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Lifestyle, Energy Efficiency, and Climate Action

Energy efficiency vis-à-vis thermal comfort: A case study of Flipkart office building

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Abstract

The case study highlights Flipkart's partnership with 75F to enhance energy efficiency and employee comfort at its headquarters in Embassy Tech Village, Bangalore. Facing challenges with inconsistent temperature zones and a lack of a Building Management System (BMS), Flipkart implemented 75F's Dynamic Airflow Balancing, Dynamic Chilled Water Balancing, and Indoor Air Quality Monitoring solutions across its 837,279 sq. ft. campus. These solutions optimized HVAC operations, reduced energy consumption by 27%, and improved thermal and air quality comfort. The installation was completed in 45 days without disrupting ongoing operations. Post-implementation, Flipkart achieved significant energy savings and earned the UL Certification for Indoor Air Quality. The project underscores the effectiveness of 75F's retrofit-friendly technology in delivering smart, sustainable, and comfortable building environments.

FLIPKART Case Study

Flipkart partnered with 75F to save up to 27% on energy efficiency and deliver exceptional comfort to its employees.

Introduction:

Flipkart, an online retail Indian company headquartered in Bangalore, has its main office campus in Embassy Tech Village (ETV), Kadubeesanahalli. The campus comprises 3 blocks, A, B, and C, with an approximate total carpet area of 837,279 sq. ft. The space cooling across all floors in the building was managed by the centralized air conditioning system, which was distributed by air-handling units (AHUs).

The Challenge:

When Flipkart approached 75F, one of the primary problems they faced was **inconsistent hot and cold spots** across the office spaces in their buildings. Additionally, they **lacked the scheduling** of the AHUs. Also, there was no building management system (BMS) in place. The site was managed by a small thermostat to control the valve, with all of their 60 AHUs manually controlled. The client wanted a solution that could help them **save on energy costs** and improve the energy efficiency of the HVAC operations.

Site details:

Location: Embassy Tech Village

(ETV), Bangalore 75F® Solutions:

- 75F® Dynamic Airflow Balancing
- 75F® Dynamic Chilled Water Balancing
- 75F® Indoor Air Quality Monitoring
- 75F® Facilisight

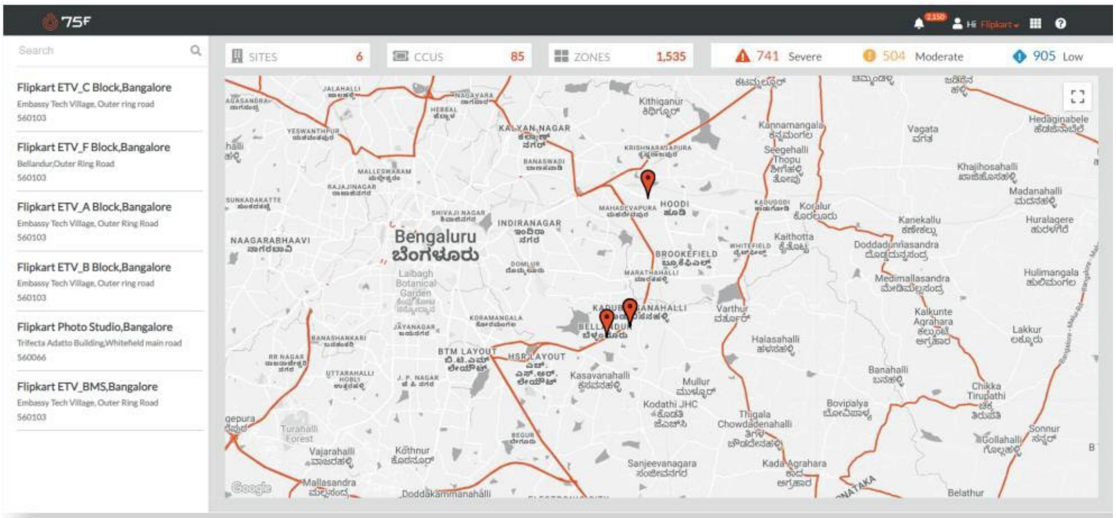
75F® Products:

- SmartNode: 1,063
- HyperStats: 216
- Central Control Units (CCUs): 60
- OTNs: 43
- SmartStats: 12

Area: 837,279 square feet | Turnaround Days: 180 Days from installation to handover

Approach

In one of the largest and one-of-its-kind, retrofit energy-saving projects, 75F competed against a legacy BMS provider and won the project based on technical and installation competencies. For the project, 75F provided DAB, DCWB, and IAQ applications to all three blocks in Flipkart's ETV campus to save energy, eliminate thermal discomfort, deliver end- to-end automation, and provide completely customizable energy dashboards.



Installation and Execution

When 75F got on board, Flipkart had already opened its office to its employees. Although the occupancy wasn't as high as that during pre-COVID times, it added to the challenge of the retrofit installation work. However, because of its retrofit-friendly technology stack, 75F could install its solutions without requiring any duct modifications. Indeed, the out-of-the-box solution avoided noisy and space-consuming onsite duct fabrication work.

Dynamic Chilled Water Balancing (DCWB)

75F deployed its Dynamic Chilled Water Balancing Solution at the Flipkart sites to optimize the HVAC system using intelligent controls and to deliver energy savings. 75F Central Control Units, installed at each AHU, acted as the cloud gateway and controlled the chilled water actuators at the AHUs. The chilled water ΔT was managed such that it matched the design set point and ensured no extra flow occurred through the chilled water line, thereby driving savings. The Chiller Management System provided insights into factors such as chiller inlet and outlet water temperatures, compressor current, suction temperature, suction pressure, and discharge pressure.

Dynamic Airflow Balancing (DAB)

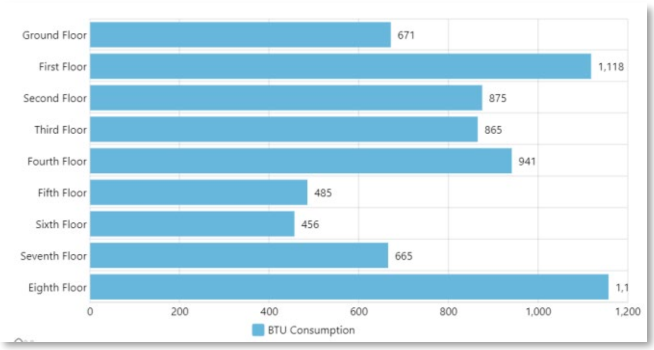
The Dynamic Airflow Balancing (DAB) used machine learning algorithms to optimize cooling by redirecting conditioned air away from unoccupied and sparsely occupied areas to the zones that required additional cooling. The systems deployed to modulate the variable frequency drives (VFDs) based on sensory inputs helped in maintaining optimal comfort levels while providing significant energy savings. The DAB monitored the comfort for every zone, created a heat map to optimally run the AHU, and maintained a superior level of comfort while reducing the envelope of air required.

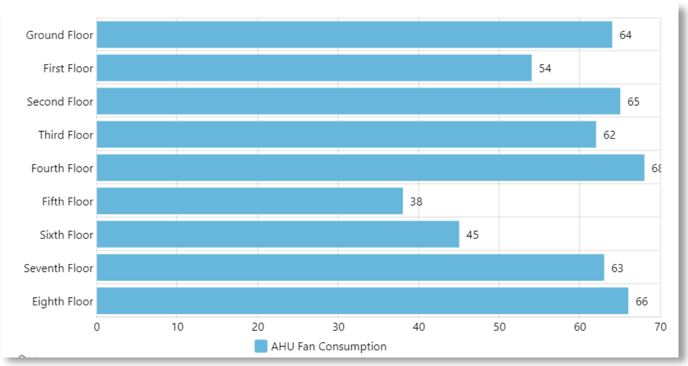
Indoor Air Quality Management (IAQM)

For a campus comprised of 3 buildings, 75F installed 216 HyperStat, making the site a highly dense RF environment. Smart Stats were provided to monitor the IAQ parameters such as CO2 VOC, PM 2.0, temperature, relative humidity, lux levels, PIR occupancy, and sound levels. HyperStat also provided visibility on the IAQ conditions experienced by the occupants instead of merely measuring the IAQ levels at the return air duct. The IAQM solution provided visibility to facility managers so that they could take necessary steps for ensuring a healthy workplace.

Facilisight

The powerful 75F Facilisight solution enabled multisite visibility and insights into the HVAC energy consumption through proactive monitoring and automatic control system capabilities. The AI-backed data analysis tool provided a single-pane view of key metrics in real-time to analyse critical factors such as heat maps and occupancy trends for granular-level reporting. The insights and analysis offered in an intuitive graphical user interface empowered the facility team of Flipkart to control their buildings with minimal intervention while increasing energy efficiency and maximizing occupant comfort. As per the client request, 75F provided in-depth energy management, IAQ, and AHU level monitoring dashboards.



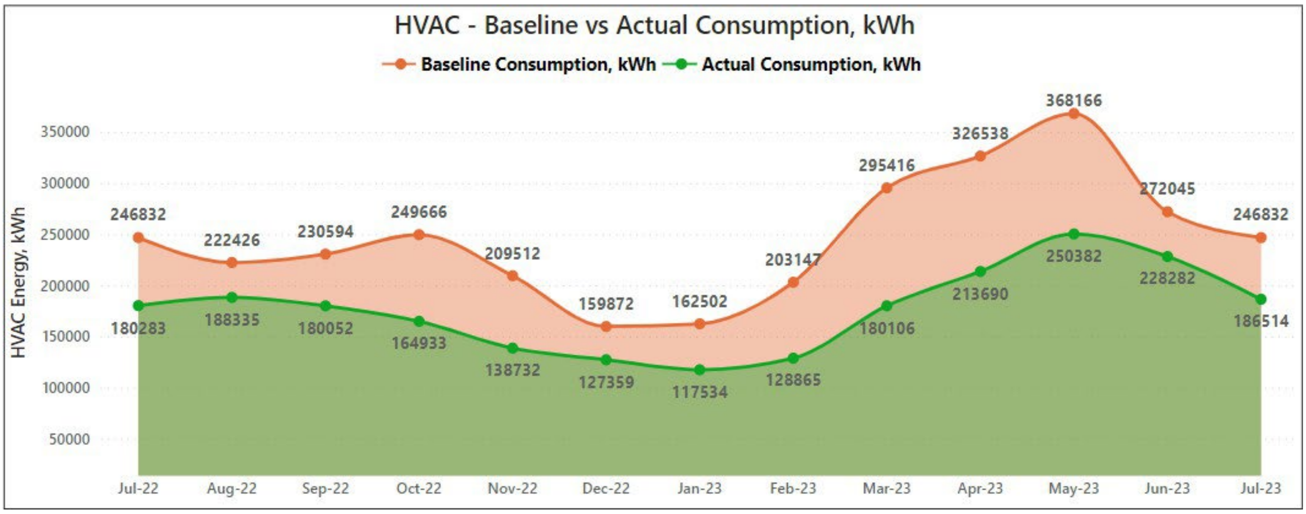


Results

The 75F solutions engineered to meet Flipkart's facility management objectives resulted in reduced energy consumption while ensuring superior ambient air quality. Added features such as live reporting and insight-driven data metrics with intuitive user interface dashboards optimized operational efficiency and enabled the e-commerce brand to deliver on its excellent working environment to its employees.

Incremental Saving in Energy Efficiency:

75F's smart solution has brought significant savings and efficiencies to the Flipkart campus. In July 2022, the first month post our installation, Flipkart had achieved energy savings of **66,549 kWh**. That is a 27% saving as compared to the baseline consumption. In the graph below, the dotted green line represents actual energy consumption and the Red line represent baseline consumption. The difference is the monthly saving in kWh.



Fast and Uninterrupted Installation:

Installation of sensors or controllers in an operational site is a difficult task. However, due to 75F's wireless

communication devices, it was relatively easily achieved. The entire end-to-end installation took merely 45 days.

Elevated Comfort Levels:

Within a short span of the project commissioning, the client witnessed a reduction in the hot and cold spot complaints from facility occupants. The occupant complaints are reduced by 60%. Additionally, the improved air quality brought the Flipkart campus accolades by earning the prestigious UL Certification for IAQ management.

These results can be translated into The Triple Bottom Line Impact: Planet,

People, Profits Environmental impact:

CO_2 Reduction of 711.4 Metric Tons compared to the baseline period.

- This is equivalent to the CO_2 emissions from 80,050 gallons of gasoline consumed.
- This is equivalent to the CO_2 emissions from 7,96,877 pounds of coal burned.
- This is equivalent to the carbon sequestered by 11,763 tree seedlings grown for 10 years. (from EPA)

Social Impact:

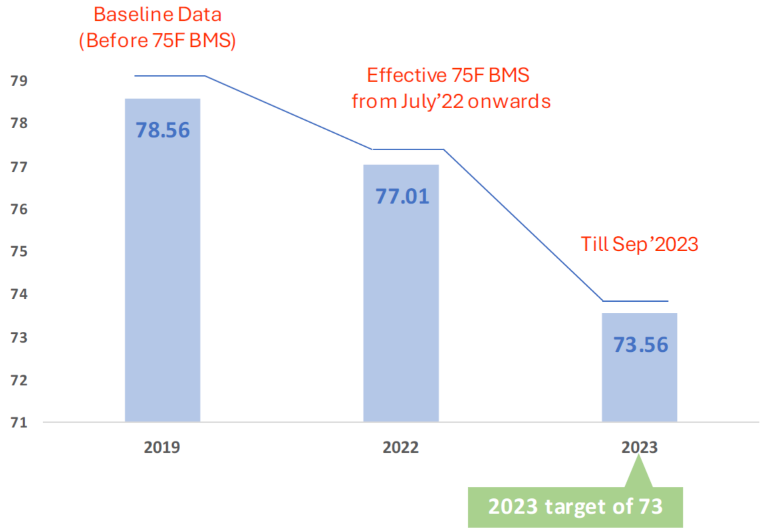
- Electricity saving of 8,98,212 kWh for 15 months compared to the baseline period.
- This is equivalent to the 1,016 number of rural homes electrified in India per annum.

Economic impact:

Cost Savings of INR 134.03 Lakhs for 15 months compared to the baseline period.

Here is the EPI Trend graph on 'how the site has achieved lowest in industry EPI numbers'.

Facility EPI Trend, kWh/m²/Year:



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A Case Study: Mainstreaming the Integration of Low-Energy Cooling Systems in Conjunction with Solar Passive Design

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Abstract

ENPRO Industries Pvt Ltd's headquarters in Pune, India, stands as an exemplary model of sustainable architecture. Situated within the Warm and Humid Climate Zone, this office building spans approximately 4184 sqm and proudly holds the prestigious LEED (BD+C) NC V4 Platinum rating. Its commitment to energy efficiency is a hallmark, achieved through adept utilization of passive cooling technologies. Notably, the building leverages indirect-direct evaporative cooling, harnessing water evaporation to efficiently cool the indoor environment, reducing reliance on conventional cooling systems and promoting environmental responsibility. Additionally, earth air tunneling is employed, tapping into the earth's stable temperature to naturally regulate the indoor climate, further enhancing energy efficiency. Furthermore, the headquarters embraces a holistic approach, integrating passive design strategies such as orientation, shading, and natural ventilation. This synergy between sustainable architecture and intelligent design optimizes thermal comfort and reduces the need for artificial cooling, enhancing the building's energy performance. An onsite renewable energy system harnesses abundant solar resources, generating clean power and underlining the company's commitment to sustainability. This case study aims to investigate the implementation of mixed-mode low-energy cooling systems as an alternative to conventional cooling systems in an office building. The objective is to comprehensively grasp how these innovative cooling approaches effectively cater to the cooling requirements of the project, promoting energy efficiency and sustainability. Ensuring that the mixed-mode approach provides consistent and satisfactory comfort to occupants is paramount challenge addressed in the case study. The utilization of passive design strategies and mixed mode cooling techniques has become an imperative for the present generation. This approach not only optimizes energy consumption but also fosters advancement in the commercial sector.

Introduction

ENPRO Industries Pvt Ltd's headquarters in Pune, India, stands as an exemplary model of sustainable architecture. Situated within the Warm and Humid Climate Zone, this office building spans approximately 4184 sqm and proudly holds the prestigious LEED (BD+C) NC V4 Platinum rating. Its commitment to energy efficiency is a hallmark, achieved through adept utilization of passive cooling technologies. Notably, the building leverages indirect-direct evaporative cooling, harnessing water evaporation to efficiently cool the indoor environment, reducing reliance on conventional cooling systems and promoting environmental responsibility. Additionally, earth air tunneling is employed, tapping into the earth's stable temperature to naturally regulate the indoor climate, further enhancing energy efficiency.

Fig1: Enpro HQ Exterior elevation

Furthermore, the headquarters embraces a holistic approach, integrating passive design strategies such as orientation, shading, and natural ventilation. This synergy between sustainable architecture and intelligent design optimizes thermal comfort and reduces the need for artificial cooling, enhancing the building's energy performance. An onsite renewable energy system harnesses abundant solar resources, generating clean power and underlining the company's commitment to sustainability.

This case study aims to investigate the implementation of mixed-mode low-energy cooling systems as an alternative to conventional cooling systems in an office building. The objective is to comprehensively grasp how these innovative cooling approaches effectively cater to the cooling requirements of the project, promoting energy efficiency and sustainability. Ensuring that the mixed-mode approach provides consistent and satisfactory comfort to occupants is paramount challenge addressed in the case study. The utilization of passive design strategies and mixed- mode cooling techniques has become an imperative for the present generation. This approach not only optimizes energy consumption but also fosters advancement in the commercial sector.

The central issue that this case study seeks to address is the exploration of mixed-mode low-energy cooling systems as a viable substitute for conventional cooling methods within an office building. The study aims to comprehensively understand how these innovative cooling systems can effectively fulfil the cooling requirements of the office space while offering energy-efficient alternatives to conventional cooling systems.

Approach

This case study centers on Sustainable Architectural Building Design and Technologies, with a primary focus on achieving significant energy efficiency through low-energy mixed-mode cooling systems. By integrating alternative cooling technologies, solar passive design, and renewable energy solutions, the study intent to drive energy savings in the project. The approach combines earth air cooling, evaporative cooling, and conventional air conditioning strategically to create a balanced and efficient cooling system.

The study assesses the tangible impact of mixed-mode low-energy cooling systems compared to conventional methods, including reduced energy consumption and a cost-benefit analysis tailored to the specific case. Solar passive architectural principles and renewable energy resources are integrated to reduce energy demands.

The anticipated outcomes hold significance for the broader field, as the study helps to promote the mainstream adoption of mixed-mode low-energy cooling systems in office buildings, aligning with the move towards near net-zero energy standards. Calculations, energy simulations, and measurements are employed to comprehensively understand the interplay between technologies and design strategies, paving the way for sustainable and energy-efficient building practices

Climate and Orientation

The project possesses a squarish layout with a predominant North-South orientation. The western facade has been strategically outfitted with services that serve as a buffer against heat gain, effectively minimizing its impact. In a thoughtful arrangement, all workstations are situated on the northern and eastern sides to capitalize on the benefits of north-facing natural light. The design further enhances energy efficiency by incorporating shading devices along the exposed North, East, and South facades to curtail heat accumulation.

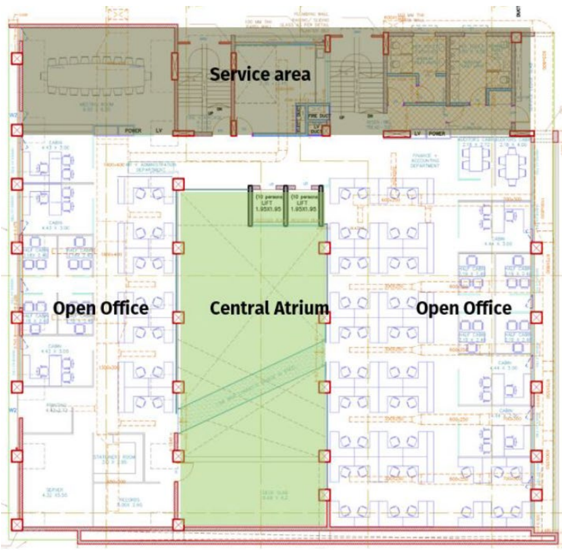


Fig 2: Typical Floor plan

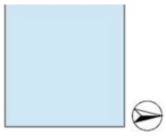


Fig 3: Square plan form: Lower perimeter to area ratio and thus lower conductive heat gain

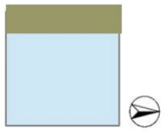


Fig 4: Service areas planned in the west

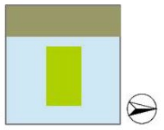


Fig 5: Central Atrium to allow ventilation and daylight

Given the local climate conditions, the region experiences a prolonged rainy season spanning from June to October. During the hot season, the average high temperature peaks at 36°C, while the low averages around 22°C. Conversely, in the cold season, temperatures average at a low of 13°C and a high of 29°C. Amidst these climatic dynamics, the low-carbon building design emerges as a pivotal player. This optimized design approach has demonstrated a commendable 3% reduction in energy consumption.

Envelope Design

Fig 6: Project is achieving 15 % Savings with the help of Energy efficient building design and selection of appropriate envelope materials

The design of the building's façade and its Window-to-Wall Ratio (WWR) holds a substantial influence over the structure's energy consumption, encompassing both heating and cooling needs, as well as its daylighting provisions. In the particular case of the low carbon commercial building, the WWR stands at 34.82%, in stark contrast to the 60% stipulated by the Energy Conservation Building Code (ECBC) of 2017 for conventional office buildings.

In addition, the façade design has been thoughtfully integrated with the installation of overhead photovoltaic (PV) panels. This synergistic approach serves a dual purpose. Firstly, it effectively curtails the ingress of heat from both the roof and the external walls, yielding a commendable 8% reduction in energy consumption. Secondly, the PV panels harness solar energy, contributing towards the building's renewable energy generation and thus mitigating its overall carbon footprint.

Selection of Material

The meticulous selection of building materials holds a pivotal role in influencing cooling consumption. The external walls of the building are constructed using 150mm thick AAC (Autoclaved Aerated Concrete) blocks, augmented with internal gypsum plaster. This construction configuration results in an impressive U value of 0.773 W/m²K, which signifies the rate of heat transfer through the material. Internal walls feature Fly Ash bricks, a material known for its sustainable attributes. The U value for these walls stands at 2.1 W/m²K, Efficient fenestration plays a crucial role in overall energy performance. The chosen glazing, SKN 176, exhibits a Solar Heat Gain Coefficient (SHGC) of 0.37 and a U value of 1.54 W/m²K. The roof's cooling efficiency is enhanced through the application of Fly Ash waterproofing. This measure not only waterproofs the roof but also contributes to lowering the

Fig 7: Roof Assembly

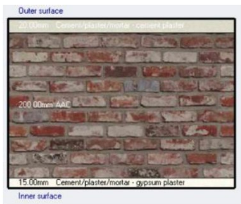


Fig 8: Wall Assembly

U value of the roofing assembly to 1.6 W/m²K. This reduction in U value directly impacts the building's heat transfer and cooling requirements.

Lighting Selection

The incorporation of energy-efficient lighting stands as a significant contributor to overall energy conservation within the project. By embracing advanced lighting technologies, the interior lighting's Lighting Power Density (LPD) has been markedly reduced. The project boasts a commendable Lighting Power Density of 5.53 W/sqm, signifying a notable achievement. A remarkable 9% energy savings have been realized in the low carbon building when juxtaposed with the conventional base case. This achievement is attributed to the strategic utilization of daylight and occupancy sensors. These sensors, thoughtfully employed for public toilets and passages, harness natural light and efficiently manage energy usage in response to occupancy patterns..

Selection of HVAC – Cooling design Details

The building's cooling strategies are thoughtfully tailored to diverse enclosed and open spaces, reflecting a comprehensive approach to energy efficiency and occupant comfort. These strategies encompass a combination of cutting- edge techniques, aiming to significantly reduce cooling energy consumption while maintaining optimal conditions within various functional areas.

The primary focus of the building's HVAC system is minimizing refrigerant usage. Within this office building, four HVAC systems are employed.

Firstly, the Indirect–Direct Evaporative system accounts for 65% of the total building's HVAC capacity. Secondly, the VRF system makes up 22% of the total conditioned space. Earth Air Tunneling (EAT) and split systems contribute 12% and 1%, respectively.

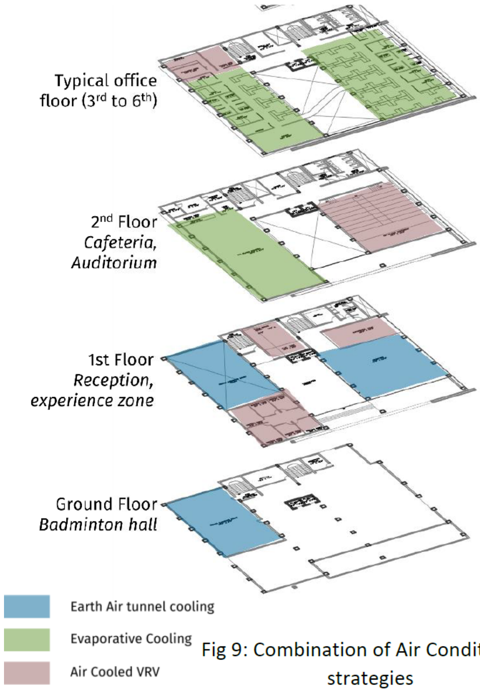


Fig 9: Combination of Air Conditioning strategies

Air Cooled VRF: Enclosed spaces such as meeting rooms, cabins, auditoriums, and the experience zone are designed with Variable Refrigerant Flow (VRF) System, having 3.26 Coefficient of Performance (COP). This technology efficiently cools these areas by transferring heat between indoor and outdoor spaces, resulting in substantial energy savings while delivering the desired cooling. 18HP Mitsubishi ODU units with a COP of 3.05 and 0.5 W/cfm fan power are utilized for cabins and meeting rooms on the first and second floors. A separate 20HP Mitsubishi ODU unit with a COP of 3.26 and 0.5 W/cfm fan power serves the 100-seater auditorium. The enclosed spaces on the 3rd, 4th, and 5th floors are equipped with 20HP Mitsubishi ODU units boasting a COP of 3.26 and 0.5 W/cfm fan power. On the sixth floor, where the CEO's cabins are located, a 20HP Mitsubishi ODU unit with a COP of 3.26 and 0.5 W/cfm fan power is installed.

Indirect direct Evaporative Cooling: Open workstations are designed with "Indirect Direct Evaporative Cooling," an innovative technique that optimizes energy consumption while ensuring comfortable conditioning of open areas with 100% fresh, treated air. This strategy represents a perfect balance between energy efficiency and occupant well-being. This cooling method, wisely chosen for open office areas, leverages water evaporation to efficiently lower temperatures within the building. This system is designed with CAV fan control which maintains the set point of 29Deg C with the help of RH and Temp Sensor as well as BMS. This system is detailed in such a way that each floor has 2 Units (one for South and one for north block separate) of 11000 CFM capacity each placed on terrace level starting from 2nd to 6th floor except Second floor having only 1 unit of 11000CFM capacity and Sixth floor South block is having 4500CFM capacity unit. Total Flow rate of whole building with indirect and direct evaporative system is 92500CFM having fan power of 0.5W/CFM

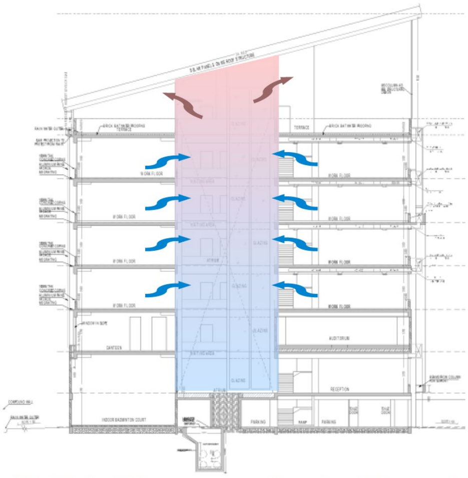


Fig 10: Building section showing Exhaust System

Earth Air Tunnel: In specific spaces such as the reception, indoor badminton court, and game zone, Earth Air Tunneling has been employed. This natural cooling method utilizes the earth's stable temperature to establish a comfortable environment, introducing a refreshing and energy-efficient element to these indoor areas, thereby enhancing the overall user experience. A 7500CFM capacity fan with having fan power of 0.5W/CFM is used to circulate the air inside the pipe and provide the coolness.

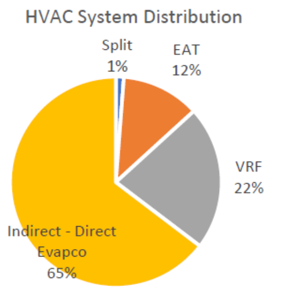


Fig 11: HVAC System Distribution

Split Ac is used for Server room of 1.9TR with 4.22 COP

The building's exhaust system is carefully designed to work in synergy with the overall space layout, creating an "Artrim" that utilizes the stack effect to efficiently remove hot air. This is achieved with the assistance of two mechanical fans, each with a capacity of 8000CFM.

The culmination of these strategies is a combination of air conditioning techniques that work in synergy to curtail cooling energy consumption. The evaporative cooling and earth air tunnel strategies help in reducing cooling energy demand by more than 60% as compared to conventional central air-conditioning system. The reduced demand in electrical energy for cooling, helps in achieving the target of a near Net Zero Building.

Analysis

The study delves into the tangible impact of the implemented low-energy cooling system and solar passive design by scrutinizing actual energy bills. These figures are then compared against the standards set by the Bureau of Energy Efficiency (BEE) to quantify the extent of energy consumption reduction achieved. This approach provides a direct and empirical understanding of the benefits yielded by these innovative strategies.

Financial considerations are also a core facet of the study. By calculating additional costs incurred by the adoption of these energy-efficient approaches, the study evaluates factors like investment, payback period, and Return on Investment (ROI). This assessment aids in comprehending the financial implications of the chosen sustainable strategies.

Occupant comfort, a pivotal aspect of any building, is also taken into account. The study conducts an in-depth survey to gauge occupants' thermal comfort. This empirical approach captures real- time data, shedding light on the actual effectiveness of the implemented measures in ensuring a comfortable indoor environment for the building's users.

Collectively, this methodology not only scrutinizes energy performance through various lenses but also presents a holistic understanding of the project's energy savings, financial implications, and occupant satisfaction. By amalgamating data-driven analyses and direct occupant feedback, the study paints a comprehensive picture of the project's success in achieving its energy efficiency and sustainability goals.

Analysis 1: The tangible impact of the implemented low-energy cooling system and solar passive design by scrutinizing actual energy bills.

Actual energy bills have been thoroughly scrutinized in this study to facilitate a comprehensive comparison with the standards set by the Bureau of Energy Efficiency (BEE). This analysis serves as a pivotal step in gauging the extent of energy consumption reduction attributed to the implementation of low-energy cooling systems and solar passive design strategies.

	Energy Consumption	**Oct 2020- Sept 21 (60 % operations)**		**Oct 2021- Sept 22 (100 % operations)**		**Oct 2022- July 23 (100 % operations)**	
a	*Total Electricity Purchased (kWh or kVAh per Annum)*	**241833**	**kWh**	**218697.6**	**kWh**	**176132.80**	**kWh**
	i) Grid/Discom	241833	kWh	218697.6	kWh	176132.80	kWh
b	*Total Electricity Generated (kWh per Annum)*	**46599.32**	**kWh**	**239198.18**	**kWh**	**212570.65**	**kWh**
	ii) DG Set	8333.32	kWh	10185.18	kWh	8487.65	kWh
	iii) Renewable Energy (solar meter started from (15/07//2021)	38266	kWh	229013	kWh	204083	kWh
c	*Electricity export (kWh/year)*	7030	kWh	60909	kWh	59110	kWh
d	*Total electricity consumption (a+b-c) (kWh/year)*	**281402.32**	**kWh**	**396986.78**	**kWh**	**329593.45**	**kWh**
e	*Solar PV Capacity kWp*	165.7	kWh	165.7	kWh	165.7	kWh
f	*Renewable Energy Consumption (%)*	**14%**		**58%**		**62%**	
g	*Energy Consumption per sq. meter built -up area /year (EPI) kWh/sq.m/year*	**67.3**		**94.9**		**78.8**	

Fig 12: Energy Consumption through energy bills and EPI calculations

Result 1

By compared the actual energy bills against the BEE standards, the study gains a tangible measure of the impact of these sustainable strategies. This empirical approach allows for a direct assessment of the achieved energy savings, providing a clear picture of the benefits yielded by the implemented measures. The project shows 82.85% savings compared to BEE 3 star rated office building.

Cascade analysis for energy performance

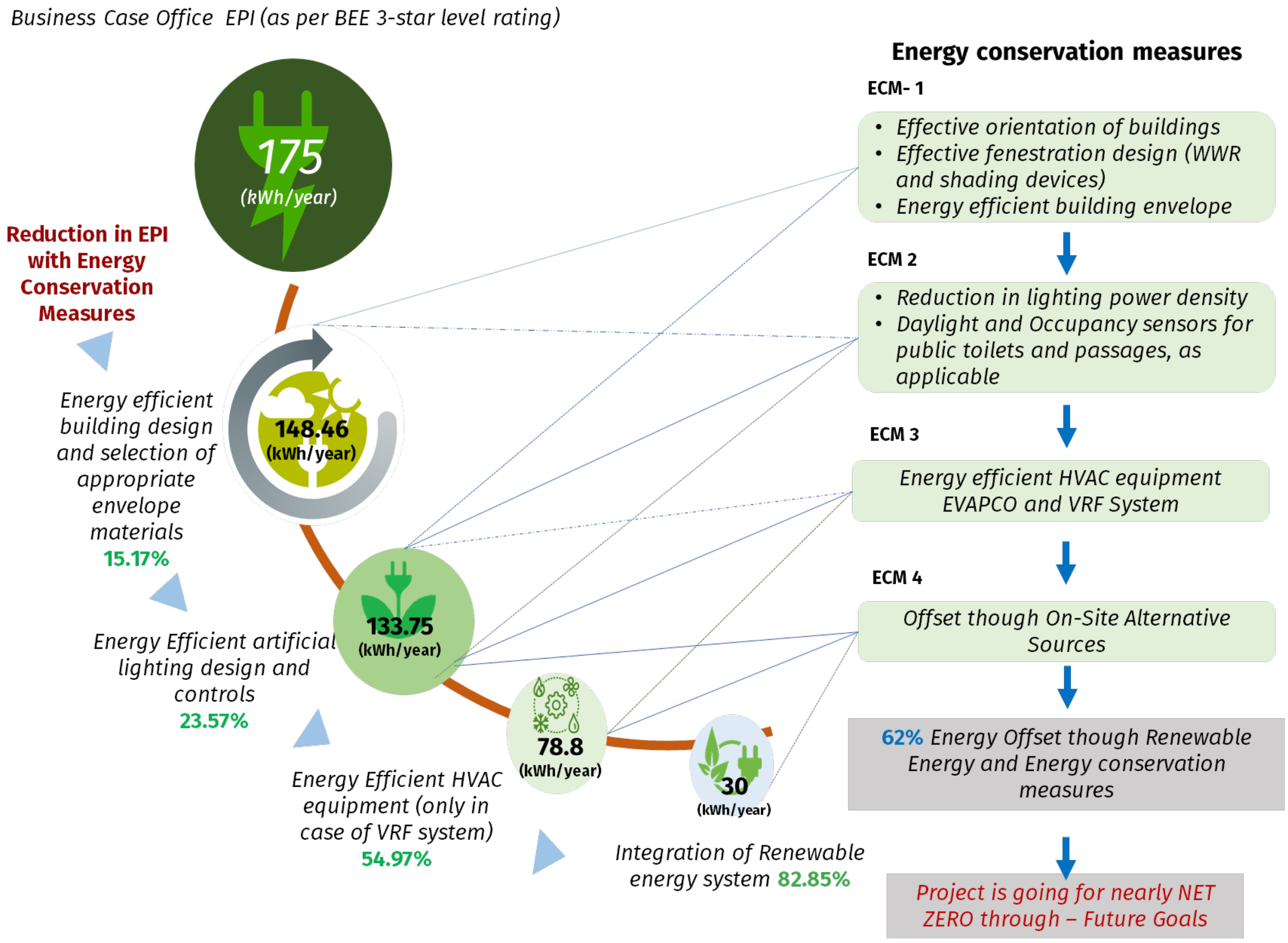


Fig 13: Cascade analysis for Energy performance w.r.t BEE 3 star Building

Furthermore, this comparison serves to validate the effectiveness of the strategies in real-world conditions. It ensures that the anticipated energy savings are substantiated by actual consumption data, bolstering the credibility of the study's findings.

Ultimately, this analytical process forms a cornerstone of the research, shedding light on the practical outcomes of the low-energy cooling systems and solar passive design. By aligning real energy consumption with established standards, the study gains a robust understanding of the project's success in reducing energy consumption and its contribution to overall sustainability goals.

Analysis 2: Additional cost increment, Payback and ROI

Additional Cost requirement will be as follows for the project to be a low carbon residential building.

Sr.no	Green measures for Low carbon residential building	Additional Incremental Investment for Energy saving in Rupees
1	Solar panels – Solar Square PV of 165.7KW	83,12000.00
2	Energy efficient lighting –LED lisntina	21,38000.00
3	Daylight and occupancy Motion Sensor	58,400.00
4	BEE 4-star rated pumps & motors	90,541.00
5	SKN 176 (DGU)	52,28663.00
6	Evapco	Capital Cost - 11427003.00
7	VRF	Capital Cost - 2935434.00
8	Earth Air tunnelling	Capital Cost -1188924.00
9	Total Additional HVAC Cost over conventional	-14889.00
	Total additional incremental cost	1,58,12,715.00

Payback Period Analysis

A Financial Payback Period and Return of Investment analysis was carried out for the project to check the financial feasibility of the proposed additional measures, it was found that proposed additional measurements are feasible and the supporting calculations to such conclusion given below –

SR. NO.	PARTICULARS	UNIT	VALUE
1	Total Additional Cost Requirement for Green measures	INR	1,58,12,715
2	Total Annual Energy Savings due to the green measures	kWh/Yr.	6,87,557
3	Annual Cost Savings in Electricity Bill @ 6.58 Inr per Unit	Inr/Yr	79,06,902.28
4	Simple Payback Period for the Additional Cost	Yrs.	2.00
5	Return on Investment for First Year	Percentage	50%

Additional cost + Maintenance cost for green building measures

RWH Pits – 1 no. of pits – approx. 1lac + 10000Rs, STP plant – 12 KLD – 7 lac + 3.6 Lac, Low Flow fixtures – 9.5 lac , Water meters – 30615 Rs, BEE 4-star rated pumps & motors – 90541 Rs and Solar PV maintenance cost – 165700 Rs. Total capital cost required = 1.76Cr approximately and Total Maintenance cost required = 5.35lac/month approximately. Hence, Total Green measures cost =

1.81Cr. As Total building construction cost = 31.81Cr. Percentage of green measures capital cost to total building cost = 5.69%. Green measures cost per Sqm = 4326 Rs and per Sqft = 400 Rs

Year	Project Description	Achievement of energy savings per year basis		Investment for ECM (Rs. Lakhs)
		Electricity (kWh)	Total savings in (Rs. lakhs)	
2020-21	The Solar PV has started functioning from 15/07/21	38266	8.45	83.12
	Energy efficient lighting –LED lisntina	24183.3	5.35	21.38
	SKN 176 (DGU)	12091.65	2.65	52.28
	Sub Total	**74540.95 kWh**	**16.45**	**156.78**
2021-22	Solar PV	229013	50.56	
	Daylight and occupancy sensors	10934.8	2.41	0.58
	BEE 4-star rated pumps & motors	4373.95	0.96	0.9
	Sub Total	**244321.75 kWh**	**53.93**	**1.48**

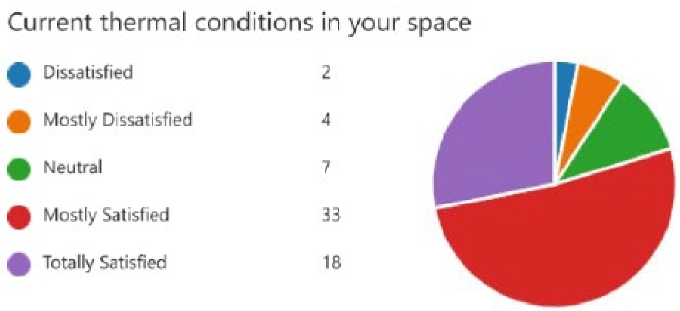
Year	Investment Rs. Lakhs/yr.	Electrical Saving in (Lakhs kWh)	Thermal Saving in (Million kCal)	Total Energy cost Saved (Rs. Lakhs/yr.)
2020-21	156.78	74540.95	49.6	16.45
2021-22	1.48	244321.75	224.81	53.93

Analysis 3: Occupant comfort survey

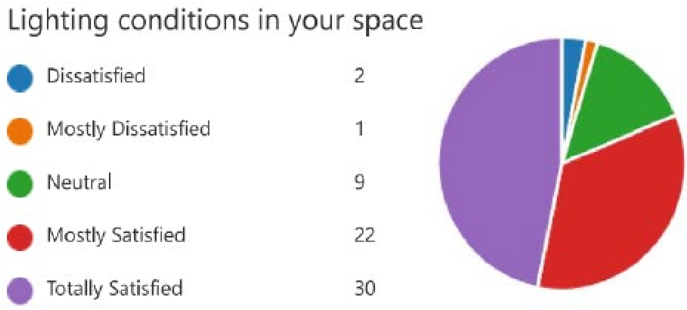
A thermal comfort survey was distributed to building occupants at ENPRO Office. The intent of this survey was to assess occupant comfort as it relates to the building environment. Answers to these survey questions helped indicate the performance of the buildings' heating, ventilation, air conditioning, acoustical, lighting and cleaning systems. The results provide direction for improving the comfort conditions for building occupants. The Survey is conducted on 10 December 2020. The ambient temperature was 28 deg C and RH was 52% noted. All the cooling system systems mentioned above were in operation Indirect direct Evapco, VRF, Earth air tunneling and Split AC. As per the BMS Indoor Temperature of 25 deg C and 45% are maintained in Indoor spaces.

RESULTS 3

Thermal Comfort

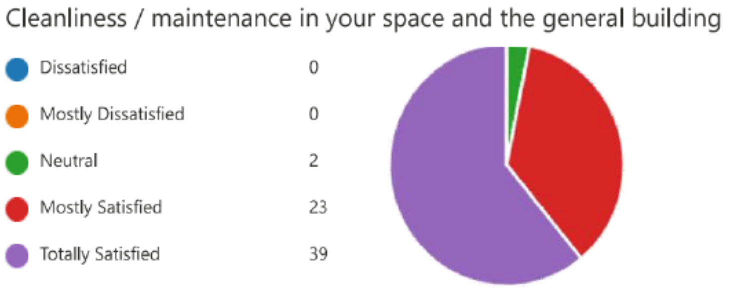


The chart represents the results of questions pertaining to thermal comfort conditions within the building. Based on these results, 9.3% of respondents were dissatisfied with thermal comfort. No corrective action is required, however building management recognizes that this represents a significant level of dissatisfaction, so possible repairs and improvements will be investigated. Building engineers will also make an effort to verify temperature set points in the relevant building zones and communicate with building occupants if complaints persist

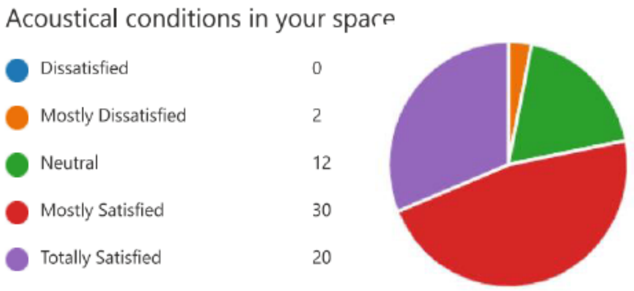


Lighting Quality: The chart represents the results of questions pertaining to lighting quality conditions within the building. Based on these results 4.68 % of respondents were dissatisfied with lighting comfort. Hence No Corrective measures are required for lighting conditions as during predesign stage lots of daylight analysis are done to design an efficient façade according to orientation.

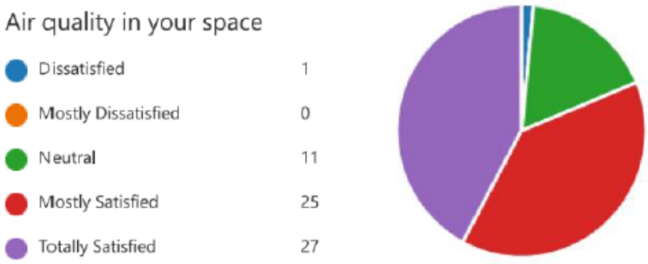
Building Cleanliness: The chart represents the results of questions pertaining to building cleanliness. Based on these results, 0% of respondents were dissatisfied with building cleanliness. This is largely due to the implementation of a building green cleaning and waste/recycling program.



Acoustics: The chart represents the results of questions pertaining to acoustical comfort. Based on these results, only 3.1% of respondents were dissatisfied with acoustics in the workplace.



Indoor Air Quality: The chart represents the results of questions pertaining to indoor air quality. Based on these results only **1.5%** of respondents were dissatisfied with air quality in the workplace.



As per the analysis building is exceling in lighting quality, indoor air quality, Building Cleaning and Acoustics parameters. There is scope of improvement in Thermal comfort. The thermal comfort conditions also do not require as such any corrective action, however building management system shall keep on observing the scope of improvements. Building engineers will also make an effort to verify temperature set points in the relevant building zones.

Recommendations:

- **Tailored Approaches:** Implement mixed-mode cooling solutions based on the specific needs and characteristics of each space within the building. Consider factors like occupancy patterns, orientation, and climate conditions to optimize system performance. **Impact –** High, Tailoring cooling solutions to each space maximizes efficiency and comfort.
- **Integration of Passive Design:** Incorporate passive design strategies, such as shading devices, orientation, and natural ventilation, in conjunction with mixed-mode cooling. This holistic approach ensures a balanced and energy-efficient solution. **Impact –** High, Combining passive design with mixed-mode cooling yields energy savings and comfort benefits.
- **Renewable Energy Integration:** Whenever feasible, integrate renewable energy sources like solar panels to offset energy consumption. This not only contributes to sustainability but also enhances the overall energy performance. **Impact –** Moderate to High, Integrating renewables can significantly reduce energy consumption and enhance sustainability.
- **Monitoring and Analysis**: Continuously monitor and analyze energy consumption data to identify any deviations from expected performance. Regular assessments allow for prompt adjustments and improvements. **Impact –** High, Continuous monitoring leads to prompt adjustments, improving overall system efficiency.

- **Occupant Engagement**: Educate occupants about the benefits and functioning of mixed-mode cooling systems to encourage responsible usage and enhance their overall experience. **Impact –** Moderate, Educating occupants promotes responsible usage, affecting energy consumption positively.

Lessons Learned:

- **Context Matters:** The success of mixed-mode cooling systems is closely tied to local climate conditions, building orientation, and occupant behavior. Contextual factors significantly influence system effectiveness. **Impact –** High, Local factors greatly affect system success; understanding them is crucial.
- **Balancing Act:** Achieving optimal balance between natural ventilation, mechanical cooling, and thermal comfort is essential. Overreliance on any single approach can lead to suboptimal outcomes. **Impact –** High, Striking a balance between cooling methods ensures optimal results.
- **Break the conventional approach:** Flexibility in system operation and control is crucial. Mixed-mode systems should be used as per changing external conditions and occupant preferences. Lack of fresh air integration reflects in Indoor air quality. Use of mix mood cooling system promotes 100% fresh air and helps to improve indoor air quality in terms of occupant comfort. **Impact –** Moderate to High, Flexible operation aligns with changing conditions and enhances indoor air quality.
- **Maintenance Planning:** Proper maintenance and upkeep of passive components like shading devices and natural ventilation openings are essential to ensure continued system effectiveness. **Impact –** Moderate, Proper maintenance sustains system effectiveness over time

Best Practices:

- **Holistic Design:** Approach cooling system design holistically by considering architectural, mechanical, and renewable energy solutions in tandem for maximum synergy and efficiency.
- **Energy Modeling:** Utilize energy modeling software to accurately predict the performance of mixed-mode cooling systems under various scenarios. This aids in making informed design decisions.
- **Collaborative Approach:** Encourage collaboration among architects, engineers, and occupants to ensure that the design, implementation, and operation of mixed-mode cooling systems align with the intended goals.
- **Continuous Improvement**: Regularly assess the system's performance post-implementation and seek opportunities for optimization. Feedback loops enable ongoing enhancement.
- **Occupant Comfort**: Prioritize occupant comfort alongside energy efficiency. A comfortable and productive indoor environment is a key indicator of the success of mixed-mode cooling solutions.

In future projects can embark on the implementation of mixed-mode low-energy cooling systems with a well-informed and strategic approach, ultimately achieving both energy efficiency and occupant satisfaction.

Acknowledgement

We would like to express our heartfelt gratitude to the individuals and organizations whose invaluable contributions made this case study report on "Mainstreaming the Integration of Low-Energy Cooling Systems in Conjunction with Solar Passive Design" possible. Their dedication, expertise, and unwavering support have played a pivotal role in the successful completion of this project We extend our deepest gratitude to the Mr. Shrikrishna Karkare, whose visionary leadership and unwavering commitment to sustainability made this endeavor possible. Mrs. Alka Karkare, your dedication to environmentally responsible design has set a precedent for the industry, and Mr. Anuj Karkare your support throughout this project has been truly instrumental. We would like to acknowledge and thank our architect, Ar. Usha Rangarajan, whose innovative design concepts and architectural prowess have set the stage for this groundbreaking case study. Your ability to seamlessly merge aesthetics with sustainable design principles has been fundamental in achieving our project's goals. A sincere appreciation goes to our HVAC consultant, Mr.Sachin Wadkar, for your expertise in low-energy cooling systems and your invaluable contributions to optimizing indoor comfort while minimizing energy consumption. Your insights and recommendations have been indispensable in the success of our project. We are grateful to our electrical consultant, Mr. Krushna, for your meticulous attention to detail and your role in seamlessly integrating electrical systems with our energy-efficient design. Lastly, I would like to emphasize that the triumph of this case study report is a testament to the remarkable synergy and dedication of this collaborative team manahed by Mr. Vilas Phalke. In conclusion, We want to convey our profound gratitude to all who have contributed to this endeavor. Your commitment to sustainable design and energy efficiency will undoubtedly leave a lasting legacy in the fields of architecture and environmental conservation.

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Comparative Assessment of VFD Driven Energy Efficient Synchronous Reluctance & Induction Motor At Partial Loads

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Abstract

Today, 45% of all electricity is converted into motion by motors in industries and commercial buildings . The integral optimization of electric-motor-driven systems, including the use of high-efficiency, well-sized components is the key strategy to effectively maximize their overall efficiency. Equipment's are designed and sized accounting for various contingencies and extreme scenarios, resulting in under utilization of their capacities during normal operation. Though the higher cost of purchase for oversized equipment is justified, most of the equipment including motors have low efficiencies in part loads. While the standards continue to focus on rated load efficiency, any attempt to improve the part load efficiency also has major contribution towards energy savings. Using variable frequency drives has helped mitigate this problem to a large extent by running the loads at desired duty points without mechanical controls like valves and dampers. This surely is also saving tremendous amount of energy from the driven equipment perspective. However, the popular industrial workhorse squirrel cage induction motor running at partial loads has low efficiency. Advanced motor technologies like Synchronous Reluctance motors (SynRM), Permanent magnet assisted Synchronous reluctance Motors (PMASR) allow improving energy efficiency of many industrial applications even at part loads. This case study compares VFD driven cage induction motor and SynRM at part loads. Considering the motors for variable torque loads operated with VFDs, this case study shows that SynRM motors outperform induction motors in achieving better efficiencies at part loads. Where SynRM motor and VSD packages really shine, is when the loads are running partial and saving every unit of energy is essential. This study would help to choose the right motor based on the actual load profile benefits of high-efficiency motors and drives; all stakeholders have critical roles.

The Vital Role of High Efficiency Motors and Drives In Reducing Energy Consumption

It is estimated that by 2050, the global economy is expected to more than double. Urbanization, automation, and the rise of living standards will increase the demand for energy globally. If we continue with business as usual, this scale of expansion will accelerate climate change, and degrade the quality of air and water upon which all living organisms depend. To protect the environment without tempering economic growth, we need to redouble our commitment to reducing the consumption of energy and natural resources. In keeping with global trends, the demand for electric motion, i.e., drive systems powered by electric motors, is expected to grow significantly. According to the IEA, industry accounts for 37% of global energy use and 24% of global CO2 emissions, and buildings account for around 30% of energy consumption and 28% of CO2 emissions. A large proportion of this activity is associated with electric motors. It is estimated that roughly 70% of electricity consumed by industry is used by electric motor systems (Fig 1). In commercial buildings, 38% of electric energy consumption is for motors[12].

Electric motors have been in use for 150 years, they have undergone a period of exceptionally rapid technological advancement in the last decade. An expanding range of highly energy-efficient electric motors (rated IE3 or higher) and the variable-speed drives are playing significant role in energy savings. These technologies hold the key to enabling many of the signatory countries of the Paris Agreement to meet their carbon reduction targets over the course of the next 10 years[2]. The scope of their impact is potentially enormous. But to realize the full benefits of high-efficiency motors and drives, all stakeholders have critical roles.

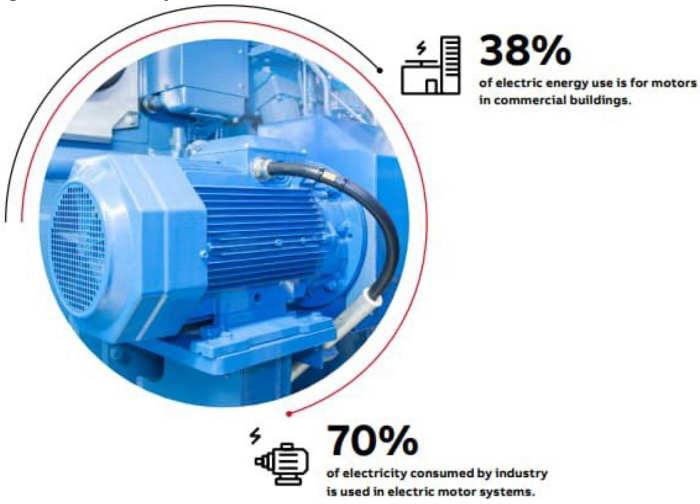

Fig-1: Estimated electric energy consumption by motors.

Why Low Voltage Motors Matters?

Motors are used extensively in industry, for pumps, conveyors, fans, and mechanical motion of all kinds. The largest electric motors are found in railway engines, cable cars, ship propulsion systems, and heavy equipment of the sort used for mining and paper mills. While large motors, drawing more than 375 kW of power, represent only 0.03% of all motors in use, they nonetheless account for about 23% of all electric consumption by motors globally, or 10.4% of all electric power usage[13]. Most of the electric power consumed by motors is used by mid- sized motors. Many of these are larger than necessary for the applications at hand and are often run at full speed, even when the extra power is not needed. Roughly 75% of the industrial motors in operation are used to run pumps, fans, and compressors, a category of machinery that is highly susceptible to major efficiency improvements (Fig 2). The potential reductions to be achieved in energy consumption and carbon footprints are dramatic, to say the least.

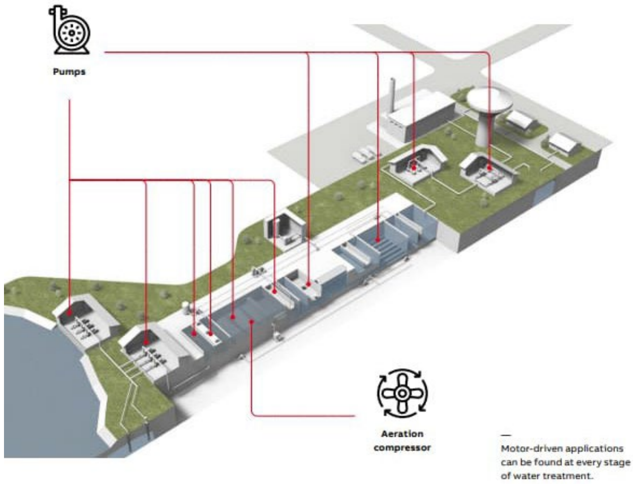

Fig-2: Motor-driven applications can be found at every stage of water treatment.

Motors are at the Forefront of Global Efforts to Improve Efficiency and Reduce Emissions

Modern induction motors are available at very high levels of efficiency. Motor efficiency is rated according to a scale published by the International Electrotechnical Commission (IEC). (Fig 3) Motors categorized as IE1 or IE2 are comparatively inefficient. A 200 kW AC induction motor that meets the IE3 standard achieves roughly 96% efficiency. Some of the very latest motors meet the IE4 standard, which specifies energy losses about 15% lower than those delivered by IE3 motors, and the more recent IE5 "ultra-premium efficiency" motor represents the highest level of efficiency that has been met by any current design.

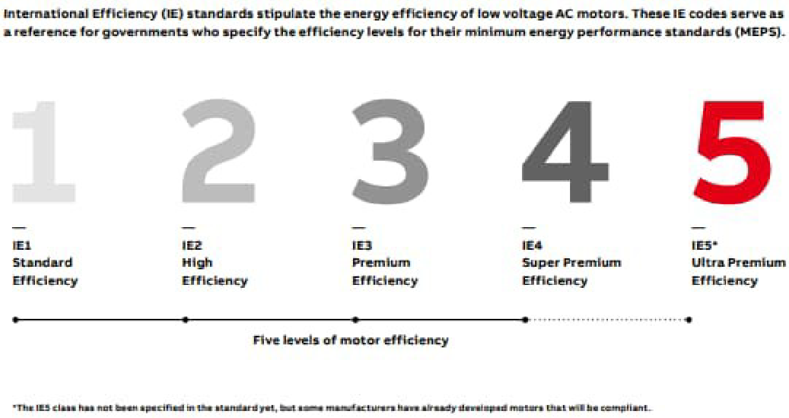

Fig-3: Five level of motor efficiency

Advanced Technologies to Meet High Efficiency in AC Motors

Understanding the options for higher efficiency motor and drives is a good first step. Variable speed drives, by design, are typically very energy efficient. There are losses in any drive, but when compared to the energy savings versus running motors direct-on-line, these losses are easily offset. Motor efficiencies focus on mitigating various losses. Reducing those losses saves energy. Currently, there are three mainstream motor efficiency options.

Adding active materials in Induction Motors.

Induction motors are most widely used technology and has been the first choice (Fig 4). Increasing induction motor efficiency is typically achieved by adding more active (usually copper) materials to the stator windings. The induction technology and motor construction are the same, so no changes are needed with the familiar maintenance schedules/workshops. However, the added copper in the stator may increase the core length and frame size, and will increase motor weight, both considerations for machine builders. However, since all the five major losses in the motor i.e., Stator losses, rotor losses, stray load losses, friction & windage losses & copper losses are still present, going forward it is impossible to meet the efficiencies beyond IE4[5].

Fig-4: Induction motor

Use permanent magnets

The second option is to use permanent magnet motors. Rare earth permanent magnets are designed into the motor's rotor, eliminating the need for a magnetizing current (Fig 5). Because of this, there is no rotor current and therefore very little heat being transferred to the rest of the motor and bearings. This immediately improves motor energy efficiency.

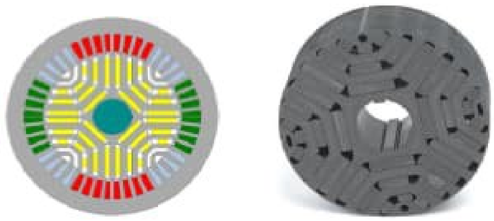

Fig-5: Permanent magnet motor

However, unlike induction motors, permanent magnet motors require the use of a variable speed drive to control the motor. The drives continuously change the stator magnetic field resulting in rotation. The rare earth magnetic material resources are scarce, in high demand for other applications thus setting a high variability in their prices based on market conditions, setting a variability in their price. Over a period, due to demagnetization, magnetic properties of Permanent magnets will deteriorate. Additionally, maintenance becomes more challenging. Considering that the PM rotors have strong magnetic forces, they need careful and expert handling to avoid any

damage to its properties as well as equipment which can have influence of high magnetic field. During planned maintenance this may result more time that the motor is not available for the process. It's important to consider these costs across the lifetime of the motor. Several other PM solution technologies like line start PM motors exist, however with limited application and range.

Best of both worlds

Alongside induction motors, some highly efficient newer motor designs are establishing themselves as practical alternatives. Among these is the synchronous reluctance motor, which combines the performance of a permanent-magnet motor with the simplicity and service-friendliness of an induction motor. Unlike permanent- magnet motors, synchronous reluctance motors do not require the use of rare earth-based components. Instead, they achieve a maximized reluctance torque from a simple but robust rotor design. It's the motor's rotor design that makes this possible. Using the stator similar to induction motor, the rotor is replaced with a specially designed rotor that aligns with the stator's magnetic field. Like permanent magnet motors, SynRM motors also require the use of a variable speed drive to control and runs at synchronous speed. The drive calculates the offset angle of the magnetic field, resulting in rotation. As there is no need for a rotor magnetizing current, the rotor runs cooler and results in less heat transferred to the motor and bearings. This also ensures that the motor relatively runs at lower temperatures, thereby contributing significantly for lower lifecycle cost (Fig 6).

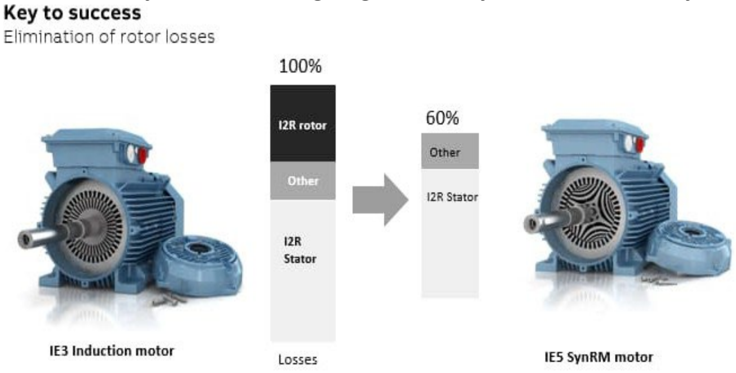

Fig-6: IE5 SynRM rotor losses

The structure of a synchronous reluctance motor from outer view of SynRM motor is similar to a traditional induction motor. Even the stator design and manufacturing are similar to induction motor. The innovation is in the rotor. The rotor is made from laminated iron layers which form a light but solid construction that allows magnetism to flow through it. The shape is precisely designed to guide magnetic reluctance within the rotor. As a result, the rotor will align itself to the magnetic flux produced by the stator coils, essentially "locking" into position. This enables the rotor to rotate at exactly the same speed as the magnetic flux, i.e., synchronously, hence the name synchronous reluctance motor. The rotor does not contain magnets or rare earth-based components and is more sustainable than traditional motor. The rotation of the magnetic flux produced by the stator and thus the speed of the rotor is controlled by a VFD. The drive monitors the rotor position, to ensure it stays synchronized.

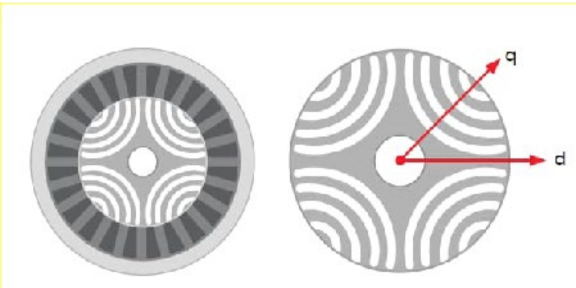

Fig-7: Torque Production in SynRM

The torque produced by a synchronous reluctance motor is proportional to the difference between the inductances on the d- and q-axes: the greater this difference, the greater the torque production. Synchronous reluctance motors are therefore designed with magnetically conductive material, iron, in the d-axis and magnetically insulating material, air, in the q-axis (Fig 7).

Partial Load Efficiencies and their Significance in Variable Loads

The main parameter of the operating mode of the pump unit is the flow rate Q. In many cases, the flow rate should significantly change during the process cycle within the range of 25-100 % of its rating value Q rate. So, all system components, such as a pump, frequency converter and a motor, should also work far from rated modes. At analyzing typical pump loading cycles, the efficiency of a pump unit at fractional loads is of no less importance for the assessment of resultant power consumption than the rated loading efficiency in most cases.

- 6% of running time at 100% flow rate(Q)[8]
- 15% of running time at 75% flow rate(Q)
- 35% of running time at 50% flow rate(Q)
- 44% of running time at 25% flow rate(Q)

From this study the full load efficiency of a system is not the most important parameter, when most pumps, most of the time is running in part load. Introducing part load, suddenly moves the focus from single component full load efficiency to a system efficiency approach with a time/load profile including the different energy consuming elements like drive motor and pump. This approach is known as: Extended product approach when it comes to standardization initiatives. Ecodesign on motors and drives are taking the first step now. Pumps are next in line to use the part load data from motors and drives and more applications (fans/compressors etc.) will come, all to the benefit of the customer focusing not only on full load efficiency of the components, but on system efficiency including part load. Today it is challenging to compare full efficiency performance of different motors. Motor losses in partial load conditions are not available easily in VSD duty today. Regulation EU 2019/1781 (Ecodesign directive)[15], Manufacturers need to give the losses in these points for the motor (1.7.2022) and drive (1.7.2021) This enables motor to motor comparison in partial load conditions with VSD (variable speed drive) duty. (Fig 9)

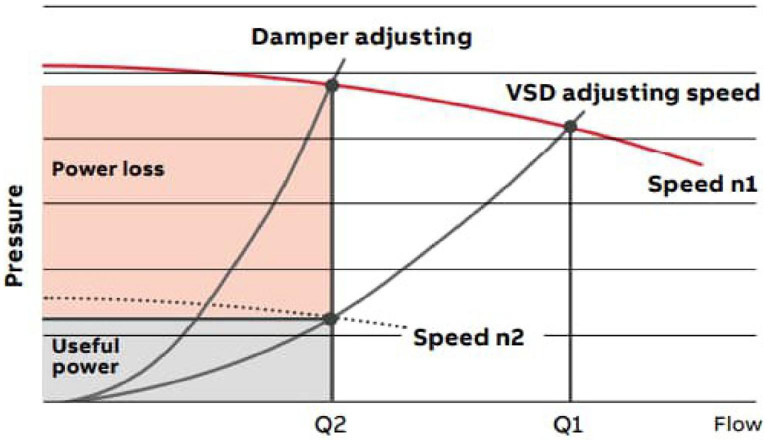

Fig-8: Power consumption changes with decreasing the flow rate from Q1 to Q2 with a damper and a VSD

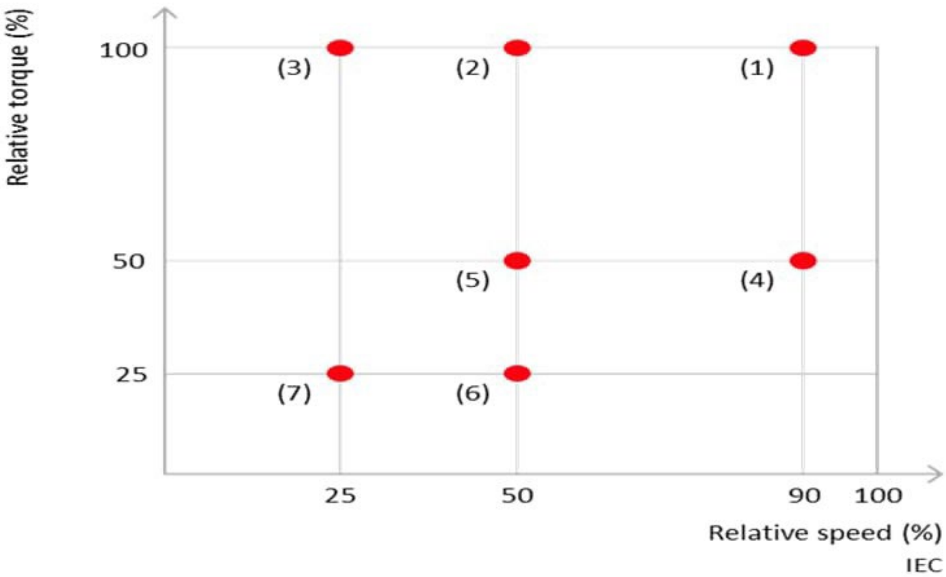

Fig-9: IEC 60034-2-3 [7]

Points (3), (2) and (1) are mostly relevant for constant torque applications (conveyor belts, lifts, hoist drives) at full load and test points (5) and (4) are relevant at half load.

Points (7), (6), (5), (4) and (1) are mostly relevant for quadratic torque applications like fans, pumps and compressors.

Synrm Motor and Drive Package – Perfect Solution for Part Load Efficiency Requirements

SynRM motors offer flat efficiency curves and considerably higher efficiencies at part loads. Though IM technology has been irreplaceable from centuries, it is also essential to explore the new technologies and start accepting them gradually to meet IE5 efficiency. To meet the stringent demands of energy efficiency & carbon emissions, there is need to slowly cut down the losses. SynRM motors are best suited in such scenario where it experiences no-rotor losses thereby improving the efficiency significantly. A VSD controls and optimizes the operation of a motor, varying the frequency and voltage of the electricity fed to the motor to adjust the torque and speed. Because VSDs control the speed of the motor directly, no valves, gears, throttles or brakes are needed to control the speed of the application the motor is powering. This means that the motor does not need to run at full speed all the time, and it means that no energy is wasted through mechanical speed control. Therefore, motors controlled by VSDs can save a lot of energy compared to motors without drives. A VSD can save 50% or more of the energy in applications that use pumps or fans. (Fig 8)[1]

Fig-10: IE5 SynRM motors

Partial load efficiency

The Flat efficiency characteristics of IE5 SynRM motors are best suited especially in the applications where motors run at part loads. According to the new Regulation EU 2019/1781 (Ecodesign directive) manufacturers need to give the losses in specified load points for the motor (1.7. 2022). This will enable the users to have clear comparison between the different technologies and select the one which has least lifecycle cost. The graph below demonstrates the comparison made between Induction Motor of IE3 efficiency and SynRM motor of IE5 efficiency with drive. There is about a 2% of benefit at full load[3], while at partial load the benefit can be as much as 6-7%.

IE5 SynRM versus IE3 induction motors in VSD duty

ABB laboratory measurements already show that SynRM motors have an advantage over IE3 motors, also in the partial load conditions, and the advantage becomes even greater when compared to the nominal point. The figure:11 shows the typical efficiency performance of SynRM IE5 versus an IE3 induction motor in pump/fan duty. Tests conducted in the laboratories to determine the efficiency of SynRM motors and IM shows significant reduction in losses of a SynRM motor. Test was conducted on a 110kW 4 Pole IE3 IM and IE5 SynRM motor, where both the motors were tested at seven different partial loads & speeds as recommended by IEC 60034-30-2.

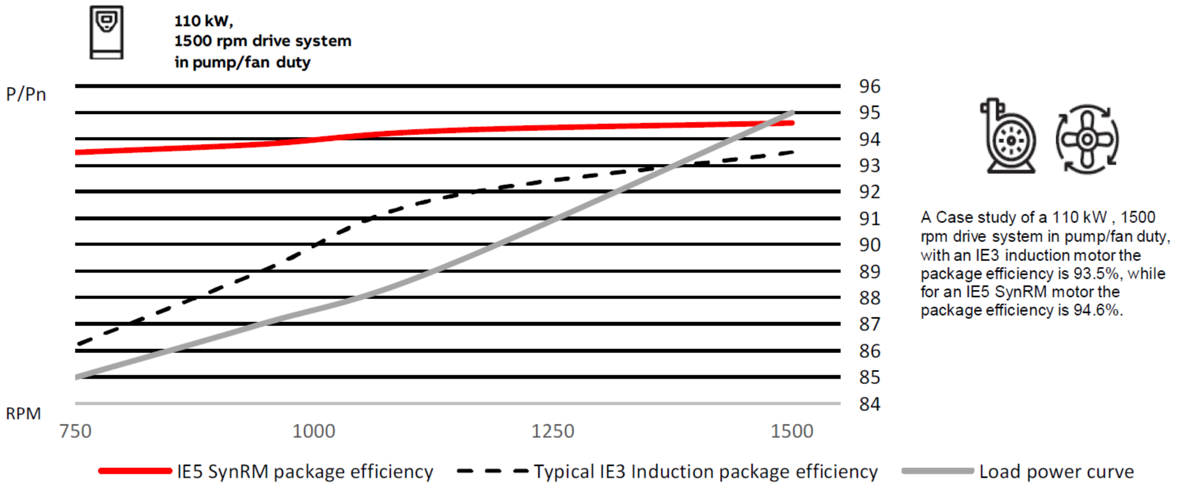

Fig-11: IE5 SynRM versus IE3 induction motors in VSD duty

Considering that the pumps are run at 50% of speed for 35% of total running hours, the test results show that the SynRM motor together with drive as a package delivers 93.5% efficiency whereas IE3 induction motor and drive as package delivers 86.20% efficiency[9].

In the case study, it was observed that, during full range of operation, SynRM motor had variation in losses of approx. 2% and the IE3 induction motor had the variation of approximately 7%. In IE5 SynRM motor, operating point at part loads & partial speeds can be optimized to achieve minimum current which results in better efficiency and Power factor. Also changing voltage does not increase or decrease slip in anyway (as the motor runs at synchronous speed), thereby no additional losses are introduced. SynRM also has the benefit of having lower weight. In this case even comparing IE5 SynRM to IE3 Induction motor, there was around 5% reduction in weight. For same efficiency class SynRM motor would a one or two frames lower than traditional induction motor.

Challenges in Current Technologies and Mitigations

Though Induction motors are best fit for most of the applications and are user friendly, they have limitations while reaching efficiencies beyond IE4. This opens the opportunity to explore new technologies & hence the SynRM motors. However, SynRM motors suffer with relatively lesser power factors when compared with other technologies. Which can lead to increase in drive sizing, Since SynRM are always run with VSD, the power factor at the drive input is however still within limits, as the drive's dc link provides the power factor improvement.

Permanent Magnet Assisted SynRM motors technology combines the advantages of SynRM and permanent magnet motors, while mitigating the challenges of both the technologies. A unique feature of this motor is that it uses ferrite (iron oxide, Fe_2O_3) magnets, which are generally more cost effective and more easily available than rare-earth permanent magnets. Their use results in a more economical and ecologically sustainable product. Ferrites have been used before in low power motor applications, but in industry a ferrite-based motor alone could not compete against an IM due to challenges in manufacturing wider range of power requirements[16].

Benefits of SynRM technology

Conclusion

This paper has compared the efficiencies of IE3 induction motor and IE5 SynRM motor at part loads for variable torque loads driven by VFD. In both the motors as the copper losses are dominant, the motor efficiencies are speed dependent. Result of the case study gives us more clarity on relatively flat efficiency behavior of SynRM motor over induction motor at part loads. There has been a significant improvement of efficiency in part loads which as per the test shows 6-7% at 50% rated speed in 110kW, 4 Pole motor considered for testing. It is also observed that the drive system losses are much lesser compared to motor losses and hence the motor-drive system efficiency resembles to motor losses[17]. Apart from the economic effect of energy savings, application of SynRM motors also provides the following: as a result of low heat losses from rotor the wear of bearing assemblies of motors is decreased. Besides, reliability and operational period of a motor due to absence of rotor winding and due to lower thermal load of stator winding insulation increases as well. SynRM motor manufacturing is more sustainable and better meets circularity requirement. The next step of this study is to improve the overall performance of the SynRM, by implementing Ferrite magnets in the rotor barriers and aid to improve the power factor. For governments and municipal decision makers, it’s important to know that more energy efficient options are already available, and the decision should be easy. What’s needed now is the will to adapt ourselves to the latest technologies making energy efficient solutions the easiest, most preferred option[3].

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[15] Regulation EU 2019/1781 (Ecodesign directive)

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Success Stories

Promoting new concepts by collaborating with end-user. Integrated solution with Synchronous reluctance motor (SynRM) and drive for improved energy efficiency beyond IE4.

Customer: Orchid Laminates, Bangalore,

Application: For pulper pumps application at Kraft Paper Division, Harohali Industrial Area, Bangalore

Sys. Integrator: Rcube Electric

ABB offering: ACS580-01-145A-4+J425 – 1 unit, SynRM Motor for 55 kW - 1 unit with smart sensor. **Benefit:** Energy saving of approx. 13% compared to conventional running with additional improvements in process and reliability

ABB enables Tarkett to improve energy efficiency by more than 15%

Tarkett's vinyl flooring factory in Ronneby, Sweden, is using ABB data insights and service expertise to save 800 megawatt-hours (MWh) of energy per year from their motor-driven systems. This is around 1 percent of the site's total energy consumption in a year and is equivalent to the energy needed to charge 68 million smartphones for the same amount of time. With the data gathered through the ABB Ability™ Digital Powertrain Energy Appraisal solution, ABB identified that upgrading 10 motors to IE5 SynRM technology would boost efficiency from 80 to 95 percent. With the current energy prices, the payback period would be only 18 months or less.

ABB’s SynRM motors are a perfect match for Rodelta’s high efficiency drinking water pumps.

Dutch pump manufacturer Rodelta has introduced drinking water pumps powered by ABB’s SynRM motors. The pumps feature diffuser technology and are designed with a wide operating range to handle large variations in water demand. SynRM motors have proven to be a great fit for the application.

“We supply our LS diffuser pumps for drinking water pumping stations because they offer high efficiency over a wide operating range. ABB SynRM motors are ideally suited for driving the pumps - they are very efficient across the entire range.” says Andre van der Moolen, Sales Engineer, Rodelta.

There are clear reasons why Rodelta focuses on this type of technology in the drinking water pump market. The pumping stations often run 24/7, so efficient equipment can quickly produce big energy savings. In terms of total cost of ownership, the motor and pump typically account for around 20 percent of total lifetime costs, with energy consumption making up the remaining 80 percent.

SynRM and Drive package lift Energy Efficiency in Husum

Husum mill outside Örnsköldsvik on the Swedish east coast produces folding board, white kraft liner and pulp. Energy-efficient operations are a prerequisite for the company to be able to meet sustainability goals.

“We want to be at the forefront of the industry in this regard. Metsä Group have a visionary view of achieving low energy consumption, and the most effective way to achieve our self-sufficiency targets is to use less energy while producing the same amount of product. That is why the SynRM project is important: by choosing energy- efficient engines, we get higher availability and lower energy consumption at the same time,” explains Agrell.

Saving energy 365 days a year

When the mill needed to upgrade their six aging 30kW DC motors – used to drive the filter drums in one of the bleachers – the choice was between IE2-standard induction motors and synchronous reluctance motors.

“These are engines that are in operation almost 365 days a year,” explains Elias Agrell, automation engineer at Husum. “If we can save even a few percent energy, during the life of the engine it adds up to significant savings in costs and energy.”

SynRM is ABB’s most energy efficient motor choice for controlling the speed of intensive operations such as pumps and fans. Thanks to the combination of conventional technology, innovative magnet-free rotor construction, and robust construction, the motor meets the IE5 ultra-premium energy class criteria.

While the system efficiency of the IE2-rated induction motor is 88.6%, for the SynRM package it amounts to 93.1%. This equals a loss reduction of over 60% compared to IE2 motors, as well as reduced maintenance costs.

Device Health: Quantifications and improvements thereon

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Abstract

Today, 45% of all electricity is converted into motion by motors in industries and commercial buildings . The integral optimization of electric-motor-driven systems, including the use of high-efficiency, well-sized components is the key strategy to effectively maximize their overall efficiency. Equipment's are designed and sized accounting for various contingencies and extreme scenarios, resulting in under utilization of their capacities during normal operation. Though the higher cost of purchase for oversized equipment is justified, most of the equipment including motors have low efficiencies in part loads. While the standards continue to focus on rated load efficiency, any attempt to improve the part load efficiency also has major contribution towards energy savings. Using variable frequency drives has helped mitigate this problem to a large extent by running the loads at desired duty points without mechanical controls like valves and dampers. This surely is also saving tremendous amount of energy from the driven equipment perspective. However, the popular industrial workhorse squirrel cage induction motor running at partial loads has low efficiency. Advanced motor technologies like Synchronous Reluctance motors (SynRM), Permanent magnet assisted Synchronous reluctance Motors (PMASR) allow improving energy efficiency of many industrial applications even at part loads. This case study compares VFD driven cage induction motor and SynRM at part loads. Considering the motors for variable torque loads operated with VFDs, this case study shows that SynRM motors outperform induction motors in achieving better efficiencies at part loads. Where SynRM motor and VSD packages really shine, is when the loads are running partial and saving every unit of energy is essential. This study would help to choose the right motor based on the actual load profile benefits of high-efficiency motors and drives; all stakeholders have critical roles.

Device Health: Quantification and improvements thereon

To find the separator that distinguish healthy devices from unhealthy ones

Introduction

Smart meters and plugs have gained quite a foothold in modern times. They help households keep a track of their energy consumption by providing real time energy consumption data as well as device level disaggregated energy data. However, they do not provide insight into long term performance of devices. It is quite possible that the performance of a device starts to deteriorate over a period of time and households are still oblivious to it. To this end we hypothesise that there is a natural decrease in the performance of devices over a long period of time. We characterise it by the term 'health' of an appliance(discussed in detail in later section). This study aims to quantify the 'health' parameters of one such major appliance, air conditioners. Furthermore, we also investigate if and how servicing of air conditioners has an impact over their health.

Approach

Definition: Health of a device would mean different things to different stakeholders. Health can be extended to mean physical condition of a device or even its safety and maintenance history. We restrict ourselves to something achievable: long term deviation of a device's Active Power(AP) (AP is the amount of total electric power which is exploited and consumed in doing a work is called active power also known as real power or true power and is measured in Watts (W)) and Reactive Power (RP)(RP is the part of total electric power which flows backwards and forwards between the source and the load in an electric circuit and it is also known as useless power, as it does nothing in a circuit consumption) can act as a proxy for health.

Methodology: We start with a wide selection of AC's as identified by Urban Company. The AC's were mostly the ones that were ripe for servicing i.e. they needed repairs of some sort. We collect these AC's and operate them and collect the data over a wide variety of externalities. The parameters to be varied are temperature, area of the room and humidity. Note that these experiments are to be performed in a NABL lab. For the collection of data we rely on smart plugs at first and maybe multi-channel sensors in future. We are mostly interested in long term changes in AP and RP data. The variation in external parameters are meant to be a catch-all term to ensure that the full spectrum of external parameters are captured in the experiment. This would ensure that the separator would be purely a separator of our defined 'health'. However, in order to keep our experiments simple, we fix the external parameters by running the AC's for 8 hours keeping ambient room temperature at 32°, RH at 75%, and ambient outside temp at 48°. We collect the data for pre and post servicing and compare the results.

Thereafter, we get the AC serviced by Urban Company to the extent that faults are removed to the maximum extent possible. We then make the AC's run under the same set of external conditions(Temperature, humidity and others). We record the AP and RP outputs as before. With both before and after servicing data, we hope to find the separator.

Overall ageing/health hypothesis:

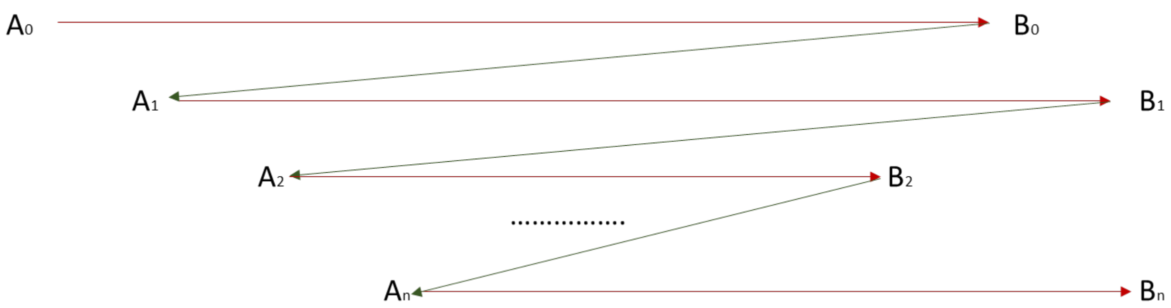

Fig1: Explaining the assumed state change of air conditioner over a period of time.

The health of an AC could deteriorate from A_0 (set of healthy AC at a particular period of time) to B_0 (set of unhealthy AC) over a period of time due to wear and tear, dust accumulation or other externalities. For the current experiment, we would avoid the unknown external influencers and would only limit it to operational or maintenance parameters.

In an ideal scenario, we would prefer to initiate an accelerated ageing process and service it in order to obtain the full cycle performance. A relatively simpler problem to solve would be de-aging of the appliance which is what we perform in our experiments.

De-aging of the appliances

In Phase 1, we would assume that the AC would already be at B_0 or tending to B_0. The impact of servicing of the AC could be measured with B_0 - A_1. A_1 should tend towards A_0. The baselining of the ML algorithm is critical to ensure that the bot is able to validate that the new state (post-servicing) should always be closer to the previous healthy state: (A_0-A_1) < (A_1-B_0).

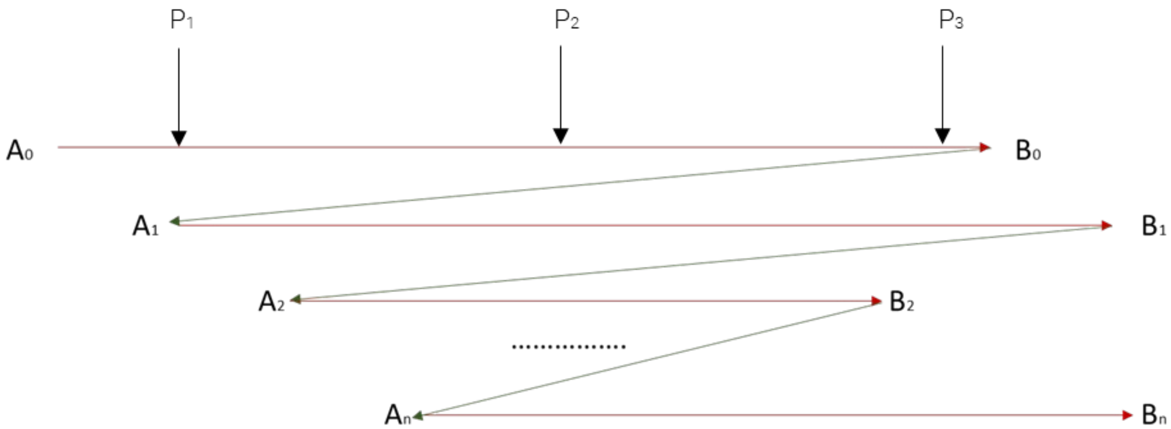

Fig2: Potential points of intervention during the experiment (P_1, P_2 & P_3) could be at any point in the cycle over a period of time.

It is important to note that the the AC that we have sourced by Urban Company have met the following criteria:

- P3 state is most desirable where P3 tends towards B0.
- P3 could be defined as a state where the deterioration could be physically observed or the user would have already complained about the cooling experience.
- The experiment should be repeated with multiple AC's of different technologies, capacities, age and types.
- P1 to A1 experiments could also be conducted in the lab to cover a spectrum of use-cases.

Results

The tables 1, 2 and 3 detail the results that we obtained through our experiments. Table 1 specifically, talks about the initial conditions of the various air conditioners. Table 2 discusses the various lab parameters such as relative humidity, indoor and outdoor dry bulb temperature as fixed for out balanced calorimeter experiments.

Initial Conditions	AC 1	AC 2	AC 3	AC 4	AC 5
Watt Power	1950	750	1900	28	19
Amp	8.5	3.2	7.5	8.0	7.5
Refrigerant	R22	R22	R22	R22	R22
Running Pressure	60 psi	60 psi	120 psi	60 psi	60 psi

Testing Conditions	BEE recomme nd ed Indian Standard	Maximum Outdoor / Indoor temperatur e (Delhi)	Maximum Outdoor / Indoor temperatur e (Kolkata)	Maximum Outdoor / Indoor temperature (Kolkata)	BEE recommended Indian Standard
Indoor Dry Bulb temperature	27	32	32	32	27
Indoor Wet Bulb	19	23	28	28	19
RH	47%	47%	75%	75%	47%
Outdoor Dry Bulb	35	48	48	48	35

Table 1.1 and 1.2: The details about the five AC's involved in the experiments and the corresponding lab setup

Lab Experiment Data	Pre	Post		Pre	Post		Pre	Post		Pre	Post		Pre	Post	
Air Temp Inlet °C	27.00	26.99		32.00	31.95										
Air Temp Discharge °C	13.05	13.43		20.33	18.45										
Cooling capacity (BTU/Hr)	12248	12340	0.75%	4383	6331	44.44%	14822	14981	1.07%	11802	12056	2.15%	8472	17015	100.84%
Cooling capacity (Watt) *[1 BTU/hr=0.293W]*	3589.8	3616.6		1284	1855.6		4344	4390.6		3458.9	3533.5		2483.1	4986.8	
Tonne (TR)	1.02	1.03		0.37	0.53		1.24	1.25		0.98	1.00		0.71	1.42	
Electricity Consumption (Watt)	1751.4	1725.2	1.52%	951.82	1042	-8.65%	2145.80	2139	0.32%	2336.10	2178.6	7.23%	1728.50	1556.7	11.04%
EER (EER - Star Rating correlation)	2.05	2.10		1.35	1.78		2.02	2.05	1.39%	1.48	1.62		1.44	3.20	
Electricity (Power consumption) / TR	1715.9	1677.7		2605.9	1975.0		1737.3	1713.4		2375.3	2168.5		2448.3	1097.9	
Units per day / Tonne	13.7	13.4		20.8	15.8		13.9	13.7		19.0	17.3		19.6	8.8	
Cost Per day (Rs) / Tonne	89.2	87.2		135.5	102.7		90.3	89.1		123.5	112.8		127.3	57.1	
Cost Per month (Rs) / Tonne	2676.9	2617.2		4065.3	3081.1		2710.1	2672.9		3705.5	3382.8		3819.3	1712.7	
Savings per month / Tonne (Rs)		60			984			37			323			2107	
Savings per month / Tonne (%)		2.2%			24.2%			1.4%			8.7%			55.2%	
Savings per season (Rs)		403			4372			248			1572			9961	

Table 1.3 : The experimental result parameters (from Urban Company led experiments)

As it can be observed from table 3.0, we witness improvements in various performance parameters of the air conditioners. Improvements in cooling capacity ranges from 0.75 percent right to 100.8 per cent. Similarly Energy Efficiency Ratio shows improvement from 2 per cent to 120 per cent. A similar pattern is observed with regards to energy savings. In future, we plan to build a machine learning model trainable over the AP and RP data in order to obtain a separator and a predictor between health and unhealthy appliances.

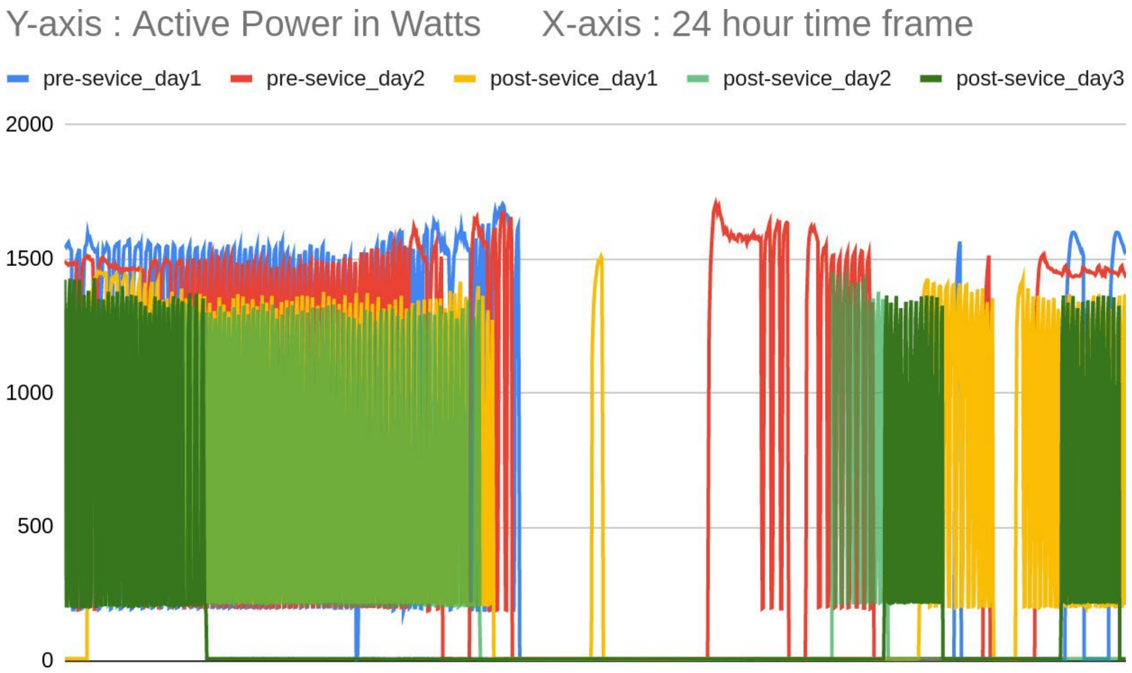

Fig 3 : Depicts a pre and post servicing of a particular AC . We can clearly dissociate the AP consumption by the AC before and after recondition, a downfall of approximately 200-300 Watts in power consumption is observed along with the minimal increase in the base AP

Recommendations

As observed from our experiments, the health of the appliance is a real, quantifiable quantity which affects its energy consumption over long periods of time. We also observe that it is possible to reverse the health of devices through simple interventions such as servicing them in a timely manner. Furthermore, this provides us with confidence to build a machine learning model which would be able to predict current ‘health’ of an appliance as well provide possible servicing prompts to the customers. This can complement smart meters and plug to provide diagnosis rather than just data collection.

Alliance for an Energy Efficient Economy | energise 2023
Lifestyle, Energy Efficiency, and Climate Action

Team SHUNYA: Promoting Eco-Conscious Living with a Net Positive House

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Abstract

Vivaan, situated within the campus of Indian Institute of Technology Bombay, Mumbai, India. Mumbai is categorized under the Tropical Savanna (Aw zone) within the Koppen Climate Classification and warm-humid climate zone as per the National Building Code of India. Vivaan is a Net Positive Energy, Net Zero Carbon, and Net Zero Water residential prototype designed and constructed by Team SHUNYA, a student technical team from IIT Bombay. The building has been awarded multiple accolades for many of its innovative aspects, aimed to create a genuinely sustainable dwelling unit, an attempt at redefining residential construction in India. Vivaan also won the 1st runner-up position out of 32 international teams at the United States Department of Energy Solar Decathlon Build Challenge 2023, held at the National Renewable Energy Laboratory, Golden, Colorado, in April 2023. The house incorporates features unique to the residential building stock in India, extensively utilizes second-life materials, and includes an in-house developed dehumidification system. A proprietary home automation system and accompanying app provide convenient controls for minimizing energy waste and maintaining adaptive thermal comfort levels in the house. The design also implements passive performance measures to maximize energy efficiency and incorporates computational simulations to achieve a data-driven approach. The major problem that this project addresses is the high demand for energy in residential buildings, which has recently started growing at a faster pace due to the effects of climate change. Moreover, Vivaan is designed with a circular economy approach, ensuring the disassembly of the structure and appropriate recycling or reuse after the end-of-life cycle. This system needs to be included in India, as traditional brick-and-mortar construction does not allow for such circularity.

Introduction

The subject of this case study is a newly constructed, 2-storey residential structure named Project Vivaan, situated within the campus of Indian Institute of Technology Bombay, Mumbai, India. Mumbai is categorized under the Tropical Savanna (Aw zone) within the Koppen Climate Classification and warm-humid climate zone as per the National Building Code of India.

Vivaan is a Net Positive Energy, Net Zero Carbon, and Net Zero Water residential prototype designed and constructed by Team SHUNYA, a student technical team from IIT Bombay. The building has been awarded multiple accolades for many of its innovative aspects, aimed to create a genuinely sustainable dwelling unit, an attempt at redefining residential construction in India. Vivaan also won the 1st runner-up position out of 32 international teams at the United States Department of Energy Solar Decathlon Build Challenge 2023, held at the National Renewable Energy Laboratory, Golden, Colorado, in April 2023. The house incorporates features unique to the residential building stock in India, extensively utilizes second-life materials, and includes an in- house developed dehumidification system. A proprietary home automation system and accompanying app provide convenient controls for minimizing energy waste and maintaining adaptive thermal comfort levels in the house. The design also implements passive performance measures to maximize energy efficiency and incorporates computational simulations to achieve a data-driven approach.

The major problem that this project addresses is the high demand for energy in residential buildings, which has recently started growing at a faster pace due to the effects of climate change. Moreover, Vivaan is designed with a circular economy approach, ensuring the disassembly of the structure and appropriate recycling or reuse after the end-of-life cycle. This system needs to be included in India, as traditional brick-and-mortar construction does not allow for such circularity.

Approach

The residential building was constructed between December 2022 and April 2023, aiming to implement and test various energy efficiency measures adopted after different considerations and iterations with the help of multiple simulation-based software. Per preliminary data analysis and calculations, Vivaan is performing as a Net Positive Energy house. As per detailed theoretical calculations, it is also Net Zero Water. It is expected to achieve Net Zero Carbon within the next five years, owing to carbon-capturing measures undertaken in the construction process. With a total carpet area of 1,367 ft^2, or 127 m^2, the residence consists of 2 bedrooms, a dining hall, a functional kitchen, two washrooms, and a double-height living room. The spatial configuration is iteratively derived from floor plans of single-family detached dwelling units found in Mumbai to ensure a resemblance between expected energy demand and physical parameters like room volume and occupancy schedule.

The architectural typology resembles houses found in the coastal regions of Western India, with sloping roofs and inclined shades above windows. In terms of performance, the design and its elements are applicable to coastal areas of India that exhibit similar tropical warm and humid climates. The design incorporates data-informed passive performance measures, such as vertical fins and movable external shading to allow useful daylight intake and reduce heat gains from excessive solar radiation; double height spaces and open floor plan allow for stack effect and cross ventilation, respectively, window sizing (wall-window ratio) and their placement were also iteratively optimized to aid in airflow and natural light. Before the design stage, rigorous micro and macro-climatic analysis of site conditions was performed, and the weather files were calibrated using measured real-time outdoor ambient temperature data acquired on-site.

Figure 2 - Floor plans of project Vivaan

Figure 1 - (a) Exterior view after completion (b) Steel structure of Project Vivaan

Vivaan is carefully designed to ensure the building's resilience against natural and man-made disasters. With a design life of 50 years, the prototype is constructed using precast steel sections for beams and columns, along with prefabricated metal decks for slabs. This decision was taken to ensure disassembling after the end of the design life. Additionally, a raft footing foundation of 1.8 m depth makes up the substructure of the building.

The primary criteria for envelope material selection were the climatic conditions of Mumbai and ECBC compliance. A detailed comparative study of multiple envelope parameters derived from an analytical hierarchical process (AHP), considering thermal transmittance (U-value), embodied energy, local availability, durability, and life cycle cost, was used to select appropriate combinations of materials for wall assemblies. An innovative and low carbon bio-degradable board made of recycled agricultural waste material, named EcoBoard, has been used to reduce the embodied energy of the wall assemblies. The external wall, starting from the outermost layer (Layer 1), is as follows:

Layer	Material	Thickness (mm)	Key Feature	Expected Life (years)
1	Fiber Cement Board (FCB)	6	Durability	30
2	Moisture Barrier	2	Impermeability	50
3	EcoBoard	9	Lower embodied energy	20
4	Fiber wool Insulation	100	Thermal resistance	50
5	EcoBoard	9	Lower embodied energy	20

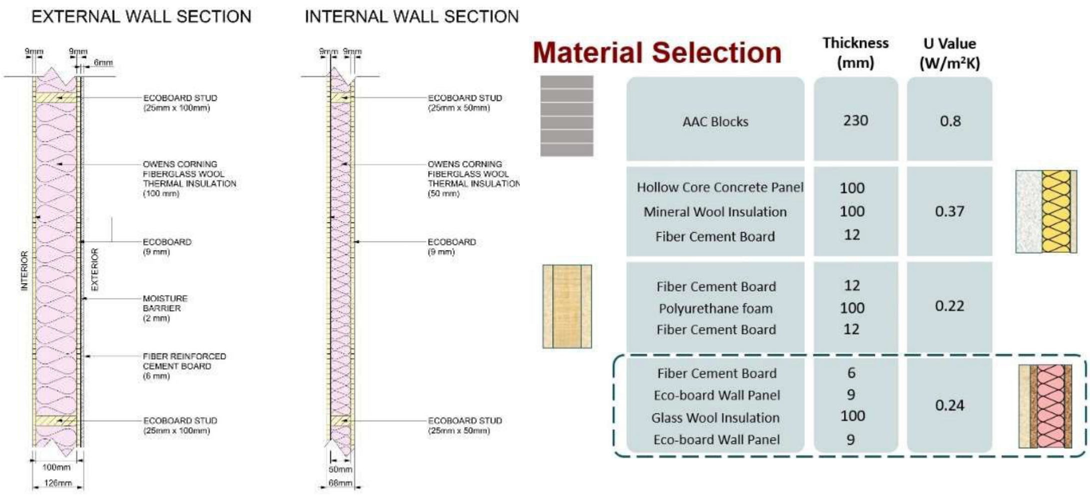

Figure 3 – Wall sections and assemblies considered for envelope and their U-value

The internal wall assembly does not incorporate the FCB and the moisture barrier, and has a reduced insulation layer of 50 mm. The final U-value of the external assembly was calculated to be 0.24 W/K-m^2, which is 70% less than that of AAC blocks, the material used most commonly in modern-day construction in India. The reduction in U-value is the first step to reducing the heat gain in the house; thus, the envelope of Vivaan was designed as per the Energy Conservation Building Code (ECBC) of India. To achieve ECBC compliance, a residential building in warm and humid climate can have a maximum U-value of 0.4 W/m^2-K for opaque external wall assemblies. The maximum U-values for an opaque external wall assembly in the same climatic zone, for ECBC+ and SuperECBC compliance are 0.34 W/m^2-K and 0.22 W/m^2-K, respectively. Vivaan is ECBC compliant with the existing assembly in 4 out of 5 climate typologies and ECBC+ in 3.

A proprietary HVAC system has been deployed, which handles latent and sensible loads separately. A Fan Coil Unit at higher chilled water temperatures with a coefficient of performance (COP) 4.2 handles the sensible load, while the liquid desiccant dehumidification system handles latent loads. This HVAC system has greater energy efficiency when compared to split air-conditioning units primarily used in Indian households. Chilled water and strong liquid desiccant are generated and stored to be used during non-solar hours, and the waste heat produced from the condenser is then used to provide hot water. The system can also be controlled by an automation system created by the team. This system is suitable for application in regions with high humidity and temperatures throughout the year. A significant proportion of central and Southern India exhibits these kinds of climatic conditions, along with the Western and Eastern coasts of the country. The system's efficiency is expected to increase with the simulated increase in demand, meaning that the system is to perform better in multi-family and low to mid-rise housing.

To meet the energy demand of the house, a solar power generation system with 12.96 kWp capacity is designed and installed on the roof. Mono-crystalline bifacial PV panels with a half-cut design were selected due to their higher power output per unit area and long-term durability.

A 28.8 kWh Lead acid battery storage is also part of the system to decrease the overall dependence on the grid. The total cumulative energy demand was calculated by accounting for all appliances, including air conditioning, which came out to be 11.8 kWh daily. The total annual generation of the PV system is expected to be about 13,635 kWh, while the calculated annual energy demand is about 12,484 kWh. Due to the excess energy produced by the system, it was concluded that the house consumes less energy than it produces, utilizing on-site renewable energy generation, making it Net Positive Energy. The solar PV panels are expected to last for 25 years, but the battery for energy storage will need replacement in about five years. Initially, the plan was for Lithium-ion batteries, which can last up to 15 years, but the budget constraints led to the current battery system. A hybrid inverter with a life span of 10 years is used with a solar PV system for trading off excess annually generated electricity.

(All values in kWh)	Min	Average	Max	Annual
Loads	24.5	34.2	44.5	12484
Generation	0.8	37.4	52.3	13635
Feed-in To Grid	0	10.2	26.6	3724
Consumption from grid	0	9.5	33.0	3464

Figure 4 - (a) Solar PV system design (b) Installed bifacial solar panels

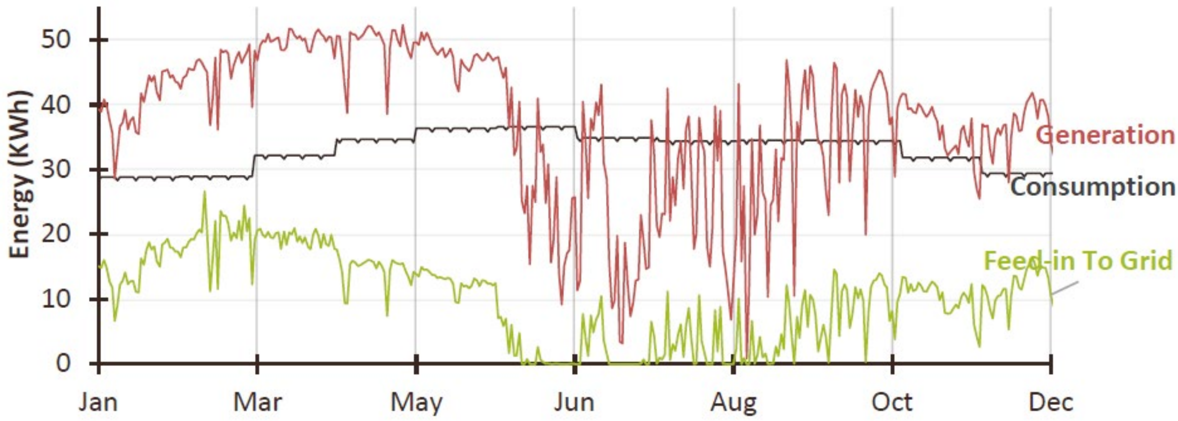

Figure 5 - Annual energy demand and production

Data Collection and Analysis:

Multiple sensors are installed in the house to measure the air temperature, humidity, and CO_2 concentration, and readings are taken at intervals of 10 seconds. Figure 6 shows the indoor air temperature, outdoor ambient temperature, and indoor relative humidity readings taken between 3rd April 2023 and 5th April 2023. The HVAC system of the house was running during this experiment. The figure shows that the indoor air temperature can be easily maintained between 21 °C to 26 °C with the help of the chilled water system. Also, the relative humidity mostly lies in the range of 50% to 60%. This shows that the designed system has the potential to increase or decrease the temperature and relative humidity of the house based on desired occupant comfort. Owing to passive performance measures, the thermal cooling load of the house is reduced by 28%, and annual thermal comfort hours increased by 16.4%, with the use of the mentioned wall and roof assembly, as compared to a typical brick-concrete structure.

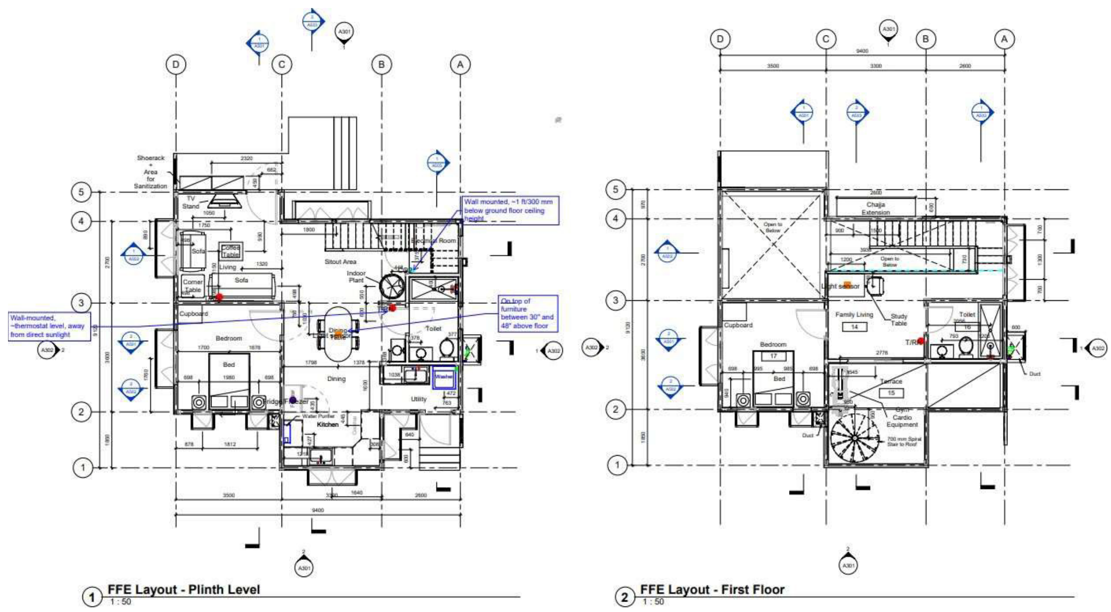

Figure 7 - Floor plans with placement of sensors

A second measurement campaign is currently being carried out, where sensors are installed on the West and south walls of the ground floor bedroom. The readings were taken as averages of 10-minute intervals under no active ventilation or cooling. No mechanical ceiling fans or air conditioning were active during this measurement period. The results, as illustrated in Figure 8, show that the internal surface temperatures of both walls remain consistently equal throughout the day, lying within the range of 27 °C to 29 °C, when the external surface temperatures were between 25 °C to 31 °C.

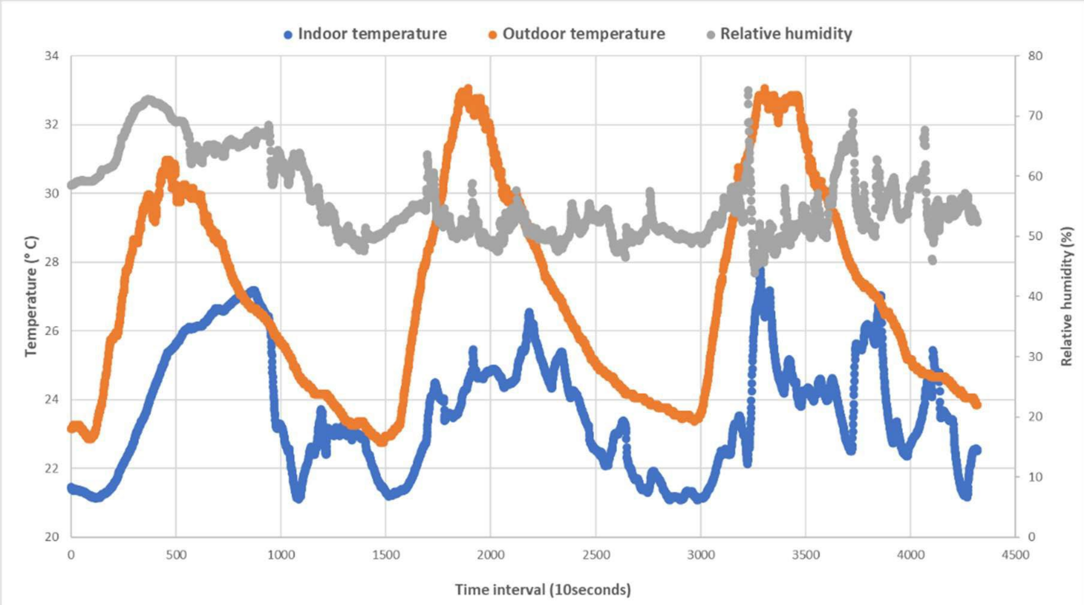

Figure 6 - Experiment reading from 03 April and 05 April 2023

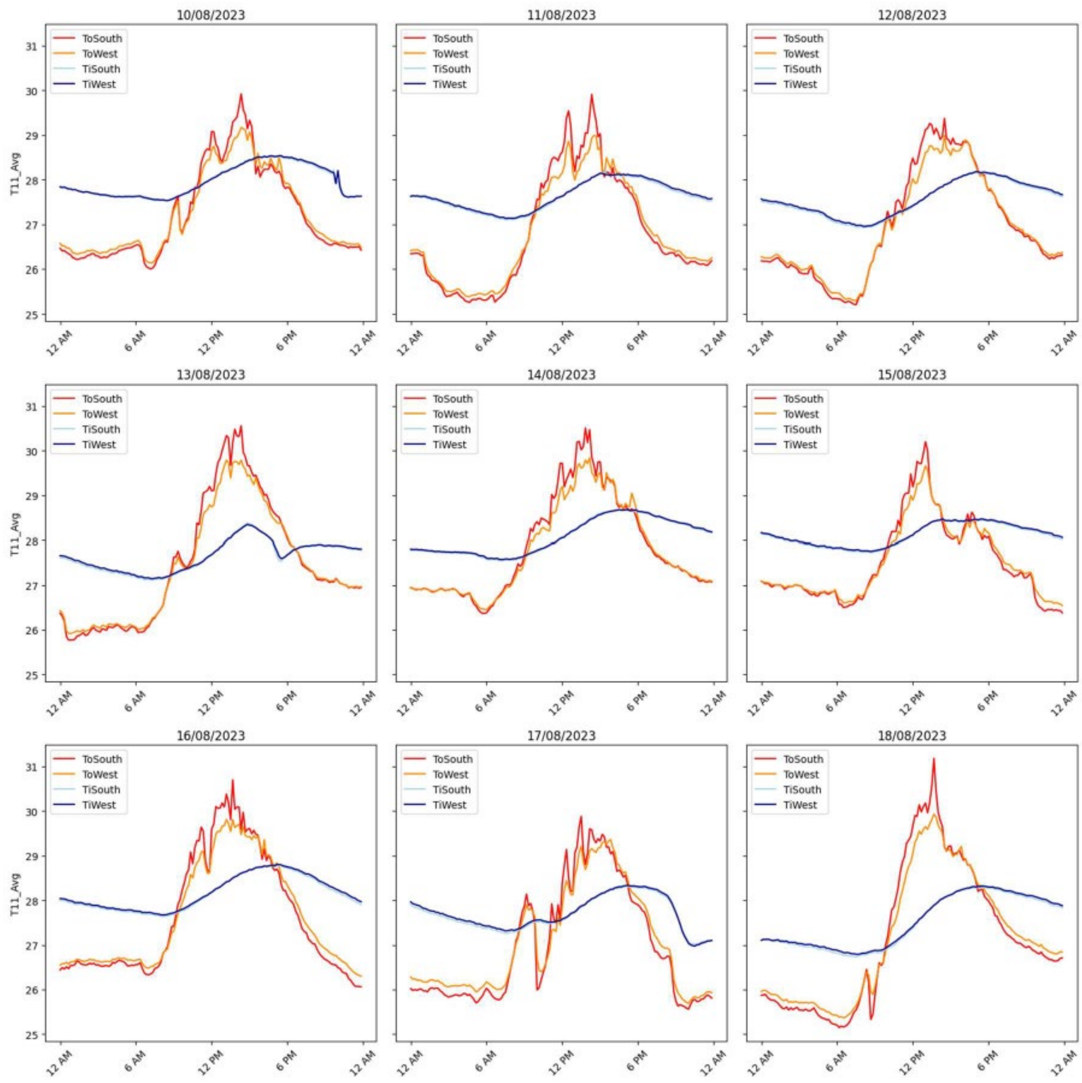

Figure 8 - External and Internal wall surface temperatures between 10 Aug and 18 Aug 2023

Results

The Ladybug and Honeybee libraries of Rhino3D, which run EnergyPlus on the backend, were used for conducting incident solar radiation analysis, case-wise energy simulations, and daylight studies, and OpenFOAM was deployed to simulate internal air flow using computational fluid dynamics and inform building geometry. All the analyses mentioned theoretically amount to a difference of 24% in energy consumption compared to the base case, i.e., the first design iteration. Optimization of building geometry using Grasshopper's native genetic algorithm solver, Galapagos, suggested a reduction of 11% between the base case and the completed design. Similar optimization for building orientation minimized the average annual incident radiation and, thus, reduced the impact of heat gains from solar radiation. The proprietary automation system and its mobile application help reduce energy waste by about 18% by reducing energy waste and maintaining optimal adaptive thermal comfort and artificial lighting levels. The app monitors energy consumption in appliances using a home assistant platform. The open-source platform allows for customization, extensibility, and deplorability. It allows monitoring of temperature, humidity, CO_2, and lux levels for each room and automates appliances based on occupancy. Remote monitoring and control of systems are possible through a web interface and companion app. The total annual energy demand is predicted to be significantly less than the annual solar PV generation, making the house Net Positive Energy.

As per the Uniform Indian Plumbing Code (UPC-I), 167 liters of water is consumed per capita per day (lpcd), but Project Vivaan uses only about 83 lpcd with the help of water-efficient fixtures and a grey water recycling system. An additional rainwater harvesting system with a storage capacity of 10,000 liters is installed, which can operate during all four months of the monsoon season and can provide non-potable water supply for up to 45 days in case of complete water shortage. The water-efficiency features result in an overall 82% water savings compared to a BAU home. Most of the freshwater purchased from the municipal corporation is used for drinking and cooking.

As per IGBC norms, if a house can use alternate water for more than 75% of the total consumption, it is characterized as a near-net zero water house. Since Vivaan's water saving amounts to about 82%, i.e., 7% more than the baseline standard, it was concluded that the house is near Net Zero Water. Since Vivaan is still in the early operational period, there isn't enough measured data regarding water consumption or savings yet.

The building extensively incorporates second-life materials, such as the use of biodegradable panels made of recycled agricultural waste. The EcoBoard panels include straws, husks, other organic materials, and a non-volatile binder. By utilizing these boards, Vivaan reduces the environmental impact of the envelope when compared to traditional construction materials and promotes sustainable practices. EcoBoard is the first company to receive EcoMark approval from the BIS, an indication of the minimal impact caused to the environment.

Lessons Learned, Recommendations, and Best Practices

The core philosophy behind Project Vivaan and Team SHUNYA is the drive and commitment to revolutionize the sustainable housing industry. Vivaan attempts to create a beacon of sustainability, embodying the principles of Net Zero Energy, Water, and Carbon. From selecting innovative second-life materials to implementing advanced fire-safety features, every aspect of Vivaan is designed to minimize environmental impact and prioritize the safety and well-being of its inhabitants. However, implementing these innovative features is challenging in India, as conventional construction laborers need more skills and experience to effectively execute the design on-site during construction. The team needed to assist the construction labor with various issues and provide solutions to implement modern technologies efficiently. Several training and education sessions about new construction technology and materials were also conducted to educate the laborers about contemporary practices. Challenges arose when ensuring air-tightness and aesthetic finishing, but were successfully tackled with correction methods and skilled labor. Additionally, while using materials like EcoBoard, construction during monsoon becomes difficult as the material degrades from direct contact with water. Implementing in-house developed technology, such as liquid desiccant for dehumidification, requires a significant amount of time and an early start for timely implementation. Also, the financial budget becomes a prominent constraint when such experimental projects are implemented practically.

Project Vivaan is built to last, with structural durability of 50 years and precautions in place to handle electrical disruptions and emergencies caused by factors like climate change. By theoretically achieving Net Zero Carbon, we reduce our ecological footprint and establish a new standard for environmentally conscious construction. Furthermore, our focus on water conservation is evident through water-saving technologies that result in up to 82% savings, coupled with a robust 45-day water backup system.

Beyond sustainability and safety, Project Vivaan offers a sanctuary of comfort and serenity. Innovative use of elements like *Jaalis* inspired by traditional Indian architecture that aids in natural ventilation, cool roof tiles for maximizing energy generation of bifacial PV panels, and automation features for convenience and comfort are seamlessly integrated. Through awareness and education, Vivaan strives to spread sustainable lifestyle principles to the masses, empowering individuals to embrace sustainable living and meeting the growing demand for urban housing in an environmentally conscious manner. The objective is to create a future where sustainable housing is inclusively accessible, inspiring a collective movement towards a more resilient and harmonious world.

Acknowledgments

We are sincerely grateful to our esteemed sponsors, the dedicated members of IIT Bombay and Team SHUNYA, and the faculty advisors for their unwavering support and invaluable contribution to this project. Their generosity and belief in our vision have been instrumental in making this endeavor successful. We extend our heartfelt appreciation to our Associate sponsors: EcoBoard Industries Ltd, Prism Johnson Ltd; Platinum sponsors: Design Builder Software Australia, Saint- Gobain Glass India Pvt Ltd, Pepperfry, Softtech Engineers Ltd, Seal for Life Group, Ecofirst Services Ltd, Prince Pipes and Fittings Ltd; Gold sponsors: Owens Corning India Pvt Ltd, Adani Solar, Polycab India Ltd, Signify Innovations India Ltd, Plan-M India Pvt Ltd, Ameet Innovations LLP; Silver sponsors: Saint-Gobain Gyproc India Ltd, SustLabs, CSD, SunInfra Energies Pvt Ltd, Origin Corporate Services Pvt Ltd, Upcycle Chakra LLP/ Anwesha Foundation, Wadbros Imports & Exports, Creatively Scientific Design, Rainy, Sugam Paryavaran Vikalp Pvt Ltd, Albatross Energetics, and Farmland Rainwater Harvesting System. Their deep commitment to sustainability has played a pivotal role in propelling this initiative forward. Their unwavering dedication to promoting sustainable housing and fostering a greener future for urban communities has been truly inspiring and has contributed significantly to the success of our project. We genuinely appreciate their trust, partnership, and shared commitment to creating a more sustainable world. Without their support, this transformative journey would not have been possible.

Infosys Hubbali: Innovation in Sustainability & MEP Services Introduction

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Abstract

The case study of Infosys Hubballi showcases the innovative approach taken by Infosys in integrating sustainability and Mechanical, Electrical, and Plumbing (MEP) services in their campus design. Located in Hubballi, Karnataka, the project emphasizes eco-friendly strategies aimed at achieving water self-sufficiency, energy efficiency, and reduced environmental impact. Key objectives include implementing rainwater harvesting, using treated wastewater for non-potable applications, and installing solar PV panels to reduce grid energy dependence. The project also focuses on enhancing operational efficiency, ensuring 100% daylight buildings, and incorporating passive design strategies for optimal solar ingress control.

Innovative measures such as radiant cooling systems, advanced HVAC techniques, and the use of high-performance filters and pre-cooling methods were employed to maximize energy savings. The strategic use of sun control devices and daylight simulations helped optimize building design, resulting in significant reductions in energy consumption and operational costs. The Infosys Hubballi campus not only meets but exceeds ASHRAE standards, demonstrating a commitment to sustainability and resilience against future environmental changes.

The outcomes of the project include substantial energy savings, water self-sufficiency, and enhanced biodiversity, setting a benchmark for sustainable development. The integration of these advanced strategies has led to a cleaner, greener community, exemplifying Infosys' leadership in sustainable building design and environmental stewardship. This case study serves as a model for future developments aiming to balance technological advancement with ecological responsibility.

Case Study

Infosys Hubbali: Innovation in Sustainability & MEP Design

Introduction

This project for Infosys stands testament to the Sustainable Development of a Dry land Ecosystem. The barren land in Hubbali was envisaged to live up to the essence of the city's name 'Hoovina Balli' meaning a flowering creeper in Kannada. The main goal of the project is to illustrate sustainable design strategies and concepts that focus on the appropriate and efficient use of resources —water, energy, air & materials — to reduce the development's environmental impact during its lifecycle, and to make the whole development a highly 'sustainable living community.'

The project site is located in Hubballi, Karnataka, India. The Geographic location is: 15° 21' North latitude, Altitude of 671 m above MSL. The construction of the project began in 2016 and was completed in 2019. The satellite images from before project inception to the present shows the transitional enrichment of the site.

Fig 1: Satellite images of project site

Integrated Design Approach

The proposed Software Development block has a built-up area of 27,290 Sqm and consists of Ground + 5 floors. The Food Court consists of 2 floors of kitchen + dining area & 1 floor of Customer care centre, with an area of 6,815 Sqm.

An integrated design approach has been adopted from a holistic site level to building level. At the macro level, Urban Heat Island Mitigation is the key factor to reduce impact of the immediate microclimate on the building cooling load requirement. Reduction of outdoor temperatures results in reduced carbon emissions as well. Outdoor Thermal Comfort is another important parameter that is addressed to ensure pedestrian comfort. Adoption of heat resilient planning, cool surface finishes and incorporation of vegetation helps in mitigating the heat islands in the otherwise barren land. Water shed management of the site turned out the main saviour in the project. Catchment area analysis was carried out to utilize the site slope of 10 to 12 m towards east to naturally collect the runoff water into a rainwater collection pond. This has helped replenish the site's ecosystem and improve its biodiversity.

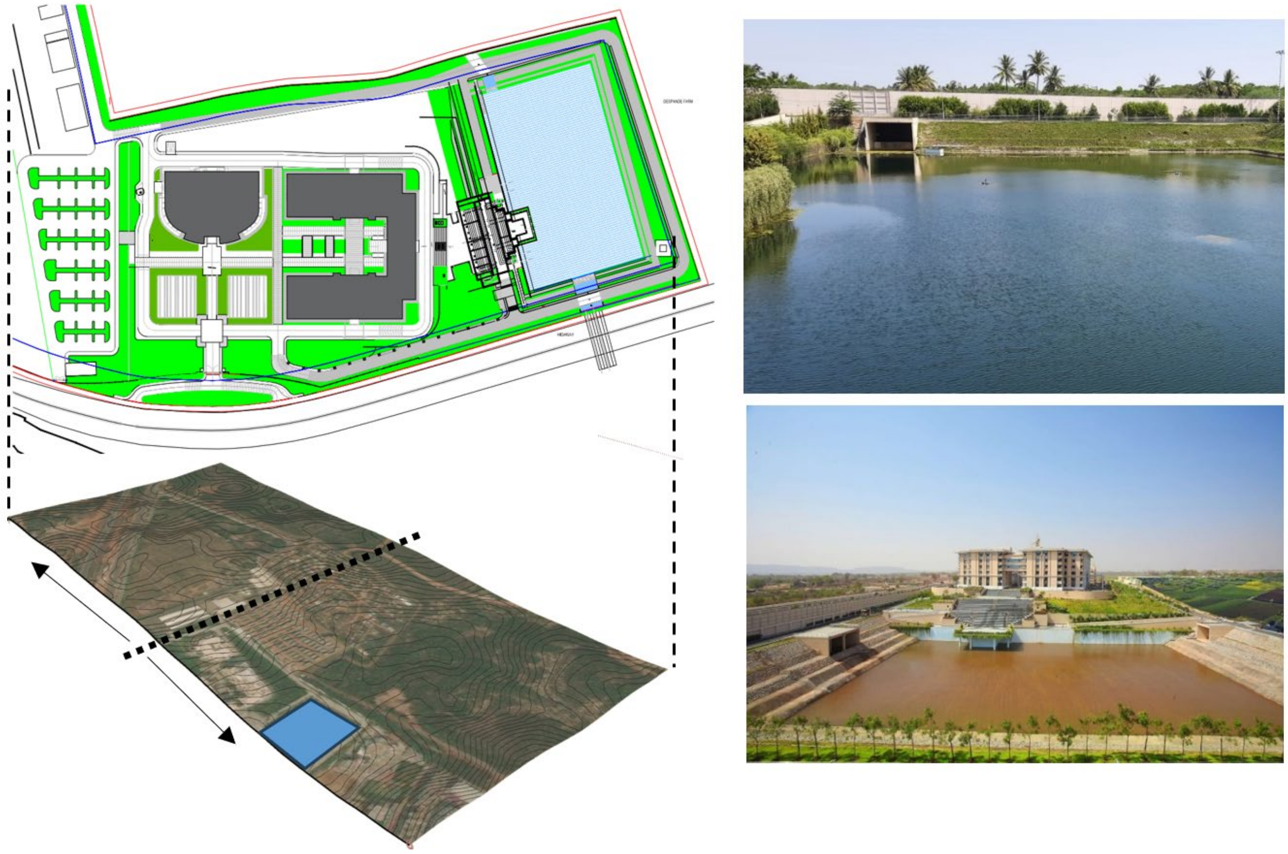


Fig 2: Water shed management.

At building level, passive strategies are primarily adopted to minimize energy consumption. Building orientation, massing, fenestration design, shading, daylight, and optimized building envelope were key parameters that were addressed.

As a next step, the active systems were designed ultra efficiently. Optimised HVAC systems were conceptualized with Radiant cooling, also using the pre-cooling advantage. This led to reduction in the cooling load. Ensuring layout planning for achieving naturally daylit buildings, thus eliminating need for artificial lighting. Further selection of efficient fixtures to arrive at reduced energy demand. Water self-sufficiency was also achieved by adoption of low flow fixtures, recycling, and reuse of STP treated water, rainwater collection, storage, and ground water recharge.

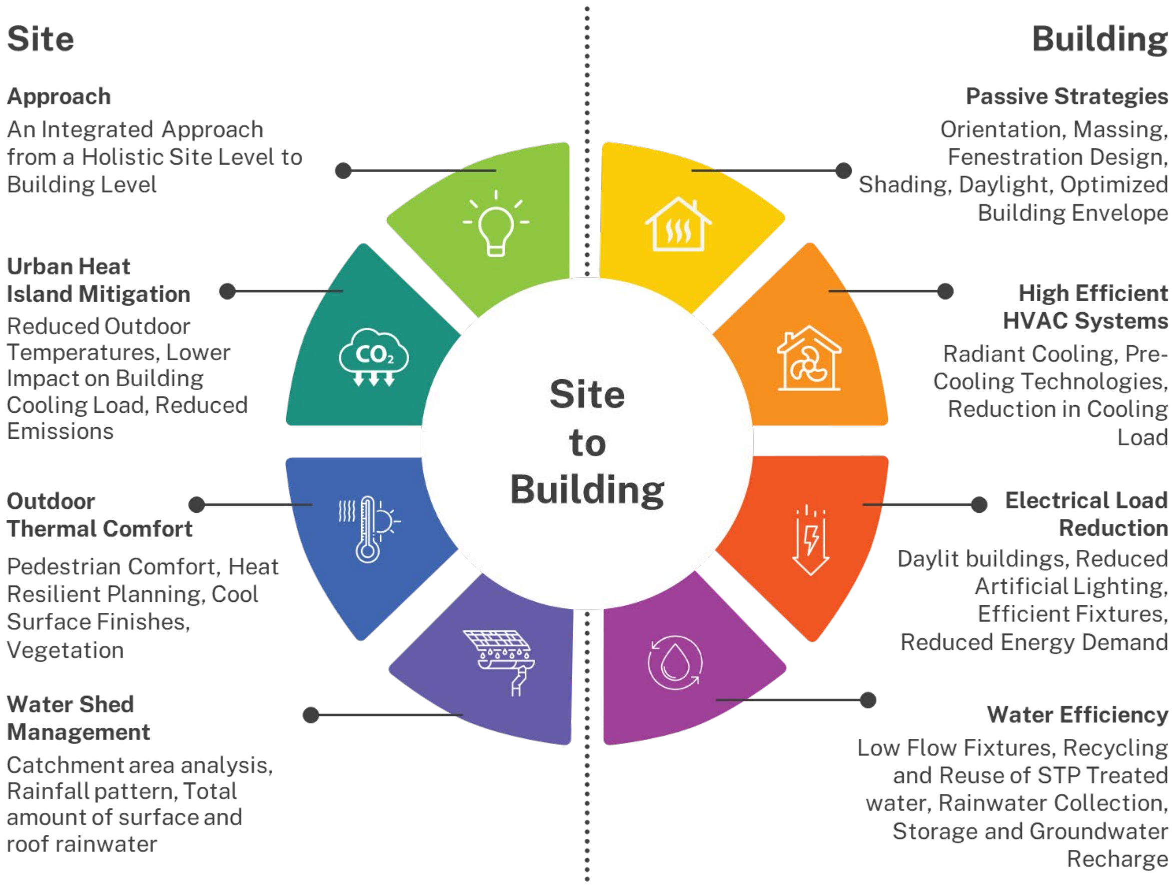


Fig 3: Integrated Design Approach

Beating the Heat | Passive Design Measures

Orientation and Massing are the principal factors whose analysis inform the architectural design process. In the initial design phase, multiple iterations are carried out to analyse the effect of orientation on the amount of solar radiation falling on the building. The building is oriented with maximum façade area facing north south. A courtyard has been carved out on the western side to minimize the effects of the western sun. The courtyard form helps in self-shading of the form.

Efficient Envelope design stands as a crucial parameter in the elimination of heat entry into the office space. Optimisation of the envelope as compared to the base case conventional building prove highly beneficial. The U-value of wall has been reduced by 50% from the business-as-usual case by adopting a double concrete block wall with cavity and insulation. The thermal transmittance of the roof assembly has also been reduced by 11% by adopting insulation and solar reflective tile.

Window to wall ratio is first targeted before going in for high performance glazing. An optimized window to wall ratio of 22% has been resorted to achieve a balance between daylight requirement and cutting down glare. Fenestration glazing properties have been specified relevant to the different orientations they face. The thermal transmittance values of glazing have been significantly reduced by close to 85% compared to conventional building scenario. This greatly contributes to a highly efficient envelope. Further shading devices have been suitably designed to minimize solar ingress.

Parameter	Base Case	Proposed Case			
Wall	U: 0.124	U: 0.061			
Roof	U: 0.063	U: 0.056			
WWR	22 %	22 % (as per Design)			
Fenestration (as per different Orientations)	**U Value** : 1.22 Btu/ hr.ft^2.^{0}F **SHGC** : 0.25 **SC** : 0.29		**VLT**	**SHGC**	**U**
		N,S & E Daylight	0.59	0.27	0.183
		N & S Vision	0.50	0.26	0.181
		E & W Vision	0.42	0.22	0.181
		W Daylight	0.10	0.10	0.176
Shading Device	None	External shading as per design			

Fig 4: Efficient Envelope

The use of sun control and shading devices has been an important strategy to drive energy-efficient building design. The following studies were carried out on the facade design to optimize the building envelope.

Sun Path Analysis which shows the following parameters and helps in finalizing the effective shading devices.

a. The time during the day that the building receives sunlight.

b. The sun's path at different times of the day and year

c. How the building shape, slope and orientation affect solar access

d. The owners' lifestyle – for example, when they want to have sun or shade.

Shading strategies

External horizontal overhang (Sun breakers), Vertical fin and Internal Light shelf are provided in the respective façade orientations to cut the direct sun entry into the workspace.

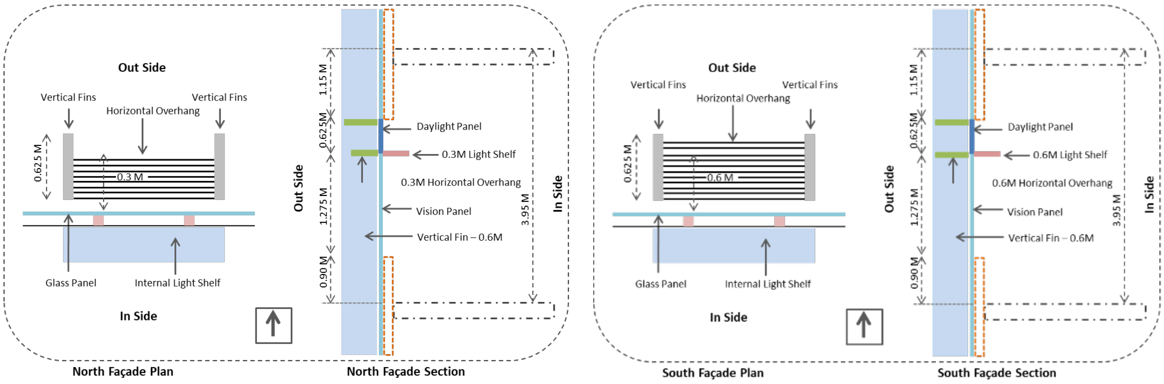


Fig 5: Fenestration and Shading Device Design

Daylight Analysis

Daylight simulations to assess illuminance levels achieved and optimize fenestration design and window to wall ratios. The fenestration glazing has been split into a lower vision window and an upper daylight panel. This assembly make certain 100% naturally daylight spaces while keeping discomfort glare at bay.

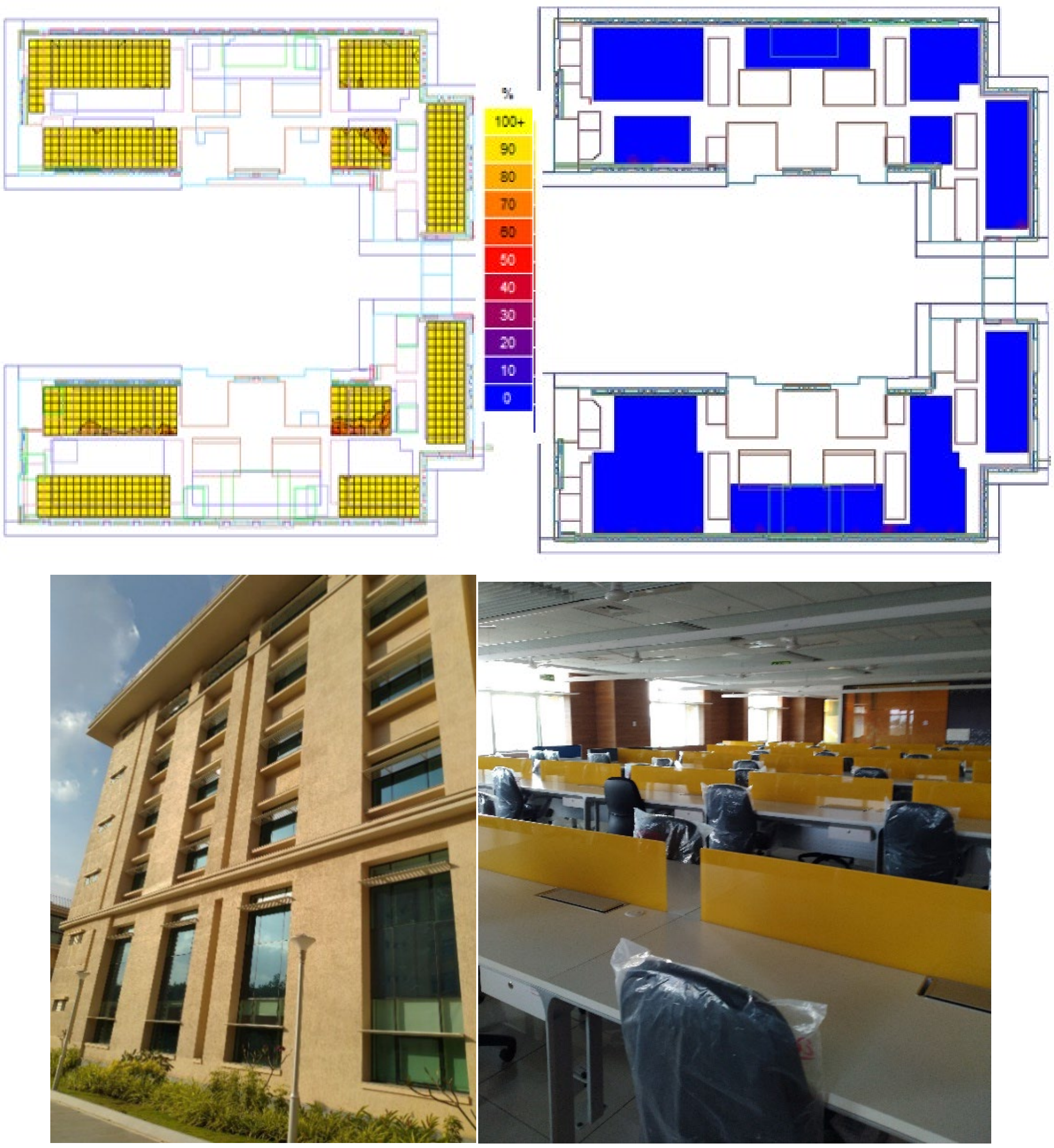


Fig 6: Daylight and solar ingress analysis, Fenestration design for 100% daylit spaces

Staying Cool | The Weather Advantage on Heating, Ventilation and Air Conditioning

To make the selected Heating, ventilation, and air conditioning (HVAC) system perform at its right possible efficiency at the time of the design stage innovative techniques in terms of sizing the system to operating the system have been taken into consideration for both the low side and the high side of HVAC system. The following have been set as targets:

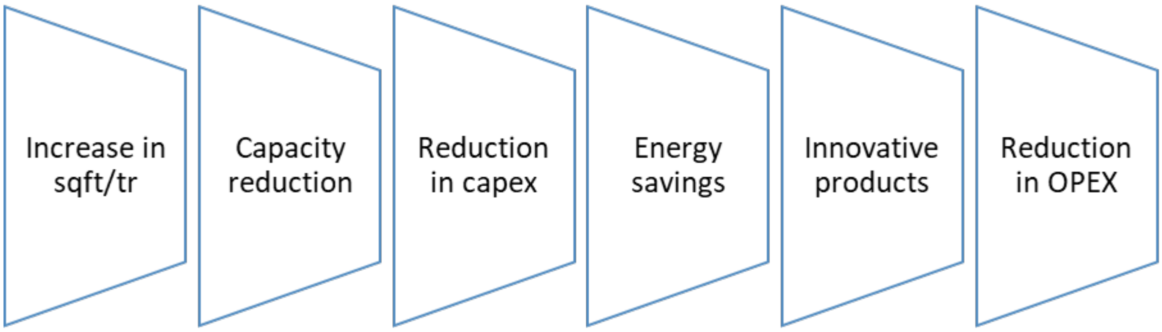


Fig 7: HVAC design innovation

From our study and with the help of previous projects (i.e., industrial experience) the optimum utilization of chillers by taking weather advantage has been proven to be carrying the best practice along with Precooling techniques. For this project, further options were explored such as Chiller sequencing selection & operation for different capacities as Infosys has a dynamic schedule of occupancy, therefore taking the project requirement as an advantage the following combinations of solutions were explored and reported:

Fig 8: HVAC design innovation

Radiant Cooling system has been implemented to further reduce the energy consumption. Cooling tower coil has been used on Treated Fresh Air units to take advantage of the weather conditions.

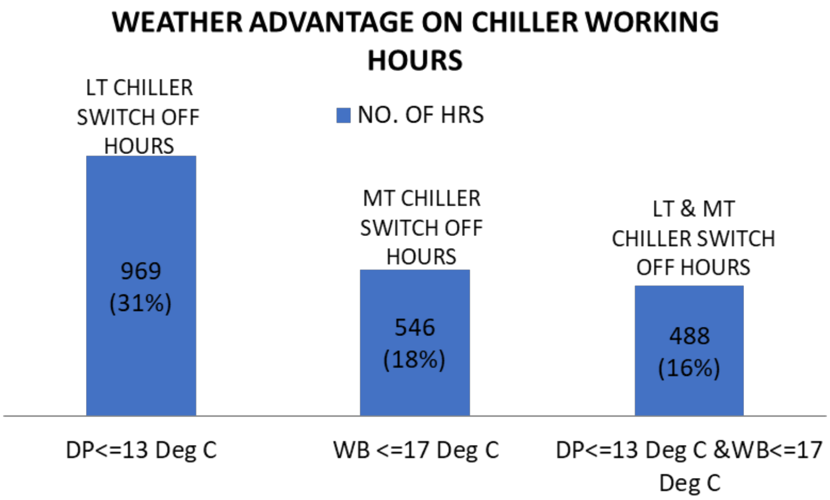


Fig 9: Weather advantage on chiller working hours.

Chillers sequencing chart has been implemented to efficiently optimize energy consumption. Some of the best practices include: Optimum utilization of chillers + weather advantage + precooling techniques. Optimum chiller utilization based on the following conditions:

- MT chiller | Off | WB<=17˚C
- LT chiller | Off | DP<=13 ˚C
- MT & LT Chillers | Off | WB<=17 ˚C & DP<=13 ˚C

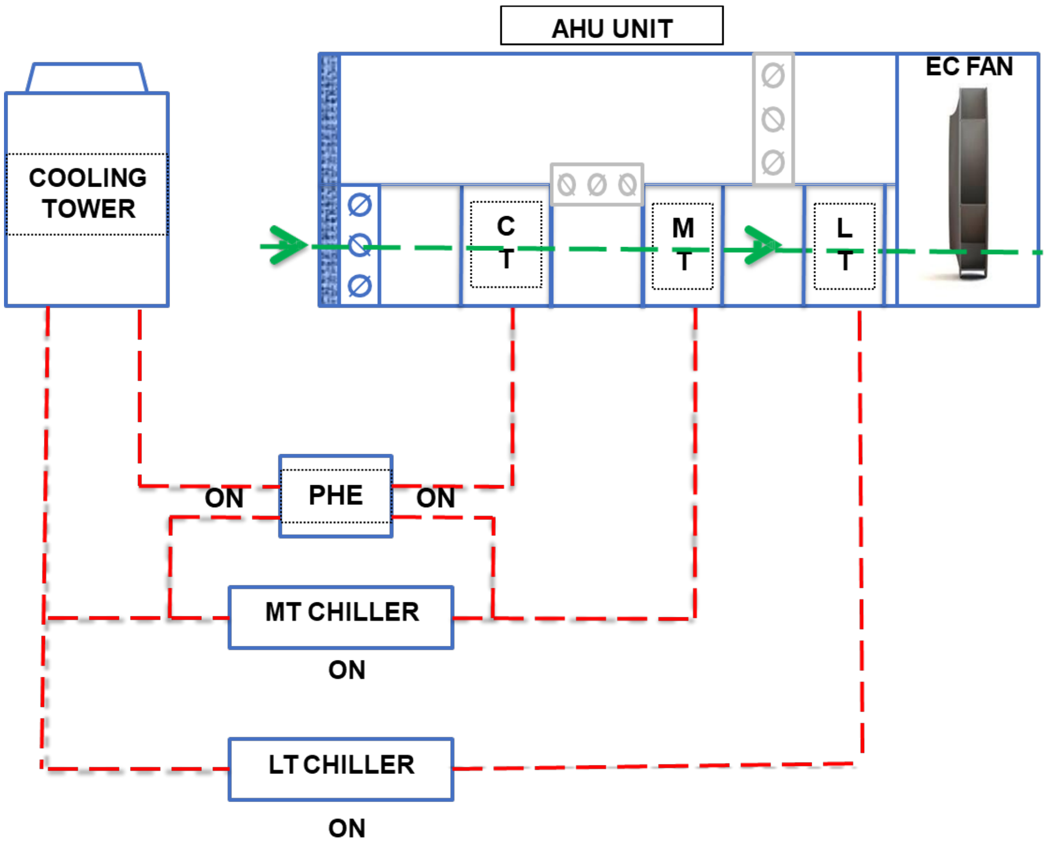


Fig 10: Chiller operations scheme

Energy Performance Index Details

The lowest HVAC EPI estimated compared to other buildings at 14.6 kWh/sqm/year. Overall HVAC efficiency estimated is 0.55 ikW/TR at plant level and 0.89 ikW/TR including internal loads. The efficient HVAC design process has helped in reduction of 74 tons of CO2 emissions and 140 KL of water consumption every year.

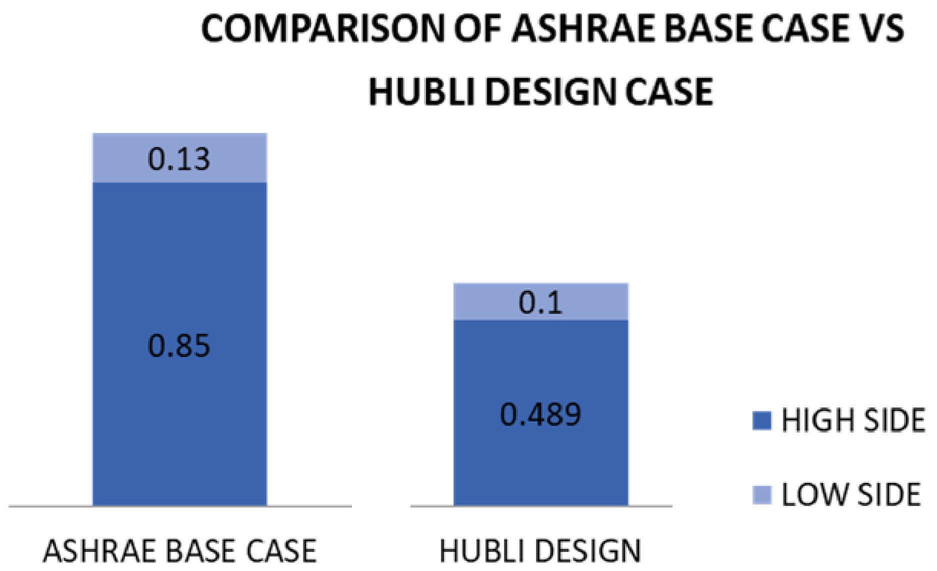


Fig 11: Comparison of ASHRAE Base case vs Hubli Design Case

Compared to the ASHRAE base case the Hubli design case has achieved a reduction of 42% with respect to high side equipment and 23% on the low side equipment.

Lighting the Spark | Electrical Load and Renewable Energy

Daylight harvesting is the first key step towards electrical load reduction. The process of fenestration design optimisation to achieve 100% daylit spaces contributes to this, followed by efficient light fixtures. By this process the Demand load has been reduced to 2.52 W/Sq. ft.

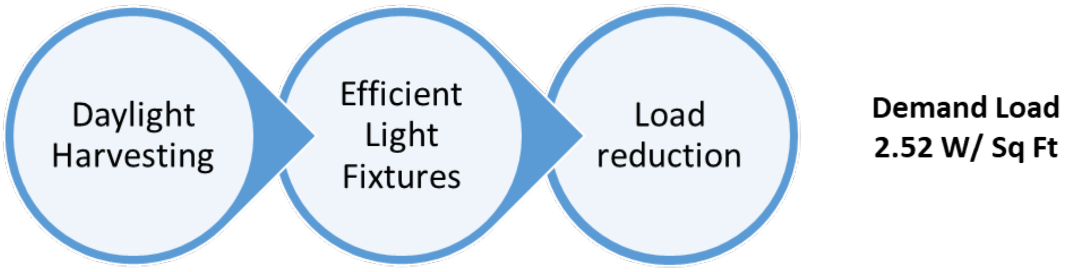


Fig 12: Comparison of ASHRAE Base case vs Hubli Design Case

The efficient HVAC systems itself contribute to reduction of 70% of electrical load on HVAC. Overall, a 58% electrical demand load reduction was estimated. Lighting automation with daylight and occupancy sensors with dimming systems have been proposed. Voltage drop has been restricted to 2%, this meets Super ECBC requirements.

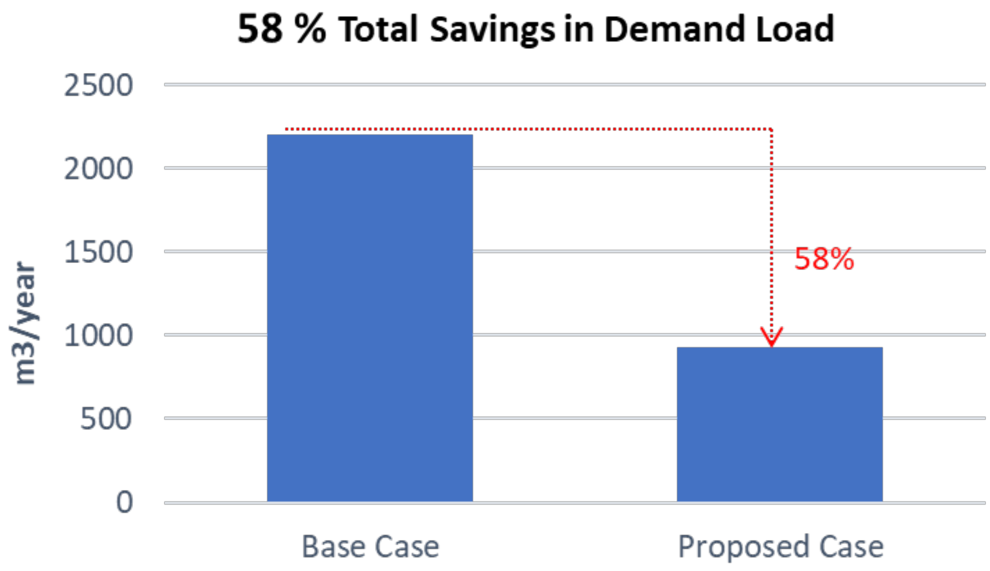
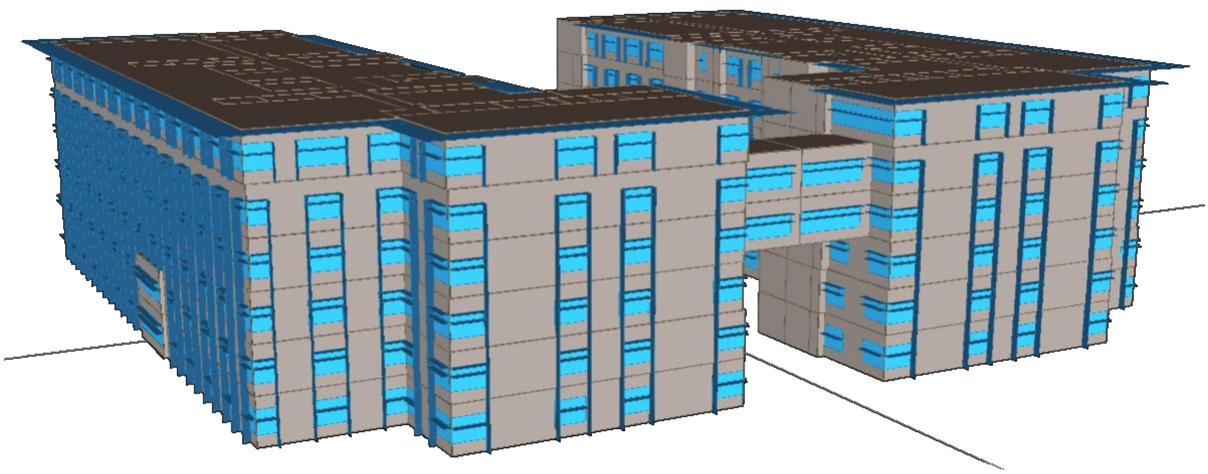


Fig 13: Savings in electrical demand load

Energy modelling indicates an EPI of 63.71, with a 52% reduction compared to ASHRAE base case.



Energy Modeling, EPI : 63.71, 52% reduction compared to ASHRAE Base Case

Fig 14: Energy Modeling

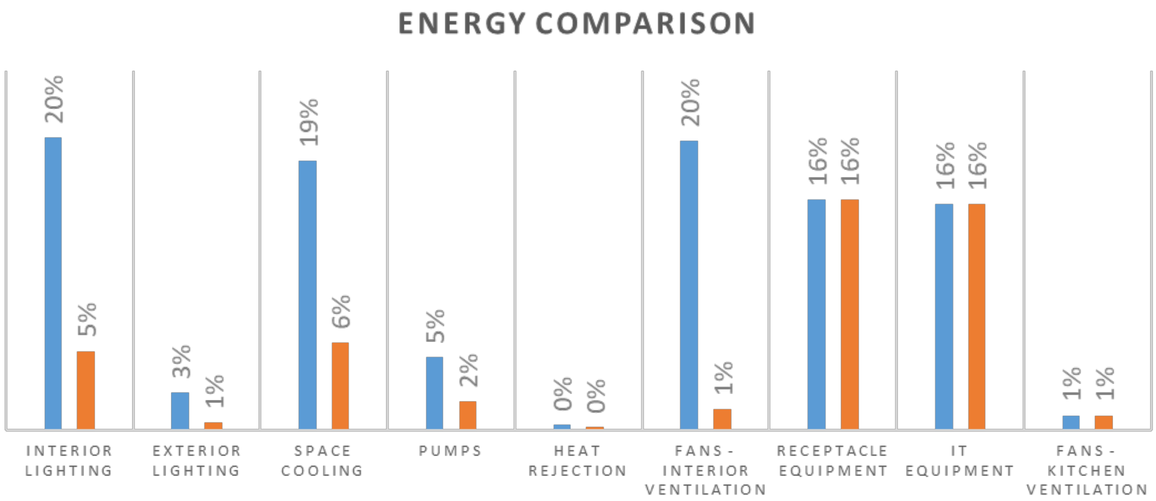


Fig 15: Energy Reduction

Getting into the Flow | Water Self Sufficiency

47% of the overall water demand reduction has been achieved by use of low flow fixtures. 100% of HVAC, landscaping and flushing water requirement shall be met by STP recycled water. 100% of domestic water requirement shall be met by roof and surface rainwater collected in the pond and underground tanks.

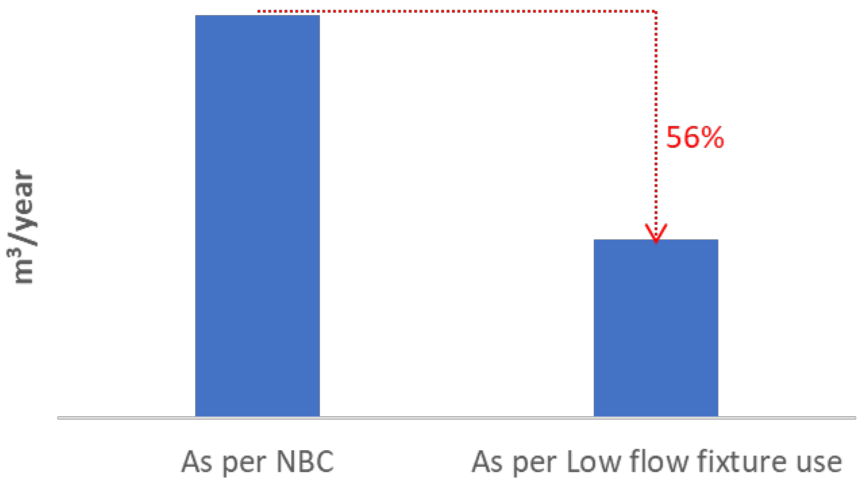


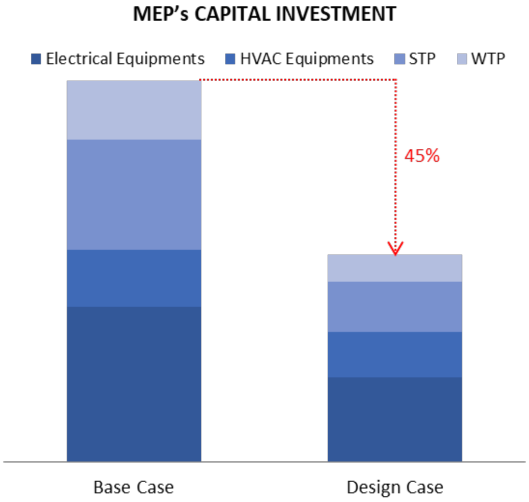
Fig 16: Water demand reduction

The 3-acre pond has been created to harvest the site surface rain water from the entire site. Water metering system have been installed to monitor and control the wastage of water. Natural swales, Sustainable Urban Drainage Systems (SUDS) have been implemented to reduce concrete drains in all possible areas.

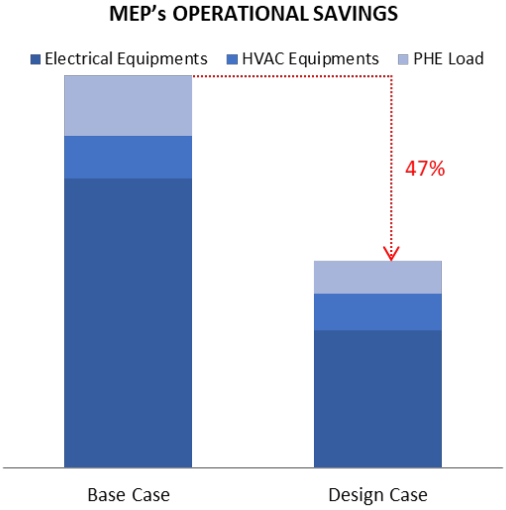
Fig 17: 3-acre lake, Water Self Sufficiency

Capital Savings

The entire process of load reduction, system optimisation has resulted in a 45% savings in capital costs and 47% operational savings.



- 45% Savings in Electrical equipment
- 20% Savings in HVAC equipment
- 54% Savings in STP equipment
- 54% Savings in WTP equipment



- 52% Savings in Electrical equipment
- 13% Savings in HVAC equipment
- 46% Savings in PHE equipment

Fig 18: Capital and Operational savings

APPLICABILITY & SCALABILITY

Infosys' achievement in terms of energy efficiency stands testimonial to their sustainability journey. They are a pioneer in integrative building design and data driven energy management.

- Optimized Building Envelope
- Ideal Fenestration and Shading Design – Light Shelves
- Integration of Daylight and Efficient Lighting Design
- Super-Efficient HVAC system design – Radiant Cooling System
- Use of innovative products that support the Design Interventions

These strategies are key to not just economic savings but ultimately environmental impact!

Acknowledgements

Mr. Guruprakash Shastry, Associate Vice President, Infosys

Ar. Vinod Kamath, Associate Director, RSP India.

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Impact of Energy Efficient Air Side in HVAC Systems

Arvind Singh[1] and Vanshaj Kaul[2]
[1]Director, Flakt Group
[2]Director, Eurovent India

Abstract

The case study examines the impact of energy-efficient airside components in HVAC systems, highlighting their role in reducing building energy loads while maintaining high Indoor Air Quality (IAQ). As India's building sector is set to expand significantly by 2050, achieving zero carbon-ready energy codes is crucial. The study uses proprietary simulation data from Eurovent certified units in India to demonstrate potential energy savings and the importance of energy labeling for accountability and enhanced Measurement and Verification (M&V) efforts. Key findings include various energy efficiency measures such as improved insulation, better windows, and efficient air handling units (AHUs), each contributing to substantial energy savings. A cost comparison of different AHU energy classes reveals the trade-offs between initial costs and long-term savings. The study calls for increased stakeholder awareness to scale up energy-efficient airside solutions, crucial for making future buildings more climate-resilient and energy-efficient.

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Impact of Energy efficient air side in HVAC systems

Life Cycle Cost Analysis

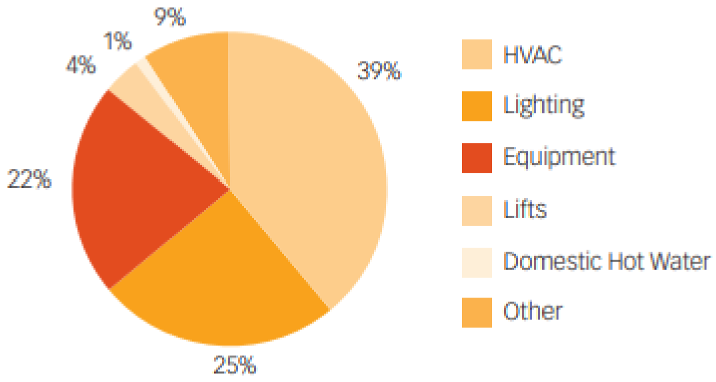
- Eurovent India & FläktGroup India

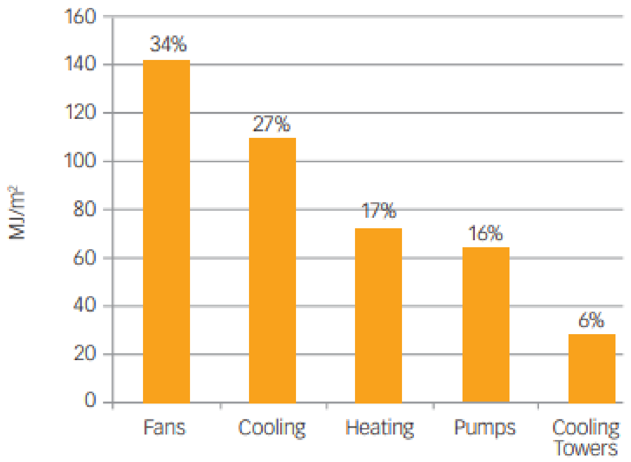
Demand to Reduce Energy Consumption in Buildings

- **Floor area in the buildings sector worldwide is expected to increase 75%** between 2020 and 2050, of which 80% would be in emerging markets and developing economies.
- In this regard, India is uniquely placed with three-quarters of the buildings, infrastructure and industrial capacity of India in 2050 yet to be built.
- Despite this demand growth the **total Co2 emissions from the buildings sector need to decline by > 70 % by 2050**. This would translate to more than 85% of buildings complying with zero-carbon-ready building energy codes by 2050.
- In addition, **Air side load contributes approximately to 14 TO 20 % of the overall Building energy load**. Under this scenario, an efficient airside in the HVAC sector becomes ever-important to ensure meeting these requirements while maintaining a high level of IAQ.

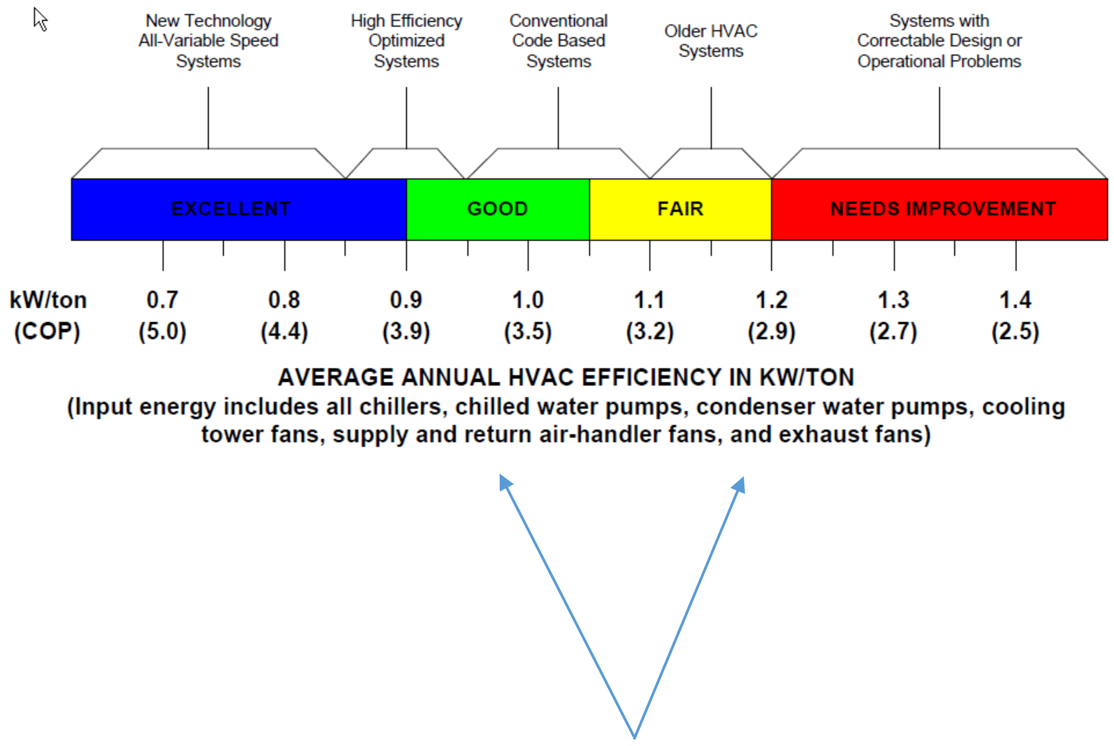
Buildings and their HVAC systems

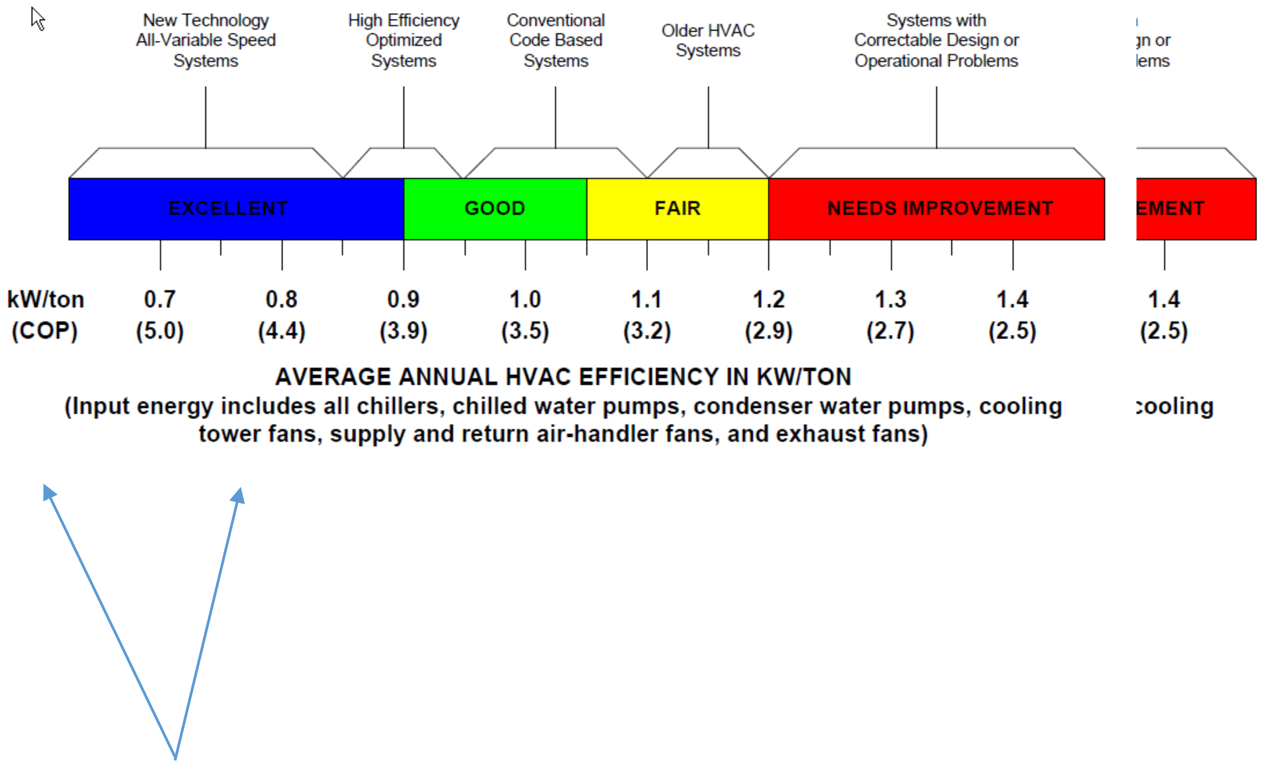
- A typical **HVAC** account is generally responsible for **approx. 40% of total building energy consumption.**
- Essences involved in mechanical ventilation
- Indispensable in new and refurbished airtight buildings to ensure IAQ
- **Air handling units have a major impact on energy consumption**
  Air transport and heat recovery





‘The Required Journey’

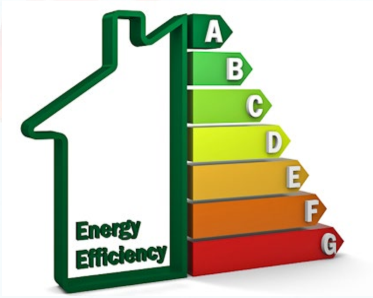




AHU Energy Labeling Classification

Data used to define the different factors:

- Climate Data: To determine the climate data methodology of the climate zones.
- Season of the year: The determination of the season is based on the “ Heating and Cooling degree days”.
- Heat Recovery Simulation: The simulations were hourly and all over the year. Two situations were made- Dry system with temperature control; Wet system with enthalpy control.
- Temperature design reference: The reference dry temperature and dew-point temperature derivate from ASHRAE 2013 data (summer criteria 2)



AHU Energy Labeling Classification

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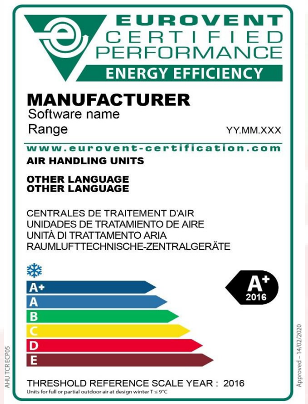
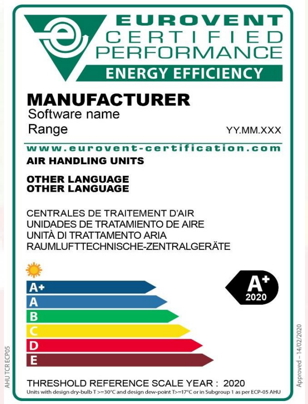
cold climate



hot and humid climate



Summer label

- Calculated based on ASHRAE weather data
- Energy label according to project location

Reference parameters for energy classes
1) Air velocity
2) Heat recovery efficiency
3) Flow resistance
4) Fan efficiency

CLASS	All Units	Units for full or partial outdoor air at design winter temperature ≤ 9°C		
	Velocity v_{class} [m/s]	Heat recovery system η_{class} [%]	Δp_{class} [Pa]	Fan Efficiency Grade $NG_{ref\text{-}class}$ [-]
A+ / A+⤷ / A+↑	1.4	83	250	64
A / A⤷ / A↑	1.6	78	230	62
B / B⤷ / B↑	1.8	73	210	60
C / C⤷ / C↑	2.0	68	190	57
D / D⤷ / D↑	2.2	63	170	52
E / E⤷ / E↑	No calculation required			No requirement

Table 6: Table for energy efficiency calculations

The lowest classes E, E⤷ and E↑ have no requirements.

AHU Energy Labeling Classification Eurovent & ISHRAE

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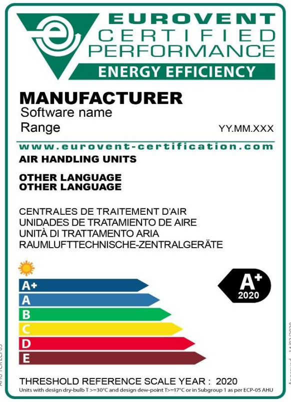
Reference parameters for energy classes

1) Air velocity
2) Heat recovery efficiency
3) Flow resistance
4) Fan efficiency

CLASS	All Units	Units for full or partial outdoor air at design winter temperature ≤ 9°C		
	Velocity	Heat recovery system		Fan Efficiency Grade
	v_{class} [m/s]	η_{class} [%]	Δp_{class} [Pa]	$NG_{ref\text{-}class}$ [-]
A+ / A+↲ / A+↑	1.4	83	250	64
A / A↲ / A↑	1.6	78	230	62
B / B↲ / B↑	1.8	73	210	60
C / C↲ / C↑	2.0	68	190	57
D / D↲ / D↑	2.2	63	170	52
E / E↲ / E↑	No calculation required			No requirement

Table 6: Table for energy efficiency calculations

The lowest classes E, E↲ and E↑ have no requirements.



Reference parameters for energy classes

1) Air velocity
2) Heat recovery efficiency
3) Flow resistance
4) Fan efficiency
5) Thermal Performance Value

Table 19: Reference table for energy efficiency calculations

CLASS	Velocity V_{class} [m/s]	Heat recovery system		Fan Efficiency Grade NGref-class [-]	Thermal performance value (TPV)
		ηclass [%]	Δpclass [Pa]		
A+ /A+↲/A+↑	1.4	83	250	64	1
A /A↲/A↑	1.6	78	230	62	0.8
B /B↲/B↑	1.8	73	210	60	0.6
C /C↲/C↑	2.0	68	190	57	0.4
D /D↲/D↑	2.2	63	170	52	0.2
E /E↲/E↑	No requirement				0

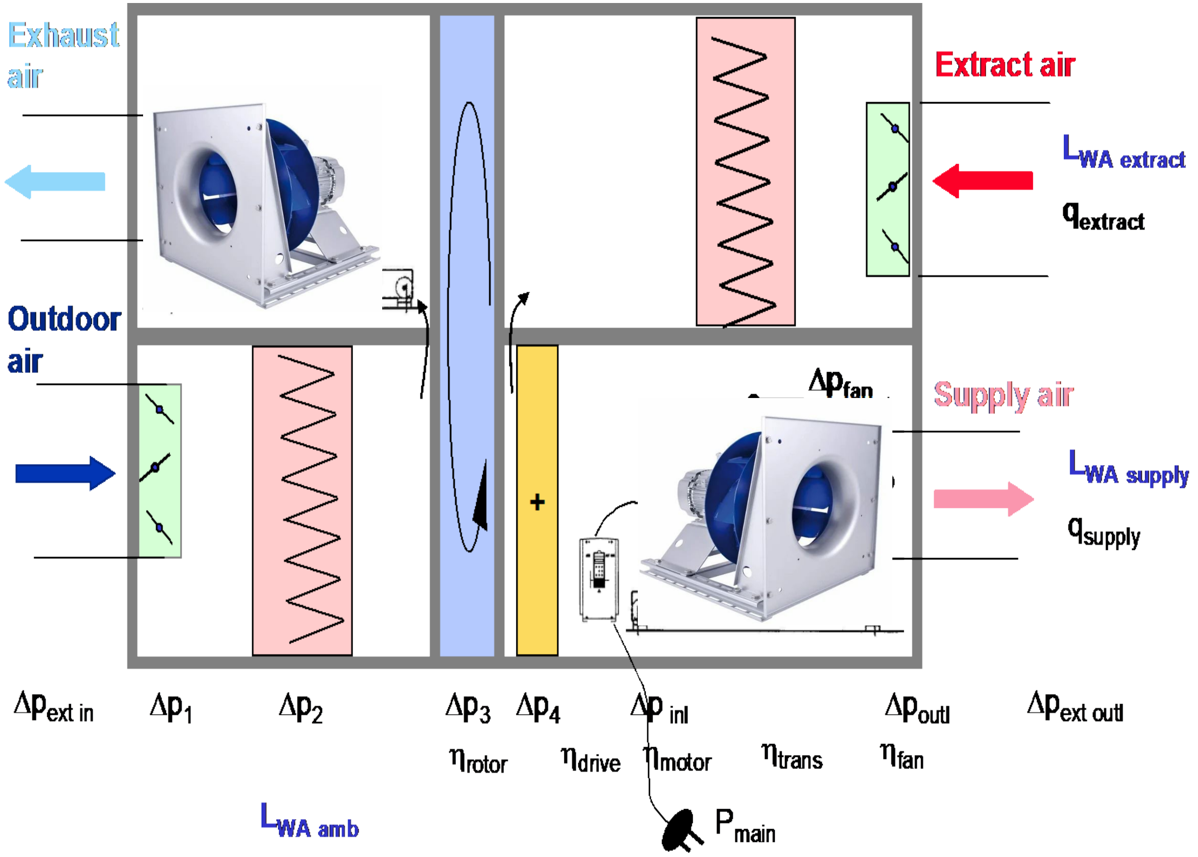
ISHRAE
RAMA

Ref: ISHRAE – RAMA Standard - 20002 : 2020
Standard For Air Handling Units – General Requirements, Performance Testing And Rating
ISHRAE – RAMA Standard - 20003 : 2020

What to Optimise ?

There are a lot of components to be optimised in an AHU:

- Recovery system
- Fans
- Motors
- Frequency inverters
- Pressure drops
- Velocity
- Size
- External issues, Etc.



Why is This Important For Us ?

Where can we reduce the energy consumption in an office building ?

- If we improve/change:
  - Heavier building → +100 mm :benefit ~ -1 kWh/m^2
  - More insulation → +200 mm :benefit ~ -3 kWh/m^2
  - Better windows (U-value) → 1.4 1.0 :benefit ~ -5 kWh/m^2
- **Lets look at the Air handling unit**
  - **Low speed AHU 2.5 1.6 m/s :benefit <u>~ -7 kWh/m^2</u>**
  - **Better efficiency 60% 85% :benefit <u>~ -16 kWh/m^2</u>**

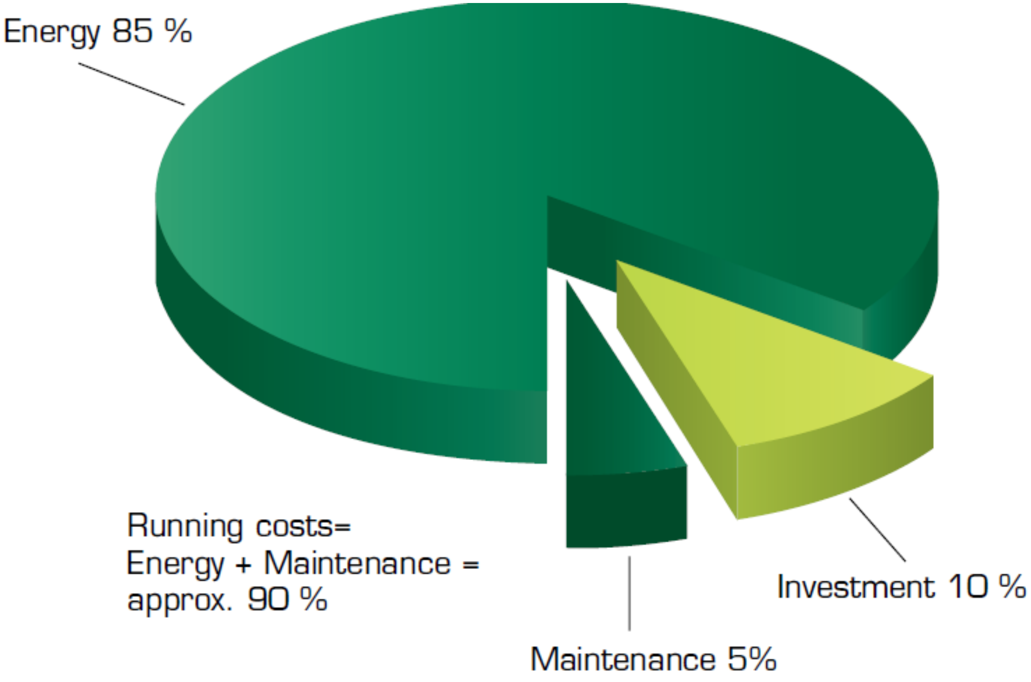
EFFICIENT AIRSIDE CAN MAKE A CONSIDERABLE IMPACT ON BUILDING ENERGY

THIS IS A 'MUST' FOR NET-ZERO BUILDINGS

The Life Cycle Cost of the AHU

The Life Cycle Costs of an Air Handling Unit

- If we are looking at the total costs for an air handling unit during it's lifetime, the impact of the energy costs are huge
- Aprox. 80-90% of the total costs are related to costs for energy (electricity, heating and cooling)
- Today it has become more and more important to be able to make LCC (life cycle costs) analyses for air handling units

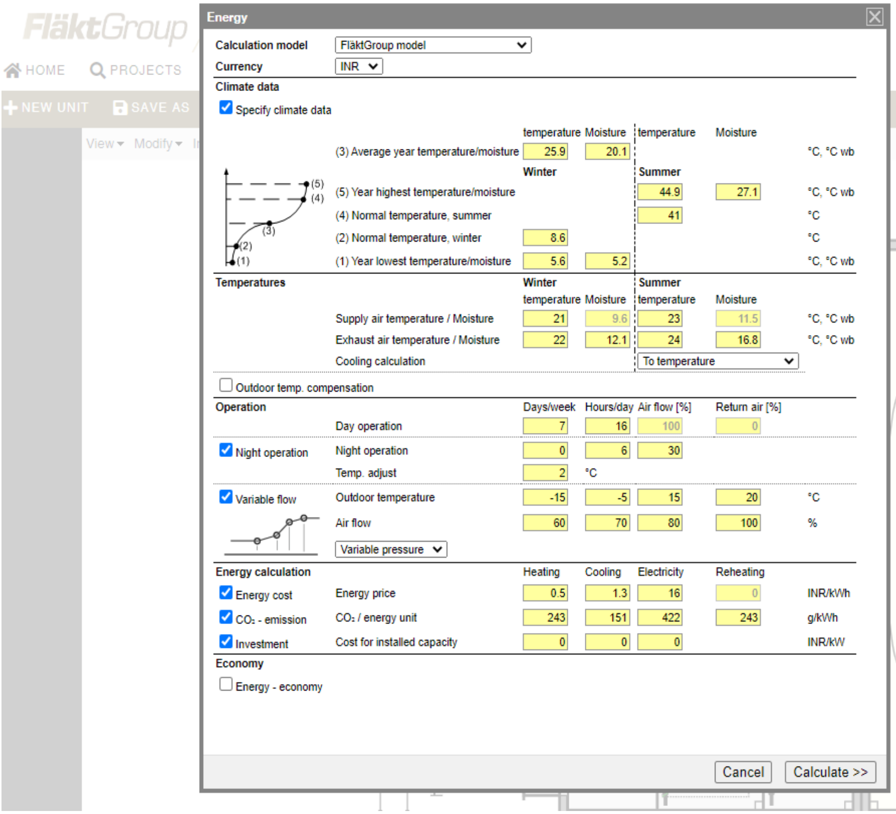


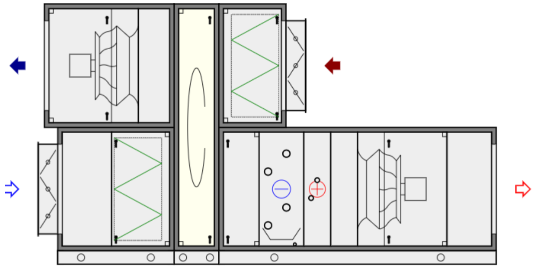
LCC Analysis:

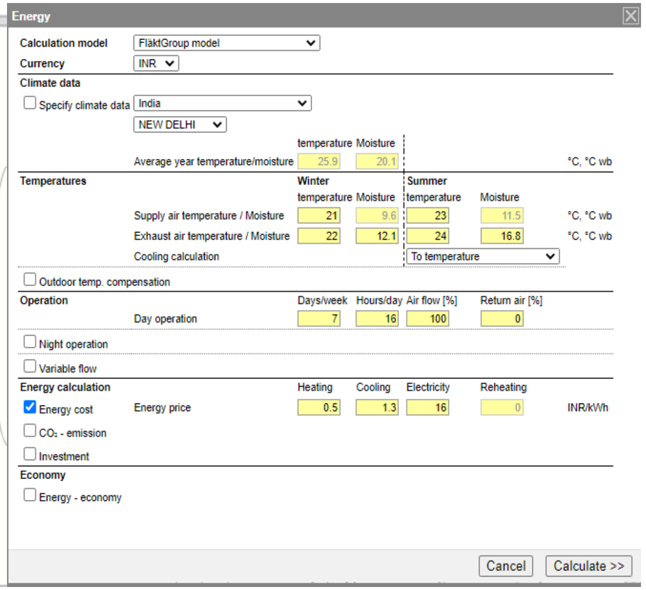
energise 2023
Lifestyle, Energy Efficiency, and Climate Action

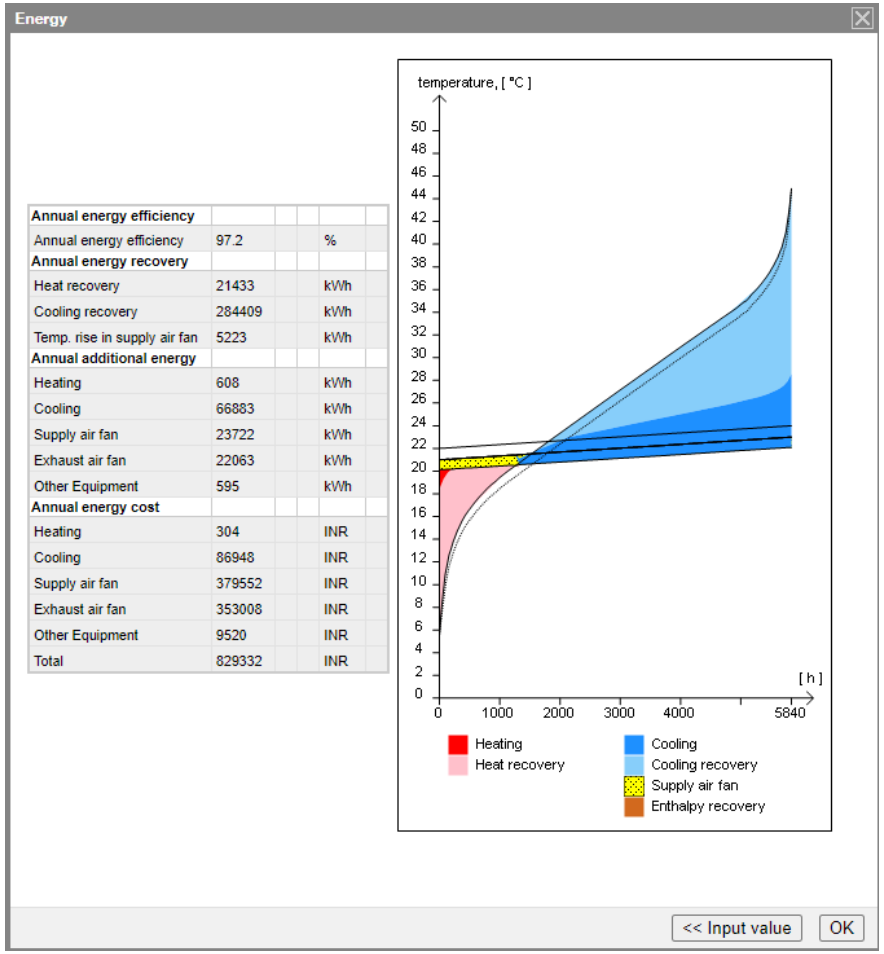
FläktGroup

Selection tool for LCC calculation

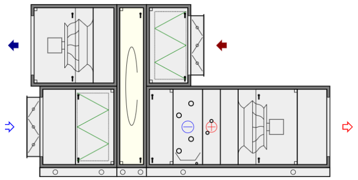






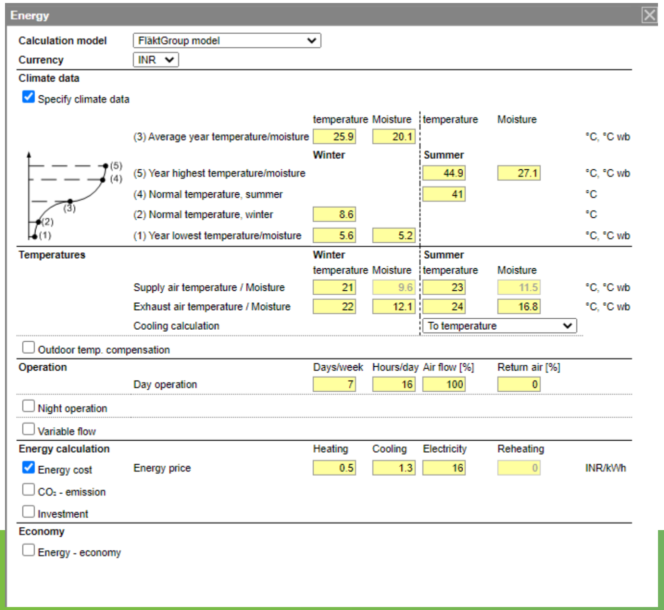


Comparison of operating costs by energy class



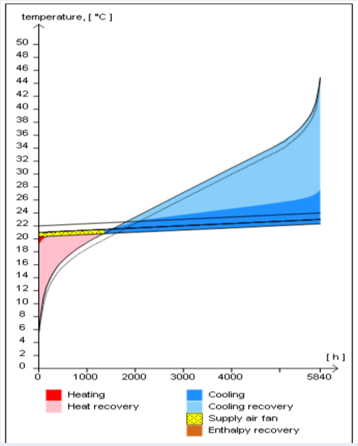
FläktGroup

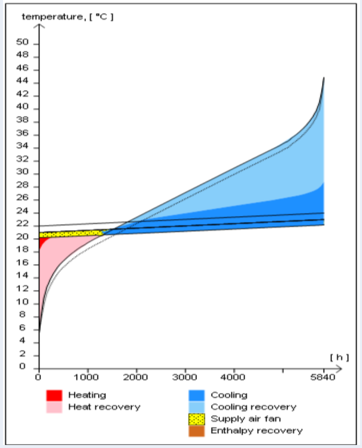
Airflow (CFM)	**8000**
Esp (Pa)	300
Location	Delhi

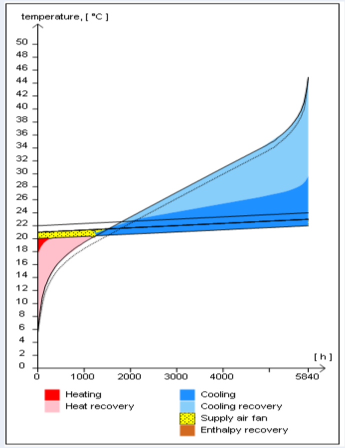


Energy Class

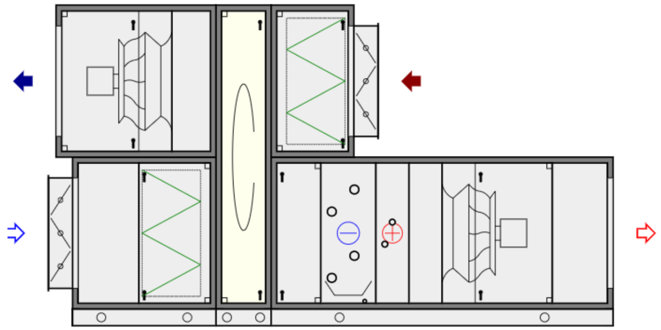
	A+		A		C	
Annual energy recovery						
Heat recovery	23072	kWh	21587	kWh	18951	kWh
Cooling recovery	321790	kWh	274777	kWh	229668	kWh
Temp. rise in supply air fan	4145	kWh	4829	kWh	5177	kWh
Annual additional energy						
Heating	331	kWh	829	kWh	998	kWh
Cooling	56335	kWh	67518	kWh	71740	kWh
Supply air fan	17968	kWh	21971	kWh	24819	kWh
Exhaust air fan	17318	kWh	21746	kWh	23842	kWh
Other Equipment	596	kWh	596	kWh	309	kWh
Annual energy cost						
Heating	166	INR	414	INR	499	INR
Cooling	73236	INR	87773	INR	93262	INR
Supply air fan	287488	INR	351536	INR	397104	INR
Exhaust air fan	277088	INR	347936	INR	381472	INR
Other Equipment	9536	INR	9536	INR	4944	INR
Total	647513	INR	797196	INR	877281	INR







Comparison of operating costs by energy class

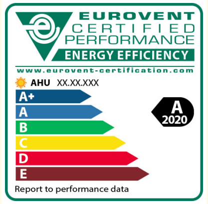


Airflow (CFM)/ l/s	8000/ 3809
Esp (Pa)	300
Location	Delhi

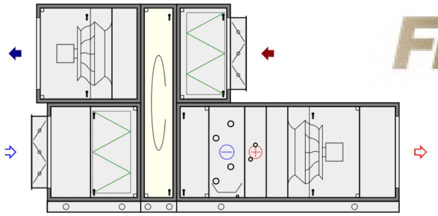
Summary:

Bigger AHU:

- Higher investment cost
- Lower air velocity
- More recovery
- More efficient fans
- Short pay back

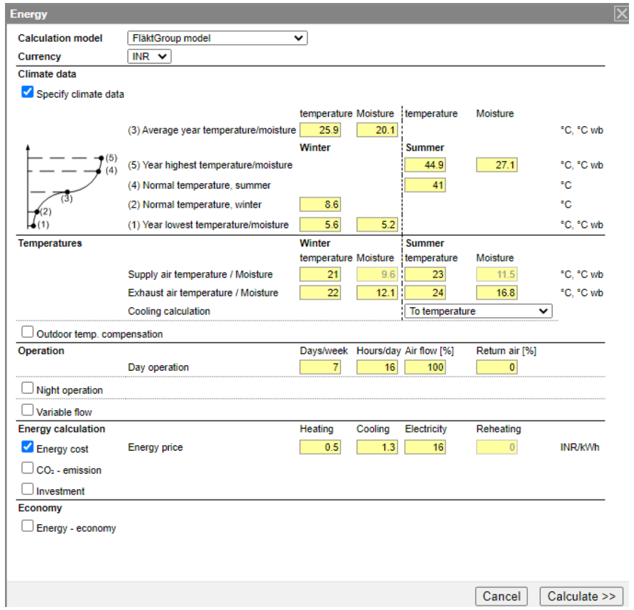
FläktGroup		Energy Class		
		A+	A	C
Electric Energy (Fans)	kWh/a	35286	43717	45785
Heating energy (Heating Coil)	kWh/a	331	829	608
Cooling energy (cooling coil)	kWh/a	56335	67518	66883
Other Equipment	kWh/a	596	596	595
Total Energy cost	01 Unit (INR/a)	₹ 647,513	₹ 797,196	₹ 893,281
Cost difference to class A+ (INR/a)	01 Unit	-	₹ 149,683	₹ 245,768
Difference after 15* years to class A+ (INR/a)	01 Unit	-	₹ 2,245,245	₹ 3,686,520
Number of AHUs (INR/a)	20 Units	-	₹ 44,904,900	₹ 73,730,400
Price of Air handling unit (INR/)	01 Unit	₹3,037,388	₹2,441,965	₹2,112,882
				

Comparison of operating costs by energy class



FläktGroup

Airflow (CFM)/ l/s	**12000/5715**
Esp (Pa)	300
Location	Delhi



Energy

Calculation model: FläktGroup model
Currency: INR

Climate data
☑ Specify climate data

	temperature	Moisture	temperature	Moisture	
(3) Average year temperature/moisture	25.9	20.1			°C, °C wb
	Winter		Summer		
(5) Year highest temperature/moisture			44.9	27.1	°C, °C wb
(4) Normal temperature, summer			41		°C
(2) Normal temperature, winter	8.6				°C
(1) Year lowest temperature/moisture	5.6	5.2			°C, °C wb

Temperatures

	Winter temperature	Winter Moisture	Summer temperature	Summer Moisture	
Supply air temperature / Moisture	21	9.6	23	11.5	°C, °C wb
Exhaust air temperature / Moisture	22	12.1	24	16.8	°C, °C wb
Cooling calculation			To temperature		

☐ Outdoor temp. compensation

Operation

	Days/week	Hours/day	Air flow [%]	Return air [%]
Day operation	7	16	100	0

☐ Night operation
☐ Variable flow

Energy calculation

		Heating	Cooling	Electricity	Reheating	
☑ Energy cost	Energy price	0.5	1.3	16	0	INR/kWh

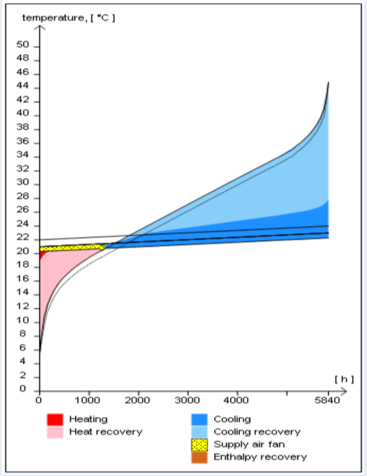
☐ CO_2 - emission
☐ Investment

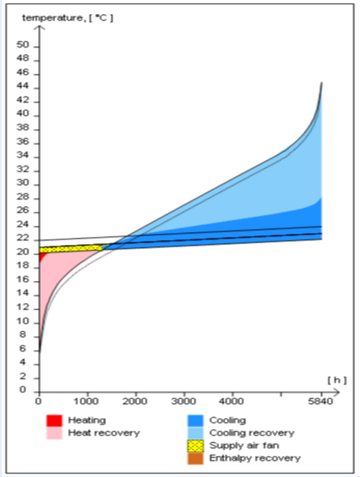
Economy
☐ Energy - economy

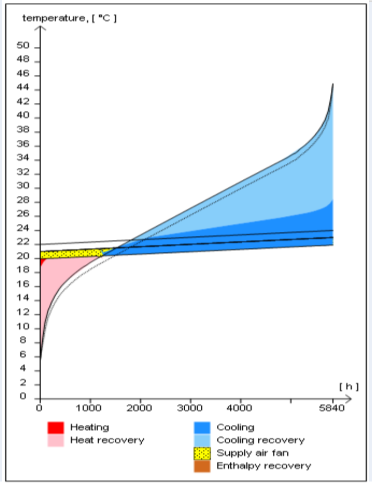
Cancel | Calculate >>

Energy Class

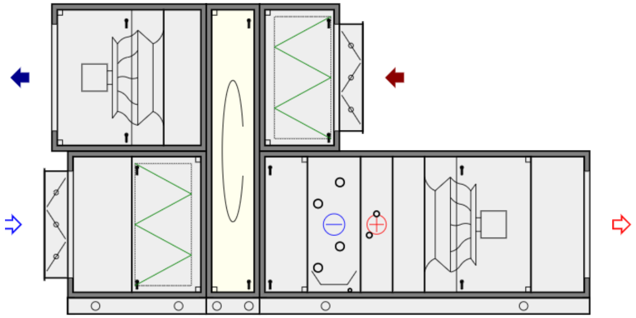
	A+		A		C	
Annual energy recovery						
Heat recovery	33836	kWh	32739	kWh	31003	kWh
Cooling recovery	467954	kWh	437991	kWh	417333	kWh
Temp. rise in supply air fan	6274	kWh	7233	kWh	8793	kWh
Annual additional energy						
Heating	653	kWh	869	kWh	485	kWh
Cooling	88298	kWh	96303	kWh	104434	kWh
Supply air fan	28627	kWh	32932	kWh	42314	kWh
Exhaust air fan	26679	kWh	29131	kWh	35704	kWh
Other Equipment	601	kWh	602	kWh	607	kWh
Annual energy cost						
Heating	326	INR	434	INR	242	INR
Cooling	114787	INR	125194	INR	135764	INR
Supply air fan	458032	INR	526912	INR	677024	INR
Exhaust air fan	426864	INR	466096	INR	571264	INR
Other Equipment	9616	INR	9632	INR	9712	INR
Total	1009626	INR	1128268	INR	1394007	INR







Comparison of operating costs by energy class



Airflow (CFM)	**12000**
Esp (Pa)	300
Location	Delhi

Summary:

Bigger AHU:

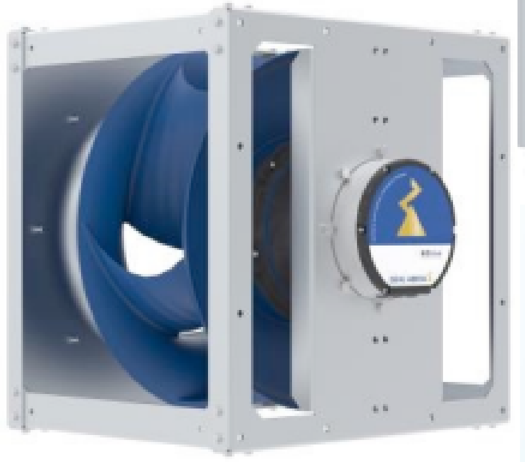
- Higher investment cost
- Lower air velocity
- More recovery
- More efficient fans
- Short pay back

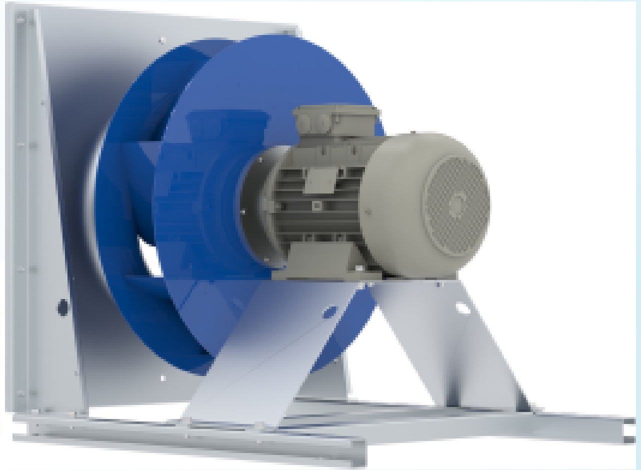
FläktGroup		Energy Class		
		A+	A	C
Electric Energy (Fans)	kWh/a	55306	62063	78018
Heating energy (Heating Coil)	kWh/a	653	869	485
Cooling energy (cooling coil)	kWh/a	88298	96303	104434
Other Equipment	kWh/a	601	602	607
Total Energy cost	01 Unit (INR/a)	₹ 1,009,626	₹ 1,128,268	₹ 1,394,007
Cost difference to class A+ (INR/a)	01 Unit	-	₹ 118,642	₹ 384,381
Difference after 15* years to class A+ (INR/a)	01 Unit	-	₹ 1,779,630	₹ 5,765,715
Number of AHUs (INR/a)	20 Units	-	₹ 35,592,600	₹ 1,15,143,300
Price of Air handling unit (INR)	01 Unit	₹ 3,558,263	₹ 3,115,165	₹ 2,840,612
				

Energy efficient direct driven fans (static pressure)

- Less number of components
- No belt = No loss of efficiency and no dust
- No maintenance
- Compact design = Saves space

EC fan with IE5 motor





Plug fan with IE3 motor

$$\eta_{fan} * \eta_{mot} * \eta_{vsd} = \eta_{sys}\ (> 65\%)$$

Changes in Fan Technology – Impact on Air Handling Units Energy Efficiency

EC technology

What is an EC motor?

EC motor = Electronically Commutated motor

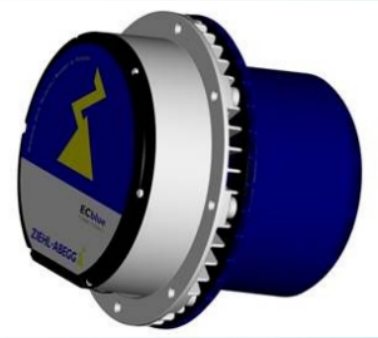
EC motors are…

…brushless DC motors, electronically commutated

…permanent magnet motors

…synchronous motors

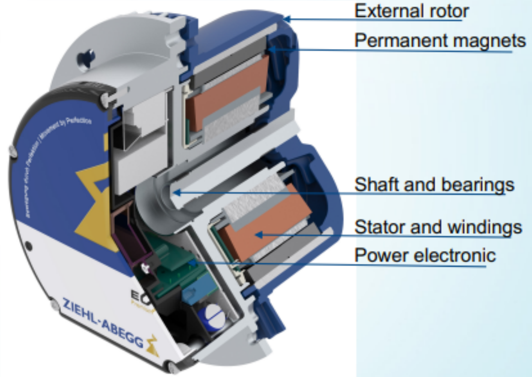
…speed controlled by an EC controller



EC Motor Overview

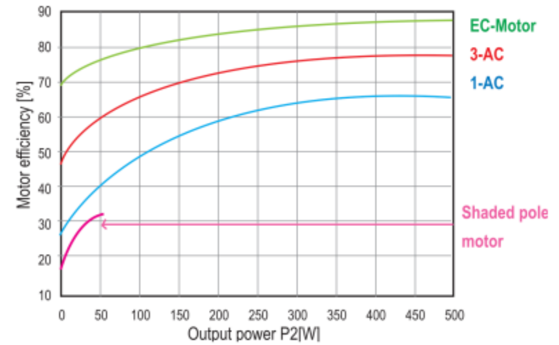
Highest Efficiency Compact Drive

- IE5 EC motor
- Inbuilt speed controller utilising EC technology: No VFD required
- IP55 rated EC motor



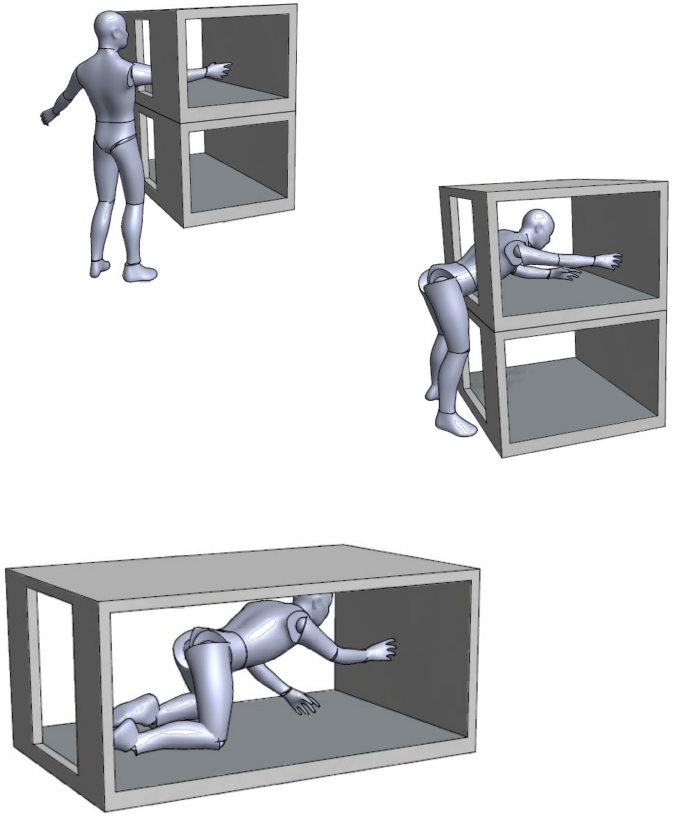
Motor efficiency

$$\text{Efficiency (\%)} = \frac{\text{Output power (Watts)}}{\text{Input power (Watts)}} \times 100$$



Air Handling Unit Service Space Requirements

Service Space is Important to Retain AHU Efficiency



- Accessibility
- Cleanability

Inspection door sizing is critical in order to ensure good maintenance

Selection Software

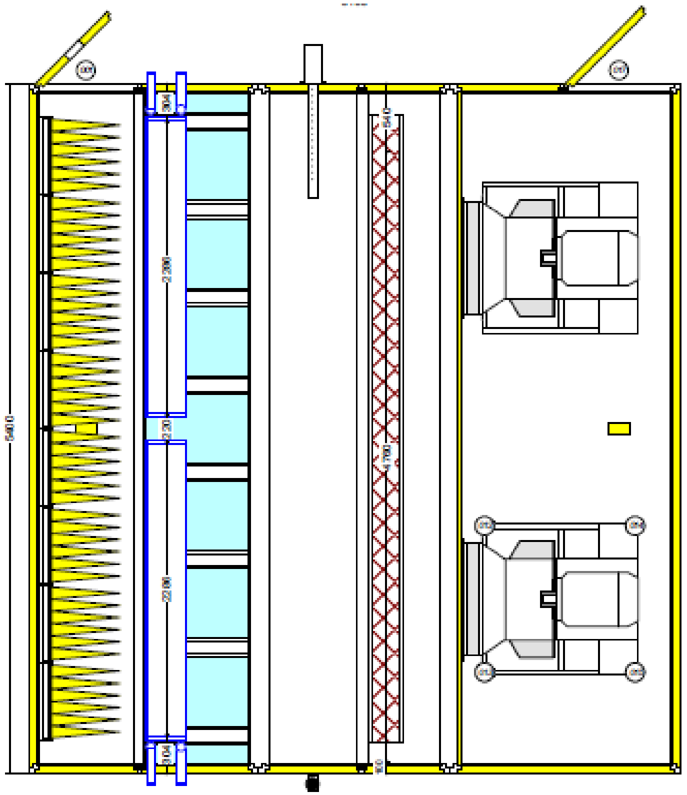
FAN		MOTOR	
Model	RLM56-8090-4D-34-58 - GEBHARDT	Qty & motor model	2xD200L-4P-30KW
Flow	2 x 11.80 m3/s		SIEMENS
diametro	900 mm	Nominal motor power	30.00 kW
Ext. static	400 Pa	motor RPM	1465(400V/3/50)
Min. I.P.D.	559 Pa	Motor efficiency	92.00 %
Max I.P.D.	796 Pa	In	59.00 Amp
Avg. I.P.D.	677 Pa	Is/In	7.80
Avg. I.P.D.	677 Pa	Power factor	0.80
Total static pressure	1077 Pa	Start Power factor	0.50
RPM	1486 rpm	Nominal torque	195.00 Nm
Efficiency	0.72 %	Locked rotor torque Ts/Tn	3.00
Shaft power	2 x 20.32 kW	Maximum torque Tmax/Tn	3.40

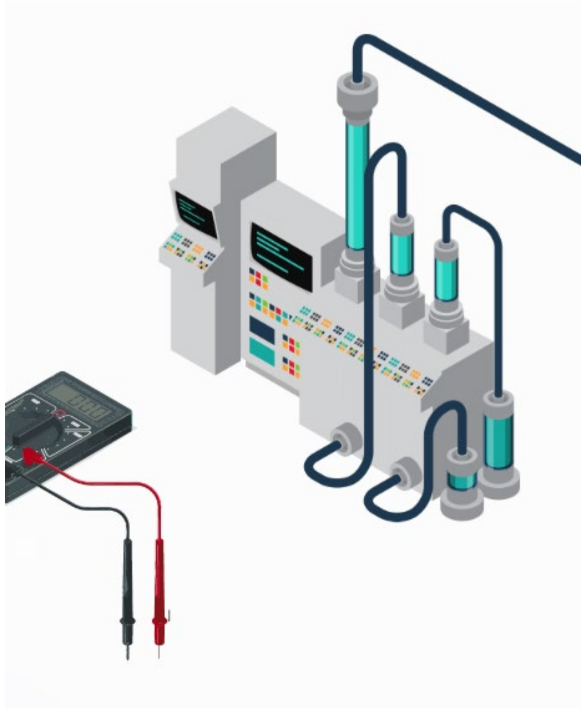
		-5%	-2.5%	100%	+2.5	+5%
Air volume	m3/s	11.210	11.505	11.800	12.095	12.390
Total static pressure	Pa	1247	1165	1077	987	891
Shaft power	kW	21.146	20.781	20.320	19.829	19.246
Electrical Power Input	kW	22.985	22.588	22.087	21.553	20.920
				1.722		
				1.872		

In-duct sound power (dB)

A	125 Hz	250 Hz	500 Hz	1 KHz	2 KHz	4 KHz	8 KHz
99.1	102	96	95	95	92	84	80

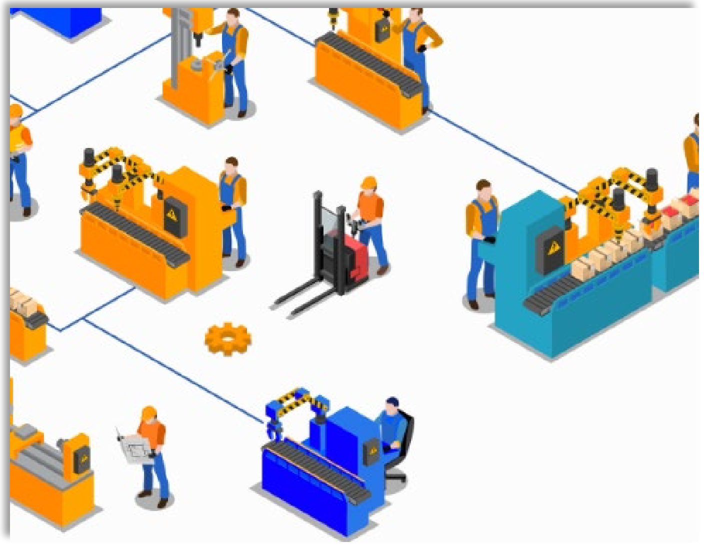
SELECTION SOFTWARE CHECK & DATA MINING





LABORATORY TEST

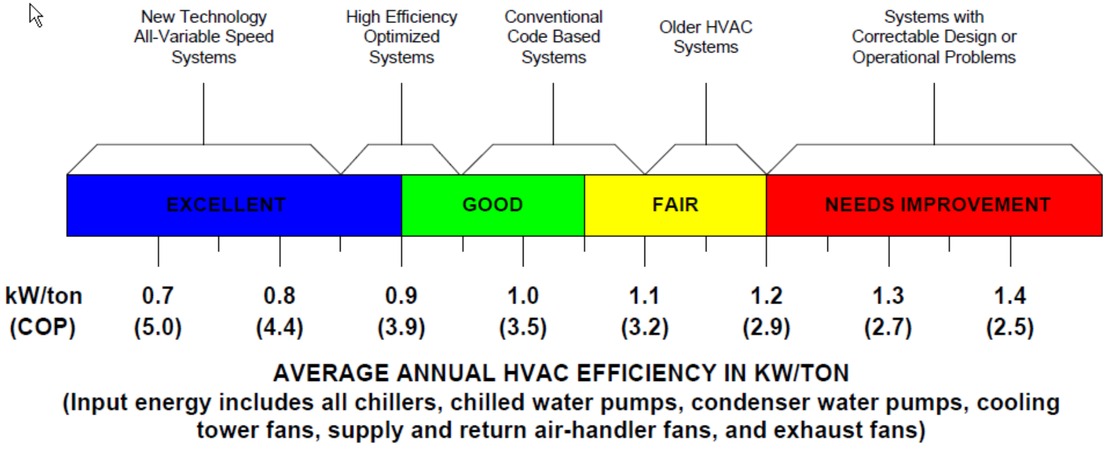
FACTORY AUDIT



'The Bigger Airside Picture '

- The role and importance of 'airside' in trying to achieve net zero

- Efficient airside system design and evaluation tools
- Energy efficient and energy certified airside equipment
- Proper airside installation
- Certified commissioning
- Operations training and hvac components energy tracking



energise 2023

Lifestyle, Energy Efficiency, and Climate Action

THANK YOU

For further, pls contact
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Arvind Singh –Director
arvind.singh@flaktgroup.com

Impact of Glass Selction on Indoor Comfort

Shailee Goswami[1] and Vardan Soi[2]
[1]Senior Research Engineer, Saint-Gobain Research India
[2]Technical Resource Group, Solar Decathlon India

Abstract

The "Impact of Glass Selection on Indoor Comfort" case study by Saint-Gobain Research India investigates the benefits of electrochromic (EC) glass, or smart glass, in commercial buildings. The study focuses on how EC glass enhances thermal and visual comfort while reducing energy demand. By controlling the tint of the glass, EC glass minimizes overheating and glare, providing superior comfort compared to static double-glazed units (DGU). Simulations conducted on a typical office building in Chennai reveal that EC glass maintains an average operative temperature of 26°C, with 95% of the area being thermally comfortable, compared to 27.5°C with DGU. Furthermore, EC glass provides three times more usable daylight and eliminates glare, resulting in uninterrupted views and enhanced occupant comfort. The findings highlight the significant energy savings, reduced HVAC costs, and improved indoor environments achievable with dynamic glass technology, making it a compelling choice for modern building designs.

IMPACT OF GLASS SELECTION ON INDOOR COMFORT

Saint-Gobain Research India

Shailee Goswami
Vardan Soi

INTRODUCTION

- **Electrochromic glass** (a.k.a. **smart glass** or **dynamic glass**) is an electronically tintable glass used for windows, skylights, facades and curtain walls.

- Electrochromic glass, which can be directly controlled by building occupants, is popular for its ability to improve occupant comfort, maximize access to daylight and outdoor views, reduce energy costs and provide architects with more design freedom.

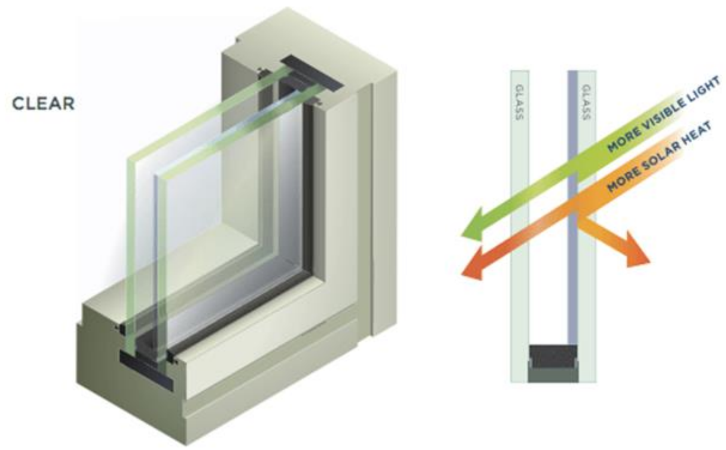
OCCUPANT COMFORT

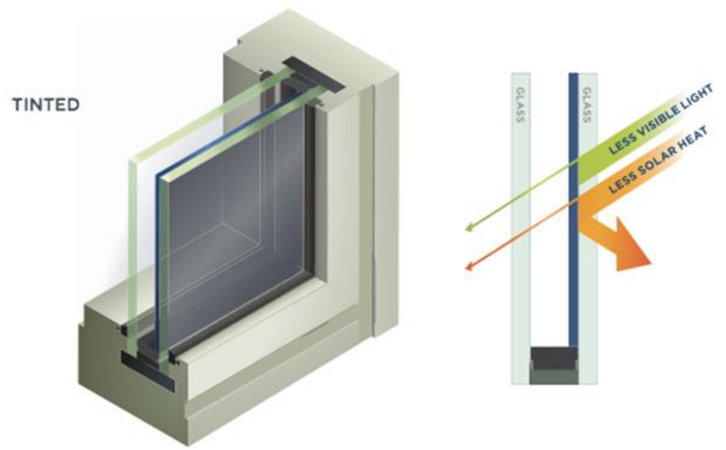
OUTDOOR CONNECTION

SUSTAINABILITY

DESIGN POSSIBILITIES

WORKING PRINCIPLE





Apply a voltage to the outer contacts (conductors) and lithium ions (shown here as blue circles) move from the innermost electrode to the outermost one (from left to right in this diagram). The window reflects more light and transmits less, causing it to appear opaque (dark).

On its inside surface, the substrate is coated with a double-sandwich of 5 ultra-thin layers:

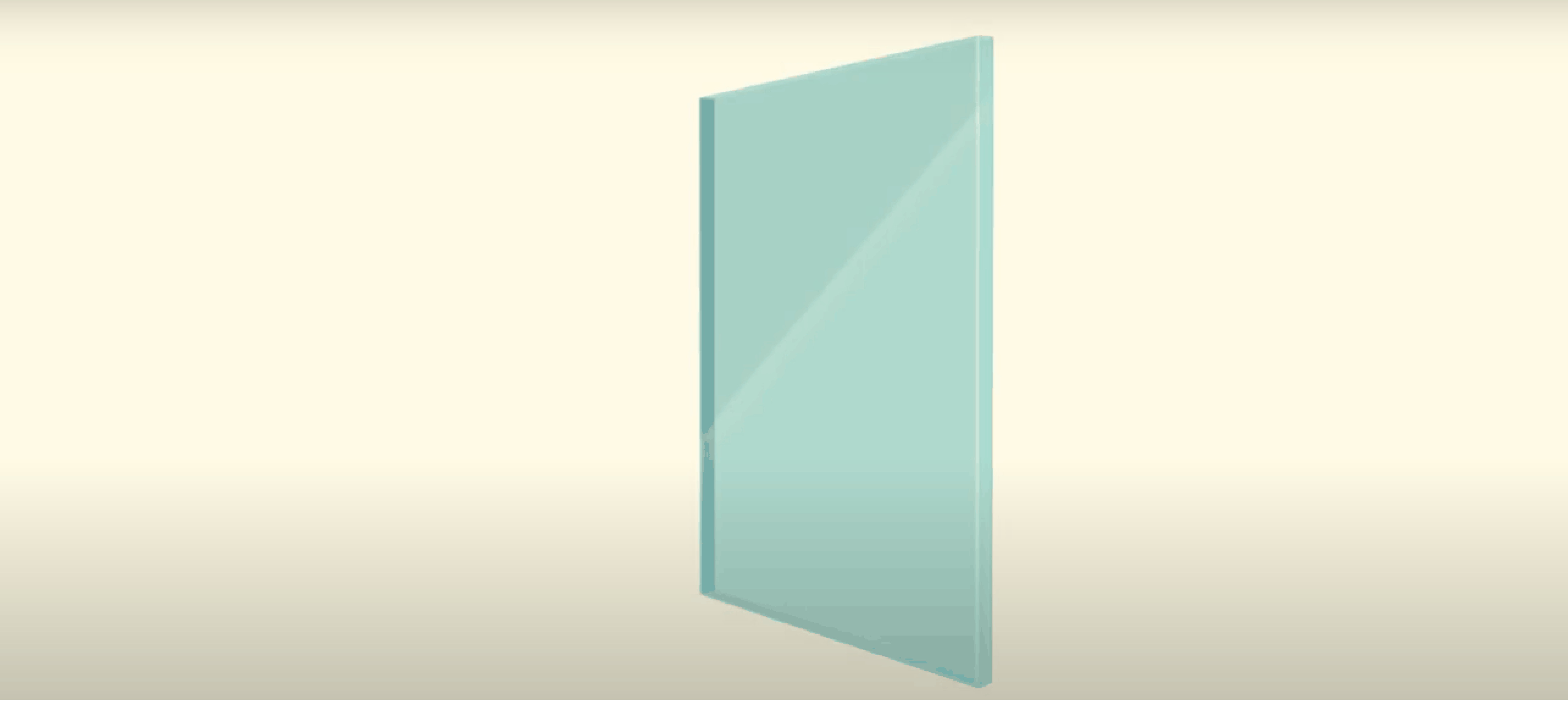
- A separator in the middle,
- Two electrodes (thin electrical contacts) on either side of the separator
- Two transparent electrically conducting layers on either side of the electrodes.

1. Normally, when the window is clear, the lithium ions reside in the innermost electrode (e.g. $LiCoO_2$).

2. When a small voltage is applied to the electrodes, the ions migrate through the separator to the outermost electrode When they "soak" into that layer (e.g. polycrystalline tungsten oxide, WO_3), they make it reflect light, effectively turning it opaque.

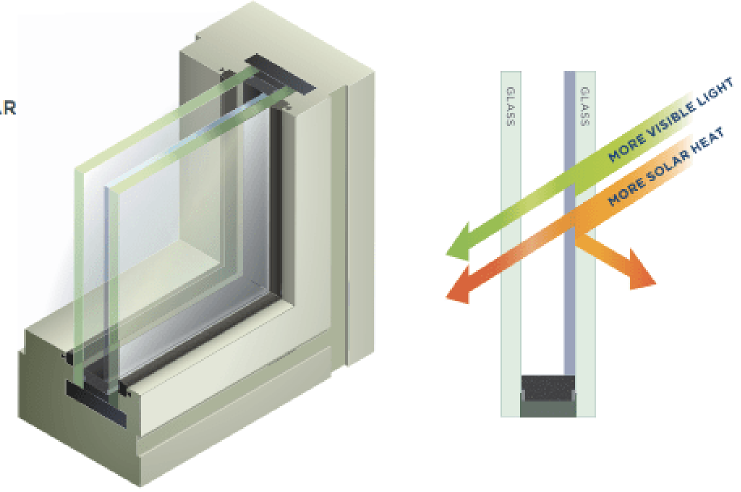
3. They remain there until the voltage is reversed, causing them to move back so the window turns transparent once again. No power is needed to maintain electrochromic windows in their clear or dark state — only to change them from one state to the other.

THE SYSTEM CONFIGURATION

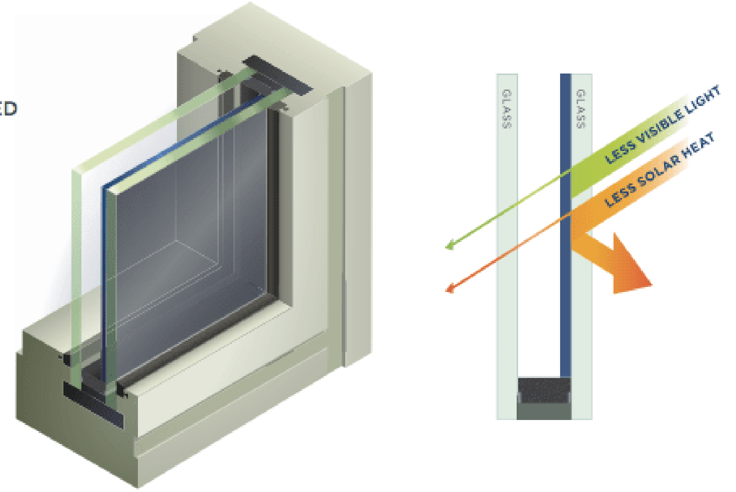


THE SYSTEM CONFIGURATION

CLEAR

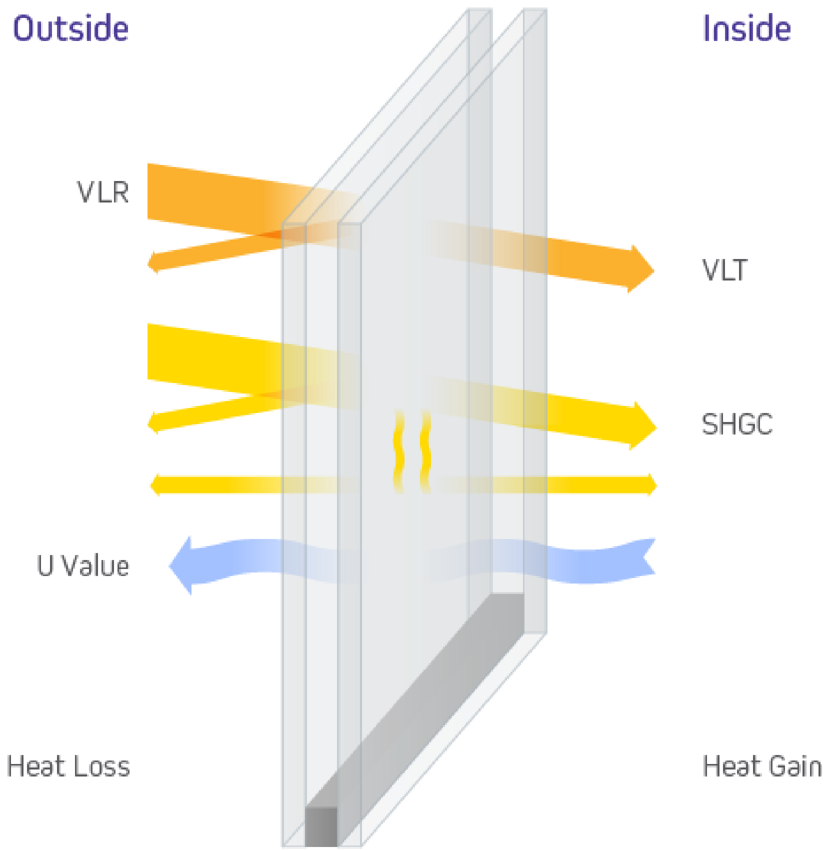


TINTED



Parameter	Clear State	Intermediate tint 1	Intermediate tint 2	Fully tinted
VLT (%)	59	17	6	1
SHGC	0.40	0.12	0.07	0.04
U value (W/m².K)	1.1	1.1	1.1	1.1

KEY PARAMETERS



Heat transmittance (U-value)

- U-value indicates the rate of heat flow due to conduction, convection, and radiation through a window as a result of a temperature difference between the inside and outside. The lower the U-value, the better it is at keeping the heat or cold out. In all cases regardless of climate zone a window with good insulation properties will help to improve the comfort of your home.
- In most countries, U-value is expressed in SI units, as watts per square metre-kelvin W/(m2·K)

Solar Heat Gain Coefficient (SHGC)

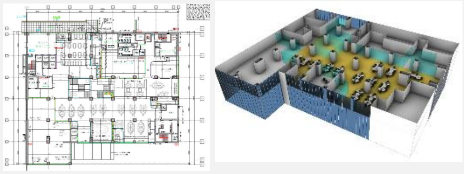
- Solar Heat Gain Coefficient or SHGC is a measure of how much solar radiation passes through the window. In a cool climate, windows which have a high SHGC allow a greater amount of solar radiation to pass through, offering free solar heating for the home.
- Glass selection has a considerable effect on the SHGC of a window or door.

Visible Light Transmittance (VLT)

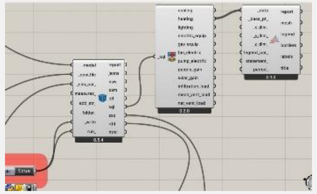
- Visible Light Transmittance is the percentage of visible light (390 – 780 nm) striking the glazing that will pass through.
- Glazing with a high visible transmittance appears relatively clear and provides sufficient daylight and unaltered views; however, they it tends to create glare. Glazing with low visible transmittance is best used in highly glare-sensitive conditions, but can create gloomy interiors under certain weather conditions and diminished views.

SIMULATION TOOLS & OVERALL METHODOLOGY

3D Model created on Rhino 3D

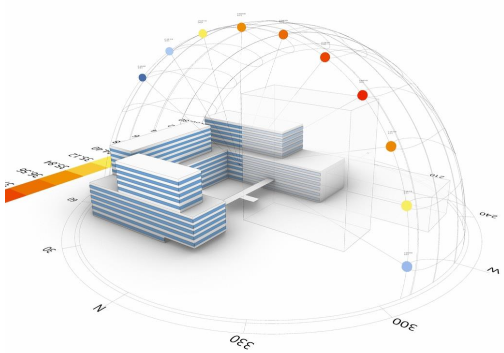


Workflow development using grasshopper tools

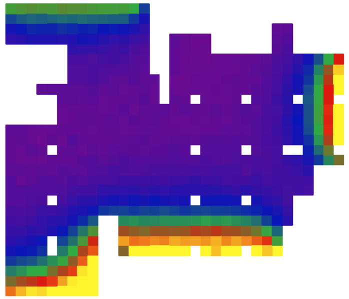


Thermal comfort workflow development using Ladybug tools

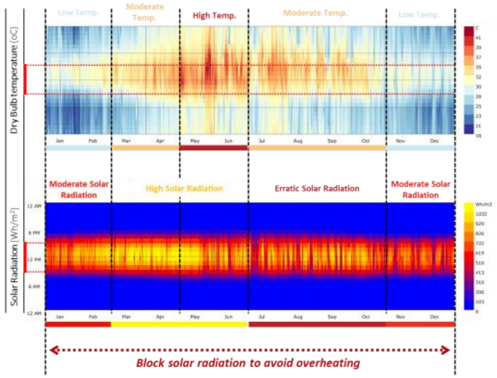
Visual comfort workflow development using Honeybee and DIVA tools



Analysis of geometry



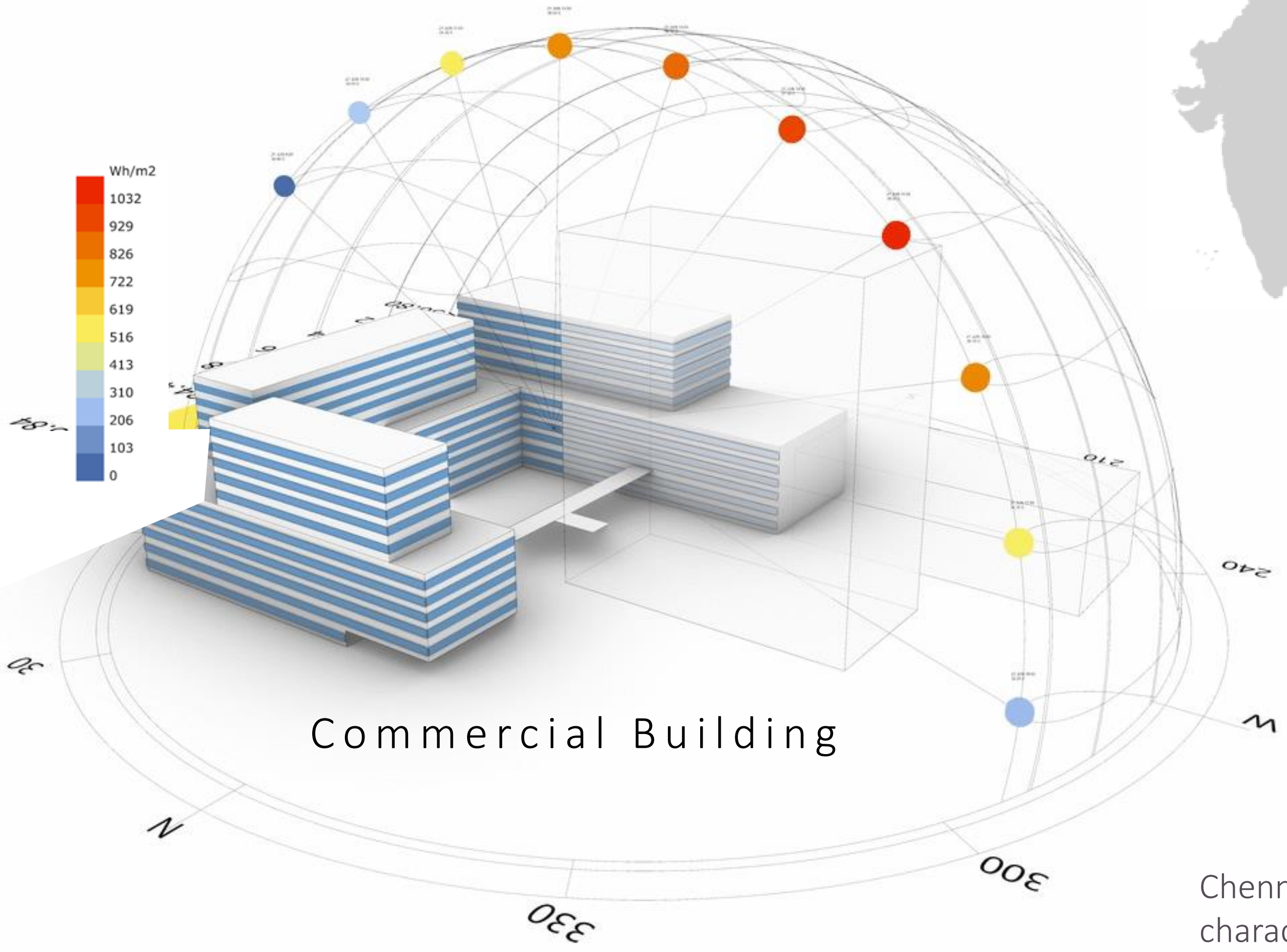
Visualization of data



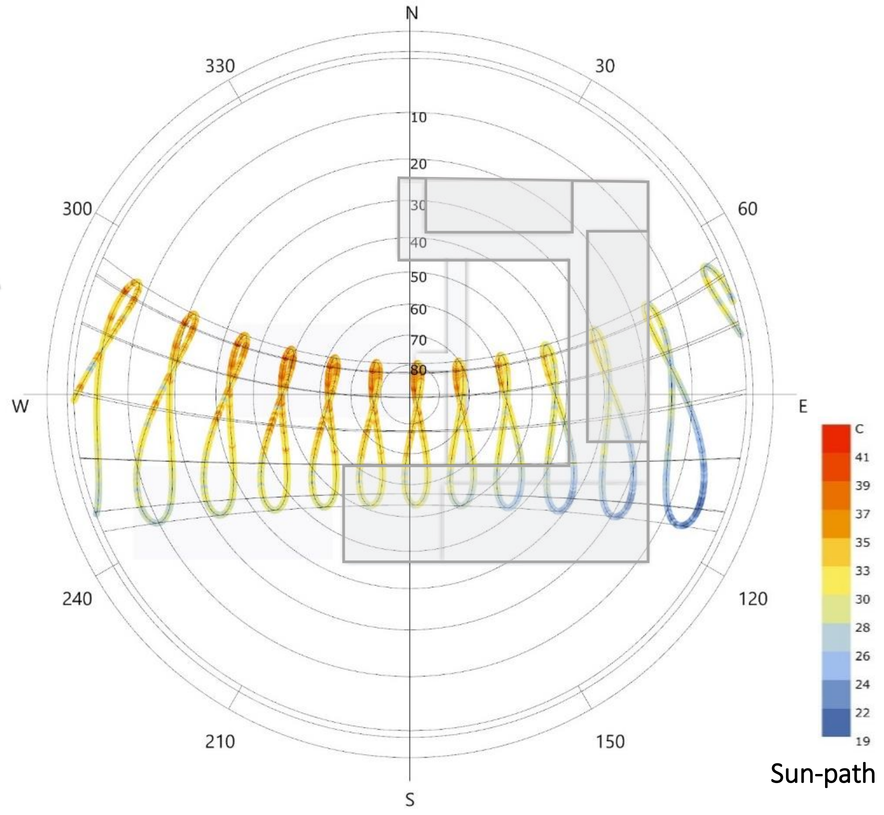
Analysis of data

BUILDING DETAILS

Chennai, Tamilnadu
Coordinates: ***13° N, 80° E***
Climate Type: ***Warm & Humid***



3D Sun-path indicating Solar radiation w.r.t solar position for 21st July, Sept & Dec (9am-4pm).



Sun-path

Chennai lies in Warm & Humid climate zone as per ECBC 2017 and is characterized by high temperature *(>30°C)* & solar radiation *(>500Wh/m2)* during occupancy hours.

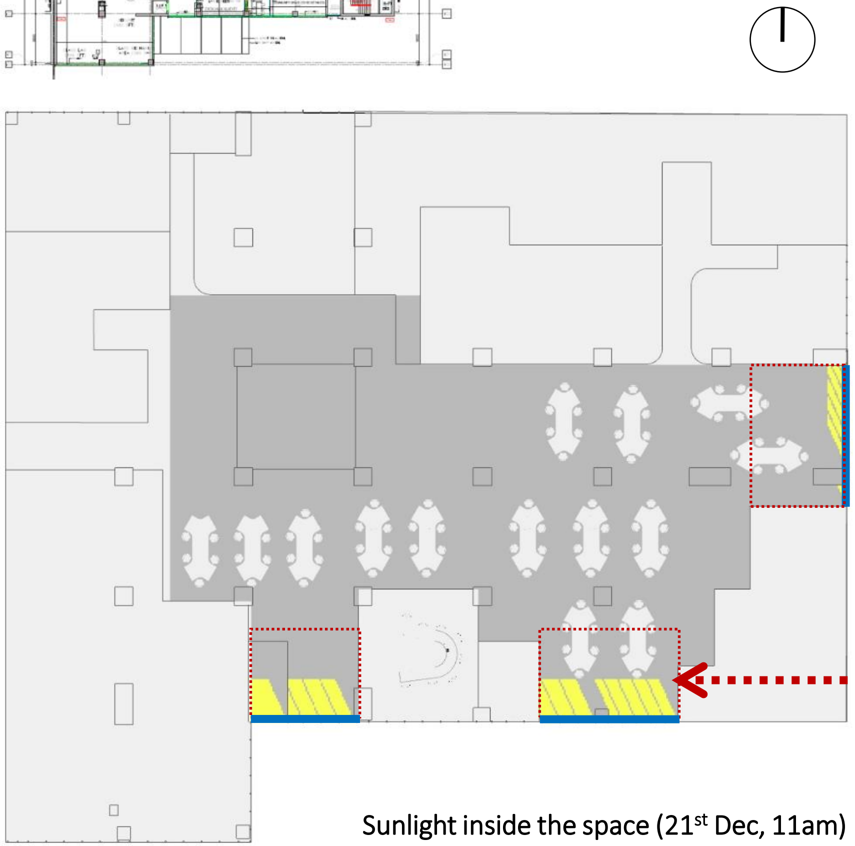
Reducing direct solar gains is the most effective passive strategy to reduce envelope heat gains not in just extreme summer months (*May-June*) but also, during the moderate & low temperature periods to avoid over heating.

BUILDING DETAILS

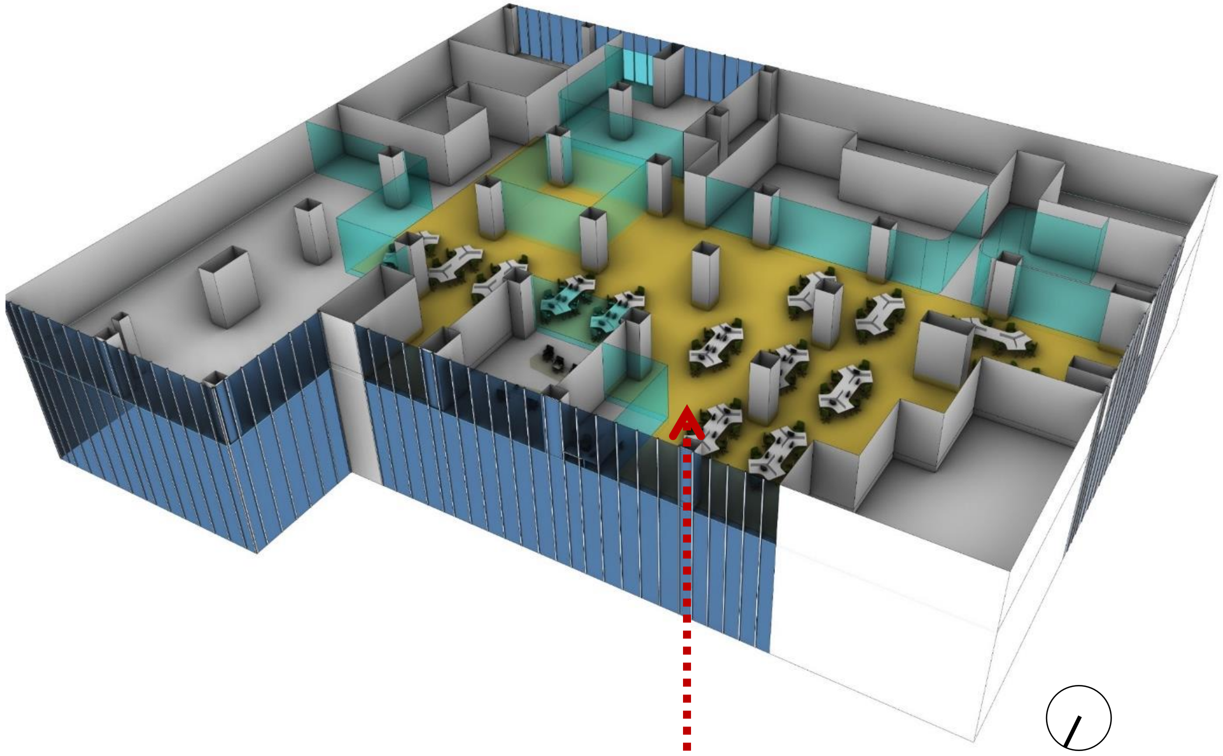
5m deep perimeter area
20m glazing length

Office space, Chennai

3rd Floor



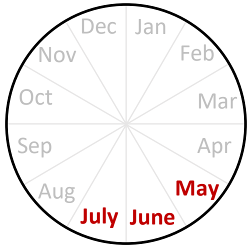
Sunlight inside the space (21st Dec, 11am)

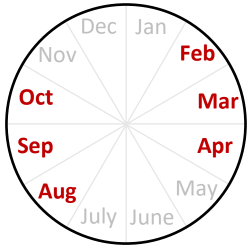


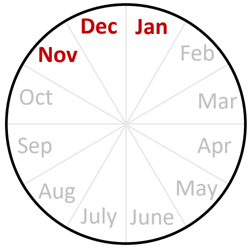
25% floor plate area lie in perimeter zone

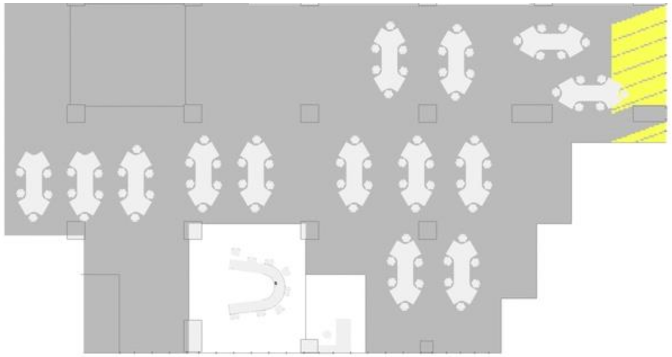
PROBLEM DEFINITION

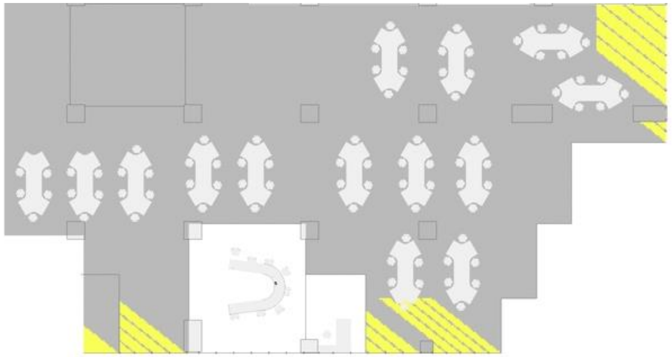
5m deep perimeter area
20m glazing length









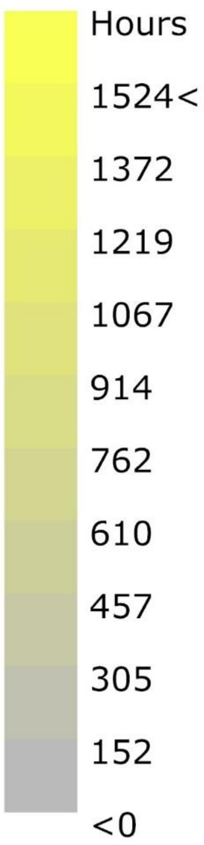


25% **area vulnerable to direct sunlight.**

PROBLEM DEFINITION

Working hours: 9am-4pm
Total hours: 3285

40-50% of occupied hours



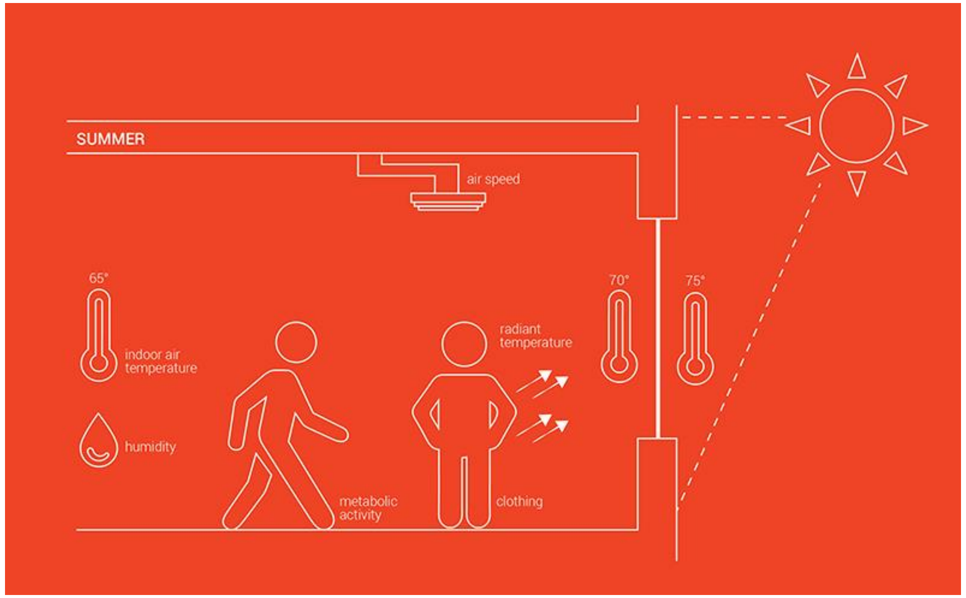
45%

of occupied hours vulnerable to direct sunlight.

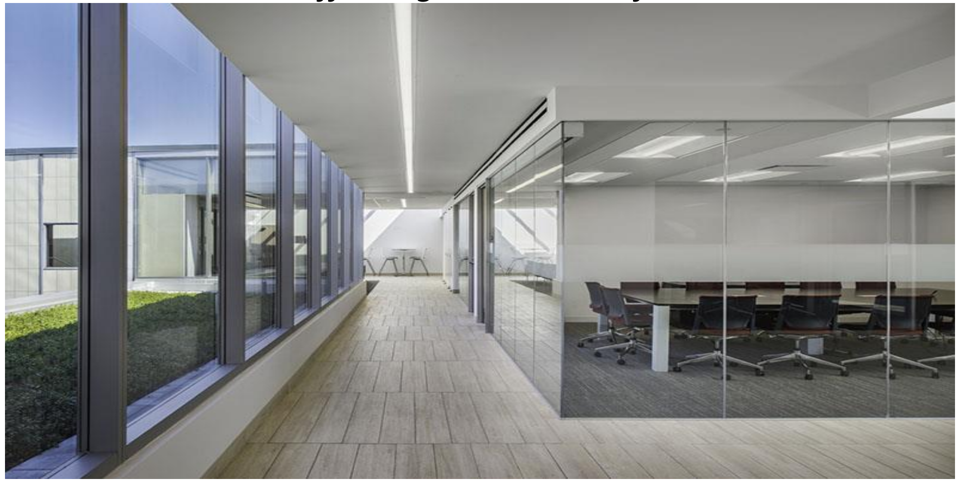
can affect both thermal and visual comfort for the occupants

Thermal Comfort

QUANTIFYING THERMAL COMFORT



Factors affecting thermal comfort



One of the strategies to improve thermal comfort

- **Operative temperature** is essentially an average of the air temperature of a space and the average of the various surface temperatures surrounding the space.

- Operative temperature is the perceived temperature by the occupant and it changes spatially due direct solar radiation (short wave) & long wave radiation of surfaces like walls, glazing roof etc.

- **Direct Solar radiation** is the major cause of thermal discomfort in **the perimeter area**.

Unlike the static glass, EC glass changes the tint state i.e. SHGC based on solar radiation, indoor & outdoor air temperature and modulate solar penetration to minimize overheating in the space. **This not only increases thermal comfort of occupants but also reduces the air conditioning load to maintain the same**.

CASE STUDY

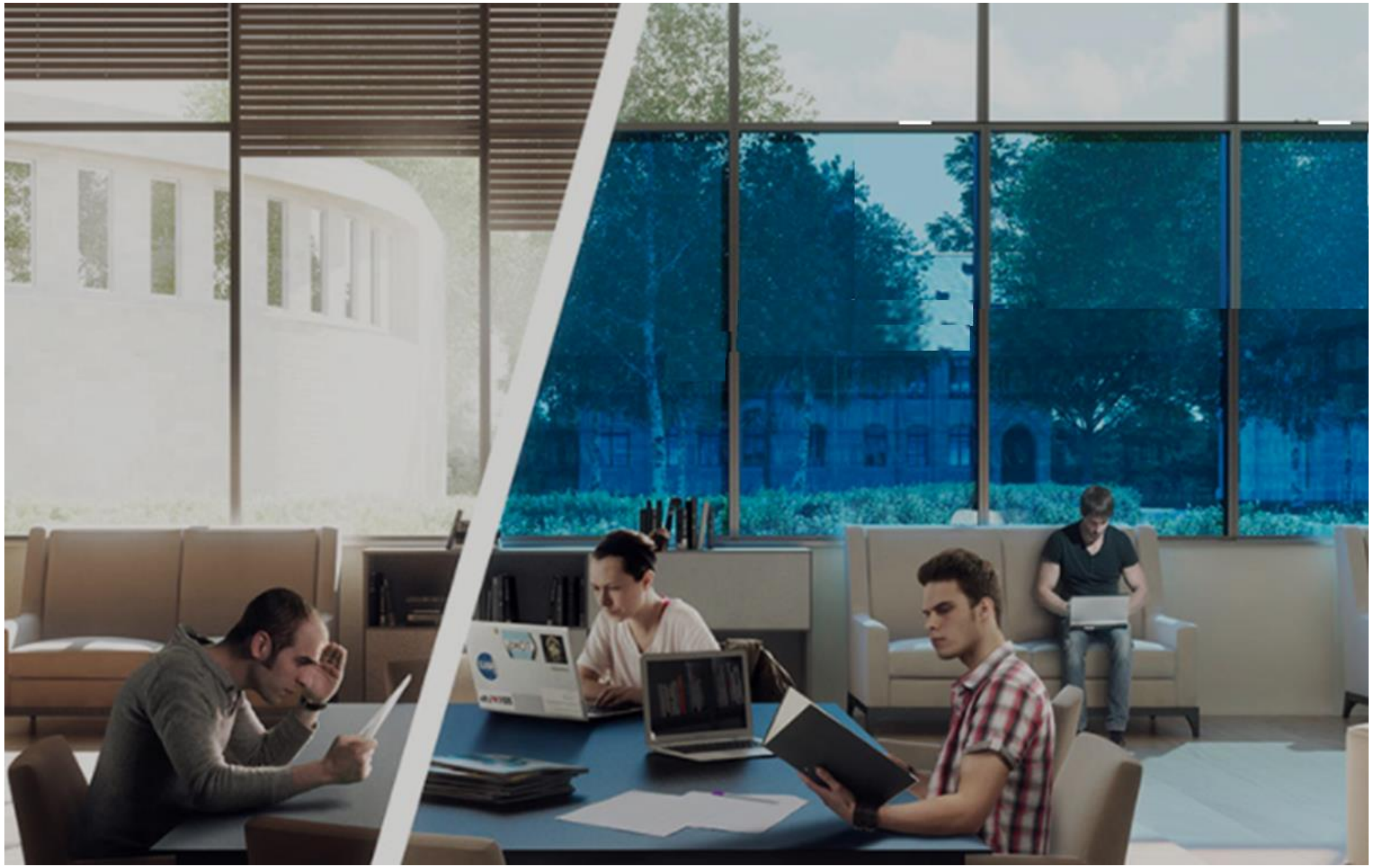
Thermal Comfort

Electrochromic (EC) glass (Dynamic)
vs.
Std. DGU (Static)

Typical Office Building, Chennai

INPUT PARAMETERS

Static glass with blinds vs. Dynamic tinting electrochromic glass



U Value of Glass: 1.195 W/m²K
SHGC: 0.21

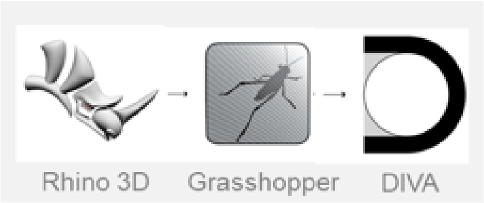
U Value of Glass: 1.195 W/m²K
SHGC: 0.4, 0.12, 0.07, 0.04

Parameter	Clear State	Intermediate tint 1	Intermediate tint 2	Fully tinted
VLT (%)	59	17	6	1
SHGC	0.40	0.12	0.07	0.04
U value (W/m².K)	1.1	1.1	1.1	1.1

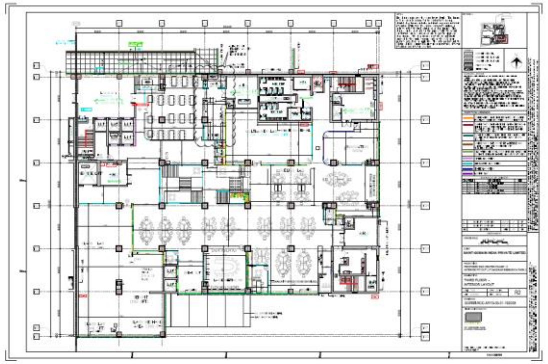
Multi Comfort BY SAINT-GOBAIN

SIMULATION METHODOLOGY

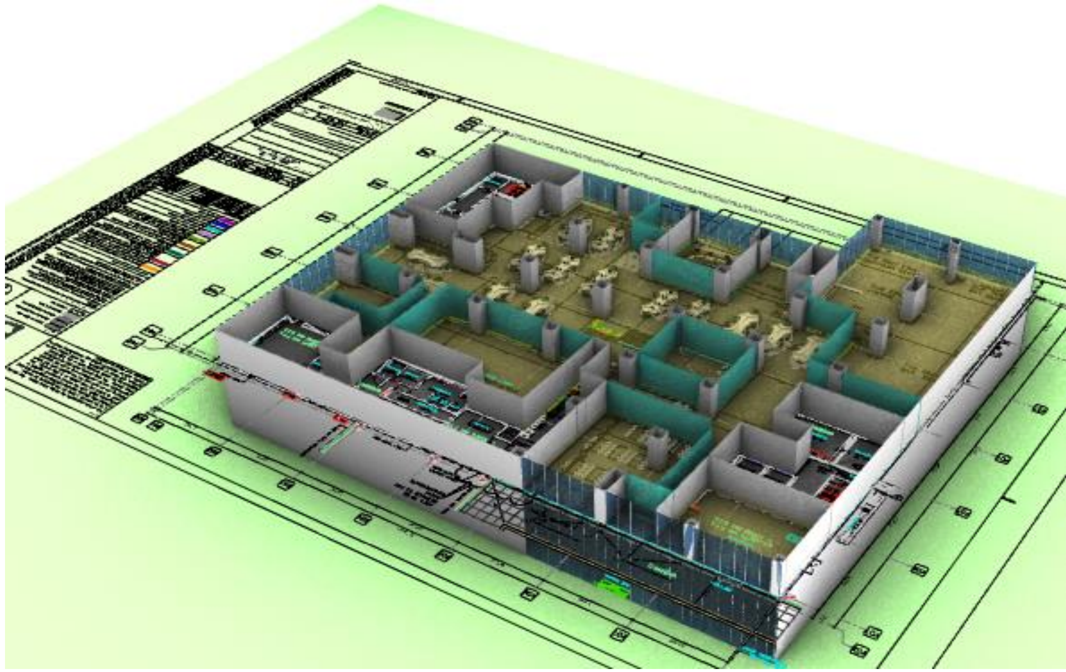
TOOLS

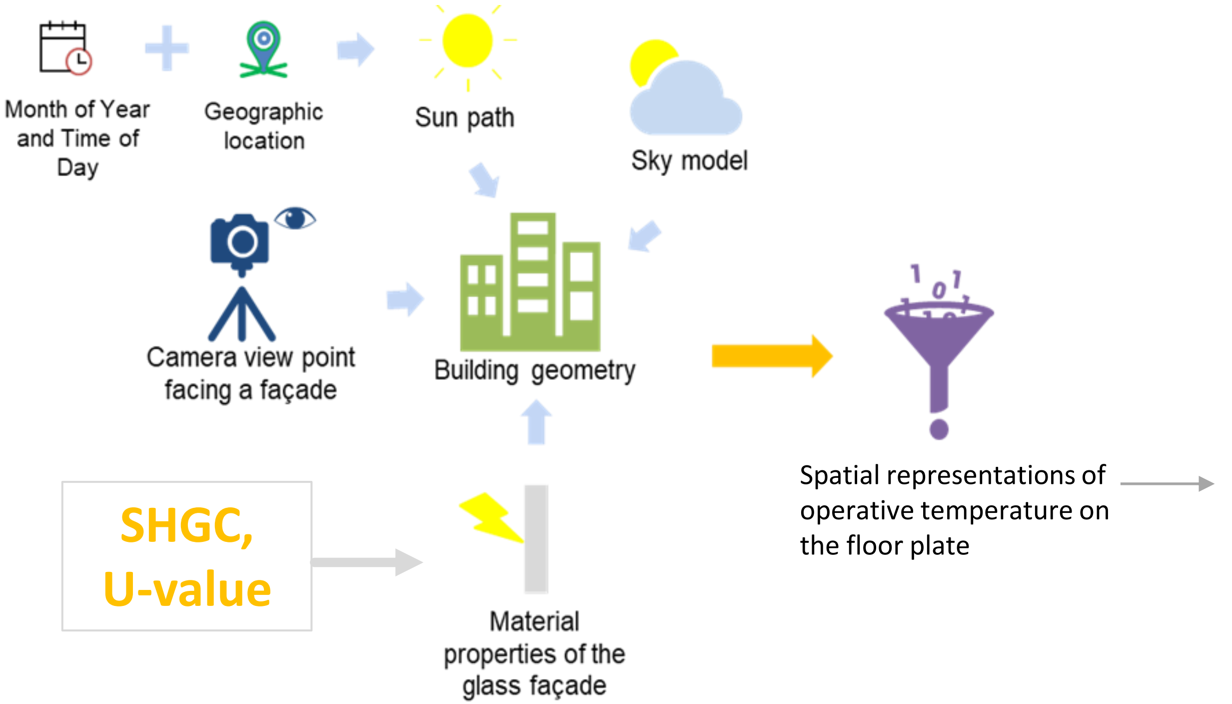


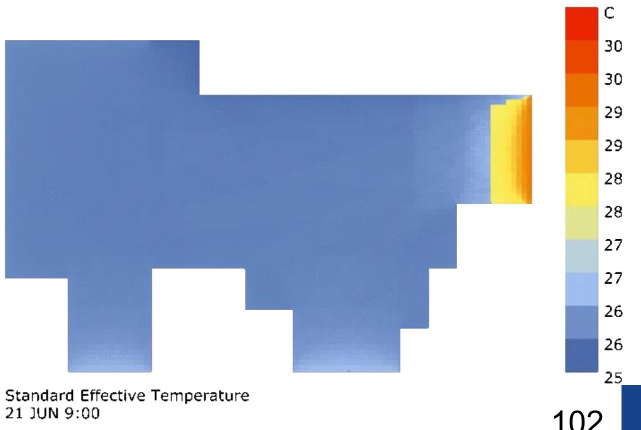
2D PLAN



3D MODEL

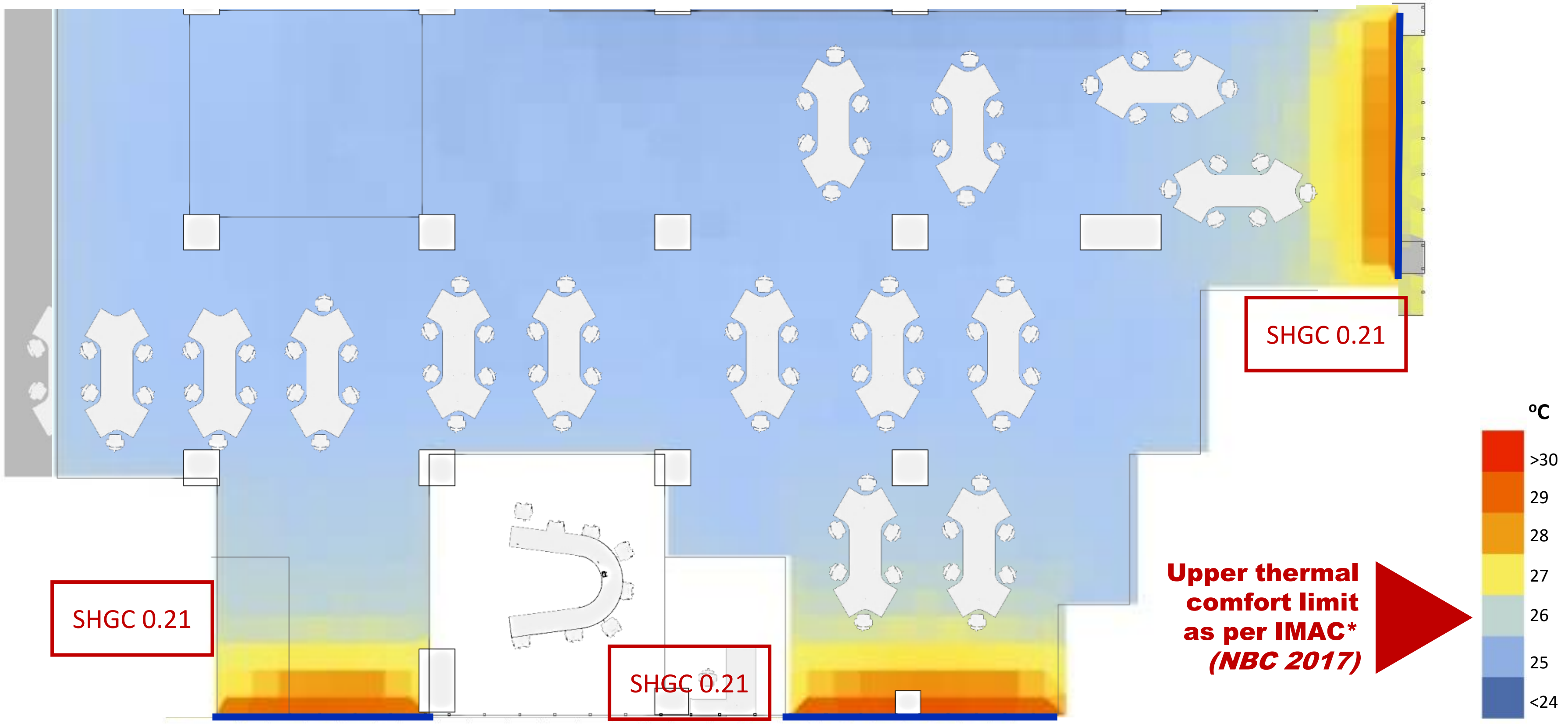






THERMAL COMFORT – DGU

U Value of Glass: 1.195 W/m²K
SHGC: 0.21
**Indian model for Adaptive Thermal Comfort*

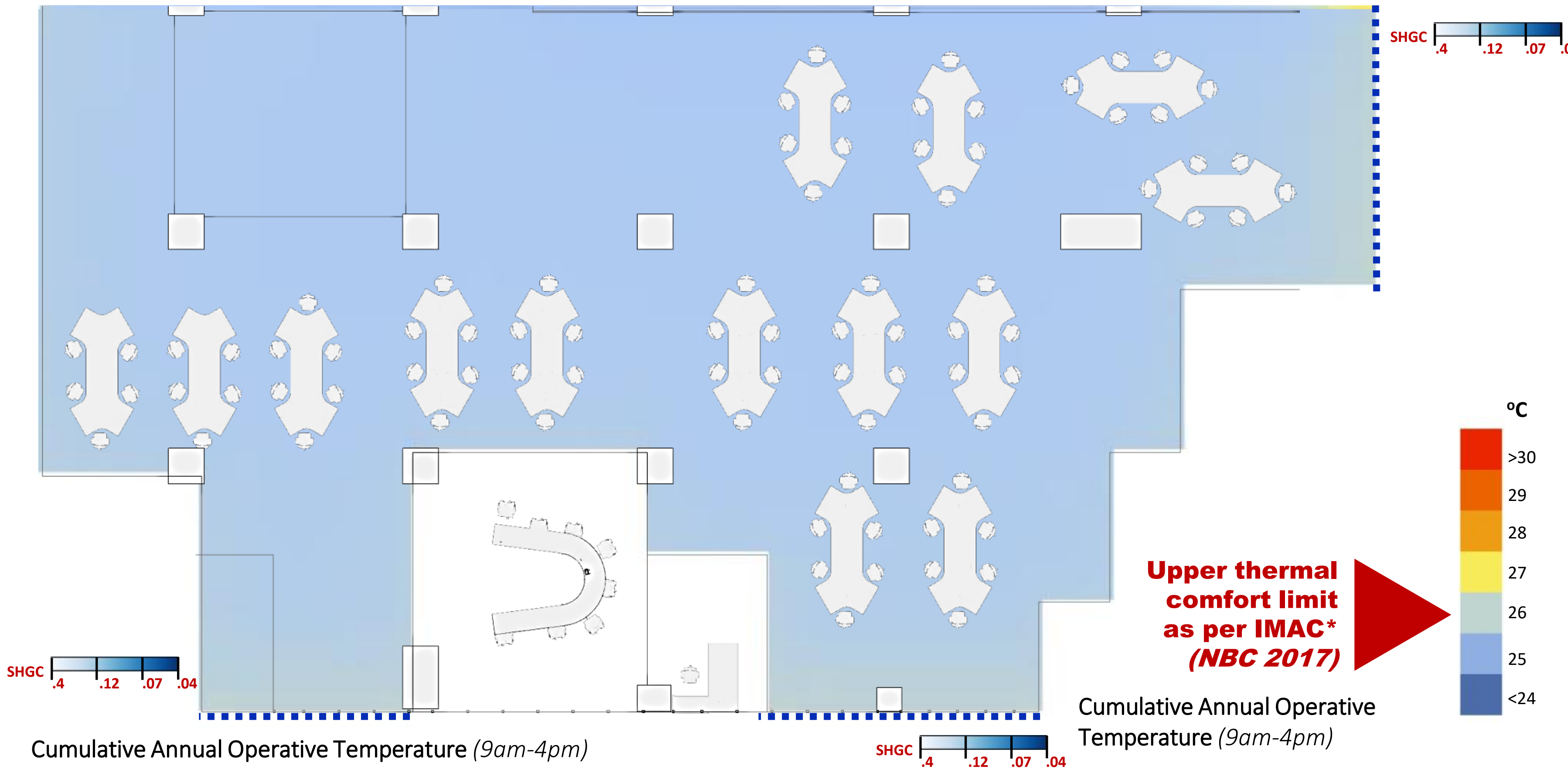


Cumulative Annual Operative Temperature *(9am-4pm)*

~27.5ºC average operative temp. in the perimeter zone

THERMAL COMFORT – Dynamic tinting EC glass

U Value of Glass: 1.195 W/m²K
SHGC: 0.4, 0.12, 0.07, 0.04
**Indian model for Adaptive Thermal Comfort*

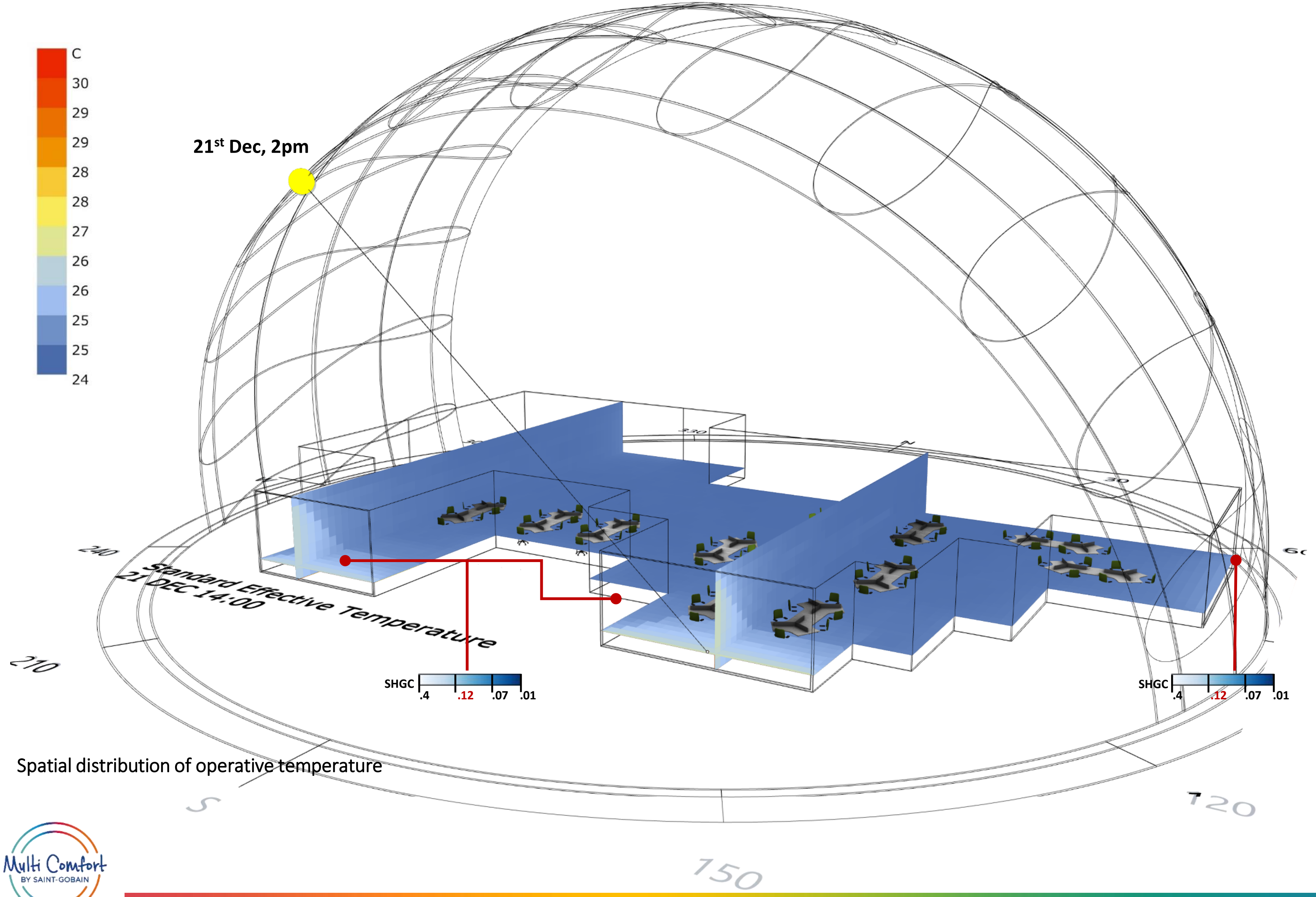


Cumulative Annual Operative Temperature *(9am-4pm)*

Cumulative Annual Operative Temperature *(9am-4pm)*

~26°C **average operative temp. in the perimeter zone**

THERMAL COMFORT – DGU VS Dynamic Tinting EC Glass



Spatial distribution of operative temperature

Less Radiant Asymmetry

~26°C average operative temp. in the perimeter zone

95% area thermally comfortable

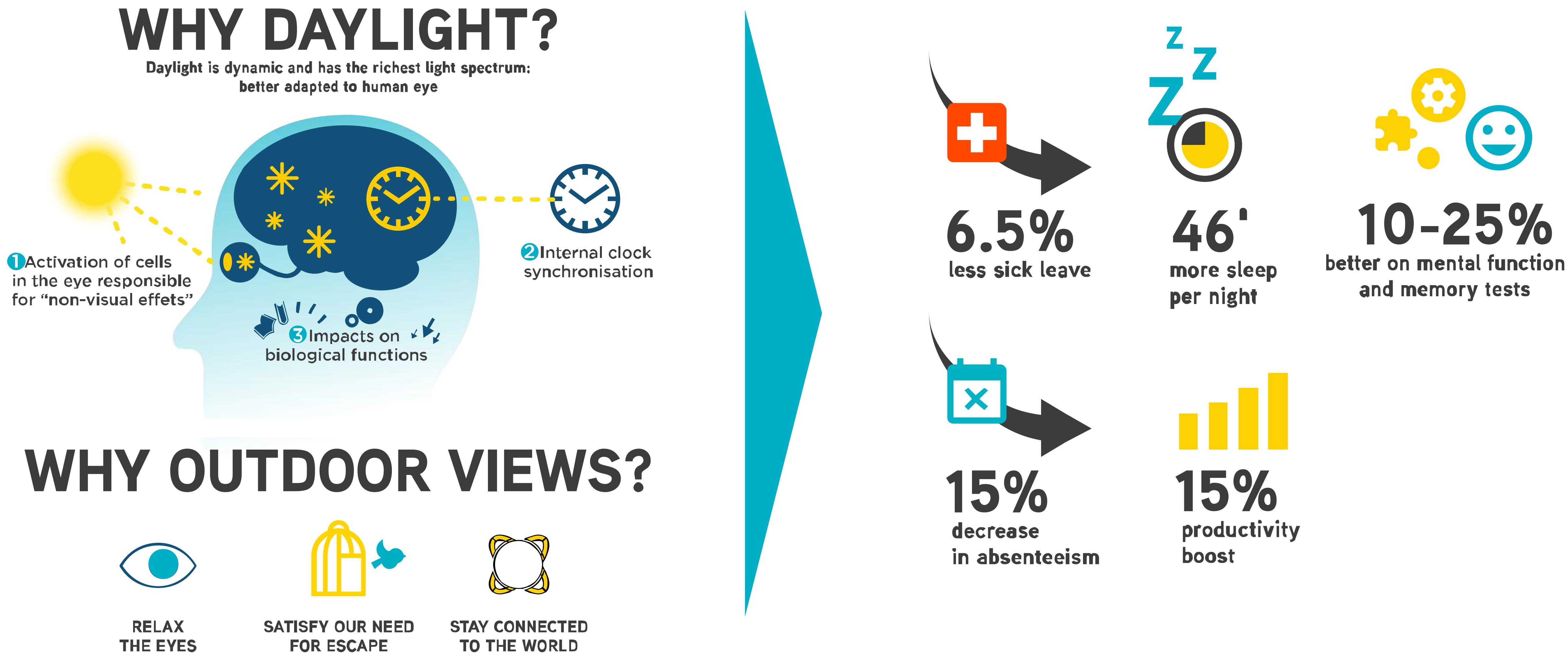
Visual Comfort

NUMBER ONE OFFICE PERK – NATURAL LIGHTING

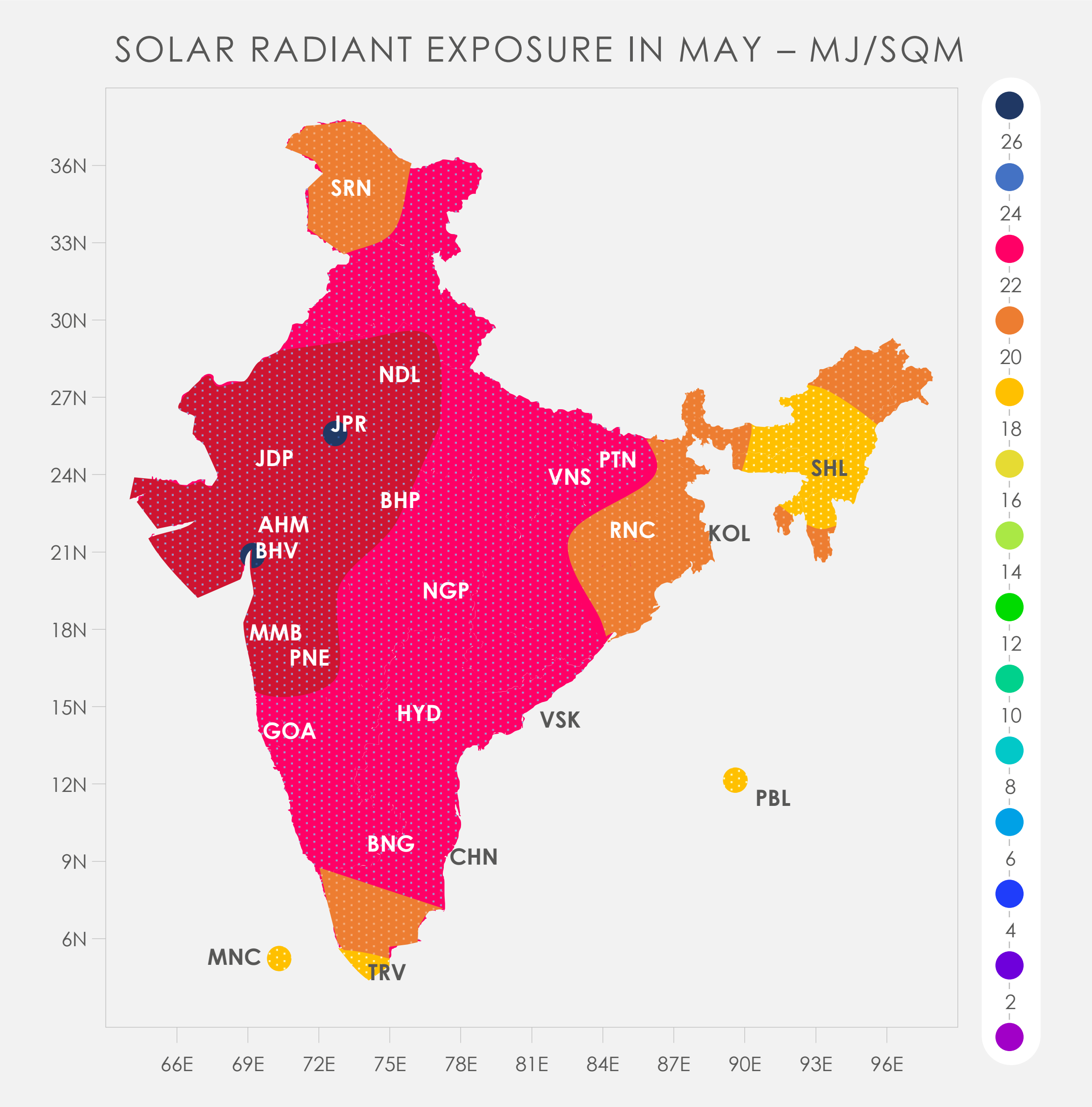
A research poll of 1,614 found that access to natural light and views of the outdoors are the number one attribute of the workplace environment. This outranks onsite cafeterias, fitness centres, and premium perks including on-site childcare.

ENABLING COMFORT & PRODUCTIVITY

- Human benefits of daylight and outdoor views



INDIAN SUBCONTINENT RICH IN DIRECT SOLAR RADIANCE



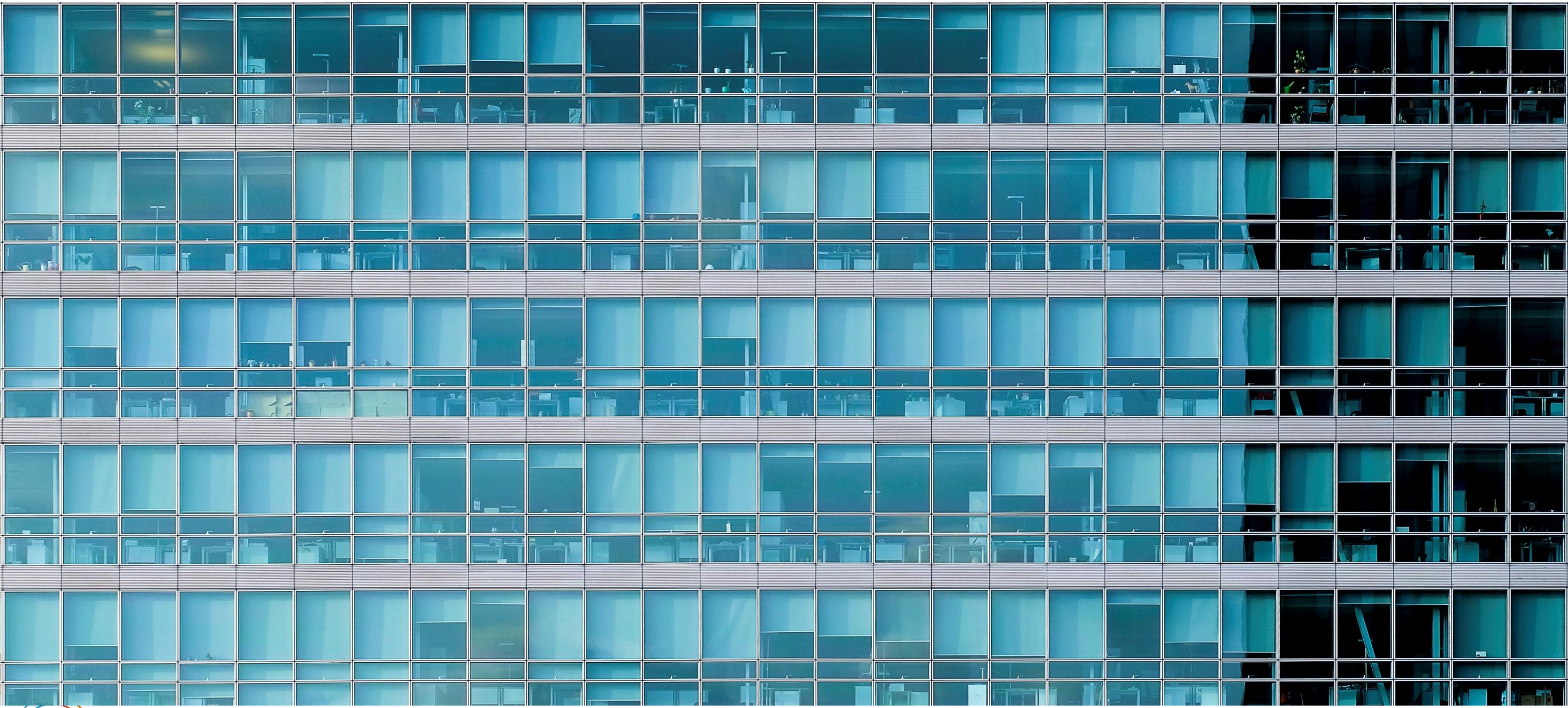
9 months of average outdoor light level of around **1,11,000 lux**

3 months of average outdoor level of around **20,000 lux**

Sites with latitudes below 50 degree nevertheless have the potential to daylight interior spaces during over 80% of core commercial hours annually

BUT WE STILL HAVE A GLARING PROBLEM

BLINDS THAT BLIND



KEY IS TO STRIKE A BALANCE

DAYLIGHT

Vs

GLARE

QUANTIFYING VISUAL COMFORT

Illuminance

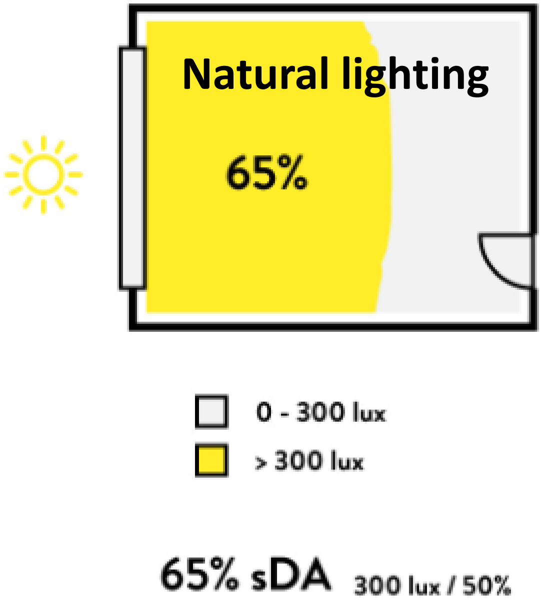
is a measure of the total "amount" of visible light spread over a given area, also correlating with how humans perceive the brightness of an illuminated area

Daylight Penetration

describes how much of a space receives sufficient daylight

sDA, DA

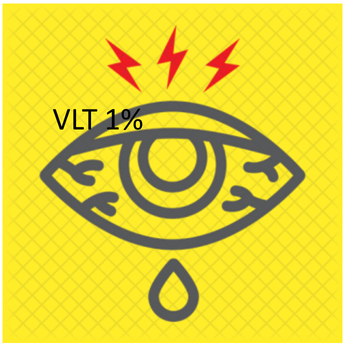
sDA



Glare

is the visual discomfort due to too much direct light in the field of view of the occupants

DGP, ASE



VLT 40%

CASE STUDY

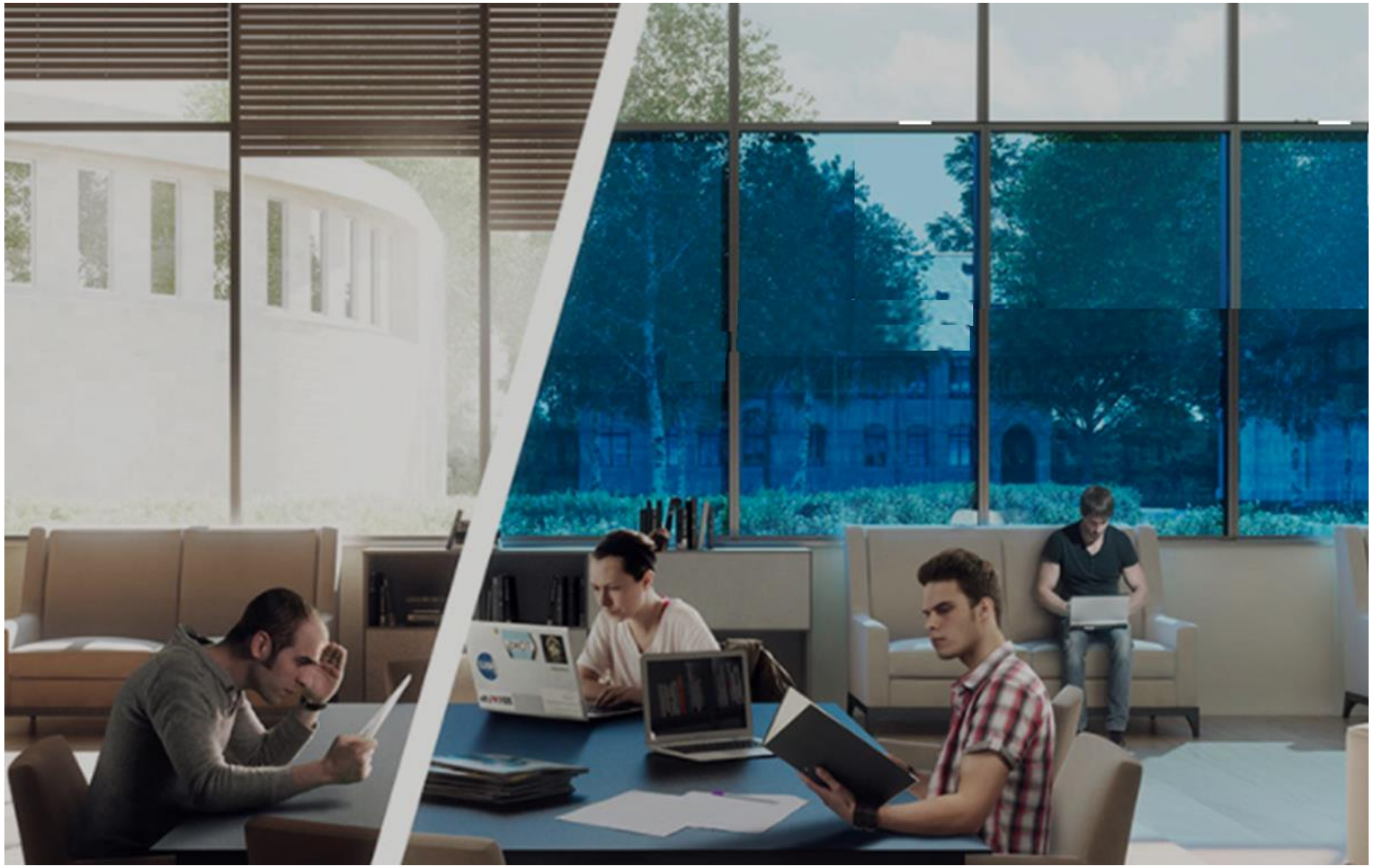
Visual Comfort

Electrochromic (EC) glass (Dynamic)
vs.
Std. DGU (Static)

Typical Office Building, Chennai

INPUT PARAMETERS

Static glass with blinds vs. Dynamic tinting electrochromic glass



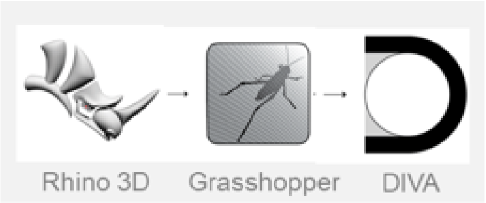
VLT of Std. DGU assumed: 42%

VLT of EC: 59%, 17%, 6%, 1%

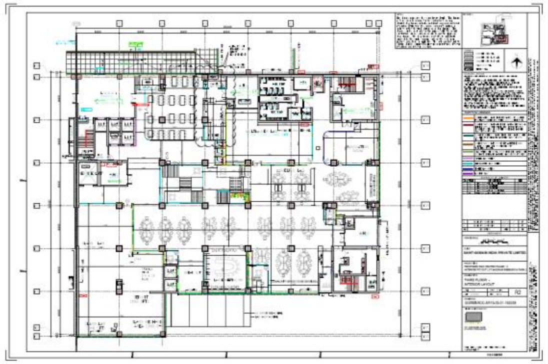
Parameter	Clear State	Intermediate tint 1	Intermediate tint 2	Fully tinted
VLT (%)	59	17	6	1
SHGC	0.40	0.12	0.07	0.04
U value (W/m².K)	1.1	1.1	1.1	1.1

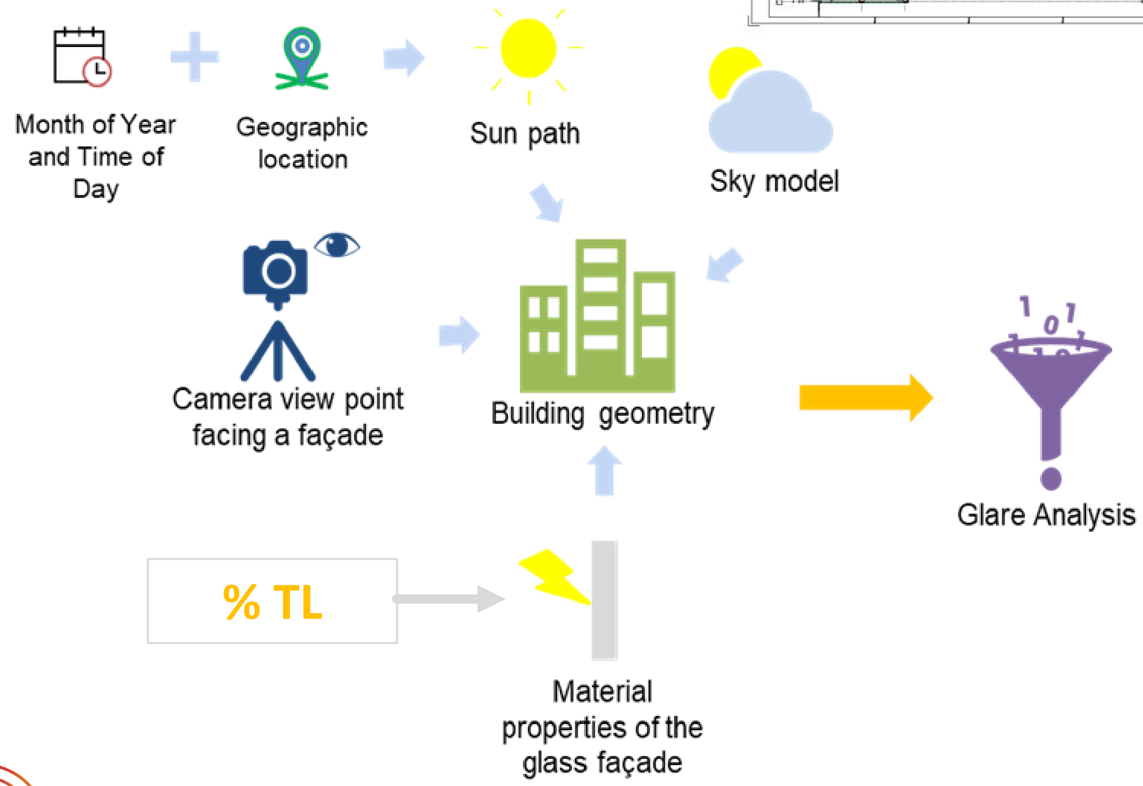
SIMULATION METHODOLOGY

TOOLS

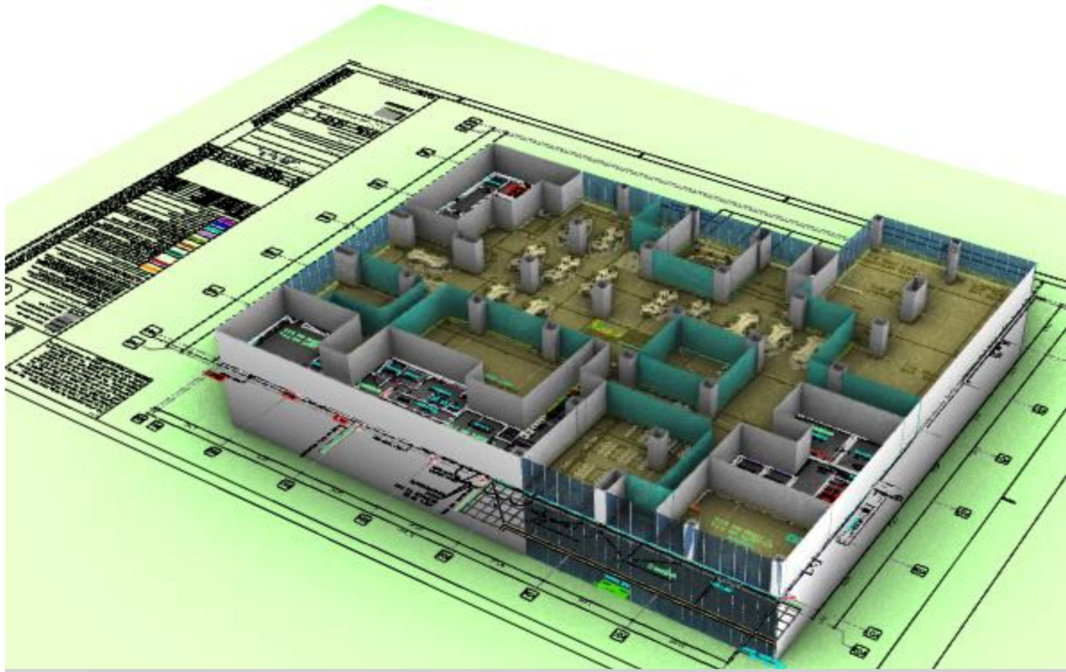


2D PLAN

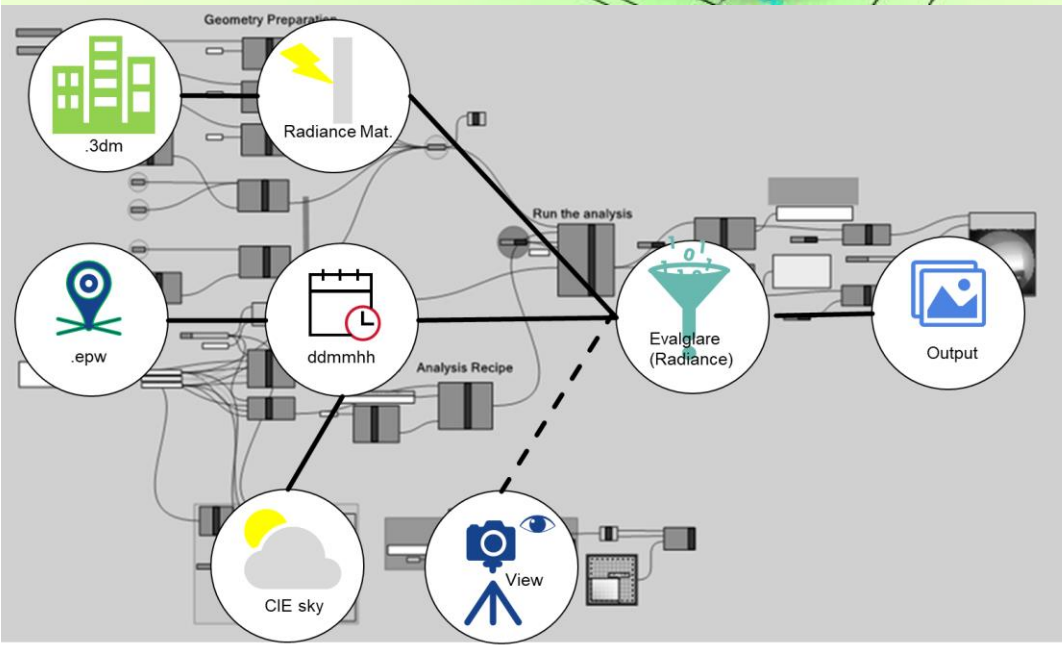




3D MODEL

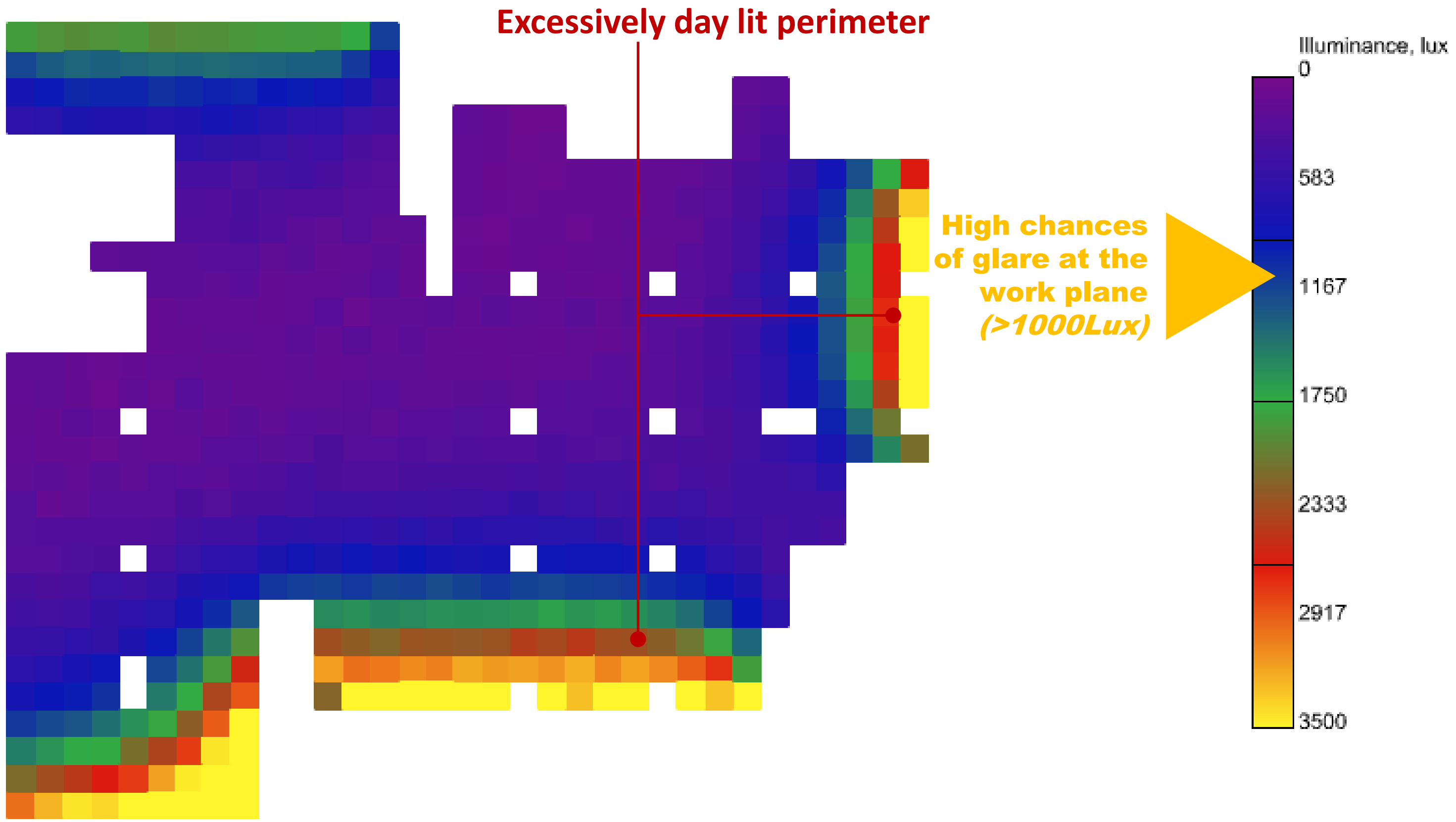


ANALYSIS SCRIPT



PROBLEM DEFINITION

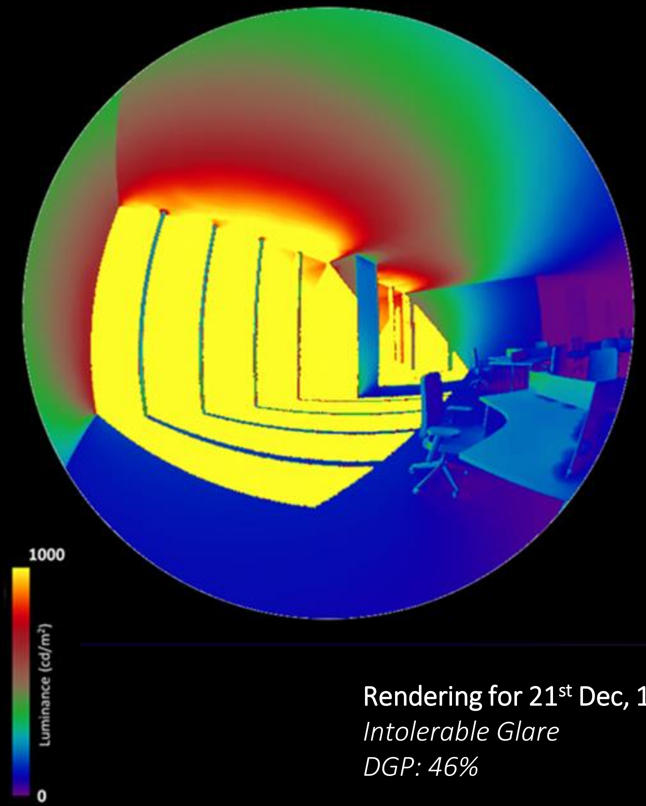
Illuminance map for 21st Dec, 10am



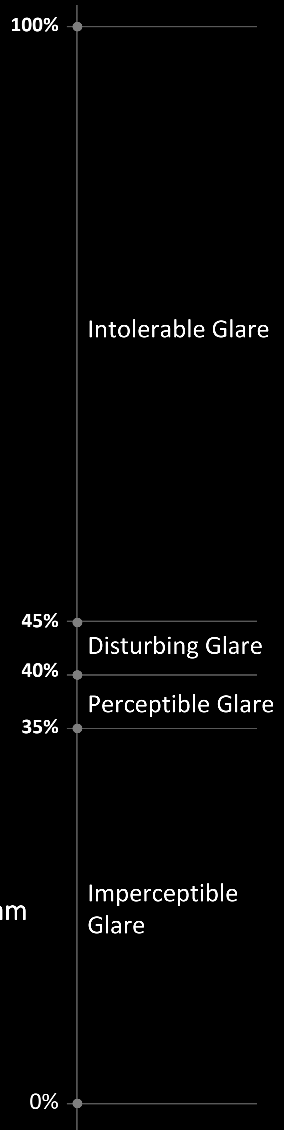
46% DGP, Intolerable Glare

DGP is a metric to predict the appearance of discomfort glare in day lit spaces. It calculates the luminance values in the field of view w.r.t. occupants position. The results are in *'percentage of people disturbed' due to vertical eye illuminance.*

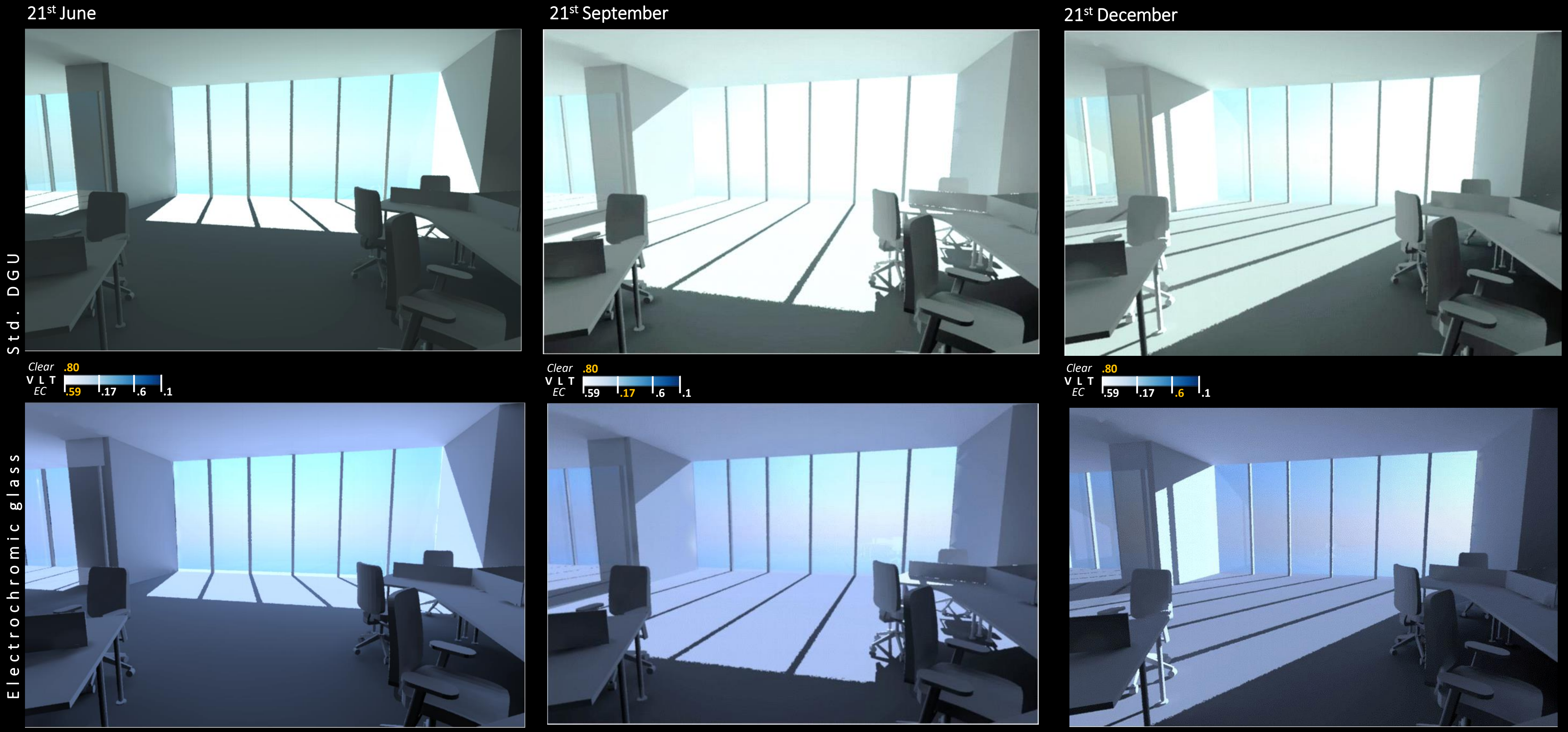
Daylight Glare Probability (DGP)



Rendering for 21st Dec, 10am
Intolerable Glare
DGP: 46%



VISUALIZATIONS: Std. DGU v/s Dynamic tinting EC Glass



Standard DGU

Outside view too bright.

Eyes adjust to window brightness. Interior looks dark causing strain while working on screens.

Shades pulled down.

Outside view lost, blocks daylight.

ELECTROCHROMIC GLASS

Tint changes based on the illuminance levels on outside and inside

Provides better visual comfort

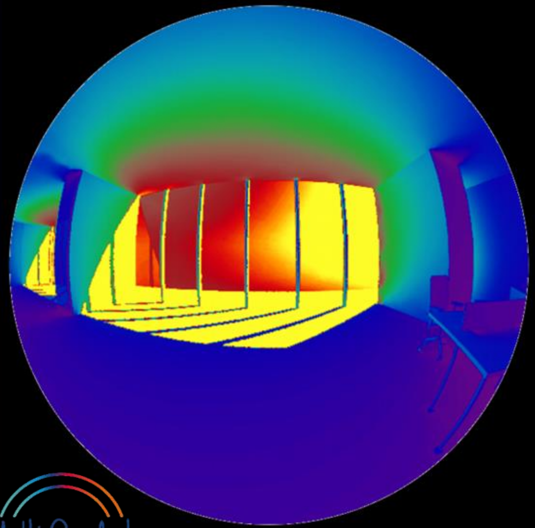
Outside view maintained.

Comfort without glare.

OCCUPANT'S VISUAL PERCEPTION: Std. DGU v/s Dynamic tinting EC Glass

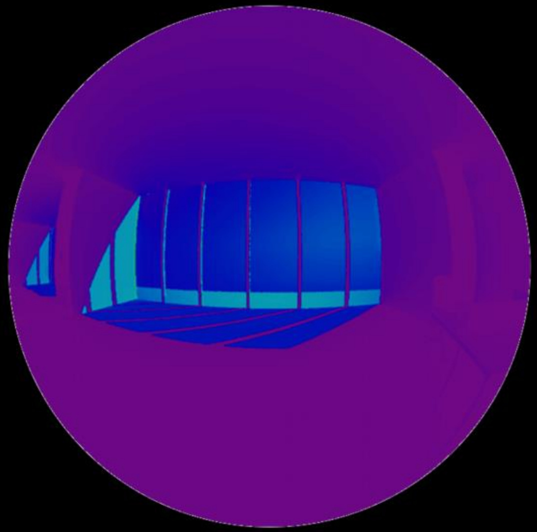
Std. DGU
VLT: 40%

Electrochromic Glass
Tint State: VLT: 1%



Harsh to look outside

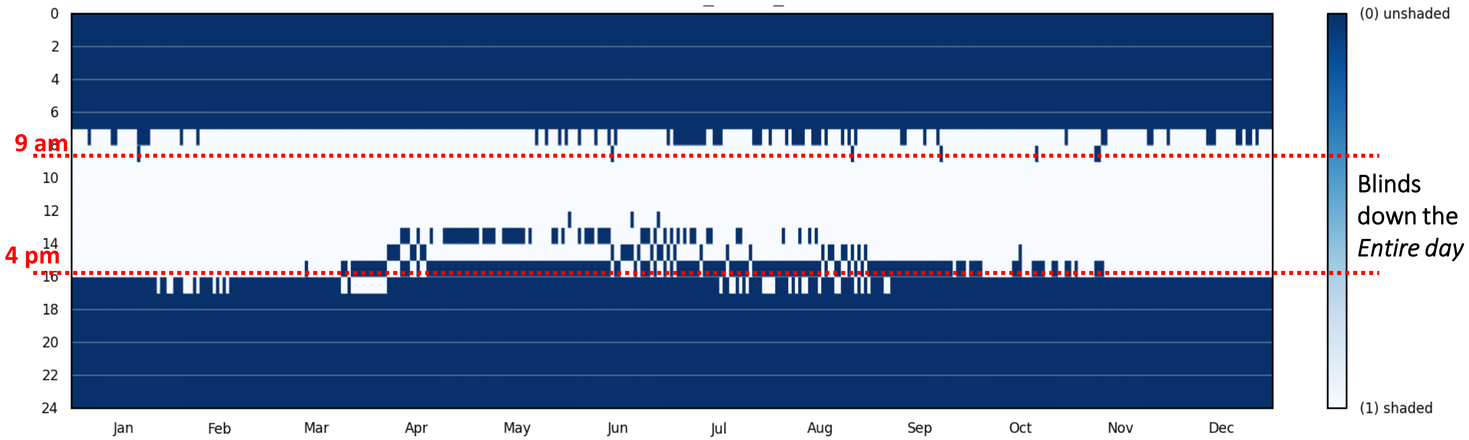
Soothing on eyes



ANNUAL GLARE AND BLIND STATE: Std. DGU v/s Dynamic tinting EC Glass

- intolerable glare, DGP ≥ .45
- disturbing glare, .45 > DGP ≥ .4
- perceptible glare, .4 > DGP ≥ .35
- imperceptible glare, .35 > DGP

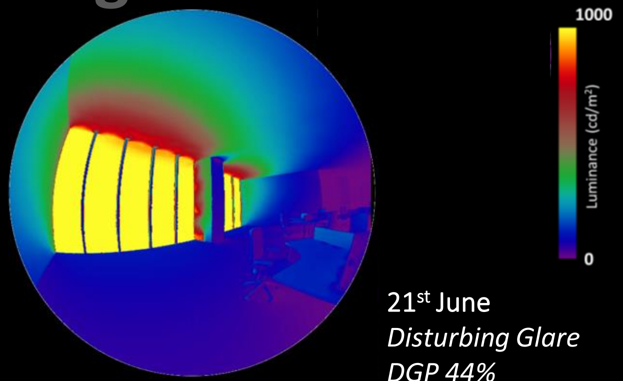
Annual Glare for South Facade



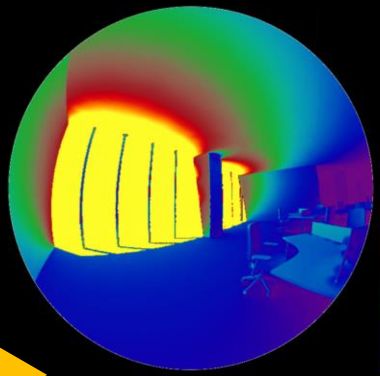
Annual Blinds Schedule for South facade

Disturbing glare across the year (DGP>40)

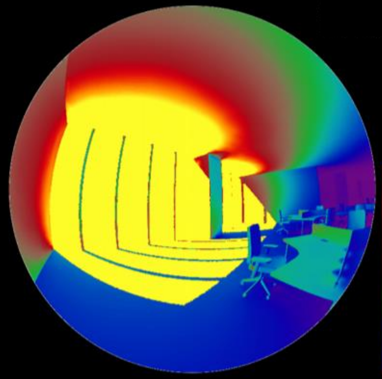
Daylight Glare Probability (DGP)



21st June
Disturbing Glare DGP 44%

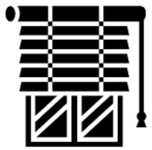


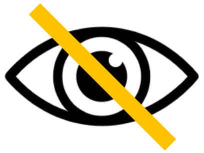
21st Sep
Disturbing Glare DGP 42%



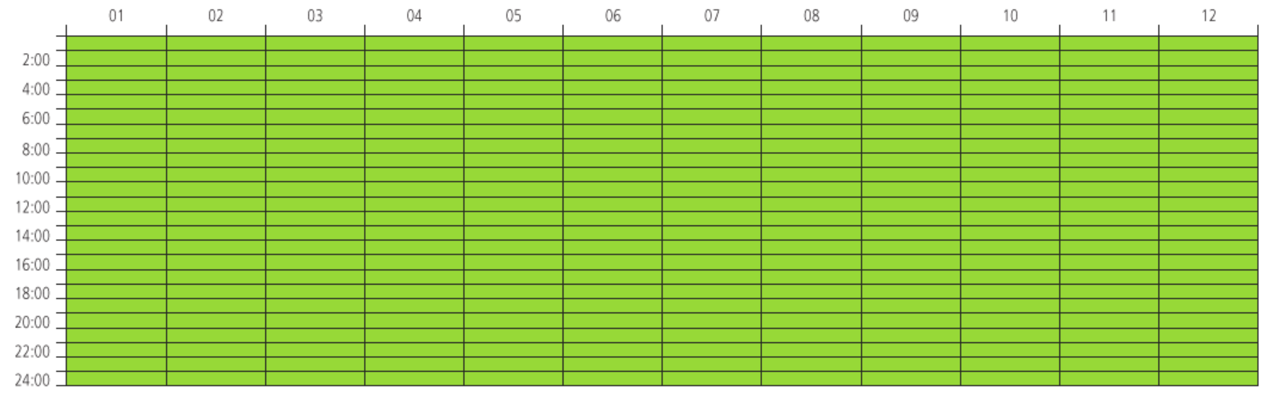
21st Dec
Disturbing Glare DGP 46%

~60% **time blinds down state**



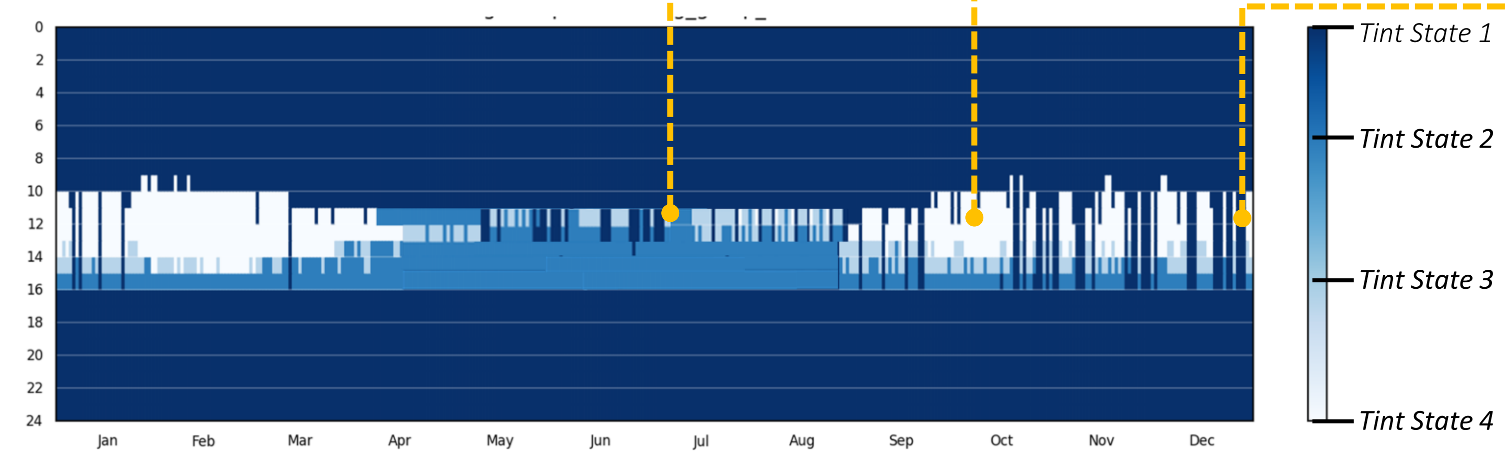


ANNUAL TINTING BEHAVIOUR: Std. DGU v/s Dynamic tinting EC Glass



- intolerable glare, DGP ≥ .45
- disturbing glare, .45 > DGP ≥ .4
- perceptible glare, .4 > DGP ≥ .35
- imperceptible glare, .35 > DGP

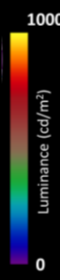
Annual Glare for South Facade

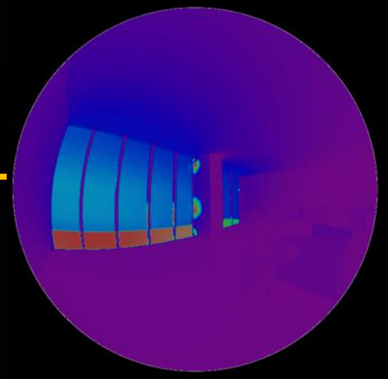


Annual Tinting Behavior for South facade

~100% **Blinds free space**

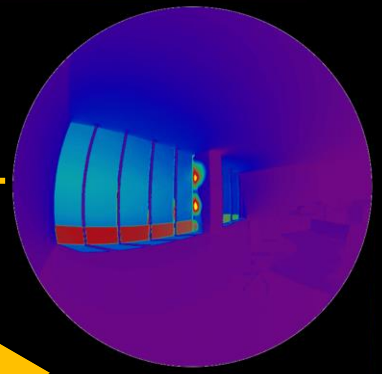
Daylight Glare Probability (DGP)





Tint State 1
VLT: 17

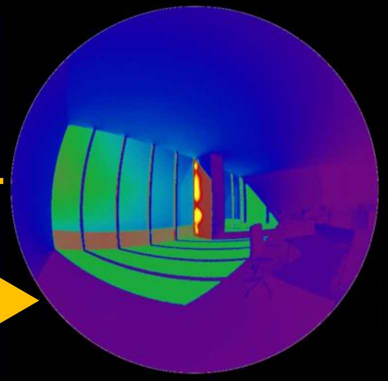
21st June
Imperceptible Glare
DGP 16%



Tint State 2
VLT: 6

21st Sep
Imperceptible Glare
DGP 17%

Disturbing glare across the year (DGP>40)



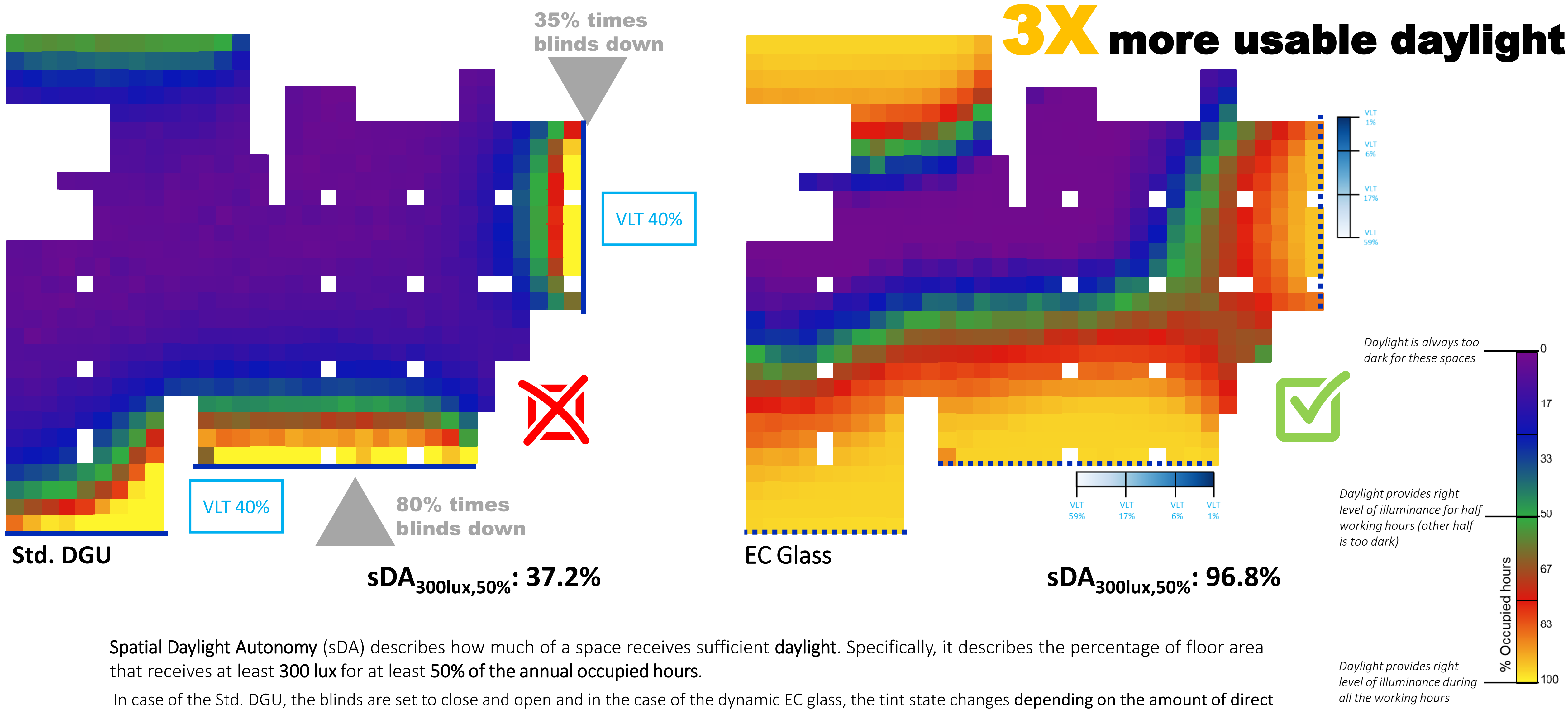
Tint State 3
VLT: 1

21st Dec
Imperceptible Glare
DGP 17%

Imperceptible glare across the year (DGP<20)

DAYLIGHT, SPATIAL DAYLIGHT AUTONOMY COMPARISON

Illuminance threshold: 300 Lux
Hours: 50%
Blind trigger state: 1000Lux



$sDA_{300lux,50\%}$: 37.2%

$sDA_{300lux,50\%}$: 96.8%

Spatial Daylight Autonomy (sDA) describes how much of a space receives sufficient **daylight**. Specifically, it describes the percentage of floor area that receives at least **300 lux** for at least **50% of the annual occupied hours**.

In case of the Std. DGU, the blinds are set to close and open and in the case of the dynamic EC glass, the tint state changes **depending on the amount of direct sunlight the space receives.**

BENEFITS, RESPONSE TO EXTERNAL ENVIRONMENT & STIMULUS

Uninterrupted views

No Glare all year

Blinds Free space

100% occupant visual comfort

3x more usable daylight

DYNAMIC TINTING EC GLASS - Hourly Rendering, 21st Dec (8am - 6pm)

Summary of Benefits

Thermal Comfort

Less Radiant Asymmetry

~26°C average operative temp. in the perimeter zone

95% area thermally comfortable

Visual Comfort

Uninterrupted outdoor views

100% occupant visual comfort

3x more usable daylight

No Glare (DGP<35) throughout the year

Blinds Free space

Glazing Performance Evaluation for Energy and Comfort

Shailee Goswami[1] and Vardan Soi[2]

[1]Senior Research Engineer, Saint-Gobain Research India

[2]Technical Resource Group, Solar Decathlon India

Abstract

The "Glazing Performance Evaluation for Energy and Comfort" case study by the Building Science Team at SGR India focuses on assessing the energy efficiency and indoor comfort of different glazing types in residential high-rise apartments in Mumbai. The study aims to quantify the performance of glazing solutions using parametric simulations to evaluate multiple glass types. Key findings include a significant reduction in cooling loads and energy costs with high-performing double-glazed units (DGU) compared to standard clear glass. The high-performing DGU reduces the average operative temperature, enhancing thermal comfort to 85% of the area, compared to 34% with clear glass. Additionally, DGU significantly lowers glare and improves sound insulation, making it a valuable proposition for building sustainability. The study underscores the importance of advanced glazing in achieving energy efficiency and comfort, providing insights for stakeholders to make informed decisions in building design and policy.

GLAZING PERFORMANCE EVALUATION FOR ENERGY AND COMFORT

Building Science Team, SGR INDIA

Vardan Soi
Shailee Goswami

TRANSVERSAL R&D CENTERS BY SAINT-GOBAIN

SAINT-GOBAIN

GLAZING PERFORMANCE EVALUATION FOR ENERGY AND COMFORT

TRANSVERSAL R&D CENTERS BY SAINT-GOBAIN

Objective

To quantify the energy and comfort performance of glazing to integrate it as a part of the value proposition.

Deliverables

1) Use appropriate and advanced metric to evaluate the indoor comfort in case study example (residential high-rise apartment).

2) Parametric simulations to evaluate multiple types of glass for a project.

3) Translate the technical findings and results into value proposition for BU teams.

Example Case study

- Residential High rise apartment
- 2 bhk typology
- Mumbai city

Energy & Comfort analysis

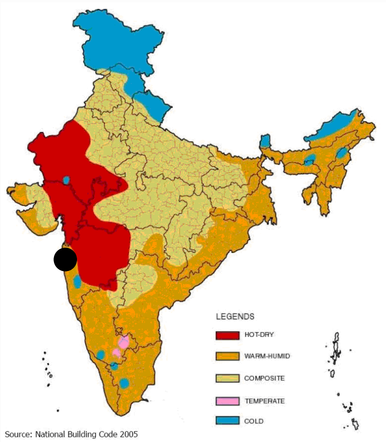
ANALYSING THE EXTERNAL CONDITIONS

TRANSVERSAL R&D CENTERS BY SAINT-GOBAIN

MUMBAI, INDIA

Coordinates: 19° N, 72° E

Climate Type: Warm & Humid



Source: National Building Code 2005

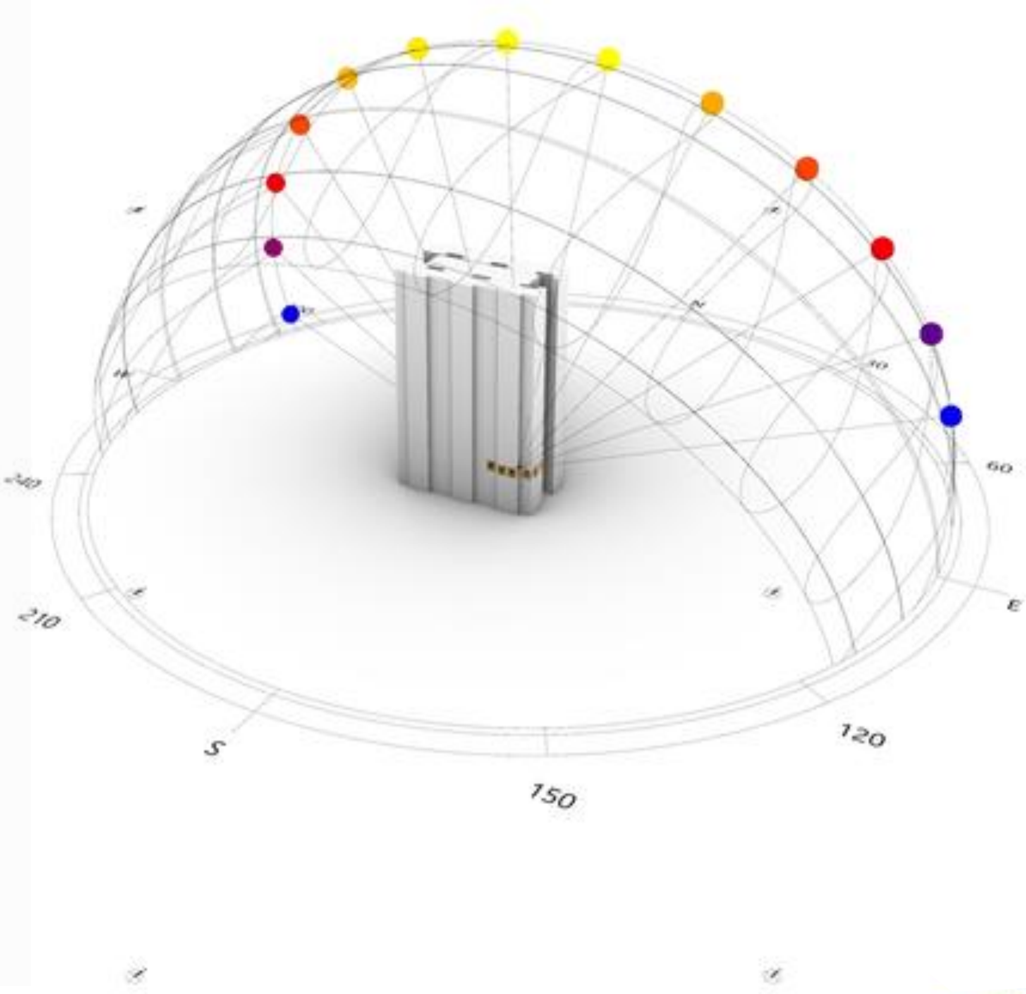
Quantifying the below:

Solar Radiation

Dry bulb or Air temperature

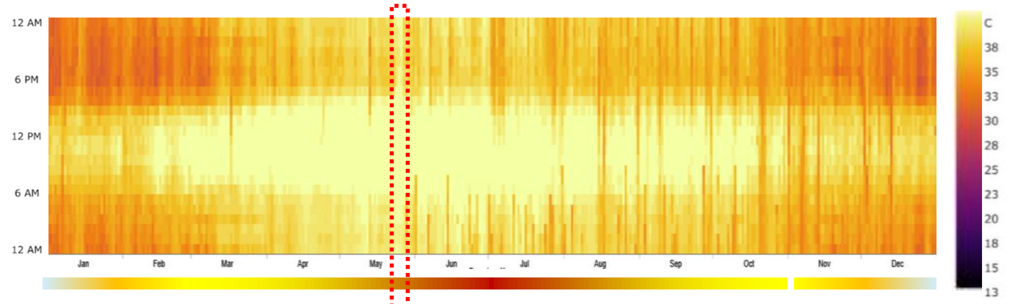
Relative Humidity

SUN POSITION W.R.T BUILDING FORM & ORIENTATION

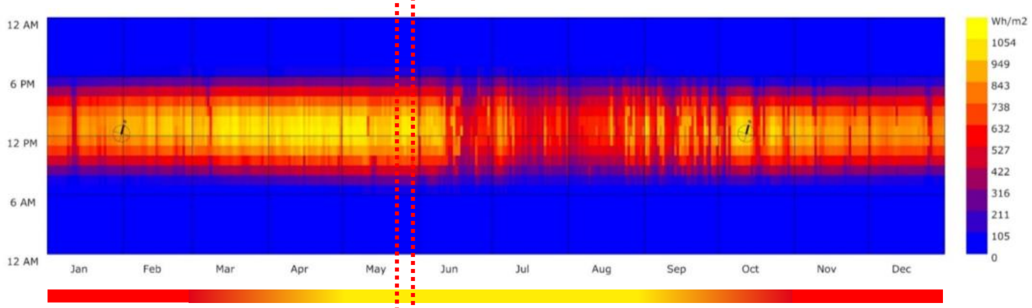


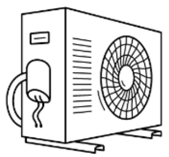
EXTERNAL CONDITIONS

Dry Bulb temperature (°C)



Solar Radiation (Wh/m²)



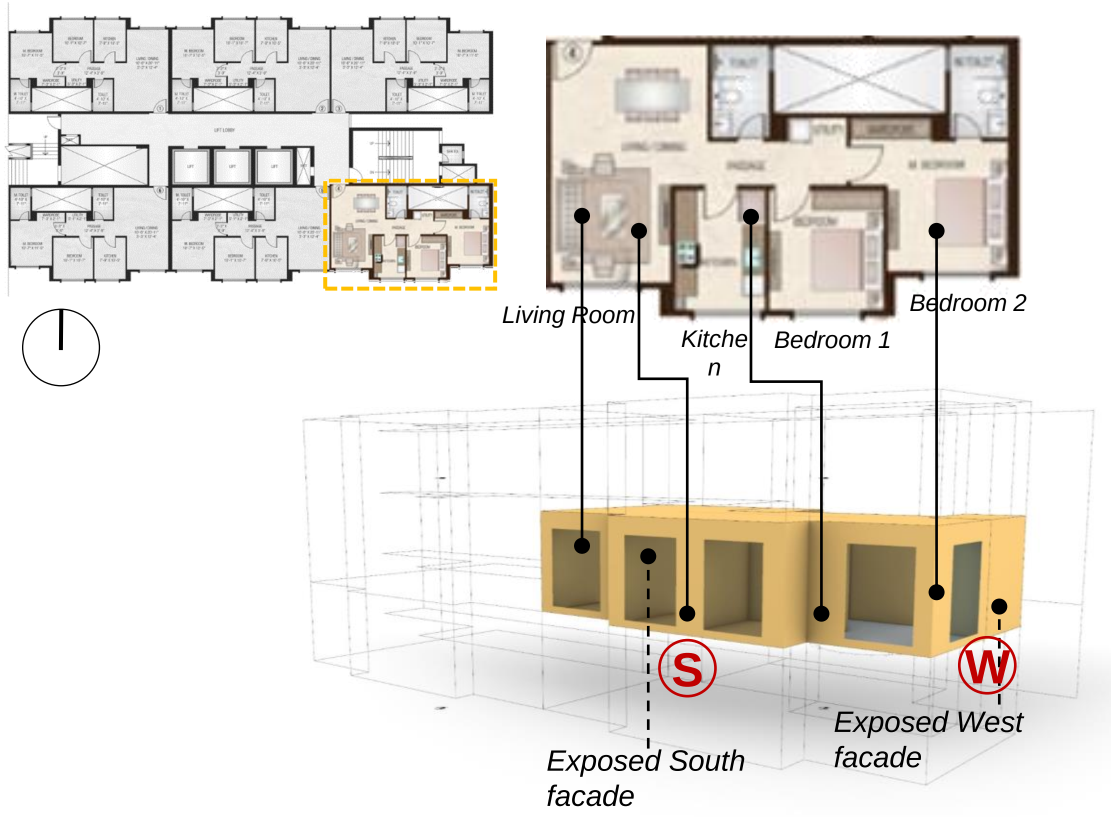


Hottest week: 21st- 27th May

AC set point (entire day): 24°C

SIMULATION MODEL

MODEL GEOMETRY



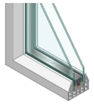
MATERIAL PROPERTIES

MY HOME BY SAINT-GOBAIN

WINDOWS

Glass type comparison

Parameters	Base Case – Clear (SGU)	High-performing DGU
U Value (W/m^2K)	5.60	2.5
SHGC *(%)*	0.85	0.27
Visual Light Transmittance *(%)*	0.85	0.34
Infiltration *(m3s-1/façade area)*	0.0003	0.0001
Sound Reduction Index (Rw) (db)	30	40

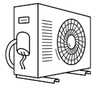


Sliding

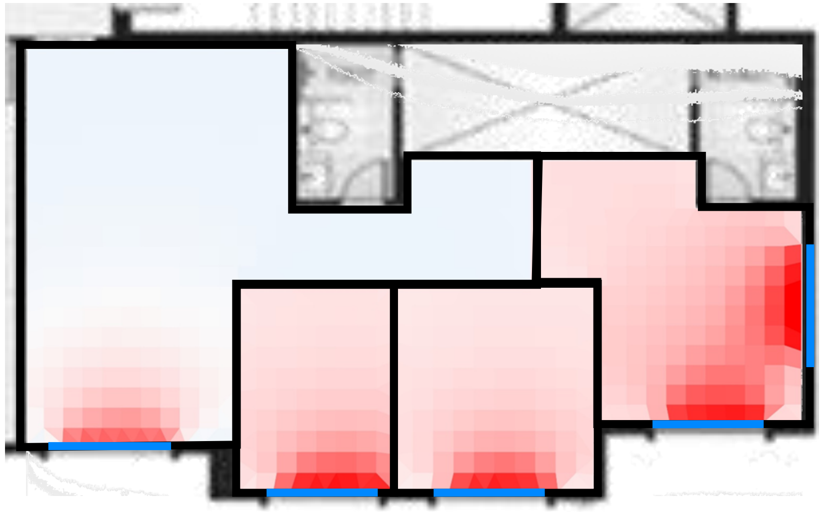
THERMAL COMFORT

Cumulative Operative Temperature (21st – 27th May, 9am-4pm)

Operative temperature is a simplified measure that represents human thermal comfort (feels like temp.) derived from air temperature & mean radiant temperature through direct sun & wall surfaces and air speed.



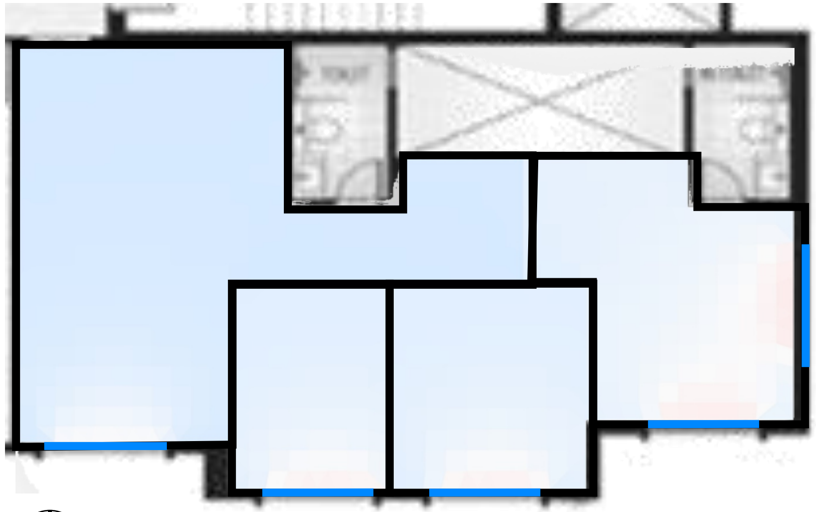
Set point: 24ºC entire day
Comfort Temp range: 20-26ºC

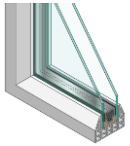


Clear Glass

Average OT: **27.7ºC**

% Area comfortable: **34%**

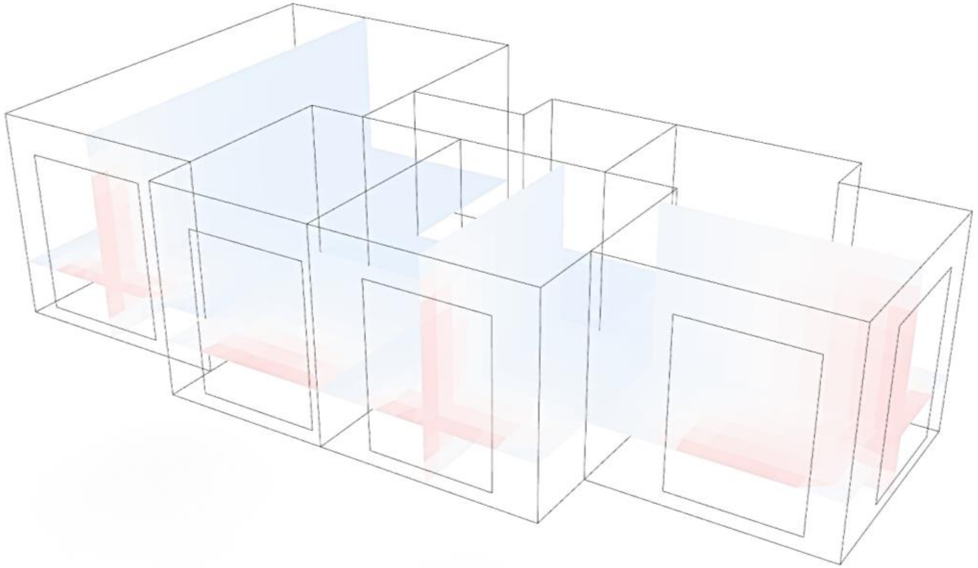




HP DGU

Average OT: **25.6ºC**

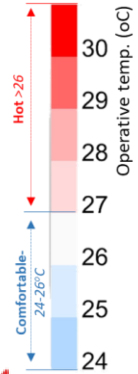
% Area comfortable: ***85%***



Lower Radiant Asymmetry

85% area thermally comfortable compared to 34% in Clear glass when building is operated in AC.

It can be observed that while the thermal performance of glass improves i.e. SHGC reduces, the direct solar heat gains through windows also reduce. As a consequence, the average operative temperature reduces thereby significantly increasing the comfortable area in these homes especially near the windows. On applying a high performance DGU almost NV radiant asymmetry can be observed with 85% home within 26ºC.



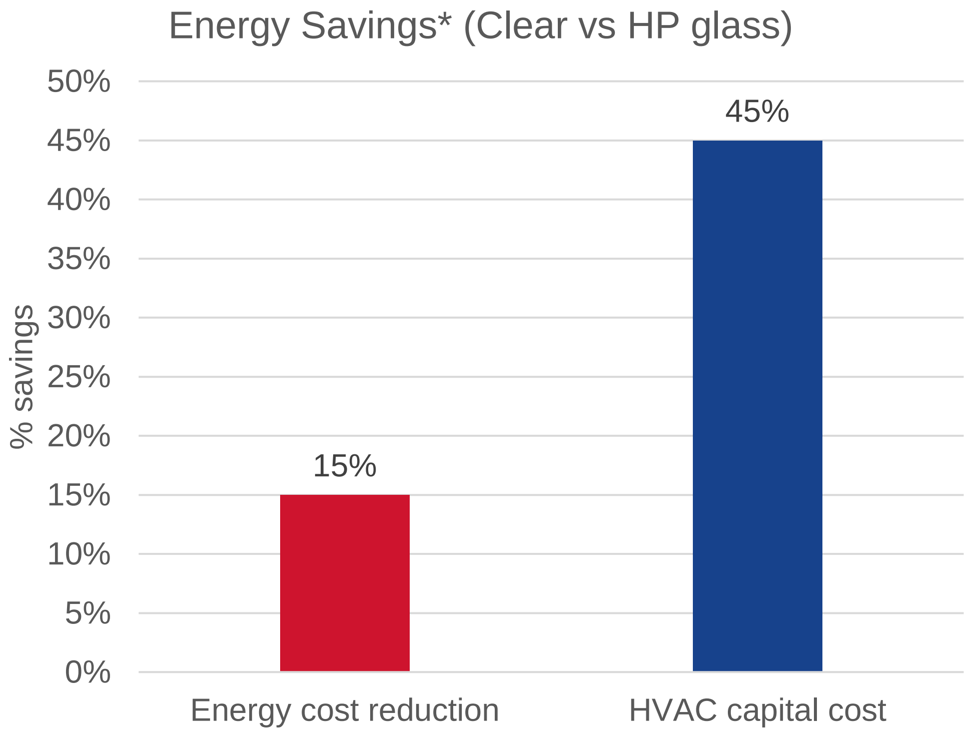
ENERGY SAVINGS | ANNUAL THERMAL SIMULATION

TRANSVERSAL R&D CENTERS BY SAINT-GOBAIN

Provide energy Efficiency

Cooling EPI: Is total cooling energy consumed in a building over a year divided by total built up area in kWh/m^2/year.
Cooling Load: The cooling load is the amount of heat energy that would need to be removed from a space (cooling) to maintain the temperature in an acceptable range.

Set point as/ schedule on slide 5- Mixed mode operation AC & NV



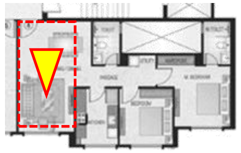
% reduction in comparison with Clear glass.

45% reduction
in the HVAC capital cost

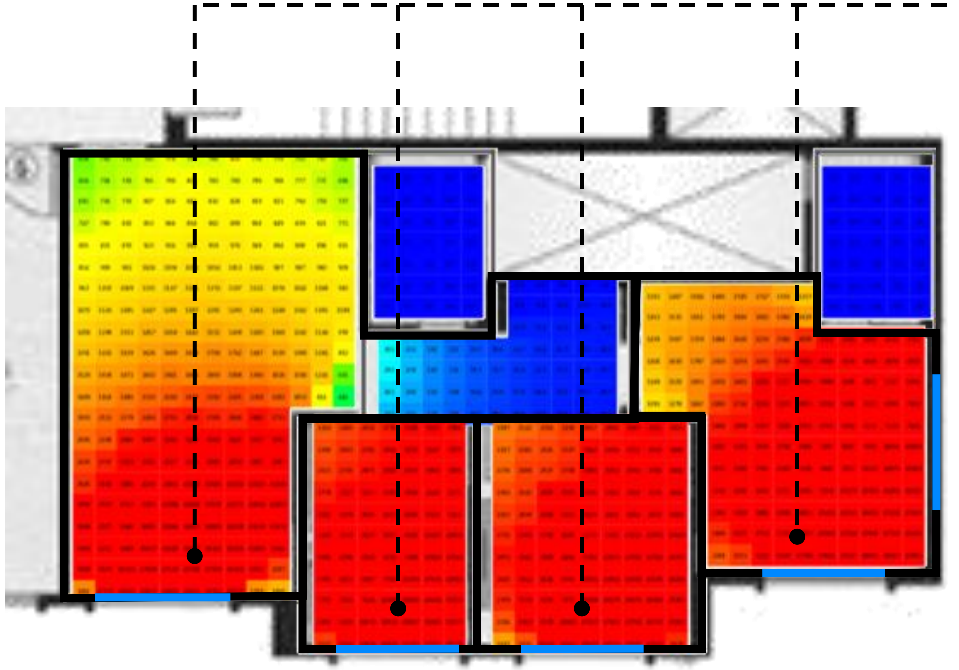
15% reduction
in the energy cost

DAYLIGHT LEVELS | CLEAR GLASS

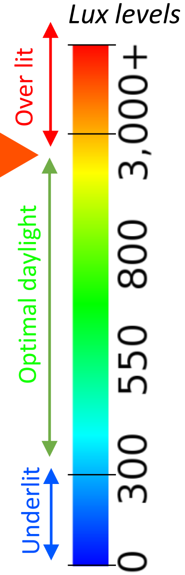
Illuminance map for 21st Dec, 2pm



Excessively day lit perimeter



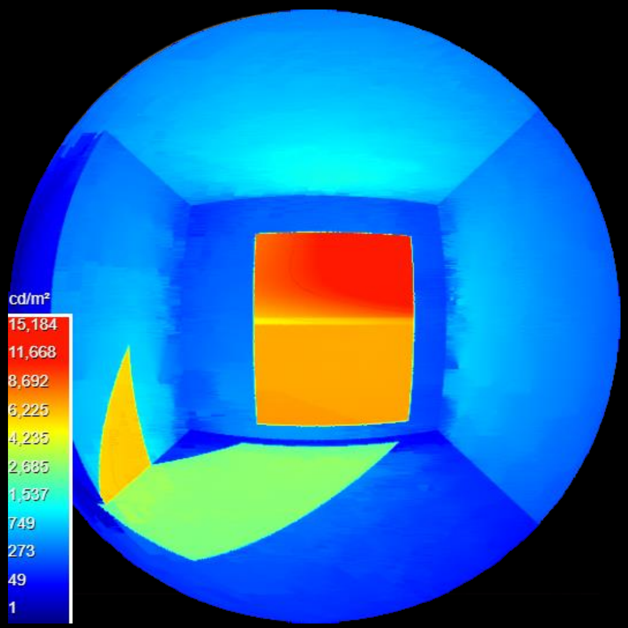
High chances of glare towards the window *(>2000Lux)*



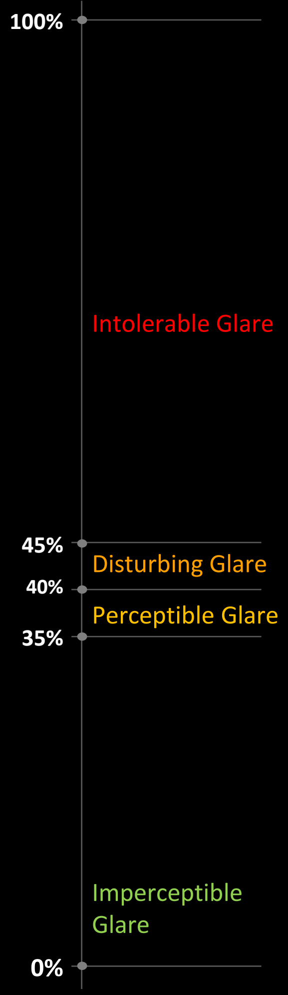
58.8% DGP, Intolerable Glare

DGP is a metric to predict the appearance of discomfort glare in day lit spaces. It calculates the luminance values in the field of view w.r.t. occupants position. The results are in *'percentage of people disturbed' due to vertical eye illuminance.*

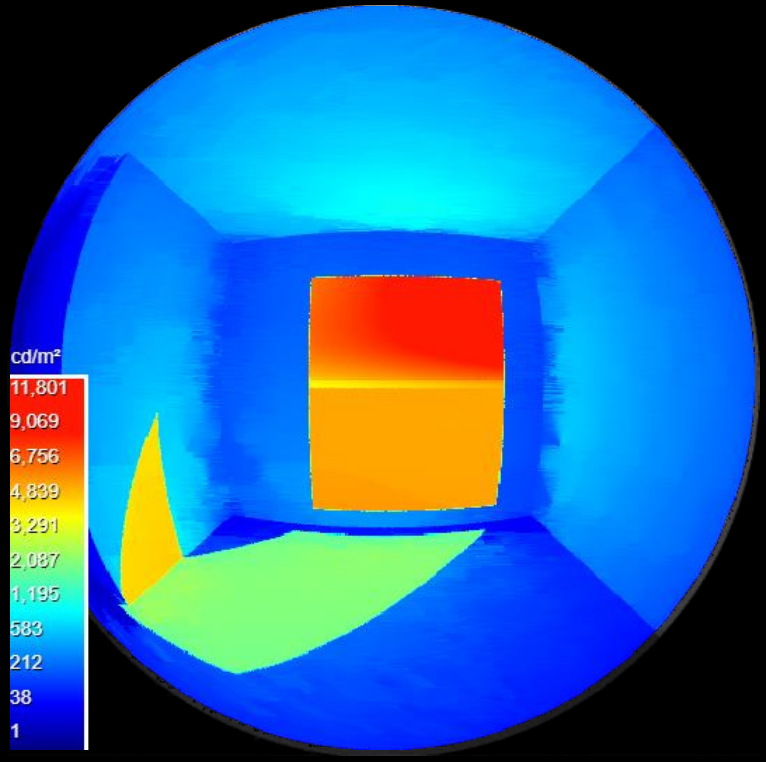
Daylight Glare Probability (DGP)



Rendering for 21st Dec, 2pm
Intolerable Glare
DGP: 58.8.7%



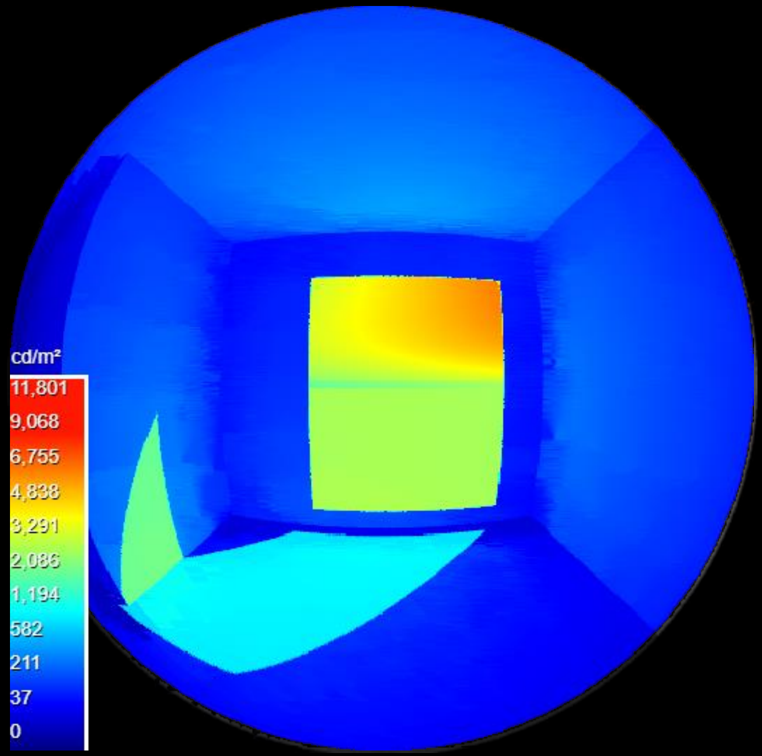
DAYLIGHT GLARE PROBABILITY



Clear Glass

DGP: 58.8%

Harsh to look outside

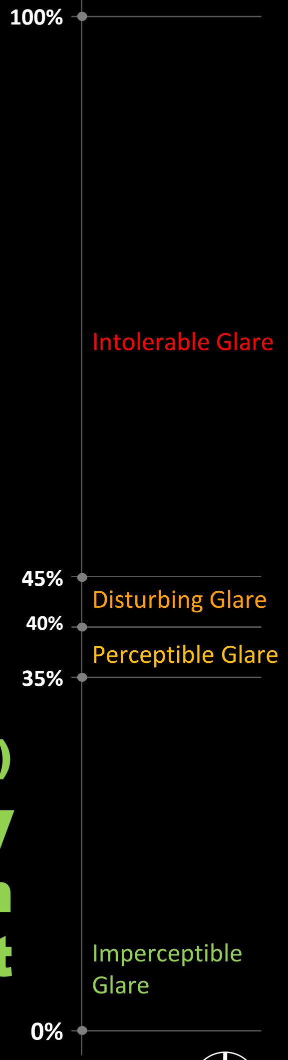


HP DGU

DGP: 35.3%

Soothing on eyes

Lower DGP (~31%) throughout the day without much loss in daylight

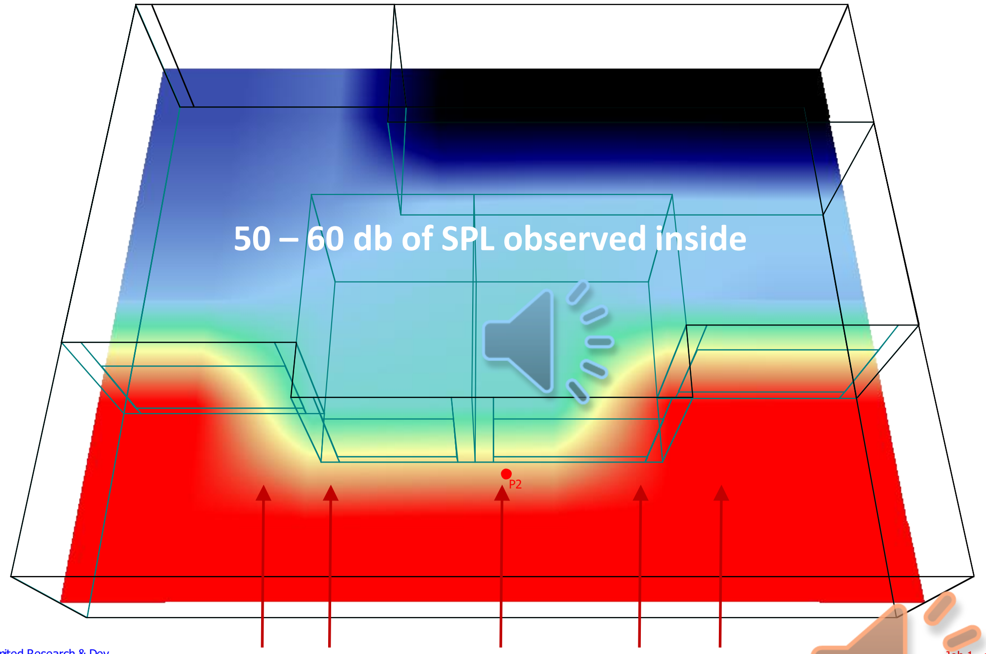


Illuminance threshold: 300 Lux; Climate based sky, NV blinds

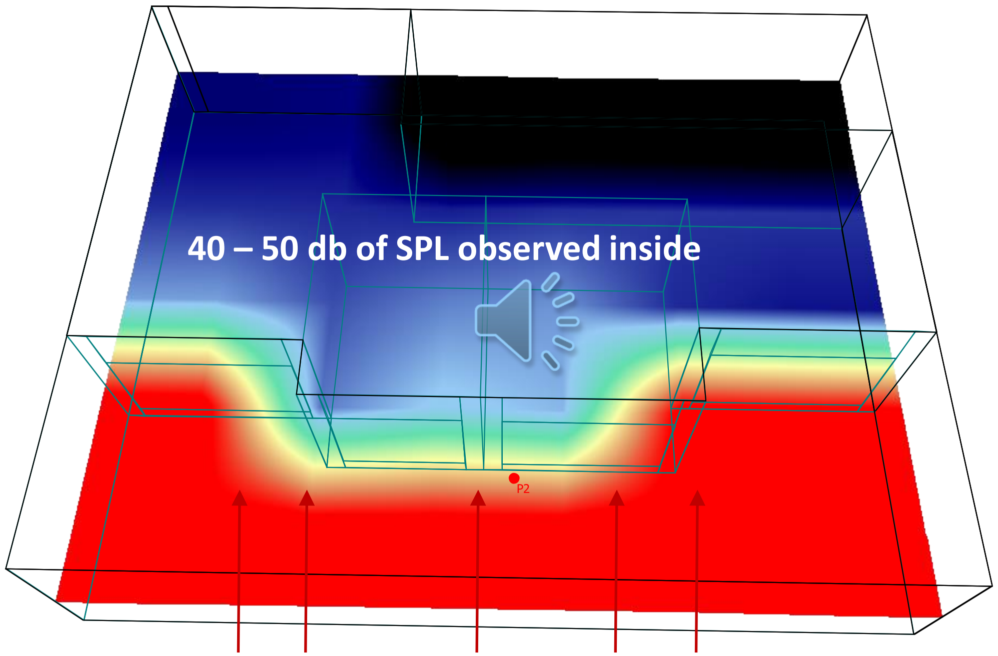
ACOUSTICS COMFORT I EXTE

Weighted Sound Reduction Index (Rw) is a number used to rate the effectiveness of a soundproofing sys
material. Increasing the Rw by one translates to a reduction of approximately 1db in noise

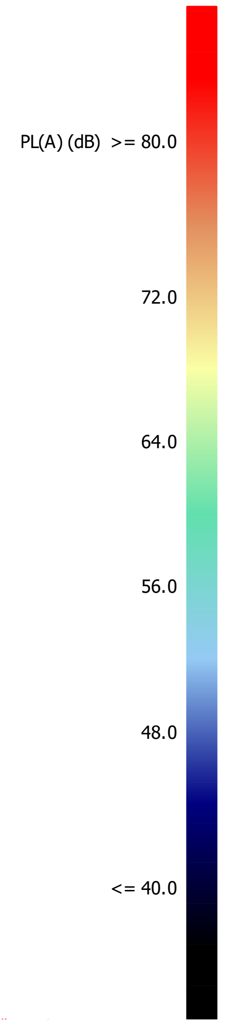
Single glazed
*Rw = **30 db***



Double glazed
*Rw = **40 db***



SPL (A) (db)



Job 1 - all

Source SPL = 80 db

Exterior noise from nearby traffic

Reduced outside noise transmission through the DGU

THANK YOU