



Ministry of Housing  
and Urban Affairs  
Government of India



# RACHNA 2.0

RESILIENT, AFFORDABLE AND COMFORTABLE HOUSING THROUGH NATIONAL ACTION

## CLIMATE SMART BUILDINGS

**Training #57: Two Day Training Program at Ranchi Municipal Corporation, Ranchi**

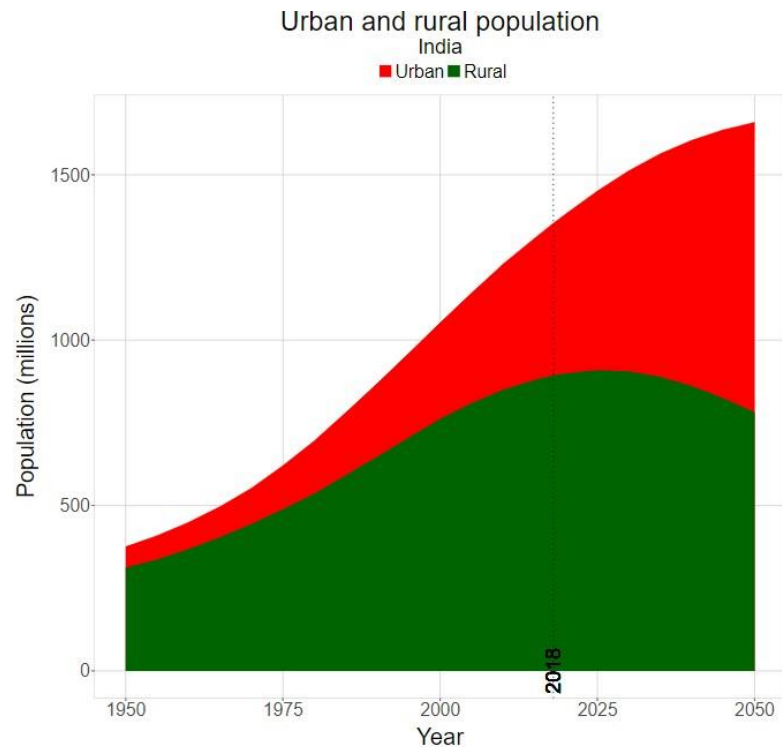
# DAY 1



01

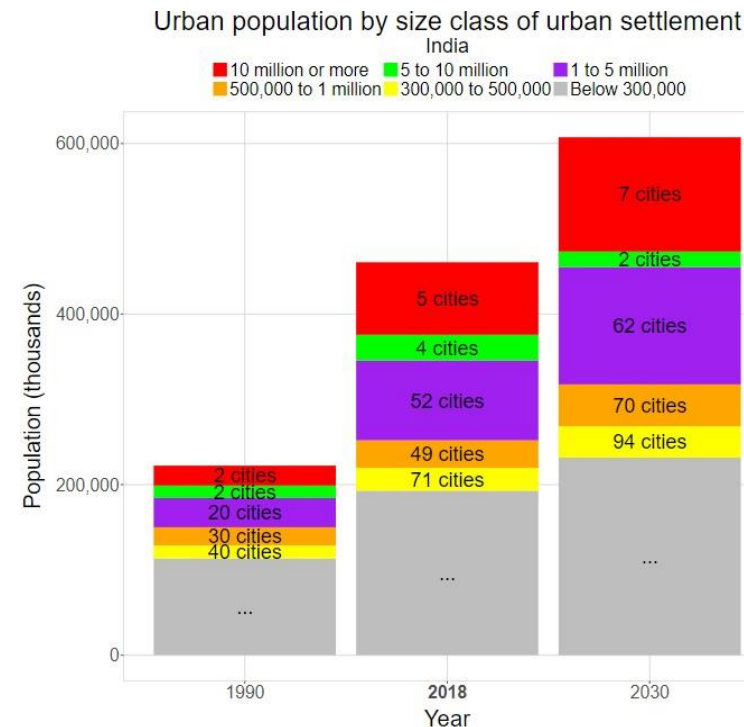
# INTRODUCTION

# Growing Opportunities with Rapid Urbanization



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Note: Urban and rural population in the current country.

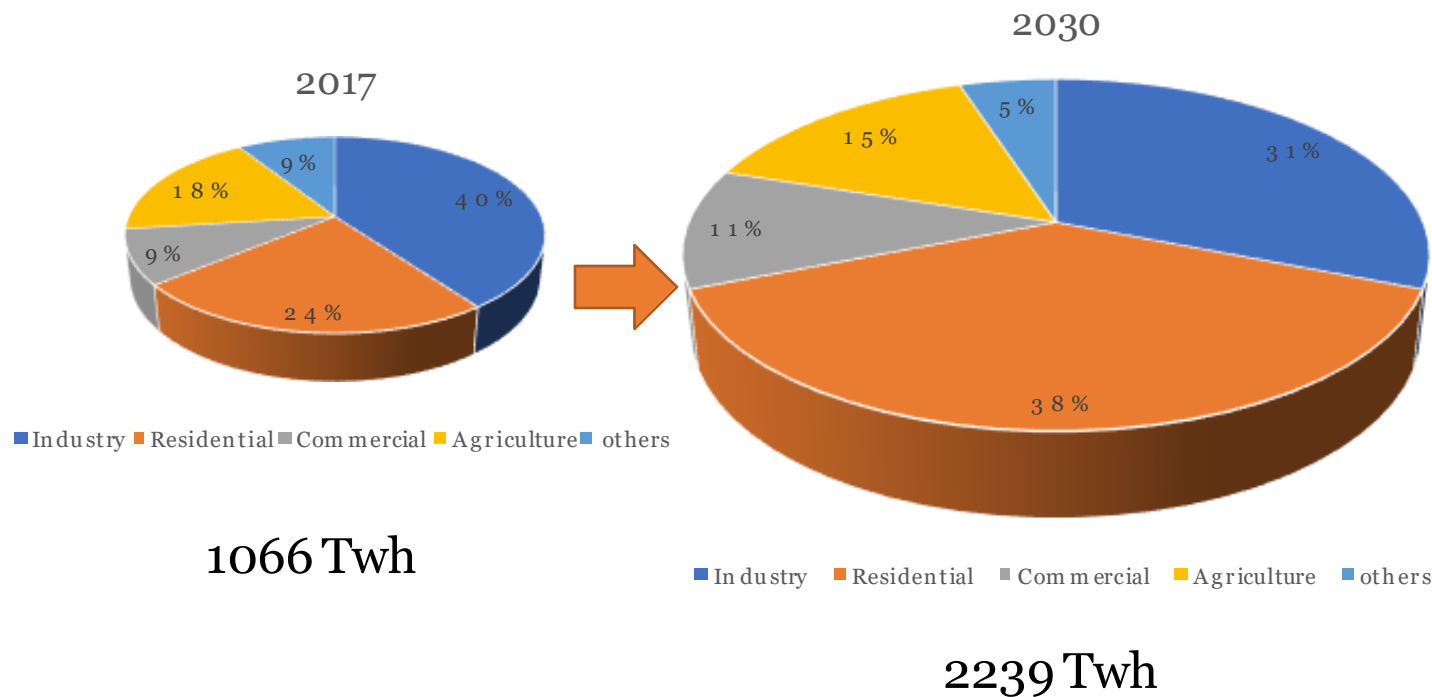


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- Cities, which will contribute over 80% to GDP by 2050, need to be Receptive, Innovative, and Productive to foster sustainable growth and ensure a better quality of living



# Energy demand with Rapid Urbanization

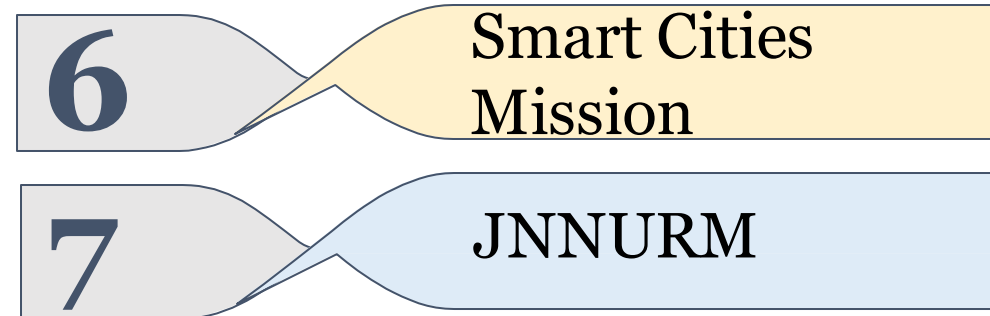
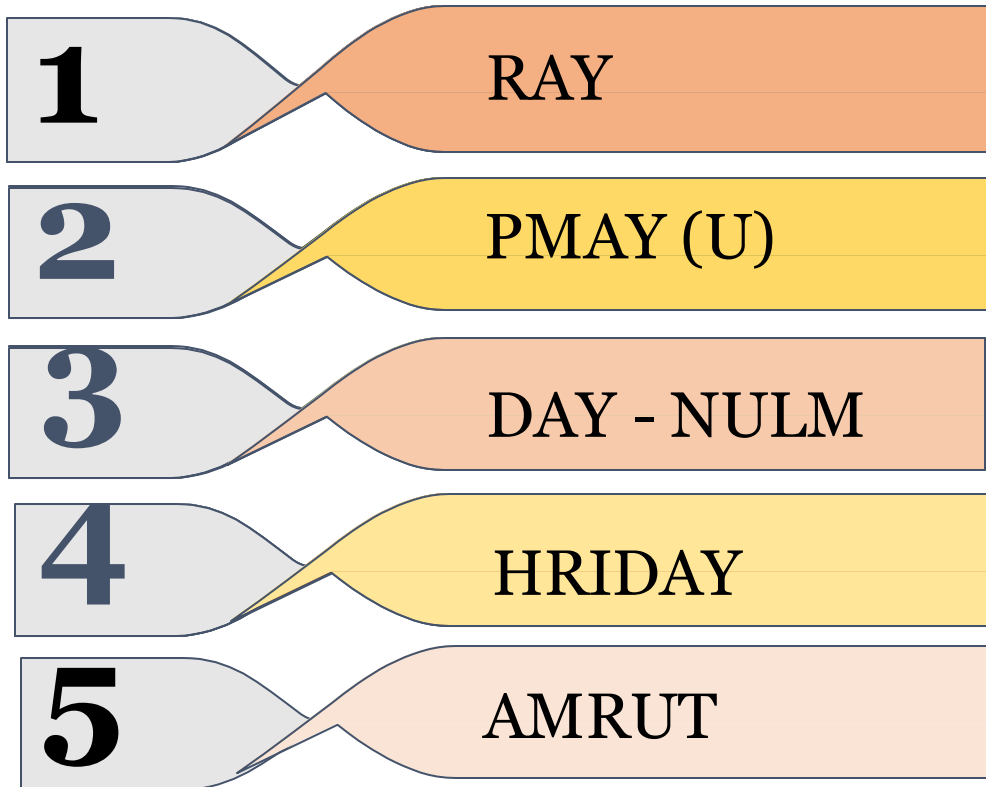


Residential Buildings: Fast Growth in Electricity Consumption.

\*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.

# MoHUA Initiates for Urban Transformation



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.

# Affordable Housing in India

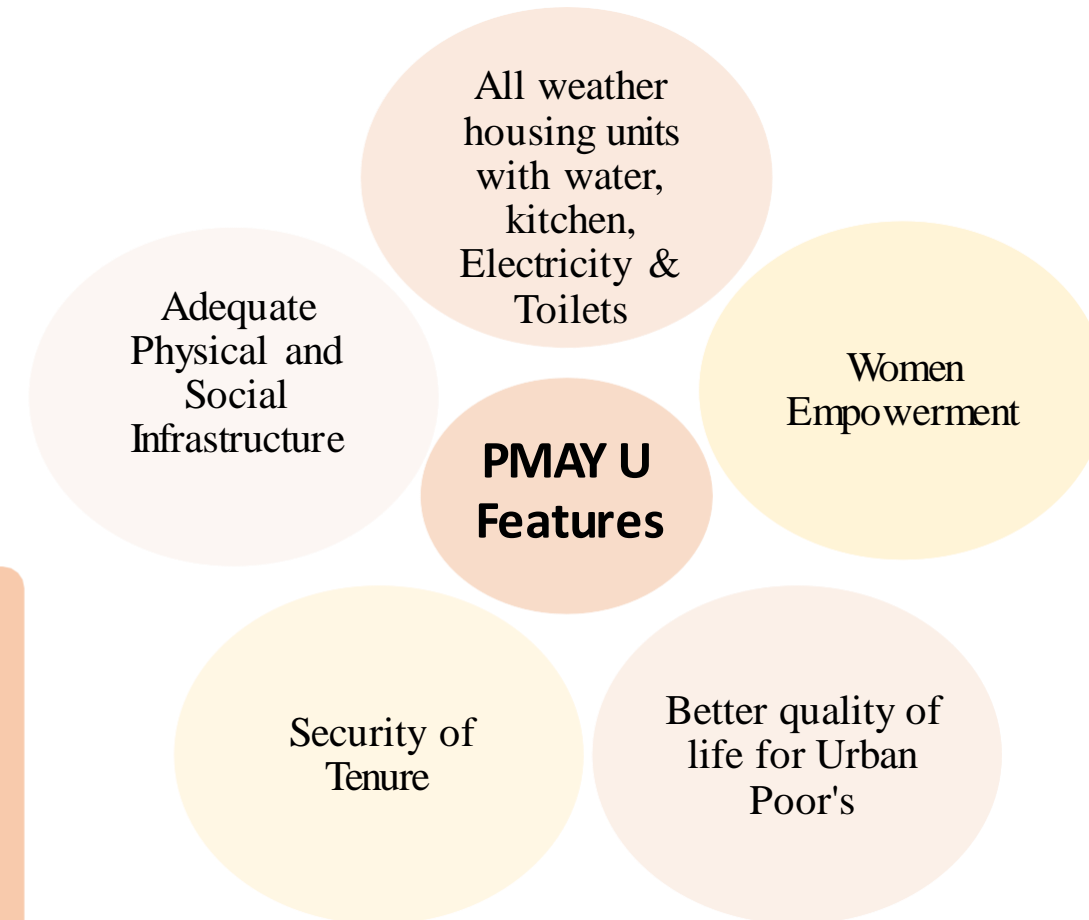
Affordable housing, as defined by the National Planning Policy Framework, is housing for sale or rent for those whose needs are not met by the market.



The provision of affordable housing is a key element of the Government's plan to end the housing crisis, tackle homelessness and provide aspiring homeowners with a step onto the housing ladder

# Pradhan Mantri Awas Yojna – Urban

- PMAY-U, launched in 2015, aims to provide houses for homeless. The Government is offering this scheme to all UT's and states. It also offers interest subsidy for Home loans for first time buyers in urban areas
- The residential buildings expected to increase by 2 times in terms of floor area by 2030
- 12 million new affordable homes in Urban areas under PMAY by 2022.



A significant percentage is in the form of high density, multi-storey residential blocks

Very low penetration of air conditioning though majority have ceiling fans

Ensuring Thermal comforts to occupants through design is of prime importance.

# Pradhan Mantri Awas Yojna – Urban

The mission is addressing the affordable housing requirement in Urban areas through following program verticals:

Subsidiary for beneficiary led individual house construction/enhancement. In-Situ Slum Redevelopment (ISSR) for Slums

Affordable housing in partnership with Public & Private Sectors

Promotion of Affordable Housing through Credit linked subsidy

Beneficiary-led Individual House Construction/ Enhancement (BLC-N/ BLC-E)

# Project Objectives

## Pradhan Mantri Awas Yojana - Urban

11.2 million dwelling  
units are being  
constructed



7.35 lakh crores  
investment



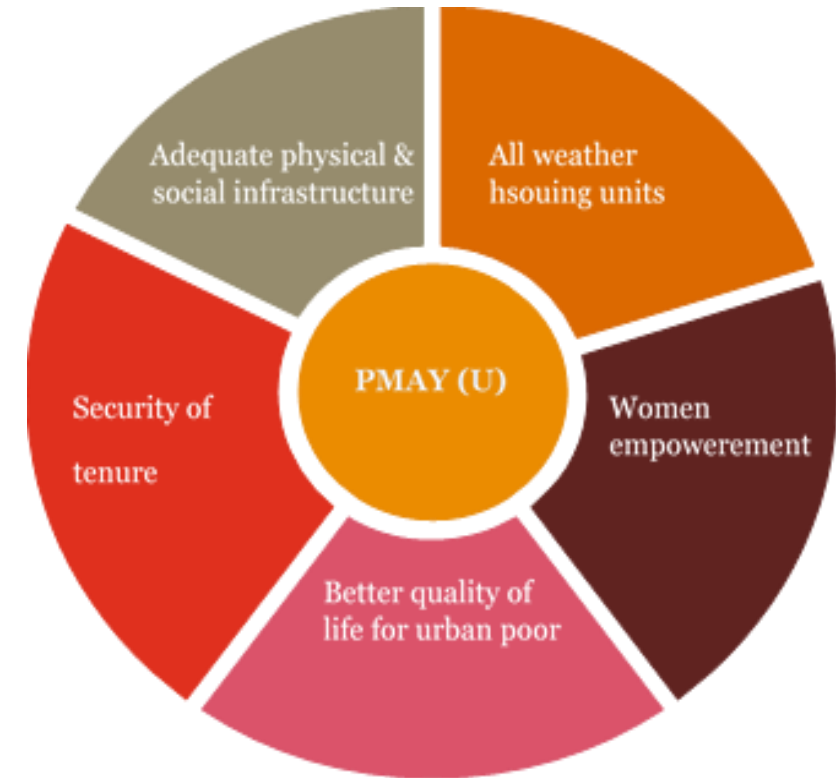
10 lakh  
occupants in the  
EWS/LIG category  
benefitting

**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)**



**Key features of PMAY-U projects**

# 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

# Components of GHTC India

1

- Grand Expo and Conference on Alternative and Innovative Construction Technologies

2

- Identifying and Mainstreaming Proven Demonstrable Technologies for the Construction of Light House Projects

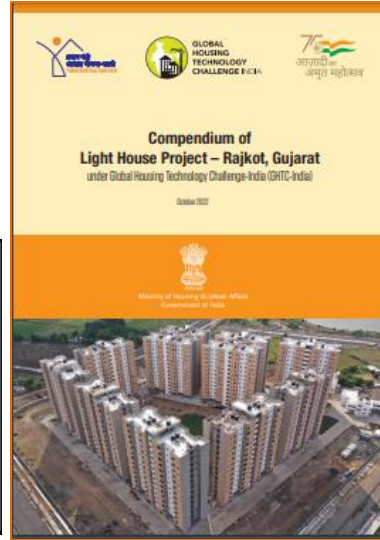
3

- Identifying Potential Future Technologies for Incubation and Acceleration Support through ASHA – India (Affordable sustainable Housing Accelerators)

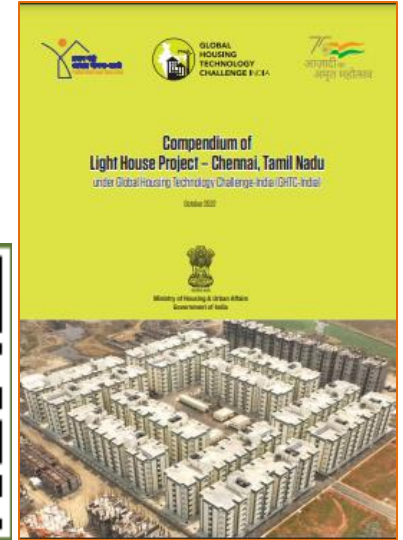


# Book Launches by MoHUA under GHTC India Challenge

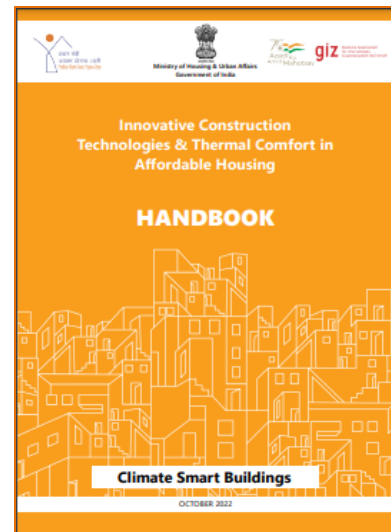
## Compendium of Light House Project Rajkot



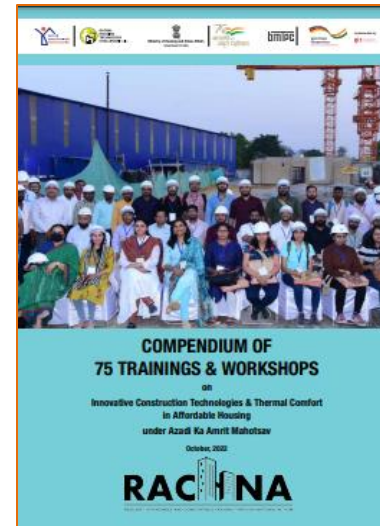
## Compendium of Light House Project Chennai



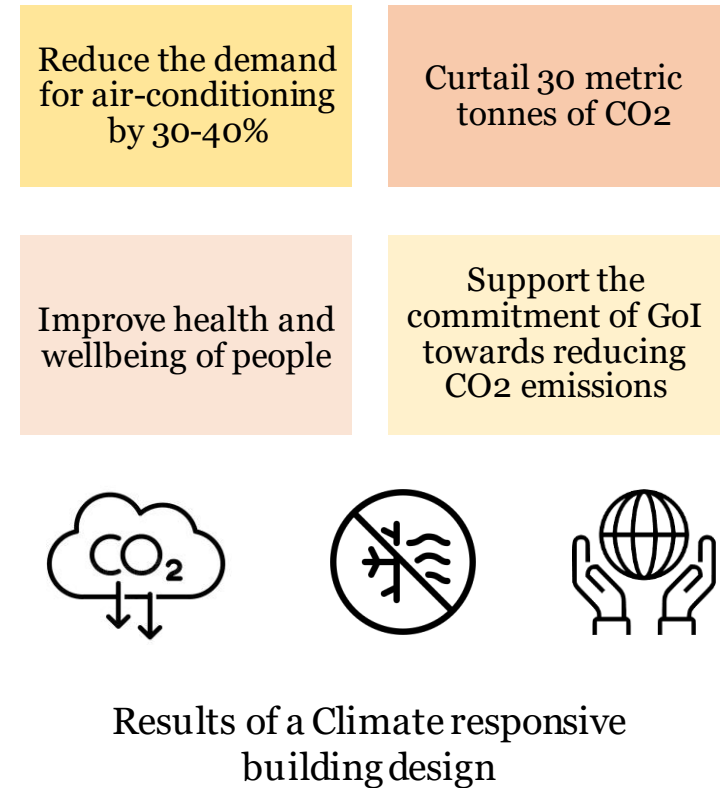
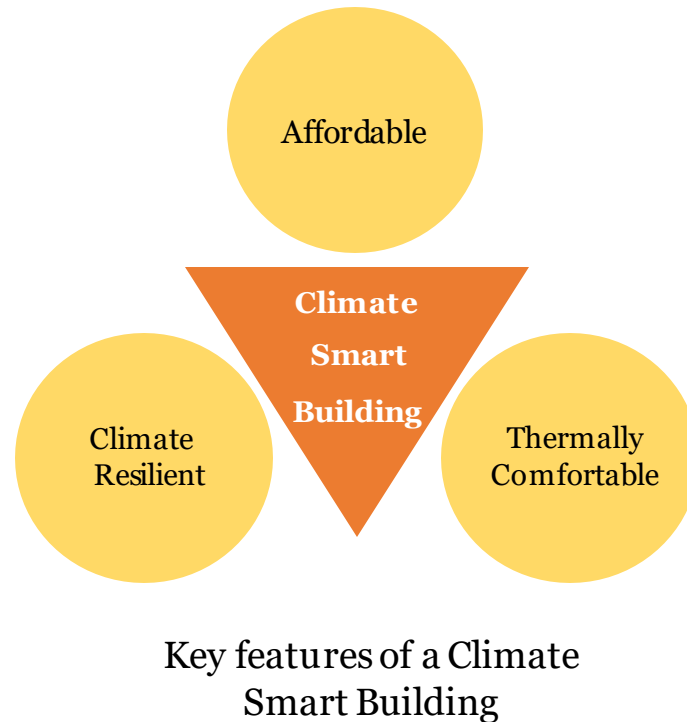
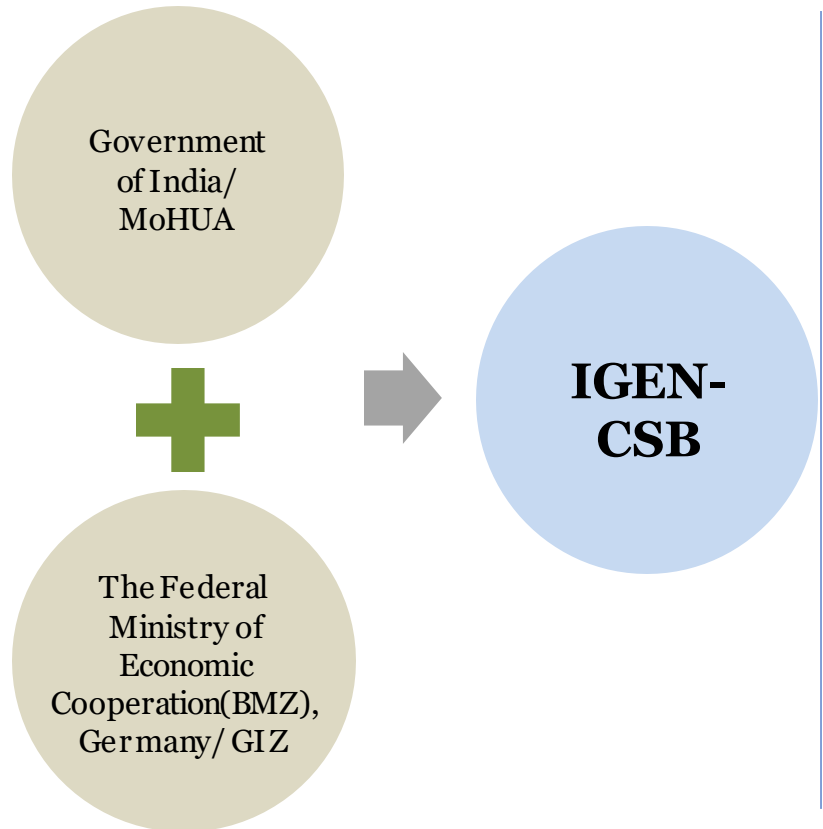
## Handbook on Innovative Construction Technologies & Thermal Comfort in Affordable Housing



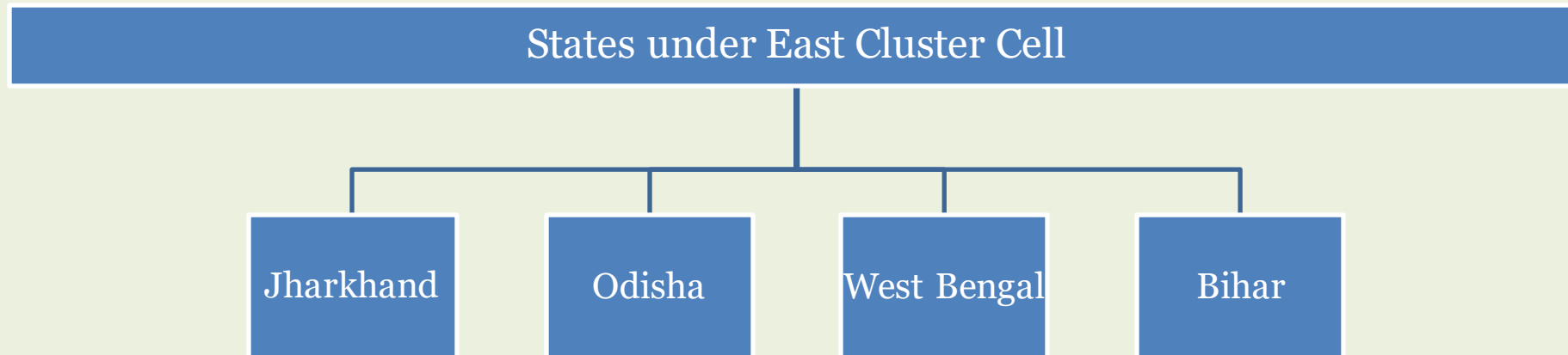
## Compendium of 75 Trainings & Workshops under RACHNA



# Climate Smart Buildings Programme (IGEN-CSB)



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



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.

# 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 West Cluster



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



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



## DAY 1

## Tea Break

## DAY 1

# Session 1: Innovative Construction Technologies of Light House Projects, LHP Study and Observations



02

# New Age Innovative Construction Technology & LHPs



# Light House Projects

- The aim of the assignment is to introduce thermal comfort into the foray of affordable housing, a critical design & thus usability aspect which unfortunately has been missing from the current nature of affordable housing in India.
- Although studies & policies like the green guidelines for PMAY projects, Eco-Niwas Samhita Part-1, Star Labelling of energy efficient homes etc have been around but what the sector really needs is specific, easy to comprehend provisions which can be mandated & enforced in a steadfast way which is exactly what this project intends to do





# Light House Projects

## Strategic Intent

- Seamless implementation of LHPs
- Assist in knowledge transfer through documentation of technologies used & implementation of LHPs
- Technical assistance to achieve thermal comfort in demonstration projects
- Support the implementation of thermal comfort provision in state legislature
- Capacity building around thermal comfort & sustainable construction



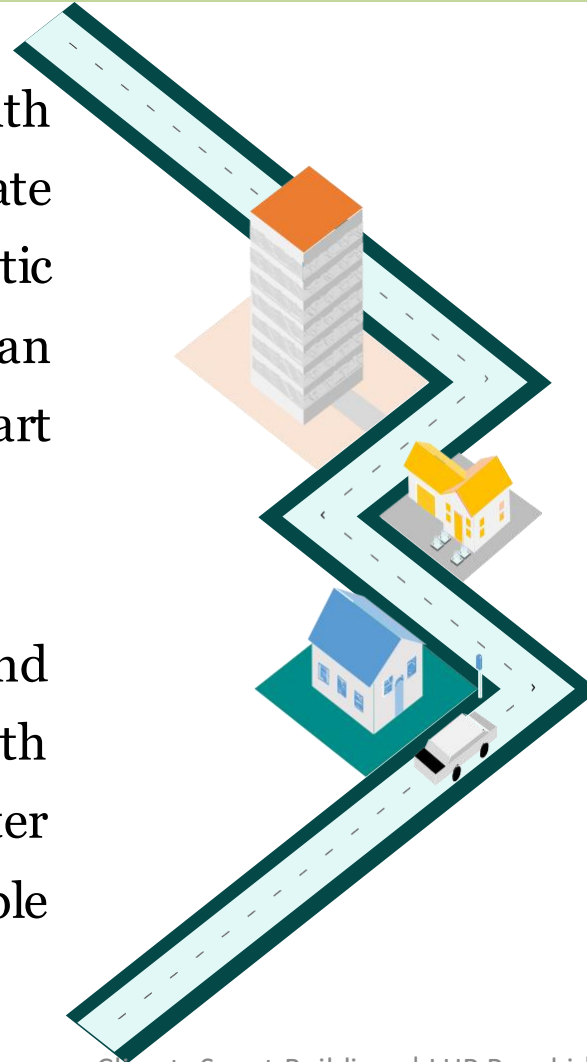
## Outcome

- Successful model for the implementation & documentation of LHPs
- Databank of technologies, relevant materials in the state analyzed around various relevant parameters
- Replicable models for thermally comfortable affordable houses in Gujarat (climate sensitive to 3 climatic conditions in the state)
- Thermal comfort provisions mandated by the law
- Better grasp of thermal comfort & sustainability in general among the concerned stakeholders & general public too

# What are we working on?

LHPs are model housing projects with houses built with shortlisted alternate technology suitable to the geo-climatic and hazard conditions of the region, an initiative under the Climate Smart Building Programme.

These projects demonstrate and deliver ready to live houses with speed, economy and with better quality of construction in a sustainable manner.



Currently the LHPs' are being implemented in six states (Uttar Pradesh, Gujarat, Madhya Pradesh, Gujarat, Jharkhand, and Tripura) of India under Global Housing Technology Challenge (GHTC) – India. These projects are constructed with modern technology and innovative processes and reduce the construction time and make a more resilient, affordable, and comfortable house for the poor.

## Details of LHP Projects along with Construction Technology Used

LHP Location	TECHNOLOGY SELECTED	NUMBER OF HOUSES TO BE CONSTRUCTED
Rajkot, Gujarat	Monolithic Concrete Construction using Tunnel Formwork	1144
Indore, Madhya Pradesh	Prefabricated Sandwich Panel System	1024
Chennai, Tamilnadu	Precast Concrete Construction System – Precast Components Assembled at Site	1152
<b>Ranchi, Jharkhand</b>	<b>Precast Concrete Construction System – 3D Volumetric</b>	<b>1008</b>
Agartala, Tripura	Light Gauge Steel Structural System & Pre-engineered Steel Structural System	1000
Lucknow, Uttar Pradesh	PVC Stay in Place Formwork System	1040

## Features of LHP

### Definition

A model housing project with approximate 1,008 houses built with shortlisted Construction technology under GHTC Challenge, demonstrating speed, economy and better quality of construction in a sustainable manner

### Minimum Size of houses

As defined by PMAY (U), the houses built are of EWS category, Each Dwelling Unit has Carpet area less than 30 sq.m. The carpet area is the habitable area excluding walls, doors etc. The DU carpet area in LHP Ranchi is 29.85 Sq.m.

### Available on-site facilities

- Site Development
- Solar PV Installation
- Sewage Treatment Plant
  - Rain-Water Harvesting
- Community Centre cum Commercial center
- Landscaping

### Design

### Construction Period

The Light House projects are conceived with a vision of fast construction using Technology. Each LHP is given 15 months time to complete. However, due to some issues the project cannot be completed in due time.

- Designed as per the dimensional requirements mandated in the National Building Code (NBC) 2016.
- Design in concurrence with existing centrally sponsored schemes and Missions such as Smart Cities, AMRUT, Swachh Bharat (U), National Urban Livelihood Mission (NULM), Ujjwala, Ujala, Make in India, etc.
- Structural details designed considering durability and safety requirements of applicable loads including earthquakes and cyclone and flood as applicable confirming to applicable Indian/International standards.
- Design of Cluster involves the possibility of innovative system of water supply, drainage and rainwater harvesting, renewable energy sources with special focus on solar energy.

# Light House Projects

Following are the details of Construction Technologies being employed at the Light House Projects shortlisted 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 System Agartala, Tripura

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



## PVC Stay in Place Formwork System

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

# Precast Concrete Construction System – 3D Volumetric – LHP Ranchi

An already established System for building construction in Europe, Singapore, Japan & Australia, this 3D Volumetric concrete construction is the modern method of building by which solid 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 are transported, erected & installed using cranes and push-pull jacks and are integrated together in the form of complete building unit.

Subject to the hoisting capacity, building of any height can be constructed using the technology.

## Construction Process

Sequential construction in the project here begins with keeping the designed foundation of the building ready, while manufacturing of precast concrete structural modules are taking place at the factory.

Factory finished building units/modules are then installed at the site with the help of tower cranes.



Gable end walls are positioned to terminate the sides of building. Pre-stressed slabs are then installed as flooring elements.



Rebar mesh is finally placed for structural screed thereby connecting all the elements together.



Consecutive floors are built in similar manner to complete the structure.



# Precast Concrete Construction System – 3D Volumetric – LHP Ranchi

## Special Features

About 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.

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

# Monolithic Tunnel Formwork Technology – LHP Rajkot

In ‘TunnelForm’ technology, concrete walls and slabs are cast in one go at site giving monolithic structure using high-precision, re-usable, room-sized, Steel forms or molds called ‘TunnelForm’. An already established System for building construction in many countries, this system intends to replace the conventional RCC Beam-Column structure which uses steel/plywood shuttering. ‘TunnelForm’ system uses customized engineered steel formwork consisting of two half shells which are placed together and then concreting is done to form a room size module. Several such modules make an apartment.

## Construction Process

Stripping of the  
formwork from the  
previous day.



Positioning of the  
formwork for the  
current day's  
phase, with the  
installation of  
mechanical,  
electrical and  
plumbing services.



Installation of  
reinforcement in  
the walls and slabs.



Concreting



# Monolithic Tunnel Formwork Technology – LHP Rajkot

## Special Features

Facilitating rapid construction of multiple/mass modular units (similar units).

Making structure durable with low maintenance requirement.

The precise finishing can be ensured with no plastering requirement.

The concrete can be designed to use 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 resource

Being Box type monolithic structure, it is safe against horizontal forces (earthquake, cyclone etc.)

The large number of modular units bring economy in construction.

# Prefabricated Sandwich Panel System – LHP Indore

- An already established System for building construction in China, Australia, African and Gulf countries, this factory made Prefabricated Sandwich Panel System is made out of cement or calcium silicate boards and cement mortar with EPS granules balls, and act as wall panels. These replace conventional brick & mortar walling construction practices and can be used as load-bearing and non-load bearing walling for residential and commercial buildings. For buildings higher than single storey, the system can be used either with RCC or steel framed structure.
- Under this LHP, houses are being constructed using Prefabricated Sandwich Panel System with Pre-Engineered Steel Structural System.
- In this system the EPS Cement Panels are manufactured at the factory in controlled condition, which are then dispatched to the site. The panels having tongue and groove are joint together for construction of the building.

## Special Features

Being 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.

# Precast Concrete Construction System – Precast Components Assembled at site – LHP Chennai

An already established technology for building construction, Precast concrete construction is a system where the individual precast components such as walls, slabs, stairs, column, beam etc, of building are manufactured in plant or casting yard in controlled conditions. The finished components are then transported to site, erected & installed. The technology provides solution for low rise to high rise buildings, especially for residential and commercial buildings.

The construction process comprises of manufacturing of precast concrete Columns, Beams and Slabs in steel moulds.

The reinforcement cages are placed at the required position in the moulds.



Concrete is poured and compaction of concrete is done by shutter/ needle vibrator.



Casted components are then moved to stacking yard where curing is done for required time and then these components are ready for transportation and erection at site.



These precast components are installed at site by crane and assembled through in-situ jointing and/or grouting etc.

# Precast Concrete Construction System – Precast Components Assembled at site – LHP Chennai

## Special Features

Nearly all components of building work are manufactured in plant/casting yard & the jointing of components is done In-situ leading to reduction in construction time.

The controlled factory environment brings resource optimization, improved quality, precision & finish.

The concrete can be designed with 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 resources.

Eliminates use of plaster.

Helps in keeping neat & clean construction site and dust free environment.

Optimum use of water through recycling.

Use of shuttering & scaffolding materials is minimal.

All weather construction & better site organization.

# Light Gauge Steel Structural System & Pre – engineered Steel Structural System – LHP Agartala

An already established System for building construction in Japan, Australia & North America; Light Gauge Steel Frame (LGSF) System uses factory made galvanized light gauge steel components. The components/sections are produced by cold forming method and assembled as panels at site forming structural steel framework up to G+3 building. LGSF is used in combination with pre-engineered steel structural system for buildings above G+3 for longevity, speedier construction, strength and resource efficiency.

Under this Light House Project, houses are being constructed using Light Gauge Steel Frame System (LGSF) with Pre-Engineered Steel Structural System.

## Construction Process

The sequence of construction comprises of foundation laying, fixing of Pre-Engineered Steel Structural System, fixing of tracks, fixing of wall panels with bracings as required, fixing of floor panels, decking sheet, fixing of electrical & plumbing services and finally fixing of concrete walling panels with light weight concrete as infill.

The other options of dry walling components such as sandwich panels with insulation material in between can also be used.

Similarly, the floors can either by composite slab/deck slabs/precast hollow core slabs as per the need & requirements.

# Light Gauge Steel Structural System & Pre – engineered Steel Structural System – LHP Agartala

## Special Features

High strength to weight ratio. Due to light weight, significant reduction in design earthquake forces is achieved. Making it safer compared to other structures.

Fully integrated computerized system with Centrally Numerical Control (CNC) machine primarily employed for manufacturing of LGSF sections provide very high Precision & accuracy.

Construction being very fast, a typical four storied building can be constructed within one month.

Structure being light, does not require heavy foundation

Structural element can be transported to any place including hilly areas to remote places easily making it suitable for far flung regions including difficult terrains.

Structure can be shifted from one location to other without wastage of materials.

Steel used can be recycled multiple times

The system is very useful for post disaster rehabilitation work.

# PVC Stay in Place Formwork System – LHP Lucknow

- Already in use in Canada & Australia, the plant manufactured rigid poly-vinyl chloride (PVC) based polymer components serve as a permanent stay-in-place finished form-work for concrete walls. The formwork System being used acts as pre-finished walls requiring no plaster and can be constructed instantly. This System is suitable for residential and commercial buildings of any height from low rise to high rise. In order to achieve speedier construction, strength and resource efficiency, the composite structure with Pre-Engineered Steel Structural System as structural members is being used in the present project.

## Construction Process

Construction is done in a sequential manner where at first, the Prefabricated PVC Wall panels and Pre-Engineered Steel Structural Sections as per the design are transported to the Site.

Then, these Sections are erected on the prepared foundation using cranes and required connections.



Floor is installed using decking sheet. Once the structural frame and floor is installed and aligned, wall panels are fixed on decking floor.



The pre-fabricated walling panels having provisions of holes for services conduits, are fixed along with the reinforcement & cavities inside the wall panels are filled with concrete.



Upon installment of wall panels, flooring and ceiling, the finishing work is executed.



# PVC Stay in Place Formwork System – LHP Lucknow

## Special Features

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.

In case of 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 very aesthetic look.





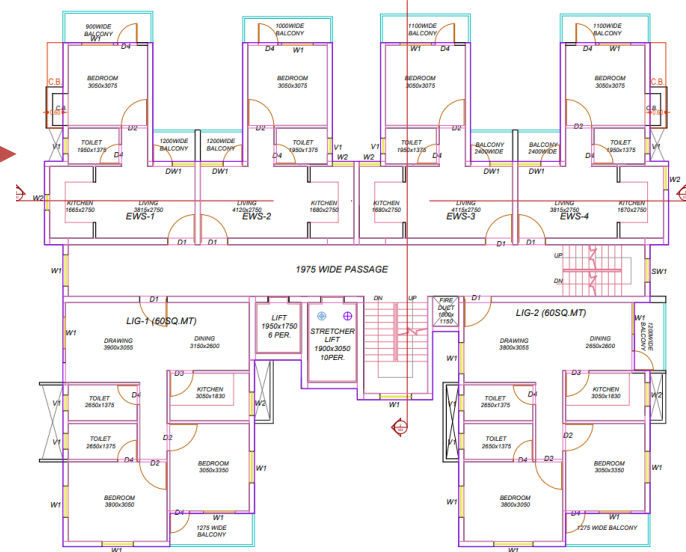
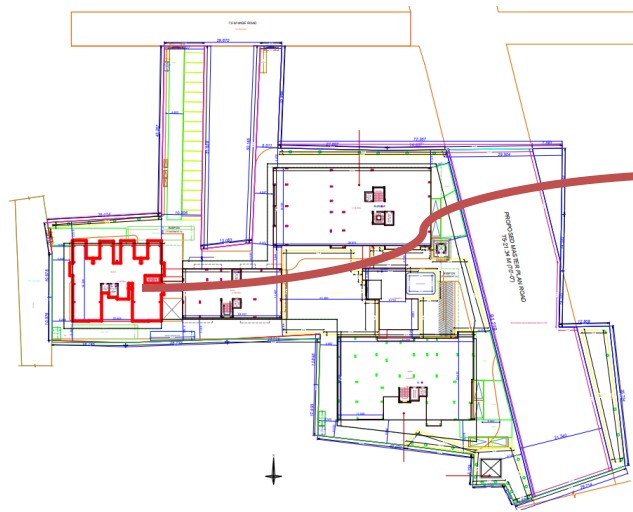
# 03

## Thermal Comfort Analysis & Recommendations on LHPs and Demo Projects

## CASE STUDY OF DEMO PROJECTS

# The Demonstration Housing Projects

Under the Climate Smart Buildings Project in Eastern Cluster, the CSB Cell have identified and are supporting 1 of upcoming affordable housing projects in Ranchi to achieve minimum Thermal Comfort standards of MoHUA – GoI.



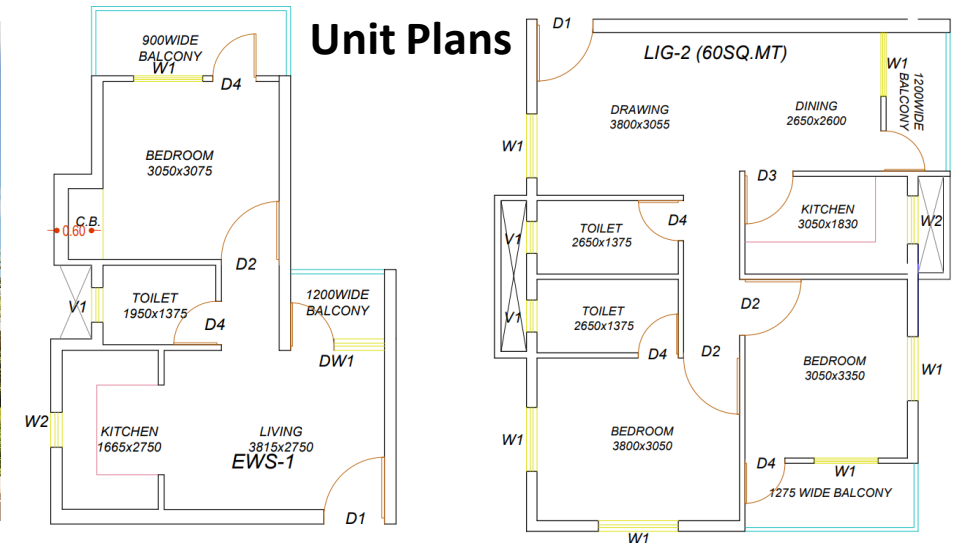
## Utopian Heights, Ranchi

Assessment reports on Demonstration Housing Project's performance have been made that highlight on results, conclusions, and recommendations for enhanced thermal comfort and energy efficiency.

# ENS compliance and improvements for Demonstration Housing Project

## Utopian Heights AHP project, Ranchi

It is recommended to provide roof insulation in order to comply with max. thermal transmittance value for roof and to increase the comfortable hours with in the units.



### As Designed

Element	U Value	RETV	ENS Part 1 Compliance	ENS Score
Wall AAC + Plaster	0.678	8.98	Yes	112
Window Aluminum+ single Glazed	5.8			
Roof 150 mm Concrete Slab	2.73	-	No	

### With Improvements

Element	U Value	RETV	ENS Part 1 Compliance	ENS Score
Wall AAC + Plaster	0.678	8.98	Yes	117
Window Aluminum+single Glazed	5.8			
Roof 150 mm Concrete Slab + 50 mm EPS insulation	0.59	-	Yes	

# Recommendations

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

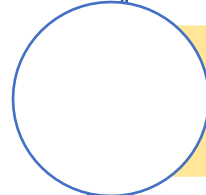
# Recommendations



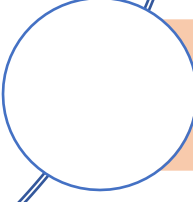
To align with GHG reduction targets and other government activities, make "Thermal Comfort for All" a government priority, and relate it to India's ambition to give a better quality of life to all of its residents.



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



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



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

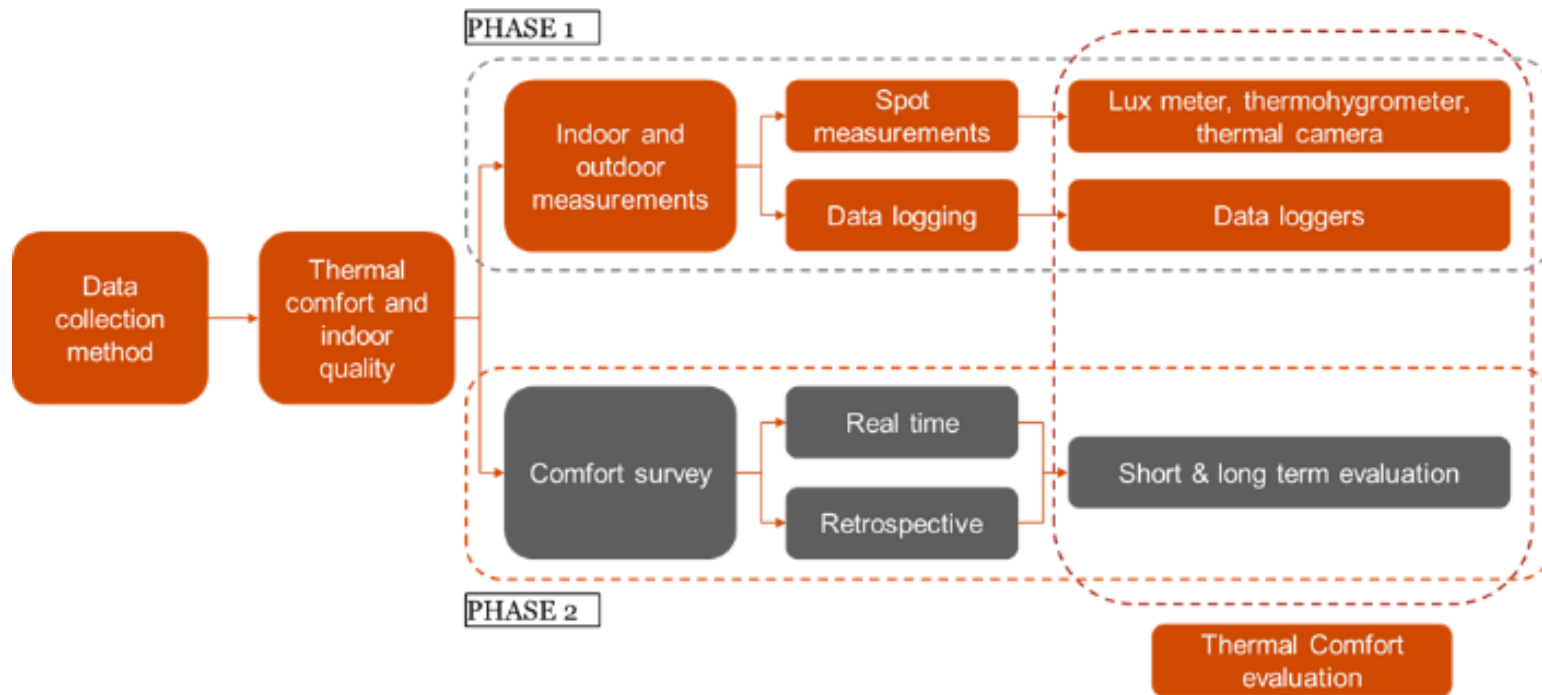


## CASE STUDY OF LHP RAJKOT



# Thermal comfort study of the Light House Project- Rajkot

The LHP in Rajkot constructed with Monolithic Tunnel formwork technology has been planned and constructed with such specification and layout which would give better thermal comfort compared to conventional construction. GIZ was assigned the task of studying aspect of thermal comfort in LHP project.

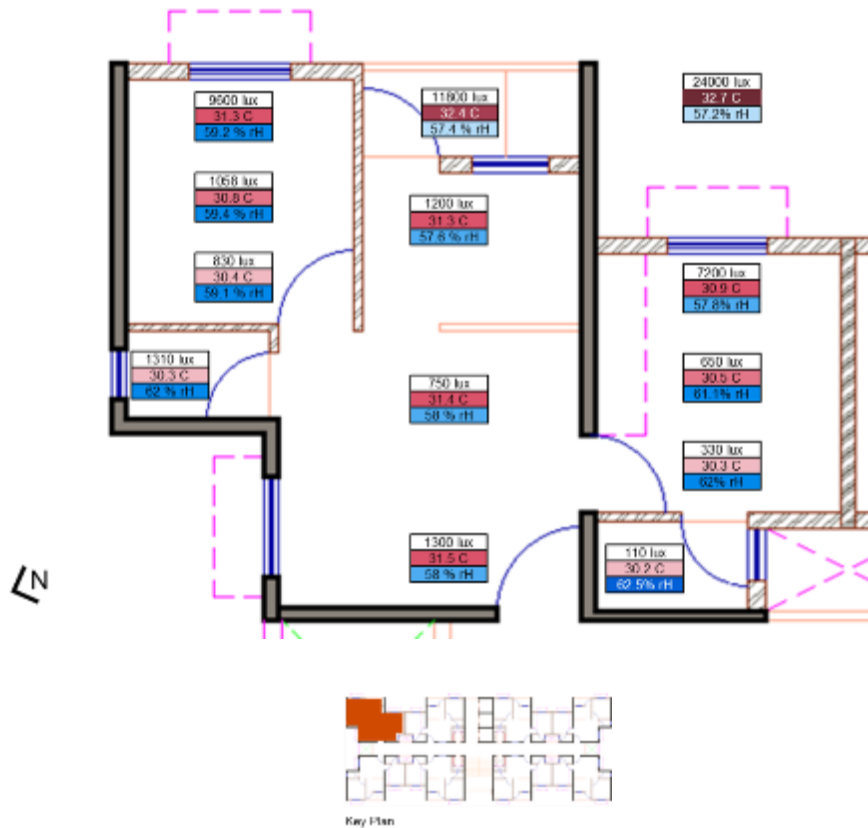


## Methodology for monitoring and evaluation

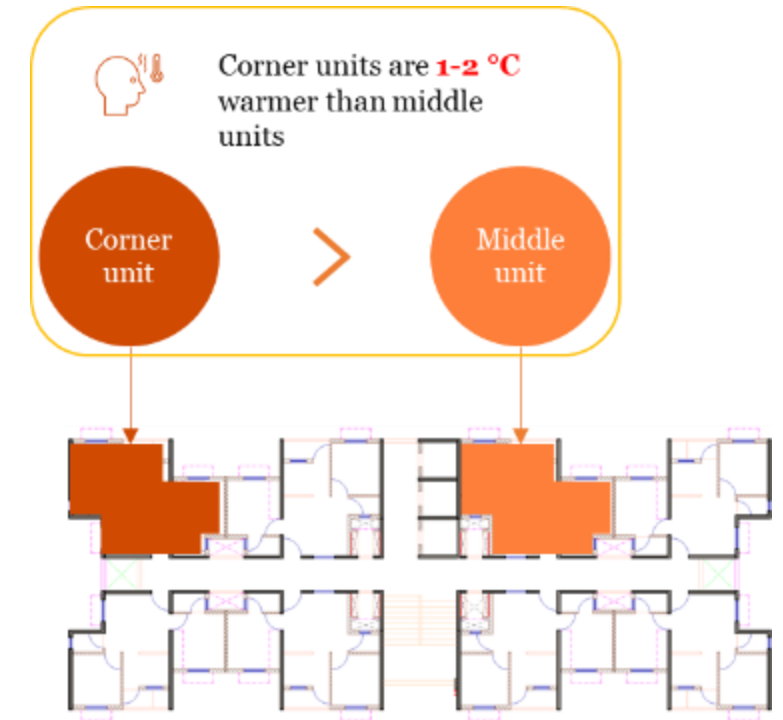
- On-site spot measurements
  - dataloggers,
- comparative graphs, and
  - a comfort chart

# Thermal comfort study of the Light House Project- Rajkot

## On-site spot measurements

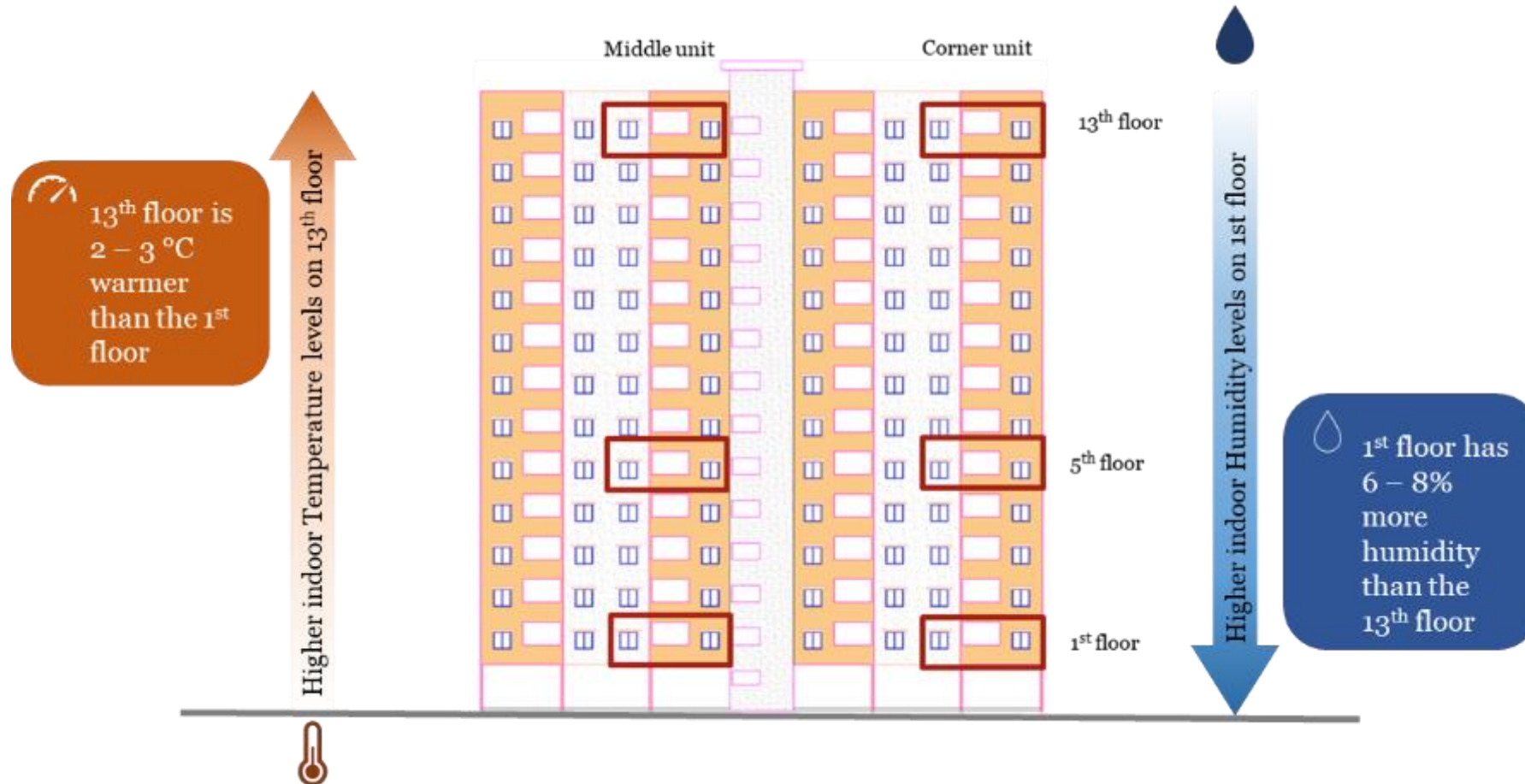


## Findings



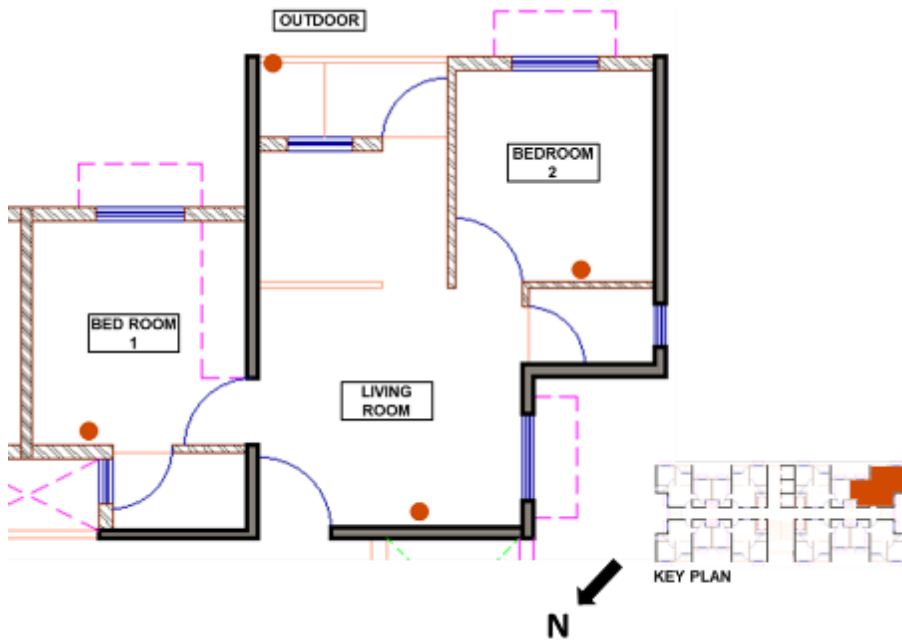
# Thermal comfort study of the Light House Project- Rajkot

## Findings (Cont.)



# Thermal comfort study of the Light House Project- Rajkot

## Datalogger placement

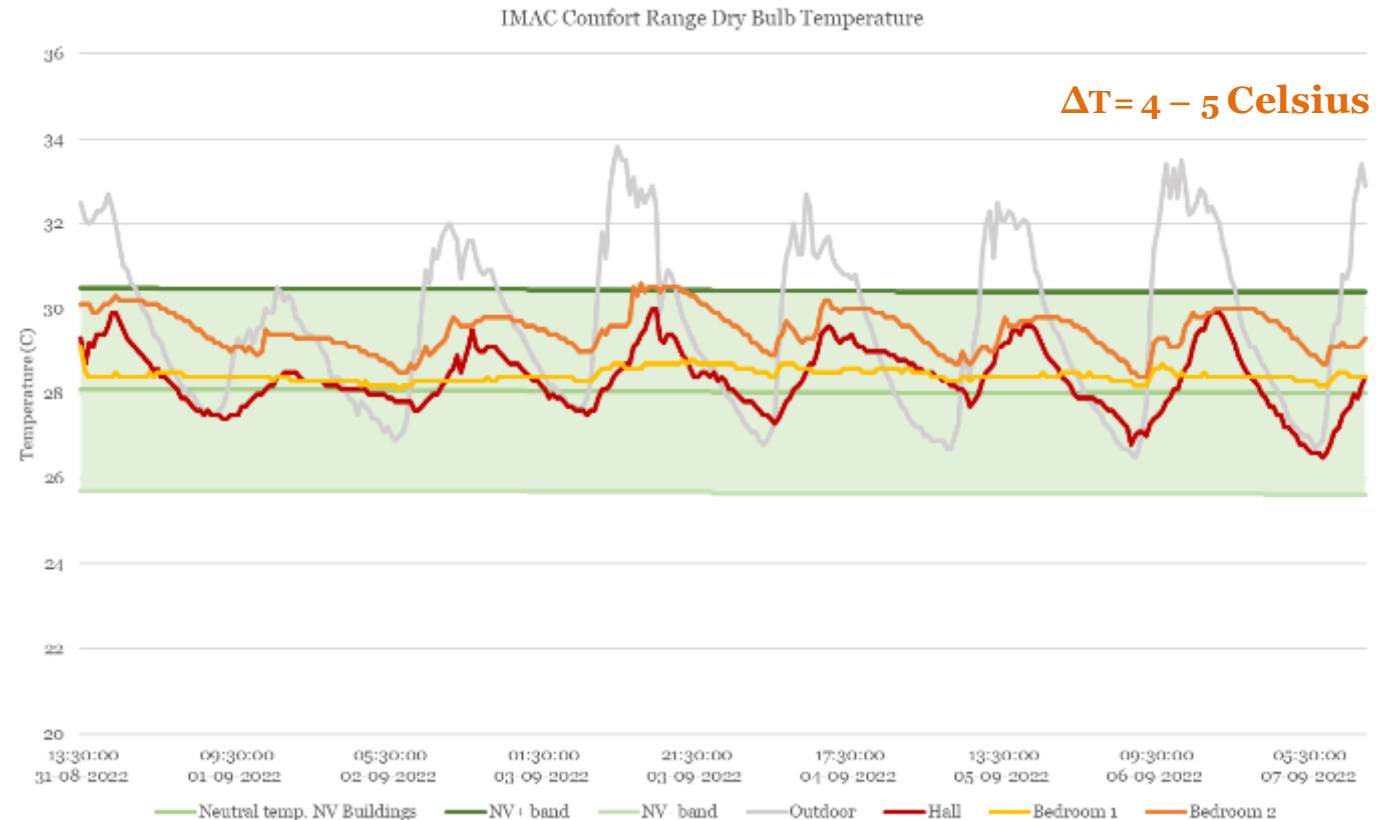


**Location:** Tower 8 | 1<sup>st</sup> floor | Corner unit

**Occupancy:** 9 am to 5 pm

**Operation mode:** No comfort system, No lighting, Natural Ventilation

## Findings




The data loggers readings from Wednesday, 31<sup>st</sup> August to 7<sup>th</sup> September 2022.

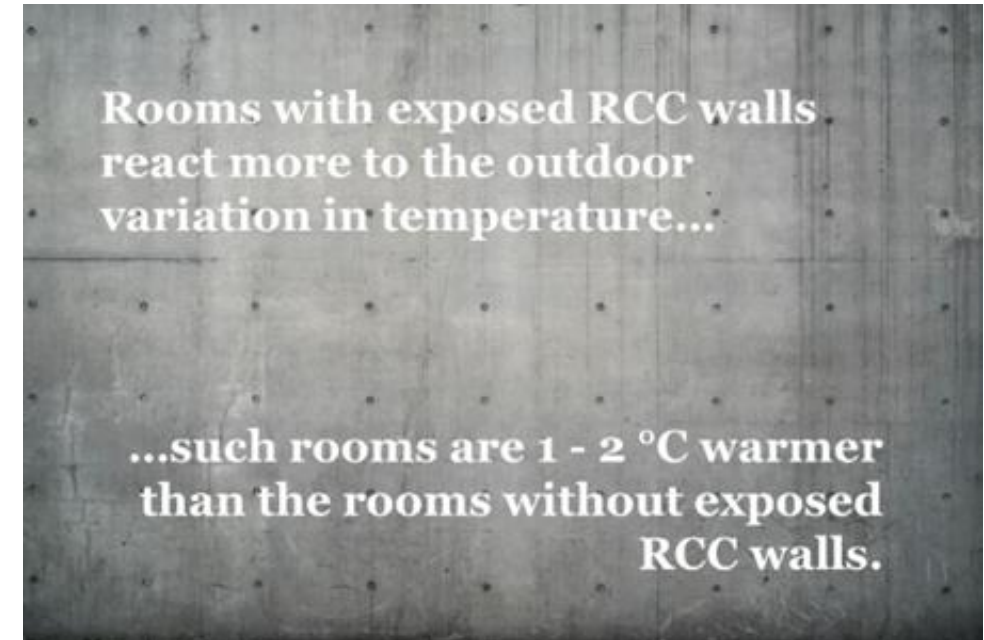


# Thermal comfort study of the Light House Project- Rajkot

## Findings (Cont.)



 **98%** of the time the indoor temperatures stayed within the IMAC comfort band



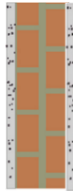


**RCC walls have no insulation properties, and they heat and cool more rapidly based on outdoor conditions**

## Key performance features of the Light House Project- Rajkot

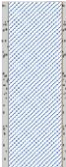


<b>Saved kWh of Power due to reduction in construction time]</b>	<b>215051 kWh</b> saved. Typical saving is <b>4.72 kWh/Sq. mtr</b> compared to building construction using conventional method.
<b>% reduction in cost of construction</b>	<b>10%</b> [Faster construction speed leading to reduction in construction cost]
<b>% reduction in water use</b>	<b>26.67%</b> (For Concrete), Approx 70% (For Masonary Work)
<b>% reduction in Construction waste</b>	<b>10%</b> Approx.[Usage of Tunnel Formwork causing reduction in construction waste]
<b>% Reduction in use of energy</b>	<b>16.67%</b>
<b>% Reduction in embodied energy</b>	<b>25%</b>

# Comparison between building envelope of conventional building vs LHP, Rajkot

## Conventional Construction Envelope Details

Envelope Type	Conventional Construction Configuration	Section	U Value*
Wall	Interior Surface Film resistance + Internal Cement Mortar (12 mm) + Brick Wall (230mm) + External Cement Mortar (12 mm) + Exterior Surface film resistance		1.97 W/m <sup>2</sup> K
Roof	Interior Surface Film resistance + External Cement Mortar (18mm) + RCC slab (150mm) + Internal Cement Mortar (12mm) + Exterior Surface film resistance		2.78 W/m <sup>2</sup> K
Fenestration & Glazing	Steel framed Single Glazing Unit (SGU) with 5mm glass, SHGC = 0.84, VLT = 0.89		6.2 W/m <sup>2</sup> K
Void	Assumed SHGC = 1, VLT = 1		7W/m <sup>2</sup> K
RETV	Residential Envelope Transmittance Value (North-South Blocks)		16.64 W/m <sup>2</sup>

## LHP Rajkot Construction Envelope Details

Envelope Type	LHP Construction Configuration	Section	U Value*
Wall	Interior Surface Film resistance + Internal Cement Mortar (10 mm) + AAC Block (200mm) + External Cement Mortar (30 mm) + Exterior Surface film resistance		0.68 W/m <sup>2</sup> K
Roof	Interior Surface Film resistance + RCC slab (160 mm) + screeding (55 mm) + External Cement Mortar (50mm) + China mosaic + Exterior Surface film resistance		2.74 W/m <sup>2</sup> K
Fenestration & Glazing	uPVC framed SGU with 5mm glass thickness, SHGC = 0.83, VLT = 0.89		5.9 W/m <sup>2</sup> K
Void	Assumed SHGC = 1, VLT = 1		7W/m <sup>2</sup> K
RETV	Residential Envelope Transmittance Value (North-South Blocks)		14.32 W/m <sup>2</sup>





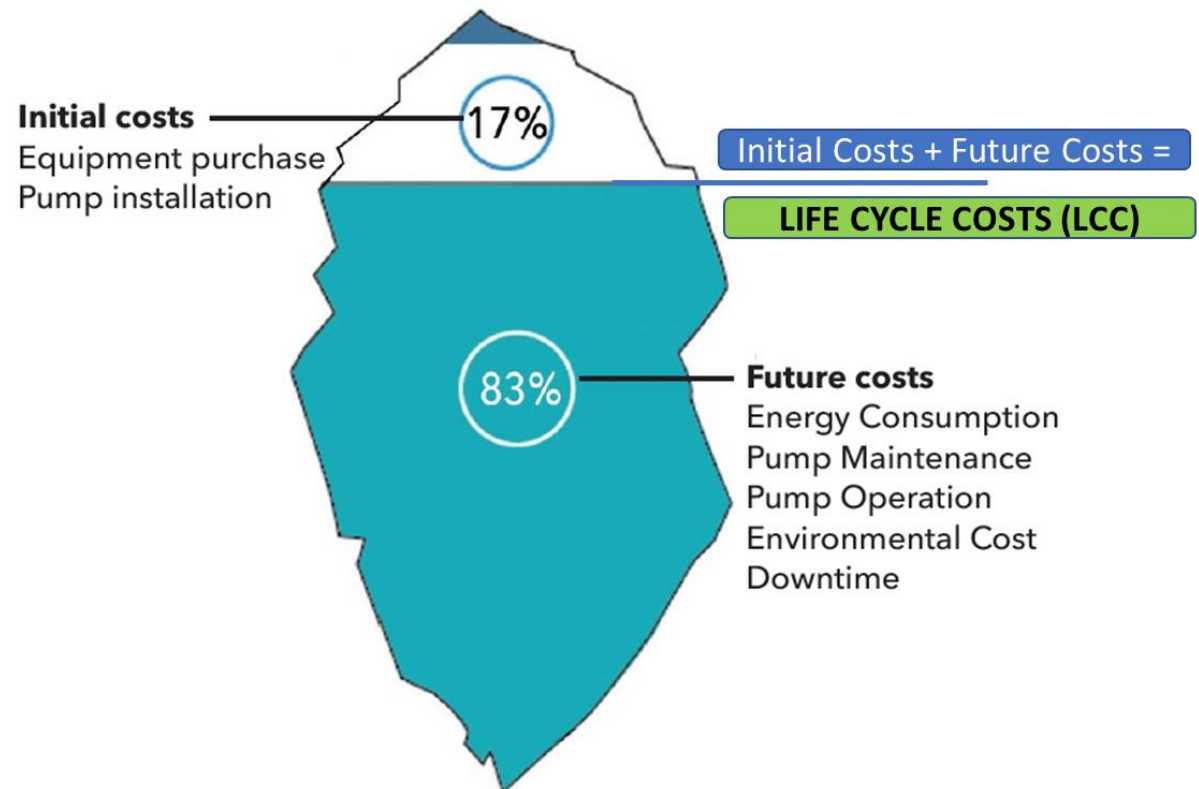
04

## Life Cycle Cost and its impact on Carbon Emission

# Concept of life cycle cost and its impact on carbon emission

## Life Cycle Cost

Life cycle costing is a method of economic analysis directed at all costs related to constructing, operating, and maintaining a construction project over a defined period of time.



# Concept of life cycle cost and its impact on carbon emission

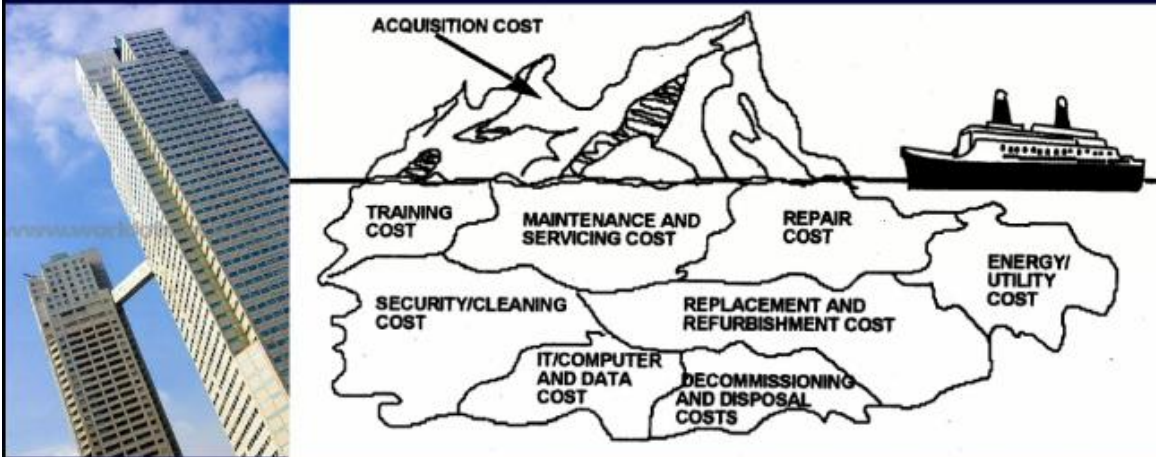
## Why LCC matters in sustainable building

Sustainable/green technology in building is commonly more expensive than its traditional counterpart. However, it is more energy efficient, lower operation and maintenance cost. The Energy saving, O&M feature occurs over the life-time of the building. Therefore, It is essential to use the analysis which recognizes the cost saving which spreads over the life-time – the Life Cycle Cost (LCC) analysis

# Concept of life cycle cost and its impact on carbon emission

## Why LCC matters in sustainable building

### Illustration: An Office building



Office building: **1 : 5 : 200\***

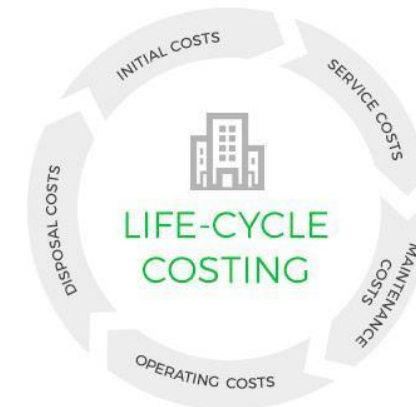
1 = Construction Cost

5 = Maintenance and Building Operating Costs

200 = Business Operating Costs

\*source: The Royal Academy of Engineering

**Total LCC** = (Investment cost +  
operation cost + Maintenance +  
Replacement cost + Disposal cost) –  
Salvage Value

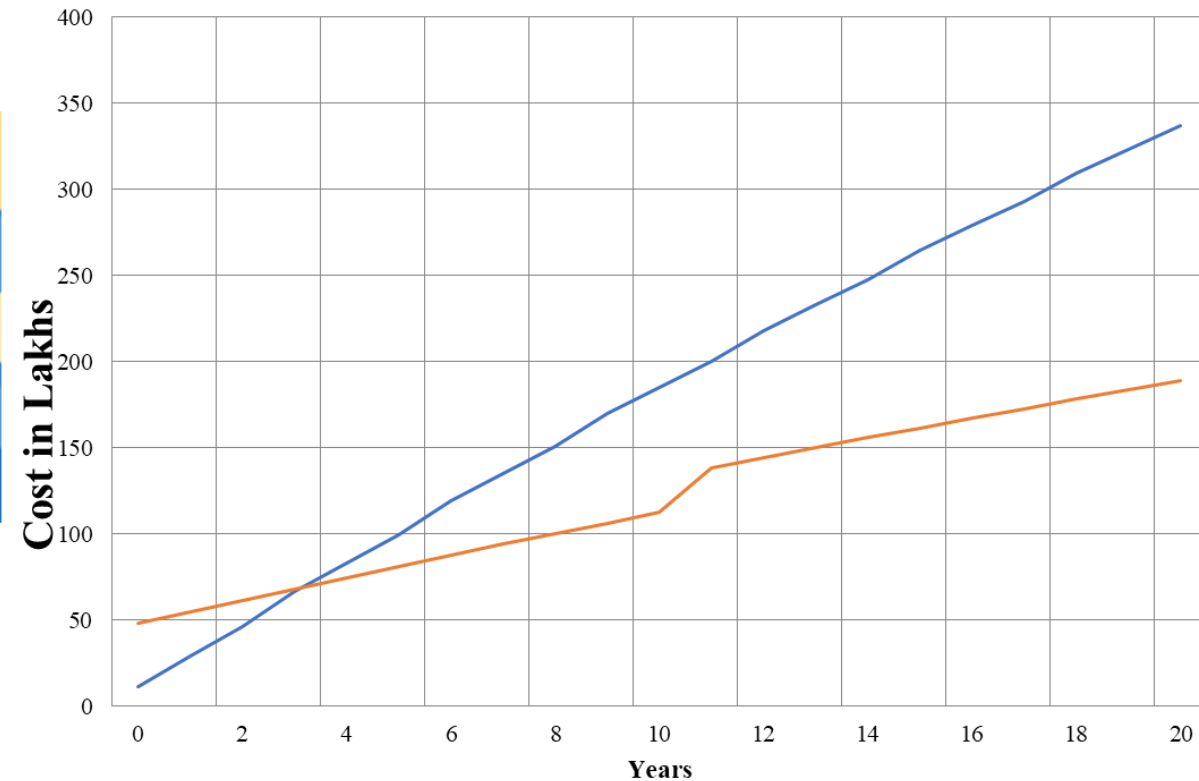


# Concept of life cycle cost and its impact on carbon emission

## LCC of CFL vs LED



LCC for Lighting system



## DAY 1

# Q&A Session on New & Innovative technologies and Thermal Comfort

## DAY 1

### Session 2: Importance of Thermal Comfort





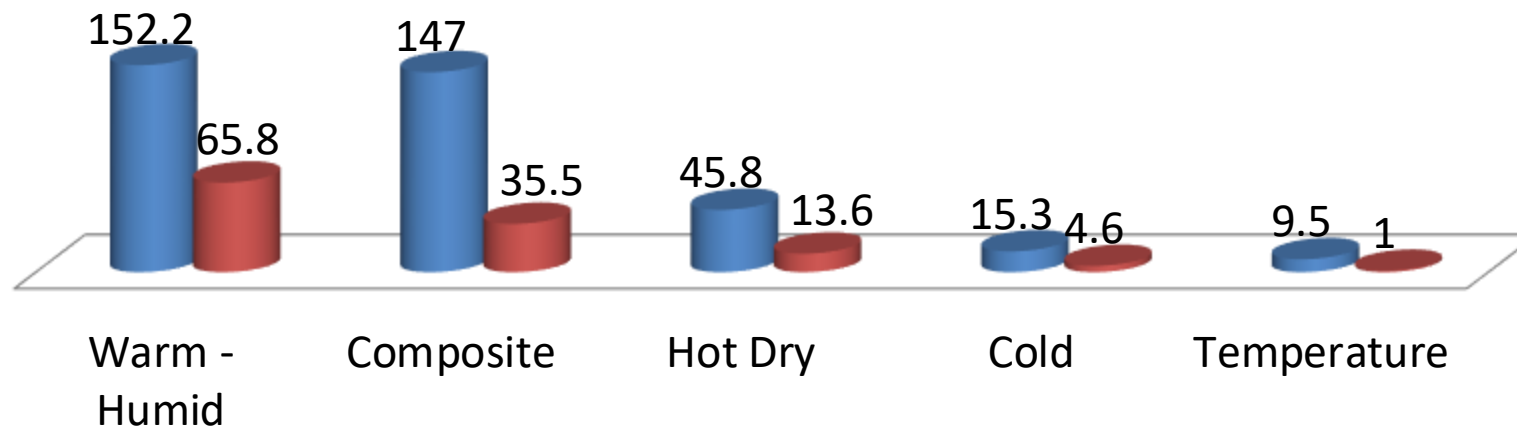
05

# Thermal Comfort and Cooling Demand

# Thermal Comfort & Cooling Demand

## Chart Title

■ Population (Millions) ■ Area ('000 Sq.km)

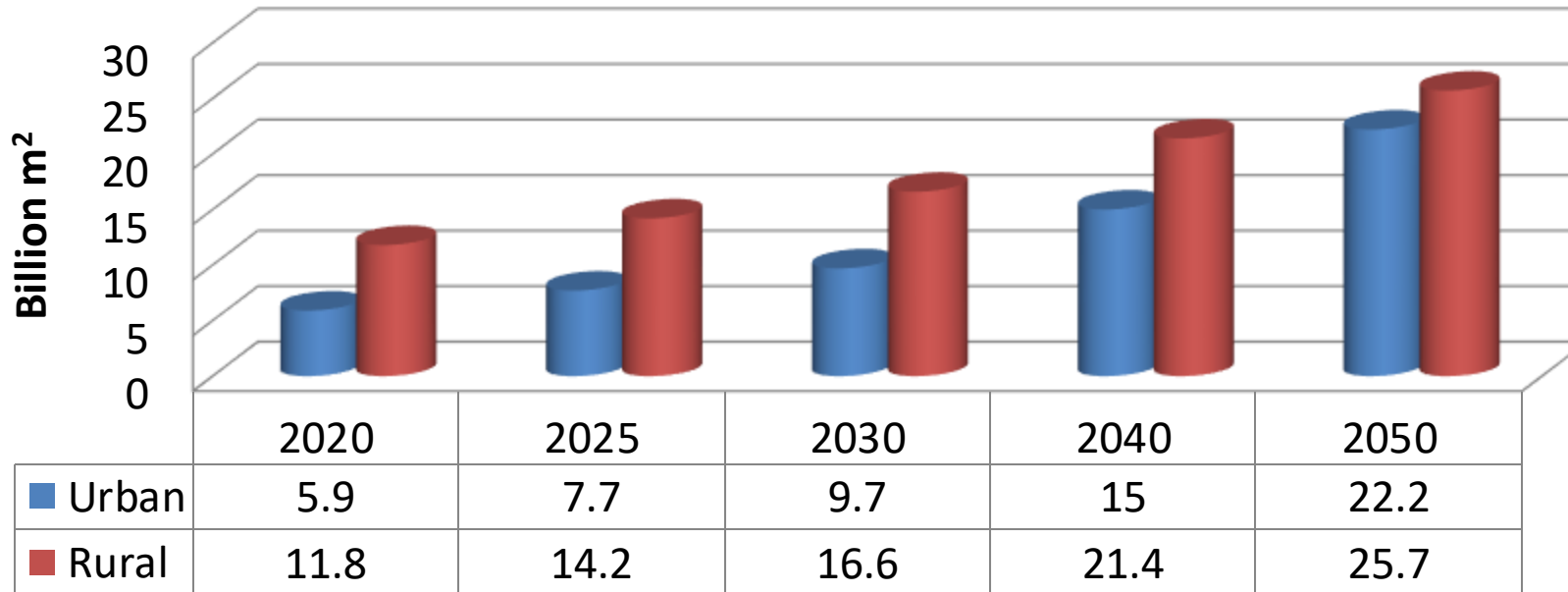


- According to the graph, the major Indian metropolitan areas with urban populations (which make up 35% of the country's total population) are located in warm, humid, and mixed climates.
- Every year, high cooling degree days are experienced by residents of the cities located in these climate zones and the hot, dry climate.

Population and area distribution in the five climate zones of India. Source: "Census 2011", Government of India, (2011), available at: <http://www.censusindia.gov.in/2011census/dchb/DCHB.html>

# Thermal Comfort & Cooling Demand

## Residential Build – Up Area (Billion m<sup>2</sup>)

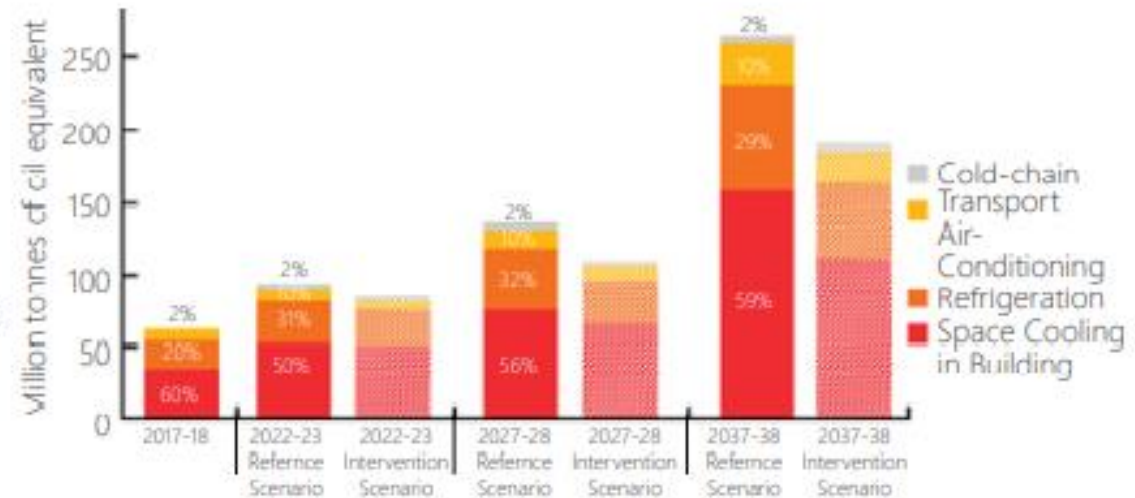
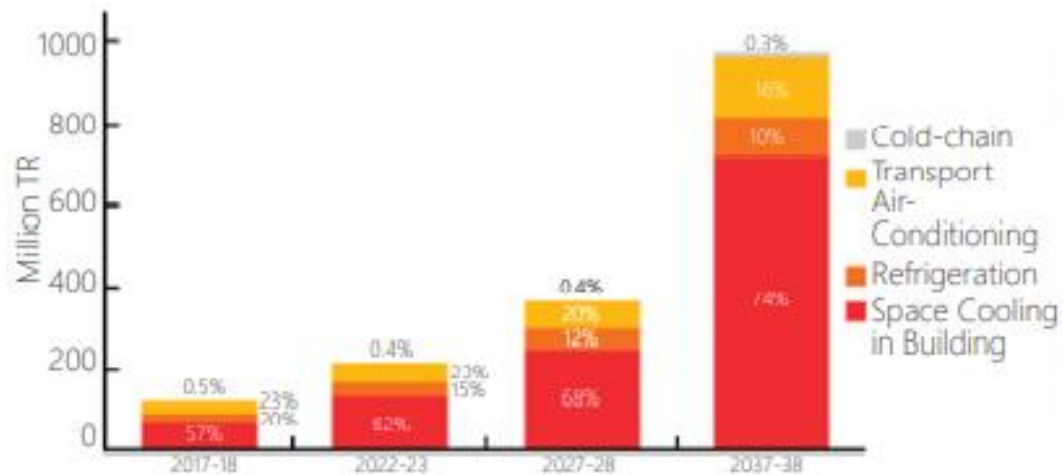


Projected increase in residential built-up area in urban and rural India. Source: ICAP

- Projections of residential built-up area expansion in both urban and rural India are shown in Graph.
- Between 2020 and 2050, it is predicted that the total area of built-up urban residential space will rise by a factor of more than three.
- Over three decades, it is anticipated to increase from 5.9 billion square metres to 22.2 billion square metres (2020-2050).
- In addition, over the same period, the per capita residential built-up area in Indian cities will rise from 12.6 sq. m. to 24.2 sq. m. (MOEFCC, 2019).

# Thermal Comfort & Cooling Demand

By 2050, only around two-thirds of our metropolitan building stock will have been constructed. Consequently, our new development must take into account both our current and future cooling needs. To make this happen, it is essential to comprehend how our cooling demand is changing. According to the India Cooling Action Plan, the demand for cooling is expected to increase eight times between 2017–2018 and 2037–2038. In just two decades, the demand for the building sector alone will increase by up to 11 times from the baseline.



Above: Sector-wise growth in cooling demand; Below: India's Total Primary Energy Supply (TPES) for cooling. Source: India Cooling Action Plan (redrawn)

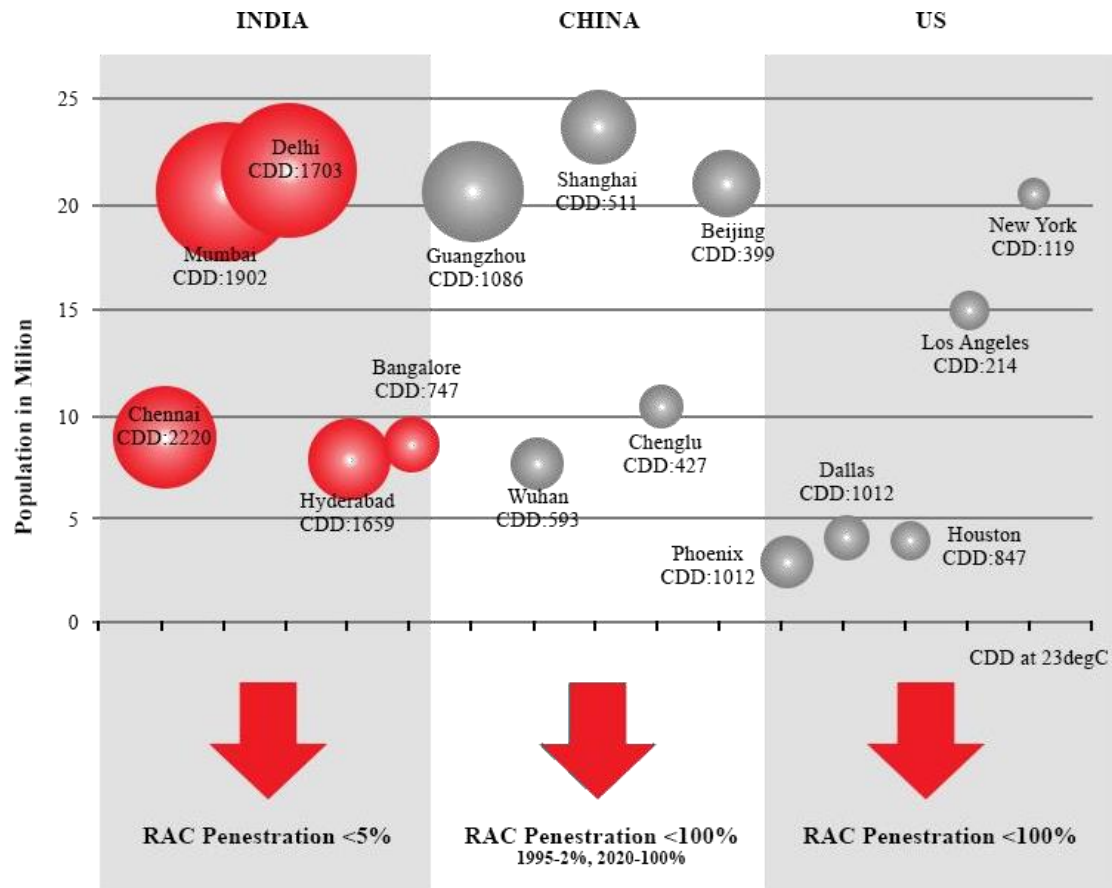
# Need for Thermal Comfort in Buildings: India Cooling Action Plan



1. 20-25% reduction of cooling demand across various sectors by 2037-2038
2. 25-40% reduction in cooling energy requirements by 2037-2038
3. 25-30% reduction in refrigerant demand by 2037-2038
4. Training and certification of 1,00,000 service technicians by 2022-2023
5. Recognizing “cooling and related areas” as a thrust area of research

Source: Ministry of Environment, Forest & Climate Change, Government of India. (2019, March). India Cooling Action Plan. Retrieved from <http://ozonecell.nic.in/wp-content/uploads/2019/03/INDIA-COOLING-ACTION-PLAN-e-circulation-version080319.pdf>

# Need for Thermal Comfort in Buildings: International Perspective

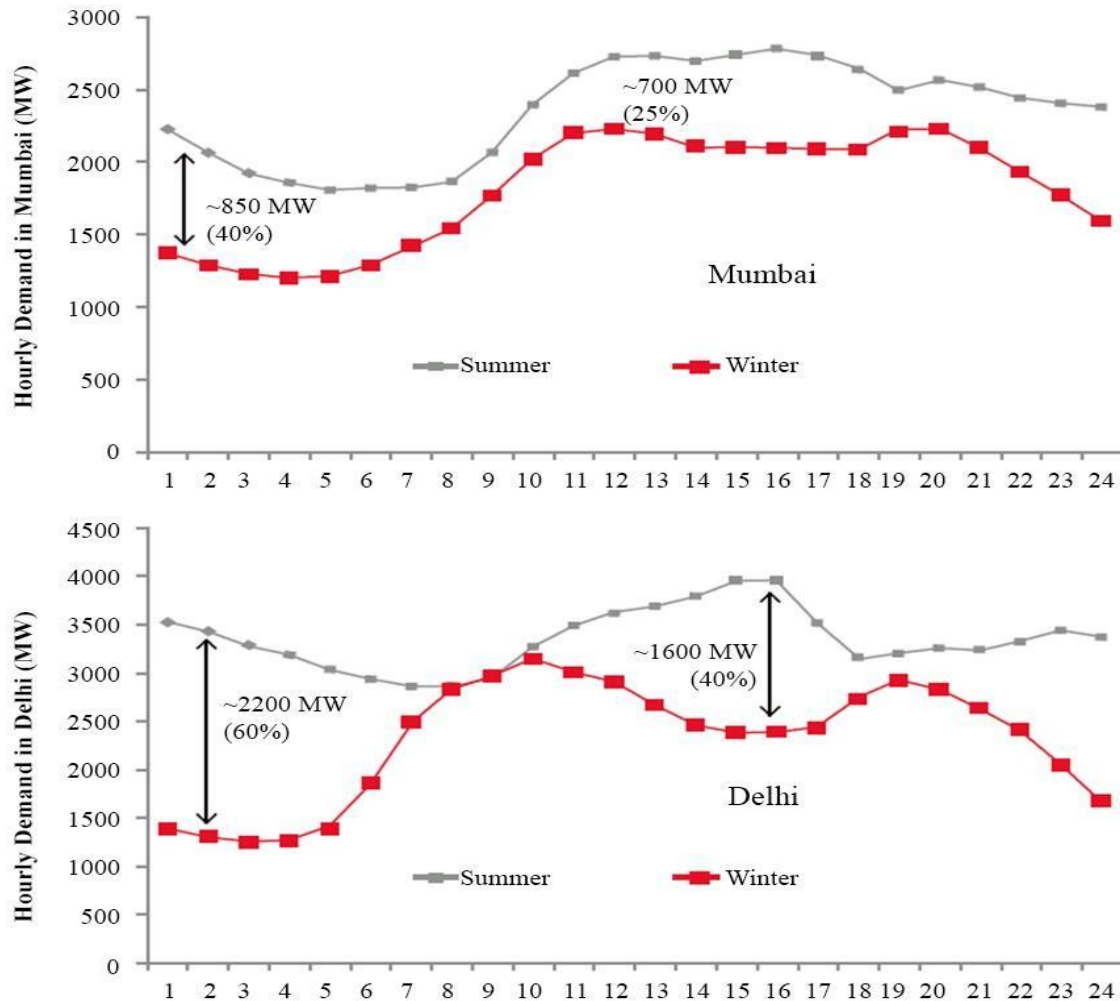


## Cooling Demand in India, China, and the US

- To combat uncomfortable conditions
- Leads to increased peak
- Leads to higher consumption

Source: Sustainable and Smart Space Cooling Coalition (2017). Thermal Comfort for All – Sustainable and Smart Space Cooling. New Delhi: Alliance for Energy Efficient Economy

# Need for Thermal Comfort in Buildings: Peak Demand



- Summer and Winter Day Profile of Electricity use
- Mumbai and Delhi Comparison
- Leads to higher consumption

**Late-night 850 MW to late afternoon 700 in Mumbai**  
**Late-night 2200 MW to late afternoon 1600 in Delhi**

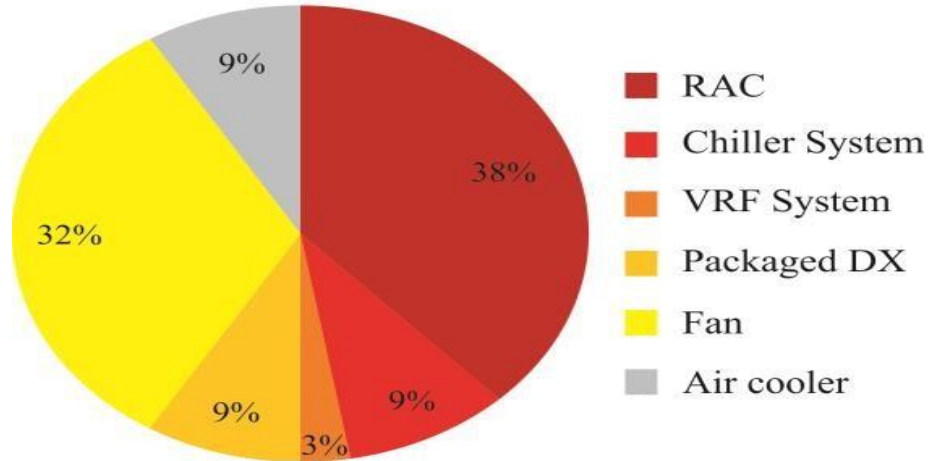
Source: Phadke, A., Abhyankar, N., & Shah, N. (2014). *Avoiding 100 New Power Plants by Increasing Efficiency of Room Air Conditioners in India: Opportunities and Challenges.*

<https://international.lbl.gov/publications/avoiding-100-new-power-plants>

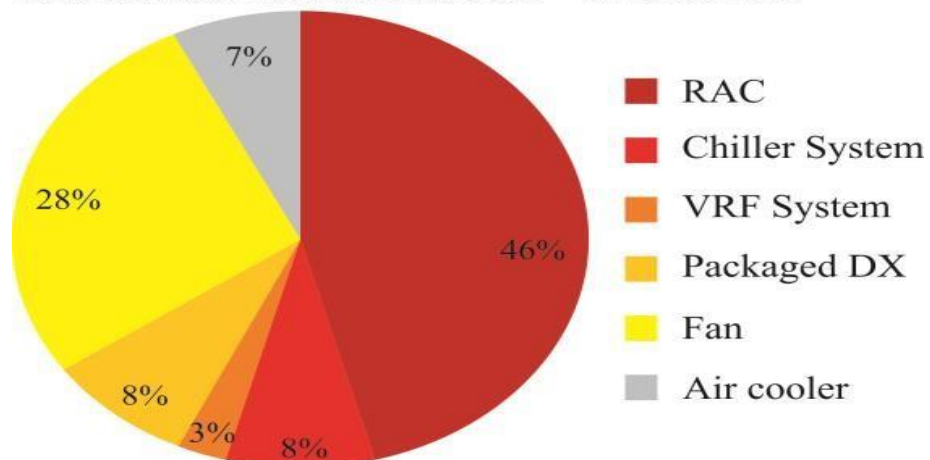


# Need for Thermal Comfort in Buildings: Consumption & Emission

2017 Annual Energy Consumption = 126TWh



2017 Annual Carbon Emission = 124 mtCO<sub>2e</sub>



- Total Consumption 126 TWh and 124 MTCO<sub>2e</sub>
- Room Air Conditioners 48.8 TWh (38%) consumption
- Room Air Conditioners 57.0 MTCO<sub>2e</sub> (46%) Carbon Emission

Source: Ministry of Environment, Forest & Climate Change, & Government of India. (2019, March). India Cooling Action Plan. Retrieved from <http://ozonecell.nic.in/wp-content/uploads/2019/03/INDIA-COOLING-ACTION-PLAN-e-circulation-version080319.pdf>

# Need for Thermal Comfort in Buildings: Consumption & Emission



- In 2017, approximately 272 million households were estimated in India
- Expected to increase to 328 by 2027
- 386 million by 2037

Source: Ministry of Environment, Forest & Climate Change, & Government of India. (2019, March). India Cooling Action Plan. Retrieved from <http://ozonecell.nic.in/wp-content/uploads/2019/03/INDIA-COOLING-ACTION-PLAN-e-circulation-version080319.pdf>



- In 2017, approximately 8% of the households were estimated to have room air conditioners
- Anticipated to rise to 21% by 2027-28
- And 40% by 2037-38



- In 2017, the estimated commercial floor was around 1.2 million sqft
- Is expected to grow about 1.5 to 2 times by 2027-2028
- 2.5 to 3 times by 2037-38, respectively



06

# Factors affecting Thermal Comfort and Cooling Demand

# Factors affecting Thermal Comfort



## PHYSIOLOGICAL FACTORS

The factors which are independent from weather and surrounding environment of the building. And are very subjective and depend on person to person



## PHYSICAL FACTORS

The factors which are dependent on weather and surrounding environment of the building. Some of which can be managed



# 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

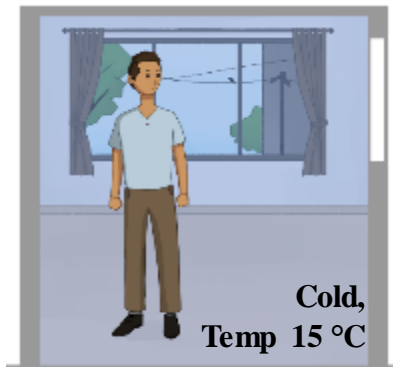
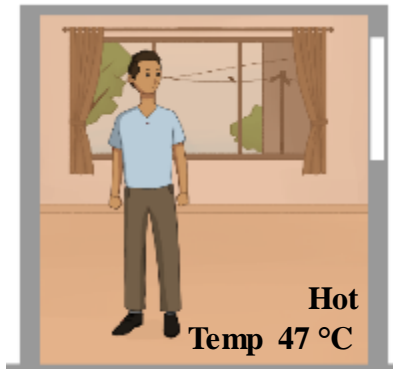
## AIR VELOCITY – the speed of air moving across the worker

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

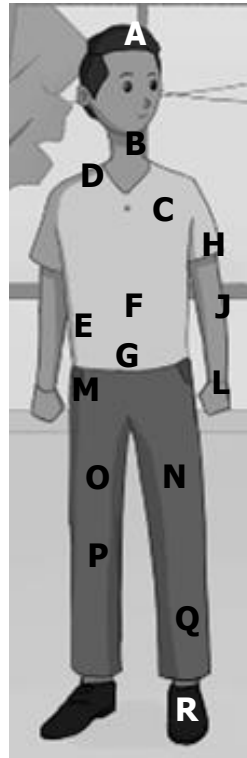
## HUMIDITY – the amount of evaporated water in the air

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

# Thermal Comfort – Cold – Neutral - Warm

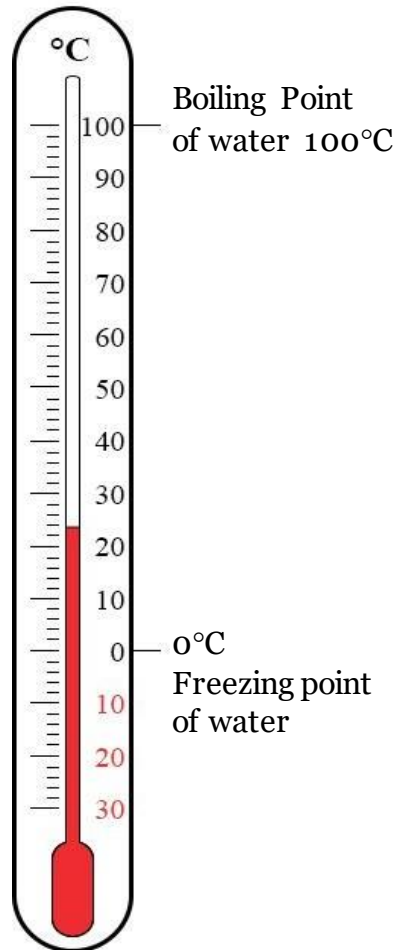


Air Temp 27 °C



Body Part	Skin Location	Cold (15 °C)	Neutral (27°C)	Hot (47 °C)
A	Forehead	31.7	35.2	37
B	Back of Neck	31.2	35.1	36.1
C	Chest	30.1	34.4	35.8
D	Upper Back	30.7	34.4	36.3
E	Lower Back	29.2	33.7	36.6
F	Upper Abdomen	29	33.8	35.7
G	Lower Abdomen	29.2	34.8	36.2
H	Tricep	28	33.2	36.6
J	Forearm	26.9	34	37
L	Hand	23.7	33.8	36.7
M	Hip	26.5	32.2	36.8
N	Side thigh	27.3	33	36.5
O	Front thigh	29.4	33.7	36.7
P	Back thigh	25.5	32.2	36
Q	Calf	25.1	31.6	35.9
R	Foot	23.2	30.4	36.2

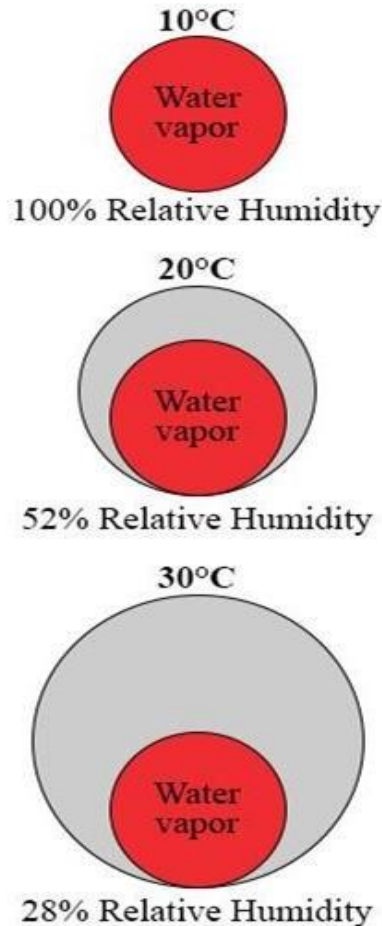
# Factors Affecting Thermal Comfort – Air Temperature



- Temperature of the air surrounding the Environment (Dry Bulb Temperature) – DBT)
- Measured in Degrees Celsius (°C), by a thermometer freely exposed to the air, but shielded from radiation and moisture.
- Affects the rate of Evaporation on skin surface of building occupants.

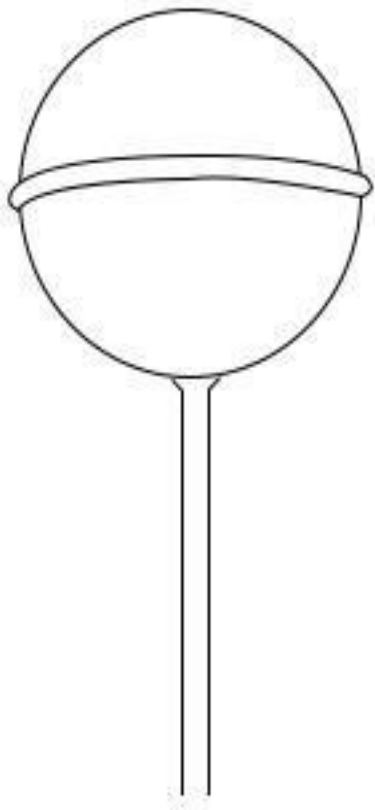


# Factors Affecting Thermal Comfort – Relative Humidity [RH]



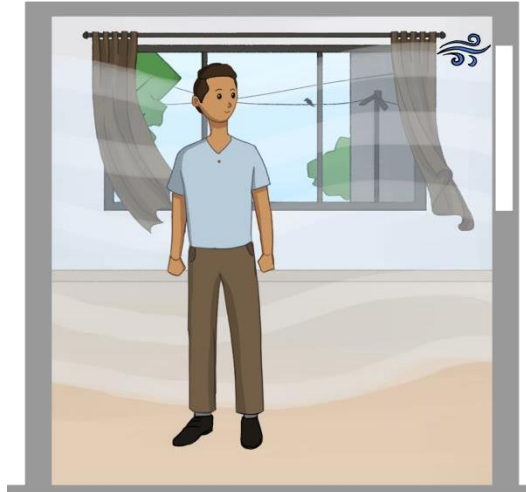
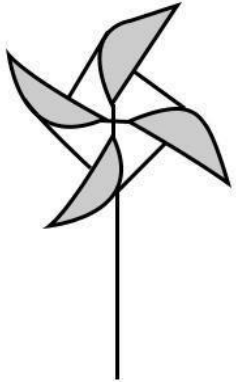
- It is defined as %ge of Amt. of water vapour present in air to max. amount of water vapour that air can hold at specific temperature and pressure.
- Affected by DBT and Pressure of Air.
- Higher the RH of the air, hotter it will feel for Building Occupants.

## Factors Affecting Thermal Comfort – Mean Radiant Temperature [MRT]



- MRT is defined as uniform temperature of an imaginary enclosure in which the radiant heat transfer from the human body is equal to the radiant heat transfer in the actual non-uniform enclosure.
- Depends on ability of a surface to emit the incident heat, also known as emissivity of the material
- Calculated using Globe Temp. ( $T_g$ ) & Air Temp. ( $T_a$ ).

# Factors Affecting Thermal Comfort – Air Speed



- Air Speed is defined as the average speed of the air surrounding an occupant, with respect to location, and time.
- Measured in Meter per second (m/s)
- Elevated air speeds can be used to improve thermal comfort beyond the maximum limit of temperature established by codes and standards (ASHRAE, 2021)

# Factors Affecting Thermal Comfort – Clothing Value



- Can be defined as “The resistance to sensible heat transfer provided by clothing ensemble”.
- The insulation provided by an individual garment includes effective resistance of the garment material and the thermal resistance of the air layer trapped between the garment and the skin (CIBSE, 2015).
- Clothing Insulation Value (clo -  $I_{cl}$ ).

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

# Factors Affecting Thermal Comfort – Metabolic Rates



- Metabolic Rate can be defined as level of transformation of chemical energy into heat and mechanical work by metabolic activities within an organism.
- Expressed in met units where  $1 \text{ met} = 58.2 \text{ W/m}^2$ .
- Depends on activity level, age, fitness level, etc. of a person.

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



# Factors affecting Thermal Comfort - Others

- **Acclimatization**
  - Short-term physiological adjustments
  - Long-term endocrine adjustments
- **Body shape and fat**
- **Age and gender**
- **Status of health**



Short term  
physiological  
adjustments



Long term physiological  
adjustments



Age



Gender



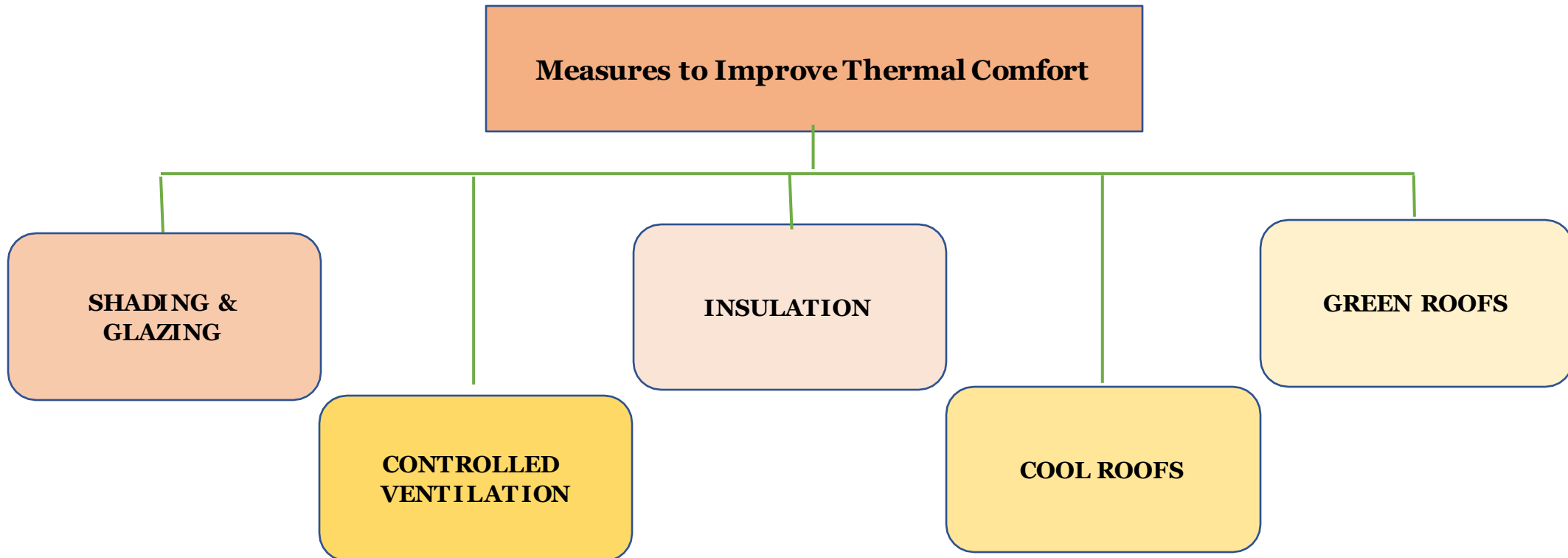
Health &  
Wellbeing



07

# Contemporary Approaches for achieving Thermal Comfort in buildings

# Measures to Improve Thermal Comfort



# Shading & Glazing

Shading reduces internal heat gain through coincident radiation.

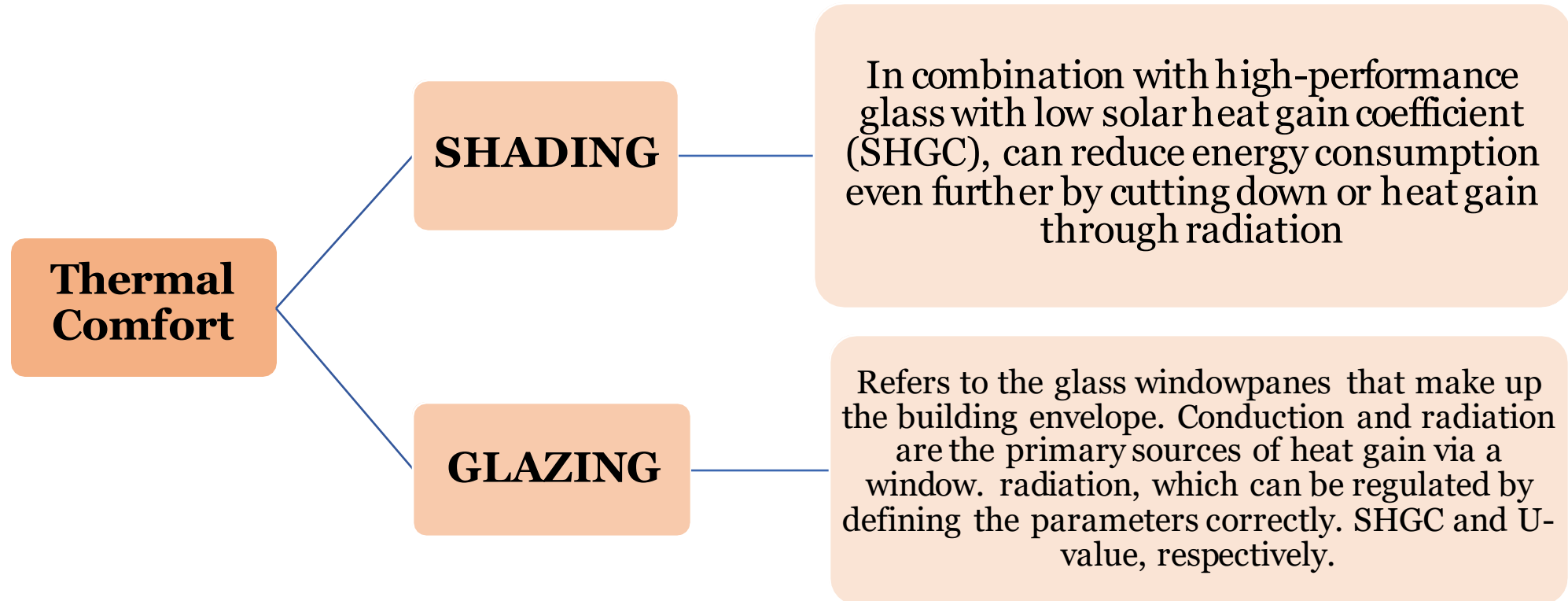
VARIOUS METHODS TO SHADE WINDOWS					
Overhangs	Awnings	Louvers	Vertical Fins	Light Shelves	Natural Vegetation

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



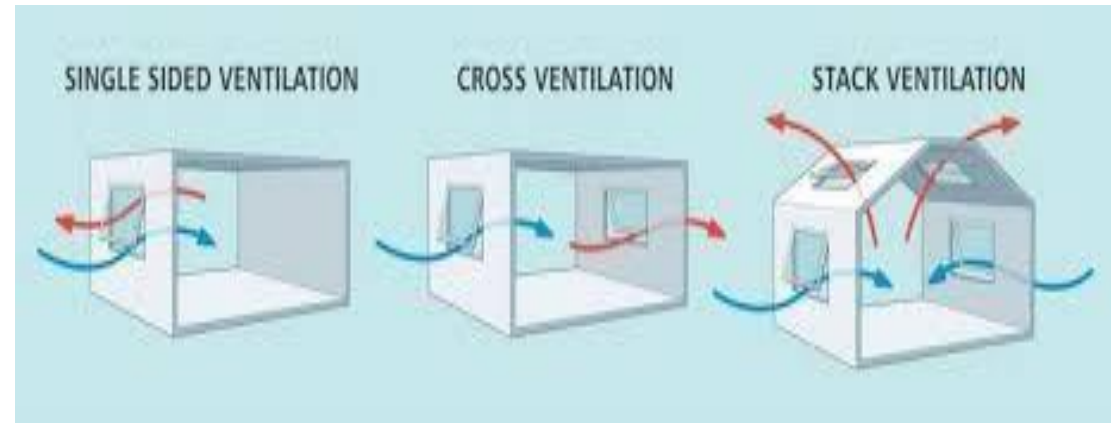
# Controlled Ventilation

**BUILDING CAN BE  
DESIGNED AS**

**CROSS  
VENTILATION**

**STACK  
VENTILATION**

**SINGLE-SIDED  
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 °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.)





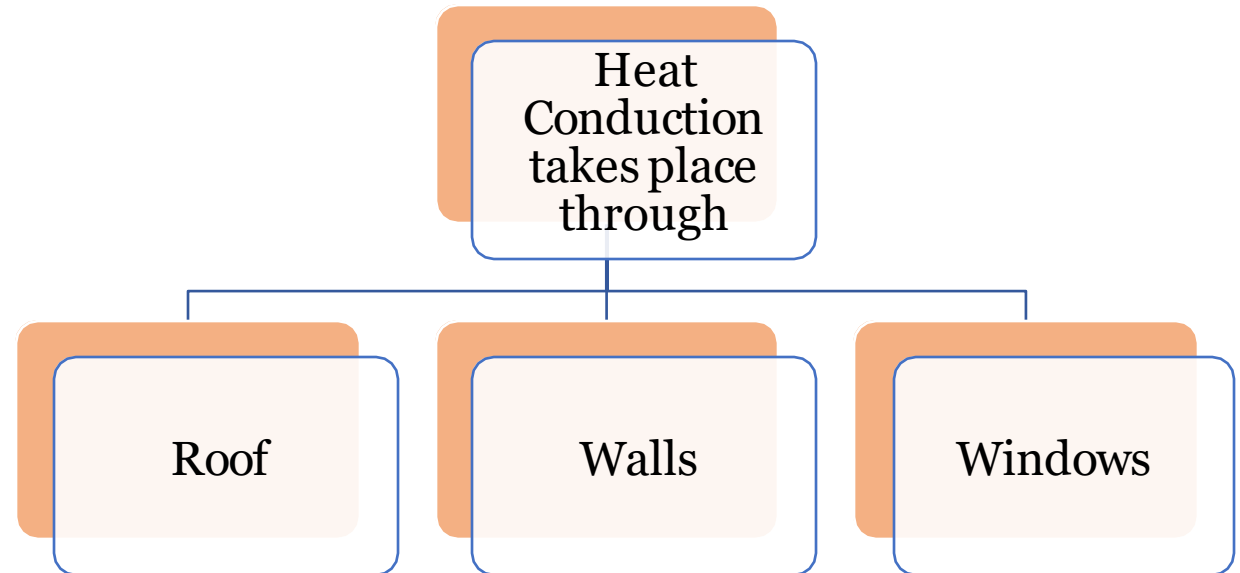
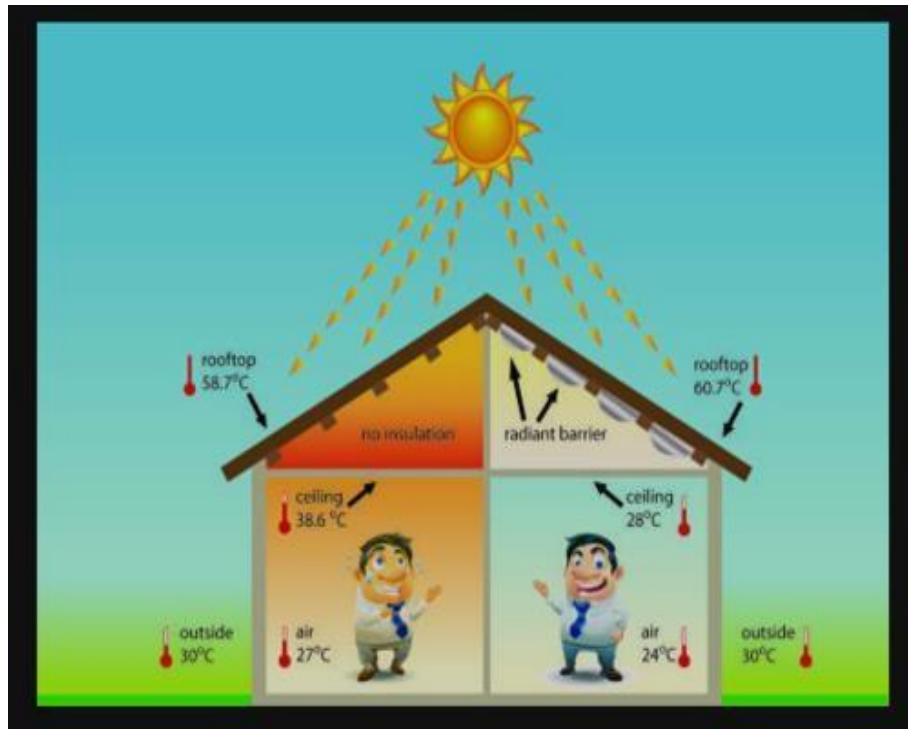
# Controlled Ventilation

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		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 <b>night ventilation</b> and <b>natural ventilation</b> during cooler seasons
With Breeze Air	Works Best	
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

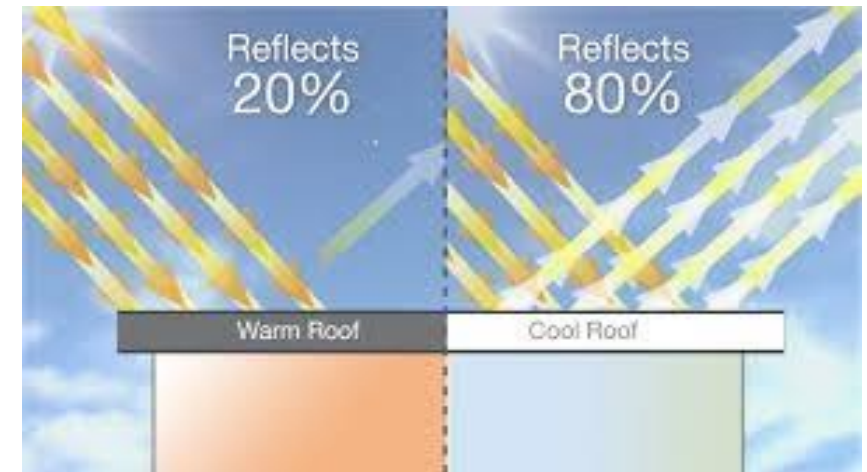


**An insulating material can resist heat transfer due to its low thermal conductivity. Insulating walls and the roof can reduce cooling energy loads by up to 8%**

# 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 are from 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

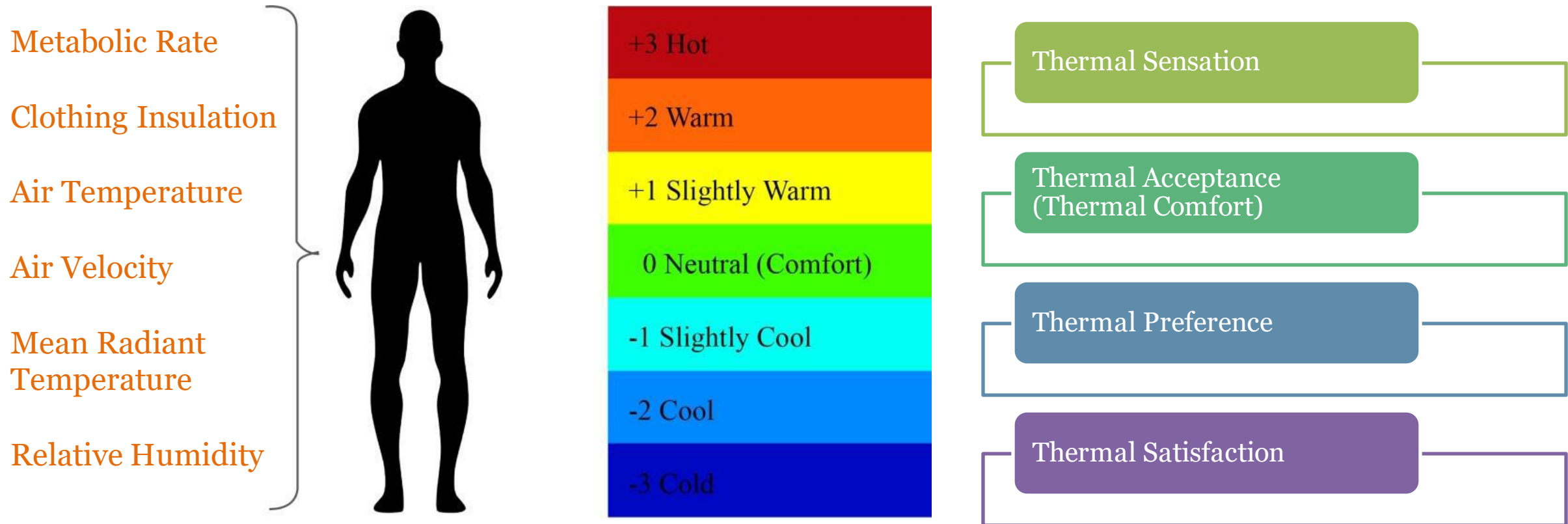


08

# Thermal Comfort Metrics



# Thermal Comfort Metrics – Preference, Comfort and Acceptability

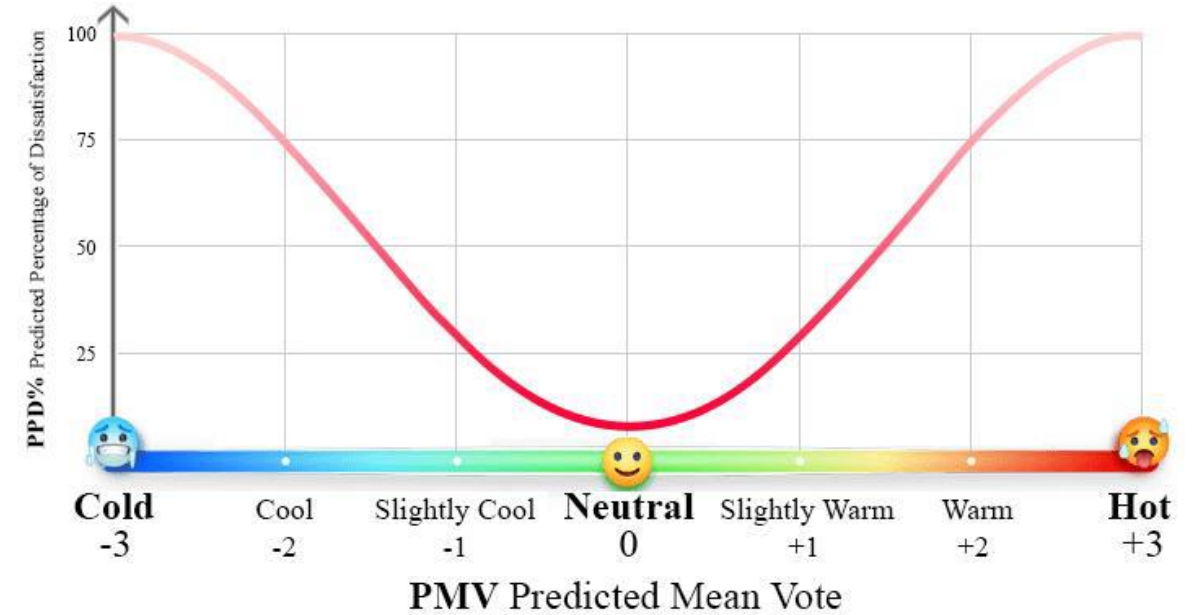
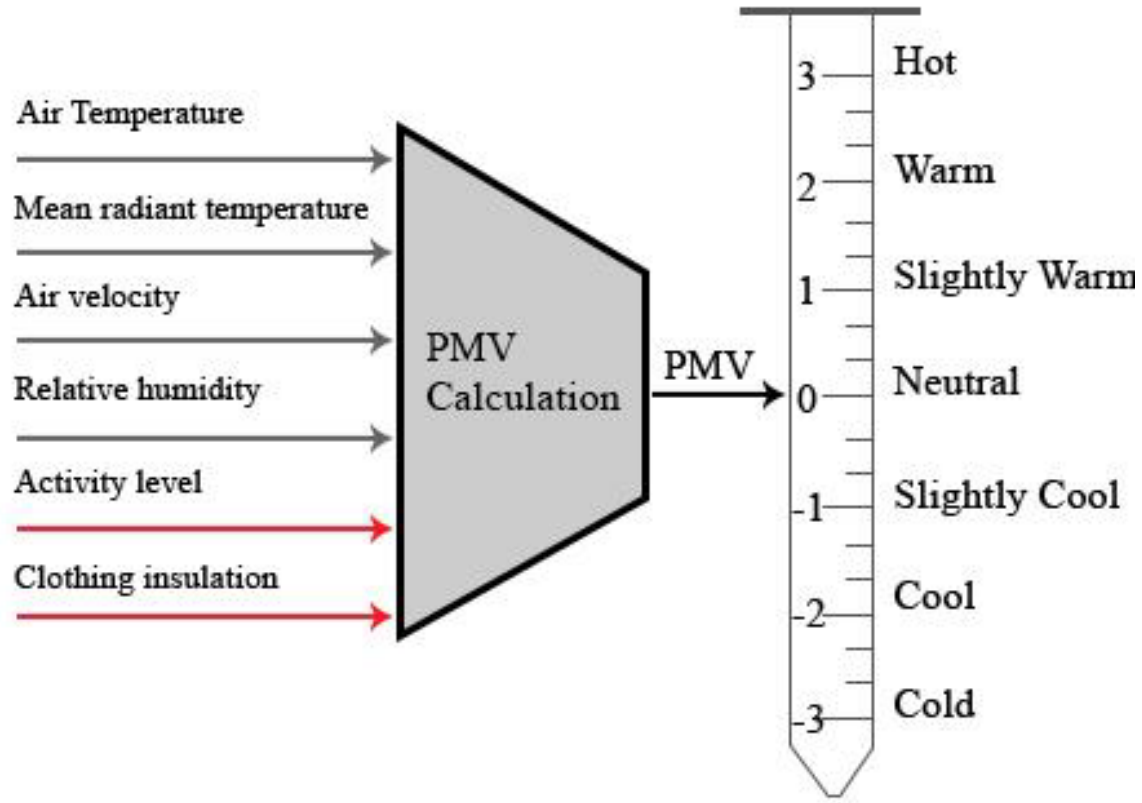


$$\text{Storage} = \text{Production} - \text{Loss}$$

# Thermal Comfort Metrics – Preference, Comfort and Acceptability

PMV	Sensation Value	Acceptance Value	Preference Value
<b>-3</b>	<b>Cold</b>	-	-
<b>-2</b>	<b>Cool</b>	<b>Very Unacceptable</b>	<b>Want Cooler</b>
<b>-1</b>	<b>Slightly Cool</b>	<b>Unacceptable</b>	<b>Want Slightly Cooler</b>
<b>0</b>	<b>Neutral</b>	-	<b>No Change</b>
<b>+1</b>	<b>Slightly Warm</b>	<b>Acceptable</b>	<b>Want Slightly Warmer</b>
<b>+2</b>	<b>Warm</b>	<b>Very Acceptable</b>	<b>Want Warmer</b>
<b>+3</b>	<b>Hot</b>	-	-

# Thermal Comfort Metrics – PMV



Acceptable thermal comfort bands listed in ISO 7730:2005

Band	PMV Range
A	$-0.2 < \text{PMV} < +0.2$
B	$-0.5 < \text{PMV} < +0.5$
C	$-0.7 < \text{PMV} < +0.7$

Source: Guenther, S. (2021). What Is Pmv? What Is Ppd? The Basics of Thermal Comfort. Simscales. Retrieved from <https://www.simscales.com/blog/2019/09/what-is-pmv-ppd/>

# Thermal Comfort Metrics – PPD

Predicted Percentage of Dissatisfied occupants (PPD) refers to the percentage of occupants likely to experience thermal dissatisfaction out of the total number of occupants. ISO 7730:2005 defines the hard limit as ranging between -2 and +2, for existing buildings between -0.7 and +0.7, and new buildings ranging between -0.5 and +0.5.

PPD ranges corresponding to acceptable PMV ranges as defined in ISO 7730:2005

Band	PMV Range	PPD%	Temperature (°C)
A	$-0.2 < \text{PMV} < +0.2$	< 6	$24.5 \pm 1$
B	$-0.5 < \text{PMV} < +0.5$	< 10	$24.5 \pm 1.5$
C	$-0.7 < \text{PMV} < +0.7$	< 15	$24.5 \pm 2.5$

# Thermal Comfort Metrics – Degree Discomfort Hours

- ❑ Calculated based on India Model for Adaptive (thermal) Comfort (IMAC).
- ❑ Summation of difference of hourly operative temperature and IMAC band acceptable temperature only for hours when temperature goes outside IMAC temperature band with 80% or 90% acceptability range.

## Formula for DDH (Annual)

$$DDH \text{ (annual)} = \sum_{i=1}^{8760} |T_i - T_{\text{acceptable}}|$$

$$T_{\text{acceptable}} = T_{\text{lower}} \text{ when } T_i < T_{\text{lower}}$$

$$T_{\text{acceptable}} = T_{\text{upper}} \text{ when } T_i > T_{\text{upper}}$$

•  $T_i$  – Measured or Achieved Operative Temp. at  $i^{\text{th}}$  hour

•  $T_{\text{acceptable}}$  – Either the lower ( $T_{\text{Lower}}$ ) or the upper limit ( $T_{\text{Upper}}$ ) of the targeted operative temperature based on IMAC comfort model.

Basis of Eco Niwas Samhita RETV value

Same as Discomfort Degree Hours

Total discomfort degree hours across the year against the comfort definition\*

\*National Building Code 2016 (India Model for Adaptive Comfort)

## DAY 1

## Lunch Break

## DAY 1

### Session 3: Building Physics and Fundamentals of Thermal Comfort





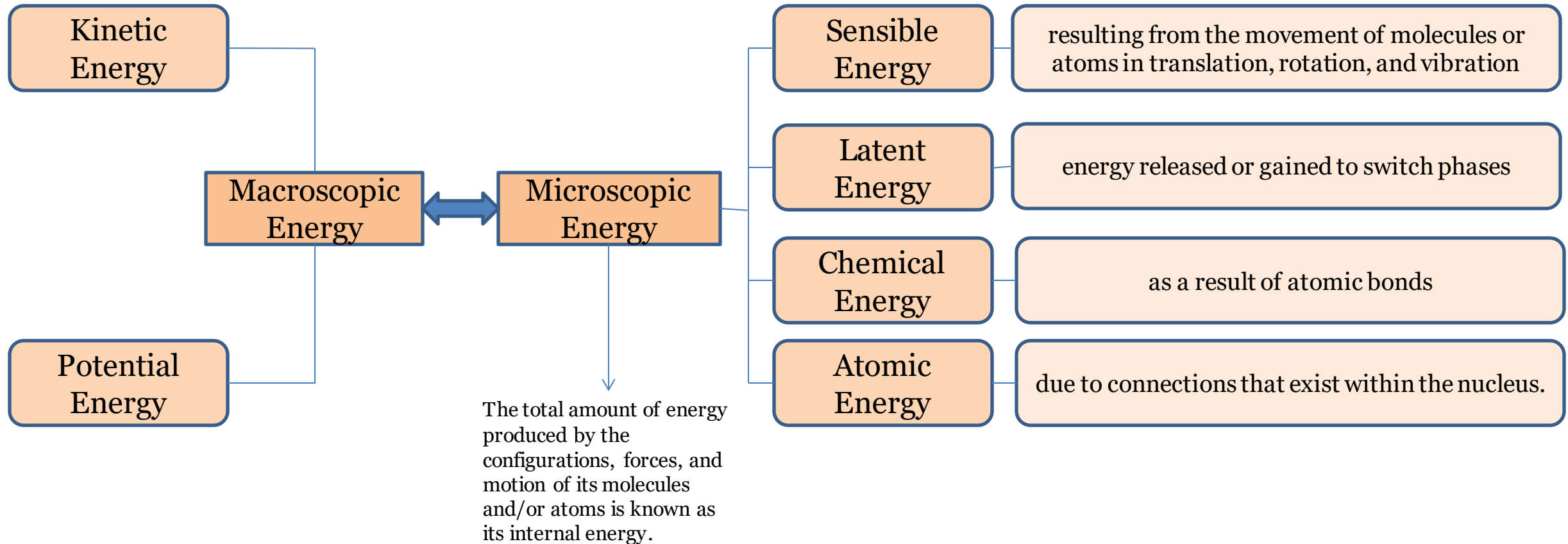
09

# Building Physics Affecting Thermal Comfort

# Building Physics Affecting Thermal Comfort

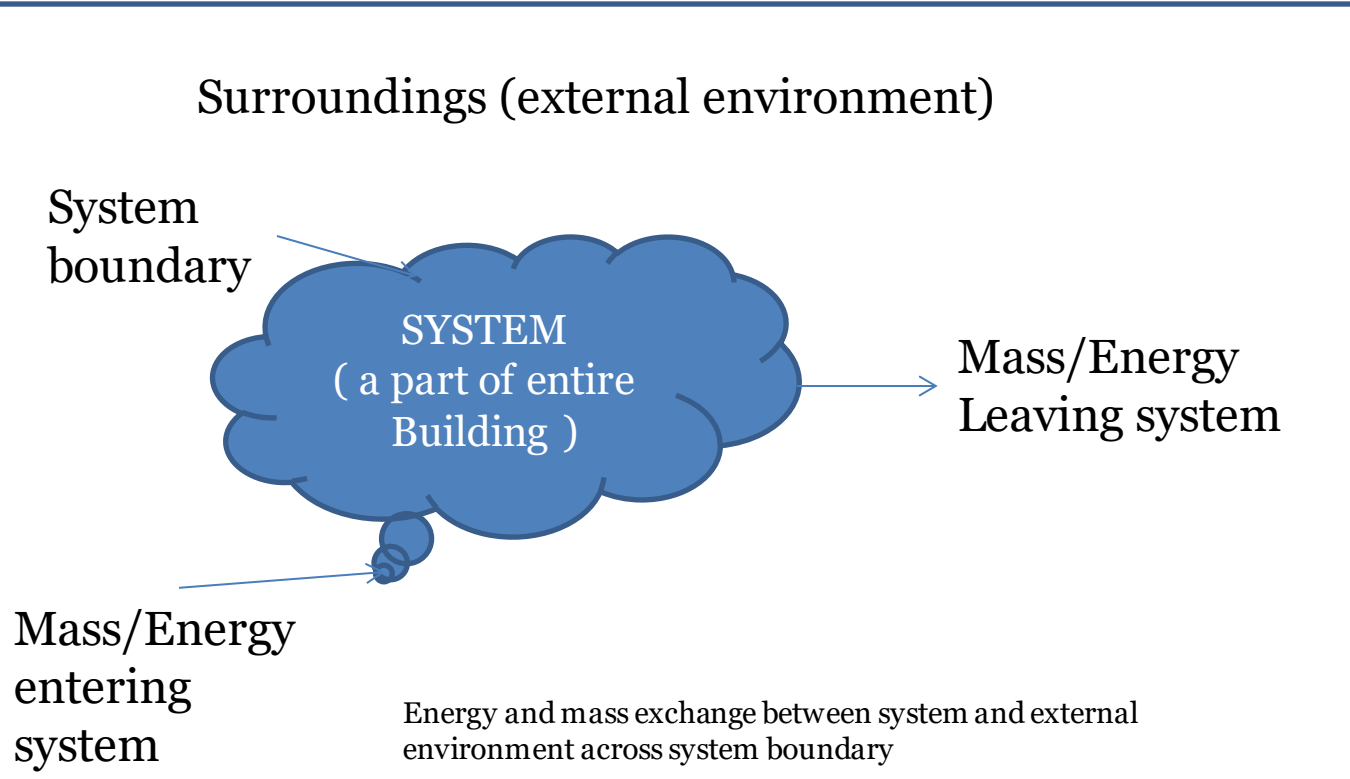
## Energy & Heat

As chemical and atomic energy are not relevant in the context of buildings, the phrase "internal energy" is limited to perceptible and latent energy.



# Building Physics Affecting Thermal Comfort

## Energy & Heat



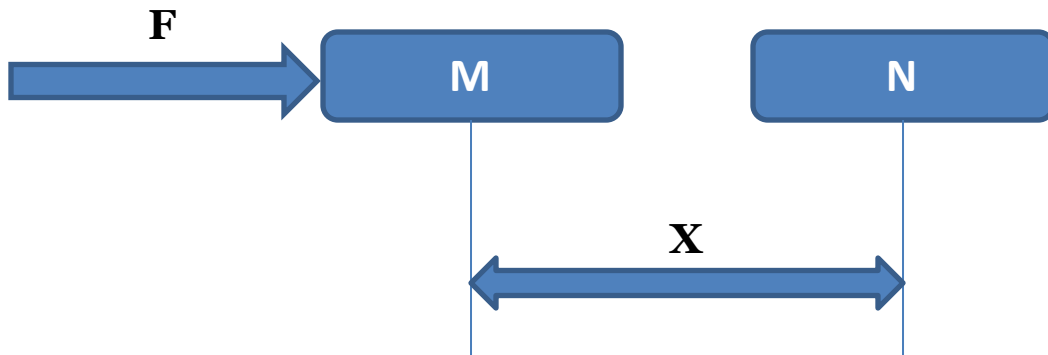
A system, in terms of thermodynamics, is an area that is being studied, such as a room, floor, or building. A system border establishes the region's size, while elements outside of that boundary make up the external environment. As a result, a thermodynamic system is defined as a space-bound area or a volume of matter enclosed by a closed surface (ASHRAE, 2021). Over this system boundary, mass and/or energy are exchanged.

An open system is one that enables both energy and mass exchange with its surroundings, whereas a closed system only permits the exchange of energy and excludes mass. However, it is important to note that in order to distinguish between the system and its surroundings in both systems, a real or hypothetical, fixed or moveable boundary must be established (ASHRAE, 2021) This line may be rigid or flexible.

The envelope is regarded as the boundary when a building is viewed as a system in order to comprehend its thermal interactions with the surrounding environment.

# Building Physics Affecting Thermal Comfort

## Energy & Heat



Work 'W' is done when Force 'F' moves a body of mass 'm' over distance 'x'

## What is Energy ?

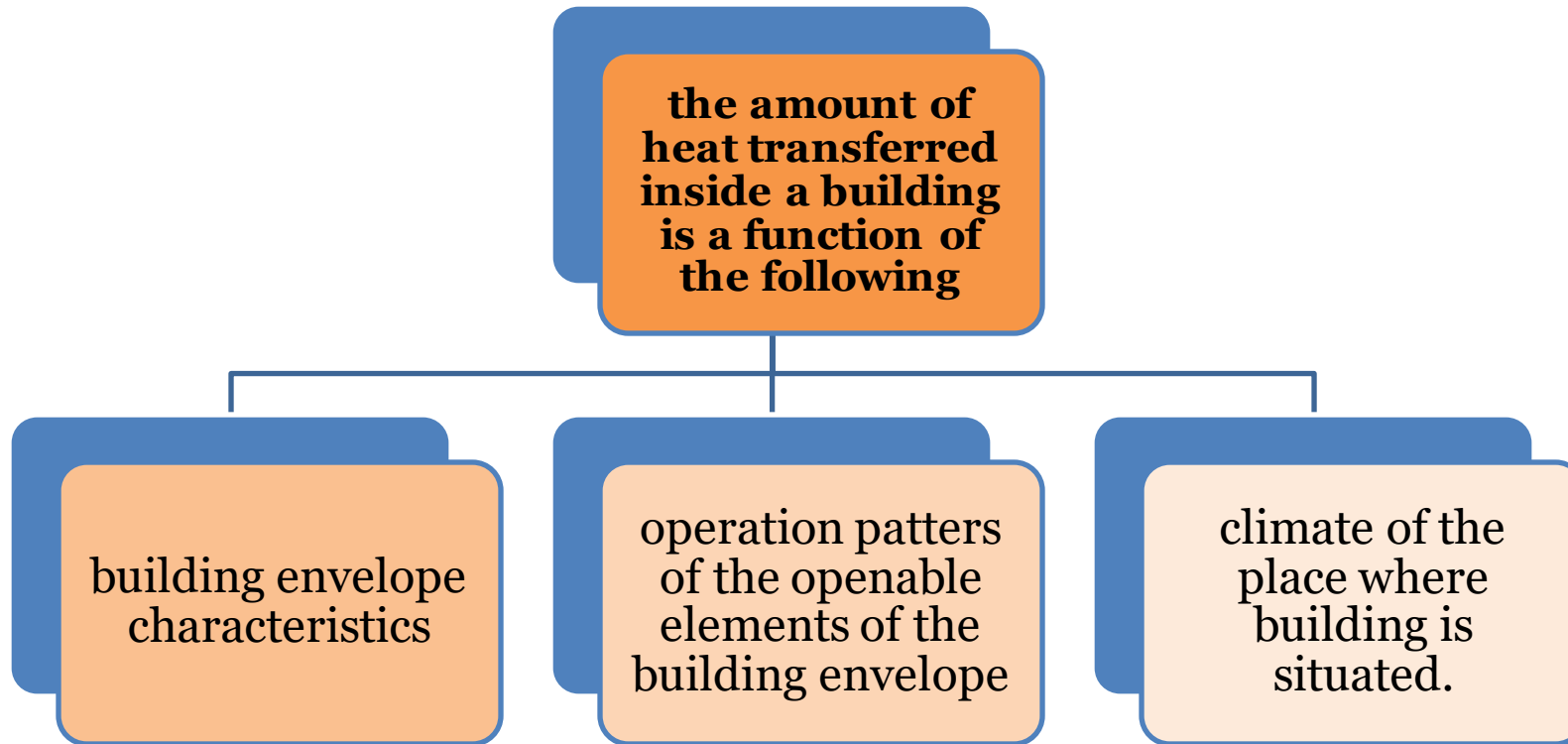
Energy of a system is its potential to do work.

Mechanical work (W) is defined as when a force (F) moves a mass (m) over a distance (x), as shown in Figure. An organism uses its internal energy to change its environment.

Similar to how heat is lost from a system at a higher temperature to a cooler environment, internal energy is also lost.

Thermal energy is caused by the motion of molecules and/ or intermolecular forces (ASHRAE, 2021).

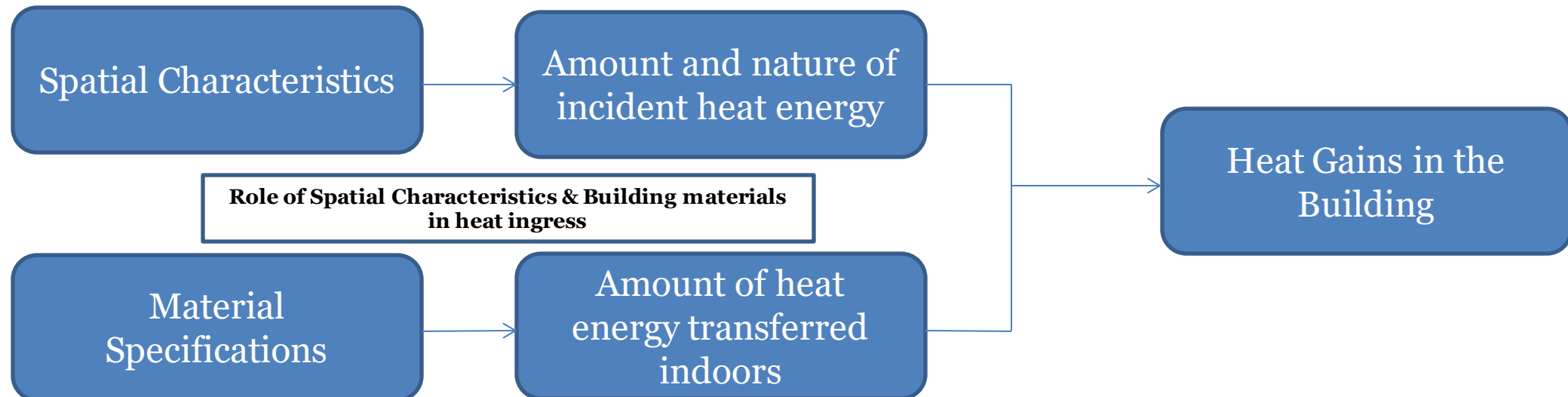
# Building Physics Affecting Thermal Comfort



# Building Physics Affecting Thermal Comfort

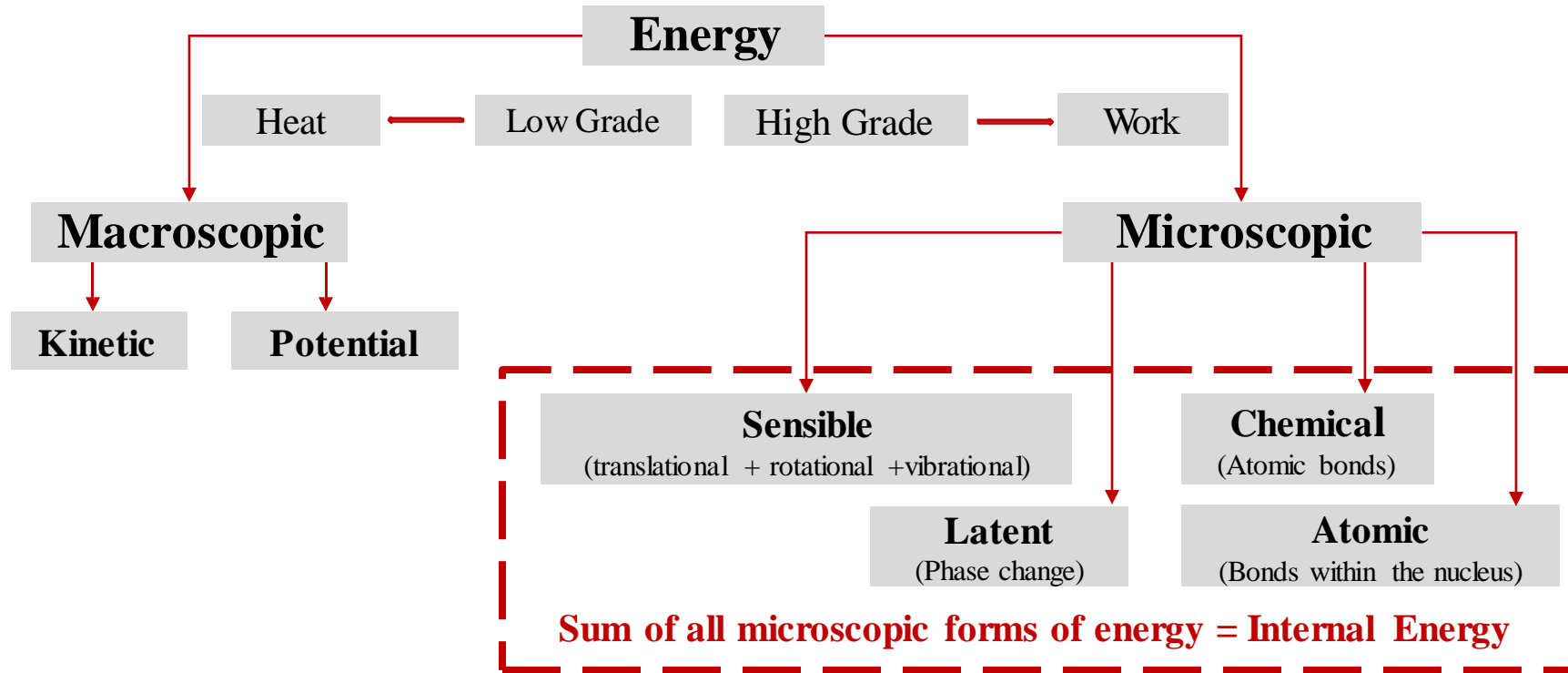
## Factors Influencing Heat Transfer

- The amount of thermal energy on the surface of various building elements is visible in thermography images of buildings and people in various built environments.



- Figure demonstrates that the distribution of thermal energy among its users and in any indoor or outdoor environment is not uniform. This implies that heat is constantly being transferred between the surfaces of different items, people inside, and the air inside. Building heat transmission occurs at the building envelope, much as how heat transfer between a human body and the air around it occurs at the skin's surface.

# Building Physics Affecting Thermal Comfort



## Forms of Energy



# Building Physics Affecting Thermal Comfort

## 1<sup>st</sup> Law of Thermodynamics

$$\Delta U = Q - W$$

$\Delta U$  - change in internal energy

$Q$  - heat added to the system

$W$  - work done by the system

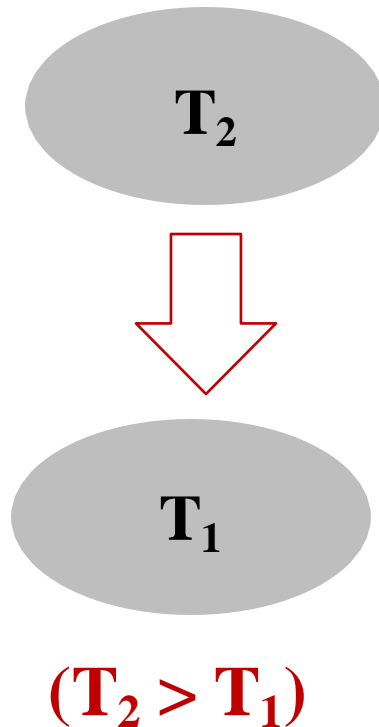
**Establishes a relationship between a system's**

- Internal energy
- The work performed by (or to) the system, and
- The heat removed from (or added to) the system

The internal energy of a system performing work or losing heat decreases, whereas a system's internal energy rises if it gains heat or is subjected to work.

# Building Physics Affecting Thermal Comfort

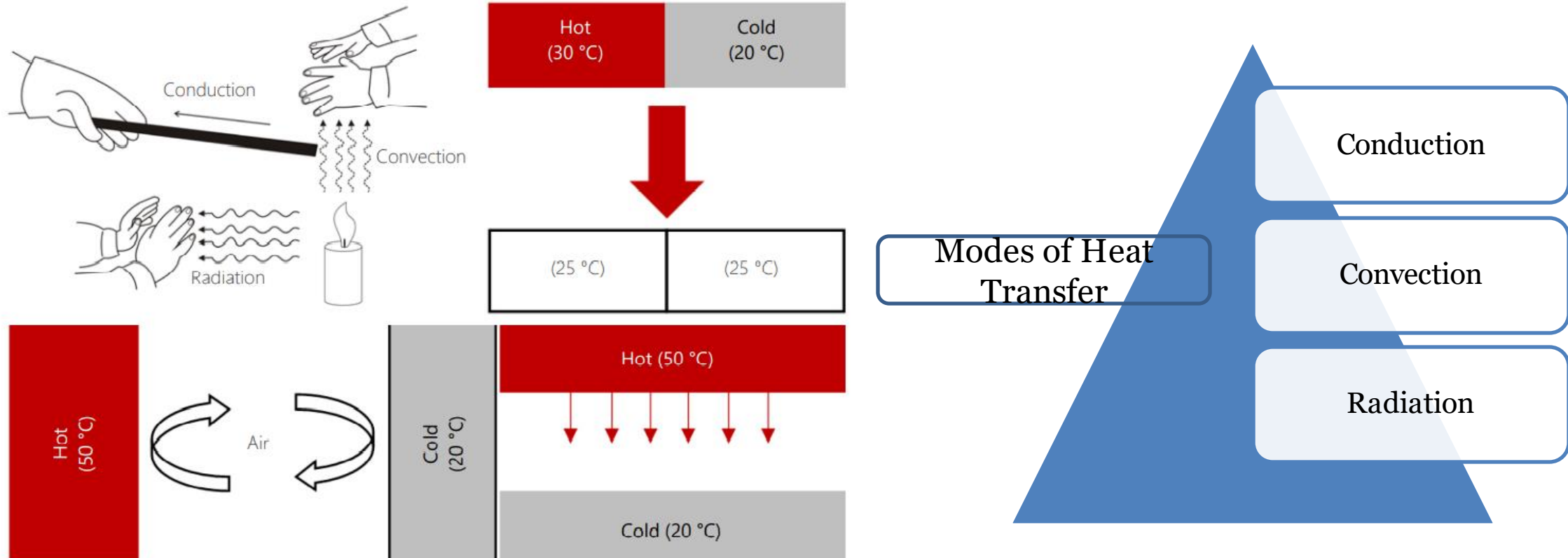
## 2<sup>nd</sup> Law of Thermodynamics



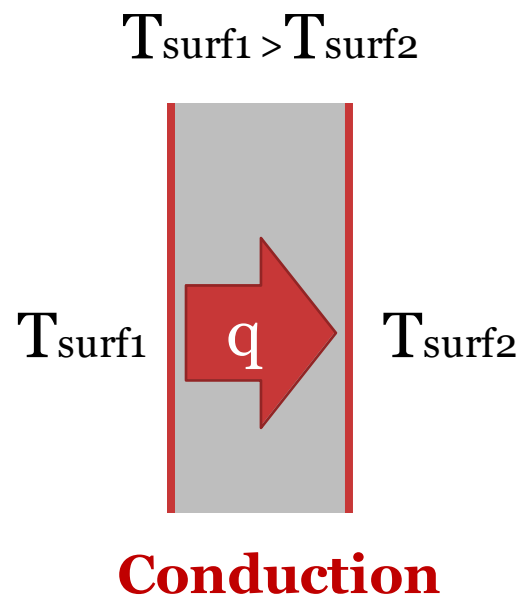
- The natural (spontaneous) direction of heat flow between bodies is from hot to cold.
- Heat moves from higher temperature to lower temperature

# Building Physics Affecting Thermal Comfort

## Modes of Heat Transfer



# Heat Transfer in Buildings – Conduction Principles



Occurs in a stationary medium

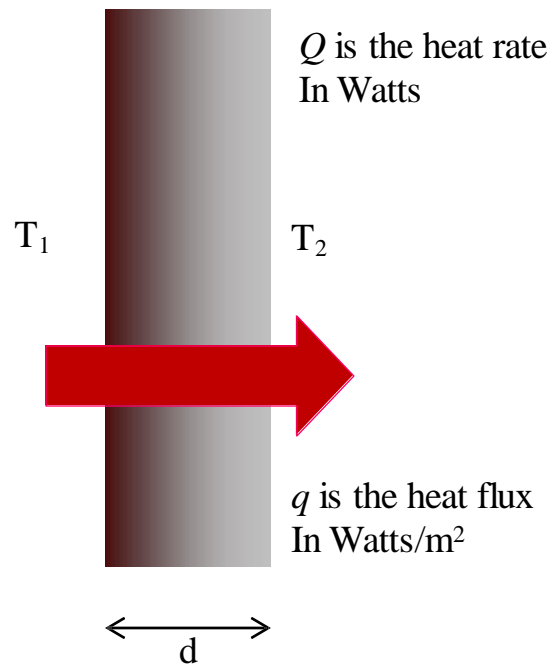
Hot objects with higher energy  
(due to intense random molecular motions)

**transfer heat to**

Cool objects with lesser energy (due to lower molecular motions)

Source: Rawal, R. (2021, December 22). Heat Transfer and Your Building Envelope. Solar Decathlon India. Retrieved April 13, 2022, from <https://solardecathlonindia.in/events/>

# Heat Transfer in Buildings – Conduction Principles

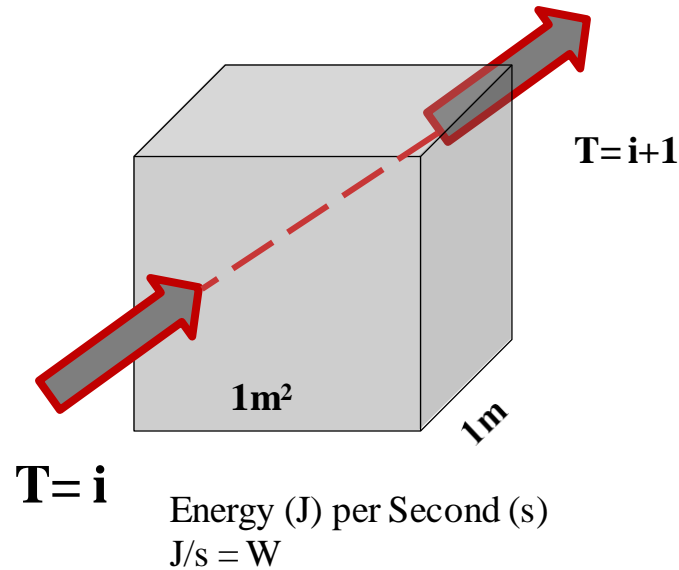


Steady-state **(time-independent)** heat conduction through a layer (thickness  $d$ , thermal conductivity  $k$ ) with surface temperatures  $T_1$  and  $T_2$

$$Q = k A \frac{T_1 - T_2}{d} \text{ (W )}$$

$$q = k \frac{T_1 - T_2}{d}$$

# Heat Transfer in Buildings – Conduction Principles



## $q$ depends on?

- Temperature difference
- Thickness of the layer ( $d$ )
- Thermal conductivity ( $k$ ) which is a property of the material

## Thermal conductivity ( $k$ )

- property of the material
- function of moisture and temperature
- $W \cdot m^{-1} \cdot K^{-1}$

# Heat Transfer in Buildings – Conduction Principles

## Energy & Heat

**Thermal conductivity,  
density and specific heat  
capacity of common  
building materials and  
surface finishes**

*Source: Thermo-Physical-Optical Property  
Database of Construction Materials, U.S.-  
India Joint Center for Building Energy  
Research and Development (CBERD) and  
Ministry of New and Renewable Energy  
(MNRE)*

MATERIALS	DENSITY (kg/m <sup>3</sup> )	THERMAL CONDUCTIVITY (W/m.k)	SPECIFIC HEAT CAPACITY ( J/kg.K)
Walls			
Autoclaved Aerated Concrete Block (AAC)	642	0.184	0.794
Resource Efficient Bricks (REB)	1520	0.631	0.9951
Concrete block (25/50)	2427	1.396	0.4751
Concrete block (30/60)	2349	1.411	0.7013
Calcium Silicate Board	1016	0.281	0.8637
Cement Board	1340	0.438	0.8113
Sandstone	2530	3.009	1.5957
Stone (Jaisalmer Yellow)	3006	2.745	2.0954
Stone (Kota)	3102	3.023	2.0732
Bamboo	913	0.196	0.6351



# Heat Transfer in Buildings – Conduction Principles

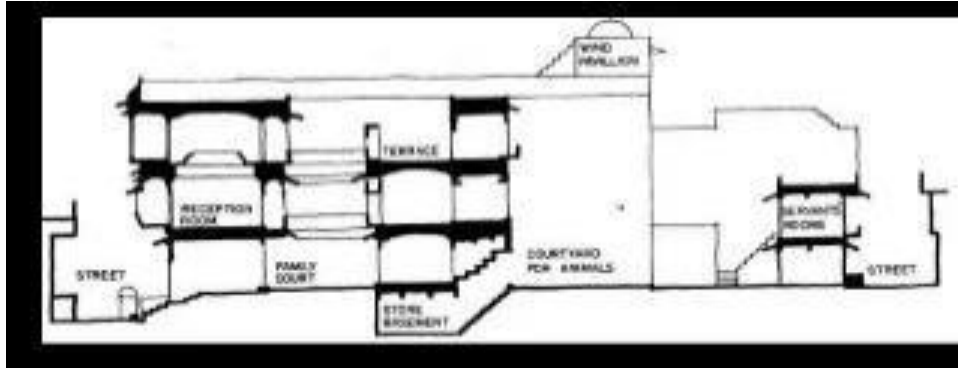
## Energy & Heat

**Thermal conductivity,  
density and specific heat  
capacity of common  
building materials and  
surface finishes**

*Source: Thermo-Physical-Optical Property  
Database of Construction Materials, U.S.-  
India Joint Center for Building Energy  
Research and Development (CBERD) and  
Ministry of New and Renewable Energy  
(MNRE)*

MATERIALS	DENSITY (kg/m <sup>3</sup> )	THERMAL CONDUCTIVITY (W/m.k)	SPECIFIC HEAT CAPACITY ( J/kg.K)
Surface Finishes			
Plaster of Paris (POP) powder	1000	0.135	0.9536
Cement Plaster	278	1.208	0.9719
Plywood	697	0.221	0.7258

# Heat Transfer in Buildings – Conduction Principles

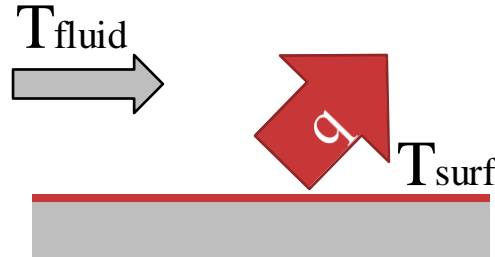


## Conduction through walls



# Heat Transfer in Buildings – Convection Principles

$$T_{\text{surf}} > T_{\text{fluid}}$$

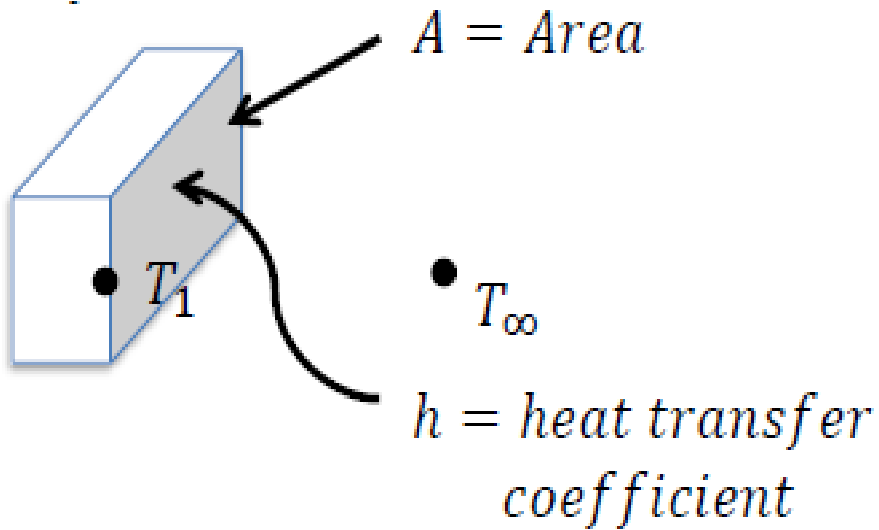


**Convection**

- Convection heat transfer needs a fluid (gas or liquid) medium and involves bulk fluid motion
- The heated fluid moves away from the source of heat, carrying energy with it causing convection currents that transport energy

Source: Rawal, R. (2021, December 22). Heat Transfer and Your Building Envelope. Solar Decathlon India. Retrieved April 13, 2022, from <https://solardecathlonindia.in/events/>

# Heat Transfer in Buildings – Convection Principles



Convective heat transfer ( $Q$ ) between a fluid and a surface is

$Q$  a temperature difference

$Q$  a area of the surface in contact

$$Q = h A \Delta T$$

$Q$  = heat transfer by convection, W

$A$  = surface area, m<sup>2</sup>

$\Delta T = T_\infty - T_1$  at some specified location, K

$h$  = heat transfer coefficient, W·m<sup>-2</sup>·K<sup>-1</sup>

# Heat Transfer in Buildings – Convection Principles

## Surface resistance (ISO 6946)

Heat flow direction	$R_{si}$ [m <sup>2</sup> ·K·W <sup>-1</sup> ]	$R_{so}$ [m <sup>2</sup> ·K·W <sup>-1</sup> ]
Horizontal (±30°)	0.13	0.04
Up	0.10	0.04
Down	0.17	0.04

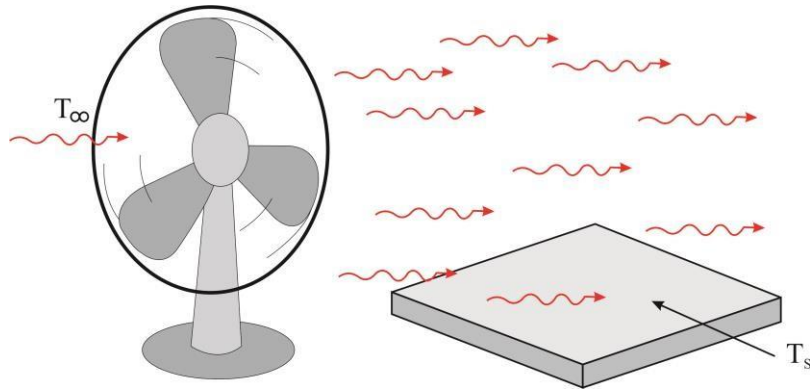
## Surface conductance

Conductance of the thin film of air at the surface of the material/body

- $h$  = surface/film conductance
- W·m<sup>-2</sup>·K<sup>-1</sup>
- Surface/film resistance  $R_s = 1/h$



# Heat Transfer in Buildings – Convection Principles



## Heat transfer coefficient

Surface conductance = Surface film conductance =  
Equivalent conductance =  
Heat transfer coefficient =  $h$

$$h = h_c + h_r$$

$h_c$  = convective heat transfer coefficient

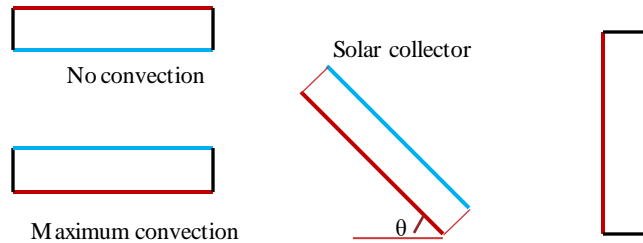
$h_r$  = radiative heat transfer coefficient

## Natural Convection – Forced Convection

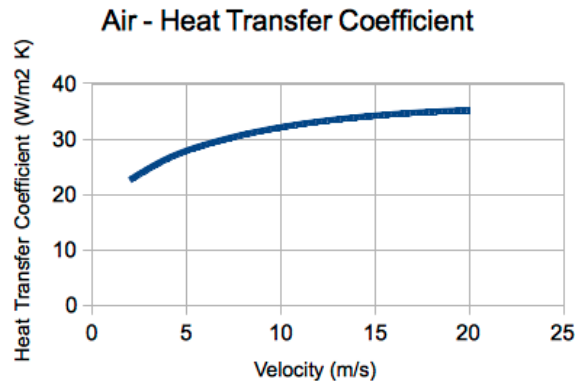


Source: Cappuccino. (n.d.). freepik. Retrieved from <https://www.freepik.com/photos/cappuccino>, Indiamart. (n.d.). Usha Table Fan. Indiamart. Retrieved from <https://www.indiamart.com/proddetail/usha-table-fan-19384320588.html>

# Heat Transfer in Buildings – Convection Principles



Convective heat transfer is a function of angle ( $\theta$ )



- Surface film resistance or conductance considers both radiative and convective heat transfer
- Varies with
  - Orientation of the surface
  - Surface emittance
  - Direction of heat flow
  - Air velocity
  - Surface and air temperature, and the temperature difference



# Heat Transfer in Buildings – Convection Principles

## Airflow through a room

Wall temperatures of the room at 30 °C

Heat transfer coefficient on inside = 10 W/m<sup>2</sup>K

## Wind-induced airflow

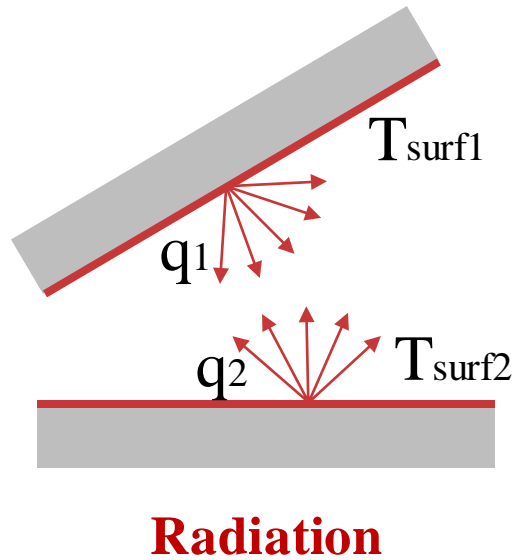
## Stack effect

## Buoyancy driven wind flow



Source: *Tripadvisor. (n.d.). Padmanabhapuram Palace. Tripadvisor. Retrieved from [https://www.tripadvisor.in/Attraction\\_Review-g608476-d3705659-Reviews-Padmanabhapuram\\_Palace\\_Kanyakumari\\_Kanyakumari\\_District\\_Tamil\\_Nadu.html](https://www.tripadvisor.in/Attraction_Review-g608476-d3705659-Reviews-Padmanabhapuram_Palace_Kanyakumari_Kanyakumari_District_Tamil_Nadu.html)*

# Heat Transfer in Buildings – Radiation Principles



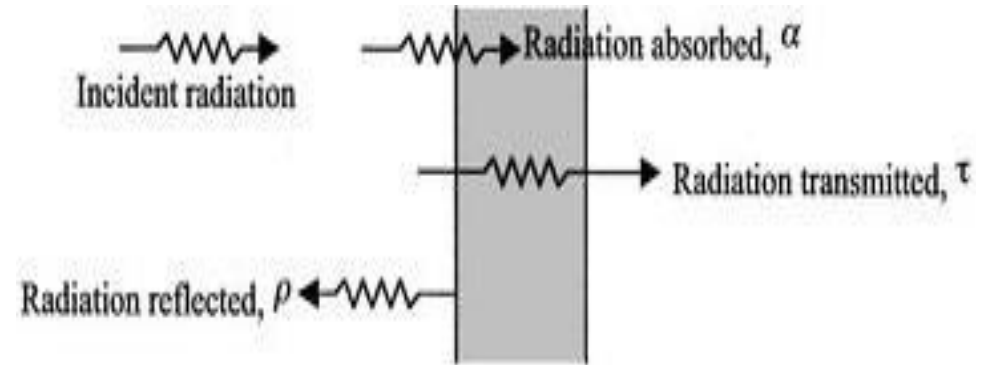
- Radiation heat transfer is a process where heatwaves are emitted that may be absorbed, reflected, or transmitted through a colder body.
- Energy has an electric field and a magnetic field associated with it,
- Wave-like properties. “electromagnetic waves”
- Wide range of electromagnetic radiation in nature. Visible light is one example.
- Others include forms like ultraviolet radiation, x-rays, and gamma rays.

Source: Rawal, R. (2021, December 22). Heat Transfer and Your Building Envelope. Solar Decathlon India. Retrieved April 13, 2022, from <https://solardecathlonindia.in/events/>

# Heat Transfer in Buildings – Radiation Principles

The behaviour of a surface with radiation incident upon it can be described by the following quantities:

- = absorptance – a fraction of incident radiation absorbed
- = reflectance - fraction of incident radiation reflected
- = transmittance – a fraction of incident radiation transmitted.



$$\alpha + \rho + \tau = 1$$

# Outdoor Climate & Heat Transfers - Climate Zones of India

	Conduction		Convection		Radiation	
	Spatial	Material & Methods	Spatial	Material & Methods	Spatial	Material & Methods
Walls		V. High				Low
Fenestrations (Windows)	High	V. High	High		V. High	V. High
Roofs	Low	High	V. Low	V. Low	High	V. High

V. Low

Low

Neutral

High






V. High

Source: Rawal, R. (2021, December 22). Heat Transfer and Your Building Envelope. Solar Decathlon India. Retrieved April 13, 2022, from <https://solardecathlonindia.in/events/>

# Heat Transfer in Buildings – Design Strategy

	Conduction	Convection	Radiation
Geometry - Massing	HD	WH	All Climates
Orientation		WH	All Climates
External Surface to Building Volume Ratio	HD	WH	HD
Extent of Fenestration and Thermal Characteristics	HD	WH	All Climates
Internal Volume – Stack Ventilation	X	HD	X
Location of Fenestration – Pressure Driven Ventilation	X	WH	X

WH: Warm Humid  
HD: Hot-Dry  
TE: Temperate CM:  
Composite CO:  
Cold

 V. Low  
 Low  
 Neutral  
 High  
 V. High

Source: Rawal, R. (2021, December 22). Heat Transfer and Your Building Envelope. Solar Decathlon India. Retrieved April 13, 2022, from <https://solardecathlonindia.in/events/>

# Heat Transfer in Buildings – Design Strategy

Thermal Conductivity  
**R Value – U Value**  
Thermal Mass  
**Specific Heat**  
Thermal Diffusivity

- **Walls**
  - Internal
  - External

Thermal Conductivity – Frames and Glass  
**R Value – U Value**  
Solar Gains  
**Solar Heat Gain Coefficient**  
Visual Light Transmittance  
**VLT**

- **Fenestrations**
  - Windows
  - Skylights
  - Doors

Thermal Conductivity  
R Value – U Value  
Thermal Emissivity  
**Solar Reflectance**

- **Roofs**
  - Floors
  - Foundations

Source: Rawal, R. (2021, December 22). Heat Transfer and Your Building Envelope. Solar Decathlon India. Retrieved April 13, 2022, from <https://solardecathlonindia.in/events/>



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# Heat Balance & Adaptive Thermal Comfort Method



# Comfort Theory - Heat Balance Method

The heat balance method presents a physics based mathematical model that establishes thermal comfort when heat loss from the body is exactly equal to heat produced within the body. The heat balance method gives following equation:

$$M - W = q_{sk} + q_{res} + S = (C + R + E_{sk}) + (C_{res} + E_{res}) + (S_{sk} + S_{cr})$$

Where,

M = Rate of metabolic heat production, W/m<sup>2</sup>

W = Rate of mechanical work accomplished, W/m<sup>2</sup>

$q_{sk}$  = Total rate of heat loss from skin, W/m<sup>2</sup>

$q_{res}$  = Total rate of heat loss through respiration, W/m<sup>2</sup>

C + R = Sensible heat loss from skin, W/m<sup>2</sup>

$E_{sk}$  = Total rate of evaporative heat loss from skin, W/m<sup>2</sup>

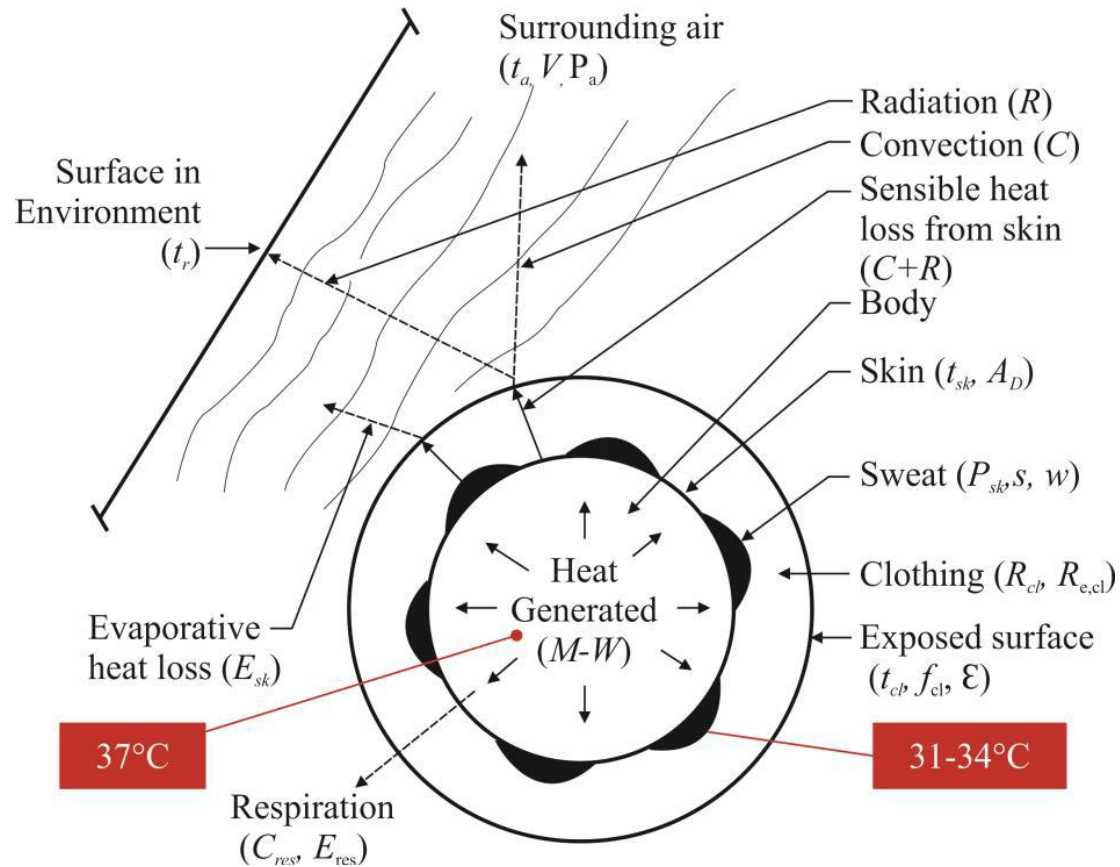
$C_{res}$  = Rate of convective heat loss from respiration, W/m<sup>2</sup>

$E_{res}$  = Rate of evaporative heat loss from respiration, W/m<sup>2</sup>

$S_{sk}$  = Rate of heat storage in skin compartment, W/m<sup>2</sup>

$S_{cr}$  = Rate of heat storage in core compartment, W/m<sup>2</sup>

# Comfort Theory - Heat Balance Method



In order to be comfortable: -

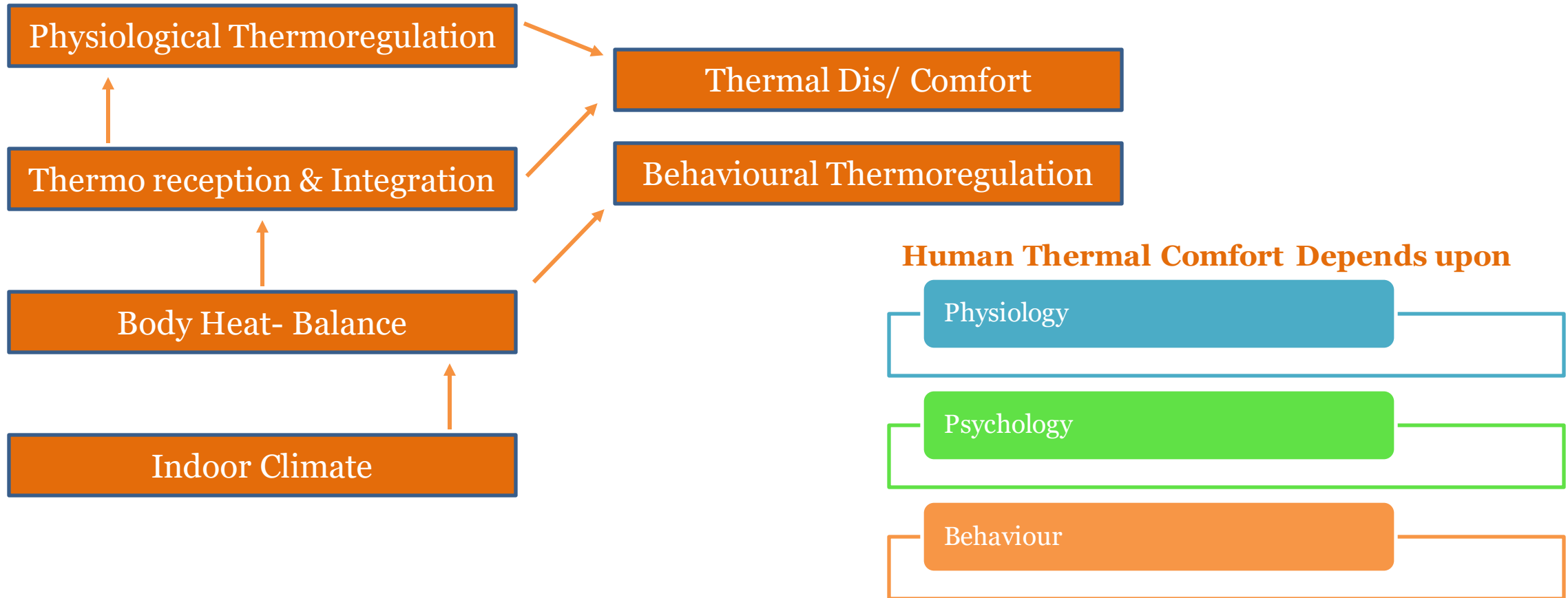
Heat production = Heat loss from the body

Heat loss > Production, then you feel Cold

Heat loss < Production, then you feel Hot

Source: Fantozzi, F., & Lamberti, G. (2019). Determination of thermal comfort in indoor sport facilities located in Moderate Environments: An overview. Atmosphere, 10(12), 769. <https://doi.org/10.3390/atmos10120769>

# Comfort Theory – Adaptive Thermal Comfort Method



Source: Fantozzi, F., & Lamberti, G. (2019). Determination of thermal comfort in indoor sport facilities located in Moderate Environments: An overview. *Atmosphere*, 10(12), 769. <https://doi.org/10.3390/atmos10120769>

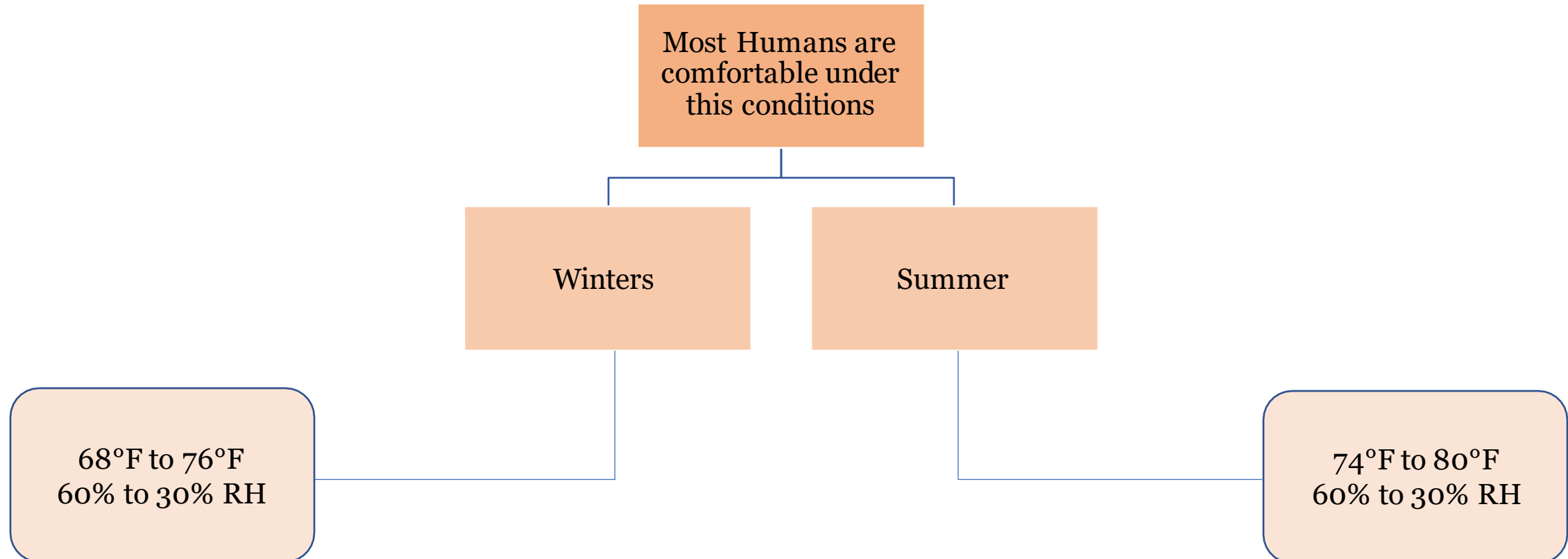


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## Local Thermal Discomfort

## Human Comfort Range as per ASHRAE 55 Standard

To accommodate Local thermal Discomfort, most standards like ASHRAE specify conditions to ensure 80% acceptability of the thermal environment amongst occupants.



## 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 COMFORT

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

### THERMAL COMFORT

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

## Local 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.

**To accommodate Local thermal Discomfort, most standards like ASHRAE specify conditions to ensure 80% acceptability of the thermal environment amongst occupants.**



# Local Thermal Discomfort - Causes

Local Thermal Discomfort is primarily caused by the Asymmetric Thermal Radiation. Where :

Radiant asymmetry is defined as the difference in radiant temperature of the environment on opposite sides of the person/ Difference in radiant temperatures seen by a small flat element looking in opposite directions  
(ASHRAE, 2021)

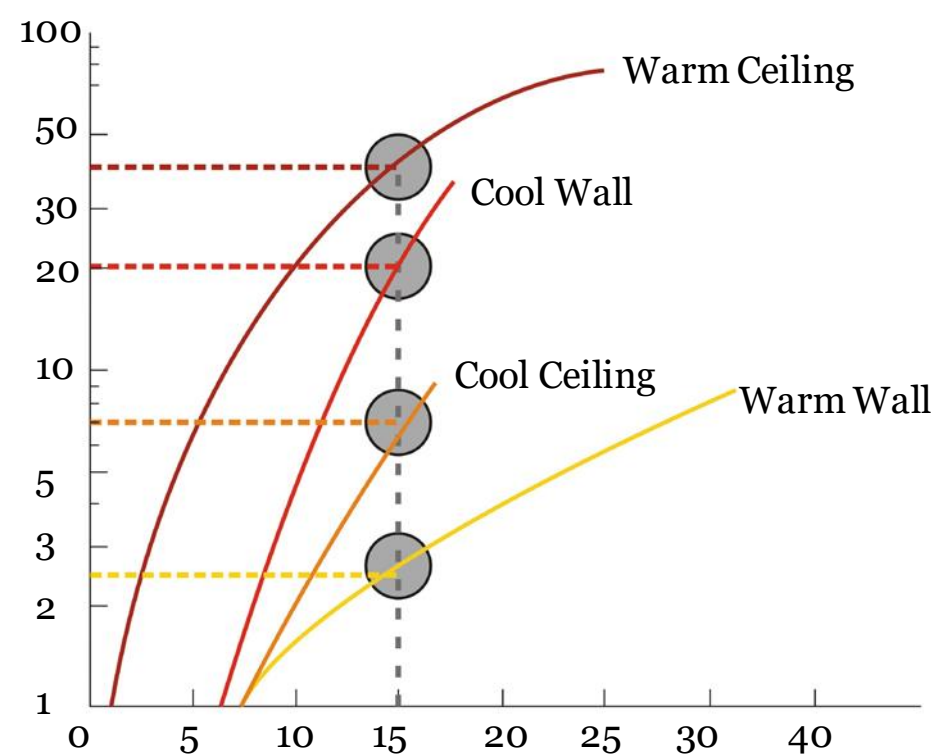
## Radiant Asymmetry Types in Buildings

Radiant Temperature Asymmetry – Walls and Roof

Radiant Temperature Asymmetry – Floors

Radiant Temperature Asymmetry Between head and ankles

# Local Thermal Discomfort due to Radiant Temperature Asymmetry – Walls and Roof



Occupant dissatisfaction levels due to radiant temperature asymmetry in walls and roof.

Source: Abushakra Bass, Akers Larry, Baxter Van, Hayte Sheila & Paranjpey Ramesh (2017). ASHRAE Fundamentals SI edition.

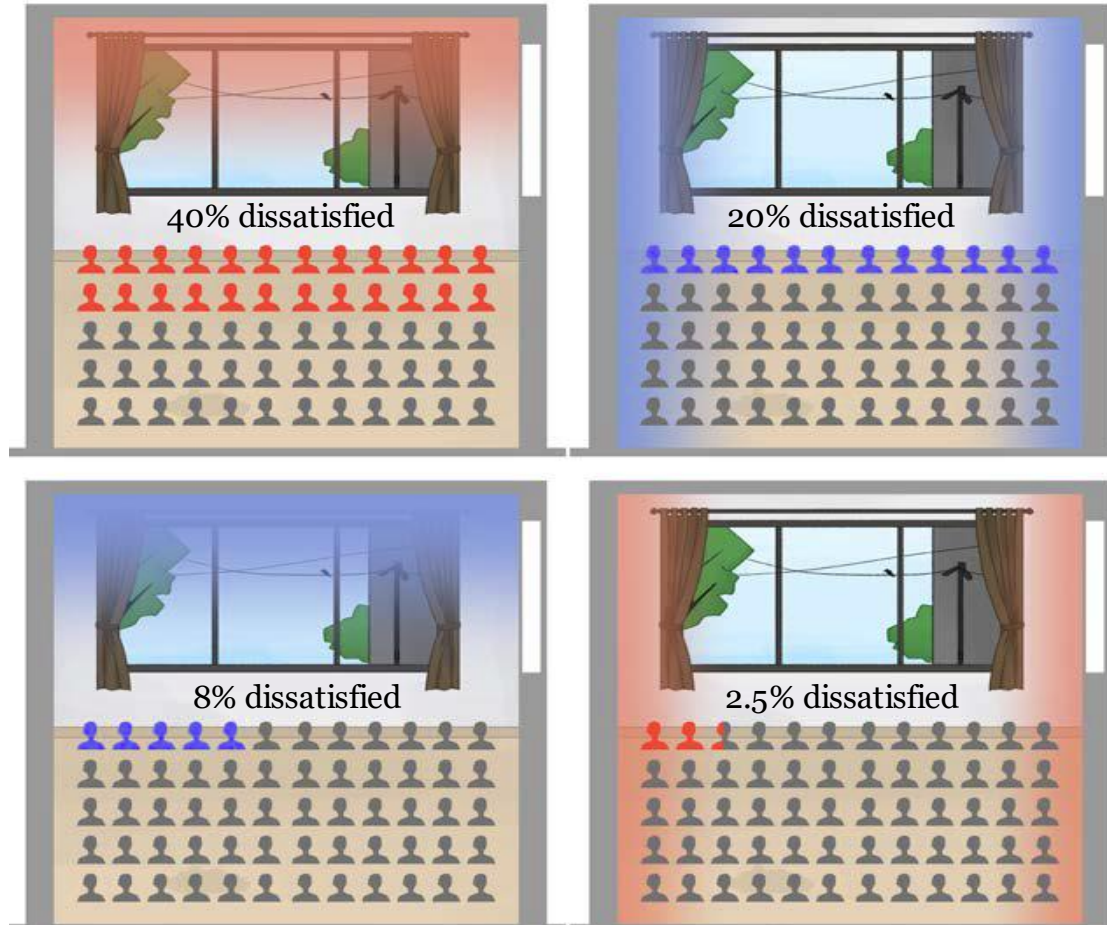
## Percentage of dissatisfied occupants with radiant thermal asymmetry of 15°C

Radiant Thermal Asymmetry (15 C) Cause	Warm Ceiling	Cool Walls	Cool Ceiling	Warm Walls
PPD	40%	20%	8%	2.5%

The descending order of PPD expressed in radiant thermal asymmetry for walls and ceilings can be given as

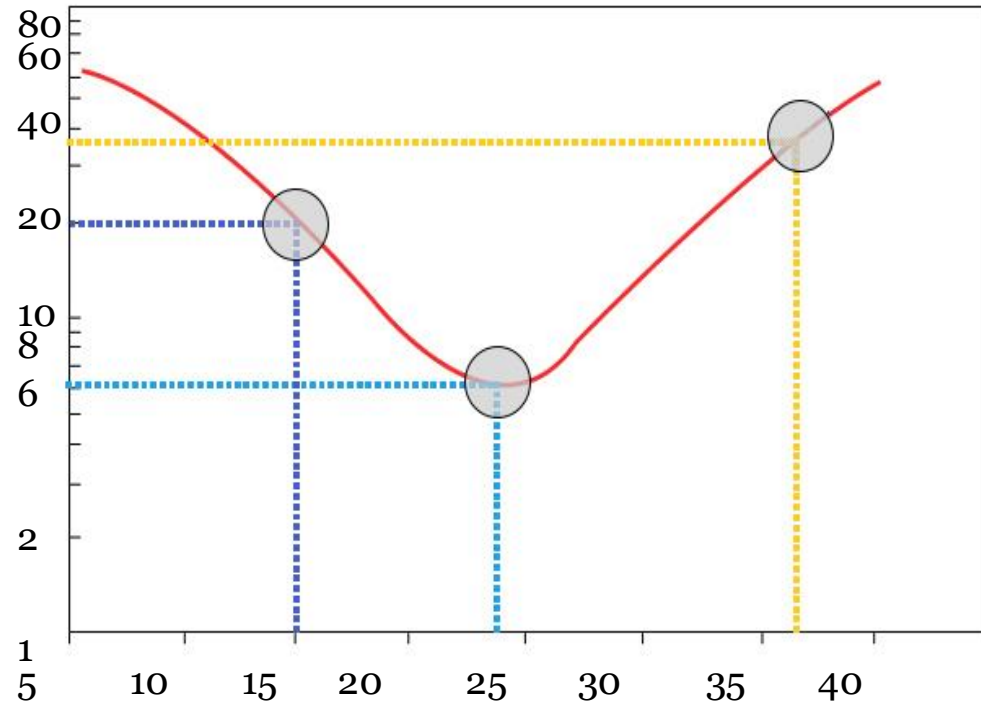
**Warm Ceiling > Cool Wall > Cool Ceiling > Warm Wall.**

# Local Thermal Discomfort due to Radiant Temperature Asymmetry – Walls and Roof



- Representation of radiant thermal asymmetry in walls and roof with resultant percentages of dissatisfied occupants.

# Local Thermal Discomfort due to Radiant Temperature Asymmetry – Floors



Occupant dissatisfaction levels due to radiant temperature asymmetry in floor.

Source: Abushakra Bass, Akers Larry, Baxter Van, Hayte Sheila & Paranjpey Ramesh (2017).  
ASHRAE Fundamentals SI edition..

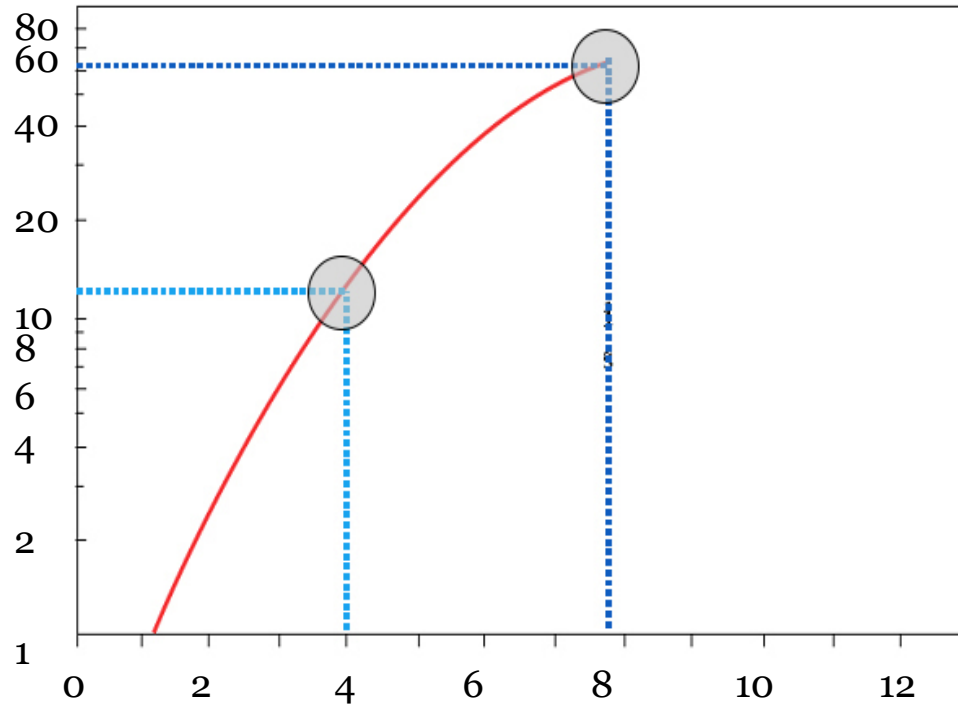
## Percentage of dissatisfied occupants with radiant thermal asymmetry of 15°C

Categorization of Floor Temp.	Cold	Cool/ Neutral	Warm
Floor Temperature	15 °C	24 °C	36 °C
PPD	20%	6%	35%

The descending order of PPD expressed due to floor temperature is Warm Floor > Cold Floor > Cool Floor. An explanation of why cooler or neutral floor temperatures are preferred over warm floors lies in the understanding of

- ❑ the amount of hot and cold receptors present at the base of our feet
- ❑ The sensitivity level of these receptors towards heat or coolth.

# Local Thermal Discomfort due to Radiant Temperature Asymmetry – Head and Ankles



Air Temp Difference between head and Ankles °C

Percentage of Seated People Dissatisfied as Function of Air Temperature Difference Between Head and Ankles

Source: Abushakra Bass, Akers Larry, Baxter Van, Hayte Sheila & Paranjpey Ramesh (2017). ASHRAE Fundamentals SI edition.

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## DAY 1

### Session 4: Passive Strategies & Building Materials



12

# Affordable Housing & Passive Design Strategies



# Passive Strategies & Building Physics

## Passive Measures

### Climatic Zone Level

Temperature, rainfall, wind direction, sun radiation, humidity, and other environmental factors are taken into consideration when designing.

### Site Level

To take advantage of the positive aspects of the site and its microclimatic features while minimising the negative aspects.

## Level of Response

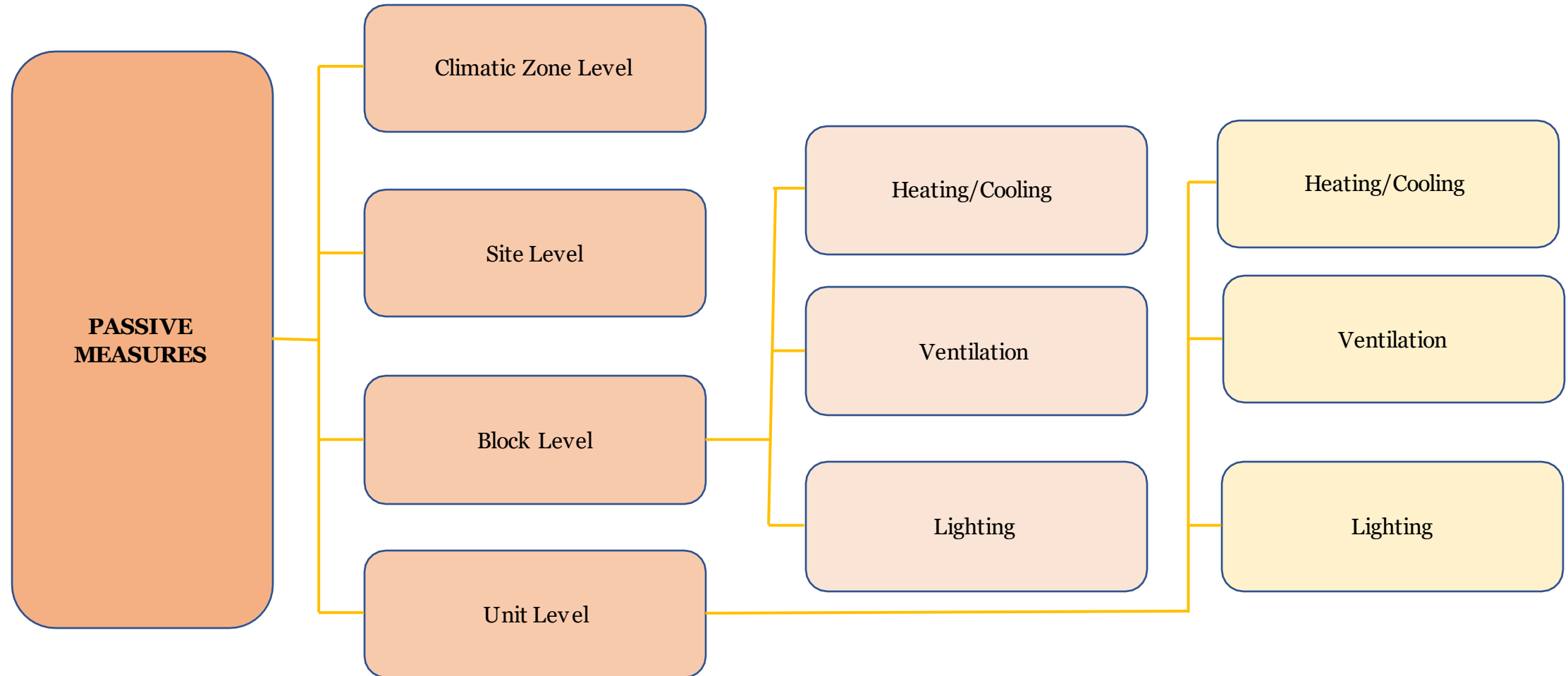
### Block Level

Interaction of the block with its surroundings and plants to ensure that it has adequate heating, ventilation, and lighting.

### Unit Level

Design solutions that influence heat, light, and ventilation based on climatic variables at the unit level.

# Passive Strategies & Building Physics



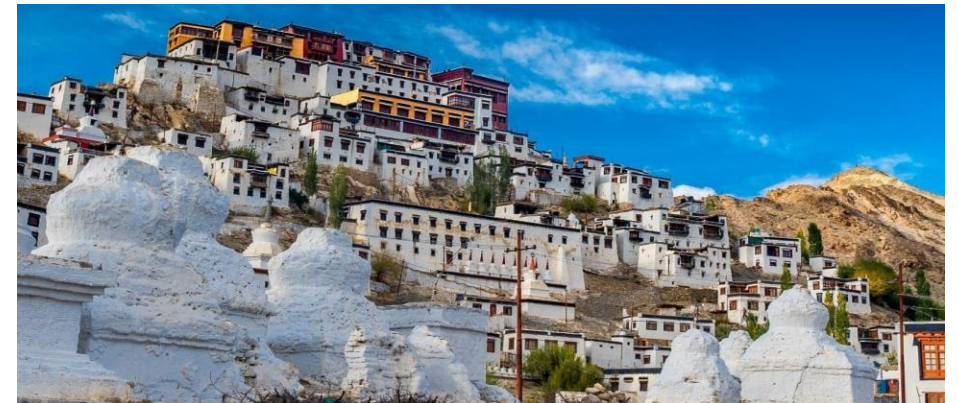
# Passive Strategies & Building Physics

## Passive Measures – Climatic Zone Level

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

### Example

- 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 Strategies & Building Physics

## Passive Measures – Site Level

Reducing the 'heat island' effect with approaches like:

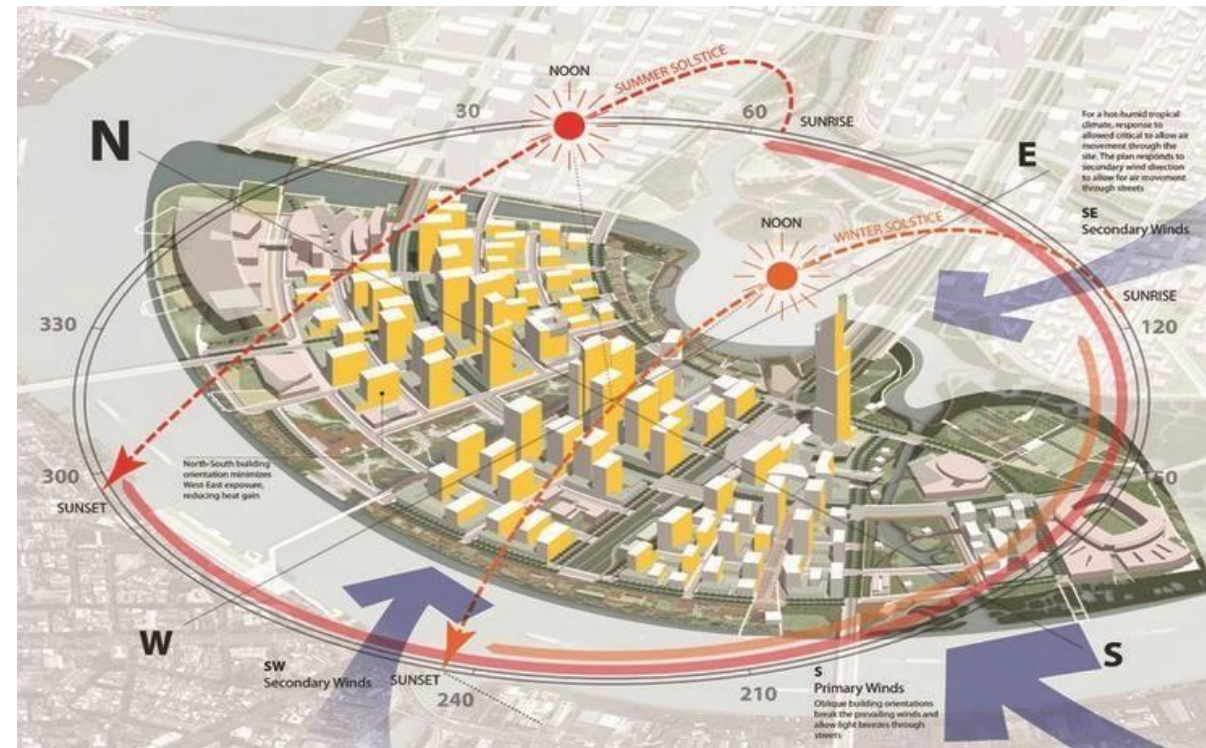
Courtyards / open courts are often surrounded by construction.

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

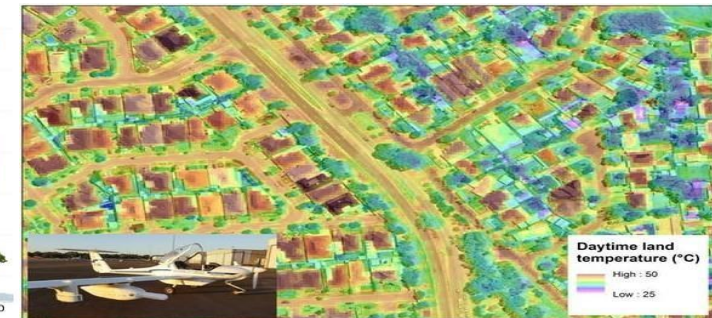
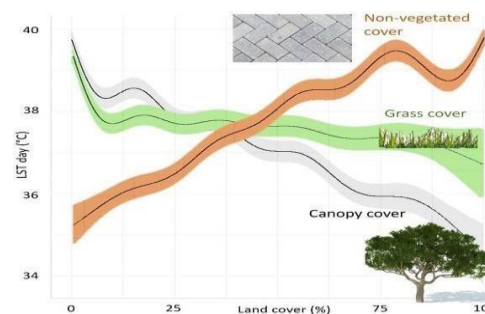
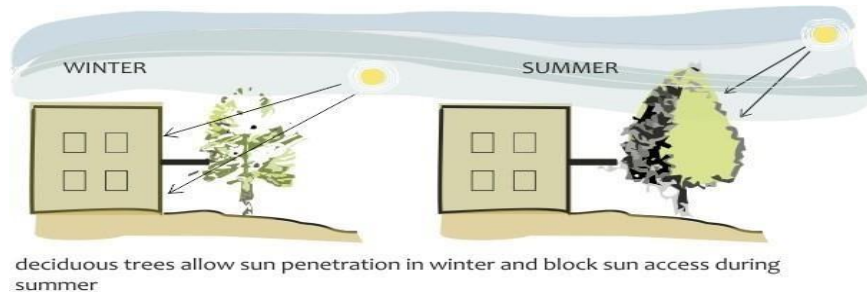
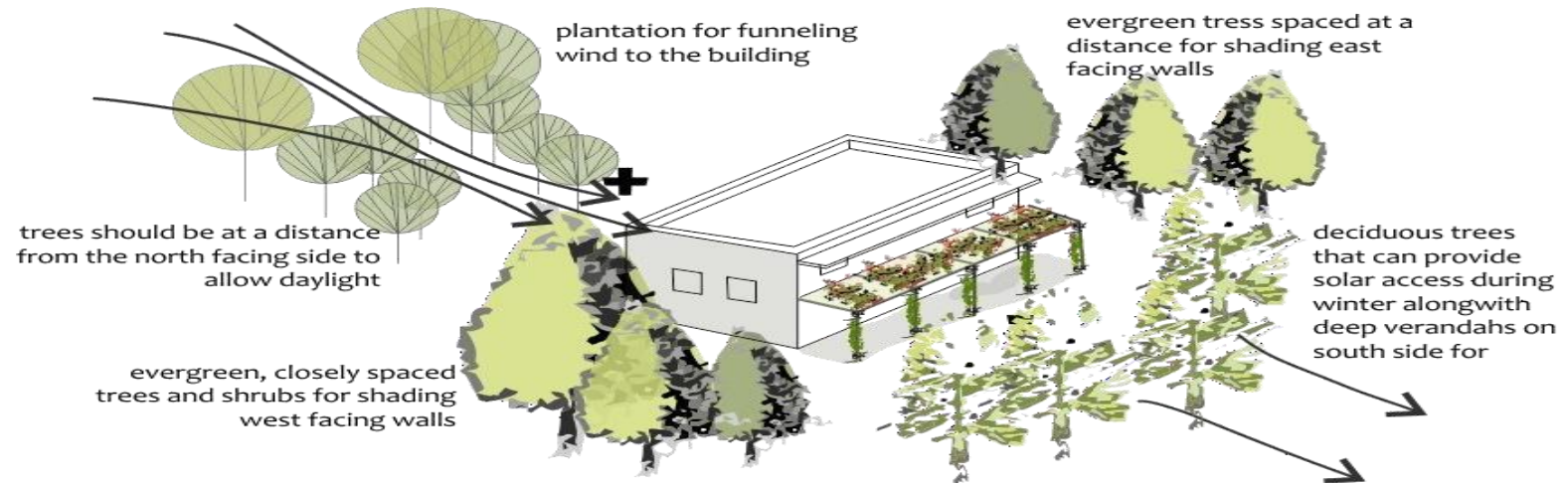




# Passive Strategies & Building Physics

## Passive Measures – Leveraging Plantation

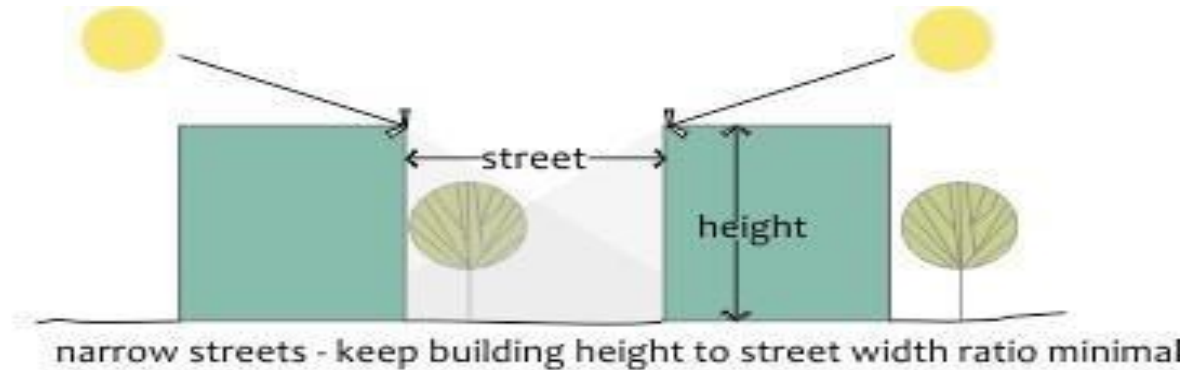
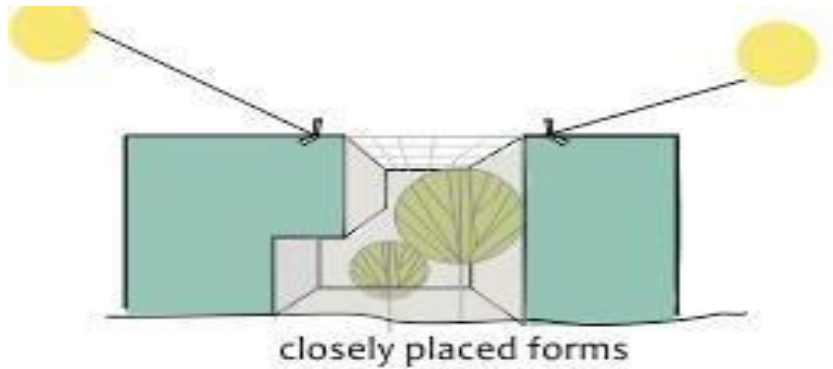
Planting trees in the right places to provide shade and ventilation can significantly reduce the severity of intense weather. During heatwaves in Adelaide, a research found that districts with more vegetation cover remained cooler by up to 6°C.



# Passive Strategies & Building Physics

## Block Level

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



HEATING/  
COOLING

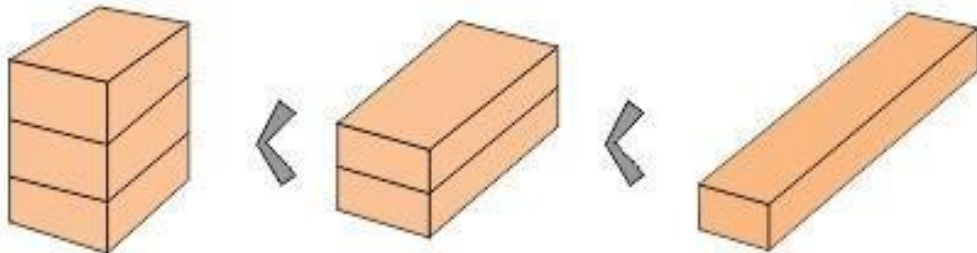


# Passive Strategies & Building Physics

## Block Level

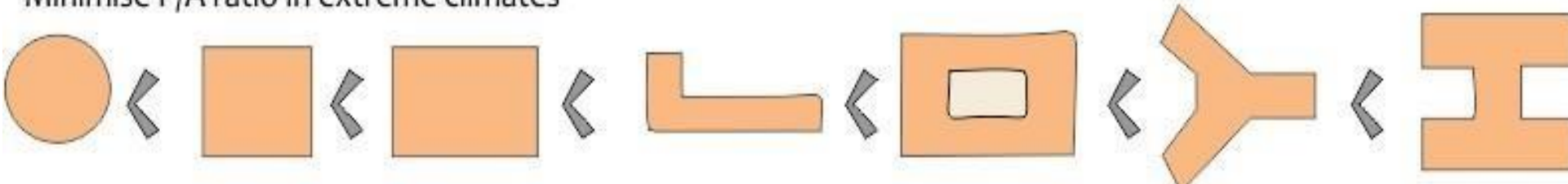
In harsh climate zones, reduce the surface area to building volume and perimeter to area ratios to reduce solar radiation exposure.

Minimise S/V ratio in extreme climates



increase compactness by reducing  
surface area for the same volume

Minimise P/A ratio in extreme climates



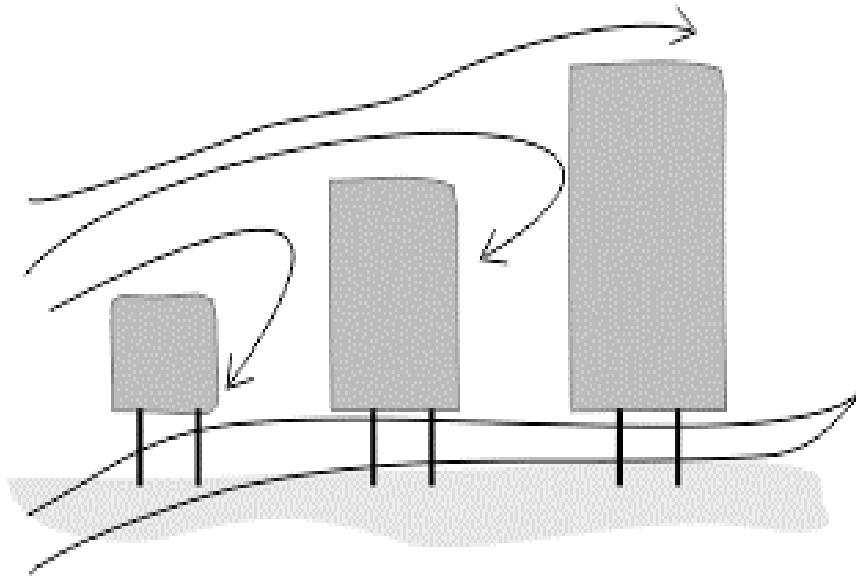
HEATING/  
COOLING



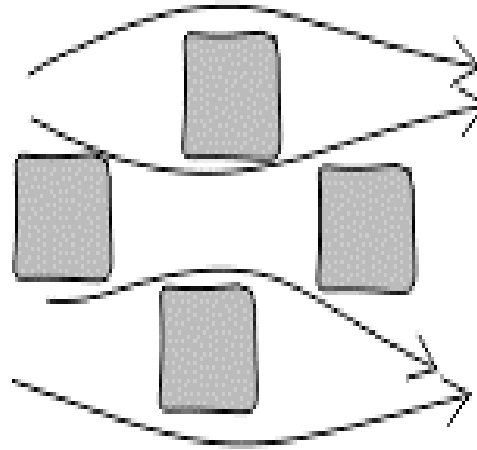
# Passive Strategies & Building Physics

## Block Level

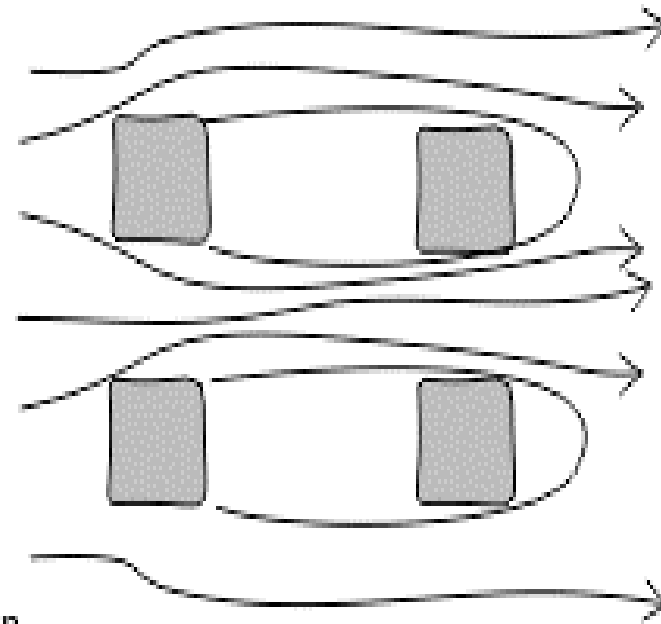
Wind shadows should be avoided by building orientation.



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

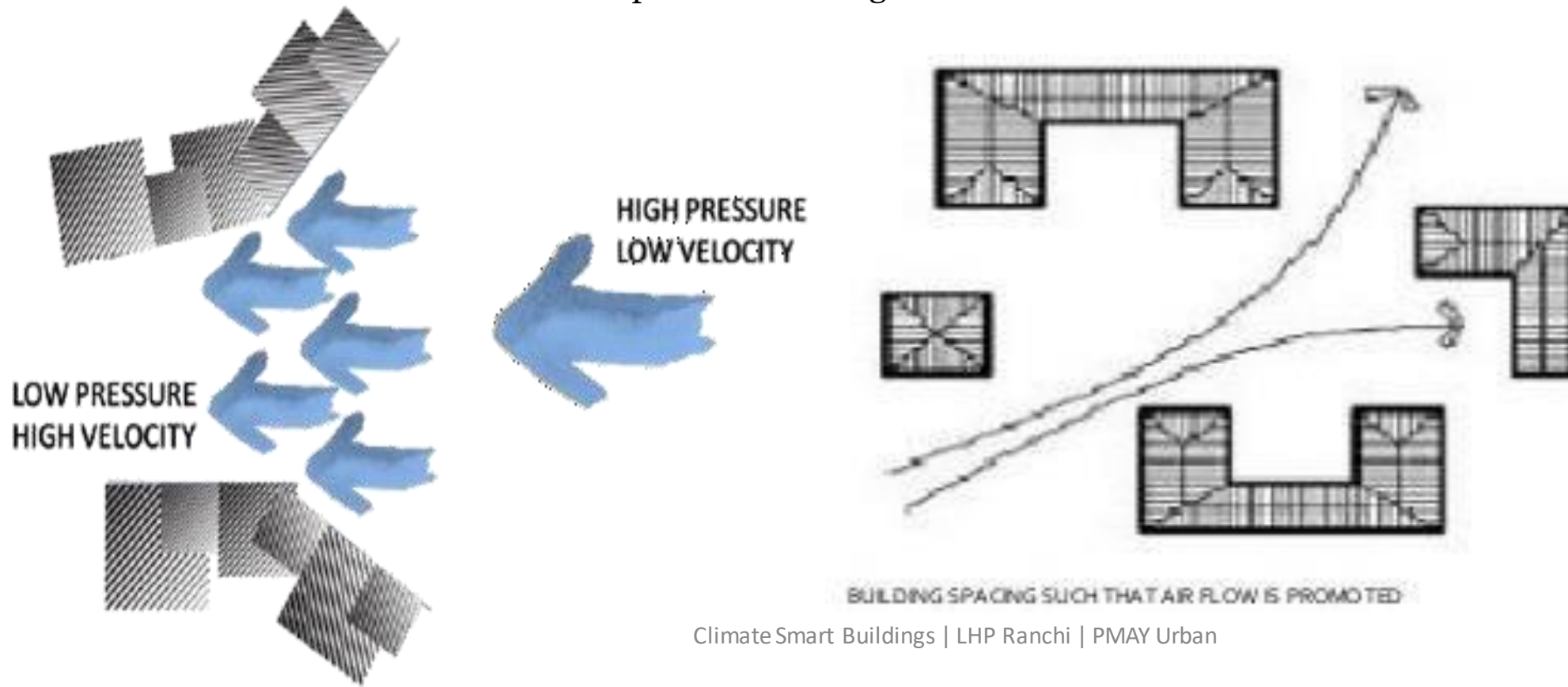


VENTILATION

# Passive Strategies & Building Physics

## 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

# Passive Strategies & Building Physics

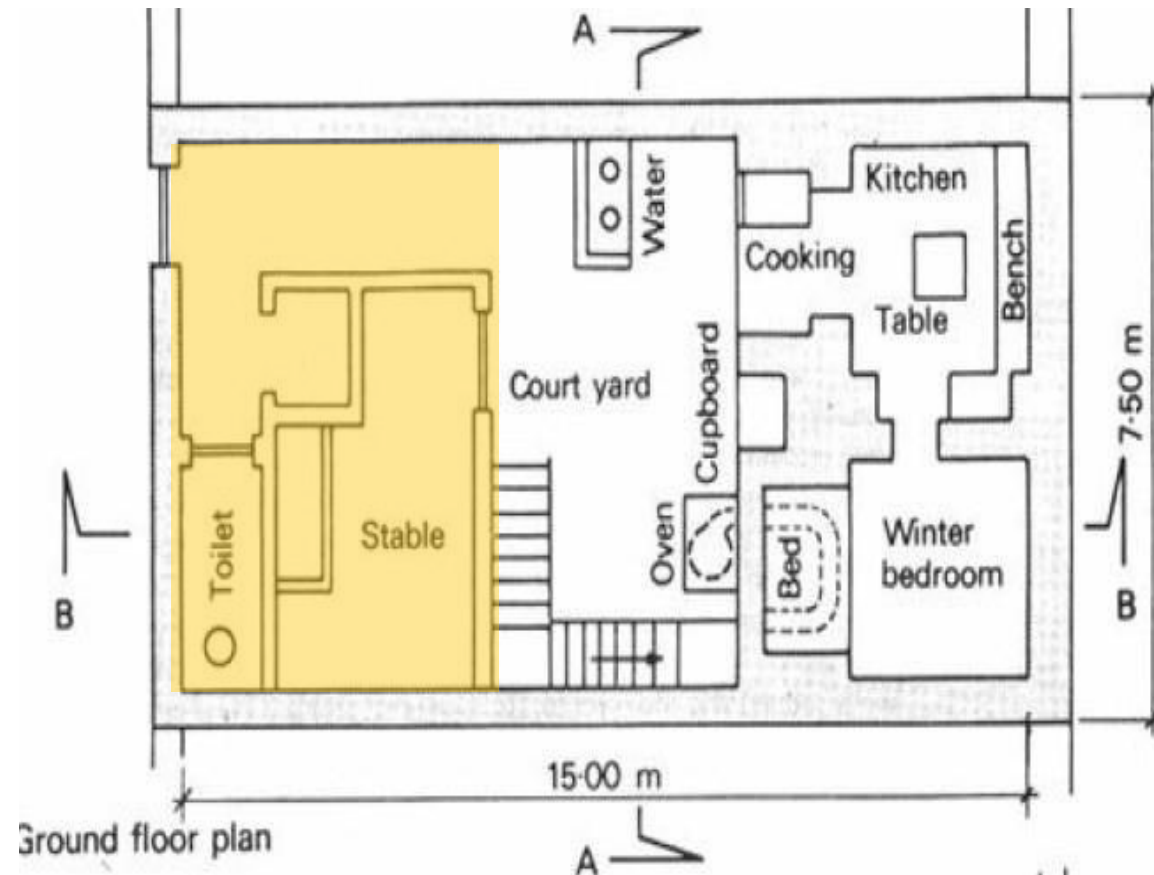
## Unit Level

### 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.



Climate Smart Buildings | LHP Ranchi | PMAY Urban

**HEATING/  
COOLING**

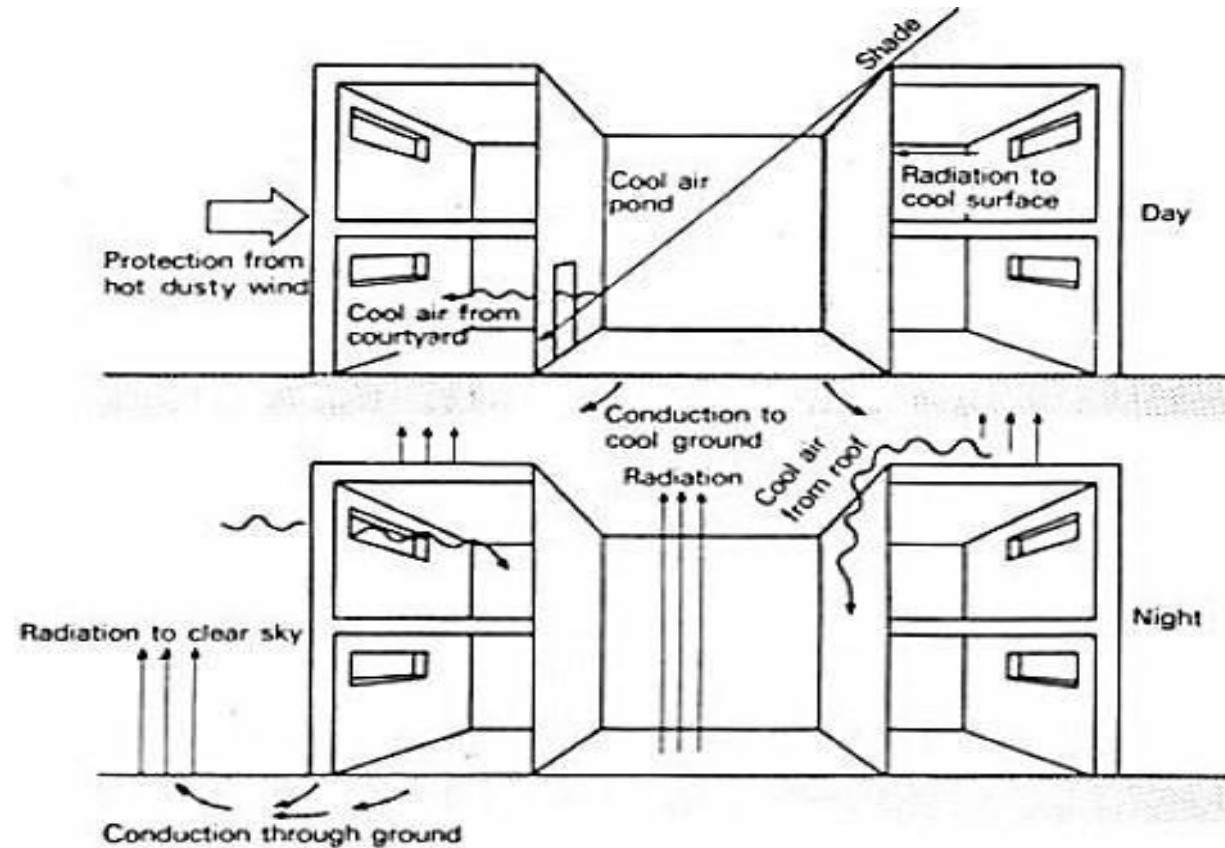
# Passive Strategies & Building Physics

## 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.

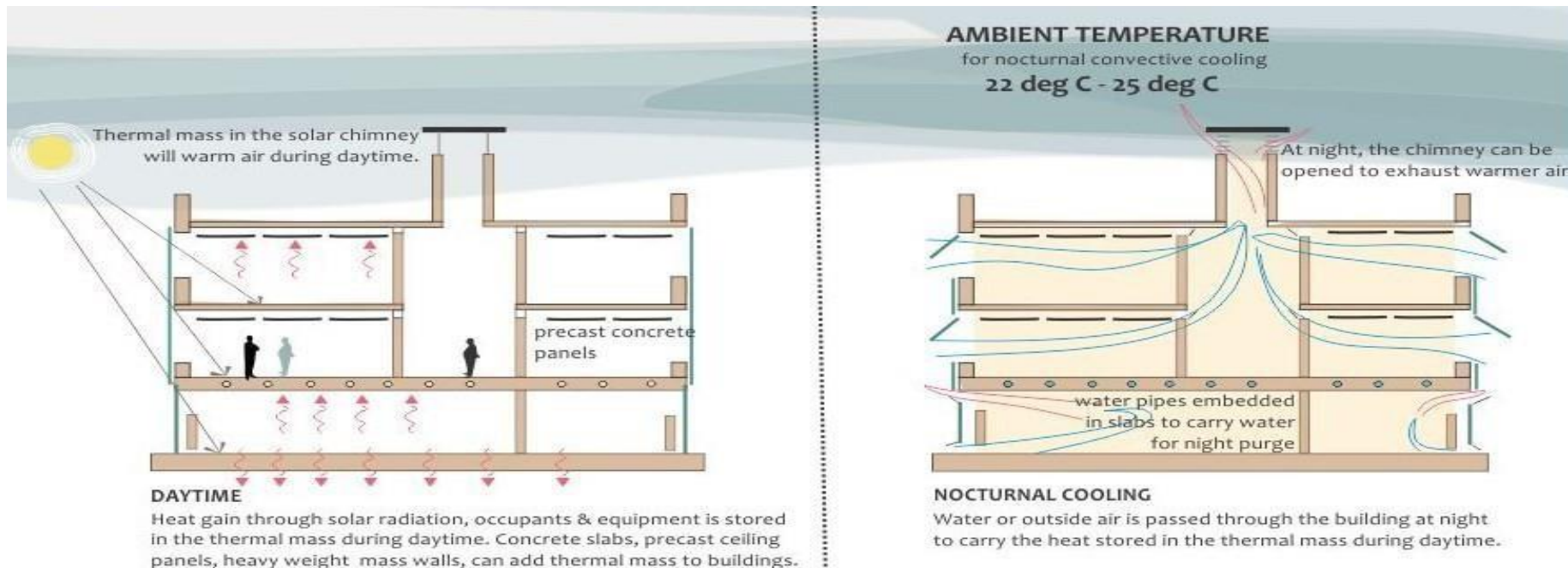


# Passive Strategies & Building Physics

## 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



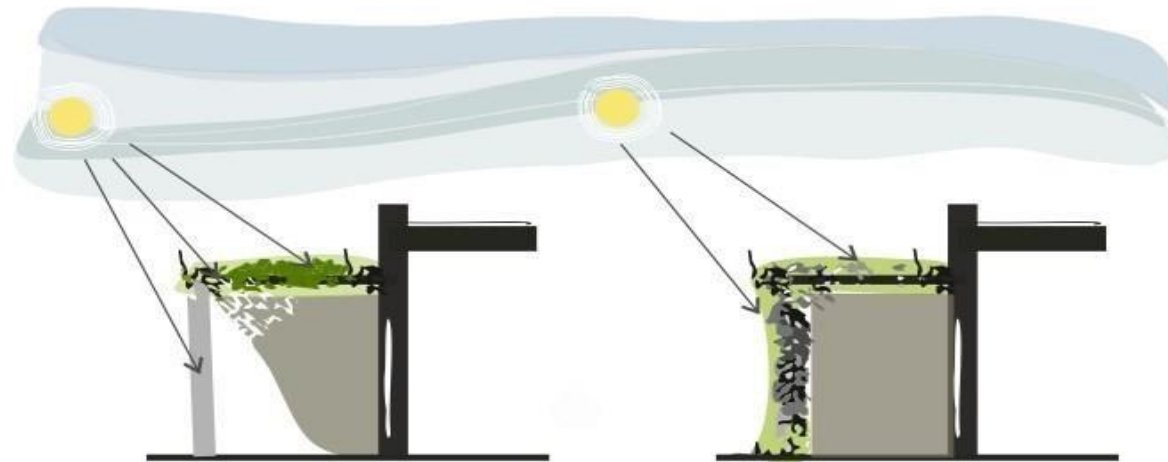
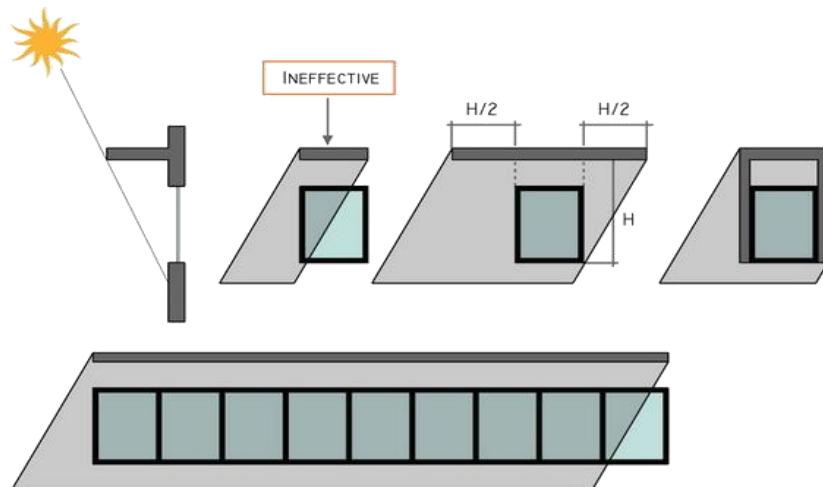
# Passive Strategies & Building Physics

## 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

# Passive Strategies & Building Physics

## Unit Level

### **ORIENTATION:**

Buildings can be orientated in relation to the prevailing wind direction at angles ranging from  $0^\circ$  to  $30^\circ$ .

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

### **CREATING PRESSURE DIFFERENCES:**

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

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

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

VENTILATION





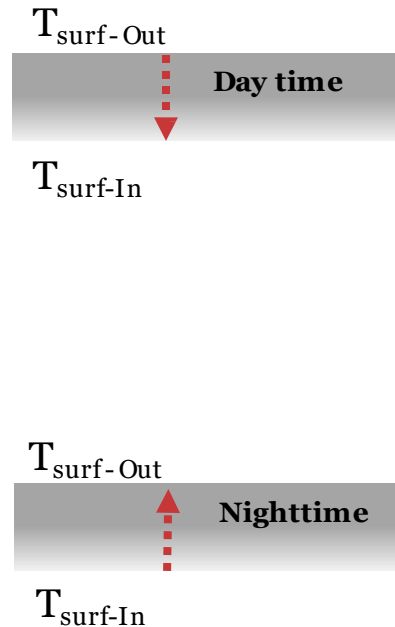
13

# Innovative Building Materials

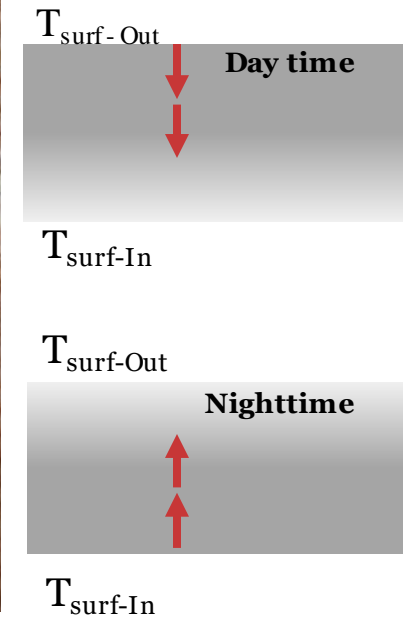
# Walling Material and Walling Assemblies

## Heat Transfer in Buildings: Insulation and Thermal Mass

### Thermal Insulation, Thermal Conductivity



### Thermal Insulation, Specific Heat Capacity



Source: unsplash. (n.d.). Cloth. unsplash. Retrieved from <https://images.unsplash.com/photo-1564814183940-fb79790e1e45?ixlib=rb-1.2.1&q=80&fm=jpg&crop=entropy&cs=tinyrgb&dl=mhrezaa-O5R-dr8E2qk-unsplash.jpg>

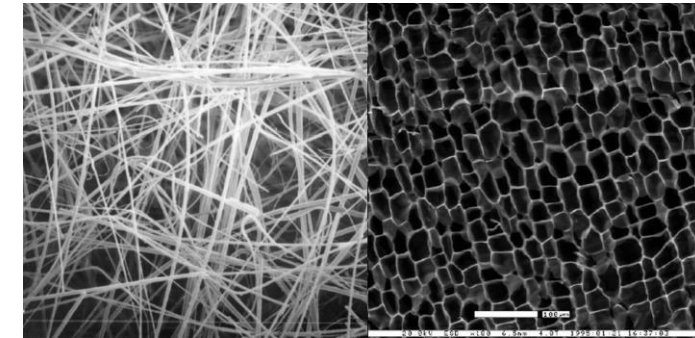
# Walling Material and Walling Assemblies

## Walling Materials and Methods: Insulation and Thermal Mass



The main thermal insulating material in buildings is locked air

Air is a poor thermal conductor



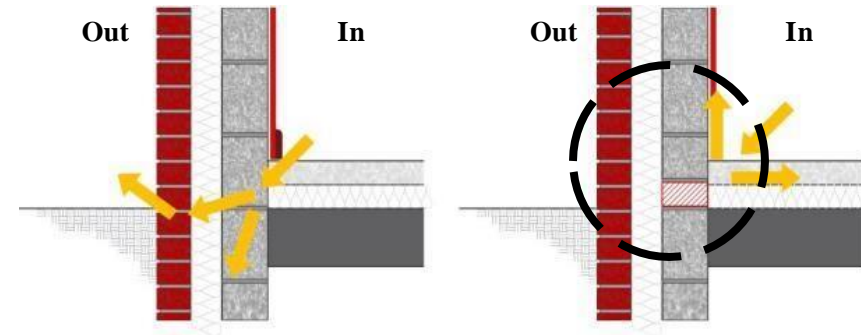
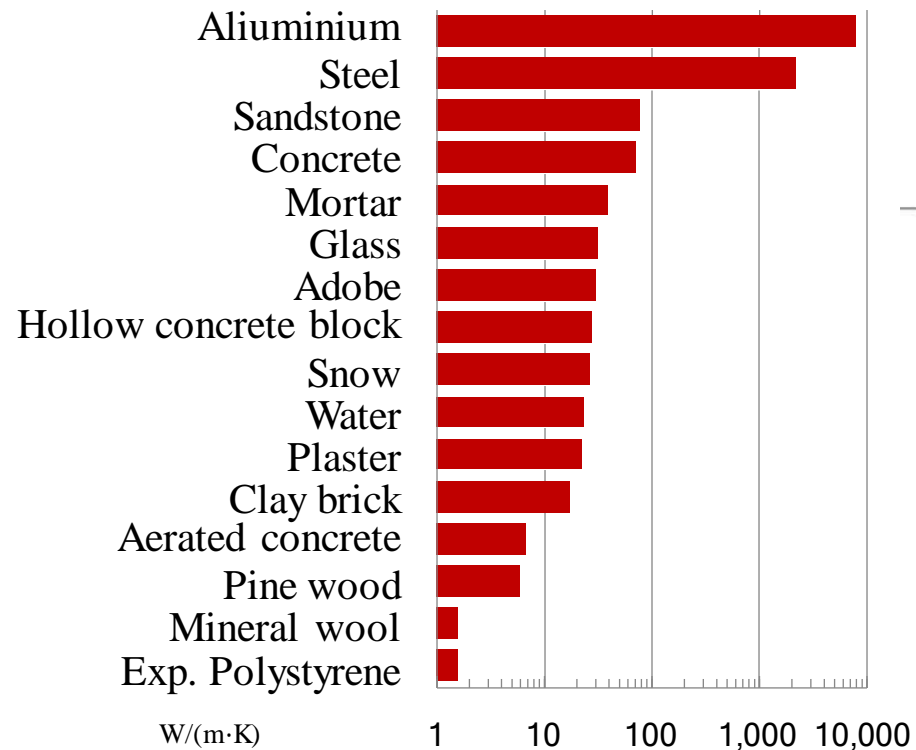
Air is locked in foam bubbles or between fibers

Bubble walls and fibers are themselves opaque to thermal radiation.

*Information and Image Courtesy: Prof. Cloude Roulet, EMPA, Switzerland, Indo Swiss BEEP project, BEE, India*

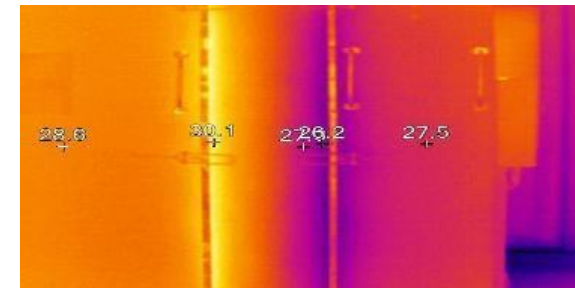
# Walling Material and Walling Assemblies

## Walling Materials and Methods : Conductivity & Thermal Bridge



Air = 1



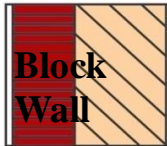
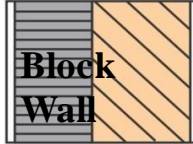
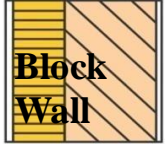
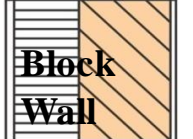

0.0002 Sq mts of aluminium (2 Sq Cms) = 1 Sq mts of insulation



Information and Image Courtesy: Prof. Claude Roulet, EMPA, Switzerland, Indo Swiss BEEP project, BEE, India

# Walling Material and Walling Assemblies

## Walling Materials and Methods : Construction

1		<b>Brick Wall</b>	<b>Minimum 200mm porosified brick</b>			
2		<b>Batt Const.</b>	<b>100 mm cellulose</b>	5		<b>75mm XPS</b>
3		<b>Block Wall</b>	<b>90mm Foam Glass</b>	6		<b>60mm PUR</b>
4		<b>Block Wall</b>	<b>80mm EPS</b>	7		<b>10 mm Vacuumed FRG</b>

**Minimum Thickness Needed to Achieve U value of  $< 0.40 \text{ W/m}^2\text{K}$**

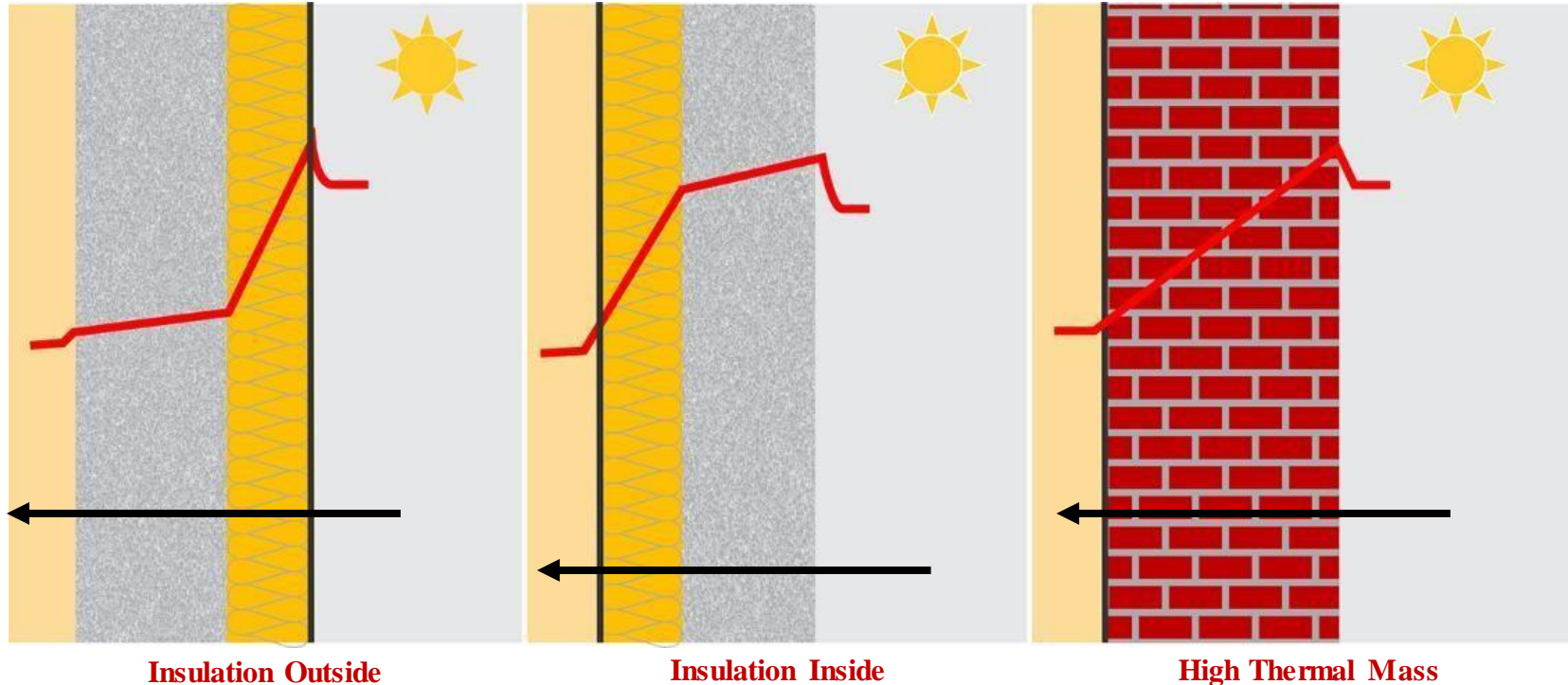
Information and Image Courtesy: Prof. Cloude Roulet, EMPA, Switzerland, Indo Swiss BEEP project, BEE, India



# Walling Material and Walling Assemblies

## Walling Materials and Methods : Construction

Steady State Indoors and Variable Outdoors – Hot and Sunny Outdoors

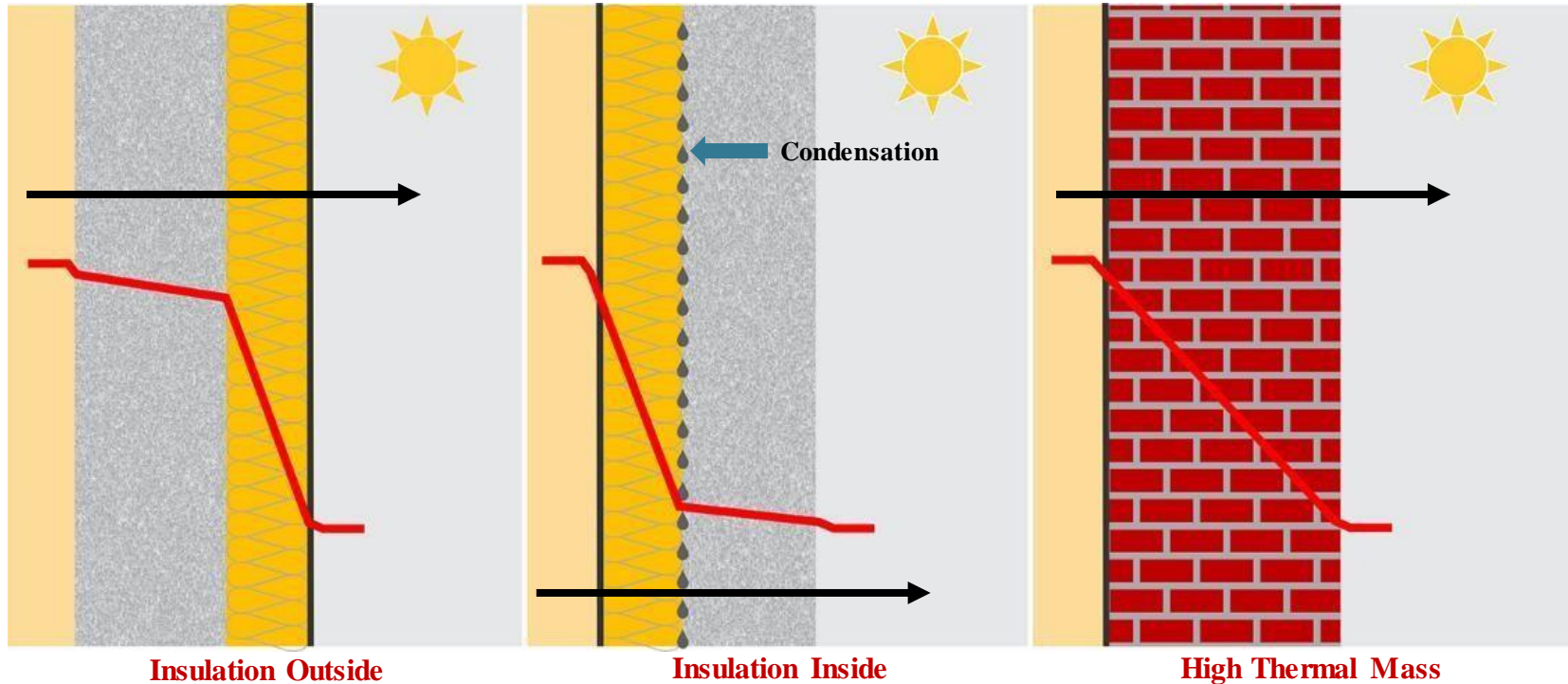


Information and Image Courtesy: Prof. Cloude Roulet, EMPA, Switzerland, Indo Swiss BEEP project, BEE, India

# Walling Material and Walling Assemblies

## Walling Materials and Methods : Construction

Steady State Indoors and Variable Outdoors – Cold and Sunny Outdoors



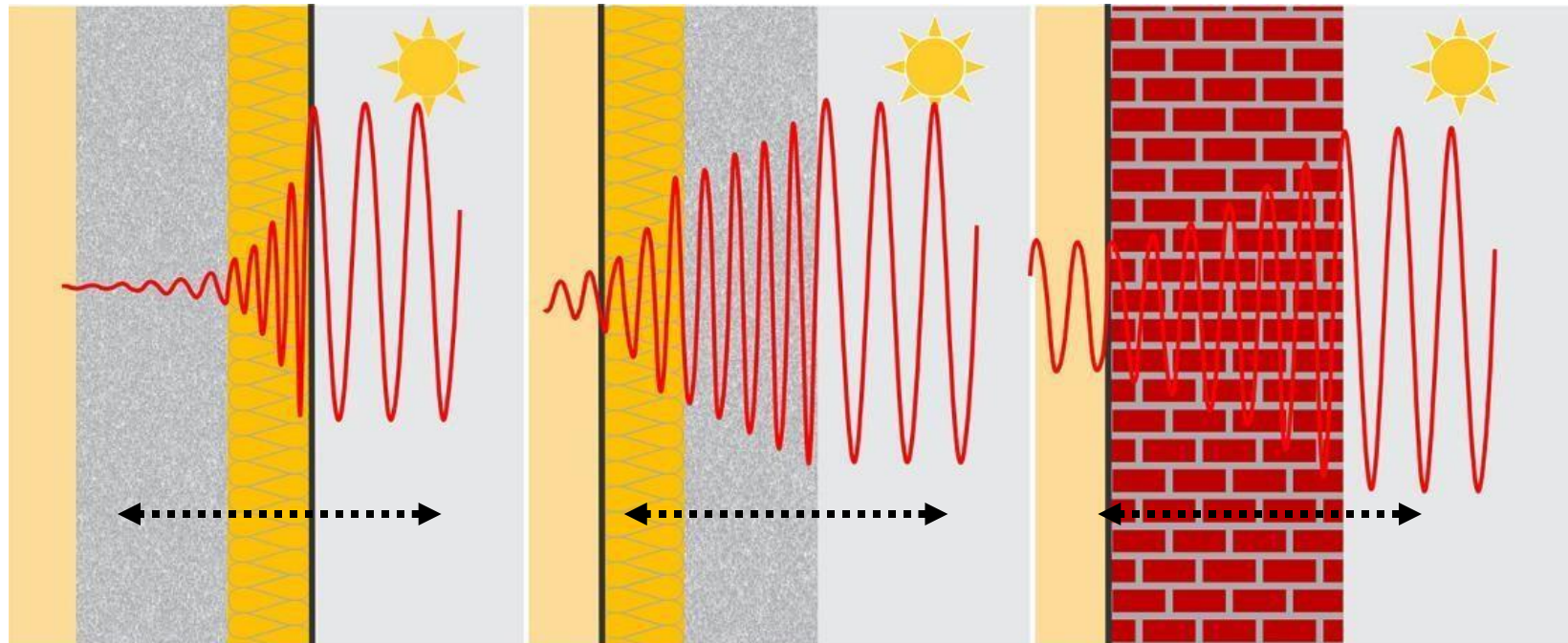
Information and Image Courtesy: Prof. Cloude Roulet, EMPA, Switzerland, Indo Swiss BEEP project, BEE, India



# Walling Material and Walling Assemblies

## Walling Materials and Methods : Construction

Variable Indoors and Variable Outdoors



**Insulation Outside**

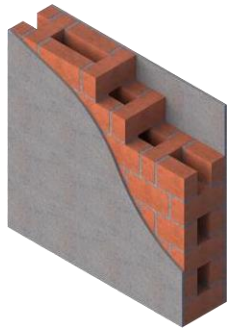
**Insulation Inside**

**High Thermal Mass**

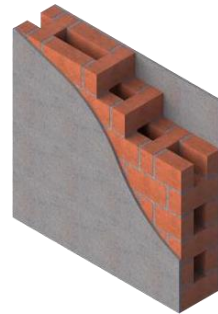
Information and Image Courtesy: Prof. Cloude Roulet, EMPA, Switzerland, Indo Swiss BEEP project, BEE, India

# Walling Material and Walling Assemblies

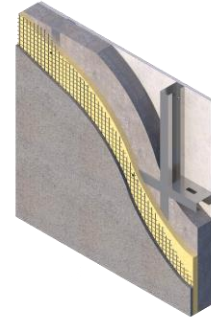
## Nonhomogeneous Walling Technologies, Industrial



**230 MM Clay Brick  
Wall Base Line**



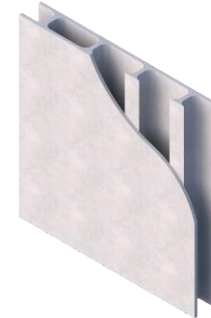
**Rat Trap Bond**



**LGFSS- EPS**



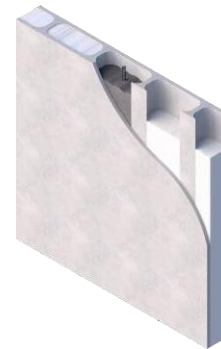
**PPGL**



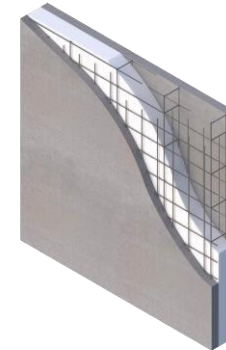
**GFRG Unfilled**



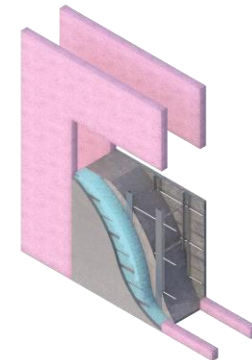
**GFRG Partially Filled**



**GFRG Fully Filled**



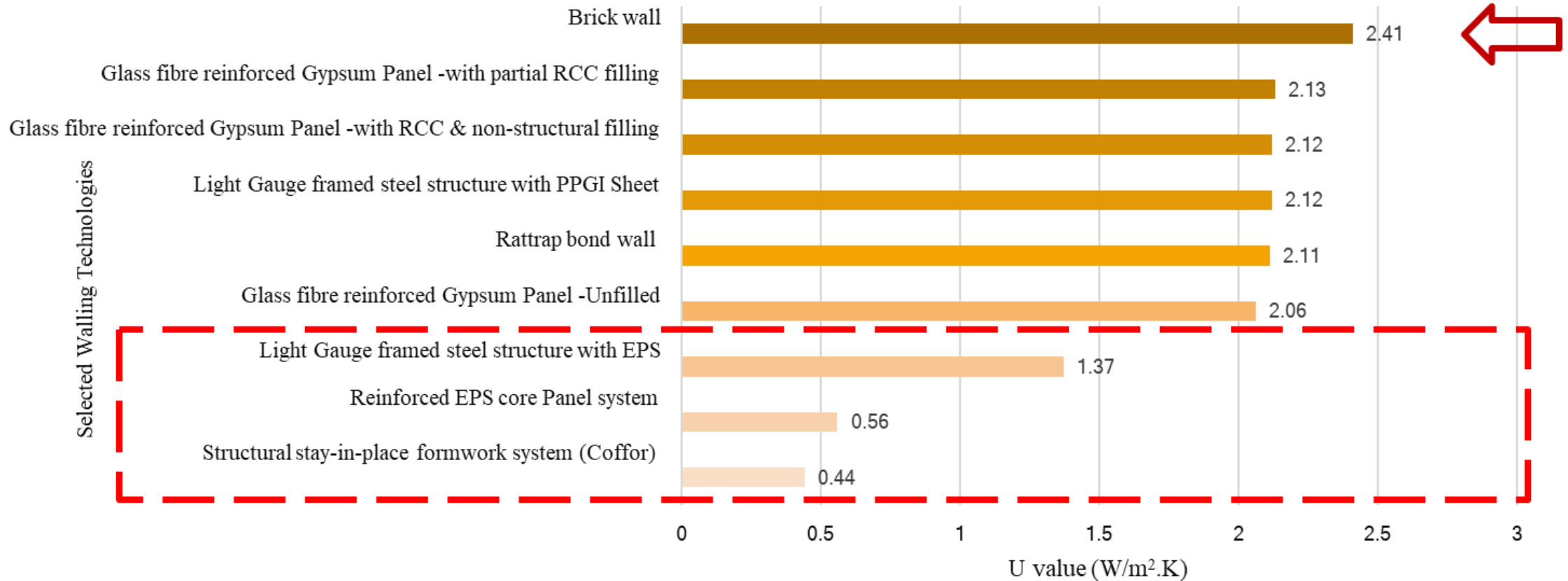
**Reinforced EPS Core**



**Stay-in-Place Coffer**

# Walling Material and Walling Assemblies

## Walling Technologies: U Values, Industrial



Source: RACHNA, Technical Session 5: Building Materials and Methods of Construction for Affordable Housing,  
CEPT

Climate Smart Buildings | LHP Ranchi | PMAY Urban

# Walling Material and Walling Assemblies

## Nonhomogeneous Walling Technologies, Traditional

Bamboo-Crete

U - VALUE ( $\text{W/m}^2\text{K}$ )= 1.82



Wattle and Daub

U - VALUE ( $\text{W/m}^2\text{K}$ )= 2.09



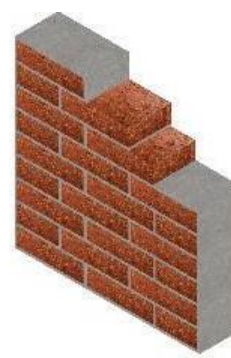
Stabilized Adobe

U - VALUE ( $\text{W/m}^2\text{K}$ )= 1.50



Laterite block wall

U - VALUE ( $\text{W/m}^2\text{K}$ )= 1.61



Unstabilized Adobe

U - VALUE ( $\text{W/m}^2\text{K}$ )= 1.57



Compressed Stabilized Earth  
block wall

U - VALUE ( $\text{W/m}^2\text{K}$ )= 1.59



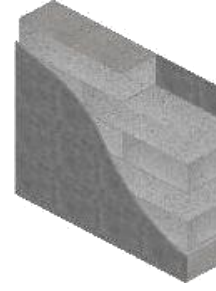
Unstabilized Compressed  
Earth block wall

U - VALUE ( $\text{W/m}^2\text{K}$ )= 1.42



AAC block wall

U - VALUE ( $\text{W/m}^2\text{K}$ )= 0.45



Unstabilized Rammed Earth  
Wall assembly

U - VALUE ( $\text{W/m}^2\text{K}$ )= 1.68



Stabilized Rammed Earth  
Wall assembly

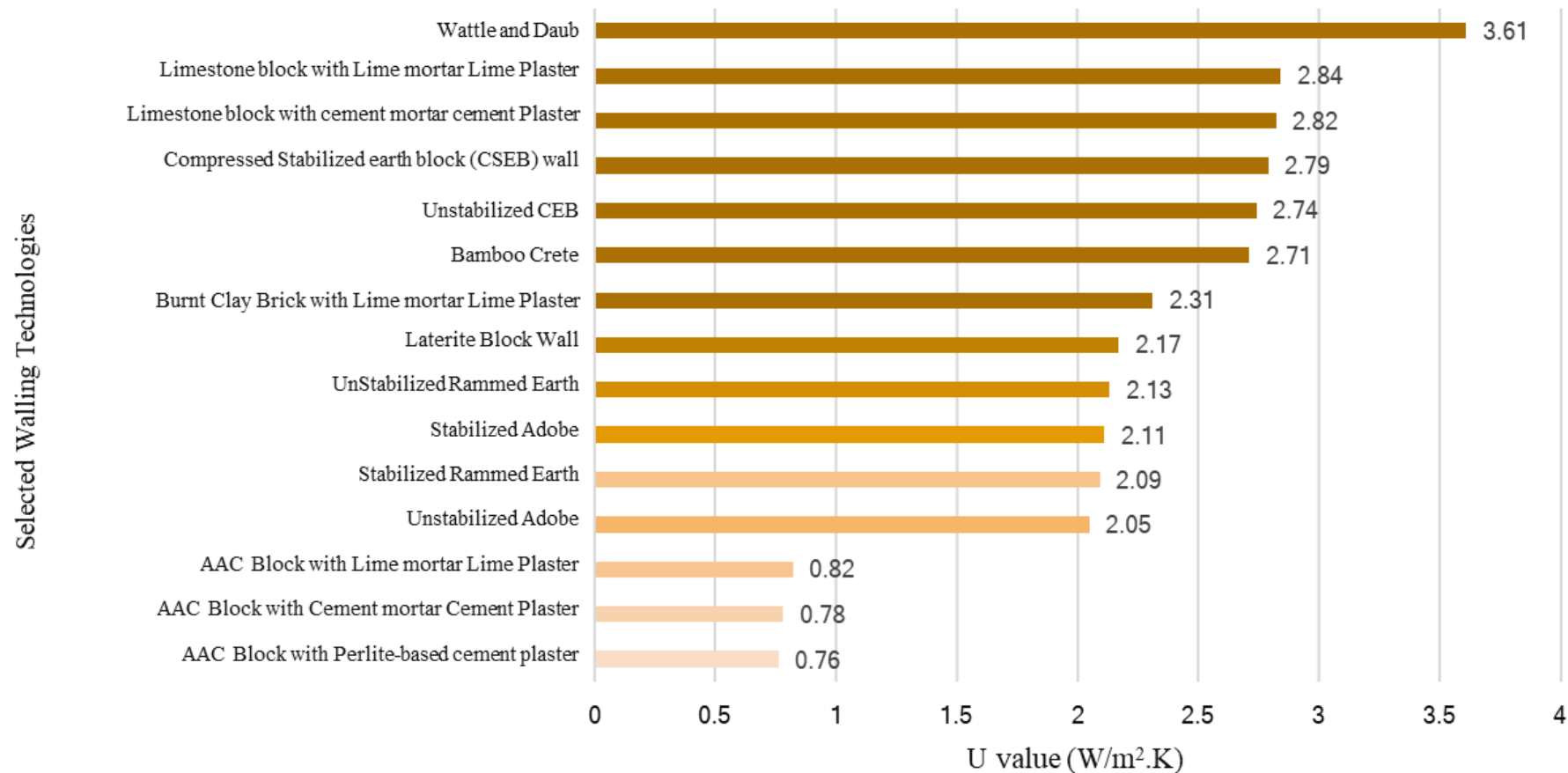
U - VALUE ( $\text{W/m}^2\text{K}$ ) = 1.495



Source: RACHNA, Technical Session 5: Building Materials and Methods of Construction for Affordable Housing, CEPT

# Walling Material and Walling Assemblies

## Walling Technologies: U Values, Traditional

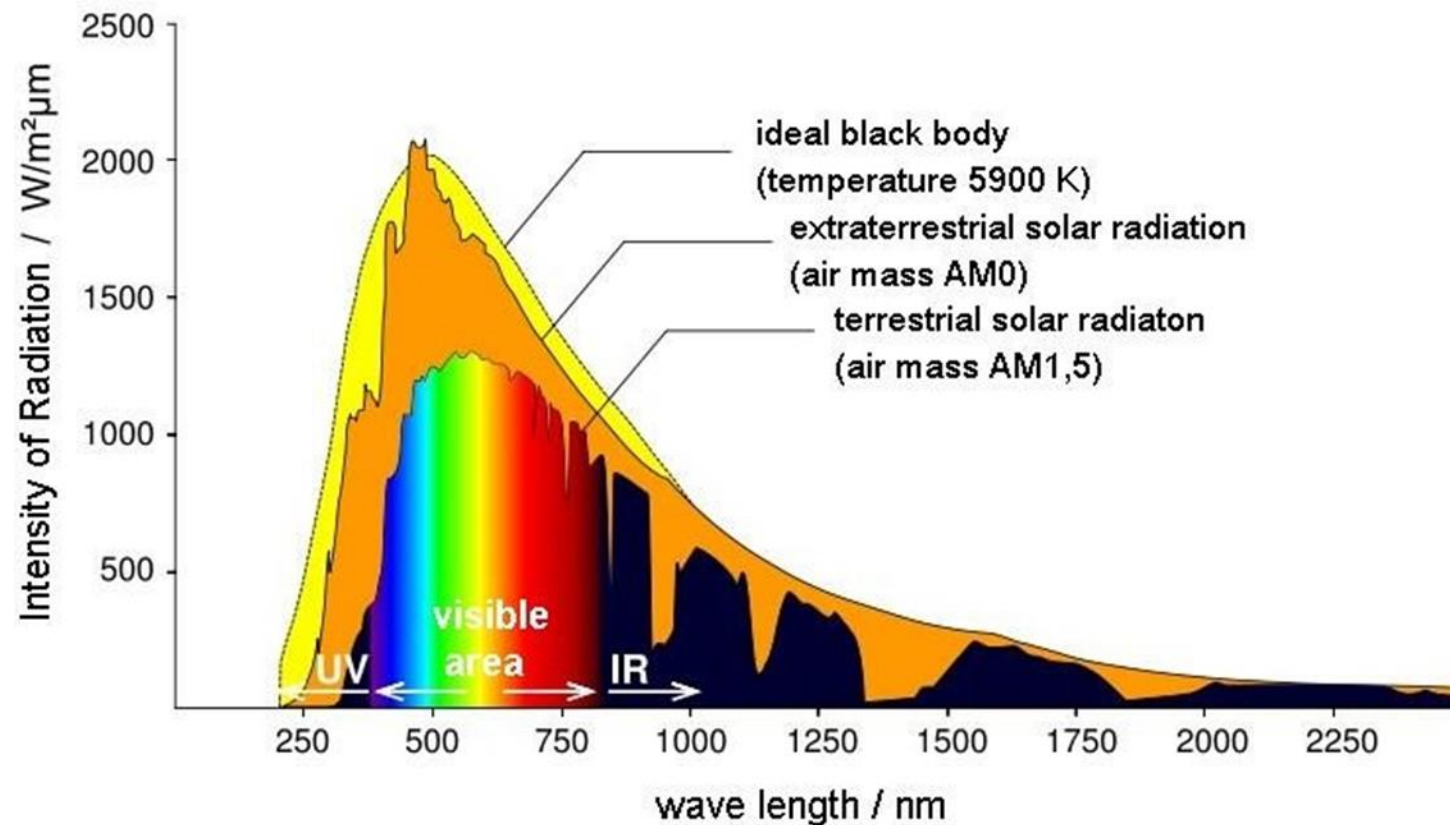




# GLAZING MATERIAL and GLAZING ASSEMBLIES

# Glazing Material and Glazing Assemblies

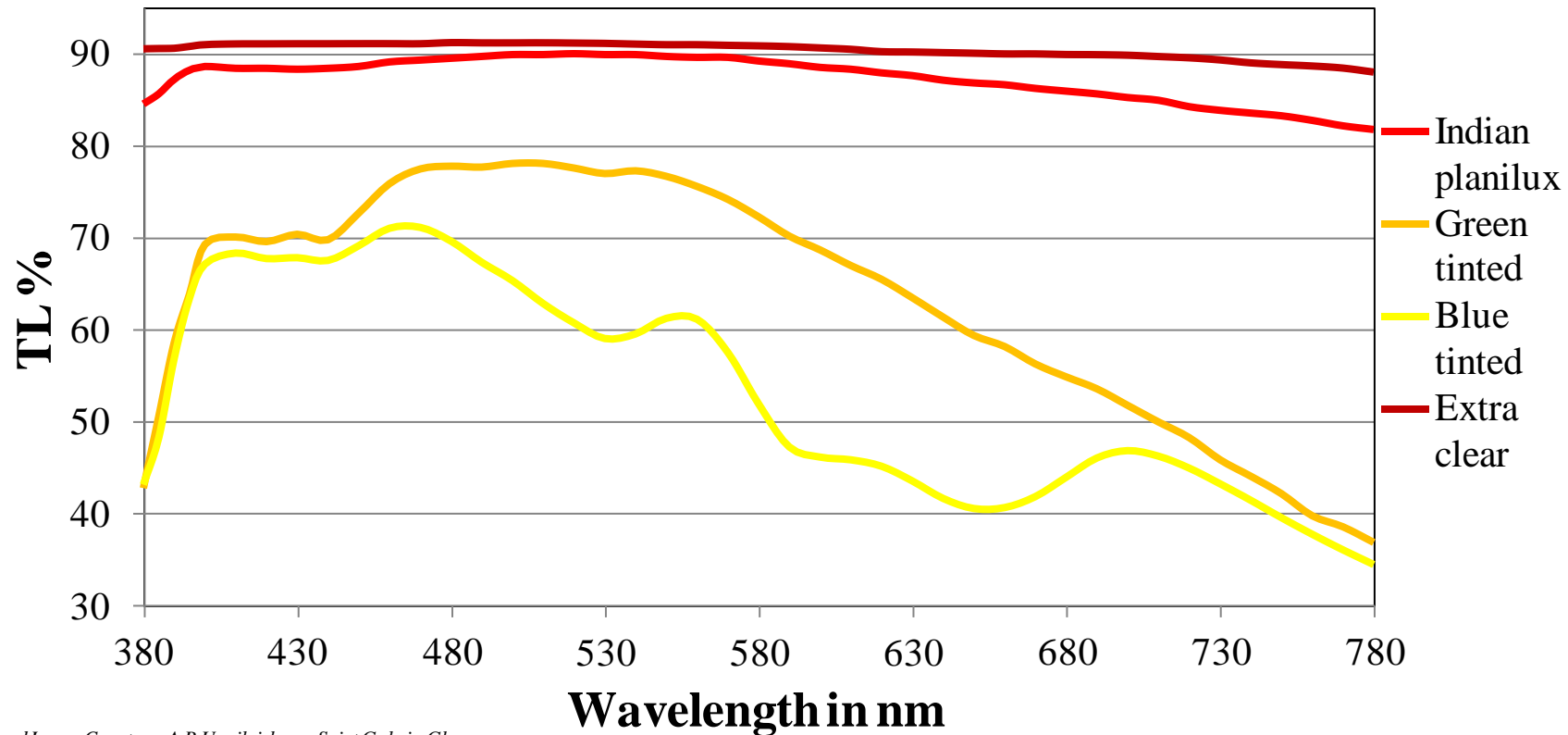
## Glazing Material and Methods: Solar Spectrum





# Glazing Material and Glazing Assemblies

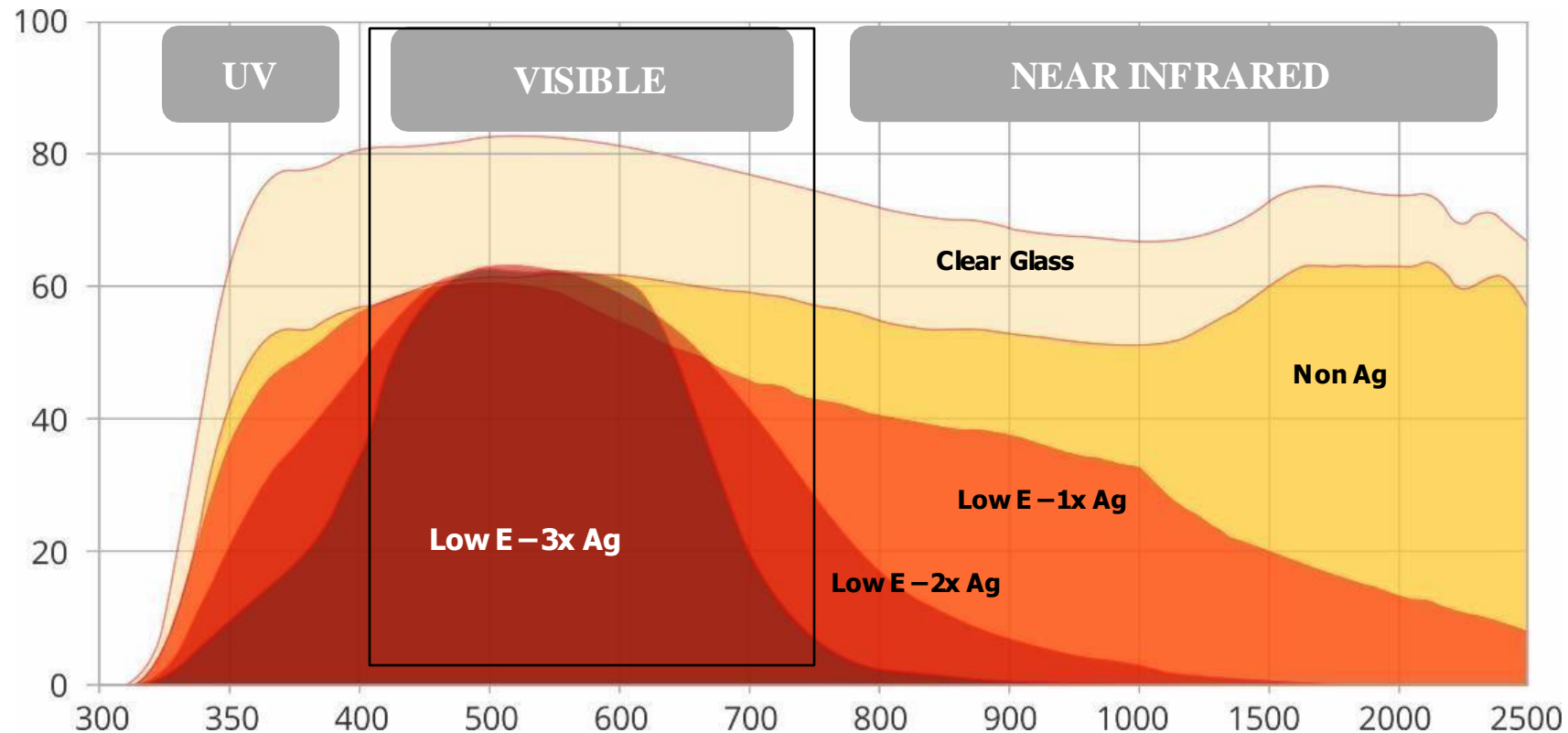
## Glazing Material and Methods : Solar Radiation through Glass



Information and Image Courtesy: A.R Umnikrishnan, Saint Gobain Glass

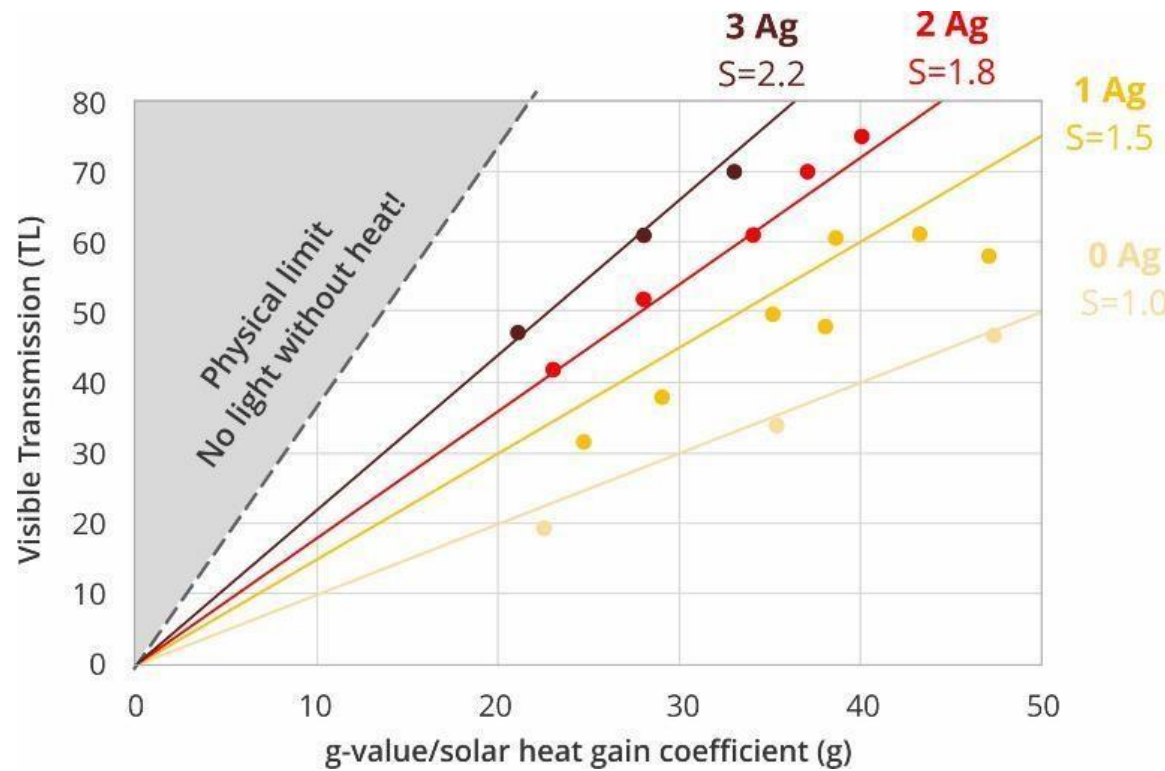
# Glazing Material and Glazing Assemblies

## Glazing Material and Methods : Solar Control



# Glazing Material and Glazing Assemblies

## Glazing Material and Methods : Solar Control



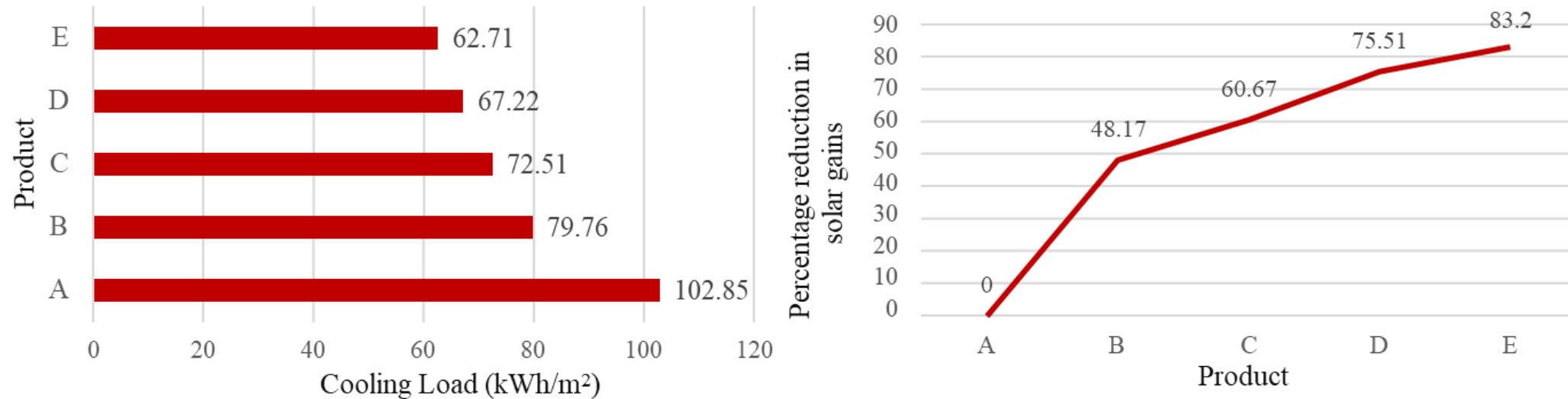
$$\text{Selectivity} = \frac{TL}{g} = \frac{\text{Light}}{\text{Heat}}$$

Silver (Ag) based coater products have the maximum selectivity

The higher the selectivity the better the performance of glass, it enables optimum light to enter our living spaces while blocking excess heat

# Glazing Material and Glazing Assemblies

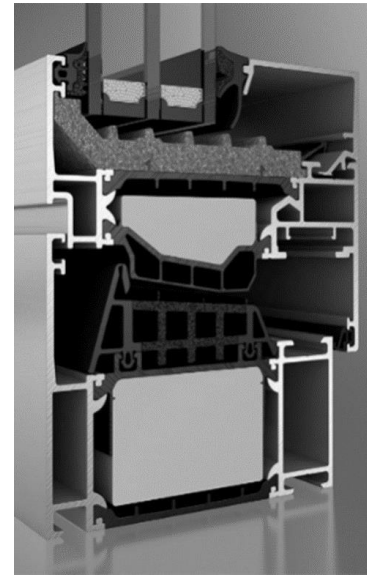
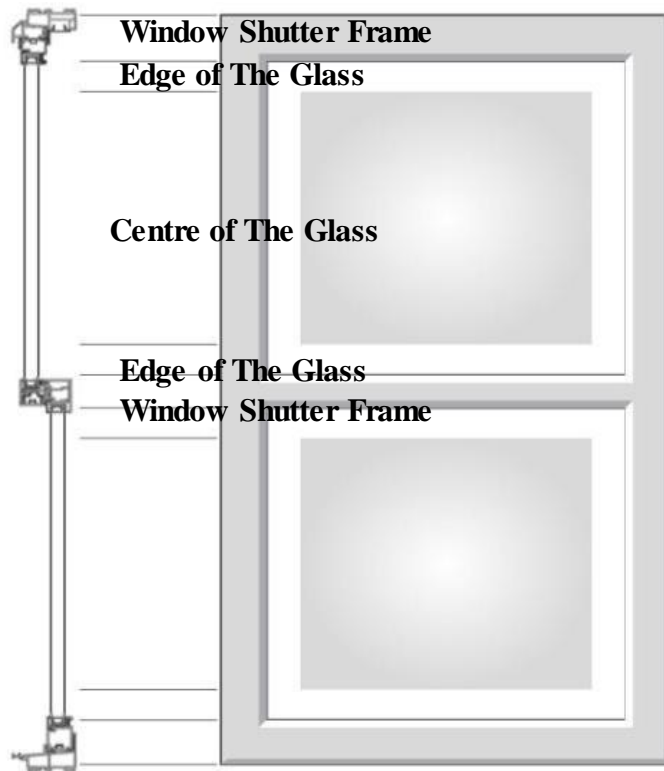
## Glazing Material and Methods : Cooling Load Reduction



Product	VLT (%)	External Reflection (%)	Internal Reflection (%)	Solar Factor	Shading coefficient	U-value
A	80	15	15	0.76	0.87	2.6
B	46	16	18	0.22	0.25	1.5
C	46	20	22	0.47	0.54	2.8
D	51	18	22	0.28	0.33	1.5
E	47	17	11	0.38	0.43	1.9

# Glazing Material and Glazing Assemblies

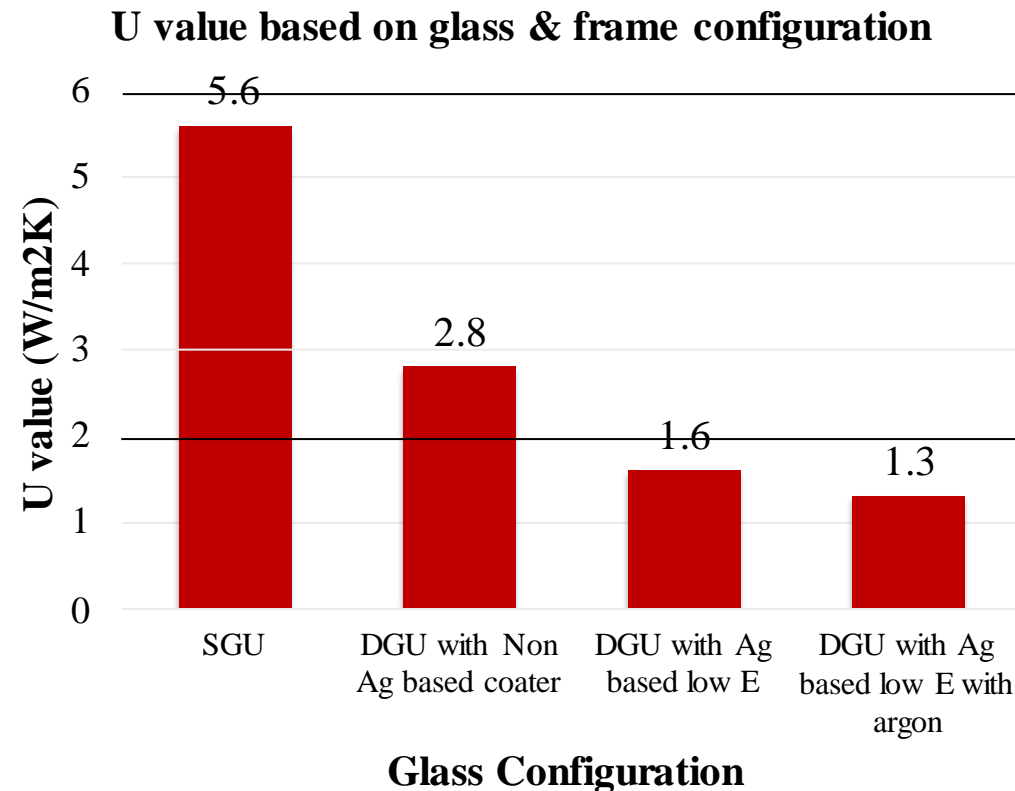
## Glazing Material and Methods : Window Frame



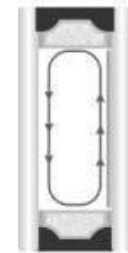
Source: Neuffer. (n.d.). Schüco Aws 90. Neuffer. Retrieved from <http://192.169.1.1:8090/httpclient.html> Grabex. (n.d.). Sliding-Folding Doors For Your Space. Grabex. Retrieved from <https://grabex.co.uk/doors/bi-fold->

# Glazing Material and Glazing Assemblies

## Glazing Material and Methods : Window Frame



SGU



1.1  
W/m².K



DGU  
with air



1.5 W/m².K



DGU with  
Argon gas

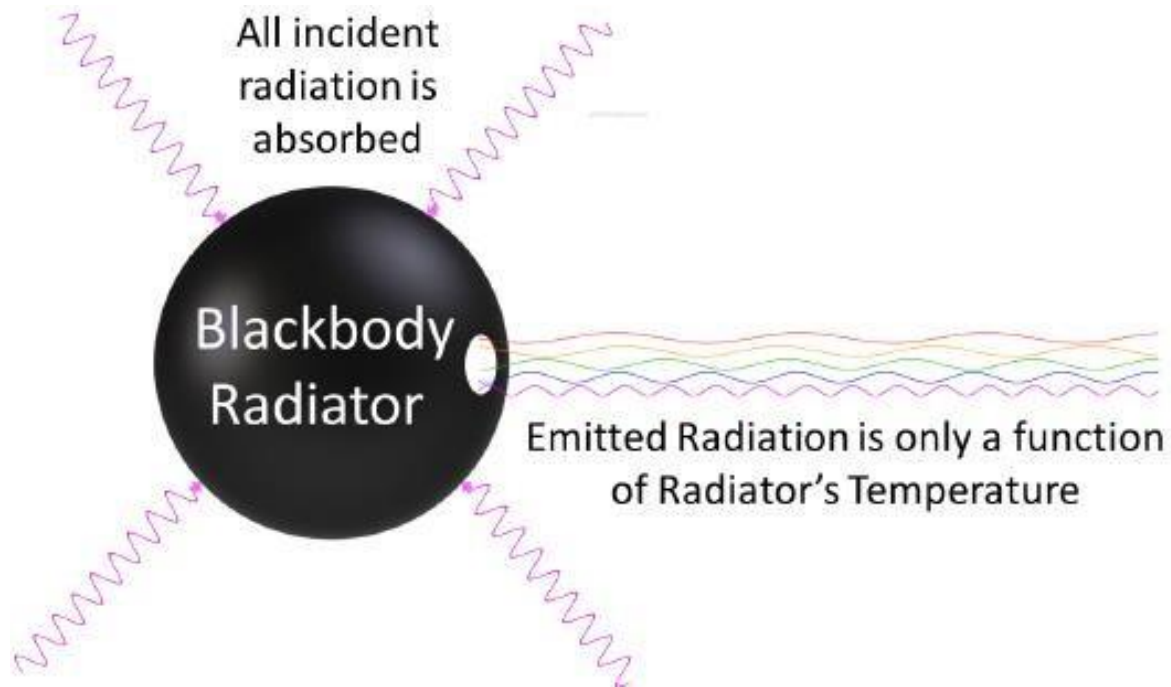
1.7 W/m².K

# ROOFING COATING MATERIAL



# Glazing Material and Glazing Assemblies

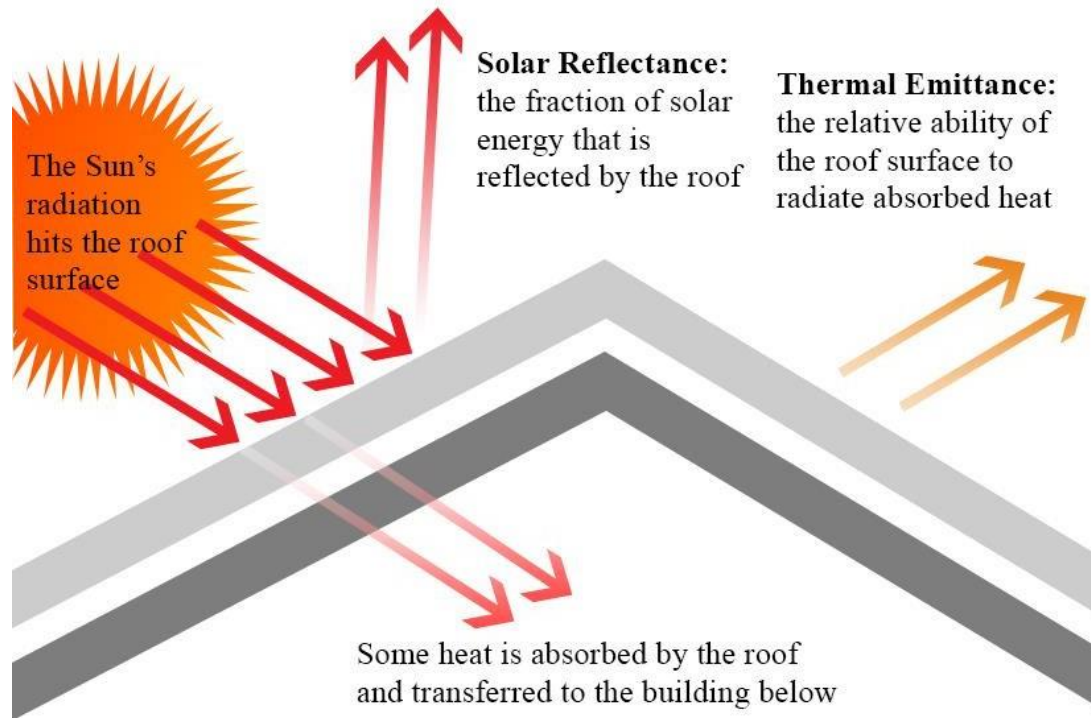
## Roofing Coating Material : Black Body



Source: freepik. (n.d.). Food Wood . freepik Retrieved from <https://www.freepik.com/photos/food-wood>, freepik. (n.d.). Saucepan. freepik. Retrieved from <https://www.freepik.com/vectors/saucepan>

# Glazing Material and Glazing Assemblies

## Roof Coating Material and Solar Reflectance Index

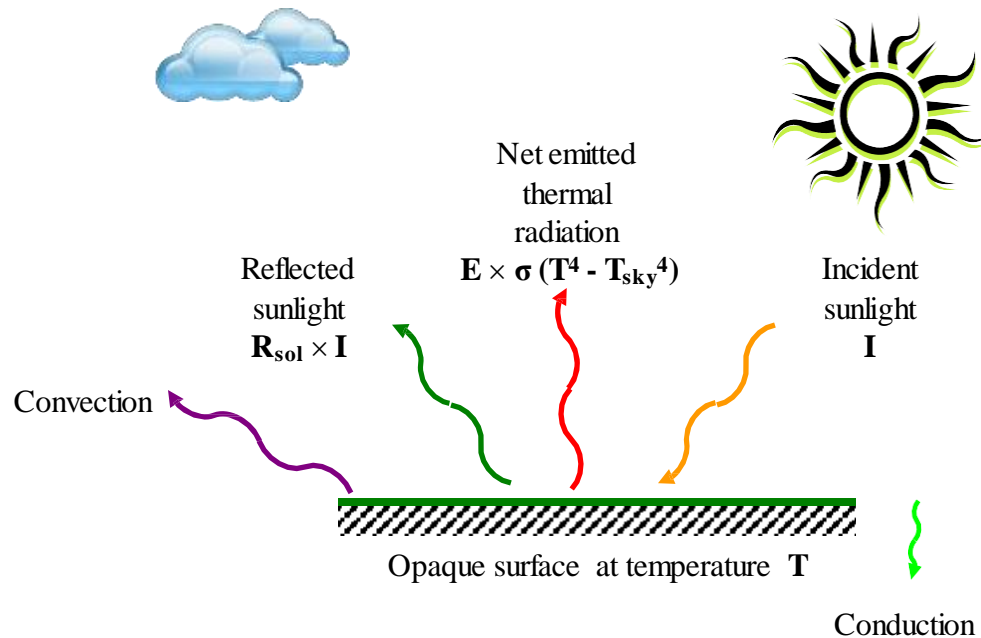


- Reflectance
- Thermal Emittance.
- Emissivity
- Solar Reflectance Index (SRI)

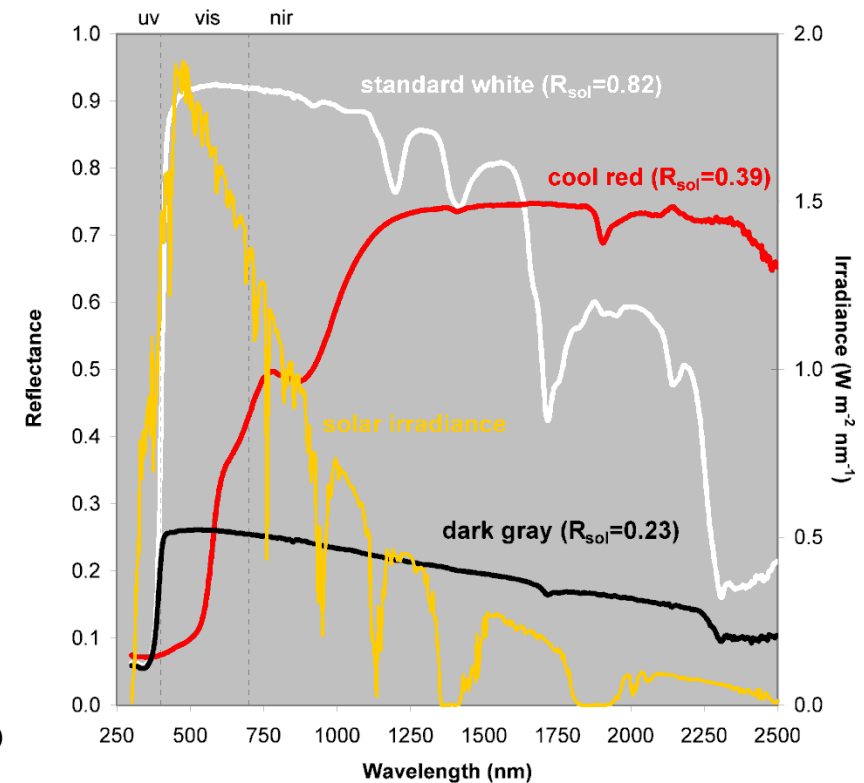
Source: ASC Building Products. (2020). Energy-Efficient Cool Colors in Today's Metal Roofing. ASC Building Products. Retrieved from <https://www.ascbp.com/cool-colors-and-energy-savings/>.

# Glazing Material and Glazing Assemblies

## Roof Coating Material and Solar Reflectance Index



- High solar reflectance ( $R_{sol}$ ) lowers solar heat gain (0.3 - 2.5  $\mu\text{m}$ )
- High thermal emittance ( $E$ ) enhances thermal radiative cooling (4 - 80  $\mu\text{m}$ )



# Glazing Material and Glazing Assemblies

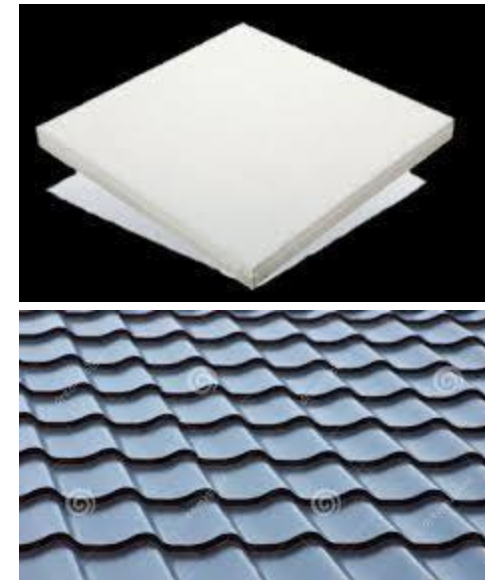
## Roof Coating Materials



Paints



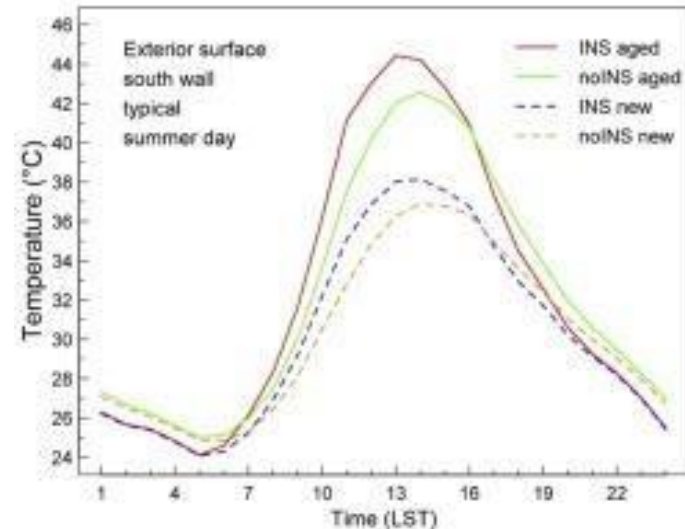
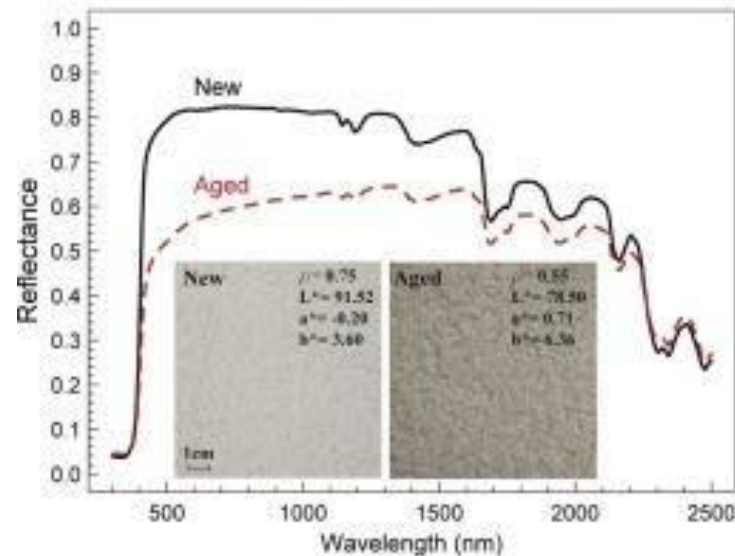
Coated Sheets



Tiles

# Glazing Material and Glazing Assemblies

## Roof Coating Materials



- PM 10, PM 2.5
- Dust, Sooth
- Vegetation

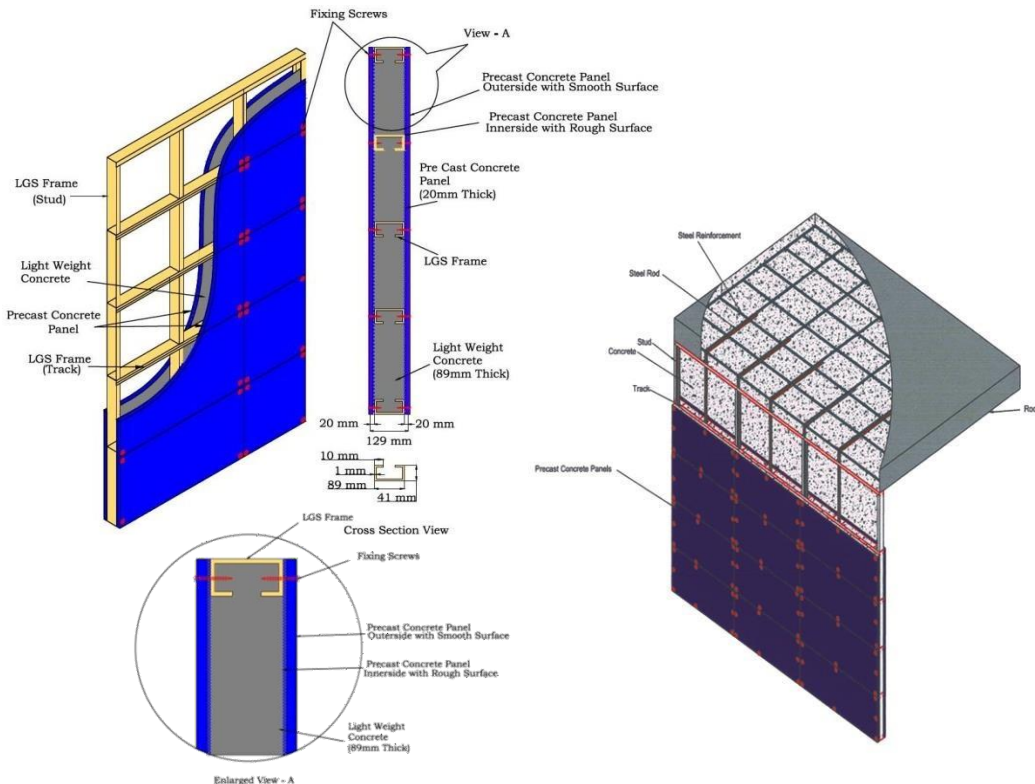
Source: Paolini, R., Zani, A., Poli, T., Antretter, F., & Zinzi, M. (2017). Natural aging of cool walls: Impact on solar reflectance, sensitivity to thermal shocks and building energy needs. *Energy and Buildings*, 153, 287–296. <https://doi.org/10.1016/j.enbuild.2017.08.017>

# WALLING MATERIAL CASE STUDIES, Light House Projects



# Walling Material Case Studies, Light House Projects

## Light House Project: Agartala

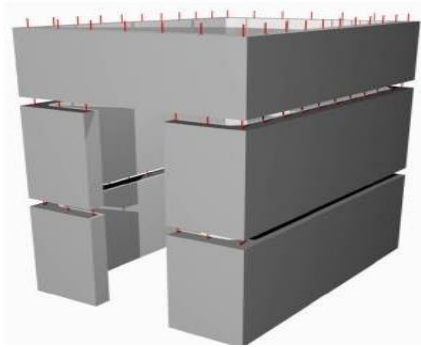


- Light Gauge Steel Framed Structure with Infill Concrete Panels (LGSFS-ICP)
- Ground and 06 Floors
- Weight of the LGSFS-ICP building is about 20-30% lighter
- The LSG frames are manufactured using numerically controlled roll forming machine using CAD design



# Walling Material Case Studies, Light House Projects

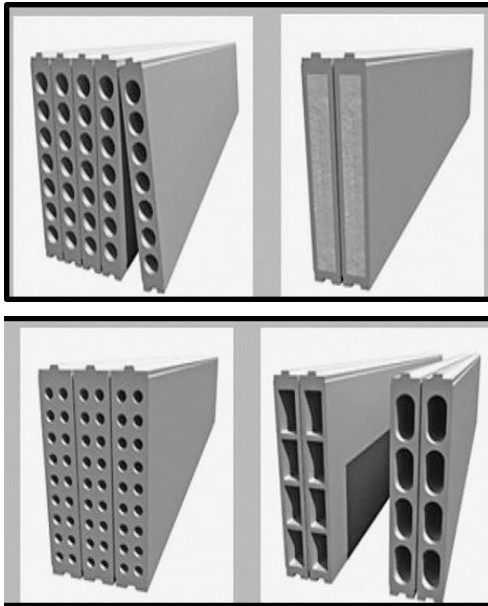
## Light House Project: Chennai



- Precast Concrete Construction System and Precast component Assembly at the site
- G and 05 Floors
- Precast dense reinforced cement concrete hollow core columns, structural RCC shear walls, T/L/Rectangular shaped beams, stairs, floor/roof solid....
- AAC blocks are used for partition walls

# Walling Material Case Studies, Light House Projects

## Light House Project: Indore



- Prefabricated Sandwich Panel System
- S and 08 Floors
- Lightweight composite wall, floor, and roof sandwich panels made of thin fiber cement/calcium silicate board
- Face covered boards and the core material is EPS granule balls

# Walling Material Case Studies, Light House Projects

## Light House Project: Lucknow



- PVC Stay in Place Formwork System
- S and 13 Floors
- Rigid polyvinyl chloride (PVC) based formwork system serves as a permanent stay-in-place durable finished form-work for concrete walls
- The PVC extrusions consist of the substrate (inner) and Modifier (outer). The two layers are co-extruded during the manufacturing process to create a solid profile.

# Walling Material Case Studies, Light House Projects

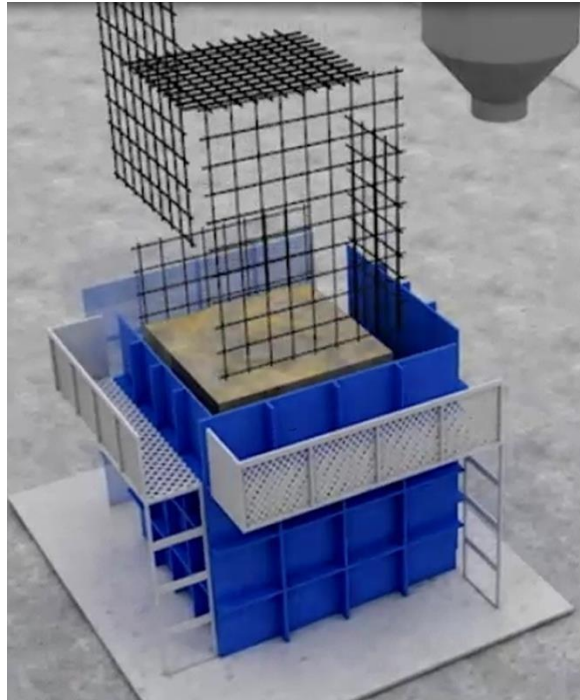
## Light House Project: Rajkot



- Monolithic Concrete Construction using tunnel formwork
- S and 8 Floors
- Tunnel forms are room size formworks that allow walls and floors to be cast in a single pour

# Walling Material Case Studies, Light House Projects

## Light House Project: Ranchi



- Pre-Cast Concrete Construction System – 3D volumetric
- Ground and 8 Floors
- 90% pre-casted at the casting yard
- Use of Fly Ash Ground granulated blast furnace slag (GGBS), micro silica.
- Minimal shutter and scaffolding





14

## Case Studies

# INFOSYS – POCHARAM CAMPUS

LOCATION

HYDERABAD,  
TELANGANA

COORDINATES

17° N, 78° E

OCCUPANCY TYPE

OFFICE

TPOLOGY

NEW CONSTRUCTION

CLIMATE TYPE

HOT AND DRY

PROJECT AREA

27,870 m<sup>2</sup>



**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.**



- 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.

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  
ENVIRONMEN  
T QUALITY

EPI –  
75kWh/m<sup>2</sup>/yr

## GODREJ PLANT 13 ANNEXE

LOCATION

MUMBAI, MAHARASHTRA

COORDINATES

19° N, 73° E

OCCUPANCY TYPE

OFFICE – PRIVATE

TPOLOGY

NEW CONSTRUCTION

CLIMATE TYPE

WARM AND HUMID

PROJECT AREA

24,443 m<sup>2</sup>



## 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. The structure is a 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.

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."

**EPI –  
75kWh/m<sup>2</sup>/yr**

# INDIRA PARYAVARAN BHAWAN, MoEF

LOCATION

NEW DELHI

COORDINATES

29° N, 77° E

OCCUPANCY TYPE

OFFICE & EDUCATIONAL

TPOLOGY

NEW CONSTRUCTION

CLIMATE TYPE

COMPOSITE

PROJECT AREA

9565 m<sup>2</sup>



**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.**

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

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 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

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.

**EPI –  
44kWh/m<sup>2</sup>/yr**

**Renewable Energy Integration 930kW PV panels with a total area of 4650m<sup>2</sup> for on-site generation, tilted at 23° facing south to generate equivalent to 70kWh/m<sup>2</sup>/yr**



# JAQUAR HEADQUARTERS

LOCATION	MANESAR HARYANA
COORDINATES	28° N, 77° E
OCCUPANCY TYPE	CORPORATE AND MANUFACTURI NG
TPOLOGY	NEW CONSTRUCTION
CLIMATE TYPE	COMPOSITE
PROJECT AREA	48000 m <sup>2</sup>





# 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
TPOLOGY	NEW CONSTRUCTION
CLIMATE TYPE	HOT AND DRY
PROJECT AREA	5574 m <sup>2</sup>



## 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
TPOLOGY	NEW CONSTRUCTION
CLIMATE TYPE	HOT AND DRY
PROJECT AREA	2322 m <sup>2</sup>



## 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
TYOLOGY	NEW CONSTRUCTION
CLIMATE TYPE	COMPOSITE
PROJECT AREA	5100 m <sup>2</sup>





# 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
TPOLOGY	NEW CONSTRUCTION
CLIMATE TYPE	HOT AND DRY
PROJECT AREA	9888 ft²



# GRIDCO BHUBANESWAR

LOCATION	BHUBANESWAR.
COORDINATES	20° N, 85° E
OCCUPANCY TYPE	OFFICE
TYOLOGY	NEW CONSTRUCTION
CLIMATE TYPE	WARM AND HUMID
PROJECT AREA	15,793.5 m <sup>2</sup>



# 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.

## DAY 1

## Tea Break

## DAY 1

## Q & A Session



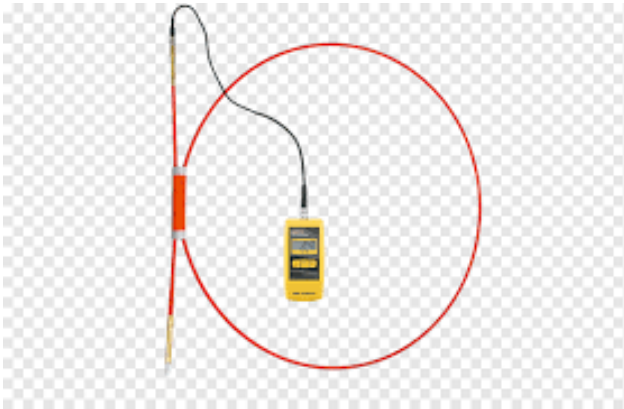
## DAY 1

## Vote of Thanks

## DAY 2

### Session 5: Thermal Comfort Study Methods

# Thermal Comfort Study Methods



## Indoor Environment (Physical)

Air Temp.  
Relative Humidity  
Air Velocity  
Mean Radiant Temperature  
(Globe Temp)



## Human Body (Physical)

Metabolic Rate  
Clothing Value  
Skin Temp  
Core Body Temp  
Skin Temp/Heat Flux of Body Parts



## Human Body (Psychological) Votes on Comfort

Air Quality  
Overall acceptance

Source: freepik. (n.d.). Tape Measure. freepik. Retrieved from <https://www.freepik.com/free-photos-vectors/tape-measure>, freepik. (n.d.). Stethoscope. freepik. Retrieved from <https://www.freepik.com/search?format=search&query=stethoscope>, freepik. (n.d.). Vote. freepik. Retrieved from <https://www.freepik.com/search?format=search&query=vote>

# Thermal Comfort Study Methods



## Field Studies

Occupant Comfort  
User Behaviour  
Productivity



## Laboratory Studies

Thermal Comfort  
Body Parts  
Cooling Systems  
Control Systems  
Productivity



## Digital Simulations

Thermal Comfort  
Body Parts  
Cooling Systems  
Control Systems

Source: freepik. (n.d.). Field studies. freepik. Retrieved from <https://www.freepik.com/search?format=search&query=field%20studies>, freepik. (n.d.). Laboratory Studies. freepik. Retrieved from <https://www.freepik.com/search?format=search&query=Laboratory%20Studies>, freepik. (n.d.). Desert. freepik. Retrieved from <https://www.freepik.com/photos/desert>

# Typical Protocol followed for Field Studies

# Field Studies: Initial Planning

Climate Zones  
Selection of cities

Selection of building  
based on typology, and  
income

Determination of Environmental  
parameters, personal parameters and  
occupant behaviour related questionnaire

Detailed Methodology Protocol  
Detailed Instrumentation Plan

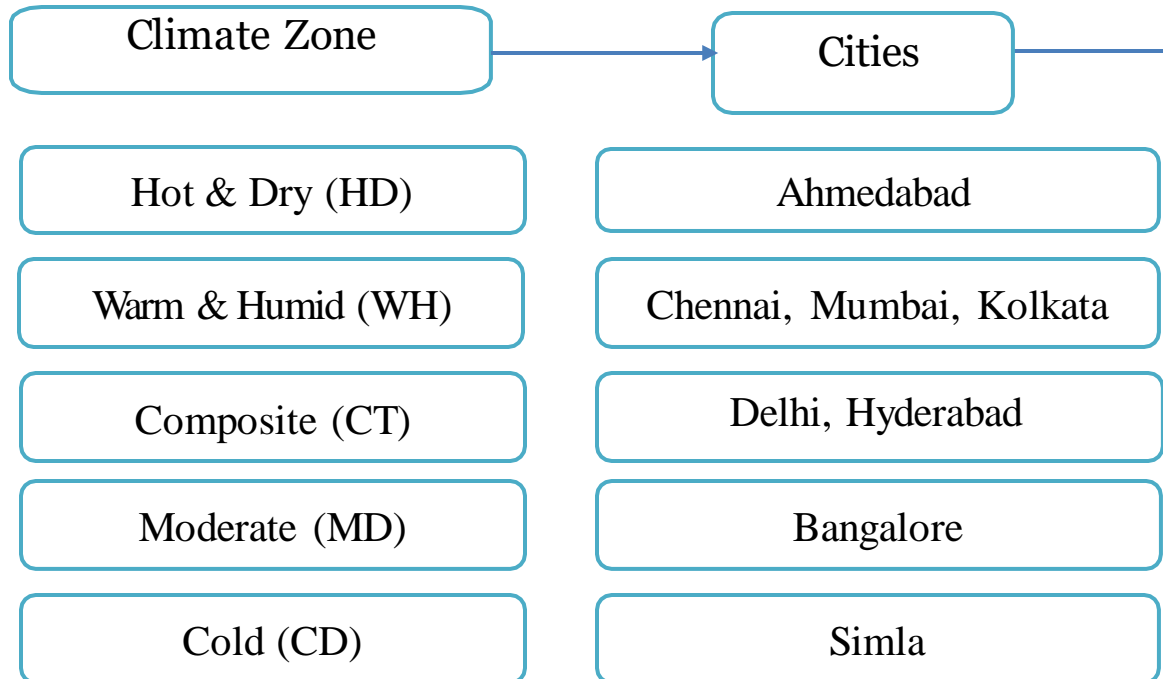
Determination of timeline for each cities, identification of  
on-site researchers and deployment of equipment

Sensitization of occupants , Training workshop for Surveyors



# Field Studies: Execution

## Building Selection Typologies



### Instantaneous, Right Now Right Here Survey -

#### Environmental Parameters

- Indoor Air Temperature
- Indoor Relative Humidity
- Air Velocity
- Globe Temperature (Mean Radiant Temperature to be derived)

### Right Now Right Here Survey – Personal Parameters

- Metabolic Rate
- Clothing - Seat
- Thermal Sensation
- Thermal Acceptance
- Thermal Preference

### One time – Background Survey

- Building Information
- Workspace – Occupation Information
- Appliances and Electricity Use Information
- Transport options Information

# Field Studies: Execution

संरचनात्मक अध्ययन

## Data Collection Methodology

**Instantaneous**  
Right here, Right now

Sensation

Acceptability

Preference

- Temperature
- Air movement
- Relative Humidity
- MRT

Clothing

CLO

Activity

MET



**One Time**  
Background

Training of  
Researchers



**Winter**

*N\**

*D\**

**J**

**F**

**M**

**Summer**

**A**

**M**

**J**

**Monsoon**

**J**

**A**

**S**

**O**

# Field Studies: Execution

Vote scale	Thermal Sensation	Thermal Acceptability	Thermal Preference	Humidity Sensation	Air movement preference
<b>-3</b>	Very cold			Very humid	
<b>-2</b>	Cold	Completely unacceptable		Humid	
<b>-1</b>	Slightly cold	Just unacceptable	Cooler	Slightly humid	Want less
<b>0</b>	Neutral	Acceptable	No change	Neutral	No change
<b>1</b>	Slightly warm	Just acceptable	Warmer	Slightly dry	Want more
<b>2</b>	Warm	Completely acceptable		Dry	
<b>3</b>	Hot			Very dry	

# Field Studies: Execution

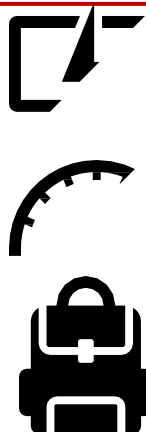
## Data Collection

**Instantaneous**  
Right here, Right now



On Line Data

**One Time**  
Background



Checklist Document

Winter

Summer

Monsoon

N

D

J\*

F

M

A

M

J

J

A

S

O

- One Researcher Per City with Kit, Daily visits to 2-3 Houses. Checklist for data collection and Data assurance
- RNRH to takes place between 09h00-10h30 and / or 18h00-20h00.
- Online data collection of the survey, a daily collection of measured data
- Monitoring of outdoor Weather Conditions on a daily basis
  - Newspaper and Websites, IMD daily data
  - Yearly data - Weather data service providers
  - Yearly data – Indian Meteorological Department

# Field Studies: Post Processing – QA/QC

Right Now Right Here  
Survey of Occupants

Mapping of  
Environmental  
Parameters

Building Characteristics and Occupant  
Behaviour Pattern

Quality Assurance and Quality Check at  
location

Continuous check on functioning of instruments

Collection of data on weekly bases, and QA/QC at central location

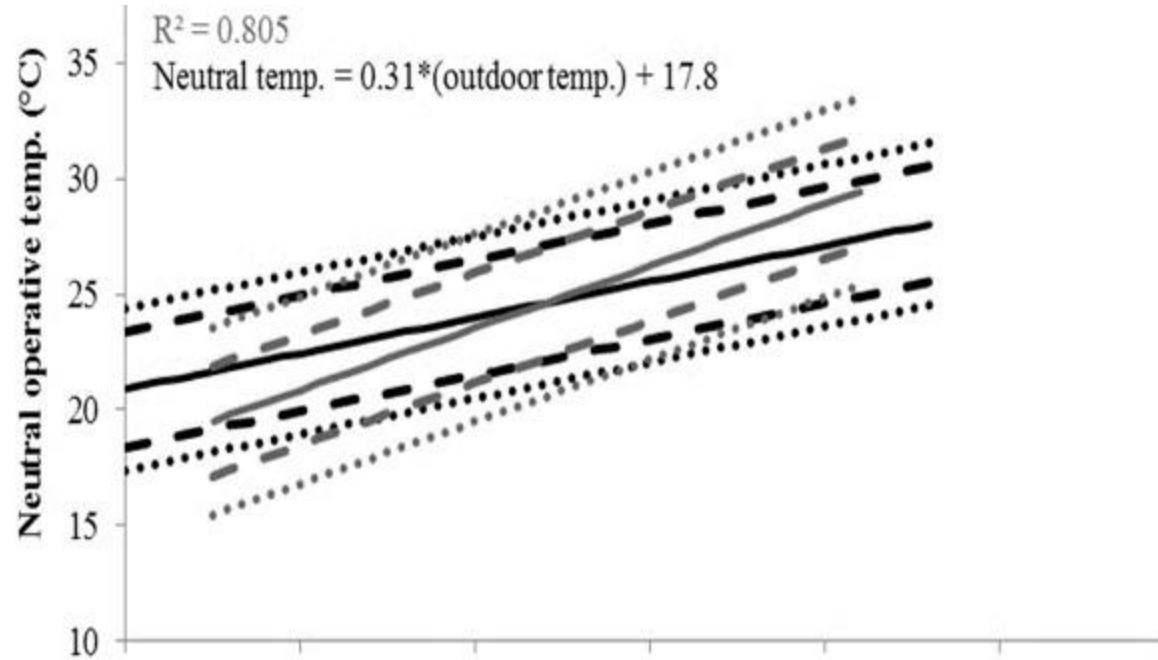
Deliverable: A Dataset having sampling with 95% confidence level and 5% margin of error

# Field Studies: Measurements: ASHRAE Class 1 and ASHRAE Class 2

Instrument	Parameter	Range	Resolution	Accuracy
Instrument A	Indoor air temperature	-10 to 60°C	0.1°C	±0.3°C
	Indoor air velocity	0 to 30 m/s	0.01 m/s	±3% of reading or (±0.015 m/s), whichever is greater
	RH	5 to 95% RH	0.1% RH	±3% RH
Instrument B	Wet Bulb Globe Temperature (WBGT) – (without sunlight)	0 to 59°C	0.1°C	WBGT = (0.7×WET)+(0.3×TG)
	Wet Bulb Globe Temperature (WBGT) – (with sunlight)	0 to 56°C	0.1°C	WBGT=(0.7×WET)+ (0.2×TG)+(0.1×TA)



# Field Studies: Post Processing – QA/QC and Results



**Indoor Operative Temperature = (0.00 x outdoor temperature) + 00.00**  
90% acceptability  $\pm 0.00$  °C  
80% acceptability  $\pm 0.00$  °C

# Typical Protocol Followed for Laboratory Studies

# Laboratory Studies: Controlled Environment – Thermal Comfort Chambers



- **Tightly Controlled Environments**
- **Varied Environmental Conditions**
  - Temperature
  - Relative Humidity
  - Surface Temperatures
  - Air Speed
- *Dynamic Conditions*
- **Combination of Cooling and Heating Systems**
- **Human and System Interactions**
  - HVAC Systems
  - Control Systems

# Laboratory Studies: Controlled Environment – Thermal Comfort Chambers



**Controlled Environments: Measurements**



**Controlled Environments: Occupants**

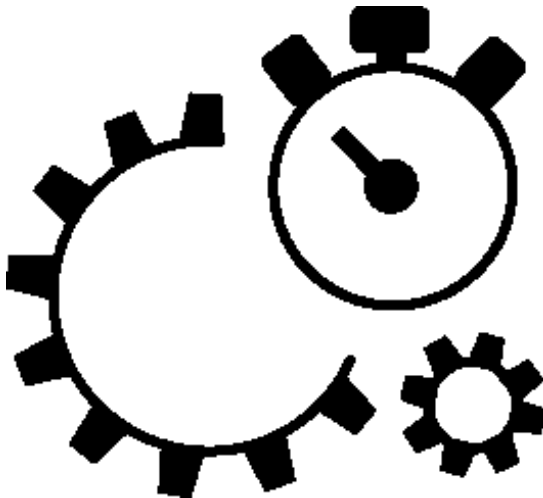
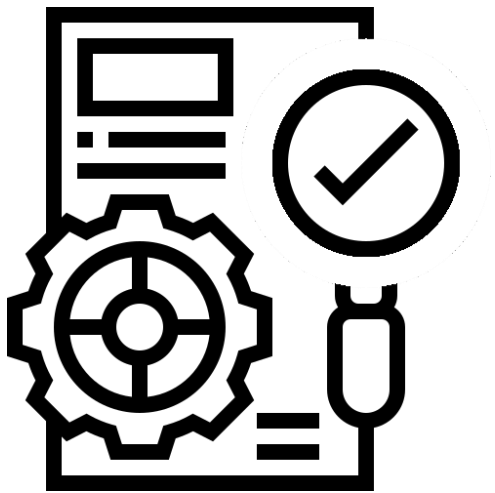
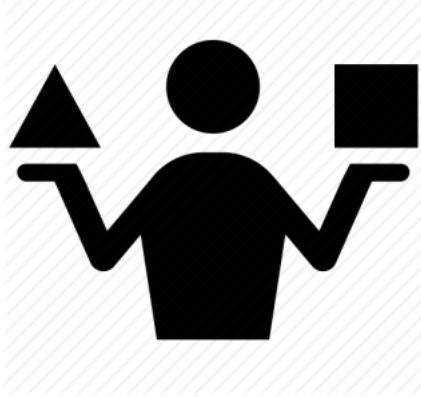


**Controlled Environments: Mannequins**



**Controlled Environments: Digital Simulation**

# Laboratory Studies: Controlled Environment – Thermal Comfort Chambers



- **Comparable cases**
  - Body Mass Index
  - Clothing Insulation
  - Age
  - Acclimatization of local weather conditions
- **Important to achieve and maintain desired indoor Environmental Conditions**
  - Stabilization time
  - Experiment time
  - Cooldown time
- **System responses are critical when conducting behaviour studies**
- **Ethical clearances and research protocols**

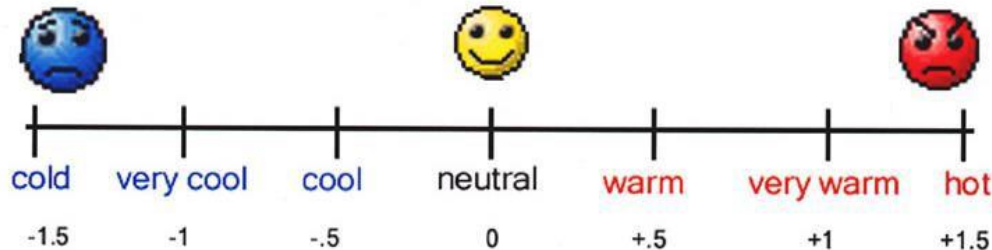
# Laboratory Studies: Controlled Environment – Thermal Comfort Chambers



## Work with Human Subjects

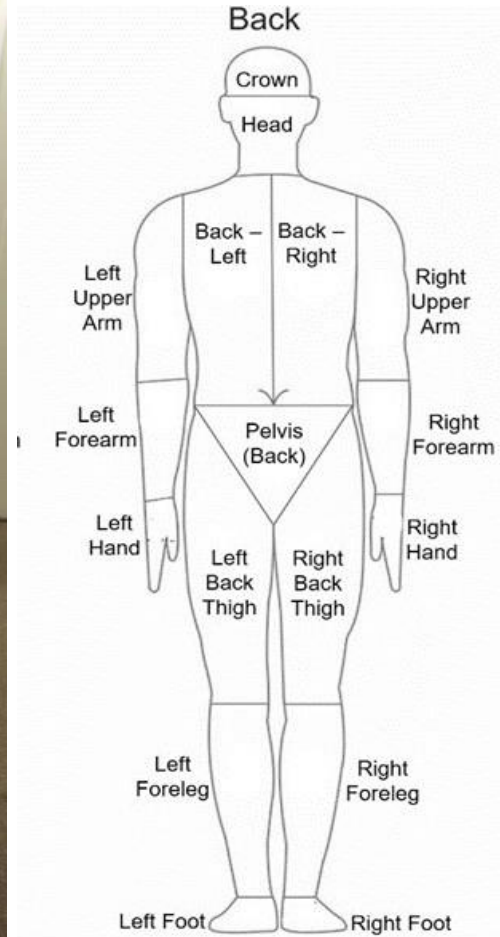
Under various environmental conditions

- Preference Vote
- Sensation Vote
- Comfort Vote
- HVAC (lighting Acoustic) System Interaction
- Behaviour Responses
- Met Value derivation





# Laboratory Studies: Controlled Environment – Thermal Comfort Chambers



## Work with Thermal Mannequin

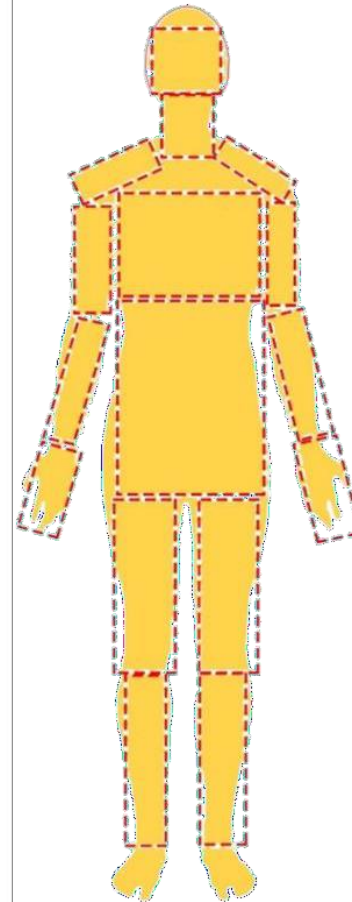
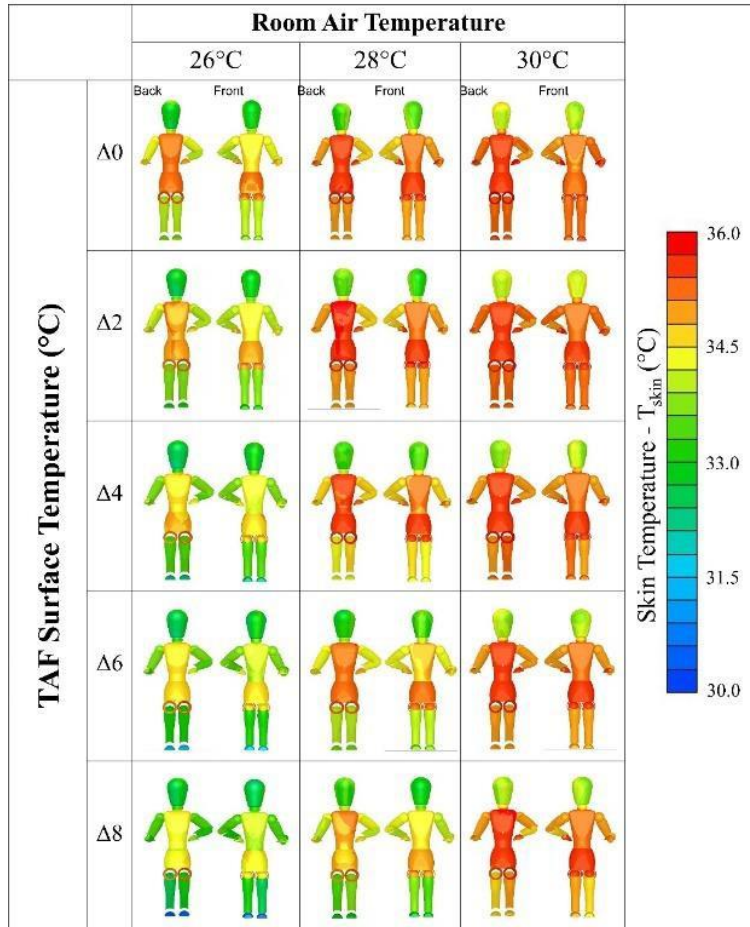
- Body Parts
- Clo Value Derivation
- Simulation Model Development
- *Airflow, – Breathing Studies*
- *Sweat – Physiological Studies*
- *Indoor Air Quality Studies*





# Digital Simulation

# Typical Protocol Followed for Simulation Studies



body

skin

core

fat

skin

skin

muscle

core

muscle

core

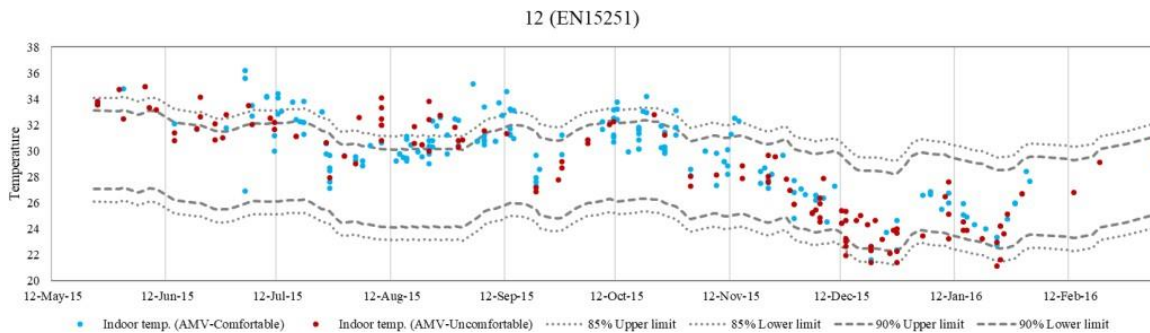
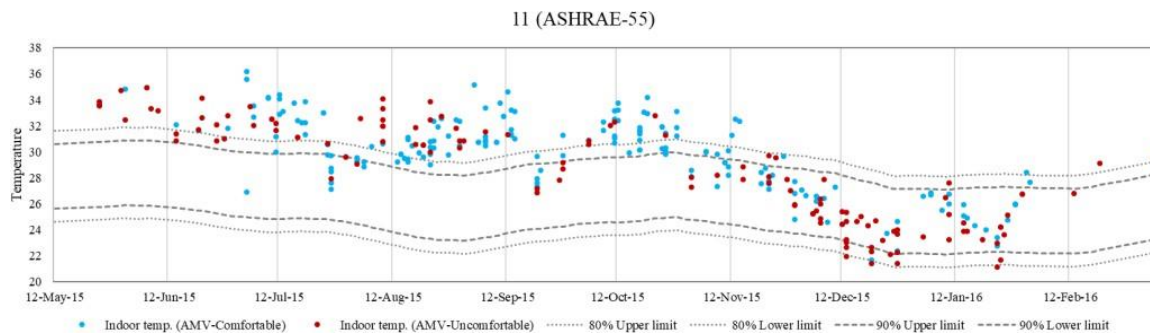
## Work with Digital Simulations

- Scalable – Cost-effective
- Calibration is a must
- Combination with Physiology and Indoor Environment
- Co- Simulation with HVAC, CFD, and Thermal Modelling of Buildings

Source: Yoshito Takahashi, Akihisa Nomoto, Shu Yoda, Ryo Hisayama, Masayuki Ogata, Yoshiichi Ozeki, Shin-ichi Tanabe, Thermoregulation model JOS-3 with new open source code., Energy and Buildings, Volume 231, 2021, 110575, ISSN 0378-7788, <https://doi.org/10.1016/j.enbuild.2020.110575>

# Statistical Analysis

# Statistics for Thermal Comfort Studies



- Null hypothesis ( $H_0$ ) - a statement of the status quo
- Alternate hypothesis ( $H_1$ ) - a contrary to the status quo

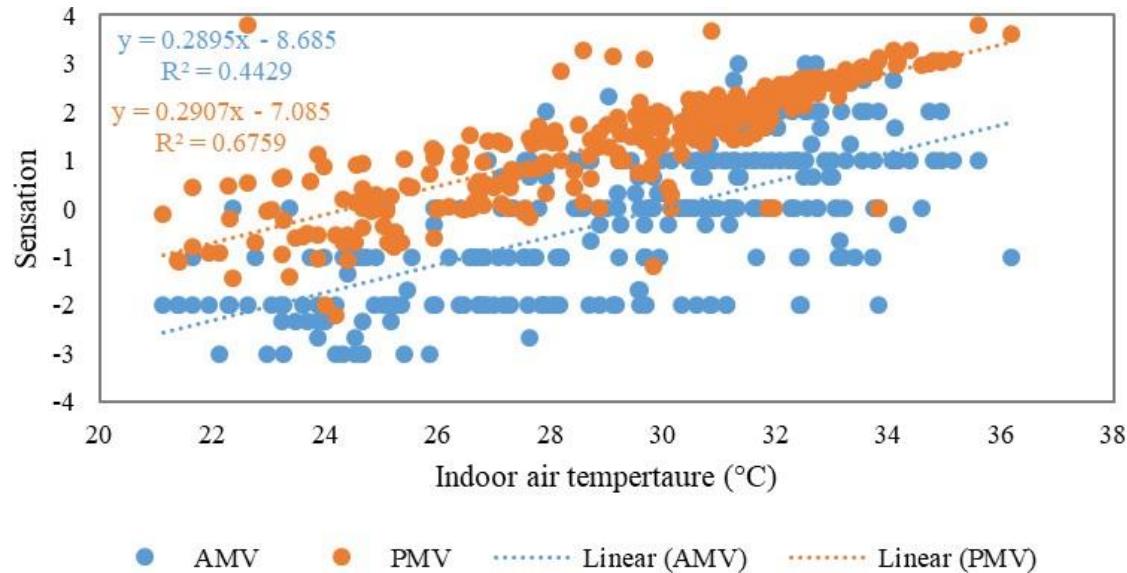
## Filtering the data

- Bogus
- Contradictory
- Mistakes

## Building correlation

- Between Objective and Subjective data
- Physical reason of causing the other
- Linear Regression
- Kendall Correlation
- Spearman Correlation



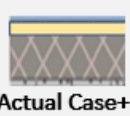

# Statistics for Thermal Comfort Studies



- **Nature of Data Distribution**
- Shapiro – Wilk test to examine the specific distribution
  - ANOVA, Analysis of Variance
    - Kruskal-Wallis Test
      - T test
    - Wilcoxon Rank test
    - Deal with ranks of data
- **Significant difference between two sets**
  - i.e., huge difference in MRT and Air Temp.



## Interventions to improve thermal comfort performance of LHP-Ranchi

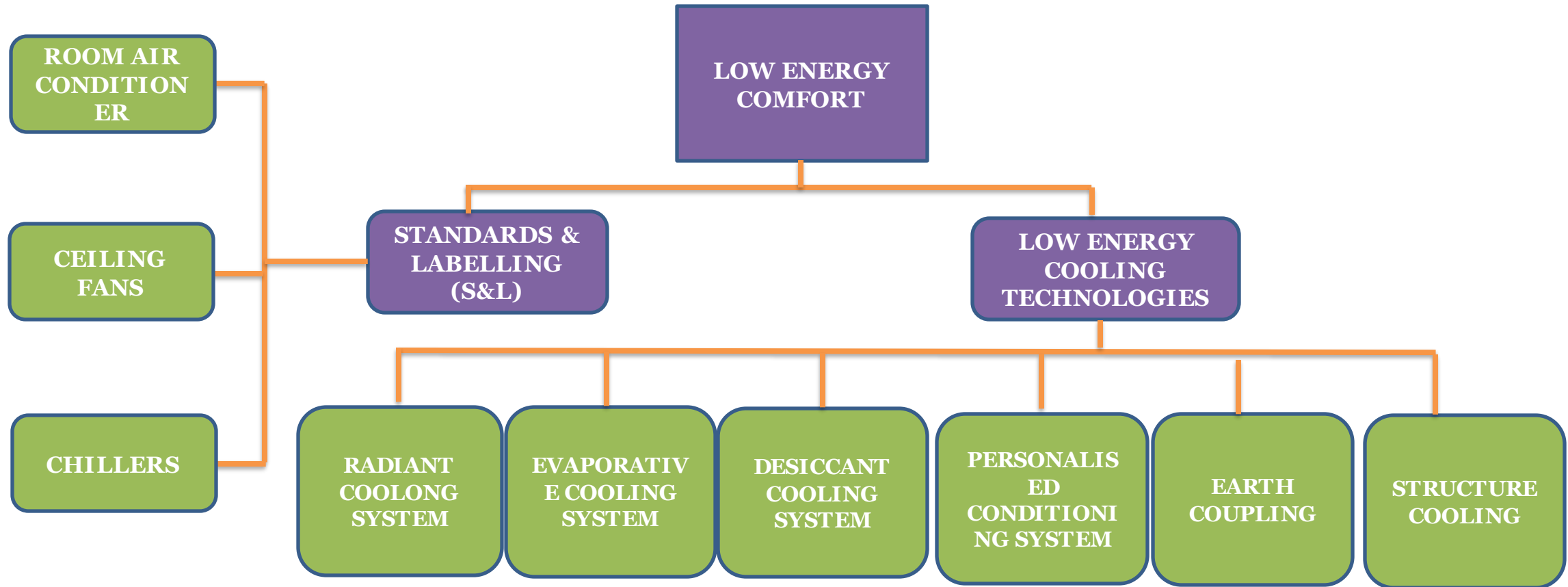
			Improvements (Individual impact of improvements is shown first and then combined impact at last)				
			A	B	C	D	A+B+C+D
Key Performance Indicator (KPI)	Units	LHP Project- Actual Case	 LHP Project- NS Orientation	 LHP Project- Actual Case+ RCC Insulation – 50mm EPS	 LHP Project- Actual Case+ Roof Insulation – 50mm EPS	 LHP Project- Actual Case+ 0.8m overhang	LHP Project- All improvements
Orientation	degrees	90°	180°	90°	90°	90°	180°
Discomfort Hours	%	3496 hrs	3308 hrs (5.4% less)	3168 hrs (9.4% less)	3256 hrs (6.9% less)	3394 hrs (2.9% less)	1887 hrs (46% less)
RETv	W/m <sup>2</sup>	22.64	21.3	9.61	Roof doesn't affect the RETv calculation	21.9	9.41
Impact (Low to High)		-	Medium	High	Medium	Low	Very High
Passive Features	Orientation, Shading etc.	0.45m Horizontal Shading devices, 160mm RCC external walls with high u-value, No Insulation of roof, single glazing	Actual case + Orientation shifted to true North-South axis	Actual case + 50mm EPS Insulation on RCC walls	Actual case + 50mm EPS Insulation on RCC roof	Actual case + 0.8 m Horizontal shading device	Combination of NS orientation, 50mm insulation on roof and walls, and horizontal shading devices



## DAY 2

# Session 6: Low Energy Cooling Technologies and Comfort

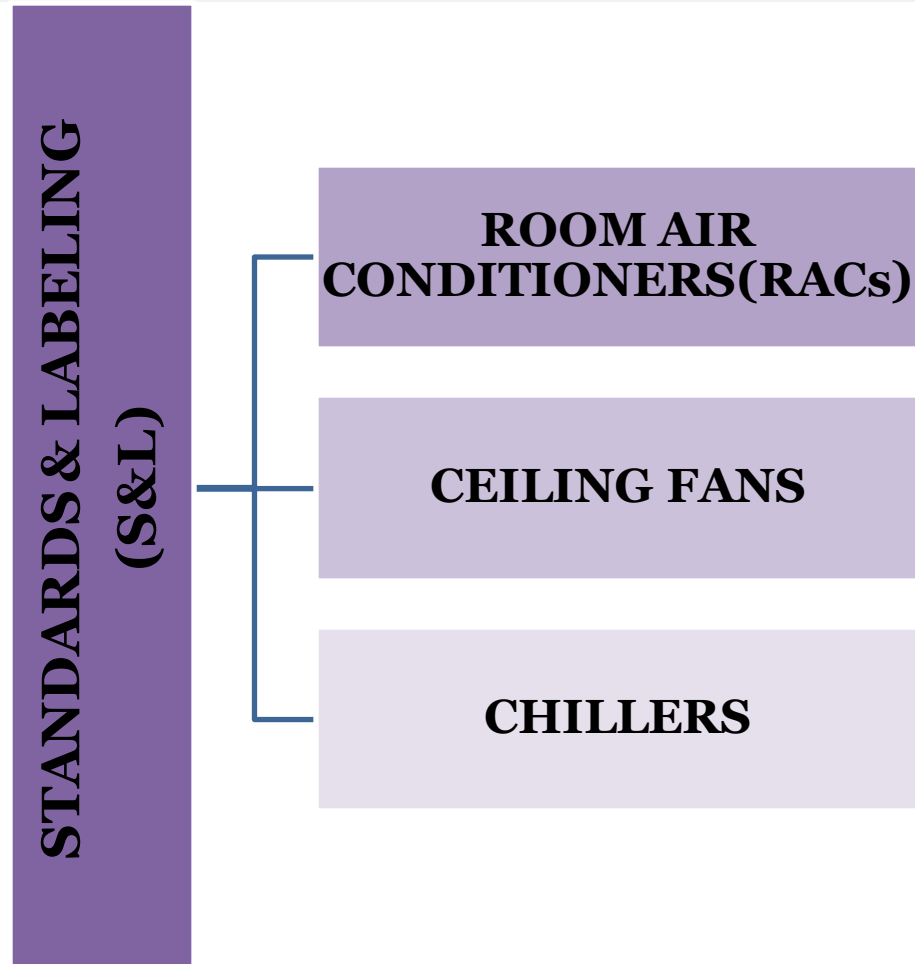
# Low Energy Comfort System in Housing



# Standards & Labeling (S&L)

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

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



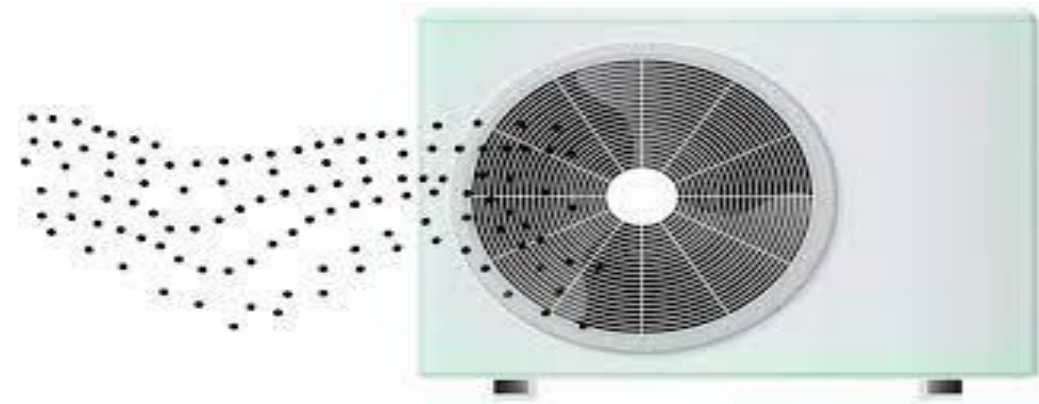
# Standards & Labeling (S&L)

## 1 - ROOM AIR CONDITIONERS (RACs):

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

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

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



# Standards & Labeling (S&L)

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

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

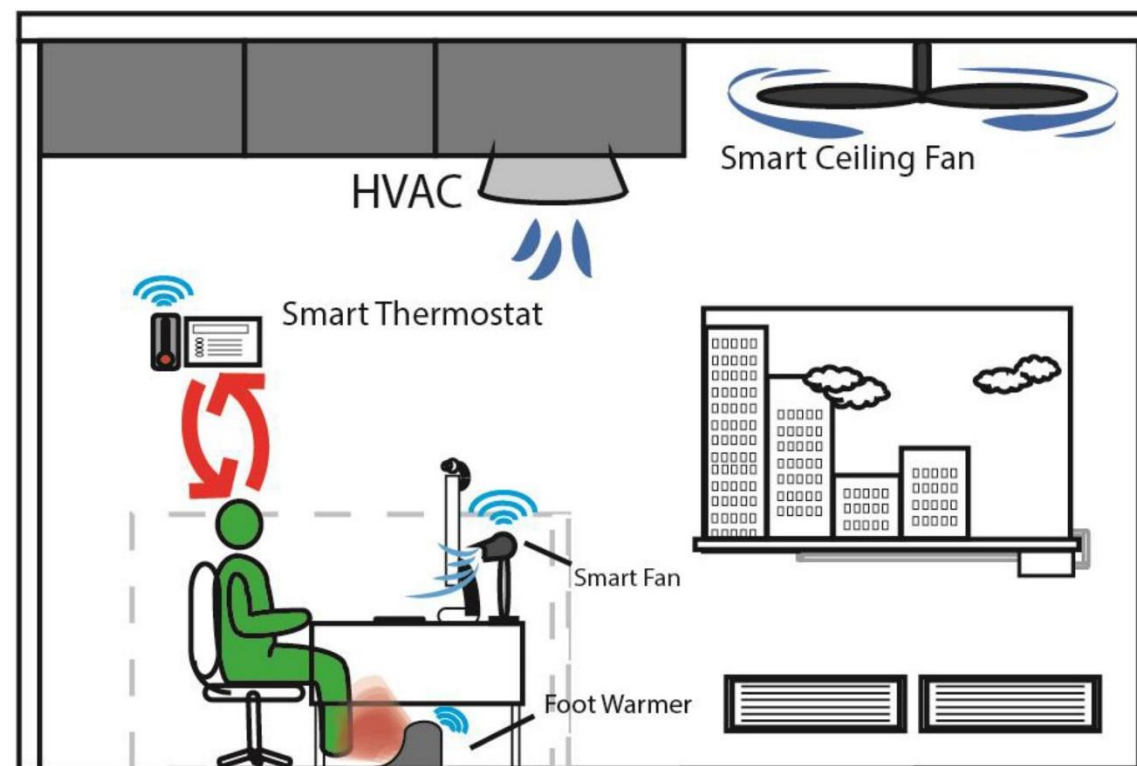
# Standards & Labeling (S&L)

## 2 - CELING FANS:

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

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

Both the BIS and the BEE give ratings to fans.





# Standards & Labeling (S&L)

## **3 - CHILLERS:**

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

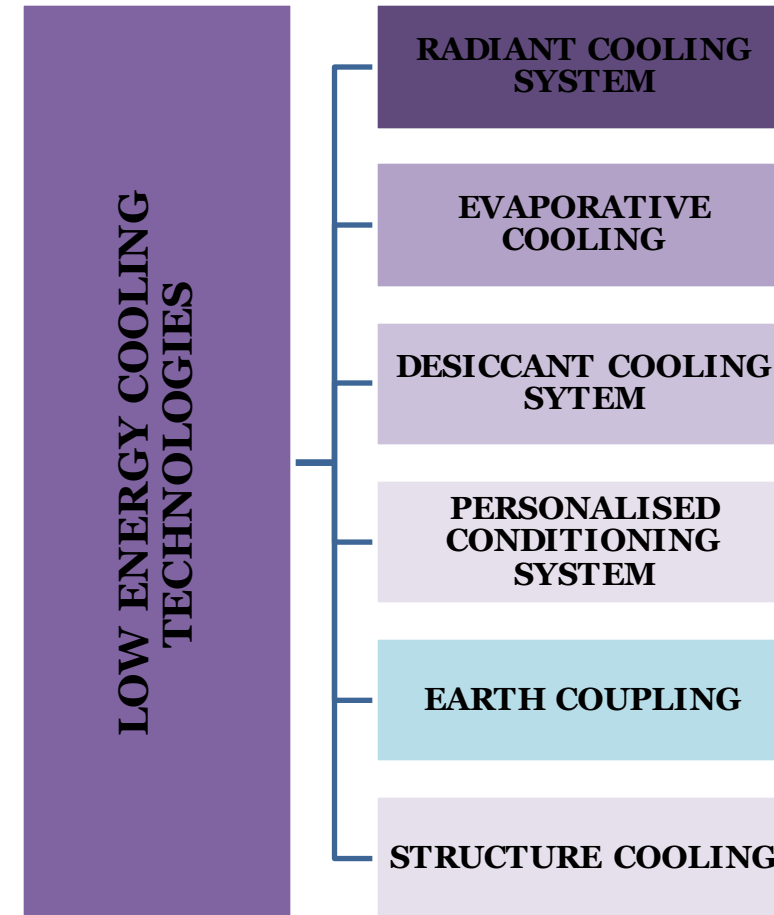
Recognizing the significance of the chiller standard, the ISHRAE has undertaken the responsibility of designing chiller test conditions. The standard, created collaboratively by ISHRAE and the RAMA, establishes a new set of rating and performance testing parameters (temperature, part load weightages,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

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



# Low Energy Cooling Technologies

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



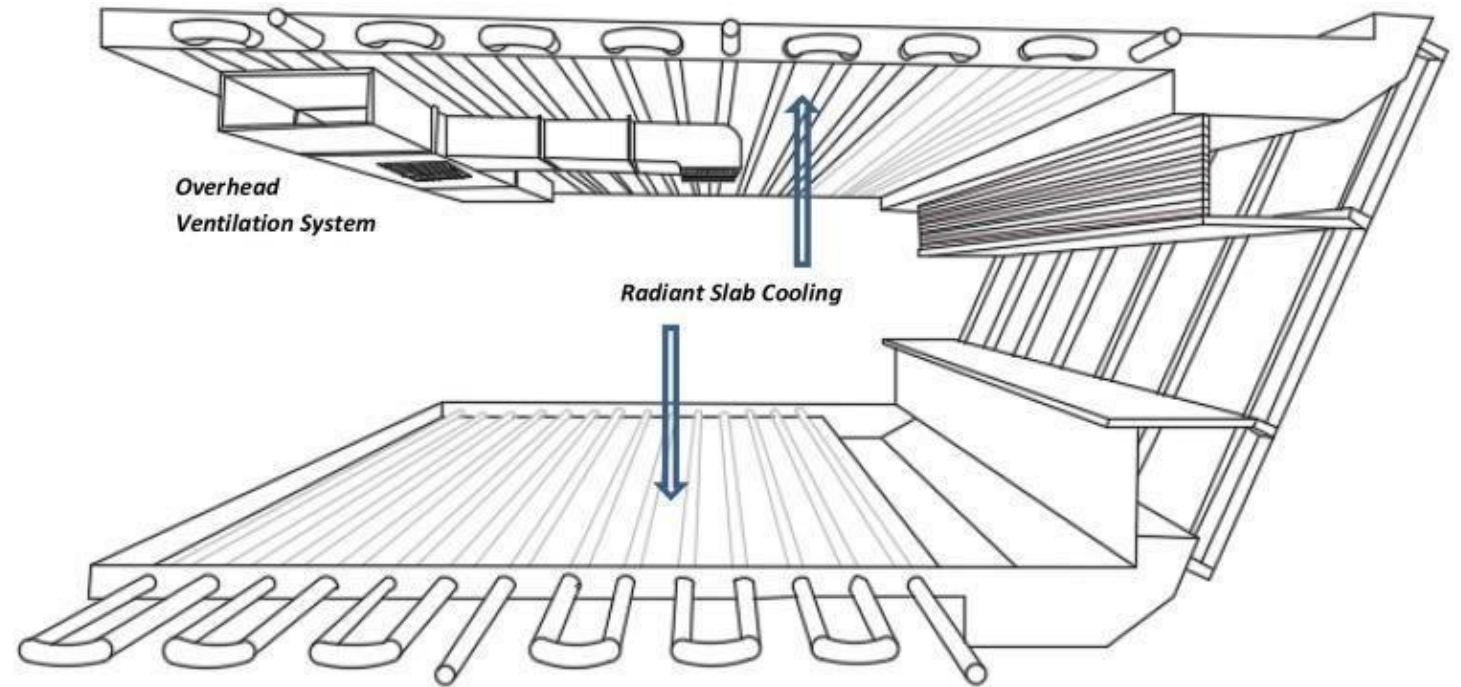
# Low Energy Cooling Technologies

## 1 - RADIANT COOLING SYSTEM:

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

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

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



# Low Energy Cooling Technologies

## 2 - EVAPORATIVE COOLING:

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



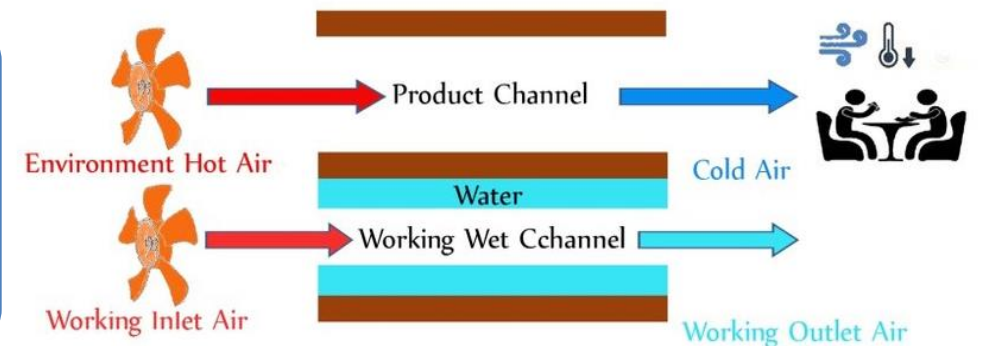
It is based on mechanical and thermal contact between air and water



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



The Direct Evaporative Cooling System

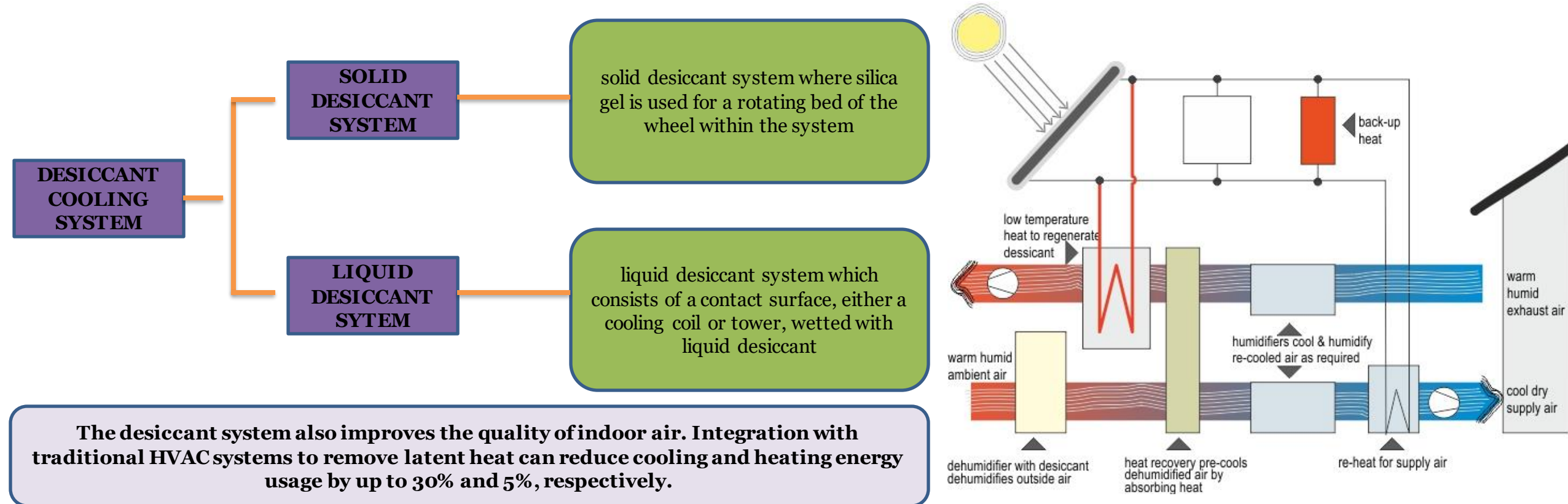


The Indirect Evaporative Cooling System

# Low Energy Cooling Technologies

## 3 - DESICCANT COOLING SYSTEM:

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





# Low Energy Cooling Technologies

## PERSONALISED CONDITIONING SYSTEM

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

## EARTH COUPLING

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



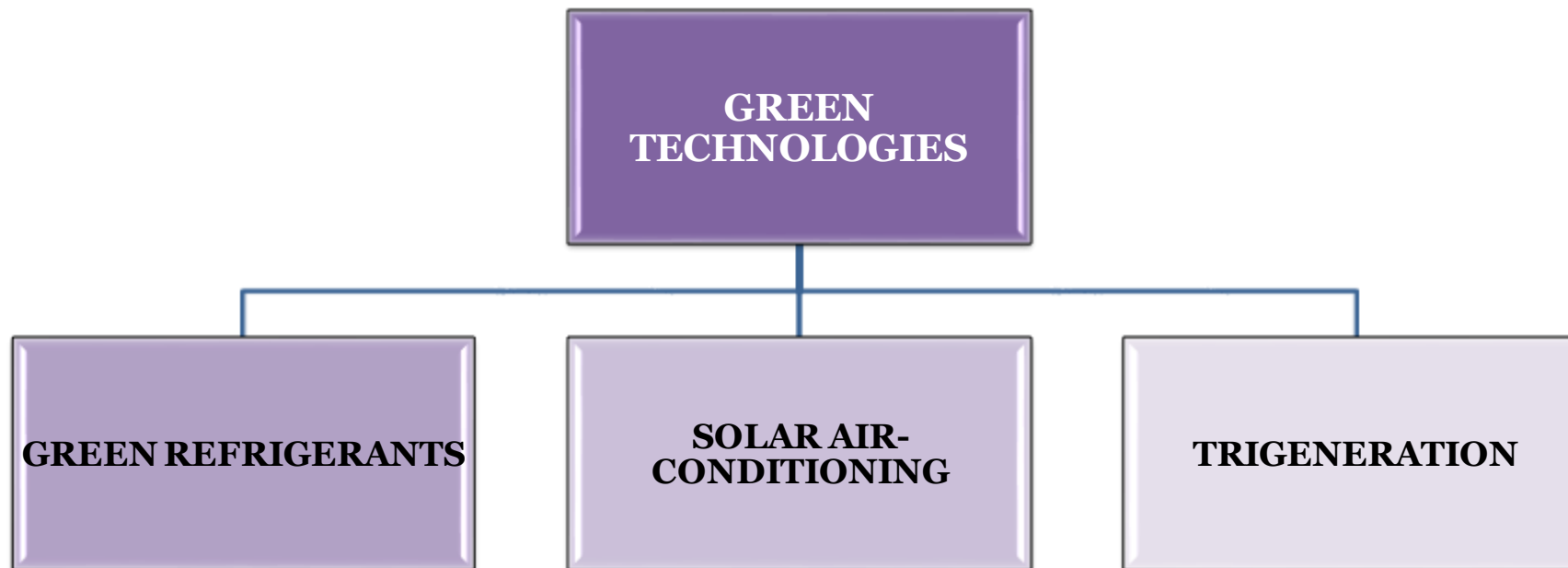
# Low Energy Cooling Technologies

## STRUCTURE COOLING

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

# Green Technologies

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



# Green Technologies

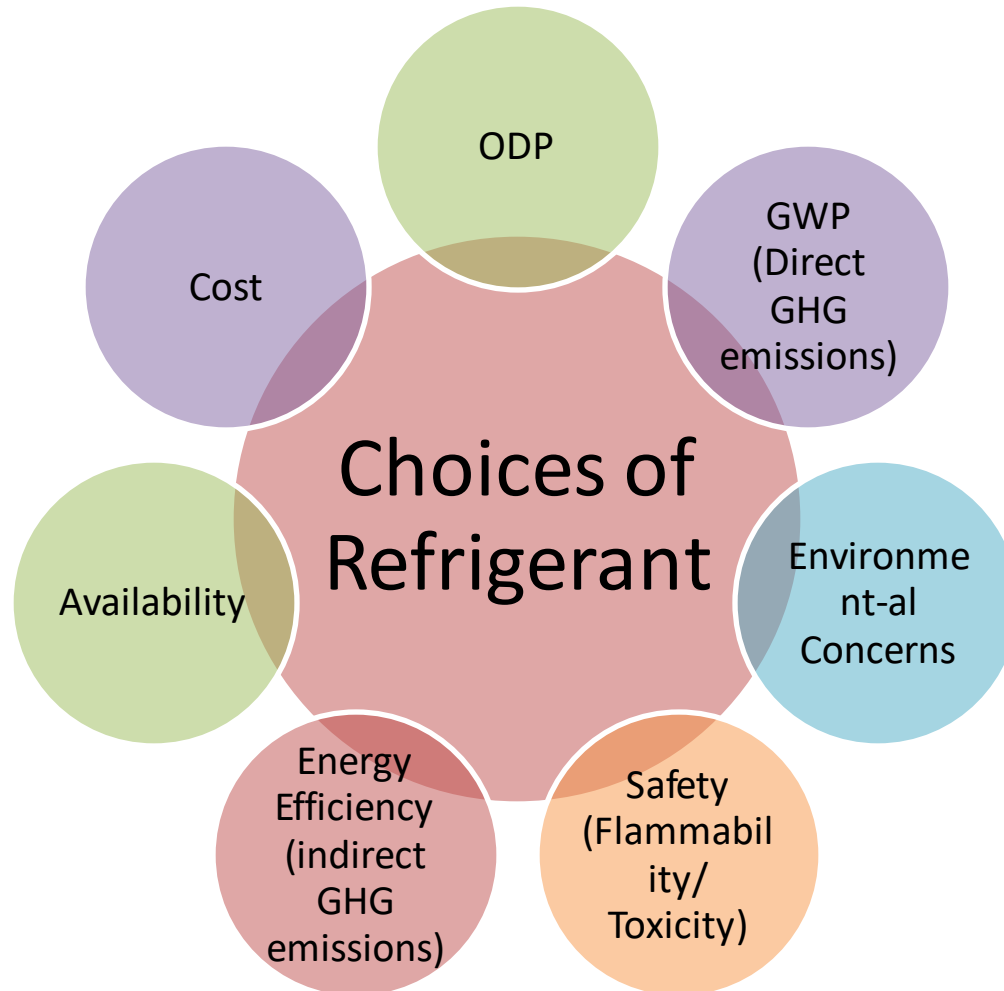
## **1 - GREEN REFRIGERANTS:**

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

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

One of the most significant issues with hydrocarbon-based natural refrigerants is the flammability, which can be mitigated by steps such as the use of appropriate materials, the selection of safe components, and operator training. CO<sub>2</sub>, a natural refrigerant, is inefficient in terms of energy use. When choosing a refrigerant, keep these considerations in mind. (2017, Green-cooling-initiative.org)

# Green Technologies



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

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

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

# Green Technologies

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

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

# Green Technologies

## 2 - SOLAR AIR-CONDITIONING:

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

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

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

SOLAR AIR-CONDITIONING CAN  
BE DONE THROUGH

PASSIVE SOLAR

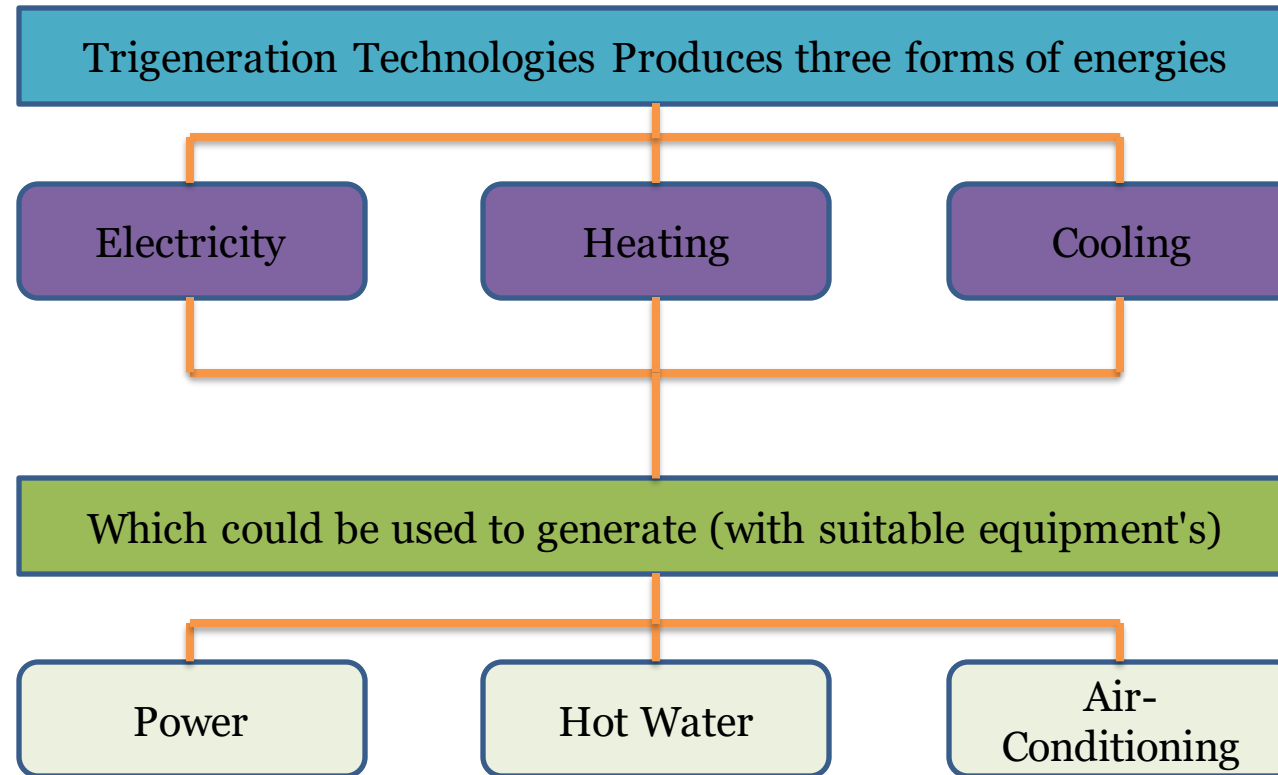
SOLAR THERMAL  
ENERGY CONVERSION

PHOTOVOLTAIC  
CONVERSION



# Green Technologies

## 3 -TRIGENERATION:

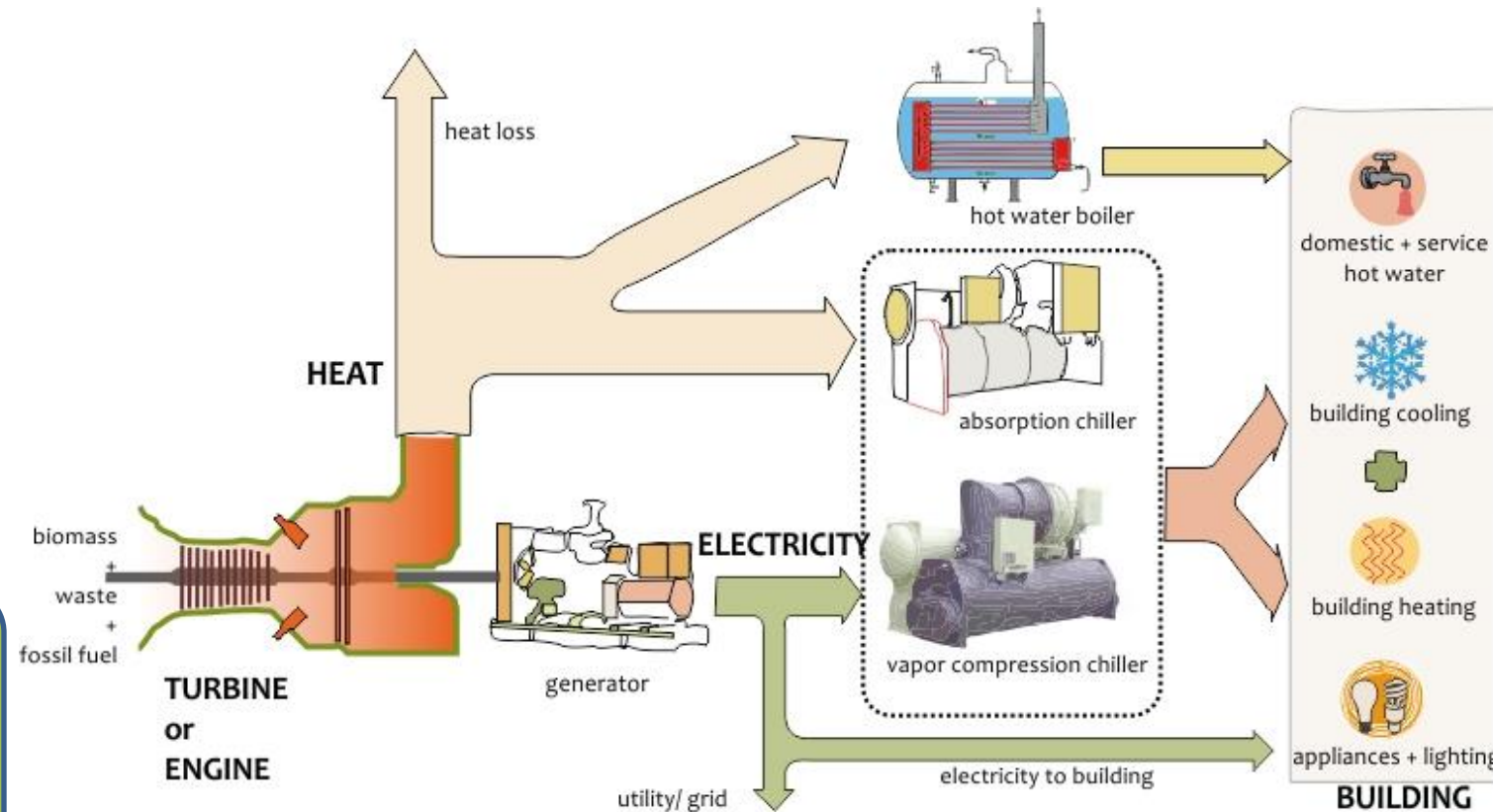


# Green Technologies

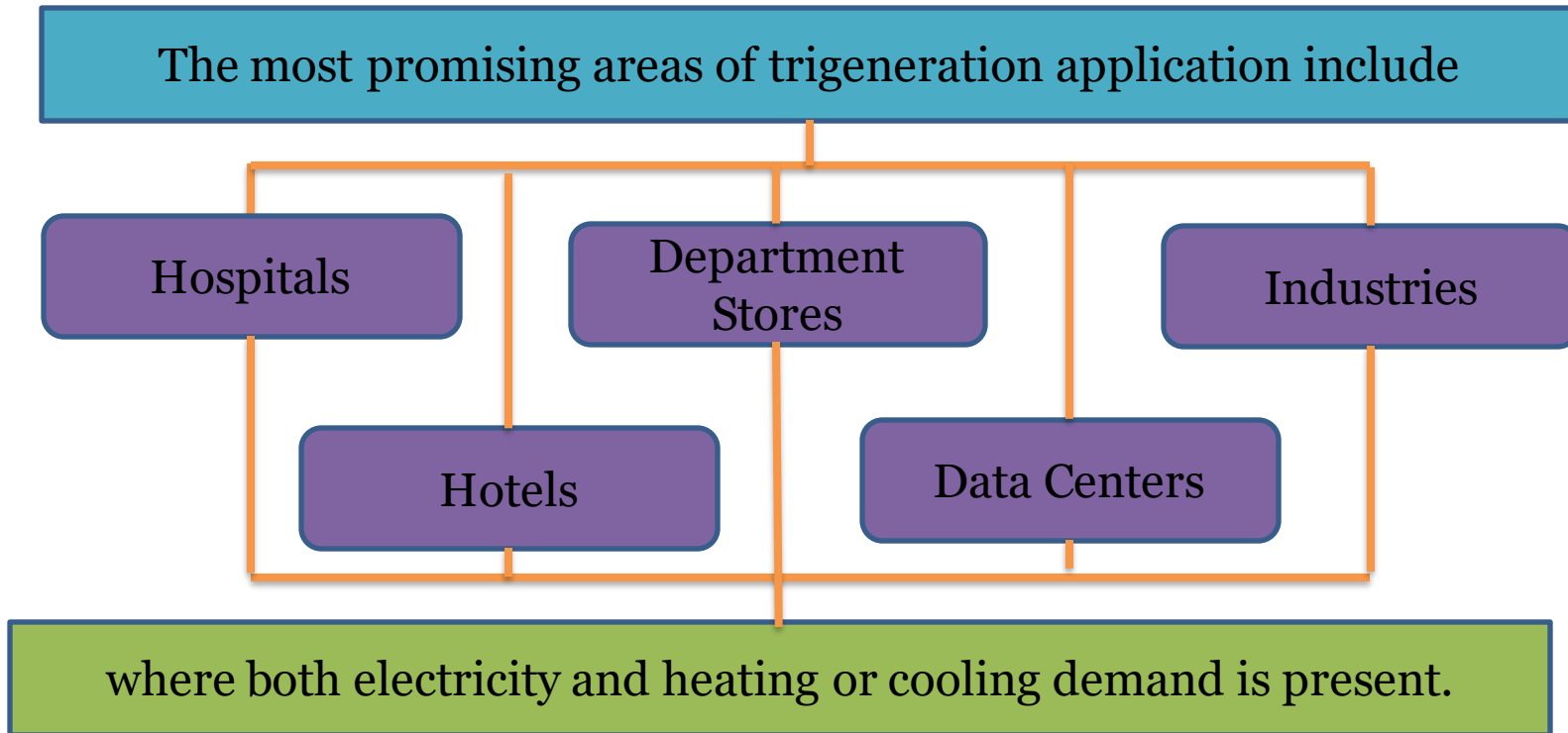
Absorption chillers can employ heat absorbed from waste burning, power generation with generators, or heat generated by solar panels to generate chilled water.

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

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



# Green Technologies





# 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

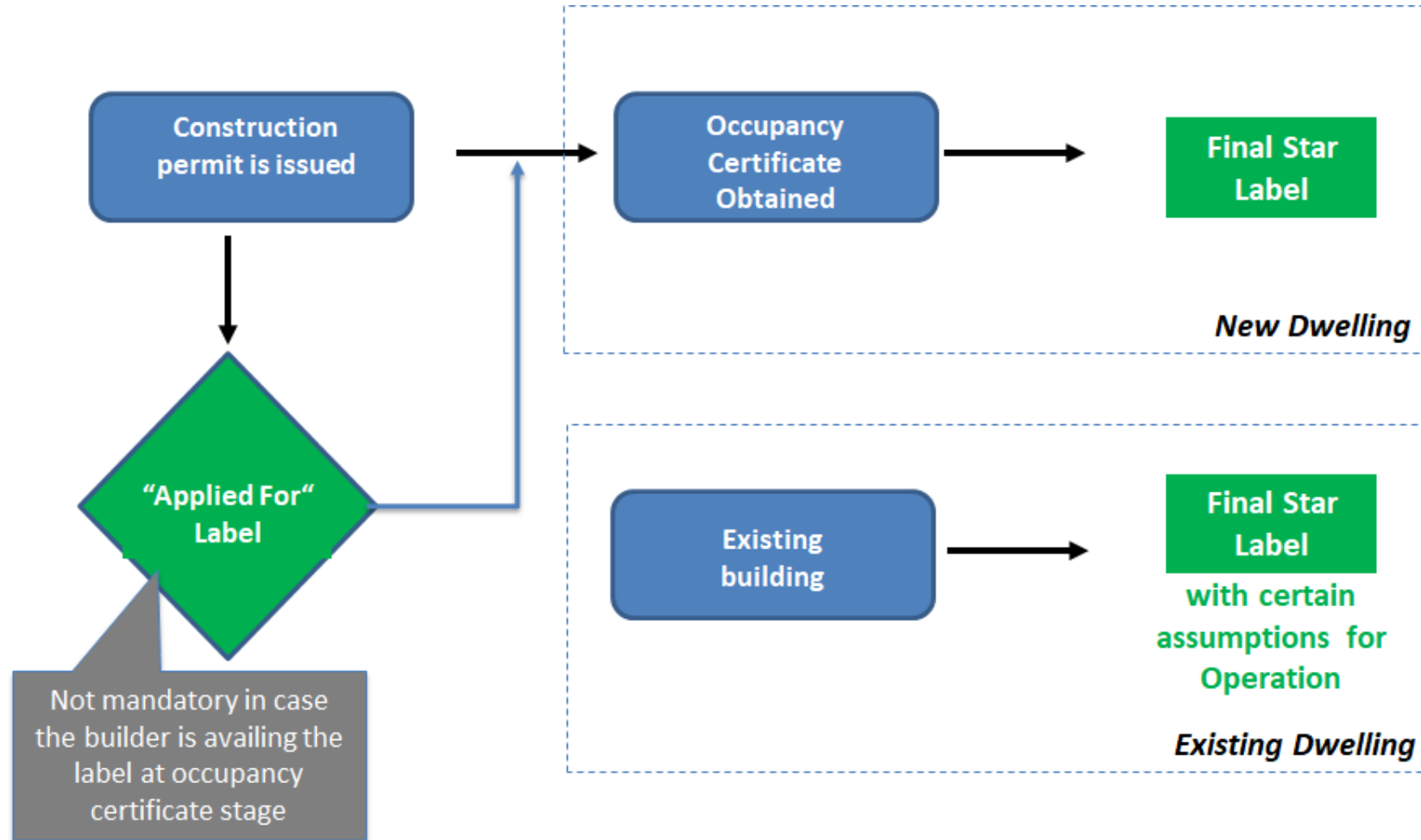
## *Market Transformation*

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 (**m<sup>2</sup>**)

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

And EPI for other appliances: E3

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

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

# Passport



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

# Passport

[illegible]

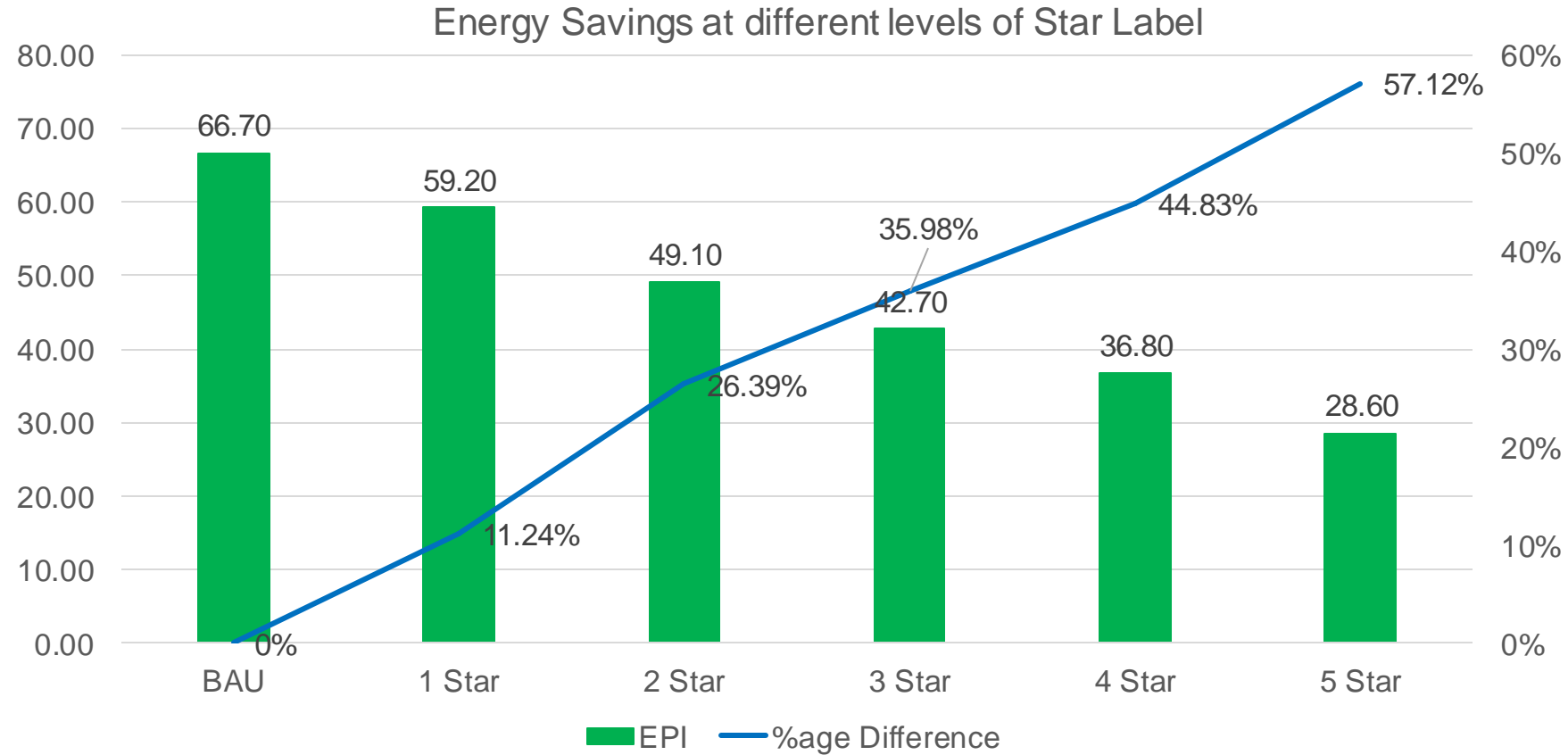
Upon approval from BEE, a building passport will be generated based on the details provided by label applicant.

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

# 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



## Warm & Humid



## Composite



## Temperate





## Scope & type of labelling Program: Bureau of Energy Efficiency



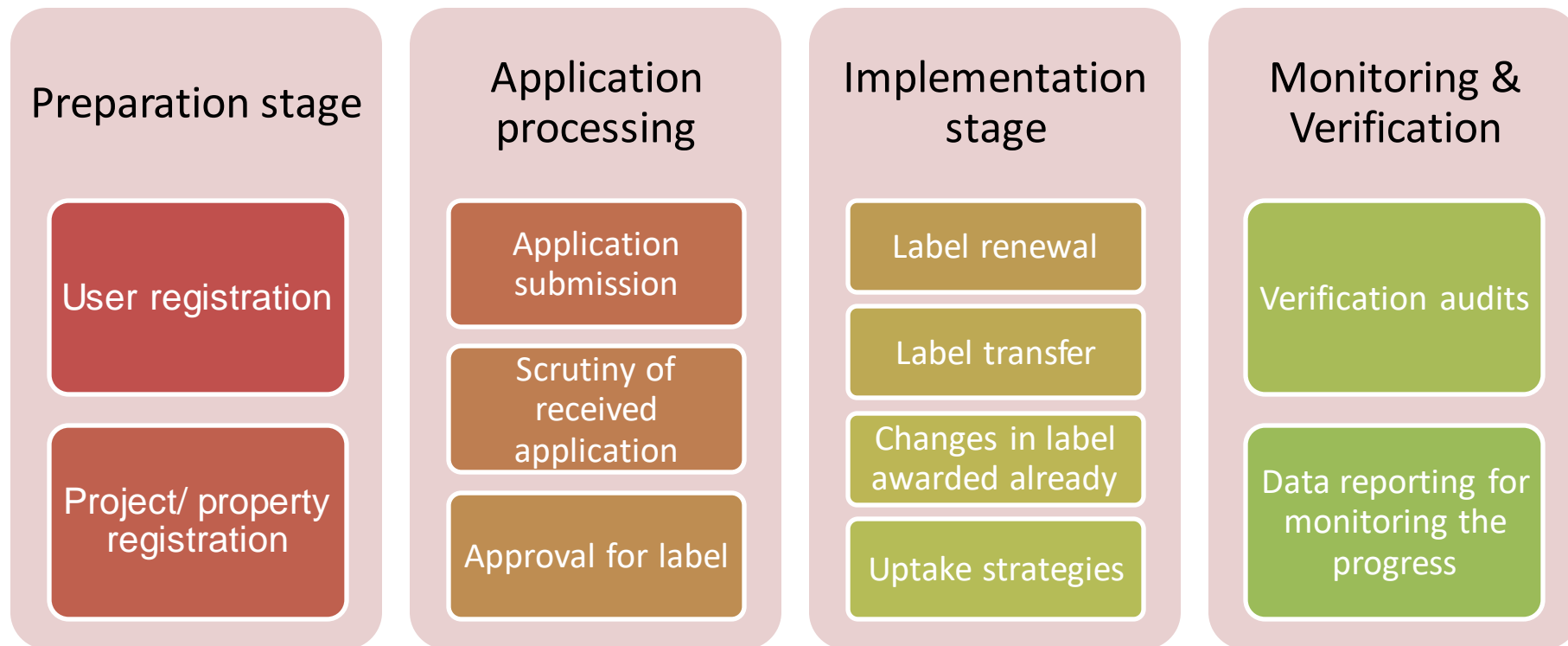
# Label Criteria

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

- ☐ Star Rating awarded in the basis on EPI (**Energy Performance Index**)
- ☐ Energy Performance Index = Annual Energy Consumption (**kWh**)/Built up area (**m<sup>2</sup>**)
- ☐ 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





# 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 m<sup>2</sup>
- Grid Connectivity Grid Connected
- EPI 56 KWh/m<sup>2</sup>/
- 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

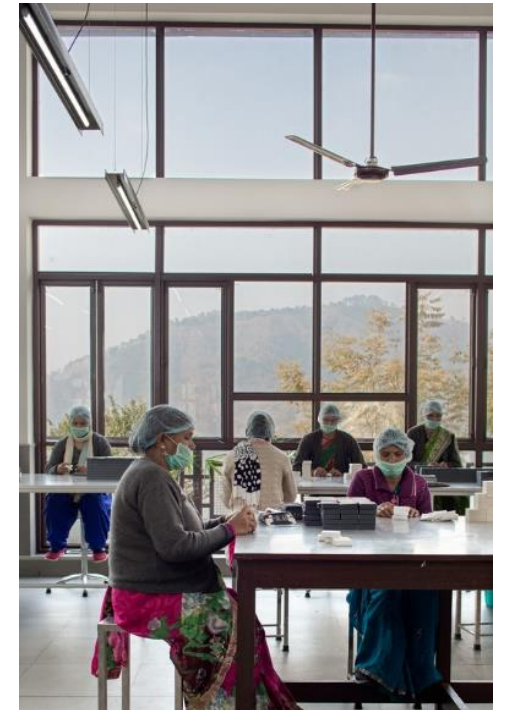
- Renewable Energy
- 60 KW rooftop solar PV with the automatic sprinkler cooling system- meets 80% of the energy demand and about 33% of the energy use further reducing the EPI to 18.8 KWh/m2/year



# 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/m<sup>2</sup>/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 m<sup>2</sup>
- Date of Completion- 2018
- Grid Connectivity- Grid-connected
- EPI 60 kWh/m<sup>2</sup>/yr.
- <https://www.archdaily.com/>
- The building performs 59% better than a conventional office building in the region, and 40% of the building energy consumption is met through on site renewable energy generation



### Ground Floor Plan – Office layout





# Unnati Office

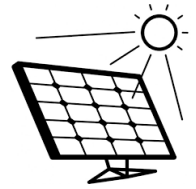
OFFICE – Active cooling system



**RADIANT COOLING**  
Radiant cooling handles  
the sensible heat load



**FRESH AIR DUCTED SUPPLY**  
Fresh air supply also  
handles the latent heat  
load



## 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 m<sup>2</sup>
- Grid Connectivity Grid Connected
- EPI 63 kWh/m<sup>2</sup>/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<sup>2</sup>°F
- Solar Heat Gain Coefficient (SHGC) 0.4
- Visual Transmittance 0.45
- Acoustic Isolation Performance 60 dbA



## Shenzhen Institute of Building Research (IBR) Headquarters



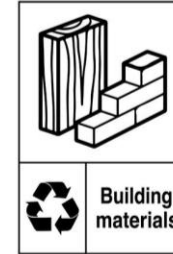
### Air-Conditioning

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.



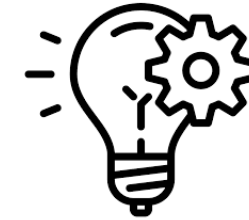
### Roof Garden

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 m<sup>2</sup>
- Date of Completion 2019
- Grid Connectivity: Grid-connected
- EPI- 10 kWh/m<sup>2</sup>/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.

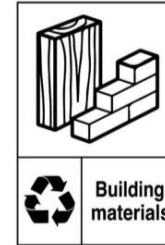
The cross-breezes through courtyards, aided by clerestory ventilation and ceiling fans, promote natural ventilation and improve comfort conditions



## Passive Strategies

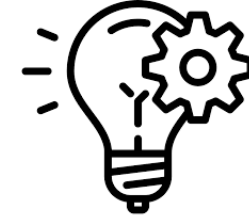
The architecture maintains a vernacular scale through setbacks, gabled roofs, and low-cost heat-storing materials.

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 m<sup>2</sup>
- 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 m<sup>2</sup>
- Date of Completion Oct 2019
- Grid Connectivity Grid-connected
- EPI (kWh/m<sup>2</sup>/yr)- 58 kWh/m<sup>2</sup>/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.

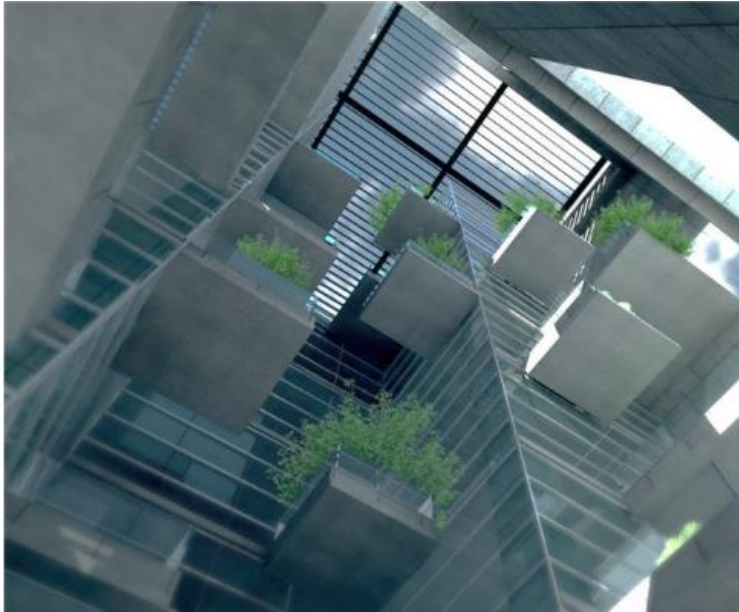
## Climate Responsive Design

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

Climate Smart Buildings | LHP Ranchi | PMAY Urban



# 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/m<sup>2</sup>k – 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

## DAY 2

### Session 5: Building Codes





# Building Codes - IMAC & ASHRAE

# 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

# 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 below equation.

$$\text{Indoor Operative Temperature (}^{\circ}\text{C)} = 0.54 \times \text{Mean Monthly Outdoor DBT} + 12.83$$

Acceptability range for naturally ventilated buildings is  $\pm 2.38^{\circ}\text{C}$

# 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.

$$\text{Indoor Operative Temperature (}^{\circ}\text{C)} = 0.28 \times \text{Mean Monthly Outdoor DBT} + 17.87$$

Acceptability range for Mixed Mode ventilated buildings is  $\pm 3.46^{\circ}\text{C}$

# IMAC – Indian Model for Adaptive Comfort

## AC Buildings – Air Temperature based Approach

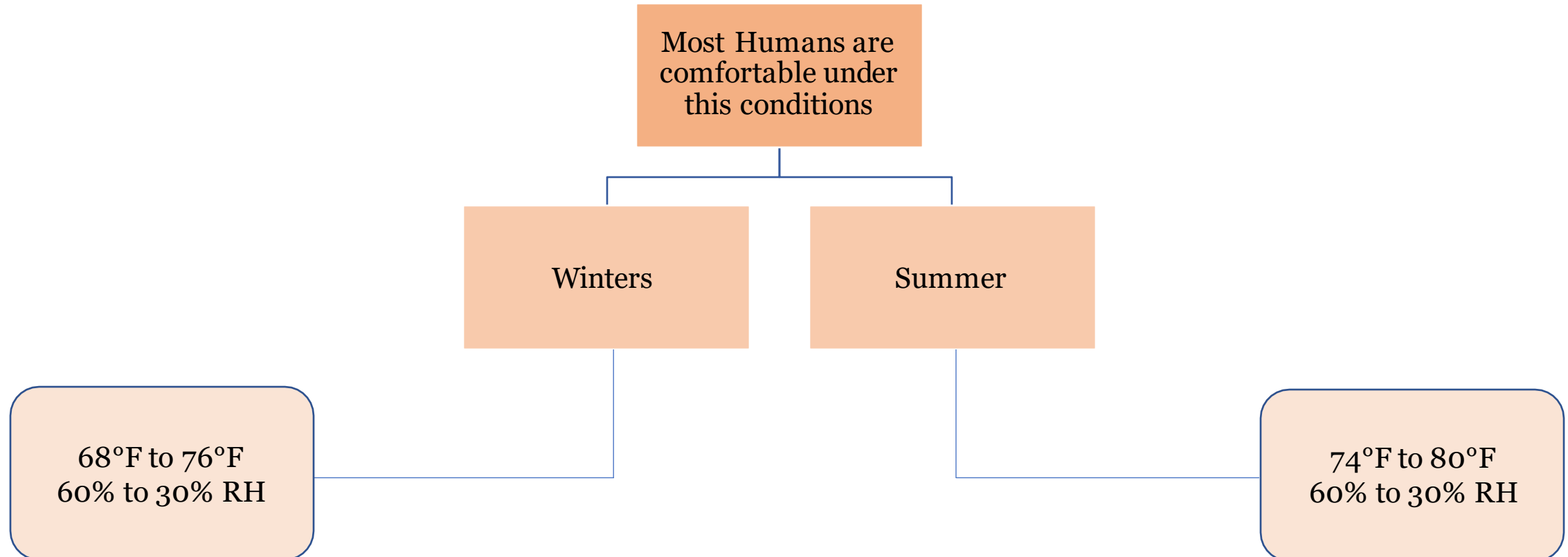
Indoor Operative Temperature (°C) =  $0.078 \times \text{Mean Monthly Outdoor DBT} + 23.25$

Acceptability range for Air-Conditioned buildings is  $\pm 1.5^\circ\text{C}$



# ASHRAE 55

## Human Comfort Range



# 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.

# General Requirements & Standard Conditions of ASHRAE 55

The standards and conditions that must be completed in order to comply with ASHRAE 55 are defined in sections 4 and 5. The criterion must be applied to the specific space being evaluated, the inhabitants who will be inhabiting the area, locations within that space if not the entire space, and any outlier occupants, according to general requirements (i.e., children, disabled persons, elderly persons, etc.).

Because satisfying everyone in a given place is impossible owing to unknown differences, the mandatory requirements that must be met to comply with ASHRAE standard 55 exist in a range of values (physiologically and psychologically). As a result, ASHRAE 55 specifies a certain percentage of occupants as acceptable, as well as the thermal environment values associated with that number.

# 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)

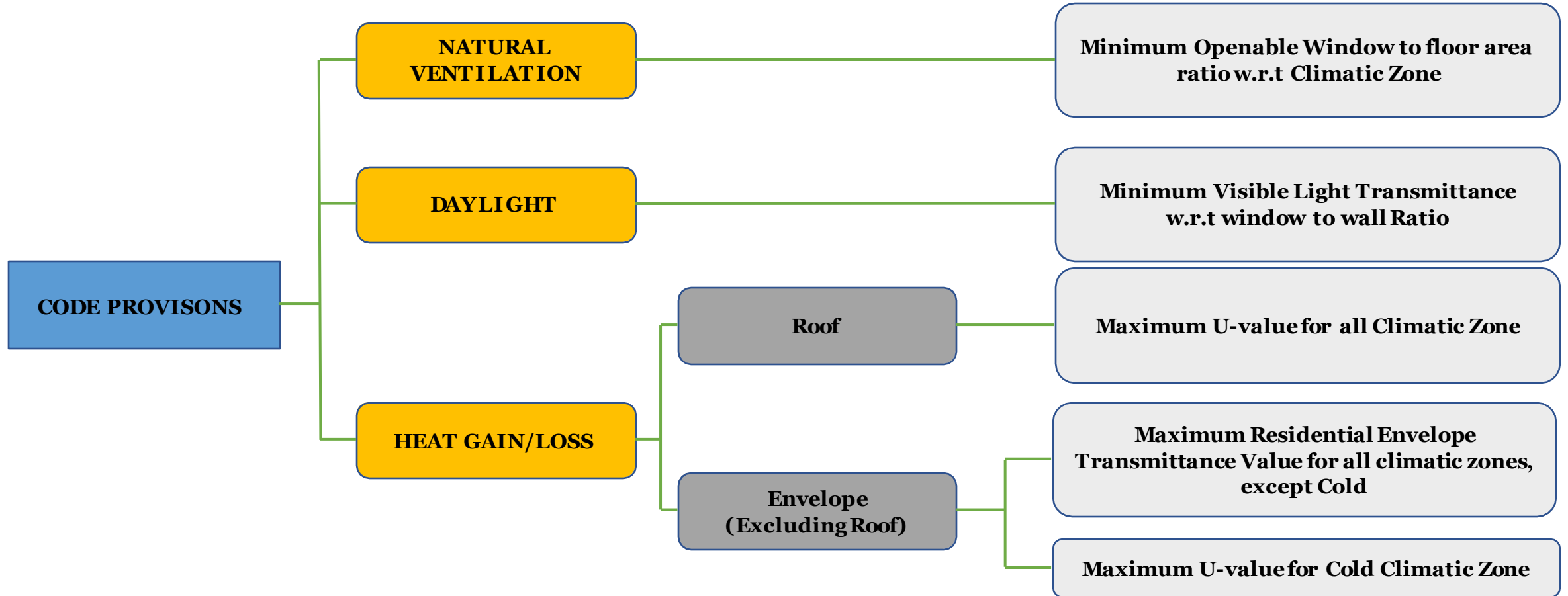
5

The system input or output capacity needed to attain the design operative thermal conditions.



# Building Codes – Eco Niwas Samhita 2018 & 2021 and Code Provisions

# Code Provisions by Eco Niwas Samhita for Thermal Comfort in Affordable Housing





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

## Openable window to floor area ratio (WFR):

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

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

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

# Openable window to floor area ratio (WFR):

## EQUATION FOR WFR

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

### Where,

WFR

Openable Window to Floor Area Ratio

$A_{Openable}$

Openable area (m<sup>2</sup>); it includes the openable area of all windows and ventilators, opening directly to the external air, an open balcony, 'verandah', corridor or shaft; and the openable area of the doors opening directly into an open balcony. Exclusions: All doors opening into corridors. External doors on ground floor, for example, ground-floor entrance doors or back-yard doors.

$A_{Carpet}$

carpet area of dwelling units; it is the net usable floor area of a dwelling unit, excluding the area covered by the external walls, areas under services shafts, exclusive balcony or verandah area and exclusive open terrace area, but includes the area covered by the internal partition walls of the dwelling unit

# VISIBLE LIGHT TRANSMITTANCE (VLT):

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

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

## EQUATION FOR VLT

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

# VISIBLE LIGHT TRANSMITTANCE (VLT):

## MINIMUM VISIBLE LIGHT 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 - $U_{\text{roof}}$ :

Thermal transmittance ( $U_{\text{roof}}$ ) characterizes the thermal performance of the roof of a building. Limiting the  $U_{\text{roof}}$  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  $U_{\text{roof}}$  value of 1.2 W/m<sup>2</sup> K.**



# THERMAL TRANSMITTANCE OF ROOF - $U_{\text{roof}}$ :

## EQUATION FOR $U_{\text{roof}}$ :

$$U_{\text{roof}} = \frac{1}{A_{\text{roof}}} \sum_{i=0}^n (U_i \times A_i)$$

$U_{\text{roof}}$

**Thermal Transmittance of Roof (W/M<sup>2</sup>.K)**

$A_{\text{roof}}$

Total Area of the Roof (m<sup>2</sup>)

$U_i$

Thermal Transmittance values of different roof constructions (W/m<sup>2</sup> .K)

$A_i$

Areas of different Roof Constructions (m<sup>2</sup>)

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

**RETV formula takes into account the following:**

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

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

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

Solar radiations through non-opaque building envelope components (transparent/translucent panel of windows , doors, ventilators, etc. )



## RESIDENTIAL ENVELOPE TRANSMITTANCE VALUE FOR RESIDENTIAL ENVELOPE (EXCEPT GLAZING)

$$\begin{aligned}
 RETV &= A_{n envelope}^1 \times [\{a_{i=1} \times (A_{opaque} \times U_{opaque} + \sum_{i=1}^n (A_{i=1} \times U_{opaque} + \sum_{i=1}^n (A_{i=1} \times U_{opaque} + \sum_{i=1}^n (A_{i=1} \times U_{opaque})))\} \\
 &\times (A_{opaque} \times U_{opaque} + \sum_{i=1}^n (A_{i=1} \times U_{opaque} + \sum_{i=1}^n (A_{i=1} \times U_{opaque} + \sum_{i=1}^n (A_{i=1} \times U_{opaque})))\}
 \end{aligned}$$

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

### RETV EQUATIONS TERMS

$A_{\text{envelope}}$	envelope area (excluding roof) of dwelling units ( $\text{m}^2$ ). It is the gross external wall area (includes the area of the walls and the openings such as windows and doors).
$A_{\text{opaque}}$	areas of different opaque building envelope components ( $\text{m}^2$ )
$U_{\text{opaque}}$	thermal transmittance values of different opaque building envelope components ( $\text{W}/\text{m}^2 \cdot \text{K}$ )
$A_{\text{non-opaque}}$	areas of different non-opaque building envelope components ( $\text{m}^2$ )
$U_{\text{non-opaque}}$	thermal transmittance values of different non-opaque building envelope components ( $\text{W}/\text{m}^2 \cdot \text{K}$ )
$\text{SHGC}_{\text{eq}}$	equivalent solar heat gain coefficient values of different non-opaque building envelope components
$\omega_I$	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:

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

Thermal transmittance  $U_{\text{envelope,cold}}$  characterizes the thermal performance of the building envelope (except roof). Limiting the  $U_{\text{envelope,cold}}$  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  $1.8 \text{ W/m}^2 \cdot \text{K}$

**EQUATION FOR**  
 **$U_{\text{envelope,cold}}$  :**

$$U_{\text{envelope,cold}} = \frac{1}{A_{\text{envelope}} \sum_{i=1}^n (U_i \times A_i)}$$

$U_{\text{envelope,cold}}$	thermal transmittance of building envelope (except roof) for cold climate ( $\text{W/m}^2 \cdot \text{K}$ )
$A_{\text{envelope}}$	envelope area (excluding roof) of dwelling units ( $\text{m}^2$ ). 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 ( $\text{W/m}^2 \cdot \text{K}$ )
$A_i$	area of different opaque and non-opaque opaque building envelope components ( $\text{m}^2$ )

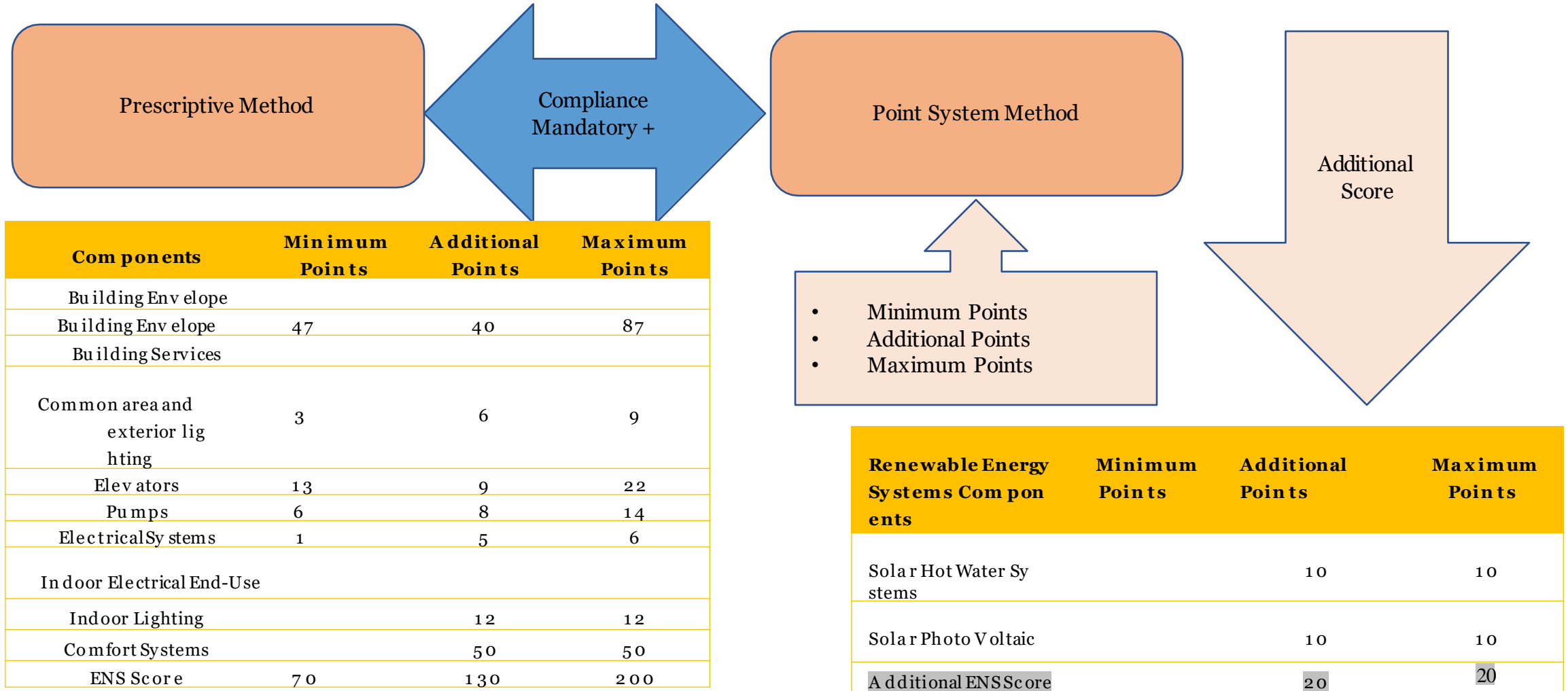
## Eco – Niwas Samhita 2021 Scope

The Code Applies to

Residential buildings  
built on a plot area of  
 $\geq 500 \text{ m}^2$

Residential part of  
**Mixed land-use  
building** projects,  
built on a plot area of  
 $\geq 500 \text{ m}^2$ .

# ECO – NIWAS SAMHITA 2021 CODE COMPLIANCE



# ECO – NIWAS SAMHITA 2021 CODE COMPLIANCE

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

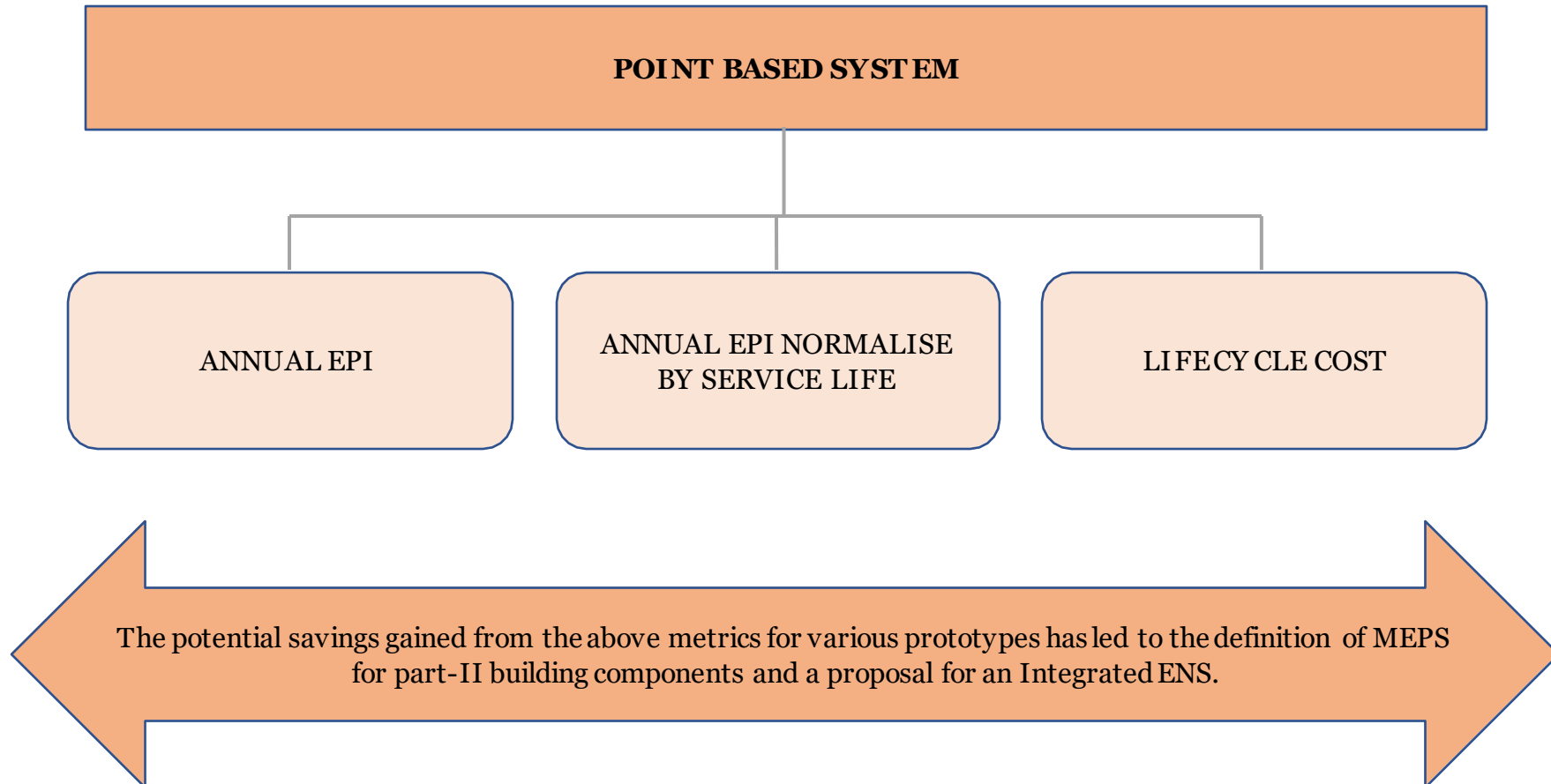
**Low Rise Buildings:** A structure of four stories or less, and/or a structure of up to 15 metres in height (without stilts) and up to 17.5 metres in height (including stilt).

## Affordable Housing Projects:

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

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

# Point Based System



# Mandatory Requirements

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



# Prescriptive Method

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

Common Areas	Maximum LPD (W/m <sup>2</sup> )	Minimum luminous efficacy (lm/W)
Corridor lighting & Stilt Parking	3.0	All the permanently installed lighting fixtures shall use lamps with an efficacy of at least 105 lumens per Watt
Basement Lighting	1.0	All the permanently installed lighting fixtures shall use lamps with an efficacy of at least 105 lumens per Watt

Exterior Lighting Areas	Maximum LPD (in W/m <sup>2</sup> )
Driveways and parking (open/ external)	1.6
Pedestrian walkways	2.0
Stairways	10.0
Landscaping	0.5
Outdoor sales area	9.0

# Prescriptive Method

## 3. Elevators, if applicable::

- Lamps: 85l/W
- Automatic switch off control
- IE4 motors
- VFDs
- Regenerative drives
- Group Automatic operation

## 4. Pumps, if applicable: Min Eff -70% or BEE 5 Star

## 5. Electrical System, if applicable:

- Distribution loss less than 3%
- Dry Type Transformer - as mentioned in table
- Oil Type Transformer – BEE 5 Star

# Point System Method

## Point System Method

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

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

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

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

# Point System Method

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

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

Thermal Transmittance of Roof	
<p>Minimum: Thermal transmittance of roof shall comply with the maximum Uroof value of 1.2 W/m<sup>2</sup>·K.</p>	Up to 4 Points
<p>Additional: 1 Point for every reduction of 0.23 W/m<sup>2</sup>·K in thermal transmittance of roof from the Minimum requirement prescribed under §6.1(a).</p>	Maximum 3Points

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

# Point System Method

## 2 – Common Area and Exterior Lighting (9 Points)

Common Areas	Maximum LPD (W/m <sup>2</sup> )	Minimum luminous efficacy (lm/W)
Corridor lighting & Stilt Parking	3.0	All the permanently installed lighting fixtures shall use lamps with an efficacy of at least 85 lumens per Watt
Basement Lighting	1.0	All the permanently installed lighting fixtures shall use lamps with an efficacy of at least 85 lumens per Watt

Exterior Lighting Areas - at least 85 lm/W and maximum LPD requirements given in Table	Maximum LPD (in W/m <sup>2</sup> )
Driveway and parking (open/ external)	1.6
Pedestrian walkways	2.0
Stairways	10.0
Landscaping	0.5
Outdoor sales area	9.0

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

# Point System Method

## 3 – ELEVATORS (22 Points)

### Minimum:

Elevators installed in the ENS building shall meet all the following requirements:

- i. Install high efficacy lamps for lift car lighting having minimum luminous efficacy of 85 lm/W
- ii. Install automatic switch-off controls for lighting and fan inside the lift car when are not occupied
- iii. Install minimum class IE 3 high efficiency motors
- iv. Group automatic operation of two or more elevators coordinated by supervisory control

13 Points

### Additional:

- i. Additional points can be obtained by meeting the following requirements:
- ii. Installing the variable voltage and variable frequency drives. (4 points)
- iii. Installing regenerative drives. (3 points)
- iv. Installing class IE4 motors. (2 points)

9 Points



# Point System Method

## 4 – Pumps (14 Points)

<p><b>Minimum:</b></p> <p><b>Either hydro-pneumatic pumps having minimum mechanical efficiency of 60% or BEE 4 star rated Pumps shall be installed in the ENS building.</b></p>	<p><b>6 Points</b></p>
<p><b>Additional:</b></p> <p>Additional points can be obtained by meeting the following requirements:</p> <ul style="list-style-type: none"> <li>i. Installation of BEE 5 star rated pumps (5 Points)</li> <li>ii. Installation of hydro-pneumatic system for water pumping having minimum mechanical efficiency of 70% (3 Points)</li> </ul>	<p><b>8 Points</b></p>

# Point System Method

## 5 – Electrical Systems (6 Points)

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

# Point System Method

## 6 – Indoor Lightings (12 Points)

<p><b>Minimum:</b></p> <p>All the lighting fixtures shall have lamps with luminous efficacy of minimum 85 lm/W installed in all bedrooms, hall and kitchen.</p>	<p><b>4 Points</b></p>
<p><b>Additional:</b></p> <p>Additional points for indoor lighting by installing all lighting fixtures in all bedrooms, hall and kitchen shall have lamps luminous efficacy as per following:</p> <ul style="list-style-type: none"> <li>i. 95 lm/w (3 Points)</li> <li>ii. 105 lm/W (8 Points)</li> </ul>	<p><b>Upto 8 Points</b></p>

# Point System Method

## 7 – Comfort Systems (50 Points) – Ceiling Fans

<p><b>Minimum:</b></p> <p>i. All ceiling fans installed in all the bedrooms and hall in all the dwelling units shall have a service value as given below:</p> <ul style="list-style-type: none"> <li>For sweep size &lt;1200 mm: equal or greater than 4 m<sup>3</sup>/minute·Watt</li> <li>For sweep size &gt;1200 mm: equal or greater than 5 m<sup>3</sup>/minute·Watt</li> </ul> <p>i. BEE Standards and Labeling requirements for ceiling fans shall take precedence over the current minimum requirement, as and when it is notified as mandatory.</p>	<p><b>6 Points</b></p>
<p><b>Additional:</b></p>	
<p>Additional points for ceiling fans by installing in all the bedrooms and hall in all the dwelling units as per following:</p>	
<p>i. 4 Star</p>	<p><b>1 Points</b></p>
<p>ii. 5 Star</p>	<p><b>3 Points</b></p>

# Point System Method

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

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

# Point System Method

## 8 – Solar Water Heating (10 Points)

### Minimum:

The ENS compliant building shall provide a solar water heating system (SWH) of minimum BEE 3Star label and is capable of meeting 100% of the annual hot water demand of top 4 floors of the residential building.

or

100% of the annual hot water demand of top 4 floors of the residential building is met by the system using heat recovery

5 Points

### Additional:

Additional points can be obtained by installing SWH system as per as per following:

- i. 100% of the annual hot water demand of top 6 floors of the residential building (2 points)
- ii. 100% of the annual hot water demand of top 8 floors of the residential building (5 points)

Upto 5 Points



# Point System Method

## 9 – Solar Photo Voltaic (10 Points)

<p><b>Minimum:</b></p> <p>The ENS compliant building shall provide a dedicated Renewable Energy Generation Zone (REGZ) –</p> <ul style="list-style-type: none"> <li>• Equivalent to a minimum of 2 kWh/m<sup>2</sup>.year of electricity; or</li> <li>• Equivalent to at least 20% of roof area.</li> </ul> <p>The REGZ shall be free of any obstructions within its boundaries and from shadows cast by objects adjacent to the zone.</p>	<p><b>5 Points</b></p>
<p><b>Additional:</b></p> <p>Additional points can be obtained by installing solar photo voltaic as per following:</p> <ol style="list-style-type: none"> <li>Equivalent to a minimum of 3 kWh/m<sup>2</sup>.year of electricity or Equivalent to at least 30% of roof area (2 points)</li> <li>Equivalent to a minimum of 4 kWh/m<sup>2</sup>.year of electricity or Equivalent to at least 40% of roof area (5 points)</li> </ol>	<p><b>Upto 5 Points</b></p>



GLOBAL  
HOUSING  
TECHNOLOGY  
CHALLENGE INDIA



Ministry of Housing  
and Urban Affairs  
Government of India




# 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

ECO-Niwas Samhita: Compliance Check Tool



Ministry of Power  
Government of India

ECO-NIWAS SAMHITA COMPLIANCE TOOL



FileHelp

Demo Building

TEST (Demo Building)

▶ Affordable High-Rise

TEST (Affordable High-Rise)

▶ Low Rise

TEST (Low Rise)

▶ High Rise

TEST (High Rise)

Project Name

Demo Building

State

Chandigarh

City

Chandigarh

Latitude

>= 23.5° N

Project Construction Type

New Building

Housing Category

High Rise

Plot Area (m²)

1500.0

Total no. of Residential Blocks




5

Compliance Method Used

☒ Points System☐ Prescriptive System

Add Category

Project Relocate

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

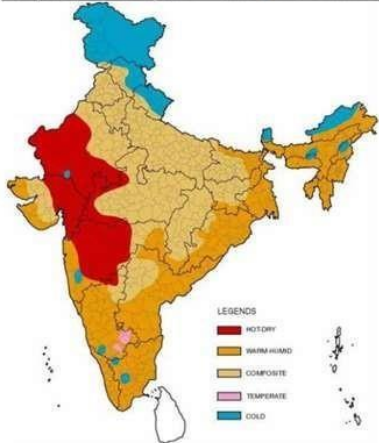
Total No. of Block16

HELP !

Climate zones of India

Composite

Does not have a predominant season for more than six months



LEGEND

Hot Dry

Warm Humid

Composite

Temperate

Cold

▶ Project Construction type for compliance check

▶ ENS Code Purpose & Applicability

▶ Project Construction Type

▶ ENS Compliance Criteria

▶ Plot Area

▶ Housing Category

▶ Total no. of Residential Blocks

Source : [www.econinvas.com](http://www.econinvas.com)

## ENS Compliance Tools Key Features

- Provisions for multiple housing category addition for compliance evaluation

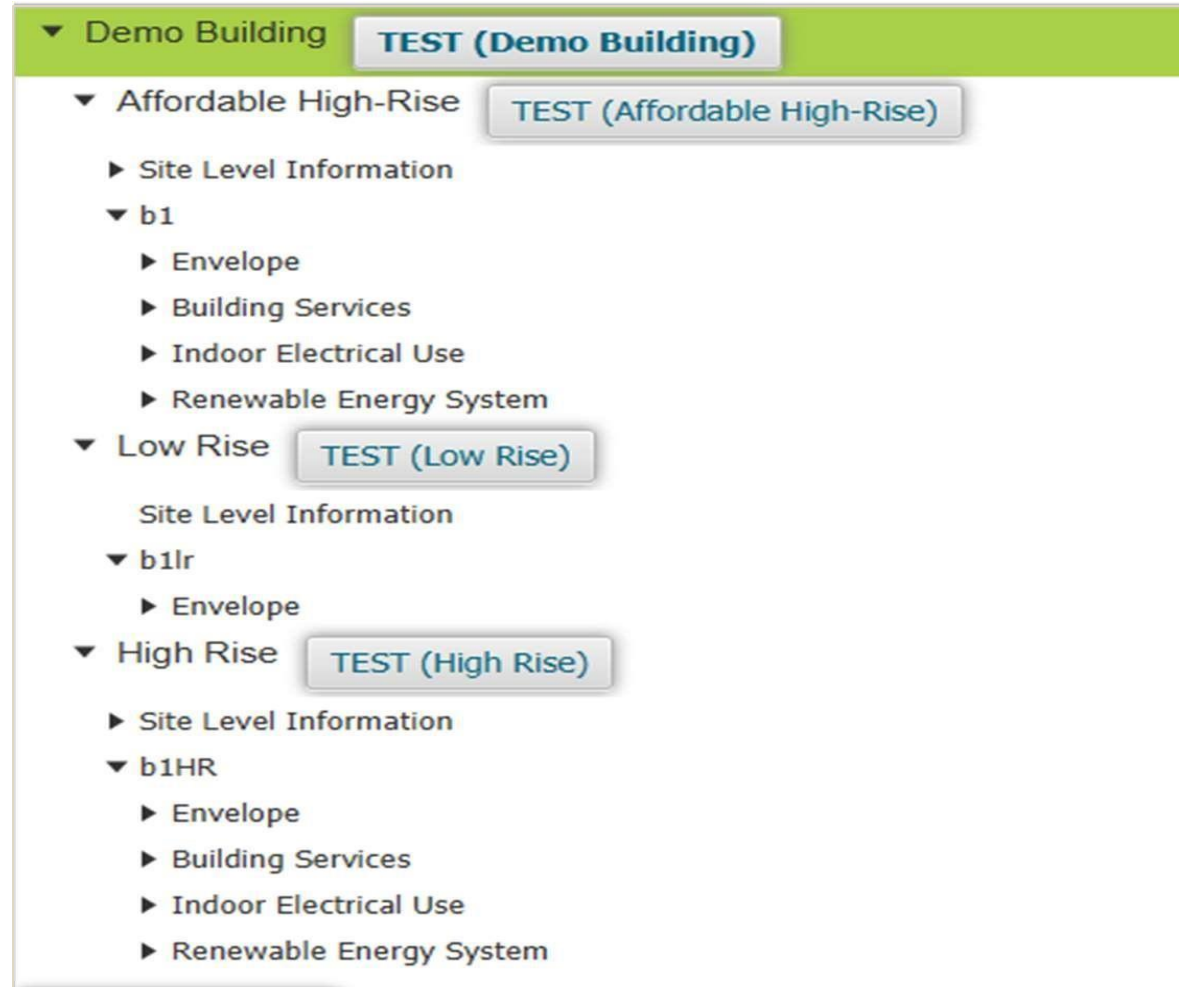
	S.No.	Housing Category	Plot Area (m <sup>2</sup> )	Total Residential Block	
	1	Affordable High-Rise	10000	10	
	2	Low Rise	1000	1	
	3	High Rise	1500	5	

**Total No. of Block      16**

Source : [www.econivias.com](http://www.econivias.com)

# ENS Compliance Tools Key Features

- Easy to navigate tree-view structure



Source : [www.econivas.com](http://www.econivas.com)

# ENS Compliance Tools Key Features

- Project relocation feature for multiple domain use

Project Name	Demo Building	State	New Delhi
City	New Delhi	Climate	COMPOSITE
Latitude	>= 23.5° N		
Project Construction Type	New Building	Housing Category	Affordable ...
Plot Area (m <sup>2</sup> )	10000	Total no. of Residential Blocks	10
Compliance Method Used	<input checked="" type="radio"/> Points System	<input type="radio"/> Prescriptive System	
		Add Category	Project Relocate

Source : [www.econivus.com](http://www.econivus.com)

# ENS Compliance Tools Key Features

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

▼ Demo Building **TEST (Demo Building)**

▼ Affordable High-Rise **TEST (Affordable High-Rise)**

▼ Site Level Information

- Basement Lighting
- Exterior Lighting
- Pumps
- Diesel Generator Set
- Power Factor
- Energy Monitoring
- EV Supply Equipment
- Transformer
- Power Distribution Loss
- Solar Photovoltaic System

▼ b1

- Envelope
- Building Services
- Indoor Electrical Use
- Renewable Energy System

► Low Rise **TEST (Low Rise)**

► High Rise **TEST (High Rise)**

Source : [www.econivus.com](http://www.econivus.com)

- Comprehensive help panel on each form for easy user referencing

**HELP !**

► Climate zones of India

▼ Project Construction type for compliance check

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

North

North West

North East

East

South East

South West

West

337.5°

22.5°

67.5°

112.5°

157.5°

202.5°

247.5°

292.5°

Angle measurement in clockwise direction from North

► ENS Code Purpose & Applicability

► Project Construction Type

► ENS Compliance Criteria

► Plot Area

► Housing Category

► Total no. of Residential Blocks



# ENS Compliance Tools Key Features

- Component level display for mandatory provisions and points achieved

The screenshot displays the ENS Compliance Tools interface. On the left is a sidebar with a tree view showing the hierarchy of components: Site Level Information, b1lr, Envelope, High Rise (selected), b1HR, Envelope, Building Services, Common Area Lighting, Lifts, Pumps, Electrical System, Diesel Generator Set, Power Factor, Energy Monitoring (selected), EV Supply Equipment, Transformer, Power Distribution Loss, Car Parking, Indoor Electrical Use, and Renewable Energy System. Below the sidebar is an 'Upload Energy Monitor' button.

The main form is titled 'Energy Monitoring:' and contains several sections:
 

- Availability:** A dropdown menu set to 'Yes' and an 'Energy MeteringType' dropdown set to 'Select'.
- Meter Segregated Recording For:** A grid of radio buttons for selecting components to monitor: Basement Lighting, Corridor Lighting, Outdoor Lighting, Power Backup Generation, Elevators, RE Generation, Lift System, Car Park Vent System, and Water Pumps.
- Data Recording Interval:** A dropdown menu set to 'Select'.
- Digital Control System/EMIS Installed:** A dropdown menu set to 'Select'.
- Reporting Frequency:** A dropdown menu set to 'Select'.
- Data Retaining Capability of DCS/EMIS (Year/s):** A dropdown menu set to 'Select'.
- Reporting Frequency:** Radio buttons for 'Hourly', 'Daily', 'Monthly', and 'Annually'.
- Add Input:** A button to add new input data.

Below the form is a table with the following columns: S.No., Energy Metering ..., Basement Li..., Corridor Li..., Power BackUp Gen..., Outdoor Light, Elevator, Car Park..., and Wa. The first row shows S.No. 1, Energy Metering Smart, and checkmarks in the Basement Li, Corridor Li, Power BackUp Gen, Outdoor Light, Elevator, and Car Park columns.

At the bottom of the interface, a red box highlights the 'Mandatory Compliance' and 'Achieved' status.

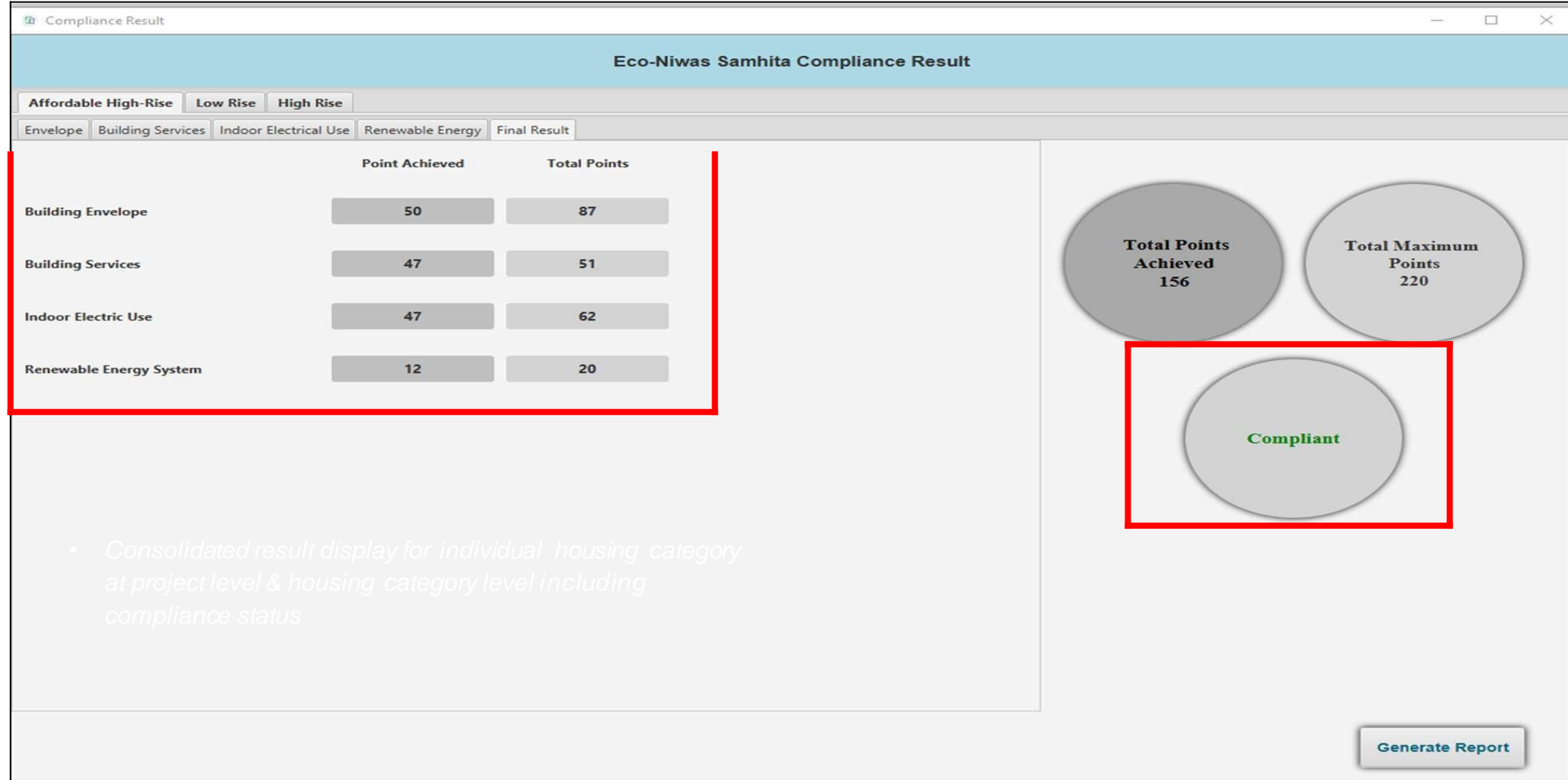
Source : [www.econivas.com](http://www.econivas.com)

## ENS Compliance Tools Key Features

[illegible]

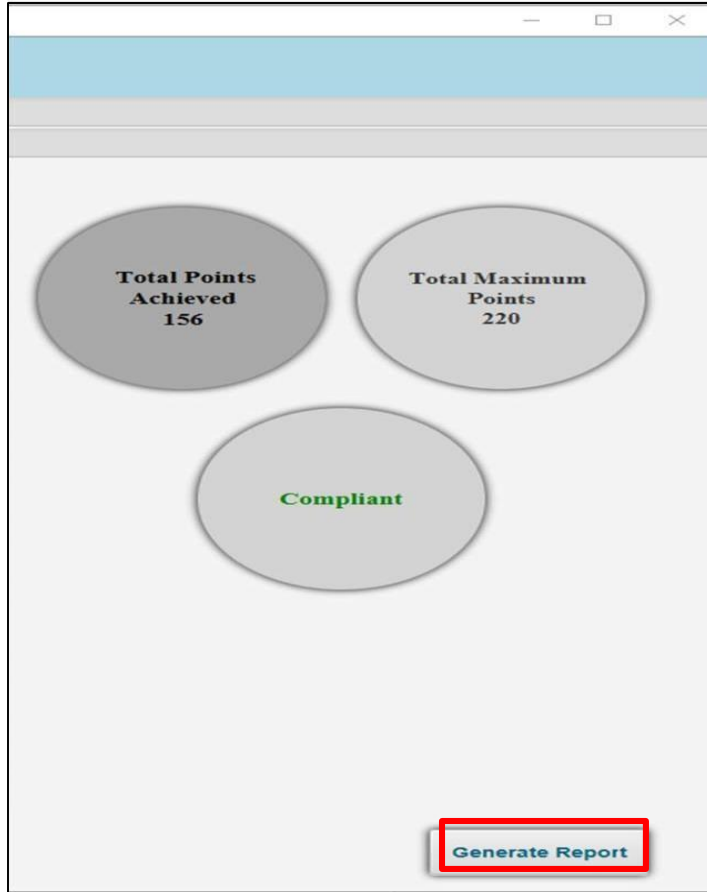
Source : [www.econinvas.com](http://www.econinvas.com)

# ENS Compliance Tools Key Features



# 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(m <sup>2</sup> )	Total No. of Residential Blocks	Total Basement Area(m <sup>2</sup> )	Total Exterior Light Area(m <sup>2</sup> )	Total Roof Area(m <sup>2</sup> )
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	RET(V/W/m <sup>2</sup> .K)	NA	14.59	44	80
2	U-Value Roof(W/m <sup>2</sup> .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



# What is Green Building?

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



# The Benefits

## Environmental Benefits

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

## Economic Benefits

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

## Social Benefits

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



# Green buildings & the Sustainable Development Goals





# Goals of Green Buildings

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

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

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

Goals of Green  
Buildings

Life Cycle Assessment  
(LCA)

Setting & Structure  
define efficiency

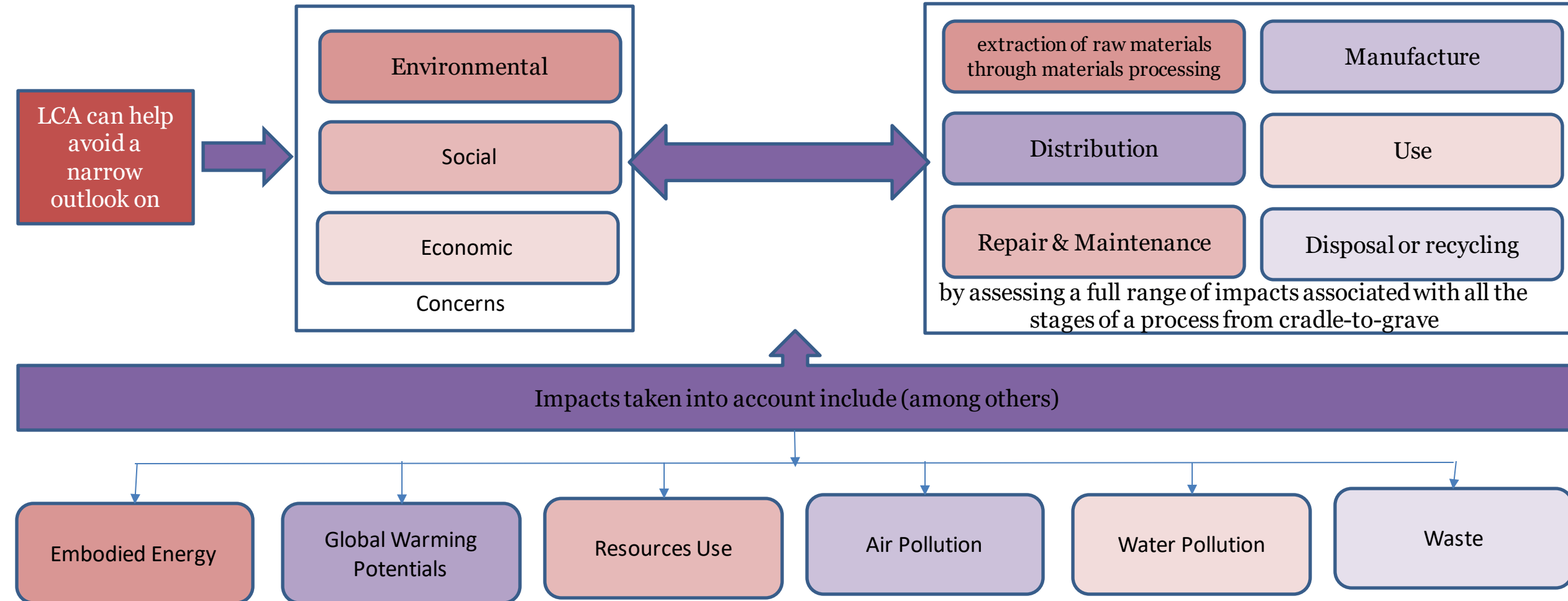
Energy Efficiency

Water Efficiency

Material Efficiency

Waste Reduction

# Life Cycle Assessment (LCA)



# Setting & Structure Design Efficiency

The foundation of any construction project is rooted in

Concept Stage

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

Design Stage

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

# Energy Efficiency

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

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

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

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

# Water Efficiency

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

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

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

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

Waste-water may be minimized

by utilizing water conserving fixtures such as

ultra-low  
flush toilets

low-flow  
shower  
heads.

Bidets help eliminate the use of

toilet paper

Reducing  
Sewer  
Traffic

increasing  
possibilities  
of re-using  
water on-  
site

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

# Material Efficiency

## Building materials

typically  
considered to be  
'green' include

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

bamboo  
and  
straw

insulating  
concrete  
forms

dimensional  
stone,

recycled  
stone

recycled  
metal

and other products  
that are

Non Toxic

reusable

renewable, and/or  
recyclable

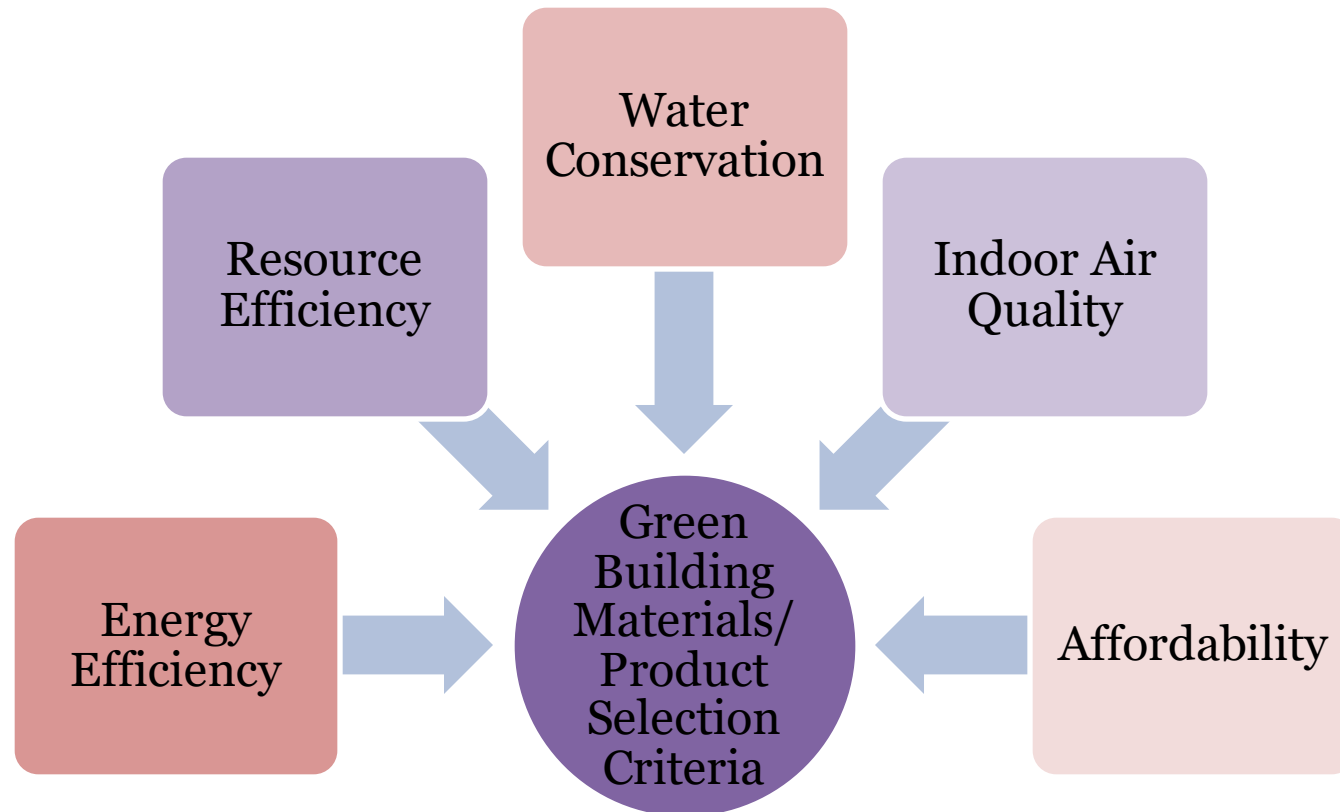
The EPA (Environmental Protection Agency) also suggests using recycled industrial goods, such as coal combustion products, foundry sand, and demolition debris in construction projects. Building materials should be extracted and manufactured locally to the building site to minimize the energy embedded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

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

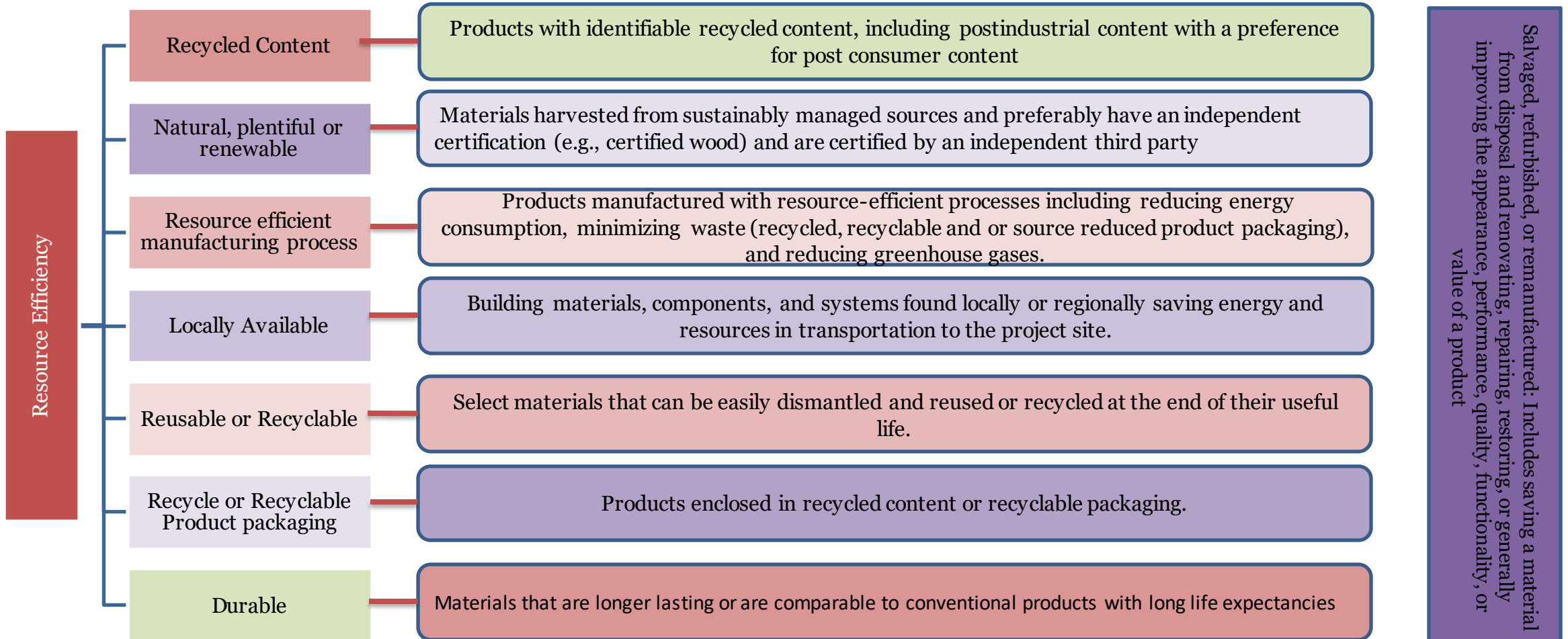


# Green Building Materials

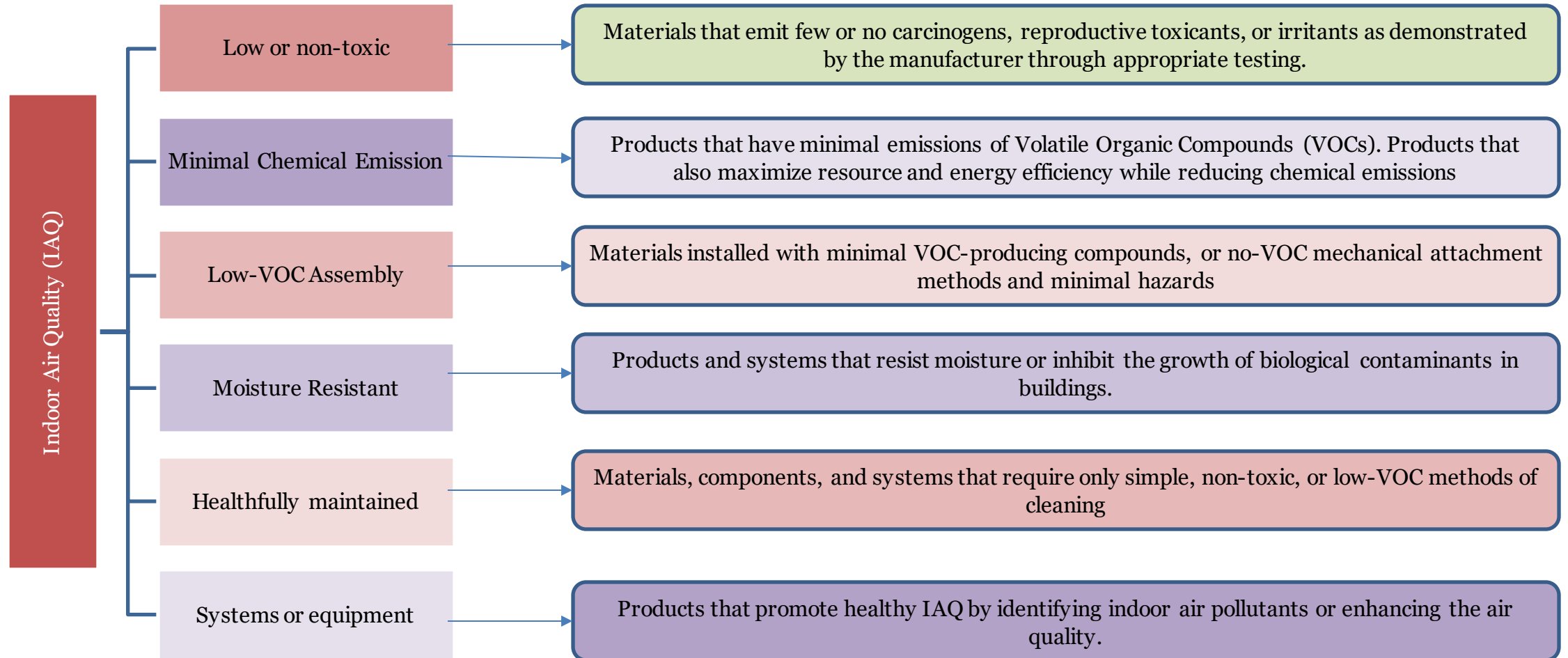
Selection criteria like what is presented below was also used for the East End Project as identified in the Review of Construction Projects Using Sustainable Materials.



# Green Building Materials - Resource Efficiency



# Green Building Materials - Indoor Air Quality (IAQ)



# Green Building Materials - Indoor Air Quality (IAQ)

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

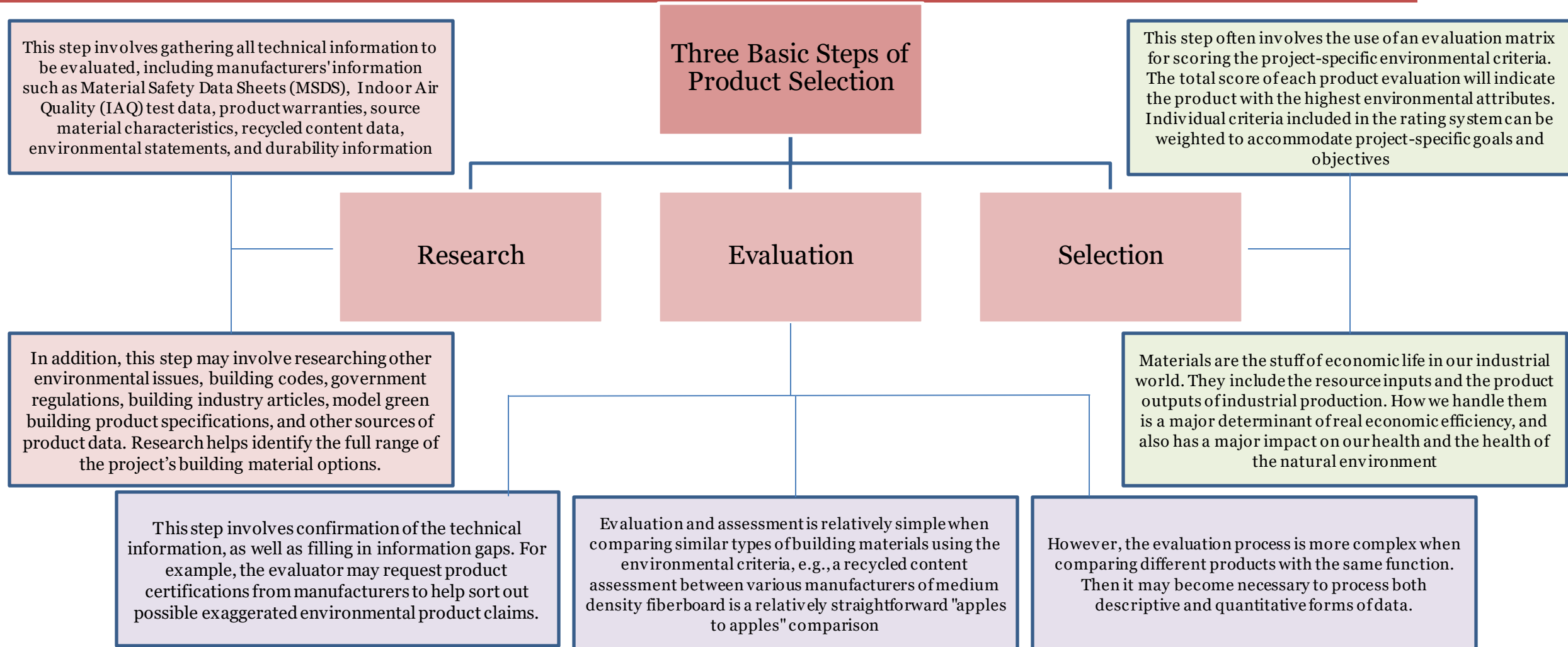
Energy Efficiency can be maximized by utilizing materials and systems that meet the following criteria:

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

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

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

# Green Building Materials – Three Basic Steps of Product Selection



# Green Building Materials – Elements of Material Solutions in Building

## Elements of Material Solutions in Buildings

### Materials use avoidance

this includes scrutiny of consumption needs themselves—do we really need to build this?—and voluntary simplicity. It includes a focus on selling services, rather than products. It also includes the redesign of products, buildings and settlements to dispense with superfluous materials. The great efficiencies resulting from ecological urban design and mixed use development are in this category.

### Increased intensity of product use

All kinds of sharing are included here, and thus there is some overlap with category #1. Cohousing developments with shared facilities, for example, can substantially reduce the volume of materials use.

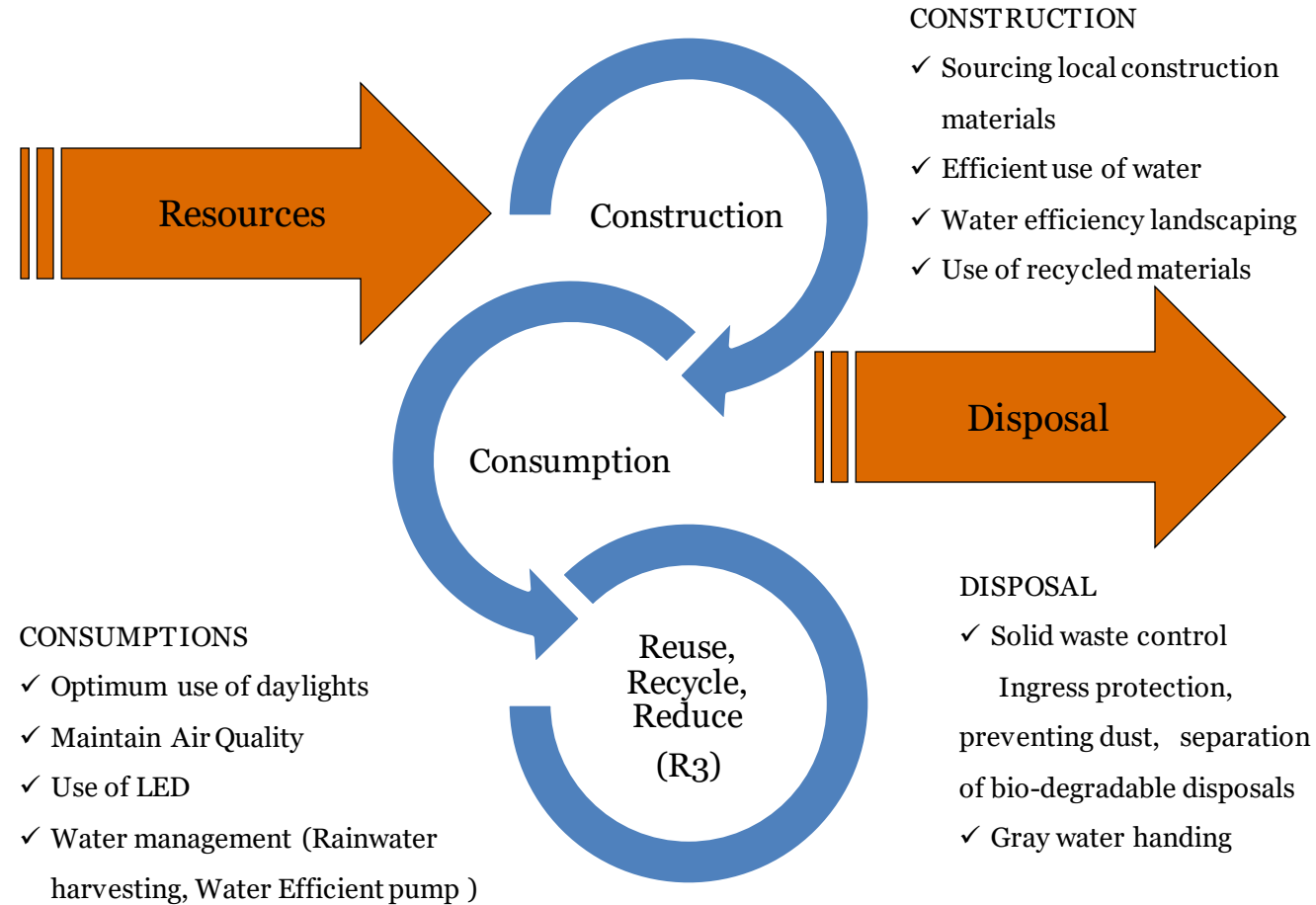
### Extended Product Life

Repair, reuse and remanufacturing are in this category, and in building there is vast potential for deconstruction (the disassembly of buildings) and the reuse of building materials. One step further is the design of buildings to be easily changed, repaired and disassembled.

### Materials recovery or recycling

This tends to require more energy, but some form of recycling will be ultimately necessary for every material at a point in its life cycle, no matter how durable, reused, or shared it has been.

# Life Cycle of Green Building





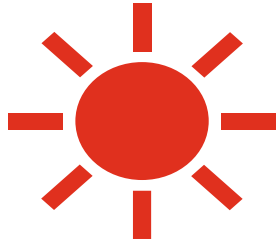
# GREEN RATING SYSTEMS



## Features that can make an Affordable building 'GREEN'



**Site  
Planning**



**Energy and  
Occupant  
Comfort**



**Water  
Saving**



**Waste  
Manageme  
nt**

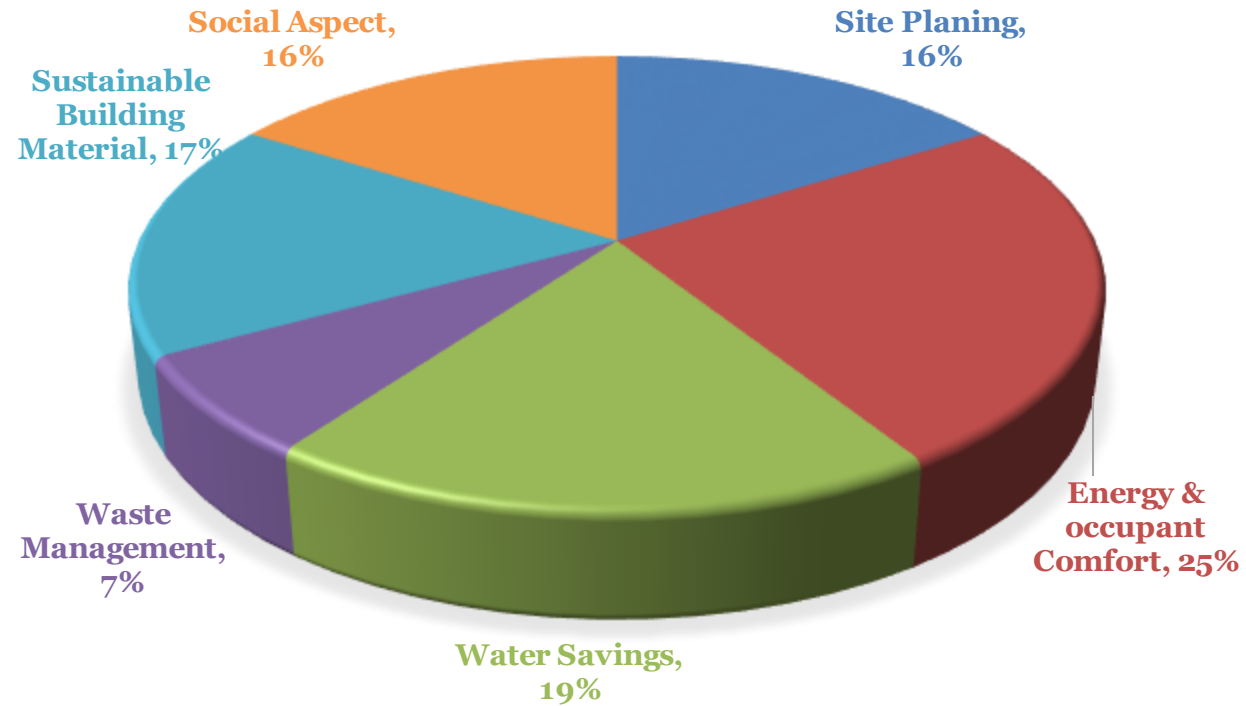


**Sustainable  
Building  
Material**



**Social  
Aspect**

# GRIHA Rating System: AFFORDABLE HOUSING



## POINTWEIGHTAGES

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

# Site Planning

1

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





# Site Planning

1



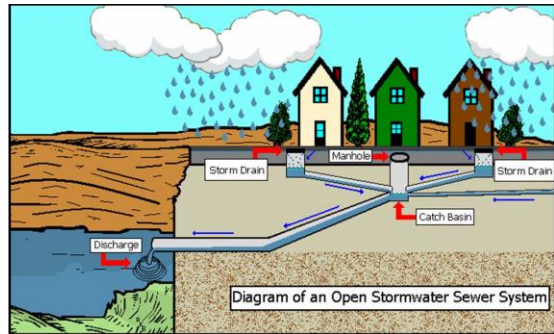
Vegetated Roof



SRI Coating



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



Storm water management  
(<https://www.thewatertreatments.com/>)



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



Mosaic tiles  
(<https://www.dreamstime.com/>)

Design to mitigate -UHIE

- SRI Coating, Grass pavers

Landscape preservation

- Protection mature trees

Storm Water management

Reduction in air and soil pollution

# Energy & Occupant Comfort

## Envelope Thermal Performance

- Peak Heat Gain Factor (W/Sq.m)
- Peak Cooling Load (W/Sq.m)

## Occupants visual comfort (Daylight)

- UDI
- Daylight Extent factor as per ECBC

## Efficient Lighting

- Minimum luminous efficacy 75 lumen/Watt
- **100% outdoor lighting**

## Energy Efficient Equipments

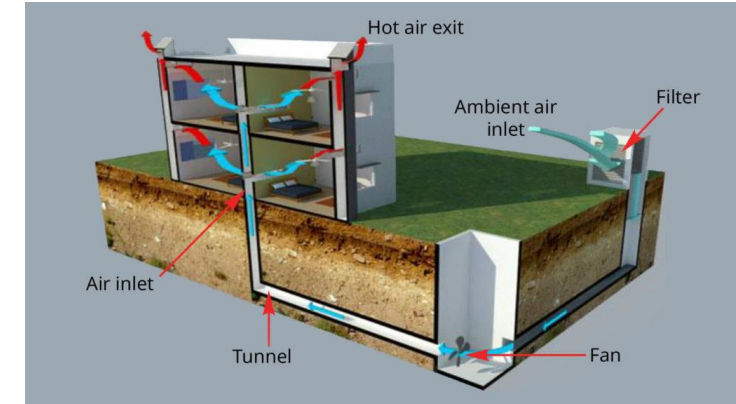
- At least BEE 3 Star Motor & Transformers

## Renewable Energy

- 1kWp per 500 sq.m

## Energy Metering

- **Dedicated energy meter in each DUs**



Earth Air System  
<https://>



BEE Star ratings

# Water Savings

3

## Efficient use of water during construction

- Gunny Bag/hessian cloth and ponding for curing
- Additives
- Use of treated wastewater/ captured rainwater

## Optimizing the Building & Landscape water demand

- **20% reduction w.r.t base case**
- Reduce the total landscape water requirement (Sprinkler Irrigation, Drip irrigation)

## Water Reuse

- Sewage Treatment Plant
- Reuse of treated and rain water

## Water Metering

- **Installation of the water meter**
- Sub-water meter in each DUs



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



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



Sprinkler



# Waste Management

4

## Construction Waste Management

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

## Post Construction Waste Management

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



<https://www.nbmcw.com/>

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

\*<https://www.cseindia.org/>

# Sustainable Building Materials

## Reduction in environmental impact of construction (Building Structure)

- Use of BIS recommended waste materials (OPC, aggregate, sand)
- Use of recycled materials (Steel frame, polystyrene components, Gypsum panels)
- Embodied energy calculation

## Use of low environmental impact materials in building interiors

- Stones from India
- Composite wood based product
- FSC Chain of custody certified products
- Products with 5% recycled content

## Use of recycled content in roads and pavements

- 8% (min) as per CPRI and IRC Guidelines

## Low VOC paints, adhesives, sealants and composite wood products

- VOC limit (g /litre) specified

## Zero ODP materials

- CFC, HCFCs free from Building insulation , HVAC & refrigeration equipment and fire fighting system

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



Compacted EPS Blocks



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

# Social Aspects

6

## Facilities for construction workers

- Compliance with NBC 2016 Safety norms
- Drinking water, hygienic working & living condition

## Universal Accessibility

- Measure to provide barrier free facilities for Specially abled persons and elderly persons

## Proximity of Transport and basic Services

- With in 500 metre transportation facilities
- Health Care, Education, Socio culture, market, sports, recreation, Bank (ATM) – 800 metre preferred

## Environmental Awareness

- Awareness tools (Brochure, poster etc.)

## Tobacco Smoke Control

- Zero exposure of non-smoking occupants

## Water Quality

- Conform to IS 10500-1991

## Provision to access clean sources of Cooking Fuel

- Basic infrastructure for PNG & LPG connection



Ramp for physically handicapped



## Q & A Session

## DAY 2

## Q & A Session

## DAY 2

## Vote of Thanks





# THANK YOU