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

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

Ministry of Housing and Urban Affairs
Government of India

आज़ादी का अमृत महोत्सव

bmtpc

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Innovative Construction Technologies & Thermal Comfort for Affordable Housing

RACHNA 2.0

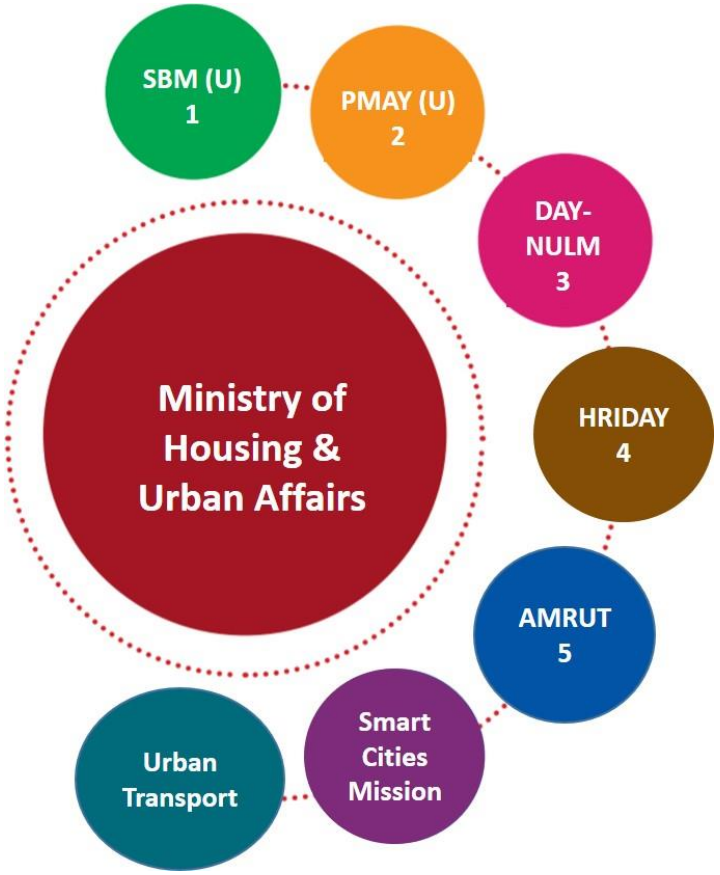
RESILIENT, AFFORDABLE AND COMFORTABLE HOUSING THROUGH NATIONAL ACTION

Prepared by

Climate Smart Building (CSB) Cell, North Cluster, LHP Lucknow

INTRODUCTION – MINISTRY OF HOUSING & URBAN AFFAIRS (MoHUA)

- **Ministry of Housing and Urban Affairs (MoHUA)** is the supreme authority of the Government of India to formulate and monitor all the programmes concerning the housing and urban development of the country.
- **The Ministry of Housing and Urban Affairs (MoHUA)** through its flagship mission **Pradhan Mantri Awas Yojna-Urban (PMAY-U)** ensures a pucca house to all eligible urban households.
- PMAY-U aims to achieve Urban Development through Transformation, Innovation and Sustainable Inclusions.



1. Swachh Bharat Mission- Urban, 2. Pradhan Mantri Awas Yojana- Urban, 3. Deendayal Antyodaya Yojana- National Urban Livelihood Mission, 4. Heritage Cities Development and Augmentation Yojana, 5. Atal Mission for Rejuvenation and Urban Transformation

INTRODUCTION- GLOBAL HOUSING TECHNOLOGY CHALLENGE (GHTC-INDIA)

- The Ministry of Housing and Urban Affairs, Government of India has conceptualized a Global Housing Technology Challenge - India (GHTC- India).
- To identify and mainstream a basket of innovative technologies from across the globe that are sustainable and disaster-resilient.
- Such technologies would be cost effective, speedier and ensure a higher quality of construction of houses, meeting diverse geo-climatic conditions and desired functional needs.
- A Technology Sub-Mission (TSM) has been set up.

EVENTS OF GLOBAL HOUSING TECHNOLOGY CHALLENGE (GHTC-INDIA)

Construction Technology India (CTI) – 2019

Expo-cum-Conference, on 2nd to 3rd March 2019, Vigyan Bhawan, New Delhi.

Indian Housing Technology Mela (IHTM) on 5th to 7th October 2021 in Lucknow, Uttar Pradesh.

Indian Urban Housing Conclave (IUHC)-2022, on 19th to 21st October 2022, at Rajkot Gujrat.

INTRODUCTION – GIZ AND IGEN (INDO GERMAN ENERGY PROGRAM)

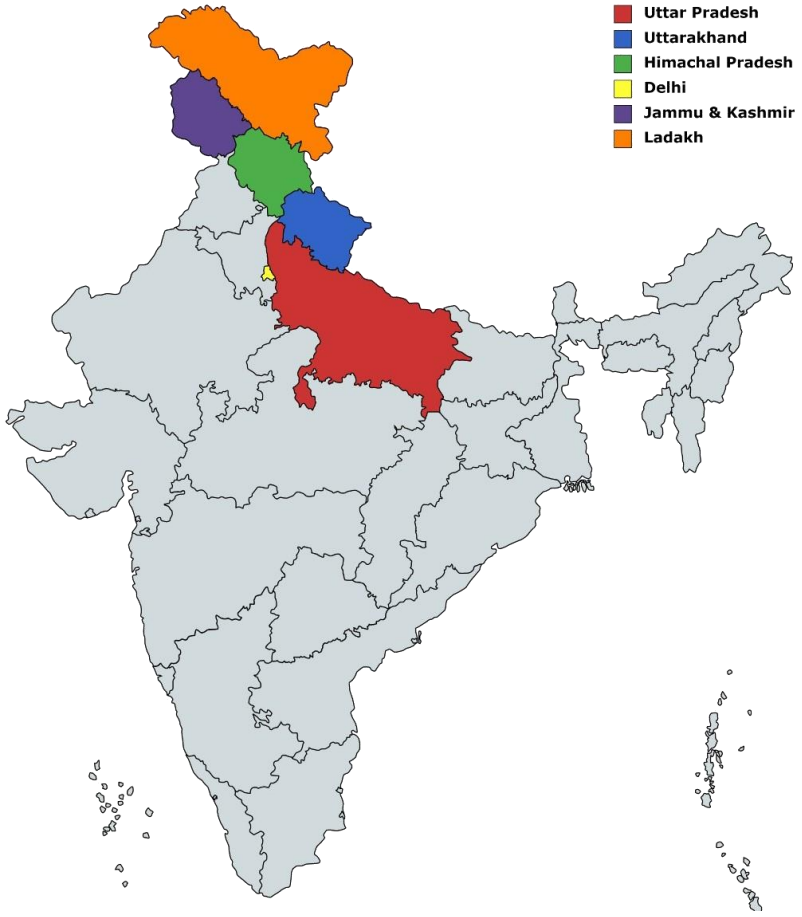
- GIZ is an international cooperation enterprise for sustainable development which operates worldwide, on a public benefit basis.
- For over 60 Years, **GIZ** has been working jointly with the partners in India for sustainable economic, ecological, and social development.
- The Government of the Republic of India and the Federal Republic of Germany under the Indo-German Technical Cooperation, agreed to jointly promote the "Indo-German Energy Programme" **(IGEN)** with the aim to foster sustainability in the built environment through GIZ.

INTRODUCTION – CLIMATE SMART BUILDINGS PROGRAMME

Ministry of Housing and Urban Affairs (MoHUA) aims to enhance climate resilience and thermal comfort in the affordable housing segment through GIZ under Indo German Energy programme (IGEN)'s programme, **Climate Smart Buildings (CSB)**.

Aim:

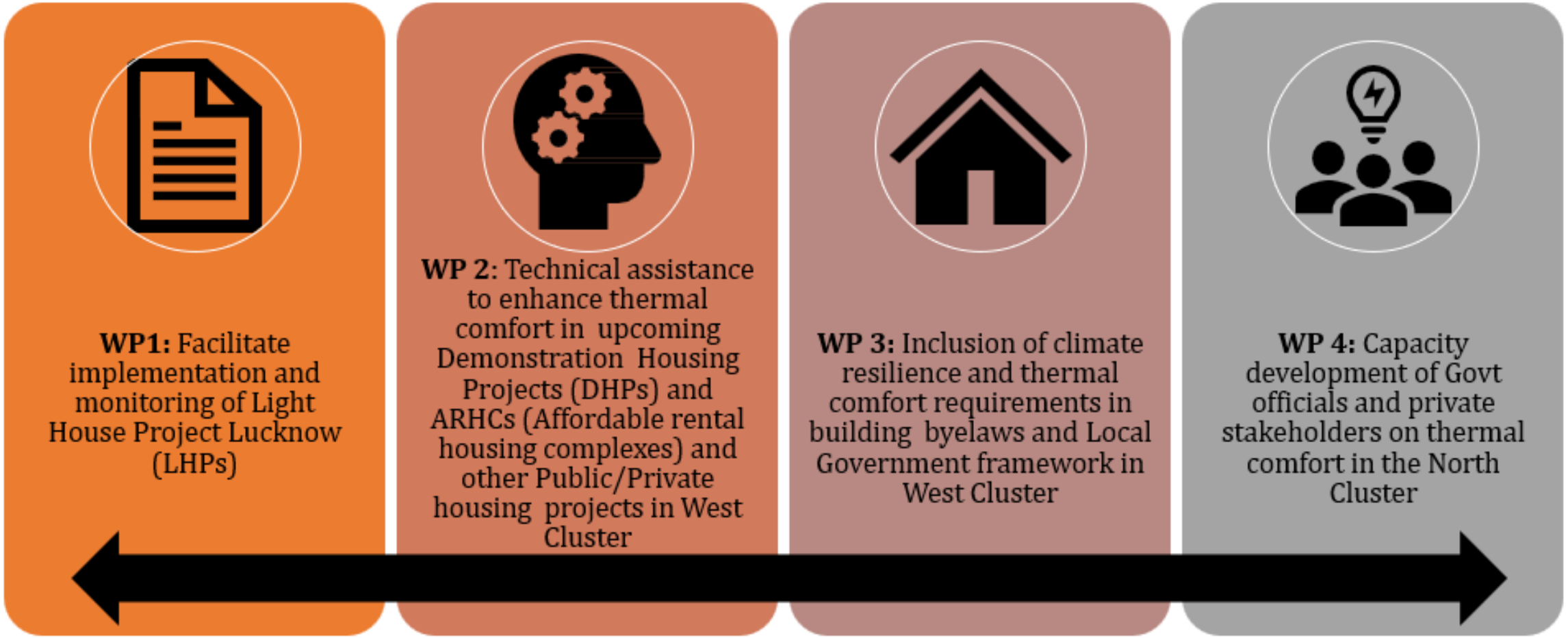
- Adopting sustainable and low-impact design.
- Adoption of best available Materials and construction technologies.
- Use of innovative technologies to provide desired thermal comfort for mass replication.



Climate Smart Buildings Cell, North Cluster

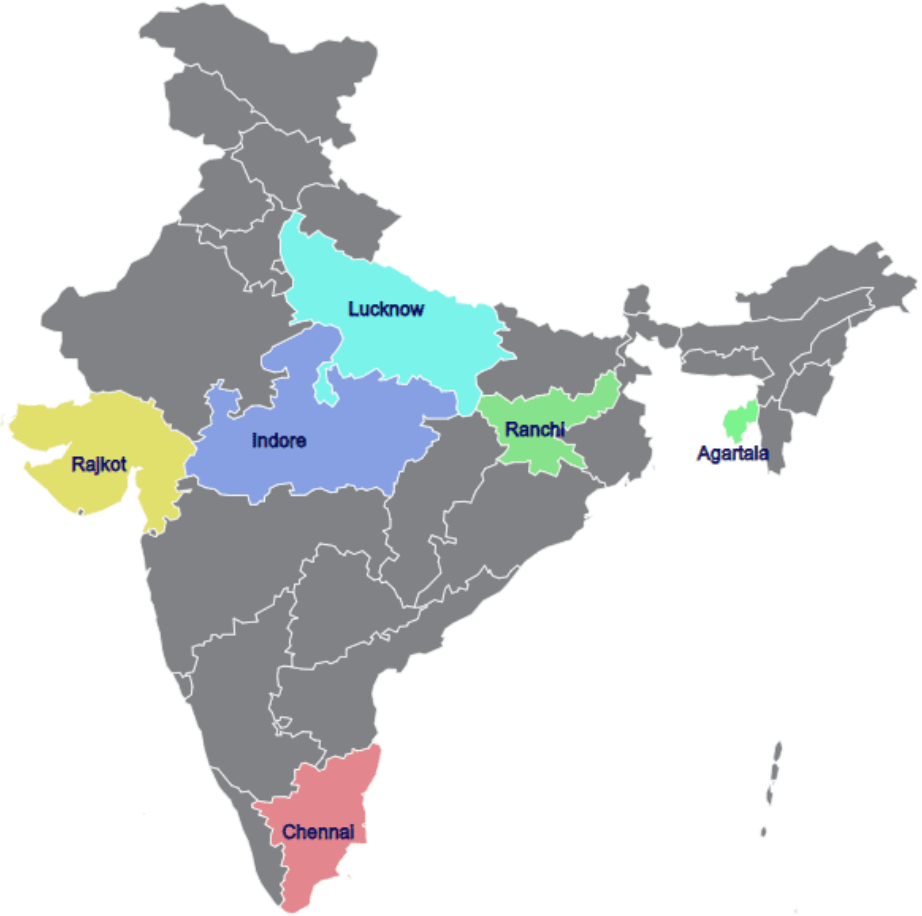
OBJECTIVES: CLIMATE SMART BUILDINGS CELL, NORTH CLUSTER

In the direction to achieve the goal of sustainability and thermal comfort in affordable housing, CSB Cell is working with following objectives:



CONCEPT OF LIGHT HOUSE PROJECTS (LHPS)

- Ministry of Housing and Urban Affairs Under **PMAY(U)**, set up a **Technology Sub-Mission (TSM**) to provide:
    - Alternative sustainable technological solutions.
    - Better, Faster & cost-effective construction methodologies.
    - Houses suiting to geo-climatic and hazard conditions of the country.
- **Light House Projects** have been conceptualized as part of **Global Housing Technology Challenge – India (GHTC-India)**
- Construction of six **LHPs** with allied infrastructure and six categories of globally proven innovative technologies were envisaged in six different states.



THE LIGHT-HOUSE PROJECTS (LHP) IN INDIA

Hon'ble Prime Minister Shri Narendra Modi laid the foundation stone of six Light House Projects (LHPs) each consisting of approx. 1000 houses in January 2021, in six cities :

Precast Concrete Construction System – Precast Components Assembled at Site

- Chennai, Tamilnadu
- No. of Houses: 1152

Monolithic Concrete Construction using Tunnel Formwork

- Rajkot, Gujarat
- No. of Houses: 1144

Prefabricated Sandwich Panel System

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

Precast Concrete Construction System – 3D Volumetric

- Ranchi, Jharkhand
- No of Houses: 1008

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

- Agartala, Tripura
- No of Houses: 1000

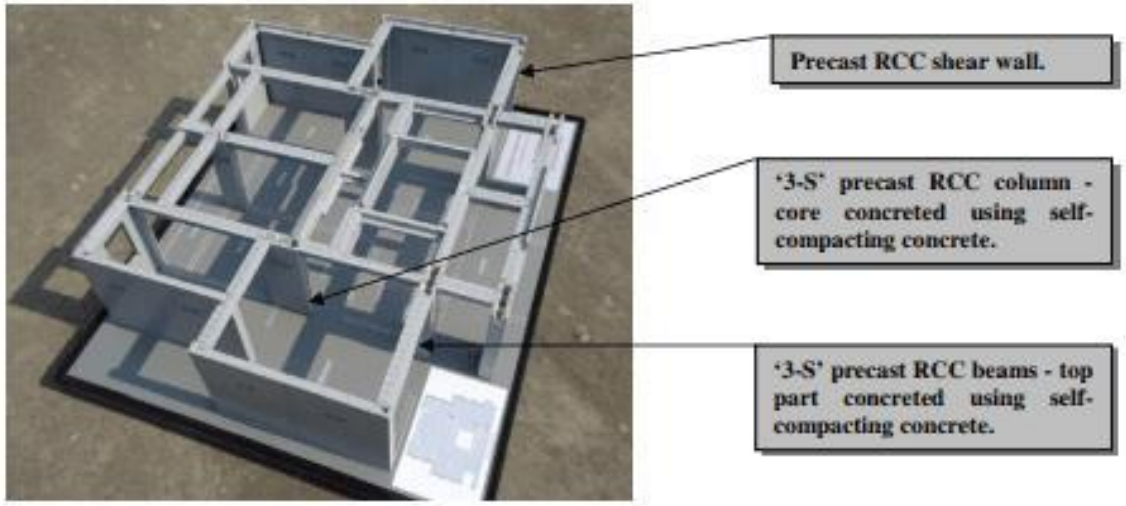
PVC Stay in Place Formwork System

- Lucknow, Uttar Pradesh
- No of Houses: 1040

Note: For more information about the live progress of Light House Projects and Climate Smart Buildings Programme. Please visit: **https://ghtc-india.gov.in**

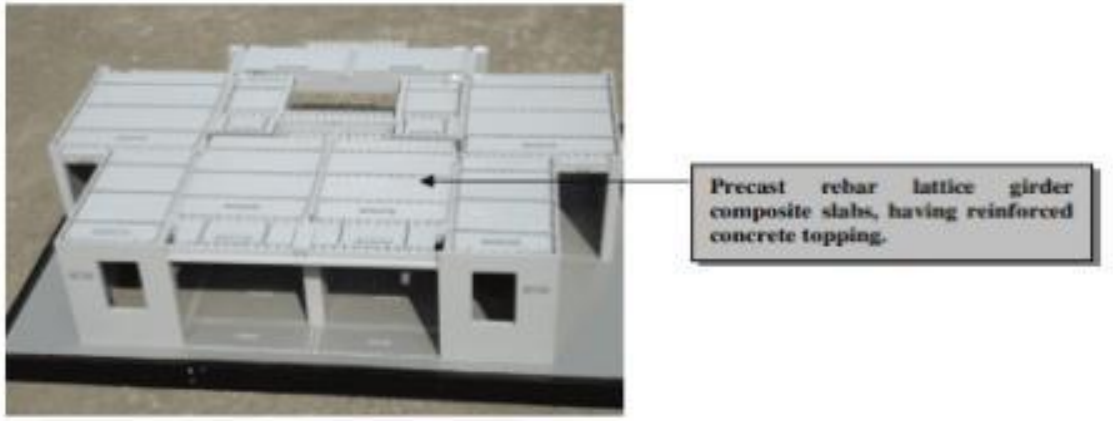
LHP Chennai-Precast Concrete Construction System Assembled at Site

- Precast dense reinforced cement concrete Columns and **RCC** shear walls has been used as structure .
- **AAC blocks** in partition walls are being used.
- Dowel bars, continuity reinforcement placed at connections.



Current Progress

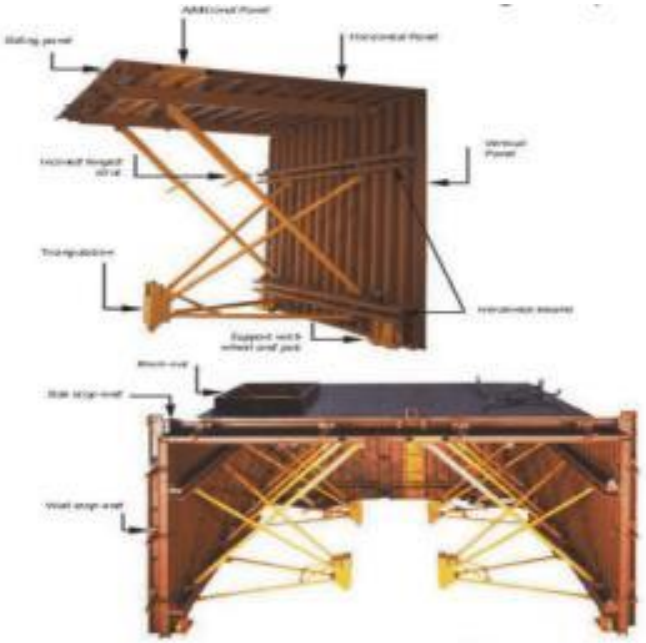
Precast concrete wall (Panels)



Precast concrete wall (Panels)

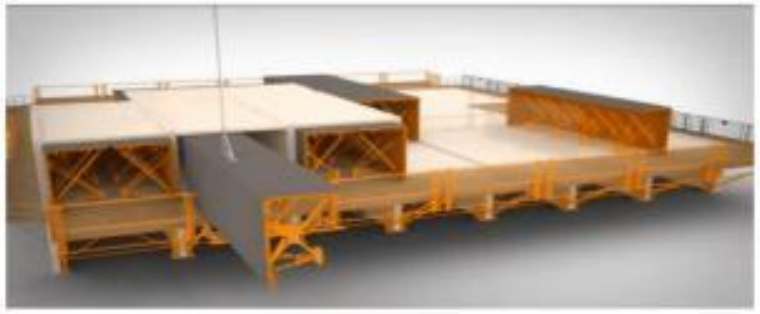
LHP Rajkot- Monolithic Concrete Construction using Tunnel Formwork

- Customized engineering formwork replacing conventional steel or plywood shuttering systems.
- Mechanized system for cellular structures.
- Two half shells which are placed together to form a room or cell.
- Walls and slab are cast in a single day.
- The formwork is stripped the next day for subsequent phase.

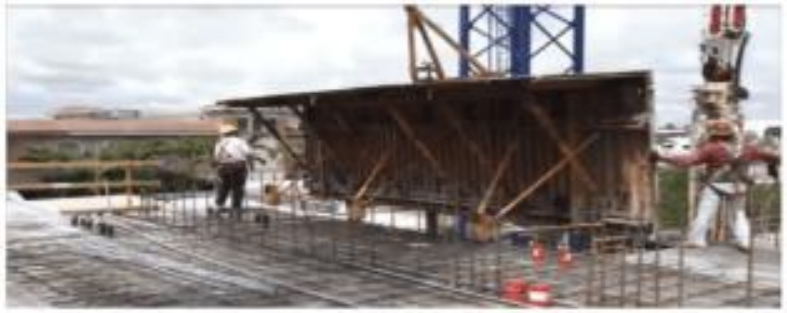


Tunnel Formwork

Current progress



Box out of door and windows

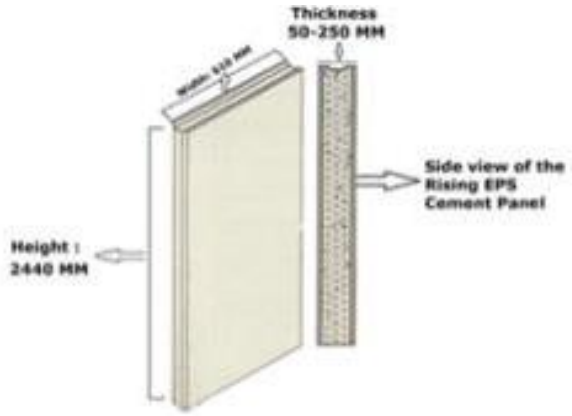


Kicker form of tunnel formwork panel

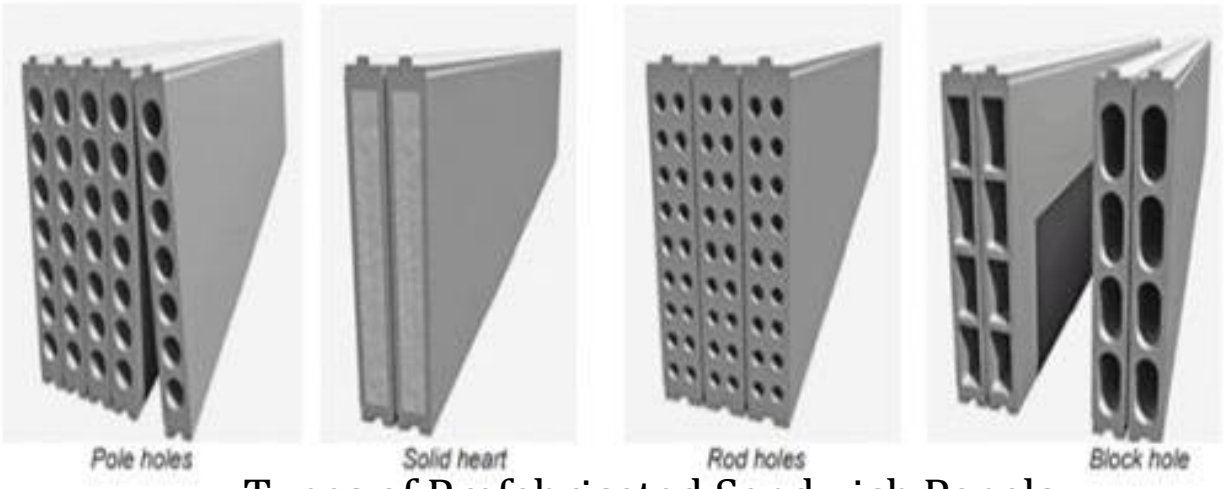
Monolithic Tunnel Formwork Panel

LHP Indore-Prefabricated Sandwich Panel System

- Lightweight composite wall, floor and roof sandwich panels made of thin fibre cement or calcium silicate board as face covered boards.
- Core material is EPS granule balls, adhesive, cement, sand, fly ash and other bonding materials in mortar form.
- The core material in slurry state is pushed under pressure into pre-set moulds.
- Once set, it shall be moved for curing and ready for use with steel support structure beams and columns.



Prefabricated EPS Sandwich Panel



Types of Prefabricated Sandwich Panels

Steel Structure Prefabricated EPS Panel

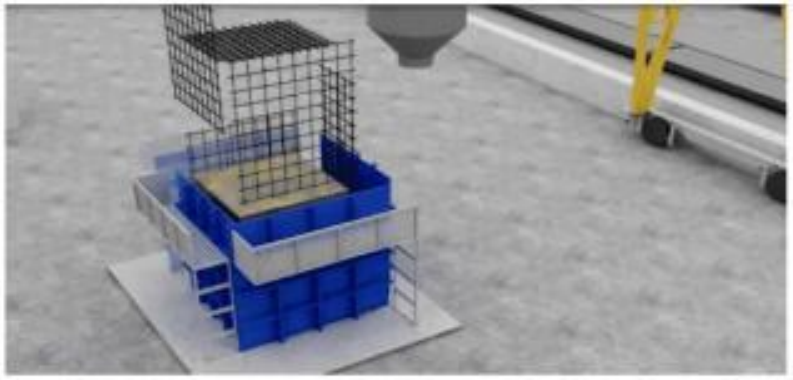
Current Status

LHP Ranchi- Precast Concrete Construction System – 3D Volumetric

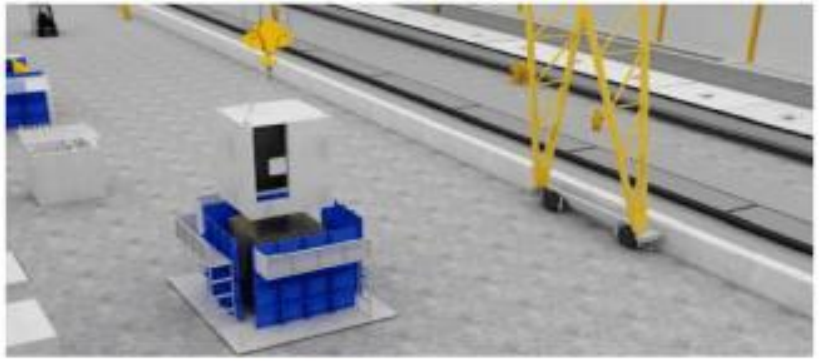
- Components like room, Bathroom, Kitchen etc are cast monolithically in Plant or Casting yard in a controlled condition.
- Magic Pods (Precast Components) are transported, erected & installed using cranes .
- Prestressed slabs are installed as flooring elements.
- Consecutive floors are built in similar manner to complete the structure.

Current Progress

Construction and installation



Pre Casting of building modules

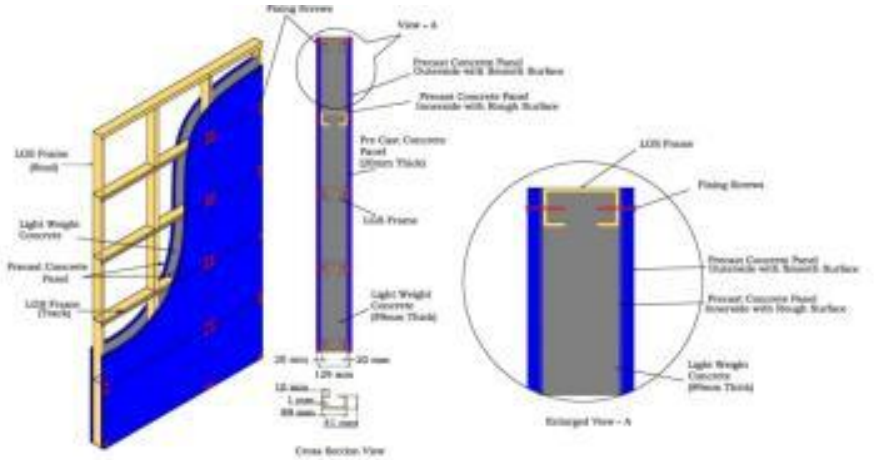


Pre Casting of building modules

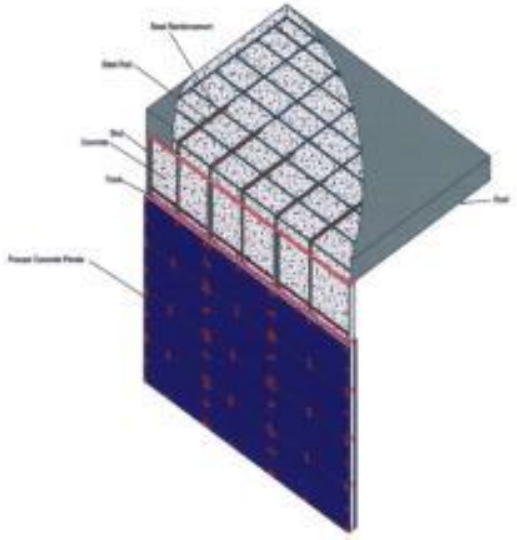
LHP Agartala- Light Gauge Steel Framed Structure with Infill Concrete Panels (LGSFS-ICP)

- Light Gauge Steel Framed Structure with Infill Concrete Panels (LGSFS-ICP) Technology.

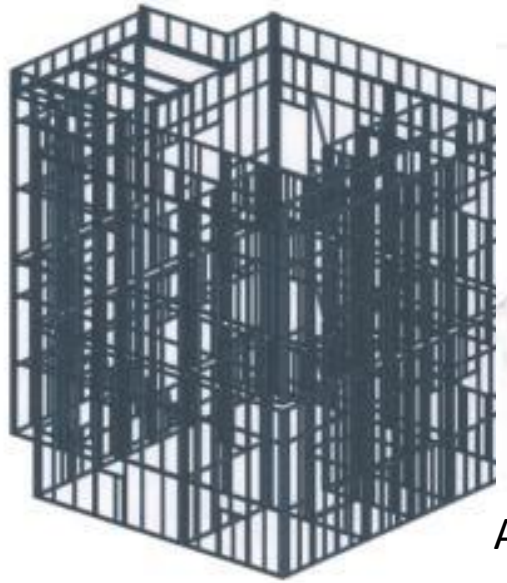
- Factory made Light Gauge Steel Framed Structure (LGSFS), light weight concrete and precast panels are being used.



Structural Details of LGSFS-Infill Concrete Wall



Precast concrete panels



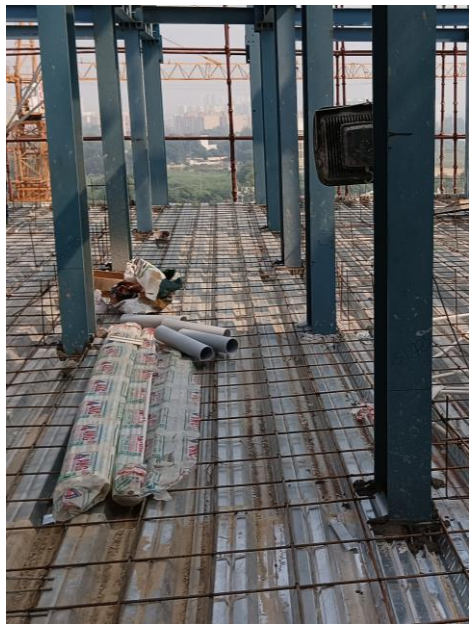
Light Gauge Steel Frame Structure

Assembly of LGS Frames and Construction of Wall

Current Progress

CONSTRUCTION TECHNOLOGY: LHP LUCKNOW

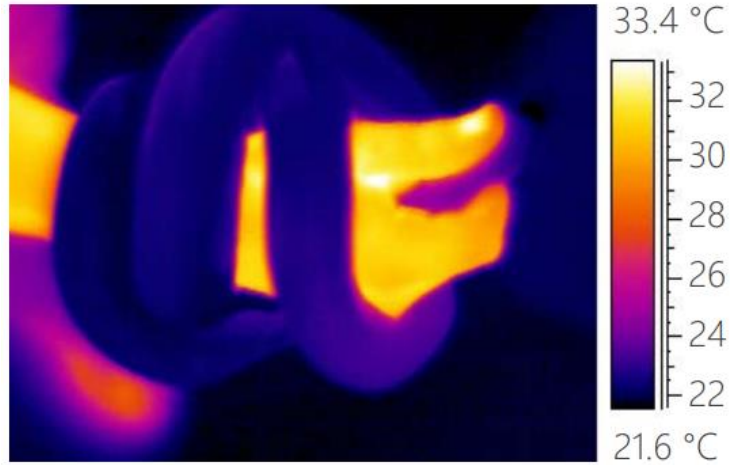
- **Hot Rolled Pre-Engineered Building (PEB)** sections act as a structural framework of the building whereas SIP (Stay-in-Place) formwork works as a partition wall.
- **0.9mm Deck Sheet** used as slab support component over which concrete is casted for enhancing strength. It reduces casting time, propping, shuttering and centering support.
- **Self-Compacting Concrete** is being poured in SIP formwork as an infill to make it more rigid and thermally sound.
- **Polyvinyl Chloride(PVC)** based polymer components serve as a permanent stay-in-place formwork with infilled **concrete** for building walls.

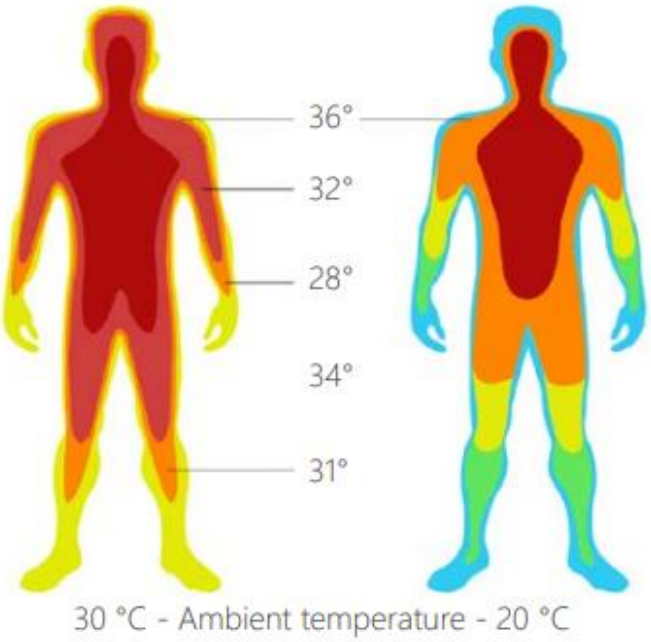


THERMAL COMFORT & ITS IMPORTANCE

"ASHRAE defines thermal comfort as the condition of mind that expresses satisfaction with the thermal environment and is assessed by subjective evaluation". (ASHRAE,2020).

- In case of humans, the core body temperature lies in a narrow range around 37° C (ASHRAE, 2021).
- To maintain the body core temperature, the human body is constantly acclimatizing itself to its external environmental conditions through exchange of heat between the body and surrounding environment.
- Both core body temperature and skin surface temperature are relevant in understanding thermal comfort.





FACTORS AFFECTING THERMAL COMFORT

Environmental

Parameters/Factors

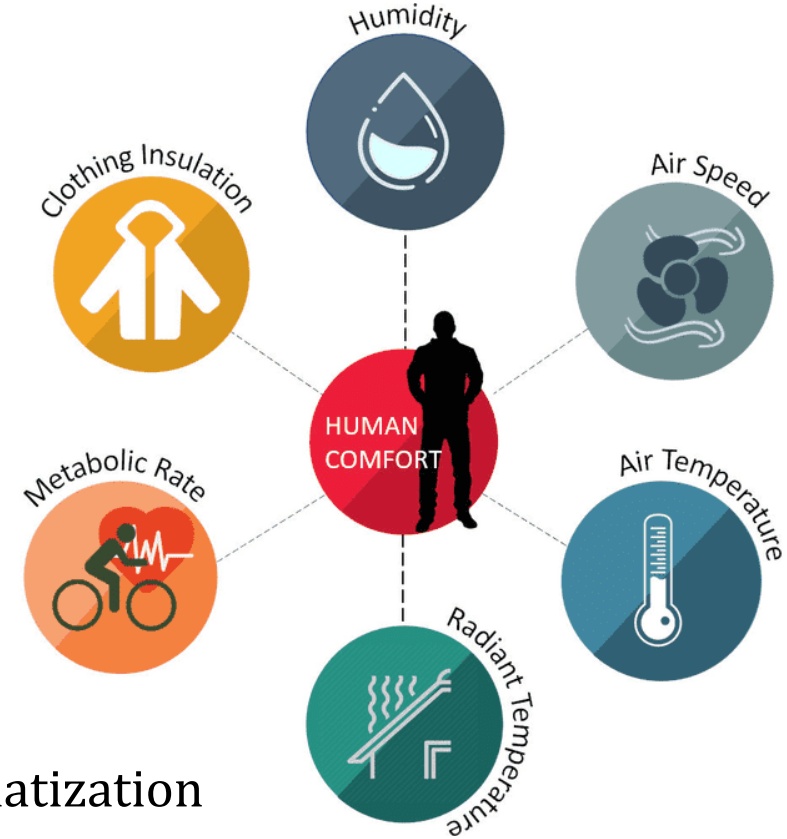
- Air Temperature
- Mean Radiant Temperature
- Air Velocity
- Humidity

Personal Parameters/Factors

- Clothing Level
- Physical Activity

Other Factors

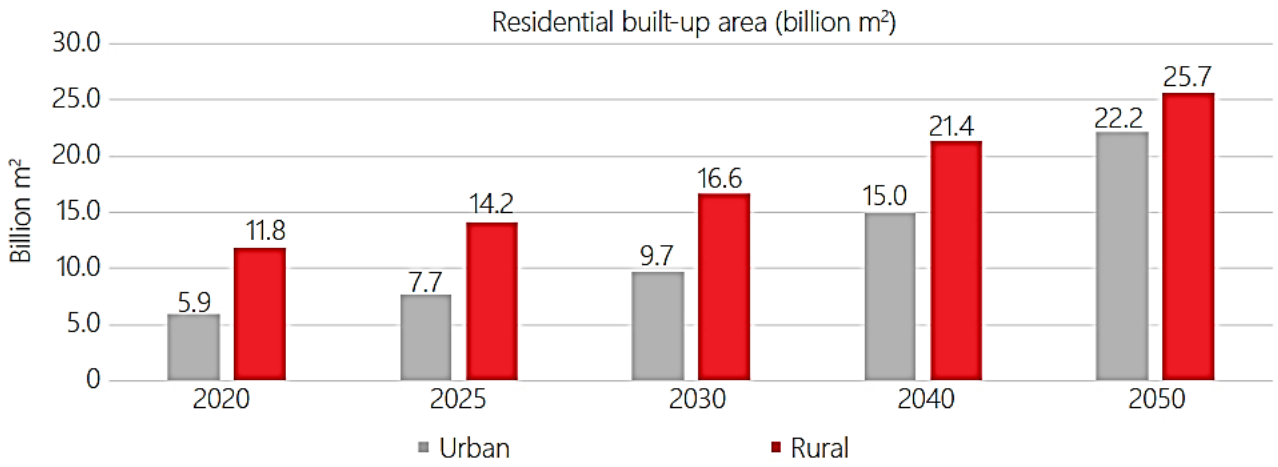
- Short-term and long-term acclimatization
- Body shape and fat
- Gender and age
- Status of health



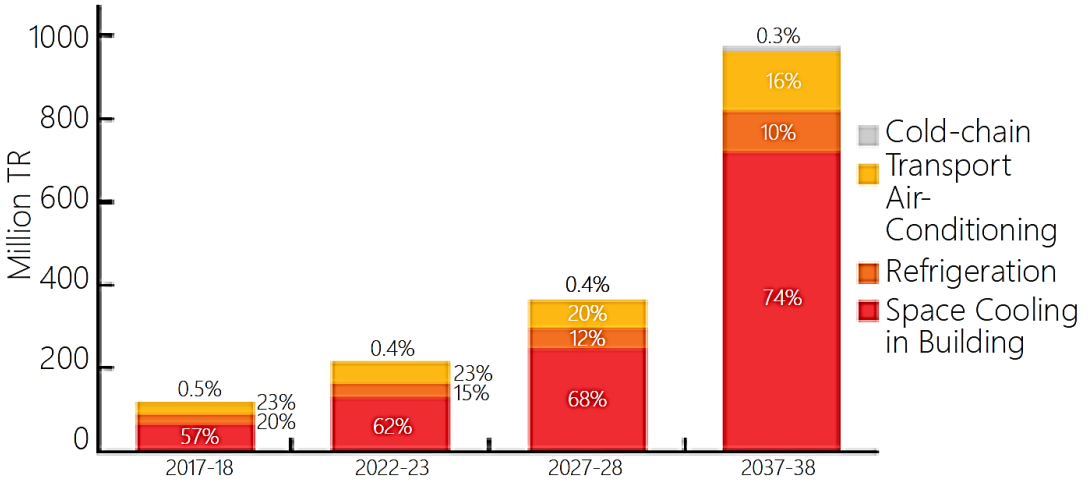
Body Part	Skin Location	Cold (15 °C)	Neutral (27 °C)	Hot (47 °C)
A	Forehead	31.7	35.2	37
B	Back of Neck	31.2	35.1	36.1
C	Chest	30.1	34.4	35.8
D	Upper Back	30.7	34.4	36.3
E	Lower Back	29.2	33.7	36.6
F	Upper Abdomen	29	33.8	35.7
G	Lower Abdomen	29.2	34.8	36.2
H	Tricep	28	33.2	36.6
J	Forearm	26.9	34	37
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

Skin surface temperature at various locations of the body in cold, neutral, and hot indoor environment.

FACTORS AFFECTING THERMAL COMFORT & COOLING DEMAND



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



Sector-wise growth in cooling demand. Source: ICAP

The India Cooling Action Plan sets the following goals to promote sustainable cooling and thermal comfort for all.

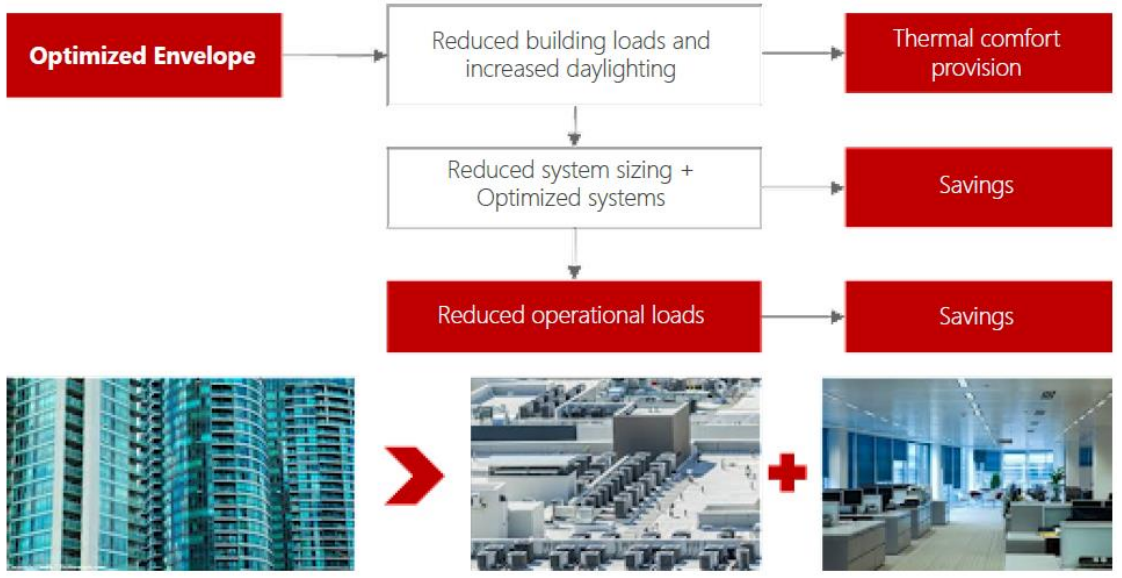
1. **20-25%** reduction of cooling demand across various sectors by 2037-2038
2. **25-40%** reduction in cooling energy requirements by 2037-2038.
3. **25-30%** reduction in refrigerant demand by 2037-2038.
4. Training and certification of **1,00,000** service technicians by 2022-2023
5. Recognizing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

CONTEMPORARAY APPROACHES

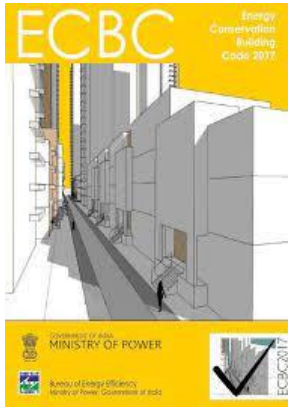
Provisions in code

To achieve the needful reduction in cooling demand, national guidelines, codes, and tools have been developed for implementation.

- ECBC 2007 & 2017(Revised Edition) to set the minimum energy performance for commercial buildings in India.
- Eco-Niwas Samhita (Part-1) was launched in 2018 to include minimum performance requirements for residential building envelope.
- Eco Niwas Samhita (Part-2) launched in 2021 with inclusion of building systems in addition to envelopes.



Reduced operational energy loads and economic benefits with thermal comfort provision in codes like ECBC, ENS 20181 & 2021 from optimized building envelope and electro mechanical systems



THERMAL COMFORT METRICS

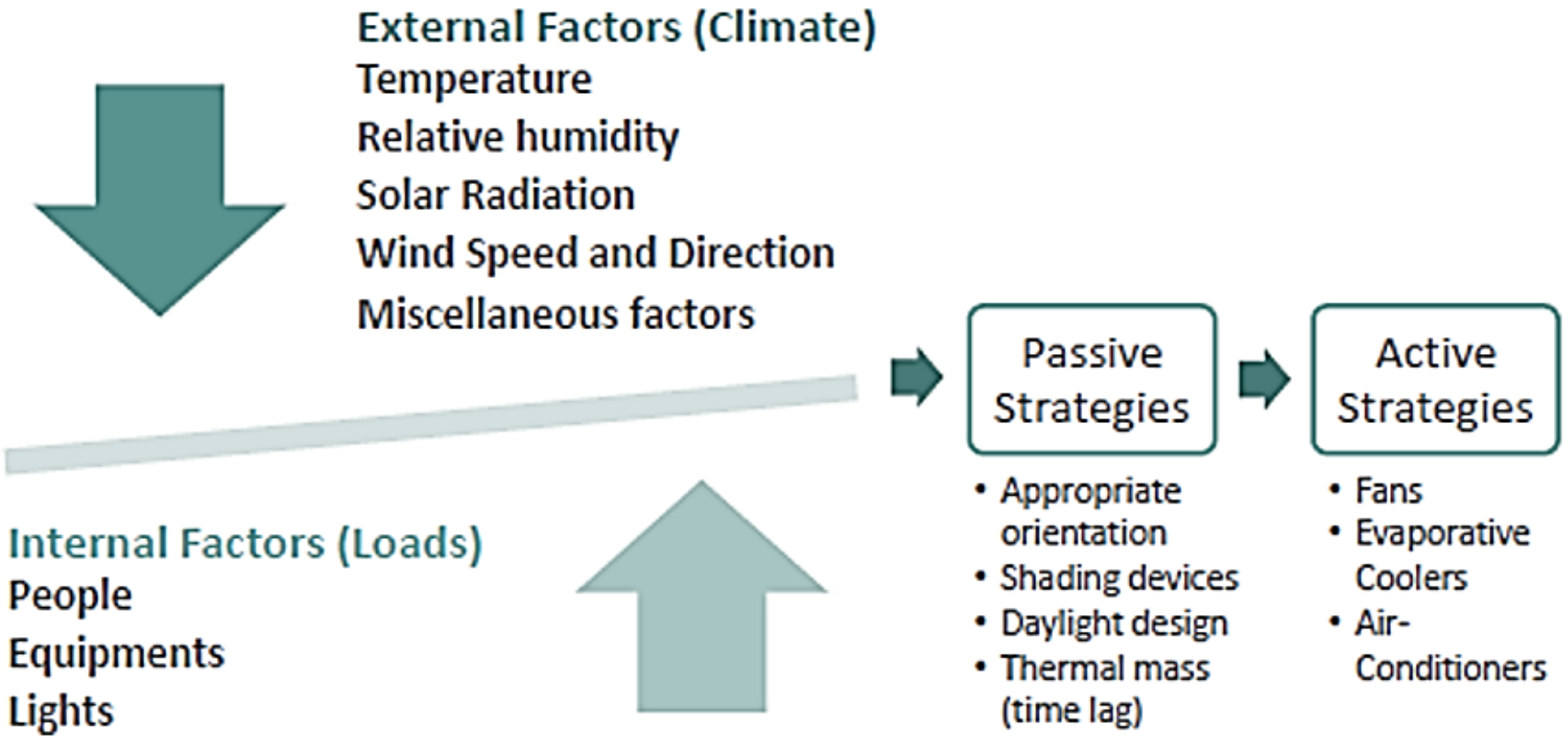
- Heat transfer through roofs can be considered similar to walling material in terms of thermal conductivity and relevance of R-value.
- To reduce radiative heat gains, surface of roof exposed to the outdoors can be treated with coatings that increase solar reflectance.

Parameter	Metric	Building envelope element
Thermal Conductivity	R value – U value	Walls • Internal • **External**
Thermal Mass	Specific heat capacity	
Thermal Conductivity (Frames and Glass)	R value – U value	**Fenestration** • **Windows** • Skylights • Doors
Solar Gains	Solar Heat Gain Coefficient	
Visible Light Transmittance	VLT	
Thermal Conductivity	R value – U value	**Roofs** Floors Foundations
Thermal Emissivity	Solar Reflectance	

Relevant metrics for building envelope elements in terms of heat transfer
Source: Rawal, R., 2021. Heat Transfer And Your Building Envelope, Solar Decathlon India

BUILDING PHYSICS &THERMAL COMFORT

Use of Building Physics to Optimize Energy use for Thermal Comfort



External Factors.(Climatic)

- ✓ Temperature
- ✓ Relative Humidity
- ✓ Solar Radiation
- ✓ Wind Speed and Direction
- ✓ Miscellaneous Factors

Internal Factors.(Loads)

- ✓ People
- ✓ Equipment
- ✓ Lights

AFFORDABLE HOUSING & PASSIVE STRATEGIES

Strategies for various modes of heat transfer

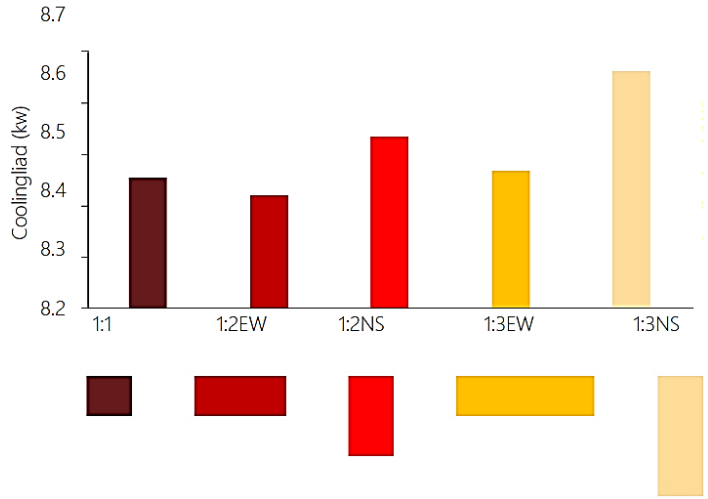
Passive design strategies may tackle either one or a combination of these modes of heat transfer.

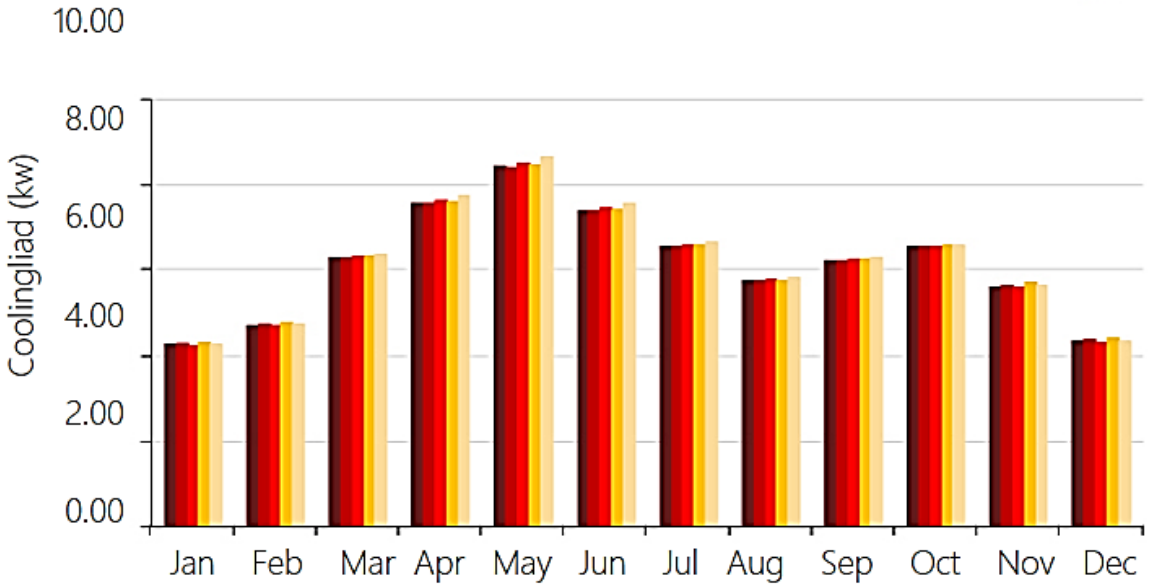
- Orientation, and massing of the building act as passive design strategies by influencing the quantity and quality of radiation reaching the envelope surface.
- Similarly, shading devices obstruct the amount of radiation entering the buildings through windows.
- Fixed or movable shading devices can be chosen depending on the trajectory of sun and direction of the façade.

Mode of heat transfer	Passive Design strategies applicable
Conduction	Materials and Construction
Convection	Space Volume, Building form- (Roof form, plan)
Radiation	Orientation Shading/ Brise Soleil, jail etc

Passive design strategies categorized based on modes of heat transfer

AFFORDABLE HOUSING & PASSIVE STRATEGIES



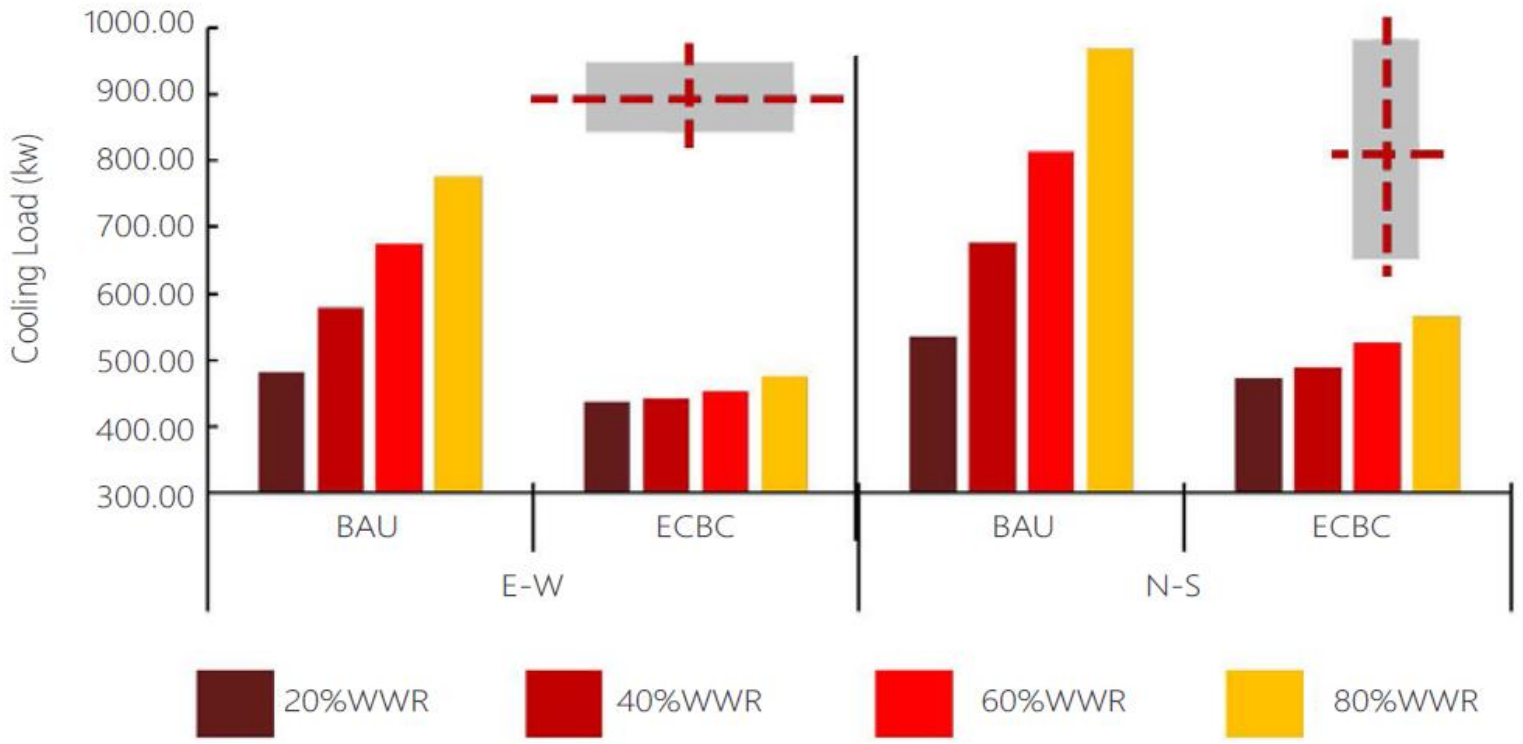


Form & orientation of the building

- Rectangular building form with 1:2 proportions is most suitable in hot and dry climate.
- Preferred orientation to reduce solar gains in northern hemisphere is east-west.
- Smarter orientation, wherever possible, can reduce peak cooling loads for the same floor

Top: peak cooling load for various forms and orientations; Bottom: variations in peak cooling load for each month for all sample cases.

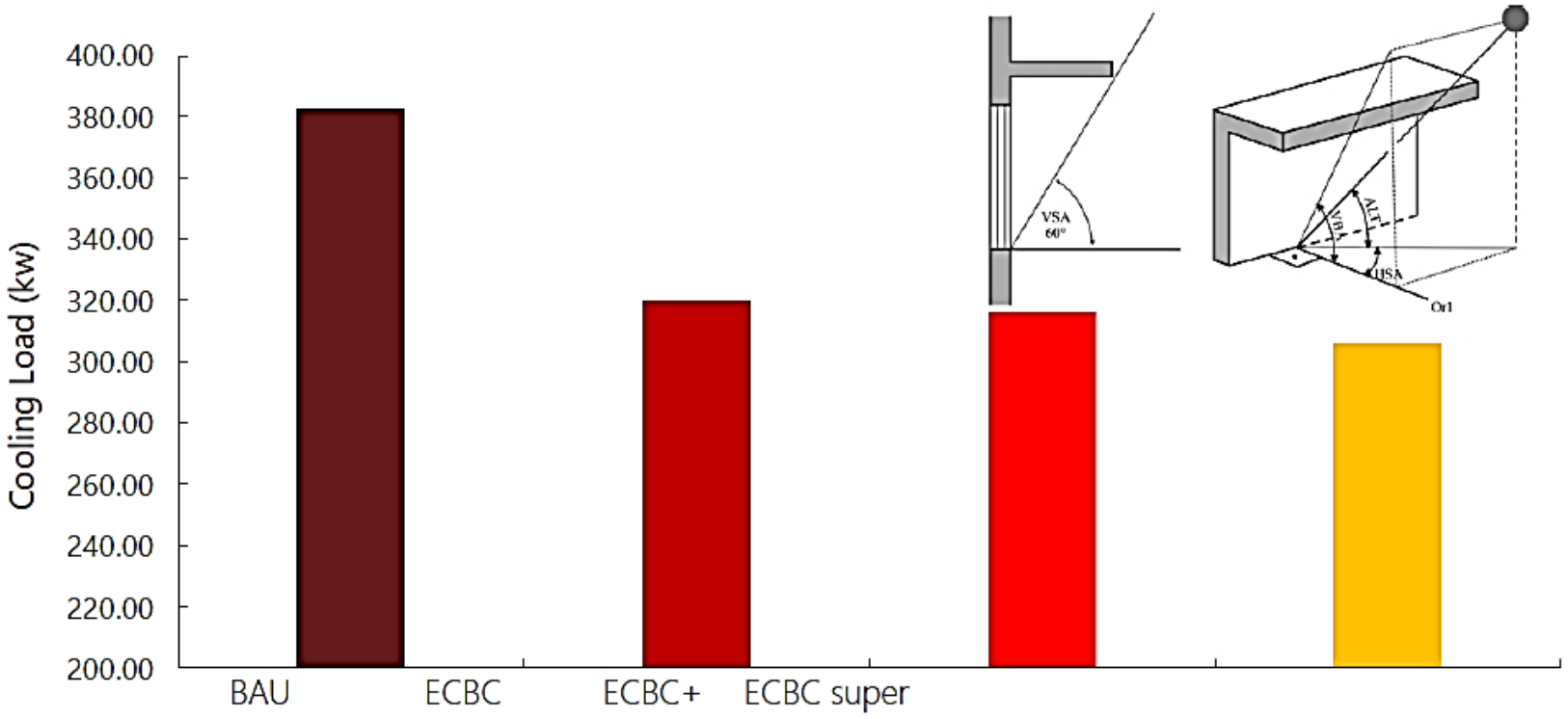
AFFORDABLE HOUSING & PASSIVE STRATEGIES



Comparative analysis of various WWR levels in East-West and North-South orientations for business-as-usual and ECBC compliant buildings

- Compliance with ECBC code results in reduced cooling load across the four WWR cases.
- Even with less favorable orientations, cooling loads can still be reduced by designing for code compliance

AFFORDABLE HOUSING & PASSIVE STRATEGIES



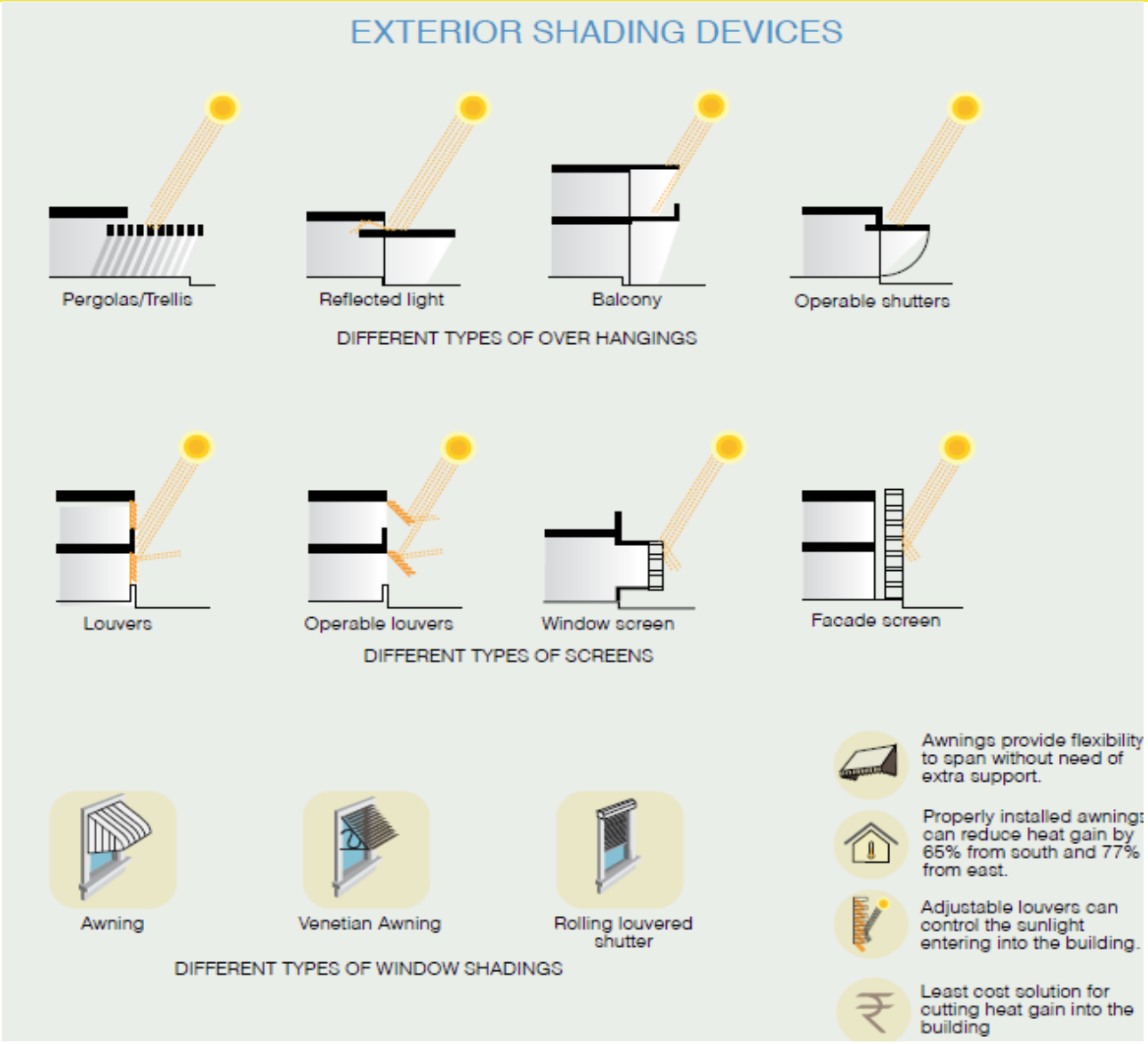
Cooling loads for BAU, ECBC, ECBC+, and ECBC super buildings having 600mm shading over windows

Shading & WWR

- Reduce heat gain and cooling energy use of the building.
- Fixed horizontal shading is useful in blocking radiations from the overhead sun in the North and South oriented facades.

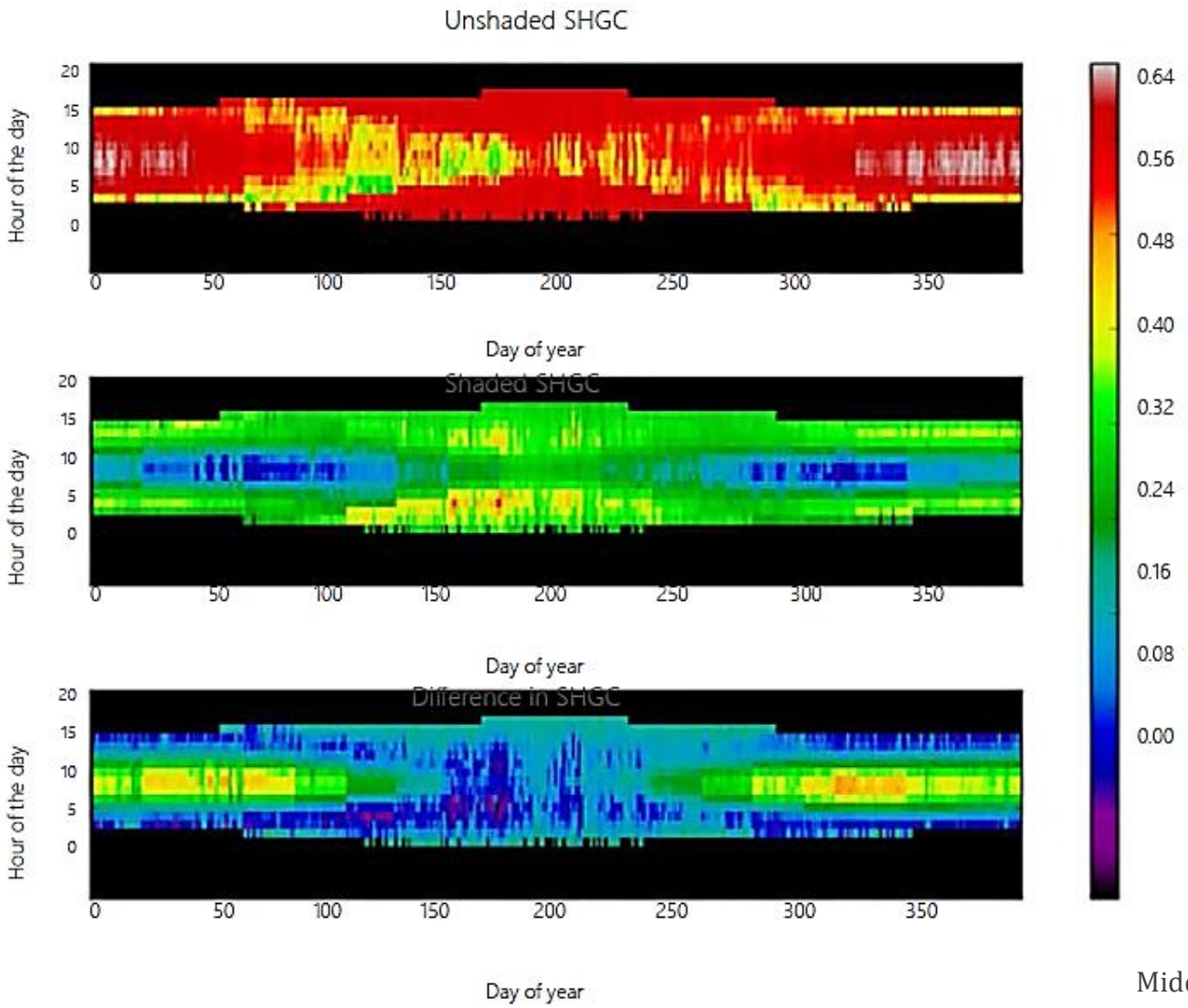
- Dynamic movable external shading systems, vertical shading elements like fins are more useful in cutting radiations when the sun is at a lower altitude i.e., in East and West facades

AFFORDABLE HOUSING & PASSIVE STRATEGIES



- Exterior shading devices can be provided in a variety of materials and designs, including sunshades, awnings, louvers, bamboo screens, Jaali, green cover through vines.
- These can be implemented with minimal cost implications and have the most favourable cost-benefit relation with respect to thermal comfort.
- To prevent summer overheating and glare, a good shading device strategy should be used with glazed openings.

AFFORDABLE HOUSING & PASSIVE STRATEGIES



Solar Heat Gain Coefficient (SHGC)

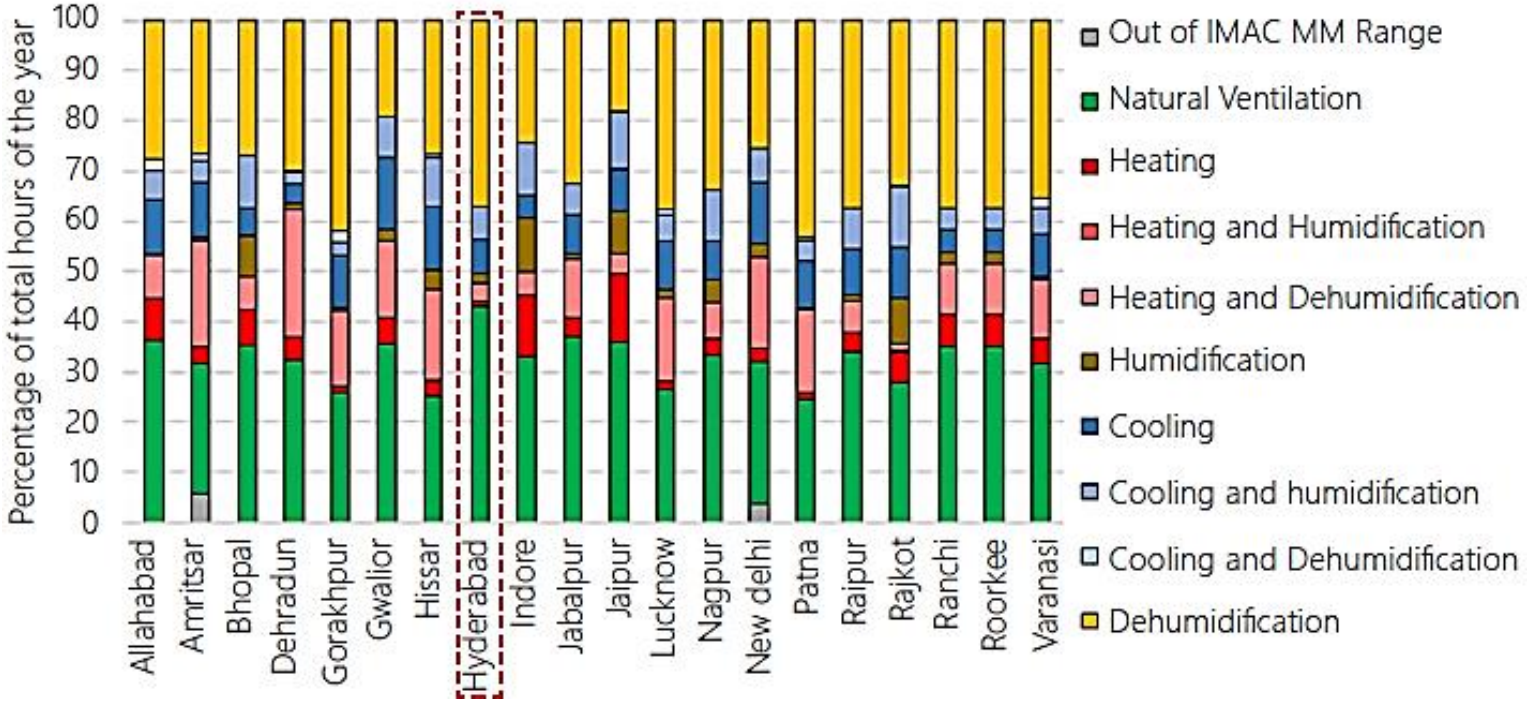
- SHGC value of glass while maintaining desirable VLT and U-value.
- Combination of multiple passive design measures can contribute to achieve RETV value of 15 W/Sqm or less for thermally comfortable buildings.

Top- SHGC values of an unshaded window throughout the year;
Middle- SHGC values of the same windows in case of shading present throughout the year;
Bottom- Difference in SHGC values of the first two graphs.

AFFORDABLE HOUSING & PASSIVE STRATEGIES

Natural ventilation

Natural ventilation is defined as provision of fresh air and removal of stale air using the naturally occurring forces of wind.

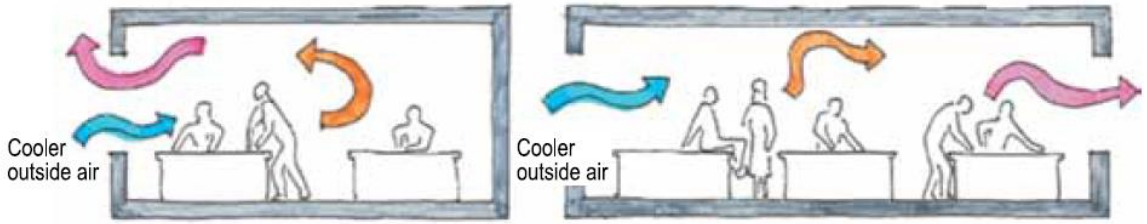


Percentage of comfort hours in a year for different building operation modes listed in IMAC-MM. Source: M., Shulka, Y., Rawal, R., Loveday, D., de Faria, L., Angelopoulos, C. (2020). Low Energy Cooling and Ventilation in Indian Residences Design Guide. CEPT Research & Development Foundation & Loughborough University. http://carbse.org/reports-and-articles/

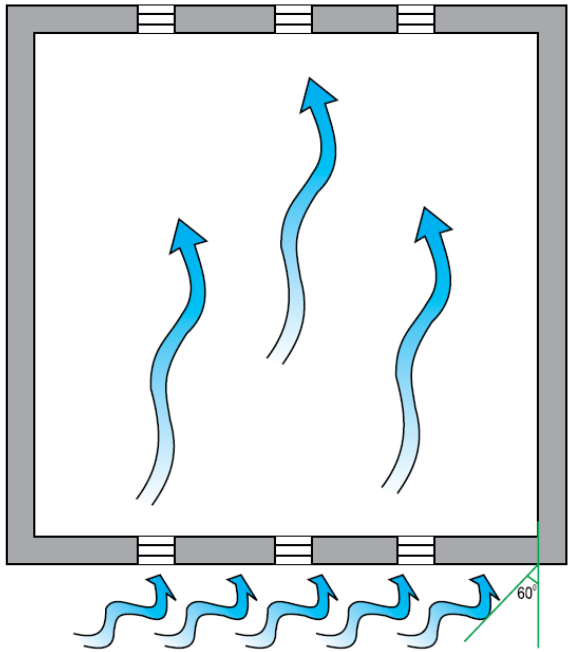
AFFORDABLE HOUSING & PASSIVE STRATEGIES

Natural ventilation

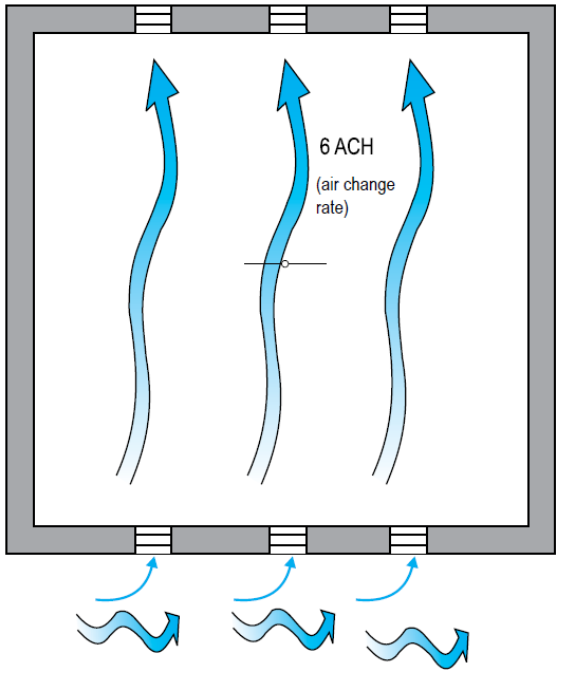
It is shown that the ACH improved from 6 ACH per hour to 14 ACH per hour with the use of the deflectors.



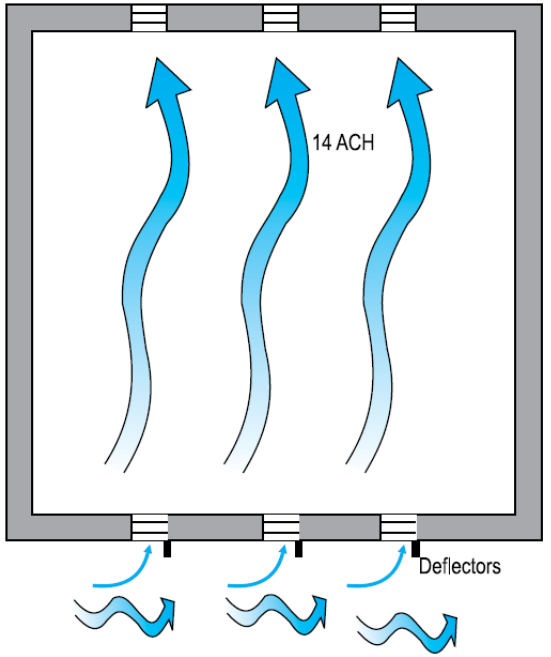
Principles of single-sided ventilation and cross-ventilation



Wind blowing at an angle of 60° from the perpendicular axis of the façade



Wind blowing parallel to the façade

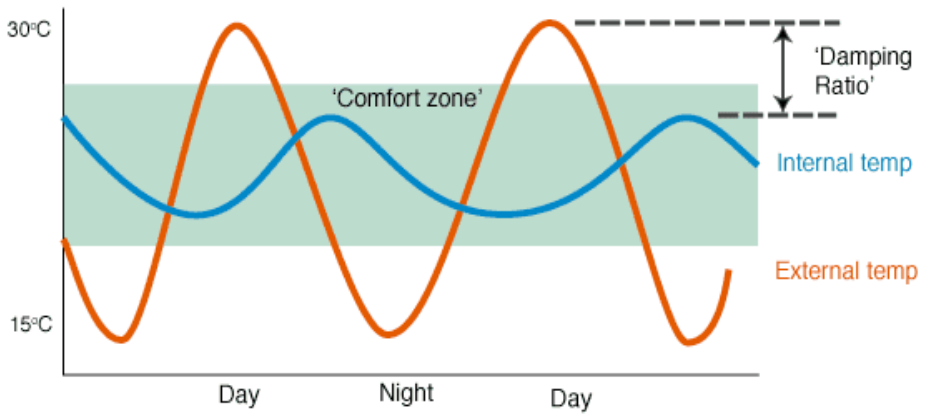


Deflectors that help in harnessing wind for natural ventilation

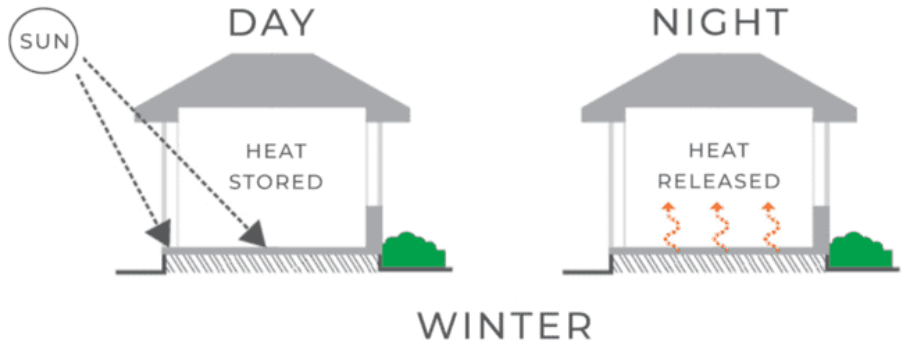
Source: Guidelines for Energy-Efficient and Thermally Comfortable Public Buildings in Karnataka

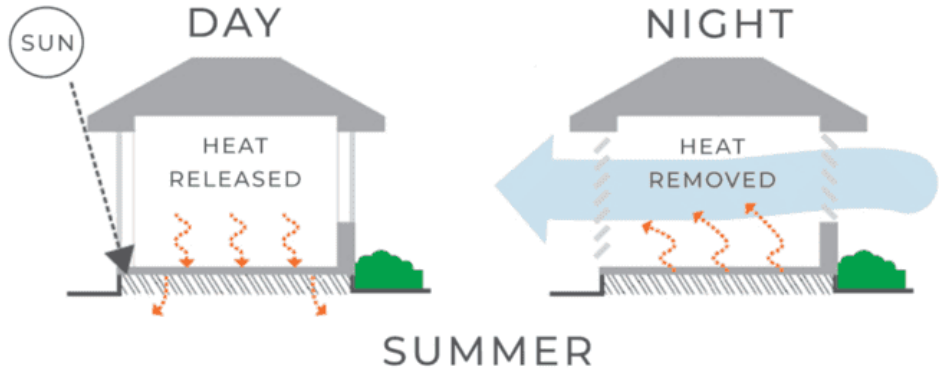
AFFORDABLE HOUSING & PASSIVE STRATEGIES

'Thermal mass' describes a material's capacity to absorb, store and release heat. A common analogy is thermal mass as a kind of thermal battery.



- **Denser thermal mass materials are more effective passive solar materials. Thus, denser the material the better it stores and releases heat.**
- **Do not substitute thermal mass for insulation. It should be used in conjunction with insulation.**

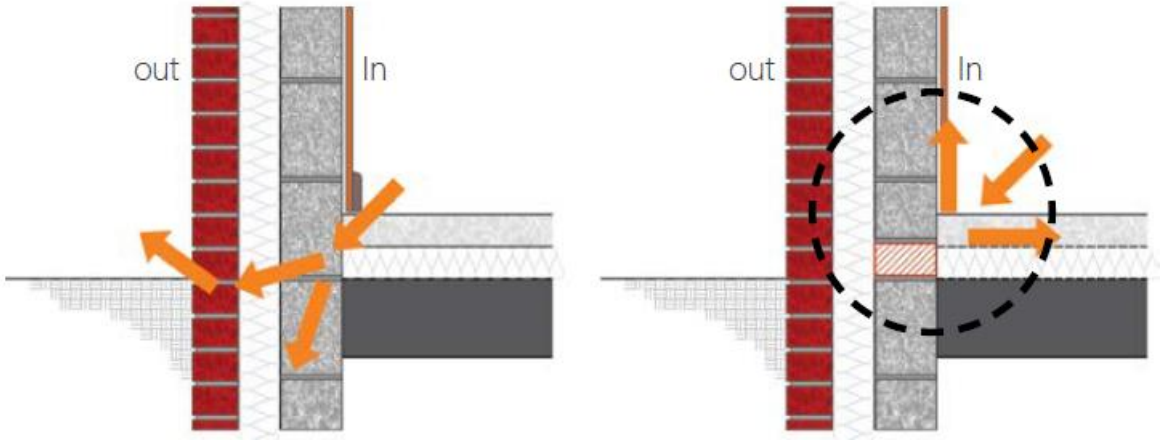




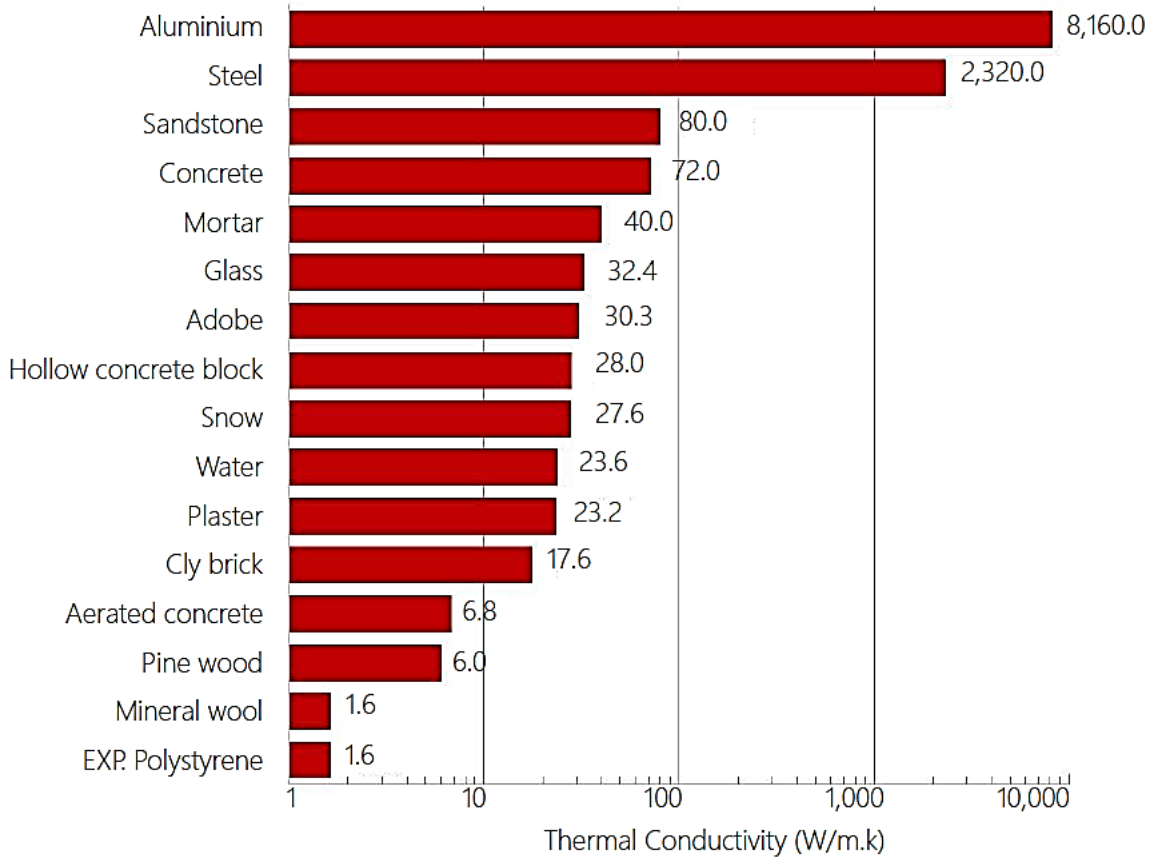
INNOVATIVE BUILDING MATERIALS (Wall, Glazing & Roof)

Thermal conductivity and thermal bridge

A thermal bridge is a part of the assembly (such as metal screws or nails) that allows direct heat transfer between indoors and outdoors due to interruptions in insulation.



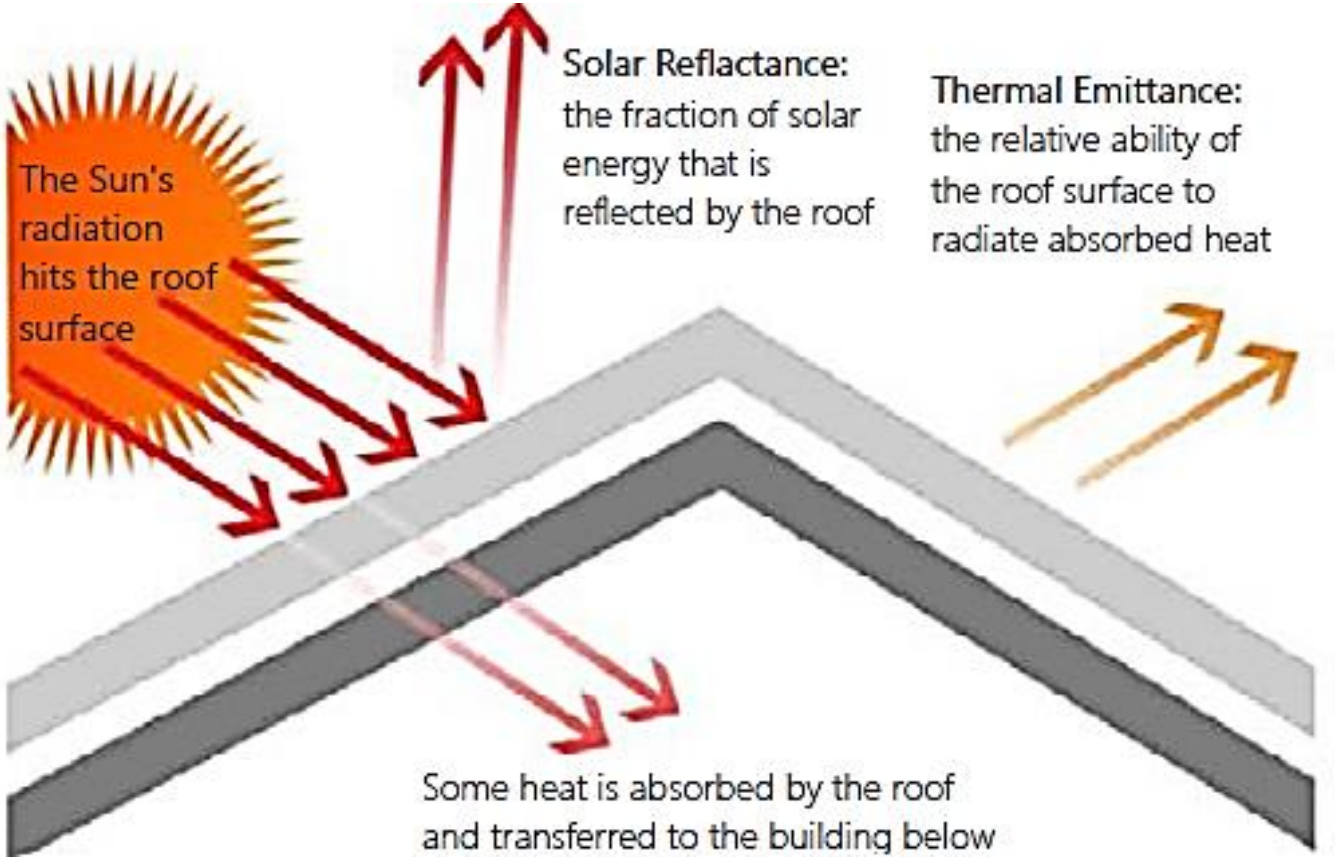
Walling assemblies and thermal bridging.
Information and Image Courtesy: Prof. Cloude Roulet, EMPA, Switzerland, Indo Swiss BEEP project, BEE, India



Thermal conductivities of common building materials.
Information and Image Courtesy: Prof. Cloude Roulet, EMPA, Switzerland, Indo Swiss BEEP project, BEE, India

INNOVATIVE BUILDING MATERIALS (Wall, Glazing & Roof)

Roof Coating Materials



Interaction of roofing materials and surfaces with incident solar radiation.
Source (left): 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/.

CASE STUDY- RAJKOT SMART GHAR III

RAJKOT SMART GHAR III

The climate of Rajkot is composite and the peak daytime temperatures during the summer reach 41°C-43°C.

Reducing heat gains through walls and roof:

Walling material was changed to 230mm thick AAC blocks. In doing so, the U-value of walls dropped to 0.8 W/Sqm.K from 2W/Sqm.K.

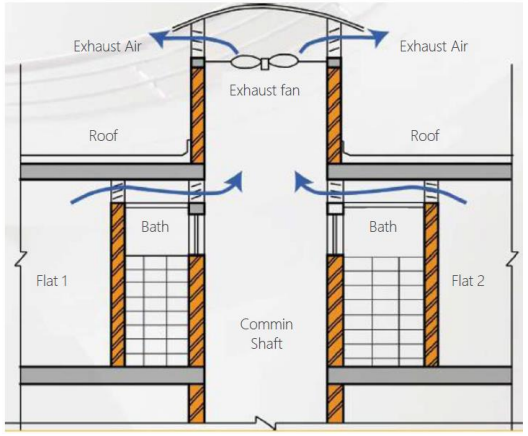
Improving Ventilation through shaft design:

A roof feature with exhaust fans on top of the shaft was added to create negative pressure in the shaft at all times

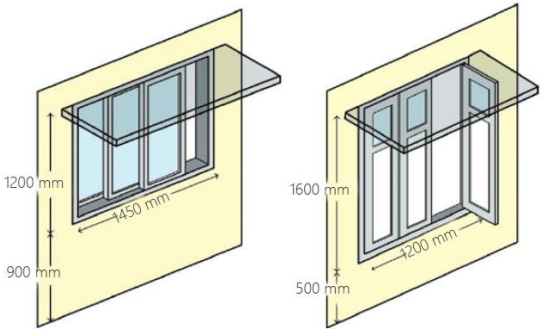
Reducing heat gains through window design and ventilation:

This design was changed to a taller partially glazed casement type for selected windows. The 90% openable casement windows allowed for better ventilation flow rates.

Site layout for Rajkot Smart GHAR-III (PMAY) project.
Source: (Rawal, Shukla, Patel , Desai, & Asrani, 2021)



Improving ventilation through common service shaft.



Fully glazed window design (left) was improved to taller, partially glazed casement windows (right)

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

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

Ministry of Housing and Urban Affairs
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आज़ादी का अमृत महोत्सव

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THANK YOU!