GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

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

Ministry of Housing and Urban Affairs
Government of India

Azadi Ka Amrit Mahotsav

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Climate Responsive and Sustainable Buildings

November 2023

Climate Smart Buildings Cell | GIZ

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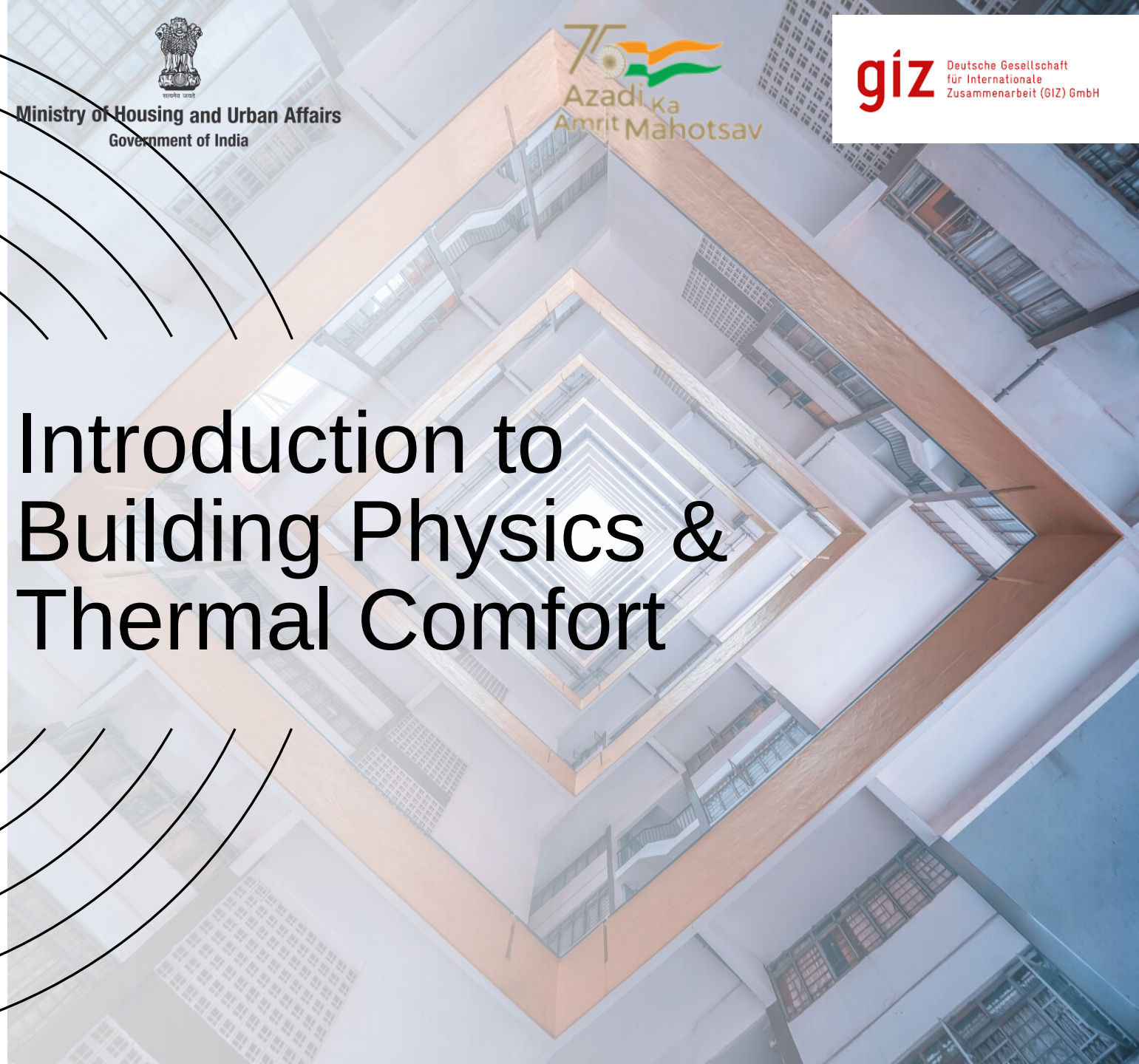
01

Introduction to Building Physics & Thermal Comfort

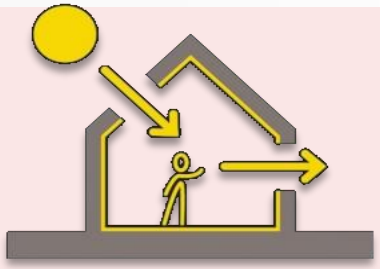


Importance of Buildings

Buildings are designed for ***PEOPLE,*** and for specific ***TASK***

- The building needs to keep people *comfortable, efficient, healthy*.
- *Energy Efficient design* seeks to create buildings that keep people *comfortable* while minimizing ***Energy Consumption*****.**
- Comfort categories:

Thermal comfort

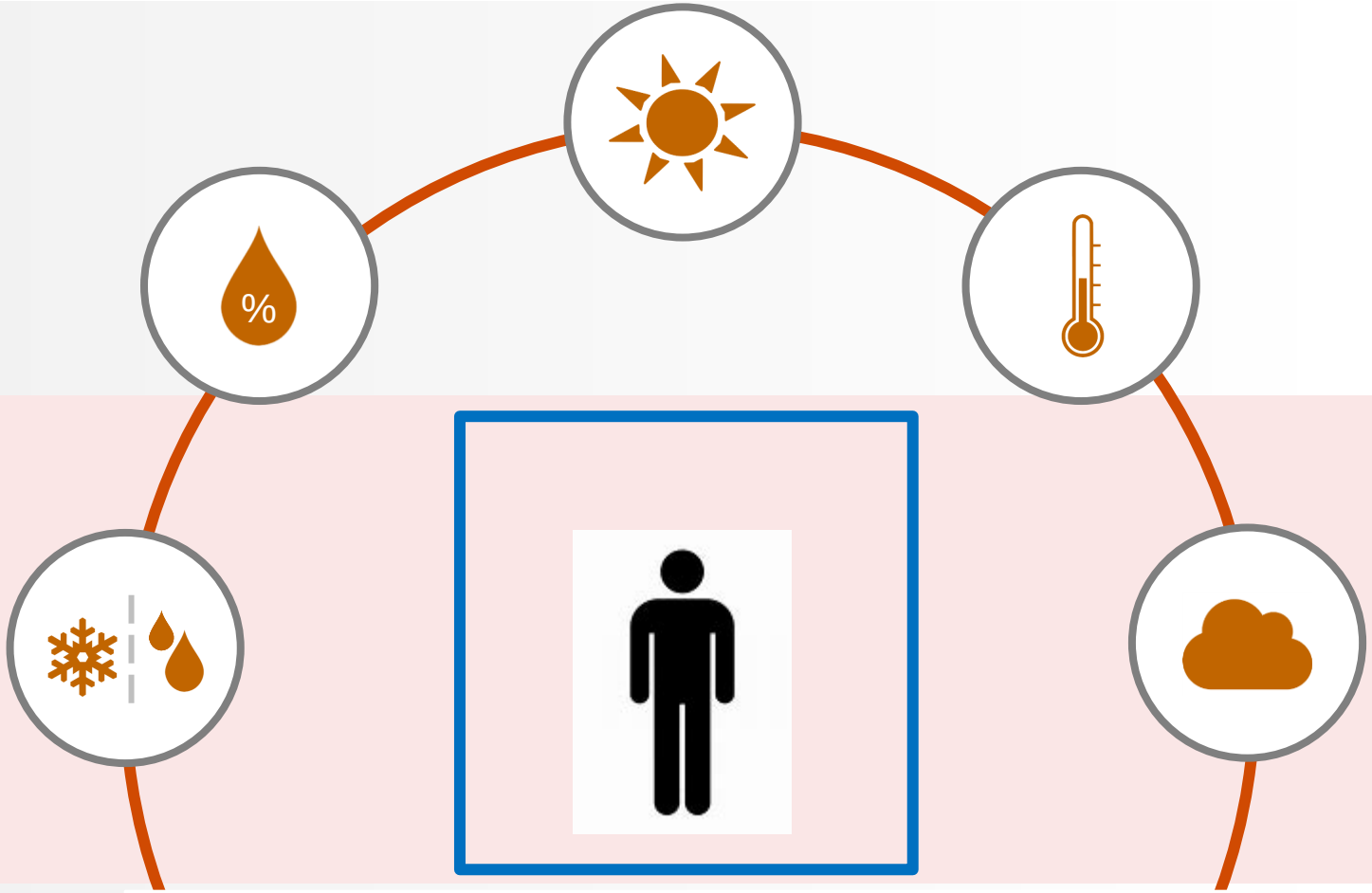


Visual Comfort

Air Quality

Acoustic Comfort

The Environment & Building relation



Surface

- Radiation budget
- Temperature
- Relative Humidity
- Wind speed & Dir
- Pressure
- Precipitation

Atmosphere Concentration

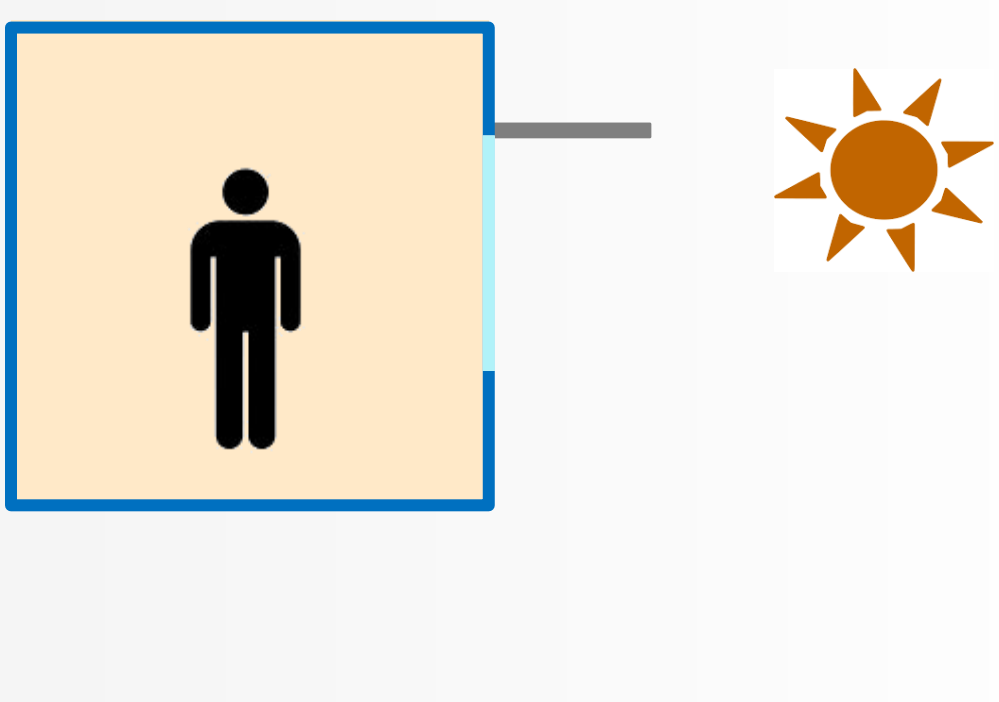
- Aerosols
- CO_2, CH_4 and other GHGs
- Ozone
- NO_2, SO_2, HCHO, CO and other precursors

Upper Atmosphere

- Radiation budget
- Lightening
- Temperature
- Water vapour
- Cloud properties
- Wind speed & Dir

The Climate Responsive Building

Climate responsive architecture is the architectural approach that focuses on designing energy-efficient buildings uniquely suited to the climate in which they are constructed. These buildings' designs are informed by, and reflective of, local weather conditions.

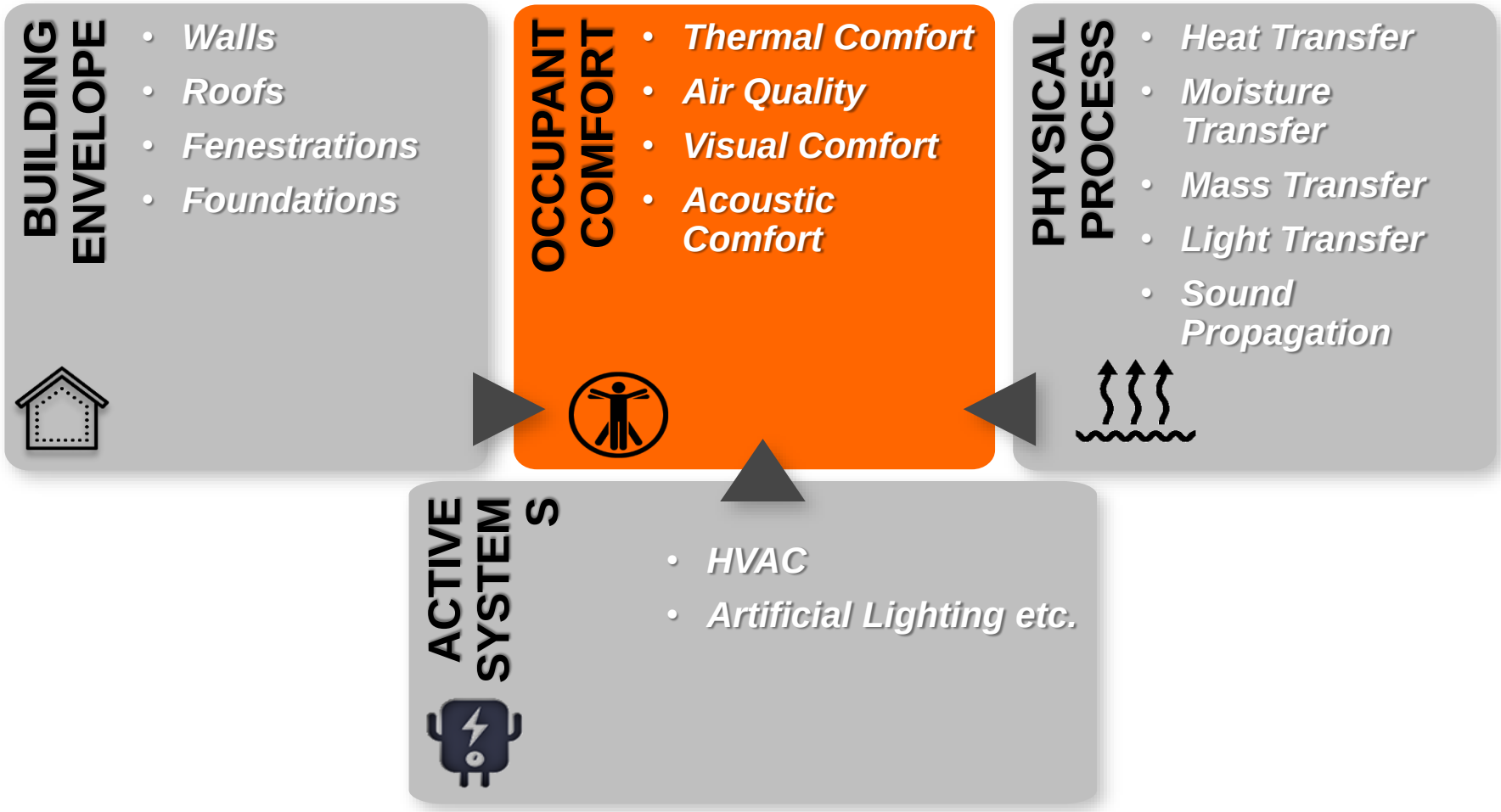


Summers

The Climate Classification – National Building Code

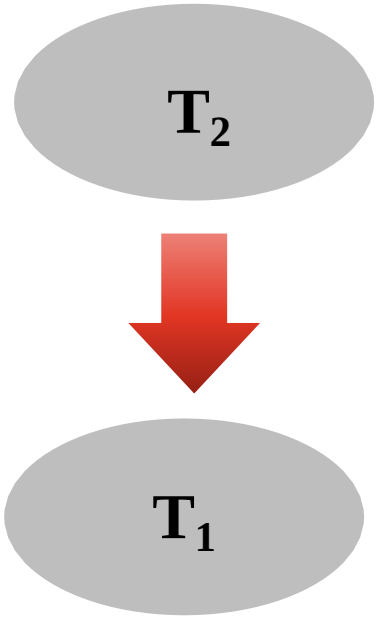
Climate Zone	Mean monthly maximum temperatures	Mean monthly relative humidity
Hot dry	Above 30°C	Below 55%
Warm humid	Above 30°C	Above 55%
	Above 25°C	Above 75%
Temperate	25°C-30°C	Below 75%
Cold	Below 25°C	All values
Composite	Doesn't comprise predominant season for more than six months	

Purpose of the building



Building Physics Affecting Thermal Comfort

2nd Law of Thermodynamics



$(T_2 > T_1)$

- The natural (spontaneous) direction of heat flow between bodies is from hot to cold.

- Heat moves from higher temperature to lower temperature

Building Physics Affecting Thermal Comfort

Factors Influencing Heat Transfer

The amount of thermal energy on the surface of various building elements is visible in thermography images of buildings and people in various built environments.

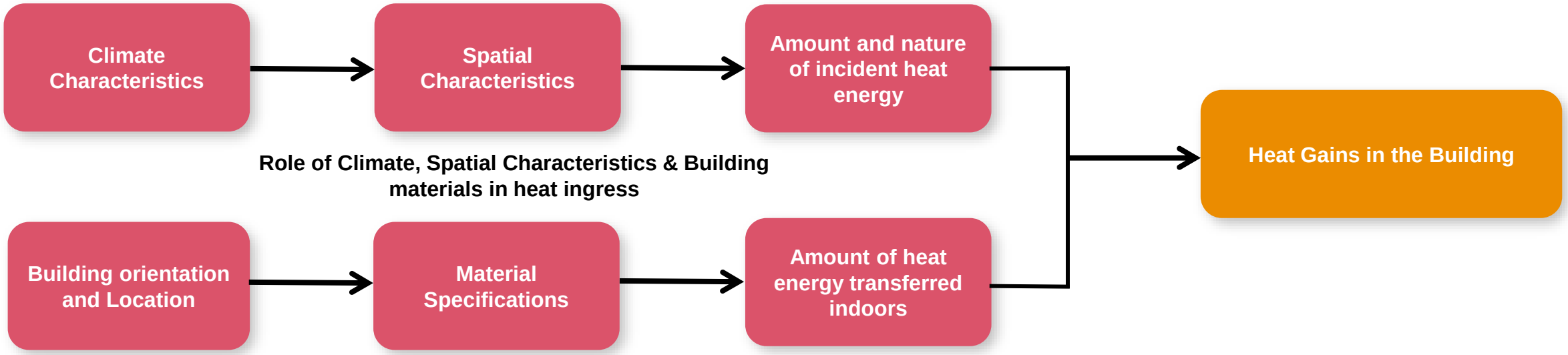


Figure demonstrates that the distribution of thermal energy among its users and in any indoor or outdoor environment is not uniform. Building heat transmission occurs at the building envelope, much as how heat transfer between a human body and the air around it occurs at the skin's surface.

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02

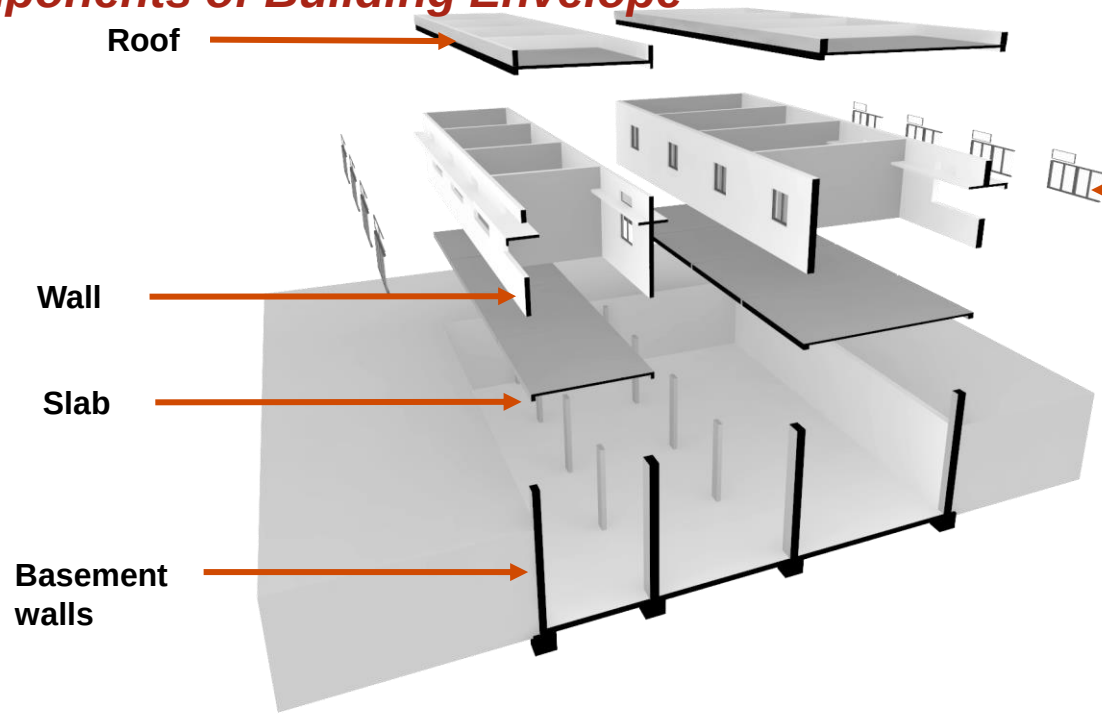
Building Envelope & its components

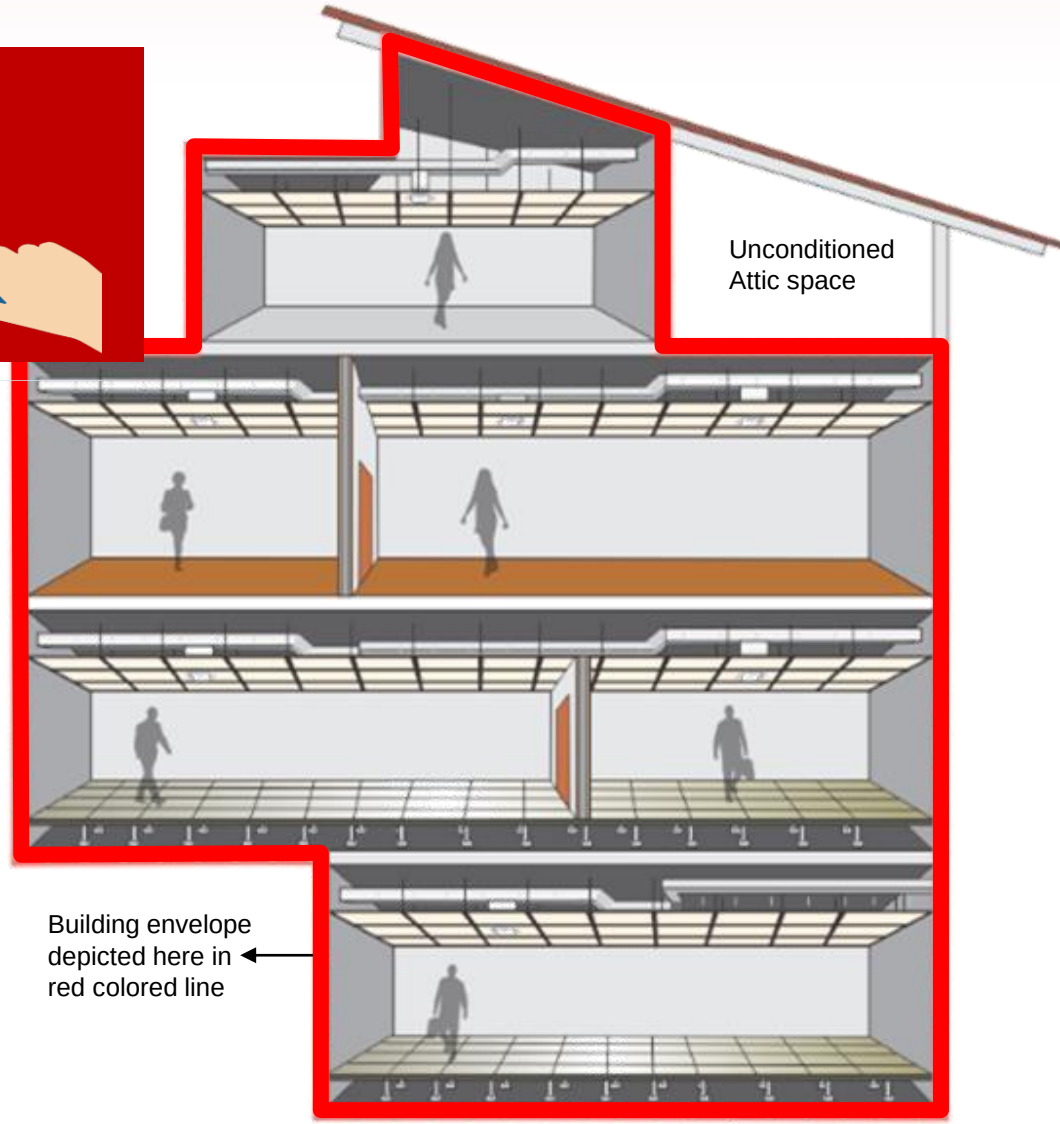
What is Building Envelope?

Envelope is a physical separator between the occupied spaces and the external environment. Majority of the heat gain occurs in a building by means of convection through the envelope which includes walls, roofs and fenestrations.

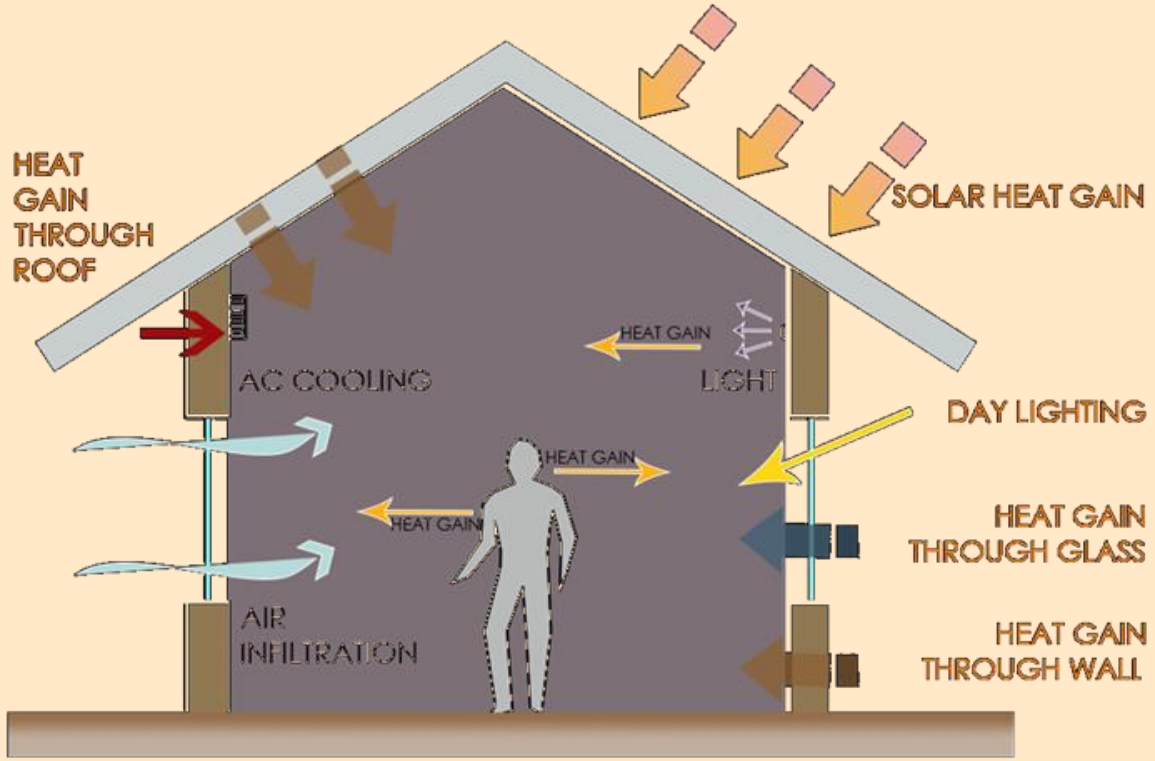
Building envelope comprises of Vertical fenestrations, Opaque constructions (walls) and Roofs

Components of Building Envelope

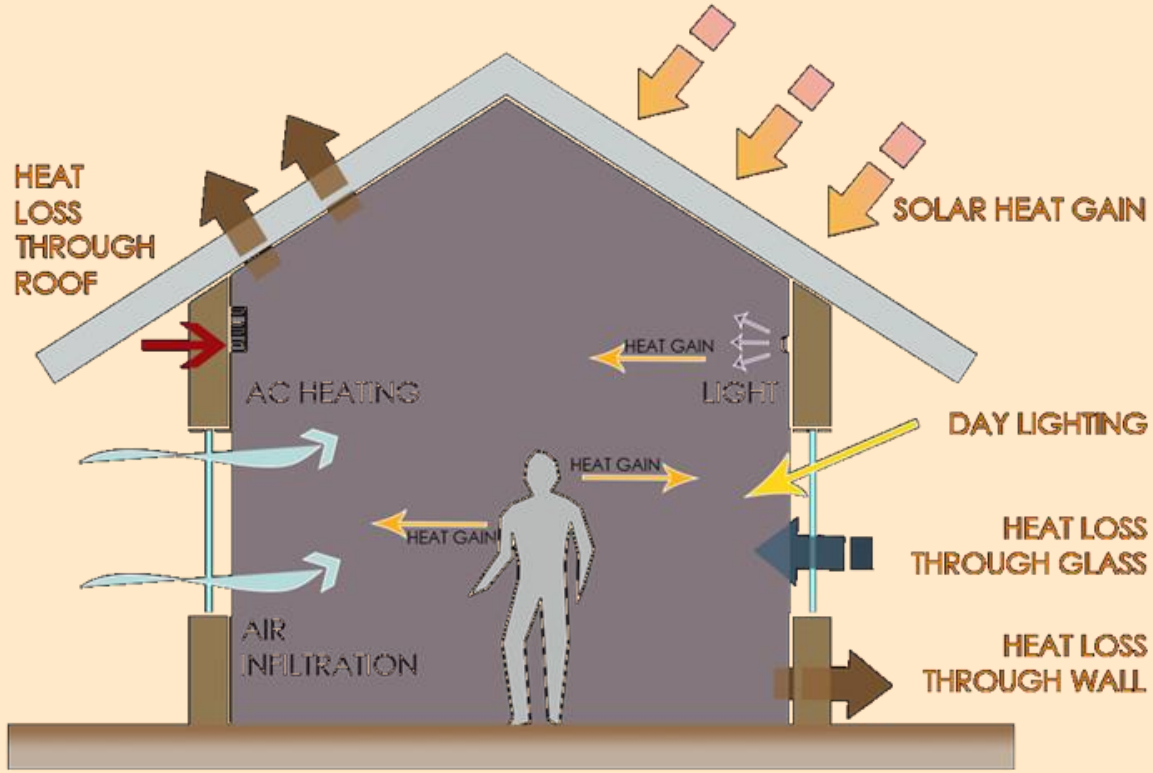




External heat gain and loss in building envelope

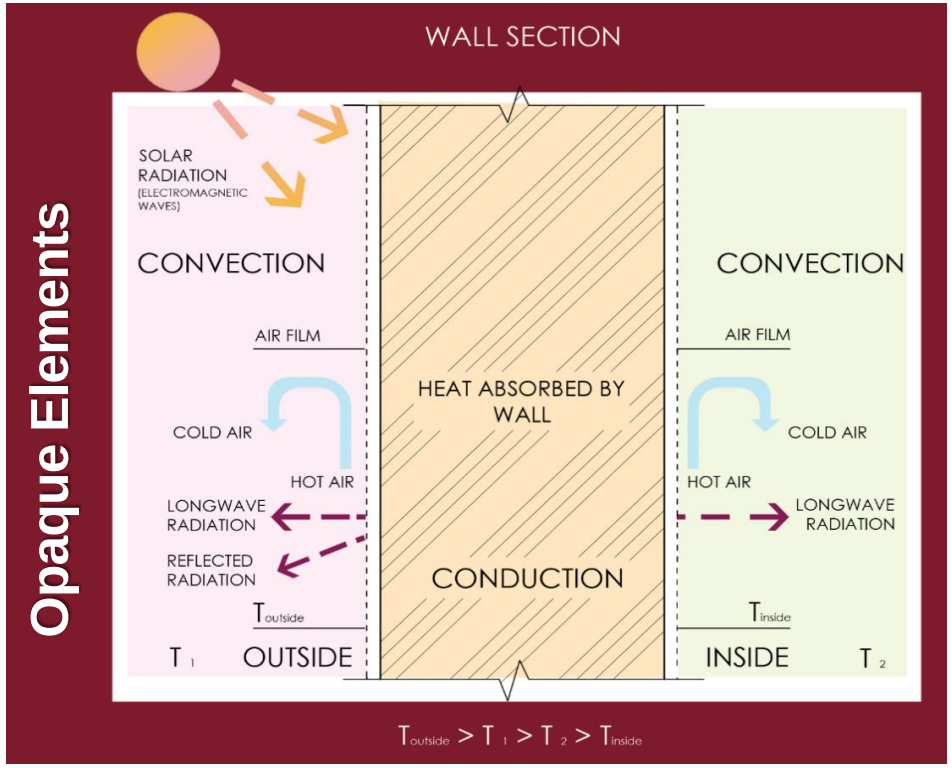


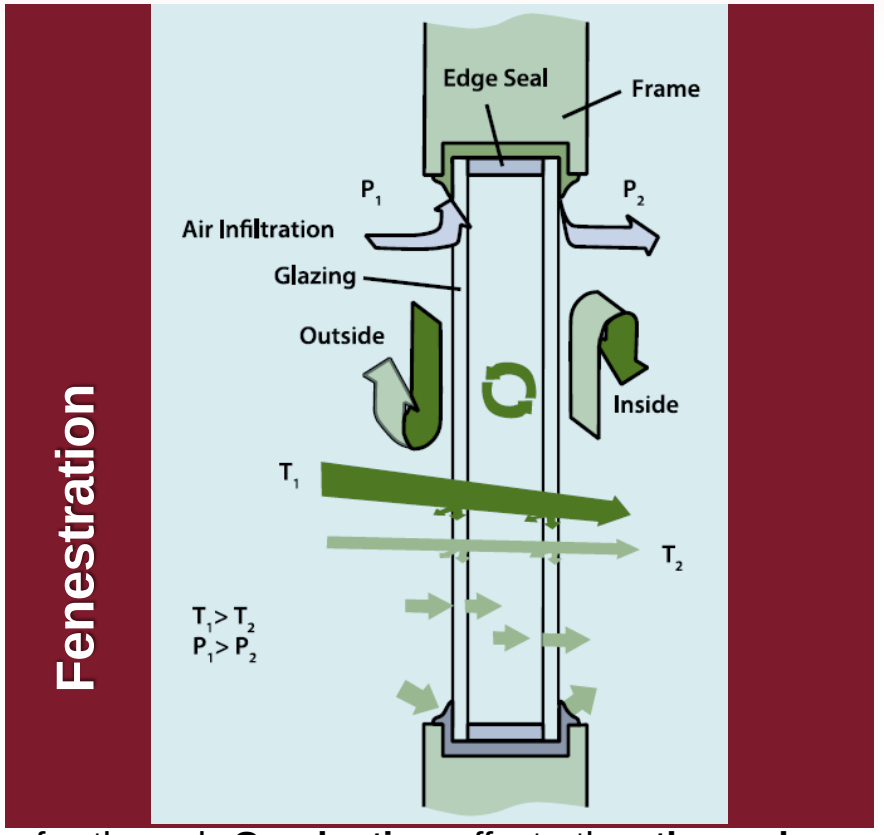
BUILDING IN COOLING MODE



BUILDING IN HEATING MODE

Heat Transfer in a building envelope





- Heat transfer through **Conduction** affects the **thermal properties of the material and effectiveness of the insulation.**
- Heat transfer through **Convection** affects the **air movement at surface.**
- Heat transfer through **Radiation** affects the building envelope through **the direct and indirect solar radiation.**

- Heat transfer through **Conduction** affects the **thermal properties** of **fenestration assembly.**
- Heat transfer through **Convection** affects the **air movement at surface.**
- Heat transfer through **Radiation** affects the **fenestration through the direct and indirect solar radiation.**

Building envelope material property that affects -**Radiation**

- **Reflectance**

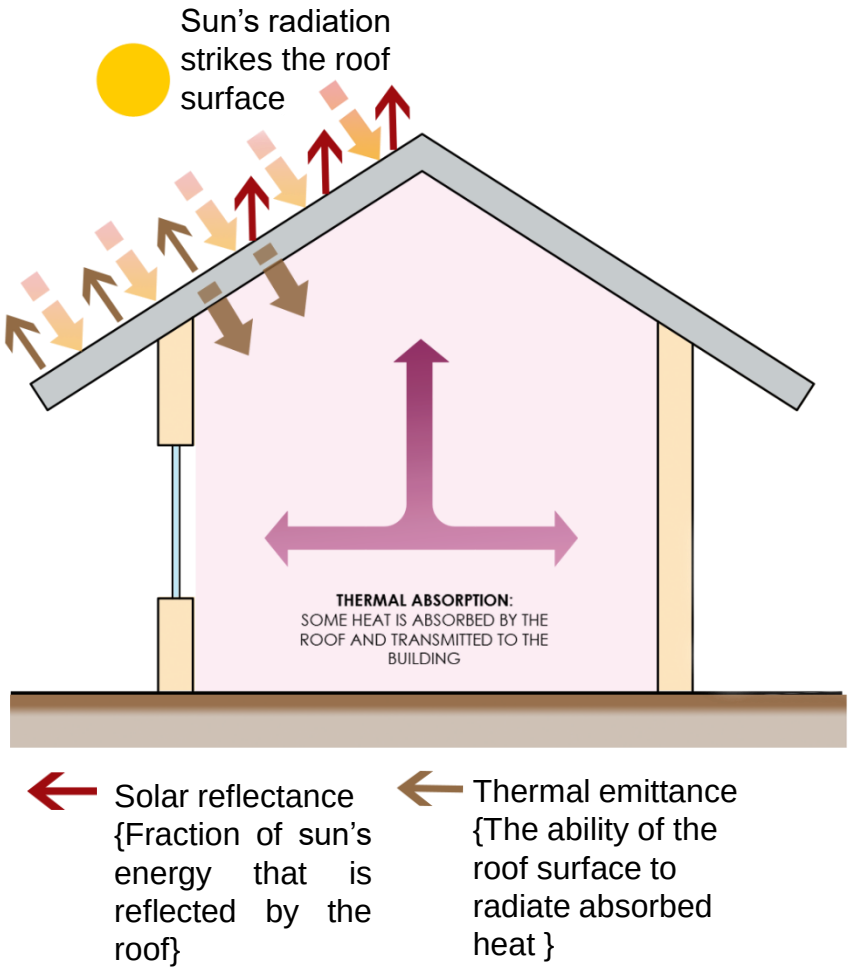
It is the ability of a material to reflect radiation without changing the temperature of the material. Surfaces with higher reflectance tend to absorb less heat.

- **Absorptance**

It is the ability of a material to absorb radiation. This is converted into sensible heat within the material, thus raising its temperature. A value of 0 indicates that the surface reflects all incident solar radiation, and a value of 1 denotes a surface that absorbs all incident solar radiation.

- **Emittance**

It is the ability of a material to re-radiate absorbed heat as invisible infrared radiation. It indicates the ability of a material to lose heat, consequently reducing the sensible heat content of the object.



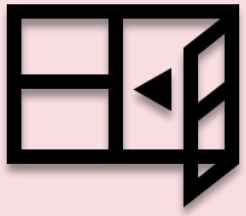
Properties of building envelope

Thermal Conductivity
R Value – U Value
Thermal Mass
Specific Heat
Thermal Diffusivity

- **Walls**
  - Internal
  - External

Thermal Conductivity – Frames and Glass
R Value – U Value
Solar Gains
Solar Heat Gain Coefficient
Visual Light Transmittance
VLT

- **Fenestrations**
  - Windows
  - Skylights
  - Doors



Thermal Conductivity
R Value – U Value
Thermal Emissivity
Solar Reflectance

- **Roofs**
  - Floors
  - Foundations

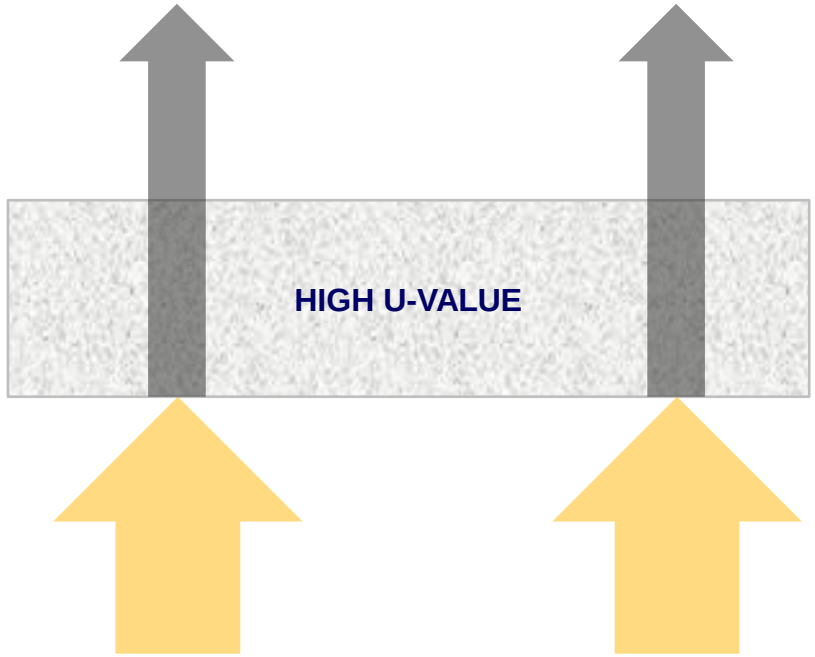
Thermal Conductance- U value

Measures **HEAT TRANSFER** through the envelope due to **CONDUCTION** (Unit = W/m²·K)

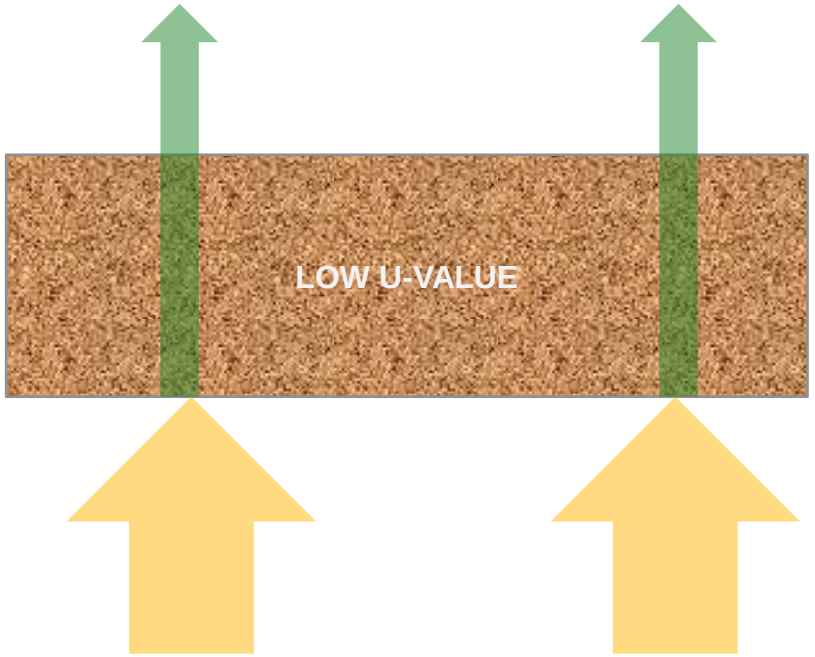
Lower the U-Value the better the **performance of insulation**

Material Specification:

HIGHER U- VALUE = HIGHER HEAT GAINS

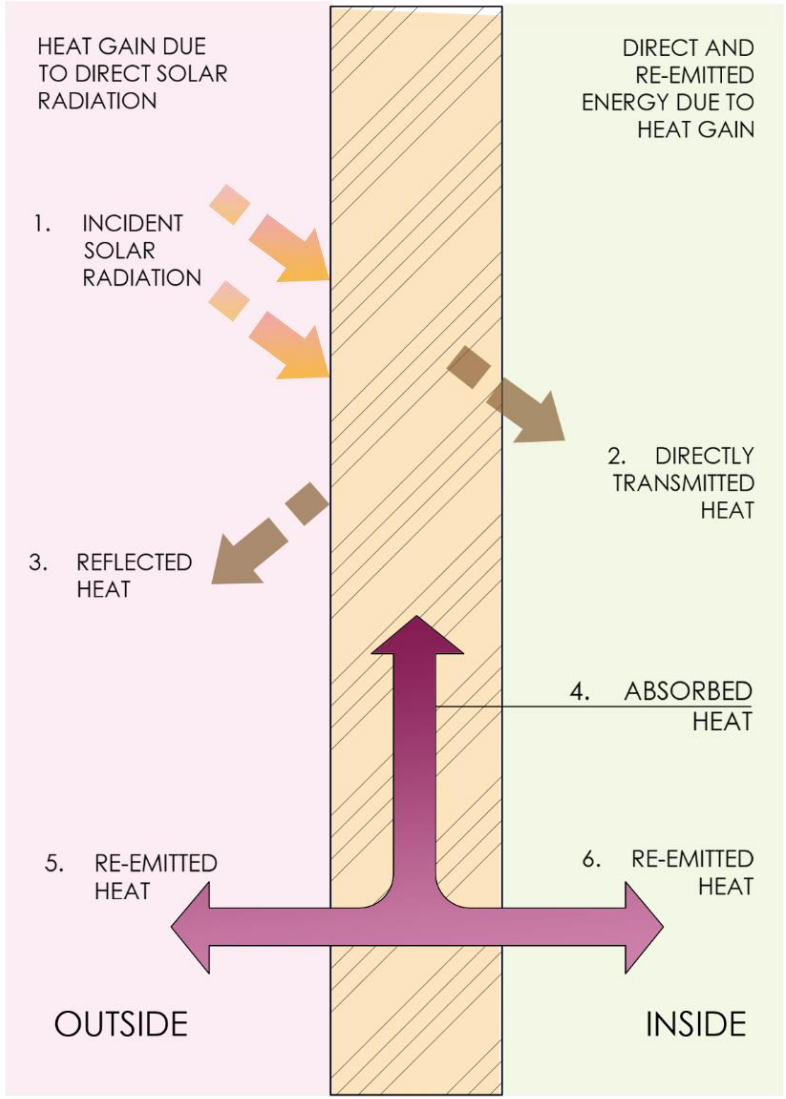


LOWER U-VALUE = LOWER HEAT GAINS



SHGC (Solar Heat Gain Coefficient)

- Ratio of the solar heat gain that passes through the fenestration to the total incident solar radiation that falls on the fenestration.
- Includes directly transmitted solar heat and absorbed solar radiation, which is then re-radiated, converted, or conducted into the interior space.
- Indicates how well the glazing/glass and fenestration products insulate heat caused by sun falling directly on the glass.
- Lower the SHGC, lesser the heat can pass through the glazing.
- Glazing units with a low SHGC will help reduce the air conditioning energy use during the cooling season.



Visual Light Transmittance (VLT)

- **Fraction of visible light transmitted through the glazing**

  Affects daylight and visibility

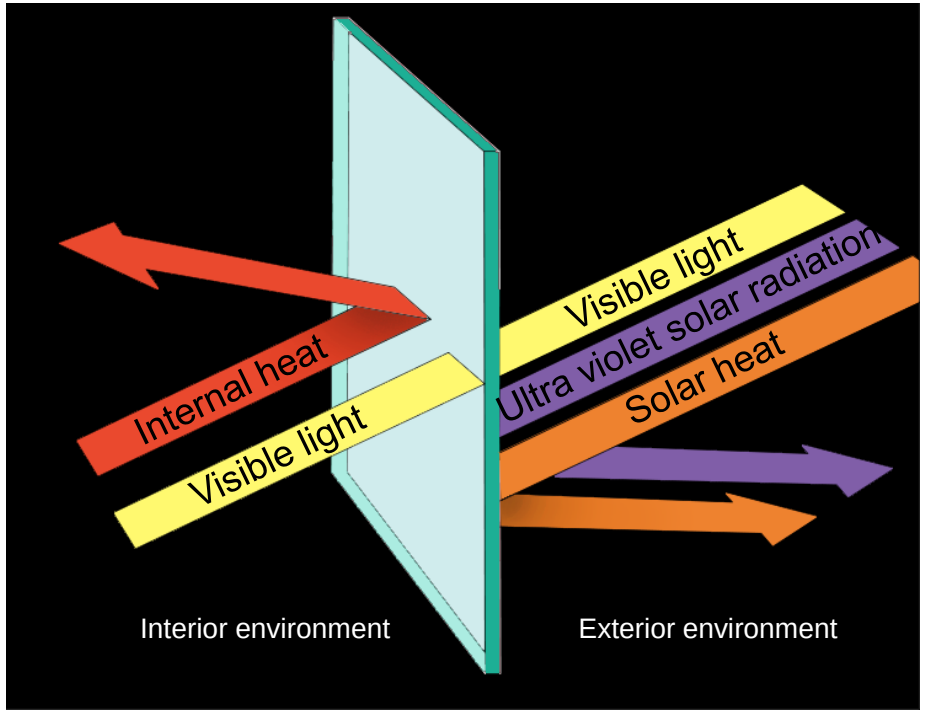
  Varies between 0 & 1

- **Typically, lower the SHGC, lower the VLT**

  Higher insulating property glass will reduce daylight

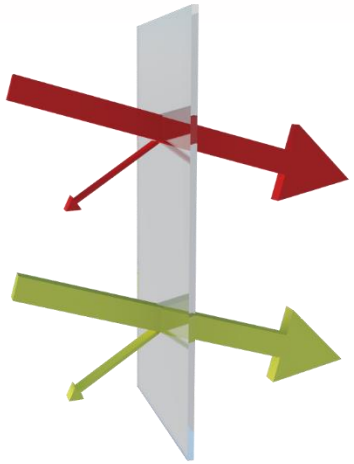
- **Higher the VLT, more light is transmitted**

  Balance is needed between daylight requirements & heat gain through windows



Comparison of different glass assembly

- **Single glazed clear glass**

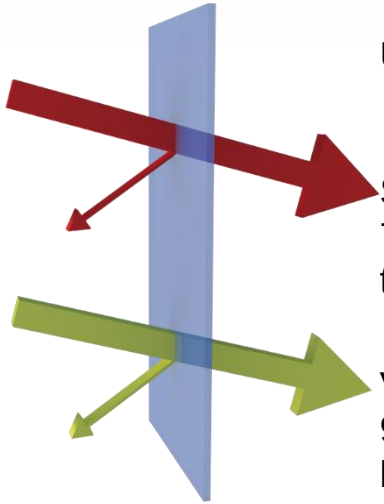


U-factor= 1.04

SHGC= 0.86
86% of solar heat transmitted

VLT= 0.90
90% of visible light transmitted

- **Single glazed tinted glass**

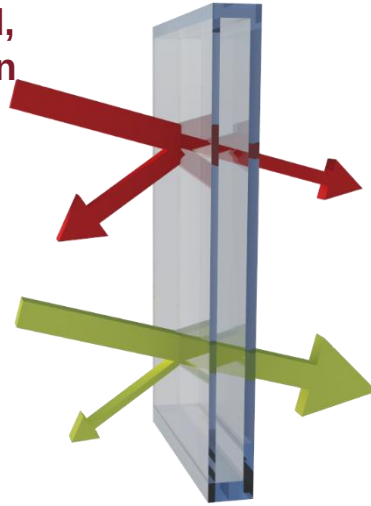


U-factor= 1.04

SHGC= 0.73
73% of solar heat transmitted

VLT= 0.68
90% of visible light transmitted

- **Double-Glazed, High-solar-gain Low-E Glass**

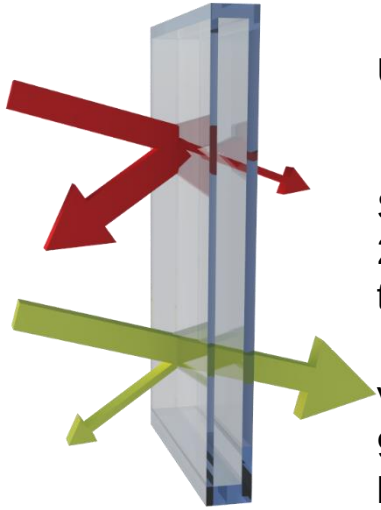


U-factor= 0.26

SHGC= 0.67
67% of solar heat transmitted

VLT= 0.78
90% of visible light transmitted

- **Double-Glazed, Low-solar-gain Low-E Glass**



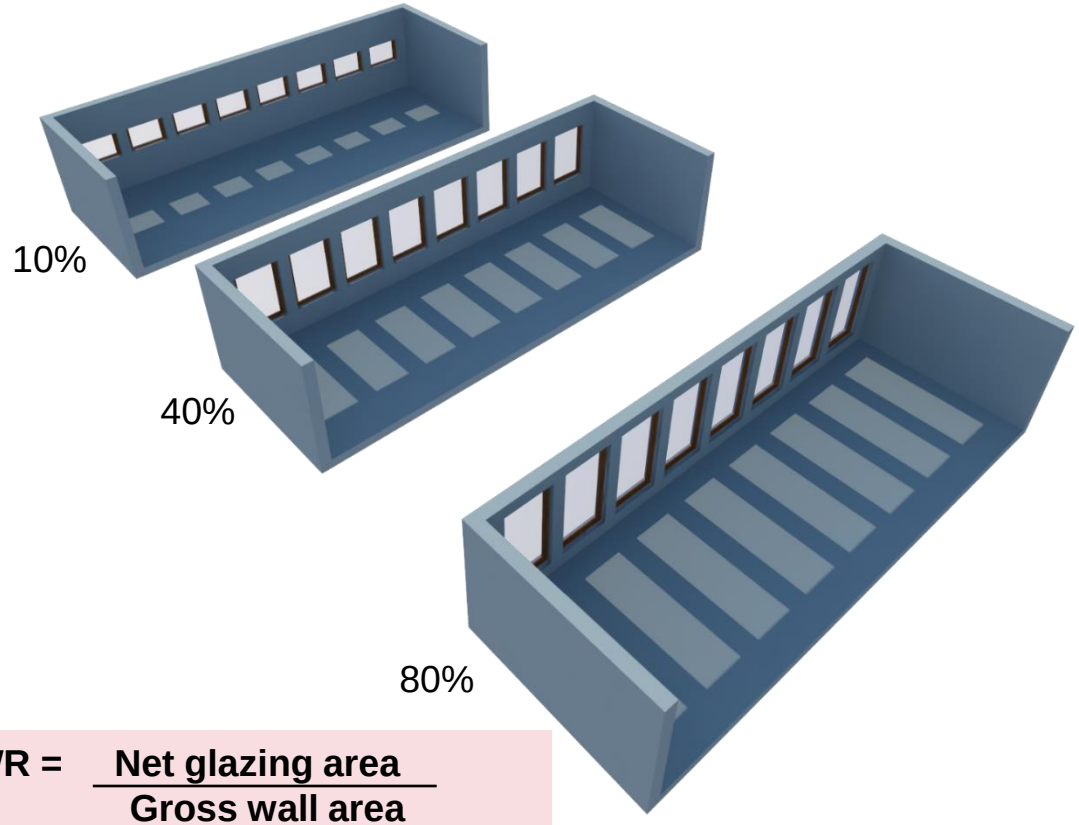
U-factor= 0.24

SHGC= 0.26
26% of solar heat transmitted

VLT= 0.64
90% of visible light transmitted

WWR (Window Wall Ratio)

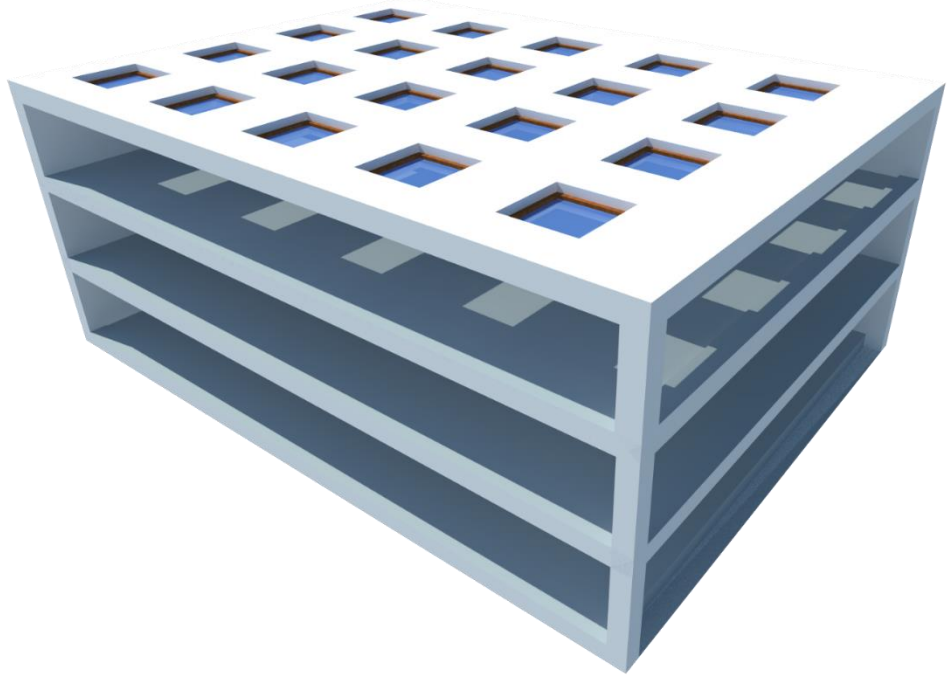
- It is the percentage of window to the wall area.



WWR = Net glazing area / Gross wall area

- Window Wall Ration (WWR) is a direct indication of the amount of heat gain due to solar radiation.
- Larger WWR will increase the cooling loads of a building.

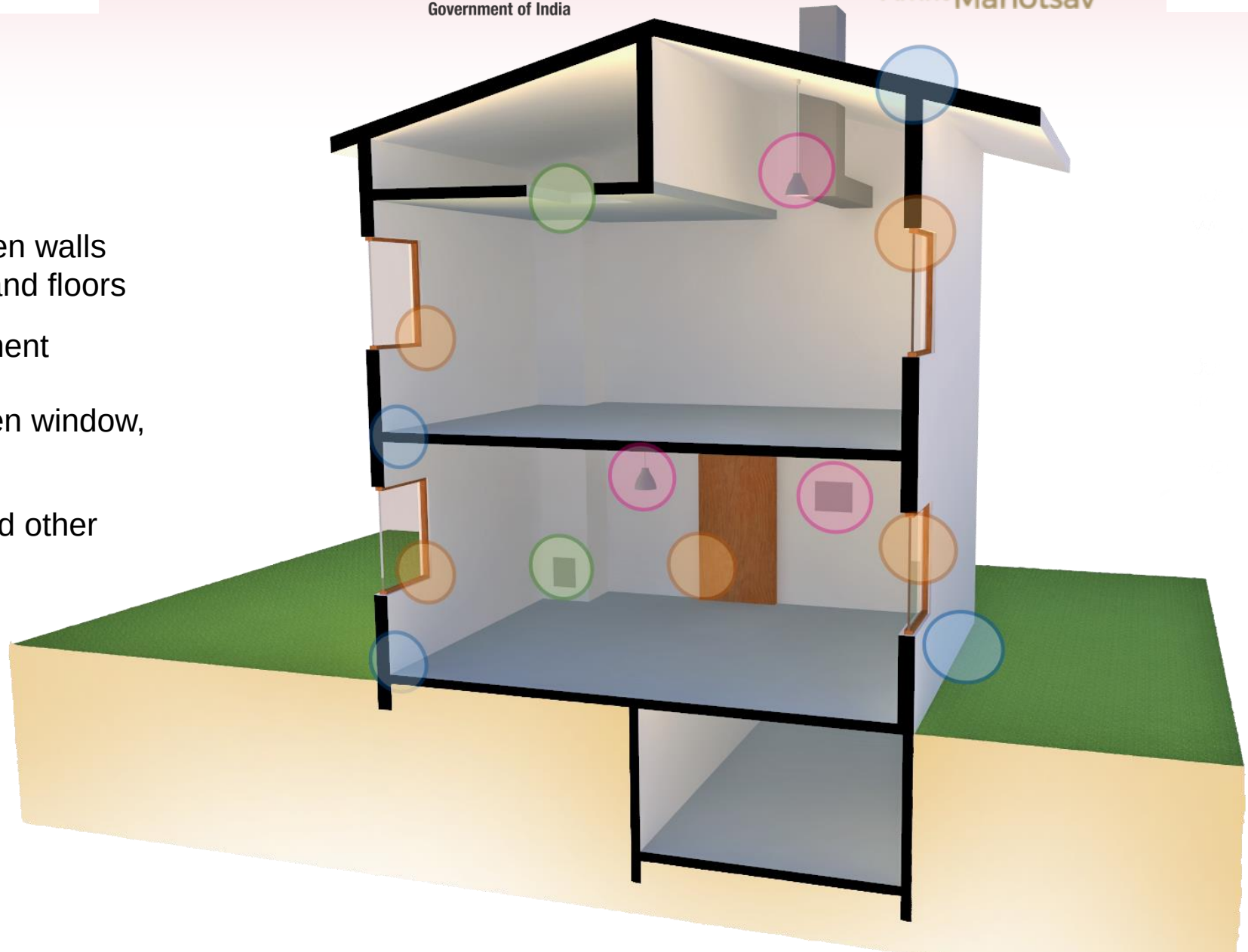
SRR (Skylight Roof Ratio)



- It is the ratio of the total skylight area of the roof, measured to the outside of the frame, to the gross exterior roof area.

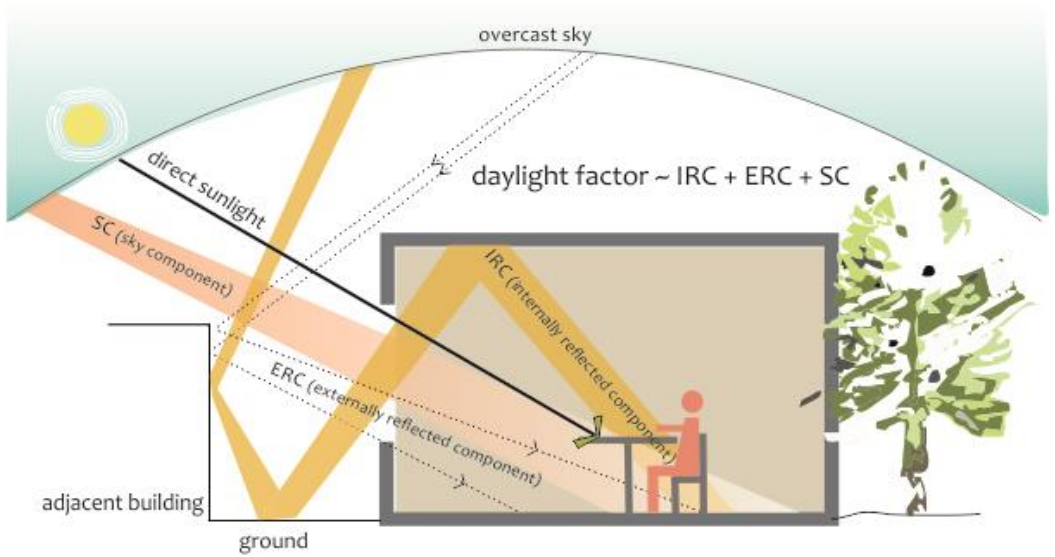
Air leakage

- Junctions between walls and other walls and floors
- Electrical equipment
- Junctions between window, frames and wall
- Access doors and other penetrations



Daylighting

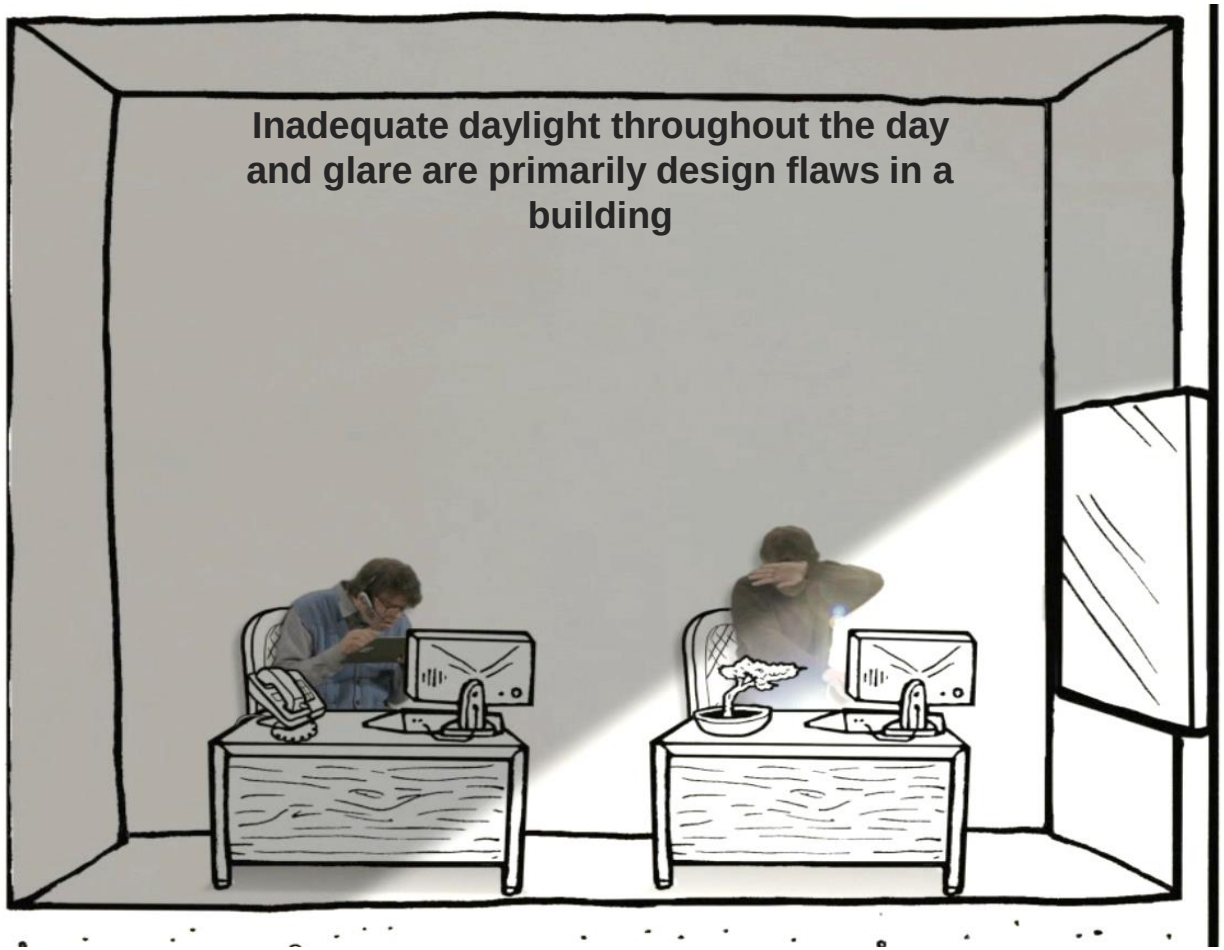
- **Daylighting** is the practice of placing windows or other openings and reflective surfaces so that during the day natural light provides effective internal lighting.
- Particular attention is given to **daylighting** while designing a building when the aim is to maximize visual comfort or to reduce energy use.

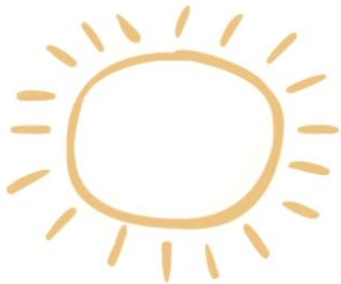


- **Daylight** is diffuse natural light from the sky. For daylighting design, you DO want daylight.
- **Sunlight** is direct light from the sun itself. For daylighting design, you DON'T want sunlight. It creates light that is too intense and can bring unwanted heat.

Source: http://www.nzeb.in/knowledge-centre/passive-design/daylighting/

Passive Strategies- Useful Daylight

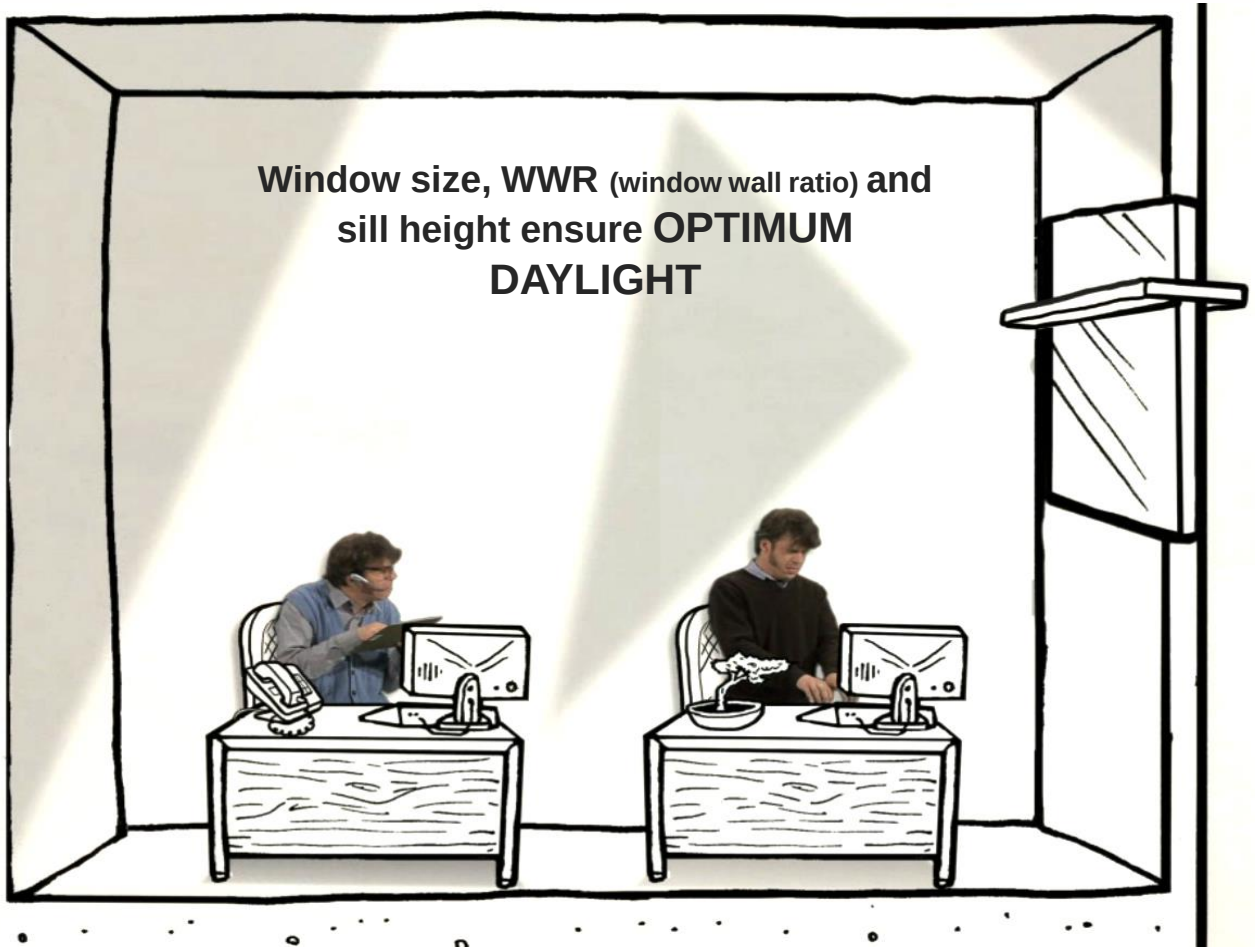


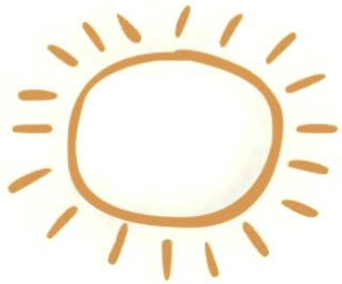


SOLAR RADIATION

has DIRECT and DIFFUSED component

Passive Strategies- Useful Daylight





DIFFUSED solar radiation provides **USEFUL DAYLIGHT** in a building

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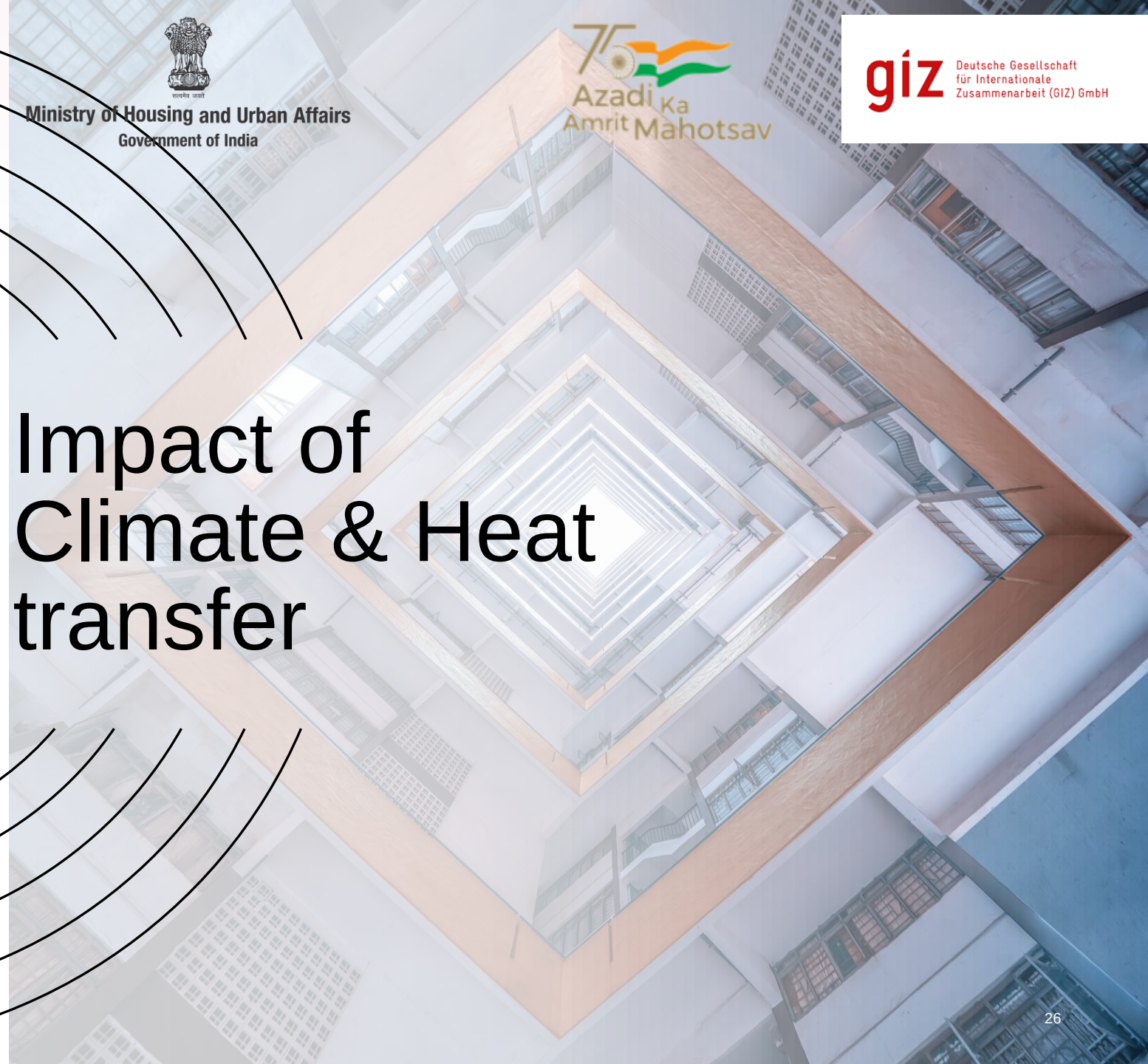
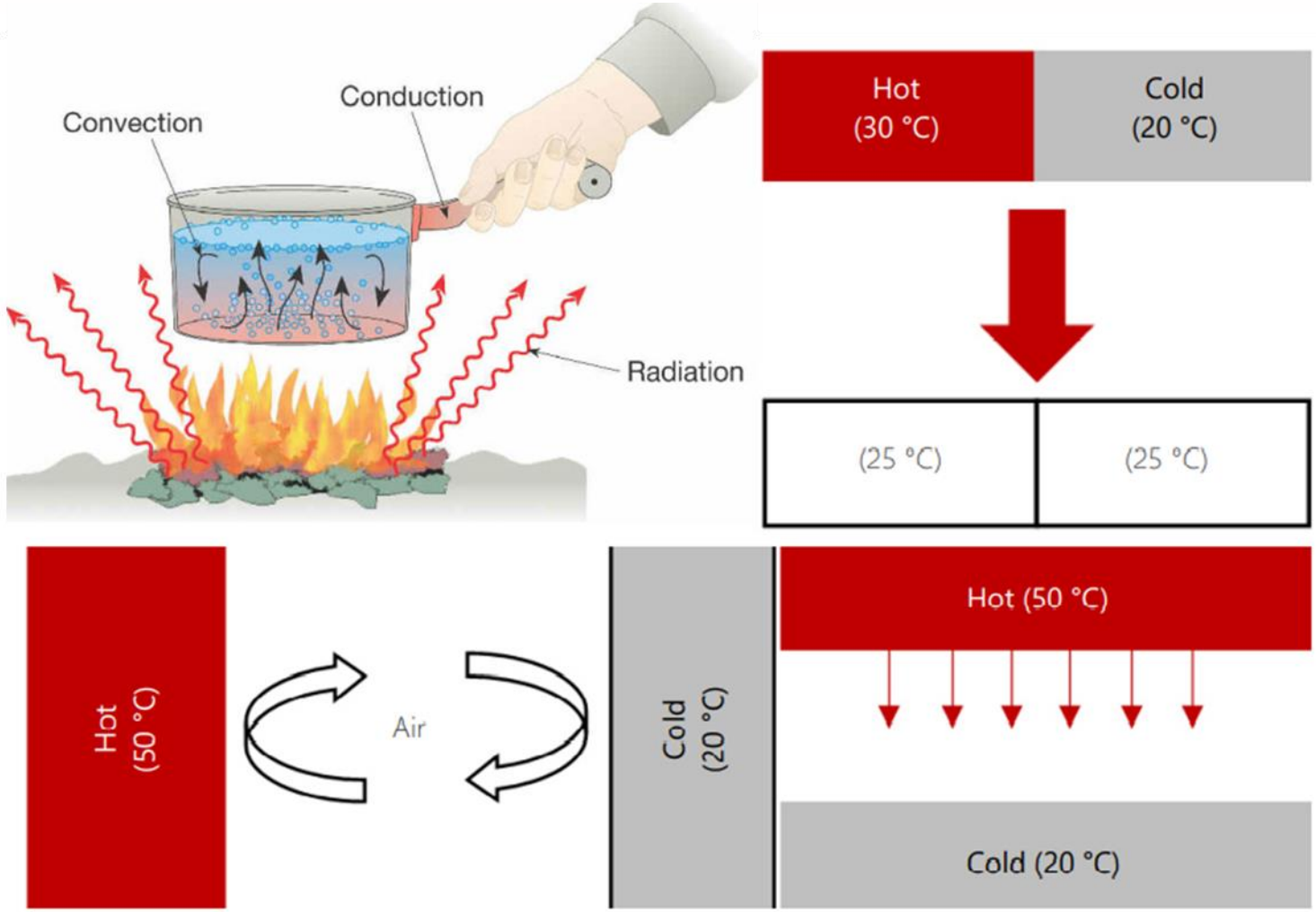
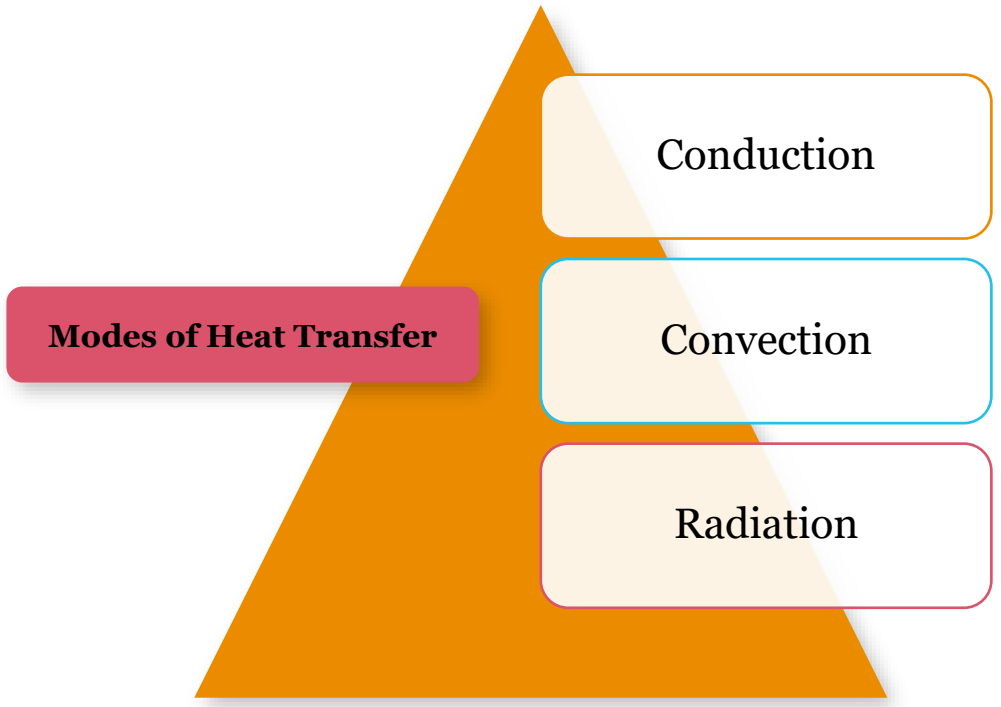
03 Impact of Climate & Heat transfer



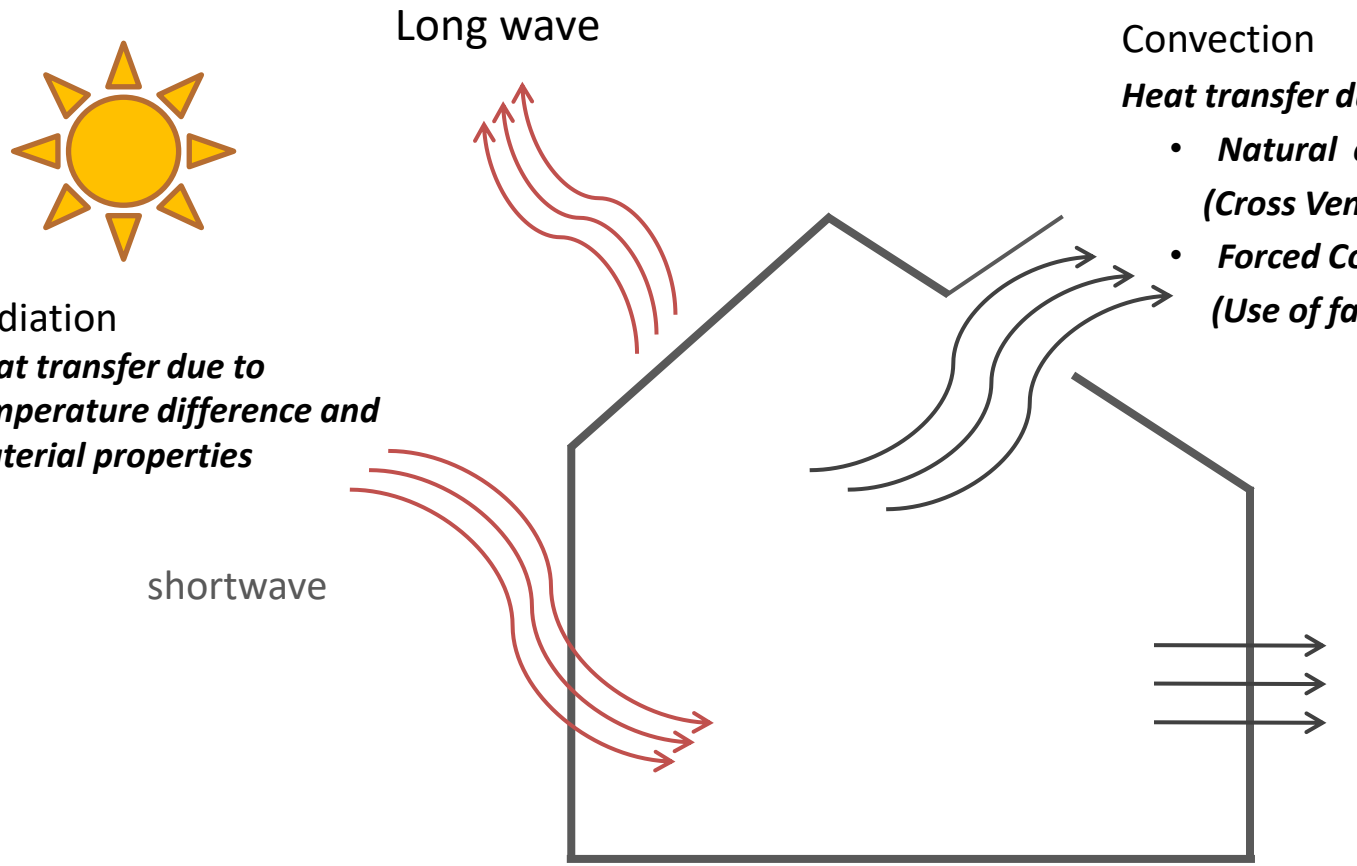
Modes of heat transfer through building envelope





Modes of heat transfer in the building

Phenomenon of Heat Transfer in Buildings



Radiation

Heat transfer due to temperature difference and material properties

Convection

Heat transfer due to air motion and temp difference

- ***Natural or Passive Convection***
  (Cross Ventilation & Stack Effect)
- ***Forced Convection***
  (Use of fans to assist airflow)

Conduction

Heat transfer due to materials in contact and temperature difference

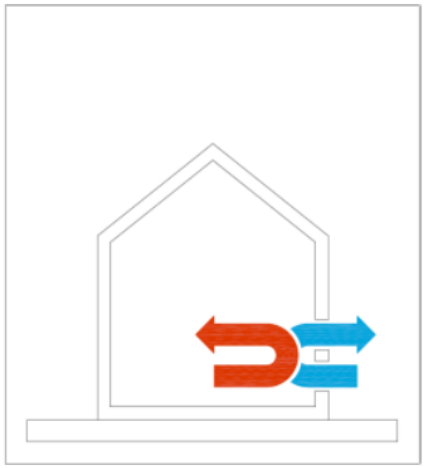
TOTAL ENVELOPE HEAT TRANSFER = Conduction + Convection + Radiation

Climate Responsive & Energy Efficient design consideration:

OPTIMIZATION OF BUILDING SHAPE AND ENVELOPE

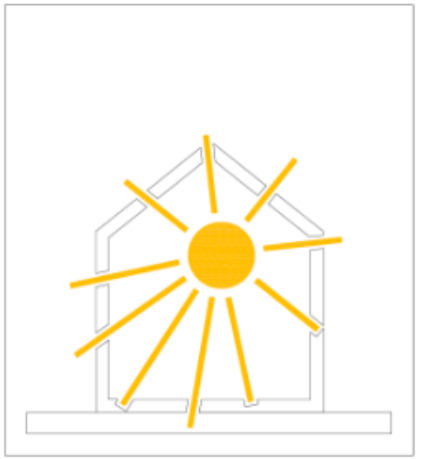
- Efficient solar passive design
- Optimized orientation
- Compact building shape (for reduced heating demand)
  - Optimized building envelope
  - Well insulated building envelope
  - Avoid thermal bridges
  - Airtight construction

PwC



EFFICIENT MECHANICAL SYSTEMS

- Components of an efficient building mechanical system:
  - Efficient heating system (heating and warm water)
  - Efficient ventilation system with heat recovery
  - Efficient equipment and appliances
- Keep system and its components simple and easy in maintenance



USE OF RENEWABLE ENERGY

- Renewable energy sources at the building can be:
  - Solar thermal
  - Solar power (photovoltaics)
  - Earth air Tunnel
- Zero-Net-Energy- and Plus-Energy-Buildings can be realized by using local renewable energy

Achieving Energy Efficiency in Building

PASSIVE DESIGN STRATEGIES

- Massing
- Zoning
- Orientation
- Shading
- Daylight integration

ENVELOPE OPTIMIZATION

- Window Wall ratio
- Wall conduction
- Roof conduction
- Selectivity of glass

EFFICIENT BUILDING SYSTEMS

- HVAC system efficiency
- System controls
- Efficient electrical systems
- Low lighting power density

OFFSET THROUGH TECHNOLOGIES

- Solar water heating
- Heat recovery
- Economizers
- Renewable power generation

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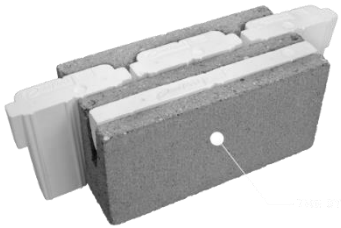
Design consideration:

WALL

MASONARY

AAC Block

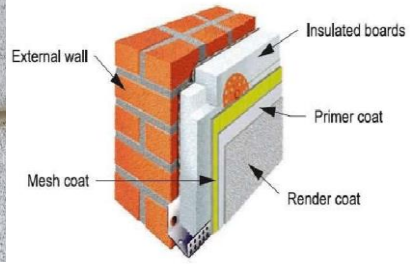


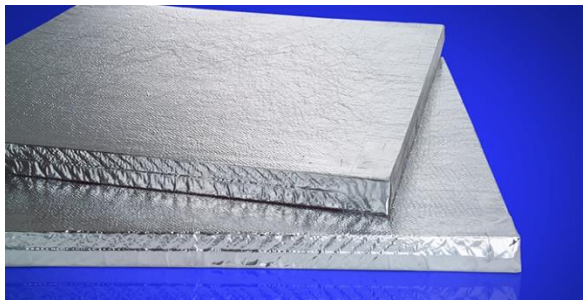
Thermal Insulated bricks

Hollow Block

Fly Ash Clay Brick

INSULATED PANELS



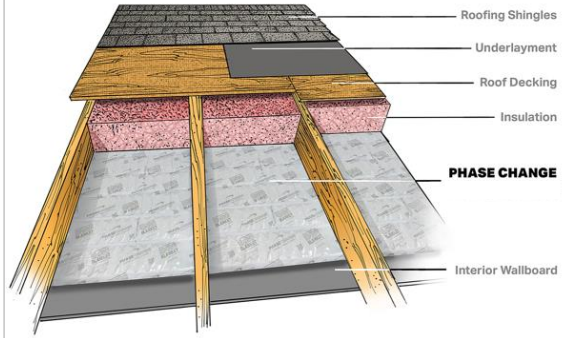


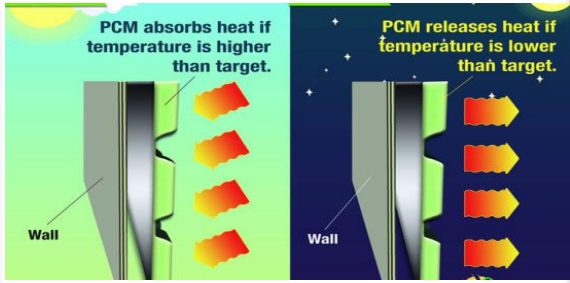
Properties:
Low thermal conductivity
0.004 W/(m·K)

SOLAR PASSIVE FACADE

OPERABLE WINDOWS AND FINS

PHASE CHANGE MATERIAL

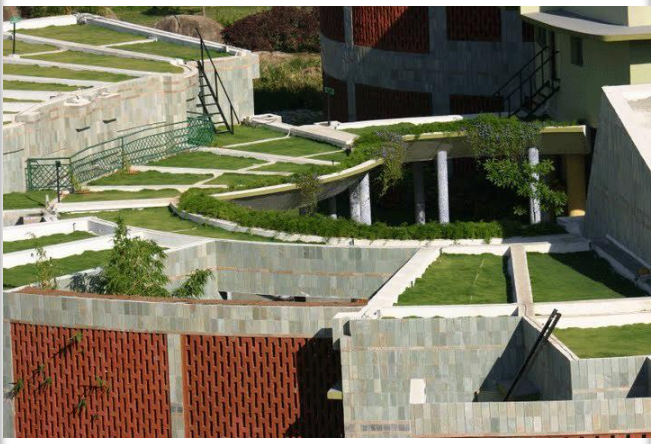




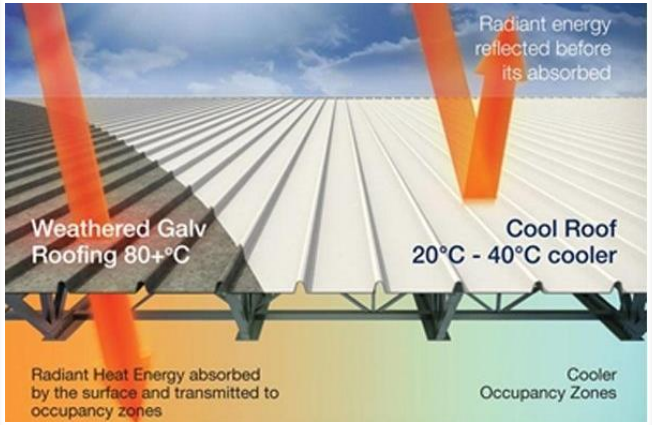
Design consideration:

ROOF

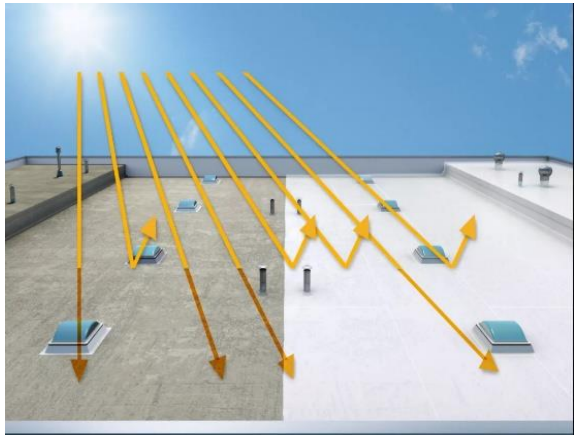
GREEN ROOF, INSULATED ROOF



COOL ROOF



REFLECTIVE SURFACE

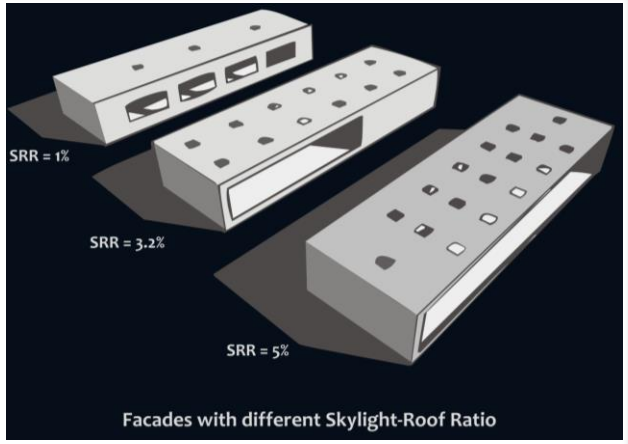


Solar Photovoltaic

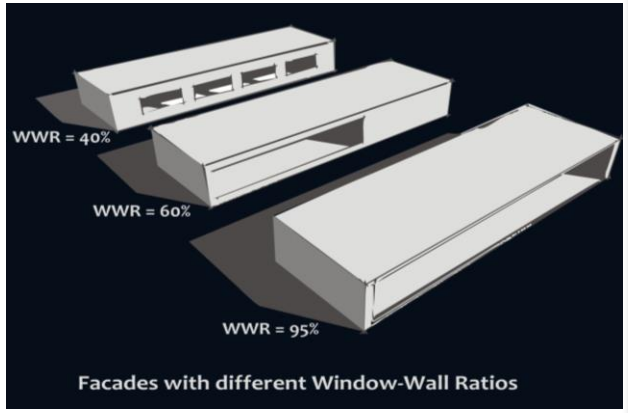
Design consideration:

WINDOWS

WINDOW WALL RATIO

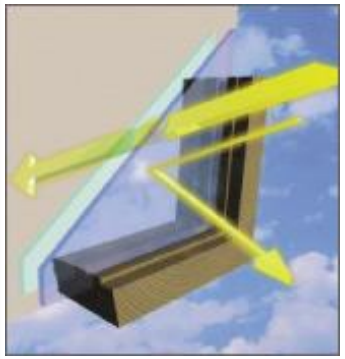


Facades with different Skylight-Roof Ratio



Facades with different Window-Wall Ratios

GLAZING SELECTION


SPECTRALLY SELECTIVE COATINGS

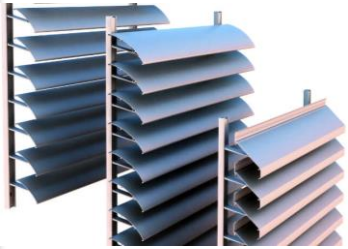

HEAT-ABSORBING TINTS

LOW-EMISSIVITY COATINGS

SUN SHADING


SUNSHADES


SUN-SCREENS




SUN BREAKER

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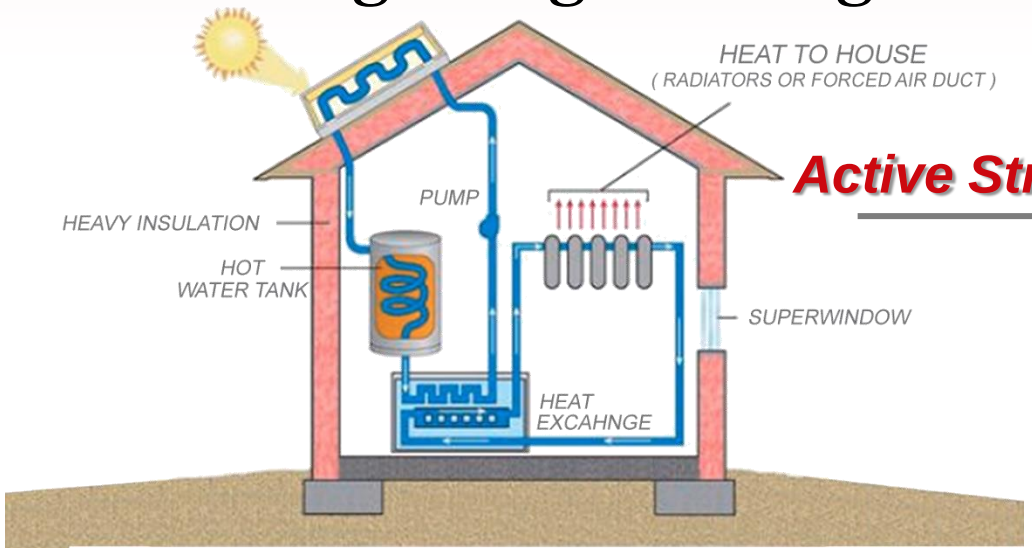
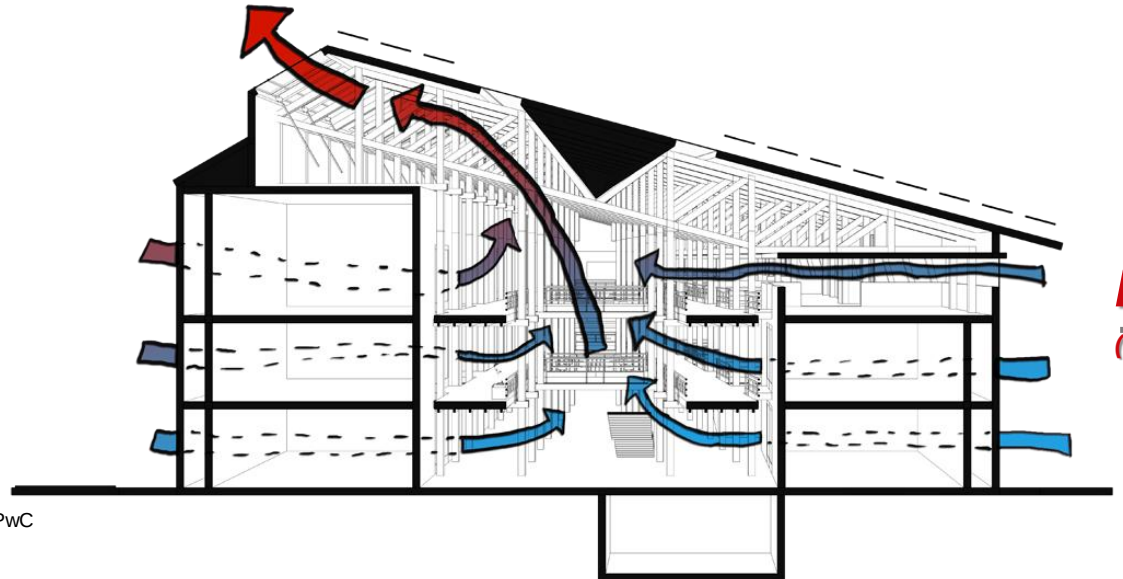
04

Sustainable Building Design Strategies

Sustainable Building Design Strategies

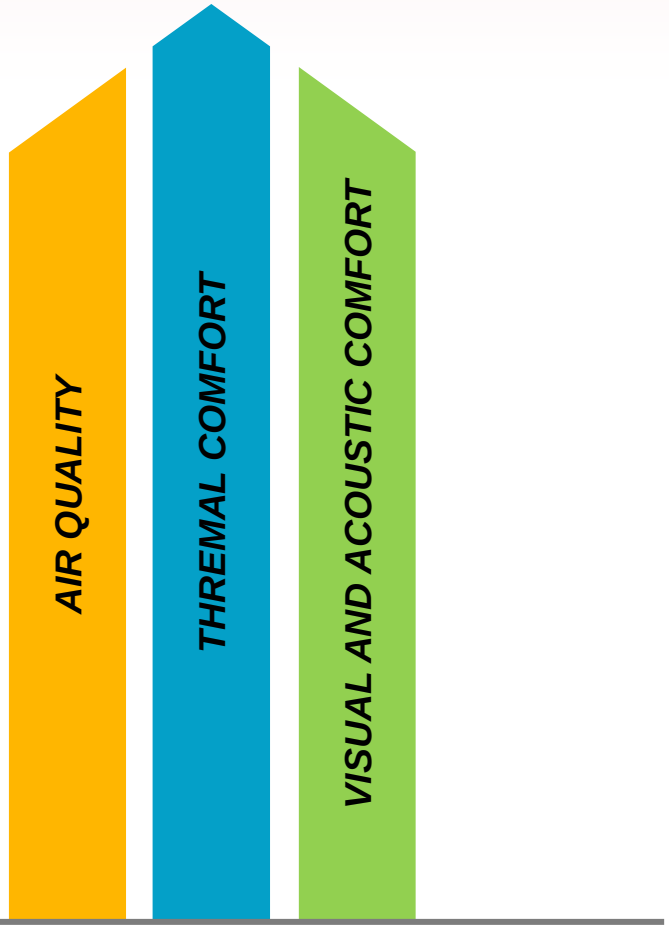


Active Strategies



Passive Strategies

(Climate Responsive)



Criteria	SUSTAINABLE STRATEGIES
Sustainable Planning and Architecture	•Optimization of building orientation and design of facades •Optimized Window placements for day lighting • Minimal exposure of external walls to outside environment • Cover the site surfaces open to sky (including building roof) with solar panels for shading and energy harvesting
Energy Efficient System	• Reduction in Lighting loads by providing efficient system for indoor and outdoor lighting & automated lighting control by utilizing occupancy sensor, daylight control and timers • Reduction on HVAC load due to energy efficient equipment and envelope • Off hours low temperature outside air circulation through automated economizer • CO2 (DCV) sensors to control the fresh air as per the requirement • CO sensors for Basement ventilation which is already minimized due to automated parking • Building Automation for controlling HVAC, lighting, Fire fighting, Security access etc
Water Efficiency	• Rainwater harvesting • Proposing Native species for landscaping or Xeriscape • Proposing Efficient irrigation system like sprinkler system, drip irrigation & microspray. • Creating a Zero discharge Building
Material Selection	• All the proposed building material will be low –embodied energy material (including – regional material , recycled material). • Attempt to minimize the waste during the construction and this waste will be re-utilize in the building and will ultimately generate zero waste. •Minimize maintenance by choosing green but hardy materials
Renewable Energy System	• Solar PV and solar concentrator systems of capacity required to reduce the demand on conventional energy systems

Integrated Sustainable Building Design Process

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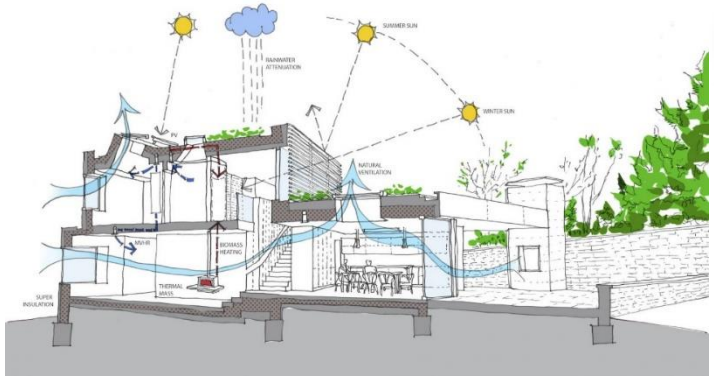
INTEGRATED BUILDING DESIGN PROCESS (IBDP) IS PROPOSED FOR A

COMPREHENSIVE DESIGN APPROACH

1

2



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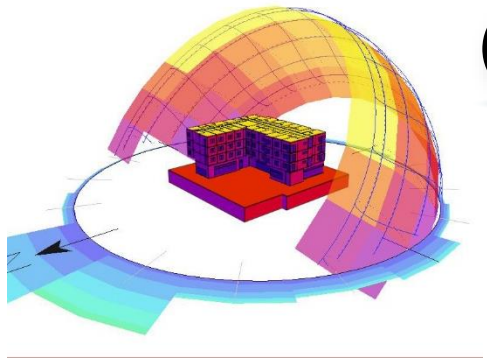

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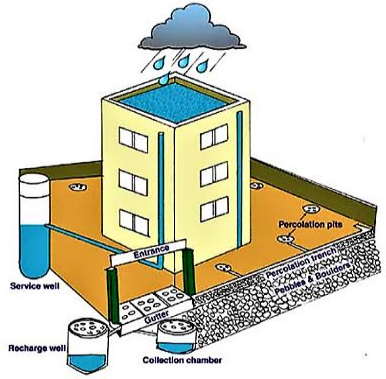

5

VARIOUS STAGES OF THE DESIGN

HELP DESIGNERS MAKE INFORMED DECISIONS

ON ENERGY-EFFICIENT AND PASSIVE DESIGN STRATEGIES

SELECTION OF SUITABLE BUILDING MATERIALS

DECREASING THE DEPENDENCY ON NON-RENEWABLE SOURCES OF ENERGY

CONSERVATION AND RECYCLING OF RESOURCES

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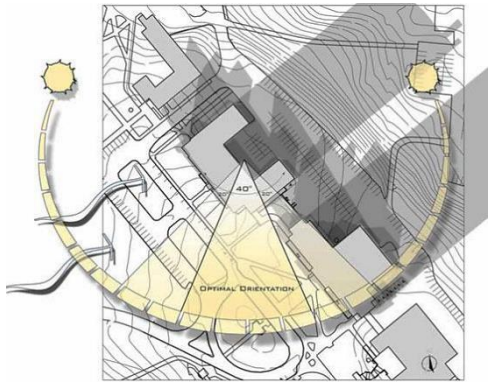
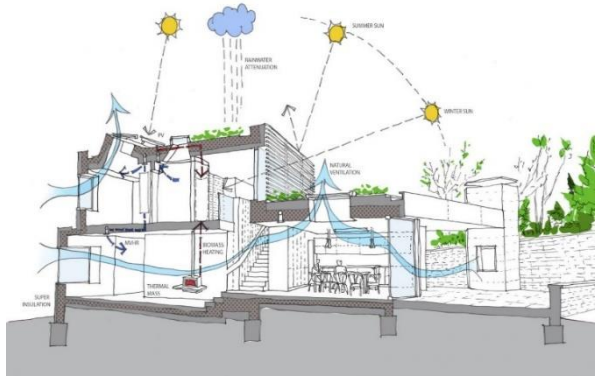
1 SITE ANALYSIS



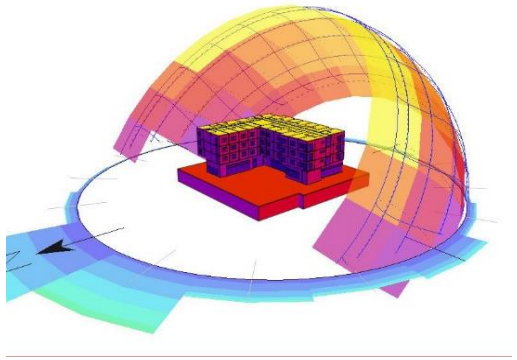
- ✓ SITE TOPOGRAPHY
- ✓ SHADOW ANALYSIS
- ✓ NATURAL WATER RESOURCES
- ✓ URBAN HEAT ISLAND ASSESSMENT
- ✓ OUTDOOR WIND CFD

2 CLIMATE ANALYSIS



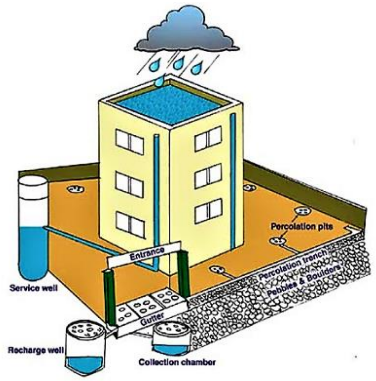
- ✓ SUN PATH ANALYSIS
- ✓ WIND FLOW ANALYSIS
- ✓ FORM AND MASSING
- ✓ PASSIVE DESIGN STRATEGIES

3 BUILDING ANALYSIS



- ✓ INDOOR CFD MODELLING
- ✓ BUILDING ENVELOPE OPTIMIZATION
- ✓ DAY LIGHTING SIMULATION
- ✓ ARTIFICIAL LIGHT SIMULATION
- ✓ THERMAL COMFORT ANALYSIS
- ✓ BOX MODELLING SIMULATION
- ✓ INNOVATIVE DESIGN
- ✓ MATERIALS CONSULTATION

4 WATER ASSESMENT



- ✓ RAINWATER HARVESTING
- ✓ STORM WATER HARVESTING
- ✓ RECYCLING AND REUSE OF WATER

5 WASTE MANAGEMENT

- ✓ SOLID WASTE MANAGEMENT
- ✓ ZERO WASTE BUIDING DESIGN

Sustainable Building Design Strategies

Site planning

- Site selection and Orientation

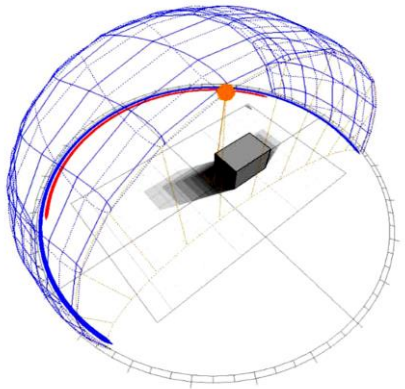
Building form and geometry

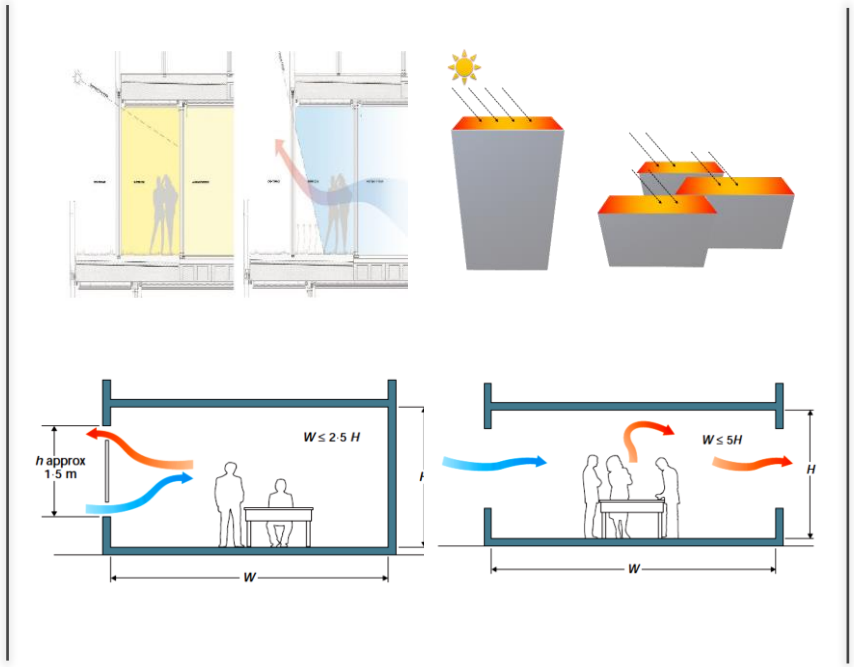
- Buffer Zone
- Compact geometry
- Natural Ventilation

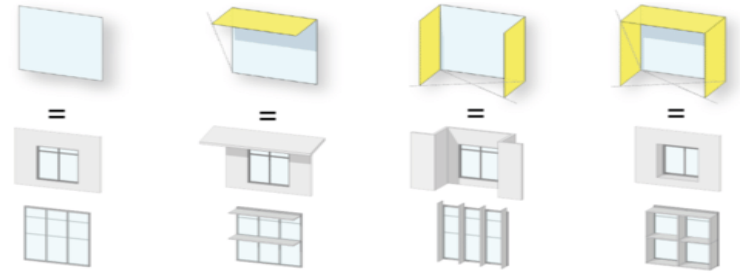
Building envelope optimization

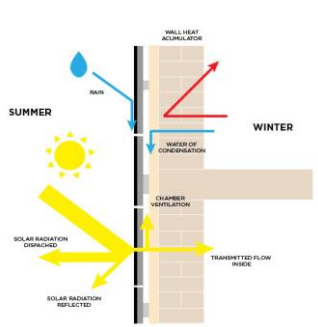
- Shading design
- Fenestration design
- Thermal resistance (insulation)
- Night cooling thermal mass
- Double skin envelope/ cavity wall

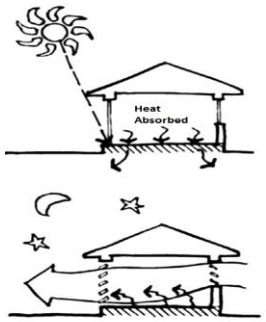
Passive cooling strategies











Sustainable Building Design – Passive Strategies

Topographical Level

- Protecting mountains, forests, watersheds, rivers, wetlands, farmlands, coasts and cities against climate change.

Climatic Zone Level

- Designing according to climatic conditions such as temperature, rainfall, wind direction, solar radiation, humidity etc.

Site Level

- To take advantage of the congenial and mitigate the adverse characteristics of the site and its micro-climatic features.

Block Level

- Interaction of block with surrounding ones and vegetation so that it is not deprived of heating/cooling, ventilation and lighting.

Unit Level

- Design strategies at unit level that influences heat, light and ventilation based on climatic conditions.

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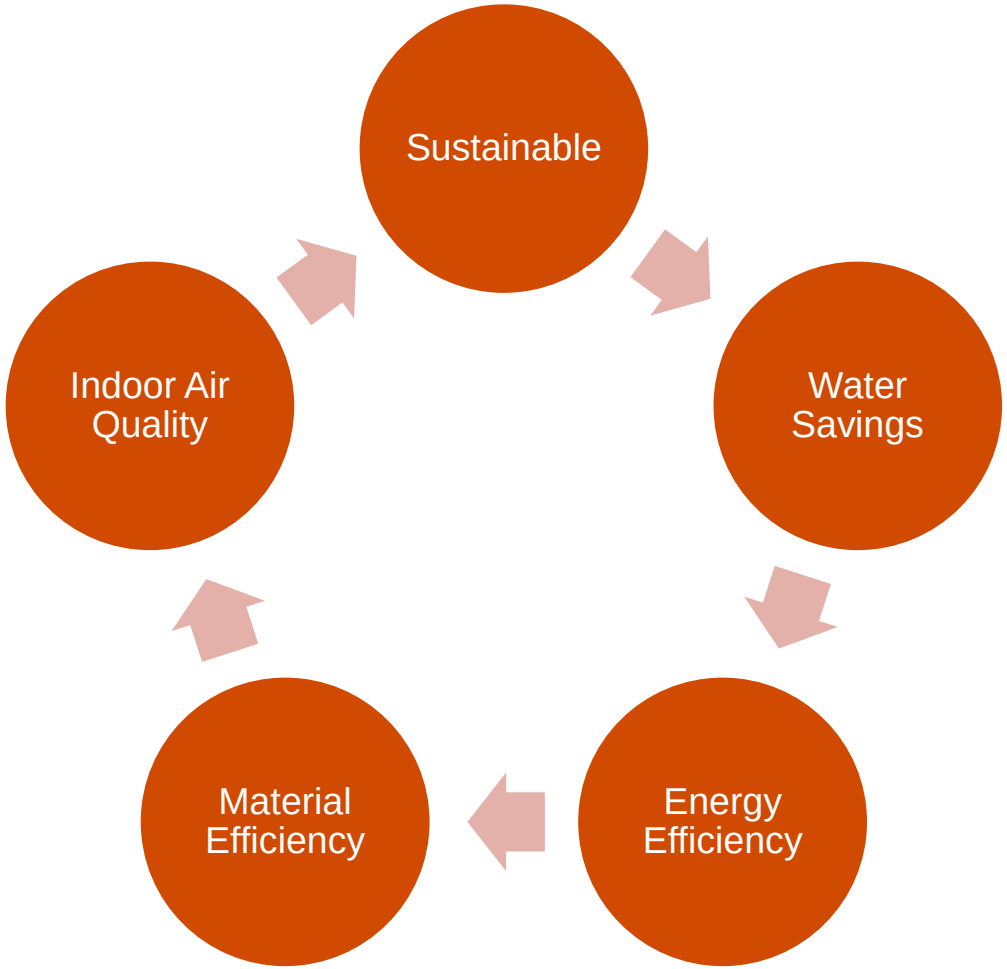
05 Case Studies

Case Study – Pocharam Campus, Infosys, Hyderabad



- Platinum rating by LEED & IGBC to Software Development Block at Pocharam Campus.
- The SDB 1 is the first commercial building in India to deploy unique Radiant-cooling technology

.

Case Study – Indira Paryavaran Bhawan, New Delhi

930 kWp Onsite High Efficiency Solar Photovoltaic panels are installed.

Measures like natural daylighting, shades to reduce ambient temperature

More than 50% of site area is covered with soft scaping and plantation.

- **The Indira Paryavaran Bhawan is now India's most environmentally friendly structure. GRIHA 5 Star and LEED Platinum certifications were awarded to the project.**
- When compared to a conventional building, **Indira Paryavaran Bhawan utilizes 70% less energy.** The project used green building principles, such as water conservation and optimization through site waste water recycling.

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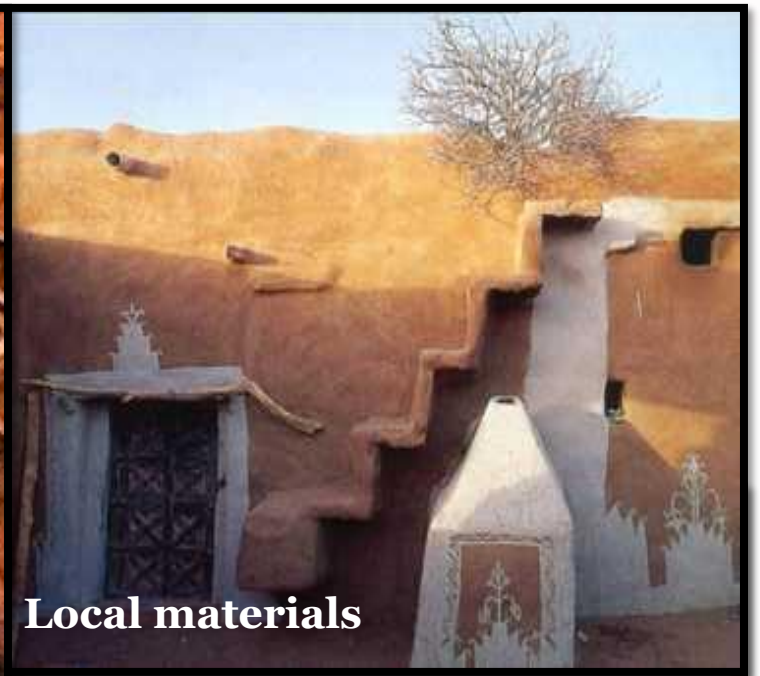
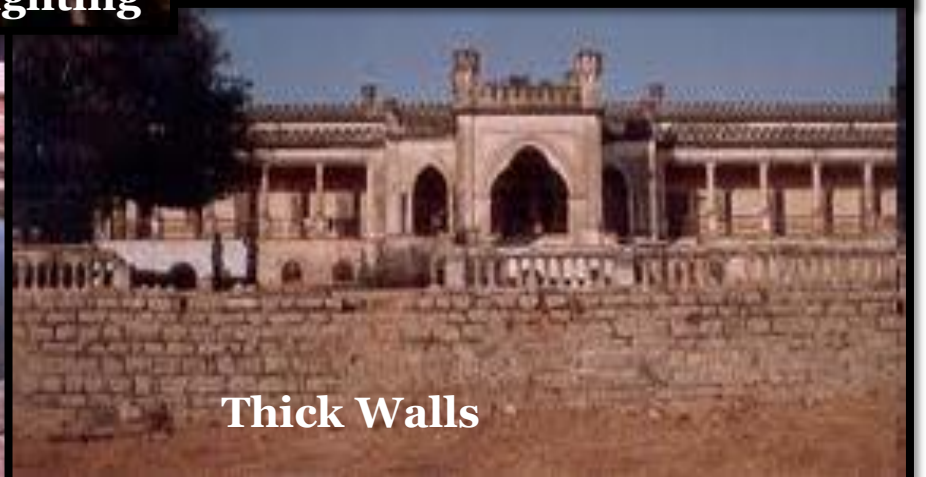
Learning from History





Thank You

Let’s continue the conversation…