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

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

Ministry of Housing and Urban Affairs
Government of India

आज़ादी का अमृत महोत्सव

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TRAINING 'D' PRESENTATION ON THERMAL COMFORT AWARENESS

Prepared by-

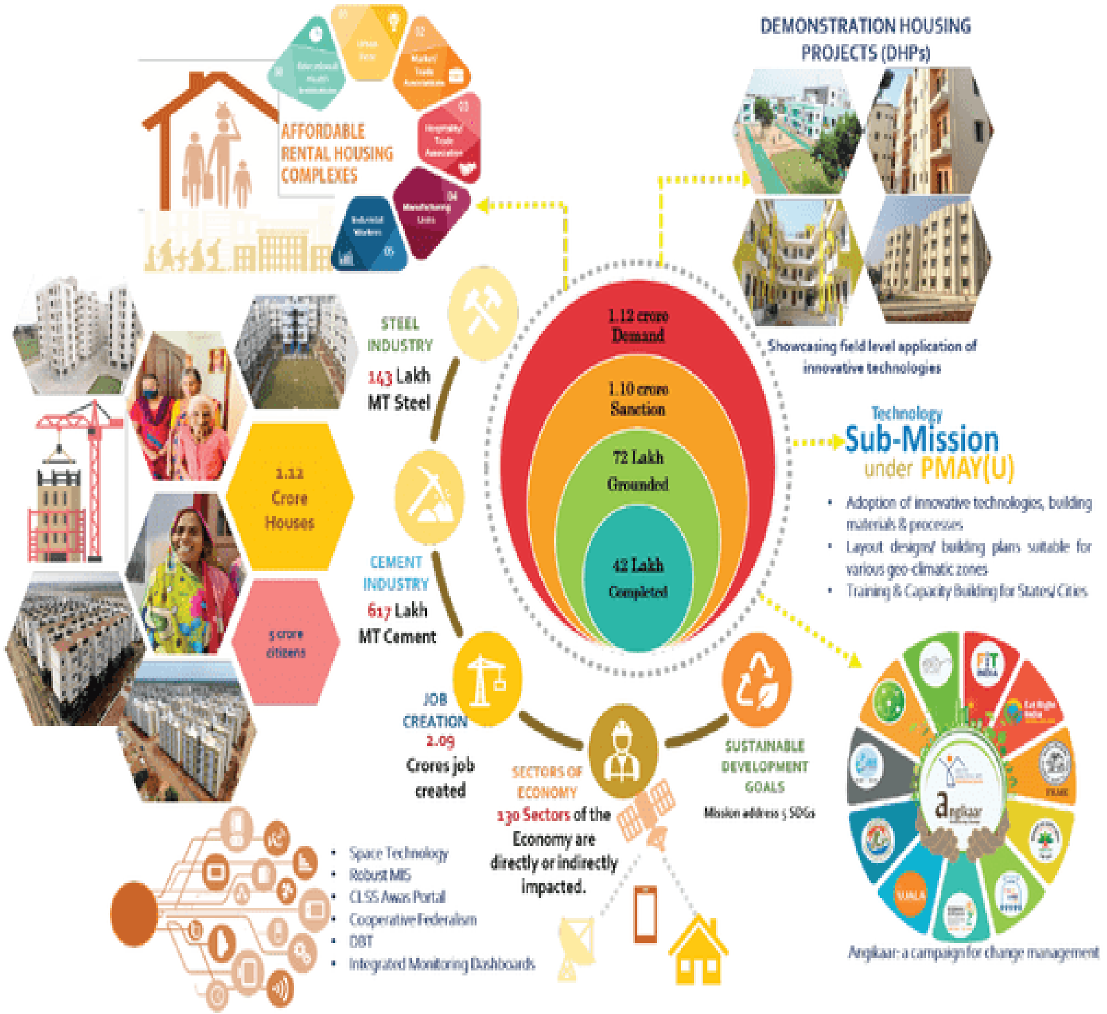
Climate Smart Building (CSB) Cell,
North Cluster, LHP Lucknow

INTRODUCTION

1. Introduction of Ministry of Housing and Urban Affairs
2. Introduction of Global Housing Technology Challenge
3. Introduction of GIZ
4. Introduction of Climate Smart Building Cell

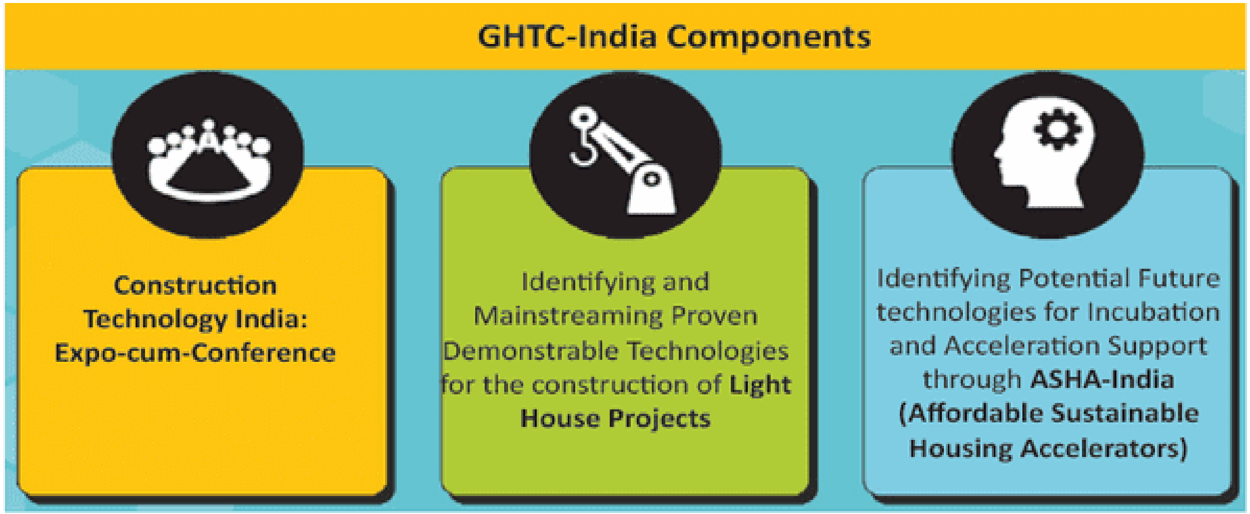
INTRODUCTION – Ministry of Housing & Urban Affairs (MoHUA)

- **Ministry of Housing and Urban Affairs (MoHUA)** is the supreme authority of the Government of India to formulate and monitor all the programmes concerning the housing and urban affairs of the country.
- MoHUA's flagship mission **Pradhan Mantri Awas Yojna-Urban (PMAY-U)** ensures a pucca house for all eligible urban households by the year 2022.



INTRODUCTION- Global Housing Technology Challenge (GHTC-INDIA)

- Due to the need for sustainable technological solutions for faster and cost-effective constructions suited to geo-climatic and hazard conditions of the country, **MoHUA** initiated the **Global Housing Technology Challenge (GHTC)-India to identify and mainstream a basket of innovative housing technologies across the globe.**
- 54 proven technologies were shortlisted suiting different climatic zone conditions in the CTI conference in 2019.



INTRODUCTION – GIZ AND IGEN (INDO GERMAN ENERGY PROGRAM)

- The Government of the Republic of India and the Federal Republic of Germany under the Indo-German Technical Cooperation, agreed to jointly promote the "Indo-German Energy Programme" **(IGEN)** with the aim to foster sustainability in the built environment.
- Deutsche Gesellschaft für Internationale Zusammenarbeit **(GIZ)** GmbH has been working jointly with the partners in India for over 60 years, for sustainable economic, ecological, and social development.
- GIZ is an international cooperation enterprise for sustainable development which operates worldwide, on a public benefit basis.

INTRODUCTION – CLIMATE SMART BUILDINGS (CSB CELL)

- Ministry of Housing and Urban Affairs (MoHUA) aims to enhance climate resilience and thermal comfort in the affordable housing segment through IGEN's programme, **Climate Smart Buildings (CSB)**.
- It will be achieved by adopting sustainable and low-impact design, materials, and the best available construction technologies.
- The intent is to demonstrate the use of innovative technologies to provide desired thermal comfort for mass replication.

OBJECTIVES AND ACTIVITIES – CLIMATE SMART BUILDINGS (CSB)- CELL

S.N.	Objectives and Activities
1	Enhance climate resilience and thermal comfort in buildings.
2	Technical support in the implementation of Global Housing Technology Challenge (GHTC)-India
3	Provide technical assistance to promote thermal comfort in LHPs.
4	Technical assistance to enhance thermal comfort in upcoming Demonstration Housing Projects (DHPs) and Affordable rental housing complexes(ARHCs).
5	Inclusion of climate resilience and thermal comfort requirements in Building Bye laws in North Cluster.
6	Capacity development of Govt officials and private stakeholders on thermal comfort in the North Cluster.

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Six Light-House Projects and its Innovative Construction Technology

THE INCEPTION OF LHP PROJECTS

Ministry of Housing and Urban Affairs Under **PMAY(U)**, set up a **Technology Sub-Mission (TSM)** to provide:

- Alternative sustainable technological solutions.
- Better, Faster & cost-effective construction methodologies.
- Houses suiting to geo-climatic and hazard conditions of the country.
- Serve as **live laboratories** for transfer of technology to the field i.e., Planning, Design, Production of components, Construction Practices, and Testing.
- Live Lab for Students, Faculties, Builder, Professionals of Public and Private sectors, and other stakeholders.
- To encourage large-scale participation of people to create technical awareness for on-site learning, Stakeholder consultation, ideas for solutions, Learning by doing experiments.

CONCEPT OF LHP PROJECTS

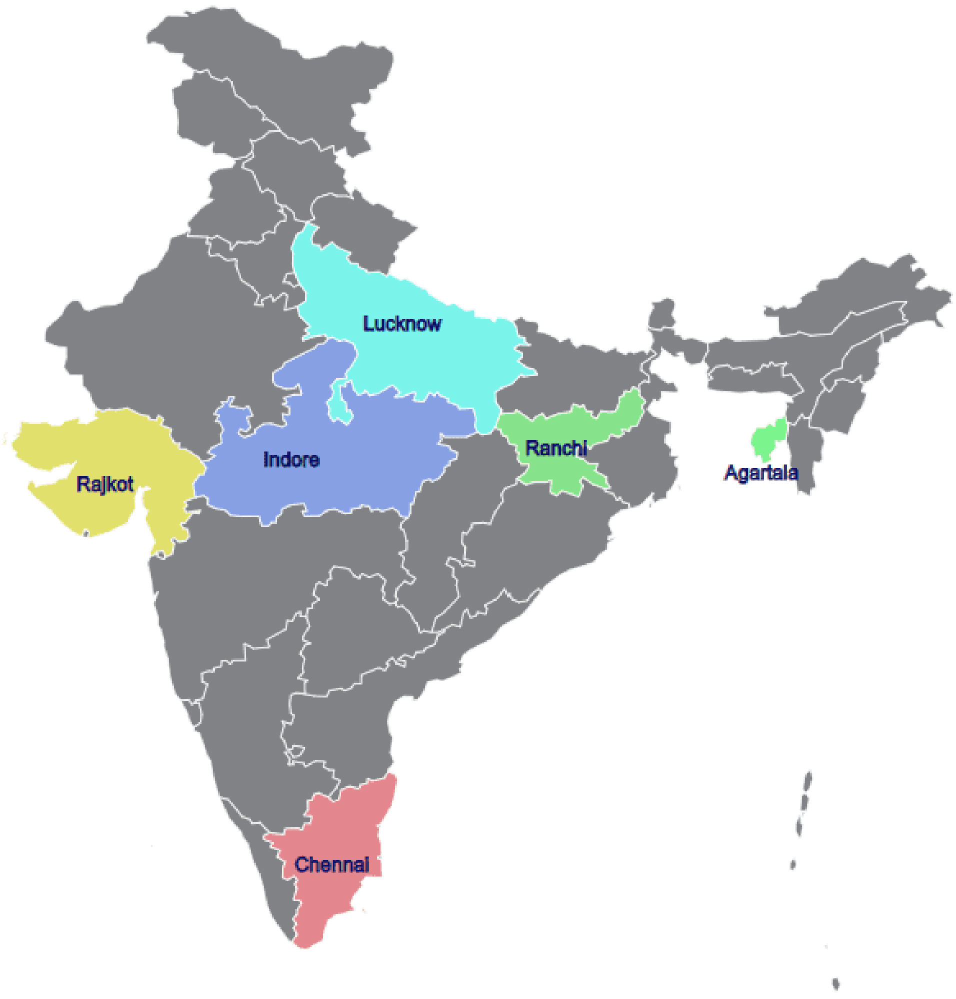
- The fundamental concept of the Light-House Projects is to encourage large-scale participation of the people of India for mainstreaming the proven technologies identified globally by the principles.

Site Visit	Pros & Cons	Regional Factor	Economy of Scale
Exposure to Technologies/ Materials/ Processes	Suitability/Safety	Acceptability	Demand
Technical knowhow	Cost Factor	Willingness to Pay	Availability of Materials/ Skilled Manpower
	Speed/ Quality	Approvals	Logistics
	Availability of Materials		

THE LIGHT-HOUSE PROJECTS- INDIA

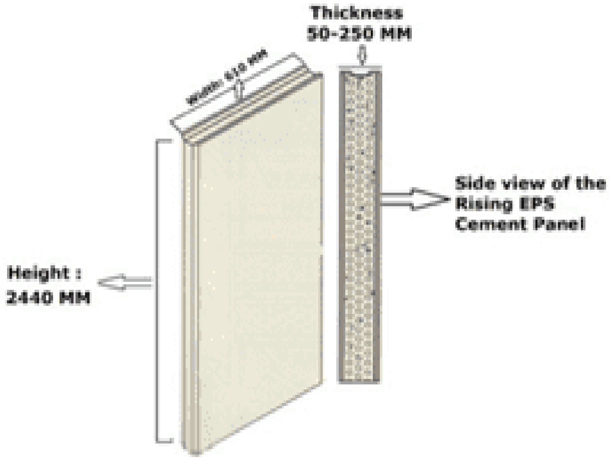
LHPs are model housing projects with houses built with shortlisted alternate technology suitable to the geo-climatic and hazard conditions of the region.

- **Indore** (Prefab Sandwich panel)
- **Rajkot** (Monolithic concrete construction using tunnel formwork)
- **Chennai** (Precast concrete construction system assembled at site)
- **Ranchi** (Precast concrete construction system-3d volumetric)
- **Agartala** (Light gauge steel and PEB)
- **Lucknow** (Stay in place formwork and PEB)



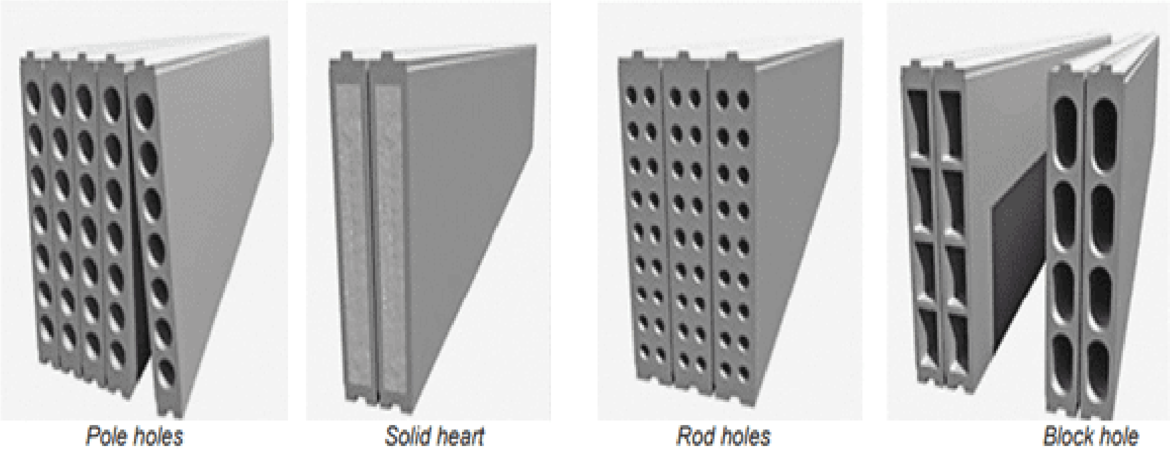
LHP Indore-Prefabricated Sandwich Panel System

- Lightweight composite wall, floor and roof sandwich panels made of thin fibre cement or calcium silicate board as face covered boards.
- Core material is EPS granule balls, adhesive, cement, sand, fly ash and other bonding materials in mortar form.
- The core material in slurry state is pushed under pressure into pre-set moulds.
- Once set, it shall be moved for curing and ready for use with steel support structure beams and columns.



Prefabricated EPS Sandwich Panel

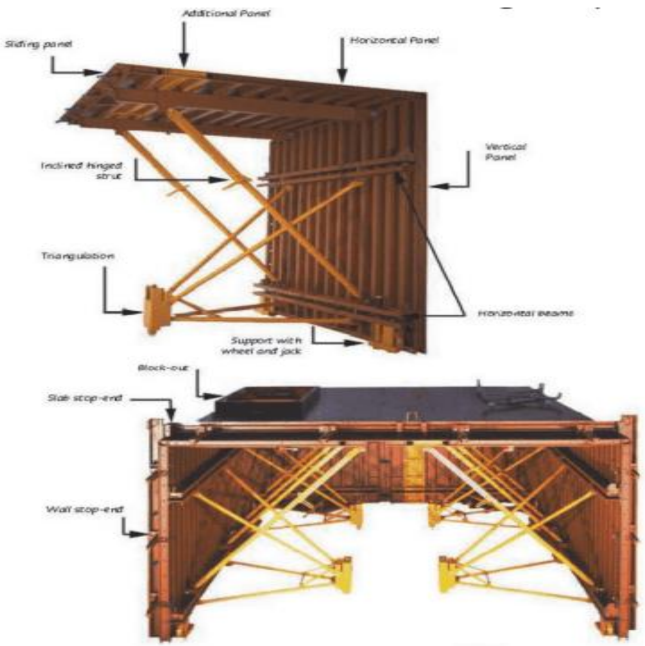
Steel Structure Prefabricated EPS Panel



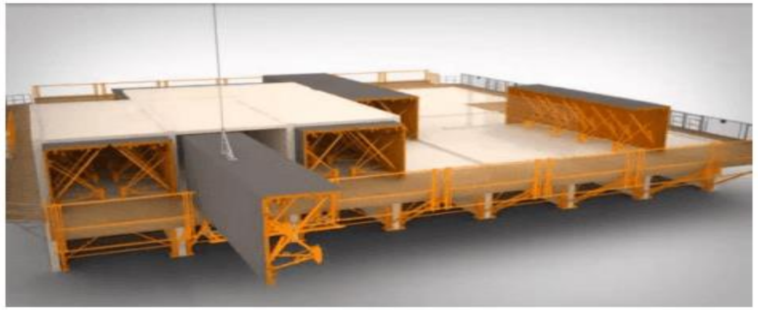
Types of Prefabricated Sandwich Panels

LHP Rajkot- Monolithic Concrete Construction using Tunnel Formwork

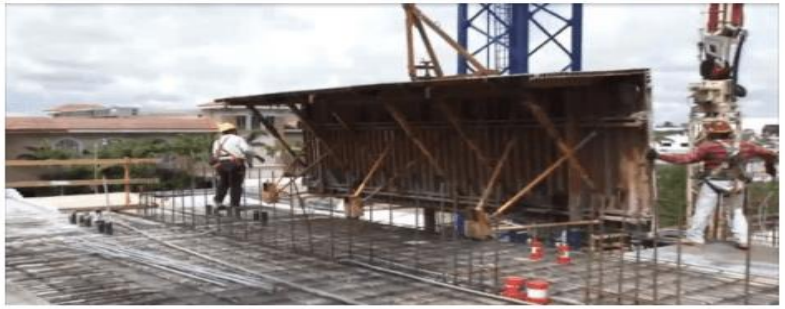
- Customized engineering formwork replacing conventional steel or plywood shuttering systems.
- Mechanized system for cellular structures.
- Two half shells which are placed together to form a room or cell.
- Walls and slab are cast in a single day.
- The formwork is stripped the next day for subsequent phase.



Tunnel Formwork



Box out of door and windows

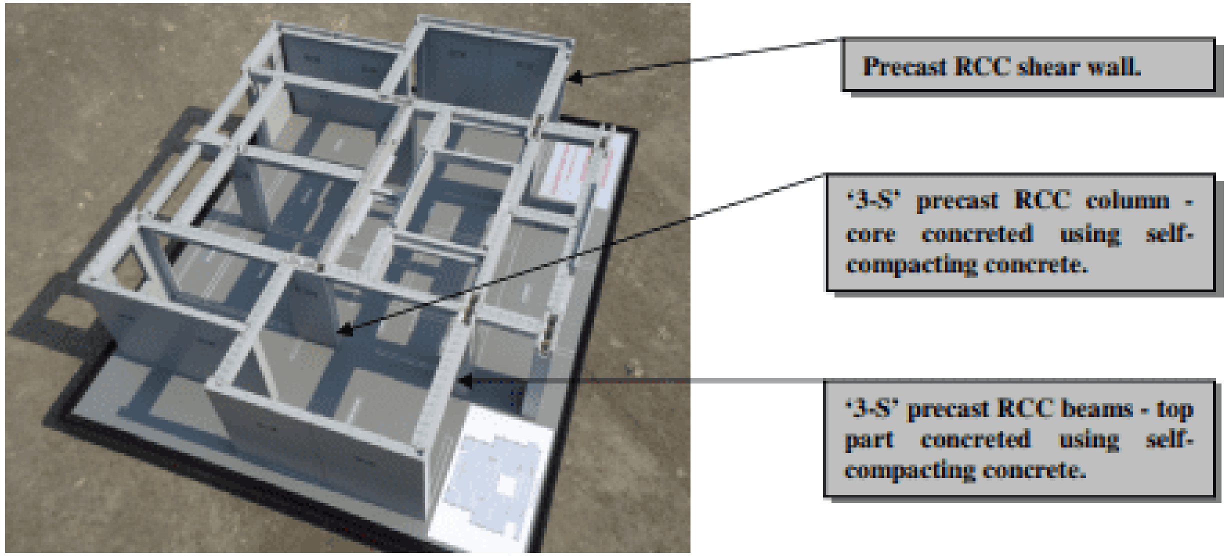


Kicker form of tunnel formwork panel

Monolithic Tunnel Formwork Panel

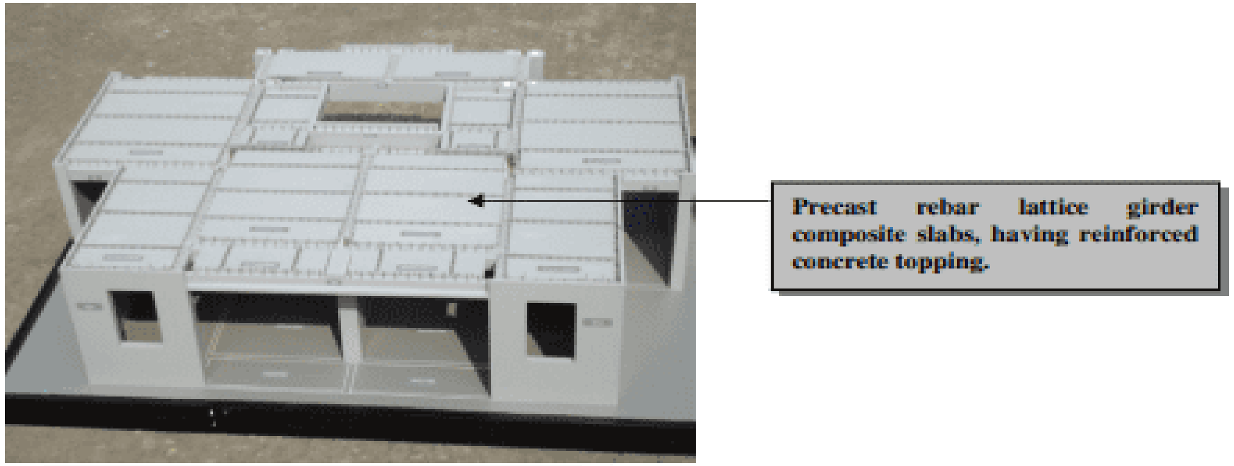
LHP Chennai-Precast Concrete Construction System Assembled at Site

- Precast dense reinforced cement concrete hollow core columns and RCC shear walls is being used as structure .
- AAC blocks in partition walls are being used.
- Dowel bars, continuity reinforcement placed at connections.
- Self-compacting concrete is being used in hollow cores of columns.



Installation of panels

Precast concrete wall (Panels)

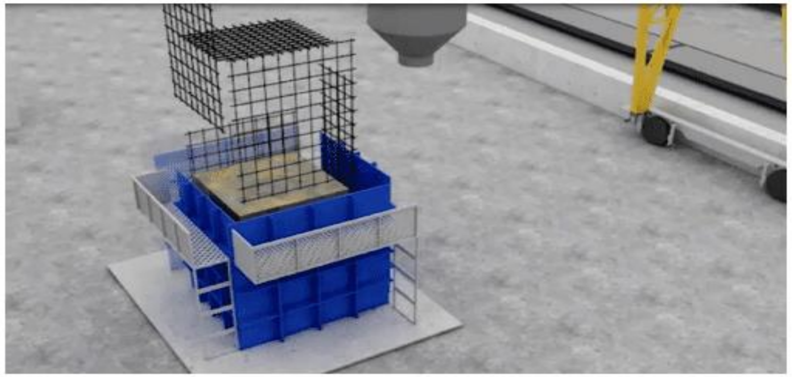


LHP Ranchi- Precast Concrete Construction System – 3D Volumetric

- Components like room, Bathroom, Kitchen etc are cast monolithically in Plant or Casting yard in a controlled condition.
- Magic Pods (Precast Components) are transported, erected & installed using cranes .
- Prestressed slabs are installed as flooring elements.
- Consecutive floors are built in similar manner to complete the structure.

Transportation of Magic Pods

Construction and installation

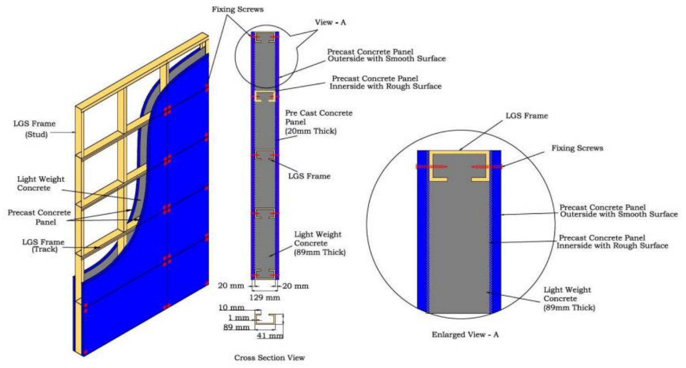


Pre Casting of building modules

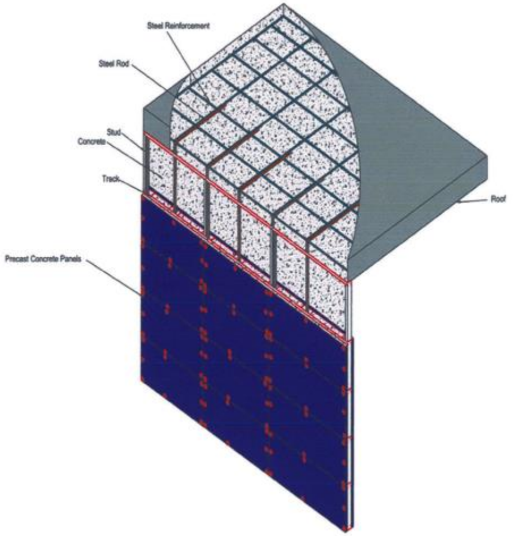
Pre Casting of building modules

LHP Agartala- Light Gauge Steel Framed Structure with Infill Concrete Panels (LGSFS-ICP)

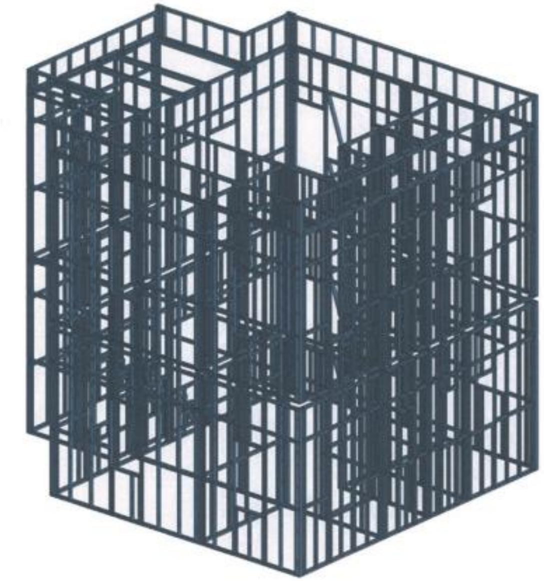
- Light Gauge Steel Framed Structure with Infill Concrete Panels (LGSFS-ICP) Technology.
- Factory made Light Gauge Steel Framed Structure (LGSFS), light weight concrete and precast panels are being used.



Structural Details of LGSFS-Infill Concrete Wall



Precast concrete panels

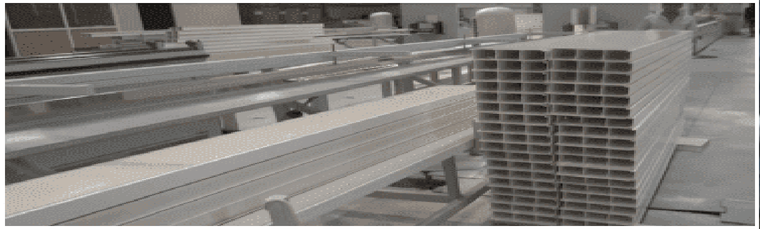


Light Gauge Steel Frame Structure

Assembly of LGS Frames and Construction of Wall

LHP Lucknow- Stay in Place Formwork

- SIP formwork is an advanced hybrid construction technology consisting of rigid polyvinyl chloride-based polymer panel infilled with self-compacting concrete in a building envelope.
- In this wall system PVC panel is used as a permanent stay-in-place finished formwork instead of concrete walls.
- Hot rolled Pre-Engineered building steel sections act as a structural framework of the building.
- SIP formwork works as a partition of building walls.
- It is a proven technology in Canada & Australia.


LHP LUCKNOW- PROJECT OVERVIEW

Project Brief	
Location of Project	Avadh Vihar, Lucknow, U.P.
No. of DUs	1,040 (S+13)
Plot area	20,036 sq.mt.
Carpet area of each DU	34.51 sq.mt.
Total built up area	48,702 sq.mt.
Technology being used	Stay In Place Formwork System with pre-engineered steel structural system
Other provisions	Community Centre, Shops
Broad Specifications Broad Specifications	
Foundation	RCC raft foundation
Structural Frame	Pre-engineered steel structural frame
Walling	Stay In Place PVC Formwork System
Floor Slabs/Roofing	Cast in-situ deck slab

LHP LUCKNOW- PROJECT PLAN

Project Layout Plan

Block Plan

Site Plan

SESSION-1

1. *Thermal Comfort (Need and Impact)*
2. *Thermal comfort in Affordable Housing*
3. *Passive Architectural Strategies*
4. *Building Physics*
5. *Case Studies*

WHAT IS THERMAL COMFORT?

Thermal comfort is "the state of mind that expresses satisfaction within the thermal environment" and is generally assessed subjectively (ASHRAE, 2004).

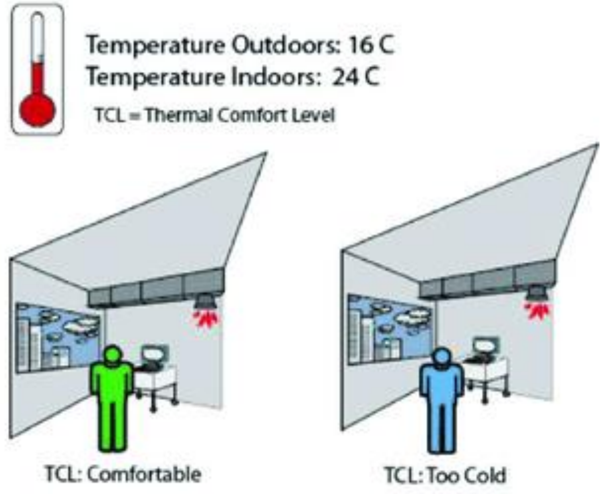
Human thermal comfort cannot be expressed in degrees and can't be defined by an average range of temperatures.

It is a very personal experience and a function of many criteria, which differs from person to person in the same environmental space.

THERMAL COMFORT IS THE OUTCOME OF A WELL-BALANCED COMBINATION OF BUILDING SYSTEMS ADAPTED TO THE LOCAL CLIMATE & THE TYPE OF ACTIVITY PERFORMED.

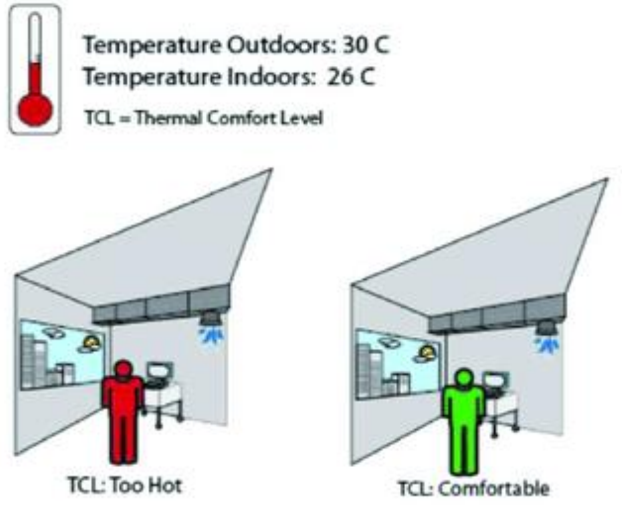
NEED AND IMPACT FOR THERMAL COMFORT IN AFFORDABLE HOUSING

A lack of thermal comfort makes us feel stressed, annoyed and distracted if it is too cold and it can make us feel sleepy, tired, and lacking concentration if it is too hot.



The need for thermal comfort is as follows:

- Thermal Comfort Increases Productivity and Performance.
- Provides insulation from harsh outside weather conditions.
- Provide better radiant and ambient temperature within the envelope of the building.
- Reduces high energy demands and conserve extra energy for future use.
- Promote sustainability to the design and surrounding environment.



TRANSFER OF HEAT IN BUILDING ENVELOPE

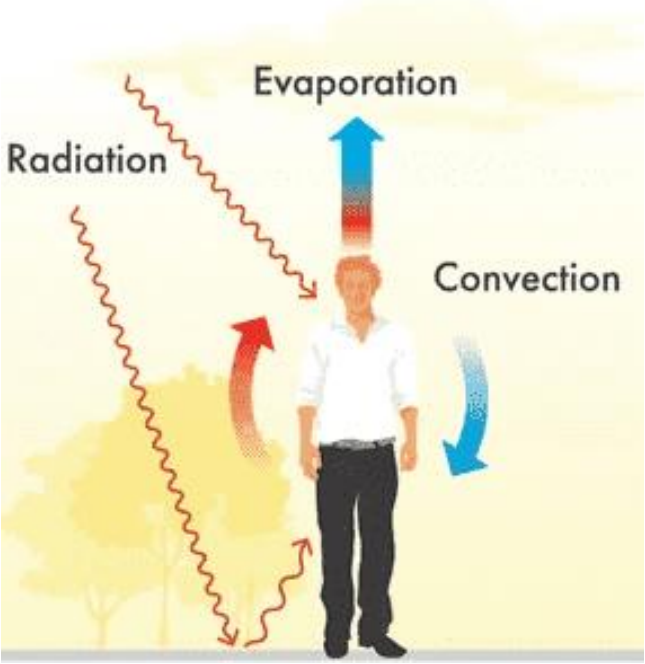
Mode of Heat Transfer

What affects the **Thermal indoor environment?**

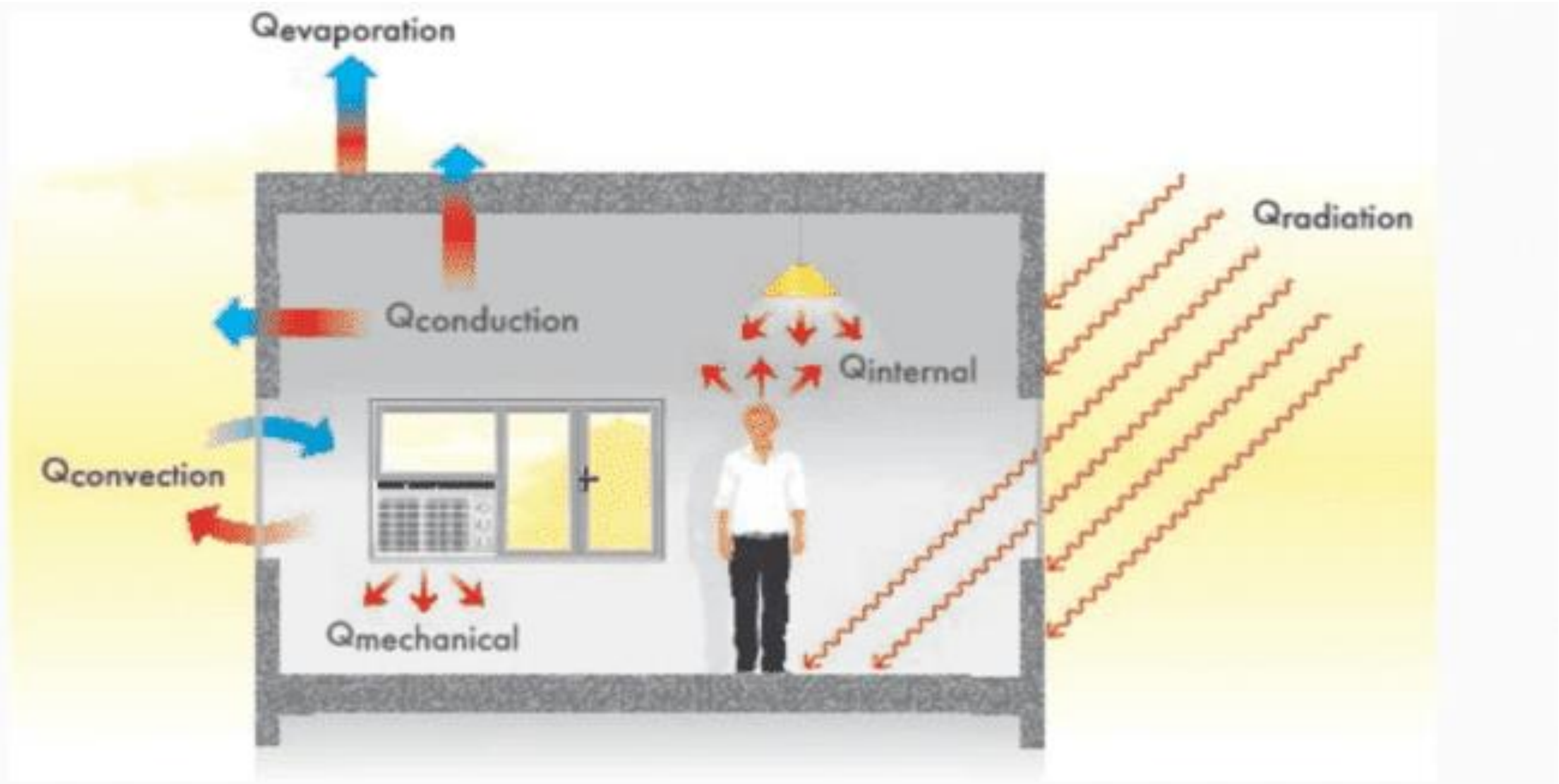
The heat exchange between the human body and its environment occurs mainly in three ways

- Conduction
- Convection
- Radiation

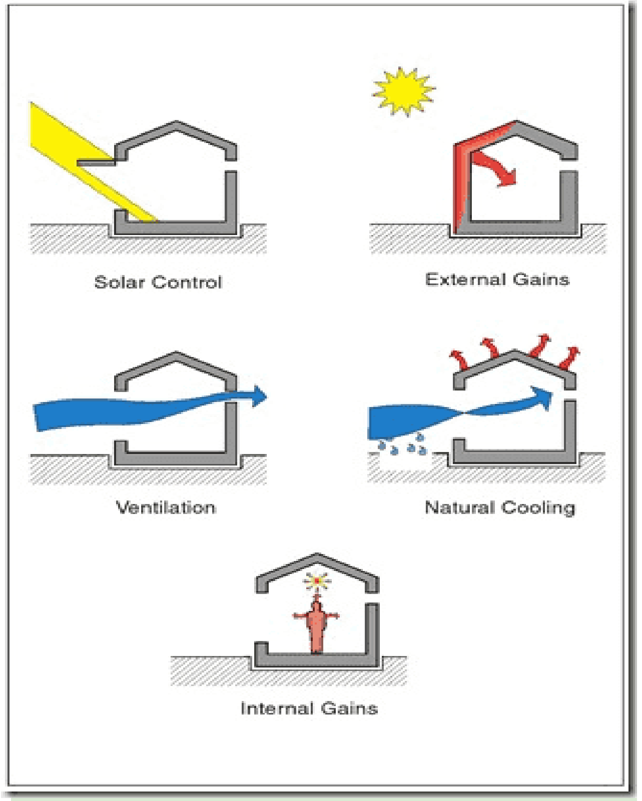
The thermal indoor environment is affected by both internal and external sources.



HUMAN BODY PERCEPTION TOWARDS THERMAL COMFORT



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



Heat mechanism and human body perception towards thermal comfort

METABOLIC RATE FOR HUMAN ACTIVITY AND OCCUPANCY

Table 3.1
Metabolic Rate *M* for Various Activities

$1\ M = 1\ met = 58.2\ W/m^2 = 18.4\ Btu/h.ft^2$

Activity	met	W/m^2	$Btu/(h \cdot ft^2)$
Sleeping	0.7	40	13
Reclining	0.8	45	15
Seated, quiet	1.0	60	18
Standing, relaxed	1.2	70	22
Walking (0.9 m/s, 3.2 km/hr, 2.0 mph)	2.0	115	37
Walking (1.8 m/s, 6.8 km/h, 4.2 mph)	3.8	220	70
Office- reading, seated	1.0	55	18
Office, walking about	1.7	100	31
House cleaning	2.0-3.4	115-200	37-63
Pick and shovel work	4.0-4.8	235-280	74-88
Dancing, social	2.4-4.4	140-255	44-81
Heavy machine work	4.0	235	74

Source: Courtesy of ASHRAE, *Standard 55-2013: Thermal Environmental Conditions for Human Occupancy*, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, GA, 2010. With permission.

- **Thermal comfort is maintained by heat mass transfer.**
- **Human body generates heat about 100W under sedentary condition with body area 1.5 to 2 sqm.**
- **More layer of clothing = More insulation = Less heat loss**

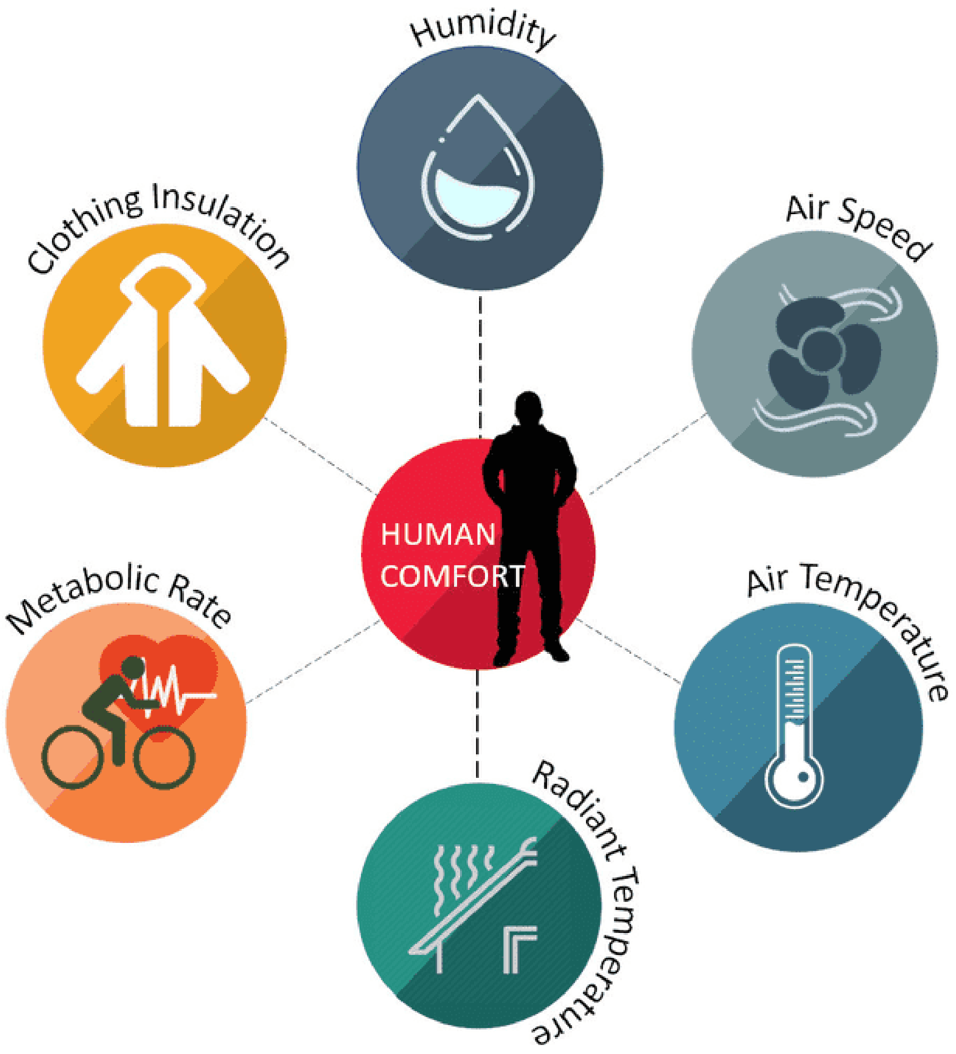
FACTORS AND INDICES AFFECTING THERMAL COMFORT

Environmental Parameters/Factors

- Air Temperature
- Mean Radiant Temperature
- Air Velocity
- Humidity

Personal Parameters/Factors

- Clothing Level
- Physical Activity



FACTORS AND INDICES AFFECTING THERMAL COMFORT

Air Temperature	It can easily be influenced with passive and mechanical heating and cooling.
Mean Radiant Temperature	It allows defining the operative temperature which is the most essential component of thermal comfort.
Air Velocity	Quantifies the speed and direction of the air movements in the room. Rapid air velocity fluctuations might result in draught complaints.
Humidity	The moisture content of the air. Too high or too low humidity levels may induce discomfort.
Clothing Level	The amount of insulation added to the human body. Higher clothing levels will reduce the heat lost through the skin and lower the environment´s temperature perceived as comfortable.
Physical Activity	The amount of heat produced by the human body and therefore also in the perception of a hot or cold environment.

FACTORS AND INDICES AFFECTING THERMAL COMFORT

Derived Parameters For Measuring Thermal Comfort

- **Mean Radiant temperature**: The mean radiant temperature (°C) is a numerical representation of how human beings experience radiation.
- **Operative temperature**: Operative temperature is defined as a uniform temperature of a radiantly black enclosure in which an occupant would exchange the same amount of heat by radiation plus convection as in the actual non-uniform environment. Numerically it is close to the average of indoor dry bulbs and MRT.
- **Effective temperature**: Combination of 50% relative humidity with the operative temperature that causes the same sensible plus latent heat exchanges as in the actual environment.

  It is an experimentally determined index of the various combinations of dry-bulb temperature, humidity, radiant conditions (MRT), and air movement.

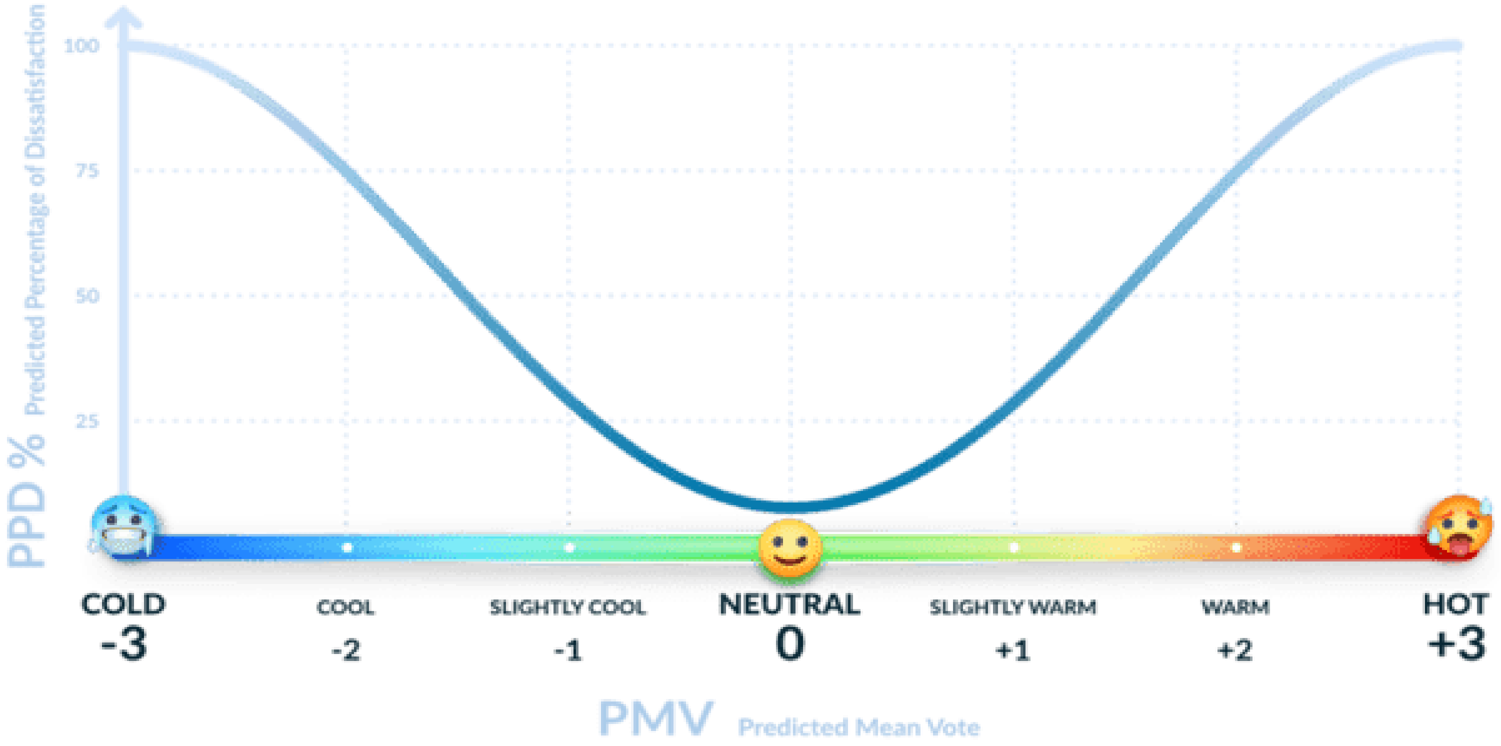
FACTORS AND INDICES AFFECTING THERMAL COMFORT

Thermal comfort limits can be expressed by the Predicted mean vote **(PMV)** and the Percentage People Dissatisfied **(PPD)** indices on the basis of the above direct and derived parameters.

- **PMV** is an index that aims to predict the mean value of votes of a group of occupants on a seven-point thermal sensation scale. The thermal sensation is generally perceived as better when occupants of space have control over indoor temperature (i.e., natural ventilation through an opening or closing windows).

FACTORS AND INDICES AFFECTING THERMAL COMFORT

- **(PPD)**Predicted percentage dissatisfied essentially gives the percentage of people predicted to experience local discomfort. The main factors causing local discomfort are unwanted cooling or heating of an occupant’s body.



FACTORS AND INDICES AFFECTING THERMAL COMFORT

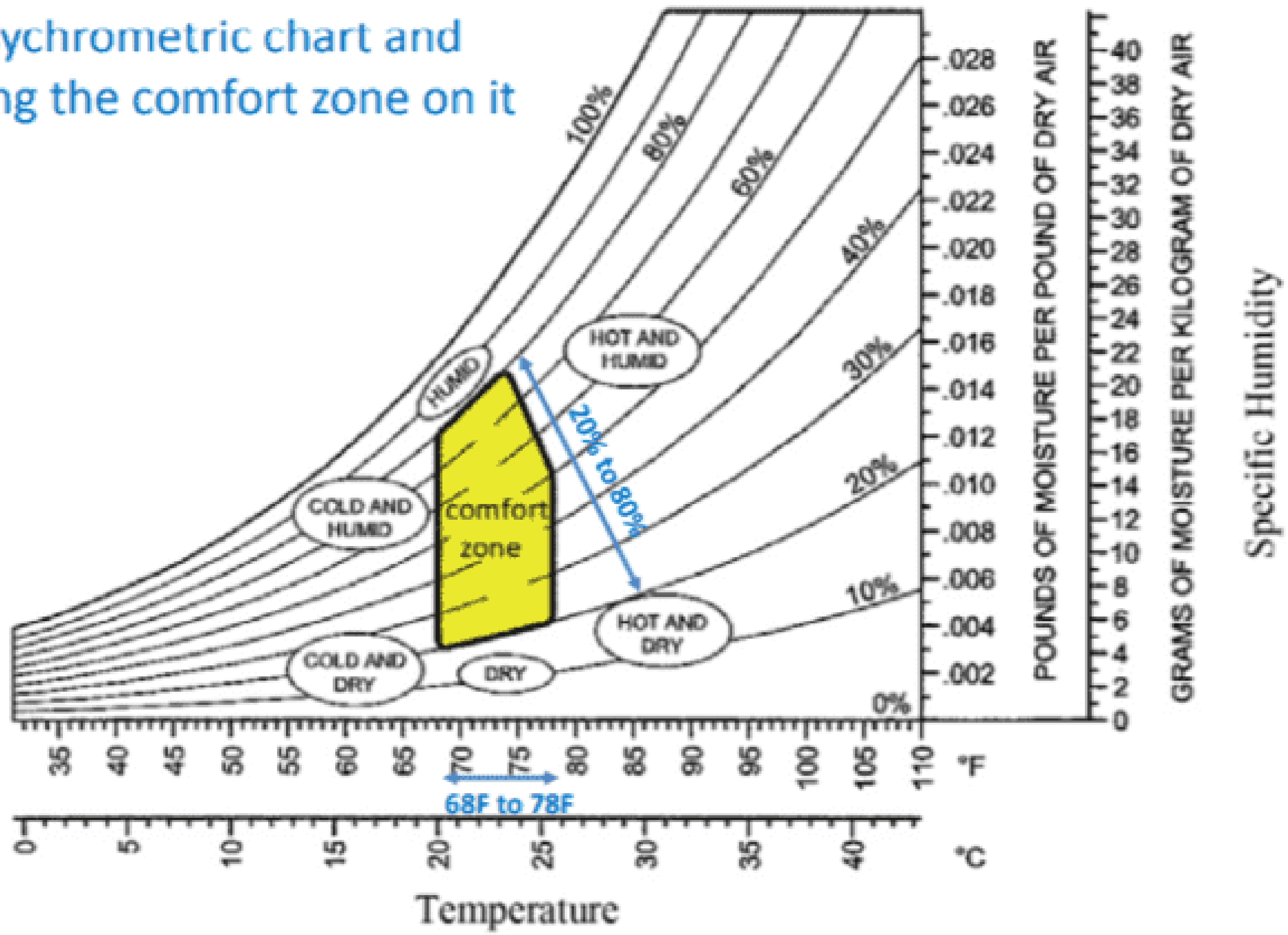
Acceptable PMV and PPD Ranges

Using both of these indices, ASHRAE 55 dictates that thermal comfort can be achieved based on 80% occupant satisfaction rate or more.

- In order to comply with ASHRAE 55, the recommended thermal limit on the 7-point scale of PMV is between -0.5 and +0.5.
- The PPD can range from 5% to 100%, depending on the calculated PMV. In order for comfort ranges to comply with standards, no occupied point in space should be above 20% PPD.

USE OF PSYCHROMETRIC CHART FOR THERMAL COMFORT

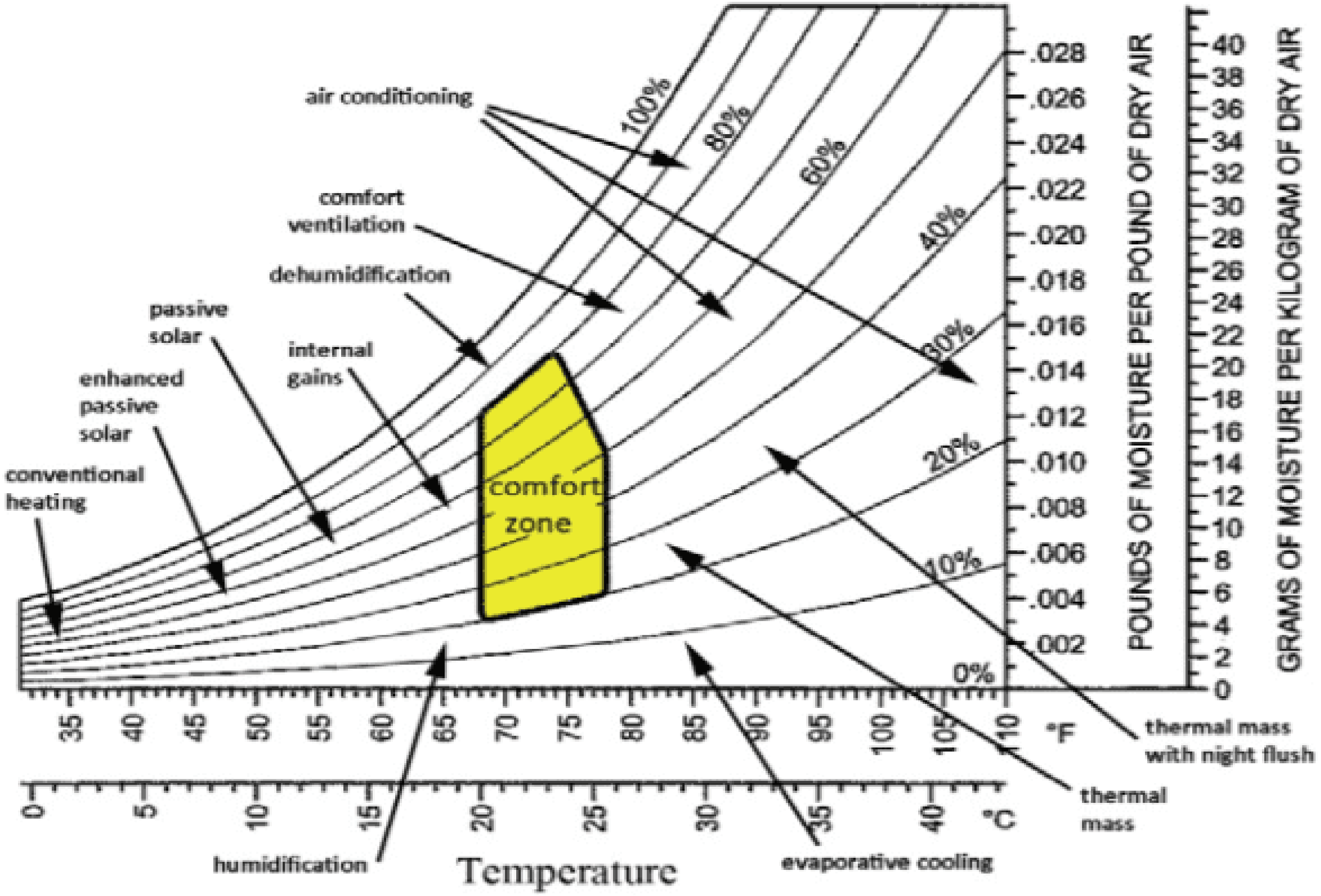
The psychrometric chart and
Defining the comfort zone on it



- **The Comfort Zone And Various Types Of The Discomfort Outside The Zone As Shown In This Psychrometric Chart.**

USE OF PSYCHROMETRIC CHART FOR THERMAL COMFORT

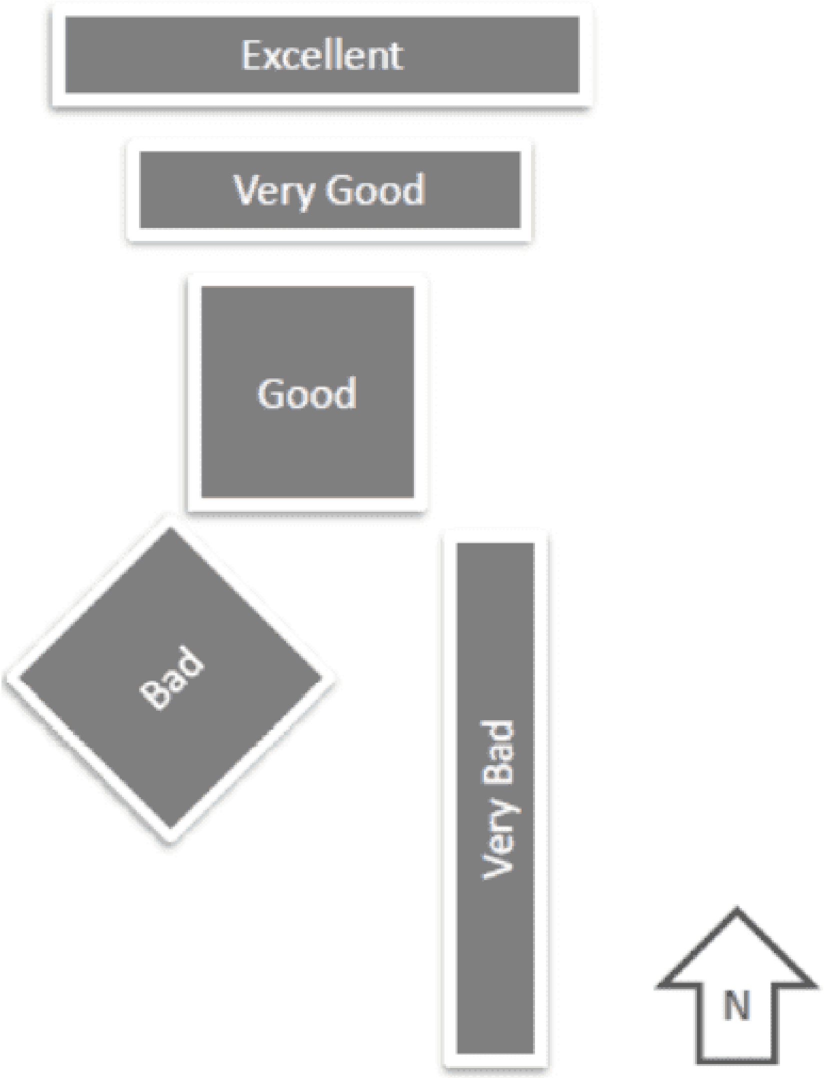
Various methods and technologies
to bring indoor air conditions into the comfort zone



Incorporate To Achieve Thermal Comfort Within Envelope:

- Comfort Ventilation.
- Internal And External Gains.
- Thermal Mass With Night Flush.
- Enhanced Passive Solar Technology.
- Conventional And Low Energy Heating And Cooling.

PASSIVE STRATEGIES FOR THERMAL COMFORT IN AFFORDABLE HOUSING

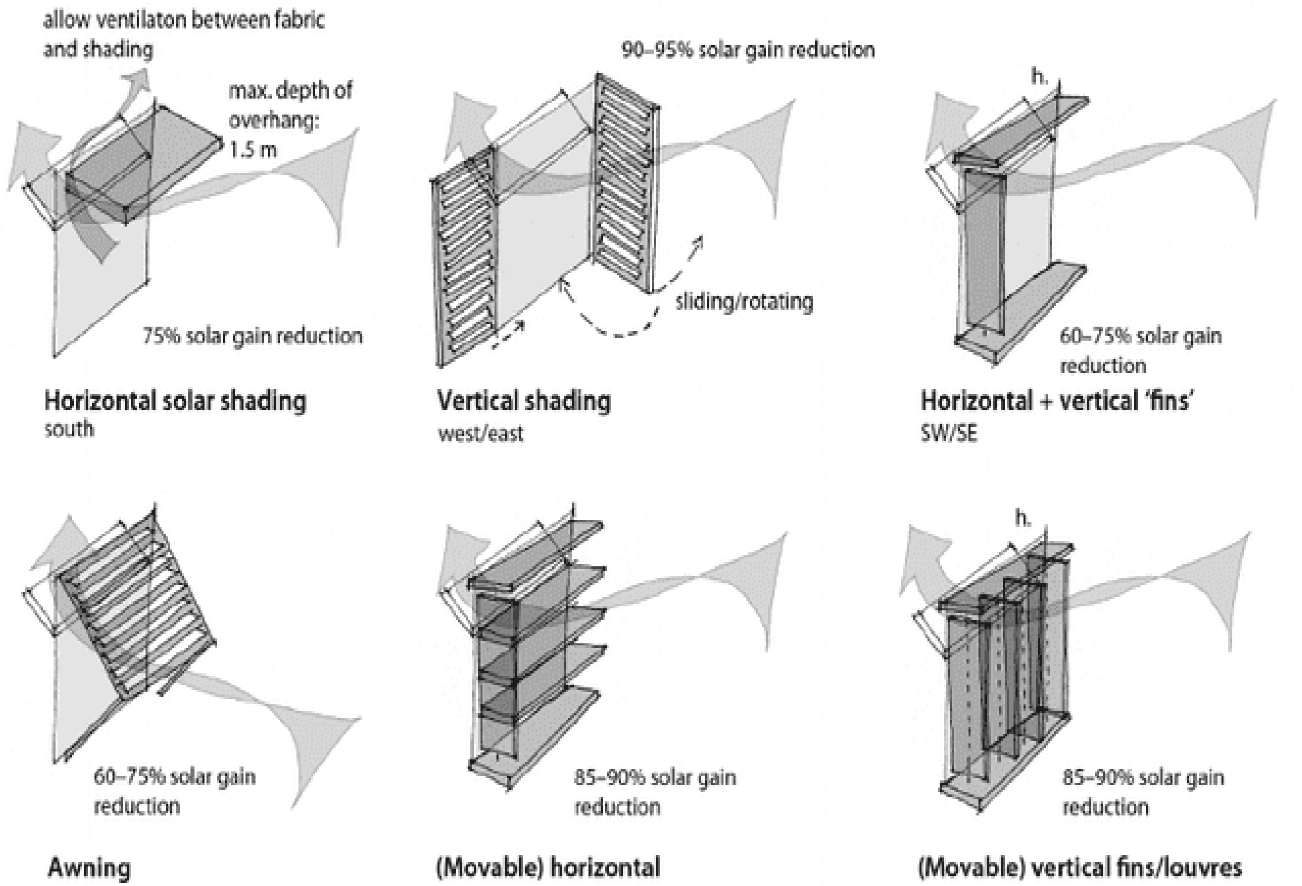


Appropriate orientation of the building

- Daylight penetration and fenestration design have implications on heat gain/loss through the building envelope.
- Careful orientation of fenestration can help achieve thermal and visual comfort
- Daylight harvesting from the north and south facade should be maximized with proper orientation of the building.

PASSIVE STRATEGIES FOR THERMAL COMFORT IN AFFORDABLE HOUSING

Most effective shading



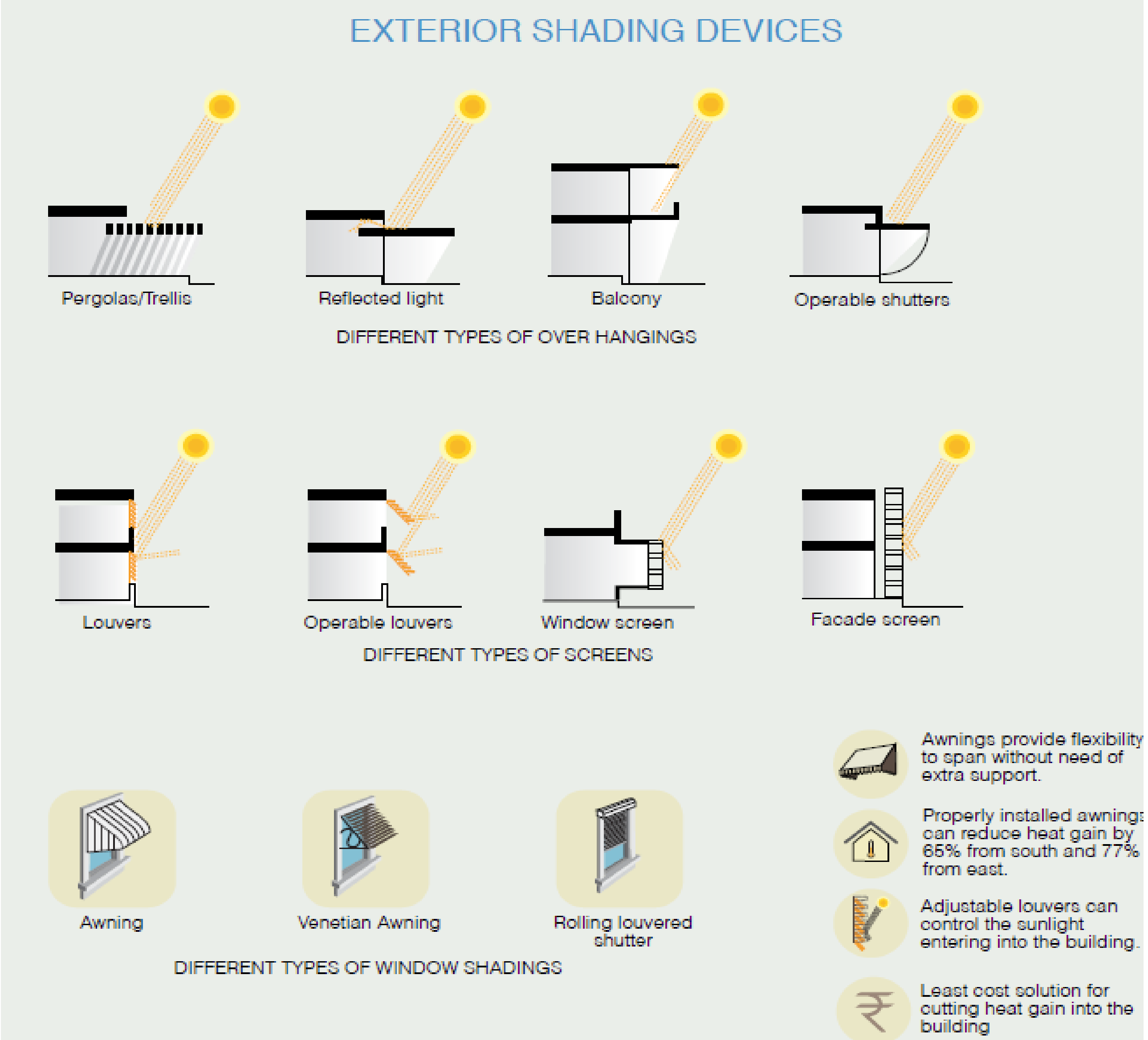
Bottom three shading devices are suitable for all orientations if movable shading fins. They are effective solar shading, but reduce daylighting and winter solar gain so use with care.

Design sliding/inward-opening windows, which do not impede natural ventilation. Design top inward-opening 'hopper' windows for night cooling (h.).

Shading Devices

- Reduce heat gain and cooling energy use of the building.
- To prevent summer overheating and glare, a good shading device strategy should be used with glazed openings.
- Well designed sun shading devices will help keep the building cool and comfortable

PASSIVE STRATEGIES FOR THERMAL COMFORT IN AFFORDABLE HOUSING



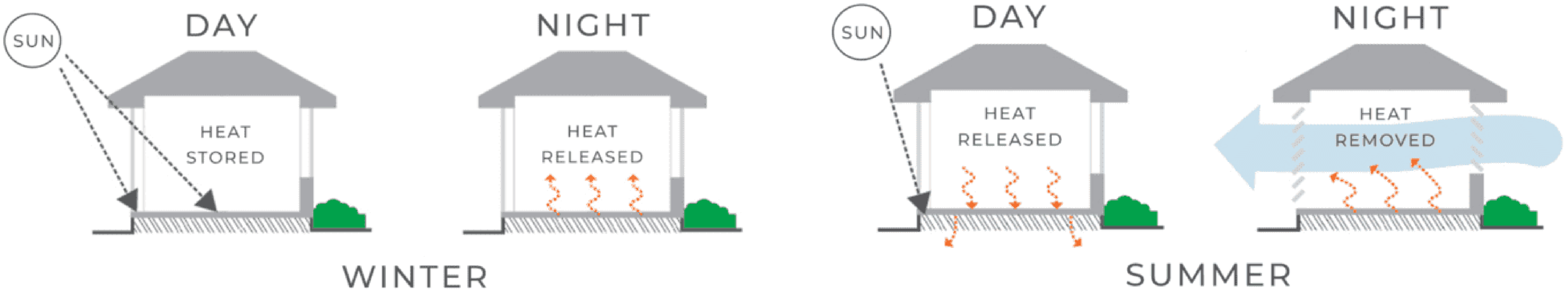
- Exterior shading devices can be provided in a variety of materials and designs, including sunshades, awnings, louvers, bamboo screens, jaali, green cover through vines.
- These can be implemented with minimal cost implications and have the most favourable cost-benefit relation with respect to thermal comfort.

PASSIVE STRATEGIES FOR THERMAL COMFORT IN AFFORDABLE HOUSING

'Thermal mass' describes a material's capacity to absorb, store and release heat.

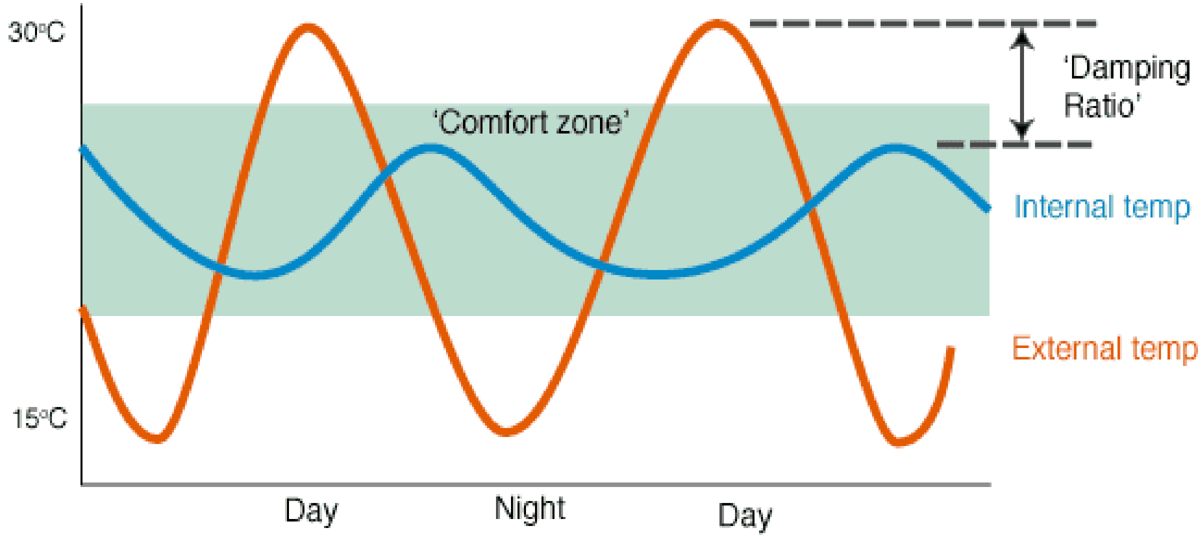
A common analogy is thermal mass as a kind of thermal battery.

- When heat is applied (to a limit) by radiation or warmer adjoining air, the battery charges up until which time it becomes fully charged.
- It discharges when heat starts to flow out as the adjoining air space becomes relatively cooler.

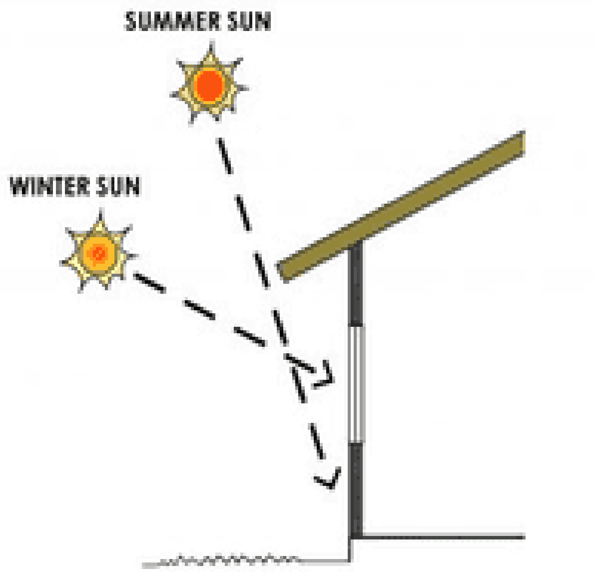


PASSIVE STRATEGIES FOR THERMAL COMFORT IN AFFORDABLE HOUSING

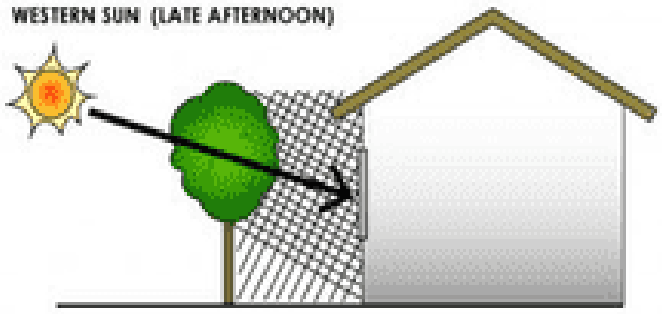
- Denser thermal mass materials are more effective passive solar materials. Thus, denser the material the better it stores and releases heat.
- Integrate thermal mass with an efficient passive solar design, by considering the placement of added mass.
- Do not substitute thermal mass for insulation. It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



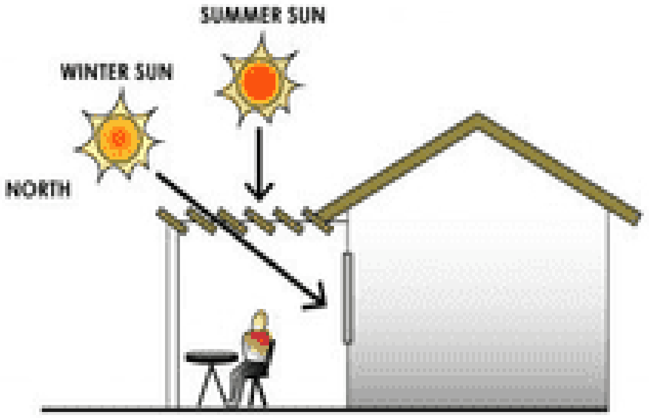
PASSIVE STRATEGIES FOR THERMAL COMFORT IN AFFORDABLE HOUSING



Eaves & shading devices can protect windows from direct sunlight in summer and allow winter sun to penetrate internal living areas



Strategic tree planting around your home can help protect windows from late afternoon western summer sun.

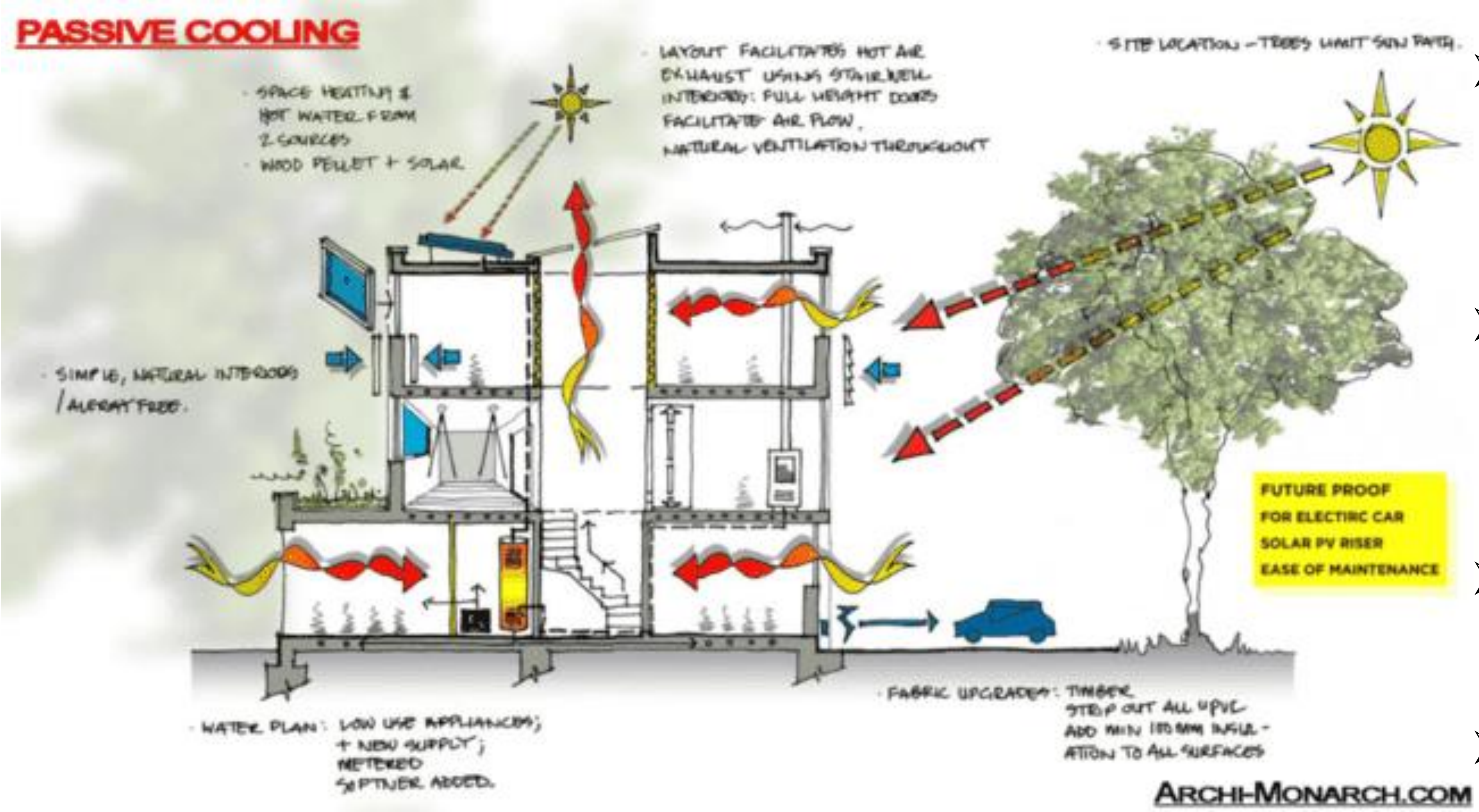


Shading devices fitted to external verandahs & pergolas can allow winter sun to penetrate internal living areas while blocking the harsh summer sun

CROSS - VENTILATION

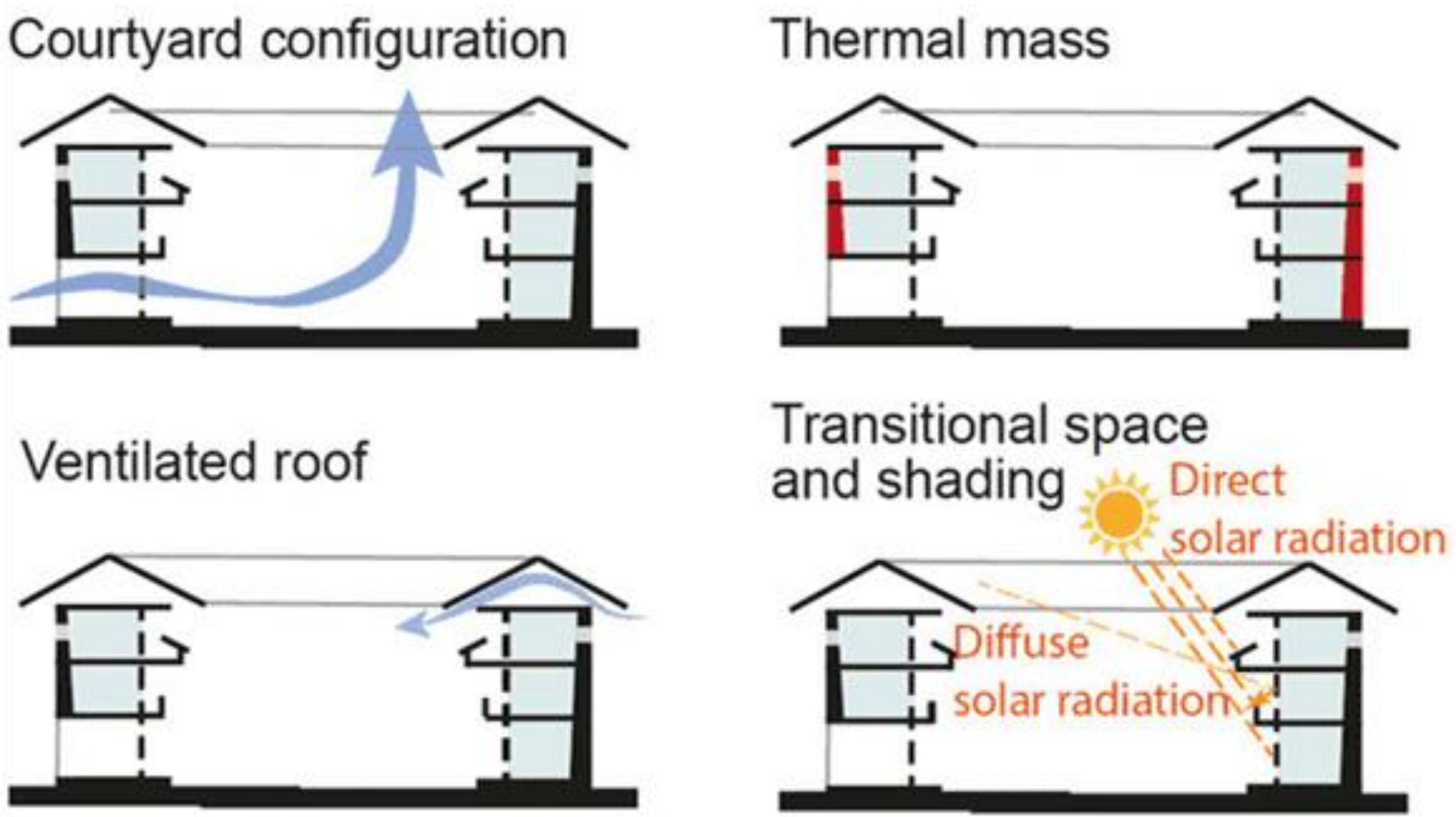
Strategically locating doors & windows during the design phase of your home can promote good conditions for cross - ventilation

PASSIVE STRATEGIES FOR THERMAL COMFORT IN AFFORDABLE HOUSING

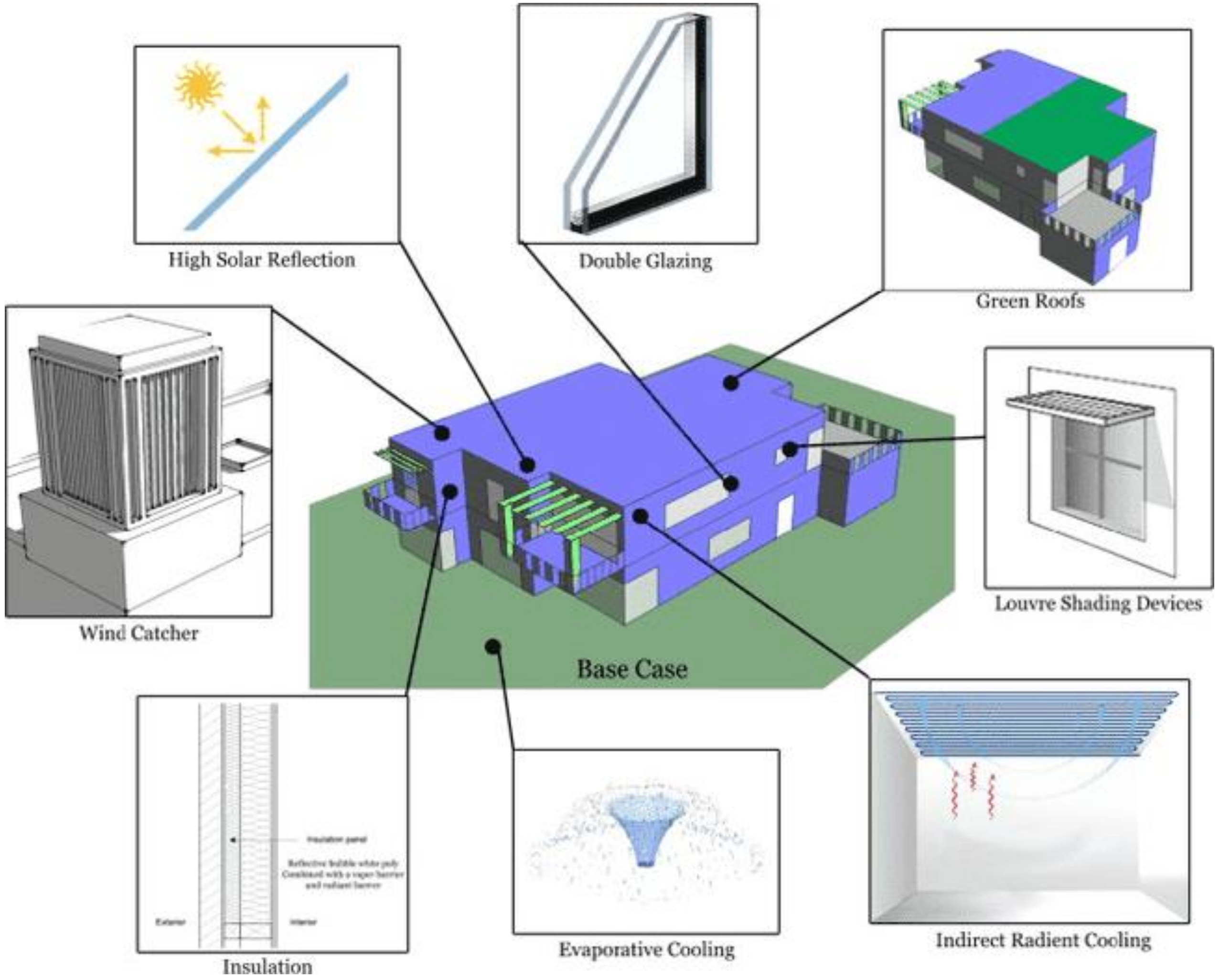


- ➢ Layout facilitates hot air exhaust using stairwell.
- ➢ Airflow facilitation and natural ventilation.
- ➢ Use of trees to limit sun path.
- ➢ High thermal mass materials in envelope.

PASSIVE STRATEGIES FOR THERMAL COMFORT IN AFFORDABLE HOUSING



PASSIVE STRATEGIES FOR THERMAL COMFORT IN AFFORDABLE HOUSING

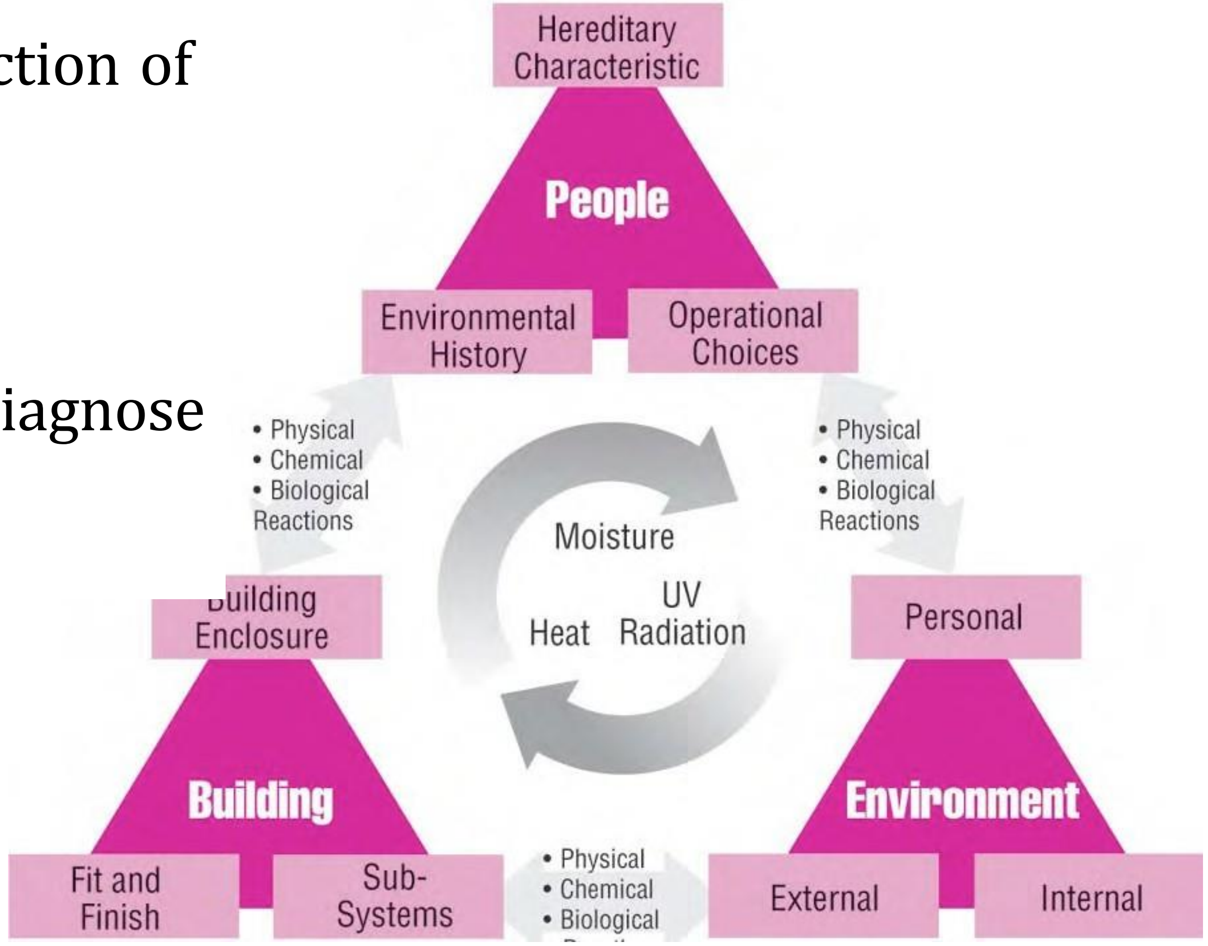


- **Green roofs.**
- **Louvre and shading devices.**
- **Insulation**
- **Low energy cooling techniques.**
- **Wind catchment and ventilation.**
- **Double glazed glass.**
- **High solar reflective surface.**

BUILDING PHYSICS

- Building Science/Physics studies the interaction of all of these functional relationships
- It tells us how buildings actually work
- It tells us how to design them, build them, diagnose them, fix them and operate them.

1. ***Energy moves from higher state to lower state (the second law of thermodynamics)***
2. ***Heat moves from warm to cold (thermal gradient)***
3. ***Moisture moves from more to less (concentration gradient)***



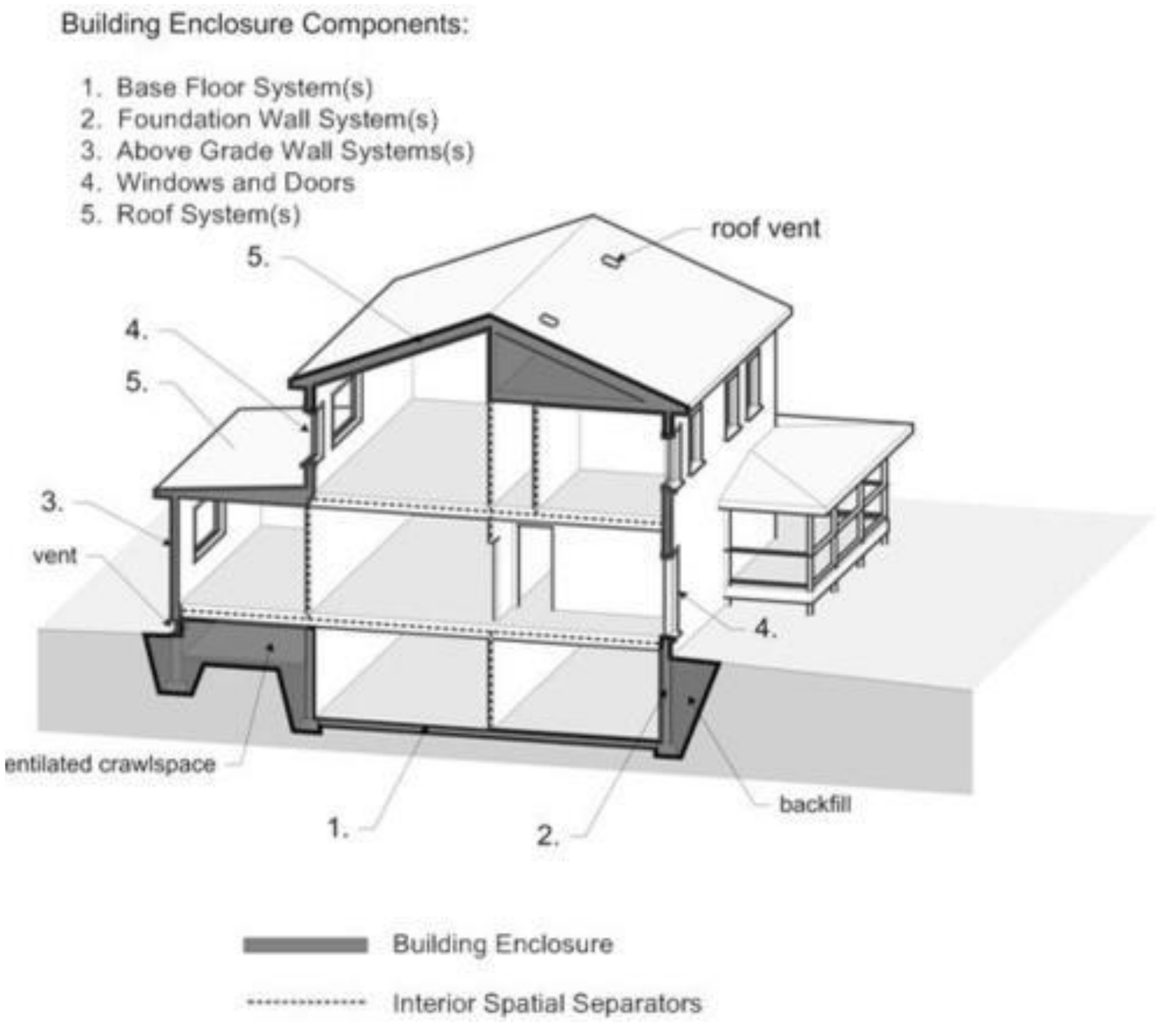
Building System-Functional Relationship

BUILDING PHYSICS

What is a *BUILDING*?

Your ***Environmental Separator***.

- A building provides shelter - shelter from the elements as well as from other dangers and the outdoor environment.
- Its' function is to separate the inside from the outside.
- A building creates an interior environment that is different from the exterior environment – it is an environmental separator.

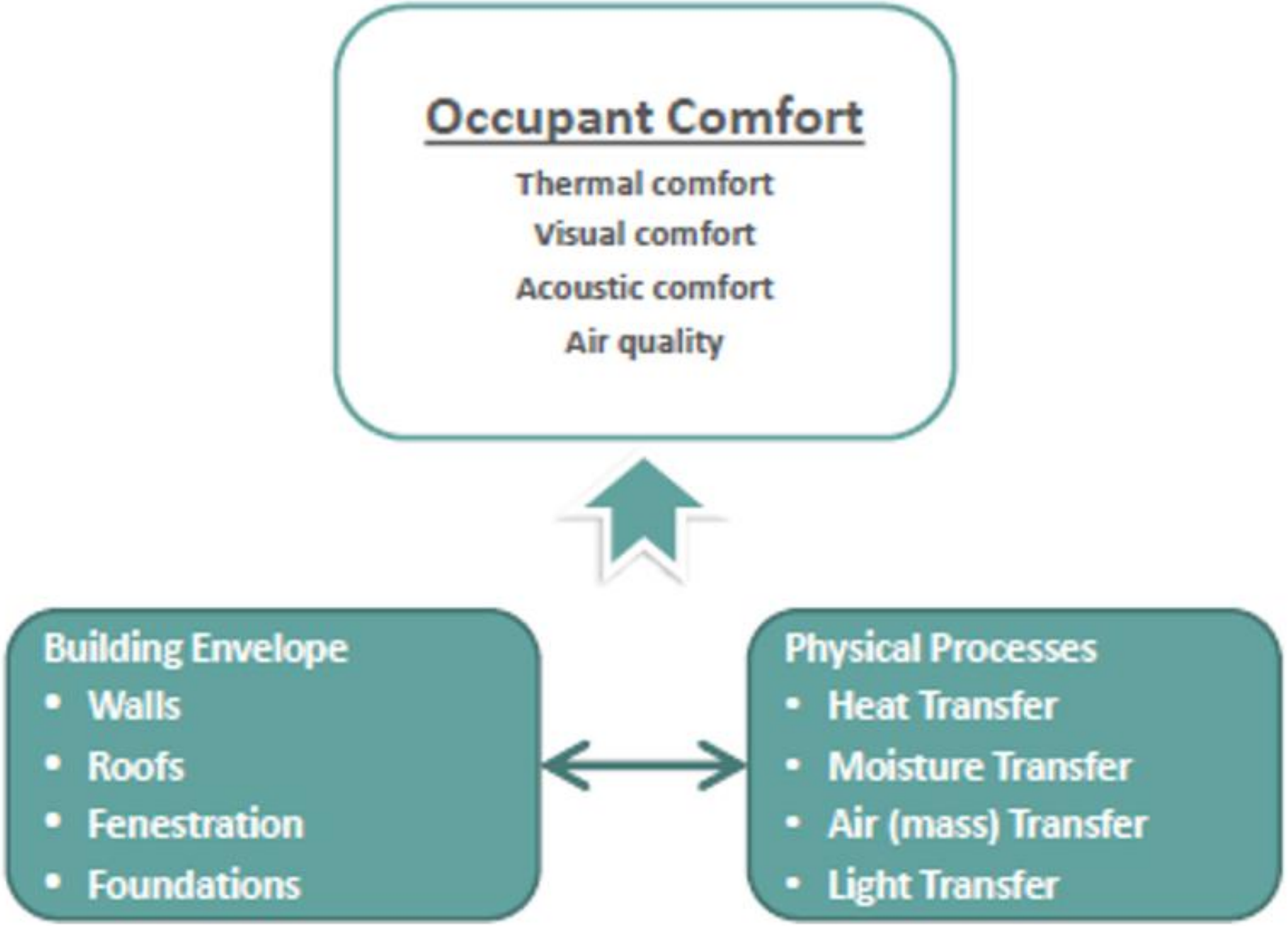


BUILDING PHYSICS

Purpose of *Buildings*?

Buildings are designed for *People* and for *Specific tasks.*

- ✓ The building needs to keep people *Comfortable, Efficient, and Healthy*.
- ✓ *Energy Efficient Design* seeks to create buildings that keep people comfortable while minimizing Energy Consumption.

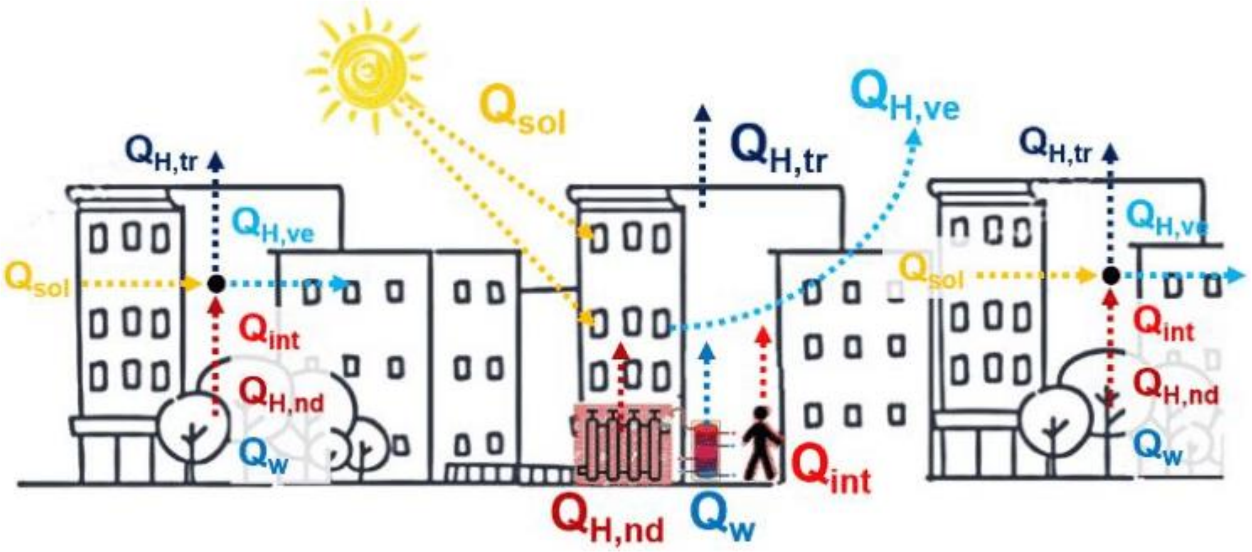


Occupant comfort, Physical processes, and Elements of building Relationship

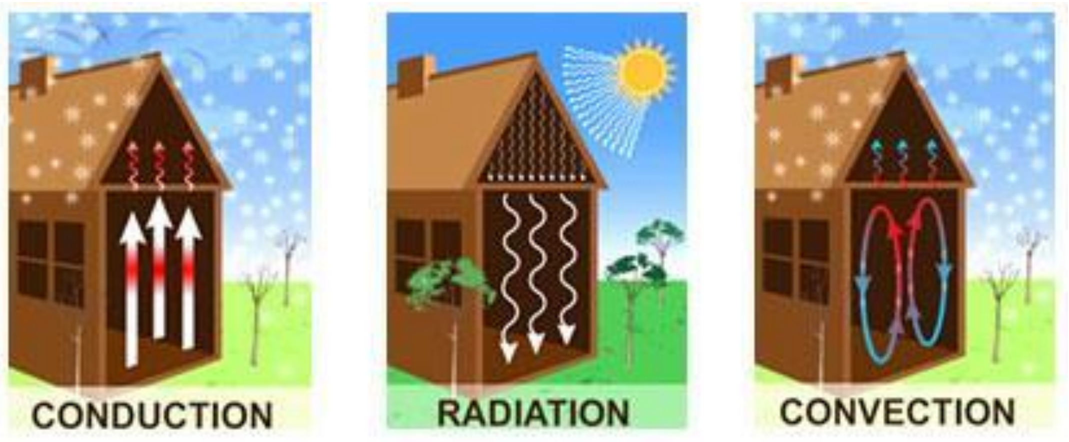
BUILDING PHYSICS

2nd Law of *Thermodynamics*

"In an isolated system, a process can occur only if it increases the total entropy of the system". -Rudolph Clausius



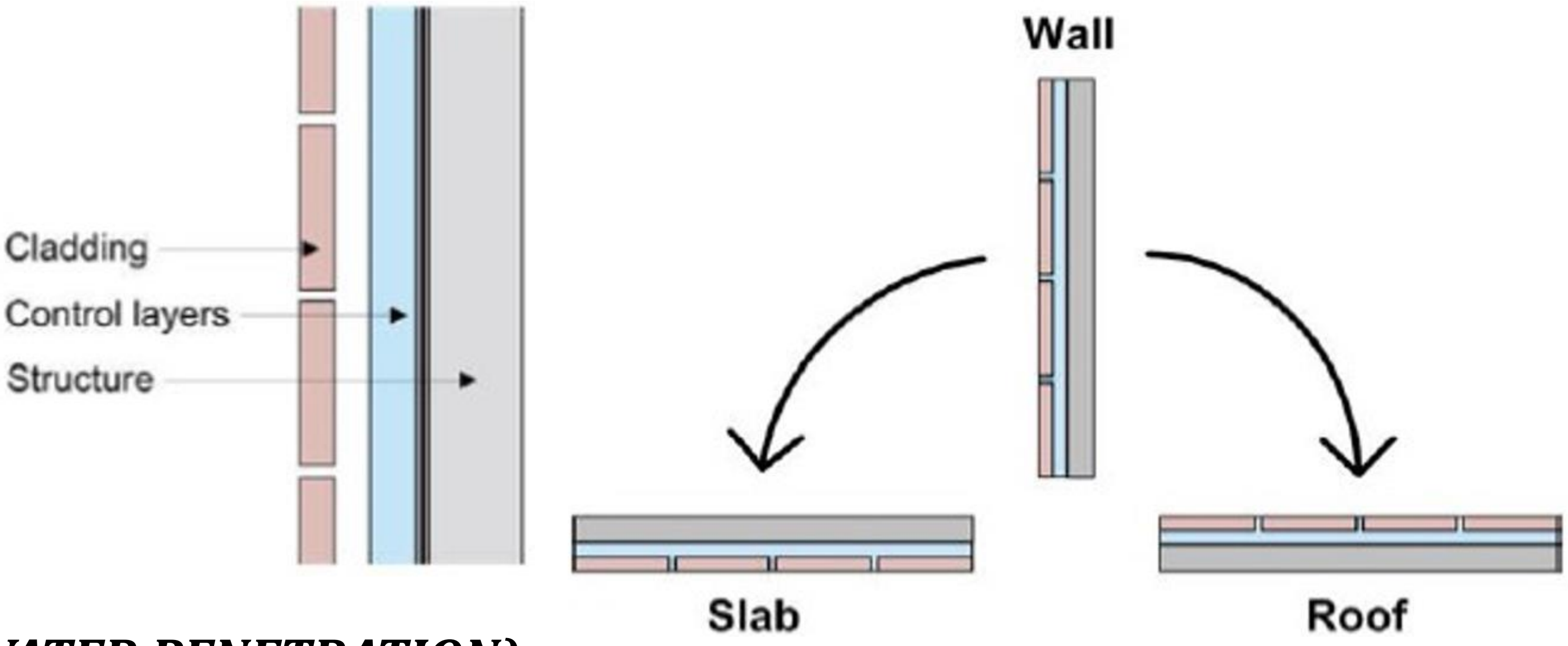
- ✓ ***Heat*** moves from warmer to cooler.
- ✓ ***Air*** moves from higher pressure to lower pressure.
- ✓ ***Moisture*** moves from wetter to drier.



BUILDING PHYSICS

Building *Control Layers*

- ✓ ***Water*** Control Layers
- ✓ ***Air*** Control Layers
- ✓ ***Vapour*** Control Layers
- ✓ ***Thermal*** Control Layers



WATER CONTROL LAYER (WATER PENETRATION)

- ✓ Water is governed by momentum, gravity, and capillary forces.
- ✓ Impervious to water, continuous, flexible, and sealed.
- ✓ Provisions for drainage to the exterior.

BUILDING PHYSICS

AIR CONTROL LAYER ***(INFILTRATION/EXFILTRATION)***

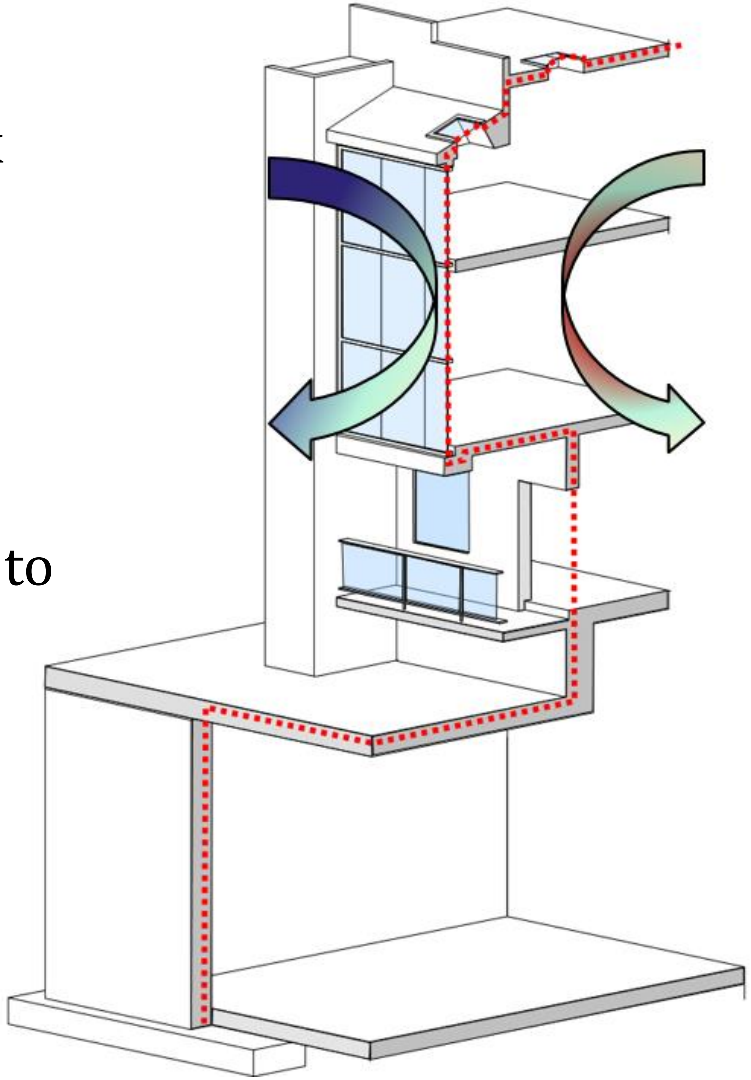
- ✓ Air movement is caused by wind loads, fan pressure, and stack effect.
- ✓ Must be continuous, flexible, strong, and sealed.

VAPOR CONTROL LAYER ***(MOISTURE FLOW)***

- ✓ Vapor diffusion is caused by vapor pressure differences inside to outside.
- ✓ Must not trap moisture.

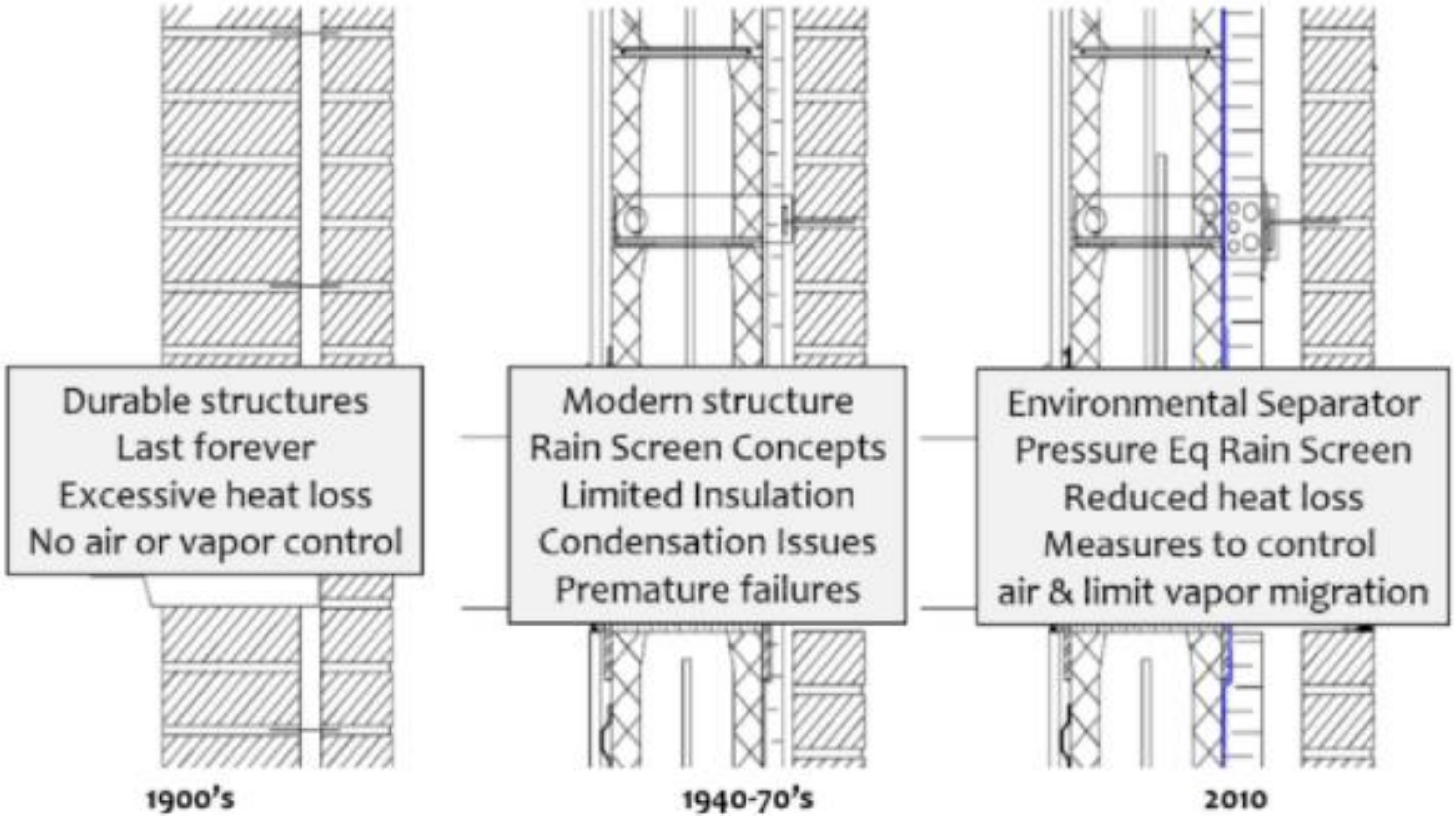
THERMAL CONTROL LAYER ***(HEAT FLOW)***

- ✓ Continuous insulation layer in conjunction reduces energy consumption.



BUILDING PHYSICS

Evolution in Building *Control Layers*



Expectations of the building envelope/control layers

- ***Keep the water out***
- ***Maintain a comfortable interior environment***
- ***Be energy efficient***
- ***Maintain a low maintenance / operating cost***
- ***Use durable materials that last forever***
- ***Have minimal impact on the environment***

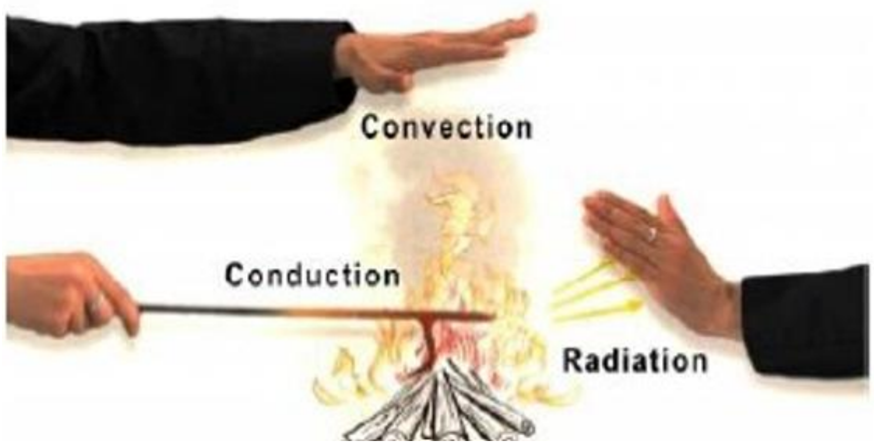
BUILDING PHYSICS

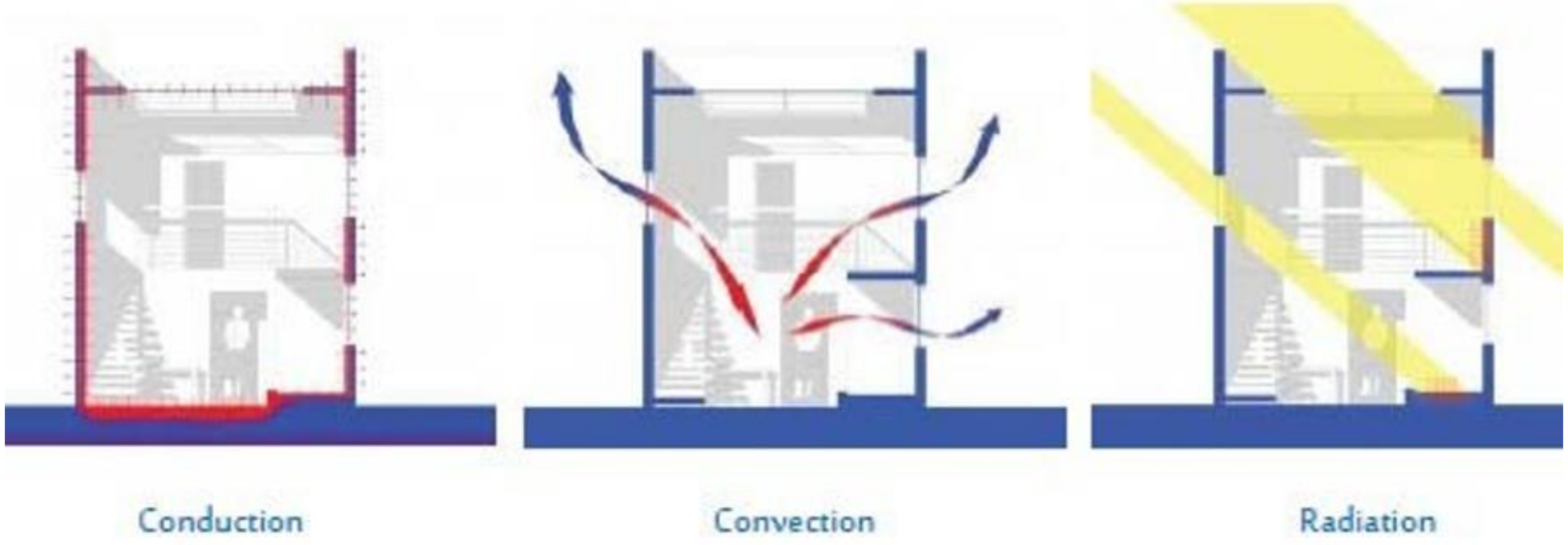
Heat Transfer in Buildings

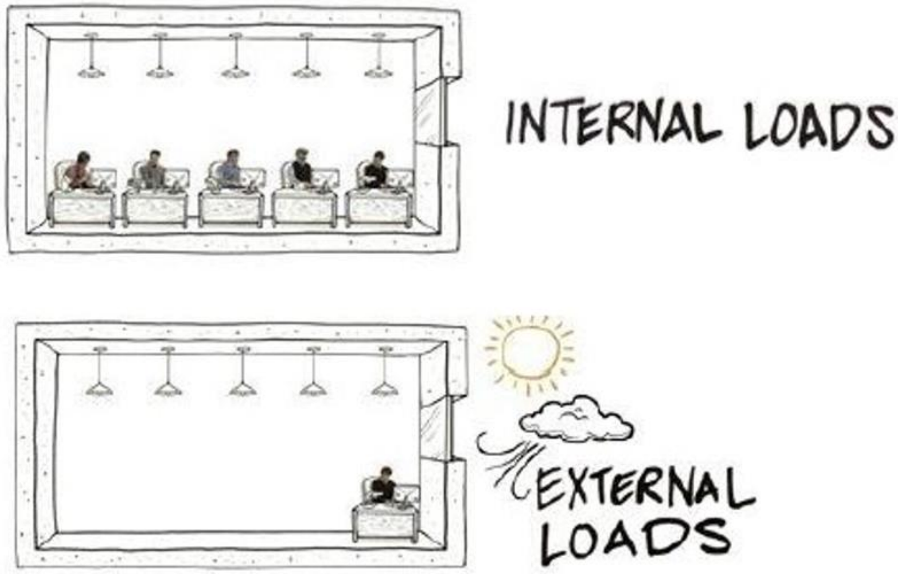
Conduction- Transfer of heat through direct contact

Convection- Transfer due to movements of gases, liquid, and vapor.

Radiation- Transfer of heat through electromagnetic waves.







BUILDING PHYSICS

Heat Transfer Calculations in Buildings

Conduction- Transfer of energy due to internal vibrations of envelop building material.

Convection- Transfer due to air infiltration from door windows.

Radiation- Transfer of heat through windows and transparent surfaces in form of electromagnetic waves.

Note:

- ✓ *ECBC/ENS regulates the U-Factor and SHGC for materials and glazing units.*
- ✓ *Solar incident radiation depends on the weather condition and solar altitude angle.*

$$Q_{Conduction} = U \cdot A \cdot (\theta_i - \theta_s)$$

Q = Heat transfer through conduction
U or U-factor = Overall heat transfer co-efficient (W/(m2·K)
A = Surface area
delta T = Temperature difference across surface; $T_{in}(\theta_i) - T_{out}(\theta_s)$ (K)

$$Q_{Convection} = h_{cv} \cdot A \cdot (\theta_s - \theta_f)$$

Q_c = Heat transfer through convection
h_{cv} = Heat Transfer Coefficient
θ_s=Temperature of the surface
θ_f=Temperature of the fluid

$$Q_{Radiation} = SHGC \cdot A \cdot E_t$$

Where:
SHGC = solar heat gain coefficient
E_t = incident solar radiation
A = area of transparent element

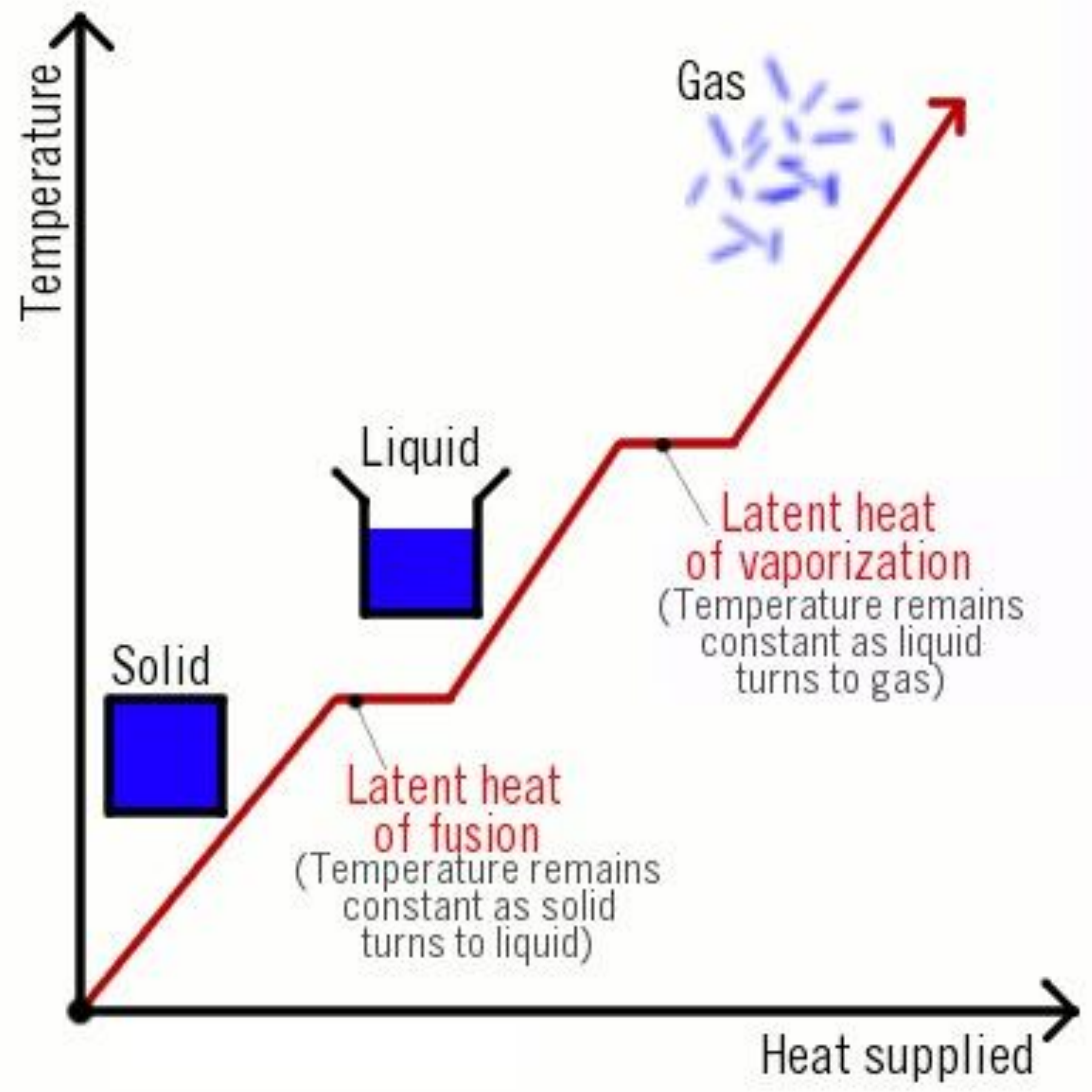
BUILDING PHYSICS

Sensible and Latent Heat

Sensible Heat – When the temperature of an object falls/rises, the heat removed/added is called 'sensible heat'. Sensible heat results in a change in temperature.

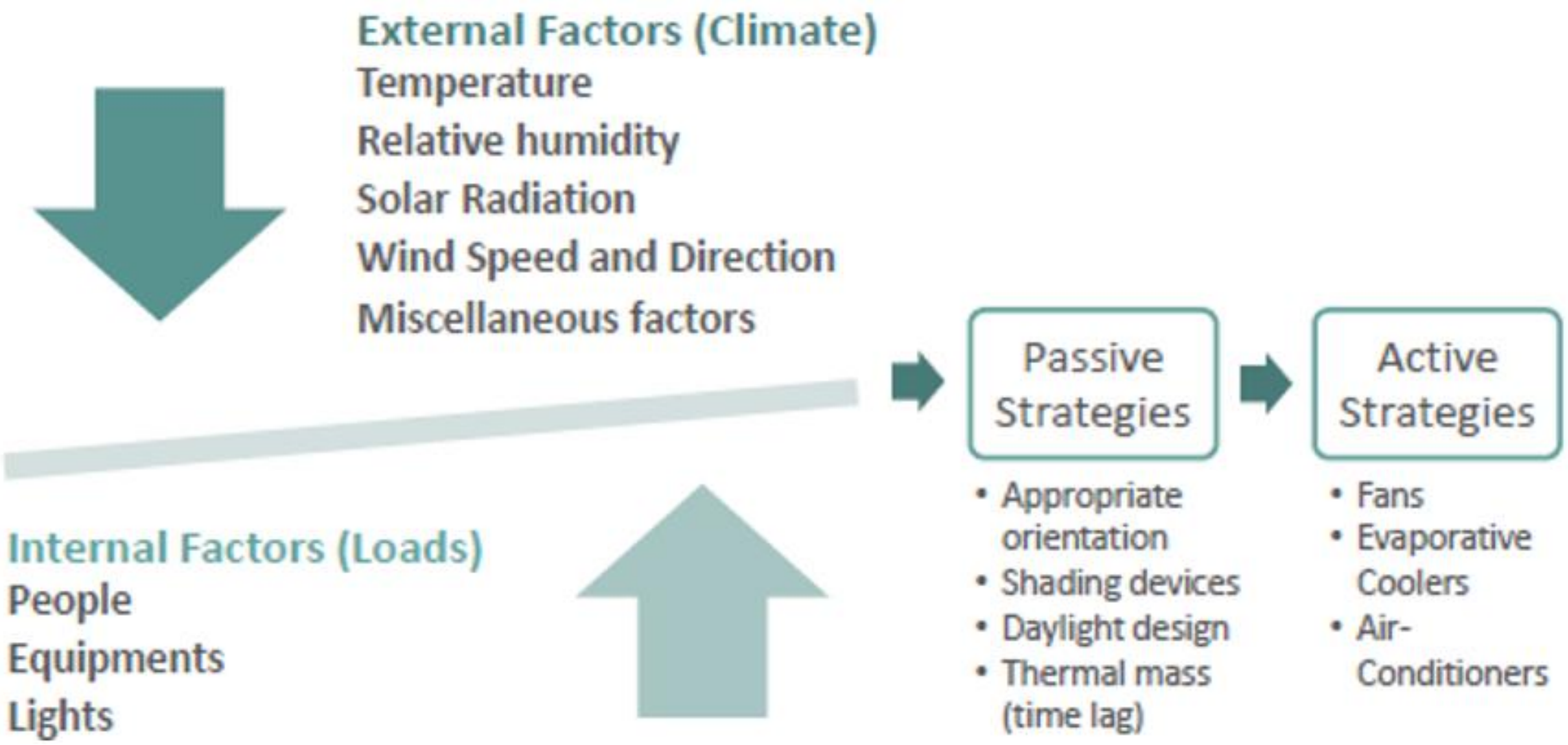
Latent Heat- Latent heat is the heat added/removed to an object in order for it to change its state. It affects the moisture content which results in a change of temperature.

Total flow of heat is the algebraic sum of sensible and latent heat within space.



BUILDING PHYSICS

Use of Building Physics to Optimize Energy use for Thermal Comfort



External Factors.(Climatic)

- ✓ Temperature
- ✓ Relative Humidity
- ✓ Solar Radiation
- ✓ Wind Speed and Direction
- ✓ Miscellaneous Factors

Internal Factors.(Loads)

- ✓ People
- ✓ Equipment
- ✓ Lights

BUILDING PHYSICS

External Factor

External Factors.(Climatic)

- ✓ Temperature
- ✓ Relative Humidity
- ✓ Solar Radiation
- ✓ Wind Speed and Direction
- ✓ Miscellaneous Factors

Temperature

- ✓ ***Dry bulb-***Ambient air temperature
- ✓ ***Wet-bulb-*** Temperature at which water by evaporates into moist air at dry-bulb temperature **T** and Relative humidity ratio **W.**

Outdoor air temperature is the major climatic variable affecting energy demand. The indices used to reflect the demand of energy are:

- ✓ ***CDH(Cooling Discomfort Hours)***
- ✓ ***HDH(Heating Discomfort Hours)***

Energy demand is directly proportional to the number of CDH and HDH.

Relative Humidity

Amount of water vapor present in the air, usually in terms of RH(%).

In areas with high Humidity:

- ✓ **Transmission of solar radiation is reduced.**
- ✓ **Evaporation Reduced.**
- ✓ **High humidity accompanied by High ambient temperature causes discomfort.**

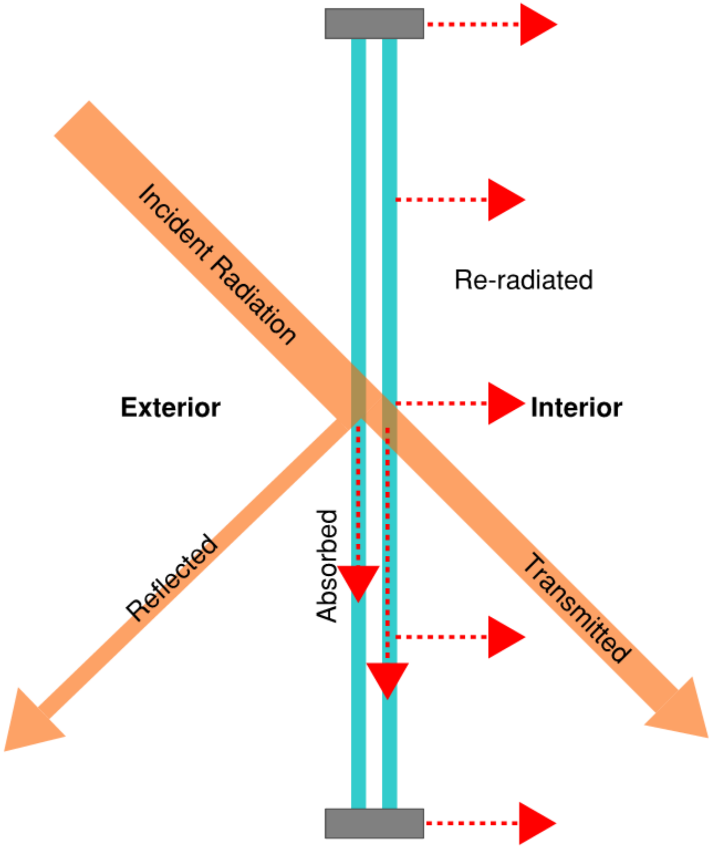
BUILDING PHYSICS

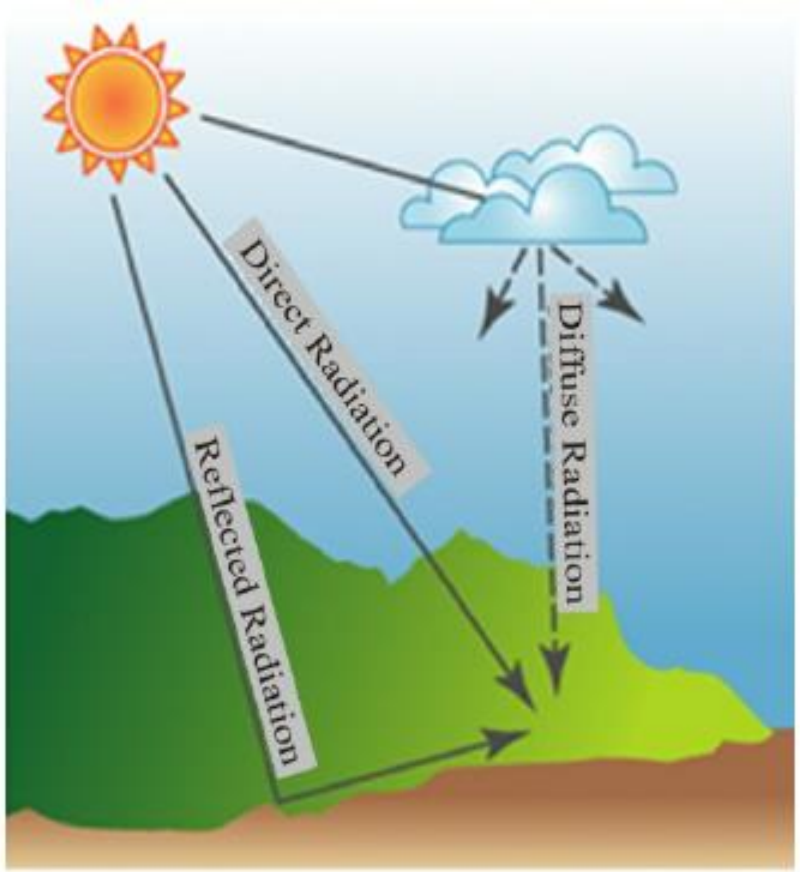
External Factors.(Climatic)

- ✓ Temperature
- ✓ Relative Humidity
- ✓ Solar Radiation
- ✓ Wind Speed and Direction
- ✓ Miscellaneous Factors

Solar Radiation

- ✓ Global Solar Radiation Components(Direct and Diffused).
- ✓ Building Solar Gain(Direct and Indirect).





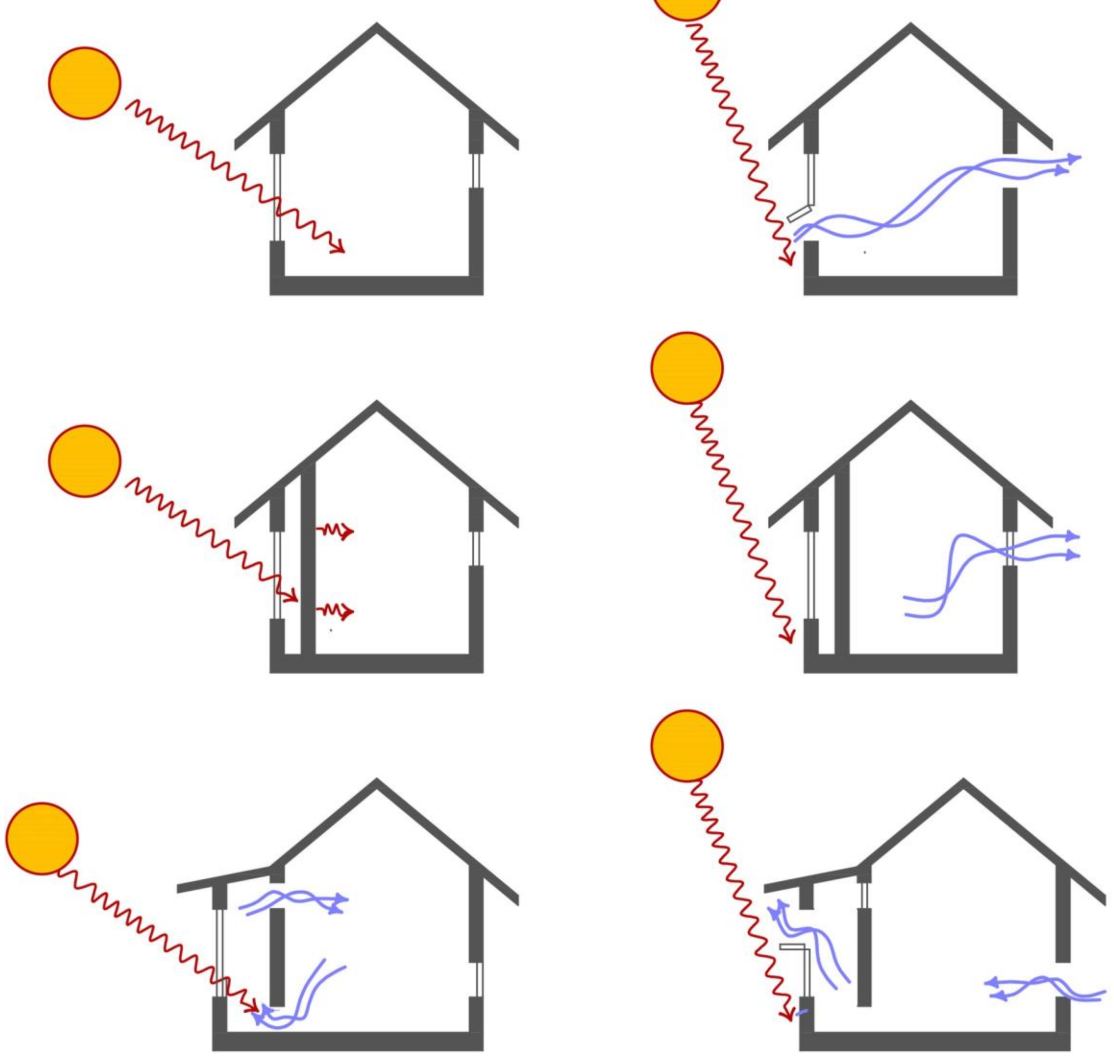
BUILDING PHYSICS

External Factors.(Climatic)

- ✓ Temperature
- ✓ Relative Humidity
- ✓ Solar Radiation
- ✓ Wind Speed and Direction
- ✓ Miscellaneous Factors

Pyranometer is used for measuring solar radiations

Summer and Winter Sun



Direct Gain System

- Sun directly heats the living space
- Simplest and least expensive

Indirect Gain System

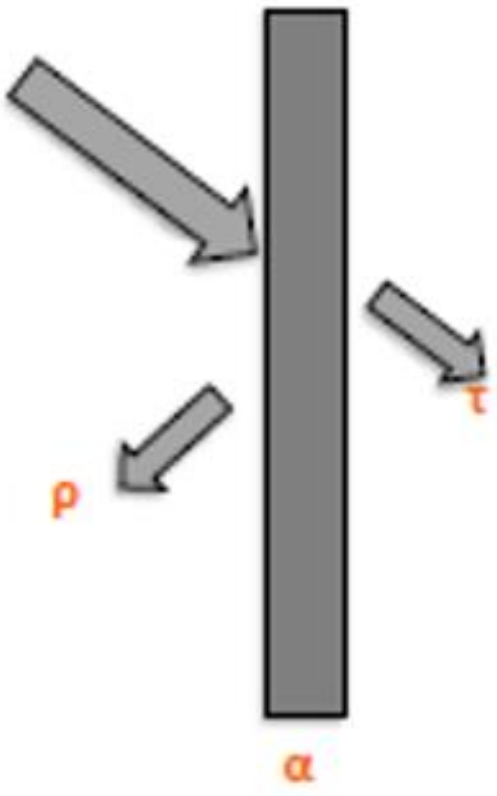
- Rely on conduction to transfer heat to living space
- Good for where daylight and view is not required.

Isolated Gain System

- Uses convection to take the hot air to living space
- Very efficient
- Sunspace- cannot always be occupied

BUILDING PHYSICS

Solar Radiation = Reflection + Absorption+ Transmission



$\rho \rightarrow$ Reflectance

$\alpha \rightarrow$ Absorption

$\tau \rightarrow$ Transmittance

$$\rho = \frac{\text{Reflected radiation}}{\text{Incident radiation}}$$

$$\alpha = \frac{\text{Absorbed radiation}}{\text{Incident radiation}}$$

$$\tau = \frac{\text{Transmitted radiation}}{\text{Incident radiation}}$$

$$\rho + \alpha + \tau = 1$$

BUILDING PHYSICS

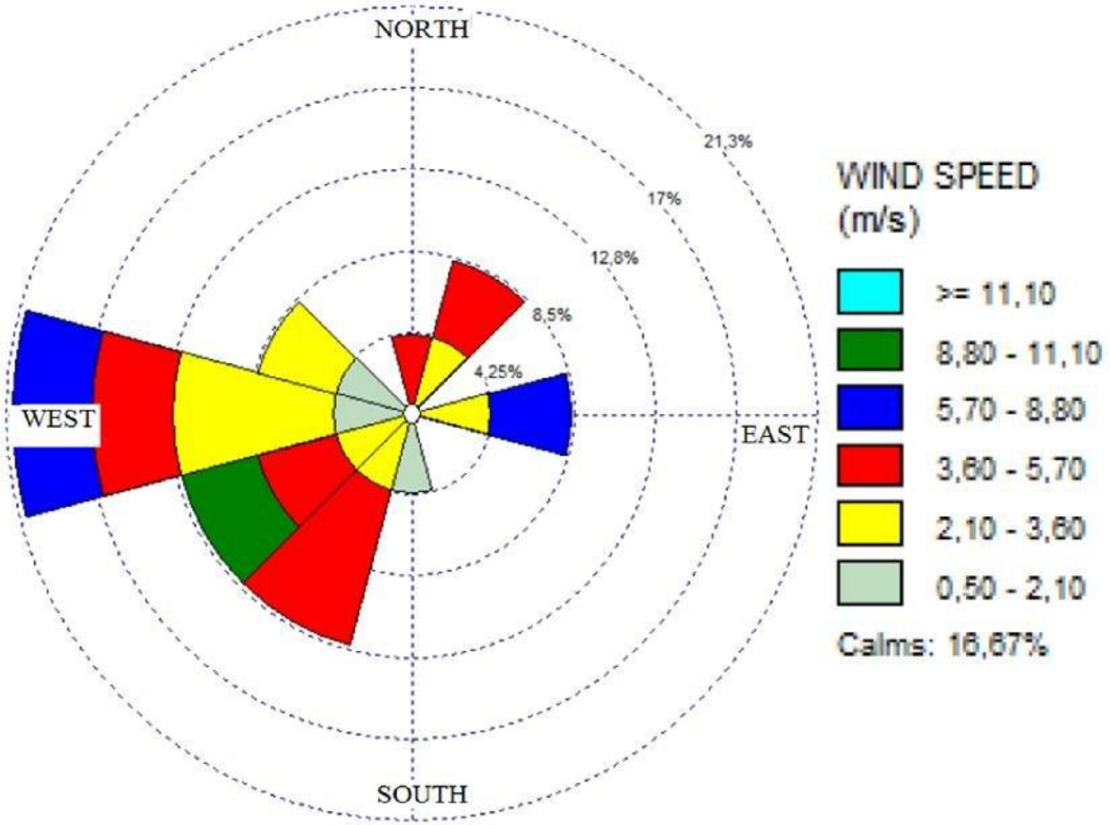
External Factors.(Climatic)

- ✓ Temperature
- ✓ Relative Humidity
- ✓ Solar Radiation
- ✓ Wind Speed and Direction
- ✓ Miscellaneous Factors

Wind Speed and Direction

Wind is the movement of air due to different atmospheric temperatures caused by differential heating of land and water masses on the earth's surface by solar radiations and rotation of the earth.

- ✓ Affects indoor comfort condition by influencing the convective heat exchanges of building envelope.
- ✓ It impacts the ventilation and infiltration rate of buildings.
- ✓ Wind is expressed in m/s and measured by ***Anemometer.***



BUILDING PHYSICS

External Factors.(Climatic)

- ✓ Temperature
- ✓ Relative Humidity
- ✓ Solar Radiation
- ✓ Wind Speed and Direction
- ✓ Miscellaneous Factors

Miscellaneous factors

Precipitation

Include water in all forms that is rain snow and hail, measured from **Rain-Gauge** in MM

Cloud cover

Regulates the amount of solar radiation reaching the earth's surface.

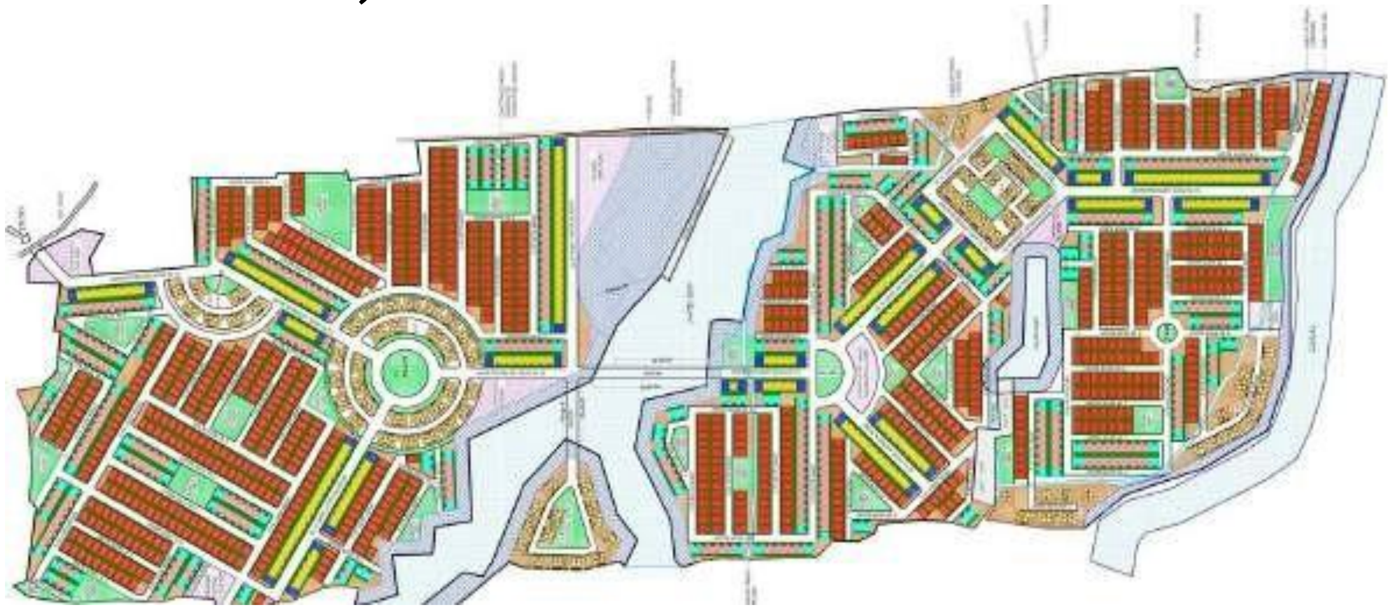
Atmospheric pressure

Atmospheric pressure is directly proportional to the evaporation rate, if the atmospheric pressure is low evaporation rate is high vice versa.

Atmospheric pressure depends on how fast a human body cools itself.

CASE STUDY- MASS HOUSING, INNO GEOCITY, CHENNAI 500 HOUSES

INNO GEO CITY, CHENNAI



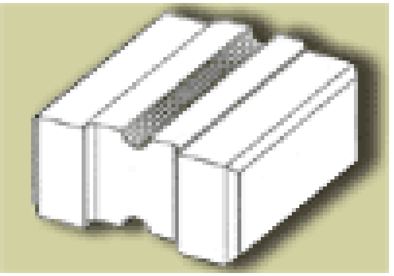
TECHNOLOGY USED

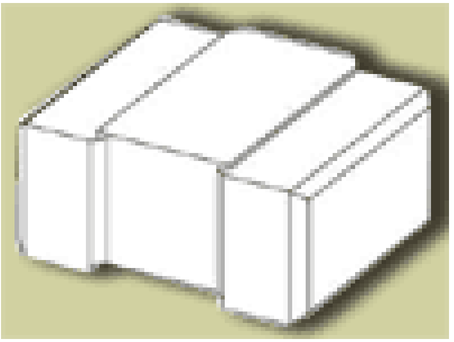
- Hydraform interlocking block walls,
- Precast RC Planks & Joists Roof
- Stone Block masonry in the foundation
- Precast Boundary wall

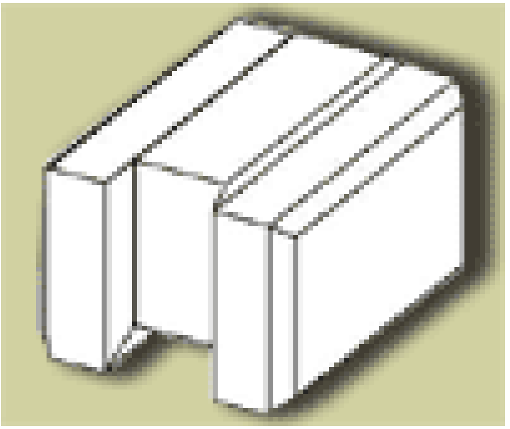
CASE STUDY- AFFORDABLE MASS HOUSING, INNO GEOCITY, CHENNAI 500 HOUSES

TECHNOLOGY HYDRAFORM BUILDING SYSTEM

- An alternate to conventional bricks & mortar for building envelope
- Male/Female Interlocking – Vertical / Horizontal Shear keys
- Suitable for Load/Framed Structures Compatible to incorporate Vertical/Horizontal reinforcements
- Suitable for Seismic structures
- Speedier construction







CASE STUDY- AFFORDABLE MASS HOUSING, INNO GEOCITY, CHENNAI 500 HOUSES

TECHNOLOGY HYDRAFORM BUILDING SYSTEM GREEN RATING

- Hydra-form creates high-quality bricks, created with nothing more than 10 percent addition of building cement and soil/fly ash, formed in a machine under hydraulic pressure.
- Hydra-form blocks are not in need of firing, they only require curing.
- The soil block also has the added benefit of preserving energy thanks to its incredible thermal properties.
- Also fulfilling the criteria 15,16 and 22 of TERI GRIHA , and LEED

LEED :

» MRCredit : 4.1,4.2 – Use of Recycled Contents.(1-2 points)
» MR Credit : 5.1,5.2 – Maximum use of Local and Regional material.(1-2 points)
» MR Credit : 6.0 - Use of rapidly renewable building materials & products.(1 point)

TERI-GRIHA:

» Criteria 15 - Utilization of flyash in building & structure.(6points)
» Criteria 16 - Reduce volume, weight and construction time by adopting efficient technologies [4 pts.)
» Criteria 22 - Minimum 5% reduction in Embodied Energy compared with equivalent products. (1pt.)

प्रधान मंत्री आवास योजना-शहरी Pradhan Mantri Awas Yojana-Urban | GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA | Ministry of Housing and Urban Affairs Government of India | आज़ादी का अमृत महोत्सव | bmtpc | giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

CASE STUDY- AFFORDABLE MASS HOUSING, INNO GEOCITY, CHENNAI 500 HOUSES

Block Production On-site

Stage 1:
Soil/Fly ash.

Stage 2: Lime/Gypsum Coarse sand/Stone Dust, Cement, and Water.

Stage 3:
Mixing and block Making in Hydra-Form machine.

Stage 4:
24Hrs Self covered Curing and 2 weeks curing by sprinkler. Quality check and dispatch.

CASE STUDY- AFFORDABLE MASS HOUSING, INNO GEOCITY, CHENNAI 500 HOUSES

Quality Check/Quality Control

PROBLEM	CAUSE	REMEDY
1. Rough surface on blocks	Mix too dry	Add more water to mix
	Rough plates	Inspect plates and change if necessary
	Soil build up in joints or on wear plates	Clean excess soil or fly ash from joints and plates
2. Cracking on blocks	Too much water in mix	Use less water in mix. Add cement to mix already made to dry out
A. Horizontal cracks seen as block ejected from chamber	Compression pressure too high	Reduce pressure
B. Cracks developing during 7 day curing period	Blocks losing too much water, too fast during curing	Cover blocks properly with plastic and water twice daily as per Hydraform rec-ommendations
	High clay content	Add coarse sand to mix
		Add more cement
3. Blocks being damaged and broken during stacking and storage	Careless handling of blocks	Closer supervision of stacking
	Blocks too weak	Check production process and/or add more cement to mix
4. Blocks shorter than chosen length	Too much water in mix	Use less water in mix
	Compression pressure too high	Reduce pressure
5. Blocks longer than chosen length	Mix too dry	Add more water to mix
	Compression pressure too low	Increase pressure
6. Block length changing continuously	Water content changing continuously	Keep water in mix constant. Check water content by checking length of block with ruler
	Soil properties changing continuously	Use same soil source for all production

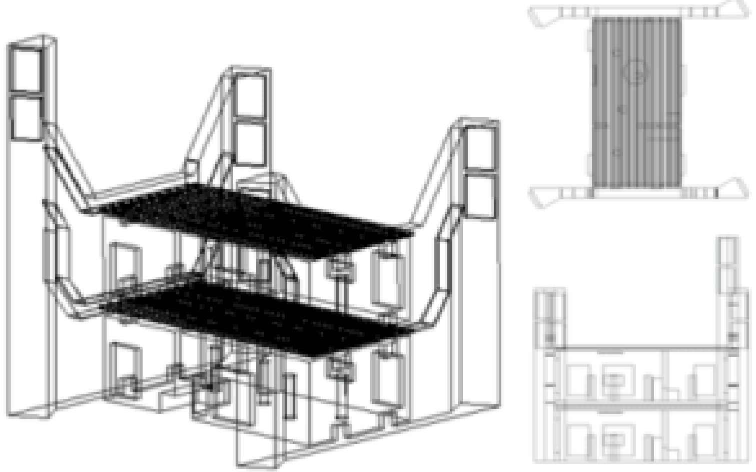
NOTE: Since raw materials change from site to site, please consult Hydra-form specialized engineers for proper raw material and mix design, block making process, and quality control procedure.

CASE STUDY- LOW ENERGY HOUSING

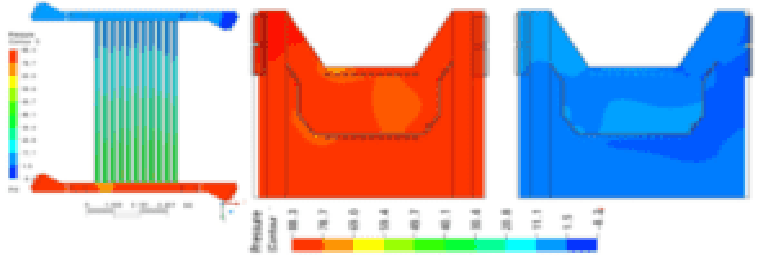
Scope & Objective:

A prototype of large number of low-cost mass housing project was to be built with the owner's mandate of using natural as well as external wind-based ventilation that create an efficient as well as comfortable living environment within the units. Further study includes.

1. Options of slab air cooling by concrete piping.
2. Estimates of how well the air changes are able to dissipate the internal heat load with slab cooling.
3. Use wind catchers as well as tower to enhance the air flow due to thermal stratification.
4. Estimate, if sufficient air changes are happening and what kind of temperatures will prevail inside the occupant spaces.



Snapshots below depicts the pressure drops in air path



Run	Run Description In (°C)	Range DBT-WBT In (°C)	Mass Flow Achieved In (Kg/s)	Temp. and Enthalpy Drop		ACH Total Volume of Geometry is 395 m^3	Ton of Cooling
1	DBT= 34 WBT= 26	8	1.01969 Kg/s	In=2C/70%	H1=63.7 KJ/Kg	7.7	7.66
				Out =31.2C/80%	H2=90.1 KJ/Kg		
2	DBT= 40 WBT= 25	15	0.956495 Kg/s	In =25C/70%	H1=60.4 KJ/Kg	7.2	7.84
				Out =31.0/80%	H2=89.2 KJ/Kg		
3	DBT= 31 WBT= 21	10	0.569413 Kg/s	In = 21C/70%	H1=48.6 KJ/Kg	4.3	4.73
				Out = 28.3C/80%	H2=77.8 KJ/Kg		
4	DBT= 28 WBT= 24	4	1.00588 Kg/s	In =24C/70%	H1=57.3 KJ/Kg	7.6	5.09
				Out =27.5/80%	H2=75.1 KJ/Kg		

SESSION-2

1. *Thermal Comfort Standards (IMAC, ASHRAE)*
2. *Effect of Building Material Properties on Thermal Comfort*

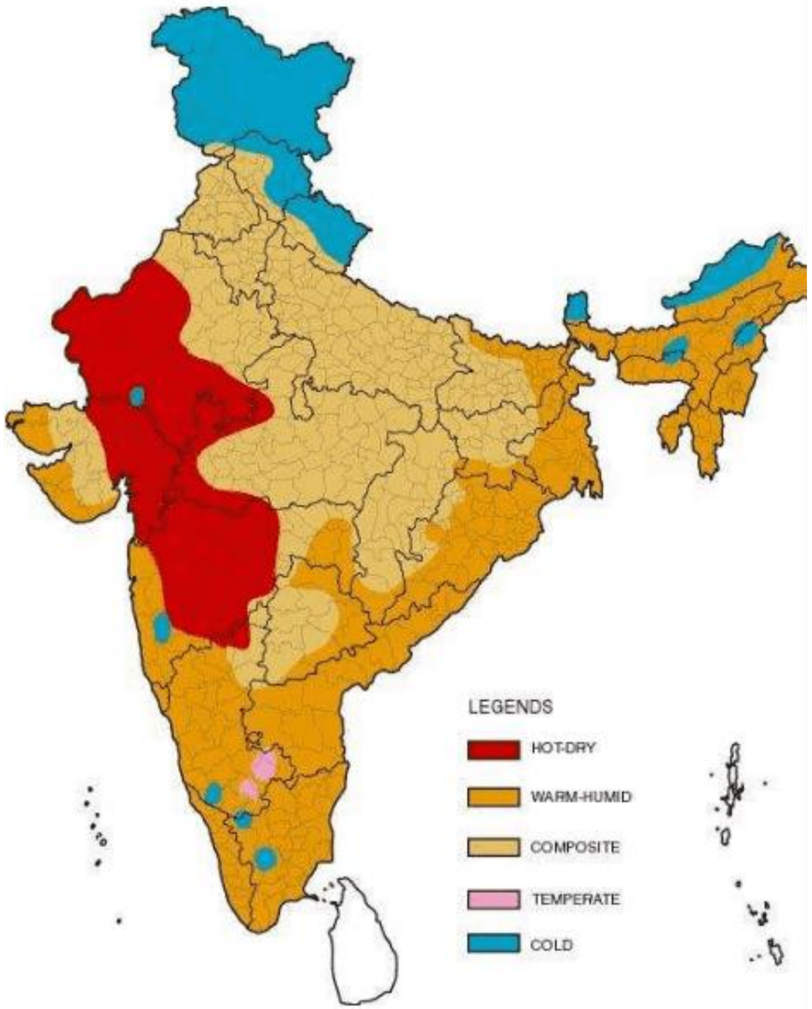
IMAC (INDIA MODEL FOR ADAPTIVE THERMAL COMFORT)

India — Standard of adaptive thermal comfort based on Indian specific model guideline (currently for office / commercial buildings),

Model for — Applicable for air conditioned, naturally ventilated and mixed-mode buildings,

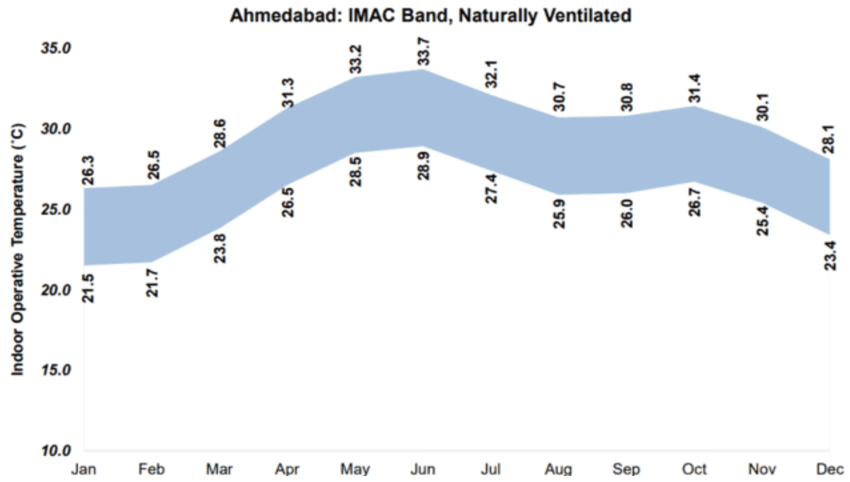
Adaptive — Includes the wide temperature ranges in all Indian climate zones,

Comfort — Shows 90% and 80% acceptability bands.

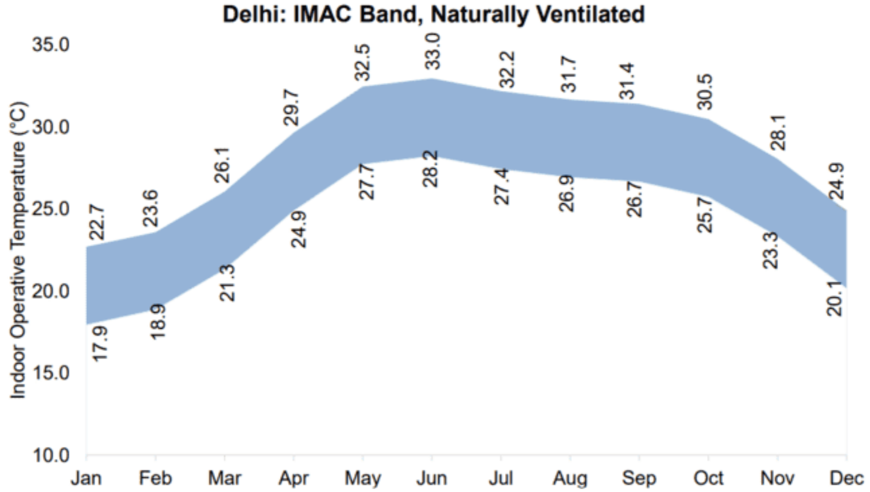


IMAC (INDIA MODEL FOR ADAPTIVE THERMAL COMFORT)

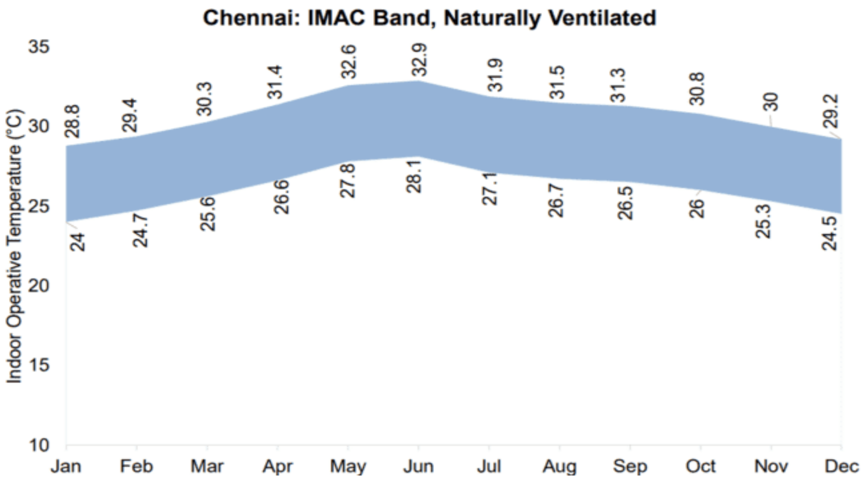
HOT & DRY



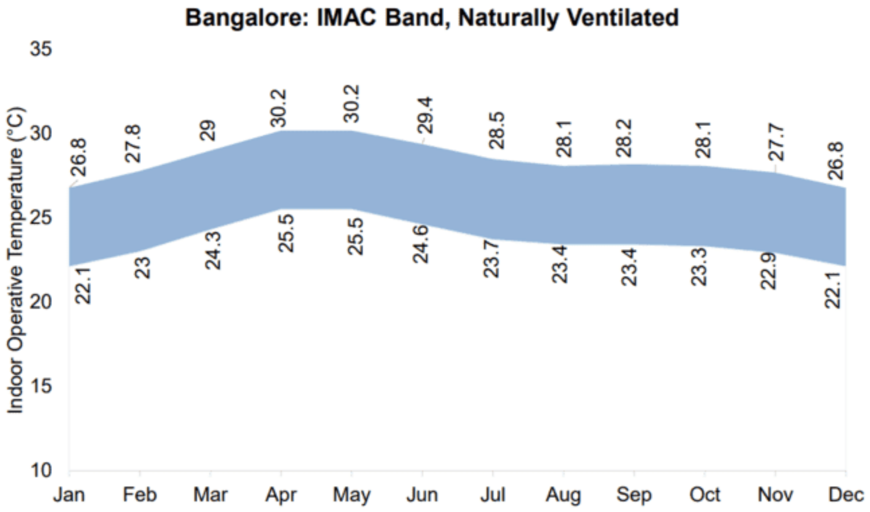
COMPOSITE



WARM & HUMID



TEMPRATE



IMAC (INDIA MODEL FOR ADAPTIVE THERMAL COMFORT)

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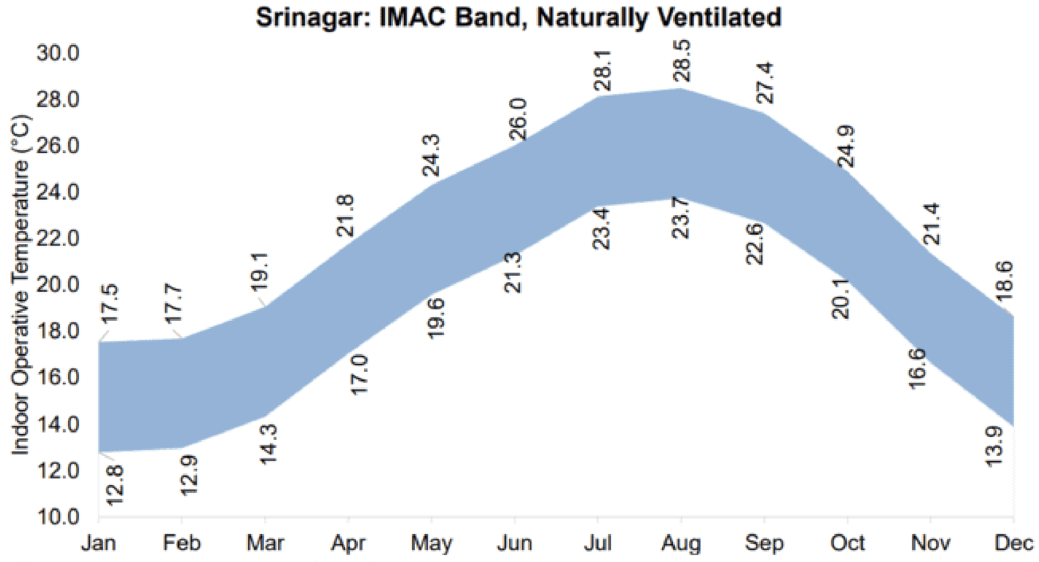
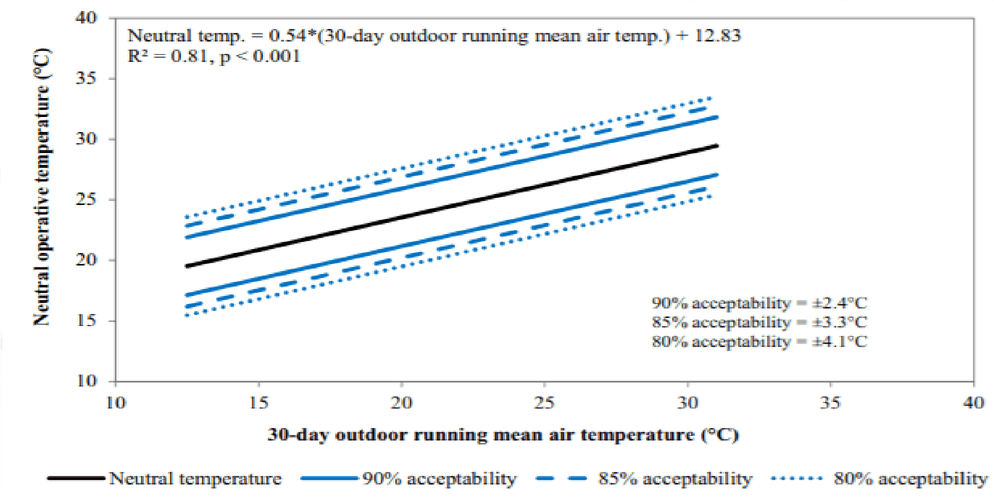
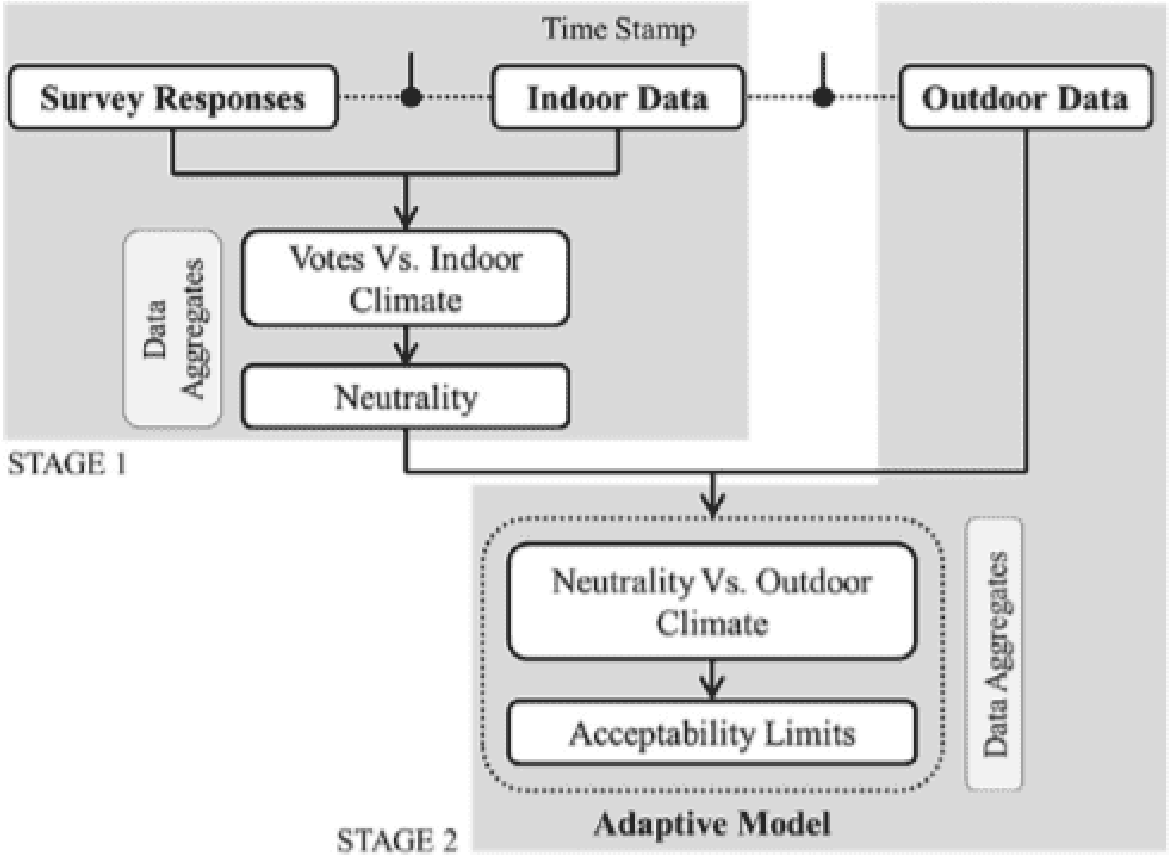


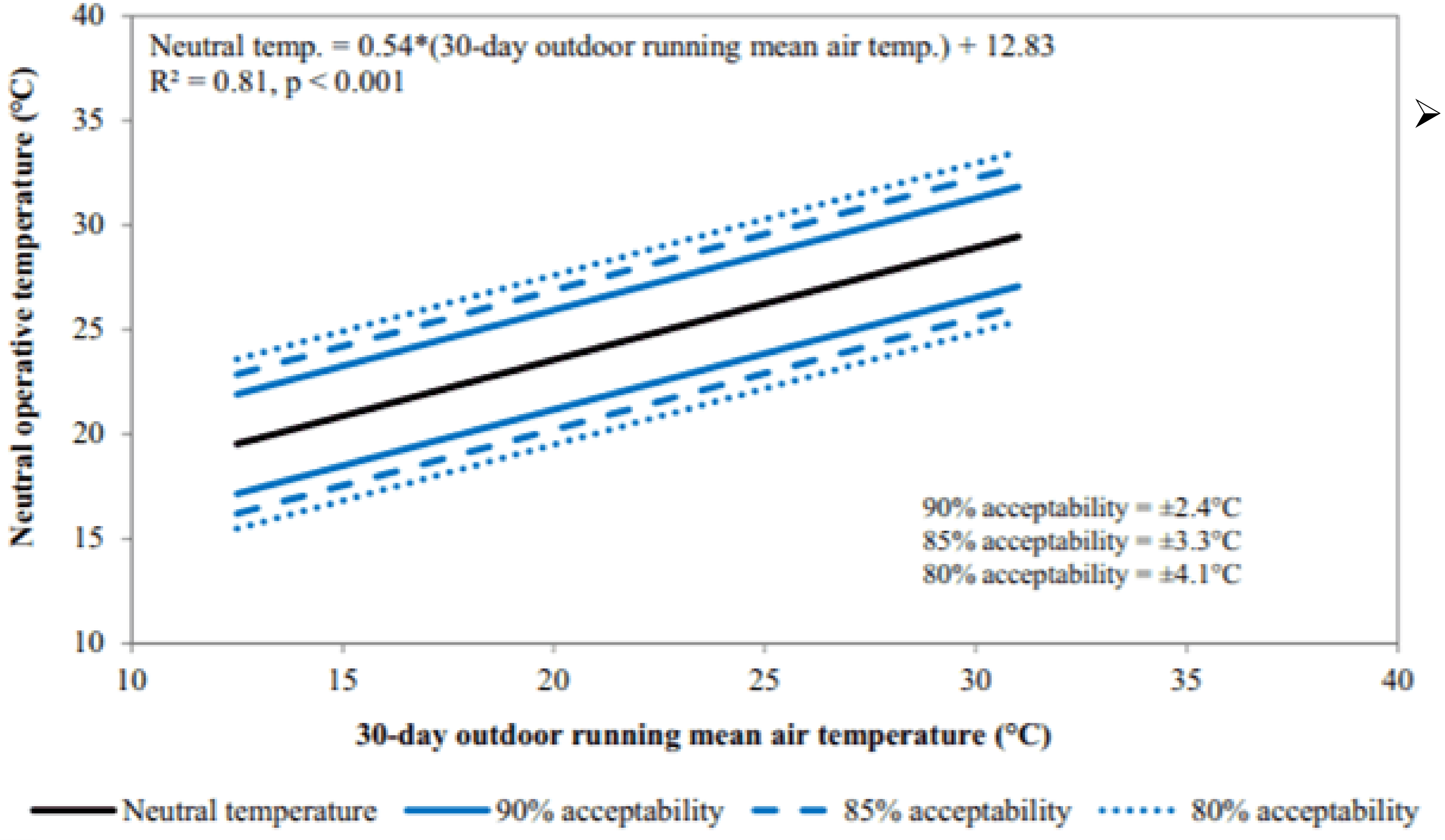


IMAC model for naturally ventilated buildings.

IMAC ANALYSIS STEPS



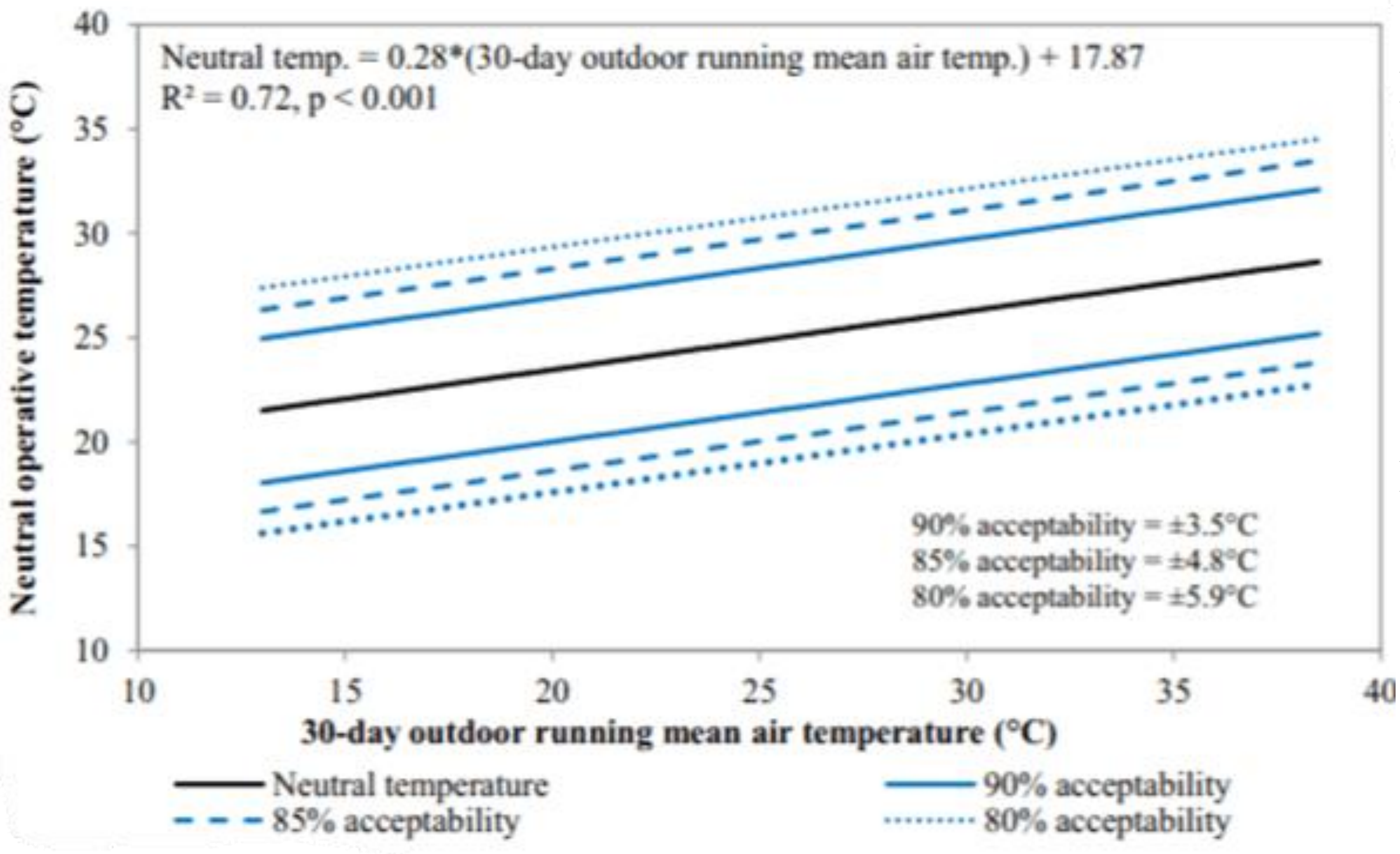
IMAC (INDIA MODEL FOR ADAPTIVE THERMAL COMFORT)



IMAC model for naturally ventilated buildings.

- The model indicates that occupants in NV buildings thermally adapt to the outdoor temperature of their location and the neutral temperature varies from 19.6 to 28.5 C for the above outdoor limits.

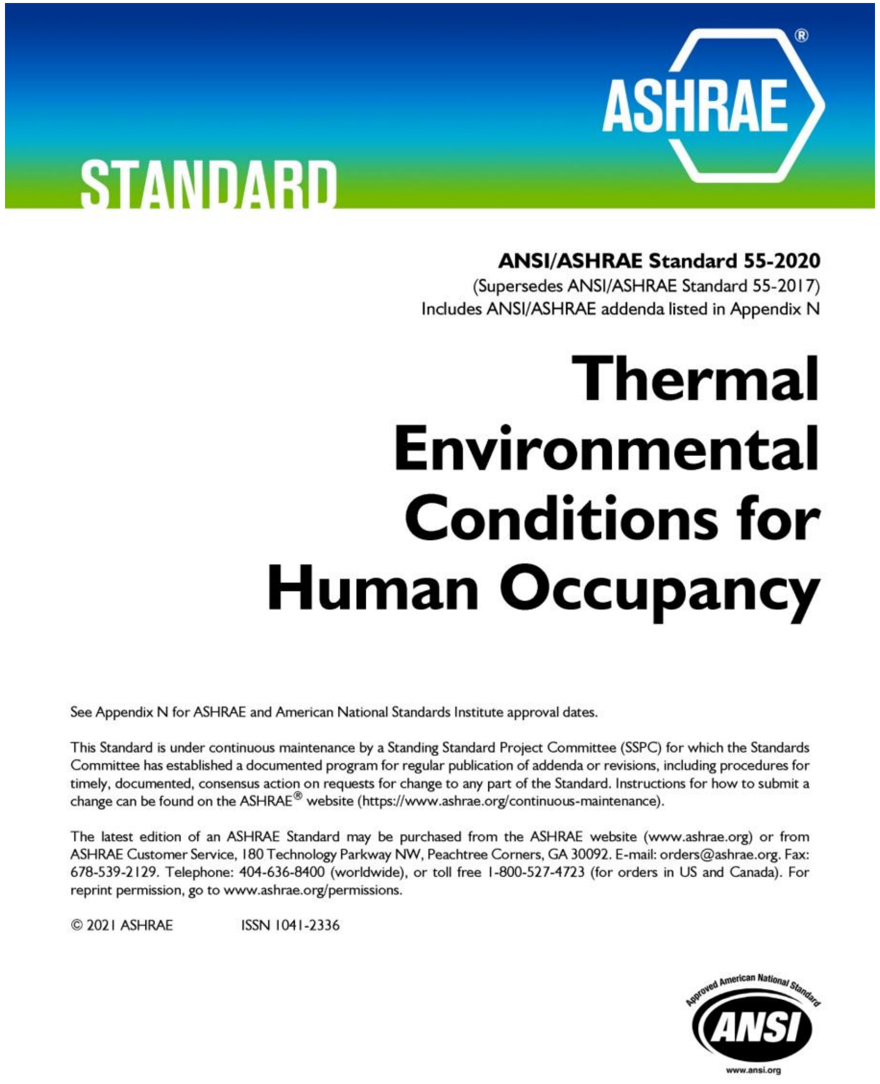
IMAC (INDIA MODEL FOR ADAPTIVE THERMAL COMFORT)



IMAC model for mixed mode buildings.

- The acceptability limits derived from the IMAC data are wider for MM buildings model than NV.
- This may be a result of the occupants knowing that the required comfort systems exist and will be operational when the external conditions are extreme.

ASHRAE 55-2020 (THERMAL COMFORT STANDARD)


STANDARD

ASHRAE®

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

Thermal Environmental Conditions for Human Occupancy

See Appendix N for ASHRAE and American National Standards Institute approval dates.

This Standard is under continuous maintenance by a Standing Standard Project Committee (SSPC) for which the Standards Committee has established a documented program for regular publication of addenda or revisions, including procedures for timely, documented, consensus action on requests for change to any part of the Standard. Instructions for how to submit a change can be found on the ASHRAE® website (https://www.ashrae.org/continuous-maintenance).

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Approved American National Standard ANSI www.ansi.org

ASHRAE *(American Society of Heating and Refrigeration Engineering)* Standard 55 specifies conditions for acceptable thermal environments and is intended for use in the design, operation, and commissioning of buildings and other occupied spaces.

ASHRAE 55 defines thermal comfort as "that condition of mind that expresses satisfaction with the thermal environment".

ASHRAE 55-2020 (THERMAL COMFORT STANDARD)

The standard was primarily designed for thermal comfort in spaces where occupants are in sedentary states (i.e., office work). However, it can also be employed to cover other types of indoor environments like residential and commercial spaces.

This standard is based upon four pillars:

- The six environmental and personal factors taken into account are ***temperature, thermal radiation, humidity, airspeed, activity level (metabolic rate), and occupant clothing*** (degree of insulation). In order to comply with ASHRAE 55, all of these factors must be accounted for in combination.
- The thermal conditions that ASHRAE-55 aims to achieve are applicable to healthy adult occupants, up to an altitude of 3K meters, where occupancy time must surpass 15 minutes.
- This standard does not take into consideration factors including air quality, acoustics, illumination, or contamination.

ASHRAE 55-2020 (THERMAL COMFORT STANDARD)

ASHRAE-55 Optional Method for Determining Acceptable Thermal Conditions in Naturally Conditioned Spaces.

- In order to apply the adaptive model, there should be no mechanical cooling system for the space; occupants should be engaged in sedentary activities with metabolic rates of 1–1.3 met; and a prevailing mean temperature greater than 10°C and less than 33.5°C.

Adaptive comfort model as per ASHRAE 55	T_{comf}=0.31T_pma +17.8
80% Acceptability Upper limit (Eq + 3.5)	T_{comf}=0.31T_pma +21.3
80% Acceptability Lower limit (Eq - 2.5)	T_{comf}=0.31T_pma +14.3
90% Acceptability Upper limit (Eq + 2.5)	T_{comf}=0.31T_pma +20.3
90% Acceptability Lower limit (Eq - 2.5)	T_{comf}=0.31T_pma +15.3

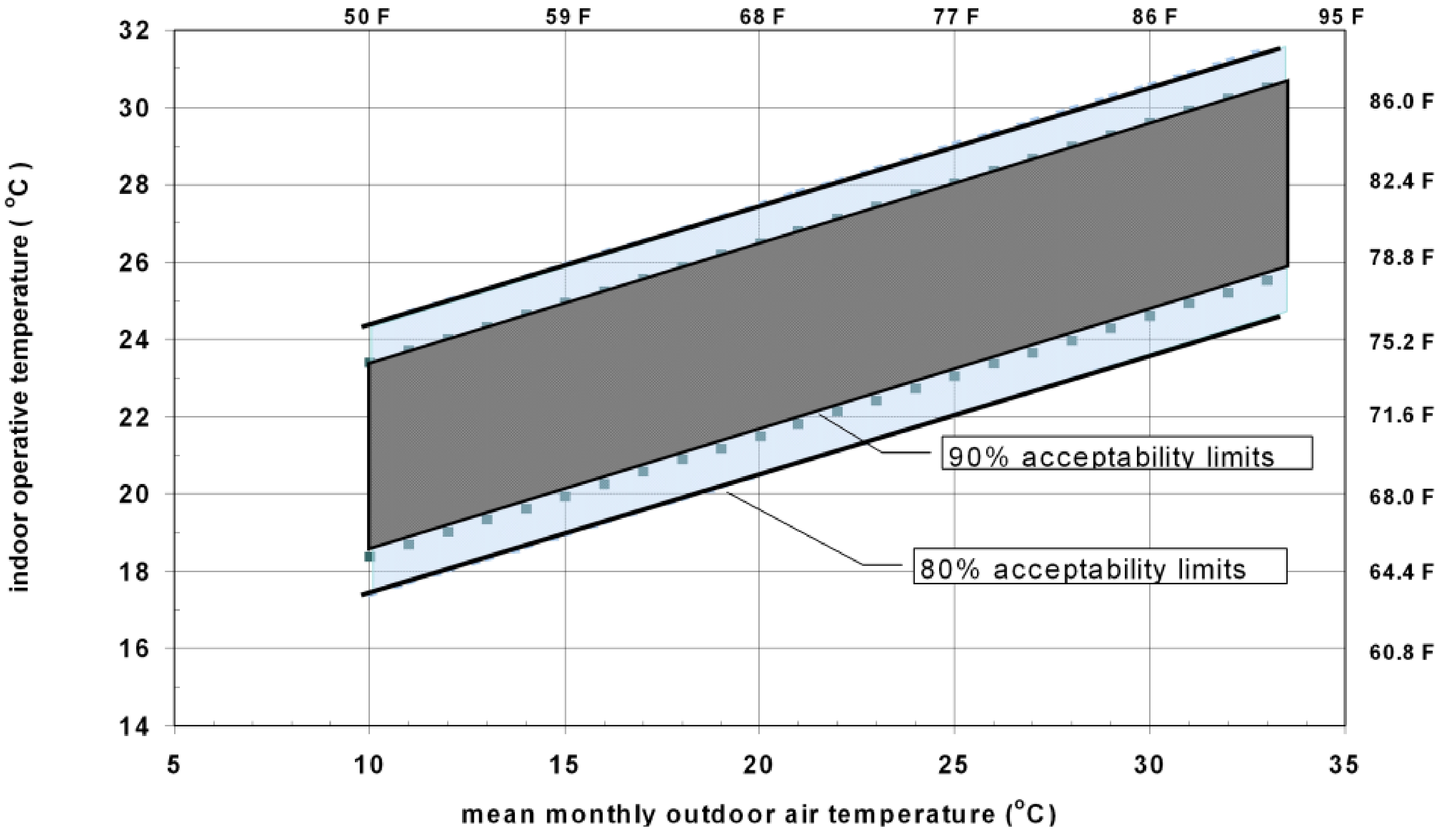
T_{comf}: Indoor comfort temperature corresponds to acceptable operative temperature

T_{pma}: Prevailing mean outdoor air temperature

ASHRAE 55-2020 (THERMAL COMFORT STANDARD)

ASHRAE-55 Optional Method for Determining Acceptable Thermal Conditions in Naturally Conditioned Spaces.

- In order for this optional method to apply, the space in question must be equipped with operable windows that are open to the outdoors and can be readily opened and adjusted by the occupants of the space.
- PMV and PPD are used to determine these acceptability ranges

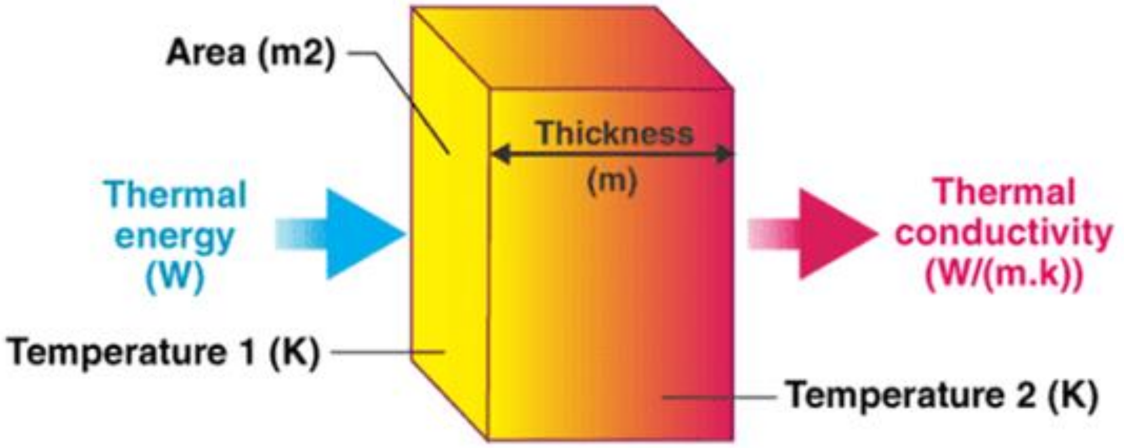


Acceptable operative temperature ranges for naturally conditioned spaces

EFFECT OF BUILDING MATERIAL PROPERTIES ON THERMAL COMFORT

- Materials has a direct impact on the achievement of the required thermal properties of a building due to their different thermal properties.

1. **Thermal Conductivity:** The amount of heat transferred through unit area of specimen with unit thickness in unit time is termed as thermal conductivity. it is measured in W/(m.K). The lower the thermal conductivity of a material, the better the thermal performance.



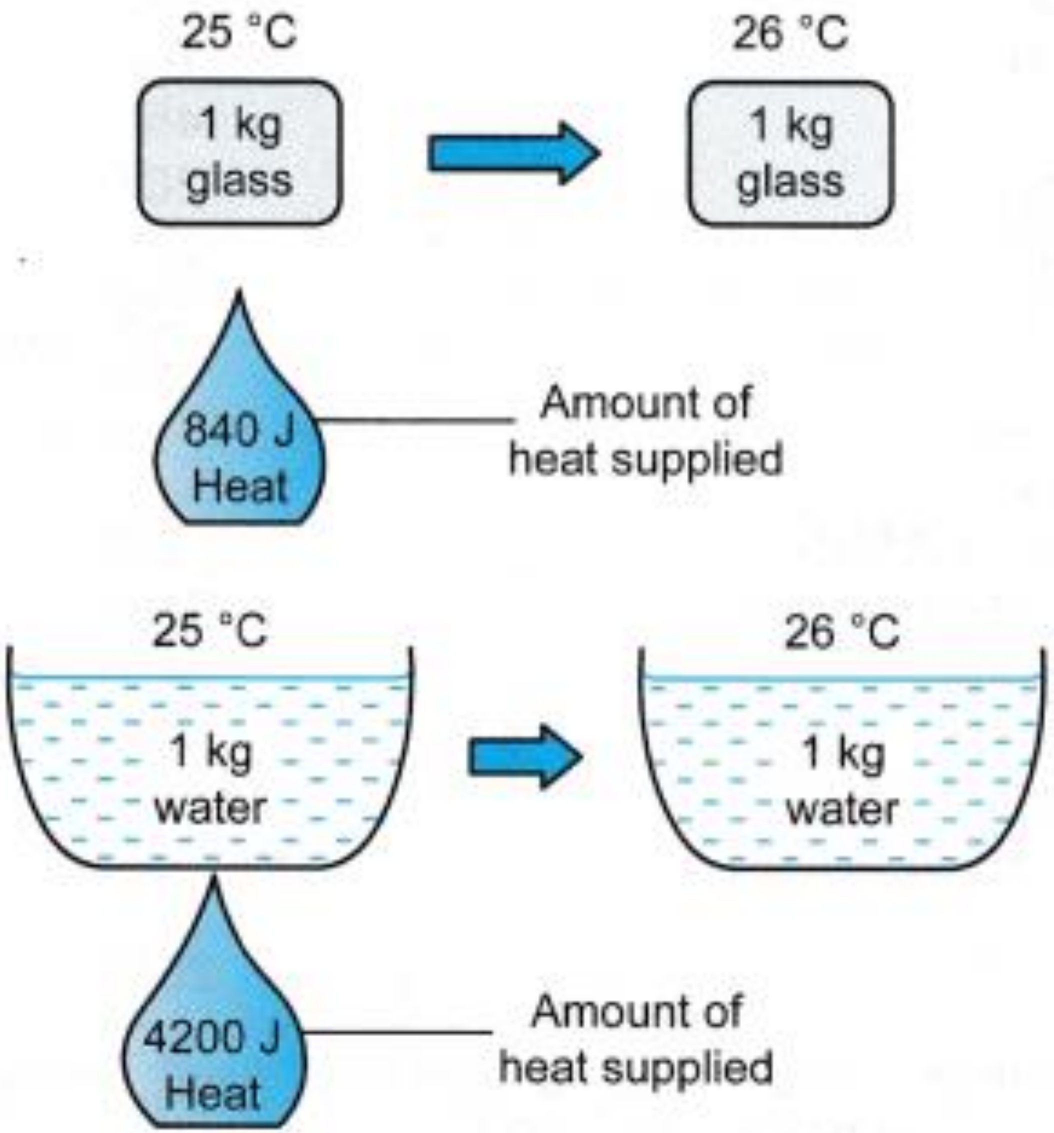
EFFECT OF BUILDING MATERIAL PROPERTIES ON THERMAL COMFORT

2. Specific Heat: Specific heat is the quantity of heat in kilo-joule required to heat 1Kg by 1 kelvin/celcius. Specific heat is useful when we use the material in high-temperature areas. Unit is **kJ/kg.K or kJ/kg.C.**

$$c = \frac{\Delta E}{m\Delta\theta}$$

$$\Delta E = mc\Delta\theta$$

m = mass (kg)
c = specific heat capacity (J/kg°C)
ΔE = change in thermal energy (J)
$\Delta\theta$= change in temperature (°C)



EFFECT OF BUILDING MATERIAL PROPERTIES ON THERMAL COMFORT

3. Thermal Mass: Thermal mass is the ability of a material to absorb, store and release heat.

Thermal lag is the rate at which a material releases stored heat. For most common building materials, the higher the thermal mass, the longer the thermal lag.

It is calculated by multiplying the specific heat capacity by the density of a material. The unit of thermal mass is **kJ/m^3.K**

4. Density of material: Density is the weight per unit volume of a material (i.e. how much a cubic meter the material weighs). Unit is **Kg/m^3**

THERMAL TRANSMITTANCE (U-VALUE)

The U-value is a measure of how much heat is lost through a given thickness of a particular material but includes the three major ways in which heat loss occurs: conduction, convection and radiation.

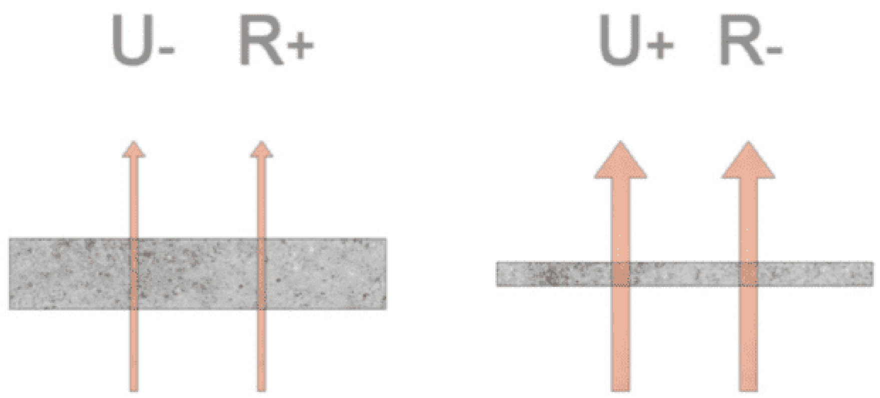
it is the inverse of resistance value R. Unit of U value is $W/m^2.K$.

The general formula for calculating the U-Value is:

U=1/Rt

Where R is total Thermal Resistance of the element composed of layers in $m^2 \cdot K/W$.

Rt=R1+R2+R3……Rn

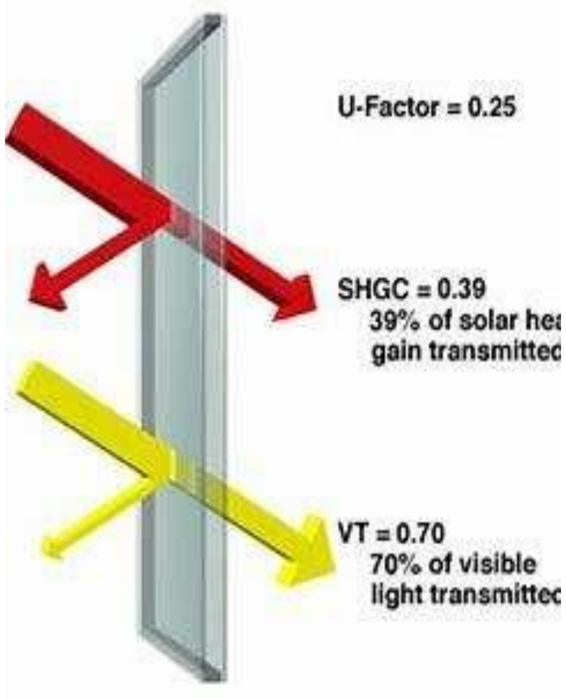


R1, R2, R3, Rn = Thermal Resistance of each layer, which is obtained according to:

R=d/K, where K is thermal conductivity. d is thickness.

GUIDANCE ON U- VALUE, SHGC AND VLT FOR FENESTRATIONS

1. **U-Factor:** Heat transmittance through the window. A lower number indicates less transmittance through the window.
2. **SHGC (Solar heat gain coefficient)**: Blocking the sun's radiant heat. Lower SHGC means less radiant solar heat gain through the window.
3. **VLT Visible light Transmittance:** Visible light passed through the window. VLT is rated between 0 and 1. A higher number indicates more light is transmitted.



Glazing Assembly	U-Factor	R-Value	SHGC	VT
Single Glass	1.1	0.9	0.87	0.90
Double pane, insul. glass	0.50	2.0	0.76	0.81
High-SHGC, low-e, insul. glass	0.30	3.3	0.74	0.76
Medium-SHGC, low-e, insul. glass	0.26	3.8	0.58	0.78
Low-SHGC, low-e, insul. glass	0.29	3.4	0.35	0.65
Triple-glazed, 2 low-e coatings	0.12	8.3	0.5	0.65

GUIDANCE ON U- VALUE, SHGC AND VLT FOR FENESTRATIONS

Design Factors that impact on U-value, SHGC, VLT Etc.

Climate Analysis : To select type of glazing as different weather impacts differently.

Optimum Orientation of Building: Before selecting any glazing material, study of building orientation is must, if rightly oriented, we may get energy efficiency without using high performance glass. (according to Indian context, South-West orientation is responsible for maximum heat gain).

Shadow Analysis: Shadow of the building as well as surrounding also impacts heat ingress (direct & defused), hence changes the glazing requirement.

Daylight Analysis : Study of available lux level, window size and other passive design should be considered before defining the required VLT of a glass.

GUIDANCE ON U- VALUE, SHGC AND VLT FOR FENESTRATIONS

Dos in Indian climatic Context

- Choose products with least SHGC and U value and optimum VLT.
- Determine an optimum set of values for U-value, solar heat gain coefficient, and visible transmittance.
- Add overhead shading, use dark tinted glass at visible height and clear at higher levels. For shaded windows, products with lower U values perform better.

Don’t in Indian climatic Context

- Do not use glass with very low U value and moderate SHGC.
- Do not assume dark tinted glass brings solar control
- Do not use un-insulated frames

Note: *Remember that same fenestration product behaves differently w.r.t. the specific design. It should not be assumed that products with Low U-value and SHGC are best and universal solution.*

SESSION-3

1. *ENS (Building Envelope) Part-1*

ENS 2018- INTRODUCTION

Why Eco-Niwas Samhita has been created?

- **Built Up Area -** India will add 3 Billion m^2 by 2030 of New residential building w.r.t Year 2018
- **Energy Demand -** There is a 4 times increase in energy demand for residential units from 1996 – 2016
- Projections show energy demand will be approximately between 630 TWh and 940 TWh by 2032

What is Eco-Niwas Samhita 2018?

- ECO-Niwas Samhita 2018 - an Energy Conservation Building Code for Residential Buildings.
- Launched on National Energy Conservation Day in 2018.
- Applicable to all residential units with plot area ≥500m^2
- (However, states and municipal bodies may reduce the plot area so that maximum residential buildings fall in the category of ENS compliance)

ENS 2018- INTRODUCTION

Why Eco-Niwas Samhita has been created?

- **Climate Responsive Building Design**
- **Efficient Building Envelope Design**
- **Energy Efficient Appliances** (5 Star A/C, Fridge, LED Lights Etc)
- **Proper Maintenance of Electrical Appliances**

To Address The Above Factors

Eco Niwas Samhita Was Created

ENS 2018- POLICIES FOR RESIDENTIAL BUILDINGS

Policies & Regulations-Residential

- ❑ Eco-Niwas Samhita (ECBC-R) Part -1
- ❑ Star Rating for Buildings (Building Label)
- ❑ Supporting Government Initiatives

- ❑ Replicable Design Catalogue of EE Homes
- ❑ Energy Efficient Building Materials Directory

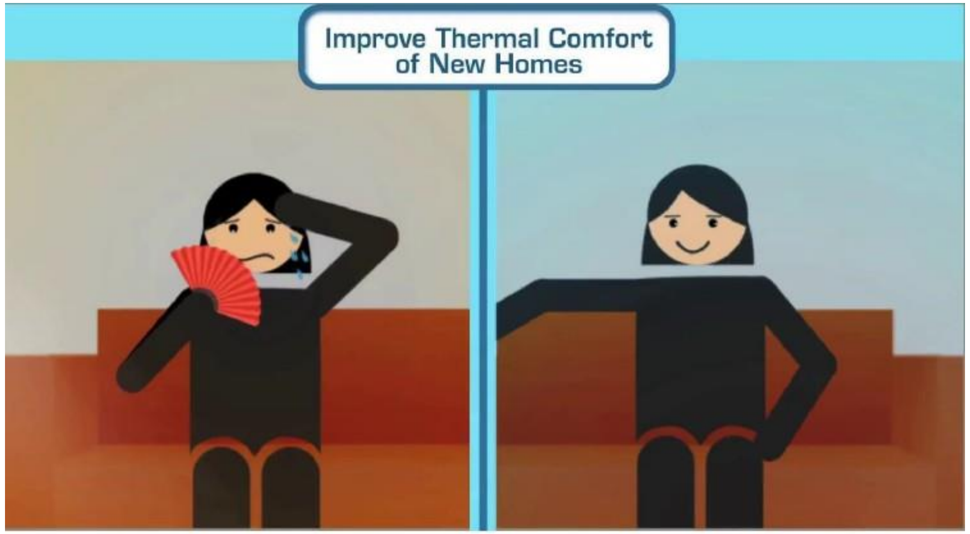
- ❑ ECONIWAS Web-Portal
- ❑ Smart Home Program

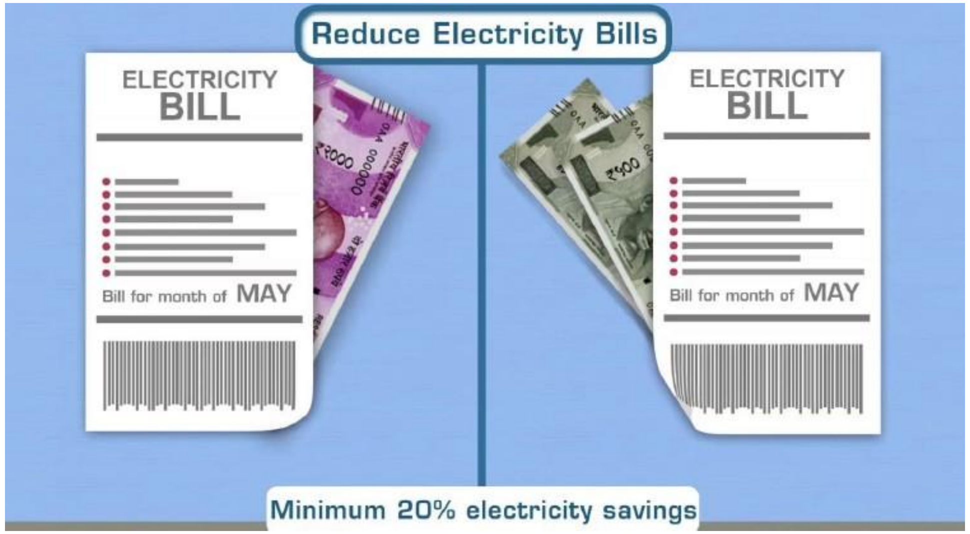
- ❑ Eco-Niwas Samhita (ECBC-R) Part -II

ENS 2018- LAUNCH

Eco-Niwas Samhita 2018 (Part I: Building Envelope) is the New ECBC for Residential Buildings, launched by Ministry of Power (MoP) on 14 December 2018.

ENS 2018- IMPACT ASSESMENT OF PART-1

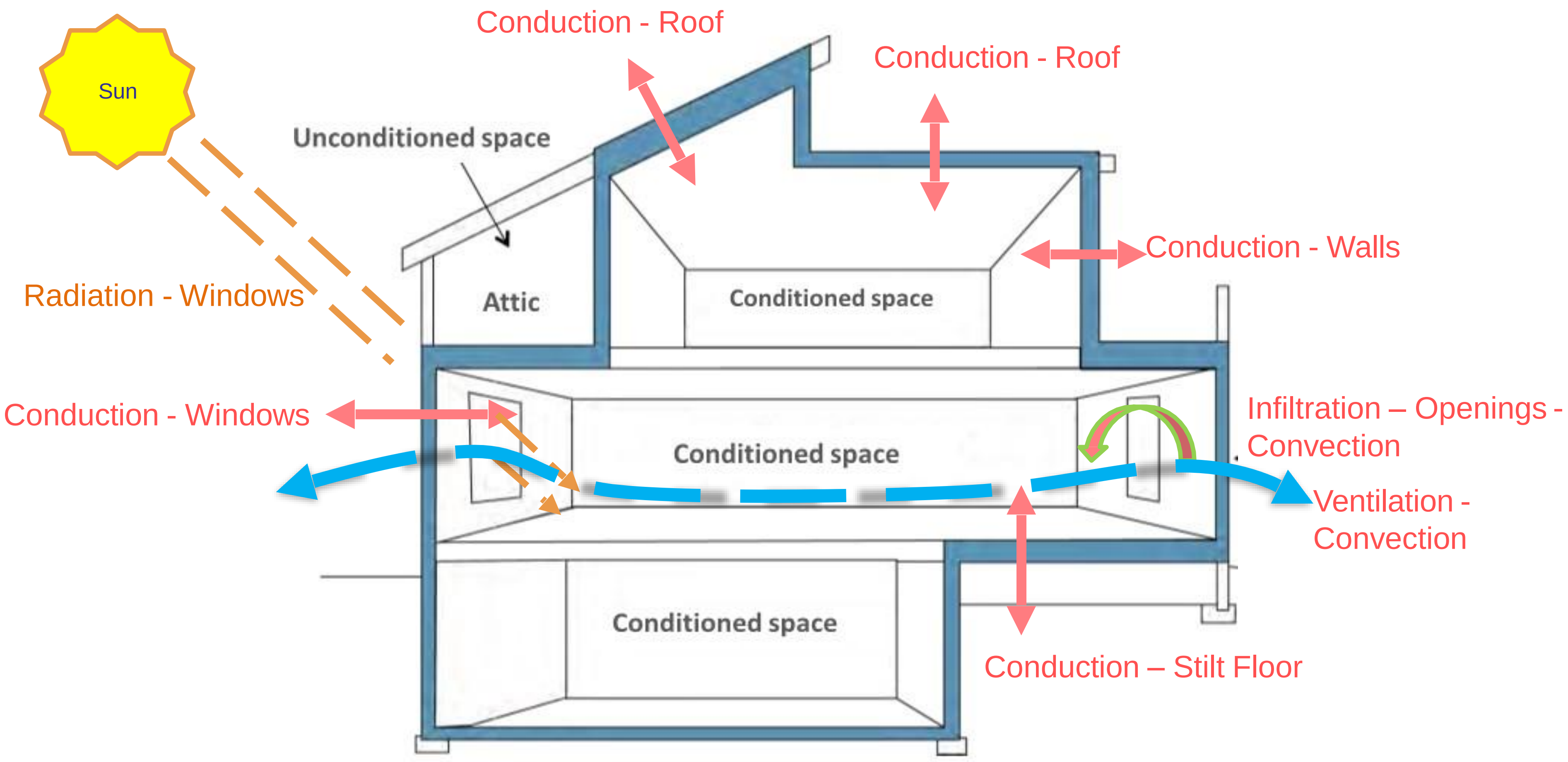




- ✓ Estimated Savings 2018 – 2030
- ✓ 20% Cooling Energy
- ✓ 25 billion kWh Electricity
- ✓ 100 million Tons of CO2 Equivalent

ENS 2018-BUILDING ENVELOPE PHYSICS

Building Envelope-Building Physics & Concepts



Building Envelope Design Is The Key Of Energy Efficient Residential Buildings

ENS 2018-BUILDING ENVELOPE PHYSICS

WHAT IS – U VALUE?

The lower the U-value, the lower the heat gain/loss in the building.

Definition:

Thermal transmittance is the rate of heat transfer through materials

Unit of U-Value : $W/(m^2K)$

$$\text{U-Value} = \frac{1}{Thermal\ Resistance\ of\ a\ material\ (R)}$$

$$\text{Where } R = \frac{Thickness\ of\ material\ (t)}{Conductivity\ (k)}$$

Conductivity (k) is the rate at which heat travels through I meter thick material. It is a property of a material

ENS 2018-BUILDING ENVELOPE PHYSICS

TYPES OF WALL AND THEIR U-VALUE

150 mm RCC (No plaster) U Value 3.77 W/m2K

→

Block with 15 mm plaster on both sides –

→

with 15 mm plaster on both sides U Value 1.72

200 mm Autoclaved Aerated Concrete (AAC) with 15 mm plaster on both side U Value 0.77 W/m2K

→

300 mm Autoclaved Aerated Concrete (AAC) with 15 mm plaster on both sides U Value 0.54 W/m2K

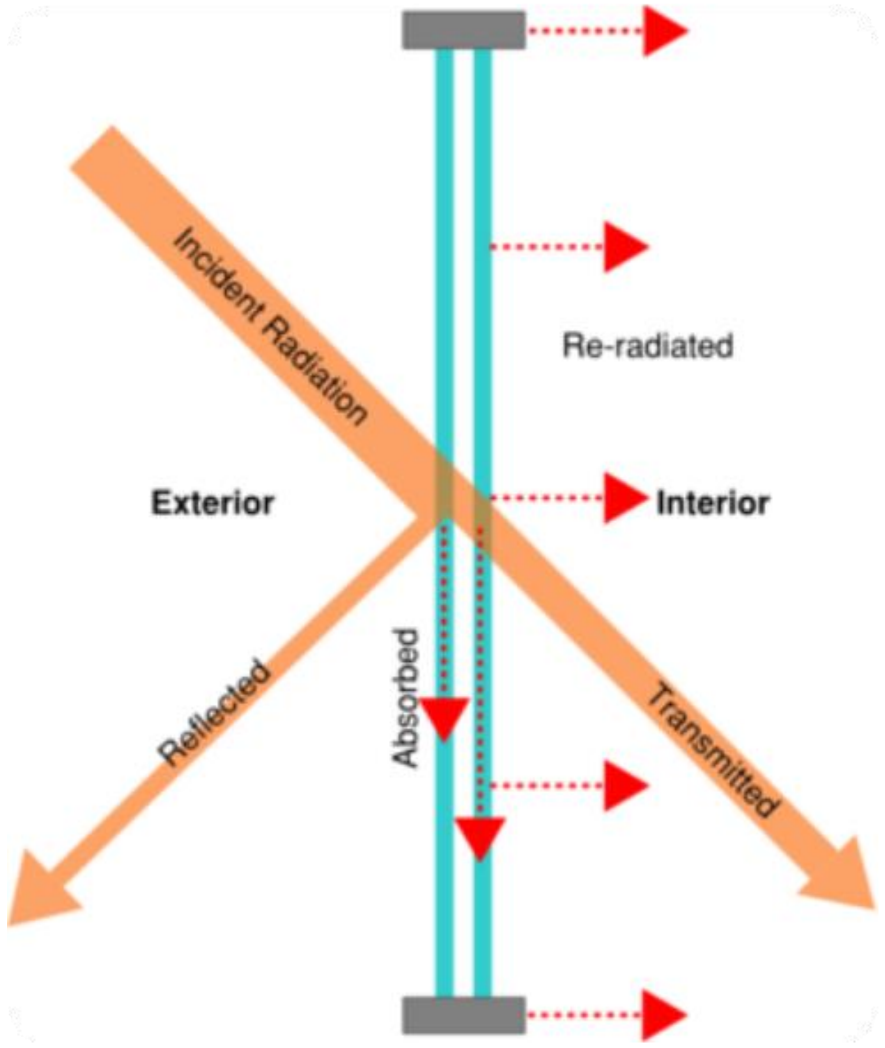
SHGC

Solar Heat Gain Coefficient

Definition:

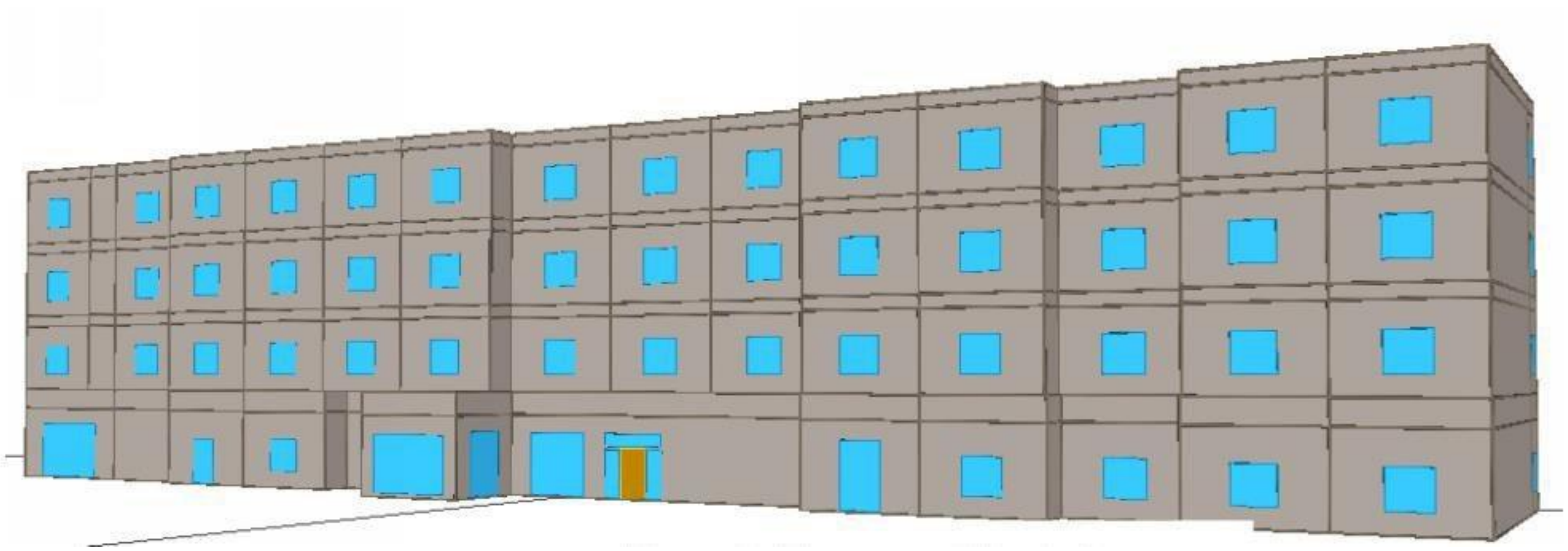
SHGC is the fraction of incident solar radiation admitted through a window, both directly transmitted and absorbed and subsequently released inward.

The value of SHGC varies from 0 - 1

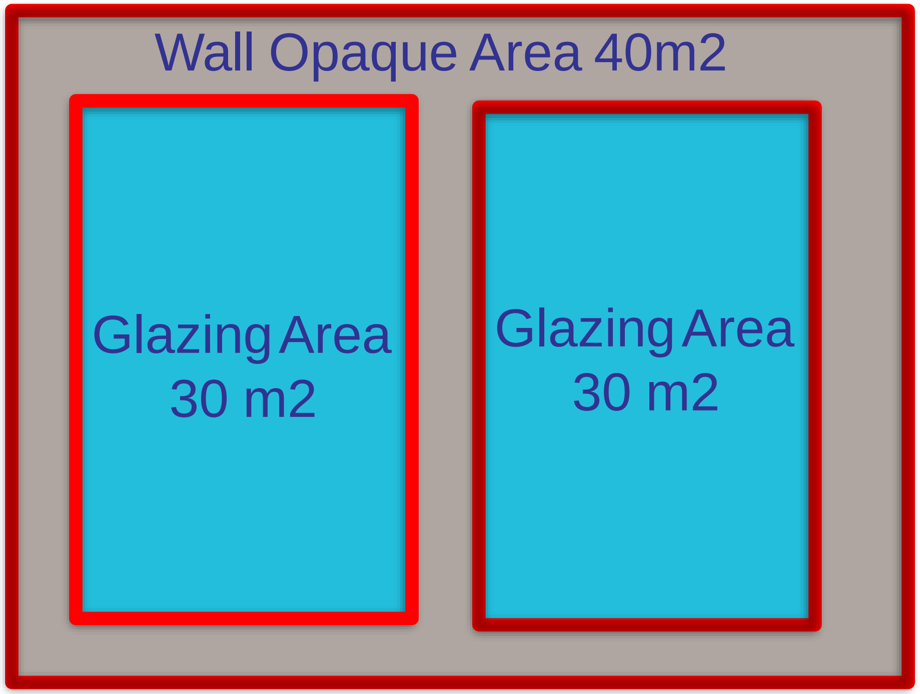


WINDOW TO WALL AREA RATIO (WWR)

$$\boldsymbol{WWR} = \frac{Area\ of\ Non-Opaque\ Windows\ \&\ Openings}{Total\ Area\ of\ Exterior\ Walls\ Including\ Windows\ \&\ Openings}$$



WINDOW TO WALL AREA RATIO (WWR)



$$WWR = \frac{30 + 30}{40 + 30 + 30}$$

$$WWR = \frac{60}{100}$$

$$WWR = 0.6$$

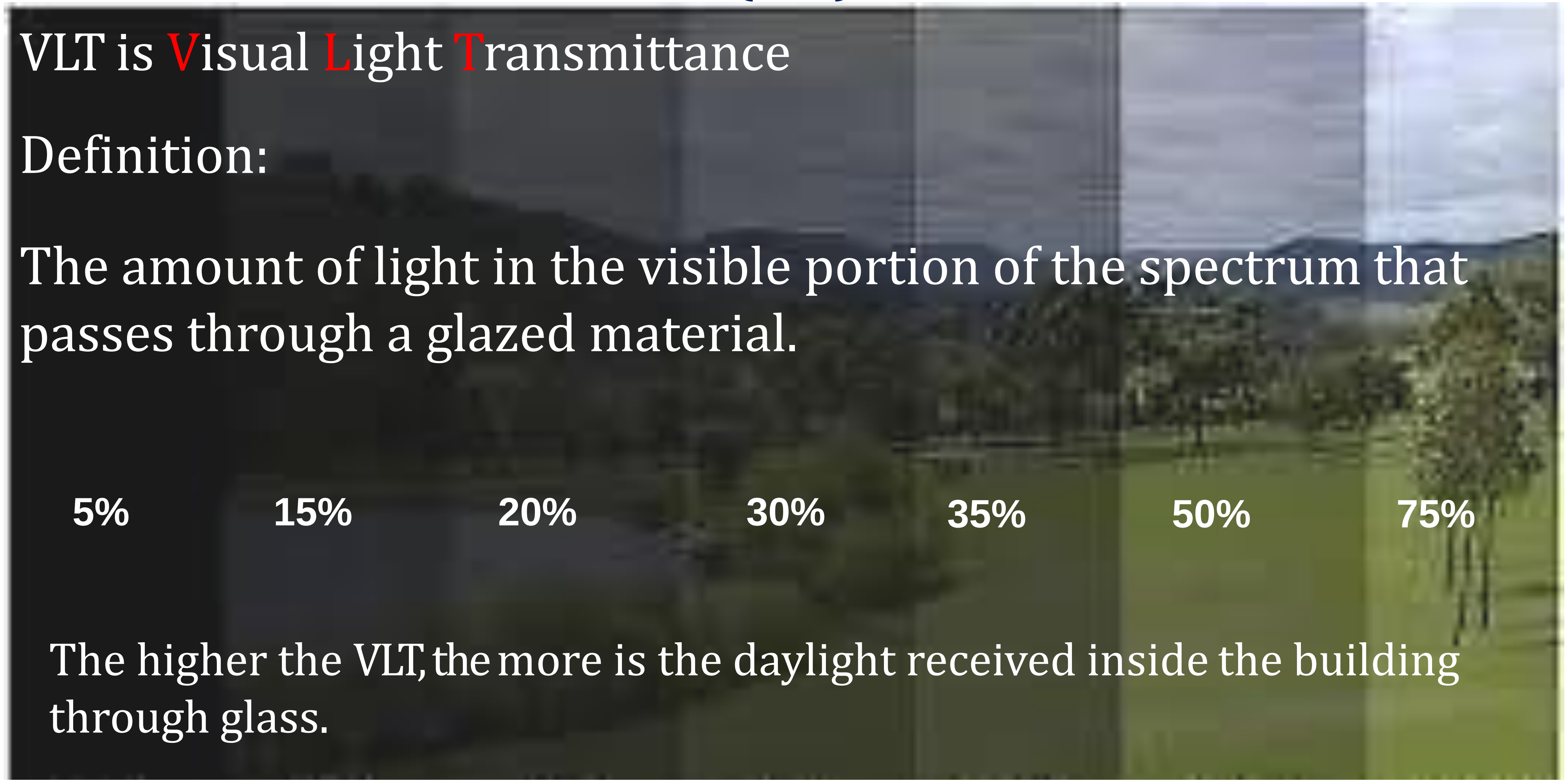
$$= 60\%$$

VISIBLE LIGHT TRANSMITTANCE (VLT)

VLT is Visual Light Transmittance

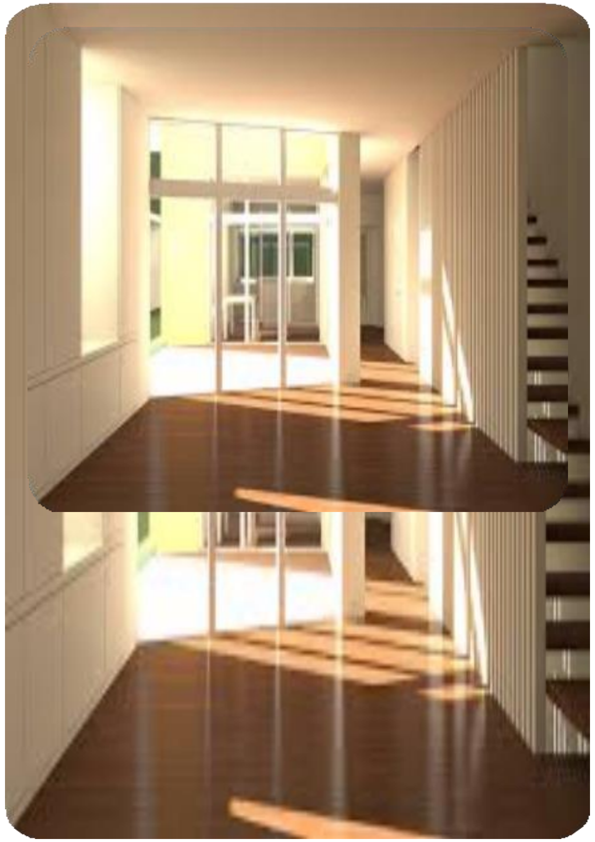
Definition:

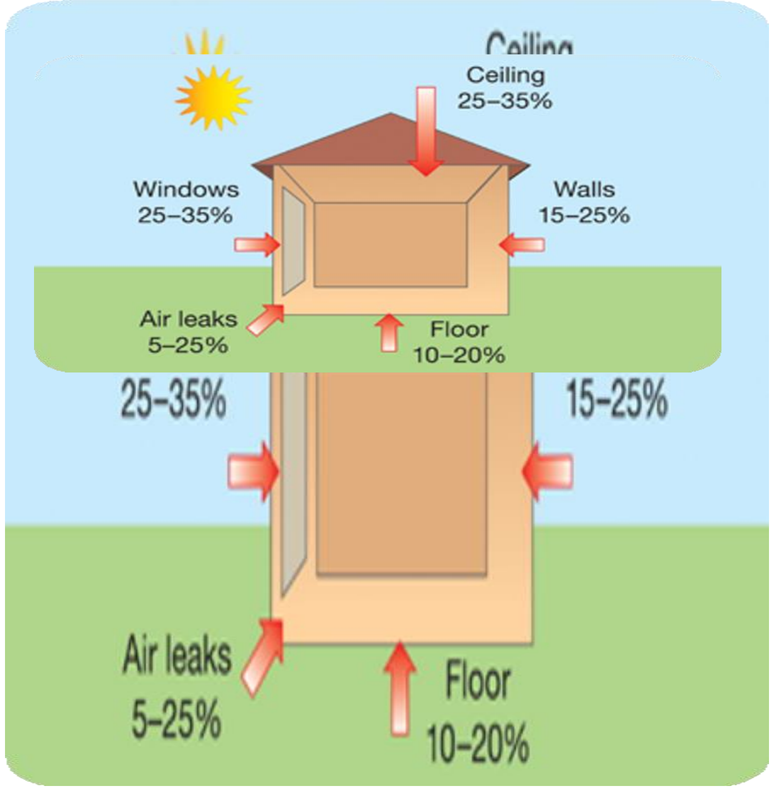
The amount of light in the visible portion of the spectrum that passes through a glazed material.



The higher the VLT, the more is the daylight received inside the building through glass.

ENS 2018-BUILDING ENVELOPE COMPLIANCE REQUIREMENTS





Transparency

1. Window to Wall Ratio
2. Visual Light Transmittance

Heat transfer

3. U-Value of Walls
4. Solar Heat Gain Coefficient
5. U-Value of Roofs

Ventilation

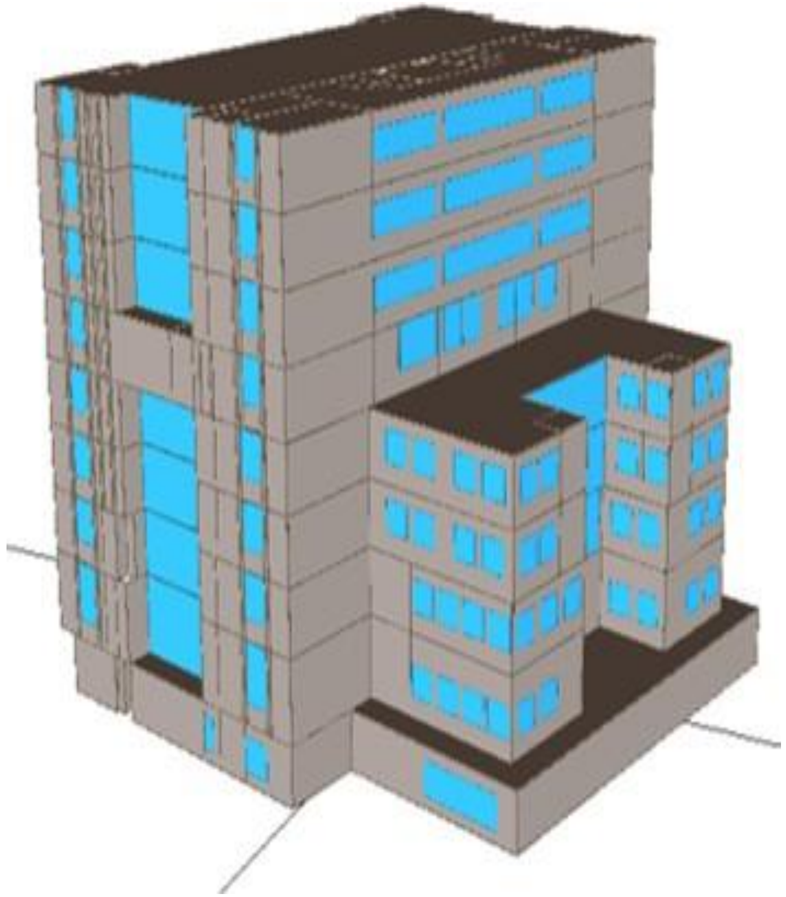
6. Window to Floor Area Ratio

ENS 2018-BUILDING ENVELOPE VLT AND WWR

Minimum VLT shall not be less than the values given in the Table below:-

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

THERMAL TRANSMITTANCE U-VALUE ROOF



Thermal Transmittance of Roof (U_{roof})

Thermal transmittance (U_{roof}) characterizes the thermal performance of the roof of a building.

Maximum U_{roof} : **1.2 W/m²K.**

RETV-RESIDENTIAL ENVELOPE TRANSMITTANCE VALUE

RETV can be calculated by using the following formula:-

$$RETV = \frac{1}{A_{envelope}} \times \left[\left\{ a \times \sum_{i=1}^{n} \left(A_{opaque_i} \times U_{opaque_i} \times \omega_i \right) \right\} + \left\{ b \times \sum_{i=1}^{n} \left(A_{non-opaque_i} \times U_{non-opaque_i} \times \omega_i \right) \right\} + \left\{ c \times \sum_{i=1}^{n} \left(A_{non-opaque_i} \times SHGC_{eq_i} \times \omega_i \right) \right\} \right]$$

Wall Conductive Heat Gains

Window Conductive Heat Gain

Window Radiation Heat Gain

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

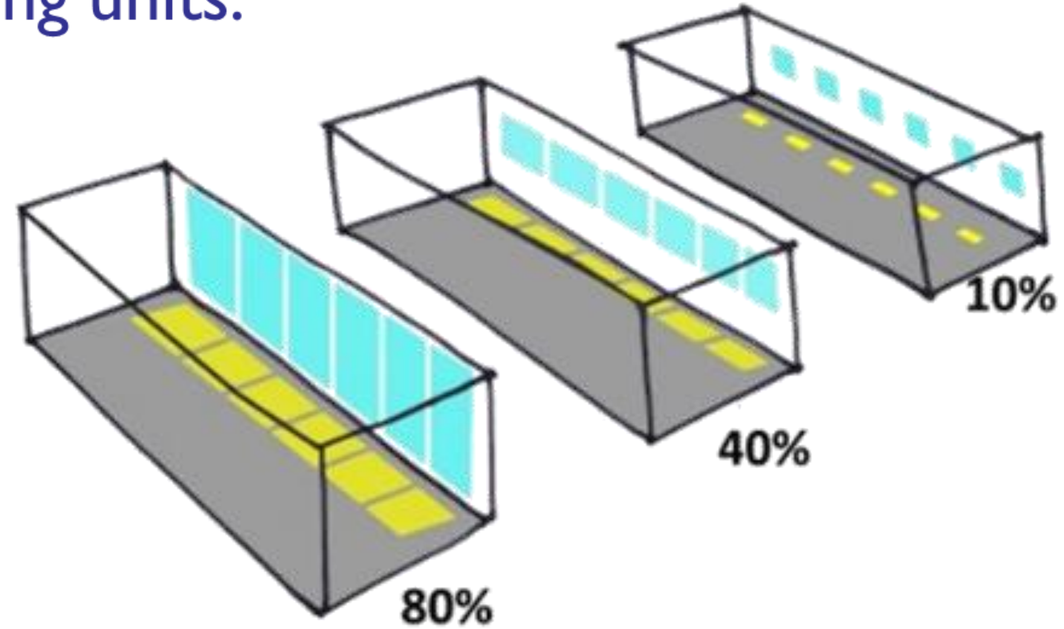
WINDOW TO FLOOR AREA RATIO

WFR_{OP} is Openable Window to Floor Area Ratio

Definition:

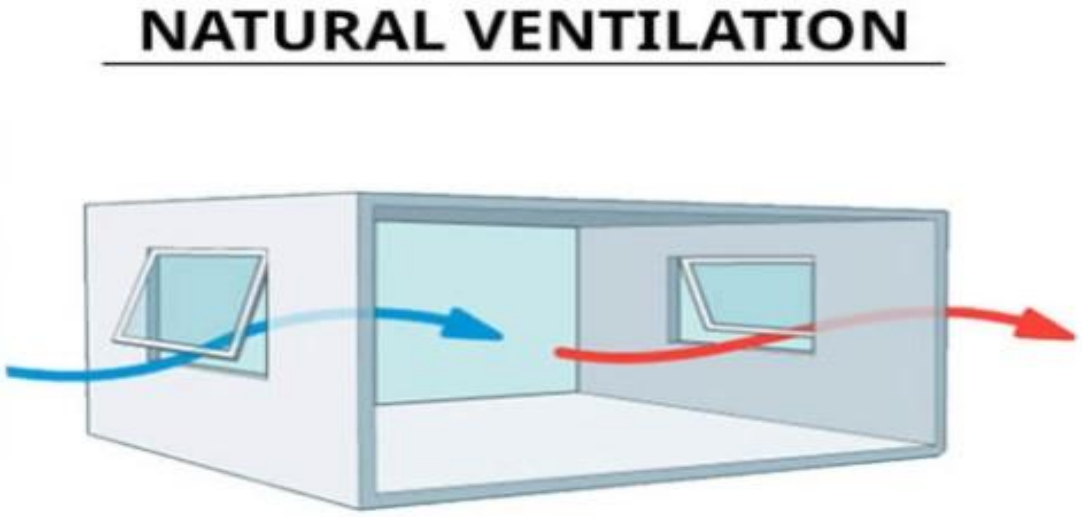
The openable window-to-floor area ratio (WFR_{op}) is the ratio of openable area to the carpet area of dwelling units.

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



WINDOW TO FLOOR AREA RATIO

- ✓ *Higher* WFR_{op} helps in enhancement in
- ✓ *Natural Ventilation*
- ✓ *Thermal comfort*
- ✓ *Cooling Energy Savings*



WINDOW TO FLOOR AREA RATIO CALCULATION

Calculation:

$$WFR = \frac{54}{100}$$

$$WFR = 0.54$$

$$= 54\%$$

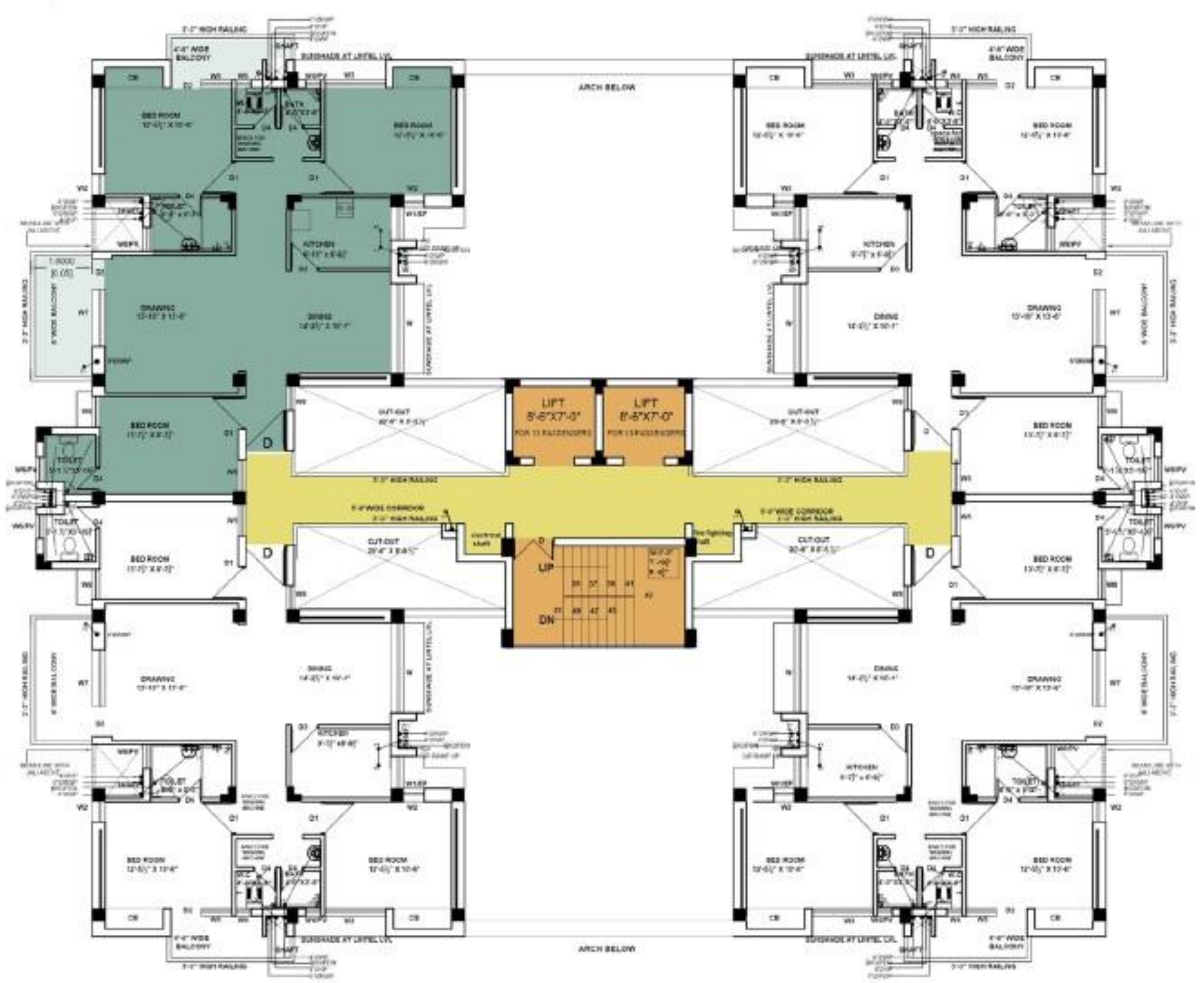
WINDOW TO FLOOR AREA RATIO REQUIREMENT

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

ENS CASE STUDY RESIDENTIAL QUARTER NABARD

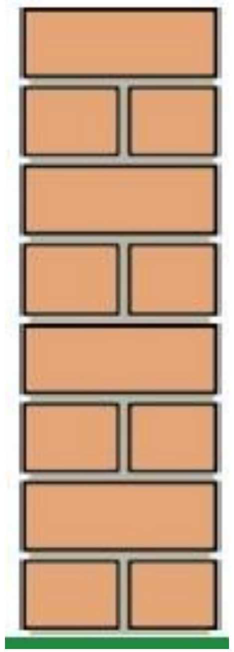
- Residential quarters built for the **NABARD** *(National Bank For Agriculture & Rural Development)* staff at Mohali.
- The climate type is composite and is similar to that of Chandigarh.

No. of dwelling units in Block II (DU): 20 (all 2 BHK) Stilt + 5 storeys



PLAN OF RESIDENTIAL QUARTER

Case I: 230 mm brick wall + Normal WWR + Single Clear Glazing + No Shading of Windows

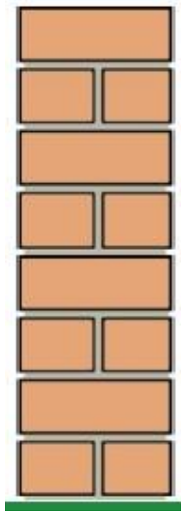


230mm Normal Brick wall with U value – 2 w/m²k

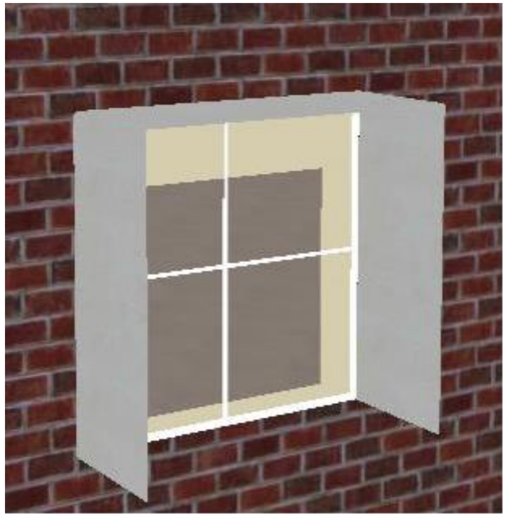
	RETV Wall conduction	RETV Window conduction	RETV Window Radiation	RETV (TOTAL)
Case.1 • Brick Wall • No Shading • Single clear glazing • WWR: ~14%	10.1	1.8	9.6	21.5

- **RETV: 21.5 W/m² higher than 15 W/m² (Non compliant)**
- **Heat conduction through wall is high and high heat gain through windows with no shading**

Case II: Case I + Proper Shading of Windows



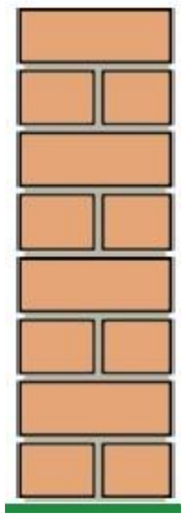
230mm Normal Brick wall with U value – 2 w/m^2k



	RETV Wall conduction	RETV Window conduction	RETV Window Radiation	RETV (TOTAL)
Case.2 • Brick Wall • **Shading with overhang & Fins** • Single clear glazing • WWR: ~14%	10.1	1.8	**6.7**	**18.6**

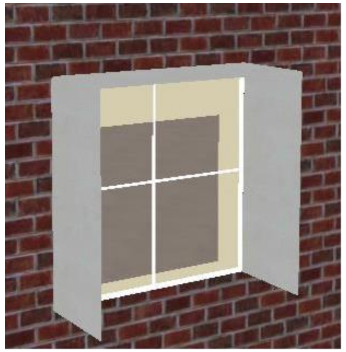
- **RETV = 18.6 W/m^2**
- **Shading helps in reducing heat gain through windows**

Case III: Case II+ Single reflective glass



230mm Normal Brick wall with U value – 2 w/m²k

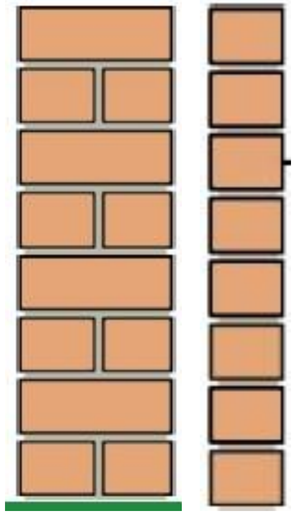
	RETV Wall conduction	RETV Window conduction	RETV Window Radiation	RETV (TOTAL)
Case.3 • Brick Wall • Shading with overhang & Fins • **Single reflective glazing** • WWR: ~14%	10.1	1.8	**4.5**	**16.3**



+

- **RETV = 16.3 W/m²**
- **High Reflective Glass also helps in reducing heat gain through windows**

Case IV: (Final Design Constructed) Brick cavity wall+ Shading+ Single reflective glass



230 mm + 40 mm cavity +115 mm brick with U value – 1.1 w/ m^2k

	RETV Wall conduction	RETV Window conduction	RETV Window Radiation	RETV (TOTAL)
Case.4 • **Brick Cavity Wall** • Shading with overhang & Fins • Single reflective glazing • WWR: ~14%	**6.6**	1.8	4.5	12.8

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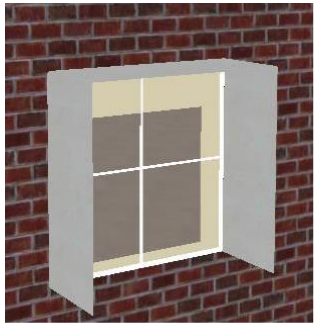

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- **RETV = 12.8 W/m^2**
- **Cavity in Brick reduces the conduction heat gain**

	RETV Wall conduction	RETV Window conduction	RETV Window Radiation	RETV (TOTAL)
Case.1 • Brick Wall • No Shading • Single clear glazing • WWR: ~14%	10.1	1.8	9.6	**21.5**
Case.2 • Brick Wall • **Shading with overhang & Fins** • Single clear glazing • WWR: ~14%	10.1	1.8	**6.7**	**18.6**
Case.3 • Brick Wall • Shading with overhang & Fins • **Single reflective glazing** • WWR: ~14%	10.1	1.8	**4.5**	**16.3**
Case.4 • **Cavity Brick Wall** • Shading with overhang & Fins • Single reflective glazing • WWR: ~14%	**6.6**	1.8	4.5	**12.8**
Case.5 • **AAC Block** • Shading with overhang & Fins • Single reflective glazing • WWR: ~14%	**4.7**	1.8	4.5	**10.9**

SESSION-3 (Continued..)

1. Eco Niwas Samhita *(ENS-2021, Electro-Mechanical, and Renewable Energy Systems)*

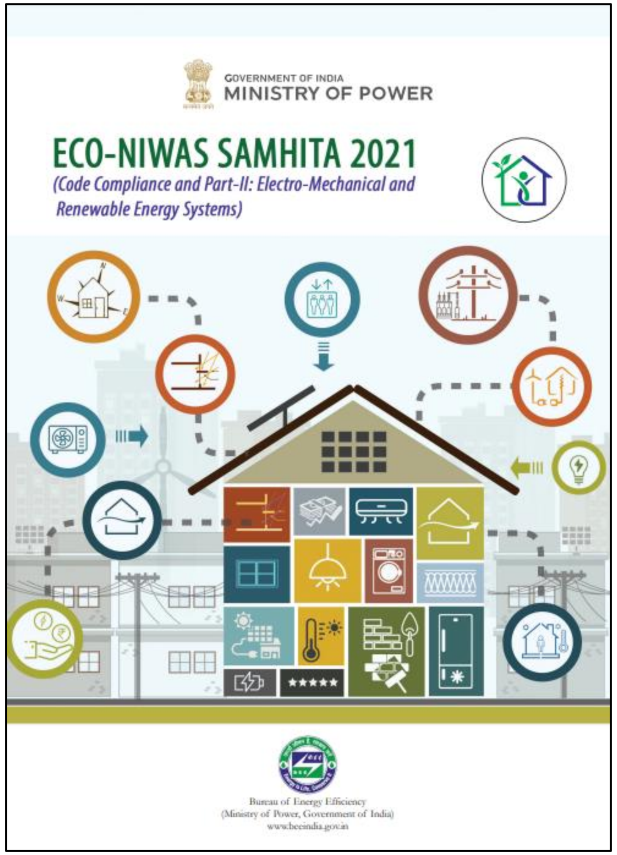
ENS(ECO NIWAS SAMHITA 2021 PART-2

Introduction

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.

ENS 2021 is for code compliance and to provide the minimum requirement(s) for:

1. ***Building services***
2. ***Electro-mechanical***
3. ***Renewable energy systems for new residential buildings.***



PART-2: **Building Services, Indoor Electrical Use, Renewable Energy Systems (launched in 2021)**

Note:-*The code sets minimum requirement for all building envelope parameters as mentioned in Eco Niwas Samhita 2018 (Part I: Building Envelope).*

ENS(ECO NIWAS SAMHITA 2021 PART-2

ENS-Part 2 Applicability

The ***ECO NIWAS SAMHITA 2021*** (based on the category of project) applies to the following essential design elements of a building:

- **Building envelope** (minimum performance requirements for RETV, Roof thermal Conductance, Window to floor area ratio and Visible Light Transmittance)
- **Building Services** (minimum performance criteria for common area lighting, lifts, pumps, DG Sets, Transformers, Car Parking etc)
- **Indoor Electrical** Use (maximum interior lighting power density allowance, minimum performance requirements for ceiling fans and cooling systems)
- **Renewable energy systems** (mandatory provisions for renewable systems in design).

ENS(ECO NIWAS SAMHITA 2021 PART-2

Mandatory Requirements

1. **Building Envelope-**All requirements for building envelope under mandatory section as mentioned in Chapter 4 of ENS Part I.

- Openable window to floor area ratio (WFR_{op})
- Visible light Transmittance*(VLT)*
- Thermal Transmittance of roof or U-Value of roof
- Residential Envelope transmittance Value*(RETV)*

2. **Power Factor Correction**
3. **Energy Monitoring**
4. **Electric Vehicle Charging System**
5. **Electrical Systems**

ENS(ECO NIWAS SAMHITA 2021 PART-2

Prescriptive Requirements

1. **Building Envelope-**All requirements for building envelope under mandatory section as mentioned in Chapter 4 of ENS Part I. The Residential Envelope Transmittance Value (RETV) for the building envelope (except roof) for four climate zones shall comply with the maximum RETV of 12 W/m2 . Thermal transmittance of building envelope for cold climate shall comply with the maximum U value of 1.3 W/m2 ·K.

- Openable window to floor area ratio (WFR_{op})
- Visible light Transmittance*(VLT)*
- Thermal Transmittance of roof or U-Value of roof
- Residential Envelope transmittance Value*(RETV)*

2. **Common Area and Exterior Lighting**

Common Areas	Maximum LPD (W/m²)	Minimum luminous efficacy (lm/W)
Corridor lighting & Stilt Parking	3.0	All the permanently installed lighting fixtures shall use lamps with an efficacy of at least 105 lumens per Watt
Basement Lighting	1.0	All the permanently installed lighting fixtures shall use lamps with an efficacy of at least 105 lumens per Watt

Exterior Lighting Areas	Maximum LPD (in W/m²)
Driveways and parking (open/ external)	1.6
Pedestrian walkways	2.0
Stairways	10.0
Landscaping	0.5
Outdoor sales area	9.0

Prescriptive Requirements

3. Elevators if Applicable

The Elevators installed in the ENS compliant building shall meet the following requirements:

i. Install high efficacy lamps for lift car lighting having minimum luminous efficacy of 85 lm/W

ii. Install automatic switch-off controls for lighting and fan inside the lift car when are not occupied

iii. Install minimum class IE 4 high efficiency motors

iv. Installing the variable voltage and variable frequency drives

v. Installing regenerative drives.

vi. Group automatic operation of two or more elevators coordinated by supervisory control

4. Pumps if Applicable

Either hydro-pneumatic pumps having minimum mechanical efficiency of 70% or BEE 5 star rated Pumps shall be installed in the ENS building.

ENS(ECO NIWAS SAMHITA 2021 PART-2

Prescriptive Requirements

5. Electrical Systems

Power transformers of the proper ratings and design must be selected to satisfy the minimum acceptable efficiency at 50% and full load rating. The permissible loss shall not exceed the values listed in Table 6 for dry type transformers and BEE 5-star rating in Table 7 for oil type transformers.

Openable Window-to-Floor Area Ratio (WFRop)

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

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

Note:

$A_{openable}$: **Openable area (m^2);** it includes the openable area of all windows and ventilators, opening directly to the external air, an open balcony, 'verandah', corridor or shaft; and the openable area of the doors opening directly into an open balcony.

Exclusions: All doors opening into corridors. External doors on ground floor, for example, ground-floor entrance doors or back-yard doors.

A_{carpet} : **Carpet area of dwelling units (m^2);** it is the net usable floor area of a dwelling unit, excluding the area covered by the external walls, areas under services shafts, exclusive balcony or verandah area and exclusive open terrace area, but includes the area covered by the internal partition walls of the dwelling unit

ENS(ECO NIWAS SAMHITA 2021 PART-2

Openable Window-to-Floor Area Ratio (WFRop)

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

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

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

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

ENS(ECO NIWAS SAMHITA 2021 PART-2

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 roof) of dwelling units.

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

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

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

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

ENS(ECO NIWAS SAMHITA 2021 PART-2

Thermal transmittance Roof

- **Thermal transmittance (U-roof)** characterizes the thermal performance of the roof assembly of a building.
- Limiting the Uroof 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 roof shall comply with the maximum U-roof value of 1.2 W/m2.K

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

where,

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

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

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

A_i : areas of different roof constructions (m²)

ENS(ECO NIWAS SAMHITA 2021 PART-2

Residential envelope transmittance value (RETV)

- Applicable for building envelope (except roof) for four climate zones, namely, Composite Climate, Hot-Dry Climate, Warm-Humid Climate, and Temperate Climate.
- **Residential envelope heat transmittance (RETV)** is the net heat gain rate (over the cooling period) through the building envelope (excluding roof) of the dwelling units divided by the area of the building envelope (excluding roof) of the dwelling units.
- Its unit is W/m2
- RETV characterizes the thermal performance of the building envelope (except roof).
- Limiting the RETV value helps in reducing heat gains from the building envelope, thereby improving the thermal comfort and reducing the electricity required for cooling.

ENS(ECO NIWAS SAMHITA 2021 PART-2

Residential envelope transmittance value (RETV)

RETV formula takes into account the following:

- Heat conduction through opaque building envelope components (wall, opaque panels in doors, windows, ventilators, etc.),
- Heat conduction through non-opaque building envelope components (transparent/ translucent panels of windows, doors, ventilators, etc.),
- Solar radiation through non-opaque building envelope components (transparent/translucent panels of windows, doors, ventilators, etc.)
- The RETV for the building envelope (except roof) for four climate zones, namely, Composite Climate, Hot-Dry Climate, Warm-Humid Climate, and Temperate Climate, shall comply with the maximum RETV* of 15 W/m2.

**BEE plans to improve the RETV norm to 12 W/m^2 in the near future and the building industry and regulating agencies are encouraged to aim for it.*

ENS(ECO NIWAS SAMHITA 2021 PART-2

Residential envelope transmittance value (RETV)

$$RETV = \frac{1}{A_{envelope}} \times \left[\begin{array}{l} \left\{ a \times \sum_{i=1}^{n} \left(A_{opaque_i} \times U_{opaque_i} \times \omega_i \right) \right\} \\ + \left\{ b \times \sum_{i=1}^{n} \left(A_{non-opaque_i} \times U_{non-opaque_i} \times \omega_i \right) \right\} \\ + \left\{ c \times \sum_{i=1}^{n} \left(A_{non-opaque_i} \times SHGC_{eq_i} \times \omega_i \right) \right\} \end{array} \right]$$

$\boldsymbol{A_{envelope}}$ **:** Envelope area (excluding roof) of dwelling units (m2). It is the gross external wall area (includes the area of the walls and the openings such as windows and doors).

$\boldsymbol{A_{opaque}}$ **:** Areas of different opaque building envelope components (m^2)

$\boldsymbol{U_{opaque}}$: thermal transmittance values of different opaque building envelope components ($W/m^2.K$)

$\boldsymbol{A_{non-opaque}}$ **:** Areas of different non-opaque building envelope components (m^2)

$\boldsymbol{U_{non-opaque}}$ **:** Thermal transmittance values of different non-opaque building envelope components ($W/m^2.K$)

$\boldsymbol{SHGC_{eqi}}$: Equivalent solar heat gain coefficient values of different non-opaque building envelope components

$\boldsymbol{\omega_i}$: Orientation factor of respective opaque and non-opaque building envelope components; it is a measure of the amount of direct and diffused solar radiation that is received on the vertical surface in a specific orientation

ENS(ECO NIWAS SAMHITA 2021 PART-2

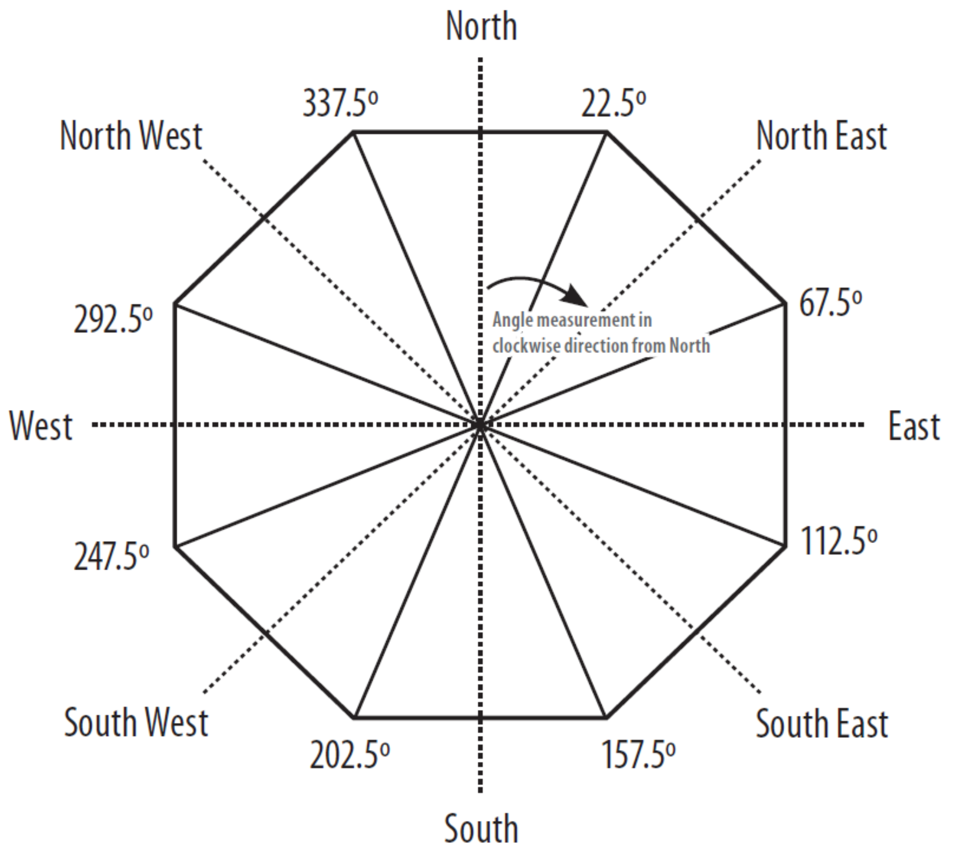
Residential envelope transmittance value (RETV)

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

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

Orientation factor (ω) for different orientations

	Orientation factor (ω)	
Orientation	Latitudes ≥23.5°N	Latitudes <23.5°N
North (337.6°–22.5°)	0.550	0.659
North-east (22.6°–67.5°)	0.829	0.906
East (67.6°–112.5°)	1.155	1.155
South-east (112.6°–157.5°)	1.211	1.125
South (157.6°–202.5°)	1.089	0.966
South-west (202.6°–247.5°)	1.202	1.124
West (247.6°–292.5°)	1.143	1.156
North-west (292.6°–337.5°)	0.821	0.908



Thermal Transmittance of building envelope (except roof) for cold climate (Uenvelope,cold)

- Thermal transmittance ($U_{envelope,cold}$) characterizes the thermal performance of the building envelope (except roof). Limiting the $U_{envelope,cold}$ helps in reducing heat losses from the building envelope, thereby improving the thermal comfort and reducing the energy required for heating

- Thermal transmittance of the building envelope (except roof) for cold climate shall comply with **the maximum of 1.8 W/m^2.K.**

$$U_{envelope,cold} = \frac{1}{A_{envelope}} \left[\sum_{i=1}^{n} (U_i \times A_i) \right] \quad ...(5)$$

where,

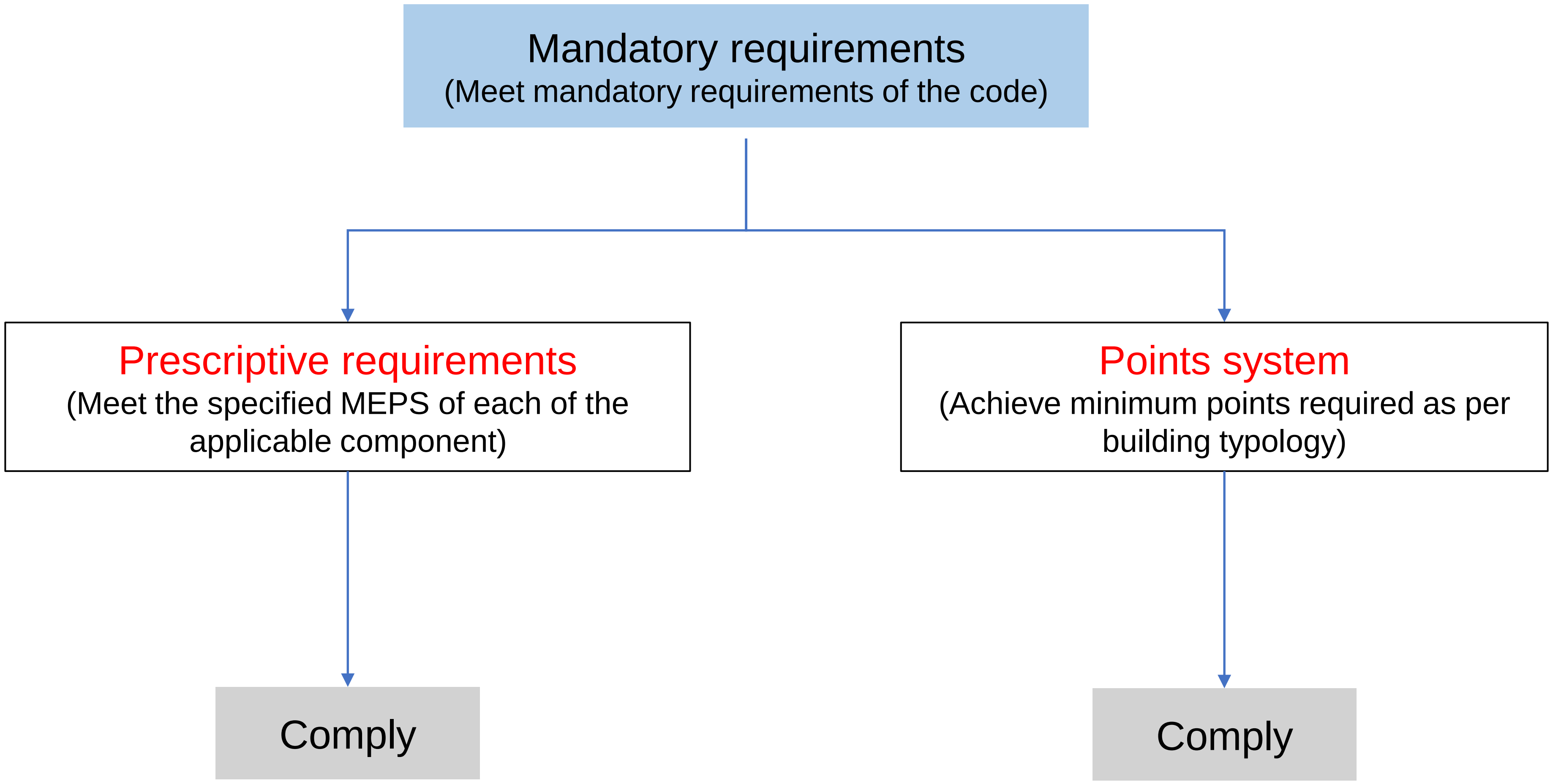
$U_{envelope,cold}$: thermal transmittance of building envelope (except roof) for cold climate (W/m^2.K)

$A_{envelope}$: envelope area (excluding roof) of dwelling units (m^2). It is the gross external wall area (includes the area of the walls and the openings such as windows and doors)

U_i : thermal transmittance of different opaque and non-opaque building envelope components (W/m^2.K)

A_i : area of different opaque and non-opaque opaque building envelope components (m^2)

Code Compliance



ENS(ECO NIWAS SAMHITA 2021 PART-2

Applicable components as per compliance method

- In order to demonstrate compliance with the code through the ***Prescriptive Method***, the ENS building shall meet mandatory requirements specified along with prescriptive requirements.
- In order to demonstrate compliance with the code through the ***Point System Method***, the ENS building shall meet all applicable mandatory requirements along with point system requirements.

		Mandatory	Prescriptive	Point System
1	**Envelope**			
1.1	RETV		✓	✓
1.2	Building Envelope Cold (Uenvelope)		✓	✓
1.3	U-value Roof		✓	✓
1.4	WFRop	✓		
1.5	VLT	✓		
2	**Building Services**			
2.1	Common area & Exterior Lighting			
2.1.1	Outdoor Lighting		✓	✓
2.1.2	Corridor Lighting		✓	✓
2.1.3	Basement Lighting		✓	✓
2.2	Lifts		✓	✓
2.3	Pumps		✓	✓
2.4	DG Set	✓		
2.5	PD Losses	✓		
2.5	Transformer		✓	✓
2.6	Power Factor Correction	✓		
2.7	Electric Vehicle Supply Equipment	✓		
2.8	Energy Monitoring	✓		
3	**Indoor Electrical End Use**			
3.1	Indoor Lighting			✓
3.3	Comfort Systems			
3.3.1	Ceiling Fans			✓
3.3.2	AC			✓
3.3.3	VRF			✓
3.3.4	Centralised Air-Conditioning System			✓
4	**Renewable Energy System**			
4.1	Solar HW			✓
4.2	Solar PV			✓

ENS(ECO NIWAS SAMHITA 2021 PART-2

Different scores based on the project types and typologies

In order to demonstrate compliance with the code, the ENS building shall comply with all applicable mandatory requirements and shall achieve a minimum ENS Score by following either the prescriptive method or the point system method. The table below gives the minimum ENS score required to be obtained as per eligible project category:

Project Category	Minimum ENS Score
Affordable high-rise housing	70
Low-rise buildings*	47
Other High-rise buildings	100

*Low-rise buildings should only meet envelope requirements to show ENS compliance

Affordable housing: Housing projects where 35% of the houses are constructed for EWS category (PMAY Definition)

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

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

ENS(ECO NIWAS SAMHITA 2021 PART-2

ENS-Part 2 Component wise score distribution for compliance

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

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

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

ENS(ECO NIWAS SAMHITA 2021 PART-2

Final Point System

- Envelope
- Building Services
- Indoor Electrical End Use
- Renewable Energy System

		Always Applicable/Elective	Minimum Points	Essential Points	Additional Points	Maximum
1	**Envelope**					87
1.1	RETV or Building Envelope Cold	Applicable	44	44	36	80
1.2	U-value Roof	Applicable	3	3	4	7
1.3	WFRop	Applicable				
1.4	VLT	Applicable				
2	**Building Services**					51
2.1	Common area Lighting	Applicable	3	3	6	9
2.1.1	Outdoor Lighting	Meet minimum requirements, as applicable				
2.1.2	Corridor Lighting	Meet minimum requirements, as applicable				
2.1.3	Basement Lighting	Meet minimum requirements, as applicable				
2.2	Lifts	Applicable	13	13	9	22
2.3	Pumps	Applicable	6	6	8	14
2.4	Transformer	Applicable	1	1	5	6
3	**Indoor Electrical End Use**					62
3.1	Indoor Lighting	Meet minimum requirements, as applicable	4		8	12
3.2	Comfort Systems	Meet minimum requirements, as applicable	26		24	50
TOTAL						200
4	**Renewable Energy System**					20
4.1	Solar HW	Meet minimum requirements, as applicable				10
4.2	Solar PV	Meet minimum requirements, as applicable				10

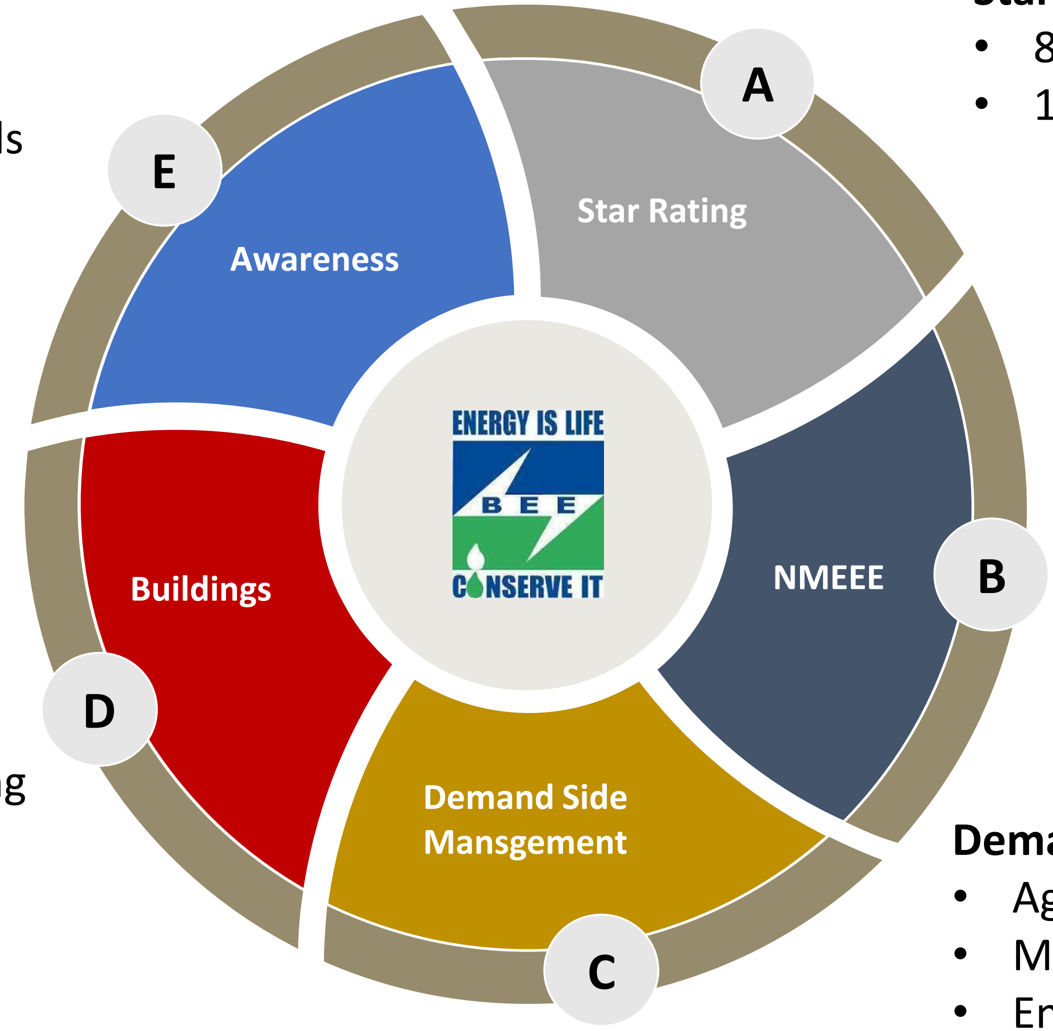
SESSION-5

1. *BEE Star Labelling*
2. *Low Energy Comfort System and Best Practices*

BUREAU OF ENERGY EFFICIENCY (BEE) AND STAR LABELLING

BEE PORTFOLIO

Awareness
- Energy Conservation Awards
- Painting Competition
- State Designated Agencies



Star Rating of Appliances
- 8 Mandatory Labelled Appliances
- 13 Voluntary Labelled Appliances

National Mission for Enhanced Energy Efficiency
- Perform, Achieve & Trade (PAT)
- Market Transformation for Energy Efficiency (MTEE)
- Framework for Energy Efficient Economic Development (FEEED)
- Energy Efficiency Financing Platform (EEFP)

Buildings
- Energy Conservation Building Codes
- Retrofit in old buildings
- Residential Building Guidelines

Demand Side Management
- Agriculture DSM
- Municipal DSM
- Energy Efficiency in SMEs

BEE STAR LABELLING FOR RESIDENTIAL BUILDING

About the Program

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

Objective of the Program

The objective of the program is to provide:-

- Information to consumers on the energy efficiency standard of the Homes.
- Facilitation in the implementation of Eco-Niwas Samhita 2018 and2021
- A consumer-driven market transformation business model solution for Energy Efficiency in the housing sector
- Steering the construction activities of India towards international best practices norms

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

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

Ministry of Housing and Urban Affairs
Government of India

आज़ादी का अमृत महोत्सव

bmtpc

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

BEE STAR LABELLING FOR RESIDENTIAL BUILDING

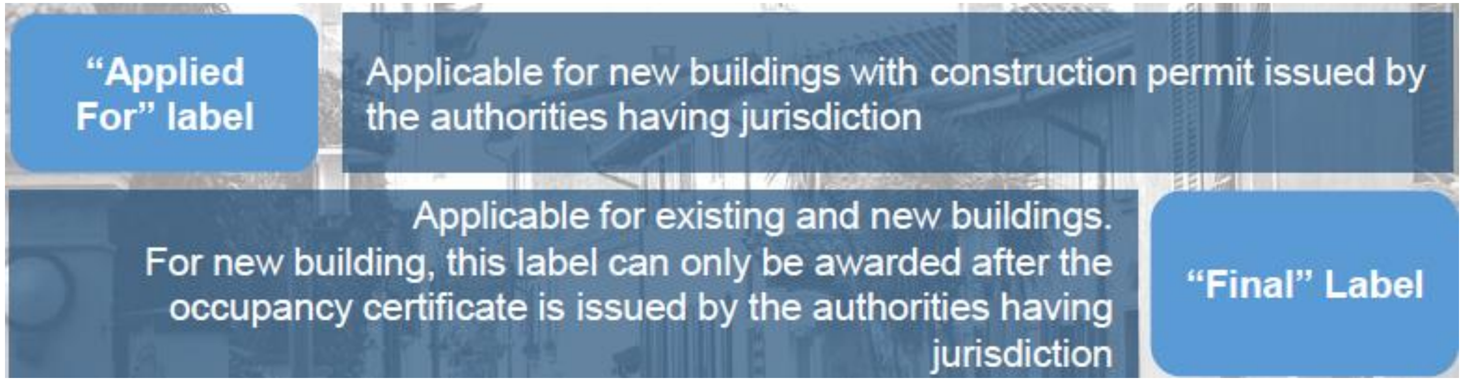
Benefits from the Labelling Program

Cumulative saving of 388 billion units of electricity by 2030

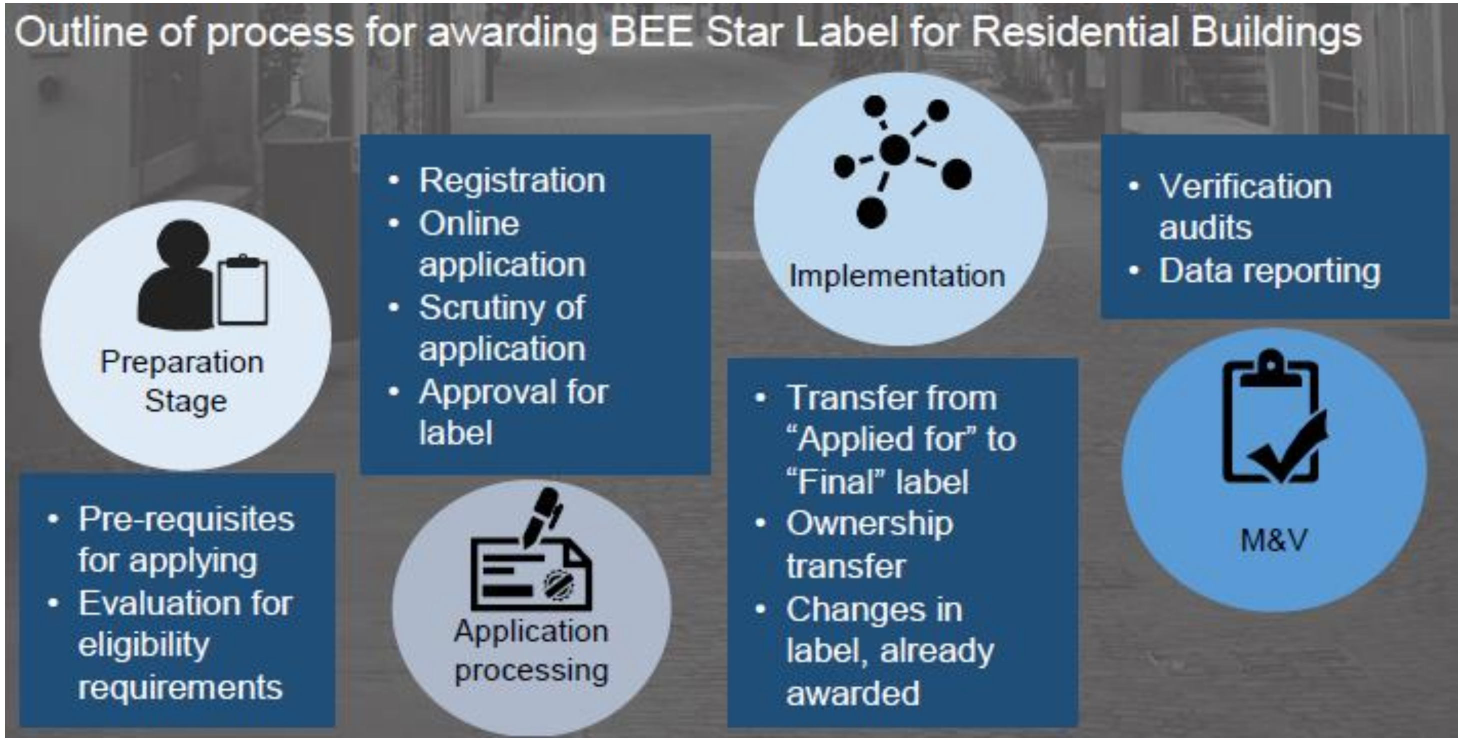
- Reduction of carbon emission by 3 billion tones by 2030
- Increased uptake of energy-efficient construction in India
- Facilitate energy-efficient materials and technologies market supporting the “Make in India” initiative
- Improve environmental resilience and energy security
- Sustainable living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

BEE STAR LABELLING FOR RESIDENTIAL BUILDING

Labelling types



Labelling Process

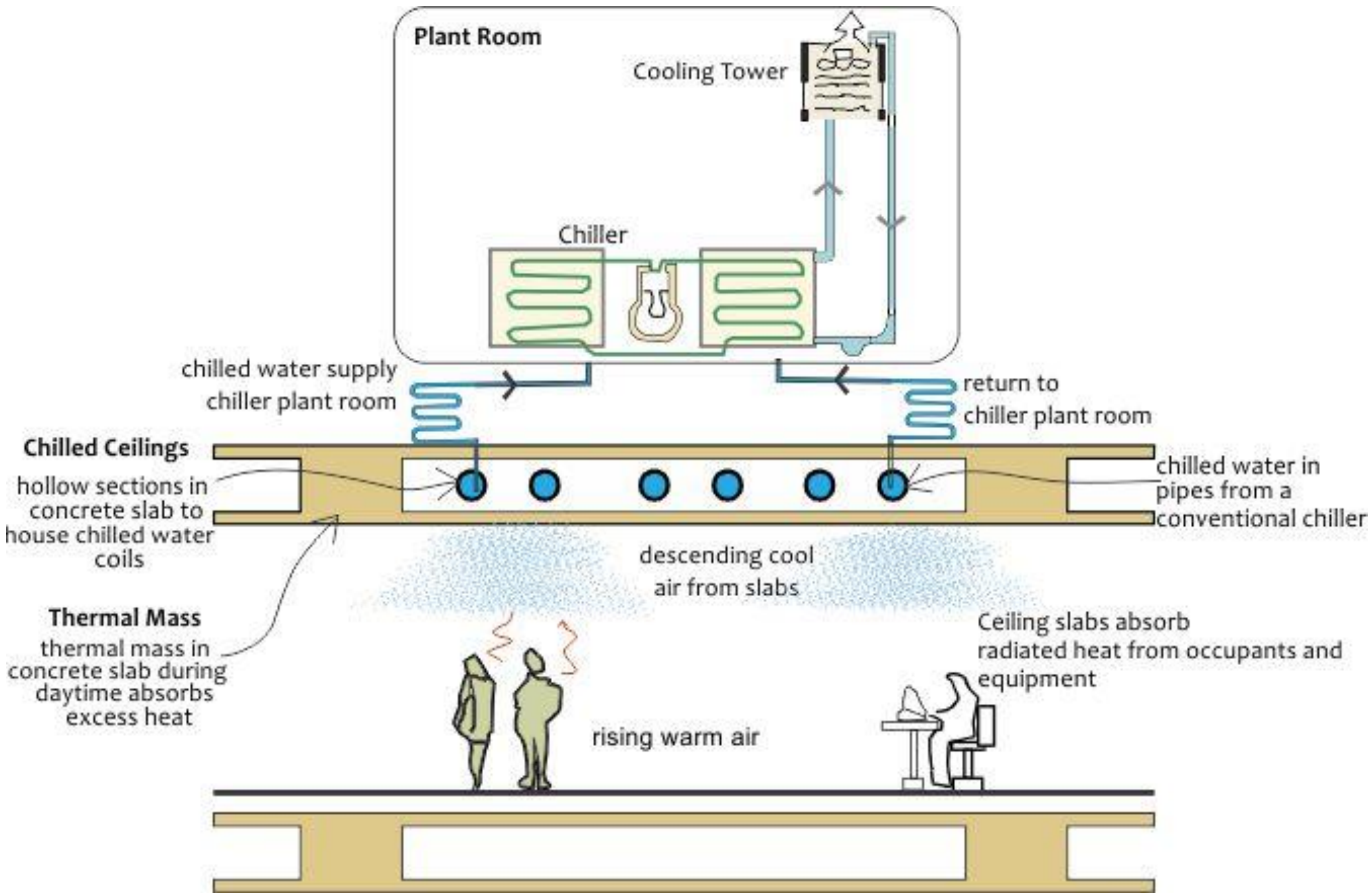


LOW ENERGY COMFORT SYSTEM

Radiant and Structure Cooling

- ✓ Radiant Cooling is based on the physical principle, that bodies with varying temperatures exchange thermal radiation until an equilibrium is achieved.

- ✓ Radiant cooling systems work by circulating chilled water through a network of polymer pipes installed on floors, walls, or ceilings.



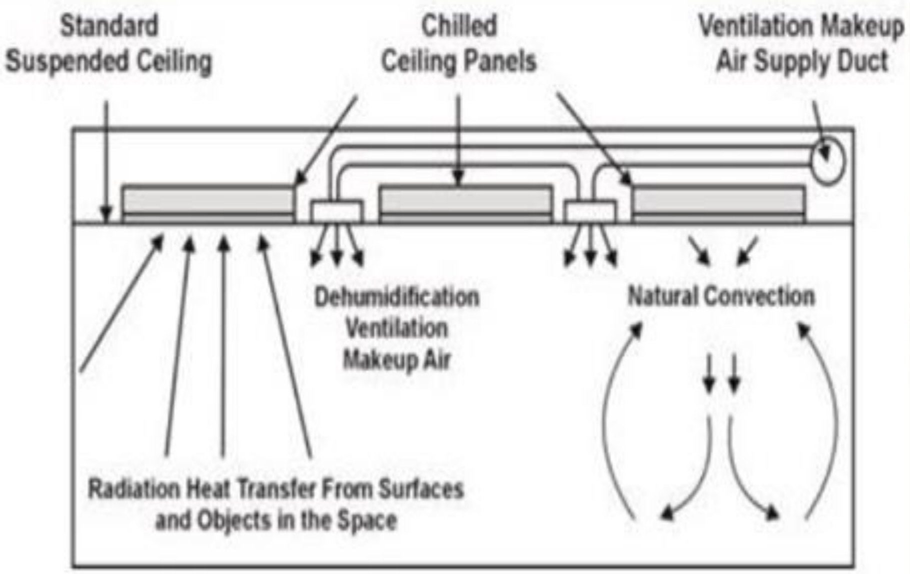
LOW ENERGY COMFORT SYSTEM

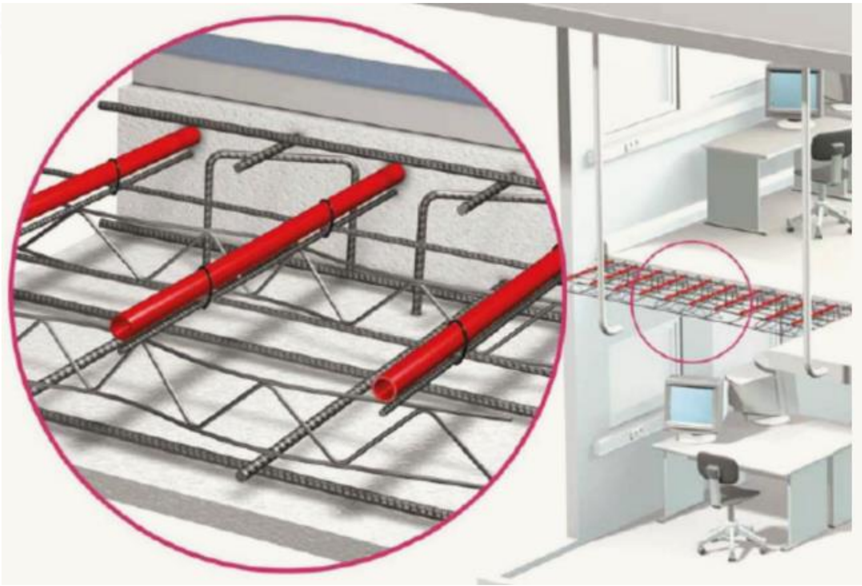
Radiant and Structure Cooling

Types of radiant cooling:

1. **Chilled slabs:** These deliver cooling through the building structure, usually slab, and are also known as thermally activated building systems.
2. **Ceiling panels:** These deliver cooling through specialized panels.

✓ Systems using concrete slabs are generally cheaper than panel systems and offer the advantage of thermal mass while panel systems offer faster temperature control and flexibility.





Chilled ceiling suspended panels and Structure cooling

LOW ENERGY COMFORT SYSTEM

Case Study Jaquar Global Headquarters, Manesar

Jaquar Group, a leading sanitary ware manufacturer, developed a net-zero energy campus spread over 12 acres that houses their manufacturing facility and business development office.

- ✓ The facility uses a radiant cooling system with 1,20,000m of piping.
- ✓ The system provides 181TR of the total cooling load of 422TR.
- ✓ Compared to a conventional system, the radiant cooling system uses 30 percent less energy.
- ✓ The system handles diverse loads by serving both offices and the manufacturing plant, demonstrating the versatility and robustness of the system.
- ✓ The site also generates power through solar PV.

LOW ENERGY COMFORT SYSTEM

Case Study School of Architecture, Vellore Institute of Technology, Vellore

The VIT School of Architecture sought a low-energy solution to meet its cooling requirement.

- ✓ Its 10,000m2 area would have required an air-conditioning installation of at least 500TR, but the school adopted structure cooling instead.
- ✓ The Network of pipes was embedded in the concrete structure; these were connected to a two-stage cooling tower rather than a chiller.
- ✓ The system provides an internal temperature range of 26-300C.
- ✓ The building is naturally ventilated and ceiling fans enhance thermal comfort.
- ✓ The structure cooling used here yielded > 80% energy savings and paid for itself within one year.

LOW ENERGY COMFORT SYSTEM

Ground source heat pumps (GSHPs)

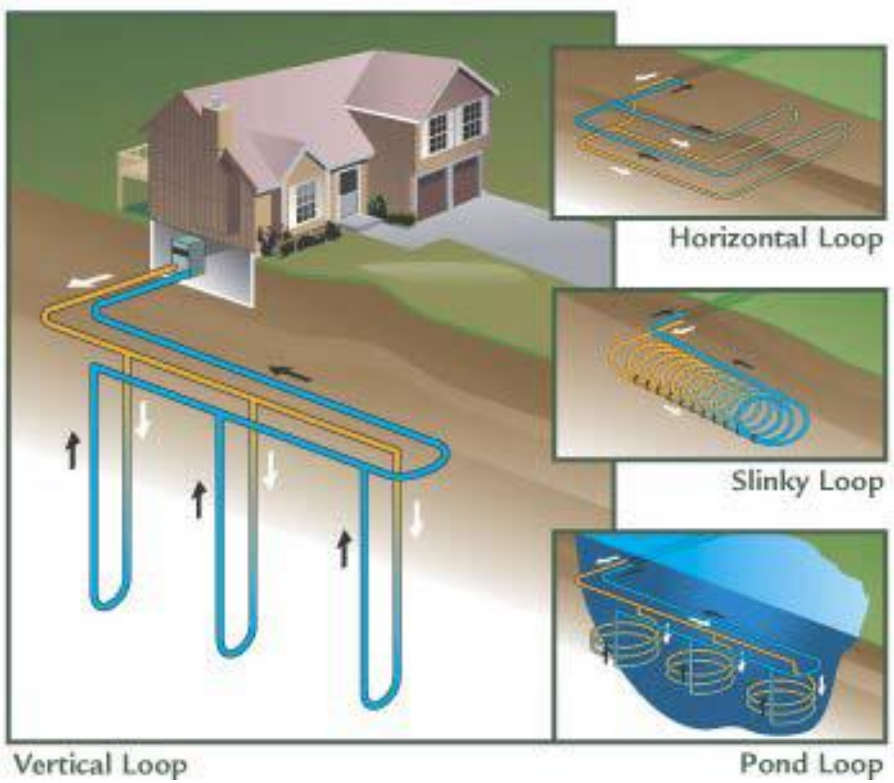
The transfer of energy to and from the earth for the purposes of heating or cooling a building or process. A Ground Source Heat Pump System consists of a water-to-air or water-to-water heat pump, connected to a series of long plastic pipe buried below the earth's surface, or placed in a pond.

Cooling In the summer

The system reverses and expels heat from your home to the cooler earth via the loop system. This heat exchange process is not only natural but is a truly ingenious and highly efficient way to create a comfortable climate in your home.

Heating-In winter

Water circulating inside a sealed loop absorbs heat from the earth. Here it is compressed to a higher temperature and sent as warm air to your indoor system for distribution throughout your home.



LOW ENERGY COMFORT SYSTEM

Case Study Metro Bhavan, Nagpur

The head office of Maha-Metro (Maharashtra Metro Rail Corporation Limited) is an energy-efficient building with rooftop solar PV and a net-zero water design.

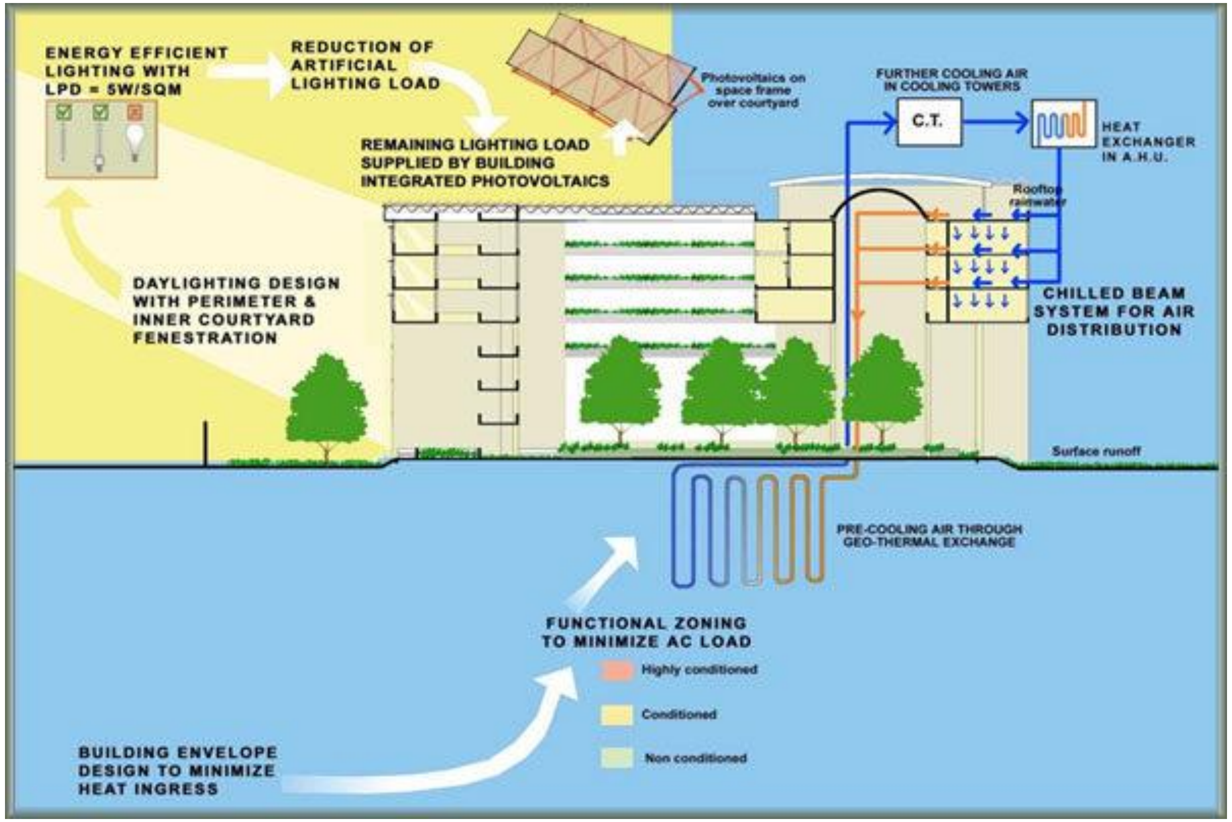
- ✓ The building is cooled by a horizontal loop GSHP that handles a 175TR cooling load with a power consumption of 0.6kW/TR (an equivalent air-cooled chiller would use 1.6kW/TR).
- ✓ The system was installed at an additional cost of ₹22 million and is projected to yield savings of ₹5.1 million of annual operational cost and payback in 3.2 years.
- ✓ Apart from the low operational energy use and low maintenance cost, the building's GSHP also benefits from a long service period (25 years), much higher than that for air-cooled chillers (12-13 years). The system is projected to generate over ₹110 million in its lifetime.

LOW ENERGY COMFORT SYSTEM

Case Study Indira Paryavaran Bhawan, New Delhi

This building houses the Ministry of Environment, Forest and Climate Change. Built in 2013, it is India’s first net zero energy building. EPI is 44 kWh/m^2/yr

- ✓ A vertical GSHP system consisting of 180 vertical borewells, each 80 m deep and 3 m apart.
- ✓ 160 TR of air conditioning load of the building is met through Chilled beam system. Chilled beam are used from second to sixth floor. This reduces energy use by 50 % compared to a conventional system.
- ✓ HVAC load of the buildings is 40 m2/TR, about 50% more efficient than ECBC requirements (20 m2/TR).
- ✓ One U-Loop has 0.9 TR heat rejection capacity. Combined together, 160 TR of heat rejection is obtained without using a cooling tower.

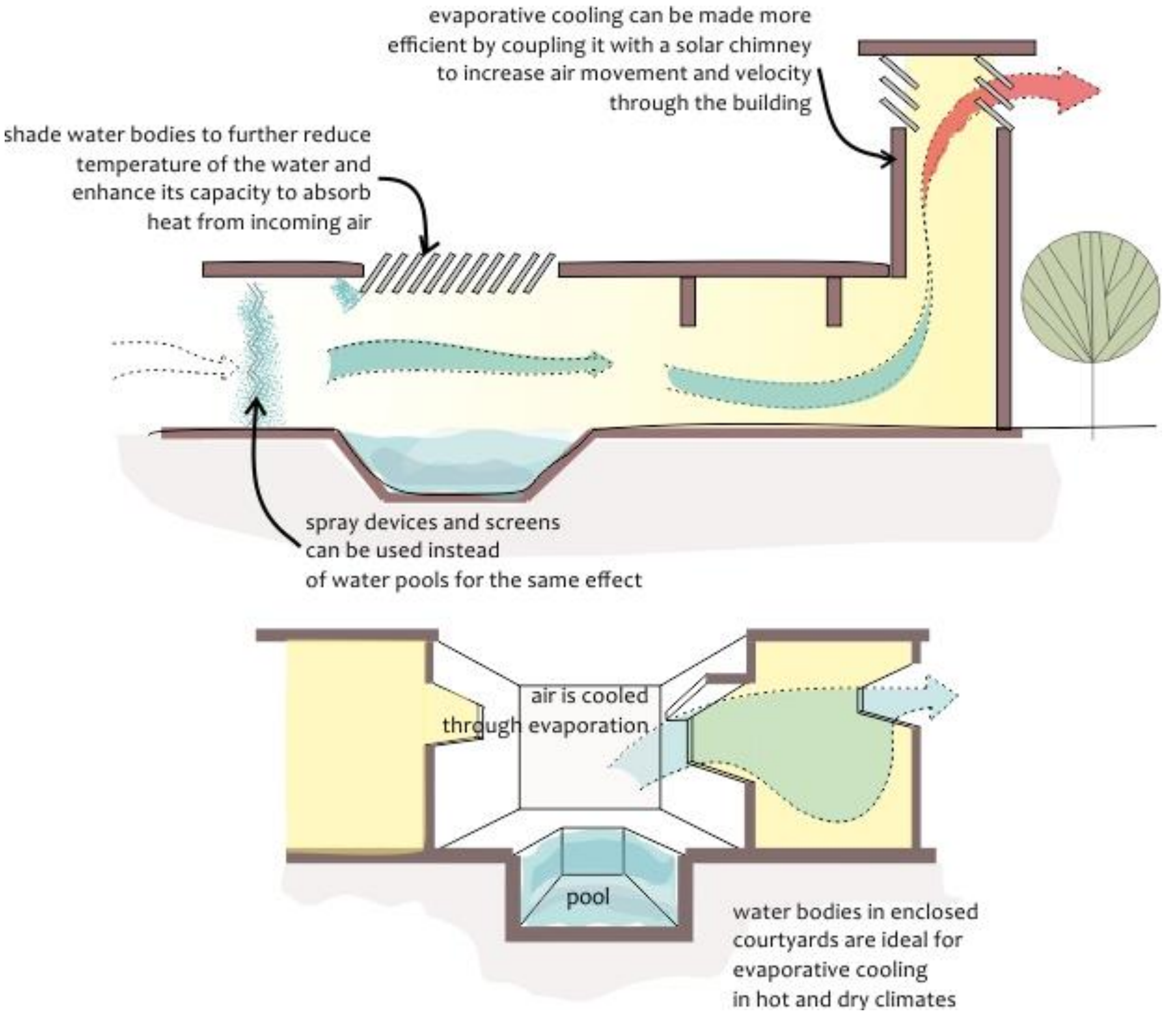


LOW ENERGY COMFORT SYSTEM

Evaporative cooling (Direct/Indirect)

Evaporative cooling is based on the principle that water evaporates by absorbing heat from the surroundings. When air is passed over a water surface, evaporation results in the cooling of the air stream.

- ✓ When hot outdoor air is passed through the cooling medium, sensible heat from the air is extracted to evaporate the water flowing through it.
- ✓ Water passing through the cooling media evaporates into the air, reducing its temperature and producing a cooling effect and increasing the air's humidity.
- ✓ Evaporative cooling is most effective in hot and dry climates where water easily evaporates.

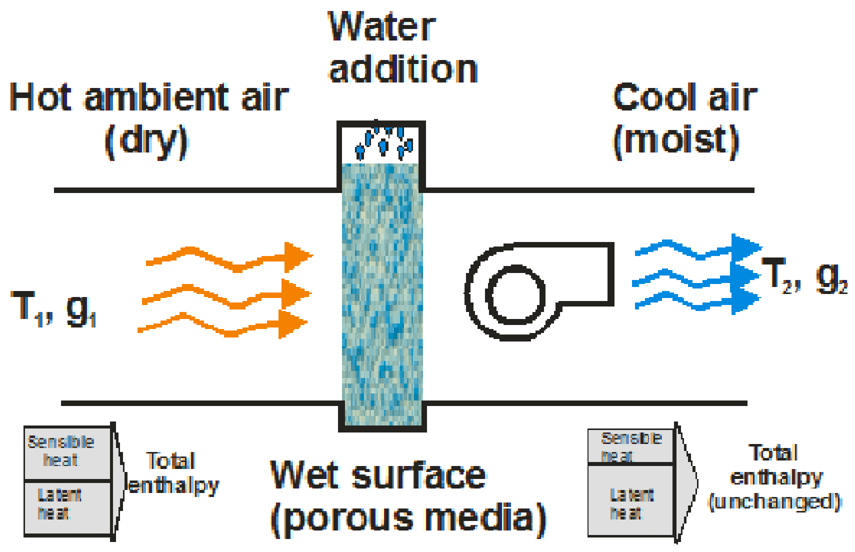


LOW ENERGY COMFORT SYSTEM

Evaporative cooling (Direct/Indirect)

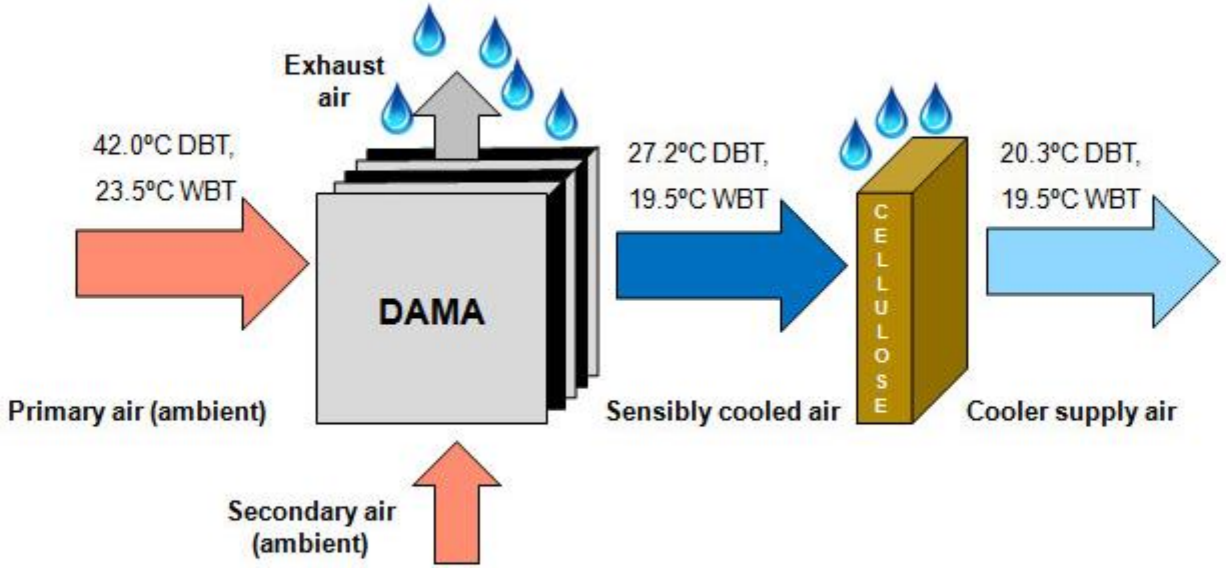
The performance of an evaporative cooling system is dependent on several critical parameters:

1. Difference in dry-bulb and wet-bulb temperature of outdoor air
2. Efficiency of the cooling media
3. Flow rate of air through system



✓ In composite climates evaporative cooling systems can be used to reduce HVAC system use during early summer months when the temperatures are high and humidity is low.

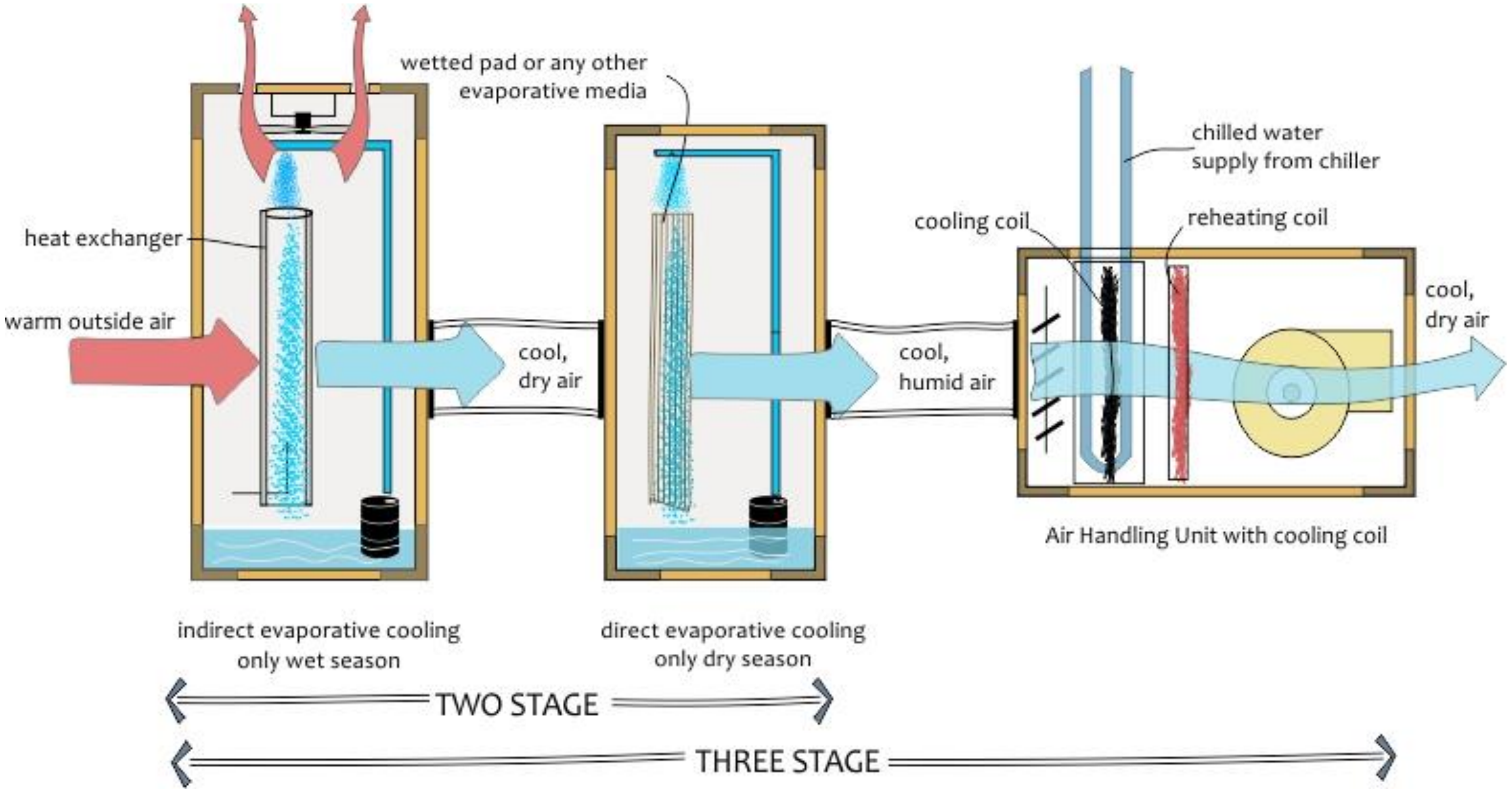
2-Stage or Indirect/Direct Evaporative Cooling



LOW ENERGY COMFORT SYSTEM

Evaporative cooling (Direct/Indirect)

- ✓ The direct system could be functional during the dry season, when humidification of air is required, and indirect system can be used when air primarily needs to be cooled.



- ✓ The addition of cooling coils (chilled water or refrigerants) is helpful in monsoon season when the humidity level is high and dehumidification is required. Fresh air passed through the coils controls both sensible and latent heat requirements. The coils are also useful in winter season when some heating is also required.

LOW ENERGY COMFORT SYSTEM

Case Study ST Mary School Pune

The school sought a low-cost, low-energy and low-noise solution to provide thermal comfort inside a 500m2 auditorium being added to the existing structure. Conventional air-conditioning solutions required high capital investment and higher operational cost.

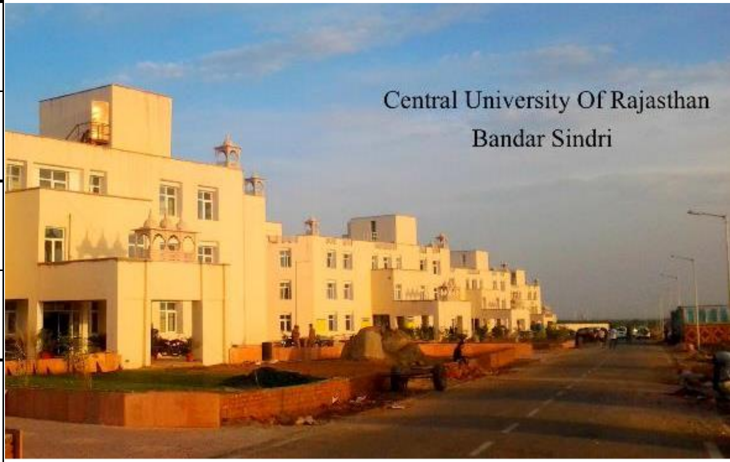
Hence, the school decided to install an IDEC system with a total capacity of 44,000CFM providing 100% fresh air to the space.

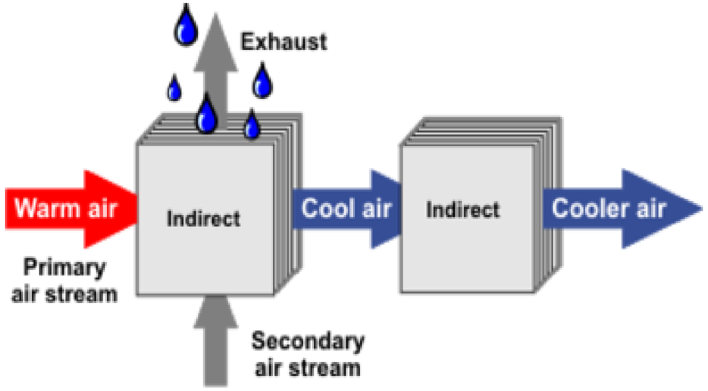
- ✓ The system was able to maintain 26 degree Celsius during its commissioning in peak summer when the outdoor dry-bulb temperature was 36 degree Celsius.
- ✓ The system consumes less than half the energy consumed by a conventional air-conditioning system. Post-occupancy evaluation of the auditorium revealed high levels of satisfaction towards thermal comfort and indoor air quality.

LOW ENERGY COMFORT SYSTEM

Case Study Central University of Rajasthan

Case study	**Central University of Rajasthan**
Location	Bandar Sindri, Ajmer, Rajasthan, India
Climate Type	Hot and dry
Building Type	Residential
System Description	Two stage evaporative cooling System consists of a direct evaporative pre cooler which provides cool and wet air to indirectly cool down the primary air in the tube bundle heat exchanger. The cool and dry air is then passed through a direct evaporative cooler to humidify it.
System Performance	Energy consumption in the hostel building is estimated to have been reduced to 1/3rd of a similar building with no major energy conservation measures and using conventional air-conditioning systems. Indoor temperatures were measured to be between 31 °C to 34 °C when the ambient was approximately 44 °C. Energy Performance Index was measured to be 60 – 65 kWh/m^2/year (2012)





THANK YOU!