



GLOBAL  
HOUSING  
TECHNOLOGY  
CHALLENGE INDIA

**RACHINA**

RESILIENT, AFFORDABLE AND COMFORTABLE HOUSING THROUGH NATIONAL ACTION

# Innovative Construction Technologies & Thermal Comfort for Affordable Housing

Training 56  
15<sup>th</sup> July 2022  
Chennai

Presented by CSB Cell - South





## Introduction - GIZ

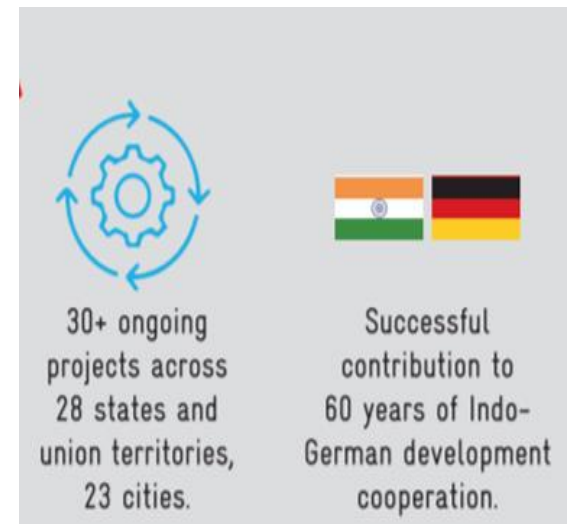
## GIZ

GIZ is an international cooperation enterprise for sustainable development which operates worldwide, on a public benefit basis. GIZ is fully owned by the **German Federal Government**, GIZ implement development programs in partner country on behalf of the German Government in achieving its development policy objectives.



The focal areas of Indo-German cooperation currently are:

- Energy
- Environment, Preservation, and Sustainable Use of Natural Resources
- Sustainable Urban & Industrial Development
- Sustainable Economic Development



## GIZ



### Energy

We support our partners in developing framework conditions for the promotion of renewable energy, improved energy efficiency and rural energy access.

- Indo-German Energy Forum - Support Office
- Indo-German Energy Programme - Access to Energy in Rural Areas
- Integration of Renewable Energies into the Indian Electricity System
- Indo-German Solar Partnership - PVRT
- Promotion of Solar Water Pumps
- Indo-German Energy Programme - Green Energy Corridors
- Energy Efficiency in Buildings Programme
- Indo-German Energy Programme - Energy Efficiency



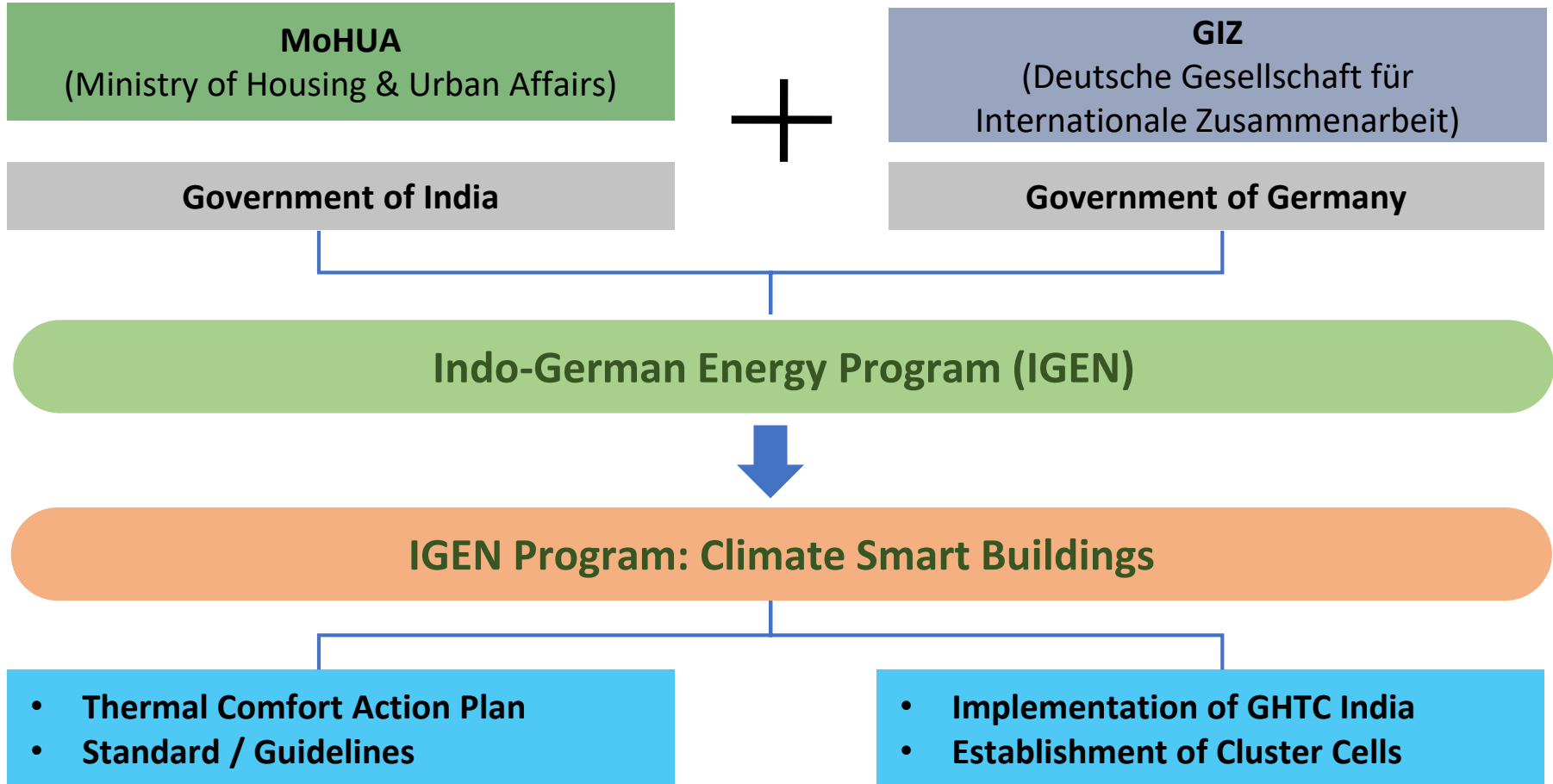
### Sustainable Urban and Industrial Development

We support the development of urban and industrial areas to become cleaner, more liveable, inclusive, climate-friendly and resilient.

- Land Use Planning and Management
- Sustainable and Environment-friendly Industrial Production
- Support to Ganga Rejuvenation
- Integrated and Sustainable Urban Transport Systems for Smart Cities in India
- Sustainable Urban Development - Smart Cities
- Climate Smart Cities



## MoHUA + GIZ





## Introduction – Climate Smart Buildings Cell

## GIZ Climate Smart Buildings Cell (CSB cell)

**Light House Project –  
Implementation  
Monitoring & Evaluation**

**Technical Assistance to  
DHPs & AHRCs**

**GIZ Climate Smart Building Cell (CSB)**

**Inclusion of Thermal  
Comfort requirements in  
Bye-laws**

**Capacity Building of  
Stakeholders**

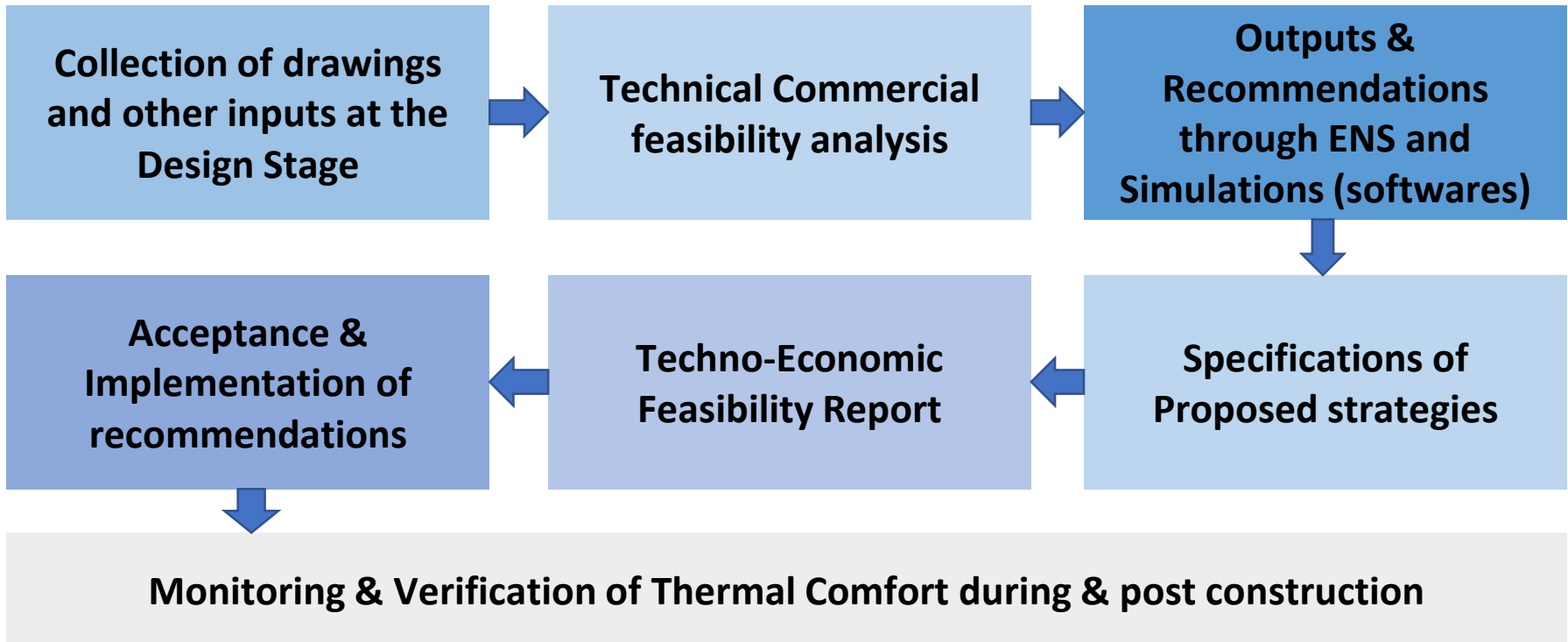
South Cluster Cell covers

- Tamilnadu**
- Karnataka**
- Kerala**
- Andhra Pradesh**
- Telangana**
- Puducherry**
- Andaman & Nicobar**
- Lakshadweep**

## Demonstration Housing Project (DHPs)

To showcase the field level application of new / alternate technologies, **MoHUA** has taken an initiative to construct Demonstration Housing Project (DHP) through **Building Materials & Technology Promotion Council (BMTPC)** as a part of Technology Sub-Mission under **PMAY(U)**.

### CSB Cell – DHP identification & analysis process



## RACHNA

Trainings & Workshops on Innovative Construction Technologies &  
Thermal Comfort for Affordable Housing

# RACHNA

Resilient, Affordable and Comfortable Housing through  
National Action

### TRAININGS:

The Climate Smart Buildings Project in partnership with Ministry of Housing & Urban Affairs is hosting **75** trainings under the following categories:

- **30 Trainings for Built-environment professionals & Govt. Departments**
- **10 Vocational Trainings**
- **20 Trainings for Senior Govt. Officials & Policy makers**
- **6 Trainings for Future trainers**
- **8 Awareness sessions for students**
- **22 Additional Capacity Building Workshops**
- **2 International knowledge exchange programs**

### IMPACT:

- **Capacity Building – 2500 stakeholders**
- **More than 1000 architects & developers** trained to design & deliver Thermally comfortable affordable housing
- **More than 450 govt officials and policy makers** trained for incorporating thermal comfort provisions in Byelaws
- **More than 300 contractors, masons and field workers** trained in working with new technologies
- **Students in 8 architectural colleges** across the country targeted for awareness at ground roots level.

**March-August 2022**



## Session 1 : GHTC and LHPs

## Global Housing Technology Challenge - India

MoHUA has initiated the **Global Housing Technology Challenge-India (GHTC-India)** which aims to identify and mainstream a basket of innovative construction technologies from across the globe for housing construction sector that are sustainable, eco-friendly and disaster-resilient.

- Cost effective
- Speedier
- Quality construction
- Diverse geo-climatic conditions

### GHTC-India Components



**Hon'ble Prime Minister Shri Narendra Modi** laid the foundation stone of these LHPs on January 1, 2021

MoHUA, through a **Technical Evaluation Committee (TEC)**, shortlisted **54 innovative** proven technologies suiting different geo-climatic conditions that could be considered for demonstration through actual ground implementation of six Light House Projects (LHP) in six different States/UTs of PMAY(U) regions across the country.



## Light House Project

- **Model housing projects with approximately 1,000 houses built with shortlisted alternate technology suitable to the geo-climatic and hazard conditions of the region.**
- Demonstrate and deliver ready to live houses with speed, economy and with better quality of construction in a sustainable manner.
- **Period of construction is maximum 12 months from the date of handing over of sites to the construction agency after all statutory approvals.**
- LHPs shall serve as LIVE Laboratories for planning, design, production of components, construction practices, testing etc.
- **Site infrastructure development such as internal roads, pathways, common green area, boundary wall, water supply, sewerage, drainage, rain water harvesting, solar lighting, external electrification, etc.**
- Cluster design may include innovative systems of water supply, drainage and rainwater harvesting, renewable energy sources with special focus on solar energy.
- **Incentives for early completion.**



## Light House Projects

As a part of **GHTC- India**, six Light House Projects (LHP) consisting of about 1,000 houses each with physical & social infrastructure facilities is being constructed at six places across the country namely

1. Indore
2. Rajkot
3. Chennai
4. Ranchi
5. Agartala
6. Lucknow

These projects will showcase the use of the six distinct shortlisted innovative technologies for field level application, learning and replication. LHPs will demonstrate and deliver ready to live mass housing at an expedited pace as compared to conventional brick and mortar construction and will be more economical, sustainable, of high quality and durability. These projects shall serve as Live laboratories for all stakeholders including R & D leading to the successful transfer of technologies from the lab to the field



## Light House Project

Six Technology providers have been selected through a rigorous online bidding process for construction of Light House Projects (LHPs) at six different locations in six states.

**1. Precast Concrete Construction System - 3D Precast volumetric**



**2. Precast Concrete Construction System - Precast components assembled at site**



**3. Light Gauge Steel Structural System & Pre-engineered Steel Structural System**



**4. Prefabricated Sandwich Panel System**



**5. Monolithic Concrete Construction**



**6. Stay In Place Formwork System**



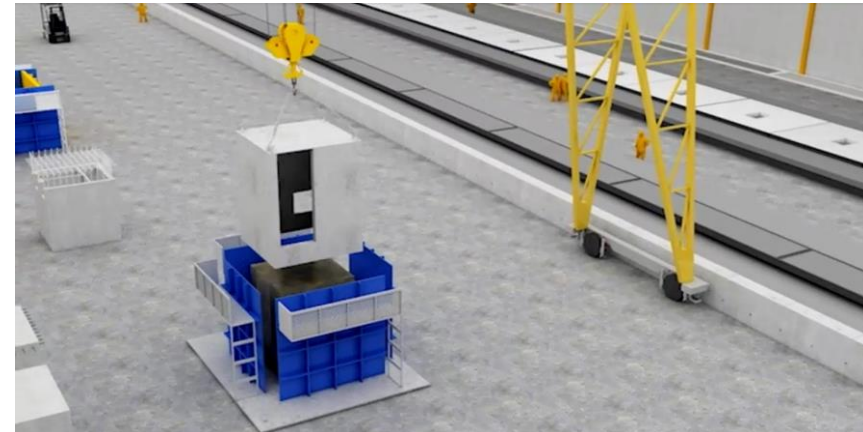


## LHP Ranchi

### Precast Concrete Construction System – 3D Volumetric

- 3D Volumetric concrete construction is the modern method of building by which solid precast concrete structural modules like room, toilet, kitchen, bathroom, stairs etc. & any combination of these are cast monolithically in Plant or Casting yard in a controlled condition.
- These Modules are transported, erected & installed using cranes and push-pull jacks and are integrated together in the form of complete building unit.
- Pre stressed slabs are then installed as flooring elements. Rebar mesh is finally placed for structural screed thereby connecting all the elements together.
  - Wall – Precast RCC
  - Floor – Pre stressed Slabs + Rebar mesh + Screed

**Number of Houses : 1008**



## LHP Rajkot

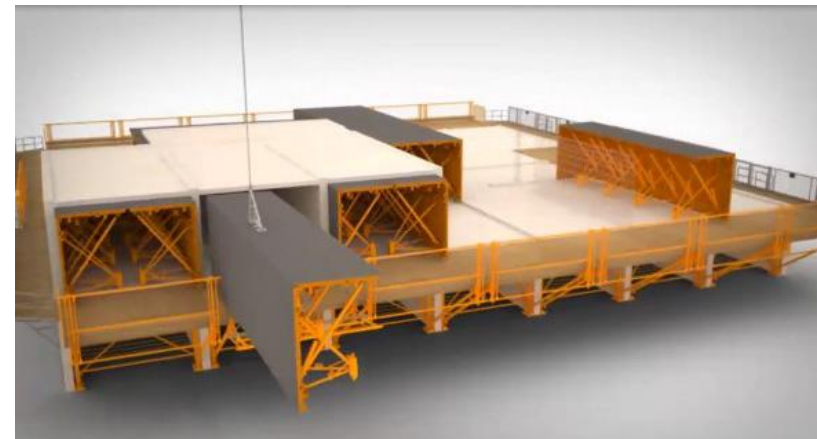
### Monolithic Concrete Construction using Tunnel Formwork

- In 'TunnelForm' technology, concrete walls and slabs are cast in one go at site giving monolithic structure using high-precision, re-usable, room-sized, Steel forms or moulds.
- This system uses customized engineered steel formwork consisting of two half shells which are placed together and then concreting is done to form a room size module. Several such modules make an apartment.

#### Construction Process:

- Stripping of the formwork from the previous day.
  - Positioning of the formwork for the current day's phase, with the installation of MEP services.
  - Installation of reinforcement in the walls and slabs.
  - Concreting
- Wall – Precast RCC (*No plaster required*)
  - Partition Wall – AAC Block (*Option – Any masonry*)
  - Floor – Rebar mesh + Screed

**Number of Houses : 1144**



## LHP Chennai

### Precast Concrete Construction System – Precast Components Assembled at Site

- Precast concrete construction is a system where the individual precast components such as walls, slabs, stairs, column, beam etc, of building are manufactured in plant or casting yard in controlled conditions.
- The reinforcement cages are placed at the required position in the moulds. Concrete is poured and compaction of concrete is done by shutter/ needle vibrator.
- Casted components are then moved to stacking yard where curing is done for required time. These precast components are installed at site by crane and assembled together through in-situ jointing and/or grouting etc.
  - Wall – AAC Block (*Options - Precast Slab*)
  - Roof - Precast Slab + Brickbat Koba + Screed
  - Floor – Precast Slab with Rebar mesh + Screed

**Number of Houses : 1152**



Ground Floor Column Work in Progress - March 2021



First Floor Column & Beam Erection - May 2021



## LHP Indore

### Prefabricated Sandwich Panel System

- Factory made Prefabricated Sandwich Panel System is made out of cement or calcium silicate boards and cement mortar with EPS granules balls, and act as wall panels.
- These can be used as load-bearing and non-load bearing walling for residential and commercial buildings.
- Under this LHP, houses are being constructed using Prefabricated Sandwich Panel System with Pre-Engineered Steel Structural System.
- EPS Cement Panels having tongue and groove joint are manufactured at the factory in controlled condition.
- Wall – EPS Cement Panels (*Options – Ca Si Boards*)
- Floor – Decking Sheet + Rebar mesh + Screed

**Number of Houses : 1024**





## LHP Agartala

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

- Light Gauge Steel Frame (LGSF) System uses factory made galvanized light gauge steel components. LGSF is used in combination with pre-engineered steel structural system for buildings above G+3 for longevity, speedier construction, strength and resource efficiency.
- The sequence of construction comprises of foundation laying, fixing of Pre-Engineered Steel Structural System, fixing of tracks, fixing of wall panels with bracings as required, fixing of floor panels, decking sheet, fixing of electrical & plumbing services and finally fixing of concrete walling panels with light weight concrete as infill.
- Wall – LGSF + Concrete filling + Wall panels  
(Options – Insulation Filling)
- Floor – Deck slab + Rebar mesh + Screed  
(Options – Precast hollow core slab)

Number of Houses : 1000



## LHP Lucknow

### PVC Stay In Place Formwork System

- Plant manufactured rigid poly-vinyl chloride (PVC) based polymer components serve as a permanent stay-in-place finished form-work for concrete walls. The formwork System being used acts as pre-finished walls requiring no plaster and can be constructed instantly.
- Then, these Sections are erected on the prepared foundation using cranes and required connections. Floor is installed using decking sheet. Once the structural frame and floor is installed and aligned, wall panels are fixed on decking floor.
- The pre-fabricated walling panels having provisions of holes for services conduits, are fixed along with the reinforcement & cavities inside the wall panels are filled with concrete.
  - Wall – PVC Formwork with Concrete filling  
(Options – Insulation Filling)
  - Floor – Decking Sheet + Rebar mesh + Screed

**Number of Houses : 1040**





## Light House Project : CHENNAI

TECHNOLOGY SELECTED:

**Precast Concrete Construction System – Precast Components Assembled at Site**

**AGENCY: M/s B.G. Shirke Construction Technology Pvt. Ltd.**

**No. of Towers: 12**

**No. of Houses: 1128**

**No. of Floors: 6**



## Light House Project : CHENNAI

### Project Brief

**Location of Project :** Nukkampalayam Road, Chennai, Tamil Nadu

**No. of DUs :** 1,128 (G+5)

**Plot area :** 29,222 sq.mt.

**Carpet area of each DU :** 26.78 sq.mt.

**Total built up area :** 43439.76 sq.m

**Technology being used :** Precast Concrete Construction System - 3S System

**Other provisions :** Anganwadi, shops, milk booth, library and ration shop.

### Broad Specifications:

- Foundation RCC isolated footing
- Structural Frame RCC precast beam/columns
- Walling AAC Blocks Floor Slabs/Roofing RCC precast

### Door Frame/ Shutters:

- Pressed steel door frame with flush shutters
- PVC door frame with PVC Shutters in toilets.
- Window Frame/ Shutter:
- uPVC frame with glazed panel and wire mesh shutters.

### Flooring:

- Vitrified tile flooring in Rooms & Kitchen
- Anti-skid ceramic tiles in bath & WC
- Kota stone Flooring in the Common area.
- Kota stone on Staircase steps.





# Light House Project : CHENNAI



Description	Unit	Length	Width	Area
Hall	Sqmt	3.175	3.025	9.60
Kitchen	Sqmt	1.8	2.8	5.04
Bed Room	Sqmt	2.725	2.528	7.70
Bed Room Offset	Sqmt	0.9	0.2	0.18
Bath Room	Sqmt	1	1.4	1.4
W.C	Sqmt	0.9	1.55	1.395
Passage	Sqmt	1	1.2	1.2
Kitchen Opening	Sqmt	0.9	0.1	0.09
Door 1	Sqmt	1	0.15	0.15
Door 2	Sqmt	0.9	0.1	0.09
Door 3	Sqmt	0.75	0.1	0.075
Column Deduction	Sqmt			0.22
<b>Total Carpet Area</b>				<b>26.78</b>



## Light House Project : CHENNAI

### Precast concrete construction

- The construction process comprises manufacturing precast concrete Columns, Beams and Slabs in steel moulds. The reinforcement cages are placed at the required position in the moulds.
- Concrete is poured and compaction of concrete is done by shutter/ needle vibrator.
- Casted components are then moved to the stacking yard where curing is done for required time and then these components are ready for transportation and erection at site.
- These precast components are installed at site by crane and assembled together through in-situ jointing and/or grouting etc.





## Light House Project : CHENNAI

### Special Features

- Nearly all components of building work are manufactured in plant/casting yard & the jointing of components is done In-situ leading to reduction in construction time.
- The controlled factory environment brings resource optimization, improved quality, precision & finish.
- The concrete can be designed as industrial by-products such as Fly Ash, Ground granulated blast furnace slag (GGBFS), Micro silica etc. resulting in improved workability & durability, while also conserving natural resources.
- Helps in keeping a neat & clean construction site and dust free environment.
- Optimum use of water through recycling.
- Use of shuttering & scaffolding materials is minimal.
- All weather construction & better site organization.





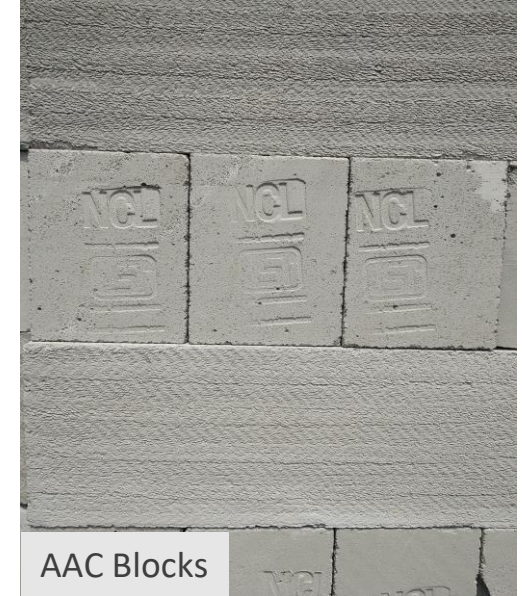
## Green Measures – LHP Chennai



Solar PV Panels



Recharge Pits



AAC Blocks



STP – Recycled water for flushing



Landscaping – Sprinkler irrigation





## Light House Project : CHENNAI



Handing over of Keys to Beneficiaries by Hon'ble Prime Minister on May 26, 2022



## Session 2: Thermal comfort

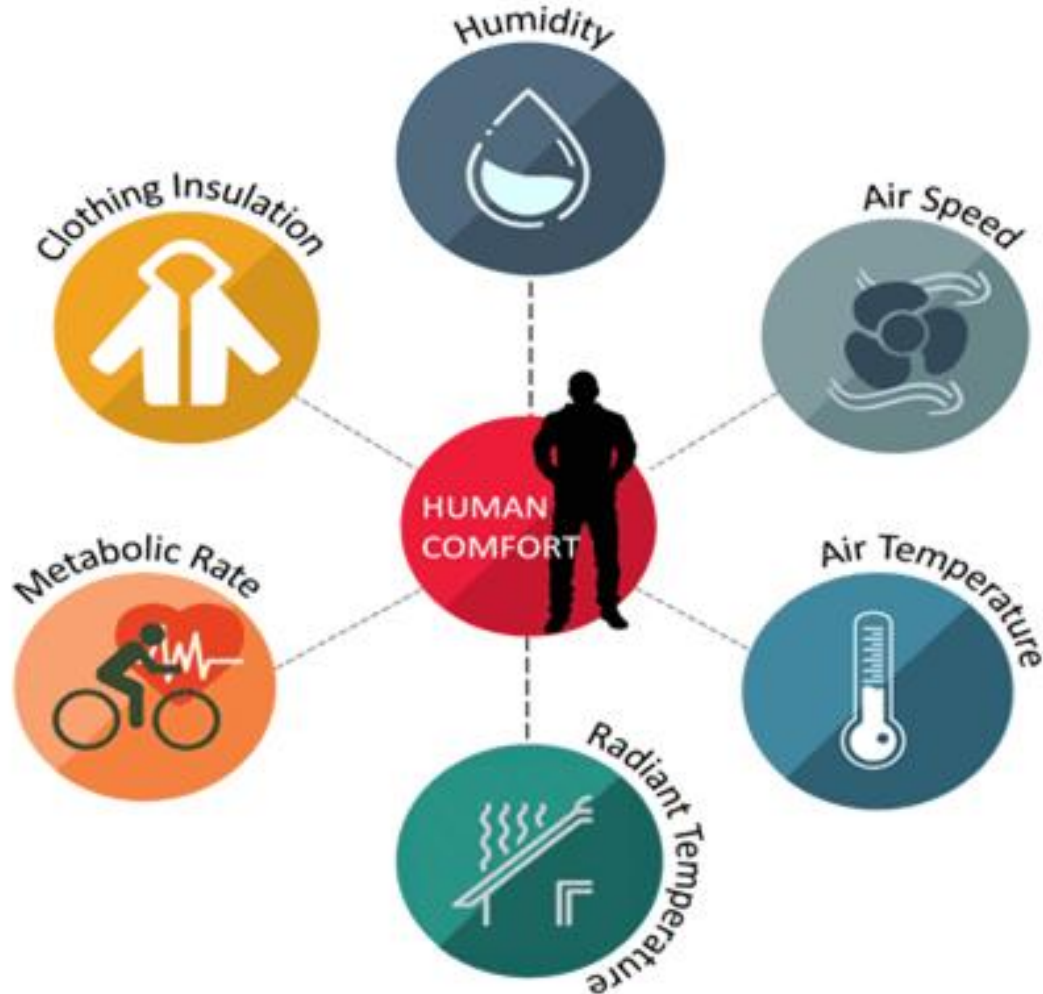
## Thermal Comfort – Definition

*It is defined as "that condition of mind which expresses satisfaction with the thermal environment." This condition is also some times called as "neutral condition", though in a strict sense, they are not necessarily same for everyone.*

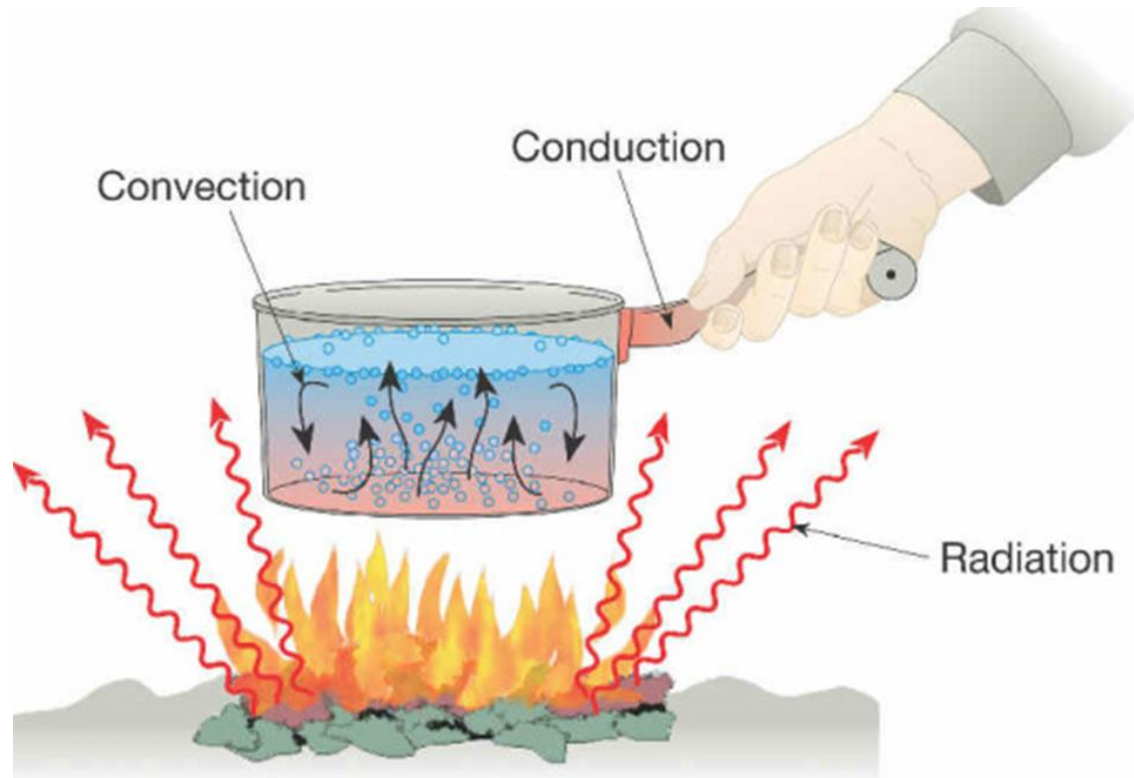
Internationally Engineers & designers look up to following standards for thermal comfort conditions:

- **ASHRAE 55** (American Society of Heating, Refrigerating, and Air Conditioning Engineers)
- **ISHRAE** (Indian Society of Heating, Refrigerating, and Air Conditioning Engineers)
- **IMAC** (Indian Model for Adaptive Thermal Comfort)

## Thermal Comfort – Indices



## Mode of Heat Transfer – Influencing Thermal comfort





## Thermal Comfort Indices – Metabolic Rate





## Thermal Comfort Indices – Clothing Insulation

- The clothing factor used to represent the thermal insulation from clothing
- The unit for measuring the resistance offered by clothes is called as "clo"

- Radiation heat loss/gain
- Convection heat loss/gain
- Surface area exposed

- 1 clo :  $0.155 \text{ m}^2\text{K/W}$
- Winter clothing : 1.0 clo
- Summer clothing : 0.5 clo

Trouser+ Half Sleeves



0.6 clo

Jeans + Blazer



1.0 clo

Woollen Clothes



1.5 clo

## Thermal Comfort – Impact of Radiant Temperature

- Uniform Temperature of an imaginary Enclosure
- Measure of the effect of Radiant interchanges at a point in space
- Depends on the surrounding environment & envelope



## Thermal Comfort Indices – Environmental Factors

Indices	Air Speed	Humidity	Air Temperature
Definitions	Rate of Air Movement	Percentage of the amount of moisture the air could possibly hold	Average temperature of air surrounding an occupant
Controls	Fan Speed Wind speed Window Opening	Humidifier Dehumidifier	Insulated Envelope Heat Ingress/Egress
Heat Influence	Convective Evaporative	Evaporation	Convective Evaporative

## Thermal Comfort Indices – Environmental Factors

### Problems due to High Humid Conditions

- Stuffy air
- Condensation on windows and walls
- Mold spots or water stains
- Musty smells
- Allergies
- Skin problems
- Swollen woods
- Moist fabrics

### Problems due to Low Humid Conditions

- Dry air
- Allergies
- Vulnerable to Cold
- Infections
- Itchy & Dry Skin
- Damage to wood furniture & paints
- Increased static electricity
- Electronics damage

## Building Physics - Air Changes per Hour (ACH)

Air changes per hour (ACH) is a measure of how many times the air within a defined space is replaced in a hour

$$N = \frac{60Q}{Vol}$$

N = number of air changes per hour

Q = Volumetric flow rate of air in cubic feet per minute (cfm)

Vol = Space volume L × W × H, in cubic feet

## Thermal Discomfort due to Building factors

### Local Thermal Discomfort

- The local thermal discomfort is **unwanted cooling or heating** on a particular part of an occupant's body

Asymmetric radiant field (Cold floor, warm wall, equipment & sunlight)

Too warm or too cold Flooring

Local convective cooling (draught)

Vertical Air temperature difference (Warm air near head & Cold air near feet)



• Draught



• Radiation Asymmetry



• Vertical Air Temperature Differences.

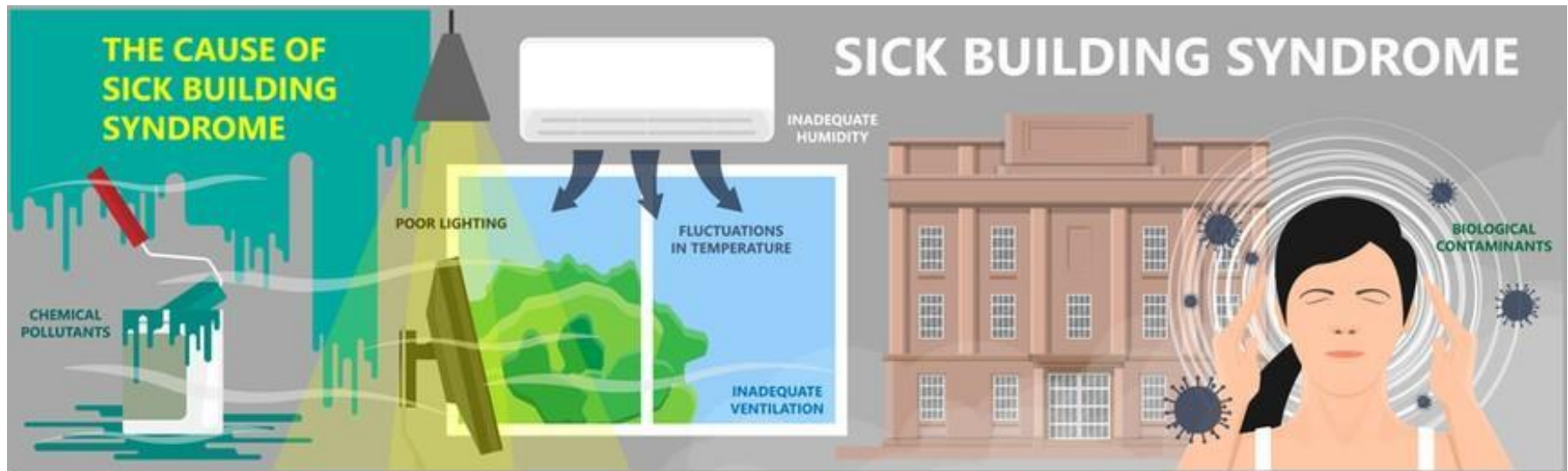


• Floor temperature

## Thermal Discomfort – Sick Building Syndrome

### SICK BUILDING SYNDROME

- **Sick building syndrome (SBS)** is used to describe situations in which building occupants experience acute health and comfort effects that appear to be linked to time spent in a building



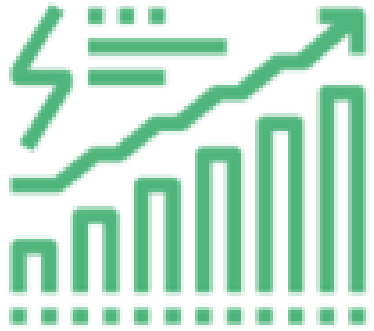
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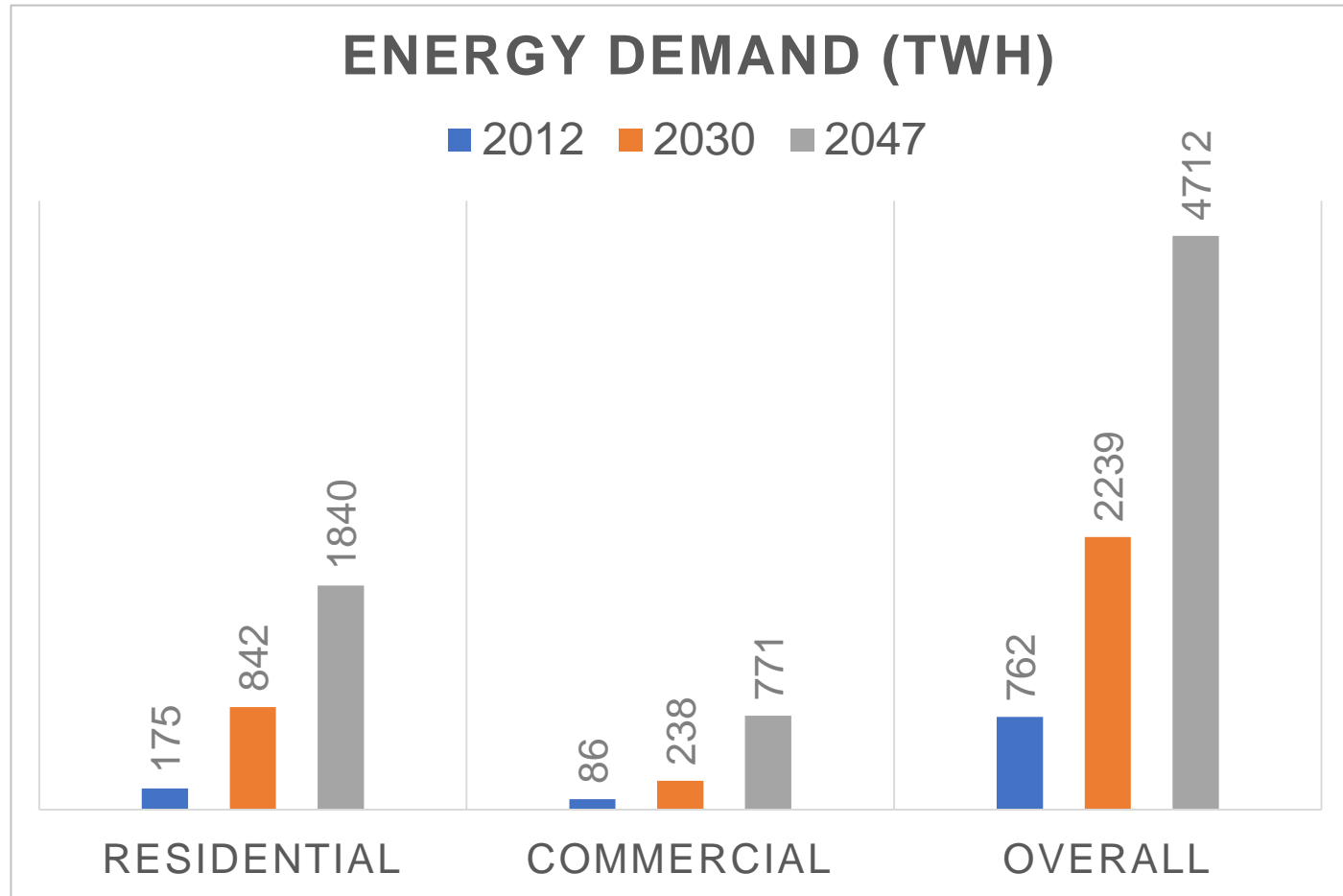
## Necessity of Thermal comfort in Affordable Housing



## Affordable Housing Demand



India is projected to double its energy demand and have the largest increase in energy consumption worldwide between 2020 and 2040.

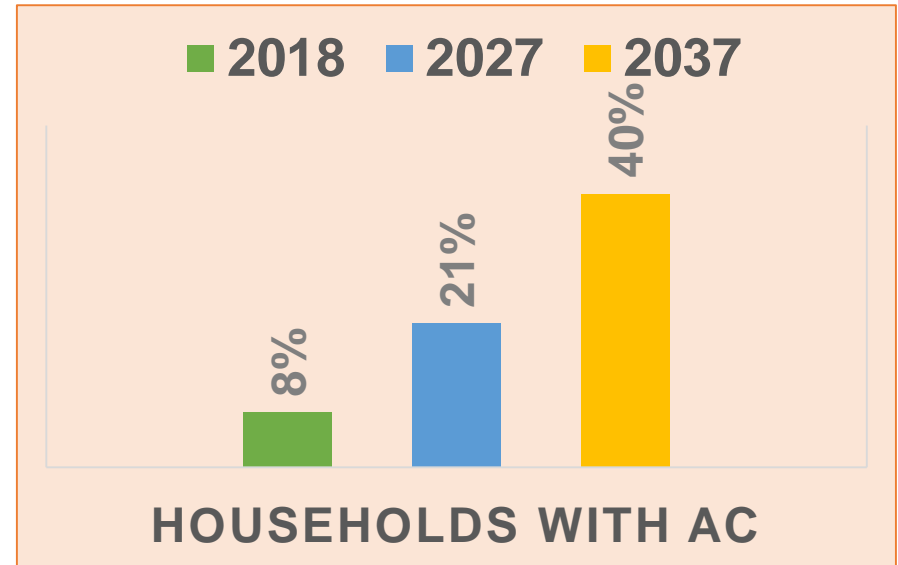
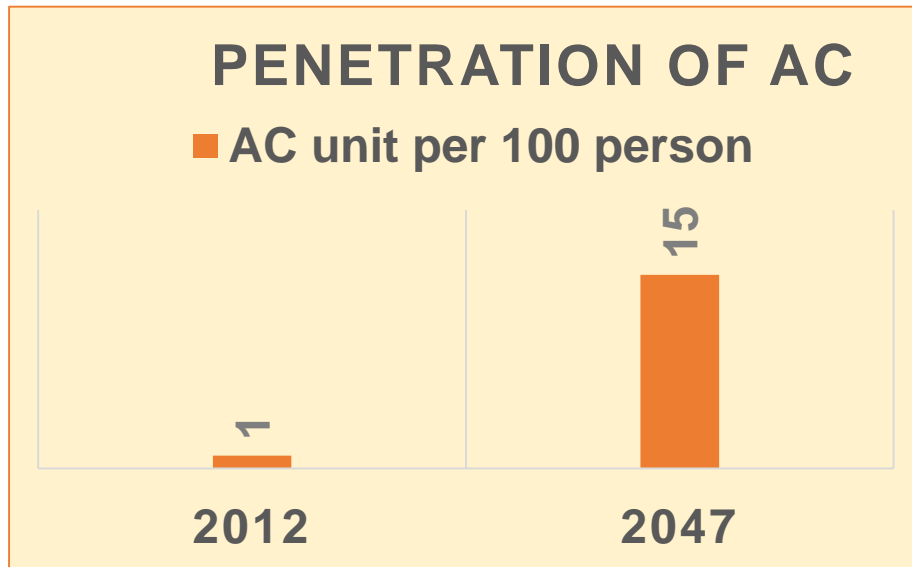


Source: India 2020 Energy Review Policy

Source: NITI Aayog 2015

## Increase in AC demand in the Residential Sector

In 2017, approximately 272 million households were estimated in India which will increase to 328 and 386 million in 2027 and 2037 respectively.



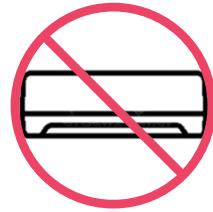
Source: Ministry of Environment, Forest & Climate Change. (2019). India Cooling Action Plan & NITI Aayog 2015

## Impetus of Thermal Comfort in Affordable Housing



11.2 Million houses under the PMAY scheme, with a lifespan of 50 to 60 years

LIG and EWS segment will not have access to active air-conditioning.



***Climate appropriate and energy efficient building design for EWS and LIG segments.  
Climate Smart Buildings (CSB)***

Passive strategies to achieve thermal comfort in Affordable housing

- Eco Niwas Samhita (ENS) – Part 1 (Building Envelope)

Active strategies to achieve thermal comfort in Affordable housing

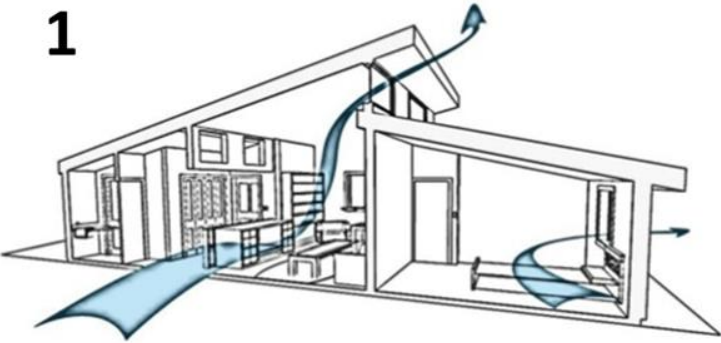
- Cool-roof programs

Implementation & Enforcement measures

- Regulatory and policy actions in the adoption of energy efficient building practices Promoting capacity building and fostering market awareness

## Thermal Comfort Improvement in a Building

1



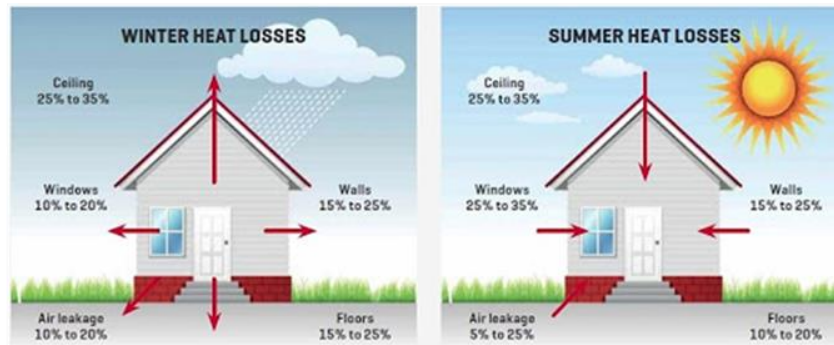
1. For Adequate natural ventilation potential for thermal comfort

2. For adequate day light for visual comfort



2

3

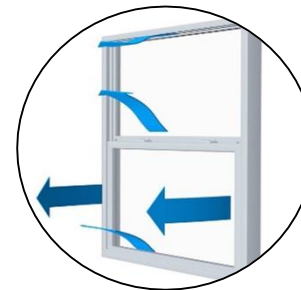
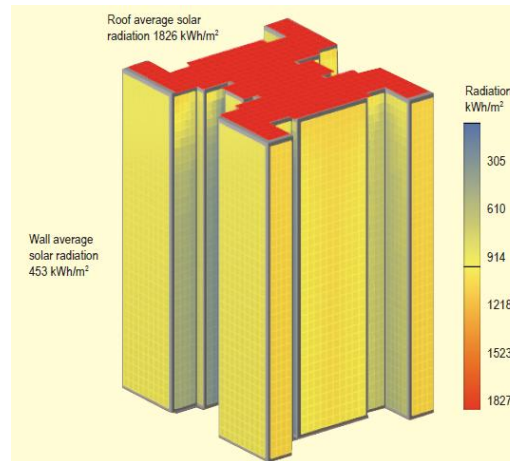
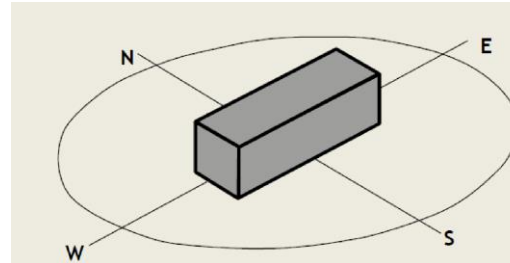


3. Limit heat gains / heat loss for energy efficiency

## Thermal Comfort Improvement Strategies

### Passive Strategies

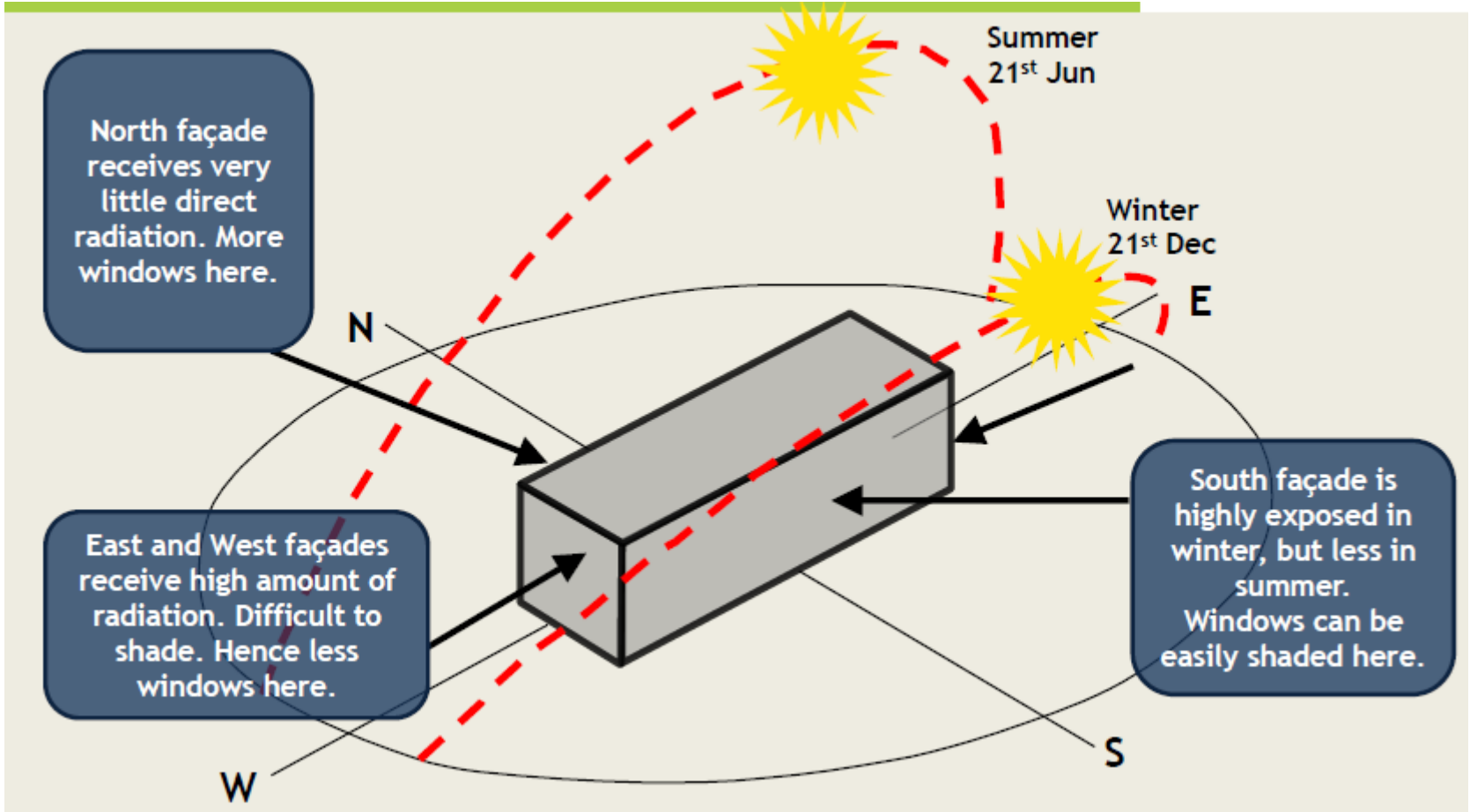
1. Orientation
2. Thermal Mass
3. Roof and Wall Materials
4. Non Opaque material properties
5. Appropriate Shading Design
6. Minimize Infiltration losses
7. Climate specific design interventions
8. Mutual / Tree Shading



### Active Strategies

1. Renewable Energy
2. Direct / Indirect Evaporative Cooling
3. Cool roofs

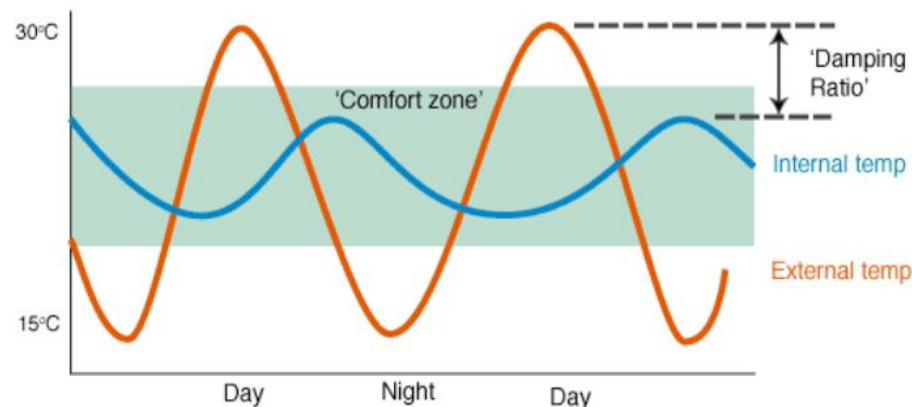
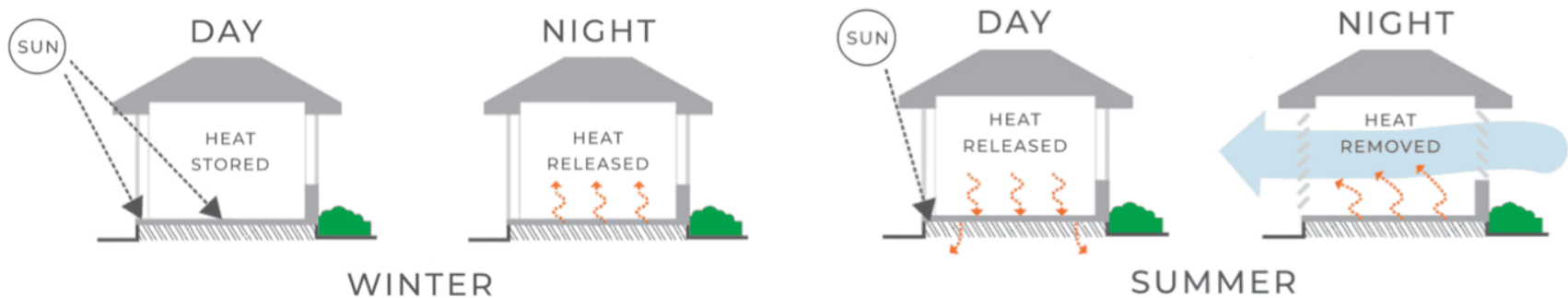
## Passive Measures - Orientation





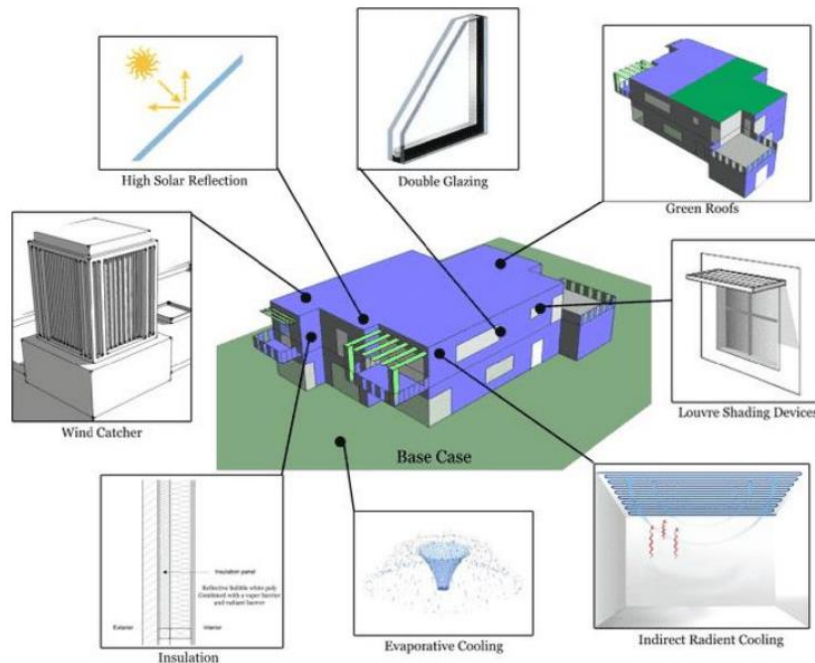
## Passive Measures - Thermal Mass

- Denser thermal mass materials are more effective passive solar materials. Thus, denser the material the better it stores and releases heat.
- Integrate thermal mass with an efficient passive solar design, by considering the placement of added mass.
- Do not substitute thermal mass for insulation. It should be used in conjunction with insulation



## Passive Measures - Roof and Wall Materials

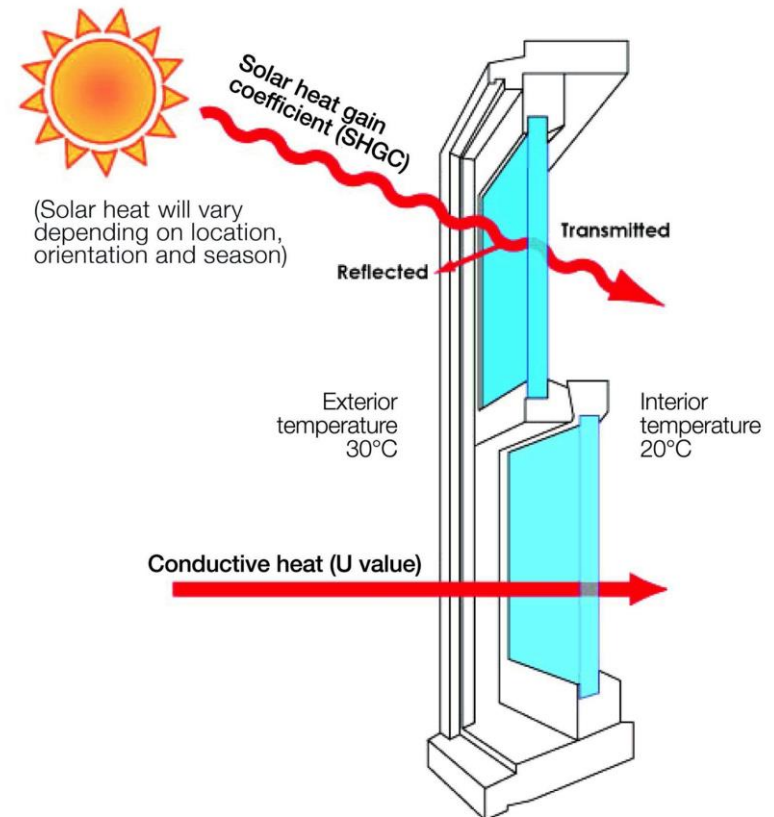
The properties of building materials act as building envelopes by resisting the external temperature and humidity, mostly influenced by indoor thermal comfort. The materials having lower thermal conductivity, thermal diffusivity, and absorptivity has the properties of less temperature swing on the inside surface of the walls compared to the materials with high thermal conductivity



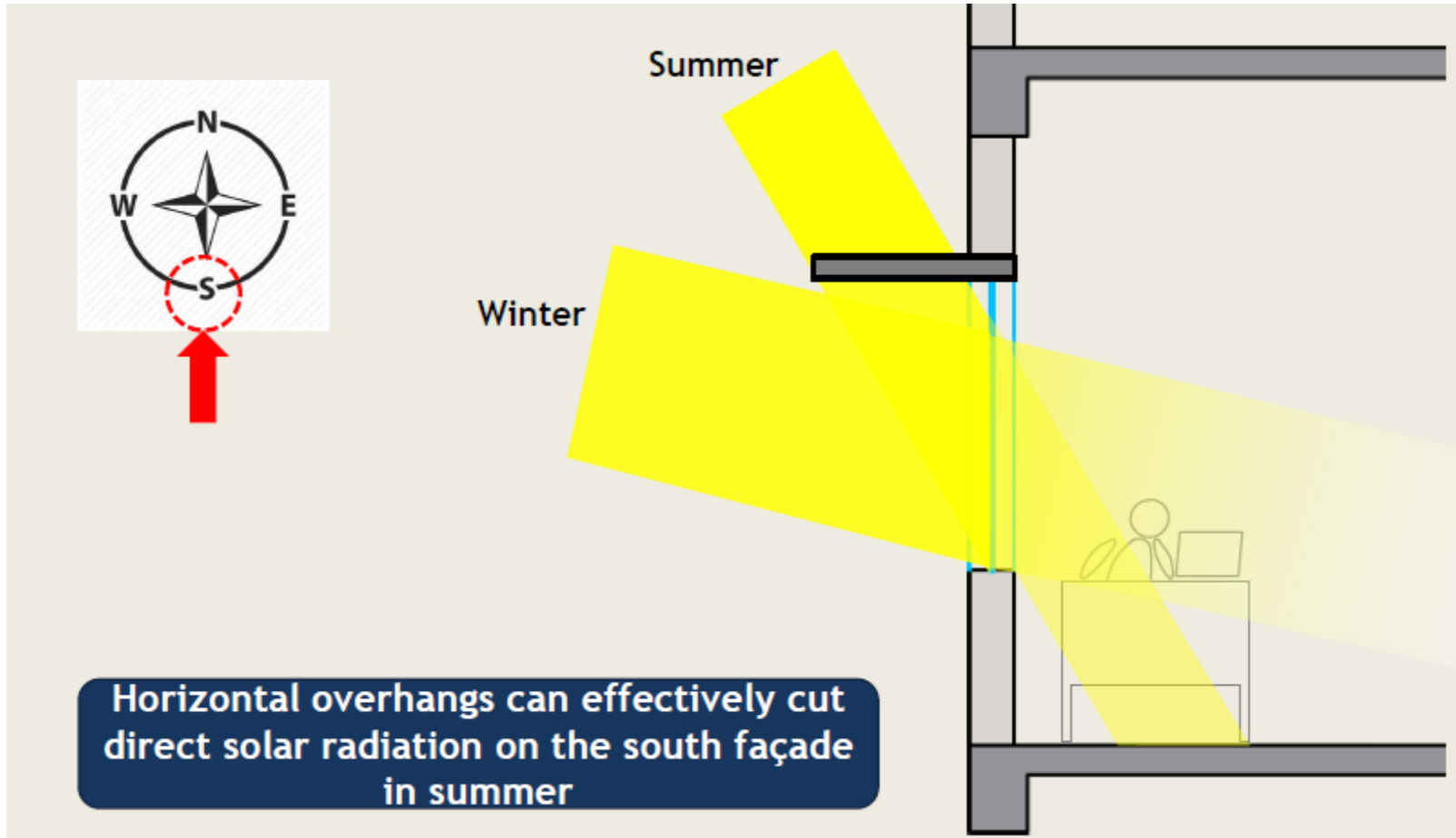
- Green roofs.
- Louvre and shading devices.
- Insulation
- Low energy cooling techniques
- Wind catchment and ventilation
- High solar reflective surface.

## Passive Measures - Non Opaque Material Properties

- Three of the most important properties of the materials, coatings, and constructions that make up windows, skylights, translucent panels, or other products used to let sunlight into a building include:
  - *Thermal conductance (U-value)*
  - *Solar Heat Gain Coefficient (SHGC)*
  - *Visible Light Transmittance (VT)*
- Appropriate values for glazing properties vary by climate, size, and placement of the aperture.



## Passive Measures - Shading



## Passive Measures - Minimal Infiltration Losses

- Infiltration is the **unintentional or accidental introduction of outside air into a building, typically through cracks in the building envelope and through use of doors for passage.** Infiltration is sometimes called air leakage.
- Reducing air infiltration is often the first action item of a weatherization plan. Caulking cracks, sealing an unused fireplace, and adding weatherstripping are simple, low-cost improvements that can reduce air infiltration.



Typical places to check for air infiltration include:

- Electrical outlets, switches, and ceiling fixtures
- Operable features of windows and doors – check for a loose fit
- Window and door frames where they meet the wall
- Wall or window-mounted air conditioners
- Plumbing, electrical, cable, and telephone penetrations
- Ducts in unconditioned spaces.

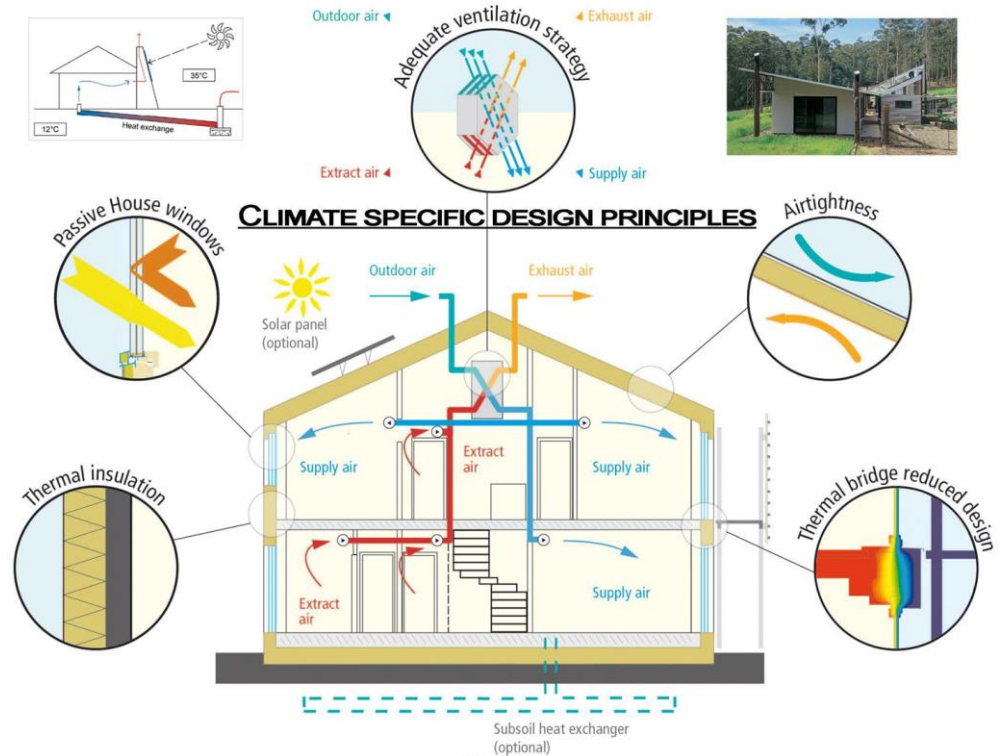


## Passive Measures - Climate Specific Design Interventions

The climate responsive design refers to **the architecture that reflects the particular region-specific weather conditions of the peculiar area**. It uses data of weather patterns and factors like sun, wind, rainfall, and humidity. The building structure is built according to the same.

Factors Affecting Climatic Design:

- **Topography** - elevation, slopes, hills and valleys, ground surface conditions.
- **Vegetation** - height, mass, silhouette, texture, location, growth patterns.
- **Built forms** - nearby buildings, surface conditions. and ventilation heat flow.

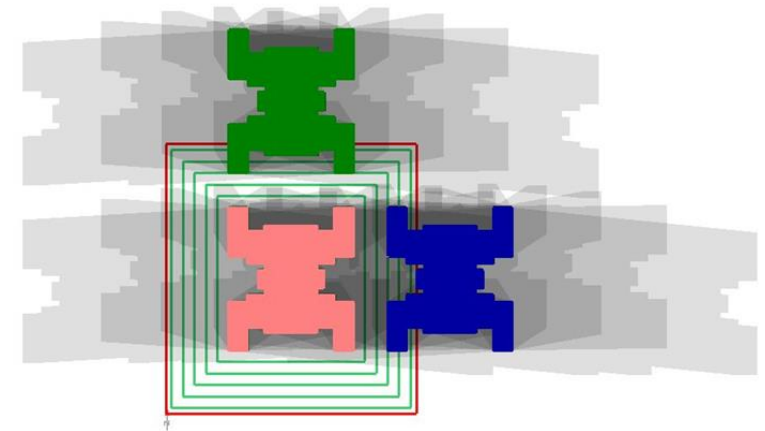
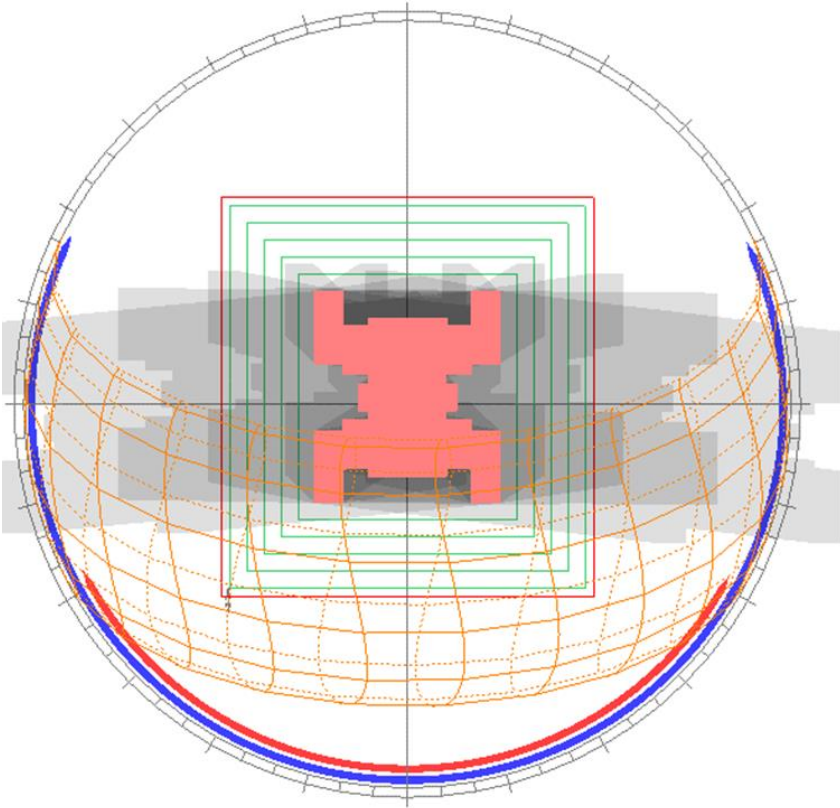


## Passive Measures - Mutual Shading

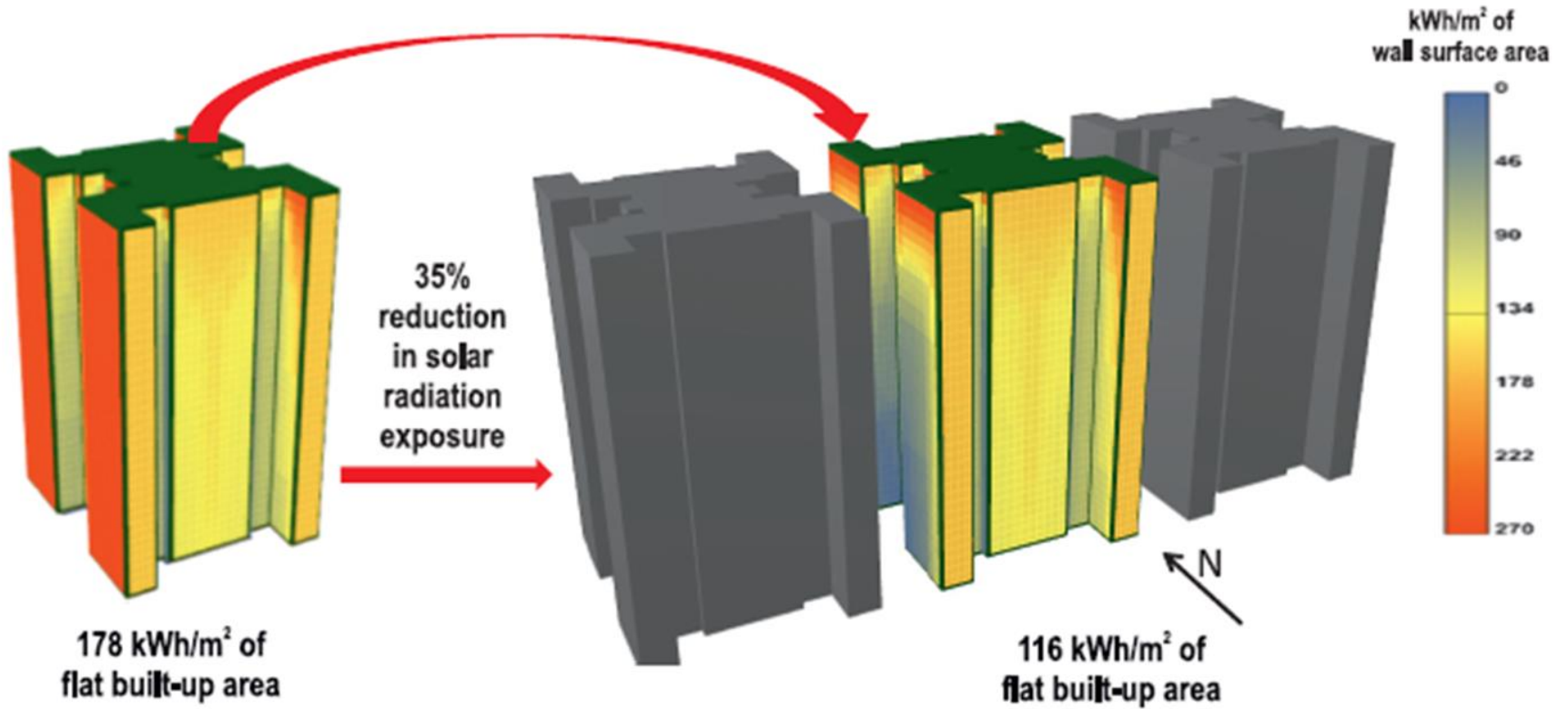
### Mutual Shading: June 21st

12 storey tower typology residential building

LATITUDE: 28.6°  
LONGITUDE: 77.2



## Passive Measures - Quantitative Impact of Mutual Shading



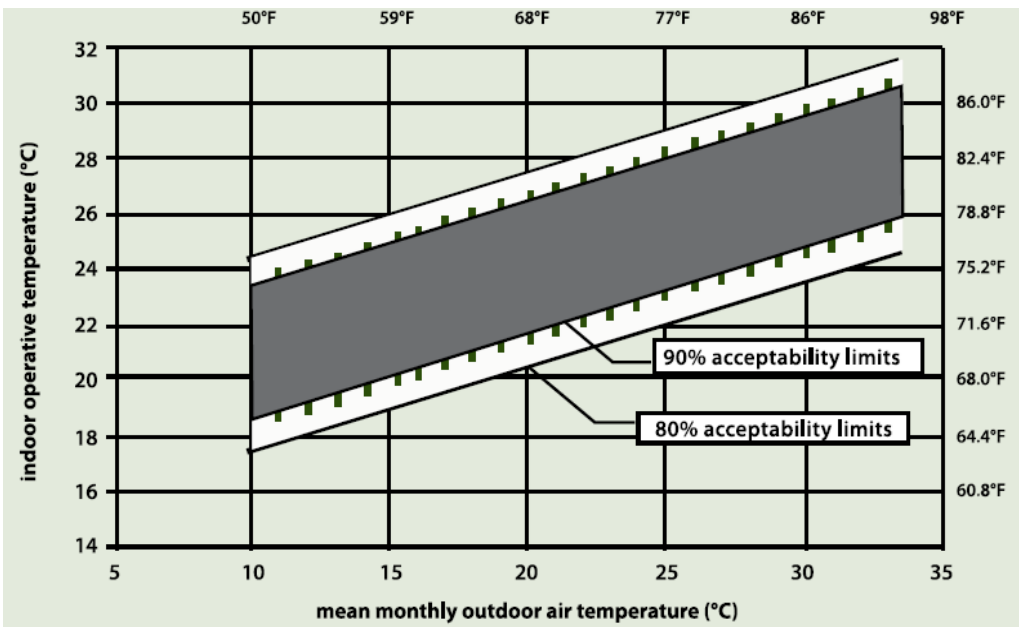


## Session 3: Thermal Comfort Models



## Thermal Comfort Standard – IMAC R

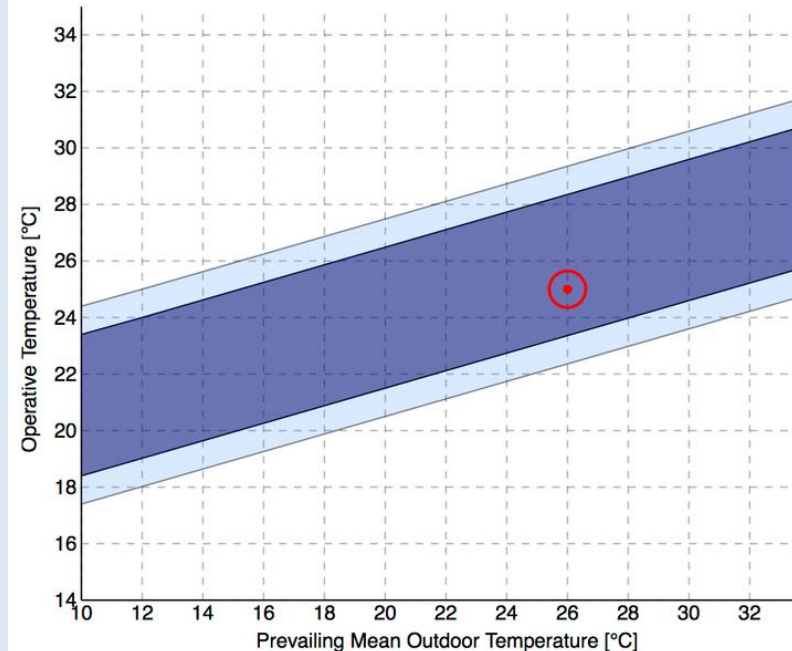
Indian Model for Adaptive Thermal Comfort (IMAC) models for neutral temperature and acceptability limits for naturally ventilated residential buildings through an empirical field study specific to the Indian context. It offers an energy-efficient pathway for the building sector without compromising occupant comfort.



Composite Location: Rajkot			
Months	Description	90% Acceptability Temperature (degC.)	80% Acceptability Temperature (degC.)
Jan	Minimum	24.13	22.68
	T nuet	26.28	26.28
	Maximum	28.43	29.88
Feb	Minimum	25.52	24.07
	T nuet	27.67	27.67
	Maximum	29.82	31.27
Mar	Minimum	26.87	25.42
	T nuet	29.02	29.02
	Maximum	31.17	32.62
Apr	Minimum	28.48	27.03
	T nuet	30.63	30.63
	Maximum	32.78	34.23
May	Minimum	28.78	27.33
	T nuet	30.93	30.93
	Maximum	33.08	34.53
Jun	Minimum	28.58	27.13
	T nuet	30.73	30.73
	Maximum	32.88	34.33
Jul	Minimum	27.38	25.93
	T nuet	29.53	29.53
	Maximum	31.68	33.13
Aug	Minimum	27.04	25.59
	T nuet	29.19	29.19
	Maximum	31.34	32.79
Sep	Minimum	27.09	25.64
	T nuet	29.24	29.24
	Maximum	31.39	32.84
Oct	Minimum	27.83	26.38
	T nuet	29.98	29.98
	Maximum	32.13	33.58
Nov	Minimum	26.56	25.11
	T nuet	28.71	28.71
	Maximum	30.86	32.31
Dec	Minimum	25.11	23.66
	T nuet	27.26	27.26
	Maximum	29.41	30.86

## Thermal Comfort Standard – ASHRAE 55

- The adaptive model is based on the idea that outdoor climate influences indoor comfort because humans can adapt to different temperatures during different times of the year.
- These results were incorporated in the ASHRAE 55-2004 standard as the adaptive comfort model. The adaptive chart relates indoor comfort temperature to prevailing outdoor temperature and defines zones of 80% and 90% satisfaction.
- This model applies especially to occupant-controlled, natural-conditioned spaces, where the outdoor climate can actually affect the indoor conditions and so the comfort zone.
- Adaptive models of thermal comfort are implemented in other standards, such as European EN 15251 and ISO 7730 standard.
- There are basically three categories of thermal adaptation, namely: behavioral, physiological, and psychological.



## Thermal Comfort Standard – ASHRAE 55

Summer design conditions: 22.5 to 26.1 °C RH 60%

Winter design conditions: 20.0 to 23.9 °C RH 60%

- The comfort zone is considered to be sufficiently comfortable if at least **80%** of its occupants can be expected to not object to the ambient condition, meaning that the majority are between **-0.5 and 0.5** on the PMV scale.



ANSI/ASHRAE Standard 55-2020  
(Supersedes ANSI/ASHRAE Standard 55-2017)  
Includes ANSI/ASHRAE addenda listed in Appendix N

## Thermal Environmental Conditions for Human Occupancy

### E1. THERMAL ENVIRONMENT POINT-IN-TIME SURVEY

1. Record the approximate outside-air temperature \_\_\_\_\_ and seasonal conditions:

Winter  Spring  Summer  Fall

2. What is your general thermal sensation? (Check the one that is most appropriate)

*(Note to survey designer: This scale must be used as-is to keep the survey consistent with ASHRAE Standard 55.)*

- Hot  
 Warm  
 Slightly Warm  
 Neutral  
 Slightly Cool  
 Cool  
 Cold

5. Are you near an exterior wall (within 15 ft)?

Yes  
 No

6. Are you near a window (within 15 ft)?

Yes  
 No

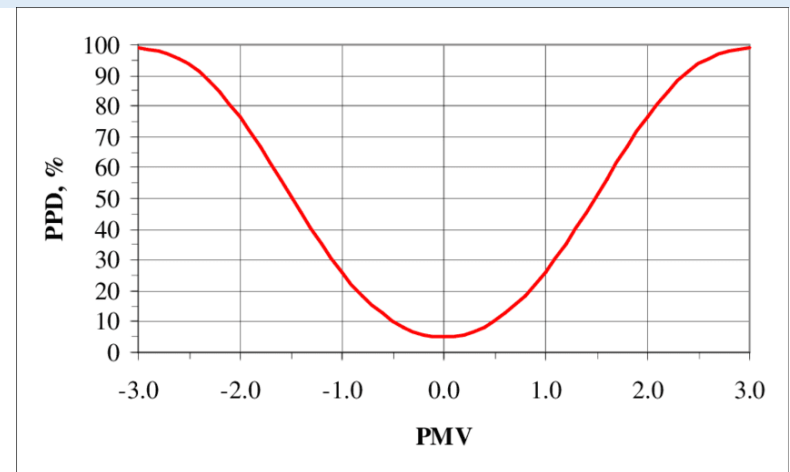
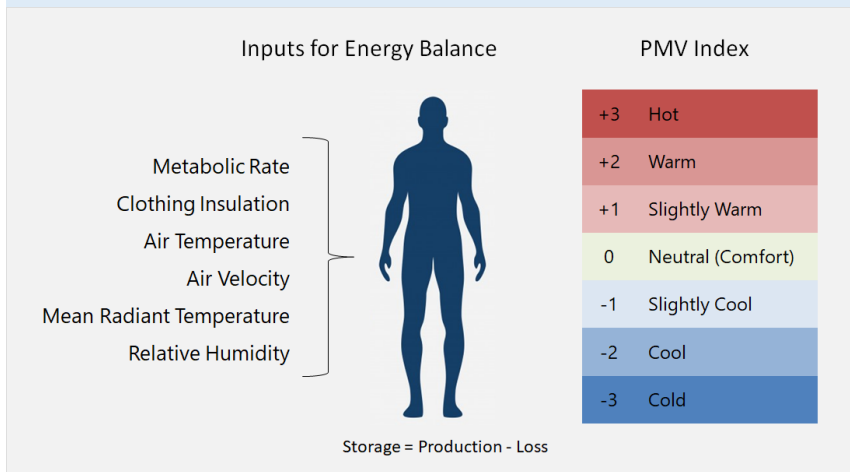
7. Using the list below, please check each item of clothing that you are wearing right now. (Check all that apply):

*(Note to survey designer: This list can be modified at your discretion.)*

- |   |  |                                 |
|---|--|---------------------------------|
| <input type="checkbox"/> Short-Sleeve Shirt | <input type="checkbox"/> Dress               | <input type="checkbox"/> Nylons |
| <input type="checkbox"/> Long-Sleeve Shirt  | <input type="checkbox"/> Shorts              | <input type="checkbox"/> Socks  |
| <input type="checkbox"/> T-shirt            | <input type="checkbox"/> Athletic Sweatpants | <input type="checkbox"/> Boots  |

## Thermal Comfort Standard – ASHRAE 55

- **Predicted mean vote (PMV)** is an index that predicts the mean value of the thermal sensation votes (self-reported perceptions) of a large group of persons on a sensation scale expressed from –3 to +3 corresponding to the categories
- **Predicted percentage of dissatisfied (PPD)** is an index that establishes a quantitative prediction of the percentage of thermally dissatisfied people





## Effects of Materials on Thermal comfort

## Thermal Comfort Improvement through Materials

### Materials without Insulation

Wall materials	U Value (W/sqmK)
150 mm RCC (No plaster)	3.77
200 mm Solid Concrete Block with plaster on both sides	2.8
230 mm Brick with plaster on both sides	1.72-2.24
200 mm Autoclaved Aerated Concrete (AAC) with plaster on both side	0.77
300 mm Autoclaved Aerated Concrete (AAC) with plaster on both side	0.54

# Thermal Comfort Improvement through Materials



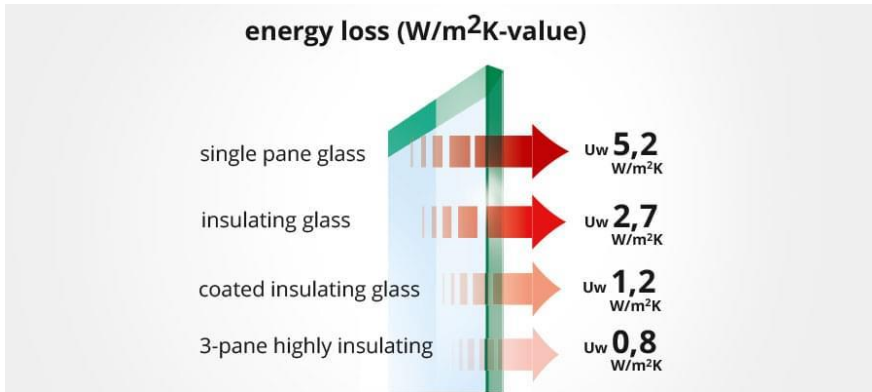
EPS Insulation



XPS Insulation

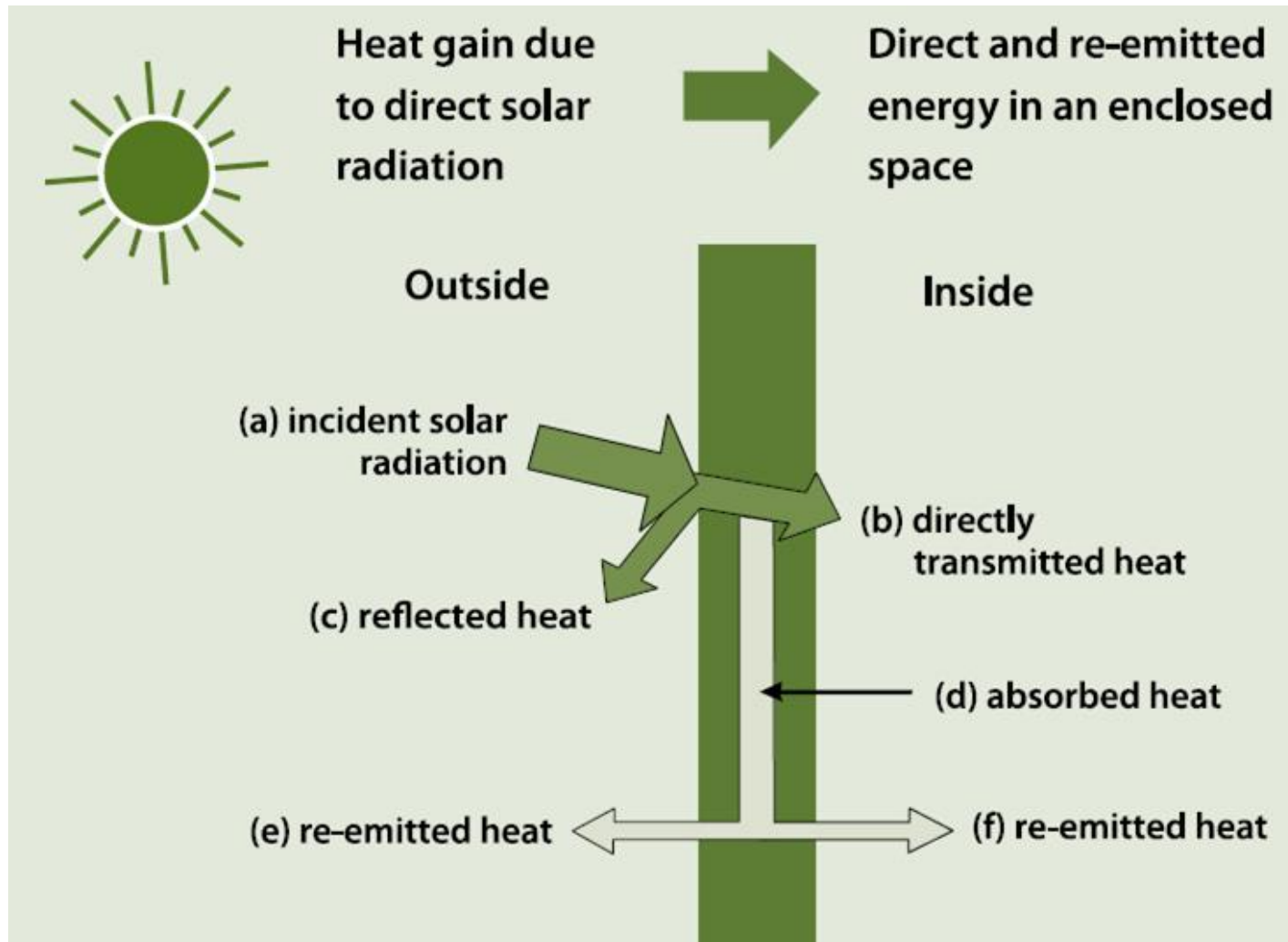


Glass Mineral Wool



Glazing Options

## Thermal Comfort Improvement through Materials



## Thermal Comfort Improvement through Materials

### Glazing Selection

#### U-value / U-factor

- Conductive Heat Transfer
- Thermal conductivity (W/sqmK)
- Glass & Frame
- Lower the better??

#### SHGC – Solar Heat Gain Coefficient

- Radiation Transmission
- Amount of Heat passes through the glass
- Lower the better??

#### VLT – Visual Light Transmission

- Light passing through the glass
- Ratio
- Useful light vs Glare
- Higher the better??

#### Selectivity

- VLT / Solar Factor
- Ratio
- Higher the better??





## Case Study

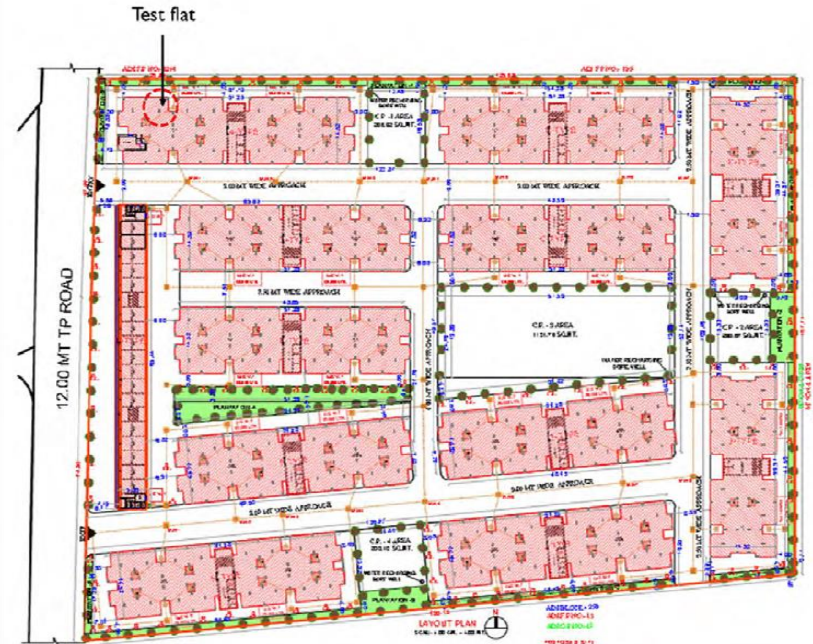
## Case Study : Smart Ghar, Rajkot

### A CASE STUDY ON DESIGN OF THERMALLY COMFORTABLE AFFORDABLE HOUSING IN COMPOSITE CLIMATE: SIMULATION RESULTS & MONITORED PERFORMANCE

by

Saswati Chetia, Sameer Maithel, Pierre Jaboyedoff, Ashok Lall, Prashant Bhanware, Akshat Gupta

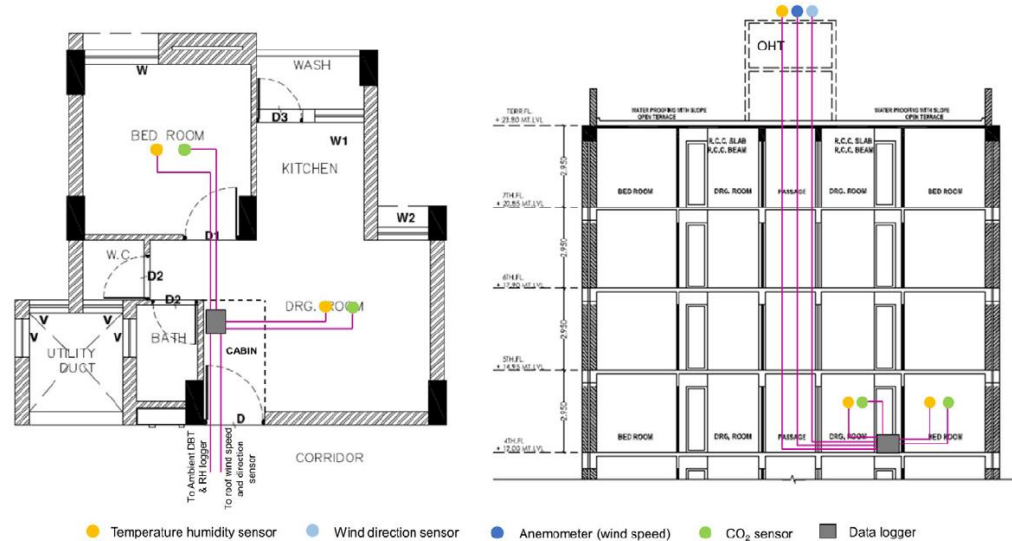
- Project Type - *PMAY Housing*
- Location - *Rajkot*
- Dwelling Units - *1176*
- DU Area - *33.6 m<sup>2</sup>*
- Ext Wall – *200mm AAC (E&N) & Cavity Wall (200mm AAC + 40mm air gap + 200mm AAC) (W&S Side)*
- Casement windows – *for ventilation improvement*
- Window shading – *Overhang & Side fins*
- *Glazed window*



## Case Study : Smart Ghar, Rajkot

### Validation by Software

- Simulated period - **May 12, 2019 to May 22, 2019**
- Software used - **DesignBuilder 4.7 (EnergyPlus 8.3 simulation engine)**

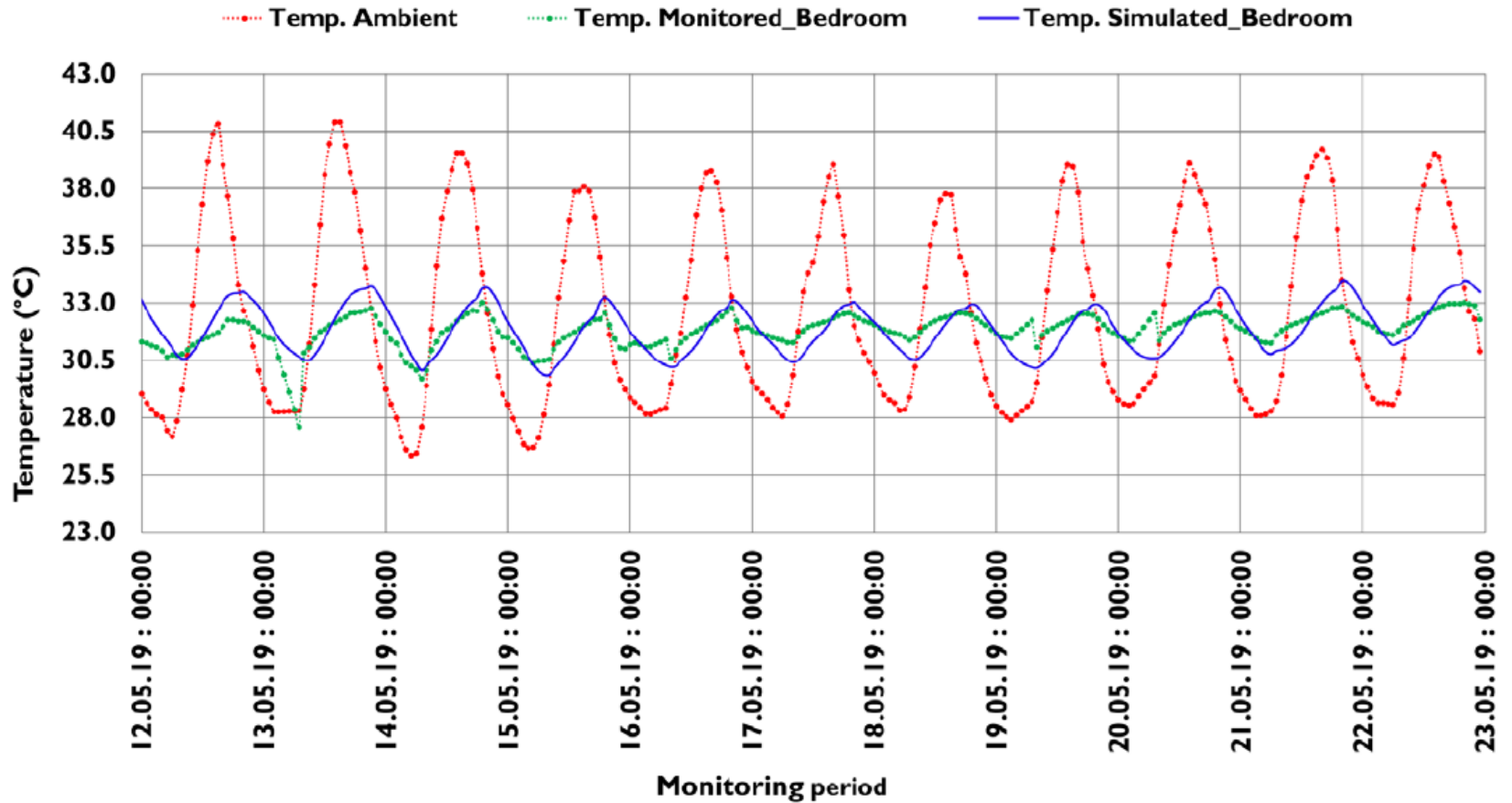


### Results

- Indoor temperature for the bedroom goes up to a **maximum average of 32.7°C during the day** and minimum average of 30.6°C early morning. The maximum average **ambient temperature was 39.3°C**, while the average minimum ambient temperature was 27.8 °C.
- Thus compared to the diurnal variation of 11.5 °C in the ambient temperatures, the diurnal variation in indoor temperature was only 2.1 °C.

## Case Study : Smart Ghar, Rajkot

### Observations



## Case Study : Smart Ghar, Rajkot

### Results

- For the present study, the **Indian Model for Adaptive Comfort (IMAC)** is chosen as the thermal comfort model. It is observed that all hours of the monitored period falls **within the 80% acceptability limits** whereas 87% of the monitored period falls within the 90% acceptability limits.

### Conclusion

- *The results of the monitoring show a **quantifiable impact of building envelope** (both construction material and openings for ventilation) on **internal temperatures**.*
- *It shows that with building envelope interventions it is possible to get **maximum average temperature of 32°C in summer** when the average maximum ambient temperature is 39°C, thus, increasing comfortable hours and reducing the need for air-conditioning.*



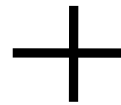


## Session 4: Eco Niwas Samhita

## Eco Niwas Samhita (ENS)

**BEE**  
(BUREAU OF ENERGY EFFICIENCY)

Government of India



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

Government of Germany



Eco Niwas Samhita Part 1



Launch of Eco Niwas Samhita in December 2018

## Eco Niwas Samhita (ENS)

EcoNiwas Samhita 2018  
Part 1: Building Envelope



EcoNiwas Samhita 2021  
Code Compliance and Part 2



ECO Niwas Samhita – The EE code for residential buildings is now comprised of 2 parts

## Scope of ENS

### New building

- Residential Buildings with (Plot area  $\geq$  500Sqm) built up area of 800 sqm/ Connected load  $\geq$  35kW

### Mixed Land Use

- Residential part of “Mixed Land-use building projects” with (Plot area  $\geq$  500Sqm) built up area of 800 sqm/ Connected load  $\geq$  35kW

### Additions

- All additions made to existing residential buildings with (Plot area  $\geq$  500Sqm) built up area of 800 sqm/ Connected load  $\geq$  35kW

### Alterations

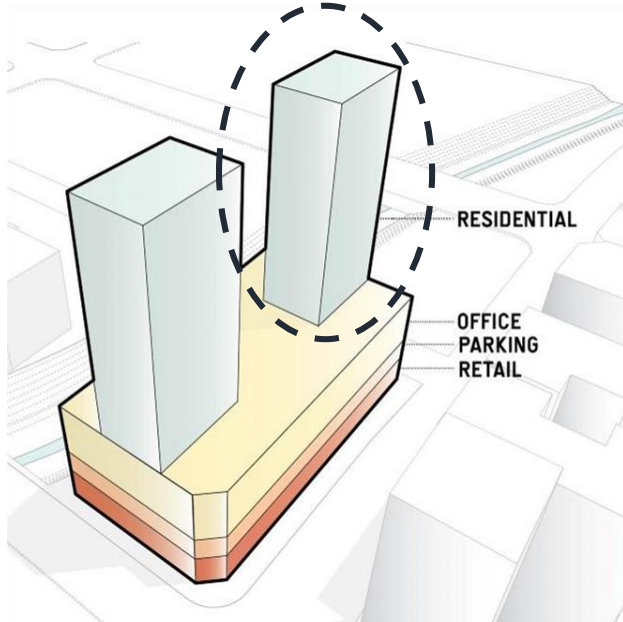
- Alterations made to existing residential buildings with (Plot area  $\geq$  500Sqm) built up area of 800 sqm/ Connected load  $\geq$  35kW



## Eco Niwas Samhita (ENS)

The code is applicable to

(a) Residential Buildings with **plot area  $\geq 500\text{m}^2$**



(b) Residential part of **“Mixed Land-use building projects”** built on plot area of  $\geq 500\text{m}^2$ .

Excluded from the code



Dormitories



Hotels



Lodging Rooms



## Scope of ENS (Setting Minimum Requirement)

### Building Envelope

- Opaque Construction Materials
- Fenestration U-factors
- Solar Heat Gain Coefficients (SHGC)
- Visible Light Transmittance (VLT)
- Overhangs + Fins
- Operable Window Area



### Building Services

- Common Area Lighting
- Pump Efficiencies
- Elevator Technologies
- Transformer Losses
- Power Factor Correction
- Basement Ventilation
- Charging Infrastructure
- Electrical Metering & Monitoring



### Indoor Electrical End Use

- Indoor Lighting
- Automatic Lighting Shutoff
- Occupancy Sensors
- Ceiling Fan Star Labelling
- Service Hot Water
- Air Conditioner system, sizes, efficiencies and controls



### Renewable Energy Systems

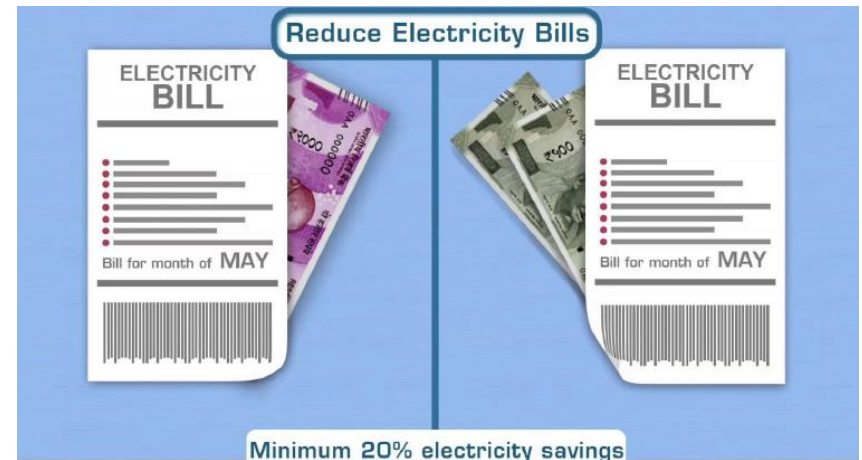
- System Peak Generation Capacity
- Solar Water Heating System
- Technical Specifications
- Renewable Energy Zone Area

## Eco Niwas Samhita (ENS) Benefits

### Improve Thermal Comforts



### Reduce Electricity Bills

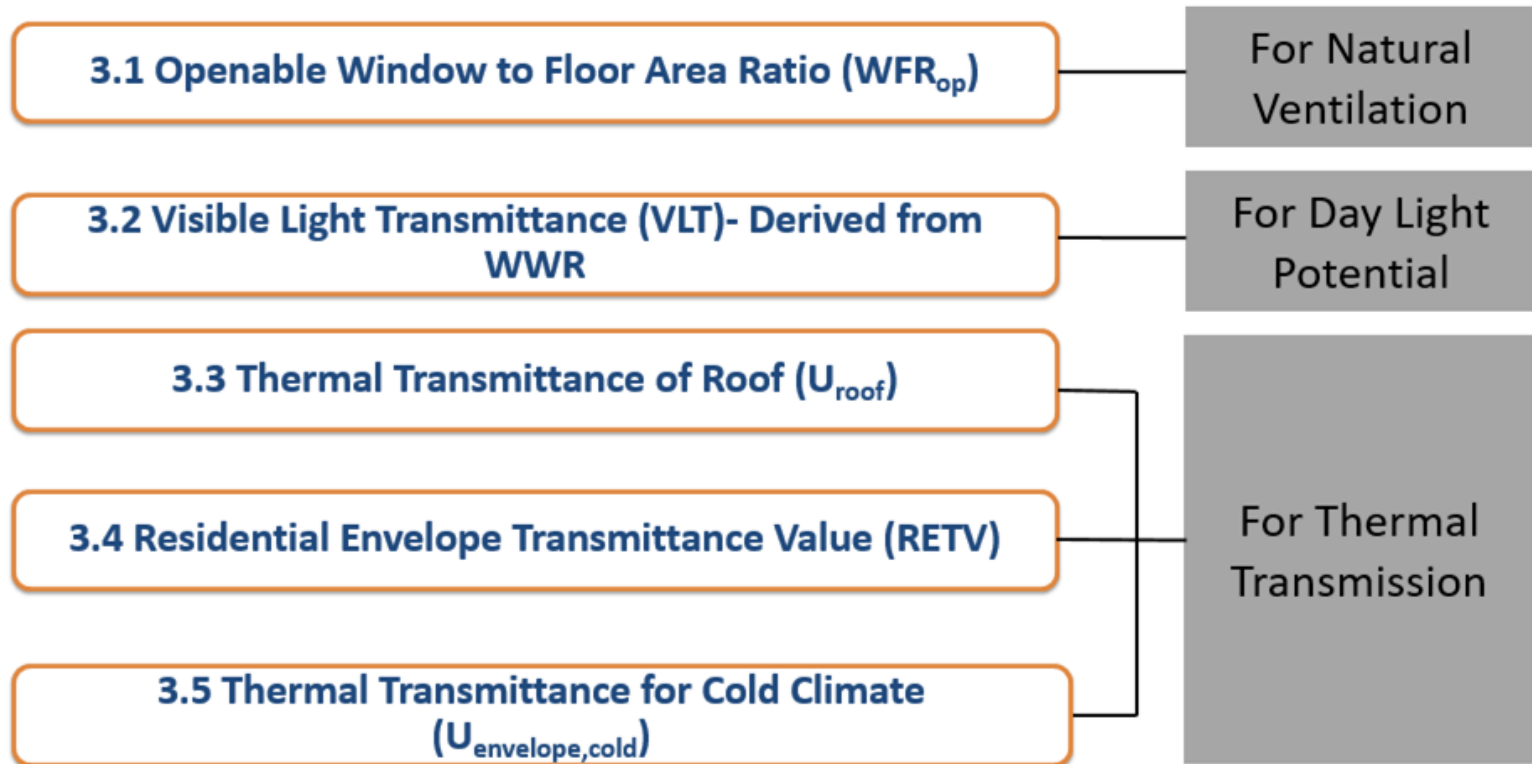


### Estimated Impact Of Implementing Eco Niwas Samhita

- Minimum **20% energy saving** as compared to a typical Building
  - **125 billion KWH** of electricity Saving
  - **100 million tonnes of CO<sub>2</sub>** equivalent abatement

## ENS – Part 1 – Building Envelope

### Performance Standards for Building Envelope



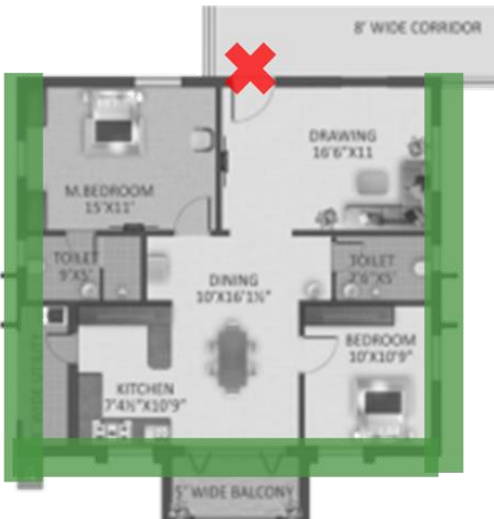
## ENS – Part 1 – Building Envelope

### 3.1 Openable Window to Floor Area Ratio ( $WFR_{op}$ )

$$WFR_{op} = \frac{A_{openable}}{A_{carpet}}$$

Window to floor area ratio is the ratio of Openable area to the carpet area of the dwelling Units.

Openable Area



**Windows, Ventilators, opening directly to**

- External air,
- Open balcony,
- Corridor,
- Shaft

**Doors opening directly into**

- Open balcony

Carpet Area



- Total Internal Area of the habitable space
- Balconies - Excluded

## ENS – Part 1 – Building Envelope

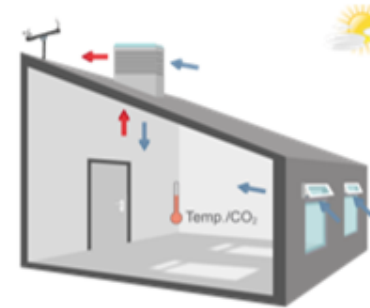
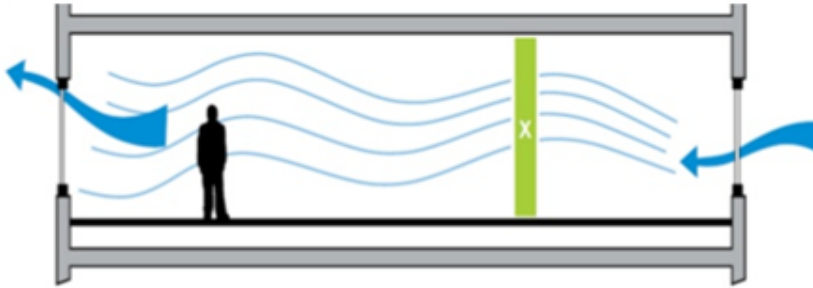
### 3.1 Openable Window to Floor Area Ratio ( $WFR_{op}$ )

Minimum  $WFR_{op}$  helps in

Natural Ventilation

Improvement in Thermal Comfort

Reduction in Cooling Energy Loads



Minimum requirement of window-to-floor area Ratio

Climate Zone	Minimum $WFR_{op}$
Composite	12.50
Hot-Dry	10.00
Warm-Humid	16.66
Temperate	12.50
Cold	8.33

Openable Area Percentages  
(In case the exact Openable is not known)

Type of Window/Door/ Ventilator	Percentage Openable Area
Casement	90%
Sliding (2 Panes)	50%
Sliding (3 Panes)	67%



## ENS – Part 1 – Building Envelope

### 3.2 Window to Wall Area Ratio (WWR)

$$WWR = \frac{A_{non-opaque}}{A_{envelope}}$$

\* Note for  $WWR \leq 0.15$ , VLT – 40%

**WWR** – Window to wall area ratio

**Area (non-opaque)** –

Total glass area in the opening .

Excluded - Opaque part of the total opening size.

**Area(Envelope)** –

Total envelope area of all facades.

Included – opaque and non-opaque

### Relation between WWR and Visual Light Transmittance

Window to Wall Ratio (WWR)	Minimum VLT
0-0.30	0.27
0.31-0.40	0.20
0.41-0.50	0.16
0.51-0.60	0.13
0.61-0.70	0.11

## ENS – Part 1 – Building Envelope

### 3.3 Thermal Transmittance ( $U_{\text{roof}}$ )



**Thermal Transmittance of roof  $U_{\text{roof}}$**  . Is the rate of transfer of heat through the roof structure (which can be a single material or an assembly), divided by the difference in temperature across that structure.

Limiting  $U_{\text{roof}}$  by helps in reducing heat gains or losses from the roof. Ex : Insulation, Cool Roofs, Green Roofs

**Thermal transmittance of roof shall comply with  $U_{\text{roof}}$  value – 1.2 W/m<sup>2</sup>.k**

## ENS – Part 1 – Building Envelope

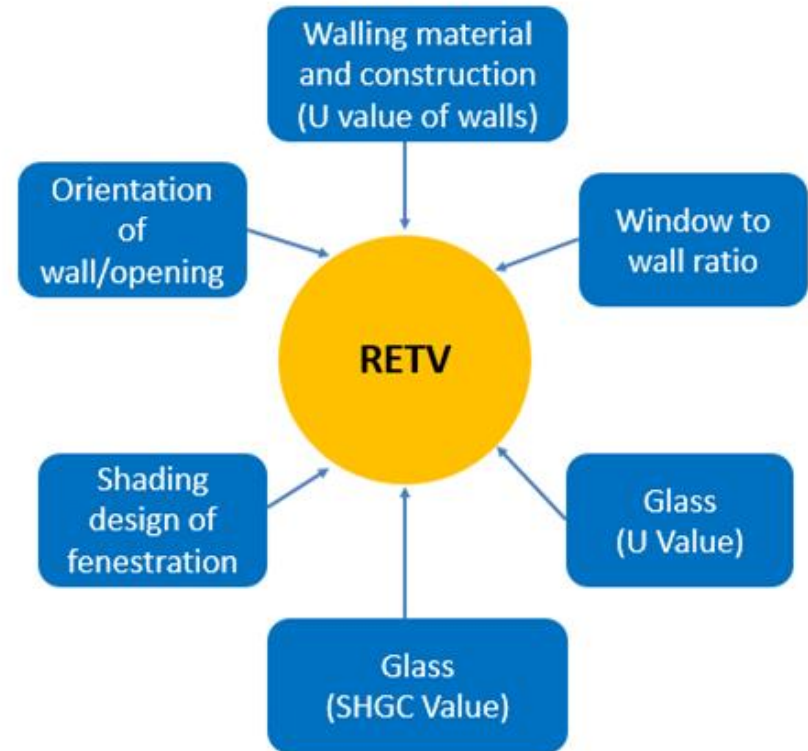
### 3.4 Residential Envelope Transmittance (RETV)



Solar Radiation through non-opaque surfaces

Conduction through opaque surfaces

Conduction through non-opaque surfaces



## ENS – Part 1 – Building Envelope

### 3.4 Residential Envelope Transmittance (RETV)

**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)		

**RETV** for the building envelope (except roof) for four climate zones, namely, Composite Climate, Hot-Dry Climate, Warm-Humid Climate and Temperate Climate shall comply with the maximum RETV of **15 W/m<sup>2</sup>**



## ENS – Part 1 – Building Envelope

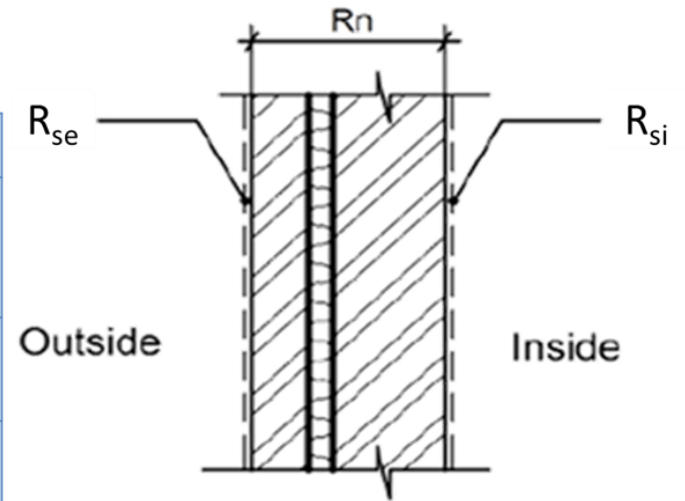
### 3.4 Thermal Transmittance Value (U-Value) Non Opaque

$$U = 1 / R_t$$

$$U = 1 / (R_{so} + \sum R_n + R_{si})$$

U-value is the reciprocal of Thermal Resistance (R)

	Wall	Roof	
	All climatic Zones	Composite , Hot-Dry, Warm-humid, and Temperate climate	Cold climate
R <sub>si</sub> (m <sup>2</sup> .K/W)	0.13	0.17	0.10
R <sub>se</sub> (m <sup>2</sup> .K/W)	0.04	0.04	0.04

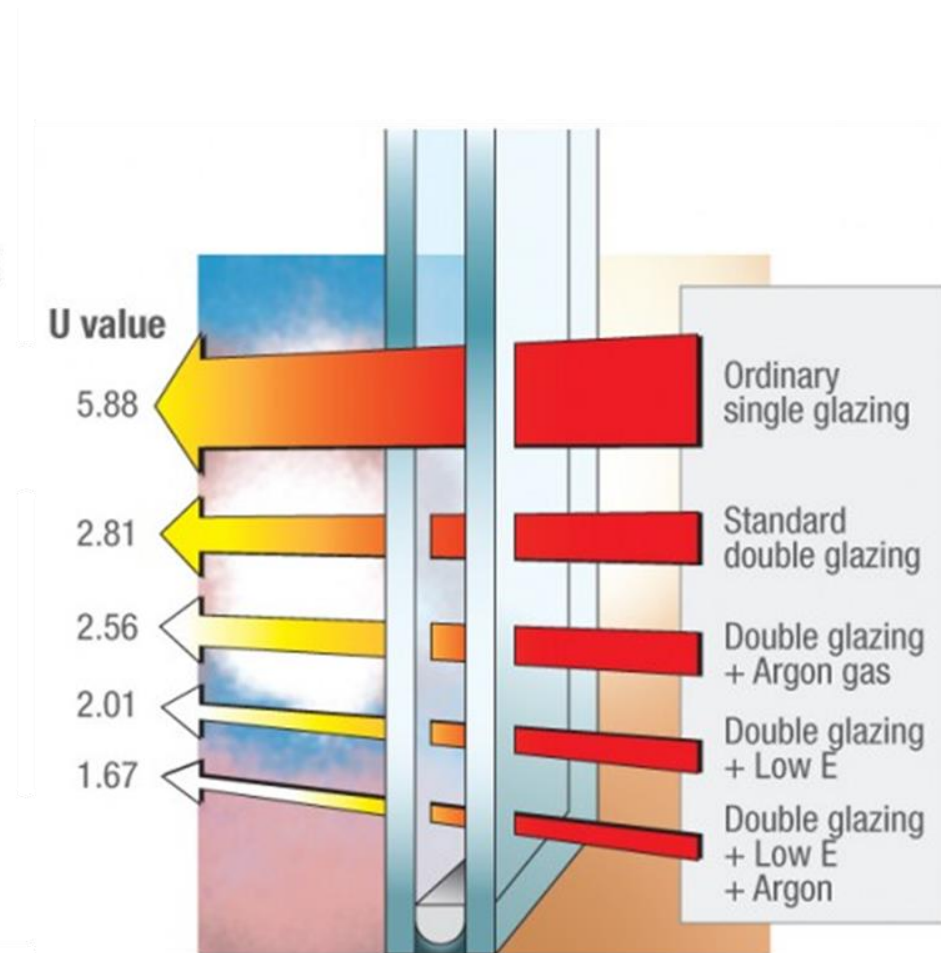
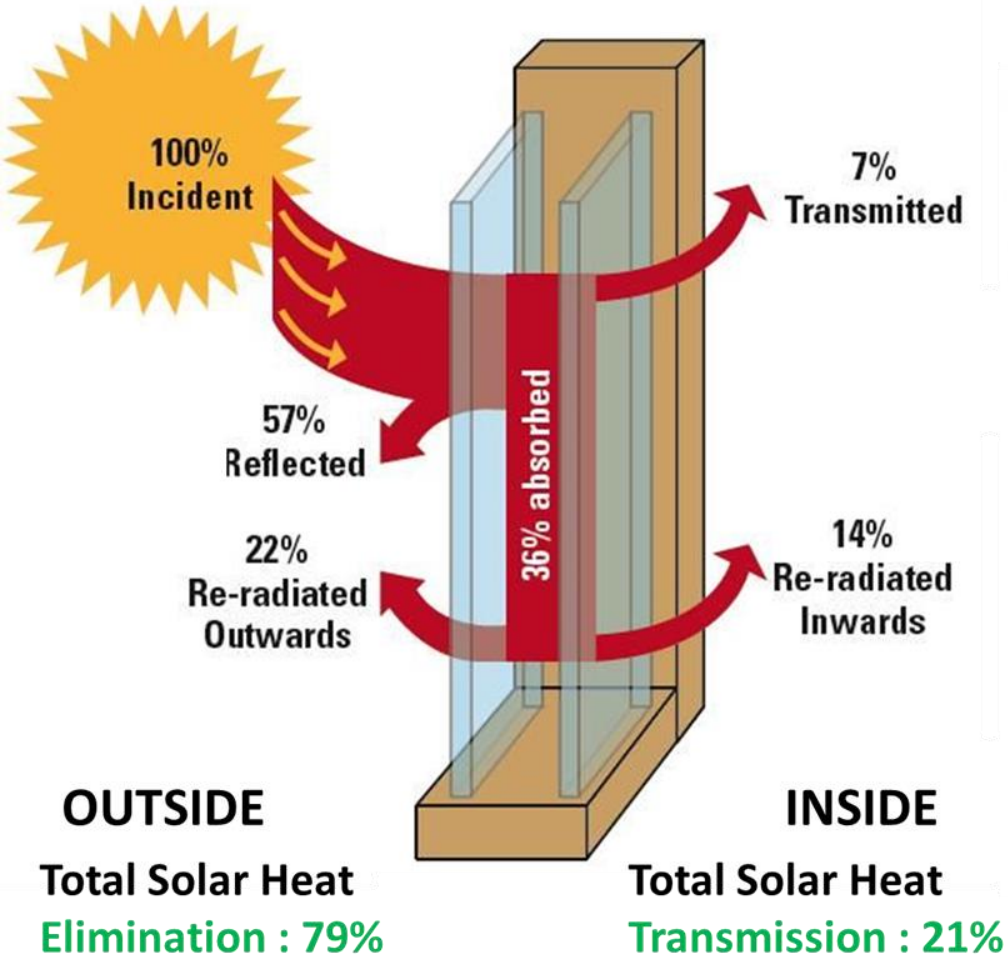


Source: Eco Niwas Samhita -2018, Table 6, Annexure - 5



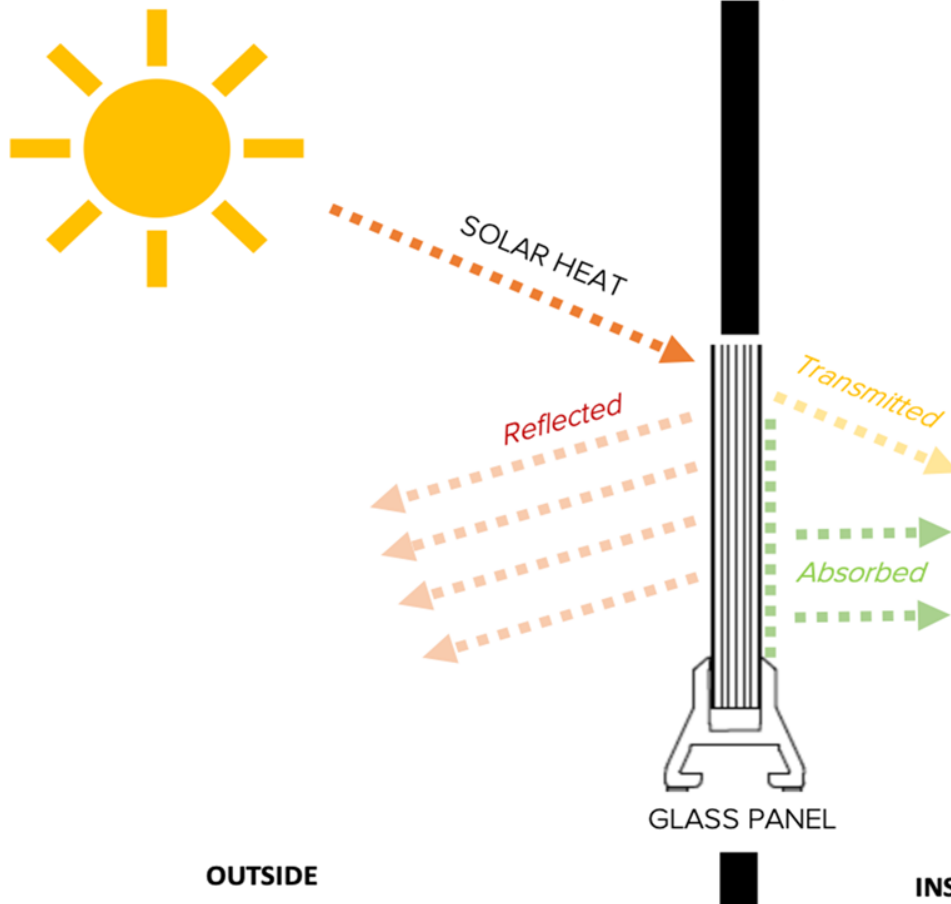
## ENS – Part 1 – Building Envelope

### 3.4 Thermal Transmittance Value (U-Value) Non Opaque



## ENS – Part 1 – Building Envelope

### 3.4 Solar Heat Gain Coefficient (SHGC) Non Opaque



Solar heat gain coefficient is the measure of solar heat –

- Absorbed
- Transmitted

Lower SHGC  $\propto$  lesser Heat Transfer

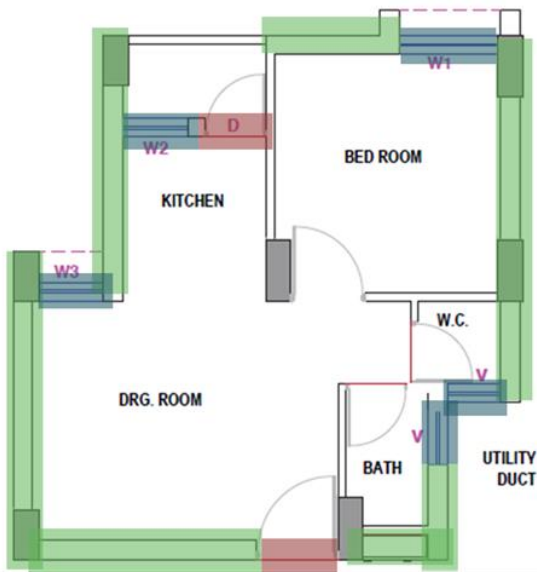
Solar Radiation is subsequently released inward through conduction, convection and radiation.

## ENS – Part 1 – Building Envelope

### 3.5 Thermal Transmittance – Wall (Except roof) for Cold Climate (U envelope, cold)

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

➤ The thermal transmittance of the building envelope (except roof) for cold climate shall comply with the maximum of **1.8 w/M<sup>2</sup>K**



	Area (sq mt)	U- value (w/m <sup>2</sup> k)
Wall (opaque)	2793.38	0.78
Door (opaque)	210	5.23
Window (non-opaque)	475.88	5.80

- AAC Wall
- Wooden Door
- Glass Window

$$U_{envelope,cold} = \frac{(2793.38 \times 0.78) + (210.00 \times 5.23) + (474.88 \times 5.80)}{2793.38 + 210.00 + 474.88} = 1.73 \text{ W / m}^2 \cdot \text{K}$$

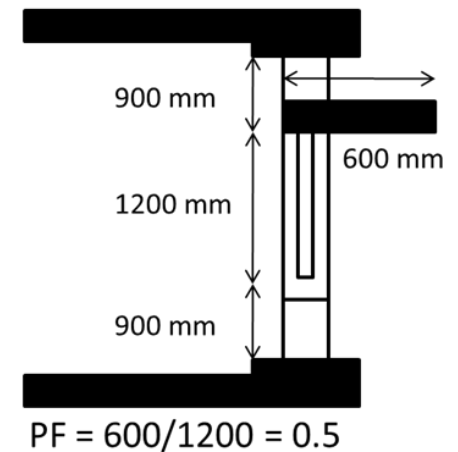
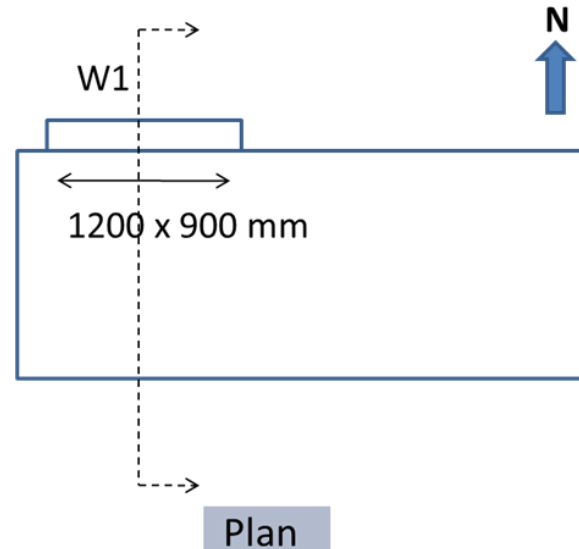
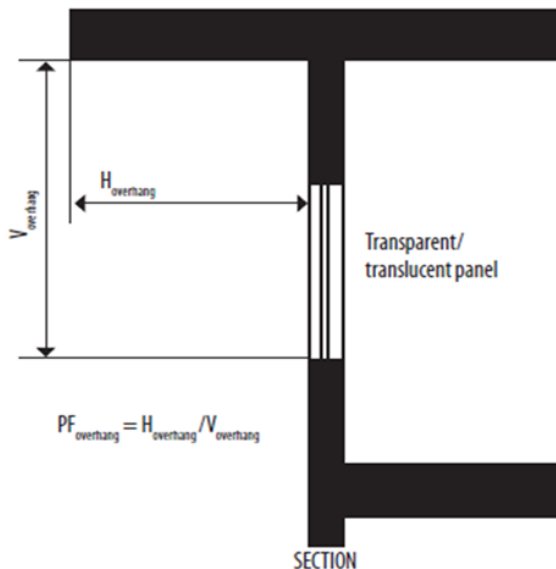
## ENS – Part 1 – Building Envelope

### 3.4 Projection Factor (PF)

Projection Factor (PF) is the ratio of the horizontal depth of the external shading projection ( $H_{\text{overhang}}$ ) to the bottom of the farthest point of the external shading projection ( $V_{\text{overhang}}$ ), in consistent units.

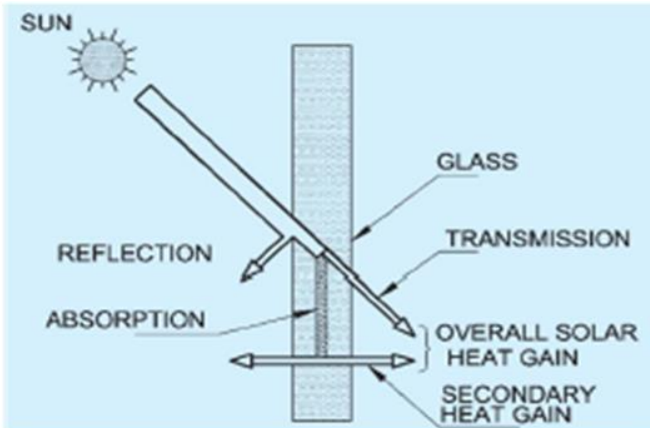
$$PF_{\text{overhang}} = \frac{H_{\text{overhang}}}{V_{\text{overhang}}}$$

**Solved exercise:** Considering a room size of 3m \* 5m, with a window W1 shown in plan and section. The projection factor for the same is calculated, to arrive at the ESF (Effective Shading Factor). Glass parameters; Single Glazing Unit (SGU), U value = 5.6 W/m<sup>2</sup> K, SHGC = 0.6, VLT = 0.7



## ENS – Part 1 – Building Envelope

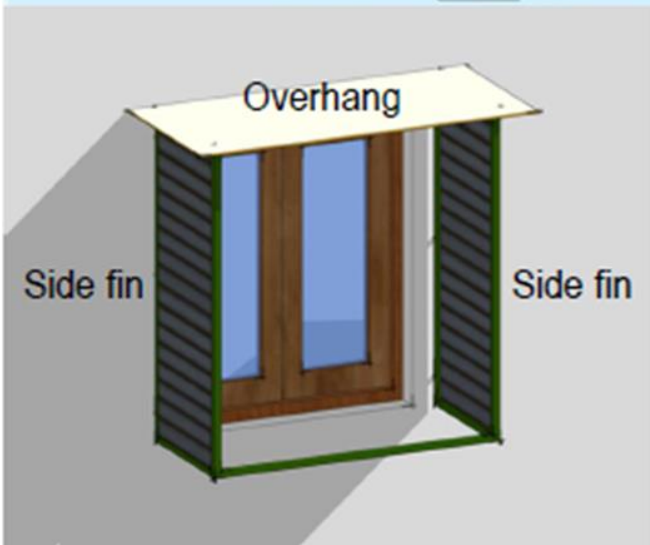
### 3.4 Equivalent SHGC



$$\text{SHGC}_{\text{unshaded}} = \frac{\text{Transmission} + \text{Secondary heat gain}}{\text{Incident Solar radiation}}$$

External Shading (overhang, side fins) cut the solar radiation

External Shading Factor ( $\text{ESF}_{\text{total}} \leq 1$ ) accounts the impact of shading.



$$\text{SHGC}_{\text{eq}} = \text{SHGC}_{\text{unshaded}} \times \text{ESF}_{\text{total}}$$

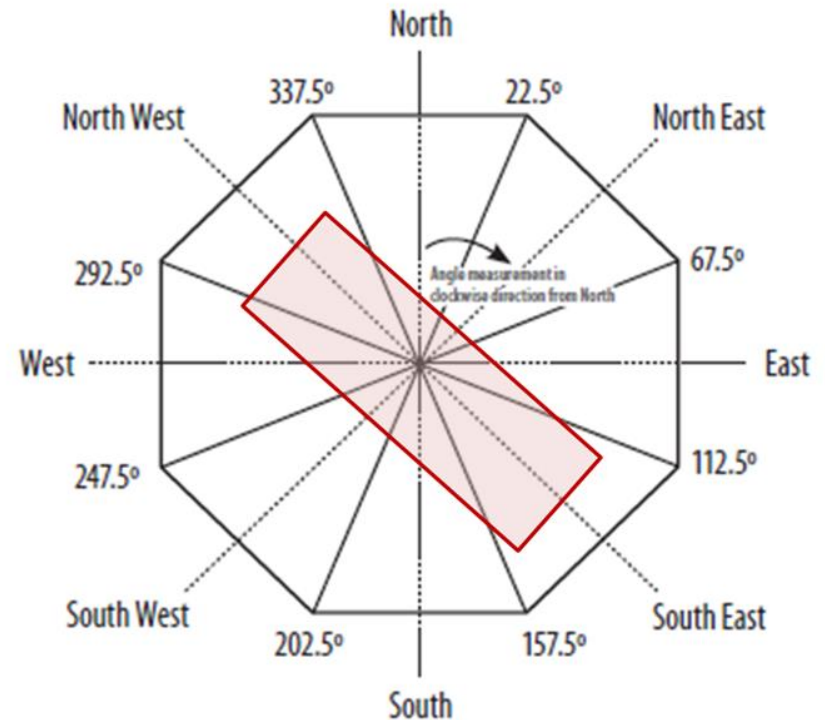


## ENS – Part 1 – Building Envelope

### 3.4 Orientation Factor



The orientation factor ( $\omega$ ) is a measure of the amount of direct and diffused solar radiation that is received on the vertical surface in a specific orientation

Orientation factor ( $\omega$ )	
Orientation	Latitudes <23.5°N
North (337.6°–22.5°)	0.659
North-east (22.6°–67.5°)	0.906
East (67.6°–112.5°)	1.155
South-east (112.6°–157.5°)	1.125
South (157.6°–202.5°)	0.966
South-west (202.6°–247.5°)	1.124
West (247.6°–292.5°)	1.156
North-west (292.6°–337.5°)	0.908



# ENS – Part 1 – Building Envelope

## 3.4 RETV – Case 1

Case 1		External wall	Roof Construction	Glazing	Window to wall Ratio
		230mm thick Solid Burnt Clay Brick	150 mm thick RCC slab + 50mm thick EPS	50 mm Steel Frame; Single glazed Unit  U Value = 5.7 W/m <sup>2</sup> k, SHGC = 0.56, VLT=0.51	22.55%
<b>RETV – 14.92 W/m<sup>2</sup>.K</b>					

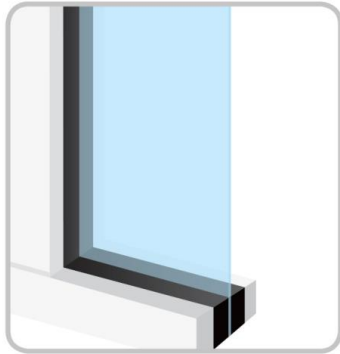
## ENS – Part 1 – Building Envelope

### 3.4 RETV – Case 2

#### Case 2



SINGLE GLAZED WINDOW



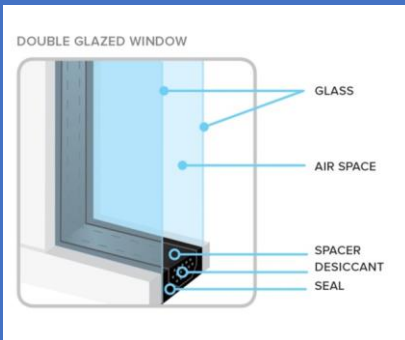
External wall	Roof Construction	Glazing	Window to wall Ratio
200mm thick AAC Block wall	150 mm thick RCC slab + 50mm thick EPS	50 mm Steel Frame; Single glazed Unit  U Value = 5.7 W/m <sup>2</sup> k, SHGC = 0.56, VLT=0.51	22.55%

**RETV – 9.71 W/m<sup>2</sup>.K**

## ENS – Part 1 – Building Envelope

### 3.4 RETV – Case 3

#### Case 3



#### External wall

200mm thick AAC Block wall

#### Roof Construction

150 mm thick RCC slab + 50mm thick EPS

#### Glazing

Double glazed Unit - Asahi LC 54/37

U Value = 1.64 W/m<sup>2</sup>k,  
SHGC = 0.36,  
VLT=0.52

#### Window to wall Ratio

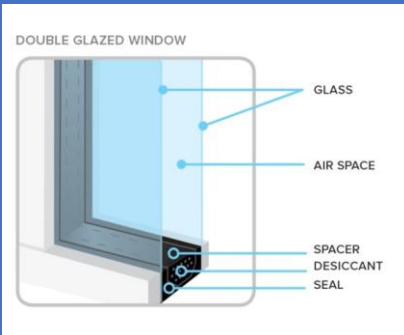
22.55%

**RETV – 6.62 W/m<sup>2</sup>.K**

## ENS – Part 1 – Building Envelope

### 3.4 RETV – Case 4

#### Case 4



External wall	Roof Construction	Glazing	Window to wall Ratio
200mm thick AAC wall, 50 mm EPS, high SRI paint	150 mm thick RCC slab + 50mm thick EPS	Double glazed Unit - Asahi LC 54/37  U Value = 1.64 W/m <sup>2</sup> k, SHGC = 0.36, VLT=0.52	22.55%

**RETV – 5.13 W/m<sup>2</sup>.K**



# ENS – Part 1 – Building Envelope

## Building Design Flexibility by ENS

### Material wall Assembly



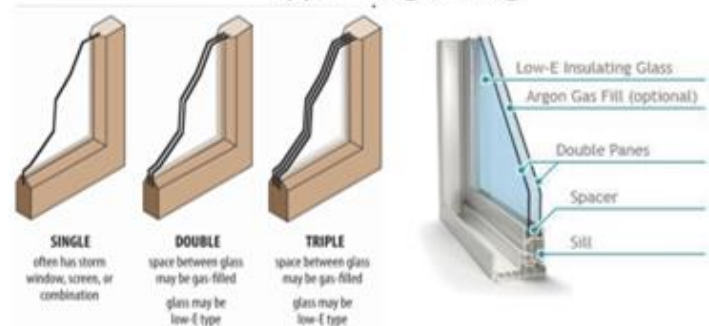
### Design of Window Panel



### Shading of external Windows



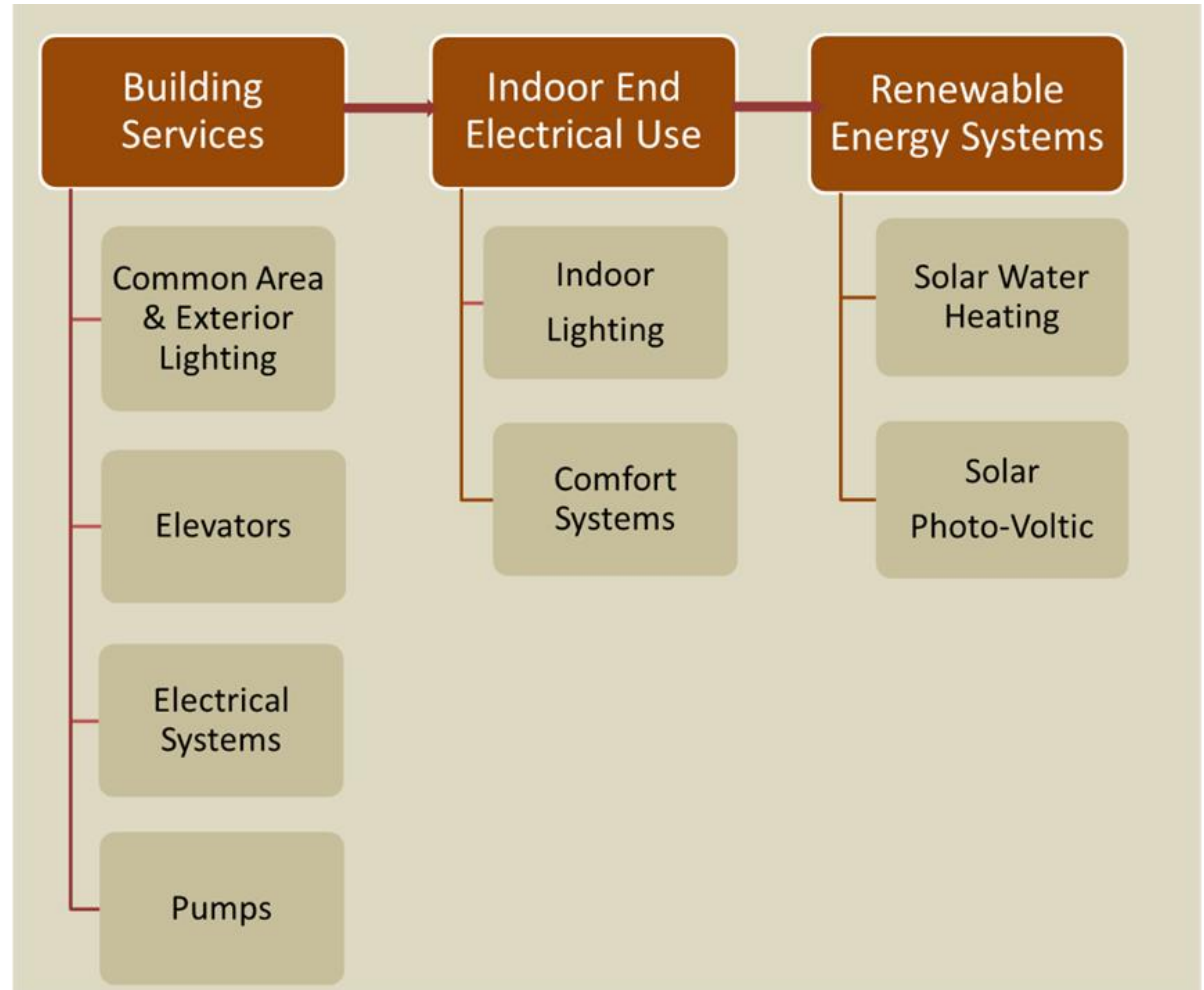
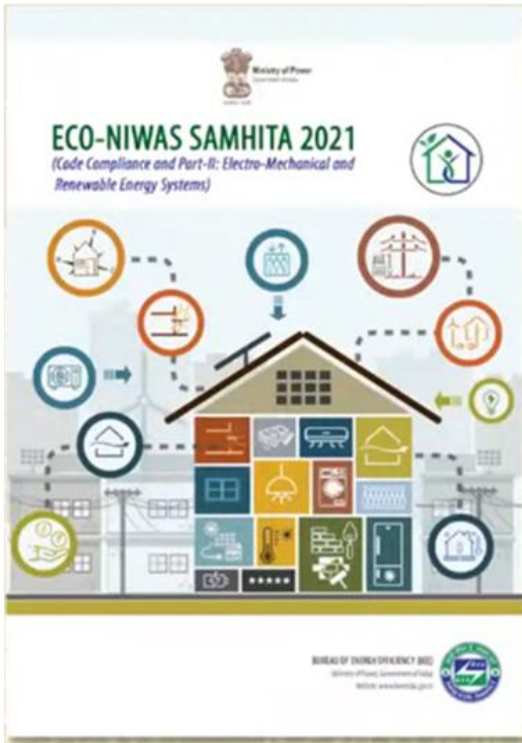
### Type of glazing



## Session 5: ENS Part 2

## ENS – Part 2 – Services

### CODE PROVISIONS



## ENS – Part 2 - Code Compliance

### Low Rise Buildings:

A building equal or below 4 stories, and/or a building **up to 15 meters in height** (without stilt) and up to 17.5 meters (including stilt).



### Affordable Housing Projects:

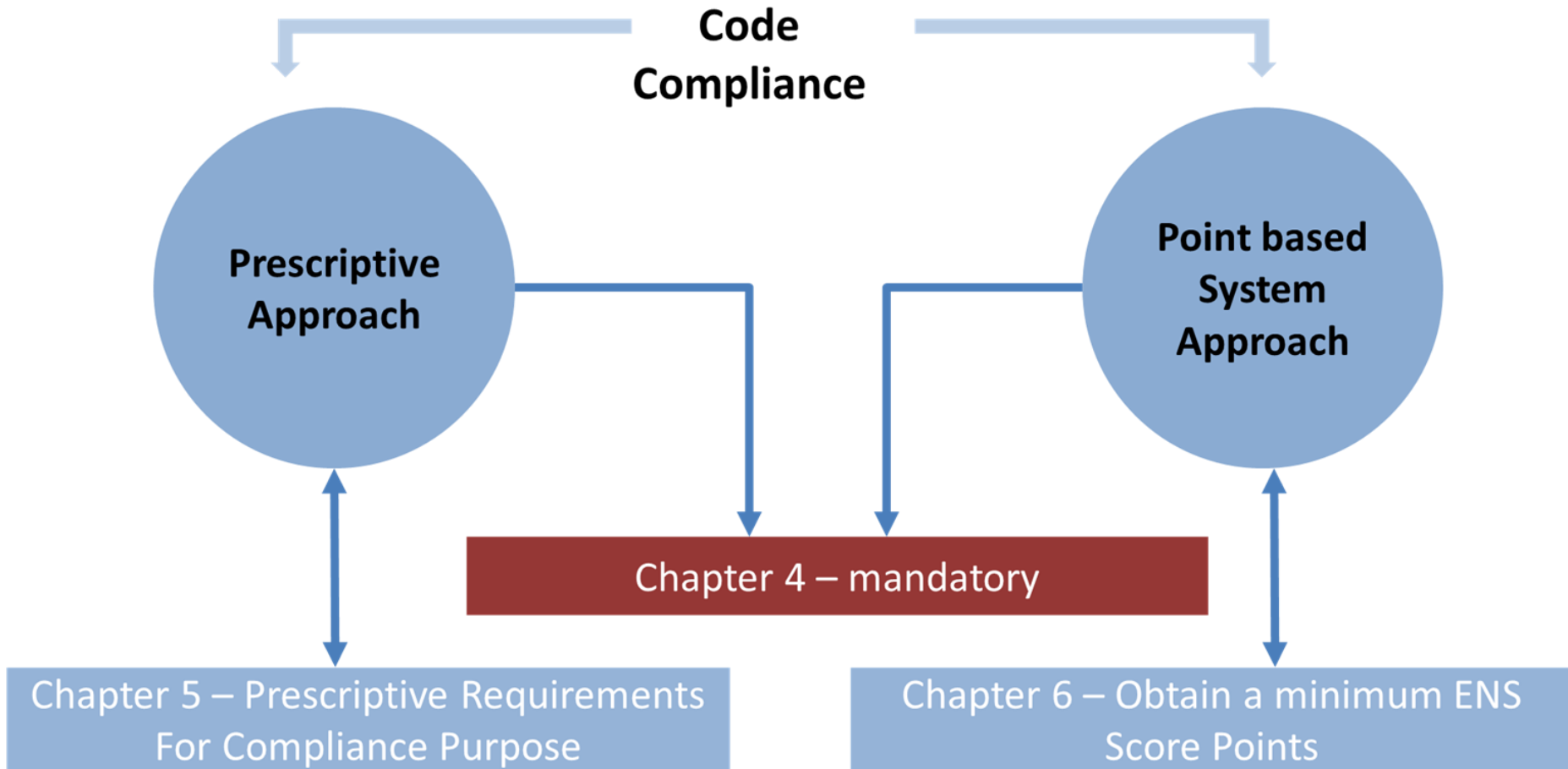
Affordable houses are Dwelling Units (DUs) with **Carpet Area less than 60 sqm**. It also includes **Economically Weaker Section (EWS) category** and **Lower Income Group (LIG) category (LIG-A: 28-40 sq. m. and LIG-B 41-60 Sq.m.)**.

### High Rise Buildings:

A building above 4 stories, and/or a building **exceeding 15 meters** or more in height (without stilt) and 17.5 meters (including stilt).



## ENS – Part 2 - Code Compliance





## ENS – Part 2 - Documentation

### Building Envelope

- Opaque Construction Materials
- Fenestration U-factors
- Solar Heat Gain Coefficients (SHGC)
- Visible Light Transmittance (VLT)
- Overhangs +Fins
- Operable Window Area



### Building Services

- Common Area Lighting
- Pump Efficiencies
- Elevator Technologies
- Transformer Losses
- Power Factor Correction
- Basement Ventilation
- Charging Infrastructure
- Electrical Metering & Monitoring



### Indoor Electrical End Use

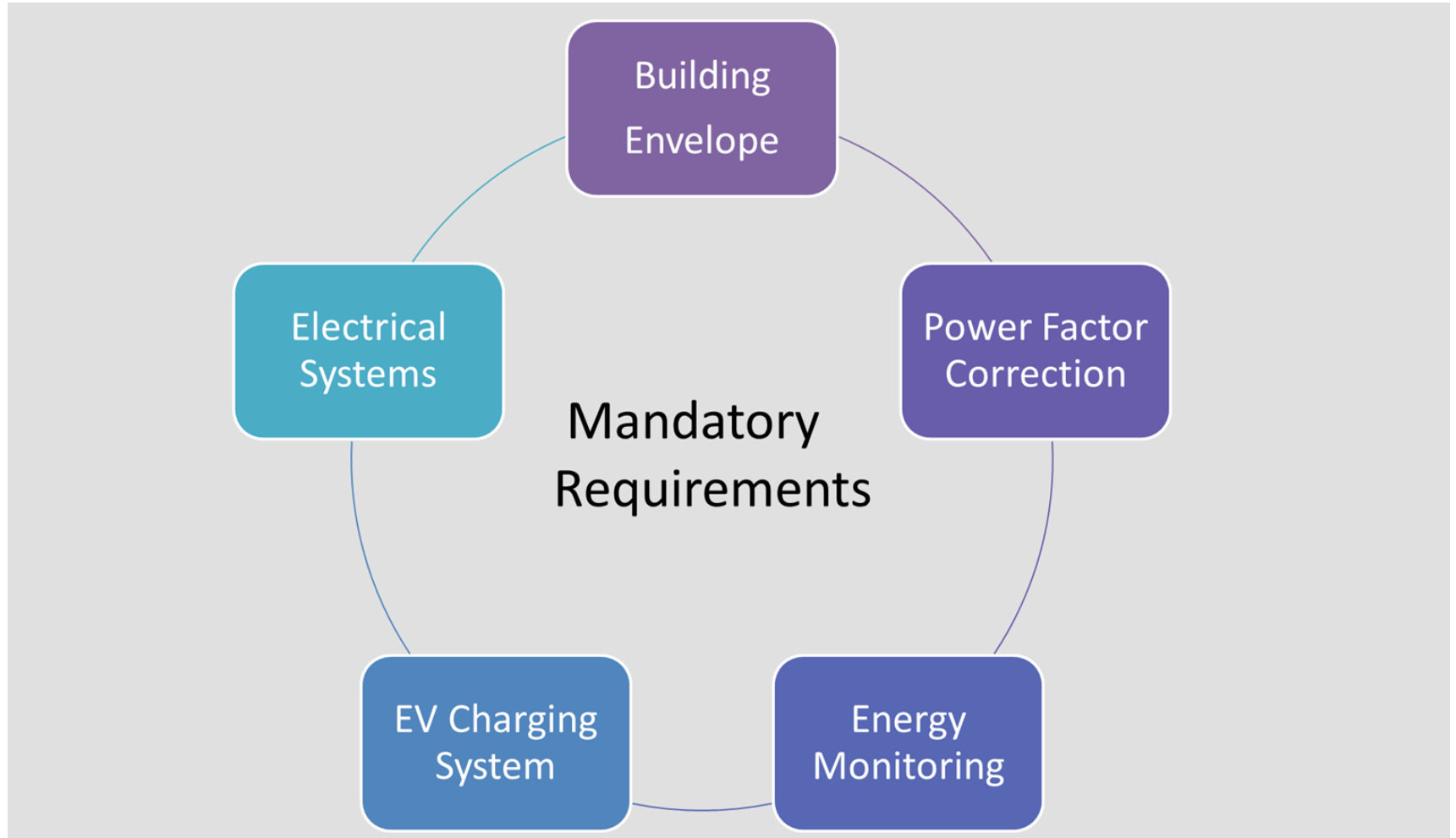
- Indoor Lighting
- Automatic Lighting Shutoff
- Occupancy Sensors
- Ceiling Fan Star Labelling
- Service Hot Water
- Air Conditioner system, sizes, efficiencies and controls



### Renewable Energy Systems

- System Peak Generation Capacity
- Solar Water Heating System
- Technical Specifications
- Renewable Energy Zone Area

## ENS – Part 2 - Mandatory Requirements



## ENS – Part 2 - Mandatory Requirements

Chapter 4 of ENS Part I

Building Envelope

All 3 phase shall maintain the power factor of 0.97 at the point of connection

Power Factor Correction

Total Electrical Energy

Energy Monitoring

Electrical Consumption of Applicable End Use Systems

Guidelines issued by Ministry of Power for EV Charging on Oct 1<sup>st</sup> 2019

EV Charging Systems

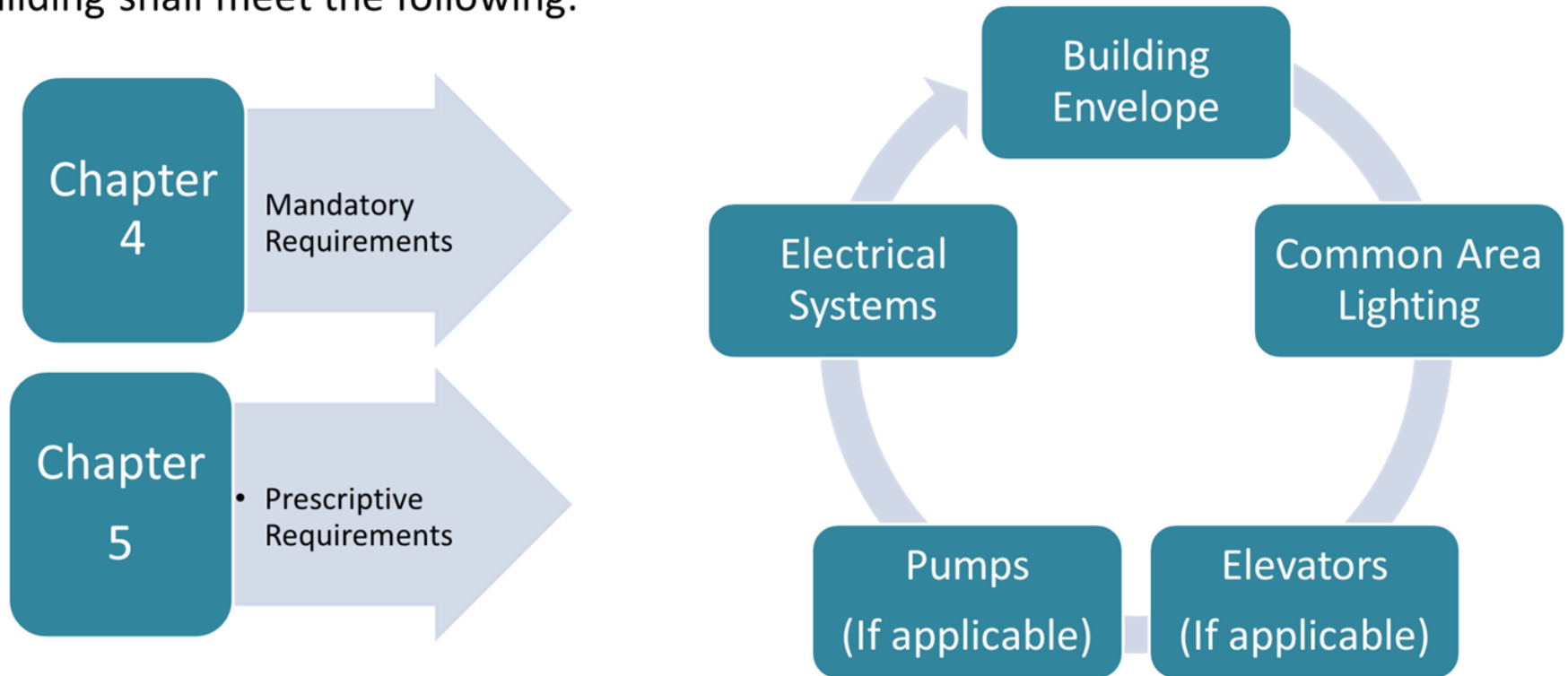
Electrical Consumption of Applicable End Use Systems

Electrical Systems

## ENS – Part 2 - Prescription Requirements

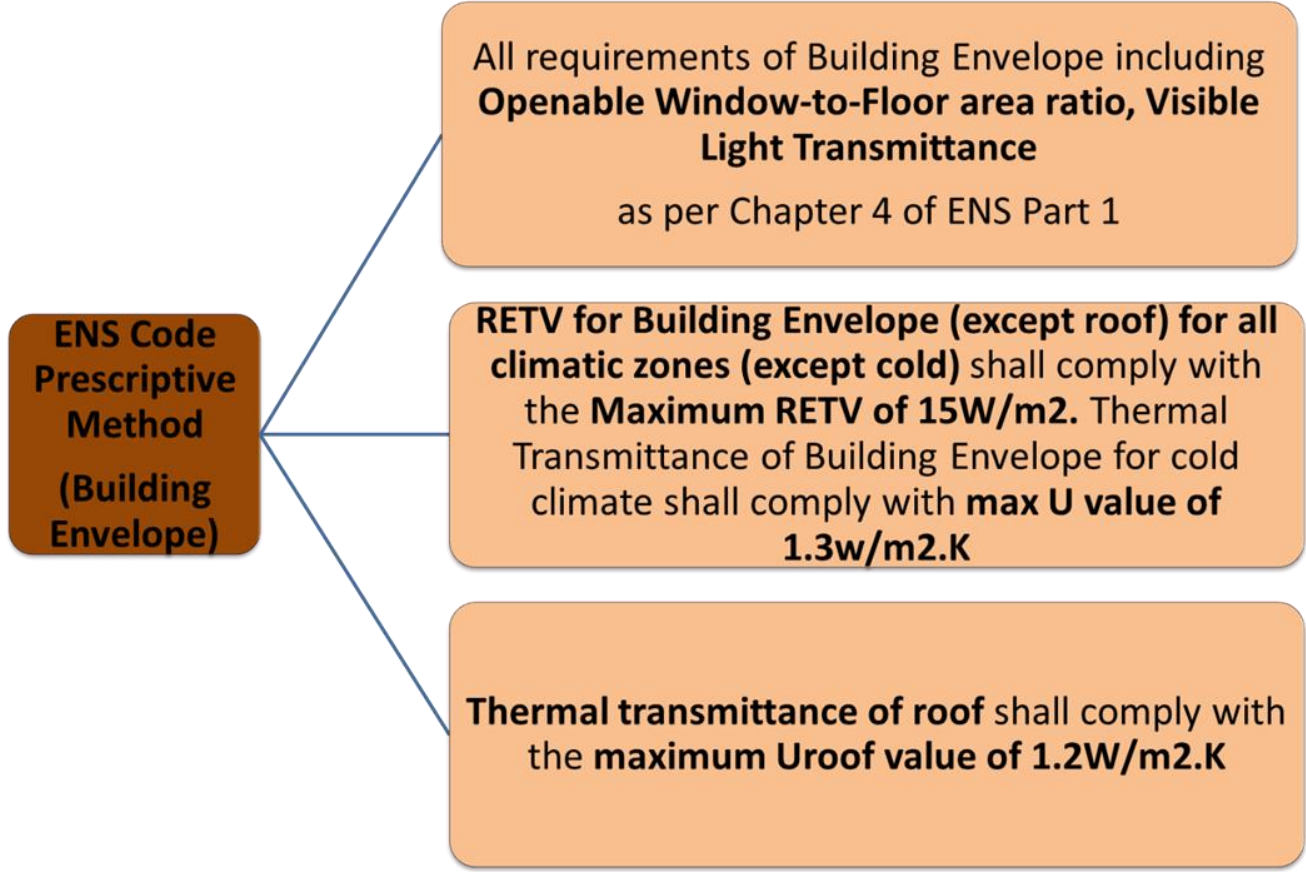
### Prescriptive Method:

To demonstrate compliance with ENS Code through Prescriptive method, ENS building shall meet the following:



# ENS – Part 2 - Prescription Requirements

## Building Envelope:





## ENS – Part 2 - Code Compliance- Point Based System

Obtain a minimum ENS Score Points as in 6.1

Get Additional Points By

Point based System Approach

Project Category	Minimum ENS Score
Low Rise Buildings	47
Affordable Housing	70
High Rise Buildings	100

Additional Points

Additional Points of **Building Envelope** under section 6.4 and/or

Requirements labelled additional of **Building Services and Indoor Electrical End Use** under Section 6.5 /6.6 and/or

Requirement labelled additional of **Renewable Energy Systems** under 6.7

## ENS – Part 2 - Code Compliance- Point Based System

**Maximum Points** are TOTAL Points available for each component

Minimum  
Points

- **Minimum Points** are set of points which are compulsory to achieve for each component to show compliance for ENS

Additional  
Points

- **Additional Points** are the set of points which are awarded for adopting additional or better energy efficiency measures in a respective component. These points are trade able with other components to achieve the total score mentioned in section 3.1.2 for ENS compliance

## ENS – Part 2 - Code Compliance- Point Based System

Components	Minimum Points	Additional Points	Maximum Points
<b>Building Envelope</b>			
Building Envelope	47 Points	40 Points	87 Points
<b>Building Services</b>			
Common area & Exterior Lighting	3 Points	6 Points	9 Points
Elevators	13 Points	9 Points	22Points
Pumps	6 Points	8 Points	14 Points
Electrical Systems	1 Point	5 Points	6 Points
<b>Indoor Electrical End Use</b>			
Indoor Lighting		12 Points	12 Points
Comfort Systems		50 Points	50 Points
<b>ENS SCORE</b>	<b>70 Points</b>	<b>130 Points</b>	<b>200 Points</b>

## ENS – Part 2 – Services

### Common Area and Exterior Lighting

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



**Corridor Lighting**



## ENS – Part 2 – Services

### Common Area and Exterior Lighting

Exterior Lighting Areas/Zones	Maximum LPD (in W/m <sup>2</sup> )
Driveways and Parking	1.6
Pedestrian Walkways	2.0
Stairways	10.0
Landscaping	0.5
Outdoor Sales Areas	9.0



**Parking (open/external)**



**Stairways**



## ENS – Part 2 – Services

### Common Area and Exterior Lighting

Areas/Zones	Points 95lm/W	Points 105lm/W + Photo
Corridor Lighting and Stilt Parking	1	2
Basement Lighting	1	2
Exterior Lighting Areas	1	2



Basement Lighting



Exterior Lighting

Lighting Power Density (LPD)



Luminous Efficacy (LE)

## ENS – Part 2 – Services

### Elevators – Maximum 22 points



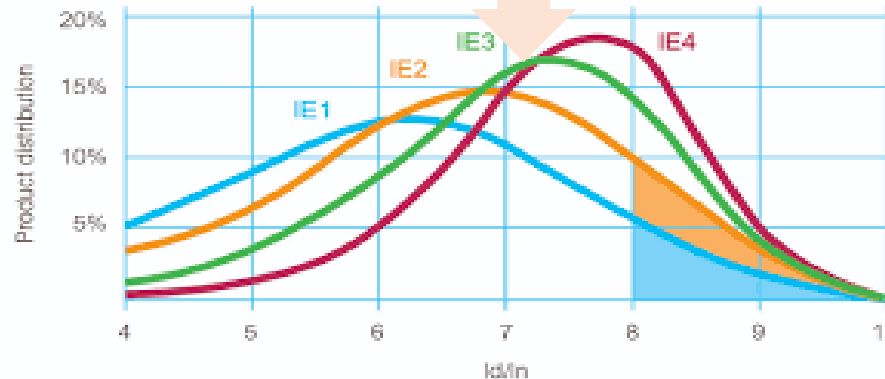
High Efficacy lamps with Luminous Efficacy of 85lm/w

Auto Switch off for Light & Fan when not in use.

Min IE3 High Efficiency Motors



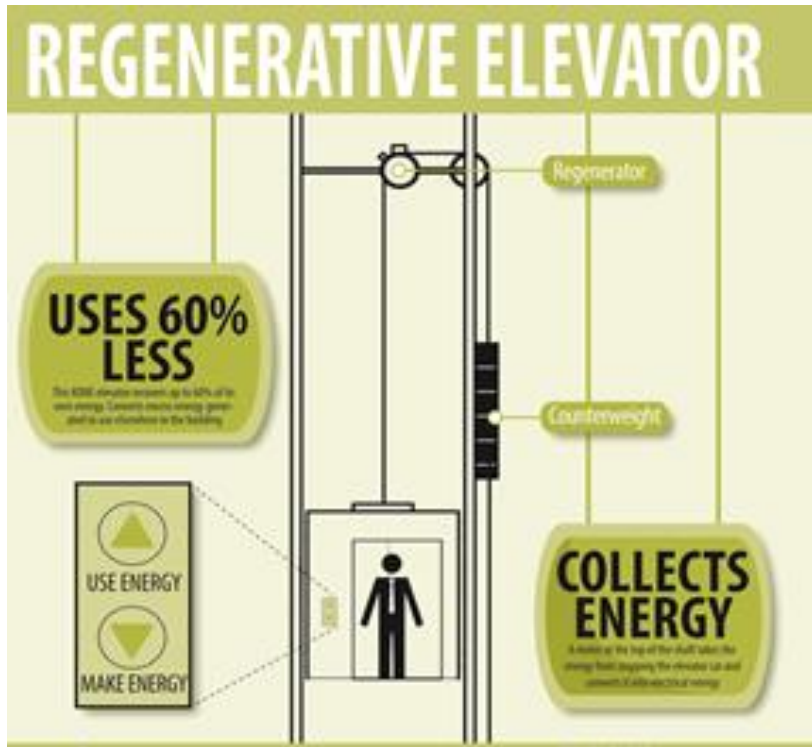
Group Automatic with Supervision



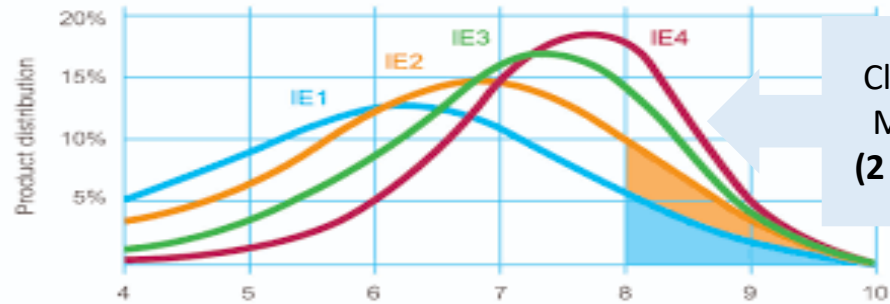
**13 POINTS**

## ENS – Part 2 – Services

### Elevators – Maximum 22 points



Regenerative Drives  
( 3 Points)



# ENS – Part 2 – Services

## Pumps – Maximum 14 points

Mechanical Efficiency

### HYDRO-PNEUMATIC PUMPS

Mechanical Efficiency

60%

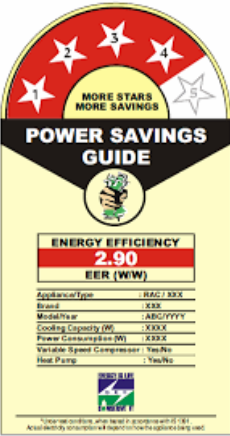
OR

70%

3 POINTS

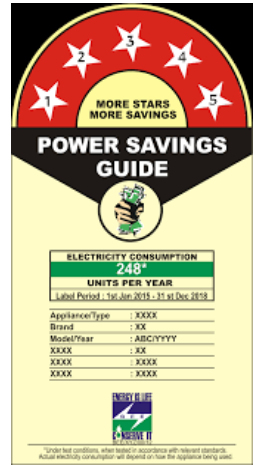


Installation of Hydro-Pneumatic Pumps or BEE Star rated pumps.



6 POINTS

8 POINTS



5 POINTS



# ENS – Part 2 – Services

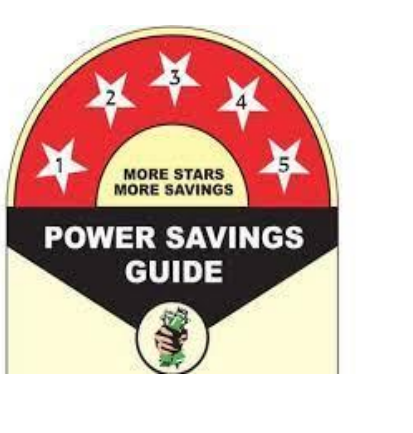
## Electrical Systems – Maximum 6 points

### POWER TRANSFORMERS



- Power transformers to satisfy minimum acceptable efficiency at 50%
  - Permissible loss as per Table 8 for dry type and Table 9 for Oil Type transformers
- (13 POINTS)

### OIL TYPE TRANSFORMERS



Oil Type Transformers With BEE 5 STAR

(5 POINTS)



## ENS – Part 2 – Services

### Indoor Lighting– Maximum 12 points

#### LIVING ROOM



#### BED ROOM



#### KITCHEN



4  
POINTS



3  
POINTS



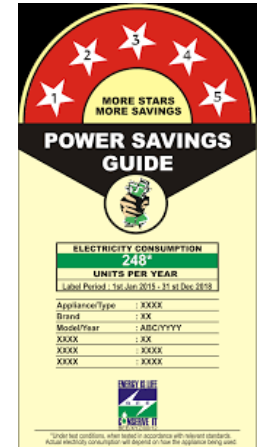
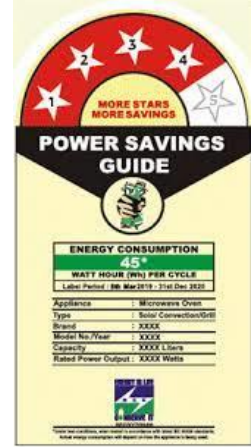
8  
POINTS

## ENS – Part 2 – Services

### Comfort Systems– Maximum 50 points

**Ceiling Fans:** Points for ceiling fans will be only applicable and could be achieved if all the bedrooms and hall in all the dwelling units are having ceiling fans

- Sweep Size < 1200mm: equal or greater than 4m<sup>3</sup>/min.Watt
- Sweep size > 1200mm: equal or greater than 5m<sup>3</sup>/min.Watt



6 POINTS

1 POINT

3 POINTS



BEE Standards and Labelling requirements for ceiling shall take precedence over current requirements

## ENS – Part 2 – Services

### Comfort Systems– Maximum 50 points

#### Air Conditioners:

Points for air conditioners will be only applicable and could be achieved if all the bedrooms in all the dwelling units are having air conditioners (either unitary, split, VRF or centralized plant)



UNITARY TYP : 5 STAR

20 POINTS



SPLIT AC : 3 STAR



CHILLER : ECBC 2017



VRF : 3.28



## ENS – Part 2 – Services

### Comfort Systems– Maximum 50 points

9 POINTS



SPLIT AC 4 STAR



CHILLER : ECBC+



*\* VRF not applicable as on Date. Whenever BEE Star rating is launched, it will be applicable.*

21 POINTS



SPLIT AC 5 STAR



CHILLER : SUPER ECBC

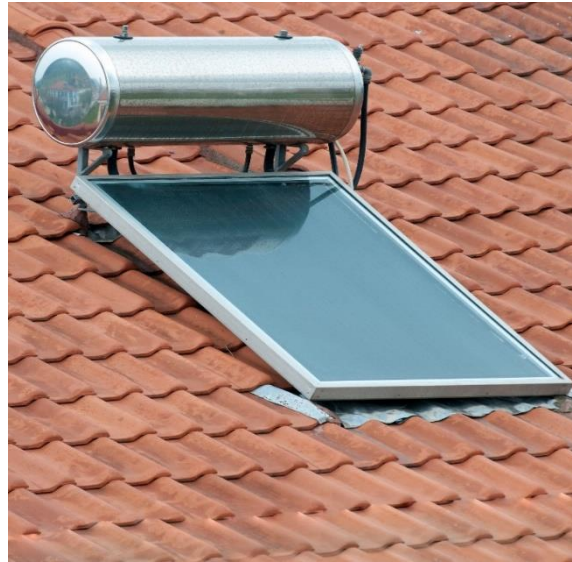
## ENS – Part 2 – Services

### Solar Water Heating

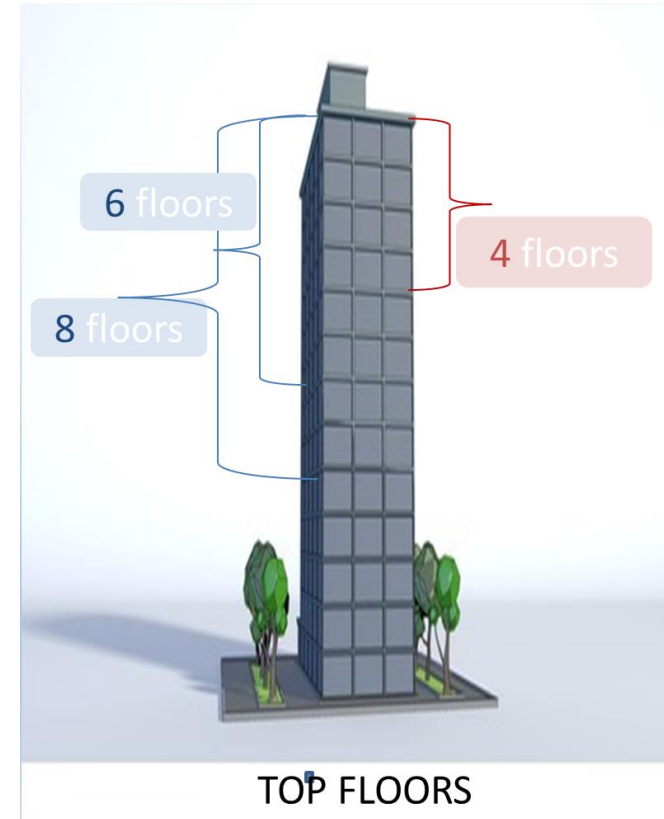
#### Solar Water Heating

- SWH of **minimum BEE 3 Star label** and meeting 100% of Top 4 floors
- **OR**
- 100% of Annual Hot Water demand of Top 4 Floors is met by using heat recovery

**6 POINTS**



- 100% of Annual water demand for Top 6 floors (**2 points**)
- 100% of Annual water demand for Top 8 floors (**5 points**)





## ENS – Part 2 – Services

### Solar Photovoltaic

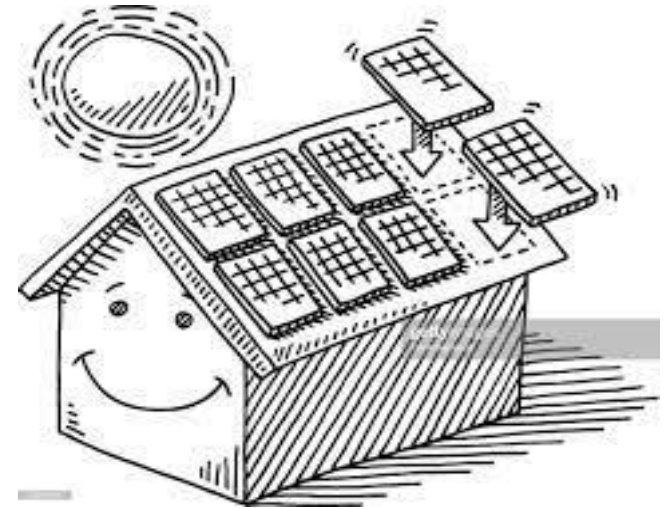


- Dedicated Renewable Energy Zone (REGZ)
- Minimum of 2kWh/m<sup>2</sup> year of electricity

**5 Points**

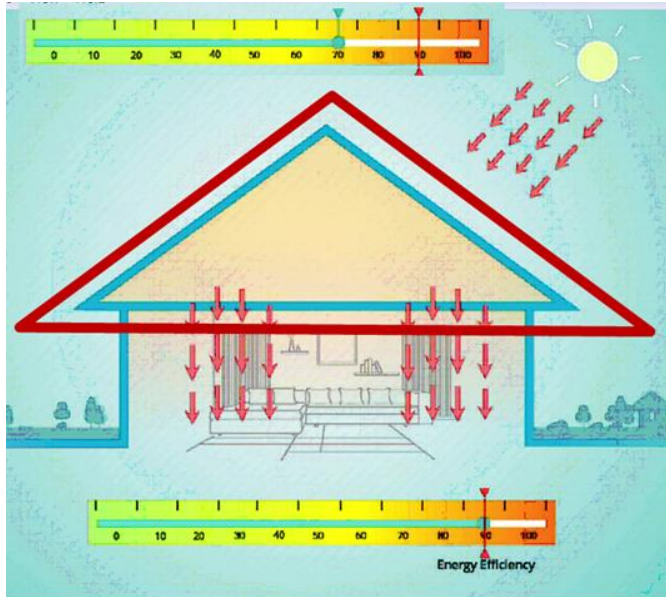


- At least 20% of roof area
- Free of any obstructions and shadows



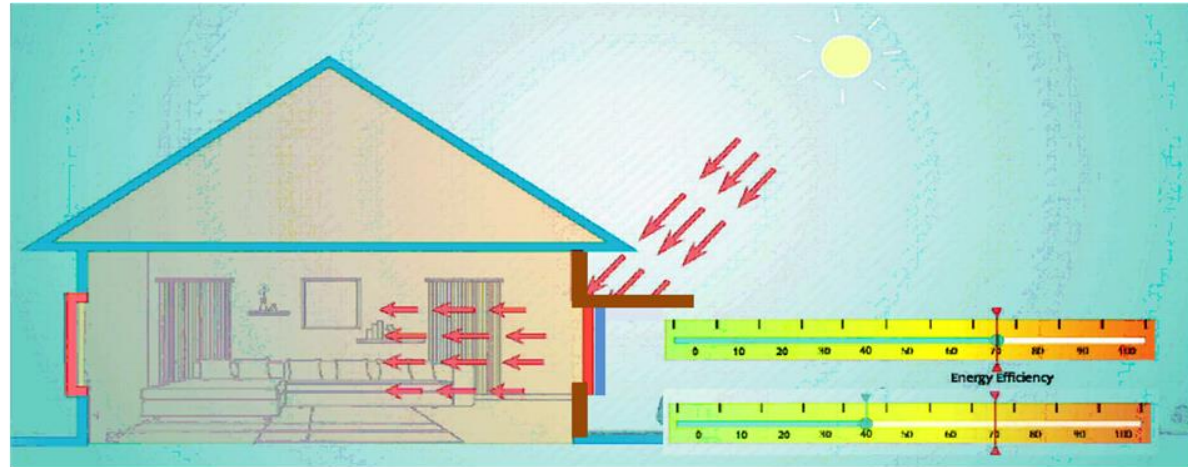
- Min. of 3kWh/m<sup>2</sup> of Electricity / 30% of roof area **(2 points)**
- Min. of 4kWh/m<sup>2</sup> of electricity /40% roof area **(5 points)**

## Conventional Building Vs ENS Building

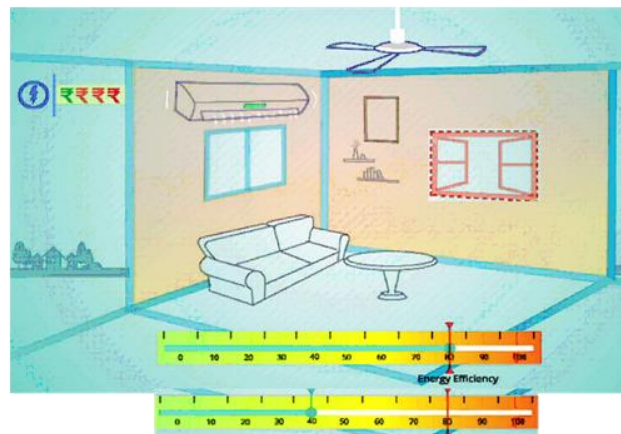


**Non-insulated roof absorbs more heat and radiates inside the building**

**Proper Insulating materials can reduced heat gain**



**Conventional Brick wall, roof and single glazed windows, traps heat**  
**Proper shading, glazing, Wall & Roof insulation reduces impact of heat**



**Increases in cross-ventilation reduces dependency on Air conditioners & coolers, thereby reduces electricity bills**

## Compliance Tool

Java based ENS compliance check tool has been developed to check compliance for residential project.

The screenshot shows the 'Eco-Niwas Samhita: Compliance Check Tool' interface. The main form contains the following fields:

- Project Name: Residential project-1
- State: Maharashtra
- City: Mumbai
- Climate: WARM & HUMID
- Latitude: < 23.5° N
- Total no. of Residential Blocks: 2
- Block Type for Compliance Check: (Empty field)
- No. of Blocks: (Empty field)

Buttons include 'Add Block' and 'Project Relocate'. A table below shows the block type and number of blocks:

Block Type for Compliance Check	Number of Blocks
Building A	2

The right-hand side features a 'Climate zones of India' section with a table and a map of India. The table lists climate zones and their characteristics:

Climate Zone	Mean monthly max. temp.	Mean monthly relative humidity
Hot dry	Above 30°C	Below 55%
Warm humid	Above 30°C	Above 55%
	Above 25°C	Above 75%
Temperate	25-30°C	Below 75%
Cold	Below 25°C	All values
Composite	Does not have a predominant season for more than six months	

The map of India is color-coded according to the legend: HOT DRY (Red), WARM HUMID (Orange), COMPOSITE (Yellow), TEMPERATE (Green), and COLD (Blue).

Available on Bureau of Energy Efficiency's website for download.

Link - <https://beeindia.gov.in/content/ecbc-residential>



## Compliance Tool

Project related details are entered in the tool for compliance check

The screenshot shows the 'Eco-Niwas Samhita: Compliance Check Tool' interface. The form fields are as follows:

- Project Name: Trial Project
- State: Karnataka
- City: Bangalore
- Climate: TEMPERATE
- Latitude: < 23.5° N
- Total no. of Residential Blocks: [Empty]
- Block Type for Compliance: [Empty]
- No. of Blo...: [Empty]

The 'HELP!' section on the right displays the 'Climate zones of India' table:

Climate Zone	Mean monthly max. temp.	Mean monthly relative humidity
Hot dry	Above 30°C	Below 55%
Warm humid	Above 30°C	Above 55%
Temperate	25-30°C	Below 75%
Cold	Below 25°C	All values
Composite	Does not have a predominant season for more than six months	

Below the table is a map of India with a red dot indicating the project location in Bangalore, Karnataka.

Climate data after entering the project location details

## Compliance Tool

Details of various building components will be added for Compliance check- Architectural drawings(plans, sections and elevations)

The screenshot shows the 'Eco-Niwas Samhita: Compliance Check Tool' interface. The main window displays a table for 'Dwelling Unit Details' with the following data:

S.No.	Type of DU	No. of Units	Carpet Area/...	Total Area (m <sup>2</sup> )
1	2-BHK	56	65.0	3640.0

Blue arrows point to the 'BLOCK-A' sidebar and the bottom of the table, indicating where details are submitted and viewed.

Details of the blocks are submitted and can be seen here



## Compliance Tool

Construction material details are entered in the tool. Window details are shown here for example

The screenshot displays the 'Eco-Niwas Samhita: Compliance Check Tool' interface. The window title bar includes the Ministry of Power logo and the text 'Ministry of Power Government of India'. The main content area is titled 'ECBC-R Compliance' and features a 'HELP!' section on the right with expandable categories: Window height and width, Window openable %, Glazed area % and Opaque area %, Glass dimension, Glazing details, and Opaque material properties. The central panel is divided into three sections: 'Window Construction Details', 'Glazing Details', and 'Opaque Elements Details'. The 'Window Construction Details' section includes a table with columns for Window Name, Window Shape, Height (m), Width (m), Area (m²), and No. of Windows. The 'Glazing Details' section includes fields for Glazing %, Height (m), Width (m), U-value (W/m²), SH, and VLT. The 'Opaque Elements Details' section includes a table with columns for Opaque %, Definition, Material Type, Thickness (m), and U-value (W/m²). A 'Properties' button is located below the 'Opaque Elements Details' table. A blue dashed box highlights the 'Window Construction Details' and 'Glazing Details' sections, and a blue arrow points to the 'Properties' button.

All the details related to window are submitted for the compliance

Similarly, other block details are added in the table for checking different design alternatives

## Compliance Tool

Result of the compliance of code provisions shown

ECBC-R Compliance Result			
Mandatory			
	Calculated	Criteria	Status
WFRop (Window to Floor Area Ratio)	22.47	12.5	Compliant
VLT (%) (Visible Light Transmittance)	85.0	27.0	Compliant
Uroof (W/m <sup>2</sup> .K) (Thermal Transmittance -Roof)	0.47	1.2	Compliant
RETV (W/m <sup>2</sup> ) (Residential Envelope Transmittance Value)	9.46	15	Compliant

A report is generated once all the design provisions are compliant to the code





## BEE Star Labelling for Residential Buildings

## BEE – STAR LABELLING

Table for Building Energy Star Rating Programme  
More than 50 % air conditioned built up area

### Climatic Zone- Composite

EPI(Kwh/sqm/year)	Star Label
190-165	1 Star
165-140	2 Star
140-115	3 Star
115-90	4 Star
Below 90	5 Star

### Climatic Zone - Warm and Humid

EPI(Kwh/sqm/year)	Star Label
200-175	1 Star
175-150	2 Star
150-125	3 Star
125-100	4 Star
Below 100	5 Star

### Climatic Zone - Hot and Dry

EPI(Kwh/sqm/year)	Star Label
180-155	1 Star
155-130	2 Star
130-105	3 Star
105-80	4 Star
Below 80	5 Star

Table for Building Energy Star Rating Programme  
Less than 50 % air conditioned built up area

### Climatic Zone- Composite

EPI(Kwh/sqm/year)	Star Label
80-70	1 Star
70-60	2 Star
60-50	3 Star
50-40	4 Star
Below 40	5 Star

### Climatic Zone - Warm and Humid

EPI(Kwh/sqm/year)	Star Label
85-75	1 Star
75-65	2 Star
65-55	3 Star
55-45	4 Star
Below 45	5 Star

### Climatic Zone - Hot and Dry

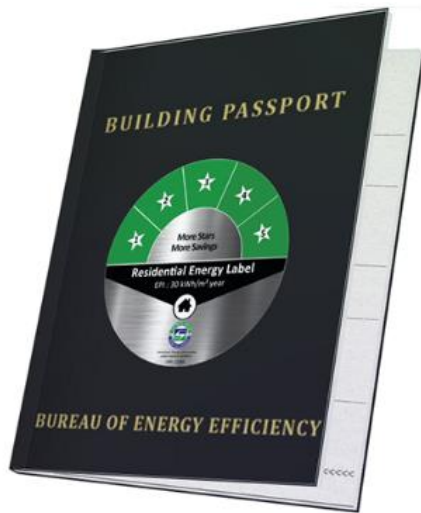
EPI(Kwh/sqm/year)	Star Label
75-65	1 Star
65-55	2 Star
55-45	3 Star
45-35	4 Star
Below 35	5 Star

The program would rate office buildings on a 1-5 Star scale with 5 Star labeled buildings being the most efficient. Five categories of buildings - **office buildings, hotels, hospitals, retail malls, and IT Parks** in five climate zones in the country have been identified for this programme.

Those buildings having a **connected load of 100 kW** and above would be considered for BEE star rating scheme.

# Energy Efficiency Label

for Residential Buildings in India



Log In

Enter email ID

Enter Password

Log In

Forgot Password ?

Don't have an account! Sign Up Here



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Type of Applicant

Select Applicant

CONFIRM

Type of Applicant

Select Applicant

Individual

Firm



Sign Up

Name	Identity Number	Email	Mobile Number
<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>

This will be username.

Address for correspondence

Property Number	Line 1	Line 2	Locality
<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
State	City/Town	District	Pincode
<input type="text" value="Choose State"/>	<input type="text" value="Choose City"/>	<input type="text"/>	<input type="text"/>

Password

Create Password	Re-enter Password
<input type="text"/>	<input type="text"/>

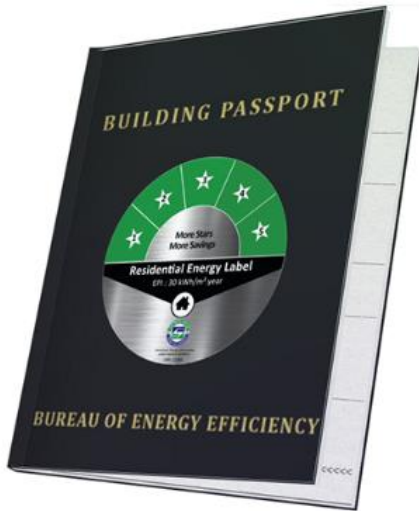
I confirm that all details are true and correct.

Register

Enter all the credentials and register as either Individual or a Firm.

## Energy Efficiency Label

for Residential Buildings in India



Log In

Enter email ID

Enter Password

Log In

Forgot Password ?

Don't have an account! [Sign Up Here](#)

Log in using registered credentials

## Session 6: ENS & Thermal Comfort analysis for the LHP Chennai & DHP Puducherry

## Case Study : Light House Project (LHP), Chennai



- Project Type - *PMAY Housing*
- Location - *Chennai*
- Dwelling Units - *1152*
- DU Area - *26.58 m<sup>2</sup>*

## LHP Site - Thermal Features

- 150mm AAC block is used for Masonry work & 100mm AAC block is used for internal partitions

20mm Plaster + 150mm AAC block + 12mm Plaster

External Wall Assembly								Wall section
Layer no.	Material	Density (kg/m <sup>3</sup> )	Specific Heat (kJ/kg.K)	Thickness (m)	Conductivity (W/m-K)	R value m <sup>2</sup> K/W	Source	
1	Interior surface film resistance	-	-	-	7.700	0.130	ENS 2018	
2	Internal cement Plaster	1762	0.840	0.012	0.721	0.017	ENS 2018	
3	AAC Block	642	1.240	0.150	0.184	0.815	ENS 2018	
4	External cement Plaster	1762	0.840	0.020	0.721	0.028	ENS 2018	
5	Exterior surface film resistance	-	-	-	25.000	0.040	ENS 2018	
<b>U value of assembly (W/m<sup>2</sup>K)</b>						<b>0.97</b>		



## LHP Site Thermal Features

- 305mm RCC wall is used for Roof. Brick bat koba is used as weathering course.

Roof Assembly								
Layer no.	Material	Density (kg/m <sup>3</sup> )	Specific Heat (kJ/kg.K)	Thickness (m)	Conductivity (W/m-K)	R value m <sup>2</sup> K/W	Source	Roof section
1	Interior Surface film resistance	-	-	-	5.900	0.169	ENS 2018	
2	Precast slab (RCC)	2288	NA	0.075	1.580	0.047	ENS 2018	
3	Screeding (RCC)	2288	0.920	0.055	1.580	0.035	ENS 2018	
4	BrickBat	1440	NA	0.100	0.620	0.161	ENS 2018	
5	External cement mortar	1648	0.840	0.075	0.719	0.104	ENS 2018	
6	Exterior Surface film resistance	-	-	-	25.000	0.040	ENS 2018	
<b>U value of assembly (W/m<sup>2</sup>K)</b>						<b>1.79</b>		

- According to ENS code, U value of roof should be within **1.2 W/sqmK**
- Inclusion of 25 mm EPS overdeck insulation would make the roof comply with ENS codes

## LHP Site Analysis

ENS Compliance Parameters	Achieved		ENS Requirement	Compliance Status
	Building 1	Building 5		
Openable Window to Floor Area Ratio ( $WFR_{op}$ )	26.59	26.59	$\geq 16.66 \%$	Complied
Visible Light Transmittance (VLT)	0.89	0.89	$\geq 0.27$	Complied
Thermal Transmittance of Roof ( $U_{roof}$ )	1.8	1.8	$\leq 1.2 \text{ W/m}^2 \cdot \text{K}$	Not Complied
Residential Envelope Transmittance Value (RETV)	11.8	14.1	$\leq 15 \text{ W/m}^2 \cdot \text{K}$	Complied

## Case Study : Light House Project (LHP), Chennai

### Discomfort Hour Percentage

#### LHP Project Building 1 ( North - South)

Building 1									
	Ground floor			Middle floor			Top floor		
	Bedroom	Living	Kitchen	Bedroom	Living	Kitchen	Bedroom	Living	Kitchen
Jan	87%	87%	52%	100%	92%	69%	100%	98%	69%
Feb	57%	84%	51%	94%	91%	68%	96%	96%	69%
Mar	51%	68%	51%	80%	89%	63%	85%	90%	67%
Apr	97%	90%	77%	100%	100%	89%	100%	100%	91%
May	94%	91%	92%	99%	96%	94%	100%	98%	95%
Jun	85%	67%	70%	94%	88%	78%	96%	91%	80%
Jul	80%	60%	67%	93%	82%	71%	94%	88%	71%
Aug	98%	78%	72%	100%	97%	74%	100%	98%	75%
Sep	92%	80%	66%	99%	94%	80%	99%	95%	81%
Oct	55%	60%	40%	74%	69%	46%	81%	71%	52%
Nov	54%	63%	44%	84%	75%	49%	89%	78%	58%
Dec	63%	67%	33%	95%	82%	48%	97%	90%	53%

## Case Study : Light House Project (LHP), Chennai

### Discomfort Hour Percentage

#### LHP Project Building 5 ( East - West)

Building 5									
	Ground floor			Middle floor			Top floor		
	Bedroom	Living	Kitchen	Bedroom	Living	Kitchen	Bedroom	Living	Kitchen
Jan	99%	98%	66%	100%	100%	72%	100%	100%	72%
Feb	87%	92%	62%	100%	100%	77%	100%	100%	79%
Mar	60%	95%	61%	99%	99%	72%	100%	100%	76%
Apr	100%	100%	84%	100%	100%	96%	100%	100%	96%
May	100%	100%	92%	100%	100%	94%	100%	100%	96%
Jun	98%	92%	74%	100%	99%	82%	100%	100%	86%
Jul	99%	92%	69%	100%	96%	73%	100%	97%	76%
Aug	100%	100%	74%	100%	100%	81%	100%	100%	82%
Sep	99%	99%	72%	100%	100%	87%	100%	100%	88%
Oct	76%	75%	42%	88%	88%	53%	92%	89%	57%
Nov	86%	82%	47%	92%	91%	58%	97%	94%	60%
Dec	94%	86%	46%	100%	96%	55%	100%	99%	62%

## Case Study : Light House Project (LHP), Chennai

### Percentage of occupied hours that meets IMAC Adaptive thermal comfort Range

IMAC Temperature		
Month	Min	Max
January	22.31	27.07
February	23.75	28.51
March	25.52	30.28
April	26.8	31.56
May	27.06	31.82
June	27.89	32.65
July	26.67	31.43
August	25.86	30.62
September	25.82	30.58
October	25.44	30.2
November	24.17	28.93
December	22.7	27.46

Zone name	Building 5			Building 1		
	Ground floor	Middle floor	Top Floor	Ground floor	Middle floor	Top Floor
<b>Percentage of Occupied hours within 90% acceptability limits</b>						
Bedroom	8%	2%	1%	24%	7%	5%
Living	7%	2%	2%	25%	12%	9%
Kitchen	34%	25%	23%	40%	31%	28%
<b>Percentage of Occupied hours within 80% acceptability limits</b>						
Bedroom	97%	57%	34%	99%	84%	72%
Living	92%	41%	26%	98%	84%	66%
Kitchen	88%	77%	62%	88%	82%	71%
<b>Percentage of Occupied hours within 70% acceptability limits</b>						
Bedroom	100%	97%	92%	100%	99%	97%
Living	100%	95%	82%	100%	99%	98%
Kitchen	99%	98%	96%	99%	98%	97%



## Thermal Comfort Improvement through Passive Measures

1. Large Window opening size
2. Cross ventilation
3. Ventilator above Main door
4. EPS insulation – Under deck (At least 25 mm Thick)
5. Casement windows
6. Increased corridor width
7. High SRI paint or white tiles

## ENS Part 2 analysis for the LHP

## Light House Project (LHP), Chennai – ENS Part 2

### 4.3.1 Common Area & Exterior Lighting

Components	Minimum Points	Additional Points	Maximum Points	Obtained Points	LHP Chennai
Corridor & Stilt Lighting – 85 Lumen/watt	1		3	1	100 lm/W Wipro LED lighting (20W & 2000 lumen)
95 Lumen/Watt		1		1	
105 Lumen/Watt		1		0	
Exterior Lighting - 85 Lumen/Watt	1		3	1	122 lm/W Philips LED lighting (90W & 11000 lumen)
95 Lumen/Watt		1		1	
105 Lumen/Watt		1		1	
Exterior Lighting Control	1			0	NIL
<b>Total obtained points in Lighting</b>				<b>5</b>	

## Light House Project (LHP), Chennai – ENS Part 2

### 4.3.2 Elevators

Components	Minimum Points	Additional Points	Maximum Points	Obtained Points	LHP Chennai
Lift Car Light	13	9	22	0	70 lm/W LED light installed
IE 3 Motor					OTIS China Energy Label 3 - IE2 equivalent motor installed
Auto Control - Light & Fan					Available
Group control					Not Applicable
Variable Voltage & Frequency drives		4		4	Available
Regenerative drive		3		3	Available

## Light House Project (LHP), Chennai – ENS Part 2

### 4.3.3 Pumps

Components	Minimum Points	Additional Points	Maximum Points	Obtained Points	LHP Chennai
Hydro pneumatic pumps - 60% Efficiency	6		14	0	Submersible pump installed
BEE 4 star rated pumps				0	Not 4 star rated pump
Hydro pneumatic pumps - 70% Efficiency		3		0	
BEE 4 star rated pumps		5		0	



## Light House Project (LHP), Chennai – ENS Part 2

### 4.3.3 Pumps

Components	Minimum Points	Additional Points	Maximum Points	Obtained Points	LHP Chennai
Hydro pneumatic pumps - 60% Efficiency	6		14	0	Submersible pump installed
BEE 4 star rated pumps				0	Not 4 star rated pump
Hydro pneumatic pumps - 70% Efficiency		3		0	
BEE 4 star rated pumps		5		0	

### 4.3.4 Electrical Systems (Transformer)

Components	Minimum Points	Additional Points	Maximum Points	Obtained Points	LHP Chennai
BEE 4 star rated Oil type	1		6	0	1 star Rated Oil type Transformer is allotted
BEE 5 star rated Oil type		5		0	

## Light House Project (LHP), Chennai – ENS Part 2

### 4.5.2 Solar Photo Voltaic

Components	Minimum Points	Additional Points	Maximum Points	Obtained Points	LHP Chennai
Min 2kWh/sqm per year	5		10	5	<i>Installed system is equivalent to 6kWh/sqm/year</i>
Min 3 kWh/sqm per year		2		0	
Min 4 kWh/sqm per year		5		5	

## Light House Project (LHP), Chennai – ENS Part 2

Components	Minimum Points	Additional Points	Maximum Points	Obtained Points	LHP Chennai
<b>Envelope</b>					
U Roof	3	4	7	0	
RETV	44	36	80	48	N-S Block - RETV = 11.8 E-W Block - RETV = 14.8
<b>Lighting</b>					
Corridor & Stilt Lighting - 85Lumen/watt	1		3	1	100 lm/W Wipro LED lighting
95 Lumen/Watt		1		1	
105 Lumen/Watt		1		0	
Exterior Lighting - 85 Lumen/Watt	1		3	1	122 lm/W Philips LED lighting
95 Lumen/Watt		1		1	
105 Lumen/Watt		1		1	
Exterior Lighting Control	1			0	NIL
<b>Elevators</b>					
Lift Car Light			22	0	70 lm/W LED light installed
IE 3 Motor	13	9			OTIS China Energy Label 3 - IE2 equivalent motor installed
Auto Control - Light & Fan					Available
Group control					Not Applicable
Variable Voltage & Frequency drives		4		4	Available
Regenerative drive		3		3	Available

## Light House Project (LHP), Chennai – ENS Part 2

Components	Minimum Points	Additional Points	Maximum Points	Obtained Points	LHP Chennai
<b>Pumps</b>					
Hydro pneumatic pumps - 60% Efficiency	6		14	0	Submersible pump installed
BEE 4 star rated pumps				0	Not 4 star rated pump
Hydro pneumatic pumps - 70% Efficiency		3		0	
BEE 4 star rated pumps		5		0	
<b>Electrical Systems</b>					
BEE 4 star rated Oil type	1		6	0	1 star Rated Oil type Transformer is allotted
BEE 5 star rated Oil type		5		0	
<b>Solar PV Systems</b>					
Min 2kWh/sqm per year		5	10	5	Installed system is equivalent to 6kWh/sqm/year
Min 3 kWh/sqm per year		2		0	
Min 4 kWh/sqm per year		5		5	
<b>Total points gained</b>	<b>70</b>	<b>85</b>	<b>155</b>	<b>70</b>	



## DHP Dubrayapet, Puducherry



## Introduction to Dubrayapet Project



Location of Dubrayapet site in Google map (11°55'7.87"N,79°49'49.01"E)

### Location of Dubrayapet Site

- The project proposal involves development of 80 low-income housing units in a plot area of 1950Sqm adhering to the various norms of the government.
- In the proposed site the building covers the plinth area /plot coverage of 31.4%.
- The FAR (floor Area Ratio) achieved for the said 80 dwelling units project is 1.56 which is within the permissible limit of Puducherry Planning Authority bye-law.

## Project Needs

- Necessitate low-income housing for 80-90 families to have a safe all weather withstanding dwelling unit. With the possibilities to harness renewable energy through solar rooftop for the high-rise structure.
- Provide a Pucca dwelling unit for the habitants with below poverty level without need to spend for retrofitting pre and post monsoon seasons.
- To provide individual toilets to all dwelling units to improve sanitation levels by routing grey water to the nearby Sewage Treatment Plant.
- Precise day to day segregation and disposal of garbage and solid wastes of all dwelling units at the proposed site.

S.NO	STAKEHOLDER	ROLE
1.	Ministry of Housing and Urban Affairs (MoHUA)	Provision of funding for CITIIS projects
2.	National Institute of Urban Affairs (NIUA)	Handholding and rolling out of CITIIS Challenge Initiative and appointment of mentors
3.	Puducherry Smart City Development Limited (PSCDL)	Nodal Agency , Tender Inviting and Tender Receiving Authority and Project Executing Authority
4.	Technical Committee	Review and approval of Tender Documents

### *Key Stakeholders in the Dubrayapet project*

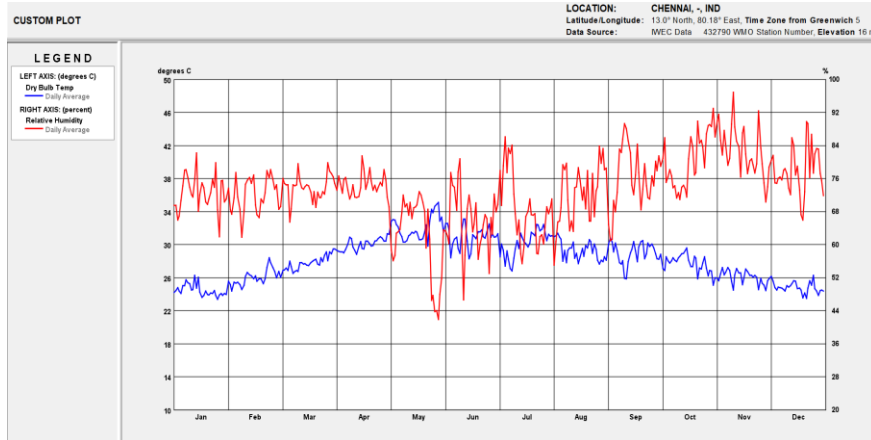
## Eco Niwas Samhita (ENS) - Part 1

Eco Niwas Samhita (ENS) (Part I: Building Envelope) is a residential energy code that has been prepared to set minimum building envelope performance standards to limit heat gains (for cooling dominated climates) and to limit heat loss (for heating-dominated climates), as well as for ensuring adequate natural ventilation and daylighting potential.

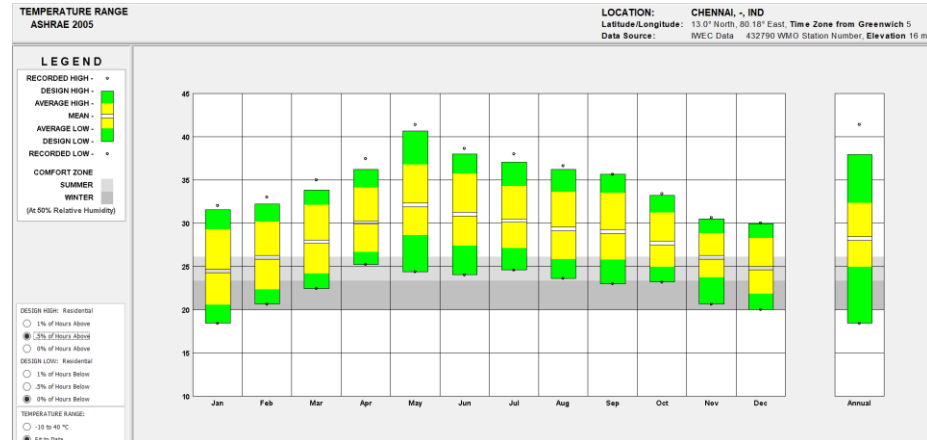
ENS Compliance Parameters	Achieved	ENS Requirement	Compliance Status
	Base Case: Building 1 & 2		
Openable Window to Floor Area Ratio (WFR <sub>op</sub> )	8.37 %	≥ 16.66 %	Not Complied
Visible Light Transmittance (VLT)	0.51	≥ 0.27	Complied
Thermal Transmittance of Roof (U <sub>roof</sub> )	2.59 W/m <sup>2</sup> . K	≤ 1.2 W/m <sup>2</sup> . K	Not Complied
Residential Envelope Transmittance Value (RETV)	18.48 W/m <sup>2</sup> . K	≤ 15 W/m <sup>2</sup> . K	Not Complied

*ENS compliance for Dubrayapet project*

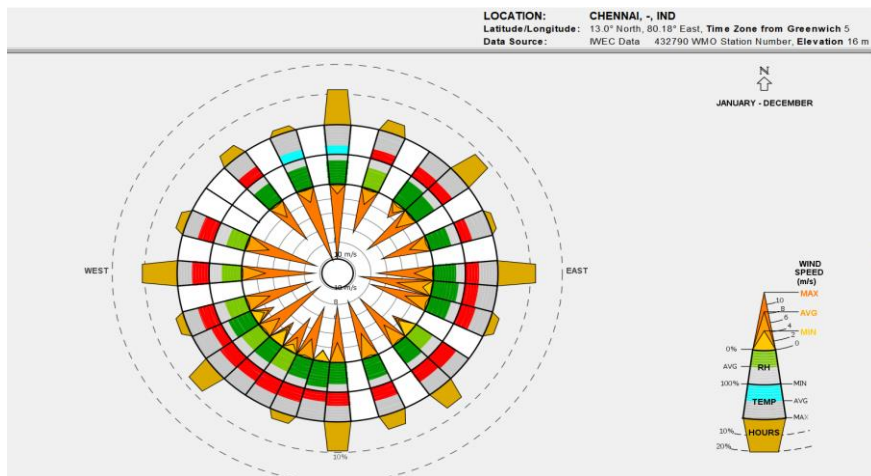
# Climate Analysis - Puducherry



Temperature and Relative Humidity



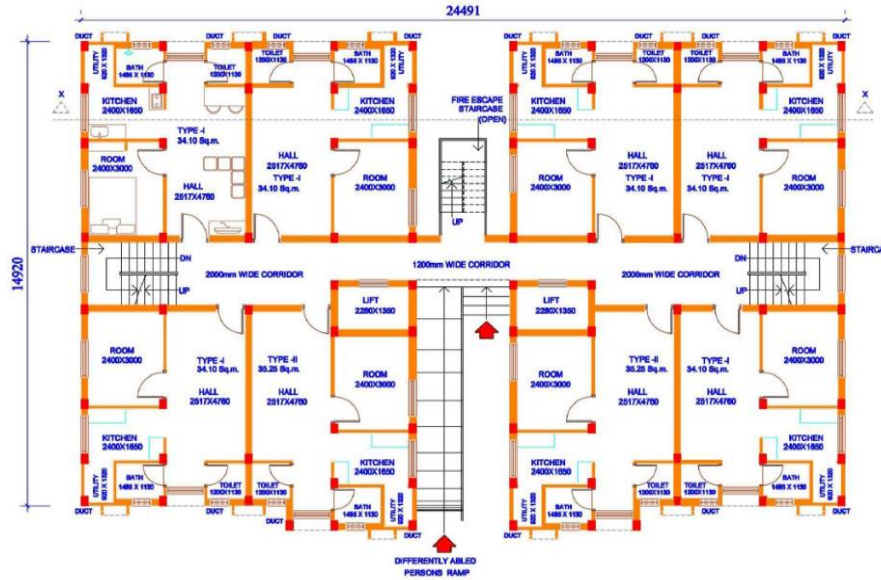
Monthly Dry Bulb Temperature (DBT) distribution



Wind Wheel

- Puducherry is placed at an altitude of 3 m.
- The Wind Wheel figure shows the wind direction is predominant in East-West at a maximum speed of 8-10 m/s, so adequate openings in this direction building should be proposed for good natural ventilation.

## Building Description & Floor Plan



*Floor Plan of Dubrayapet project*

- This project has 2 Buildings. Each building has typical 1 BHK unit. Each 1 BHK unit has 1 bedroom, 1 toilet, Hall, Bath, kitchen and a Utility. Each tower has a total of G + 4 floors. On each floor, there are 8 units.
- The building is constructed Conventional construction with Brick wall and 18mm clay tiles for roof and Lime concrete for roof RCC roof, Single glazed units with wooden frames for building is constructed



## Cases selected for Simulation

- The project was analysed for 4 cases (Case 1, Case 2, Case 3 and Case 4) apart from the proposed construction as mentioned in the Detailed Project Report (DPR). This case is considered as the Base case.
- **Case 1:** Wall – AAC blocks; Window – Casement; Roof – Same as Base case
- **Case 2:** Wall – AAC blocks; Window – Casement window-sized modified to suit WFR requirements; Roof – Addition of 25mm EPS insulation
- **Case 3:** Wall – AAC blocks; Window – Casement + ventilators on top of windows, Glass – Single Glazed Unit with lower SHGC, Shading – Addition of vertical fins on E & W windows; Roof – Addition of 25mm EPS insulation
- **Case 4:** Wall – AAC blocks + double layer external plaster; Window – Casement + ventilators on top of windows, Glass – Single Glazed Unit with lower SHGC, Shading – Addition of vertical fins on E & W windows; Roof – Addition of 25mm EPS insulation

## Building Envelope Construction Details

Envelope Type	Base Case (As per existing DPR)	Case 1	Case 2	Case 3	Case 4
Wall	Internal Cement Mortar (12 mm) + Brick wall (230mm) + External Cement Mortar (15 mm)	Internal Cement Mortar (12 mm) + AAC wall (200mm) + External Cement Mortar (15 mm)	Internal Cement Mortar (12 mm) + AAC wall (200mm) + External Cement Mortar (15 mm)	Internal Cement Mortar (12 mm) + AAC wall (200mm) + External Cement Mortar (15 mm)	Internal Cement Mortar (12 mm) + AAC wall (200mm) + External Cement Mortar (15 mm) + External Cement Mortar (10 mm)
Roof	18mm Clay tile + 25 mm Lime concrete mortar + 150mm RCC slab + 12 mm plaster thickness	18mm Clay tile + 25 mm Lime concrete mortar + 150mm RCC slab + 12 mm plaster thickness	18mm Clay tile + 25 mm Lime concrete mortar + 25 mm EPS insulation+ 150mm RCC slab + 12 mm plaster thickness	18mm Clay tile + 25 mm Lime concrete mortar + 25 mm EPS insulation+ 150mm RCC slab + 12 mm plaster thickness	18mm Clay tile + 25 mm Lime concrete mortar + 25 mm EPS insulation+ 150mm RCC slab + 12 mm plaster thickness
Fenestration & Glazing	Wood Frame SGU with 6mm glass thickness, SHGC = 0.84, VLT = 0.89; Sliding Windows	Wood Frame SGU with 6mm glass thickness, SHGC = 0.84, VLT = 0.89; Casement Windows	Wood Frame SGU with 6mm glass thickness, SHGC = 0.84, VLT = 0.89; Casement Windows size changed, bedroom window (1.65m*1.3m)	Wood Frame SGU with 6mm glass thickness, SHGC = 0.43, VLT = 0.37; Casement Windows with Base case windows added with ventilators above window	Wood Frame SGU with 6mm glass thickness, SHGC = 0.43, VLT = 0.37; Casement Windows with Base case windows added with ventilators above window
Shading	600 mm horizontal shading device on all windows.	600 mm horizontal shading device on all windows	600 mm horizontal shading device on all windows.	600 mm horizontal shading device on all windows + vertical fins on East and West windows	600 mm horizontal shading device on all windows + vertical fins on East and West windows

## Project evaluation as per ENS compliance requirements

### Openable Window to Floor Area Ratio ( $WFR_{op}$ )

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.

Openable area to Floor Ratio (WFR)				
	Openable Area (m <sup>2</sup> )	Floor Area (m <sup>2</sup> )	WFR	Minimum requirement
Base case (Sliding Window)	2.7	32.26	8.37%	16.66%
Case 1 (Casement Window)	4.86	32.26	15.07%	
Case 2 (Casement window - Bedroom size modified)	5.3865	32.26	16.70%	
Case 3,4 (Casement+Ventilators)	5.94	32.26	18.41%	

Window to Floor Area Ratio (WFR)

Climate Zone	Minimum $WFR_{op}$ (%)
Composite	12.5
Hot-Dry	10
<b>Warm-Humid</b>	<b>16.66</b>
Temperate	12.5
Cold	8.33

minimum requirement of  $WFR_{op}$  as per ENS code

## Project evaluation as per ENS compliance requirements

### Visible Light Transmittance (VLT)

Visible light transmittance (VLT) of non-opaque building envelope components (transparent/translucent panels in windows, doors, ventilators, etc.), indicates the potential of using daylight. Ensuring minimum VLT helps in improving daylighting, thereby reducing the energy required for artificial lighting. The VLT requirement is applicable as per the window-to-wall ratio (WWR) of the building. WWR is the ratio of the area of non-opaque building envelope components of dwelling units to the envelope area (excluding the roof) of dwelling units.

	WWR	Minimum VLT requirement	VLT
Basecase	0.15	0.27	0.89
Case 1,2	0.15	0.27	0.89
Case 2,3	0.18	0.27	0.51

*Window to Wall area Ratio*

Window to Wall Ratio (WWR)	Minimum VLT
0-0.3	0.27
0.31-0.4	0.2
0.41-0.5	0.16
0.51-0.6	0.13
0.61-0.7	0.11

*Minimum visible light transmittance (VLT) requirement*

## Project evaluation as per ENS compliance requirements

### Thermal Transmittance of Roof

Thermal transmittance ( $U_{\text{roof}}$ ) characterizes the thermal performance of the roof of a building. Limiting the  $U_{\text{roof}}$  helps in reducing heat gains or losses from the roof, thereby improving the thermal comfort and reducing the energy required for cooling or heating. Thermal transmittance of the roof shall comply with the **maximum  $U_{\text{roof}}$  value of 1.2 W/m<sup>2</sup>. K.**

Base Case	Outside to Inside	Thickness (m)	Specific Heat (kJ/kg K)	Density (kg/m <sup>3</sup> )	Conductivity (W/mK)	R - Value (m <sup>2</sup> K / W)	U - Value (W/m <sup>2</sup> K)
Roof	Brick tile	0.018	0.88	1890	0.8	0.0225	2.640234
	Lime concrete	0.025	0.84	1762	0.721	0.03467406	
	RCC slab	0.15	0.88	2288	1.58	0.09493671	
	Cement plaster	0.012	0.84	1762	0.721	0.01664355	
	Rsi					0.17	
	Rse					0.04	
	<b>Assembly (Total)</b>					<b>0.37875432</b>	

### Thermal Transmittance of Roof for Base Case

Case 4	Outside to Inside	Thickness (m)	Specific Heat (kJ/kg K)	Density (kg/m <sup>3</sup> )	Conductivity (W/mK)	R - Value (m <sup>2</sup> K / W)	U - Value (W/m <sup>2</sup> K)
Roof	Brick Tile	0.018	0.88	1890	0.8	0.0225	0.91488
	Lime Concrete	0.025	0.84	1792	0.721	0.03467406	
	25 mm EPS insulation	0.025	1.34	24	0.035	0.71428571	
	Cement plaster	0.012	0.84	1762	0.721	0.01664355	
	RCC slab	0.15	0.88	2288	1.58	0.09493671	
	Rsi					0.17	
	Rse					0.04	
	<b>Assembly (Total)</b>					<b>1.09304004</b>	

### Thermal Transmittance of Roof for Proposed Case



## Project evaluation as per ENS compliance requirements

### Thermal Transmittance of Roof

	U- Value in W/m <sup>2</sup> K	U- Value in W/m <sup>2</sup> K -Basecase	U- Value in W/m <sup>2</sup> K - Case 1	U- Value in W/m <sup>2</sup> K Case 2	U- Value in W/m <sup>2</sup> K - Case 3	U- Value in W/m <sup>2</sup> K - Case 4
Thermal Transmittance of Roof	1.2	2.64	2.64	0.92	0.92	0.92

*U roof for all the Cases*

The current project has its roof configuration common to all buildings. **The project has attained U-value of 2.64 W/m<sup>2</sup>. K** which is higher than the prescribed limit. **Hence the building's roof configuration not complies with the ENS requirement.** A roof insulation of 25mm EPS insulation is proposed to achieve the desired thermal transmittance value. Roof insulation helps in a greater extent to reduce the heat ingress in a Warm & Humid Climate.

## Project evaluation as per ENS compliance requirements

### Residential Envelope Transmittance Value (RETV)

Residential Envelope Transmittance Value (RETV)																			
Levels	Properties	Wall						Glass										RETV (W/m <sup>2</sup> K)	
		U value	Net Area (m <sup>2</sup> )				SHGC	Effective SHGC				U value	VLT	Window Area (m <sup>2</sup> )				Standard	Achieved
			North	East	South	West		North	East	South	West			North	East	South	West		
Basecase	Solid Burnt Clay Brick	2.07	14.25	16.50	0.00	0.00	0.84	0.73	0.63	0.00	0.00	5.8	0.89	2.28	3.12	0.00	0.00	15	18.48
Case 1	AAC Block Masonry	0.77	14.25	16.50	0.00	0.00	0.84	0.73	0.63	0.00	0.00	5.8	0.89	2.28	3.12	0.00	0.00	15	12.23
Case 2	AAC Block Masonry	0.77	14.25	15.92	0.00	0.00	0.84	0.73	0.63	0.00	0.00	5.8	0.89	2.28	3.71	0.00	0.00	15	13.01
Case 3	AAC Block Masonry	0.77	0.00	0.00	13.65	15.90	0.56	0.00	0.00	0.46	0.43	5.6	0.51	0.00	0.00	2.88	3.72	15	10.90
Case 4	AAC Block + Double layer plaster	0.760	0.00	15.90	13.65	0.00	0.56	0.00	0.43	0.46	0.00	5.6	0.51	0.00	3.72	2.88	0.00	15	8.96

*RETV for all Cases*

The RETV value attained for the conventional case is 18.48 W/m<sup>2</sup>K and with AAC masonry wall (12.23 W/m<sup>2</sup>K), reduces the thermal transmittance through the envelope to a greater extent.

## Thermal Comfort Analysis

The project is a 1BHK house with G+4 floors. Energy simulation is carried out in Design Builder software and detailed modelling is carried out in the Energy Plus engine. The modelling is carried out for the Ground Floor, Middle Floor and Top floor units for NE, NW, SE, SW dwelling units. Detailed inputs in terms of number floors, building geometry, Envelope details, internal loads and active systems are provided in the simulation software. Detailed natural ventilation modeling is carried out in Energy plus.

The modelling methodology is adopted based on IMAC - R (Indian Model for Adaptive thermal Comfort - Residential). In the 1BHK dwelling the rooms are considered to run on 100% natural ventilation. Window operation condition is that the window opens when the Zone Operative Temperature is greater than or equal to IMAC - R Neutral Temperature (T<sub>nuet</sub>) and Outside air Temperature equal to less than Neutral Temperature or the window opens when the Zone Operative Temperature is less than Minimum IMAC (90% Acceptability) and Outside air temperature is greater than Minimum IMAC Temperature to facilitate maximum indoor thermal comfort in affordable housing.

## Thermal Comfort Analysis

Level of discomfort												
Levels	MF NW Dwelling unit			MF SW Dwelling unit			TF NW Dwelling unit			TF SW Dwelling unit		
	Bedroom	Living Room	Area weighted average	Bedroom	Living Room	Area weighted average	Bedroom	Living Room	Area weighted average	Bedroom	Living Room	Area weighted average
<b>Basecase</b>	8760	8691	<b>8717</b>	8759	8666	<b>8701</b>	8743	8663	<b>8693</b>	8745	8684	<b>8707</b>
<b>Case-1</b>	4111	3610	<b>3798</b>	4033	3110	<b>3457</b>	6983	8380	<b>7855</b>	6950	6174	<b>6466</b>
<b>Case-2</b>	4112	3607	<b>3797</b>	4037	3110	<b>3459</b>	5480	8548	<b>7395</b>	5331	4385	<b>4741</b>
<b>Case-3</b>	3175	3172	<b>3173</b>	3035	2861	<b>2926</b>	4745	6467	<b>5820</b>	4921	4150	<b>4440</b>
<b>Case-4</b>	3144	3114	<b>3125</b>	2978	2788	<b>2859</b>	4749	6414	<b>5788</b>	4925	4137	<b>4433</b>

### Annual Level of Discomfort hours for select Dwelling Units

Percentage of Discomfort hours												
Levels	MF NW Dwelling unit			MF SW Dwelling unit			TF NW Dwelling unit			TF SW Dwelling unit		
	Bedroom	Living Room	Area weighted average	Bedroom	Living Room	Area weighted average	Bedroom	Living Room	Area weighted average	Bedroom	Living Room	Area weighted average
<b>Basecase</b>	100%	99%	<b>100%</b>	100%	99%	<b>99%</b>	100%	99%	<b>99%</b>	100%	99%	<b>99%</b>
<b>Case-1</b>	47%	41%	<b>43%</b>	46%	36%	<b>39%</b>	80%	96%	<b>90%</b>	79%	70%	<b>74%</b>
<b>Case-2</b>	47%	41%	<b>43%</b>	46%	36%	<b>39%</b>	63%	98%	<b>84%</b>	61%	50%	<b>54%</b>
<b>Case-3</b>	36%	36%	<b>36%</b>	35%	33%	<b>33%</b>	54%	74%	<b>66%</b>	56%	47%	<b>51%</b>
<b>Case-4</b>	36%	36%	<b>36%</b>	34%	32%	<b>33%</b>	54%	73%	<b>66%</b>	56%	47%	<b>51%</b>

### Annual Percentage of Discomfort hours for select Dwelling Units

## Thermal Comfort Analysis

Level of discomfort												
Levels	MF NW Dwelling unit			MF SW Dwelling unit			TF NW Dwelling unit			TF SW Dwelling unit		
	Bedroom	Living Room	Area weighted average	Bedroom	Living Room	Area weighted average	Bedroom	Living Room	Area weighted average	Bedroom	Living Room	Area weighted average
<b>Basecase</b>	4392	4392	<b>4392</b>	4392	4392	<b>4392</b>	4392	4392	<b>4392</b>	4392	4392	<b>4392</b>
<b>Case-1</b>	3389	3041	<b>3172</b>	3128	2661	<b>2837</b>	4172	4347	<b>4281</b>	4119	3903	<b>3984</b>
<b>Case-2</b>	3390	3039	<b>3171</b>	3129	2661	<b>2837</b>	4046	4387	<b>4259</b>	3800	3462	<b>3589</b>
<b>Case-3</b>	2726	2639	<b>2672</b>	2438	2377	<b>2400</b>	3666	4181	<b>3987</b>	3521	3161	<b>3296</b>
<b>Case-4</b>	2720	2621	<b>2658</b>	2414	2357	<b>2378</b>	3707	4118	<b>3963</b>	3582	3220	<b>3356</b>

### Summer Months (Apr - Sept) Level of Discomfort Hours for select Dwelling Units

Percentage of Discomfort hours												
Levels	MF NW Dwelling unit			MF SW Dwelling unit			TF NW Dwelling unit			TF SW Dwelling unit		
	Bedroom	Living Room	Area weighted average	Bedroom	Living Room	Area weighted average	Bedroom	Living Room	Area weighted average	Bedroom	Living Room	Area weighted average
<b>Basecase</b>	50%	50%	<b>100%</b>	50%	50%	<b>100%</b>	50%	50%	<b>100%</b>	50%	50%	<b>100%</b>
<b>Case-1</b>	39%	35%	<b>72%</b>	36%	30%	<b>65%</b>	48%	50%	<b>97%</b>	47%	45%	<b>45%</b>
<b>Case-2</b>	39%	35%	<b>72%</b>	36%	30%	<b>65%</b>	46%	50%	<b>97%</b>	43%	40%	<b>41%</b>
<b>Case-3</b>	31%	30%	<b>61%</b>	28%	27%	<b>55%</b>	42%	48%	<b>91%</b>	40%	36%	<b>38%</b>
<b>Case-4</b>	31%	30%	<b>61%</b>	28%	27%	<b>54%</b>	42%	47%	<b>90%</b>	41%	37%	<b>38%</b>

### Summer Months (Apr - Sept) Percentage of Discomfort Hours for select Dwelling Units



## Thermal Comfort Analysis

### Inference

From the Discomfort hours and percentage, it is clearly understood that for a Warm & Humid climate the following passive design recommendations needs to be considered

- Envelope with lower Thermal conductivity, Higher thermal mass for walls, double plastering, Higher WWR
- Higher window openable area (WFR), Ventilators on top of Windows to facilitate stack ventilation and promote cross ventilation
- Roof with lower thermal conductivity by adding adequate insulation

## Cost Implication

Cost for construction for Base Case: INR 56,24,385

Base Case						
	Unit	Specification	Quantity	Unit cost (Rs./-)	Costing/block (Rs./-)	Source
Wall	cum	230mm brick	369.84	₹ 6,184.12	₹ 22,87,134.94	DPR Serial No:26
Plaster	sqm	15mm external	1608	₹ 271.42	₹ 4,36,443.36	DPR Serial No:48
Plaster	sqm	12mm internal	1608	₹ 179.60	₹ 2,88,796.80	DPR Serial No:49
Window (glass)	sqm	Sliding Windows, SGU; SHGC = 0.84	216	₹ 537.00	₹ 1,15,992.00	CPWD SOR
Roof finishing	sqm	Bitumen Paint + 18mm Clay brick tiles+25mm Lime Mortar	332		₹ 21,41,650.00	DPR Serial No:VIII
Shading device	sqm	Horizontal shading device	634	₹ 558.94	₹ 3,54,367.96	CPWD SOR
<b>Total Material Cost (Rs./-)</b>					<b>₹ 56,24,385.06</b>	

## Cost Implication

### Cost for construction for Case 1: INR 51,71,657

Case-1						
	Unit	Specification	Quantity	Unit cost (Rs./-)	Costing/block (Rs./-)	Source
Wall	cum	200 mm AAC	369.84	₹ 4,960.00	₹ 18,34,406.40	CPWD SOR
Plaster	sqm	15mm external	1608	₹ 271.42	₹ 4,36,443.36	DPR Serial No:48
Plaster	sqm	12mm internal	1608	₹ 179.60	₹ 2,88,796.80	DPR Serial No:49
Window (glass)	sqm	Casement Windows, SGU; SHGC = 0.84	216	₹ 537.00	₹ 1,15,992.00	CPWD SOR
Roof finishing	sqm	Bitumen Paint + 18mm Clay brick tiles+25mm Lime Mortar	332		₹ 21,41,650.00	DPR Serial No:VIII
Shading device	sqm	Horizontal shading device	634	₹ 558.94	₹ 3,54,367.96	CPWD SOR
<b>Total Material Cost (Rs./-)</b>					<b>₹ 51,71,656.52</b>	

## Cost Implication

### Cost for construction for Case 2: INR 53,30,604

Case-2						
	Unit	Specification	Quantity	Unit cost (Rs./-)	Costing/block (Rs./-)	Source
Wall	cum	200 mm AAC	369.84	₹ 4,960.00	₹ 18,34,406.40	CPWD SOR
Plaster	sqm	15mm external	1608	₹ 271.42	₹ 4,36,443.36	DPR Serial No:48
Plaster	sqm	12mm internal	1608	₹ 179.60	₹ 2,88,796.80	DPR Serial No:49
Window (glass)	sqm	Casement Windows, SGU; SHGC = 0.84; Bedroom window (1.65m*1.3m)	252	₹ 537.00	₹ 1,35,324.00	CPWD SOR
Roof finishing	sqm	Bitumen Paint + 18mm Clay brick tiles+25mm Lime Mortar + 25 mm EPS insulation	332	368 (Unit cost of EPS insulation)	₹ 22,63,826.00	DPR Serial No:VIII
Shading device	sqm	Horizontal shading device + Vertical fins for 2 windows Bedroom and Kitchen (E&W) windows (0.3*1.3m)	665.2	₹ 558.94	₹ 3,71,806.89	CPWD SOR
<b>Total Material Cost (Rs./-)</b>					<b>₹ 53,30,603.45</b>	

## Cost Implication

### Cost for construction for Case 3: INR 53,31,892

Case-3						
	Unit	Specification	Quantity	Unit cost (Rs./-)	Costing/block (Rs./-)	Source
Wall	cum	200 mm AAC	369.84	₹ 4,960.00	₹ 18,34,406.40	CPWD SOR
Plaster	sqm	15mm external al	1608	₹ 271.42	₹ 4,36,443.36	DPR Serial No:48
Plaster	sqm	12mm internal	1608	₹ 179.60	₹ 2,88,796.80	DPR Serial No:49
Window (glass)	sqm	Casement Windows, SGU; SHGC = 0.56 + ventilators on top of two windows; Bedroom and Living room window (0.5*1.2m)	254.4	₹ 537.00	₹ 1,36,612.80	CPWD SOR
Roof finishing	sqm	Bitumen Paint + 18mm Clay brick tiles+25mm Lime Mortar + 25 mm EPS insulation	332	368 (Unit cost of EPS insulation)	₹ 22,63,826.00	DPR Serial No:VIII
Shading device	sqm	Horizontal shading device + Vertical fins for 2 windows Bedroom and Kitchen (E&W) windows (0.3*1.3m)	665.2	₹ 558.94	₹ 3,71,806.89	CPWD SOR
<b>Total Material Cost (Rs./-)</b>					<b>₹ 53,31,892.25</b>	



## Cost Implication

### Cost for construction for Case 4: INR 56,20,689

Case-4						
	Unit	Specification	Quantity	Unit cost (Rs./-)	Costing/block (Rs./-)	Source
Wall	cum	200 mm AAC	369.84	₹ 4,960.00	₹ 18,34,406.40	CPWD SOR
Plaster	sqm	15mm external + 10mm external	1608	₹ 451.02	₹ 7,25,240.16	DPR Serial No:48
Plaster	sqm	12mm internal	1608	₹ 179.60	₹ 2,88,796.80	DPR Serial No:49
Window (glass)	sqm	Casement Windows, SGU; SHGC = 0.56 + ventilators on top of two windows; Bedroom and Living room window (0.5*1.2m)	254.4	₹ 537.00	₹ 1,36,612.80	CPWD SOR
Roof finishing	sqm	Bitumen Paint + 18mm Clay brick tiles+25mm Lime Mortar + 25 mm EPS insulation	332	368 (Unit cost of EPS insulation)	₹ 22,63,826.00	DPR Serial No:VIII
Shading device	sqm	Horizontal shading device + Vertical fins for 2 windows Bedroom and Kitchen (E&W) windows (0.3*1.3m)	665.2	₹ 558.94	₹ 3,71,806.89	CPWD SOR
<b>Total Material Cost (Rs./-)</b>					<b>₹ 56,20,689.05</b>	

## Conclusion and Remarks

### Cost implication of proposed Cases

Base Case	Case 1	Case 2	Case 3	Case 4
56,24,385	51,71,657	53,30,603	53,31,892	56,20,689
NA	4,52,729	2,93,782	2,92,493	3,696
NA	8.05%	5.22%	5.20%	0.07%

It is recommended to go for Case 2;

- AAC wall
- 25 mm EPS roof insulation
- Casement windows with an increase in the size of the bedroom window

## Conclusion and Remarks

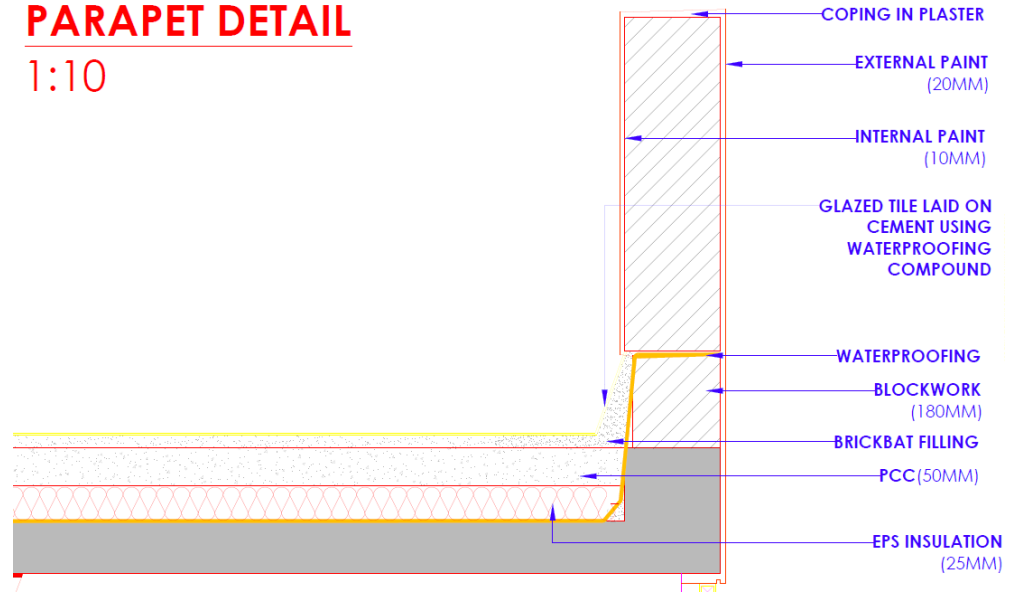
### ➤ AAC wall



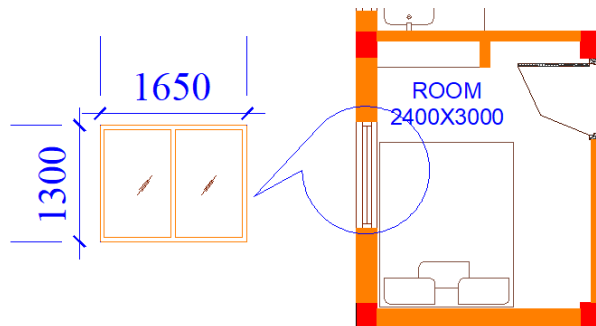
### ➤ 25 mm EPS roof insulation

#### PARAPET DETAIL

1:10



### ➤ Casement windows with an increase in the size of the bedroom window



## Tender Inclusion

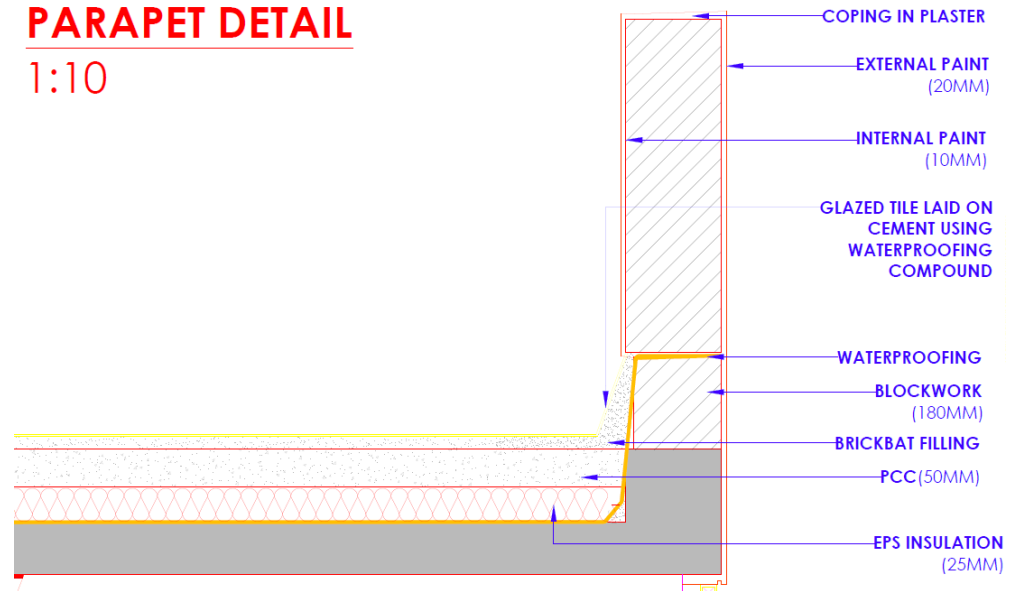
### ➤ AAC wall



### ➤ 50 mm EPS roof insulation

## PARAPET DETAIL

1:10



## Q&A

**Please fill the Feedback form**

**Thank you !**

**Presented by:**

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