

# RACHNA 2.0

RESILIENT, AFFORDABLE AND COMFORTABLE HOUSING THROUGH NATIONAL ACTION

## THERMAL COMFORT IN AFFORDABLE HOUSING

### Climate Smart Buildings (CSB)

- Head Office, LHP Indore (M.P.)

Cluster cell Indore, Madhya Pradesh under Global Housing Technology Challenge - India (GHTC-India)

## MoHUA

### 'Housing for All' -2022

Under the Mission, Ministry of Housing and Urban Affairs (MoHUA), provides Assistance to Central Government in implementing through States and Union Territories for providing houses to all eligible beneficiaries by 2022. Addressing the affordable housing requirement in urban areas through:

#### AFFORDABLE HOUSING

Partnership with Public and Private Sectors

#### PROMOTION

Affordable housing through CLSS

#### SUBSIDY

In-situ Slum Redevelopment (IsSR) & other Beneficiary

#### SLUM RE-HABILITATION

Developers (PnP) using land resource

## GIZ

### Under IGEN Program

For over 60 years, the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH has been working jointly with partners in India for sustainable economic, ecological, and social development.

- an international cooperation enterprise for sustainable development, operates worldwide, for public benefits
- owned by the German Federal Government, looking forward to implement sustainable development programs in partner countries
- it supports key initiatives such as Smart Cities, Clean India and Skill India. GIZ is also in close cooperation with Indian partners, devises tailor-made, jointly-developed solutions to meet local needs and achieve sustainable and inclusive development in various sectors.



Aware  
Stakeholders



Role &  
Responsibilities



PnP  
Associations



Technical  
Advisory



Smart  
Measures

TOWARD'S  
SUSTAINABLE DEVELOPMENT GOALS



ECONOMY

**9. Industry Innovation and Infrastructure:**  
Build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation



SOCIETY

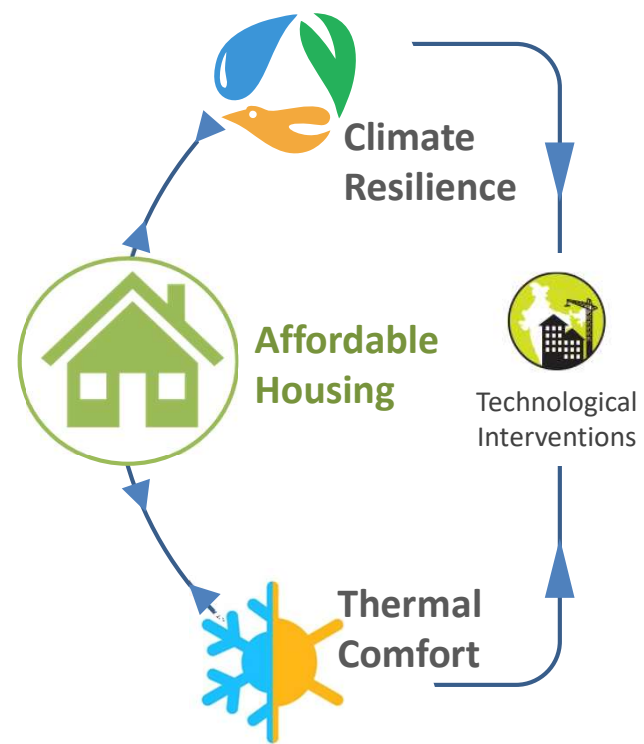
**7. Affordable and Clean Energy:**  
Ensure access to affordable, reliable, sustainable, and modern energy for all

**11. Sustainable Cities and Communities:**  
Make cities and human settlements inclusive, safe, resilient, and sustainable



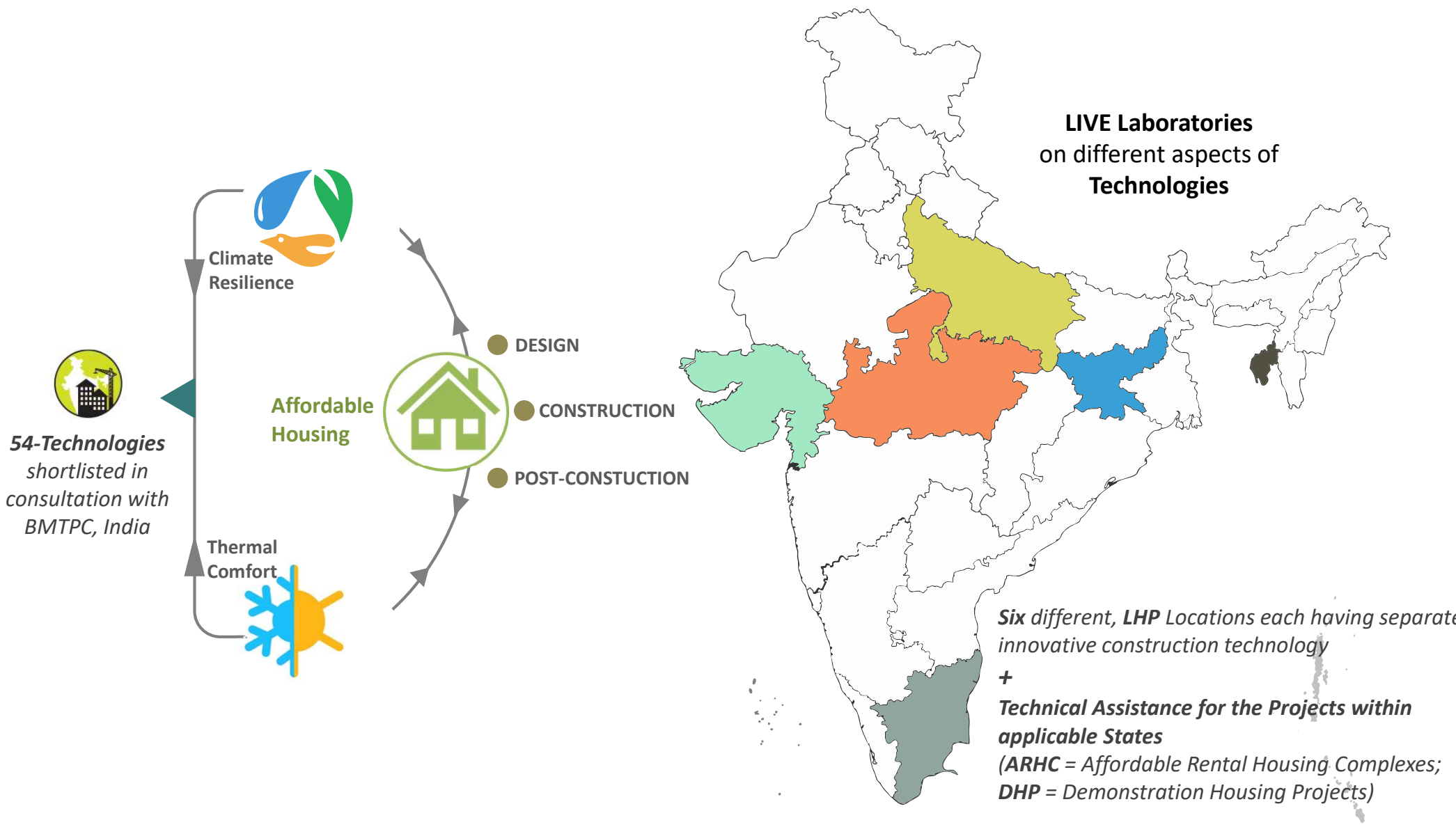
BIOSPHERE

**13. Climate Action:**  
Take urgent action to combat climate change and its impacts



**Global Housing Technology Challenge-India (GHTC-I)**  
Intends to identify the best innovative construction technologies available globally and implement through a challenge process.  
This challenge seeks to promote future potential technologies through incubation support; and it's acceleration by means of workshops, in order to foster an environment of research and development in the country.

# AIM & CONCEPT





# ABOUT CSB-CELL (Madhya Pradesh)

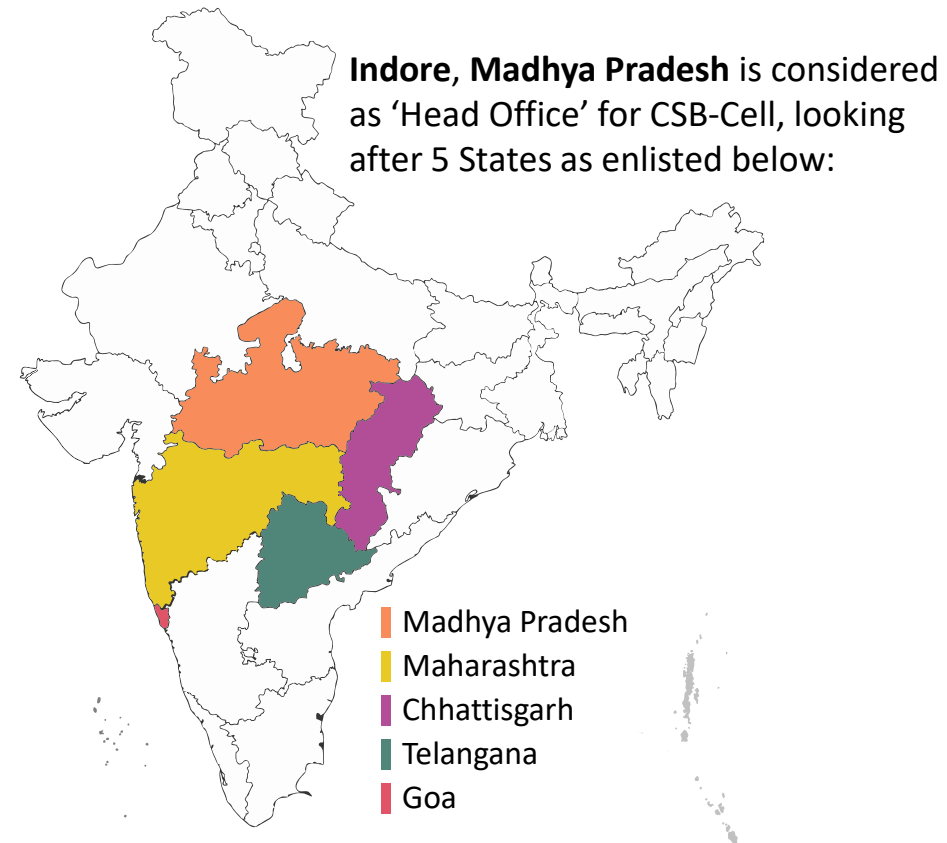


## CLIMATE SMART BUILDINGS (CSB)

A Program initiated under Indo-German Energy Programme (aka *IGEN*) to nurture the commitment of Indian Government towards SDG Goals.

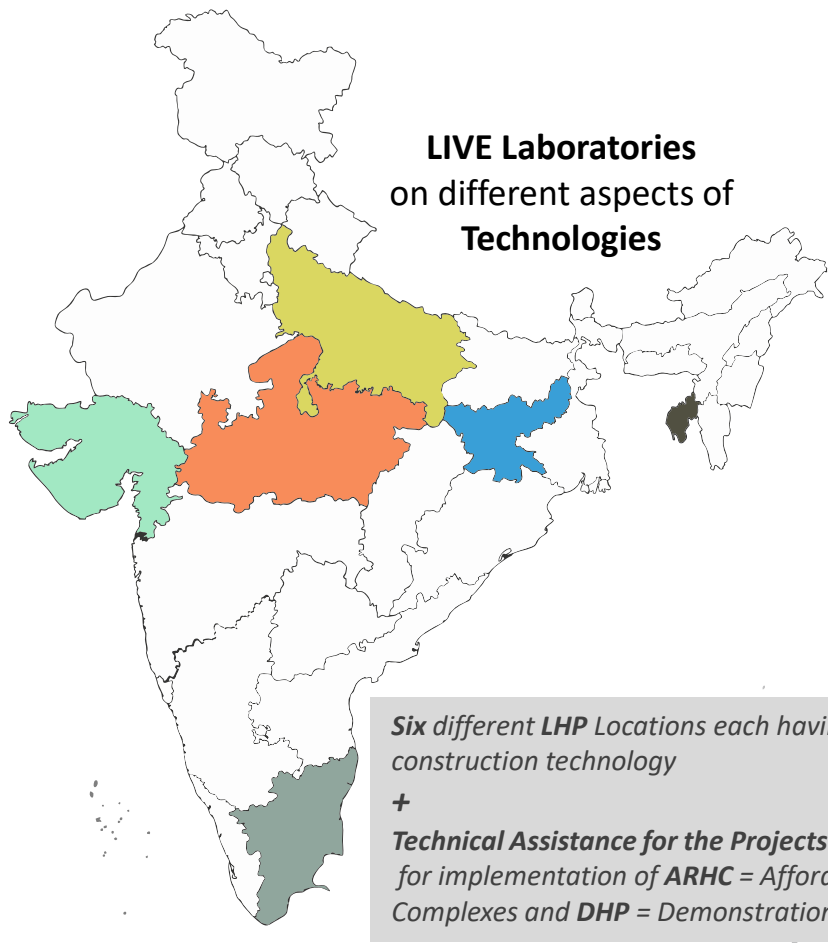
Thus, a CSB-Cell is proposed to extend the technical assistance and cooperation for the following:

- in developing action plan to design building which are thermally comfort and climate resilient, for mass scale application-
- in implementation of Global Housing Technology Challenge-India (GHTC-India)





# LHP INTRODUCTION



- RAJKOT,** Gujarat | Monolithic Concrete Construction using Tunnel Formwork
- INDORE,** Madhya Pradesh | Prefabricated Sandwich Panel System
- LUCKNOW,** Uttar Pradesh | PVC Stay In Place Formwork System
- RANCHI** Jharkhand | Precast Concrete Construction System-3D Volumetric
- AGARTALA** Tripura | Light Gauge Steel Structural System & Pre-engineered Steel Structural System
- CHENNAI** Tamil Nadu | Precast Concrete Construction System- Precast Components Assembled at Site



Transfer of  
Technology



Mass  
Production



Awareness &  
Learning



Thermal  
Comfort



Climate  
Resilient



Live  
Laboratory

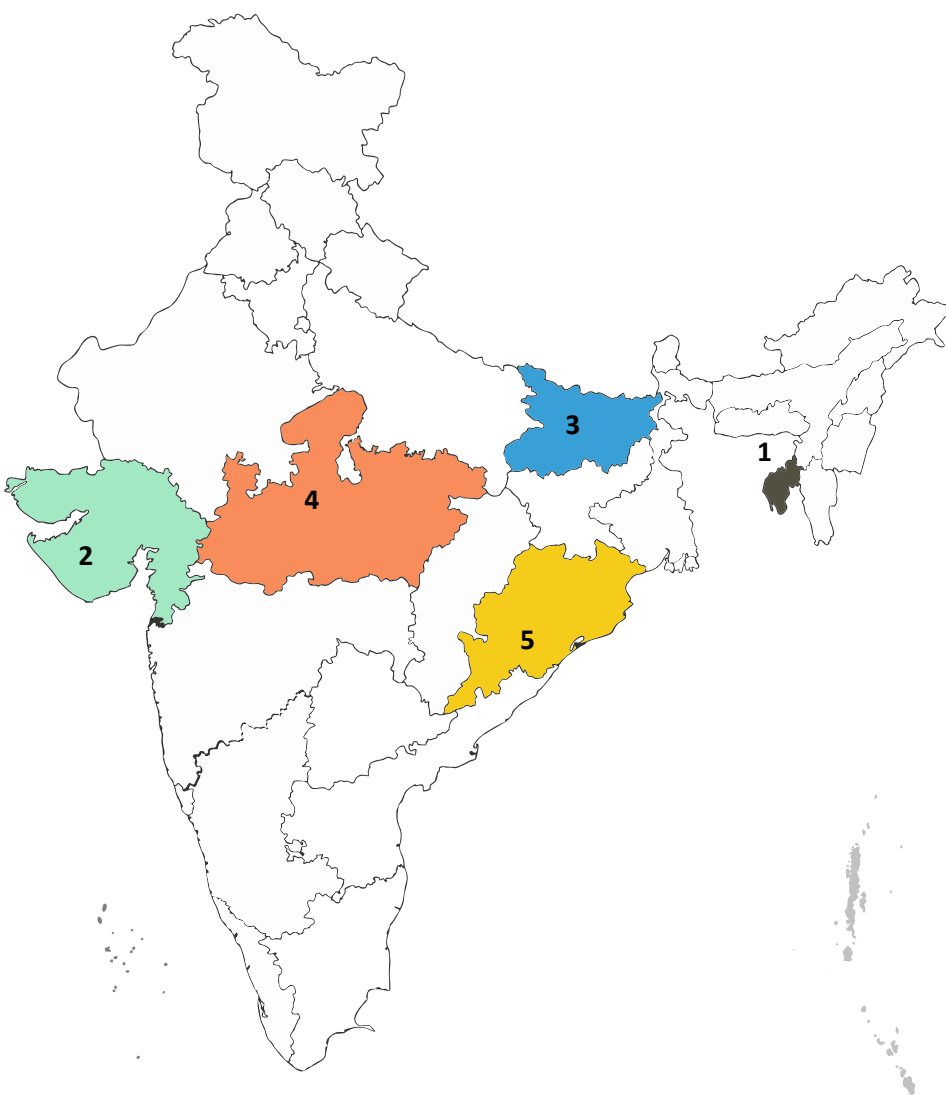


Rapid and  
Economical



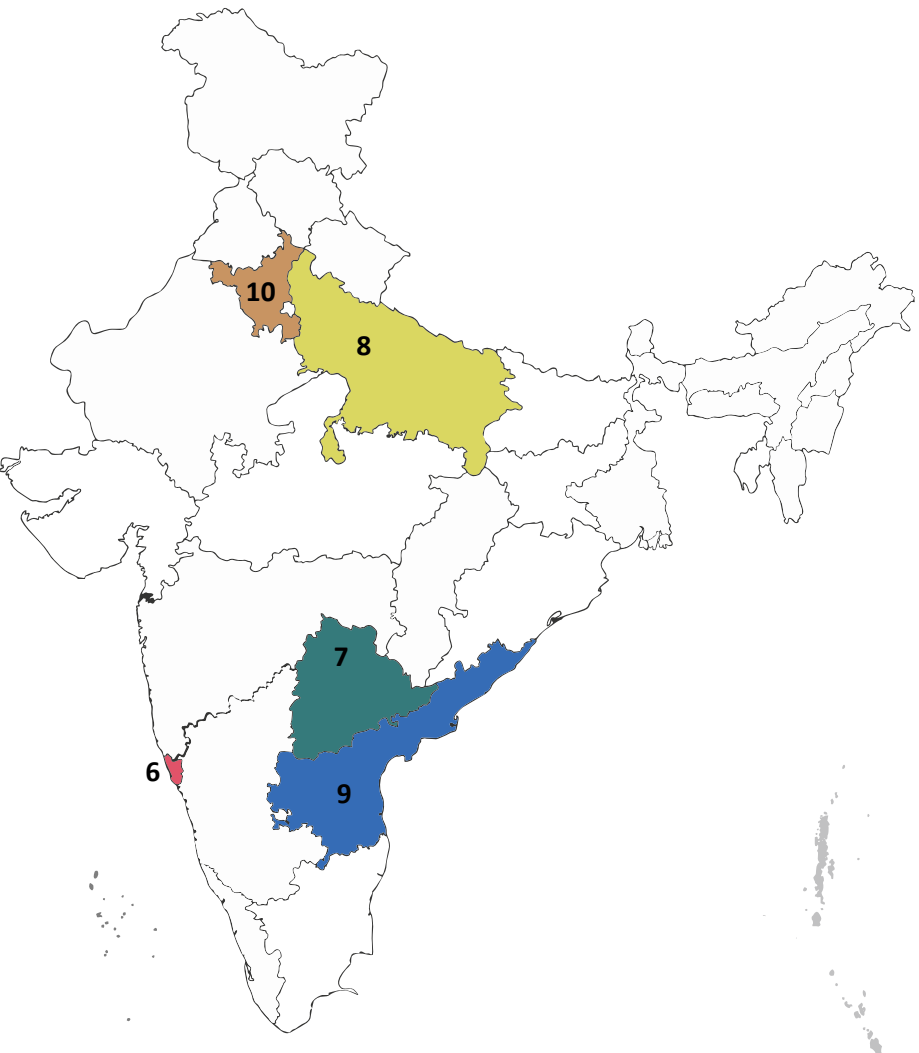
Compliance  
& Validation

# DEMONSTRATION HOUSING PROJECTS



1	Agartala, Tripura	<b>STAY IN PLACE FORMWORK SYSTEM -</b> Structural stay in place steel formwork system <i>End-user: Shelter for Destitute Women Houses: 40; (G+1)/1</i>
2	Ahmedabad, Gujrat	<b>PRECAST CONCRETE CONSTRUCTION SYSTEM -</b> Integrated Hybrid Solution-One <i>End-user: PMAY(U) Beneficiaries Houses: 40; (G+3)/1</i>
3	Bihar Sharif, Bihar	<b>STAY IN PLACE FORMWORK SYSTEM -</b> Structural stay in place steel formwork system <i>End-user: Sports Hostel and other Social Welfare Activities Houses: 36; (G+2)/1</i>
4	Bhopal, Madhya Pradesh	<b>INSULATED CONCRETE FOAM WORK</b> External foam based insulation sprayed on exposed walls <i>End-user: Sports Hostel Houses:40; (G+3)/1</i>
5	Bhubneshwar, Odisha	<b>PREFABRICATED SANDWICH PANEL SYSTEM-</b> Reinforced Expanded Polystyrene sheet core with sprayed concrete as wall & slab <i>End-user: PMAY(U) Beneficiaries Houses:32 (G+3)</i>

# DEMONSTRATION HOUSING PROJECTS



6	<b>Chimbel, Goa</b>	<b>PRE-ENGINEERED STRUCTURE WITH PRE-FAB PANELS -</b> Light gauge steel framed structure with precast concrete panels on both side of wall and light weight concrete as infill <i>End-user: Old-age Homes</i> Houses: <b>40; (G+3)/1</b>
7	<b>Hyderabad, Telangana</b>	<b>LGS STRUCTURE &amp; STEEL FORMWORK SYSTEM -</b> Light gauge steel structure system (16-houses); Stay in place form work (16-houses) <i>End-user: Training Hostel</i> Houses: <b>32; (G+3)/1</b>
8	<b>Lucknow, Uttar Pradesh</b>	<b>STAY IN PLACE FORMWORK SYSTEM -</b> Stay in place EPS based double walled panel system with concrete infilled <i>End-user: Hospital Patients &amp; Attendees</i> Houses: <b>40; (G+1)/1</b>
9	<b>Nellore, Andra Pradesh</b>	<b>STAY IN PLACE FORMWORK SYSTEM -</b> Glass-fibre reinforced gypsum panel (GFRG) <i>End-user: Social Welfare Activities</i> Houses: <b>36; (G+1)/1</b>
10	<b>Panchkula, Haryana</b>	<b>PREFABRICATED SANDWICH PANEL SYSTEM-</b> Light Gauge Steel Framework System (LGSF) with cement-fibre board on both side of walls and infill of rock wool <i>End-user: PMAY(U) Beneficiaries</i> Houses: <b>40; (G+3)</b>

# AFFORDABLE RENTAL HOUSING COMPLEXES

## ARHCs

### Affordable Rental Housing Complexes

Progress - March, 2022

5,478

Existing Government funded vacant houses converted into ARHCs for Urban Migrants/ Poor

Proposal for converting 7,483 vacant houses into ARHCs processed in the States of Gujarat, Himachal Pradesh, Haryana, Madhya Pradesh, Uttarakhand and Rajasthan



#### UT of Chandigarh

2,195 vacant houses converted into ARHCs



#### Rajasthan

480 vacant houses converted into ARHCs in Chittorgarh



#### Gujarat

2,467 vacant houses converted into ARHCs (Ahmedabad-1,376, Rajkot-698 & Surat-393)



#### UT of J&K

336 vacant houses converted into ARHCs in Jammu

The ARHC scheme will be implemented through two models:

1. Utilizing existing vacant houses funded by Government, converted into ARHCs through Public Private Partnership or by Public Agencies
2. Construction, Operation and Maintenance of ARHCs by Public/ Private Entities on their own available vacant land



# AFFORDABLE RENTAL HOUSING COMPLEXES





# LAUNCH OF HANDBOOK – THERMAL COMFORT & INNOVATIVE TECHNOLOGIES



## Innovative Construction Technologies & Thermal Comfort in Affordable Housing

### HANDBOOK

Climate Smart Buildings

OCTOBER 2022



Ministry of Housing & Urban Affairs, Government of India  
Nirman Bhawan, New Delhi - 110001

#### Supported by



Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH  
Climate Smart Buildings (IGEN-CSB),  
B-5/5, Safdarjung Enclave, New Delhi 110029, India

#### Knowledge Partner



CEPT Research and Development Foundation (CRDF)  
CEPT University, K.L. Campus, Navrangpura,  
Ahmedabad 380009, India

#### Development Team

Prof. Rajan Rawal, Ph.D., CRDF, CEPT University  
Bhavya Pathak, CRDF, CEPT University  
Prof. Yash Shukla, Ph.D., CRDF, CEPT University  
Dr. Shailesh Kr. Agrawal, BMTPC  
Manish Kumar, Consultant, MoHUA  
S Vikash Ranjan, GIZ  
Govinda Somani, GIZ  
Prof. Rashmin Damle, CEPT University  
Palak Patel, CRDF, CEPT University

#### Graphics and layout by

Mona Galsar, CRDF, CEPT University, Dalip Kumar

**Published: October, 2022**

#### Disclaimer

Ministry of Housing & Urban Affairs (MoHUA), Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH and CRDF, CEPT University does not advertise any specific products and technologies pertaining to building envelope components in this handbook unless explicitly mentioned.

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

The Handbook is Comprehensive resource material on thermal comfort fundamentals and detailed exploration on innovative construction technologies. The handbook will equip the readers with theoretical knowledge, and with tools that will enhance their skills on mainstreaming thermal comfort in affordable housing.

Handbook



LHP Chennai Compendium



LHP Rajkot Compendium



### **Compendium of LHP Chennai & Rajkot**

The compendium capture the journey of design, planning and construction of LHP projects. It lays emphasis on the construction technologies used in two LHPs along with the construction process, project management and monitoring.

Further, it documents the series of activities being undertaken under the live laboratory component of GHTC-India for disseminating the learnings on use of innovative technologies for various stakeholders.

## **Compendium of 75 RACHNA Trainings on Affordable Housing & Thermal Comfort**

MoHUA in collaboration with BMTPC & GIZ Climate Smart Building program launched the initiative RACHNA. Under RACHNA, 75 trainings & events were hosted in various cities across India from March – August 2002, covering more than 4500 stakeholder from different domains. The Compendium is a compilation of these 75 training events, giving a glimpse of the concept behind these trainings, the focus areas and the proceedings of each of the 75 events.

Compendium on 75 RACHNA



**TEA BREAK**

## SESSION - 01

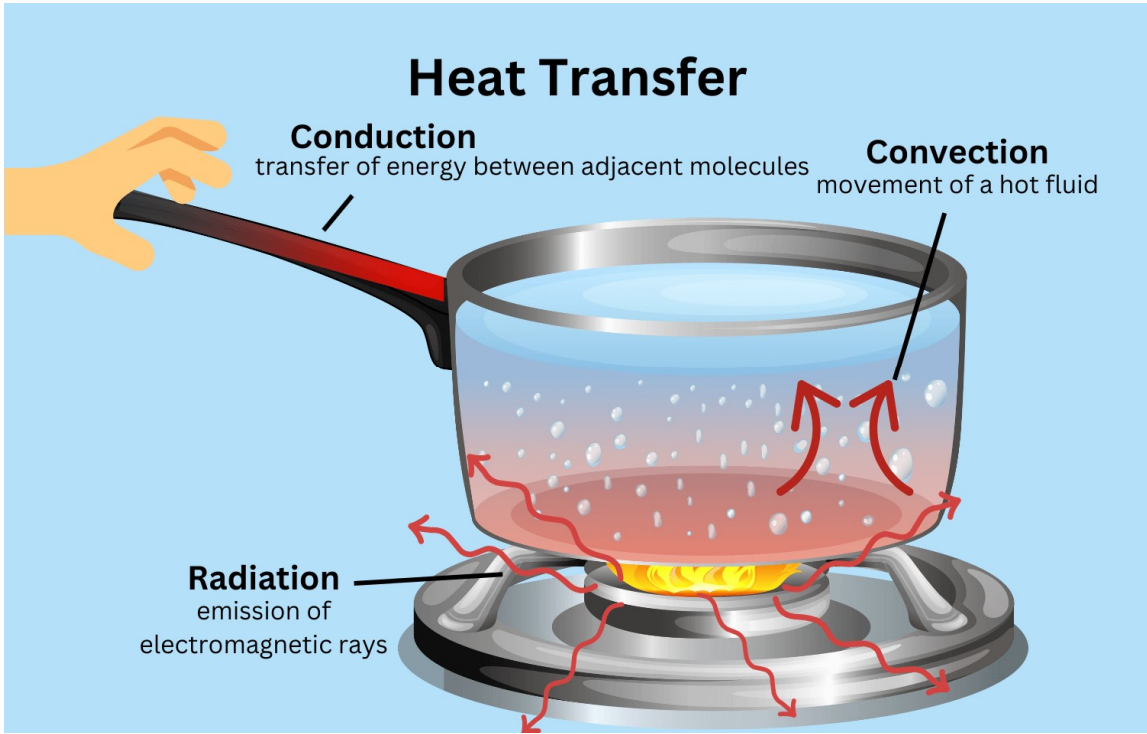
# THERMAL COMFORT IN AFFORDABLE HOUSING

Details mentioned under this section is taken from Handbook –

**“Innovative Construction Technologies & Thermal Comfort in Affordable Housing”**

More details about the topics can be taken from the document. It is freely available at

[https://ghtc-india.gov.in/Content/pdf/rachna/Rachna\\_Handbook.pdf](https://ghtc-india.gov.in/Content/pdf/rachna/Rachna_Handbook.pdf)



Modes Of Heat Transfer In Building Envelop

- ✓ Conduction
- ✓ Convection
- ✓ Radiation

Impact of design strategies on heat transfer through building envelope in various climates. Conduction Convection Radiation

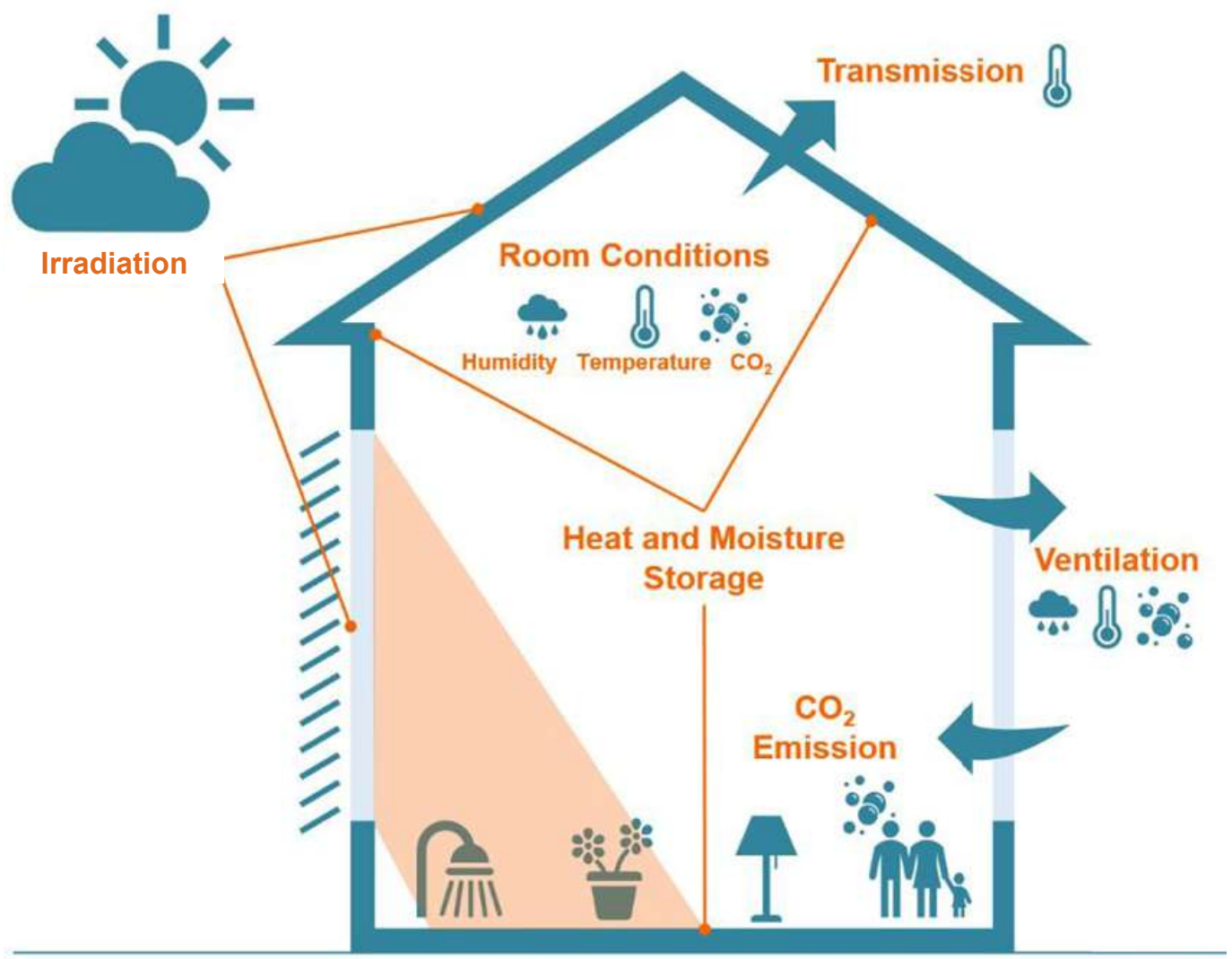
	Conduction	Convection	Radiation
Geometry - Massing	HD	WH	All Climates
Orientation		WH	All Climates
External Surface to Building Volume Ratio	HD	WH	HD
Extent of Fenestration and Thermal Characteristics	HD	WH	All Climates
Internal Volume – Stack Ventilation	X	HD	X
Location of Fenestration – Pressure Driven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

V. Low Low Neutral High V. High

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



CONCEPT



Design Considerations

- Humidity
- Air-speed
- Air Temperature
- Radiant Temperature

Design Aspects

- Health
- Resource Use
- Comfort
- Efficiency

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.



# FACTOR AFFECTING THERMAL COMFORT

## Environmental Factors

Air Temperature

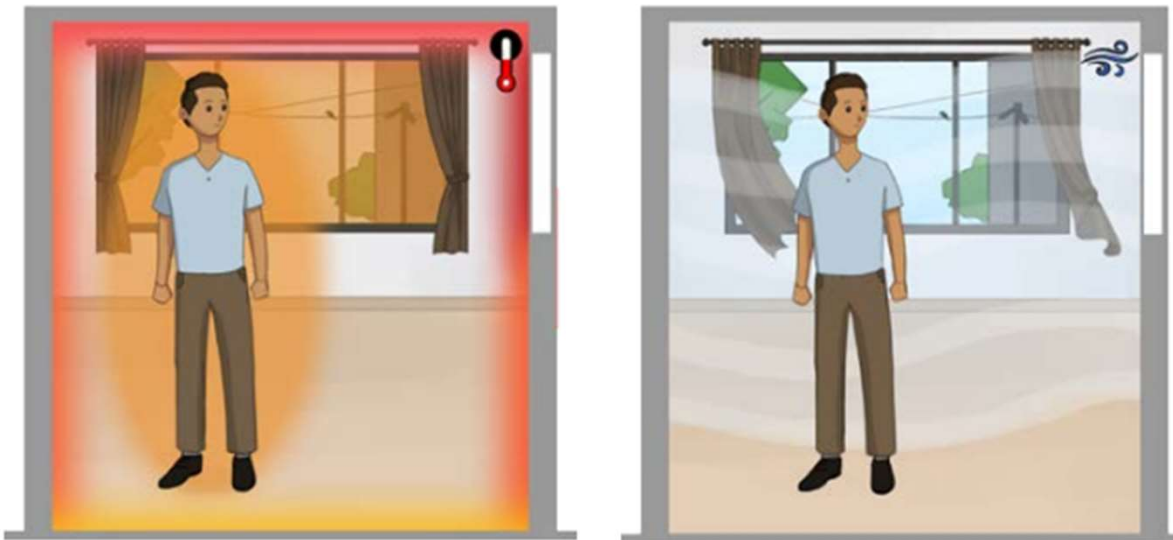
Relative Humidity

Mean radiant Temperature  
(MRT)

Air Speed



Factors affecting thermal comfort- Air Temperature ( $T_{air}$ ) and Relative Humidity (RH)



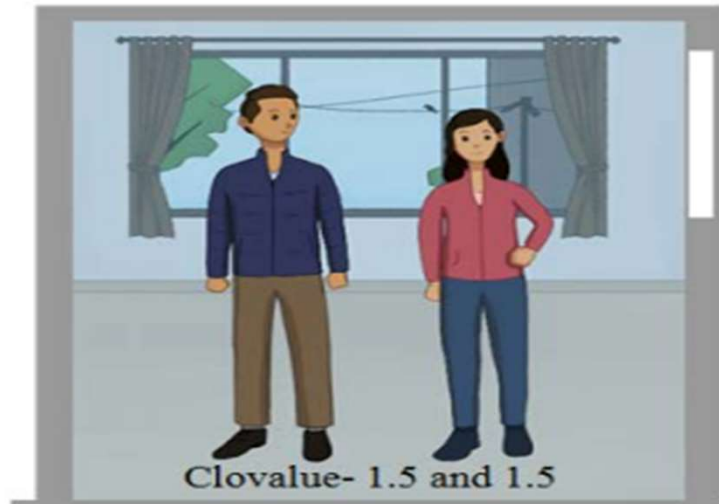
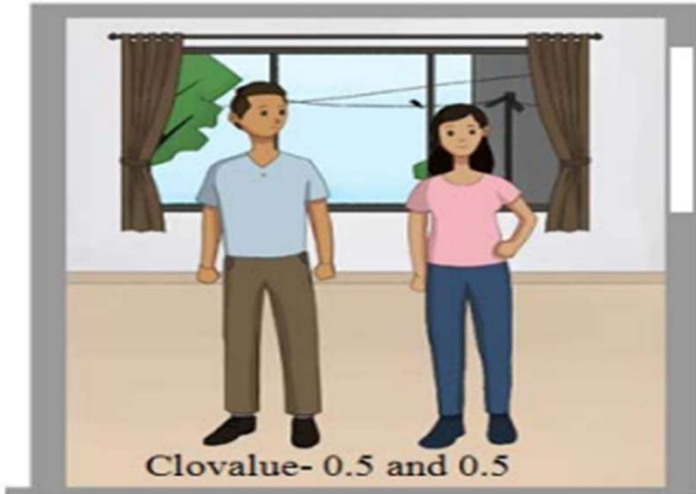
Factors affecting thermal comfort- Mean Radiant Temperature (MRT) and Air Speed

Moving air facilitates the evaporation of sweat from the skin surface, thereby contributing to thermal comfort.



# FACTOR AFFECTING THERMAL COMFORT

## Personal Factors - Clothing Value, Metabolic Rate

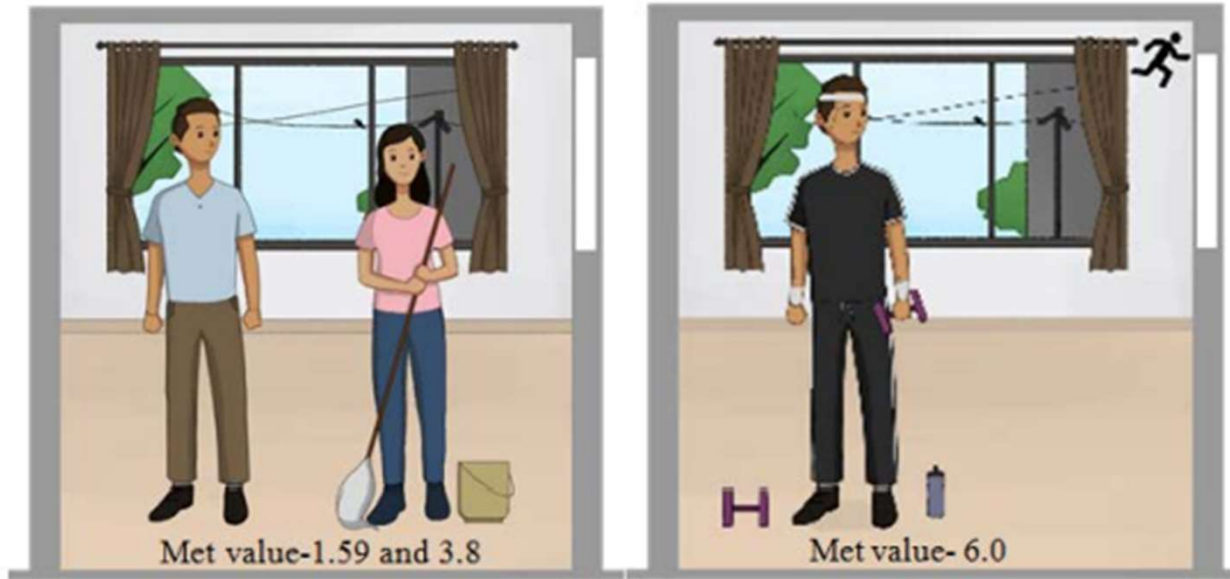


Factors affecting thermal comfort: Clothing Value (CLO)

- The amount and type of clothing worn by an individual affects the transfer of heat from the skin to the surrounding environment.
- Clothing acts as a barrier or resistance to sensible heat transfer.
- The degree of resistance depends on material of the clothing and number of layers in the ensemble

# FACTOR AFFECTING THERMAL COMFORT

**Other Factors** - Short term physiological adjustment, Long term physiological adjustment, Body shape and fat, Age and gender, State of health



Factors affecting Thermal Comfort: Metabolic Rates (MET)

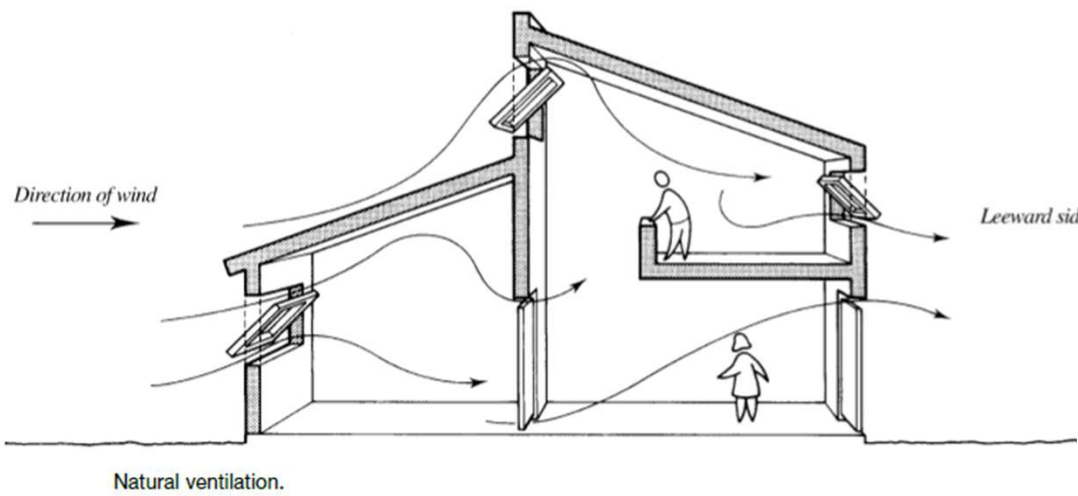


Other factors affecting Thermal Comfort Left: short term physiological adjustments; Right: Long term physiological adjustments

# FUNDAMENTAL OF BUILDING VENTILATION

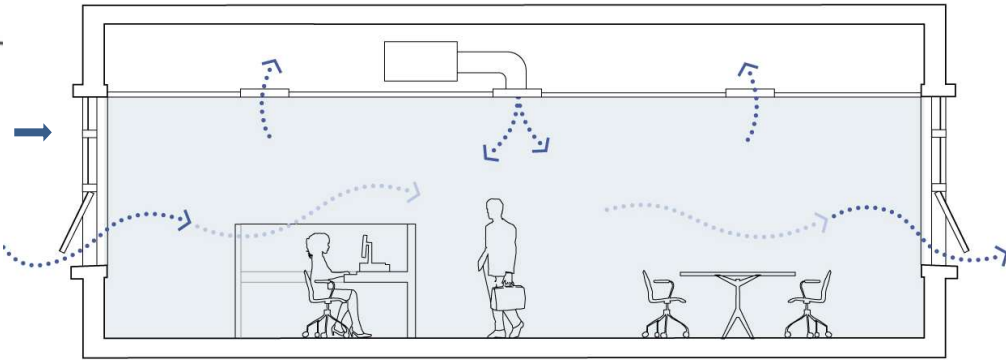
## Building operation modes

- ✓ Naturally Ventilated Buildings
- ✓ Mixed Mode Buildings
- ✓ Air-Conditioned Buildings

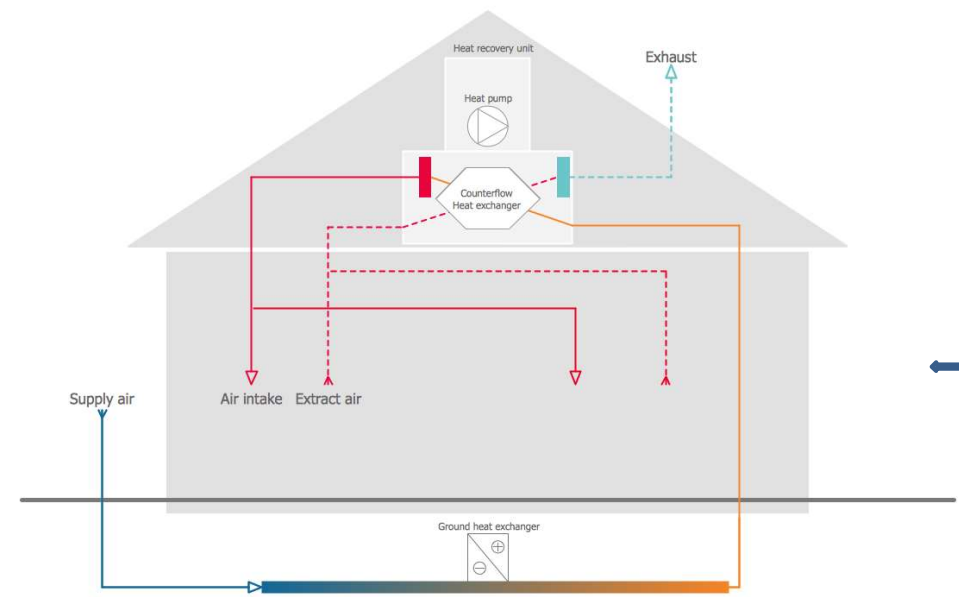


← Naturally Ventilated Buildings

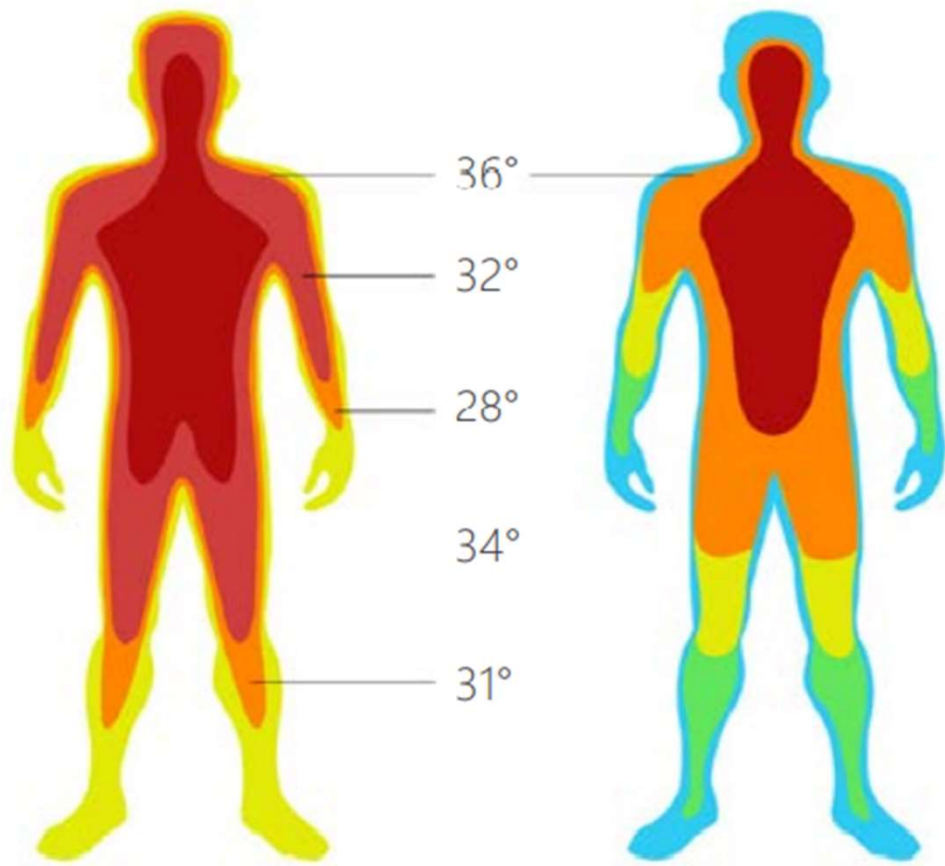
Mixed Mode Buildings →



← Air-Conditioned Buildings

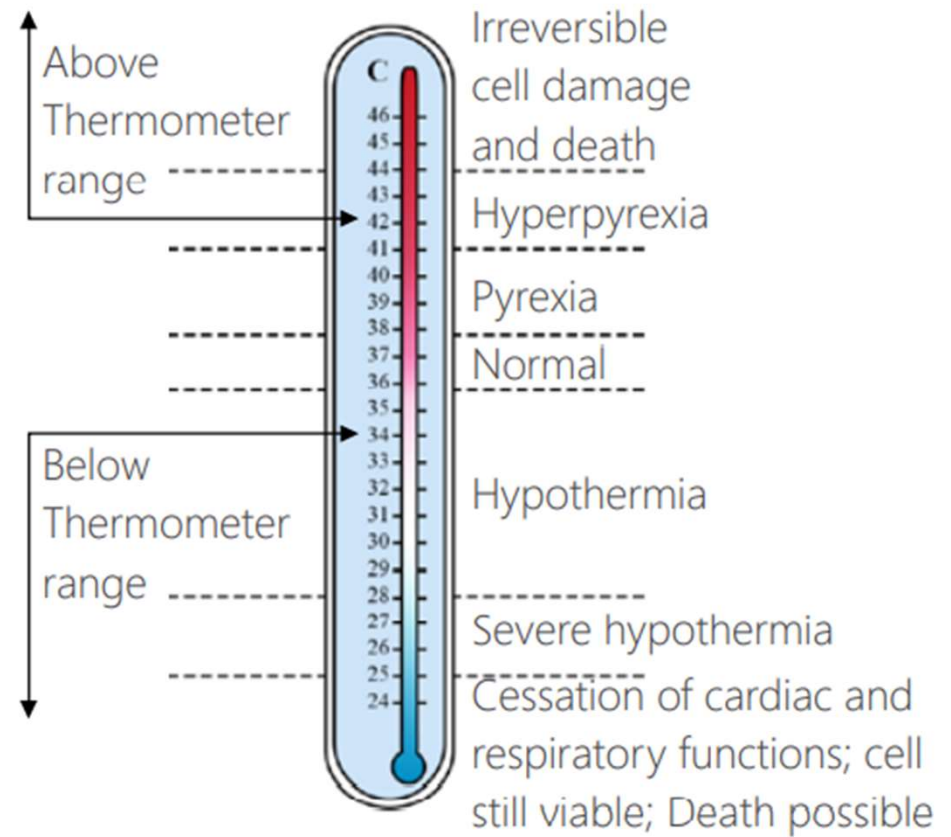


# DISCOMFORT IMPACT



30 °C - Ambient temperature - 20 °C

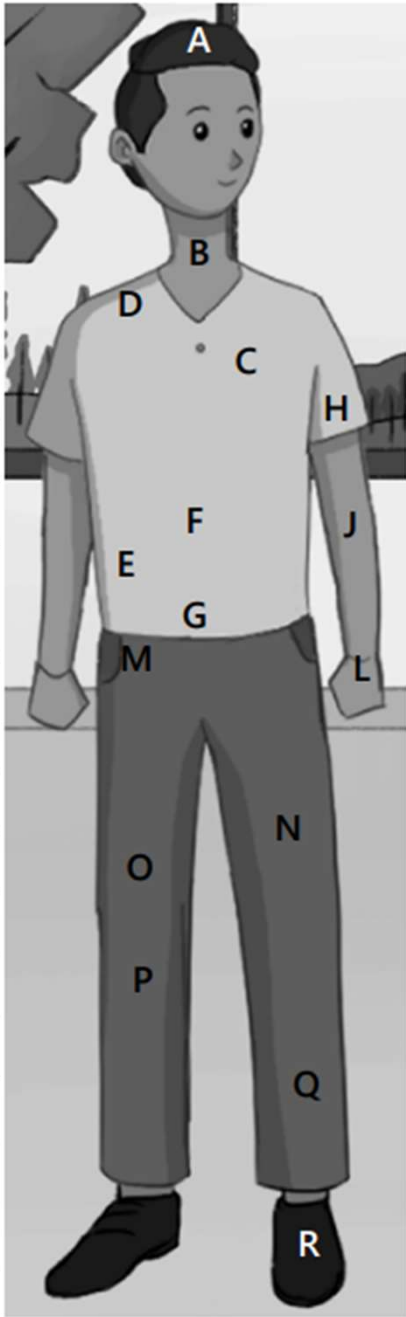
Skin surface temperatures of human body at various body parts in ambient temperature of 30°C vs 20°C



Comfort band of human body



# DISCOMFORT IMPACT

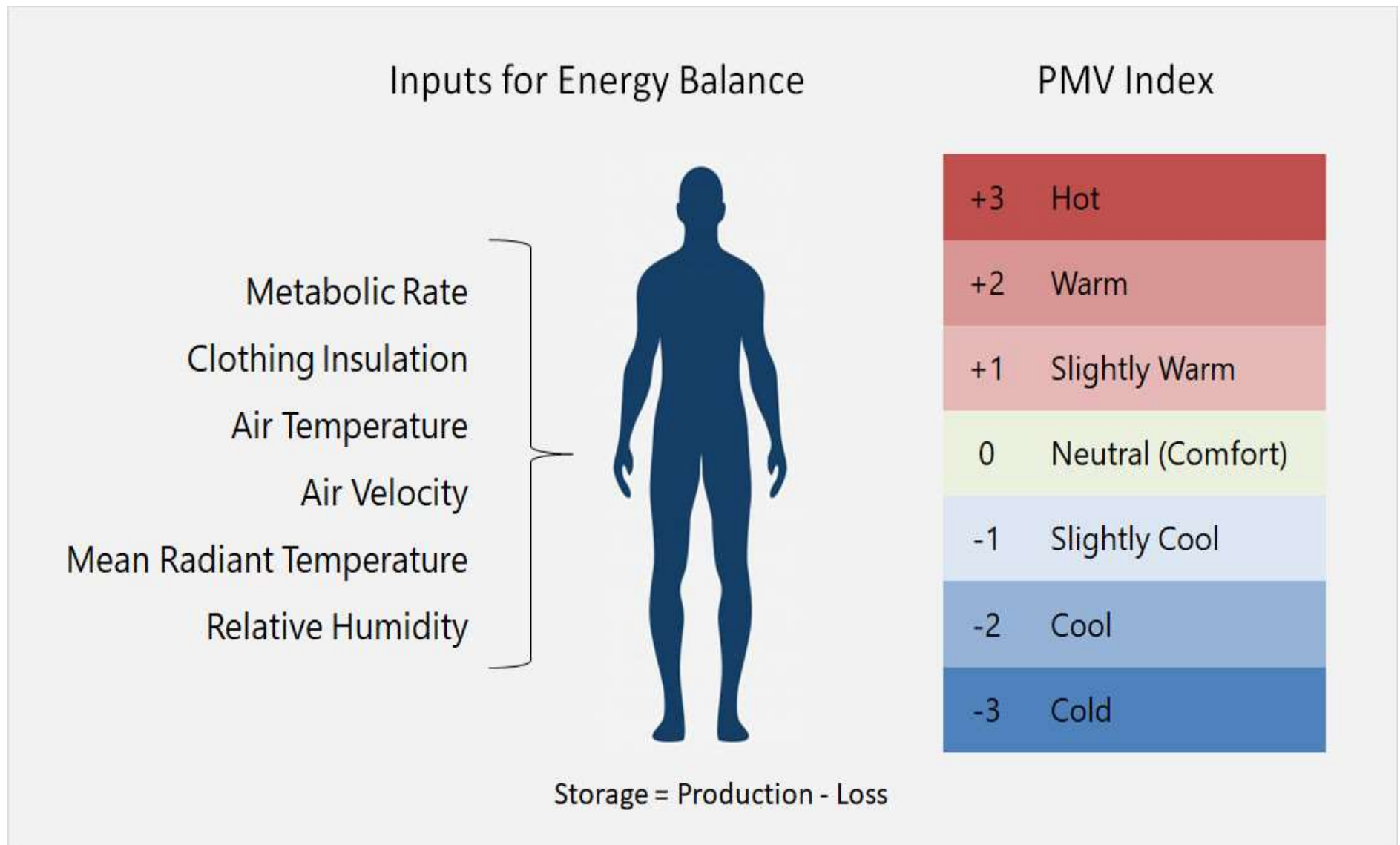


Body Part	Skin Location	Cold (15 °C)	Neutral (27 °C)	Hot (47 °C)
A	Forehead	31.7	35.2	37
B	Back of Neck	31.2	35.1	36.1
C	Chest	30.1	34.4	35.8
D	Upper Back	30.7	34.4	36.3
E	Lower Back	29.2	33.7	36.6
F	Upper Abdomen	29	33.8	35.7
G	Lower Abdomen	29.2	34.8	36.2
H	Tricep	28	33.2	36.6
J	Forearm	26.9	34	37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

# MEASUREMENT TECHNIQUES

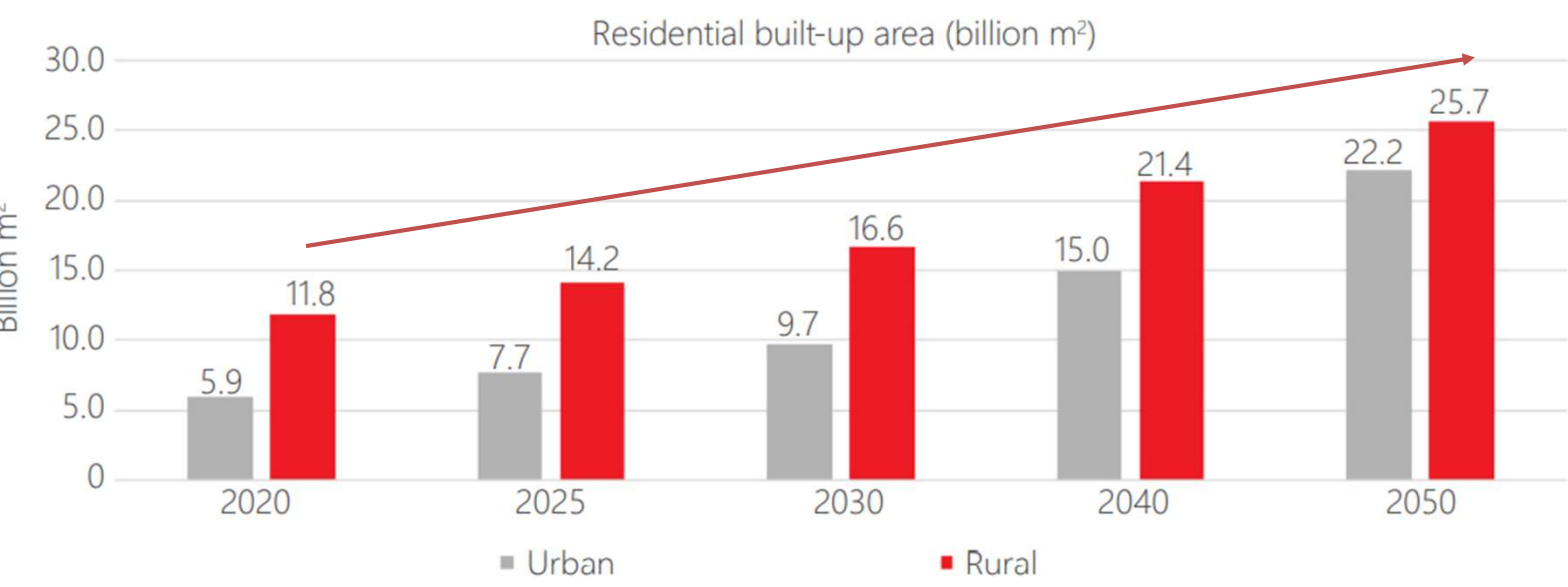
## THE PREDICTED MEAN VOTE (PMV)

- ✓ 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)**

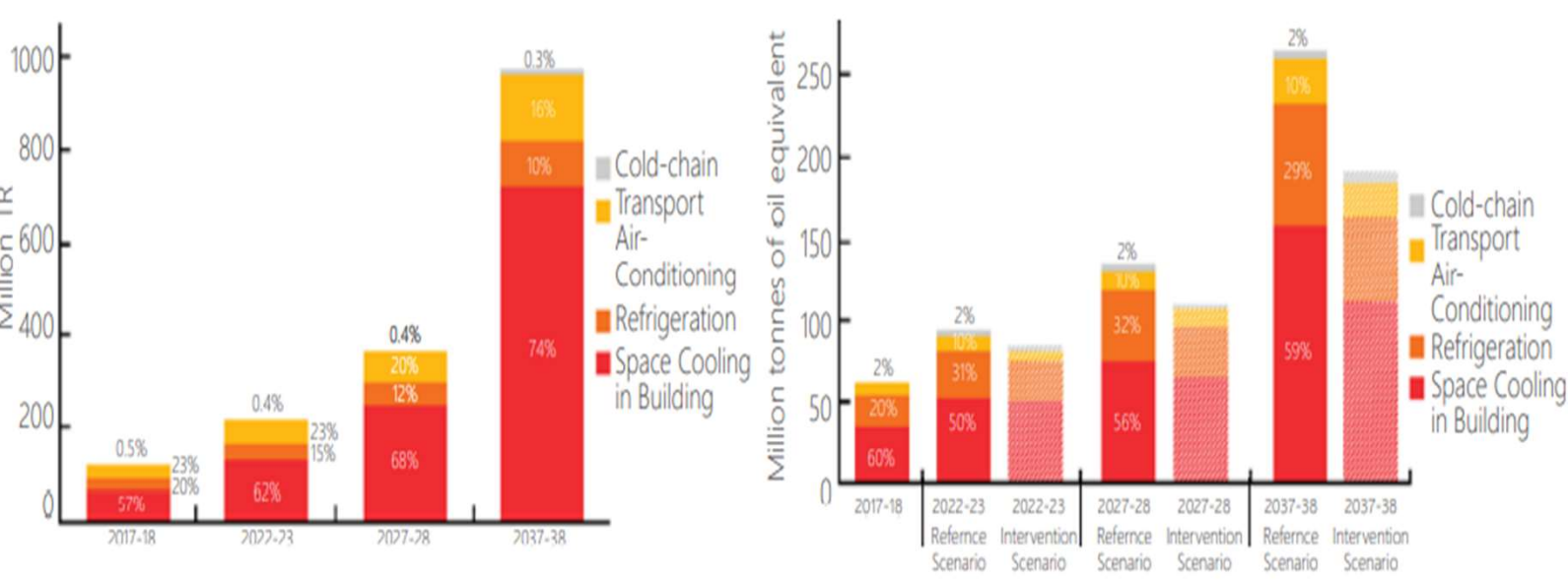


# IMPACT ON ENERGY & ENVIRONMENT

## COOLING DEMAND GROWTH & ITS MITIGATIONS



The total increase in urban residential built-up area is estimated to be greater than threefold between 2020 and 2050. It is projected to rise from 5.9 billion sq. m. to 22.2 billion sq. m. over three decades (2020-2050)



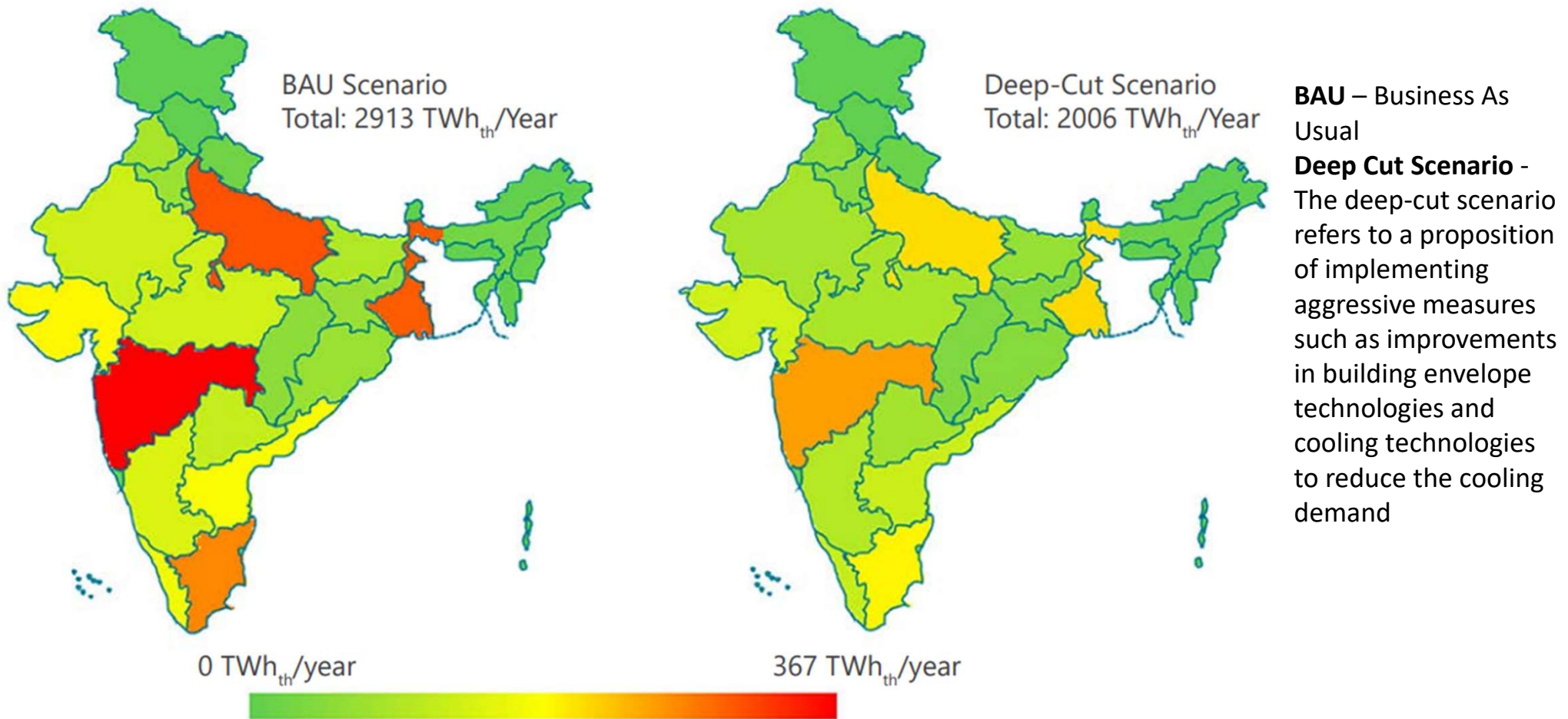
For buildings sector alone, Cooling demand will swell up to 11 times from the baseline over a span of mere two decades. Up to a 30% reduction is possible in the Total Primary Energy Supply (TPES)



# IMPACT ON ENERGY & ENVIRONMENT

## COOLING REQUIREMENT IN BAU Vs DEEP-CUT SCENARIOS

**TWh<sub>th</sub>/ year** is a unit to measure the amount of thermal energy that must be removed from the building to maintain thermal comfort for occupants

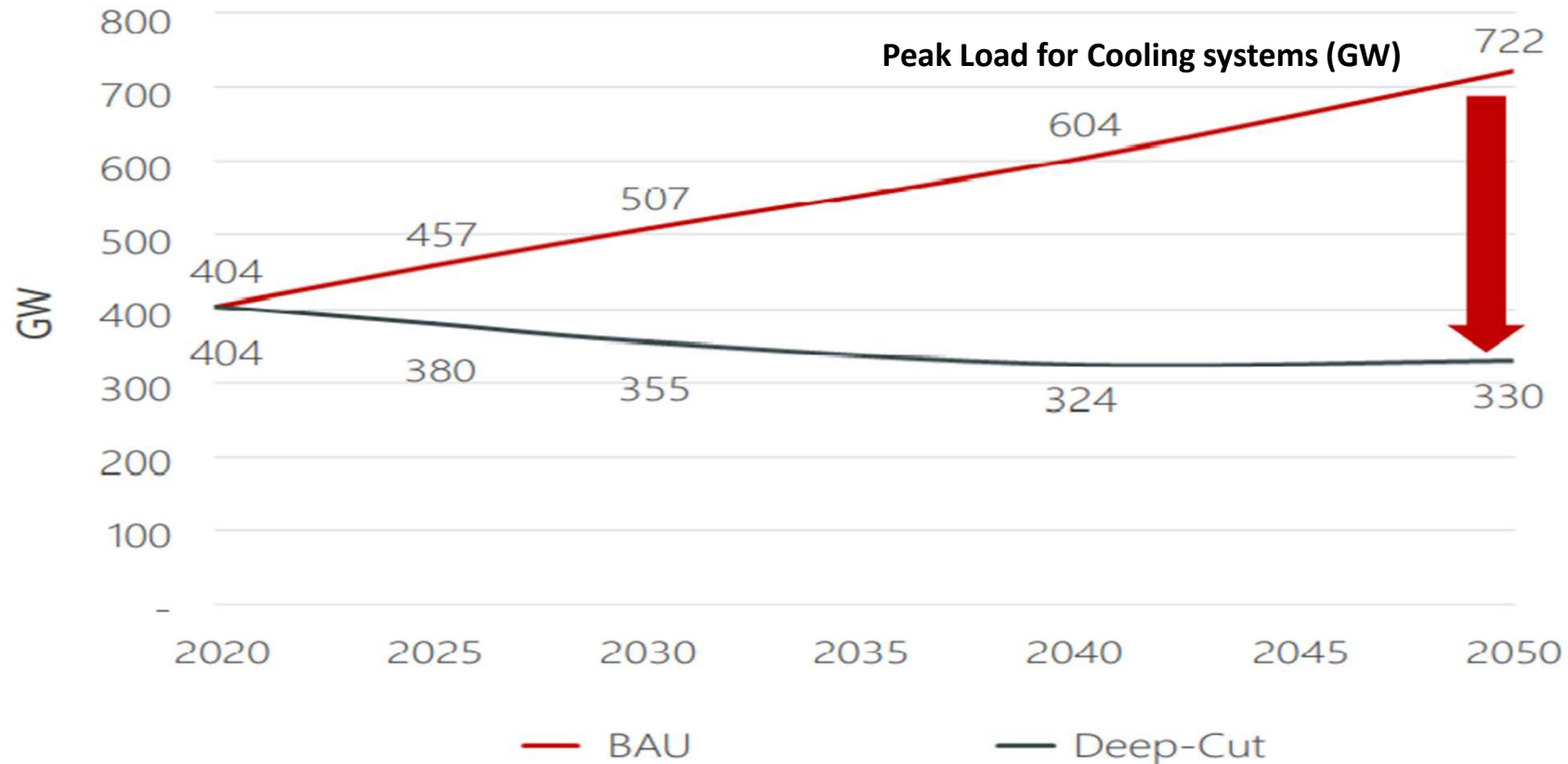


### Urban residential space cooling energy requirement map of India, 2050

- the space cooling requirement in urban residential buildings was estimated to be 896 TWh<sub>th</sub>/year in 2020 in India
- The same demand races upwards of 2914 TWh<sub>th</sub>/year by 2050 in Business-As-Usual (BAU) scenario
- However, it is possible to redefine the curve of rising space cooling demand in urban residential India in a deep-cut scenarios to a 30% reduced value of 2006 TWh<sub>th</sub>/year

# IMPACT ON ENERGY & ENVIRONMENT

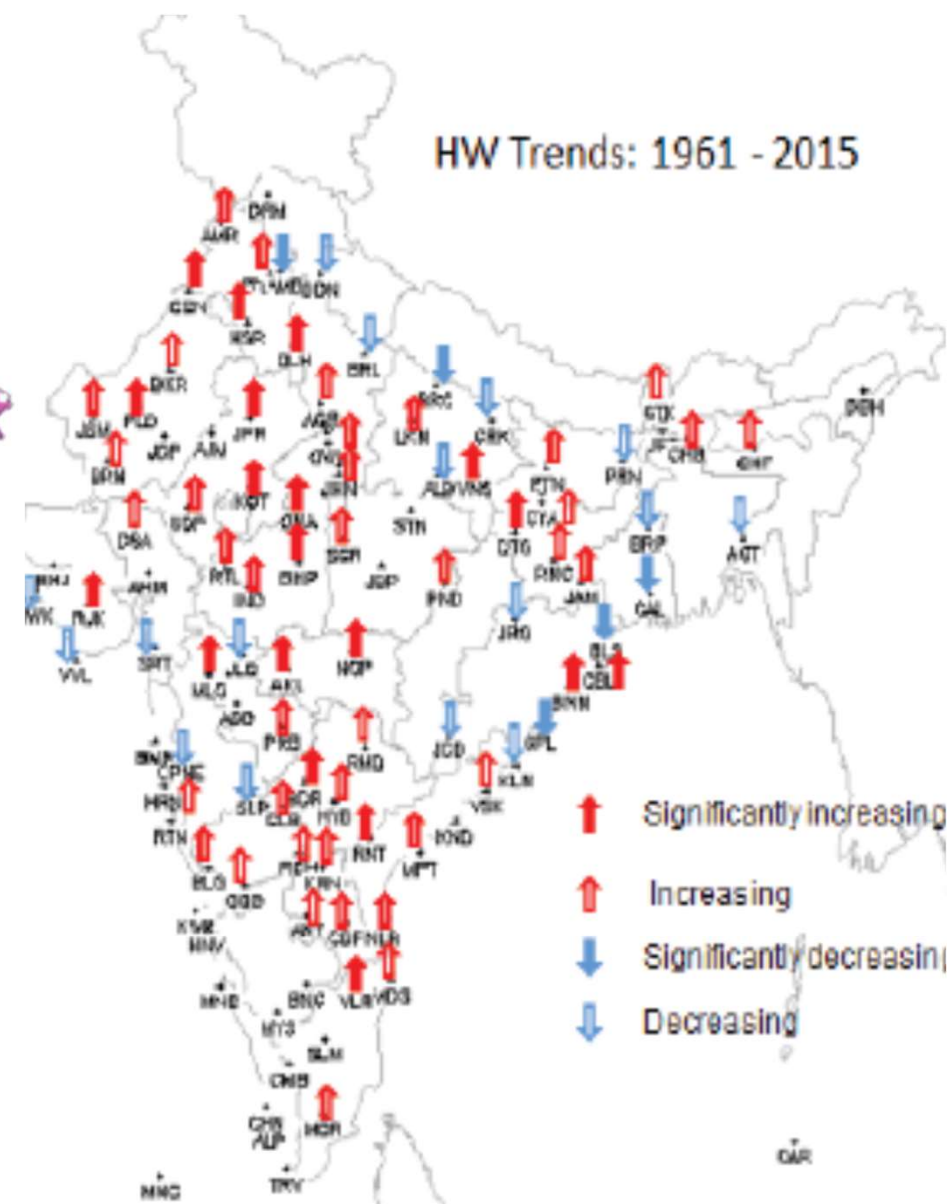
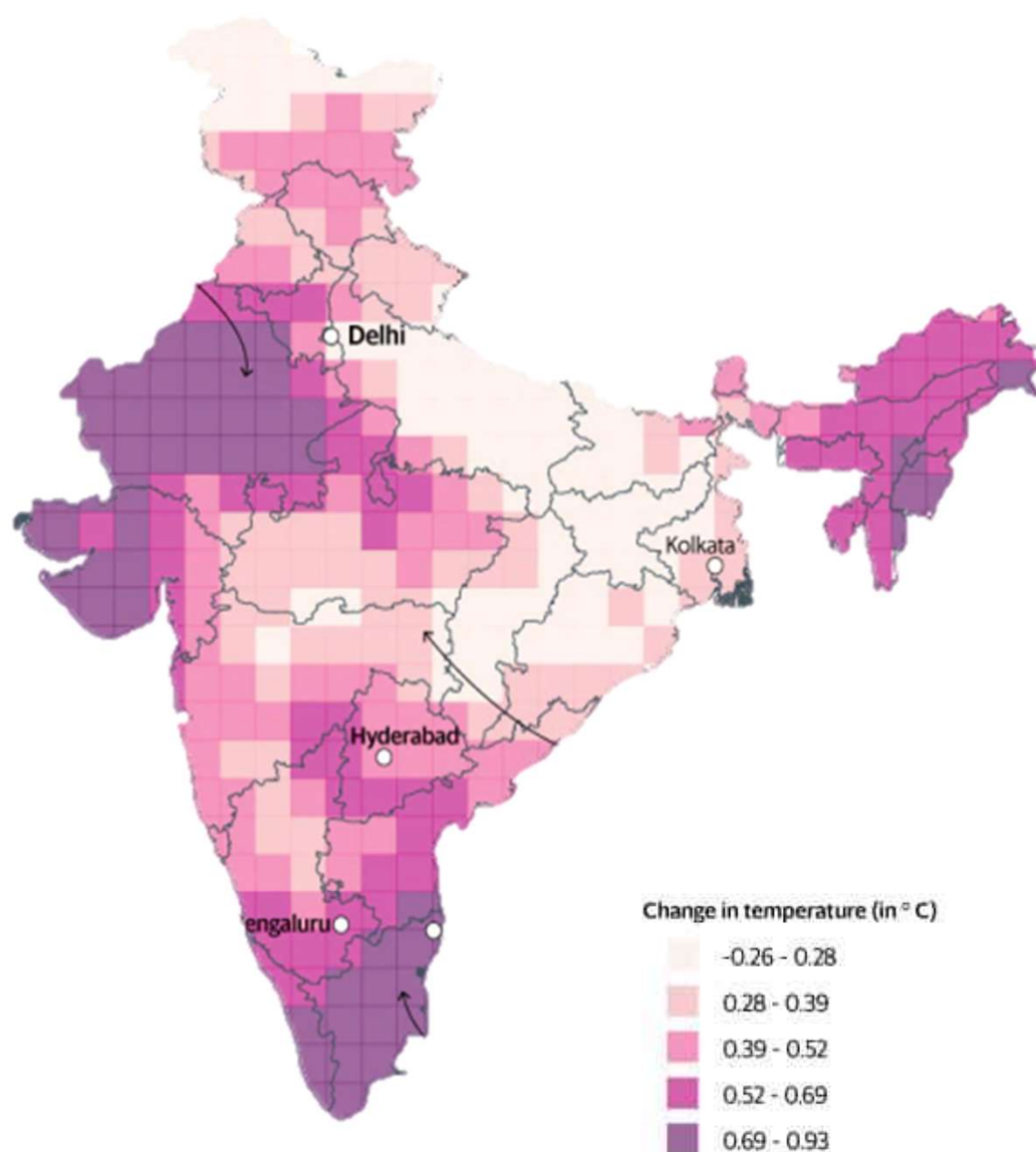
## IMPACT OF BUILDING ENVELOPE



**In India, buildings typically have a lifespan of 60-80 years**

- ✓ scope of reducing energy impact of the systems is limited until it is time to retrofit with more efficient alternatives
- ✓ the envelope of a building undergoes retrofitting at much greater intervals. This translates into higher energy and environmental costs for decades if the envelope assembly is not developed to reduce cooling loads during the design phase of the project
- ✓ Therefore, it becomes crucial to ensure optimized building envelope design before construction as it presents two-fold benefit
- ✓ Optimizing building envelope as a standalone strategy with respect to its RETV value demonstrates opportunity to significantly reduce cooling demand by decreasing the discomfort degree hours (DDH)

# IMPACT ON ENERGY & ENVIRONMENT

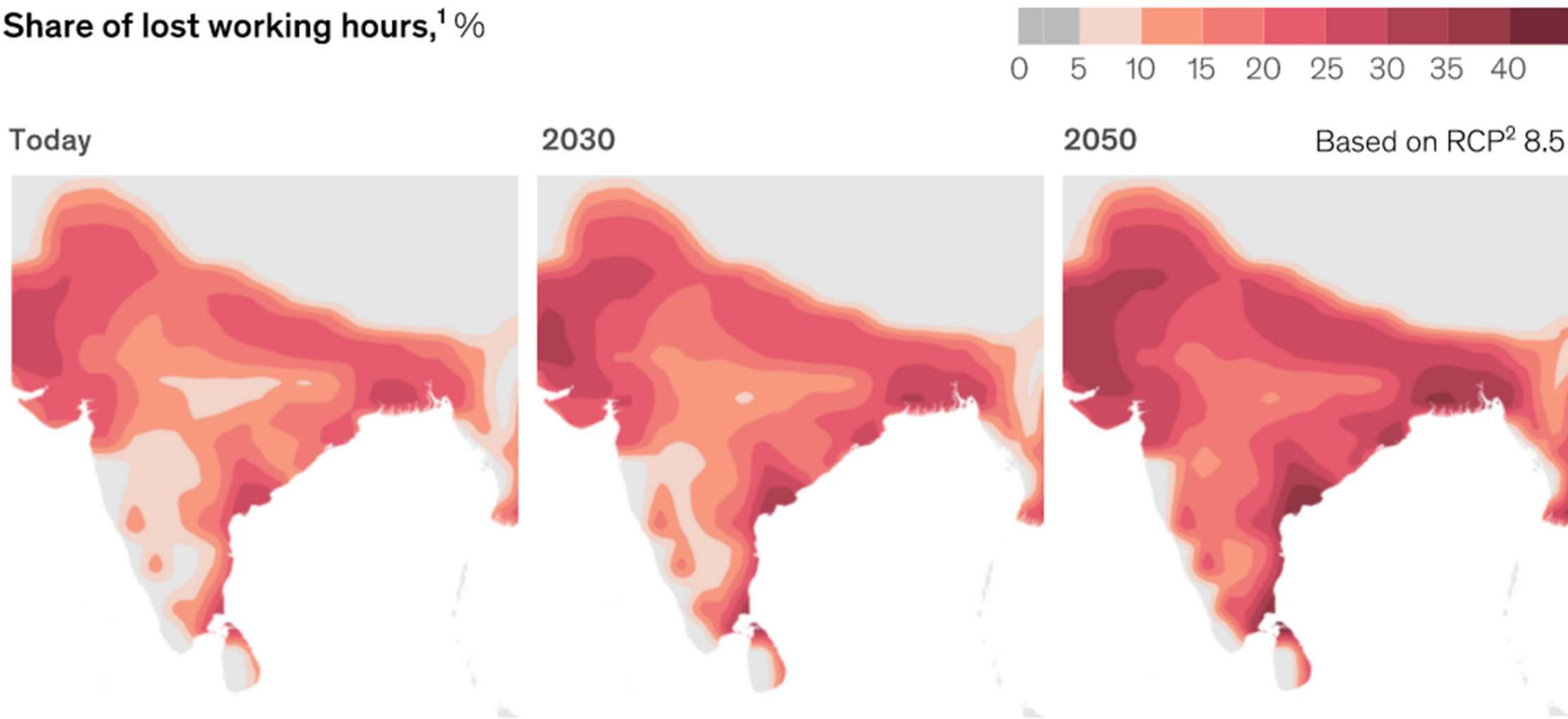


India could lose the equivalent of 34 million jobs in 2030 due to global warming, says ILO

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

# IMPACT ON ENERGY & ENVIRONMENT

The affected area and intensity of extreme heat and humidity is projected to increase, leading to a higher expected share of lost working hours in India.



Note: See the technical appendix to the report for why we chose Representative Concentration Pathway (RCP) 8.5. All projections are based on the RCP 8.5 and Coupled Model Intercomparison Project 5 multimodel ensemble. Corrected for heat-data bias. Following standard practice, future (ie, 2030 and 2050) states as the average climatic behavior over multidecade periods. Climate for today is the average between 1998 and 2017; for 2030, the average between 2021 and 2040; and for 2050, the average between 2041 and 2060.

<sup>1</sup>Lost working hours include loss in worker productivity as well as breaks, based on an average year that is an ensemble average of climate models.

<sup>2</sup>Representative Concentration Pathway.

Source: Woods Hole Research Center

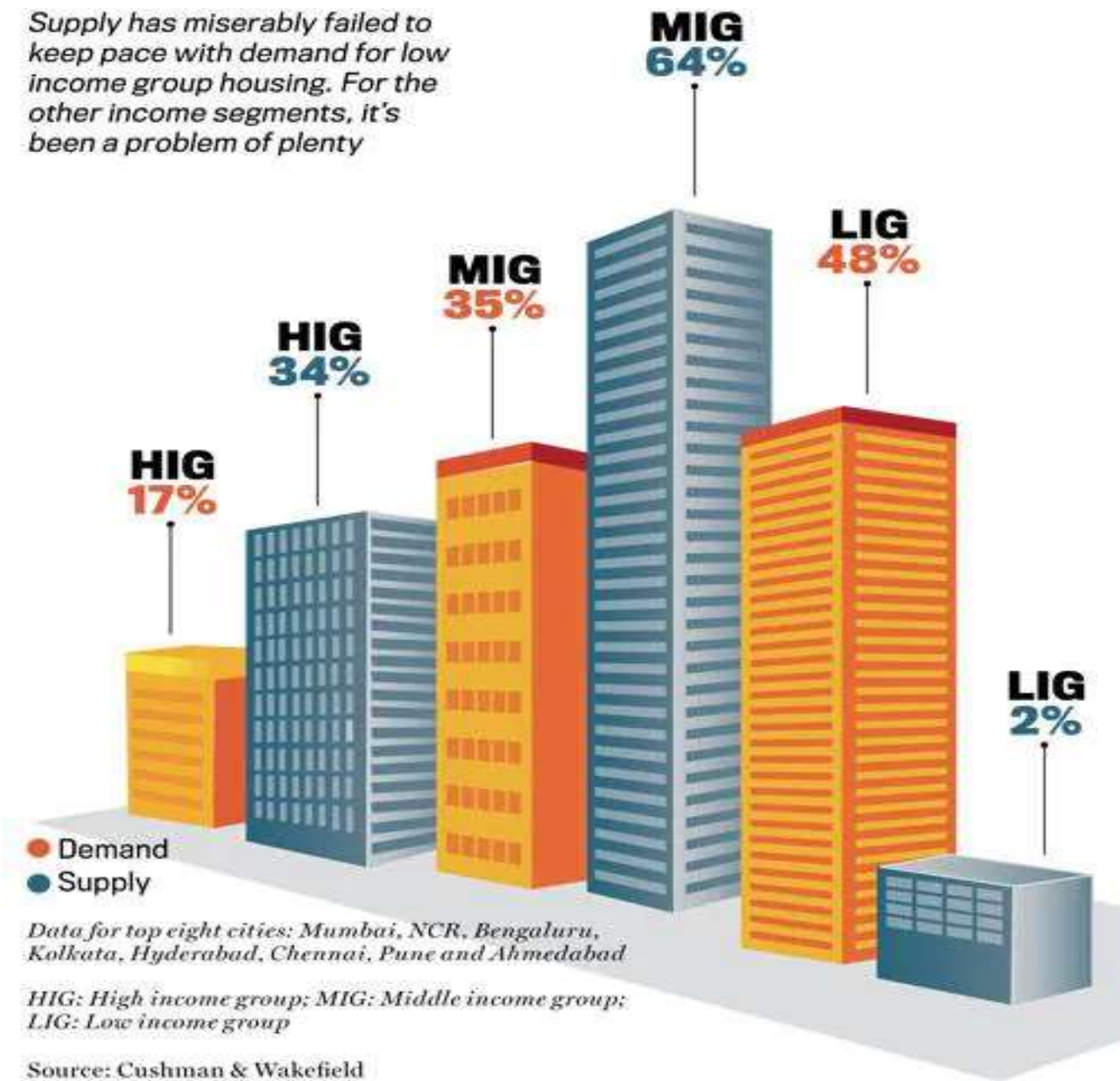


Affordable housing refers to housing units that are affordable by that section of society whose income is below the median household income.

## WHY AFFORDABLE HOUSING NEEDS A PUSH

### Demand-supply gap (2016-2020)

Supply has miserably failed to keep pace with demand for low income group housing. For the other income segments, it's been a problem of plenty



# CONCLUSION

## Mitigating Heat Transfer within the Buildings

Parameter	Metric	Building envelope element
Thermal Conductivity	R value – U value	Walls
Thermal Mass	Specific heat capacity	<ul style="list-style-type: none"><li>• Internal</li><li>• <b>External</b></li></ul>
Thermal Conductivity (Frames and Glass)	R value – U value	<b>Fenestration</b>
Solar Gains	Solar Heat Gain Coefficient	<ul style="list-style-type: none"><li>• <b>Windows</b></li><li>• Skylights</li><li>• Doors</li></ul>
Visible Light Transmittance	VLT	
Thermal Conductivity	R value – U value	<b>Roofs</b>
Thermal Emissivity	Solar Reflectance	Floors Foundations

# STRATEGIES TO ACHIEVE THERMAL COMFORT



# AFFORDABLE HOUSING PASSIVE DESIGN STRATEGIES

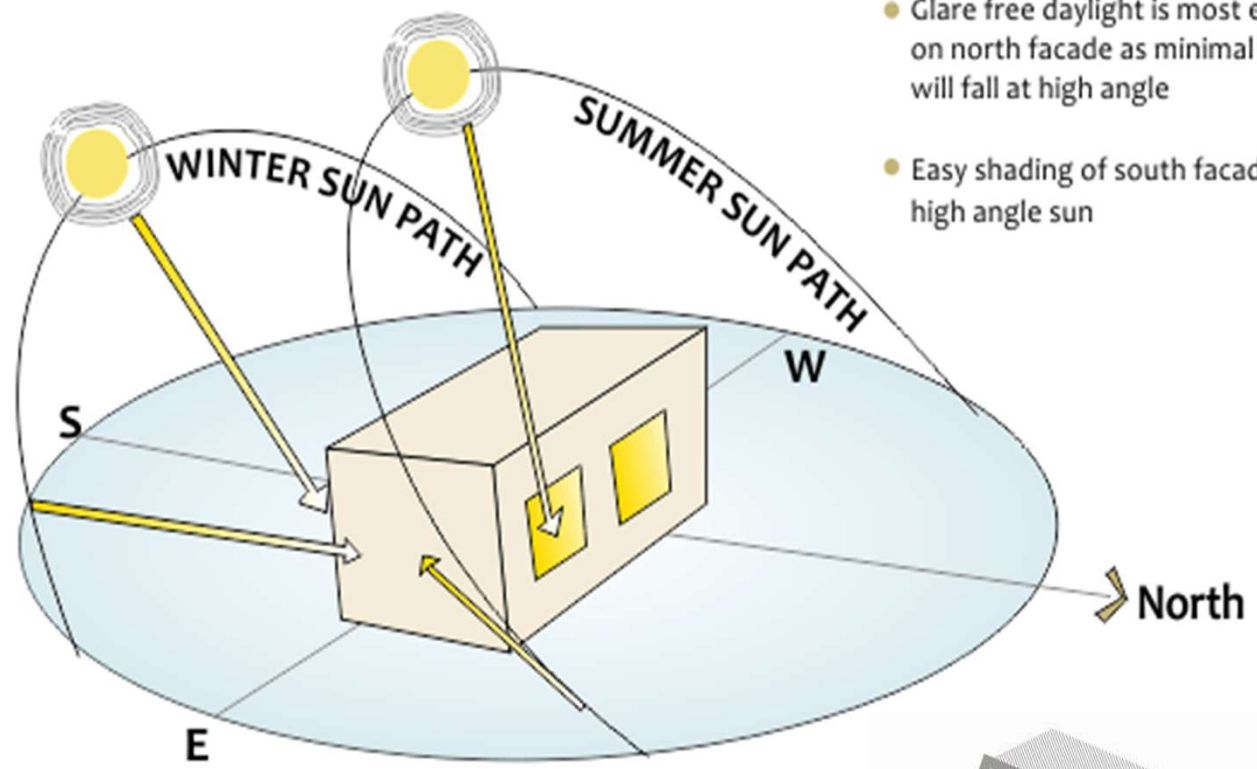
## ORIENTATION OF BUILDING BLOCKS:

### WINTER SUN

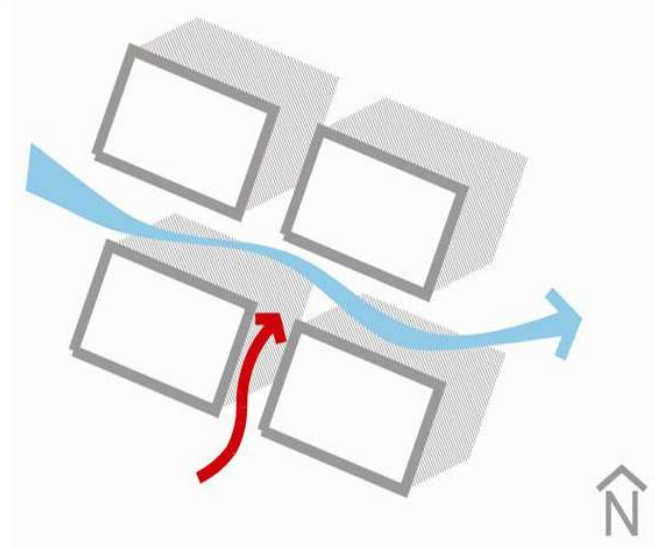
- Sun path at a low angle, south to E-W axis
- Solar radiation will penetrate south facing facades at a low angle during winter

### 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 radiation will fall at high angle
- Easy shading of south facade from high angle sun

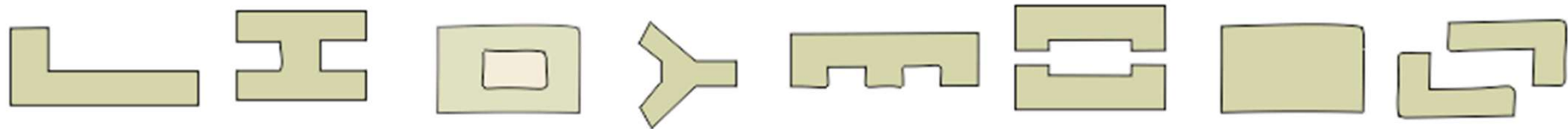


East and west facades continue to receive uniform, strong solar radiation at a low angle through the year.

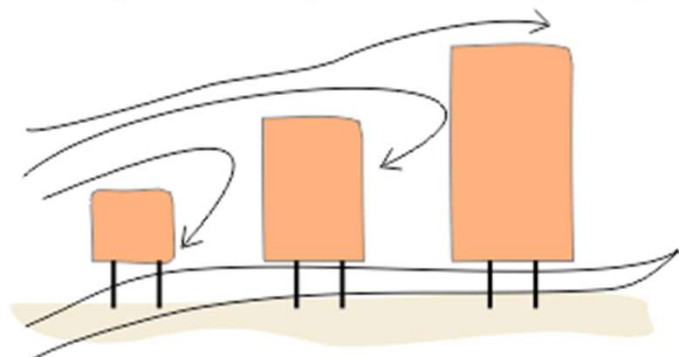


# AFFORDABLE HOUSING PASSIVE DESIGN STRATEGIES

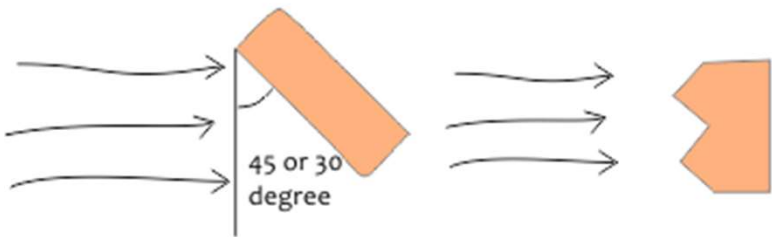
## ORIENTATION OPTIMIZATION OF BUILDING BLOCKS



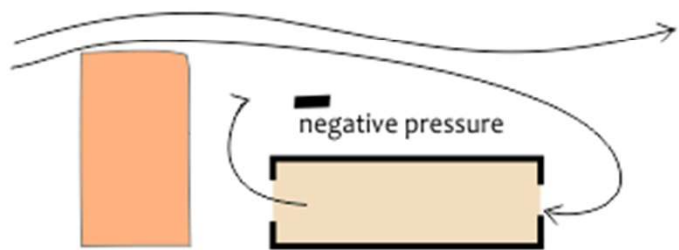
Orient longer facades along the north. This will provide glare free light in summer from north without shading and winter sun penetration from the south.



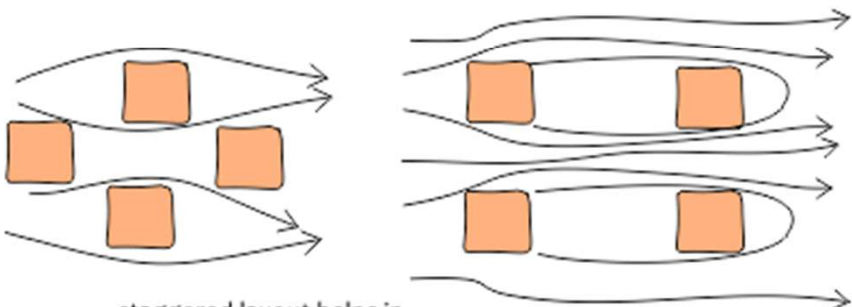
if a site has multiple buildings, they should be arranged in ascending order of their heights and be built on stilts to allow ventilation



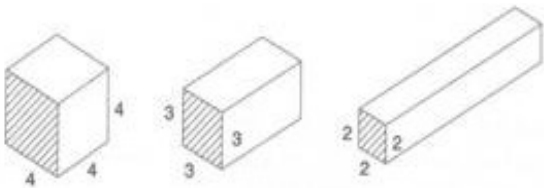
Place buildings at a 30 or 45 degree angle to the direction of wind for enhanced ventilation.  
Form can be staggered in the wind facing direction also to achieve the same result.



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 move



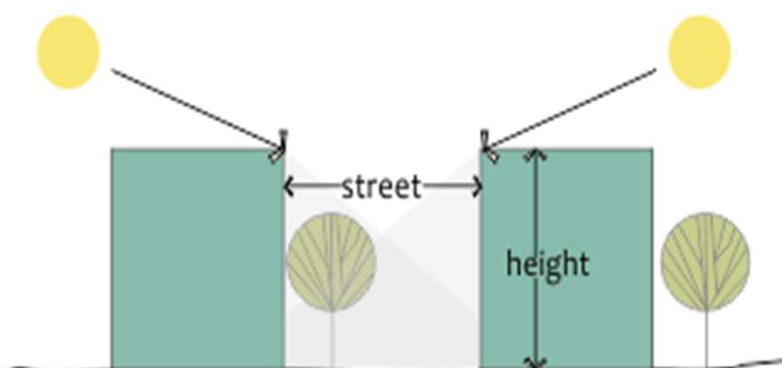
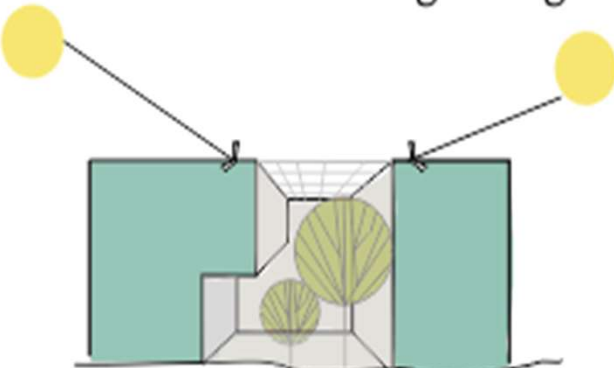
Solid shape type	Surface area (S)	Volume (V)	Ratio (S/V)
a	96	64	1.5
b	103.2	64	1.61
c	136	64	2.13

# AFFORDABLE HOUSING PASSIVE DESIGN STRATEGIES

## THERMAL MASSING THROUGH BUILDING BLOCKS:

1

Maximise mutual shading through built forms

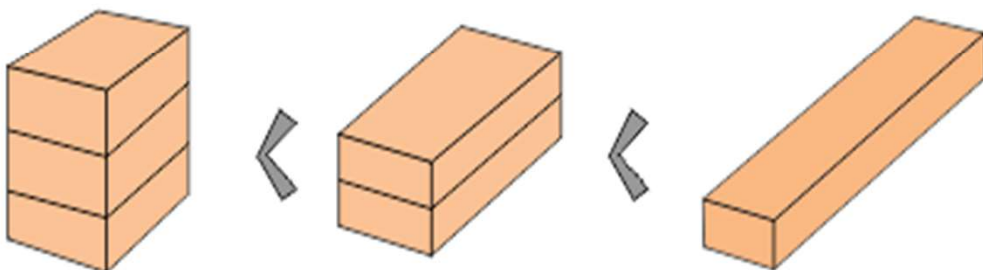


closely placed forms

narrow streets - keep building height to street width ratio minimal

2

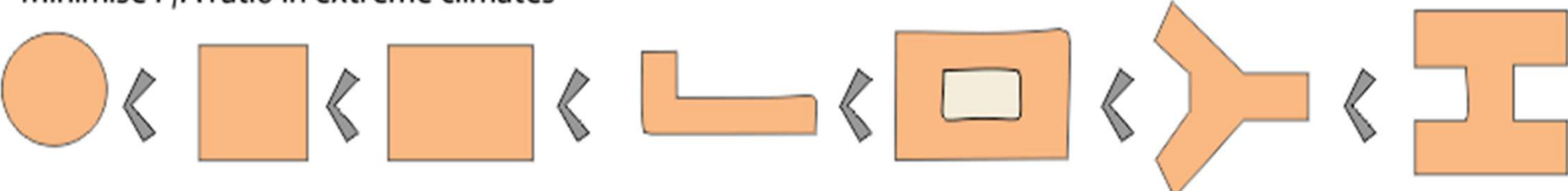
Minimise S/V ratio in extreme climates



increase compactness by reducing surface area for the same volume

3

Minimise P/A ratio in extreme climates



# AFFORDABLE HOUSING PASSIVE DESIGN STRATEGIES

## GLIMPSE ON THERMAL MASSING AND ORIENTATION OF BUILDING BLOCKS:



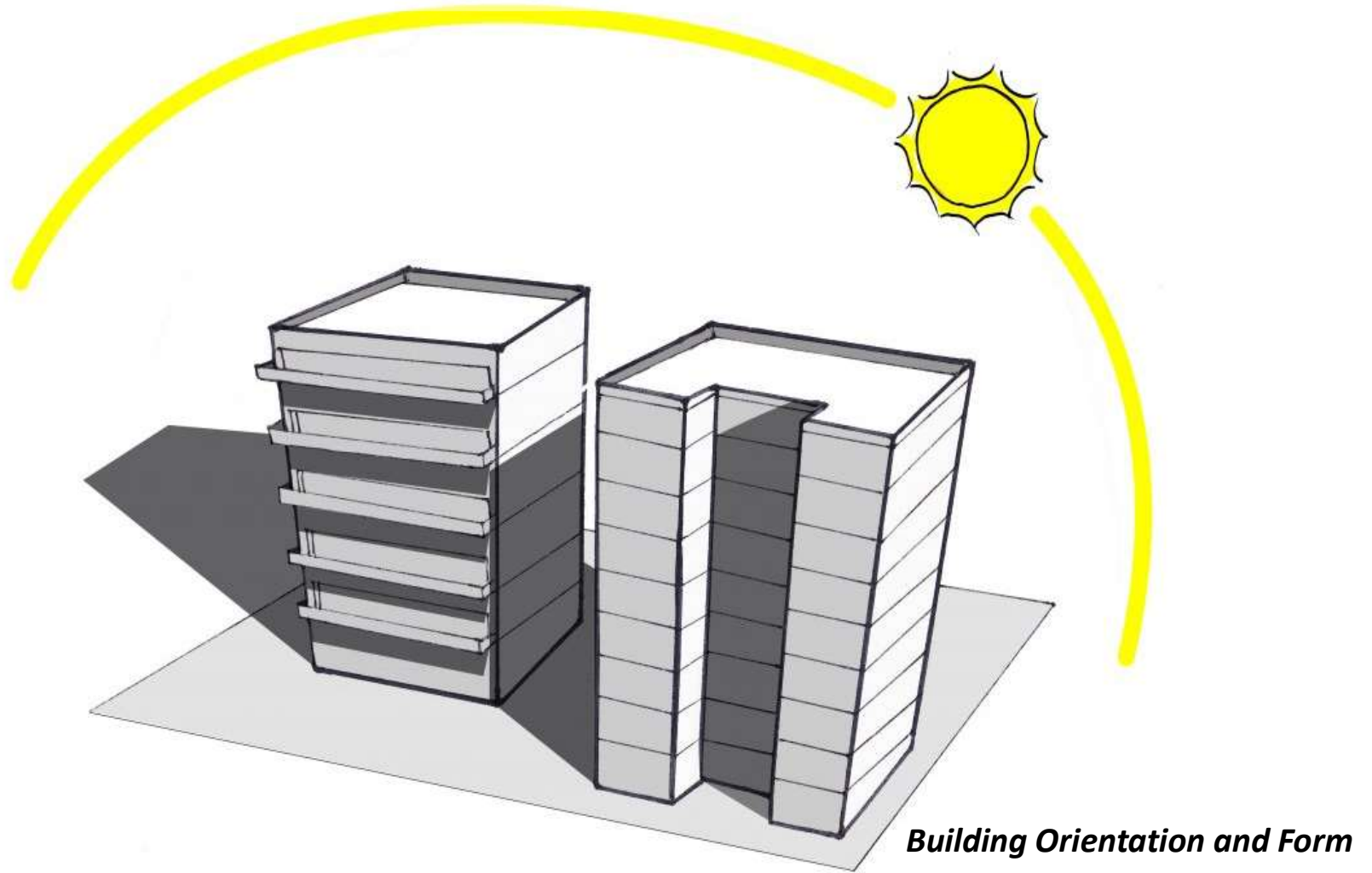
*UDAAN, low cost mass housing project at Mumbai*

- Maximum daylight
- Proper ventilation

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

# AFFORDABLE HOUSING PASSIVE DESIGN STRATEGIES

## INTER-SHADING OF BUILDING BLOCKS:



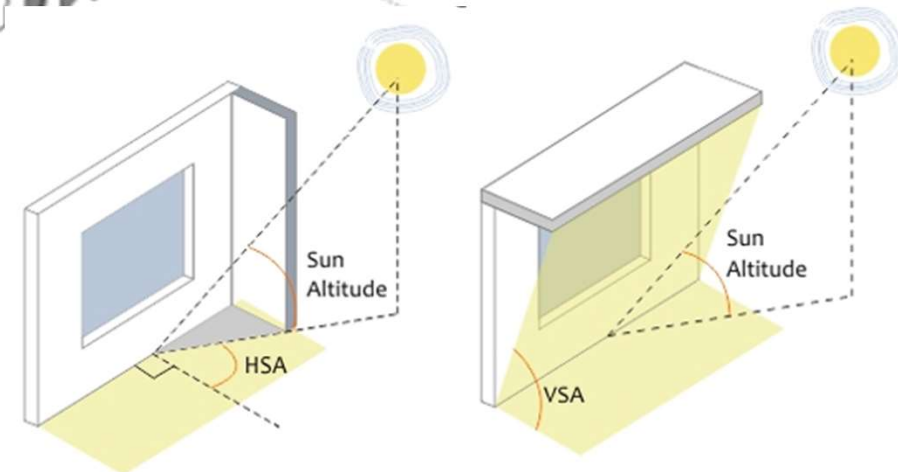
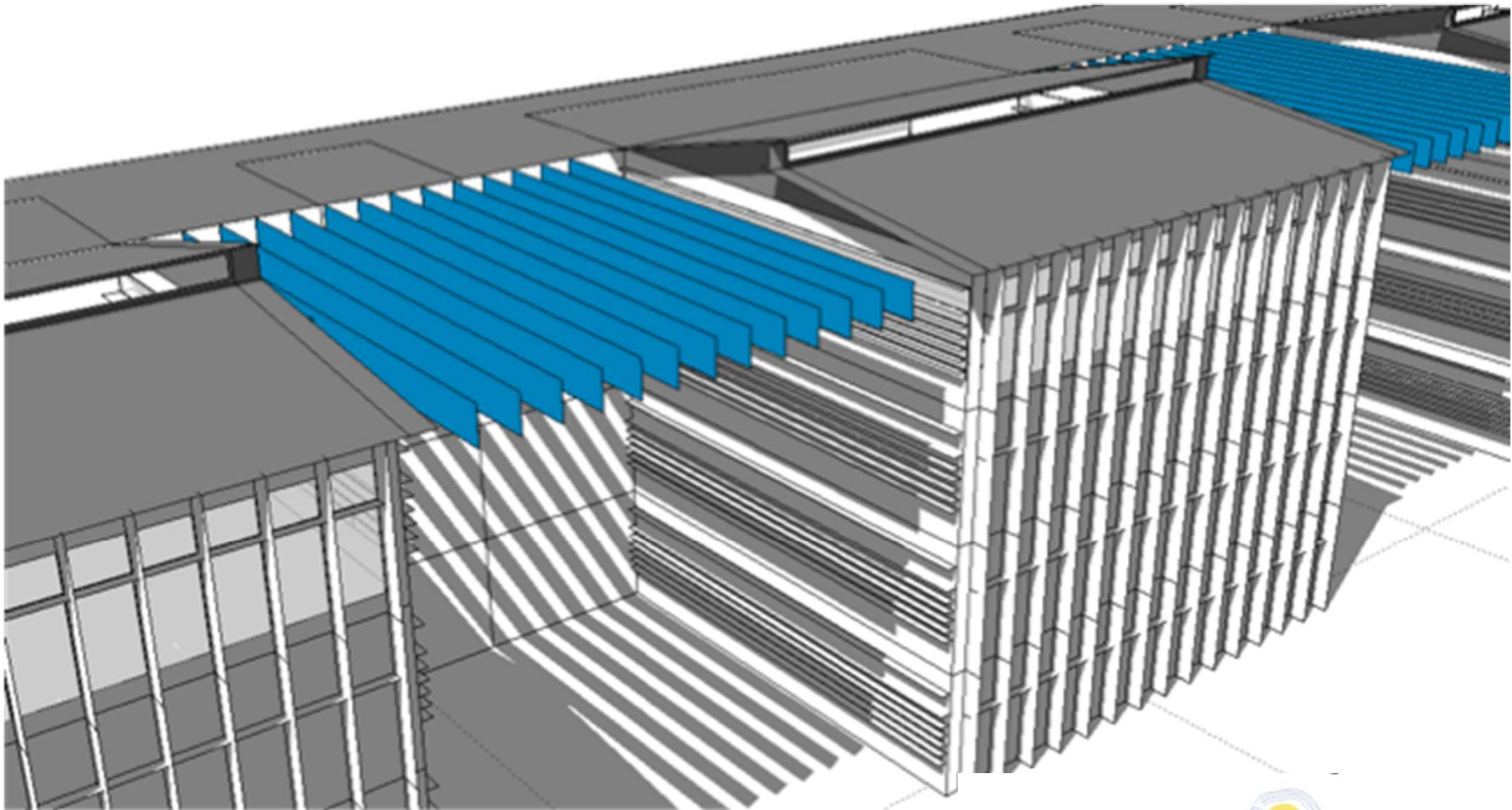
- In extreme climatic condition *compact planning* is more preferable
- Minimising the perimeter to area ratio of building form, building performs better in terms of thermal comfort
- *Compact forms* gain less heat at day time and loss heat during night time

***Minimizing the surface area to volume ratio minimizes heat transfer.***



# AFFORDABLE HOUSING PASSIVE DESIGN STRATEGIES

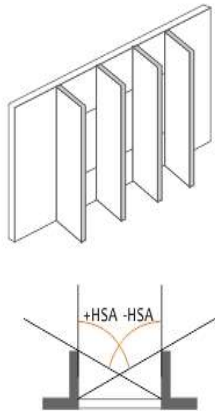
## INTER-SHADING THROUGH SHADIN DEVICES ON BUILDING BLOCKS:



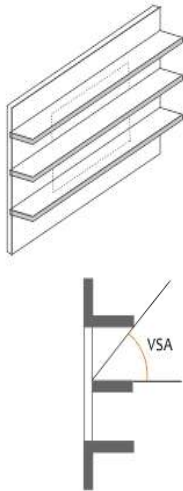
# AFFORDABLE HOUSING PASSIVE DESIGN STRATEGIES

## SHADING OF OPENING /WINDOWS

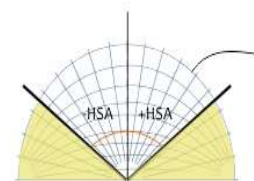
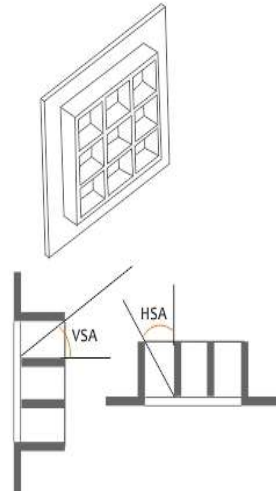
Vertical Shading



Horizontal Shading

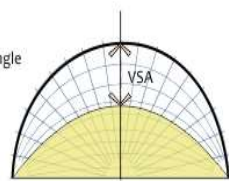


Horizontal & Vertical Shading



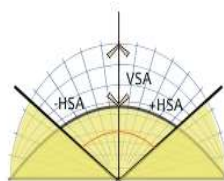
Shading mask of vertical shading device

vertical shading devices protect from sun at sides of the elevation such as east and west side



Shading mask of horizontal shading device

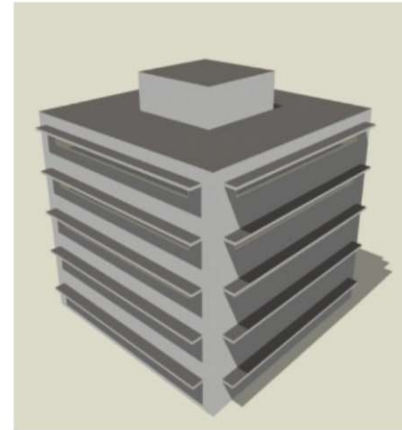
horizontal shading devices protect from sun at high angles and opposite to the wall to be shaded such as north and south sides



Shading mask of egg crate shading device

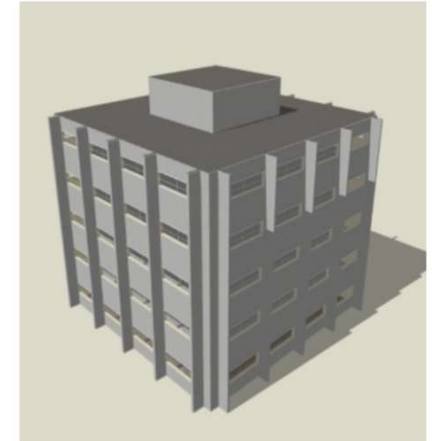
combination of horizontal and vertical shading devices protect from sun in all orientations

Horizontal BIPV Shading Devices Cases

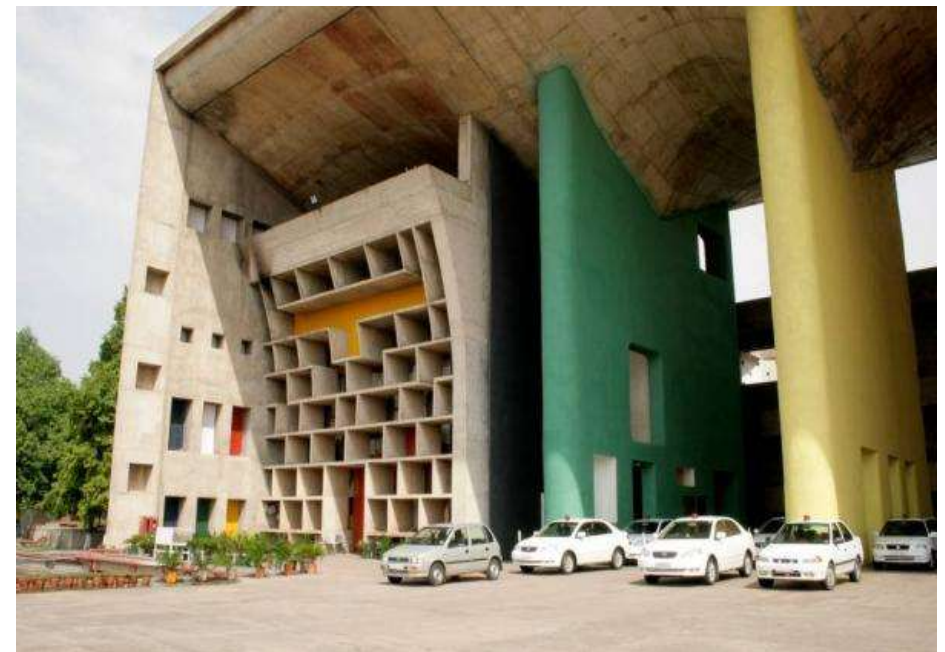


H-SD-0 (no inclination)  
H-SD-30 (inclined at 30°)  
H-SD-45 (inclined at 45°)  
H-SD-60 (inclined at 60°)

Vertical BIPV Shading Devices 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*

Solar shading devices helps

- Diffusing light
- Control heat
- Improving daylight

**Comfortable living**

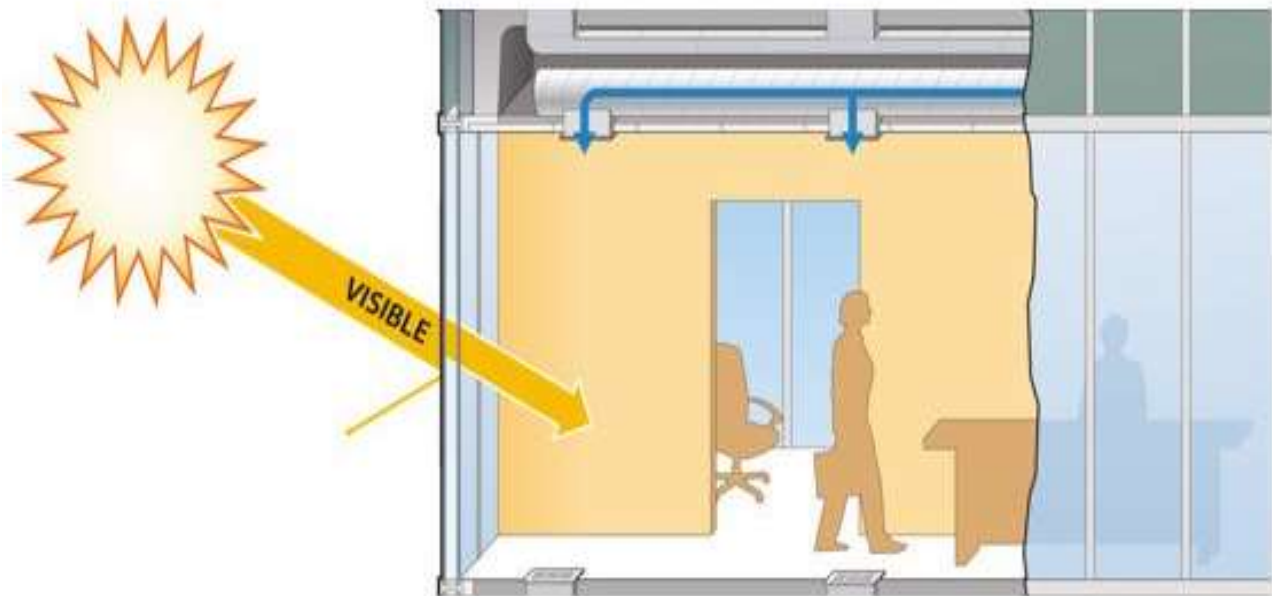
# AFFORDABLE HOUSING PASSIVE DESIGN STRATEGIES

## WWR (Window-to-wall ratio)

### 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

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



**TABLE 2** Minimum visible light tra

Window-to-wall ratio (WWR) <sup>16</sup>	Minimum VLT <sup>17</sup>
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.

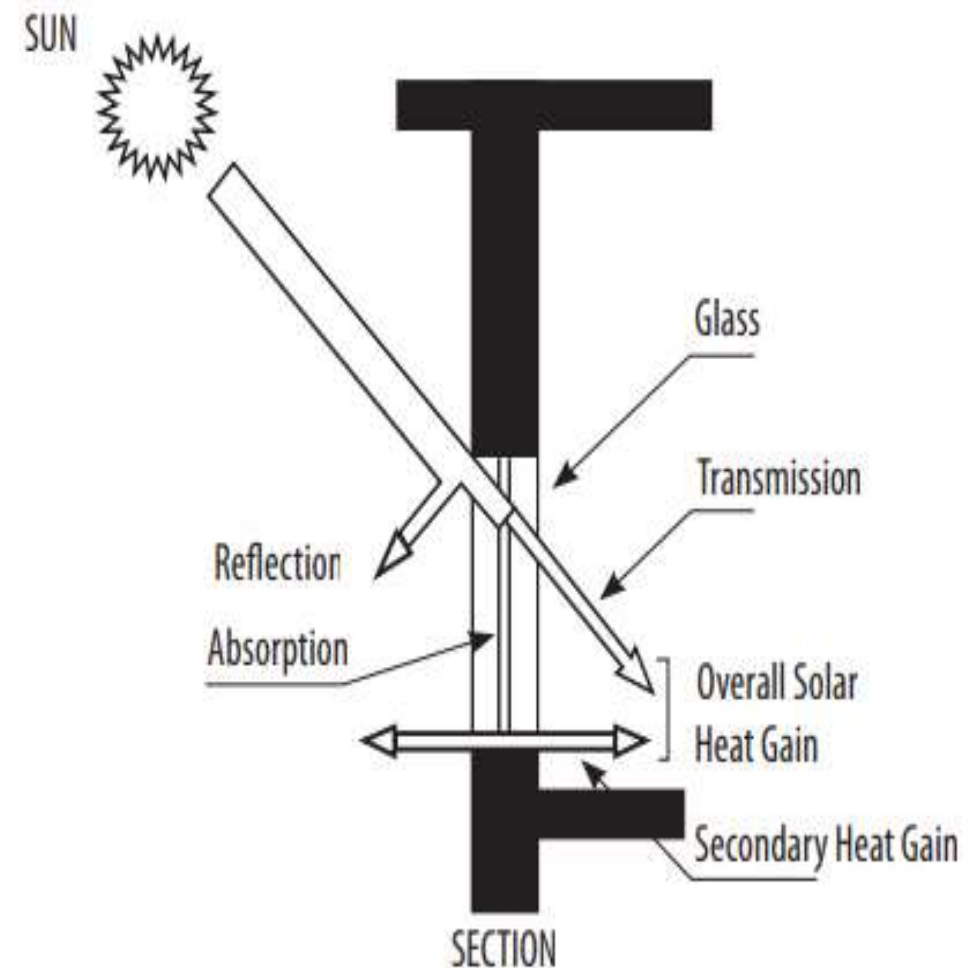
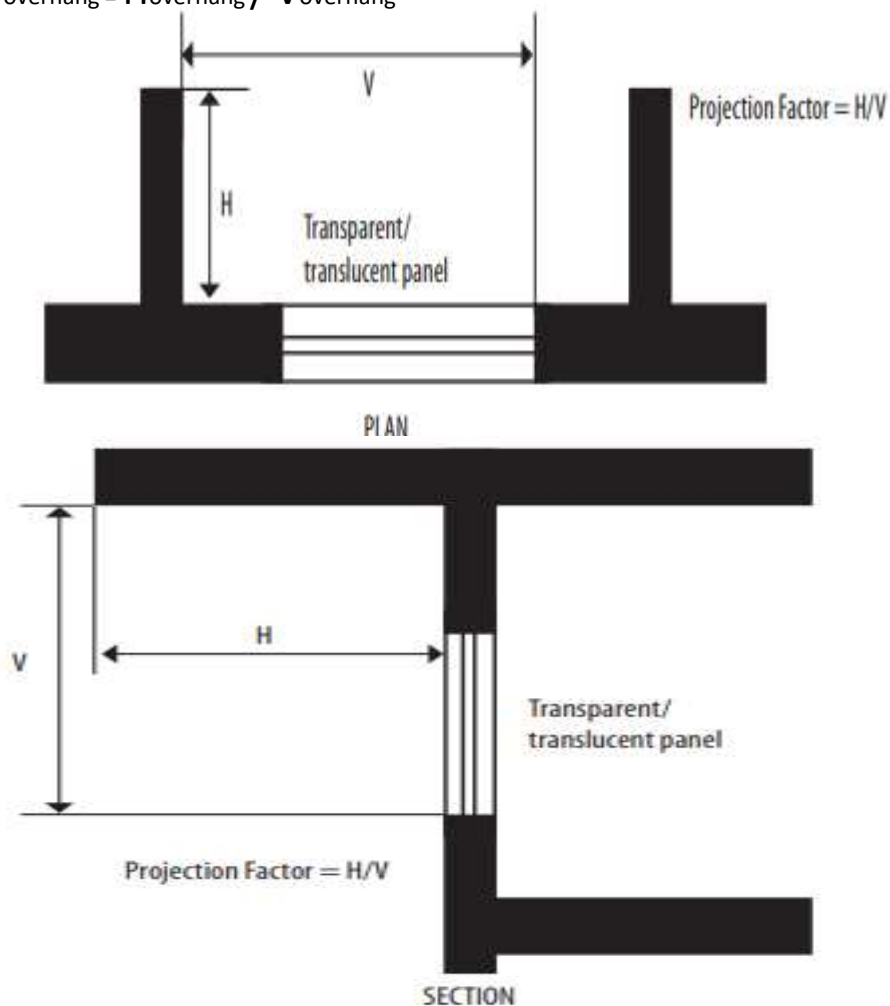


# AFFORDABLE HOUSING PASSIVE DESIGN STRATEGIES

**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.

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



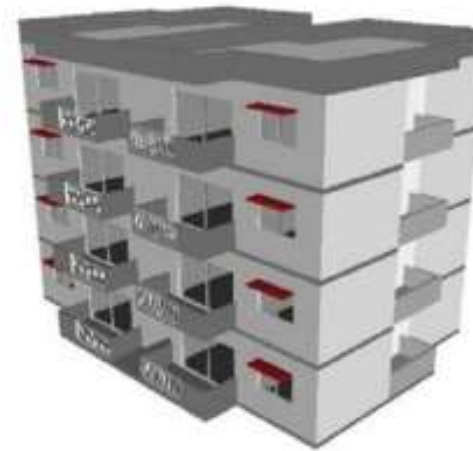
# AFFORDABLE HOUSING PASSIVE DESIGN STRATEGIES

## Residential Envelope Transmittance Value

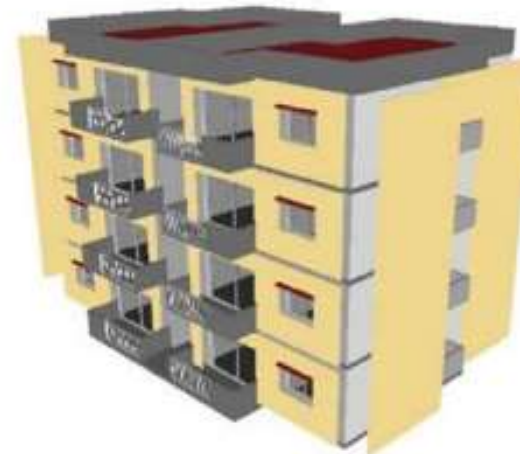
RETV characterizes the thermal performance of the building envelope (*except roof*).

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/m<sup>2</sup>.

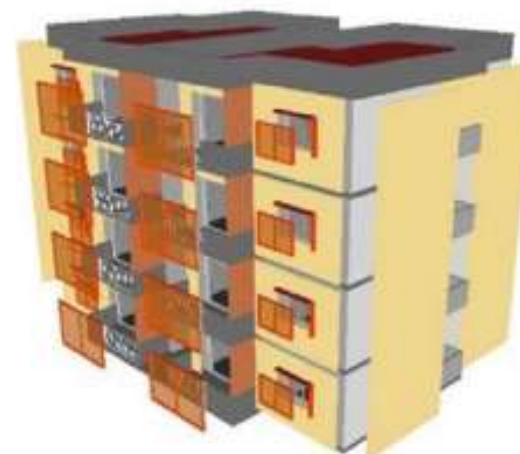
$$RETV = \frac{1}{A_{envelope}} \times \left[ \begin{array}{l} \left\{ 6.06 \times \sum_{i=1}^n \left( A_{opaque_i} \times U_{opaque_i} \times \omega_i \right) \right\} \\ + \left\{ 1.85 \times \sum_{i=1}^n \left( A_{non-opaque_i} \times U_{non-opaque_i} \times \omega_i \right) \right\} \\ + \left\{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



**RETV - 21.0 W/m<sup>2</sup>**  
Business-As-Usual  
Building Envelope



**RETV - 18.0 W/m<sup>2</sup>**  
Building Envelope Details:  
Better insulation in walls and roof  
(U-value)  
High solar reflectance on  
roof (SRI)

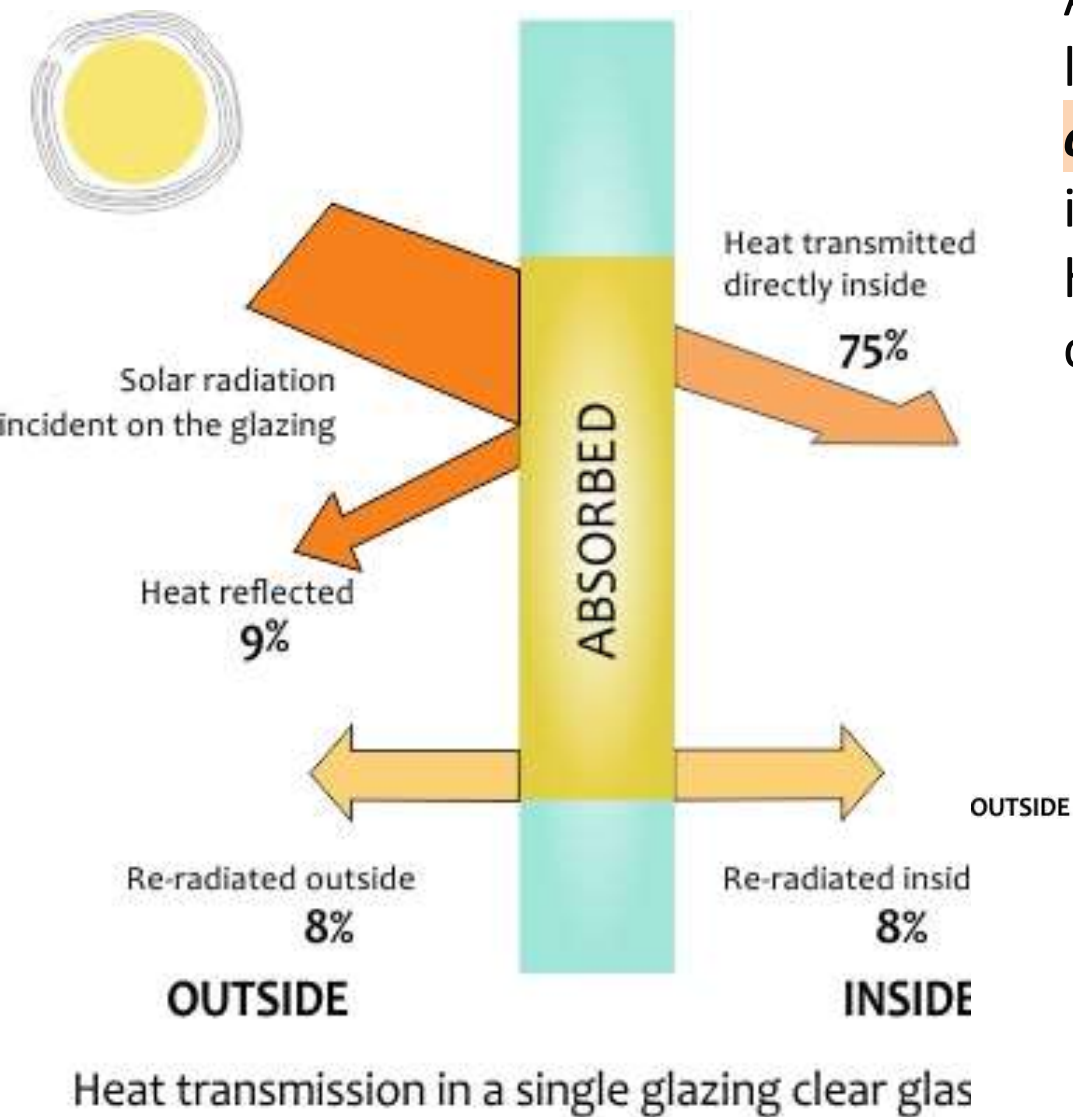


**RETV - 15.0 W/m<sup>2</sup>**  
Better Windows (U Value, SHGC, VLT,  
Building Envelope Optimization)

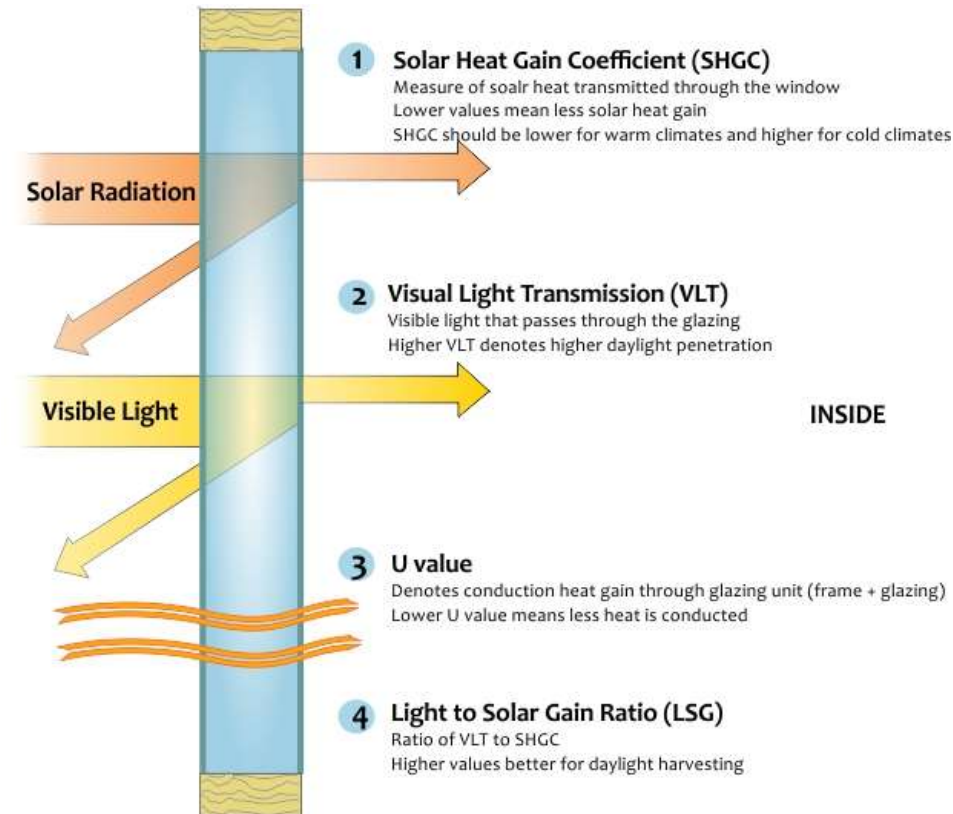


# AFFORDABLE HOUSING PASSIVE DESIGN STRATEGIES

## Fenestration



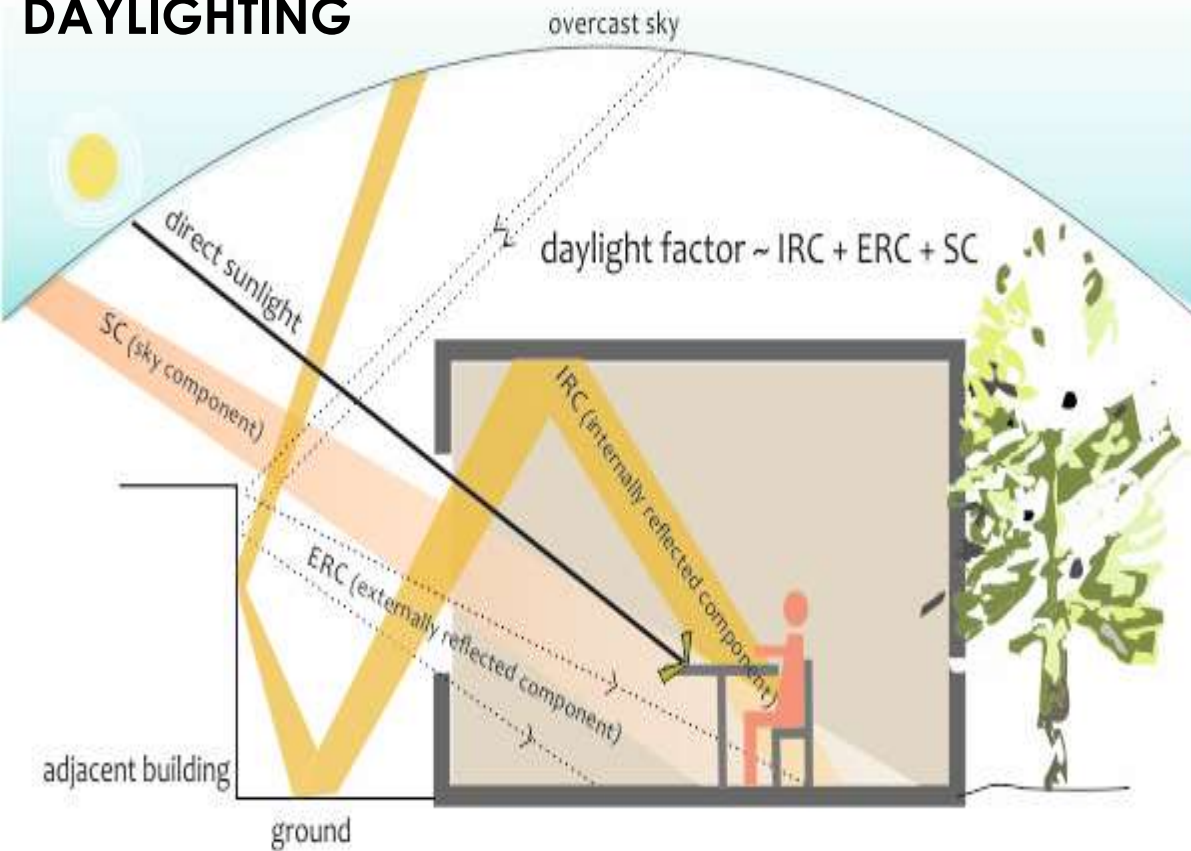
A fenestration system with low U-value and low effective SHGC can result in **reduction of heating and cooling demand** by 6-11% in moderate climate and between 8-16% in hot humid, hot dry, and composite climates.



## Fenestration type

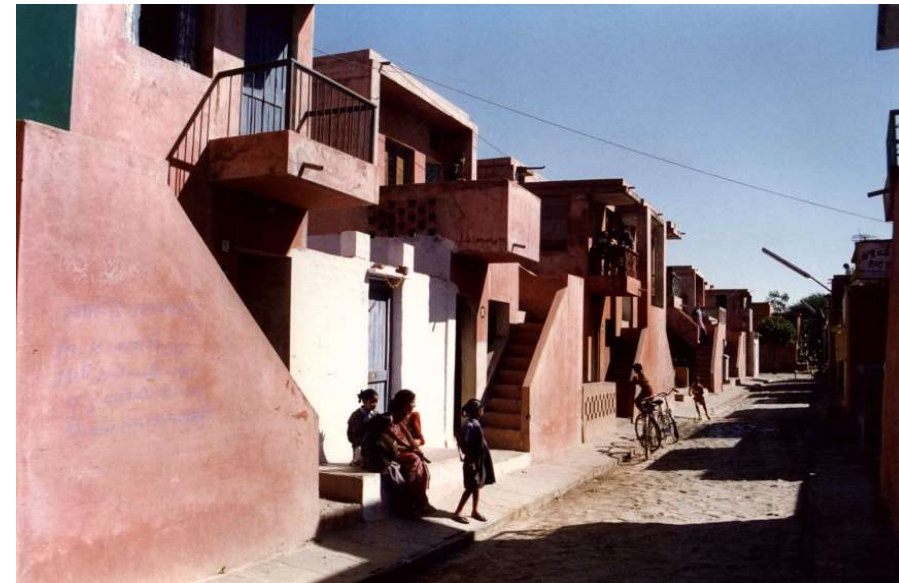
# AFFORDABLE HOUSING PASSIVE DESIGN STRATEGIES

## DAYLIGHTING



- Designed daylighting features enhance
  1. Indoor environmental quality,
  2. Building occupant performance

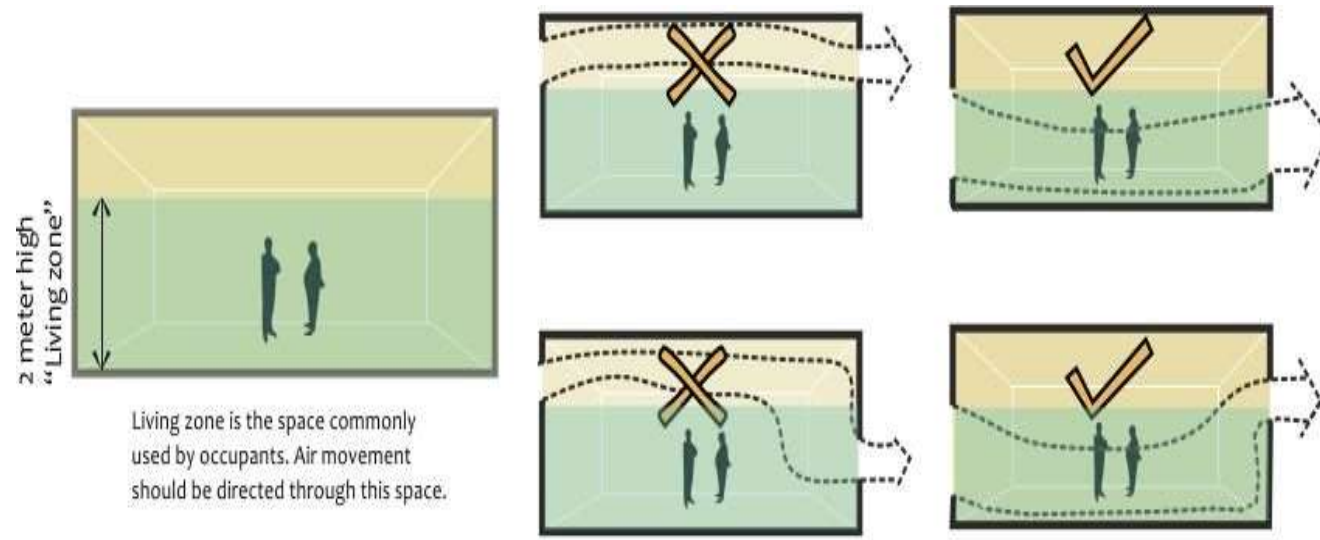
Daylighting can impact the energy use by **reducing** the lighting energy demand up to **20-30%**.



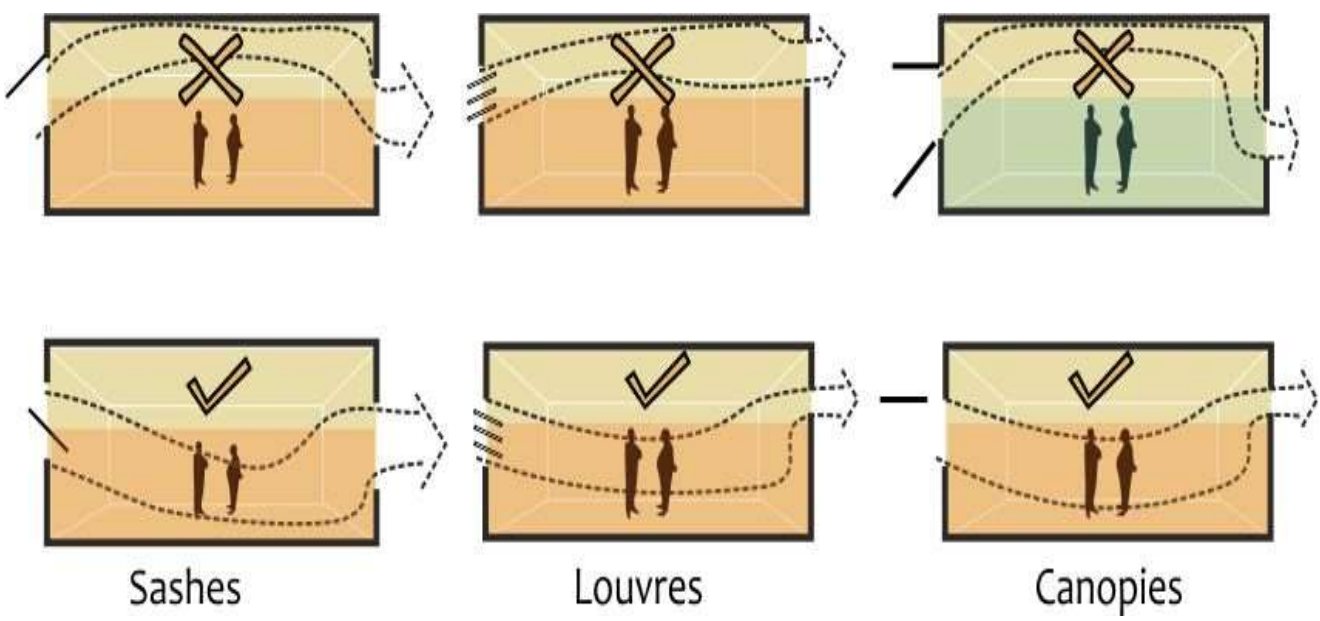
*Day lighting and Shading at Aranya Housing, Indore*

NATURAL VENTILATION

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



Types of opening and their location



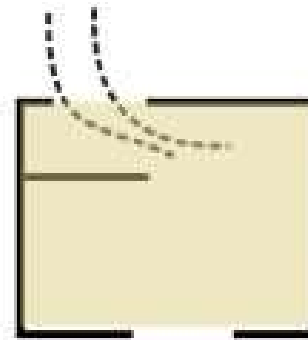
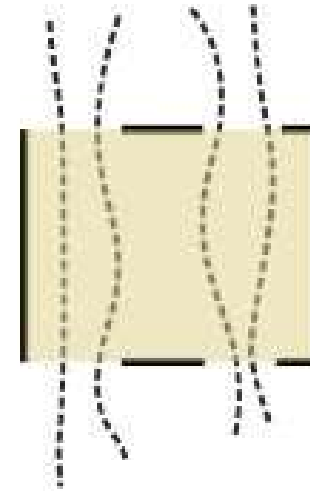
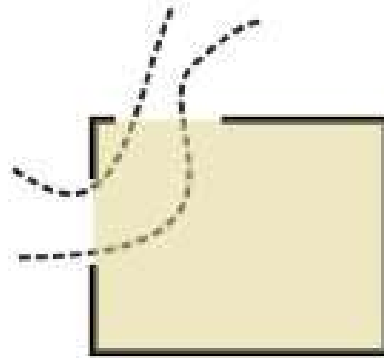
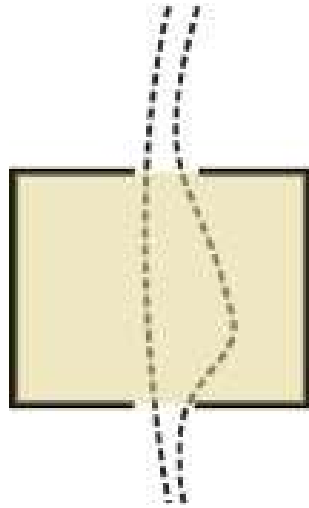
**Natural ventilation helps in reducing mechanical cooling load of the building**



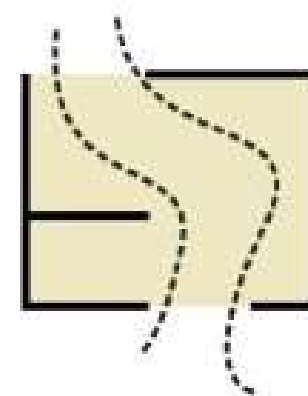
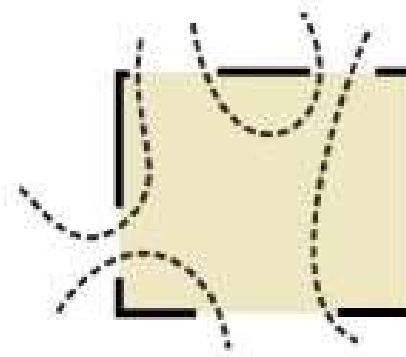
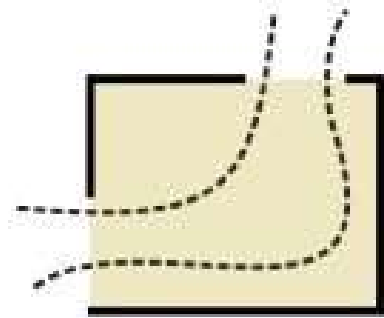
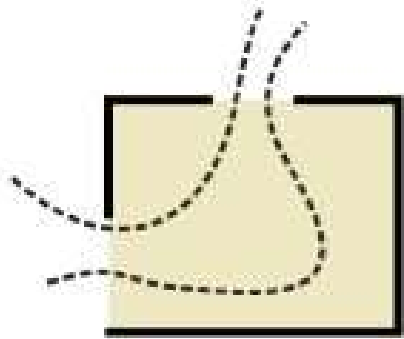
# AFFORDABLE HOUSING PASSIVE DESIGN STRATEGIES

## NATURAL VENTILATION

✗ Don't



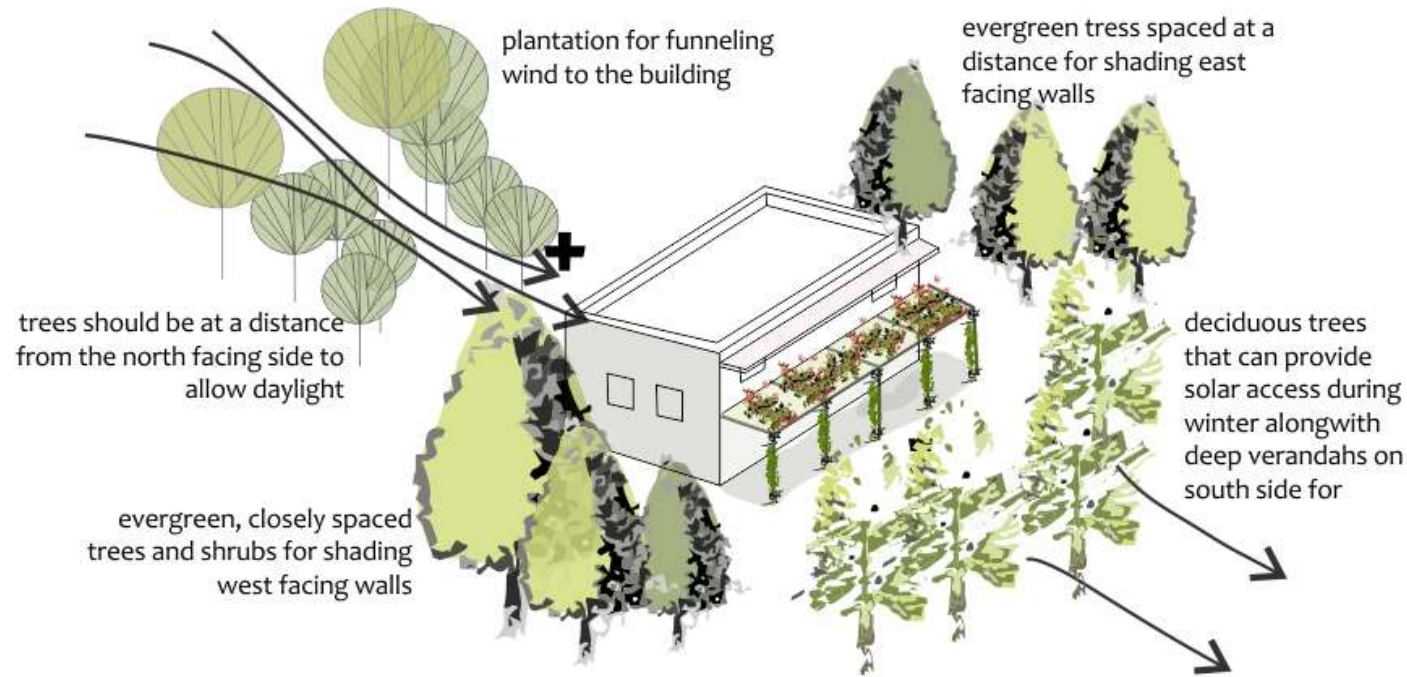
✓ Do



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

# AFFORDABLE HOUSING PASSIVE DESIGN STRATEGIES

## 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



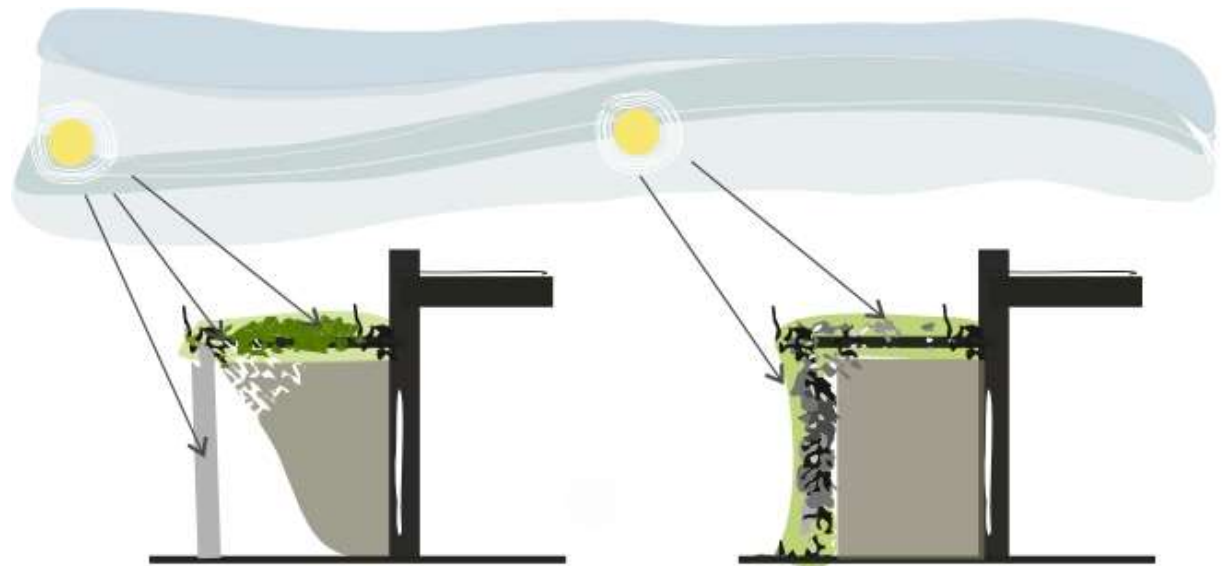
# AFFORDABLE HOUSING PASSIVE DESIGN STRATEGIES

## VEGETATION

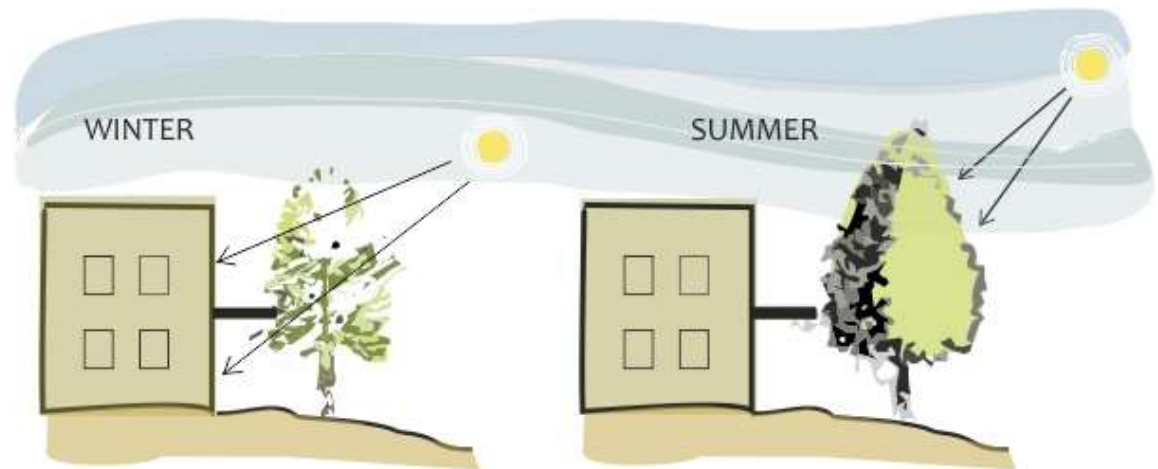
Trees and shrubs create different air flow patterns, provide shading and keep the surroundings cooler in warm weather.

Vegetation can be used for energy conservation in buildings in the following ways:

- ✓ 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



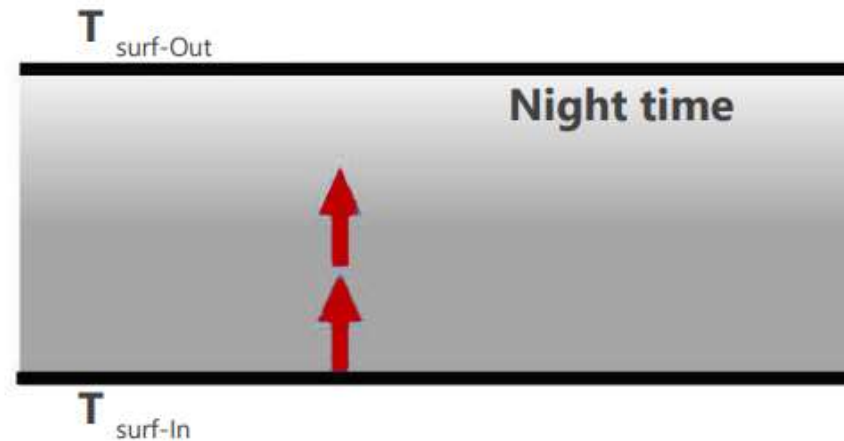
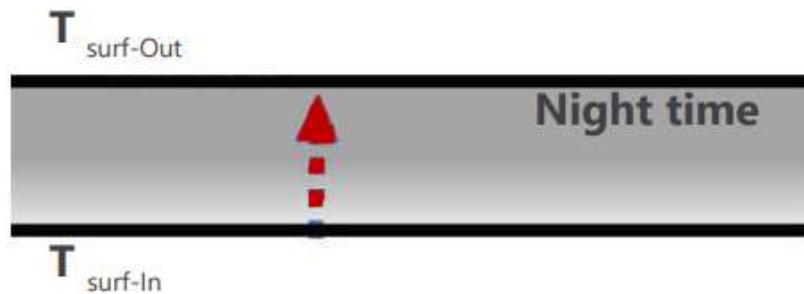
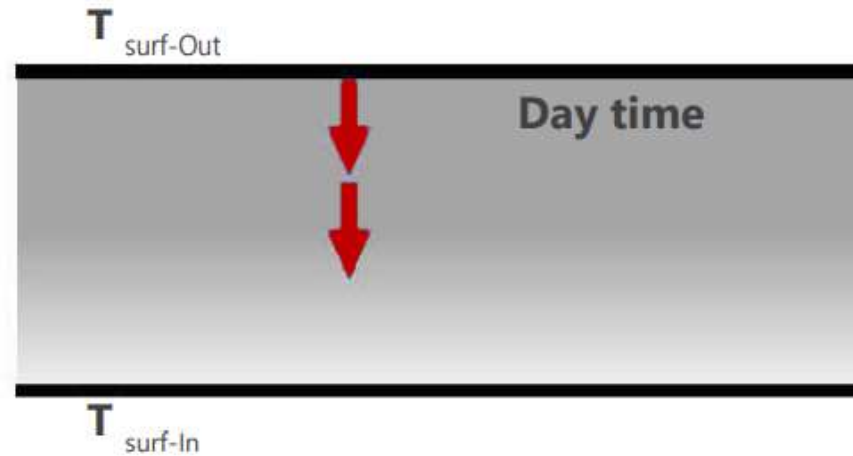
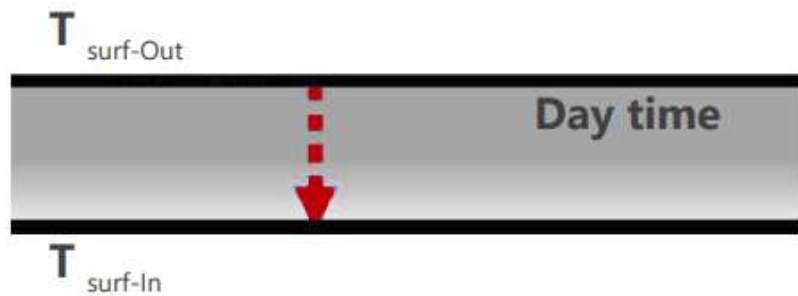
creepers are flexible shading devices for shading verandahs and interior spaces as per the season



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

# **INNOVATIVE BUILDING MATERIALS AND NEW METHODS OF CONSTRUCTION FOR AFFORDABLE HOUSING**

## Thermal Insulation and Thermal Mass



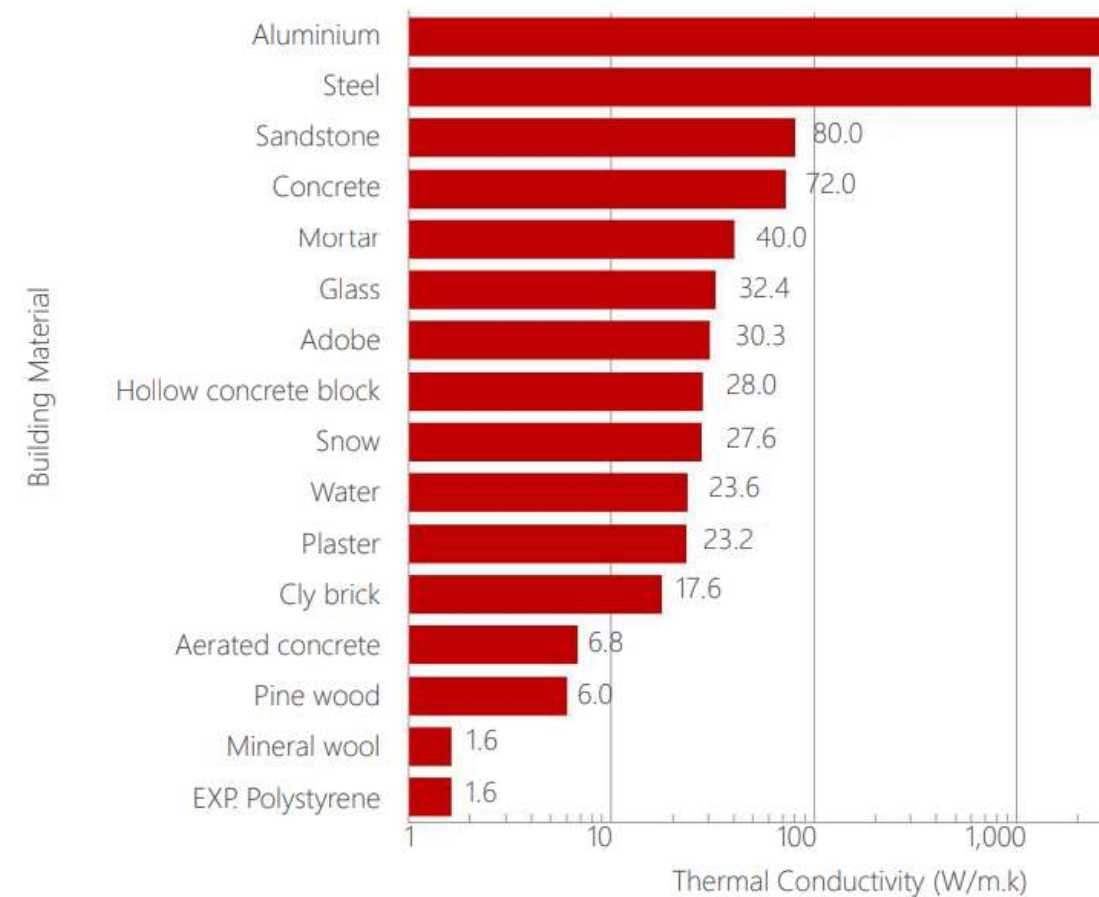
A- Thermal insulation through thermal conductivity

B- Thermal insulation through thermal mass

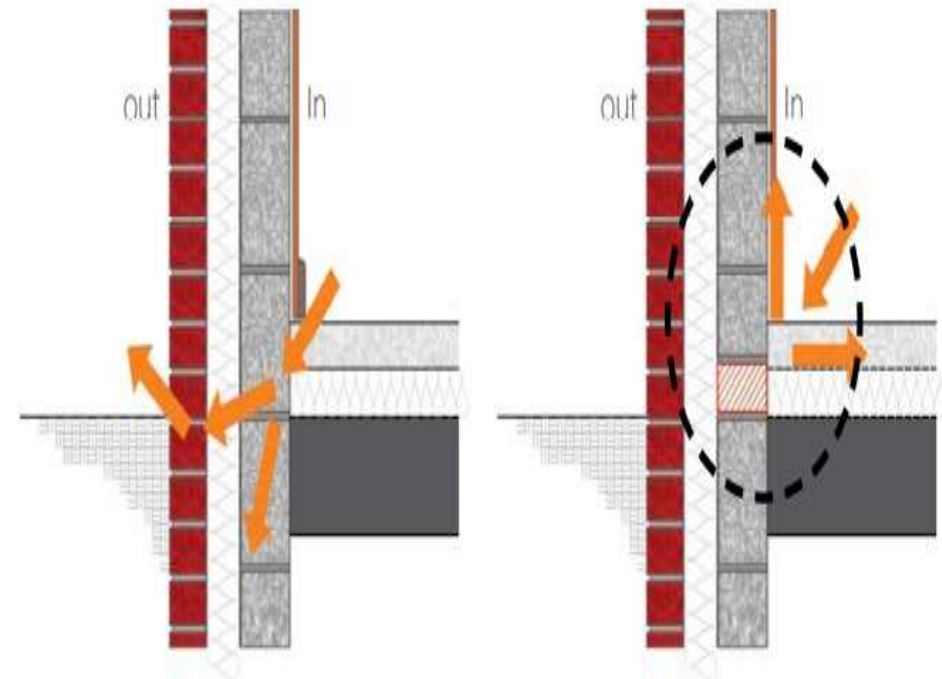
# INNOVATIVE BUILDING MATERIALS AND NEW METHODS OF CONSTRUCTION FOR AFFORDABLE HOUSING

## 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.



Thermal conductivities of common building materials



Walling assemblies and thermal bridging



# INNOVATIVE BUILDING MATERIALS AND NEW METHODS OF CONSTRUCTION FOR AFFORDABLE HOUSING

U-value database of all selected walling assemblies and technologies

## Walling Technologies

- ✓ The assemblies presented are a mix of commonly used traditional systems and emerging technologies in the Indian context.
- ✓ It can be observed from the figure that assemblies with insulation such as EPS, insulated panels have lower U-values and hence, can help in reducing heat gains through wall.

S/N	Test Phase	Wall types	Thickness (in mm)	U value (W/m <sup>2</sup> .K)
1	1	Base case: Burnt Clay Brick Wall	250	2.41
2	1	Rattrap bond wall	250	2.11
3	1	Light Gauge framed steel structure with EPS	136	1.37
4	1	Light Gauge framed steel structure with PPGI Sheet	150	2.12
5	1	Reinforced EPS core Panel system	150	0.56
6	1	Glass fibre reinforced Gypsum Panel -Unfilled	124	2.06
7	1	Glass fibre reinforced Gypsum Panel -with RCC & non-structural filling	124	2.12
8	1	Glass fibre reinforced Gypsum Panel -with partial RCC filling	124	2.13
9	1	Structural stay-in-place formwork system (Coffor) – Insulated panel	230	0.44
10	2	Bamboo Crete	65	2.71
11	2	Wattle and Daub	45	3.61
12	2	Stabilized Adobe	230	2.11
13	2	Laterite Block Wall	205	2.17
14	2	Unstabilized Adobe	230	2.05
15	2	CSEB	230	2.79
16	2	Unstabilized CEB	230	2.74

S/N	Test Phase	Wall types	Thickness (in mm)	U value (W/m <sup>2</sup> .K)
17	2	AAC Block Wall with Perlite based Cement Plaster	230	0.76
18	2	Unstabilized Rammed Earth	230	2.13
19	2	Stabilized Rammed Earth	230	2.09
20	2	AAC Block Wall with Cement Mortar and Cement Plaster	230	0.78
21	2	AAC Block Wall with Lime mortar and Lime Plaster	220	0.82
22	2	Burnt Clay Brick with Lime Mortar and Lime Plaster	250	2.31
23	2	Limestone with Lime Mortar and Lime Plaster	224	2.84
24	2	Limestone with Cement Mortar and Cement Plaster	230	2.82
25	3	Hollow Clay Brick (100 mm thick) with Cement Plaster	130	2.71
26	3	Hollow Clay Brick (100 mm thick) with Cement Plaster and XPS (25 mm)	158	0.89
27	3	Hollow Clay Brick (200 mm thick) with Rockwool and Cement Plaster	230	1.28
28	3	Hollow Clay Brick (200 mm thick) with Cement Plaster	230	1.83
29	3	Hollow Clay Brick (200 mm thick) with Cement Plaster and XPS (25 mm)	258	0.75
30	3	RCC Wall (100mm thick)	100	3.59
31	3	RCC Wall (100mm thick) + EPS (50 mm thick)	150	0.58
32	3	RCC Wall (100mm thick) + Styrofoam (24 mm thick) at both sides	154	0.65
33	3	RCC Wall (100mm thick) + PVC panel (6mm thick) at both sides	112	2.62
34	3	RCC Wall (100mm thick) + PVC panel (6mm thick) at both sides + EPS Board (50 mm thick) at one side	165	0.52

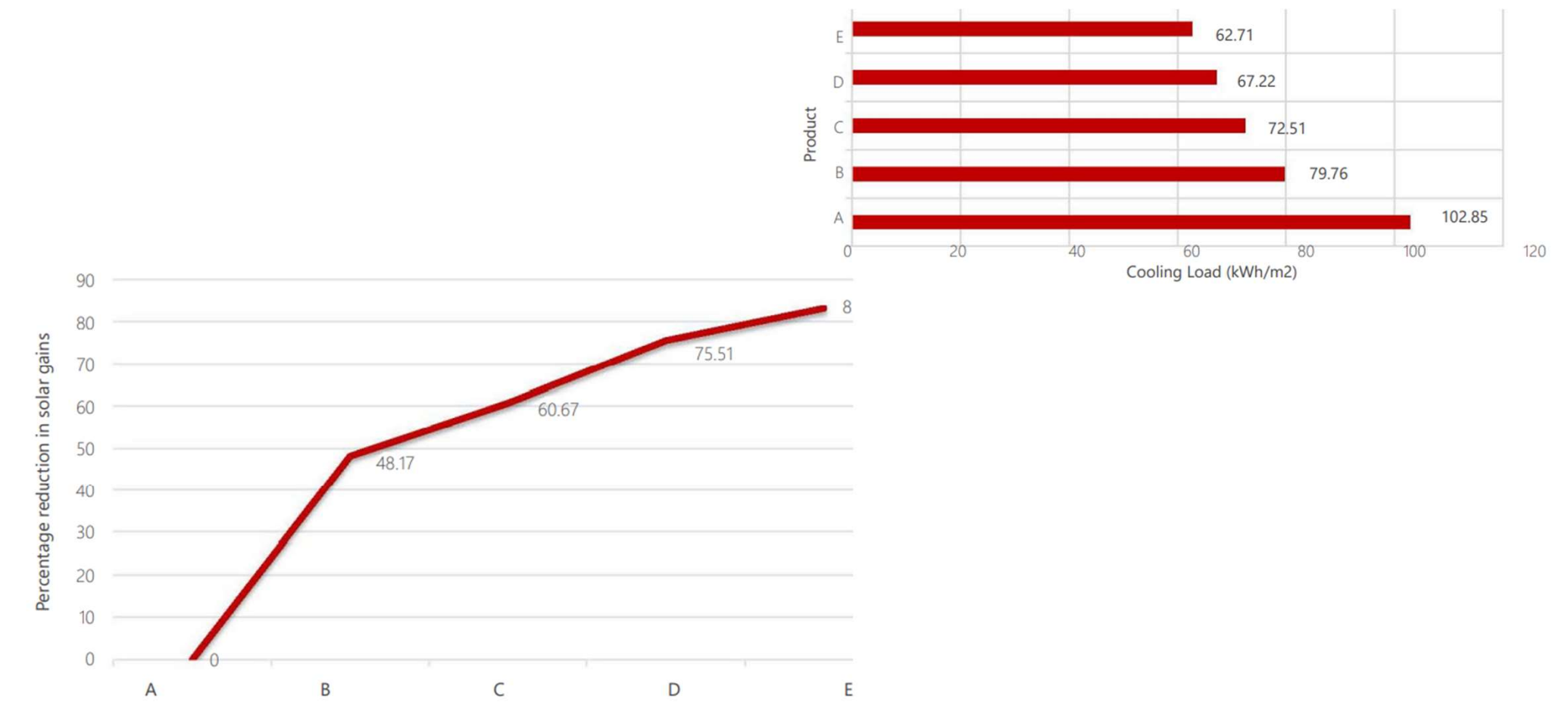


# INNOVATIVE BUILDING MATERIALS AND NEW METHODS OF CONSTRUCTION FOR AFFORDABLE HOUSING

Table 25: Properties of glazing assemblies

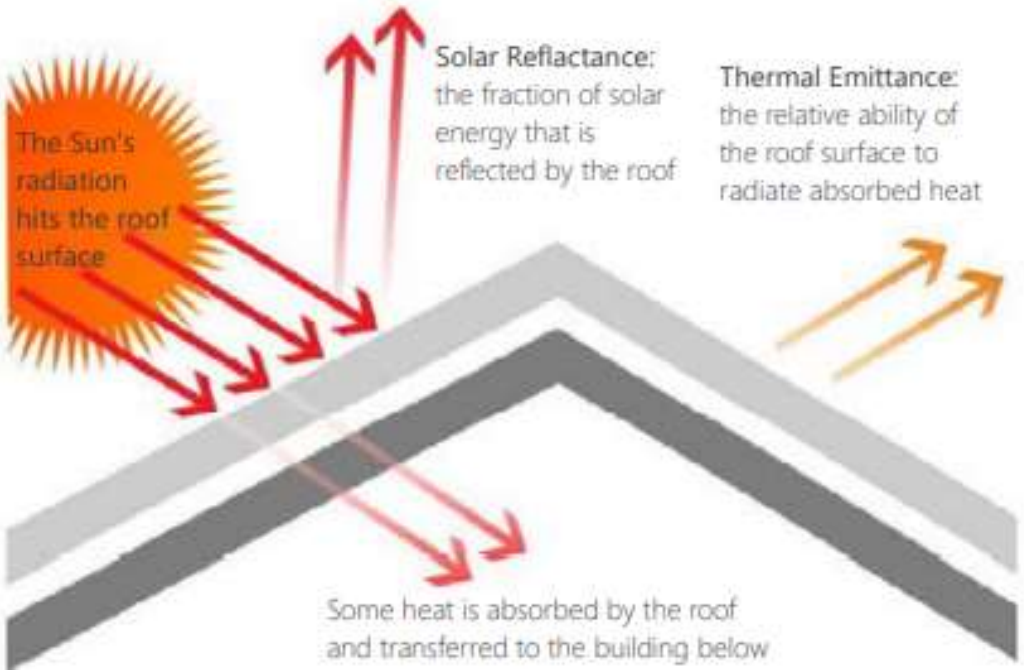
Product	VLT (%)	External Reflection (%)	Internal Reflection (%)	Solar Factor	Shading coefficient	U-value
A	80	15	15	0.76	0.87	2.6
B	46	16	18	0.22	0.25	1.5
C	46	20	22	0.47	0.54	2.8
D	51	18	22	0.28	0.33	1.5
E	47	17	11	0.38	0.43	1.9

Properties of glazing assemblies

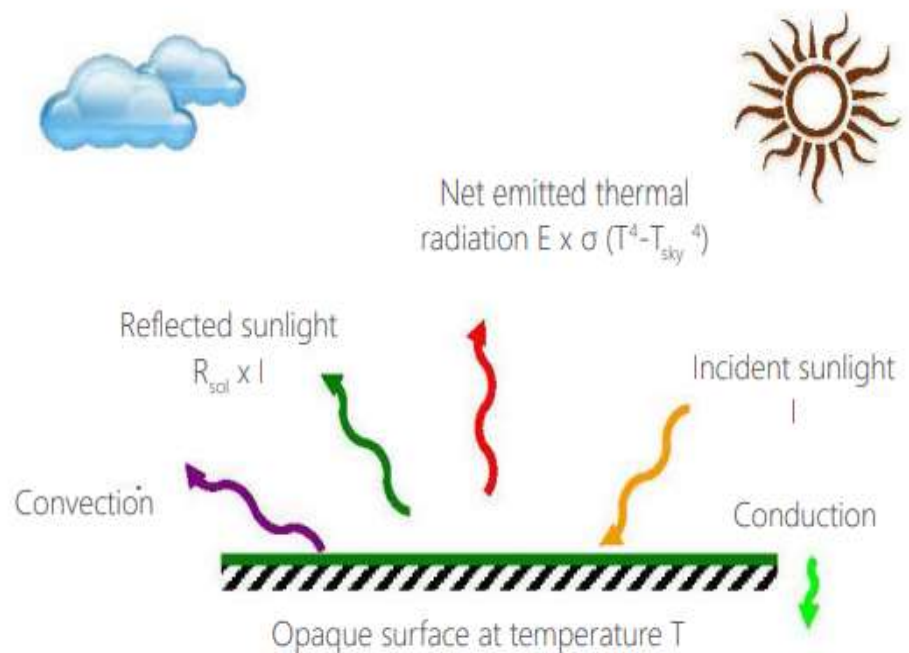


# INNOVATIVE BUILDING MATERIALS AND NEW METHODS OF CONSTRUCTION FOR AFFORDABLE HOUSING

## Roofing Coating Materials    Reflectance, Emittance, Emissivity



surfaces with incident solar radiation



Factors affecting surface temperature of roof and/or roof coating materials



roofing materials

# 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

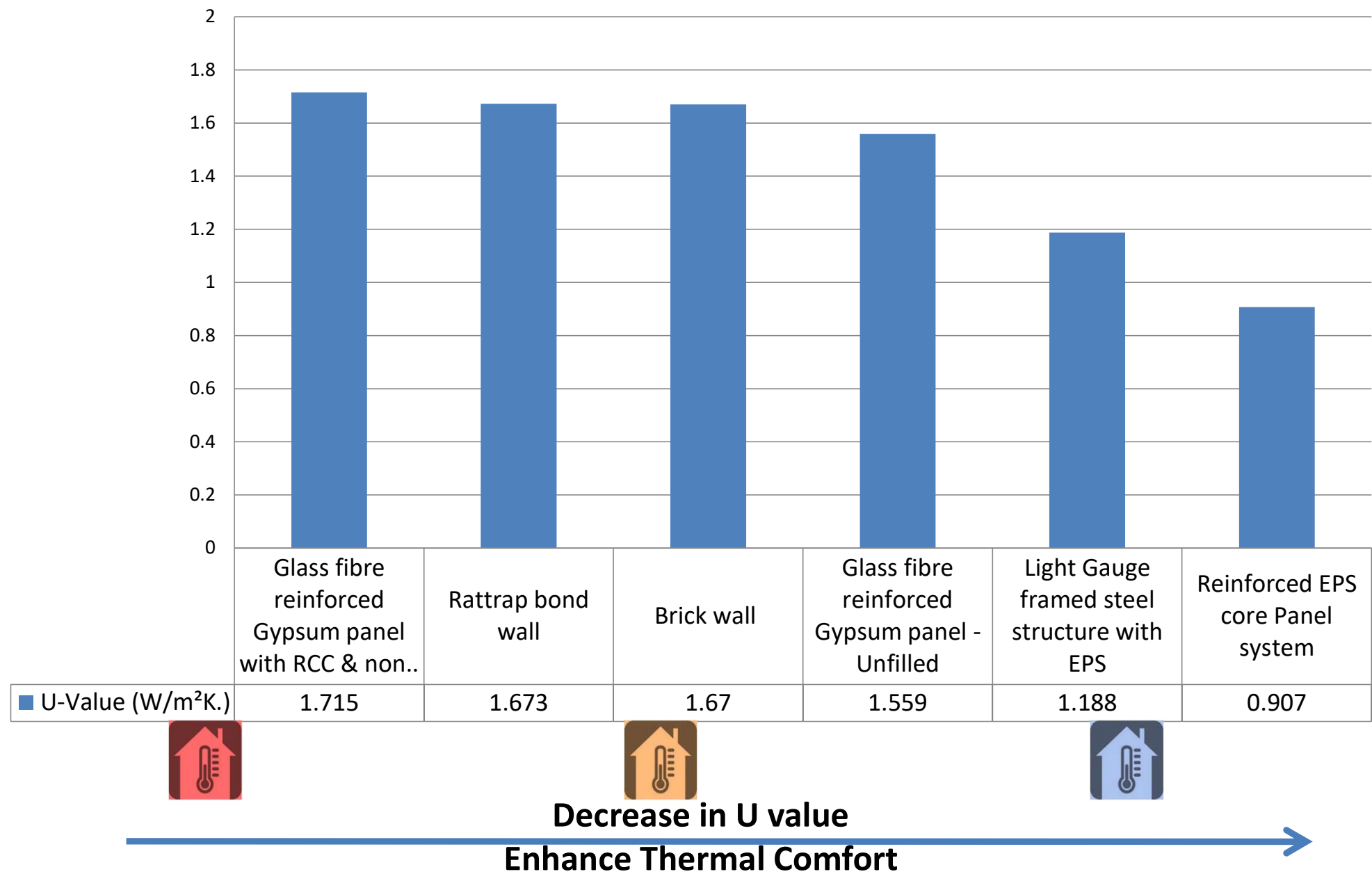
Characteristic of insulating materials	Insulating Power	Density	Fire Resistance	Water vapor diffusion	Resistance to water	Compression Strength	Traction Strength	Heat Resistance	Absorption of vibrations	Absorption of aerial noise	Cost at given insulation	Embodied Energy
Light mineral Wool	+	_-	++	-	0	_-	_-	+		++	+	_-
Dense Mineral Wool	++	+	++	_-	0	0	-	++	++	+	+	0
Glass foam	+	+	++	++	++	++	++	++	_-	-	+++	0
PUR	++	-	0	-	0	+	+	++	-	_-	+	++
EPS	++	_-	+	+	0	+	+	0	-	_-	+++	-
XPS	++	0	+	++	+	+	++	0	-	_-	+	+

++ Very high; + High; 0 Average; - Low; \_- Very low

Comparison of commonly used insulation material

# MATERIAL CHARACTERISTICS FOR BETTER THERMAL COMFORT

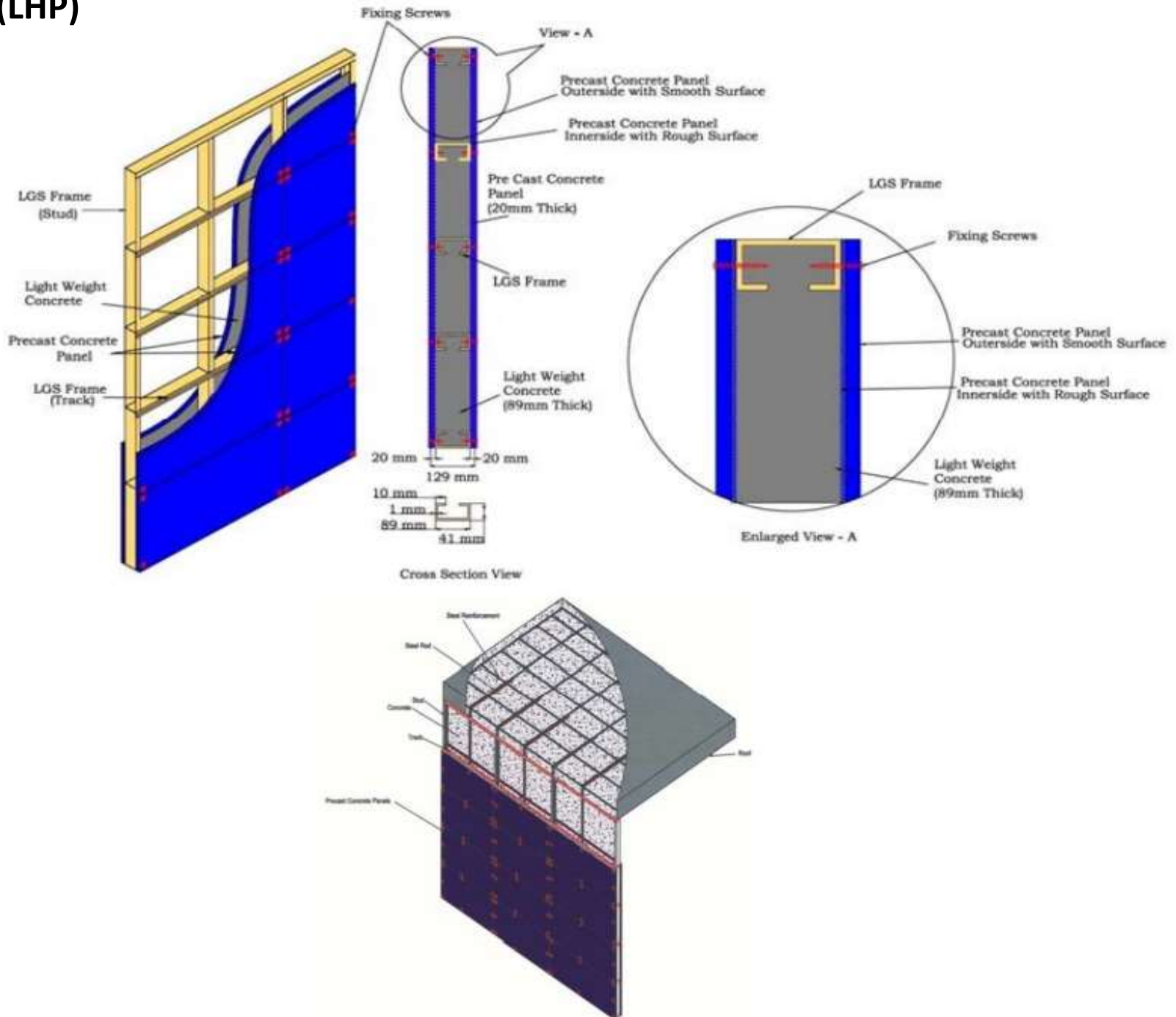
*Lower the U-value, lower the rate of heat transfer and better the insulating property of the element*



# INNOVATIVE BUILDING MATERIALS AND NEW METHODS OF CONSTRUCTION FOR AFFORDABLE HOUSING

## Light House Projects (LHP)

LHP – Agartala  
(Light Gauge  
Framed Steel  
Structure – Infill  
Concrete Panel)





# INNOVATIVE BUILDING MATERIALS AND NEW METHODS OF CONSTRUCTION FOR AFFORDABLE HOUSING

# INNOVATIVE BUILDING MATERIALS AND NEW METHODS OF CONSTRUCTION FOR AFFORDABLE HOUSING

## LHP- Chennai (Precast Concrete Construction System)

3S system incorporates precast dense reinforced cement concrete hollow core columns, structural RCC shear walls (as per design demand), T/L/Rectangular shaped beams, stairs, solid precast RCC slabs for floor/ roof, lintels, parapets and chajjas.

### Salient features

- ✓ Precast dense reinforced cement concrete hollow core columns, structural RCC shear walls, T/L/Rectangular shaped beams, stairs, floor/roof solid.
- ✓ AAC blocks are used for partition walls



Precast RCC shear wall.

'3-S' precast RCC column-core concreted using self-compacting concreted.

'3-S' precast RCC beams-top part concreted using self-compacting concreted.

# INNOVATIVE BUILDING MATERIALS AND NEW METHODS OF CONSTRUCTION FOR AFFORDABLE HOUSING

## LHP- Indore (Prefabricated Sandwich Panel System)

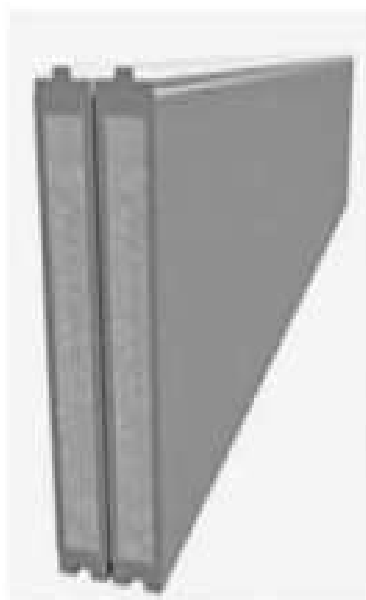
- ✓ Prefabricated Sandwich Panels are lightweight composite wall, floor, and roof sandwich panels.
- ✓ They are made of thin fiber cement/calcium silicate board acting as face covered boards with the core material as a mix of EPS granule balls, adhesive, cement, sand, fly ash, and other bonding materials in mortar form.
- ✓ The core material is pushed under pressure into preset molds in a slurry state.

### Salient features

- ✓ Facilitate quick and cost-effective construction
- ✓ EPS granule balls used as core material make the board lightweight



Pole Holes



Solid Heart



Rod Holes



Block Holes

# INNOVATIVE BUILDING MATERIALS AND NEW METHODS OF CONSTRUCTION FOR AFFORDABLE HOUSING

## LHP- Lucknow (PVC Stay-in-place formwork)

- ✓ Stay-in-place formwork refers to an innovative formwork system made of rigid polyvinyl chloride (PVC) that acts as durable finished formwork for concrete walls.
- ✓ It has slide and interlock technology for the extruded components to create continuous formwork.
- ✓ The two faces of the wall are connected by continuous web members to form hollow rectangular components

### Salient features

- ✓ Rigid polyvinyl chloride (PVC) based formwork system serves as a permanent stay-in-place durable finished formwork for concrete walls
- ✓ The PVC extrusions consist of the substrate (inner) and modifier (outer). The two layers are co-extruded during the manufacturing process to create a solid profile.



# INNOVATIVE BUILDING MATERIALS AND NEW METHODS OF CONSTRUCTION FOR AFFORDABLE HOUSING

## LHP- Rajkot (Monolithic concrete construction with tunnel formwork)

- ✓ LHP Rajkot utilized tunnel formwork as the innovative construction technology which uses customized engineering formwork replacing the conventional steel/plywood shuttering system.
- ✓ Tunnel formwork is used cellular structures. It is based on two half shells which are placed together to form a room or cell and several cells constitute an apartment.

### Characteristics of the system

- Maximum span between walls shall be 5.60 m without accessory units and 7.00 m with accessory units.
- Height of the formwork – Typically, the forms are designed for a floor to ceiling height of at least 2.51 m. However, it can be increased by using the leg jacks or movable panels.
- Appearances of the faces after form removal – The joints connecting the units may have fins which should be sanded off and smoothed with paint filler. Remaining surfaces allow direct application of finishing paint or wallpaper.
- Working rhythm using the system – Under average temperature conditions, the normal rhythm is two days per cycle with one day and two nights for drying and setting the concrete, given ordinary cement is used.
- Time period required for execution of the process – The time required for execution varies according to the cell plan. For a cell consisting of two formed wall surfaces and a floor surface, the average time is less than 1-1.5 hours per square meter of building. This time includes the form removal, oiling, displacement of the units, formwork, and adjustment.





# INNOVATIVE BUILDING MATERIALS AND NEW METHODS OF CONSTRUCTION FOR AFFORDABLE HOUSING

## LHP-Ranchi (Pre-cast concrete construction- 3D Volumetric)

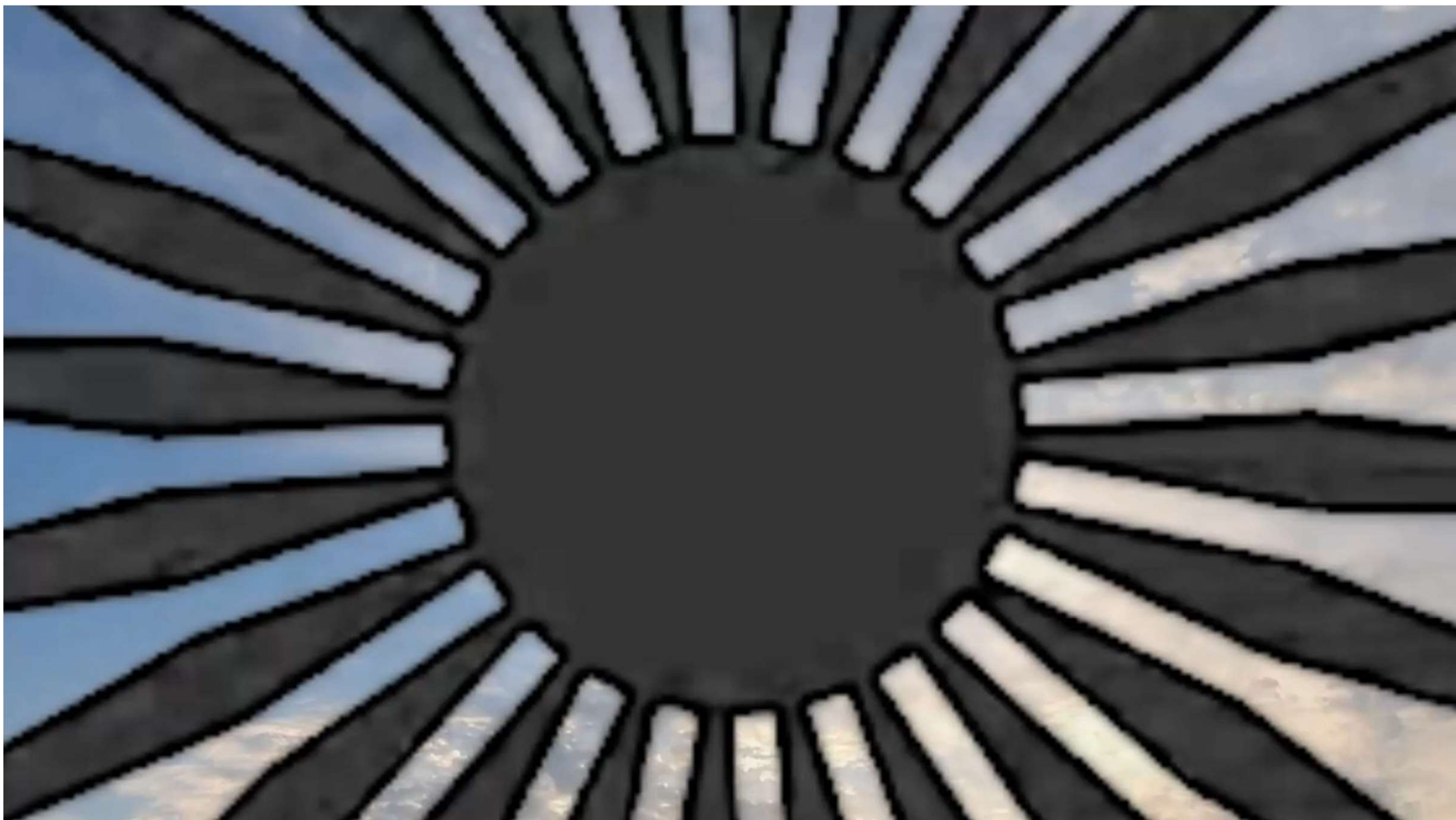
3D Volumetric concrete construction involves construction with solid precast concrete structural modules like room, toilet, kitchen, bathroom, stairs etc. & any combination of these. The modules are cast monolithically either at a plant or a casting yard in a controlled condition.

### Salient features

- ✓ About 90 % of the building work including finishing is complete in the plant/ casting yard resulting in significant reduction in construction and occupancy time
- ✓ The required concrete can be designed using industrial by-products such as Fly Ash, Ground granulated blast furnace slag (GGBS), Micro silica etc. resulting in improved workability
- ✓ Minimal shutter and scaffolding

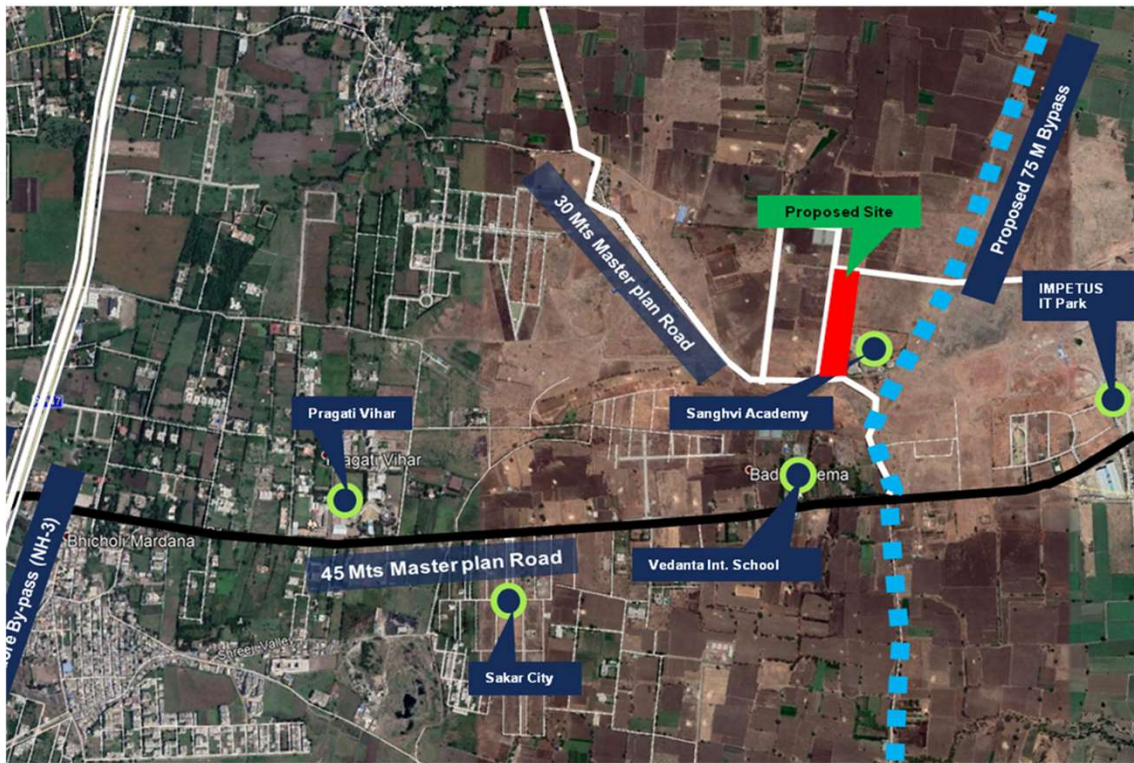


# **CASE STUDIES FOR APPLICATION OF THERMAL COMFORT IN AFFORDABLE HOUSING**





# LIGHT HOUSE PROJECT, 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
Threshold Area	Sqmt			0.50
Total Carpet Area	Sqmt			29.92





# LIGHT HOUSE PROJECT, 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 – 31-02-2023*

*Amenities –*  
Rain Water Harvesting  
Rooftop Solar Power System  
Fire Equipment (s)  
Elevator / Lift  
Emergency Power Back-up  
Sewage Treatment Plant  
Central Waste Collection Plant

# LIGHT HOUSE PROJECT, 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



# LIGHT HOUSE PROJECT, INDORE- TECHNOLOGY

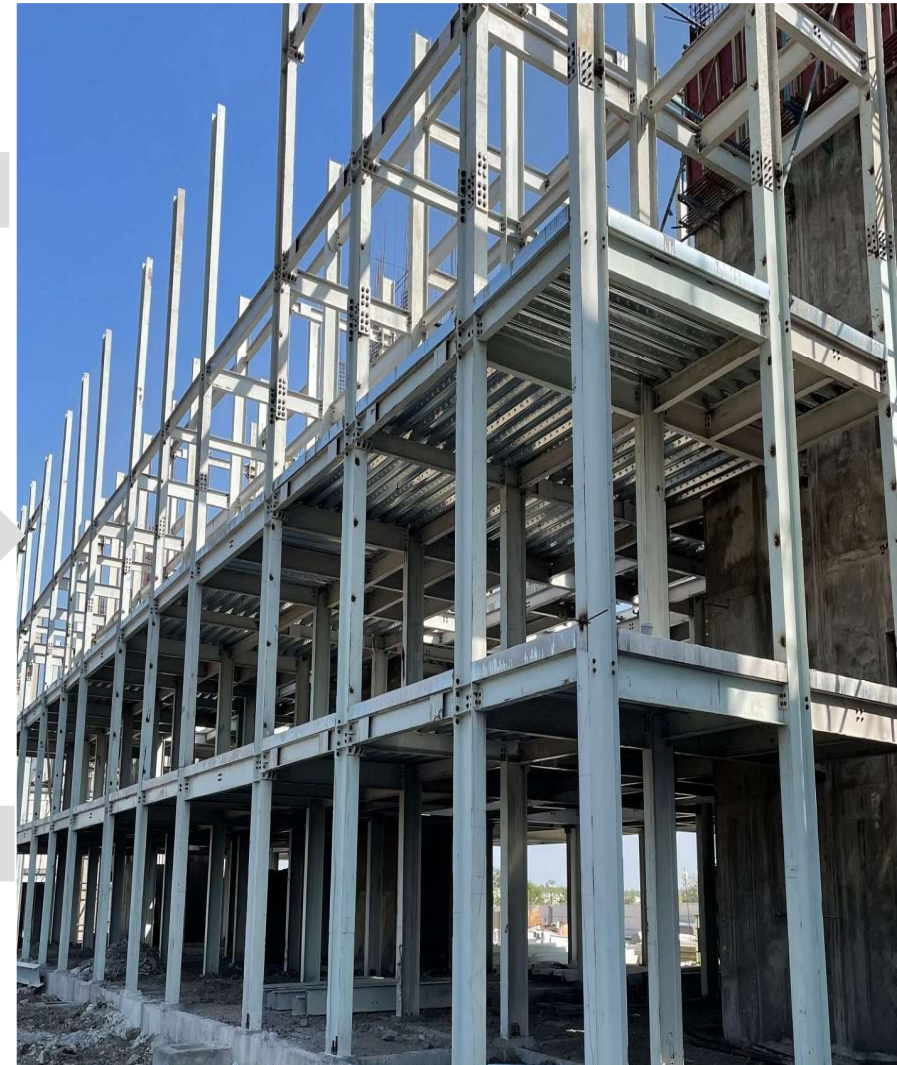
## PEB STRUCTURE

- 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*





# LIGHT HOUSE PROJECT, INDORE- TECHNOLOGY

## DECK SLAB

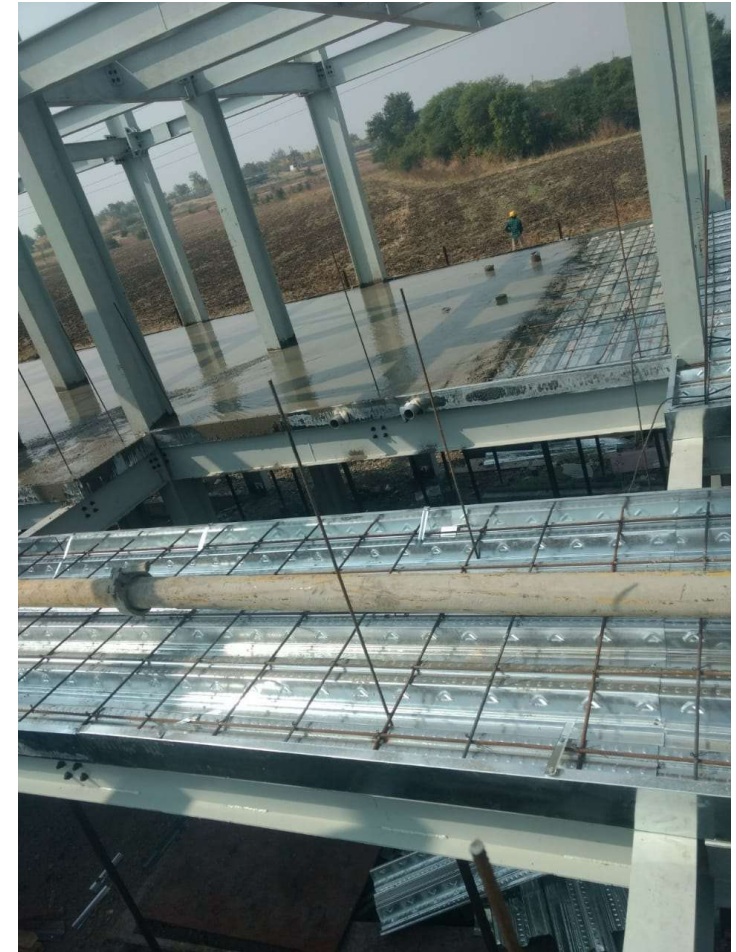
Deck sheet laying



Services & reinforcement laying



Concreting

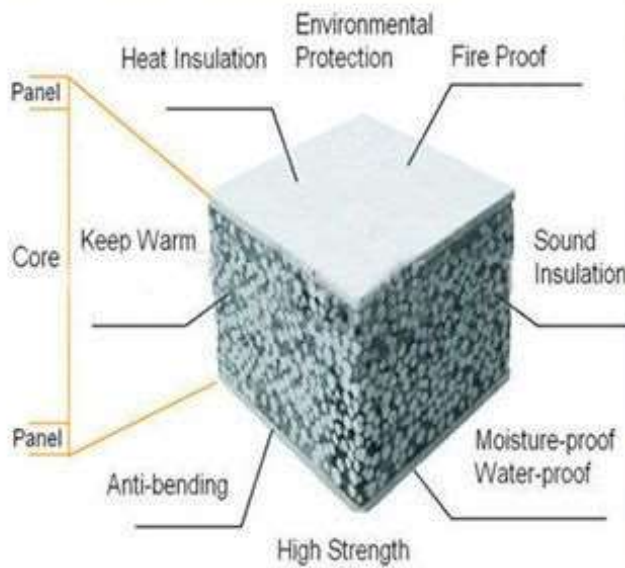






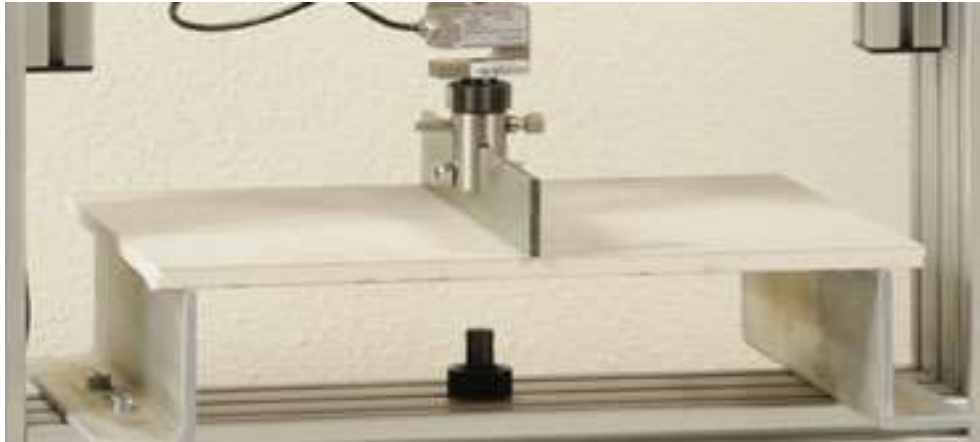
# LIGHT HOUSE PROJECT, INDORE- TECHNOLOGY

## PRE FABRICATED SANDWICH PANEL SYSTEM



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

# 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

<https://youtu.be/3ENcie5HUqk>





# CASE STUDY – DEMONSTRATION HOUSING PROJECT BHOPAL

Insulating concrete forms (ICFs) cast-in-place concrete walls that are sandwiched between two layers of insulation material. These systems are strong and energy efficient.

## ***Energy Efficient***

It has the potential to significantly reduce the heating and cooling costs of a particular building. That's also the most impressive feature of ICF walls; they can release heat in the summer and store heat in the winter. In some instances, ICFs are estimated to save about **20%** of total energy costs.



# CASE STUDIES FOR APPLICATION OF THERMAL COMFORT IN AFFORDABLE HOUSING

## Vernacular Buildings of North-East India

Features	Warm and Humid	Cool and Humid (Urban)	Cold and cloudy
Built up-area	94 sq. m.	77 sq. m.	44 sq. m.
Wall material and thickness	Brick, cement, and sand (0.127 m)	Processed mud and bamboo (0.076 m)	Rock slab, cement, and sand (0.20 m–0.25 m)
False ceiling and roof type	Asbestos sheet/wood. Galvanized tin sheet and tilted on two sides	Rare. Galvanized tin sheet and tilted on three sides	Asbestos sheet/cane/bamboo mat/wood. Galvanized tin sheet and tilted on four sides
Ventilation	High ventilation	Medium ventilation	Low ventilation
Layout and orientation	Open layout with courtyard; No specific orientation	Courtyard in rural housing only; East–west orientation and south facing	No courtyard; South sloping and east–west orientation
Prominent passive features	Air gap in ceiling, shading, extended roof used as overhang, chimney arrangement for effective ventilation	Houses are compact, proper care for ventilation	More compact, minimum surface to volume ratio, south sloping to receive maximum sun



# CASE STUDIES FOR APPLICATION OF THERMAL COMFORT IN AFFORDABLE HOUSING

The study analyzed the relationship between indoor operative temperatures and the corresponding thermal sensation votes of occupants of the selected houses in Tezpur (warm-humid) and Imphal (cool-humid).

## Major conclusions of the research have been listed below

- ✓ Indoor temperature swings are within 10°C for all months in the case of representative houses located in warm-humid and cool-humid climates which is permissible limit for naturally ventilated buildings.
- ✓ For the representative house in the cold and cloudy climate, the temperature swings are higher. This can be attributed to lower insulation and thermal inertia of walls than required.
- ✓ Larger adaptability in Tezpur and Imphal as observed in Figure 128 (larger width of neutral temperatures) indicates higher adaptability of occupants in naturally ventilated buildings.
- ✓ None of the houses exhibit significantly thermally comfortable environments in the winter months
- ✓ Occupants have enhanced control over indoor environments in the vernacular houses because they have the flexibility to control their personal and environmental conditions in the form of different adaptations.
- ✓ For all the cases studied, range of comfort temperatures lies between 6°C and 7.3°C



# CASE STUDIES FOR APPLICATION OF THERMAL COMFORT IN AFFORDABLE HOUSING

## Pol Houses And Conventional Houses In Ahmedabad

A comparison of thermal performance of pol houses (PH) with contemporary houses (CH) in the city of Ahmedabad is discussed in this case study. The locations of five PH and five CH selected for the research are highlighted in images. The climate of Ahmedabad is classified as hot-dry according to the National Building Code of India (BIS, 2016).



### Observations

- ✓ Both PH and CH perform almost similar with respect to comfort hours for both IMAC and ASHRAE-55 models
- ✓ The relationship between indoor air temperature and outdoor air temperature for pol houses (red regression line) and contemporary houses (blue regression line) is quite similar and moderately strong as
- ✓ In terms of response time to the outdoor conditions, PH were found to be marginally faster than CH.

### Conclusions

Traditional knowledge and qualitative literature highlight thermal mass as one of the most important strategies to keep the heat out. However, the observations indicated that thermal mass alone may not be the best strategy in all situations



# CASE STUDIES FOR APPLICATION OF THERMAL COMFORT IN AFFORDABLE HOUSING

## Rajkot Smart GHAR III

The Smart GHAR III in Rajkot is an affordable housing project under PMAY Untenable Slum Redevelopment.

Some of the project details are listed below (Indo-Swiss Building Energy Efficiency Project (BEEP), 2021):

Site Area: 17,593 m<sup>2</sup> ,

No. of dwelling units (DU): 1176

Built-up area per DU: 33.6 m<sup>2</sup>

No. of residential towers: 11

Built-up Area: 57,408 m<sup>2</sup>

Type of dwelling units: 1bhk

Carpet area per DU: 29 m<sup>2</sup>

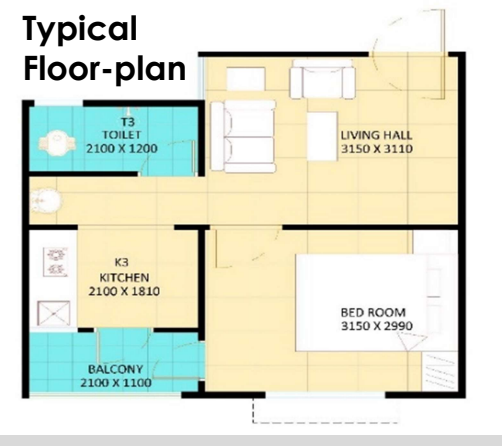
No. of floors: Stilt + 7



Site layout for Rajkot Smart GHAR-III (PMAY) project.

# CASE STUDIES FOR APPLICATION OF THERMAL COMFORT IN AFFORDABLE HOUSING

## LHP Indore Project Actual View



- Wall U Value 1.37 W/m² °K**  
EPS Sandwich Panel, 120 mm
- Roof U Value 1.80 W/m² °K**  
Deck sheet + RCC slab + brick-bat-coba + china mosaic tile, 135mm
- Glass U Value 5.35 W/m² °K**  
VLT: 0.90, SHGC: 0.86
- Natural Ventilated**  
Openings: Windows , doors
- LPD (W/m²): 13:BR & LR, 10:Kt, 7.5:RR**  
LED technology based lightings
- External Auxiliary Load Density: 8W/m²**  
If conventional utilities are being used
- 40+ lakh of investment to be done for upgradation of roof assembly for all towers**

**PROPOSED PARAMETERS & ESTIMATIONS**

**Wall U Value 1.37 W/m² °K**  
EPS Sandwich Panel, 120 mm

**Glass U Value 3.50 W/m² °K**  
VLT: 0.45, SHGC: 0.43

**LPD (W/m²): 2.3:BR, 11.2:LR, 7.7:Kt, 5.0:RR**  
LED technology based lightings

**₹ 950/ flat/ month**  
i.e. approx. 135 unit consumption/ flat/ month

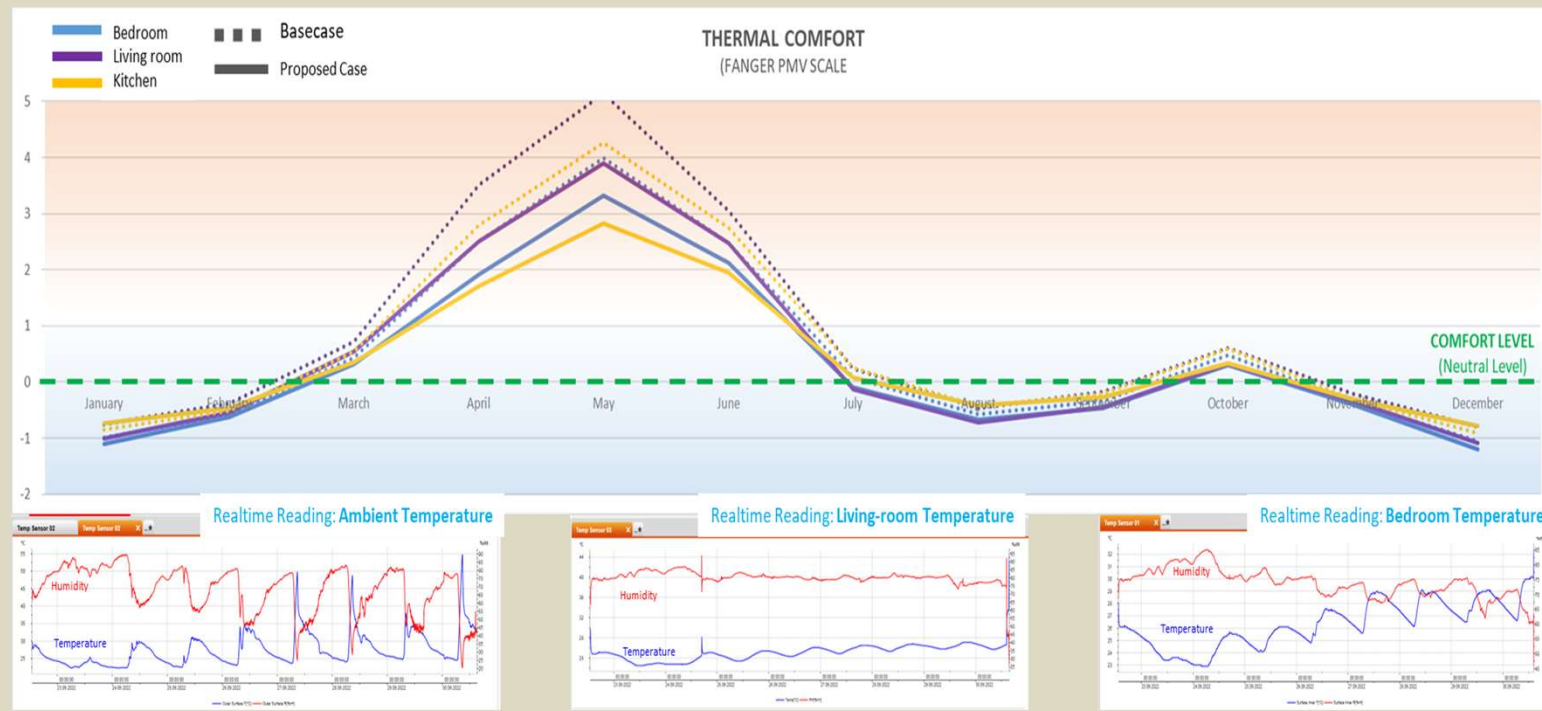
**26%**  
(Reduction of annual energy consumption against conventional practice)  
*\*estimation on the basis of simulation analysis*

**Roof U Value 0.45 W/m² °K**  
Deck sheet + over deck Insulation + RCC slab + brick-bat-coba + china mosaic tile, 150mm

**'0.72' PMV Scale i.e. Comfort level**  
Fanger's Natural Ventilated Index

**External Auxiliary Load Density: 7.2W/m²**  
BEE Certified utilities are used

**₹ Approx. ₹4850 annual savings on Energy Bills**  
i.e. approx. 700 unit consumption/ flat/ month



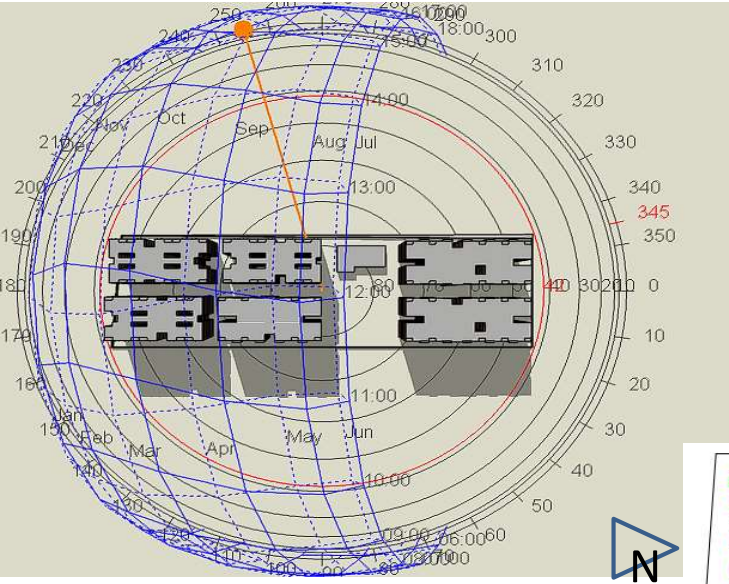
- Advantages:**
  - Reduction in Cooling Load – Approx 30%
  - Reduction in Electricity Consumption – Approx 26%
- Key features:**
  - Provision of Solar Rooftop System
  - Provision of Rain Water Harvesting
  - Provision of STP for re-use of treated water

# CASE STUDIES FOR APPLICATION OF THERMAL COMFORT IN AFFORDABLE HOUSING

## DEMO PROJECTS

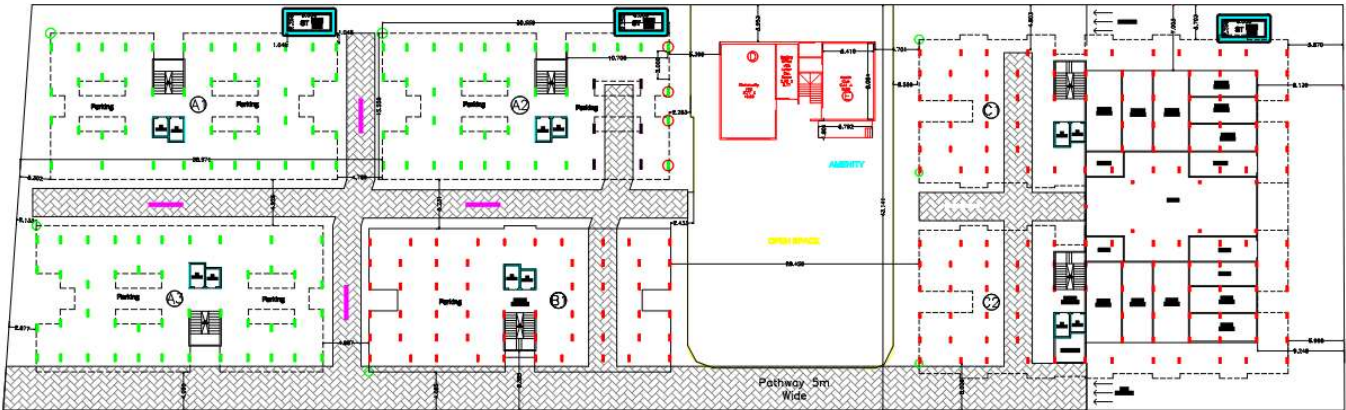


# CASE STUDIES FOR APPLICATION OF THERMAL COMFORT IN AFFORDABLE HOUSING

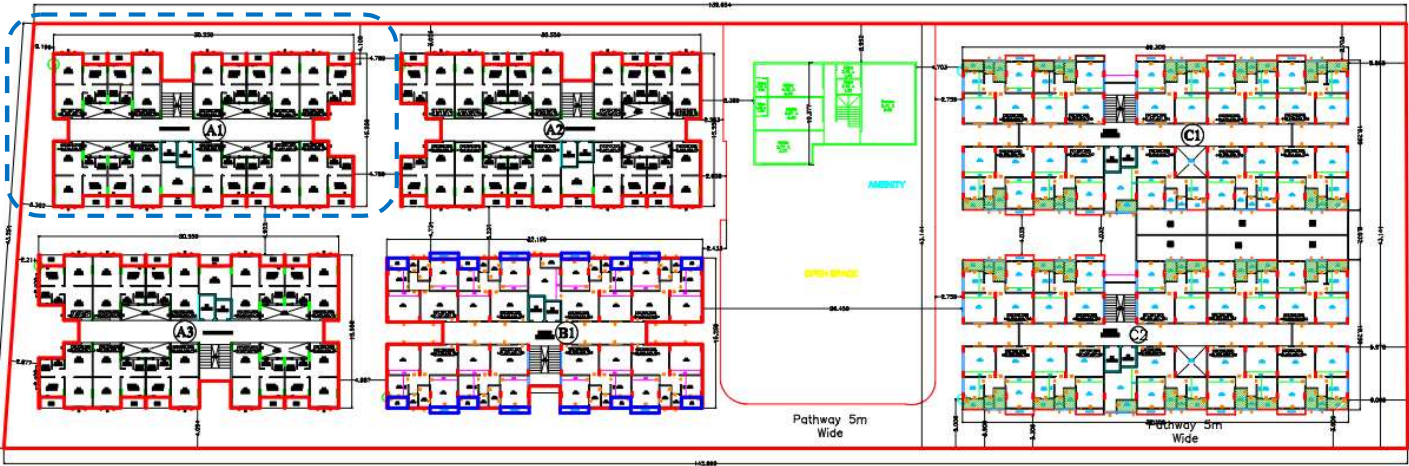


## Project Details

Projects name- Lotus Green, Gita Nagar, Akola, Maharashtra  
Climate Zone (as per NBC 2016) - Hot & Dry  
Site Area - 6100.00 sq. mt  
Total Built-up Area 19751.26 sq. mt  
Structural system- RCC  
Innovative design - Sandwich EPC Sheet in Outer concrete wall.  
Aluform ( mione – Technology) Construction work.



GROUND FLOOR - LAYOUT



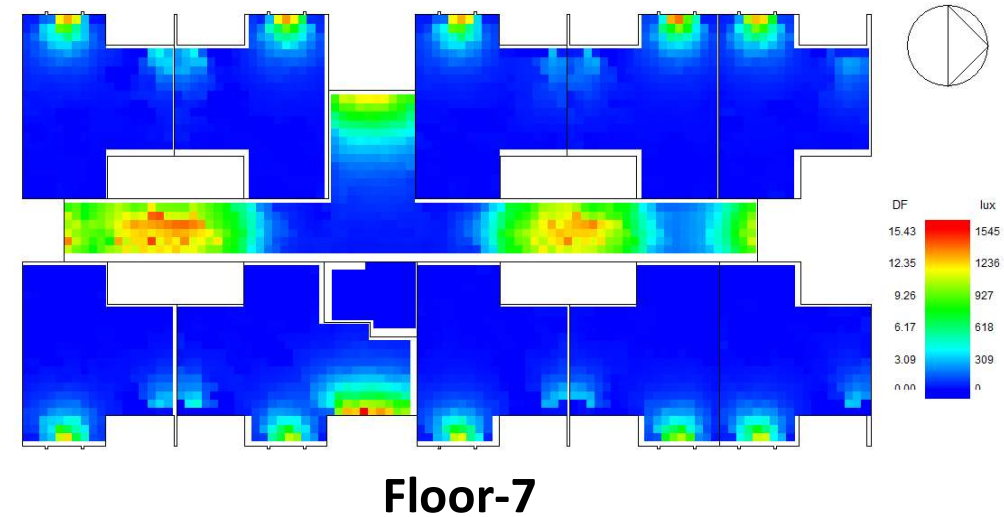
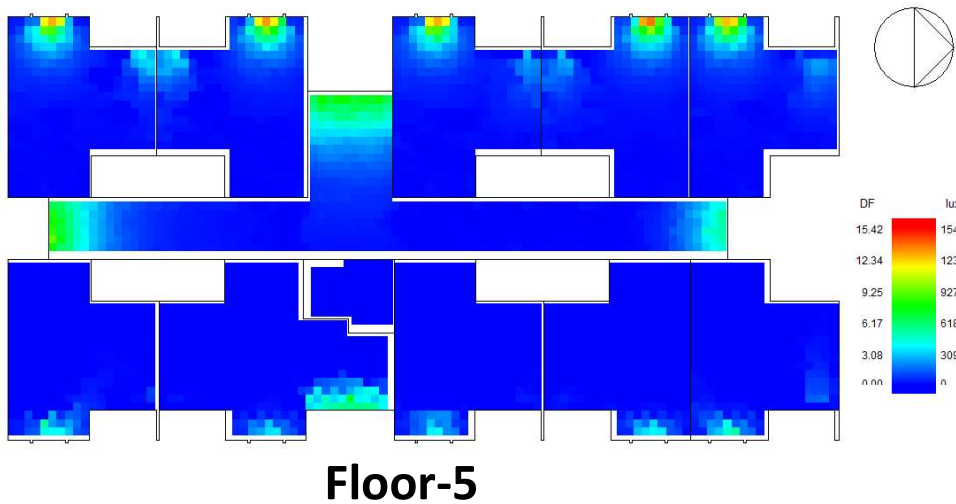
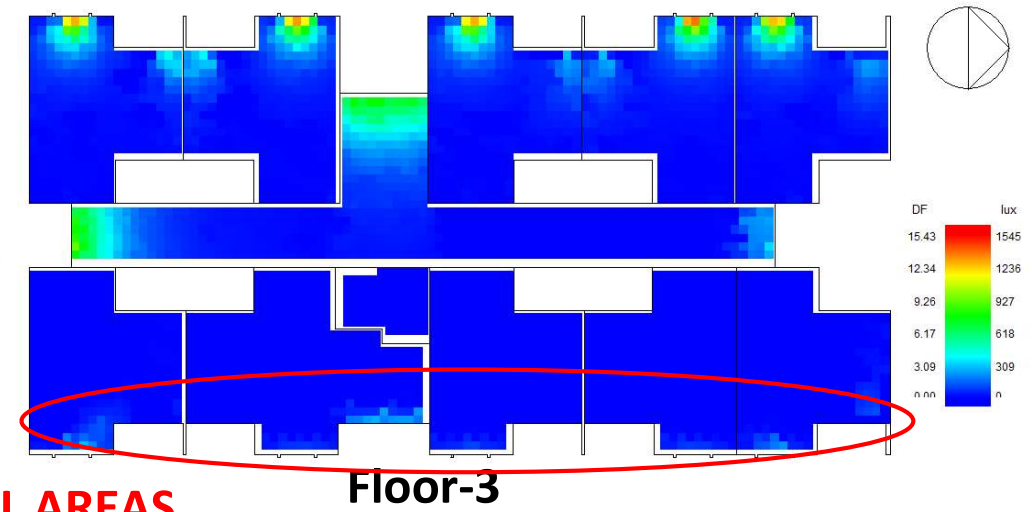
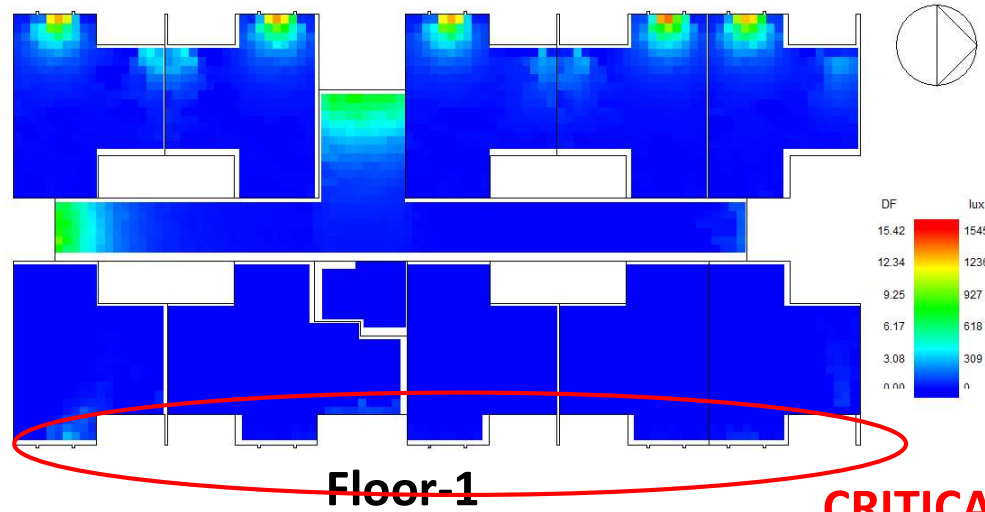
TYPICAL 1ST TO 7TH FLOOR - LAYOUT

**\*Under Analysis Stage**



# CASE STUDIES FOR APPLICATION OF THERMAL COMFORT IN AFFORDABLE HOUSING

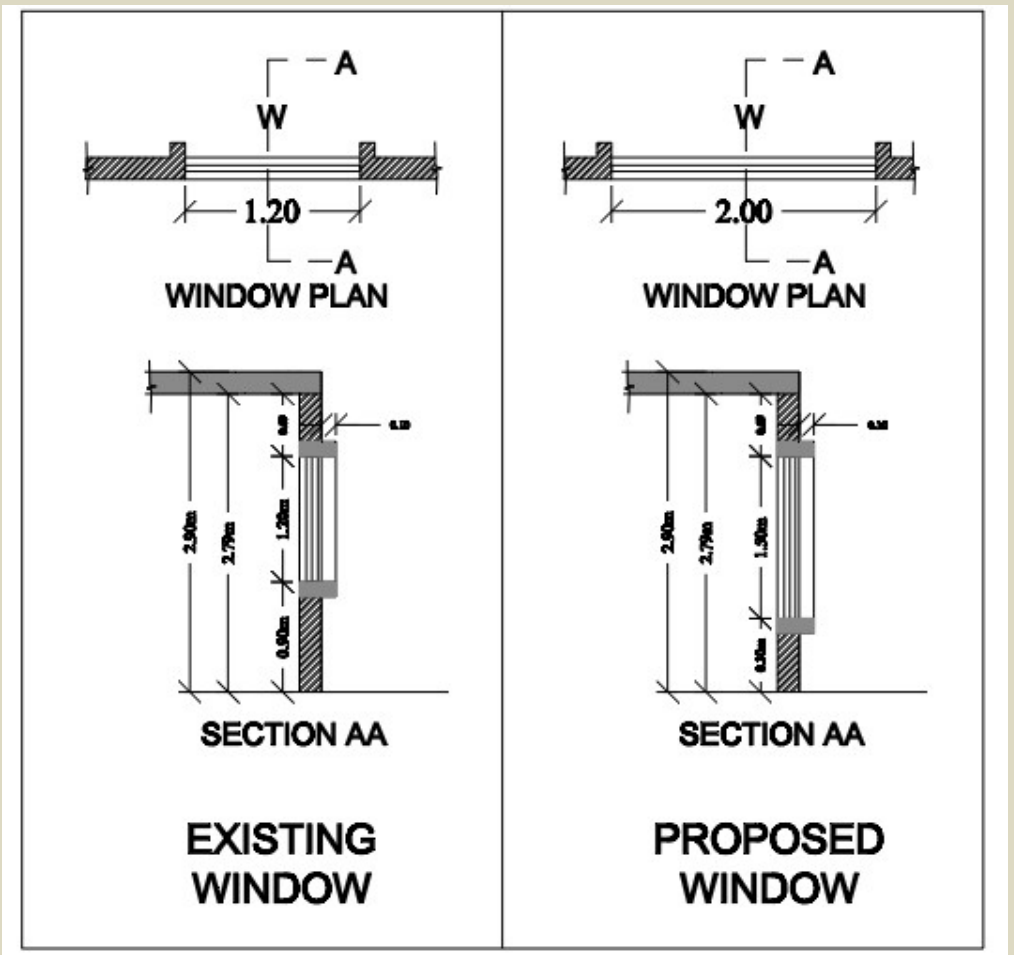
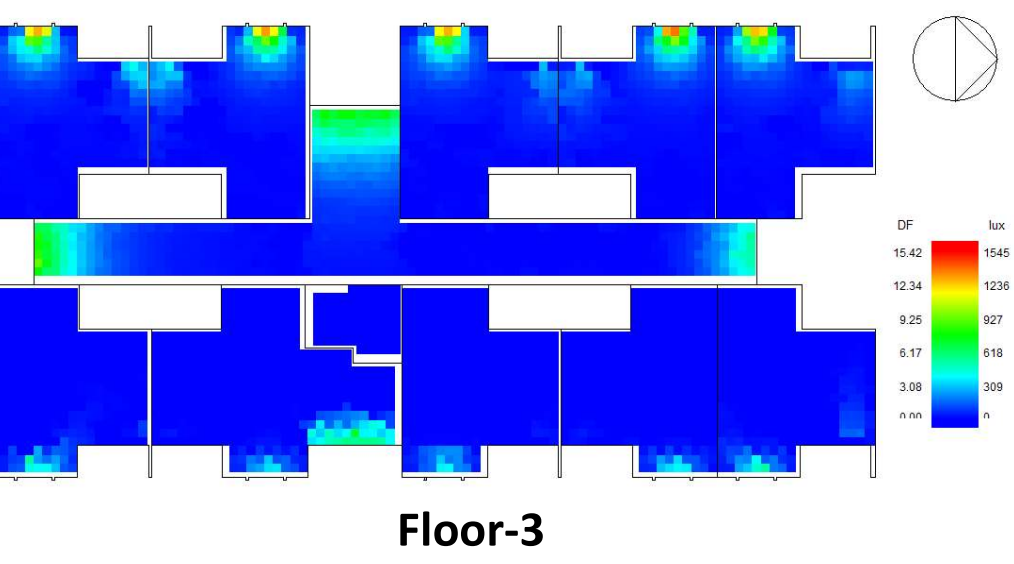
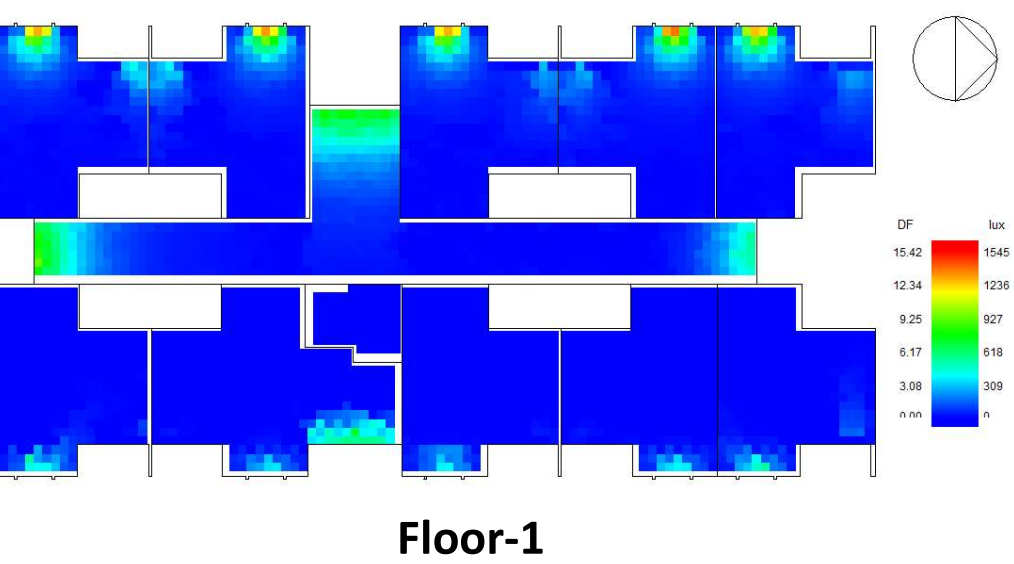
## Daylight Analysis : Block-A1 (Base case)



Analysis: shows that the inner side of blocks does not get daylighting up to 3<sup>rd</sup> floor due to mutual shading of nearby building blocks, above that 4<sup>th</sup> to 5<sup>th</sup> floor get the daylight but not in sufficient amount & Above 5<sup>th</sup> floor sufficient daylight is achieved.

# CASE STUDIES FOR APPLICATION OF THERMAL COMFORT IN AFFORDABLE HOUSING

## Daylight Analysis : Proposed Case Block-A1,A2 Vise-versa for A3 (Proposed case)

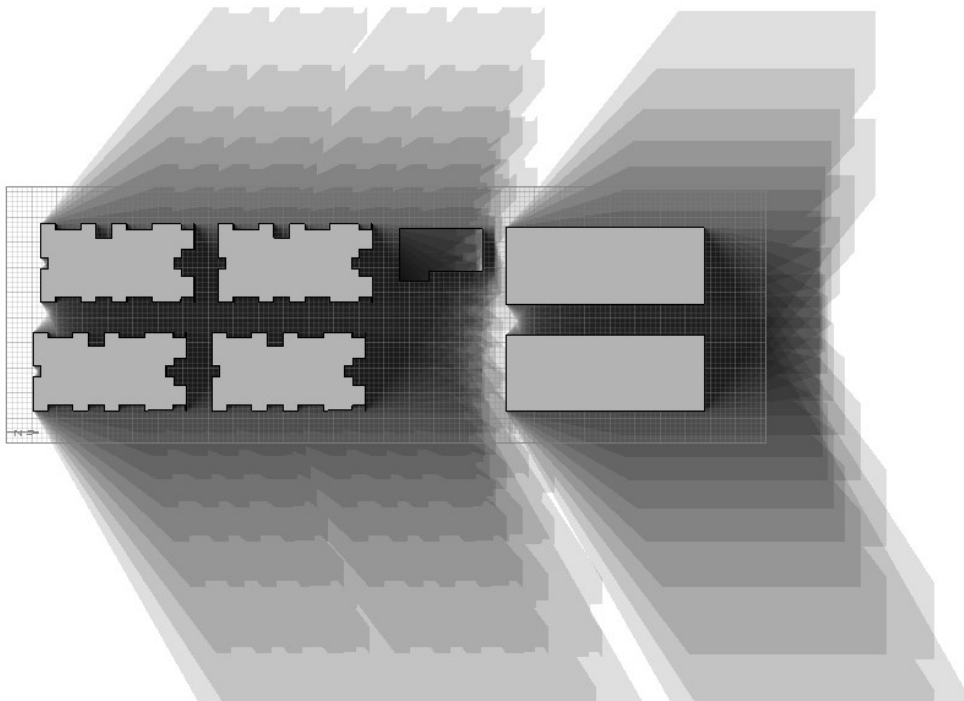


As the Horizontal shading is provided only 100 mm depth, for Windows increasing the height by 300mm & width 800mm will enhance the daylight in the flats. But still won't be able to match the required useful Day lighting in the first to third floor.

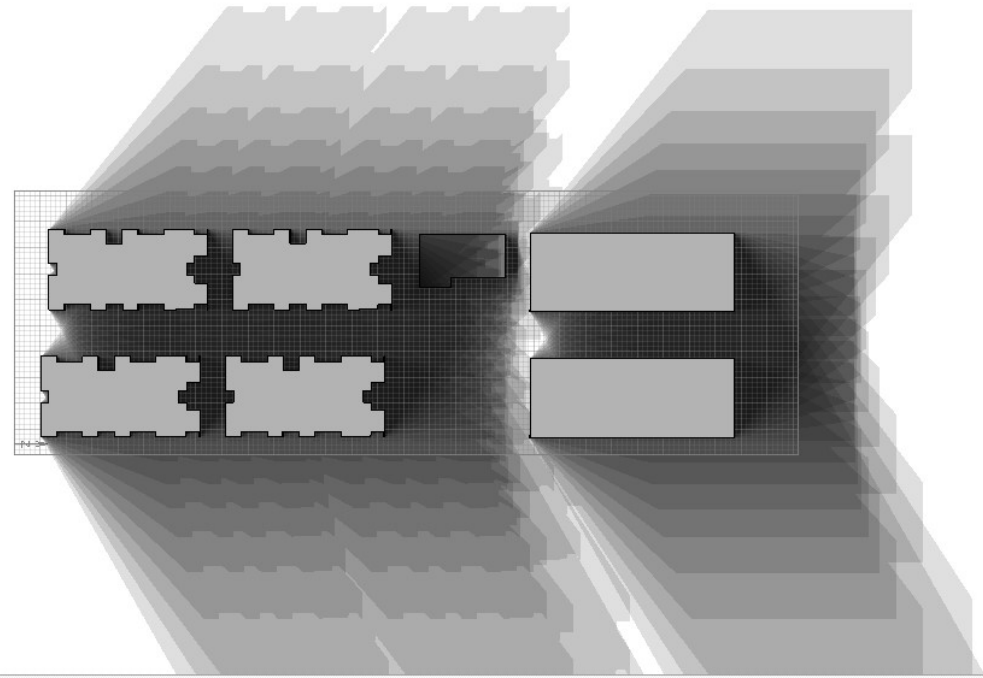
# CASE STUDIES FOR APPLICATION OF THERMAL COMFORT IN AFFORDABLE HOUSING

Due to Mutual Shading of blocks on each other, internal façade will not be able to get sufficient daylighting in the first 4 floors (First to Fourth), Following Measures should be taken in the internal facades.

- A. Window Size
- B. Window Specifications
- C. Fenestration Design
- D. External Paint Selections
- E. Light Shelves



*FMutual Shading 4.5.meter Distance  
(Reference from DHP Analysis)*



*Mutual Shading @ 9 meter Distance  
(Reference from DHP Analysis)*

Window To Floor Area Ratio (WFR)

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

CODE PROVISIONS

- **Openable Window-to-Floor Area Ratio (*WFR<sub>op</sub>*)** - it indicates the potential of using external air for ventilation.
- Ensuring minimum *WFR<sub>op</sub>* 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<sub>OP</sub>** = **A<sub>openable</sub>** / **A<sub>carpet</sub>**

3.1.3 The openable window-to-floor area ratio (*WFR<sub>op</sub>*) shall not be less than the values<sup>14</sup> given in Table 1.

**TABLE 1** Minimum requirement of window-to-floor area ratio (*WFR<sub>op</sub>*)

Climatic zone	Minimum <i>WFR<sub>op</sub></i> (%)
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.

Blocks	Windows Area	Carpet Area	16.13
Block-A1	324.45	1906.75	
Block-A2	324.45	1906.75	
Block-A3	324.45	1906.75	
Block-B1	367.92	2345.00	
Block-C1	436.59	2833.04	
Block-C2	436.59	2833.04	
Total WFR	2214.45	13731.33	
			(Required >10% as per ENS-Hot & dry Climate)



## Window To Wall Area Ratio (WWR)

The Window-to-Wall Ratio (WWR) is the fraction of the above grade wall area that is covered by fenestration, calculated as the ratio of the wall fenestration area to the gross above grade wall area.

Block A1,A2,& A3					
Windows	WallArea	WWR (%)			
225.54	2464.42	9.15	(Excluding staircase & Passage Area)		
Block B1					
Windows	WallArea	WWR (%)			
335.44	2633.925	12.74	(Excluding staircase & Passage Area)		
Block C1 & C2					
Windows	WallArea	WWR(%)			
390.32	3019.625	12.93	(Excluding staircase & Passage Area)		
TOTAL WWR (%)					
Windows	WallArea	WWR(%)			
951.3	8117.97	11.72	(Excluding staircase & Passage Area)		

The Window-to-Wall Ratio (WWR) is found 11.72%, WWR is directly proportional to daylighting areas, Hence, impact of WWR is shown in floor plans, therefore increasing in WWR helps to enhance the daylight area in the building blocks.

## CASE STUDIES FOR APPLICATION OF THERMAL COMFORT IN AFFORDABLE HOUSING

Projects name- Lotus Park, S.No. 4/1A Of Mouje Shivni, Akola, Maharashtra

Climate Zone (as per NBC 2016) - Hot & Dry

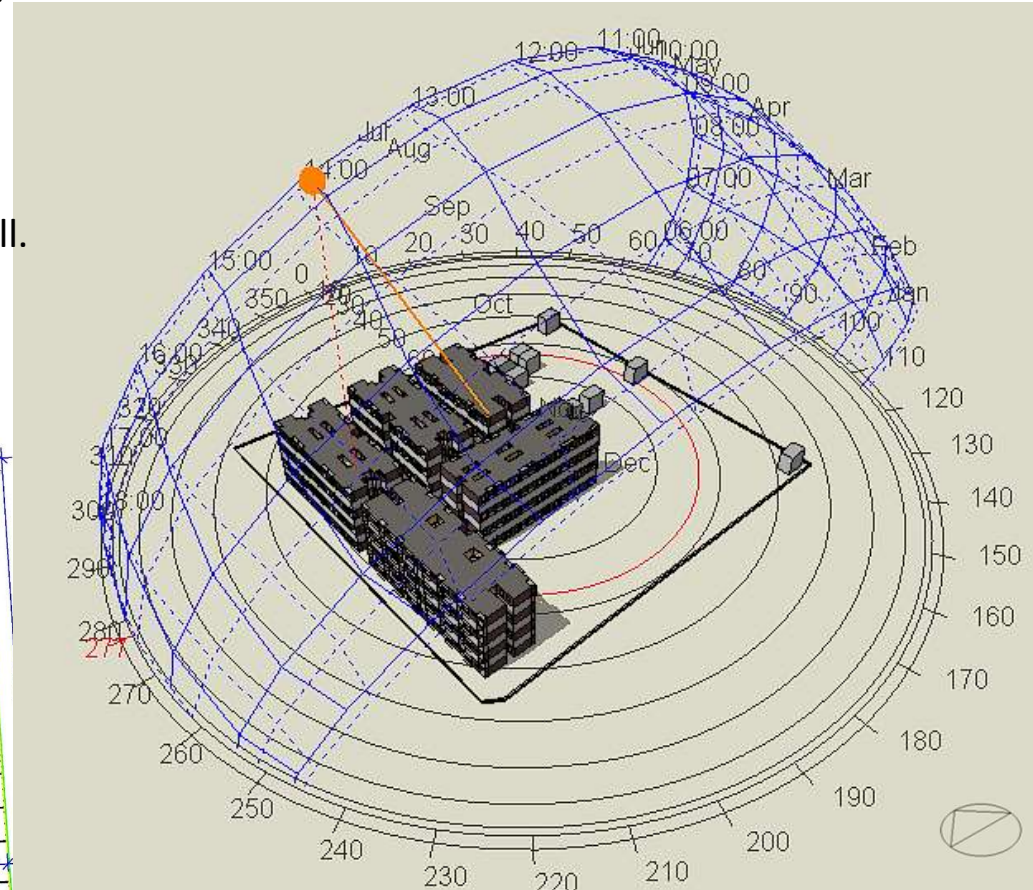
Site Area - 12700.00 sq. mt

Total Built-up Area - 19995.45 sq. mt

## Structural system - RCC

## Innovative design - Sandwich EPC Sheet in Outer concrete wall.

Aluform ( mione – Technology) Construction work.

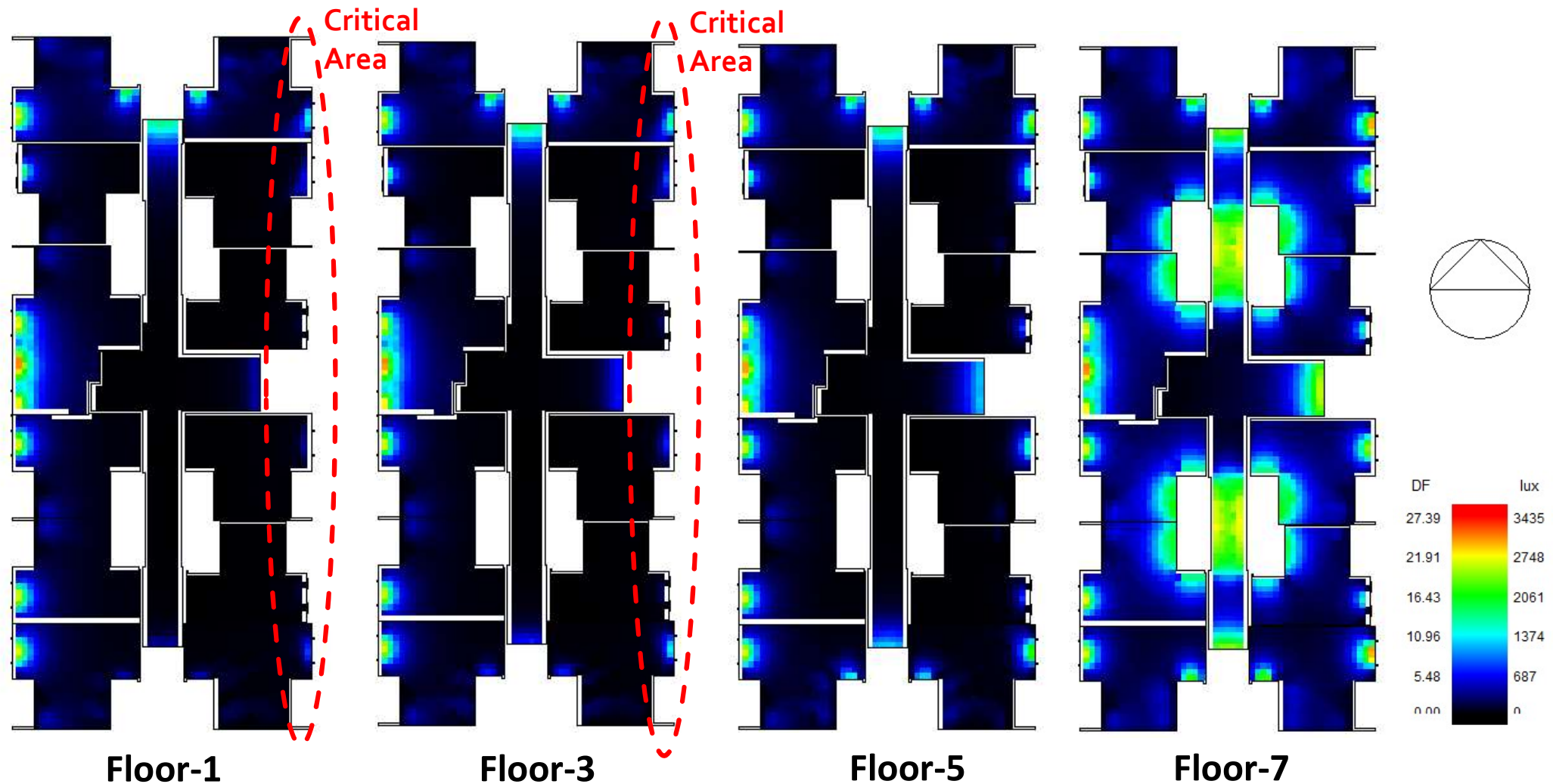


**\*Under Analysis Stage**



# CASE STUDIES FOR APPLICATION OF THERMAL COMFORT IN AFFORDABLE HOUSING

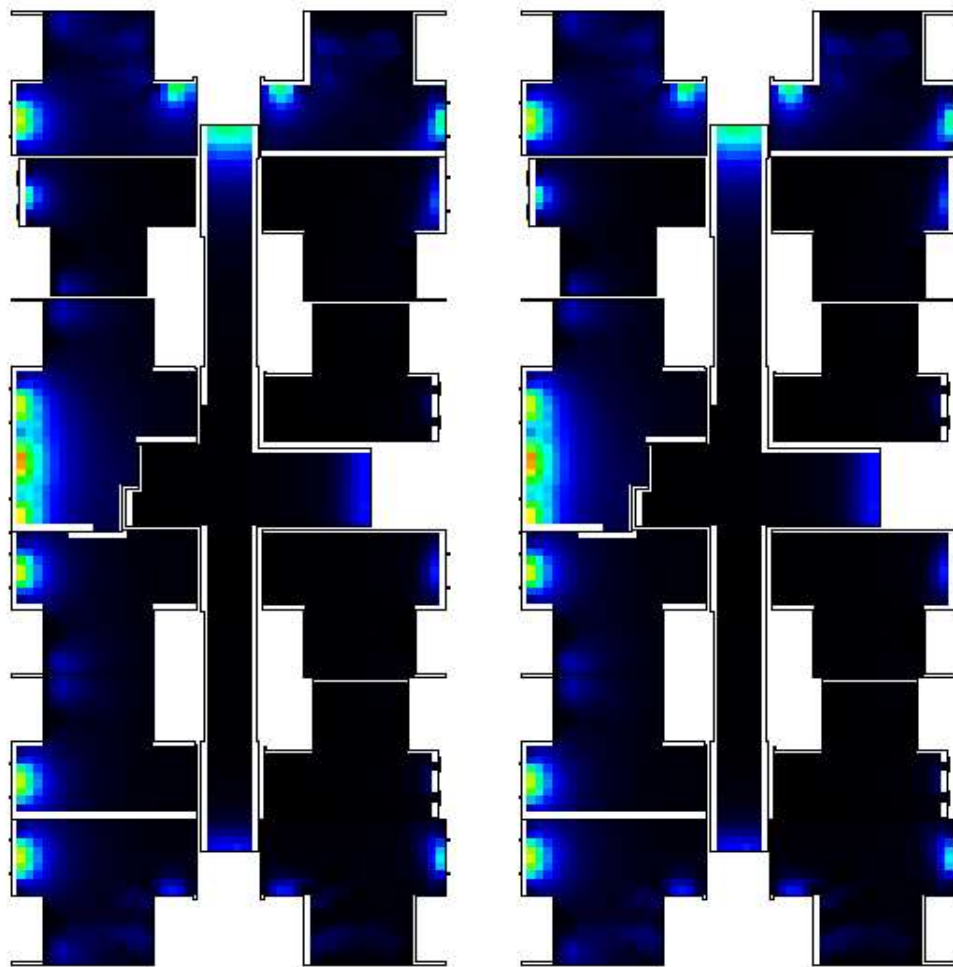
## Daylight Analysis : Block-A1 (Base case)



Daylight Analysis in Block A1 shows that floors 1<sup>st</sup> & 3<sup>rd</sup> are the most critical areas where daylight is not in sufficient Amount due to mutual shading of neighbour Building block (i.e. shading form East side)

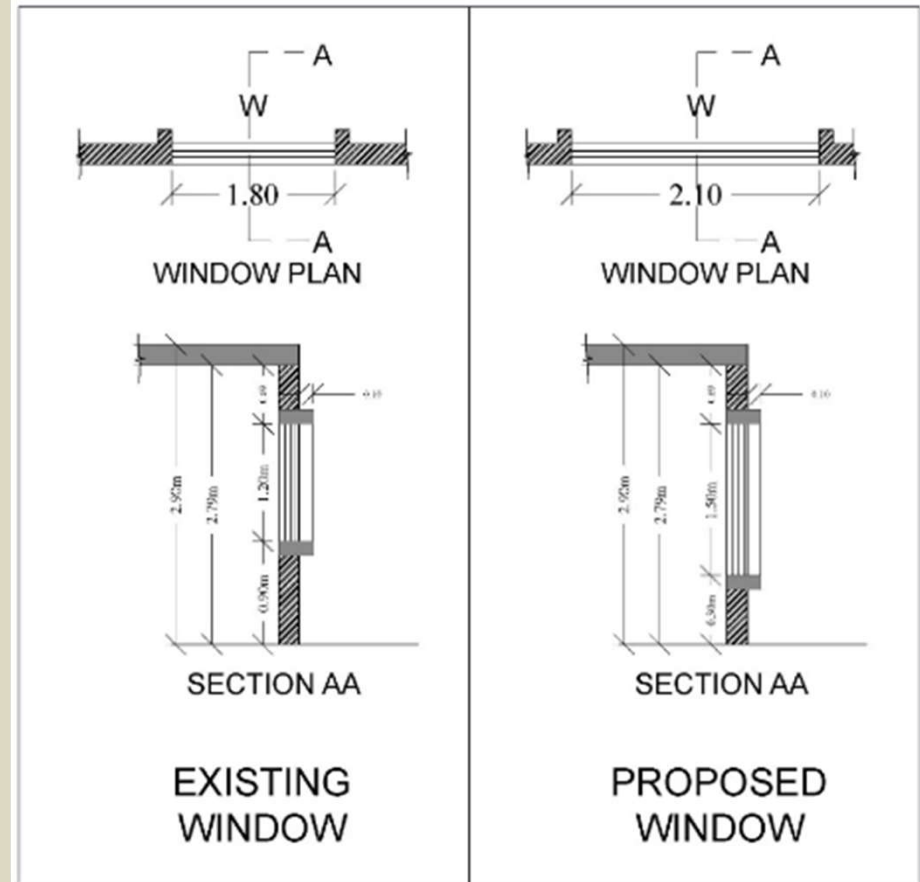
# CASE STUDIES FOR APPLICATION OF THERMAL COMFORT IN AFFORDABLE HOUSING

## Daylight Analysis : Proposed Case Block-A1, A2



Floor-1

Floor-3



As the Horizontal shading is provided only 100 mm depth, for Windows increasing the height by 300mm & width 300mm will enhance the daylight in the flats. But still won't be able to match the required useful Day lighting in the first to third floor.



# CASE STUDIES FOR APPLICATION OF THERMAL COMFORT IN AFFORDABLE HOUSING

## Window To Floor Area Ratio (WFR)

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

### CODE PROVISIONS

- **Openable Window-to-Floor Area Ratio ( $WFR_{op}$ )** - it indicates the potential of using external air for ventilation.
- Ensuring minimum  $WFR_{op}$  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<sup>14</sup> 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.

Blocks	Windows Area	Carpet Area	15.91
Block-A1	387.87	2330.23	
Block-A2	387.87	2330.23	
Block-A3	387.87	2330.23	
Block-B1	551.34	3495.73	
Block-C1	349.37	2340.66	
Block-C2	349.37	2340.66	
Total WFR	2413.69	15167.74	
			>10% (as per ENS-Hot & dry Climate)

## Window To Wall Area Ratio (WWR)

The Window-to-Wall Ratio (WWR) is the fraction of the above grade wall area that is covered by fenestration, calculated as the ratio of the wall fenestration area to the gross above grade wall area.

Block A1 & A2					
Windows	WallArea	WWR (%)			
284.76	2760.8	10.31	(Excluding staircase & Passage)		
Block A3					
Windows	WallArea	WWR (%)			
291.48	2963.8	9.83	(Excluding staircase & Passage)		
Block B1					
Windows	WallArea	WWR(%)			
415.8	3339.35	12.45	(Excluding staircase & Passage)		
Block B2					
Windows	WallArea	WWR(%)			
359.94	3019.625	11.92	(Excluding staircase & Passage)		
TOTAL WWR (%)					
Windows	WallArea	WWR(%)			
1351.98	12083.575	11.19	(Excluding staircase & Passage)		

The Window-to-Wall Ratio (WWR) is found **11.19%**, WWR is directly proportional to daylighting areas, Hence, impact of WWR is shown in floor plans, therefore increasing in WWR helps to enhance the daylight area in the building blocks.

# CASE STUDIES FOR APPLICATION OF THERMAL COMFORT IN AFFORDABLE HOUSING

Project	Construction of 235 EWS DU's under PMAY Scheme
Location	Talegaon Dabhade, Pune, Maharashtra.
Climate Zone	Composite
Site Area	3941 sq meter
Built Up Area	15286 sq meter
Wall Material	AAC Block Masonry

Project	Construction of 560 EWS DU's and Commercial under PMAY
Location	Talegaon Dabhade, Pune, Maharashtra.
Climate Zone	Composite
Site Area	8729 sq meter
Built Up Area	35262 sq meter
Wall Material	AAC Block Masonry

Project	Construction of 210 EWS Dwelling Units under PMAY – AHP at Gut No. 818, Chakan. Ta. Khed, Dist - Pune
Location	Chakan, Pune, Maharashtra.
Climate Zone	Composite
Site Area	11434 sq meter
Built Up Area	12133 sq meter
Wall Material	AAC Block Masonry

**\*Under Analysis Stage**

# THERMAL COMFORT STUDY METHODS

Thermal comfort studies can be undertaken in one or combination of following ways:

## Field Studies

- Occupant Behaviour
- User Behaviour
- Productivity

## Laboratory Studies

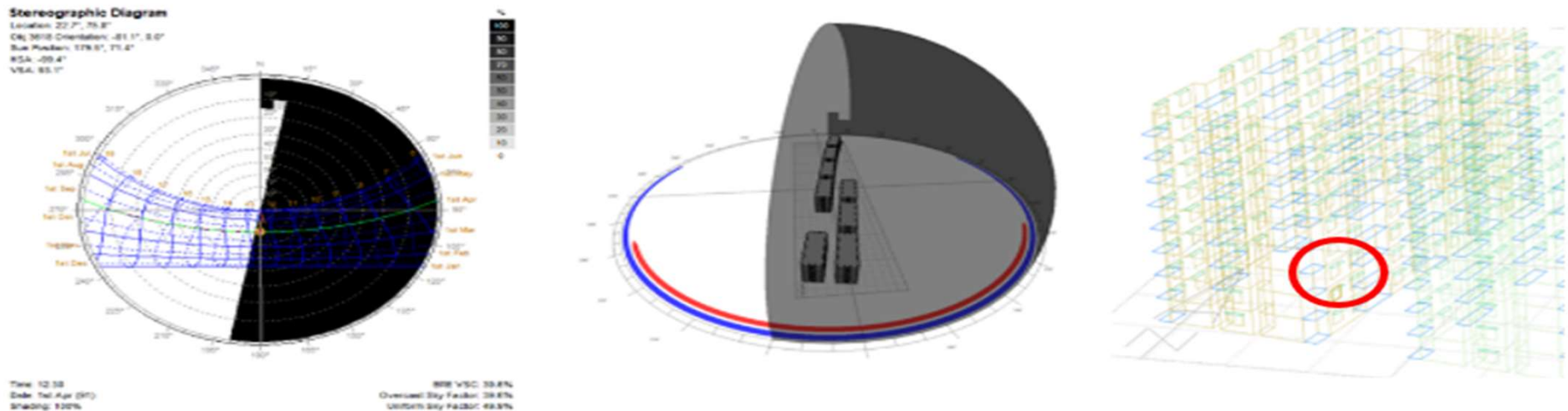
- Thermal Comfort
- Body Parts
- Cooling Systems
- Control Systems
- Productivity

## Digital Simulations

- Thermal Comfort
- Body Parts
- Cooling Systems
- Control Systems

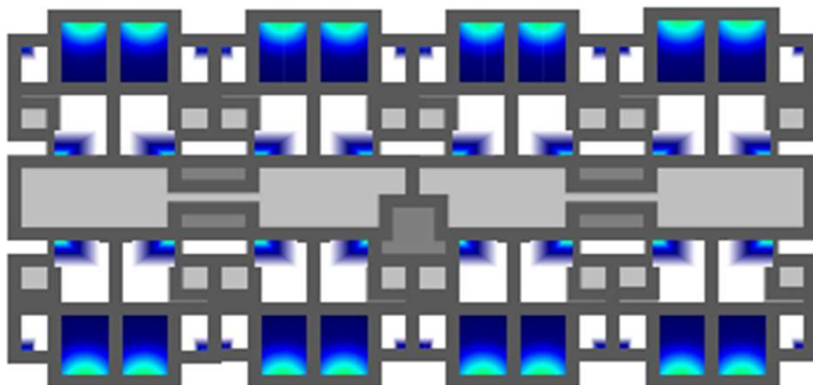


### WINDOW SHADING ANALYSIS



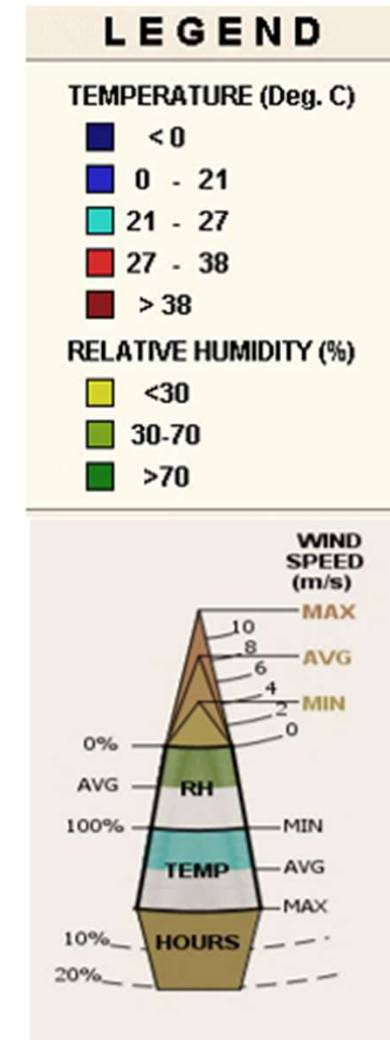
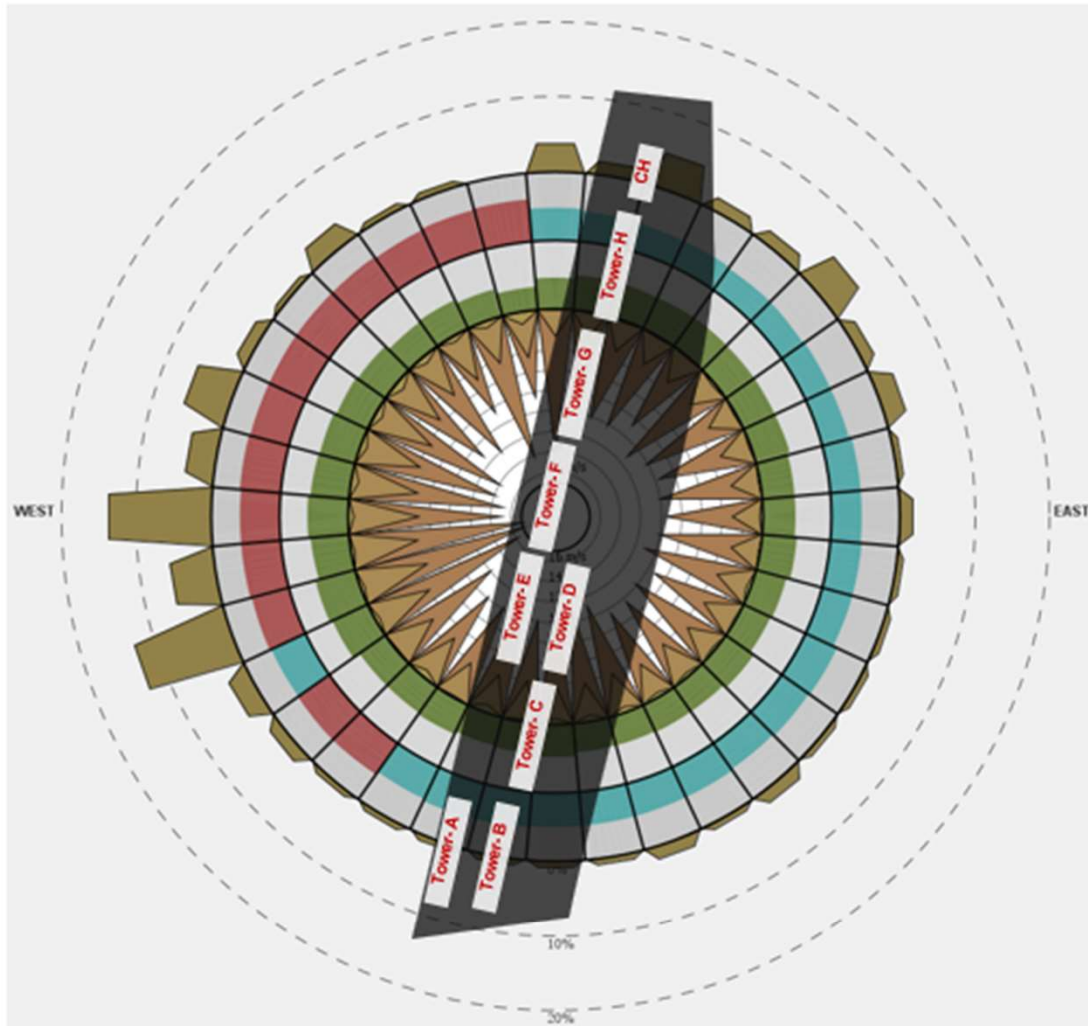
**Shading Analysis shows East side window shading (Chajja-450mm ) Will suffice shading requirements, eventually cut off direct heat gain from East side. On other side, West side too suffice shading requirements.**

### DAY LIGHTING ANALYSIS



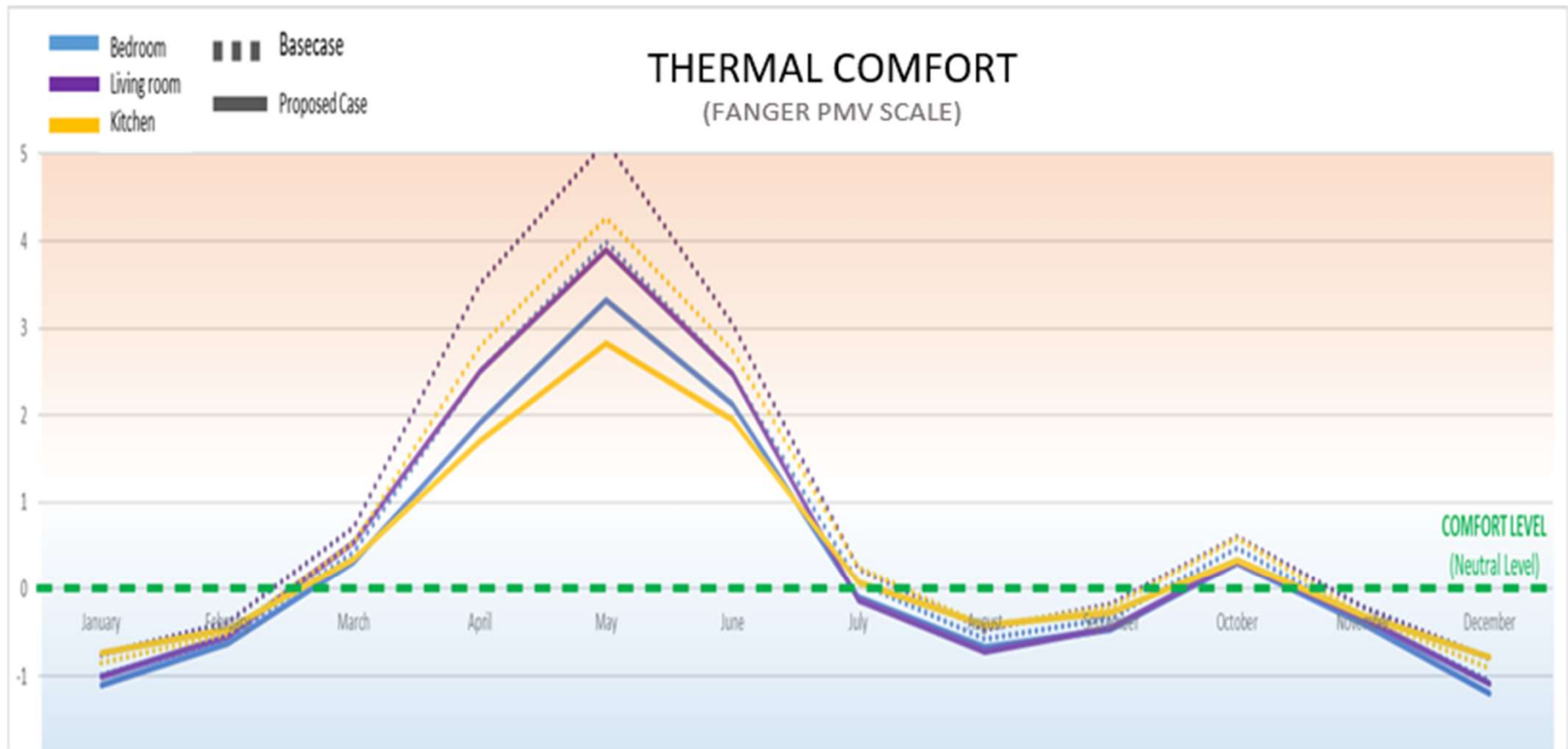
**Daylighting analysis shows that 1<sup>st</sup> & 5<sup>th</sup> floors having sufficient day lighting in Bedroom & Kitchen while Living room is having less day light while 8<sup>th</sup> floor, all spaces having sufficient day light availability.**

### ORIENTATION OPTIMIZATION AS PER SITE



Analysis shows that building blocks orientation getting maximum hours wind from west side throughout the year which help to enhance the natural ventilation.

### THERMAL COMFORT OPTIMIZATION



**Analysis shows Thermal Comfort can be achieved as Fanger PMV Index is 0.72 (<1) for Naturally Ventilated Building. Achieving Thermal Comfort, related to reduction in Cooling Load requirement of the building.**



ENS RETV COMPLIANCE



POSSIBLE ENERGY SAVINGS & CARBON EMISSION REDUCTION



approx. **7.1 Lakh units** to be saved per annum  
savings as compare to conventional Operational Practices

savings as compare to conventional Operational Practices



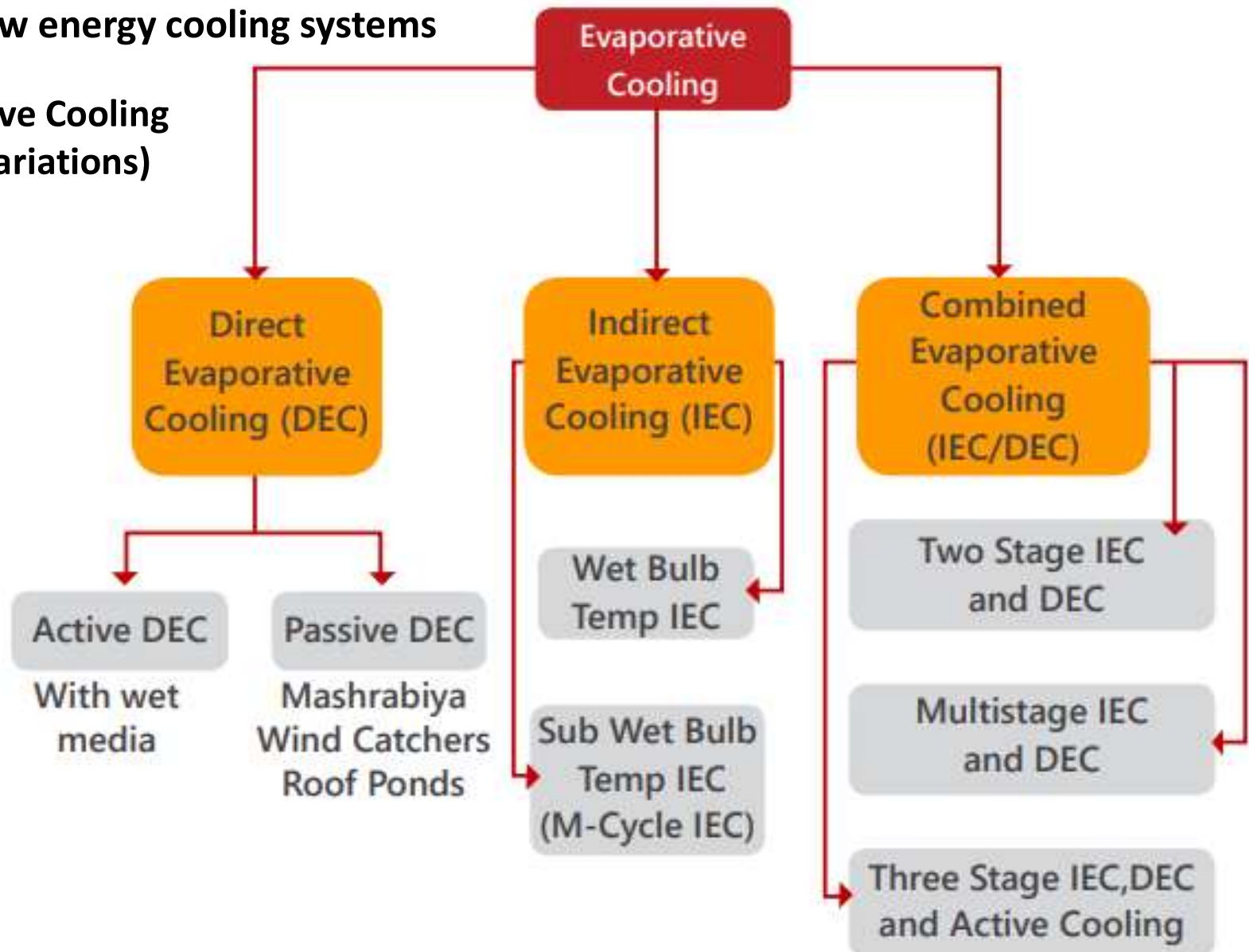
# LOW ENERGY COOLING TECHNOLOGIES AND COMFORT

## Importance of Low-energy Cooling Systems

- ✓ Low energy cooling technologies is a relatively new term with no commonly accepted scientific definition
- ✓ It can be loosely defined to include technologies that do not use vapor compression cycles which is traditionally the most used refrigeration cycle in current mechanical devices for cooling

## Categories of Low energy cooling systems

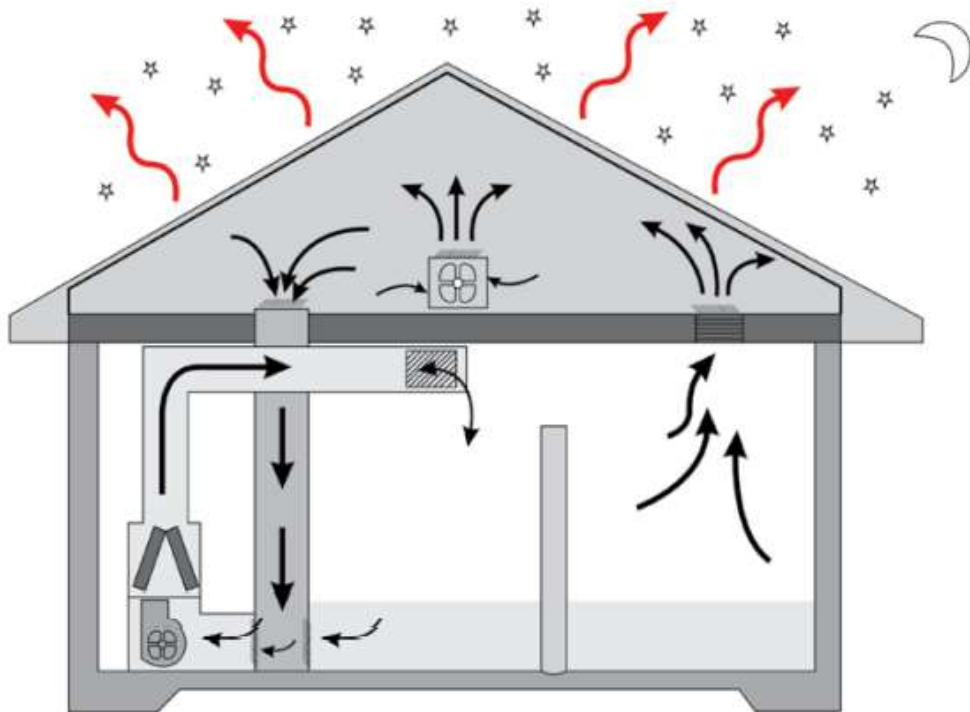
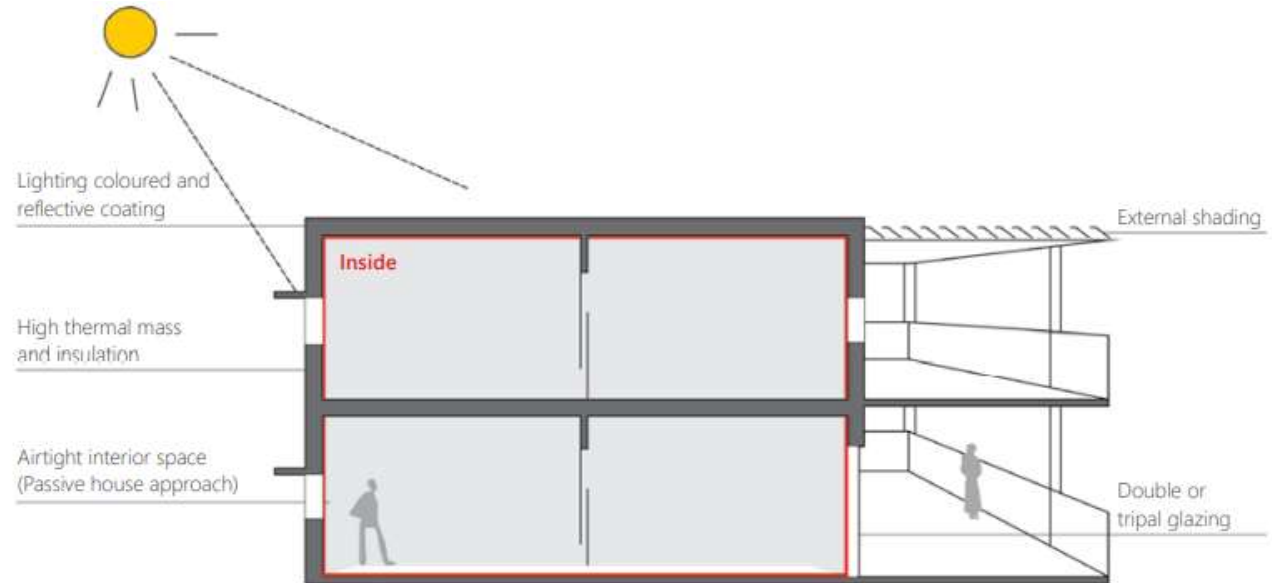
### Evaporative Cooling (and its variations)



# LOW ENERGY COOLING TECHNOLOGIES AND COMFORT

## Categories of Low energy cooling systems

### Night Cooling through Natural Ventilation

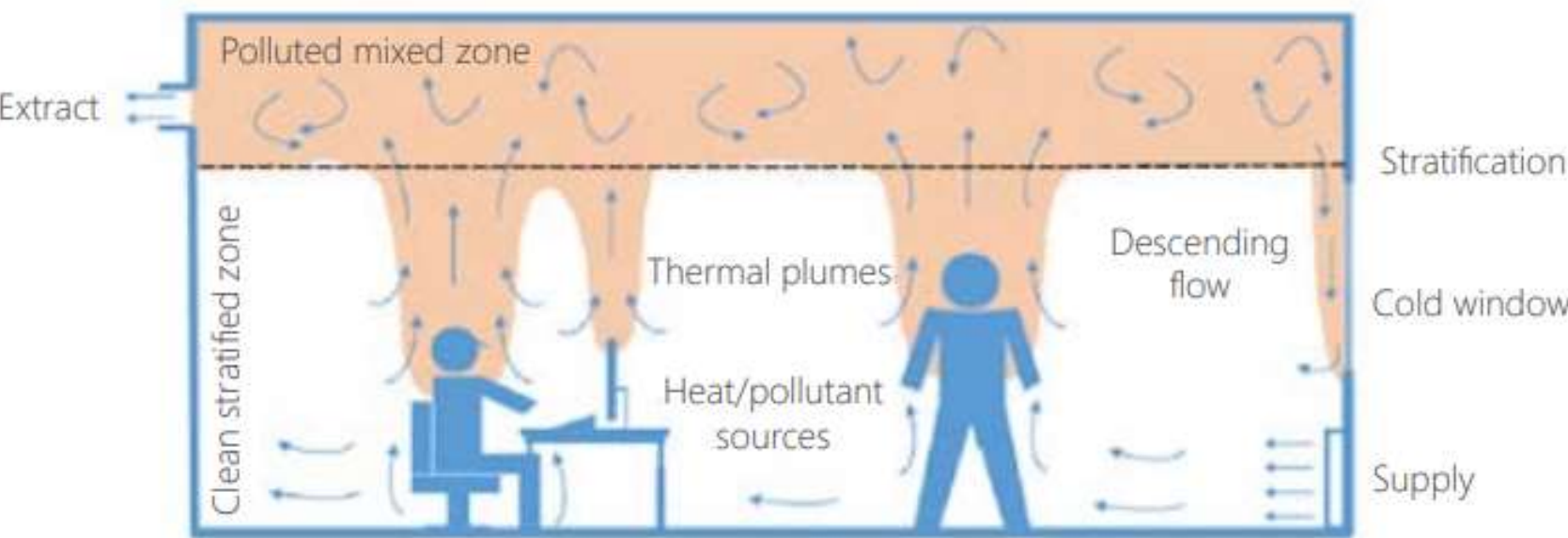
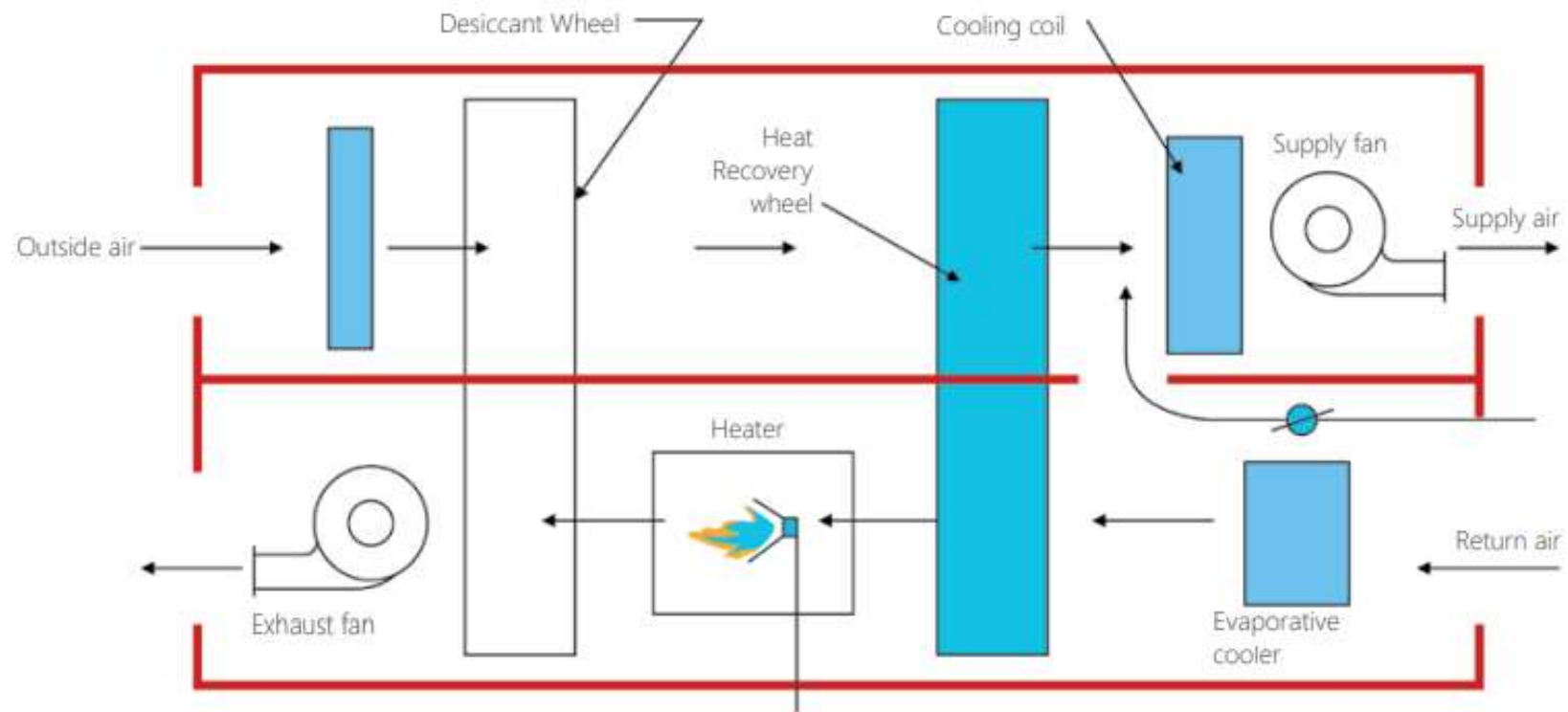


### Night cooling through mechanical ventilation

# LOW ENERGY COOLING TECHNOLOGIES AND COMFORT

## Categories of Low energy cooling systems

### Desiccant Cooling Systems

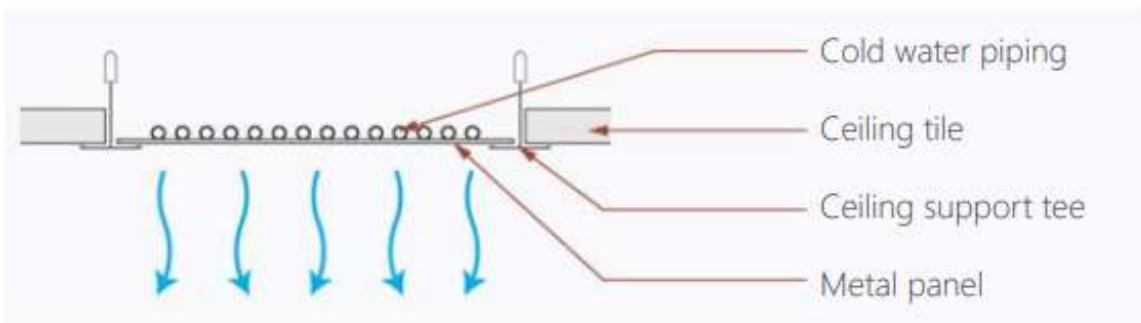
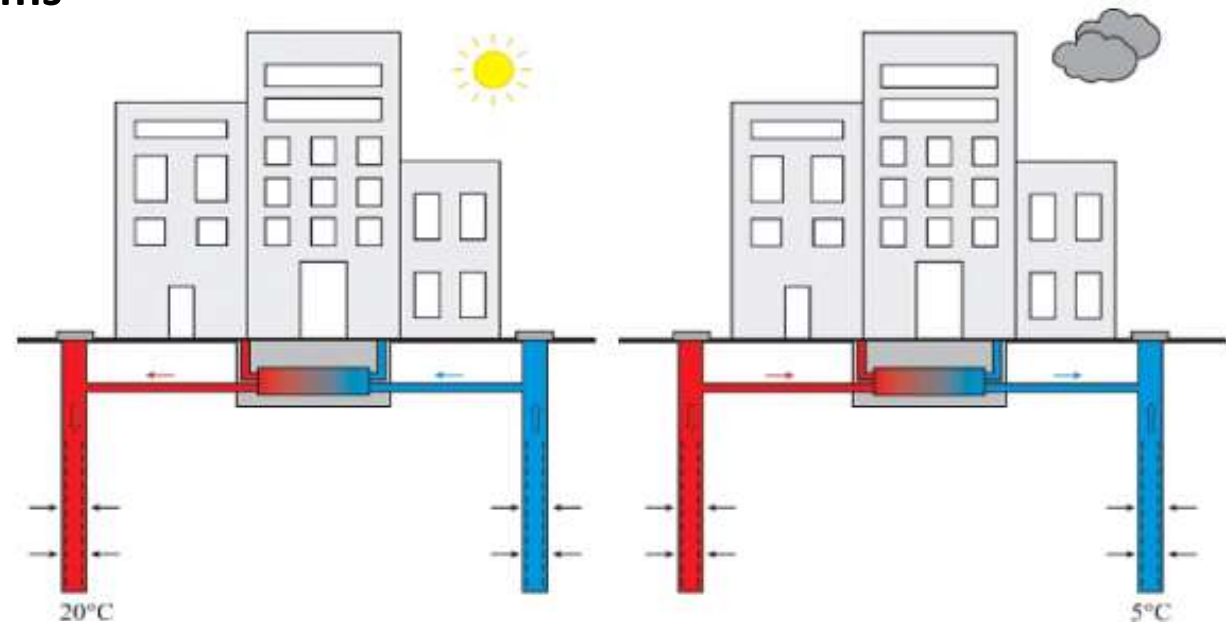


### Displacement Ventilation

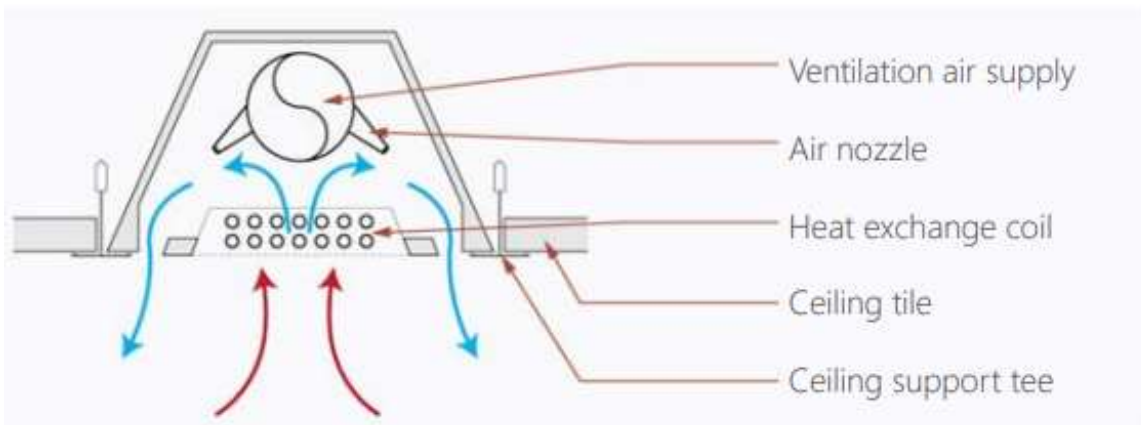
# LOW ENERGY COOLING TECHNOLOGIES AND COMFORT

## Categories of Low energy cooling systems

### Ground and Aquifer cooling



### Chilled Ceiling and Beams

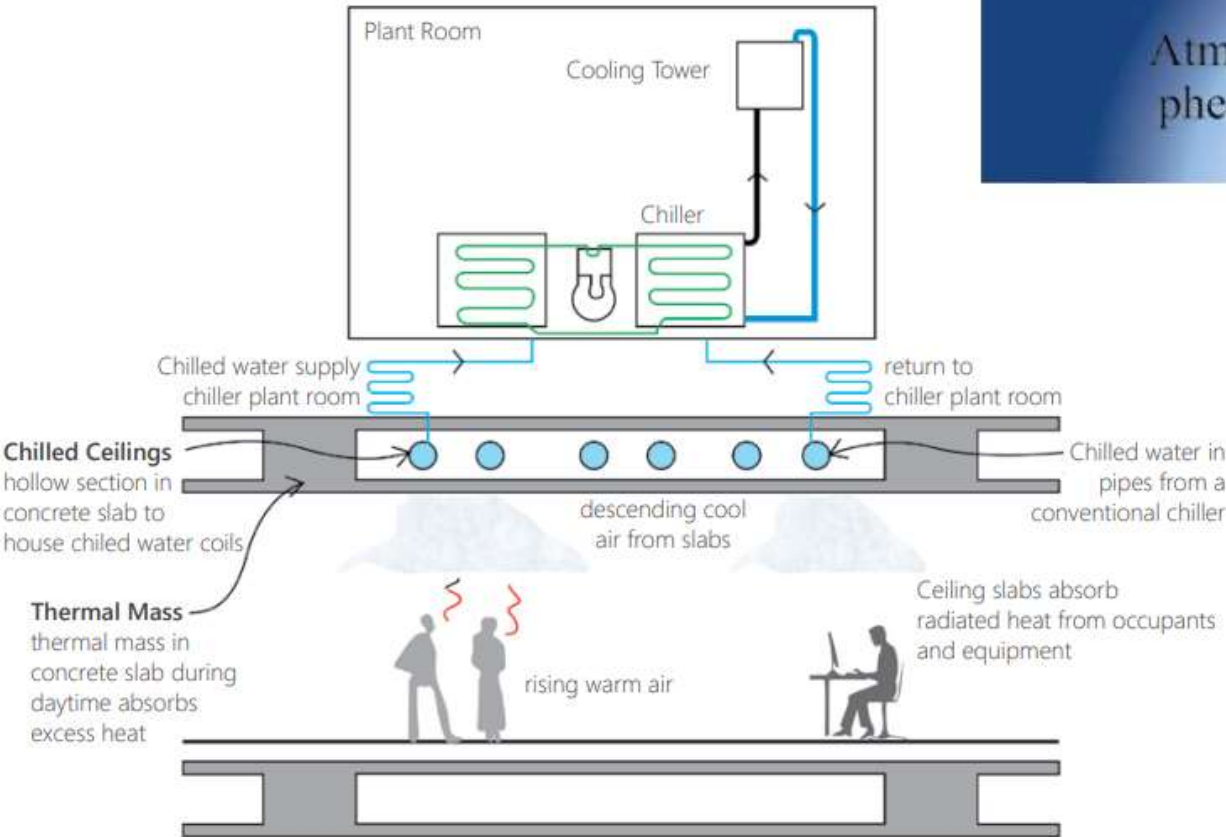
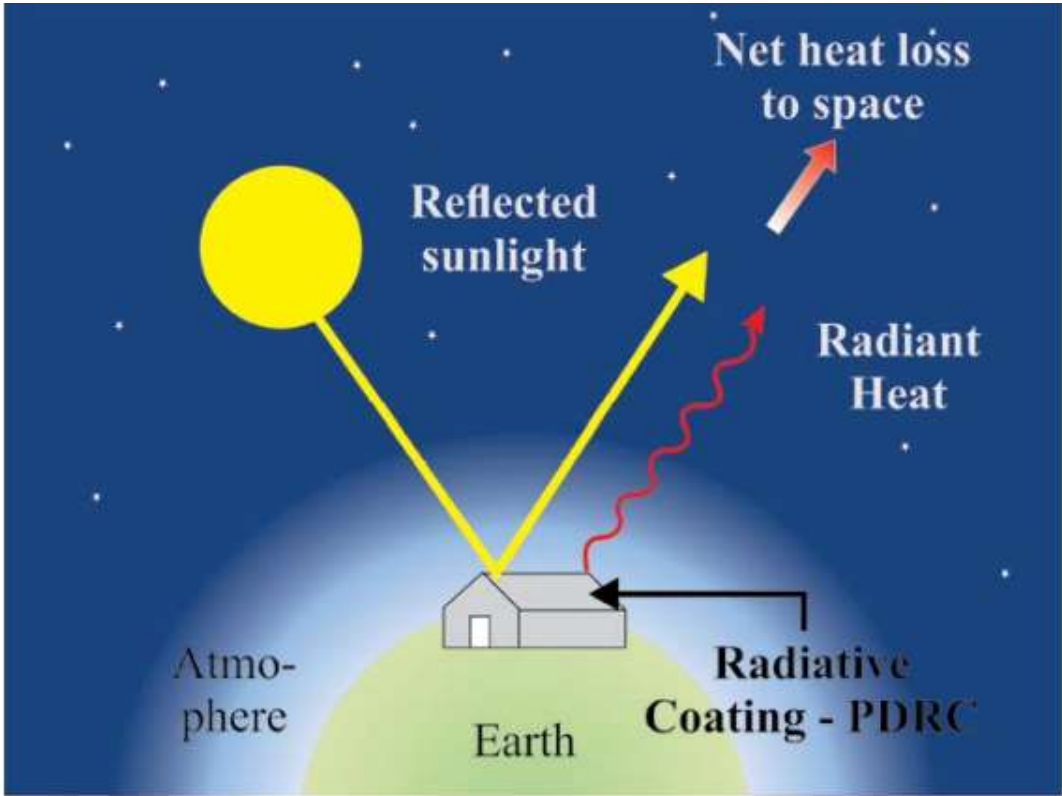




# LOW ENERGY COOLING TECHNOLOGIES AND COMFORT

## Categories of Low energy cooling systems

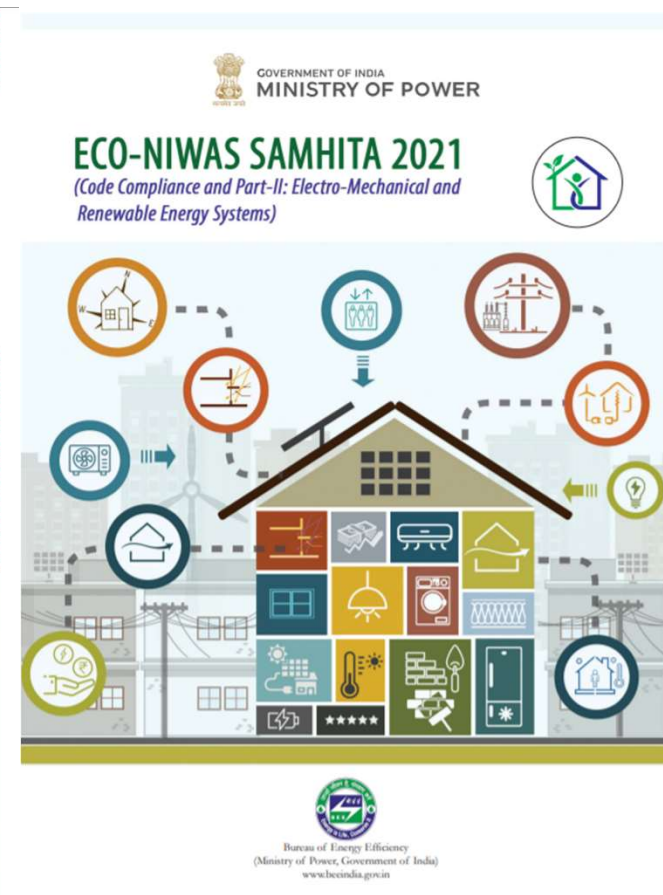
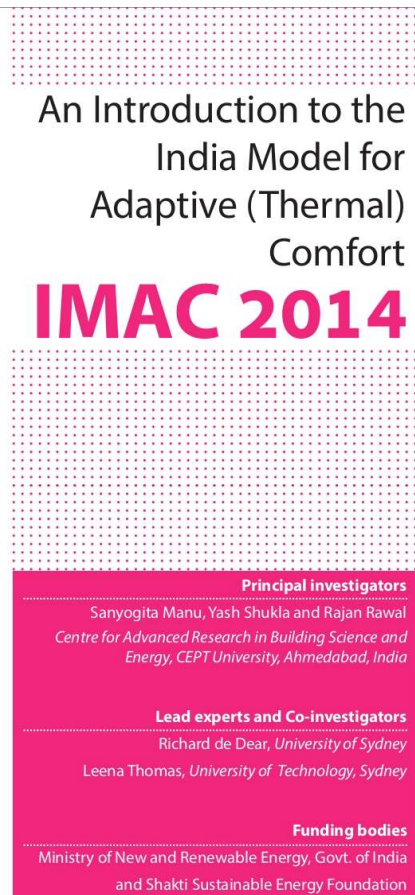
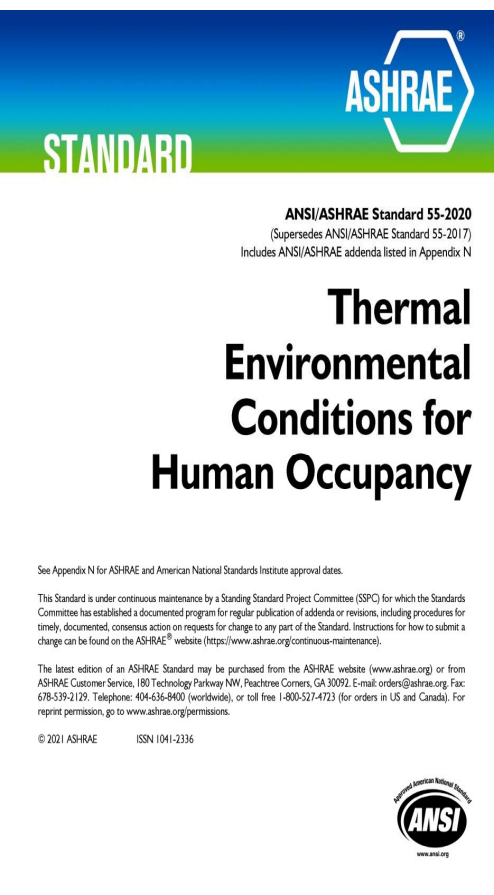
### Radiative Cooling



### Radiant Structural Cooling

**LUNCH BREAK**

# EXISTING STANDARDS FOR IMPROVING THERMAL COMFORT



Standard 55-2020, Thermal Environmental Conditions for Human Occupancy (ANSI Approved)  
Standard 62.1-2019, Ventilation for Acceptable Indoor Air Quality  
Standard 62.2-2019, Ventilation and Acceptable Indoor Air Quality in Residential Buildings  
Standard 90.1-2019, Energy Standard for Buildings Except Low-Rise Residential Buildings  
Standard 90.2-2018, Energy Efficient Design of Low-Rise Residential Buildings  
Standard 100-2018, Energy Efficiency in Existing Buildings

# 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

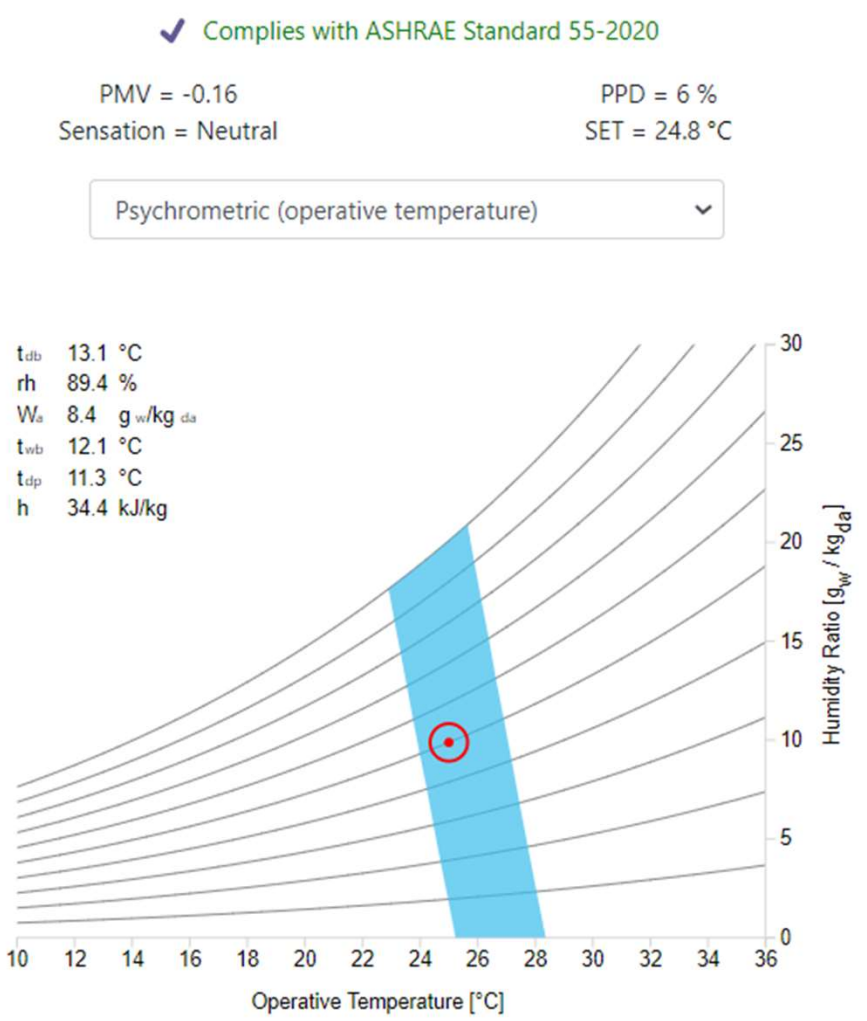
Solar gain on occupants

Set pressure SI/IP

Local discomfort Globe temp

Reset Save Reload Share

Documentation





# EXISTING STANDARDS FOR IMPROVING THERMAL COMFORT

## National Building Code of India (NBC 2016)

National Building Code (NBC) of India is a standard which unifies the building regulations all over the country.

Type	Adaptive comfort model as per NBC 2016
Naturally ventilated building	$T_{in}=0.54T_{rm} +12.83$ 90% acceptability range: $\pm 2.38\text{ }^{\circ}\text{C}$
Mixed mode building	$T_{in}=0.28T_{rm} +17.87$ 90% acceptability range: $\pm 3.48\text{ }^{\circ}\text{C}$
Air-conditioned building	Air temperature-based approach: $T_{in}=0.078T_{rm} +23.25$ 90% acceptability range: $\pm 1.5\text{ }^{\circ}\text{C}$
	Standard Effective Temperature based approach: $SET_{in}=0.014T_{rm} +24.53$ 90% acceptability range: $\pm 1.0\text{ }^{\circ}\text{C}$

*T<sub>in</sub>*: Indoor operative temperature (in °C) is neutral temperature

*T<sub>rm</sub>*: 30-days running mean outdoor temperature

*SET<sub>in</sub>*: Standard effective temperature (in °C) is neutral temperature

**Adaptive Thermal Comfort Equation for determining acceptable indoor conditions as per NBC 2016**

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.**

# 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.

# ENS CODE *ANALYSIS WITH LHP, INDORE*

## CODE PROVISIONS

1. Openable Window-to-Floor Area Ratio (WFRop)
2. Visible Light Transmittance (VLT)
3. Thermal Transmittance of Roof (Uroof)
4. Residential envelope transmittance value (RETV) for building envelope (except roof) for four climate zones, namely, Composite Climate, Hot-Dry Climate, Warm-Humid Climate, and Temperate Climate
5. Thermal transmittance of building envelope (except roof) for cold climate (Uenvelope,cold)

## CODE COMPLIANCE

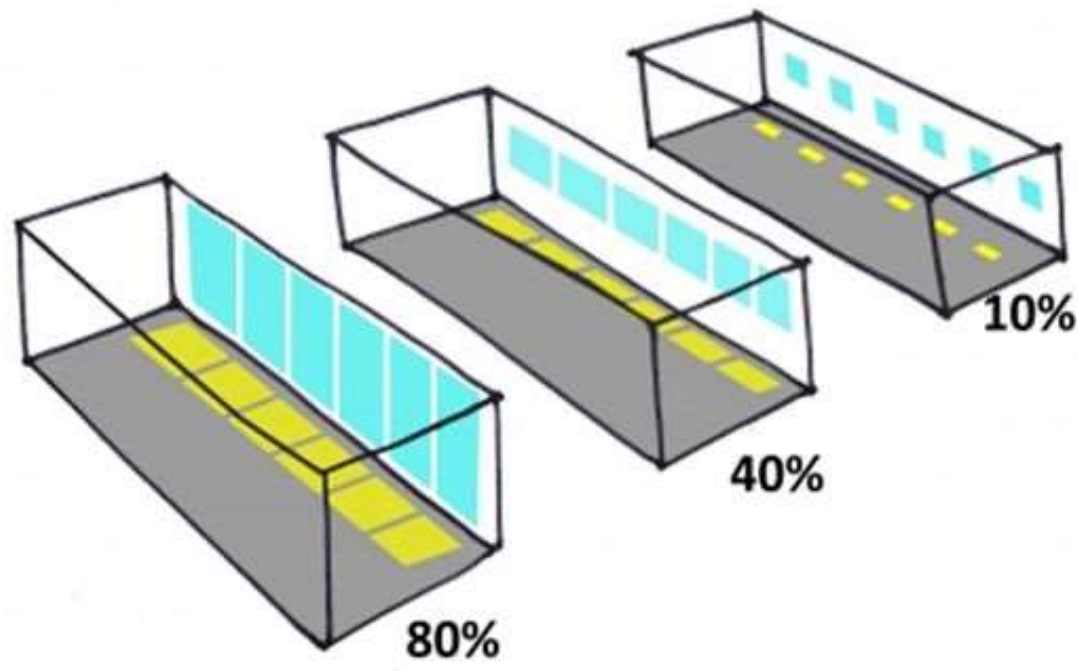




CODE PROVISIONS

- **Openable Window-to-Floor Area Ratio (WFR<sub>op</sub>)** - it indicates the potential of using external air for ventilation.
- Ensuring minimum WFR<sub>op</sub> 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<sub>OP</sub> = A<sub>openable</sub> / A<sub>carpet</sub>



3.1.3 The openable window-to-floor area ratio (WFR<sub>op</sub>) shall not be less than the values<sup>14</sup> given in Table 1.

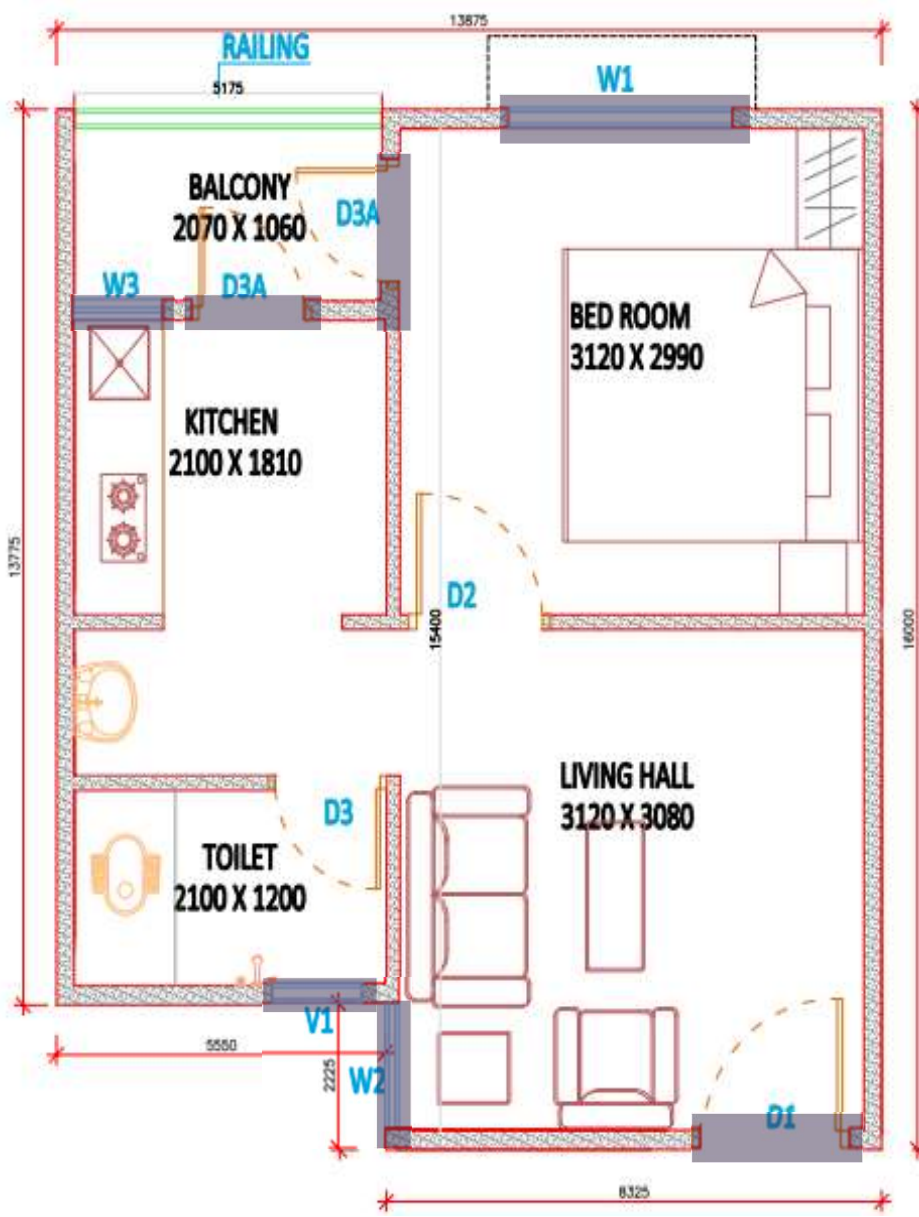
TABLE 1 Minimum requirement of window-to-floor area ratio (WFR<sub>op</sub>)

Climatic zone	Minimum WFR <sub>op</sub> (%)
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.

LHP INDORE

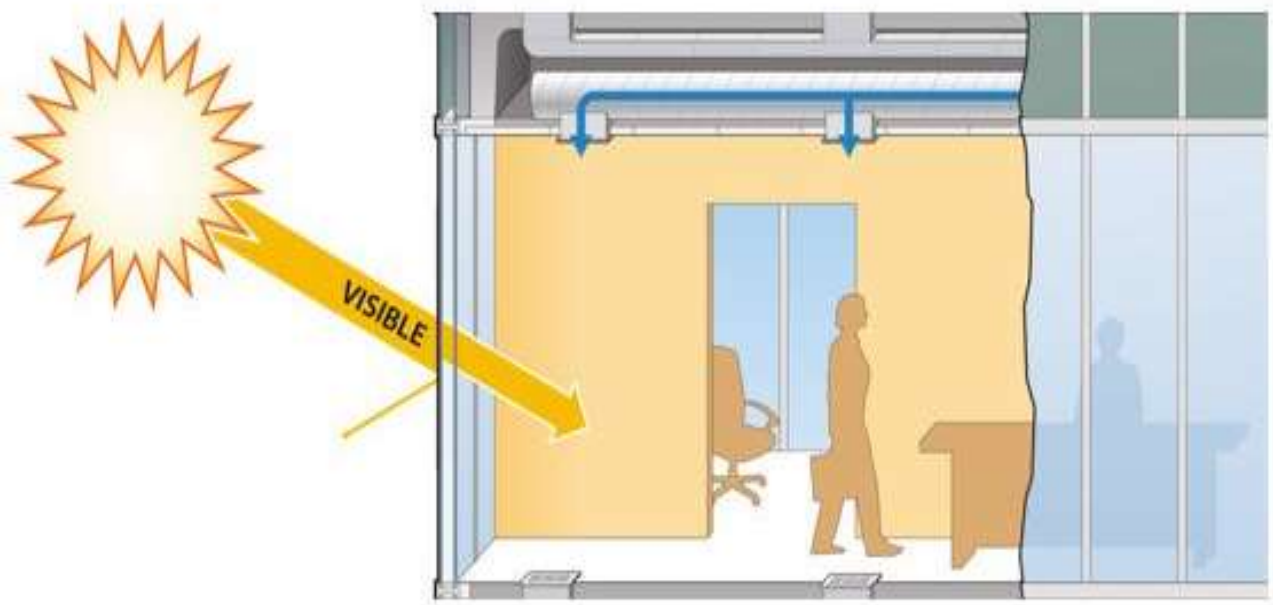
Opening Name	Opening Area, m2	Openable Area, m2	No	Effective Openable area m2	Remarks
W1	1.80	0.81	1.00	0.81	Sliding window @ 45% opening
W2	0.96	0.43	1.00	0.43	Sliding window @ 45% opening
W3	0.66	0.59	1.00	0.59	Openable window @ 90% opening
V1	0.27	0.24	1.00	0.24	Openable window @ 90% opening
GD 1	1.58	1.42	1.00	1.42	Openable window @ 90% opening
GD 2	1.58	1.42	1.00	1.42	
openable area for 1 flat				4.91	
openable area for 128 flat				628.99	
A <sub>carpet</sub> of unit		128	27.75	3552.00	
WFR	A <sub>OPNEABLE</sub> / A <sub>CARPET</sub>			17.71	
For Composite minimum 12.5%					



**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

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



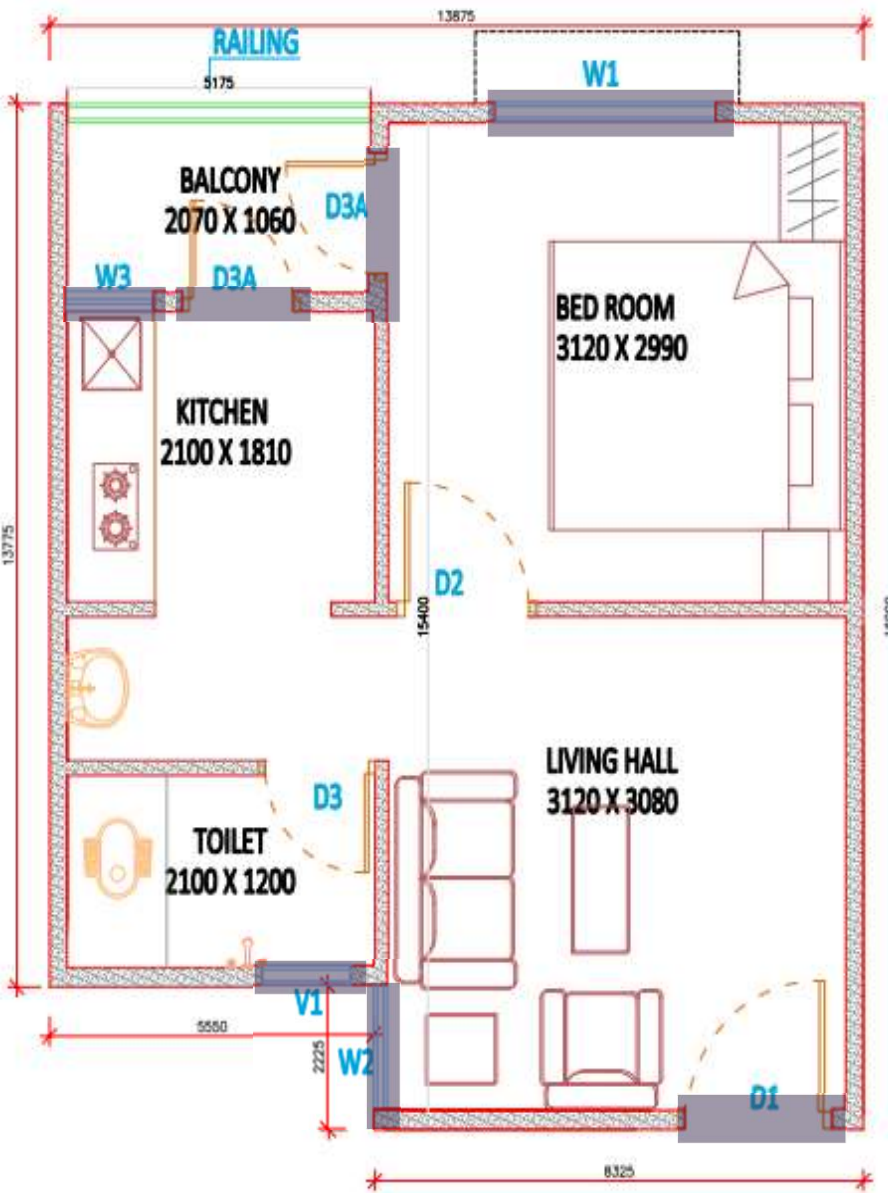
**TABLE 2** Minimum visible light transmittance (VLT) requirement<sup>15</sup>

Window-to-wall ratio (WWR) <sup>16</sup>	Minimum VLT <sup>17</sup>
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.

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Orientation	Opening Name	Opening Area, m2	Non - opaque (Glass) Area in Opening, m2	No of openings	Total Opening Area, m2	Total Non-opaque (Glass) Area, m2	Total opaque (PVC, Frame) Area, m2
North	W2	0.96	0.60	16.00	15.36	9.60	5.76
North	W4	0.00	0.00	9.00	0.00	0.00	0.00
South	W2	0.96	0.60	16.00	15.36	9.60	5.76
South	W4	0.00	0.00	0.00	0.00	0.00	0.00
East	W1	1.80	1.25	64.00	115.20	80.00	35.20
East	W3	0.66	0.35	64.00	42.24	22.50	19.74
East	W5	0.00	0.00	0.00	0.00	0.00	0.00
West	W1	1.80	1.25	64.00	115.20	80.00	35.20
West	W3	0.66	0.35	64.00	42.24	22.50	19.74
West	W5	0.00	0.00	0.00	0.00	0.00	0.00
East	V1	0.27	0.15	16.00	4.32	2.42	1.90
West	V1	0.27	0.15	16.00	4.32	2.42	1.90
East	GD	1.58	0.00	128.00	201.60	0.00	0.00
West	GD	1.58	0.00	128.00	201.60	0.00	0.00
					757.44	229.03	125.21
					WWR	0.07	
WWR			Minimum VLT				
0–0.30			0.27				
MINIMUM IS 0.27 IN LHP INDORE IT IS 90%							



As per Table 2, for WWR of 0.21 (range 0–0.30), the minimum required VLT is 27%. The glass used in this project has a VLT of 90% (as per certified specification for the product). Thus, this project complies with this requirement. Also, it complies with the recommended value.



## HOW SOLAR REFLECTANCE HELPS MODERATE TEMPERATURES, RESULTING IN LOWER DEMAND ON COOLING SYSTEMS

### ***Thermal transmittance***

( $U_{\text{roof}}$ ) characterizes the thermal performance of the roof of a building.

*Thermal transmittance of roof shall comply with the maximum  $U_{\text{roof}}$  value of  $1.2 \text{ W/m}^2 \cdot \text{K}$ .*

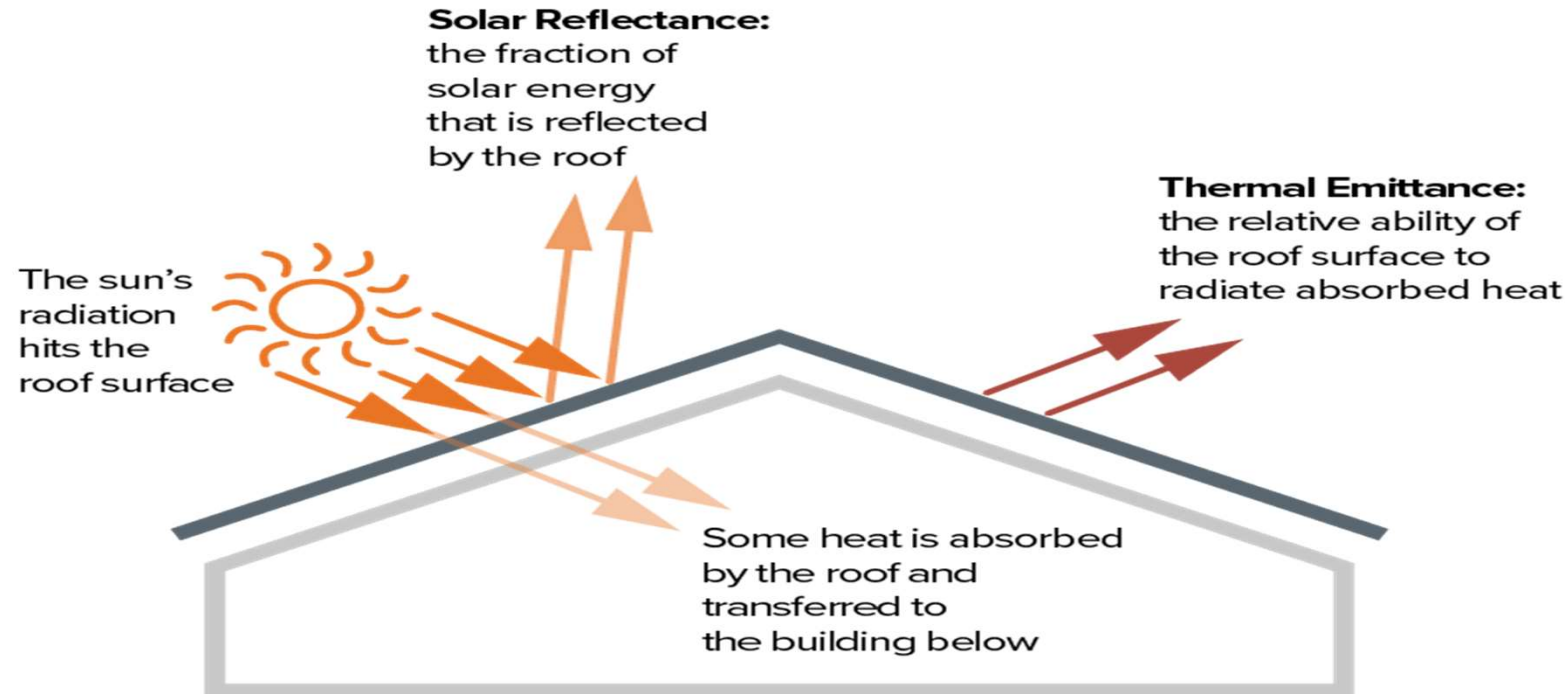


Illustration: Cool Roof Rating Council

3.3.3 The calculation<sup>18</sup> shall be carried out, using Equation 3 as shown below.

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

where,

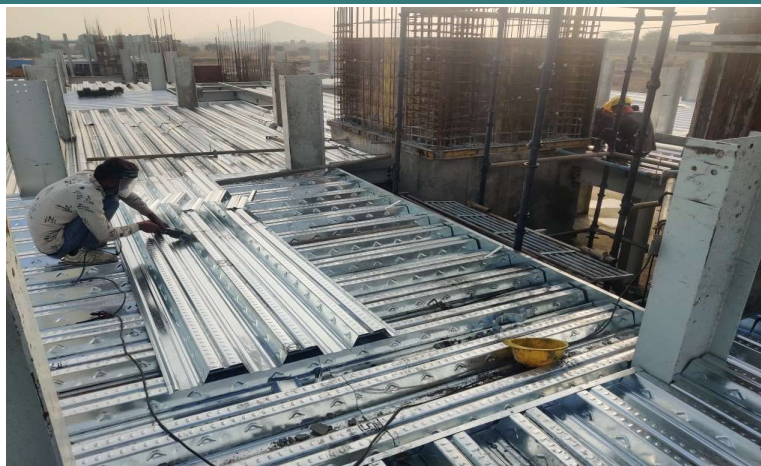
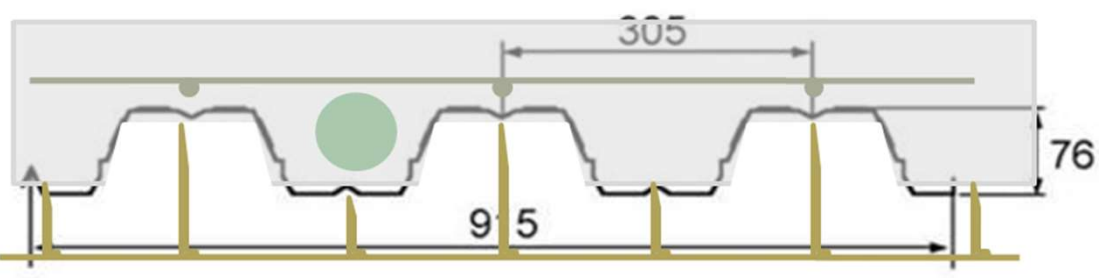
$U_{\text{roof}}$  : thermal transmittance of roof ( $\text{W/m}^2 \cdot \text{K}$ )

$A_{\text{roof}}$  : total area of the roof ( $\text{m}^2$ )

$U_i$  : thermal transmittance values of different roof constructions ( $\text{W/m}^2 \cdot \text{K}$ )

$A_i$  : areas of different roof constructions ( $\text{m}^2$ )

LHP INDORE



Layer no.	Material	Density	Specific Heat	Thickness	Conductivity	R value	Source
		(kg/m3)	(kJ/kg.K)	(m)	(W/m-K)	m²K/W	
1	Rsi	-	-	0.003	-	0.170	As per ENS guidelines 2018 (roof section), Composite climate
2	Gypsum Board (False Ceiling)	8	-	12.500	0.160	0.078	From Manufacturer (Gyproc) Technical Data Sheet
3	Air Gap, 100 mm	1.225	-	0.100	0.500	0.200	As per ENS guidelines 2018, Composite climate
4	Deck Sheet (GI sheet)	7520	0.500	0.001	61.060	0.000	As per ENS guidelines 2018, Composite climate
5	RCC Slab	2500	0.800	0.098	1.580	0.062	Density Value - from Site team Others (Spc heat, R & K Values) - as per ENS guidelines 2018
6	Brick Bat Coba (Solid Burnt Black Clay Bricks)	1440	-	0.090	0.620	0.145	As per ENS guidelines 2018, Composite climate
7	China mosaic tile			0.007	1.500	0.005	As per ENS guidelines 2018, Composite climate
8	Rse	-	-	0.003	-	0.04	As per ENS guidelines 2018 (roof section), Composite climate
	R Total					0.700	
U value of assembly						1.429	

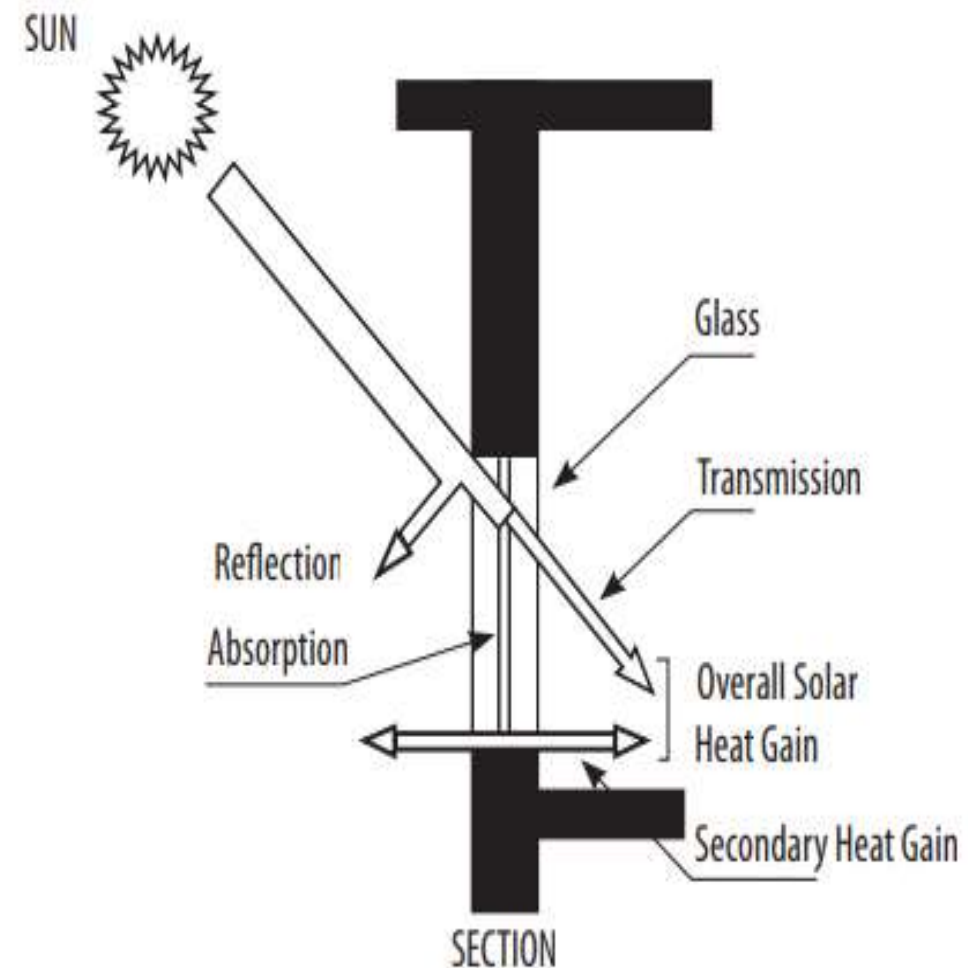
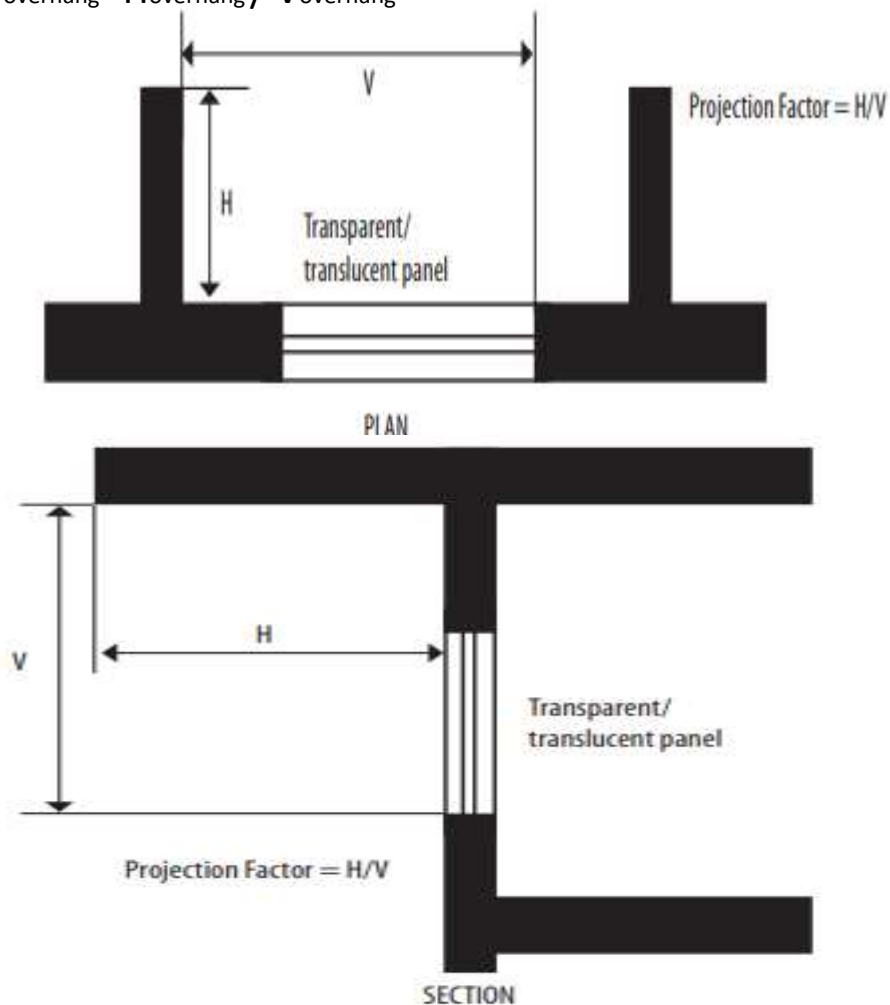
This is greater than the maximum Uroof value of 1.2 W/m2 .K.

Roof U value is 1.43, it can be reduced further with addition of PUF Insulation

**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 (H<sub>overhang</sub>) 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 (V<sub>overhang</sub>), in consistent units.

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



LHP INDORE

TABLE 11 External Shading Factor for Overhang (ESF<sub>overhang</sub>) for LAT<23.5°N

External Shading Factor for Overhang (ESF <sub>overhang</sub> ) for LAT < 23.5°N								
Orientation pf <sub>overhang</sub>	North (337.6°–22.5°)	North-east (22.6°–67.5°)	East (67.6°–112.5°)	South-east (112.6°–157.5°)	South (157.6°–202.5°)	South-west (202.6°–247.5°)	West (247.6°–292.5°)	North-west (292.6°–337.5°)
<0.10	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
0.10-0.19	0.931	0.924	0.922	0.910	0.896	0.910	0.922	0.924
0.20-0.29	0.888	0.864	0.855	0.834	0.816	0.834	0.854	0.864
0.30-0.39	0.860	0.818	0.797	0.771	0.754	0.771	0.796	0.818
0.40-0.49	0.838	0.782	0.747	0.721	0.708	0.720	0.746	0.782
0.50-0.59	0.820	0.755	0.705	0.682	0.675	0.681	0.705	0.755

$SHGC_{eq} = SHGC_{Unshaded} \times ESF_{total}$

Orientation	Name	Width of Glass, m	Height of Glass, m	Nos of Windows	Glass Area, m2	H <sub>overhang</sub>	V <sub>overhang</sub>	PF <sub>overhang</sub>	H <sub>right</sub> m	V <sub>right</sub> m	PF <sub>right</sub>	H <sub>left</sub> m	V <sub>left</sub> m	PF <sub>left</sub>	ESF <sub>overhang</sub>	ESF <sub>right</sub>	ESF <sub>left</sub>	ESF <sub>sidefin</sub>	ESF <sub>total</sub>	SHGC <sub>unshaded</sub>	SHGC <sub>Eq</sub>
North	W2	0.6	1	16	9.6	0	0	0.00	2.2	0.8	2.75	2.2	0.8	2.75	1	0.86	0.85	0.71	0.71	0.86	0.61
South	W2	0.6	1	16	9.6	0	0	0.00	2.2	0.8	2.75	2.2	0.8	2.75	1	0.86	0.86	0.72	0.72	0.86	0.62
East	W1	1.25	1	64	80	0.45	1.2	0.37	0	0	0	0	0	0	0.85	1	1	1	0.85	0.86	0.73
East	W3	0.37	0.95	64	22.49	1.1	1.2	0.92	1.2	0.6	2.00	2.1	1.2	1.75	0.67	0.88	0.94	0.82	0.55	0.86	0.47
West	W1	1.25	1	64	80	0.45	1.2	0.37	0	0	0	0	0	0	0.85	1	1	1	0.85	0.86	0.73
West	W3	0.37	0.95	64	22.49	1.1	1.2	0.92	1.2	0.6	2.00	2.1	1.2	1.75	0.67	0.91	0.91	0.83	0.55	0.86	0.48



# ECO NIWAS SAMHITA 2018 -Energy Conservation Building Code for Residential Buildings

## LHP INDORE



External Wall Assembly, 120 mm							
Layer no.	Material	Density	Specific Heat	Thickness	Conductivity	R value	Source
		(kg/m3)	(kJ/kg.K)	(m)	(W/m-K)	m²K/W	
1	Rsi	-	-	0.003	-	0.130	As per ENS guidelines 2018, Composite climate
2	sandwich panel 120mm	780.0	-	0.120	0.220	0.560	
3	Rse	-	-	0.003	-	0.040	As per ENS guidelines 2018, Composite climate
4	R Total					0.730	
U value of assembly						1.370	

Internal Wall Assembly, 90 mm							
Layer no.	Material	Density	Specific Heat	Thickness	Conductivity	R value	Source
		(kg/m3)	(kJ/kg.K)	(m)	(W/m-K)	m²K/W	
1	Rsi	-	-	0.003	-	0.130	As per ENS guidelines 2018, Composite climate
2	sandwich panel 90mm	780.000	-	0.090	0.220	0.420	Test Certificate - Rising Japan Infra Mumbai Rising HONGFA ( R90 value provided by Manufacturer)
3	Rse	-	-	0.003	-	0.040	As per ENS guidelines 2018, Composite climate
4	R Total					0.590	
U value of assembly						1.695	

Internal Wall Assembly, 60 mm							
Layer no.	Material	Density	Specific Heat	Thickness	Conductivity	R value	Source
		(kg/m3)	(kJ/kg.K)	(m)	(W/m-K)	m²K/W	
1	Rsi	-	-	0.003	-	0.130	As per ENS guidelines 2018, Composite climate
2	sandwich panel 60mm	780.0	-	0.060	0.220	0.280	
3	Rse	-	-	0.003	-	0.040	As per ENS guidelines 2018, Composite climate
4	R Total					0.450	
U value of assembly						2.222	

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 .

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

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)		

LHP INDORE

Material	Orientation	Description	Area, m²	U Value, W/m².k	Orientation Factor, w	TERM-I a*b*c	TERM-II a*b*c
Glass	NORTH	Non-opaque (glass) area	9.60	5.35	0.66	0.00	33.85
Panel	NORTH	Opaque area 1 (Sandwich Panel)	390.44	1.37	0.66	352.47	
PVC	NORTH	Opaque area 2 (PVC FRAME)	5.76	4.80	0.66	18.22	
Wooden	NORTH	Opaque area 3 ( Wooden doors)	0.00	0.17	0.66	0.00	
Glass	SOUTH	Non-opaque (glass) area	9.60	5.35	0.97	0.00	49.61
Panel	SOUTH	Opaque area 1 (Sandwich Panel)	390.44	1.37	0.97	516.66	
PVC	SOUTH	Opaque area 2 (PVC FRAME)	5.76	4.80	0.97	26.71	
Wooden	SOUTH	Opaque area 3 ( Wooden doors)	0.00	0.17	0.97	0.00	
Glass	EAST	Non-opaque (glass) area	104.92	5.35	1.16	0.00	648.30
Panel	EAST	Opaque area 1 (Sandwich Panel)	878.44	1.37	1.16	1389.86	
PVC	EAST	Opaque area 2 (PVC FRAME)	56.84	4.80	1.16	315.15	
Wooden	EAST	Opaque area 3 ( Wooden doors)	201.60	0.17	1.16	40.52	
Glass	WEST	Non-opaque (glass) area	104.92	5.35	1.16	0.00	648.86
Panel	WEST	Opaque area 1 (Sandwich Panel)	878.44	1.37	1.16	1391.06	
PVC	WEST	Opaque area 2 (PVC FRAME)	56.84	4.80	1.16	315.42	
Wooden	WEST	Opaque area 3 ( Wooden doors)	201.60	0.17	1.16	40.55	
						4406.62	1380.62

Panel Thickness, mm	120	150	170	200
U Values, W/m².k	1.37	1.15	1.04	0.91
RETv, W/m²	14.26	14.2	13.69	13.07

RETv is <15 W/m2 where clear glass SHGC is 0.86. RETv can be further enhanced with EPS Panel thickness

Orientation	Name	Total Opening Area, M²	Orientation Factor, w	TERM-II, a*b*c
North	W2	15.36	0.66	6.17
South	W2	15.36	0.97	9.16
East	W1	115.2	1.16	97.84
East	W3	42.24	1.16	23.02
West	W1	115.2	1.16	97.81
West	W3	42.24	1.16	23.24
				257.24

# 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

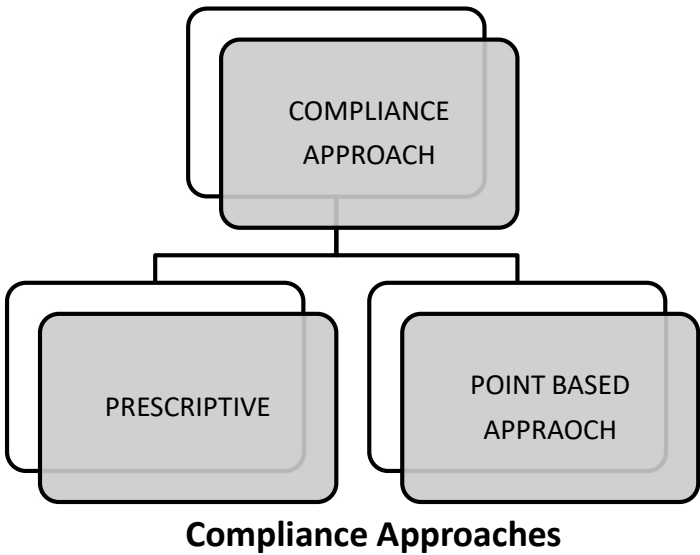
Table 9: Score for Renewable Energy System Components

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





# ENS CODE COMPLIANCE

## LHP INDORE Component wise Distribution of ENS Score

ENS Score	80	210	100
Components	Minimum Points	Maximum Points	LHP Indore (Proposed)
Building Envelope	47	87	51
Building Services			
Common area & exterior lighting	3	9	6
Elevators	13	22	17
Pumps	6	14	6
Electrical Systems	1	6	0
Indoor Electrical End-Use			
Indoor Lighting	-	12	9
Comfort Systems	-	50	6
Renewable	10	10	5

### Common Area and exterior Lighting

- Light installation will be done in a way where W/m2 will meet the criteria
- Fixture Lm/W, Lumens will be selected in a way where Lm/W will be more than 95

### Elevators

- Proposal from Elevator OEM meeting all the requirement / criteria. It is proposed to go for same proposal / BOQ line items
- Choose VVVF technology based elevator. (part of proposal). This will help in achieving extra points

### Pumps

Expected that PMC team will go for BEE 4 star rated pumps as Hydro-Pneumatic is expensive technology. Project can achieve 06 points

### Renewable Energy Systems

As per drawings provided, Installation of 79 Panels need approx. 132 sqm area which is approx. to 24% of tower roof area occupied by Panels. Hence project can achieve 5 points.

# 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>

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## 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 of energy 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](#)

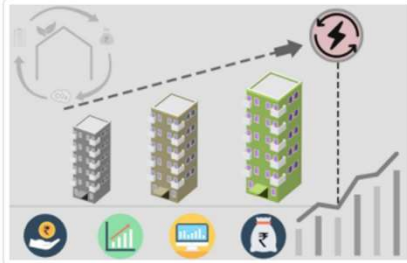
### Advanced Tool (Trial Version)



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, HVAC and Economics to check the project performance. Dive in to learn more!

[Tutorial Video](#)

### Optimization Tool (Trial Version)



The ECONIWAS Optimization tool is a quick evaluation module to compute the most optimized set of envelope 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 - MODULES

## 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.





# ECONI WAS 2.0 – BASIC TOOLS

Quick and Easy Inputs for defining primary information of Building including location, shading, area and orientation.

Welcome to ECO-NI WAS Tool

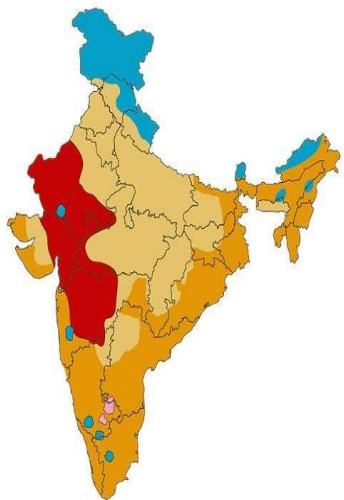
Please select your State and closest City

State  
National Capital Territory of Delhi

City  
New Delhi

Climate Zone

- Hot and Dry
- Warm and Humid
- Composite
- Temperate
- Cold



Continue Back

Please select your Building Type

Stand-Alone  
A Stand-Alone building does not have any neighbouring buildings.

3-Sides-Open  
A 3-Sides-Open building has one building attached on one side.

2-Sides-Open  
A 2-Sides-Open building has two buildings attached, one on each side.

Area per Floor  
200 m<sup>2</sup>

Building Area  
Building Area is equivalent to 800 m<sup>2</sup>

Which direction should your building face?  
South-Facing


Continue Back

Most interactive drag and drop features to select and install energy efficient parameters in building design

Project Information: National Capital Territory of Delhi, New Delhi, Composite, Stand-Alone, 200 m<sup>2</sup>, South-Facing

Select EE Measures

- Roof
- Wall
  - Efficient Wall (AAC Block + Plaster)
  - More Efficient Wall (Brick + 50 mm insulation)
  - Highly Efficient Wall (Brick + 100 mm insulation)
- Window Size
- Window Type
- Shading
- Air Conditioner
- Natural Ventilation



My Savings per Year

- 69,600 Energy Savings kWh
- 56,800 CO<sub>2</sub> Savings
- 280,000 Money Savings INR

for whole Building

Best Combination

Reset to Baseline

Report Card

My Energy Savings (85%)

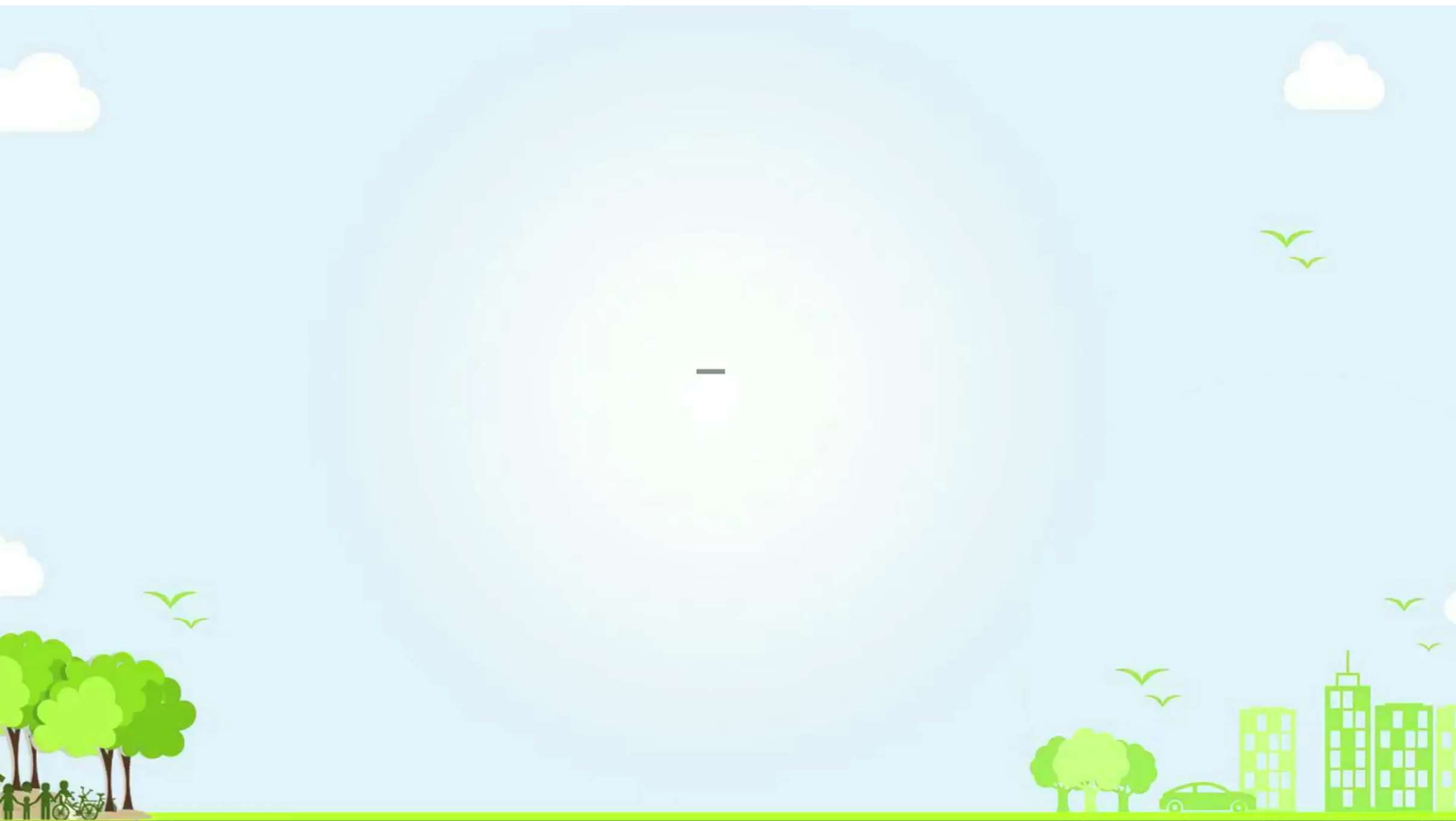
EPI 0 25 50 75 100 125 150 175 200

Baseline

One click export of results to PDF file

Ready reference on the effect on EPI of the design as compared to conventional (baseline) design

Quick inference on the impact of selected design features on the energy, environment and monetary level.



# ECONIWAS 2.0 – MODULES AND BASIC INFORMATION

## 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.

NAVIGATION

BASIC INFORMATION

LAYOUT

ENVELOPE

LIGHTING

EQUIPMENTS

HVAC

ECONOMICS

LAYOUT

Layout Shape

T-Shape

Building Orientation

North

T Shape

X1

Y1

X2

Y2

X3

16

10

3

meters

meters

meters

Number of Floors

3

Floor Height

2.00

meters

Home Advanced Tool Envelope Optimization Tool

Welcome: giz@yahoo.com Logout

NAVIGATION

BASIC INFORMATION

LAYOUT

ENVELOPE

LIGHTING

EQUIPMENTS

HVAC

ECONOMICS

ADVANCED TOOL

BASIC INFORMATION

Project Name

GIZ

State

Delhi

City

New Delhi

Climate

Composite

Closest Weather Profile

IND\_DL\_New.Delhi-Safdarjung.AP.4216

Building Typology

Single Family

Occupancy

4

m<sup>2</sup>/person

Latitude

Greater than 23.5 deg N

Effective and responsible user form that takes essential inputs from the user to generate desired results

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





For Wall & Roof Construction Assembly Definition

Define Wall/Roof constructions through property (U-value) or layer definition method. The construction once created can be used multiple times.

ENVELOPE

Construction Details

WALL DETAILS

Definition Type

Layer

Wall Name

BrickWall





Layer Name (outside to inside)

Cement plaster (1762 kg/m3)





Thickness (mm)

15

Add Layer

S.No.	Wall Name	Layer Name	Thickness (mm)	R Value (K.m²/W)	Action
1	BrickWall	Solid burnt clay brick (1760 kg/m3)	230	0.295	 
2		Cement plaster (1762 kg/m3)	15	0.021	 

Add Wall

S.No.	Wall Name	Definition Type	U-value (W/m²K)	Action
1	Brick wall	1- Solid burnt clay brick (1920 kg/m3) [230 mm] 2- Cement plaster (1762 kg/m3) [15 mm] 3- Cement plaster (1762 kg/m3) [12 mm]	2.151	 
2	Rat Trap Bond Wall	1- Cement plaster (1762 kg/m3) [12 mm] 2- Solid burnt clay brick (1760 kg/m3) [75 mm] 3- Air Cavity (50mm Thickness) [80 mm] 4- Solid burnt clay brick (1760 kg/m3) [75 mm] 5- Cement plaster (1762 kg/m3) [12 mm] 6- Brick tile (1892 kg/m3) [8 mm]	1.441	 

See layer by layer construction of your desired assembly in this construction table along with thermal performance values.

Large number of construction Materials as per ENS are available in the list

All the assembled constructions are listed in this table for later use.

For Fenestration Definition

Define fenestration constructions through property U-value, SHGC & VLT, glazing area and opaque frame selection. The construction once created can be used multiple times.

FENESTRATION DETAILS

Fenestration Type

Window

Name of Window

Window1

Fenestration Opening Type

Casement

U-value (W/m²K)

4.2

SHGC

0.60

VLT

0.70





Glazing (%)

50

Opaque Frame U-Value (W/m².K)

Metal Frame

Add Fenestration

S.No.	Fenestration Type	Name of the window	Fenestration Opening Type	U-value (W/m²K)	SHGC	VLT	Glazing (%)	Opaque Frame U-Value (W/m².K)	Action
1	Window	wind_1	Casement	1.4	0.4	0.47	50	1.90	 
2	Window	wind_2	Casement	0.4	0.4	0.44	40	0.40	 

All the window constructions are listed in this table for later use.

For Fenestration & Shading Dimension Definition

Select window type from predefined window constructions types to be installed on the selected wall of the building. Define dimension of windows and numbers

Options to install shading elements on the selected window. Select one and input dimensions.

Fenestration

Type

Win1

Number

2

Length

1

m

Height

1

m

Area (including Frame)

2.33

m²

Shading Type

Overhang

No Shading

Overhang

Left Side Fin

Right Side Fin

Overhang and Left Side Fin

Overhang and Right Side Fin

Overhang and Left Side Fin and Right Side Fin

Overhang

Height Above Window

meters

Left Extension from Window

meters

Projection

meters

# ECONIWAS 2.0 – ADVANCECD TOOL – LIGHTING/EQUIPMENT & HVAC INFORMATION

User can define the lighting/equipment power density using Building Area Method or Space Function Method as per ECBC

LIGHTING

Definition Method

Space by Space Method

Lighting Power

Area Type	Percent Area (%)	Design Load (Watts)
Guest Room		
	Percent Area Sum (%)	75

Add LPD

S.No.	Area Type	Percent Area (%)	Design Load (Watts)	Action
1	Corridor	15	100	<div></div> <div></div>
2	Guest Room	60	500	<div></div> <div></div>

This table represents the design lighting/equipment load in different areas of the building.

HVAC

HVAC Present

Yes

Conditioned Area %

5

50

100

Cooling Present

Yes

Heating Present

Yes

Cooling Thermostat Setpoint °C

20

25

32

Heating Type

Electric

Co-efficient of Performance

4

Heating Thermostat Setpoint °C

10

15

22

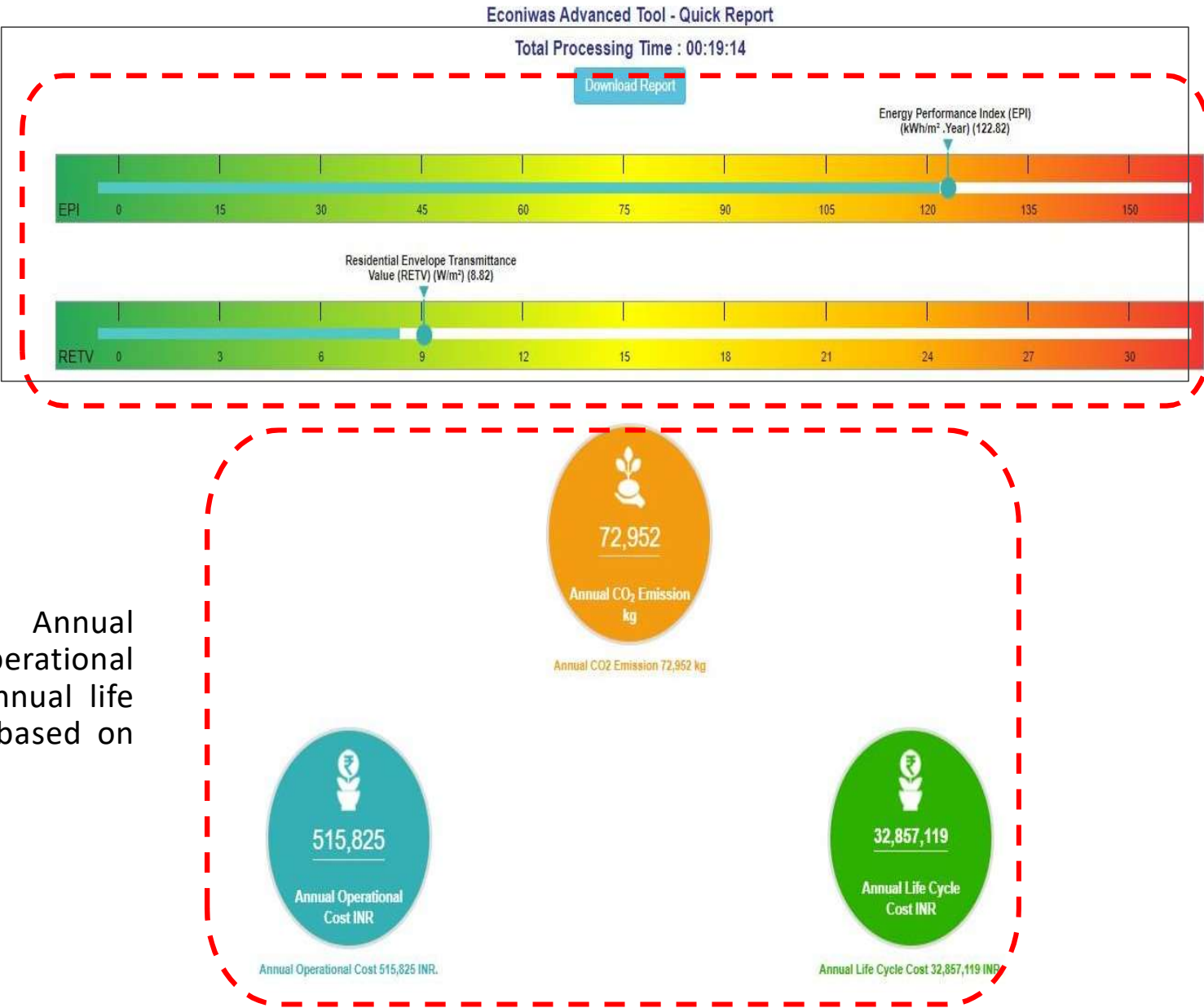
In case the HVAC is present, some essential information about the efficiency of equipment and conditioned area is asked from the user.

User has the option to choose whether the building is conditioned or naturally ventilated.

# ECONIWAS 2.0 – 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.

NAVIGATION

 BASIC INFORMATION

 CONSTRUCTION

CONSTRUCTION DETAIL

Wall

Type of Wall

110 mm Red Brick Wall

Wall Section Thickness (mm)

110

Wall Construction Cost (₹/m³)

4000

Type of Wall Insulation

Expanded Polystyrene Foam

Wall Insulation Cost (₹/m³)

20000

Roof

Type of Roof

150mmRCC slab with False ceiling

Roof Section Thickness (mm)

150

Roof Construction Cost (₹/m³)

3000

Type of Roof Insulation

Polyurethane Foam

Roof Insulation Cost (₹/m³)

20000

# ECONIWAS 2.0 – ENVELOPE OPTIMIZATION TOOL – BASIC INFORMATION

Effective and responsible user form that takes essential inputs from the user to generate desired results. Project location, energy inflation rate, tariff rate and life cycle years are few basic inputs which are required by the user.

The screenshot displays the user interface of the ECONIWAS 2.0 Envelope Optimization Tool. It is organized into three primary panels:

- NAVIGATION:** A sidebar on the left with a tree view containing 'BASIC INFORMATION' (selected) and 'CONSTRUCTION'.
- OPTIMIZATION TOOL:** The central workspace, currently showing the 'BASIC INFORMATION' form. This form includes the following input fields:
  - Project Name:** A text box containing 'EnvelopeChoice1'.
  - State:** A dropdown menu with 'Delhi' selected.
  - City:** A dropdown menu with 'New Delhi' selected.
  - Climate:** A dropdown menu with 'Composite' selected.
  - Closest Weather Profile:** A dropdown menu with 'IND\_DL\_New.Delhi-Safdarjung.' selected.
  - Energy Inflation Rate (%):** A numeric input field containing '4'.
  - Life Cycle Years:** A numeric input field containing '25'.
  - Electricity Tariff (₹/kWh):** A numeric input field containing '7'.
- HELP:** A panel on the right that provides explanatory text for the 'Life Cycle Years' input field, stating: 'This input field represents the amount of years for which the life cycle cost is to be calculated. It plays a very important role in determining the capital cost to operational cost ratios for optimization. Enter the amount of years for which the life cycle cost is to be calculated.'

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

# ECONIWAS 2.0 – ENVELOPE OPTIMIZATION TOOL – BASIC INFORMATION

User is required to select the choice of base wall/roof assembly on which insulation of optimized thickness shall be installed. Similarly, selection of insulation material is required as input.

CONSTRUCTION DETAIL

Wall

Type of Wall

230mm Red Brick Wall

Wall Section Thickness (mm)

230

Wall Construction Cost (₹/m³)

5000

Type of Wall Insulation

Expanded Polystyrene Foam

Wall Insulation Cost (₹/m²)

3800

Roof

Type of Roof

100mm RCC Slab

Roof Section Thickness (mm)

100

Roof Construction Cost (₹/m³)

6000

Type of Roof Insulation

-Select-One-

-Select-One-

Expanded Polystyrene Foam

Polyurethane Foam

Rockwool

Glasswool

Mud Phuska

Straw

Extruded polystyrene (XPS)

Aerogel

Wood fibre

Cellulose / Wool / Hemp

Roof Insulation Cost (₹/m²)

Window Cost (₹/m²)

Building Height (m)

WWR-East (%)

0

50

100

User is required to define the cost per cubic meter for base wall roof assembly and the selected insulation.

Large number of insulation options for user to choose from.

# ECONIWAS 2.0 – ENVELOPE OPTIMIZATION TOOL – OTHER DESIGN INFORMATION

Similarly, selection of Window type and corresponding cost is required as input. Based on the window type, the optimization tool shall limit the U-value output.

For example, if user selects SGU, the tool can predict U values close to 7 W/m2.K, whereas if user selects DGU, the tool will limit the prediction of U-value upto 4 W/m2.K

Window

Type of Window

Double Glazed

Window Cost (₹/m²)

5500

Other Design Specifications

Conditioned Area (%)

1010055

Building Height (m)

20

WWR-East (%)

010050

WWR-West (%)

010050

WWR-North (%)

010050

WWR-South (%)

010050

Submit

Apart from this, a few other relevant information on the envelope such as Building Height, Conditioned Area and WWR of each façade is required as input from the user

NAVIGATION

BASIC INFORMATION

CONSTRUCTION

Optimization in progress. This procedure generally takes 4-5 minutes. The results will be shown on the screen once the optimization is finished. Thanks!!

Please Wait ...

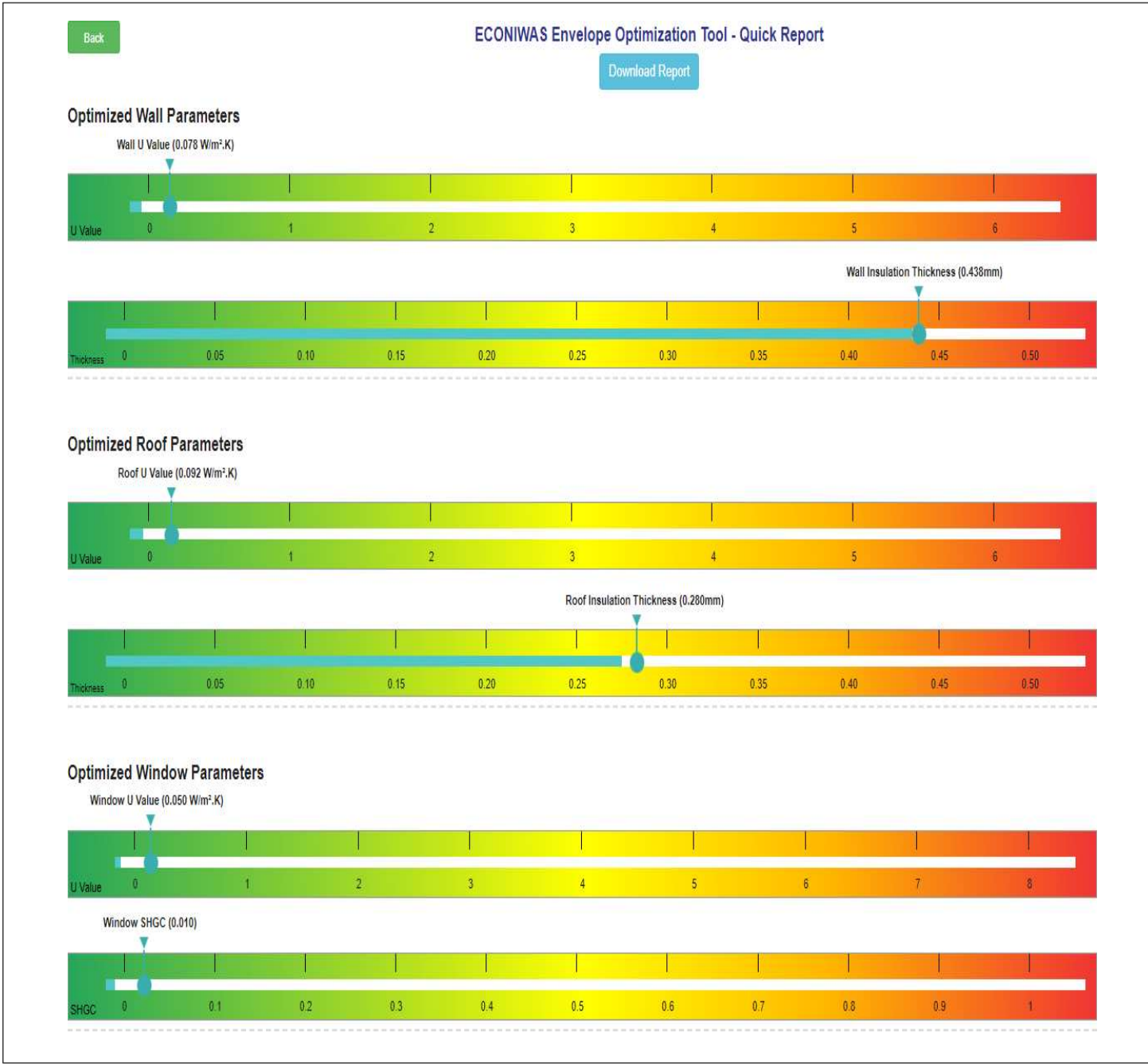
Generally, the optimization process takes 4-5 minutes to complete. The following message is shown in the tool during execution of optimization.

After filling all the required information, the user is required to click on the Submit button to start the optimization engine.



# ECONIWAS 2.0 – 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.



# GREEN BUILDING CONCEPTS

## What is green building?

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



## Six Major Elements Of Green Building Designe

Sustainable Site Design Water

Conservation And Quality

Energy And Environment

Indoor Environmental Quality

Conservation Of Materials And Resources

Creativity In Design



# INDIGENOUS AND LOW-EMBODIED MATERIALS

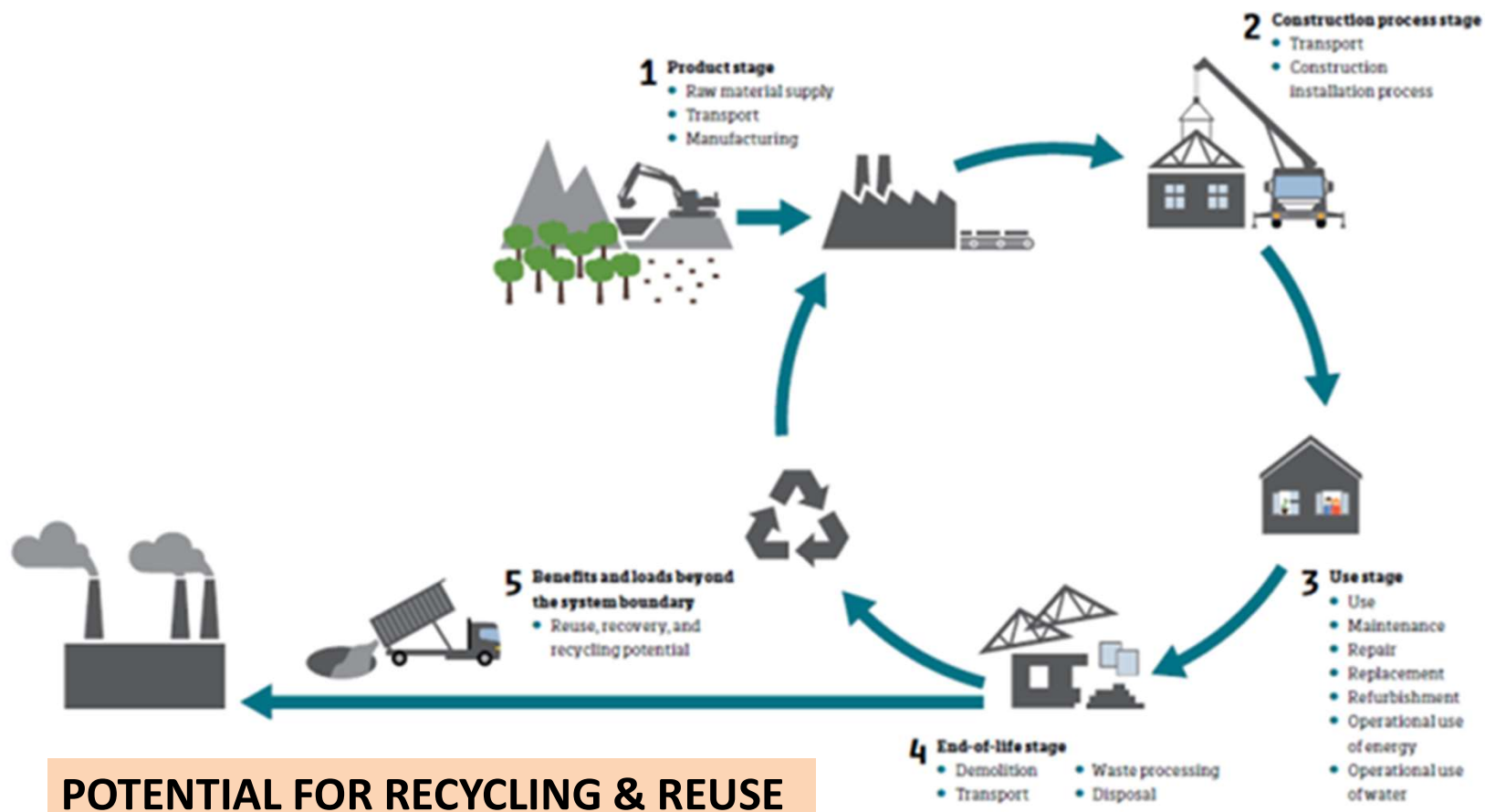


LEAST CARBON FOOTPRINT

MATERIALS WITH

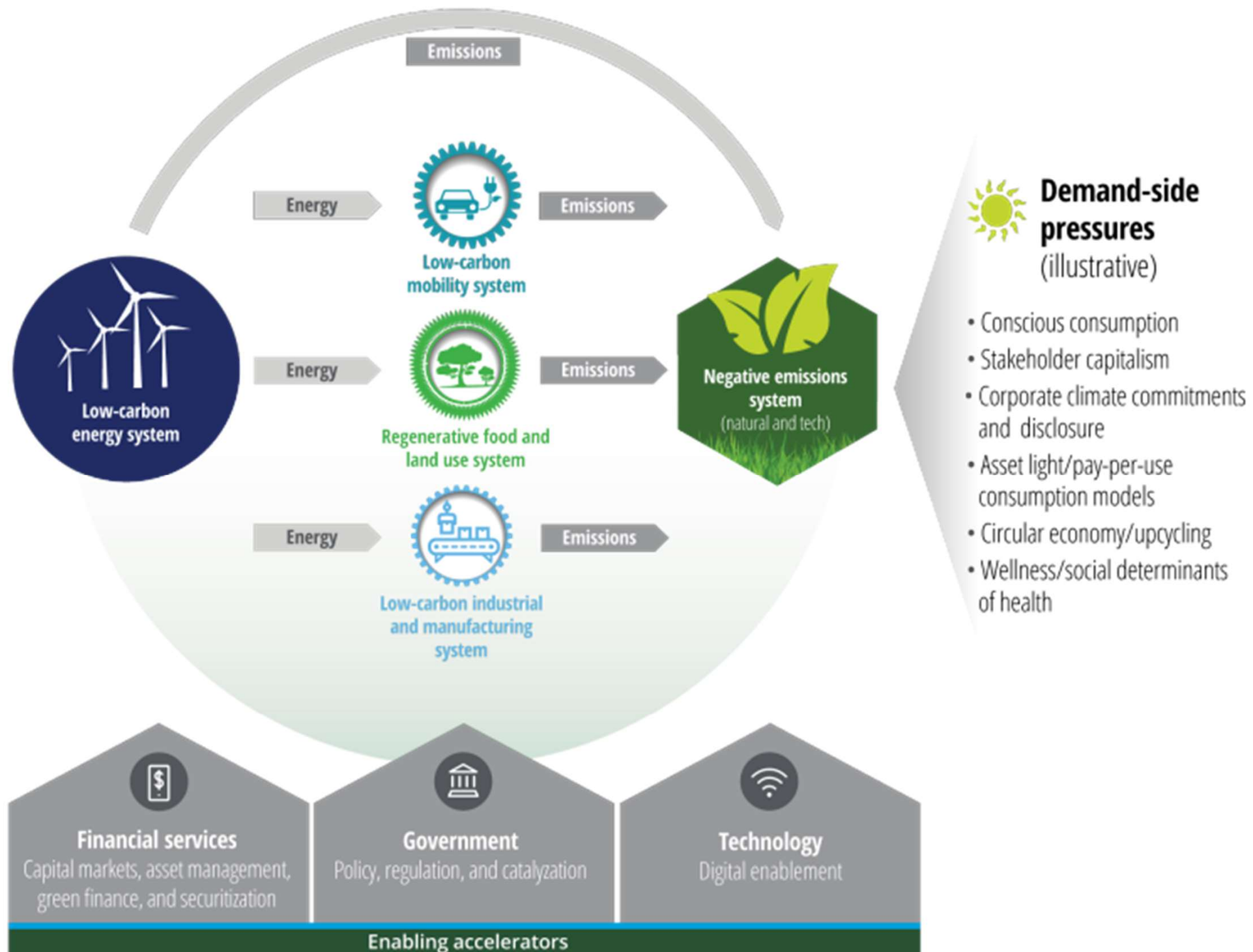


LOW CARBON EMISSION



POTENTIAL FOR RECYCLING & REUSE

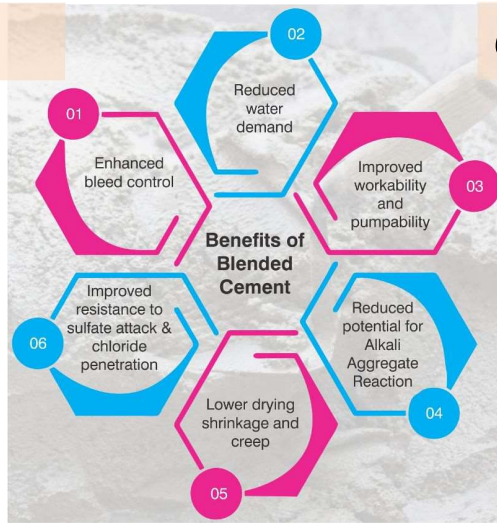
# INDIGENOUS AND LOW-EMBODIED MATERIALS



# INDIGENOUS AND LOW-EMBODIED MATERIALS

## BLENDING CEMENTS

Blended cement can be defined as **uniform mix of ordinary Portland cement (OPC) and blending materials** such as silica fumes, fly ash, limestone and slag to enhance its properties for **different uses**. Blended cement can improve workability, strength, durability and chemical resistance of concrete.



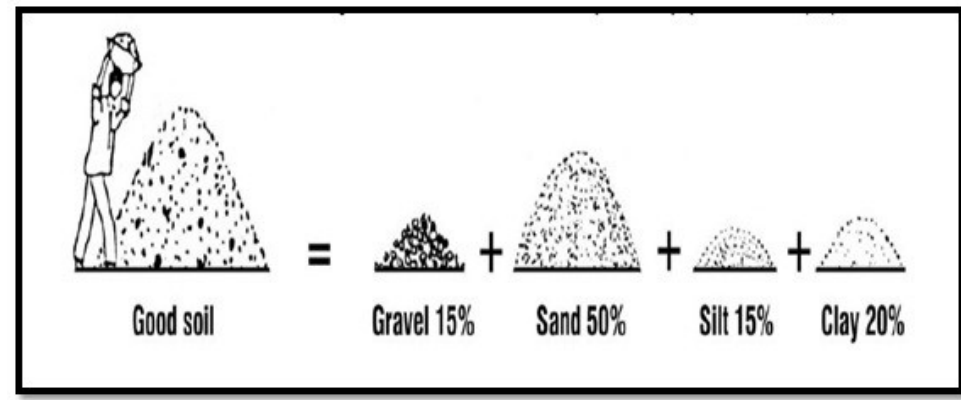
## COMPACTED FLY ASH BLOCKS

containing class C or class F fly ash and water. Compressed at 28 MPa (272 atm) and cured for 24 hours in a 66 °C steam bath, then toughened with an air entrainment agent, the bricks can last for more than 100 freeze-thaw cycles.



## STABILIZED MUD BLOCKS FOR MASONRY

Stabilized mud blocks (SMBs) are **manufactured by compacting a wetted mixture of soil, sand, and stabilizer in a machine into a high-density block**. Such blocks are used for the construction of load-bearing masonry. Cement soil mortar is commonly used for SMB masonry.



## LOW ENERGY INTENSITY FLOOR AND ROOFING SYSTEMS



## RAMMED EARTH WALLS

Rammed earth walls are constructed by ramming a mixture of selected aggregates, including gravel, sand, silt, and a small amount of clay, into place between flat panels called formwork. Traditional technology repeatedly rammed the end of a wooden pole into the earth mixture to compress it.





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

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



# GREEN BUILDING – BEST PRACTICES

1

Increased water  
preservation efforts

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

2

Improved Environmental  
product market

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

3

Fewer Wastewater  
Treatment Plants

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



4

Fewer Power Plants  
& Power lines

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- Use of energy efficient appliances and systems

5

Equitable access to  
transportation infrastructure

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

6

Better comfort  
and productivity

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- Thermal comfort will lead to better productivity



# BEE Star labelling for Residential Buildings

# BEE STAR LABELLING FOR RESIDENTIAL BUILDINGS



## Labeling Types

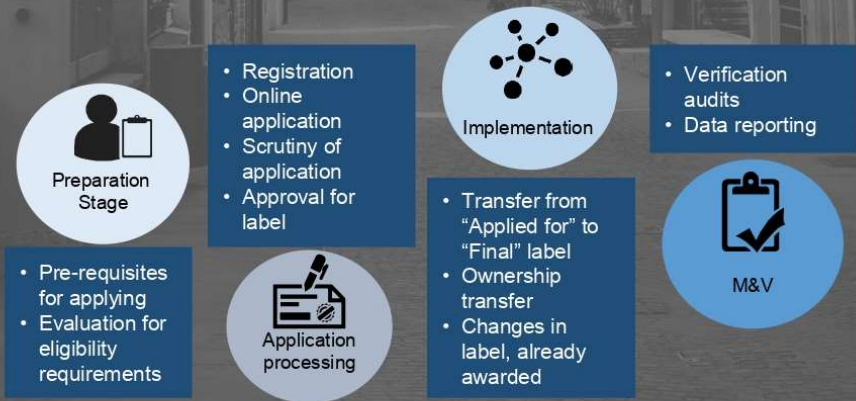
**"Applied For" label**  
Applicable for new buildings with construction permit issued by the authorities having jurisdiction

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



## 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

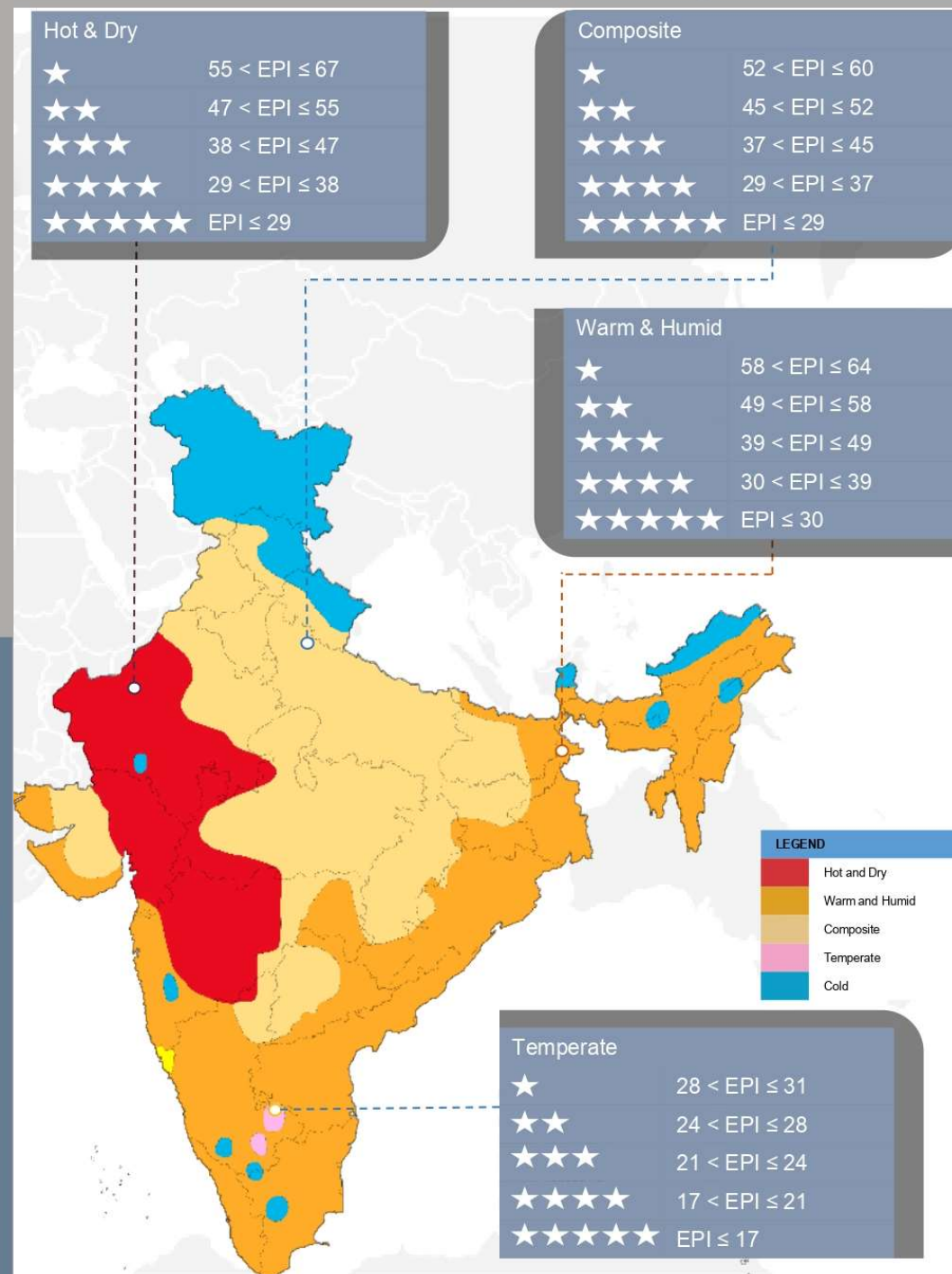
The program is applicable for all single and multiple dwelling unit in the country for residential purpose



## 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





GLOBAL  
HOUSING  
TECHNOLOGY  
CHALLENGE INDIA



Ministry of Housing and Urban Affairs  
Government of India



**giz** Deutsche Gesellschaft  
für Internationale  
Zusammenarbeit (GIZ) GmbH

**Thank you.**