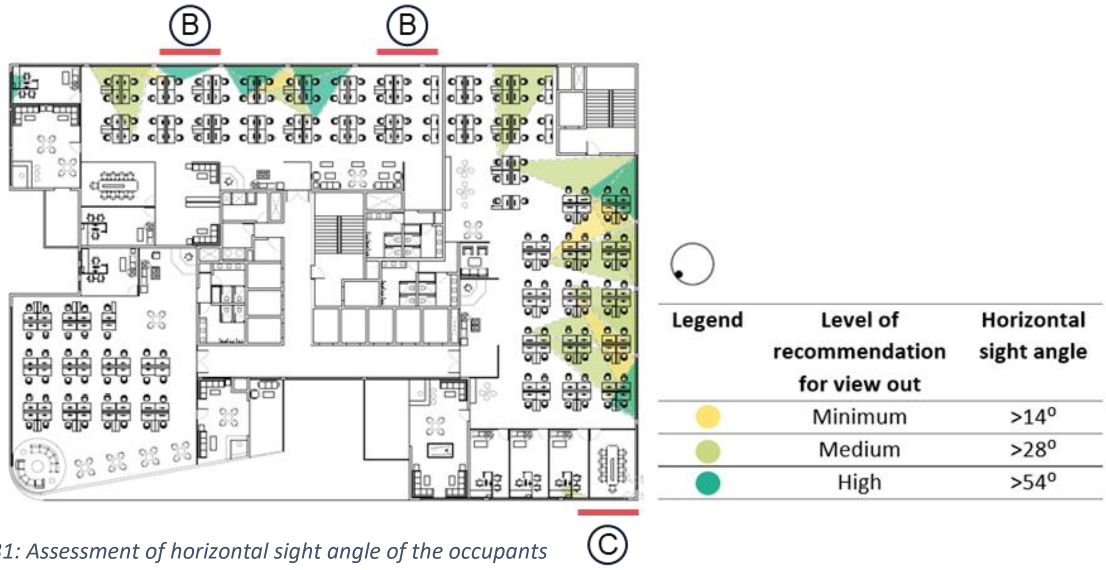


Figure 31: Assessment of horizontal sight angle of the occupants

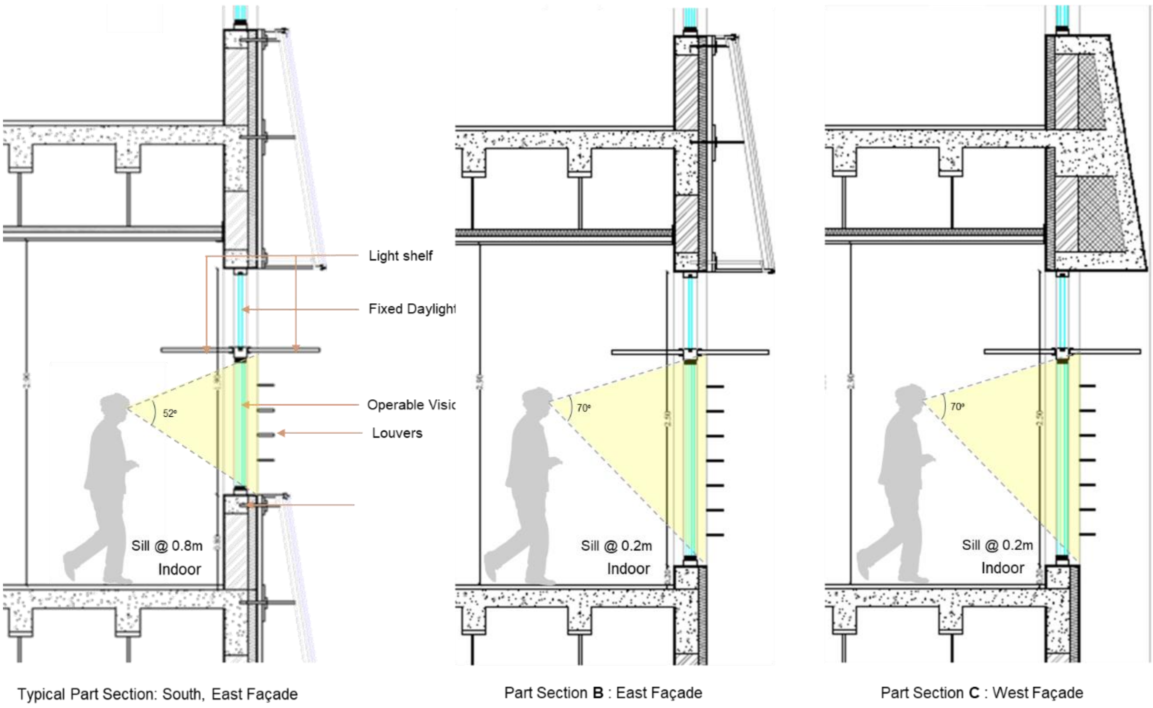


Figure 32: Assessment of sight angle of the occupant for different window geometry

Similarly, for the occupant to create a link with the external environment, the sill height of one ribbon window was reduced to 0.2m in the east and west façade. It helped to increase the sight angle to 70^{o} which will enable an occupant to see all the three layers: sky, landscape, and ground. Whereas for sill at 0.8m, the angle reduces to 52^{o} and will enable the occupant to see the only landscape and one additional layer as seen in Figure 32.

7.4 Engineering Design and Operation

Structural System

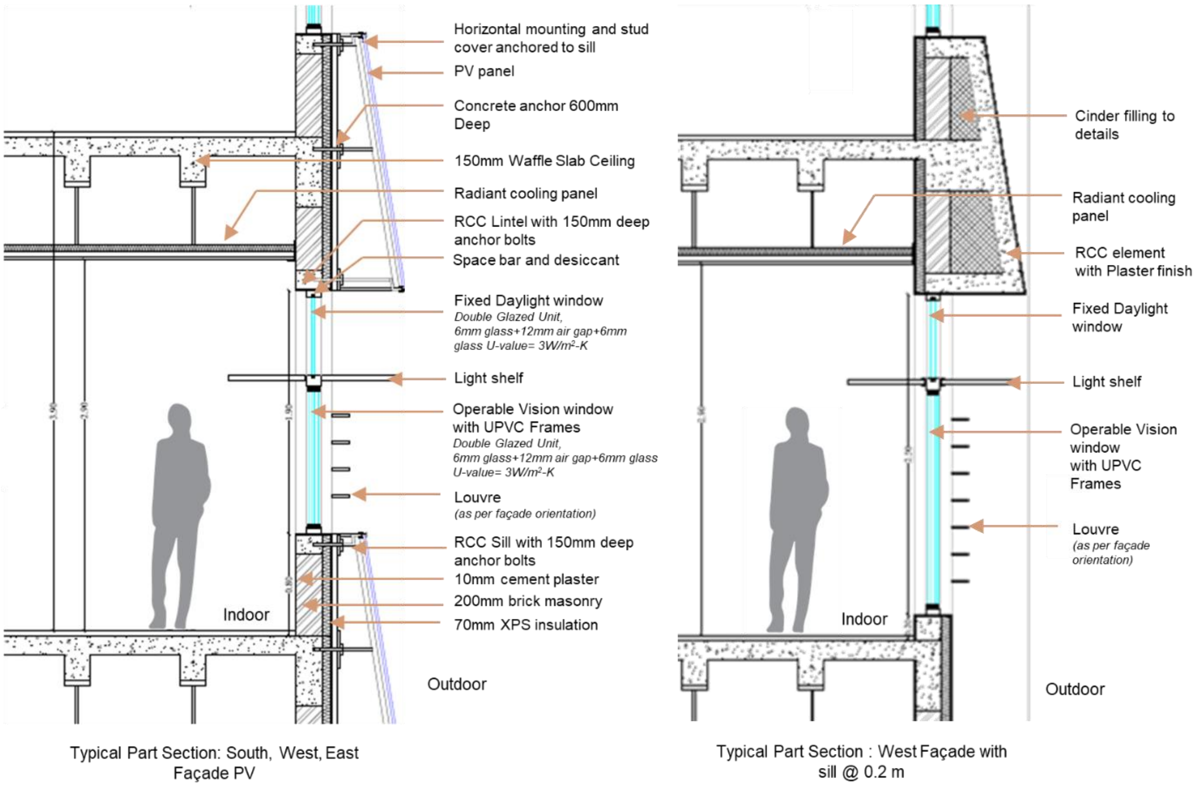


Figure 33: Typical Part Section of the facade Details. (a) Facade PV details (b) Full height Ribbon Window

Understanding the performance of the building envelope is the key to designing more efficient buildings. This building envelope is designed as shown in Figure 33, in which the insulation is placed on the outside to benefit from the thermal mass of the envelope. During the early hours of the day, when the cooling load is less, the radiant system cools the thermal mass of the internal wall thus acting as a thermal store during the peaks hours. Thus, coupling the active system with thermal mass to maintain the operative temperature during the peak hour (Bansal, Hauser, Minke 1994).

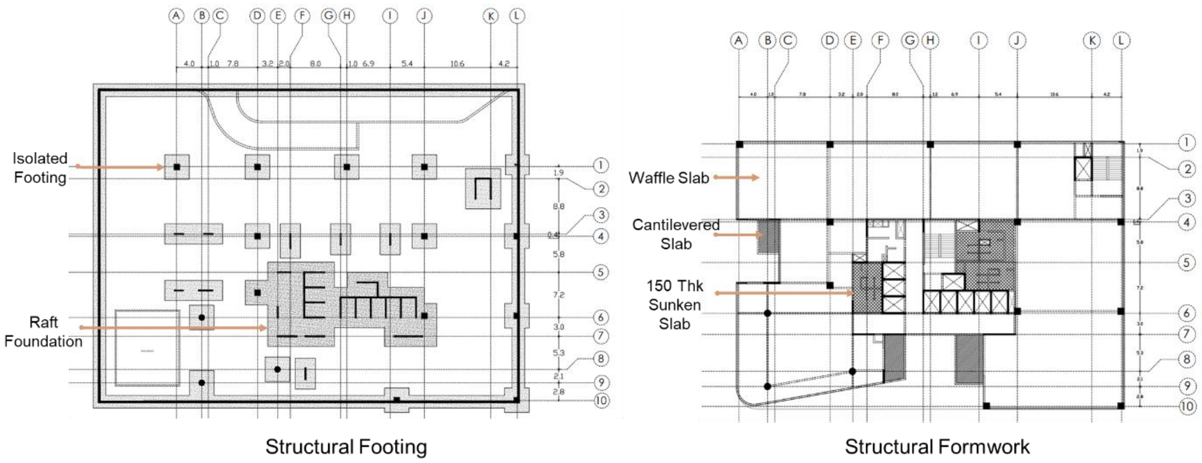


Figure 34: Foundation Layout and Structural Layout

To achieve the smallest floor to floor height, largest possible spans, lowest weight of floors and quickest floor cycle, waffle slab structure with post-tensioned columns and slabs were selected as structural elements. This will help in saving on vertical structural members as well as an increase in rentable space. For a similar span and loading conditions, the waffle slab will have less weight than the 2-way slab and beam and flat slabs. The selected system can provide a span length >20 m and can handle the load > 10 kN/m^2.

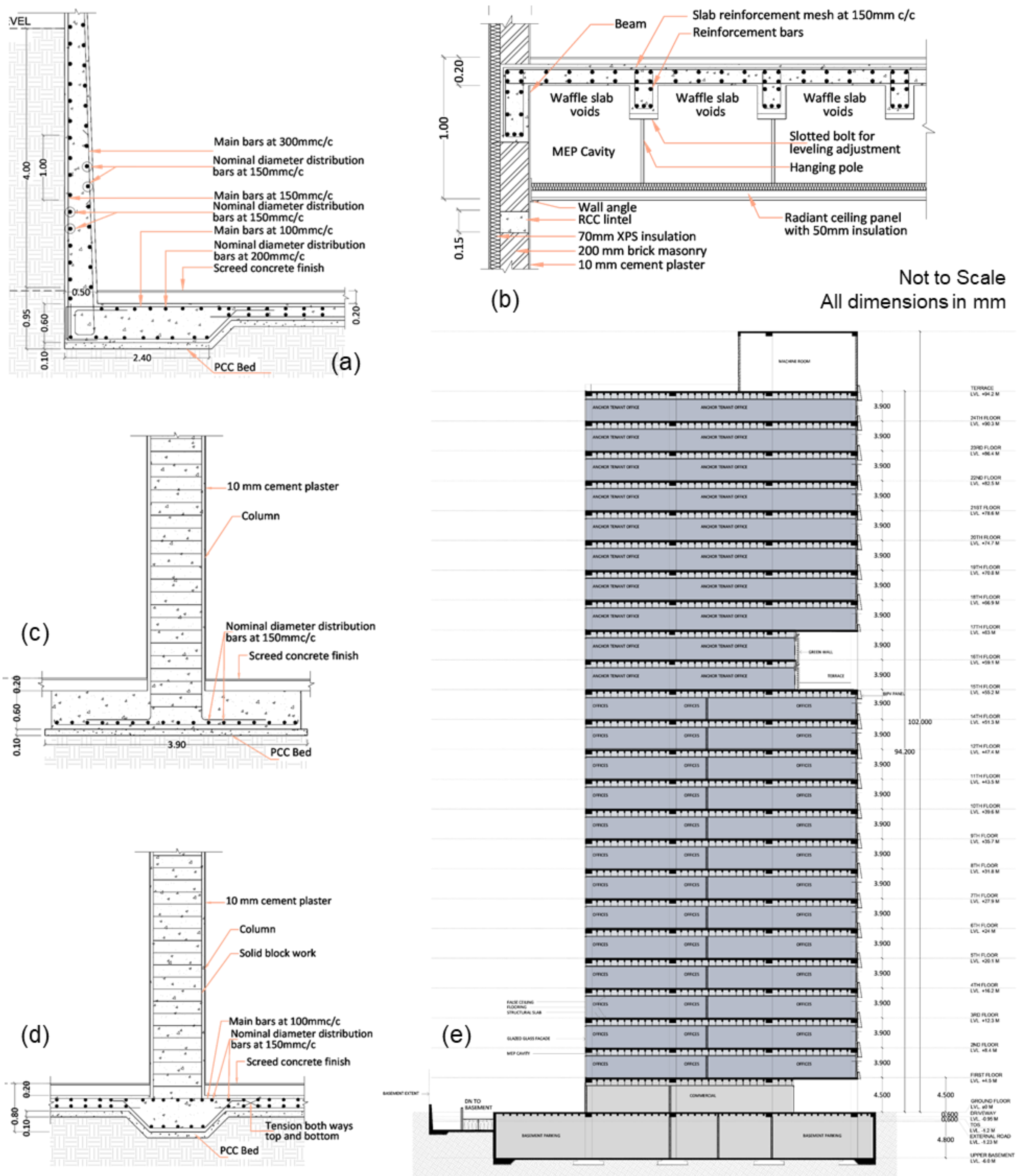


Figure 35: Structural Details (a) Retaining Wall (b) Waffle Slab (c) Isolated Footing (d) Raft Foundation (e) Tower: Typical Section

HVAC

A simulation model of the finalized design was created in DesignBuilder software. The 24-story building with a zone multiplier for similar floors with the same boundary condition was model. The cooling load was calculated using cooling design calculation in DesignBuilder, which uses ASHRAE Heat Balance method with the coincident design cooling load of 2800 kW for the building under ECBC Standard Design specification with a cooling setpoint of 24°C during the occupancy hours.

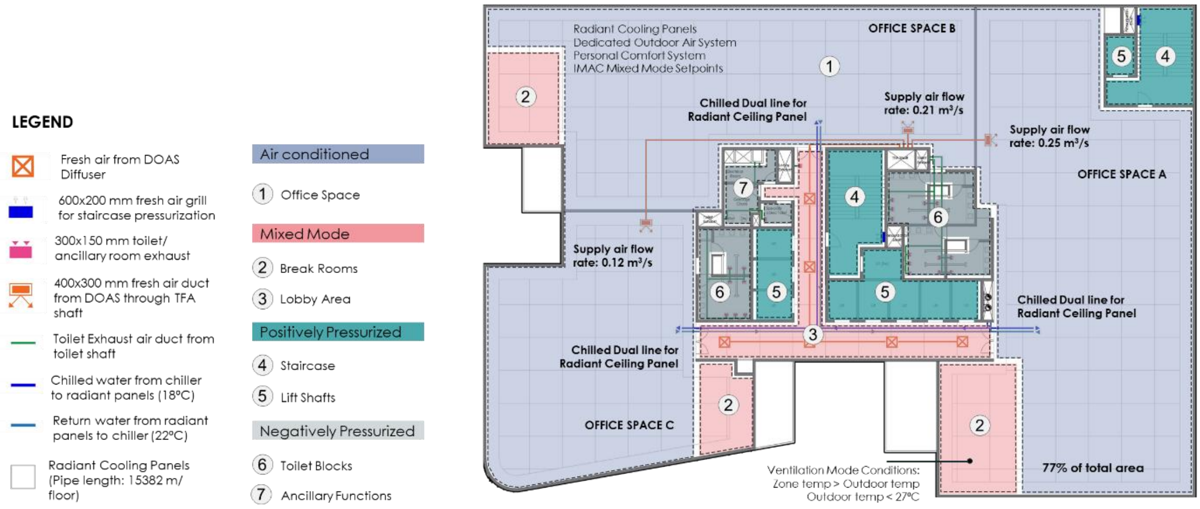


Figure 36: Operational Zones for Air-conditioning for typical office floor

IMAC Mixed Mode Operation

During the summer months where outdoor DBT reaches >40°C with the indoor setpoint of 24°C, transitioning often between vastly different indoor and outdoor thermal environments can lower the respiratory defence systems making people more susceptible to infections from latent viruses (Eccles 2002). Thus, the building was zoned and designed to operate as per the IMAC mixed-mode operation since 23% of the area (transitional and breakroom spaces) can utilize natural ventilation.

By mixed-mode operation, we can take advantage of favourable outdoor conditions as well as a broader range of comfort temperature because of the adaptive behavior of occupants based on outdoor environmental conditions. IMAC Mix Mode (MM) model was used to provide comfort to the occupants. IMAC MM neutral band was used as setpoint temperature with a target of providing thermal comfort to 100% occupants.

Personal Comfort System

As part of the innovation matrix of the competition, the personal comfort system was identified as a potential system. According to (Zhang, 2009) (Amai H., 2007) (Zhang Y, 2008) ambient temperature range for thermal comfort can be expanded to as much as 18-30 °C if occupants are provided with access to the personal environmental control system. Ventilation-based personal comfort system (of power- 3W) that can provide an air speed of 0.6m/s is selected which raises the upper limit of the comfort band by 2.8°C (ASHRAE-55, 2017). Zone thermostat setpoint was increased by 2.8 °C from IMAC MM neutral setpoints and maximum setpoint was limited till 30 °C. Because the higher setpoint is achievable by providing PCS with MM operation cooling demand was decreased by 40% from the standard case. Overall, a 35% reduction in EPI is achieved.

Radiant Cooling System

The radiant system has been successfully used in net-zero buildings around the world. According to (Carbonnier, 2017) more than half of the net-zero energy building in North America uses a radiant system. In India, one of the most well-known examples is Infosys Hyderabad where a 35% reduction in HVAC energy consumption is achieved using a radiant system compared to the conventional system.

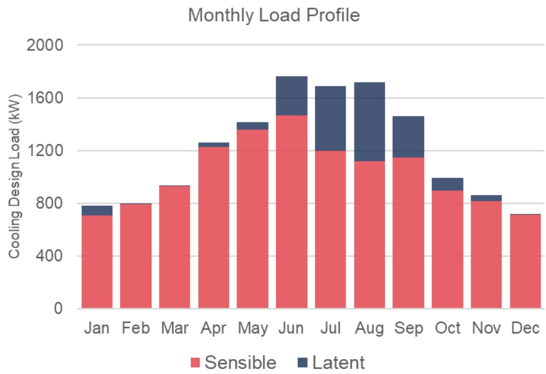


Figure 37: Monthly load profile of the Proposed Design

As Gandhinagar is a hot and dry climate during most months with sensible load dominating with a sensible load factor is 0.7 (with the exception of the monsoon period of July-September), a radiant cooling system was identified as a potential Energy Conservation Measure. To address the latent load and fresh air supply separate DOAS system is designed. DOAS system will only provide 100% fresh air requirement as per NBC 2016 are a supply temperature of 14 °C to take care of the latent load. Panel type radiant cooling system is provided as it has a higher cooling capacity and easy installation process.

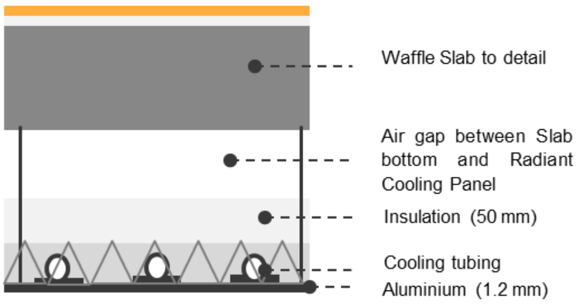


Figure 38: Ceiling Slab with Radiant cooling panel details

Coldwater pipe will run through this panel and it was provided at a 0.1 m distance. A variable flow type low-temperature radiant cooling system was selected. Coldwater at 14 ^{0}C was provided to these chilled water pipes through a separate chiller.

Thermal comfort of 100% is achieved even after a 70% reduction in HVAC consumption compared to the standard case.

Figure 39 shows the performance of the radiant system during monsoon day (worst case) and summer day (typical day), where temp. difference between radiant ceiling surface and dew point is maintained

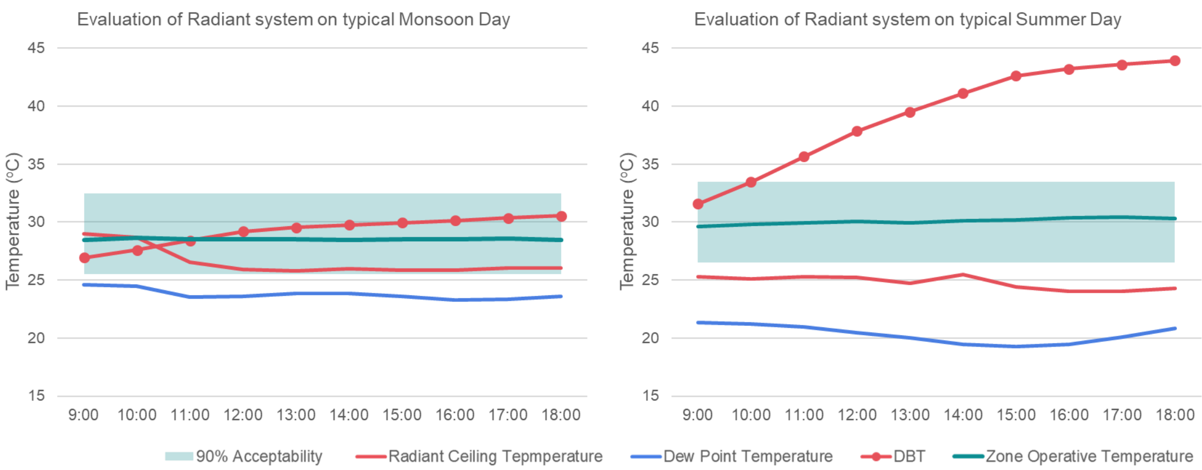


Figure 39: Radiant System Performance evaluation showing radiant ceiling surface temperature and indoor dew point temperature

7.5 Water Performance

The low rainfall intensity in the region and the lack of adequate catchment area poses a challenge to the project in achieving net-zero water status. However, we can reduce the dependency on an external freshwater supply by 25%, from the base case, by incorporating the water conservation strategies mentioned in the subsequent paragraphs in the section.

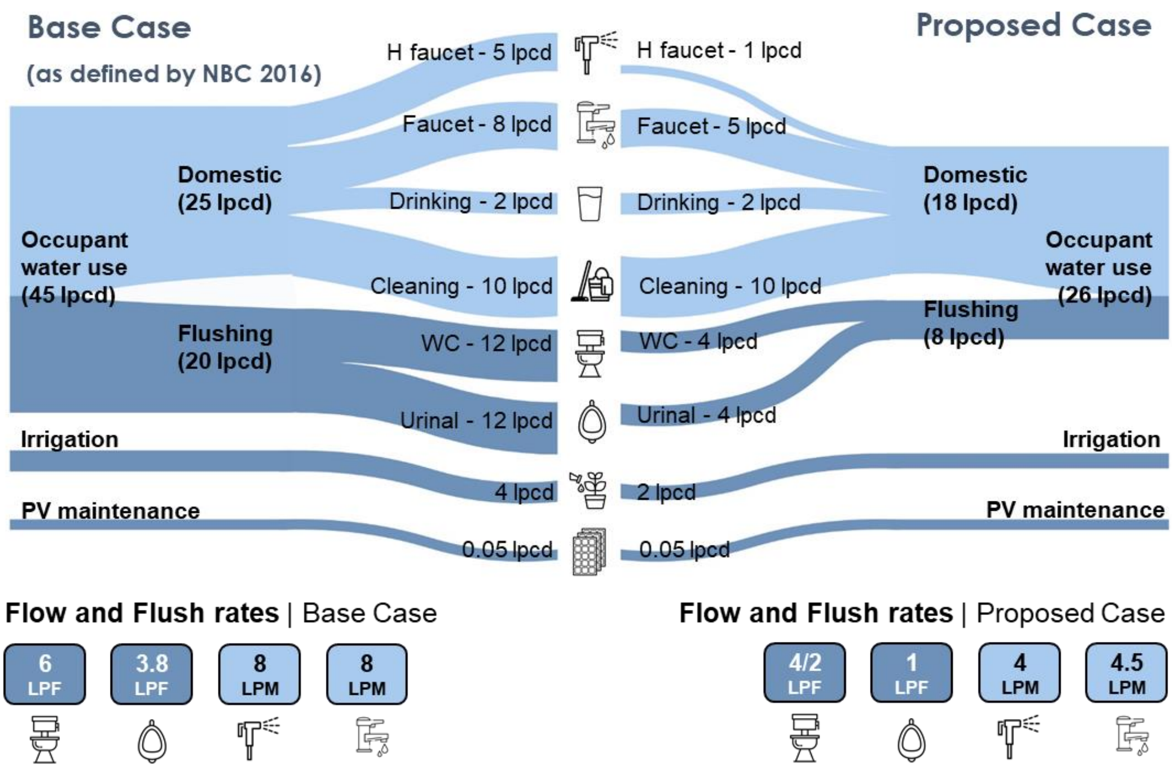


Figure 40: Base case and proposed case per capita water demand

Occupant water demand reduction achieved: 36%

A 56% reduction in daily flush water consumption has been achieved by installing water closets with dual-flush cisterns and low flush urinals while a 22% reduction in daily domestic water consumption has been achieved by installing low-flow faucets.

Landscape water demand reduction achieved: 50%

The vertical green wall of the building comprises *euphorbia tithymaloides*, *eranthemum* and *ophiopogon japonicus* which are drought-tolerant and native flora of Gujarat. This green wall is integrated with a micro-drip irrigation system with a combination of soil moisture sensors, pressure regulating devices and time-based controllers which resulted in a reduction of 50% water consumption, from the base case.

On-site rainwater and stormwater runoff management

Annually, 3,440 kl of rainwater run-off and 900 kl of stormwater run-off are generated from the site. The harvested rooftop rainwater is treated by 'RAINY' FL-500 dual intensity RWH filters that work on the principle of cohesive and centrifugal forces and are used to meet the partial domestic water requirement. The stormwater runoff is channelled to the centralized STP and is later reused for flushing and irrigation requirements.

Wastewater treatment and reuse

It is estimated that 57 kl of greywater and 24 kl of blackwater is generated from the building every day. The wastewater is sent to the centralized sewage treatment facility at GIFT city where it is treated to tertiary level (BOD, TSS <10 mg/ l) as per BIS (Bureau of Indian Standards) and CPCB (Central Pollution Control Board) ENVIS 2015 standards of reuse before being returned to the building. This recycled water is used for flushing, irrigation and PV maintenance. Any excess greywater is channelled to the municipal sewage line. A 25% reduction, from the base case, in dependence on an external freshwater source is achieved by reusing the recycled water.

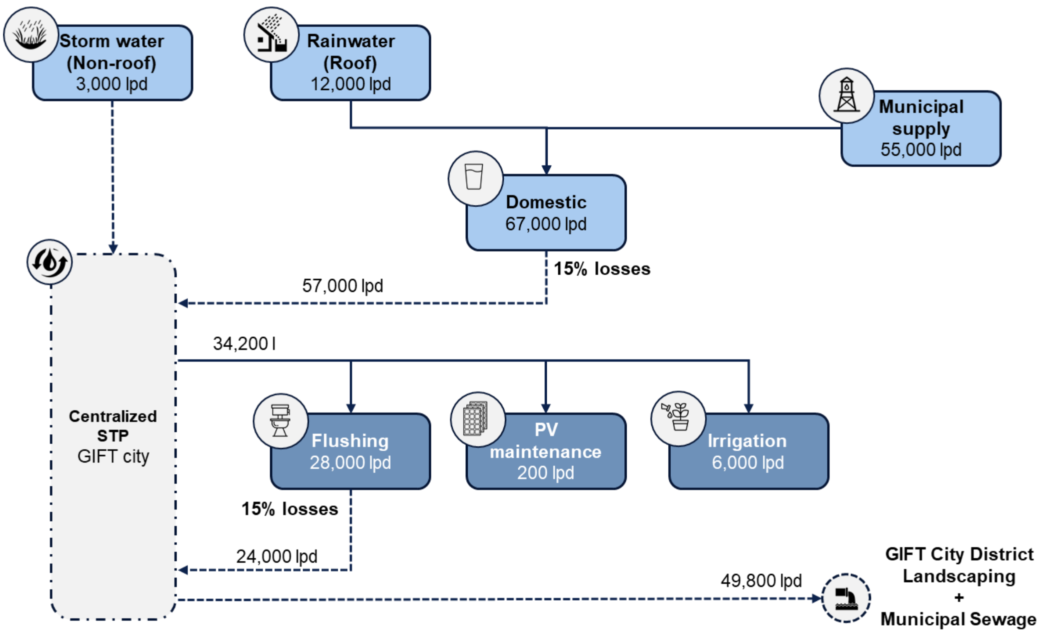


Figure 41: Schematic of daily Water Use Cycle

Table 5: Tank Sizing

Tank Type		Volume (m^3)	Remarks
UGT	Rainwater	100	6% average peak month rainfall run-off
	Fresh water	300	4.5 x daily domestic water requirement
	Recycled water	105	3.0 x daily flush water requirement
OHT	Fire water	25	As per NBC 2016 guidelines
	Domestic water	100	1.5 x daily domestic water requirement
	Recycled water	52	1.5 x daily flush water requirement

Water from the underground tank is pumped to the overhead tank using BEE 5-star rated submersible pumps. Water from the overhead tanks is distributed by gravity to various parts of the building by the system of the piping network.

7.6 Resilience

Gandhinagar is prone to various calamities like earthquakes, cyclones, floods, droughts and heatwaves. Designing the building and its infrastructure to have a minimum impact during such calamities was the prime focus.

The city had faced extreme droughts twice in a period of 10yrs. (2010, 2018) and extreme flooding once in 10yrs. (2017), which shows it's vulnerable to drought and flooding. Some strategies adopted are to zone service and equipment rooms above flood levels, preventing backflow of sewage with valves, means to pump out water accumulated in basement, raised basement entry to prevent flooding in the basement.

The building is designed to help maximize the PV output enabling the building for self-sustainability in case of power failure or grid disruption. The water management system is designed to be self-sufficient for 1.5 working days.

Vulnerability to other disasters like earthquakes and cyclones is also being addressed. The façade PV panel's truss structure is centrally supported onto the perimeter beam reinforcement of the waffle slab by anchoring up to 300mm and the top and bottom end anchored up to 150mm with threaded rods onto the lintel and sill structure.

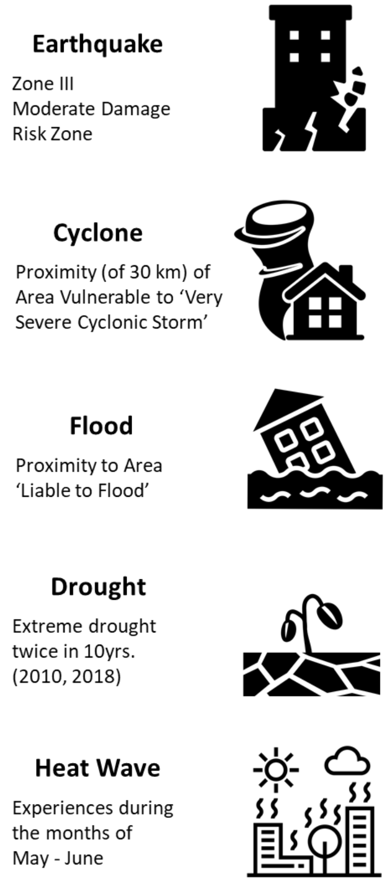


Figure 42: Potential threats in Gandhinagar

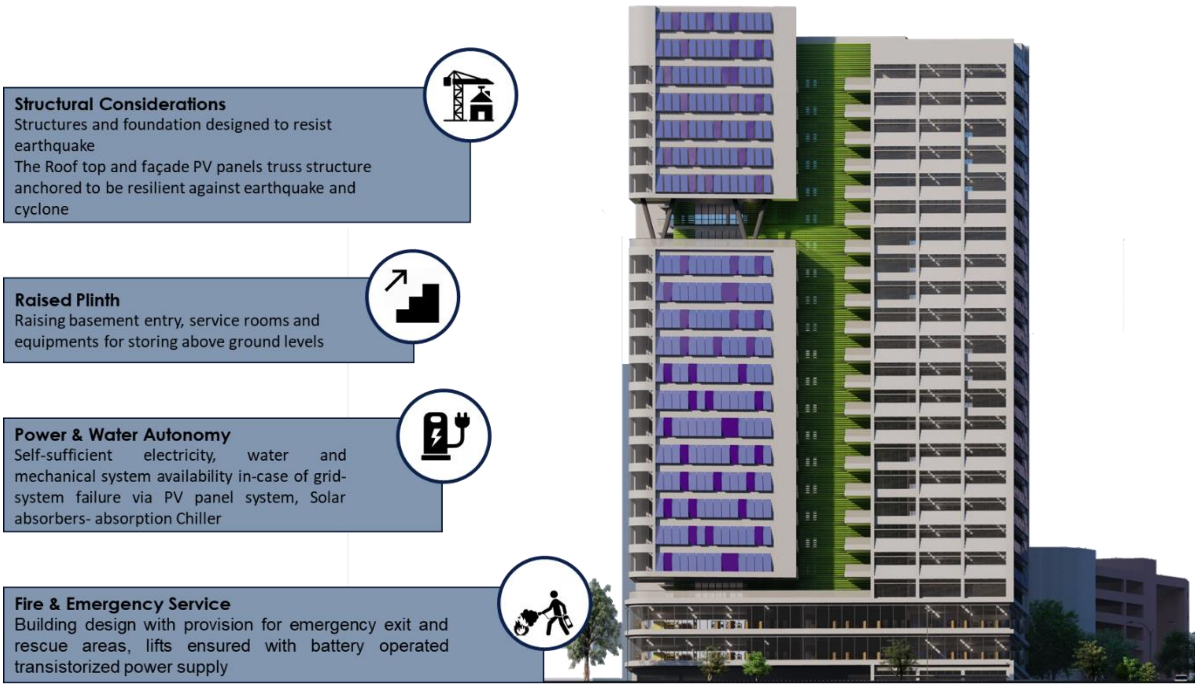


Figure 43: Resilience feature in Pragya

Reinforcement with a concrete grade of M30 is used which is suitable to withstand an earthquake, structurally sound and largely unblemished. The entire structure is build using a tie beam which provides an increase in the stiffness of the columns and avoids buckling. The use of a waffle slab reduces vibrations in case of an earthquake. Further, while the structure is made stable, the foundation is made disaster resistant with the use of raft foundation at the core and isolated footing in the rest.

The building design has ensured provision for emergency exit, rescue areas and lifts are ensured to have a battery-operated transistorized power supply (in case of any power failures). For fire safety purposes NBC 2016 suggests the need for a fire extinguisher, hose reel, wet riser, yard hydrant, automatic sprinkler system, manually operated electric fire alarm, automatic detection and fire alarm system, and firewater tank and pump.

Table 6: Fire safety specifications

Fire safety installation	Detail
Fire extinguisher	Travel distance to the extinguisher not more than 9m to 15m
Hose reel	FHC is envisaged with a twin hydrant valve and hose reel at each staircase landing level
Wet riser	1 Wet riser of 150mm dia is provided for every 1000m2 of floor area.
Yard hydrant	Yard hydrants at 60m of building peripheral length are provided
Automatic sprinkler system	The minimum distance between sprinklers not less than 1.8m on centre
Manually operated electric fire alarm	Smoke detectors do not have a listed spacing. They have a recommended spacing of 30 feet between detectors.
Automatic detection and fire alarm system	
Firewater tank and pump	OHT of 25Kl capacity has been provided in addition to UGT and pump

7.7 Affordability

India is experiencing unprecedented growth in the financial sector, and with the rapid development in technology and infrastructure, affordability becomes a key to the success of these businesses. With limited supply and increasing demand for office spaces in the banking, financial services and insurance sectors the developer's timely financial management towards net-zero buildings is crucial.

Total Project Cost (Rs. In Cr)		
Base case	137.94	6% ⬆
Proposed case	146.62	
Construction cost per sqm (Rs.)		
Base case	17,339	6% ⬆
Proposed case	18,422	
ECM investment	15.31 Cr.	

Key Investment - Commercial spaces entail substantial investments, and a prospective tenant or owner requires to make informed decisions. The rates of these spaces are driven by majorly the developer, demand for the design and supply. While the architectural design takes care of the demand for engrossing work environments, the feasibility of investments by the developer, the tenants/owners and a third-party investor is assessed. The design solutions require a nominal incremental cost towards energy-efficient solutions and reap long-term benefits to all.

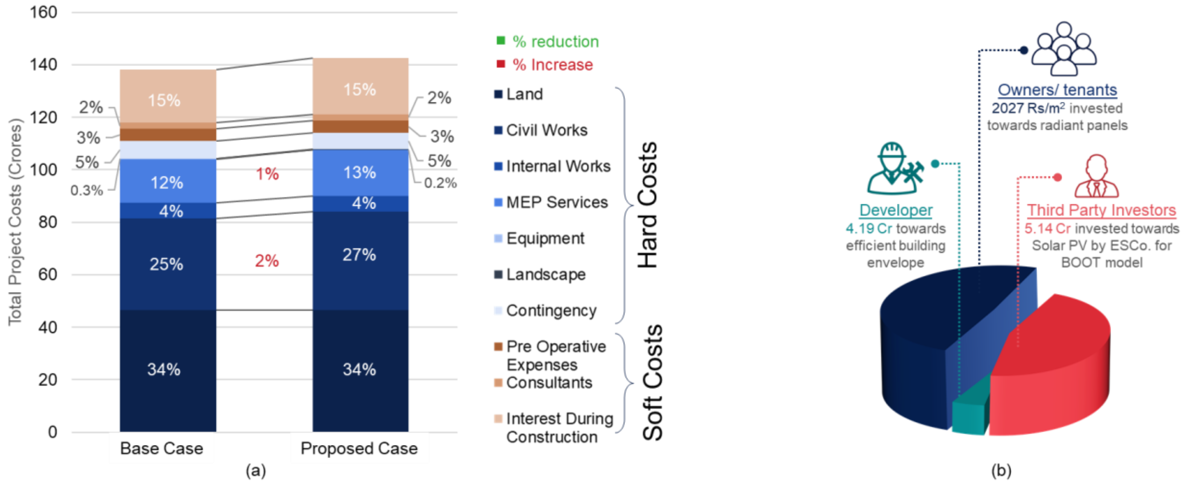


Figure 44: (a) Comparison of total project cost (b) Incremental costs for stakeholders

Energy-efficient building poses lower financial risks, as the green initiatives increase the opinion amongst the stakeholders that the building is very economical to operate, also due to measures such as thermal and visual comfort, indoor air quality addressed, is viewed as a way to incur more rent, increased resale value, increase the life of the building. Banks provide loans at a lower rate of interest and assure a faster process of sanctions as the risks involved is decreased. These factors play a major role in funding for the execution of the project. Assessing the leveraged returns on the project for future projections i) Increasing the debt-to-equity ratio and ii) Increase in the benefit of financial leverage. These factors also increase the debt-to-equity ratio and are obtained as 1.5 for this project. With a 9.7% rate of interest, moratorium period of 1 year, the internal rates of return increased by 7%.

Recurring benefits - The base case design is optimized to increase functioning / leasable spaces by 5% with only a cost of civil work rise of 2% to achieve an efficient building envelope. Green walls designed with an additional 1% CAPEX increase demand and marketability. With only an incremental cost of 4.19 Cr, the saleability of the office spaces is increased by a factor of 2.5 through a market survey. The owner upfront cost is estimated to increase by 2027/m^2 which will be recovered through the operations over the life cycle of the systems.

Cost Performance Review

Design Intervention

- Increased leasable area by 6% to 31290 sq. m. in proposed design gaining additional rent.
- Continual design concept ensures faster tenant occupancy increasing the internal rate of returns to 20.75% which is 7% higher than the base case.
- The brutalist style of architecture cut down the cost of finishes.

Energy Interventions

- Optimized daylight reducing the need for electrical lighting which converts to a 30% reduction in lighting power density.
- Optimized envelope design with an incremental cost of 0.82 Cr. towards insulation.
- 2.68 Cr towards façade with optimum window-wall-ratio.
- Cost to tenants/ owner towards the installation of radiant panels at Rs. 2072/m2 which is gains as returns of 51% in energy savings over the period of operation.
- Personal comfort systems shall be installed by the tenants/owners.
- Energy conservation measures reduced the consumption by 53% reducing the upfront cost to district cooling system connection to GIFT city by 40% and saving 0.12 Cr

Water management

- Increased cost for water-efficient plumbing and sanitary fixtures with long-run water savings, reducing the future dependency on municipal freshwater supply by 25%.
- Overhead tank supply to reduce the energy consumption utilizing gravity-fed plumbing.
- Intense work environment to nature intervention to include a green wall with an investment of 0.14 Cr. Green wall also designed to utilise the treated on-site water.

Life Cycle Cost - Calculation of returns, mostly based on upfront costs, at times might not be able to obtain a clear picture of the total benefits of green initiative and net-zero buildings. Life cycle cost analysis is hence used to enable decision-making that is beneficial to the developer and the tenants/owner.

Life cycle cost analysis for a period of 25 years, for base case, compared to proposed case incurred incremental cost of 4.2 Cr for energy conservation measures, to improve the occupant environment. The life cycle cost decreased by 6% i.e., from 165 Cr to 154 Cr. The cost to benefit ratio, calculated for the net present value, at a discount rate of 10% indicated a value of 3.52. The cost to benefit ratio is greater than 1 indicating a relative cost and benefits of the project to be expected to deliver a positive net present value.

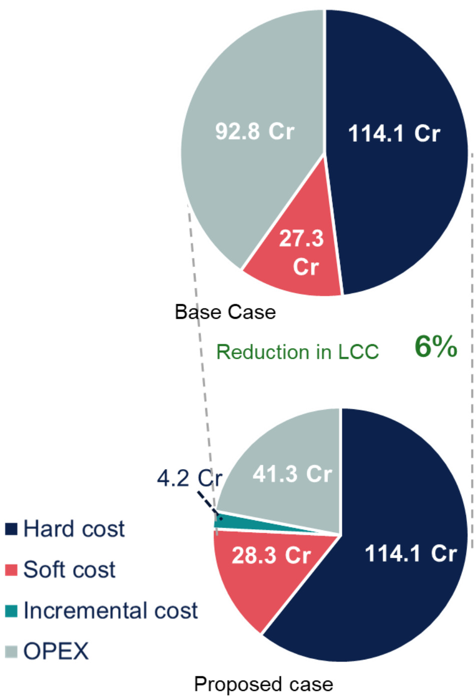


Figure 45: Life Cycle Cost comparison

Energy is generated through solar photovoltaics on-site to achieve Net-Zero Energy. Resolving the challenge of making a high-rise commercial complex, a solar PV array is installed on the South, East, West façade, the roof of the tower (Pragya roof) and the roof of multi-level car parking (MLCP). Façade solar PV array is known to generate less energy as compared to the ones installed on the roof. This makes it critical to understand the trade-off between the investment and the cost benefits of solar PV installation over the life of the solar photovoltaic panels.

Renewable energy cost evaluation

The feasibility of investment is assessed by accounting for the costs of the hardware, equipment, installation costs and indirect labor costs for each of the orientations individually before the proposal to install the solar PV array. The array of monocrystalline panels was proposed only for areas such that the Net Present Value greater than zero. The return on investment is lower for the façade than the roof. The west façade breaks even after a span of 19 years, for a life of 20 years of the solar panel, yet it generates together with the other areas a total of 110% of energy consumption.

Table 7: Feasibility of solar PV array on-site

	Tower South	Tower East	Tower West	Tower Roof	MLCP Roof
Generation (10^3 kWh)	324	165	39	359	659
Peak capacity (kW_p)	290	156	39	219	375
PV cost (Rs. In Crores)	1.38	0.74	0.19	1.04	1.79
R.O.I. (%)	9%	8%	8%	13%	14%
Payback period (Years)	16	17	19	9	8

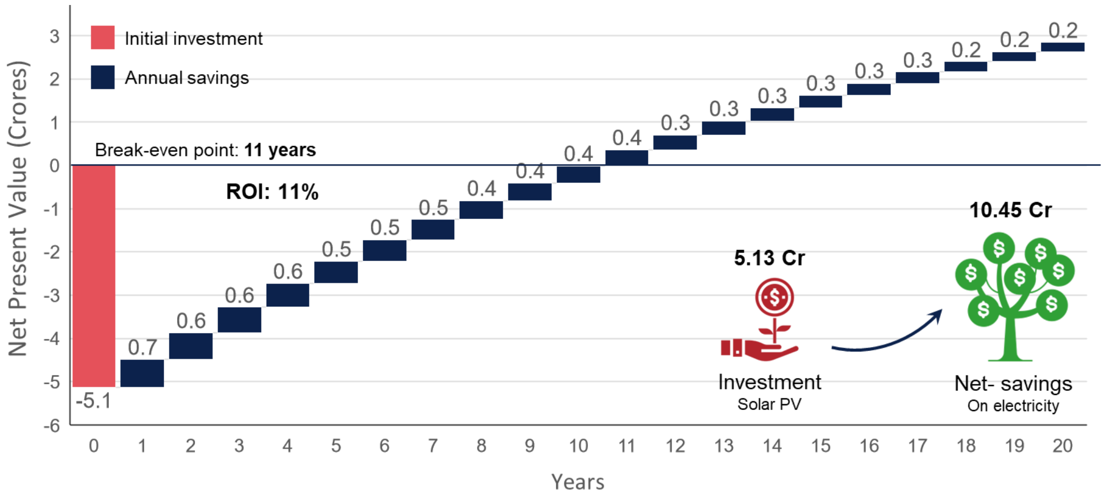
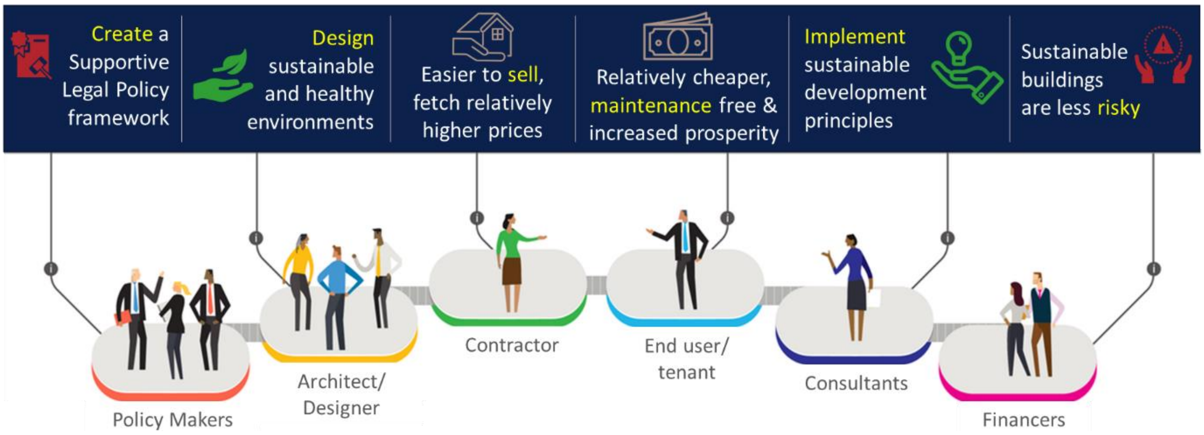


Figure 46: Economic feasibility of Solar PV array

The solar PV array is installed on the façade and the roof with a capital investment of 5.14 Cr. Over a period of 20 years life of the solar PV, the operation and maintenance are estimated at 1% of the capital expenditure and degradation of generation of 1% annually is considered for the solar panels. The entire system of the solar PV array yields an annualised ROI of 11% with a payback period of 11 years. The Net Present Value is greater than zero which indicates the feasibility of the investment.
The renewable system is proposed to be invested & maintained by an Energy Service Company (ESCo.), through a BOOT business model developed. The ESCo. will be a third party in the project and will function as per the agreement with the developer. The developer also has an option to act as ESCo.

7.8 Scalability and Market Potential

India, arriving at the world stage, demands a world-class business environment to redefine the nature of business and global trade. India ranks 4th among the LEED participating countries. 54% of registered and certified projects are office and commercial buildings. As per the current flex spaces, market penetration stands at 3% into India's total office stock, which by 2023 is expected to rise to 4.2%. This is estimated to grow non-linearly by an average of 15-20% per annum over the next five years. The working population in these offices constitutes 23.3 % female and 76.7% male workers. Together backed by technology and manpower, there is a need for a conceptualized commercial tower, to lay the foundations for global trade to establish India as a financial hub.



Working with green initiatives in any project, end-user satisfaction and financial viability are also of importance and hence the need to gauge the willingness of stakeholders to collaborate on an approach towards net-zero energy, water, and waste. Due to a lack of awareness about the green component, investors haven't paid much attention to green real estate. But considering green buildings to be a key to economic growth and generating skilled jobs in the AEC sector, banks and companies are moving forward and emerging in Indian markets to offer investment opportunity, also a direct investor and provide loans at a lower rate of interest and faster processing to accelerate sustainable development and reduce carbon footprint.

Green buildings create long-term value for all the stakeholders in a project. Indian banks and foreign banks with India presence like IndusInd Bank, HDFC, Bank of America (BOFA) have set aside a budget to lessen the environmental impact and sometimes cover the rental contracts on green clauses. Initiatives like installing on-site solar for office spaces, ATMs, financial centers are undertaken to reduce location-based energy use and water use.

India Union Budget 2021 also aims to reduce the burgeoning air pollution in an urban centre such as Ahmedabad. Also implementing Swatch Bharat Mission 2.0 for the next 5 years, the budget aims at wastewater treatment and management. Extensive effort is put into reforms in the power sector and to reach additional households. With initiatives of increased customs duty to encourage domestic production of solar panels, an attempt is made to increase generation through renewable energy.

The proposed design aims to address the need for renewable energy generation through solar photovoltaics and solar thermal absorption chiller to achieve net-zero energy. Façade integrated Solar

PV and solar thermal flat plate collectors on the roof are designed and optimized to produce the energy required per year. Wastewater is managed by using greywater for flushing/irrigation. Measures such as rainwater harvesting, high-efficiency water fixtures and drip irrigation and an on-site chemical-based wastewater treatment facility are implemented.

Build Own Operate and Transfer (BOOT) model

A business model has been developed for the renewable energy generated on-site to achieve net-zero energy. The BOOT model is a multistage program involving different parties which can be scaled up to larger or smaller projects of different building types.

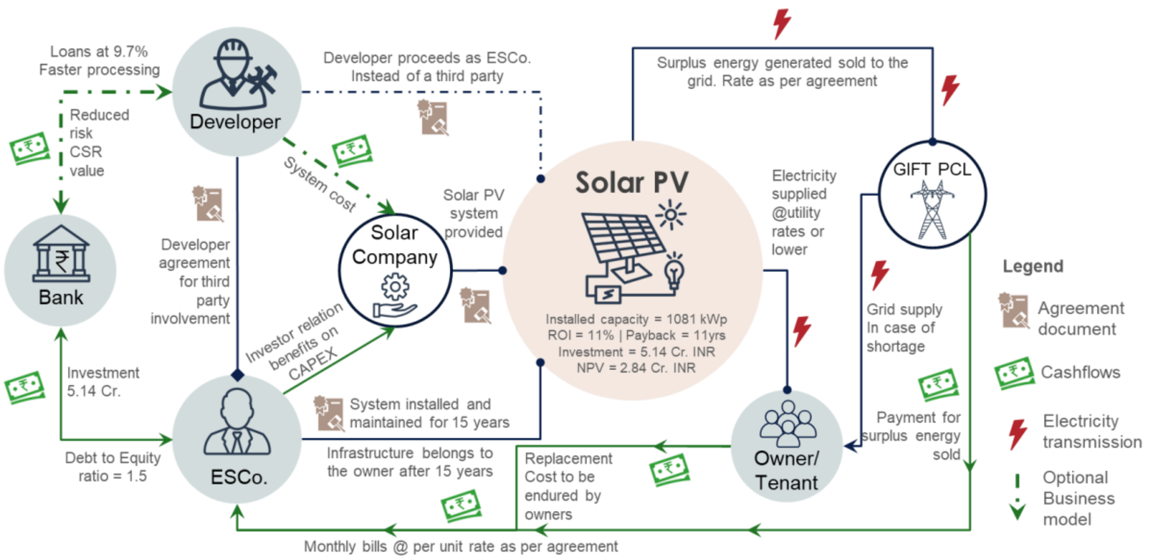


Figure 47: Business model for Renewables on-site

Installation of the solar PV array requires an upfront investment of 5.14 Cr. An Energy Service Company (ESCo.) is approached to invest in the system, operate and maintain it for a span of 15 years and reap the cost benefits at an annualised ROI of 11%. The entire system cost breaks even after 11 years. Since ESCo. is a third party, they require a written agreement from the developer for involvement. ESCo. the company can approach a bank which can provide loans at a lower rate of interest and process the sanction faster as renewable solution pose a lower financial risk. The debt-to-equity ratio of 1.5 also reduces upfront cost gaining higher leveraged returns. The ESCo. ties up with a solar company for the installation of the PV system. ESCo may also benefit from the CAPEX from the inter-relations with the solar company. The system installed of 1081kW$_p$ capacity yields 110% of the energy requirement of the proposed case. The tenant/owner of the commercial spaces buys the electricity from ESCo. As the system is connected to the grid, any surplus electricity produced is sold to GIFT PCL at predefined rates. The cost-benefit of the surplus energy is gained by ESCo. In case of shortage in the generation of electricity, the demand is met by GIFT PCL. After a span of 15 years, the investment is calculated to have made profits for ESCo. and the system is transferred to the owner or the developer of the project. And they will be responsible for any replacement costs that incur. The developer can be a prospective ESCo. instead of third-party involvement and the BOOT model provides it as optional feasibility. The hybrid solar thermal HVAC system developed can also function through the BOOT model reducing the incremental cost incurred by the developer.

7.9 Innovation

Personal Comfort System

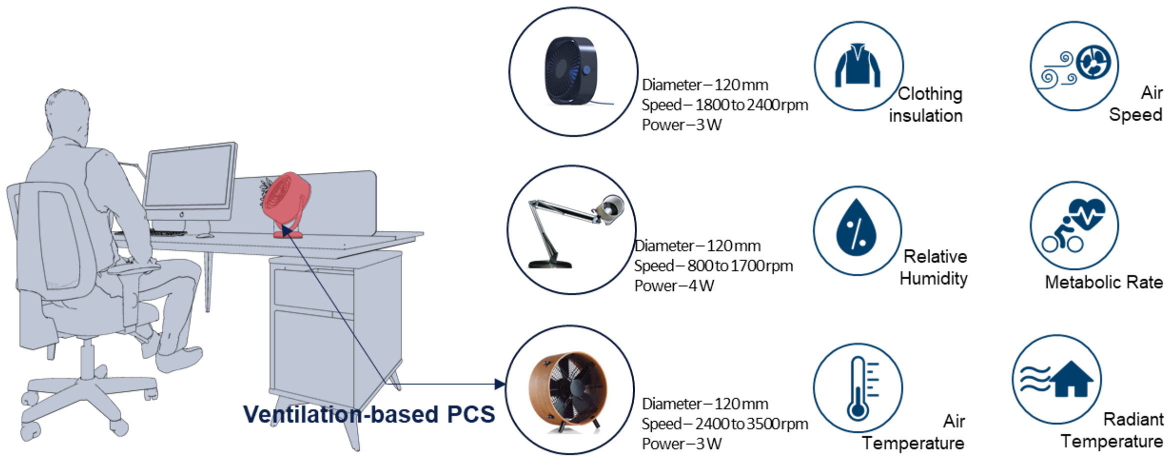


Figure 48: Personal comfort system

As part of the innovation category in the competition, a ventilation-based personal comfort system was identified as a potential innovative system. The systems function by reducing the skin temperature of the occupant by increasing the air movement around them. This facilitates increased evaporation of sweat by inducing a 'cool' effect through the use of desk fans (Rawal et al., 2020). As it was studied by (Zhang, 2009), (Amai H., 2007), (Zhang Y, 2008) the ambient temperature range for thermal comfort can be expanded to as much as 18-30^{0}C if occupants are provided with access to their personal comfort systems.

Hence a desktop-based ventilation device was selected as the personal comfort system that will increase the air velocity near the occupants by 0.6 m/s and because of that upper limit of the comfort band will increase by 2.8 °C. Thus, the zone thermostat setpoint was increased by 2.8 ^{0}C from IMAC MM neutral setpoints with the maximum setpoint limited to 30 ^{0}C.

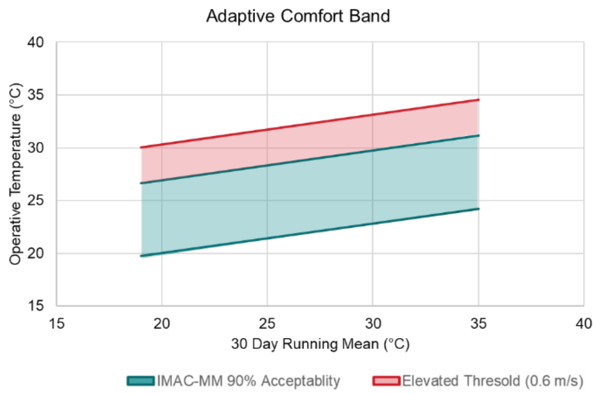


Figure 49: Elevated thermal comfort threshold

Table 8: The corresponding rise in the acceptable temperature with the increase in the air speed

Fan Speed Mode	Airspeed	Corresponding Rise in Temperature (°C) As per ASHRAE 55-2017
Off	0.1 m/s	-
I	**0.6 m/s**	**2.80**
II	0.9 m/s	3.40
III	1.2 m/s	3.75

Potential for Hybrid Solar Thermal HVAC System.

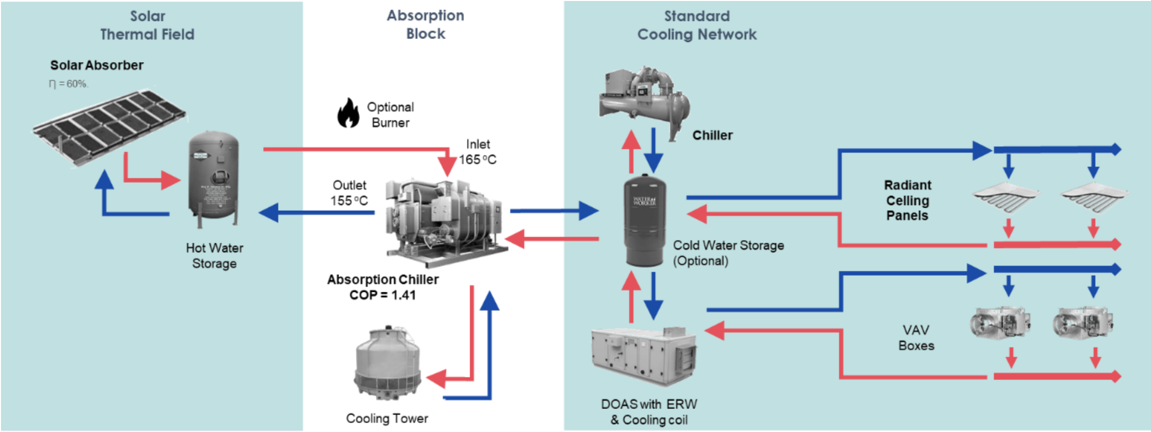


Figure 50: Schematic for the Hybrid Solar Thermal HVAC System

The proposed design has a design load of 1750 kW. A hybrid HVAC system of electric chiller and district cooling system with a double effect absorption chiller (COP: 1.41, to meet the baseload: 700kW) was analysed.

The absorption chiller, with a cooling capacity for the annual baseload, driven by solar absorbers (Vaccum Flat Plate collectors, Efficiency 60%) operates during daytime (8hrs per day). The burner becomes operational only to provide the lift between solar field temperature and the minimum chiller temperature when required. The standard cooling system (conventional electric chiller or district cooling system) will provide for the seasonal and deficient load. The team's performance and cost evaluation of Absorption Chiller with Solar Absorbers concludes with the potential of return of interest (ROI) of 5% with a payback period of 4 years; Case B against Case A.

Table 9: Specification of the Studied HVAC System

Case A	1.47 cr	Electric Chiller COP 4.8 Capacity 1700kW
Case B	1.95 cr	Electric Chiller COP 4.8 Capacity 1000kW Absorption Chiller COP 1.41 Capacity 700kW with Solar Absorbers; η= 60
Case C	0.19 cr	District Cooling System COP 6.65 Capacity 1700kW

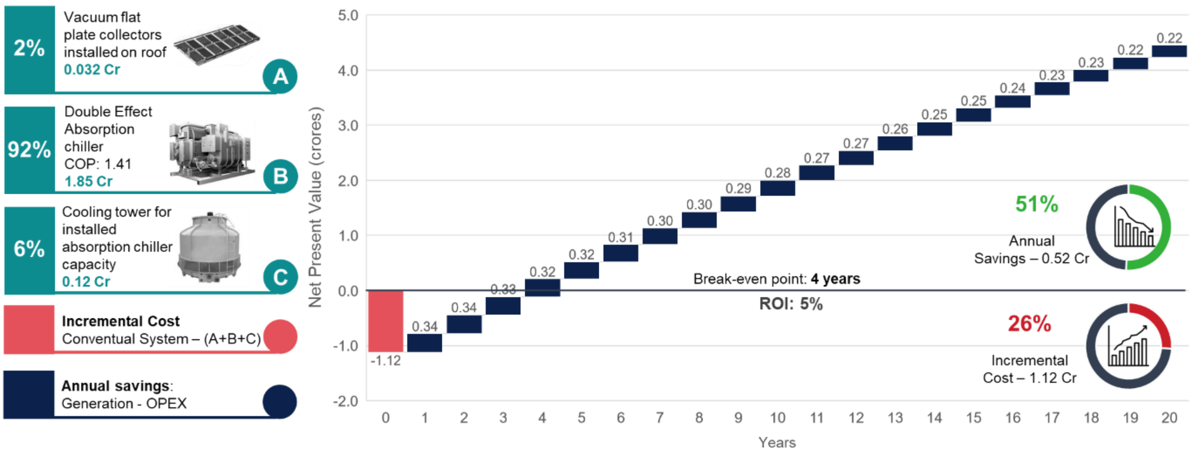


Figure 51: Economic feasibility of Hybrid Solar Thermal Air-Conditioning System

8.0 Pitch to Project Partner

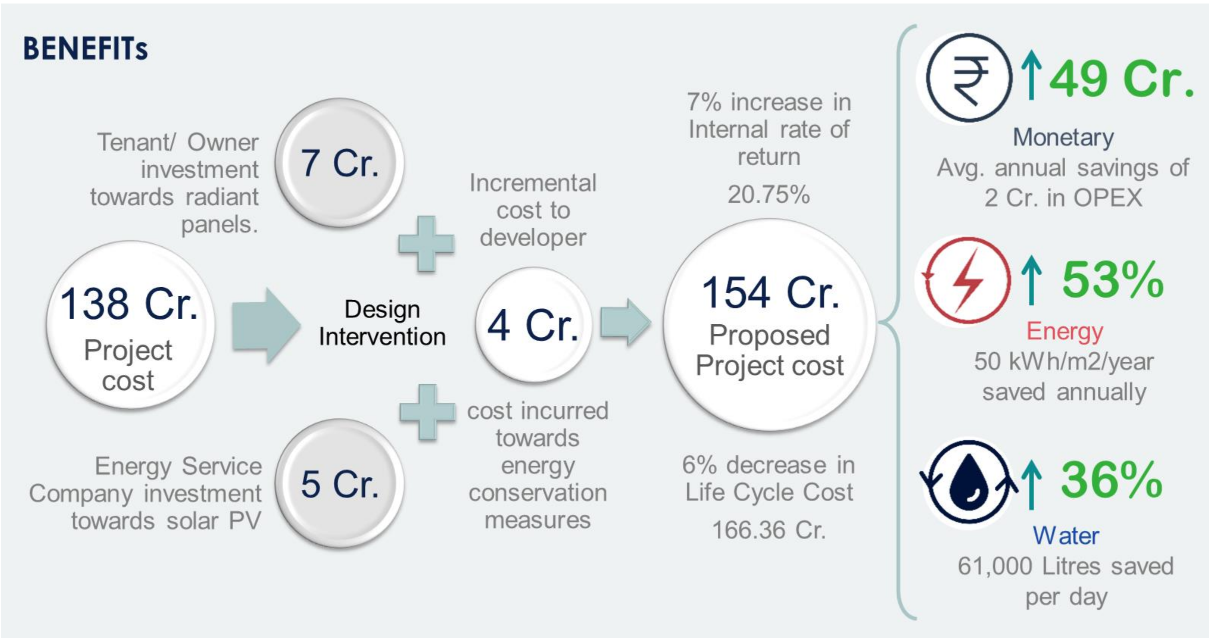
Pragya, a Net-zero Energy and Water commercial tower is in Gujarat International Finance Tec-City (GIFT) City and provides tenants/owner-based office and retail spaces for a leasable area of 31290 m^2. Pragya helps in effective energy management through sustainability analytics, thus surpassing the benchmarks in reducing greenhouse gas emissions. Pragya reaps benefits from the GIFT city-level integrated district cooling system, solid waste management, and a plasma gasification system.

PROJECT OVERVIEW

KillBill 4.O is working towards achieving Net-Zero energy and water. The goals achieved for the proposed design include but are not limited to

- Increased daylight spaces, by minimizing the service footprint towards the façade. Develops connection between intense work environment and nature, achieved through the green wall.
- Optimized ventilation and air conditioning solution to reduce energy consumption and improve occupant comfort. Integrated high-performance building materials to reduce thermal gains. Personal comfort systems (PCS) such as desk fans provide comfort at an individual level.
- Effective water management strategies to reduce water usage with water-efficient plumbing fixture, management of rainwater and stormwater run-off on site and wastewater treatment.
- Embracing green wall to increase thermal comfort, decrease proximal noise levels, and reduce air pollutants with native species requiring minimum water and utilizing on-site treated water.
- Photo-voltaic (PV) systems and water management systems were developed to function as a backup during calamities. The PV system is proposed to be installed by an Energy Service Company.

The core principle guiding our design decisions was to minimize energy and water use by simultaneously identifying cost-effective solutions.



Cost summary

Apart from the energy conservation measures and occupant-comfort-centric design, the building and its infrastructure is also designed with prime focus to be resilient during natural calamities such as earthquakes, cyclones, floods, drought, and the heatwave that are prone to Gandhinagar.

Life cycle cost analysis for 25 years indicates a 6% decrease from the base case, with only an incremental cost for Savvy of 4.2 Cr towards energy conservation measures to improve the occupant environment. The cost to benefit ratio, calculated for the net present value at a discount rate of 10%, indicated a value of 3.52. Savvy's investment is calculated to also take advantage of leveraged returns with increased debt to equity ratio and is obtained as 1.5 for this project.

Energy-efficient buildings pose lower financial risks than conventional buildings. Ergo banks provide loans at lower rate of interest and assure a faster process of sanctions. With a 9.7% rate of interest, moratorium period of 1 year, the proposed design also ensures faster tenant occupancy increasing the internal rate of returns for Savvy to 20.75%, which is 7% higher. The proposed design solution reaps Savvy 6% increased leasable area and benefits from the tenants' willingness to pay by an increased factor of 2.5 for spaces with the potential of future energy savings. On-site Solar PV plant is installed by an ESCo., Savvy is also provided with an option to act as an ESCo. instead of a third-party involvement.

We present to you our vision of an **iconic Net-Zero-Energy-water tower**, a pioneer in the building industry and one of a kind in the GIFT City! Pragya, promises cutting edge Architecture with a bold **vertical living wall** dominating its façade ensuring biodiversity and **visual comfort** while a highly efficient radiant cooling system provides **thermal comfort** to the occupants. We introduce our comfortable and flexible mixed mode spaces crafted to connect the users with their environment. Expansive views of the city and **a luxurious business environment** define the building spaces that have been designed for user comfort and work efficiency. The building also boasts of a **100% wastewater management** system. And NO, good Architecture does not come at the cost of our environment!

Tackling the conventional…

KillBill 4.O design solutions addressed the challenges to achieve Net-Zero energy and water for a high-rise office building such as

1. **Loss of aesthetics** - Conventional buildings tend to face losses in terms of the building aesthetics due to façade integrated solar PV. This was addressed by integrating the solar PV plant in the architectural design.
2. **Reduced WWR** – The window to wall ratio (WWR) for office buildings are maximized, with curtain wall glazing. The proposed design optimized the WWR for thermal gains for the climate of Ahmedabad. Without losing sight of the view factor for the occupants in the office space, which was enhanced based on the view angle and glare analysis.
3. **Schedule of construction** – Installation of solar PV plant would require an additional time and labour assigned in the construction timeline. Since the solar PV plant is proposed to be installed, operated, and maintained by a third party, the burden of the installation falls on Energy Service Company (ESCo.)

WHY Pragya - Zero?

Solar facade generates clean energy and supports biodiversity

Good neighbor In sync with GIFT city regulations and reduces carbon emissions of the city.

Diversity in thermal environments

Cracks the split-incentives puzzle

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