GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

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

Ministry of Housing and Urban Affairs
Government of India

Azadi Ka Amrit Mahotsav

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RACHNA

RESILIENT, AFFORDABLE AND COMFORTABLE HOUSING THROUGH NATIONAL ACTION

Innovative Construction Technologies & Thermal Comfort for Affordable Housing

Training 73
02nd & 3rd August 2022
Vijayawada

Presented by CSB Cell - South

Introduction - GIZ

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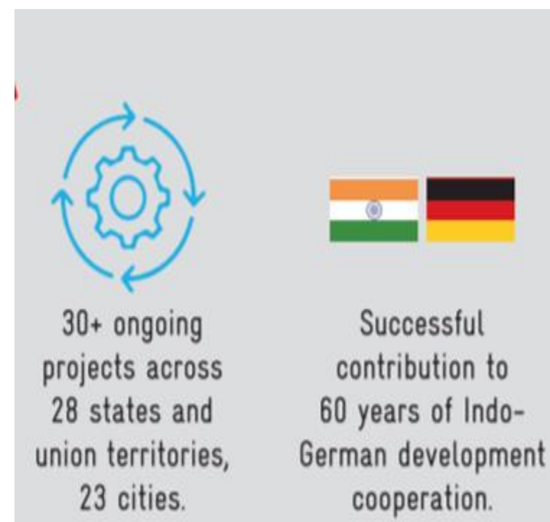
GIZ

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.

german cooperation
DEUTSCHE ZUSAMMENARBEIT

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	Sustainable Urban and Industrial Development
We support our partners in developing framework conditions for the promotion of renewable energy, improved energy efficiency and rural energy access.	We support the development of urban and industrial areas to become cleaner, more liveable, inclusive, climate-friendly and resilient.
• 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	• 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

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MoHUA + GIZ

MoHUA
(Ministry of Housing & Urban Affairs)

Government of India

+

GIZ
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Government of Germany

Indo-German Energy Program (IGEN)

IGEN Program: Climate Smart Buildings

- **Thermal Comfort Action Plan**
- **Standard / Guidelines**

- **Implementation of GHTC India**
- **Establishment of Cluster Cells**

Introduction – Climate Smart Buildings Cell

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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

Collection of drawings and other inputs at the Design Stage → **Technical Commercial feasibility analysis** → **Outputs & Recommendations through ENS and Simulations (softwares)** → **Specifications of Proposed strategies** → **Techno-Economic Feasibility Report** → **Acceptance & Implementation of recommendations** → **Monitoring & Verification of Thermal Comfort during & post construction**

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

Construction Technology India: Expo-cum-Conference	Identifying and Mainstreaming Proven Demonstrable Technologies for the construction of **Light House Projects**	Identifying Potential Future technologies for Incubation and Acceleration Support through **ASHA-India (Affordable Sustainable Housing Accelerators)**

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.

Ministry of Housing and Urban Affairs
Government of India

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.**

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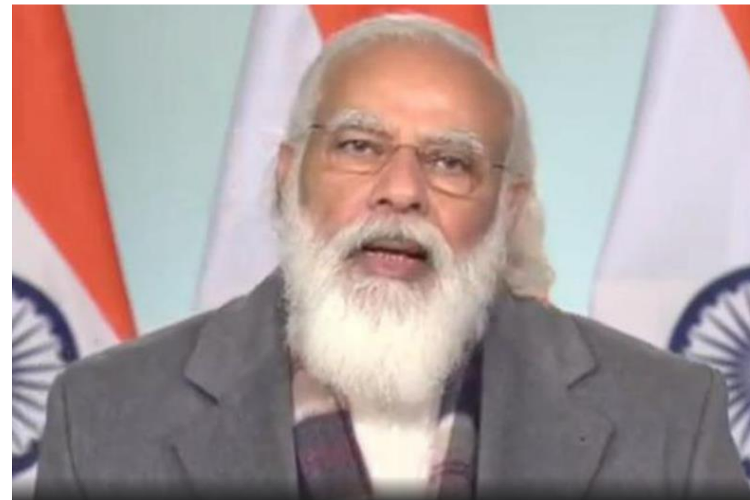
Light House Projects

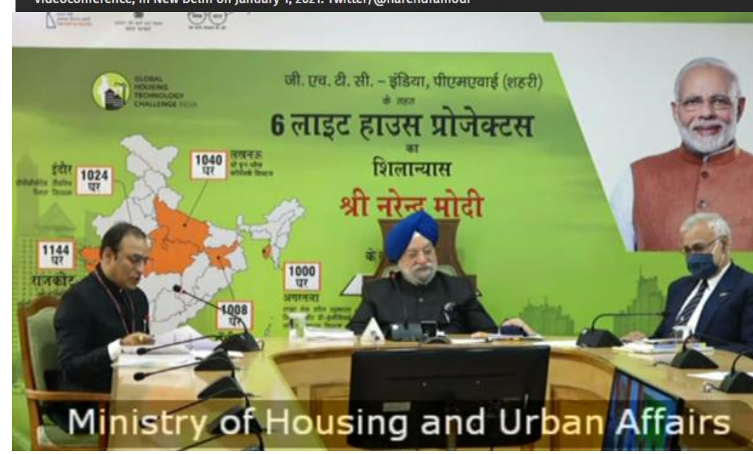
As a part of **GHTC- India**, six Light House Projects (LHP) consisting of about 1,000 houses each with physical & social infrastructure facilities is being constructed at six places across the country namely

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



Prime Minister Narendra Modi during the foundation laying ceremony of Light House Projects in six States, via videoconference, in New Delhi on January 1, 2021. Twitter/@narendramodi



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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

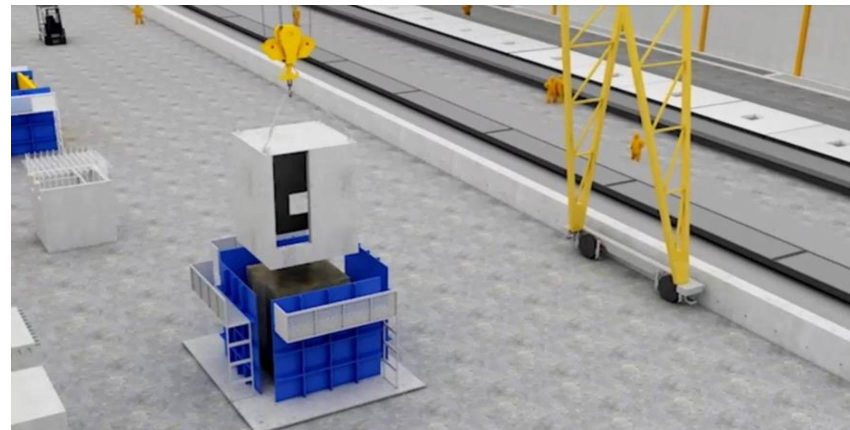
6.Stay In Place Formwork System

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



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LHP Rajkot

Monolithic Concrete Construction using Tunnel Formwork

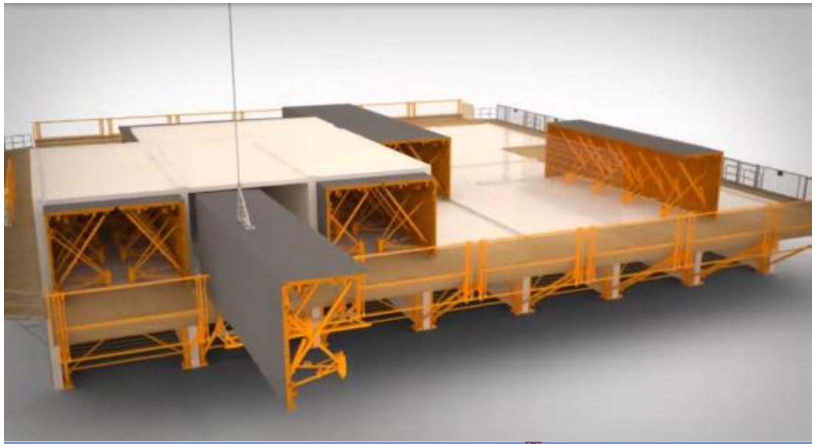
- In 'TunnelForm' technology, concrete walls and slabs are cast in one go at site giving monolithic structure using high-precision, re-usable, room-sized, Steel forms or moulds.
- This system uses customized engineered steel formwork consisting of two half shells which are placed together and then concreting 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 requited 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 are 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

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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**

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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
Total Carpet Area				26.78

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 requited time and then these components are ready for transportation and erection at site.
- These precast components are installed at site by crane and assembled 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

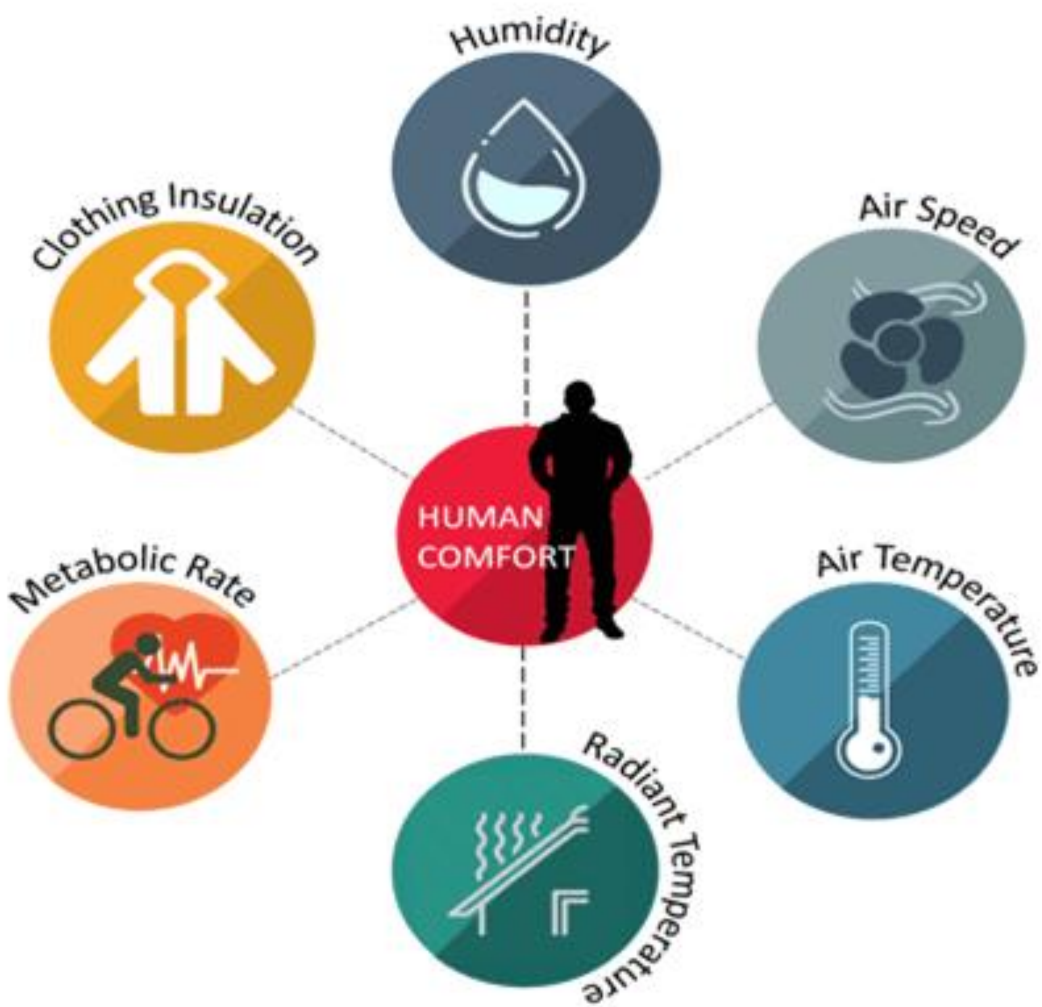
Thermal Comfort – Definition

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:

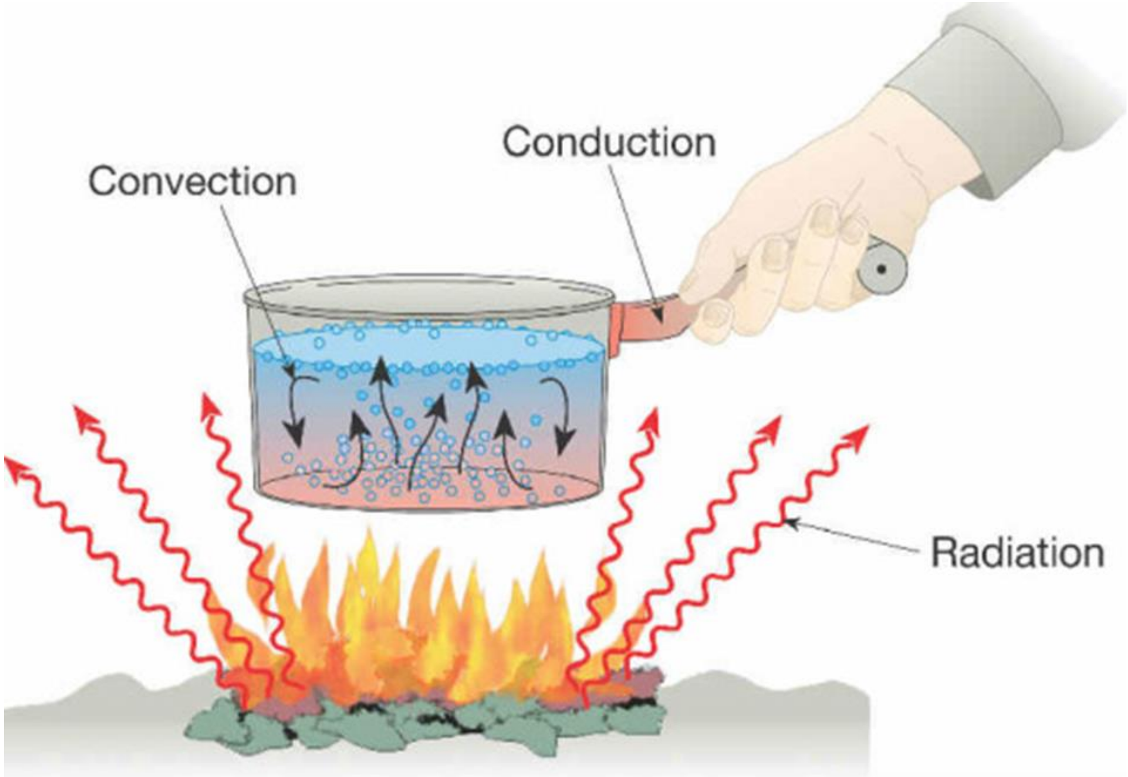
- **ASHRAE 55** (American Society of Heating, Refrigerating, and Air Conditioning Engineers)
- **ISHRAE** (Indian Society of Heating, Refrigerating, and Air Conditioning Engineers)
- **IMAC** (Indian Model for Adaptive Thermal Comfort)

Thermal Comfort – Indices



Source: https://www.simscale.com/blog/2019/08/what-is-ashrae-55-thermal-comfort/

Mode of Heat Transfer – Influencing Thermal comfort



Thermal Comfort Indices – Metabolic Rate

Source: https://www.simscale.com/blog/2019/08/what-is-ashrae-55-thermal-comfort/

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 m^2K/W
  - Winter clothing : 1.0 clo
  - Summer clothing : 0.5 clo

Trouser+ Half Sleeves	Jeans + Blazer	Woollen Clothes

0.6 clo	1.0 clo	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

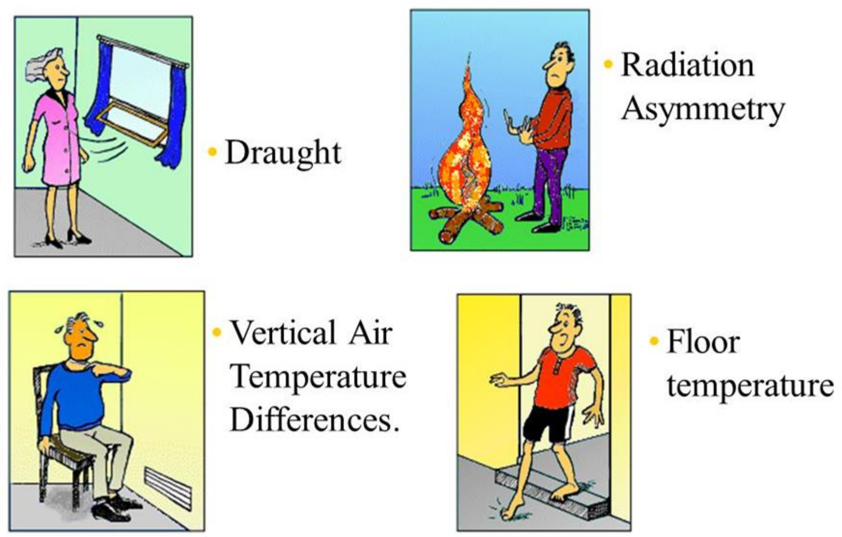
- The local thermal discomfort is **unwanted cooling or heating** on a particular part of an occupant's body

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)



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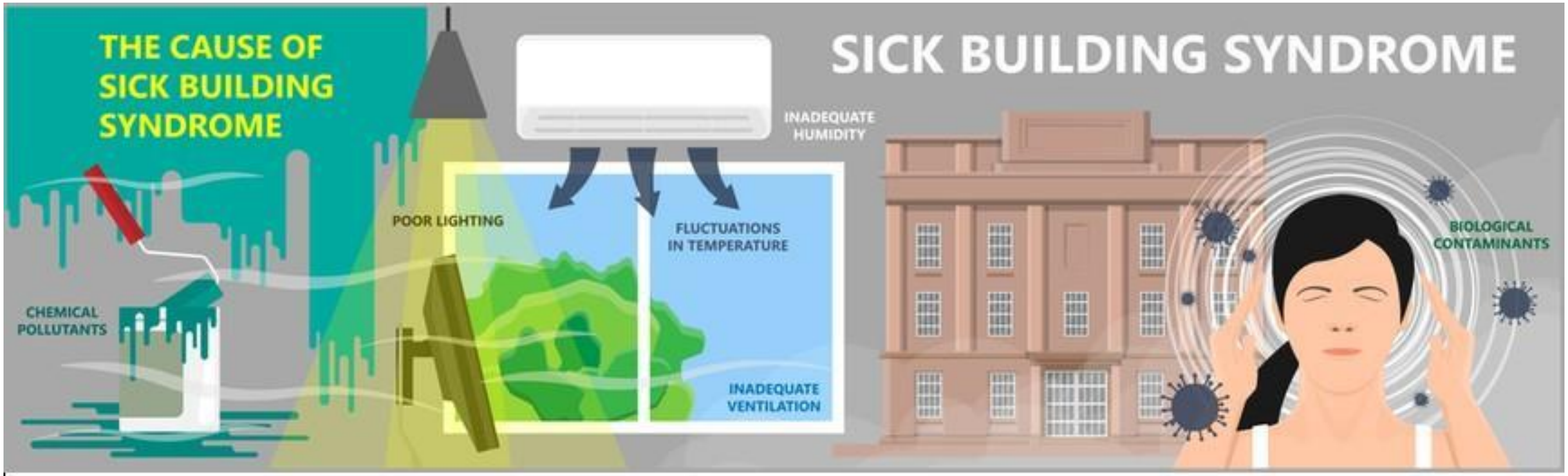
Thermal Discomfort – Sick Building Syndrome

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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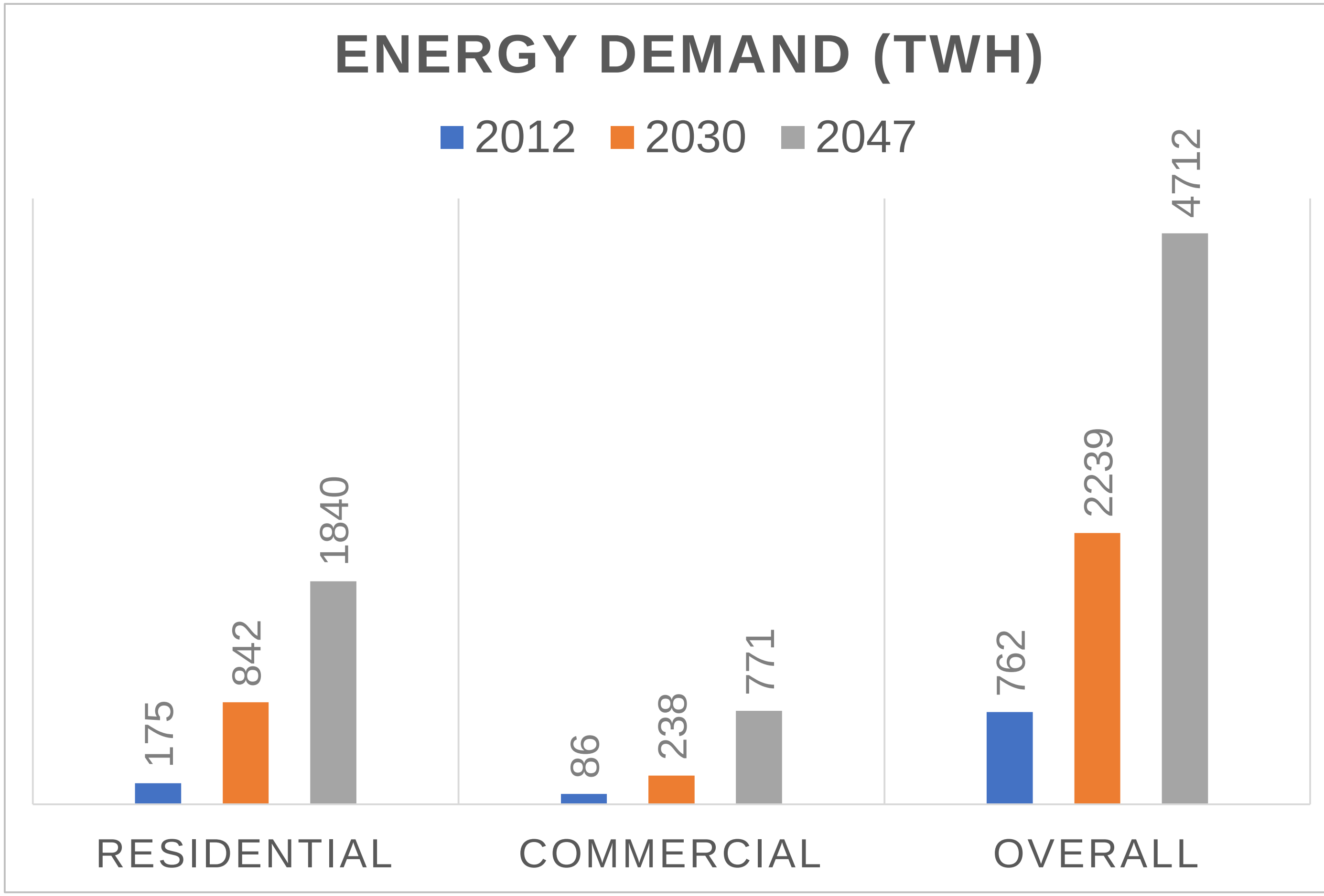
Necessity of Thermal comfort in Affordable Housing

Affordable Housing Demand

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

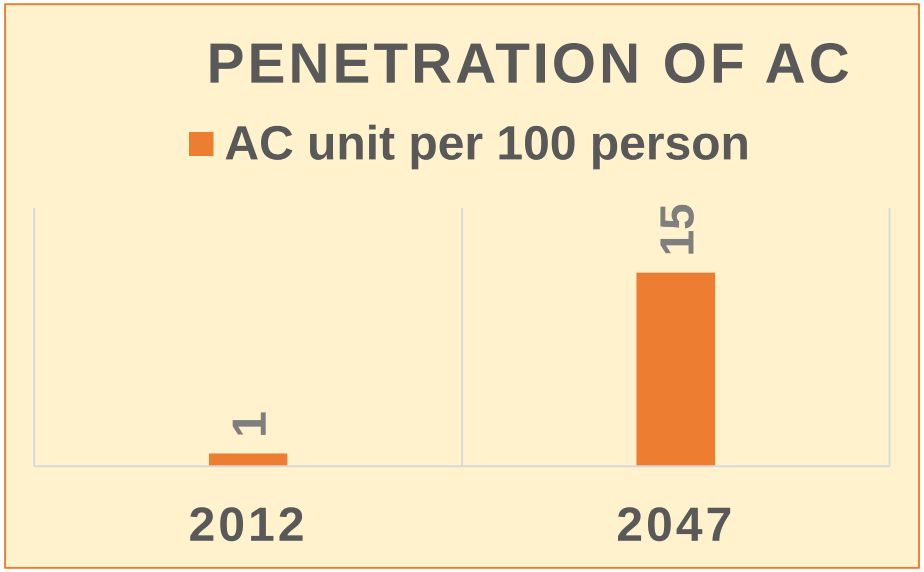
Source: India 2020 Energy Review Policy

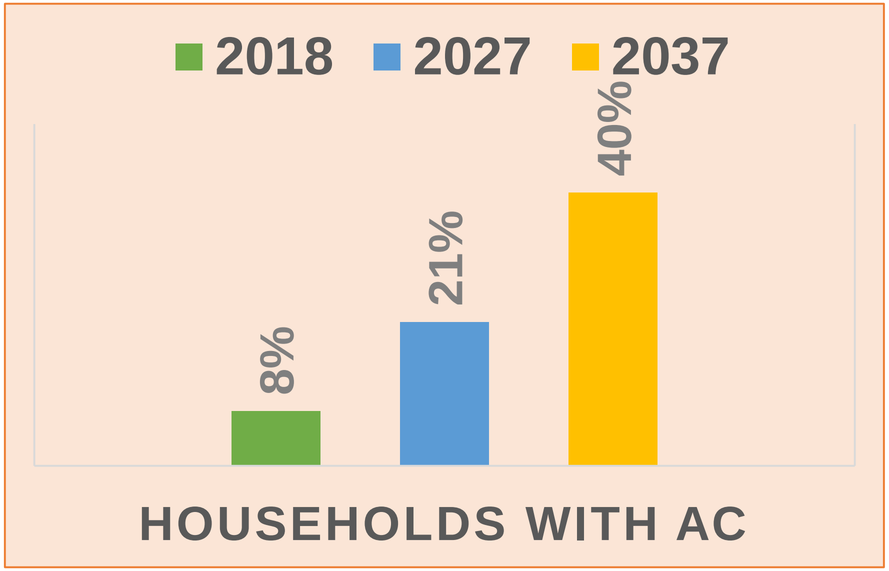


Source: NITI Aayog 2015

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.

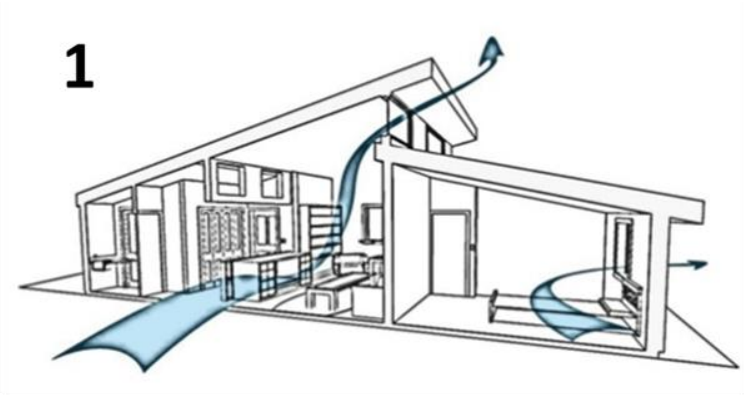
Climate appropriate and energy efficient building design for EWS and LIG segments.
Climate Smart Buildings (CSB)

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

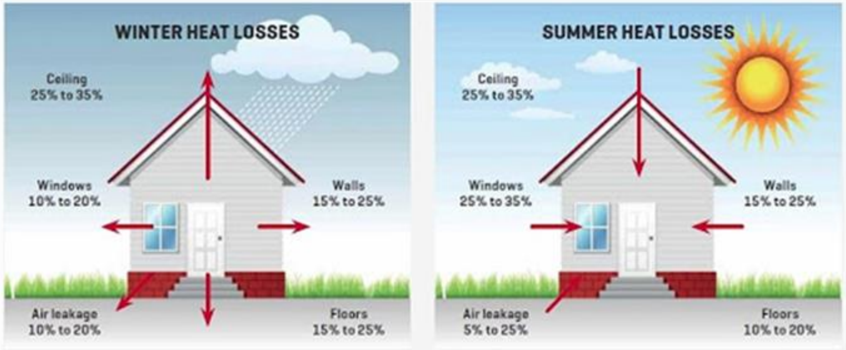
Thermal Comfort Improvement in a Building



1. For Adequate natural ventilation potential for thermal comfort

2. For adequate day light for visual comfort

3



3. Limit heat gains / heat loss for energy efficiency

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Ministry of Housing and Urban Affairs
Government of India

Azadi Ka Amrit Mahotsav

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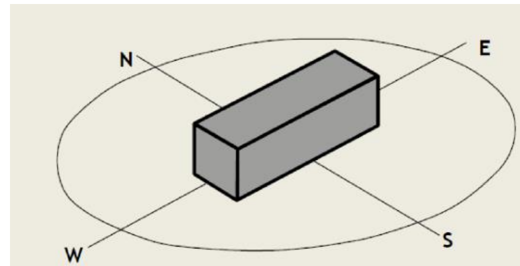
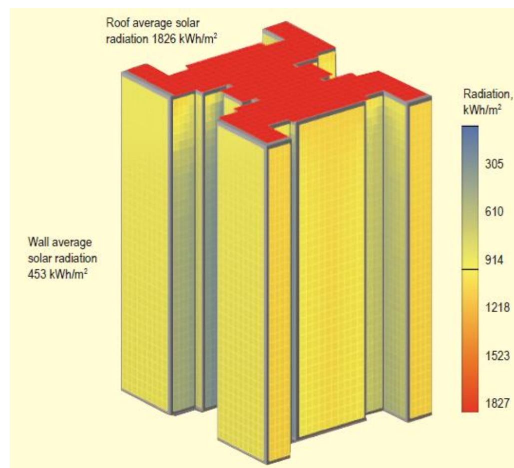
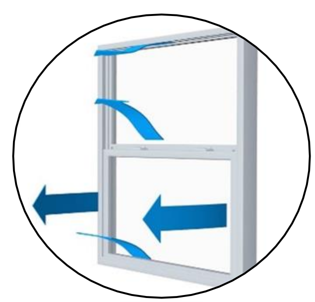
Thermal Comfort Improvement Strategies

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



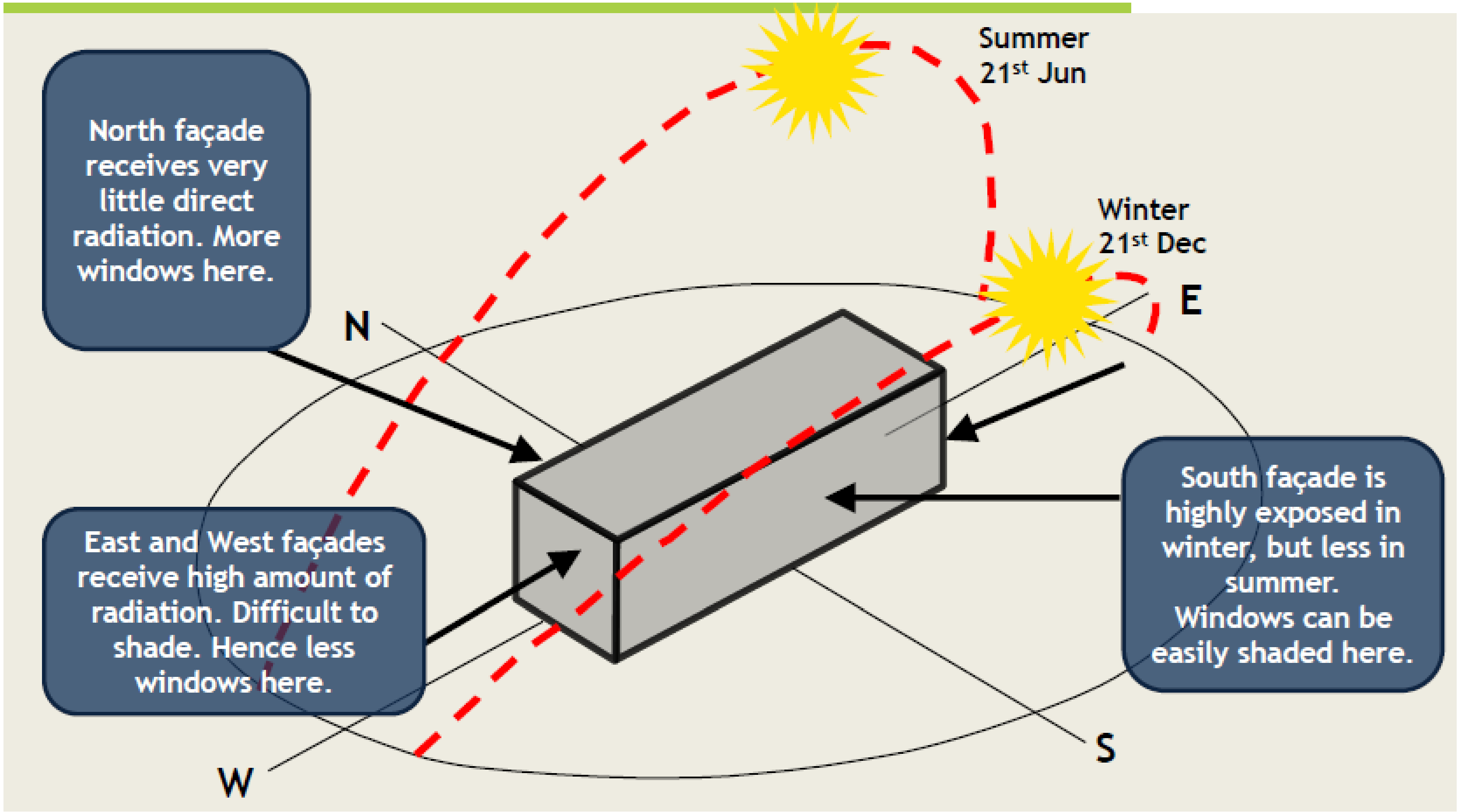




Active Strategies

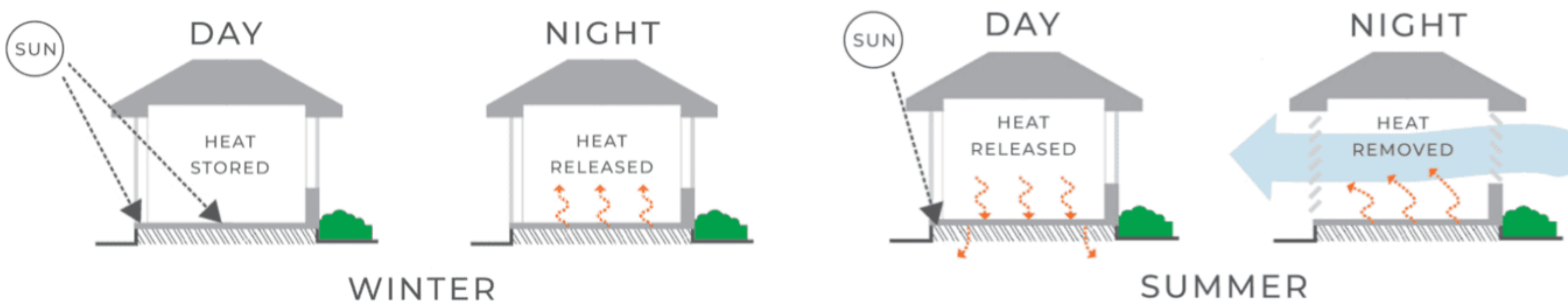
1. Renewable Energy
2. Direct / Indirect Evaporative Cooling
3. Cool roofs

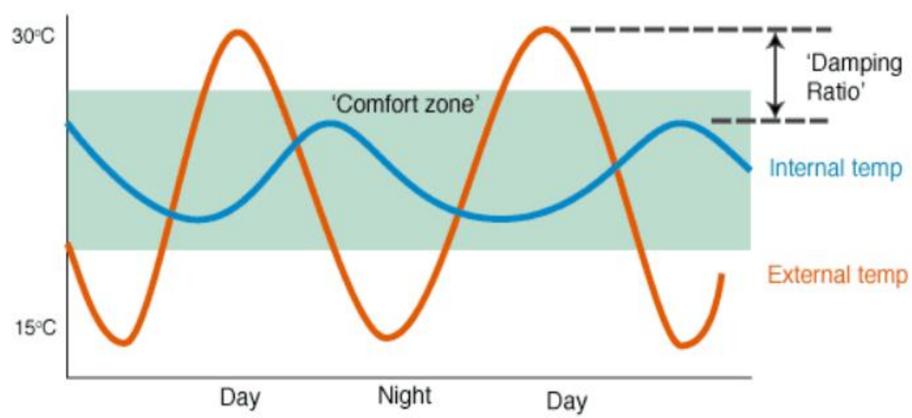
Passive Measures - Orientation



Passive Measures - Thermal Mass

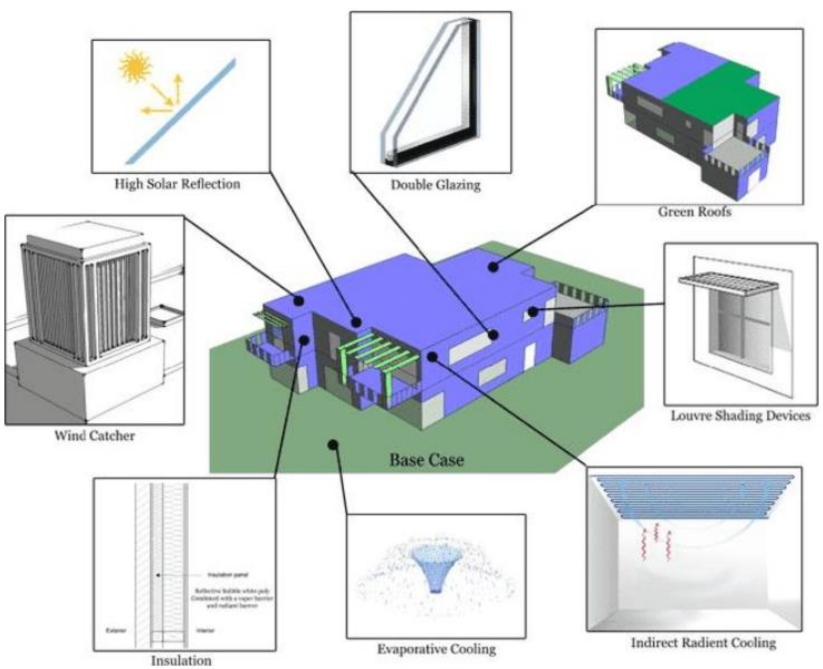
- Denser thermal mass materials are more effective passive solar materials. Thus, denser the material the better it stores and releases heat.
- Integrate thermal mass with an efficient passive solar design, by considering the placement of added mass.
- Do not substitute thermal mass for insulation. It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

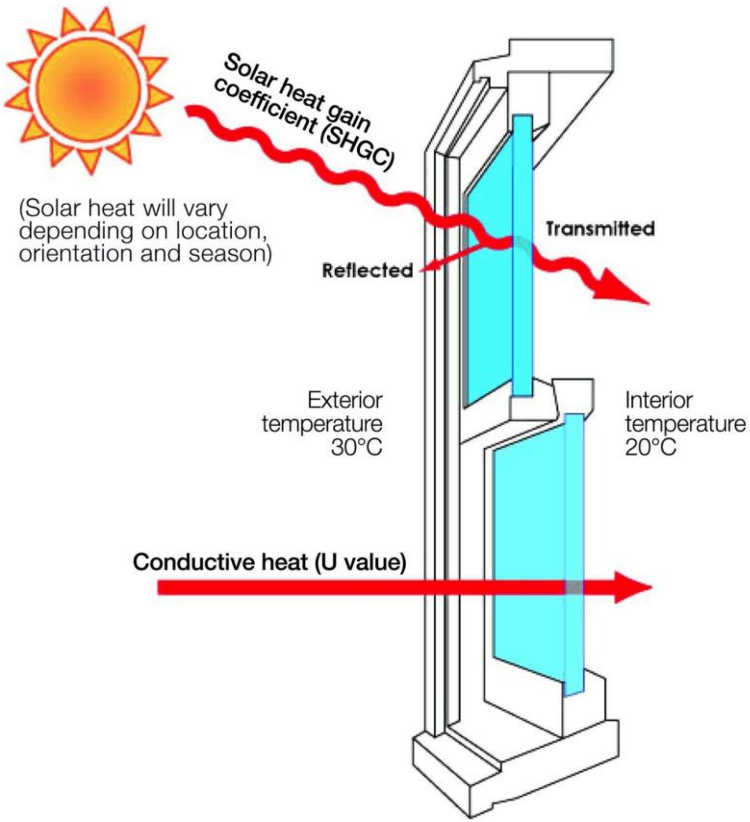


- Green roofs.
- Louvre and shading devices.
- Insulation
- Low energy cooling techniques
- Wind catchment and ventilation
- High solar reflective surface.

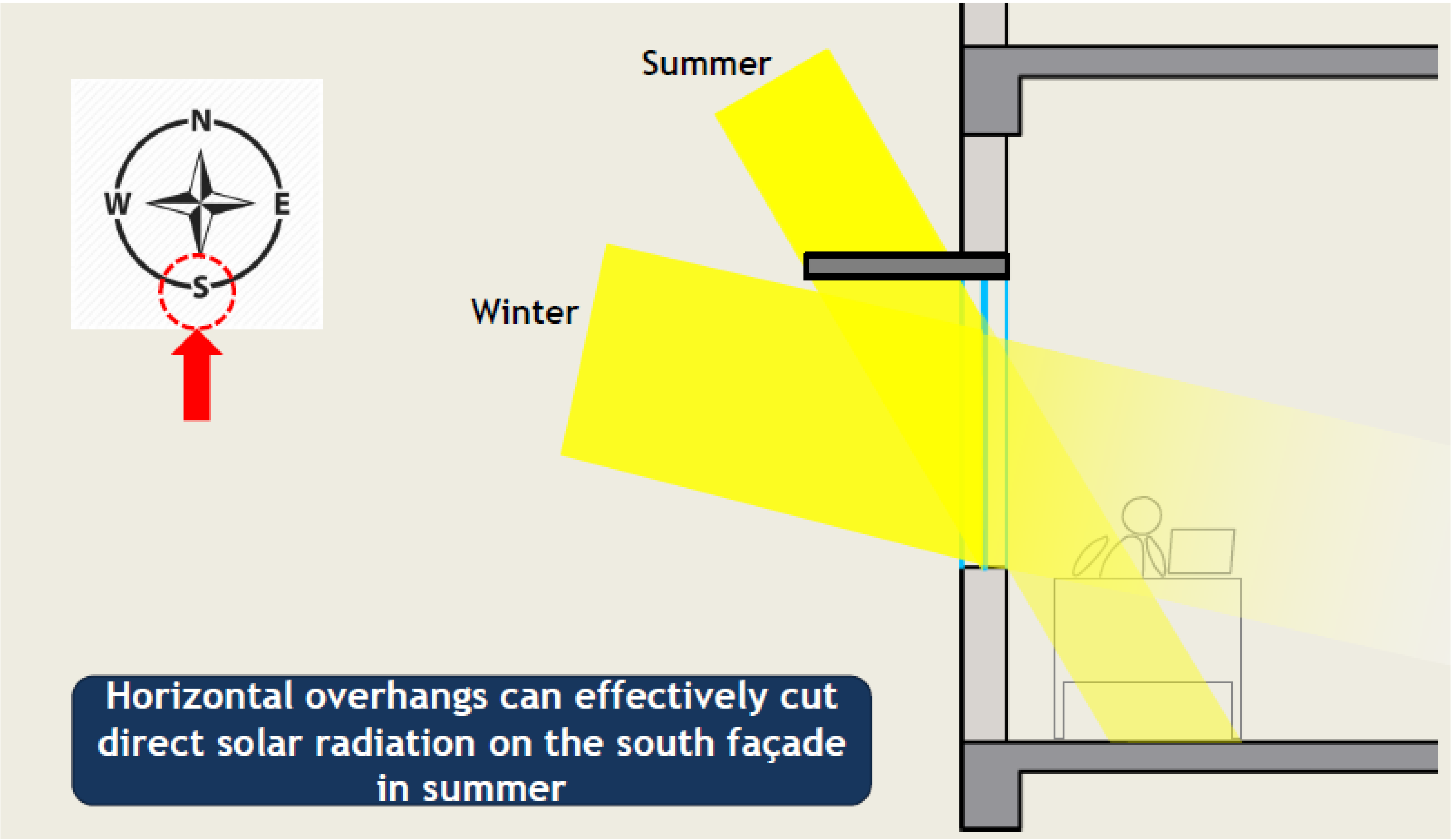
Passive Measures - Non Opaque Material Properties

- 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.



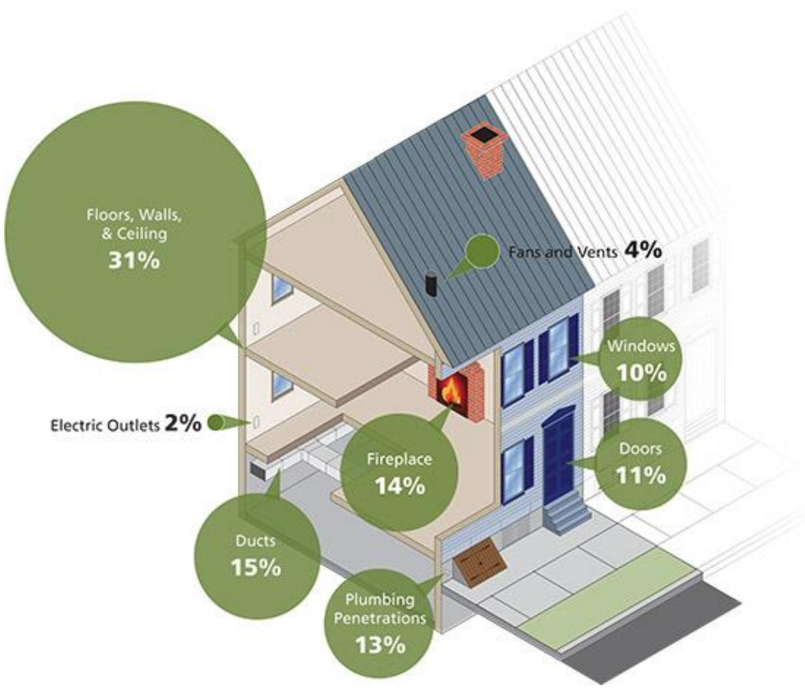
Passive Measures - Shading



Horizontal overhangs can effectively cut direct solar radiation on the south façade in summer

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:

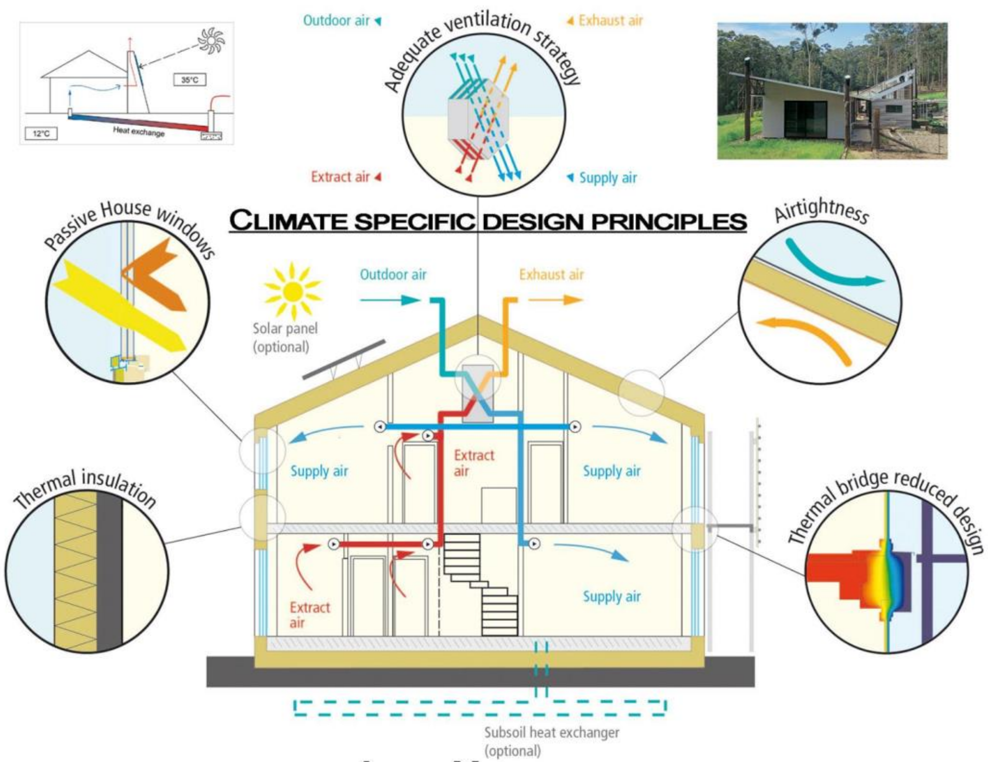
- Electrical outlets, switches, and ceiling fixtures
- Operable features of windows and doors – check for a loose fit
- Window and door frames where they meet the wall
- Wall or window-mounted air conditioners
- Plumbing, electrical, cable, and telephone penetrations
- Ducts in unconditioned spaces.

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.



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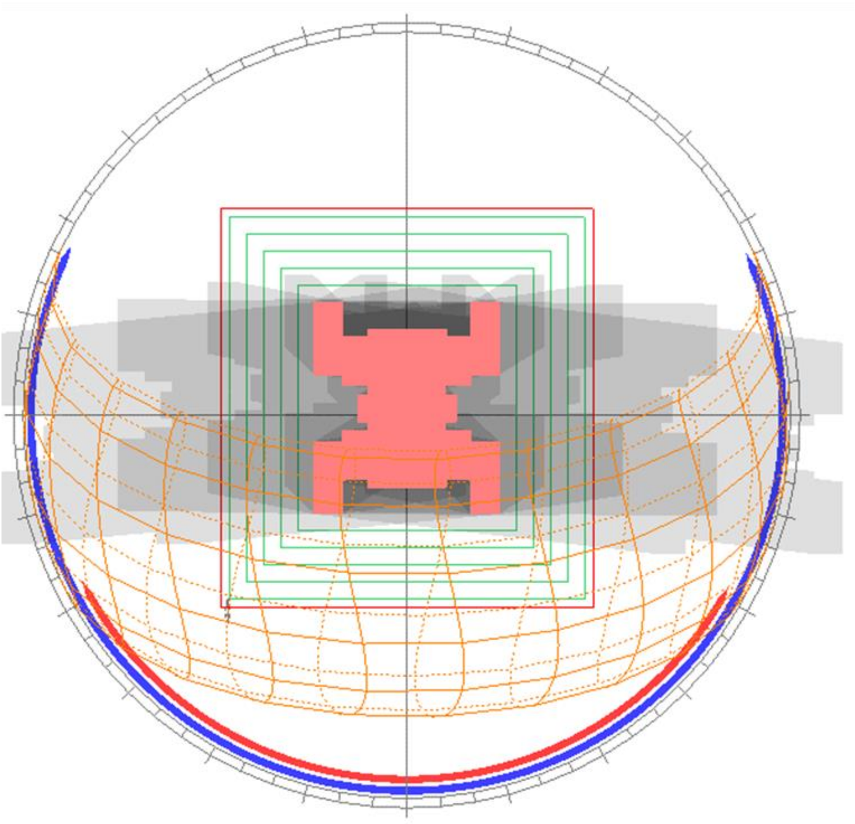
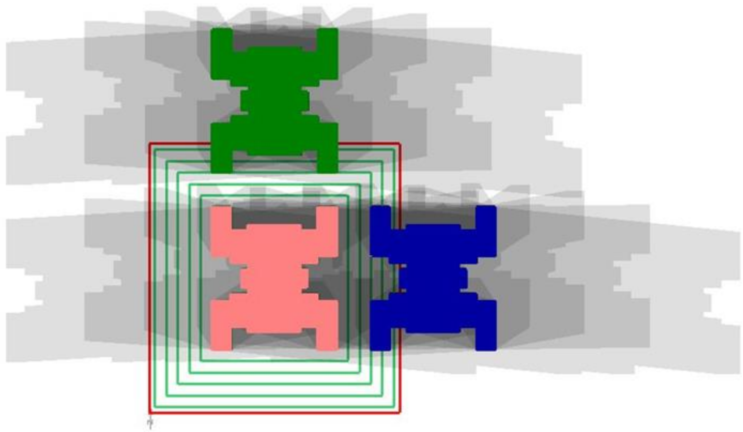
Passive Measures - Mutual Shading

Mutual Shading: June 21st

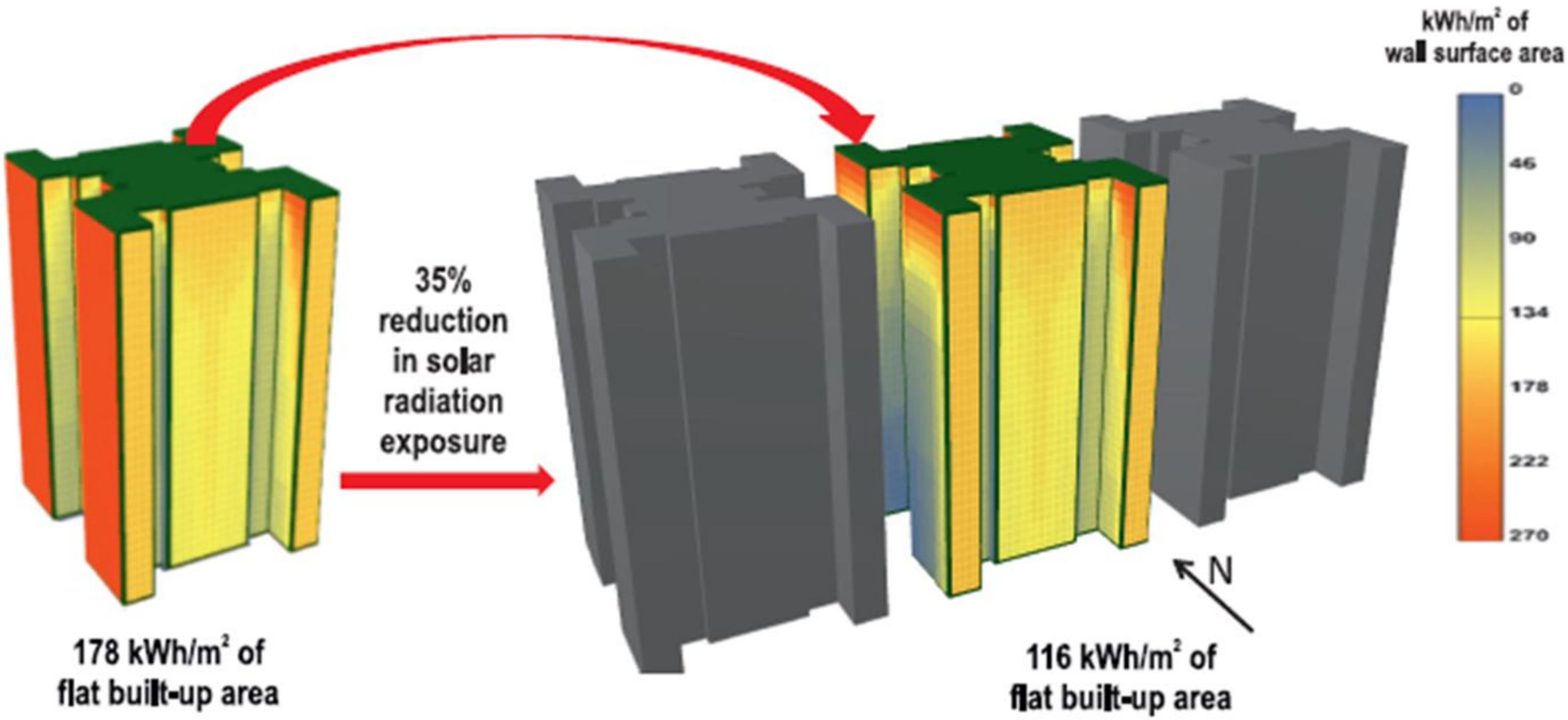
12 storey tower typology residential building

LATITUDE: 28.6°
LONGITUDE: 77.2





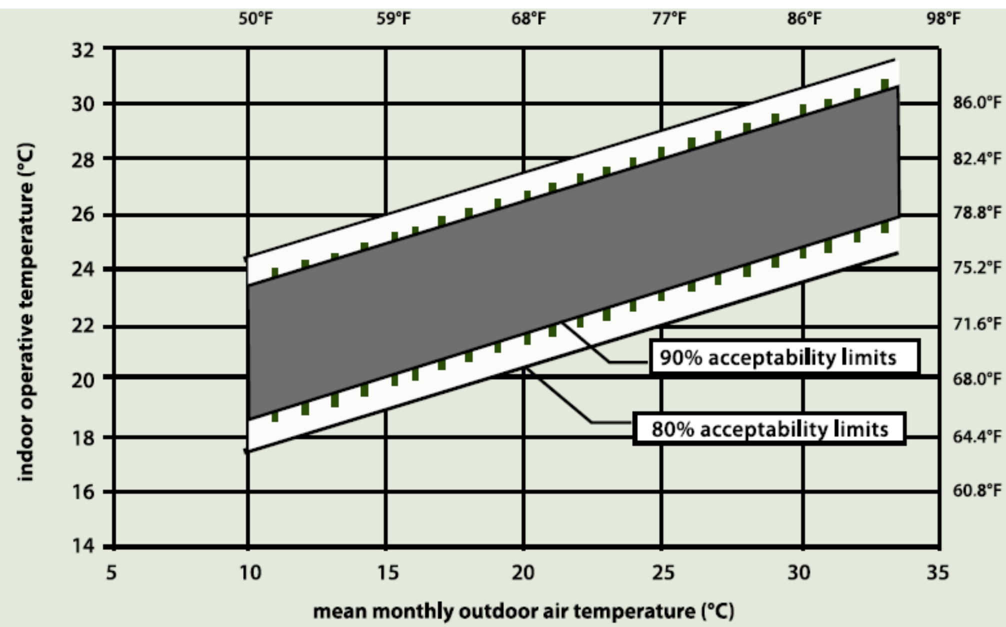
Passive Measures - Quantitative Impact of Mutual Shading



Session 3: Thermal Comfort Models

Thermal Comfort Standard – IMAC R

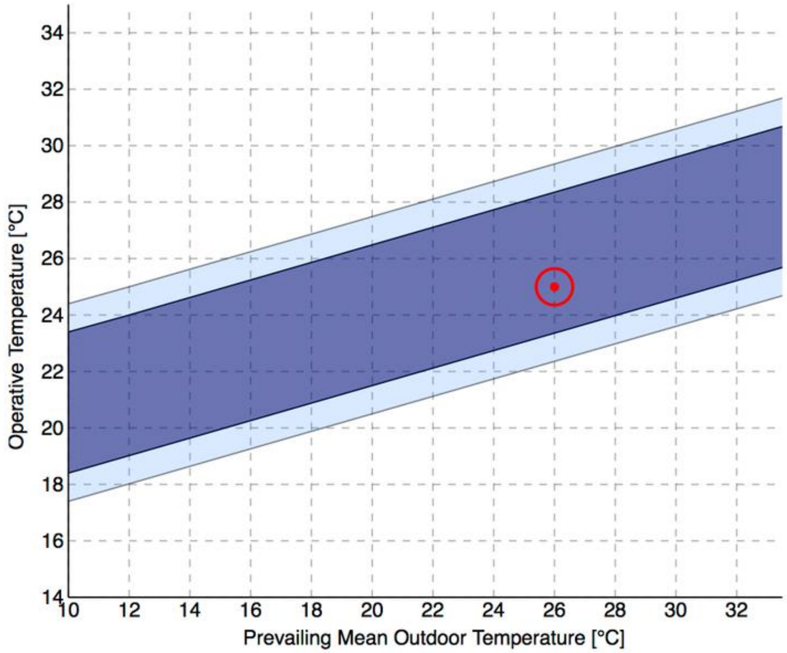
Indian Model for Adaptive Thermal Comfort (IMAC) models for neutral temperature and acceptability limits for naturally ventilated residential buildings through an empirical field study specific to the Indian context. It offers an energy-efficient pathway for the building sector without compromising occupant 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 ^{0}C RH 60%

Winter design conditions: 20.0 to 23.9 ^{0}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.

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.)

☐ Short-Sleeve Shirt	☐ Dress	☐ Nylons
☐ Long-Sleeve Shirt	☐ Shorts	☐ Socks
☐ T-shirt	☐ Athletic Sweatpants	☐ Boots

STANDARD ASHRAE®

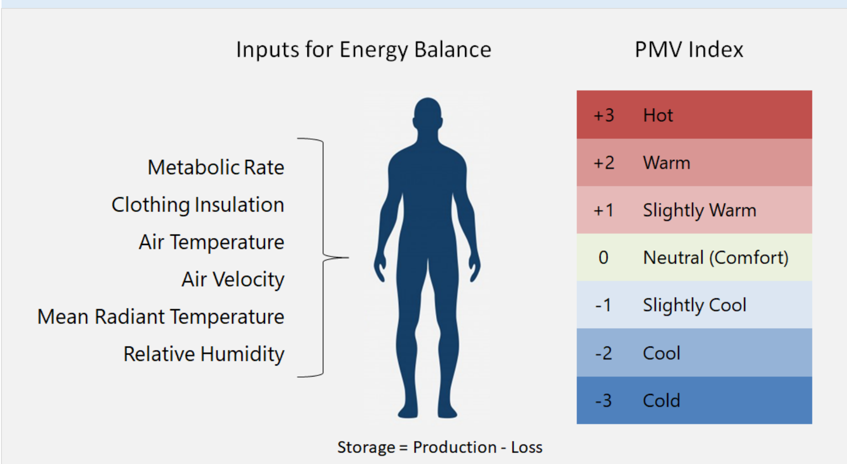
ANSI/ASHRAE Standard 55-2020
(Supersedes ANSI/ASHRAE Standard 55-2017)
Includes ANSI/ASHRAE addenda listed in Appendix N

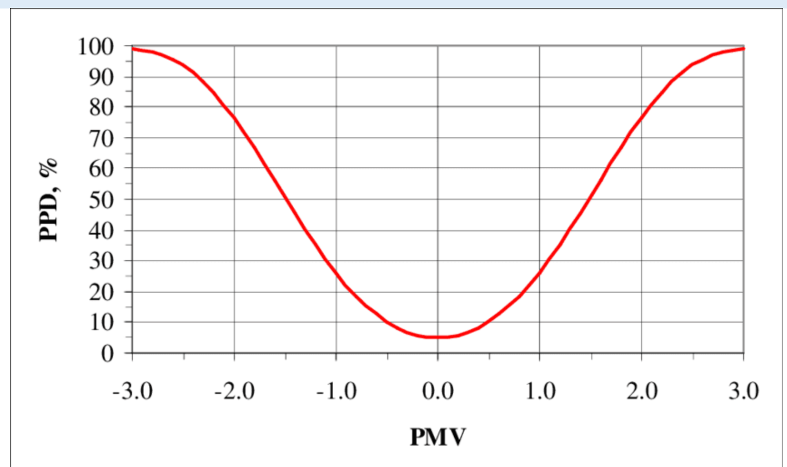
Thermal Environmental Conditions for Human Occupancy

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

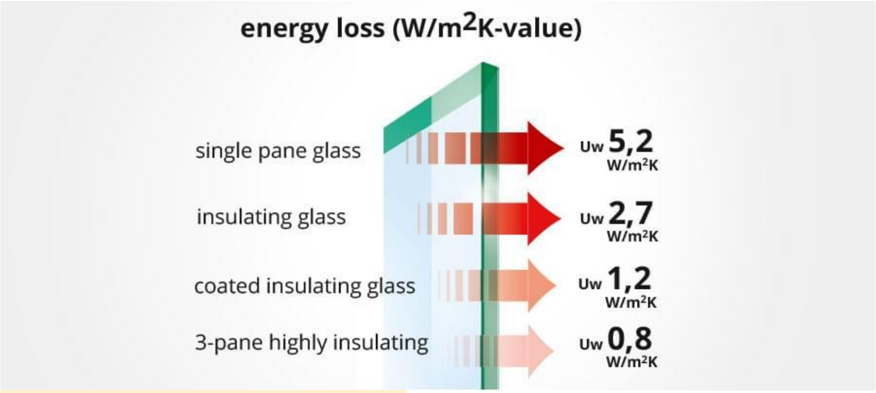
Wall materials	U Value (W/sqmK)
150 mm RCC (No plaster)	3.77
200 mm Solid Concrete Block with plaster on both sides	2.8
230 mm Brick with plaster on both sides	1.72-2.24
200 mm Autoclaved Aerated Concrete (AAC) with plaster on both side	0.77
300 mm Autoclaved Aerated Concrete (AAC) with plaster on both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

Thermal Comfort Improvement through Materials

EPS Insulation

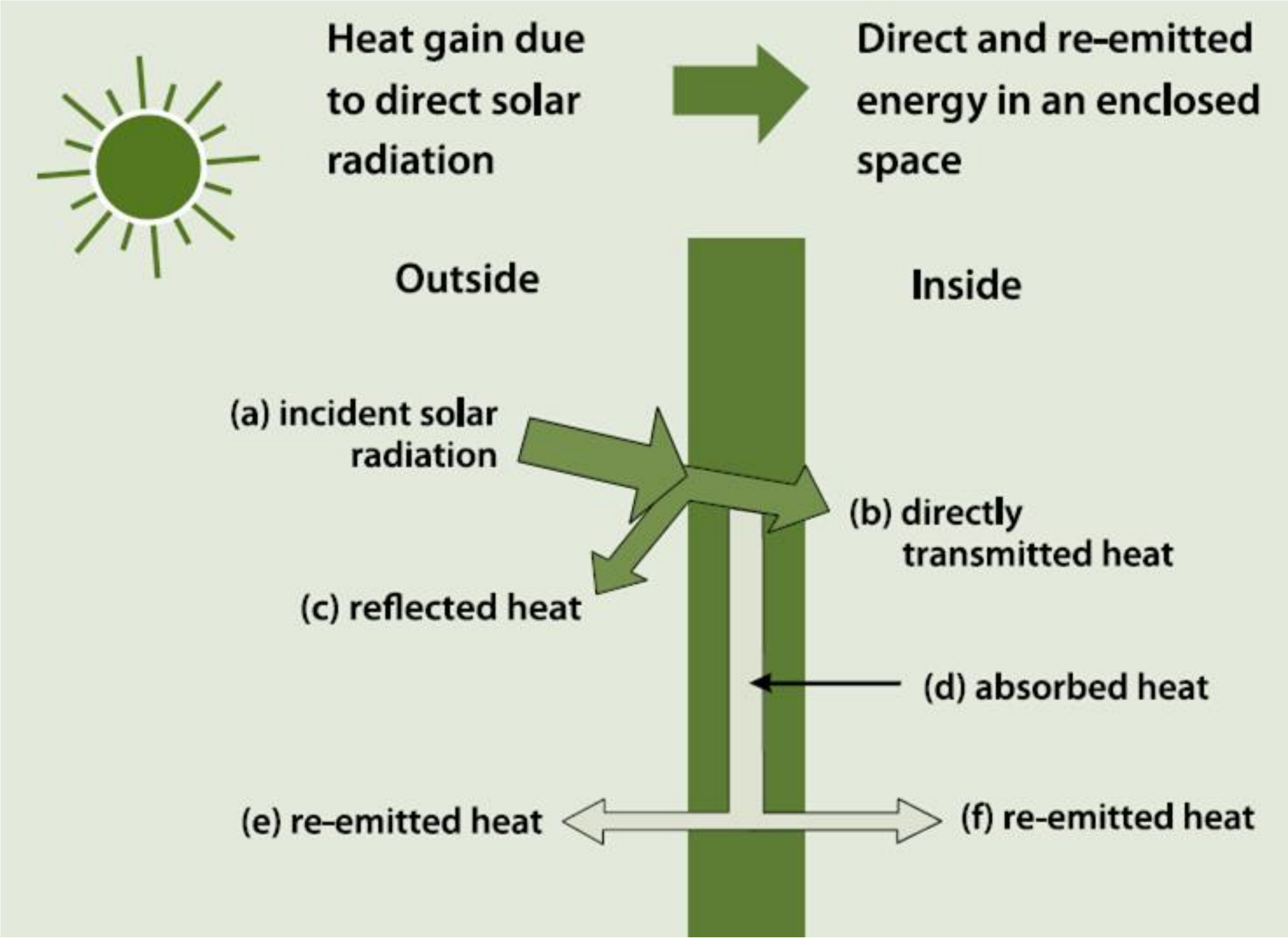
XPS Insulation

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??

VLT – Visual Light Transmission

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

SHGC – Solar Heat Gain Coefficient

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

Selectivity

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

Case Study

Case Study : Smart Ghar, Rajkot

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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 m²*
- 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*

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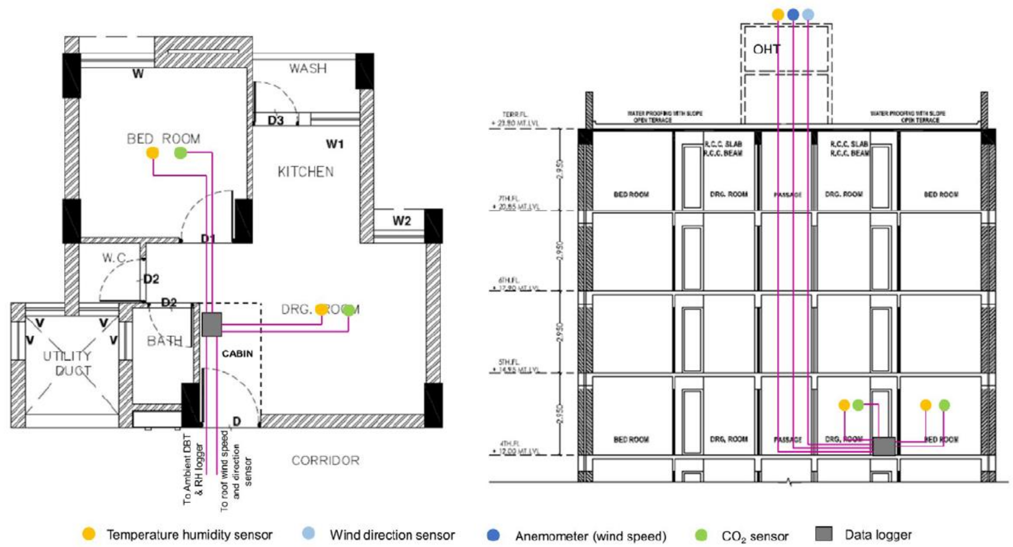
Case Study : Smart Ghar, Rajkot

Validation by Software

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

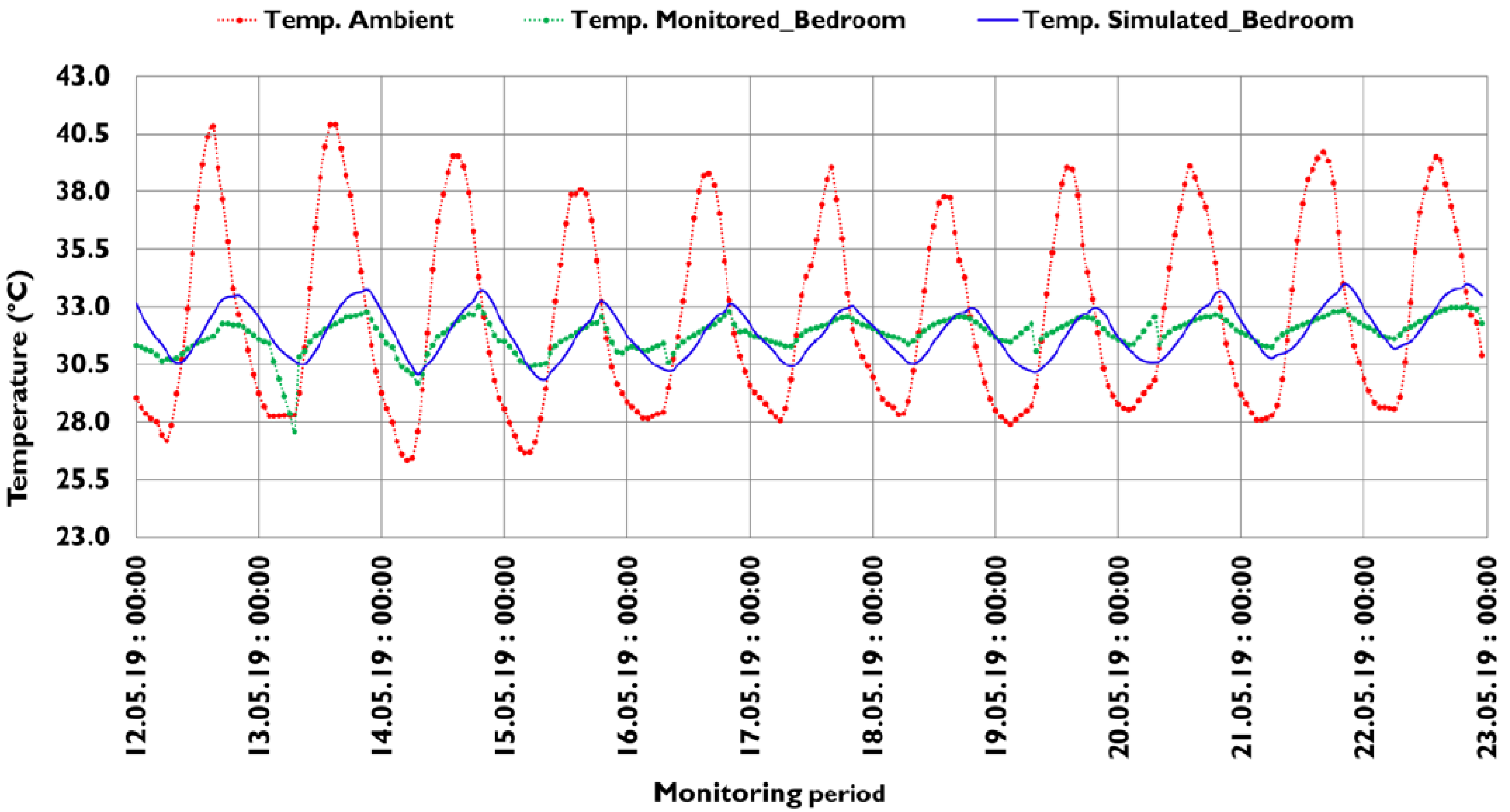


Results

- 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

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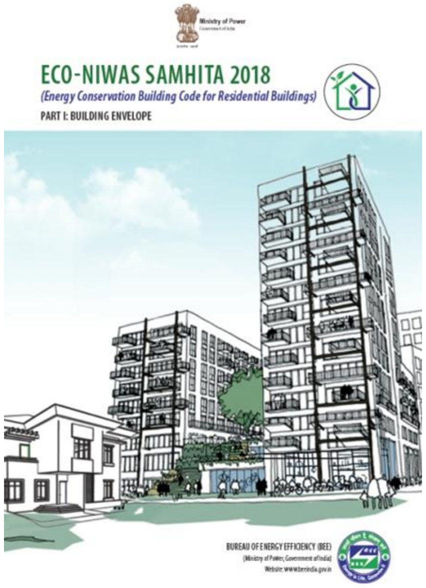
Eco Niwas Samhita (ENS)

BEE (BUREAU OF ENERGY EFFICIENCY)	+	**GIZ** (Deutsche Gesellschaft für Internationale Zusammenarbeit)
Government of India		**Government of Germany**



Eco Niwas Samhita Part 1

Launch of Eco Niwas Samhita in December 2018

Eco Niwas Samhita (ENS)

Scope of ENS

New building

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

Mixed Land Use

- Residential part of "Mixed Land-use building projects" with (Plot area ≥ 500Sqm) built up area of 800 sqm/ Connected load ≥ 35kW

Additions

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

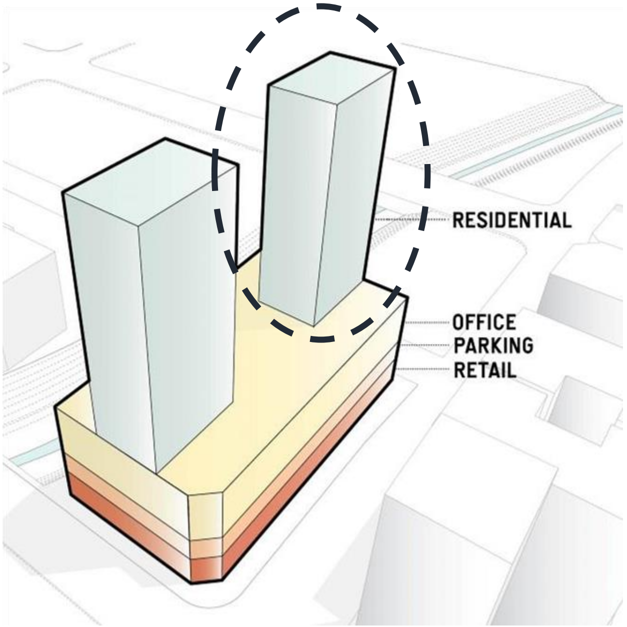
Alterations

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

Eco Niwas Samhita (ENS)

The code is applicable to

(a)Residential Buildings with **plot area ≥ 500m²**



(b) Residential part of **"Mixed Land-use building projects" built on plot area of ≥ 500m².**

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

+

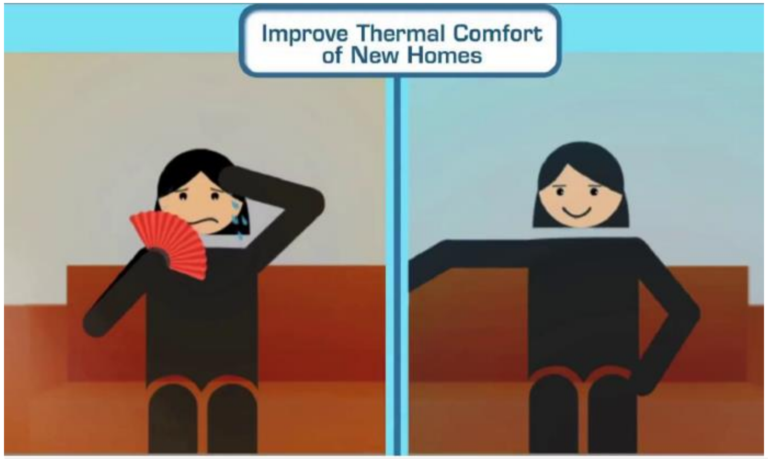
Indoor Electrical End Use
- Indoor Lighting
- Automatic Lighting Shutoff
- Occupancy Sensors
- Ceiling Fan Star Labelling
- Service Hot Water
- Air Conditioner system, sizes, efficiencies and controls

+

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_2** equivalent abatement

ENS – Part 1 – Building Envelope

Performance Standards for Building Envelope

Performance standard	Purpose
3.1 Openable Window to Floor Area Ratio (WFR_{op})	For Natural Ventilation
3.2 Visible Light Transmittance (VLT)- Derived from WWR	For Day Light Potential
3.3 Thermal Transmittance of Roof (U_{roof})	For Thermal Transmission
3.4 Residential Envelope Transmittance Value (RETV)	For Thermal Transmission
3.5 Thermal Transmittance for Cold Climate ($U_{envelope,cold}$)	For Thermal Transmission

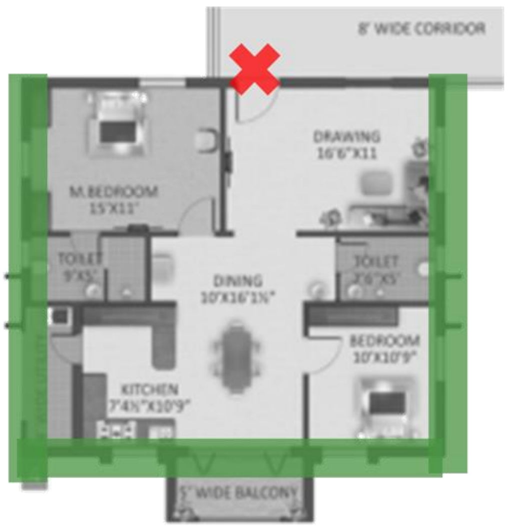
ENS – Part 1 – Building Envelope

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

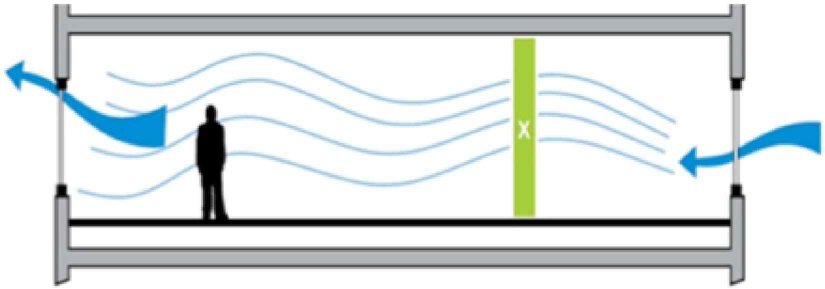
- Total Internal Area of the habitable space
Balconies - Excluded

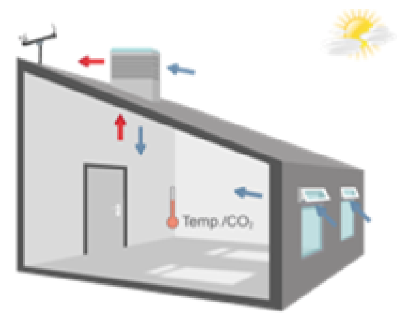
ENS – Part 1 – Building Envelope

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

Minimum WFRop helps in

- Natural Ventilation
- Improvement in Thermal Comfort
- Reduction in Cooling Energy Loads





Minimum requirement of window-to-floor area Ratio	
Climate Zone	**Minimum WFRop**
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 ≤ 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_{roof})

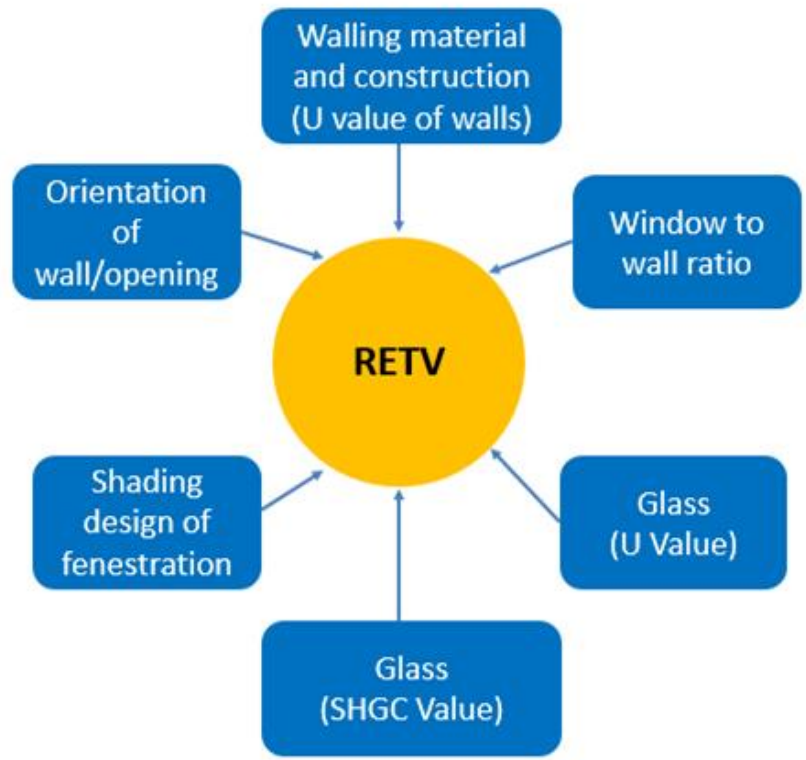
Thermal Transmittance of roof U_{roof} - Is the rate of transfer of heat through the roof structure (which can be a single material or an assembly), divided by the difference in temperature across that structure.

Limiting U_{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_{roof} value – 1.2 W/m².k

ENS – Part 1 – Building Envelope

3.4 Residential Envelope Transmittance (RETV)



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/m²**

ENS – Part 1 – Building Envelope

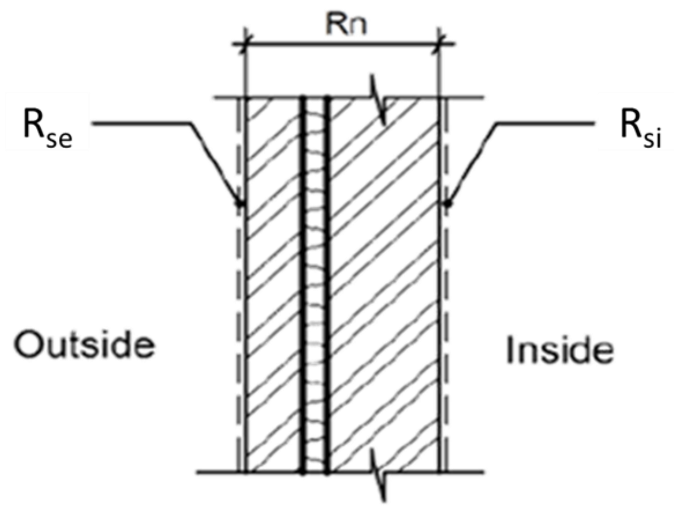
3.4 Thermal Transmittance Value (U-Value) Non Opaque

$$U = 1 / R_t$$

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

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

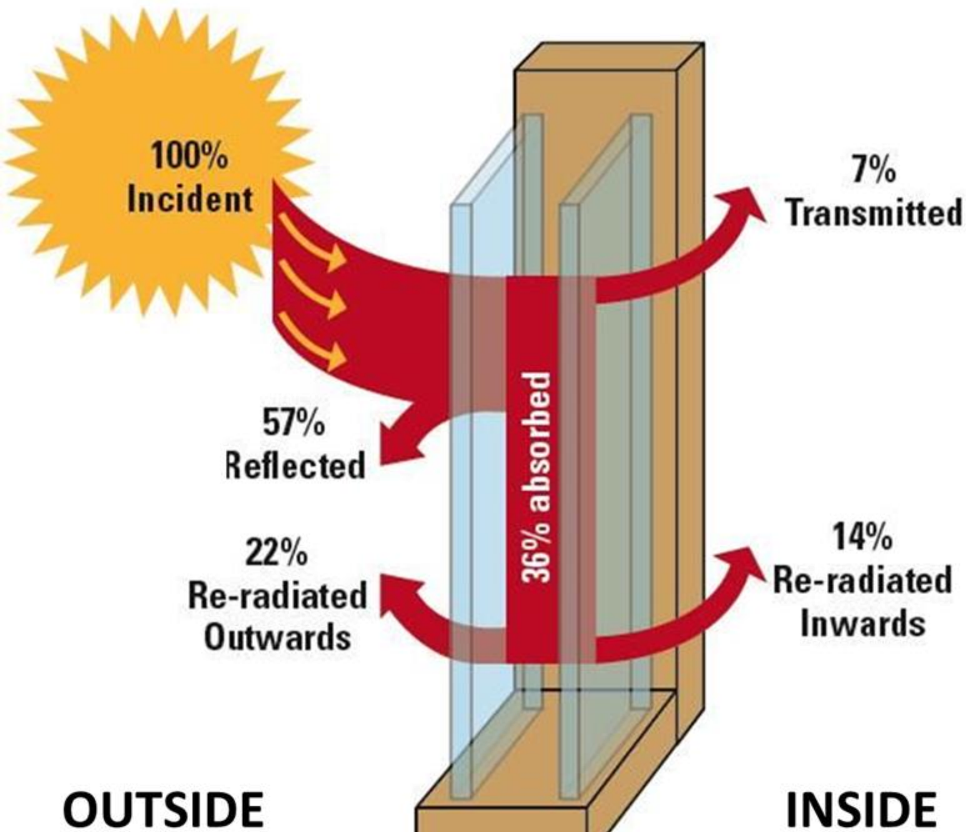
	Wall	Roof	
	All climatic Zones	Composite , Hot-Dry, Warm-humid, and Temperate climate	Cold climate
Rsi (m2.K/W)	0.13	0.17	0.10
Rse (m2.K/W)	0.04	0.04	0.04



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

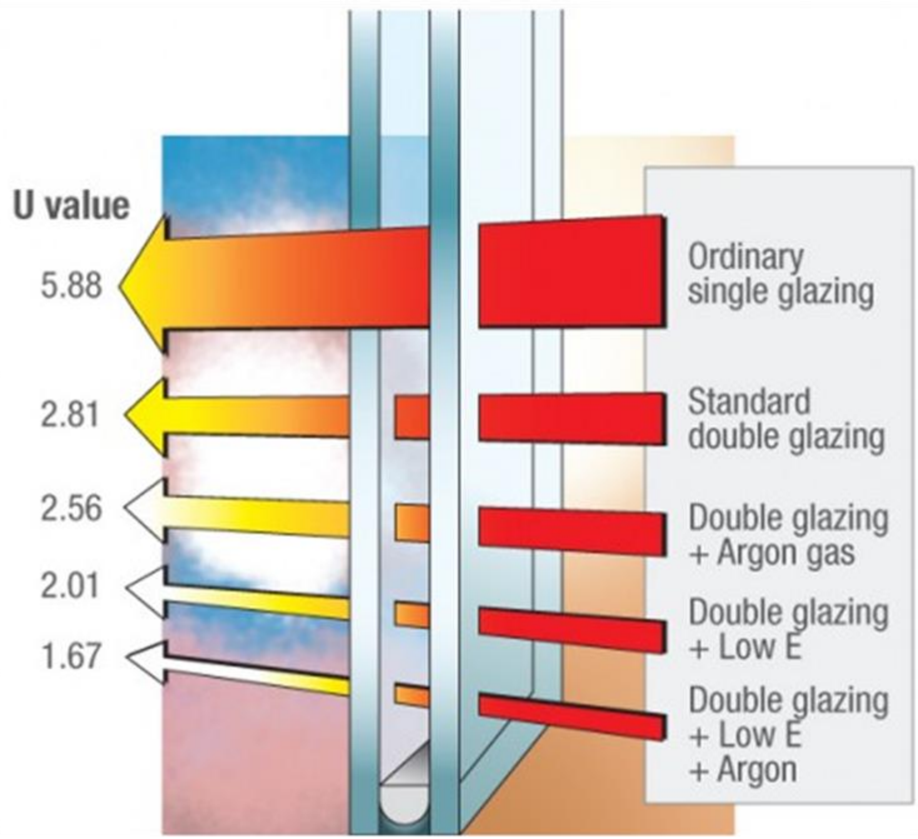
ENS – Part 1 – Building Envelope

3.4 Thermal Transmittance Value (U-Value) Non Opaque



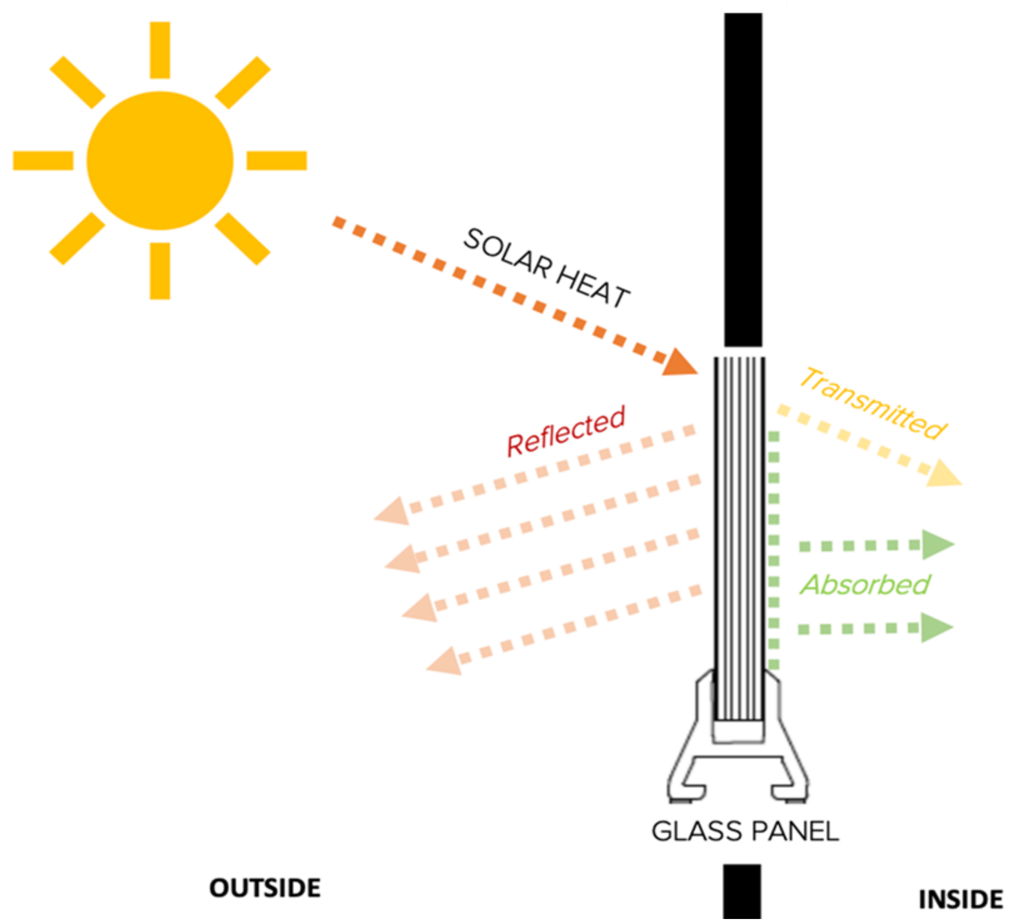
Total Solar Heat Elimination : 79%

Total Solar Heat Transmission : 21%



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 ∝ lesser Heat Transfer

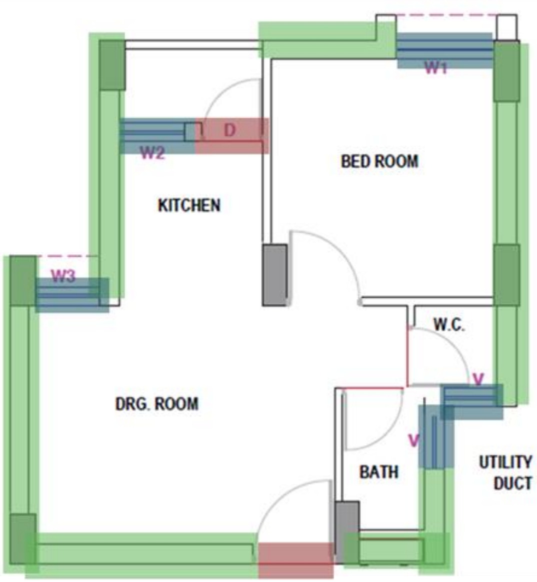
Solar Radiation is subsequently released inward through conduction, convection and radiation.

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/M²K**



	Area (sq mt)	U- value (w/m²k)
Wall (opaque)	2793.38	0.78
Door (opaque)	210	5.23
Window (non-opaque)	475.88	5.80

AAC Wall
Wooden Door
Glass Window

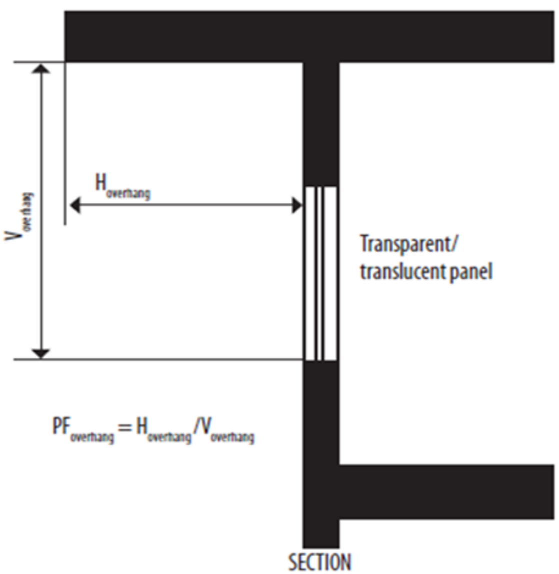
$$U_{envelope,cold} = \frac{(2793.38 \times 0.78) + (210.00 \times 5.23) + (474.88 \times 5.80)}{2793.38 + 210.00 + 474.88} = 1.73 \;\; W/m^2.K$$

ENS – Part 1 – Building Envelope

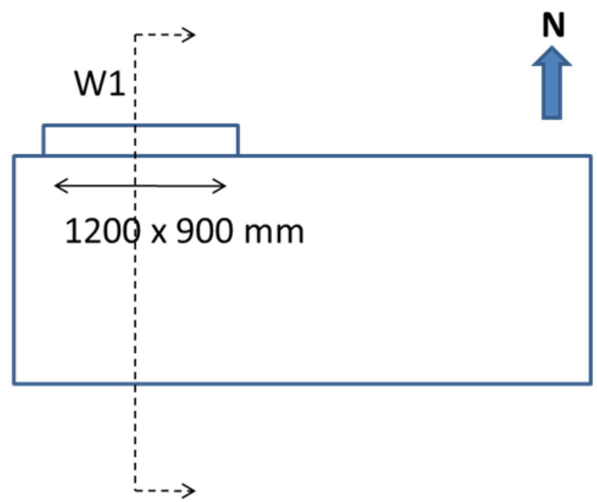
3.4 Projection Factor (PF)

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

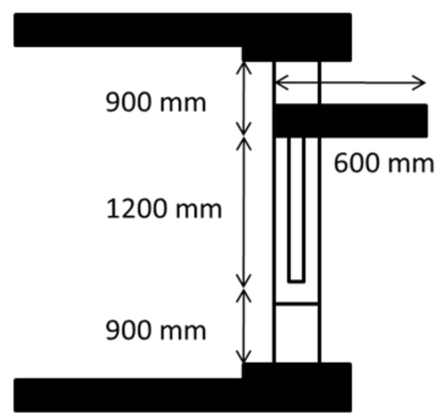
$$PF_{overhang} = \frac{H_{overhang}}{V_{overhang}}$$



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/m2 K, SHGC = 0.6, VLT = 0.7



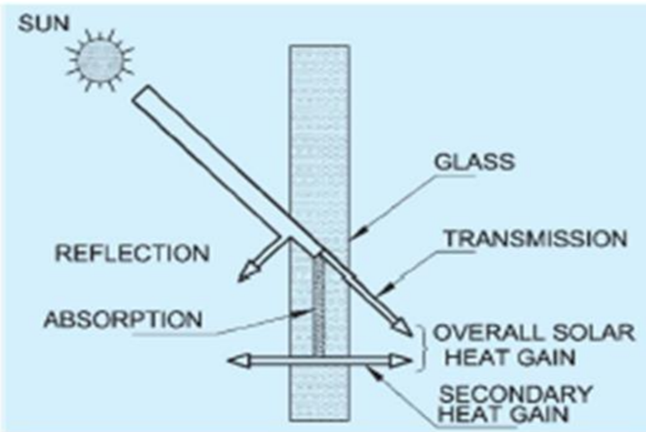
Plan

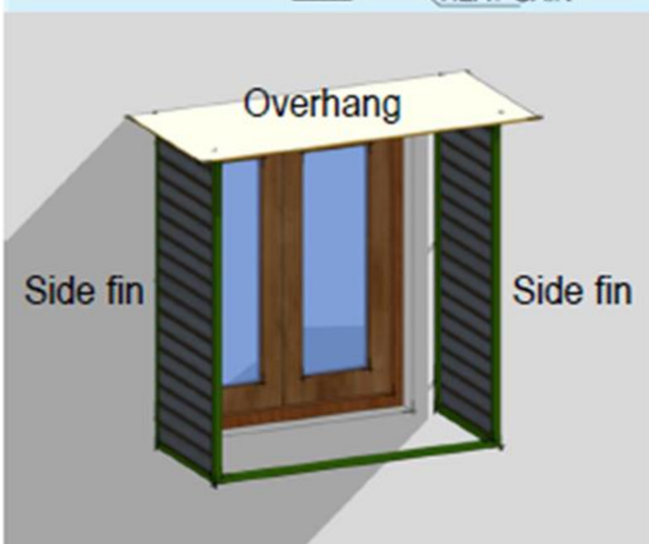


Section

ENS – Part 1 – Building Envelope

3.4 Equivalent SHGC





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

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

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

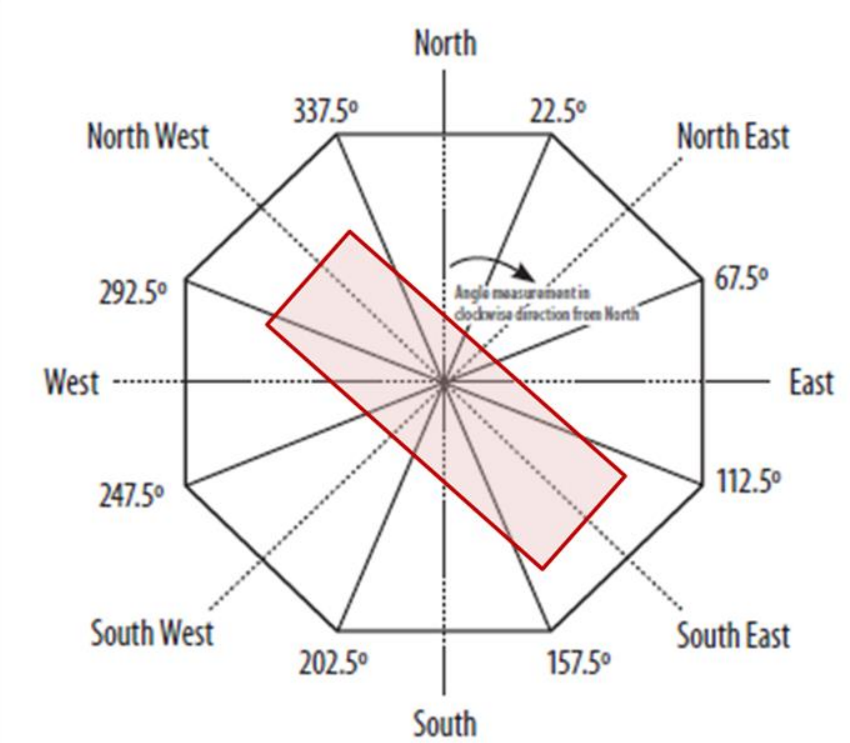
$$SHGC_{eq} = SHGC_{unshaded} \times ESF_{total}$$

ENS – Part 1 – Building Envelope

3.4 Orientation Factor

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

Orientation	Orientation factor (ω) 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/m2k, SHGC = 0.56, VLT=0.51	22.55%
RETV – 14.92 W/m^2.K			

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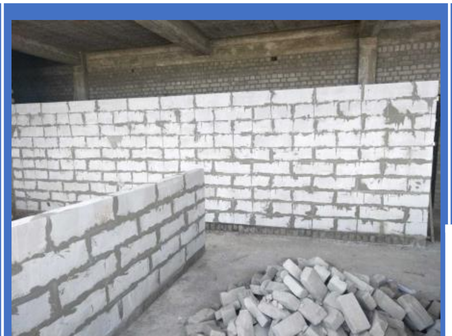
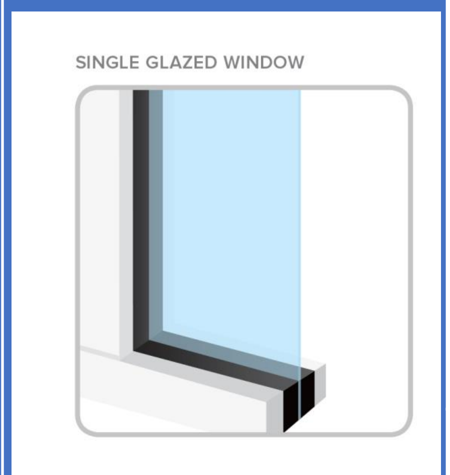
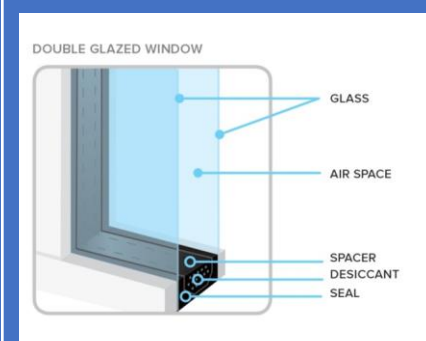
ENS – Part 1 – Building Envelope

3.4 RETV – Case 2

Case 2		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/m2k, SHGC = 0.56, VLT=0.51	22.55%
		RETV – 9.71 W/m².K			

ENS – Part 1 – Building Envelope

3.4 RETV – Case 3

Case 3		External wall	Roof Construction	Glazing	Window to wall Ratio
	 	200mm thick AAC Block wall	150 mm thick RCC slab + 50mm thick EPS	Double glazed Unit - Asahi LC 54/37 U Value = 1.64 W/m2k, SHGC = 0.36, VLT=0.52	22.55%
		RETV – 6.62 W/m².K			

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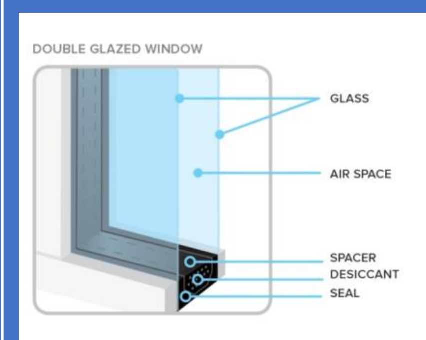
ENS – Part 1 – Building Envelope

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/m2k, SHGC = 0.36, VLT=0.52	22.55%

RETV – 5.13 $W/m^2.K$

ENS – Part 1 – Building Envelope

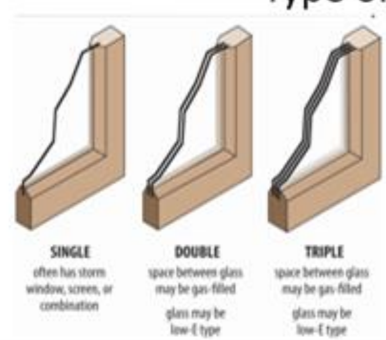
Building Design Flexibility by ENS

Material wall Assembly

Design of Window Panel

Shading of external Windows

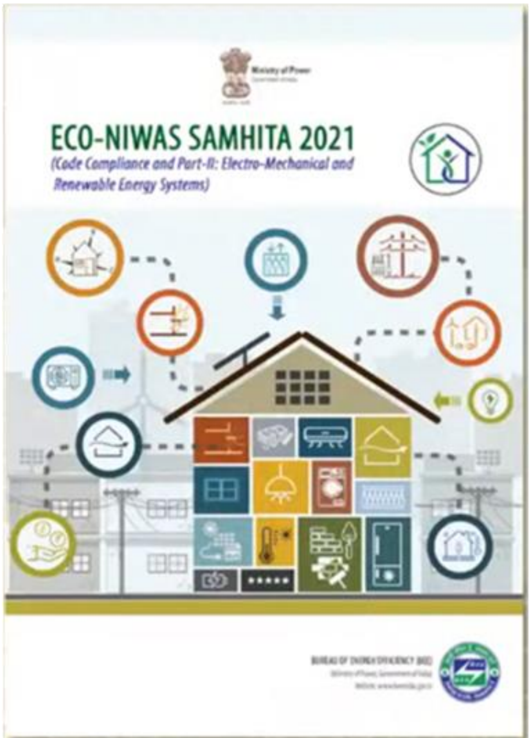
Type of glazing



Session 5: ENS Part 2

ENS – Part 2 – Services

CODE PROVISIONS



- **Building Services**
  - Common Area & Exterior Lighting
  - Elevators
  - Electrical Systems
  - Pumps
- **Indoor End Electrical Use**
  - Indoor Lighting
  - Comfort Systems
- **Renewable Energy Systems**
  - Solar Water Heating
  - Solar Photo-Voltic

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).

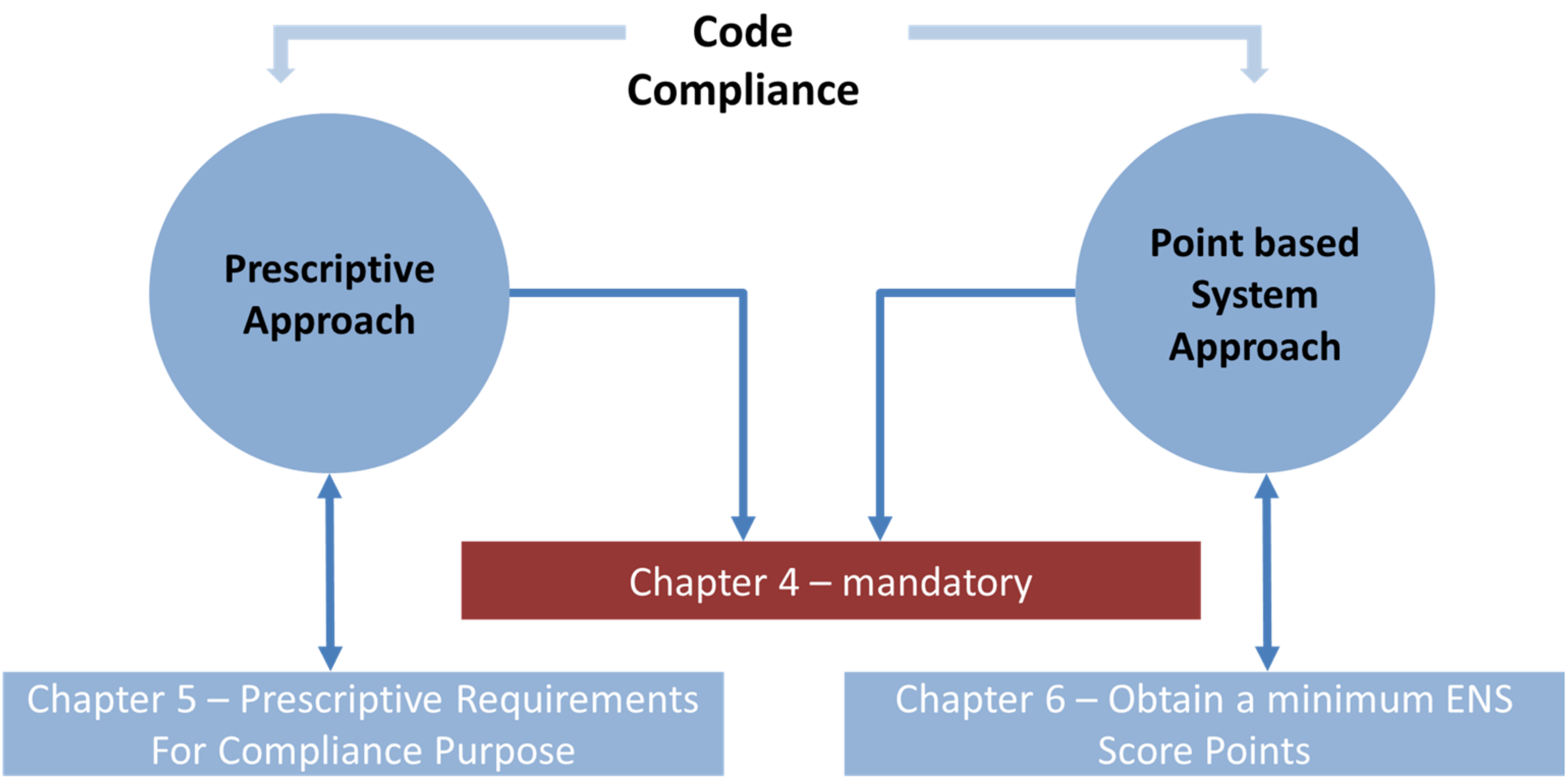
Affordable Housing Projects:

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

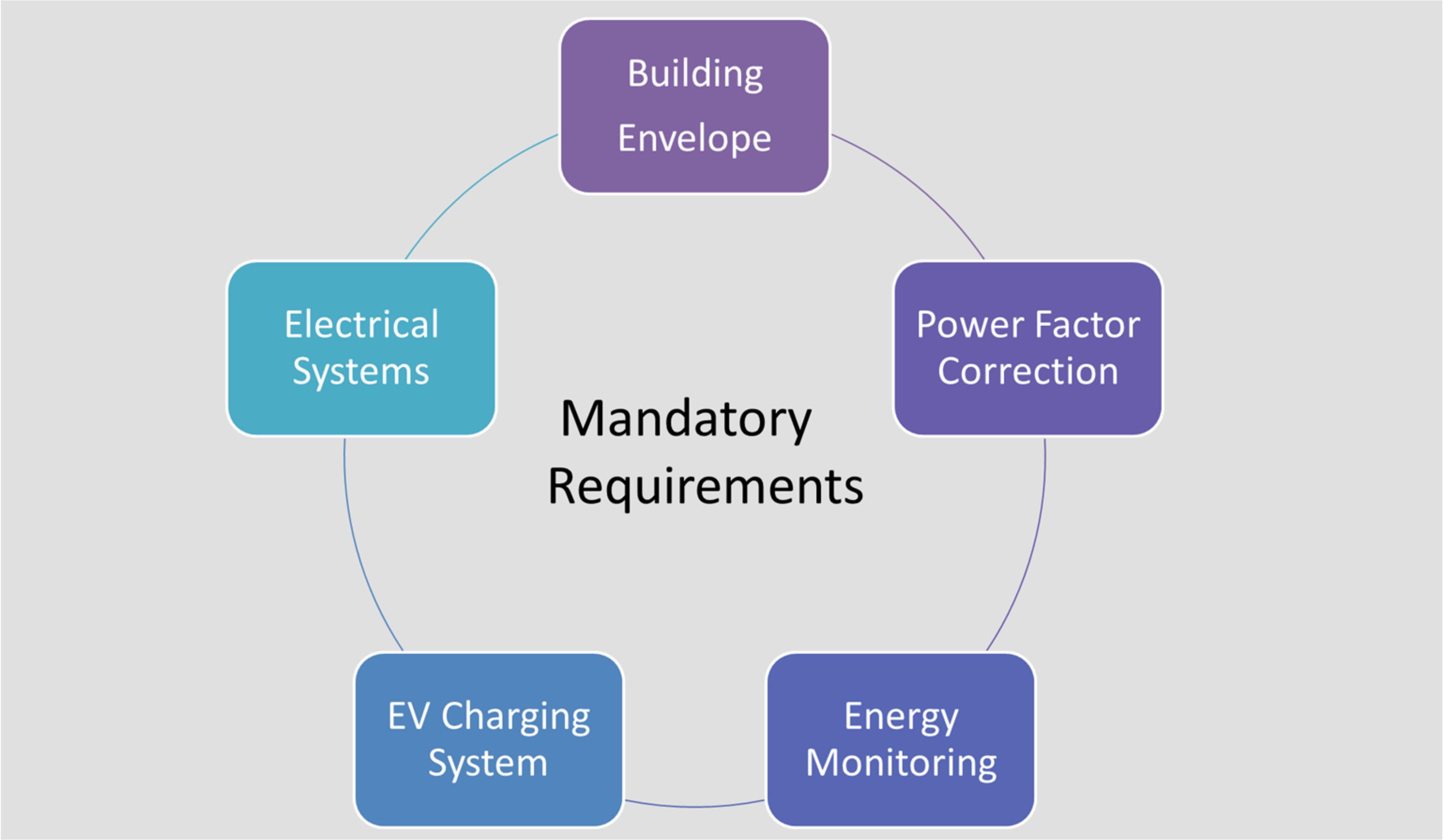
+

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



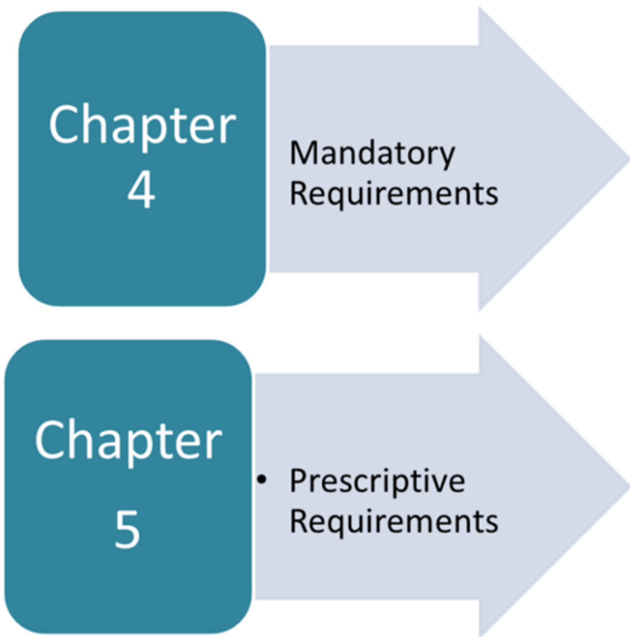
ENS – Part 2 - Mandatory Requirements

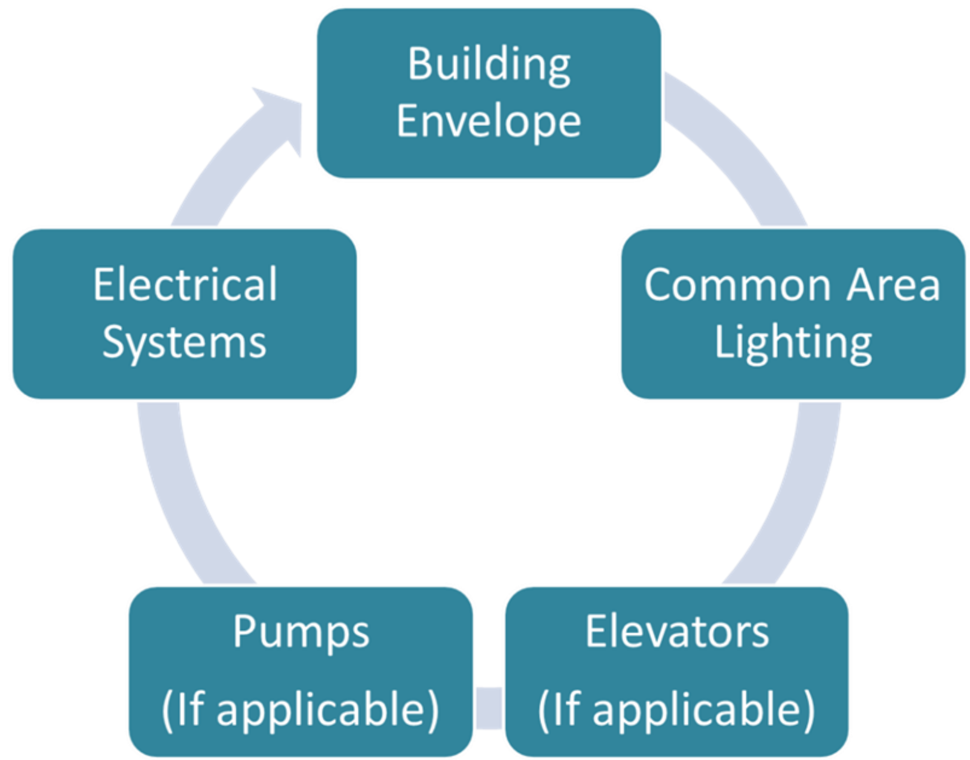
Chapter 4 of ENS Part I	Building Envelope
All 3 phase shall maintain the power factor of 0.97 at the point of connection	Power Factor Correction
Total Electrical Energy	Energy Monitoring
Electrical Consumption of Applicable End Use Systems	Energy Monitoring
Guidelines issued by Ministry of Power for EV Charging on Oct 1st 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 Code Prescriptive Method

(Building Envelope)

- All requirements of Building Envelope including **Openable Window-to-Floor area ratio, Visible Light Transmittance**

  as per Chapter 4 of ENS Part 1

- **RETV for Building Envelope (except roof) for all climatic zones (except cold)** shall comply with the **Maximum RETV of 15W/m2.** Thermal Transmittance of Building Envelope for cold climate shall comply with **max U value of 1.3w/m2.K**

- **Thermal transmittance of roof** shall comply with the **maximum Uroof value of 1.2W/m2.K**

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ENS – Part 2 - Code Compliance- Point Based System

Point based System Approach

Obtain a minimum ENS Score Points as in 6.1

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

Get Additional Points By

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
Building Envelope			
Building Envelope	47 Points	40 Points	87 Points
Building Services			
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
Indoor Electrical End Use			
Indoor Lighting		12 Points	12 Points
Comfort Systems		50 Points	50 Points
ENS SCORE	**70 Points**	**130 Points**	**200 Points**

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ENS – Part 2 – Services

Common Area and Exterior Lighting

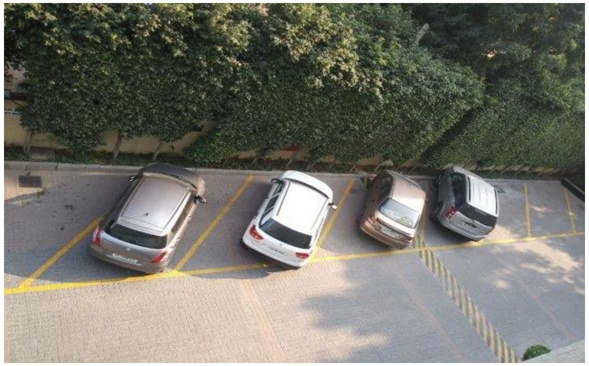
Common Areas	Maximum LPD (W/m2)	Minimum Luminous Efficacy (lm/W)
Corridor Lighting & Stilt Parking	3.0	All permanently installed lighting fixtures shall use lamps with an efficacy of at least 85 lumens per Watt
Basement Lighting	1.0	All permanently installed lighting fixtures shall use lamps with efficacy 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/m2)
Driveways and Parking	1.6
Pedestrian Walkways	2.0
Stairways	10.0
Landscaping	0.5
Outdoor Sales Areas	9.0



Parking (open/external)

Stairways

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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)

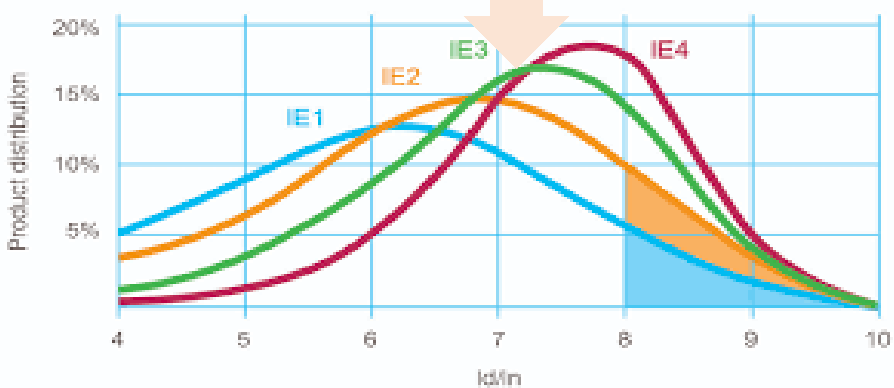
ENS – Part 2 – Services

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

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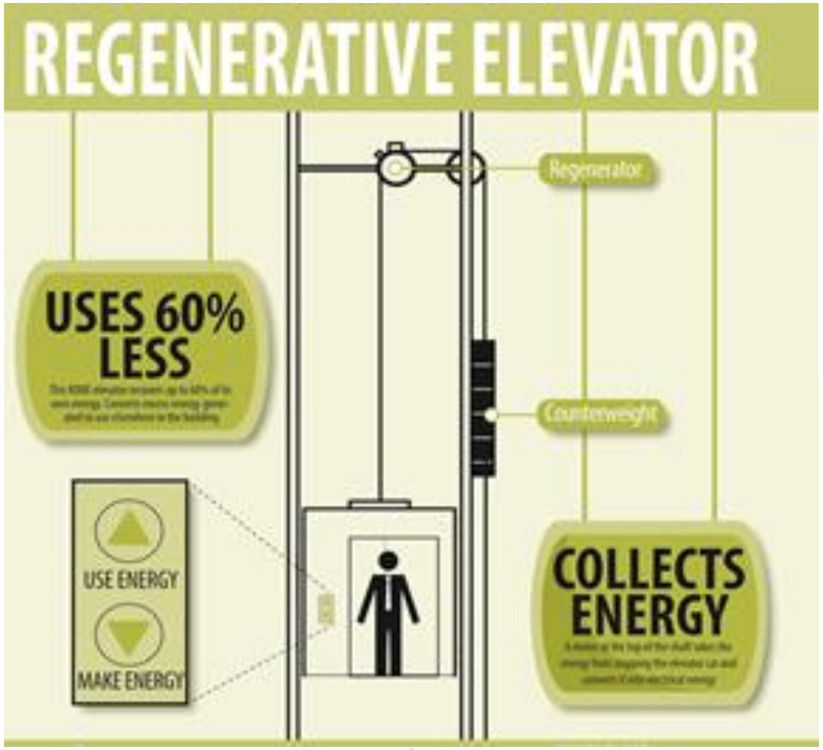
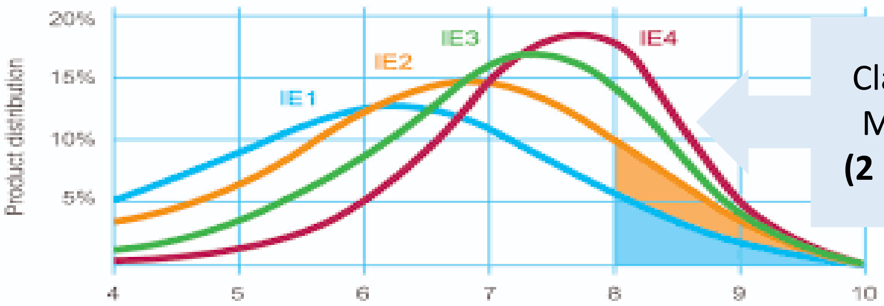
ENS – Part 2 – Services

Elevators – Maximum 22 points



Regenerative Drives
(3 Points)



Class IE4 Motors
(2 Points)

Variable Voltage & Variable Frequency Drives
(4 Points)

ENS – Part 2 – Services

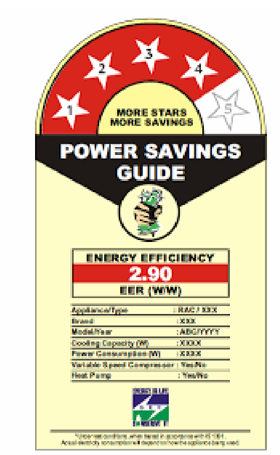
Pumps – Maximum 14 points

HYDRO-PNEUMATIC PUMPS

Mechanical Efficiency

60%

OR



6 POINTS

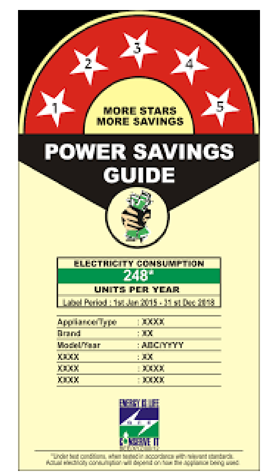
Installation of Hydro-Pneumatic Pumps or BEE Star rated pumps.

Mechanical Efficiency

70%

3 POINTS

\+



8 POINTS

5 POINTS

ENS – Part 2 – Services

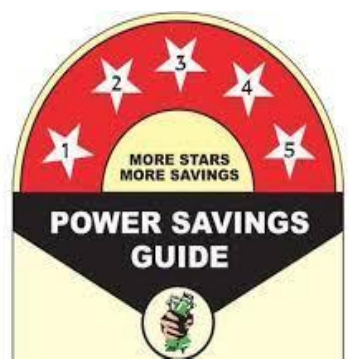
Electrical Systems – Maximum 6 points

POWER TRANFORMERS

- 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 TRANFORMERS



Oil Type Transformers With BEE 5 STAR

(5 POINTS)

ENS – Part 2 – Services

Indoor Lighting– Maximum 12 points

LIVING ROOM

85lm/W

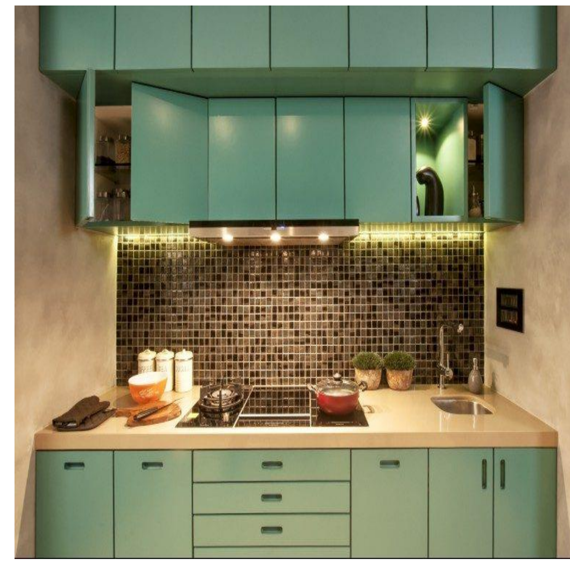
4 POINTS

BED ROOM

95lm/W

3 POINTS

KITCHEN



105lm/W

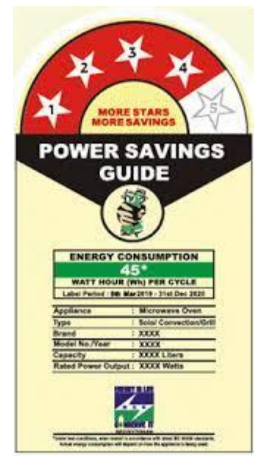
8 POINTS

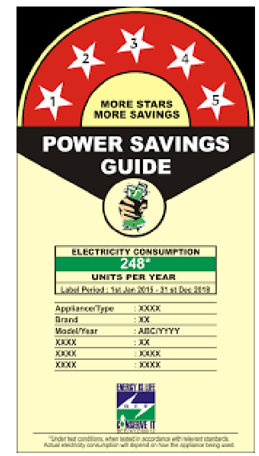
ENS – Part 2 – Services

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^3/min.Watt
- Sweep size > 1200mm: equal or greater than 5m^3/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)

20 POINTS

UNITARY TYP : 5 STAR

SPLIT AC : 3 STAR

CHILLER : ECBC 2017

VRF : 3.28

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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

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ENS – Part 2 – Services

Solar Water Heating

Solar Water Heating

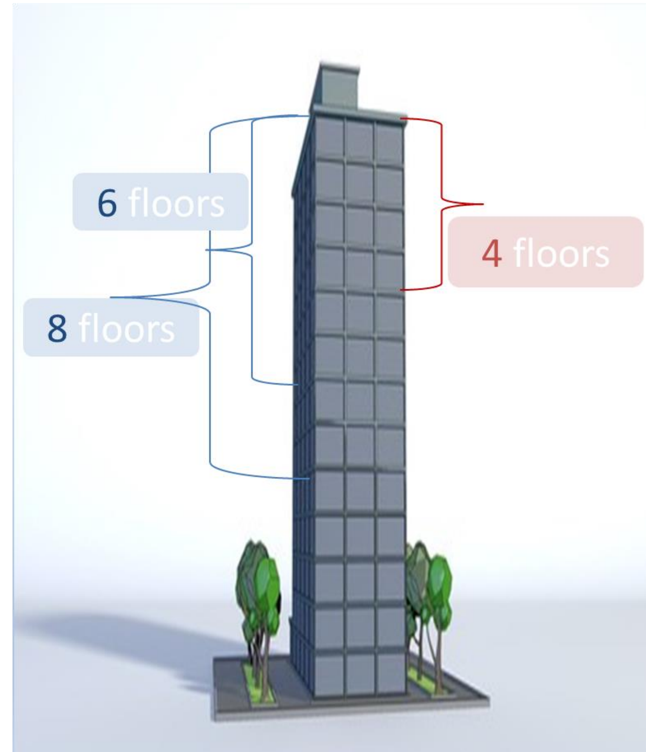
- SWH of **minimum BEE 3 Star label** and meeting 100% of Top 4 floors

OR

- 100% of Annual Hot Water demand of Top 4Floors is met by using heat recovery

6 POINTS

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



TOP FLOORS

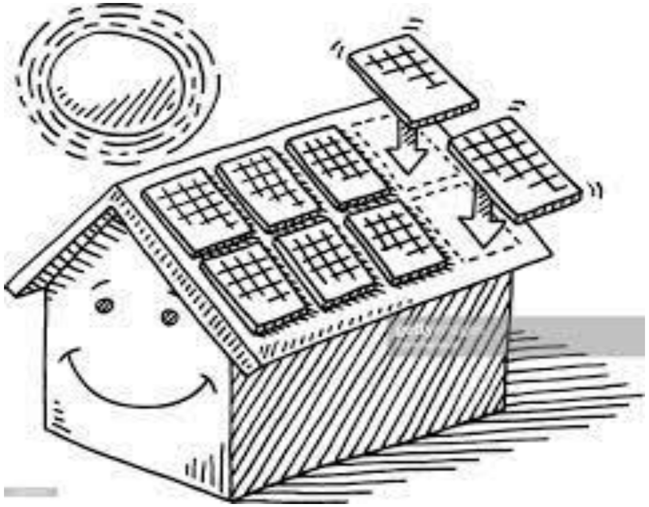
ENS – Part 2 – Services

Solar Photovoltaic

- Dedicated Renewable Energy Zone (REGZ)
- Minimum of 2kWh/m2 year of electricity

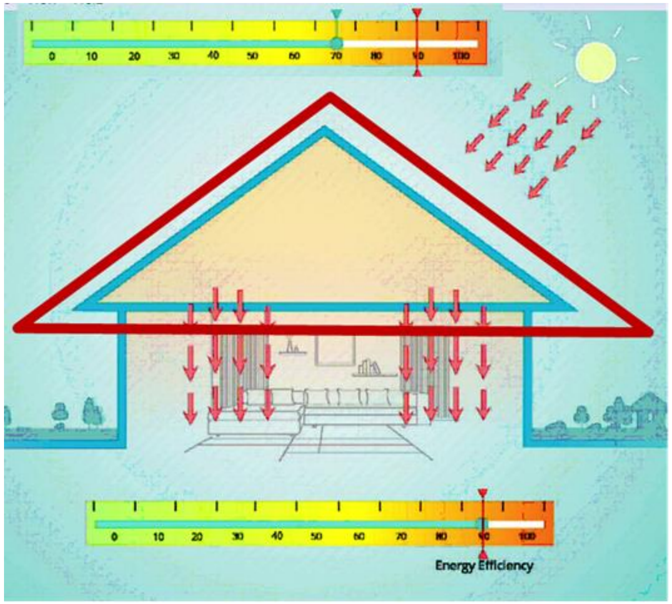
- At least 20% of roof area
- Free of any obstructions and shadows

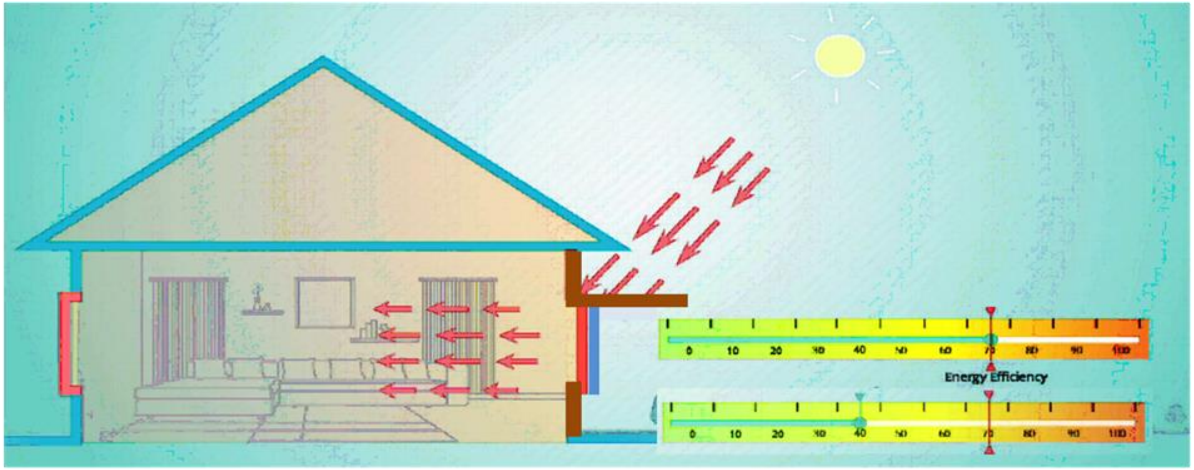
5 Points



- Min. of 3kWh/m2 of Electricity / 30% of roof area **(2 points)**
- Min. of 4kWh/m2 of electricity /40% roof area **(5 points)**

Conventional Building Vs ENS Building



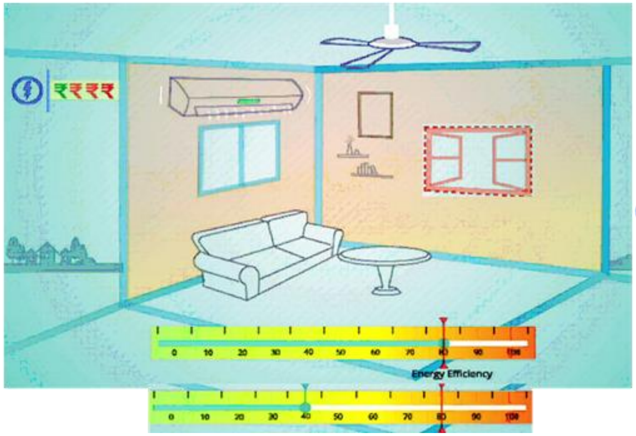


Conventional Brick wall, roof and single glazed windows, traps heat

Proper shading, glazing, Wall & Roof insulation reduces impact of heat

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

Proper Insulating materials can reduced heat gain



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

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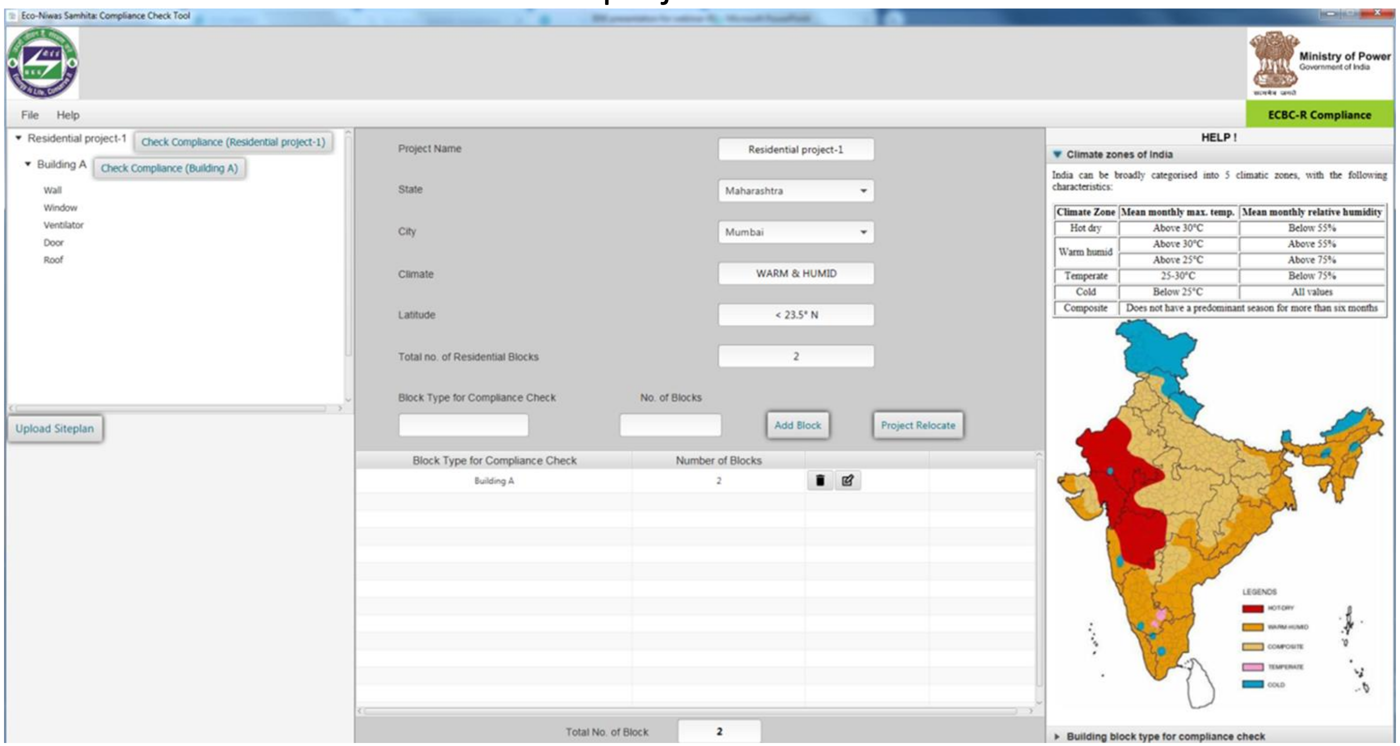
Compliance Tool

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



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

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

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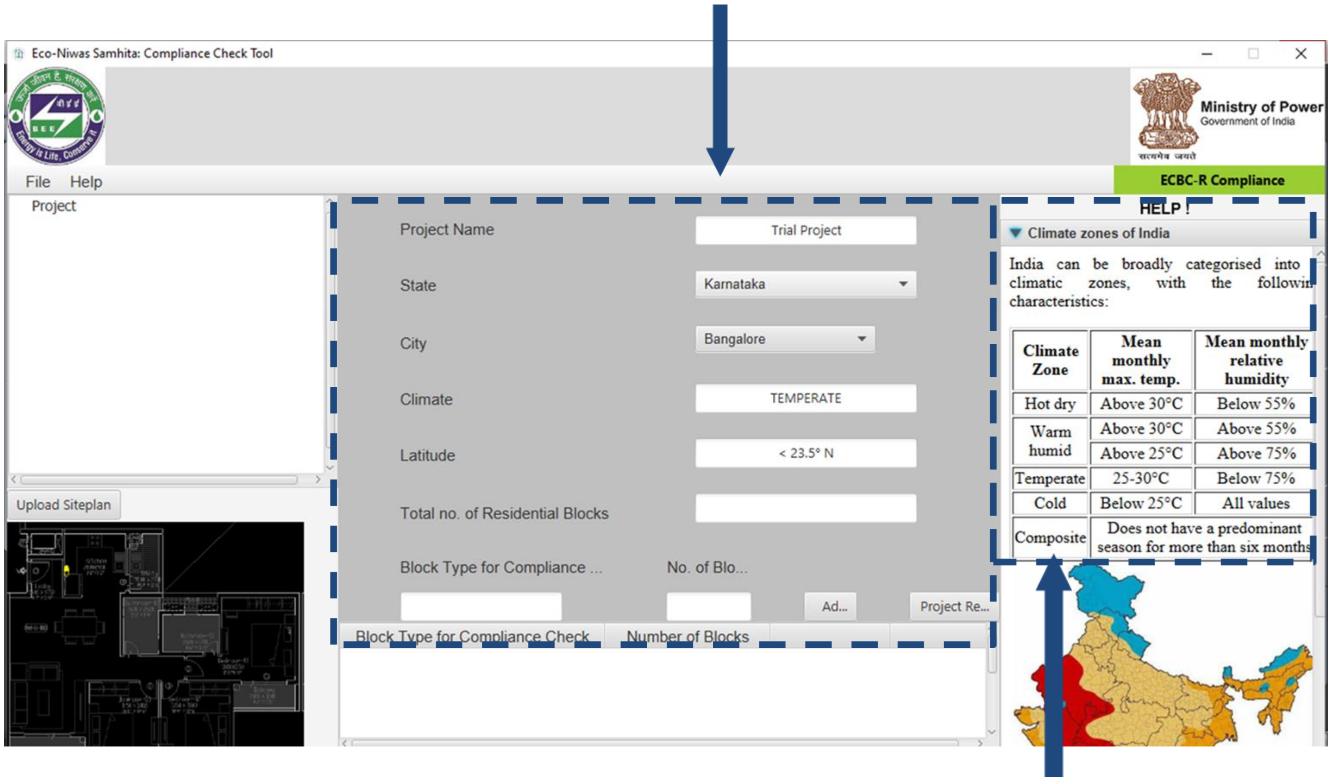
Compliance Tool

Project related details are entered in the tool for compliance check



Climate data after entering the project location details

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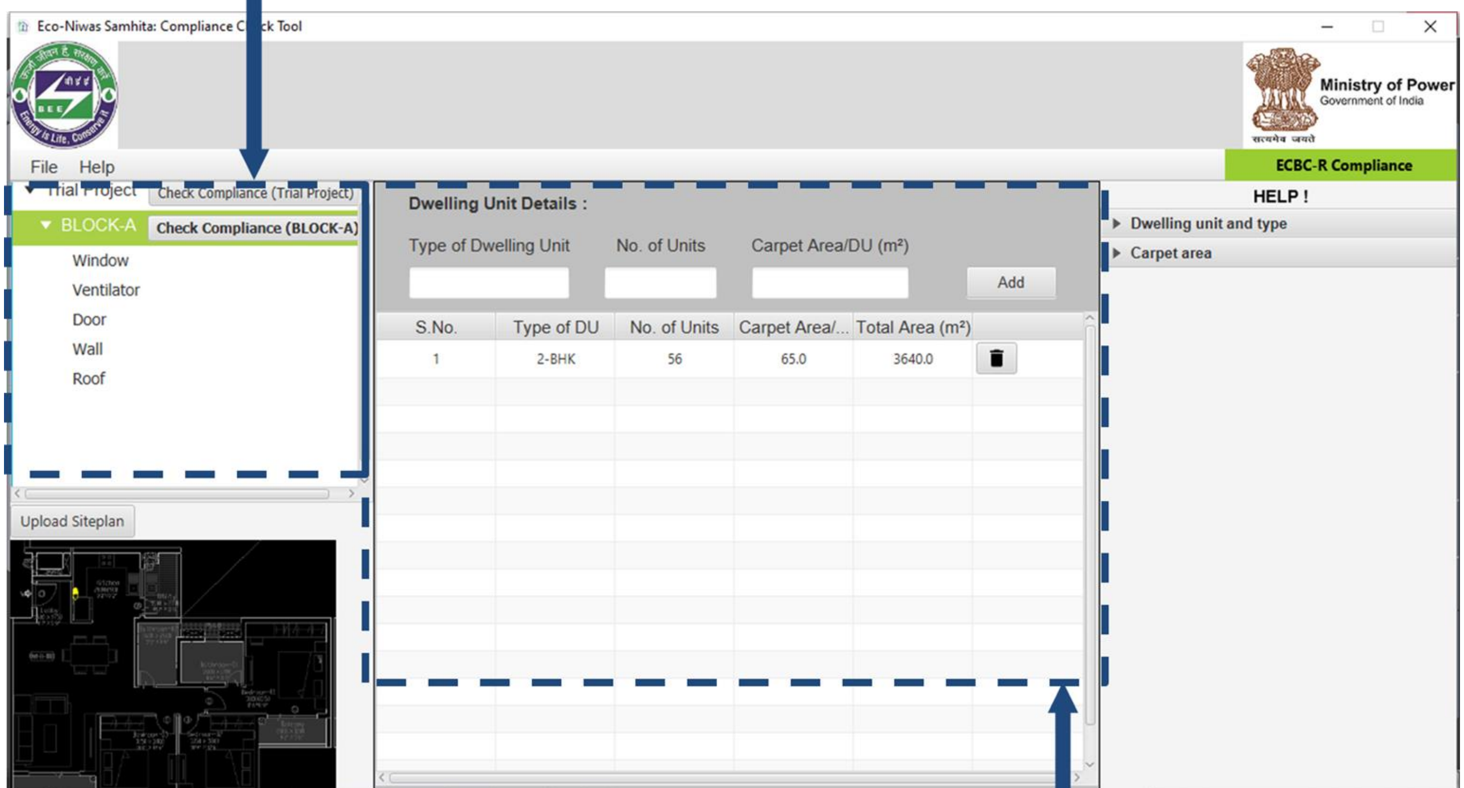
Compliance Tool

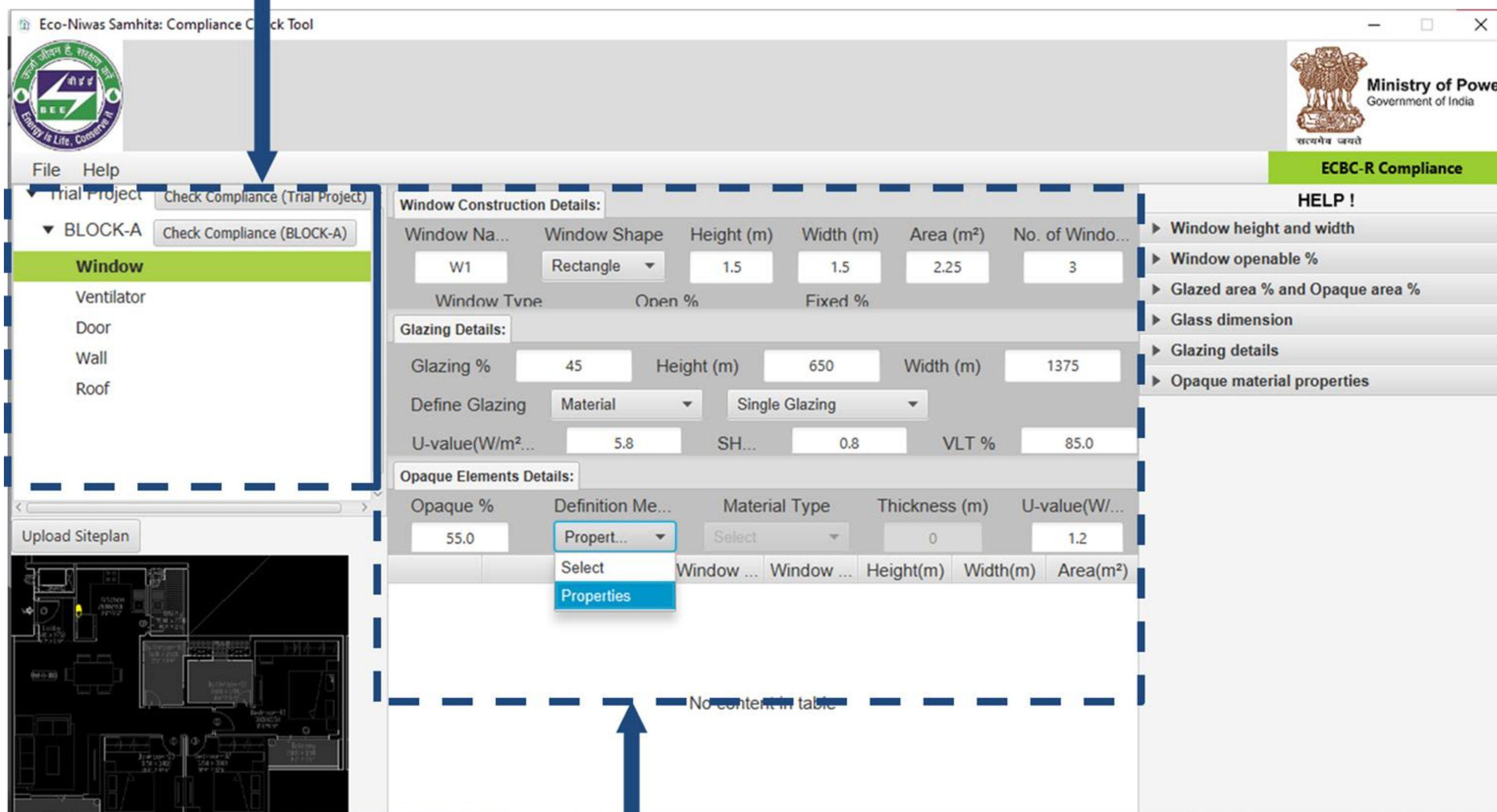
Details of various building components will be added for Compliance check- Architectural drawings(plans, sections and elevations)



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

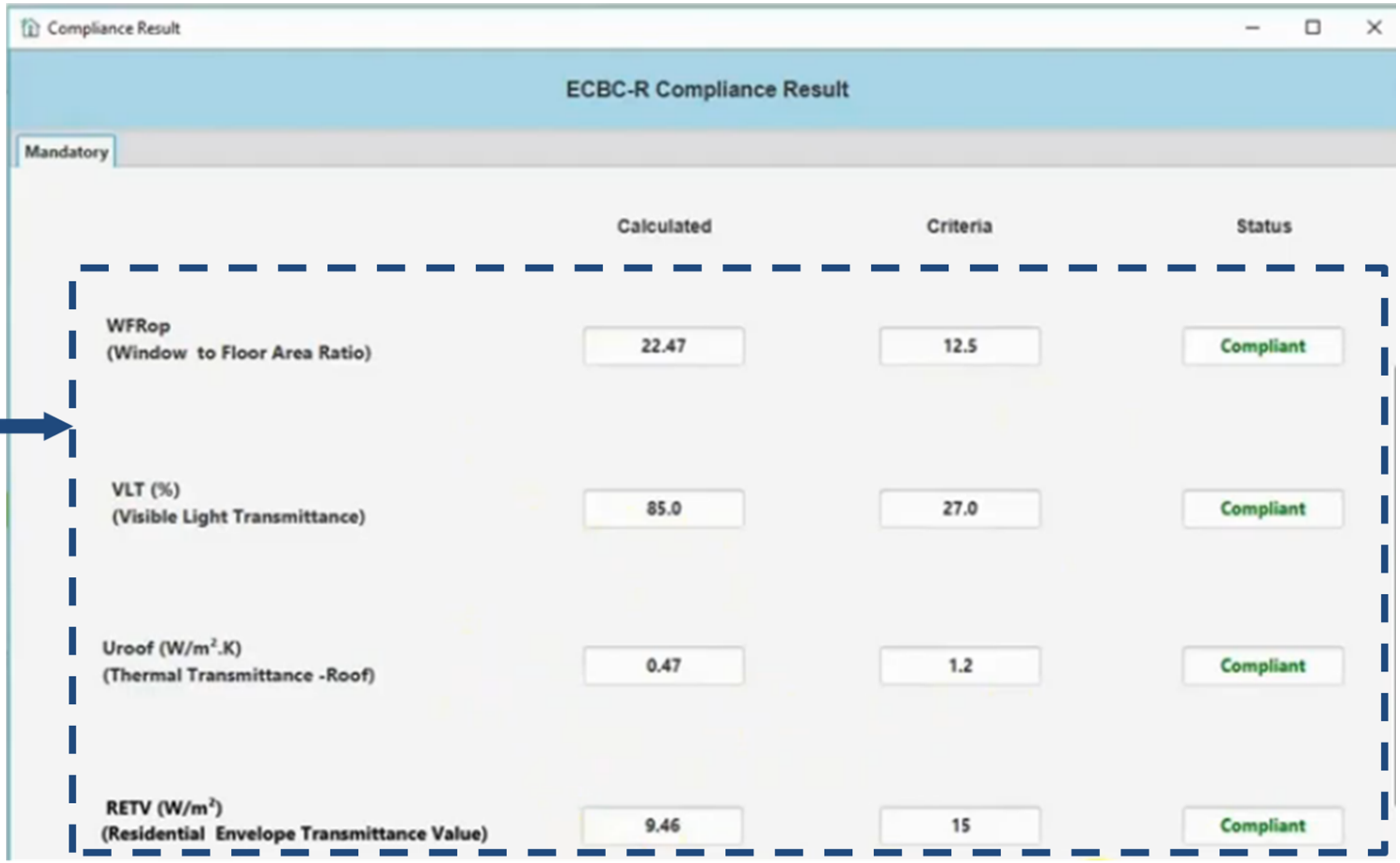


All the details related to window are submitted for the compliance

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

Compliance Tool

Result of the compliance of code provisions shown



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

BEE Star Labelling for Residential Buildings

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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

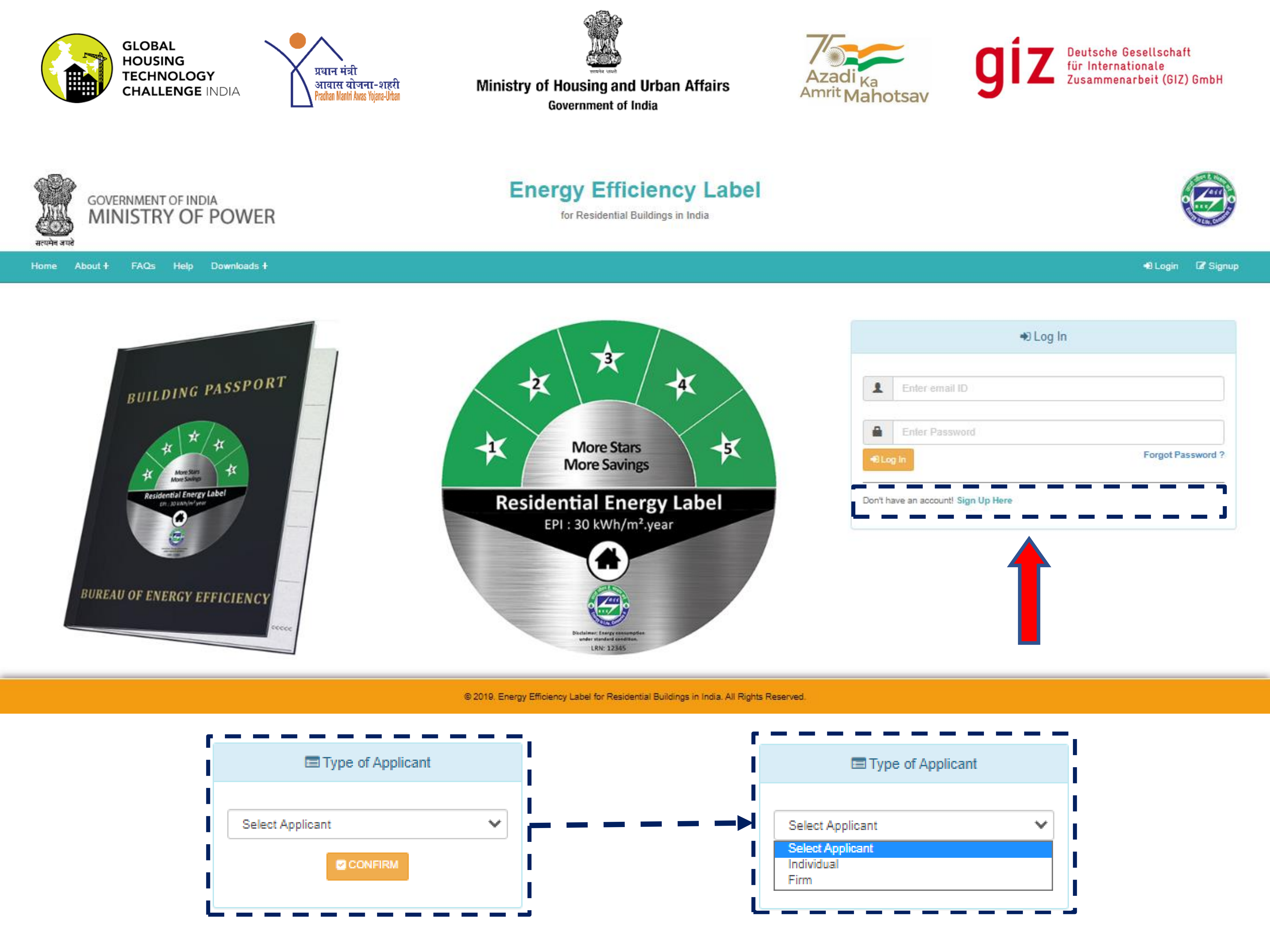
EPI(Kwh/sqm/year)	Star Label
85-75	1 Star
75-65	2 Star
65-55	3 Star
55-45	4 Star
Below 45	5 Star

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.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Signup
BUILDING PASSPORT
BUREAU OF ENERGY EFFICIENCY
More Stars More Savings
Residential Energy Label
EPI : 30 kWh/m².year
LRN: 12345
Log In
Enter email ID
Enter Password
Log In
Forgot Password ?
Don't have an account! Sign Up Here
© 2019. Energy Efficiency Label for Residential Buildings in India. All Rights Reserved.
Type of Applicant
Select Applicant
CONFIRM
Type of Applicant
Select Applicant
Select Applicant
Individual
Firm

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Sign Up

Name

Identity Number

Email

This will be username.

Mobile Number

Address for correspondence

Property Number

Line 1

Line 2

Locality

State

Choose State

City/Town

Choose City

District

Pincode

Password

Create Password

Re-enter Password

☐ I confirm that all details are true and correct.

Register

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

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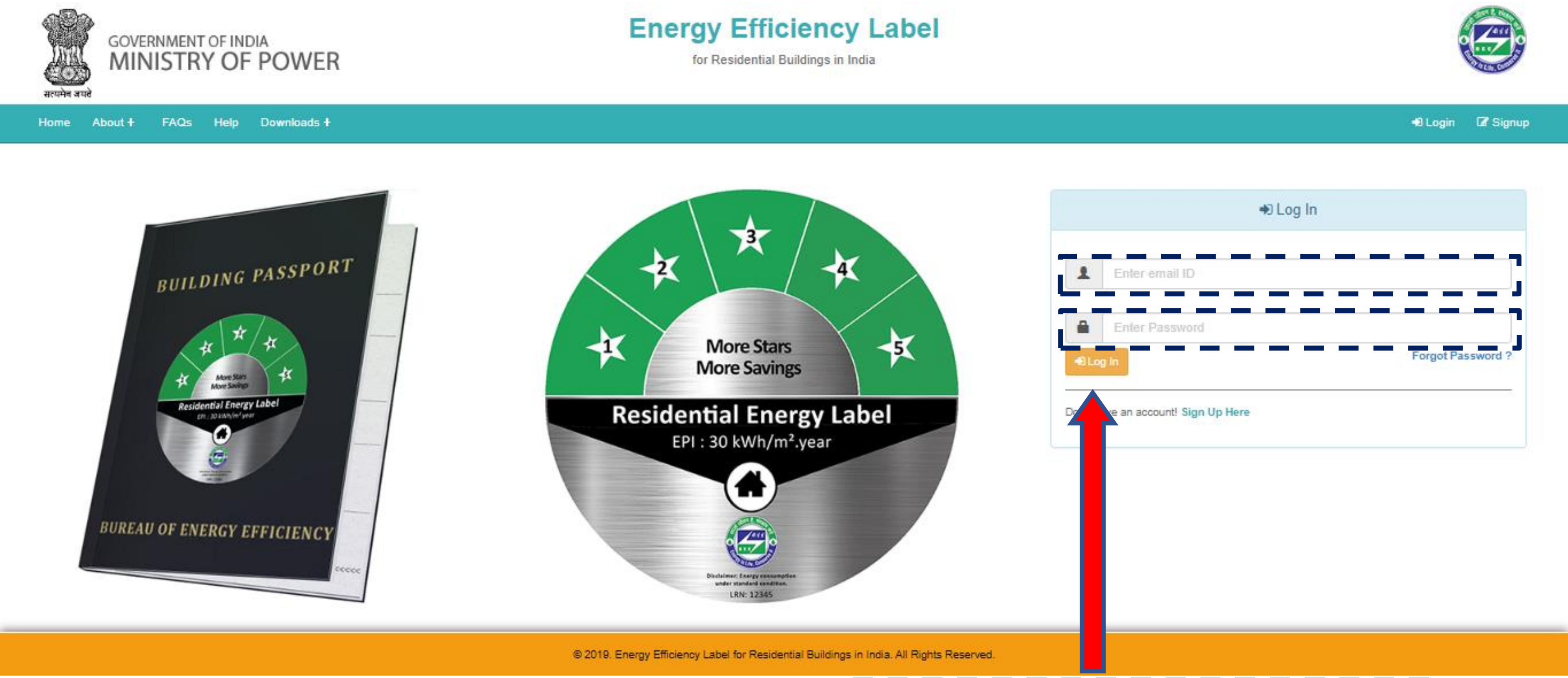


Log in using registered credentials

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

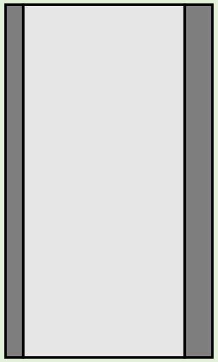
Case Study : Light House Project (LHP), Chennai

- Project Type - *PMAY Housing*
- Location - *Chennai*
- Dwelling Units - *1152*
- DU Area - *26.58 m²*

LHP Site - Thermal Features

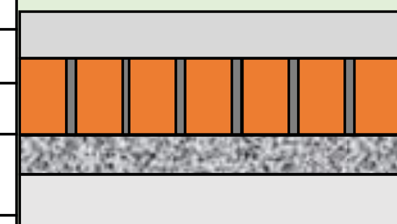
- 150mm AAC block is used for Masonry work & 100mm AAC block is used for internal partitions

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

External Wall Assembly								
Layer no.	***Material***	***Density (kg/m3)***	***Specific Heat (kJ/kg.K)***	***Thickness (m)***	***Conductivity (W/m-K)***	***R value m^2K/W***	***Source***	***Wall section***
1	Interior surface film resisitance	-	-	-	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 resisitance	-	-	-	25.000	0.040	ENS 2018	
U value of assembly (W/m2K)						**0.97**		

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/m3)*	*Specific Heat (kJ/kg.K)*	*Thickness (m)*	*Conductivity (W/m-K)*	*R value m²K/W*	*Source*	*Roof section*
1	Interior Surface film resisitance	-	-	-	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 resisitance	-	-	-	25.000	0.040	ENS 2018	
U value of assembly (W/m2K)						**1.79**		

- 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**	≥ 16.66 %	Complied
Visible Light Transmittance (VLT)	**0.89**	**0.89**	≥ 0.27	Complied
Thermal Transmittance of Roof (U_{roof})	**1.8**	**1.8**	≤ 1.2 W/m^2. K	Not Complied
Residential Envelope Transmittance Value (RETV)	**11.8**	**14.1**	≤ 15 W/m^2.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
Percentage of Occupied hours within 90% acceptability limits						
Bedroom	8%	2%	1%	24%	7%	5%
Living	7%	2%	2%	25%	12%	9%
Kitchen	34%	25%	23%	40%	31%	28%
Percentage of Occupied hours within 80% acceptability limits						
Bedroom	97%	57%	34%	99%	84%	72%
Living	92%	41%	26%	98%	84%	66%
Kitchen	88%	77%	62%	88%	82%	71%
Percentage of Occupied hours within 70% acceptability limits						
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

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
	Total obtained points in Lighting			**5**	

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

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	

4.3.3 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 alloted
BEE 5 star rated Oil type		5		0	

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	*Installed system is equivalent to 6kWh/sqm/year*
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
Envelope					
U Roof	3	4	7	0	
RETV	44	36	80	48	N-S Block - RETV = 11.8 E-W Block - RETV = 14.8
Lighting					
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
Elevators					
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

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

Components	Minimum Points	Additional Points	Maximum Points	Obtained Points	LHP Chennai
Pumps					
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	
Electrical Systems					
BEE 4 star rated Oil type	1		6	0	1 star Rated Oil type Transformer is alloted
BEE 5 star rated Oil type		5		0	
Solar PV Systems					
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	
Total points gained	**70**	**85**	**155**	**70**	

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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

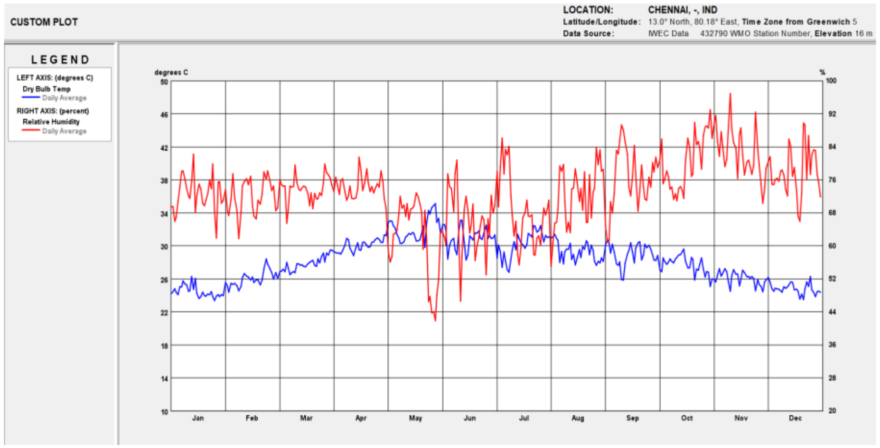
Eco Niwas Samhita (ENS) - Part 1

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.

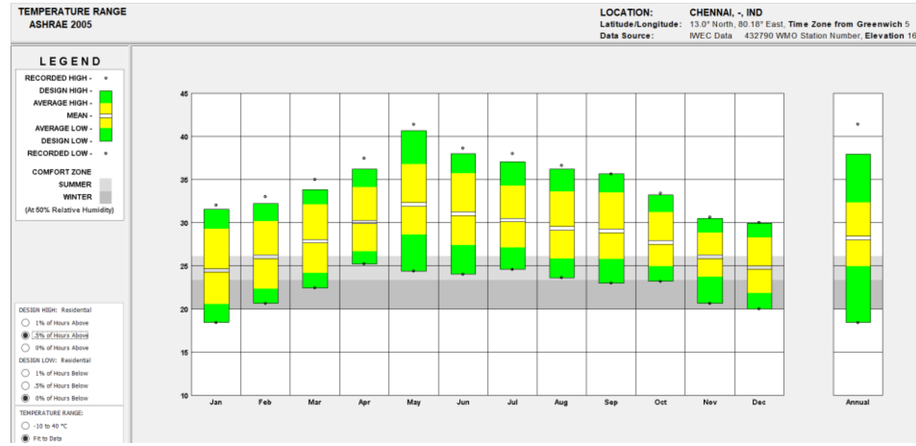
ENS Compliance Parameters	Achieved Base Case: Building 1 & 2	ENS Requirement	Compliance Status
Openable Window to Floor Area Ratio (WFR_{op})	8.37 %	≥ 16.66 %	**Not Complied**
Visible Light Transmittance (VLT)	0.51	≥ 0.27	**Complied**
Thermal Transmittance of Roof (U_{roof})	2.59 $W/m^2.K$	≤ 1.2 $W/m^2.K$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

ENS compliance for Dubrayapet project

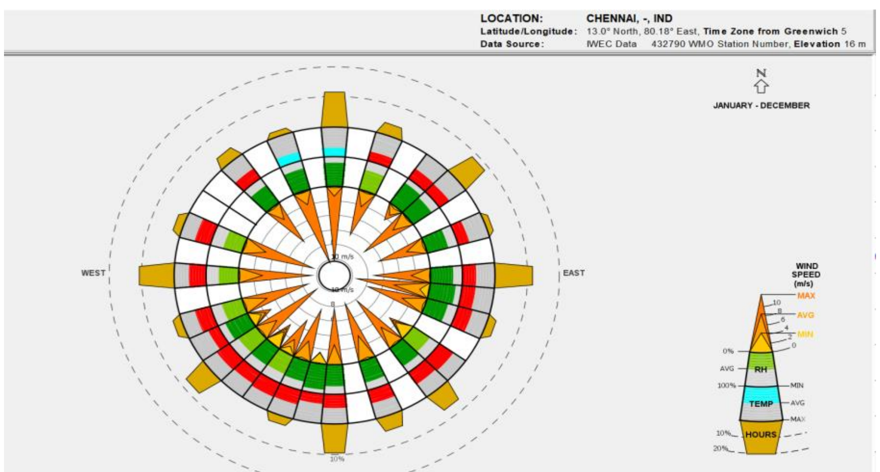
Climate Analysis - Puducherry



Temperature and Relative Humidity



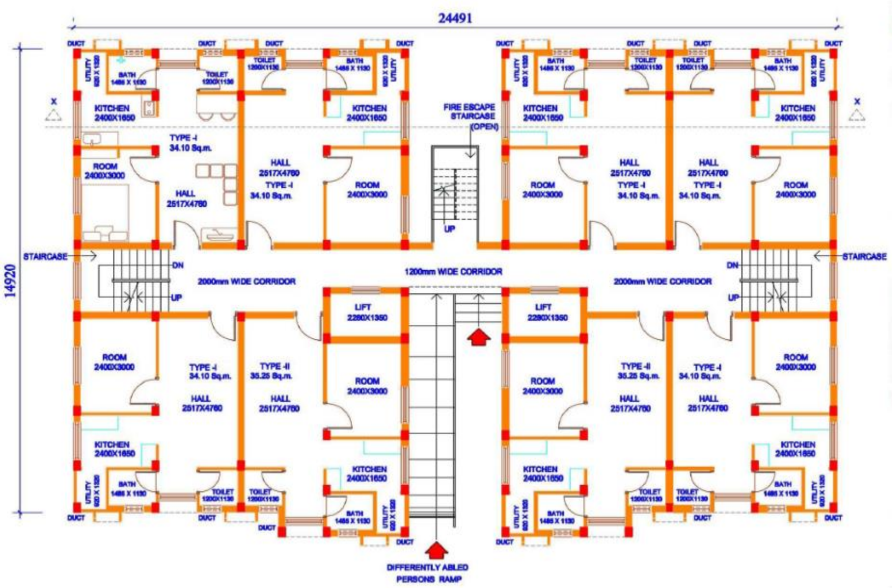
Monthly Dry Bulb Temperature (DBT) distribution



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

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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 (m2)	Floor Area (m2)	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
Warm-Humid	**16.66**
Temperate	12.5
Cold	8.33

minimum requirement of WFRop 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

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Project evaluation as per ENS compliance requirements

Thermal Transmittance of Roof

Thermal transmittance (U_{roof}) characterizes the thermal performance of the roof of a building. Limiting the U_{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_{roof} value of 1.2 W/m^2. K.**

Base Case	Outside to Inside	Thickness (m)	Specific Heat (kJ/kg K)	Density (kg/m3)	Conductivity (W/mK)	R - Value (m2 K / W)	U - Value (W/m2 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	
	Assembly (Total)					**0.37875432**	

Thermal Transmittance of Roof for Base Case

Case 4	Outside to Inside	Thickness (m)	Specific Heat (kJ/kg K)	Density (kg/m3)	Conductivity (W/mK)	R - Value (m2 K / W)	U - Value (W/m2 K)
Roof	Brick Tile	0.018	0.88	1890	0.8	0.0225	
	Lime Concrete	0.025	0.84	1792	0.721	0.03467406	0.91488
	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	
	Assembly (Total)					**1.09304004**	

Thermal Transmittance of Roof for Proposed Case

Project evaluation as per ENS compliance requirements

Thermal Transmittance of Roof

	U- Value in W/m2 K	U- Value in W/m2 K -Basecase	U- Value in W/m2 K - Case 1	U- Value in W/m2 K Case 2	U- Value in W/m2 K - Case 3	U- Value in W/m2 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^2. 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	Wall						Glass											RETV (W/m2 K)	
	Properties		Net Area (m2)					Effective SHGC						Window Area (m2)					
		U value	North	East	South	West	SHGC	North	East	South	West	U value	VLT	North	East	South	West	Standard	Achieved
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/m2K and with AAC masonry wall (12.23 W/m2K), 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 nuet) 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**
Basecase	8760	8691	**8717**	8759	8666	**8701**	8743	8663	**8693**	8745	8684	**8707**
Case-1	4111	3610	**3798**	4033	3110	**3457**	6983	8380	**7855**	6950	6174	**6466**
Case-2	4112	3607	**3797**	4037	3110	**3459**	5480	8548	**7395**	5331	4385	**4741**
Case-3	3175	3172	**3173**	3035	2861	**2926**	4745	6467	**5820**	4921	4150	**4440**
Case-4	3144	3114	**3125**	2978	2788	**2859**	4749	6414	**5788**	4925	4137	**4433**

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**
Basecase	100%	99%	**100%**	100%	99%	**99%**	100%	99%	**99%**	100%	99%	**99%**
Case-1	47%	41%	**43%**	46%	36%	**39%**	80%	96%	**90%**	79%	70%	**74%**
Case-2	47%	41%	**43%**	46%	36%	**39%**	63%	98%	**84%**	61%	50%	**54%**
Case-3	36%	36%	**36%**	35%	33%	**33%**	54%	74%	**66%**	56%	47%	**51%**
Case-4	36%	36%	**36%**	34%	32%	**33%**	54%	73%	**66%**	56%	47%	**51%**

Annual Percentage of Discomfort hours for select Dwelling Units

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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**
Basecase	4392	4392	**4392**	4392	4392	**4392**	4392	4392	**4392**	4392	4392	**4392**
Case-1	3389	3041	**3172**	3128	2661	**2837**	4172	4347	**4281**	4119	3903	**3984**
Case-2	3390	3039	**3171**	3129	2661	**2837**	4046	4387	**4259**	3800	3462	**3589**
Case-3	2726	2639	**2672**	2438	2377	**2400**	3666	4181	**3987**	3521	3161	**3296**
Case-4	2720	2621	**2658**	2414	2357	**2378**	3707	4118	**3963**	3582	3220	**3356**

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**
Basecase	50%	50%	**100%**	50%	50%	**100%**	50%	50%	**100%**	50%	50%	**100%**
Case-1	39%	35%	**72%**	36%	30%	**65%**	48%	50%	**97%**	47%	45%	**45%**
Case-2	39%	35%	**72%**	36%	30%	**65%**	46%	50%	**97%**	43%	40%	**41%**
Case-3	31%	30%	**61%**	28%	27%	**55%**	42%	48%	**91%**	40%	36%	**38%**
Case-4	31%	30%	**61%**	28%	27%	**54%**	42%	47%	**90%**	41%	37%	**38%**

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
Total Material Cost (Rs./-)					**₹ 56,24,385.06**	

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
Total Material Cost (Rs./-)					**₹ 51,71,656.52**	

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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
Total Material Cost (Rs./-)					**₹ 53,30,603.45**	

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
Total Material Cost (Rs./-)					**₹ 53,31,892.25**	

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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
Total Material Cost (Rs./-)					**₹ 56,20,689.05**	

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Conclusion and Remarks

Cost implication of proposed Cases

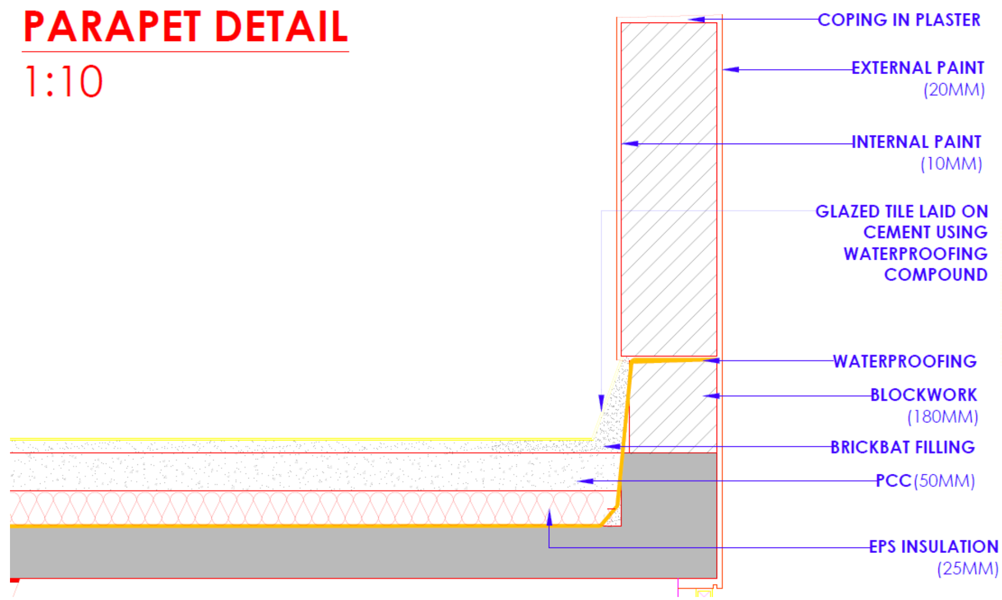
Base Case	Case 1	Case 2	Case 3	Case 4
56,24,385	51,71,657	53,30,603	53,31,892	56,20,689
NA	4,52,729	2,93,782	2,92,493	3,696
NA	8.05%	5.22%	5.20%	0.07%

- 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

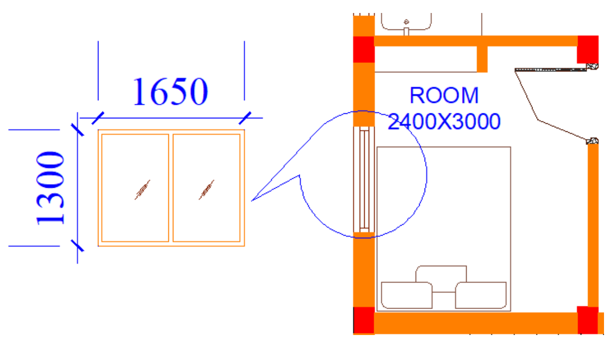
Conclusion and Remarks

- AAC wall

- 25 mm EPS roof insulation



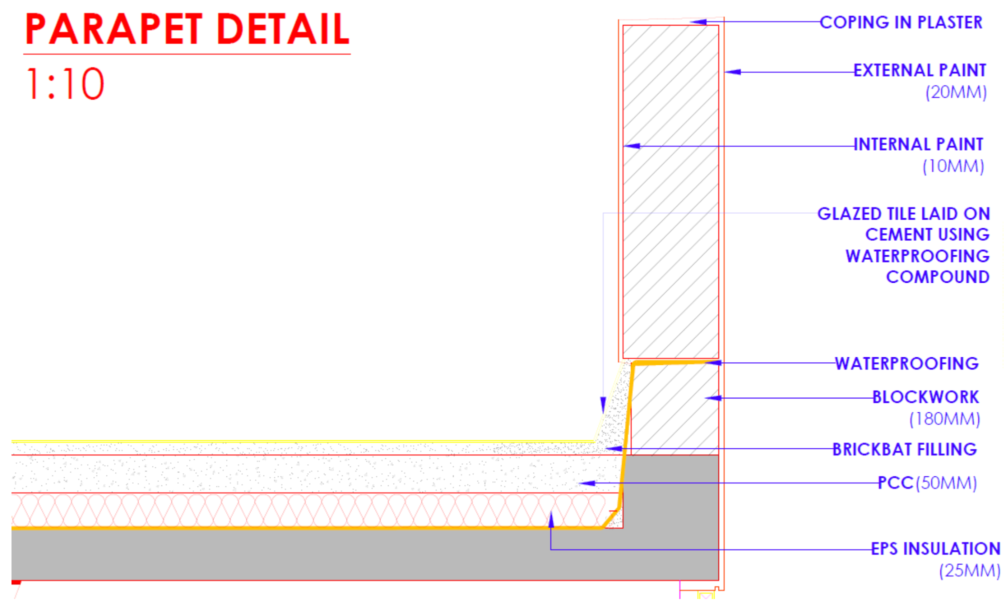
- Casement windows with an increase in the size of the bedroom window



Tender Inclusion

- **AAC wall**

- **50 mm EPS roof insulation**



Q&A

Please fill the Feedback form

Thank you !

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