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 34
16 & 17 June 2022
Chennai

Presented by CSB Cell - South

DAY 1

Introduction - GIZ

GIZ

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

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

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

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

Sustainable Urban and Industrial Development

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

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

MoHUA + GIZ

MoHUA
(Ministry of Housing & Urban Affairs)

Government of India

+

GIZ
(Deutsche Gesellschaft für Internationale Zusammenarbeit)

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***

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Demonstration Housing Project (DHPs)

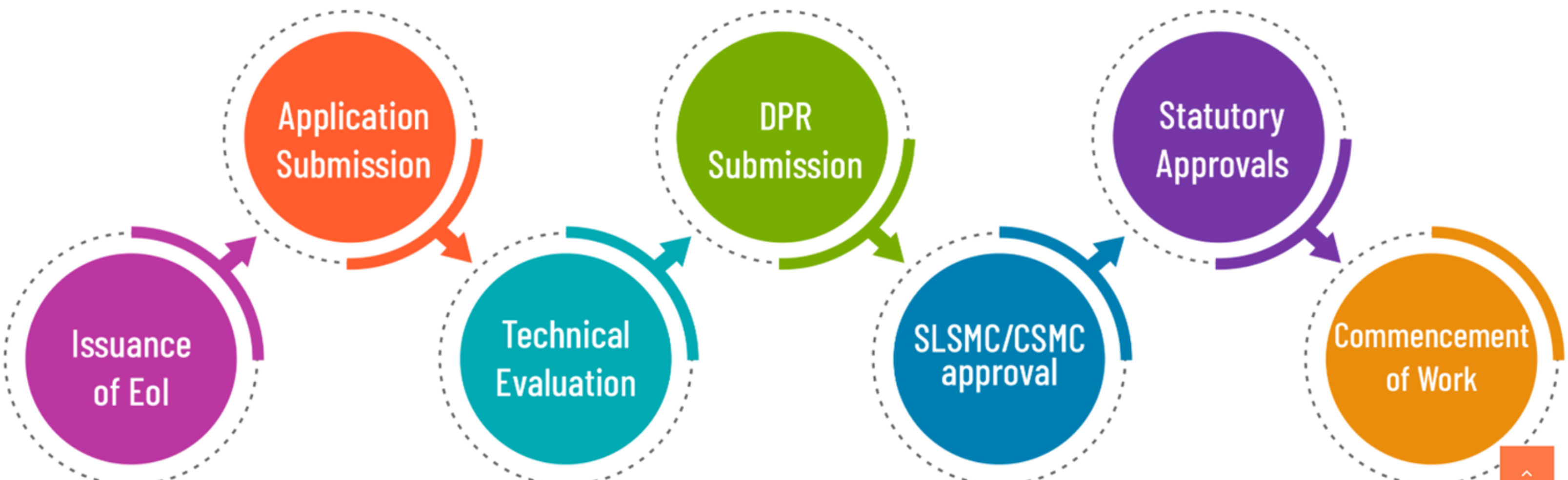
To showcase the field level application of new / alternate technologies, **MoHUA** has taken an initiative to construct Demonstration Housing Project (DHP) through **Building Materials & Technology Promotion Council (BMTPC)** as a part of Technology Sub-Mission under **PMAY(U)**.

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**

ARHCs

- COVID-19 pandemic has resulted in **reverse migration** of urban migrants/ poor in the country. They need **decent rental housing** at affordable rate at their work sites.
- In order to address this need, **Ministry of Housing & Urban Affairs** has initiated **Affordable Rental Housing Complexes (ARHCs),** a sub-scheme under Pradhan Mantri AWAS Yojana- Urban (**PMAY-U**).
- Scheme will be implemented in 2 models: **Model 1** (Utilizing vacant Gov. houses)

MODEL-2



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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

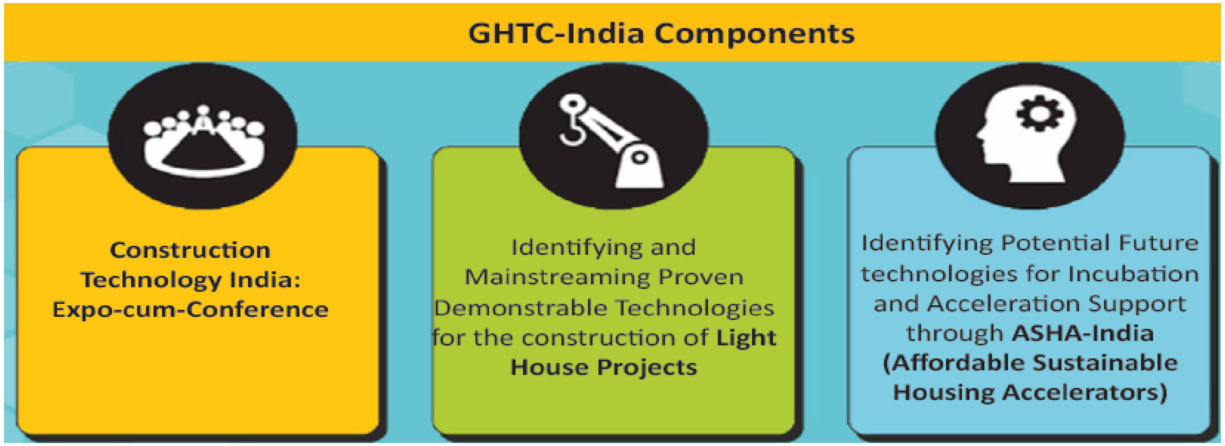
Global Housing Technology Challenge - India

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.

They are to be cost effective and speedier while enabling the quality construction of houses, meeting diverse geo-climatic conditions and desired functional needs.

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.

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



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Light House Project

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

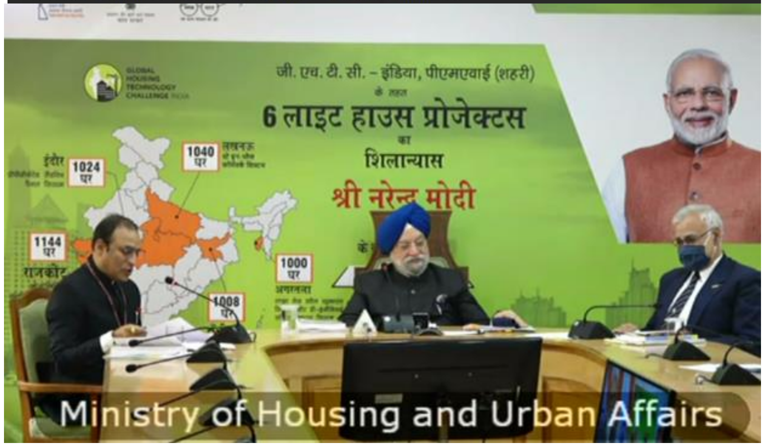
Light House Projects

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

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

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


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 Indore

Prefabricated Sandwich Panel System

Number of Houses : 1024

- 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 replace conventional brick & mortar walling construction practices and 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.
- In this system the EPS Cement Panels are manufactured at the factory in controlled condition, which are then dispatched to the site. The panels having tongue and groove are joint together for construction of the building.

LHP Rajkot

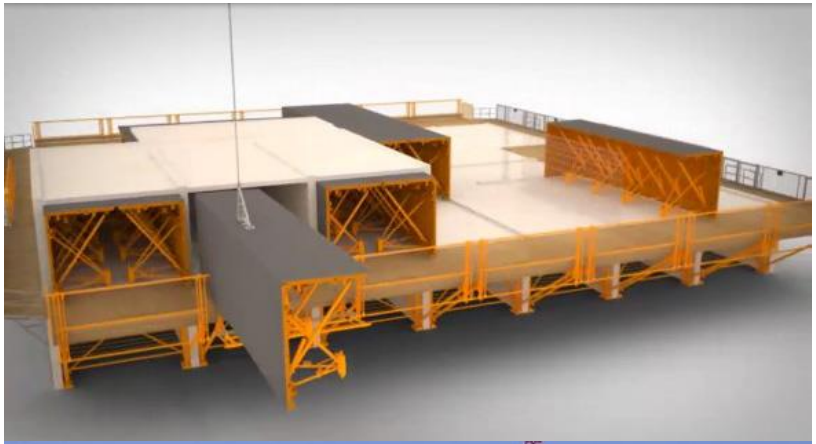
Monolithic Concrete Construction using Tunnel Formwork

- 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.
- The system intends to replace the conventional RCC Beam-Column structure which uses steel/plywood shuttering.
- ‘TunnelForm’ 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 mechanical, electrical and plumbing services.
- Installation of reinforcement in the walls and slabs.
- Concreting

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 finished components are then transported to site, erected & installed.
- The construction process comprises of manufacturing of 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 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.

Number of Houses : 1152


Ground Floor Column Work in Progress - March 2021

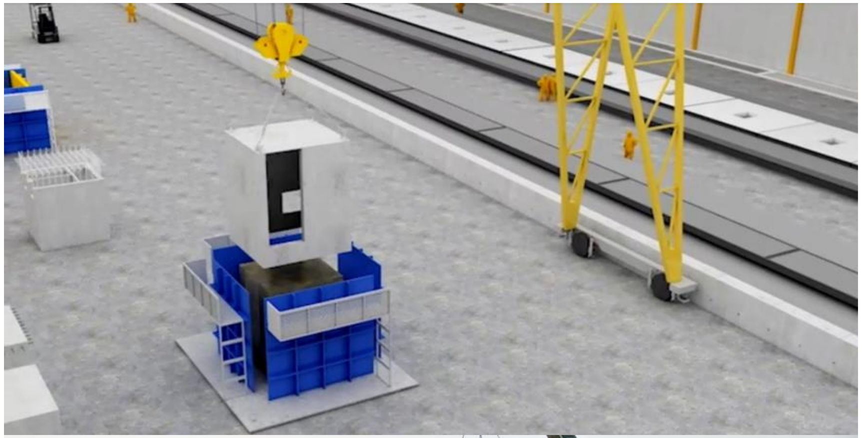

First Floor Column & Beam Erection - May 2021

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.
- Factory finished building units/modules are installed at the site with the help of tower cranes. Gable end walls are positioned to terminate the sides of building.
- Pre stressed slabs are then installed as flooring elements. Rebar mesh is finally placed for structural screed thereby connecting all the elements together. Consecutive floors are built in similar manner to complete the structure.

Number of Houses : 1008



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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.
- The other options of dry walling components such as sandwich panels with insulation material in between can also be used. Similarly, the floors can either by composite slab/deck slabs/precast hollow core slabs as per the need & requirements.

Number of Houses : 1000

LHP Agartala

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.
- Construction is done in a sequential manner where at first, the Prefabricated PVC Wall panels and Pre-Engineered Steel Structural Sections as per the design are transported to the Site.
- 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. Upon installment of wall panels, flooring and ceiling, the finishing work is executed.

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.

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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.

Session 2: Thermal comfort

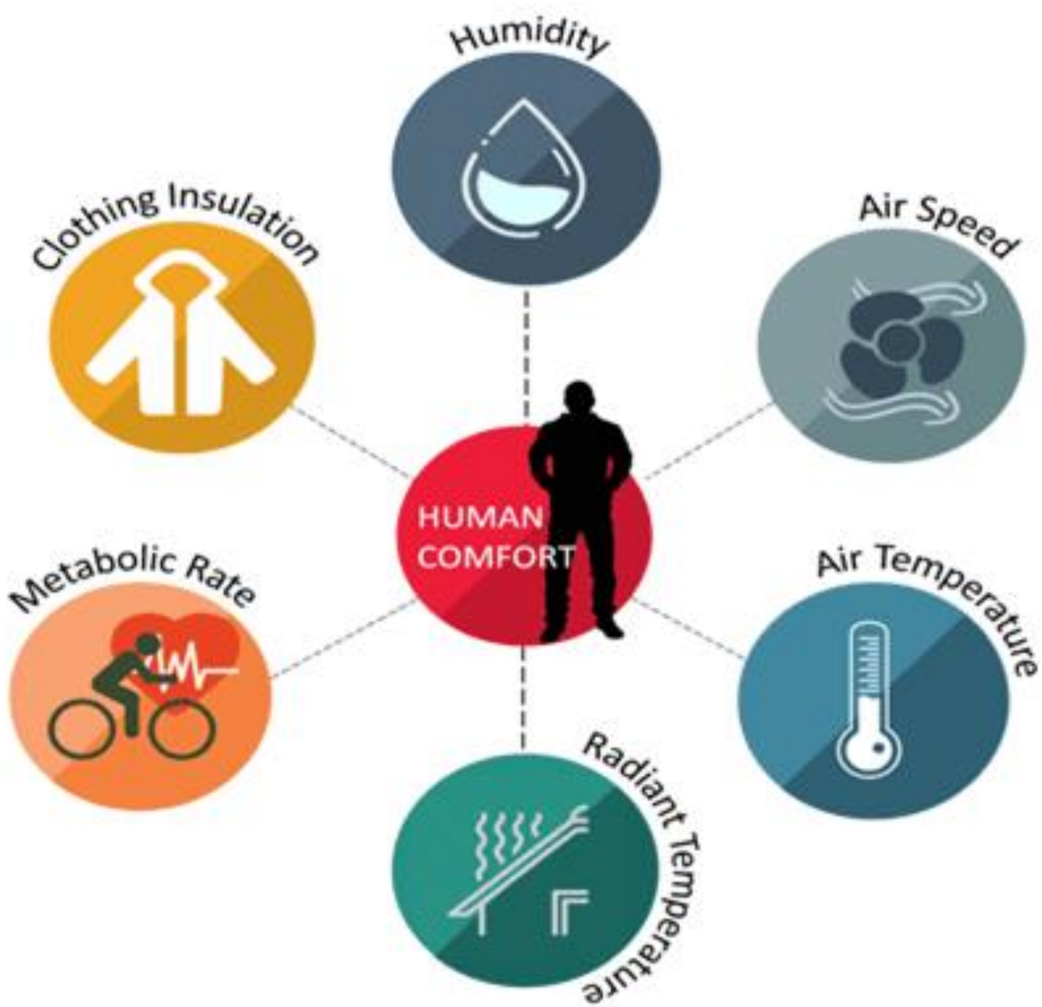
Thermal Comfort – Definition

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/

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

0.6 clo

Jeans + Blazer

1.0 clo

Woollen Clothes

1.5 clo

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

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Thermal Discomfort

- **Local Thermal Discomfort**

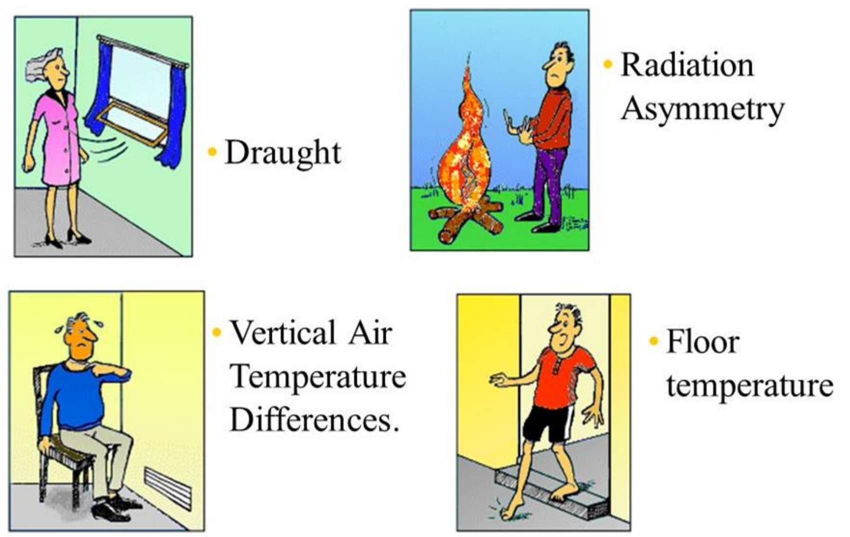
- The local thermal discomfort is **unwanted cooling or heating** on a particular part of an occupant's body

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

Too warm or too cold Flooring

Local convective cooling (draught)

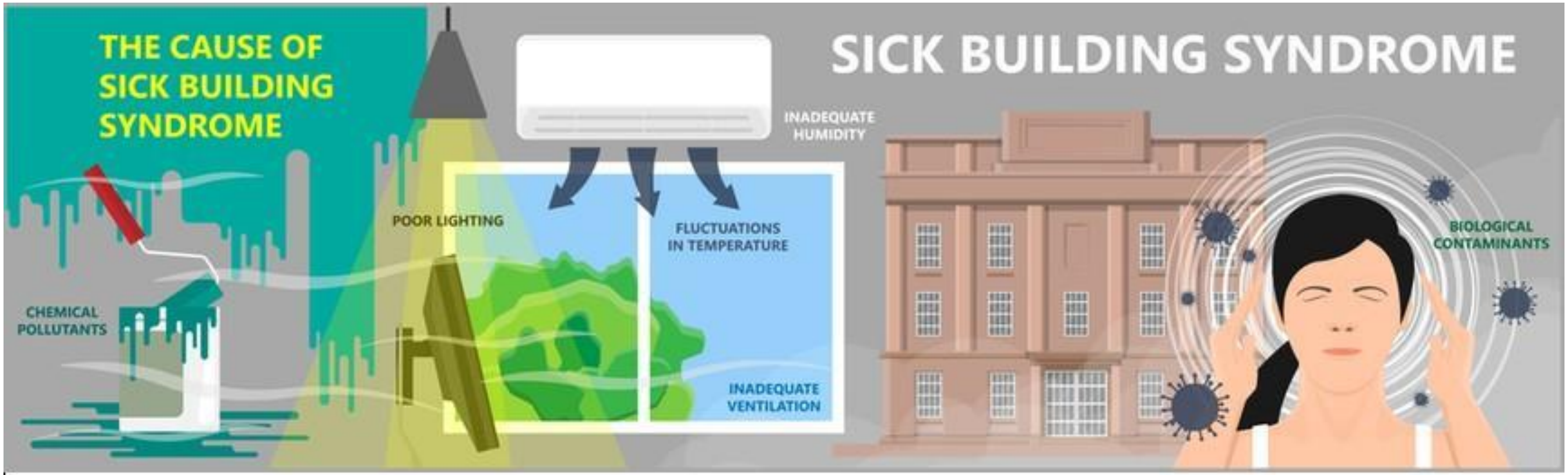
Vertical Air temperature difference (Warm air near head & Cold air near feet)



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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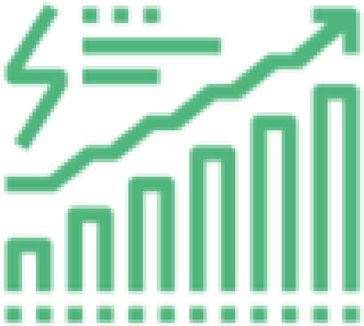
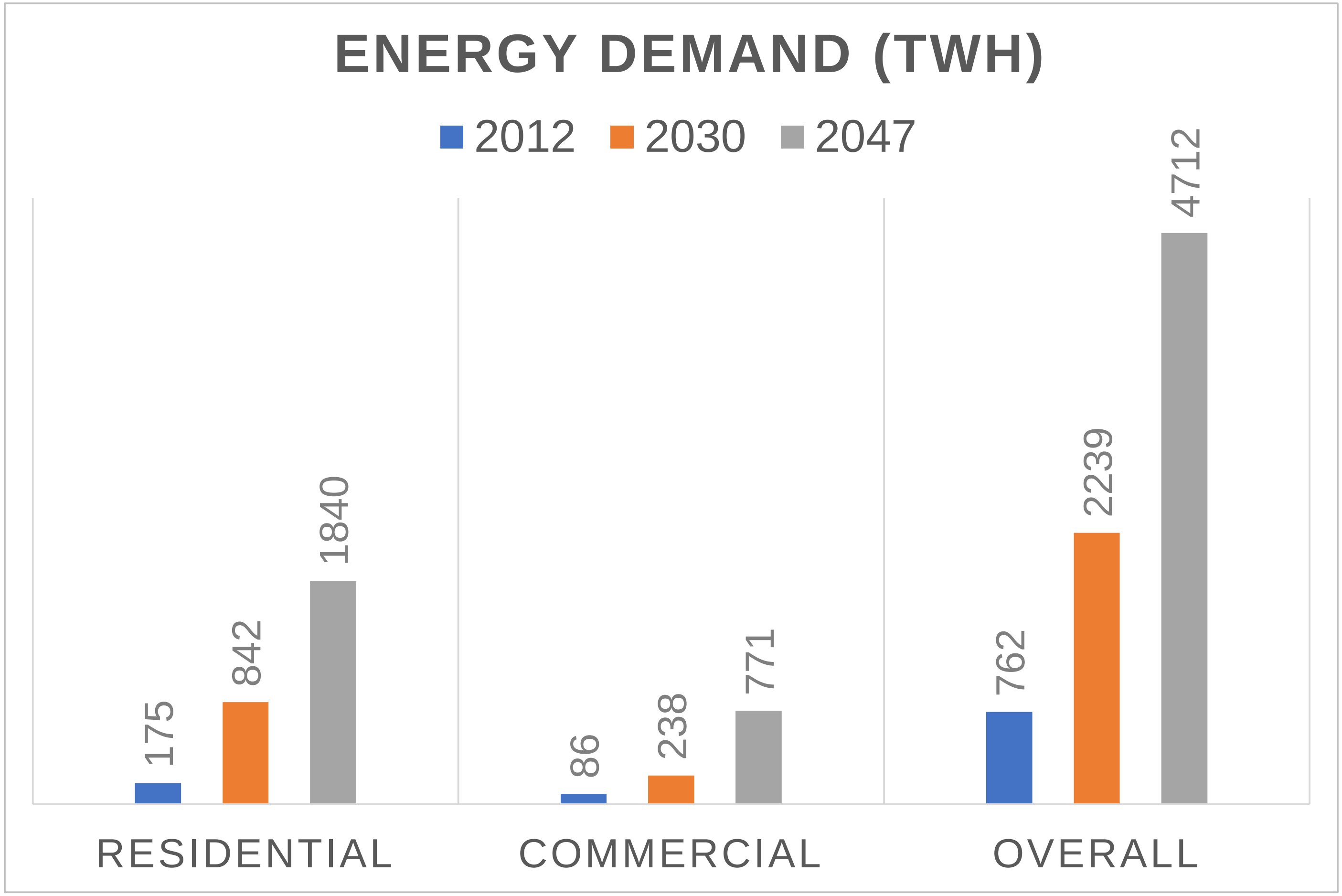
Necessity of Thermal comfort in Affordable Housing

Affordable Housing Demand



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

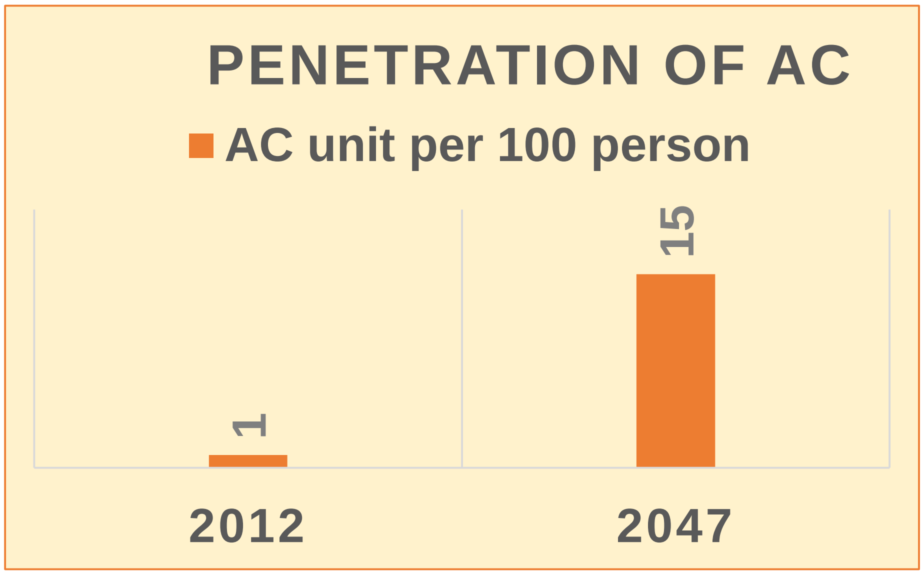
Source: India 2020 Energy Review Policy

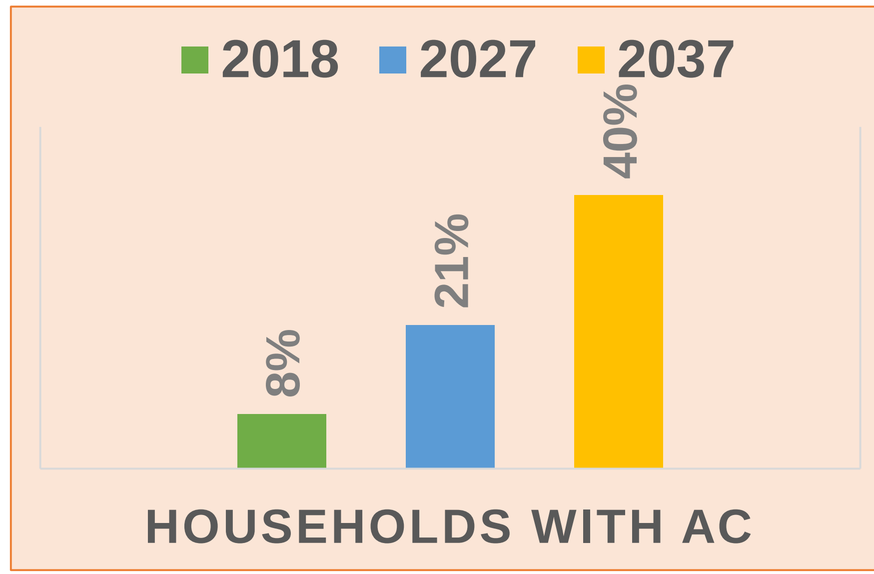


Source: NITI Aayog 2015

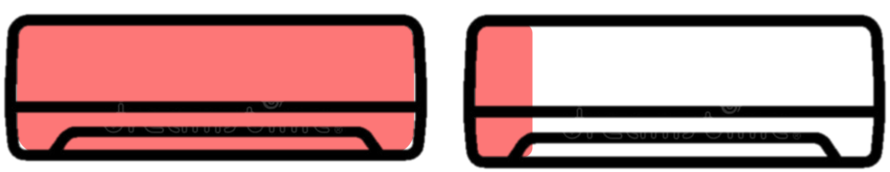
Increase in AC demand in the Residential Sector

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



1.2 ACs (Average) for all households that have AC

National Sample Survey Office,2011

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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
- Off-grid micro-systems for cooling
- Localized heat-action plans could be provided.

Implementation & Enforcement measures

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

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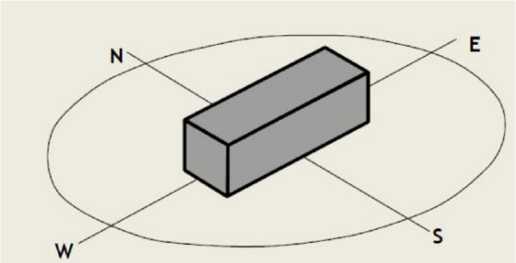
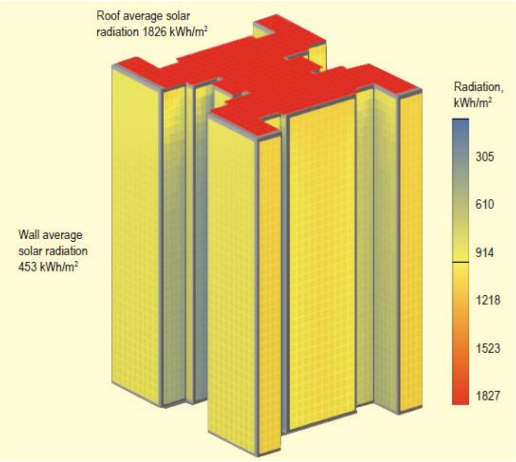
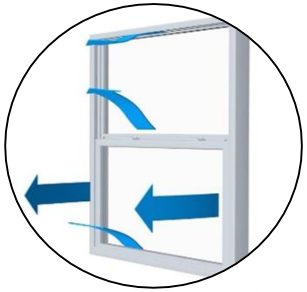
Thermal Comfort Improvement through Design

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





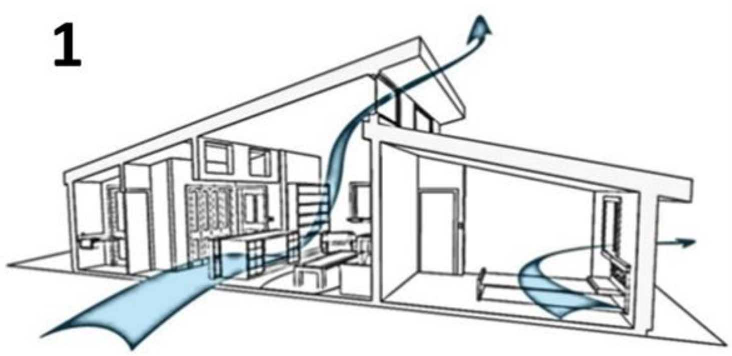


Active Strategies

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

Thermal Comfort Improvement through Passive Measures

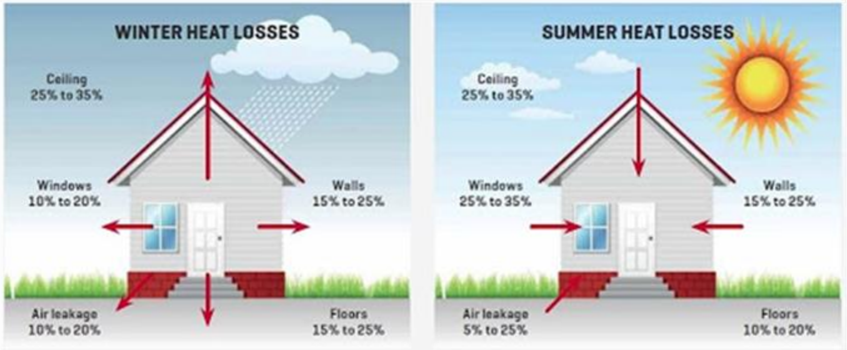
Minimum Building Envelope design standards are developed to improve Energy Efficiency in Residential Buildings



1. For Adequate natural ventilation potential for thermal comfort

2. For adequate day light for visual comfort

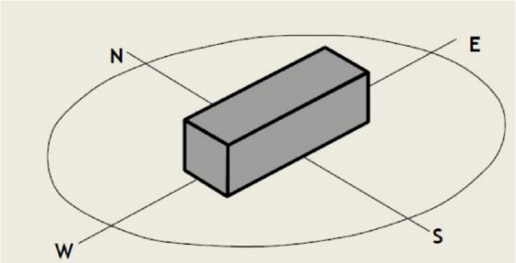
3

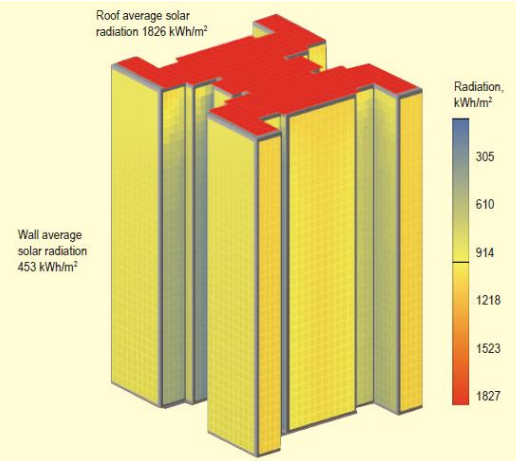


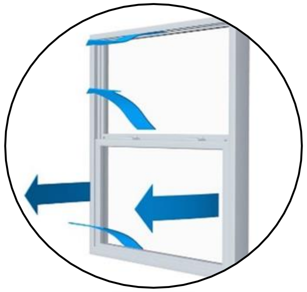
3. Limit heat gains / heat loss for energy efficiency

Thermal Comfort Improvement through Passive Measures

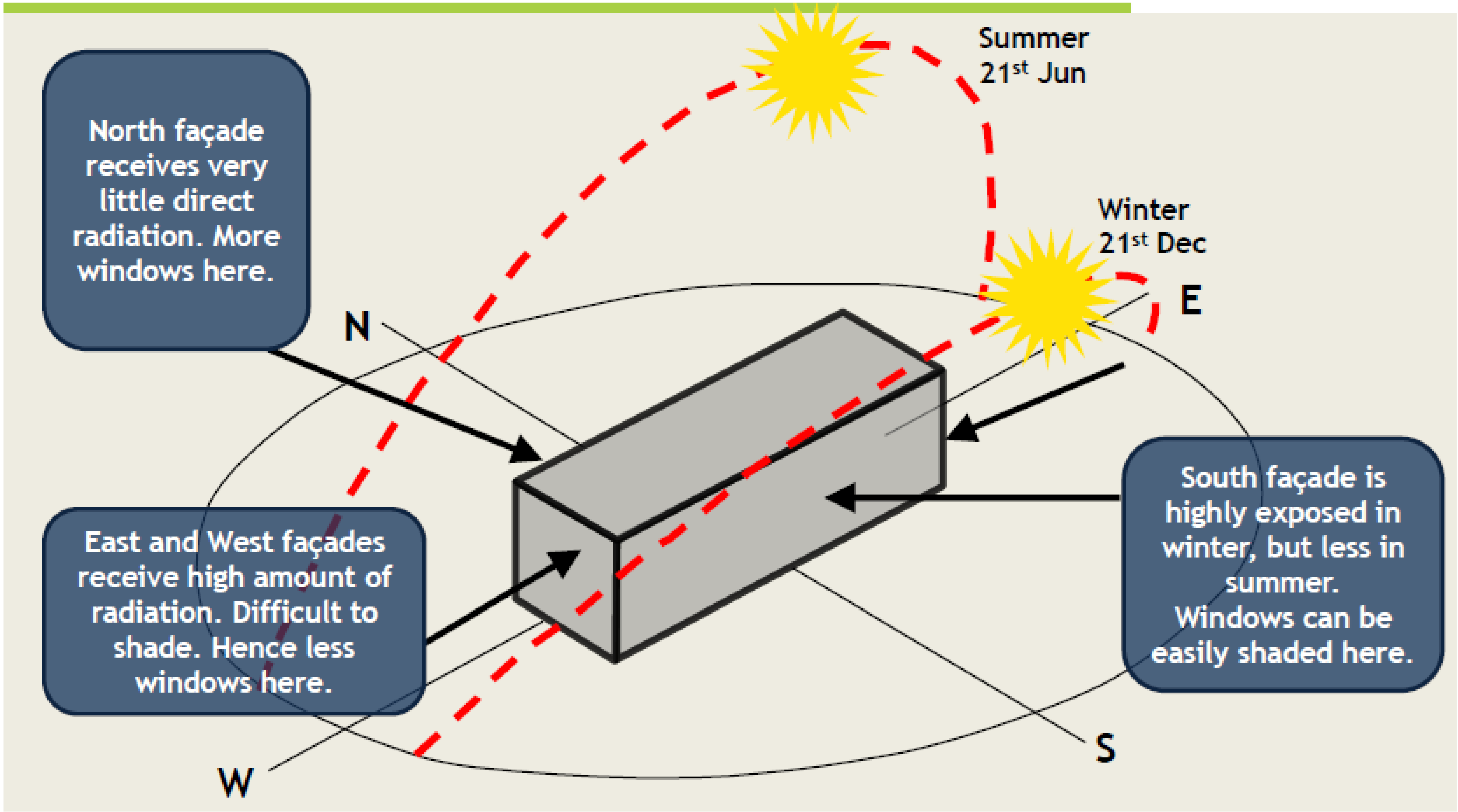
1. Orientation
2. Thermal Mass
3. Roof and Wall Materials
4. Non Opaque material properties
5. Appropriate Shading Design
6. Minimize Infiltration losses
7. Climate specific design interventions
8. Mutual / Tree Shading



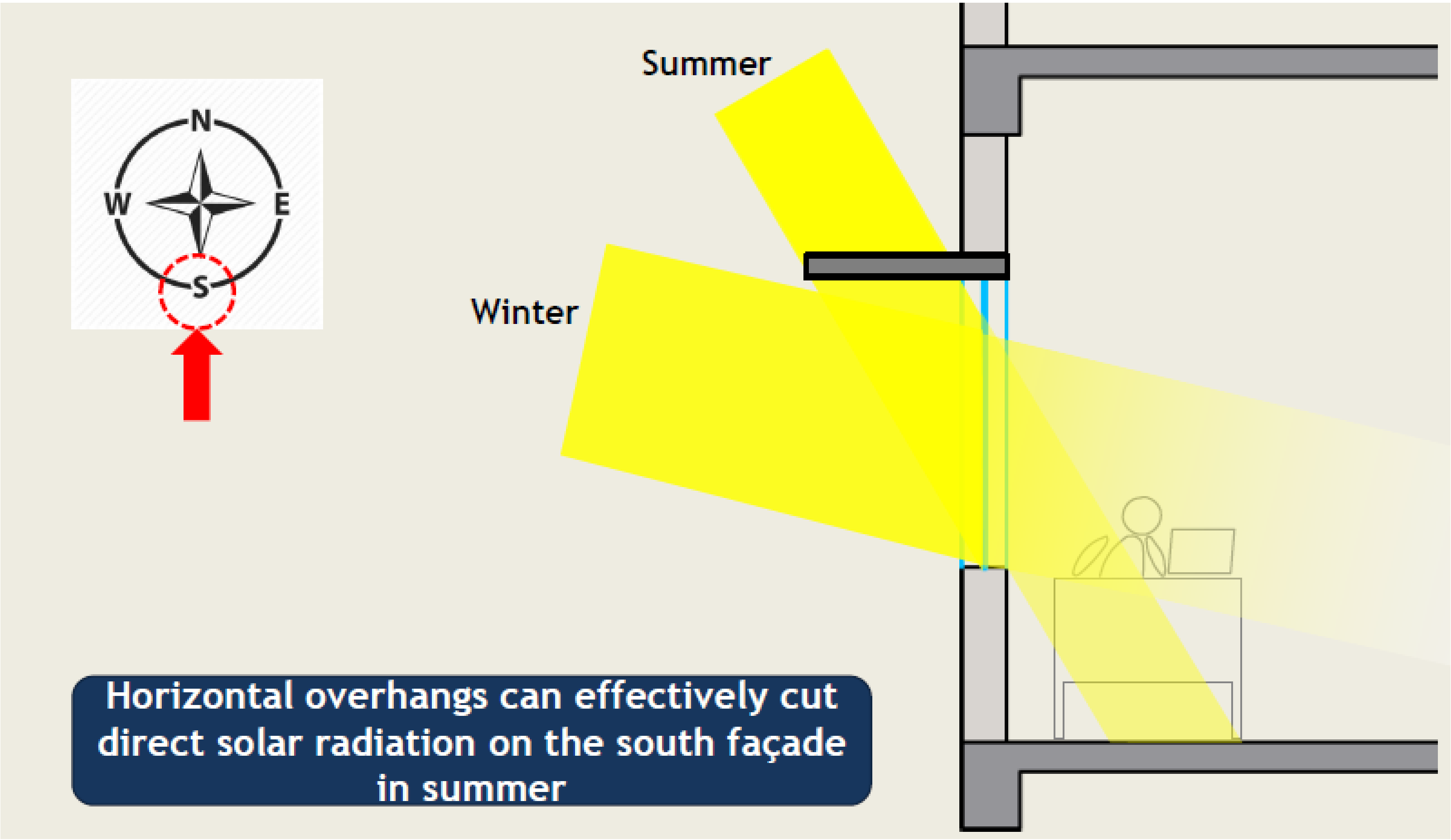




Passive Measures - Orientation



Passive Measures - Shading



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

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

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Pradhan Mantri Awas Yojana-Urban

Ministry of Housing and Urban Affairs
Government of India

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Session 3: Thermal Comfort Models

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

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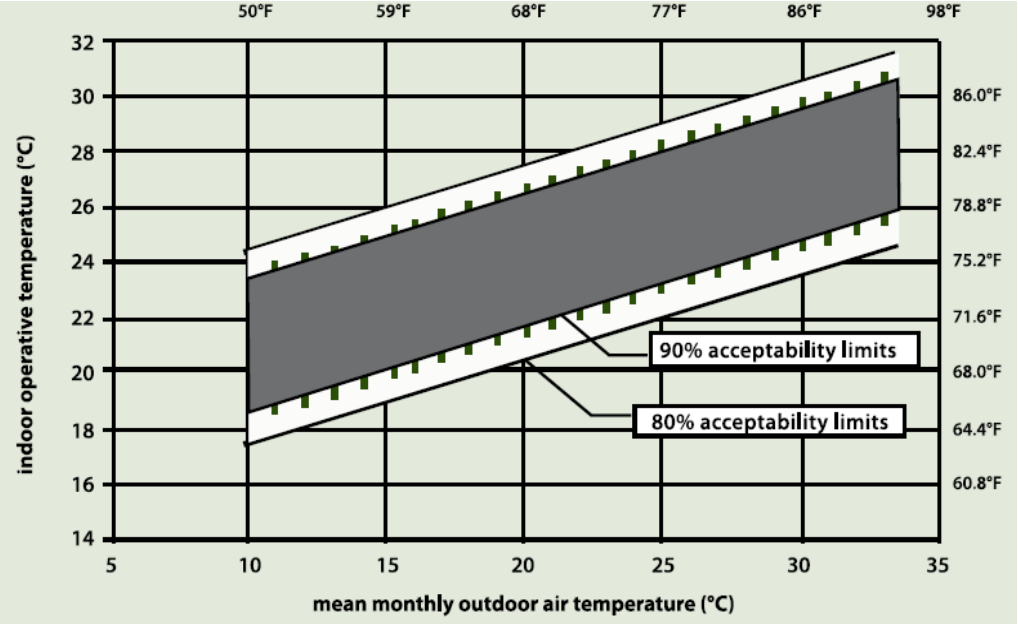
Thermal Comfort Standard – IMAC R

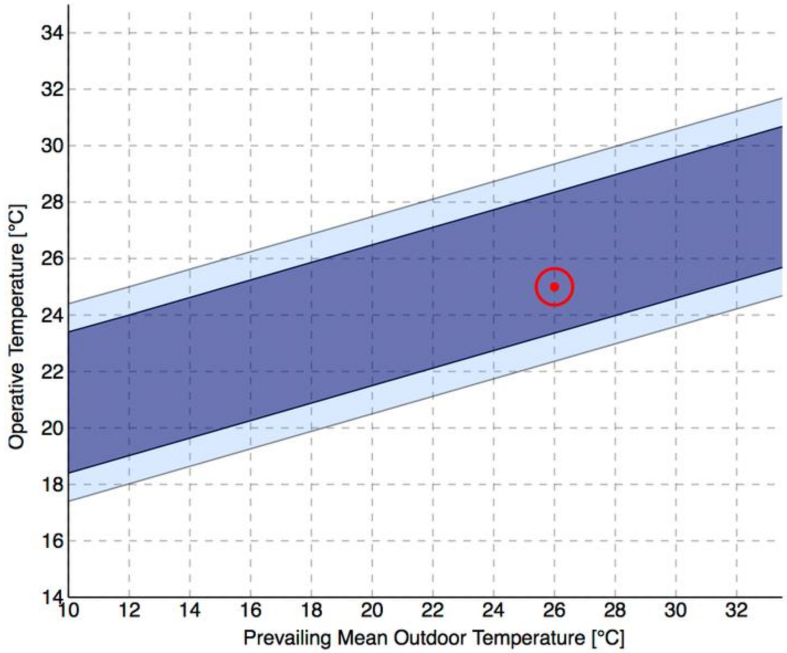
Indian Model for Adaptive Thermal Comfort (IMAC) models for neutral temperature and acceptability limits for naturally ventilated residential buildings through an empirical field study specific to the Indian context. It offers an energy-efficient pathway for the building sector without compromising occupant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



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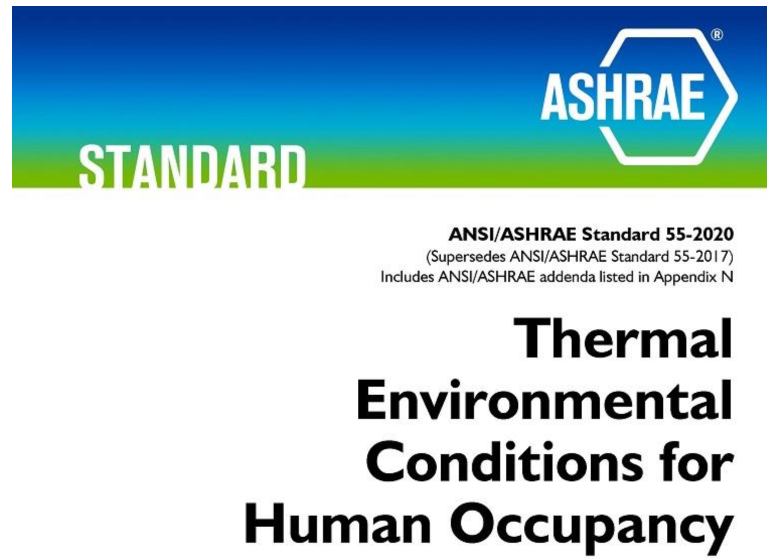
Thermal Comfort Standard – ASHRAE 55

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

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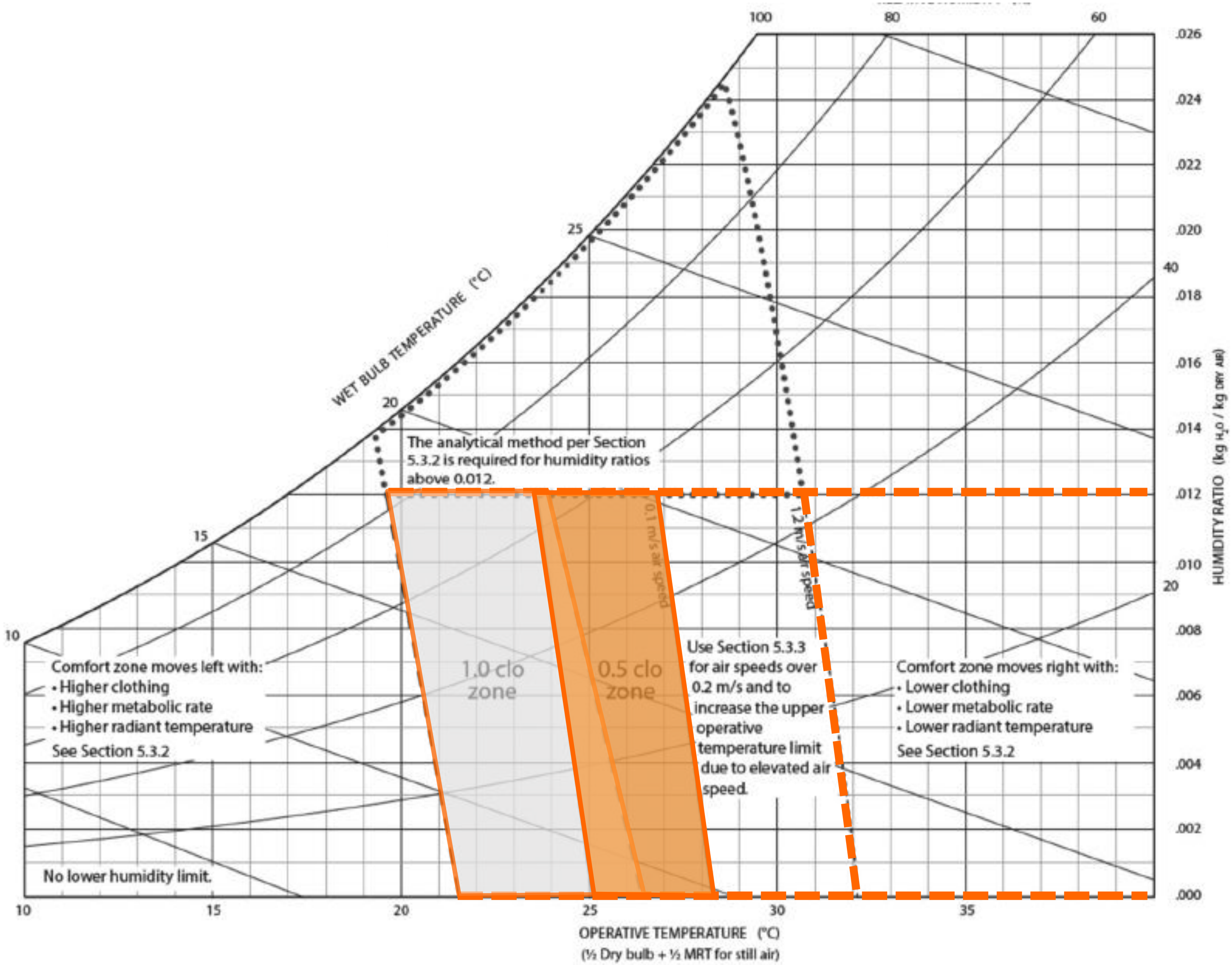
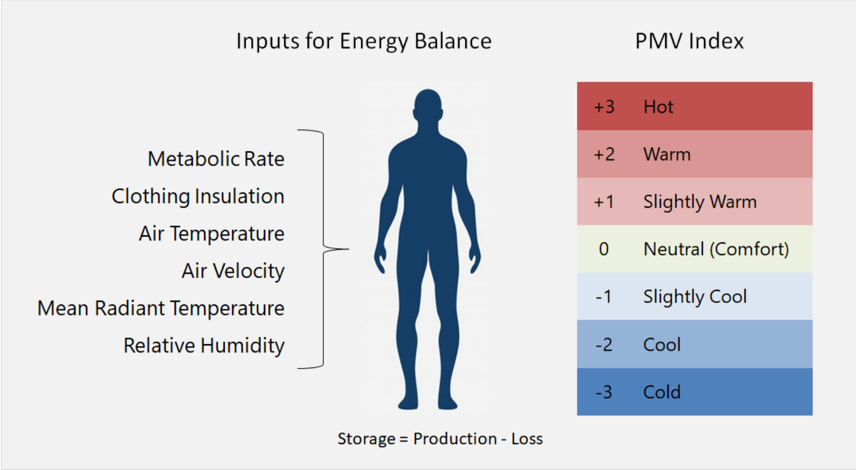
Thermal Comfort Standard – ASHRAE 55

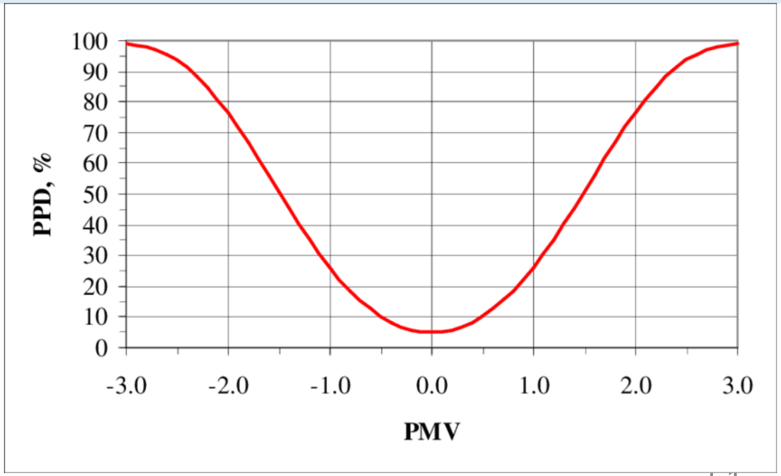


Thermal Comfort Standard – ASHRAE 55

- **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

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Thermal Comfort Improvement through Materials

Materials without Insulation

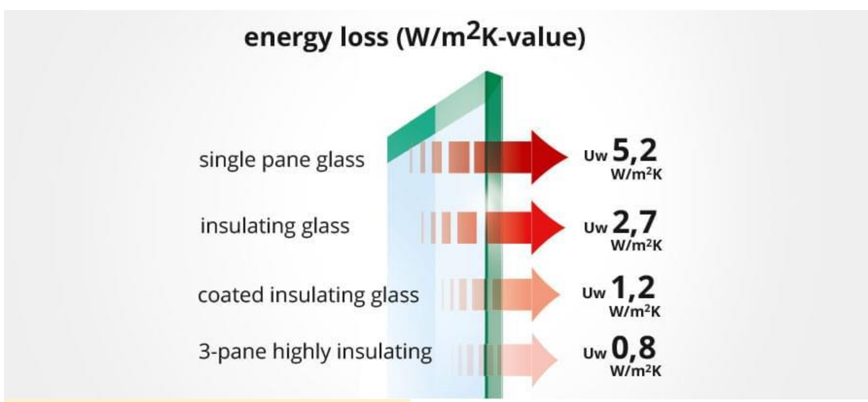
Wall materials	U Value (W/sqmK)
150 mm RCC (No plaster)	3.77
200 mm Solid Concrete Block with plaster on both sides	2.8
230 mm Brick with plaster on both sides	1.72-2.24
200 mm Autoclaved Aerated Concrete (AAC) with plaster on both side	0.77
300 mm Autoclaved Aerated Concrete (AAC) with plaster on both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

Thermal Comfort Improvement through Materials

EPS Insulation

XPS Insulation

Glass Mineral Wool



Glazing Options

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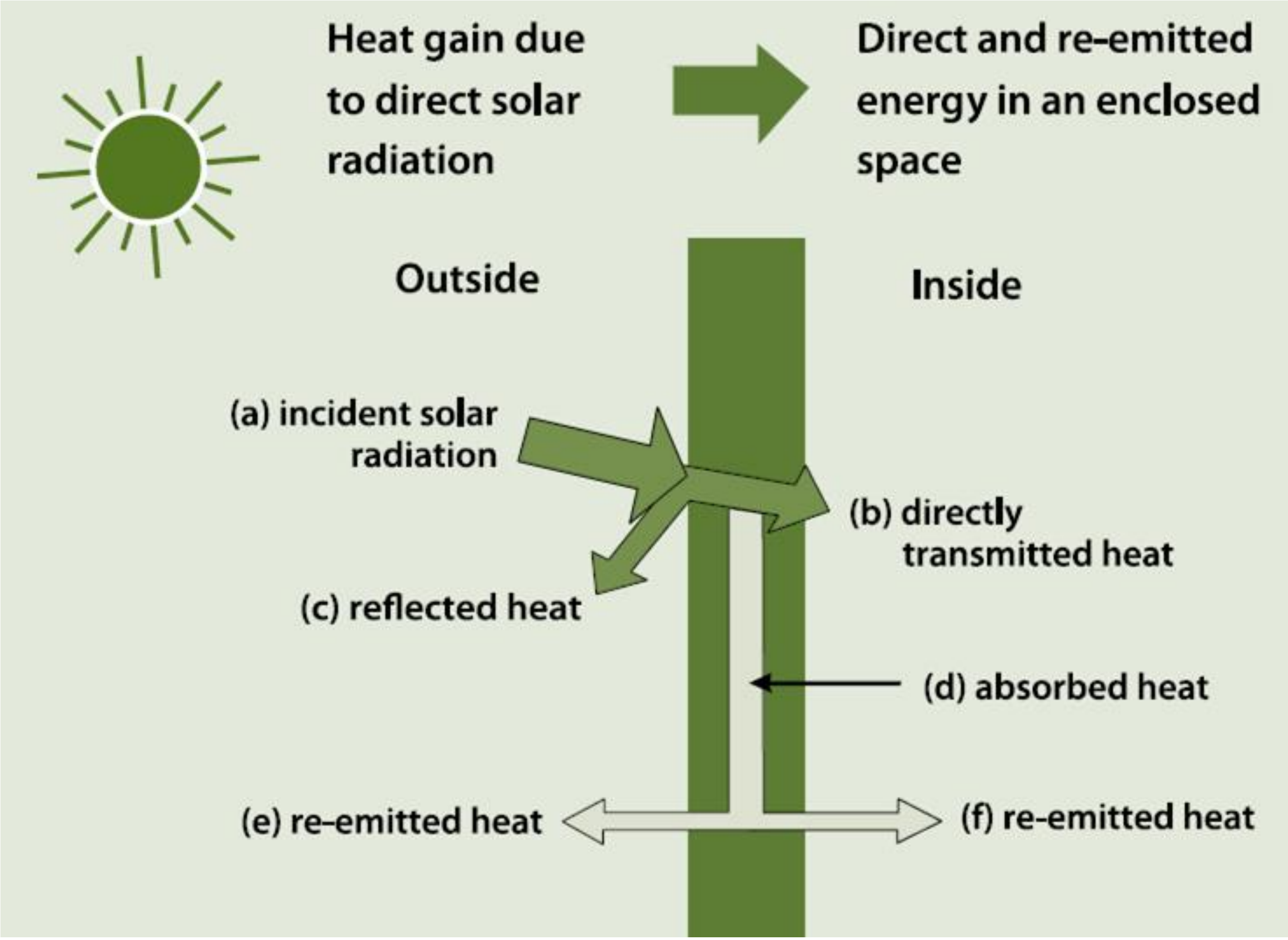
Thermal Comfort Improvement through Materials



Thermal Comfort Improvement through Materials

Glazing Selection

U-value / U-factor

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

SHGC – Solar Heat Gain Coefficient

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

Case Study

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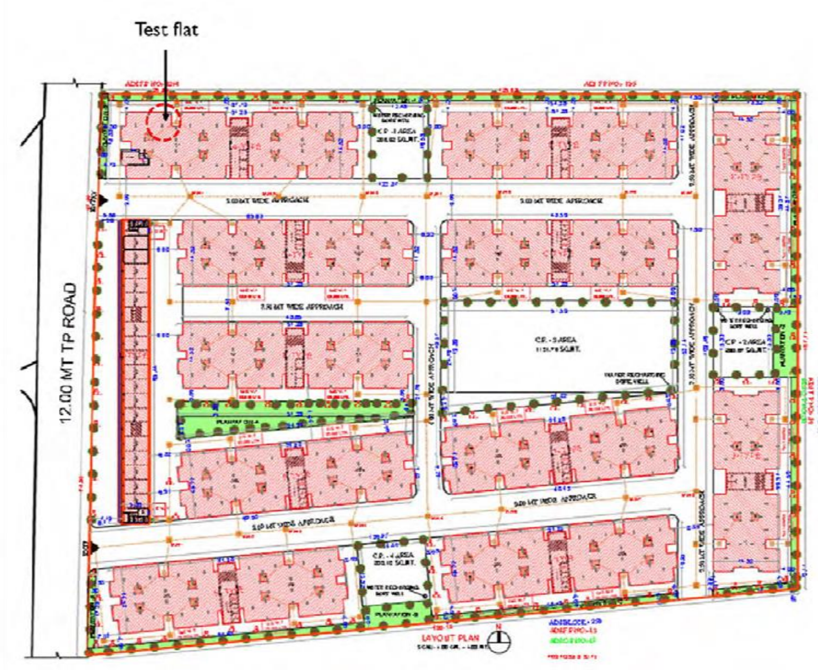
Case Study : Smart Ghar, Rajkot

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

by

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

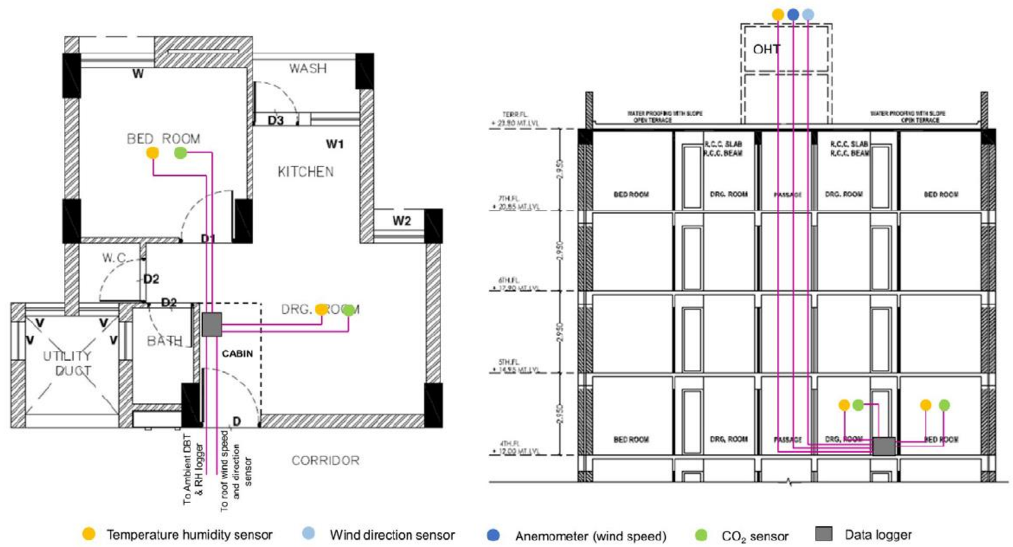
- Project Type - *PMAY Housing*
- Location - *Rajkot*
- Dwelling Units - *1176*
- DU Area - *33.6* m^2
- Ext Wall – *200mm AAC (E&N) & Cavity Wall (200mm AAC + 40mm air gap + 200mm AAC) (W&S Side)*
- Casement windows – for ventilation improvement
- Window shading – *Overhang & Side fins*
- *Glazed window*



Case Study : Smart Ghar, Rajkot

Validation by Software

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



Results

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

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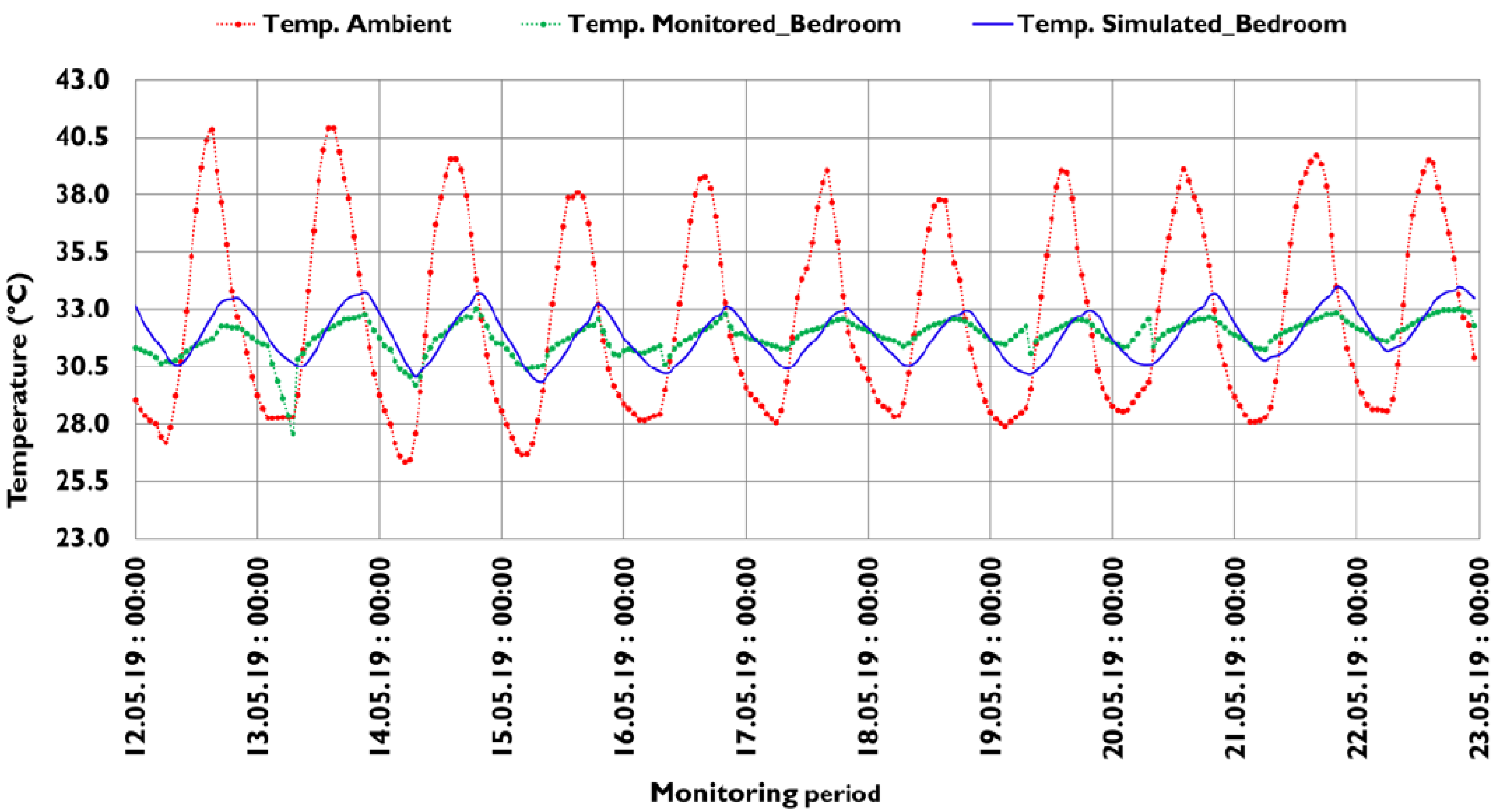
Case Study : Smart Ghar, Rajkot

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.*

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Green Building

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

There are a number of features which can make a building 'green'. These include:

- Efficient use of energy, water and other resources
- Use of renewable energy, such as solar energy
- Pollution and waste reduction measures, and the enabling of re-use and recycling
- Good indoor environmental air quality
- Use of materials that are non-toxic, ethical and sustainable
- Consideration of the environment in design, construction and operation
- Consideration of the quality of life of occupants in design, construction and operation
- A design that enables adaptation to a changing environment

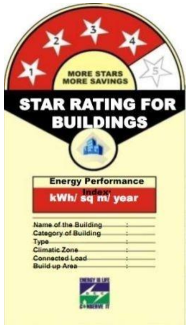
Green Building Rating Systems

INDIA

GRIHA

"GRIHA"
Green building
'Design evaluation system'
A tool
To design, operate, evaluate and maintain
resource efficient
'healthy'
and
'intelligent' building

Indian Green Building Council
Greening India since 2001



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Green Measures – LHP Chennai

Solar PV Panels

Recharge Pits

AAC Blocks

STP – Recycled water for flushing

Landscaping – Sprinkler irrigation

DAY 2

Session 1: Eco Niwas Samhita

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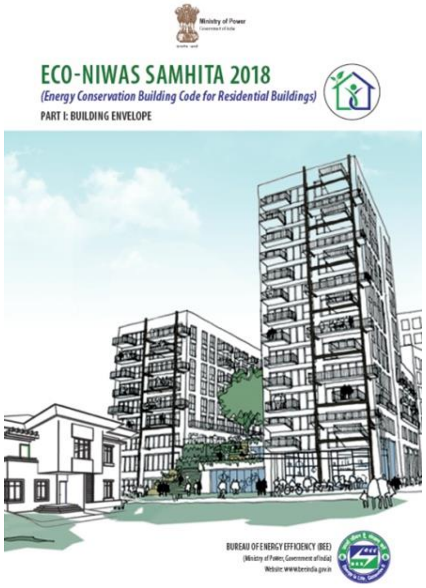
Eco Niwas Samhita (ENS)

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



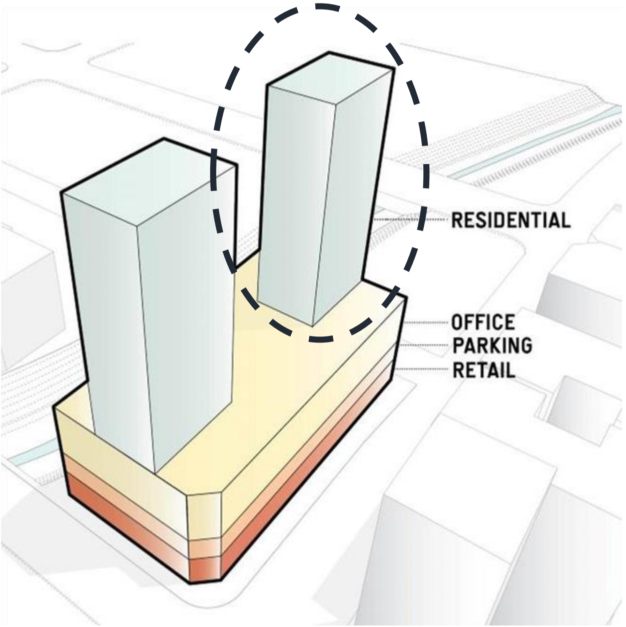
Eco Niwas Samhita Part 1

Launch of Eco Niwas Samhita in December 2018

Eco Niwas Samhita (ENS)

The code is applicable to

(a)Residential Buildings with **plot area ≥ $500m^2$**



(b) Residential part of **"Mixed Land-use building projects" built on plot area of ≥ $500m^2$.**

Excluded from the code

Dormitories

Hotels

Lodging Rooms

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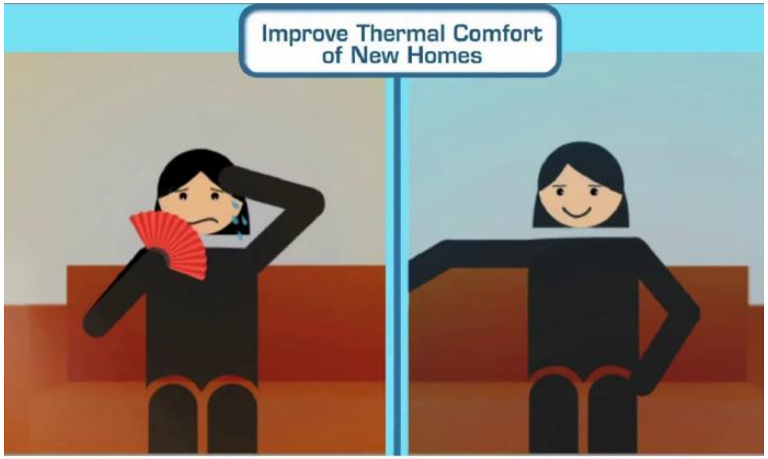
Eco Niwas Samhita (ENS) Benefits

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

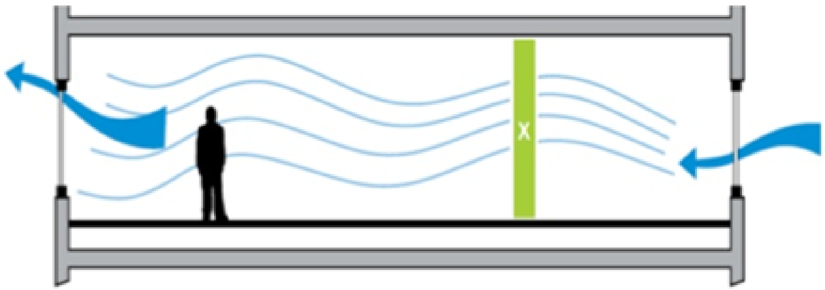
3.1 Openable Window to Floor Area Ratio (WFR_{op})	For Natural Ventilation
3.2 Visible Light Transmittance (VLT)- Derived from WWR	For Day Light Potential
3.3 Thermal Transmittance of Roof (U_{roof})	For Thermal Transmission
3.4 Residential Envelope Transmittance Value (RETV)	For Thermal Transmission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

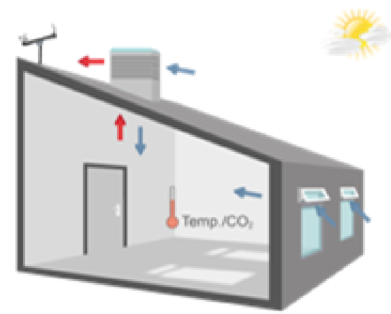
ENS – Part 1 – Building Envelope

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

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)

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

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

*** Note for WWR ≤ 0.15 , VLT – 40%**

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})

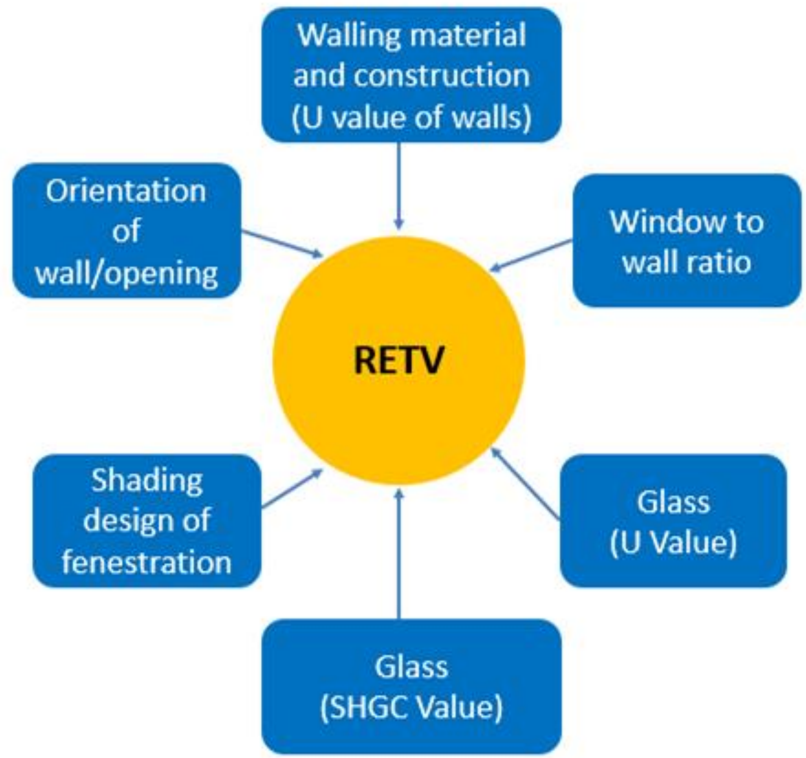
Thermal Transmittance of roof U_{roof} - Is the rate of transfer of heat through the roof structure (which can be a single material or an assembly), divided by the difference in temperature across that structure.

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

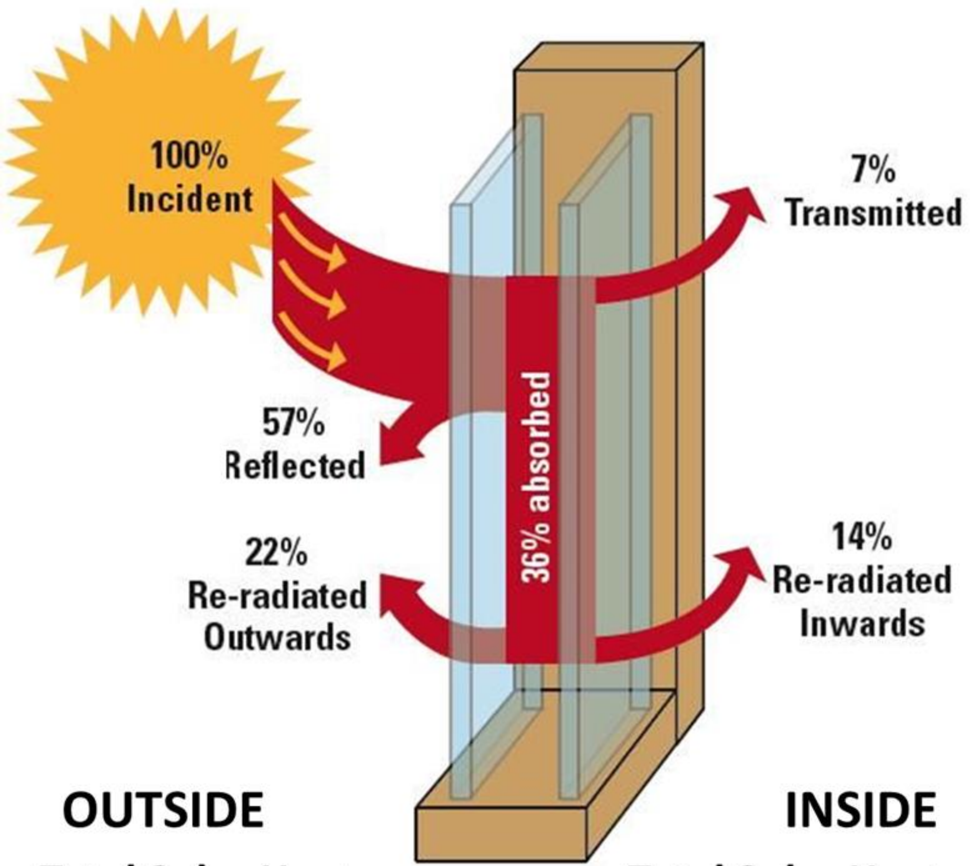
ENS – Part 1 – Building Envelope

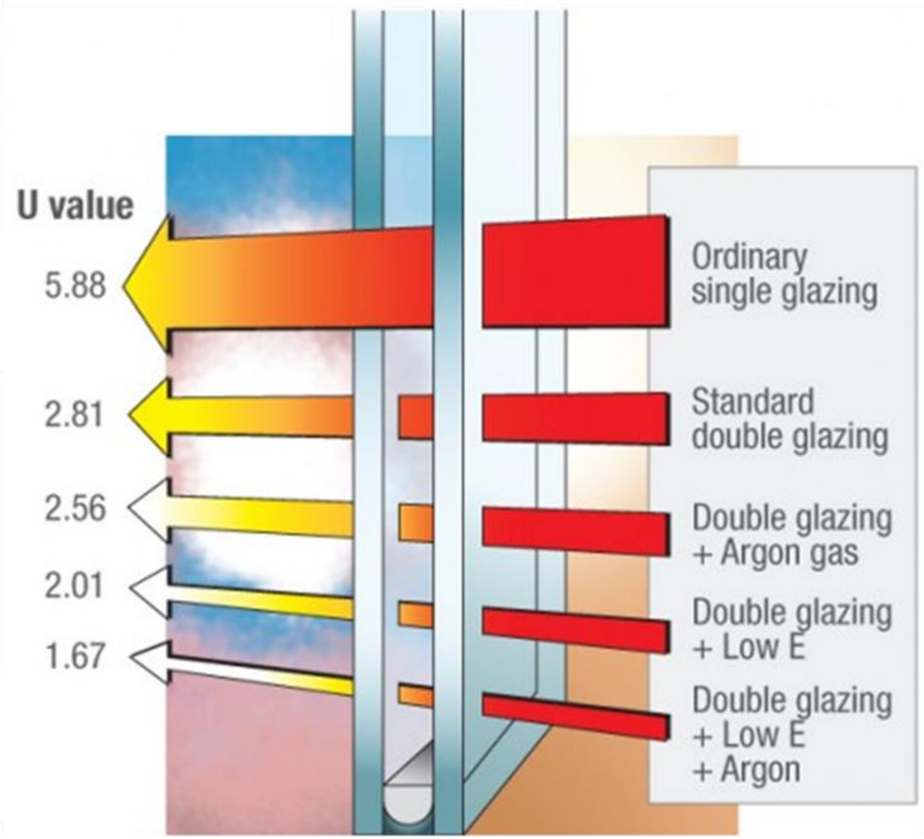
3.4 Residential Envelope Transmittance (RETV)



ENS – Part 1 – Building Envelope

3.4 Thermal Transmittance Value (U-Value) Non Opaque





Total Solar Heat **Elimination : 79%**

Total Solar Heat **Transmission : 21%**

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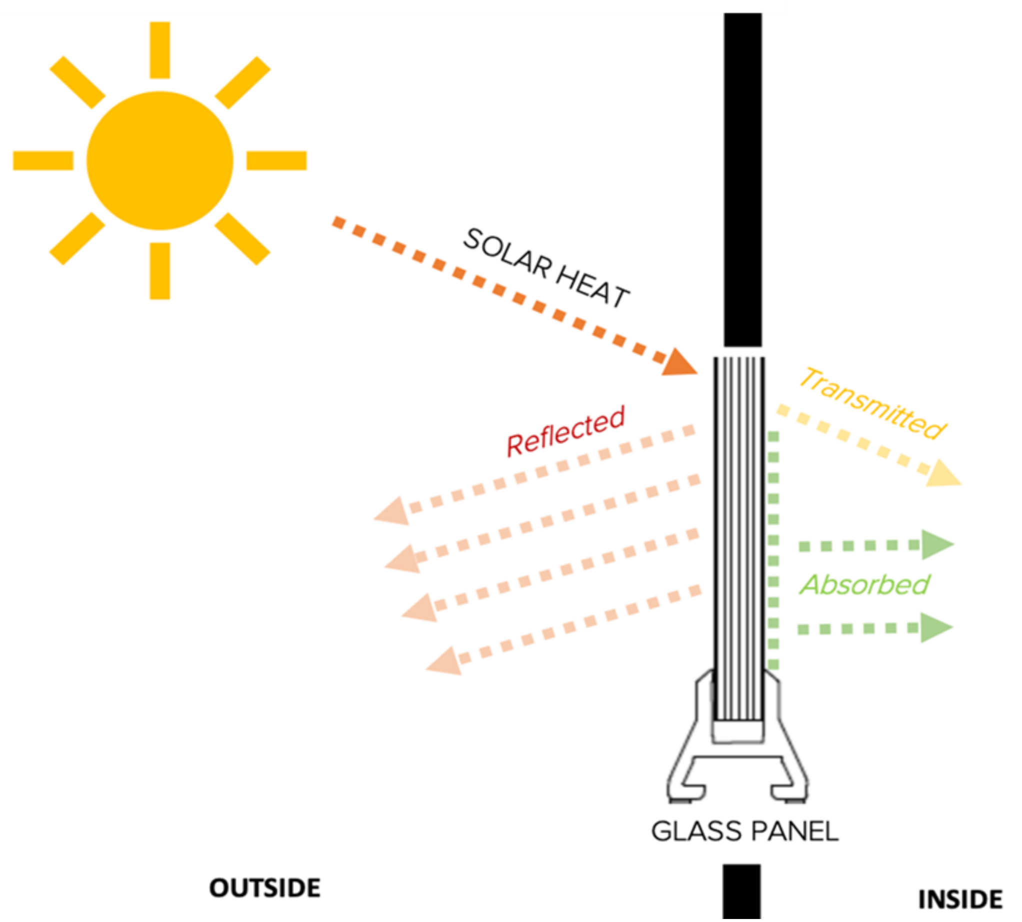
ENS – Part 1 – Building Envelope

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

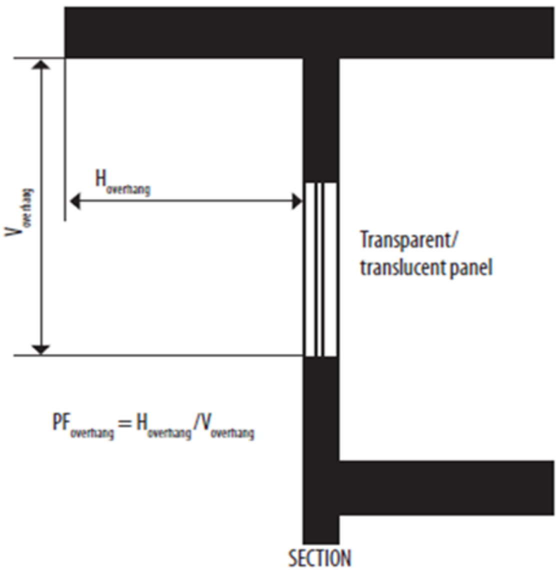
Solar Radiation is subsequently released inward through conduction, convection and radiation.

ENS – Part 1 – Building Envelope

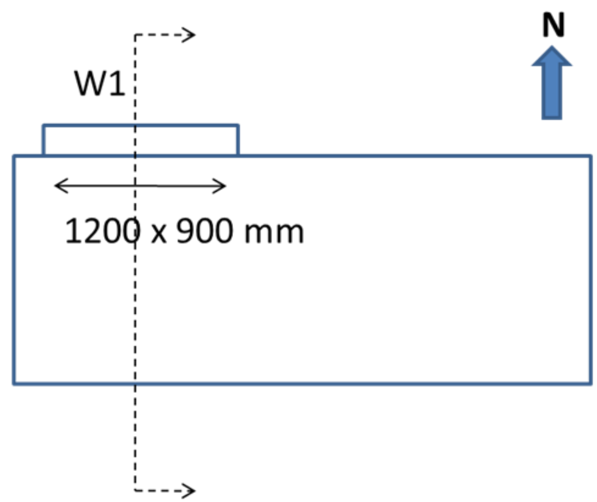
3.4 Projection Factor (PF)

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.

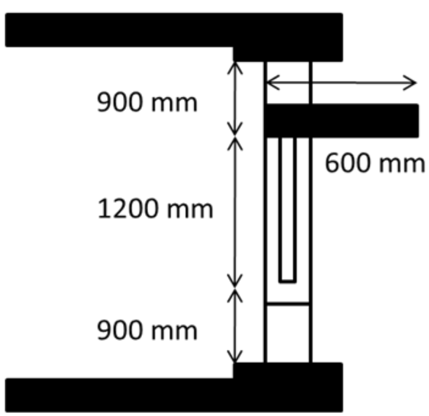
$$PF_{overhang} = \frac{H_{overhang}}{V_{overhang}}$$



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

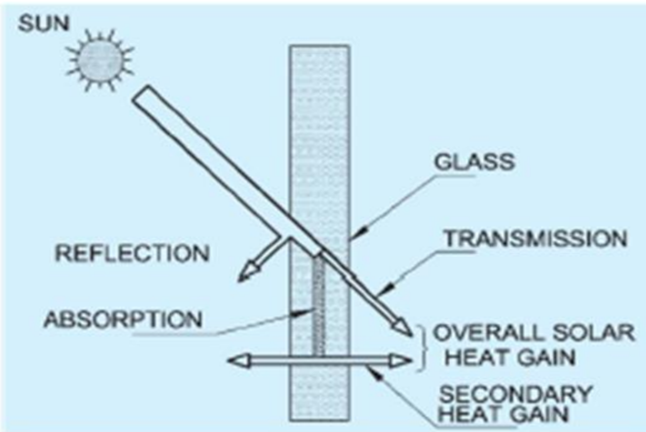


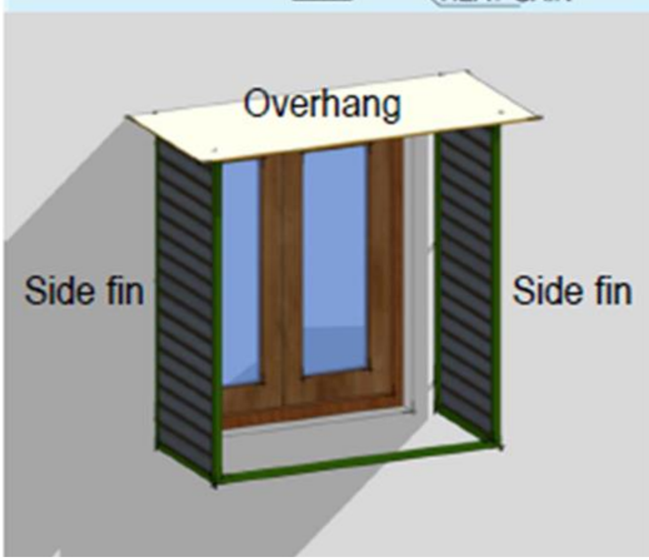
PF = 600/1200 = 0.5

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.

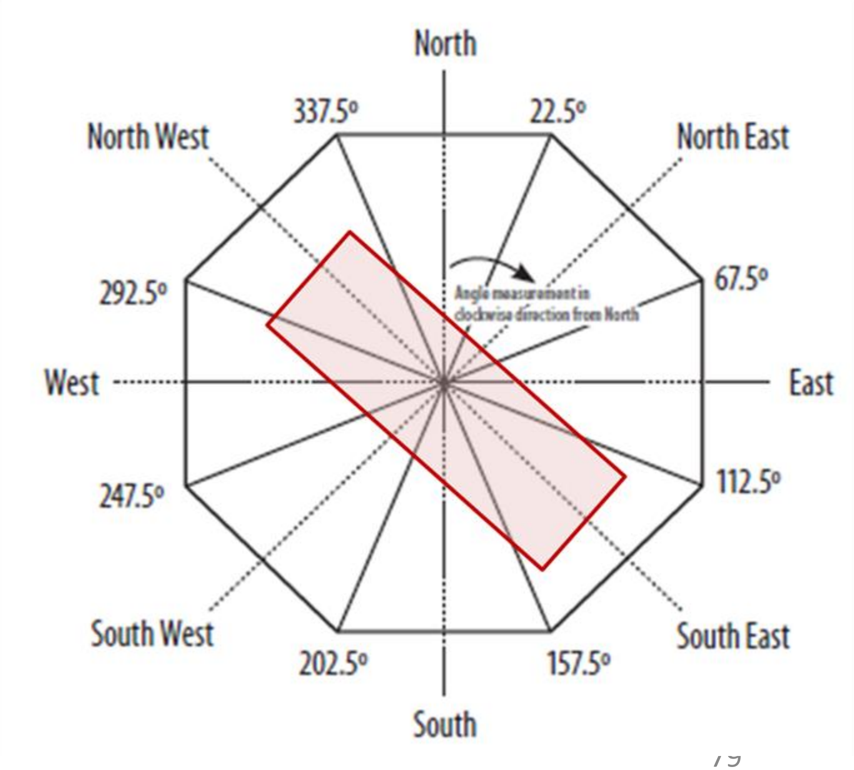
$$SHGC_{eq} = SHGC_{unshaded} \text{ X } ESF_{total}$$

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



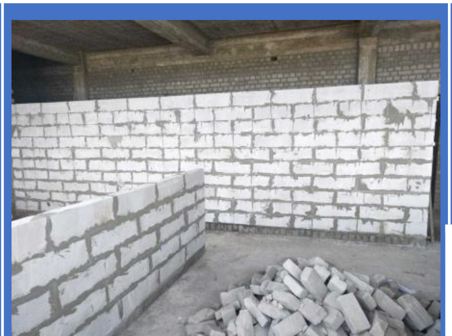
ENS – Part 1 – Building Envelope

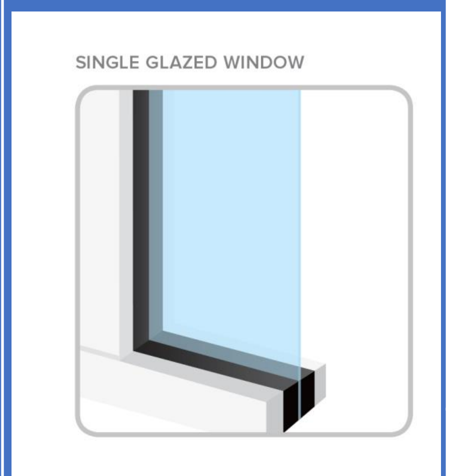
3.4 RETV – Case 1

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			

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 $W/m^2.K$			

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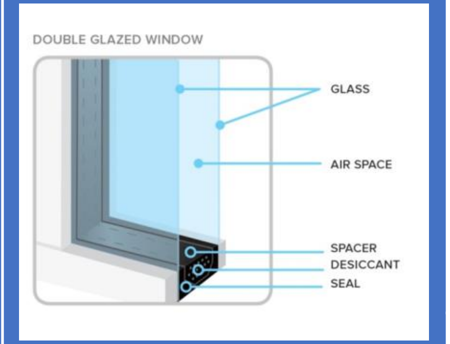
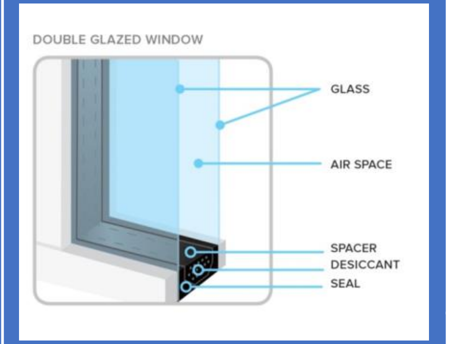
3.4 RETV – Case 3

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 $W/m^2.K$			

ENS – Part 1 – Building Envelope

3.4 RETV – Case 4

Case 4	External wall	Roof Construction	Glazing	Window to wall Ratio
 	200mm thick AAC wall, 50 mm EPS, high SRI paint	150 mm thick RCC slab + 50mm thick EPS	Double glazed Unit - Asahi LC 54/37 U Value = 1.64 W/m2k, SHGC = 0.36, VLT=0.52	22.55%

RETV – 5.13 W/m².K

ENS – Part 1 – Building Envelope

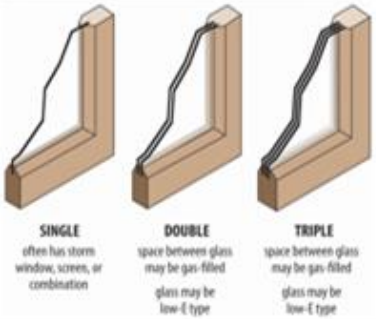
Building Design Flexibility by ENS

Material wall Assembly

Design of Window Panel

Shading of external Windows

Type of glazing



Session 2: ENS & Thermal Comfort analysis for the LHP Chennai

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Case Study : Light House Project (LHP), Chennai

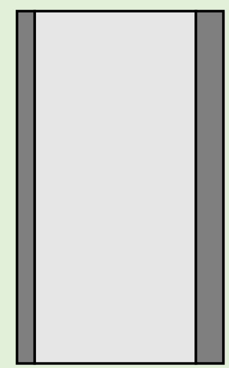
- Project Type - *PMAY Housing*
- Location - *Chennai*
- Dwelling Units - *1152*
- DU Area - *26.58 m^2*
- Precast Concrete Construction System Precast Components Assembled at Site

LHP Site - Thermal Features

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

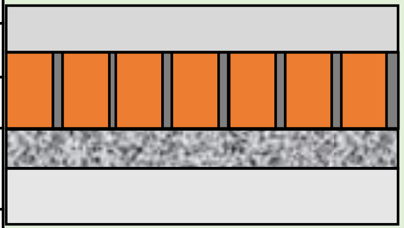
20mm Plaster + 150mm AAC block + 12mm Plaster

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.

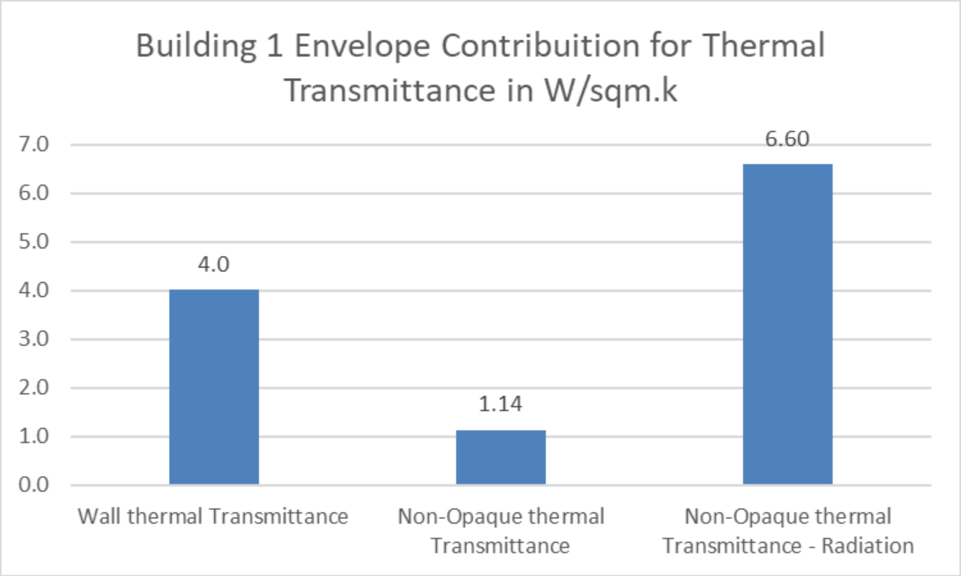
Roof Assembly								
Layer no.	***Material***	***Density (kg/m3)***	***Specific Heat (kJ/kg.K)***	***Thickness (m)***	***Conductivity (W/m-K)***	***R value m^2K/W***	***Source***	***Roof section***
1	Interior Surface film resisitance	-	-	-	5.900	0.169	ENS 2018	
2	Precast slab (RCC)	2288	NA	0.075	1.580	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**		

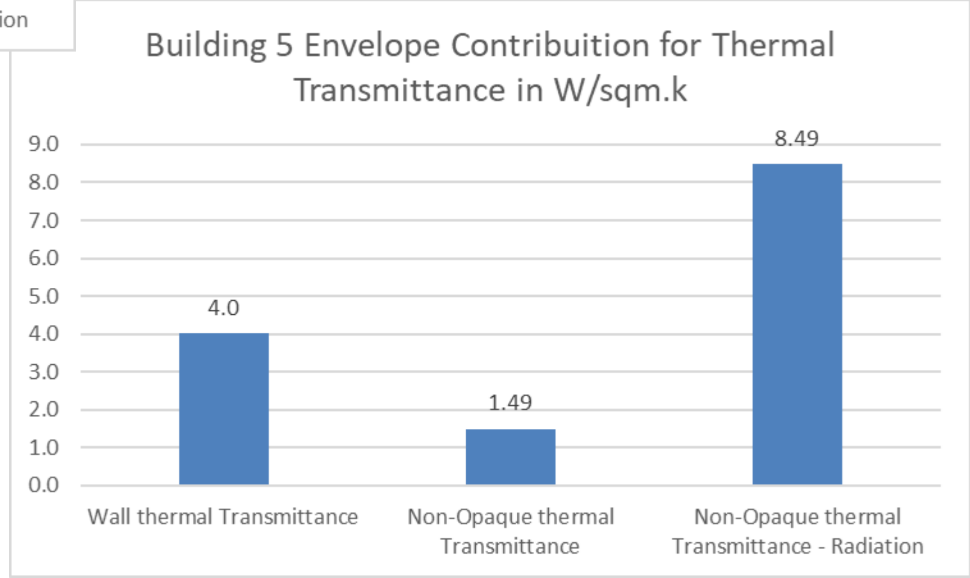
- According to ENS code, U value of roof should be within **1.2 W/sqmK**
- Inclusion of 25 mm EPS overdeck insulation would make the roof comply with ENS codes

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

LHP Site Analysis





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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%

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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%

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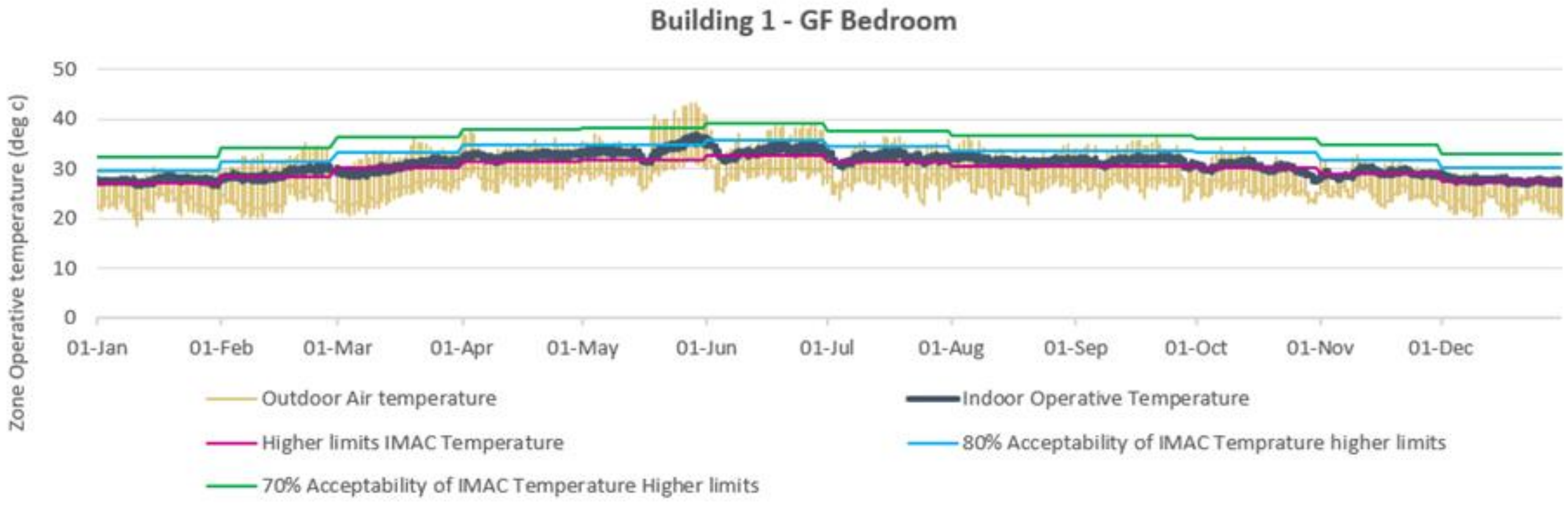
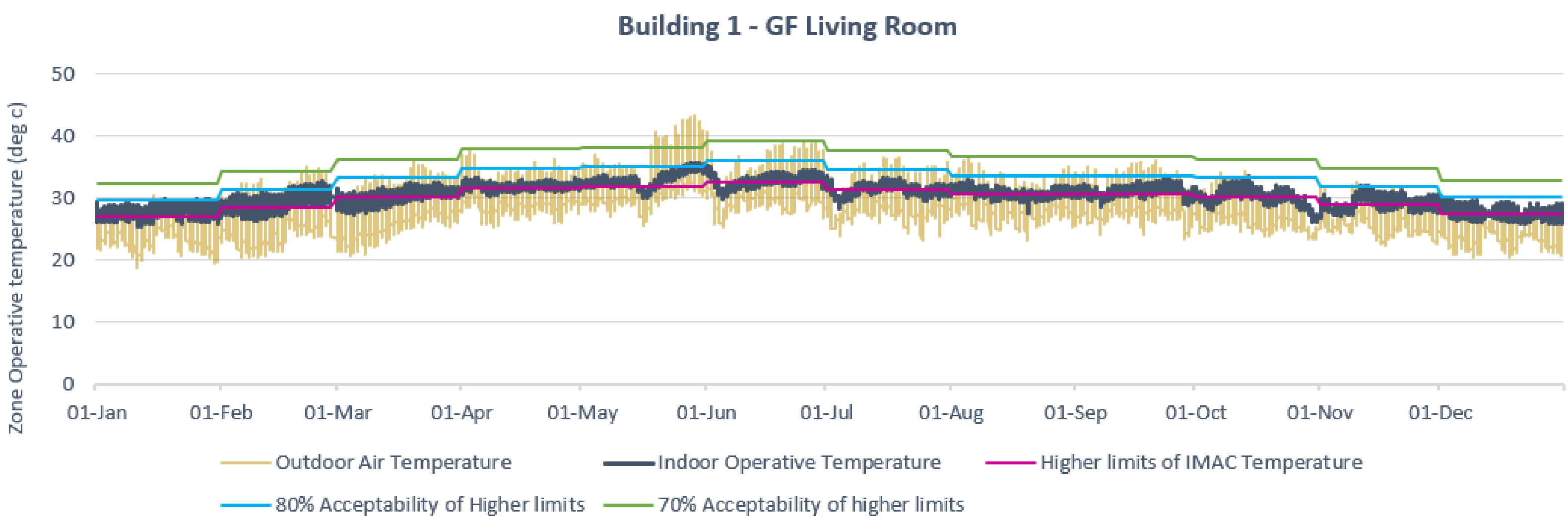
LHP Project Building 1 (North - South)





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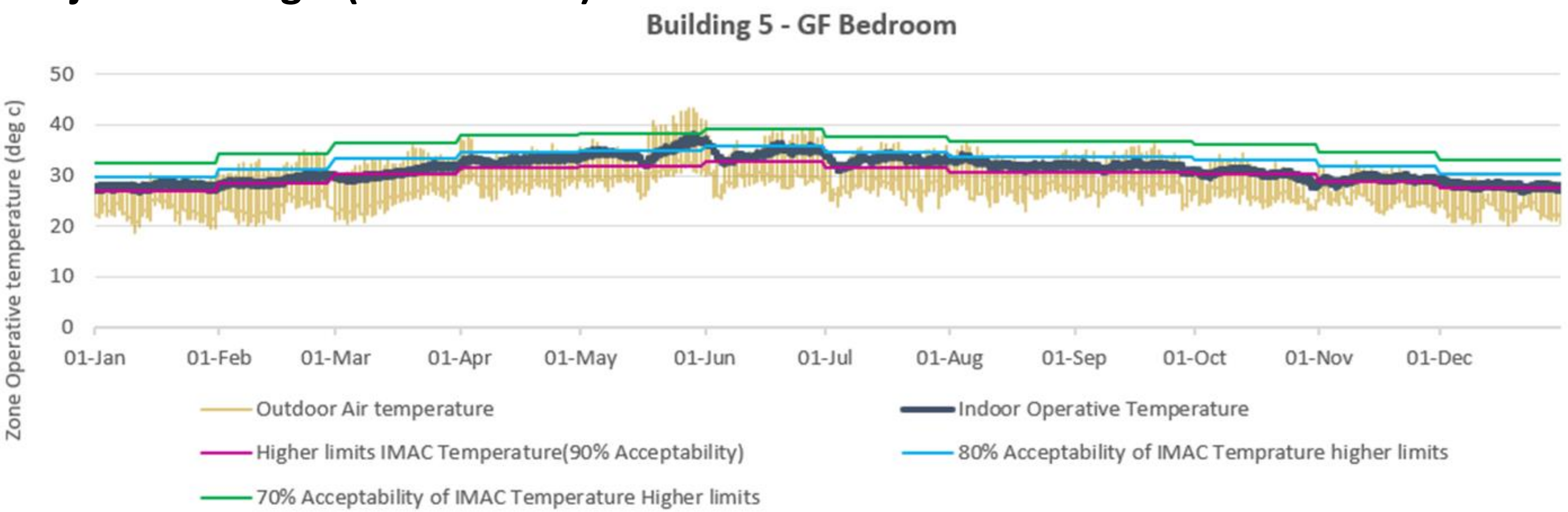
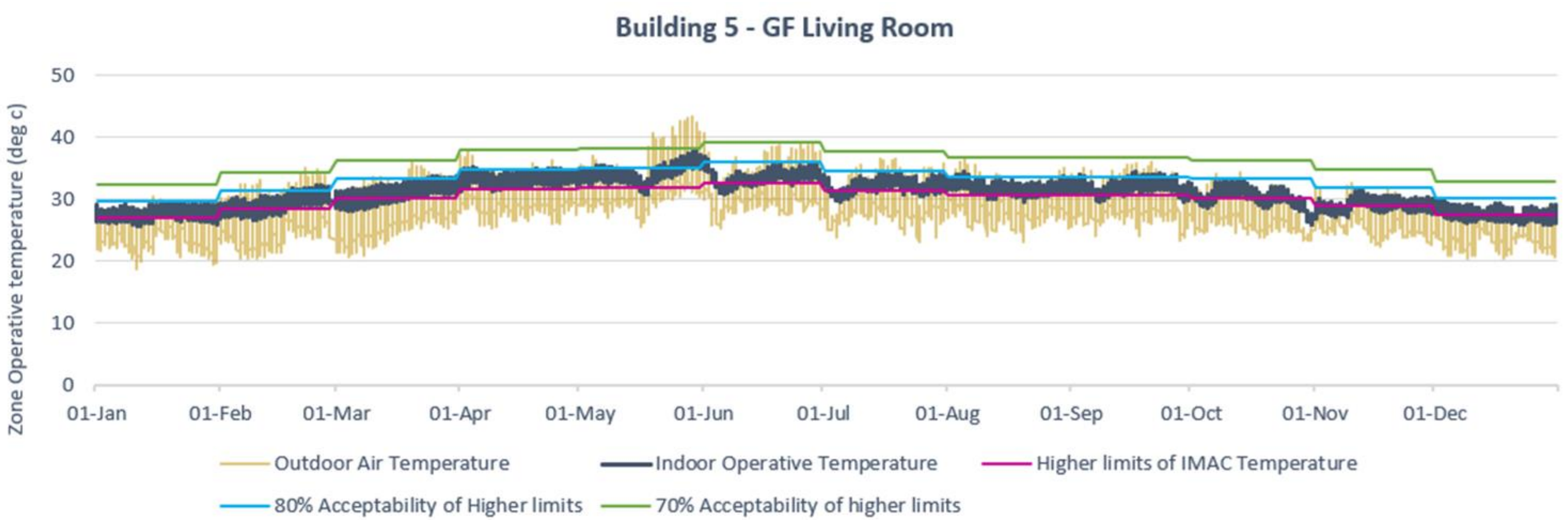
Case Study : Light House Project (LHP), Chennai

LHP Project Building 5 (East - West)





Thermal Comfort Improvement through Passive Measures

1. Large Window opening size
2. Cross ventilation
3. Shading for windows
4. Ventilator above Main door
5. EPS insulation – Under deck (At least 25 mm Thick)

LHP Site Thermal Improvements

- Dwelling units have two panel sliding window system for Living, Bedroom & kitchen openings
- Sliding windows open up only to 50% of Openable area

- Instead of using Sliding windows, **Casement windows** can provide opening up to 90% of Openable area
- This increase the quantity of fresh natural air comes into the space & aids to thermal comfort of occupants

Session 3: ENS Part 2

ENS – Part 2 – Services

Common Area and Exterior Lighting

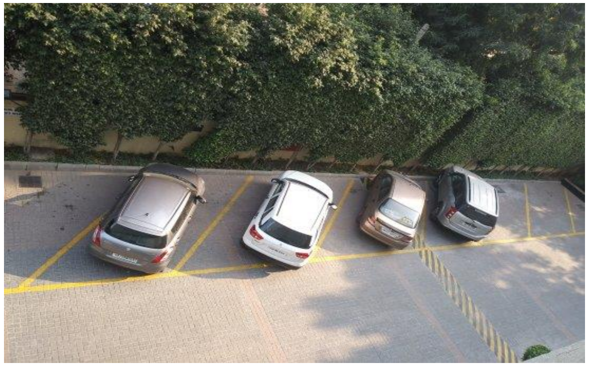
Common Areas	Maximum LPD (W/m2)	Minimum Luminous Efficacy (lm/W)
Corridor Lighting & Stilt Parking	3.0	All permanently installed lighting fixtures shall use lamps with an efficacy of at least 85 lumens per Watt
Basement Lighting	1.0	All permanently installed lighting fixtures shall use lamps with efficacy 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

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)

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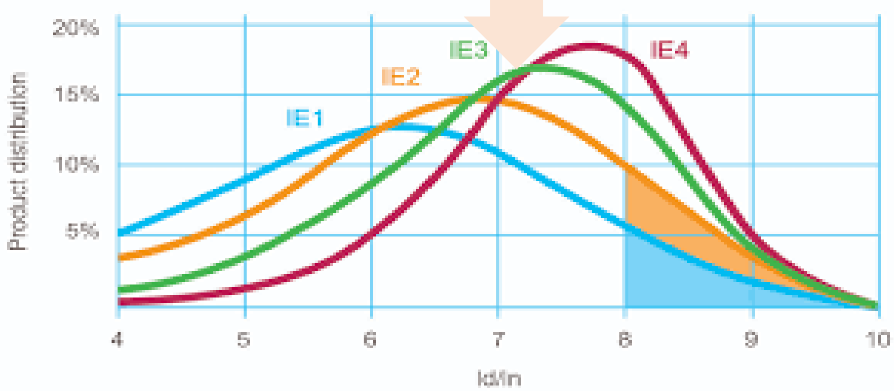
ENS – Part 2 – Services

Elevators – Maximum 22 points

High Efficacy lamps with Luminous Efficacy of 85lm/w

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

Min IE3 High Efficiency Motors

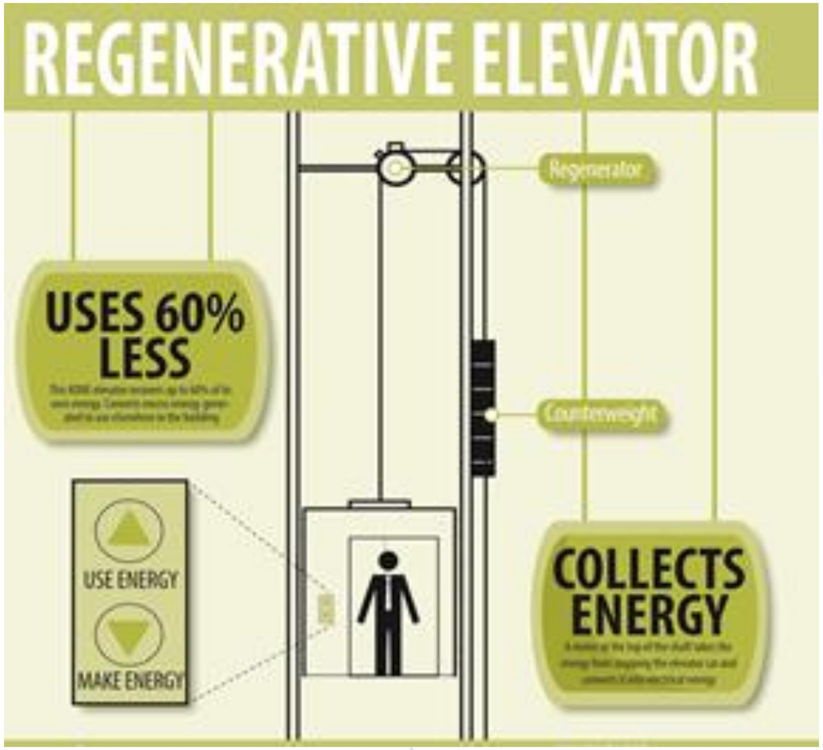


Group Automatic with Supervision

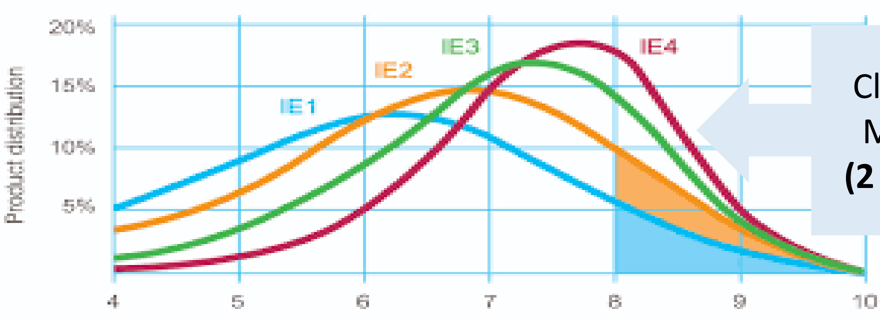
13 POINTS

ENS – Part 2 – Services

Elevators – Maximum 22 points



Regenerative Drives
(3 Points)



Class IE4 Motors
(2 Points)

Variable Voltage & Variable Frequency Drives
(4 Points)

ENS – Part 2 – Services

Pumps – Maximum 14 points

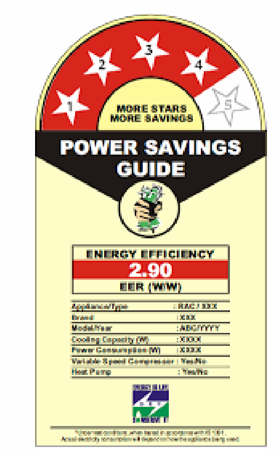
HYDRO-PNEUMATIC PUMPS

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

Mechanical Efficiency

60%

OR



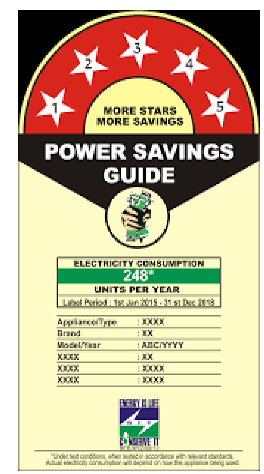
6 POINTS

Mechanical Efficiency

70%

3 POINTS

\+



5 POINTS

8 POINTS

ENS – Part 2 – Services

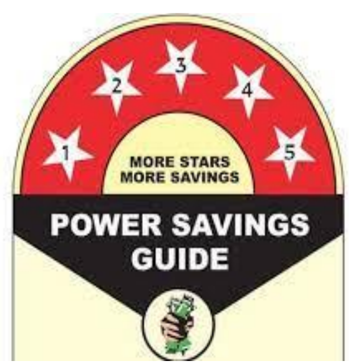
Electrical Systems – Maximum 6 points

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

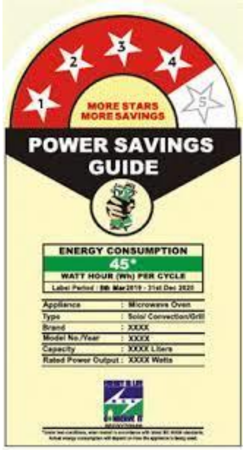
8 POINTS

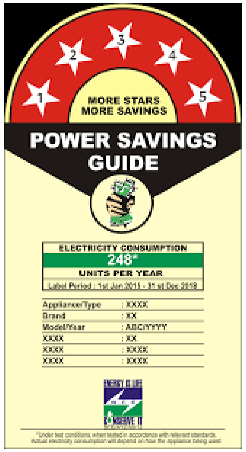
ENS – Part 2 – Services

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 4m³/min.Watt
- Sweep size > 1200mm: equal or greater than 5m³/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

ENS – Part 2 – Services

Comfort Systems– Maximum 50 points

9 POINTS

SPLIT AC 4 STAR

CHILLER : ECBC+

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

21 POINTS

SPLIT AC 5 STAR

CHILLER : SUPER ECBC

ENS – Part 2 – Services

Solar Water Heating

Solar Water Heating

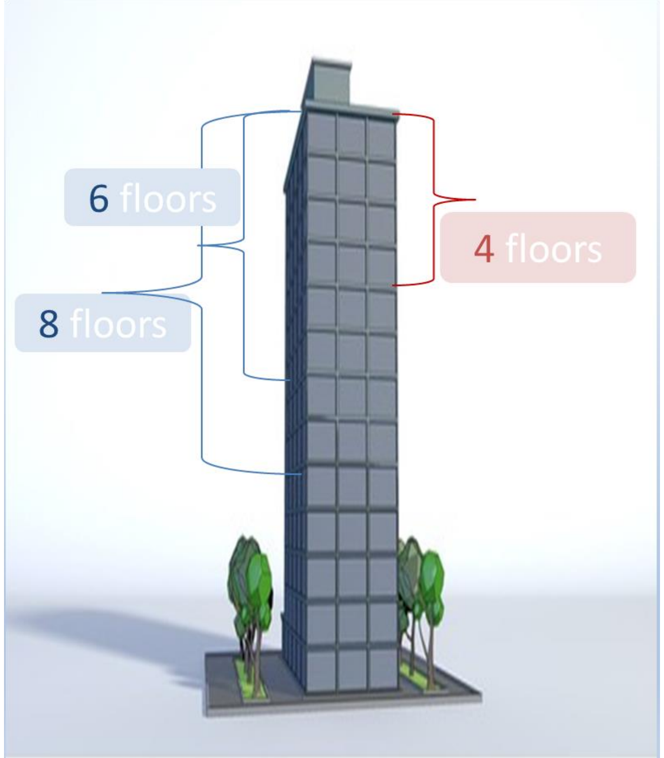
- SWH of **minimum BEE 3 Star label** and meeting 100% of Top 4 floors

OR

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

6 POINTS

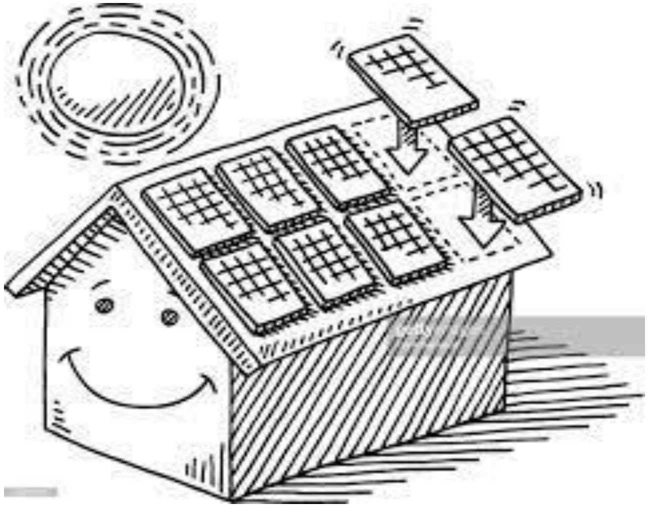
- 100% of Annual water demand for Top 6 floors **(2points)**
- 100% of Annual water demand for Top 8 floors **(5 points)**



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)**

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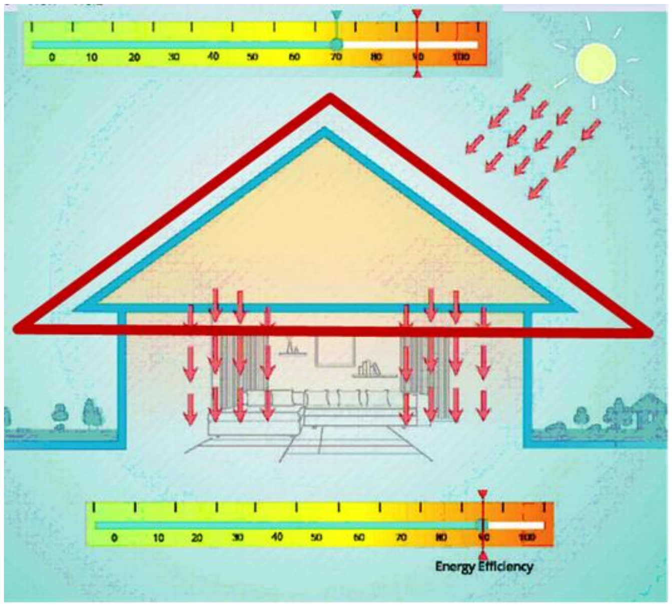
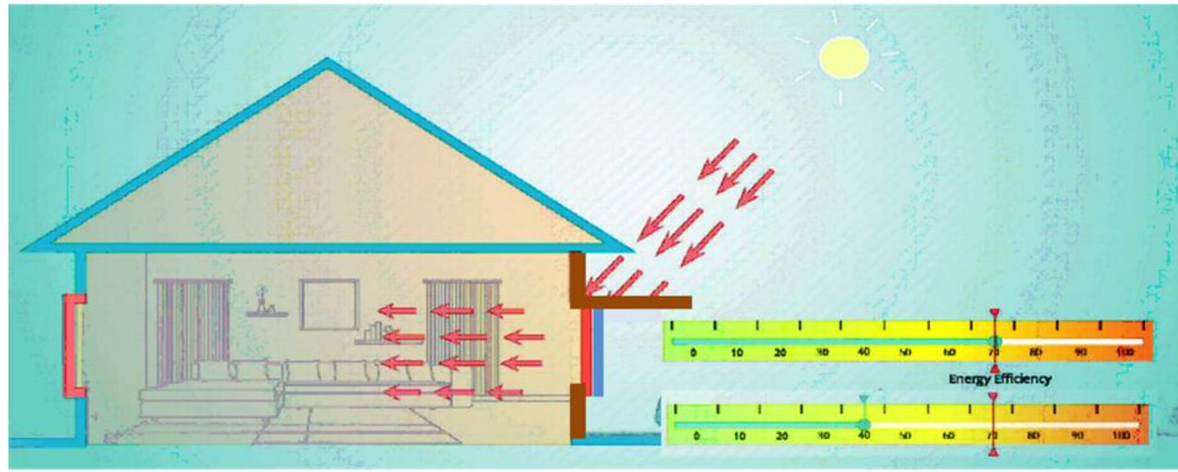
Conventional Building Vs ENS Building



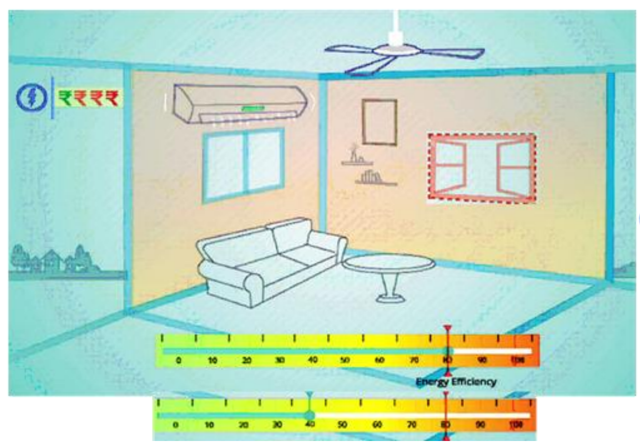


Conventional Brick wall, roof and single glazed windows, traps heat

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



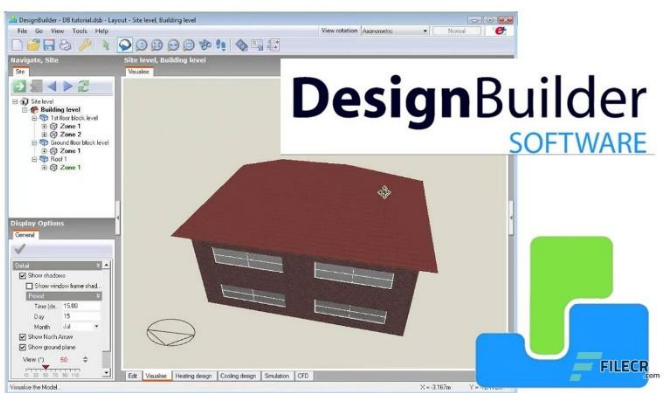
Increases in cross-ventilation reduces dependency on Air conditioners & coolers, thereby reduces electricity bills

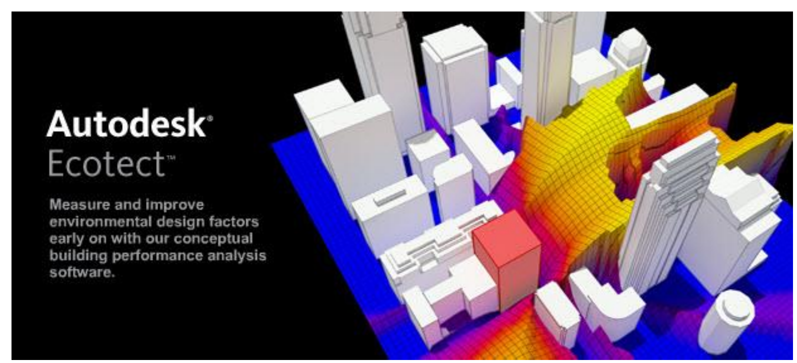
Simulation Tools

eQuest
Quick Energy Simulation Tool

eQUEST

EnergyPlus





Session 4: 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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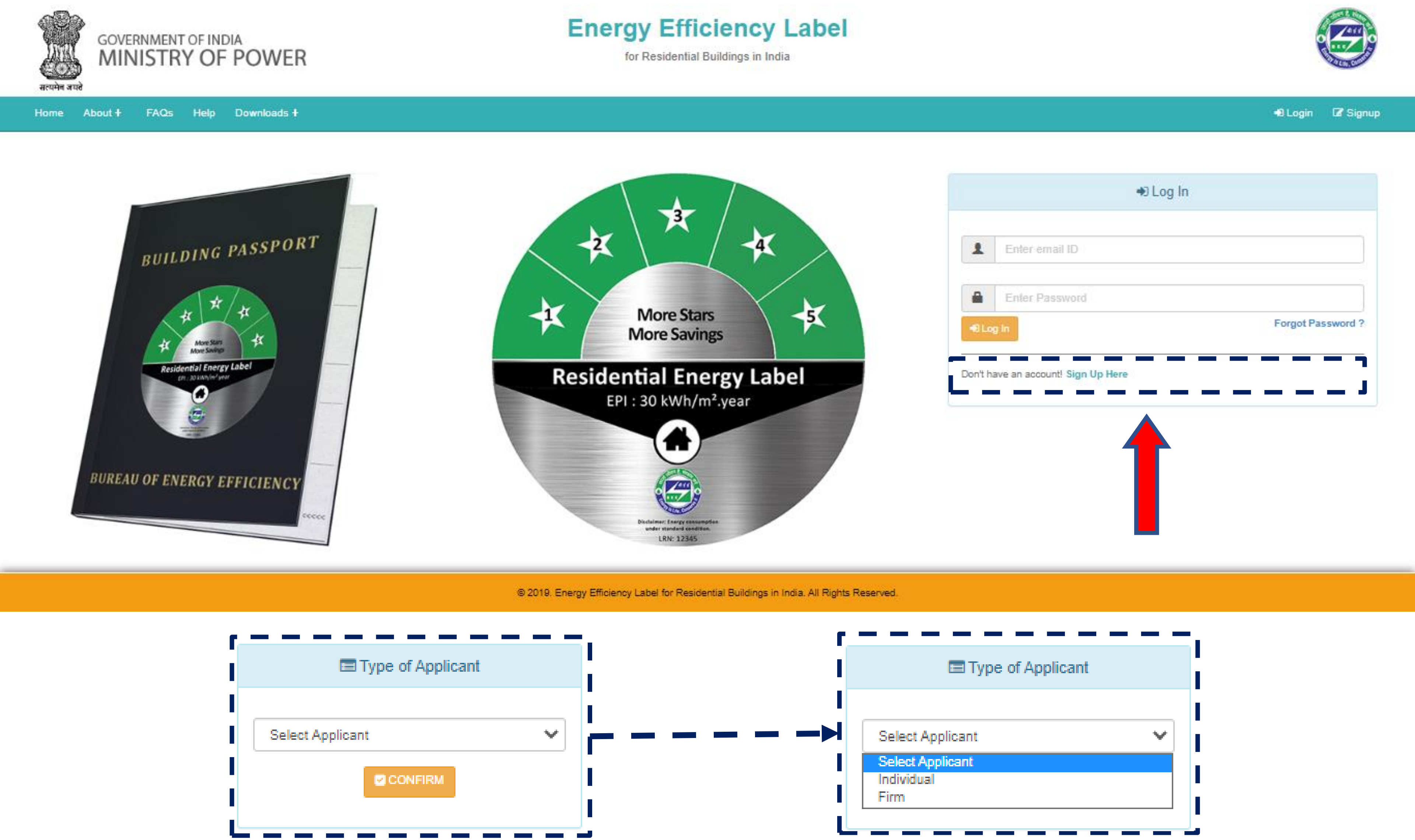

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Sign Up

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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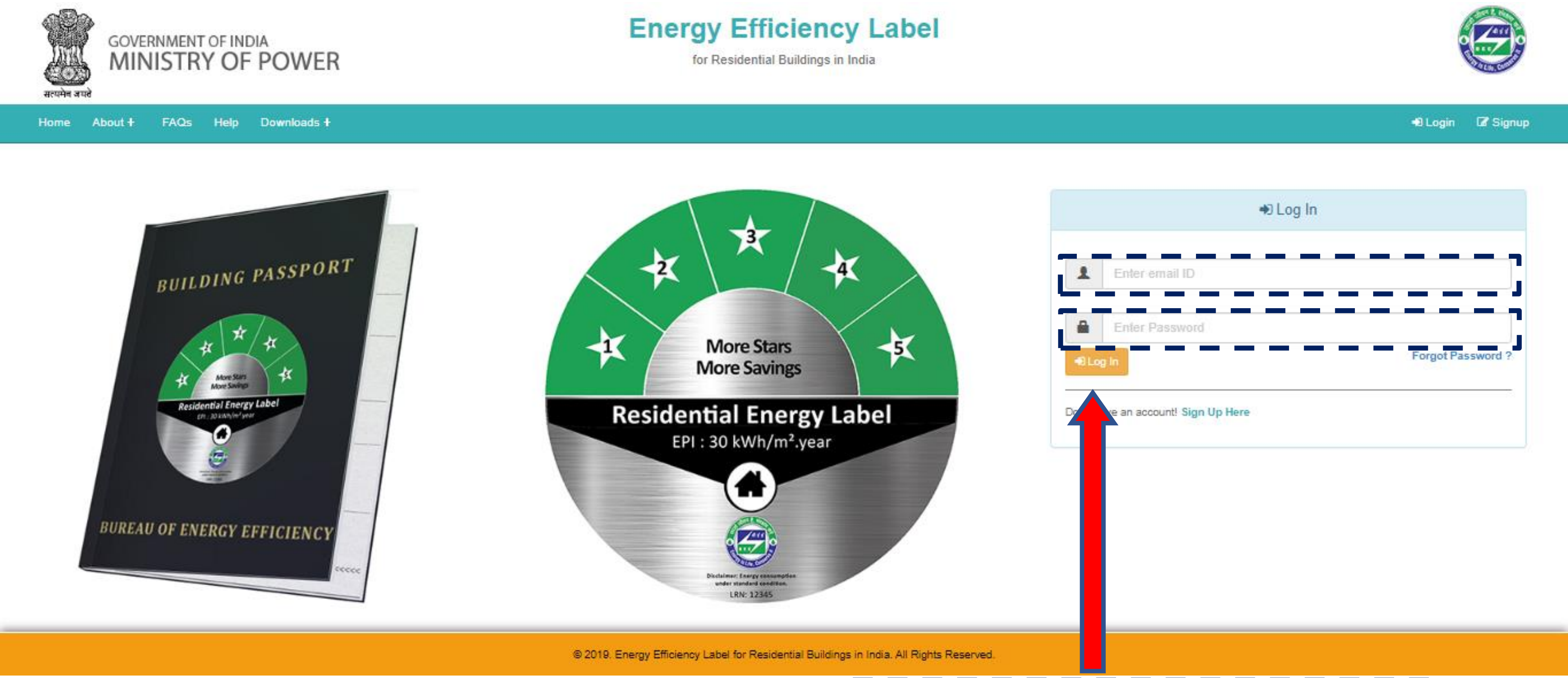

Log in using registered credentials

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GOVERNMENT OF INDIA
MINISTRY OF POWER

Energy Efficiency Label

for Residential Buildings in India

Home | About + | FAQs | Help | Downloads + | kanika gupta | My Account | Logout | 28-07-2020

Registered User

Register
New Property

View
Registered Property

Label
Transfer

Registered User

Register New Property

View Registered Property

Label Transfer

Help

Criteria
No minimum requirement with respect to the Area or Connected load (KW)

Ministry of Housing and Urban Affairs
Government of India

Register New Property

Name of the Property

Registered Address of Property

Line 1 | Line 2 | Locality | State: Choose State

City/Town: Choose City | District | Pincode

Latitude: Choose

Climate: Choose Climate

Approved Architectural Drawings: Upload (0)

Property Authentication Proof: List of Document — Upload (0)

☐ I confirm that all details are true and correct.

Register Project

Help

Latitude

Select if the latitute for your location is 'Less than 23.5N' or 'Greater than 23.5N'

Help

Approved Architectural Plans

Upload the approved architectural drawings for your property in case of 'final label' & good for Construction drawings in case of 'applied for' label

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Register New Property

Name of the Property

Registered Address of Property

Line 1

Line 2

Locality

State: Choose State

City/Town: Choose City

District

Pincode

Latitude: Choose

Climate: Choose Climate

Approved Architectural Drawings: Upload (0)

Property Authentication Proof: List of Document — Upload (0)

☐ I confirm that all details are true and correct.

Register Project

Help

Property Authentication Proofs

Upload any of the following documents :
A) Property Registration Certificate
B) Property Tax Reciepts
C) Mutation Document
D) Any other relevant document stating the ownership of the property

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Registered User

Register
New Property

View
Registered Property

Label
Transfer

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Registered Property

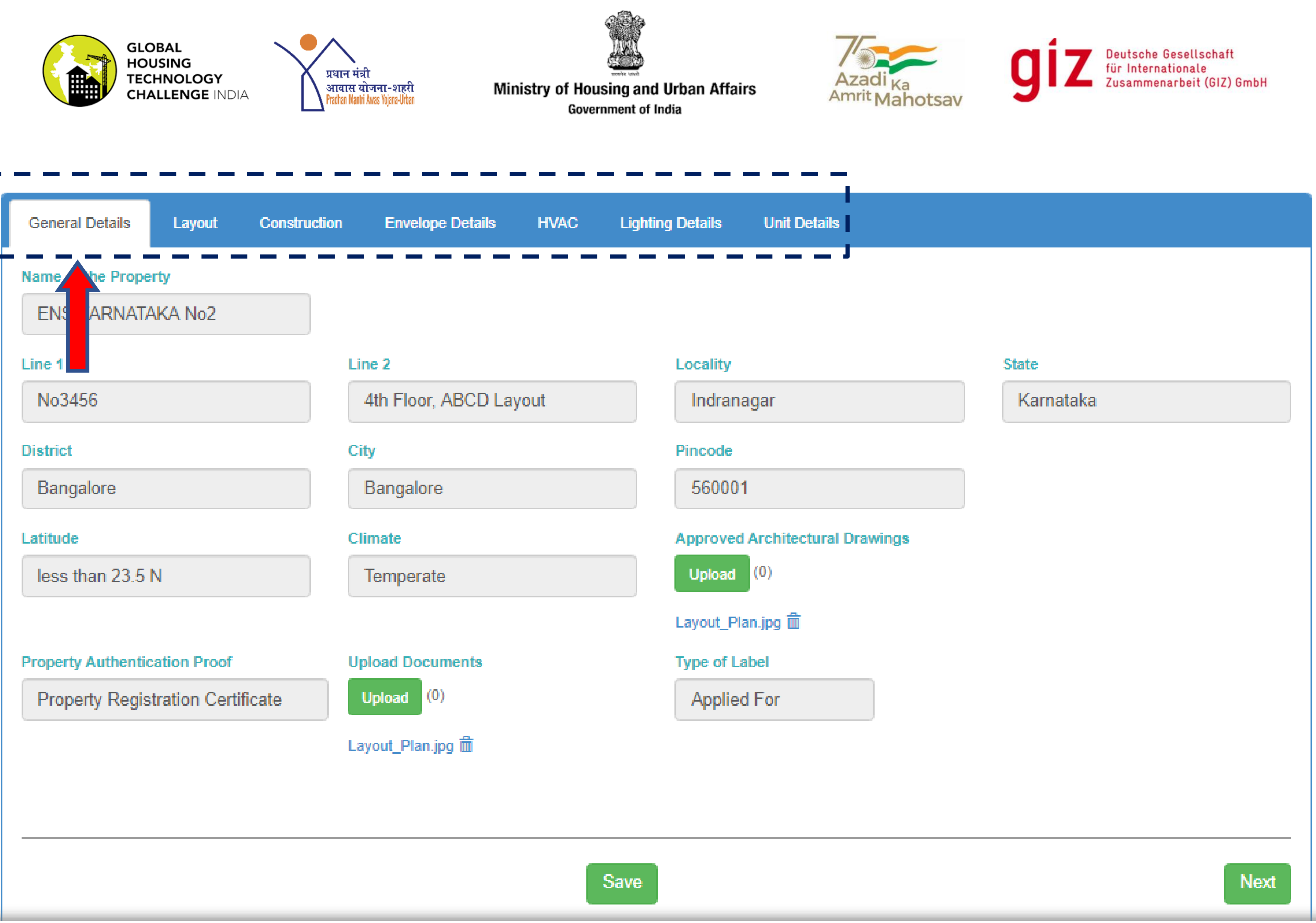
Show 10 entries Search:

S. No.	Identification Number	Property Name	Address	Date of Registration	Type of Label	Status	Action
1	KA/SAC/203/I	ENS KARNATAKA No2	No3456, Bangalore	22-07-2020	Applied For	In Progress	
2	KA/BDW/950/I	ENS K[illegible]TAKA	No1234, Bangalore	21-07-2020	Final	In Progress	

Showing 1 to 2 of 2 entries

Previous 1 Next

Registered property can be viewed under Registered property tab. Click on the Property for detailing the project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General Details
Layout
Construction
Envelope Details
HVAC
Lighting Details
Unit Details
Name
he Property
ENS
ARNATAKA No2
Line 1
No3456
Line 2
4th Floor, ABCD Layout
Locality
Indranagar
State
Karnataka
District
Bangalore
City
Bangalore
Pincode
560001
Latitude
less than 23.5 N
Climate
Temperate
Approved Architectural Drawings
Upload
(0)
Layout_Plan.jpg
Property Authentication Proof
Property Registration Certificate
Upload Documents
Upload
(0)
Layout_Plan.jpg
Type of Label
Applied For
Save
Next

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General Details | Layout | Construction | Envelope Details | HVAC | Lighting Details | Unit Details

Name of the Property
ENS KARNATAKA No2

Line 1
No3456

Line 2
4th Floor, ABCD Layout

Locality
Indranagar

State
Karnataka

District
Bangalore

City
Bangalore

Pincode
560001

Latitude
less than 23.5 N

Climate
Temperate

Approved Architectural Drawings
Upload (0)
Layout_Plan.jpg

Property Authentication Proof
Property Registration Certificate

Upload Documents
Upload (0)
Layout_Plan.jpg

Type of Label
Applied For

Help

Approved Architectural Plans

Upload the approved architectural drawings for your property in case of 'final label' & good for Construction drawings in case of 'applied for' label

Save

Next

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General Details | Layout | Construction | Envelope Details | HVAC | Lighting Details | Unit Details

Name of the Property
ENS KARNATAKA No2

Line 1
No3456

Line 2
4th Floor, ABCD Layout

Locality
Indranagar

State
Karnataka

District
Bangalore

City
Bangalore

Pincode
560001

Latitude
less than 23.5 N

Climate
Temperate

Approved Architectural Drawings
Upload (0)
Layout_Plan.jpg

Property Authentication Proof
Property Registration Certificate

Upload Documents
Upload (0)
Layout_Plan.jpg

Type of Label

Help

Property Authentication Proofs

Upload any of the following documents :
A) Property Registration Certificate
B) Property Tax Reciepts
C) Mutation Document
D) Any other relevant document stating the ownership of the property

Next


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General Details
Layout
Construction
Envelope Details
HVAC
Lighting Details
Unit Details
Name of the Property
ENS KARNATAKA No2
Line 1
No3456
Line 2
4th Floor, ABCD Layout
Locality
Indranagar
State
Karnataka
District
Bangalore
City
Bangalore
Pincode
560001
Latitude
less than 23.5 N
Climate
Temperate
Approved Architectural Drawings
Upload
(0)
Layout_Plan.jpg
Property Authentication Proof
Property Registration Certificate
Upload Documents
Upload
(0)
Layout_Plan.jpg
Type of Label
Choose Label
Choose Label
Applied For
Final
Help
Type of label
Select from the dropdown the type of application:
A) Applied for Label - This label is applicable for new buildings with construction permit issued by the authorities having jurisdiction. This label shall be mainly used for marketing of the property.
B) Final Label - This label is applicable for existing and new buildings. For new building, this label can only be awarded after the occupancy certificate is issued by the authorities having jurisdiction.
Save
Next

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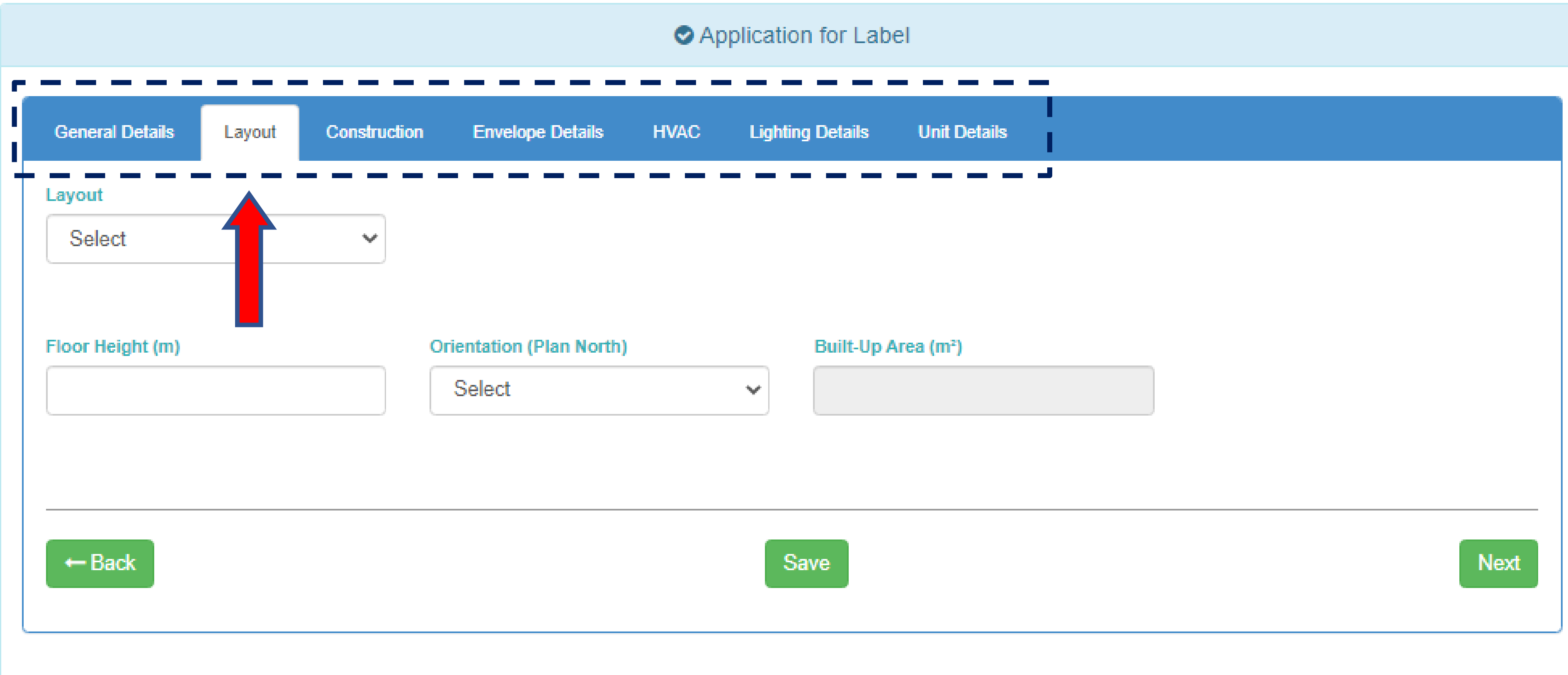

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Application for Label

General Details | Layout | Construction | Envelope Details | HVAC | Lighting Details | Unit Details

Layout

Select

Floor Height (m)

Orientation (Plan North)

Select

Built-Up Area (m²)

← Back

Save

Next

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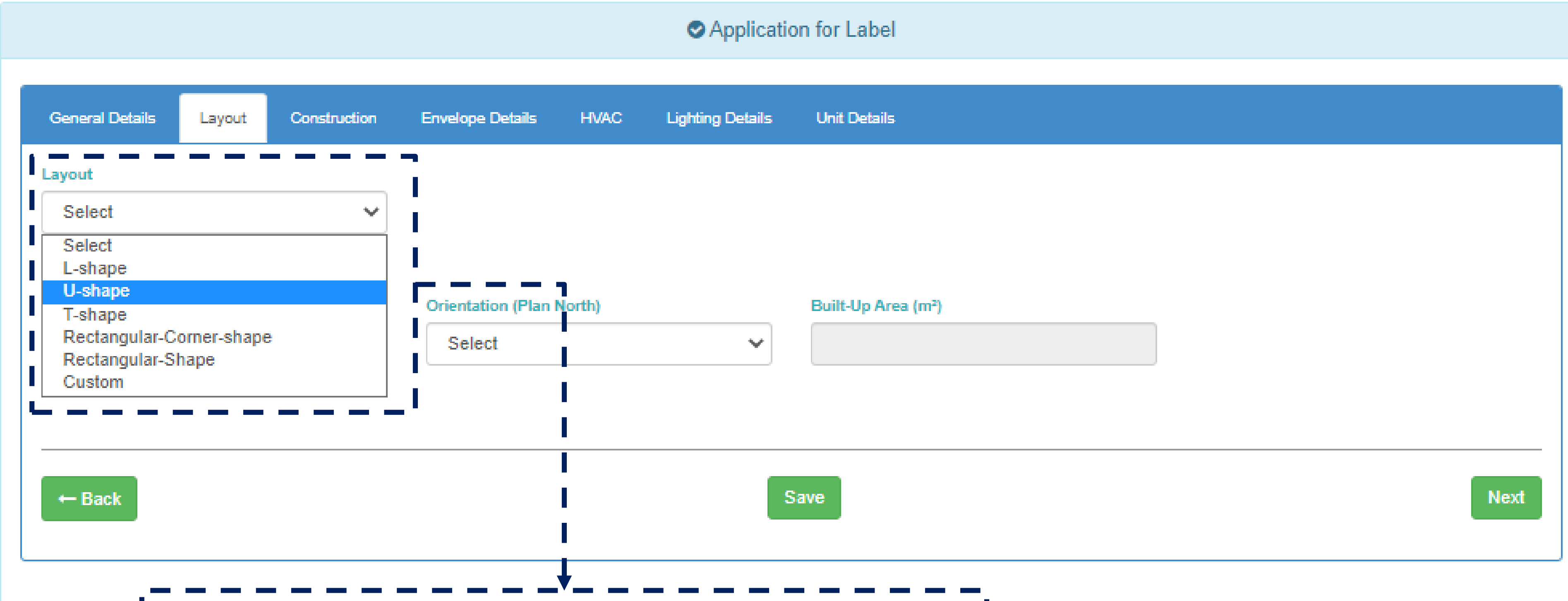
Government of India



Select the most appropriate shape of the building

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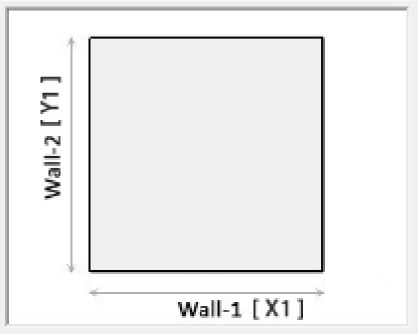
General Details | Layout | Construction | Envelope Details | HVAC | Lighting Details | Unit Details

Layout

Rectangular-Shape



X1 (m)

4

Y1 (m)

5

Floor Height (m)

3

Orientation (Plan North)

Select

Built-Up Area (m²)

20.00

← Back

Save

Next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General Details
Layout
Construction
Envelope Details
HVAC
Lighting Details
Unit Details
Layout
Rectangular-Shape
Wall-2 [Y1]
Wall-1 [X1]
X1 (m)
4
Y1 (m)
5
Help
Orientation (Plan North)
"Plan North" is always considered to be the top of the plan sheet (Architectural Plan Drawing).
Example:
Consider the plan diagram on layout tab to be an architectural plan sheet. If Plan North = "South", this indicates that the top of the plan 'sheet' faces South. To indicate this on an actual architectural floor plan, a draftsperson would add a north near the lower right corner of the plan sheet pointing 'down' (or towards plan south).
Floor Height (m)
3
Orientation (Plan North)
N
Select
N
S
E
W
NE
NW
SE
SW
Built-Up Area (m²)
20.00
← Back
Save
Next

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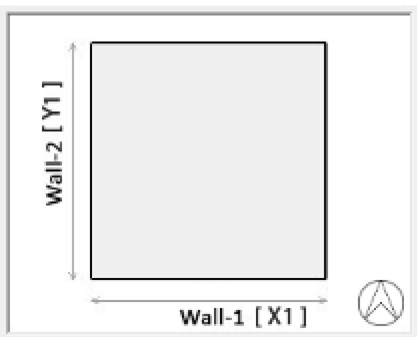
Layout

Rectangular-Shape

Click to Change



X1 (m)

4.00

Y1 (m)

5.00

Floor Height (m)

3

Orientation (Plan North)

N

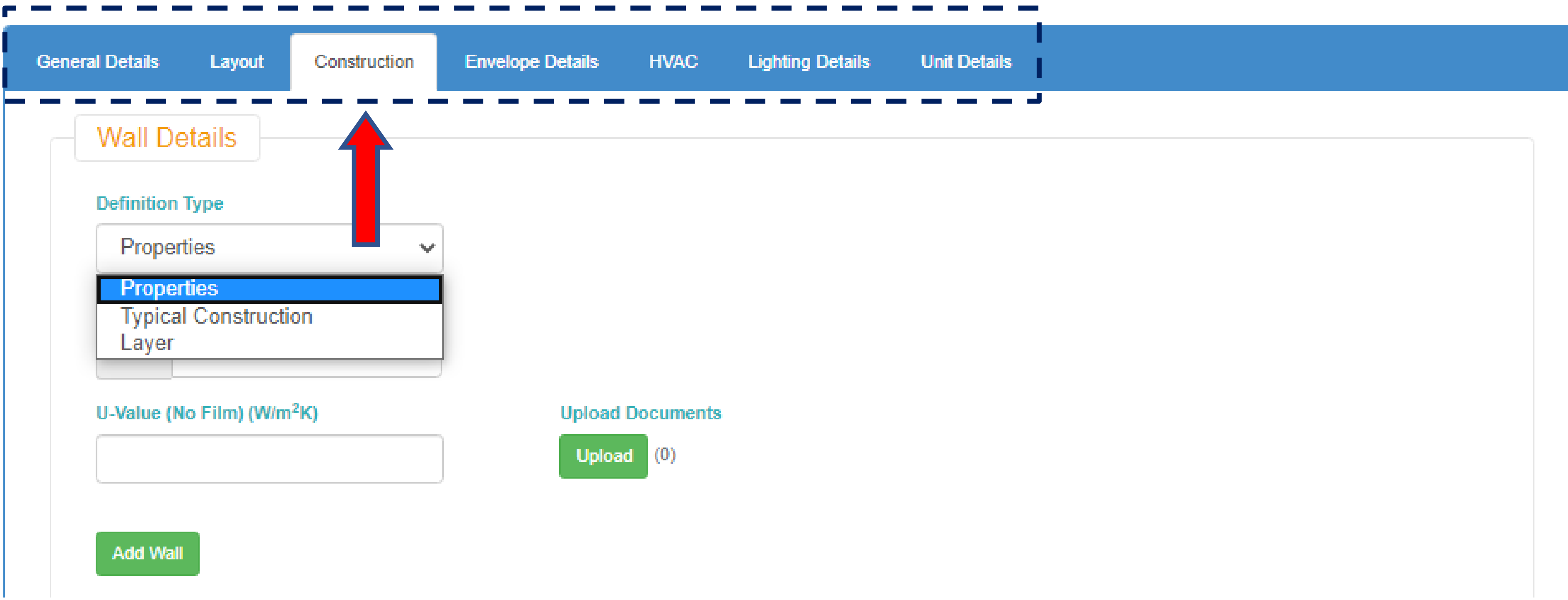
Built-Up Area (m²)

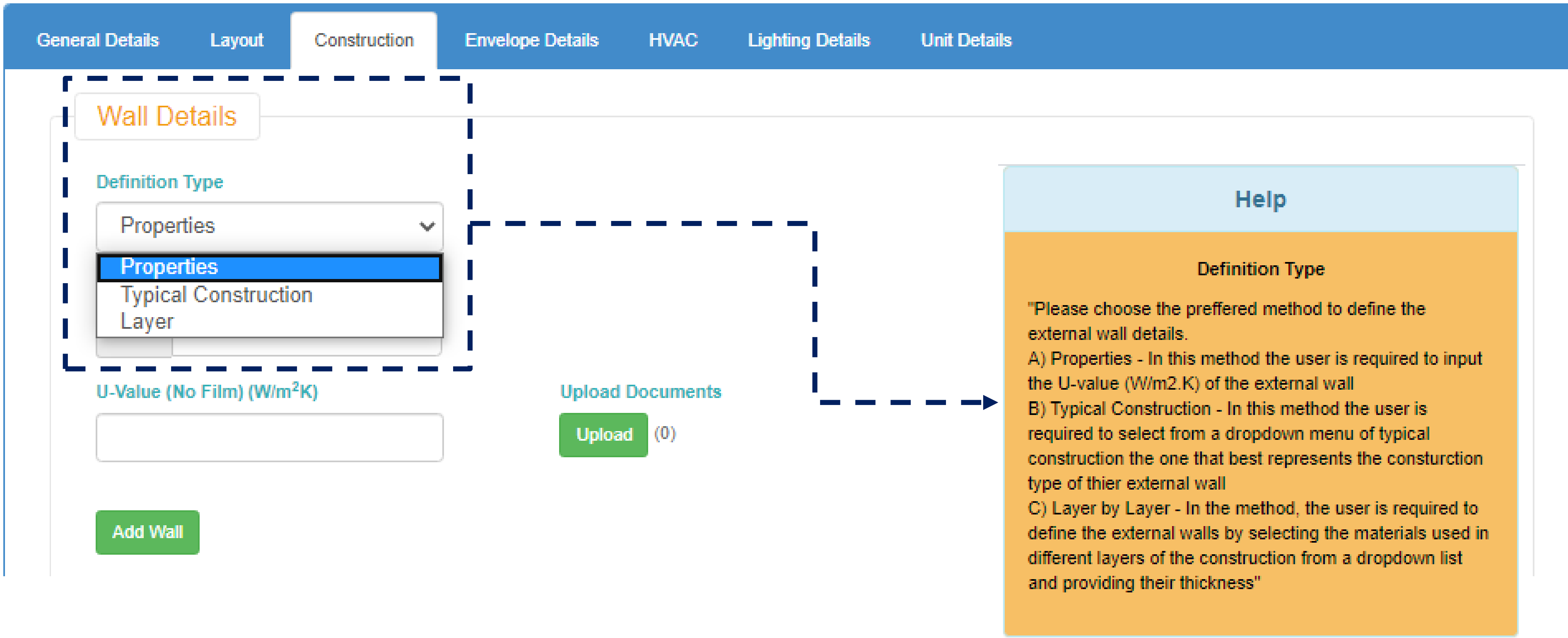
20.00

← Back

Save

Next


General Details
Layout
Construction
Envelope Details
HVAC
Lighting Details
Unit Details
Wall Details
Definition Type
Properties
Properties
Typical Construction
Layer
U-Value (No Film) (W/m2K)
Upload Documents
Upload
(0)
Add Wall


General Details
Layout
Construction
Envelope Details
HVAC
Lighting Details
Unit Details
Wall Details
Definition Type
Properties
Properties
Typical Construction
Layer
U-Value (No Film) (W/m²K)
Upload Documents
Upload
(0)
Add Wall
Help
Definition Type
"Please choose the preffered method to define the external wall details.
A) Properties - In this method the user is required to input the U-value (W/m2.K) of the external wall
B) Typical Construction - In this method the user is required to select from a dropdown menu of typical construction the one that best represents the consturction type of thier external wall
C) Layer by Layer - In the method, the user is required to define the external walls by selecting the materials used in different layers of the construction from a dropdown list and providing their thickness"

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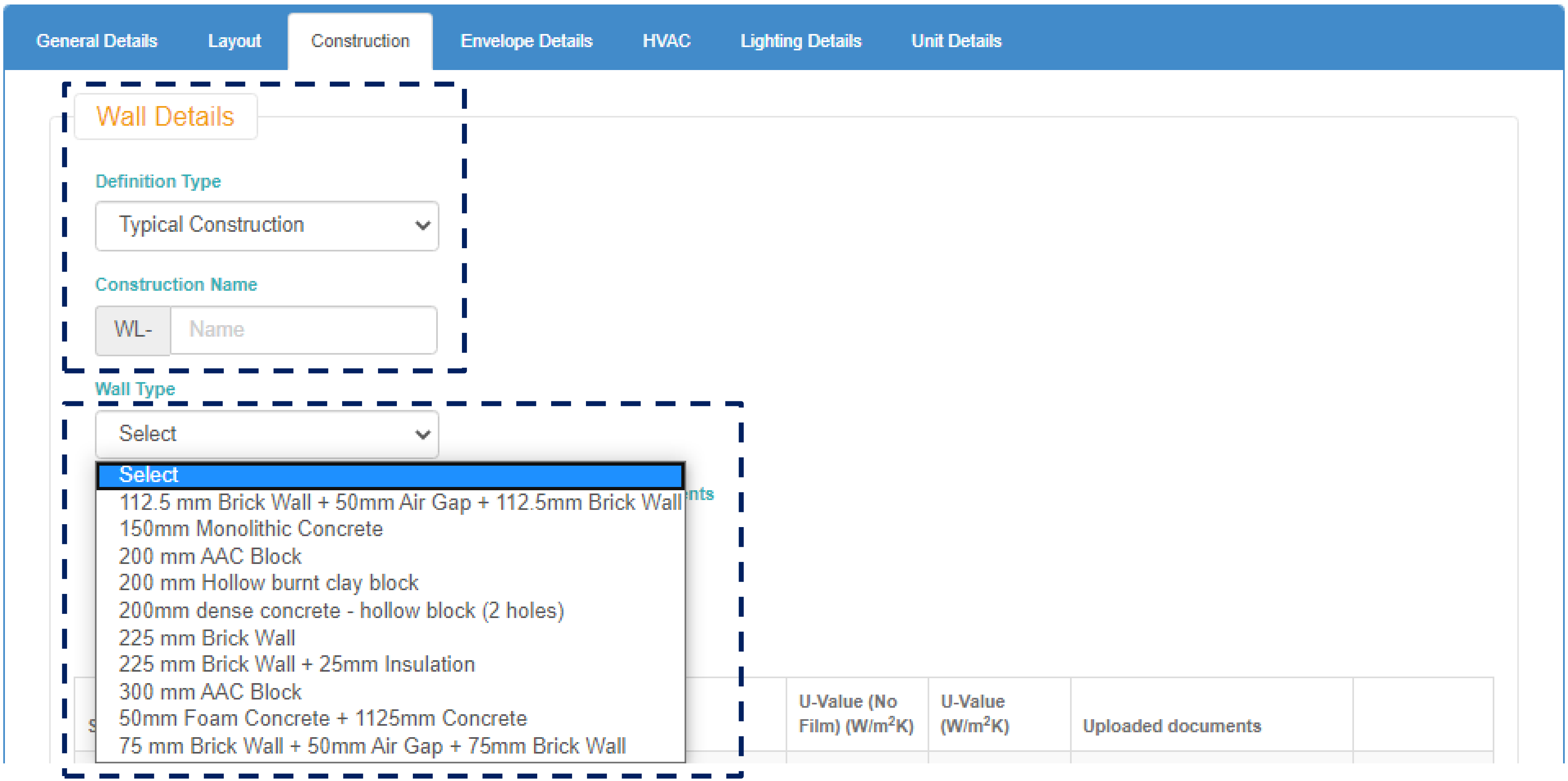

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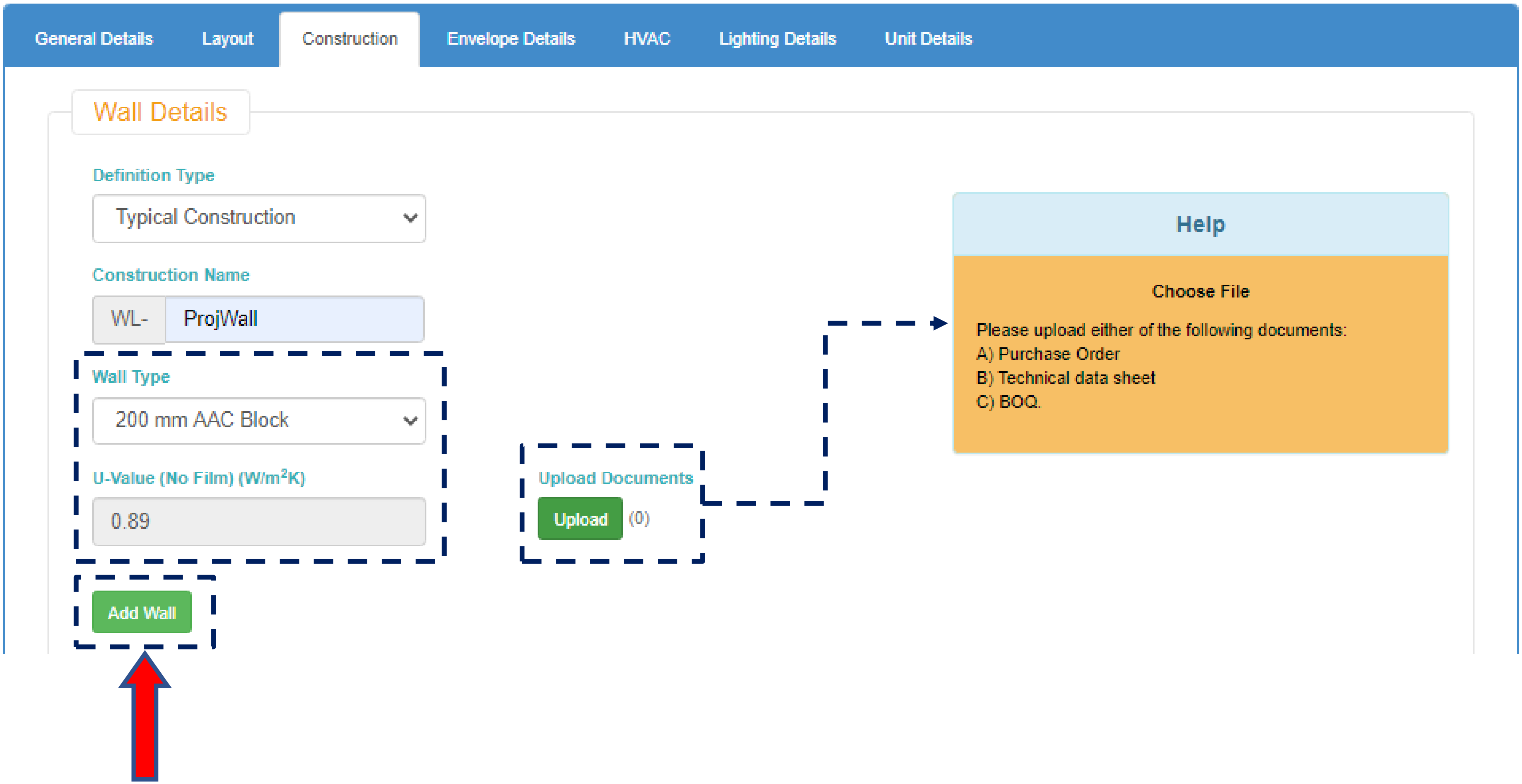

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प्रधान मंत्री आवास योजना-शहरी Pradhan Mantri Awas Yojana-Urban

Ministry of Housing and Urban Affairs
Government of India

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General Details | Layout | Construction | Envelope Details | HVAC | Lighting Details | Unit Details

Wall Details

Definition Type

Typical Construction

Construction Name

WL- ProjWall

Wall Type

200 mm AAC Block

U-Value (No Film) (W/m^2K)

0.89

Upload Documents

Upload (0)

Help

Choose File

Please upload either of the following documents:
A) Purchase Order
B) Technical data sheet
C) BOQ.

Add Wall

S.No.	Construction Name	Layer Name	U-Value (No Film) (W/m^2K)	U-Value (W/m^2K)	Uploaded documents	
1	WL-ProjectWal	Typical Construction	0.89	0.78	Layout_Plan.jpg	

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

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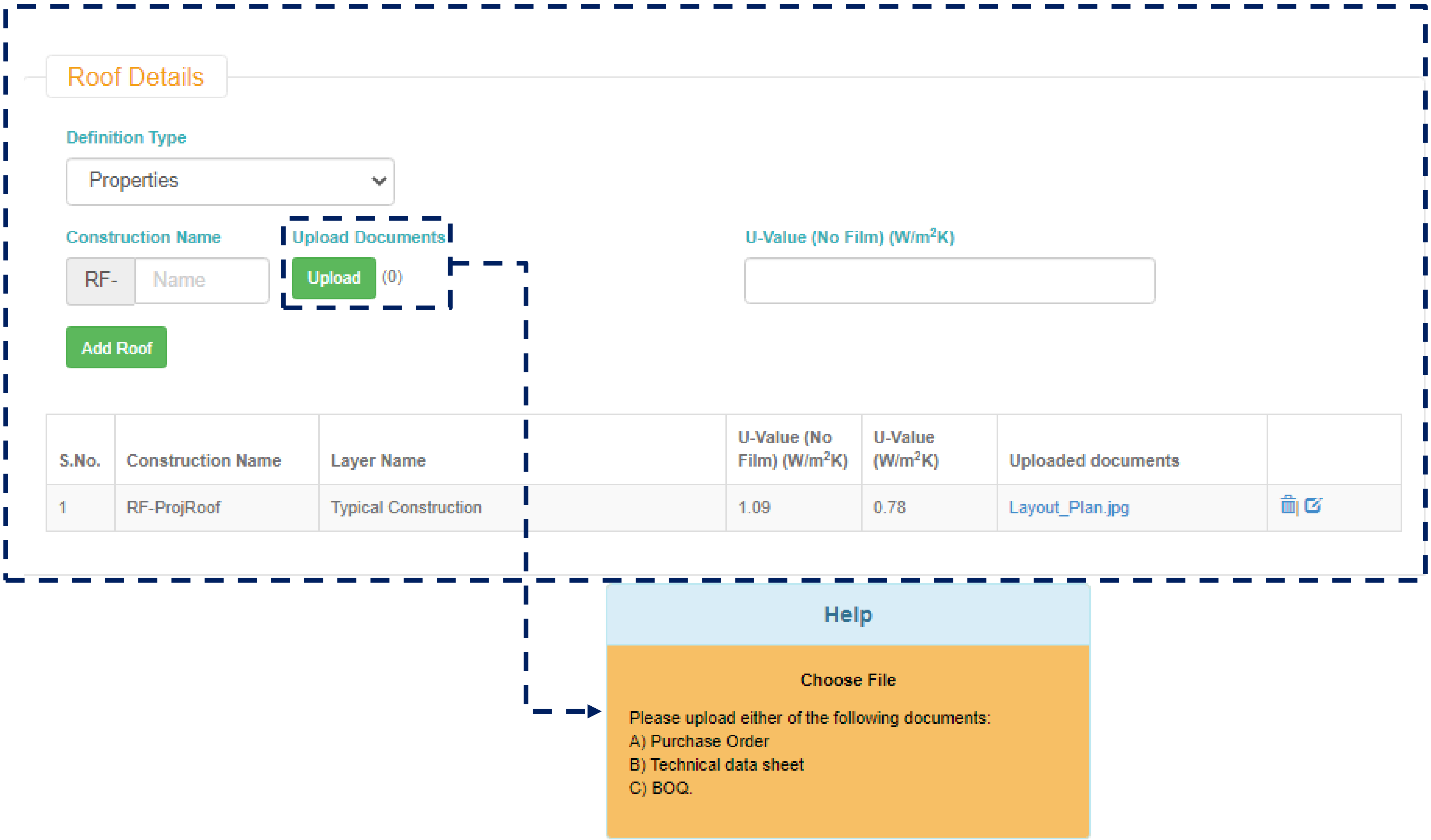

Ministry of Housing and Urban Affairs
Government of India

Fenestration Details

Definition Type

Properties

Select Fenestration

Select

Select
Window
Ventilator
Door
Balcony Door

Name of the fenestration

Type

Select

U-Value (W/m²K)

SHGC

Visual Light Transmission

Glazing %

Upload Glazing Documents

Upload (0)

Opaque Frame U-Value (W/m²K)

Upload Frame Documents

Upload (0)

Add Fenestration

Help

Glazing %

Enter the %age of area of the window consituted of the glass without the frame

Help

Upload Technical Data Sheets

Please upload either of the following documents:
A) Purchase Order
B) Technical data sheet
C) BOQ
The details required in the documents will be the U-value, SHGC & VLT of the glass used.

Help

Opaque Frame U-Factor

Thermal transmittance (U value) is the heat transmission in unit time through unit area of a material or construction and the boundary air films, induced by unit temperature difference between the environments on either side. Unit of U value is W/m2 .K. The U value for a opaque frame indicates its ability to transfer heat through conduction.

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Fenestration Details

Definition Type

Properties

Select Fenestration

Select

- Select
- Window
- Ventilator
- Door
- Balcony Door

Name of the fenestration

Type

Select

U-Value (W/m^2K)

SHGC

Visual Light Transmission

Glazing %

Upload Glazing Documents

Upload (0)

Opaque Frame U-Value (W/m^2K)

Upload Frame Documents

Upload (0)

Add Fenestration

S.No.	Fenestration	Name of Fenestration	Type	U-Value (W/m^2K)	SHGC	VLT	Glazing %	Glazing Documents	Opaque Frame U-Value (W/m^2K)	Opaque Frame Documents	
1	Window	W-W1	2 Door Sliding	5.778	0.819	0.881	40	Layout_Plan.jpg	3.48	Layout_Plan.jpg	

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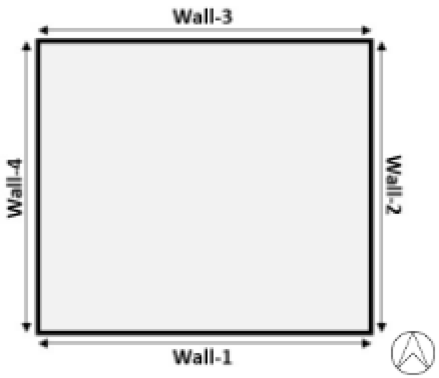
General Details | Layout | Construction | Envelope Details | HVAC | Lighting Details | Unit Details

Modelling Exceptions



Wall-1 (South)

Wall Name	Length	Height	Area
Wall1	4.00 m	3 m	12 m^2

Construction Details

S.No.	Wall Name	Length(m)	Height(m)	Area(m^2)	View Fenestration	Action
1	WL-ProjWall	4	3	12	View	

Add Construction

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

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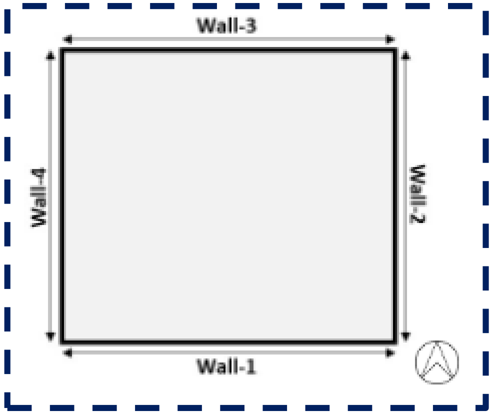
General Details | Layout | Construction | Envelope Details | HVAC | Lighting Details | Unit Details

Modelling Exceptions



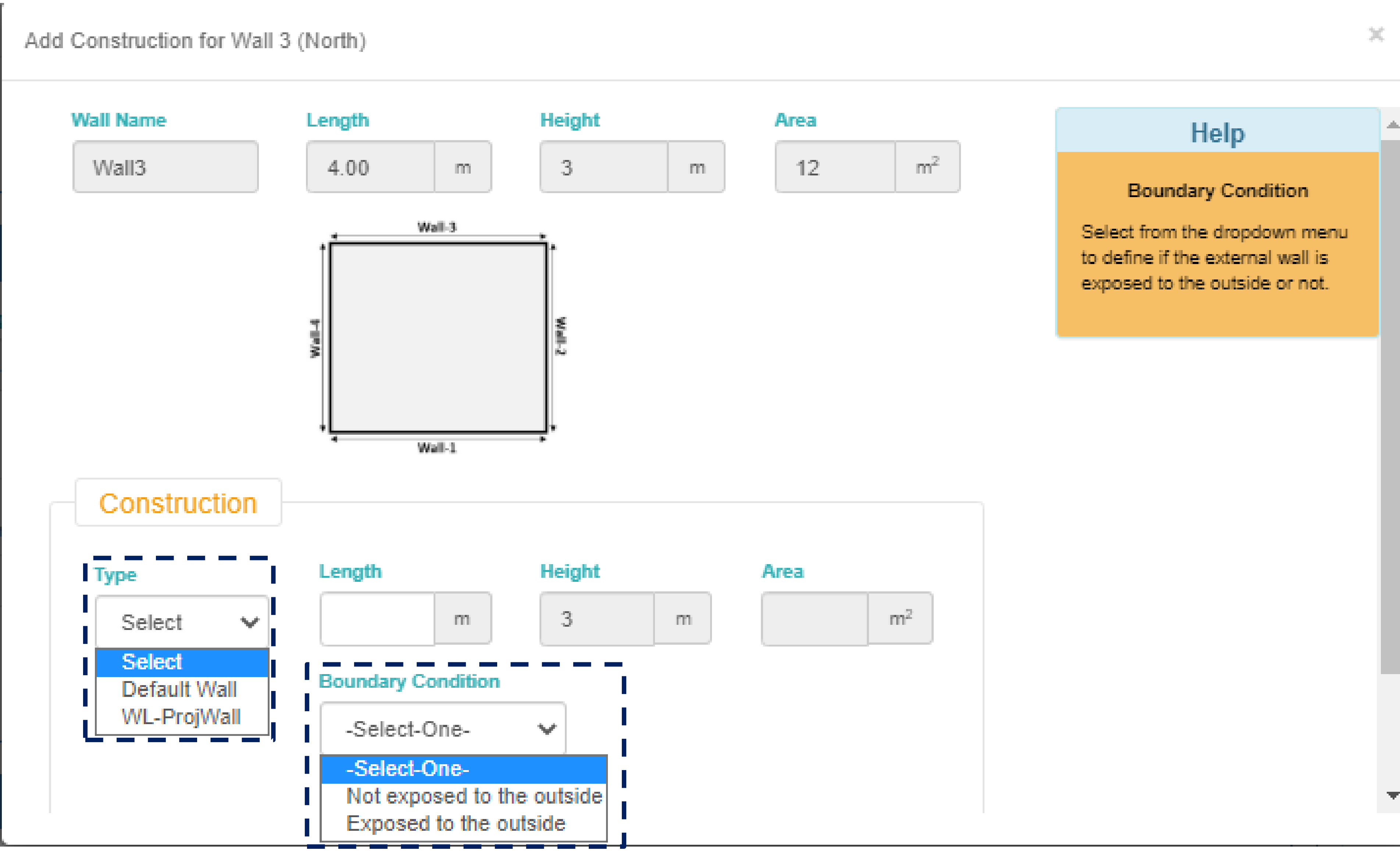
Wall-1 (South)

Wall Name	Length	Height	Area
Wall1	4.00 m	3 m	12 m^2

Construction Details

S.No.	Wall Name	Length(m)	Height(m)	Area(m^2)	View Fenestration	Action
1	WL-ProjWall	4	3	12	View	

Add Construction


Add Construction for Wall 3 (North)
Wall Name
Wall3
Length
4.00
m
Height
3
m
Area
12
m2
Wall-3
Wall-4
Wall-2
Wall-1
Help
Boundary Condition
Select from the dropdown menu to define if the external wall is exposed to the outside or not.
Construction
Type
Select
Select
Default Wall
WL-ProjWall
Length
m
Height
3
m
Area
m2
Boundary Condition
-Select-One-
-Select-One-
Not exposed to the outside
Exposed to the outside

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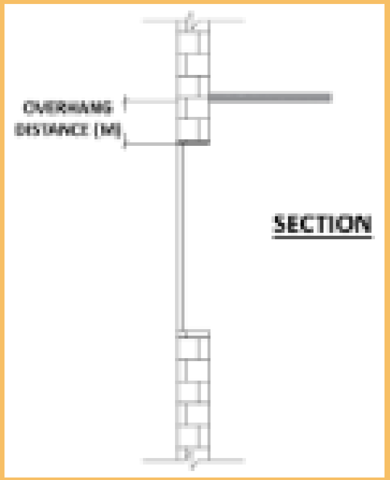
Fenestration

Type	W-W1
Number	1
Length	1.5 m
Height	1.5 m
Area	2.25 m^2
Shading Type	Overhang+L.S+R.
Overhang Depth	0.3 m
Overhang Distance	1.5 m
Left Sidefin Depth	0.2 m
Left Sidefin Distance	1.5 m
Right Sidefin Depth	0.2 m
Right Sidefin Distance	1.5 m

Help

Overhang distance

Overhang distance is the distance from the top of the window to the bottom of the farthest point of the external shading projection.



Wall-2 (East)

Wall Name: Wall2 | Length: 5.00 m | Height: 3 m | Area: 15 m^2

Construction Details

S.No.	Wall Name	Length(m)	Height(m)	Area(m^2)	View Fenestration	Action
1	WL-ProjWall	5	3	15	View	

Add Construction

Wall-3 (North)

Wall Name: Wall3 | Length: 4.00 m | Height: 3 m | Area: 12 m^2

Construction Details

S.No.	Wall Name	Length(m)	Height(m)	Area(m^2)	View Fenestration	Action
1	WL-ProjWall	4	3	12	View	

Add Construction

Detailing of fenestration is carried out for other walls based on the orientation of the façade.

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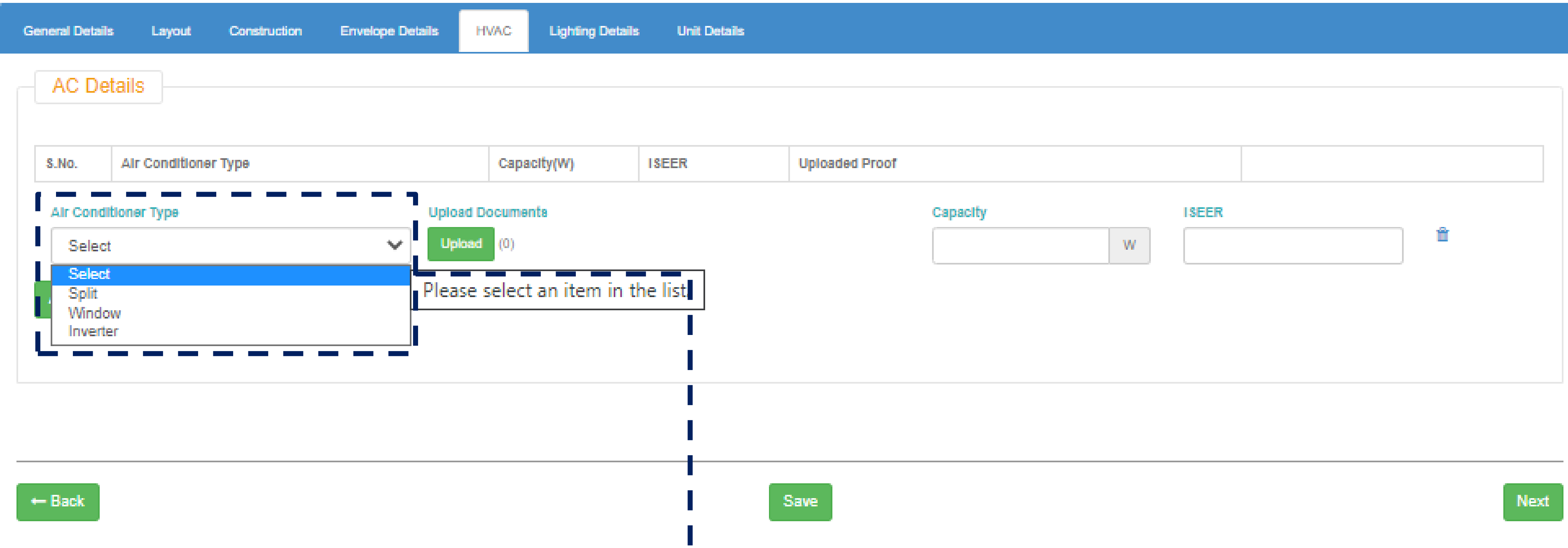
General Details | Layout | Construction | Envelope Details | HVAC | Lighting Details | Unit Details

AC Details

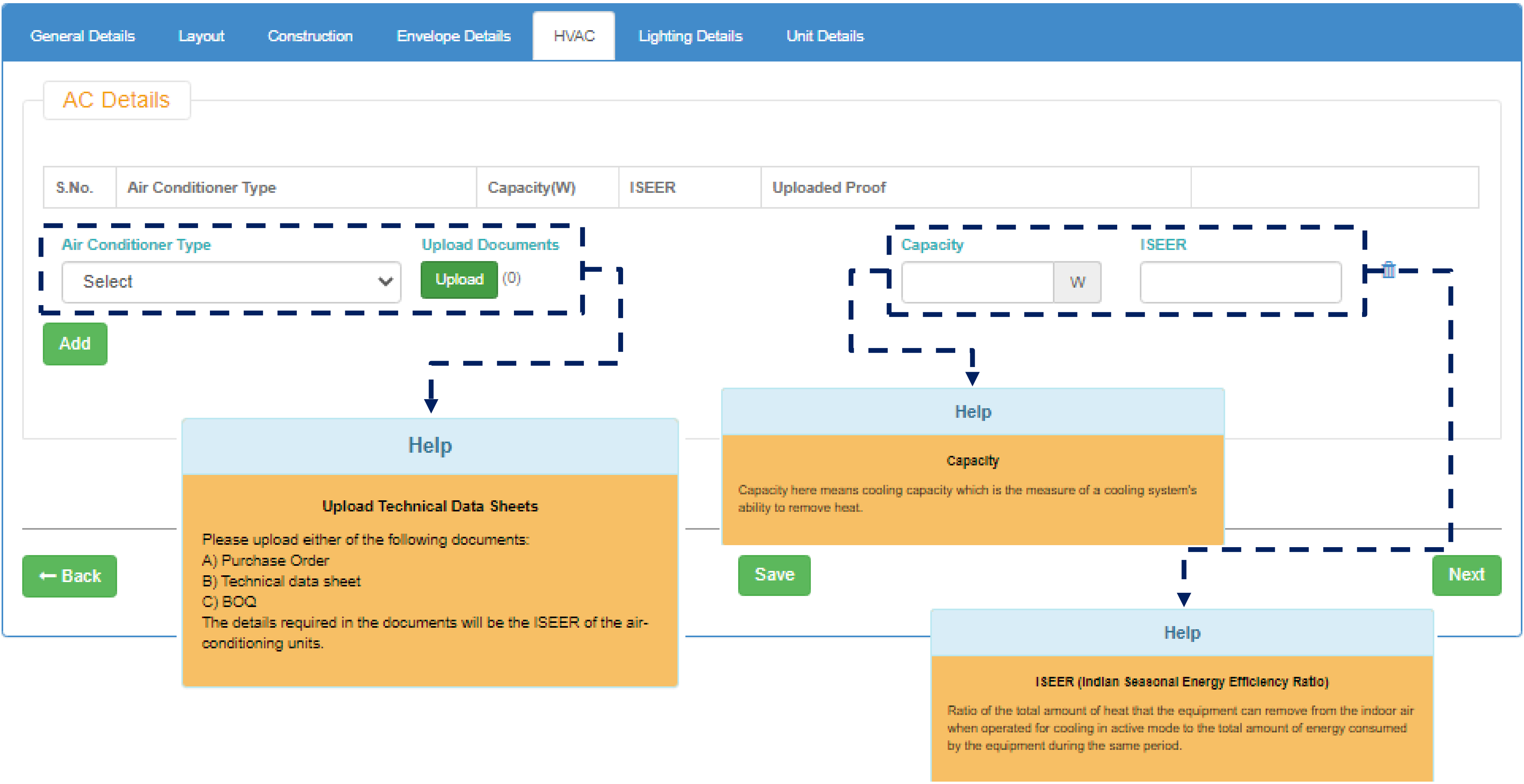
S.No.	Air Conditioner Type	Capacity(	ISEER	Uploaded Proof	

Add AC

← Back | Save | Next



Select the equipment type catering to human thermal comfort


General Details
Layout
Construction
Envelope Details
HVAC
Lighting Details
Unit Details
AC Details
S.No.
Air Conditioner Type
Capacity(W)
ISEER
Uploaded Proof
Air Conditioner Type
Select
Upload Documents
Upload
(0)
Capacity
W
ISEER
Add
Help
Upload Technical Data Sheets
Please upload either of the following documents:
A) Purchase Order
B) Technical data sheet
C) BOQ
The details required in the documents will be the ISEER of the air-conditioning units.
Help
Capacity
Capacity here means cooling capacity which is the measure of a cooling system's ability to remove heat.
Back
Save
Next
Help
ISEER (Indian Seasonal Energy Efficiency Ratio)
Ratio of the total amount of heat that the equipment can remove from the indoor air when operated for cooling in active mode to the total amount of energy consumed by the equipment during the same period.

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General Details | Layout | Construction | Envelope Details | HVAC | Lighting Details | Unit Details

AC Details

S.No.	Air Conditioner Type	Capacity(W)	ISEER	Uploaded Proof	

Air Conditioner Type: Split

Upload Documents: Upload (0)

Capacity: 1.25 W

ISEER: 4.2

Add

← Back | Save | Next

General Details | Layout | Construction | Envelope Details | HVAC | Lighting Details | Unit Details

Fill the lighting system details

S.No.	Fixture Type	Power of the luminaire(W)	Number of luminaires	Uploaded Proof	

Fixture Type: LI- System1
Upload Documents: Upload (0)
Power of the luminaire: W
Number of luminaires

Add

Back | Save | Next

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General Details | Layout | Construction | Envelope Details | HVAC | Lighting Details | Unit Details

Fill the lighting system details

S.No.	Fixture Type	Power of the luminaire(W)	Number of luminaires	Uploaded Proof	

Fixture Type: LI- System1

Upload Documents: Upload (0)

Power of the luminaire: W

Number of luminaires

Add

Help

Upload Technical Data Sheets

Please upload either of the following documents:
A) Purchase Order
B) Technical data sheet
C) BOQ
The details required in the documents will be the wattage (W) of the lighting fixtures & their type (for ex. LED, CFL, T5 etc.).

← Back | Save | Next

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General Details | Layout | Construction | Envelope Details | HVAC | Lighting Details | Unit Details

Fill the lighting system details

S.No.	Fixture Type	Power of the luminaire(W)	Number of luminaires	Uploaded Proof	
1	LI-LED	15	1	Layout_Plan.jpg	
2	LI-CFL	9	1	Layout_Plan.jpg	

Add lighting system type

← Back | Save | Next

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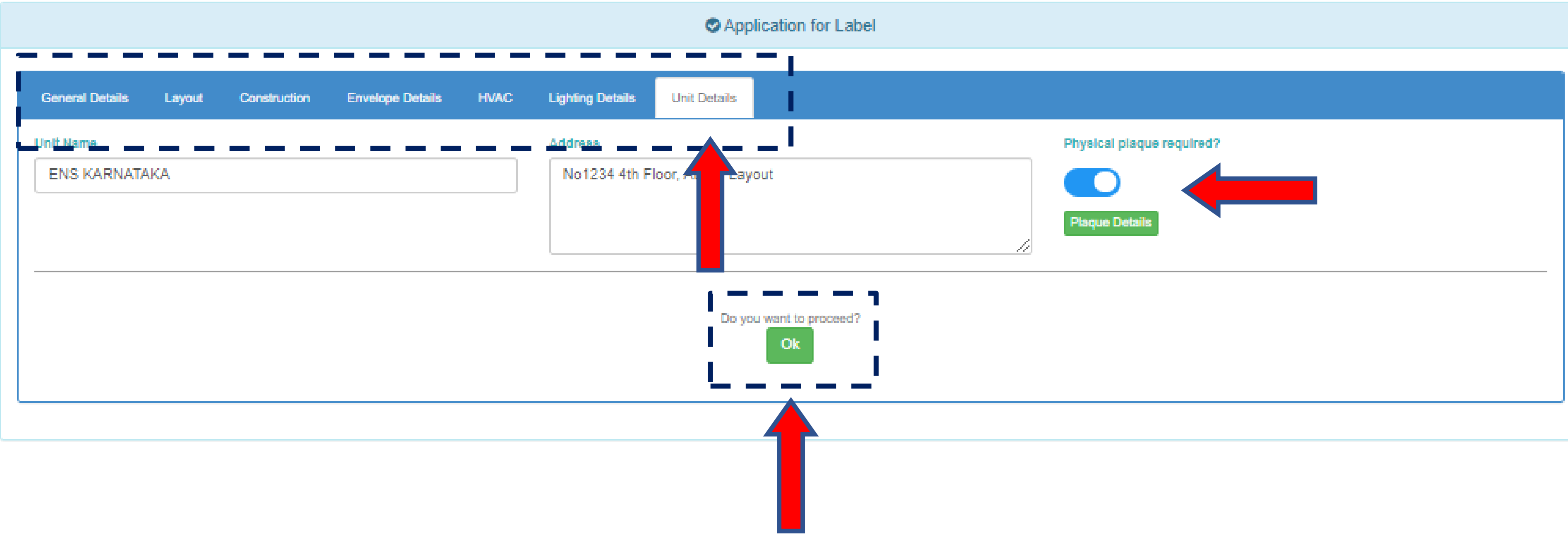

ऊर्जा दक्षता ब्यूरो
(भारत सरकार, विद्युत मंत्रालय)

GOVERNMENT OF INDIA
MINISTRY OF POWER

BUREAU OF ENERGY EFFICIENCY
(Government of India, Ministry of Power)

Application Summary	
Identification Number	KA/SAC/203/I
Name of property	ENS KARNATAKA No2
Address	No3456, 4th Floor, ABCD Layout, Indranagar, Bangalore, Bangalore, Karnataka
Climate Zone	Temperate
Type of Label	Applied For
Wall Details	

Name	Type	U-Value(W/m²K) (No Film)	Area

☑ I confirm that I want to apply for label

I Agree | Print

Close

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Government of India

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GOVERNMENT OF INDIA
MINISTRY OF POWER

Energy Efficiency Label

for Residential Buildings in India

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Please wait for a while to calculate EPI and Star Label

Please Wait ...

Computation based on the inputs provided are run in the background

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GOVERNMENT OF INDIA
MINISTRY OF POWER

Energy Efficiency Label

for Residential Buildings in India

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Proceed for Payment

Congratulations!

Your application reference number is KA/SAC/203/I

Name	ENS KARNATAKA No2
Address	4th Floor, ABCD Layout
City	Bangalore
Pin code	560001
Builtup area(m^2) area	20.00
Type of Label	Applied For
Application Reference Number	KA/SAC/203/I
RETV	1.161

Unit Name	Predicted EPI (kWh/m² .Year)	Predicted Star Label
ENS KARNATAKA No2 No3456 4th Floor, ABCD Layout	24.27	2 Star

Display of results and the performance of the building with star label.

Ministry of Housing and Urban Affairs
f India

Congratulations!

Your application reference number is KA/SAC/203/I

Name	ENS KARNATAKA No2
Address	4th Floor, ABCD Layout
City	Bangalore
Pin code	560001
Builtup area(m^2) area	20.00
Type of Label	Applied For
Application Reference Number	KA/SAC/203/I
RETV	1.161

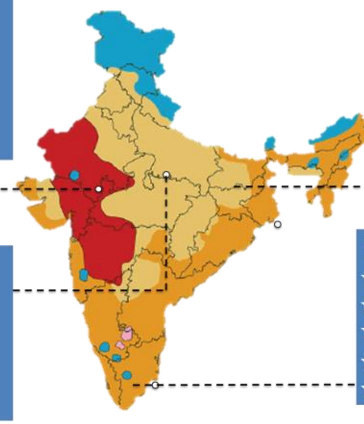
Unit Name	Predicted EPI (kWh/m² .Year)	Predicted Star Label
ENS KARNATAKA No2 No3456 4th Floor, ABCD Layout	24.27	2 Star

Hot & Dry

★	55 < EPI ≤ 67
★★	47< EPI ≤ 55
★★★	38< EPI ≤ 47
★★★★	29 < EPI ≤ 38
★★★★★	EPI ≤ 29

Warm & Humid

★	58<EPI≤64
★★	49<EPI≤58
★★★	39<EPI≤49
★★★★	30<EPI≤39
★★★★★	EPI≤30



Composite

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

Temperate

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

Help

EPI (Energy Performance Index)

$$\text{Energy Performance Index} = \frac{\text{Annual Energy Consumption (kWh)}}{\text{Built up area (m}^2\text{)}}$$

PDF version of the label is also saved in the registered project tab which can be downloaded.

International and Indian Case Studies

International Practices

The Masoro Village Project, Rwanda

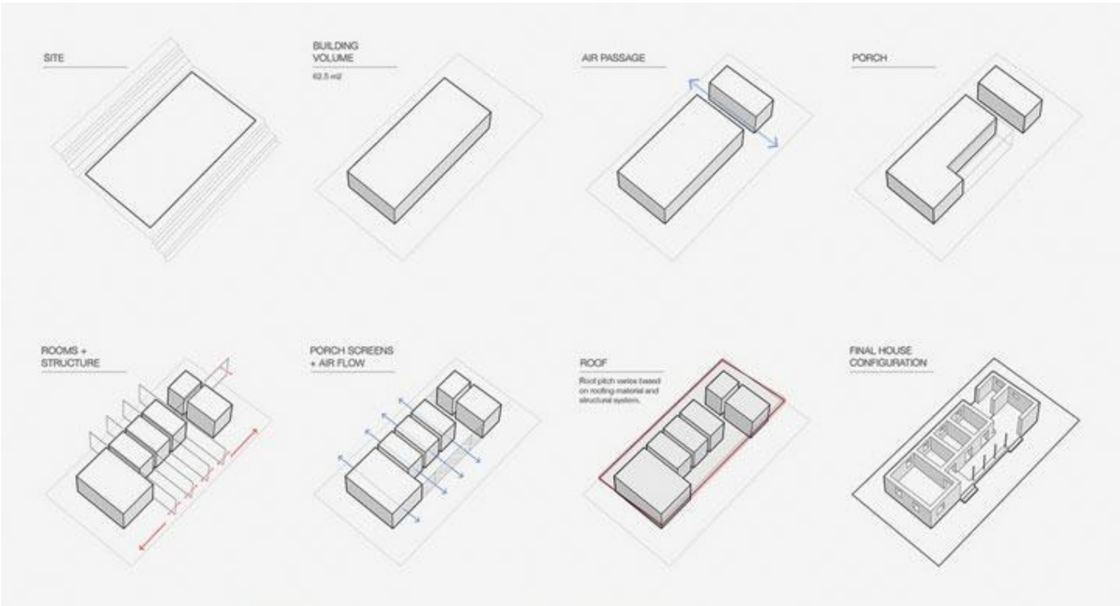
Background

- The project is a result of a Rwanda Government plan to redistribute its population to planned housing settlements.
- Any material that has to be imported to Rwanda is very expensive as it is a landlocked country.

The Project

- The project is an initiative of an American non-profit organization, GAC, to provide access to affordable houses to the people of Rwanda.
- A prototype home was built in 2013, using the earth bag technology in Masoro Village.
- With no access to electricity and indoor plumbing the project took advantage of every natural system possible. It uses a number of passive ventilation, day-lighting and thermal regulation techniques.
- ROOFING: Recycled Corrugated Steel
- FLOORING: Compressed Earth
- CEILINGS: Hand-woven Reed Matting
- SCREENS: Hand-woven Sisal
- WATER: Rainwater Harvesting
- LIGHTING: Solar Powered Lamps

International Practices



International Practices

- Windows and doors can be constructed with a traditional masonry lintel, corbeling, or brick-arch techniques. Skylights, glass-capped pipes, and bottles put between bag courses during construction can help bring in light.
- Cover the wall with cement-based stucco, lime or clay plaster to protect the bags from UV radiation and moisture. If the walls are made of 'raw' earth, the crevices between the bags or courses are filled with an earthen infill plaster made of straw. On top of that, a finish plaster is put.
- Although plaster on lower walls may be stronger and more water-resistant than plaster on upper walls, roof overhangs can help reduce plaster waterproofing requirements.
- Some structures have a "living roof" ("green-roof") made of planted earth, while others have more traditional frame and roofs atop earth-bag walls.

Thermal Comfort Properties

The thermal insulation property increases due to increase in thermal mass of the wall. The wall also helps in thermal lag, and retains the coolth inside the space and vice versa. The exact U-Value of the earth bags is not determined.

International Practices

Bamboo for Construction in China

Background

- Bamboo is growing in popularity as a building material in China.
- Its abundance, cost, flexibility and structural strength has been the reason for its success.

The Project

- Local officials in China have been encouraging the use of bamboo in construction, especially the Provinces that have bamboo in abundance.
- Many architecture firms have been proposing bamboo as a cost effective material to solve the housing problems in the country.
- China has traditionally used bamboo as a construction material.
- Energy Efficient Bamboo House, a two storey house was built in 2016, in the context of new policies for the sustainable growth of China.
- Bamboo eye pavilion- the largest bamboo project yet was built in China in 2019, to showcase the possibilities of bamboo in modern and low carbon construction.

International Practices

Energy Efficient Bamboo House, Baoxi

- The house was conceived by Milan designers at Studio Cardenas, and is constructed primarily from bamboo.
- The use of local material is just the beginning for the bamboo’s long list of impressive energy saving features.
- The architects at Studio Cardenas have developed a modular, “industrialized bamboo construction system” that will allow fast creation of multiple houses.
- The design uses dry-mounted connections that don’t weaken the bamboo through perforation. This design also means the bamboo poles can be replaced if and when needed.
- The design explores the potentiality of minimize carbon emissions, protection and natural ecological development through the use of the natural elements available in the area, such as sun, water, plants, wind and natural materials to achieve a high standard innovative house for the Chinese context.

International Practices

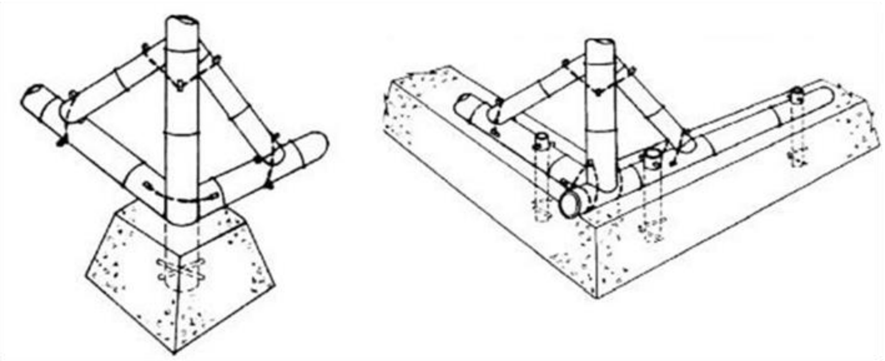
- The layer of the house is divided into nine squares in keeping with the ancient design guidelines. Positive energy, known as Qi is encouraged to flow around the house with the minimal use of dividing walls.
- This open plan also helps facilitate maximum natural ventilation. The house sits on a rammed earth base. On the lower floor sits the technical room of the house.
- The house cleverly uses a combination of groundwater and a geothermal heat pump for indoor heating and cooling.
- By digging into the earth the temperature is stable no matter what the season, no matter what the temperature above ground. By taking advantage of this more constant, even temperature, we can heat or cool the house
- This method of heating and cooling leverages off the earth's naturally stabilized temperatures which allows it to be at least **25 percent** more energy efficient than conventional systems.
- The geothermal heat pump and groundwater system are also reported to use around **15 percent** less energy than traditional chiller plants.

International Practices

Detailed Building Construction Methodology

Bamboo for Foundations

Bamboo is rarely used as a foundation material since it decays quickly when it comes into touch with moisture. However, with correct treatment and the use of appropriate chemicals, this problem can be addressed to a large extent.



Bamboo as foundation

Bamboos are utilized to construct foundations in a variety of shapes and forms. The following are some of the most common bamboo shapes:

a) Flattened bamboo, which is made by dividing freshly cut bamboo stalks and then rolling and flattening them.

b) Bamboo mats as thin as 5-6mm or as thick as 10-15mm are woven to design specifications. Bamboo mat structures are made using phenolic resins.

c) Bamboo plastic composite is a cutting-edge technology that combines bamboo fiber as a raw material with plastic as the core. These carpets are more moisture resistant and structurally durable.

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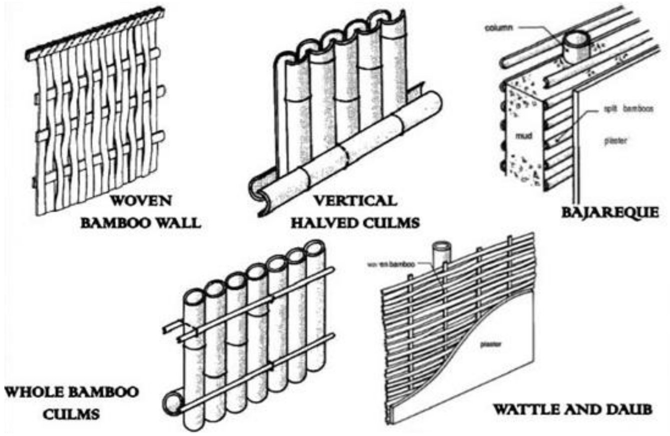
International Practices

Walls Construction with Bamboo as a Building Material

•Bamboo is often utilized for wall and partition construction. The essential elements of bamboo construction are posts and beams, which provide structural foundation for walls.

•They positioned themselves to be able to endure natural pressures. To enhance strength and stability to the walls, an infill is employed between framing sections.



Roofing with Bamboo as a Building Material

•Bamboo is one of the best roofing materials, and it gives the structure a lot of strength.

•It is a proven barrier against natural or animal pressures, and it is quite light in weight, making it simple to build.

•Purlins, rafters, and trusses are all included in the bamboo roofs.

International Practices

Scaffolding with Bamboo as a Building Material

•Bamboos are one of the most widely recommended materials for scaffolding, especially for towering structures, due to their excellent capabilities of sustaining huge loads.

•Cane extensions are obtained by attaching cane ends with many ropes for scaffolding construction.

•The ties are positioned in the lashing so that forces acting vertically downward lodge the nodes.Because the joints may be re-aligned to the proper degree, this approach is extremely important.

International Practices

Disadvantages of Bamboo

Bamboos come with their own set of drawbacks such as:

1. They must be preserved.
2. Shrinkage: Bamboo shrinks substantially more than any other species of wood, particularly when water is lost.
3. Durability: Before being used for construction, bamboo should be appropriately treated against insect or fungus attack.
4. Jointing: Despite the predominance of numerous jointing procedures, bamboo's structural durability is in question.

Advantages of Bamboo as a Building Material

The various advantages of bamboo are as mentioned below:

1. Tensile strength: Because bamboo strands run axially, it has a higher tensile strength than steel.
2. Fire Resistance: Bamboo has a great fire resistance and can sustain temperatures of up to 4000 degrees Celsius. This is owing to the high concentration of silicate acid and water present.
3. Elasticity: Because of its elastic properties, bamboo is often used in earthquake-prone areas.
4. Bamboo's low weight allows it to be quickly displaced or installed, which makes transportation and building much easier.
5. Bamboo, unlike other building materials such as cement and asbestos, poses no health risk.
6. They are inexpensive and simple to use.
7. They're particularly popular in earthquake-prone areas.

International Practices

Background

- Low Energy building was a legal required standard in Sweden and Denmark in the mid 80's. Further development on the basic low- energy housing principles led to 'Passive Houses.

The Project

- The project was a result of the research by Bo Adamson, Robert Hastings and Wolfgang Feist.
- This concept was inspired from the ancient turf houses built in Iceland during the Middle Ages.
- The first Passive House was built in 1990 in Germany.

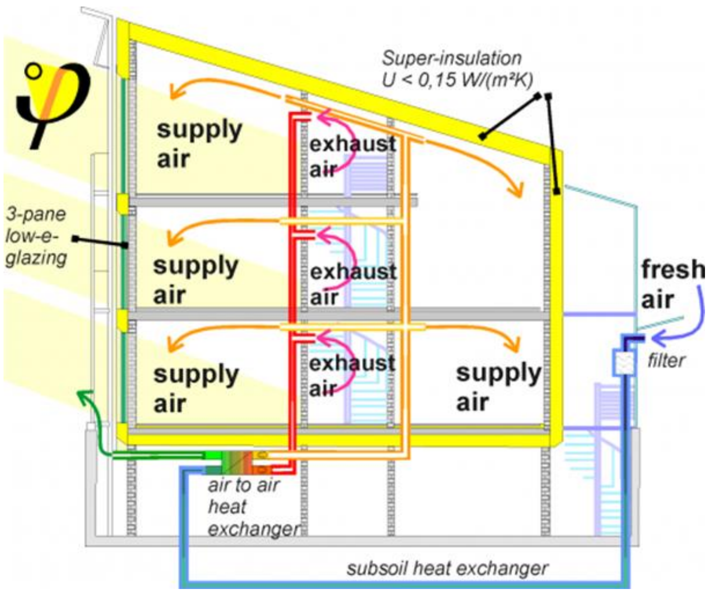
International Practices

Passive Haus Germany

Technology Overview

Definition – Passive Houses are buildings which required no active heating with very low energy demand even in the Central European Climate. The houses are kept warm using internal heat sources and through solar energy from openings & fenestrations.

- It is an approach to regulate internal temperature without relying on artificial heating or cooling.
- The houses are designed using a combination of high-performance glazing, insulation, airtight envelope and ensured prevention of thermal bridges.
- The material choice for the envelope design included high insulating and High-quality doors and windows to ensure that it is well insulated and fitted with double glazing or low emissivity glass.



International Practices

Other noteworthy projects after the first Passive House are **Paul-Roosen-Straße ensemble in Hamburg St. Pauli, Hamburg.**

More than 100 new Passive House projects were presented in the 4th International Passive House Conference in Kassel. One of the projects was the first social Passive house project built by the GWG Kassel and planned by the Architects Prof, Dr. Schneider, Hegger and Nolte. This Project was a part of the European "CEPHEUS" Project which proved that the Passive House Standard can also be implemented in publicly funded multi-storey buildings, with overall energy savings of 82% in comparison with similar new "non-passive house" building

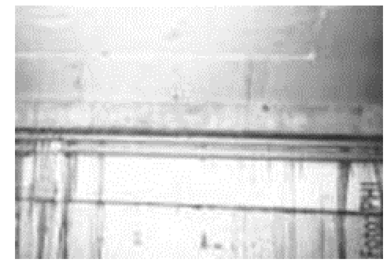
Detailed Building Construction Methodology

The emphasis of these Passive House measures was on the **conservation of heat: thermal protection and heat recovery** are the decisive components. This still applies for subsequently built Passive Houses. Design features of the Passive House in Darmstadt-Kranichstein (first passive house in Germany) are shown in the table.

International Practices

Building component	Description	Photograph of site	U-value W/(m²K)
Roof	Grass roof: Humus, non-woven filter, root protective membrane, 50 mm formaldehyde-free chip board; Wooden light-weight beam (I-beam of wood, stud link of hardboard), counter lathing, sealing with polyethylene sheeting bonded without jointing, gypsum plasterboard 12.5 mm, wood-chip wallpaper, emulsion paint coating, entire cavity (445 mm) filled with **blown-in mineral wool insulation**.		0.1
Exterior **wall**	Fabric reinforced mineral render; 275 mm of expanded polystyrene insulation (EPS) (installed in two layers at that time, 150+125 mm); 175 mm sand-lime brick masonry; 15 mm continuous interior gypsum plastering; wood-chip wallpaper, emulsion paint coating		0.14

International Practices

Building component	Description	Photograph of site	U-value $W/(m^2K)$
Basement **ceiling**	Surface finish on fibreglass fabric; 250 mm polystyrene insulation boards; 160 mm concrete; 40 mm polystyrene acoustic insulation; 50 mm cement floor finish; 8-15 mm of parquet, adhesive; sealing solvent-free		0.13
Windows	Triple-pane low-e glazing with Krypton filling: U_g-value 0.7 $W/(m^2K)$. Wooden window with polyurethane foam insulated framework (CO2-foamed, HCFC free, handcrafted)		0.7
Heat recovery **ventilation**	Counterflow air-to-air heat exchanger; Located in the cellar (approx. 9°C in the winter), carefully sealed and thermally insulated, the first one to use electronically commutated DC fans.		heat recovery rate approx. 80%

International Practices

- The hot water is heated using solar vacuum flat collectors (5.3 m^2 per household or 1.4 m^2 per person).
- Natural gas is used for secondary heating. The flat-collector thermal system covers about 66% of the dhw consumption in the Passive House in Darmstadt-Kranichstein.
- Because the provision of domestic hot water represents the greatest energy requirement of this house, an efficient domestic hot water system is of great importance. The heat distribution and circulation pipes have therefore been placed inside the thermal envelope and are well insulated

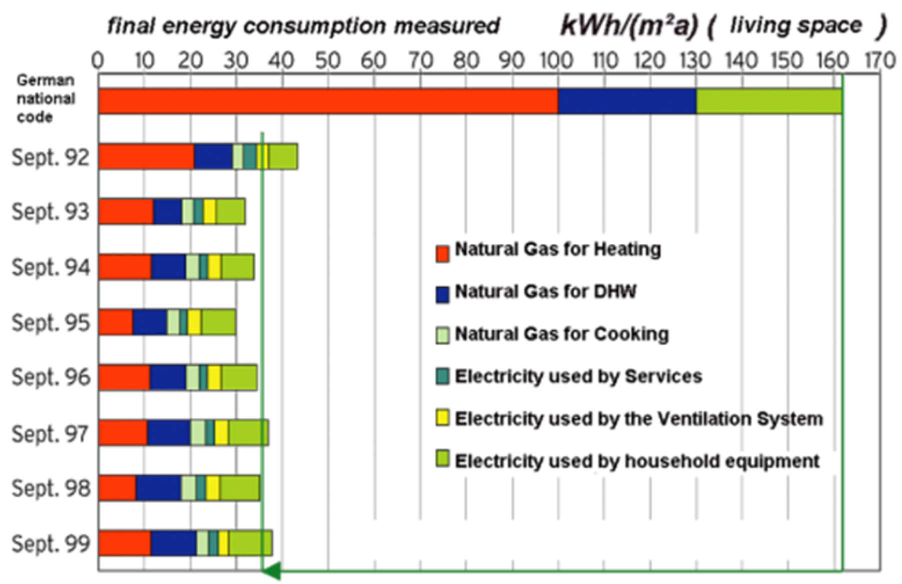
Thermal Comfort Properties

The measurements in the Passive House in Darmstadt-Kranichstein have confirmed that the electrical consumption for household appliances can be reduced to one third of its current average value with presently available technology. The additional gas consumption for applications which require heating energy amounts to less than 15% without compromising on the comfort levels.

Results of the Energy Consumption measurements in the Passive House in Darmstadt- Kranichstein show the reduction of heat energy drastically of upto 90% compared to a normal new building of the same year. It also reduced the gas consumption for domestic hot water and household electricity consumption due to good insulation properties and use of efficient appliances.

After the completion of the Project, continuous monitoring helped to recognize the impact of the design. The heat consumption was 19.8kWh in 1991-92, 11.8kWh in 1992-93 and less than 10kWh in the following years which is only 8%, 5.5% and <4% of the consumption in comparable homes respectively.

International Practices



The Passive House coped successfully with the icy cold winter of 1996/97, during which the designed standard external temperatures were considerably exceeded, causing problems in relation to comfort in conventionally heated houses. Not only did the heating consumption remain below 11 kWh/(m²a) (almost the same as the previous consumption), but also all homes were equally warm.

The first prototype of Passive House had successfully fulfilled the expectations. Now the way forward of the research involved in mitigating the additional costs involved in the design, which led to the next phase of **the development: the second-generation, cost-efficient Passive Houses**.

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.
- The main road is around 450 meters from the site.
- 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.
- The said dwelling units fulfill all present bye laws of the line departments such Electricity, fire, Public Works department, municipality, traffic etc
- The petty shops within the premises are accomplished for the benefits of the occupants and nearby communities. Effective disposal of greywater to the Sewage treatment plant present in close proximity.
- The accumulated household wise waste is segregated with separate collecting units at source.

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

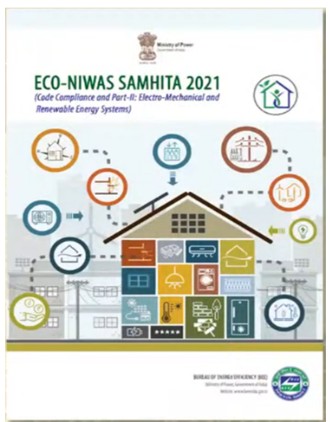
Eco Niwas Samhita (ENS) (Part I: Building Envelope) is a residential energy code that has been prepared to set minimum building envelope performance standards to limit heat gains (for cooling dominated climates) and to limit heat loss (for heating-dominated climates), as well as for ensuring adequate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

Eco Niwas Samhita (ENS) - Part 2

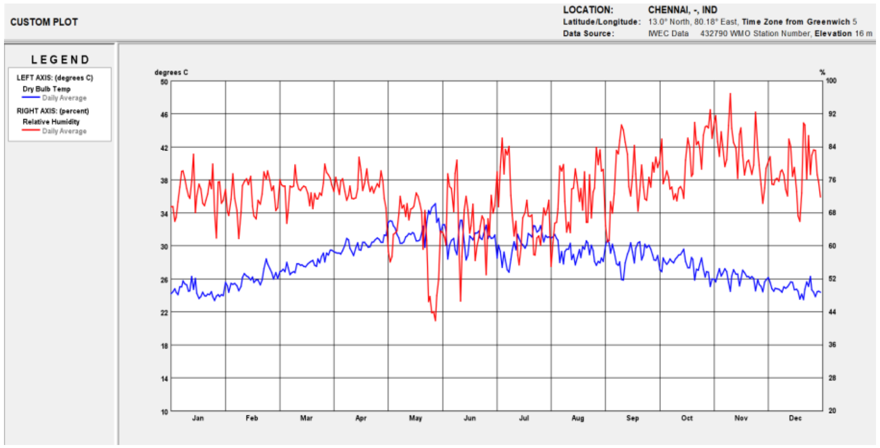
The Eco Niwas Samhita 2021 (Code Compliance and Part-II: Electro- Mechanical and Renewable Energy Systems) is a code specifying code compliance approaches and minimum energy performance requirements for building services, indoor electrical end-use and renewable energy system.



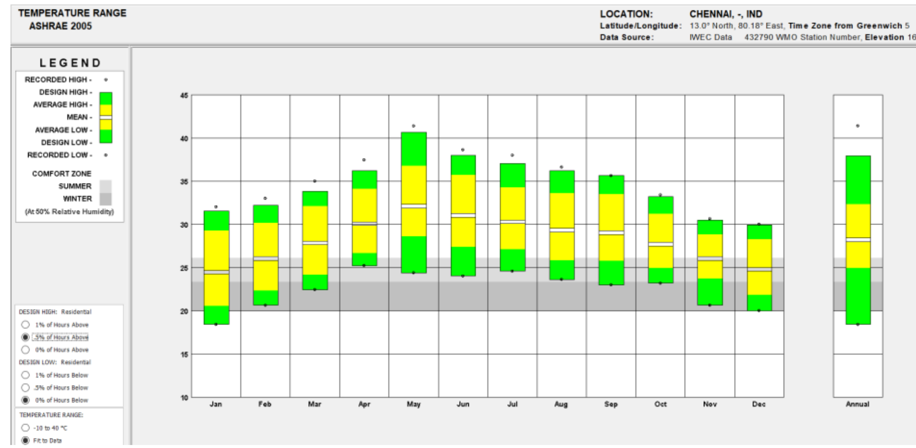
- **Building Services**
  - Common Area & Exterior Lighting
  - Elevators
  - Electrical Systems
  - Pumps
- **Indoor End Electrical Use**
  - Indoor Lighting
  - Comfort Systems
- **Renewable Energy Systems**
  - Solar Water Heating
  - Solar Photo-Voltaic

Details of procurement of Electro Mechanical and Renewable Energy system needs to be collected from the project team, and recommendations needs to be provided to score 75 points, under the affordable housing category to become and ENS compliant building.

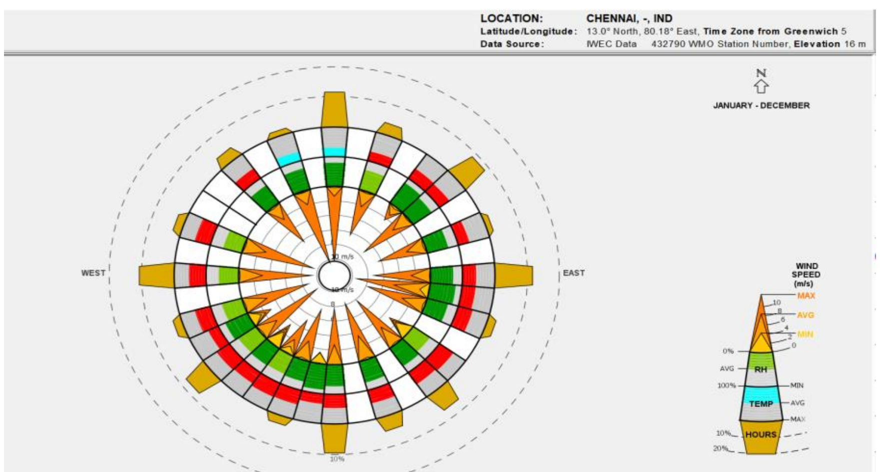
Climate Analysis - Puducherry



Temperature and Relative Humidity



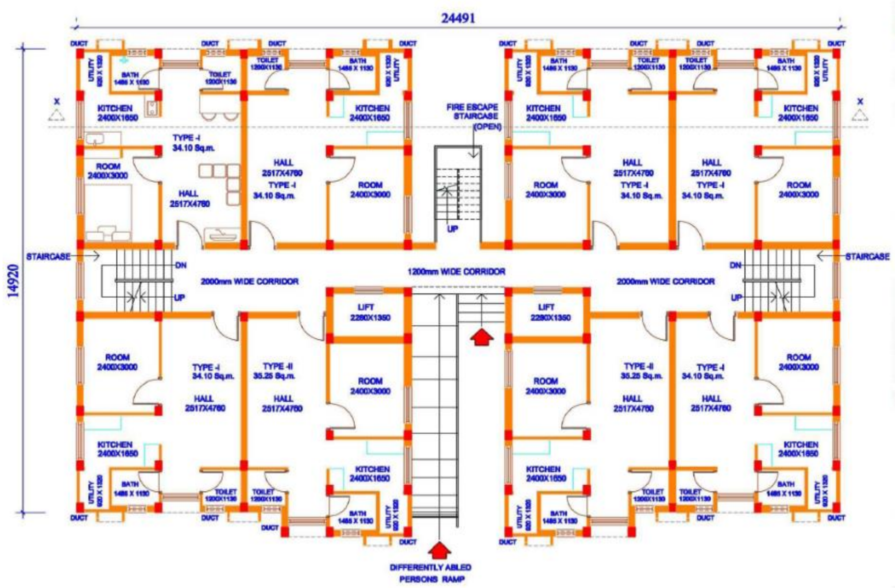
Monthly Dry Bulb Temperature (DBT) distribution



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 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 windows.

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

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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

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/m². 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/m². 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.

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Project evaluation as per ENS compliance requirements

Residential Envelope Transmittance Value (RETV)

Residential envelope heat transmittance (RETV) is the net heat gain rate (over the cooling period) through the building envelope (excluding the roof) of the dwelling units divided by the area of the building envelope (excluding the roof) of the dwelling units.

RETV formula takes into account the following:

- Heat conduction through opaque building envelope components.
- Heat conduction through non-opaque building envelope components.
- Solar radiation through non-opaque building envelope components.

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

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**	

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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**	

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**	

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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**	

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

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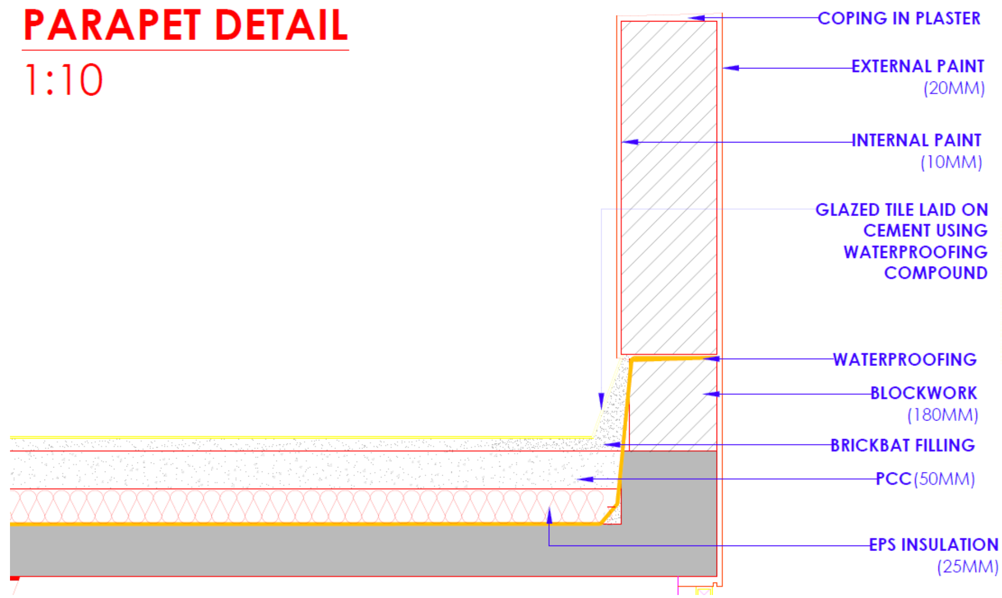
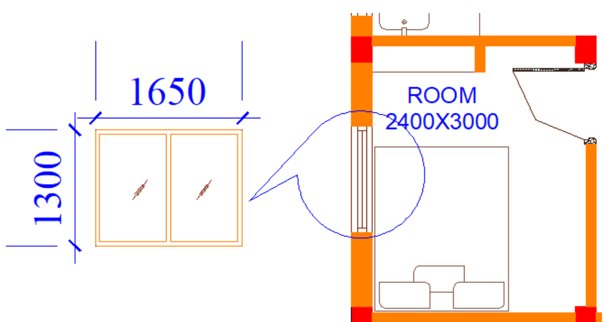
Conclusion and Remarks

- **AAC wall**

- **25 mm EPS roof insulation**



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



Thank you !

Presented by:

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