Ministry of Housing and Urban Affairs
Government of India

Two-day Training: Professionals

|Location: Patna, Bihar |

|Date: 15th-16th June,2022 |

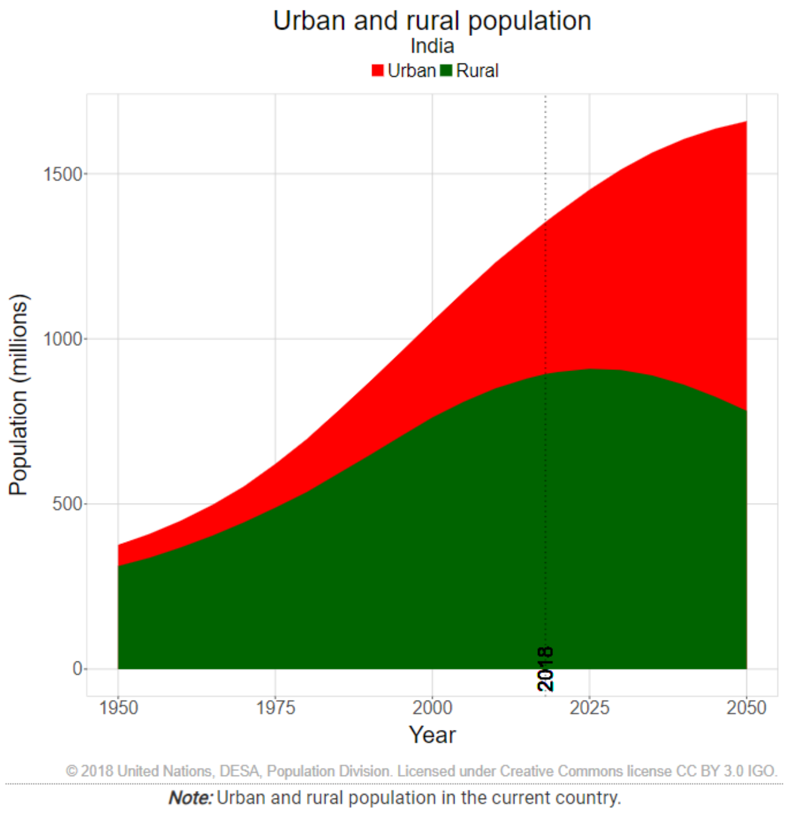
RACHNA

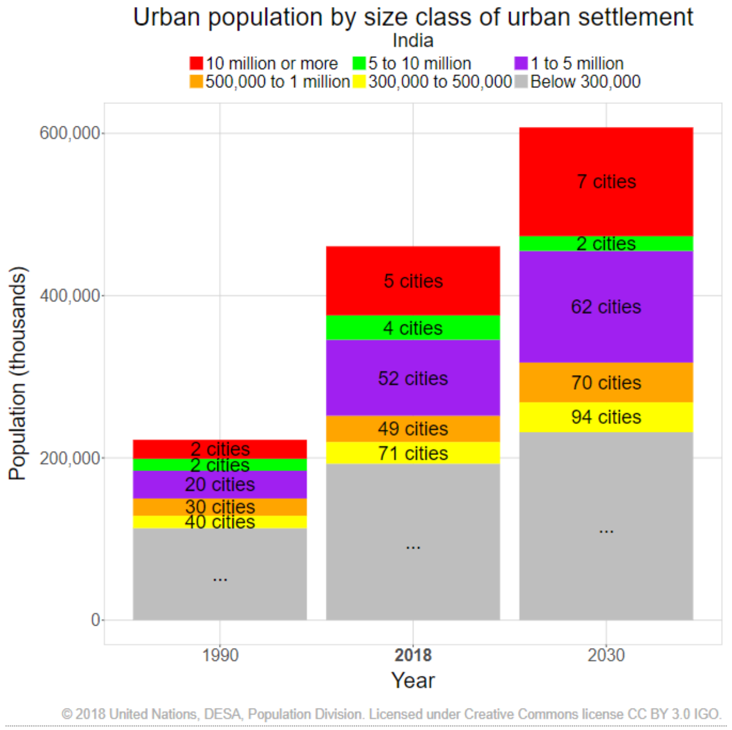
RESILIENT, AFFORDABLE AND COMFORTABLE HOUSING THROUGH NATIONAL ACTION

" Innovative Construction Technologies & Thermal Comfort for Affordable Housing"

INTRODUCTION

Growing Opportunities with Rapid Urbanization





Cities, which will contribute over 80% to GDP by 2050, need to be Receptive, Innovative, and Productive to foster sustainable growth and ensure a better quality of living

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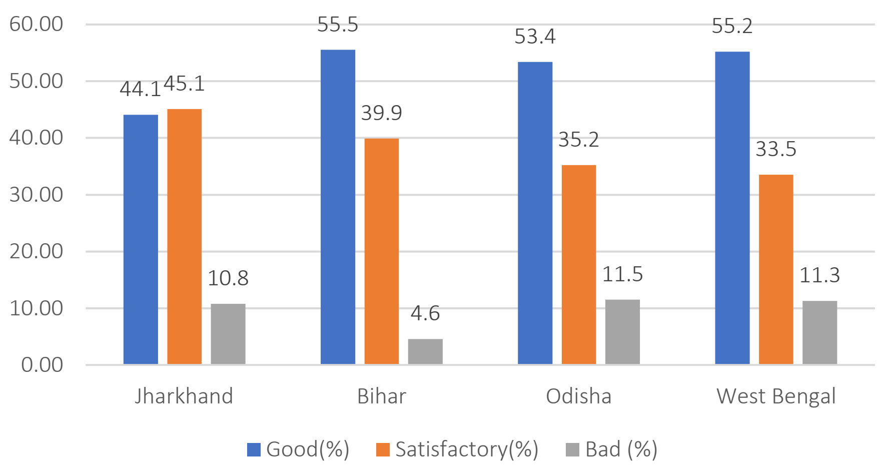
Challenges with Rapid Urbanization



Percentage of households with the condition of Census House

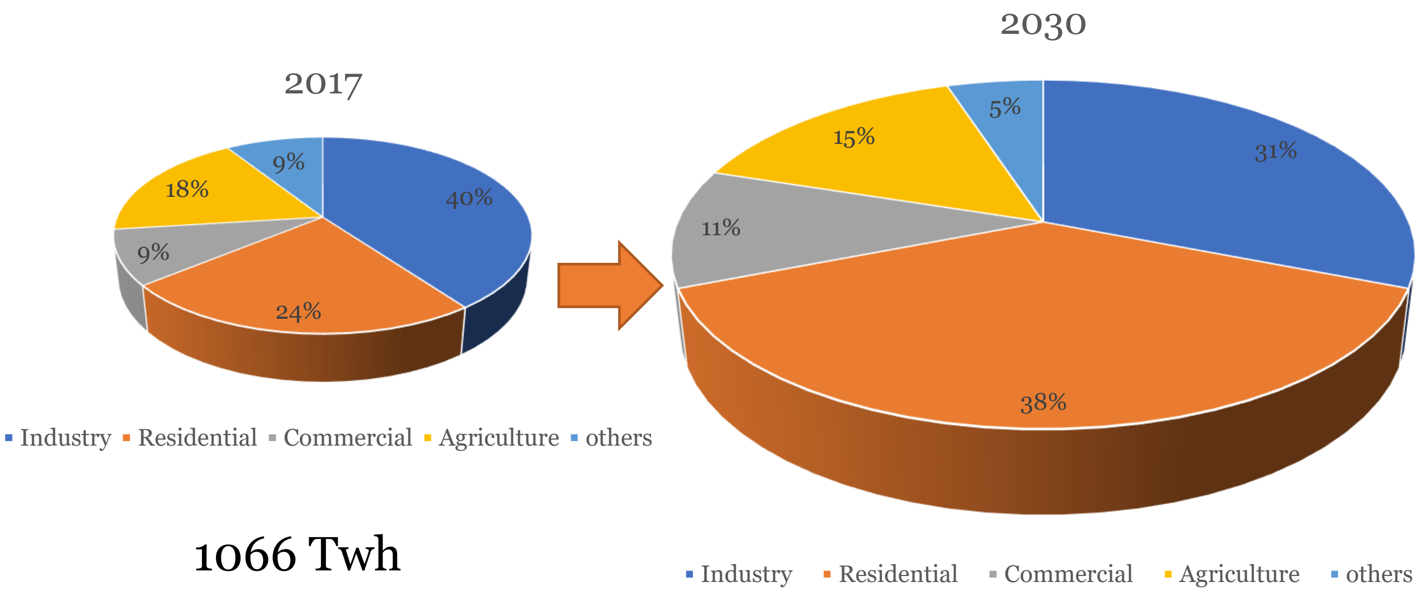
State	Owned	Hired	Any other
Jharkhand	60.50%	31.50%	7.90%
Bihar	72.60%	25.90%	1.60%
Odisha	54.10%	39.10%	6.80%
West Bengal	74.20%	21.50%	4.40%

Ownership of HH, Urban India

State	Estimated no. of households below poverty line in Urban Areas	No. of Households with Kachha Houses in Urban Areas	State %ge in National Urban housing shortage	State Wise Distribution of housing shortage (in Millions)
Jharkhand	500000	118126	3.35	0.63
Bihar	933333	230961	6.31	1.19
West Bengal	1302083	3118	7.08	1.33
Odisha	368750	37057	2.20	0.41

* Handbook of Urban Statistic by NIUA2018

Energy demand with Rapid Urbanization



2239 Twh

Residential Buildings: Fast Growth in Electricity Consumption. *IESS, NITI Aayog

- Residential buildings consumes around 255 TWh electricity in 2017, the electricity consumption in residential buildings is expected to multiply by **more than 3X** and reach around 850 TWh by 2030. Increased penetration of **air-conditioning / HVAC** in residential building is the key reason for this growth.
- Residential buildings will become the **largest end-user of electricity** in the country accounting for 38% of the total electricity consumption.

MoHUA Initiates for Urban Transformation

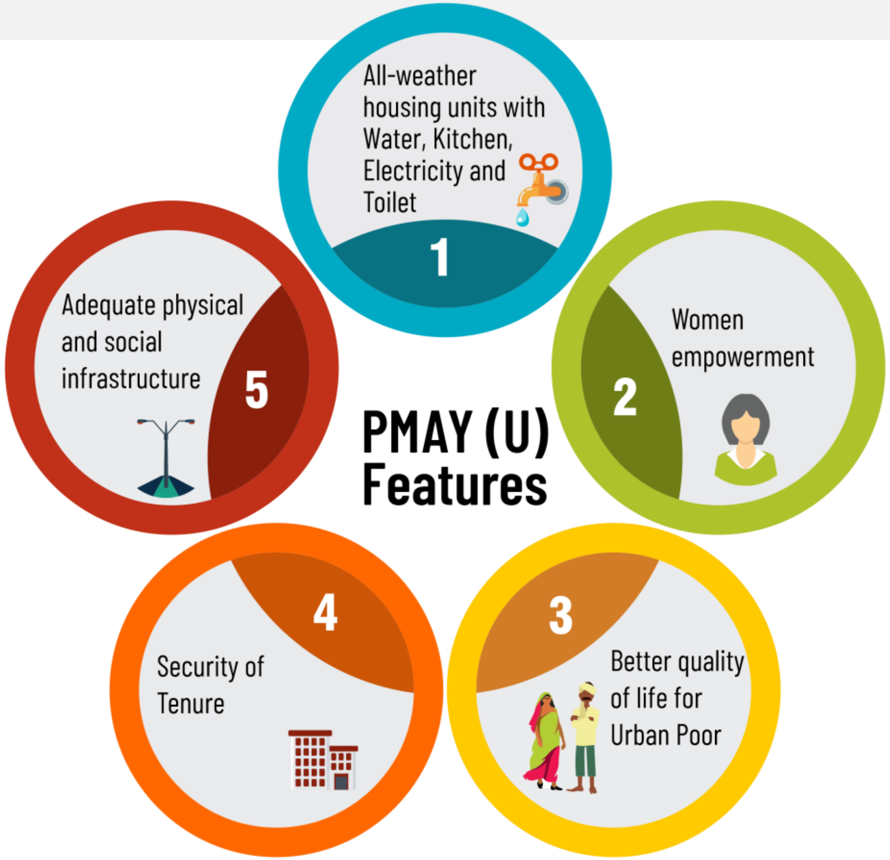
1. SMU (U)
2. PMY (U)
3. DAY-NULM
4. HRIDAY
5. AMRUT
6. Smart City
7. Urban Transport

Flagship Missions under the Ministry of Housing & Urban Affairs (MoHUA) aim to achieve Transformative, Inclusive and Sustainable development through planning, development and reforms for achieving Urban Transformation.

PMAY-U projects

- **Construction of affordable housing in Partnership with Public & Private Sectors**
- **Promotion of affordable Housing through Credit Linked Subsidy**
- **Slum rehabilitation with private developers using land as a resource**
- **Subsidy for beneficiary-led individual house construction/enhancement. (ISSR)**

11.2 million dwelling units are being constructed + **7.35 lakh crores** investment → **10 lakh** occupants in the EWS/LIG category benefitting



Key features of PMAY-U projects

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GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

Ministry of Housing and Urban Affairs
Government of India

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Pradhan Mantri Awas Yojna (Urban):

ISSR (In-Situ Slum Redevelopment)

BLC (Beneficiary-Led Construction)

Physical Progress PMY(U)

CLSS (Credit Linked Subsidiary Scheme)

AHP (Affordable Housing in Partnership)

Objective

- Security of tenure
- Women empowerment
- Better quality of life of urban poor
- All-weather housing water, kitchen, electricity & toilet
- Adequate physical and social infrastructure
- Securing SDGs

Global Housing Technology Challenge- India (GHTC-India)

MoHUA has initiated the GHTC-India to identify and mainstream a basket of innovative construction technologies from across the globe for the housing construction sector that is sustainable, eco-friendly, and disaster-resilient.

GHTC-India → 54 Innovative Construction Technologies Shortlisting → Light House projects with 6 selected technologies

AGARTALA, TRIPURA
Light Gauge Steel Structural System & Pre-Engineered Steel Structural System

CHENNAI, TAMIL NADU
Precast Concrete Construction System- Precast Components Assembled at Site

INDORE, MADHYA PRADESH
Prefabricated Sandwich Panel System

LUCKNOW, UTTAR PRADESH
Stay in-place Formwork System

RAJKOT, GUJARAT
Monolithic Concrete Construction System

RANCHI, JHARKHAND
Precast Concrete Construction System-3D Pre-Cast Volumetric

About the project-"Climate Smart Buildings (CSB): Establishment of the Cluster Cell in Ranchi, Jharkhand under Global Housing Technology Challenge-India (GHTC-India)"

States and UTs in East Cluster for establishing the Cell:

Jharkhand	Bihar	Odisha	West Bengal

The climate smart building project intends to address the majority of gaps identified in the affordable housing sector

- By introducing of thermal comfort & climate resilience in the Local Government framework through Byelaws as an overarching objective.

- In order to achieve this objective, activities like documentation of LHP construction process from a sustainability perspective, knowledge transfer & capacity building through LHPs, performance monitoring & demonstration of thermal comfort in selected housing projects among others.

Climate Smart Buildings Programme (ICEN-CSB)

Government of India/ MoHUA

+

The Federal Ministry of Economic Cooperation(BMZ), Germany/ GIZ

→ ICEN-CSB

Affordable

Climate Smart Building

Climate Resilient

Thermal Comfortable

Key features of a CSB

Reduce the demand for air-condition by 30-40%	Curtail 30 metric tones of CO2
Improve health and wellbeing of people	Support the commitment of GoI towards reducing CO2 emissions

Results of a Climate responsive building design

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Climate Smart Buildings (CSB) - Project Objectives

WP1: Facilitate implementation and monitoring of Light House Projects (LHPs)

WP 2: Technical assistance to enhance thermal comfort in upcoming Demonstration Housing Projects (DHPs) and ARHCs (Affordable rental housing complexes) and other Public/Private housing projects in East Cluster

WP 3: Inclusion of climate resilience and thermal comfort requirements in building byelaws and Local Government framework in East Cluster

WP 4: Capacity development of Govt officials and private stakeholders on thermal comfort in the East Cluster

Light House Project (LHP)- Ranchi

Sr. No.	Sub Task	Progress as on 22.03.2022 (42%)						
		Bldg. 1	Bldg. 2	Bldg. 3	Bldg. 4	Bldg. 5	Bldg. 6	Bldg. 7
1	Excavation for Foundation	100%	100%	100%	100%	100%	100%	100%
2	PCC for Foundation	100%	100%	100%	100%	100%	100%	
3	RCC of Foundation	100%	100%	100%	100%	100%	100%	
4	RCC of Shear walls	100%	100%	40%	10%	100%	100%	
5	RCC of Grade Slab	50%	10%					

No. of Houses: 1,008
No. of Floors: G+8
No. of Towers: 7
Community Hall: 1
Technology used: Precast Concrete Construction – 3D Volumetric
Construction Agency: SGC Magicrete LLP.
Start date of project: **January, 2021**
Expected completion: **October 2022**

Construction Approach - Traditional vs 3D precast

Design, Engineering, approval process → Site Preparation infrastructure → Step wise Building Construction and inspection → Skilled and unskilled labor resourcing at every step. → Construction steps at Foundation level → Various steps at superstructure level on site- column, beam, slab casting → Wall construction and plaster → Electrical, plumbing, Mechanical conduiting and in-lays → Final finishing on site. → Inspection and Handover

Traditional Construction timeline

Pods Construction timeline

- Design, engineering, Approval Process
- Site Preparation, infrastructure and Manufacturing offsite
- **Transportation**
- Installation
- Inspection

3D Precast process

1. *Precast wall panels are stacked in the stockyard*
2. *Precast slabs are to be stacked in the horizontal position*
3. *Vertical elements are transported in the A-Frame trailer*
4. *Horizontal elements are transported in the regular flatbed trailer*
5. *Elements will be loaded in the trailer by the Gantry Crane or EOT crane*





- Resource Efficiency (up to 60% less manpower)
- Time-Saving (Around 50% less)
- Portland slag cement & water efficiency

Tea Break : 10 minutes

Session 1

01

THERMAL COMFORT

Thermal comfort is a mental state that reflects happiness with the thermal environment and is measured by subjective assessment.

Importance of Thermal Comfort

1

You can increase morale and productivity while also enhancing health and safety by regulating thermal comfort. Because their capacity to make decisions and/or do manual tasks deteriorates in excessively hot and cold conditions, people are more prone to behave unsafely

2

People adjust their behavior to cope with their thermal environment, such as by adding or removing clothing, changing their posture unconsciously, selecting a heating source, moving closer to or farther away from cooling/heating sources, and so on.

3

When this option (removing a jacket or moving away from a heat source) is gone, issues develop since people are no longer able to adjust. People are unable to adapt to their environment in some cases because the environment in which they work is a product of the processes of the task they are doing.

THERMAL ENVIRONMENTS CAN BE DIVIDED LOOSELY INTO THREE BROAD CATEGORIES:

THERMAL COMFORT

Broad satisfaction with the Thermal Environment i.e. most people are neither too hot nor too cold.

THERMAL DISCOMFORT

People start to feel uncomfortable i.e. they are too hot or too cold, but are not made unwell by the conditions.

THERMAL DISCOMFORT

Heat stress or cold stress, is where the thermal environment will cause clearly defined harmful medical conditions, such as dehydration or frost bite

THERMAL DISCOMFORT

Thermal Discomfort can be induced

by a generalized warm or cool discomfort of the body

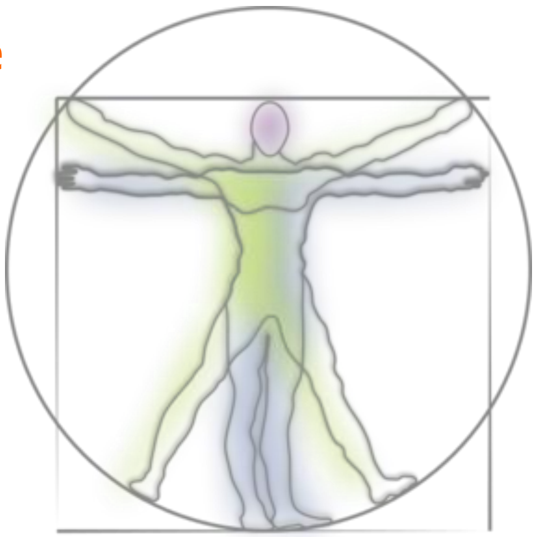
by an unpleasant chilling or heating of a specific region of the body.

Factors affecting Thermal Comfort

PHYSICAL FACTORS

Environmental Parameters

- Mean Radiant Temperature
- Air Temperature
- Air Speed
- Humidity



PHYSIOLOGICAL FACTORS

Personal Parameters

- Metabolic Rate
- Clothing

PHYSICAL FACTORS

•01

•Air Temperature

•02

•Mean Radiant Temperature

•03

•Radiant Temperature Asymmetry

•04

Floor Surface Temperature

•05

•Relative Humidity

•06

•Air Speed

PHYSICAL FACTORS

PHYSICAL FACTORS

AIR TEMPERATURE – the temperature of the air surrounding a body

The ideal temperature for sedentary work is usually between **20°C and 26°C**

RADIANT TEMPERATURE – the heat that radiates from a warm object

Heat can be generated by equipment, which raises the temperature in a specific region.

AIR VELOCITY – the speed of air moving across the worker

It's best if the air flow rate is between **0.1 and 0.2 m/s.**

HUMIDITY – the amount of evaporated water in the air

Air-conditioning can easily attain ideal relative humidity values of **40 percent to 70 percent**.

PHYSIOLOGICAL FACTORS

CLOTHING LEVEL

Because it affects heat loss and, as a result, the thermal balance, the amount of thermal insulation worn by a person has a significant impact on thermal comfort. Layers of insulating clothing keep a person warm or cause overheating by preventing heat loss. The better the insulating ability of a garment, the thicker it is in general. Air movement and relative humidity can reduce the insulating effectiveness of clothing, depending on the type of material it is constructed of.

METABOLIC RATE

The rate at which chemical energy is converted into heat and mechanical effort by metabolic activities within an organism, commonly measured in units of total body surface area. People have different metabolic rates that can fluctuate due to activity level and environmental conditions.

PHYSIOLOGICAL FACTORS

CLOTHING	Clo
T-shirts, shorts, Light socks, Sandals	0.30
Shirt, Trousers socks, Shoes	0.70
Jacket, Blouse, Long skirt, stockings	1.00
Trousers, Vest, Jacket Coat, Socks Shoes	1.50

CLOTHING LEVELS & INSULATION

PHYSIOLOGICAL FACTORS

ACTIVITY	Met
Seated, Relaxed	1.0
Sedentary Activity (office, dwelling, school, laboratory)	1.2
Standing, Light Activity (shopping, laboratory, light industry)	1.6
Standing, Medium activity (shop assistant, domestic work, machine work)	2.0

METABOLIC RATE

Thermal Comfort Indices

Two of the thermal indices which find applications for hot environments are described as follows.

THERMAL INDICES

1. Effective Temperature (ET)

2. Tropical Summer Index (TSI)

Thermal Comfort Indices

1 - Effective Temperature

- The temperature of still, saturated air at which the same amount of heat is released is known as the effective temperature.as well as a general influence on comfort the atmosphere is being investigated.
- Temperature, humidity, and other factors the same thermal output is produced by the same wind velocity. A person's sensations are assumed to have a temperature that is effective.

Initially two scales were developed

Basic Scale	**Normal Scale of Effective Temperature**
one of which referred to men stripped to the waist and called the basic scale.	The other applies to men fully clad in indoor clothing and called the normal scale of effective temperature. B

The same effective temperature is defined as a combination of temperature, humidity, and wind velocity that produces the same thermal experience in an individual.

Thermal Comfort Indices

CORRECTED EFFECTIVE TEMPERATURE (CET)

The use of globe temperature reading instead of the air temperature reading to make allowance for the radiant heat.

The scale was compiled only for men either seated or engaged in light activity.

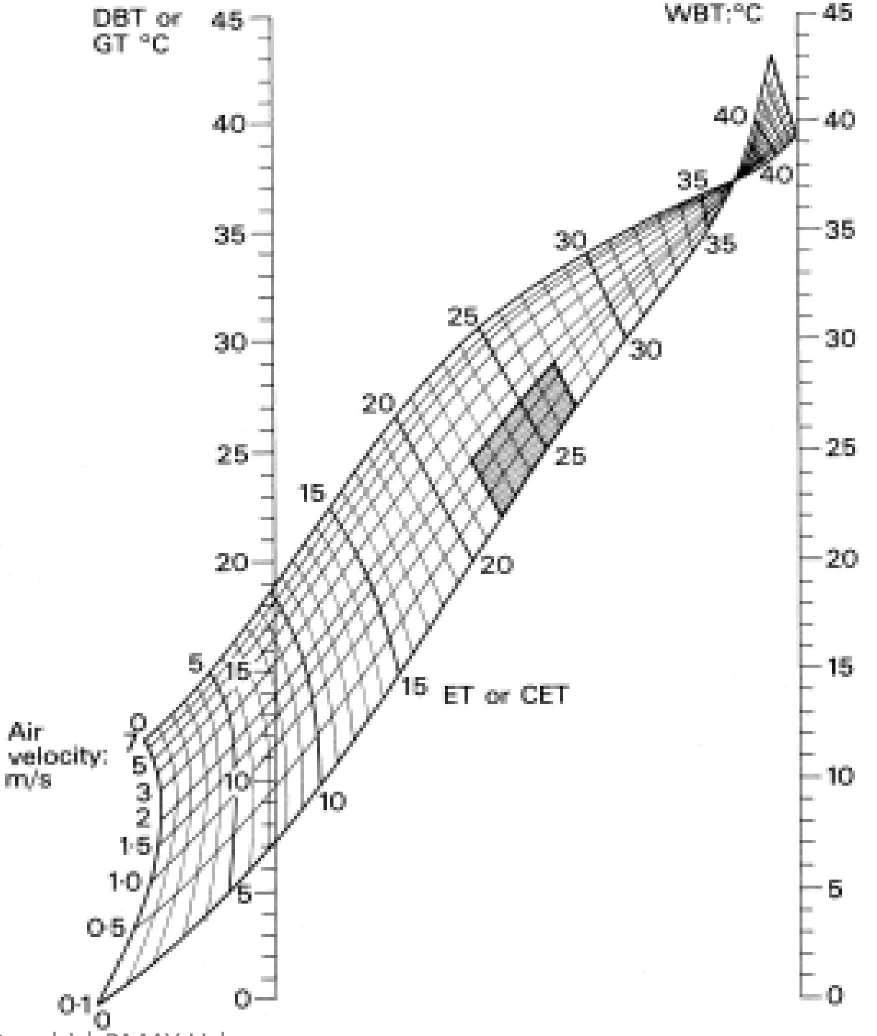


Figure represents the Corrected Effective Temperature (CET) Nomogram

Thermal Comfort Indices

2 - Tropical Summer Index

The TSI is defined as the temperature of calm air at 50% relative humidity which imparts the same thermal sensation as the given environment .The 50% level of relative humidity is chosen for this index as it is a reasonable intermediate value for the prevailing humidity conditions.

Mathematically, TSI (°C) is expressed as

$$TSI = 0.308tw + 0.745tg - 2.06\sqrt{V + 0.841}$$

Where,	
Tw	Wet bulb temperature in °C
Tg	Globe temperature in °C
V	Air speed in m/s

Thermal Comfort Indices

The ranges of environmental conditions and TSI covered in this study are:

Globe Temperature	20-42 °C
Wet Bulb Temperature	18-30 °C
Air Speed	0-2.5 m/s
TSI	15-40 °C

The thermal comfort of subjects was found to lie between TSI values of 25 and 30°C with optimum conditions at 27.5°C.

Thermal Comfort Indices

REDUCTION IN TSI VALUE FOR VARIOUS WIND SPEED	
Air Speed (m/s)	**Decrease in TSI (°C)**
0.5	1.4
1.0	2.0
1.5	2.5
2.0	2.8
2.5	3.2

The warmth of the environment was found tolerable between 30 and 34°C (TSI), and too hot above this limit. On the lower side, the coolness of the environment was found tolerable between 19 and 25°C (TSI) and below 19°C (TSI), it was found too cold.

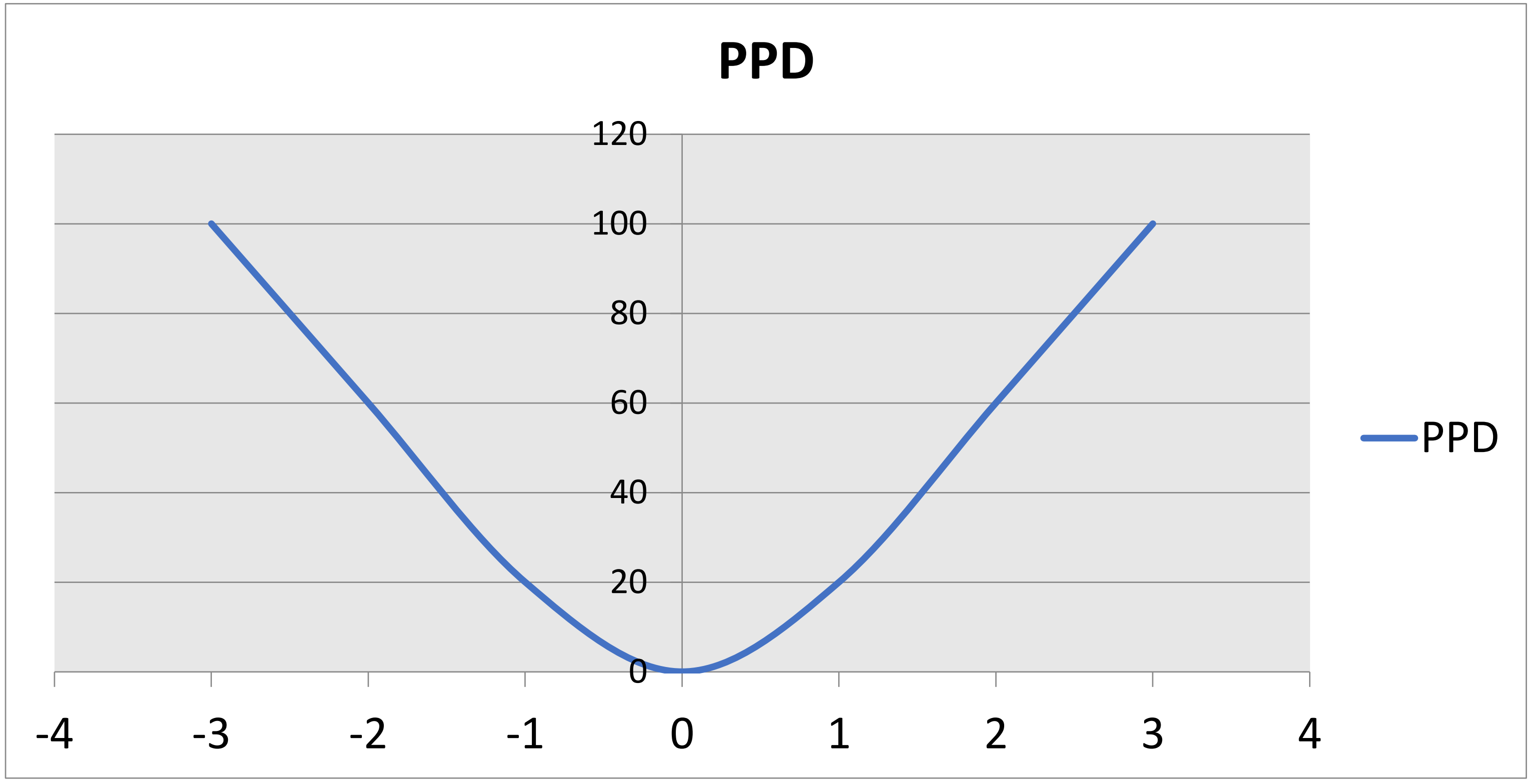
Methods to find Thermal Comfort

- **Methods to find Thermal Comfort**
  - **PMV/PPD Methods**
  - **Local Thermal Discomfort**
    - **Radian Temperature Asymmetry**
    - **Draft**
    - **Floor Surface Temperature**

Methods to find Thermal Comfort

1 - PMV/PPD Methods

To describe comfort, the PMV/PPD model was constructed utilizing heat-balance equations and empirical investigations on skin temperature. Subjects are asked to rate their thermal comfort on a seven-point scale ranging from cold (-3) to hot (+3) in standard thermal comfort surveys.



Methods to find Thermal Comfort

The comfort zone is determined by the combinations of the six parameters for which the PMV is within the recommended range (-0.5PMV+0.5), with the PMV equal to zero denoting thermal neutrality. While anticipating a population's thermal feeling is a crucial step in determining what conditions are pleasant, it is more vital to assess whether or not individuals will be satisfied.

-3	-2	-1	0	1	2	3
COLD	COOL	SLIGHTLY COOL	PMV	SLIGHTLY WARM	WARM	HOT

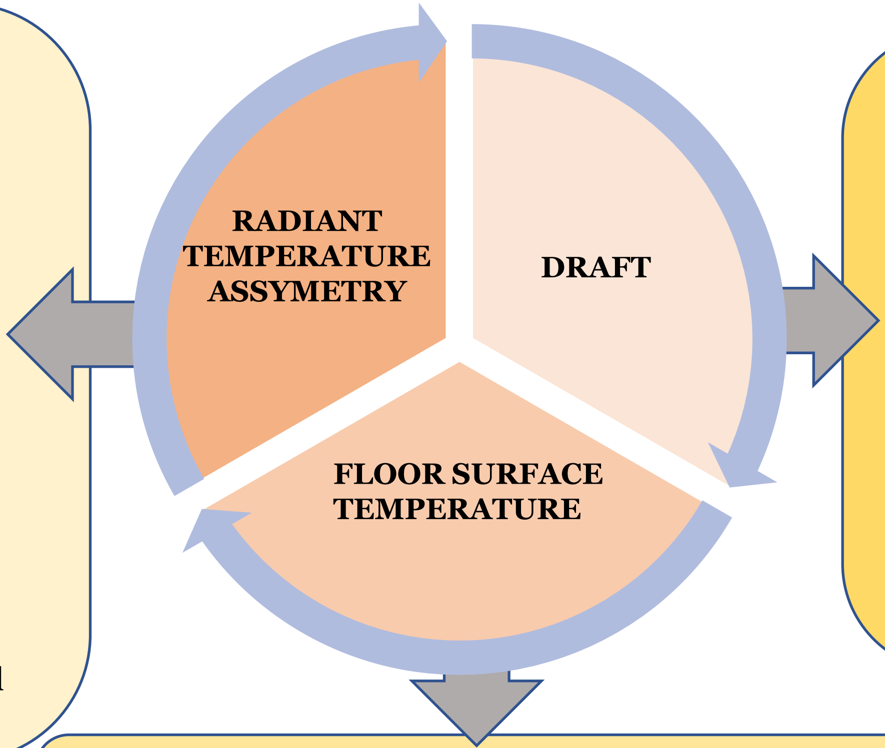
Methods to find Thermal Comfort

It is critical to avoid local thermal discomfort, whether it is produced by a vertical air temperature difference between the feet and the head, an asymmetric radiant field, local convective cooling (draught), or contact with a hot or cold floor. When a person's thermal sensitivity is cooler than neutral, they are more sensitive to local discomfort, and when their body is warmer than neutral, they are less sensitive.

LOCAL THERMAL DISCOMFORT		
RADIANT TEMPERATURE ASSYMETRY	DRAFT	FLOOR SURFACE TEMPERATURE

Local Thermal Discomfort

- **Large variances** in the heat radiation of the surfaces that surround a person might create local discomfort or impair acceptance of the temperature circumstances.
- The temperature disparities across diverse surfaces are limited by **ASHRAE Standard 55**. Because some asymmetries are more sensitive than others, such as a warm ceiling against hot and cold vertical surfaces, the limitations vary depending on which surfaces are involved.
- The ceiling cannot be more than **+5 °C (9.0 °F)** warmer than the other surfaces, but a wall can be up to **+23 °C (41 °F) warmer**.



- While **air movement** can be enjoyable and give pleasure in some situations, it can also be unwelcomed and cause discomfort in others.
- The undesired air movement is known as "**draught**," and it is most noticeable when the complete body's thermal sense is cool.
- A **draught** is most likely to be felt on exposed body regions such as the head, neck, shoulders, ankles, feet, and legs, although the sensation is also affected by air speed, air temperature, activity, and clothing.

Depending on the **footwear**, too hot or too cold floors might be uncomfortable. In rooms where users will be wearing lightweight shoes, ASHRAE 55 advises keeping floor temperatures between **19–29 °C (66–84 °F).**

Methods to find Thermal Comfort

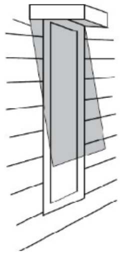
There will always be a percentage dissatisfied occupants.
Often it will be the same person, therefore the values should not be added

CATEGORY	PPD (PREDICTED PERCENTAGE DISSATISFIED)	PMV (PREDICTED MEAN VOTE)	DR (DRAUGHT RISK)
	%	-	%
A	< 6	-0.2 < PMV < +0.2	< 10
B	< 10	-0.5 < PMV < +0.5	< 20
C	<15	-0.7 < PMV < +0.7	< 30

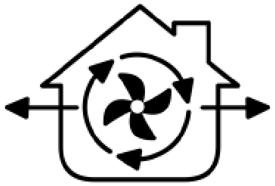
Measures to Improve Thermal Comfort

Measures to Improve Thermal Comfort

- **SHADING & GLAZING**



- **CONTROLLED VENTILATION**



- **INSULATION**

- **COOL ROOFS**

- **GREEN ROOFS**

Shading & Glazing

Shading reduces internal heat gain through coincident radiation.

VARIOUS METHODS TO SHADE WINDOWS					
Overhangs	Awnings	Louvers	Vertical Fins	Light Shelves	Natural Vegetation

These can reduce cooling energy consumption by 10-20%

The shading mechanism can be fixed or movable (manually or automatically) for allowing varying levels of shading based on

1. **the sun's position and**
2. **movement in the sky**

Shading & Glazing

Thermal Comfort

SHADING

In combination with high-performance glass with low solar heat gain coefficient (SHGC), can reduce energy consumption even further by cutting down or heat gain through radiation

GLAZING

refers to the glass windowpanes that make up the building envelope. Conduction and radiation are the primary sources of heat gain via a window. radiation, which can be regulated by defining the parameters correctly. SHGC and U-value, respectively.

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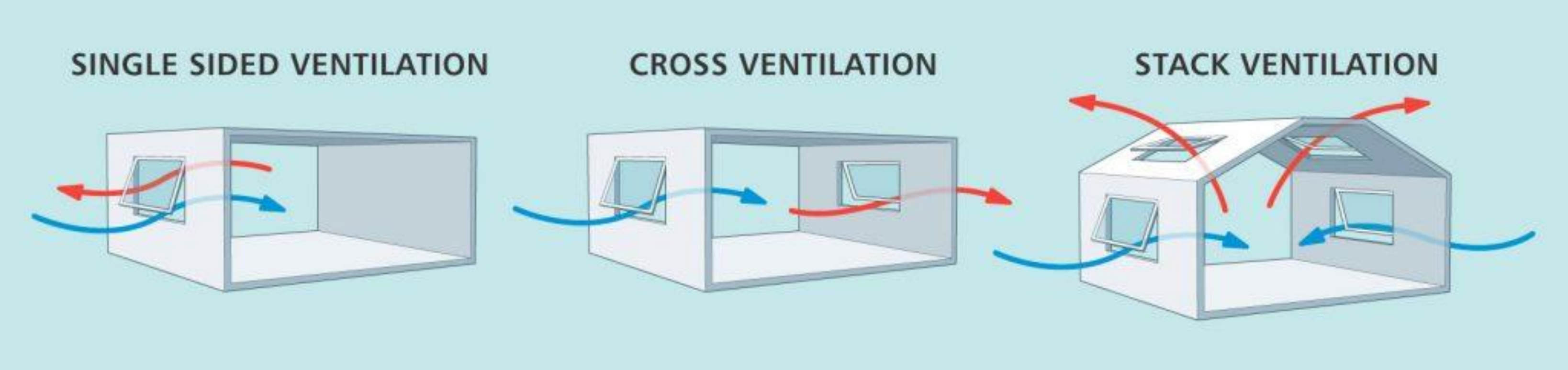
Controlled Ventilation

BUILDING CAN BE DESINED AS

- **Single Sided Ventilation**
- **Cross Ventilation**
- **Stack Ventilation**



Controlled Ventilation

Designing windows and vents to dissipate warm air and allow the ingress of cool air can **reduce cooling energy consumption by 10-30%**

Air Velocity range between 0.5 to 1 m/s	**Drops temperature at about 3 ^{o}C at 50% relative Humidity**

AIR VELOCITY OF 1 m/s	
Office Environment	Too High
Home Environment	Acceptable (Especially if there is no resource to active air conditioning.)

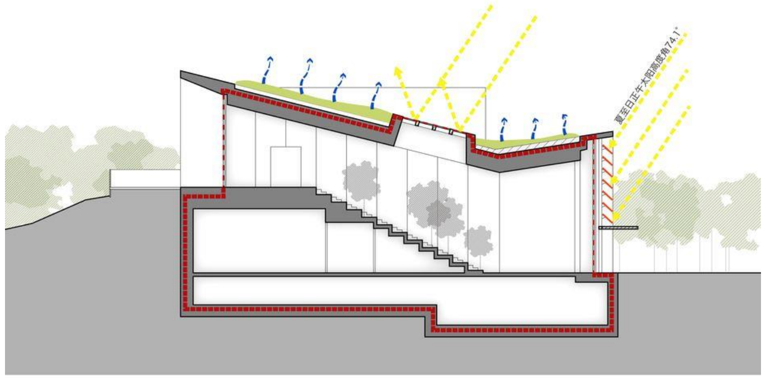
Controlled Ventilation

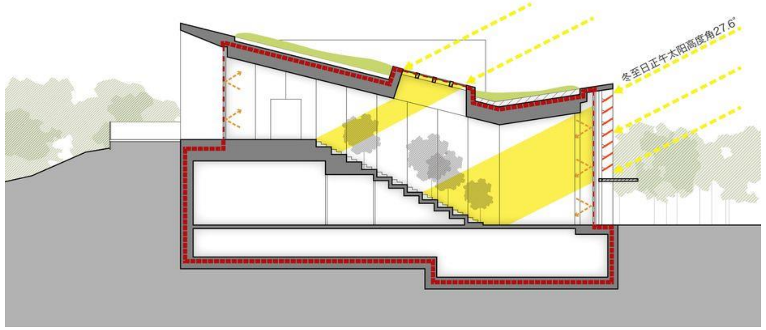
Natural ventilation takes advantage of the differences in air pressure between warm air and cool air, as well as convection currents, to remove warm air from an indoor space and allow fresh cooler air in.

This also has the added advantage of cooling the walls and roofs of the buildings that hold significant thermal mass, further enhancing the thermal comfort of the occupants

NATURAL VENTILATION		
With Breeze Air	Works Best	Even in hot-dry and warm-humid climate zones where some air-conditioning may be required during peak Thermal Comfort for All summer, buildings can be designed to operate in a mixed mode to enable **night ventilation** and **natural ventilation** during cooler seasons
Absence of natural breeze	Fans can be used to improve the flow of cool air	
Natural ventilation promotes the occupants' adaptation to external temperature, called adaptive thermal comfort		

Insulation





Heat Conduction takes place through

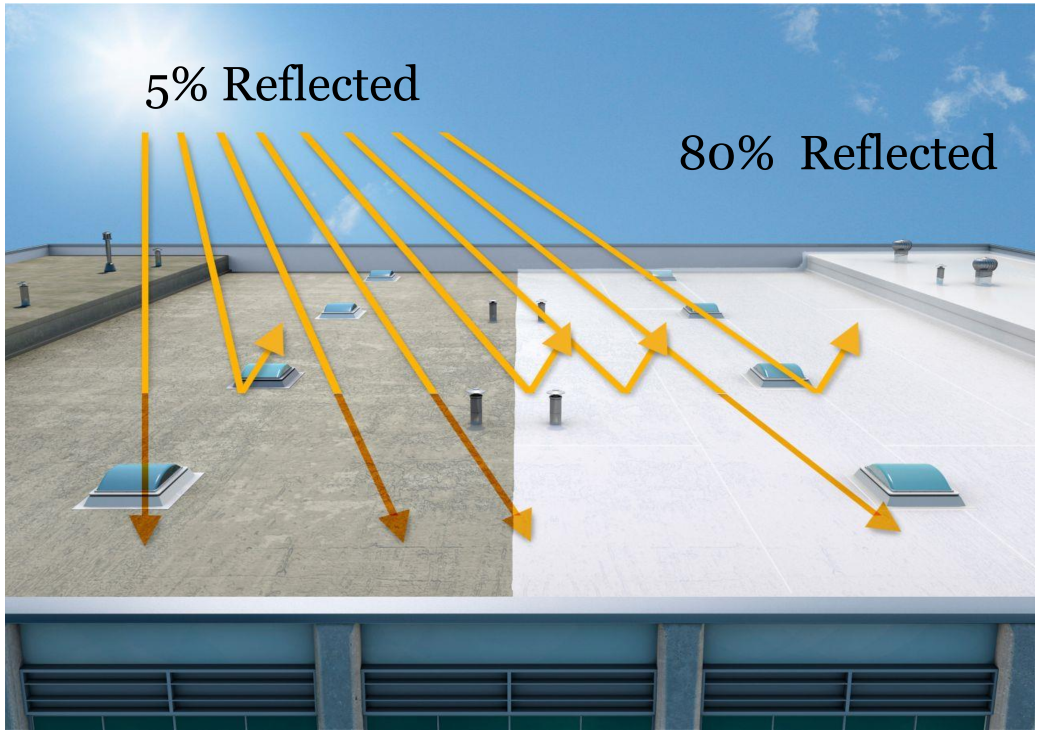
- Roof
- Walls
- Windows

An insulating material can resist heat transfer due to its low thermal conductivity. Insulating walls and the roof can reduce cooling energy loads by up to 8%

Cool Roofs

Cool roofs are one of the passive design options for reducing cooling loads in buildings. Cool roofs reflect most of the sunlight (about 80% on a clear day)

When sunlight is incident on a dark roof	**When Sunlight is incident on a cool roof**
38% heats the atmosphere	10% heats the environment
52% heats the city air	8% heats the city air
5% is reflected	80% is reflected
	1.5% heats the building



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Cool Roofs

In the summer, a typical cool roof surface temperature keeps 25-35°C cooler than a conventional roof, lowering the internal air temperature by roughly 3-5°C and improving the **thermal performance**.

The comfort of the inhabitants is improved, and the **roof's lifespan** is extended.

Cool roofs increase the durability of the roof itself by reducing thermal expansion and contraction.

Apart from helping enhance the thermal comfort in the top floor and helping **reduce air-conditioning load**, cool or white roof or pavements also offer significant reduction in urban heat island effect

The cities of Jodhpur and Jaipur is the extremely hot state of Rajasthan, where most of the city homes are painted in light blue and light pink colours, are examples of practical application of this age-old traditional design style.

Green Roofs

A green roof is a roof of a building that is partially or completely covered with vegetation

GREEN ROOFS PURPOSE

- Absorbing Rain Water
- Providing Insulation
- Helping lower urban air temperatures
- Mitigating the urban heat island effect

Green Roofs

Reduction in Energy use is an important feature of Green Roofing

GREEN ROOFS IN BUILDINGS ALLOWS	
During cooler Winter Months	Retain their heat
During hotter Summer Months	Reflecting and absorbing solar radiations

Thermal Comfort in Affordable Housing

70% of the buildings needed in India by 2030 have yet to be constructed. Maintaining the status quo is pointless, and there is a huge opportunity to properly incorporate passive design strategies across our built environment.

Passive solutions for thermal comfort in buildings can greatly reduce cooling, ventilation, and lighting requirements

Less reliance on mechanical cooling/heating approaches reduces the generation of surface ozone, resulting in better air quality

Building techniques that are more sensitive will tend to reduce disparities in thermal comfort between different income classes as more people become aware of the benefits of **sustainable building design**.

Thermal Comfort in Affordable Housing

Impact of Thermally Comfortable Affordable Housing

Thermal comfort in housing is one of the key pillars to achieve India's National Cooling Action Plan target of reducing cooling energy need by 20-40 per cent by 2037-38.

Overview of affordable housing sector

80 million households in India are estimated to be living in slums

20 million current housing shortage in Urban areas

40 million current housing shortage in Rural areas

70% housing shortage in Rural areas is mainly in affordable segment

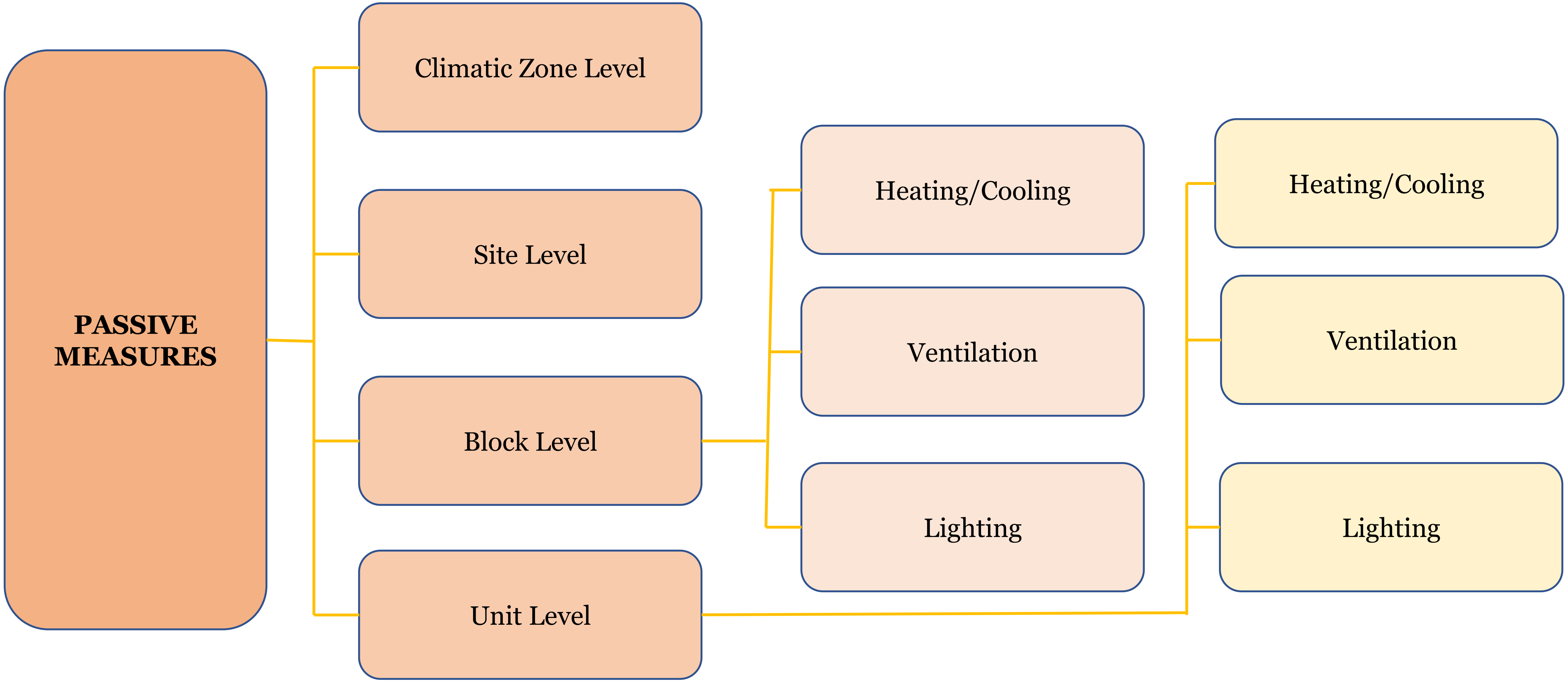
Thermal comfort housing can have numerous positive impacts

- Lower operational costs for the economically weaker sections
- Broader market & outreach for the sustainable material & technology market
- Social benefits rising from belter comfort conditions like boost in academic performance of kids, improvement in quality of life of the women
- Boost to meet the targets of Paris Agreement & achievement of sustainable development goal specially number 3, 11 & 13
- Better health and well being of the occupants

Passive Strategies & Building Physics

Passive Measures		Level of Response	
Climatic Zone Level	Temperature, rainfall, wind direction, sun radiation, humidity, and other environmental factors are taken into consideration when designing.	Block Level	Interaction of the block with its surroundings and plants to ensure that it has adequate heating, ventilation, and lighting.
Site Level	To take advantage of the positive aspects of the site and its microclimatic features while minimising the negative aspects.	Unit Level	Design solutions that influence heat, light, and ventilation based on climatic variables at the unit level.

Passive Strategies & Building Physics



Passive Measures – Climatic Zone Level

Vernacular / traditional architectural typologies that respond to the region's distinct environment are best exemplified.

- In Ladakh, earth architecture with thick walls and limited windows provides optimal insulation.

- In Rajasthan, courtyard havelis take advantage of pressure differences and reciprocal shading to provide natural cooling and ventilation.

- In Kerala, sloping roofs are used to guard against severe rains.

Passive Measures – Site Level

Reducing the 'heat island' effect with approaches like:

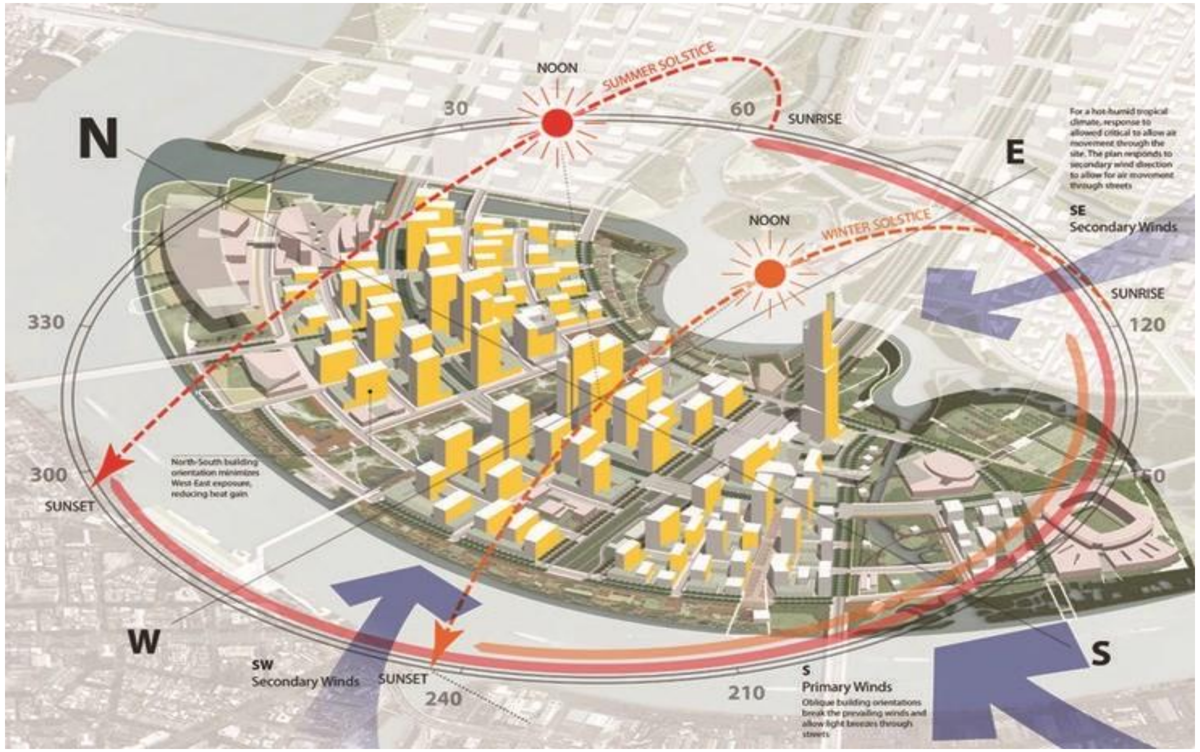
Courtyards / open courts are often surrounded by construction.

Taking advantage of block mutual shading

Using site massing to create wind passageways

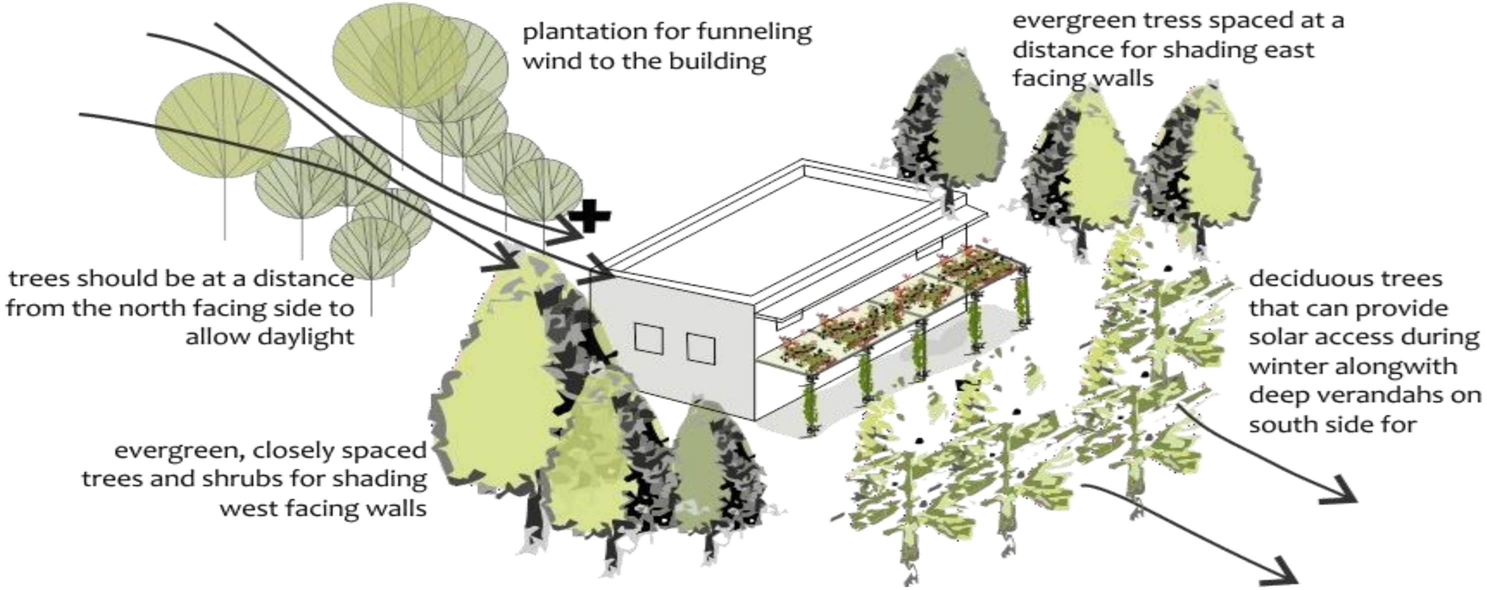
lowering the amount of hard paving to allow for water absorption

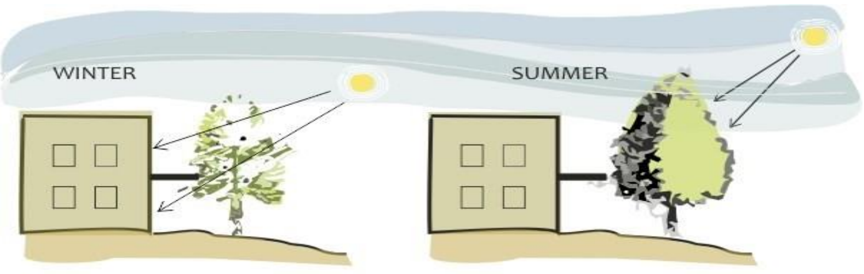
Using complementary vegetation to manage the amount of sunlight that gets through as the seasons change



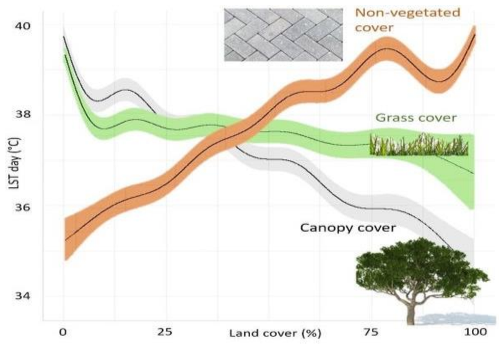
Passive Measures – Leveraging Plantation

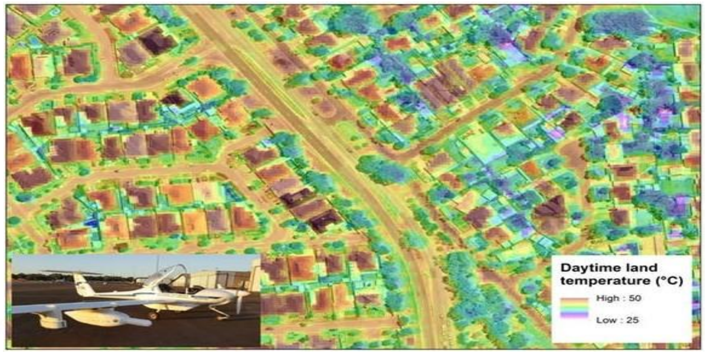
Planting trees in the right places to provide shade and ventilation can significantly reduce the severity of intense weather. During heatwaves in Adelaide, a research found that districts with more vegetation cover remained **cooler by up to 6°C.**





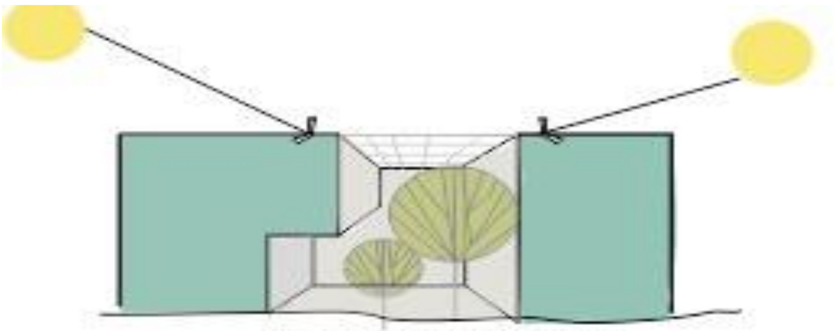
deciduous trees allow sun penetration in winter and block sun access during summer



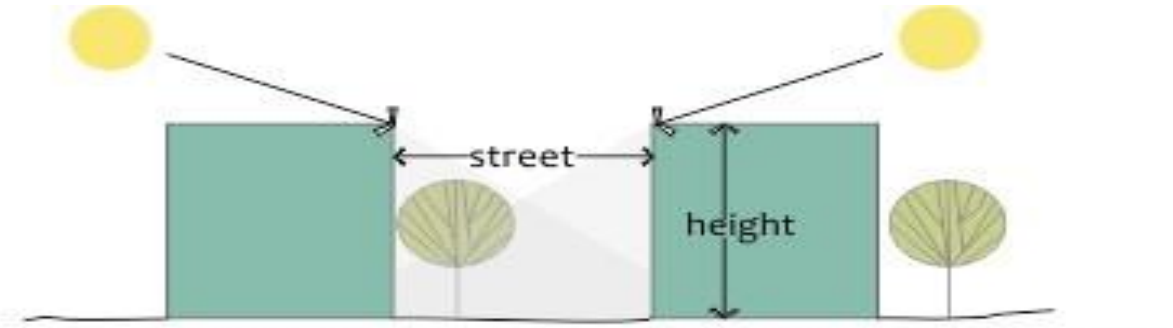


Passive Measures - Block Level

Arrange the blocks so that mutual shade is obtained, avoiding solar heat buildup throughout the summer.



closely placed forms

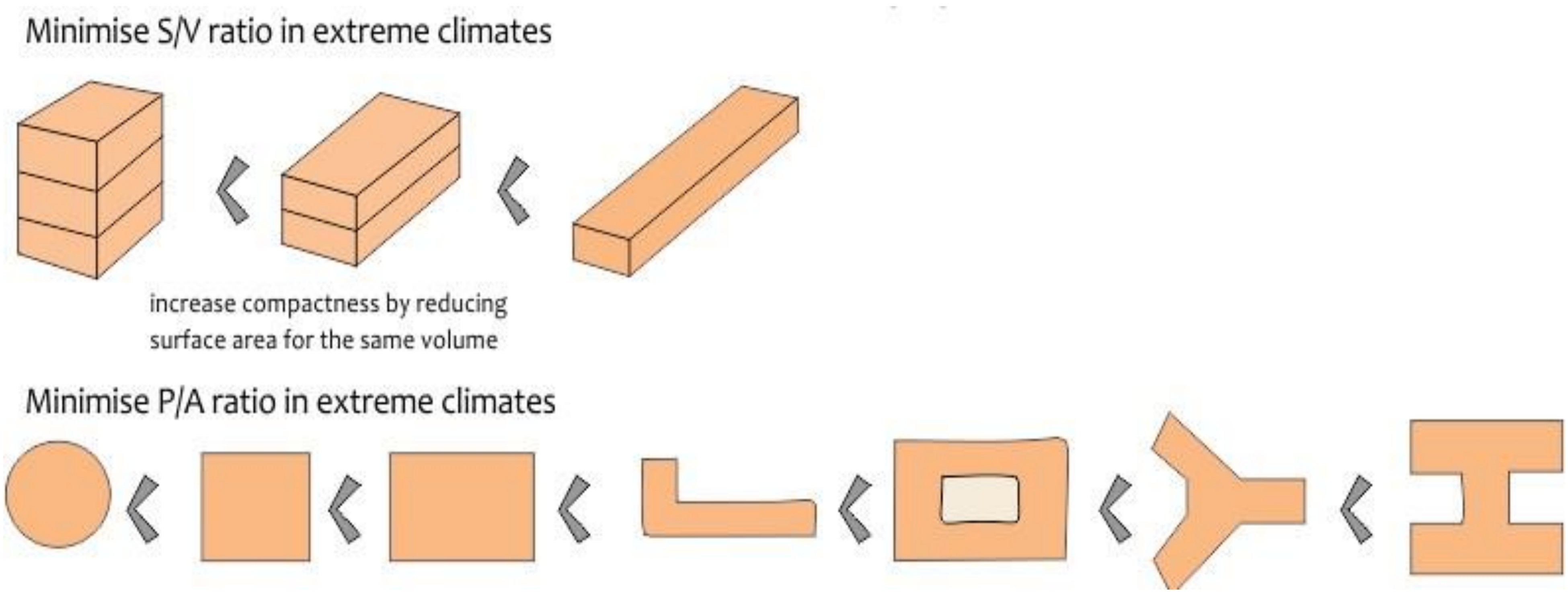


narrow streets - keep building height to street width ratio minimal

HEATING/COOLING

Passive Measures - Block Level

In harsh climate zones, reduce the surface area to building volume and perimeter to area ratios to reduce solar radiation exposure.

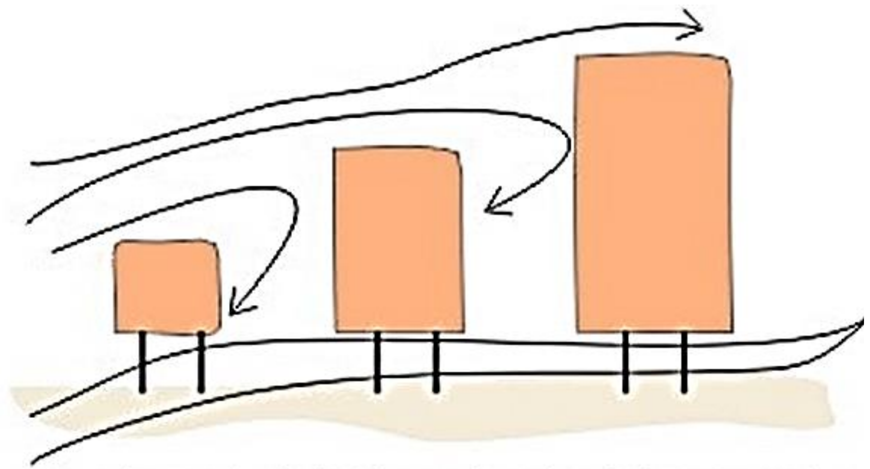


HEATING/COOLING

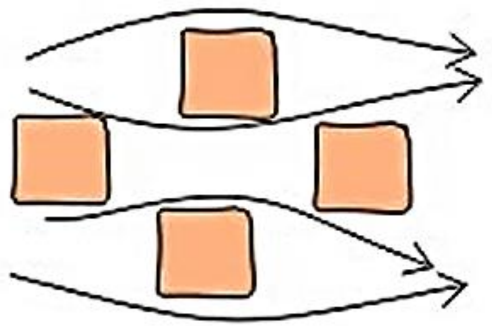
Passive Measures - Block Level

VENTILATION

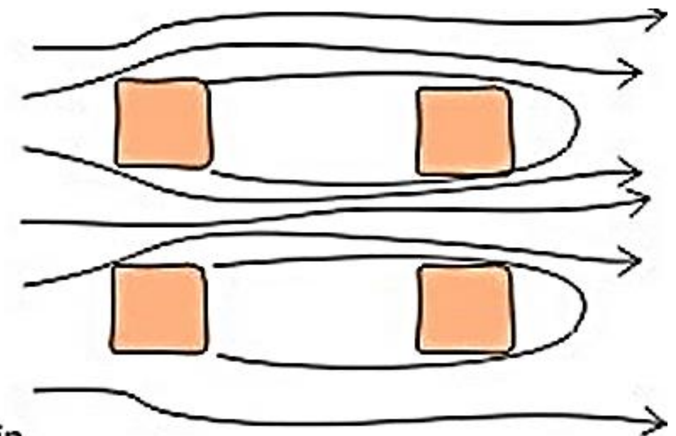
Wind shadows should be avoided by building orientation.



if a site has multiple buildings, they should be arranged in ascending order of their heights and be built on stilts to allow ventilation

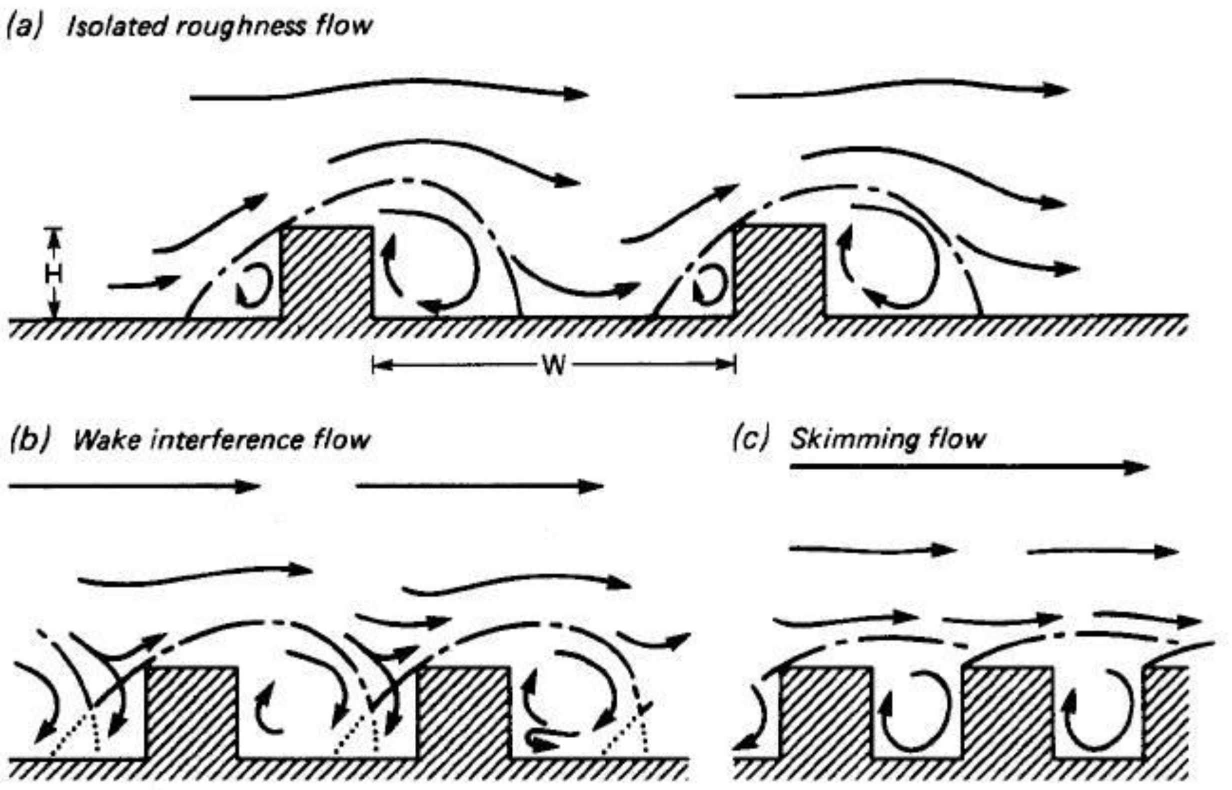


staggered layout helps in accentuating wind movement



Passive Measures - Block Level

Wind flows can be harnessed by constructing courts and catchment zones of various sizes. This can help to improve airflow and provide a cooling effect for the blocks.



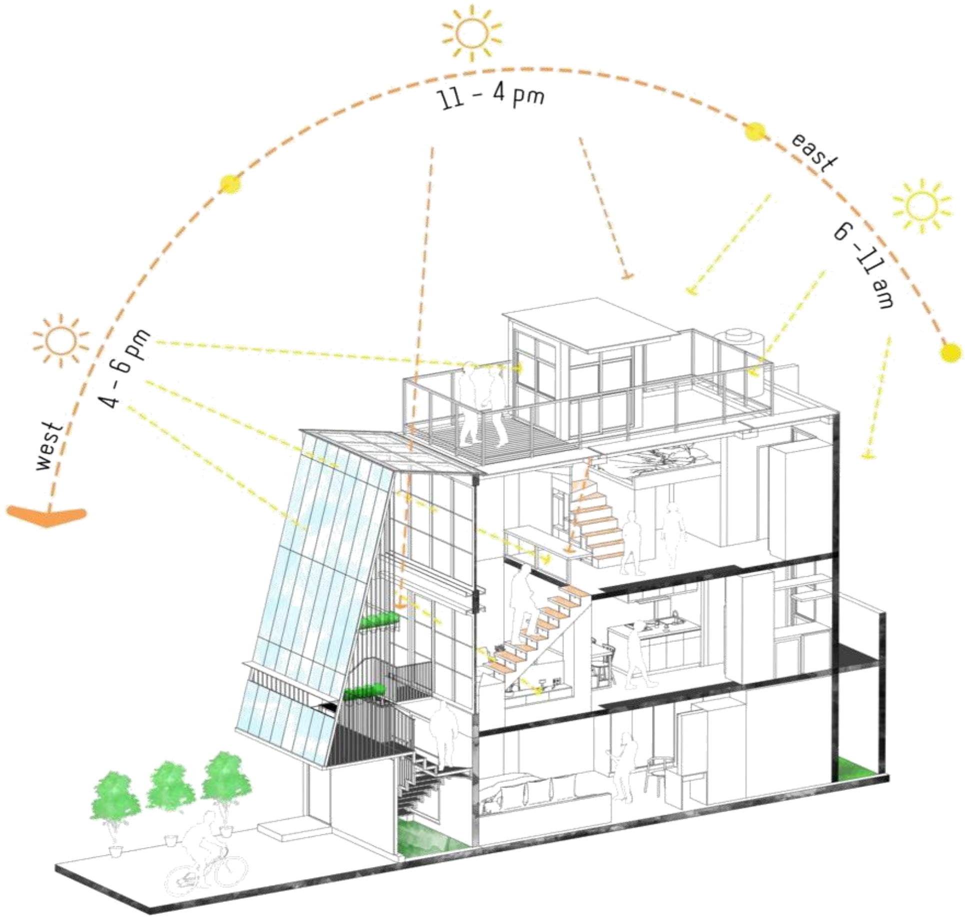
VENTILATION

Unit Level – Forms and Orientation

Sun radiation penetration patterns and, as a result, heat uptake and loss in a building are affected by changes in solar route during different seasons.

Internal layout is of the **courtyard type**, which is rather compact. Reduced sun exposure on East-West external walls to reduce heat gain.

If planned and situated on the east and, especially, the west end of the structure, non-habitable rooms (stores, bathrooms, etc.) can be efficient thermal barriers.

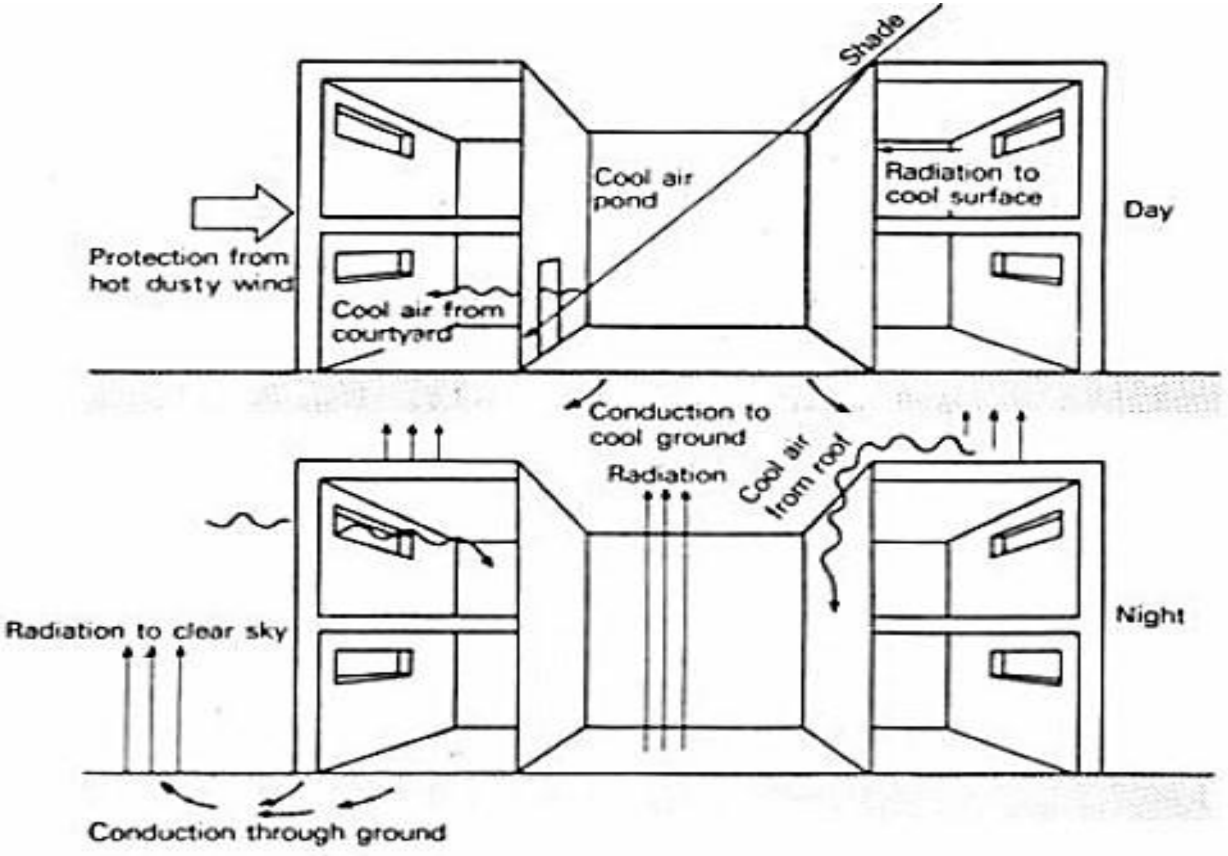


HEATING/COOLING

Unit Level – Forms and Orientation

High walls block the sun, resulting in significant portions of the inner surfaces and courtyard floor being shaded during the day.

The dirt beneath the courtyard will extract heat from the surrounding places and remit it to the open sky during the night, resulting in cooler air and surfaces.

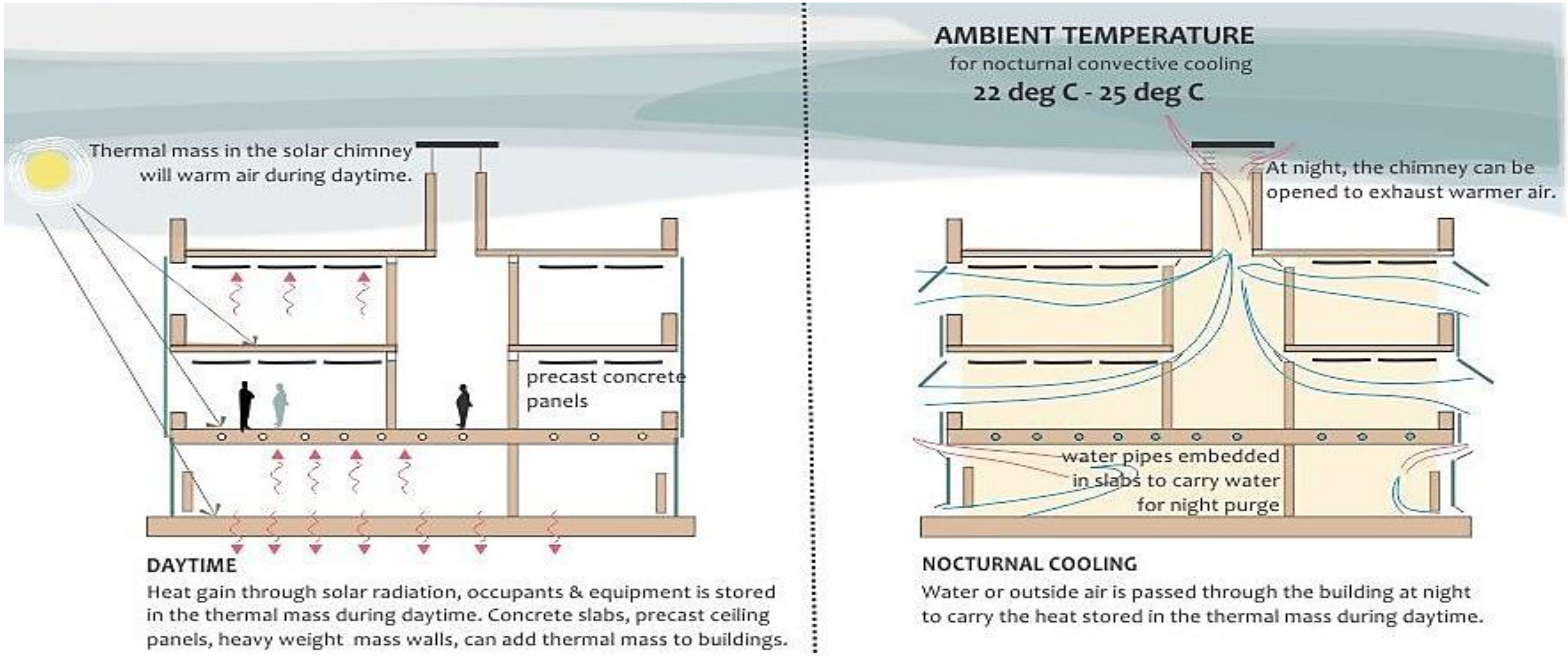


HEATING/COOLING

Unit Level – Thermal Mass

Thermal mass can be combined with night-time convective cooling, sometimes known as "night cooling," to passively cool buildings.

Thermal mass as a passive cooling and heating approach requires a large diurnal swing.

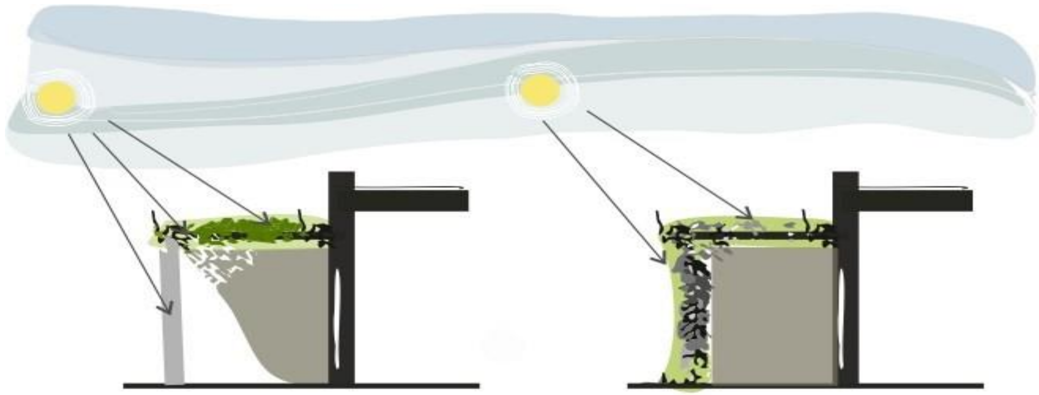


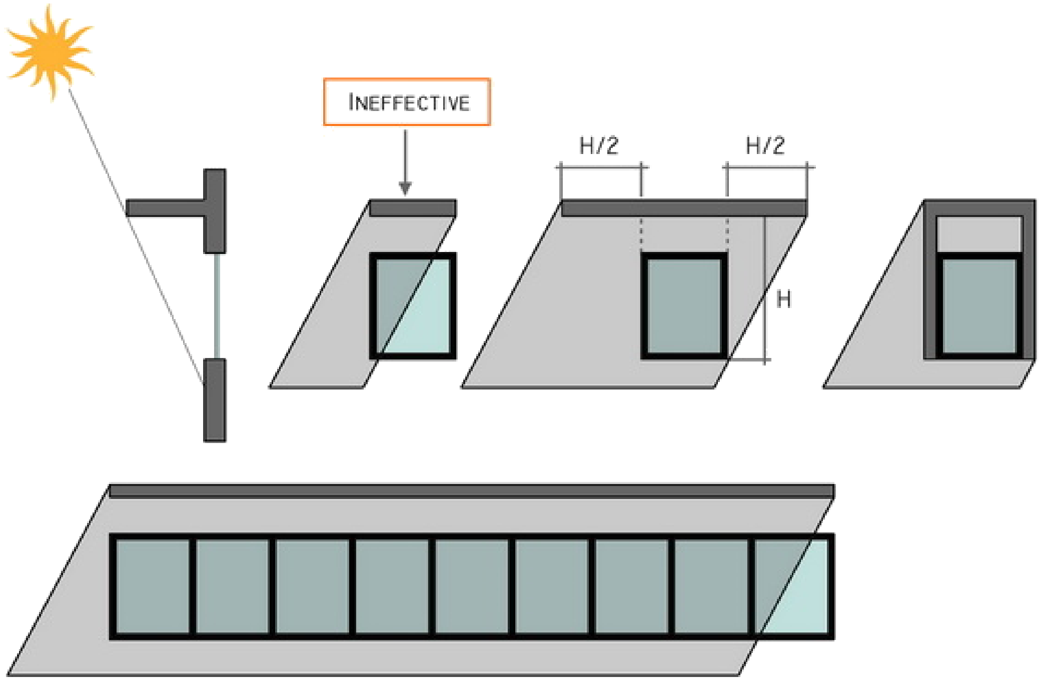
HEATING/COOLING

Unit Level – Shading

Shade-producing plants, such as creepers, can be used.

Fenestrations and shades/chajjas can be built to maximise solar radiation depending on the environment.





HEATING/COOLING

Unit Level

ORIENTATION:

Buildings can be orientated in relation to the prevailing wind direction at angles ranging from 0° to 30°.

In buildings with a courtyard, positioning the courtyard 45 degrees from the prevailing wind maximises wind flow into the courtyard and improves cross ventilation in the building (in climates where cooling is required).

CREATING PRESSURE DIFFERENCES:

A 'squeeze point' occurs when wind enters through a smaller opening and escapes through a larger opening. This generates a natural vacuum, which speeds up the wind.

The total area of apertures should be at least 30% of the total floor space.

The window-to-wall-ratio (WWR) should not exceed 60%.

VENTILATION

CASE STUDIES

INFOSYS – POCHARAM CAMPUS

LOCATION	HYDERABAD, TELANGANA
COORDINATES	17° N, 78° E
OCCUPANCY TYPE	OFFICE
TYPOLOGY	NEW CONSTRUCTION
CLIMATE TYPE	HOT AND DRY
PROJECT AREA	27,870 m²

Given the high-standards in terms of building design achieved at the SDB1 in Hyderabad, it has now been showcased in the 'Best Practices Guide for High Performance Indian Office Buildings' by Lawrence Berkeley National Lab, a U.S. Department of Energy (DoE) National Laboratory.

INFOSYS – POCHARAM CAMPUS

It has been built keeping in mind a holistic approach to sustainability in five key areas

- Sustainable site development
- Water savings
- Energy efficiency
- Materials selection
- Indoor environment quality

- The Indian Green Building Council (IGBC) has given Infosys, a worldwide consulting and technology firm, the LEED (Leadership in Energy and Environmental Design) India 'Platinum' designation for its Software Development Block 1 (SDB 1) at its Pocharam site in Hyderabad, India.
- The SDB 1 is the first commercial building in India to deploy unique Radiant-cooling technology, setting new norms for energy efficiency in building systems design.

EPI – 75kWh/m²/yr

GODREJ PLANT 13 ANNEXE

LOCATION	**MUMBAI, MAHARASHTRA**
COORDINATES	19° N, 73° E
OCCUPANCY TYPE	OFFICE – PRIVATE
TYPOLOGY	NEW CONSTRUCTION
CLIMATE TYPE	WARM AND HUMID
PROJECT AREA	24,443 m^2

GODREJ PLANT 13 ANNEXE

The Plant 13 Annexe Building at Godrej & Boyce (G&B) in Mumbai has been designated as India's first **CII-IGBC accredited Net Zero Energy Building.**

Its **mixed-use office/convention center** (with office spaces, conference and meeting rooms, auditoriums (90 to 250 seats), banquet hall, 300-person eating facilities, and an industrial kitchen), making certification extremely difficult.

EPI – 75kWh/m²/yr

In 2015, the building received an **IGBC Platinum grade in the EB (Existing Building)** category, which was recertified in 2019. In 2016, it was also awarded the **BEE 5 Star Rating**. In 2019, he received the **'Energy Performance Award'** for meticulous energy measuring and monitoring. At the CII National Energy Management Award event in 2020, it was named **"Excellent Energy Efficient Unit."**

INDIRA PARYAVARAN BHAWAN, MoEF

LOCATION	NEW DELHI
COORDINATES	29° N, 77° E
OCCUPANCY TYPE	OFFICE & EDUCATIONAL
TYPOLOGY	NEW CONSTRUCTION
CLIMATE TYPE	COMPOSITE
PROJECT AREA	9565 m^2

The Indira Paryavaran Bhawan is now India's most environmentally friendly structure. GRIHA 5 Star and LEED Platinum certifications were awarded to the project. The structure has already received accolades, including the MNRE's Adarsh/GRIHA Award for Outstanding Integration of Renewable Energy Technologies.

INDIRA PARYAVARAN BHAWAN, MoEF

To reach **net zero criterion**, several energy saving measures were implemented to lower the building's energy loads, with the residual demand being satisfied by producing energy from **on-site installed high efficiency solar panels**.

The new office building for the Ministry of Environment and Forest (MoEF), Indira Paryavaran Bhawan, is a significant departure from traditional architectural design

The project team focused on measures for lowering energy demand, such as **ample natural light, shade, landscape to reduce ambient temperature, and energy-efficient active building technologies**

EPI – 44kWh/m²/yr

When compared to a conventional building, **Indira Paryavaran Bhawan utilizes 70% less energy.** The project used green building principles, such as water conservation and optimization through site waste water recycling.

Renewable Energy Integration 930 kW PV panels with a total area of 4650m² for on-site generation, tilted at 23⁰ facing south to generate equivalent to 70kWh/m²/yr

JAQUAR HEADQUARTERS

LOCATION	**MANESAR HARYANA**
COORDINATES	28° N, 77° E
OCCUPANCY TYPE	CORPORATE AND MANUFACTURING
TYPOLOGY	NEW CONSTRUCTION
CLIMATE TYPE	COMPOSITE
PROJECT AREA	48000 m^2

JAQUAR HEADQUARTERS

The building is a perfect blend of modern design sensibilities, biophilic inspiration, and a brand ambition of soaring high.

The **Jaguar Headquarters in Manesar** is not only a stunning structure, but also a painstakingly constructed complex with cutting-edge technology that has resulted in **a net zero campus** with a **LEED Platinum (USGBC) rating**. This project is known for its complex organic design and space arrangement, making it a visual pleasure.

Through its characteristic wing-shaped architecture, the design redefines a business workplace by giving it a memorable experience. The spreading wings of a symbolic eagle, poised to take flight, are atop the horizontal glass edifice, suggesting a firm with worldwide ambitions.

ST. ANDREWS BOYS HOSTEL BLOCK, GURUGRAM

LOCATION	**GURUGRAM HARYANA**
COORDINATES	28° N, 76° E
OCCUPANCY TYPE	HOSTEL
TYPOLOGY	NEW CONSTRUCTION
CLIMATE TYPE	HOT AND DRY
PROJECT AREA	5574 m^2

ST. ANDREWS BOYS HOSTEL BLOCK, GURUGRAM

The goal of the design process was to increase student interaction within the indoor areas, which then spilled outdoors and interacted with the surrounding landscape.

On the south and north facades, the linear block was twisted to create a shaded entry (summer court) and an open terrace (winter court), respectively, to stimulate activities at all times of the day and season. The ramp serves as a buffer between the hot outdoors and the cooler interior, preventing kids from experiencing heat shock.

ST. ANDREWS GIRLS HOSTEL BLOCK, GURUGRAM

LOCATION	**GURUGRAM HARYANA**
COORDINATES	28° N, 76° E
OCCUPANCY TYPE	HOSTEL
TYPOLOGY	NEW CONSTRUCTION
CLIMATE TYPE	HOT AND DRY
PROJECT AREA	2322 m^2

ST. ANDREWS GIRLS HOSTEL BLOCK, GURUGRAM

Indoor and outdoor spaces that connect physically and aesthetically at different levels to encourage interactions and social activities are incorporated into the building's plan.

The **entrance foyer and lobby** were planned as outdoor spaces facing west and connected to the pantry so that students can enjoy their nights outside with a spill-out into the green landscape.

AKSHAY URJA BHAWAN HAREDA

LOCATION	**PANCHKULA HARYANA**
COORDINATES	30° N, 76° E
OCCUPANCY TYPE	OFFICE - PUBLIC
TYPOLOGY	NEW CONSTRUCTION
CLIMATE TYPE	COMPOSITE
PROJECT AREA	5100 m²

AKSHAY URJA BHAWAN HAREDA

Mechanical air conditioning is used to guarantee thermal comfort in apical zones at all times.

Zones are created based on the intended temperature set points. 25 1 °C for apex offices, 25 3 °C for regulated office and public areas, and 25 5 °C for passive zones.

In the summer, controlled zones are cooled, and in the monsoon, they are chilled. In the summer, passive zones are cooled, while in the monsoon, they are aired. The centre atrium has a mist system for cooling the controlled and passive zones. Water that has been chilled to a temperature of 15°C.

SUN CARRIER OMEGA

LOCATION	BHOPAL M.P.
COORDINATES	23° N, 77° E
OCCUPANCY TYPE	OFFICE – PRIVATE
TYPOLOGY	NEW CONSTRUCTION
CLIMATE TYPE	HOT AND DRY
PROJECT AREA	9888 ft^2

GRIDCO BHUBANESWAR

LOCATION	**BHUBANESWAR.**
COORDINATES	20° N, 85° E
OCCUPANCY TYPE	OFFICE
TYPOLOGY	NEW CONSTRUCTION
CLIMATE TYPE	WARM AND HUMID
PROJECT AREA	15,793.5 m^2

GRIDCO BHUBANESWAR

The structure was created using computer simulation to determine how long direct sunshine or radiation was tolerable for human habitat based on the sun-path of Bhubaneswar.

The structure encourages natural light and screen radiation. It would feature photovoltaic glass panels and geothermal cooling systems strategically placed, as well as indigenous solar producing technologies, to ensure that it is self-sustaining.

Rainwater can be collected, purified, and utilised as drinkable water. Grey water that has been treated can be reused for flushing and landscape irrigation.

Live Exercise

Lunch Break : 60 minutes

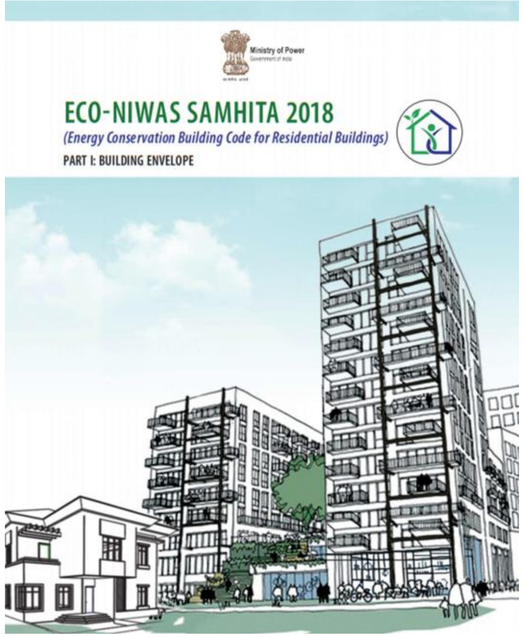
Session 2

02-A

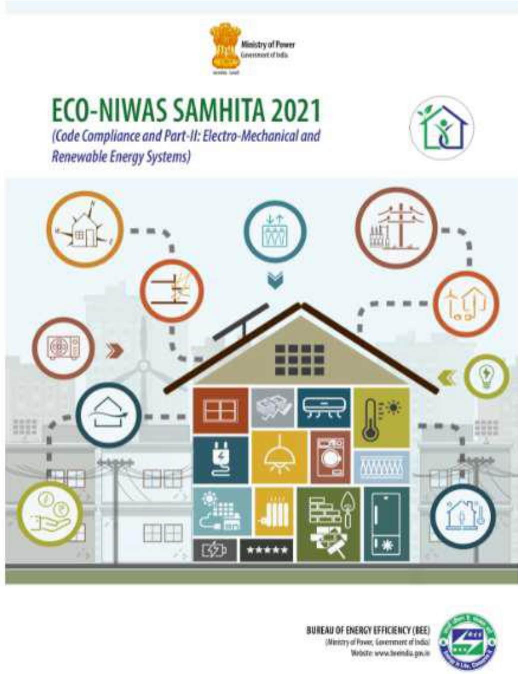
THERMAL COMFORT STANDARDS

Thermal Comfort Standards

- ASHRAE - 55
- National Building Code - 2016
- Handbook of Functional Requirements of Buildings 1987 by BIS
- Eco Niwas Samhita Part 1 and Part 2
- ISHRAE – Indoor Environmental Quality Standards 2018-19



EcoNiwas Samhita 2018
Part 1: Building Envelope



EcoNiwas Samhita 2021
Code Compliance and Part 2

ASHRAE 55

Meeting the standards for Thermal Comfort

ASHRAE standard 55, Thermal Environmental condition for Human Occupancy

ISO 7726:1998	Ergonomics of the Thermal Environment – Instruments for measuring Physical quantities
ISO 7730:1994	Moderate Thermal Environments – Determination of the PMV and PPD Indices and specification of the conditions for Thermal Comfort

ASHRAE 55

Reasons for Building Occupants Thermal Complaints

- Air Temperature & Humidity
- Radiant Temperatures
  - Walls
  - Ceilings
- Floor Temperature
- Vertical Temperature Difference
- Drafts (Air Velocity)
- Secondary Factors
  - Daily & Seasonal Changes
  - Occupant age
  - Occupant adaptability

ASHRAE 55

Human Comfort Range

Most Humans are comfortable under this conditions

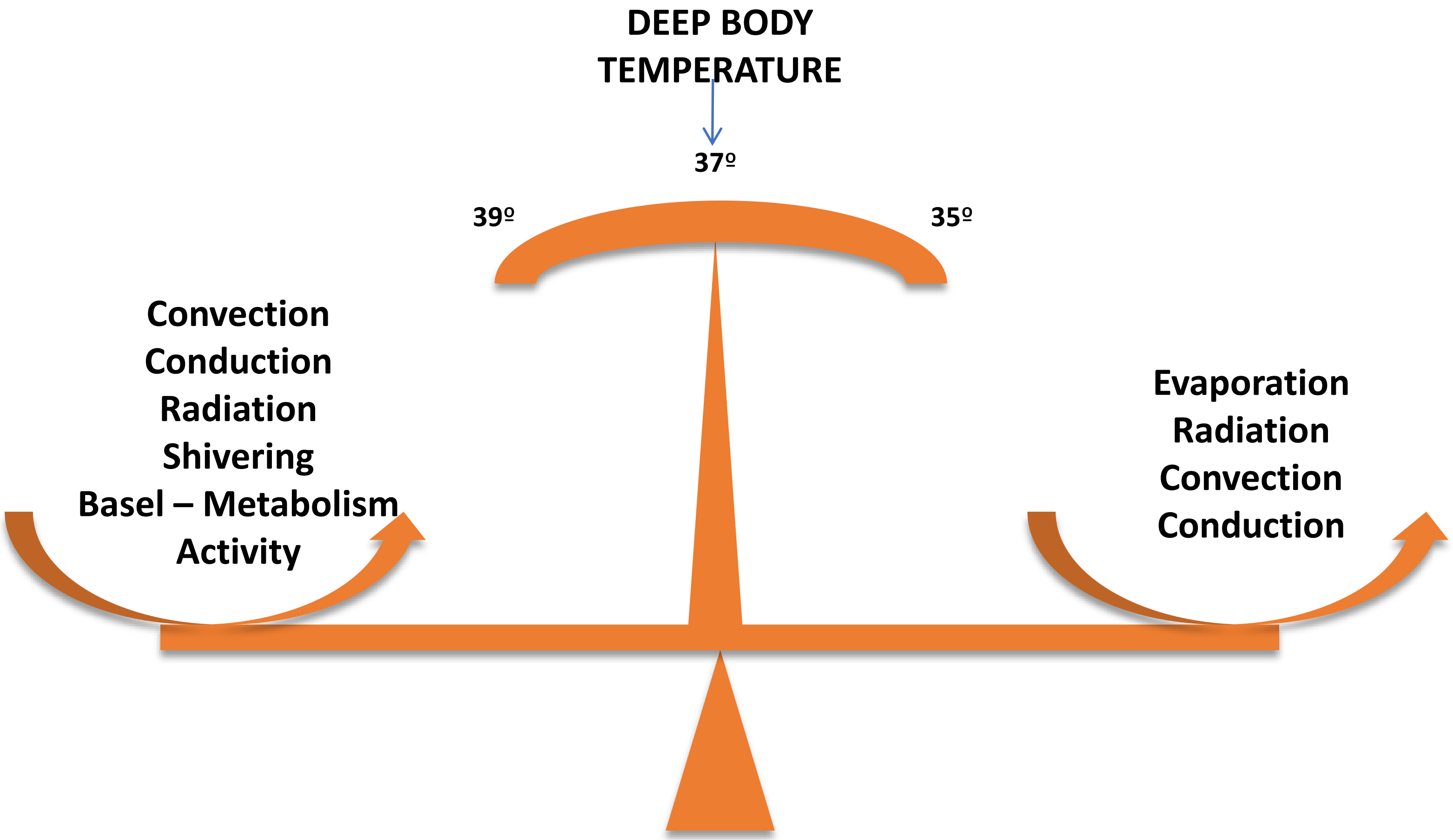
Winters

68°F to 76°F
60% to 30% RH

Summer

74°F to 80°F
60% to 30% RH

Body Regularity Mechanism



Body Regularity Mechanism

The Thermal balance of the body can be shown by following equation, if the heat gain and lost factors are

Gain	Met = Metabolism (basel and muscular)
	Cnd = Conduction (contact with warm bodies)
	Cnv = Convection (if the air is warmer than skin)
	Red -= Radiation (from the sun, the sky and hot bodies)
Loss	Cnd = Conduction (contact with cold bodies)
	Cnv = Convection (if the air is cooler than the skin)
	Red = Radiation (to night sky and cold surface)
	Evp = Evaporation (of moisture and sweat)

Then Thermal Balance exist when:

Met – Evp + Cnd + Cnv + Red = 0

Body Thermal Balance

The body generates heat on a constant basis. The majority of the metabolic processes involved, such as tissue formation, energy conversion, and muscular effort, are all exothermic. Food ingestion and digestion provide the energy required, and metabolism refers to the process of converting food into living matter and usable energy.

METABOLIC HEAT PRODUCTION

BASEL METABOLISM	Heat Production of Vegetative, automatic process
MUSCULAR METABOLISM	Heat Production due to consciously controlled work

Body Thermal Balance

- Only 20% of the heat generated in the body is used, thus any excess heat must be evacuated.
- The mechanism by which the human body maintains its core internal temperature is known as thermoregulation.
- Homeostasis is the state of having a constant internal temperature. All thermoregulation systems aim to bring the body back to a state of homeostasis.
- The temperature range for a healthy safe temperature is between 98.6^{o} F (37^{o}C) and 100^{o} F (37.8^{o}C). The temperature on your skin is between 31^{o} and 34^{o}.

HUMAN BODY RELEASES HEAT TO THE ENVIRONMENT BY

EVAPORATION

RADIATION

CONVECTION

CONDUCTION

Body Thermal Balance – Heat Loss by Human Body

CONVECTION

- The heat from the body is transferred to the air in contact with the skin or clothing, which rises and is replaced by cooler air.
- Faster air movement, lower temperature, and a higher skin temperature all enhance the rate of convective heat loss.

RADIATION

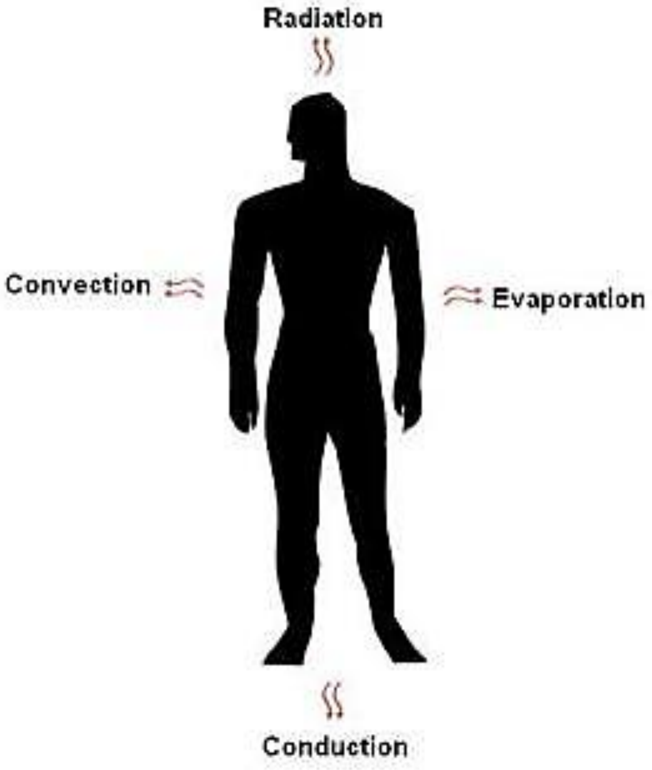
- The temperature of the body surface and the temperature of the opposing surface affects radiant heat loss.

CONDUCTION

- It is determined by the temperature difference between the body surface and the object with which the body is in direct touch.

EVAPORATION

- Is determined by evaporation rate, which is influenced by air humidity (the dryer the air, the faster the evaporation) and the amount of moisture available for evaporation.
- Perspiration and sweating cause evaporation, as does breathing in the lungs.



Body Thermal Balance – Heat Loss in Various Thermal Environment

CALM, WARM AIR, MODERATE HUMIDITY:

Air temperature is 18°.

In the indoors of temperature climate

Air velocity does not exceed 0.25 m/s and when humidity is 40% to 60%, a person engaged in sedentary work will easily dissipate heat as

By Radiation – 45%

By Convection – 30%

By Evaporation – 20%

If the temperature of bounding surface is same as air temperature

Body Thermal Balance – Heat Loss in Various Thermal Environment

HOT AIR AND CONSIDERABLE RADIATION

The Human body temperature is 37^o. But skin temperature is 31-34^o.

Body can gain substantial heat by radiation: Sun, radiator, bonfire.

Even if heat loss is small in the above scenario, evaporation can still occur if the air is suitably dry.

Heat loss via convection steadily declines as air temperature approaches skin temperature, and the body performs vasomotor adjustments to raise temperature to the higher limit (34^o), but once the air temperature hits this point, there is no more heat loss by convection.

Body Thermal Balance – Heat Loss in Various Thermal Environment

HOT AIR, RADIATION AND APPRECIABLE AIR MOVEMENT

When the air is hot (equal to or above skin temperature), the surrounding objects are hot (no heat loss by radiation), and when the air is humid (less than 100% RH), air movement will speed up evaporation, even though the air temperature is higher than skin temperature. Moving air constantly replaces saturated air in the surrounding area.

Inadequately planned houses can generate a lethal condition in which the air is entirely saturated, there is no air flow, and the air is warmer than the skin, resulting in heat stroke.

Ministry of Housing and Urban Affairs
Government of India

Body Thermal Balance – Heat Loss in Various Thermal Environment

SATURATED STILL AIR, ABOVE BODY TEMPERATURE

Air is hot (over 34°.)

Unappreciable air movement (≤ 0.25 m/s)

Humidity is near 100%

This leads to profuse sweating and no evaluation and body temperature begins to rise.

At 45°, death is unavoidable.

At 41°, coma sets in and death is imminent

A body temperature of 40° will cause heat stroke. (Failure in circulation system, followed by rapid increase in body temperature)

At adverse situation

Measurements of Thermal Comfort

- Developed in parallel with ASHRAE 55
- Evaluate and measure the moderate Thermal Environment
- Extreme Environments
  - ✓ ISO 7243:2017
  - ✓ ISO 7933: 2004
  - ✓ ISO/TR 11079:1993

BS EN ISO 7730

Ergonomics of the Thermal Environment – Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local Thermal comfort criteria

BS EN ISO 7726

Ergonomics of the Thermal Environment – Instruments for measuring Physical quantities

General Requirements & Standard Conditions of ASHRAE 55

- ASHRAE 55 specifies conditions for acceptable thermal environments and is intended for use in design, operation, and commissioning of buildings and other occupied spaces.
- specifies a certain percentage of occupants as acceptable, as well as the thermal environment values associated with that number.

ASHRAE 55 is oriented toward six factors:

- **metabolic rate,**
- **clothing insulation,**
- **air temperature,**
- **radiant temperature,**
- **air speed, and**
- **humidity**

Compliance with ASHRAE Standard 55

The comfort zone is regarded sufficient if at least 80% of its occupants are unlikely to object to the ambient state, implying that the majority are between -0.5 and 0.5 on the PMV scale.

Design conditions must maintain the spatial conditions within the acceptable range using one of the methodologies outlined in section 5 of the standard for building systems to comply with ASHRAE, including

- Natural ventilation systems
- Mechanical ventilation systems
- Combinations of these systems
- Control systems
- Thermal envelopes

They must also account for all expected conditions (summer and winter, although barring extremes), external and internal environmental elements, and any essential documents.

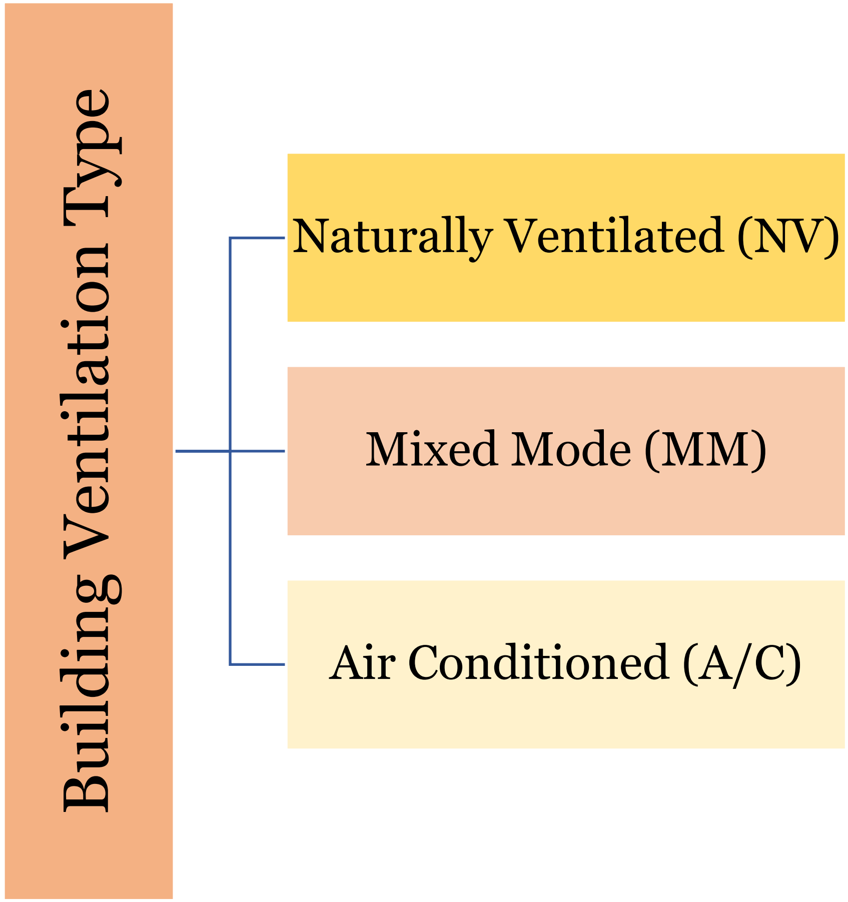
Needed Thermal Comfort Compliance Documentation

Except in the case of naturally ventilated areas, all of the following documentation is required to comply with ASHRAE:

1. The operative temperature, humidity, and total interior loads are all specified in the design.
2. The hours of each seasonal exceedance associated with the outdoor weather percent design conditions
3. The values assumed for comfort parameters (clothing insulation, metabolic rate, indoor airspeed, etc.) at the different assumed conditions (i.e., seasonal).
4. Local discomfort effects (i.e., if someone sits next to a radiator or right below a cooling vent this can lead to local discomfort although the entire space overall is in thermal equilibrium. These effects can easily be determined using thermal modeling tools)
5. The system input or output capacity needed to attain the design operative thermal conditions.

IMAC – Indian Model for Adaptive Comfort

- The adaptive thermal comfort model saves more energy in buildings that are naturally ventilated when compared to air-conditioned buildings as residents adjust to wider indoor temperatures than the peripheral thermal comfort zones determined by the PMV model.
- IMAC Classifies the Building Ventilation into three types based on their HVAC system ranging from naturally ventilated to complete Air Conditioning



IMAC – Indian Model for Adaptive Comfort

- The Standard Classification is based on the **ADAPTIVE Thermal Comfort model** which differentiate the thermal tolerance of occupants accustomed to monotonic temperature (such as air-conditioned places) and people habituated to variation in internal temperatures (such as naturally ventilated structures)

- The Indoor operative temperature values for different building types (NV, MM & A/C) are Pre – Calculated for most Indian cities

IMAC – Indian Model for Adaptive Comfort

Naturally Ventilated Buildings

- The Occupants in NV buildings are Thermally adapted to the outdoor temperature of their location.
- The Indoor Operative Temperature of the occupants to stay thermally comfortable is given by the belove equation.

Indoor Operative Temperature (°C) = **0.54 x Mean Monthly Outdoor DBT + 12.83**

Acceptability range for naturally ventilated buildings is **±2.38°C**

IMAC – Indian Model for Adaptive Comfort

Mixed Mode Ventilated Buildings

- The MM Ventilated buildings takes into consideration the combination of natural ventilation and the availability of air-conditioning when necessary.
- The Occupants in MMV Buildings thermally adapt to the outdoor temperature more than the A/C buildings & somewhat less adaptive to NV building
- The Indoor Operative temperature for the occupants to stay thermally comfortable is given by the below equation.

Indoor Operative Temperature (°C) = **0.28 x Mean Monthly Outdoor DBT + 17.87**

Acceptability range for Mixed Mode ventilated buildings is **±3.46°C**

IMAC – Indian Model for Adaptive Comfort

AC Buildings – Air Temperature based Approach

Indoor Operative Temperature (°C) = **0.078 x Mean Monthly Outdoor DBT + 23.25**

Acceptability range for Air-Conditioned buildings is **±1.5°C**

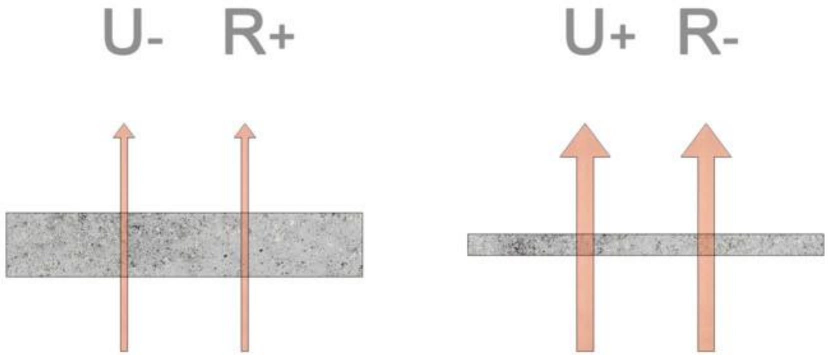
02-B

EFFECTS OF MATERIALS ON THERMAL COMFORT

U-Value or Thermal Transmittance

U-Value or Thermal Transmittance (Reciprocal of R-Value)

Thermal performance is quantified in terms of heat loss and is often represented as a U-value or R-value in the building sector.
The rate of heat transfer through a structure (which can be a single material or a composite) divided by the temperature differential across that structure is known as thermal transmittance, also known as **U-value.**



- W/m²K is the unit of measurement.
- The lower the U-value, the better insulated the structure is.
- Workmanship and installation standards can have a significant impact on thermal transmission.
- The thermal transmittance can be much higher than desirable if insulation is installed improperly, with gaps and cold bridges.
- Thermal transmittance accounts for heat loss by conduction, convection, and radiation

U-Value Calculation

U-Value or Thermal Transmittance (Reciprocal of R-Value)

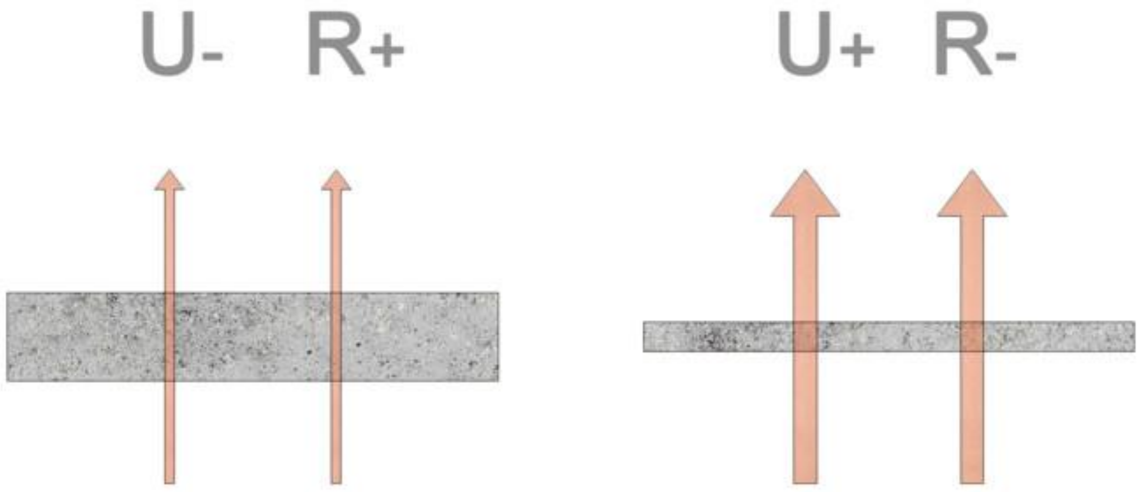
Thermal transmittance is the rate of heat transfer through materials

Unit of U value is $W/(m^2K)$

$$U = \frac{1}{Thermal\ Resistance\ of\, a\ material\ (R)}$$

$$\text{Where } R = \frac{Thickness\ of\ material\ (t)}{Conductivity\ (k)}$$

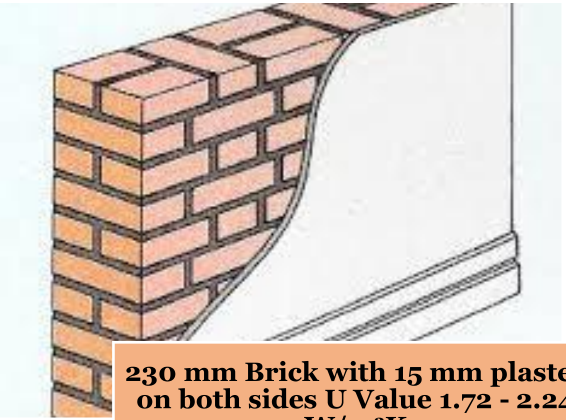
Conductivity (k) is the rate at which heat is transferred by conduction though material



Comparative in terms of U-Value

150 mm RCC (No plaster) – U Value 3.77 W/m²K

200 mm Solid Concrete Block with 15 mm plaster on both sides – U Value 2.8 W/m²K



230 mm Brick with 15 mm plaster on both sides U Value 1.72 - 2.24 W/m²K

200 mm Autoclaved Aerated Concrete (AAC) with 15 mm plaster on both side U Value 0.77 W/m²K

300 mm Autoclaved Aerated Concrete (AAC) with 15 mm plaster on both sides U Value 0.54 W/m²K

Conventional Materials vs Local Materials vs Materials used at LHP

Sr. No.	CONVENTIONAL MATERIALS		LOCAL MATERIALS		MATERIALS USED AT LHP	
	MATERIALS	U-VALUE	MATERILAS	U-VALUE	MATERIALS	U-VALUE
1	Red Bricks (230mm)	2.8 W/m²K	Concrete Block (200mm)	2.8 W/m²K	RCC Wall (150mm)	10.53 W/m²K
2	Fly Ash Bricks (200mm)	4.28 W/m²K	Sand Stone Blocks (200mm)	2.6 W/m²K	AAC Blocks (200mm)	0.77 W/m²K

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Session 3

03-A

NEW AGE INNOVATIVE TECHNOLOGY

Light House Projects

Objective of Light House projects is to demonstrate and deliver ready to live houses

Houses built with shortlisted alternate technology

House built with speed, economy

Green and sustainble

Better quality of construction in a e manner

LHP serves as LIVE Laboratories for different aspects of Transfer of technologies to field application, such as planning, design, production of components, construction practices, testing etc. for both faculty and students, Builders, Professionals of Private and Public sectors, and other stakeholders involved in such construction

Light House Projects

Following are the details of Construction Technologies being employed at the Light House Projects selected under the Global Housing Technology Challenge (GHTC) – India

Monolithic Concrete Construction using Tunnel Formwork

- LHP Location: Rajkot, Gujarat
- No. of Houses: 1144

Prefabricated Sandwich Panel System

- LHP Location: Indore, Madhya Pradesh
- No. of Houses: 1024

Precast Concrete Construction System – Precast Components Assembled at Site

- LHP Location: Chennai, Tamilnadu
- No. of Houses: 1152

Precast Concrete Construction System – 3D Volumetric

- LHP Location: Ranchi, Jharkhand
- No of Houses: 1008

Light Gauge Steel Structural System & Pre-engineered Steel Structural SystemAgartala, Tripura

- LHP Location: Agartala, Tripura
- No of Houses: 1000

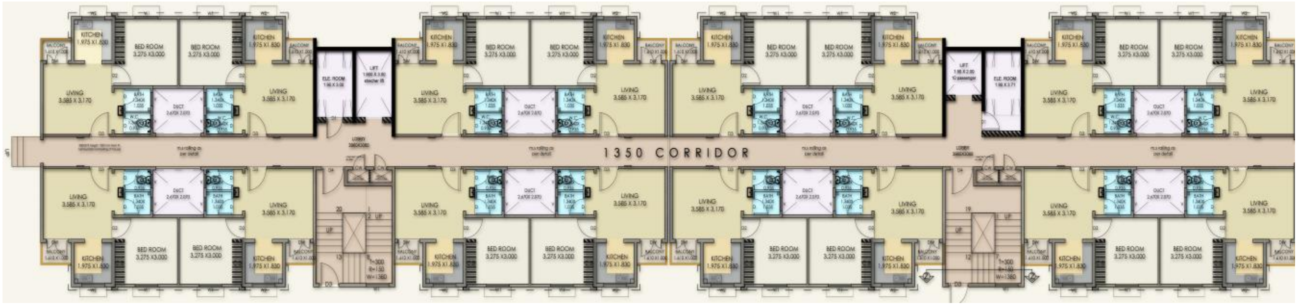
PVC Stay in Place Formwork System

- LHP Location: Lucknow, Uttar Pradesh
- No of Houses: 1040

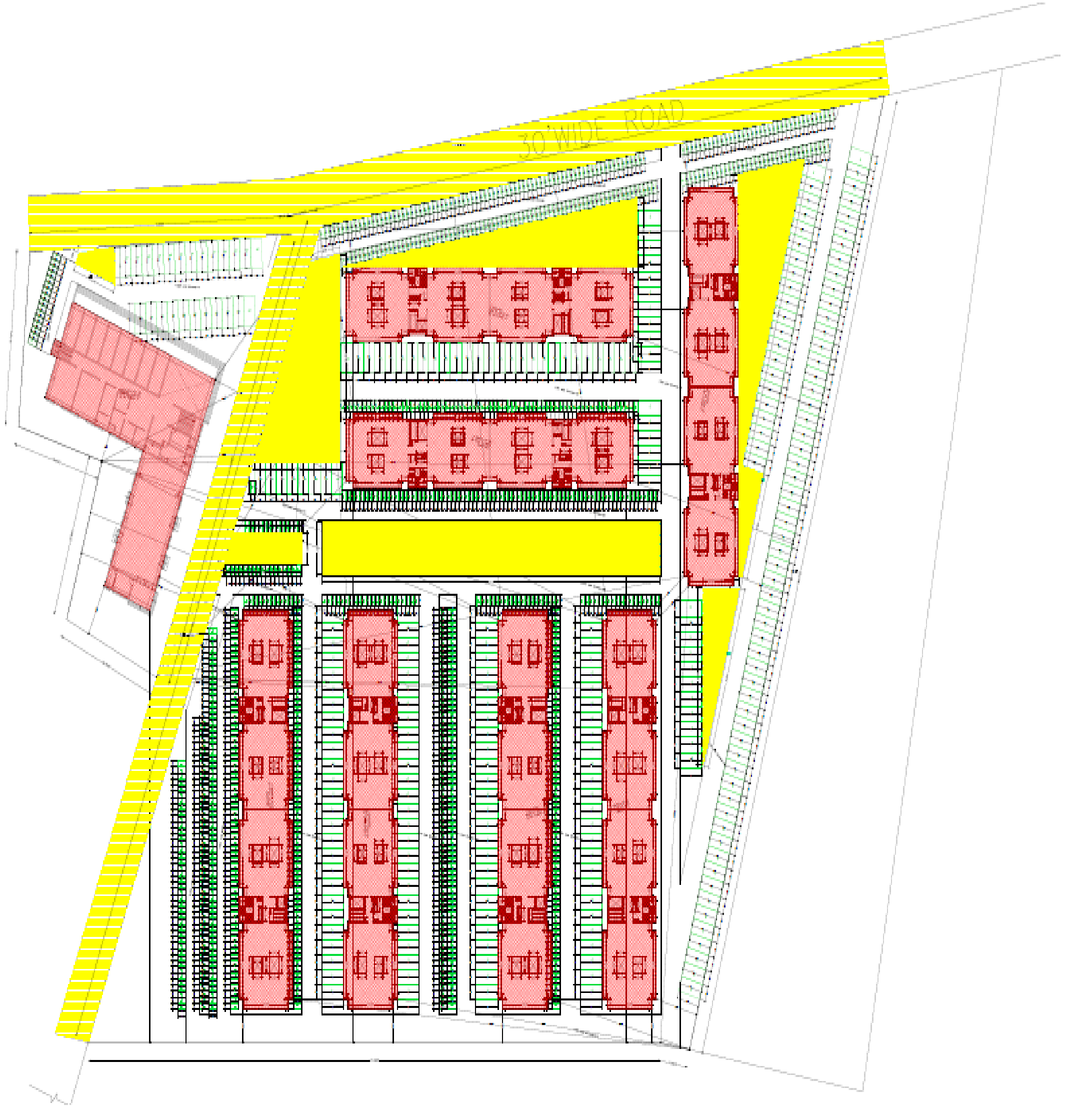
Summary of Six Light House Projects (LHPs)

LHP Location			Chennai (Tamil Nadu)	Rajkot (Gujarat)	Indore (Madhya Pradesh)	Ranchi (Jharkhand)	Agartala (Tripura)	Lucknow (Uttar Pradesh)
Sl. No.	Particulars	Units						
1	Name of Technology	Name	Precast Concrete Construction System-Precast Components	Monolithic Concrete Construction using Tunnel Formwork	Prefabricated Sandwich Panel System	Precast Concrete Construction System – 3D Volumetric	Light Gauge Steel Frame System (LGSF) with Pre-Engineered Steel Structural System	Stay in Place Formwork System
2	No. of Houses	No.	1,152	1,144	1,024	1,008	1,000	1,040
3	No. of Floors	No.	G+5	S+13	S+8	G+8	G+6	S+13
4	Plot Area	Sqm	33,596	39,599	41,920	31,160	24,000	20,000
5	Per House Carpet Area	Sqm	26.58	39.77	29.04	29.85	30.00	34.50
6	Project Cost	INR (in Cr)	116.27	118.90	128.00	134.00	162.50	130.90
7	Per House cost (with infrastructure)	INR (in Lakh)	10.09	10.39	12.50	13.29	16.25	12.58

- There are 7 blocks in Ground + 8 configuration with 1008 houses along with basic and social infrastructure.
- Ground coverage of the project is 29.3% and FAR is 2.21.
- Green space is 20%.

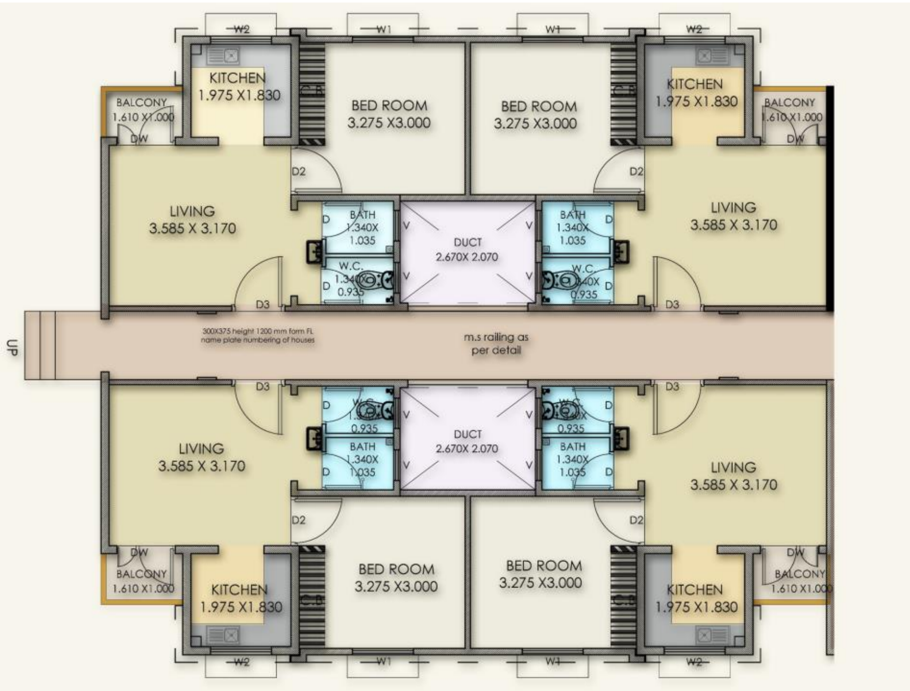


Typical floor plan



16 dwelling units at each floor of building block with provision of lifts and staircases.

Typical Dwelling Unit plan



Each dwelling unit consists of one hall, one bed room, a kitchen, WC, Bath and a balcony. The carpet area of each unit is 29.85 Sq.mt. The sizes of individual rooms & service areas conform to NBC norms.

Other special features:

- Green rating as per GRIHA
- Use of renewable resources:
  - Rain water harvesting
  - Solar lighting
- Solid waste management
- STP with recycling of waste water
- Fire Fighting System conforming to NBC

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Conventional Construction Systems

The prevalent construction systems in India are:

Load bearing Structure

In this system, walls are constructed using bricks/stone/block masonry and floor/roof slabs are of RCC/stone/composite or truss. It is cast in-situ system and called load bearing system as load of structure is transferred to foundation and then to ground through walls.

RCC Framed Structure

In this cast in-situ system, the skeleton of a structure is of RCC column and beam with RCC slab. The infill walls can be of bricks/blocks/stone /panels. The load of the structure is transferred through beam and column to the foundation.

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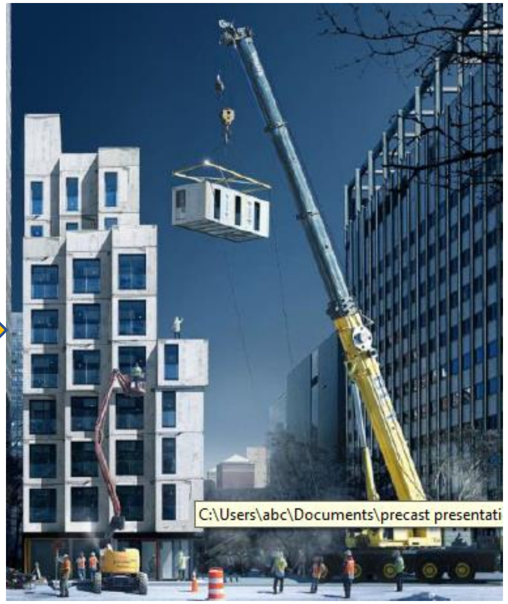
Prevalent Construction Systems

Technology being Used

Load bearing Structure

RCC Framed Structure

Precast Concrete Construction - 3D Volumetric



It is the modern method of building by which precast concrete structural modules like room, toilet, kitchen, bathroom, stairs etc. & any combination of these are cast monolithically in Plant or Casting yard in a controlled condition.

These Modules transported, erected & installed using cranes and are integrated together in the form of complete building unit.

Conventional Construction Systems	Alternate Construction Systems
Slow	**Fast**
Maximum Use of Natural Resources	**Optimum use of Resources**
Waste Generation	**Minimum Waste**
Air/Land/Water Pollution	**Minimum Pollution**
Labor Intensive	**Industrialized System**
Prescriptive Design	**Cost-effective Design**
Unhealthy Indoor Quality	**Better health & Productivity**
Regular Maintenance	**Low Life Cycle Cost**
Energy Intensive	**Energy Efficient**
Cast-in-situ Poor Quality	**Factory Made Quality Products**
High GHG Emissions	**Low GHG Emissions**
Unsustainable	**Sustainable**

MAP SHOWING SIX DIFFERENT LHP LOCATIONS

Establishment of the Cluster Cell in Ranchi, Jharkhand under Global Housing Technology Challenge-India (GHTC-India)”

Jharkhand	Bihar
Odisha	West Bengal

LHPs shall serve **as LIVE Laboratories** for different aspects of **Transfer of technologies**

Sustainable Buildings

- 30%-50% reduction in energy use
- 40% reduction in water use
- 35% reduction in GHG emission
- 75% reduction in waste

3D Precast Volumetric Construction

- Replacing cast in situ RCC structural frame with factory made structural components – 3D

- Customized factory-made volumetric construction i.e. the entire module (room)

LHP-RANCHI (Precast Concrete Construction System – 3D Volumetric)

Advantages

- Upto 90% of the building work including finishing is complete in plant/casting yard leading to significant reduction in construction & occupancy time
- The controlled factory environment brings resource optimization, improved quality, precision & finish
- The required concrete can be designed using industrial by-products such as Fly Ash, Ground granulated blast furnace slag (GGBS), Micro silica etc. resulting in improved workability & durability, while also conserving natural resources. In this project Ground granulated blast furnace slag & silica fume is proposed in concrete.
- With smooth surface it eliminates use of plaster
- The monolithic casting of walls & floor of a building module reduces the chances of leakage
- The system has minimal material wastage (saving in material cost), helps in keeping neat & clean construction site and dust free environment
- Use of optimum quantity of water through recycling
- Use of shuttering & scaffolding materials is minimal
- All weather construction & better site organization

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Light House Project (LHP) at Chennai, Tamil Nadu

(Technology: Precast Concrete Construction System-Precast Components)

2

No. of Dwelling Units : 1152 Nos. (G+5)
No. of Block / Tower : 12 Blocks
Units in each Block / Tower : 96 Nos.

2D Precast Concrete Construction

- Replacing cast in situ RCC structural frame with factory made structural components – 2D planar elements
- Customized Factory-made beams, columns, wall panels, slab/floors, staircases etc.

Concrete components prefabricated in precast yard or site and installed in the building during construction

LHP-CHENNAI (Precast Concrete Construction System-Precast Components Assembled at Site)

Advantages

- Quality of construction is enhanced significantly due to pre-casting of components by using sophisticated moulds and machineries in factory like environment, assured curing, assured specified cover to reinforcement, proper compaction of concrete results in to dense and impermeable concrete etc. Thus lesser maintenance cost during lifetime of project.

- Inbuilt eco-friendly method of construction in terms of more off-site works in controlled factory like environment results in to significant reduction in wastage of water, natural resources, air pollution and noise pollution.

- Safety of workforce achieved automatically as most of the works are carried out at ground floor in factory like environment, which ultimately enhances the work efficiency and quality.

- Wooden shuttering material is completely avoided and wastage of other construction materials reduced significantly; which results in to conservation of scarce natural resources like soil, sand, aggregate, wood etc.

- Advance procurement of major construction materials, advance pre-casting of structural components and assured completion of work within stipulated completion period will save cost towards escalation & early returns on investments, thus Substantial cost benefit to the client.

Light House Project (LHP) at Agartala, Tripura

(Technology: Light Gauge Steel Structural System & Pre-Engineered Steel Structural System)

No. of Dwelling Units : 1000 Nos. (G+6)
No. of Block / Tower : 7 Blocks
Units in each Block / Tower : A(112), B(154), C(118), D(168), E(168), F(168) & G(112)

PRE-ENGINEERED STEEL STRUCTURAL SYSTEM

- Replacing cast in situ RCC structural frame with factory made steel (hot rolled) structural system

Steel skeleton with Aerocon panel infills

LIGHT GAUGE STEEL STRUCTURAL SYSTEMS

- Replacing cast in situ RCC structural frame with factory made light gauge steel (cold rolled) structural system

LHP-AGARTALA (Light Gauge Steel Structural System & Pre-engineered Steel Structural System)

Advantages

- Due to light weight, significant reduction in design earthquake forces is achieved. Making it safer compared to other structures.
- Fully integrated computerised manufacturing of LGSF sections provide very high precision & accuracy.
- Speedier
- Structure being light, does not require heavy foundation
- Structural elements can be transported to any place including hilly areas/ remote places easily
- Structure can be shifted from one location to other with minimum wastage of materials.
- Steel used can be recycled multiple times
- The system is very useful for post disaster rehabilitation work.

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Light House Project (LHP) at Indore, M.P.

4

(Technology: Prefabricated Sandwich Panel System & Pre-Engineered Steel Structural System)

No. of Dwelling Units : 1024 Nos. (S+8)
No. of Block / Tower : 8 Blocks
Units in each Block / Tower : 128 Nos.

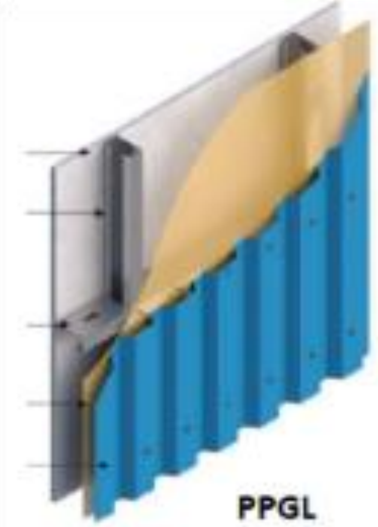
PREFABRICATED SANDWICH PANEL SYSTEMS

- EPS Core Panel Systems
- Other Sandwich Panel Systems
  - Fibre cement board
  - MgO Board
  - AAC panels

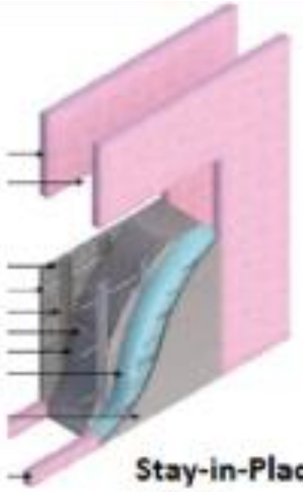
Reinforced EPS Core

230 MM Clay Brick Wall

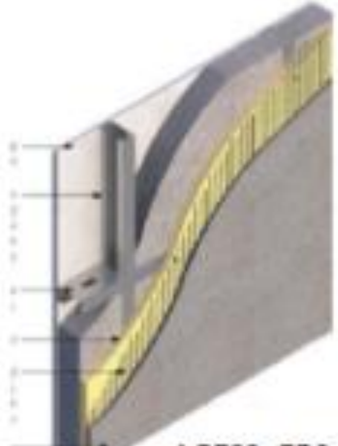
Rat Trap Bond



PPGL



Stay-in-Place Coffer



LGFSS- EPS

- **Replacing brick and mortar walls with dry customized walls made in factory**

LHP-INDORE (Prefabricated Sandwich Panel System)

Advantages

- The system is dry walling system, brings speed in construction, water conservation (no use of water for curing of walling components at site).
- The sandwich panels have light weight material as core material, which brings resource efficiency, better thermal insulation, acoustics & energy efficiency
- Being light in weight, results in lower dead load of building & foundation size.

Light House Project (LHP) at Lucknow, U.P.

5

(Technology: Stay in-place Formwork System & Pre-Engineered Steel Structural System)

No. of Dwelling Units : 1040 Nos. (S+13)
No. of Block / Tower : 4 Blocks
Units in each Block / Tower : A(494), B(130), C(208) & D(208)

Modular Tunnel form

- Tunnel formwork is a mechanized system for cellular structures. It is based on two half shells which are placed together to form a room or cell. Several cells make an apartment. With tunnel forms, walls and slab are cast in a single day.
- The formwork is set up for the day's pour in the morning. The reinforcement and services are positioned and concrete is poured in the afternoon. Once reinforcement is placed, concrete for walls and Slabs shall be poured in one single operation. The formwork is stripped the early morning and positioned for the subsequent phase.
- Here the walls and slabs are cast in a form of a tunnel leaving two sides open whereas in monolithic concrete construction the entire room is cast in a single pour..

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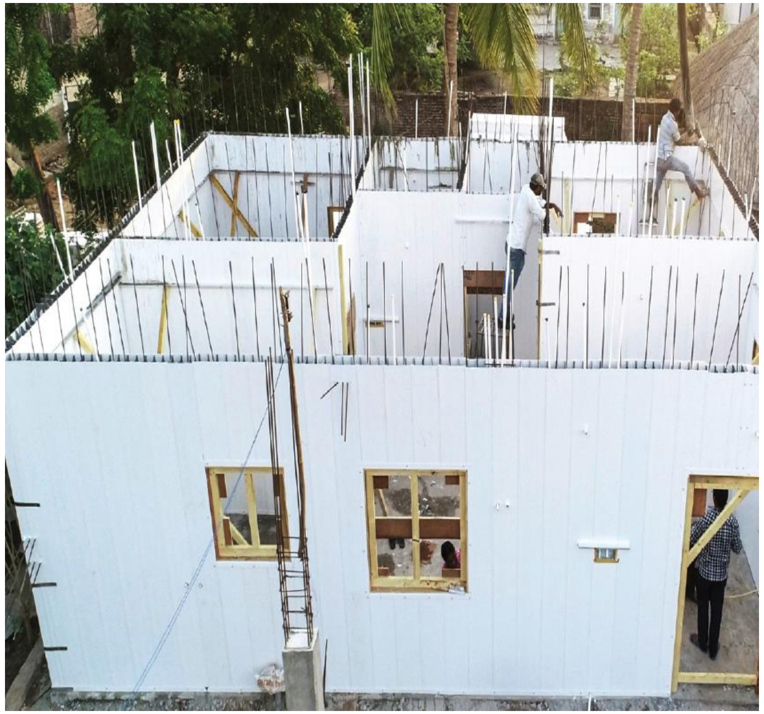
STAY-IN-PLACE FORMWORK SYSTEM

- Replacing cast-in-situ Formwork with factory made formwork systems
- It is sacrificial formwork or lost formwork means formwork is left in the structural system to later act as insulation or reinforcement cage

Stay-In-Place PVC Wall Forms

- This is a prefinished wall formwork from M/s Novel Assembler Pvt. Ltd. comprising of rigid Poly-Vinyl Chloride (PVC) based polymer components that serve as a permanent stay-in-place durable finished form-work for concrete walls.

- The extruded components slide and interlock together to create continuous formwork with the two faces of the wall connected together by continuous web members forming hollow rectangular components. The web members are punched with oval-shaped cores to allow easy flow of the poured concrete between the components.
- The hollow Novel Wall components are erected and filled with concrete, in situ, to provide a monolithic concrete wall.



LHP-LUCKNOW (Stay in Place PVC formwork System)

Advantages

- Having formwork already as part of system, the construction of building is faster as compared to conventional buildings. The formwork needs some support only for alignment purpose.
- The formwork consists of rigid PVC components, which do not corrode, chip or stain & resistant to UV, bacteria, fungi etc., thus ensuring long life of the structure.
- The polymer content used in manufacturing of formwork is up to 55% recycled content and are further recyclable, making it an eco-friendly material.
- The form work system has specific advantage for use in coastal areas as due to polymer encasement it offers higher durability.
- With concrete as filling material, the curing requirement of concrete is significantly reduced, thus saving in precious water resources.
- The formwork system does not have plastering requirement & gives a aesthetic finished surface in different color options.
- The system provides advantages in terms of structural strength, durability enhancement, weather resistance, flexural strength, thermal insulation and ease of construction.

Light House Project (LHP) at Rajkot, Gujarat

(Technology: Monolithic Concrete Construction System)

6

No. of Dwelling Units : 1144 Nos. (S+13)
No. of Block / Tower : 11 Blocks
Units in each Block / Tower : 104 Nos.

MONOLITHIC CONCRETE CONSTRUCTION

- Replacing cast-in-situ Formwork with factory made customized formwork systems
- Formwork material is Aluminium / composites / steel having 100 to 500 repetitions
- Assembly line construction i.e. placing the formwork, pouring the concrete, moving the formwork to upper level

LHP-RAJKOT (Monolithic Concrete Construction using Tunnel Formwork)

Advantages

- Facilitates rapid construction of multiple/ mass modular units (similar units)
- Results in durable structure with low maintenance requirement
- The precise finishing can be ensured with no plastering requirement
- The concrete can use industrial by-products such as Fly Ash, Ground granulated blast furnace slag (GGBFS), Micro silica etc. resulting in improved workability & durability, while also conserving natural resource
- Being Box type structure, highly suitable against horizontal forces (earthquake, cyclone etc.)
- The large number of modular units bring economy in construction.

03-B

Light House Project at RANCHI

Construction Sequence

• Sub-Structure:	Foundation
• Super-structure:	Structural System comprising of 3D modules, walling panels & solid core pre-stressed slab
• MEP:	Plumbing & Electrical
• Finishing	

Construction Sequence

Construction sequence in the project;

- Making the designed foundation of the building ready, while manufacturing of precast concrete structural modules are taking place at the factory.
- Factory finished building units/modules are installed at the site with the help of tower cranes.
- Gable end walls are positioned to terminate the sides of building.
- Pre stressed slabs are installed as flooring elements.
- Rebar mesh is finally placed for structural screed thereby connecting all the elements together. Consecutive floors are built in similar manner to complete the structure.

Structural Elements

- Foundation

- Structural System comprising of 3D modules, walling panels & solid core pre-stressed slab

https://www.youtube.com/watch?v=5im2EeF_C1A&t=90s

Structural Elements

Foundation

- Conventional as per geo-technical investigations, bearing capacity, soil strata, water table, etc.
- Raft foundation with RCC shear wall upto plinth level.
- Grade slab at plinth level.

Manufacturing of structural modules

- 3D Steel Moulds are created as suiting to various sizes of Building units (Pods).
- High strength steel as per the structural design is placed inside 3D moulds.
- Electrical and plumbing lines are set up. Block outs for doors and windows are also set up at the same time.
- The pods are cast into their final shape using high-performance concrete.
- Strict quality checks are taken for each pod before they are transported for erection and assembly at the site.


ENDEAVOUR
20 T.
DANGER


CAM 8)22 04:50:19 PM

Essential requirements

- Space for casting yard is required in addition to site for actual construction. The project is not viable if the factory is located far away. Setting up of casting yard requires time in month/(s) depending on project size & delivery schedule
- Approach road to site for movement of high capacity trailers, Cranes etc.
- Site should have space for proper leveraging & functioning of cranes
- Requires skilled labour & strict supervision
- Plumbing & electrical services need to be pre-planned

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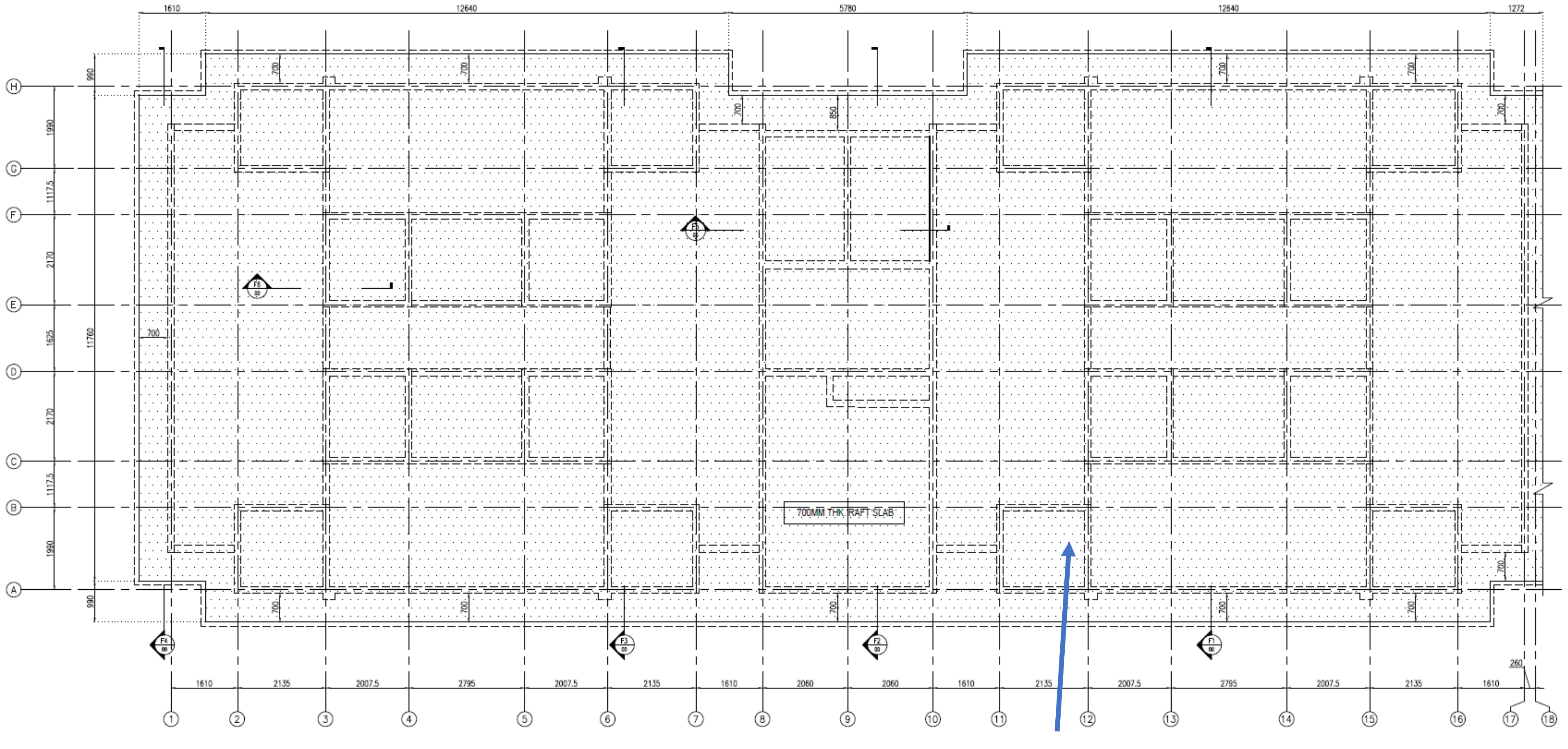
Structural Drawings



LAYOUT AT FOUNDATION LEVEL
SCALE 1:70

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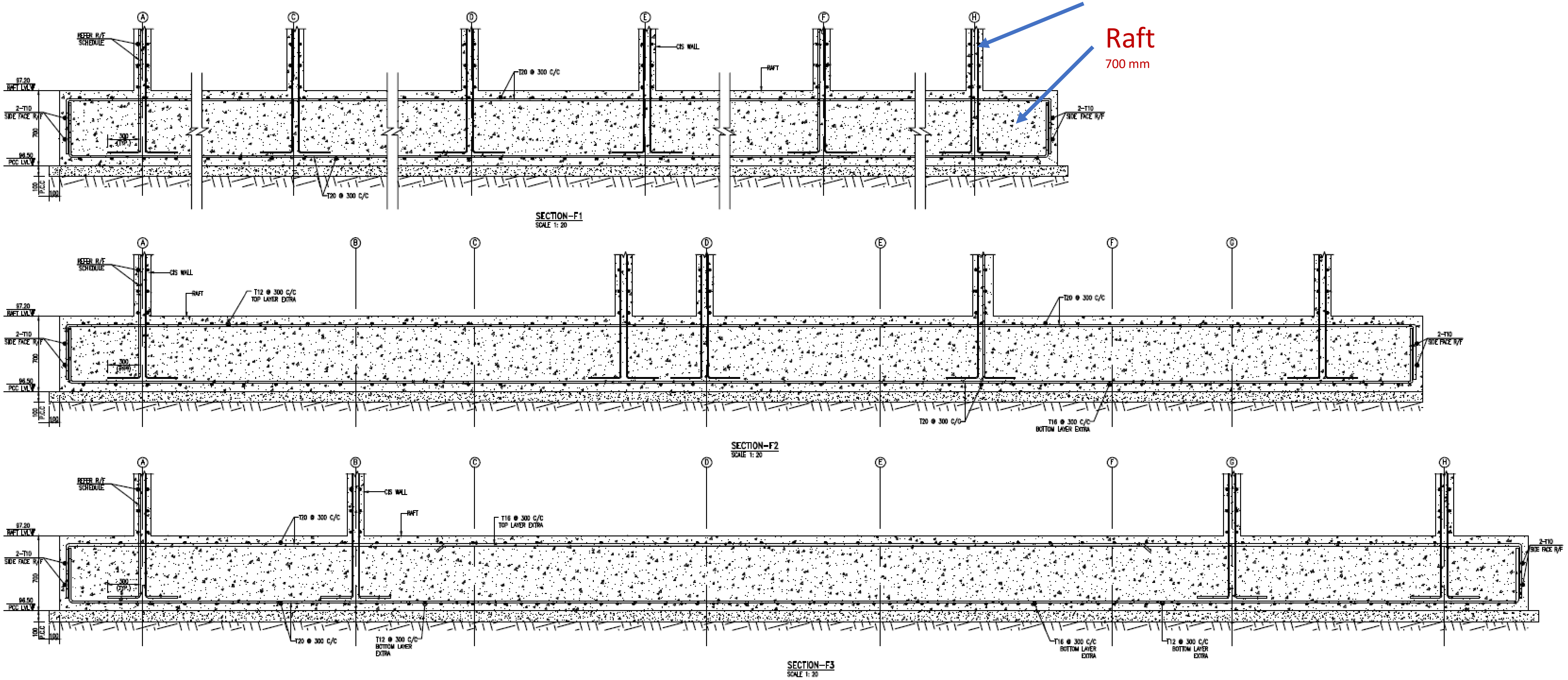
Structural Drawings

Shear Wall – 160 mm

Raft
700 mm



Concrete & Reinforcement Steel Specifications

Item	Concrete Grade
Raft foundation, Precast Shear wall, Precast Partition walls (Non-Load bearing)	M30
Precast Pre-stressed solid slab	M50
Structural Screed	M35

- Mix design for concrete and all Concrete work shall conform to IS 456-2000 & Liquid retaining structures shall conform to IS 3370:2009
- All Super structure precast walls, Reinforcement Steels are to be HYSD/TMT bars of Fe 500 as per IS 1786-2008.
- Flooring Pre-stressed solid slabs: fpu = 1860 N/mm^2
- Structural Screed: Fe 500 of wire mesh

Concrete mix design

Cement Name	Conc. Grade	Water (kg)	Cement (kg)	W/C Ratio	Fly Ash (kg)	Coarse Aggregate (kg)		ADMIXTURE (kg)	YIELD (kg per cubic metre)
						10 mm	20 mm		
JK Lakshmi PSC	M-30	136	390	0.35	658	644	644	1.56	2473

28 days Target Strength: M30 38.25 Mpa

Design Slump range for the above mix: 100 mm

Portland slag cement has been used in the design mix of the Concrete, making the concrete **green and sustainable,** by conserving natural resources i.e. lime stone.

प्रधान मंत्री आवास योजना-शहरी
Pradhan Mantri Awas Yojana-Urban

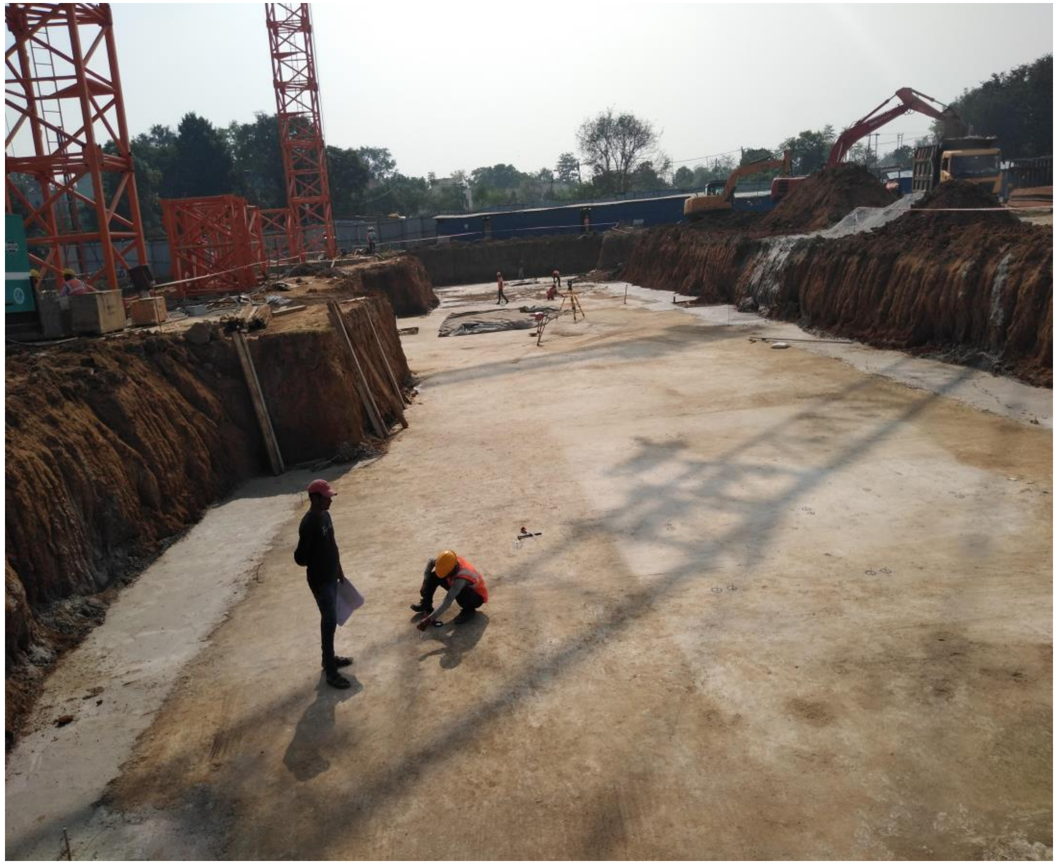
GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

Ministry of Housing and Urban Affairs
Government of India

आज़ादी का अमृत महोत्सव

Batching Plant

To bring resource efficiency, optimization of building materials and for quality control, a computerized batching plant has been established at site.



- The project starts with layout and excavation.
- After the layout at site, the excavation of each block is done using mechanical excavators up to the required depth of foundation which is 2.0 m for blocks.

- The foundation work starts with the PCC of 100 mm thickness (M10 Grade)

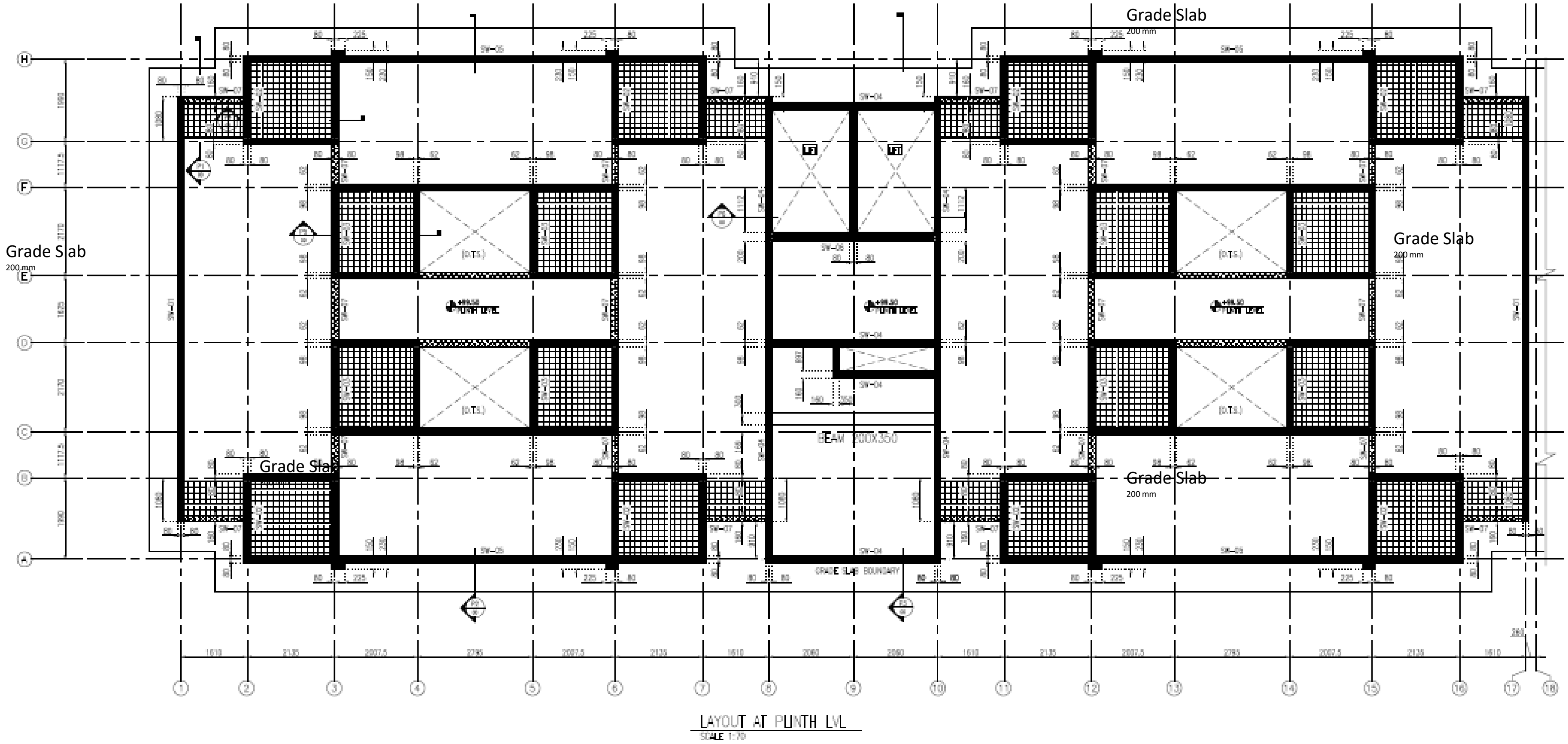
- Reinforcement and shuttering for raft foundation

- All building blocks have Raft foundation with 700 mm thick M-30 Concrete.

- Shear wall of M30 Grade Concrete are being cast upto plinth height over already laid cured raft.

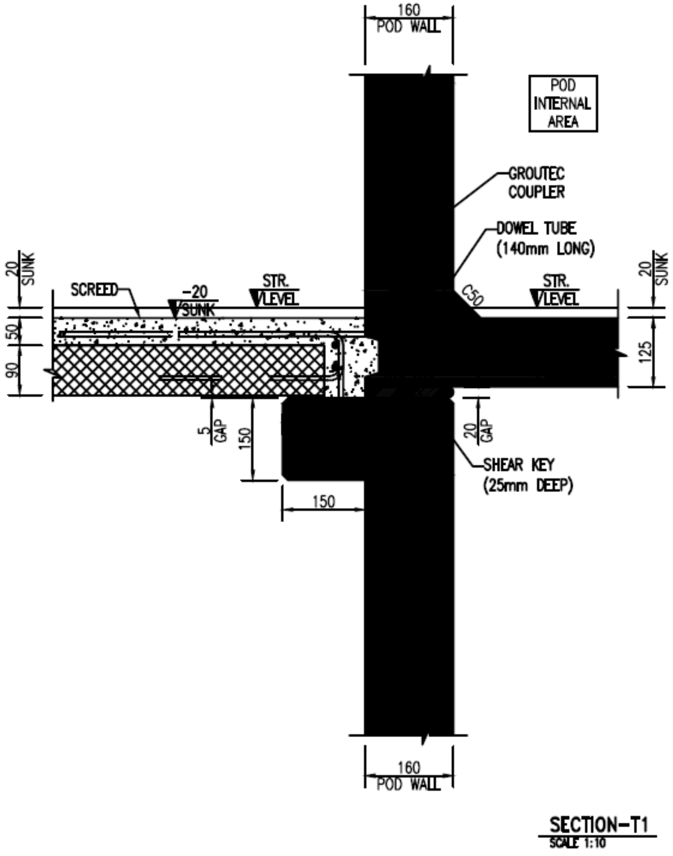
- Deshuttering from wall.

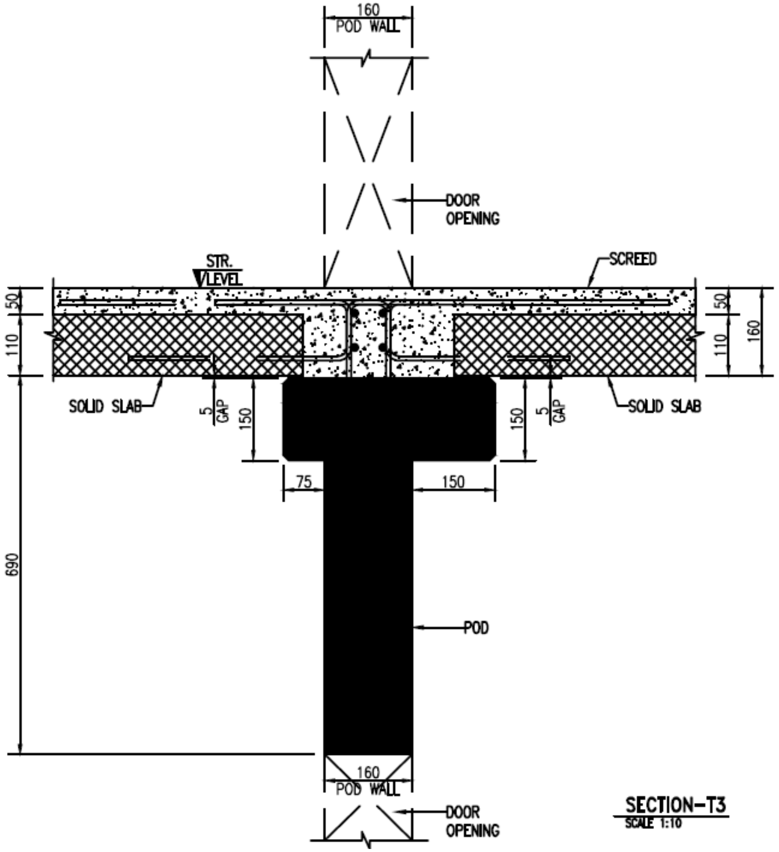
- Structural Plans and Connections

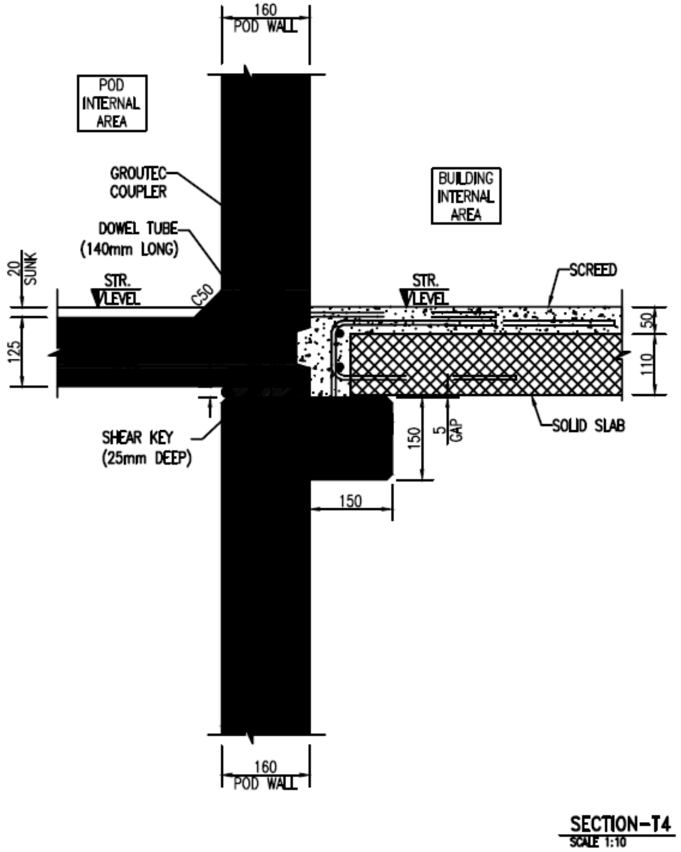


Plinth level Framing Plan

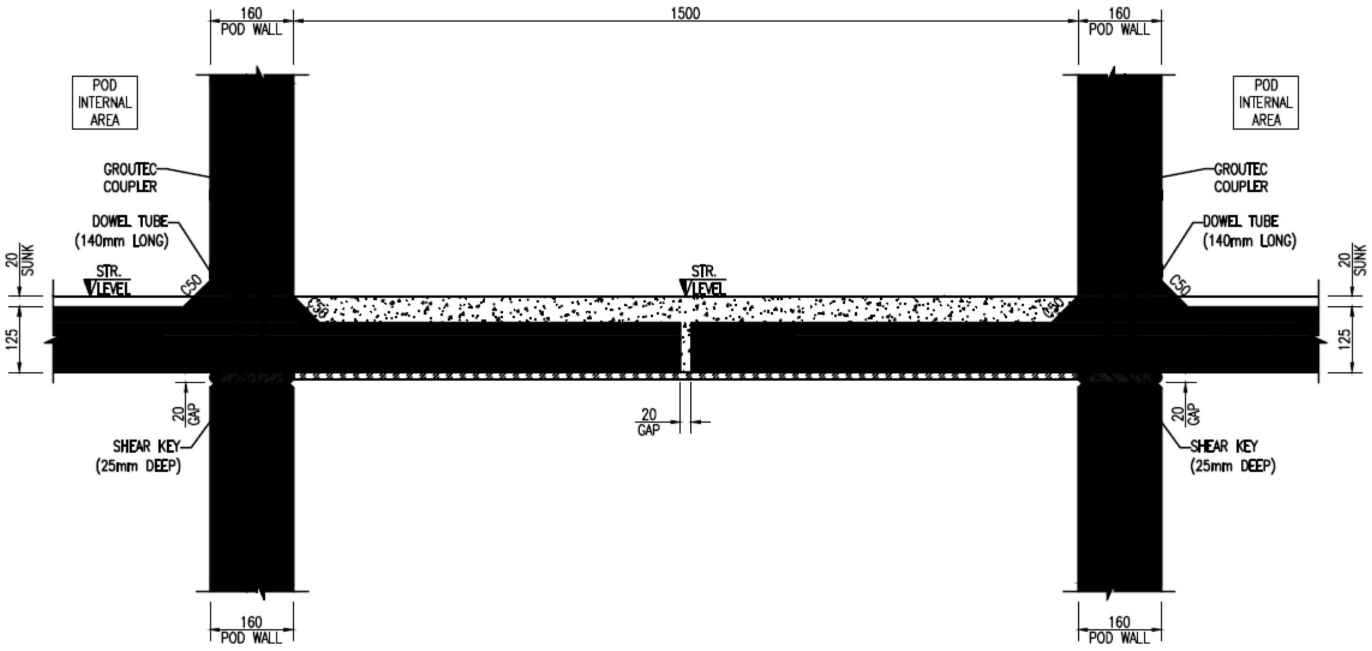
- Typical Connection Details



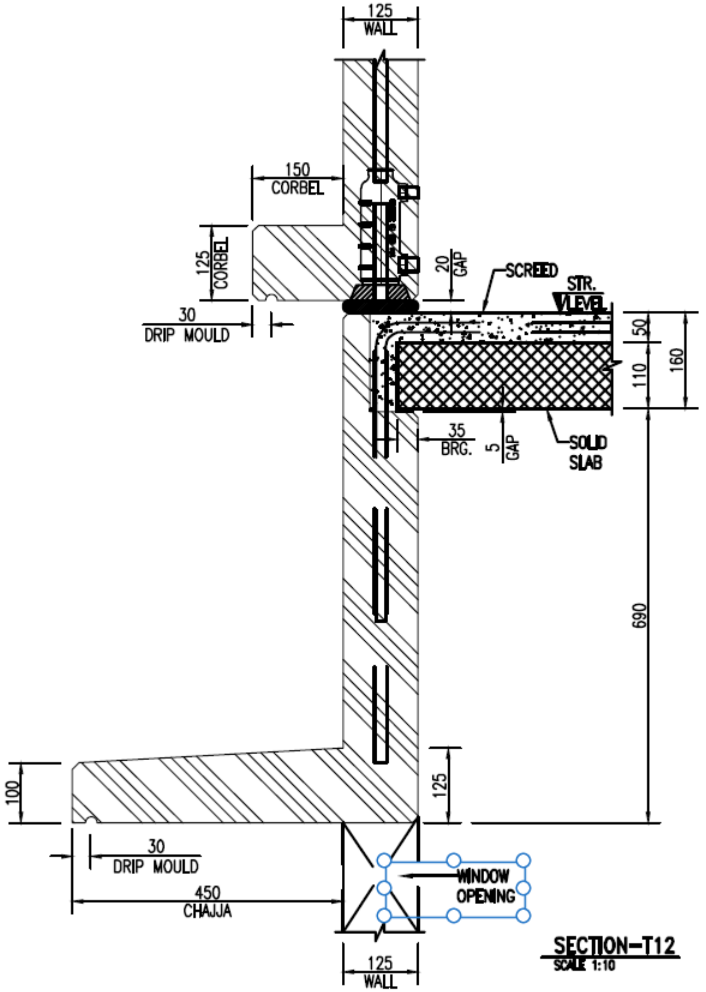




• Typical Connection Details



SECTION-T6
SCALE 1:10



SECTION-T12
SCALE 1:10

istry of Housing and Urban Affairs
Government of India

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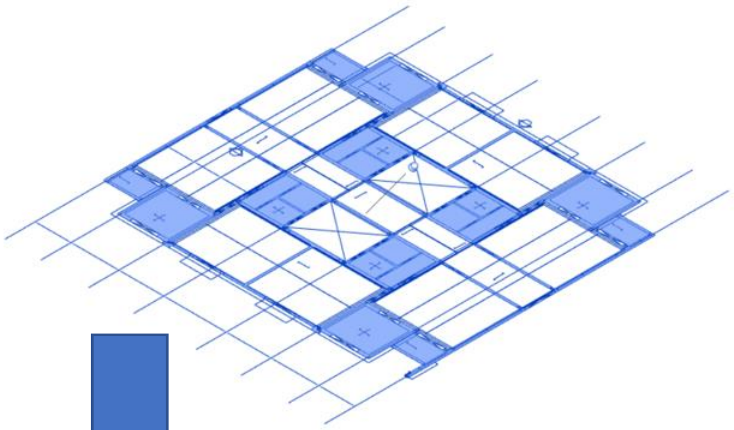
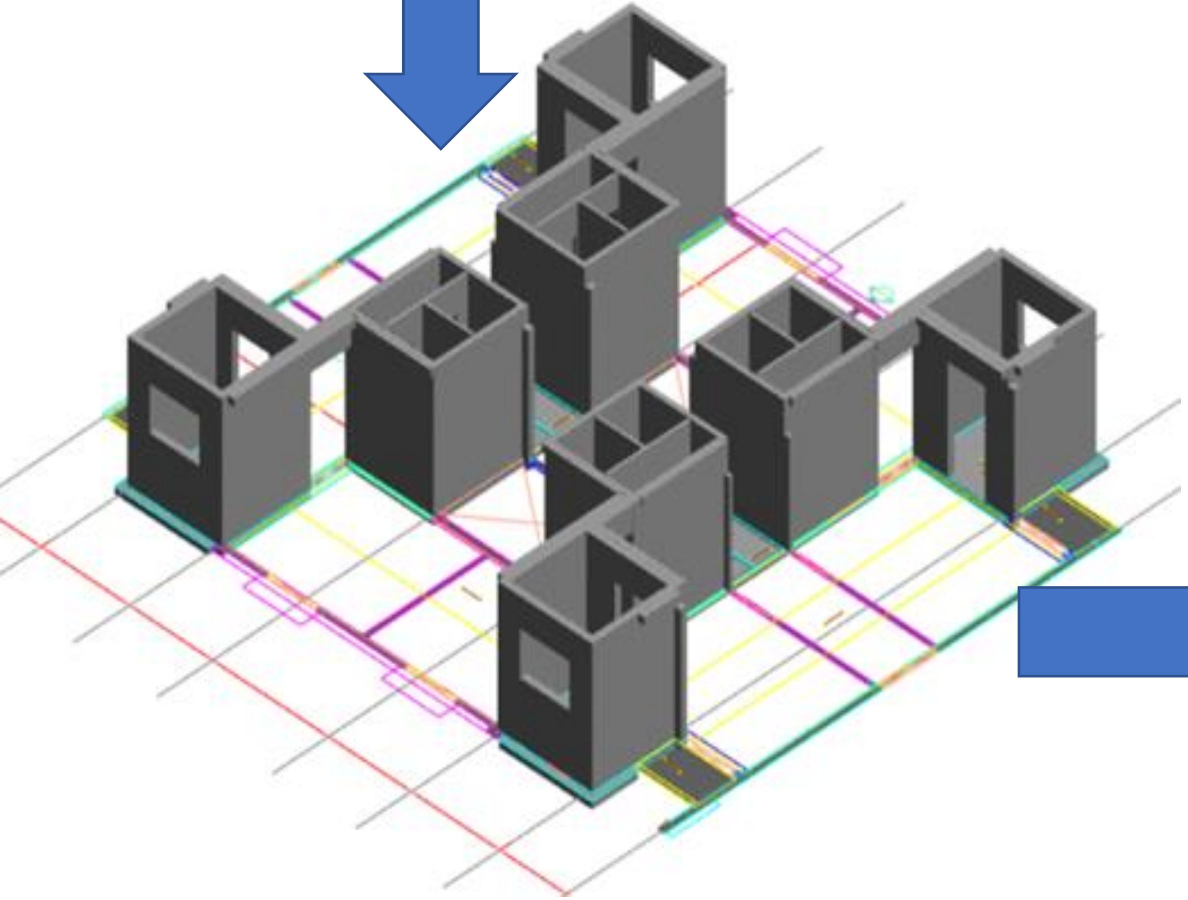
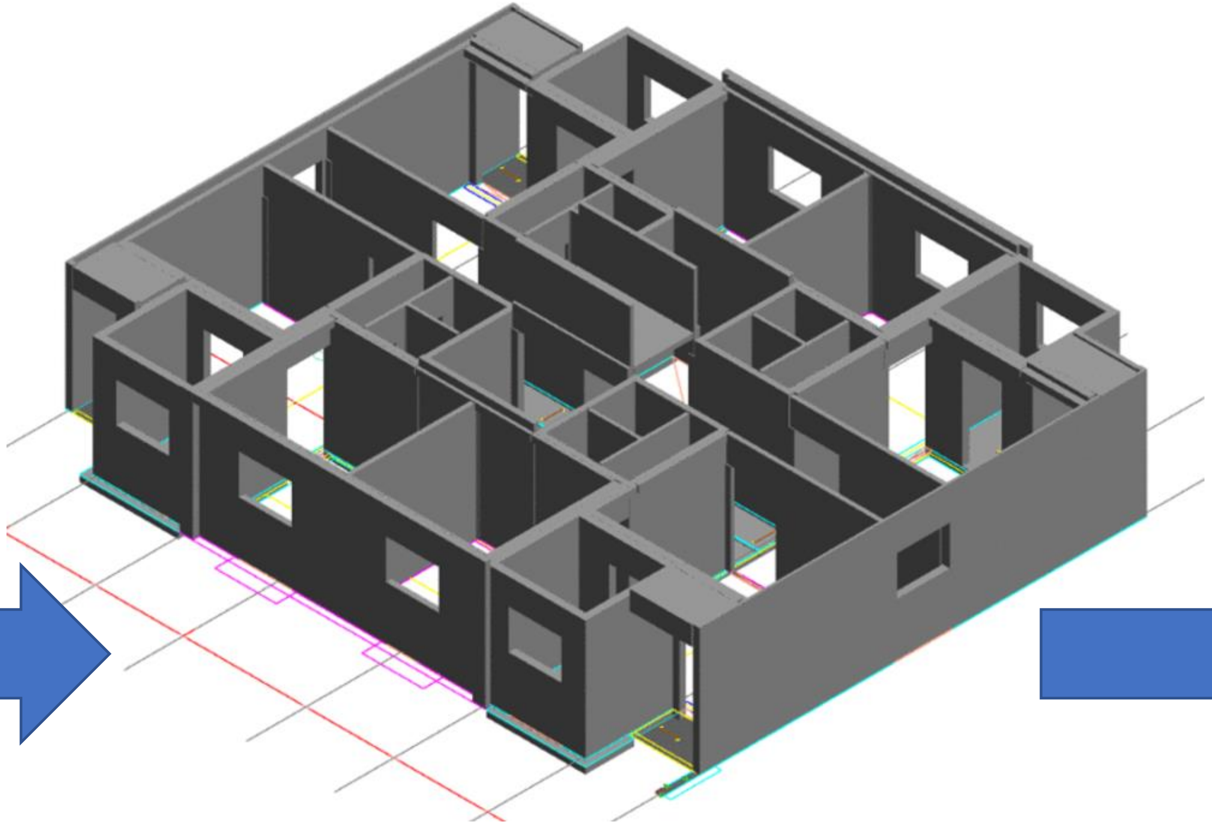
bmtpc | giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

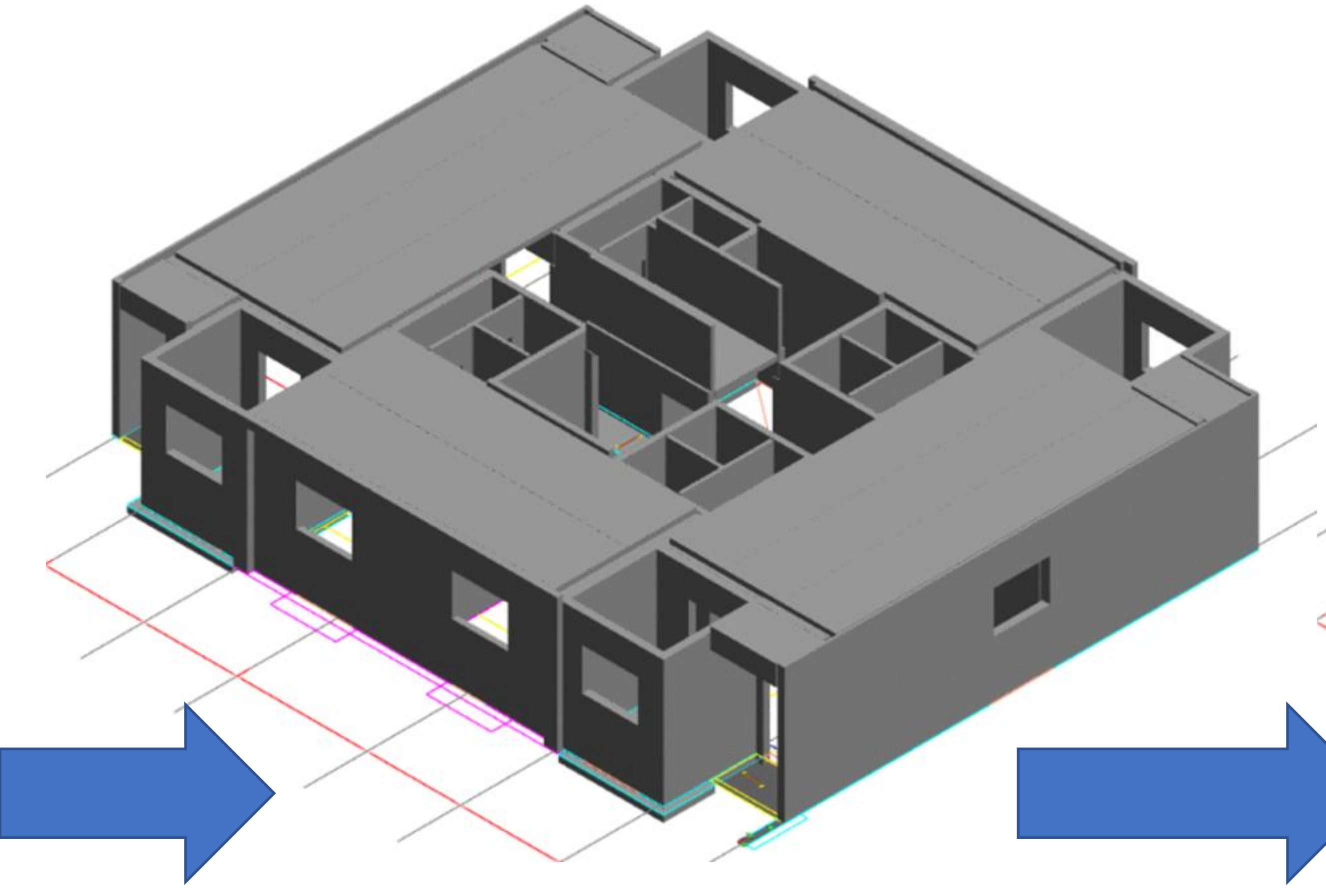
STRUCTURAL SYSTEM

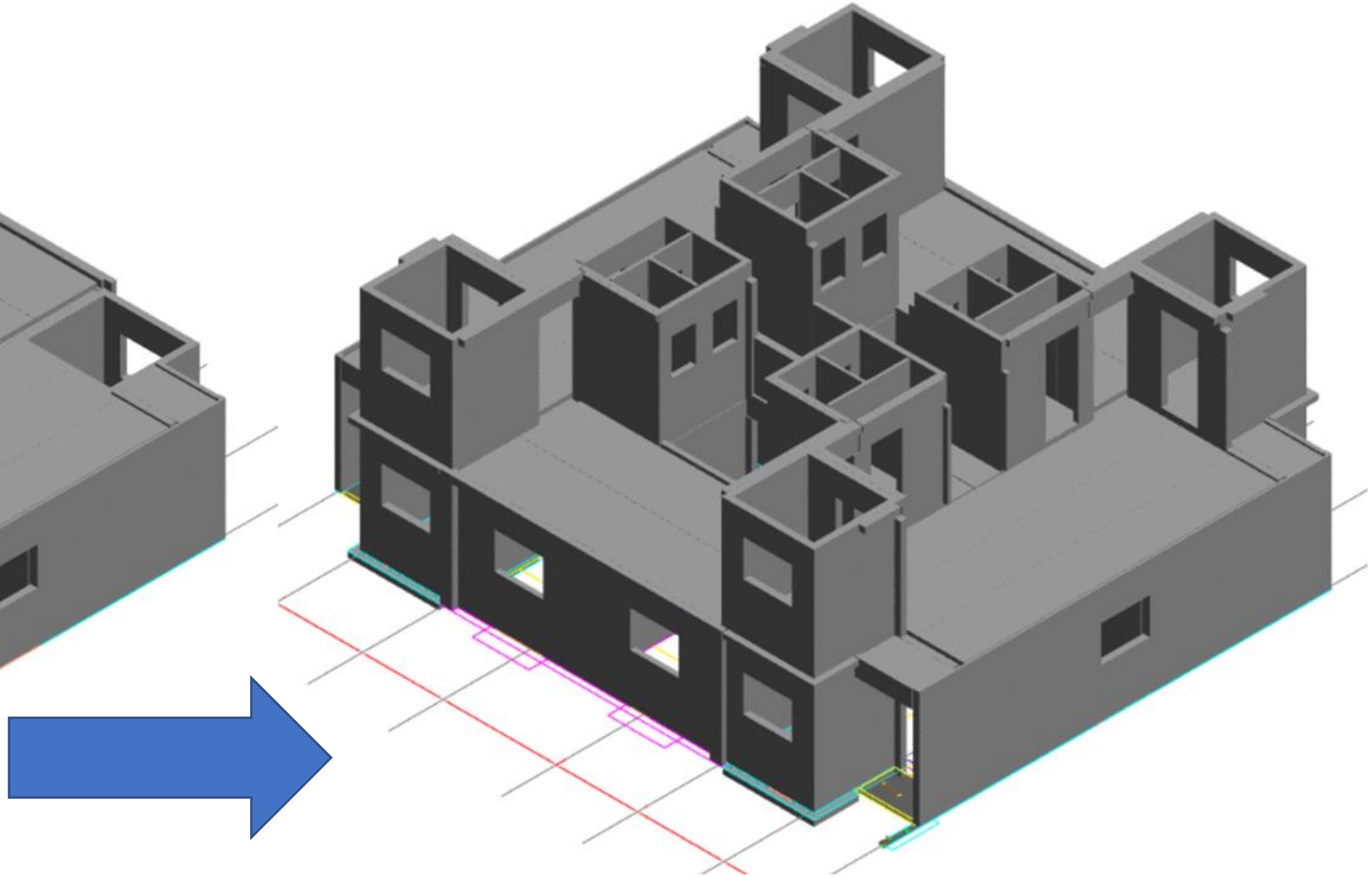




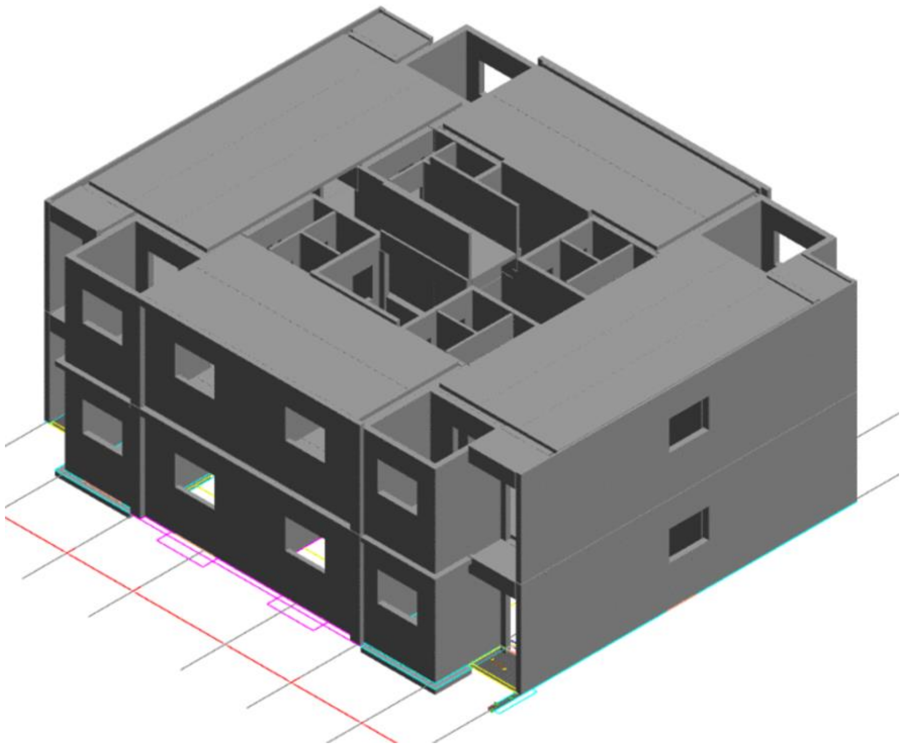


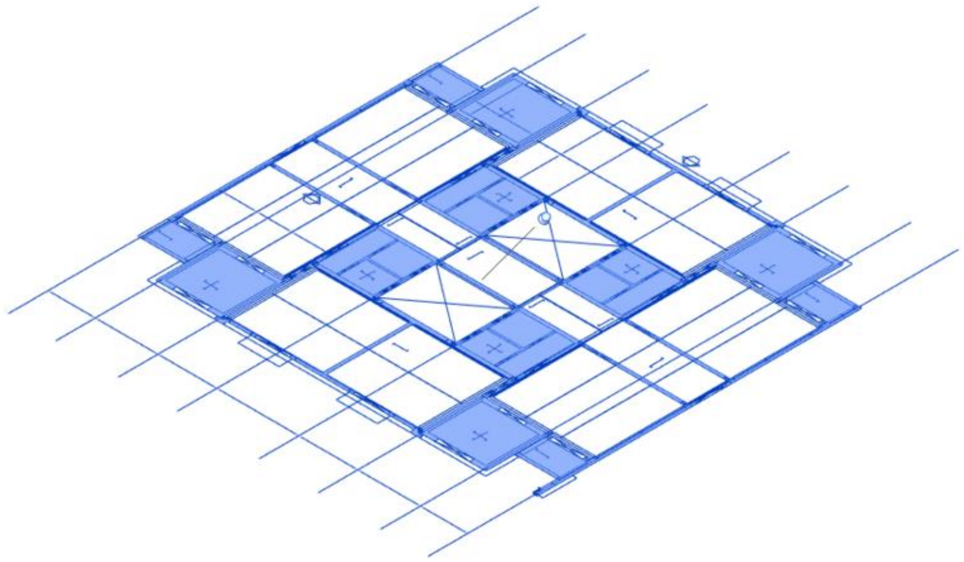
STRUCTURAL SYSTEM





STRUCTURAL SYSTEM





Animation

• Erection of Components

Erection

Erection

Erection

Erection

Tea Break : 10 minutes

04

GREEN BUILDINGS

What is Green Building?

- A 'green' building is a building that, in its **design, construction or operation, reduces or eliminates negative impacts**, and **can create positive impacts**, on our climate and natural environment.
- Green buildings preserve precious natural resources and improve our quality of life.

The Benefits

Environmental Benefits

- Protect Biodiversity & ecosystems
- Improve air and water quality
- Reduce Water streams
- Conserve natural resources

Economic Benefits

- Reduce operating cost
- Tax incentives and subsidies for green buildings and renewable energy concepts
- Create, expand and shape markets for green product and services
- Improve Occupant Productivity

Social Benefits

- Enhance occupant comfort & health
- Heighten aesthetic qualities
- Minimize strain on local infrastructure
- Improve overall quality of life

Green buildings & the Sustainable Development Goals

Global Housing Technology Challenge India

Ministry of Housing and Urban Affairs
Government of India

Goals of Green Buildings

Green building brings together a vast array of practices and techniques to reduce and ultimately eliminate the impacts of buildings on the environment and human health.

It often emphasizes taking advantage of renewable resources, e.g., using sunlight through passive solar, active solar, and photovoltaic techniques and using plants and trees through green roofs, rain gardens, and for reduction of rainwater run-off.

Many other techniques, such as using packed gravel or permeable concrete instead of conventional concrete or asphalt to enhance replenishment of ground water, are used as well. While the practices, or technologies, employed in green building are constantly evolving and may differ from region to region, there are fundamental principles that persist from which the method is derived:

Goals of Green Buildings

- Life Cycle Assessment (LCA)
- Setting & Structure define efficiency
- Energy Efficiency
- Water Efficiency
- Material Efficiency
- Waste Reduction

Life Cycle Assessment (LCA)

LCA can help avoid a narrow outlook on

Concerns
- Environmental
- Social
- Economic

- extraction of raw materials through materials processing
- Manufacture
- Distribution
- Use
- Repair & Maintenance
- Disposal or recycling

by assessing a full range of impacts associated with all the stages of a process from cradle-to-grave

Impacts taken into account include (among others)

- Embodied Energy
- Global Warming Potentials
- Resources Use
- Air Pollution
- Water Pollution
- Waste

Setting & Structure Design Efficiency

The foundation of any construction project is rooted in

Concept Stage

The concept stage, in fact, is one of the major steps in a project life cycle, as it has the largest impact on cost and performance. In designing environmentally optimal buildings, the objective is to minimize the total environmental impact associated with all life-cycle stages of the building project. However, building as a process is not as streamlined as an industrial process, and varies from one building to the other, never repeating itself identically

Design Stage

In addition, buildings are much more complex products, composed of a multitude of materials and components each constituting various design variables to be decided at the design stage. A variation of every design variable may affect the environment during all the building's relevant life-cycle stages.

Energy Efficiency

Green buildings often include measures to reduce energy consumption – both the embodied energy required to extract, process, transport and install building materials and operating energy to provide services such as heating and power for equipment

To reduce operating energy use, high-efficiency windows and insulation in walls, ceilings, and floors increase the efficiency of the building envelope, (the barrier between conditioned and unconditioned space). Another strategy, passive solar building design, is often implemented in low-energy homes

Designers orient windows and walls and place awnings, porches, and trees to shade windows and roofs during the summer while maximizing solar gain in the winter

In addition, effective window placement (day lighting) can provide more natural light and lessen the need for electric lighting during the day. Solar water heating further reduces energy costs.

Water Efficiency

Reducing water consumption and protecting water quality are key objectives in sustainable building. One critical issue of water consumption is that in many areas, the demands on the supplying aquifer exceed its ability to replenish itself.

To the maximum extent feasible, facilities should increase their dependence on water that is collected, used, purified, and reused on-site.

The protection and conservation of water throughout the life of a building may be accomplished by designing for dual plumbing that recycles water in toilet flushing.

Point of use water treatment and heating improves both water quality and energy efficiency while reducing the amount of water in circulation.

Waste-water may be minimized

by utilizing water conserving fixtures such as

ultra-low flush toilets

low-flow shower heads.

Bidets help eliminate the use of

toilet paper

Reducing Sewer Traffic

increasing possibilities of re-using water on-site

The use of non-sewage and greywater for on-site use such as site-irrigation will minimize demands on the local aquifer.

Material Efficiency

Building materials

typically considered to be 'green' include

lumber from forests that have been certified to a third-party forest standard, rapidly renewable plant materials like

- bamboo and straw
- insulating concrete forms
- dimension stone,
- recycled stone
- recycled metal

and other products that are

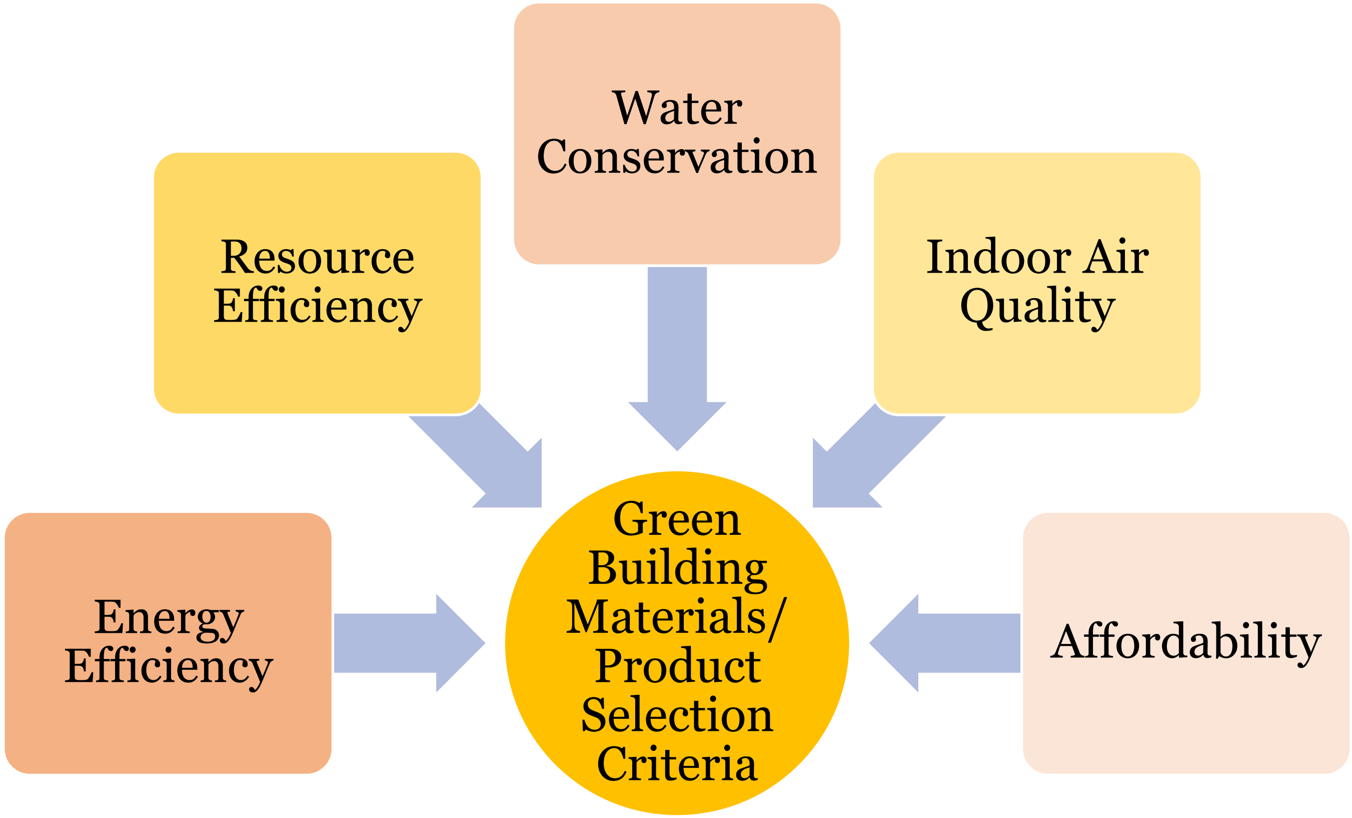
- Non Toxic
- reusable
- renewable, and/or recyclable

The EPA (Environmental Protection Agency) also suggests using recycled industrial goods, such as coal combustion products, foundry sand, and demolition debris in construction projects Building materials should be extracted and manufactured locally to the building site to minimize the energy embedded in their transportation

Where possible, building elements should be manufactured off-site and delivered to site, to maximize benefits of off-site manufacture including minimizing waste, maximizing recycling (because manufacture is in one location), high quality elements, better OHS management, less noise and dust.

Green Building Materials

Selection criteria like what is presented below was also used for the East End Project as identified in the Review of Construction Projects Using Sustainable Materials.



Green Building Materials - Resource Efficiency

Resource Efficiency

- **Recycled Content** – Products with identifiable recycled content, including postindustrial content with a preference for post consumer content
- **Natural, plentiful or renewable** – Materials harvested from sustainably managed sources and preferably have an independent certification (e.g., certified wood) and are certified by an independent third party
- **Resource efficient manufacturing process** – Products manufactured with resource-efficient processes including reducing energy consumption, minimizing waste (recycled, recyclable and or source reduced product packaging), and reducing greenhouse gases.
- **Locally Available** – Building materials, components, and systems found locally or regionally saving energy and resources in transportation to the project site.
- **Reusable or Recyclable** – Select materials that can be easily dismantled and reused or recycled at the end of their useful life.
- **Recycle or Recyclable Product packaging** – Products enclosed in recycled content or recyclable packaging.
- **Durable** – Materials that are longer lasting or are comparable to conventional products with long life expectancies

Salvaged, refurbished, or remanufactured: Includes saving a material from disposal and renovating, repairing, restoring, or generally improving the appearance, performance, quality, functionality, or value of a product

Green Building Materials - Indoor Air Quality (IAQ)

Indoor Air Quality (IAQ)

Low or non-toxic	Materials that emit few or no carcinogens, reproductive toxicants, or irritants as demonstrated by the manufacturer through appropriate testing.
Minimal Chemical Emission	Products that have minimal emissions of Volatile Organic Compounds (VOCs). Products that also maximize resource and energy efficiency while reducing chemical emissions
Low-VOC Assembly	Materials installed with minimal VOC-producing compounds, or no-VOC mechanical attachment methods and minimal hazards
Moisture Resistant	Products and systems that resist moisture or inhibit the growth of biological contaminants in buildings.
Healthfully maintained	Materials, components, and systems that require only simple, non-toxic, or low-VOC methods of cleaning
Systems or equipment	Products that promote healthy IAQ by identifying indoor air pollutants or enhancing the air quality.

Green Building Materials - Indoor Air Quality (IAQ)

Materials, components, and systems that help reduce energy consumption in buildings and facilities

Energy Efficiency can be maximized by utilizing materials and systems that meet the following criteria:

Water Conservation can be obtained by utilizing materials and systems that meet the following criteria:

Products and systems that help reduce water consumption in buildings and conserve water in landscaped areas

Affordability can be considered when building product life-cycle costs are comparable to conventional materials or, are within a project-defined percentage of the overall budget.

Green Building Materials – Three Basic Steps of Product Selection

Three Basic Steps of Product Selection

Research

This step involves gathering all technical information to be evaluated, including manufacturers' information such as Material Safety Data Sheets (MSDS), Indoor Air Quality (IAQ) test data, product warranties, source material characteristics, recycled content data, environmental statements, and durability information

In addition, this step may involve researching other environmental issues, building codes, government regulations, building industry articles, model green building product specifications, and other sources of product data. Research helps identify the full range of the project's building material options.

Evaluation

This step involves confirmation of the technical information, as well as filling in information gaps. For example, the evaluator may request product certifications from manufacturers to help sort out possible exaggerated environmental product claims.

Evaluation and assessment is relatively simple when comparing similar types of building materials using the environmental criteria, e.g., a recycled content assessment between various manufacturers of medium density fiberboard is a relatively straightforward "apples to apples" comparison

However, the evaluation process is more complex when comparing different products with the same function. Then it may become necessary to process both descriptive and quantitative forms of data.

Selection

This step often involves the use of an evaluation matrix for scoring the project-specific environmental criteria. The total score of each product evaluation will indicate the product with the highest environmental attributes. Individual criteria included in the rating system can be weighted to accommodate project-specific goals and objectives

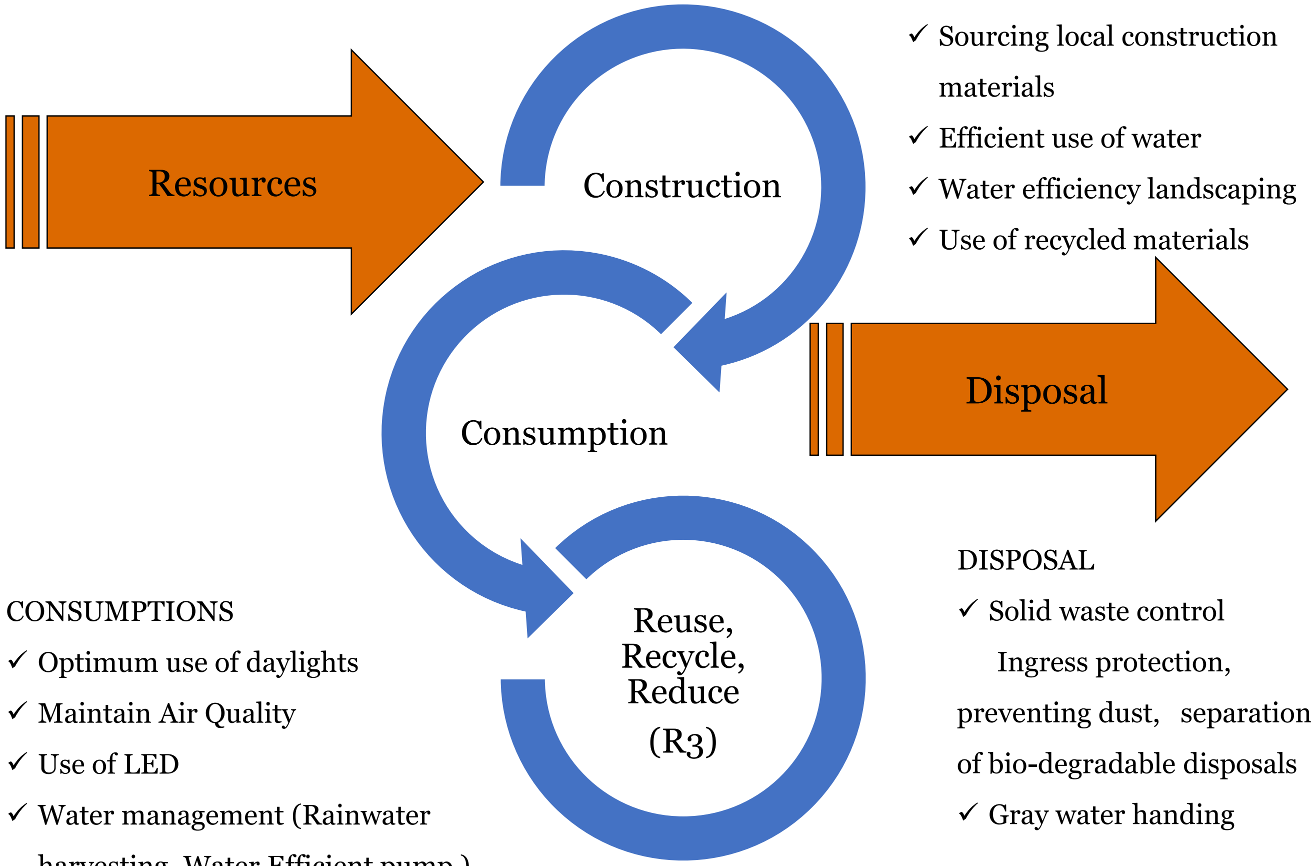
Materials are the stuff of economic life in our industrial world. They include the resource inputs and the product outputs of industrial production. How we handle them is a major determinant of real economic efficiency, and also has a major impact on our health and the health of the natural environment

Green Building Materials – Elements of Material Solutions in Building

Elements of Material Solutions in Buildings

Materials use avoidance	this includes scrutiny of consumption needs themselves—do we really need to build this?—and voluntary simplicity. It includes a focus on selling services, rather than products. It also includes the redesign of products, buildings and settlements to dispense with superfluous materials. The great efficiencies resulting from ecological urban design and mixed use development are in this category.
Increased intensity of product use	All kinds of sharing are included here, and thus there is some overlap with category #1. Cohousing developments with shared facilities, for example, can substantially reduce the volume of materials use.
Extended Product Life	Repair, reuse and remanufacturing are in this category, and in building there is vast potential for deconstruction (the disassembly of buildings) and the reuse of building materials. One step further is the design of buildings to be easily changed, repaired and disassembled.
Materials recovery or recycling	This tends to require more energy, but some form of recycling will be ultimately necessary for every material at a point in its life cycle, no matter how durable, reused, or shared it has been.

Life Cycle of Green Building



CONSTRUCTION

- ✓ Sourcing local construction materials
- ✓ Efficient use of water
- ✓ Water efficiency landscaping
- ✓ Use of recycled materials

CONSUMPTIONS

- ✓ Optimum use of daylights
- ✓ Maintain Air Quality
- ✓ Use of LED
- ✓ Water management (Rainwater harvesting, Water Efficient pump)

DISPOSAL

- ✓ Solid waste control Ingress protection, preventing dust, separation of bio-degradable disposals
- ✓ Gray water handing

GREEN RATING SYSTEMS

LEADERSHIP IN ENERGY & ENVIRONMENTAL DESIGN
LEED

GRIHA

Indian Green Building Council
Greening India since 2001

GEM
Green and Eco-friendly Movement
Care for the Mother Earth

Edge

Features that can make an Affordable building 'GREEN'

Site Planning

Energy and Occupant Comfort

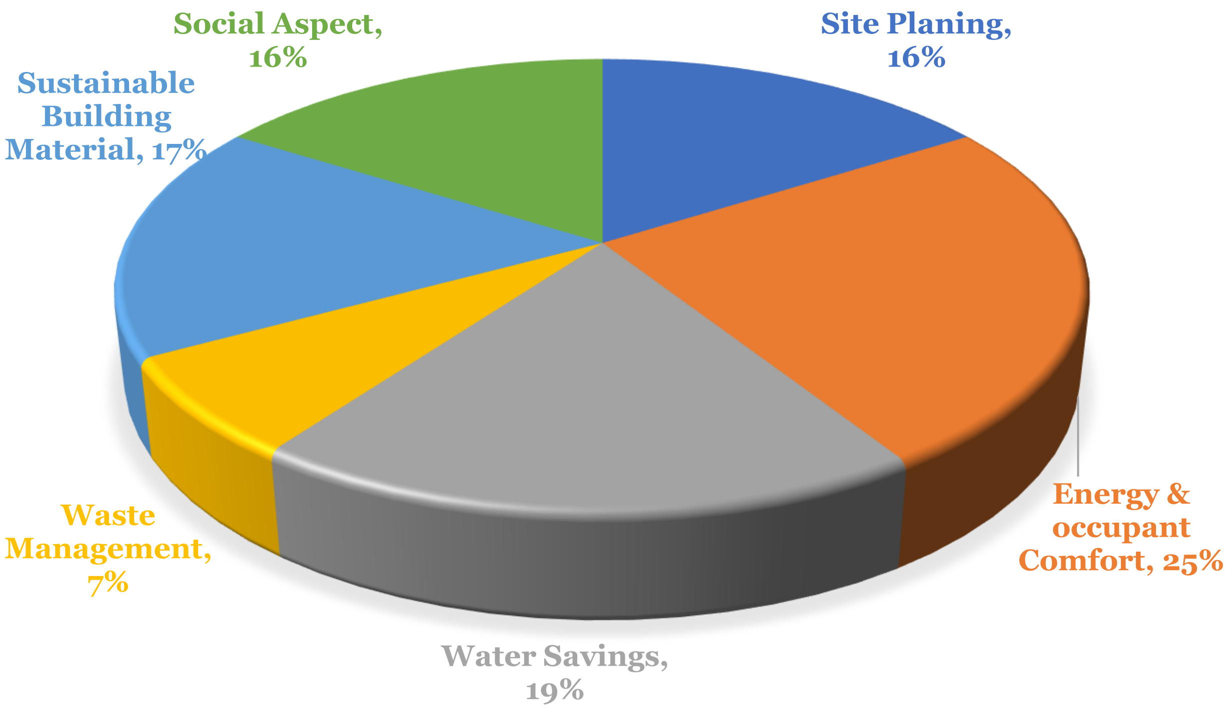
Water Saving

Waste Manageme
nt

Sustainable Building Material

Social Aspect

GRIHA Rating System: AFFORDABLE HOUSING



POINT WEIGHTAGES

Rating Thresholds	Rating
86 and above	5 Star
71-85	4 Star
56-70	3 Star
41-55	2 Star
25-40	1 Star

Site Planning

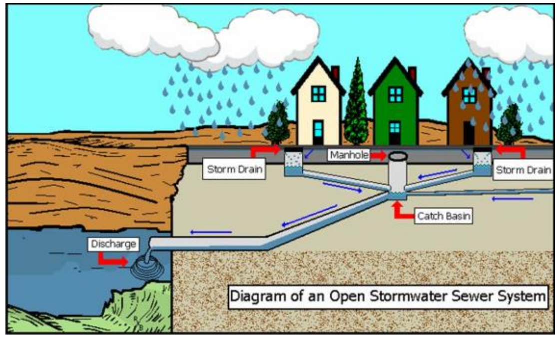
Climate Type	Passive Design Strategies
	Solar Chimney/ Wind Tower
	Courtyards
	Roof Pond for Evaporative Cooling
	Reduce Solar Access
	Building/ Site planning to increase cross ventilation (layout of windows in the rooms and building for wind flow)
	Cavity Walls/ Thermal mass to reduce heat gain/loss
	Dense vegetarian cover to moderate micro-climate
	Design accordingly site slope
	Light Shelves
	Internal distribution of spaces to be carried out such that buffer spaces like store rooms, staircases , toilets etc are located on the eastern and western facades
	Cool roofs in the form of vegetated roof/ terrace gardens/ roof ponds

Site Planning

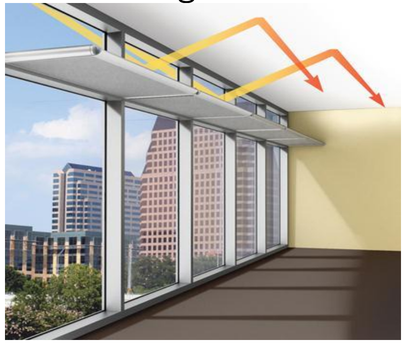
Vegetated Roof

SRI Coating

Grass pavers (https://greenroutesolutions.com/)



Strom water management (https://www.thewatertreatments.com)



Light Shelves (https://www.designingbuildings.co.uk/)

Mosaic tiles (https://www.dreamstime.com/

Design to mitigate -UHIE

- SRI Coating, Grass pavers

Landscape preservation

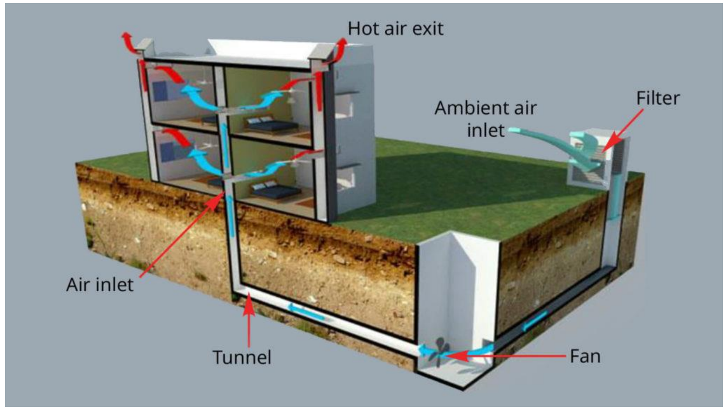
- Protection mature trees

Strom Water management

Reduction in air and soil pollution

Energy & Occupant Comfort

Envelope Thermal Performance	• Peak Heat Gai Factor (W/Sq.m) • Peak Cooling Load (W/Sq.m)
Occupants visual comfort (Daylight)	• UDI • Daylight Extent factor as per ECBC
Efficient Lighting	• Minimum luminous efficacy 75 lumen/Watt • **100% outdoor lighting**
Energy Efficient Equipments	• At least BEE 3 Star Motor & Transformers
Renewable Energy	• 1kWp per 500 sq.m
Energy Metering	• **Dedicated energy meter in each DUs**



Earth Air System
https:/

BEE Star ratings

Water Savings

Efficient use of water during construction	• Gunny Bag/hessian cloth and ponding for curing • Additives • Use of treated wastewater/ captured rainwater
Optimizing the Building & Landscape water demand	• **20% reduction w.r.t base case** • Reduce the total landscape water requirement(Sprinkler Irrigation, Drip irrigation)
Water Reuse	• Sewage Treatment Plant • Reuse of treated and rain water
Water Metering	• **Installation of the water meter** • Sub-water meter in each DUs

GUNNY Bags (https://blog.fabricuk.c

Water meter (https://www.nobroker.in/)

Sprinkler

Waste Management

Construction Waste Management

- Waste management plan as per 'Construction and Demolition Waste Management Rules, 2016

Post Construction Waste Management

- Compliance with Solid Waste Management Rules, 2016
- Collection & Segregation (multi-coloured bins)
- Safe & hygienic storage
- Safe recycling
- Treating organic waste (biogas/manure) (>100kg/day)

https://www.nbmcw.com/

150 million tonnes of construction and demolition (C&D) waste every year. (2019) Recycling capacity is a about 6,500 tonnes per day (TPD) -- just about 1 per cent.*

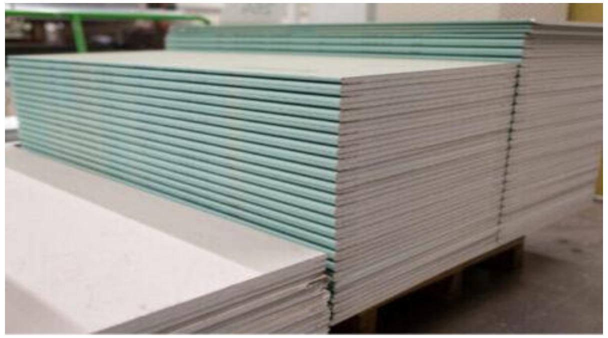
*https://www.cseindia.org/

Sustainable Building Materials

Reduction in environmental impact of construction (Building Structure)	• Use of BIS recommended waste materials (OPC, aggregate, sand) • Use of recycled materials (Steel frame, polystyrene components, Gypsum panels) • Embodied energy calculation
Use of low environmental impact materials in building interiors	• Stones from India • Composite wood based product • FSC Chain of custody certified products • Products with 5% recycled content
Use of recycled content in roads and pavements	• 8% (min) as per CPRI and IRC Guidelines
Low VOC paints, adhesives, sealants and composite wood products	• VOC limit (g /litre) specified
Zero ODP materials	• CFC, HCFCs free from Building insulation , HVAC & refrigeration equipment and fire fighting system

Portland Slag Cement, commonly known as PSC
Up to 45- 50% slag, 45% – 50% clinker, and 3-5% gypsum

Compacted EPS Blocks



Gypsum Board
(https://www.boardandwall.com/)

Social Aspects

Facilities for construction workers	•Compliance with NBC 2016 Safety norms •Drinking water, hygienic working & living condition
Universal Accessibility	•Measure to provide barrier free facilities for Specially abled persons and elderly persons
Proximity of Transport and basic Services	•With in 500 metre transportation facilities •Health Care, Education, Socio culture, market, sports, recreation, Bank (ATM) – 800 metre preferred
Environmental Awareness	• Awareness tools (Brochure, poster etc.)
Tobacco Smoke Control	• Zero exposure of non-smoking occupants
Water Quality	• Conform to IS 10500-1991
Provision to access clean sources of Cooking Fuel	• Basic infrastructure for PNG & LPG connection

Ramp for physically handicapped

Q & A Session

DAY 2

05

ENS 2021

Eco – Niwas Samhita 2021 Scope

The Code Applies to

Residential buildings built on a plot area of ≥ 500 m²

Residential part of ***Mixed land-use building*** projects, built on a plot area of ≥ 500 m².

ECO – NIWAS SAMHITA 2021 CODE COMPLIANCE

Prescriptive Method

Compliance Mandatory +

Point System Method

Additional Score

- Minimum Points
- Additional Points
- Maximum Points

Components	Minimum Points	Additional Points	Maximum Points
Building Envelope			
Building Envelope	47	40	87
Building Services			
Common area and exterior lighting	3	6	9
Elevators	13	9	22
Pumps	6	8	14
Electrical Systems	1	5	6
Indoor Electrical End-Use			
Indoor Lighting		12	12
Comfort Systems		50	50
ENS Score	70	130	200

Renewable Energy Systems Components	Minimum Points	Additional Points	Maximum Points
Solar Hot Water Systems		10	10
Solar Photo Voltaic		10	10
Additional ENS Score		20	

ECO – NIWAS SAMHITA 2021 CODE COMPLIANCE

Project Category	Minimum ENS Score
Low rise buildings	47
Affordable Housing	70
High rise buildings	100

Low Rise Buildings: A structure of four stories or less, and/or a structure of up to 15 metres in height (without stilts) and up to 17.5 metres in height (including stilt).

Affordable Housing Projects:

- for Affordable houses are Dwelling Units (DUs)
- for Economically Weaker Section (EWS) category
- For Lower Income Group (LIG) category

High Rise Buildings: A structure with more than four stories and/or a height of more than 15 metres (without stilts) and 17.5 metres (including stilt).

Point Based System

POINT BASED SYSTEM

- ANNUAL EPI
- ANNUAL EPI NORMALISE BY SERVICE LIFE
- LIFE CYCLE COST

The potential savings gained from the above metrics for various prototypes has led to the definition of MEPS for part-II building components and a proposal for an Integrated ENS.

Advantages of Point Based System

- A point system is a less complicated way of assigning weight to building components that are relevant in terms of energy efficiency and compliance. Each dot does not always imply a percentage reduction in energy consumption.
- Singapore began with prescriptive compliance, but as the code grew, the point-based model was adopted as a means of compliance, combining trade-off and prescriptive criteria.

Ease of comprehending by the citizens	• **Easy to comprehend by citizens for both overall energy performance of a residential building and incorporated component level energy efficiency**
Trade-off	• Trade-off among components is possible but on a stepped EE improvements giving limited flexibility to owner to show compliance • Easy to deter possibility of gaming
Compliance	• Low expertise is required for doing and checking the compliance • Require simpler tool for showing compliance • Will have only one compliance approach
Future revision	• Easy to accommodate additions and removal of components from code. • Easier for states to make any revisions/amendments

Mandatory Requirements

1. Building Envelope: All of the ENS Part I requirements must be met.
2. Power Factor Correction: In all three phases, 0.97 at the point of connection or the state requirement, whichever is more strict.
3. Energy Monitoring: Common area lighting (Outdoor lighting, corridor lighting and basement lighting)
   - Elevators
   - Water pumps
   - Basement car parking ventilation system
   - Electricity generated from power back-up
   - Electricity generated through renewable energy systems
   - Lift pressurization system
4. Electrical Vehicle Charging Station: If it is installed, it must follow the new criteria for Charging Infrastructure established by the Ministry of Power.
5. Electrical Systems: Distribution losses in the ENS building must not exceed 3% of total power demand. At design load, the voltage drop for feeders is less than 2%.At design load, the voltage drop for the branch circuit is less than 3%.

Prescriptive Method

1. Building Envelope:
   - VLT and WFR – as per ENS Part 1
   - RETV (for all climate except cold) – max 12 W/m2
   - Thermal Transmittance for cold – max 1.3W/m2K
   - Roof – 1.2W/m2K
2. Common Area & Exterior Lighting: Either LPD or Efficacy and use of PhotoSensor

Common Areas	Maximum LPD (W/m²)	Minimum luminous efficacy (lm/W)
Corridor lighting & Stilt Parking	3.0	All the permanently installed lighting fixtures shall use lamps with an efficacy of at least 105 lumens per Watt
Basement Lighting	1.0	All the permanently installed lighting fixtures shall use lamps with an efficacy of at least 105 lumens per Watt

Exterior Lighting Areas	Maximum LPD (in W/m²)
Driveways and parking (open/ external)	1.6
Pedestrian walkways	2.0
Stairways	10.0
Landscaping	0.5
Outdoor sales area	9.0

Prescriptive Method

3. Elevators, if applicable::
    - Lamps: 85l/W
    - Automatic switch off control
    - IE4 motors
    - VFDs
    - Regenerative drives
    - Group Automatic operation

4. Pumps, if applicable: Min Eff -70% or BEE 5 Star
5. Electrical System, if applicable:
    - Distribution loss less than 3%
    - Dry Type Transformer - as mentioned in table
    - Oil Type Transformer – BEE 5 Star

Point System Method – ENS 2021 Compliance

Point System Method

Minimum Points - are a set of points that must be obtained for each component in order to demonstrate ENS compliance

Additional Points - These are the points provided for implementing additional or improved energy efficiency measures in a component. These points can be combined with others to get the total score for ENS compliance described in section 3.1.2.

The total points available for each component are the **maximum points.**

Components	Minimum Points	Additional Points	Maximum Points
Building Envelope			
Building Envelope	47	40	87
Building Services			
Common area and exterior lighting	3	6	9
Elevators	13	9	22
Pumps	6	8	14
Electrical Systems	1	5	6
Indoor Electrical End-Use			
Indoor Lighting		12	12
Comfort Systems		50	50
ENS Score	70	130	200

Point System Method – ENS 2021 Compliance

1 - Building Envelope (87 Max Points out of which 47 are essential)

- Thermal Transmittance of Roof (7 Points)
- RETV (80 Points)

Thermal Transmittance of Roof	
Minimum: Thermal transmittance of roof shall comply with the maximum Uroof value of 1.2 W/m2·K.	Up to 4 Points
Additional: 1 Point for every reduction of 0.23 W/m2·K in thermal transmittance of roof from the Minimum requirement prescribed under §6.1(a).	Maximum 3Points

RETV	
The RETV for the building envelope (except roof) for four climate zones, namely, Composite Climate, Hot-Dry Climate, Warm-Humid Climate, and Temperate Climate, shall comply with the maximum RETV of 15 W/m2.	44 Points
For RETV less than 15 and upto 12 W/m2, score will be calculated by following equation: 74 – 2 x (RETV) (@2 points per RETV reduction)	Up to 50 Points
Additional: For RETV less than 12 and upto 6 W/m2, score will be calculated by following equation: 110 – 5 x (RETV) (@ 5 points per RETV reduction)	Up to 80 points
Additional: For RETV less than 6 W/m2	80 Points

Point System Method – ENS 2021 Compliance

2 – Common Area and Exterior Lighting (9 Points)

Common Areas	Maximum LPD (W/m²)	Minimum luminous efficacy (lm/W)
Corridor lighting & Stilt Parking	3.0	All the permanently installed lighting fixtures shall use lamps with an efficacy of at least 85 lumens per Watt
Basement Lighting	1.0	All the permanently installed lighting fixtures shall use lamps with an efficacy of at least 85 lumens per Watt

Exterior Lighting Areas - at least 85 lm/W and maximum LPD requirements given in Table	Maximum LPD (in W/m²)
Driveways and parking (open/ external)	1.6
Pedestrian walkways	2.0
Stairways	10.0
Landscaping	0.5
Outdoor sales area	9.0

Additional Points (6 points)	
Corridor lighting & Stilt Parking	1 Point for installing 95 lm/W Or 2 Point for installing 105 lm/W
Basement Lighting	1 Point for installing 95 lm/W Or 2 Point for installing 105 lm/W
Exterior Lighting Areas	2Points for Installing photo sensor or astronomical time switch

Point System Method – ENS 2021 Compliance

3 – ELEVATORS (22 Points)

Minimum: **Elevators installed in the ENS building shall meet all the following requirements:** **i. Install high efficacy lamps for lift car lighting having minimum luminous efficacy of 85 lm/W** **ii. Install automatic switch-off controls for lighting and fan inside the lift car when are not occupied** **iii. Install minimum class IE 3 high efficiency motors** **iv. Group automatic operation of two or more elevators coordinated by supervisory control**	**13 Points**
Additional: i. Additional points can be obtained by meeting the following requirements: ii. Installing the variable voltage and variable frequency drives. (4 points) iii. Installing regenerative drives. (3 points) iv. Installing class IE4 motors. (2 points)	9 Points

Point System Method – ENS 2021 Compliance

4 – Pumps (14 Points)

Minimum: **Either hydro-pneumatic pumps having minimum mechanical efficiency of 60% or BEE 4 star rated Pumps shall be installed in the ENS building.**	**6 Points**
Additional: Additional points can be obtained by meeting the following requirements: i. Installation of BEE 5 star rated pumps (5 Points) ii. Installation of hydro-pneumatic system for water pumping having minimum mechanical efficiency of 70% (3 Points)	8 Points

Point System Method – ENS 2021 Compliance

5 – Electrical Systems (6 Points)

Minimum: **i. Power transformers of the proper ratings and design must be selected to satisfy the minimum acceptable efficiency at 50% and full load rating. The permissible loss shall not exceed the values listed in Table 8 for dry type transformers and BEE 4-star rating in Table 9 for oil type transformers.**	**1 Points**
Additional: Additional points can be obtained by providing all oil type transformers with BEE 5 star rating.	5 Points

Point System Method – ENS 2021 Compliance

6 – Indoor Lightings (12 Points)

Minimum: **All the lighting fixtures shall have lamps with luminous efficacy of minimum 85 lm/W installed in all bedrooms, hall and kitchen.**	**4 Points**
Additional: Additional points for indoor lighting by installing all lighting fixtures in all bedrooms, hall and kitchen shall have lamps luminous efficacy as per following: i. 95 lm/w (3 Points) ii. 105 lm/W (8 Points)	Upto 8 Points

Point System Method – ENS 2021 Compliance

7 – Comfort Systems (50 Points) – Ceiling Fans

Minimum: **i. All ceiling fans installed in all the bedrooms and hall in all the dwelling units shall have a service value as given below:** **• For sweep size <1200 mm: equal or greater than 4 m3/minute·Watt** **• For sweep size >1200 mm: equal or greater than 5 m3/minute·Watt** **i. BEE Standards and Labeling requirements for ceiling fans shall take precedence over the current minimum requirement, as and when it is notified as mandatory.**	**6 Points**
Additional:	
Additional points for ceiling fans by installing in all the bedrooms and hall in all the dwellingunits as per following:	
i. 4 Star	1 Points
ii. 5 Star	3 Points

Point System Method – ENS 2021 Compliance

Weighted Average of different Comfort Systems installed in a building allowed for better flexibility (Points Achieved for AC)

Minimum: **i. Unitary Type: 5 Star** **ii. Split AC: 3 Star** **iii. VRF: 3.28 EER** **iv. Chiller: Minimum ECBC Level**	**20 Points**
Additional 9 points for : i. Split AC: 4 Star ii. VRF: Not Applicable as on date, however, whenever Star labelling of BEE is launched, Star 4 will be applicable iii. Chiller: Minimum ECBC+ Level as mentioned in ECBC 2017	9 Points
Additional 21 points for : i. Split AC: 5 Star ii. VRF: Not Applicable as on date, however, whenever Star labelling of BEE is launched, Star 5 will be applicable iii. Chiller: Minimum SuperECBC Level as mentioned in ECBC 2017	21 Points

Point System Method – ENS 2021 Compliance

8 – Solar Water Heating (10 Points)

Minimum: **The ENS compliant building shall provide a solar water heating system (SWH) of minimum BEE 3Star label and is capable of meeting 100% of the annual hot water demand of top 4 floors of the residential building.** **or** **100% of the annual hot water demand of top 4 floors of the residential building is met by the system using heat recovery**	**5 Points**
Additional: Additional points can be obtained by installing SWH system as per as per following: i. 100% of the annual hot water demand of top 6 floors of the residential building (2 points) ii. 100% of the annual hot water demand of top 8 floors of the residential building (5 points)	Upto 5 Points

Point System Method – ENS 2021 Compliance

9 – Solar Photo Voltaic (10 Points)

Minimum: **The ENS compliant building shall provide a dedicated Renewable Energy Generation Zone (REGZ) –** • **Equivalent to a minimum of 2 kWh/m2.year of electricity; or** • **Equivalent to at least 20% of roof area.** **The REGZ shall be free of any obstructions within its boundaries and from shadows cast by objects adjacent to the zone.**	**5 Points**
Additional: Additional points can be obtained by installing solar photo voltaic as per following: i. Equivalent to a minimum of 3 kWh/m2.year of electricity or Equivalent to at least 30% of roof area (2 points) ii. Equivalent to a minimum of 4 kWh/m2.year of electricity or Equivalent to at least 40% of roof area (5 points)	Upto 5 Points

06

ENS 2018

Code Provisions by Eco Niwas Samitha

CODE PROVISONS

Thermal Comfort in Affordable Housing

- **NATURAL VENTILATION**
  - Minimum Openable Window to floor area ratio w.r.t Climatic Zone
- **DAYLIGHT**
  - Minimum Visible Light Transmittance w.r.t window to wall Ratio
- **HEAT GAIN/LOSS**
  - **Roof**
    - Maximum U-value for all Climatic Zone
  - **Envelope (Excluding Roof)**
    - Maximum Residential Envelope Transmittance Value for all climatic zones, except Cold
    - Maximum U-value for Cold Climatic Zone

Code Provisions by Eco Niwas Samitha

SR.NO.	CODE PROVISONS
1	Openable Window to Floor Area Ratio
2	Visible Light Transmission
3	Thermal Transmittance of Roof
4	Residential Envelope Transmittance Value for Building Envelope (Except Roof) for four Climate Zones, namely, Composite Climate, Hot-Dry Climate, Warm-Humid Climate, and Temperature Climate
5	Thermal Transmittance of Building Envelop (Except Roof) for Cold Climate

Openable window to floor area ratio (WFR):

Openable window-to-floor area ratio (WFR) indicates the potential of using external air for ventilation. Ensuring minimum WFR helps in ventilation, improvement in thermal comfort, and reduction in cooling energy

The openable window-to-floor area ratio (WFR) shall not be less than the values given in Table. (Source Adapted from Bureau of Indian Standards (BIS). 2016. National Building Code of India 2016. New Delhi: BIS.)

Climatic Zone	Minimum WFR
Composite	12.50
Hot-Dry	10.00
Warm-Humid	16.66
Temperature	12.50
Cold	8.33

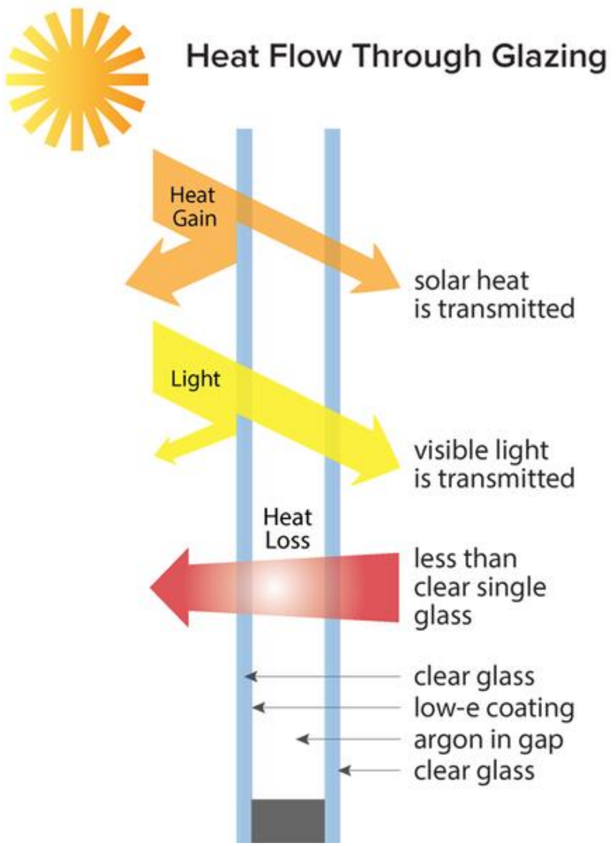
Openable window to floor area ratio (wfr):

EQUATION FOR WFR

$$WFR = \frac{A_{openable}}{A_{carpet}}$$

WFR	**Openable Window to Floor Area Ratio**
$A_{Openable}$	Openable area (m^2); it includes the openable area of all windows and ventilators, opening directly to the external air, an open balcony, 'verandah', corridor or shaft; and the openable area of the doors opening directly into an open balcony. Exclusions: All doors opening into corridors. External doors on ground floor, for example, ground-floor entrance doors or back-yard doors.
A_{Carpet}	carpet area of dwelling units; it is the net usable floor area of a dwelling unit, excluding the area covered by the external walls, areas under services shafts, exclusive balcony or verandah area and exclusive open terrace area, but includes the area covered by the internal partition walls of the dwelling unit

VISIBLE LIGHT TRANSMITTANCE (VLT):



Visible light transmittance (VLT) of non-opaque building envelope components (transparent/translucent panels in windows, doors, ventilators, etc.), indicates the potential of using daylight. Ensuring minimum VLT helps in improving day lighting, thereby reducing the energy required for artificial lighting

EQUATION FOR VLT

$$WWR = \frac{A_{non\_opaque}}{A_{envelope}}$$

The VLT requirement is applicable as per the window-to-wall ratio (WWR) of the building. WWR is the ratio of the area of non-opaque building envelope components of dwelling units to the envelope area (excluding roof) of dwelling units.

VISIBLE LIGHT TRANSMITTANCE (VLT):

MINIMUM VISIBLE LIGHT TRANSMITTANCE (VLT) REQUIREMENT:

The glass used in non-opaque building envelope components (transparent/translucent panels in windows, doors, etc.) shall comply with the requirements given in Table .(Source Bureau of Indian Standards (BIS). 2016. National Building Code of India 2016. New Delhi: BIS)

Window-to-wall Ratio (WWR)	Minimum VLT
0 - 0.30	0.27
0.31 - 0.40	0.20
0.41 - 0.50	0.16
0.51 - 0.60	0.13
0.61 - 0.70	0.11

THERMAL TRANSMITTANCE OF ROOF - U_{roof}:

Thermal transmittance (U_{roof}) characterizes the thermal performance of the roof of a building. Limiting the U_{roof} helps in reducing heat gains or losses from the roof, thereby improving the thermal comfort and reducing the energy required for cooling or heating.

Thermal transmittance of roof shall comply with the maximum U_{roof} value of 1.2 W/m² K.

THERMAL TRANSMITTANCE OF ROOF - U_{roof}:

EQUATION FOR U_{roof}:

$$U_{roof} = \frac{1}{A_{roof}} \sum_{i=0}^{n} (Ui \times Ai)$$

U_{roof}	**Thermal Transmittance of Roof (W/M².K)**
A_{roof}	Total Area of the Roof (m²)
U_i	Thermal Transmittance values of different roof constructions (W/m² .K)
A_i	Areas of different Roof Constructions (m²)

RESIDENTIAL ENVELOPE TRANSMITTANCE VALUE FOR BUILDING ENVELOPE (EXCEPT ROOF):

RETV formula takes into account the following:

Residential envelope heat transmittance (RETV) is the net heat gain rate (over the cooling period) through the building envelope (excluding roof) of the dwelling units divided by the area of the building envelope (excluding roof) of the dwelling units. Its unit is W/m^2 .

- Heat Conduction through opaque building envelope components (Wall, Opaque, panels in doors, windows, ventilators, etc.
- Heat Conduction through non-opaque building, envelope components (transparent/translucent panels of windows, doors, ventilators, etc.)
- Solar radiations through non-opaque building envelope components (transparent/translucent panel of windows , doors, ventilators, etc.)

RESIDENTIAL ENVELOPE TRANSMITTANCE VALUE FOR BUILDING ENVELOPE (EXCEPT ROOF):

$$RETV = \frac{1}{A_{envelope}} \times [\{a \times \sum_{i=1}^{n} (Aopaque \times Uopaque \times \omega_i)\} + \{b \times \sum_{i=1}^{n} (Anon\_{opaque} \times Unon\_{opaque} \times \omega_i)\} + \{c \times \sum_{i=1}^{n} A_{non\_opaque} \times SHGCeq \times \omega_i)\}]$$

RESIDENTIAL ENVELOPE TRANSMITTANCE VALUE FOR BUILDING ENVELOPE (EXCEPT ROOF):

RETV EUQATIONS TERMS

$A_{envelope}$	envelope area (excluding roof) of dwelling units (m^2). It is the gross external wall area (includes the area of the walls and the openings such as windows and doors).
A_{opaque}	areas of different opaque building envelope components (m^2)
U_{opaque}	thermal transmittance values of different opaque building envelope components ($W/m^2 .K$)
$A_{non\text{-}opaque}$	areas of different non-opaque building envelope components (m^2)
$U_{non\text{-}opaque}$	thermal transmittance values of different non-opaque building envelope components ($W/m^2 .K$)
$SHGC_{eq}$	equivalent solar heat gain coefficient values of different non-opaque building envelope components
ω_I	orientation factor of respective opaque and non-opaque building envelope components; it is a measure of the amount of direct and diffused solar radiation that is received on the vertical surface in a specific orientation

RESIDENTIAL ENVELOPE TRANSMITTANCE VALUE FOR BUILDING ENVELOPE (EXCEPT ROOF):

The coefficients of RETV formula, for different climate zones, are given in Table

Climate Zone	a	b	c
Composite	6.06	1.85	68.99
Hot-Dry	6.06	1.85	68.99
Warm-Humid	5.15	1.31	65.21
Temperature	3.38	0.37	63.69
Cold	Not Applicable for RETV		

THERMAL TRANSMITTANCE OF BUILDING ENVELOPE:

$U_{envelope,cold}$ takes into account the following

Thermal transmittance $U_{envelope,cold}$ characterizes the thermal performance of the building envelope (except roof). Limiting the $U_{envelope,cold}$ helps in reducing heat losses from the building envelope, thereby improving the thermal comfort and reducing the energy required for heating

Heat Conduction through opaque building envelope components (Wall, Opaque, panels in doors, windows, ventilators, etc.

Heat Conduction through non-opaque building, envelope components (transparent/translucent panels of windows, doors, ventilators, etc.)

THERMAL TRANSMITTANCE OF BUILDING ENVELOPE:

The Thermal transmittance of the building envelope (except roof) for cold climate shall comply with the maximum of 1.8 W/m² .K

EQUATION FOR $U_{envelope,cold}$:

$$U_{envelope,cold} = \frac{1}{A_{envelope}} \sum_{i=1}^{n} (Ui \times Ai)$$

$U_{envelope,cold}$	**thermal transmittance of building envelope (except roof) for cold climate (W/m² .K)**
$A_{envelope}$	envelope area (excluding roof) of dwelling units (m²). It is the gross external wall area (includes the area of the walls and the openings such as windows and doors)
U_i	thermal transmittance of different opaque and non-opaque building envelope components (W/m² .K)
A_i	area of different opaque and non-opaque opaque building envelope components (m²)

Group Exercise

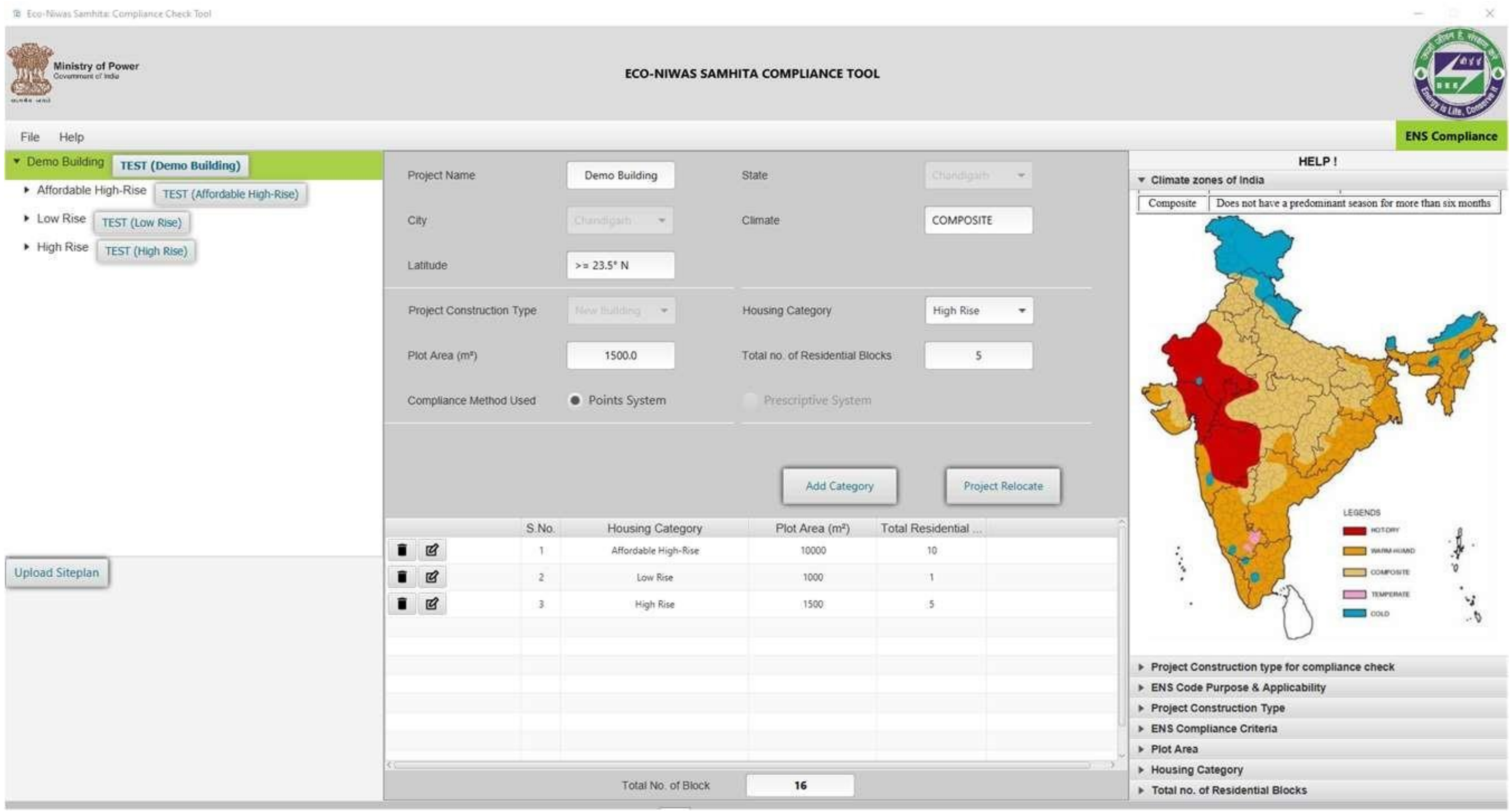
Tea Break : 10 minutes

06-A

ENS COMPLIANCE TOOLS

Introduction

- Quick design and compliance checks benchmarks of ECONIWAS SAMHITA.
- 5 key features in consideration:
  1. User friendliness
  2. Responsiveness
  3. Adaptability
  4. Dynamism
  5. Resourcefulness.
- Compliance for Both Prescriptive and Points Based Systems.
- Categories included:
  1. High rise
  2. Low Rise
  3. Affordable
  4. Mixed Use



ENS Compliance Tools Key Features

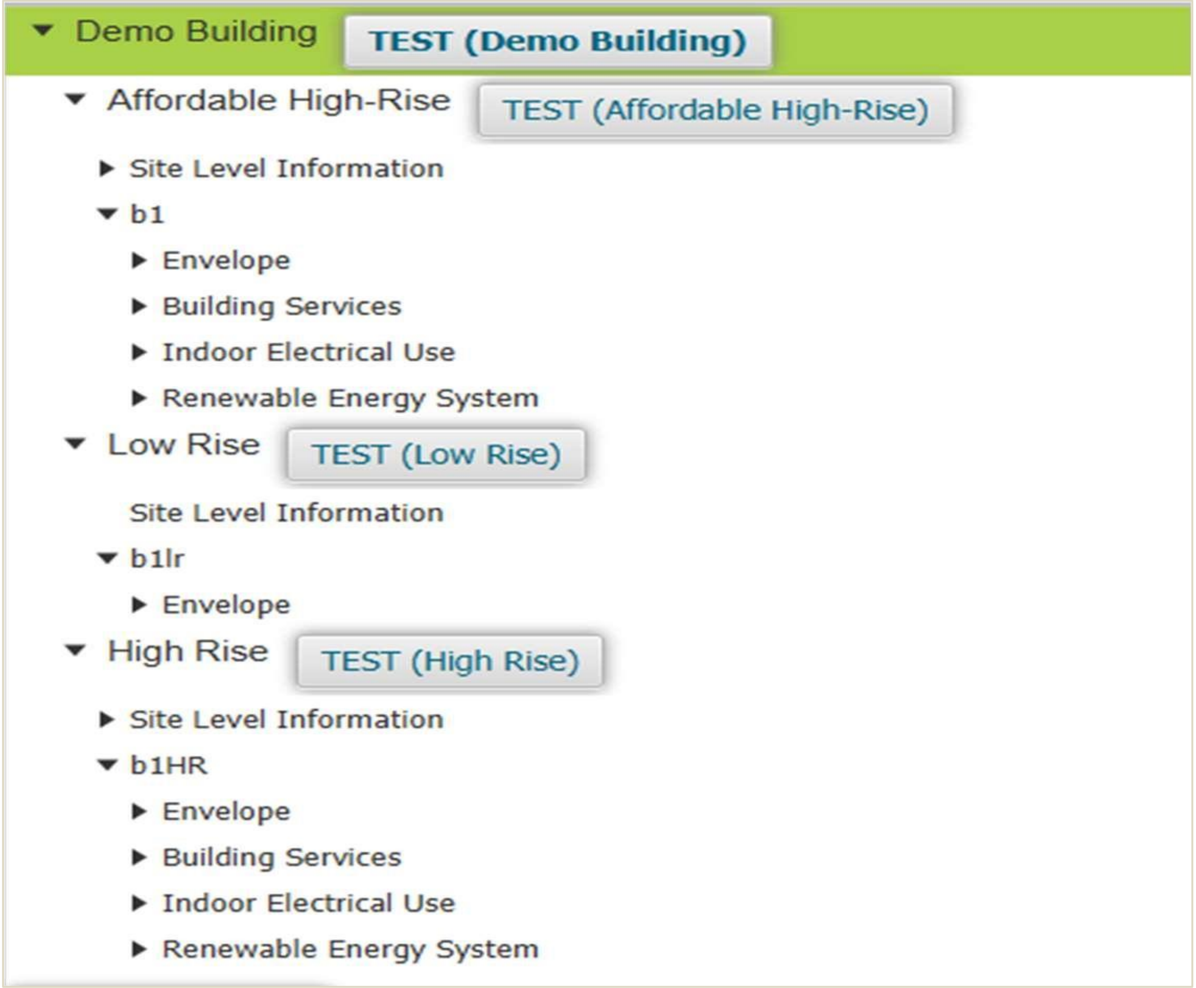
- Provisions for multiple housing category addition for compliance evaluation

	S.No.	Housing Category	Plot Area (m²)	Total Residential Block
	1	Affordable High-Rise	10000	10
	2	Low Rise	1000	1
	3	High Rise	1500	5

Total No. of Block: **16**

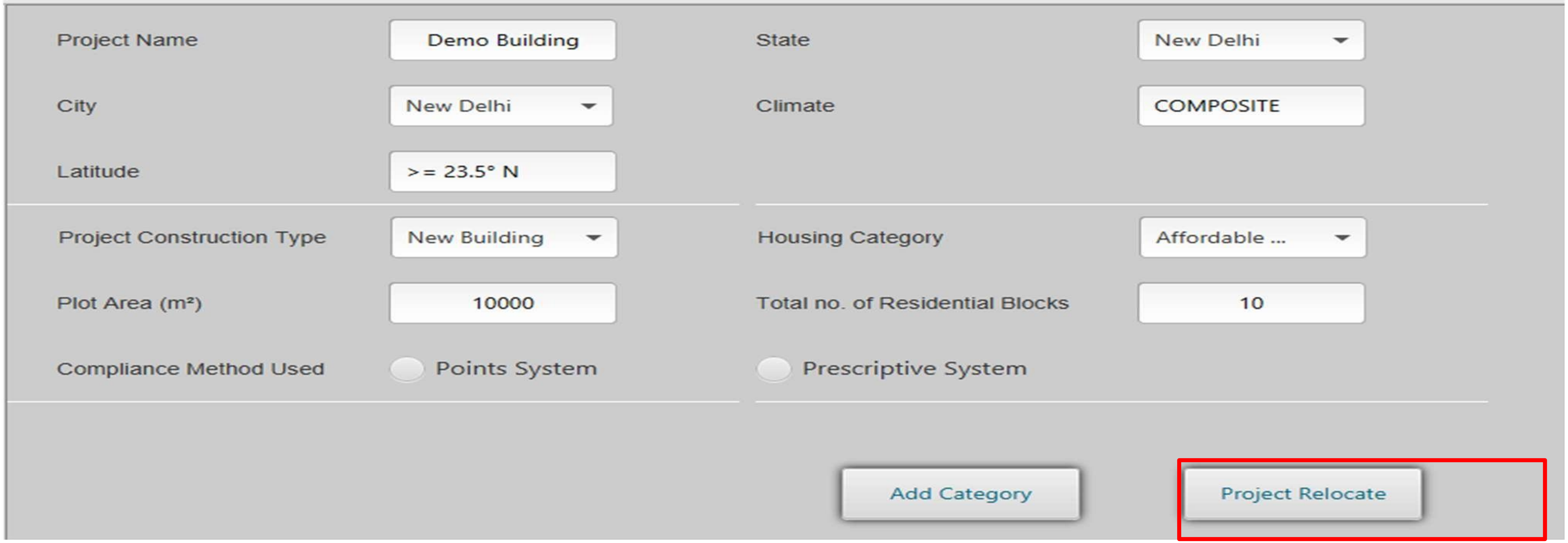
ENS Compliance Tools Key Features

- Easy to navigate tree-view structure



ENS Compliance Tools Key Features

- Project relocation feature for multiple domain use



ENS Compliance Tools Key Features

- Segregated site level & block level inputs for ease in information flow

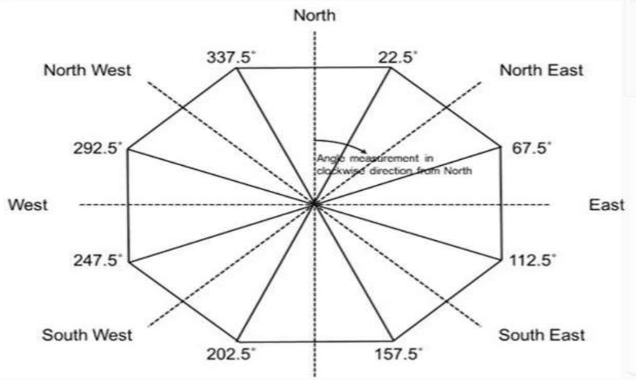
- Demo Building — TEST (Demo Building)
  - Affordable High-Rise — TEST (Affordable High-Rise)
    - Site Level Information
      - Basement Lighting
      - Exterior Lighting
      - Pumps
      - Diesel Generator Set
      - Power Factor
      - Energy Monitoring
      - EV Supply Equipment
      - Transformer
      - Power Distribution Loss
      - Solar Photovoltaic System
    - b1
      - Envelope
      - Building Services
      - Indoor Electrical Use
      - Renewable Energy System
  - Low Rise — TEST (Low Rise)
  - High Rise — TEST (High Rise)

- Comprehensive help panel on each form for easy user referencing

HELP !

- Climate zones of India
- Project Construction type for compliance check

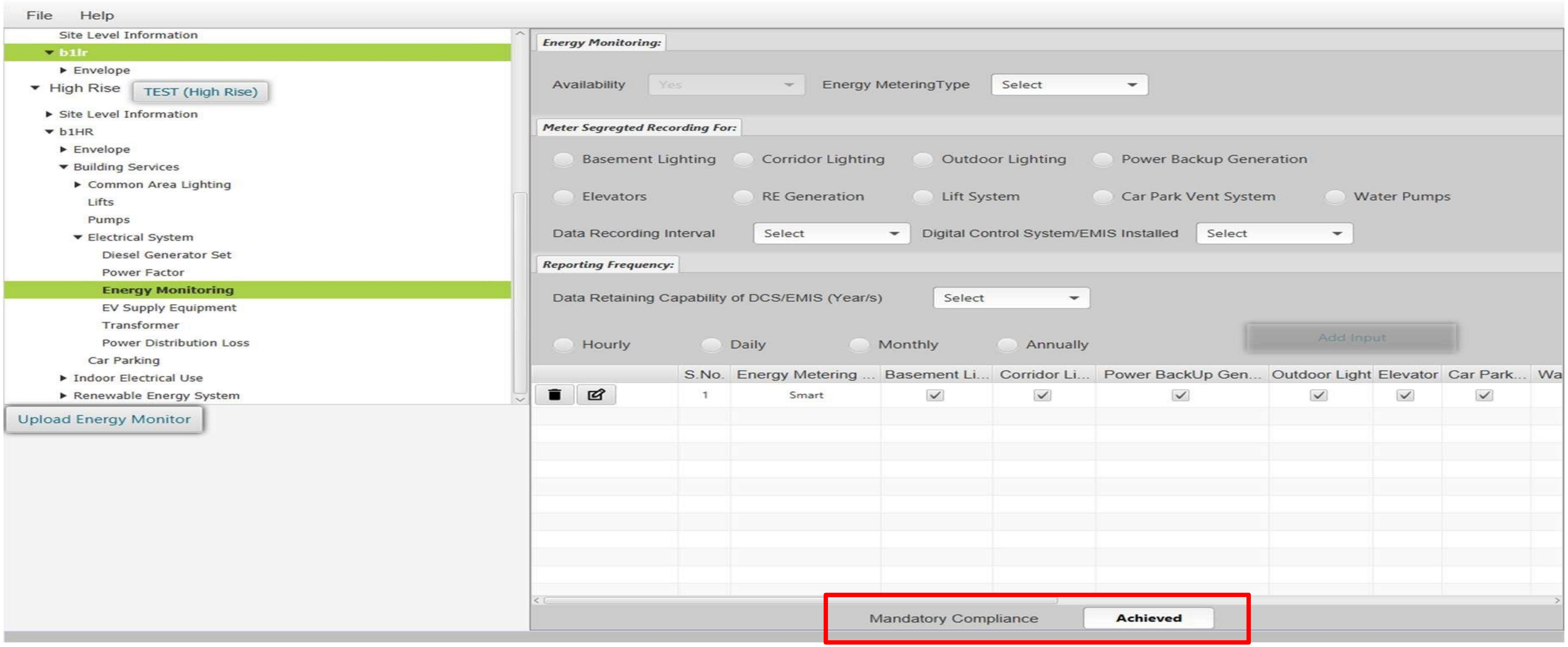
Orientation	Range (0° being north and 90° being east)
North	337.6° – 22.5°
North-east	22.6° – 67.5°
East	67.6° – 112.5°
South-east	112.6° – 157.5°
South	157.6° – 202.5°
South-west	202.6° – 247.5°
West	247.6° – 292.5°
North-west	292.6° – 337.5°



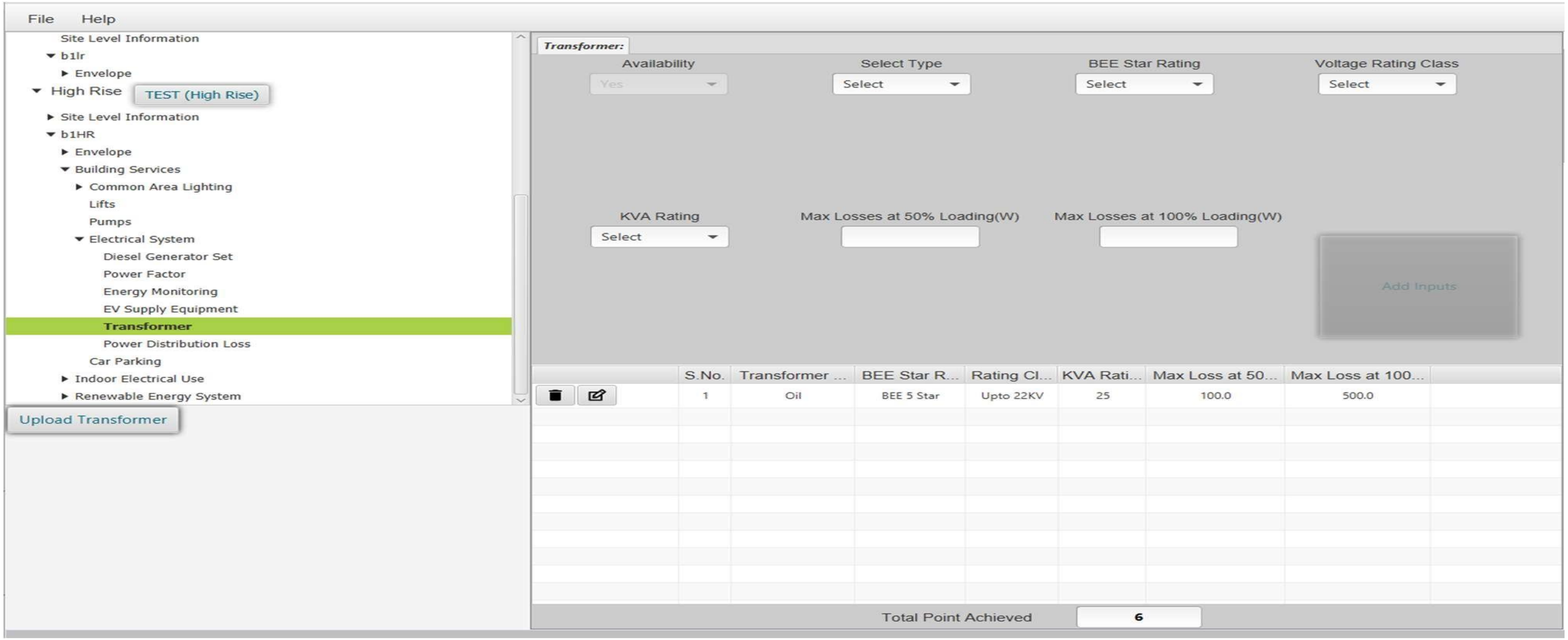
- ENS Code Purpose & Applicability
- Project Construction Type
- ENS Compliance Criteria
- Plot Area
- Housing Category
- Total no. of Residential Blocks

ENS Compliance Tools Key Features

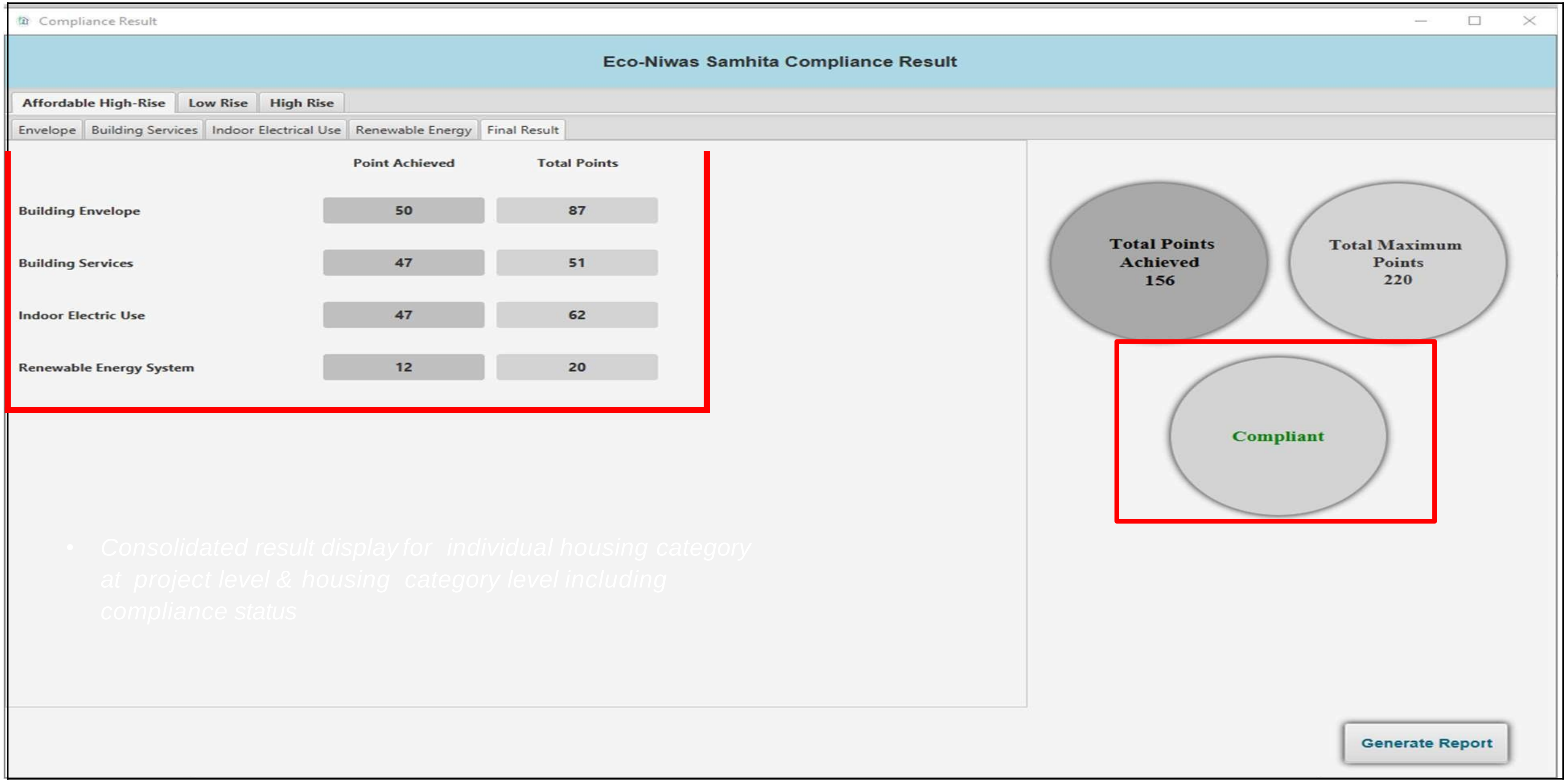
- Component level display for mandatory provisions and points achieved



ENS Compliance Tools Key Features



ENS Compliance Tools Key Features



- Consolidated result display for individual housing category at project level & housing category level including compliance status

ENS Compliance Tools Key Features

- Provisions for PDF output reporting for each input and corresponding output

Eco-Niwas Samhita: Compliance Check Report

ECO-NIWAS SAMHITA (ENS) COMPLIANCE EVALUATION REPORT

Project Information

Project Name	Demo Building
State	Chandigarh
City	Chandigarh
Climate	COMPOSITE
Latitude	>= 23.5° N
Building Construction Type	New Building
Compliance Method Used	Point System

Housing Category Information

Housing Category	Plot Area(m²)	Total No. of Residential Blocks	Total Basement Area(m²)	Total Exterior Light Area(m²)	Total Roof Area(m²)
Affordable High-Rise	10000	10	1000.0	1000.0	1000.0
Low Rise	1000	1	1000.0	1000.0	1000.0
High Rise	1500	5	100.0	100.0	100.0

Eco-Niwas Samhita: Compliance Check Report

Consolidated Compliance Status of the Project:

S.No.	Housing Categories	Total Points	Maximum Points	Minimum Points	Compliance Status
1	Affordable High-Rise	156	220	70	Compliant
2	Low Rise	53	87	47	Compliant
3	High Rise	82	220	100	Non Compliant

Eco-Niwas Samhita: Compliance Check Report

1. Affordable High-Rise : Compliance Result

1.1. Building Envelope:

S.No.	Component	Mandatory Requirements	Calculated value	Points Achieved	Maximum Points
1	RETV(W/m².K)	NA	14.59	44	80
2	U-Value Roof(W/m².K)	NA	0.53	6	7
3	WFRop	Achieved	32.0	NA	NA
4	VLT %	Achieved	60.0	NA	NA

1.2. Building Services:

S.No.	Component	Mandatory Requirements	Calculated value	Points Achieved	Maximum Points
1	Exterior Lighting	NA	--	3	3
2	Basement Lighting	NA	--	2	3
3	Corridor Lighting	NA	--	3	3
4	Lift	NA	--	22	22
5	Pump	NA	--	11	14
6	Diesel Generator Sets	Achieved	--	NA	NA
7	Power Factor Correction	Achieved	--	NA	NA
8	Energy Monitoring System	Achieved	--	NA	NA
9	Electric Vehicle Supply Equipment	Achieved	--	NA	NA
10	Transformer	NA	--	6	6
11	Power Distribution Loss	Achieved	--	NA	NA
12	Car Parking Basement Ventilation	Achieved	--	NA	NA

1.3. Indoor Electrical End Use:

S.No.	Component	Mandatory Requirements	Calculated value	Points Achieved	Maximum Points
1	Indoor Lighting	NA	--	12	12
2	Ceiling Fan	NA	--	7	9
3	Cooling Equipment	NA	--	28	41

1.4. Renewable Energy System:

S.No.	Component	Mandatory Requirements	Calculated value	Points Achieved	Maximum Points
1	Solar Hot Water Requirements	NA	--	7	10
2	Solar Photovoltaic System	NA	--	5	10

प्रधान मंत्री आवास योजना-शहरी
Pradhan Mantri Awas Yojana-Urban

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

Ministry of Housing and Urban Affairs
Government of India

आज़ादी का अमृत महोत्सव

bmtpc

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06-B

THERMAL COMFORT ANALYSIS

Ministry of Housing and Urban Affairs
Government of India

06-A

THERMAL COMFORT ANALYSIS

Executive Summary: ENS Compliance of LHP-Ranchi

Sr. No.	Eco Niwas Samhita Code Parameters	Actual or Base Case	Compliance Status Base Case	Recommended Case	Standard Value
1	Window-To-Floor Area Ratio ($WFR_{openable}$)	12.57%	Yes	Already Complying	Minimum Value 12.50%
2	Visible Light Transmittance (VLT)	50% for WWR of 0.22	Yes	Already Complying	(Range 0–0.30) Minimum Value 27%
3	Thermal transmittance of roof (U_{roof})	7.191 W/m^2K	No	0.687 W/m^2K	Maximum Value 1.2 W/m^2K
4	Residential Envelope Transmittance Value (RETV)	27.20 W/m^2	No	9.41 W/m^2	Maximum Value 15 W/m^2

Recommendations

- Proper orientation of Buildings, this reduce the impact of unfavorable weather conditions like solar radiation, driving rain and thunderstorm
- Proper Ventilation – Proper positioning the windows and opening them create air movement in the house. Walls and vegetation should not be too close to the building in order to avoid diversion of wind away from the openings, thereby reducing air flow within the building. If possible, the rooms should be cross ventilated.
- Using Shading Device – use of overhangs or horizontal projections over windows. Double pane windows with tinted glass and glass coated with reflective film should be used for windows instead of steels, wood and zincs.
- Creation of Microclimate – trees can be planted to create micro – climate that is, small-scale climatic condition at a spot or area or site
- Preventing Infiltration – Infiltration can be prevented by sealing the sites of air leaks. This can be achieved by caulking, weatherizing, good workmanship, and replacing some aged parts of buildings, etc.

Recommendations

To align with GHG reduction targets and other government activities, make "Thermal Comfort for All" a government priority, and relate it to India's ambition to give a better quality of life to all of its residents.

Create market momentum for smart cooling through public awareness campaigns, information access, and technical support.

Consistent testing and rating processes, as well as market communication initiatives, can help to mainstream the use of energy efficient building materials and equipment.

Take significant steps to phase out HFCs and encourage the industry to switch to renewable refrigerants.

DAY 2

Lunch Break

Lunch Break : 60 minutes

Ministry of Housing and Urban Affairs
Government of India

07

ENS 2018

Code Provisions by Eco Niwas Samitha for Thermal Comfort in Affordable Housing

- **CODE PROVISONS**
  - **NATURAL VENTILATION**
    - Minimum Openable Window to floor area ratio w.r.t Climatic Zone
  - **DAYLIGHT**
    - Minimum Visible Light Transmittance w.r.t window to wall Ratio
  - **HEAT GAIN/LOSS**
    - **Roof**
      - Maximum U-value for all Climatic Zone
    - **Envelope (Excluding Roof)**
      - Maximum Residential Envelope Transmittance Value for all climatic zones, except Cold
      - Maximum U-value for Cold Climatic Zone

SR.NO.	CODE PROVISONS
1	Openable Window to Floor Area Ratio
2	Visible Light Transmission
3	Thermal Transmittance of Roof
4	Residential Envelope Transmittance Value for Building Envelope (Except Roof) for four Climate Zones, namely, Composite Climate, Hot-Dry Climate, Warm-Humid Climate, and Temperature Climate
5	Thermal Transmittance of Building Envelop (Except Roof) for Cold Climate

Openable window to floor area ratio (wfr):

Openable window-to-floor area ratio (WFR) indicates the potential of using external air for ventilation. Ensuring minimum WFR helps in ventilation, improvement in thermal comfort, and reduction in cooling energy

The openable window-to-floor area ratio (WFR) shall not be less than the values given in Table. (Source Adapted from Bureau of Indian Standards (BIS). 2016. National Building Code of India 2016. New Delhi: BIS.)

Climatic Zone	Minimum WFR
Composite	12.50
Hot-Dry	10.00
Warm-Humid	16.66
Temperature	12.50
Cold	8.33

Openable window to floor area ratio (wfr):

EQUATION FOR WFR

$$WFR = \frac{A_{openable}}{A_{carpet}}$$

Where,

WFR	Openable Window to Floor Area Ratio
$A_{Openable}$	Openable area (m^2); it includes the openable area of all windows and ventilators, opening directly to the external air, an open balcony, 'verandah', corridor or shaft; and the openable area of the doors opening directly into an open balcony. Exclusions: All doors opening into corridors. External doors on ground floor, for example, ground-floor entrance doors or back-yard doors.
A_{Carpet}	carpet area of dwelling units; it is the net usable floor area of a dwelling unit, excluding the area covered by the external walls, areas under services shafts, exclusive balcony or verandah area and exclusive open terrace area, but includes the area covered by the internal partition walls of the dwelling unit

VISIBLE LIGHT TRANSMITTANCE (VLT):

Visible light transmittance (VLT) of non-opaque building envelope components (transparent/translucent panels in windows, doors, ventilators, etc.), indicates the potential of using daylight. Ensuring minimum VLT helps in improving day lighting, thereby reducing the energy required for artificial lighting

The VLT requirement is applicable as per the window-to-wall ratio (WWR) of the building. WWR is the ratio of the area of non-opaque building envelope components of dwelling units to the envelope area (excluding roof) of dwelling units.

EQUATION FOR VLT

$$WWR = \frac{A_{non\_opaque}}{A_{envelope}}$$

VISIBLE LIGHT TRANSMITTANCE (VLT):

MINIMUM VISIBLE LIGHT TRASNSMITTANCE (VLT) REQUIREMENT:

The glass used in non-opaque building envelope components (transparent/translucent panels in windows, doors, etc.) shall comply with the requirements given in Table .(Source Bureau of Indian Standards (BIS). 2016. National Building Code of India 2016. New Delhi: BIS)

Window-to-wall Ratio (WWR)	Minimum VLT
0 - 0.30	0.27
0.31 - 0.40	0.20
0.41 - 0.50	0.16
0.51 - 0.60	0.13
0.61 - 0.70	0.11

THERMAL TRANSMITTANCE OF ROOF - U_{roof}:

Thermal transmittance (U_{roof}) characterizes the thermal performance of the roof of a building. Limiting the U_{roof} helps in reducing heat gains or losses from the roof, thereby improving the thermal comfort and reducing the energy required for cooling or heating.

Thermal transmittance of roof shall comply with the maximum U_{roof} value of 1.2 W/m² K.

THERMAL TRANSMITTANCE OF ROOF - U_{roof}:

EQUATION FOR U_{roof}:

$$U_{roof} = \frac{1}{A_{roof}} \sum_{i=0}^{n} (Ui \times Ai)$$

U_{roof}	**Thermal Transmittance of Roof (W/M².K)**
A_{roof}	Total Area of the Roof (m^2)
U_i	Thermal Transmittance values of different roof constructions (W/m^2 .K)
A_i	Areas of different Roof Constructions (m^2)

RESIDENTIAL ENVELOPE TRANSMITTANCE VALUE FOR BUILDING ENVELOPE (EXCEPT ROOF):

Residential envelope heat transmittance (RETV) is the net heat gain rate (over the cooling period) through the building envelope (excluding roof) of the dwelling units divided by the area of the building envelope (excluding roof) of the dwelling units. Its unit is W/m² .

RETV formula takes into account the following:

- Heat Conduction through opaque building envelope components (Wall, Opaque, panels in doors, windows, ventilators, etc.
- Heat Conduction through non-opaque building, envelope components (transparent/translucent panels of windows, doors, ventilators, etc.)
- Solar radiations through non-opaque building envelope components (transparent/translucent panel of windows , doors, ventilators, etc.)

RESIDENTIAL ENVELOPE TRANSMITTANCE VALUE FOR BUILDING ENVELOPE (EXCEPT ROOF):

$$\boldsymbol{RETV} = \frac{1}{A_{envelope}} \times [\{a \times \sum_{i=1}^{n} (Aopaque \times Uopaque \times \omega_i)\} + \{b \times \sum_{i=1}^{n} (Anon\_opaque \times Unon\_opaque \times \omega_i)\} + \{c \times \sum_{i=1}^{n} A_{non\_opaque} \times SHGCeq \times \omega_i)\}]$$

RESIDENTIAL ENVELOPE TRANSMITTANCE VALUE FOR BUILDING ENVELOPE (EXCEPT ROOF):

RETV EUQATIONS TERMS

$A_{envelope}$	envelope area (excluding roof) of dwelling units (m^2). It is the gross external wall area (includes the area of the walls and the openings such as windows and doors).
A_{opaque}	areas of different opaque building envelope components (m^2)
U_{opaque}	thermal transmittance values of different opaque building envelope components ($W/m^2.K$)
$A_{non\text{-}opaque}$	areas of different non-opaque building envelope components (m^2)
$U_{non\text{-}opaque}$	thermal transmittance values of different non-opaque building envelope components ($W/m^2.K$)
$SHGC_{eq}$	equivalent solar heat gain coefficient values of different non-opaque building envelope components
ω_I	orientation factor of respective opaque and non-opaque building envelope components; it is a measure of the amount of direct and diffused solar radiation that is received on the vertical surface in a specific orientation

RESIDENTIAL ENVELOPE TRANSMITTANCE VALUE FOR BUILDING ENVELOPE (EXCEPT ROOF):

The coefficients of RETV formula, for different climate zones, are given in Table

Climate Zone	a	b	c
Composite	6.06	1.85	68.99
Hot-Dry	6.06	1.85	68.99
Warm-Humid	5.15	1.31	65.21
Temperature	3.38	0.37	63.69
Cold	Not Applicable for RETV		

THERMAL TRANSMITTANCE OF BUILDING ENVELOPE:

Thermal transmittance $U_{envelope,cold}$ characterizes the thermal performance of the building envelope (except roof). Limiting the $U_{envelope,cold}$ helps in reducing heat losses from the building envelope, thereby improving the thermal comfort and reducing the energy required for heating

$U_{envelope,cold}$ takes into account the following

- Heat Conduction through opaque building envelope components (Wall, Opaque, panels in doors, windows, ventilators, etc.
- Heat Conduction through non-opaque building, envelope components (transparent/translucent panels of windows, doors, ventilators, etc.)

THERMAL TRANSMITTANCE OF BUILDING ENVELOPE:

The Thermal transmittance of the building envelope (except roof) for cold climate shall comply with the maximum of 1.8 W/m² .K

EQUATION FOR $U_{envelope,cold}$:

$$U_{envelope,cold} = \frac{1}{A_{envelope}} \sum_{i=1}^{n} (Ui \times Ai)$$

$U_{envelope,cold}$	**thermal transmittance of building envelope (except roof) for cold climate (W/m² .K)**
$A_{envelope}$	envelope area (excluding roof) of dwelling units (m²). It is the gross external wall area (includes the area of the walls and the openings such as windows and doors)
U_i	thermal transmittance of different opaque and non-opaque building envelope components (W/m² .K)
A_i	area of different opaque and non-opaque opaque building envelope components (m²)

DAY 2

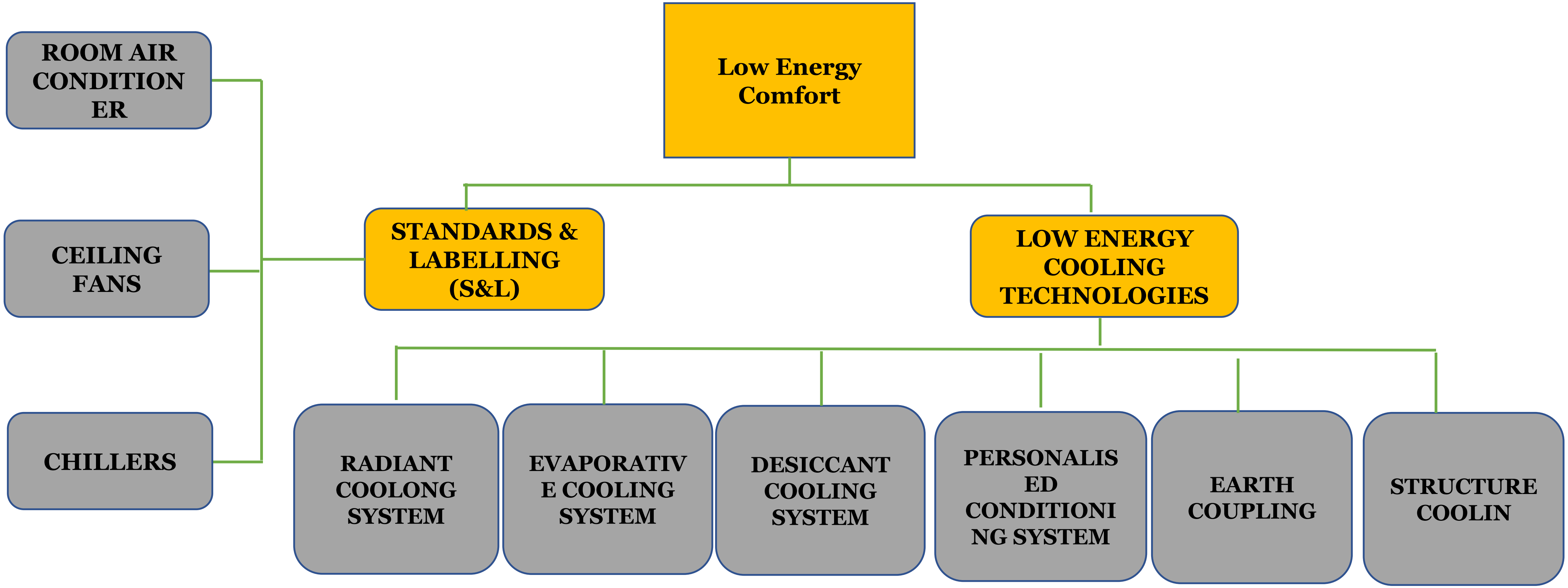
DAY 2

Technical exercise

08-A

LOW ENERGY COMFORT SYSTEM IN HOUSING

Low Energy Comfort System in Housing



Standards & Labeling (S&L)

S&L assists consumers in making educated decisions about appliance energy usage and promotes the market penetration of energy efficient appliances and equipment. BEE established the S&L program in 2006.

RACs are the only space cooling appliance under the mandatory labeling scheme. Ceiling fans and variable speed ACs are under the voluntary labeling scheme.

STANDARDS & LABELING (S&L)

- **ROOM AIR CONDITIONERS(RACs)**
- **CEILING FANS**
- **CHILLERS**

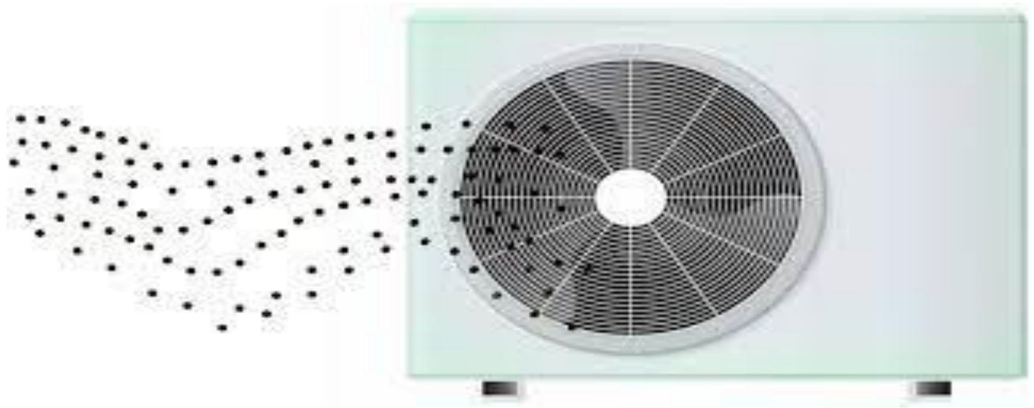
Standards & Labeling (S&L)

1 - ROOM AIR CONDITIONERS (RACs):

For variable capacity (inverter type) ACs, BEE established a new star grading technique called the Indian Seasonal Energy Efficiency Ratio (ISEER) in 2015.

This metric, which is based on the ISO-16358 standard with revisions to account for India's higher outdoor temperature ranges, will be used instead of the Energy Efficiency Ratio (EER).

ISEER takes into account the range of temperatures in Indian climate zones throughout the year to produce a more realistic estimate of cooling efficiency for the full year.



Standards & Labeling (S&L)

BEE star rating levels for inverter ACs effective from June 2015 through December 2019 (BEE, 2015)

STAR RATING	MINIMUM ISEER	MAXIMUM ISEER
1 – Star	3.10	3.29
2 – Star	3.30	3.49
3 – Star	3.50	3.99
4 – Star	4.00	4.49
5 – Star	4.50	-

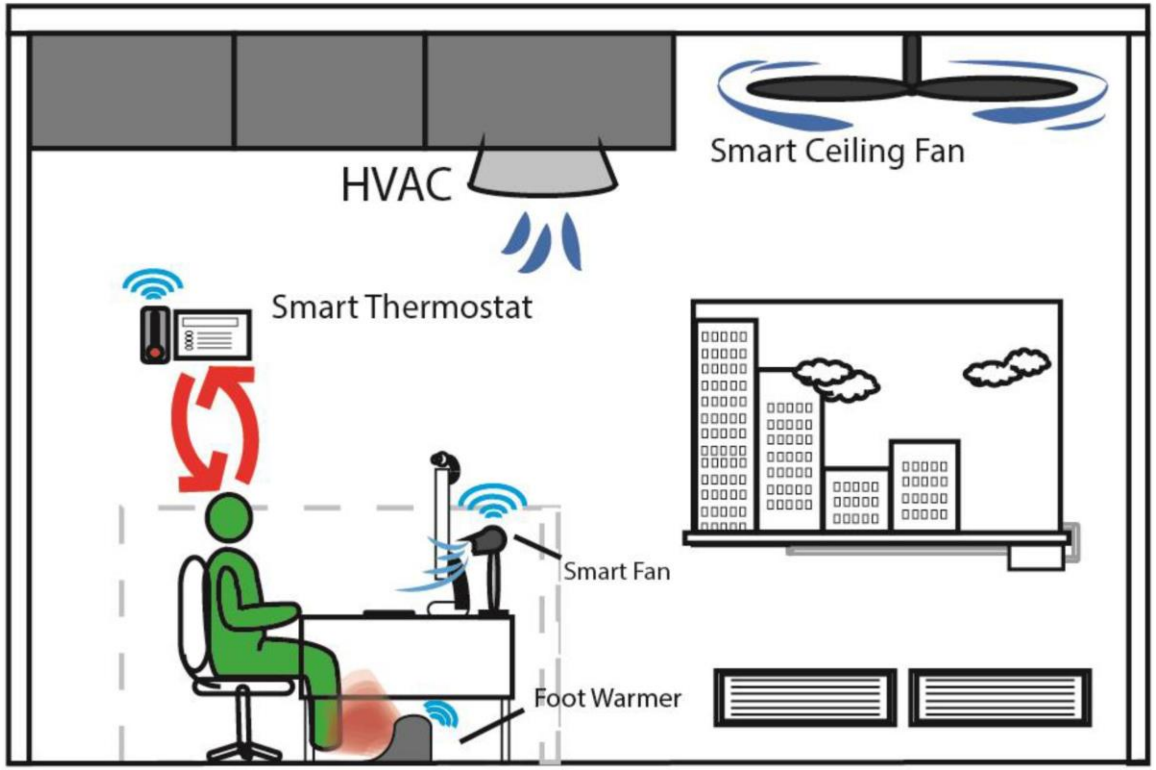
Standards & Labeling (S&L)

2 - CELING FANS:

Ceiling fans consumed 6% of the energy consumed by residential buildings in 2000, and are predicted to consume 9% by 2020 due to an increase in the number of ceiling fans installed.

Fan effectiveness, rather than efficiency, is a phrase used to describe the volume of air provided per minute per unit of power (m^3 /minute/W) delivered by a ceiling fan.

Both the BIS and the BEE give ratings to fans.



Standards & Labeling (S&L)

3 - CHILLERS:

ECBC (version 2) sets minimum chiller performance efficiency based on Air-conditioning, Heating, and Refrigeration Institute (AHRI) standards that provide test circumstances more reflective of climate in the United States and Europe.

Recognizing the significance of the chiller standard, the ISHRAE has undertaken the responsibility of designing chiller test conditions. The standard, created collaboratively by ISHRAE and the RAMA, establishes a new set of rating and performance testing parameters (temperature, part load weightages, and fouling conditions) for both air and water cooled chillers.

ISHRAE has also created a standard for evaluating and testing variable refrigerant flow (VRF) systems.

Low Energy Cooling Technologies

These are energy-efficient cooling systems that are not commonly used. These can be utilized as stand-alone cooling systems or in conjunction with traditional air conditioning systems.

LOW ENERGY COOLING TECHNOLOGIES

- RADIANT COOLING SYSTEM
- EVAPORATIVE COOLING
- DESICCANT COOLING SYTEM
- PERSONALISED CONDITIONING SYSTEM
- EARTH COUPLING
- STRUCTURE COOLING

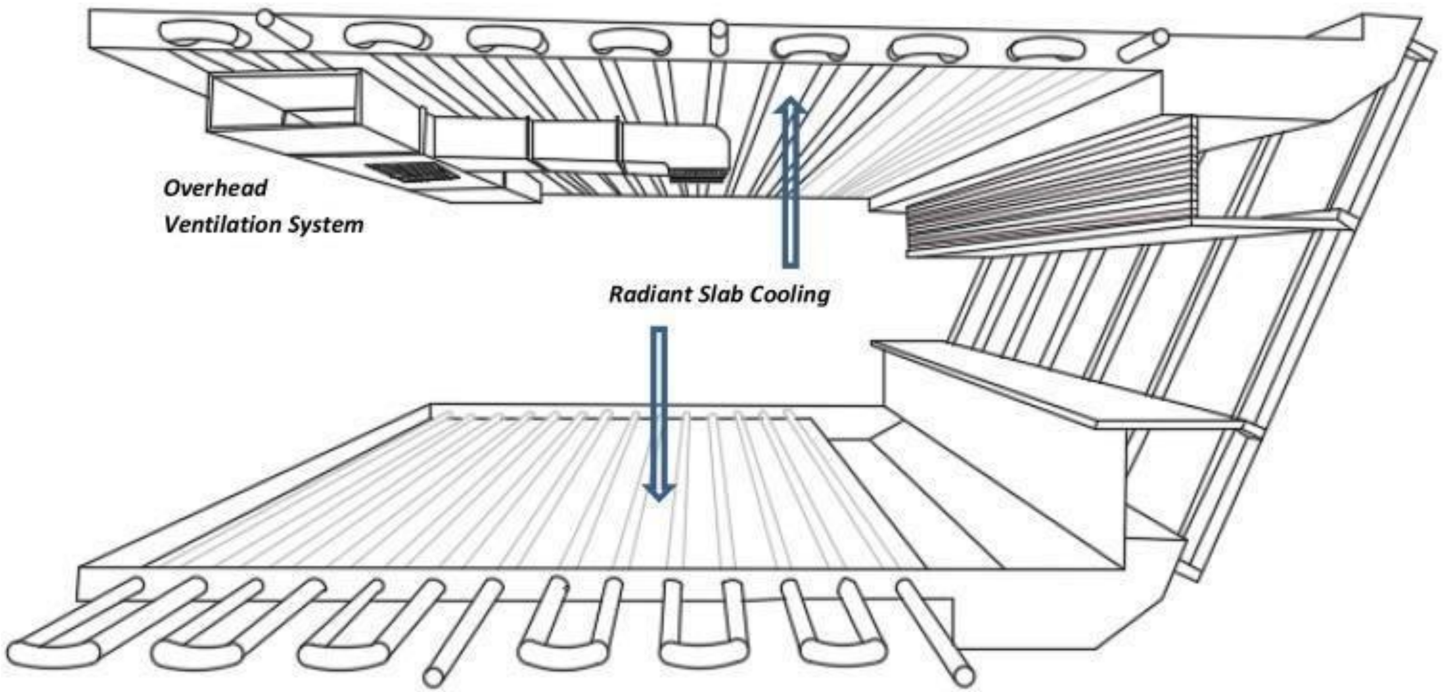
Low Energy Cooling Technologies

1 - RADIANT COOLING SYSTEM:

Radiant cooling makes use of actively cooled surfaces to enhance thermal comfort by transferring heat from the human body to the cooled surface via radioactive heat transfer.

Radiant-based HVAC systems absorb heat from the room, which is then removed by chilled water flowing through pipes installed in the floors, walls, or ceilings, or through externally fixed wall and ceiling panels.

The technique makes advantage of water's far higher thermal capacity than air.



Low Energy Cooling Technologies

2 - EVAPORATIVE COOLING:

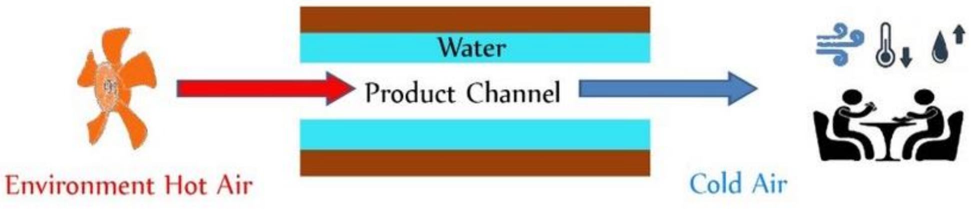
The evaporative cooling technology is based on heat and mass transfer between air and cooling water

DIRECT EVAPORATIVE COOLING

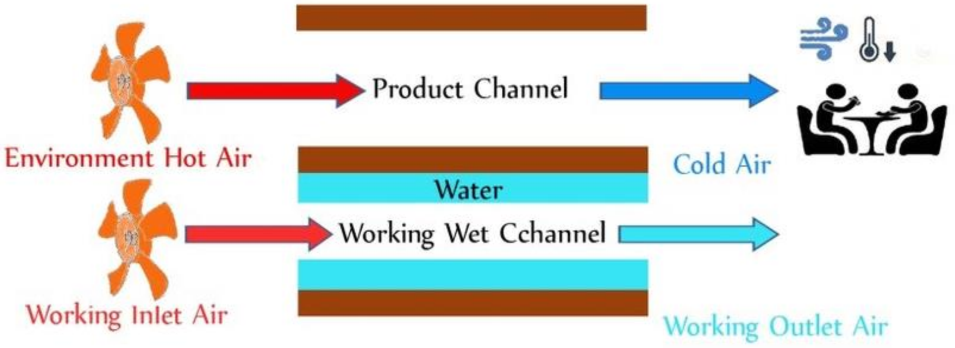
It is based on mechanical and thermal contact between air and water

INDIRECT EVAPORATIVE COOLING

It is based on heat and mass transfer between two streams of air, separated by a heat transfer surface with a dry side where only air is cooling and a wet side where both air and water are cooling



The Direct Evaporative Cooling System



The Indirect Evaporative Cooling System

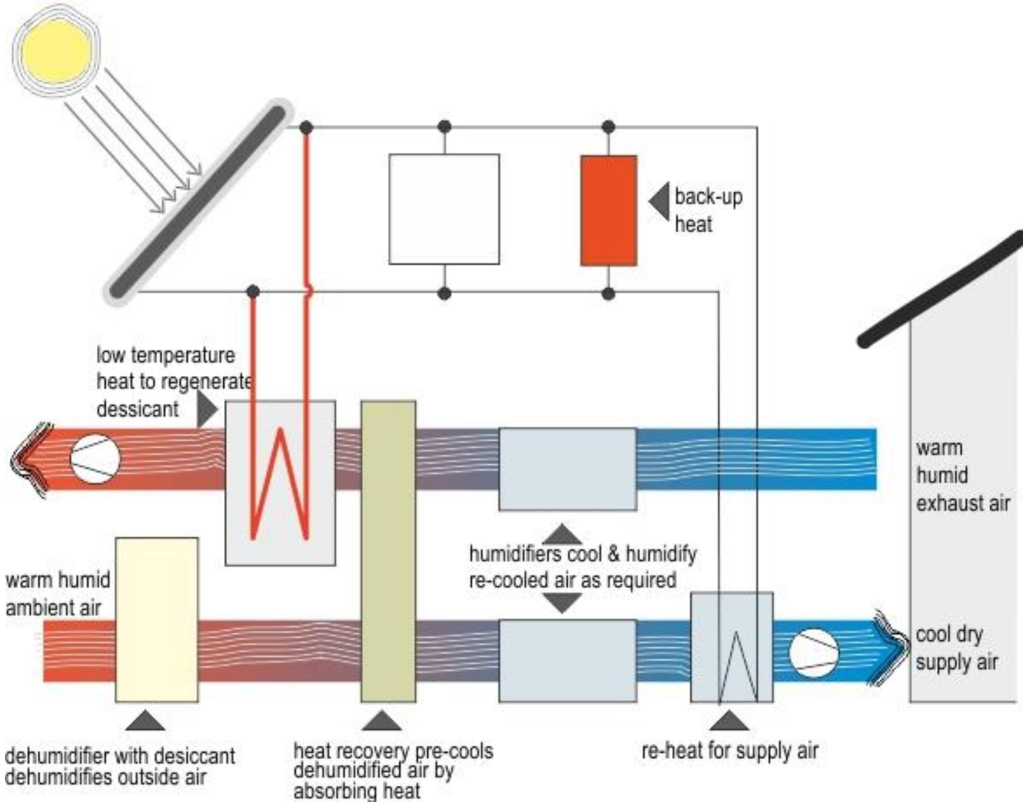
Low Energy Cooling Technologies

3 - DESICCANT COOLING SYSTEM:

A desiccant is a substance, either liquid or solid, which absorbs water molecules from the air and dehumidifies it.

DESICCANT COOLING SYSTEM

- **SOLID DESICCANT SYSTEM** – solid desiccant system where silica gel is used for a rotating bed of the wheel within the system
- **LIQUID DESICCANT SYTEM** – liquid desiccant system which consists of a contact surface, either a cooling coil or tower, wetted with liquid desiccant



The desiccant system also improves the quality of indoor air. Integration with traditional HVAC systems to remove latent heat can reduce cooling and heating energy usage by up to 30% and 5%, respectively.

Low Energy Cooling Technologies

PERSONALISED CONDITIONING SYSTEM

- A customized air-conditioning system at the office produces a microclimatic zone around a single occupant, ensuring that energy is only used where it is required.
- Because of its excellent localized energy utilization, this technology serves to improve thermal comfort for occupants while also reducing energy consumption.

EARTH COUPLING

- Due to the great thermal inertia of soil, the Earth maintains a relatively constant temperature just a few meters below the surface, which is less than the outside temperature in summer and higher in winter.
- By pumping or exchanging heat with the earth, geothermal technologies such as the Earth Air Tunnel Heat Exchanger (EATHE) and Ground Source Heat Pump (GSHP) utilize the earth's temperature stabilizing property to deliver central heating or cooling to a structure.

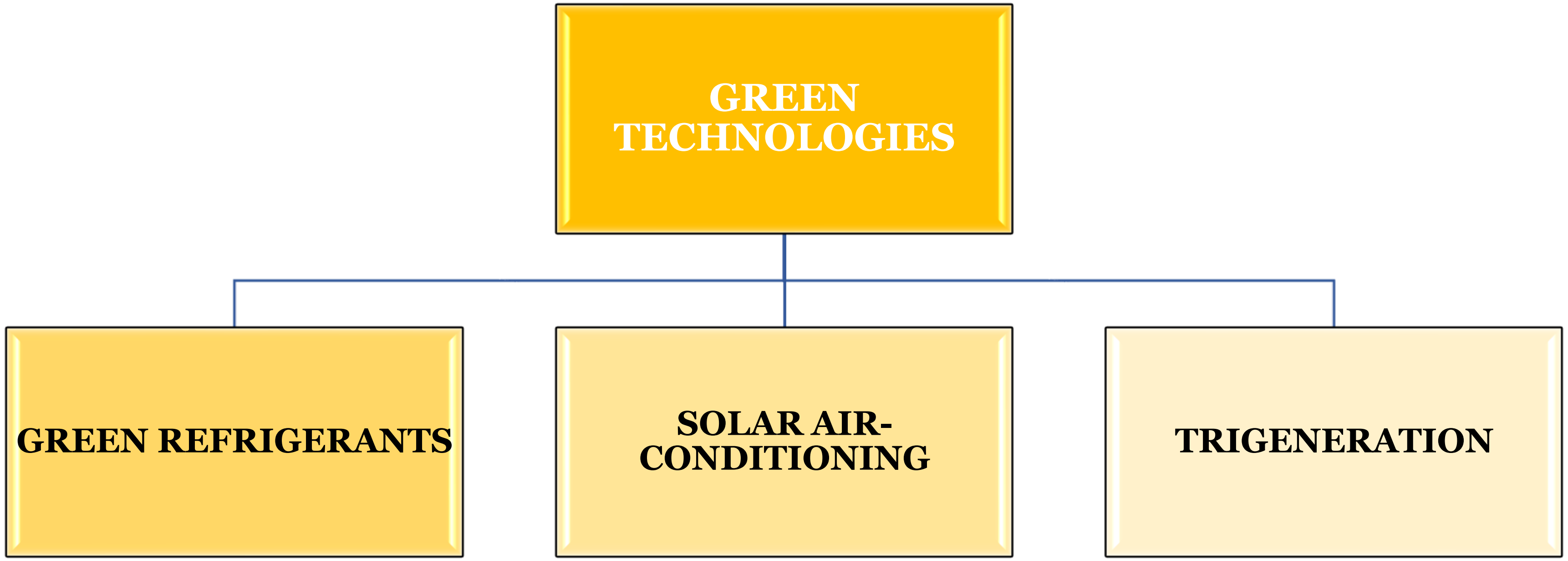
Low Energy Cooling Technologies

STRUCTURE COOLING

- By removing heat from the structure, structure cooling tries to lower the mean radiant temperature. This is accomplished by circulating water at room temperature through pipes implanted in slabs to drain heat from the building and prevent it from overheating. The larger thermal mass of water slows the transport of heat from the environment to the structure's innards.
- The heated water runs to the radiator, where it gives away the heat obtained and returns to the tank for recirculation, while the circulated water drains heat from the structure. Because it is a closed loop system, there is only one water requirement. There is no need to cold the water or use refrigerants; just the pump consumes energy.

Green Technologies

Green technology, such as RACs with green refrigerants, solar air-conditioning, and trigeneration, will have a significant influence on the environment if used wherever practical. India's energy security and contribution to minimizing climate change Changes in the climate.



Green Technologies

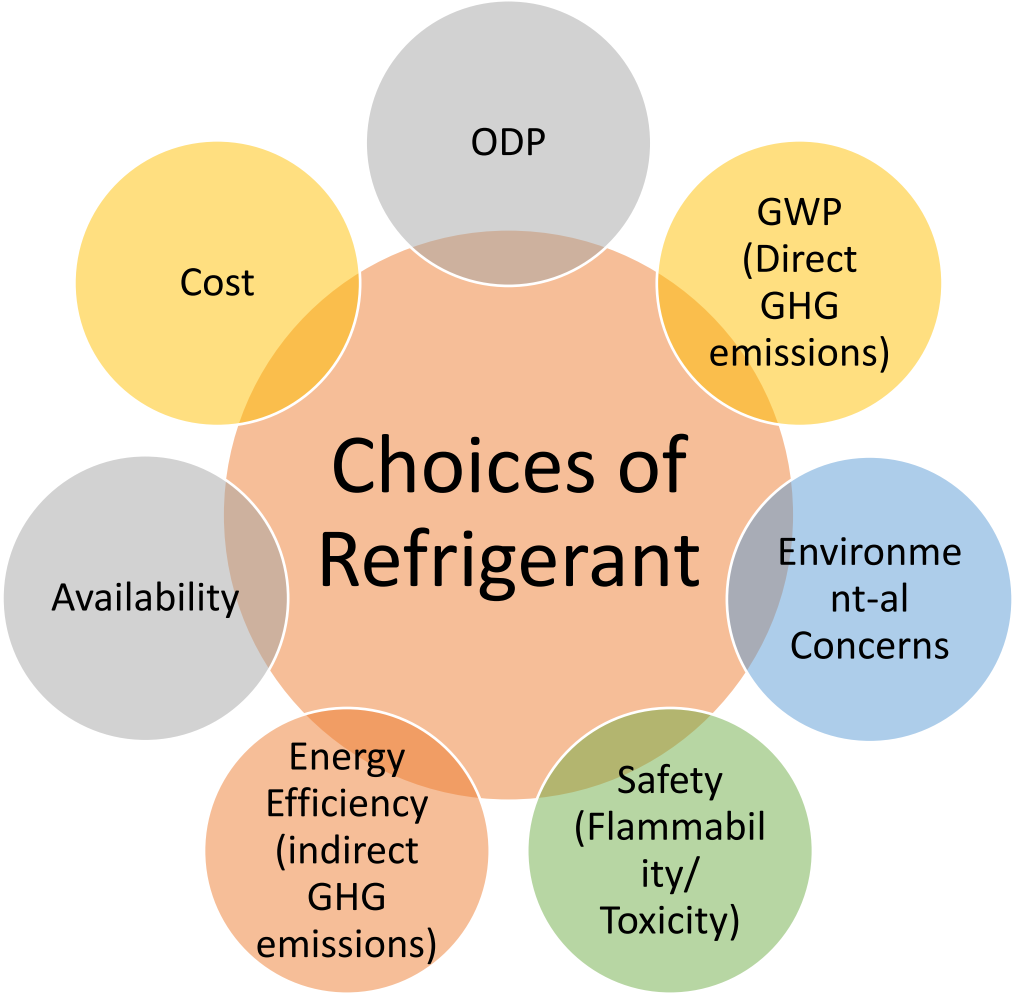
1 - GREEN REFRIGRANTS:

A green refrigerant would have the benefits of natural refrigerants and be energy efficient

Natural refrigerants have numerous advantages, including 0% ODP, a low GWP, participation in natural biogeochemical cycles, and the absence of permanent chemicals in the atmosphere, water, or biosphere. Carbon dioxide, ammonia, and hydrocarbons like propane, propene, and isobutene are among them. Natural refrigerants, like as isobutene in residential freezers and ammonia in big cooling systems, are commonly employed in various RAC applications.

One of the most significant issues with hydrocarbon-based natural refrigerants is the flammability, which can be mitigated by steps such as the use of appropriate materials, the selection of safe components, and operator training. CO2, a natural refrigerant, is inefficient in terms of energy use. When choosing a refrigerant, keep these considerations in mind. (2017, Green-cooling-initiative.org)

Green Technologies



A good refrigerant should be non-flammable, non-toxic, and odorless, with a very low GWP and no risk for ozone depletion.

Many next-generation refrigeration options are non-flammable and have an ultra-low GWP, making them suited for chiller applications with bigger refrigerant charge sizes, or non-flammable refrigerant mixes with a moderate GWP of less than 750.

The quickest way to accomplish environmental goals is to use non-flammable, low-GWP refrigerants in high-performance products.

Green Technologies

TYPES OF REFRIGERANTS AND THEIR GWP (ASSIMILATED FROM AEEE's SECONDARY RESEARCH

REFRIGERANT	GWP	ENERGY EFFICIENCY	COMPANIES	MARKET STATUS	COST
HCFC-22	High (1800)	High	All Phasing Out	GHG, scheduled for phase out under Montreal protocol	High
HFC-410a	High (1923)	Low	LG, Samsung, GE, Carrier	GHG, Ozone Safe	High
HFC-32	Medium (675)	High	Daikin, Fujitsu, Hitachi, Mitsubishi, Panasonic, Toshiba	Ozone Safe, Mildly flammable	Low
HC-290	Very Low (<5)	High	Godrej	Low GWP, best available for ozone safe in small room AC, highly flammable	Low
HFC BLENDS (DR7, L41, L20)	Medium (300-450)	Medium	DuPont, Honeywell	Low GWP, Low Flammable	Medium
HFOs	Very Low (<4)	Very High	In Research Phase	Environmental friendliness, cost-effectiveness	Low

Green Technologies

2 - SOLAR AIR-CONDITIONING:

Solar air-conditioning refers to any air-conditioning system that uses solar power

The vapor absorption method is used to provide cooling in thermally operated chillers. Instead of employing compressors, desorption is used to enhance the refrigerant's vapor pressure and temperature. Chilled water is produced by thermally driven chillers, which is subsequently utilized to cool hot or warm areas of a building.

Solar absorption chillers have very cheap operating and maintenance expenses, and they use very little electricity. Solar air-conditioning has a current market potential of over 0.7 million TR and is growing at a pace of around 17% per year.

SOLAR AIR-CONDITIONING CAN BE DONE THROUGH

- PASSIVE SOLAR
- SOLAR THERMAL ENERGY CONVERSION
- PHOTOVOLTAIC CONVERSION

Green Technologies

3 -TRIGENERATION:

Trigeneration Technologies Produces three forms of energies

- Electricity
- Heating
- Cooling

Which could be used to generate (with suitable equipment's)

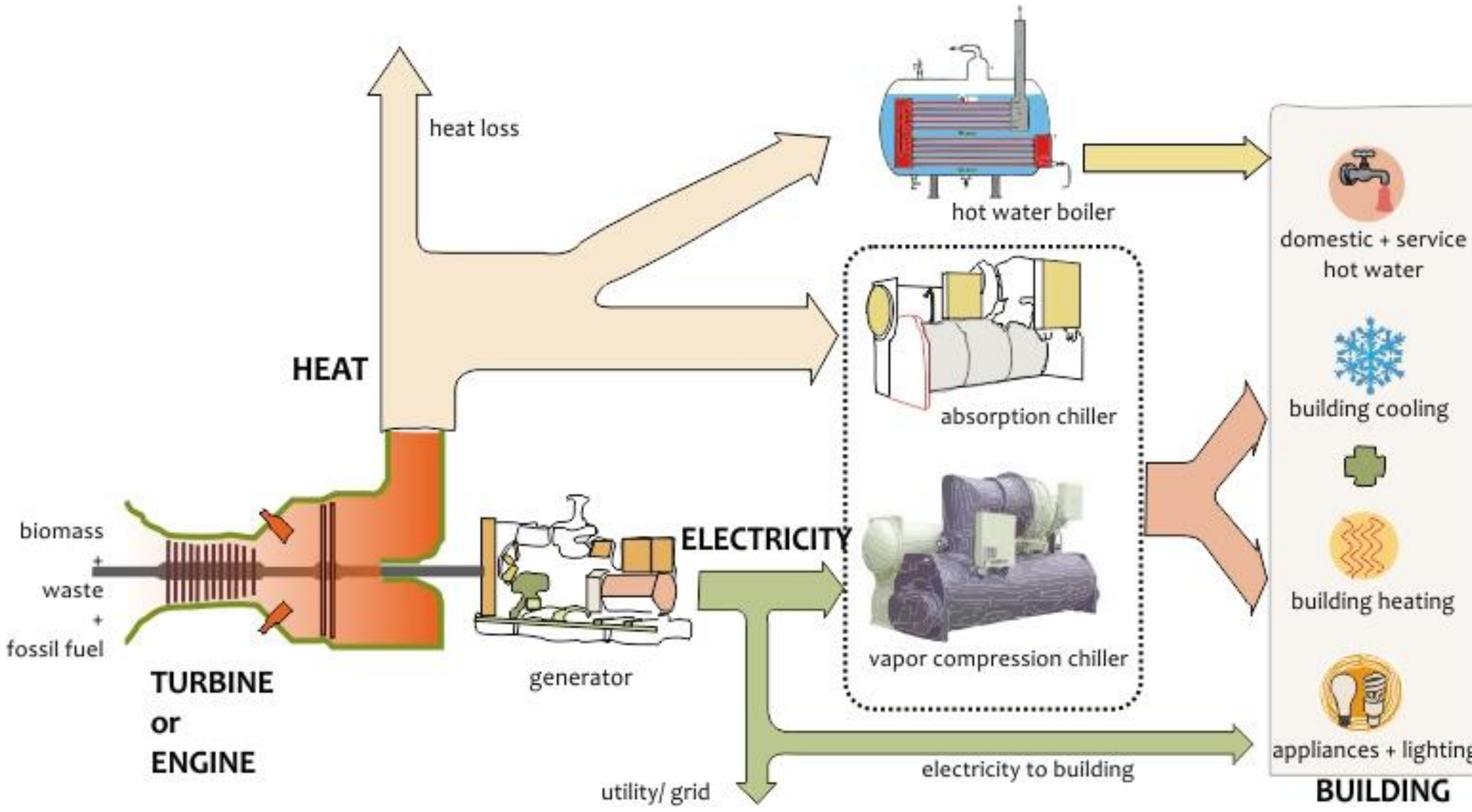
- Power
- Hot Water
- Air-Conditioning

Green Technologies

Absorption chillers can employ heat absorbed from waste burning, power generation with generators, or heat generated by solar panels to generate chilled water.

By utilizing a waste heat recovery system at the end user site, trigeneration systems can achieve great efficiency with no transmission losses.

If they can sell to the grid, they could potentially help India meet peak power demand and avoid harmful power outages.



Green Technologies

The most promising areas of trigeneration application include

- Hospitals
- Hotels
- Department Stores
- Data Centers
- Industries

where both electricity and heating or cooling demand is present.

08-B

RESIDENTIAL STAR LABEL

Objectives of Star Labelling

Informing the user

Helping consumer make a informed decision while buying/leasing through the provision of direct, reliable and costless information

Assistance for Energy Efficiency

- Assist the home owner & building industry to identify the extent to which a new or existing house has the potential through design & construction to be of high efficiency via the design tool developed for the program

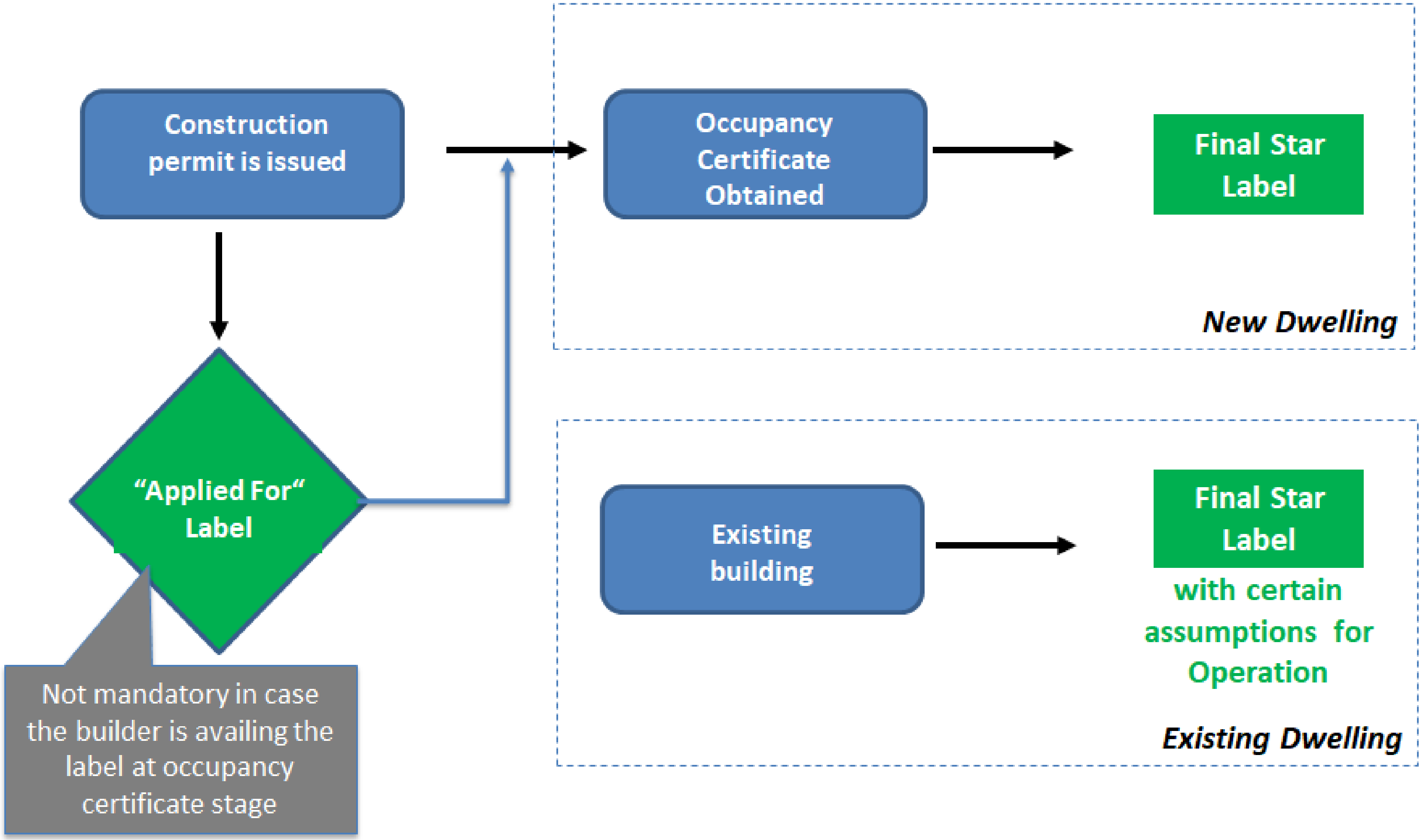
Market Transformation

Help transform the market by creating demand for energy efficient construction material and appliances and continue the process by scheduled revisions of labelling standards

Making Energy Efficient Homes

Make energy efficient homes to tackle the problem of growing power consumption in the sector which is projected to rise from 250 BU in 2018-19 to 700~ BU in 2030

Classification of labelling stages



Application processing stage

Label generation	New Dwelling stages			Existing Dwelling
	Developer	Developer	Owner	Owner
	"Applied For" Label	Final Star Label	Final Star Label	Final Star Label
Approval letter for the Label	Yes	Yes	Yes	Yes
Dwelling Passport (soft copy)	NA	Yes	Yes	Yes
Dwelling Name Plaque	NA	Yes	Yes	Yes

Star Rating Criteria & Calculation

Star Rating awarded in the basis on EPI (**Energy Performance Index**)

Energy Performance Index = Annual Energy Consumption (**kWh**)/Built up area (**m²**)

EPI Calculation = EPI for air conditioned spaces (~20% area) with 24 °C as set point (**E1**) with Air conditioner switched ON during occupied hours + EPI for other spaces (~80%) with natural ventilation (**E2**) set points defined by IMAC.
And EPI for other appliances: E3

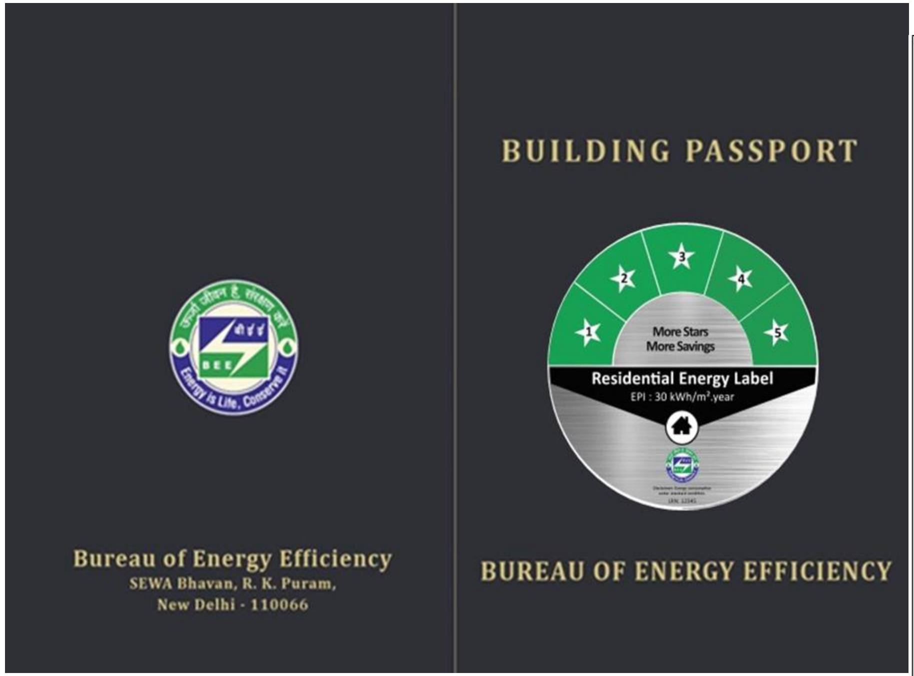
E1 & E2 includes following systems: Building envelope characteristics, Lighting system, and comfort system (AC)

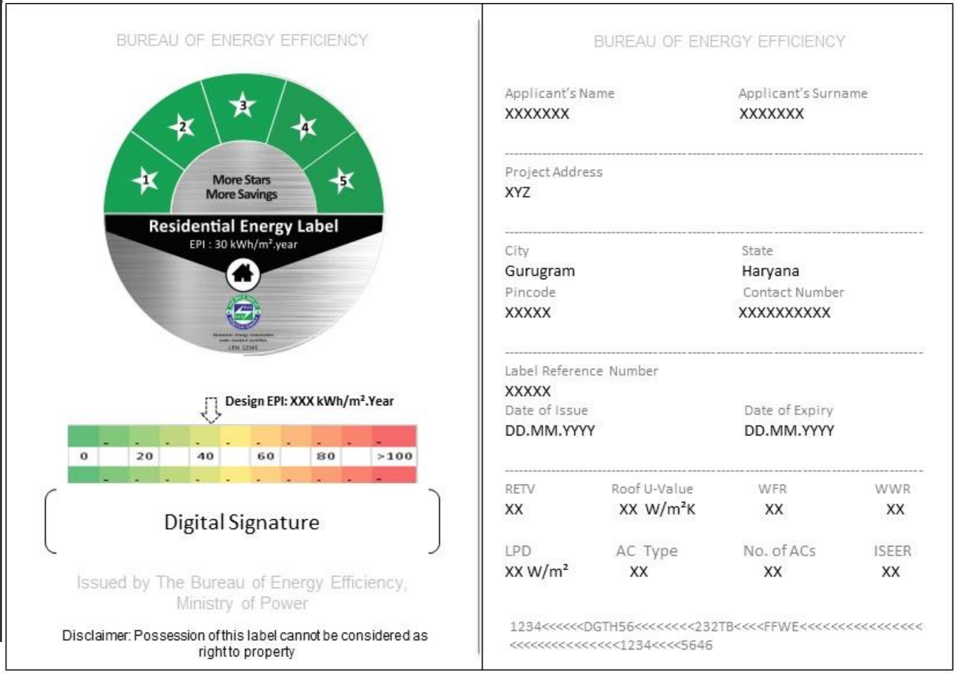
E3 includes appliances such as: Microwave oven, Grinder, , Refrigerators, TV, Water Pump, Washing Machine, etc.

Passport

The plaque will be provided to the applicant (developer / owner) of the respective residential dwelling upon approval of 'Final' label. The developer or owner would be required to submit request to BEE for the plaque.

Passport





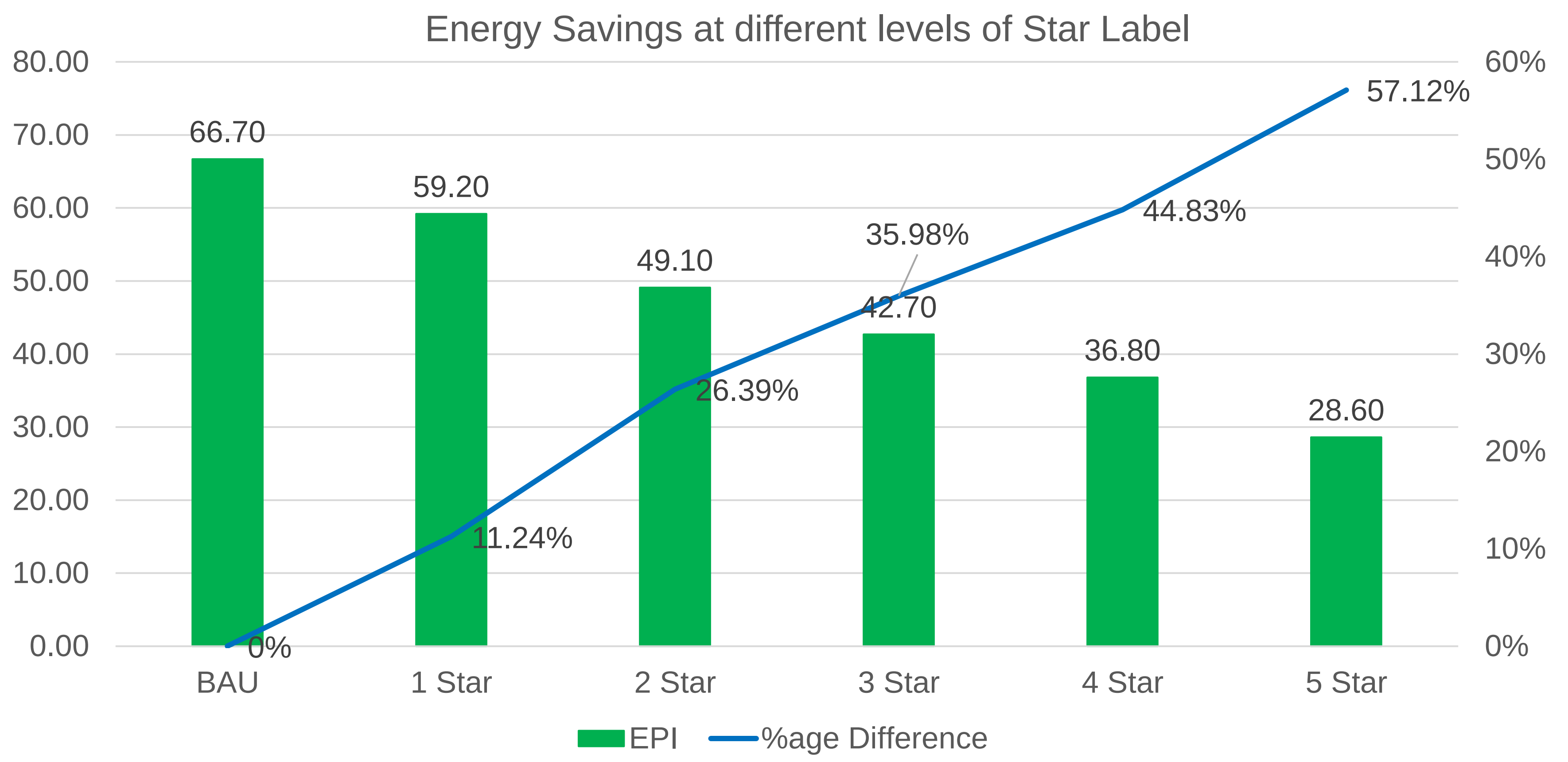
Upon approval from BEE, a building passport will be generated based on the details provided by label applicant.

The e-passport will be auto-emailed to the applicant

Indicative measures to achieve different star labels

Inputs	1 star	2 star	3 star	4 star	5 star
Wall U-Value ($W/m^2.K$)	**2.34 $W/m^2.K$ (230mm Burnt Clay Brick)**	**1.78 $W/m^2.K$ (230mm Flyash Brick + Plaster)**	**1.55 $W/m^2.K$ (112.5mm Brick Wall + 50mm Air Gap + 112.5mm Brick Wall)**	**0.8 $W/m^2.K$ (200mm AAC Block)**	**0.88 $W/m^2.K$ (230mm Brick Wall + 25mm Insulation)**
Glass U-Value ($W/m^2.K$)	**5.8** $W/m^2.K$ (Single Glazed Unit 6mm)	**5.8** $W/m^2.K$ (Single Glazed Unit 6mm)	**1.76** $W/m^2.K$ (6mm LowE Glass + 13mm Air + 6mm Clear Glass)	1.76 $W/m^2.K$ (6mm LowE Glass + 13mm Air + 6mm Clear Glass)	**1.34** $W/m^2.K$ (6mm LowE Glass + 13mm Air + 6mm Clear Glass)
SHGC	**0.82**	**0.82**	**0.57**	**0.57**	**0.57**
Roof U-Value ($W/m^2.K$)	**1.76** $W/m^2.K$ (100mm RCC + 40mm Foam Concrete + 15mm Inner Plaster)	**1.76** W/m2.K (100mm RCC + 40mm Foam Concrete + 15mm Inner Plaster)	**1.76** W/m2.K (100mm RCC + 40mm Foam Concrete + 15mm Inner Plaster)	**1.02** $W/m^2.K$ (150mm RCC + 25mm Insulation XPS + Brick Tile + 15mm inner plaster)	**0.7** $W/m^2.K$ (150mm RCC + 40mm Expanded polystyrene + 15mm inner plaster)
AC ISEER	**3.1**	**3.5**	**3.5**	**4.0**	**4.5**
LPD (W/m^2)	**3.0**	**2.0**	**2.0**	**2.0**	**1.4**
WWR	20%	15%	15%	15%	10%
EPI	**59.21**	**49.1**	**42.7**	**36.8**	**28.6**

Energy Savings at different star labels



This energy consumption reduction can be attributed to the reduced WWR at 15% compared to 25% for BAU case, a thermally efficient double-glazed unit, air cavity in the external wall assembly and a layer of foamed concrete in the roof

Residential Building Star Rating Plan

Hot & Dry

★	55 < EPI ≤ 67
★★	47< EPI ≤ 55
★★★	38< EPI ≤ 47
★★★★	29 < EPI ≤ 38
★★★★★	EPI ≤ 29

Warm & Humid

★	58<EPI≤64
★★	49<EPI≤58
★★★	39<EPI≤49
★★★★	30<EPI≤39
★★★★★	EPI≤30

Composite

★	52<EPI≤60
★★	45<EPI≤52
★★★	37<EPI≤45
★★★★	29<EPI≤37
★★★★★	EPI≤29

Temperate

★	28<EPI≤31
★★	24<EPI≤28
★★★	21<EPI≤24
★★★★	17<EPI≤21
★★★★★	EPI≤17

Scope & type of labelling Program: Bureau of Energy Efficiency

Energy Efficiency Label for Residential Buildings

‘**Applied For**’ Label

‘**Final**’ Label

New Residences

Existing Residences

EE Label for Res Buildings

Label Criteria

There is **no minimum requirement** with respect to Area or Connected load (kW) for a dwelling unit to be covered under this labeling program.

- Star Rating awarded in the basis on EPI (**Energy Performance Index**)
- Energy Performance Index = Annual Energy Consumption (**kWh**)/Built up area (**m^2**)
- BEE has prepared an **online platform** for the User of Label to apply for seeking an award of label under this program
- The online platform consists of a **Simulation-Based Tool** that will calculate the EPI of respective dwelling unit

Outline of the process for awarding BEE Star Label

- BEE Star Label for Residential Building:
- Applied For Label (specifically for developers or under construction residential buildings – Voluntary)
- Final Asset Label

Preparation stage
- User registration
- Project/ property registration

Application processing
- Application submission
- Scrutiny of received application
- Approval for label

Implementation stage
- Label renewal
- Label transfer
- Changes in label awarded already
- Uptake strategies

Monitoring & Verification
- Verification audits
- Data reporting for monitoring the progress

08-C

BEST PRACTICES

Best Practices in Indian Buildings

SIERRA's eFACiLiTY® Green Office Building, Coimbatore

• Location	Coimbatore, Tamil Nadu
• Coordinates	11° N, 77° E
• Occupancy Type	Office
• Typology	New Construction
• Climate Type	Warm and Humid
• Project Area	2,322 m2
• Grid Connectivity	Grid Connected
• EPI	56 KWh/m2/

- Window Wall Ratio (WWR) is less than 40%
- glazing-harvest 86% daylight
- 100% rainwater harvesting and 100% wastewater treatment to tertiary standards- Zero discharge
- species- Landscape water demand reduce 40%

SIERRA's eFACiLiTY® Green Office Building, Coimbatore

Air-Conditioning

- Variable Refrigerant Flow system- Energy Efficiency Ratio (EER) of 13.85
- Smart Sensors - intelligently maintain temperature and fresh air supply

Indoor Air Quality

- Triple filtering & Demand Controlled Ventilation aided by CO_2 sensors
- Real-time IoT sensors- levels of volatile organic compounds, humidity, and particulate matter 2.5 & 10

Water Efficiency

- 89% water savings are achieved using waterless urinals, high efficiency sensor faucets, reuse of treated water for flushing and reuse of stored rainwater for domestic use.
- Sequencing Batch Reactor (SBR) based STP System, rainwater filtration, Raw water treatment UV treatment etc.

Artificial Lighting and Controls

- 100% LED lights- 0.26 W per sq ft
- Sensor-activated passage lights, occupancy sensors, and lux sensors

Energy Monitoring

- Renewable Energy
- 60 KW rooftop solar PV with the automatic sprinkler cooling system- meets 80% of the energy demand and about 33% of the energy use further reducing the EPI to 18.8 KWh/m2/year

Best Practices in Indian Buildings

Industrial building

- Location: Lodsi, India
- Year :2019
- Area: 1000 Sqft
- Architects: Morphogenesis
- Purpose: manufacturing facility for a modern skincare company
- EPI (energy performance index) of 35kWh/m2/year
- https://www.archdaily.com/

Industrial building

Climate Responsive Design

- The built form draws inspiration from the traditional Garwahli 'kholi' (house).
- A rectilinear volume-oriented along the East-West axis has been planned with a central entry that divides the facility into two parts.
- The functions that require a cooler environment (herb grinding, packaging, and storage) are located on the ground floor, whereas the preparatory functions with high internal heat gain are located on the upper floor.
- The North-South-oriented butterfly roof form, reminiscent of the traditional roof not only provides a modern aesthetic but also permits the use of large openable windows that take advantage of the prevailing Northeast and Southeast winds for ventilation further providing 80% naturally daylit spaces.

Renewable Energy

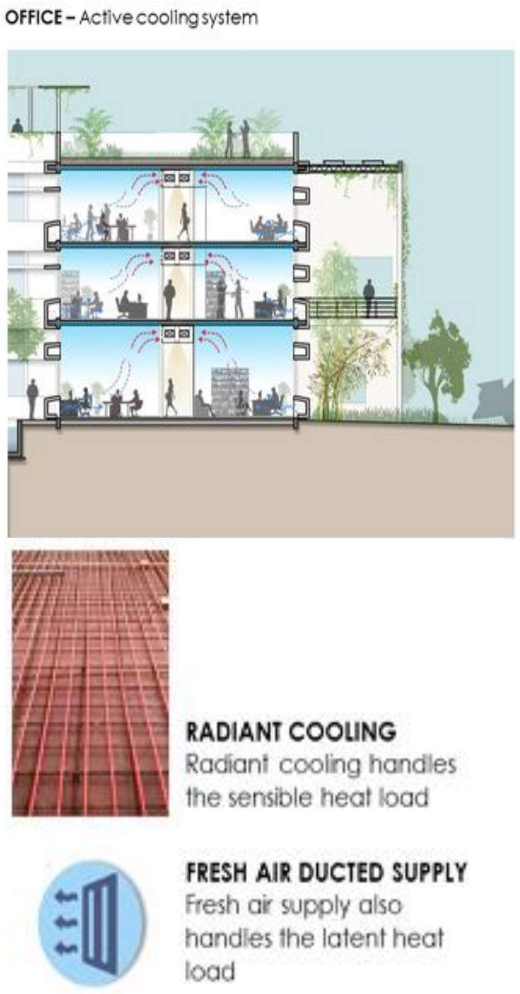
- Solar roof generating 50kWp

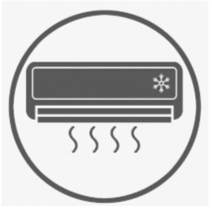
Unnati Office

- Location Greater Noida, Uttar Pradesh
- Coordinates 29° N, 78° E
- Occupancy Type: Office, Private
- Typology New Construction
- Climate Type Composite
- Project Area 3,740 m2
- Date of Completion- 2018
- Grid Connectivity- Grid-connected
- EPI 60 kWh/m2/yr.
- https://www.archdaily.com/
- The building performs 59% better than a conventional office building in the region, and 40% of the building energy consumption is met through on site renewable energy generation

Ground Floor Plan – Office layout

Unnati Office



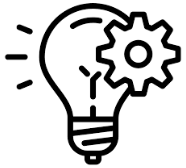


Air-Conditioning

- The building has a hybrid HVAC system which is a combination of water-cooled air handling units and ceiling-embedded radiant cooling system.
- Cooling load distribution of the system is such that 55% of the load is met by the radiant cooling system and 45% by AHUs.

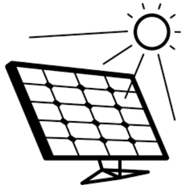
Building Envelope and Fenestration

- Truss reinforced insulated concrete panels (TRIC) used for the exterior walls are 25 mm concrete (AAC), 60 mm expanded polystyrene (EPS), and 25 mm concrete (AAC), and 10 mm plaster.
- The green roof insulation materials are 13 mm extruded polystyrene insulation and a 300 mm layer of green roof soil substrate



DayLighting

- 90% of the office spaces, including the core and service areas, receive uniformly distributed daylight.
- This can be attributed to the form, central courtyard, shallow floor plates, appropriate sizing and distribution of openings.
- All the windows have box shading that prevents glare.



Renewable Energy

The building draws 40% of its energy from the roof-top PV plant. The installed 100 kW solar PV generates 146 MWh/yr.

Best Practices in International Buildings

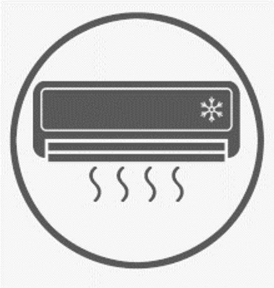
Shenzhen Institute of Building Research (IBR) Headquarters

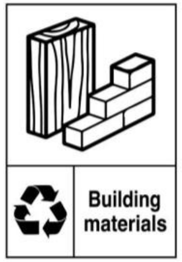
- Location Shenzhen, China
- Coordinates 39° N, 116° E
- Occupancy Type Office + research labs
- Typology New Construction
- Climate Type Humid subtropical
- Project Area 18,169 m2
- Grid Connectivity Grid Connected
- EPI 63 kWh/m2/yr
- https://www.hpbmagazine.org/
- Roof garden (green roof) shaded with a PV canopy

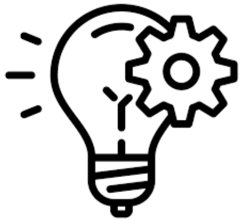
- Walls Type Insulated concrete panel with aluminum cladding
- Glazing Percentage Varies by orientation from 30% to 70%
- Windows-Effective U-factor for Assembly 0.35 Btu/h·ft°F
- Solar Heat Gain Coefficient (SHGC) 0.4
- Visual Transmittance 0.45
- Acoustic Isolation Performance 60 dbA

Ministry of Housing and Urban Affairs
Government of India

Shenzhen Institute of Building Research (IBR) Headquarters







Air-Conditioning

Natural ventilation in all the office spaces allows for direct contact with nature, and uses 30% less air conditioning

Water-loop heat pump, water-source heat pump, temperature and humidity are independently controlled, and high-efficiency and energy-saving air conditioning.

Roof Garden

A vertical landscape distributed throughout the building doubles the area available for greenery compared to the building's original footprint. The roof garden, "sky garden," and patio garden all help restore the ecological balance of the building site.

Material

Concrete with high-percent recycled material, wood products with 10% recycled materials. Construction materials sorted and collected for recycling. Use of local and native materials. Low-emission interior finishes

Artificial Lighting and Controls

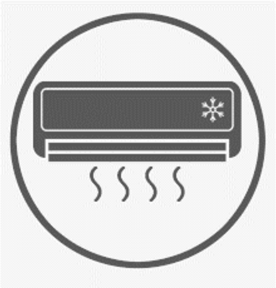
Daylight for all the office spaces means no artificial lighting is needed during the day and provides views of the surrounding mountains from all of the workstations

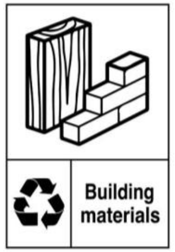
Best Practices in International Buildings

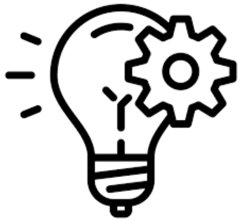
Bayalpata Hospital

- Location: Achham Nepal
- Coordinates: 29° N, 81° E
- Occupancy Type: Medical Complex
- Climate Type- Subtropical (due to elevation)
- Project Area: 4,225 m2
- Date of Completion 2019
- Grid Connectivity: Grid-connected
- EPI- 10 kWh/m2/yr
- The architecture maintains a vernacular scale through setbacks, gabled roofs, and low-cost heat-storing materials.

Bayalpata Hospital







Air-Conditioning

The structures comprises of massive rammed earth walls with insulated roofs. Material with thermal mass retains daytime heat gain in winter, while keeping the interiors cool by preventing overheating during summer.

The cross-breezes through courtyards, aided by clerestory ventilation and ceiling fans, promote natural ventilation and improve comfort conditions

Passive Strategies

The architecture maintains a vernacular scale through setbacks, gabled roofs, and low-cost heat-storing materials.

The complex includes low-rise one- and two-story structures organized around landscaped courtyards. The structures are heated and cooled passively (with the exception of the operating theatre and laboratories that are mechanically conditioned).

Material

Soil from the site was mixed with 6% cement content to stabilize the earth for better durability and seismic resistance. Reusable, plastic lock-in-place formwork facilitated faster construction, while local stone was used for foundations, pathways, and retaining walls.

Artificial Lighting and Controls

Inside the buildings, tall narrow windows and south-facing series of glazed clerestories brings in natural daylight reducing the need for artificial lighting.

Best Practices in International Buildings

Nowon Energy Zero House (EZ House)

- Location: Seoul, South Korea
- Coordinates 37° N, 127° E
- Occupancy Type- Multi-unit housing complex
- Climate Type Continental
- Project Area 17,652 m2
- Grid Connectivity Grid Connected
- https://www.schoeck.com/en/case-studies/nowon-energy-zero-house-ez-house

प्रधान मंत्री आवास योजना-शहरी
Pradhan Mantri Awas Yojana-Urban
GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA
Ministry of Housing and Urban Affairs
Government of India
आज़ादी का अमृत महोत्सव
bmtpc
giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Nowon Energy Zero House (EZ House)

- **Nowon EZ House,** Korea's first zero-energy multi-unit housing complex, is the result of the project “Zero Energy Housing Activation Optimization Model Development and Demonstration Complex Development”
- Nowon EZ House was built using the highest level of passive technology and materials in Korea, some of which were the first to be used in the country.
- Structural thermal break solutions Schöck Isokorb® XT type K and XT type Z have been applied to prevent the thermal bridges in the balcony area.
- Thanks to the new technologies, EZ House is aimed to maintain a temperature of 20°C to 22°C in winter and 26°C to 28°C in summer – without any heating or cooling

Mobil House

- Location Dhaka
- Coordinates 23.8° N, 90.4° E
- Occupancy Type: Office
- Climate Type Tropical wet and dry climate
- Project Area 6,673 m2
- Date of Completion Oct 2019
- Grid Connectivity Grid-connected
- EPI (kWh/m2/yr)- 58 kWh/m2/yr

Site Layout & Planning
Due to size constraints of the site, the green cover on site is minimal. However, significant foliage has been incorporated within the large terraces distributed throughout the building. Potted plants and vertical gardens compensate for the lack of surface green cover.

Climate Responsive Design
The most striking feature of the building includes the landscaped and shaded terraces. These act as thermal buffers for the interior spaces.

Mobil House

Form and Massing

- The building mass has been oriented such that circulation elements like lift core and staircases are situated along the West façade.
- This shields the regularly occupied spaces like offices and reception from the solar gains from the west façade.
- The northeast façade, with less solar gain potential, incorporates large windows to allow daylight and outdoor views.

Facade and Envelope

- The envelope is made of 300 mm thick concrete walls, leading to high thermal mass which shields the buildings from heat gain during the daytime.
- The deep building terraces and courtyards enhance biophilia and create shaded outdoor breakout spaces.
- the windows – double-glazed panels with low emissivity and a U-value 1.1 W/m2k – also reduce heat gain.
- The glazing has a shading coefficient of less than 0.25, leading to further reduction in solar heat gain.

Daylight Design

- The building form is optimized to let in daylight, blocking solar heat gain.
- This is done through the deep terraces of the building which provide shading to the north-east façade.
- This façade, with its row of large windows, also lets in plenty of daylight.
- A significant number of occupants have access to daylight and views to the outside

Q&A

Vote of Thanks