
सत्यमेव जयते

Ministry of Housing
and Urban Affairs
Government of India

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

प्रधान मंत्री आवास योजना
Pradhan Mantri Awaas Yojana

Azadi Ka Amrit Mahotsav

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

# RACHNA 2.0

RESILIENT, AFFORDABLE AND COMFORTABLE HOUSING THROUGH NATIONAL ACTION

# CLIMATE SMART BUILDINGS

Training #47 (RACHNA 2.0) : 1 Day Training Program for senior govt. officials at Panchkula

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

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

Ministry of Housing and Urban Affairs
Government of India

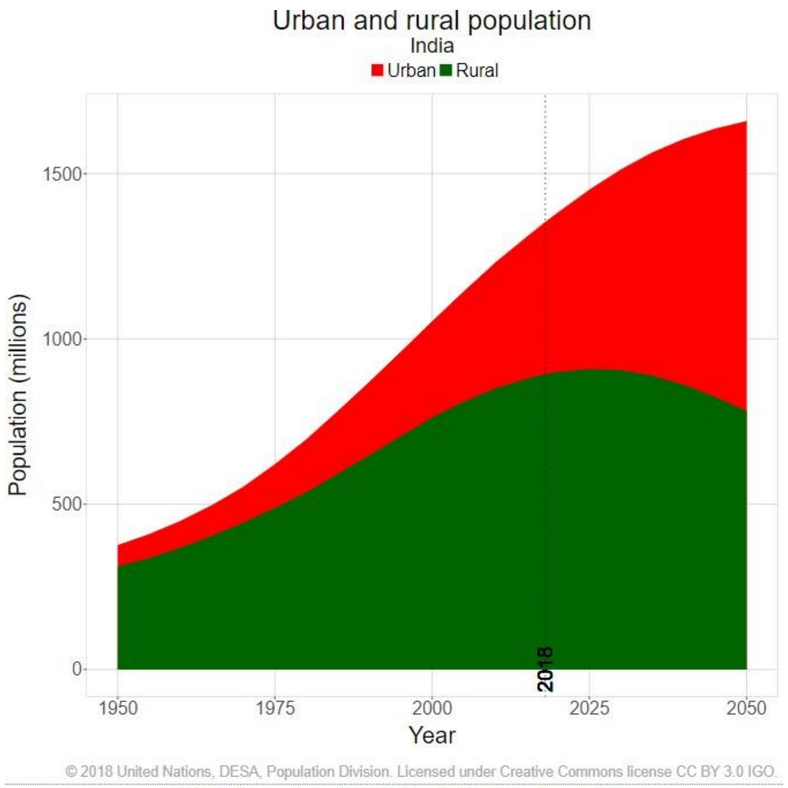
Azadi Ka Amrit Mahotsav

giz

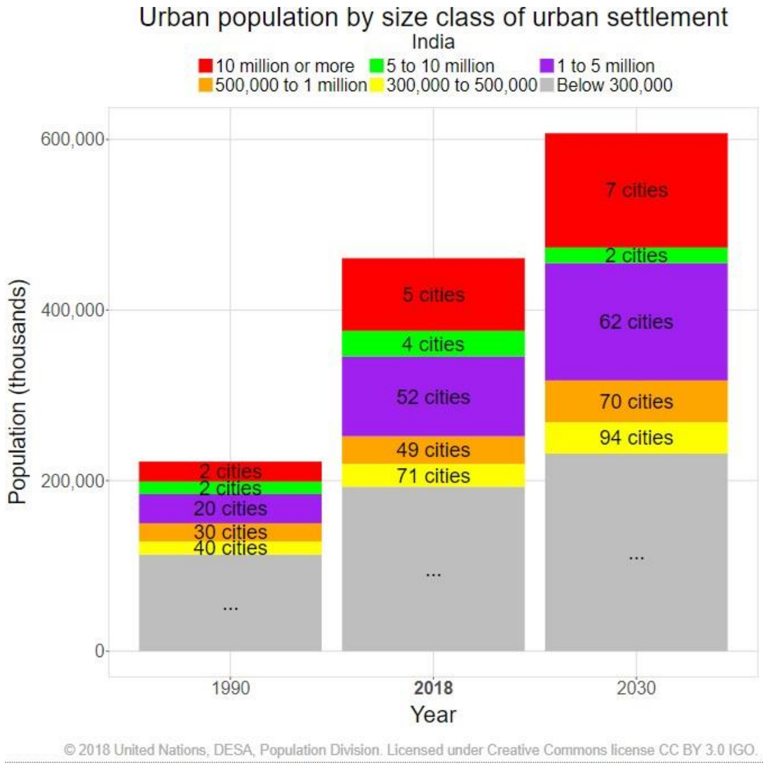
# 01

# INTRODUCTION

# Growing Opportunities with Rapid Urbanization

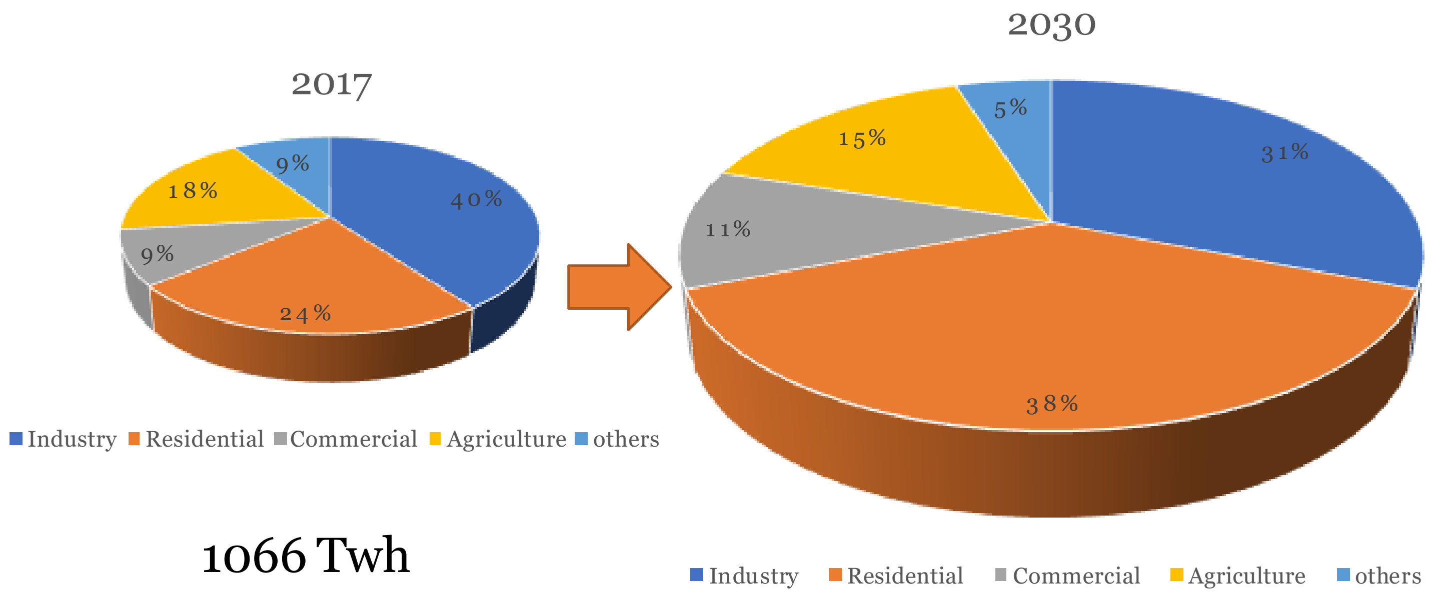



***Note:*** Urban and rural population in the current country.




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




2239 Twh

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

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

# MoHUA Initiates for Urban Transformation

1. RAY
2. PMAY (U)
3. DAY - NULM
4. HRIDAY
5. AMRUT
6. Smart Cities Mission
7. JNNURM

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.

**PMAY U Features**

- All weather housing units with water, kitchen, Electricity & Toilets
- Women Empowerment
- Better quality of life for Urban Poor's
- Security of Tenure
- Adequate Physical and Social Infrastructure

# Pradhan Mantri Awas Yojna – Urban

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

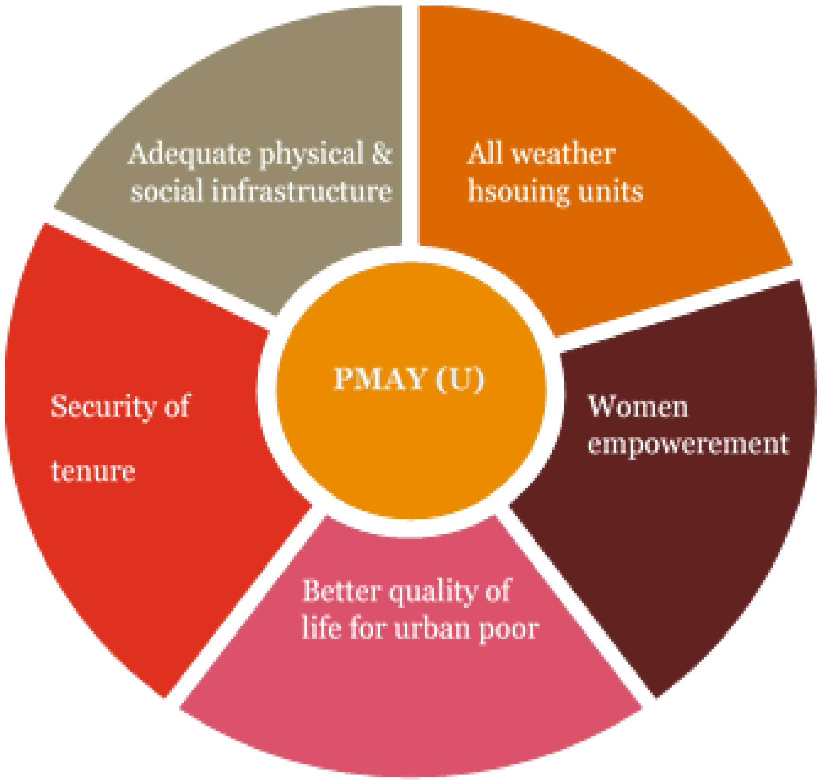
- Subsidiary for beneficiary led individual house construction/enhancement. In-Situ Slum Redevelopment (ISSR) for Slums
- Affordable housing in partnership with Public & Private Sectors
- Promotion of Affordable Housing through Credit linked subsidy
- Slum rehabilitation of Slum dwellers with participation of private developers using Land as a resource

# 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)

# Events organized by MoHUA w.r.t. GHTC India Challenge

**GHTC-India Launch: 14th Jan 2019**



**Indian Housing Technology Mela, Lucknow: 5th Oct 2021**



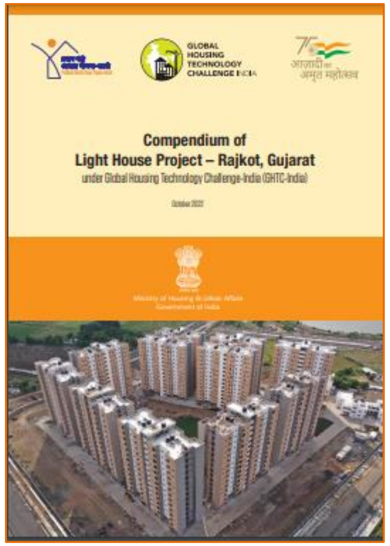
**Indian Urban Housing Conclave, Rajkot: 19th Oct 2022**



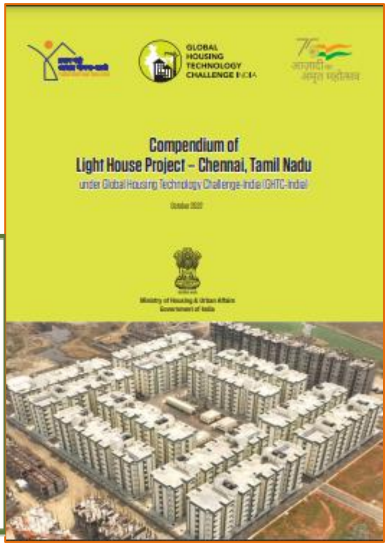


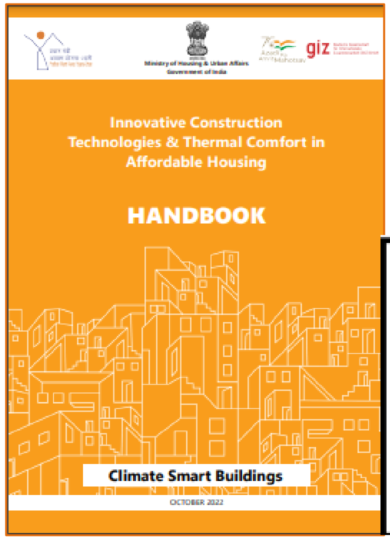
# Book Launches by MoHUA under GHTC India Challenge

## Compendium of Light House Project Rajkot

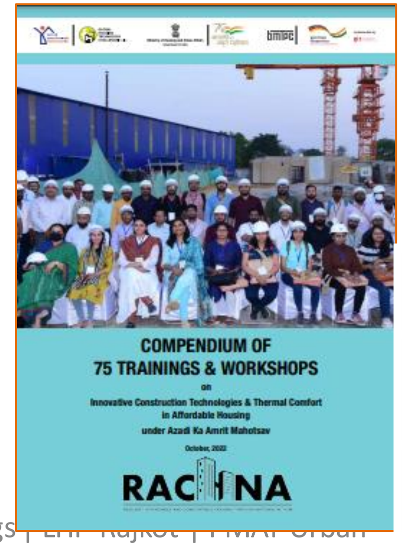



## Compendium of Light House Project Chennai




## Handbook on Innovative Construction Technologies & Thermal Comfort




## Compendium of 75 Trainings & Workshops under RACHNA

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

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

Ministry of Housing and Urban Affairs
Government of India

Azadi Ka Amrit Mahotsav

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

# Climate Smart Buildings Programme (IGEN-CSB)

Government of India/ MoHUA

+

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

→ IGEN-CSB

Affordable

Climate Smart Building

Climate Resilient

Thermally Comfortable

Key features of a Climate Smart Building

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

Curtail 30 metric tonnes of $CO_2$

Improve health and wellbeing of people

Support the commitment of GoI towards reducing $CO_2$ emissions


Results of a Climate responsive building design

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

| | | | | | |
|---|---|---|---|---|---|
| **Chandigarh** | **Dadar & Nagar Haveli, Daman & Diu** | **Gujarat** | **Haryana** | **Punjab** | **Rajasthan** |

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

# Tea Break

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

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

Ministry of Housing and Urban Affairs
Government of India

Azadi Ka Amrit Mahotsav

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

# 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 buildings around thermal comfort & sustainable construction

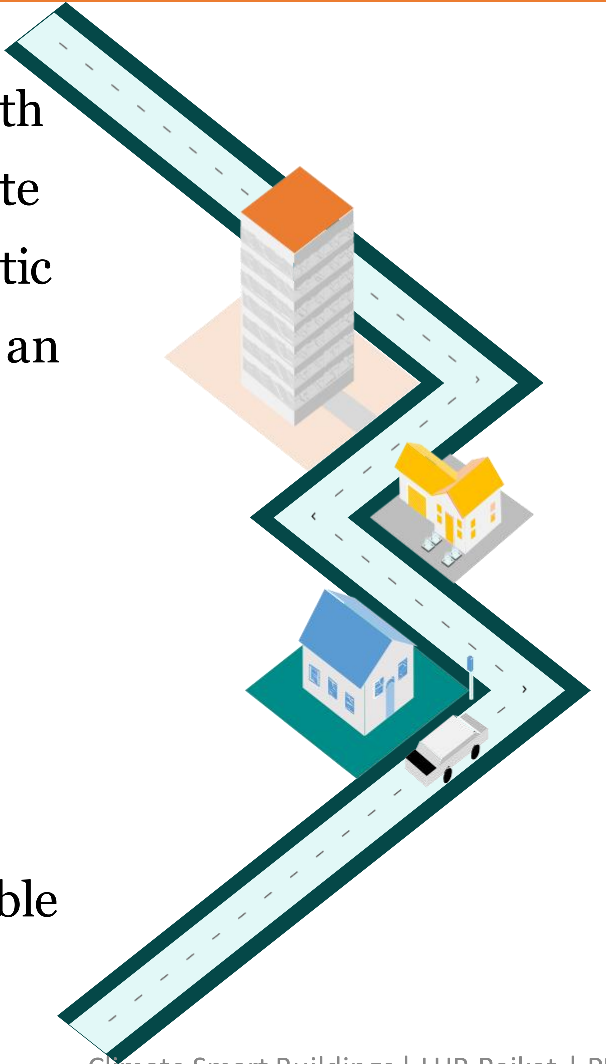
## Outcome

- 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 will be made up of 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 |
| Ranchi, Jharkhand | Precast Concrete Construction System – 3D Volumetric | 1008 |
| 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 1,000 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

A model housing project with approximate 1,000 houses built with shortlisted Construction technology under GHTC Challenge, demonstrating speed, economy and better quality of construction in a sustainable manner

## Available on-site facilities

A model housing project with approximate 1,000 houses built with shortlisted Construction technology under GHTC Challenge, demonstrating speed, economy and better quality of construction in a sustainable manner

## Design

- 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), Ujjwalla, 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.

## Construction Period

A model housing project with approximate 1,000 houses built with shortlisted Construction technology under GHTC Challenge, demonstrating speed, economy and better quality of construction in a sustainable manner

# Construction Methodology of LHP Rajkot

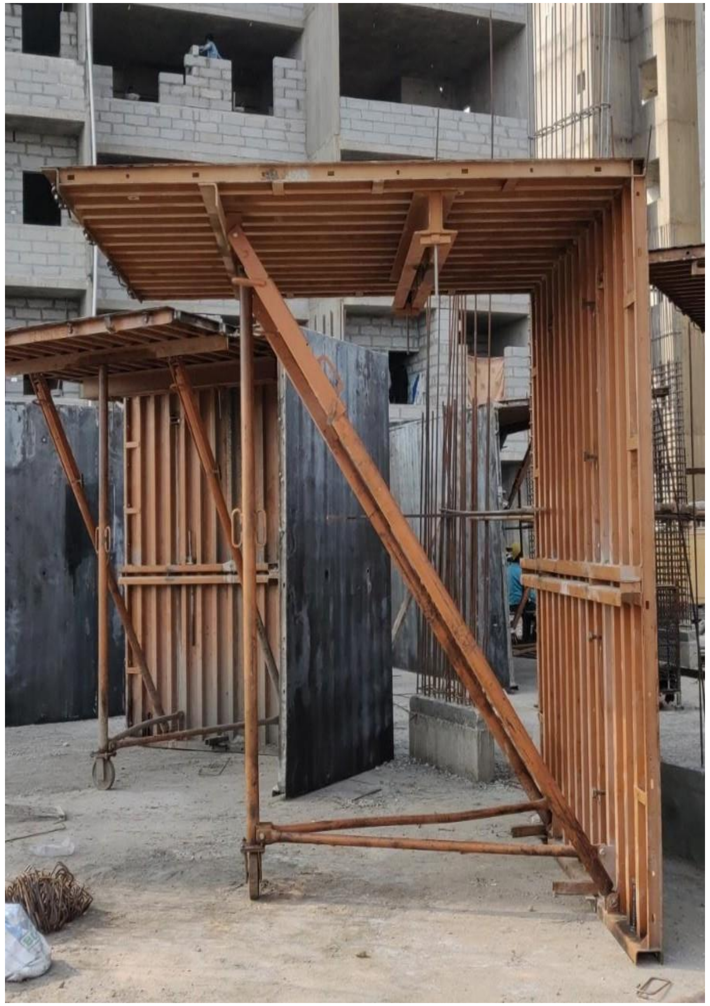
## Monolithic Concrete Construction using Tunnel Formwork

Tunnel formwork is a mechanised cellular structure construction system. It is made up of two half shells that are joined to make a room or a cell. An apartment is made up of several cells.

Tunnel forms allow walls and slabs to be cast in one day through several phases to the structure. The programme and the amount of floor area that can be poured in one day define the phasing. The task to be done each day is defined by the 24-Hour cycle. In the morning, the formwork is set up for the day's pour. In the afternoon, the reinforcement and services are installed, and concrete is poured. Concrete for walls and slabs must be poured in one operation once reinforcing has been installed. Early in the morning, the formwork is removed and positioned for the next phase.

The assembly-line approach of the system to construction provides developers and contractors with benefits relating to the certainty of their site schedule, efficient time management and an overall reduction in cost. This enables companies to develop a better quality, monolithic structure that is more acoustically and thermally efficient. The repetitive nature of tunnel form tasks ensures high productivity, and optimum use of labour and these are of considerable benefit to the project manager.

This formwork is manufactured in a completely automated facility in France and there is no manufacturing plant in India.



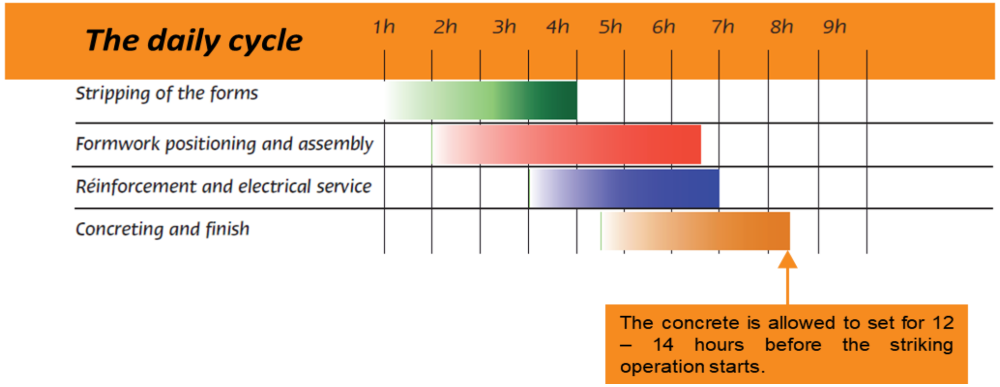
GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA | प्रधान मंत्री आवास योजना-शहरी (Pradhan Mantri Awas Yojana-Urban) | Ministry of Housing and Urban Affairs, Government of India | Azadi Ka Amrit Mahotsav | giz

# Construction Methodology – 24 Hour Cycle

1. Stripping of the formwork from previous day
2. Positioning of the formwork for the current day's phase, with the installation of mechanical, electrical and plumbing services
3. Installation of reinforcement in walls and slabs
4. Concreting and if necessary, the heating equipment

The implementation of 24-Hour Cycle shall be in accordance with IS 456:2000 – Code of practice for plain and reinforced concrete. However, the structural engineer shall furnish details about the actual process of removal of formwork after casting of concrete

The task to be done each day is defined by the 24-Hour cycle. The overall structure is divided into a number of more or less comparable construction phases, each matching to a day's work, to establish this cycle. The amount of labour and equipment required is then calculated based on the magnitude of these phases. Every day, the phases are similar to achieve optimal efficiency.



# 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 SystemAgartala, Tripura**

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

**PVC Stay in Place Formwork System**

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

# 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 Assembeled 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 requited 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 Assembeled 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.

# 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

# 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.

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

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

Ministry of Housing and Urban Affairs
Government of India

Azadi Ka Amrit Mahotsav

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

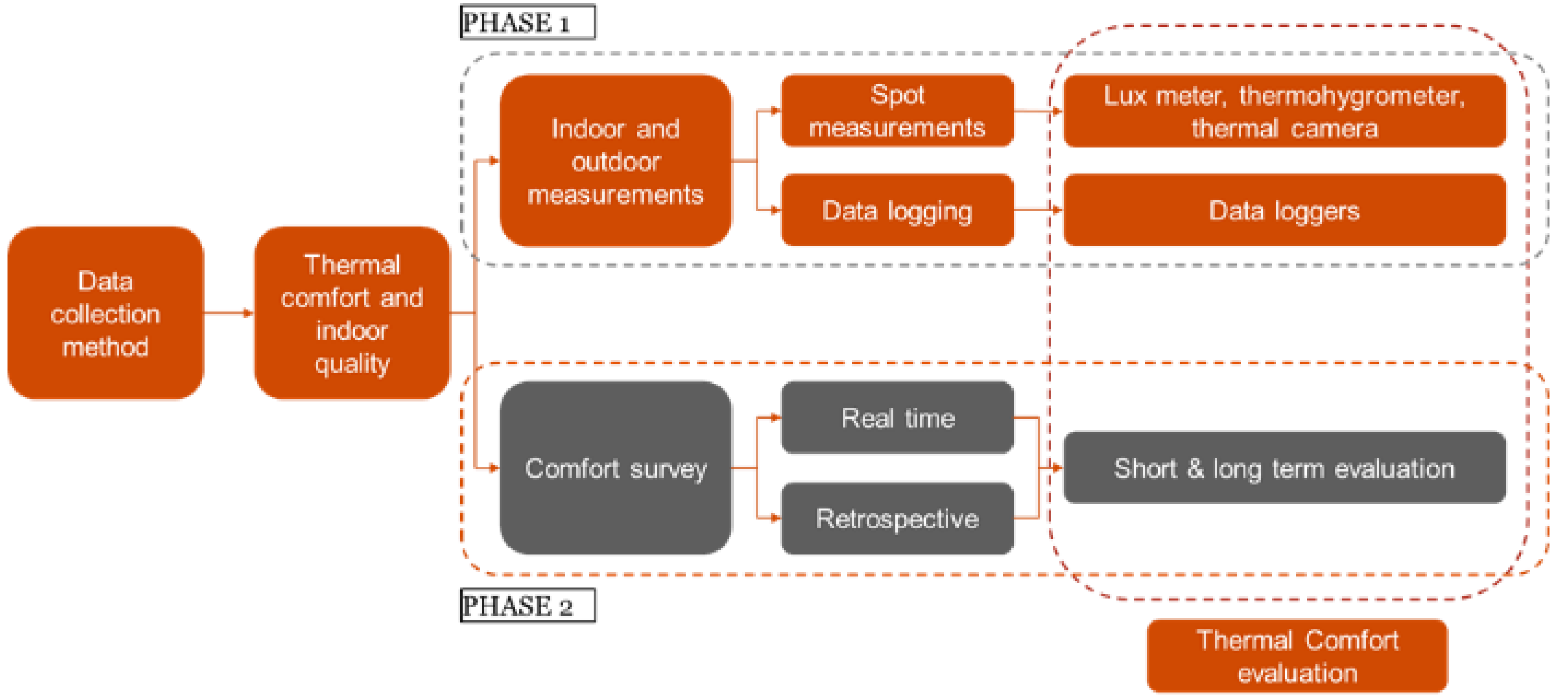
# 03

# Thermal Comfort Analysis & Recommendations on LHPs and Demo Projects

# 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.

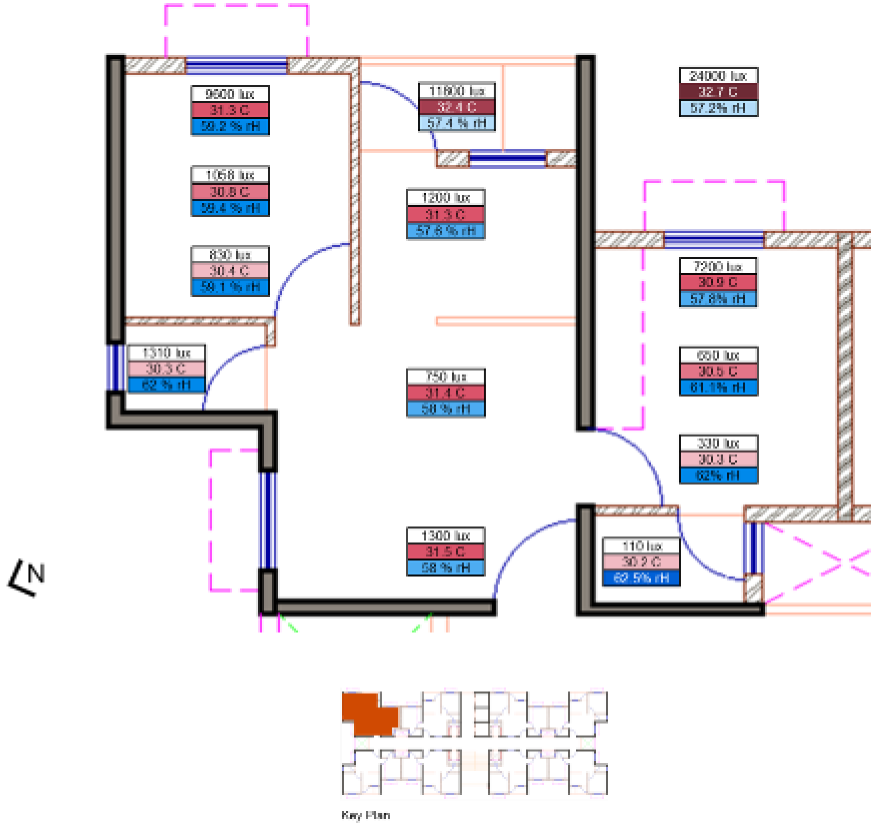



## Methodology for monitoring and evaluation

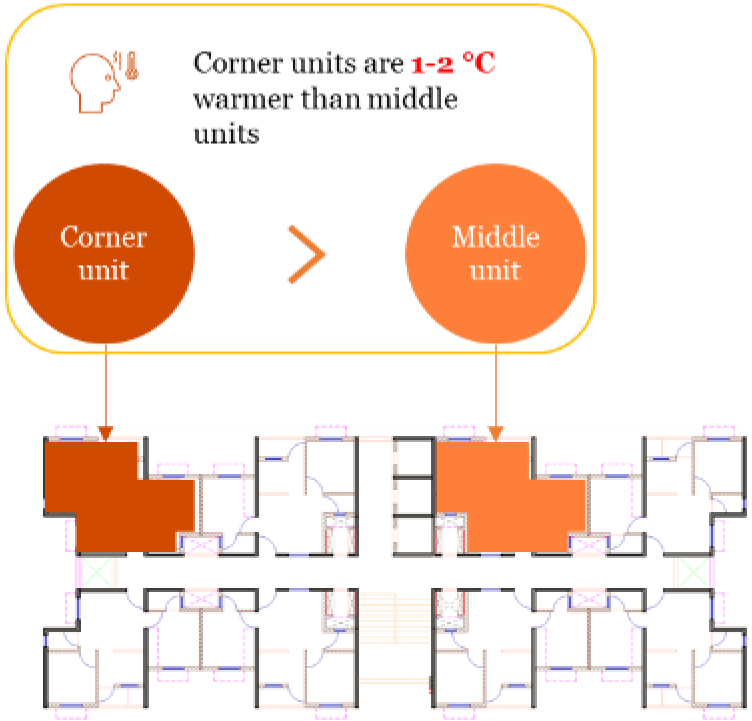
- On-site spot measurements
- dataloggers,
- comparative graphs, and
- a comfort chart

# Thermal comfort study of the Light House Project- Rajkot

## On-site spot measurements




## Findings

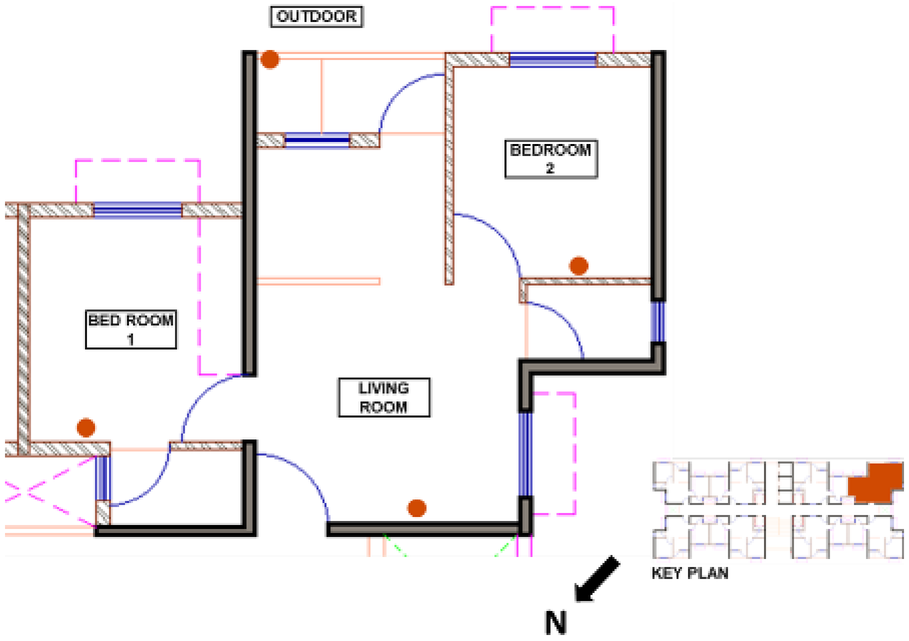
Global Housing Technology Challenge India | प्रधान मंत्री आवास योजना-शहरी Pradhan Mantri Awas Yojana-Urban | Ministry of Housing and Urban Affairs, Government of India | Azadi Ka Amrit Mahotsav | giz

# Thermal comfort study of the Light House Project- Rajkot

## Findings (Cont.)

# Thermal comfort study of the Light House Project- Rajkot

## Datalogger placement

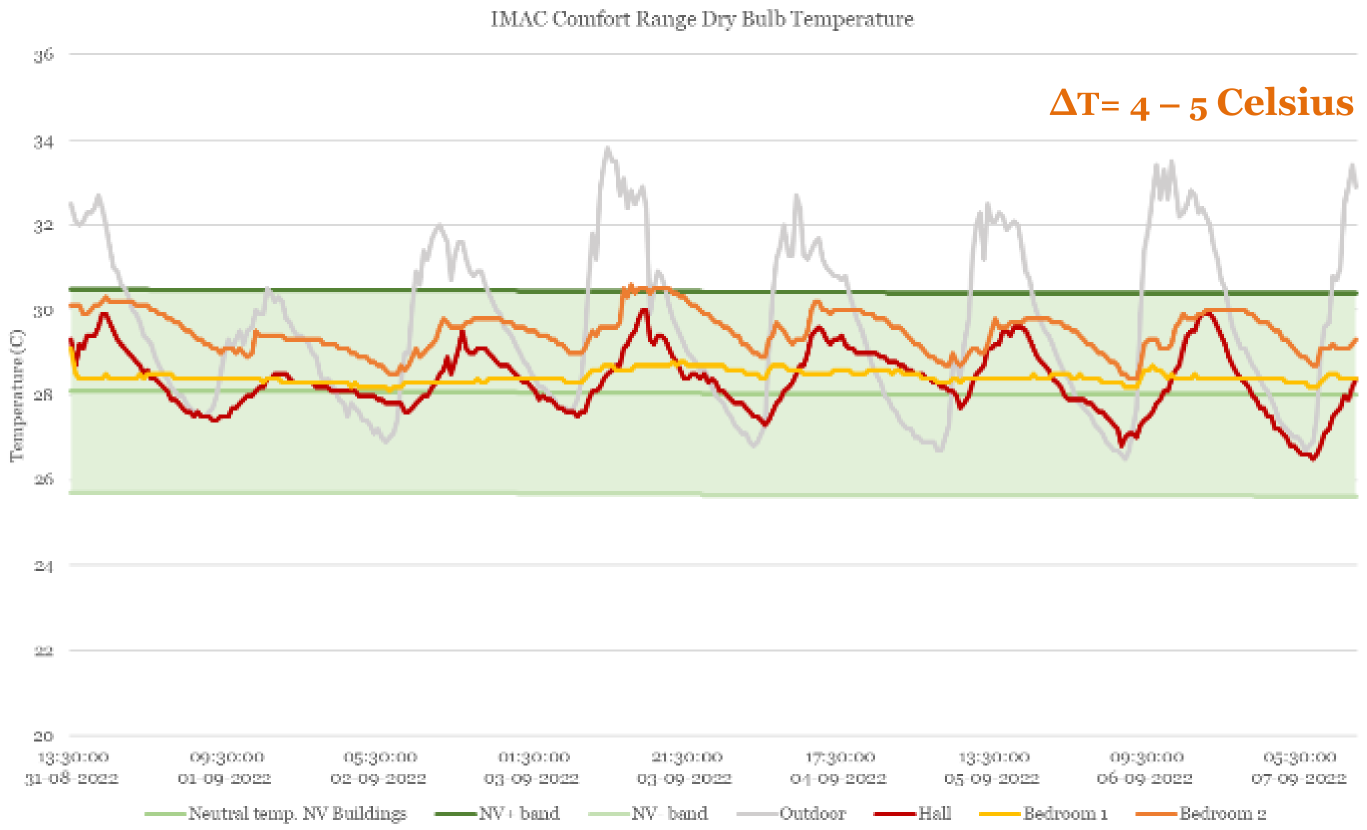



Location: Tower 8 | 1st floor | Corner unit

Occupancy: 9 am to 5 pm

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

## Findings

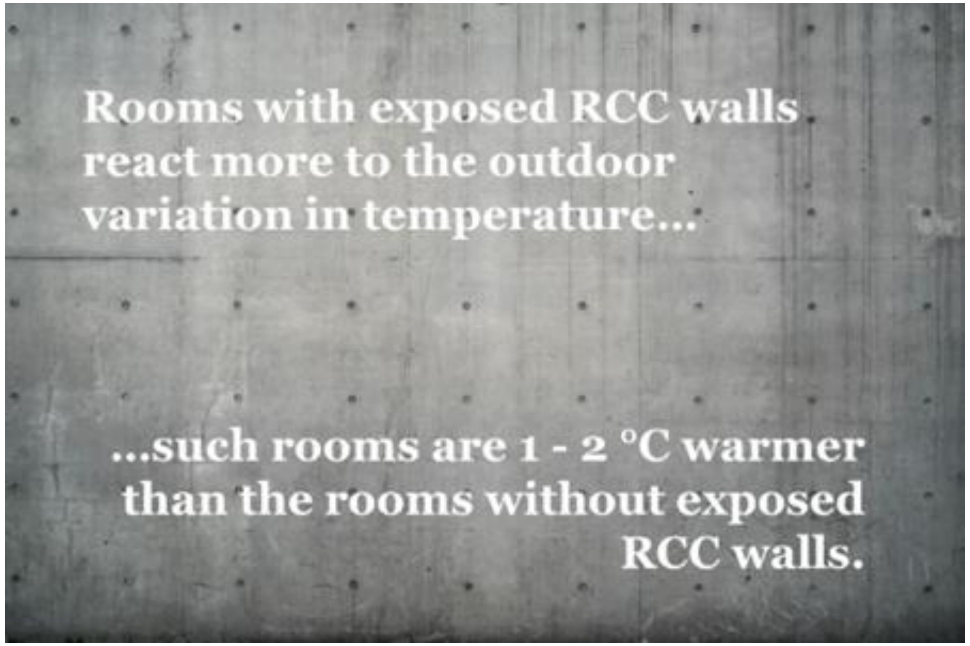



The data loggers readings from Wednesday, 31st August to 7th September 2022.

# Thermal comfort study of the Light House Project- Rajkot

## Findings (Cont.)


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



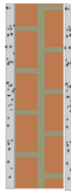

**RCC walls have no insulation properties, and they heat and cool more rapidly based on outdoor conditions**

# Key performance features of the Light House Project- Rajkot

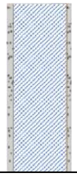
| | |
|---|---|
| **Saved kWh of Power due to reduction in construction time]** | **215051 kWh** saved. Typical saving is **4.72 kWh/Sq. mtr** compared to building construction using conventional method. |
| **% reduction in cost of construction** | **10%** [Faster construction speed leading to reduction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

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

## Conventional Construction Envelope Details

| Envelope Type | Conventional Case - 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/m2K |
| Roof | Interior Surface Film resistance + External Cement Mortar (18mm) + RCC slab (150mm) + Internal Cement Mortar (12mm) + Exterior Surface film resistance |  | 2.78 W/m2K |
| Fenestration & Glazing | Steel framed Single Glazing Unit (SGU) with 5mm glass, SHGC = 0.84, VLT = 0.89 |  | 6.2 W/m2K |
| Void | Assumed SHGC = 1, VLT = 1 | | 7W/m2K |
| RETV | Residential Envelope Transmittance Value (North-South Blocks) | | 16.64 W/m2 |

## LHP Rajkot Construction Envelope Details

| Envelope Type | LHP Case - 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/m2K |
| 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/m2K |
| Fenestration & Glazing | uPVC framed SGU with 5mm glass thickness, SHGC = 0.83, VLT = 0.89 |  | 5.9 W/m2K |
| Void | Assumed SHGC = 1, VLT = 1 | | 7W/m2K |
| RETV | Residential Envelope Transmittance Value (North-South Blocks) | | 14.32 W/m2 |

# CASE STUDY OF DEMO PROJECTS

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

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

Ministry of Housing and Urban Affairs
Government of India

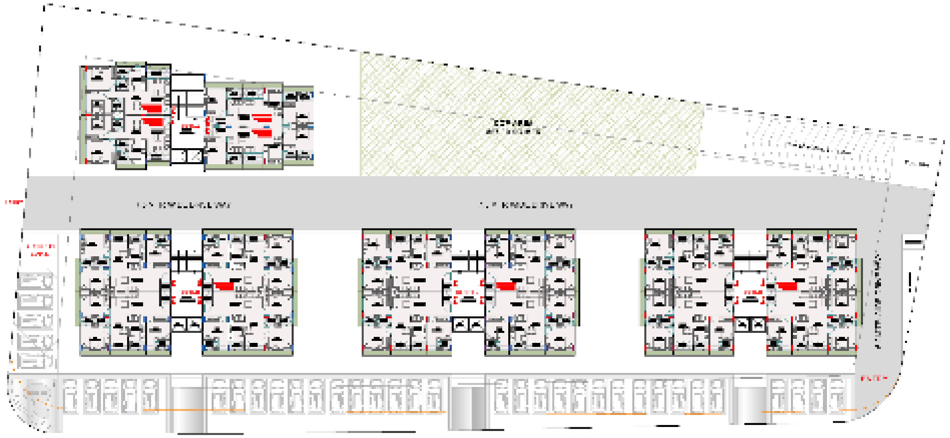
Azadi Ka Amrit Mahotsav

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

# The Demonstration Housing Projects

Under the Climate Smart Buildings Project in Western Cluster, the CSB Cell have identified and are supporting 2 no. of upcoming affordable housing projects in Ahmedabad to achieve minimum Thermal Comfort standards of MoHUA – GoI.

**Zundal, AUDA Project, Ahmedabad**

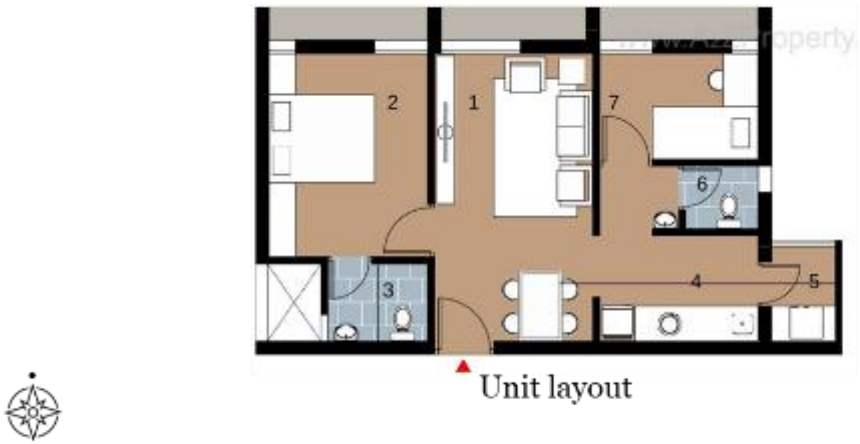


**Re-anand, Ahmedabad**

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 improvemnets for Demonstration Housing Project

## Zundal, AUDA AHP project, Ahmedabad




Unit layout

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 W/m².k | RETV W/m² | ENS Part 1 Compliance | ENS Score |
|---|---|---|---|---|
| WALL<br>ACC 150mm + plaster | 0.86 | 11 | ✓ | 132 |
| WINDOW<br>Aluminium + single glazed | 5.8 | | | |
| ROOF<br>120mm concrete slab | 2.94 | - | ✗ | |

**With improvements**

| Element | U value W/m².k | RETV W/m² | ENS Part 1 Compliance | ENS Score |
|---|---|---|---|---|
| WALL<br>ACC 150mm + plaster | 0.86 | 11 | ✓ | 140 |
| WINDOW<br>Aluminium + single glazed | 5.8 | | | |
| ROOF<br>150mm concrete slab + EPS Insulation | 0.7 | - | ✓ | |

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

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

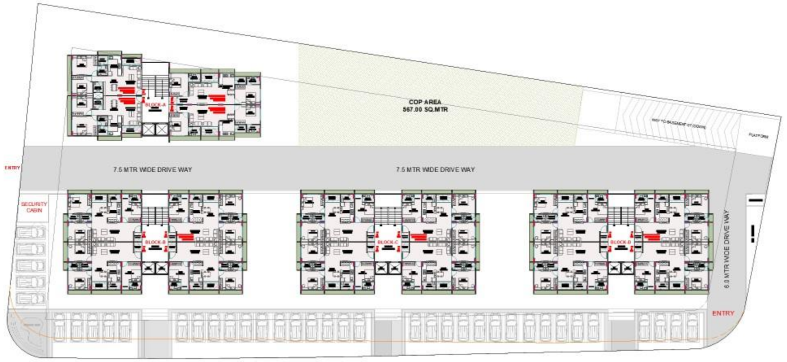
Ministry of Housing and Urban Affairs Government of India

Azadi Ka Amrit Mahotsav

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

# ENS compliance and recommendations for Demonstration Housing Project

## Re-anand, Private APH project, Ahmedabad



Site layout


Unit layout

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 $W/m^2.k$ | RETV $W/m^2$ | ENS Part 1 Compliance | ENS Score |
|---|---|---|---|---|
| WALL<br>ACC 200mm + plaster | 0.68 | 11.2 | ✓ | 132 |
| WINDOW<br>Aluminium + single glazed | 5.8 | | | |
| ROOF<br>150mm concrete slab | 2.8 | - | ✗ | |

**With improvements**

| Element | U value $W/m^2.k$ | RETV $W/m^2$ | ENS Part 1 Compliance | ENS Score |
|---|---|---|---|---|
| WALL<br>ACC 200mm + plaster | 0.68 | 11.2 | ✓ | 140 |
| WINDOW<br>Aluminium + single glazed | 5.8 | | | |
| ROOF<br>150mm concrete slab + EPS Insulation | 0.6 | - | ✓ | |

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

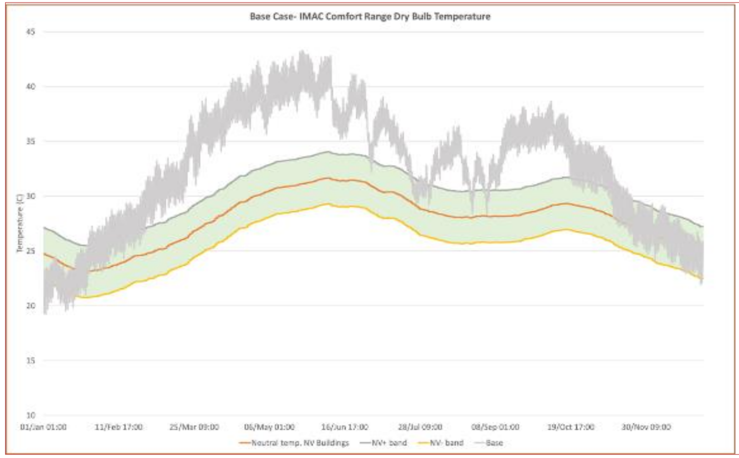
प्रधान मंत्री आवास योजना-शहरी
Pradhan Mantri Awas Yojana-Urban

Ministry of Housing and Urban Affairs
Government of India

Azadi Ka Amrit Mahotsav

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

# Thermal Performance of the Demonstration Housing Project




**ROOF**

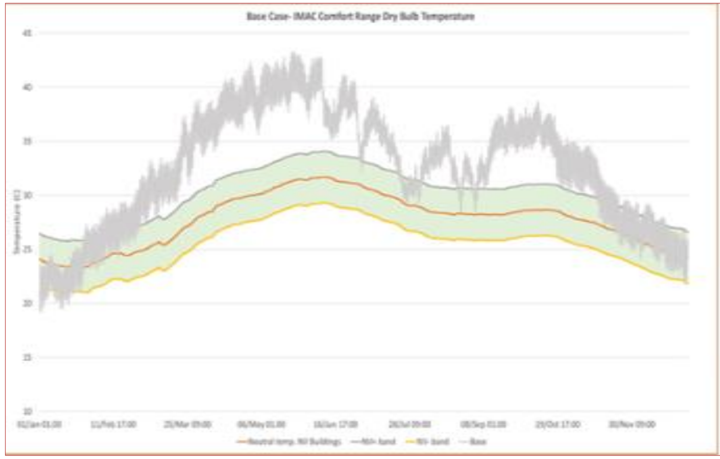
150mm concrete slab

**ANNUAL DISCOMFORT HOURS**

6539 hours

74% of the time in a year the units in the top floor remain uncomfortable

**Re – anand Project - Thermal Performance of the top floor unit – without insulation.**




**ROOF**

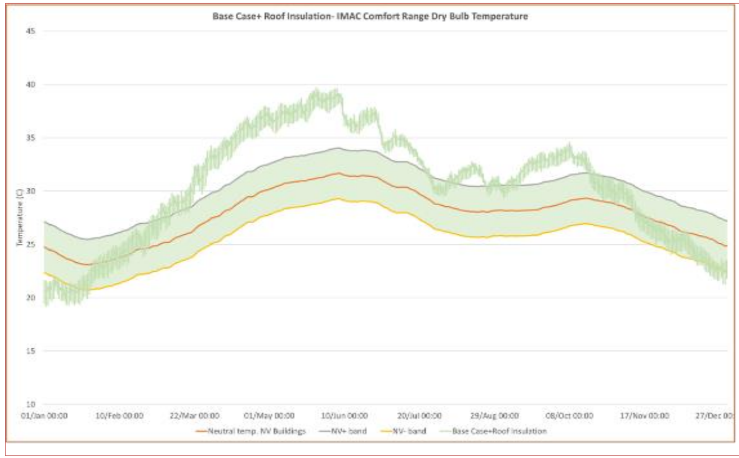
150mm concrete slab

**ANNUAL DISCOMFORT HOURS**

6606 hours

75% of the time in a year the units in the top floor remain uncomfortable

**Zundal AHP Project - Thermal Performance of the top floor unit – without insulation.**




**ROOF**

150mm concrete slab + 50mm EPS insulation

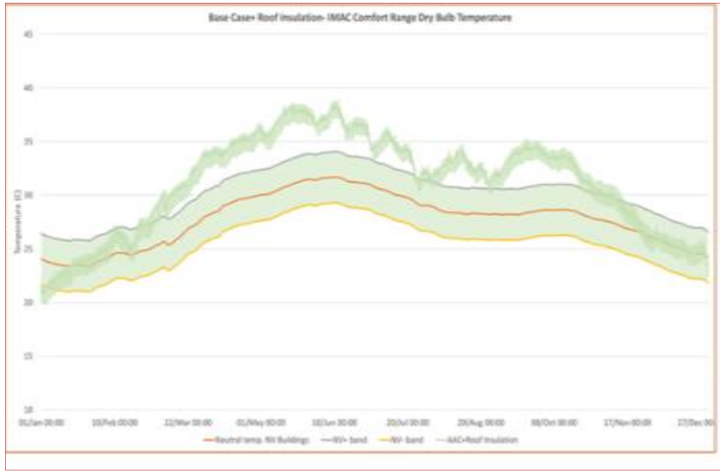
**ANNUAL DISCOMFORT HOURS**

5614 hours

64% of the time in a year the units in the top floor remain uncomfortable

Roof insulation provides 14% less discomfort hours when compared to roof without insulation

**Re – anand Project - Thermal Performance of the top floor unit – with insulation.**




**ROOF**

150mm concrete slab + 50mm EPS insulation

**ANNUAL DISCOMFORT HOURS**

6008 hours

68% of the time in a year the units in the top floor remain uncomfortable

Roof insulation provides 9% less discomfort hours when compared to roof without insulation

**Zundal AHP Project - Thermal Performance of the top floor unit – with insulation.**

# Recommendations

Proper orientation of Buildings, this reduce the impact of unfavorable weather conditions like solar radiation, driving rain and thunderstorm

Proper Ventilation – Proper positioning the windows and opening them create air movement in the house. Walls and vegetation should not be too close to the building in order to avoid diversion of wind away from the openings, thereby reducing air flow within the building. If possible, the rooms should be cross ventilated.

Using Shading Device – use of overhangs or horizontal projections over windows. Double pane windows with tinted glass and glass coated with reflective film should be used for windows instead of steels, wood and zincs.

Creation of Microclimate – trees can be planted to create micro – climate that is, small-scale climatic condition at a spot or area or site

Preventing Infiltration – Infiltration can be prevented by sealing the sites of air leaks. This can be achieved by caulking, weatherizing, good workmanship, and replacing some aged parts of buildings, etc.

# Recommendations

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

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

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

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

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

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

Ministry of Housing and Urban Affairs
Government of India

Azadi Ka Amrit Mahotsav

giz

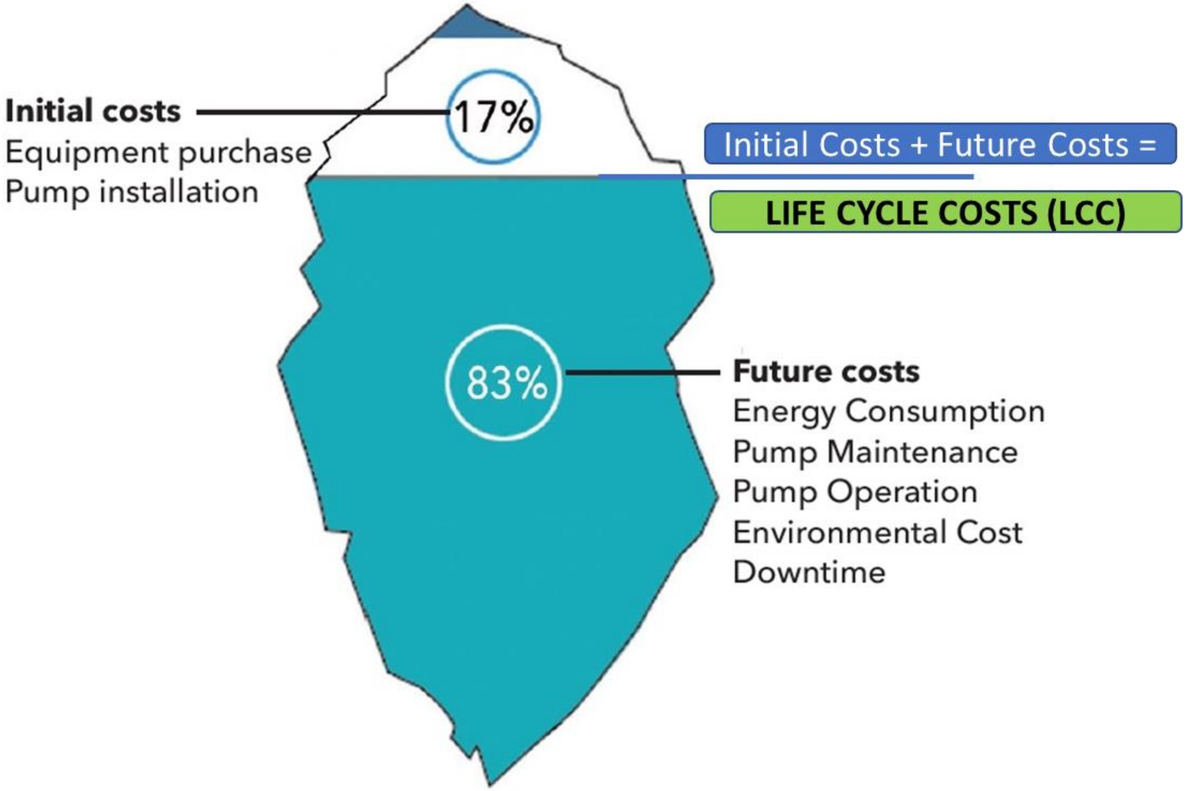
# 04

# 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

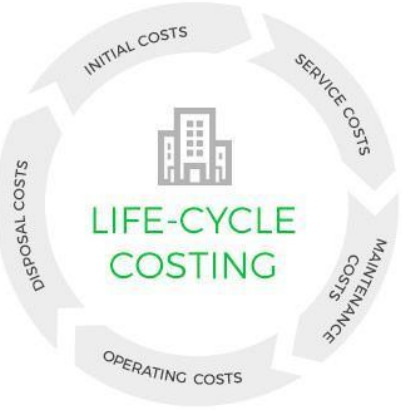
## Why LCC matters in sustainable building

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

Concept of life cycle cost and its impact on carbon emission

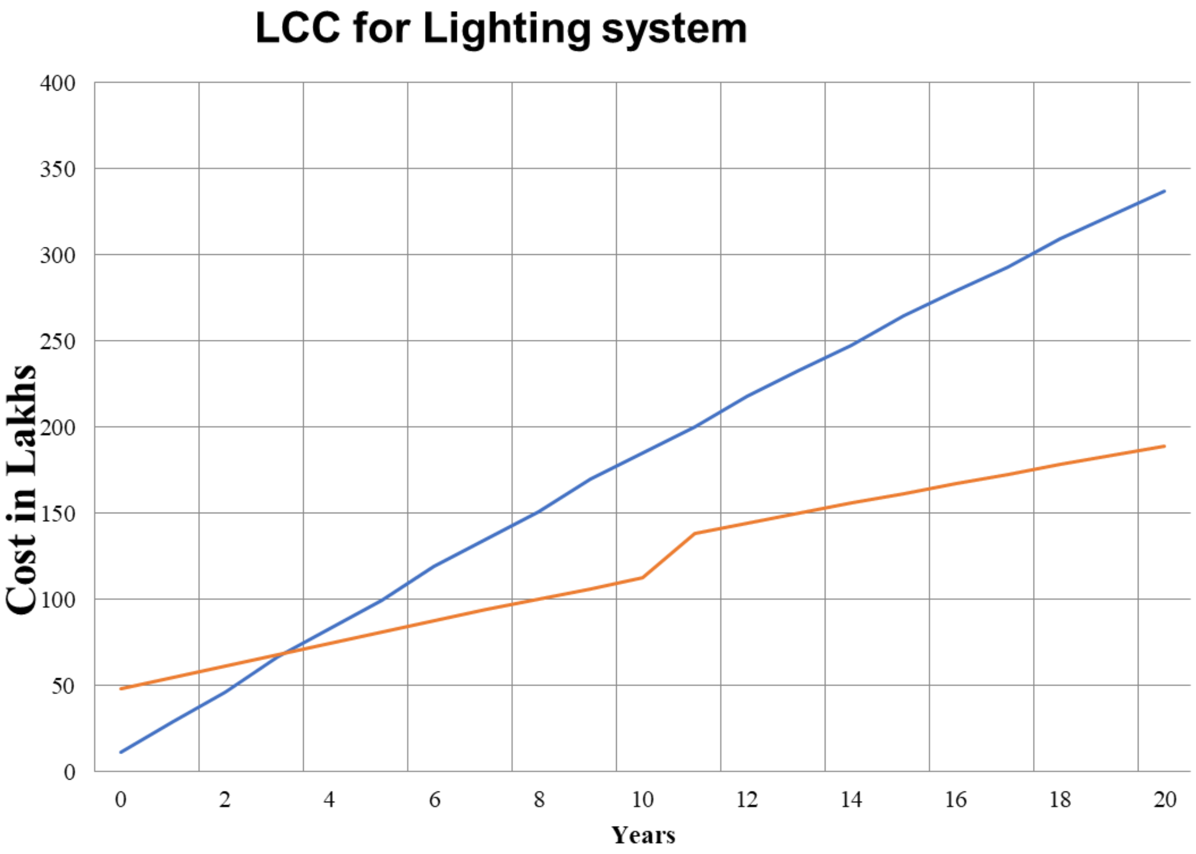
## Why LCC matters in sustainable building


**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

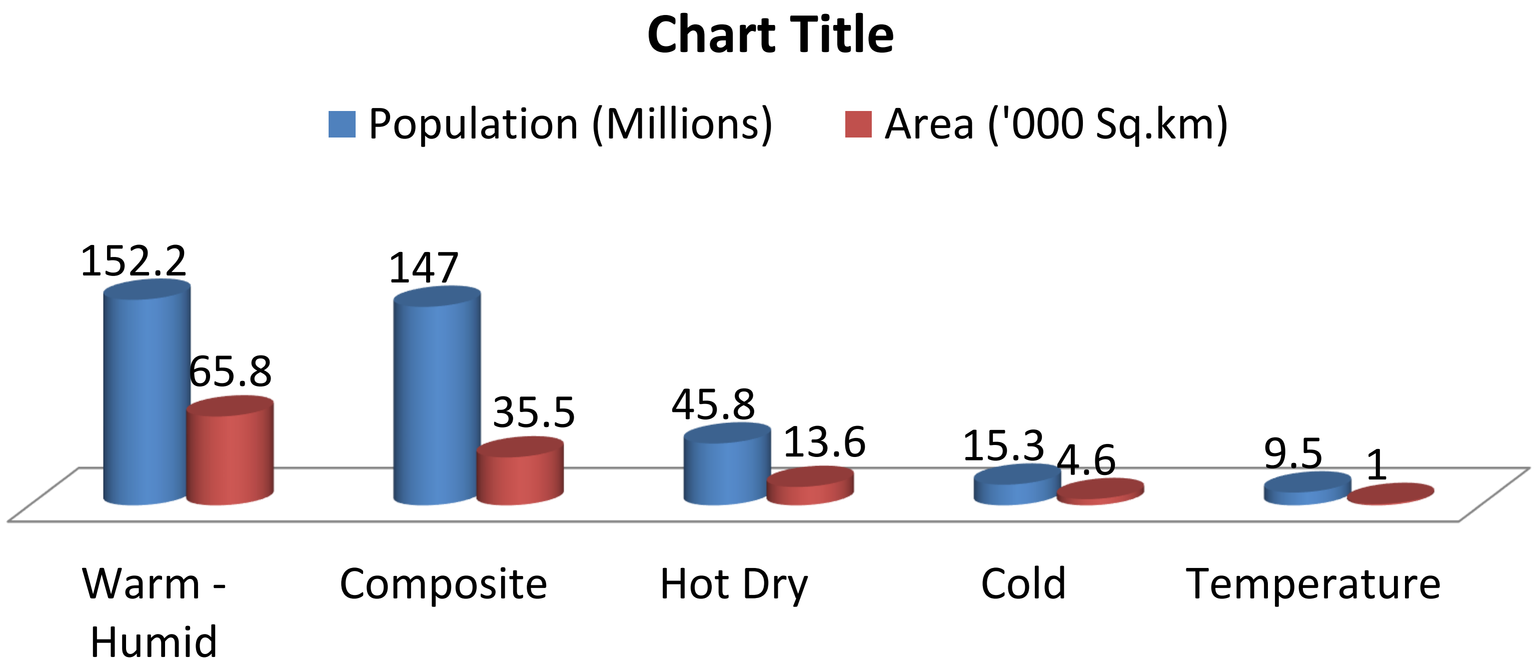
# Q&A Session on New & Innovative technologies and Thermal Comfort

# Session 2: Importance of Thermal Comfort

# 05

# Thermal Comfort and Cooling Demand

# Thermal Comfort & Cooling Demand

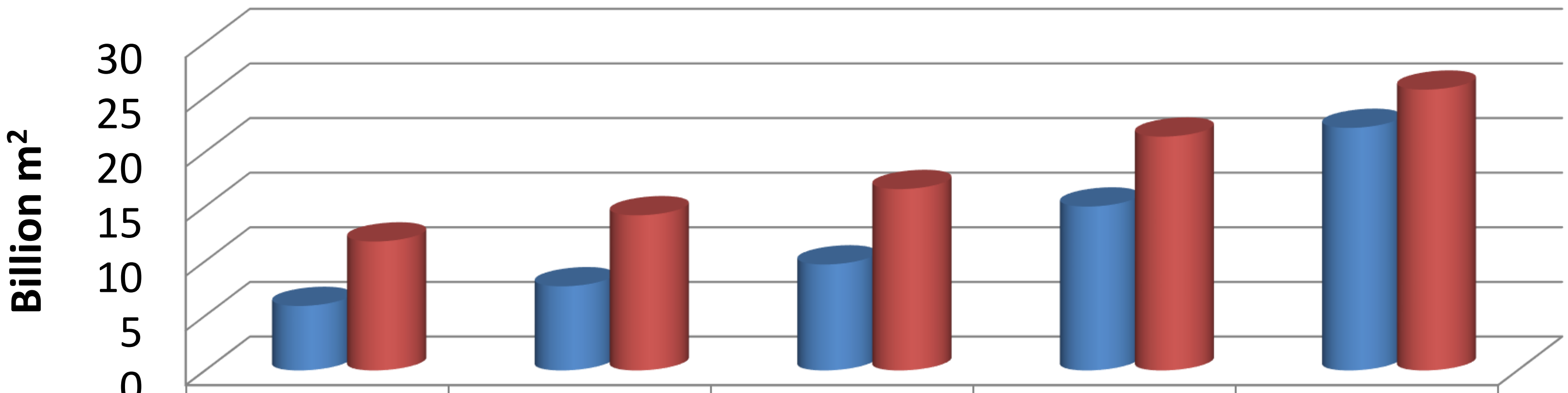



Population and area distribution in the five climate zones of India. Source: "Census 2011", Government of India, (2011), available at: http://www.censusindia.gov.in/2011census/ dchb/DCHB.html

- 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.

# Thermal Comfort & Cooling Demand

**Residential Build – Up Area (Billion $m^2$)**



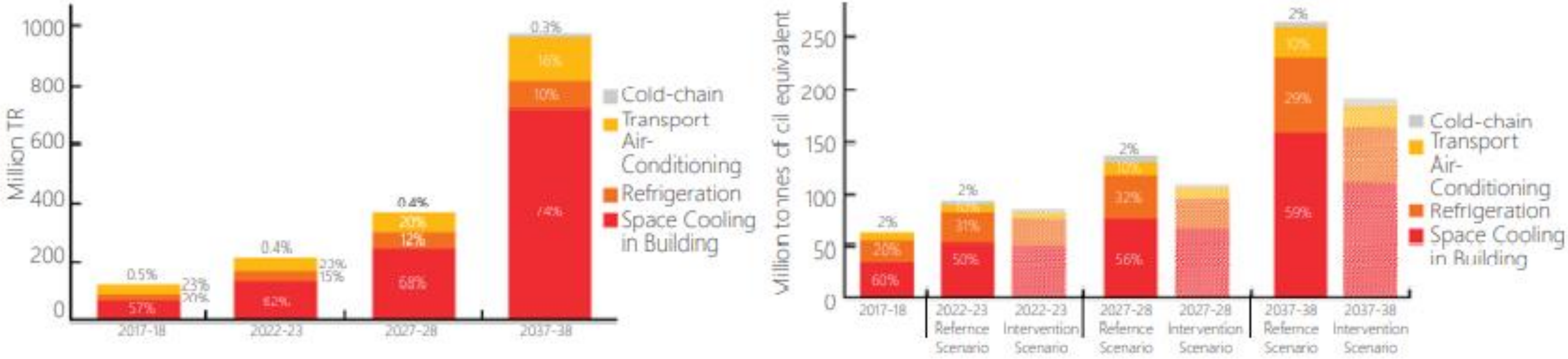

| | 2020 | 2025 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|
| Urban | 5.9 | 7.7 | 9.7 | 15 | 22.2 |
| Rural | 11.8 | 14.2 | 16.6 | 21.4 | 25.7 |

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)

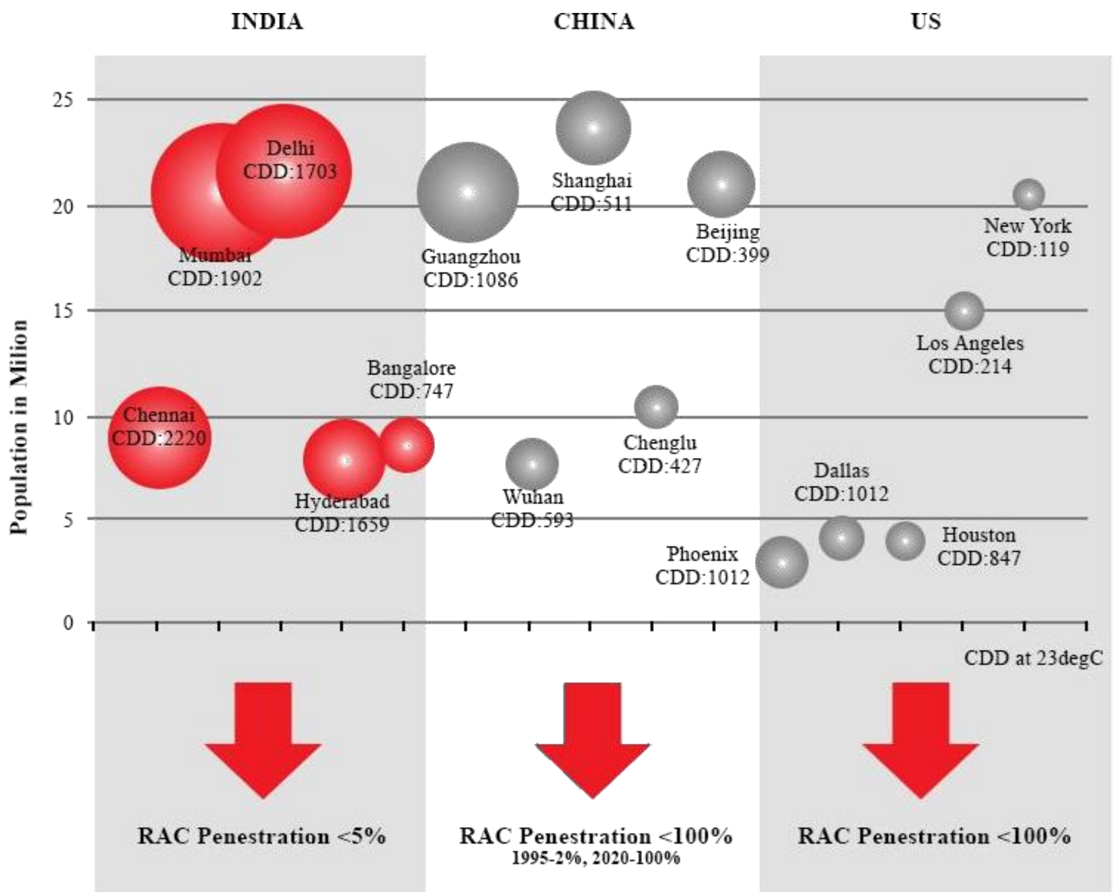
GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA | प्रधान मंत्री आवास योजना-शहरी Pradhan Mantri Awas Yojana-Urban | Ministry of Housing and Urban Affairs Government of India | Azadi Ka Amrit Mahotsav | giz

# 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: India Cooling Action Plan

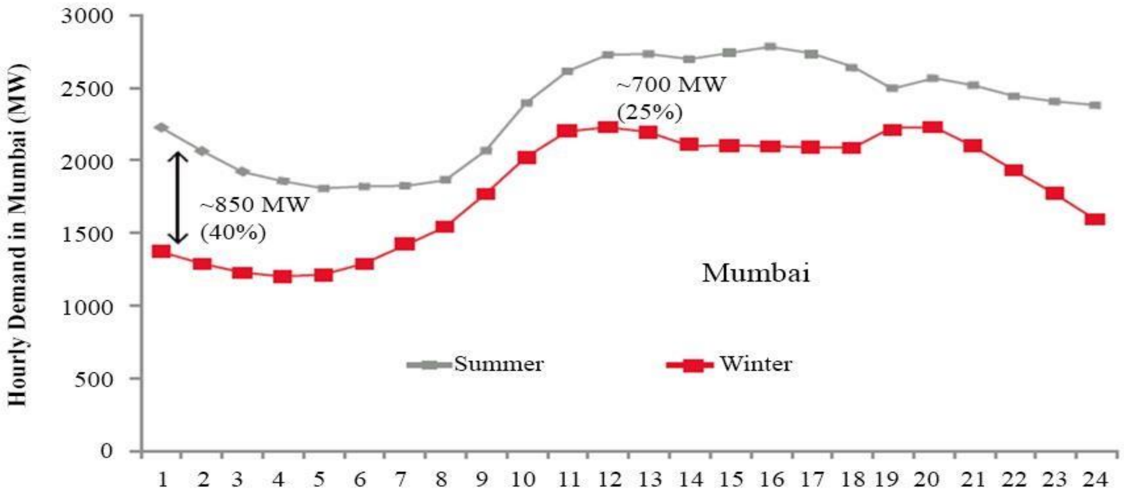


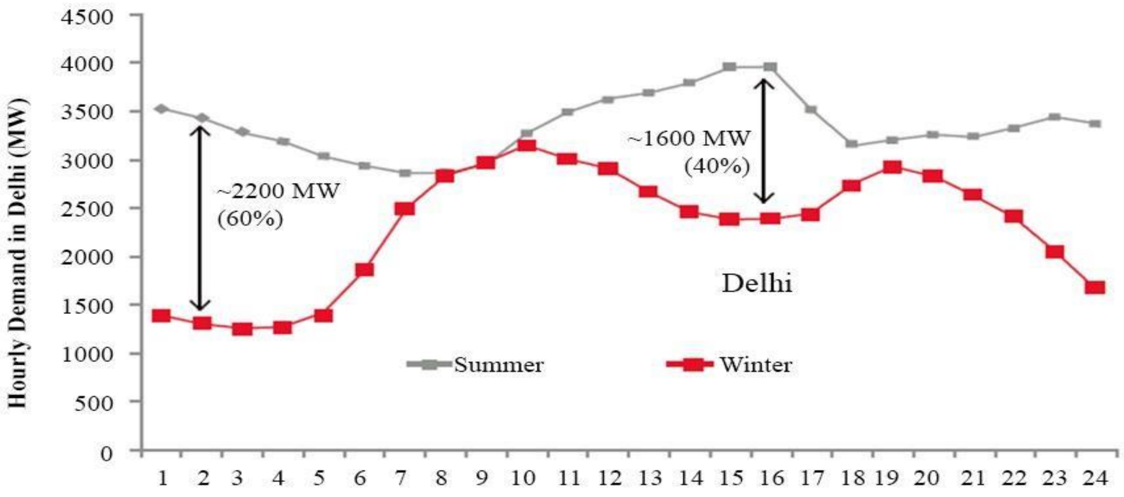

## Cooling Demand in India, China, and the US

- 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: India Cooling Action Plan




- 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*

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

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

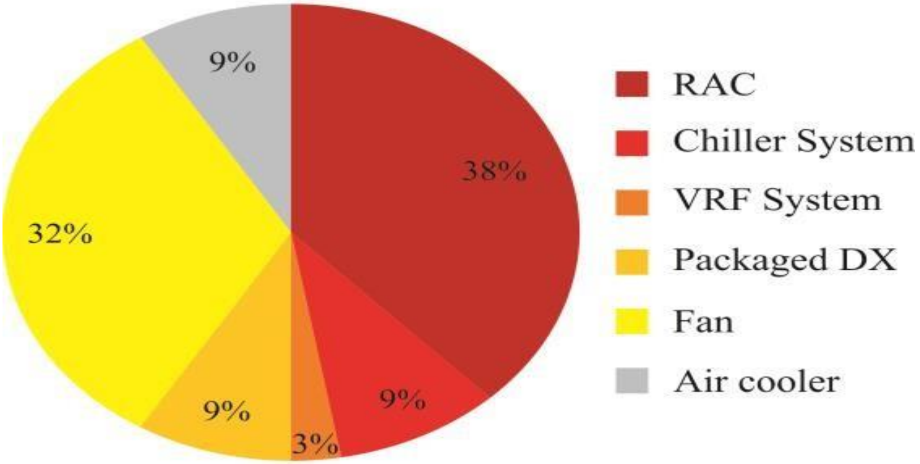
Ministry of Housing and Urban Affairs
Government of India

Azadi Ka Amrit Mahotsav

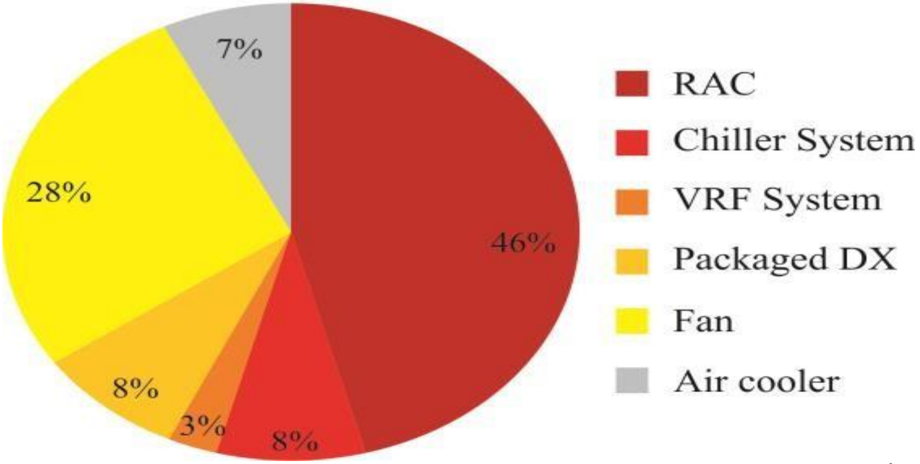
giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

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

**2017 Annual Energy Consumption = 126TWh**




**2017 Annual Carbon Emission = 124 mtCO2e**




- Total Consumption 126 TWh and 124 $MTCO_{2e}$
- Room Air Conditioners 48.8 TWh (38%) consumption
- Room Air Conditioners 57.0 $MTCO_{2e}$ (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*

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

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

Ministry of Housing and Urban Affairs
Government of India

Azadi Ka Amrit Mahotsav

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

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

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

- 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

*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*

# 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

•01

•Air Temperature

•02

•Mean Radiant Temperature

•03

•Radiant Temperature Asymmetry

•04

Floor Surface Temperature

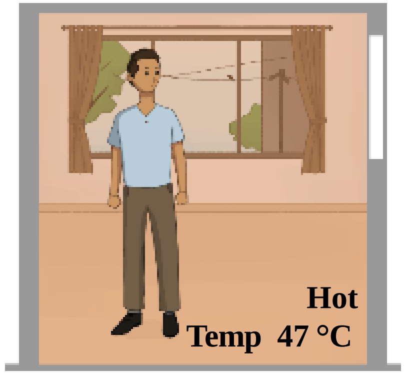
•05

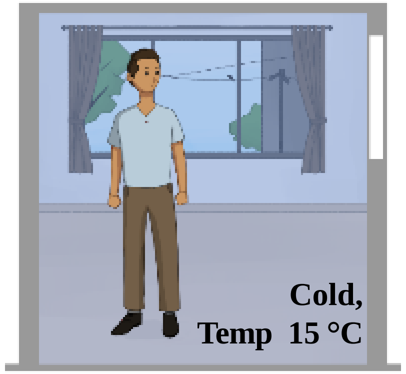
•Relative Humidity

•06

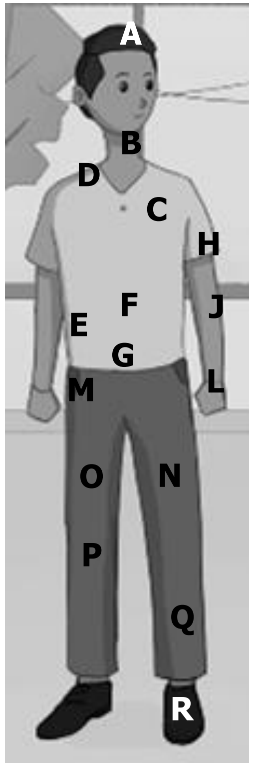
•Air Speed

# Thermal Comfort – Cold – Neutral - Warm



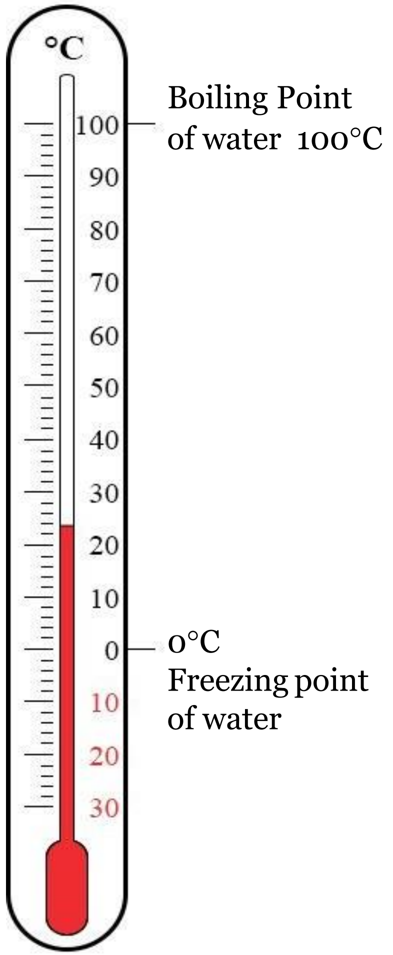




Air Temp 27 °C



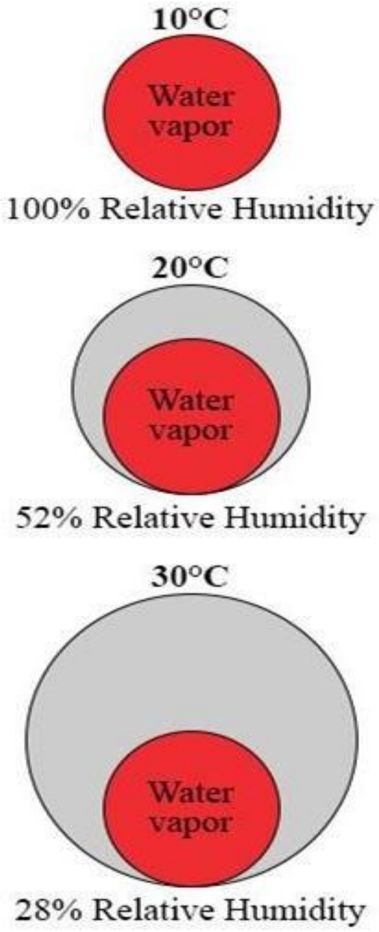

| Body Part | Skin Location | Cold (15 °C) | Neutral (27°C) | Hot (47 °C) |
|---|---|---|---|---|
| A | Forehead | 31.7 | 35.2 | 37 |
| B | Back of Neck | 31.2 | 35.1 | 36.1 |
| C | Chest | 30.1 | 34.4 | 35.8 |
| D | Upper Back | 30.7 | 34.4 | 36.3 |
| E | Lower Back | 29.2 | 33.7 | 36.6 |
| F | Upper 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



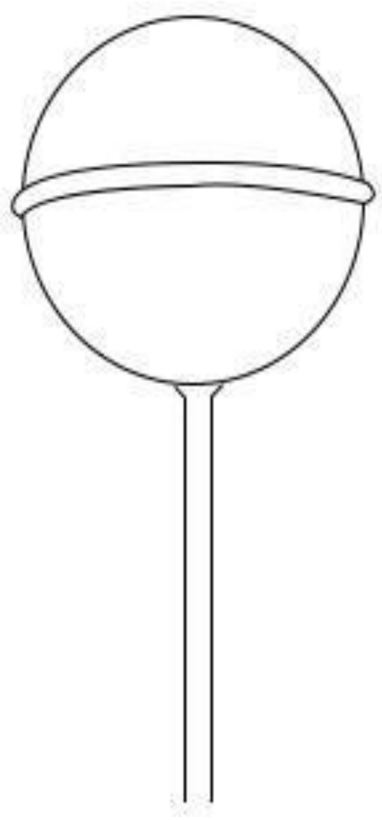

- Temperature of the air surrounding the Environment (Dry Bulb Temperature) – DBT)
- Measured in Degrees Celsius (°C), by a thermometer freely exposed to the air, but shielded from radiation and moisture.
- Affects the rate of Evaporation on skin surface of building occupants.

# 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]

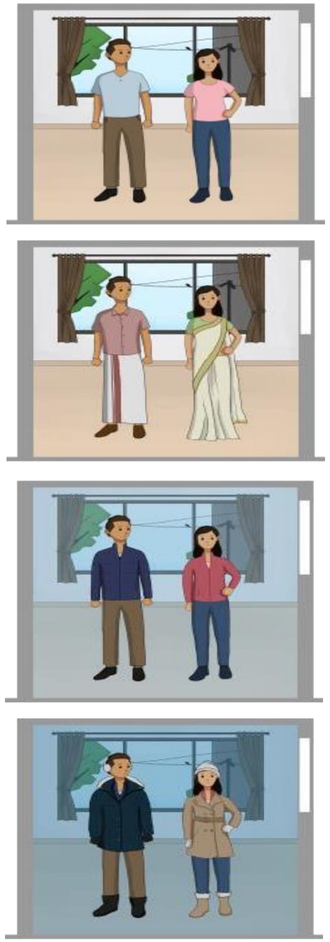


- MRT is defined as uniform temperature of an imaginary enclosure in which the radiant heat transfer from the human body is equal to the radiant heat transfer in the actual non-uniform enclosure.
- Depends on ability of a surface to emit the incident heat, also known as emissivity of the material
- Calculated 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

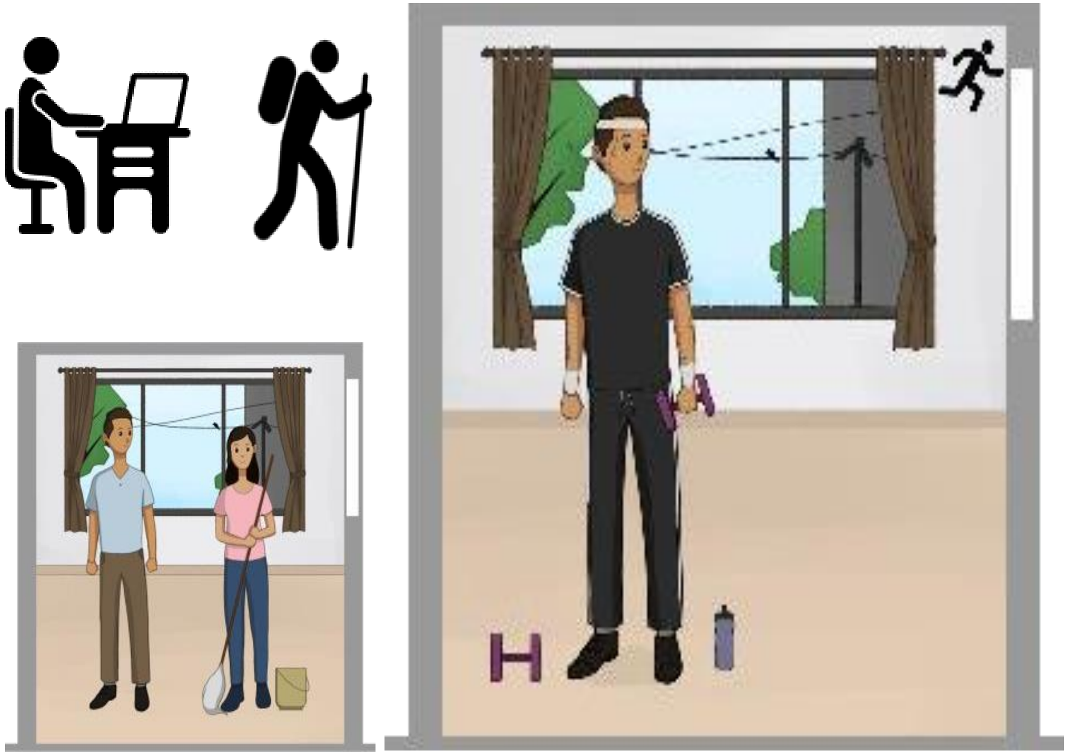


- Can be defined as "The resistance to sensible heat transfer provided by clothing ensemble".
- The insulation provided by an individual garment includes effective resistance of the garment material and the thermal resistance of the air layer trapped between the garment and the skin (CIBSE, 2015).
- 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 met = 58.2 W/m2.
- 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

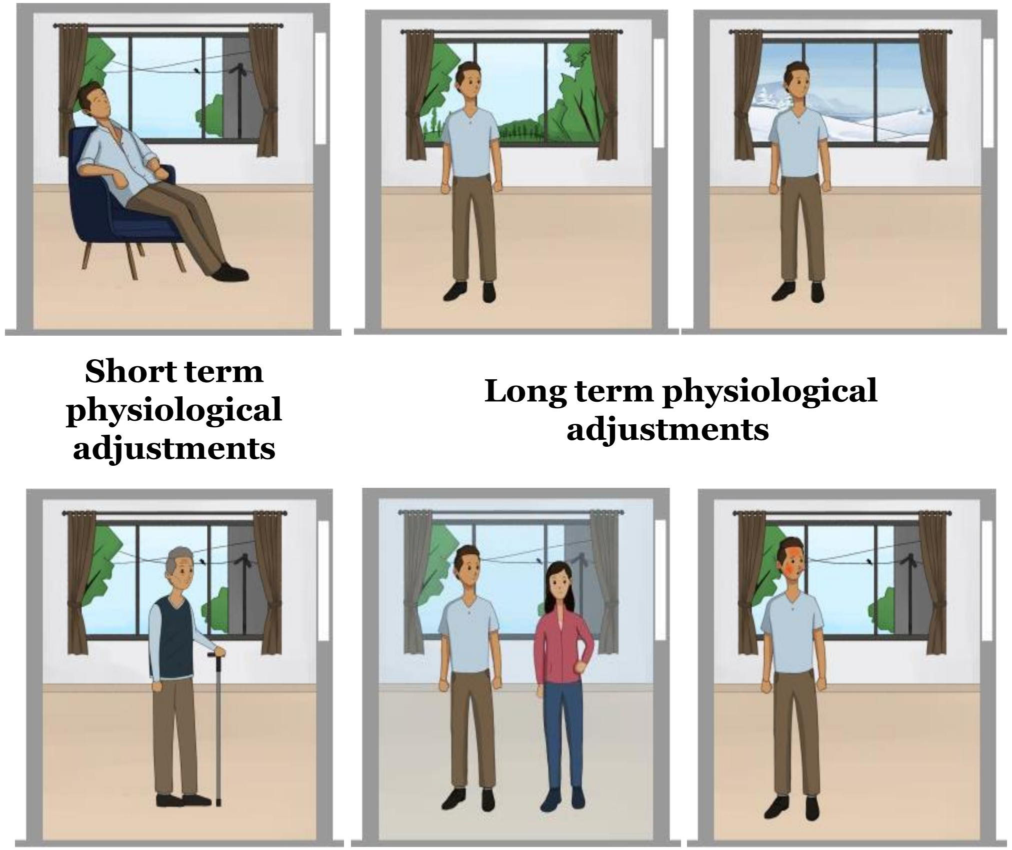
# Factors affecting Thermal Comfort - Others

- **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

**Measures to Improve Thermal Comfort**

- **SHADING & GLAZING**
- **CONTROLLED VENTILATION**
- **INSULATION**
- **COOL ROOFS**
- **GREEN ROOFS**

# Shading & Glazing

Shading reduces internal heat gain through coincident radiation.

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

These can reduce cooling energy consumption by 10-20%

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

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

# Shading & Glazing

**Thermal Comfort**

**SHADING**

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

**GLAZING**

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

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

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

Ministry of Housing and Urban Affairs
Government of India

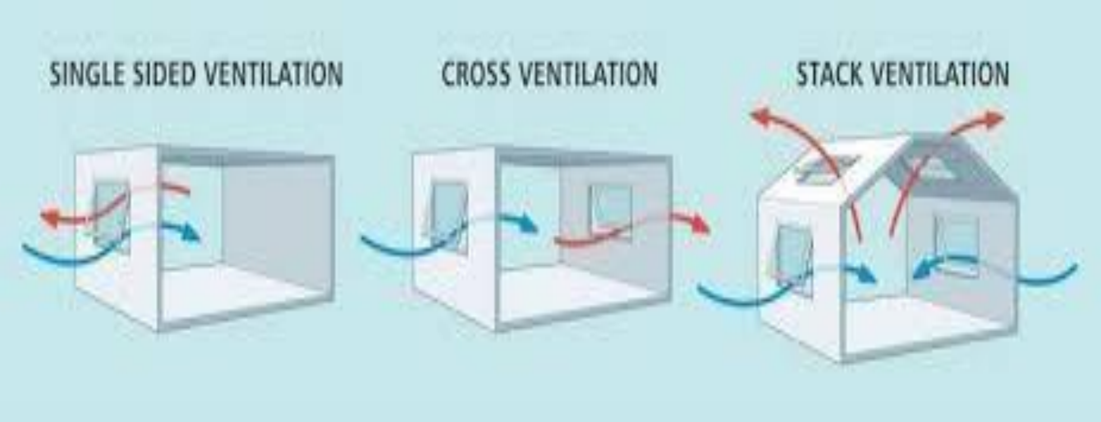
Azadi Ka Amrit Mahotsav

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

# Controlled Ventilation

**BUILDING CAN BE DESINED AS**

- **CROSS VENTILATION**
- **STACK VENTILATION**
- **SINGLE-SIDED VENTILATION**



GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

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

Ministry of Housing and Urban Affairs
Government of India

Azadi Ka Amrit Mahotsav

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

# Controlled Ventilation

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

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

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

# Controlled Ventilation

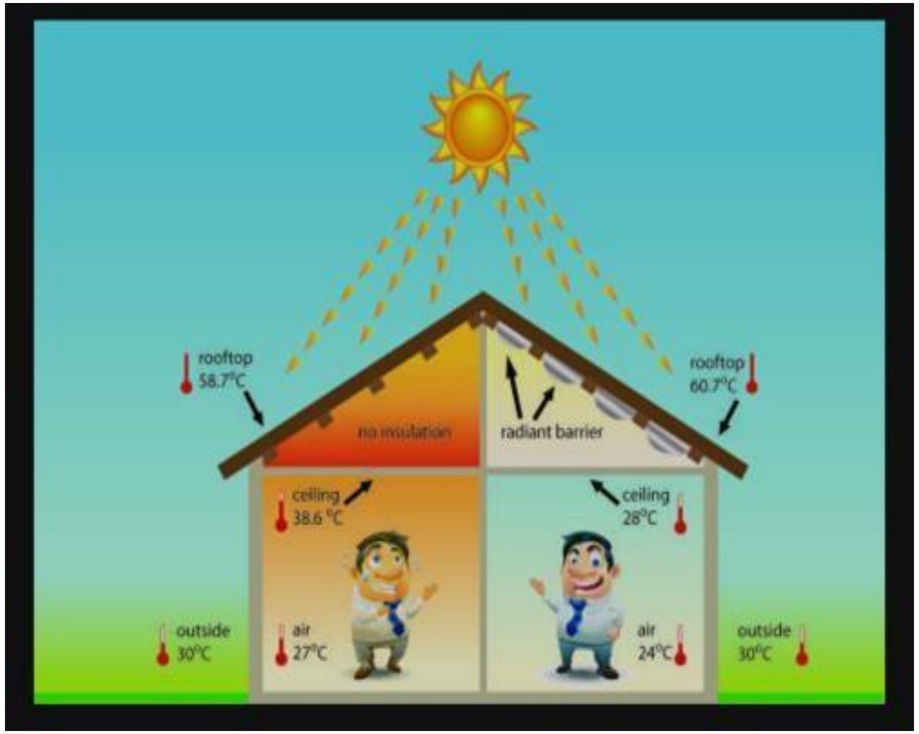
Natural ventilation takes advantage of the differences in air pressure between warm air and cool air, as well as convection currents, to remove warm air from an indoor space and allow fresh cooler air in.

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

| NATURAL VENTILATION | |
|---|---|
| With Breeze Air | Works Best |
| 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 | |

Even in hot-dry and warm-humid climate zones where some air-conditioning may be required during peak Thermal Comfort for All summer, buildings can be designed to operate in a mixed mode to enable **night ventilation** and **natural ventilation** during cooler seasons

# Insulation




Heat Conduction takes place through

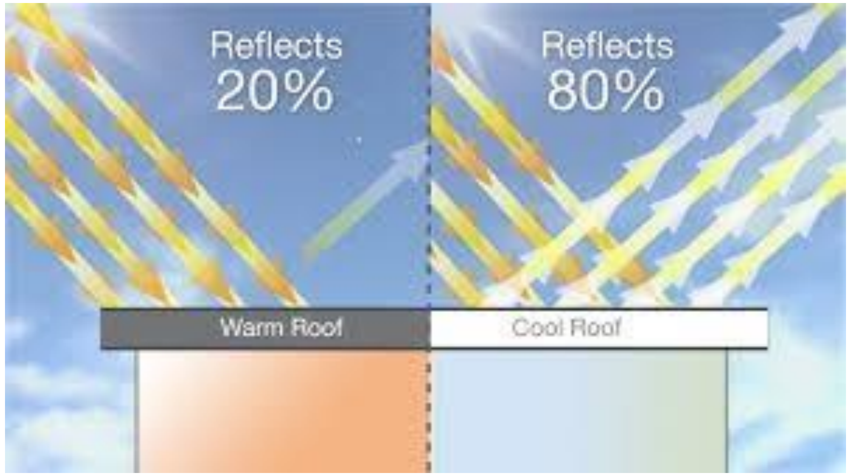
- Roof
- Walls
- Windows

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

# Cool Roofs

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

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



# Cool Roofs

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

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

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

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

**The cities of Jodhpur and Jaipur 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**

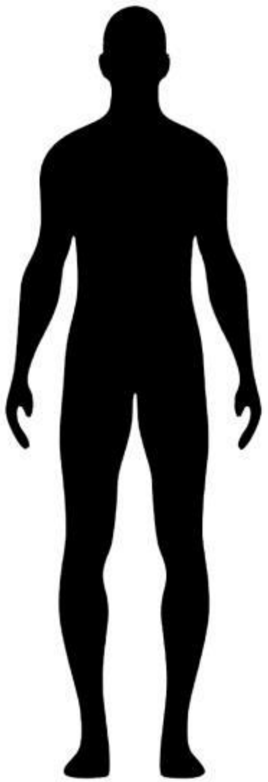
| GREEN ROOFS IN BUILDINGS ALLOWS | |
|---|---|
| During cooler Winter Months | Retain their heat |
| During hotter Summer Months | Reflecting and absorbing solar radiations |

# 08

# Thermal Comfort Metrics

# Thermal Comfort Metrices – Preference, Comfort and Acceptability

- Metabolic Rate
- Clothing Insulation
- Air Temperature
- Air Velocity
- Mean Radiant Temperature
- Relative Humidity



## PMV Balance

- +3 Hot
- +2 Warm
- +1 Slightly Warm
- 0 Neutral (Comfort)
- -1 Slightly Cool
- -2 Cool
- -3 Cold

## Thermal Comfort Metrices

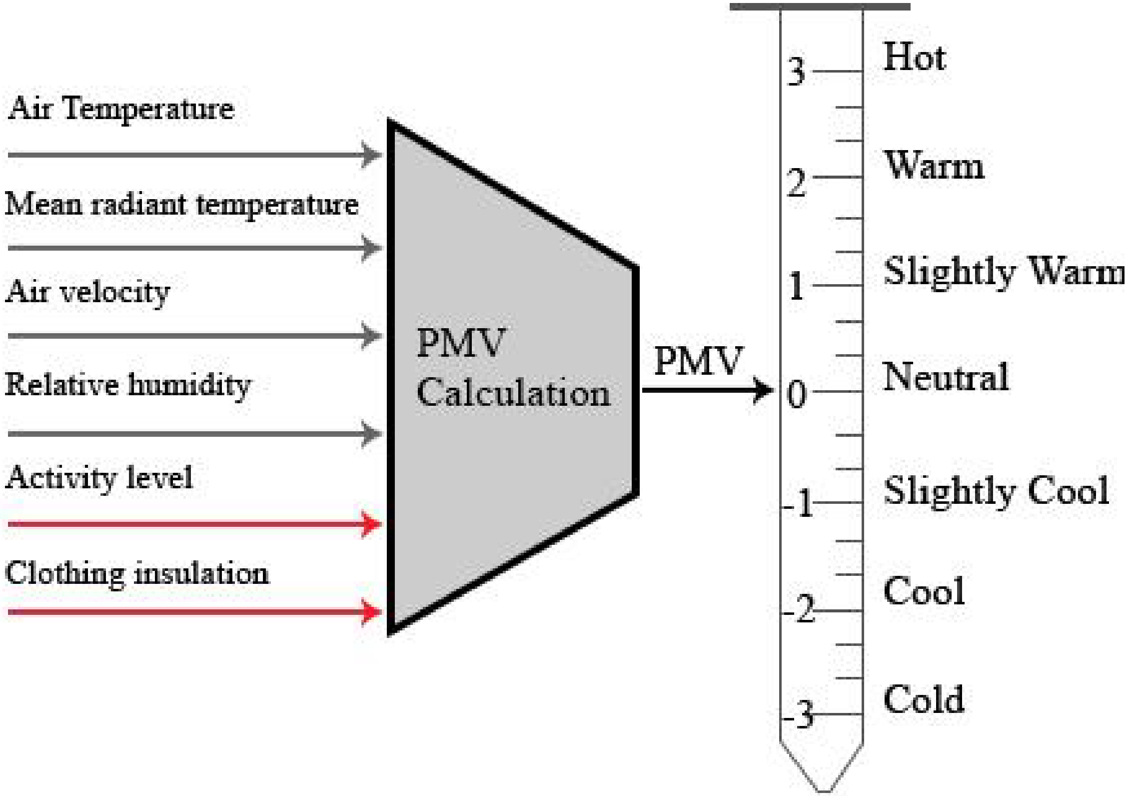
- Thermal Sensation
- Thermal Acceptance (Thermal Comfort)
- Thermal Preference
- Thermal Satisfaction

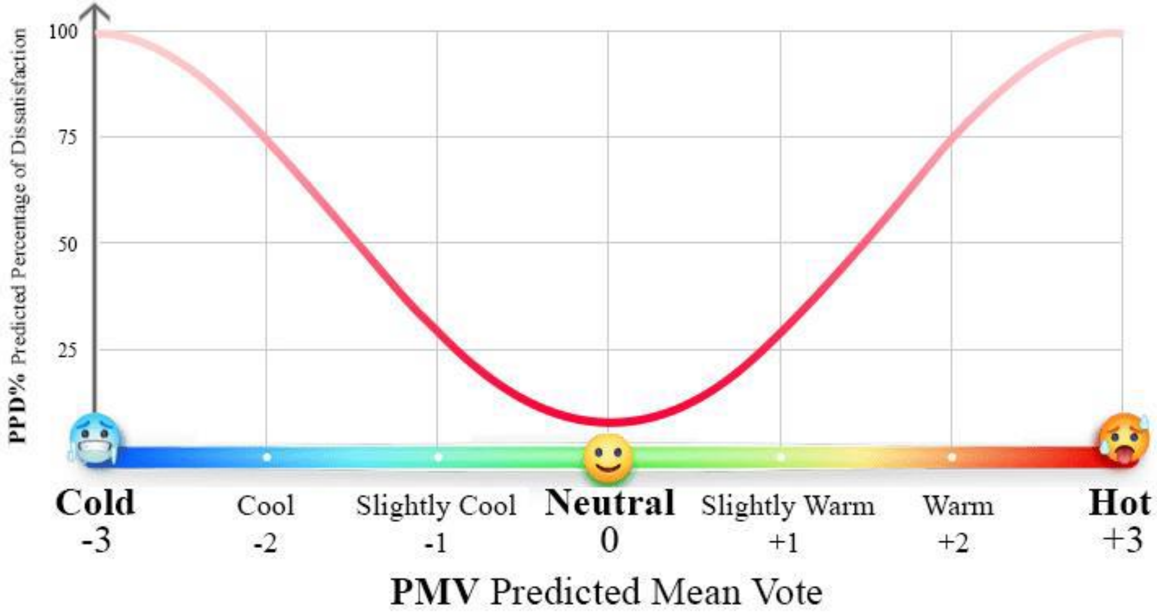
Storage = Production - Loss

# Thermal Comfort Metrices – Preference, Comfort and Acceptability

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

# Thermal Comfort Metrices – PMV




Acceptable thermal comfort bands listed in ISO 7730:2005

| Band | PMV Range |
|---|---|
| A | -0.2 < PMV < +0.2 |
| B | -0.5 < PMV < +0.5 |
| C | -0.7 < PMV < +07 |

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

# Thermal Comfort Metrices – 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 < PMV < +0.2 | < 6 | 24.5 ± 1 |
| B | -0.5 < PMV < +0.5 | < 10 | 24.5 ± 1.5 |
| C | -0.7 < PMV < +07 | < 15 | 24.5 ± 2.5 |

# Thermal Comfort Metrices – 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)

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

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

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

- $T_i$ – Measured or Achieved Operative Temp. at $i^{th}$ hour
- $T_{acceptable}$ - Either the lower ($T_{Lower}$) or the upper limit ($T_{Upper}$) 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)

*Source: vecteezy. (n.d.). Hot weather thermometer. vecteezy. Retrieved from https://www.vecteezy.com/vector-art/583489-hot-weather-thermometer-icon-vector*

# DAY 1

# Lunch Break

# DAY 1

# Session 3: Building Physics and Fundamentals of Thermal Comfort

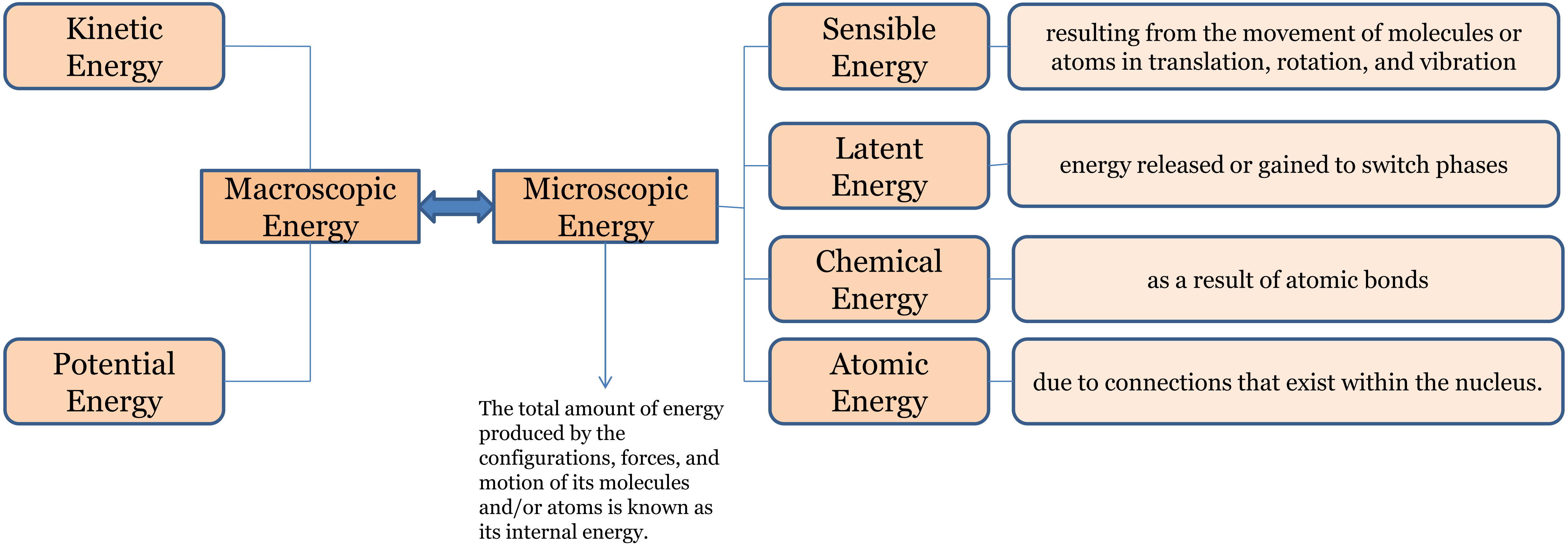
# 09

# Building Physics Affecting Thermal Comfort

# Building Physics Affecting Thermal Comfort

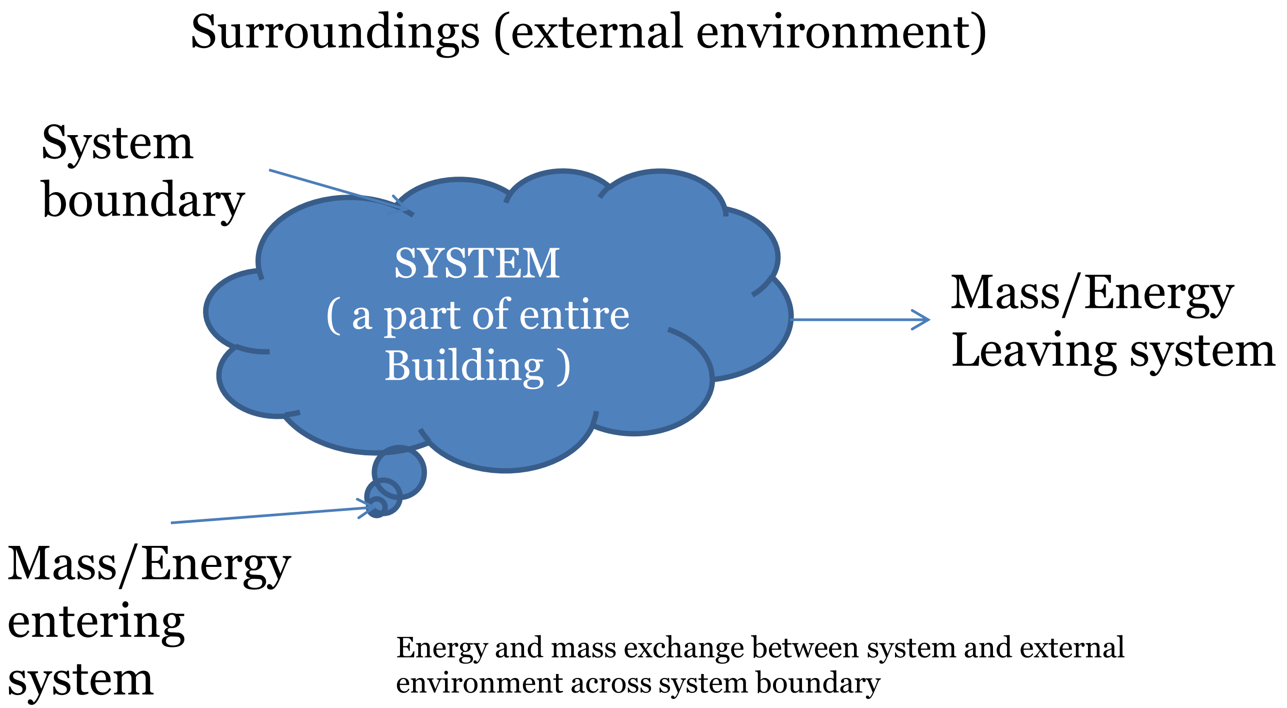
## Energy & Heat

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




Energy and mass exchange between system and external environment across system boundary

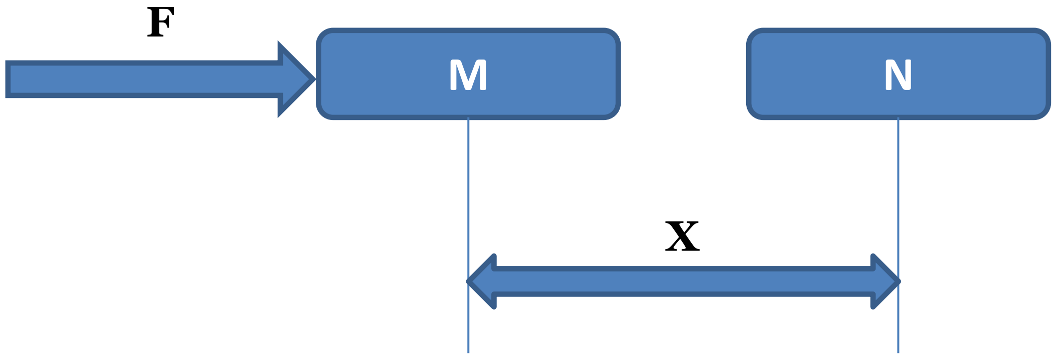
The envelope is regarded as the boundary when a building is viewed as a system in order to comprehend its thermal interactions with the surrounding environment.

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.

# 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

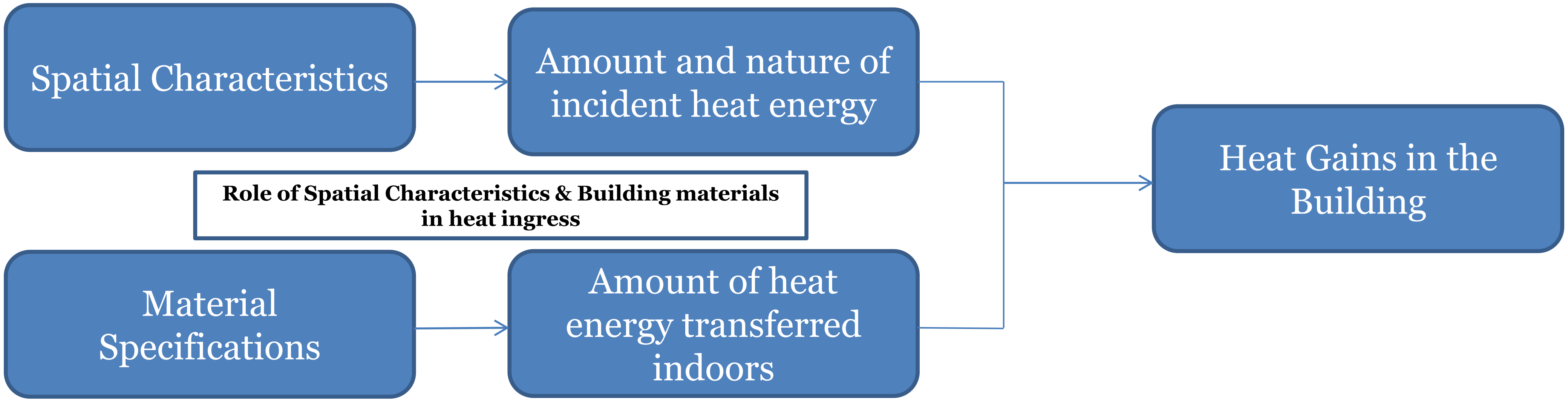
**the amount of heat transferred inside a building is a function of the following**

- building envelope characteristics
- operation patters of the openable elements of the building envelope
- climate of the place where building is situated.

# Building Physics Affecting Thermal Comfort

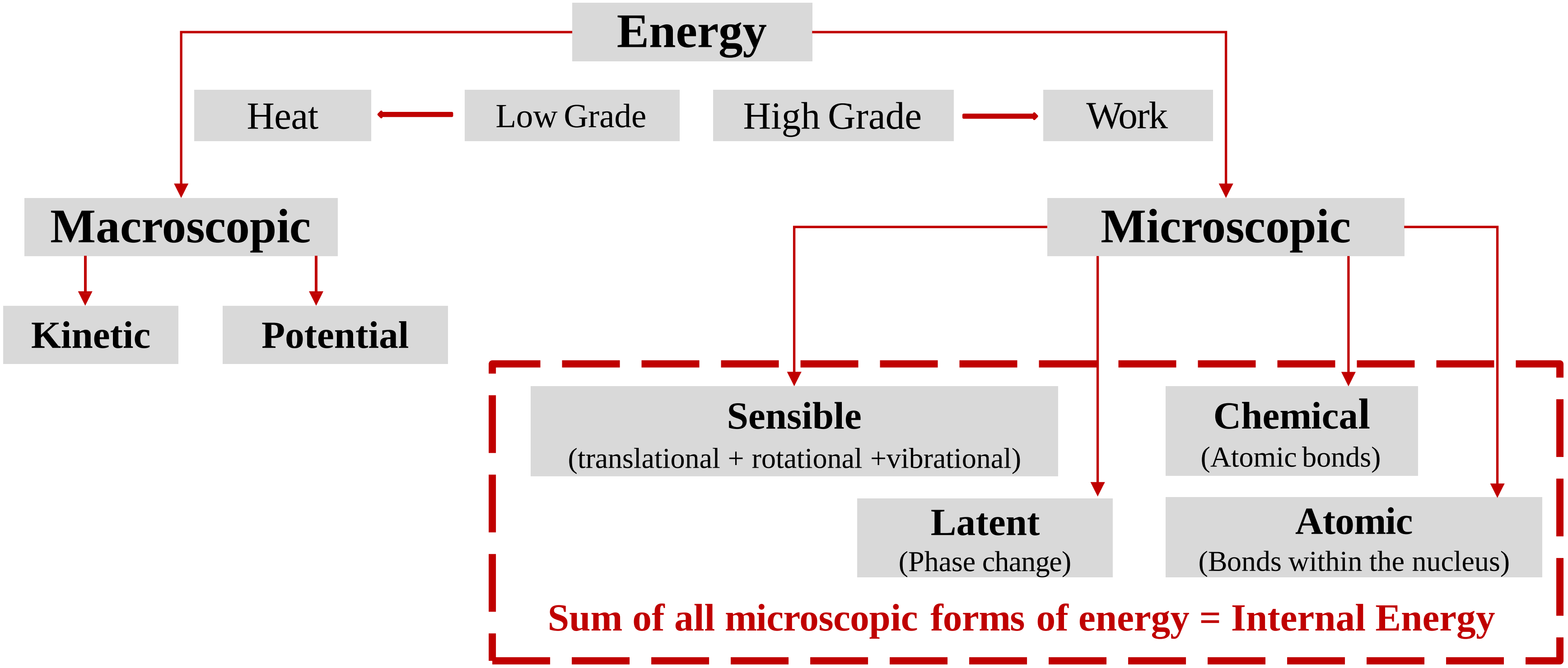
## Factors Influencing Heat Transfer

- 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

## 1st 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

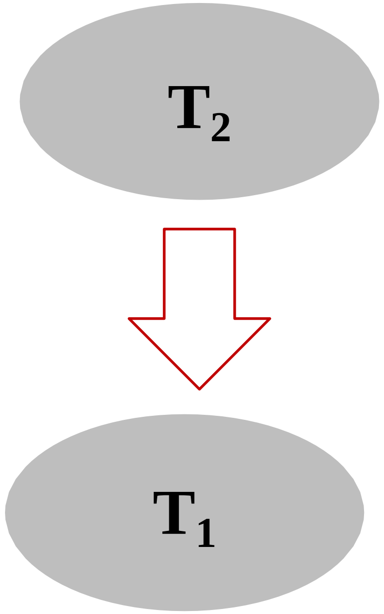
**Establishes a relationship between a system's**

- 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

## 2nd Law of Thermodynamics

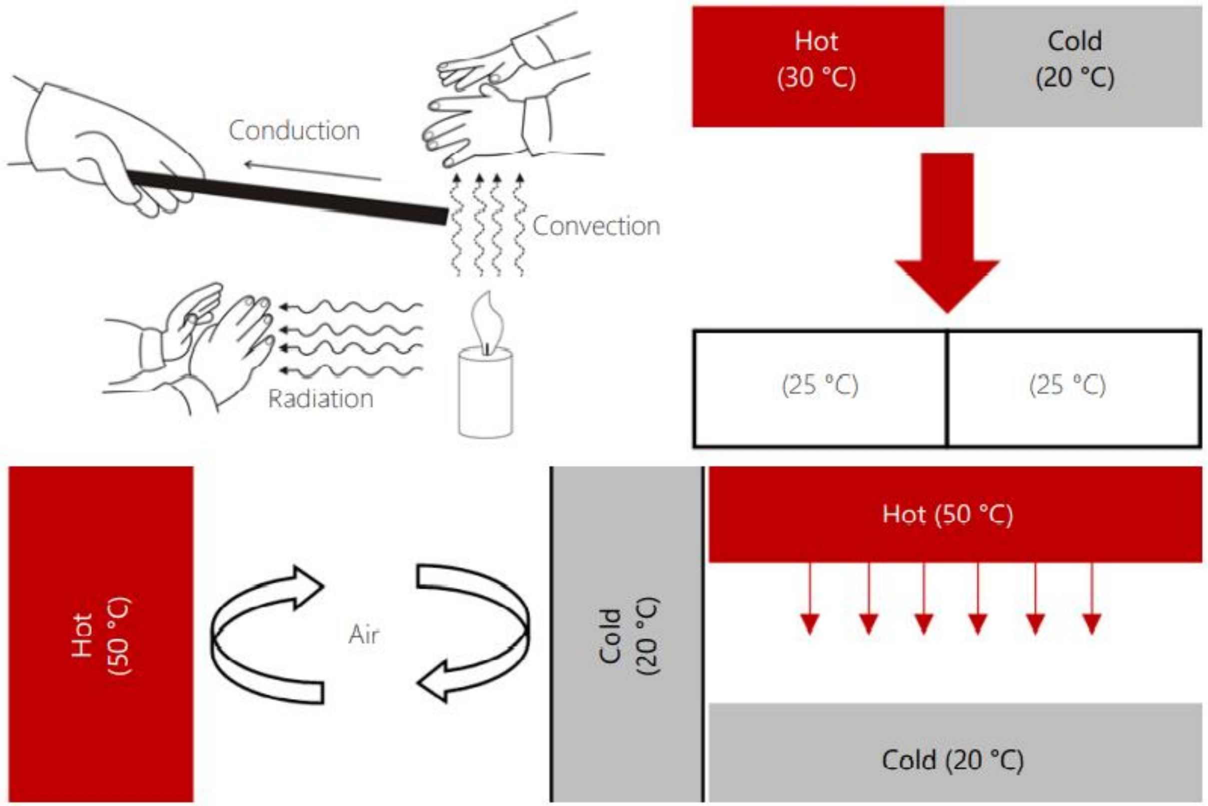


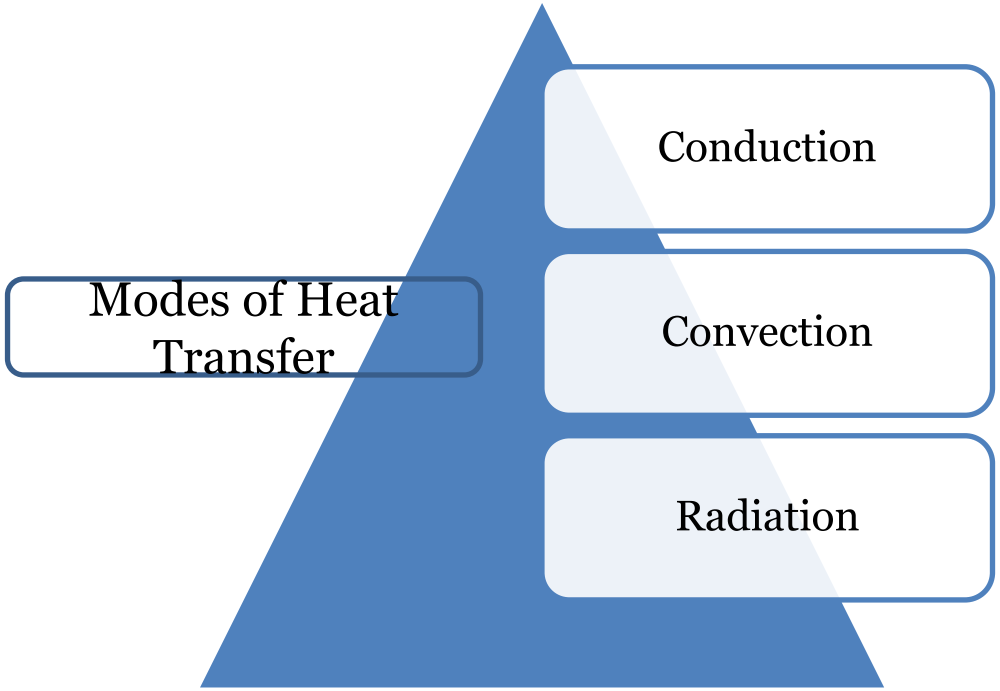

$(T_2 > T_1)$

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

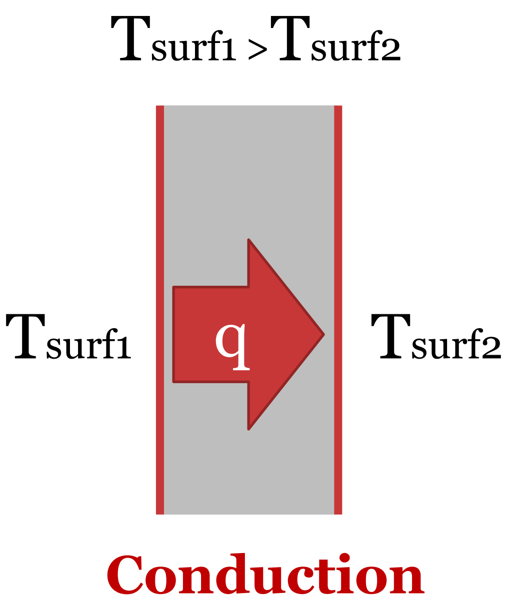
# Building Physics Affecting Thermal Comfort

## 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**

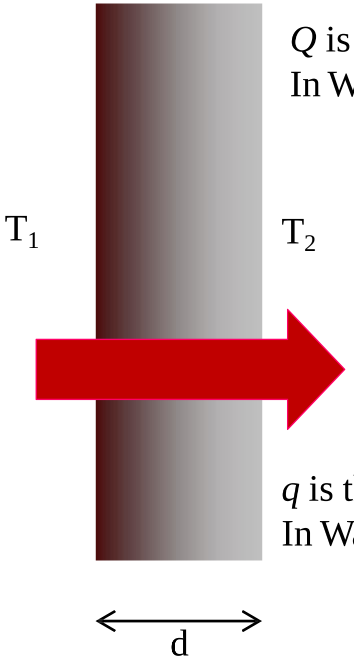
Cool objects with lesser

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




*Q* is the heat rate
In Watts

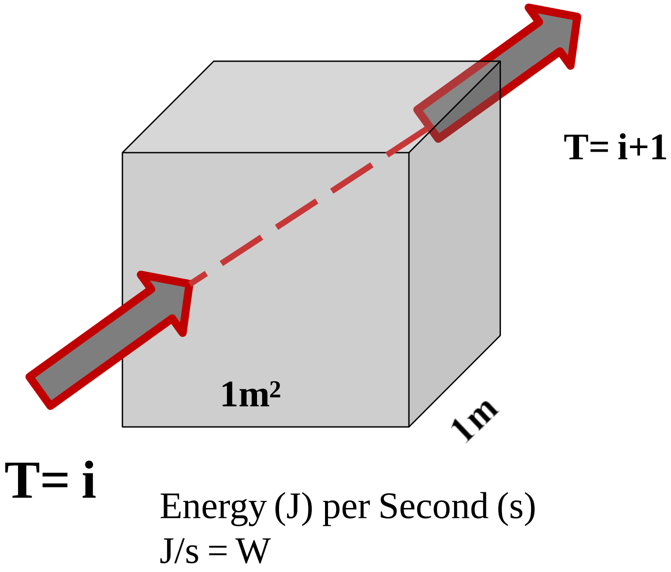
*q* is the heat flux
In Watts/m²

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

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

$$q = k\,\frac{T_1 - T_2}{\;}$$

# 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/m³) | 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

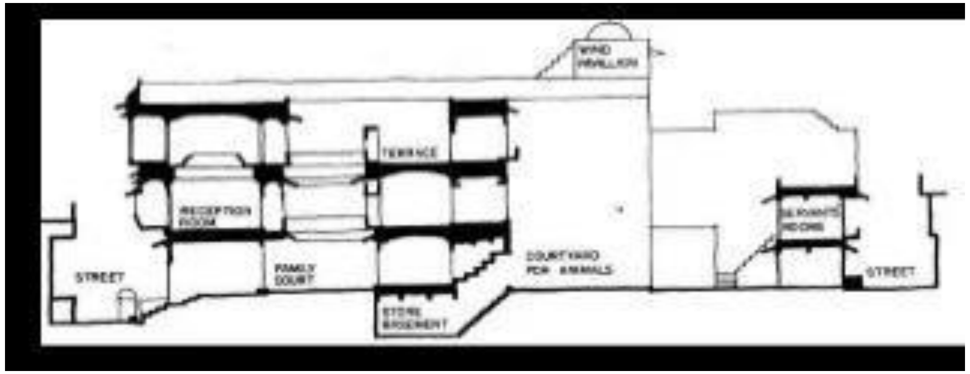
## Energy & Heat

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

| MATERIALS | DENSITY ($kg/m^3$) | 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 |

*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)*

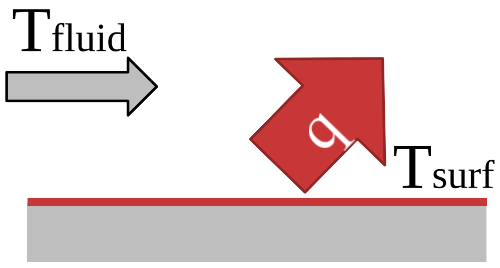
# Heat Transfer in Buildings – Conduction Principles




**Conduction through walls**

# Heat Transfer in Buildings – Convection Principles

$T_{surf} > T_{fluid}$

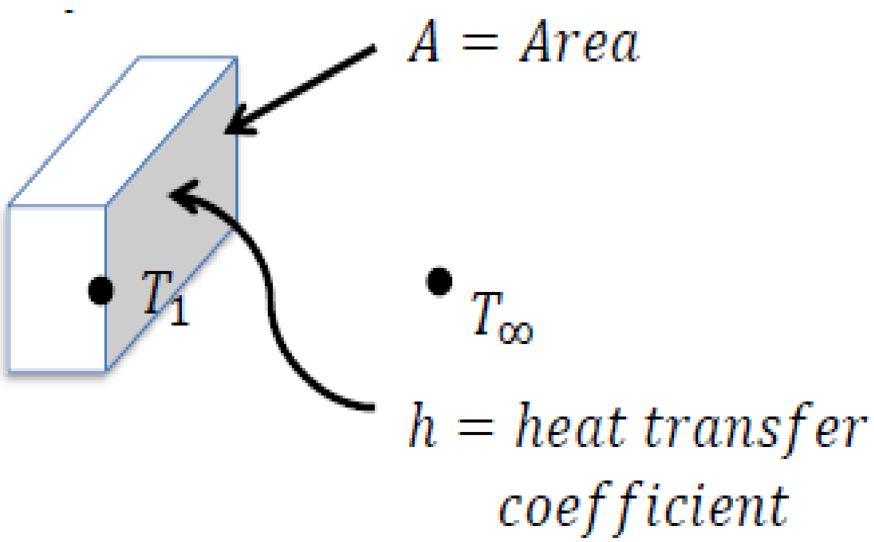



**Convection**

- 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

$Q = \mathbf{h}\, A\, \mathbf{\Delta T}$

Q = heat transfer by convection, W

A = surface area, m2

ΔT = T∞ – T1 at some specified location, K

h = heat transfer coefficient, W·m-2·K-1

# Heat Transfer in Buildings – Convection Principles

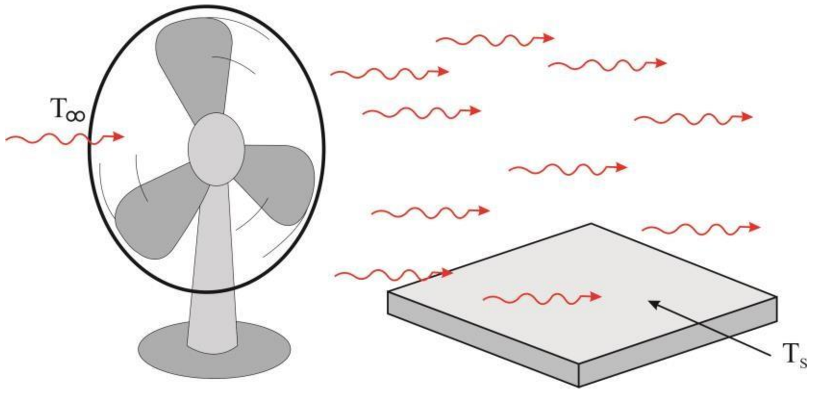
| Surface resistance (ISO 6946) | | |
|---|---|---|
| Heat flow direction | $R_{si}$ [$m^2 \cdot K \cdot W^{-1}$] | $R_{so}$ [$m^2 \cdot K \cdot W^{-1}$] |
| Horizontal (±30°) | 0.13 | 0.04 |
| Up | 0.10 | 0.04 |
| Down | 0.17 | 0.04 |

## Surface conductance

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

- h = surface/film conductance
- $W \cdot m^{-2} \cdot K^{-1}$
- 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

$h = h_c + h_r$

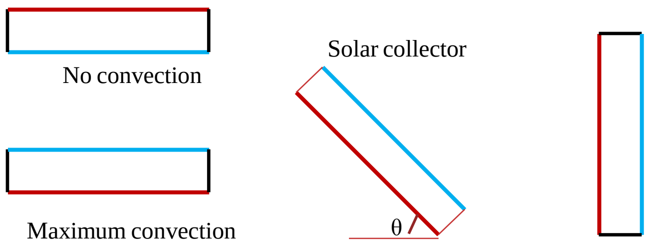
$h_c$ = convective heat transfer coefficient

$h_r$ = radiative heat transfer coefficient

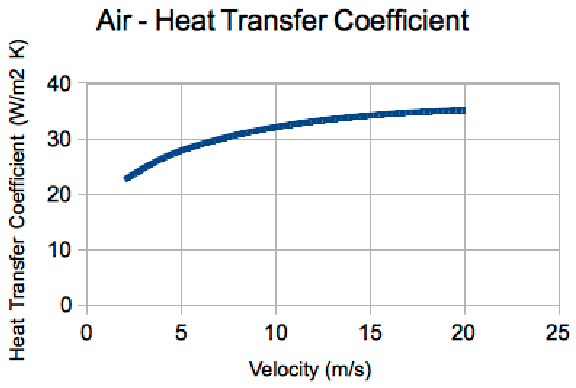
**Natural Convection – Forced Convection**

*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 (θ)




- 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

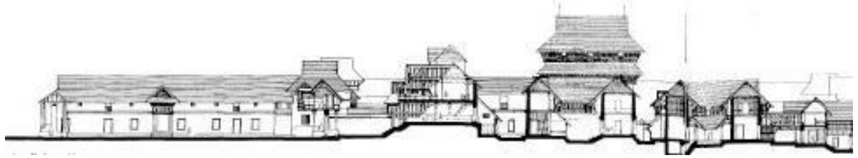
# Heat Transfer in Buildings – Convection Principles

**Airflow through a room**
Wall temperatures of the room at 30 °C
Heat transfer coefficient on inside =10 W/m2K

**Wind-induced airflow**

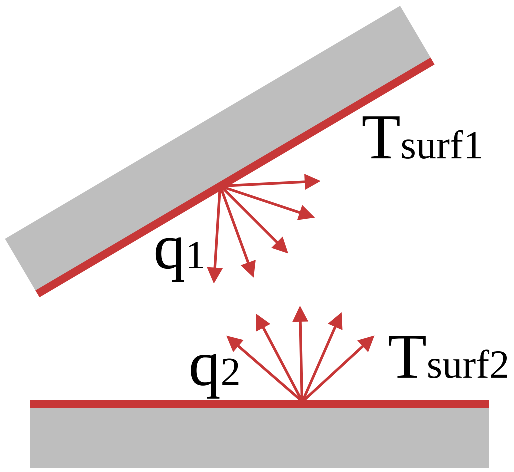
**Stack effect**

**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*

# Heat Transfer in Buildings – Radiation Principles




**Radiation**

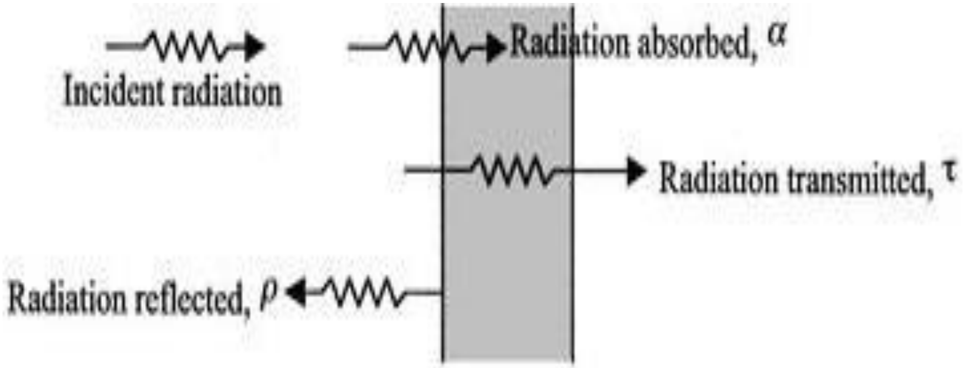
- Radiation heat transfer is a process where heatwaves are emitted that may be absorbed, reflected, or transmitted through a colder body.
- Energy has an electric field and a magnetic field associated with it,
- Wave-like properties. “electromagnetic waves”
- Wide range of electromagnetic radiation in 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

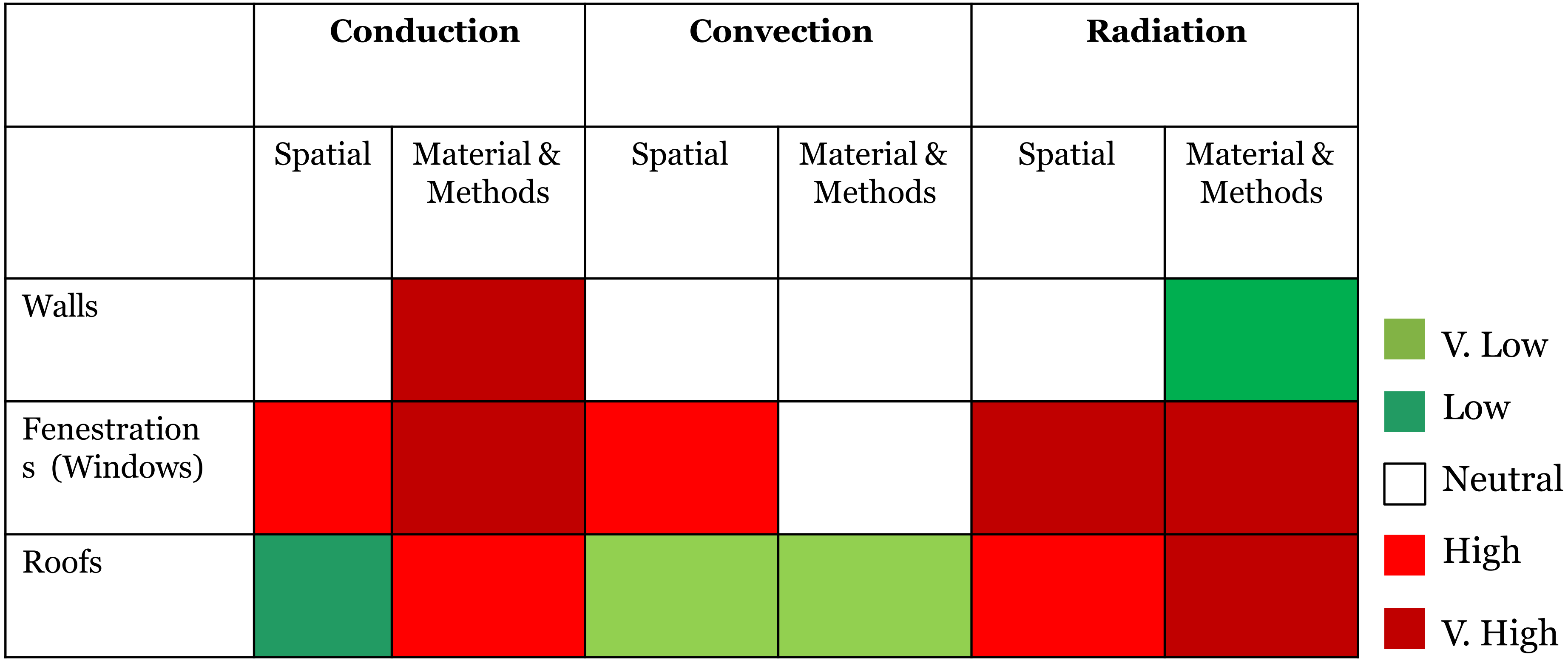
The behaviour of a surface with radiation incident upon it can be described by the following quantities:

= 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




*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/*

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

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

Ministry of Housing and Urban Affairs
Government of India

Azadi Ka Amrit Mahotsav

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

# 10

# Heat Balance & Adaptive Thermal Comfort Method

# Comfort Theoory - 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= qsk+qres+S=(C+R+ Esk )+(Cres+ Eres )+(Ssk+ Scr)

Where,

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

W = Rate of mechanical work accomplished, W/m 2

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

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

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

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

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

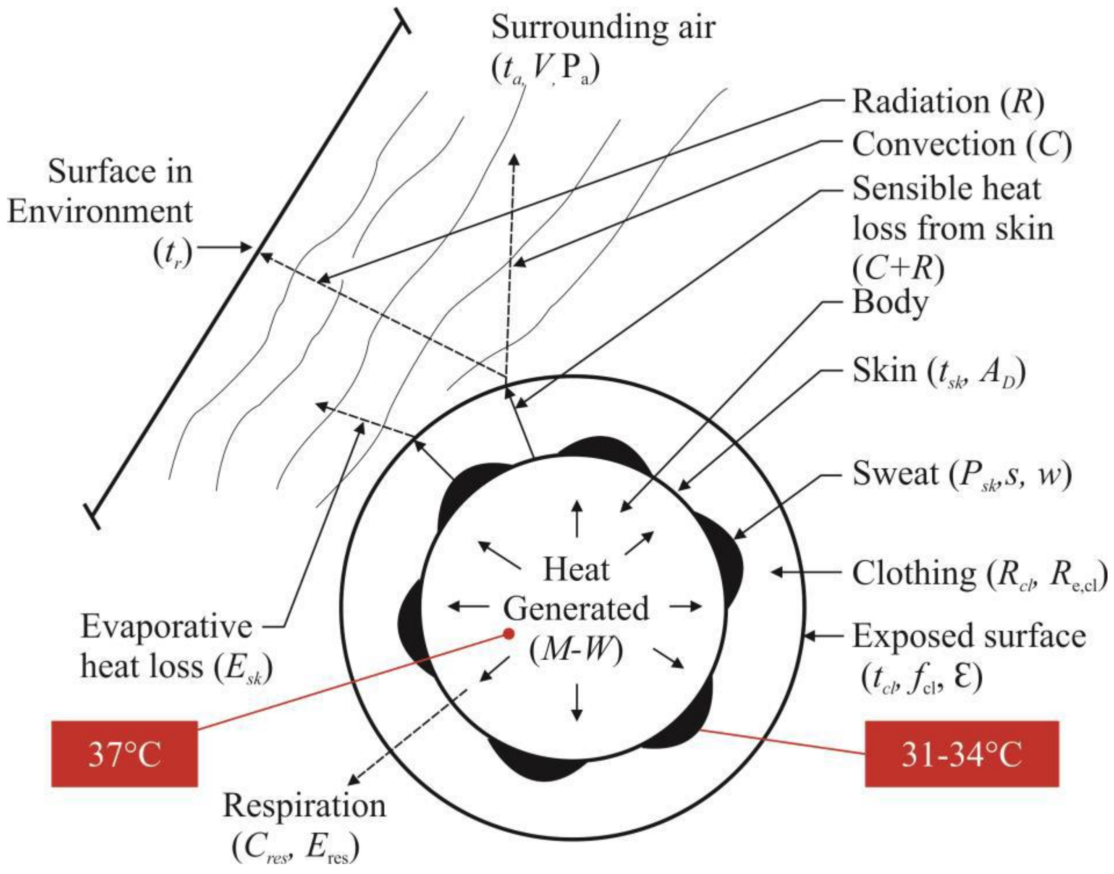
$E_{res}$ = Rate of evaporative heat loss from respiration, W/m 2

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

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

*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*

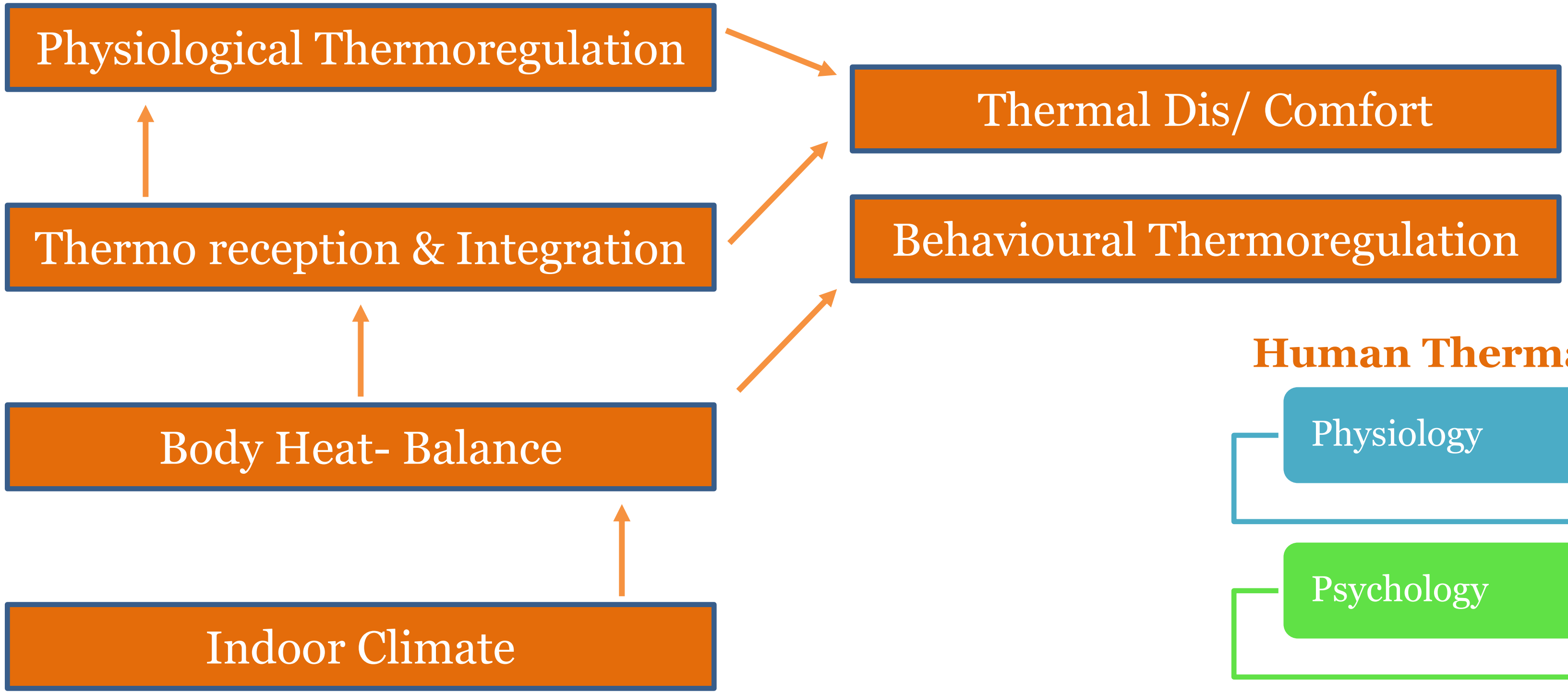
# Comfort Theoory - Heat Balance Method




| | |
|---|---|
| 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 Theoory – Adaptive Thermal Comfort Mehod




**Human Thermal Comfort Depends upon**

- Physiology
- Psychology
- Behaviour

*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*

# 11

# 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.

Most Humans are comfortable under this conditions

- Winters
  - 68°F to 76°F
  - 60% to 30% RH
- Summer
  - 74°F to 80°F
  - 60% to 30% RH

# 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

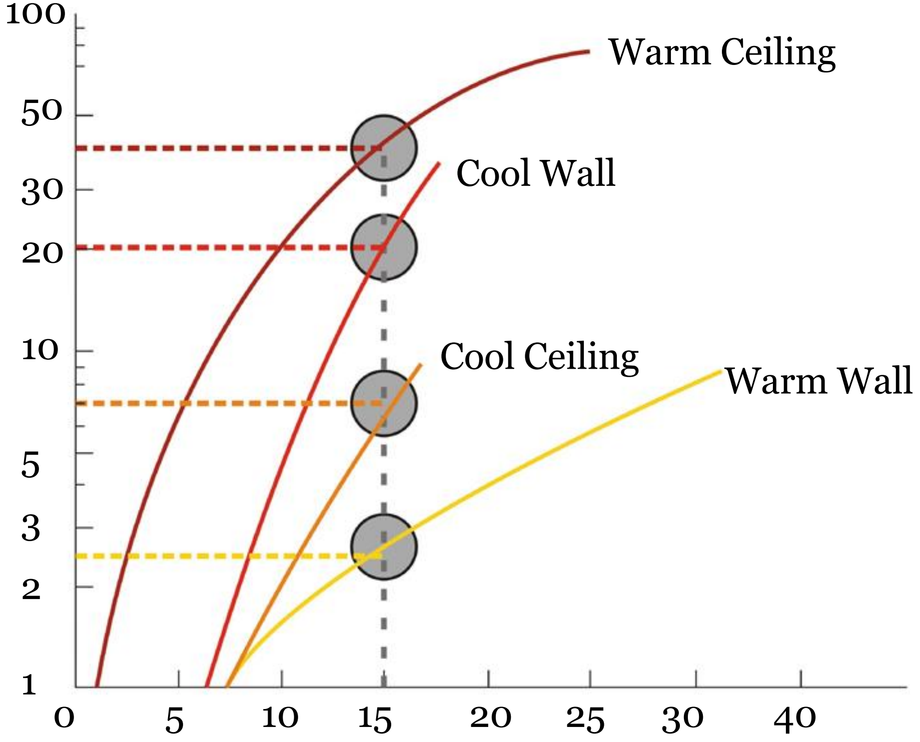
Local Thermal Discomfort is primarily caused by the Asymetric Thermal Radiation. Where :

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.

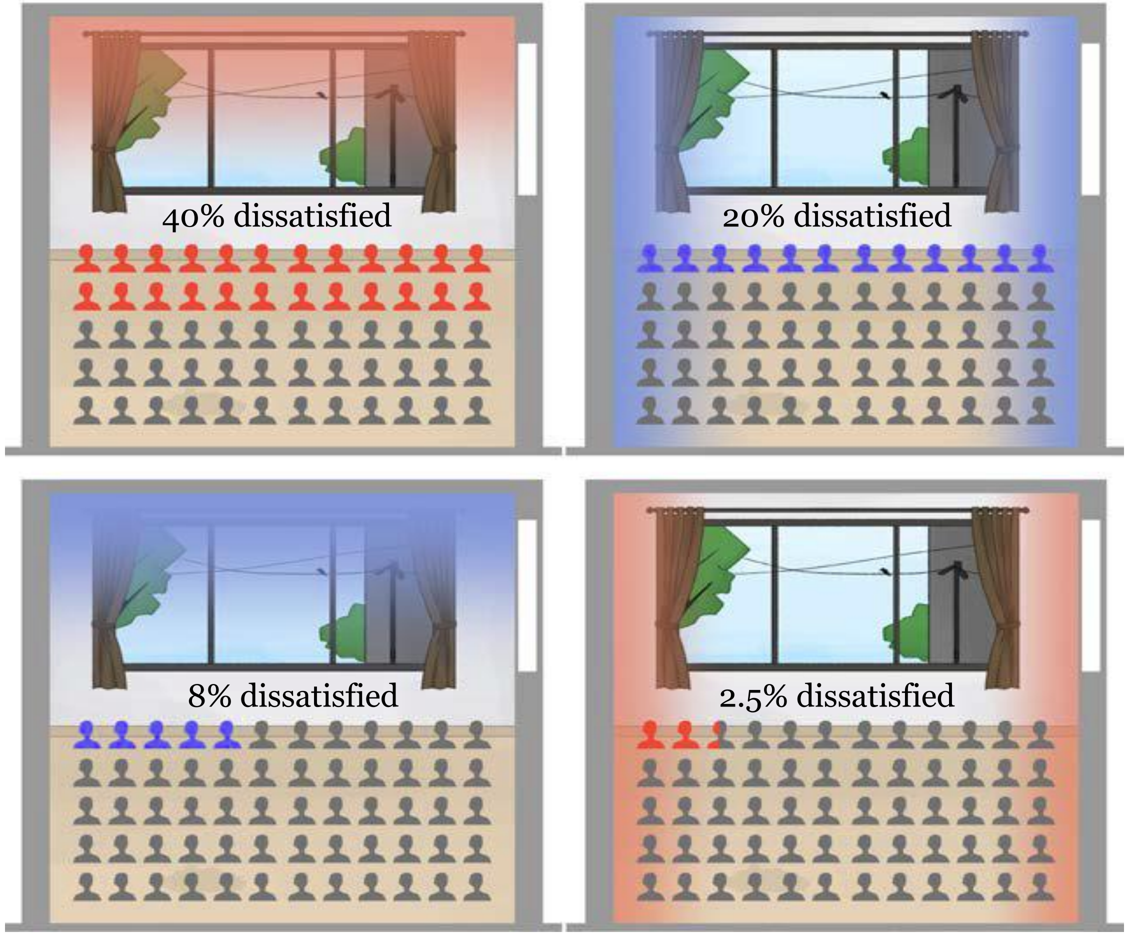
## Percentage of dissatisfied occupants with radiant thermal asymmetry of 15°C

| 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

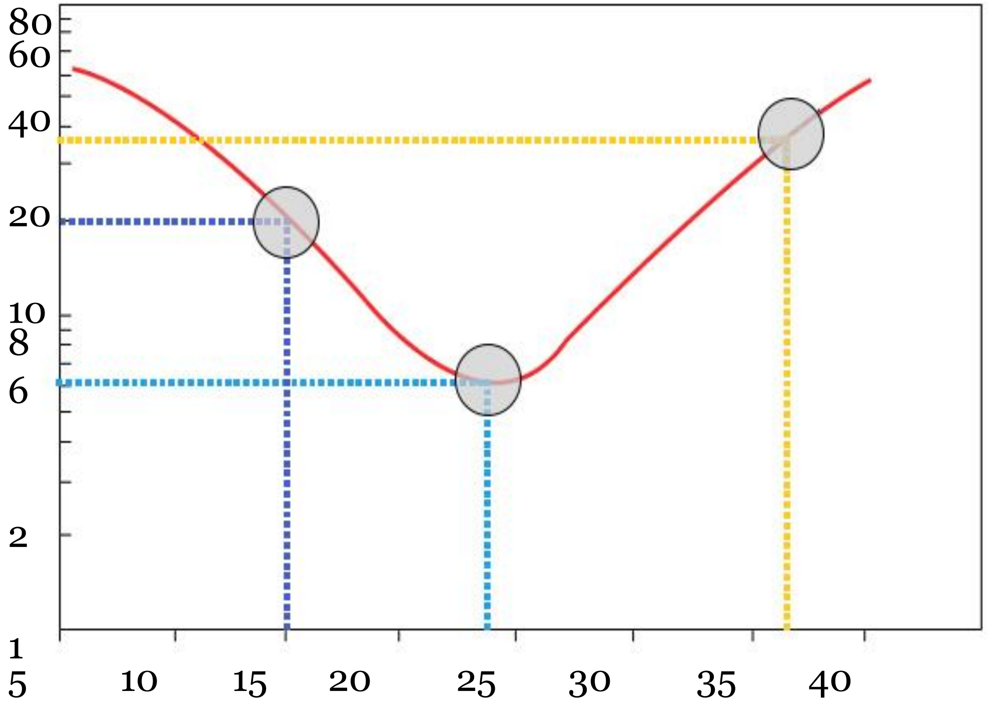
**Warm Ceiling > Cool Wall > Cool Ceiling > Warm Wall**.

# 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

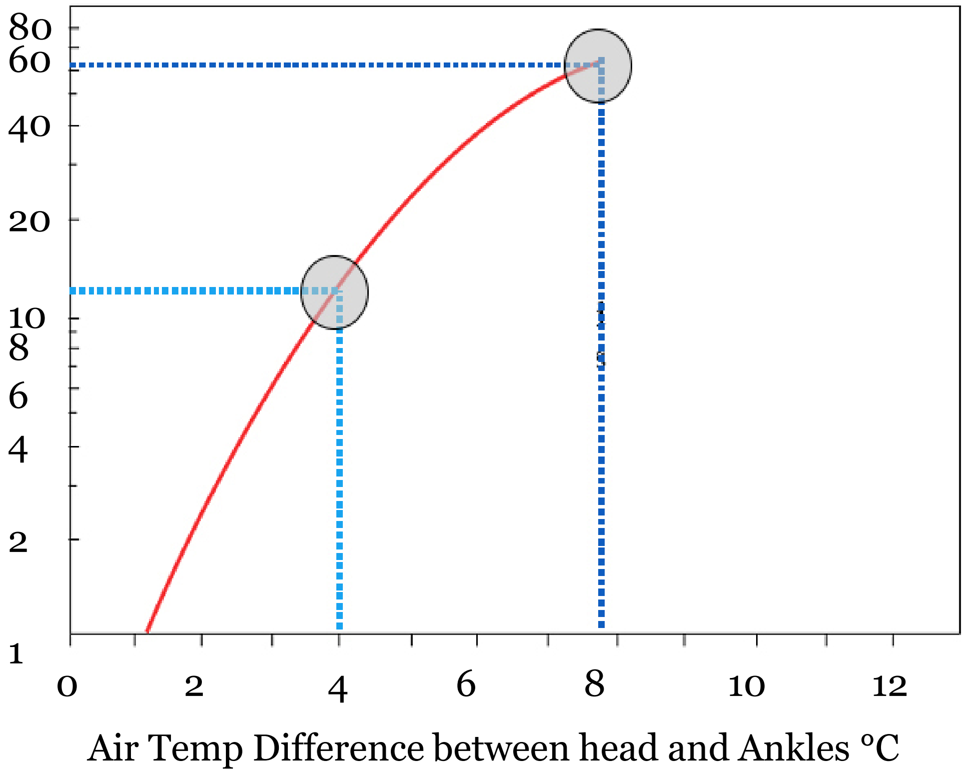
| Categorization of Floor Temp. | Cold | Cool/ Neutral | Warm |
|---|---|---|---|
| Floor Temperature | 15 °C | 24 °C | 36 °C |
| PPD | 20% | 6% | 35% |

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.

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA | प्रधान मंत्री आवास योजना-शहरी Pradhan Mantri Awas Yojana-Urban | Ministry of Housing and Urban Affairs Government of India | Azadi Ka Amrit Mahotsav | giz

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




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.

## 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.

# Session 4: Passive Strategies & Building Materials

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

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

Ministry of Housing and Urban Affairs
Government of India

Azadi Ka Amrit Mahotsav

giz

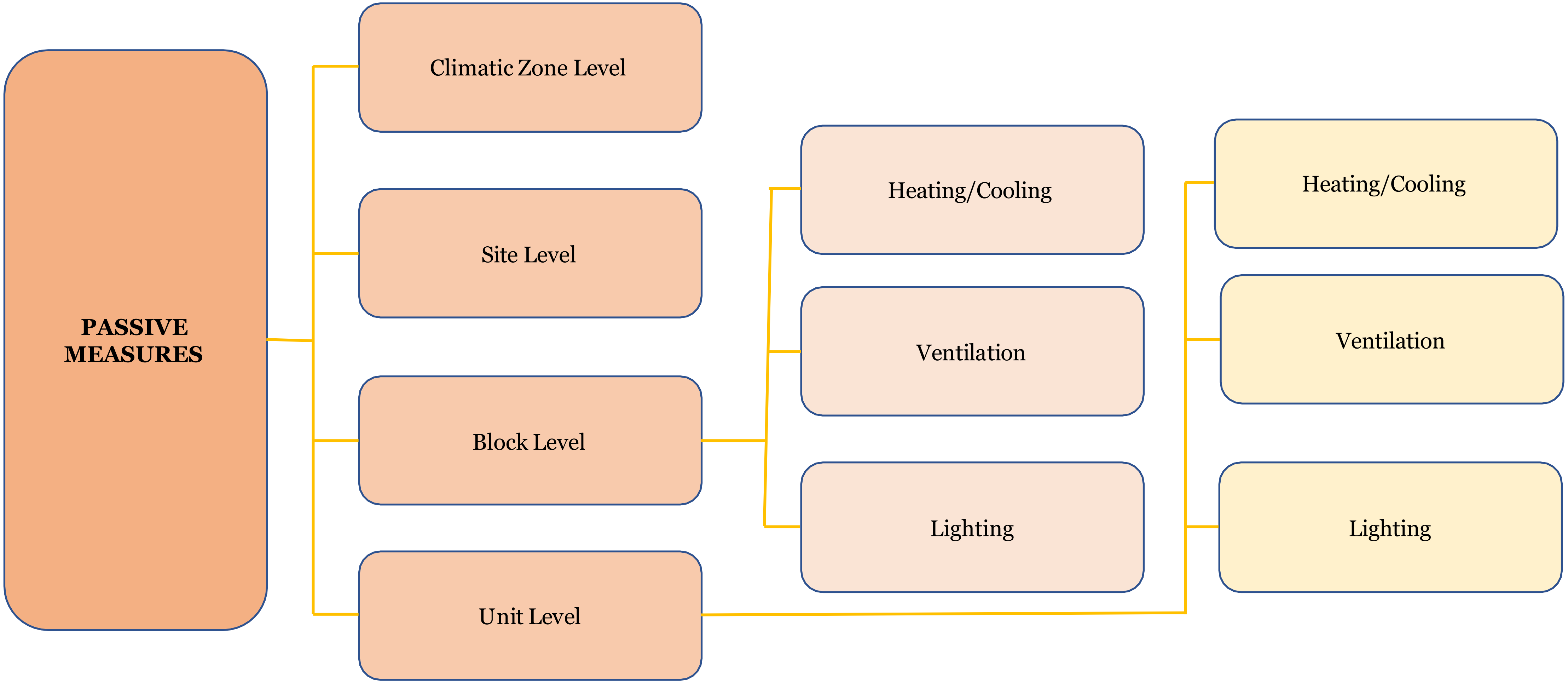
# 12

# Affordable Housing & Passive Design Strategies

# Passive Strategies & Building Physics

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

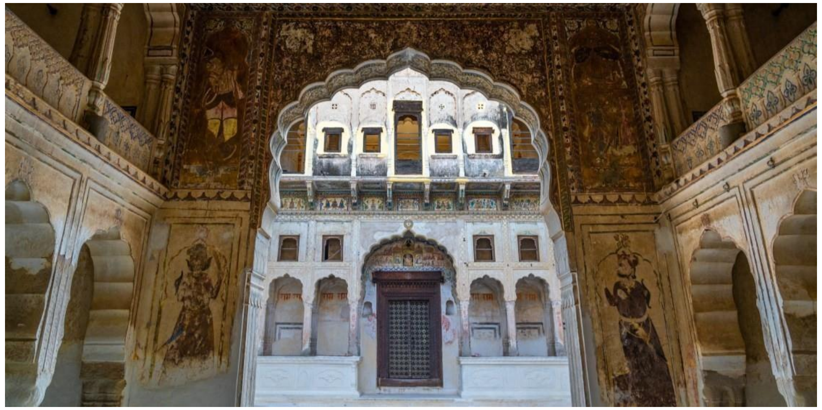
# Passive Strategies & Building Physics



# Passive Strategies & Building Physics

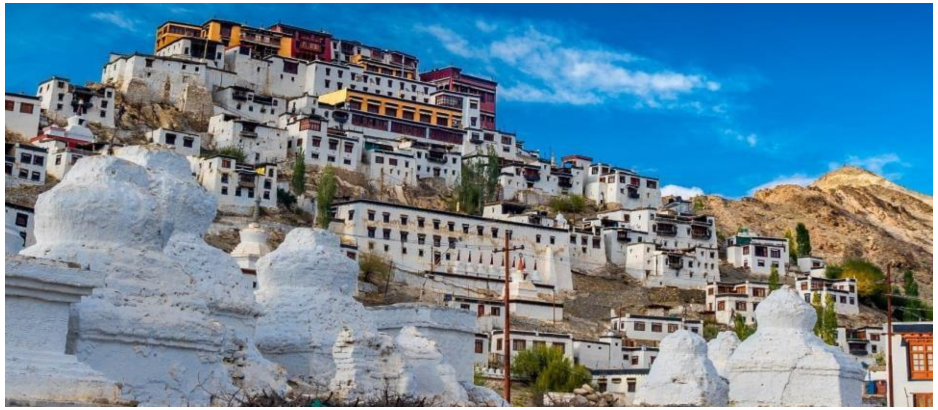
## Passive Measures – Climatic Zone Level

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.



GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA | प्रधान मंत्री आवास योजना-शहरी Pradhan Mantri Awas Yojana-Urban | Ministry of Housing and Urban Affairs Government of India | Azadi Ka Amrit Mahotsav | giz

# Passive Strategies & Building Physics

## Passive Measures – Site Level

Reducing the 'heat island' effect with approaches like:

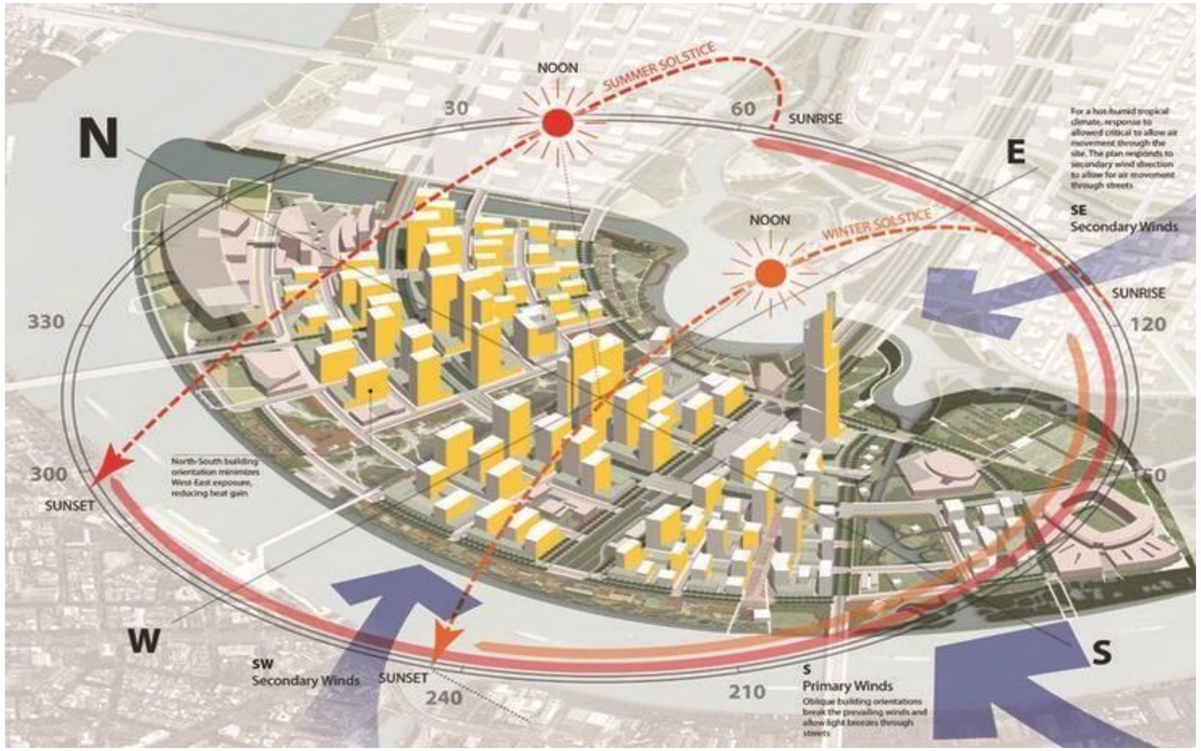
Courtyards / open courts are often surrounded by construction.

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

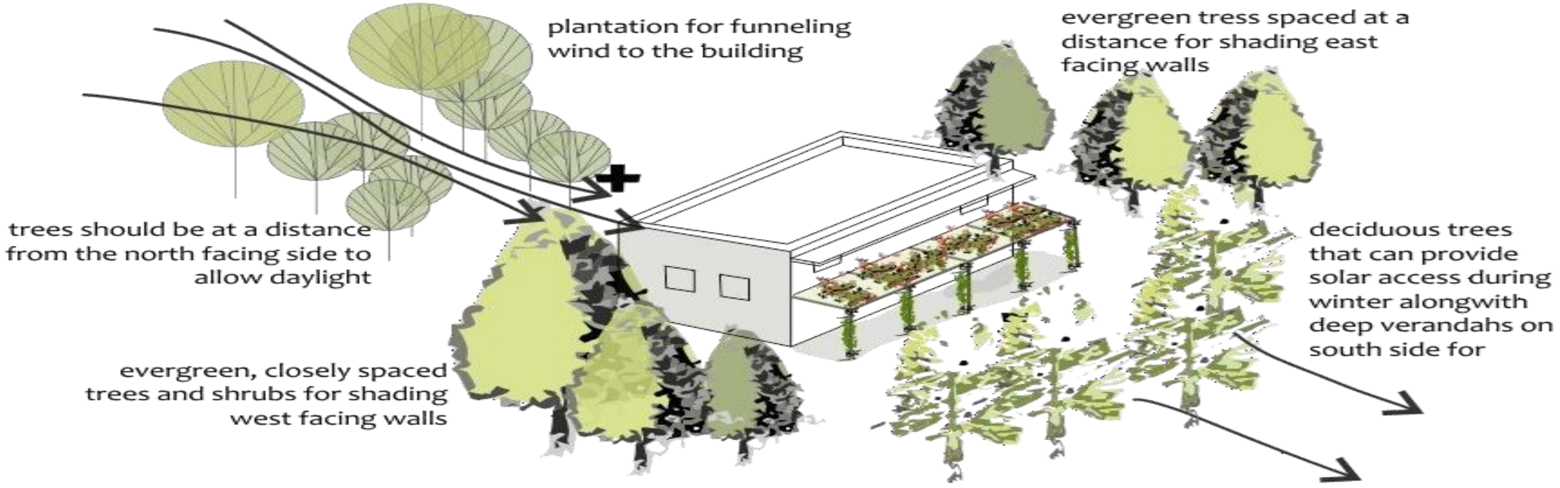


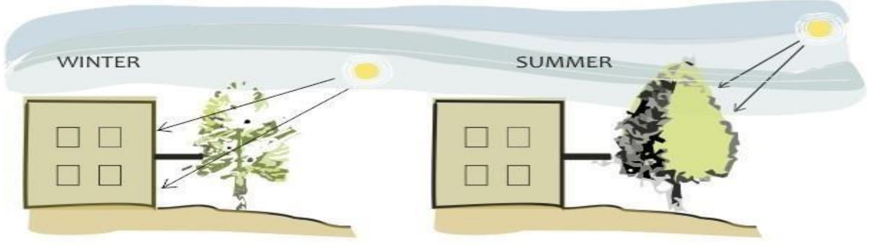
GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA | प्रधान मंत्री आवास योजना-शहरी Pradhan Mantri Awas Yojana-Urban | Ministry of Housing and Urban Affairs, Government of India | Azadi Ka Amrit Mahotsav | giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

# Passive Strategies & Building Physics

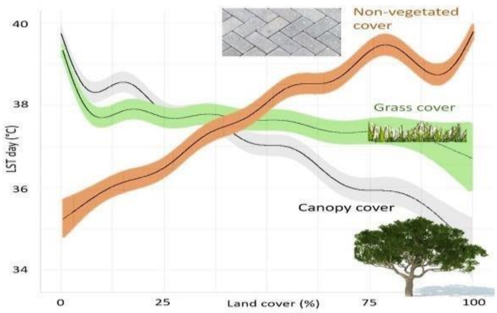
## Passive Measures – Leveraging Plantation

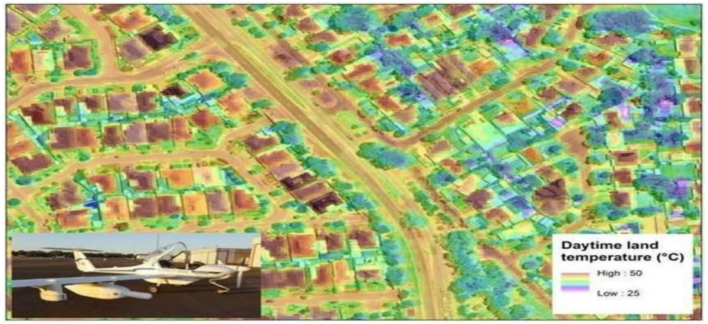
Planting trees in the right places to provide shade and ventilation can significantly reduce the severity of intense weather. During heatwaves in Adelaide, a research found that districts with more vegetation cover remained cooler by up to 6°C.




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

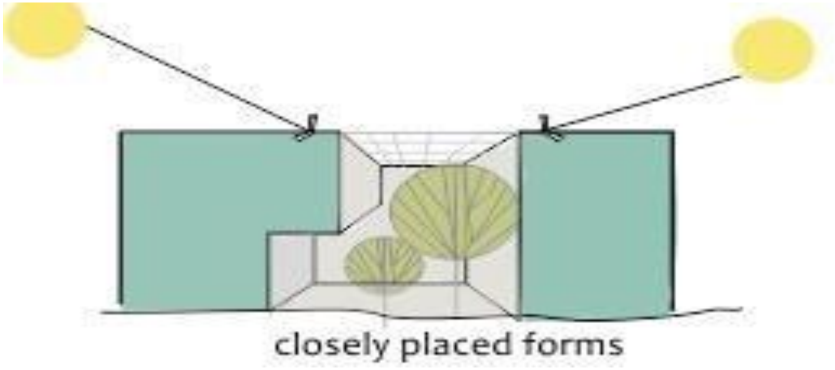


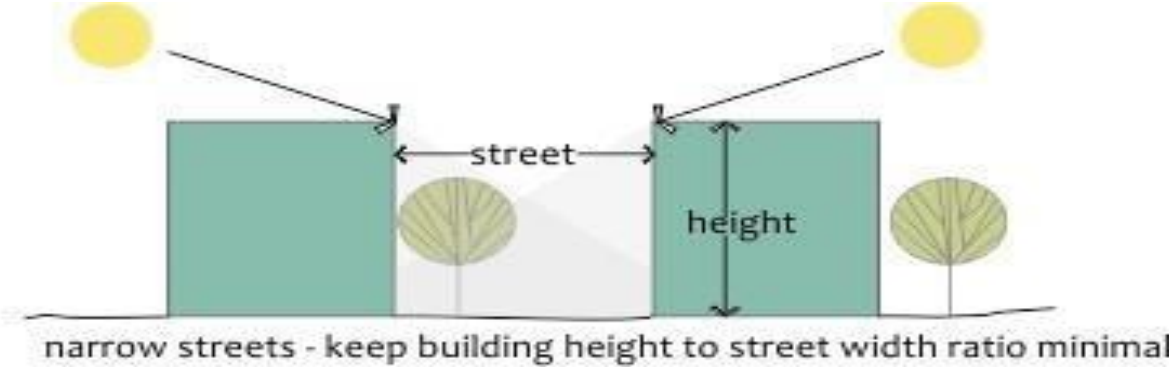



# Passive Strategies & Building Physics

## Block Level

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



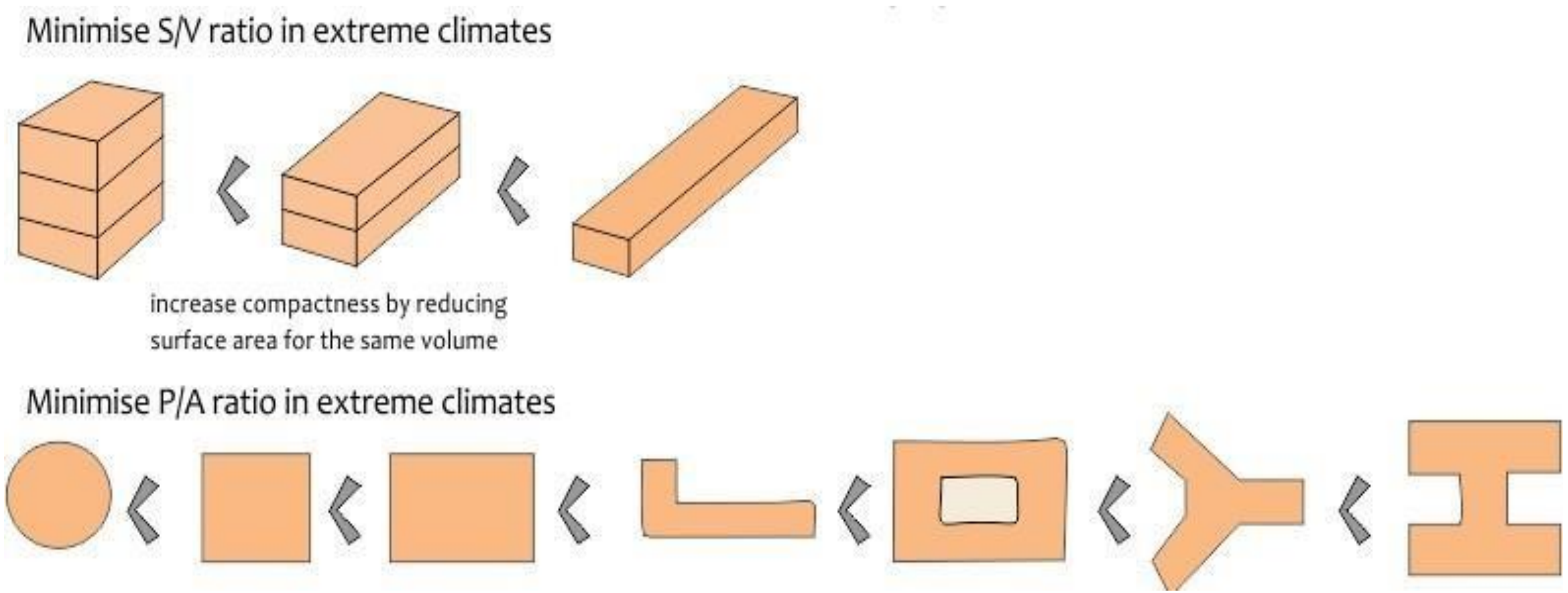

**HEATING/ COOLING**

•

# 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.




**HEATING/ COOLING**

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

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

Ministry of Housing and Urban Affairs
Government of India

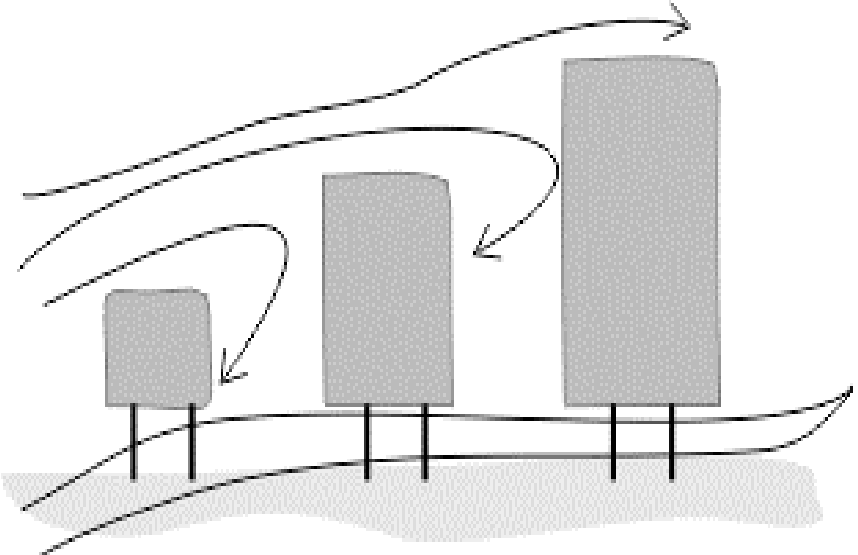
Azadi Ka Amrit Mahotsav

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

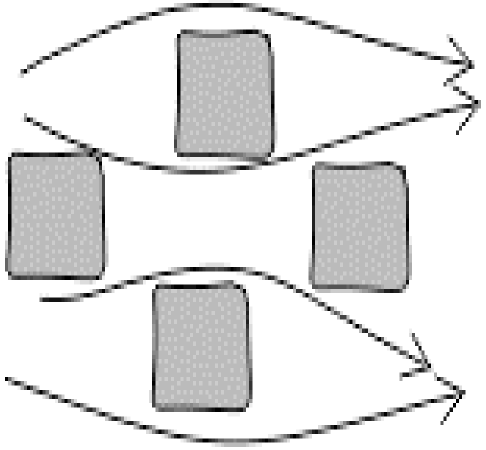
# Passive Strategies & Building Physics

## Block Level

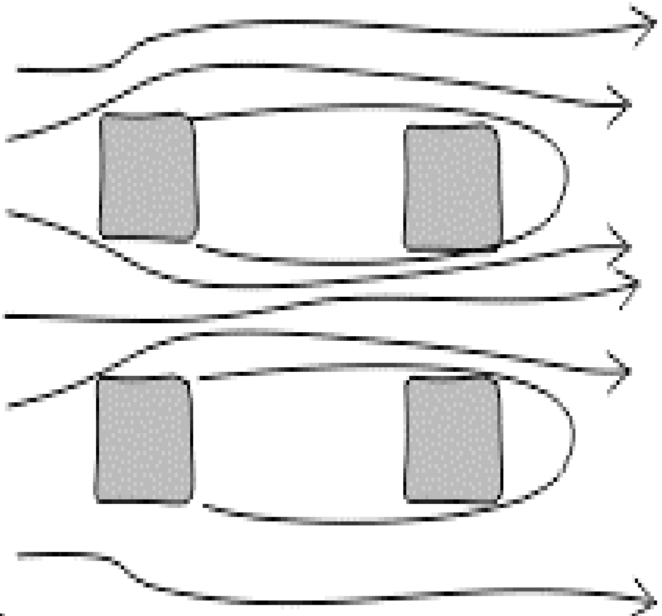
Wind shadows should be avoided by building orientation.



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



**VENTILAT
ION**

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

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

Ministry of Housing and Urban Affairs
Government of India

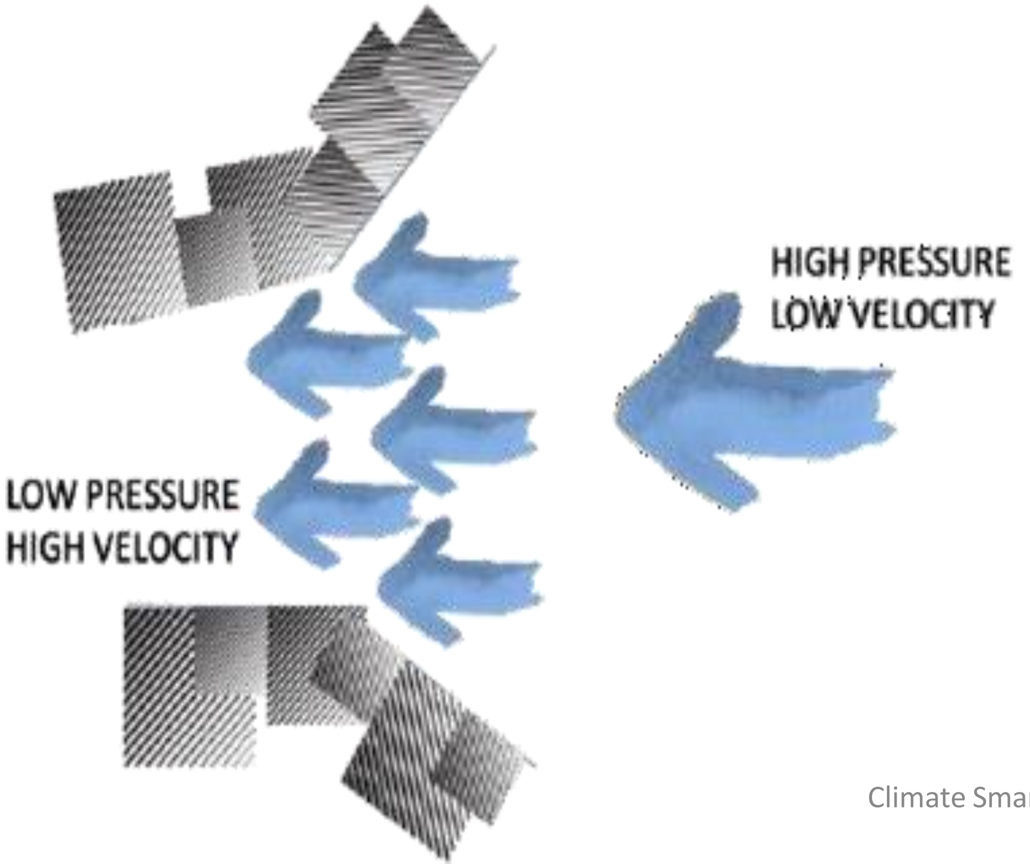
Azadi Ka Amrit Mahotsav

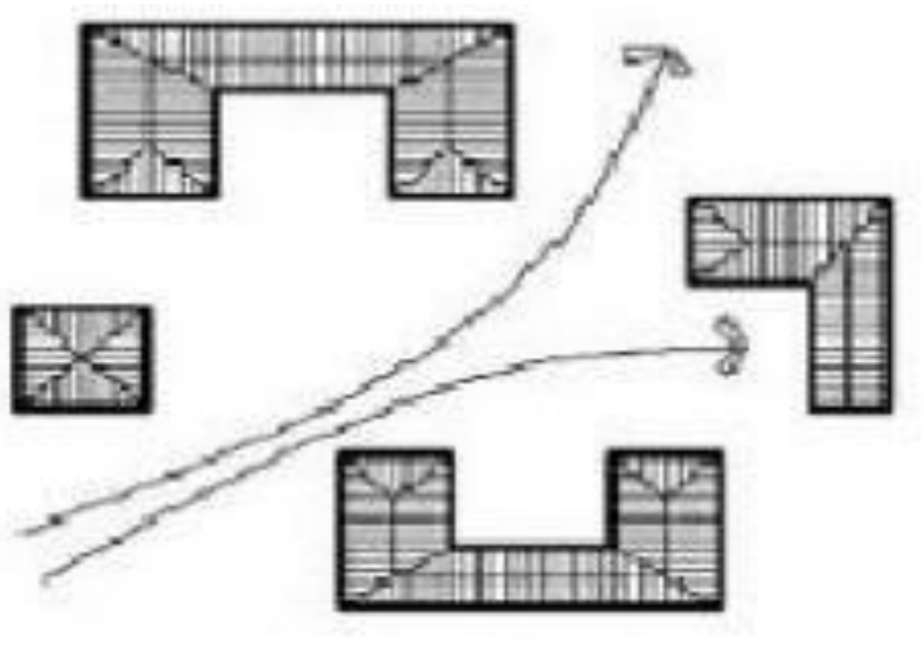
giz

# 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.



BUILDING SPACING SUCH THAT AIR FLOW IS PROMOTED

**VENTILATION**

# Passive Strategies & Building Physics

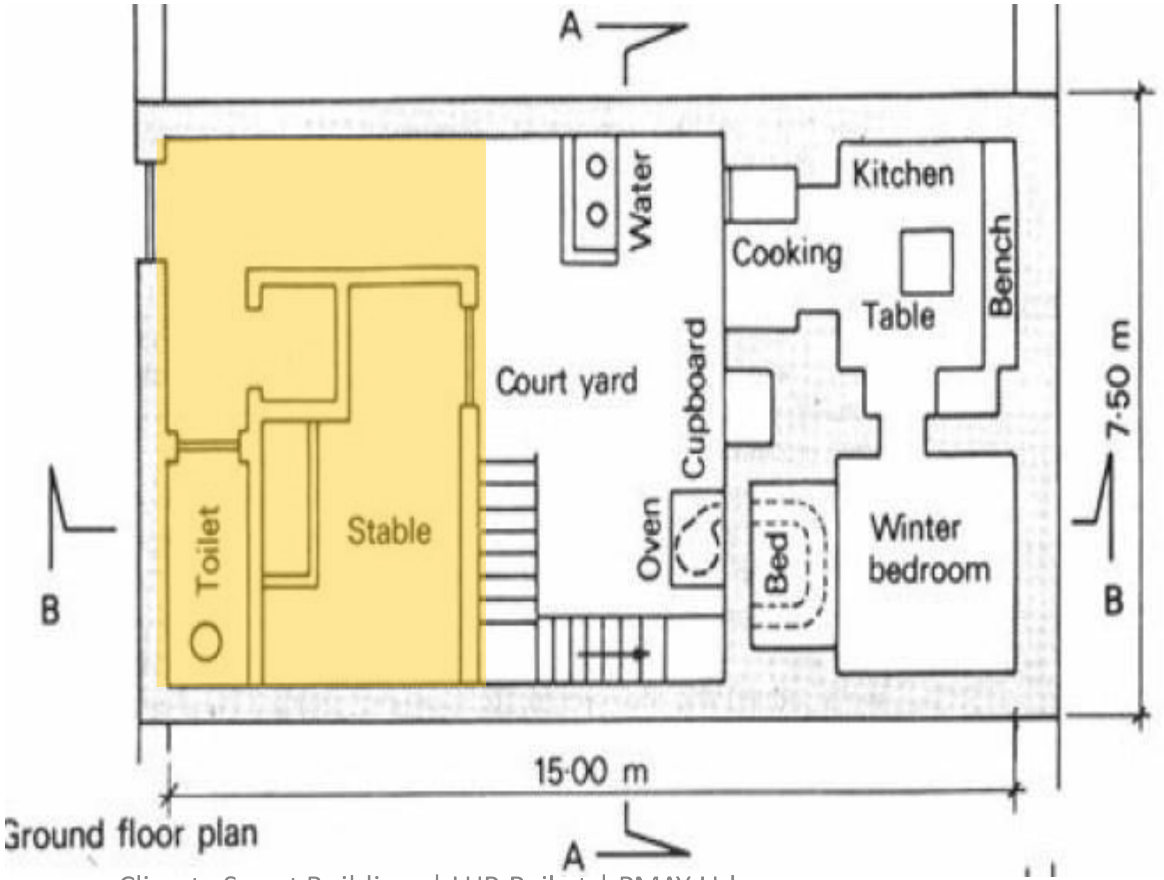
## Unit Level

### 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.




**HEATING/ COOLING**

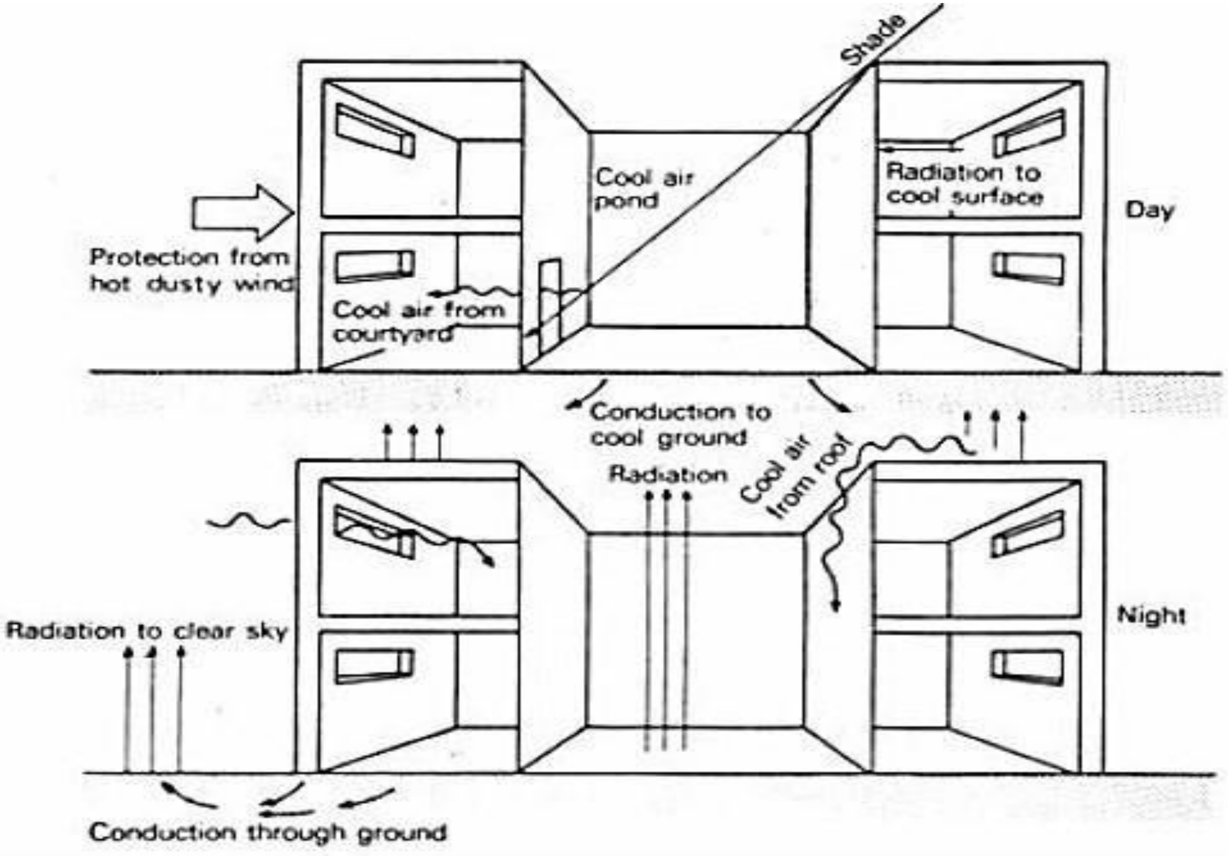
# Passive Strategies & Building Physics

## 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.




HEATING/ COOLING

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA | प्रधान मंत्री आवास योजना-शहरी Pradhan Mantri Awas Yojana-Urban | Ministry of Housing and Urban Affairs Government of India | Azadi Ka Amrit Mahotsav | giz

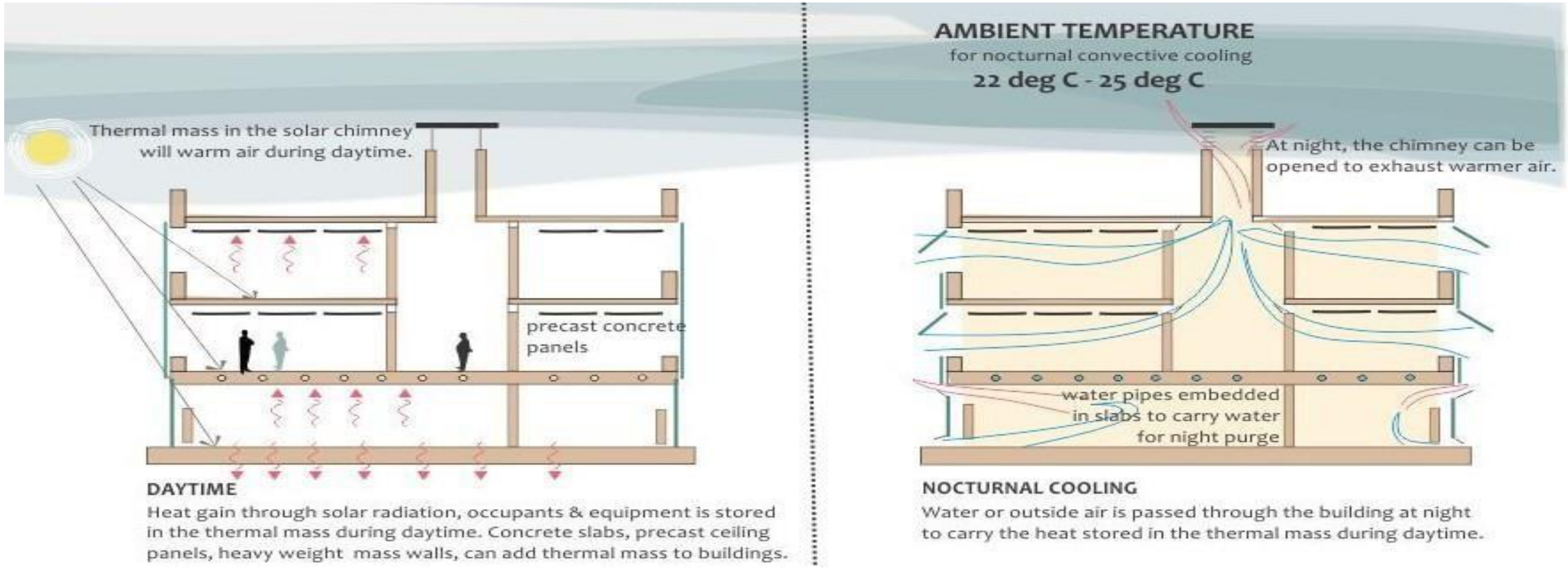
# Passive Strategies & Building Physics

## 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

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA | प्रधान मंत्री आवास योजना-शहरी Pradhan Mantri Awas Yojana-Urban | Ministry of Housing and Urban Affairs Government of India | Azadi Ka Amrit Mahotsav | giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

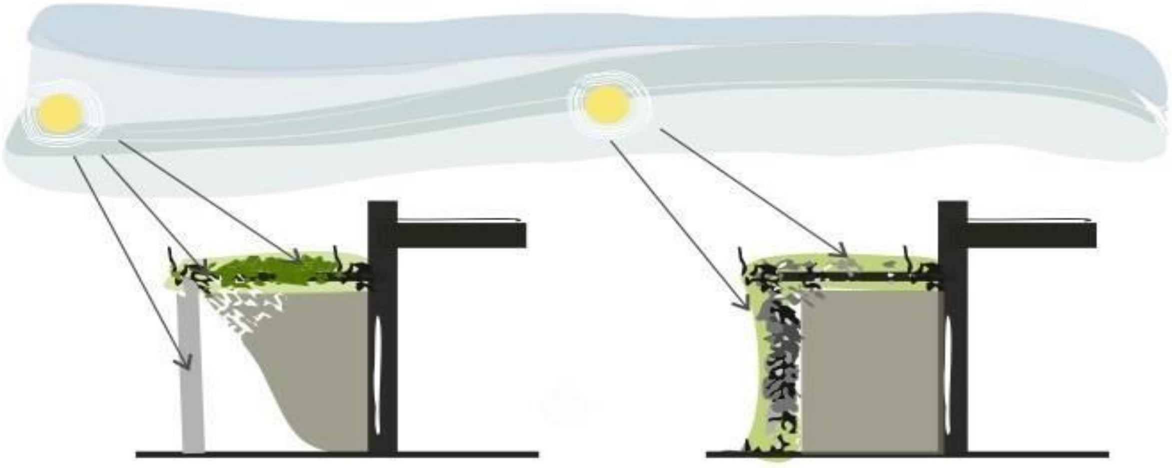
# Passive Strategies & Building Physics

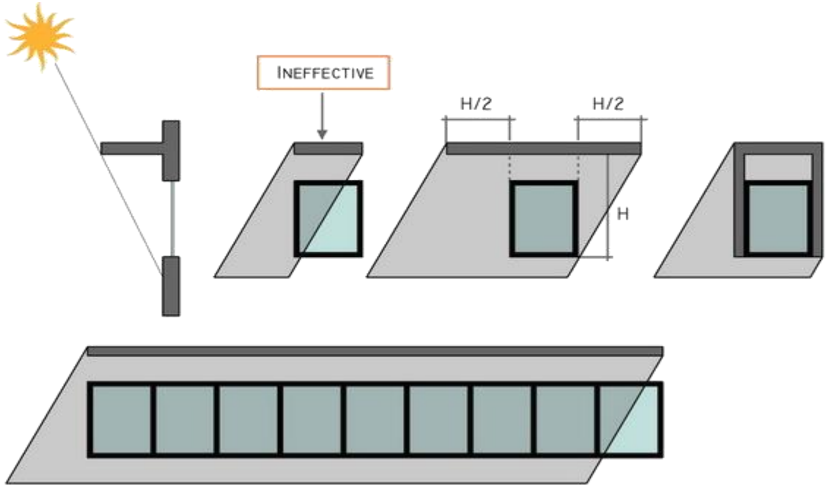
## Unit Level

**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° to 30°.

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

### CREATING PRESSURE DIFFERENCES:

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

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

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

**VENTILATION**

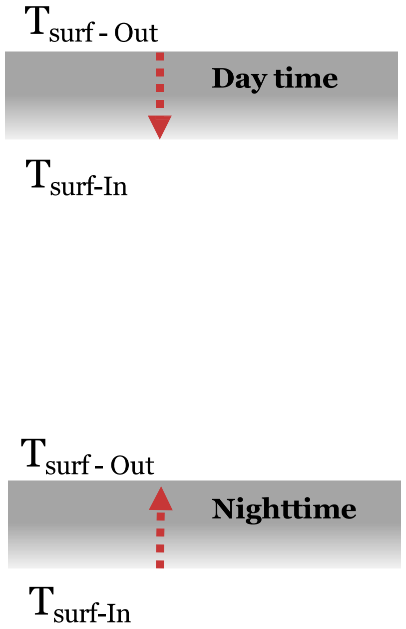
# 13

# Innovative Building Materials

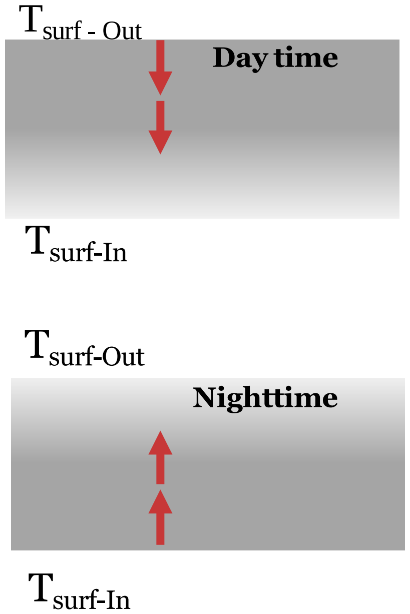
# Walling Material and Walling Assemblies

## Heat Transfer in Buildings: Insulation and Thermal Mass

**Thermal Insulation, Thermal Conductivity**



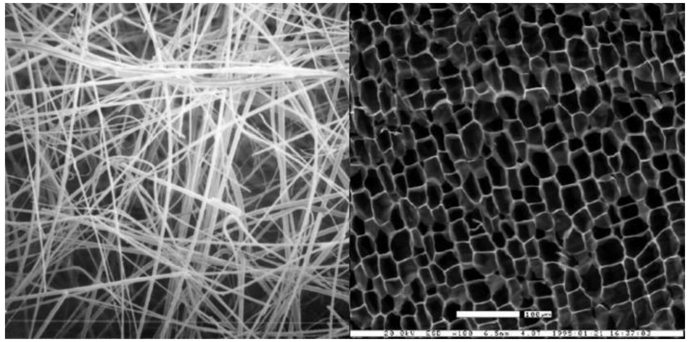

**Thermal Insulation, Specific Heat Capacity**




*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=tinysrgb&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

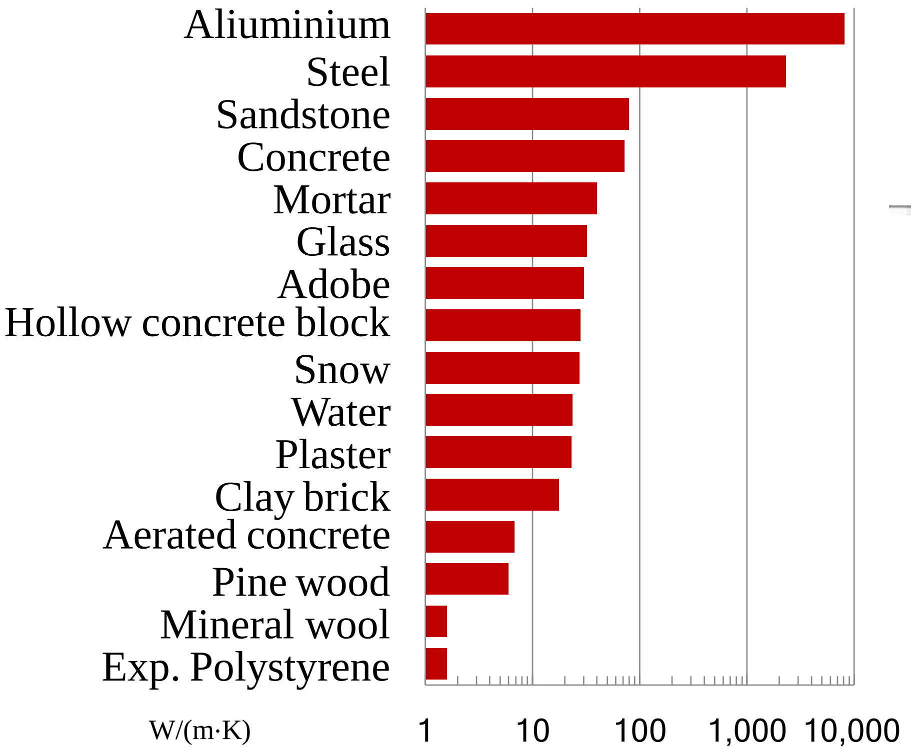
Air is locked in foam bubbles or between fibers

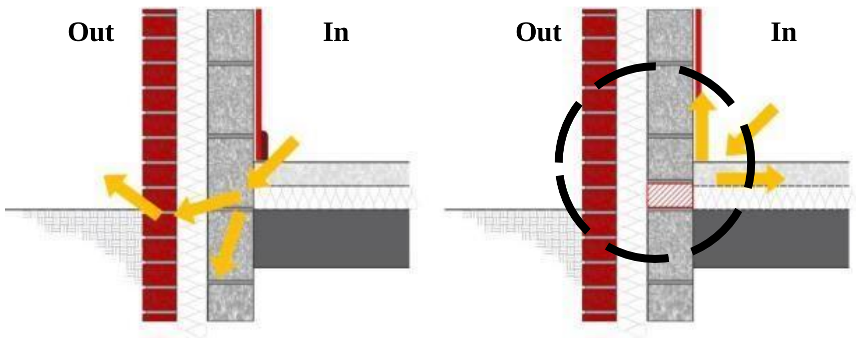
Bubble walls and fibers are themselves opaque to thermal radiation.

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

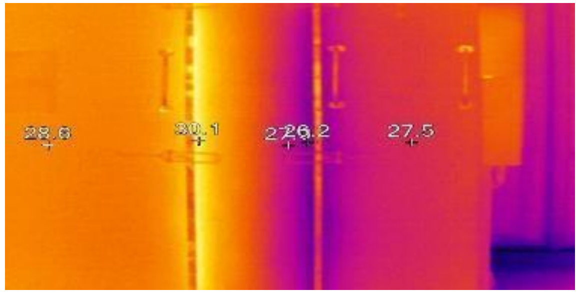
# Walling Material and Walling Assemblies

## Walling Materials and Methods : Conductivity & Thermal Bridge



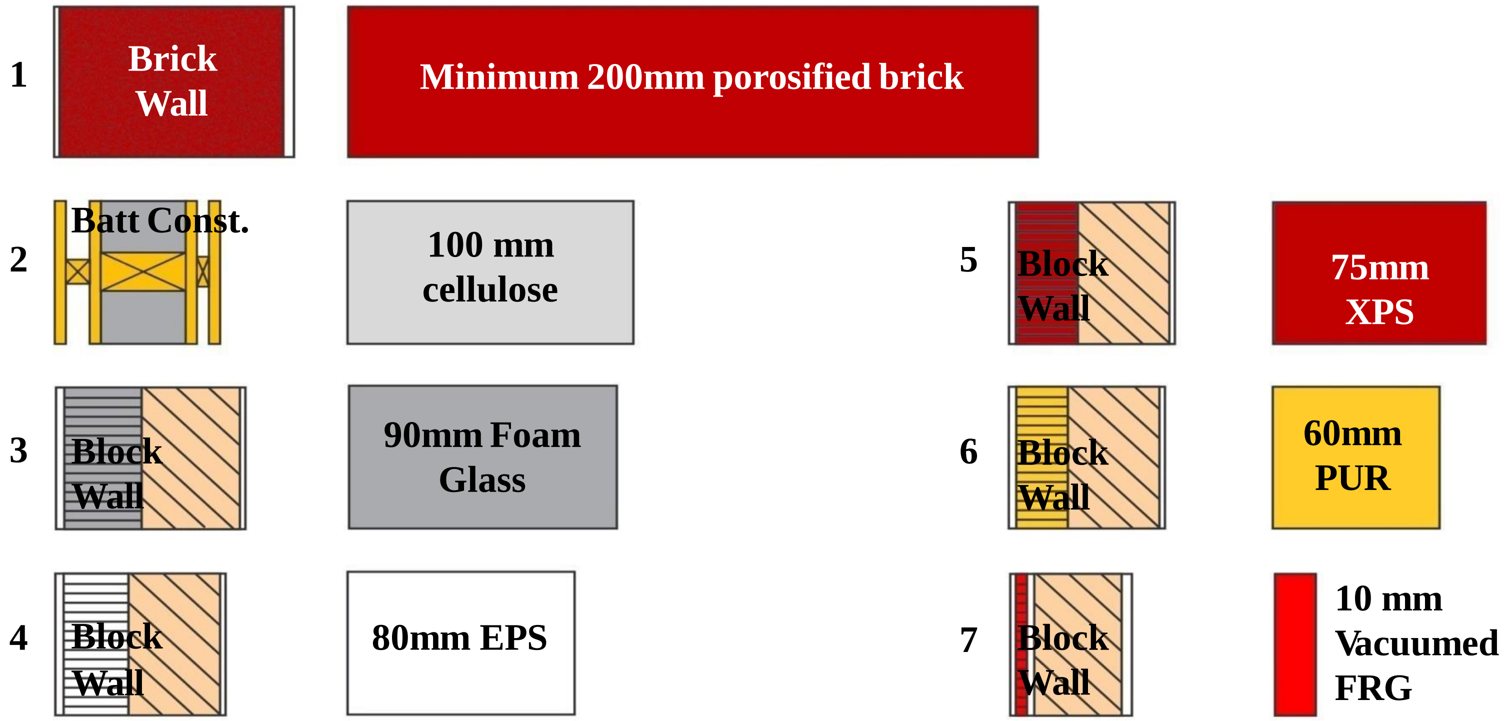

Air = 1
0.0002 Sq mts of aluminium (2 Sq Cms) = 1 Sq mts of insulation



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

# Walling Material and Walling Assemblies

## Walling Materials and Methods : Construction



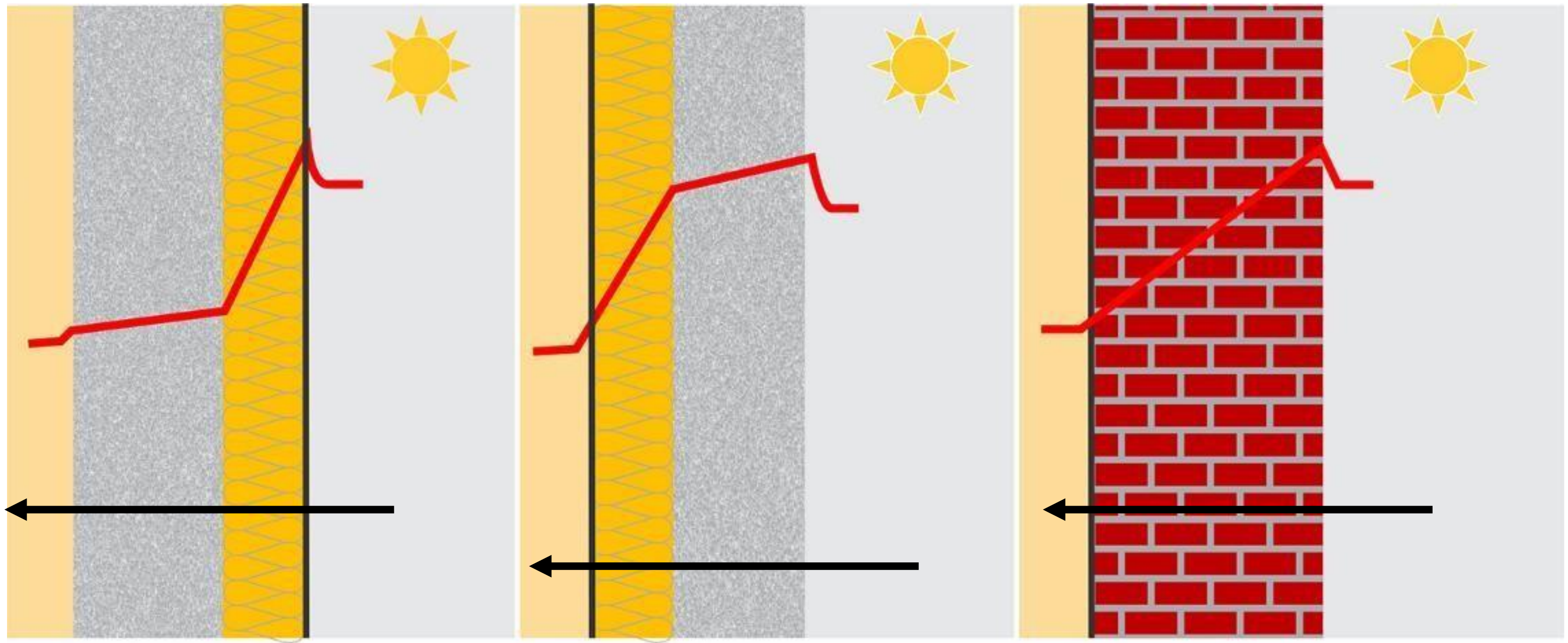

**Minimum Thickness Needed to Achieve U value of < 0.40W/m²K**

*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



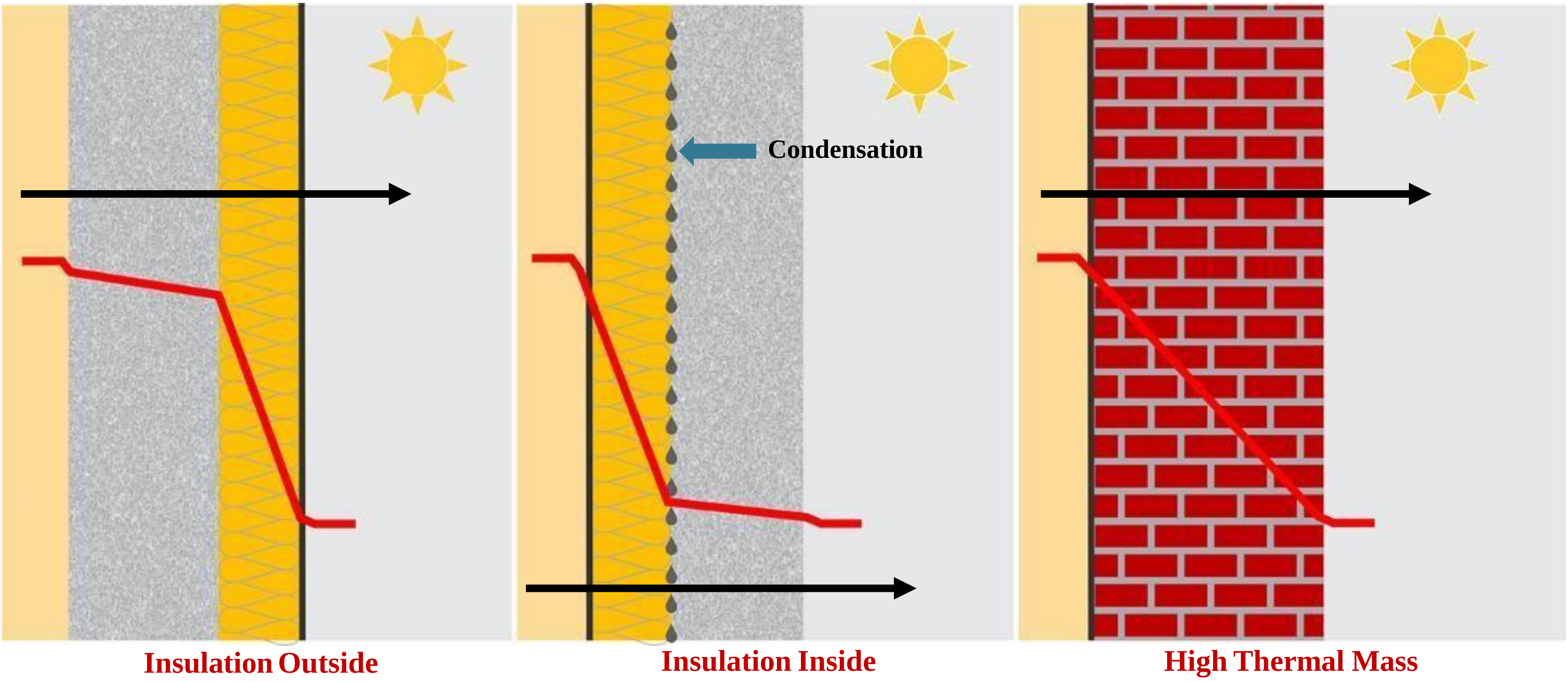
**Insulation Outside** | **Insulation Inside** | **High Thermal Mass**

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

# Walling Material and Walling Assemblies

## Walling Materials and Methods : Construction

Steady State Indoors and Variable Outdoors – Cold and Sunny Outdoors

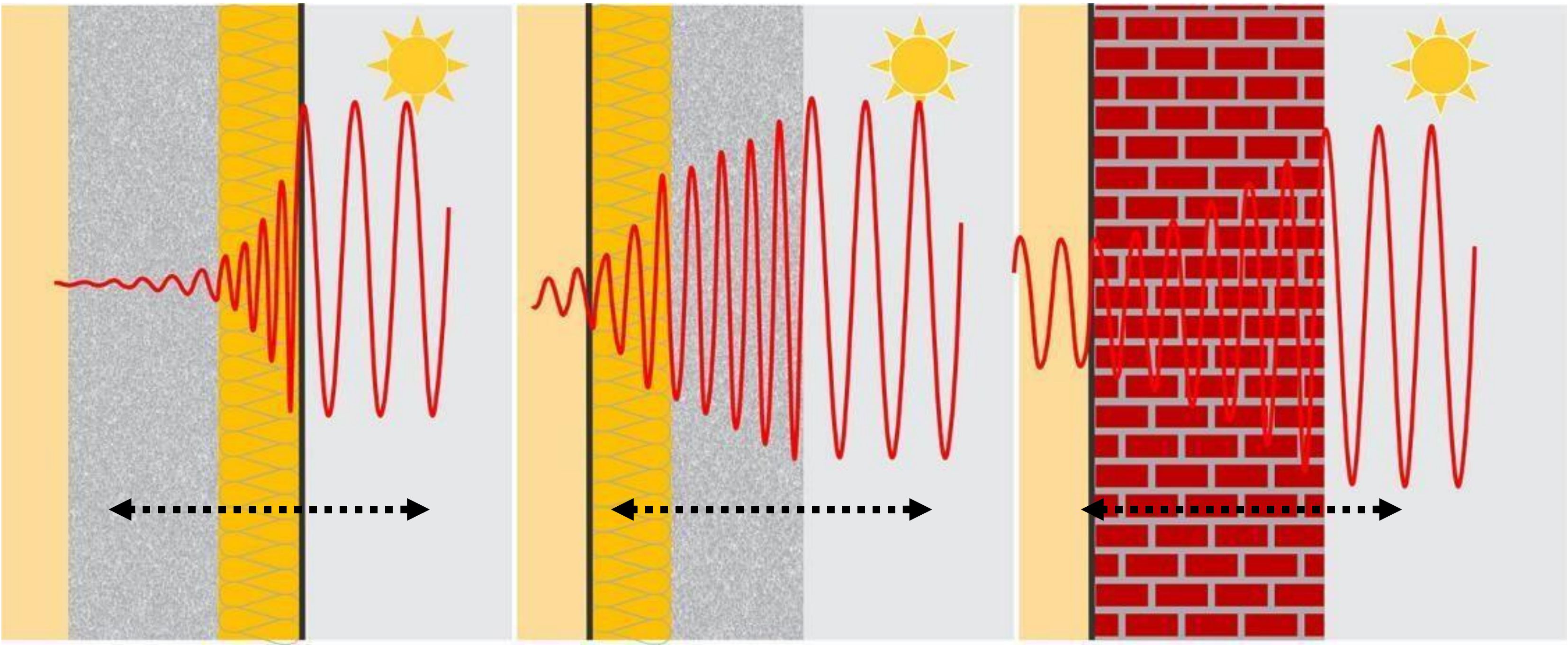



*Information and Image Courtesy: Prof. Cloude Roulet, EMPA, Switzerland, Indo Swiss BEEP project, BEE, India*

# Walling Material and Walling Assemblies

## Walling Materials and Methods : Construction

Variable Indoors and Variable Outdoors

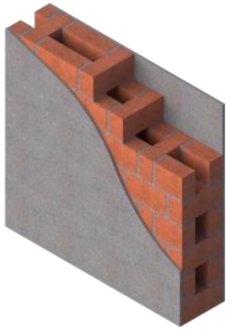


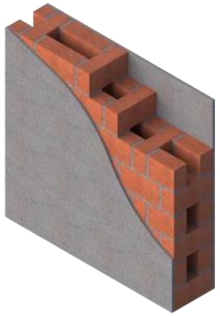
**Insulation Outside** **Insulation Inside** **High Thermal Mass**

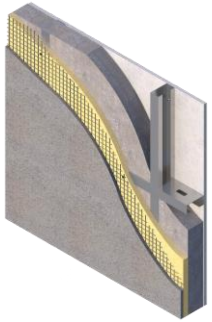
*Information and Image Courtesy: Prof. Cloude Roulet, EMPA, Switzerland, Indo Swiss BEEP project, BEE, India*

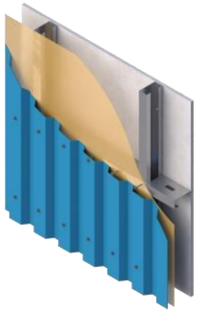
# Walling Material and Walling Assemblies

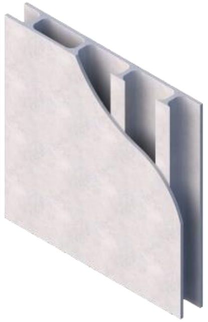
## Nonhomogeneous Walling Technologies, Industrial


**230 MM Clay Brick Wall Base Line**


**Rat Trap Bond**


**LGFSS- EPS**

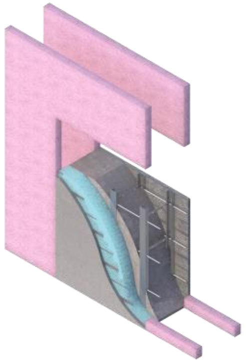

**PPGL**


**GFRG Unfilled**


**GFRG Partially Filled**


**GFRG Fully Filled**

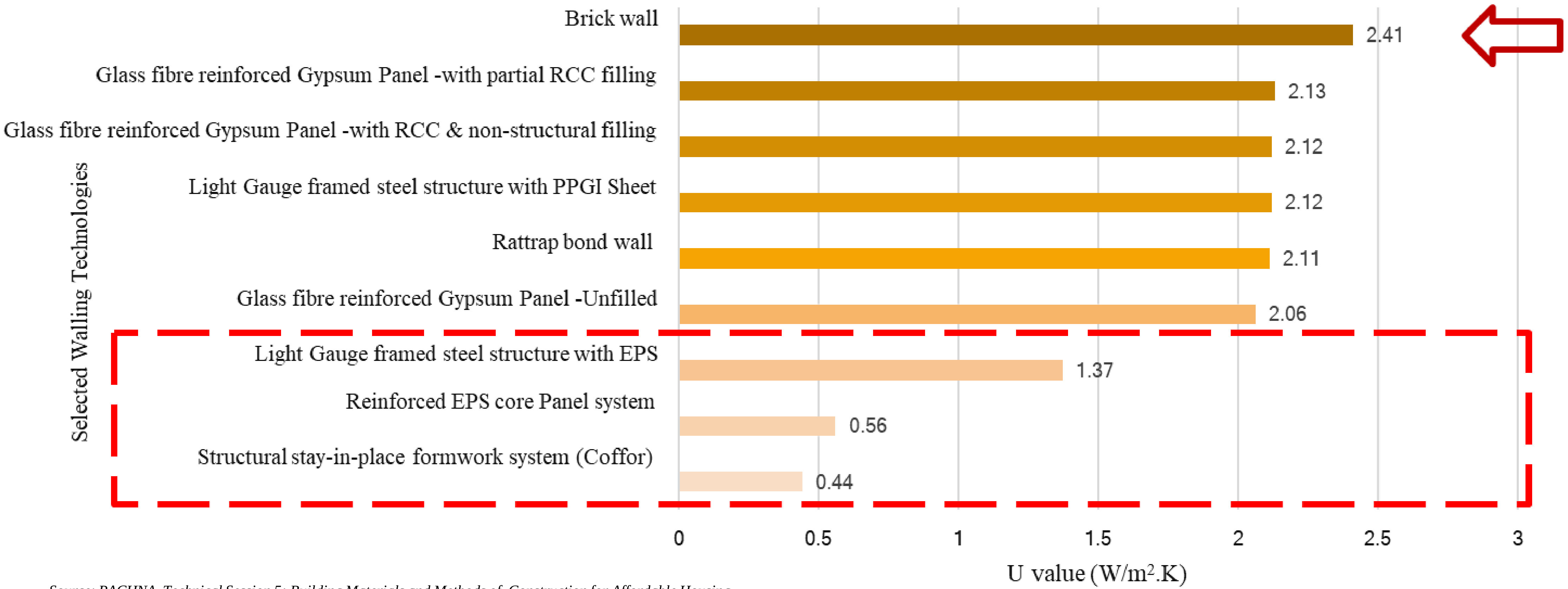

**Reinforced EPS Core**


**Stay-in-Place Coffer**

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

# 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*

# Walling Material and Walling Assemblies

## Nonhomogeneous Walling Technologies, Traditional

**Bamboo-Crete**
**U - VALUE (W/m$^2$K)= 1.82**

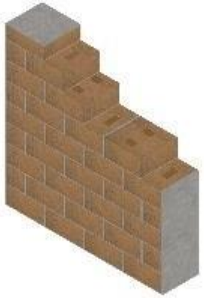
**Wattle and Daub**
**U - VALUE (W/m$^2$K)= 2.09**

**Stabilized Adobe**
**U - VALUE (W/m$^2$K)= 1.50**

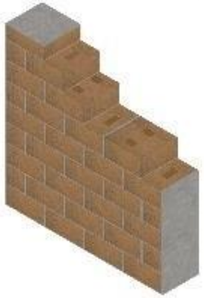
**Laterite block wall**
**U - VALUE (W/m$^2$K)= 1.61**

**Unstabilized Adobe**
**U - VALUE (W/m$^2$K)= 1.57**

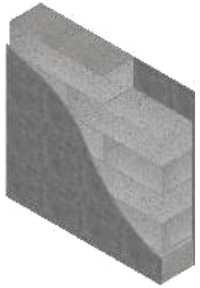
**Compressed Stabilized Earth block wall**
**U - VALUE (W/m$^2$K)= 1.59**



**Unstabilized Compressed Earth block wall**
**U - VALUE (W/m$^2$K)= 1.42**



**AAC block wall**
**U - VALUE (W/m$^2$K)= 0.45**



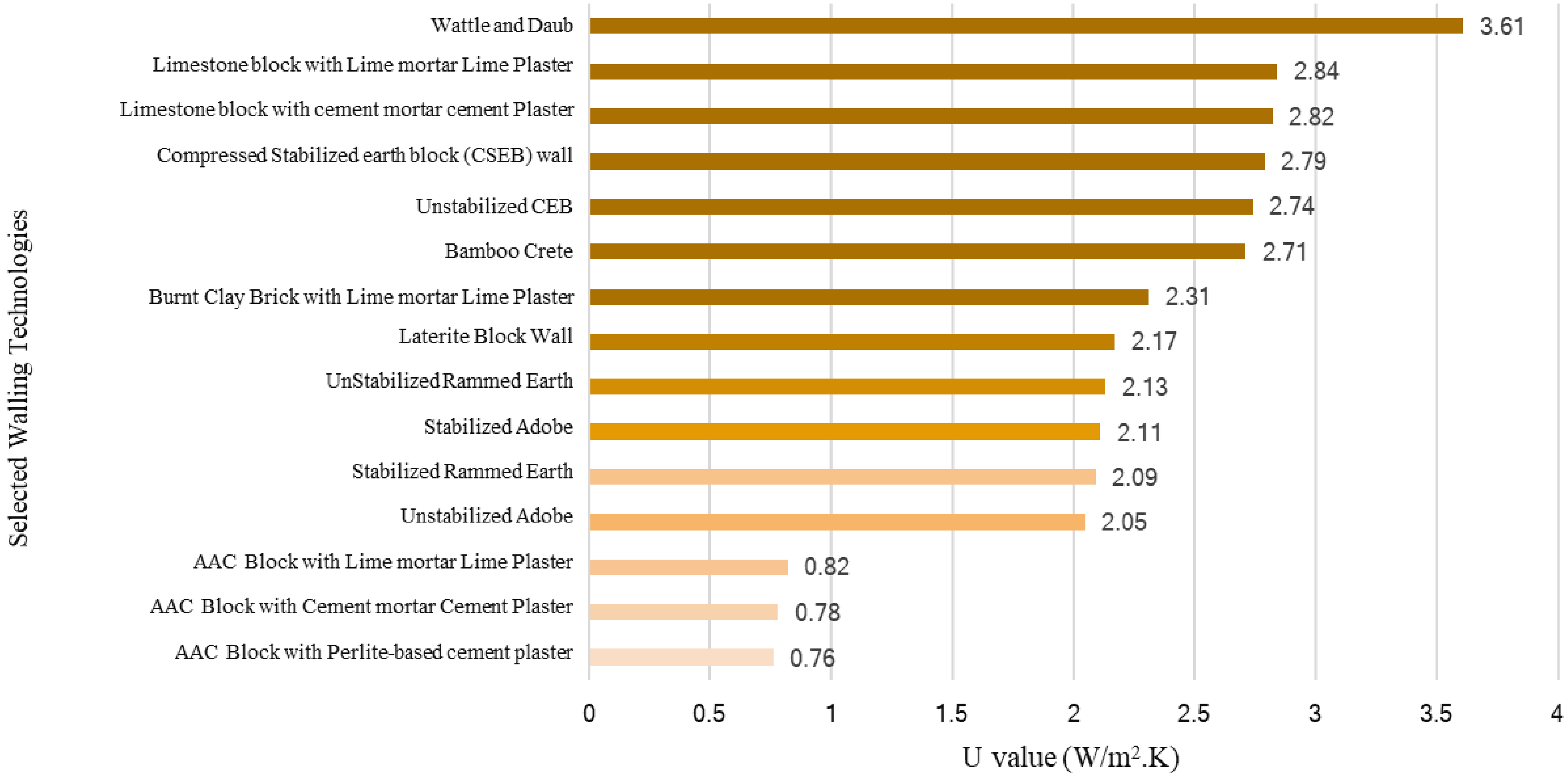
**Unstabilized Rammed Earth Wall assembly**
**U - VALUE (W/m$^2$K)= 1.68**

**Stabilized Rammed Earth Wall assembly**
**U - VALUE (W/m$^2$K) = 1.495**

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

# Walling Material and Walling Assemblies

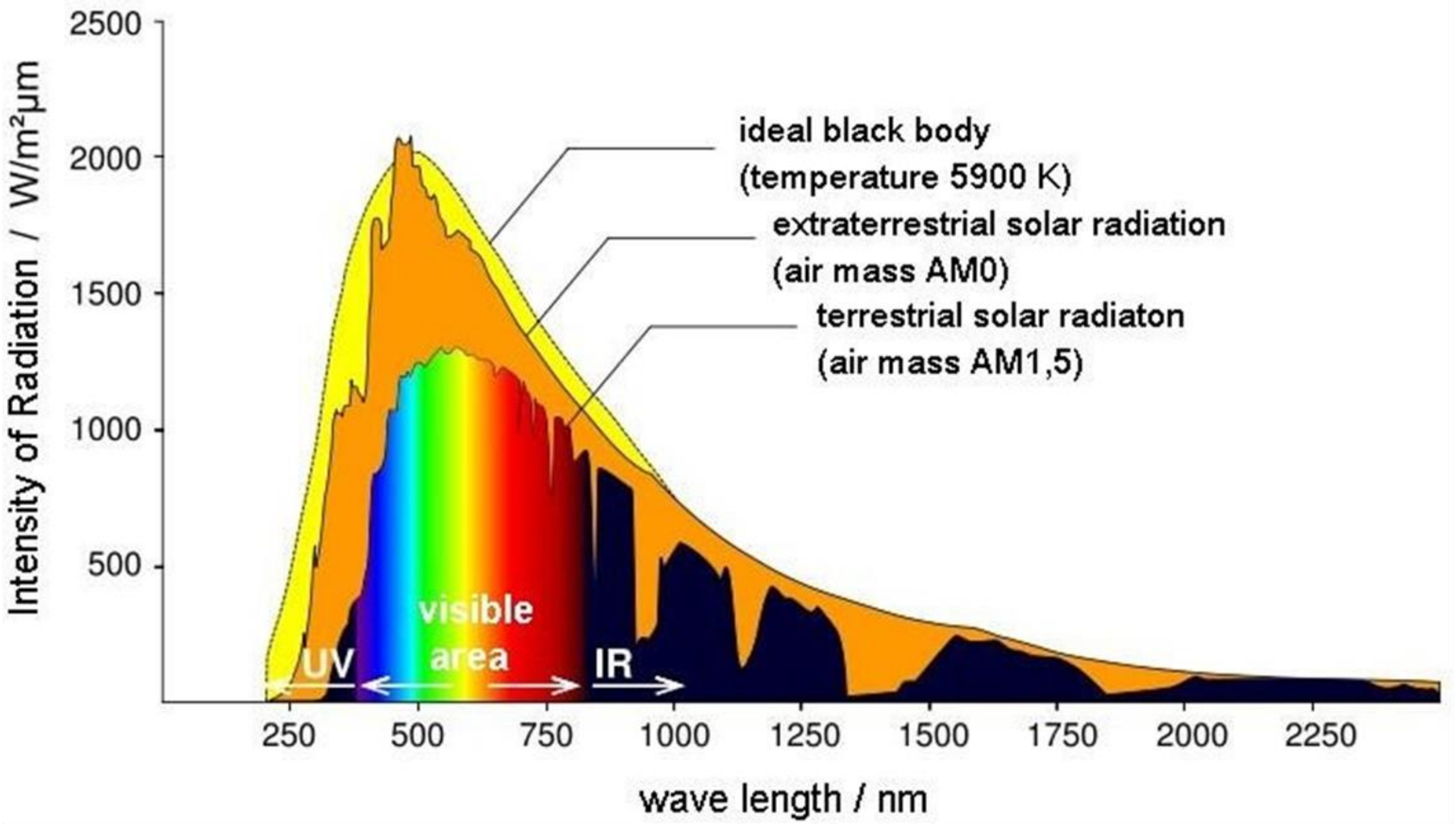
## Walling Technologies: U Values, Traditional



# GLAZING MATERIAL and GLAZING ASSEMBLIES

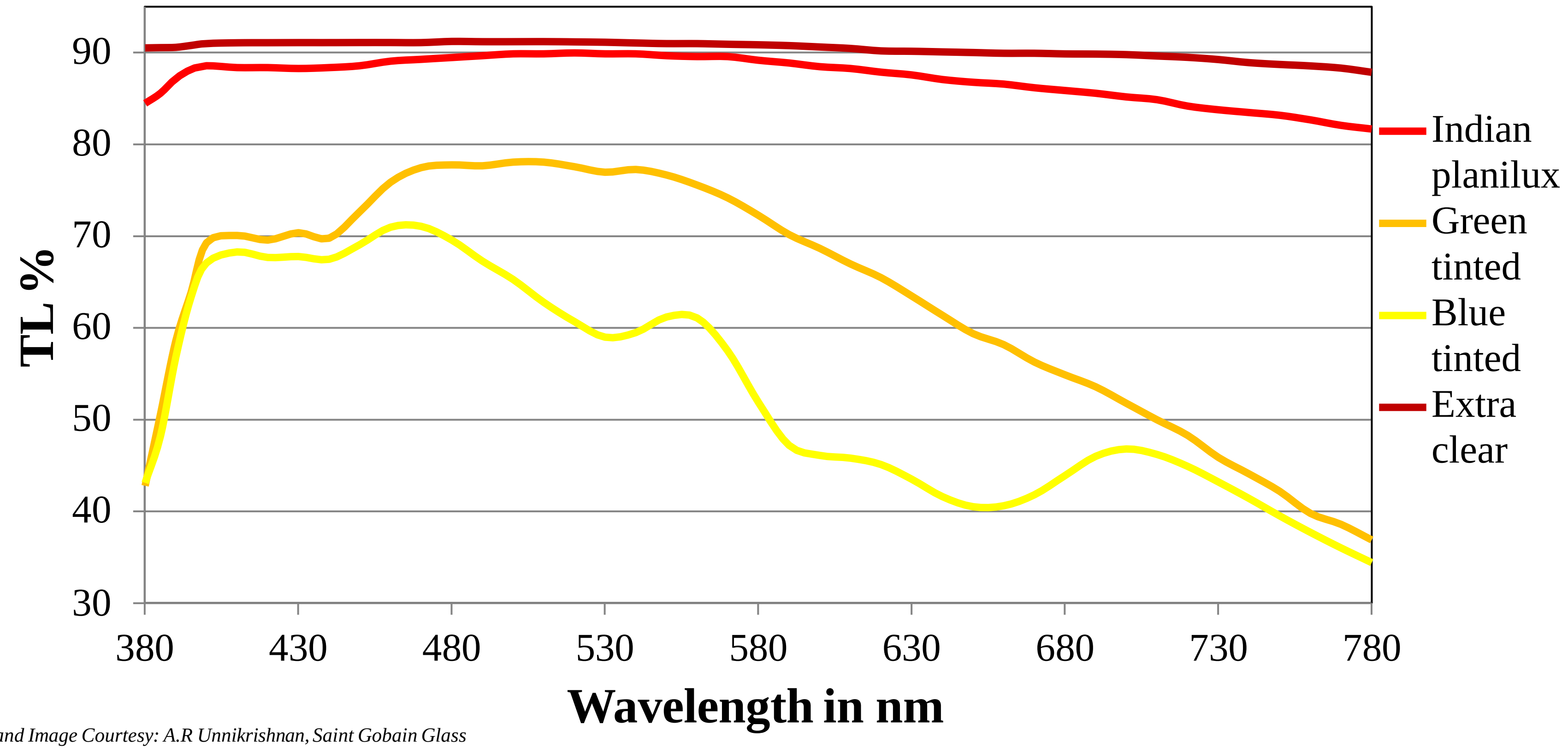
# Glazing Material and Glazing Assemblies

## Glazing Material and Methods: Solar Spectrum



# Glazing Material and Glazing Assemblies

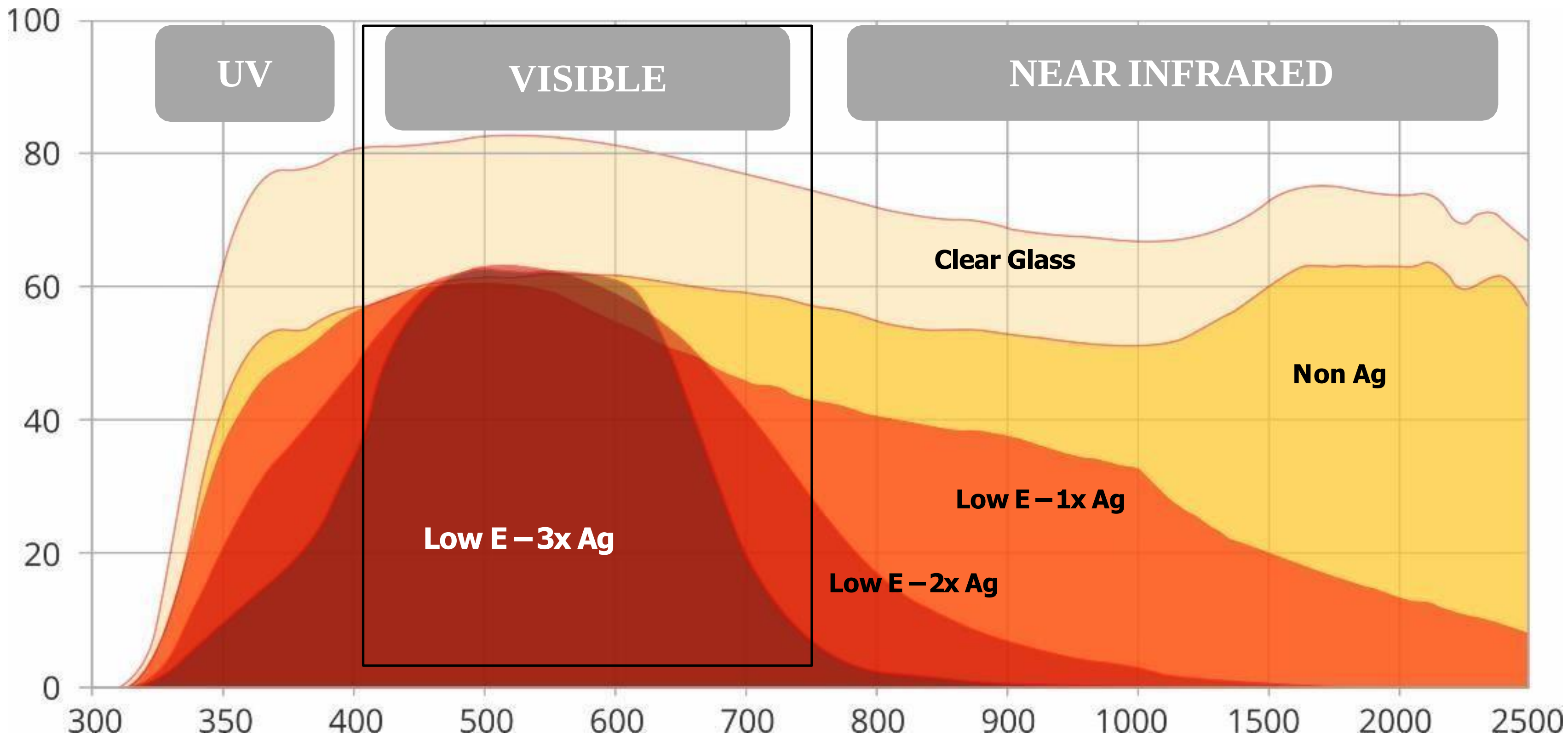
## Glazing Material and Methods : Solar Radiation through Glass




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

# Glazing Material and Glazing Assemblies

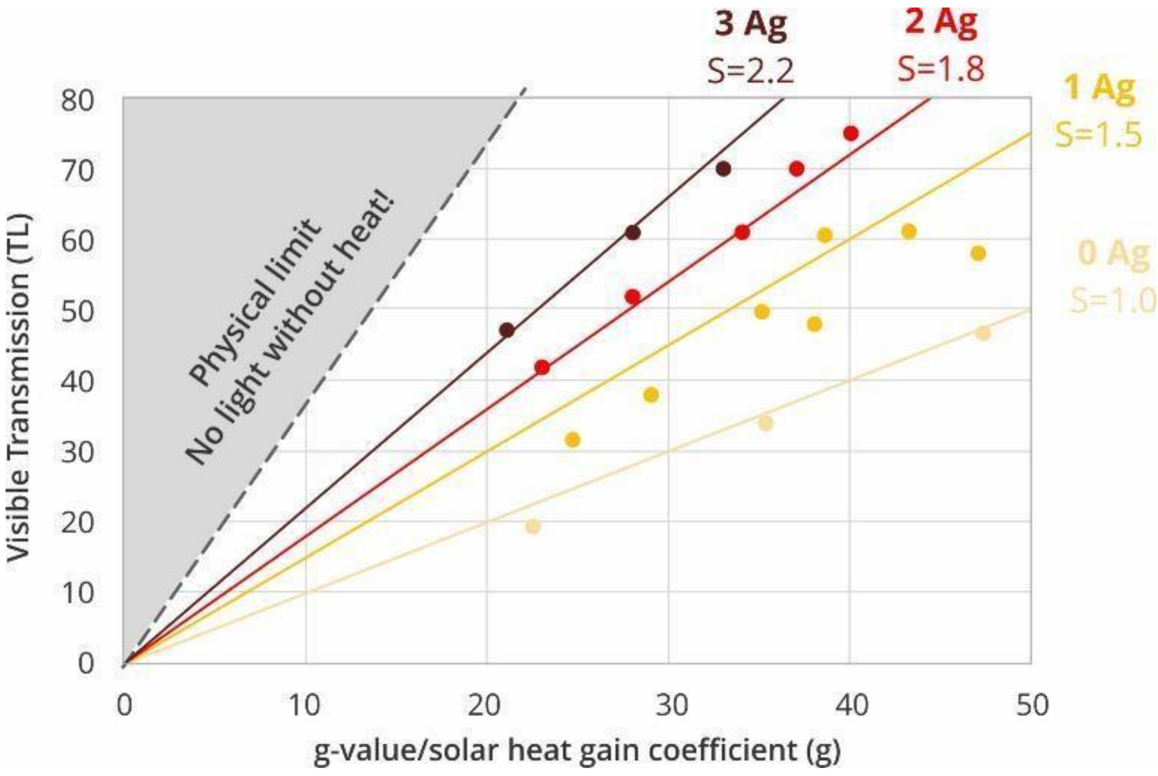
## Glazing Material and Methods : Solar Control




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

# Glazing Material and Glazing Assemblies

## Glazing Material and Methods : Solar Control




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

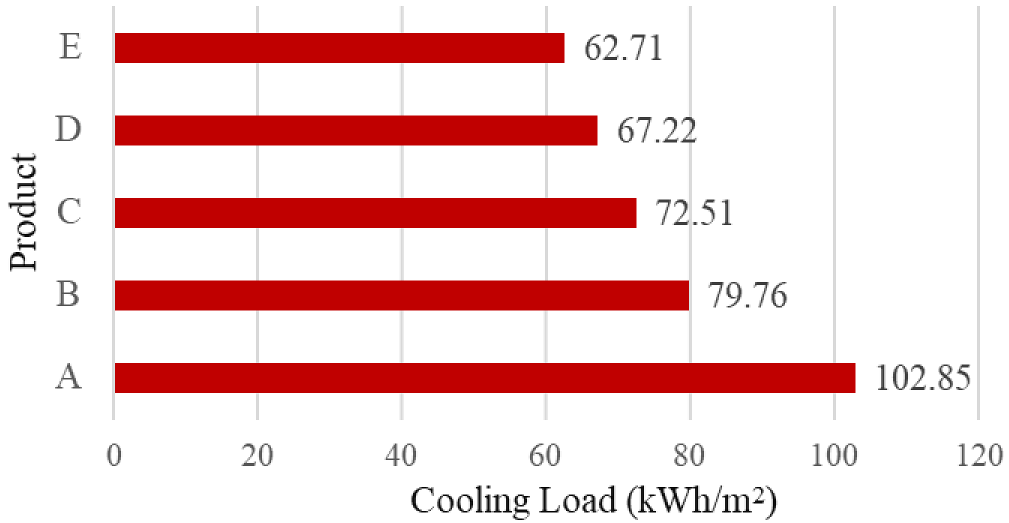
Silver (Ag) based coater products have the maximum selectivity

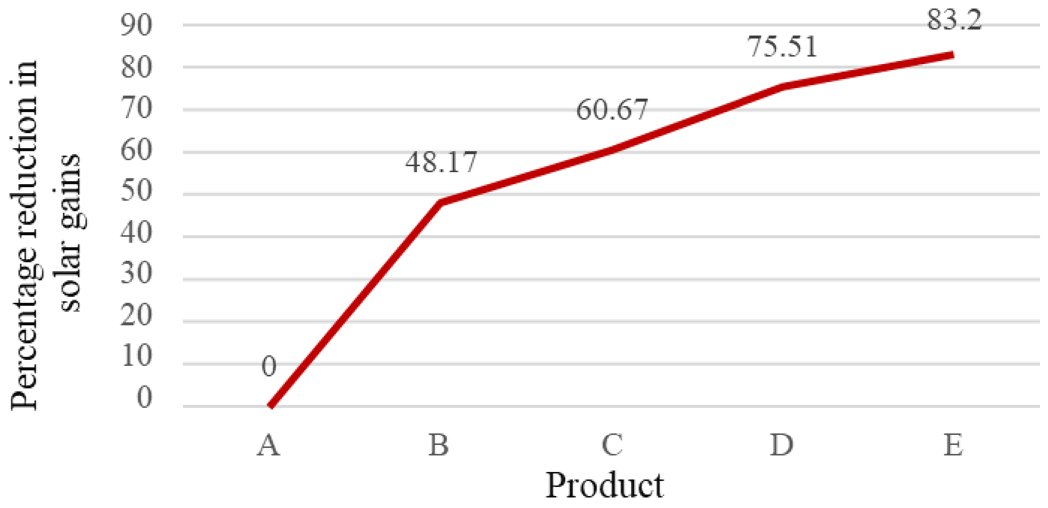
The higher the selectivity the better the performance of glass, it enables optimum light to enter our living spaces while blocking excess heat

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

# Glazing Material and Glazing Assemblies

## Glazing Material and Methods : Cooling Load Reduction



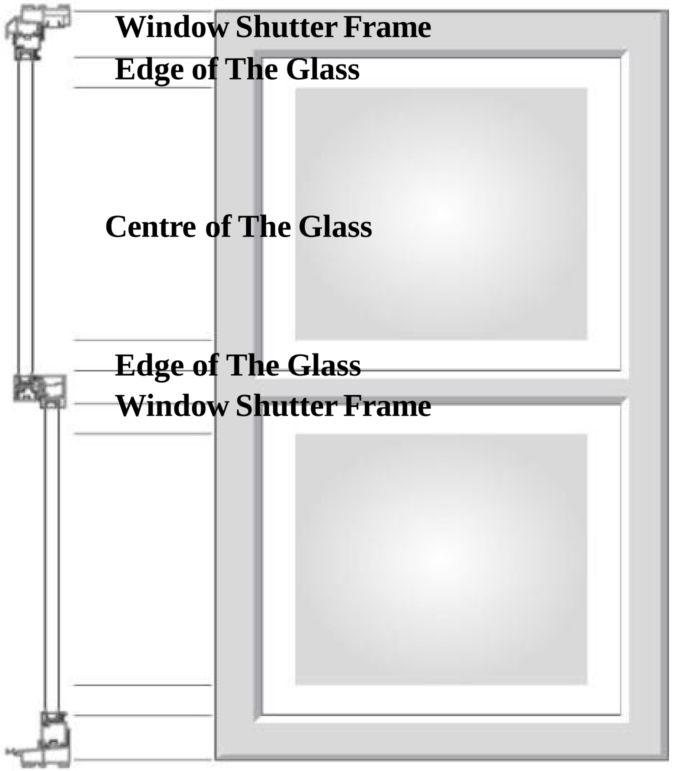



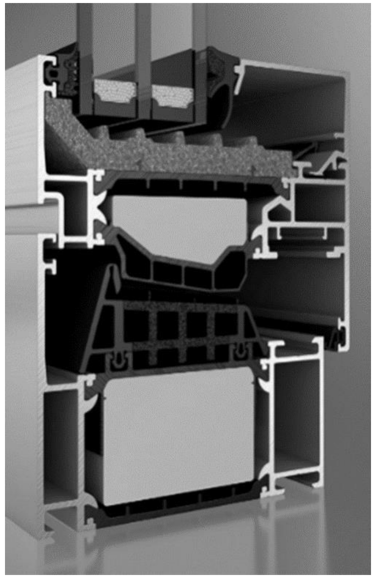

| Product | VLT (%) | External Reflection (%) | Internal Reflection (%) | Solar Factor | Shading coefficient | U-value |
|---|---|---|---|---|---|---|
| **A** | 80 | 15 | 15 | 0.76 | 0.87 | 2.6 |
| **B** | 46 | 16 | 18 | 0.22 | 0.25 | 1.5 |
| **C** | 46 | 20 | 22 | 0.47 | 0.54 | 2.8 |
| **D** | 51 |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

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

# Glazing Material and Glazing Assemblies

## Glazing Material and Methods : Window Frame



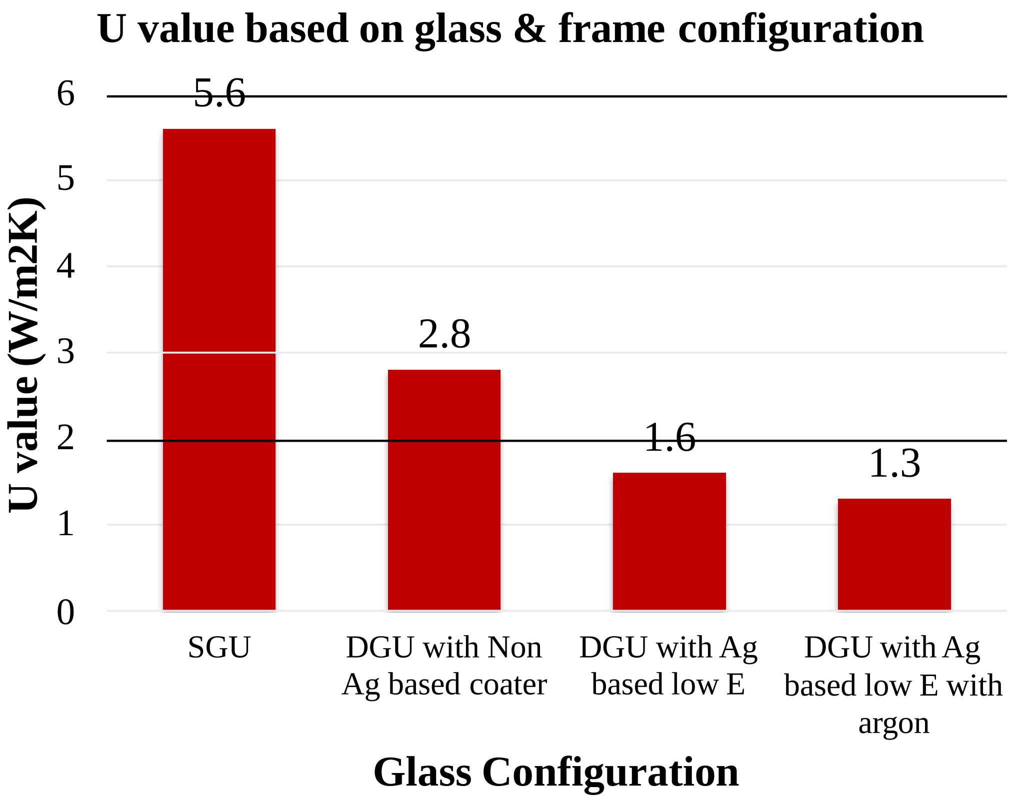



*Source: Neuffer. (n.d.). Schüco Aws 90. Neuffer. Retrieved from http://192.169.1.1:8090/httpclient.html Grabex. (n.d.). Sliding-Folding Doors For Your Space. Grabex. Retrieved from https://grabex.co.uk/doors/bi-fold-*

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

# Glazing Material and Glazing Assemblies

## Glazing Material and Methods : Window Frame



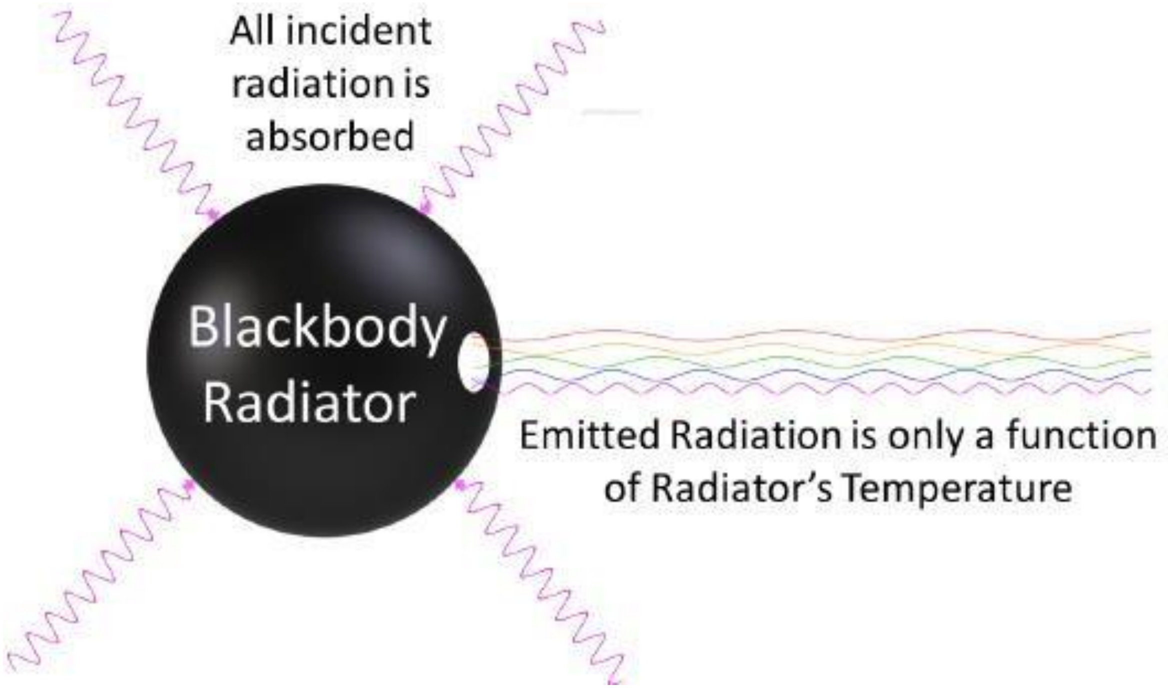

SGU | DGU with air | DGU with Argon gas

1.1 W/m².K | 1.5 W/m².K | 1.7 W/m².K

# ROOFING COATING MATERIAL

# Glazing Material and Glazing Assemblies

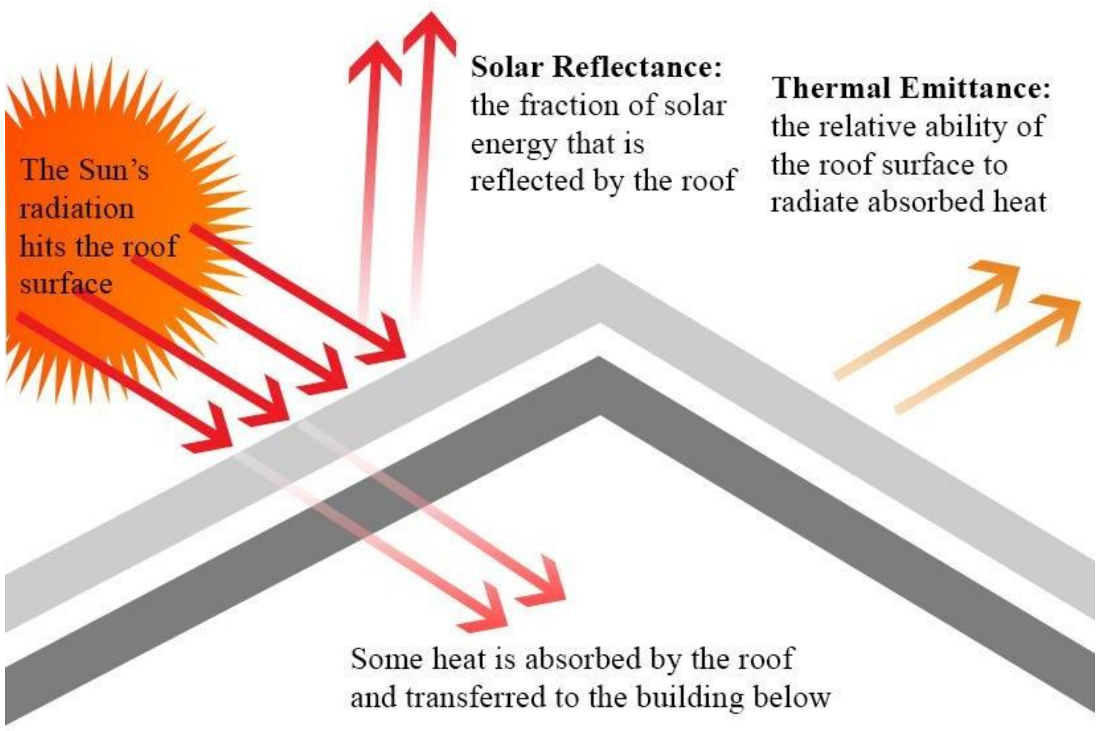
## Roofing Coating Material : Black Body




*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

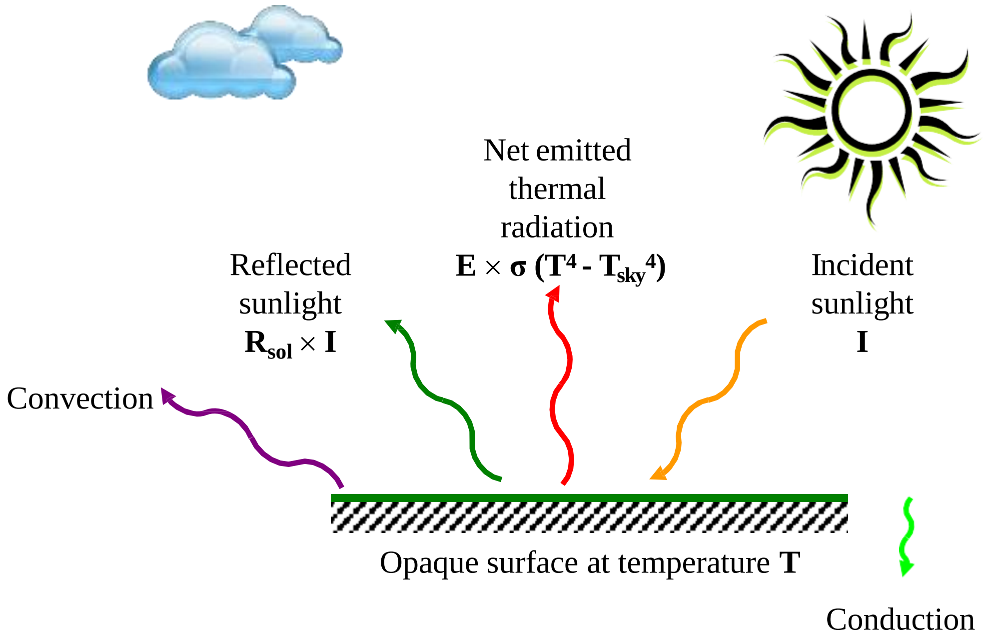


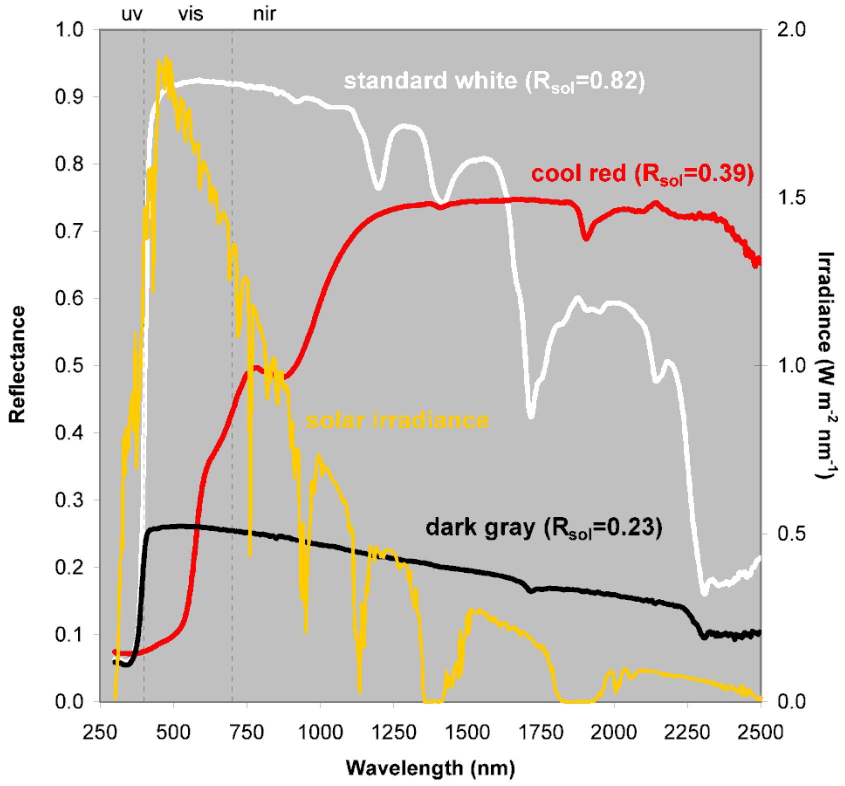

- Reflectance
- Thermal Emittance.
- Emissivity
- Solar Reflectance Index (SRI)

*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



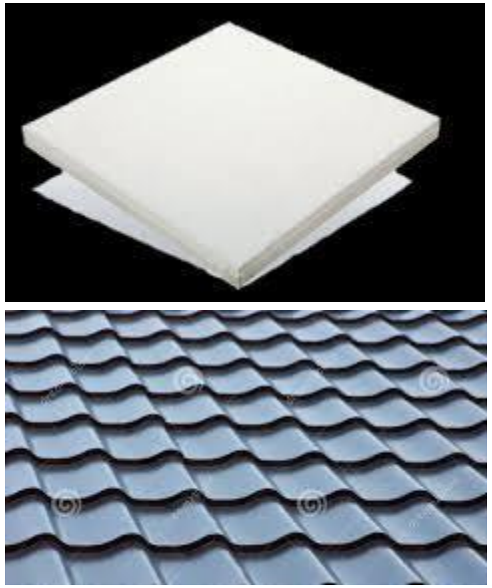

- High solar reflectance ($R_{sol}$) lowers solar heat gain (0.3 - 2.5 µm)
- High thermal emittance (E) enhances thermal radiative cooling (4 - 80 µm)

# Glazing Material and Glazing Assemblies

## Roof Coating Materials


Paints

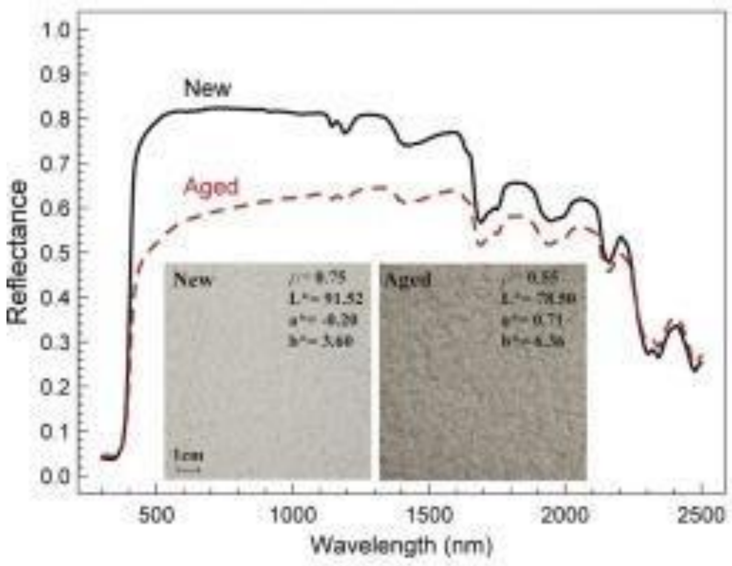
Coated Sheets

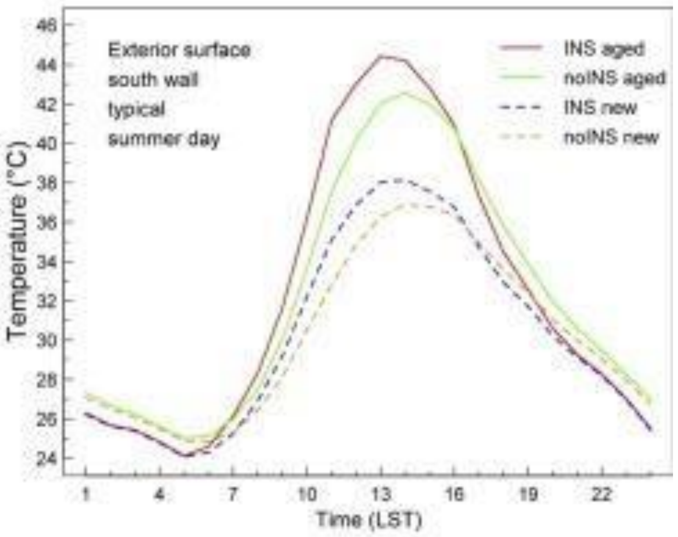


Tiles

# Glazing Material and Glazing Assemblies

## Roof Coating Materials



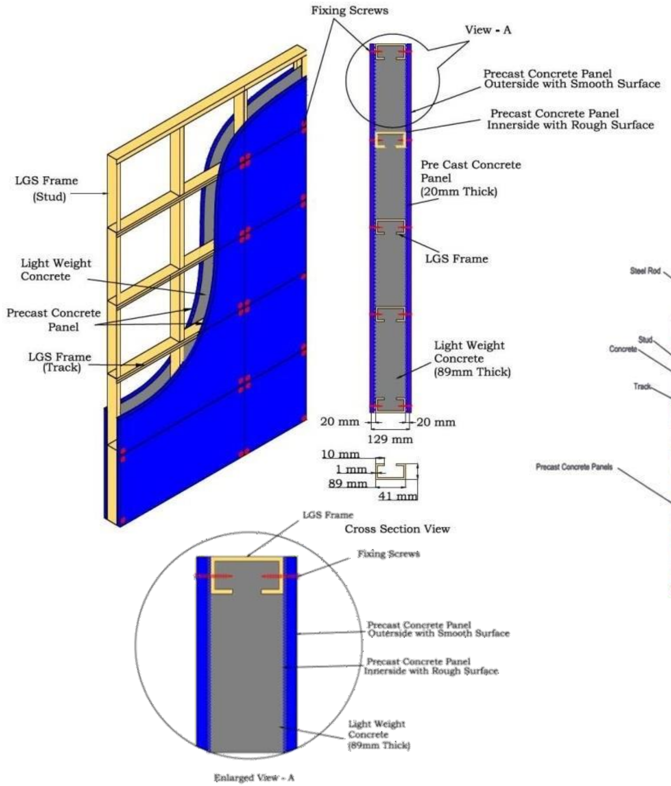

- PM 10, PM 2.5
- Dust, Sooth
- Vegetation

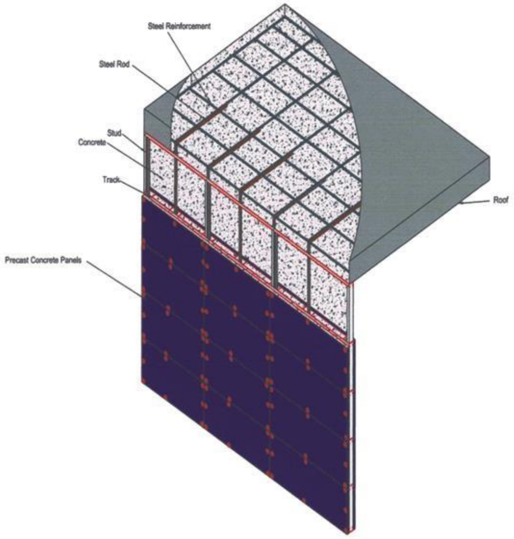
*Source: Paolini, R., Zani, A., Poli, T., Antretter, F., & Zinzi, M. (2017). Natural aging of cool walls: Impact on solar reflectance, sensitivity to thermal shocks and building energy needs. Energy and Buildings, 153, 287–296. https://doi.org/10.1016/j.enbuild.2017.08.017*

# WALLING MATERIAL CASE STUDIES, Light House Projects

# Walling Material Case Studies, Light House Projects

## Light House Project: Agartala

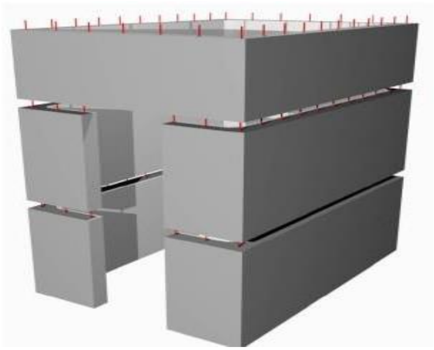


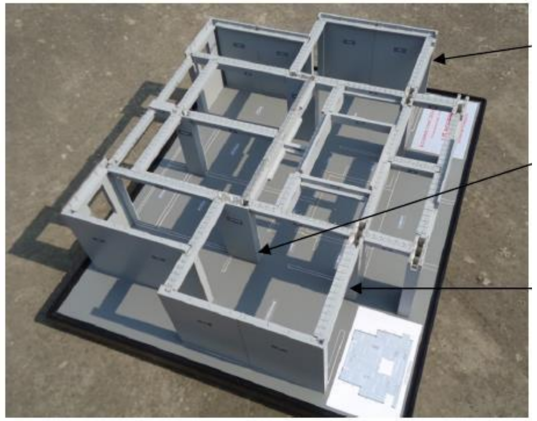




- Light Gauge Steel Framed Structure with Infill Concrete Panels (LGSFS-ICP)
- Ground and 06 Floors
- Weight of the LGSFS-ICP building is about 20-30% lighter
- The LSG frames are manufactured using numerically controlled roll
- forming machine using CAD design

# Walling Material Case Studies, Light House Projects

## Light House Project: Chennai

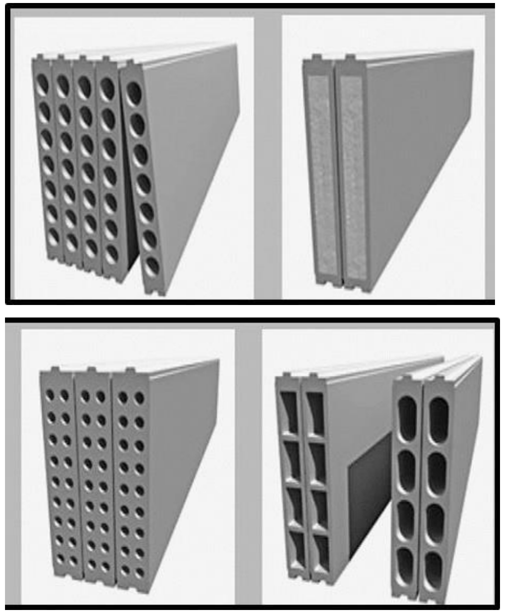




- Precast Concrete Construction System and Precast component Assembly at the site
- G and 05 Floors
- Precast dense reinforced cement concrete hollow core columns, structural RCC shear walls, T/L/Rectangular shaped beams, stairs, floor/roof solid….
- AAC blocks are used for partition walls

# 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 caste 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 |
| TYPOLOGY | NEW CONSTRUCTION |
| CLIMATE TYPE | HOT AND DRY |
| PROJECT AREA | 27,870 m² |

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

- 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 ENVIRONMENT QUALITY

**EPI – 75kWh/m²/yr**

# GODREJ PLANT 13 ANNEXE

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

# GODREJ PLANT 13 ANNEXE

The Plant 13 Annexe Building at Godrej & Boyce (G&B) in Mumbai has been designated as India's first CII-IGBC accredited Net Zero Energy Building. 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/m²/yr**

# INDIRA PARYAVARAN BHAWAN, MoEF

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

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

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/m²/yr**

**Renewable Energy Integration 930 kW PV panels with a total area of 4650m² for on- site generation, tilted at 23° facing south to generate equivalent to 70kWh/m²/yr**

# JAQUAR HEADQUARTERS

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

# JAQUAR HEADQUARTERS

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

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

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

# ST. ANDREWS BOYS HOSTEL BLOCK, GURUGRAM

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

# ST. ANDREWS BOYS HOSTEL BLOCK, GURUGRAM

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

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

# ST. ANDREWS GIRLS HOSTEL BLOCK, GURUGRAM

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

# ST. ANDREWS GIRLS HOSTEL BLOCK, GURUGRAM

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

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

# AKSHAY URJA BHAWAN HAREDA

| LOCATION | PANCHKULA HARYANA |
|---|---|
| COORDINATES | 30° N, 76° E |
| OCCUPANCY TYPE | OFFICE - PUBLIC |
| TYPOLOGY | NEW CONSTRUCTION |
| CLIMATE TYPE | COMPOSITE |
| PROJECT AREA | 5100 $m^2$ |

# AKSHAY URJA BHAWAN HAREDA

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

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

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

# SUN CARRIER OMEGA

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

# GRIDCO BHUBANESWAR

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

# GRIDCO BHUBANESWAR

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

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

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

# Tea Break

# Vote of Thanks

# THANK YOU