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

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RACHNA

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

RESILIENT, AFFORDABLE AND COMFORTABLE HOUSING THROUGH NATIONAL ACTION

One-day Training Program: Senior Govt. Officials

|Date: 4th August 2022 |

| Venue: Hotel Le Lac Sarovar, Ranchi |

“ Innovative Construction Technologies & Thermal Comfort for Affordable Housing”

INTRODUCTION

प्रधान मंत्री आवास योजना-शहरी
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RACHNA

RESILIENT, AFFORDABLE AND COMFORTABLE HOUSING THROUGH NATIONAL ACTION

1938+ STAKEHOLDERS trained in 50 Trainings across 17 States

495+ Government officials

595+ Practitioners & Professionals

390+ Contractors & Const. workers

458+ Students

Rising global temperatures

A frightening reality in times of extreme weather events like heatwaves.

India's energy commitment

Housing for all mission needs to fulfill housing needs without any compromise on environmental concerns.

Thermal comfort for all

Habitants need housing that is thermally comfortable to live in – reducing the need for active cooling means like AC/Desert coolers.

SUSTAINABLE DEVELOPMENT GOALS

3 GOOD HEALTH AND WEL-BEING | 7 AFFORDABLE & CLEAN ENERGY | 9 INDUSTRY, INNOVATION AND INFRASTRUCTURE | 11 SUSTAINABLE CITIES AND COMMUNITIES | 13 CLIMATE ACTION

The Climate Smart Buildings Project in partnership with Ministry of Housing & Urban Affairs is hosting **75** trainings under the following categories:

- 22 Trainings for Built-environment professionals & Govt. Departments
- 13 Vocational Trainings
- 31 Trainings for Senior Govt. Officials & Policy makers
- 9 Awareness sessions for students
- 22 Additional Capacity Building Workshops
- 2 International knowledge exchange programs

Ministry of Housing & Urban Affairs in partnership with The Climate Smart Buildings Project is hosting **75** trainings and events attended by over **2500** participants across **30** cities to raise awareness on Thermal comfort in affordable housing

Session 1

01

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 an efficient 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

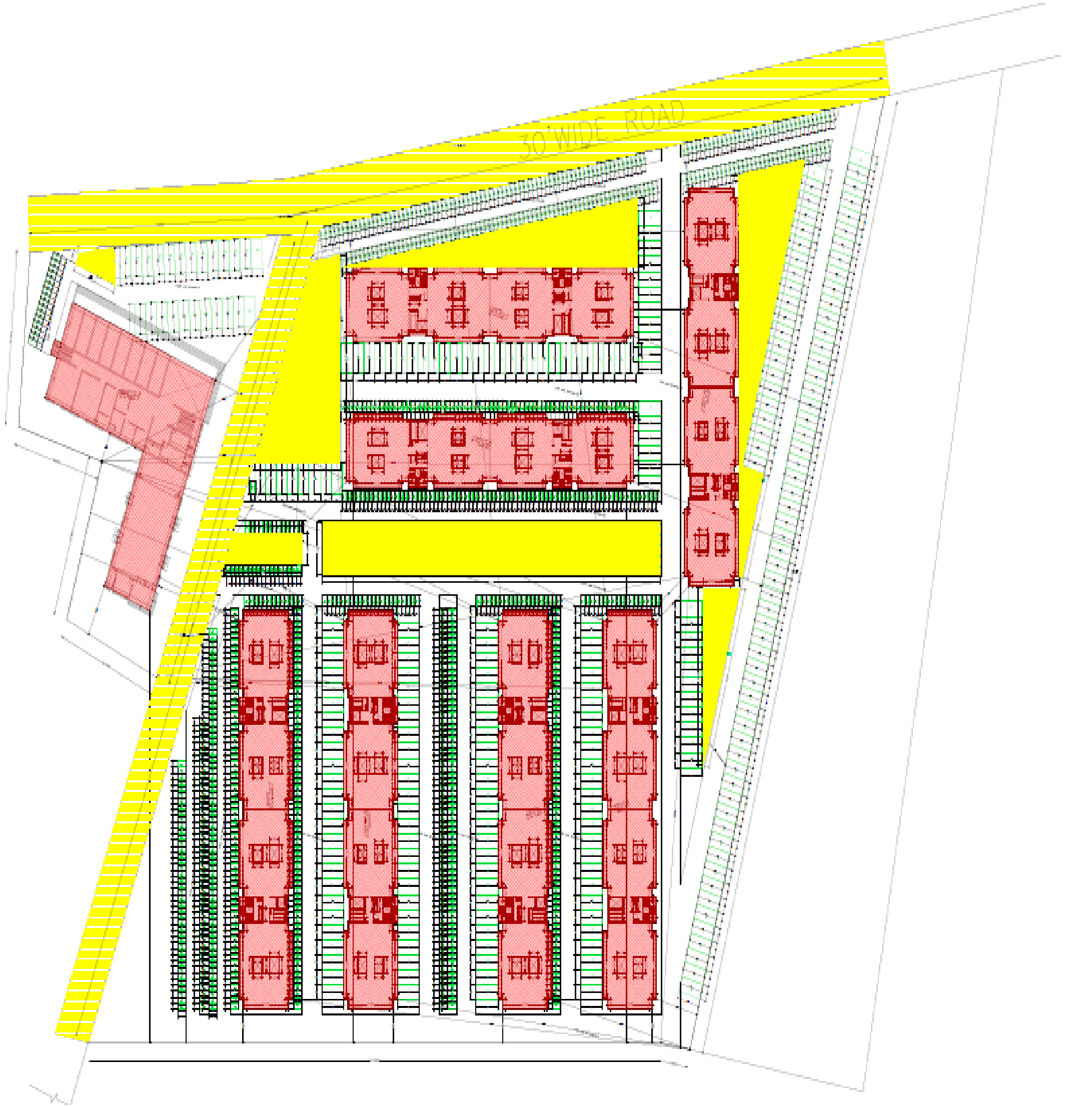
PVC Stay in Place Formwork System

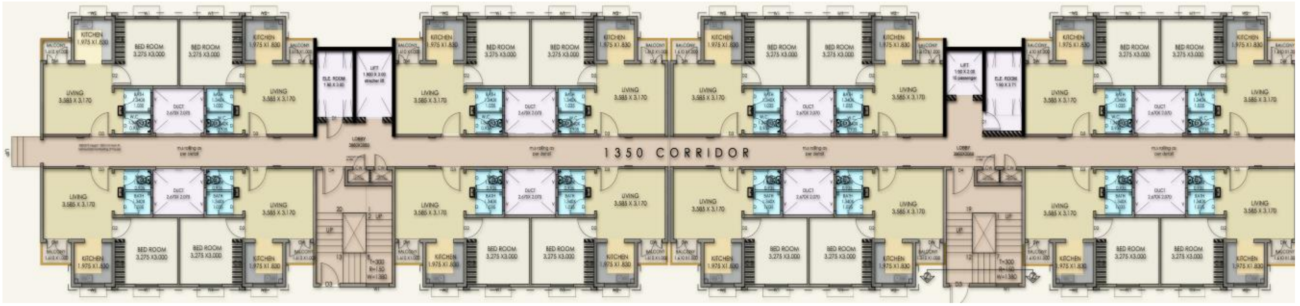
- LHP Location: Lucknow, Uttar Pradesh
- No of Houses: 1040

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%.



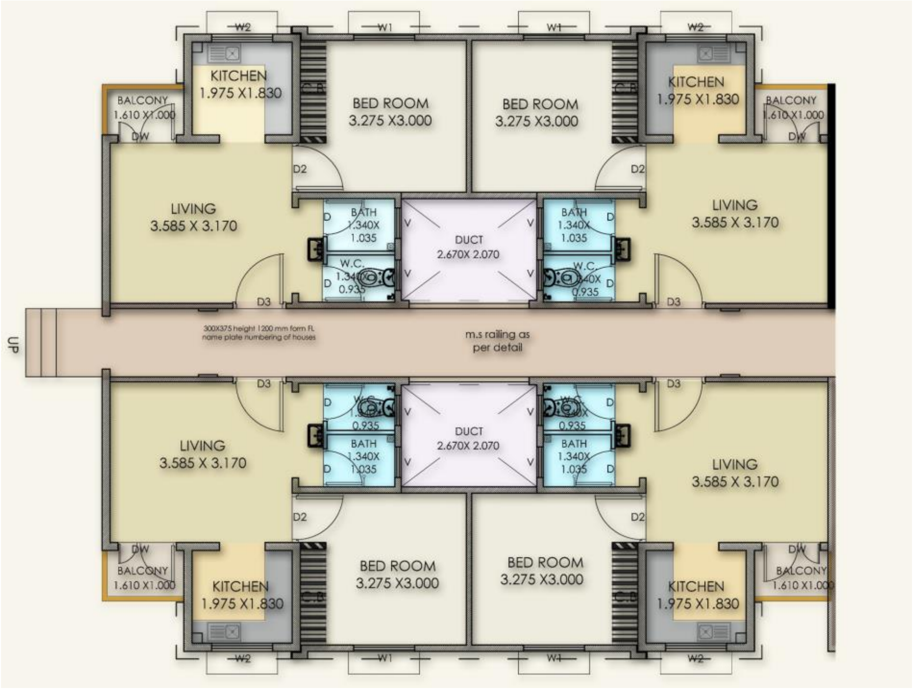


Typical floor plan

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

Ministry of Housing and Urban Affairs
Government of India

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

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.

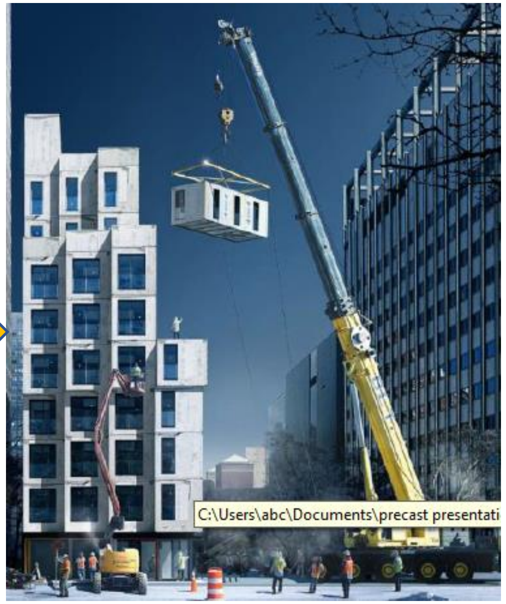
Prevalent Construction Systems

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

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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

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.

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

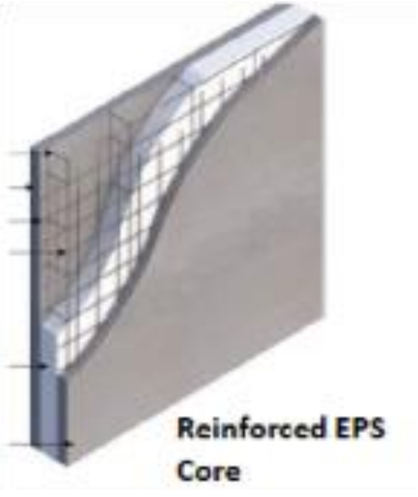
4

(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.

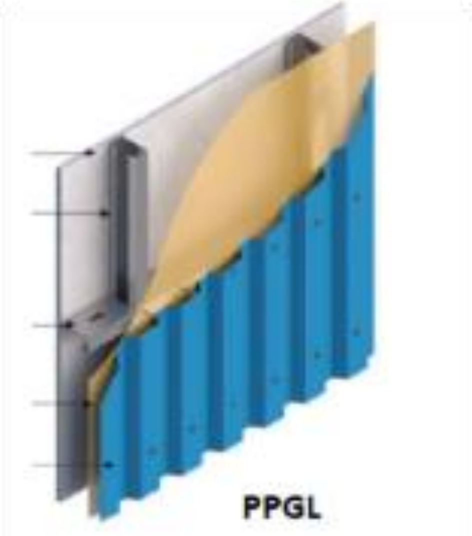
PREFABRICATED SANDWICH PANEL SYSTEMS

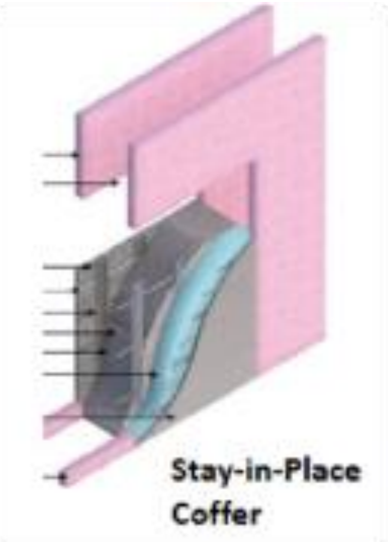
- EPS Core Panel Systems
- Other Sandwich Panel Systems
  - Fibre cement board
  - MgO Board
  - AAC panels

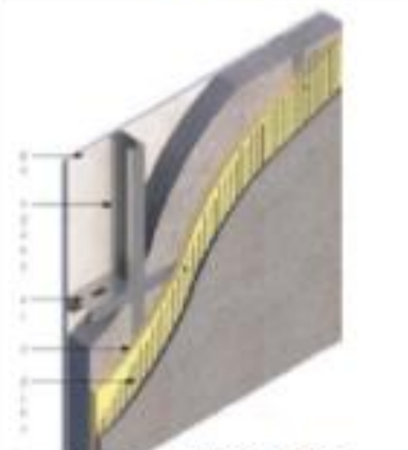

Reinforced EPS Core


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.

(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..

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.

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Light House Project (LHP) at Rajkot, Gujarat

6

(Technology: Monolithic Concrete Construction System)

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 Aluminum / 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.

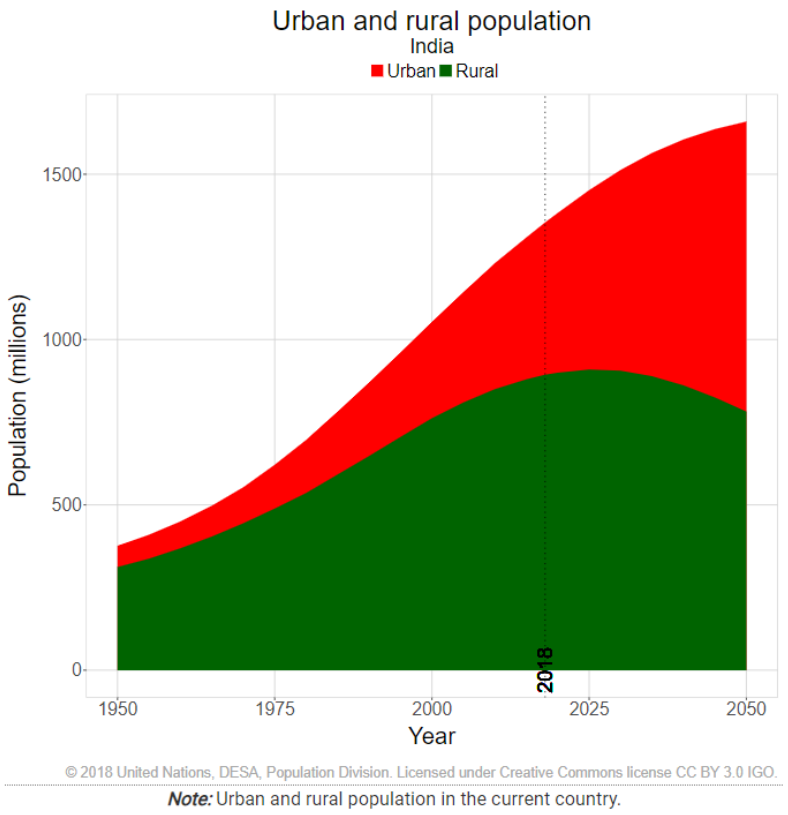
Break : 10 minutes

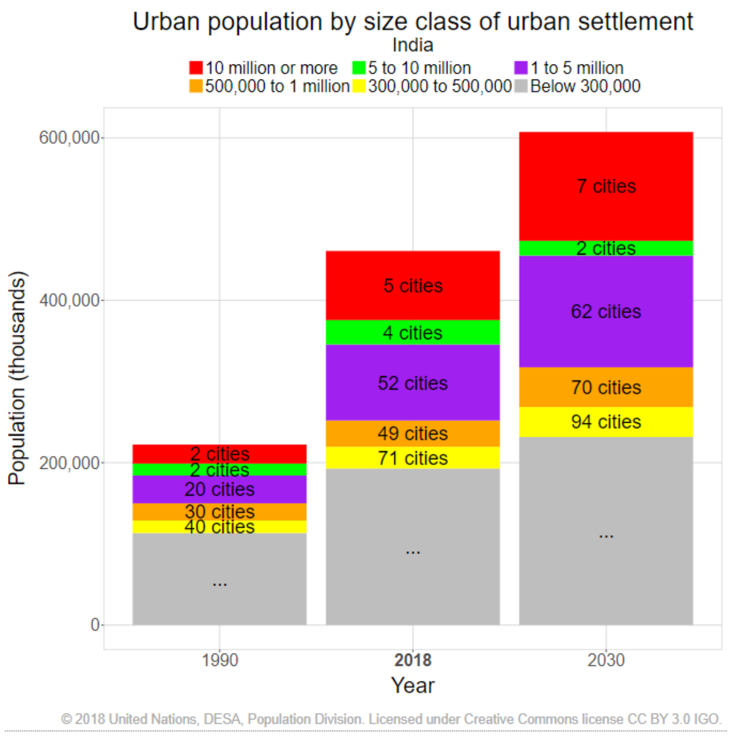
Session 2

02 A

Need for thermal comfort in affordable housing

Growing Opportunities with Rapid Urbanization

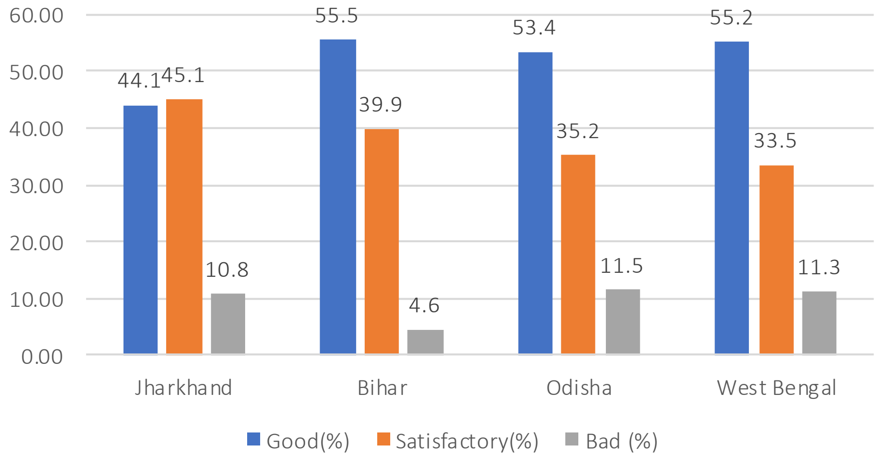




Cities, which will contribute over 80% to GDP by 2050, need to be Receptive, Innovative, and Productive to foster sustainable growth and ensure a better quality of living

Ministry of Housing and Urban Affairs
Government of India

Challenges with Rapid Urbanization



Percentage of households with the condition of Census House

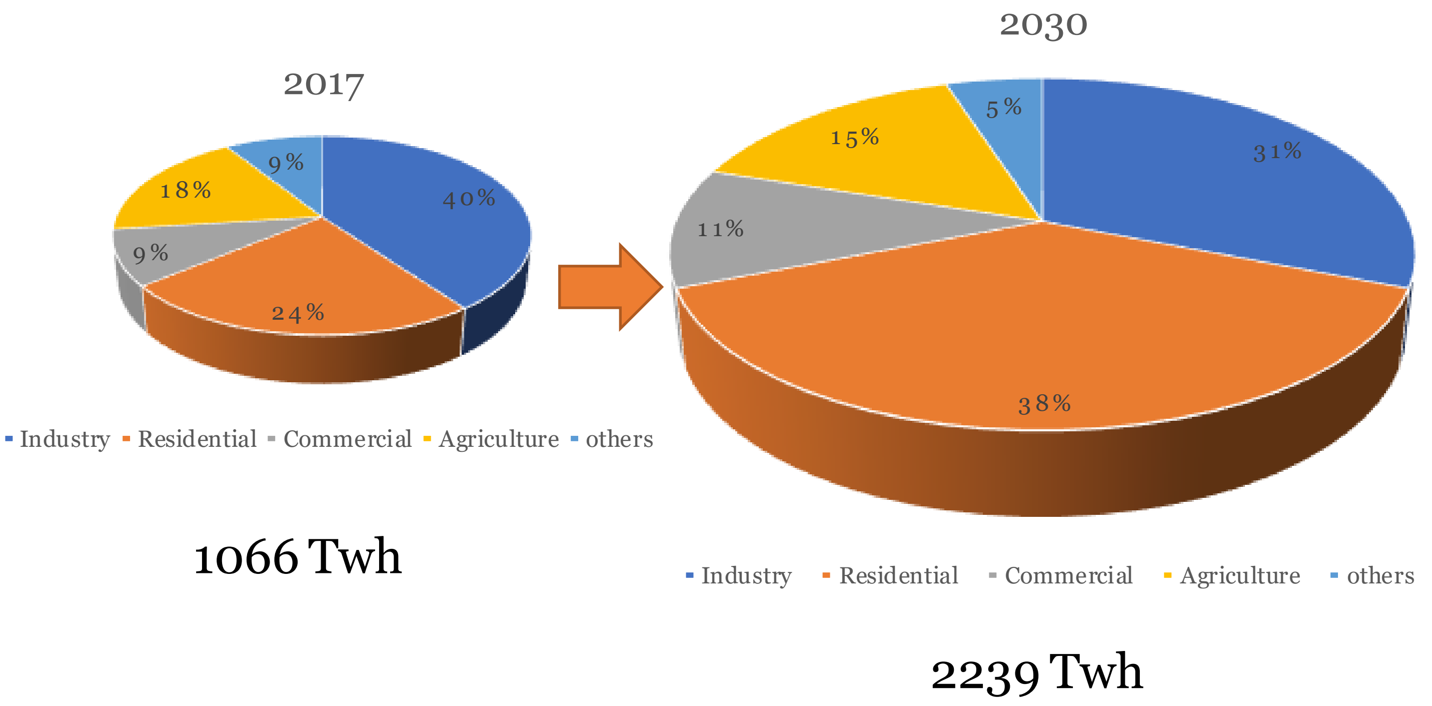
State	Owned	Hired	Any other
Jharkhand	60.50%	31.50%	7.90%
Bihar	72.60%	25.90%	1.60%
Odisha	54.10%	39.10%	6.80%
West Bengal	74.20%	21.50%	4.40%

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



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.

What is housing affordability?

"Housing affordability is an expression of the social and material experiences of people, constituted as households, in relation to their individual housing situations"- *Michael E Stone*

Affordability is an expression of the challenge each household faces in balancing the cost of its current or potential housing and its other expenditures, within the limits of the household's income.

Major Factors*:

- household income level,
- dwelling unit size
- The proportion of overall household expenditure on housing and related expenses

Reference: Wadhwa Committee, 2009, Ministry of Housing and Urban Poverty Alleviation

Income Group	Income range (INR)	EMI percentage of monthly income	Dwelling Units Size (sq. m)
EWS	Below 0.3 million	20	30
LIG	0.3-0.6 million	30-40	60
MIG-I	0.6-1.2	30-40	160
MIG-II	1.2-1.8	30-40	200

(PMAY(U) Guideline 2021)

What constitutes housing expenditure?

Total Housing Expenditure*

** Reference: Deepak Parekh Committee, 2008, Ministry of Housing and Urban Poverty Alleviation*

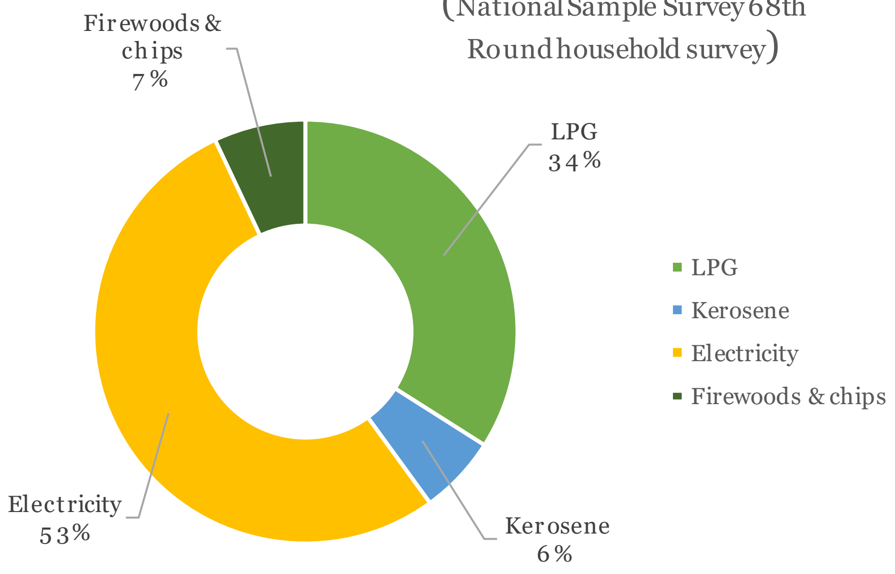
Initial Cost:

- Land Cost
- Material Cost
- Construction Cost
- Initial down payment to access housing finance
- Transaction cost (stamp duty, registration fees, GST)

Recurring Cost:

- Fuel (excluding transport)
- Water
- O&M
- Repair
- EMI interest payment

Fuel Consumption in Urban Areas (National Sample Survey 68th Round household survey)



The India Cooling Action Plan estimates that, as of 2017-18, 10% of the population consumes 60% of the energy for space cooling

MoHUA Initiates for Urban Transformation

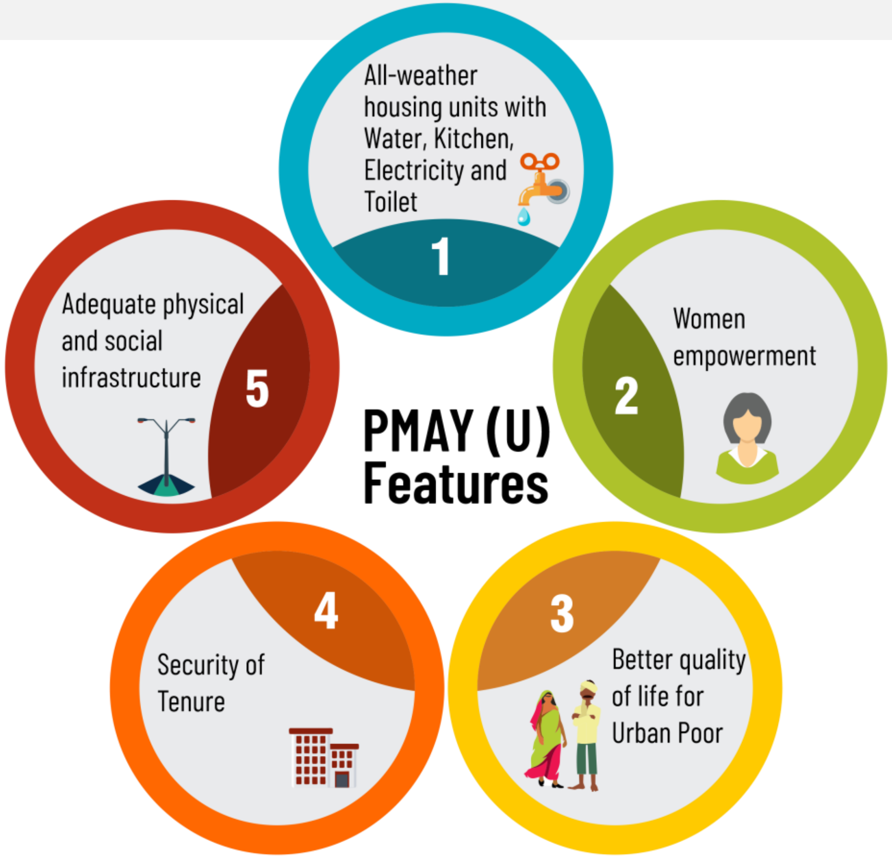
1. SMU (U)
2. PMY (U)
3. DAY-NULM
4. HRIDAY
5. AMRUT
6. Smart City
7. Urban Transport

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

Pradhan Mantri Aawas Yojana (Urban):

PMY(U)

ISSR (In-Situ Slum Redevelopment)

- Aims to leverage the locked potential of land to provide houses to the eligible slum dwellers

BLC (Beneficiary-Led Construction)

- For households of EWS category requiring individual houses

CLSS (Credit Linked Subsidiary Scheme)

- Demand-side intervention
- Home loans at subsidized interest rate for the EWS/LIG/MIG-1/MIG-2 households

AHP (Affordable Housing in Partnership)

- Supply-side intervention
- Central assistance for EWS

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)”

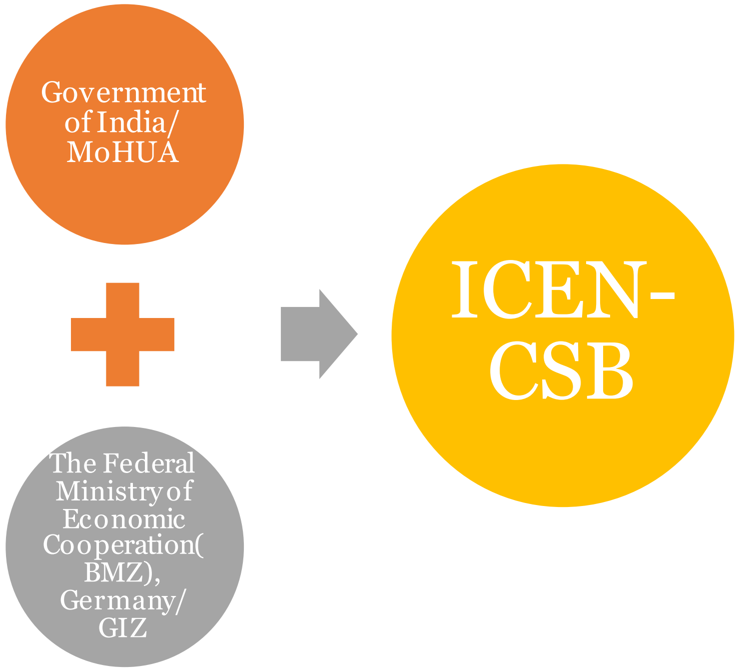
States and UTs in East Cluster for establishing the Cell:

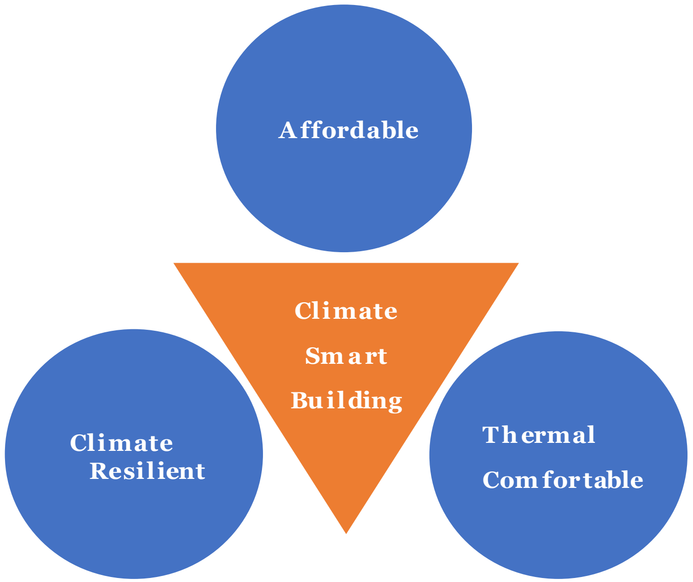
Jharkhand	Bihar	Odisha	West Bengal

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)





Key features of a CSB

Reduce the demand for air-condition by 30-40%

Curtail 30 metric tones of CO_2

Improve health and wellbeing of people

Support the commitment of GoI towards reducing CO_2 emissions

Results of a Climate responsive building design

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

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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

02 B

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

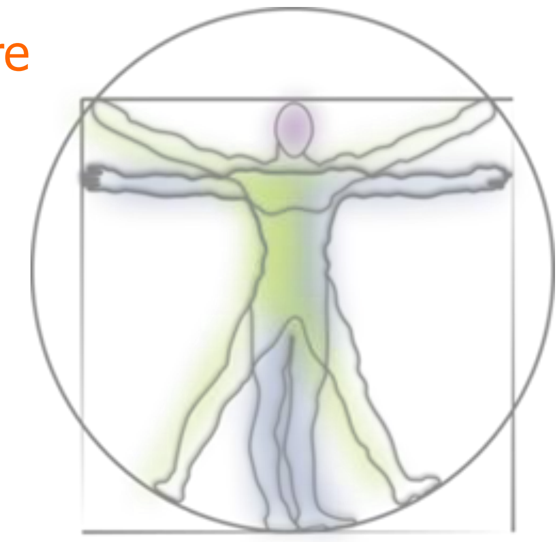
by an unpleasant chilling or heating of a specific region of the body.

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

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.

PHYSICAL FACTORS

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.

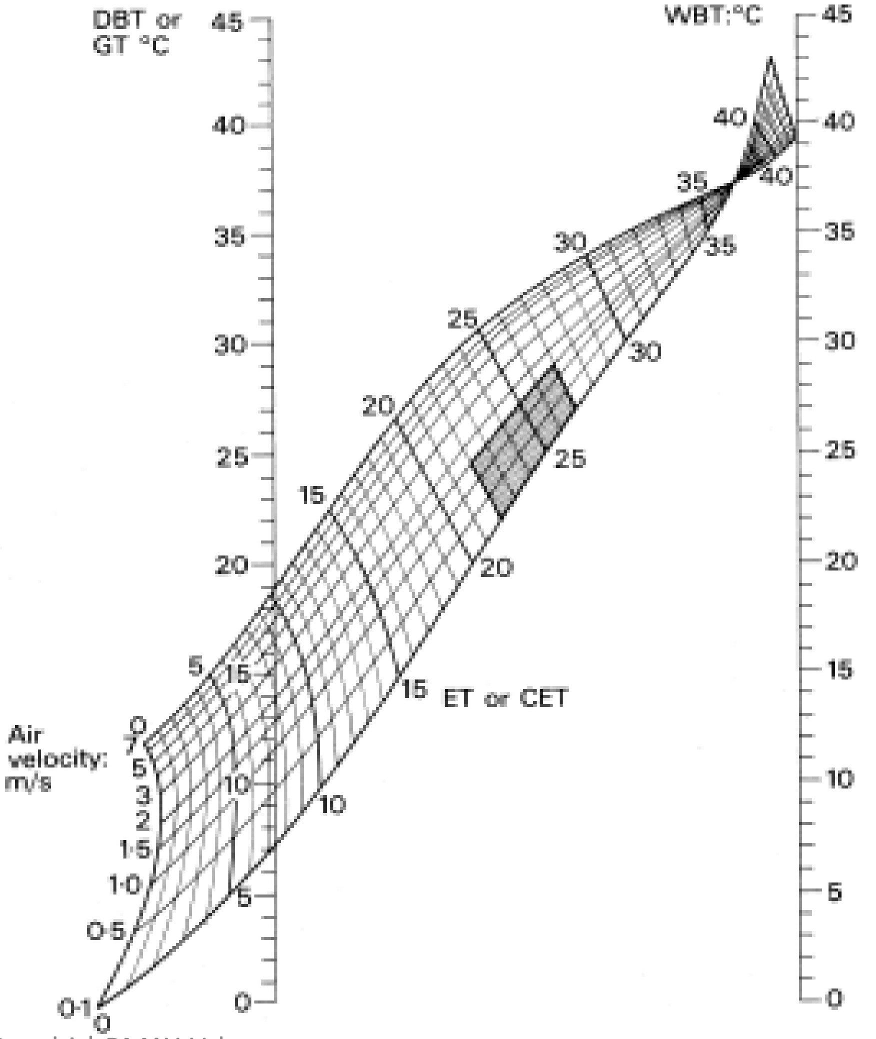


Figure represents the Corrected Effective Temperature (CET) Nomogram

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

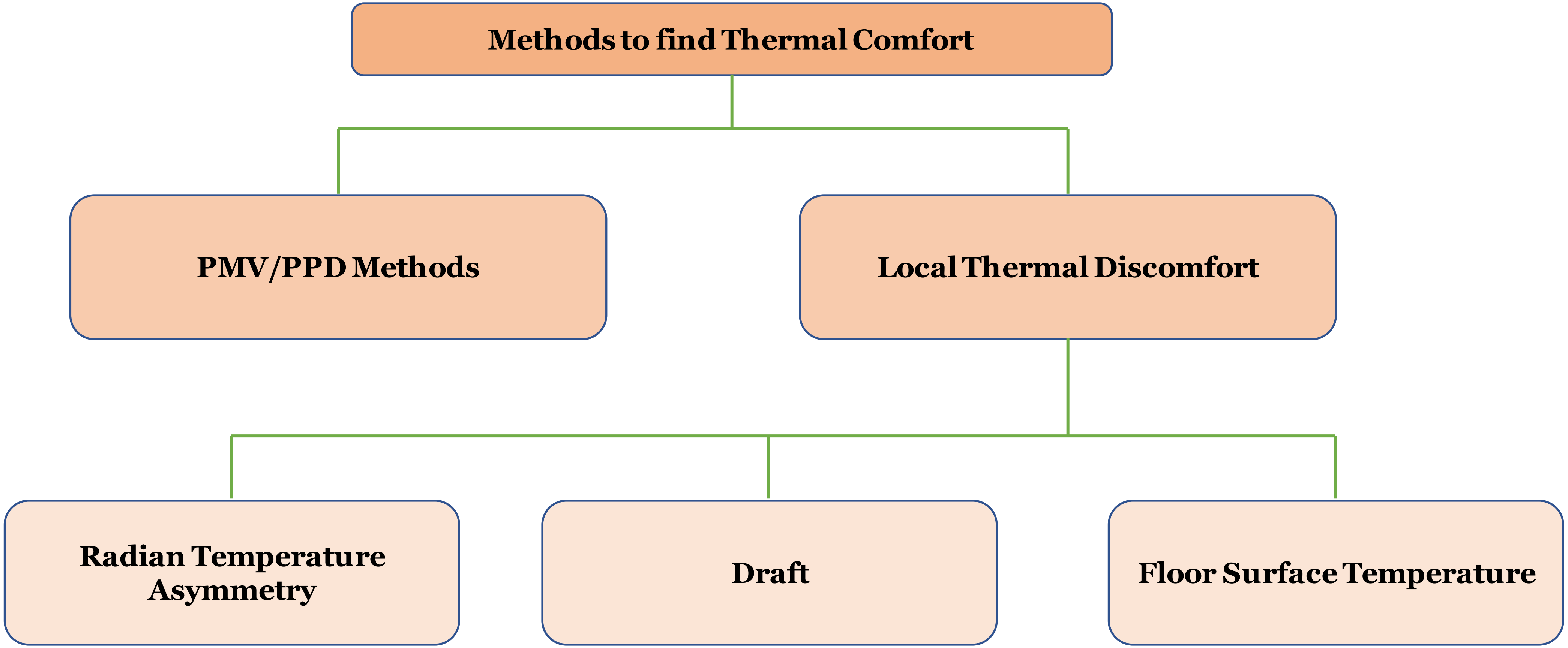
The thermal comfort of subjects was found to lie between TSI values of 25 and 30°C with optimum conditions at 27.5°C.

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



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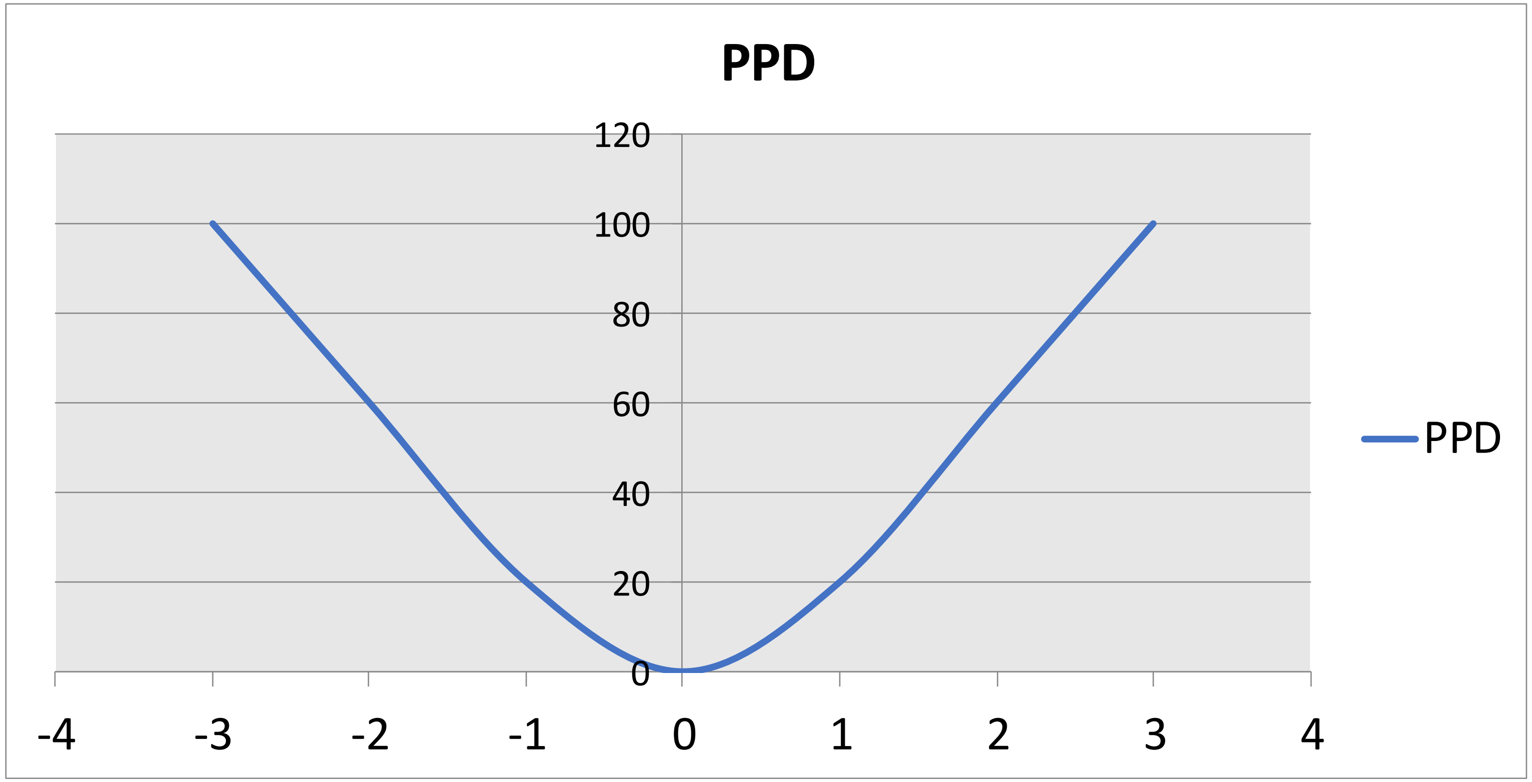
Methods to find Thermal Comfort

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

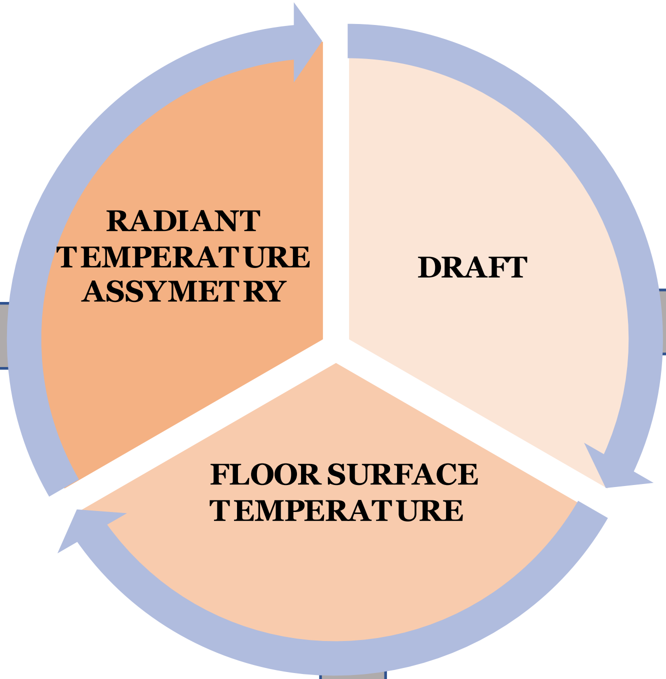
Methods to find Thermal Comfort

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.

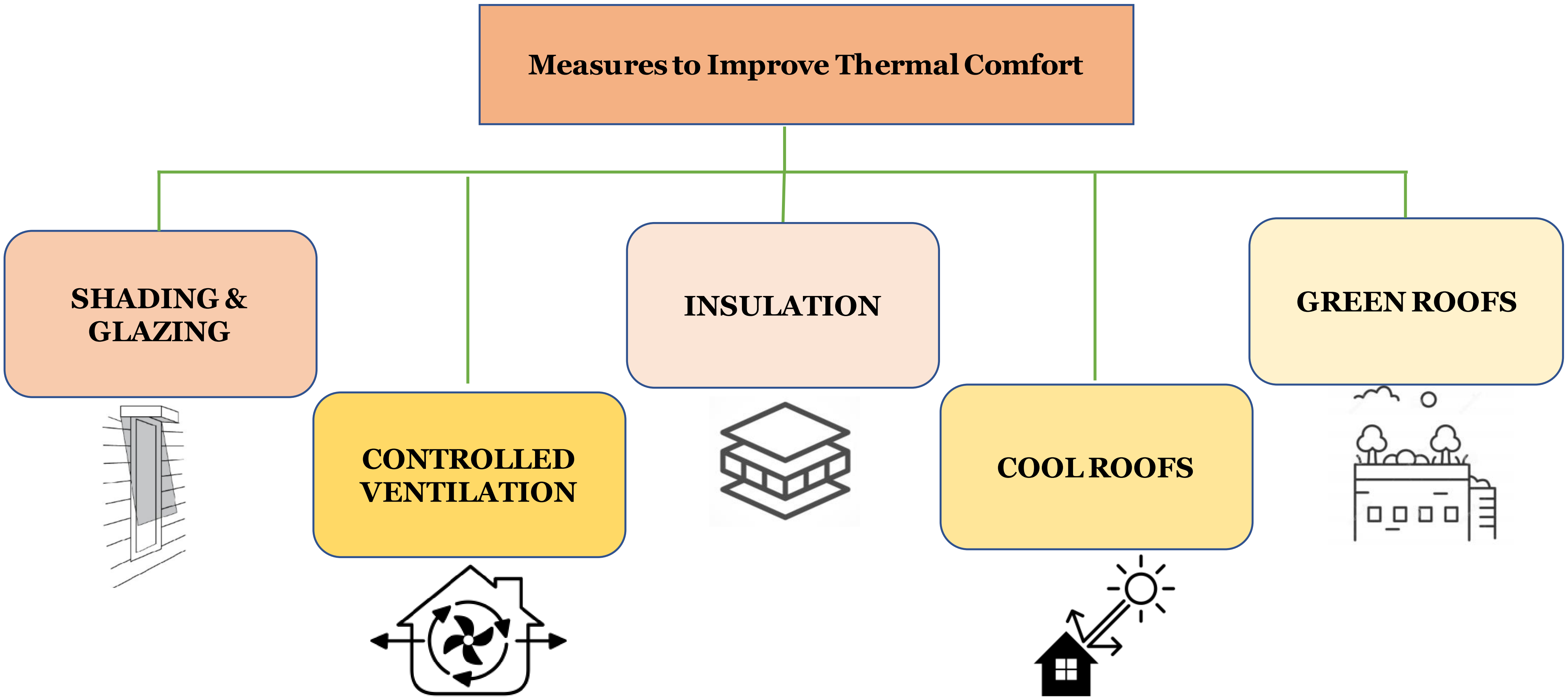
Depending on the **footwear**, too hot or too cold floors might be uncomfortable. In rooms where users will be wearing lightweight shoes, ASHRAE 55 advises keeping floor temperatures between **19–29 °C (66–84 °F).**

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



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

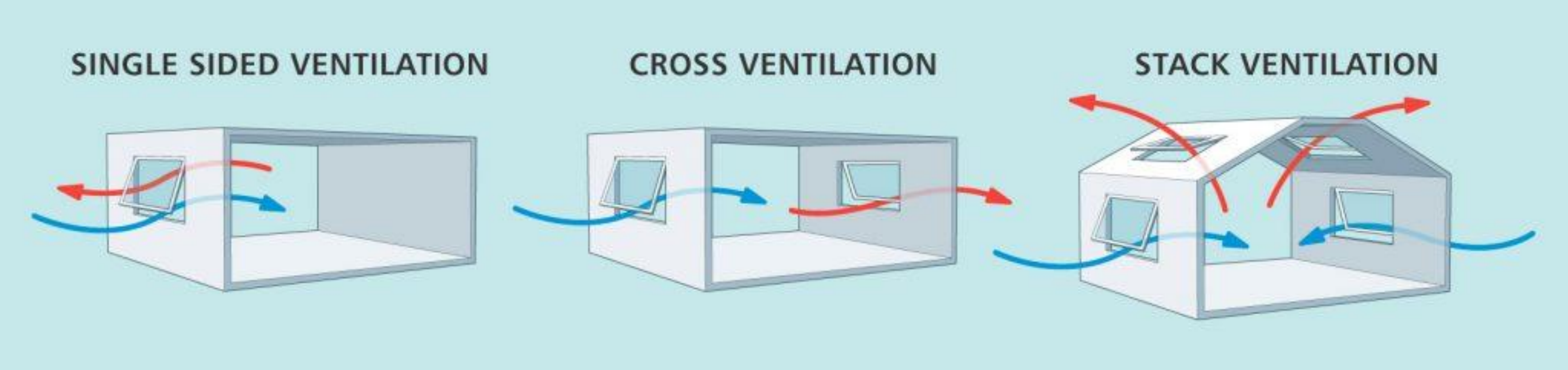
Thermal Comfort

- **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.

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.)

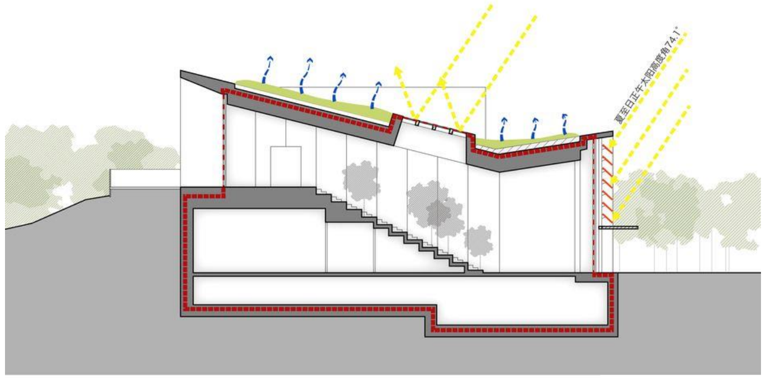
Controlled Ventilation

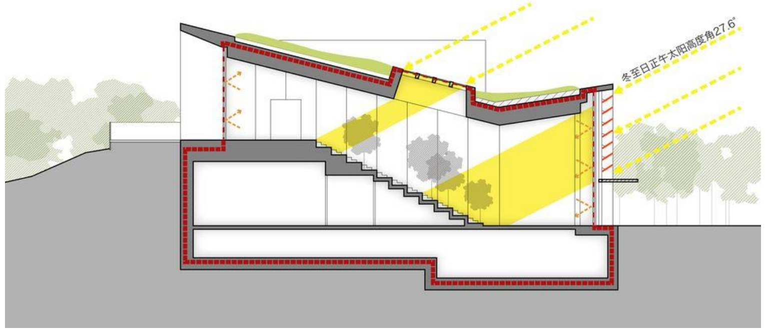
Natural ventilation takes advantage of the differences in air pressure between warm air and cool air, as well as convection currents, to remove warm air from an indoor space and allow fresh cooler air in.

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

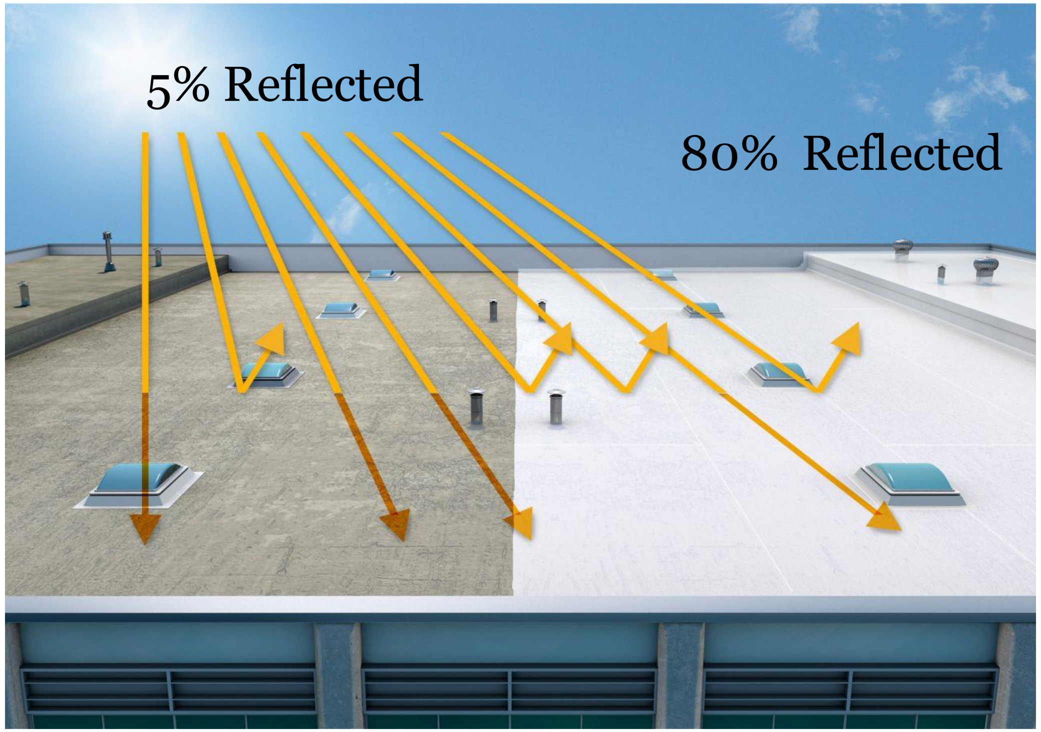
- Roof
- Walls
- Windows

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



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

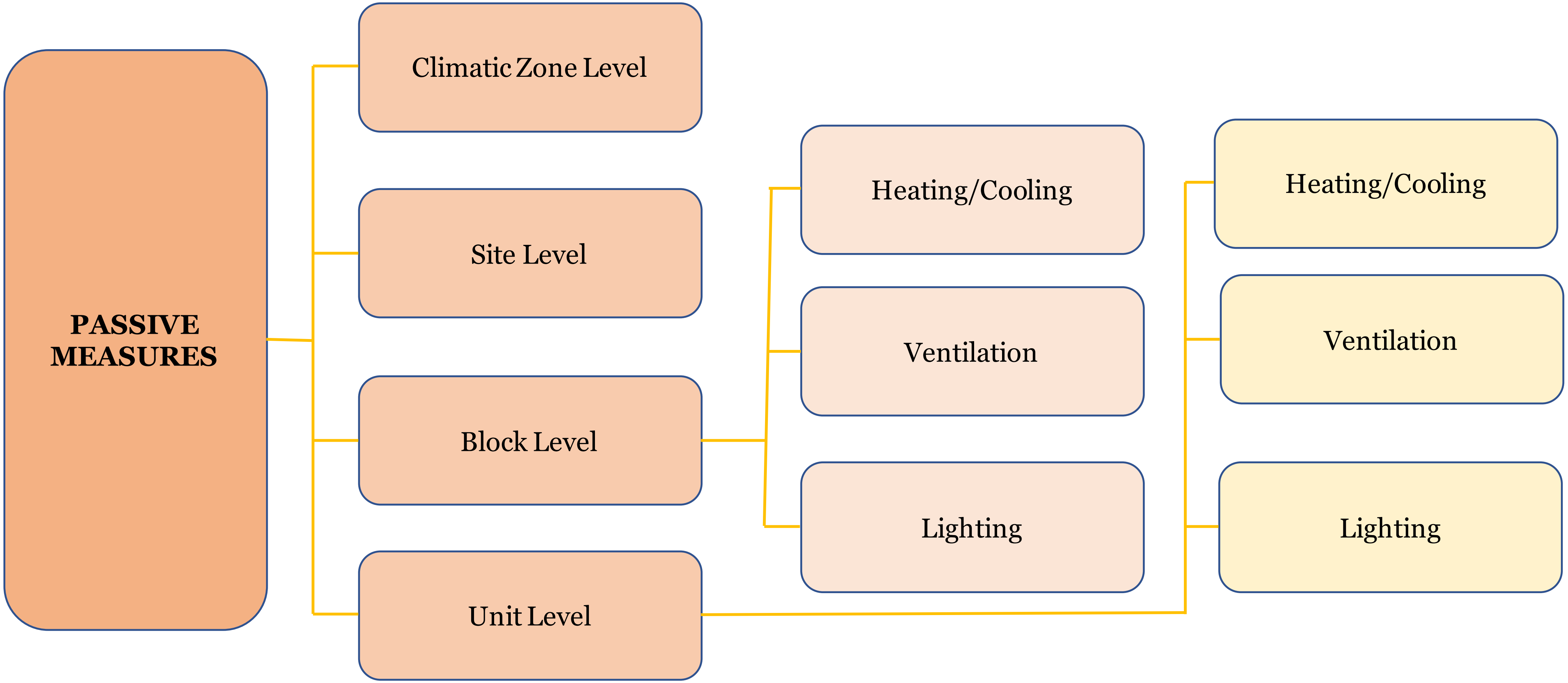
Thermal comfort housing can have numerous positive impacts

- 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:

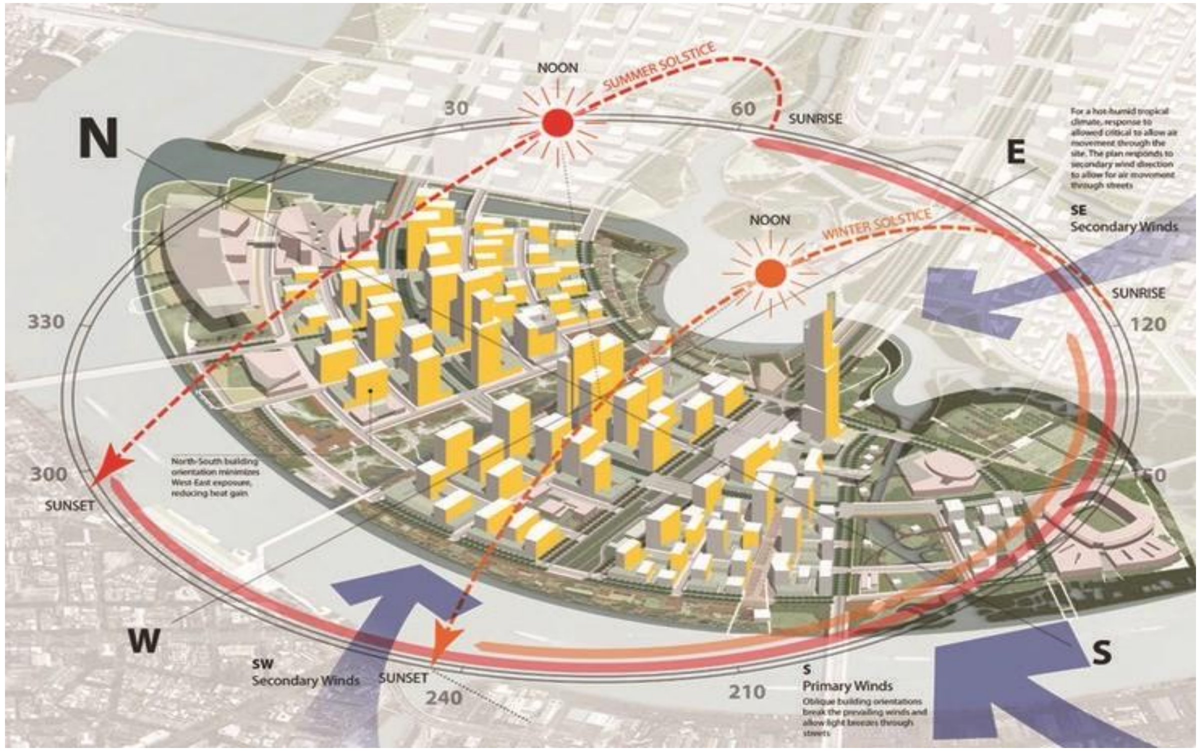
Courtyards / open courts are often surrounded by construction.

Taking advantage of block mutual shading

Using site massing to create wind passageways

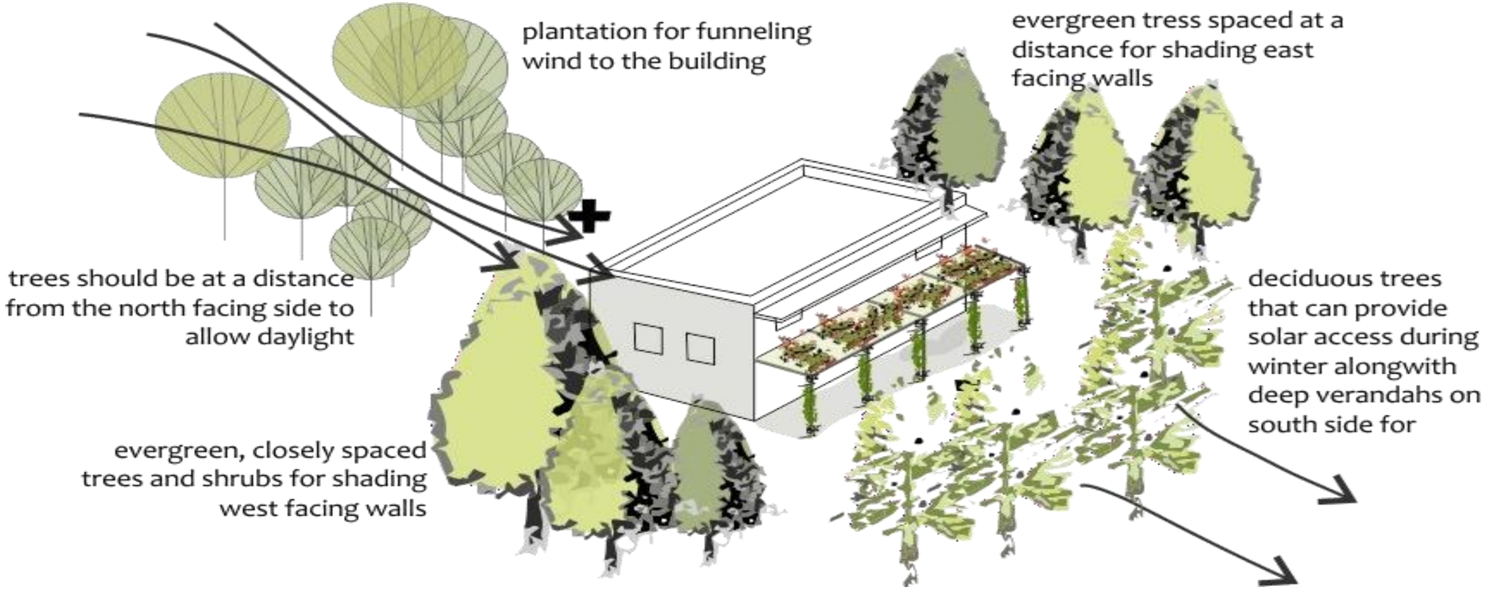
lowering the amount of hard paving to allow for water absorption

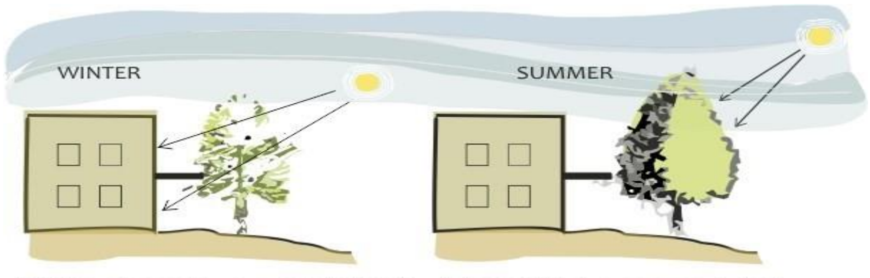
Using complementary vegetation to manage the amount of sunlight that gets through as the seasons change



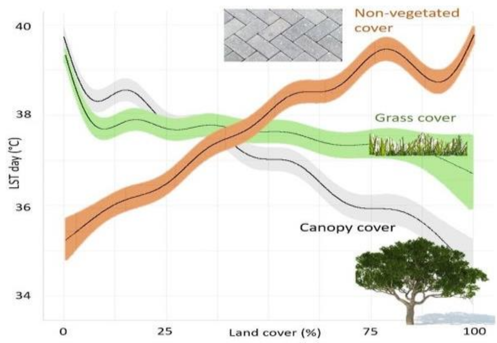
Passive Measures – Leveraging Plantation

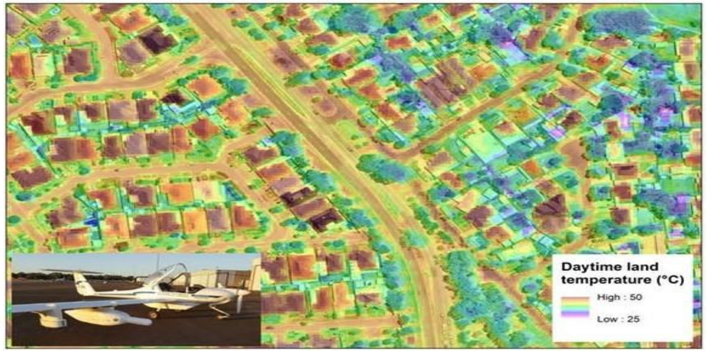
Planting trees in the right places to provide shade and ventilation can significantly reduce the severity of intense weather. During heatwaves in Adelaide, a research found that districts with more vegetation cover remained **cooler by up to 6°C.**





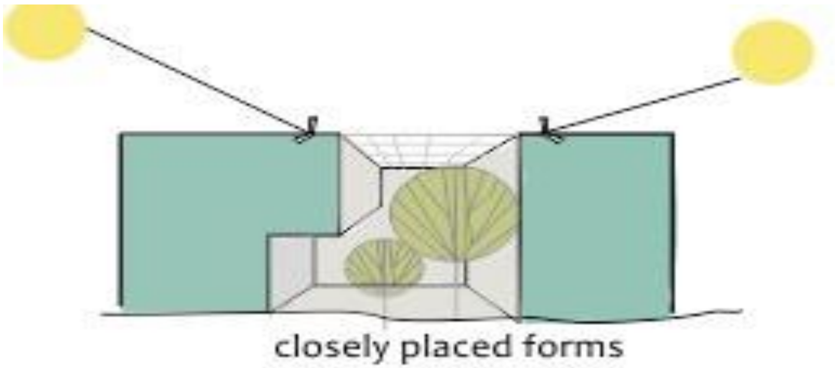
deciduous trees allow sun penetration in winter and block sun access during summer

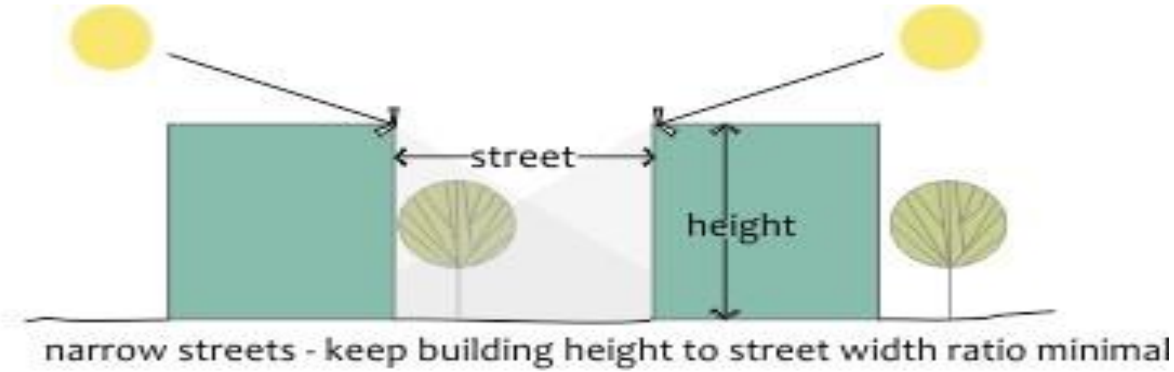




Passive Measures - Block Level

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

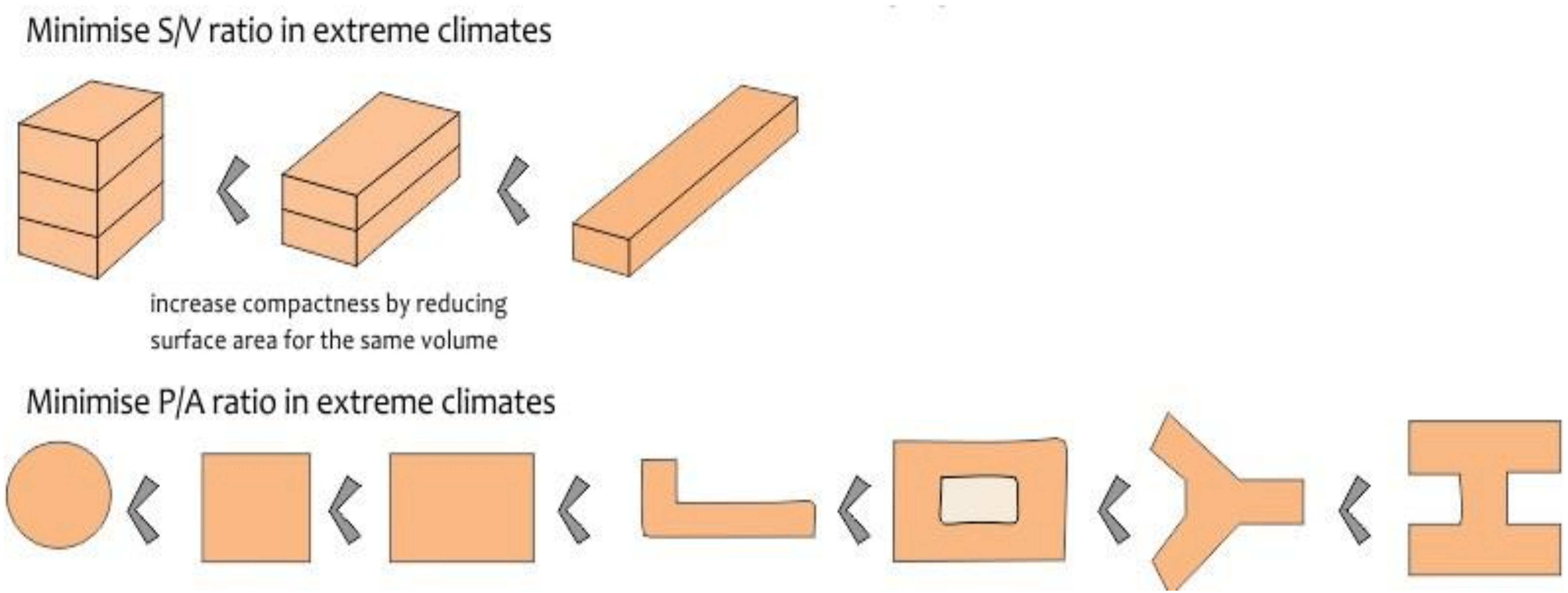




HEATING/COOLING

Passive Measures - Block Level

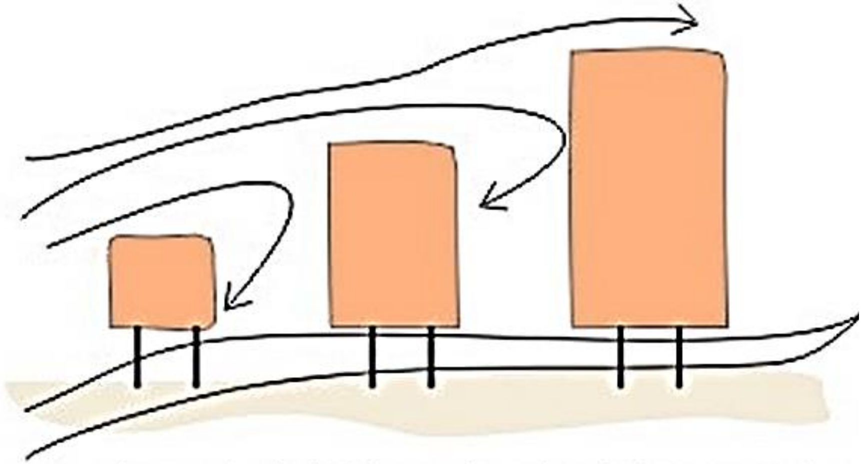
In harsh climate zones, reduce the surface area to building volume and perimeter to area ratios to reduce solar radiation exposure.



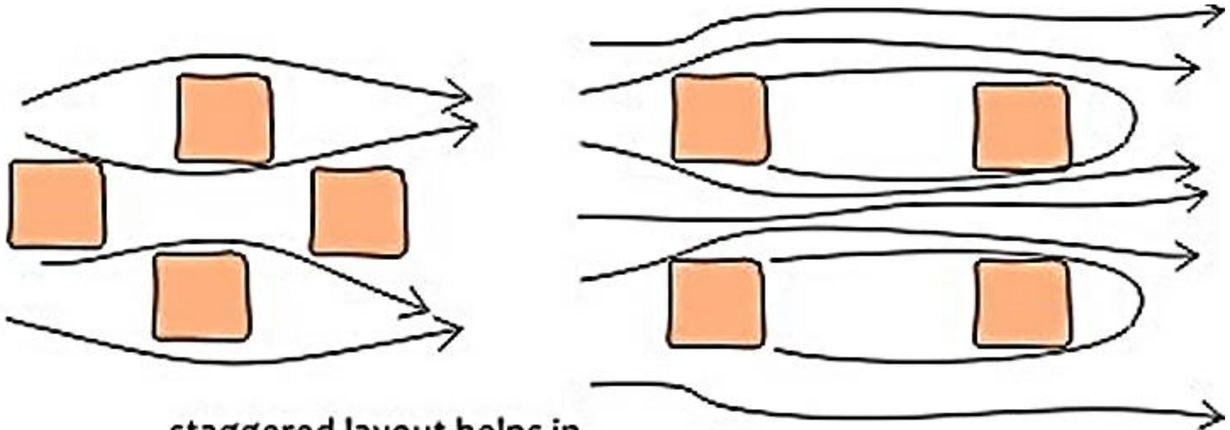
HEATING/COOLING

Passive Measures - Block Level

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

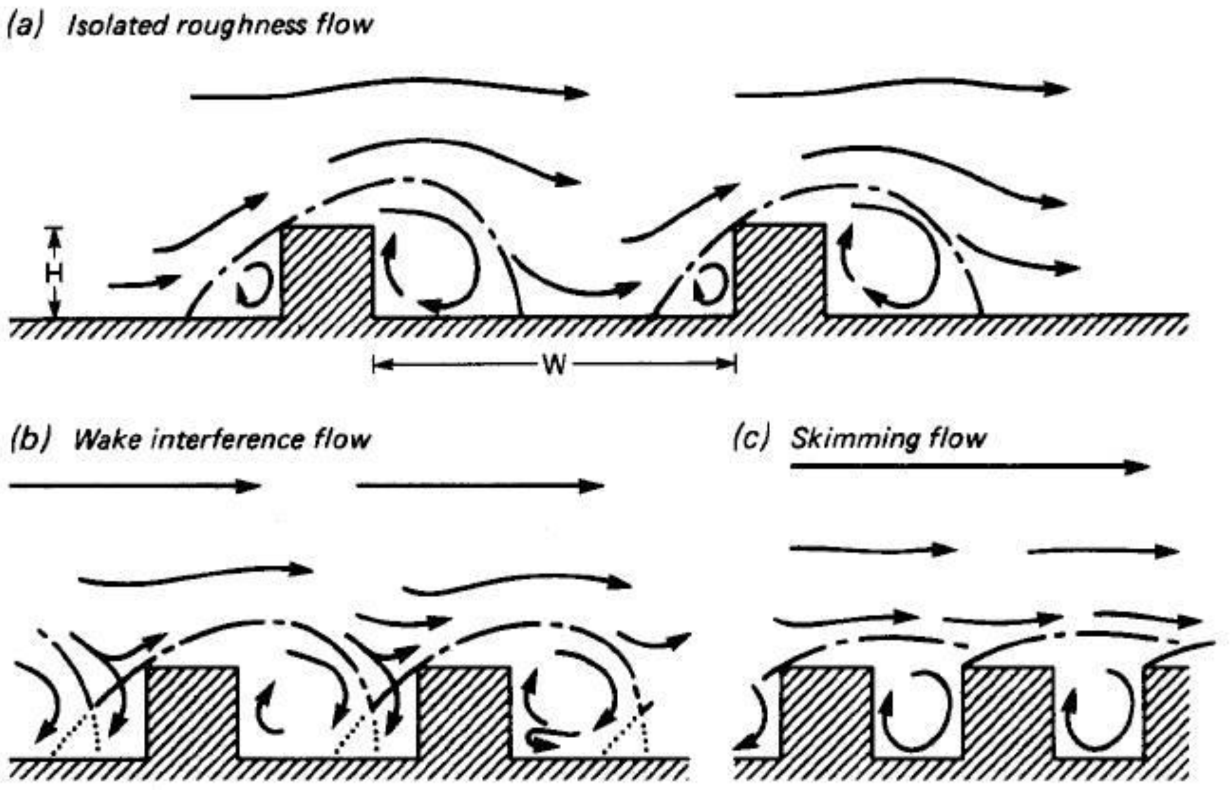


staggered layout helps in accentuating wind movement

VENTILATION

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.



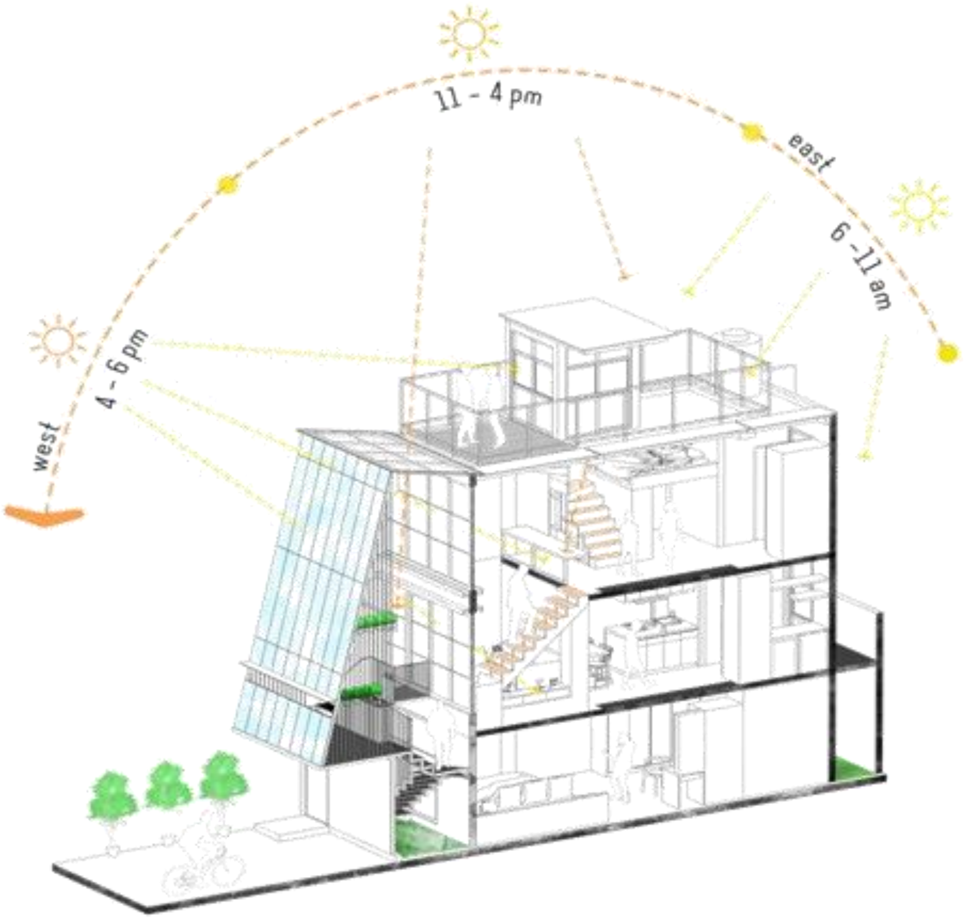
VENTILATION

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.

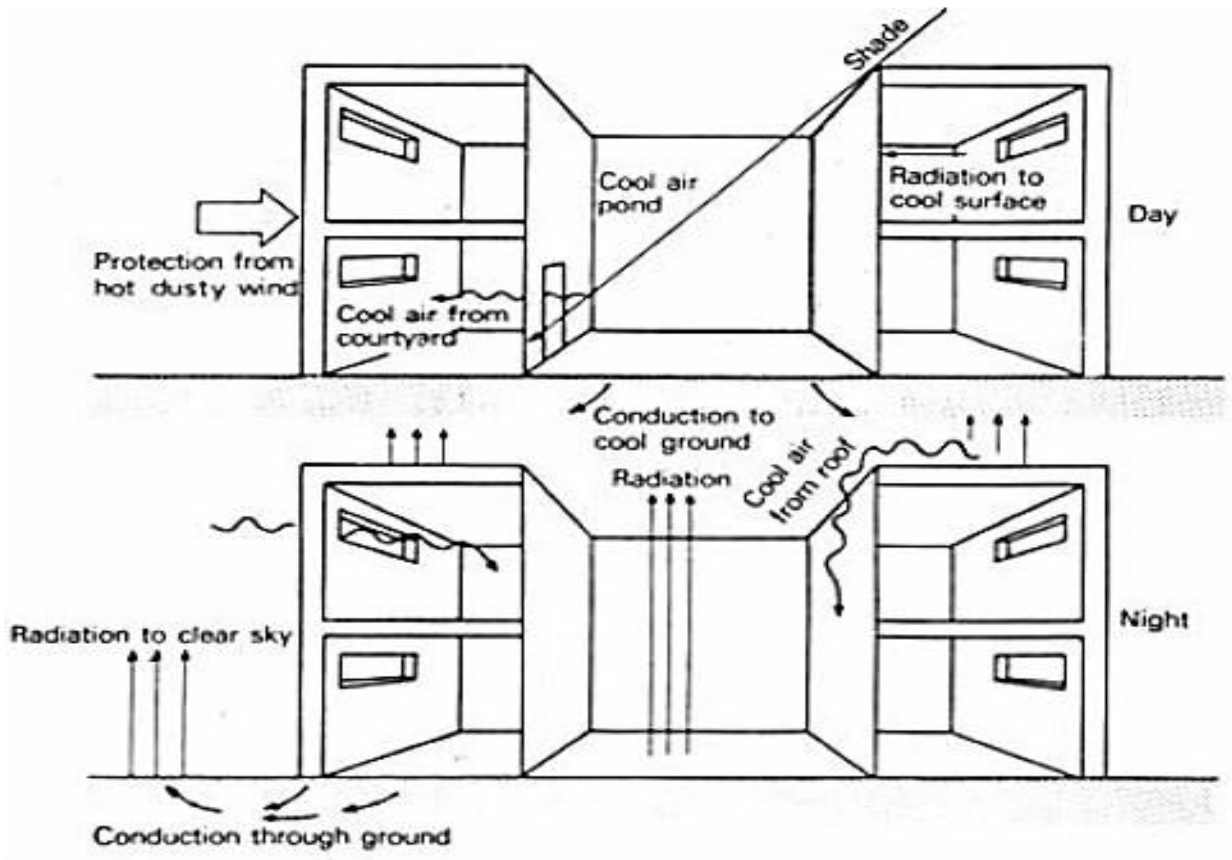


HEATING/COOLING

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.

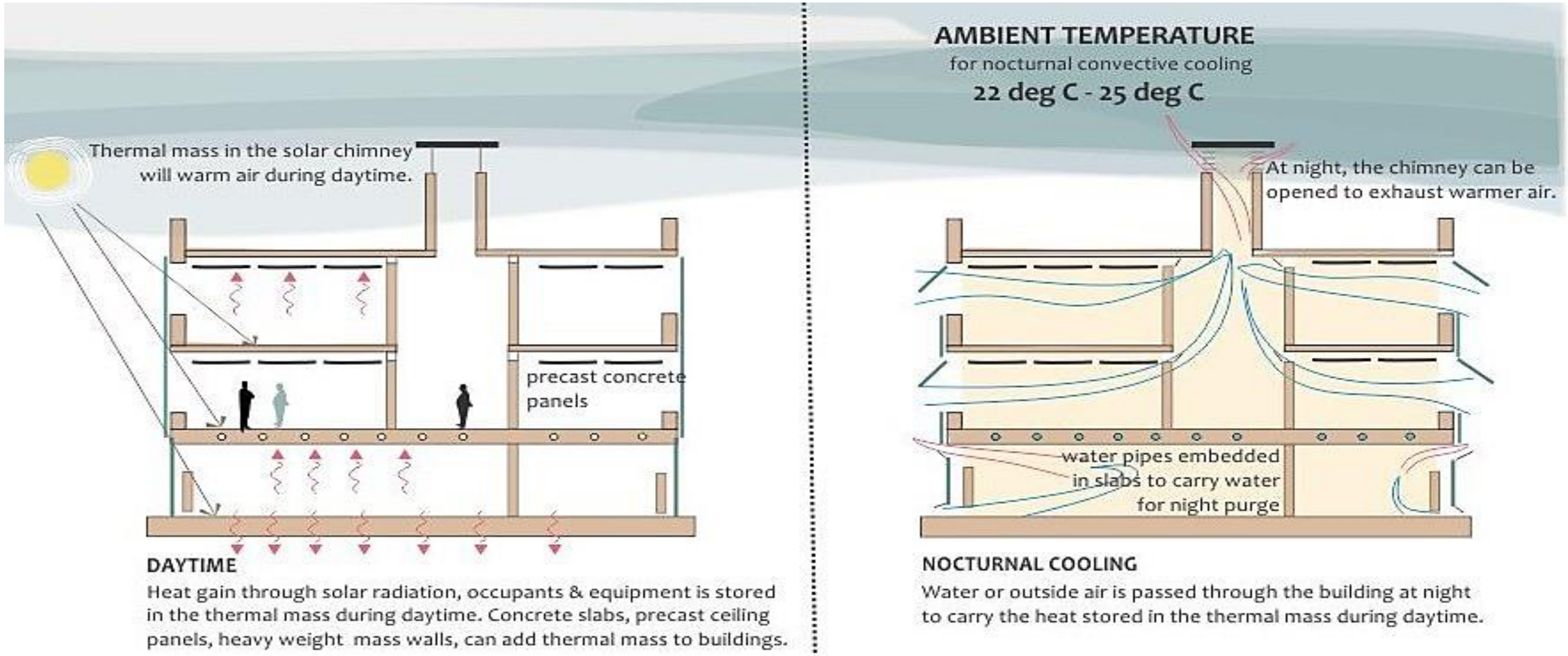


HEATING/COOLING

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.

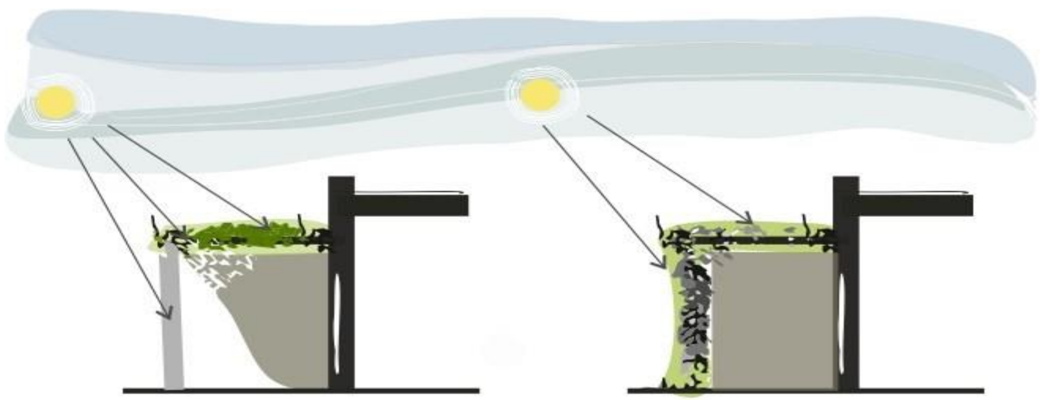


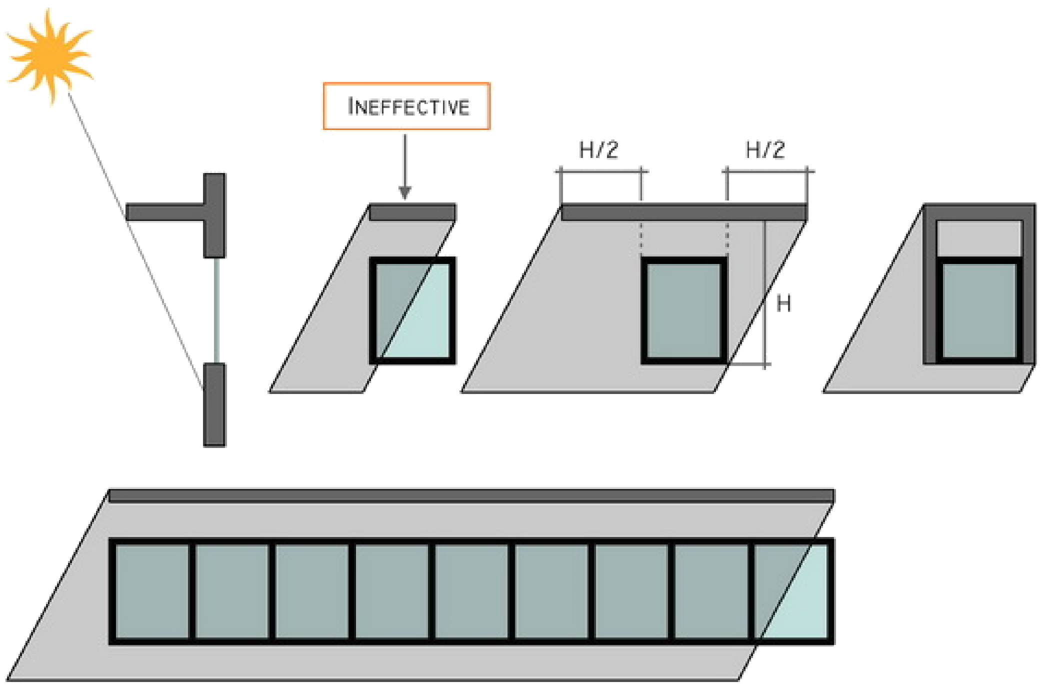
HEATING/COOLING

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

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%.

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 m^2

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 m²

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 m²

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 ft²

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.

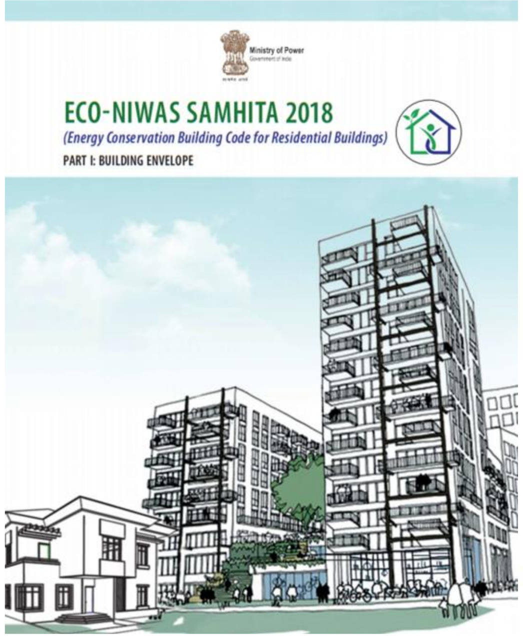
Rainwater can be collected, purified, and utilised as drinkable water. Grey water that has been treated can be reused for flushing and landscape irrigation.

02-C

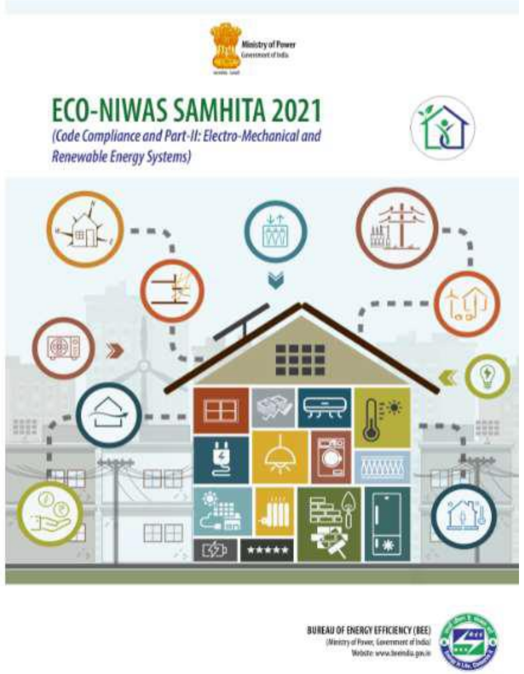
THERMAL COMFORT Models

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

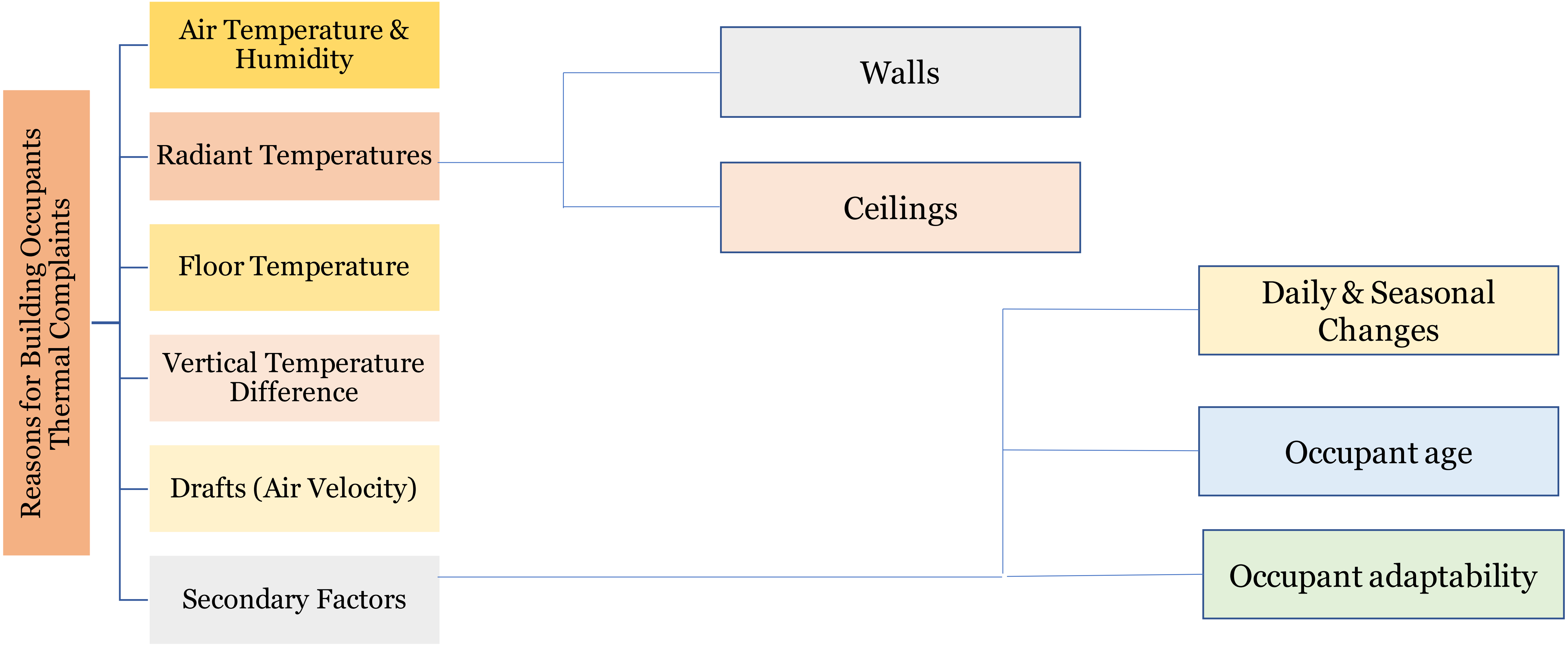
ASHRAE 55

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

ASHRAE 55

Human Comfort Range

Most Humans are comfortable under this conditions

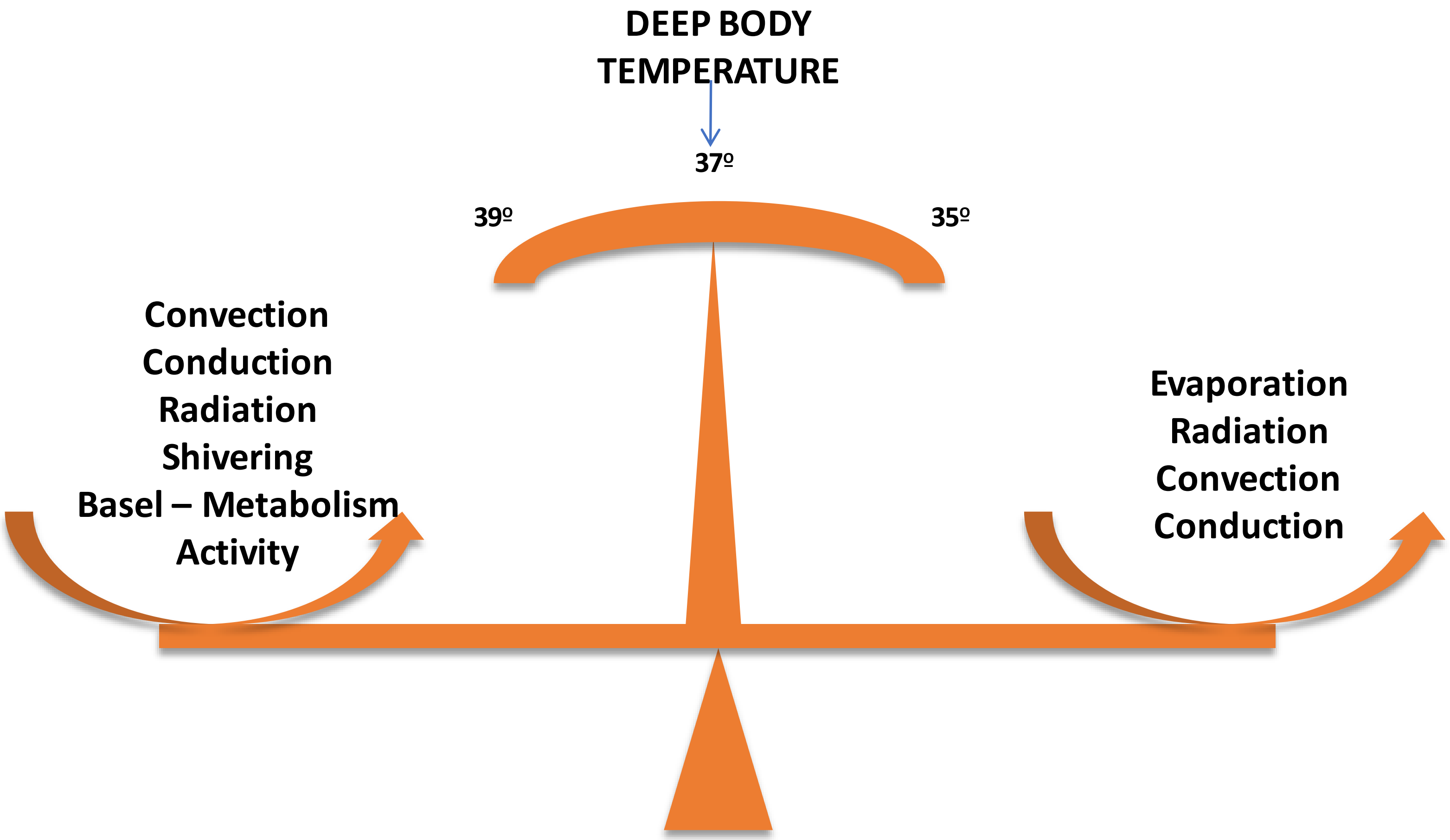
Winters

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

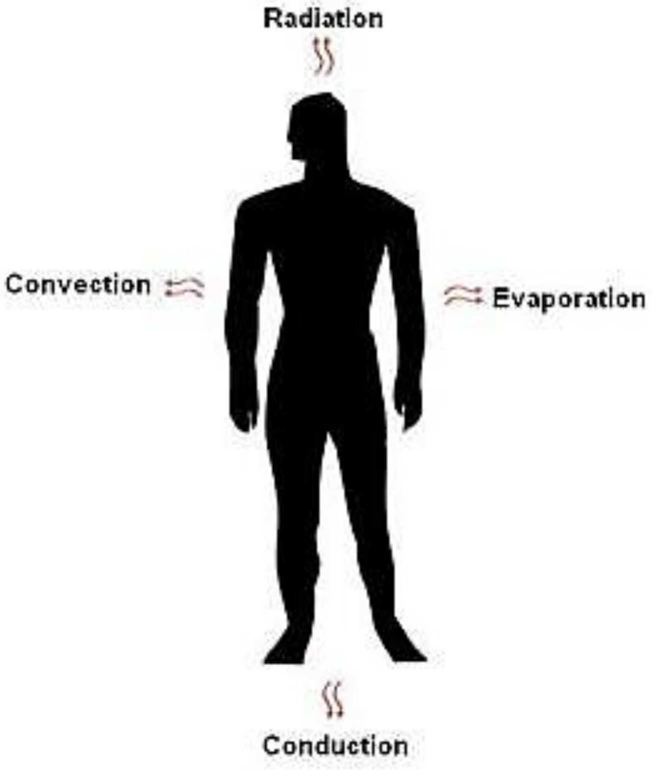
- The temperature of the body surface and the temperature of the opposing surface affects radiant heat loss.

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^{0}. But skin temperature is $31\text{-}34^{0}$.

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^{0}), 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.

Body Thermal Balance – Heat Loss in Various Thermal Environment

SATURATED STILL AIR, ABOVE BODY TEMPERATURE

At adverse situation

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)

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

Building Ventilation Type

- Naturally Ventilated (NV)
- Mixed Mode (MM)
- Air Conditioned (A/C)

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

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

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**

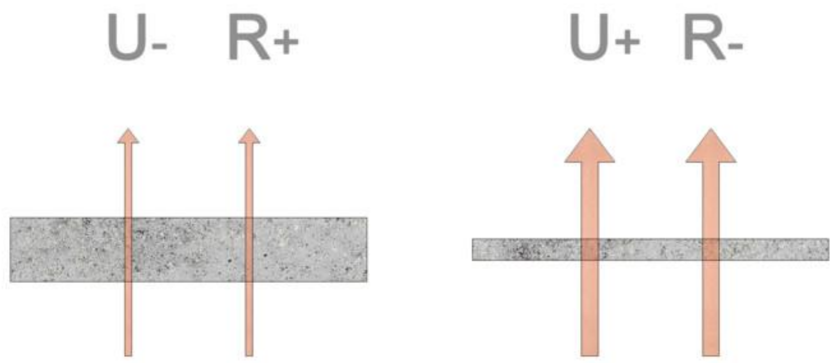
02-D

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)

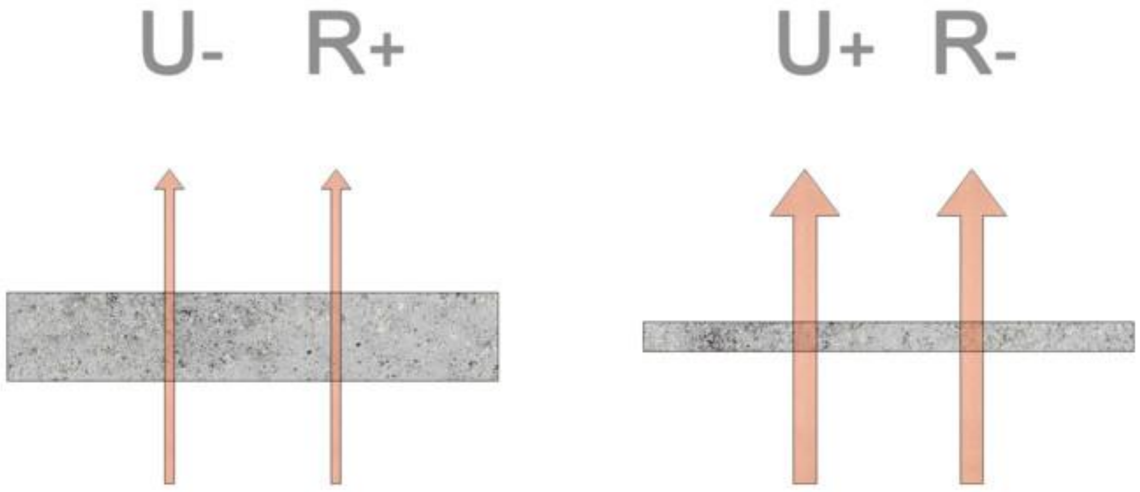
Thermal transmittance is the rate of heat transfer through materials

Unit of U value is W/(m²K)

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

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

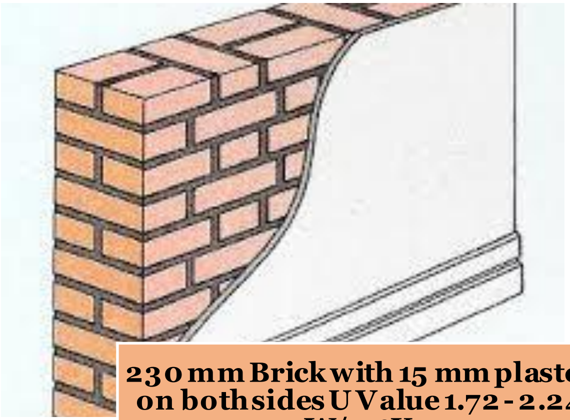
Conductivity (k) is the rate at which heat is transferred by conduction though material



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

Lunch Break : 60 minutes

02 E

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

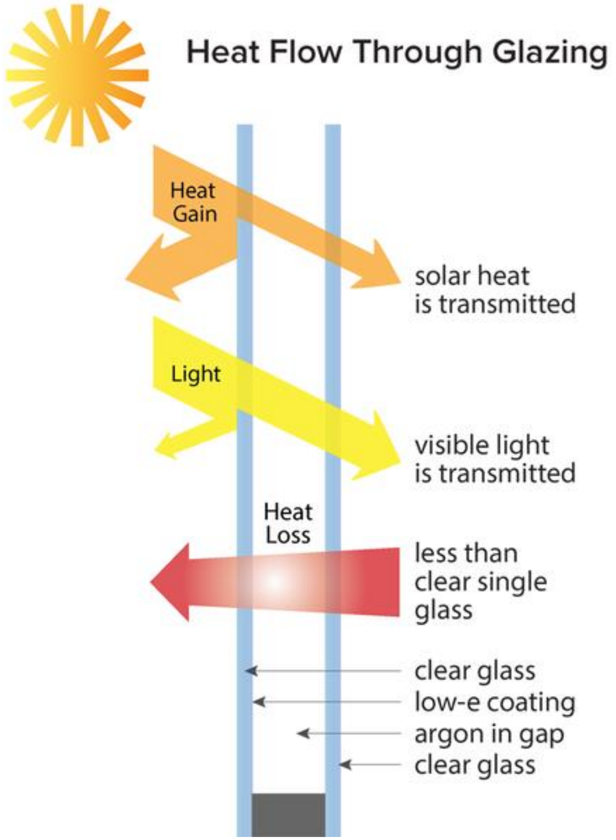
Openable window to floor area ratio (wfr):

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/m² .

- 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)

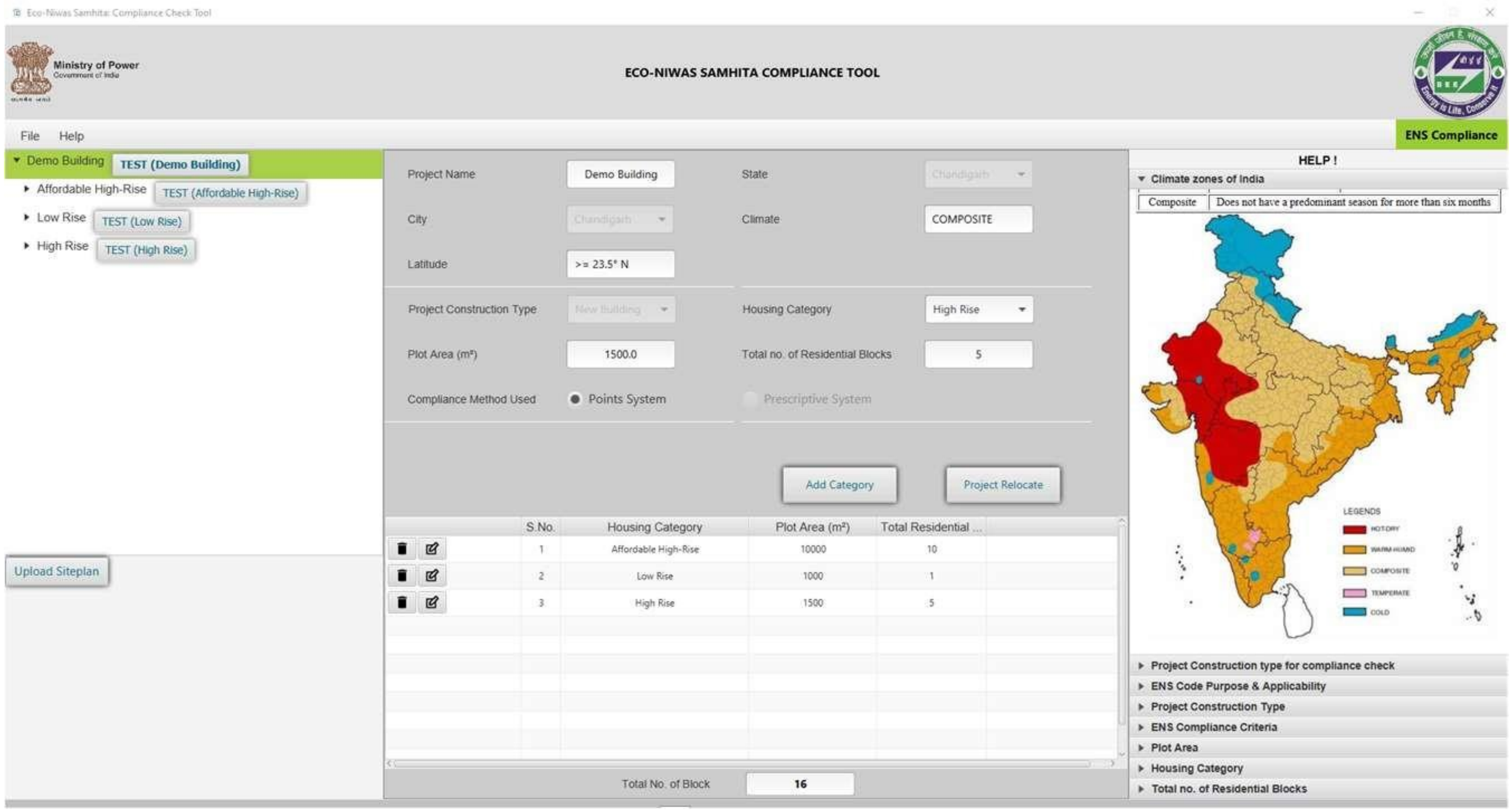
02-F

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

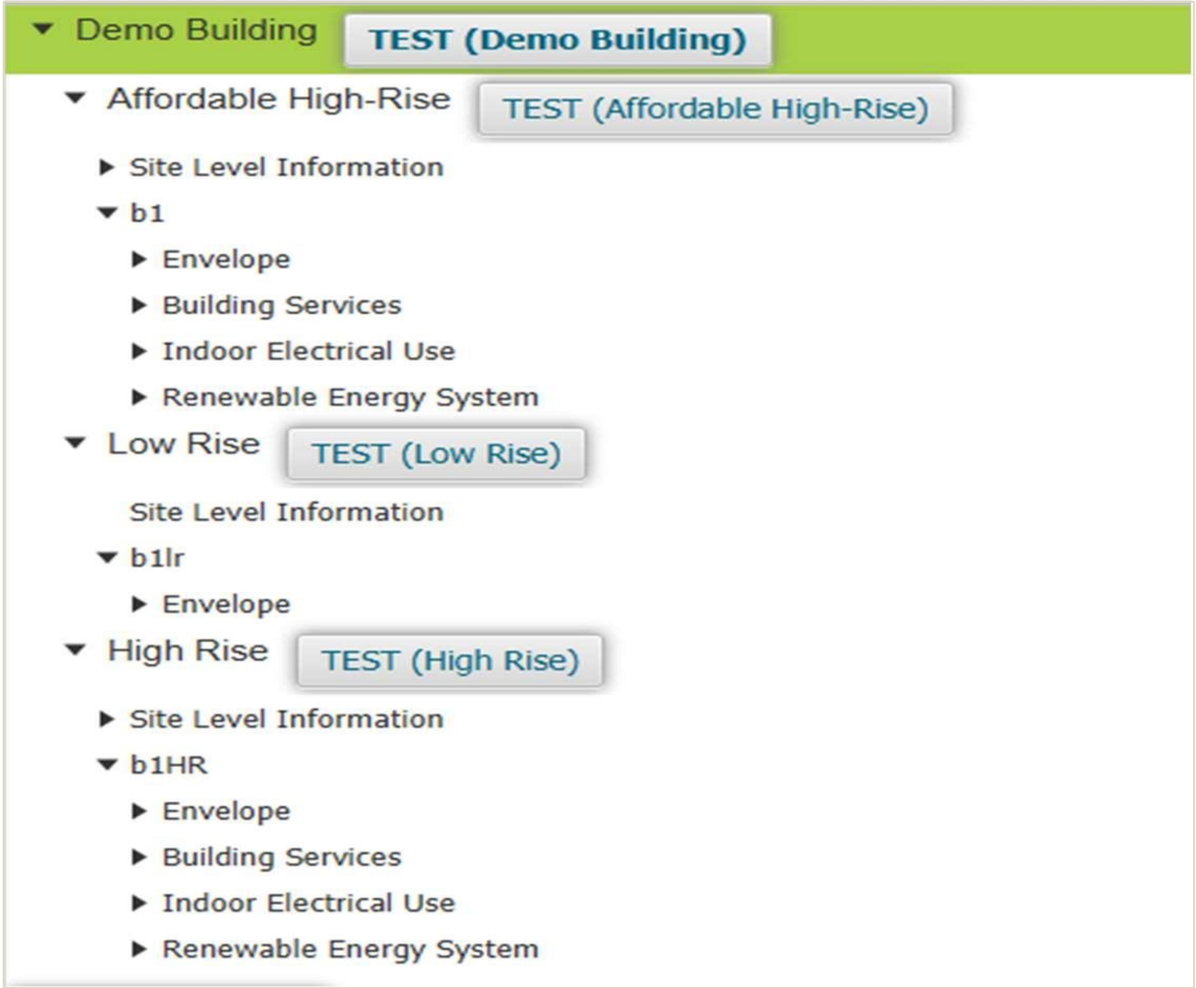
- Provisions for multiple housing category addition for compliance evaluation

	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

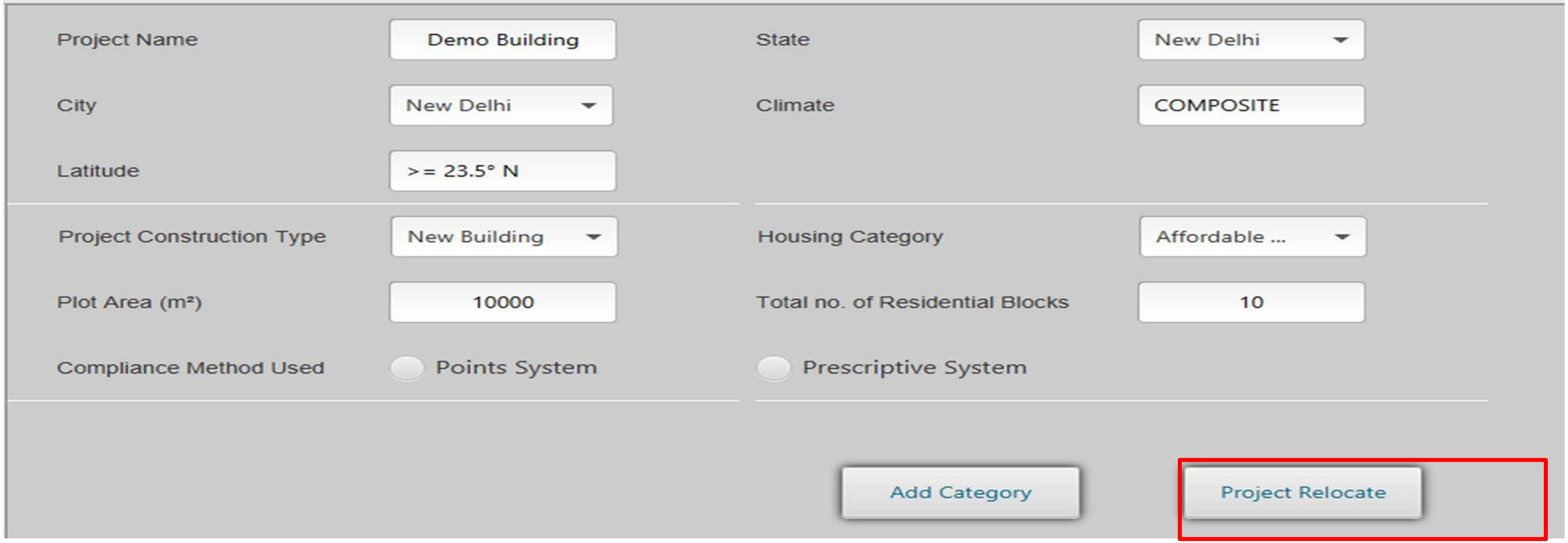
ENS Compliance Tools Key Features

- Easy to navigate tree-view structure



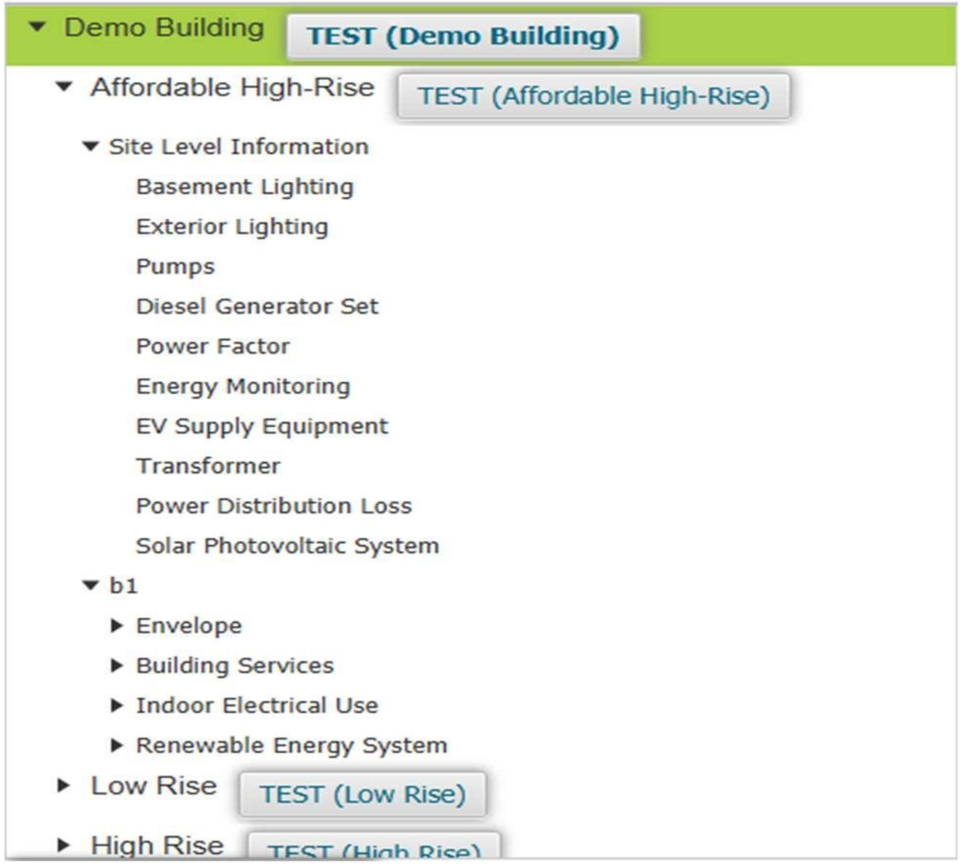
ENS Compliance Tools Key Features

- Project relocation feature for multiple domain use

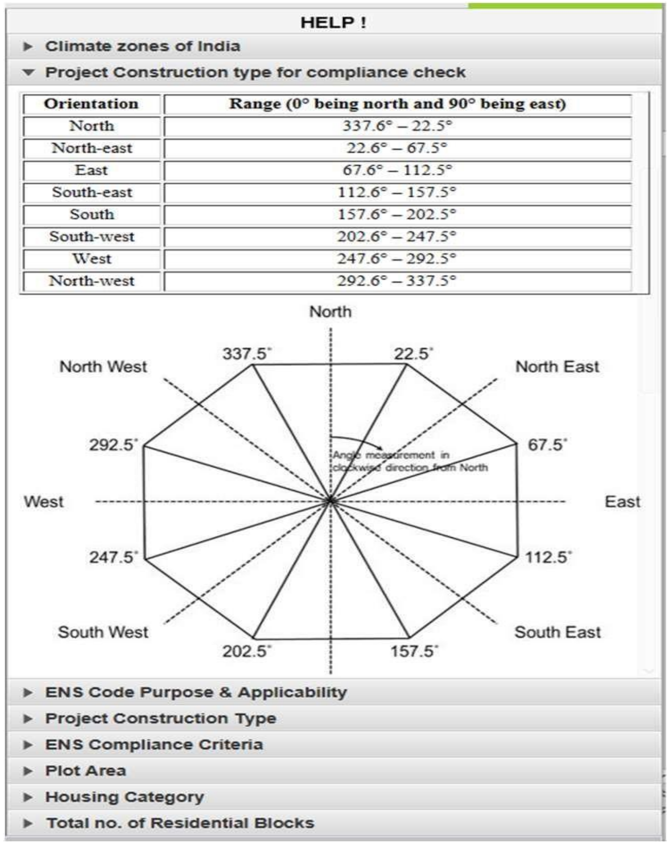


ENS Compliance Tools Key Features

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

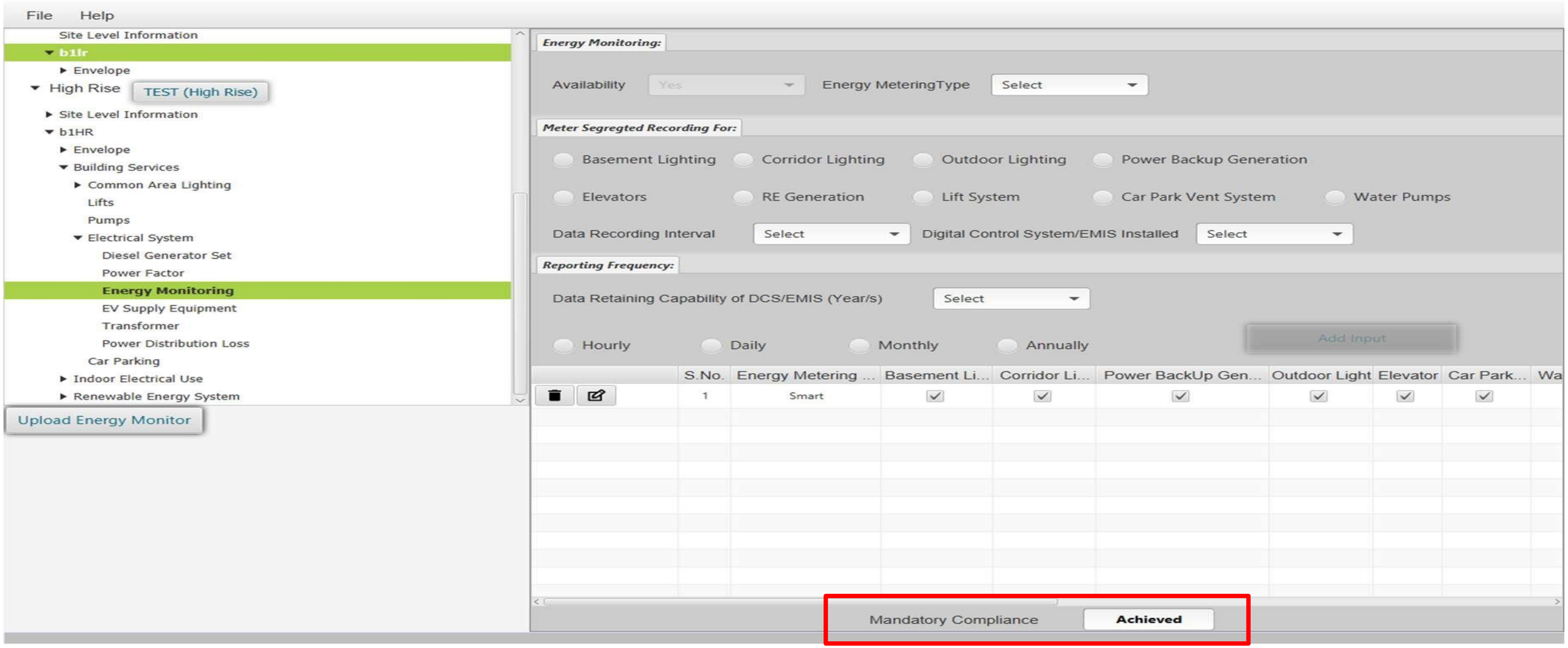


- Comprehensive help panel on each form for easy user referencing

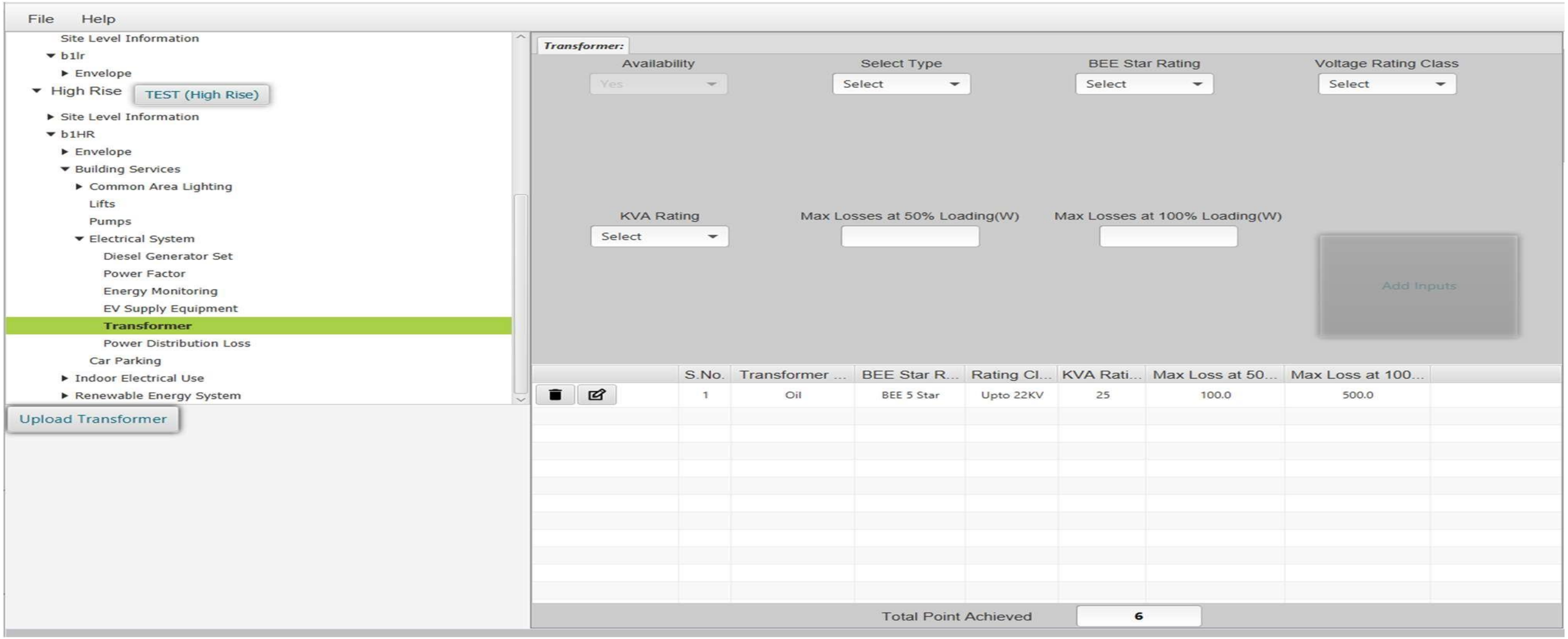


ENS Compliance Tools Key Features

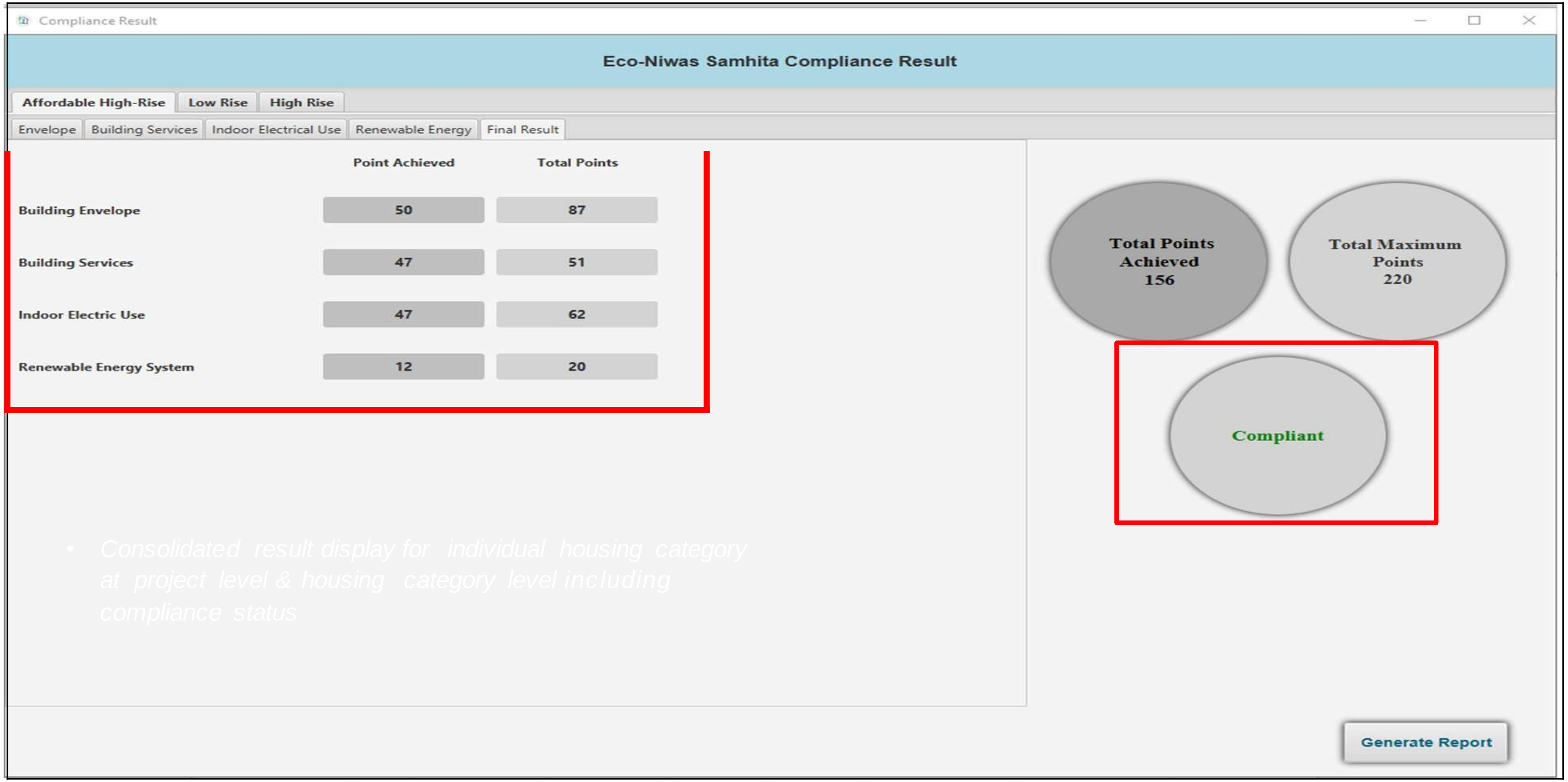
- Component level display for mandatory provisions and points achieved



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

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

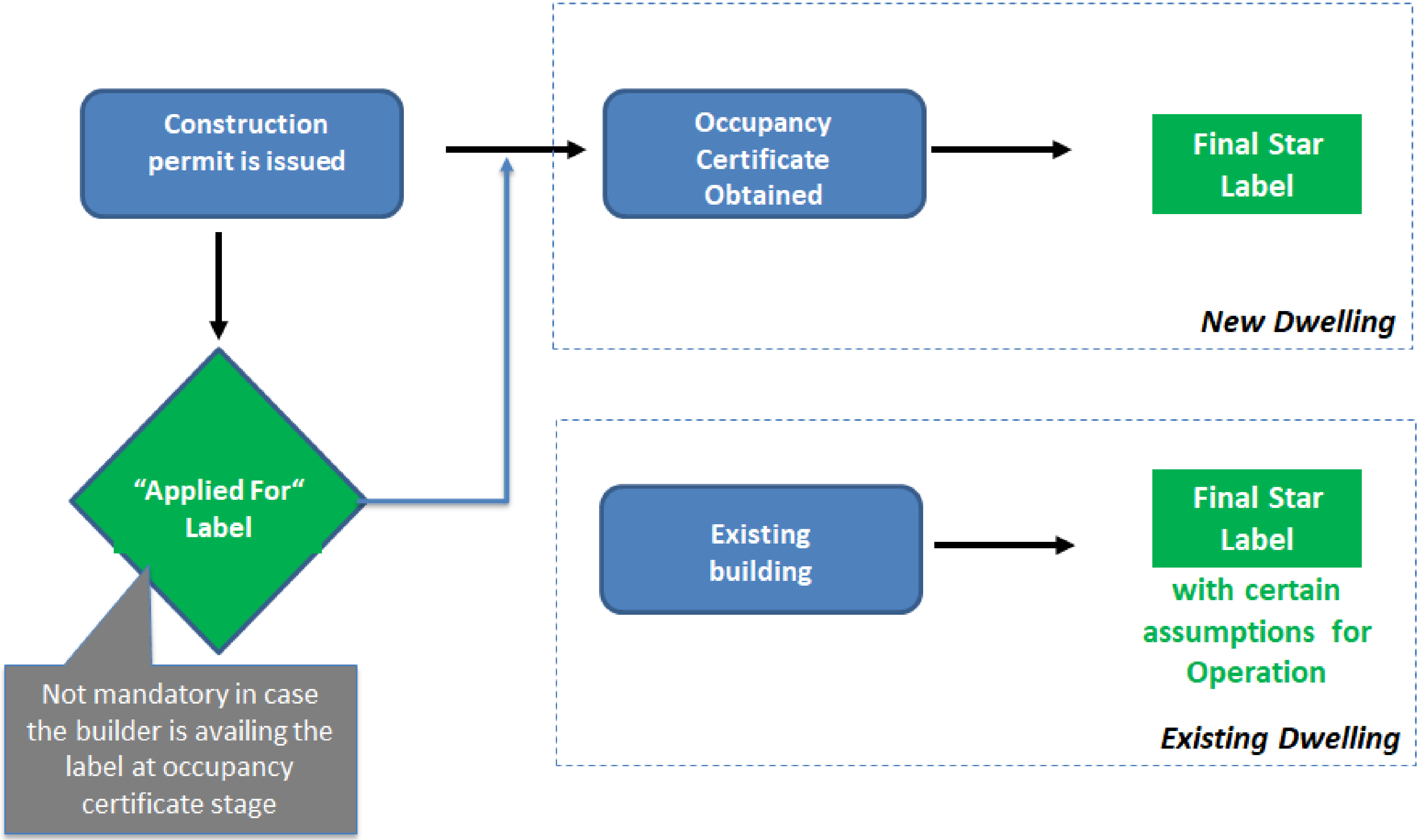
Market Transformation

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.

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

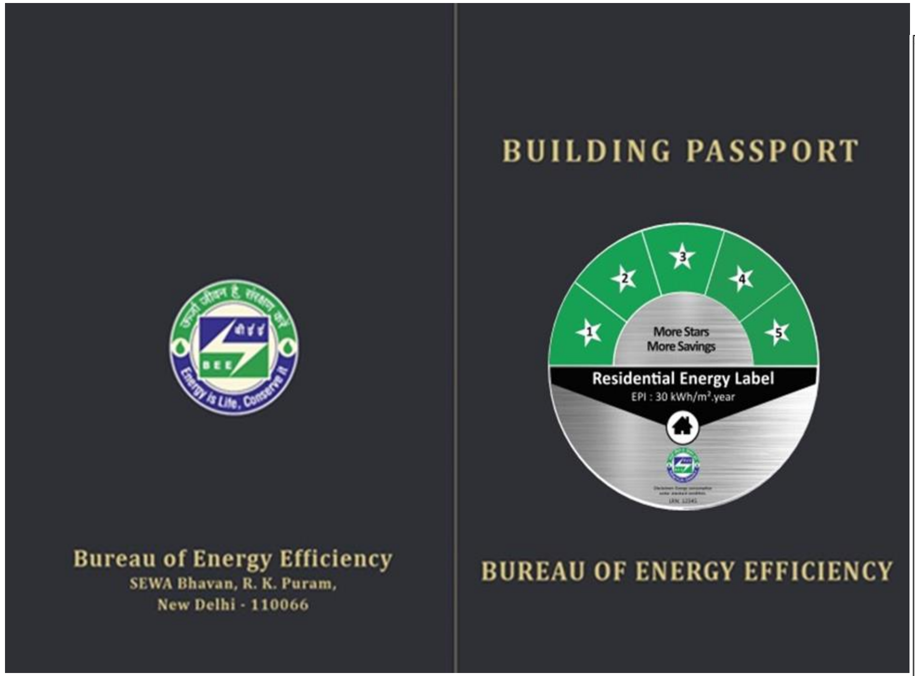
GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

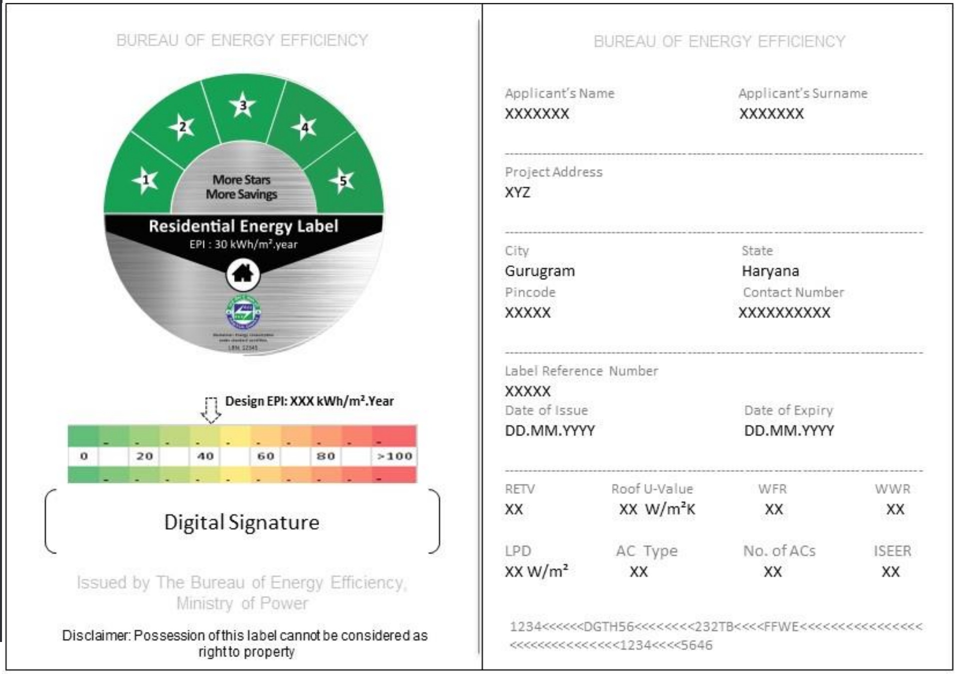
Ministry of Housing and Urban Affairs
Government of India

आज़ादी का अमृत महोत्सव

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

Passport





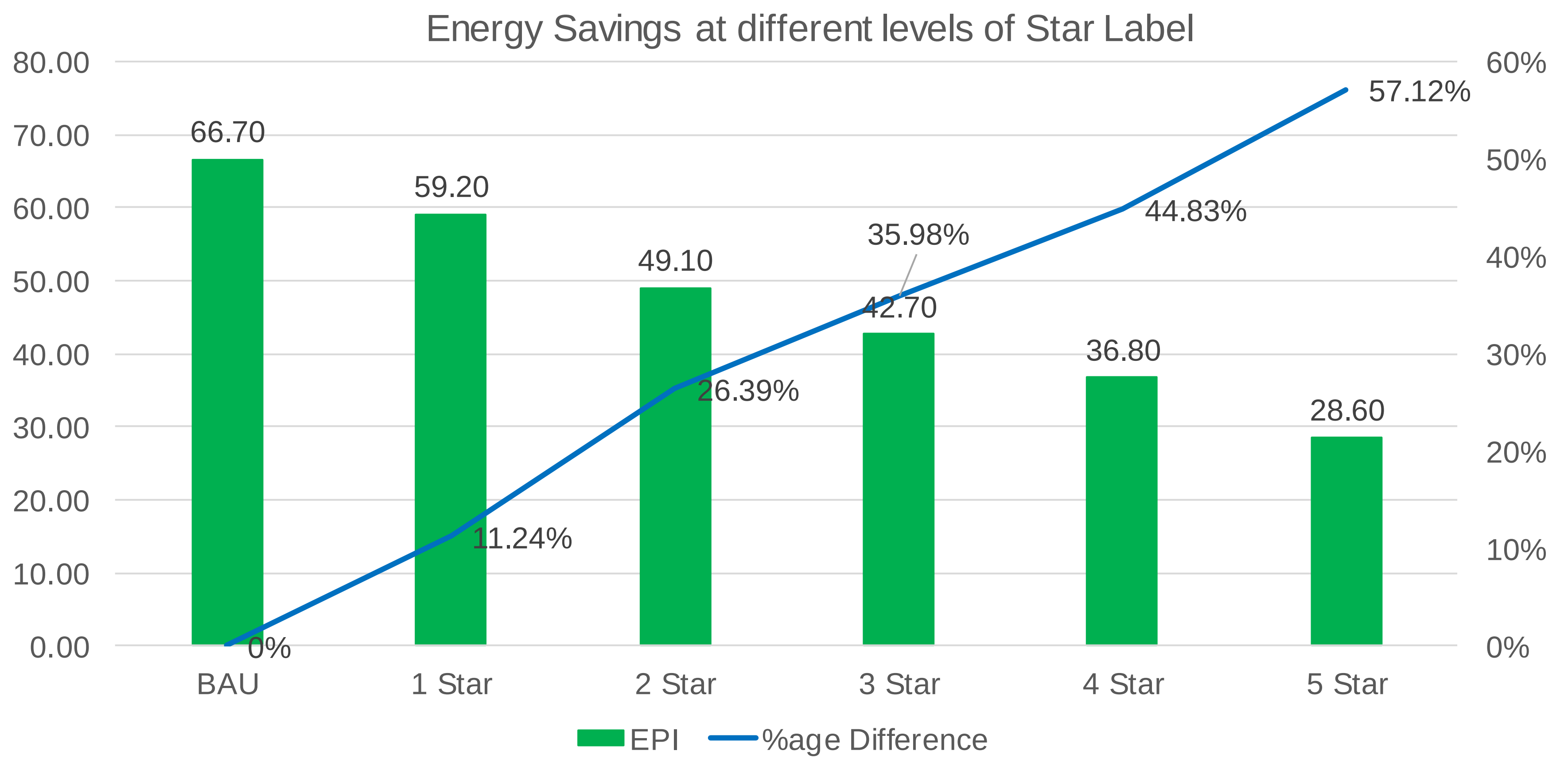
Upon approval from BEE, a building passport will be generated based on the details provided by label applicant.

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 → EE Label for Res Buildings ← Existing Residences

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 (**m²**)
- 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

02-G

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 CO2 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

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Ministry of Housing and Urban Affairs
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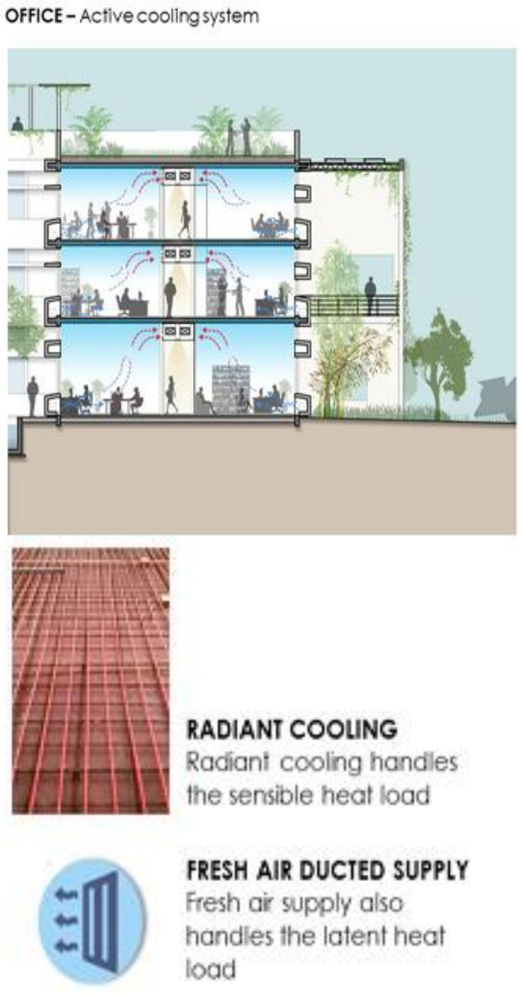
bmtpc
giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

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

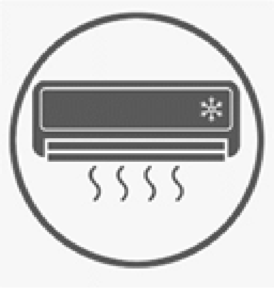
Shenzhen Institute of Building Research (IBR) Headquarters

- 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



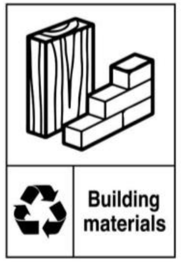
Air-Conditioning

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

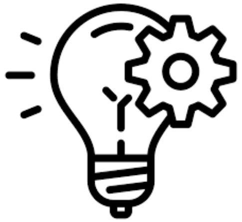
A vertical landscape distributed throughout the building doubles the area available for greenery compared to the building's original footprint. The roof garden, "sky garden," and patio garden all help restore the ecological balance of the building site.



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

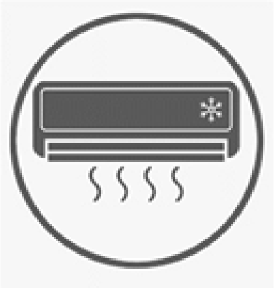
Daylight for all the office spaces means no artificial lighting is needed during the day and provides views of the surrounding mountains from all of the workstations

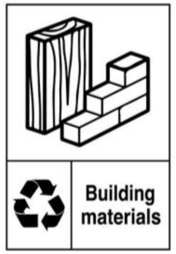
Best Practices in International Buildings

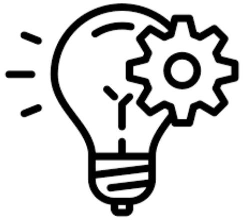
Bayalpata Hospital

- 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

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

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

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

Ministry of Housing and Urban Affairs
Government of India

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