Climate Smart Buildings (CSB)

Cluster Cell - Indore, Madhya Pradesh

under Global Housing Technology Challenge - India (GHTC-India)

RACHNA

RESILIENT, AFFORDABLE AND COMFORTABLE HOUSING THROUGH NATIONAL ACTION

Training A Indore - 9th June 2022

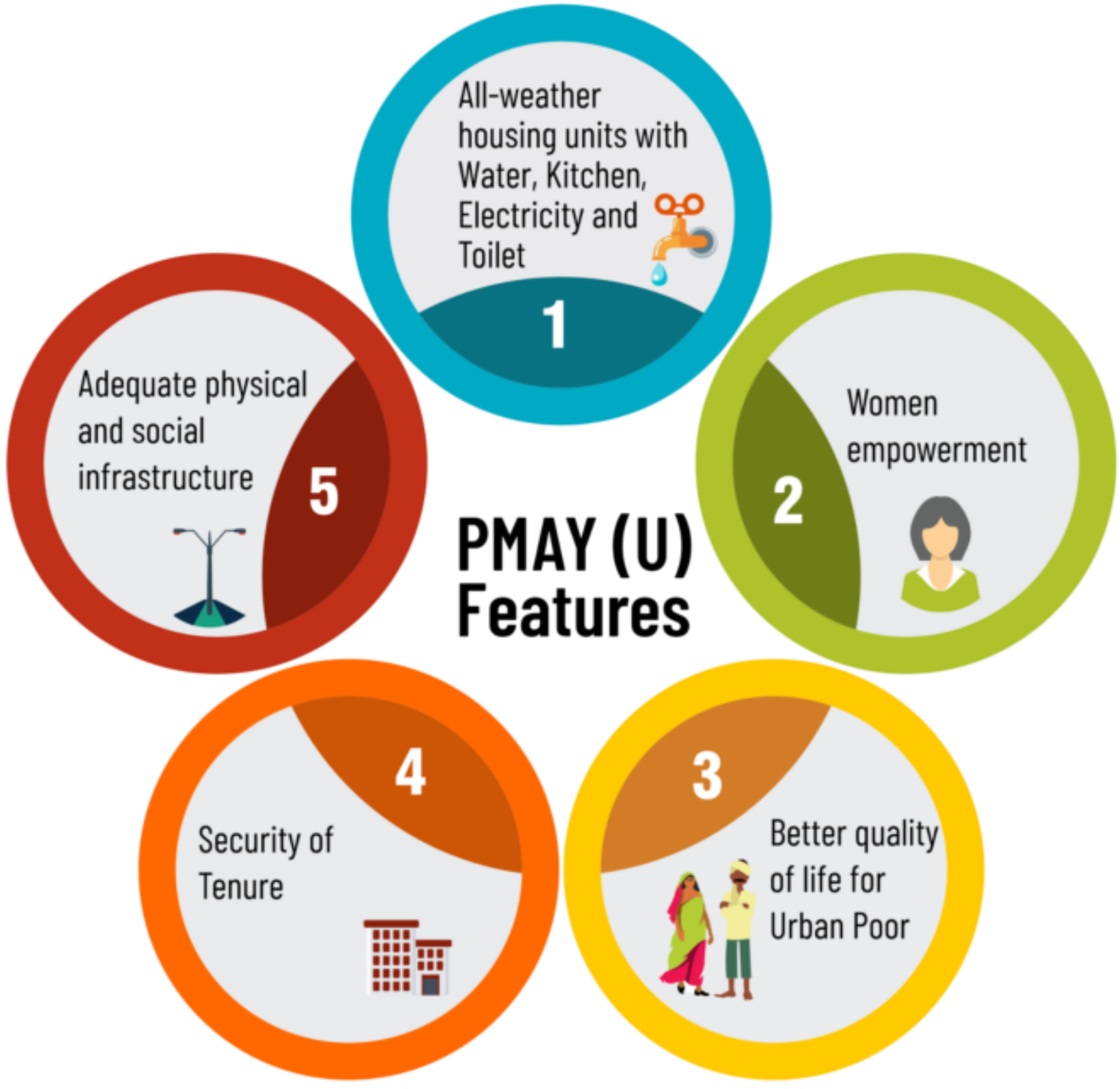
INTRODUCTION

Pradhan Mantri Awas Yojana – Urban (PMAY-U), a flagship Mission of Government of India being implemented by **Ministry of Housing and Urban Affairs (MoHUA)**, was launched on 25th June 2015.

The Mission addresses urban housing shortage among the EWS/LIG and MIG categories including the slum dwellers by ensuring a pucca house to all eligible urban households by the year 2022, when Nation completes 75 years of its Independence.

Under the Mission, **Ministry of Housing and Urban Affairs (MoHUA),** provides assistance to implementing agencies across the States and Union Territories to execute the program with following objectives:

- **In-situ SLUM REDEVELOPMENT (ISSR)**
- **AFFORDABLE HOUSING**
- **SLUM REHABILITATION**
- **PROMOTION**



INTRODUCTION

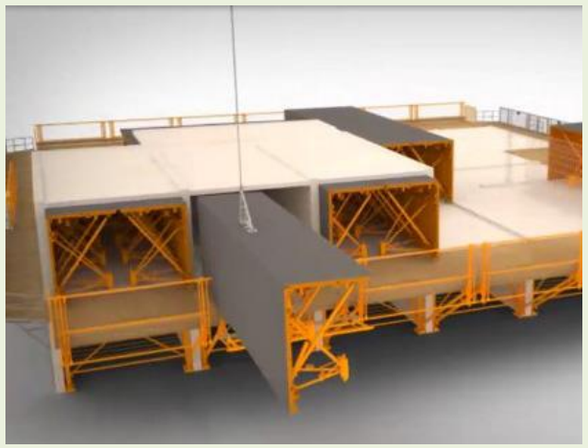
Ministry of Housing & Urban Affairs has initiated Affordable Rental Housing Complexes (ARHCs), a sub-scheme under Pradhan Mantri Awas Yojana - Urban (PMAY-U). This will provide ease of living to urban migrants/ poor in Industrial Sector as well as in non-formal urban economy to get access to dignified affordable rental housing close to their workplace.

INTRODUCTION

Under the flagship Mission of Government of India '**PMAY-U',** being implemented by **Ministry of Housing and Urban Affairs (MoHUA).** Under the Mission, **MoHUA,** has initiated the Global Housing Technology Challenge - India (GHTC-India) which aims - ***to identify and mainstream a basket of innovative construction technologies from across the globe for housing construction sector that are sustainable, eco-friendly and disaster-resilient.***

54-Innovative
Construction Technologies

1. Stay in Place Formwork System (Lucknow, Uttar Pradesh)



2. Monolithic Concrete Construction (Rajkot, Gujrat)

3. 3D Volumetric, Precast concrete construction system (Ranchi, Jharkhand)

4. On-site assembled Precast concrete construction system (Chennai, Tamil Nādu)

5. Light Gauge Steel Structural System & Pre-engineered Steel Structural System (Agartala, Tripura)

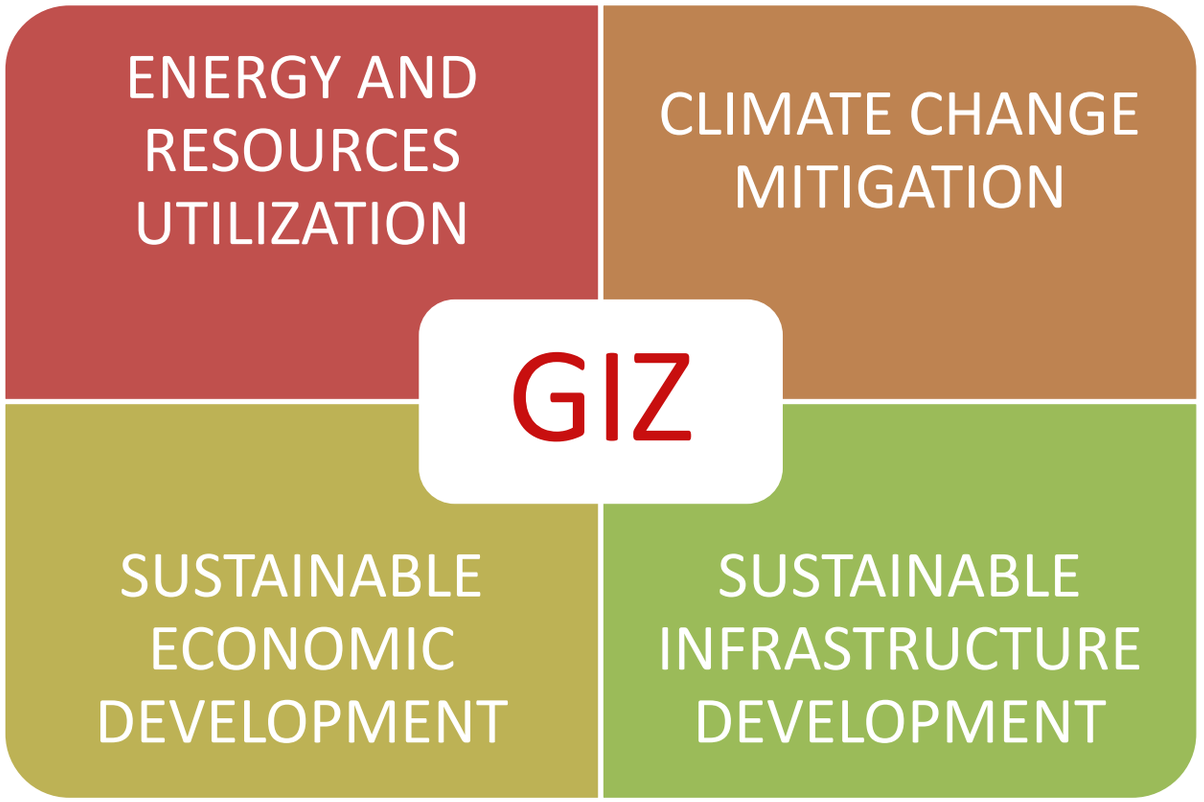
6. Precast fabricated sandwich panel system (Indore, Madhya Pradesh)

named as **'LIGHT HOUSE PROJECT' (LHP)**

TECHNICAL PARTNER

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

"GIZ offers customized solutions to complex challenges"



- GIZ is an international cooperation enterprise for sustainable development which operates worldwide, on a public benefit basis.
- GIZ is fully owned by the German Federal Government, GIZ implement development programs in partner country on behalf of the German Government in achieving its development policy objectives.
- For over **60 years**, the GIZ has been working jointly with partners in India for **sustainable economic, ecological, and social development.**

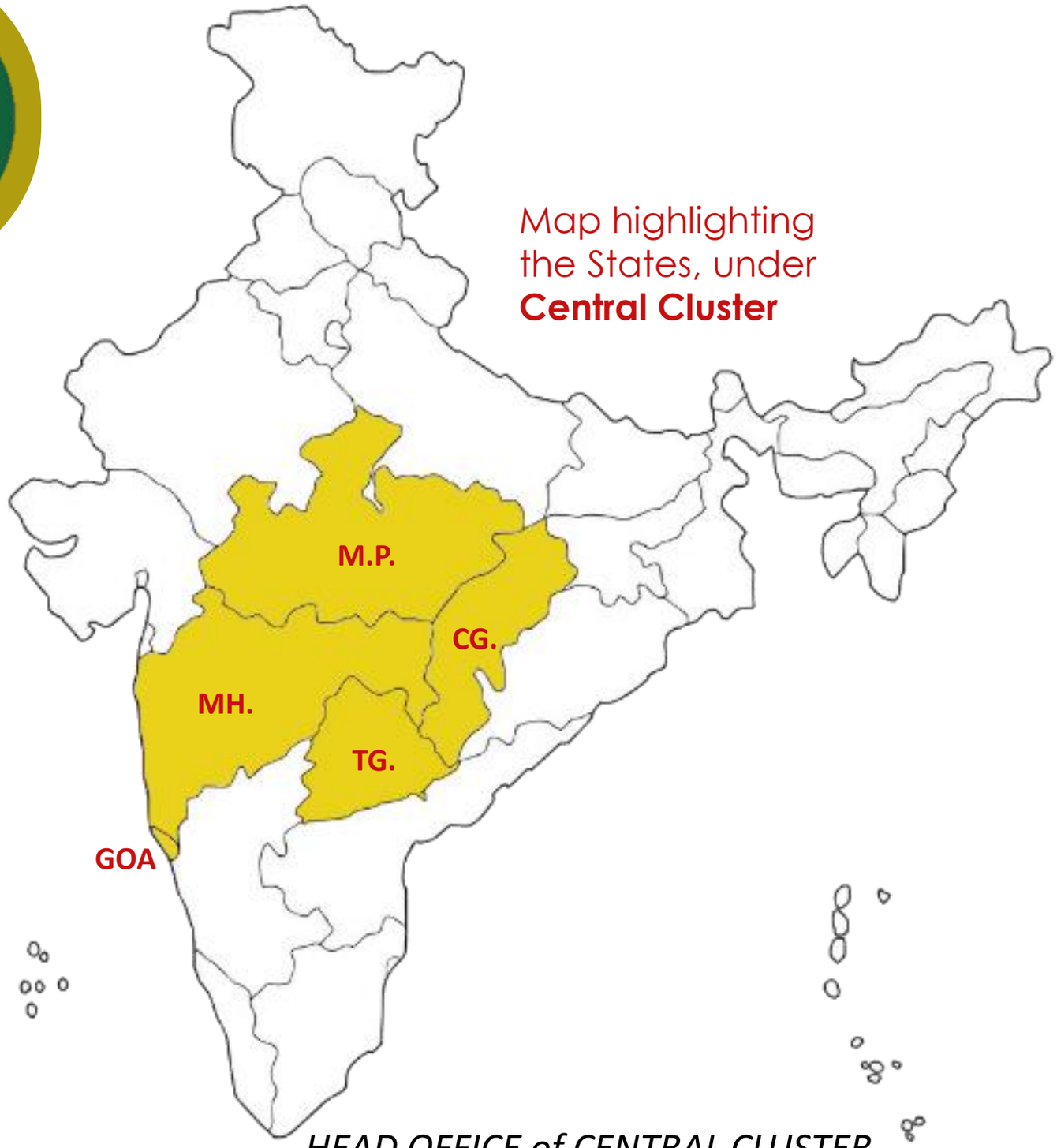
APPROACH

CLIMATE SMART BUILDINGS

The Climate Smart Buildings (CSB) program is aligned with the commitments made by the Indian Government to meet its objectives submitted under SDG 11.

Indo-German Energy programme (IGEN's Programme), Climate Smart Buildings (CSB) proposes to extend technical assistance and cooperation for the followings:

- Developing action plan for Thermal Comfort to build Climate Resilient Buildings for mass scale application
- Implementation of Global Housing Technology Challenge-India (GHTC-India)



Map highlighting the States, under **Central Cluster**

HEAD OFFICE of CENTRAL CLUSTER
Indore, Madhya Pradesh
known as 'Central Cluster Building Cell'
(alias **CSB Cell**)

CONCEPT

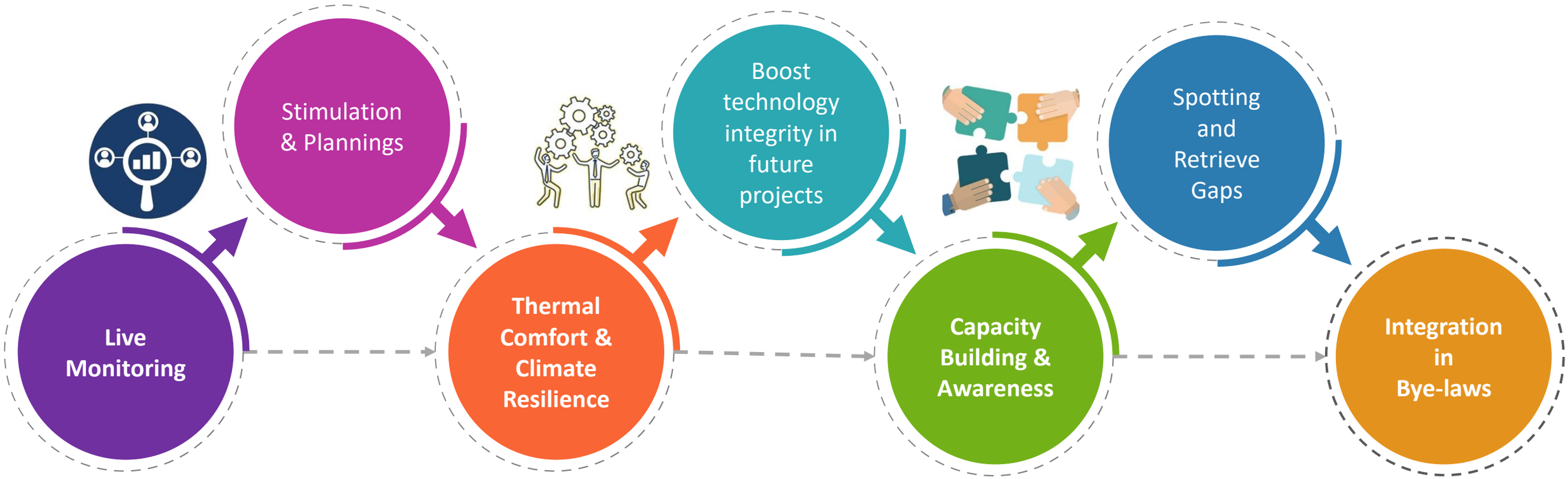
7 AFFORDABLE AND CLEAN ENERGY
Ensure access to affordable, reliable, sustainable, and modern energy for all

9.INDUSTRY, INNOVATION AND INFRASTRUCTURE
Build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation

11.SUSTAINABLE CITIES AND COMMUNITIES
Make cities and human settlements inclusive, safe, resilient, and sustainable

13. PROTECT THE PLANET
Take urgent action to combat climate change and its impacts

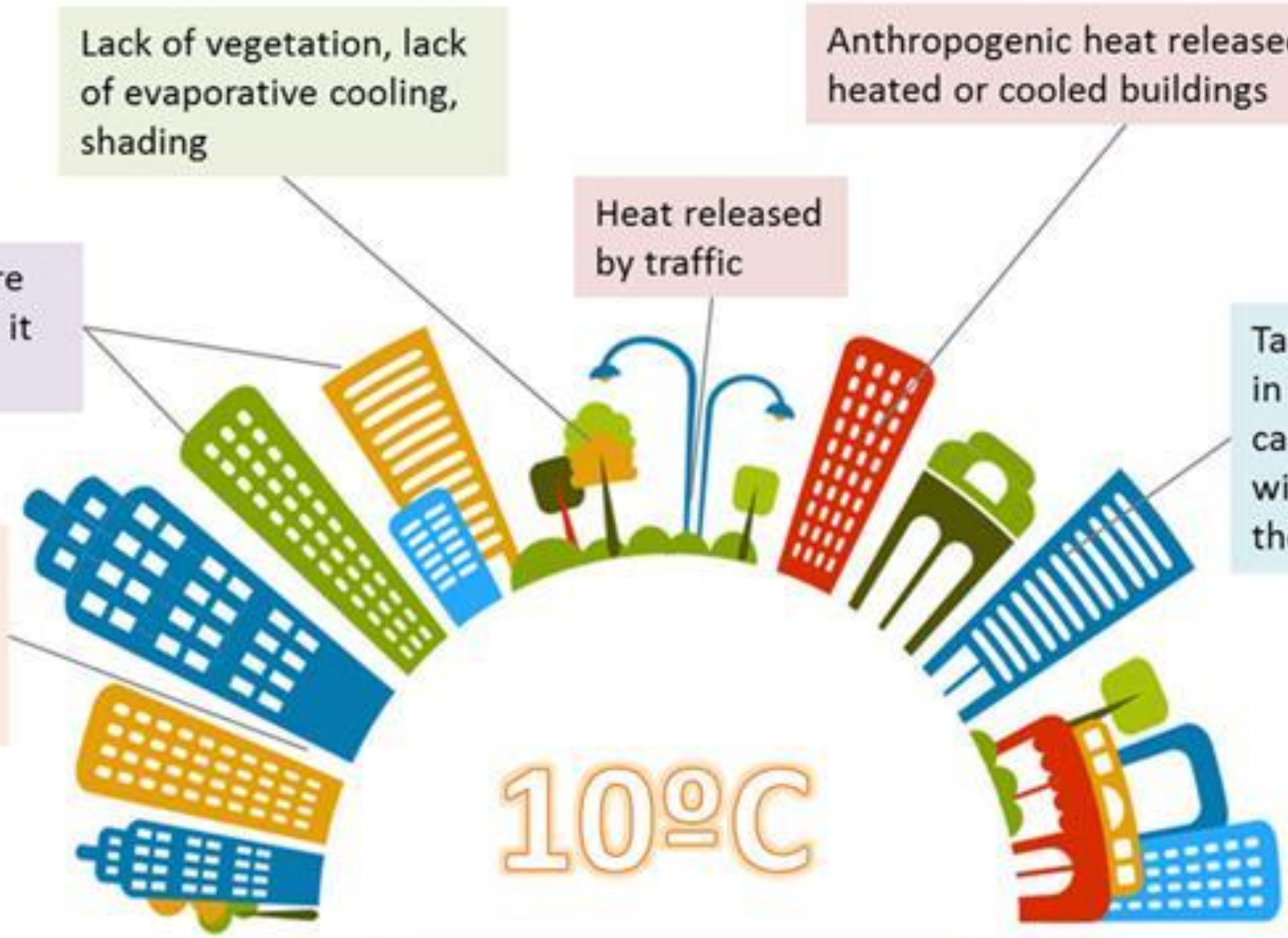
STRATEGY FOR EXECUTION – CSB CELL



11:15AM – 11:45AM Mehta & Associates

11:45AM – 12:00PM HIGH TEA & NETWORKING

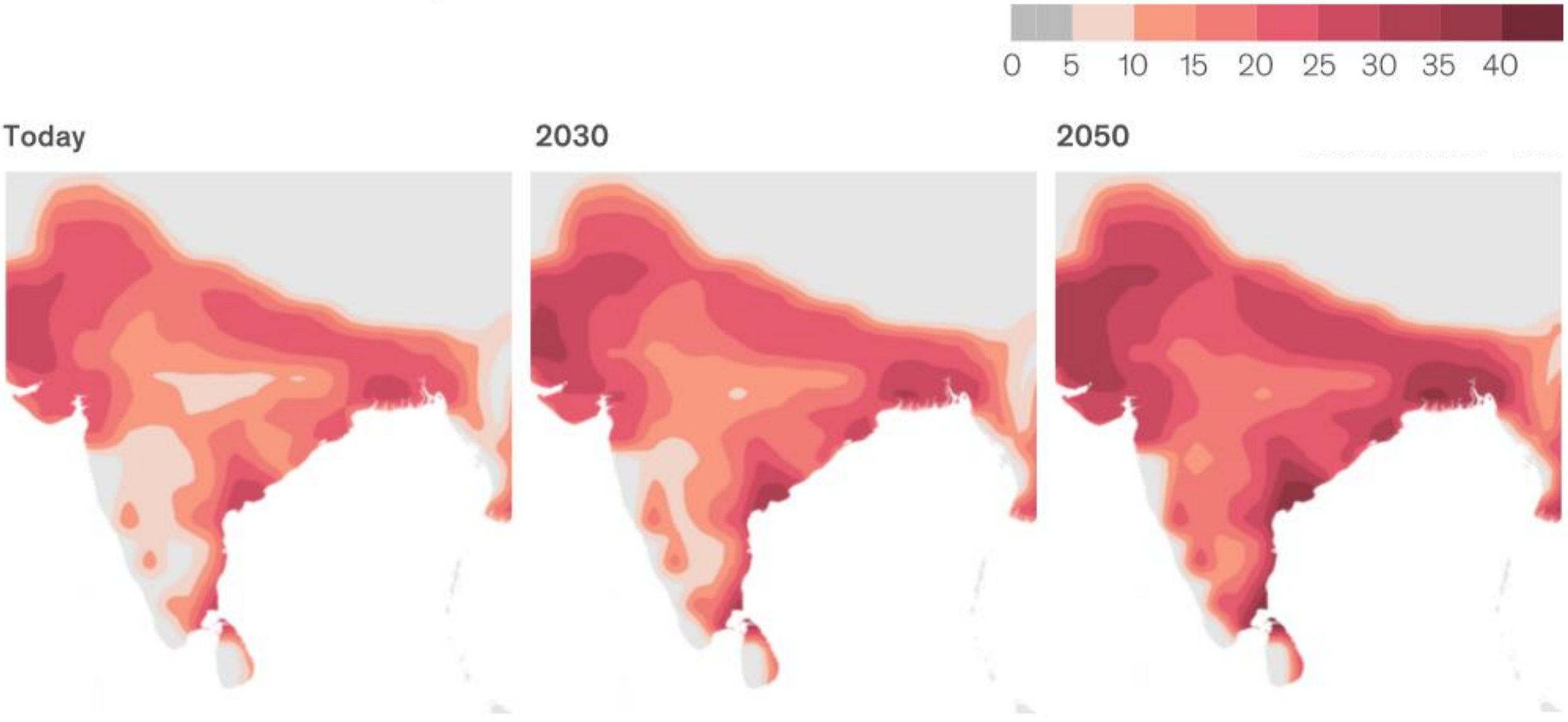
NEED FOR THERMAL COMFORT AND HOW IT IMPACT US – QUALITATIVE AND QUANTITATIVE



Due to the UHI a city centre can be over 10 degrees warmer than the surrounding countryside

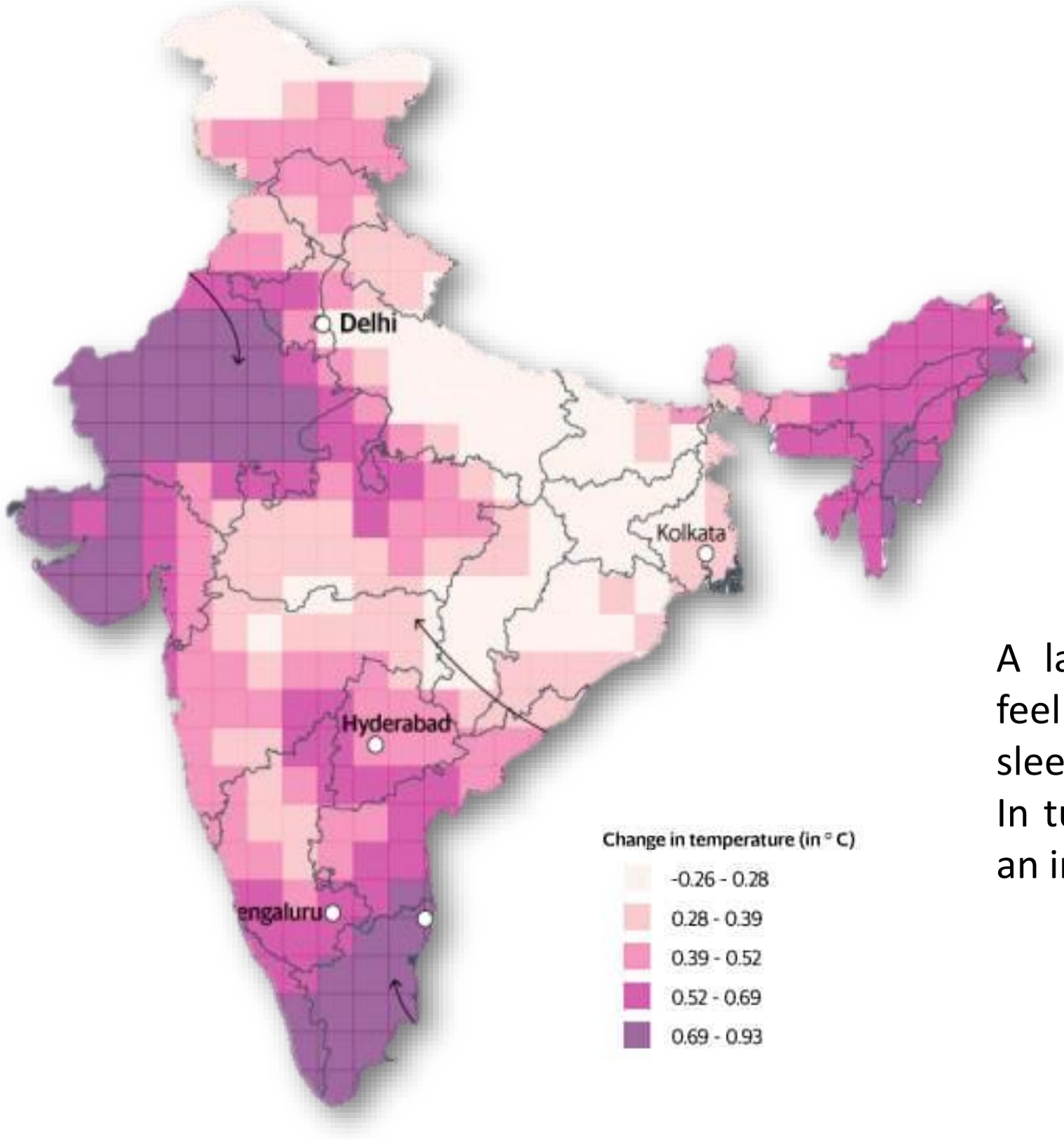
NEED FOR THERMAL COMFORT AND HOW IT IMPACT US – QUALITATIVE AND QUANTITATIVE

Impact of Heat-wave
Impact on working hours



https://www.mckinsey.com/business-functions/sustainability/our-insights/climate-risk-and-response-physical-hazards-and-socioeconomic-impacts

NEED FOR THERMAL COMFORT AND HOW IT IMPACT US – QUALITATIVE AND QUANTITATIVE



A lack of thermal comfort makes us feel **stressed**, annoyed, distracted, feel sleepy, tired and lacking concentration. In turn, thermal comfort inevitably has an impact on well-being, productivity

Source Biannial update report India

SESSION :1 THERMAL COMFORT

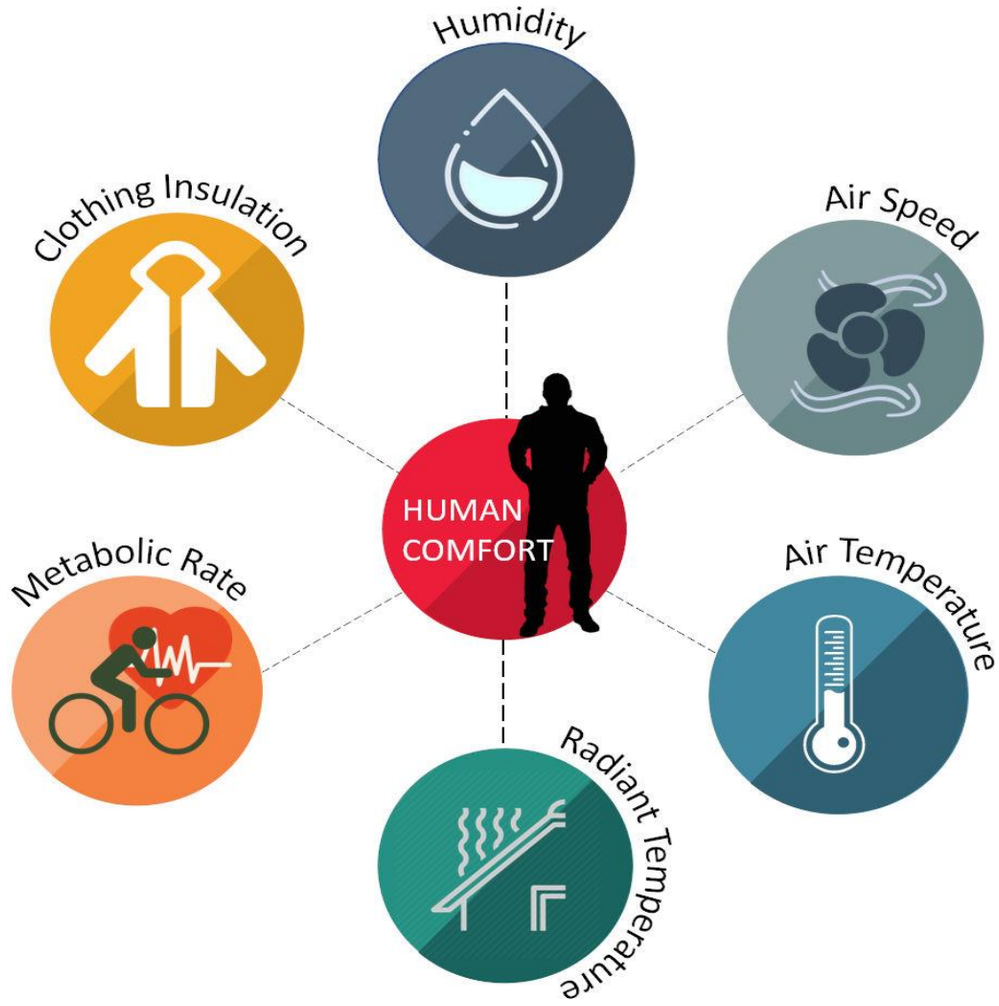
***Session 1*: Thermal Comfort:**

- **Indices**
- **Thermal comfort in Affordable Housing**
- **Passive strategies**
- **Case studies**

THERMAL COMFORT, FACTORS AFFECTING THERMAL COMFORT

Thermal comfort is the condition of mind that expresses satisfaction with the thermal environment and is assessed by subjective evaluation (ANSI/ASHRAE Standard 55)

Thermal comfort is difficult to measure because it is highly subjective. It depends on the air temperature, humidity, radiant temperature, air velocity, metabolic rates, and clothing levels.



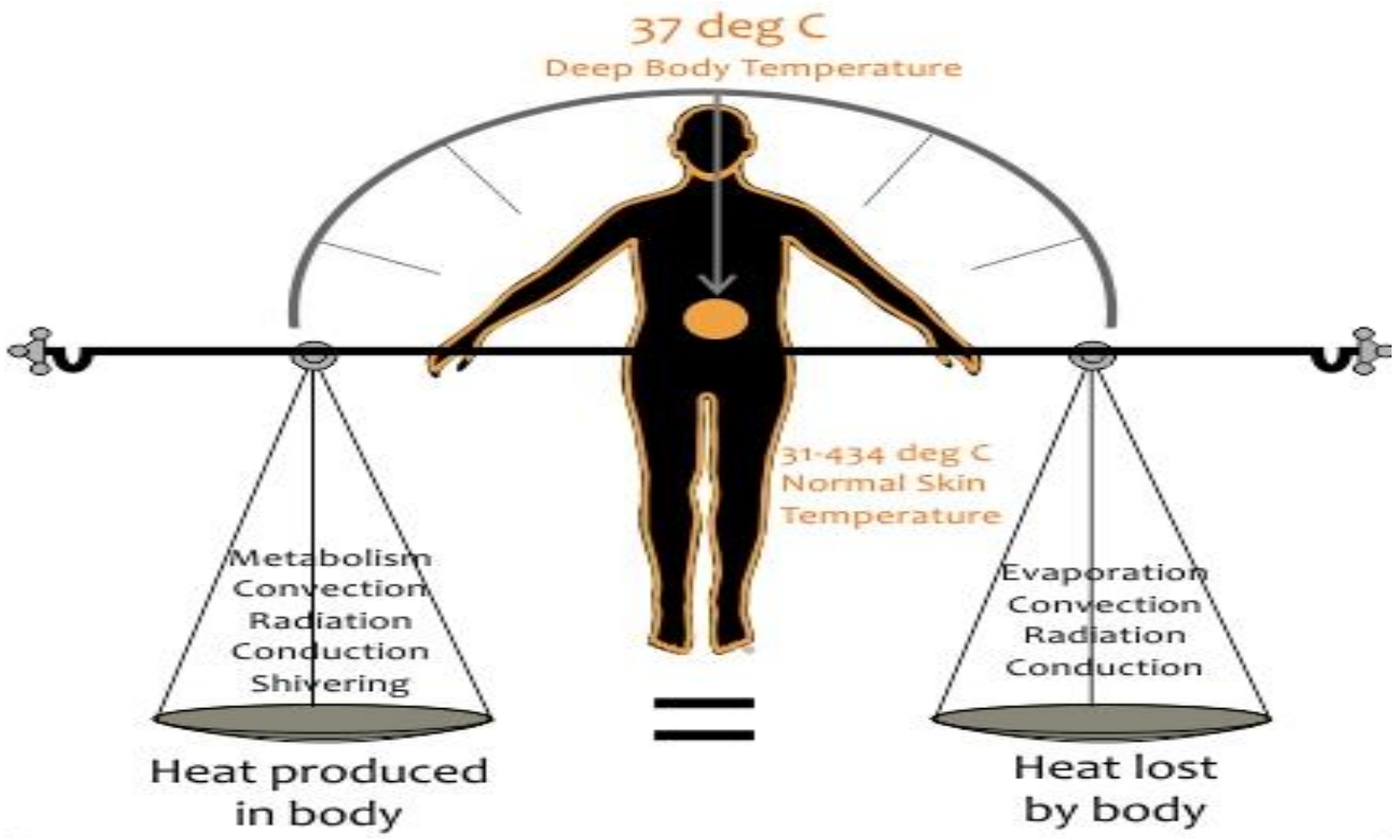
Personal factor

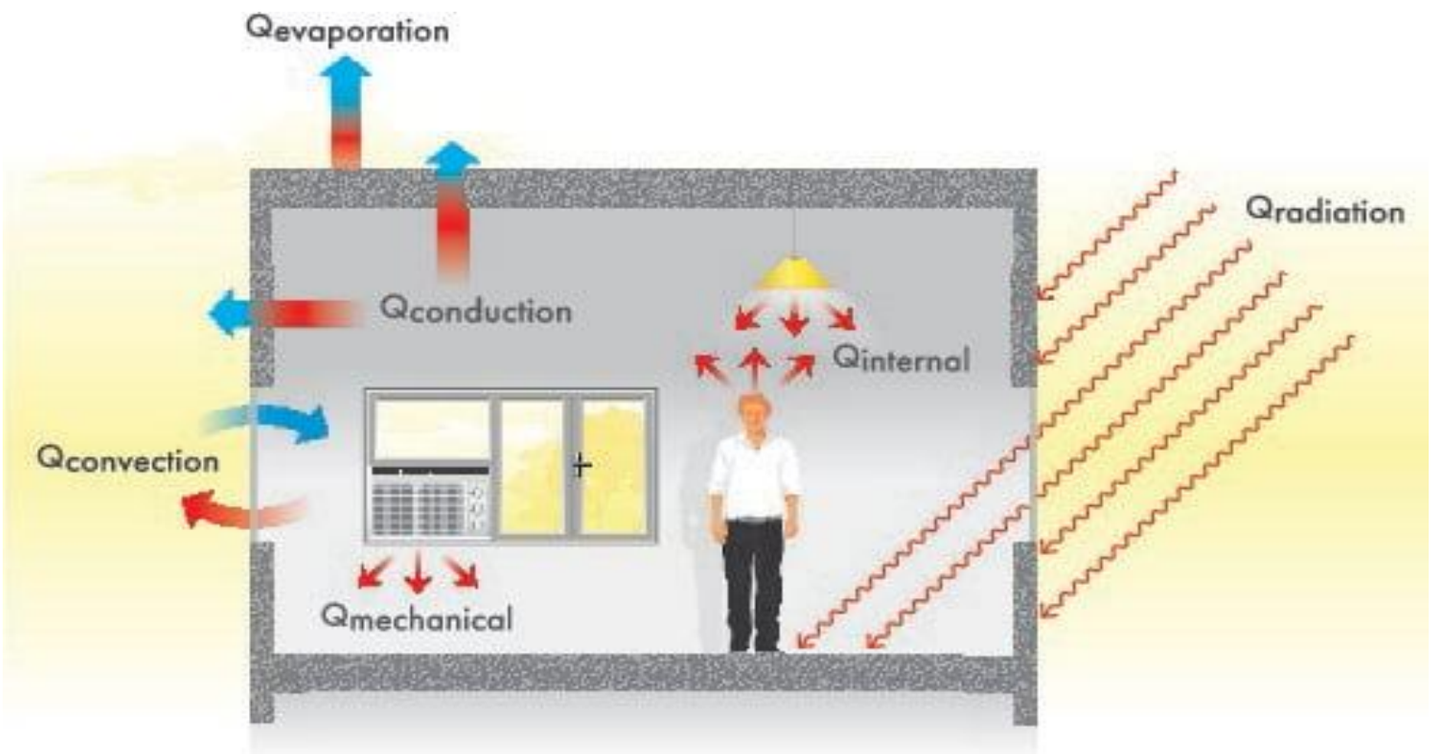
- ✓ **Clothing insulation**
- ✓ **Metabolic Rate(met)**

Environmental factor

- ✓ **Humidity**
- ✓ **Air Speed**
- ✓ **Air Temperature**
- ✓ **Radiant Temperature**

FACTORS AFFECTING THERMAL COMFORT - INDOOR ENVIRONMENT





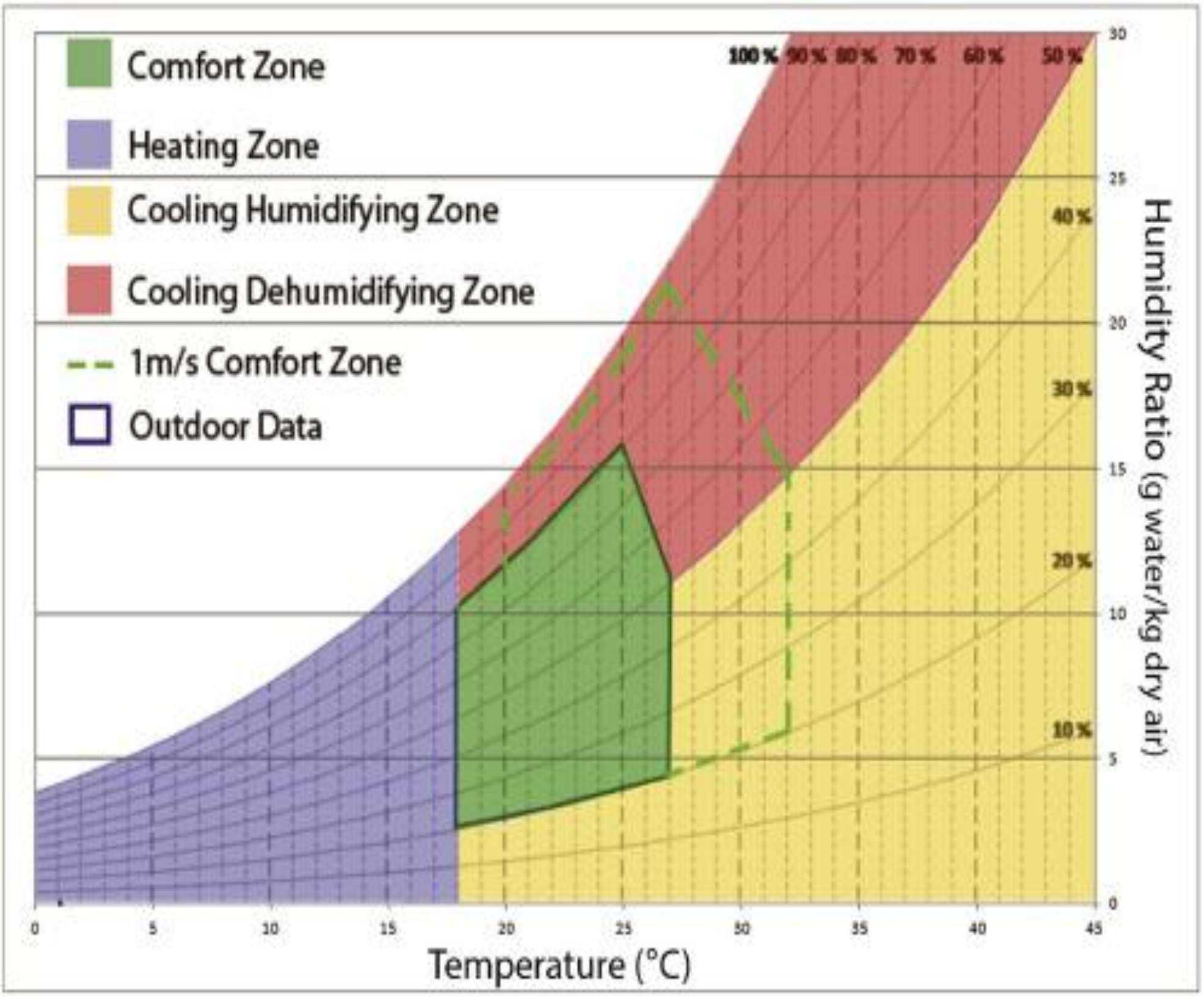
Thermal comfort refers to the perceived feeling on the human body as the result of the effect of heat and cold sources in the environment.

Heat exchange between the human body and its environment via

- **Radiation**
- **Convection**
- **Evaporation**

THERMAL COMFORT INDICES

Thermal comfort indices describe how the human body experiences atmospheric conditions, specifically air temperature, humidity, wind and radiation.



Direct Indices

- Dry Bulb Temperature
- Dew Point Temperature
- Wet Bulb Temperature
- Relative Humidity
- Air Movement

Rationally Derived Indices

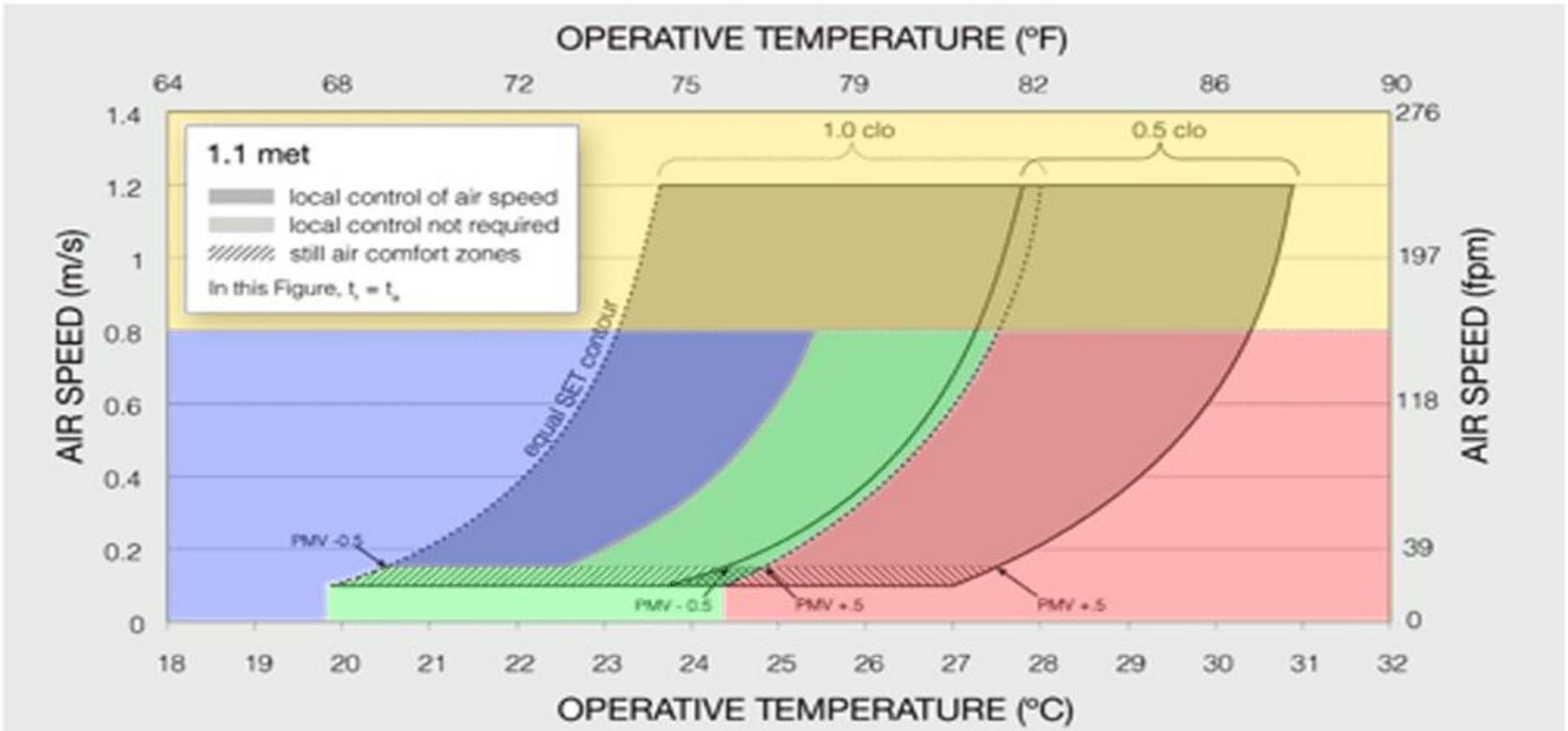
- Mean Radiant temp
- Operative Temperature
- Heat Stress
- Thermal Stress

THERMAL COMFORT INDICES

Operative temperature is defined as a uniform temperature of an imaginary black enclosure in which an occupant would exchange the same amount of heat by radiation plus convection as in the actual non uniform environment

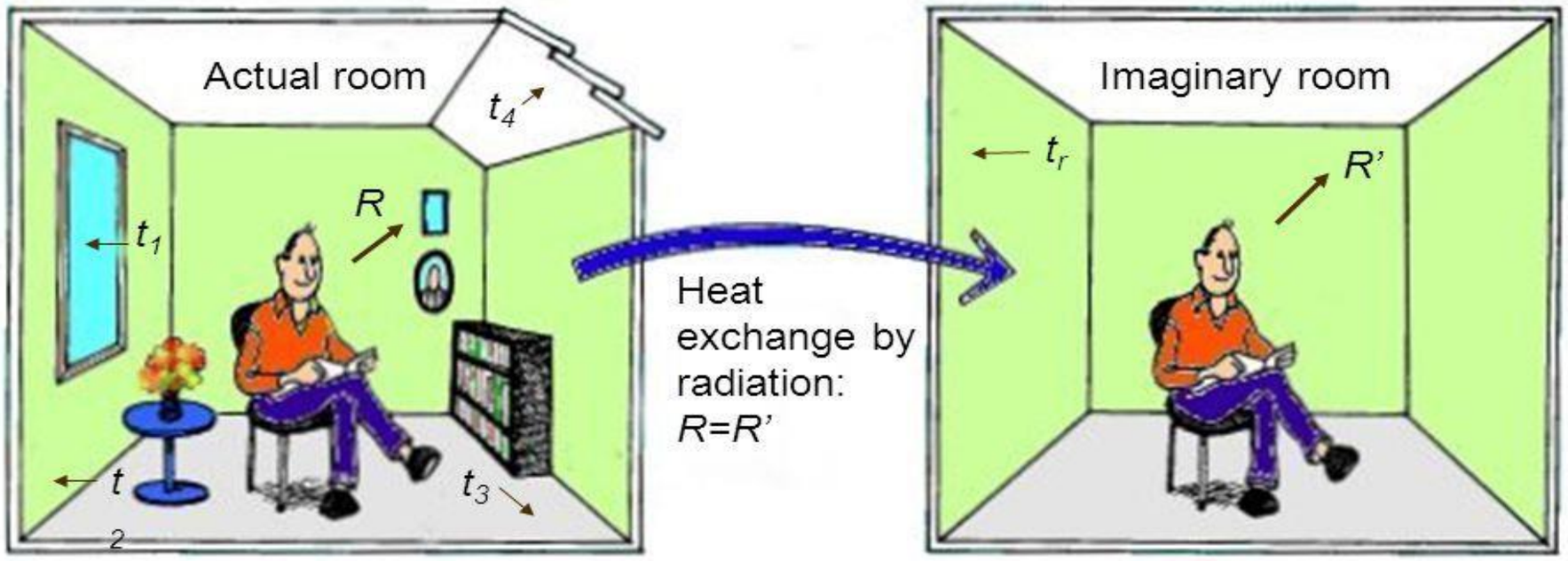
Naturally Ventilated Buildings

Indoor Operative Temperature = (0.54 x outdoor temperature) + 12.83



Comfortable | **Too Hot** | **Too Cold** | **Too Drafty**

Mean Radiant Temperature



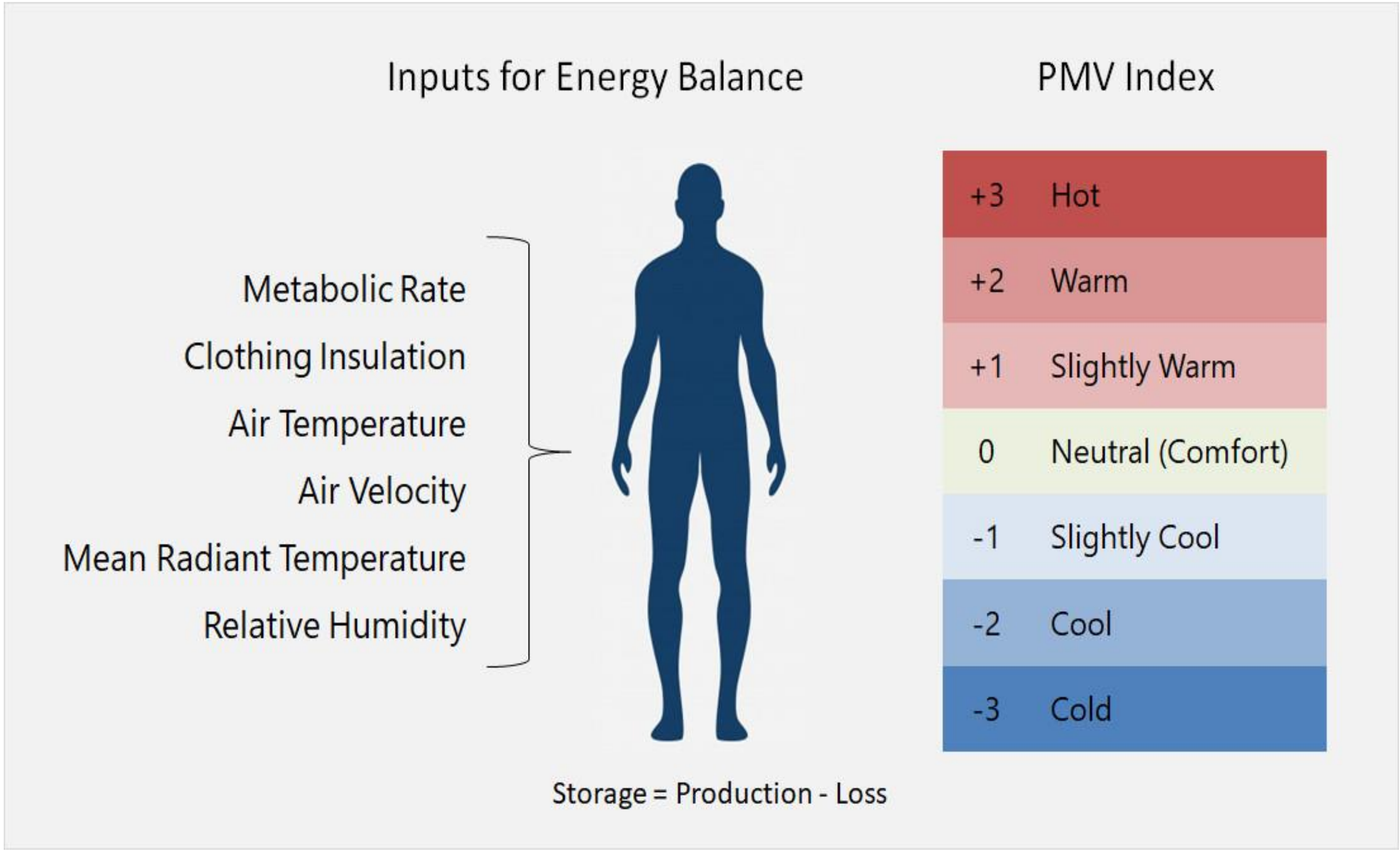
- The Mean Radiant Temperature is that uniform temperature of an imaginary black enclosure resulting in same heat loss by radiation from the person, as the actual enclosure.
- Measuring all surface temperatures and calculation of angle factors is time consuming. Therefore use of Mean Radiant Temperature is avoided when possible.

$$MRT = T_1 F_{p-1} + T_2 F_{p-2} + \ldots + T_n F_{p-n}$$

THERMAL COMFORT INDICES

THE PREDICTED MEAN VOTE (PMV)

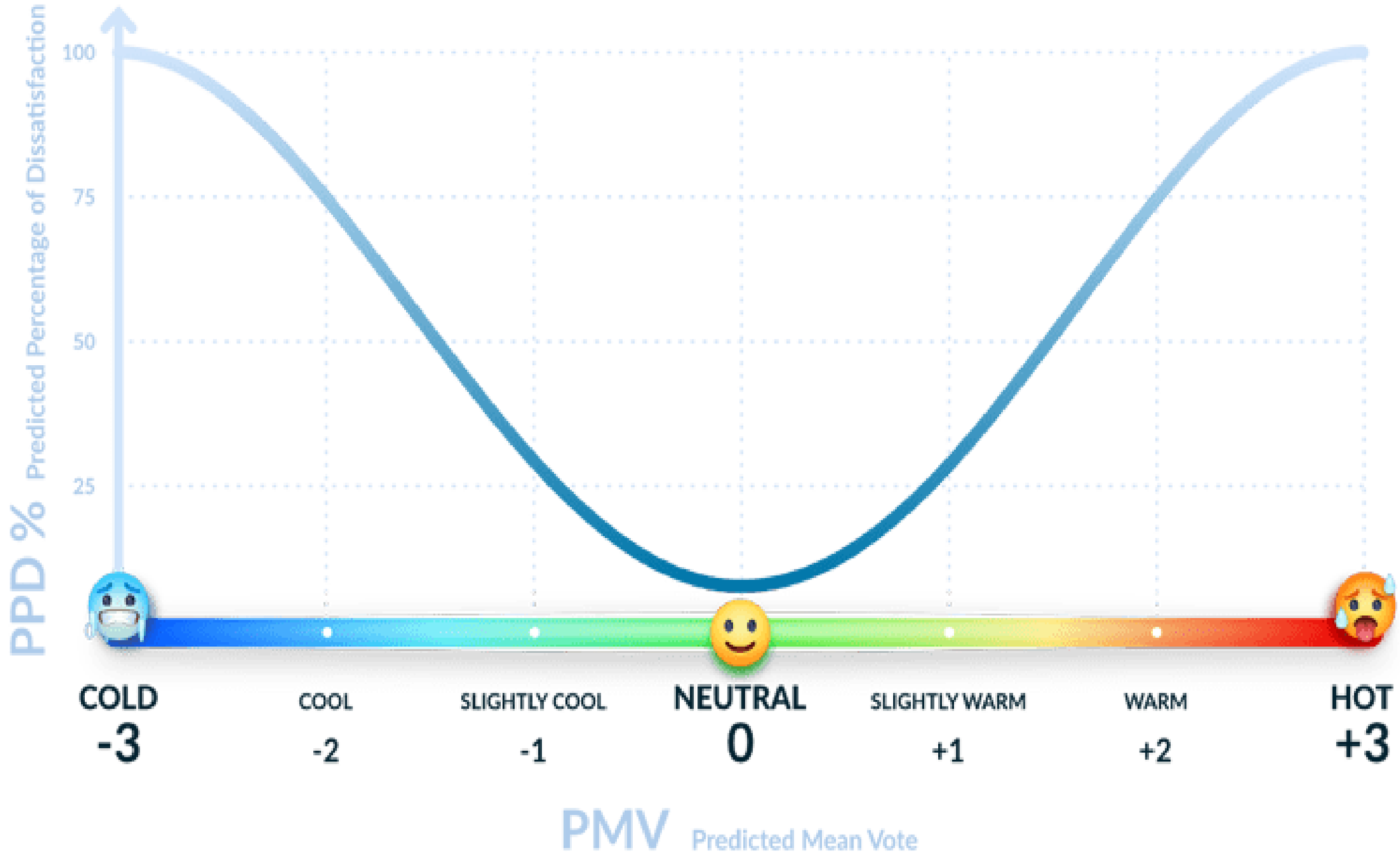
- PMV refers to a thermal scale that runs from Cold (-3) to Hot (+3).
- PMV range for thermal comfort = **-0.5 and +0.5** for an interior space.**(ASHARE 55)**



THERMAL COMFORT INDICES

PREDICTED PERCENTAGE OF DISCOMFORT

PPD, or index that establishes a quantitative prediction of the percentage of thermally dissatisfied occupants (i.e. too warm or too cold)



MEASURES TO IMPROVE THERMAL COMFORT VIA DESIGN

Passive Design

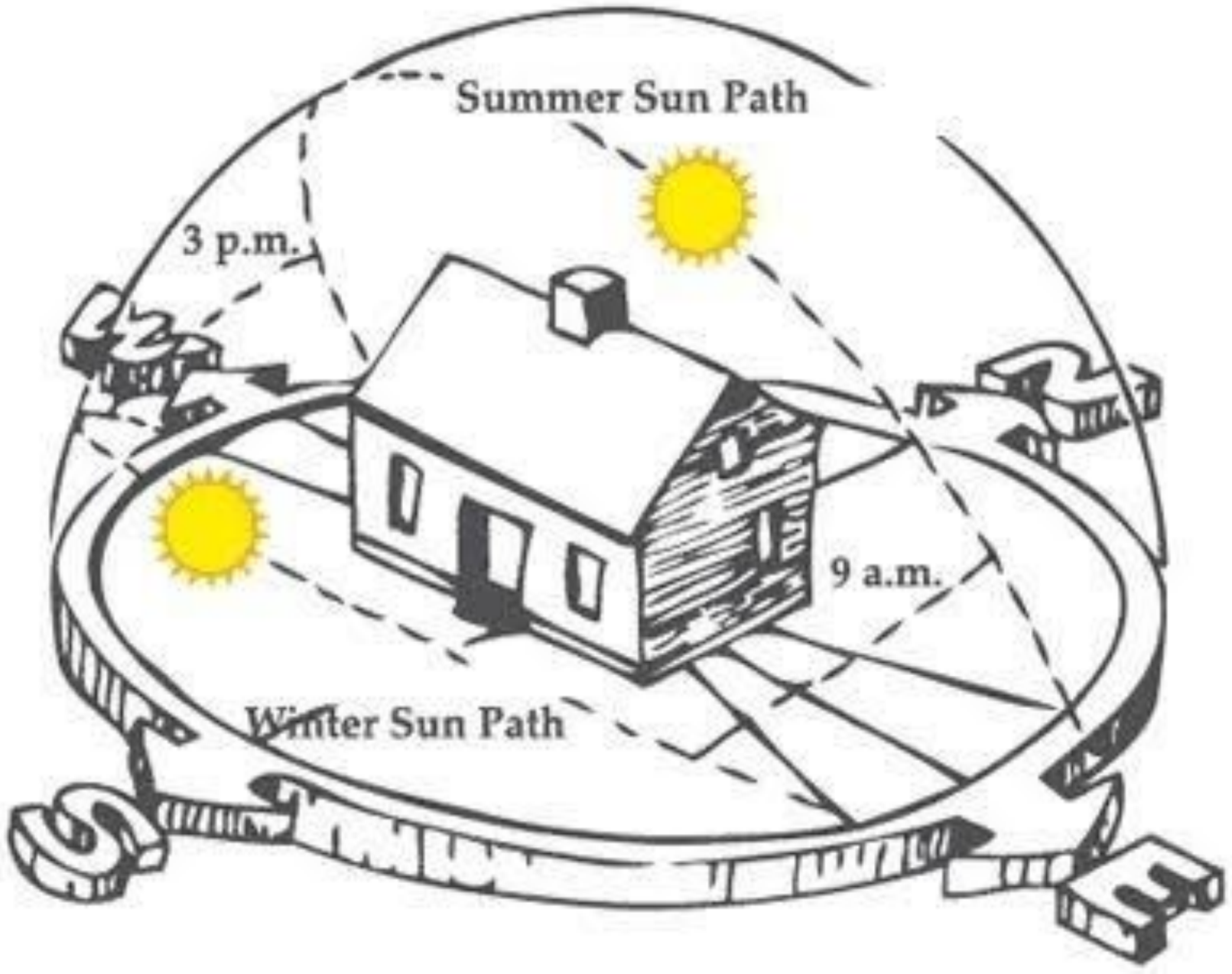
Design that leverages climatologically responsive design to encourage natural heating/cooling, ventilation, and lighting.

Active Design

Design that relies largely on mechanical / electrical sources of heating / cooling, ventilation, and lighting.

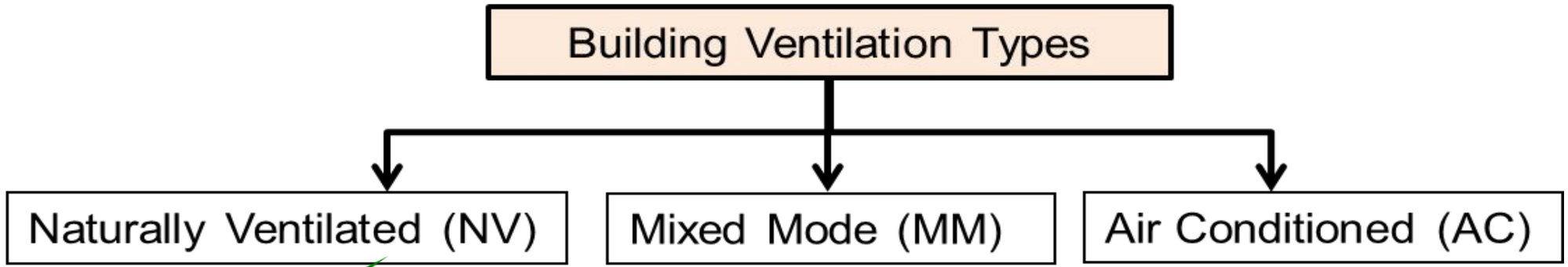
Passive design needs **active users.**

Active design needs **passive users.**



MEASURES TO IMPROVE THERMAL COMFORT

PASSIVE DESIGN STRATEGIES



- **FORM & ORIENTATION OF BUILDING BLOCKS**
- **FENESTRATION**
- **SHADING OF OPENING /WINDOWS**
- **DAYLIGHTING**
- **NATURAL VENTILATION**
- **VEGETATION**

MEASURES TO IMPROVE THERMAL COMFORT

PASSIVE DESIGN STRATEGIES

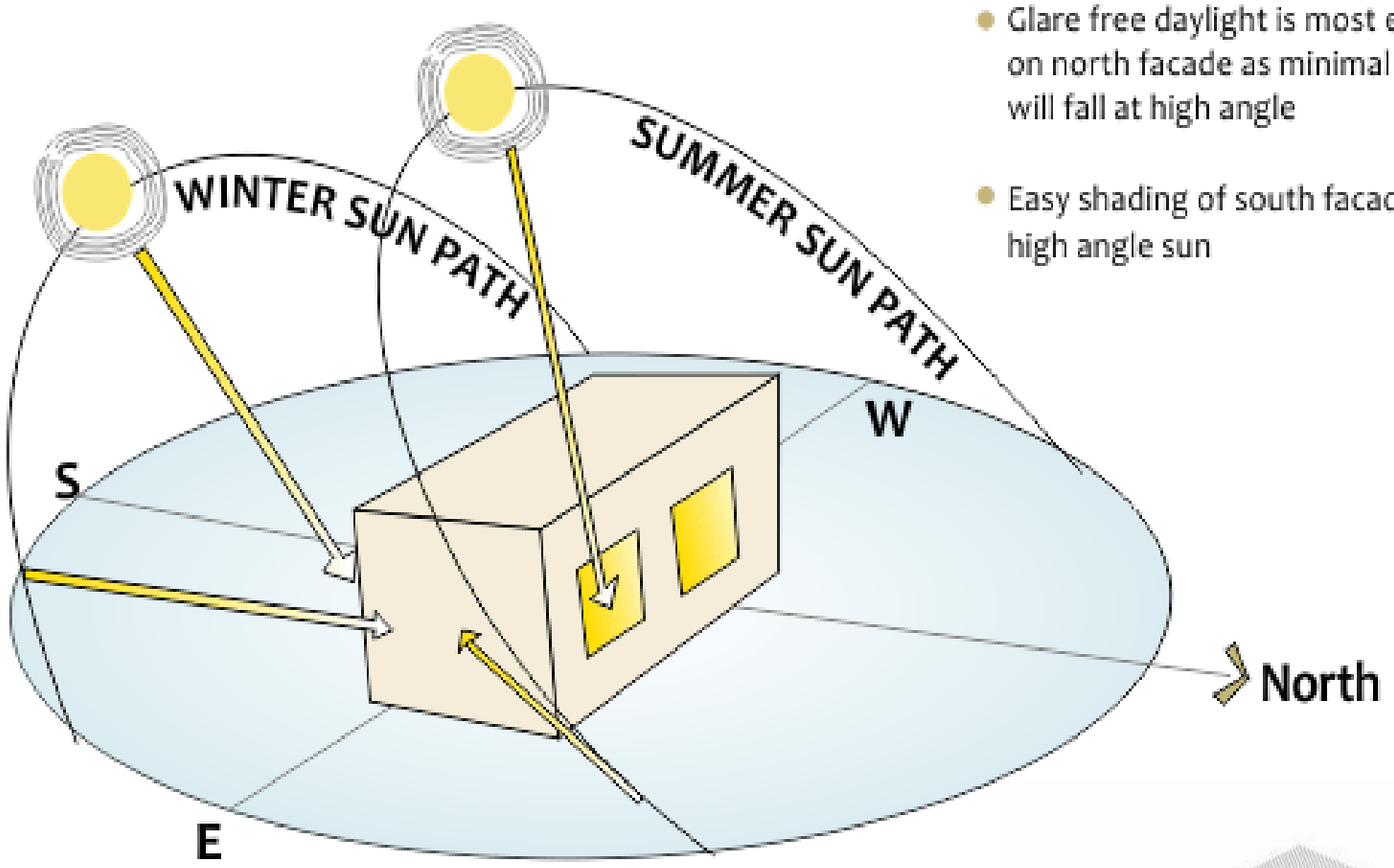
ORIENTATION OF BUILDING BLOCKS:

WINTER SUN

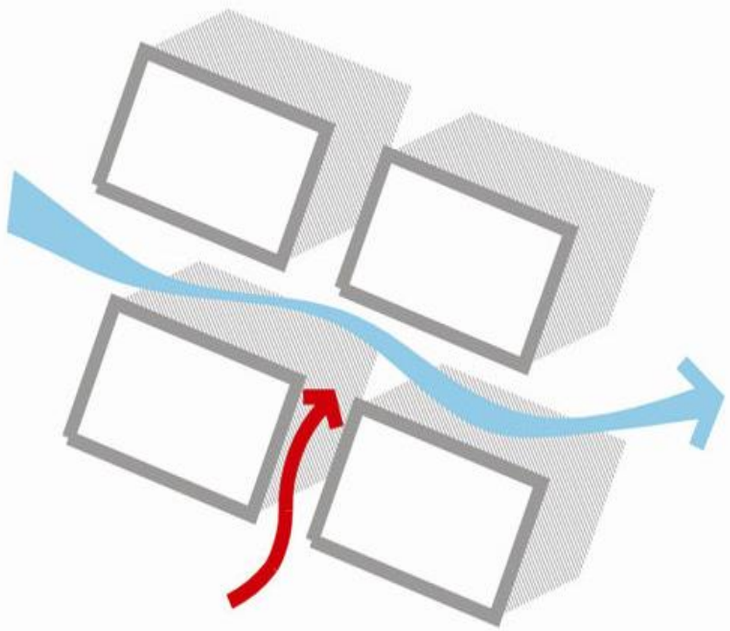
- Sun path at a low angle , south to E-W axis
- Solar radation will penetrate south facing facades at a low angle during winter

SUMMER SUN

- Sun path at a high angle sun, north to E-W axis
- Glare free daylight is most easily available on north facade as minimal solar radation will fall at high angle
- Easy shading of south facade from high angle sun



East and west facades continue to receive uniform, strong solar radiation at a low angle through the year.

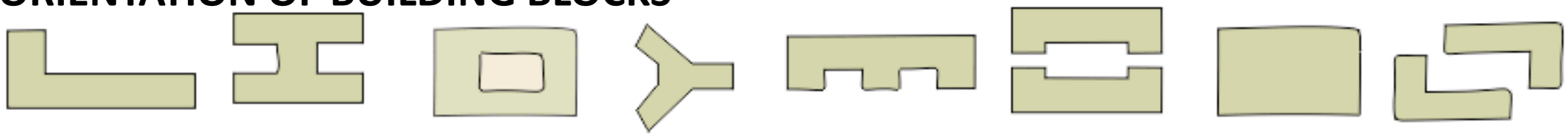


Source: NZEB

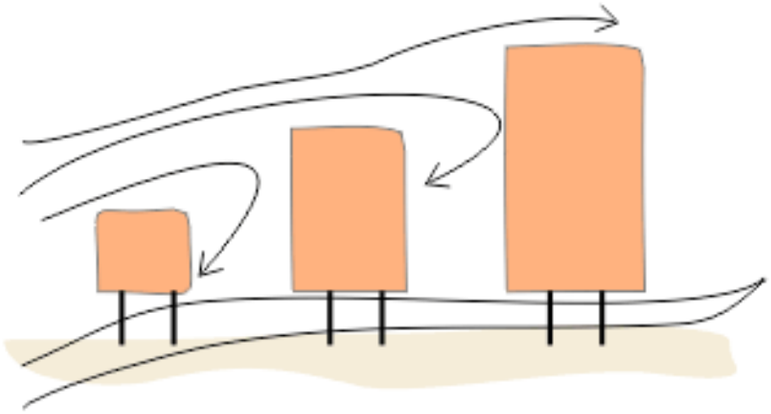
MEASURES TO IMPROVE THERMAL COMFORT

PASSIVE DESIGN STRATEGIES

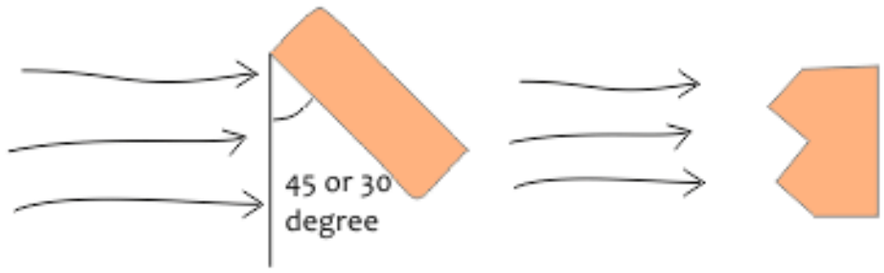
ORIENTATION OF BUILDING BLOCKS



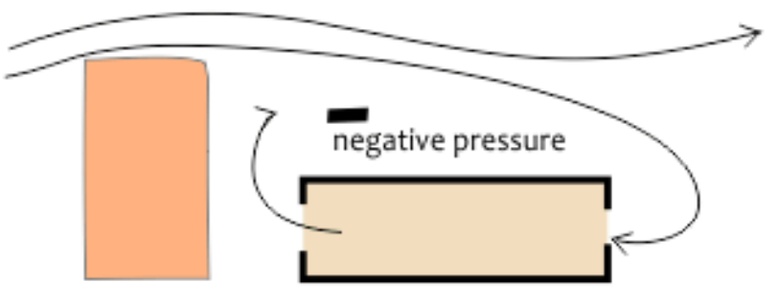
Orient longer facades along the north. This will provide glare free light in summer from north without shading and winter sun penetration from the south.



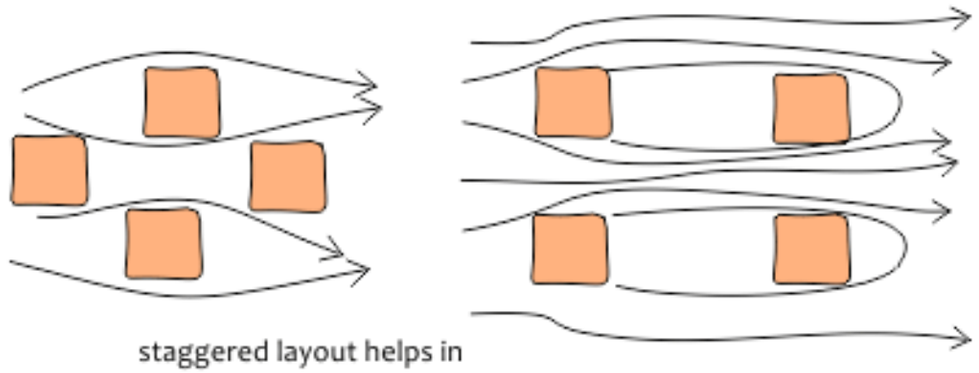
if a site has multiple buildings, they should be arranged in ascending order of their heights and be built on stilts to allow ventilation



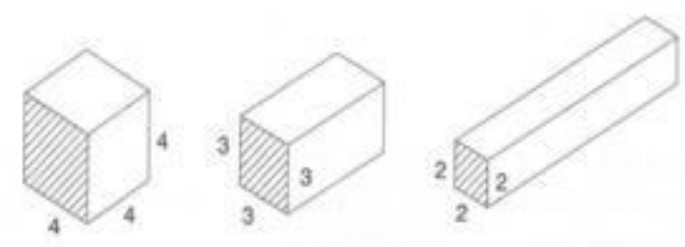
Place buildings at a 30 or 45 degree angle to the direction of wind for enhanced ventilation. Form can be staggered in the wind facing direction also to achieve the same result.



Taller forms in the wind direction of prevailing wind can alter the wind movement pattern for low lying buildings behind them



staggered layout helps in accentuating wind movement



Solid shape type	*Surface area (S)*	*Volume (V)*	*Ratio (S/V)*
a	96	64	1.5
b	103.2	64	1.61
c	136	64	2.13

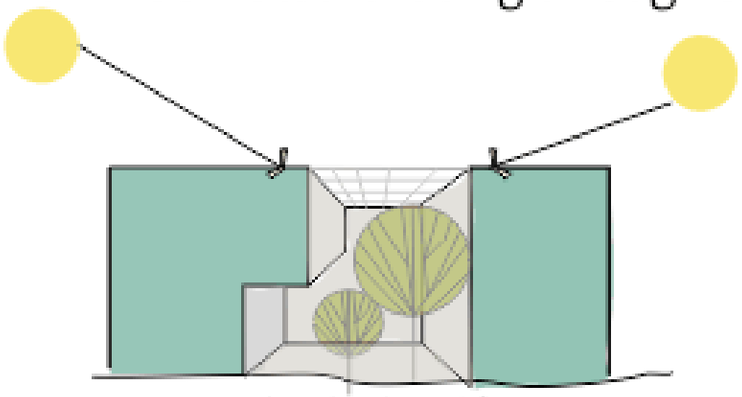
Source: NZEB

MEASURES TO IMPROVE THERMAL COMFORT

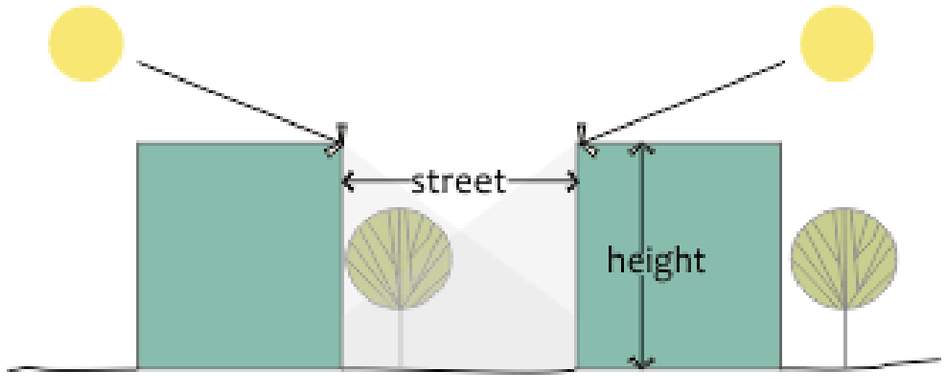
PASSIVE DESIGN STRATEGIES

FORM OF BUILDING BLOCKS:

1 Maximise mutual shading through built forms

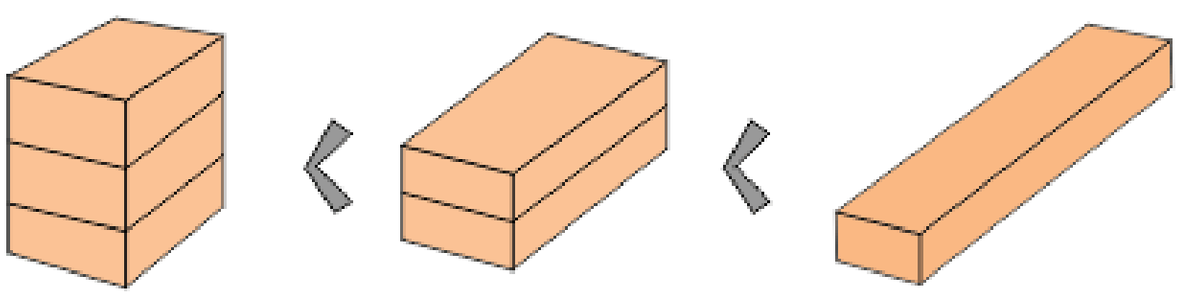


closely placed forms



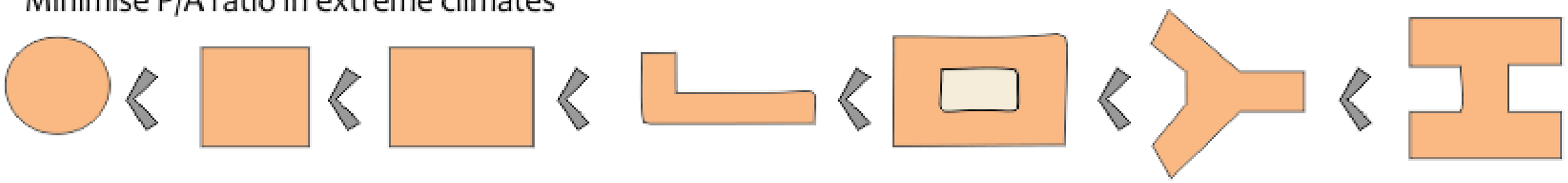
narrow streets - keep building height to street width ratio minimal

2 Minimise S/V ratio in extreme climates



increase compactness by reducing
surface area for the same volume

3 Minimise P/A ratio in extreme climates

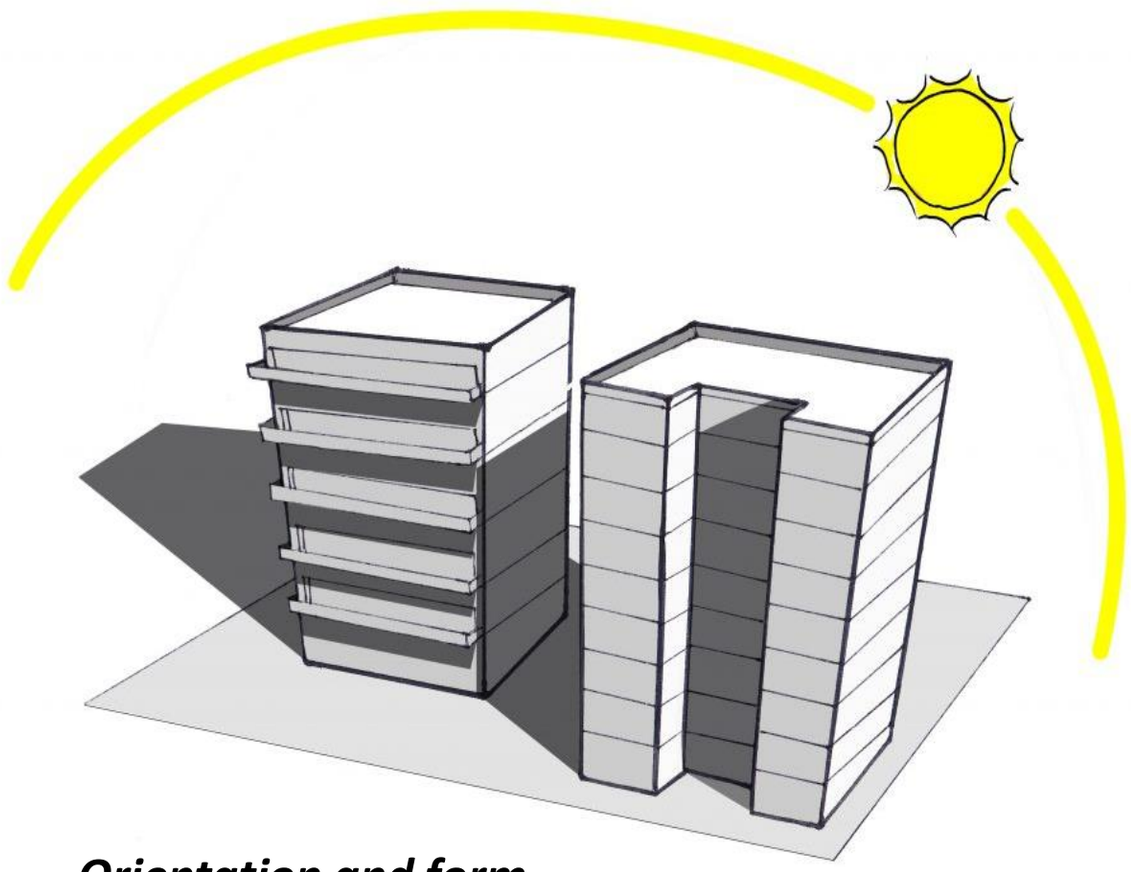


MEASURES TO IMPROVE THERMAL COMFORT

passive design strategies for affordable housing

ORIENTATION OF BUILDING BLOCKS:

UDAAN, low cost mass housing project at Mumbai



Orientation and form

- Maximum daylight
- Proper ventilation

•In extreme climatic condition *compact planning* is more preferable
•Minimising the perimeter to area ratio of building form, building performs better in terms of thermal comfort
•*Compact forms* gain less heat at day time and loss heat during night time

The Orientation can alter the thermal comfort up to – 9 % as the area of the wind facing wall varies with the orientation

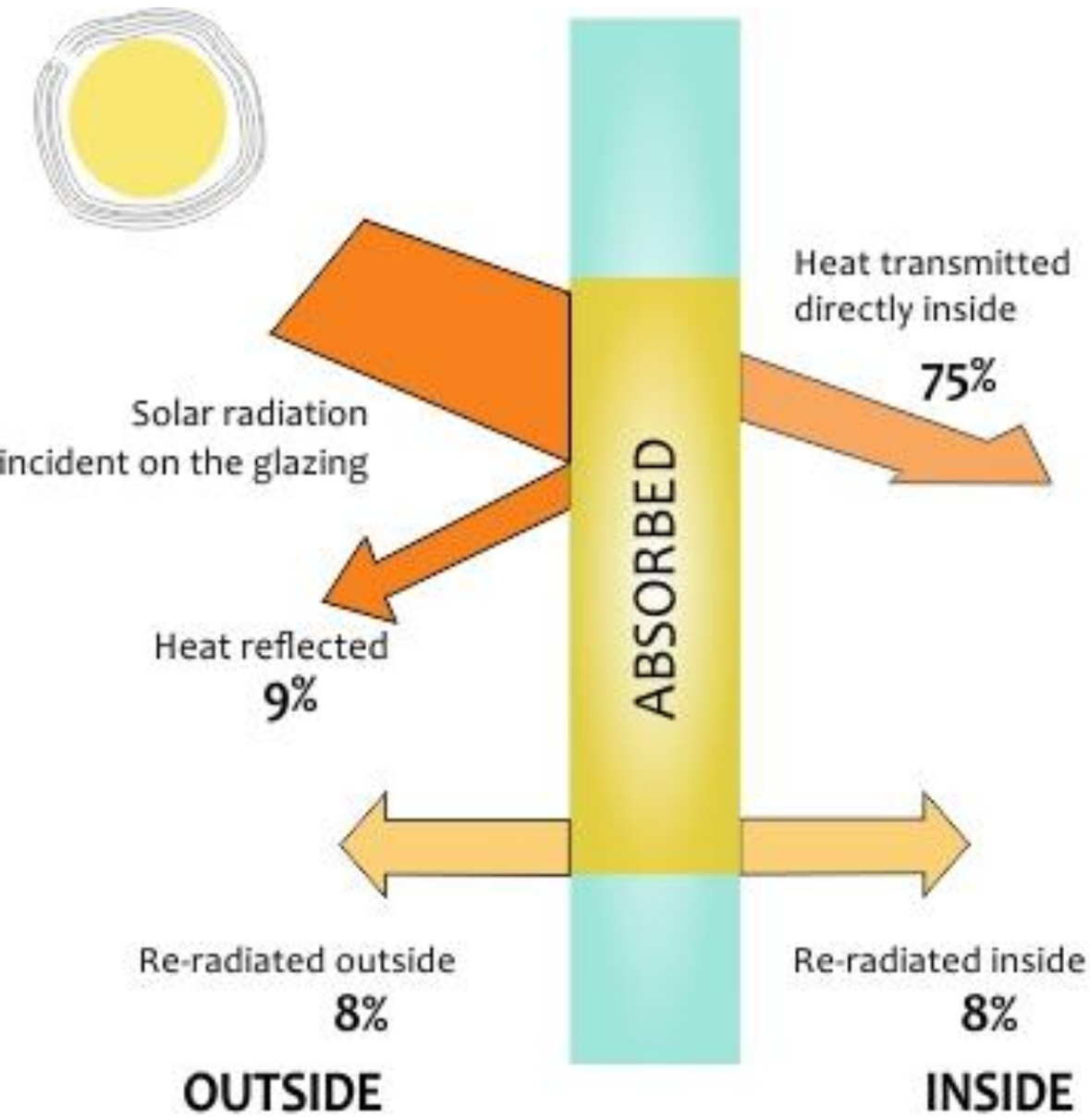
Minimizing the surface area to volume ratio minimizes heat transfer.

Source: NZEB

MEASURES TO IMPROVE THERMAL COMFORT

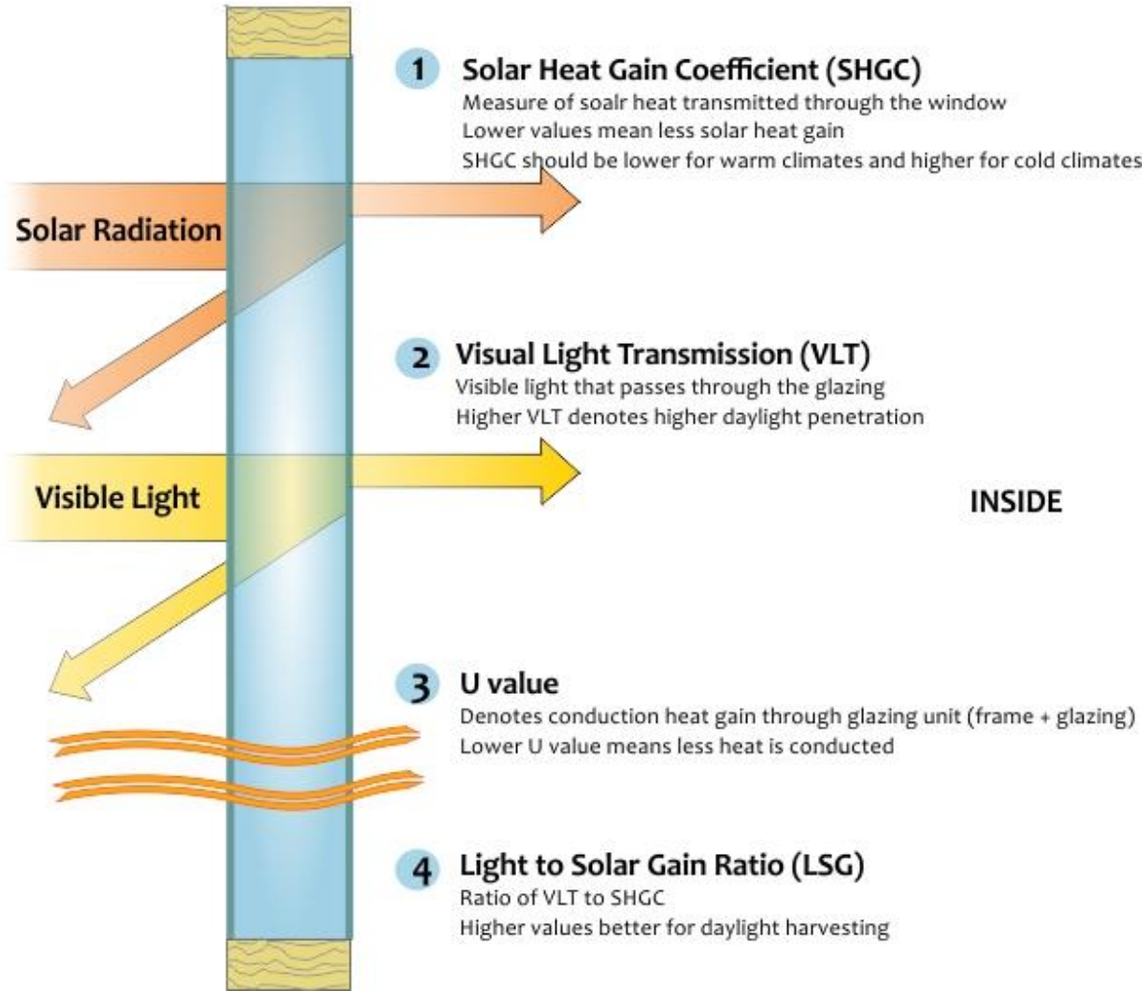
PASSIVE DESIGN STRATEGIES

Fenestration



Heat transmission in a single glazing clear glass

A fenestration system with low U-value and low effective SHGC can result in ***reduction of heating and cooling demand*** by 6-11% in moderate climate and between 8-16% in hot humid, hot dry, and composite climates.



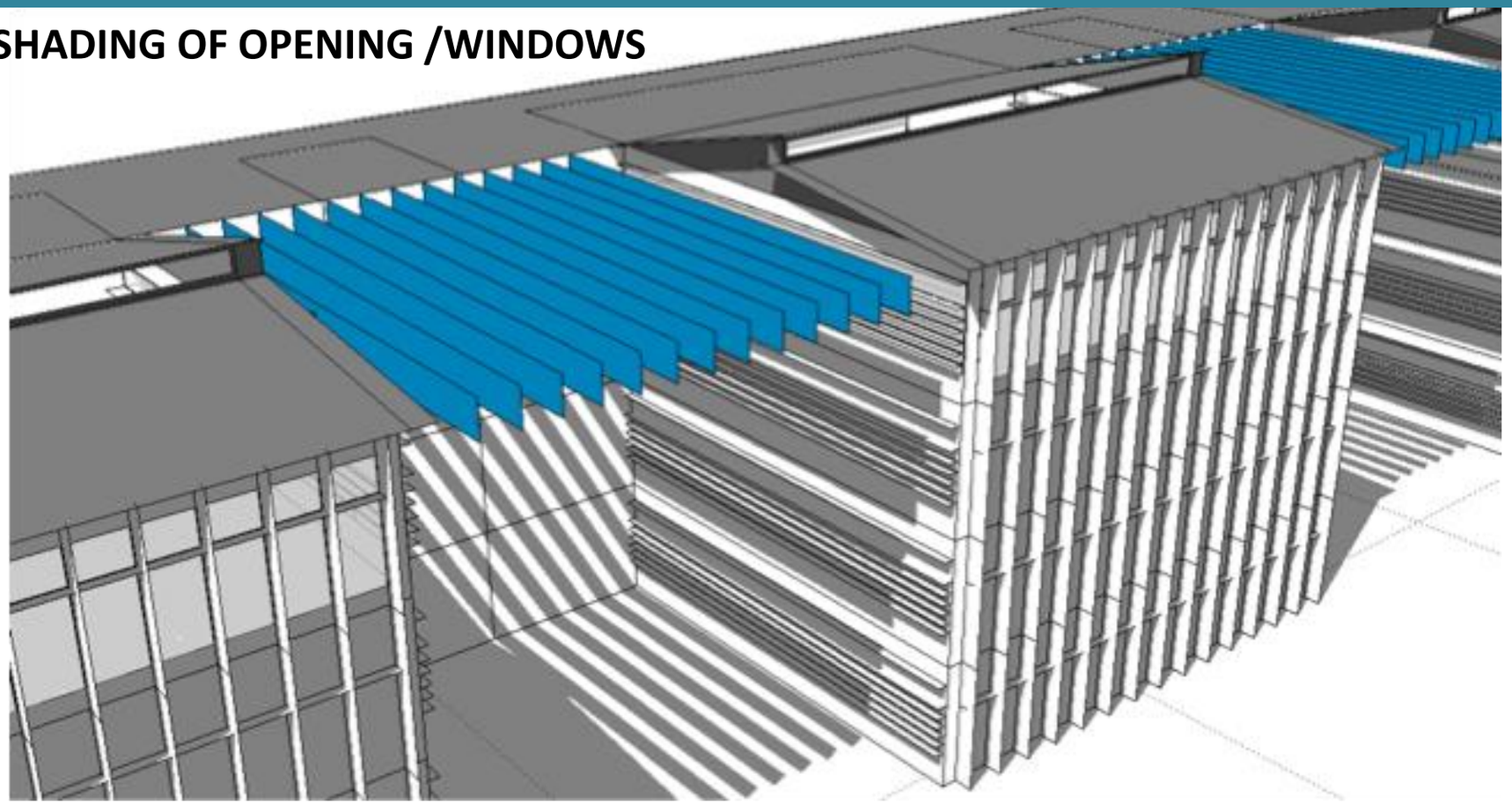
Fenestration type

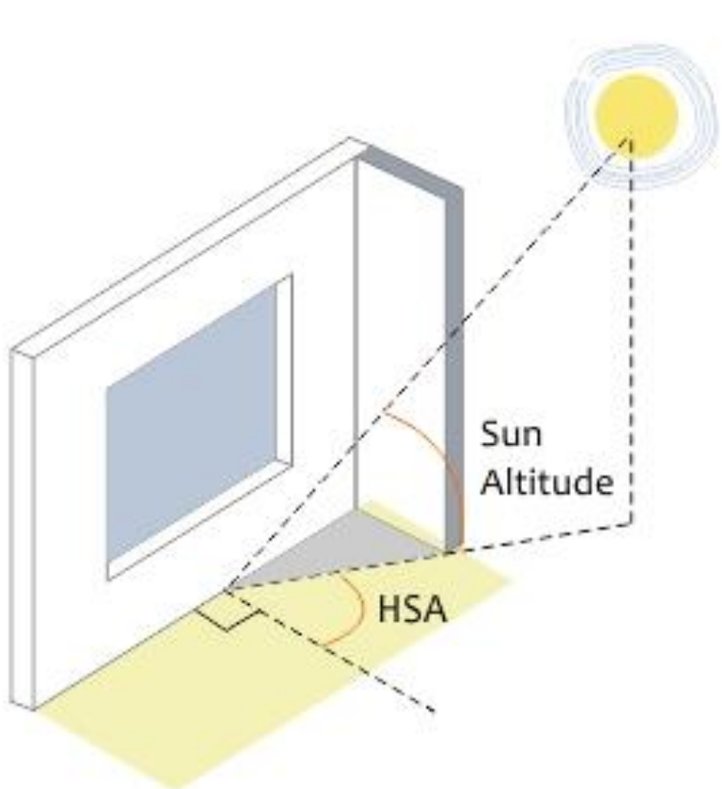
Source: NZEB

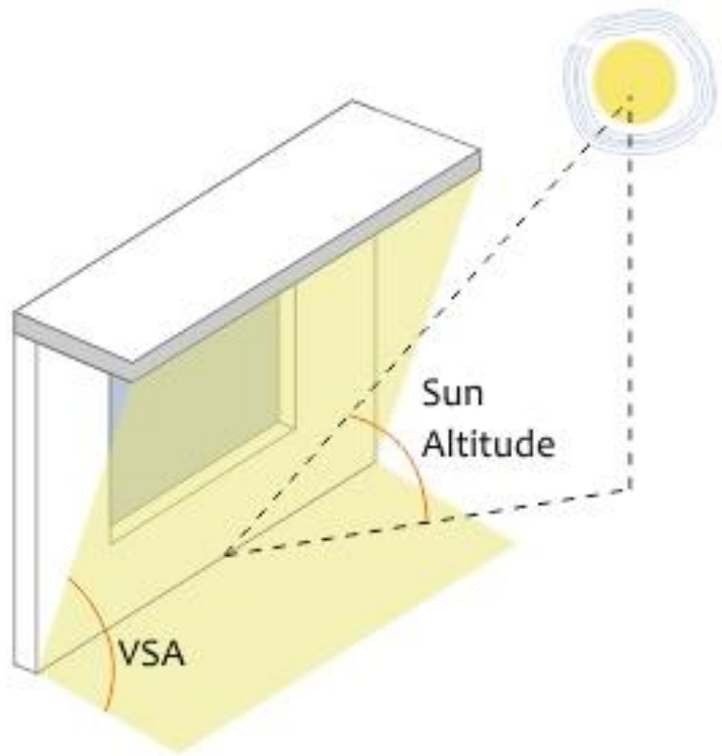
MEASURES TO IMPROVE THERMAL COMFORT

PASSIVE DESIGN STRATEGIES

SHADING OF OPENING /WINDOWS



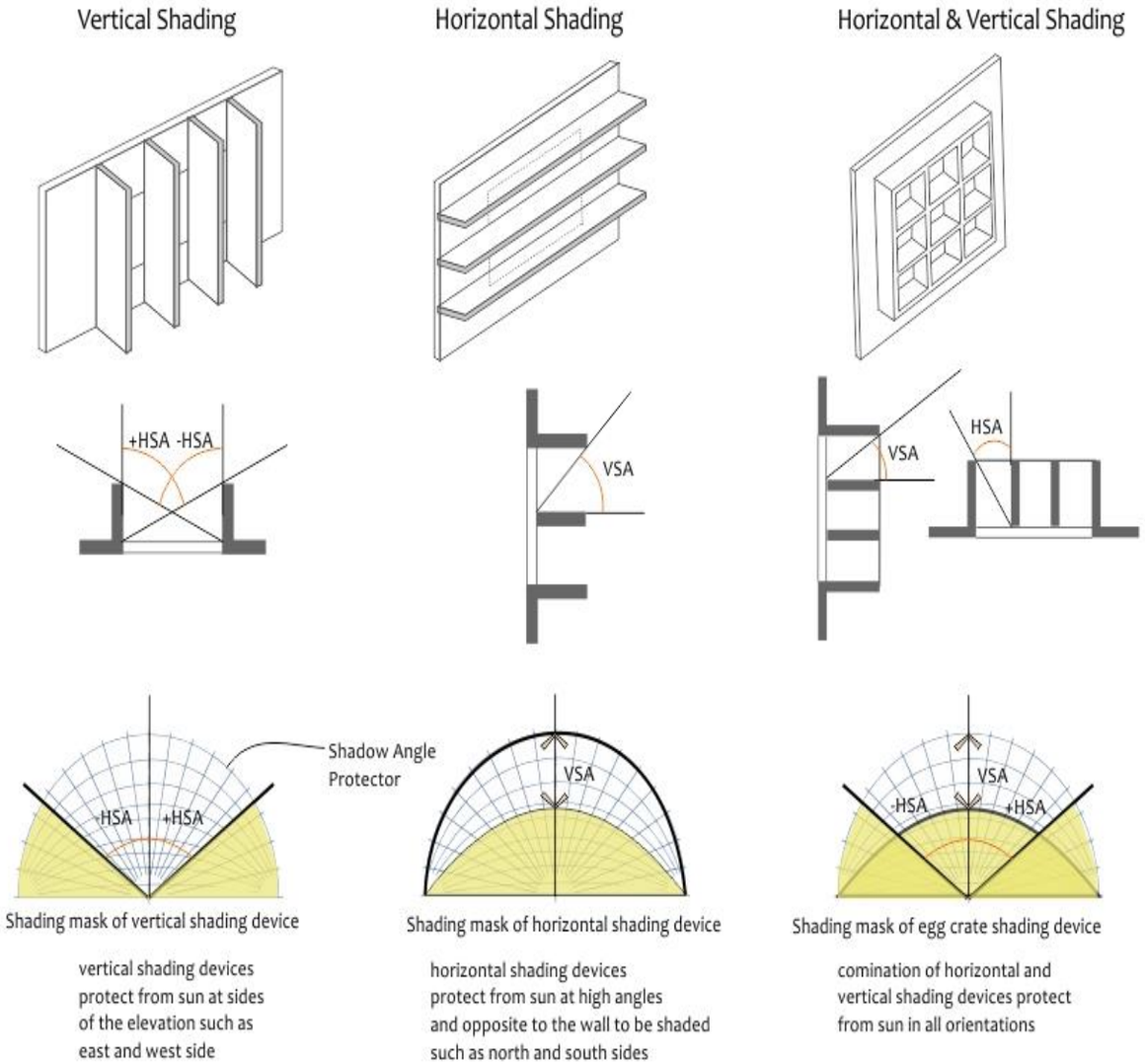




MEASURES TO IMPROVE THERMAL COMFORT

PASSIVE DESIGN STRATEGIES

SHADING OF OPENING /WINDOWS

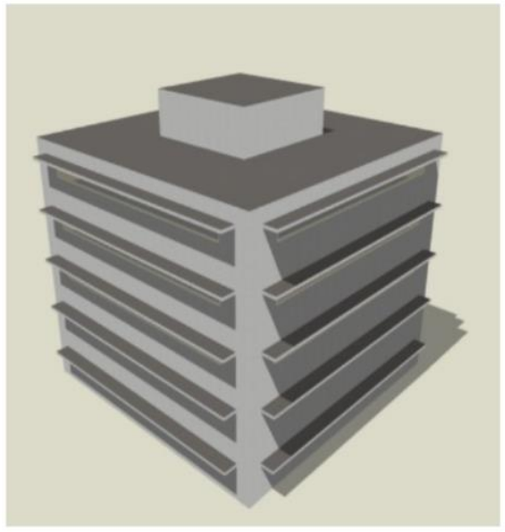


Solar shading devices helps

- Diffusing light
- Control heat
- Improving daylight

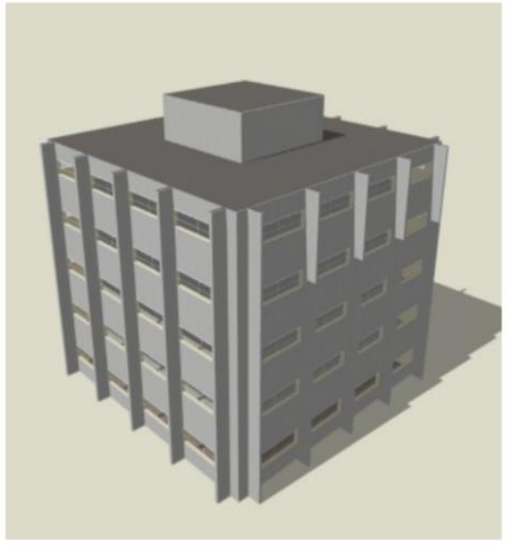
Comfortable living

Cases



H-SD-0 (no inclination)
H-SD-30 (inclined at 30°)
H-SD-45 (inclined at 45°)
H-SD-60 (inclined at 60°)

Cases



V-SD-0 (no inclination)
V-SD-30 (inclined at 30°)
V-SD-45 (inclined at 45°)
V-SD-60 (inclined at 60°)

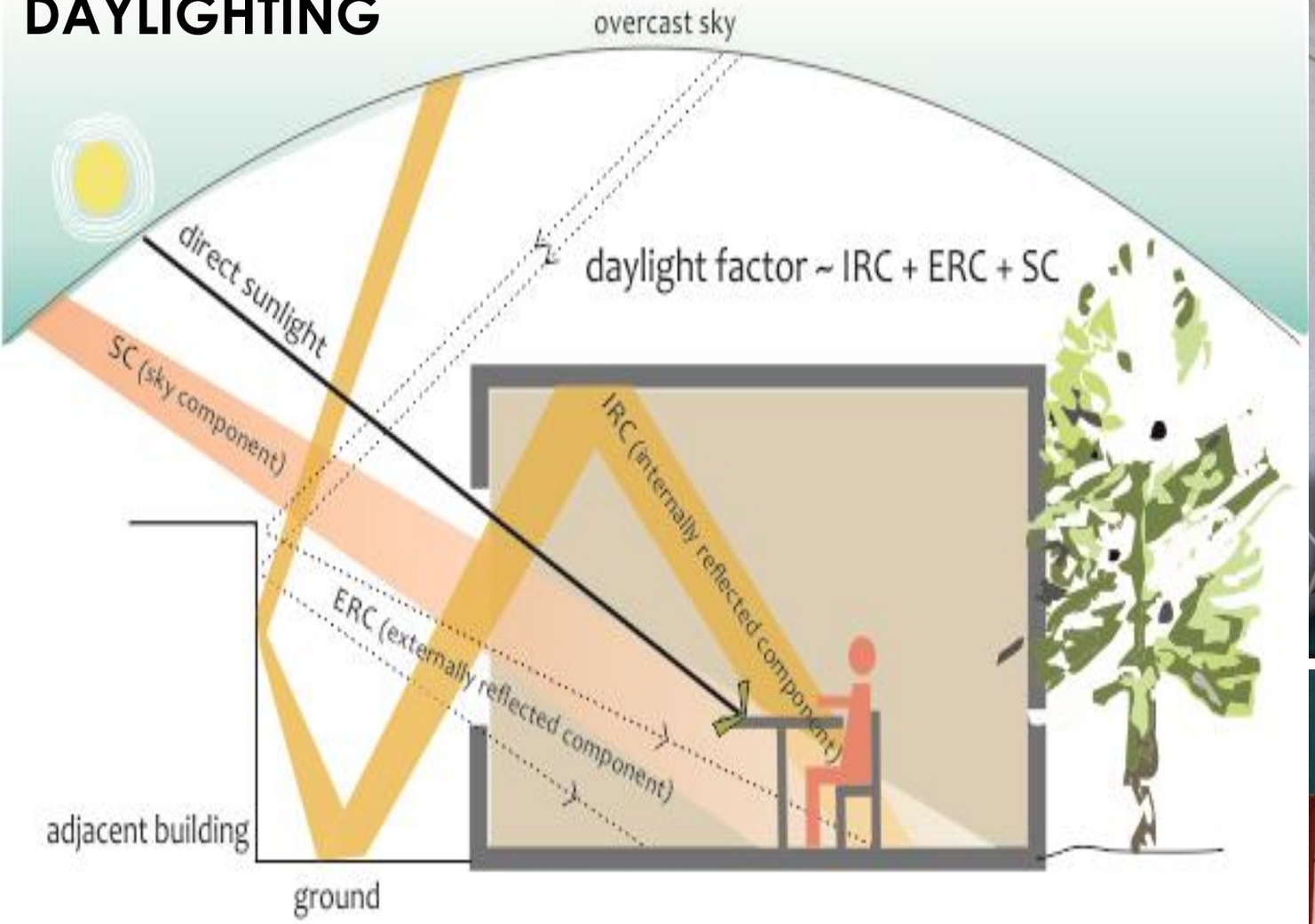
Use of shading device at Palace of Assembly, Chandigarh

Source: NZEB

MEASURES TO IMPROVE THERMAL COMFORT

passive design strategies for affordable housing

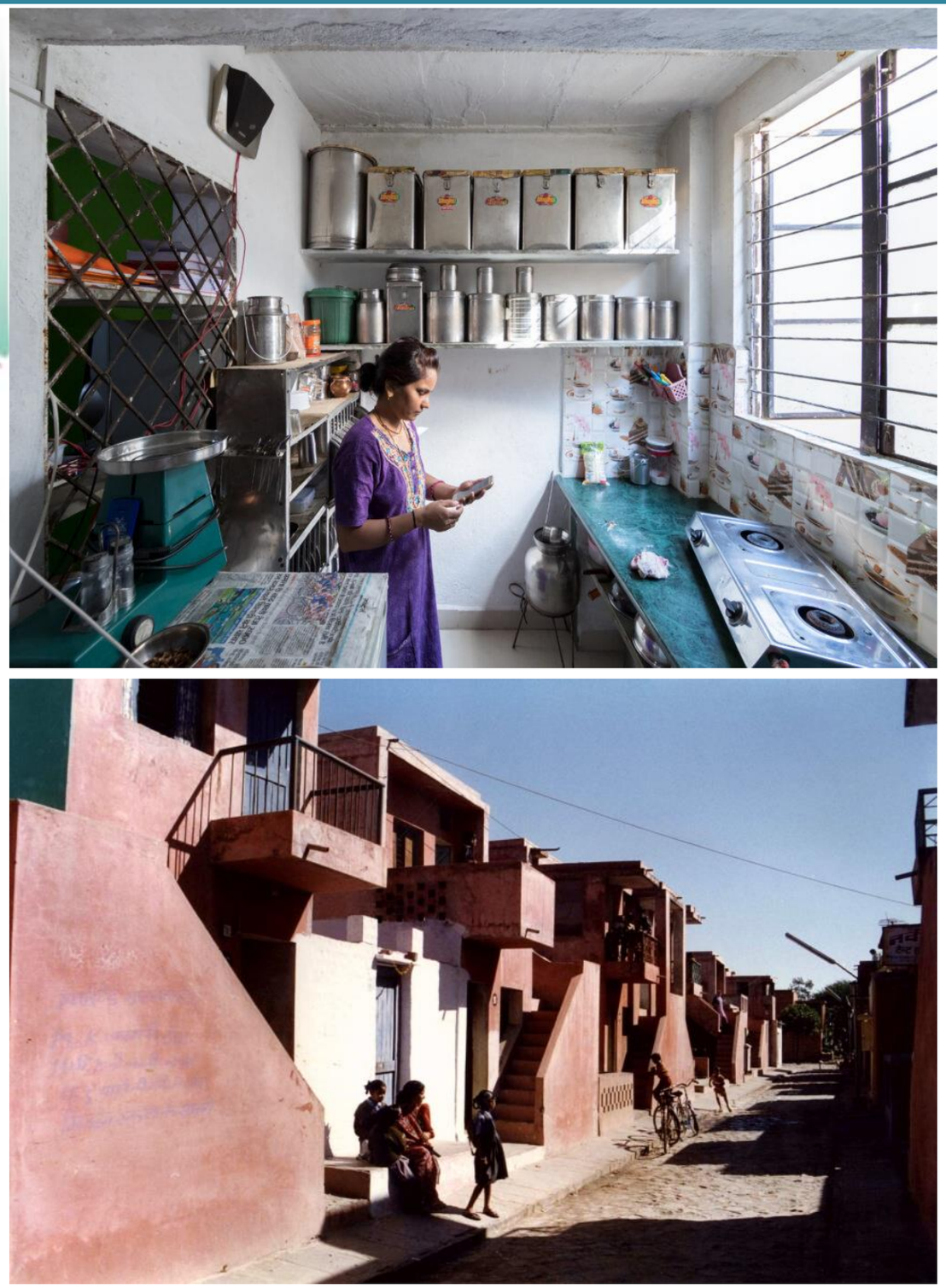
DAYLIGHTING



- Designed daylighting features enhance

1. Indoor environmental quality,
2. Building occupant performance

Daylighting can impact the energy use by **reducing** the lighting energy demand up to **20-30%.**



Day lighting and Shading at Aranya Housing, Indore

Source: NZEB

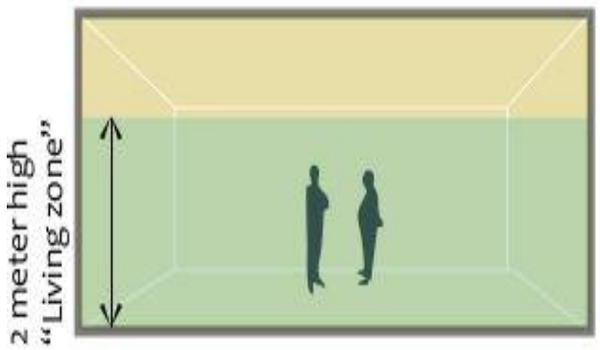
MEASURES TO IMPROVE THERMAL COMFORT

passive design strategies for affordable housing

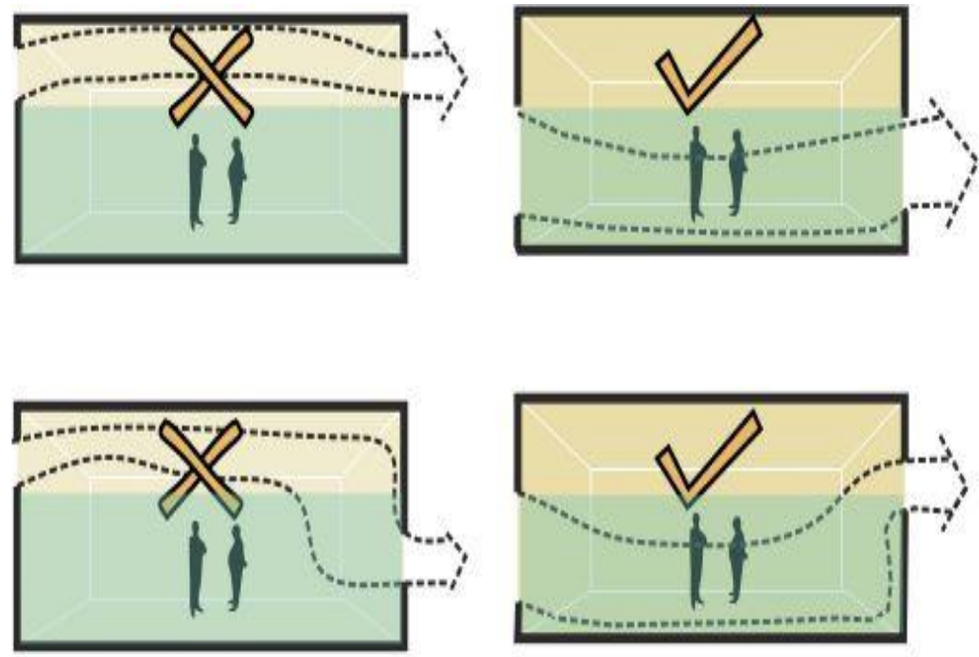
NATURAL VENTILATION

Cross ventilation

to allow ***maximum air flow*** inside the space

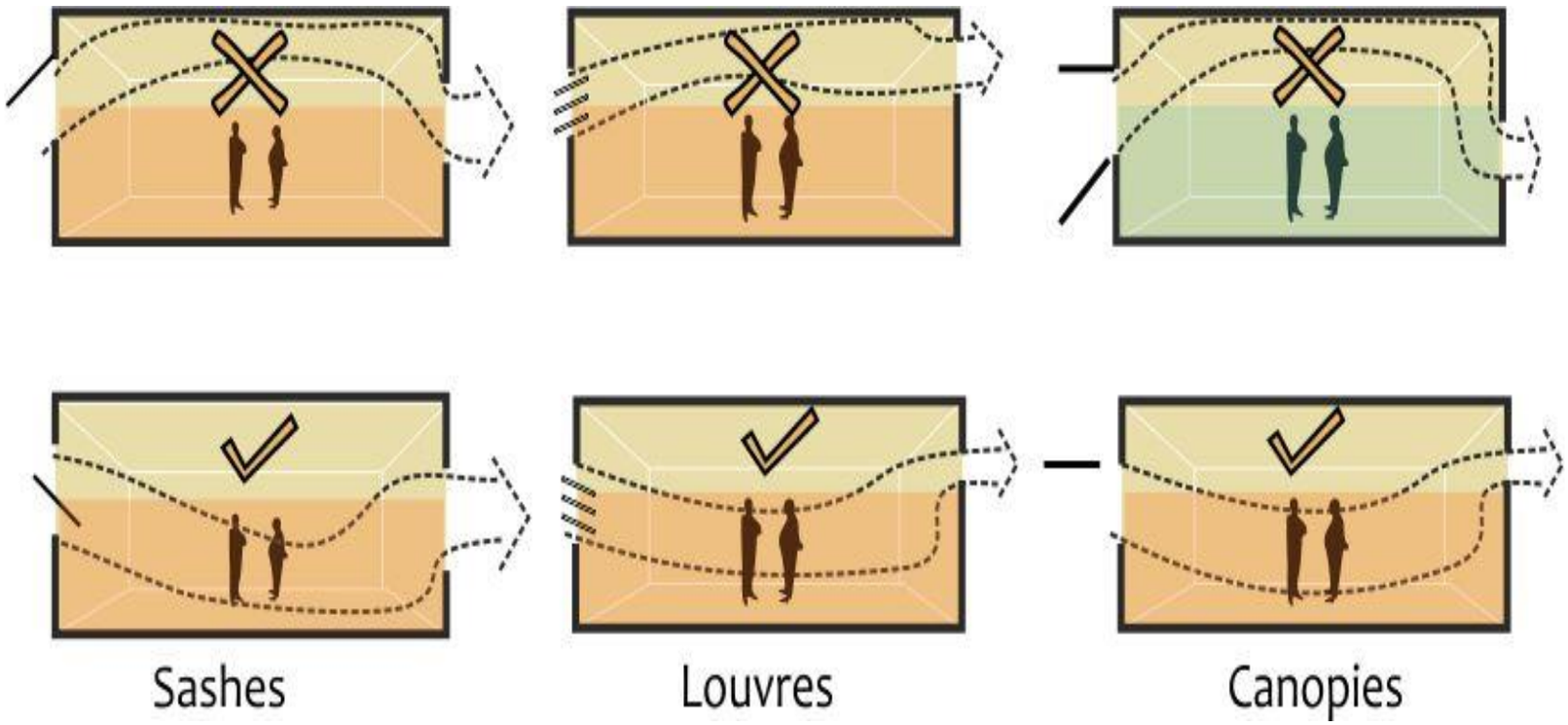


Living zone is the space commonly used by occupants. Air movement should be directed through this space.



inlet openings placed at high level deviate air flow away from the living zone irrespective of outlet position

Types of opening and their location



Natural ventilation helps in reducing mechanical cooling load of the building

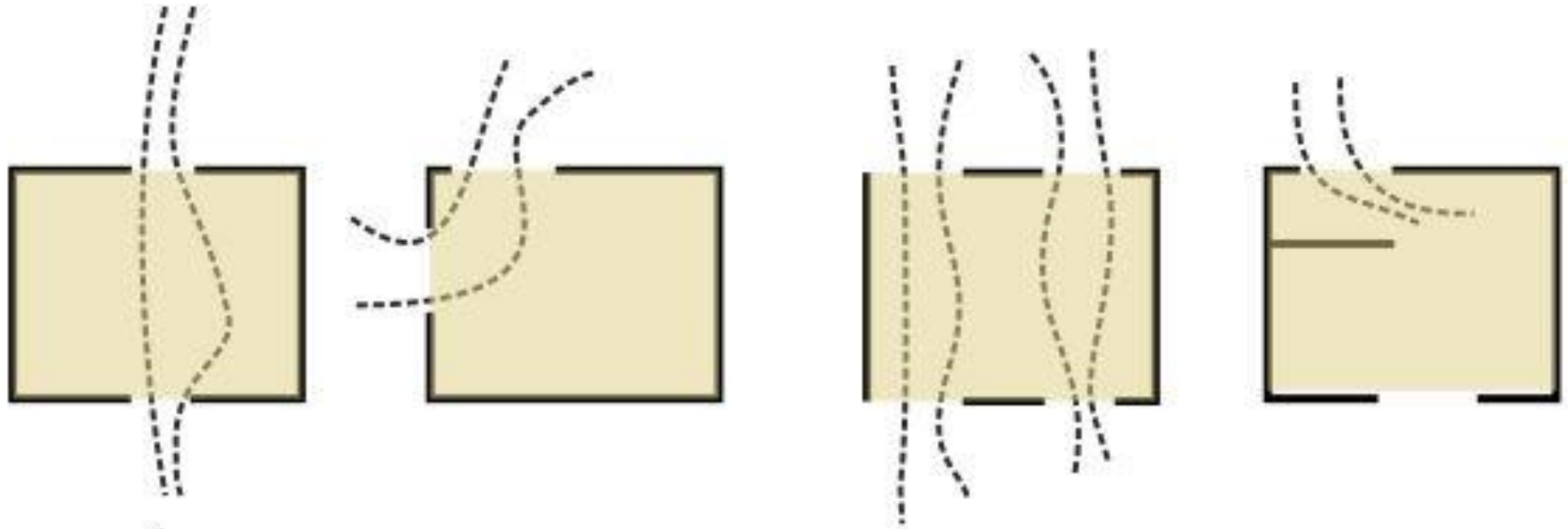
Source: NZEB

MEASURES TO IMPROVE THERMAL COMFORT

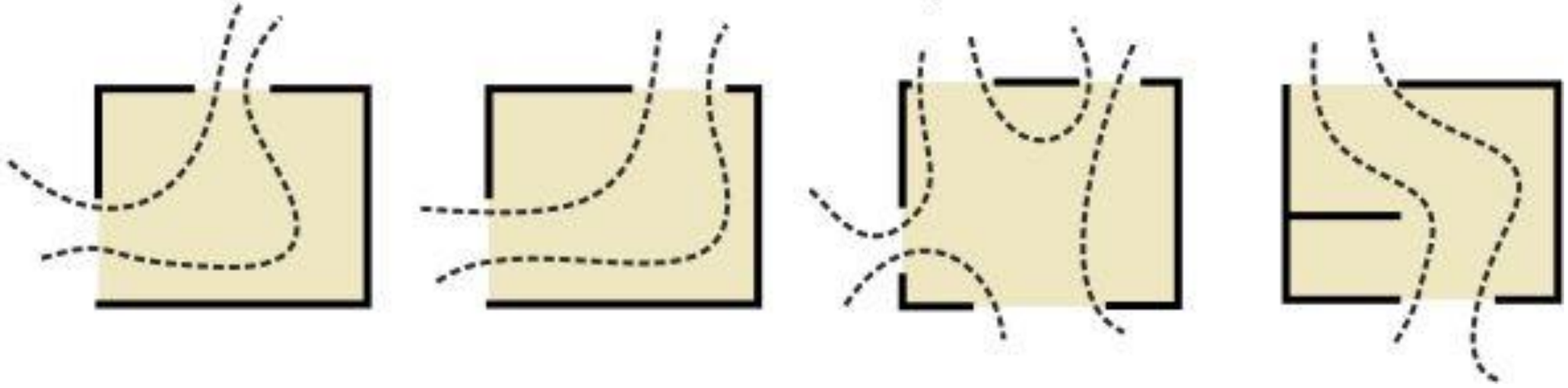
passive design strategies for affordable housing

NATURAL VENTILATION

✕ Don't



✓ Do



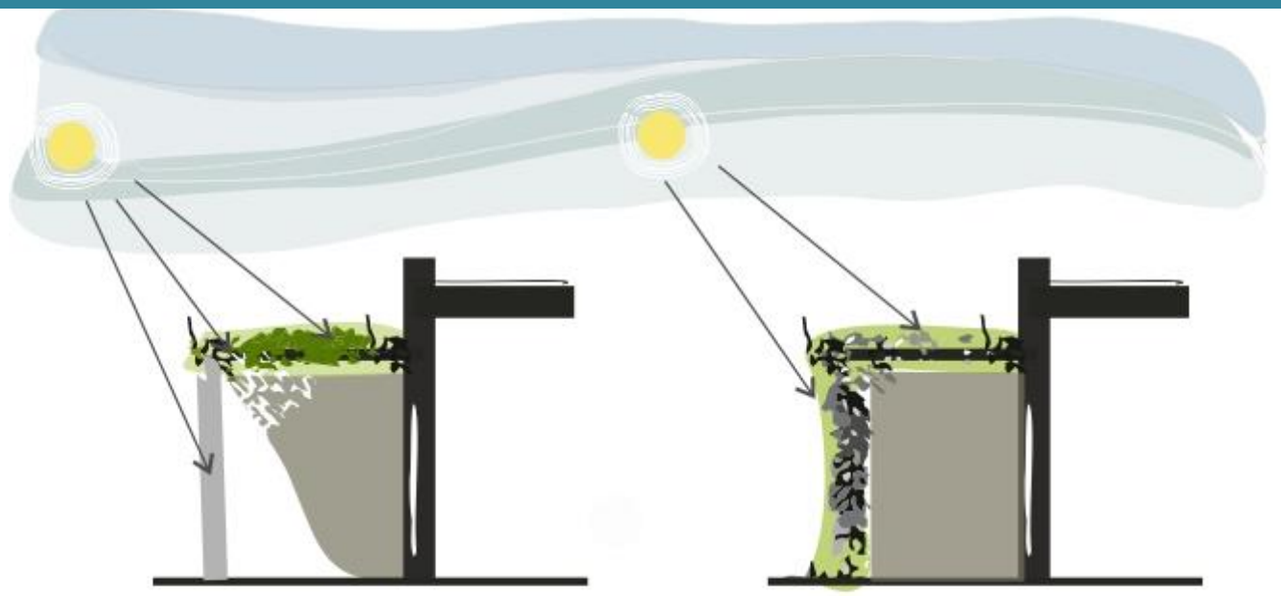
Horizontal placing of openings and internal partitions can alter the direction and spread of air stream

MEASURES TO IMPROVE THERMAL COMFORT

passive design strategies for affordable housing

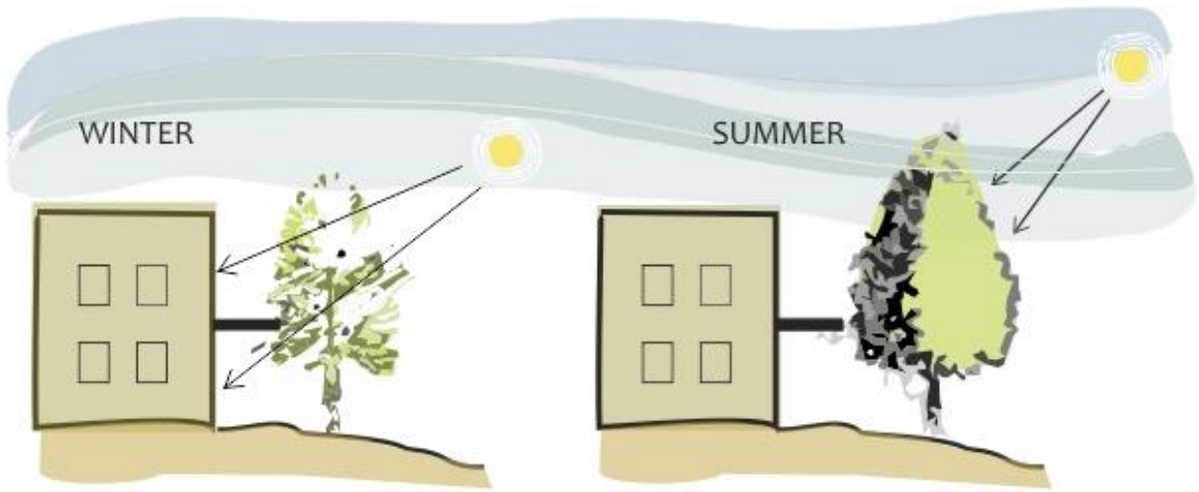
VEGETATION

Trees and shrubs create different air flow patterns, provide shading and keep the surroundings cooler in warm weather. Vegetation can be used for energy conservation in buildings in the following ways:



creepers are flexible shading devices for shading verandahs and interior spaces as per the season

- Shading of buildings and open spaces through landscaping
- Roof gardens (or green roofs)
- Shading of vertical and horizontal surfaces (green walls)
- Buffer against cold and hot winds
- Changing direction of wind

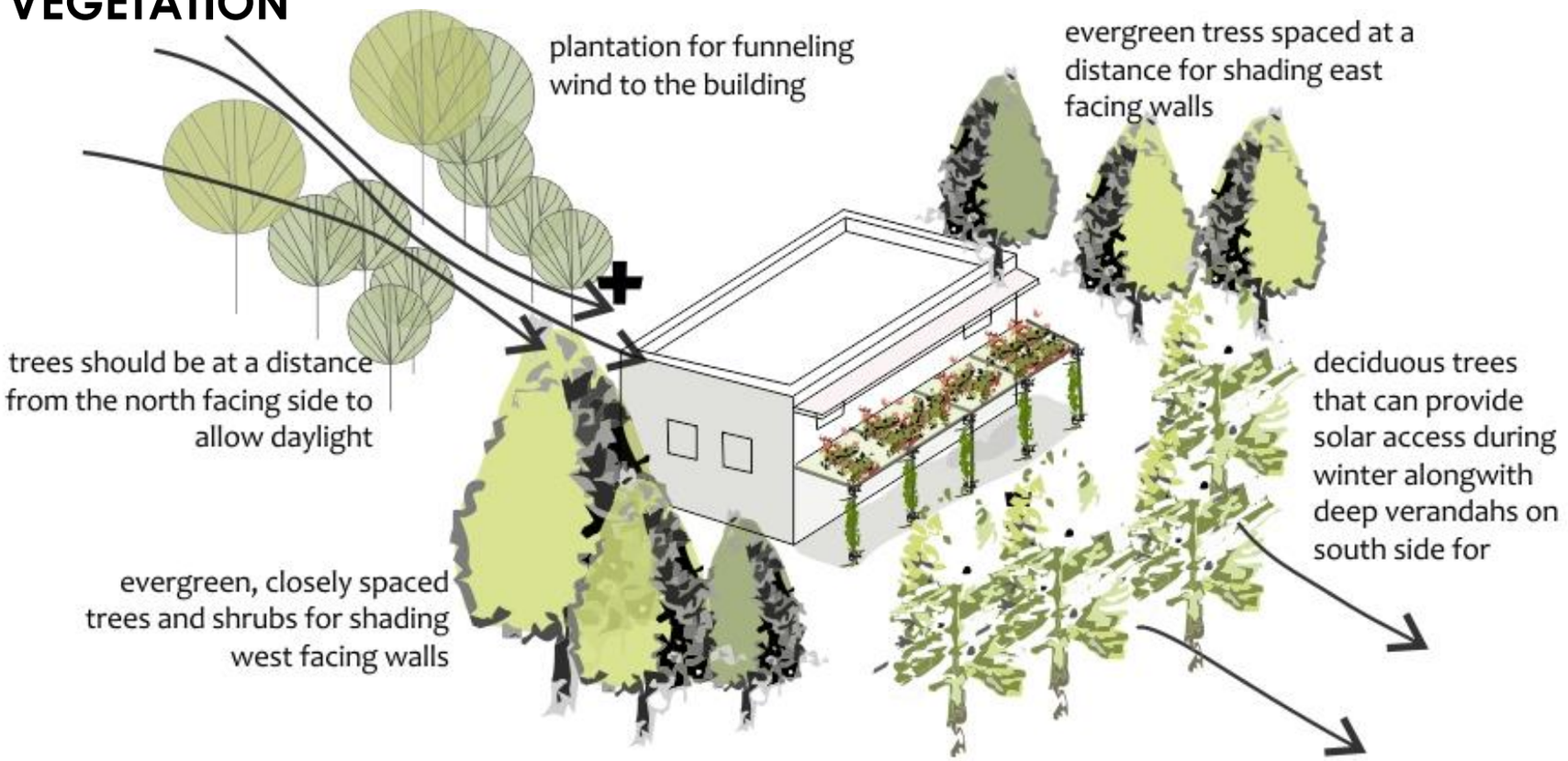


deciduous trees allow sun penetration in winter and block sun access during summer

MEASURES TO IMPROVE THERMAL COMFORT

passive design strategies for affordable housing

VEGETATION



An increase in urban **vegetation** to reduce urban heat and improve outdoor **thermal comfort.**

Trees also reduce ambient air temperature due to evapo-transpiration.

Study shows that ambient air under a tree adjacent to the wall is about 2 – 2.5°C lower than that for unshaded areas.

Community, Gary Horton, Landscape Development

Source: NZEB

CASE STUDY

CASE STUDY - SMART GHAR III, RAJKOT

Project: Affordable housing in Rajkot under PMAY Untenable Slum Redevelopment.

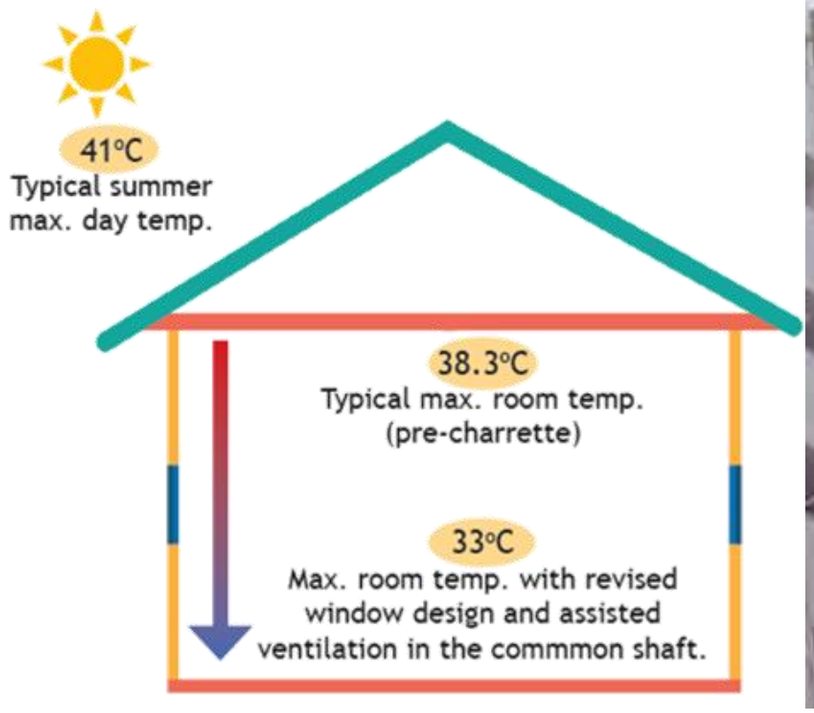
- Site area: 17,593 m2
- Built-up area: 57,408 m2
- Number of dwelling units (DU): 1176 (All 1 BHK)
- 11 residential towers : Stilt + 7

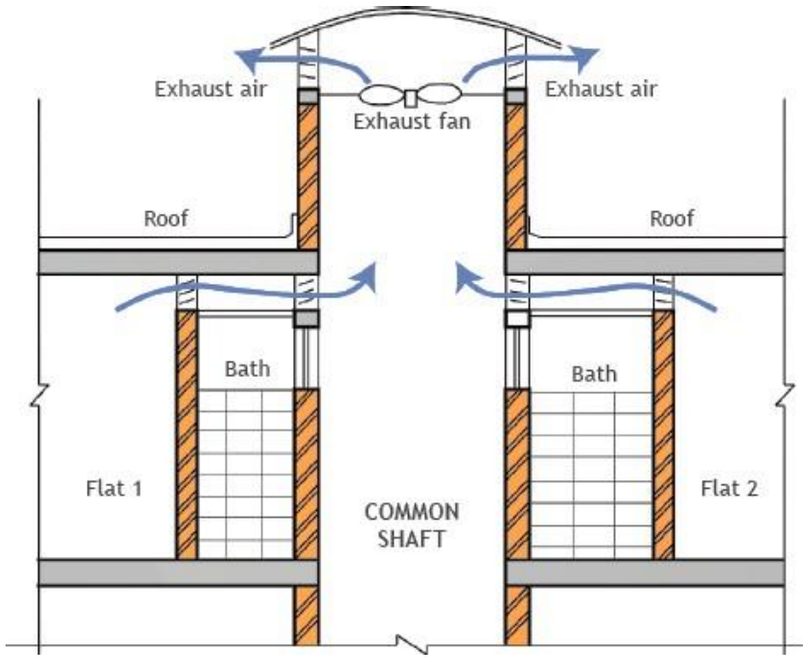
Key Features

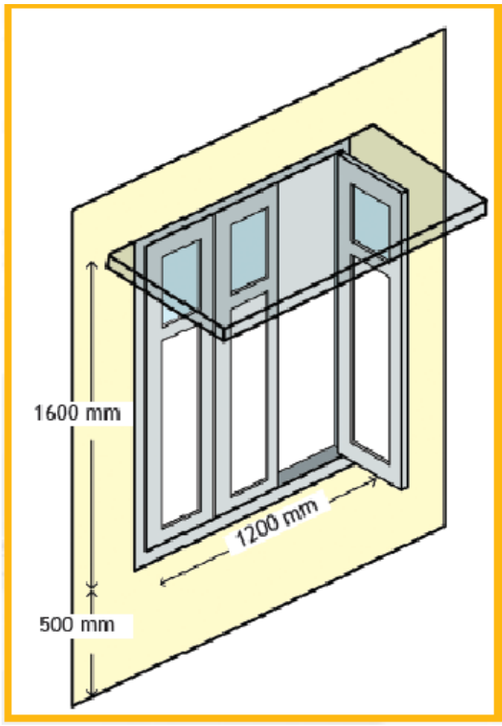
- Sensitively designed window shades to reduce heat gains while improving day light.
- Use of a fan-serviced ventilation shaft to improve air quality inside.

Outcomes

- Reduced peak summer room temperature by >5°C
- Increased number of comfortable hours from ~2600 hours to ~6300 hours.





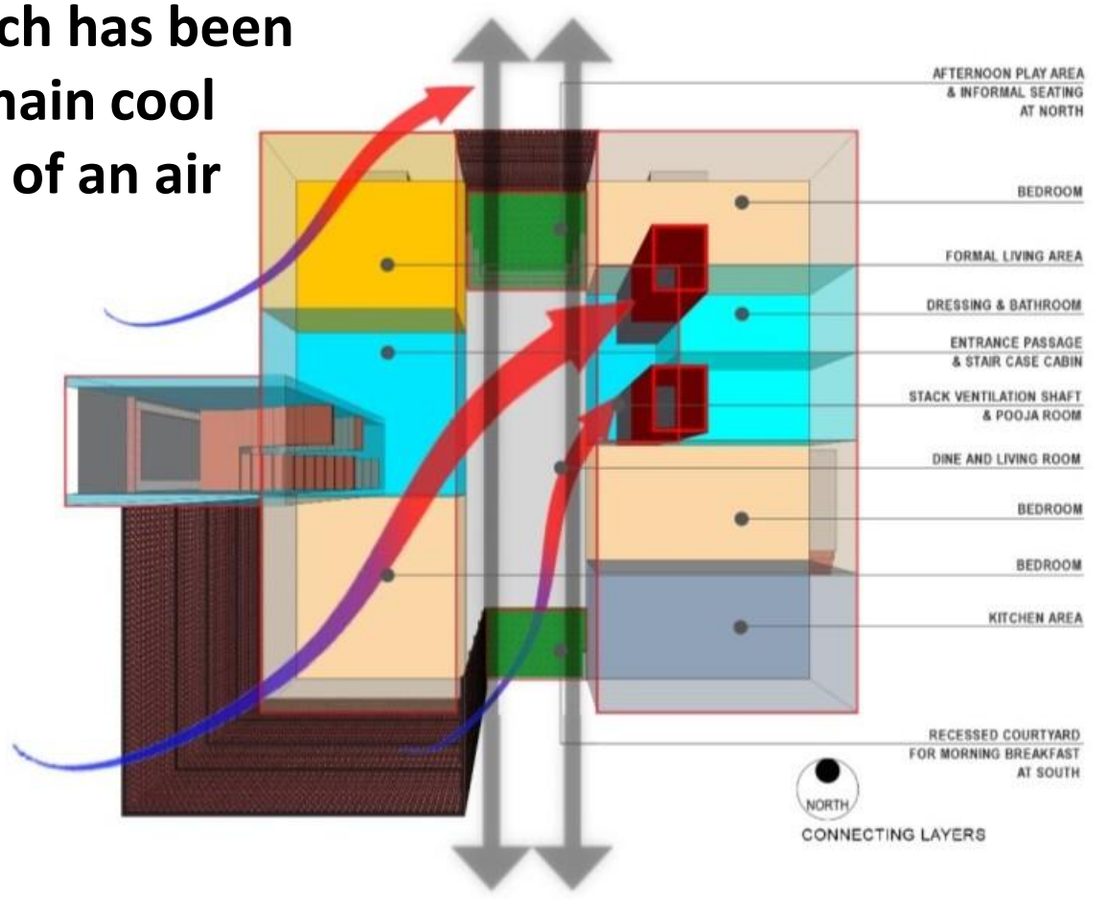


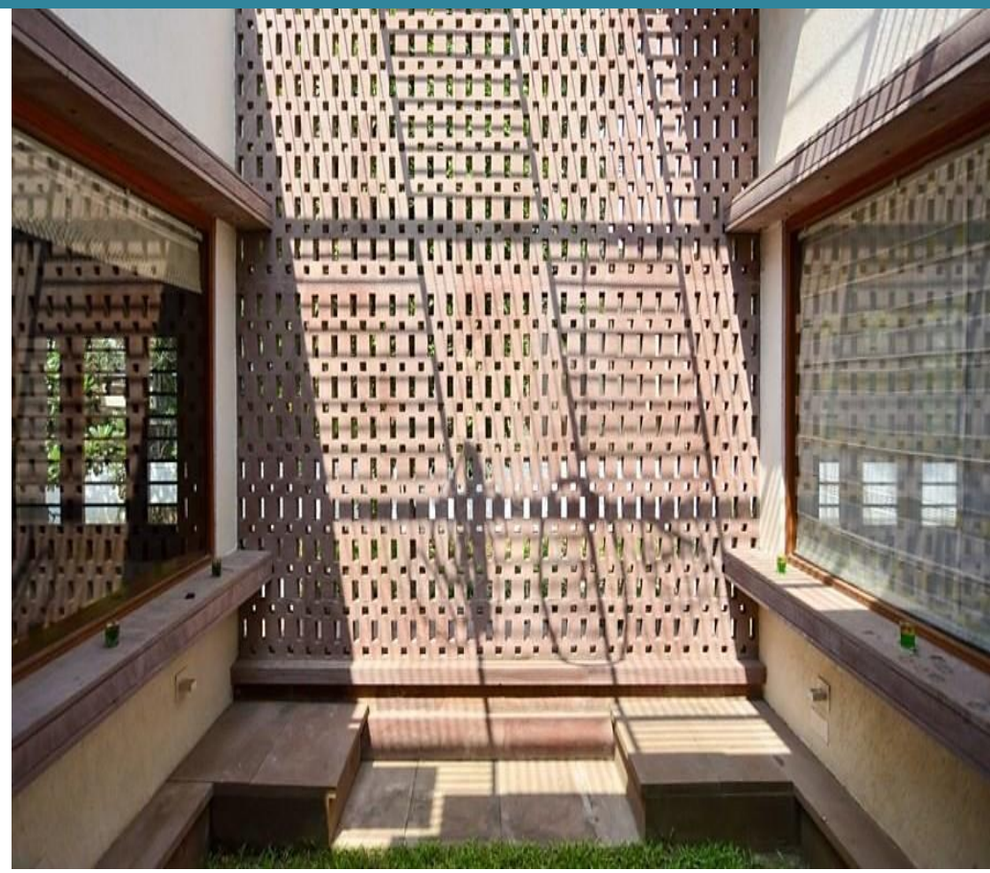
After charrette:
Taller, partially glazed casement windows. Casement windows provide better natural ventilation as they are 90% openable. The window shutters are 2/3rd opaque, which prevents heat gains from entering. Glazing is reduced to 1/3rd, which provides adequate daylight.

Source: BEEP

CASE STUDY - RAM BAUGH, BURHANPUR

A residence which has been designed to remain cool without the use of an air conditioner.





Key Features

- mutual shading
- optimal building orientation

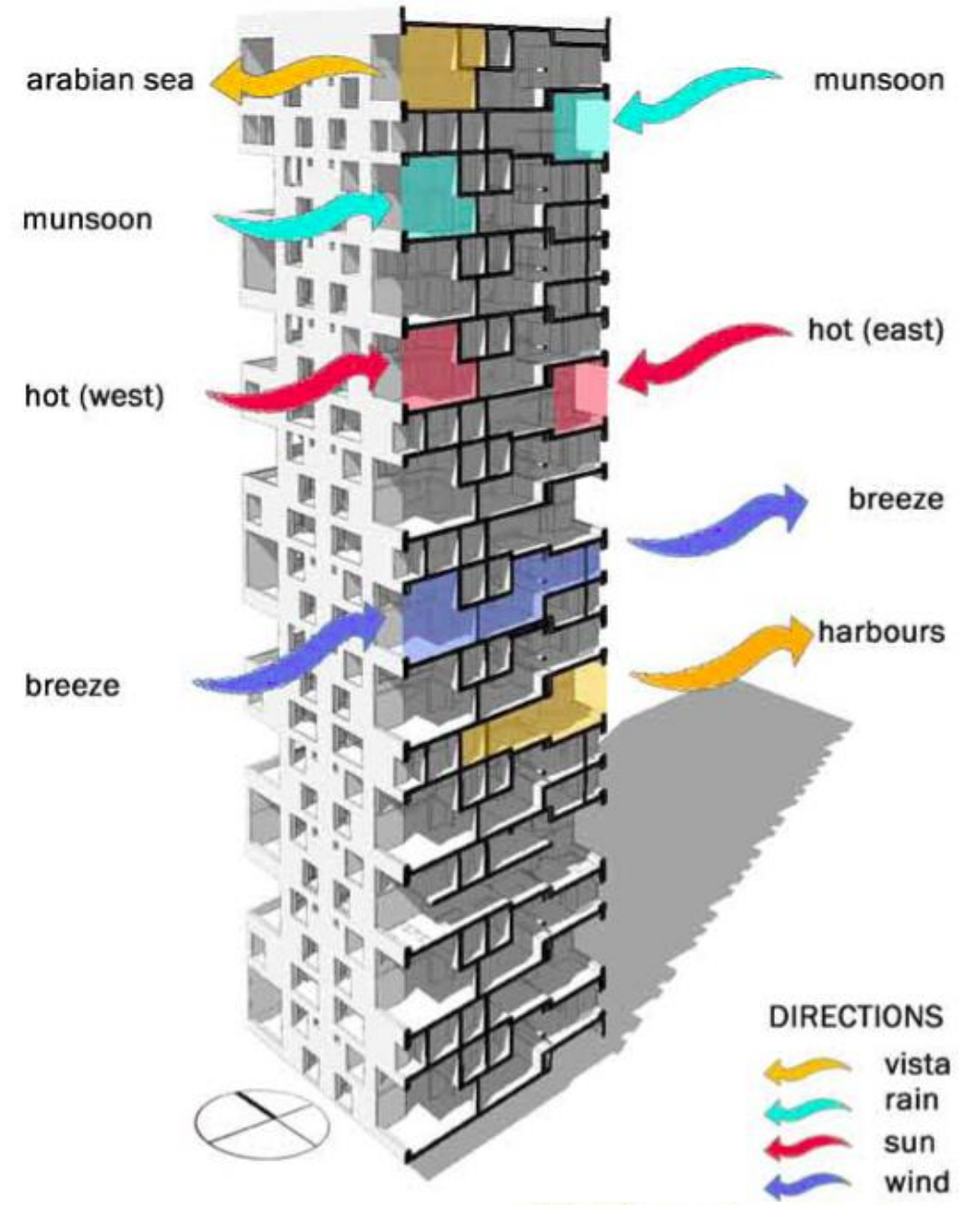
Source: Parekh Collaborative

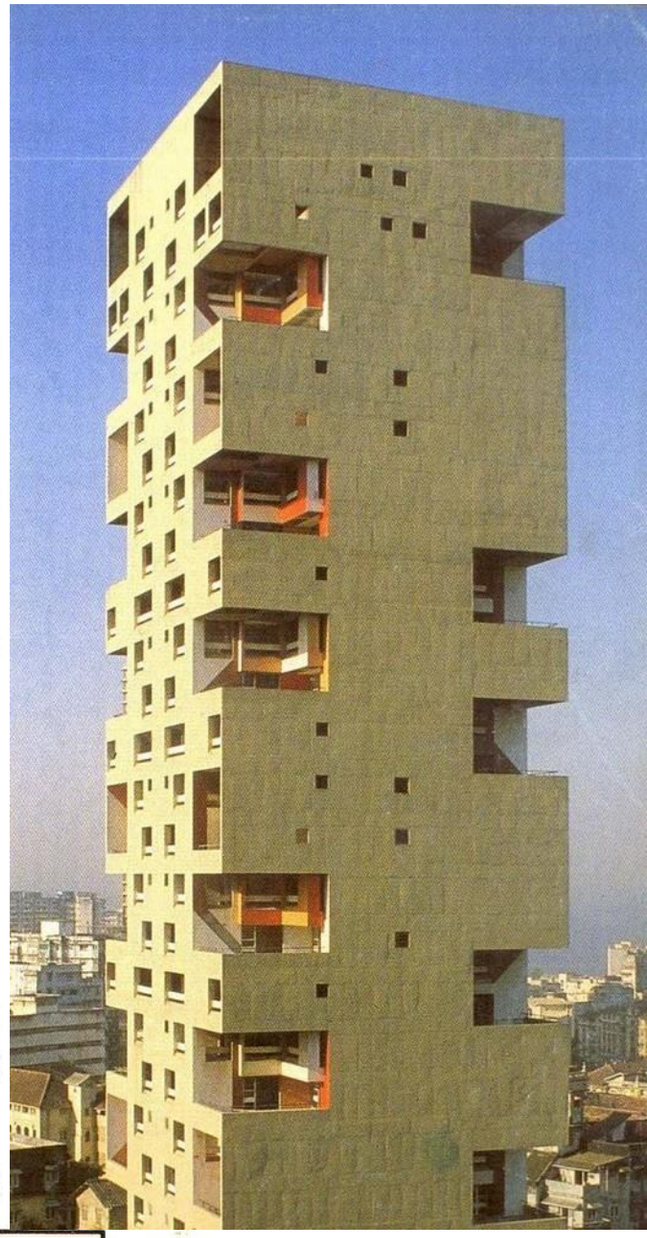
CASE STUDY - KANCHANJUNGA APARTMENTS

- **Architect:** Charles Correa
- **Location:** Bombay, India
- **Completed on:** 1983
- **Building Type:** Skyscraper multi-family housing
- **Construction System:** Concrete
- **Floors:** 32

Key Features

The main living spaces with an enclosed verandah whilst turning that buffer zone into a garden, thriving on the problem. Because of climatic considerations with existing views, the massing settled upon a configuration facing east and west



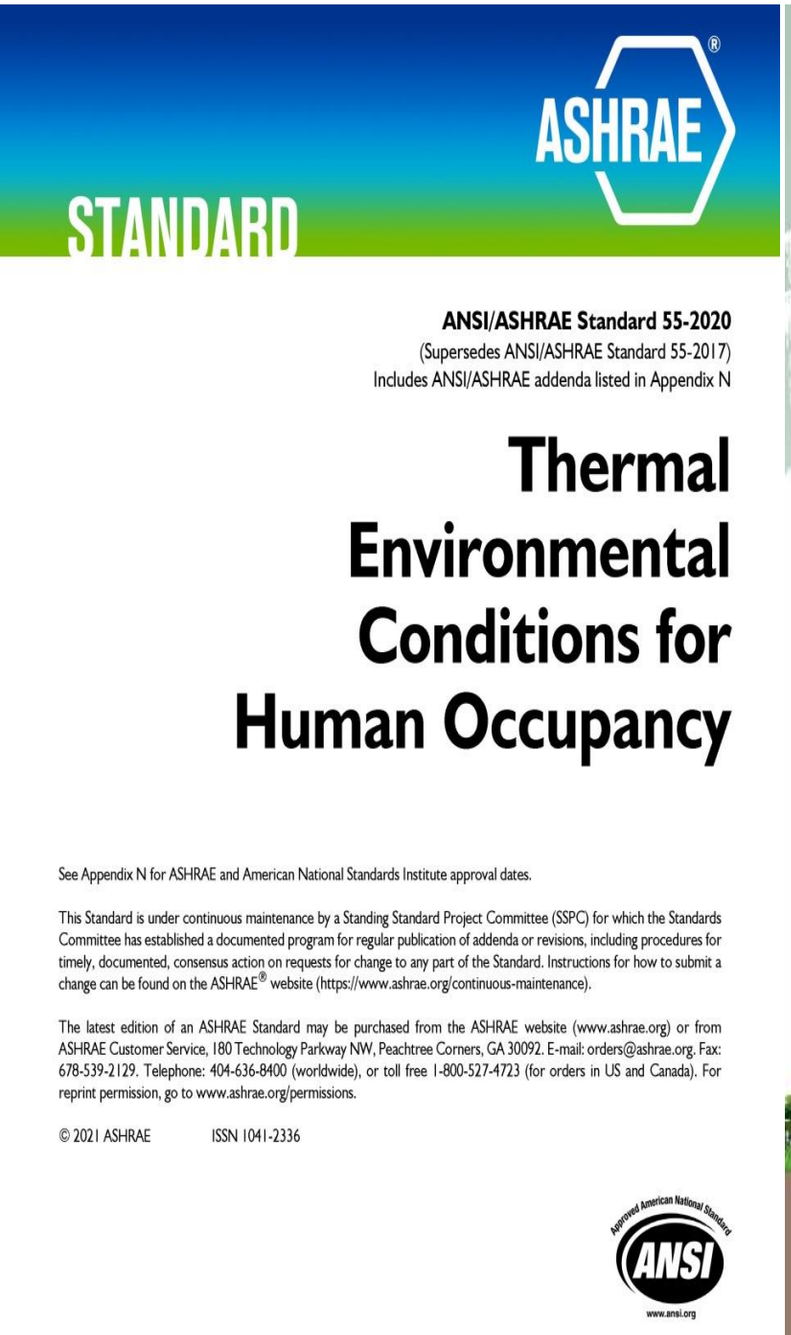


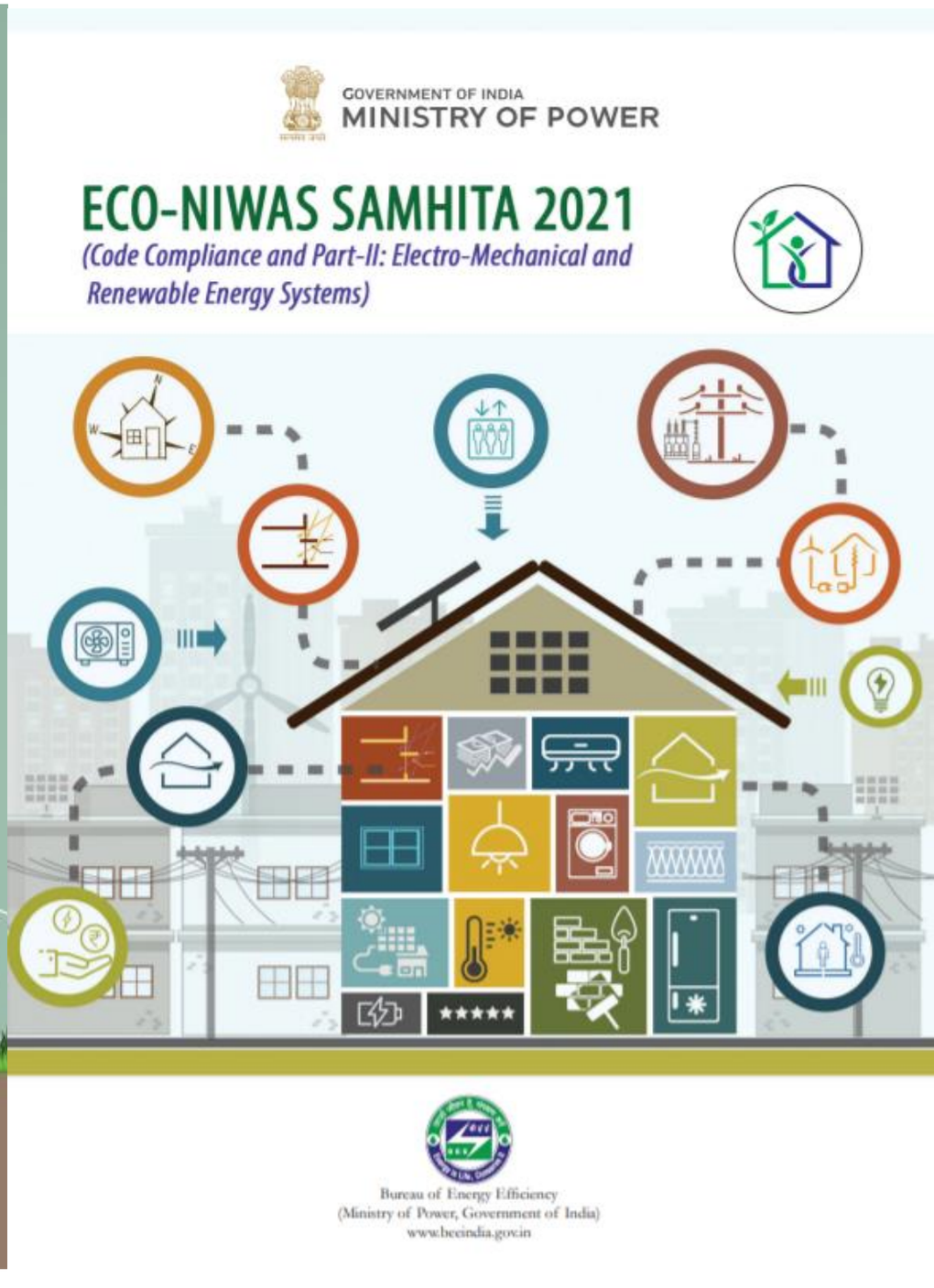
Thermal Comfort Standards

Session 2:

a) **Thermal Comfort standards**
b) **Effect of materials on thermal comfort**

EXISTING STANDARDS FOR IMPROVING THERMAL COMFORT





EXISTING STANDARDS FOR IMPROVING THERMAL COMFORT

According to the IMAC model, **neutral temperature in naturally ventilated buildings varies from 19.6 to 28.5 °C for 30-day outdoor running mean air temperatures ranging from 12.5 to 31 °C**.

An Introduction to the India Model for Adaptive (Thermal) Comfort

IMAC 2014

Principal investigators

Sanyogita Manu, Yash Shukla and Rajan Rawal

Centre for Advanced Research in Building Science and Energy, CEPT University, Ahmedabad, India

Lead experts and Co-investigators

Richard de Dear, *University of Sydney*

Leena Thomas, *University of Technology, Sydney*

Funding bodies

Ministry of New and Renewable Energy, Govt. of India

and Shakti Sustainable Energy Foundation

Introduction

Buildings represent around 40% of world's primary energy consumption. They are, therefore, directly responsible for increase in greenhouse gases and can play a key role in climate change adaptation. To achieve an energy efficient building regime, governments, businesses and individuals must transform the way buildings are designed, built and operated. Energy consumption in new and existing buildings can be reduced through design interventions, low-energy systems and behavioural changes.

In India, electricity demand already exceeds supply. The largest and most significant end use of electricity in commercial buildings is air-conditioning. The rapid growth in new floor space combined with an increase in thermal comfort expectations and aspirations, will lead to a surge in demand for air conditioning. If permitted unchecked, the growth in building air-conditioning will add immense pressure on electricity infrastructure and exacerbate the already extreme peak-demand problem in the country.

In order to prevent an increase in energy use associated with space cooling, the deployment of low energy adaptive strategies in building operation is critical. This could also help increase our resilience to the effects of climate change. When the occupants are allowed to adapt to a building's environment by means of adjusting their clothing, cooling or heating set points, operation of windows, or any other measures, they are able to tolerate a wider range of environmental conditions, which, in turn, helps save energy. At present, the predominant trend in India is to design air-conditioned office buildings that operate at 22.5 ± 1˚C all year round to meet the stringent specifications outlined by ISO 2005 and ASHRAE 55. These buildings are designed as sealed and fully controlled environments, and do not take advantage of favourable outdoor conditions whenever available. This conventional approach to design and

EXISTING STANDARDS FOR IMPROVING THERMAL COMFORT

ASHRAE-55

CBE Thermal Comfort Tool

Help Other CBE tools

ASHRAE-55 EN-16798 Compare Ranges Upload Fans & Heat PHS

Inputs

Select method: PMV method

Operative temperature

25 °C

Air speed

0.1 m/s No local control

Relative humidity

50 % Relative humidity

Metabolic rate

1 met Seated, quiet: 1.0

Clothing level

0.61 clo Trousers, long-sleeve shi

Create custom ensemble

Dynamic predictive clothing

Solar gain on occupants

Set pressure SI/IP

Local discomfort Globe temp

Reset Save Reload Share

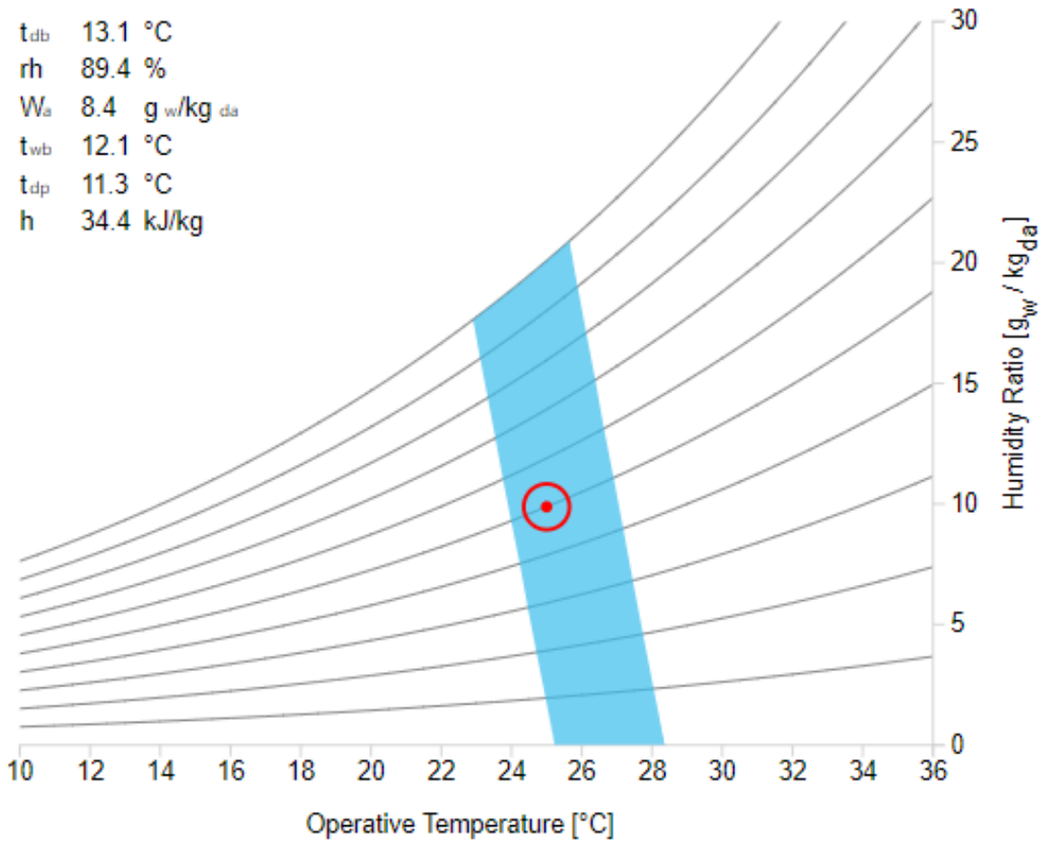
Documentation

✓ Complies with ASHRAE Standard 55-2020

PMV = -0.16 PPD = 6 %

Sensation = Neutral SET = 24.8 °C

Psychrometric (operative temperature)



NOTE: In this psychrometric chart the abscissa is the operative temperature and for each point dry-bulb temperature equals mean radiant temperature (DBT = MRT). The comfort zone represents the combination of conditions with the same DBT and MRT for which the PMV is between -0.5 and +0.5, according to the standard.

Limits of Applicability: This standard is only applicable to healthy individuals. This standard does not apply to occupants: a) whose clothing insulation exceed 1.5 clo; b) whose clothing is highly impermeable; or c) who are sleeping, reclining in contact with bedding, or able to adjust blankets or bedding.

The CBE comfort tools automatically calculates the relative air speed and the dynamic clothing insulation .

EXISTING STANDARDS FOR IMPROVING THERMAL COMFORT

Eco-Niwas Samhita (Energy Conservation Building Code for Residential Buildings)

Eco-Niwas Samhita 2018 (BEE, 2018) is the new Energy Conservation Building Code for Residential Buildings (ECBC-R) which has following provisions:

1. To minimize the heat gain in cooling dominated climate or heat loss in heating dominated climate,

a. Through the building envelope (excluding roof):

i. Maximum RETV for cooling dominated climate (Composite Climate, Hot-Dry Climate, Warm-Humid Climate, and Temperate Climate)

ii. Maximum U-value for the cold climate

b. Through the Roof: Maximum U-value for Roof

2. For natural ventilation potential

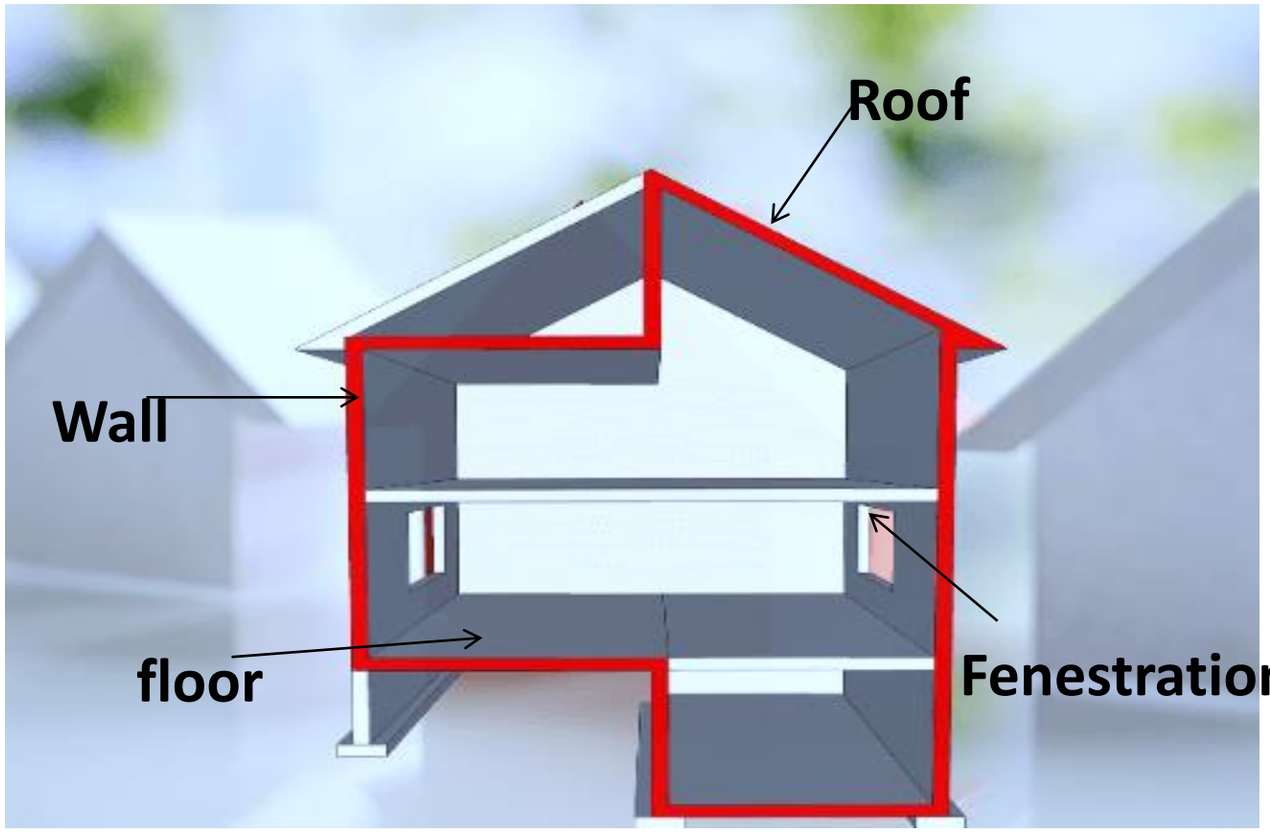
a. Minimum openable window-to-floor area ratio with respect to the climatic zone

3. For daylight potential

a. Minimum visible light transmittance with respect to window-to-wall ratio

This code focuses on building envelope and aims to improve the thermal comfort and reduce the energy required for cooling and lighting in Residential buildings.

EFFECT OF MATERIALS ON THERMAL COMFORT



CONDUCTION

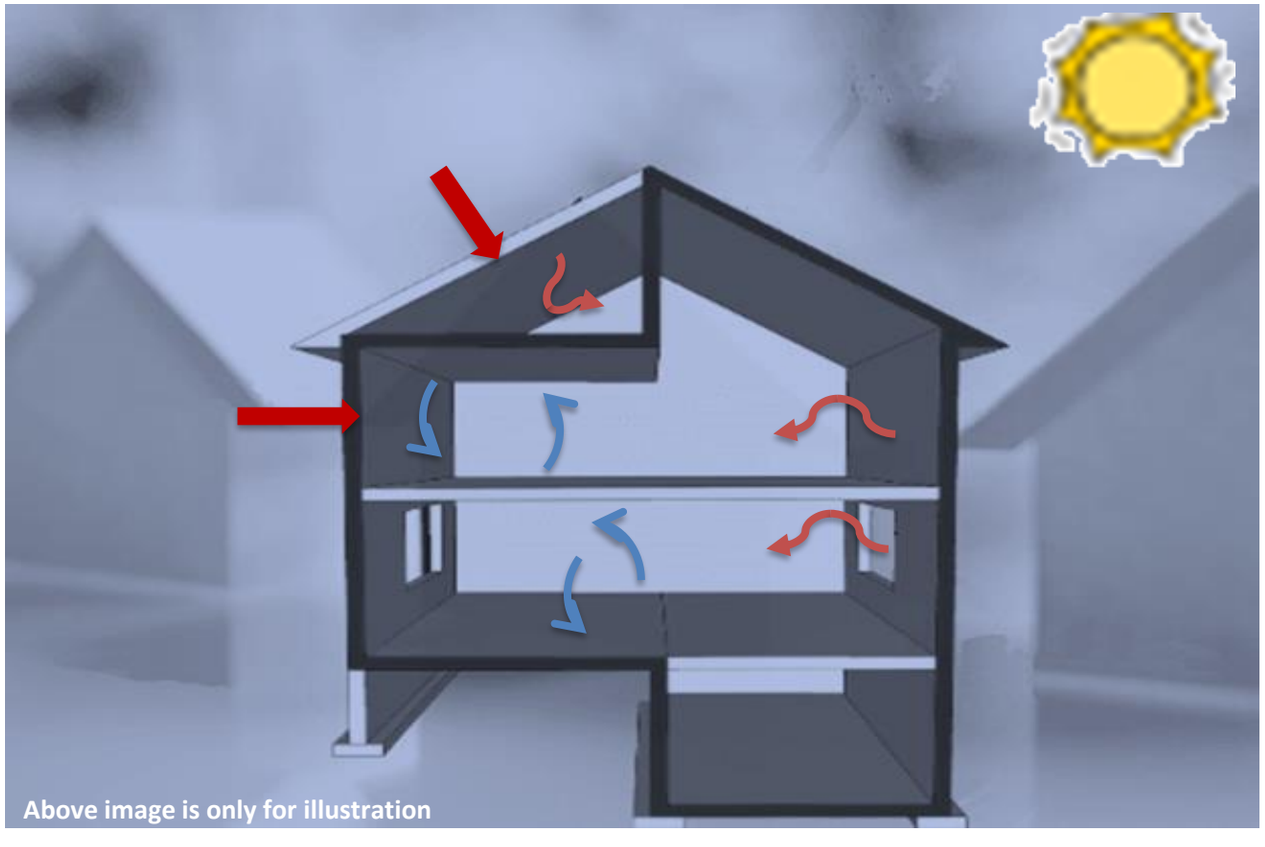
Transfer of heat from one material to another, through direct contact

CONVECTION

Transfer of heat through a medium, in case of buildings it is mostly air

RADIATION

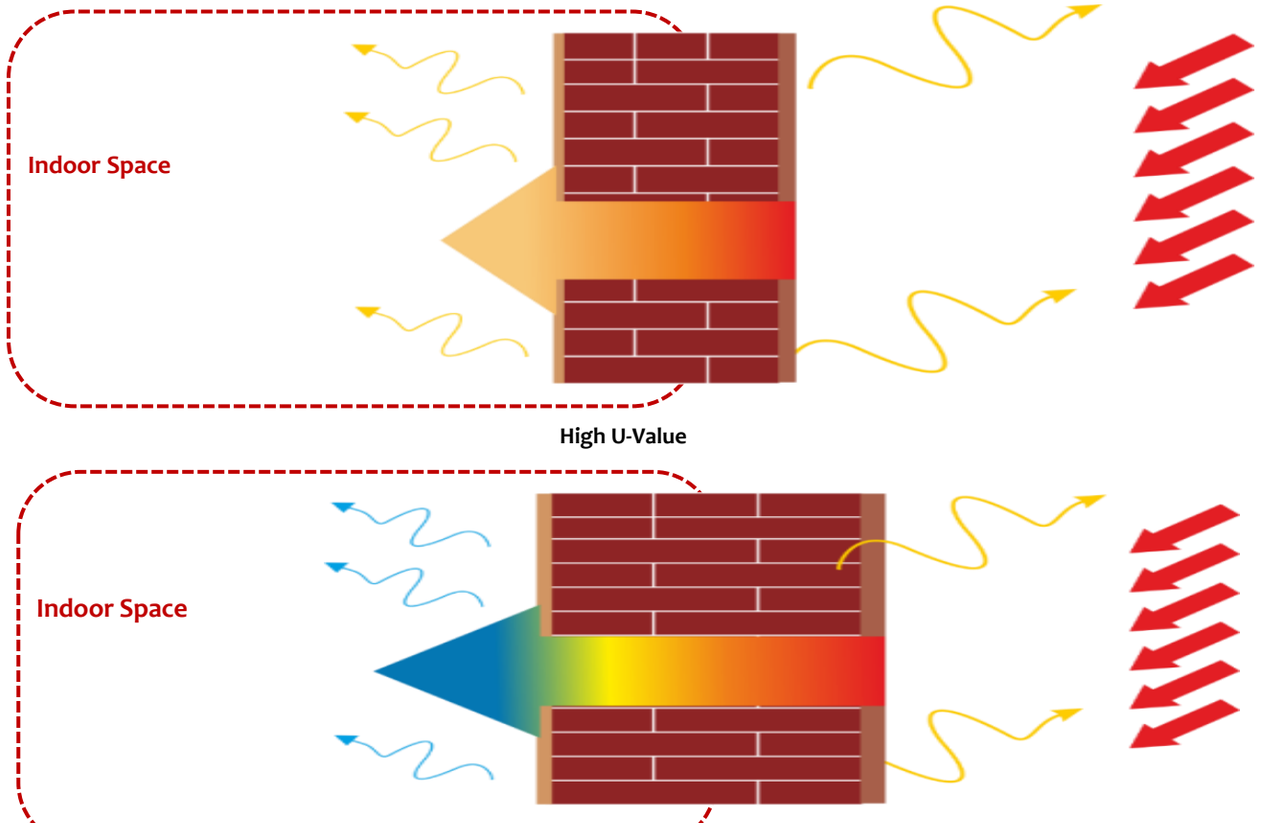
Energy that is radiated in form of rays/ waves



Building consist of wall, roof, fenestration, floor, sky light, columns, beams, doors

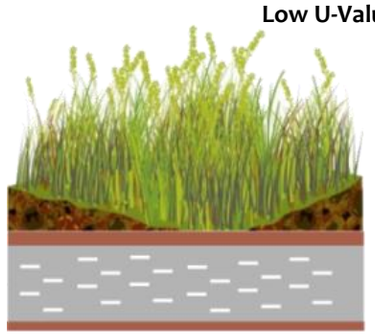
For the same we do require different materials to fulfil the user requirements such as aesthetics, safety, visibility, etc.

EFFECT OF MATERIALS ON THERMAL COMFORT

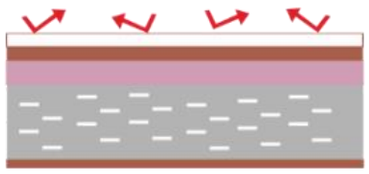


Thermal transmittance U-value

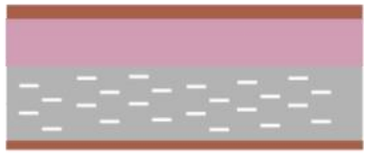
- Heat transfer due to temperature difference, inside & outside
- Heat transmission in unit time through unit area of a material or construction and the boundary air films, induced by unit temperature difference between the environments on each side
- Unit of U value is **W/m²k**.



Above Deck Insulation



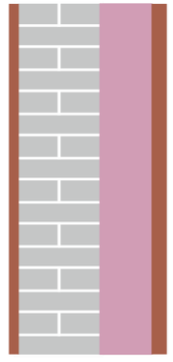
Reflective Tiles with above deck insulation of low thickness



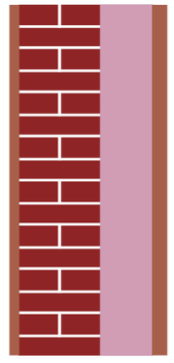
Above Deck Insulation

For Roof

- Reflective paints
- Roof garden
- Insulation
- Reflective tiles- China Mosaic



External Insulation with AAC Block



Externally Insulated Wall

For External Wall

- Increase wall thickness
- Insulations over walls
- Cavity

EFFECT OF MATERIALS ON THERMAL COMFORT

Before selecting insulation material for a building, the following factors need to be considered:

- ✓ The climatic conditions of the region
- ✓ The material flammability in case of an accident
- ✓ Material toxicity
- ✓ Ease of replacement of the material
- ✓ Material affordability
- ✓ Material durability
- ✓ Ease of installation

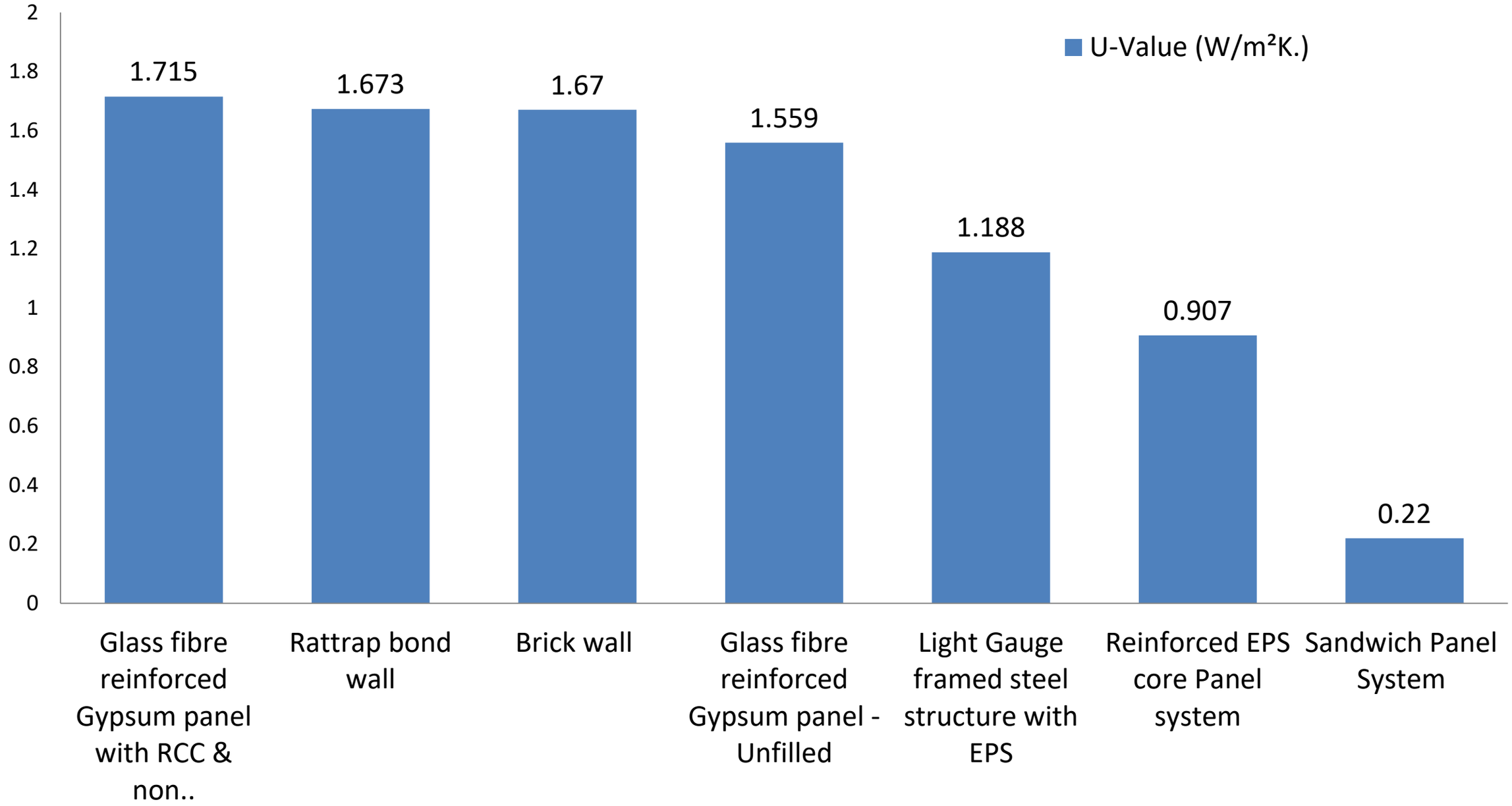
Characteristic of insulating materials	Insulating Power	Density	Fire Resistance	Water vapor diffusion	Resistance to water	Compression Strength	Traction Strength	Heat Resistance	Absorption of vibrations	Absorption of aerial noise	Cost at given insulation	Embodied Energy
Light mineral Wool	+	_·_	++	-	O	_·_	_·_	+		++	+	_·_
Dense Mineral Wool	++	+	++	_·_	O	O	_	++	++	+	+	O
Glass foam	+	+	++	++	++	++	++	++	_·_	_	+++	O
PUR	++	-	O	-	O	+	+	++	_	_·_	+	++
EPS	++	_·_	+	+	O	+	+	O	_	_·_	+++	_
XPS	++	O	+	++	+	+	++	O	-	_·_	+	+

++ Very high; + High; O Average; - Low; _·_ Very low

Comparison of commonly used insulation material

MATERIAL CHARACTERISTICS FOR BETTER THERMAL COMFORT

Thus, the lower the U-value, the lower the rate of heat transfer, and the better the insulating property of the element



Decrease in U value

Enhance Thermal Comfort

@source :CRDF Document of CEPT

LUNCH BREAK

Lunch Break

SESSION 3: INNOVATIVE TECHNOLOGIES

Session 3: New age innovative technologies along with the 6 LHP construction technologies focusing on - efficiency in construction, mainstreaming & replication of technologies, and sustainable cum thermal comfort aspects.

LHP INTRODUCTION

6 LHP ACROSS INDIA

Map showing six different LHP Locations

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

6 LHPs

1.Indore,Madhya Pradesh

- Prefabricated Sandwich Panel System

2.Rajkot,Gujarat

- Monolithic Concrete Construction using Tunnel Formwork

3.Chennai,Tamil Nadu

- Precast Concrete Construction System – Precast Components Assembled at Site

4.Ranchi,Jharkhand

- Precast Concrete Construction System – 3D Volumetric

5.Agartala,Tripura

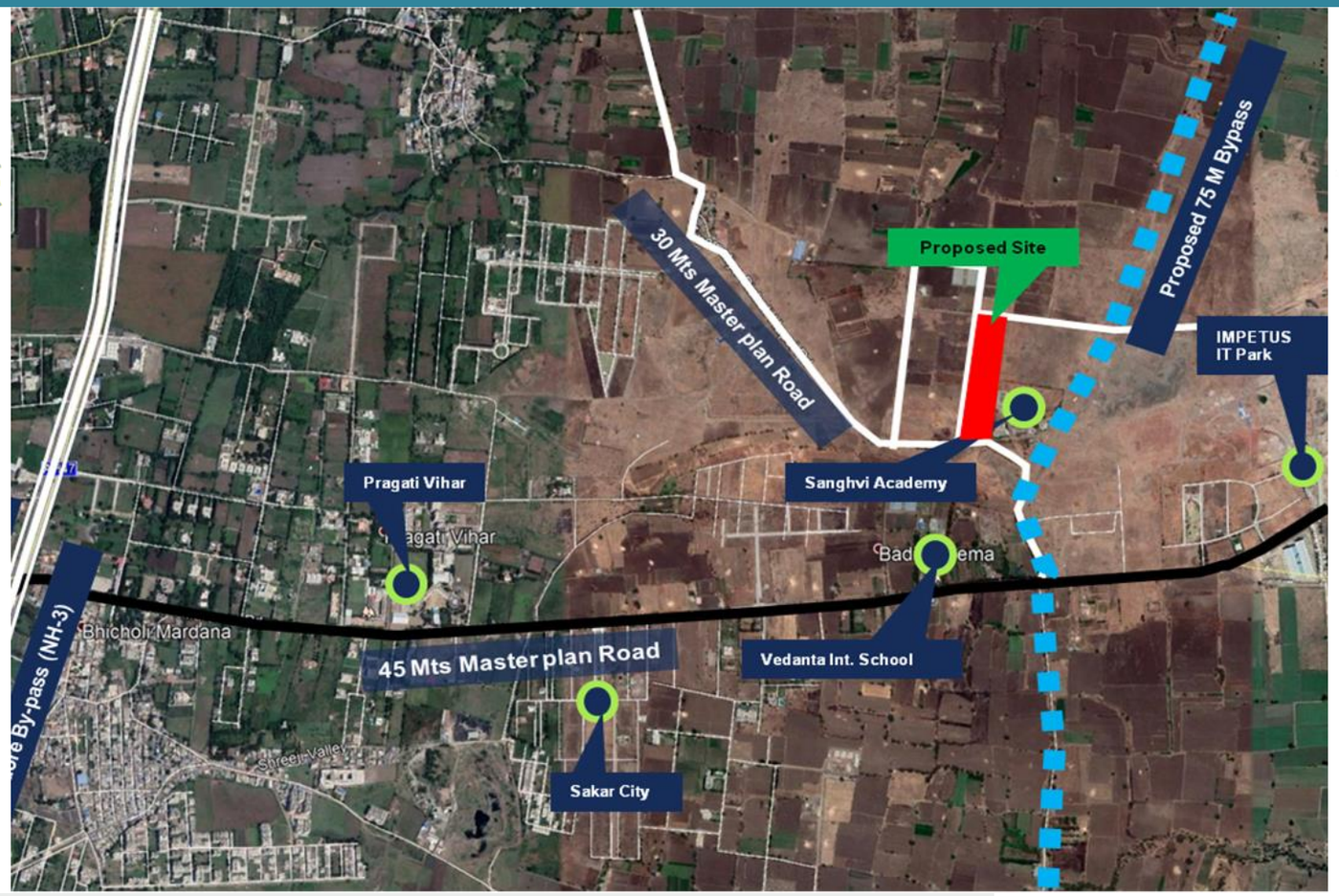
- Light Gauge Steel Structural System & Pre-engineered Steel Structural System

6.Lucknow,Uttar Pradesh

- PVC Stay In Place Formwork System

6 LHPs Explained Via Video

LHP INDORE



Description	Unit	Length	Width	Area
Living Room	Sqmt	3.12	3.08	9.61
Bed Room	Sqmt	3.12	2.99	9.33
Kitchen	Sqmt	2.1	1.81	3.80
Toilet	Sqmt	2.1	1.2	2.52
Balcony	Sqmt	2.07	1.06	2.19
Circulation Area	Sqmt	2.19	0.9	1.97
Thresold Area	Sqmt			0.50
Total Carpet Area	Sqmt			29.92

LHP INDORE

LHP INDORE

Project Details

Land Area – 41920 sqm
Net Plot Area – 34276 sqm
No's of Dwelling Unit – 1024
No's of Tower – 08
No's of Floor – *SF +* 08
No's of DU / Tower – 128
Community Hall – 169.5 sqm

Key Highlights

Technology – Pre-Fabricated Sandwich Panel & PEB Structure
Project Start Date – 01-01-2021
Project Expected End Date – 31-03-2022
Amenities –
Rain Water Harvesting
Rooftop Solar Power System
Fire Equipment (s)
Elevator / Lift
Emergency Power Back-up
Sewage Treatment Plant
Central Waste Collection Plant

LHP INDORE

CONSTRUCTION METHDOLOGY

6. Staircase –
Fabricated MS sections are being welded at site for staircase frame preparation

1.Substructure
RCC Isolated column footing

5. Lift Wall –
RCC structure is being prepared for lift walls. Onsite RMC plant for RCC material preparation

2.Structural System
Pre Engineered structure consists of factory manufactured steel column and beam erected on site.

4. Walling System
Factory made Prefabricated sandwich panels are being used for wall preparation

3. Slab –
Deck sheet is placed on structure. over it, slab casting is done

LHP INDORE - TECHNOLOGY

Structural System – *Pre Engineering Building*
Slab- *Deck Sheet Slab*
Walling System - *Pre fabricated sandwich panel system*

PEB STRUCTURE

DECK SHEET SLAB

PREFABRICATED SANDWICH PANEL WALLING

LHP INDORE - TECHNOLOGY

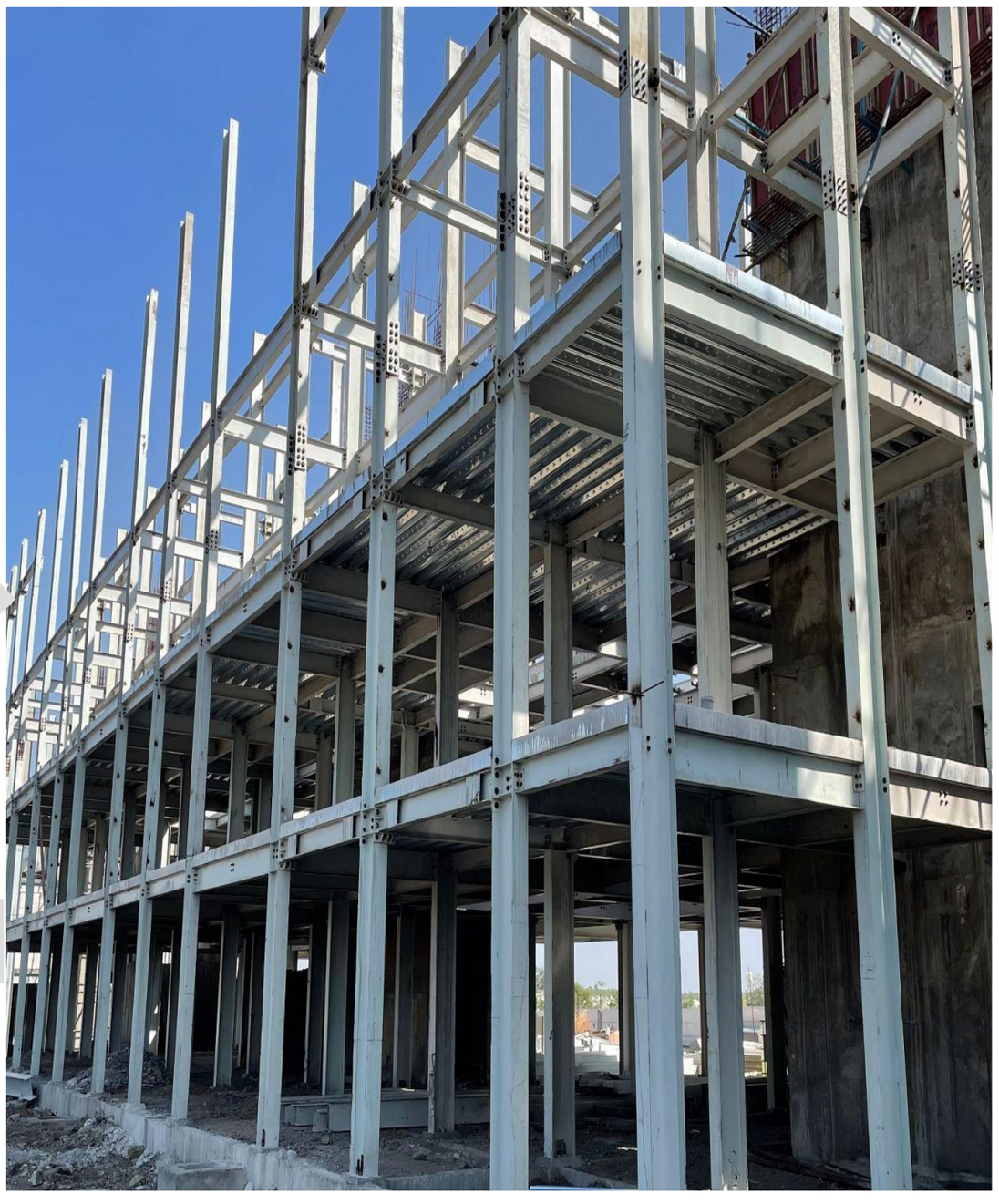
PEB STRUCTURE

- With **Pre-engineered steel building** systems, multi-stories can now be scripted in the shortest "set-up" time
- Speed in Construction

Lifting

Assembled Structure

Bolting

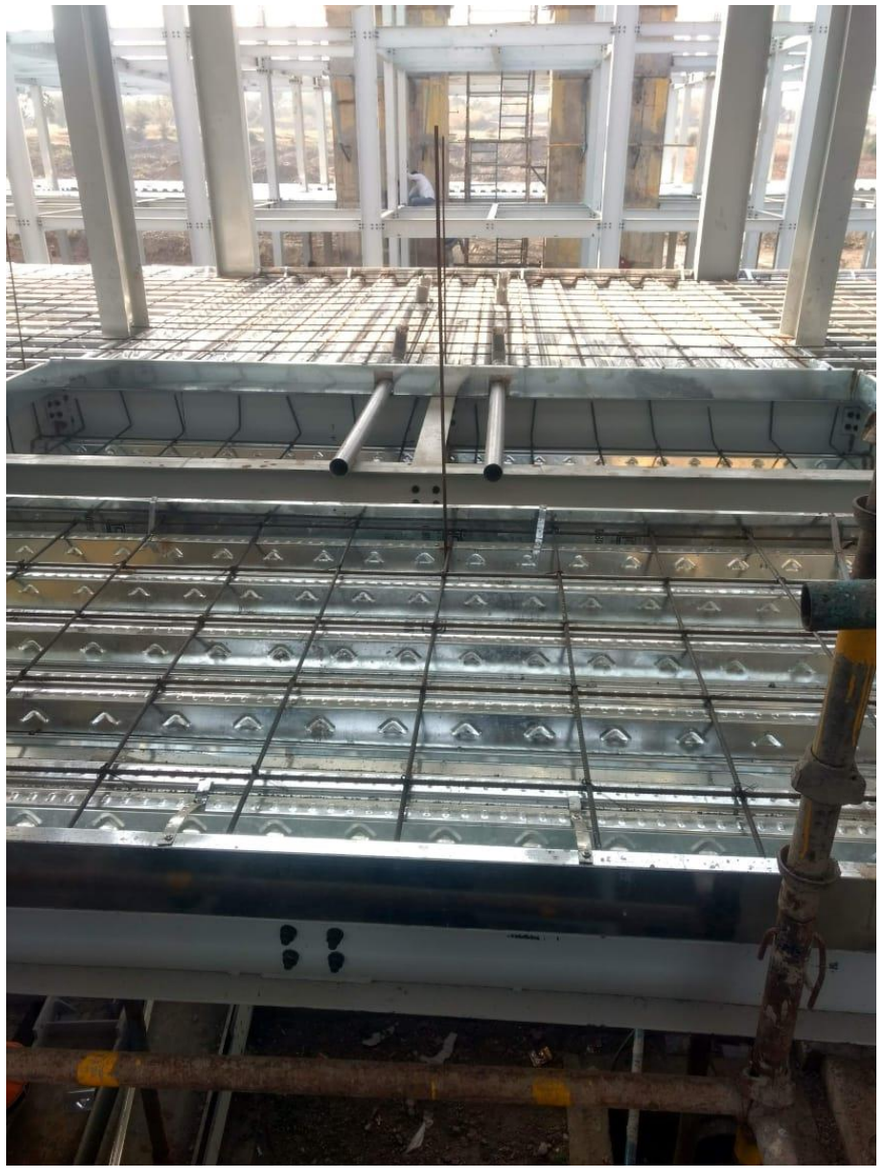


LHP INDORE - TECHNOLOGY

DECK SLAB

Deck sheet laying

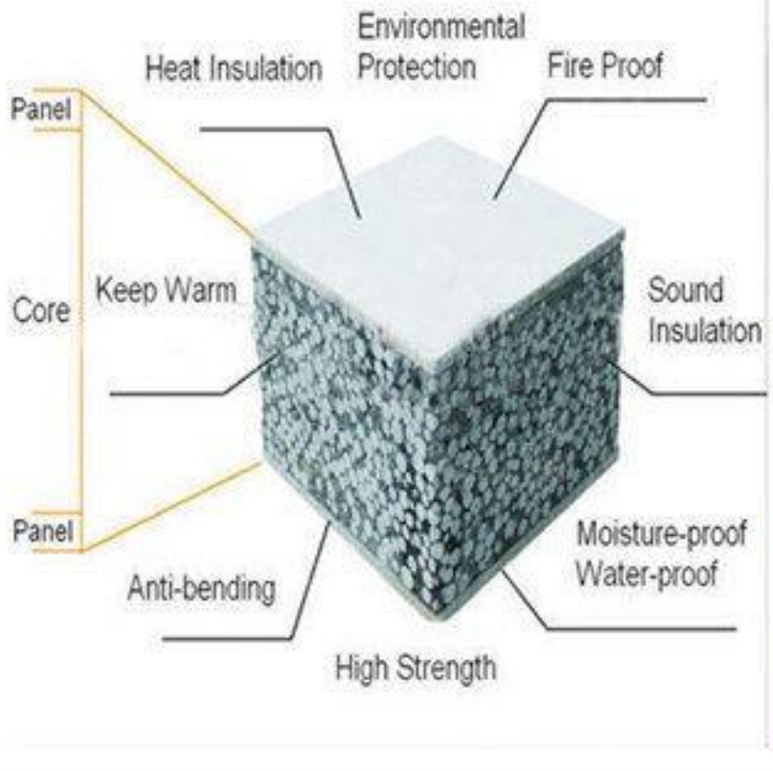
Services & reinforcement laying



Concreting

LHP INDORE - TECHNOLOGY

PRE FABRICATED SANDWICH PANEL SYSTEM



- Speed in Construction
- No use of water in curing
- Panels bring resource efficiency, better thermal insulation, acoustics & energy efficiency.

EPS SANDWICH PANEL MANUFACTORING PROCESS

Digital control center

Stock dynamic monitoring

Cement

Sand

EPS

Additive

Lightweight aggregate

Water

Raw material feeding sequence control

E-metering accurate feeding calculation

Mixing agitation

Pouring into mould car/vibratory compaction

Form removal

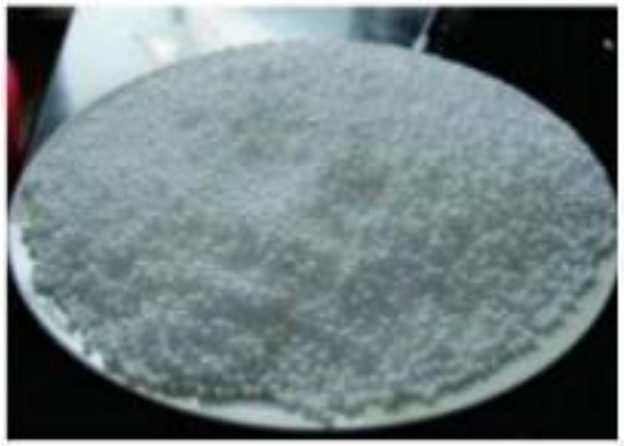
Maintenance

Transport to the ordered location

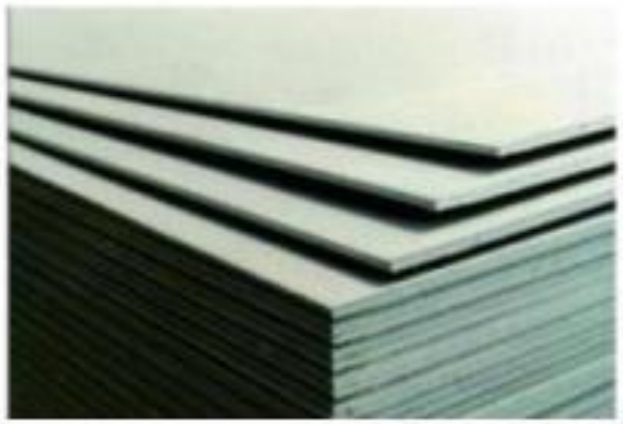
Loading

Packing

EPS SANDWICH PANEL RAW MATERIALS



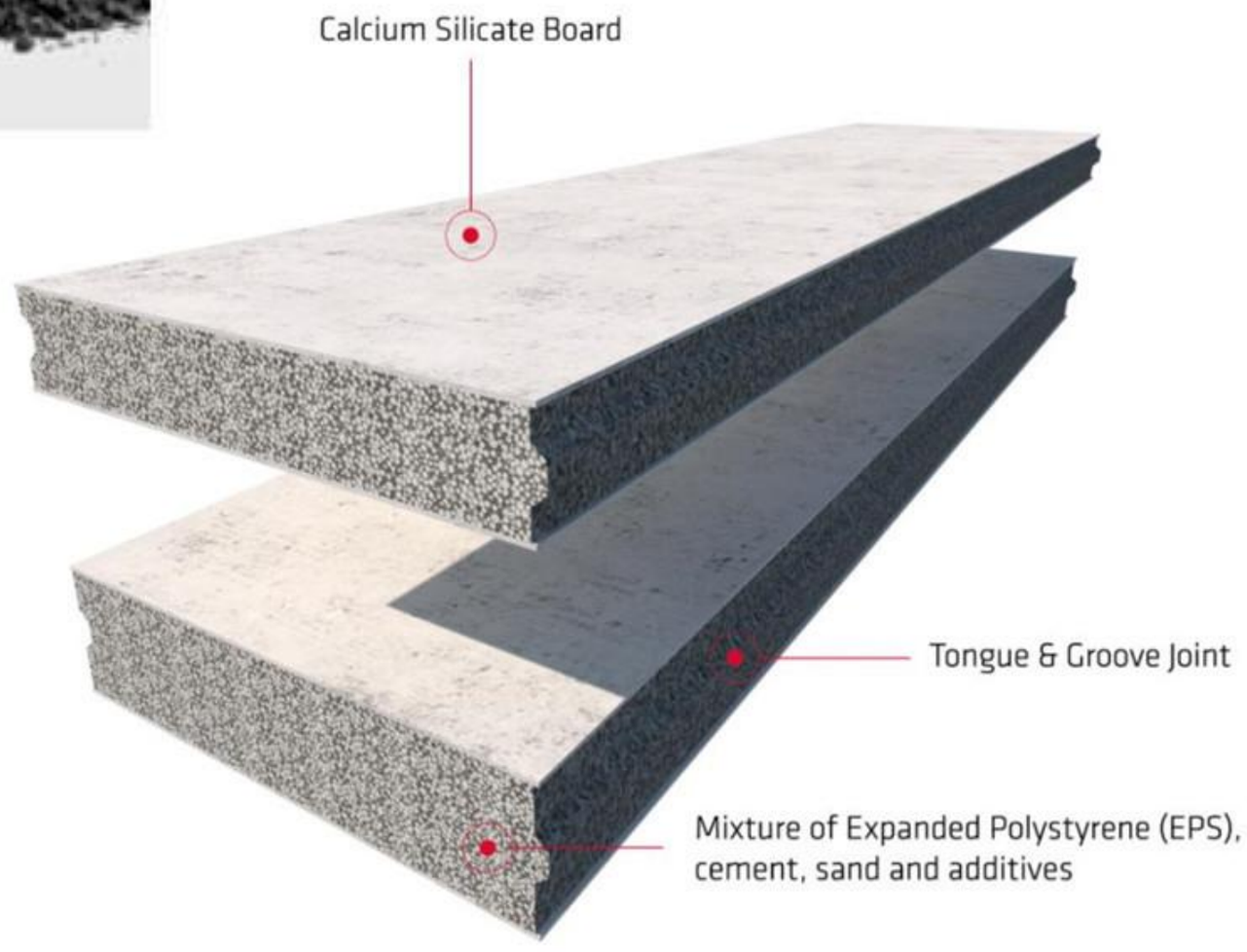
EPS



Calcium silicate board

Fly ash

Cement



EPS SANDWICH PANEL- FIXING TOOLS

No.	Name	Picture	Function	Picture
1	Cement adhesive		Special cement adhesive for EPS cement sandwich panel connection	
2	Triangle wood		Support, ensure the panel be sticked firmly	
3	Steel bar		Reinforce the connection of the EPS cement sandwich panels	
4	PU foam		Filling the gaps between panel and structure, door, window.	
Decoration remark: if you choose painting for the decoration, you need to put fiber mesh cloth on the wall or fiber mesh tape at the joint before painting, if you decorate the wall by wallpaper, wall tile or other covered materials, no need for the following materials, can put the wallpaper, wall tile on the wall directly.				
5	Fiber mesh cloth		For whole wall anti-crack	
6	Fiber mesh tape		Between panels connection for anti-crack	
7	Anti-crack mortar		Stick (cover) the fiber mesh cloth/fiber mesh tape on the panel	

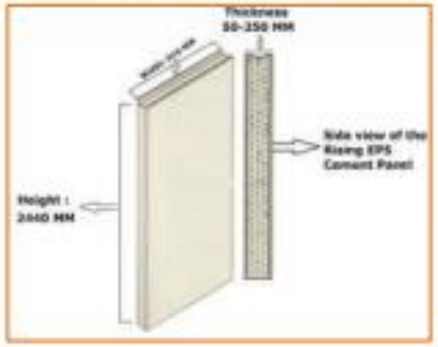
EPS PANEL PERFORMANCE APPRAISAL CERTIFICATE

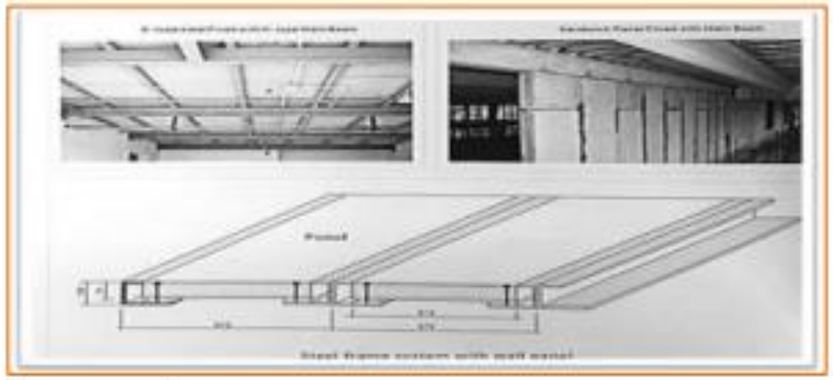
BMTPC
PACS
PERFORMANCE APPRAISAL CERTIFICATION

Rising EPS (Beads) Cement Panels

User should check the validity of the Certificate by contacting Member Secretary, BMBA at BMTPC or the Holder of this Certificate.

Name and Address of Certificate Holder:	Performance Appraisal Certificate No.
M/s Rising Japan Infra Pvt. Ltd., **I-203,Som Vihar, R K Puram** **New Delhi -- 110022** **Tel: 08826195032** **E-mail:rpg@rijapaninfra.com**	PAC No.:**1032-S/2017** Issue No. **01** Date of Issue: **04.07.2017**





bmtpc

Building Materials & Technology Promotion Council
Ministry of Housing & Urban Poverty Alleviation
Government of India
Core 5A, First Floor, India Habitat Centre,
Lodhi Road, New Delhi – 110 003

Tel: +91-11-2463 8096, 2463 8097; Fax: +91-11-2464 2849
E-mail: bmtpc@del2.vsnl.net.in Web Site: http://www.bmtpc.org

EPS SANDWICH PANEL- PANEL SIZES

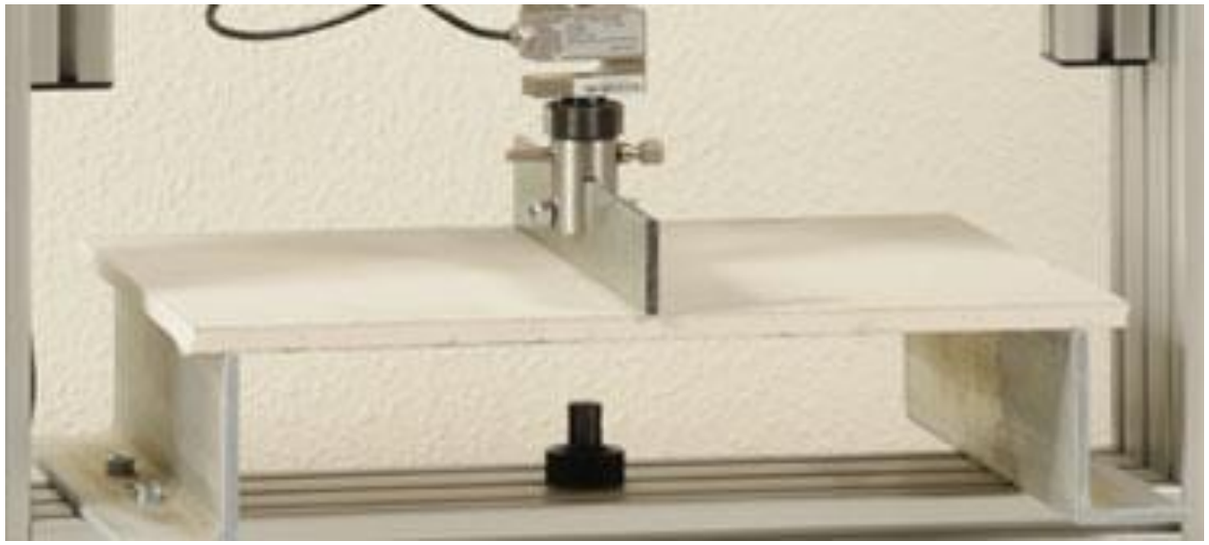
EPS Cement Sandwich Panel			
Specification L*W*T (mm)	Weight (kg/m2)	Packing (pcs/m2 per 20′ GP / 40′ HQ)	Application
2270 / 2440 x 610 x 60	45-48	315pcs*436m2/ 384pcs*572m2	Interior wall/ Roof system
2270 / 2440 x 610 x 75	50-53 / 55-58	252pcs*349m2/ 312pcs*464m2	Interior wall
2270 / 2440 x 610 x 90	55-58 / 69-72	207pcs*287m2/ 251pcs*375m2	Interior/ Exterior wall
2270 / 2440 x 610 x 100	60-65 / 72-75	189pcs*262m2/ 240pcs*357m2	Interior/ Exterior wall
2270 / 2440 x 610 x 120	65-75 / 90-93	153pcs*212m2/ 192pcs*286m2	Exterior wall
2270 / 2440 x 610 x 150	80-90 / 111-114	126pcs*175m2/ 156pcs*232m2	Exterior wall

PANEL TECHNICAL SPECIFICATION

Items	National Standards					Testing Indexes				
Thickness	60mm	90mm	100mm	120mm	150mm	60mm	90mm	100mm	120mm	150mm
Anti-impact performance/ times	≥5	≥5	≥5	≥5	≥5	≥8	≥10	≥15	≥18	≥22
Anti-bending damage load/ times over dead-weight	≥1.5	≥1.5	≥1.5	≥1.5	≥1.5	≥3	≥4	≥5	≥6	≥7
Anti-pressure strength/ Mpa	≥3.5	≥3.5	≥3.5	≥3.5	≥3.5	≥3.5	≥3.5	≥3.5	≥3.5	≥3.5
Surface density/ kg/㎡	≤70	≤90	≤110	--	--	≤45	≤55	≤65	≤75	≤85
Single point hanging strength/ N	≥1000	≥1000	≥1000	≥1000	≥1000	≥1000	≥1200	≥1300	≥1400	≥1500
Fire proof limit/ h	≥1	≥1	≥1	≥1	≥1	≥3	≥3	≥4	≥4	≥4
Sound insulation capacity in the air/ db	≥30	≥35	≥40	≥45	≥50	≥35	≥40	≥45	≥50	≥55
Soften coefficient	≥0.8	≥0.8	≥0.8	≥0.8	≥0.8	≥1	≥1	≥1	≥1	≥1
Moisture coefficient/ a%	≤12	≤10	≤10	≤8	≤8	≤10	≤9	≤7	≤6	≤6
Heat transfer coefficient/ B/W/M2.K	≤2.0	≤2.0	≤2.0	≤2.0	≤1.0	≤0.4	≤0.25	≤0.2	≤0.18	≤0.15
Drying shrinkage/ mm/m	≤0.6	≤0.6	≤0.6	≤0.6	≤0.6	≤0.4	≤0.5	≤0.5	≤0.5	≤0.5
Inner radiation index	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1
Outer radiation index	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1
Radioactivity limit	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1

EPS PANEL INSTALLATION

LHP INDORE – TECHNOLOGY ADVANTAGES



Strength Test

Fast and Easy Construction

Fire Resistance Test

Energy saving by thermal resistance

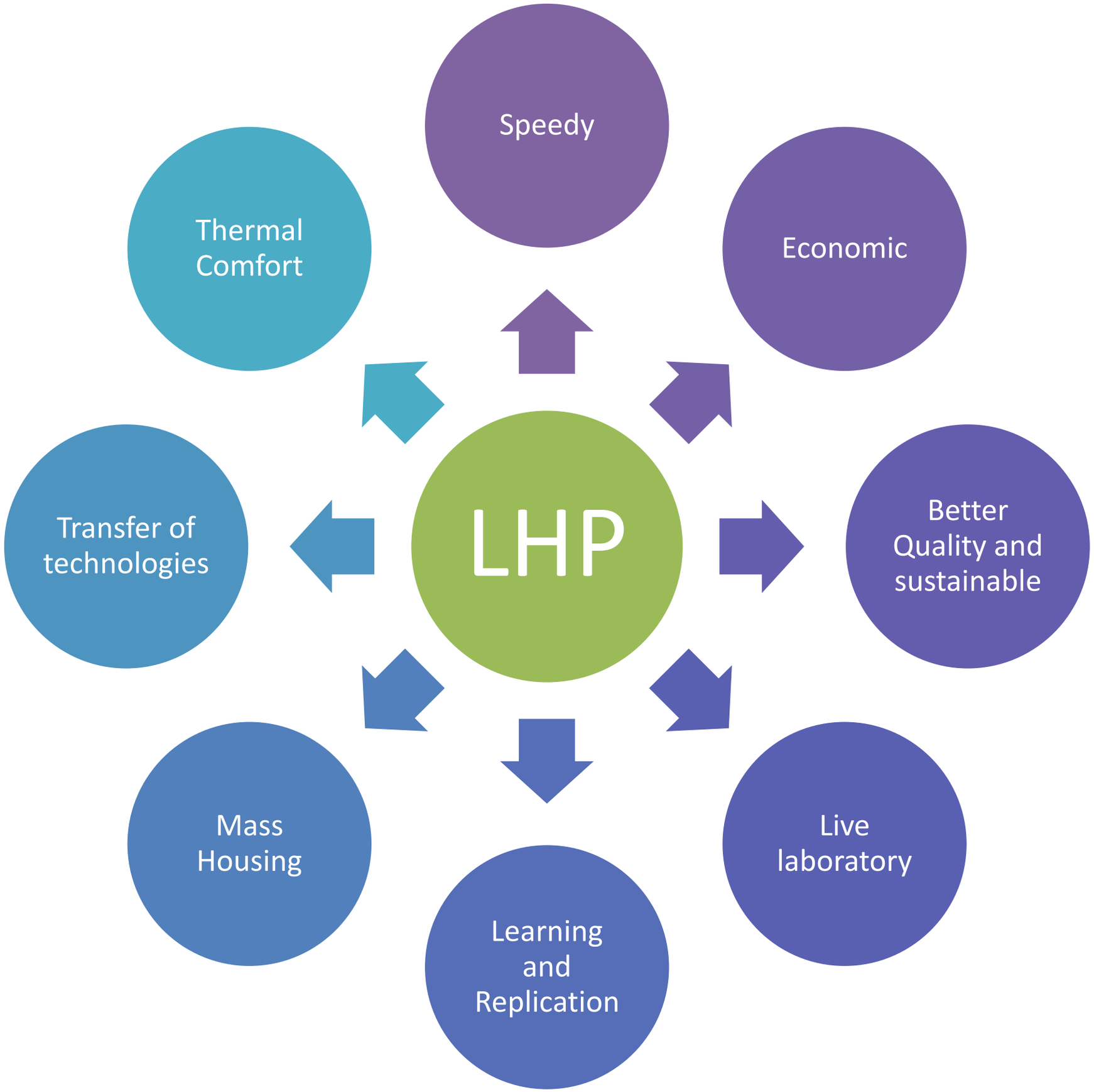
Recyclable

Eco friendly dry construction

1. Light weight and cost effective
2. Easy and faster construction
3. Fireproof
4. Water proof and damp proof
5. Non-toxic & environment-friendly
6. Energy saving & environment-friendly
7. Water saving due to dry construction
8. Smooth and flat surface, thus no plastering needed
9. High sound insulation
10. Cost effective
11. Ground staff optimization
12. Increase in carpet area up to 15% which saves money

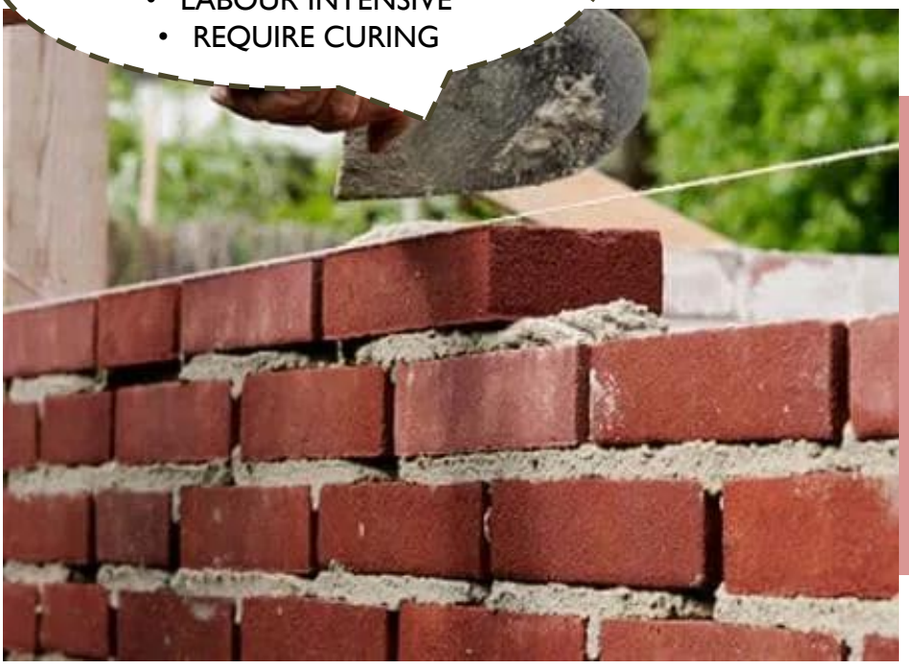
LHP INDORE

6 LHPS – FOCUSES ON



PLANNING ASPECTS

WALL CONSTRUCTED BRICK BY BRICK / LAYER BY LAYER
- LABOUR INTENSIVE
- REQUIRE CURING



DESIGN PROCESS
SELECTION OF TECHNOLOGIES

Sandwich panel system replaces brick-mortar with dry wall

FACTORY MADE EPS PANELS ARE PRE FINISHED
REQUIRES NO CURING

The cast-in-situ conventional construction systems need to be replaced by industrialized systems which
- Reduce the construction time
- Produce quality,
- Resilient and
- Sustainable structures.

These panels are
- ❑ Stronger,
- ❑ Durable with better quality control.
- ❑ Their functional performance in terms of acoustics, thermal, fire, rain water penetration, termite is much superior than cast-in-situ walls.
- ❑ These panels can be used as load bearing structural panels to build single to three storey houses or as non-load bearing infill walls to replace brick masonry walls between RCC frame.
- ❑ These panels can be cut to suitable sizes, made hollow so as to minimize wastages & accommodate services.

COST COMPARISION

Considering 10 Sq.M. Wall

S.no.	EPS WALL 120MM					BRICKWORK 230MM				
	Description	Area		Rate	Total	Description	Area		Rate	Total
1	EPS PANEL	10	Nos	1440	14400	Bricks	1065	Nos	7	7455
2	Tape	20	m	5	100	Mortar	0.46	Cu m	1850	851
2	Mortar	10	Kg	12	120	Plaster	20	sq m	530	10600
4	Labour	10	Sq M	190	1900	Labour	2.3	Cu m	700	1610
					16520					**20516**
				Per Sq M	**1652**				**Per Sq M**	**2051.6**
	Carpet Area - Increased by 1.1 SQ M									

SESSION 4 -ECO-NIWAS SAMHITA 2021

ECO NIWAS SAMHITA TOOL Via Video

ENS CODE COMPLIANCE

Table 1: Minimum ENS Score Requirement

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

Table 2: Component wise Distribution of ENS Score

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

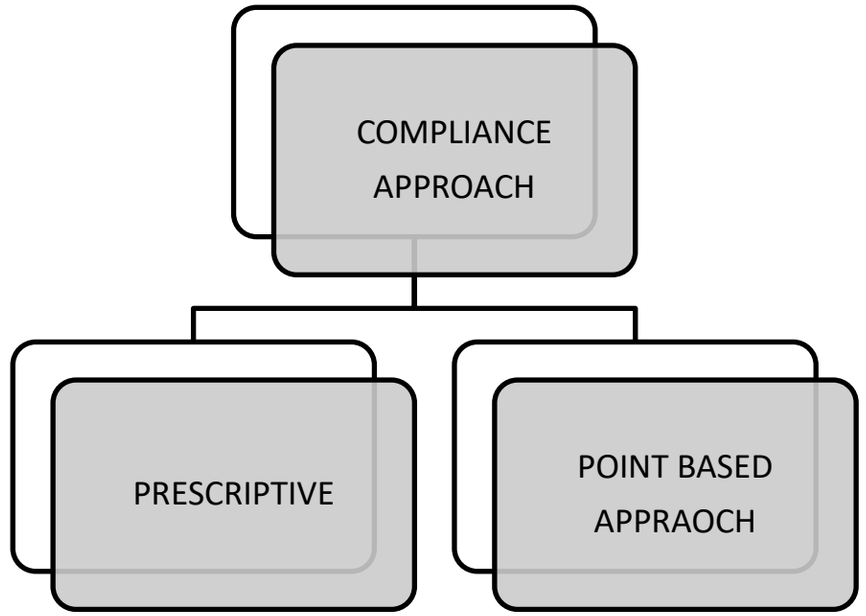
Table 9: Score for Renewable Energy System Components

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

The purpose of Eco Niwas Samhita 2021

The code applies to –

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

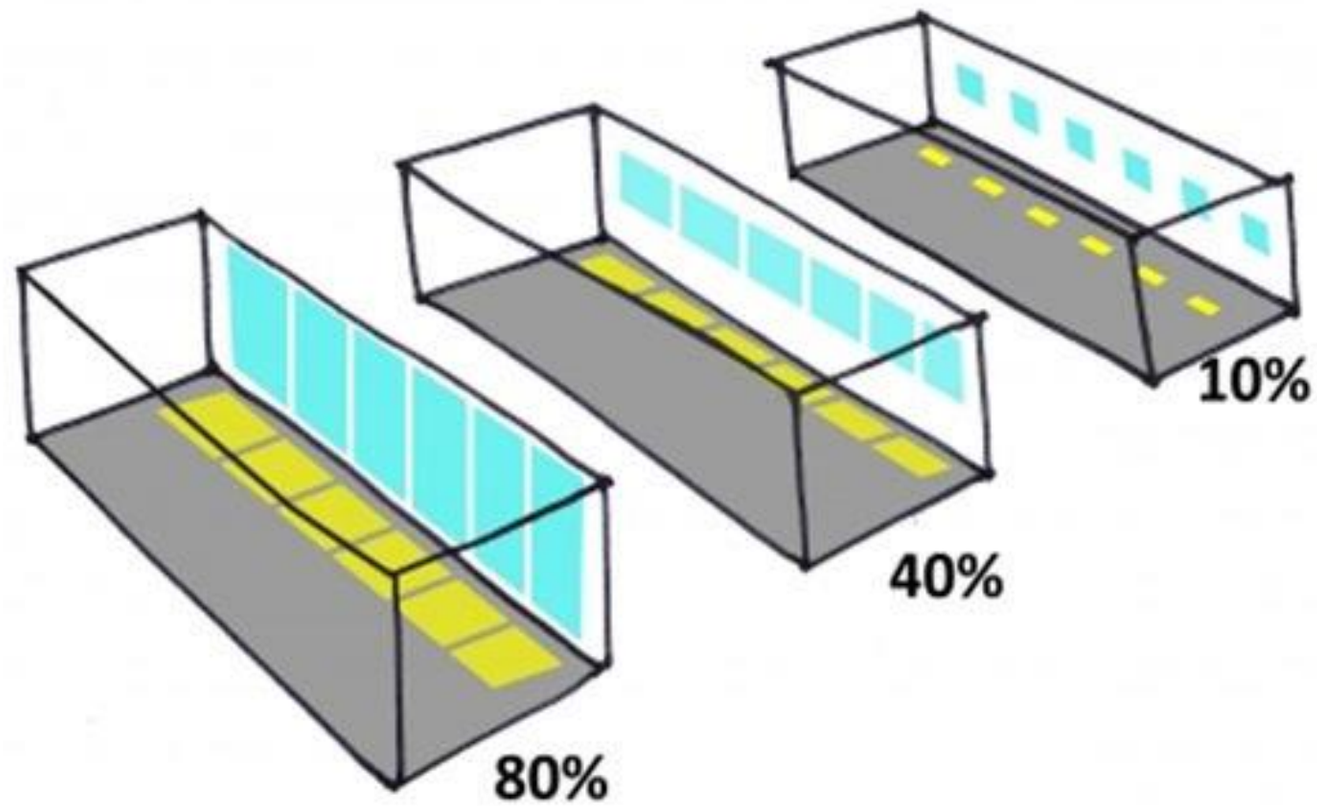


Compliance Approaches

CODE PROVISIONS

- ***Openable Window-to-Floor Area Ratio (WFRop)*** - it indicates the potential of using external air for ventilation.
- Ensuring minimum WFRop helps in ventilation, improvement in thermal comfort, and reduction in cooling energy
- It is the ratio of openable area to the carpet area of dwelling units.

$WFR_{OP} = A_{openable} / A_{carpet}$



3.1.3 The openable window-to-floor area ratio (WFR_{op}) shall not be less than the values[14] given in Table 1.

TABLE 1 Minimum requirement of window-to-floor area ratio (WFR_{op})

Climatic zone	Minimum WFR_{op} (%)
Composite	12.50
Hot-Dry	10.00
Warm-Humid	16.66
Temperate	12.50
Cold	8.33

SOURCE Adapted from Bureau of Indian Standards (BIS). 2016. National Building Code of India 2016. New Delhi: BIS.

Visible Light Transmittance (VLT)

VLT of non-opaque building envelope indicates the potential of using daylight. Ensuring minimum VLT helps in improving day lighting, thereby reducing the energy required for artificial lighting

WWR = $A_{(Non - Opaque)} / A_{(envelope)}$

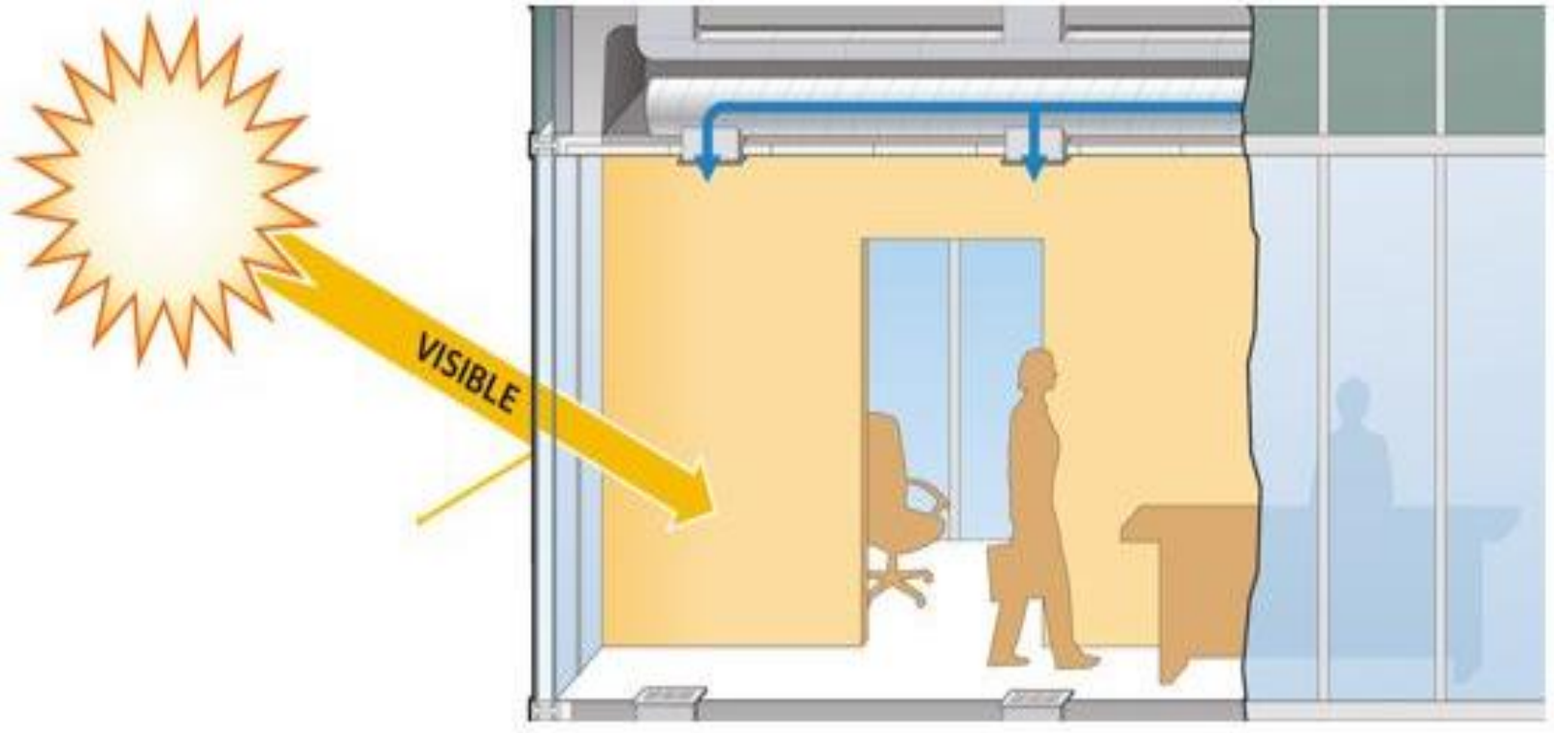


TABLE 2 Minimum visible light transmittance (VLT) requirement[15]

Window-to-wall ratio (WWR)[16]	Minimum VLT [17]
0–0.30	0.27
0.31–0.40	0.20
0.41–0.50	0.16
0.51–0.60	0.13
0.61–0.70	0.11

SOURCE Bureau of Indian Standards (BIS). 2016. National Building Code of India 2016. New Delhi: BIS.

Thermal transmittance

(U_{roof}) characterizes the thermal performance of the roof of a building. *Thermal transmittance of roof shall comply with the maximum* U_{roof} *value of 1.2 W/m2 .K.*

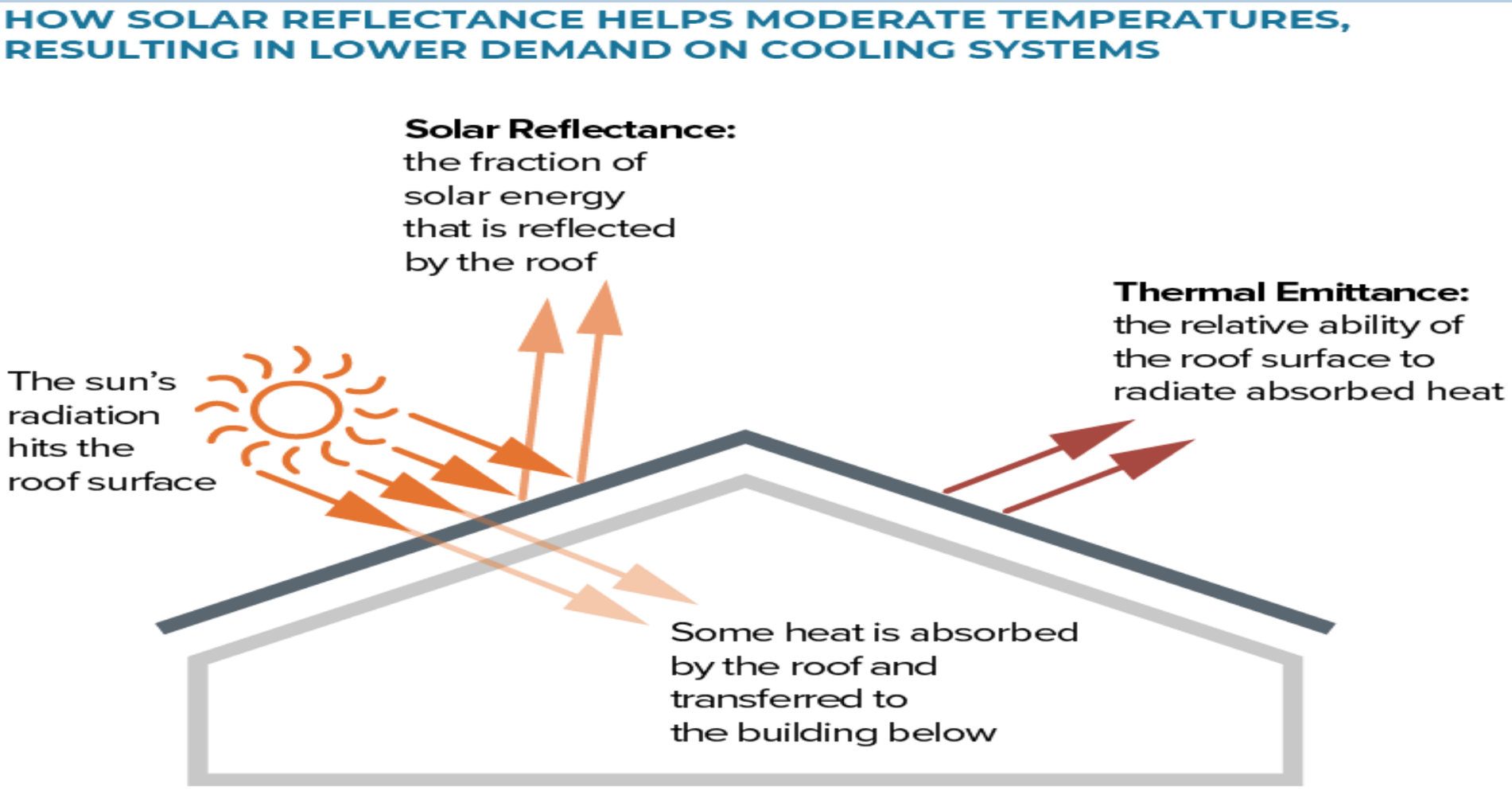


Illustration: Cool Roof Rating Council

3.3.3 The calculation[18] shall be carried out, using Equation 3 as shown below.

$$U_{roof} = \frac{1}{A_{roof}}\left[\sum_{i=1}^{n}(U_i \times A_i)\right] \quad \ldots(3)$$

where,

U_{roof} : thermal transmittance of roof (W/m².K)

A_{roof} : total area of the roof (m²)

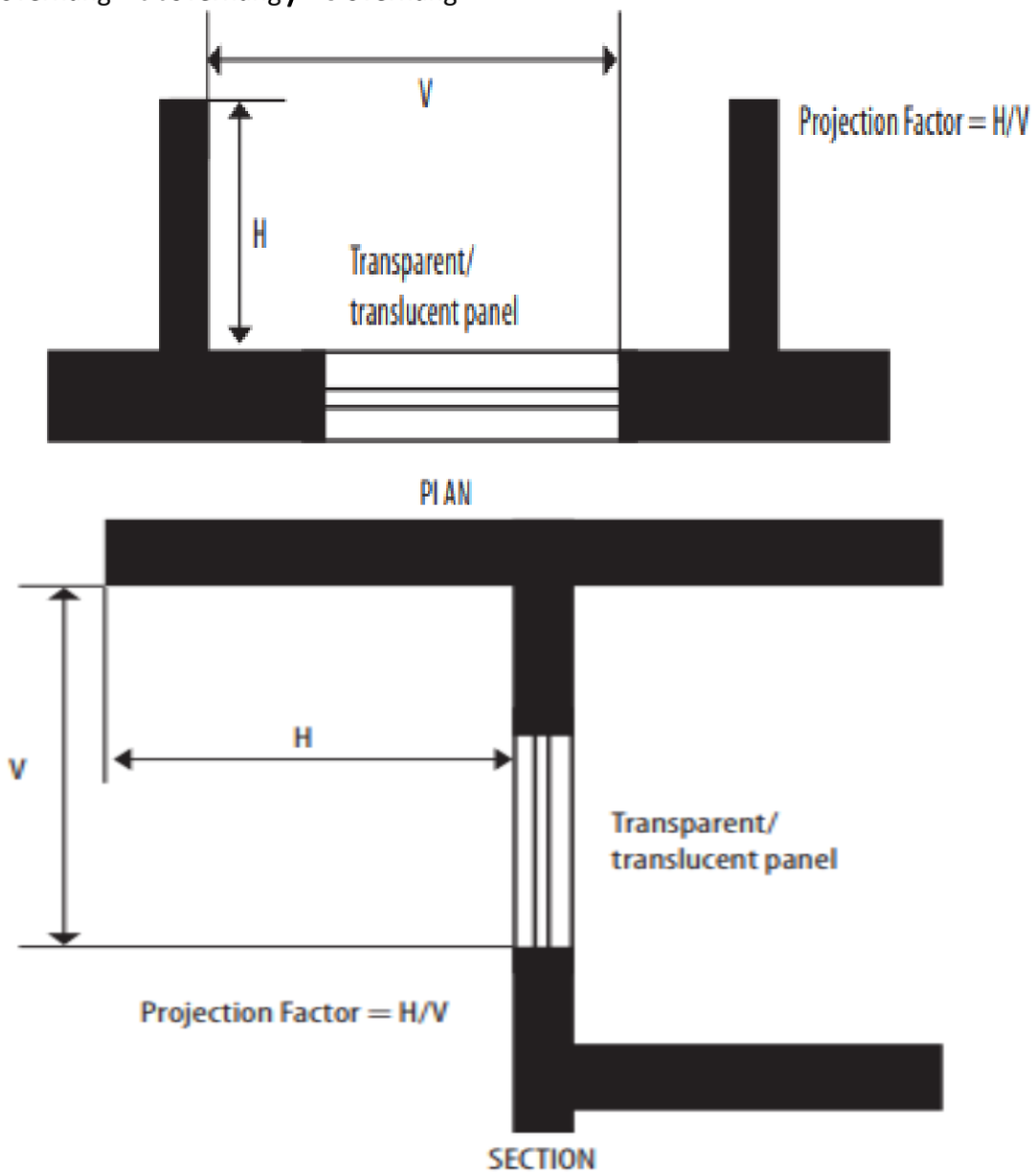
U_i : thermal transmittance values of different roof constructions (W/m².K)

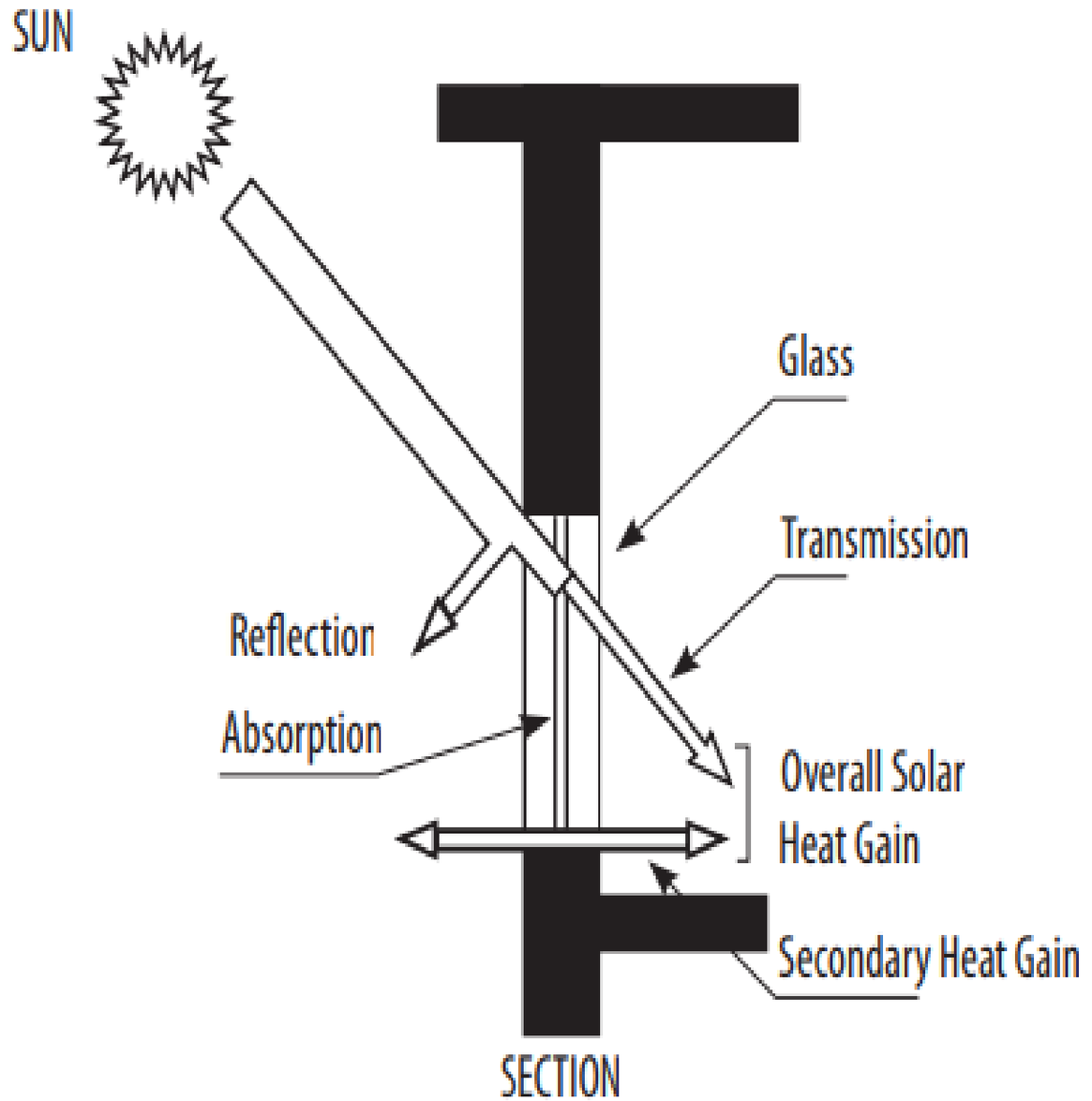
A_i : areas of different roof constructions (m²)

Solar Heat Gain Coefficient (SHGC): SHGC is the fraction of incident solar radiation admitted through non-opaque components, both directly transmitted, and absorbed and subsequently released inward through conduction, convection, and radiation

Projection factor, overhang: the ratio of the horizontal depth of the external shading projection (Hoverhang) to the sum of the height of a non-opaque component and the distance from the top of the same component to the bottom of the farthest point of the external shading projection (Voverhang), in consistent units.

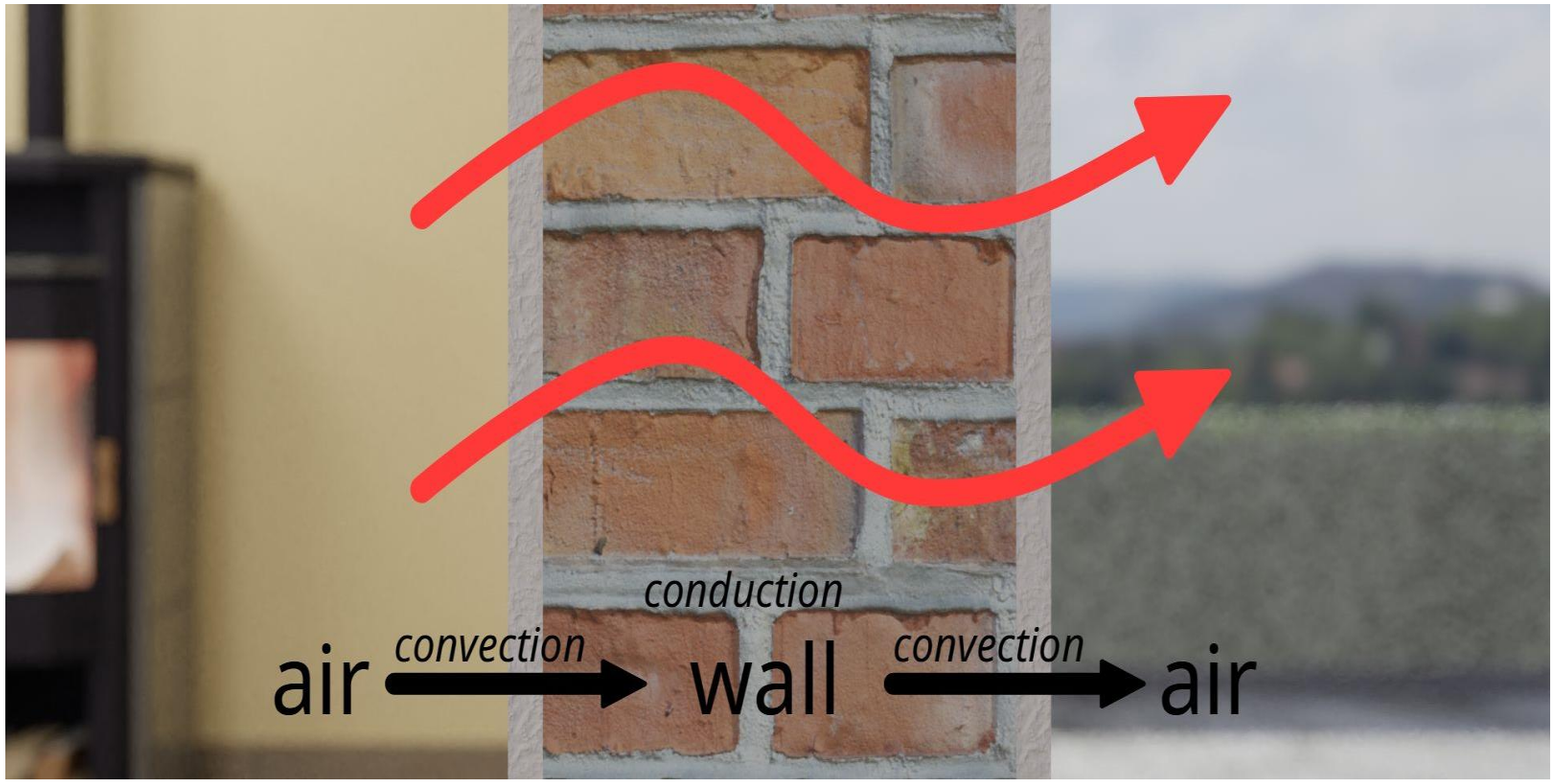
$PF_{overhang} = H_{overhang} / V_{overhang}$

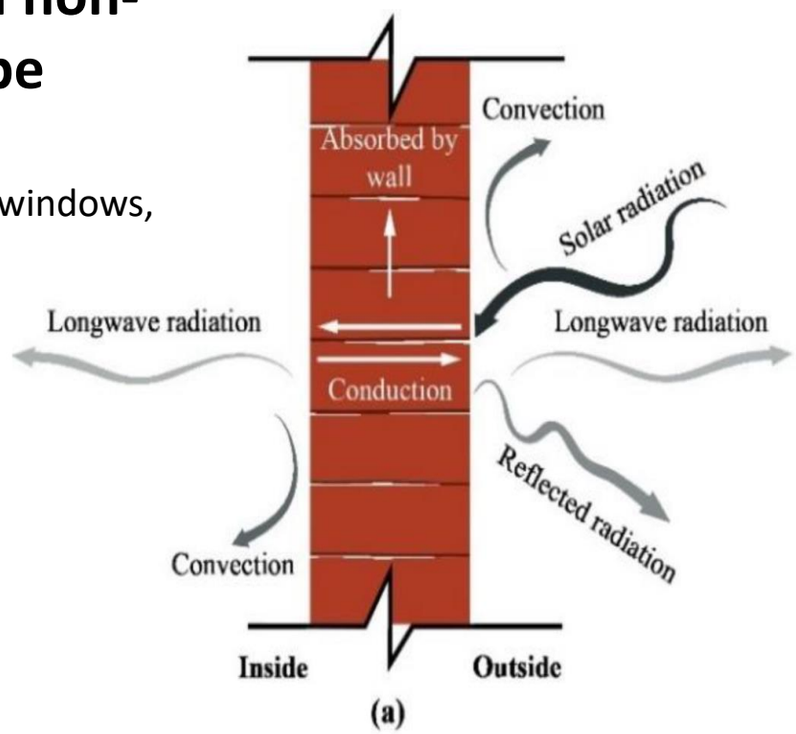


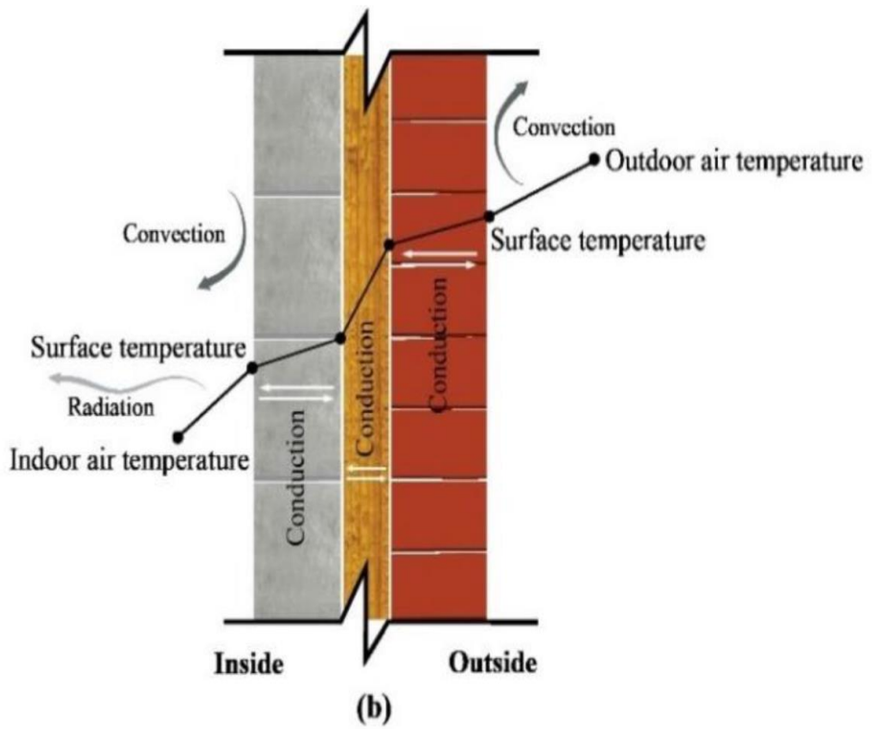


Thermal transmittance of building envelope (except roof)

- Thermal transmittance characterizes the thermal performance of the building envelope (except roof).
- U value takes into account the following:
    - Heat conduction through ***opaque building envelope components***
      (wall, opaque panels in door, window, ventilators, etc.)
    - Heat conduction through **non-opaque building envelope components**
      (transparent/translucent panels in windows, doors, ventilators, etc.).







Residential Envelope Transmittance Value

RETV characterizes the thermal performance of the building envelope ***(except roof).*** Limiting the RETV value helps in reducing heat gains from the building envelope, thereby improving the thermal comfort and reducing the electricity required for cooling.

Its unit is W/m2 .

$$RETV = \frac{1}{A_{envelope}} \times \left[\begin{array}{l} \left\{ 6.06 \times \sum_{i=1}^{n} \left(A_{opaque_i} \times U_{opaque_i} \times \omega_i \right) \right\} \quad Term\text{-}I \\ + \left\{ 1.85 \times \sum_{i=1}^{n} \left(A_{non-opaque_i} \times U_{non-opaque_i} \times \omega_i \right) \right\} \quad Term\text{-}II \\ + \left\{ 68.99 \times \sum_{i=1}^{n} \left(A_{non-opaque_i} \times SHGC_{eq_i} \times \omega_i \right) \right\} \quad Term\text{-}III \end{array} \right]$$

TABLE 3 Coefficients (a, b, and c) for RETV formula

Climate zone	a	b	c
Composite	6.06	1.85	68.99
Hot-Dry	6.06	1.85	68.99
Warm-Humid	5.15	1.31	65.21
Temperate	3.38	0.37	63.69
Cold	Not applicable (Refer Section 3.5)		

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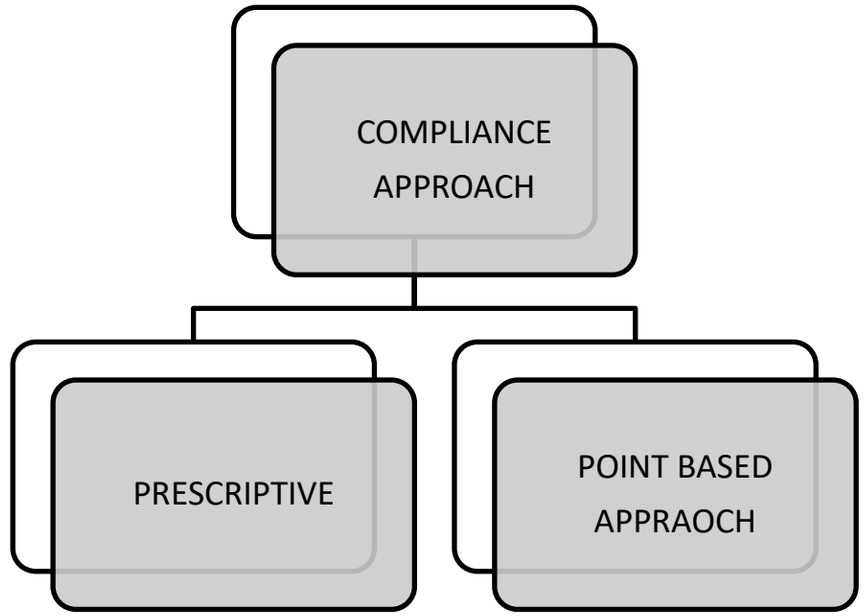


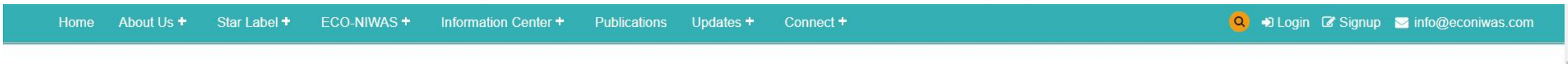
Compliance Approaches

ENS SIMULATION TOOLS

ENS TOOLS ECONIWAS 2.0 - INTRODUCTION

- Building simulation allows engineers and architects to address key aspects of building performance throughout the whole building life cycle from early design stages through construction and even for major energy retrofitting.
- Building simulation is a way to test how elements of building design will perform under real-world conditions
- **Basic Tool**
- **Advanced Tool**
- **Envelope Optimization Tool**

https://www.econiwas.com/tools.php



BUILDING PERFORMANCE ANALYTICS

Basic Tool

The basic tool is a quick evaluation platform for home owners, contractors and builders alike to rapidly evaluate the project's preliminary design intent on the scale ofenergy efficiency, carbon footprint and monetary savings with the selected project location, user specified area and orientation. The tool has various category of options from building envelope (wall, roof & window), Air-conditioning and Ventilation techniques to check the project performance. Click on the tool to explore more!

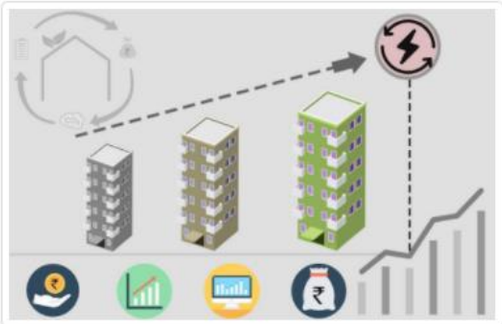
Tutorial Video

Advanced Tool (Trial Version)

The simulation based ECONIWAS Advanced tool is for the professionals (Architects,Engineers, MEP consultants, project developers, Industry professionals) who wish to perform detailed analysis of the project design features in terms of energy efficiency and economic feasibility. The tool has the provision of various inputs of building design parameter options ranging from Building Geometry, Envelope, Lighting, Equipment, HVACand Economicsto check the project performance. Dive in to learn more!

Tutorial Video

Optimization Tool (Trial Version)



The ECONIWAS Optimization tool is a quick evaluation moduleto compute the most optimized set of envelop parameters (best wall, best roof and best window)for the selected location based on life cycle cost of the envelope options. Just input the cost of most common envelope assemblies available at the project site and tool will indicate which envelope will be the best for your site. Click on the tool to explore more!

Tutorial Video

ECONIWAS 2.0

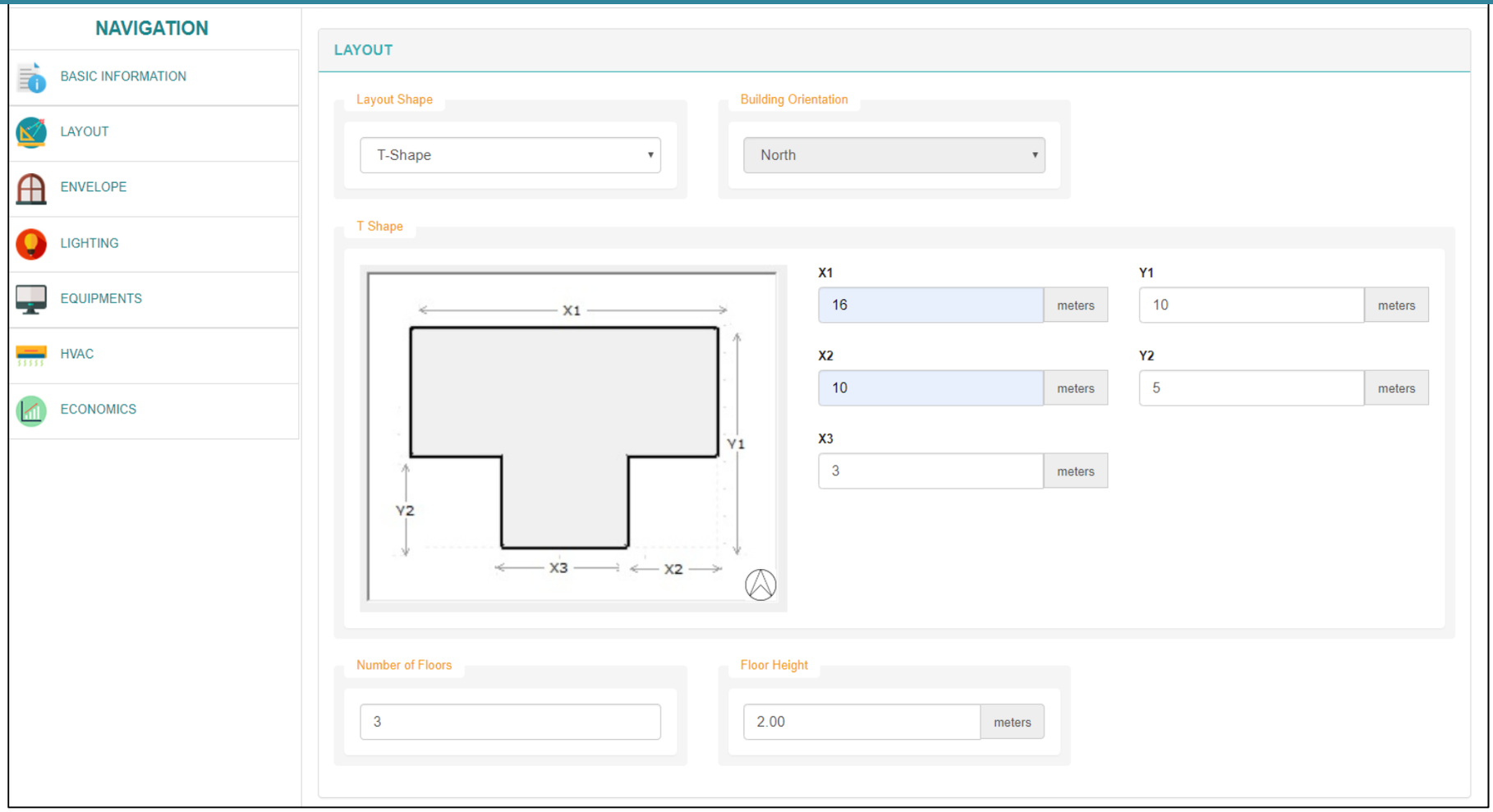
Basic Tool:

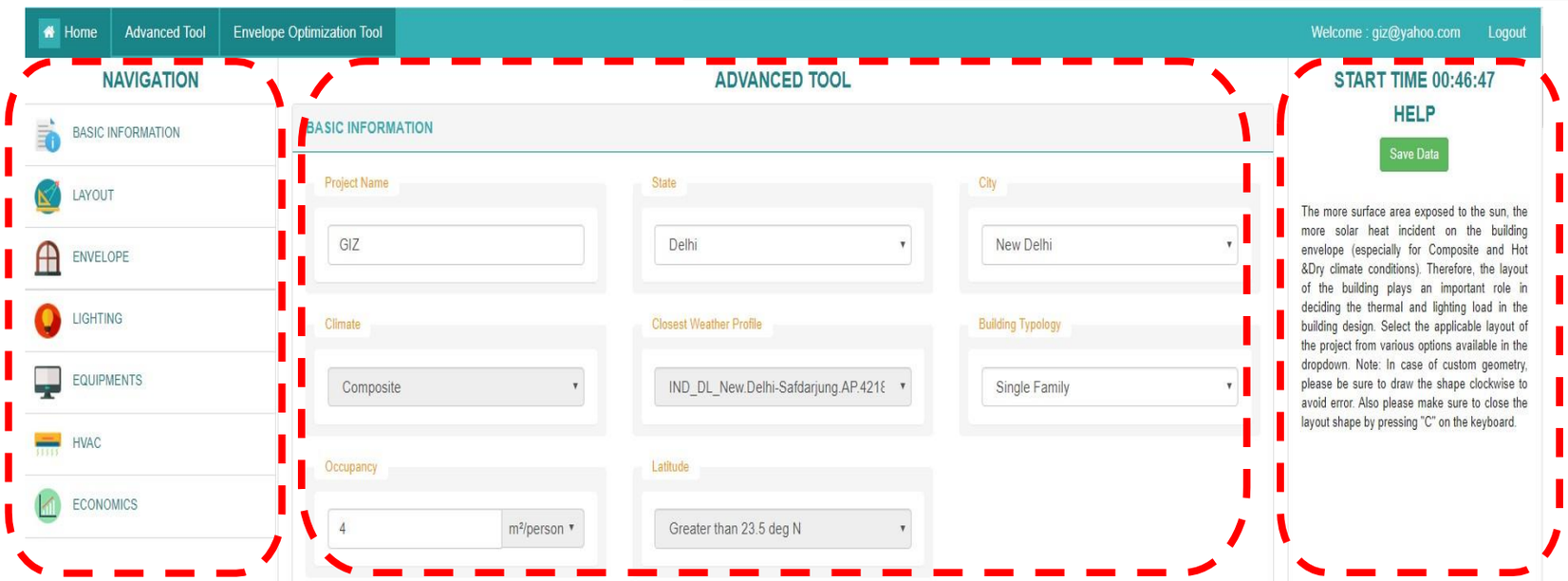
Quick evaluation platform for homeowners, contractors and builders alike to rapidly evaluate the project's preliminary design intent on the scale of energy efficiency, carbon footprint and monetary savings with the selected project location, user specified area and orientation, building envelope (wall, roof & window), Air-conditioning and Ventilation techniques.

ECONIWAS 2.0

ADVANCED TOOL

Simulation based tool for the professionals (Architects, Engineers, MEP consultants, project developers, Industry professionals) who wish to perform detailed analysis of the project design features in terms of energy efficiency, economic feasibility and environmental impact.





Easy to Navigate, tree view layout for quick navigations between various building parameters.

Self explanatory help panel for easy understanding of inputs for the users

Effective and responsible user form that takes essential

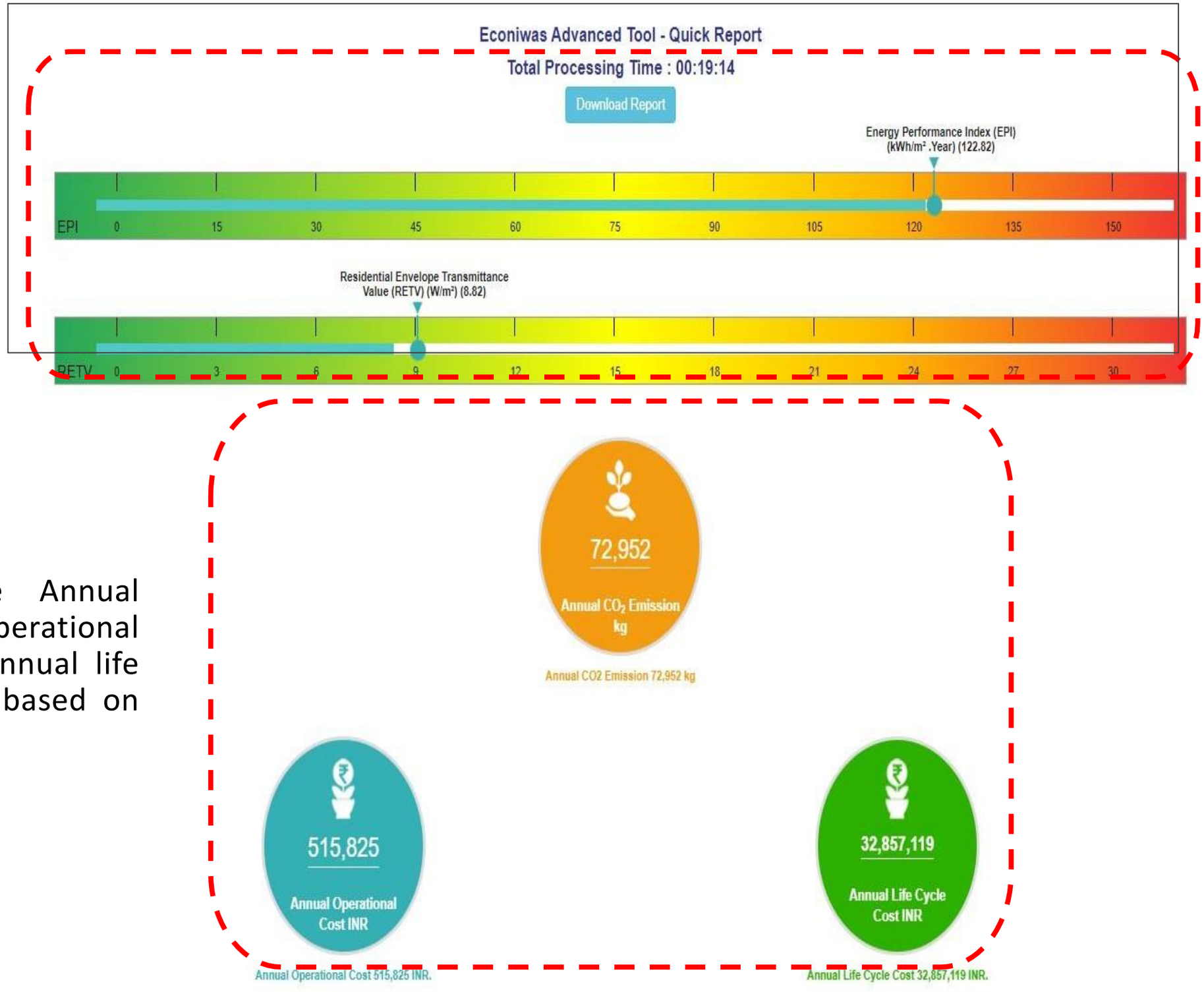
inputs from the user to generate desired results

ADVANCECD TOOL – RESULTS

On the submission of the form, the tool performs the energy simulation using energy plus server-side simulation platform to predict the EPI and RETV values of the designed building.

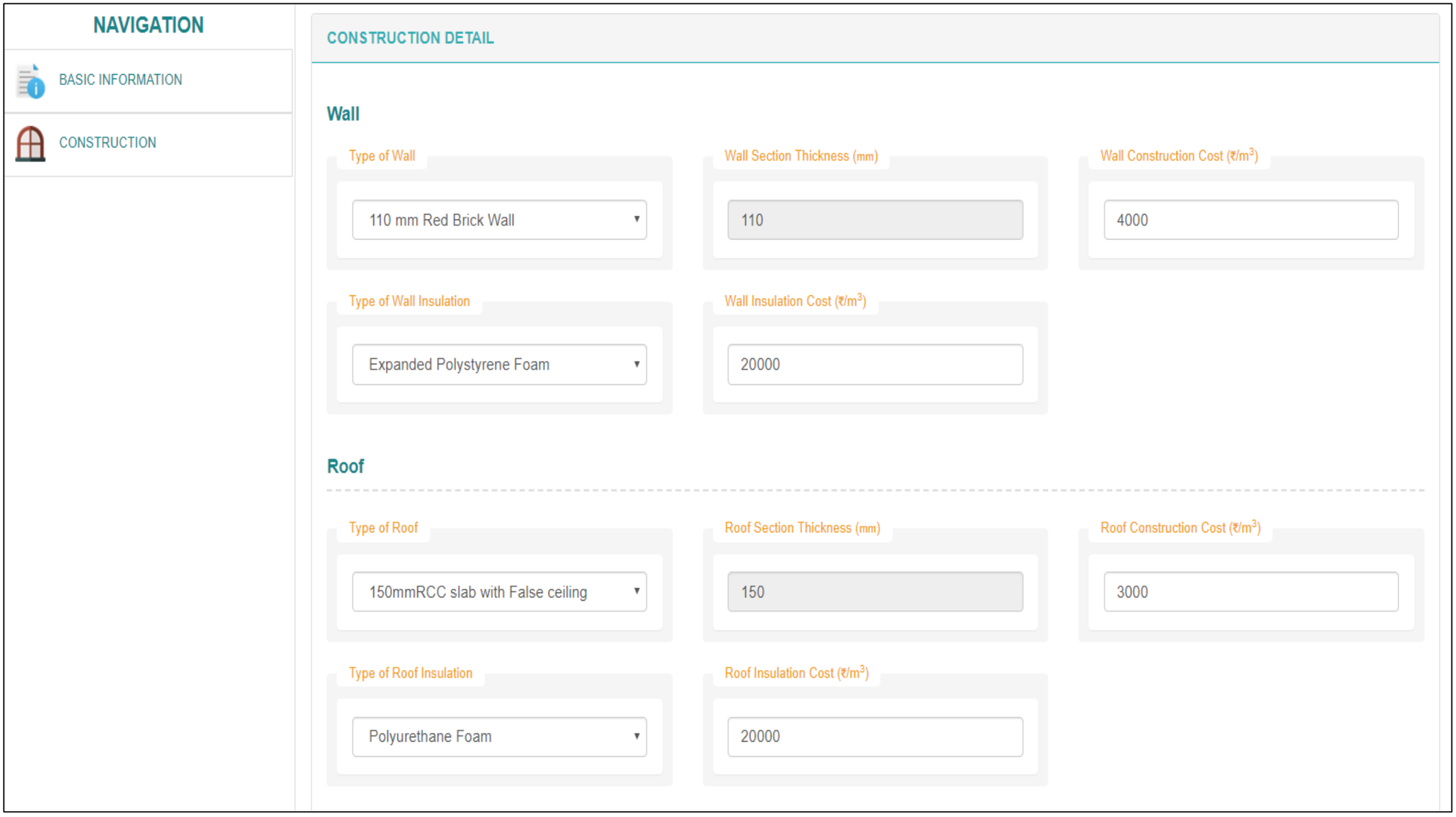
The user has the option to export the results in PDF format for later use, using the "Download Report" button on the results page.

The tool also predicts the Annual CO2 generation, Annual Operational cost of the design and Annual life cycle cost of the project based on the inputs given by the user



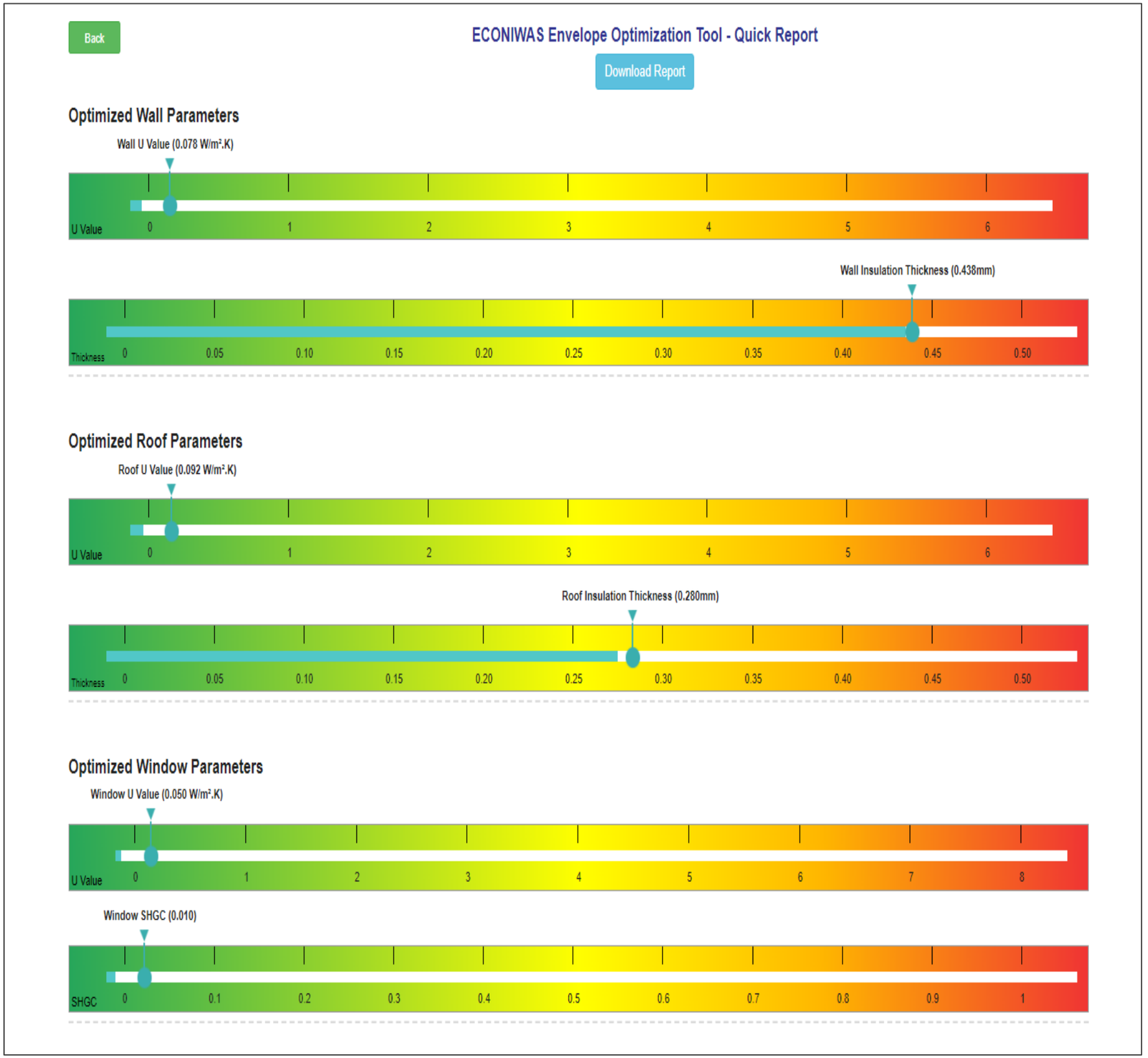
Envelope Optimization Tool

A quick envelope evaluation module to compute the most optimized set of U-values & SHGC for best wall, best roof and best window including thickness of selected insulation required on the selected base assemblies of wall and roof for the selected location based on life cycle cost of the building envelope.



ENVELOPE OPTIMIZATION TOOL - RESULTS

On the submission of the form, the tool performs the optimization using energy plus server-side simulation platform to predict the optimized U-value, SHGC for envelope components (wall, roof windows) as well as thickness of insulation for wall and roof assemblies. The user also has the option to export the results in PDF format for later use, using the “Download Report” button on the results page.



Session 5

a) **Low Energy Comfort Systems and BEE Star Labelling**
b) **Indian & International Best Practices**

BEE STAR LABELLING FOR RESIDENTIAL BUILDINGS

Labeling Types

"Applied For" label

Applicable for new buildings with construction permit issued by the authorities having jurisdiction

Applicable for existing and new buildings. For new building, this label can only be awarded after the occupancy certificate is issued by the authorities having jurisdiction

"Final" Label

Labeling Process

Outline of process for awarding BEE Star Label for Residential Buildings

Preparation Stage

- Pre-requisites for applying
- Evaluation for eligibility requirements

Application processing

- Registration
- Online application
- Scrutiny of application
- Approval for label

Implementation

- Transfer from "Applied for" to "Final" label
- Ownership transfer
- Changes in label, already awarded

M&V

- Verification audits
- Data reporting

For more information: www.econiwas.com and www.beeindia.gov.in

About the Program

The program aims to develop national energy efficiency label for residential buildings to enhance energy efficiency in the residential sector.

A residential building label is a benchmark to compare a home over the other on the energy efficiency standards

Need of Residential Building Labeling Program

Real estate market is expected to climb up to US$ 180 billion by 2020

Residential sector is expected to contribute 11% to India's GDP by 2020.

More than 3 billion square meters of new residential buildings will be added by 2030

Electricity demand due to residential sector is expected to reach 698 billion units by 2030 from 2018 value of 250 billion units

BEE STAR LABELLING FOR RESIDENTIAL BUILDINGS

Program Objectives

The objective of the program is to provide:-

- information to consumers on the energy efficiency standard of the Homes
- Facilitation in the implementation of EcoNiwas Samhita 2018
- a consumer driven market transformation business model solution for Energy Efficiency in housing sector
- steering the construction activities of India towards international best practices norms

Program Scope

The program is applicable for all single and multiple dwelling unit in the country for residential purpose

5 star rated home is **40%** more energy efficient than 1 star rated home

Energy Savings

Annual saving of 90 Billion Units in the year of 2030

Benefits from the labeling program

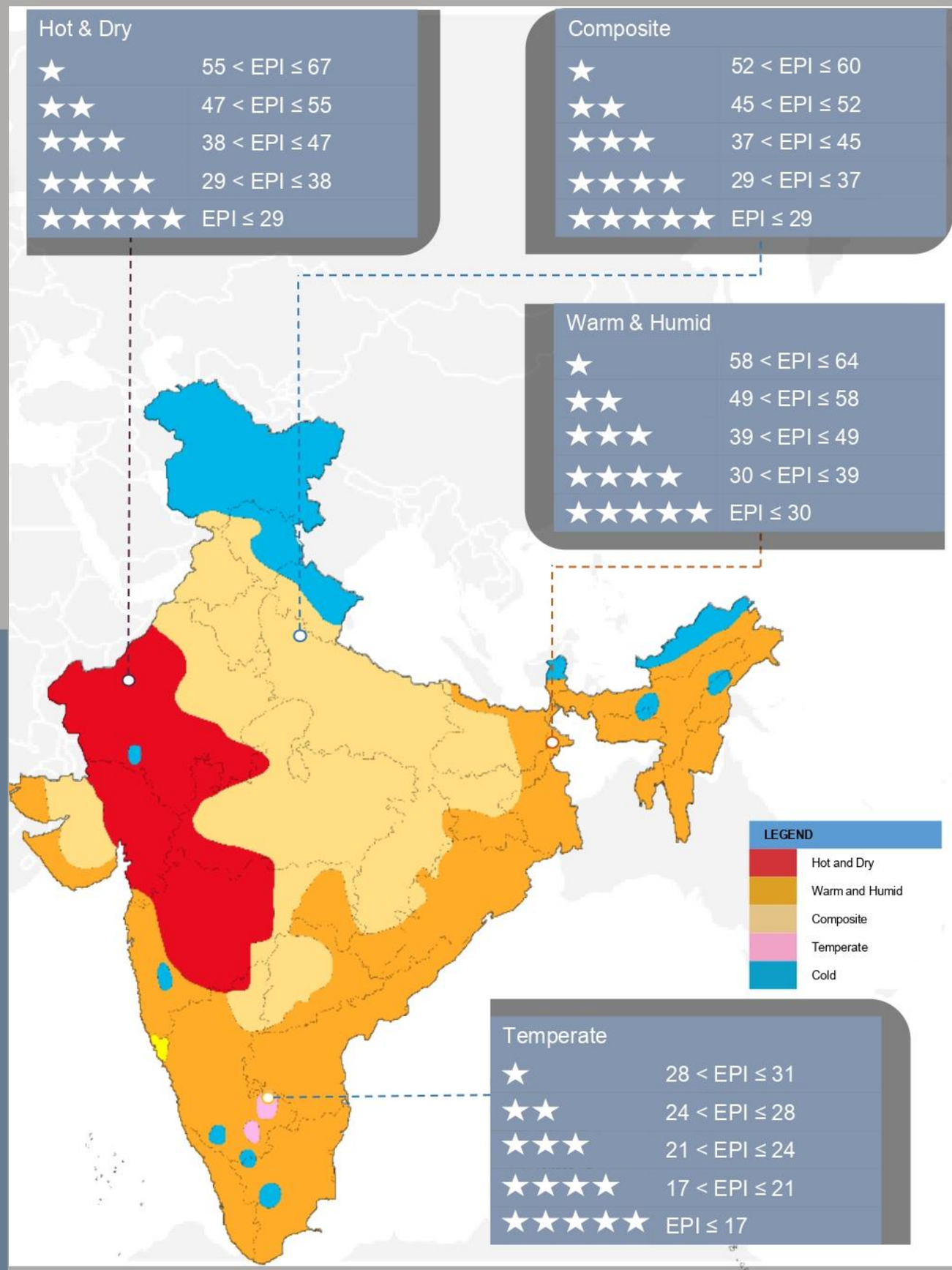
- Cumulative saving of 388 billion units of electricity by 2030
- Reduction of carbon emission by 3 billion tones by 2030
- Increased uptake of energy efficient construction in India
- Facilitate energy efficient materials and technologies market supporting the "Make in India" initiative
- Improve environmental resilience and energy security
- Sustainable living standards

Residential Building Star Rating Plan

Hot & Dry	
★	55 < EPI ≤ 67
★★	47 < EPI ≤ 55
★★★	38 < EPI ≤ 47
★★★★	29 < EPI ≤ 38
★★★★★	EPI ≤ 29

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

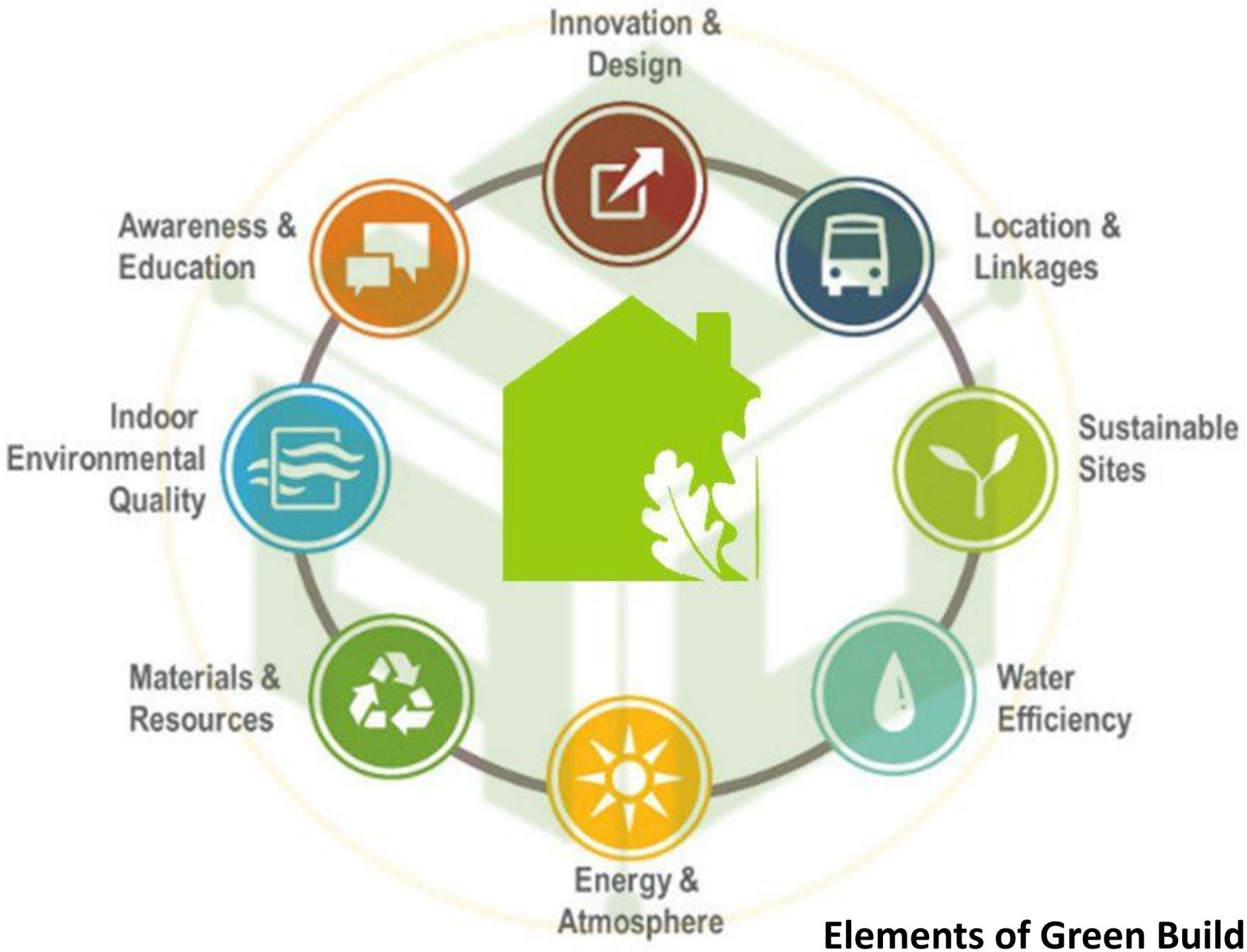
Warm & Humid	
★	58 < EPI ≤ 64
★★	49 < EPI ≤ 58
★★★	39 < EPI ≤ 49
★★★★	30 < EPI ≤ 39
★★★★★	EPI ≤ 30



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

GREEN BUILDING

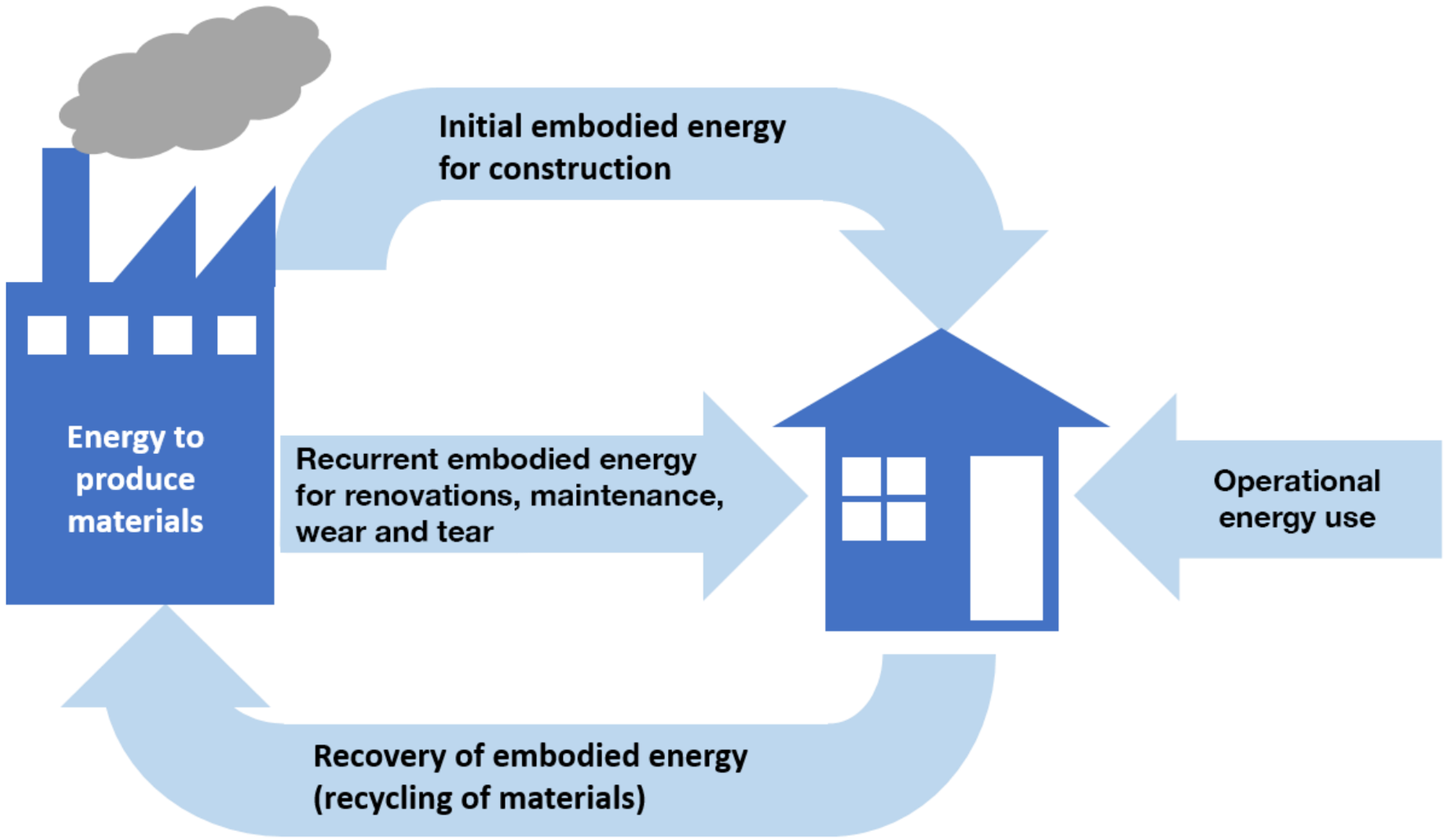
A ‘green’ building is a building that, in its design, construction or operation, reduces or eliminates negative impacts, and can create positive impacts, on our climate and natural environment. Green buildings preserve precious natural resources and improve our quality of life.



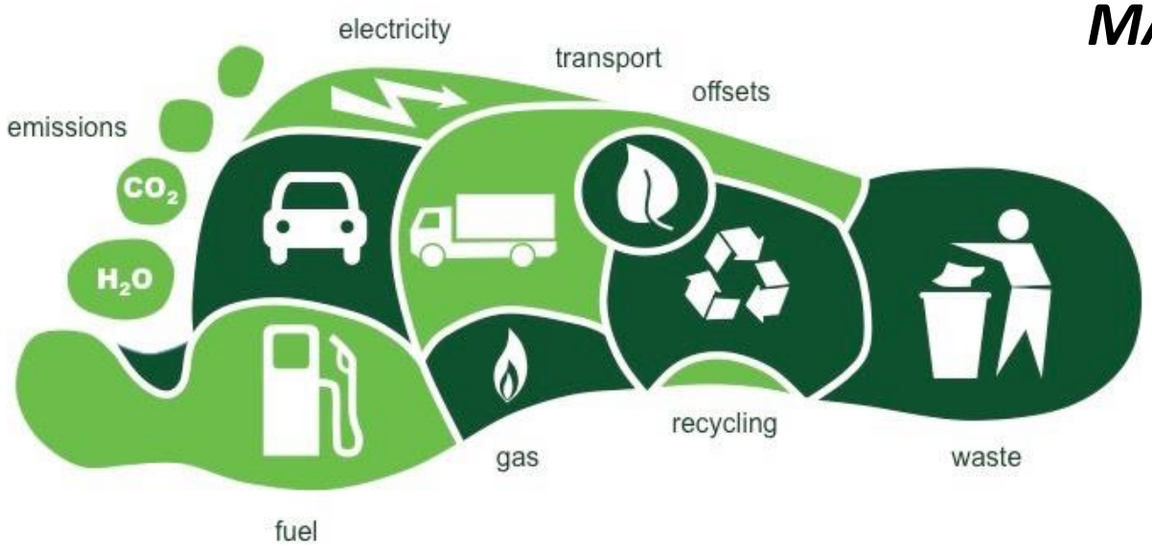
Elements of Green Building Design

EMBODIED ENERGY

Embodied energy is the energy consumed by all of the processes associated with the production of a building, from the mining and processing of natural resources to manufacturing, transport and product delivery. Embodied energy does not include the operation and disposal of the building material. This would be considered in a life cycle approach. Embodied energy is the 'upstream' or 'front-end' component of the lifecycle impact of a home.



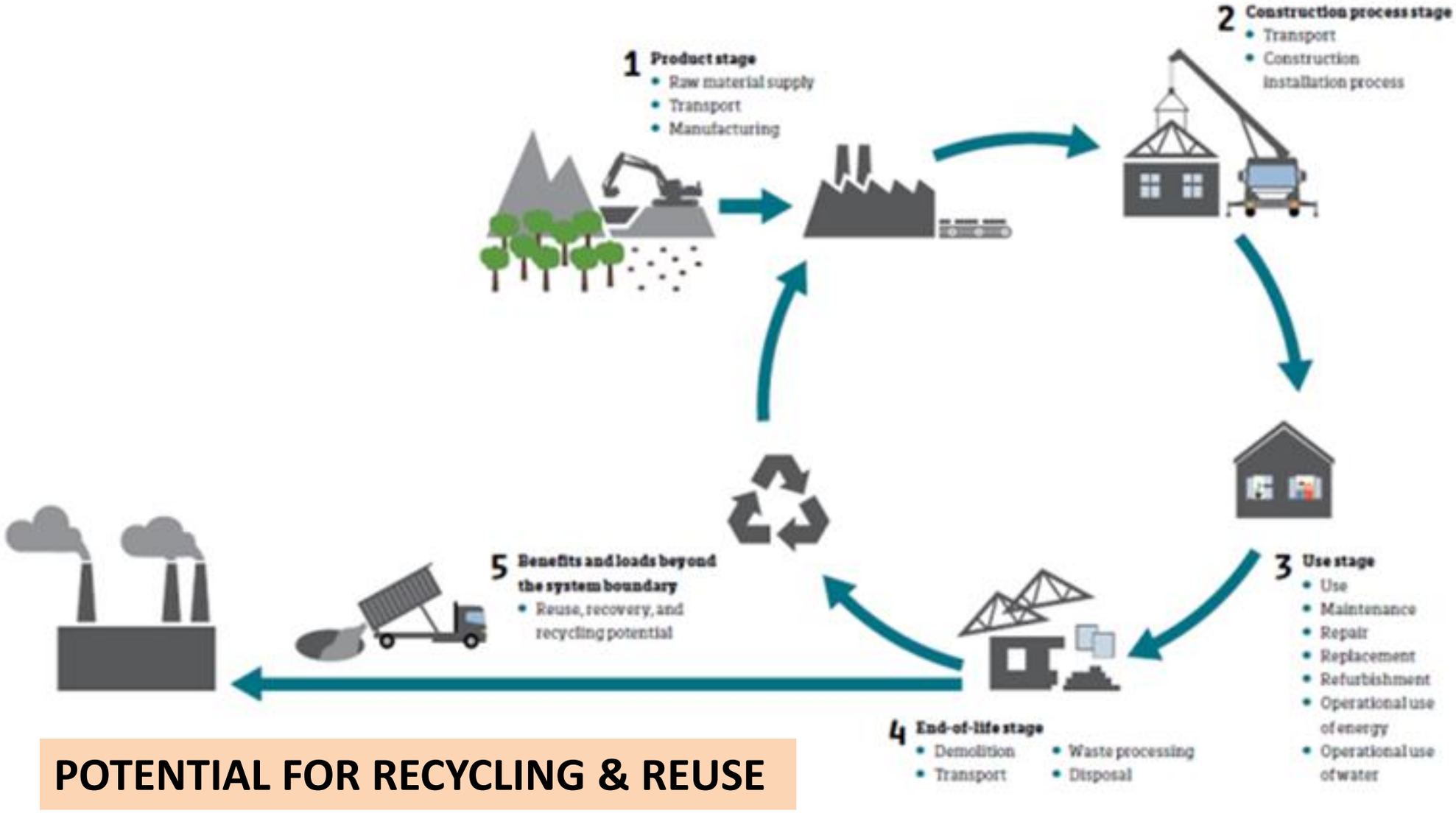
INDIGENOUS AND LOW-EMBODIED MATERIALS



MATERIALS WITH

LEAST CARBON FOOTPRINT

LOW CARBON EMISSION



POTENTIAL FOR RECYCLING & REUSE

Table 4. *Embodied energy in various walling and floor/roofing systems.*

Type of building element	Energy per unit (GJ)
Burnt clay brick masonry (m^3)	2.00–3.40
SMB masonry (m^3)	0.50–0.60
Fly ash block masonry (m^3)	1.00–1.35
Stabilized rammed earth wall (m^3)	0.45–0.60
Unstabilized rammed earth wall (m^3)	0.00–0.18
Reinforced concrete slab (m^2)	0.80–0.85
Composite SMB masonry jack-arch (m^2)	0.45–0.55
SMB filler slab (m^2)	0.60–0.70
Unreinforced masonry vault roof (m^2)	0.45–0.60

GREEN BUILDING – BEST PRACTICES

1 Increased water preservation efforts

- Rain water harvesting
- Using building material, which requires less curing or water after
- Use of native species in landscape

2 Improved Environmental product market

- Use of low VOC content material
- High SRI paints
- Fly ash bricks
- EPS Panel

3 Fewer Wastewater Treatment Plants

- Use of water efficient fixtures
- Monitoring and optimization of overflow of water

GREEN BUILDING – BEST PRACTICES

4 Fewer Power Plants & Power lines

- Use of energy efficient appliances and systems

5 Equitable access to transportation infrastructure

- Encourage use of public transport / encourage to use vehicle with low emission

6 Better comfort and productivity

- Thermal comfort will lead to better productivity

LEARNINGS

- Mainstreaming passive strategies in buildings for thermal comfort can significantly reduce cooling, ventilation and lighting requirements in buildings;

- Lesser dependency on mechanical cooling/ heating approaches will decrease formation of surface ozone, hence better air quality.

- Greater awareness of the benefits of sustainable building design will spur greater demand from all strata of society

- Sensitivity in building practices will tend to decrease disparity in thermal comfort of different economic classes.

- **Make active strategies passive, and passive strategies active.**

- **70% of the buildings required in India by 2030 are yet to be built. Maintaining status quo is irrelevant, and there is a great opportunity for incorporating passive design strategies successfully across our built environment.**

Source: McKinsey

Thank you.

time for a little

question & answer

session