Unit-1-Energy Transfer in Buildings **9 Hour**

Concepts of thermal comfort and energy efficient buildings, Conventional versus Energy Efficient Buildings-Climate and its influence in building design for energy requirement- Thermal properties of building materials, Heat transmission in building structures, Energy balance for cooling and heating of buildings- Estimation of heating and cooling loads, Low and zero energy buildings- Global and Indian energy scenario-Future building design aspects.

THERMAL COMFORT

THERMAL COMFORT

DEFINITION 1:

The state of mind that expresses satisfaction within in the thermal environment.

DEFINTION 2:

Thermal comfort is the outcome of a well-balanced combination of building systems adapted to the local climate and the type of activity performed.

DEFINITION 3:

Thermal comfort in simple terms can be defined as the state of mind, which shows satisfaction with the natural environment. It depends on the heat lost/gained by the body to its surroundings. In cold regions body loses more heat while in hot regions it is vice versa. Both the conditions leads to discomfort. Thus, a body having thermal neutrality is very important.

NEED FOR THERMAL COMFORT

The lack of thermal effect makes us feel stressed, annoyed and distracted. If the working environment is too cold it can make us feel sleepy, tired and lack of concentration if its too hot.

- **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.**

FACTORS AND INDICES AFFECTING THERMAL COMFORT

- Interest in establishing thermal comfort criteria dates back to **Europe to the beginning of the 19th century**.
- It started during the **Industrial revolution** when significant reforms to industry and housing were being introduced.
- This was done as heat and humidity stress led to illnesses and accidents.

FACTORS AND INDICES AFFECTING THERMAL COMFORT

Air temperature: Air temperature can be easily influenced by passive and mechanical heating and cooling systems.

Mean radiant temperature: It can be defined as the average value of temperature of all surfaces surrounding the target and plays a key factor in evaluating thermal comfort.

Air velocity: The speed at which the air travels in and out of the building.

Humidity: Humidity refers to the moisture content present in the air. Often too high and too low humidity levels may lead to discomfort.

Attire: The level of insulation that is attached or added over the human body.

Physical activity: The amount of heat produced by the human body during activity in hot and cold environment.

ENERGY EFFICIENT BUILDINGS

Energy Efficient Buildings (EEB):

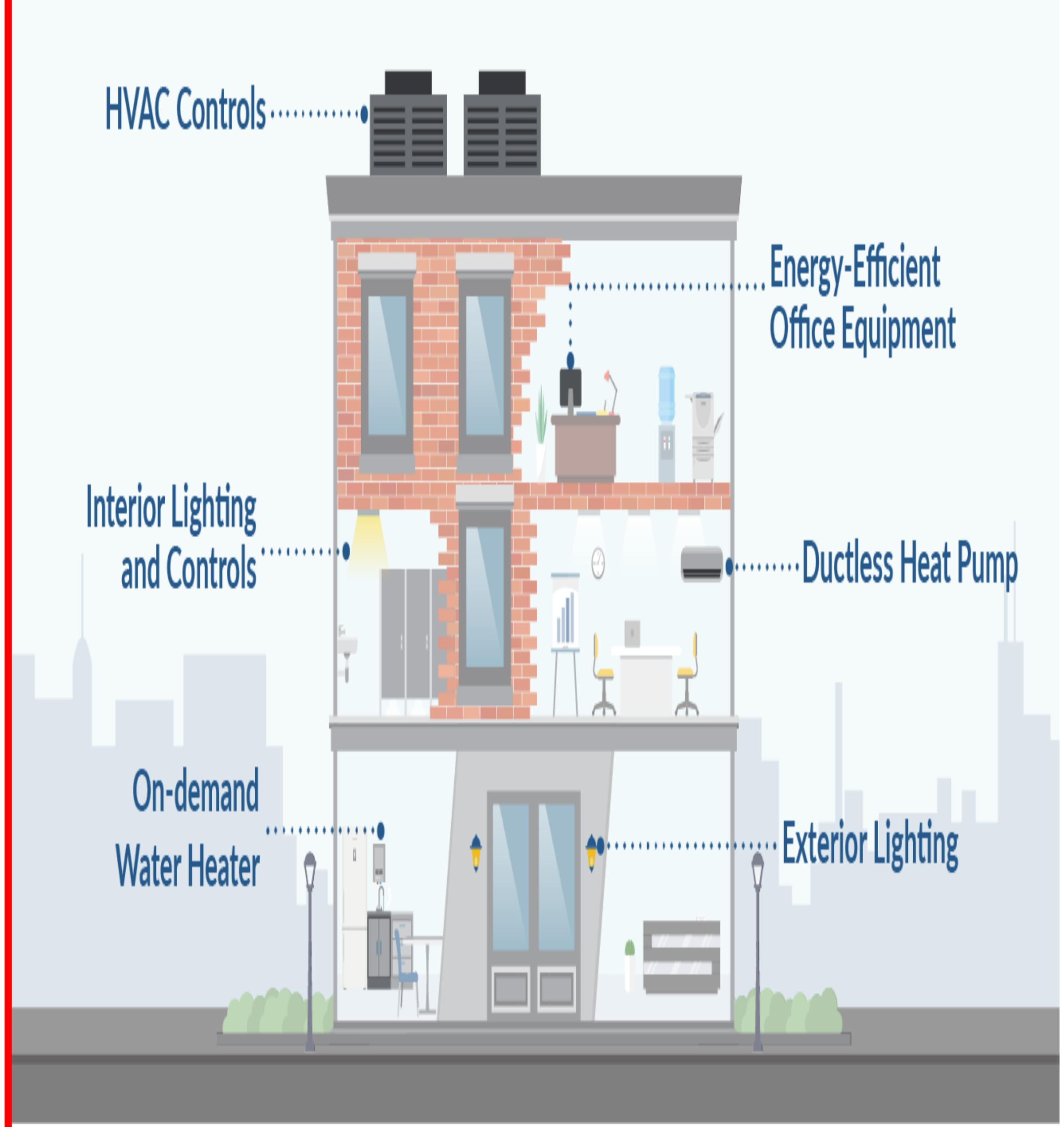
- Energy-efficient buildings are designed and constructed to **minimize energy consumption while providing comfortable and functional indoor spaces**.
- This is achieved through various strategies, including **optimizing building design, using energy-efficient equipment and appliances, and integrating renewable energy sources**.
- The goal is to **reduce energy waste, lower utility costs, and minimize the environmental impact of building operations.**
- Overall, energy efficient buildings provide **significant long-term cost savings** and additionally they contribute to **environmental sustainability, and promote a greener future**.

Energy efficient buildings – FEATURES

Heating and Cooling Systems

- To improve heating and cooling efficiency, it's important to choose a system that suits your specific needs, such as split-system air conditioners, wall-mounted units, or ceiling fans.
- Different energy sources like natural gas, electricity, solar power etc., to help lower long-term energy bills.
- Adding insulation is another effective way to reduce energy use, as it helps keep the home warm during winter and cool during summer.
- Additionally, installing double-glazed or Low-E glazed windows can significantly reduce heat loss in colder months, further enhancing energy efficiency.

Energy efficient buildings – FEATURES



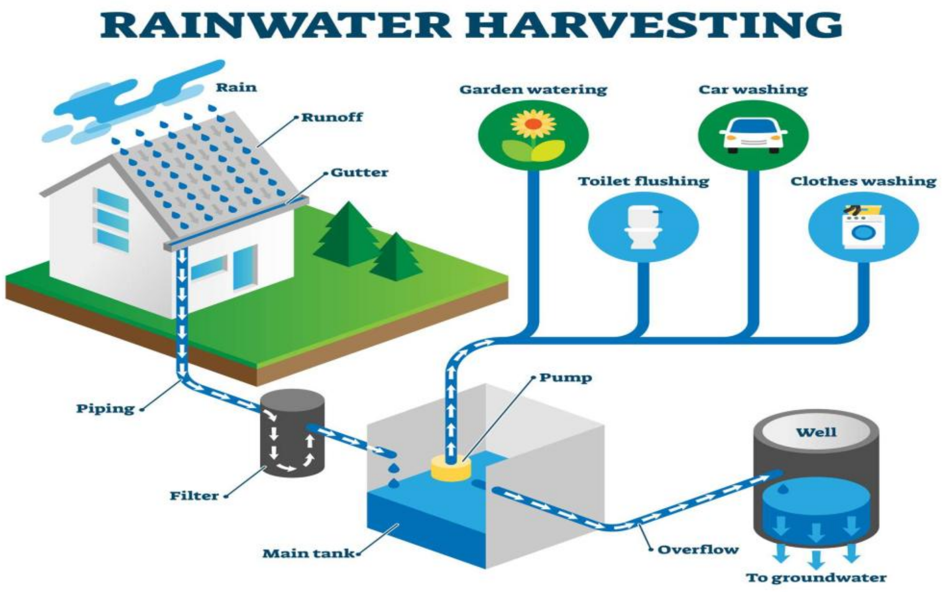
Hot Water Systems

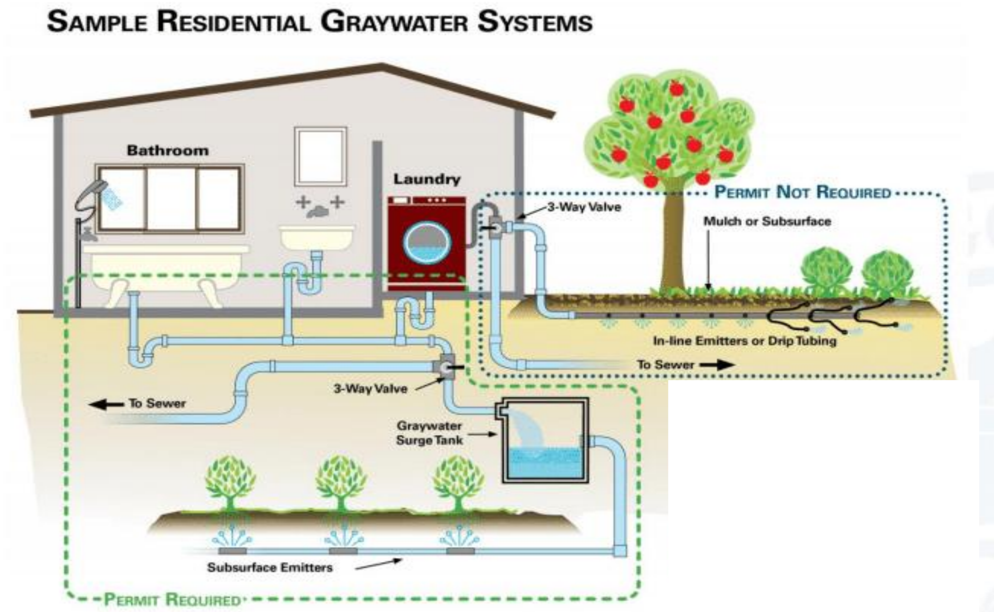
- The hot water system is another major contributor to energy usage.
- Consider installing a solar hot water system to lower energy bills and reduce your carbon footprint.
- This system works by using solar panels to heat your water, which can then be stored in a tank for later use.

Lighting (LED and Natural light)

- LED lights are one of the most energy-efficient lighting solutions available.
- They use up to 90% less energy than traditional incandescent bulbs and last up to 25 times longer.
- LEDs also produce very little heat, making them a great choice for both indoor and outdoor applications.

Energy efficient buildings – FEATURES





Water Conservation Strategies

- Installing low-flow fixtures such as showerheads, and faucets can save up to 20 gallons of water per day per person.
- Additionally, installing energy-efficient dishwashers and washing machines can also help conserve water by using less hot water during operation.
- **Rainwater collection** systems gather rain from rooftops into storage tanks for use in irrigation or other building needs. They help reduce demand on municipal water supplies and provide a free source of clean water.
- **Greywater reuse systems** collect and treat wastewater from sources like showers, sinks, and washing machines to be reused for non-potable purposes like irrigation or flushing purposes.

Energy efficient buildings – FEATURES

- Additionally, many states offer tax credits for installing wind turbines as an incentive for people to switch to this form of renewable energy.

Renewable Energy Strategies

- **Solar panels** are one of the most popular renewable energy options available for commercial buildings.
- Solar panels use **photovoltaic cells** to convert sunlight into electricity, which can then be used to power lights, appliances, and other electrical devices in a building.
- Solar panels require minimal maintenance and can provide significant savings on utility bills over time. Plus, they are easy to install and come in a variety of sizes and styles that can fit any budget or aesthetic preference.
- **Wind turbines** are another renewable energy option that is becoming increasingly popular among building designers. Wind turbines generate electricity by harnessing the kinetic energy from the wind passing through their blades. This type of system requires more space than solar panels but may offer greater cost savings depending on local wind conditions.

ENERGY EFFICIENT BUILDINGS

(General classifications)

GENERAL TYPES OF ENERGY EFFICIENT BUILDINGS

1. Low Energy Buildings

- These buildings are designed to use significantly less energy than conventional buildings, often achieving a **50% reduction in energy consumption.**

Features:

- ➢They are built with high-quality insulation and windows that help keep heat inside in winter and outside in summer.
- ➢They use energy-efficient systems, like heat pumps and energy-saving HVAC systems.
- ➢Use of energy-saving lights (LEDs) and appliances that consume less electricity.

GENERAL TYPES OF ENERGY EFFICIENT BUILDINGS

2. Passive House / Passive Energy Buildings

- The **Passive House** standard is one of the most rigorous energy-efficient building standards, focusing on **achieving very low energy demand for heating and cooling**. This standard is based on super-insulation, airtightness, and heat recovery ventilation to ensure that the building remains comfortable **without any mechanical HVAC systems**.

- **Features:**

➢ Super insulation (walls, roofs, windows).

➢ Air tight construction to minimize heat loss.

➢ Minimal need for active heating or cooling.

GENERAL TYPES OF ENERGY EFFICIENT BUILDINGS

3. Net Zero Energy Buildings (NZEB)

- A **Net Zero Energy Building** **<u>produces as much energy as it consumes on an annual basis</u>**. This is achieved by combining energy-efficient design with on-site renewable energy generation, such as solar panels, wind turbines, or geothermal systems. The building's energy demand is reduced to a minimum through insulation, high-performance HVAC, and smart technologies.
- **Features:**

➢ On-site renewable energy generation (solar, wind, geothermal).

➢ Advanced energy storage systems (batteries).

➢ Typically equipped with energy monitoring systems to track energy production and consumption.

GENERAL TYPES OF ENERGY EFFICIENT BUILDINGS

4. Plus Energy Buildings

- A **plus energy building** not only uses very little energy, but it actually **produces more energy than it consumes over a period of one year**. It generates surplus energy, usually through renewable sources.

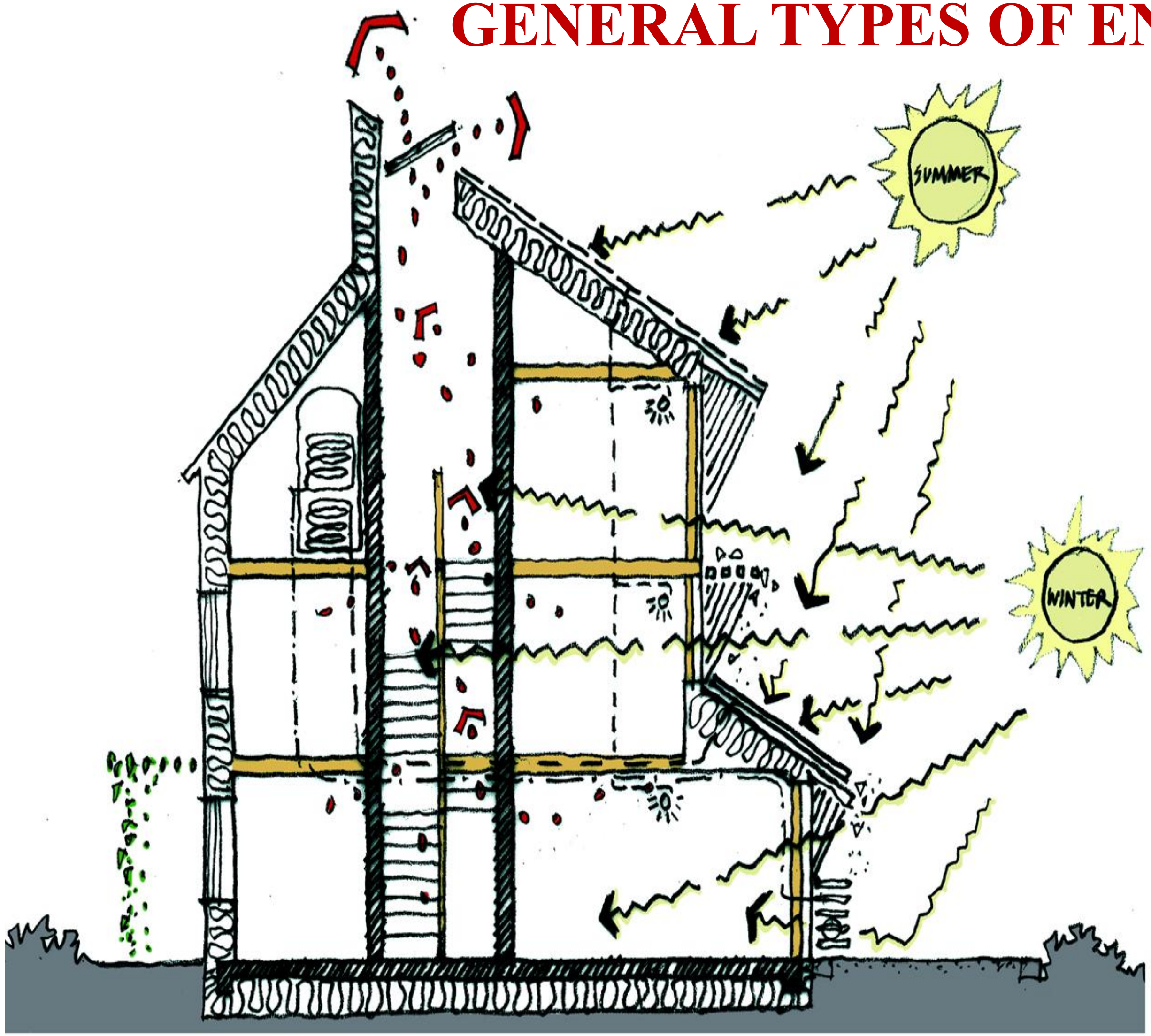
- **Features:**

➢ These buildings have solar panels or wind turbines that generate more energy than the building needs.

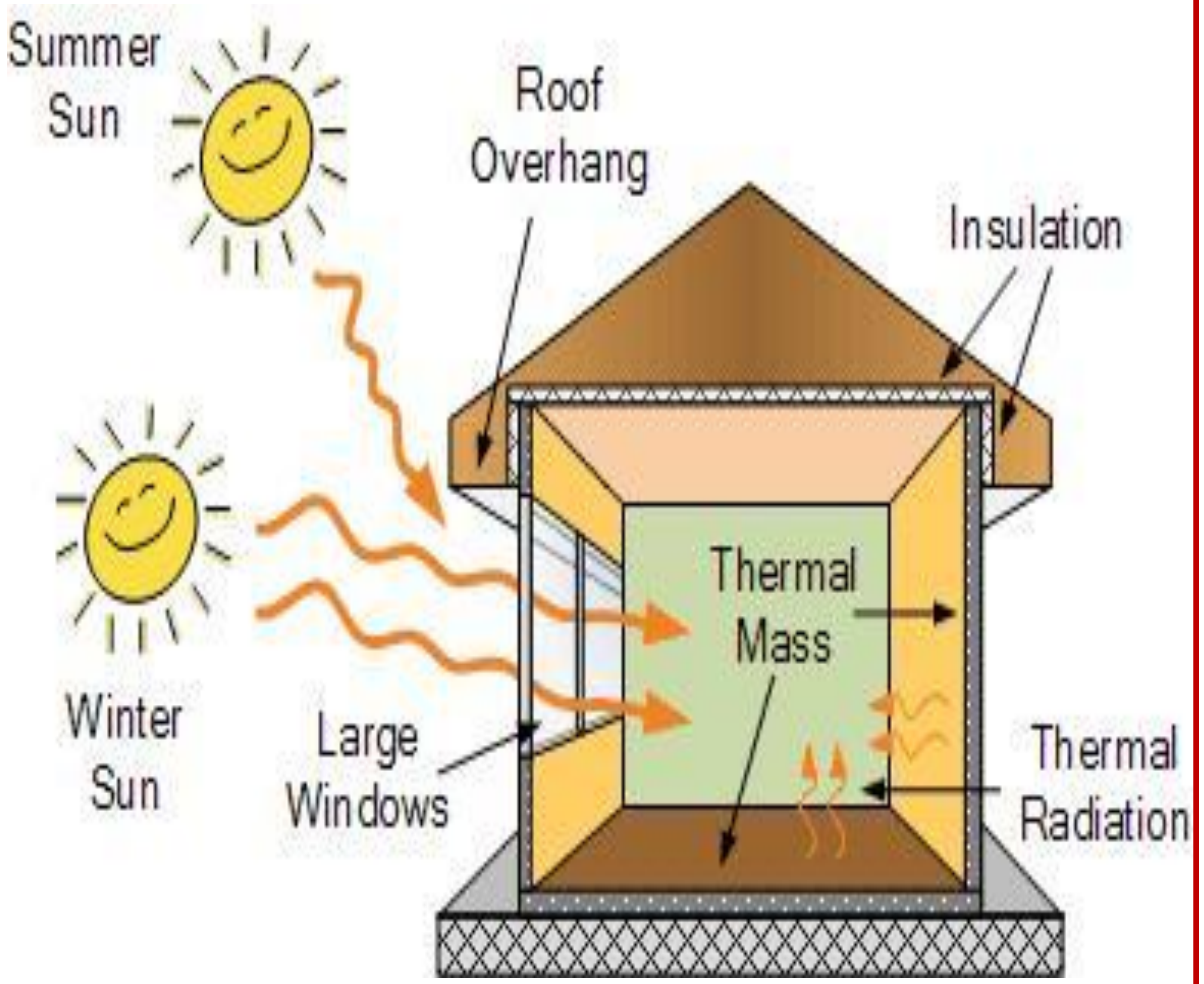
➢ Built with great insulation, energy-efficient systems, and lighting.

➢ They often store the extra energy in batteries or send it back to the power grid.

GENERAL TYPES OF ENERGY EFFICIENT BUILDINGS

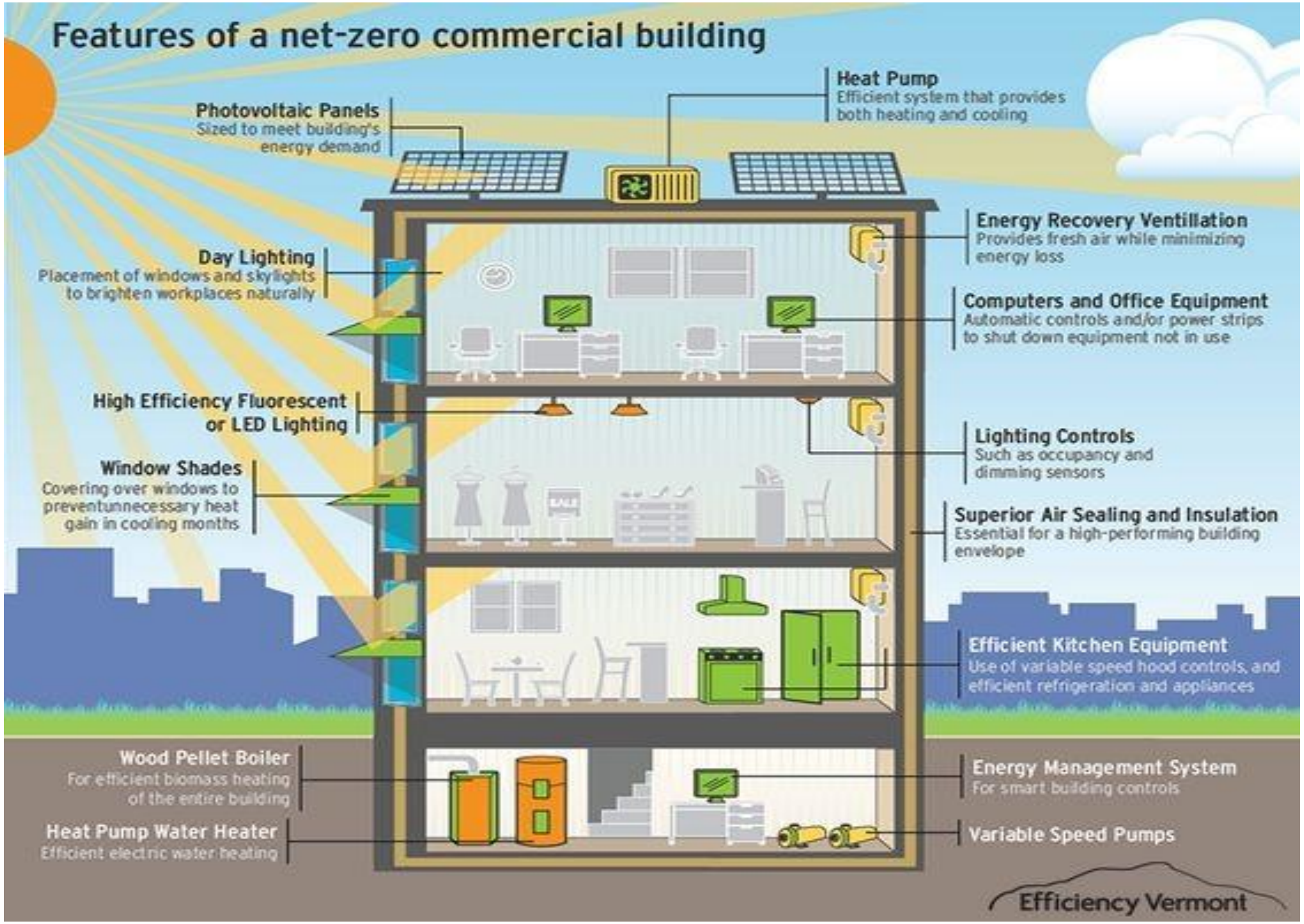


Low Energy Buildings



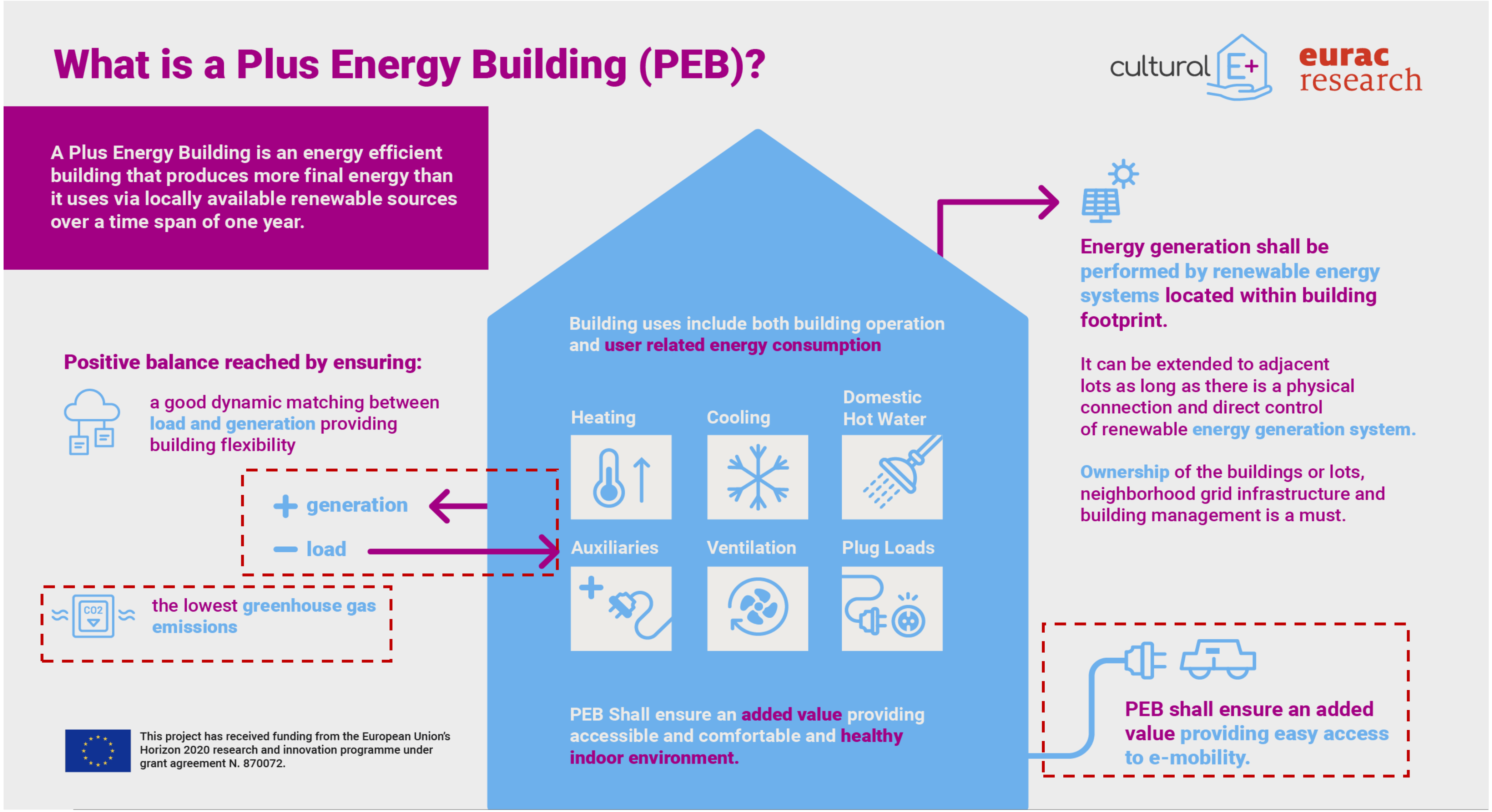
Passive House / Passive Energy Buildings

GENERAL TYPES OF ENERGY EFFICIENT BUILDINGS



Net Zero Energy Buildings (NZEB)

GENERAL TYPES OF ENERGY EFFICIENT BUILDINGS



Plus Energy Buildings

ENERGY EFFICIENT BUILDINGS

(Classifications-Materials)

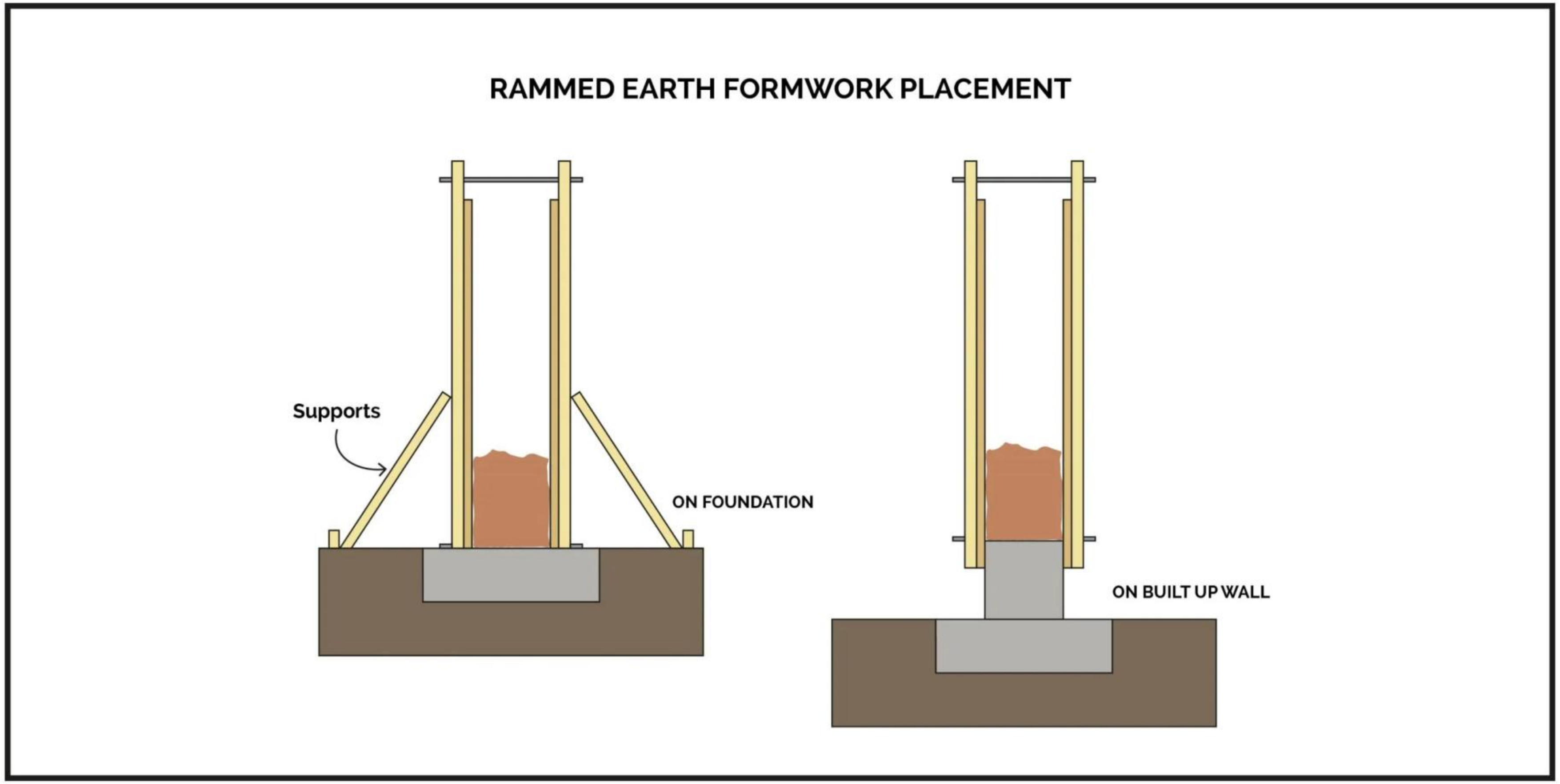
Energy Efficient Buildings: Types

The following are the various types of EEB based on material used for construction.

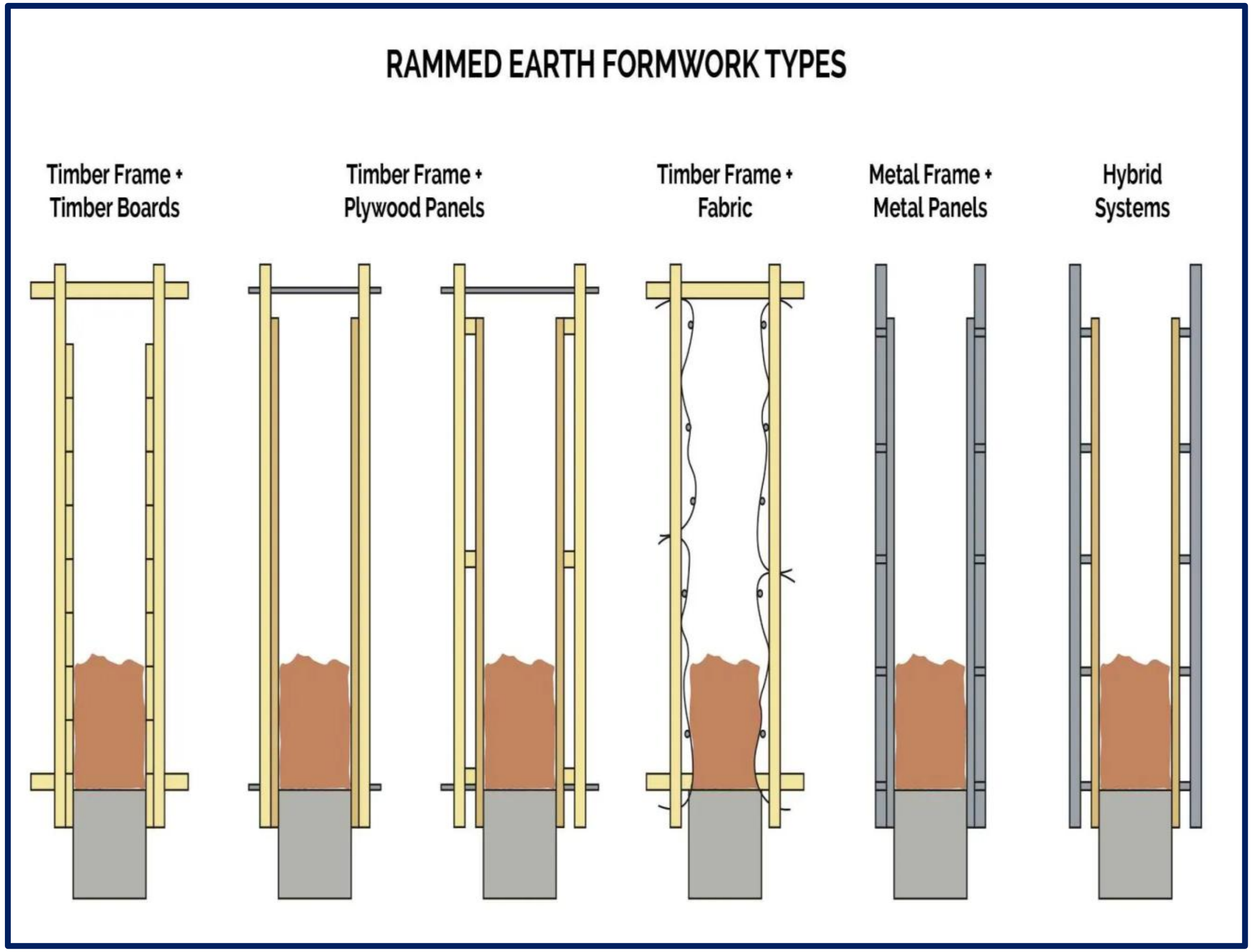
- *Rammed Earth*
- *Hempcrete*
- *Strawable*
- *Bamboo*
- *Cork*
- *Recycled Steel*
- *Reclaimed Wood*
- *Low Emission Glass*
- *Wood Composite Lumber*

Energy Efficient Buildings: Rammed Earth

- Rammed earth construction is the process of ramming a mixture of natural aggregates, like gravel, sand, silt and clay into a formwork to create solid walls.
- When the earth is dry the formwork is removed to reveal striking monolithic walls.

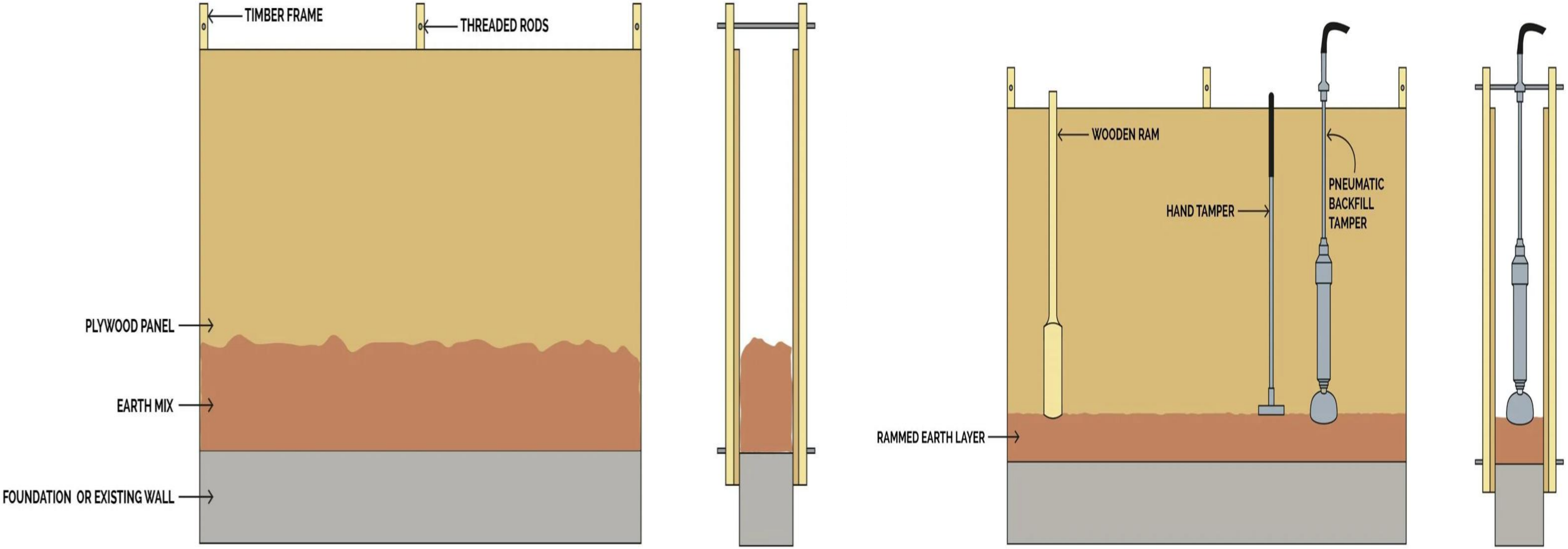


Energy Efficient Buildings: Rammed Earth



- Once the formwork is in place, the construction process begins by filling the frame with a layer of damp earth mix.
- Traditionally, a wooden pole was used to compress this layer to about half its original volume but today more efficient **pneumatically powered tampers** are used. This process is repeated until the frame is filled with compacted earth.
- When the formwork is removed, a free-standing rammed earth wall remains.

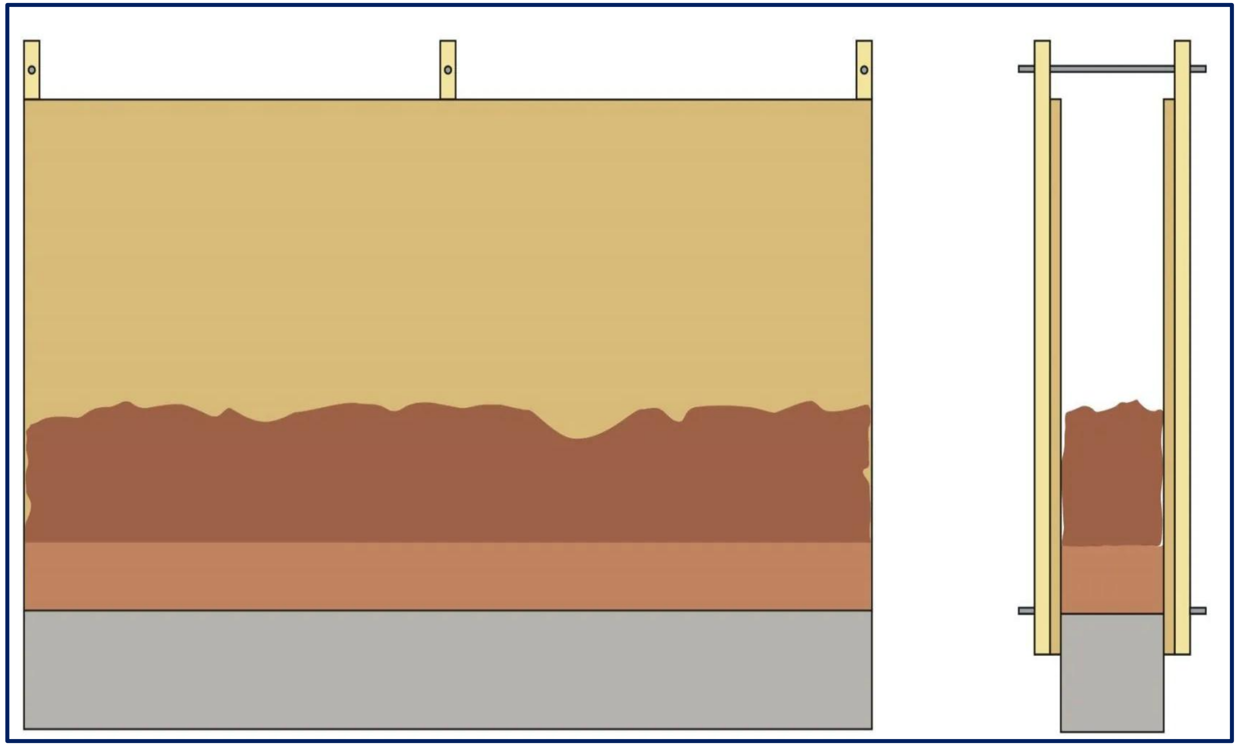
Energy Efficient Buildings: Rammed Earth - Construction

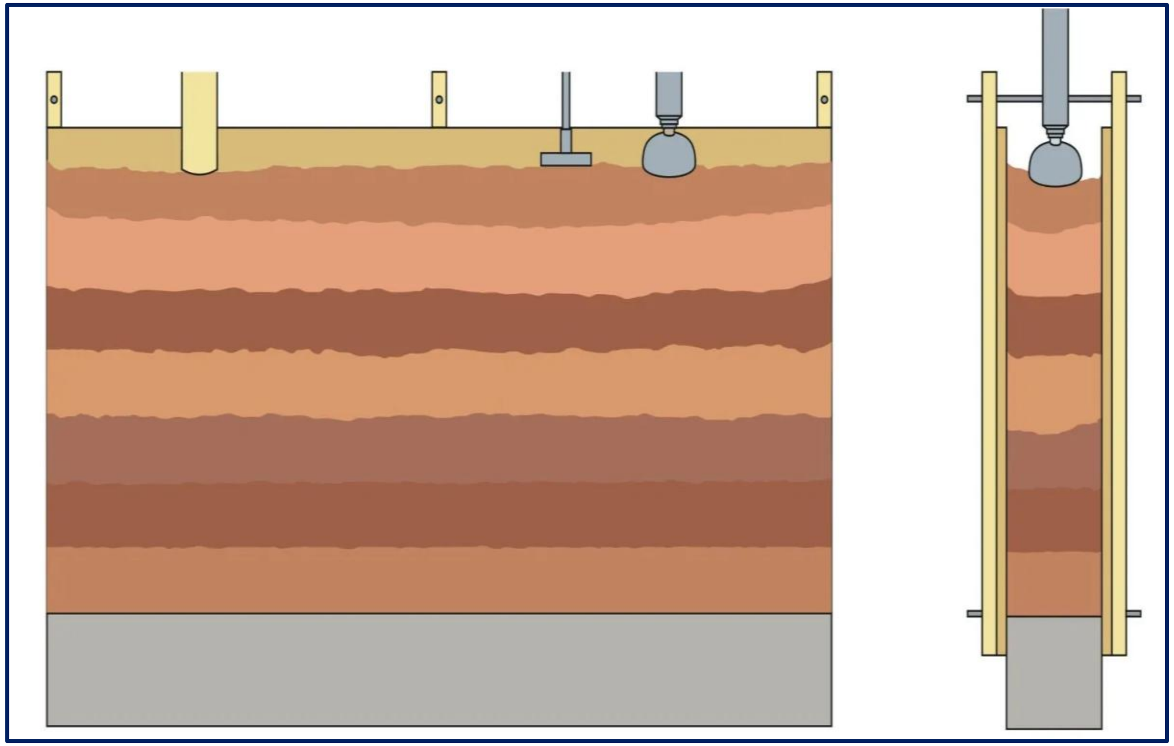


Step 1 : The plywood formwork is constructed and filled with a layer of moist earth mix (concrete, gravel, sand, clay etc.,)

Step 2:The earth layer is compacted using pneumatic backfill tamper, or a metal hand tamper. Traditionally, a wooden ram was used.

Energy Efficient Buildings: Rammed Earth - Construction

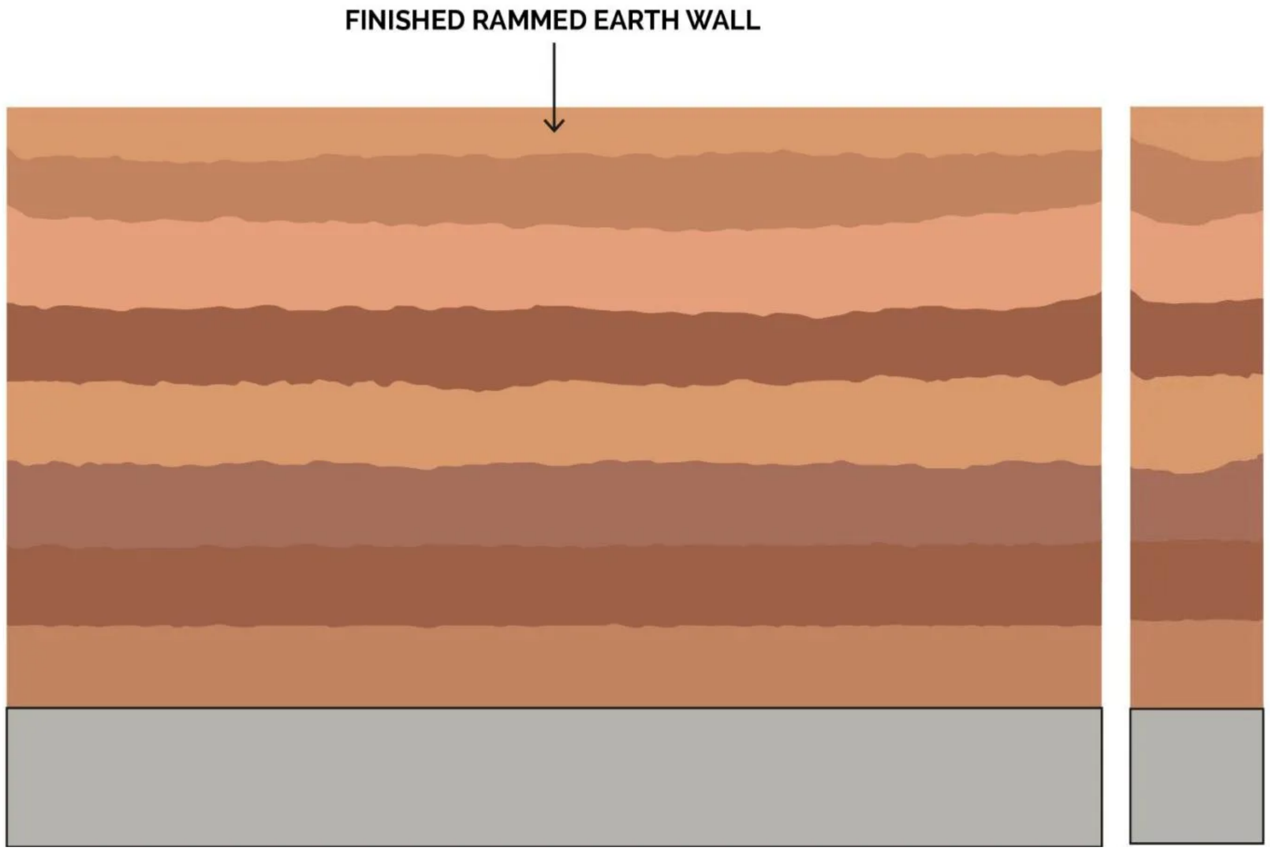




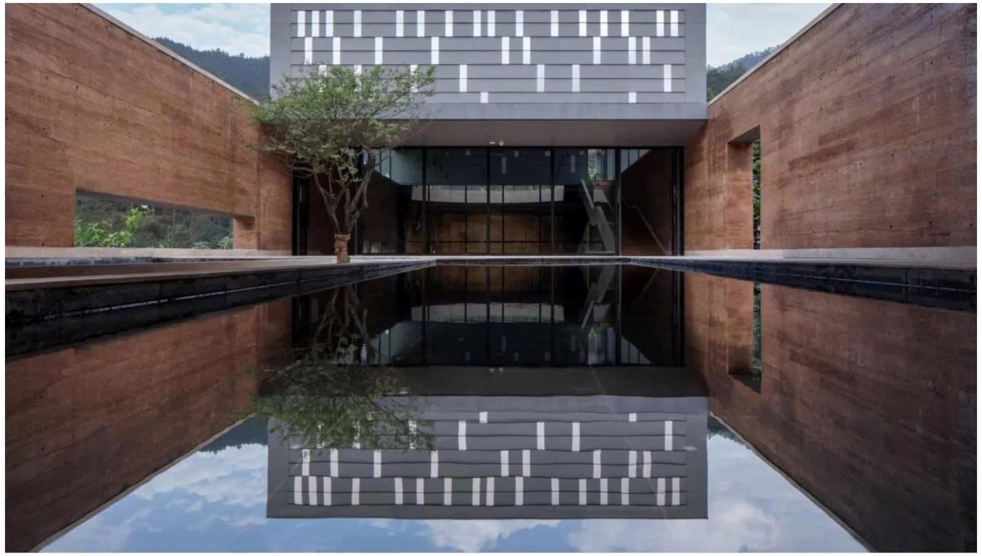
Step 3 : The next layer is added and the process is repeated.

Step 4 : Additional layers of moist earth are added and compressed until the desired wall height is achieved.

Energy Efficient Buildings: Rammed Earth - Construction



Step 5: Sometimes a protective layer is added to the top for extra durability and moisture protection. Once the compressed layers are all dry, the formwork is removed to reveal the rammed earth wall



Sanbaopeng Art Museum, Sanbao village, China

Dos Hijas Gallery, Ensenada, Mexico

Energy Efficient Buildings: Rammed Earth – Benefits

Sustainability & Eco-Friendliness

- Naturally available materials are used for building, which reduces the need for products to be newly manufactured (cement, brick etc.,)

Excellent Thermal Mass

- The walls made of natural earth material has the ability to absorb heat during the day and release it at night, which decreases the need for mechanical heating/ cooling systems.

Durability and Strength

- Rammed earth structures can sustain for longer centuries when properly maintained.
- Termites and rodents don't affect compacted soil walls.

Fire and Sound Resistance

- Highly resistant to fire.
- The material is dense which offers good acoustic separation, making interiors quieter.

Energy Efficient Buildings: Rammed Earth – Benefits

Low Maintenance

- No frequent painting or plastering

Aesthetic Appeal

- Earthy tones, visible layers, and textures provide a rustic and elegant appearance without added finishes.
- Pigments or materials can be added to alter colors and textures.

Cost-Effective (Long-Term)

- Reduced energy bills
- Low maintenance needs
- Extended lifespan

Energy Efficient Buildings: Hempcrete

- Hempcrete is a bio-composite material made from hemp fibres mixed with lime and water.
- This material is lightweight, strong, and possesses exceptional insulation properties.
- Hemp fibers are mixed with lime and water to create a versatile construction material that can be used for walls, floors, and roofs.
- Its excellent thermal insulation abilities reduce the energy required for climate control.

- Hempcrete is also a carbon-negative material, which hides away carbon dioxide during its production and further enhancing its sustainability credentials.
- Moreover, the cultivation of hemp itself is eco- friendly, requiring minimal water, pesticides, and synthetic fertilizers, making hempcrete a truly green building choice.

Energy Efficient Buildings: Hempcrete

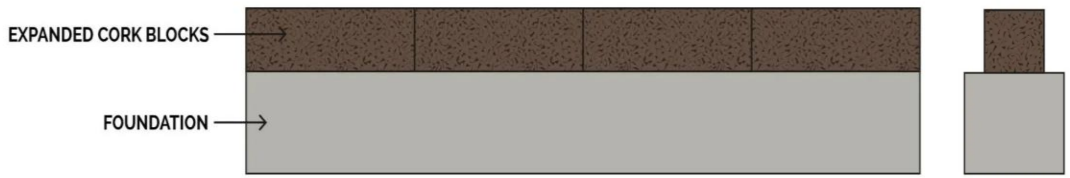
Energy Efficient Buildings: Bamboo

- Bamboo is a rapidly renewable grass that has gained recognition as an energy- efficient building material.
- Due to its quick growth, bamboo reduces the strain on forests and contributes to forest preservation.
- It possesses impressive strength and durability, making it a reliable choice for structural elements in construction.
- Beyond its structural qualities, bamboo's insulation properties are noteworthy.
- It acts as an organic insulator, helping maintain stable indoor temperatures and reducing the energy required for heating and cooling.
- Bamboo is a testament to nature's capacity to provide sustainable materials for the built environment, making it a preferred choice for eco-conscious architects and builders.

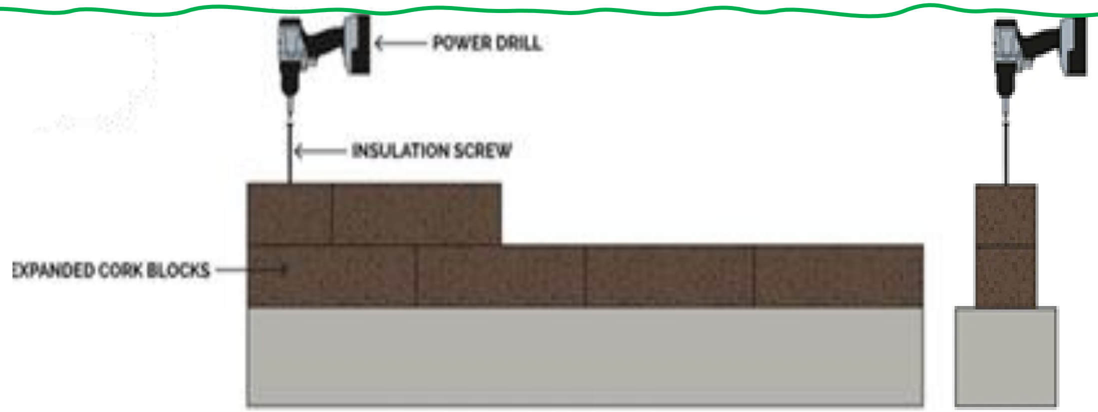
Energy Efficient Buildings: Cork

- Cork is harvested from cork oak trees and is used in construction as insulation or a component of composite materials.
- As a natural insulator, cork boasts low thermal conductivity, which reduces heat transfer and assists in keeping indoor temperatures stable.
- This not only enhances energy efficient building design but also lessens the demand for energy-intensive heating and cooling systems.
- Cork's sustainable harvesting methods are particularly environmentally friendly.
- The process doesn't harm the cork oak tree, allowing it to continue absorbing carbon dioxide, thus making cork an eco-conscious choice for builders committed to reducing their environmental impact.

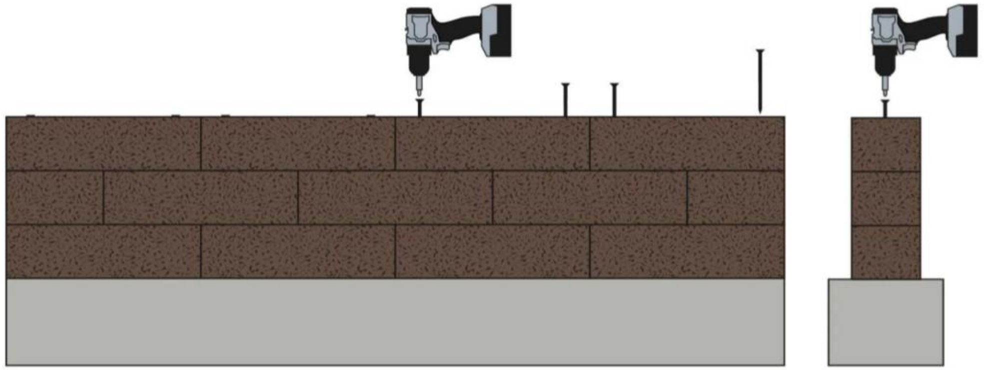
Energy Efficient Buildings: Steps involved in cork buildings



Step 1 - The expanded cork blocks are cut to desired size and laid directly onto the foundation in a stretcher bond pattern.



Step 2 - The second course of blocks is fixed to the first using long insulation screws, driven in with a power drill for strength and stability.



Step 3 - On the third course, the screws are staggered slightly to avoid hitting any joints between the blocks below.

Step 4- The fourth course uses the same screw positions as the second. The process is repeated till the desired wall height is reached.

Energy Efficient Buildings: Strawable

- Strawbale construction employs straw bales as building blocks, often covered with plaster for protection.
- Straw as an energy-efficient building material is a superb natural insulator, offering superior thermal performance.
- Homes constructed with strawbale provide excellent insulation, leading to reduced energy consumption for both heating and cooling throughout the year.
- Strawbale structures are known as energy saving materials and can maintain comfortable indoor temperatures with minimal heating or cooling.
- Additionally, strawbale is typically used when targeting energy efficient construction.
- Utilizing locally sourced materials, reducing transportation-related to emissions and supporting local economies.

Energy Efficient Buildings: Recycled steel

- Recycled steel, often used for structural elements, is manufactured from steel scrap.
- Utilizing recycled steel significantly reduces the environmental impact associated with steel production, as it requires fewer resources and energy compared to producing steel from raw materials.
- Furthermore, steel's durability and longevity make it a compelling choice as an energy-efficient building material for large-span structures.
- It contributes to the overall sustainability of buildings by minimizing the need for replacements or maintenance.

Energy Efficient Buildings: Recycled steel

1. Existing steel frame building

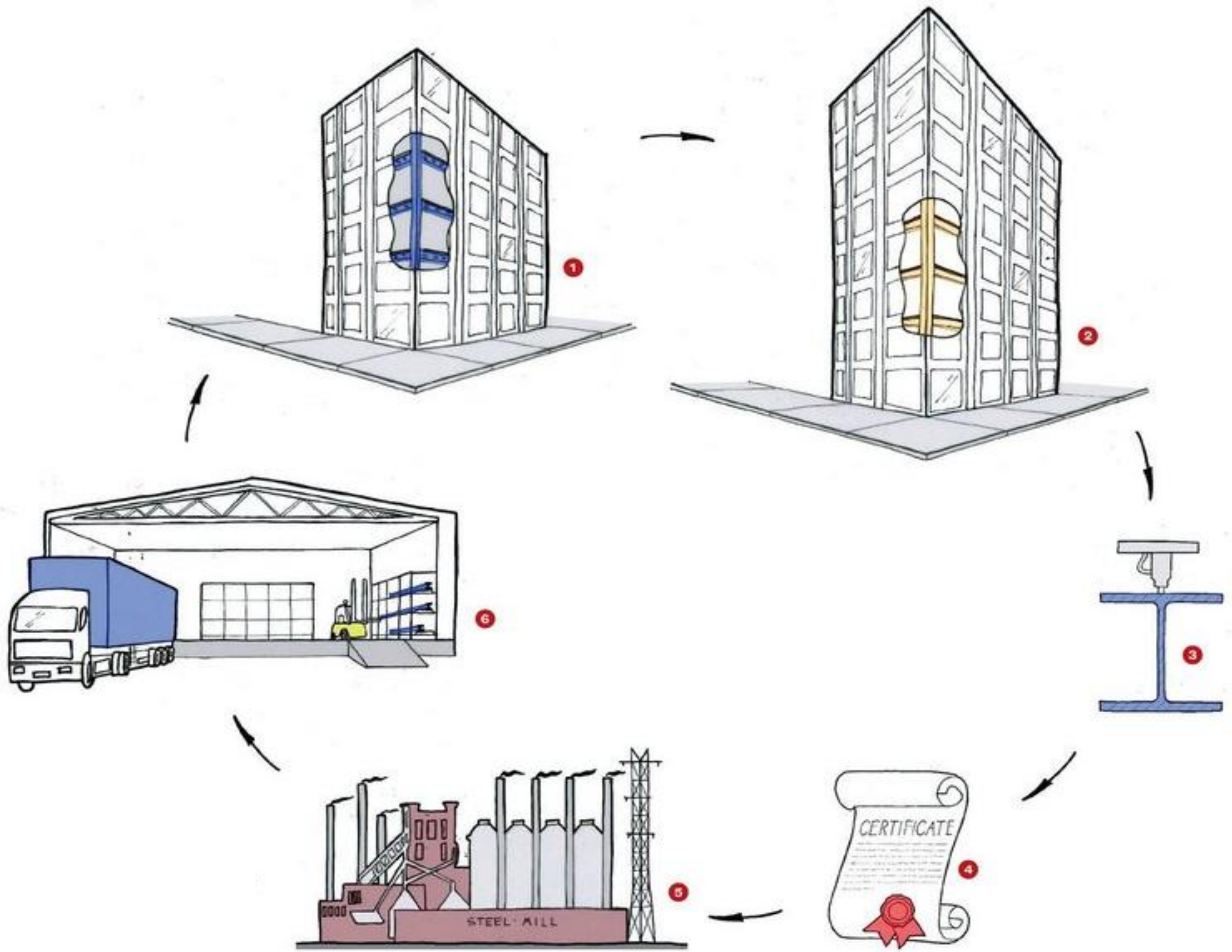
2. Existing steel frame building replaced with timber-frame building

3. Salvaged steel testing centre

4. Certification and warranty is issued for the tested steel

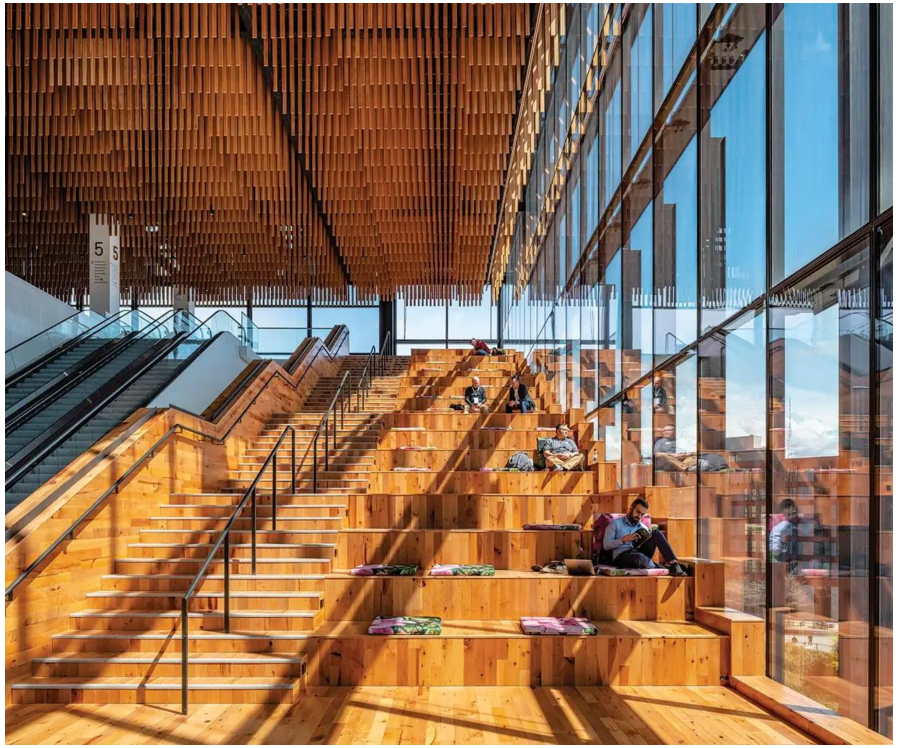
5. Recycling materials not fit for reuse are sent to steel mills

6. Storing reused and recycled steel



Energy Efficient Buildings: Reclaimed wood

- Reclaimed wood is salvaged from old structures and repurposed in modern construction.
- Beyond its aesthetic appeal and unique character, reclaimed wood offers natural insulation properties.
- This wood has the ability to regulate indoor temperatures, reducing the need for additional heating and cooling.
- Furthermore, by reusing old wood, builders are diverting materials from landfills and reducing the demand for new timber production.
- This not only reduces waste but also lessens the carbon footprint associated with harvesting and processing new wood.

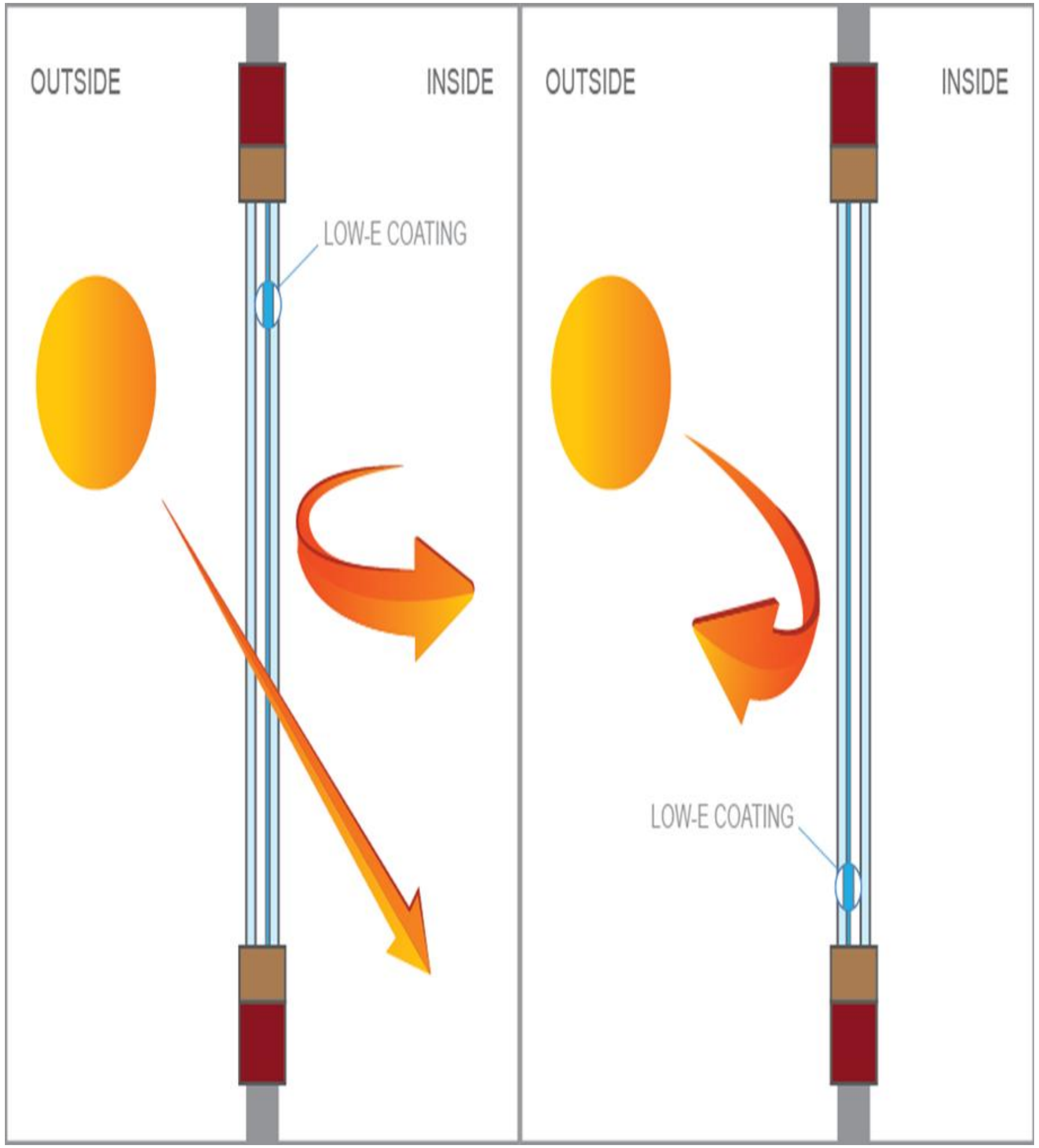


Energy Efficient Buildings: Reclaimed wood

- No need for complete demolition.
- Instead, the parts of the house can be disassembled and can be used for preparing other products.

Energy Efficient Buildings: Low Emission Glass

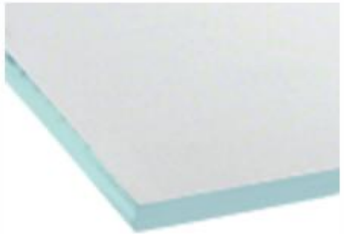
- Low-Emission (Low-E-low emissivity) glass is a technological innovation in the realm of windows and glass facades.
- This glass is treated with a microscopically thin, nearly invisible coating that controls heat flow.
- Low-E glass enhances the energy performance of windows by reflecting heat while allowing visible light to pass through to achieve energy efficient building design.
- In practice, this means that during hot weather, less heat enters the building, reducing the need for air conditioning.
- Conversely, during colder months, less heat escapes, diminishing heating demands.



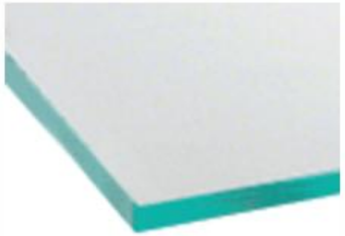
Energy Efficient Buildings: Low Emission Glass

Common Glass Thickness

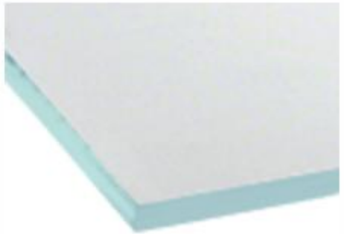
1/2" (12mm) Low Iron Clear Tempered Glass Custom Size



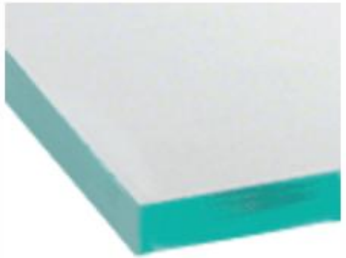
5/8" (15mm) Clear Tempered Glass Custom Size



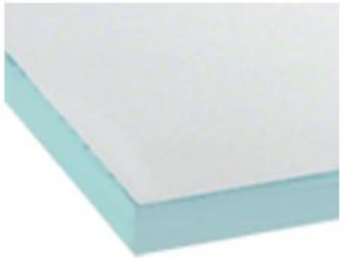
5/8" (15mm) Low Iron Clear Tempered Glass Custom Size



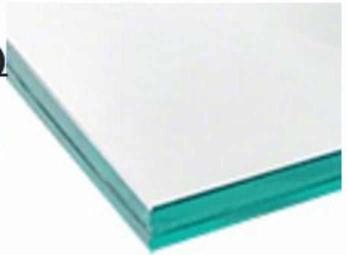
3/4" (19mm) Clear Tempered Glass Custom Size



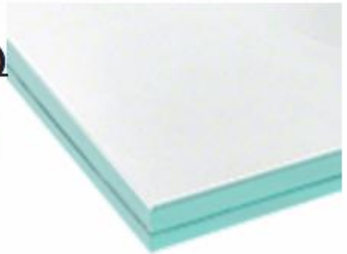
3/4" (19mm) Low Iron Clear Tempered Glass Custom Size



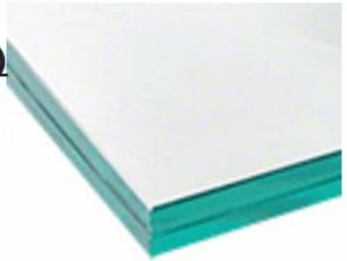
9/16" (13.52mm) Clear Laminated Tempered Panel Custom Size



9/16" (13.52mm) Clear Laminated Tempered Panel Custom Size ...

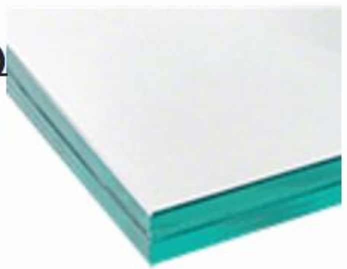


11/16" (17.52mm) Clear Laminated Glass Custom Size

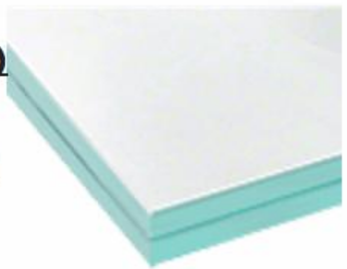


11/16" (17.52mm) Low Iron Clear Laminated Glass Custom Size

27/32" (21.52mm) Clear Laminated Custom Size



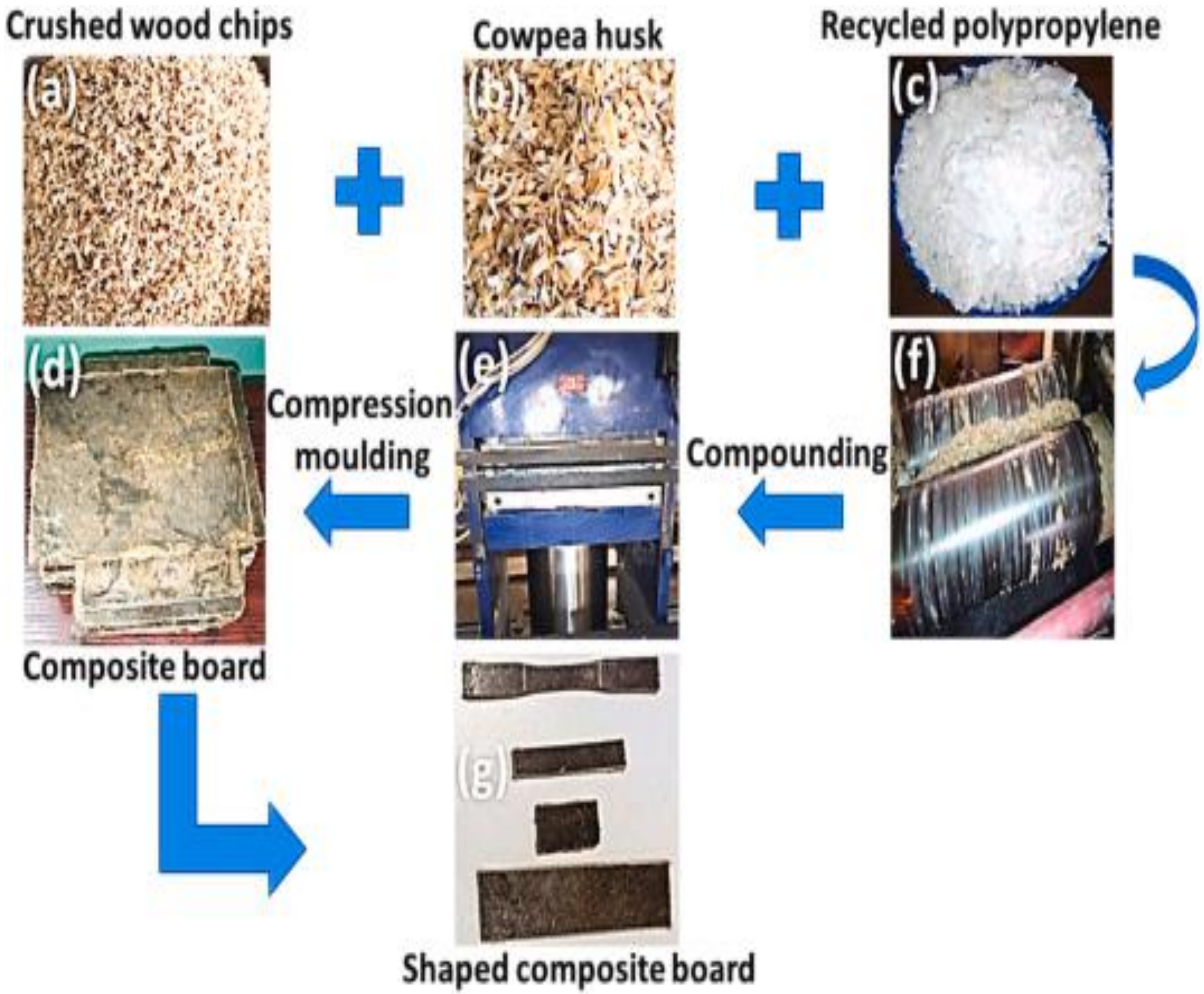
27/32" (21.52mm) Low Iron Clear Laminated Custom Size



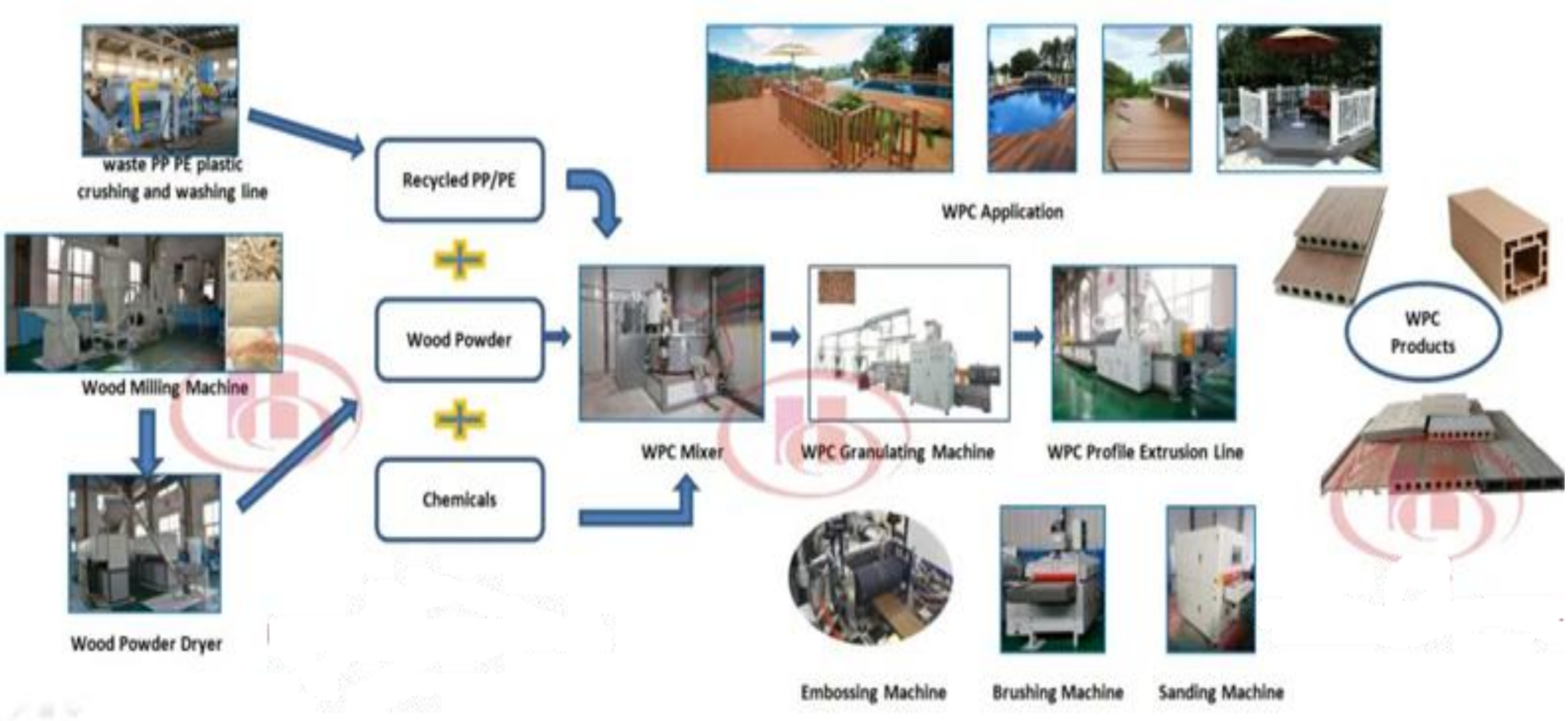
Energy Efficient Buildings: Wooden composite

- Wood composite lumber as an energy-efficient building material is crafted from recycled wood fibers and plastics, often referred to as composite decking or lumber.
- This material is gaining popularity as an eco-friendly alternative to traditional wood.
- It plays a crucial role in reducing the demand for virgin timber, which helps conserve forests and biodiversity.
- Additionally, wood composite lumber offers excellent insulation properties, making it an ideal choice for energy-efficient construction.

Steps involved in preparing Wooden composite



Energy Efficient Buildings: Wooden composite



Steps involved in manufacturing wooden composite

Energy Efficient Buildings: Wooden composite

Plastic wastage recycling machine - Making PPPE plastic wastage into plastic flakes

Wood powder making machine Making fiber material into 40-100 mesh wood powder

WPC mixing machine Mixing plastic and wood and chemicals, the wood powder content can be 60–70%

WPC granulation machine (PVC Wood Product no need) Making mixed material into uniform WPC granules with good composition

WPC profile extrusion line Making WPC granules into required WPC products; manufacturer can change mold for size/shape

Embossing machine Making wooden grain on the WPC surface

Sanding machine Making wood cutting section feeling on the WPC surface

Brushing machine Making wood skin feeling on the WPC surface

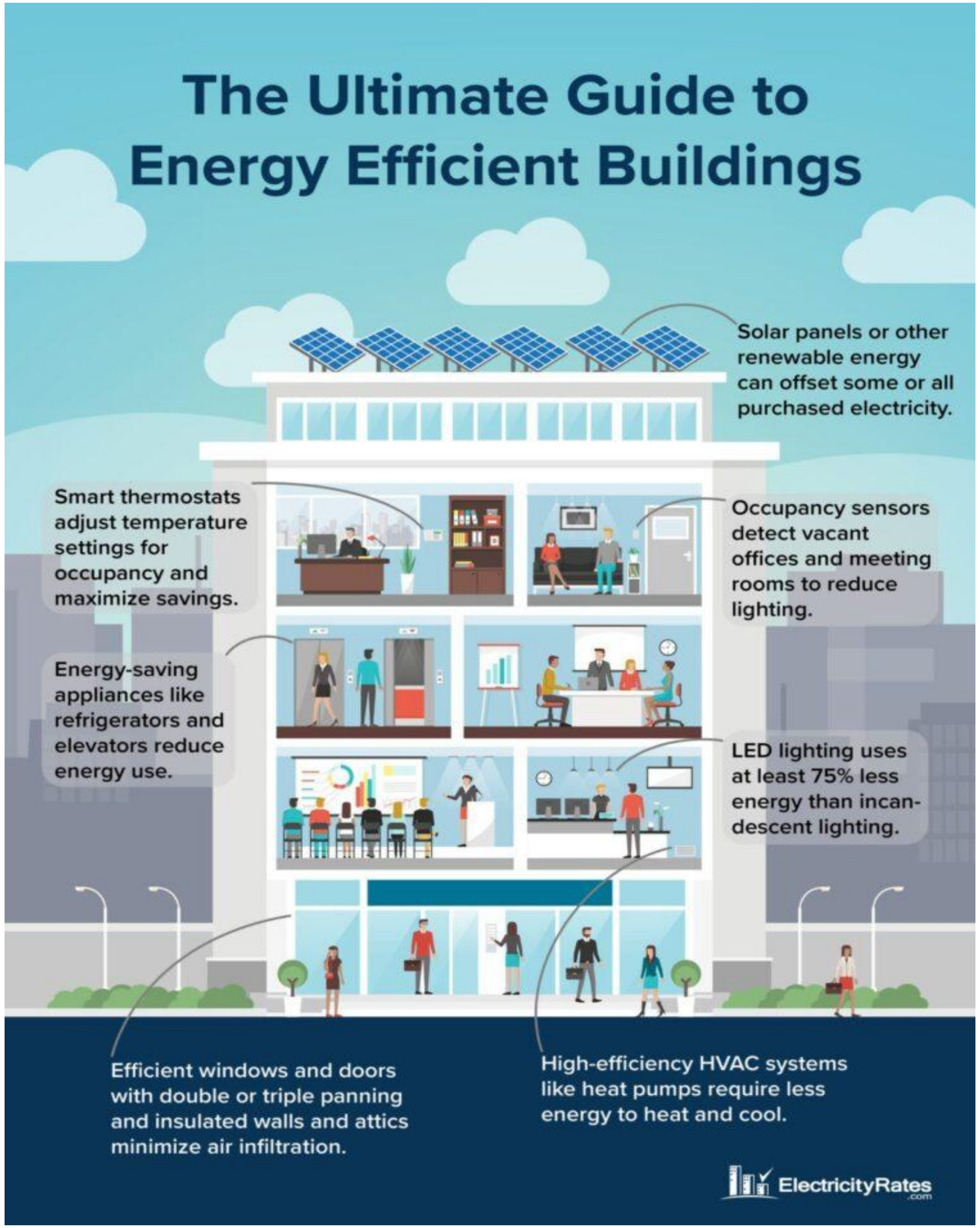
Cutting machine Cutting WPC products into required length

WPC installation tools Installing WPC products into required construction according to the application requirements

Energy Efficient Buildings:

Some of the existing energy efficient buildings around the world are.

- Bullitt Center – Seattle , Washington
- One central part, Sydney
- Shangai tower, Shangai



Energy Efficient Buildings: Central Park Sydney

- Central Park Sydney, specifically the "One Central Park" residential towers, are considered highly energy-efficient buildings.
- They incorporate various sustainable design elements and technologies to minimize their environmental impact and energy consumption.

CONVENTIONAL BUILDINGS

VS

ENERGY EFFICIENT BUILDINGS

Conventional buildings vs Energy efficient buildings

Aspect	Conventional Buildings	Energy-Efficient Buildings
Design Approach	Focus on function and appearance	Integrated energy-saving and sustainable design principles
Insulation	Little or no insulation	High-quality insulation in walls, roofs, and windows
Lighting	Incandescent or fluorescent lighting	LED lighting and **natural daylight optimization**
Heating & Cooling Systems	Often outdated and inefficient systems	High-efficient HVAC systems with **smart thermostats**
Material Use	Common materials, not always sustainable	Use of sustainable materials such as recycled steel, reclaimed wood, low-carbon.
Energy Consumption	High due to poor design and inefficient appliances	Low due to optimized systems and **passive design**

Conventional buildings vs Energy efficient buildings

Aspect	Conventional Buildings	Energy-Efficient Buildings
Natural Ventilation	Rarely utilized	Designed for cross-ventilation and passive cooling
Water Use	No water-saving technologies	Low-flow fixtures, water recycling, and rainwater harvesting
Initial Cost	Low technology – low cost	Technology incorporated buildings – high cost
Operating Cost	Higher energy bills and maintenance cost	Lower energy bills and reduced maintenance costs
Carbon Footprint	High due to energy inefficiency	Low due to reduced emissions and often usage of renewable energy
Certifications	Usually none	Often certified (e.g., LEED, GRIHA, IGBC, BREEAM)

- ✓ **LEED - Leadership in Energy and Environmental Design – US Green Building Council**
- ✓ **GRIHA - Green Rating for Integrated Habitat Assessment – Indian Council**
- ✓ **IGBC - Indian Green Building Council - Indian**
- ✓ **BREEAM - Building Research Establishment Environmental Assessment Method**

INFLUENCE OF CLIMATE ON BUILDING DESIGN FOR ENERGY REQUIREMENTS

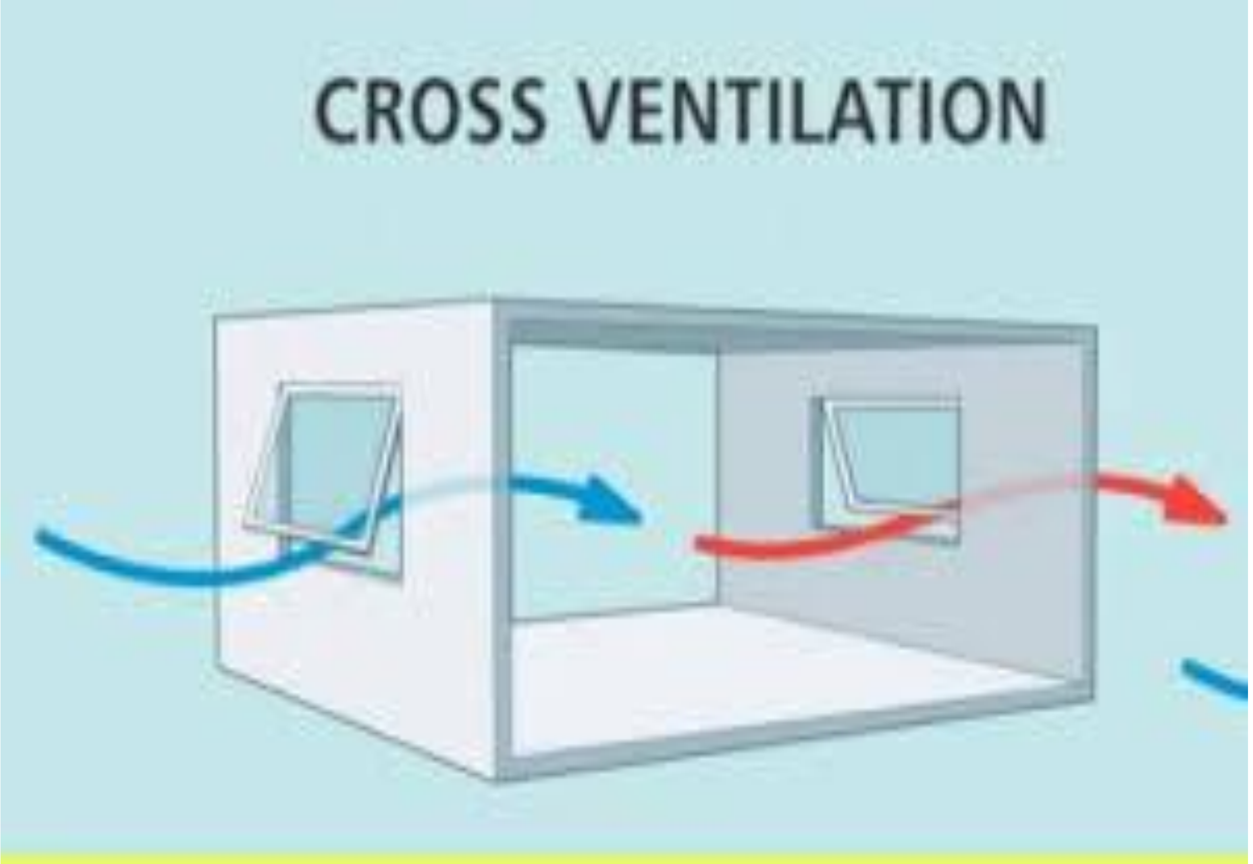
INFLUENCE OF CLIMATE ON BUILDING DESIGN FOR ENERGY REQUIREMENTS

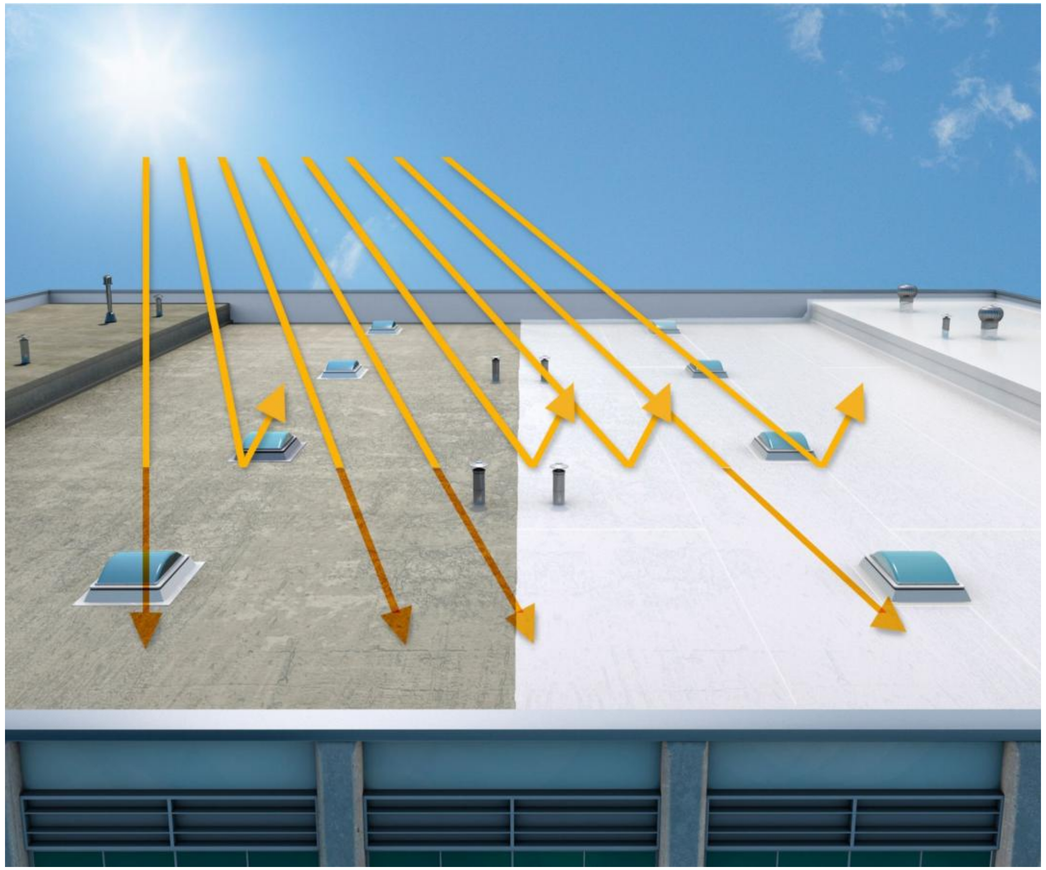
- The climate of a region including its temperature, humidity, sunlight, wind, and rainfall directly affects how much energy a building will need for heating, cooling, lighting, and ventilation.
- A well-designed building that responds to its climate can significantly reduce energy consumption, improve occupant comfort, and lower operating and maintenance costs.

Climatic factor that influence on design and usage of energy

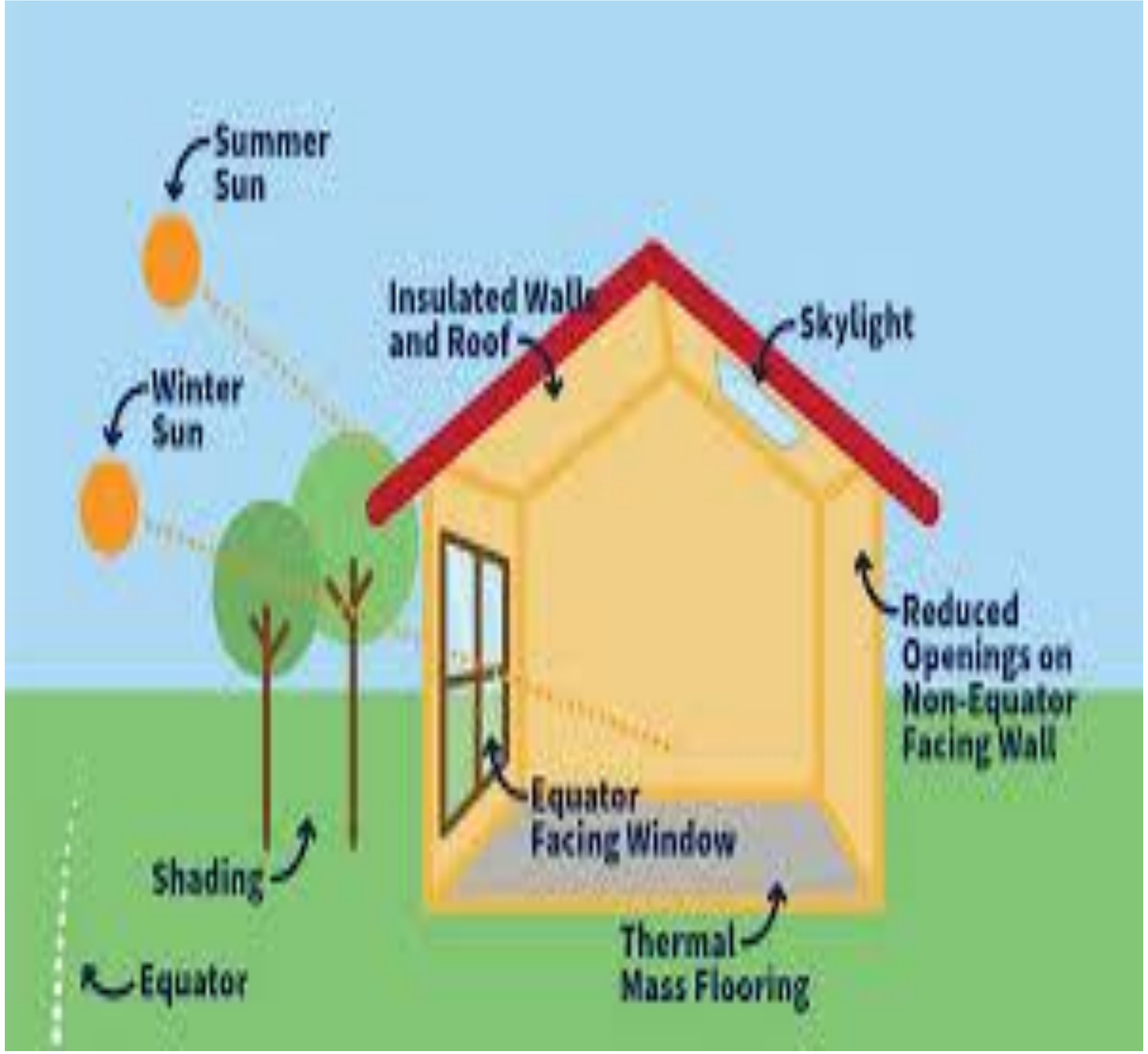
Climatic Factor	Influence on Design & Energy Use
Temperature	- **Hot climates** require designs that minimize heat gain (e.g., reflective roofs, insulation, cross ventilation, shading). - **Cold climates** need heat retention (e.g., thick insulation, double-glazed windows).
Solar Radiation	- In **sunny regions**, buildings can utilize **solar panels** and **solar water heaters** to reduce electrical load. - Strategic window placement can allow **natural lighting**, reducing artificial lighting needs. - **Overhangs** and **shading devices** help block excess sunlight.
Wind Patterns	- Orientation of the building can use **prevailing winds** for **natural ventilation**, reducing air conditioning needs. - **Windbreaks** (trees, walls) are used in cold/windy regions to reduce heat loss.
Humidity	- In **humid areas**, ventilation is essential to avoid discomfort and maintain comfort. - Materials must be **moisture-resistant** (like treated wood, cement-based products). - **Dehumidifiers** or proper HVAC systems are needed in tropical climates.
Rainfall & Snow	- In heavy rainfall or snow zones, roofs need proper **slopes** and **drainage systems**. - **Waterproofing** and **elevated foundations** help prevent structural damage. - Roofing and external walls must withstand prolonged moisture exposure.

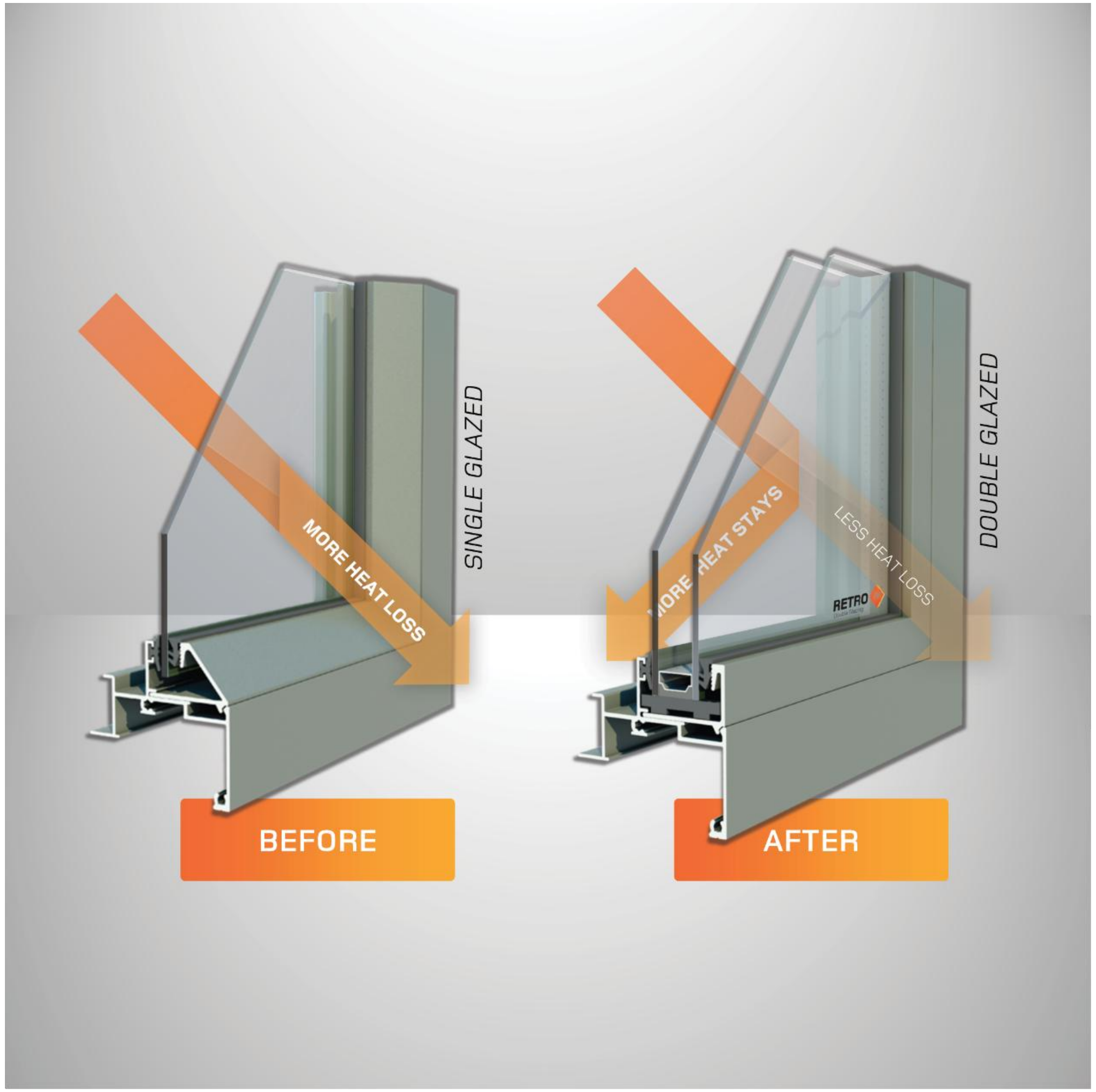
Design for hot climates – Cross ventilation and reflective roofs





Design for cold climates – passive solar heating and double glazed windows





Design for sunny regions – utilize solar panels and solar water heaters

Natural case studies for influence of climate on buildings

- Hurricane Katrina (2005) – New Orleans, United States
- Superstorm Sandy (2012) – Northeastern United States
- Green Building Practices – Singapore
- Seawall Construction – Netherlands
- Passive House Design – Germany

THERMAL PROPERTIES

OF

BUILDING MATERIALS

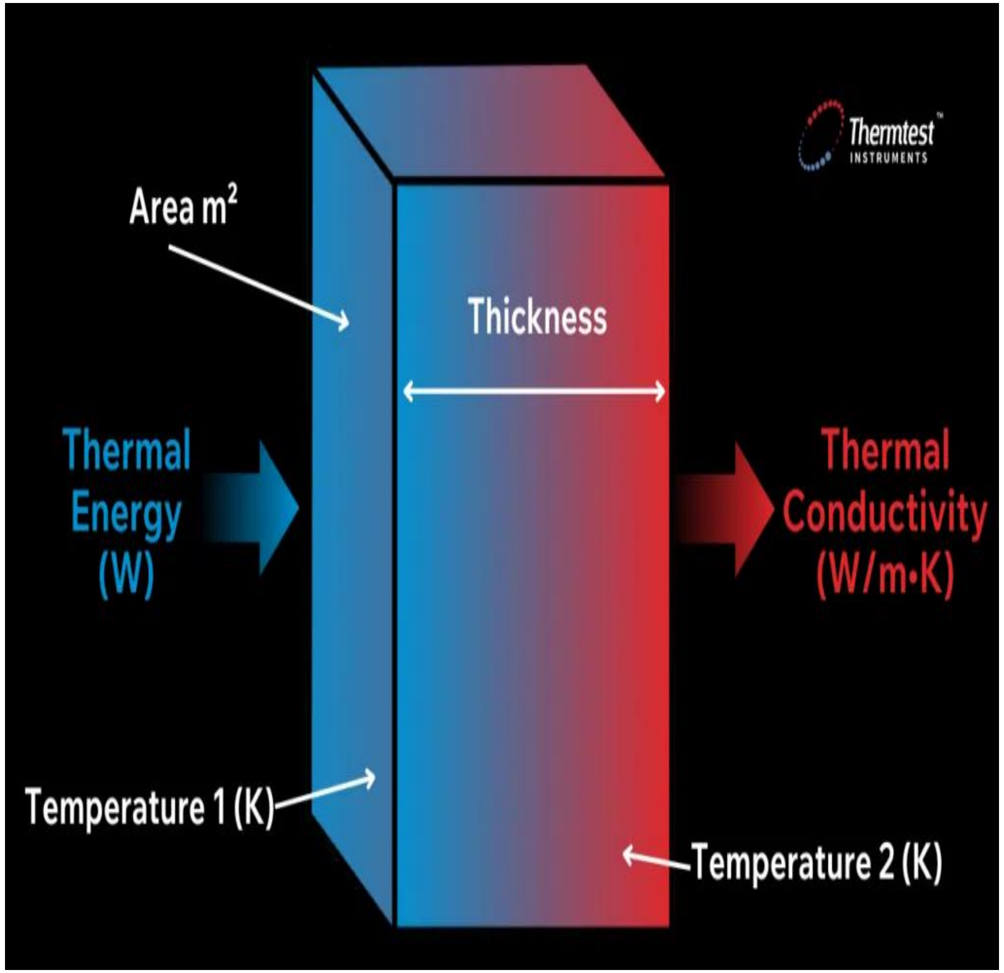
THERMAL PROPERTIES OF BUILDING MATERIALS

- The building materials possess various thermal properties that indicate the behavior of materials when exposed to heat.
- The following are some of the thermal properties that are very essential in optimizing the performance of the building, energy efficient and enhances the comfort of the occupants.
  - ✓ **Thermal Conductivity (k)**
  - ✓ **Specific Heat Capacity (c)**
  - ✓ **Thermal Mass**
  - ✓ **Thermal Diffusivity (α)**
  - ✓ **Thermal Resistance (R)**

THERMAL PROPERTIES OF BUILDING MATERIALS

Colder area = high (k) value
Hotter area = low (k) value

Thermal Conductivity (k)



- **Thermal conductivity is a material property that measures its ability to conduct heat.**
- It is defined as the rate at which heat is transferred through a unit area of a substance, per unit temperature gradient.
- Materials with high thermal conductivity efficiently conduct heat, allowing it to flow rapidly, while those with low thermal conductivity resist heat transfer.

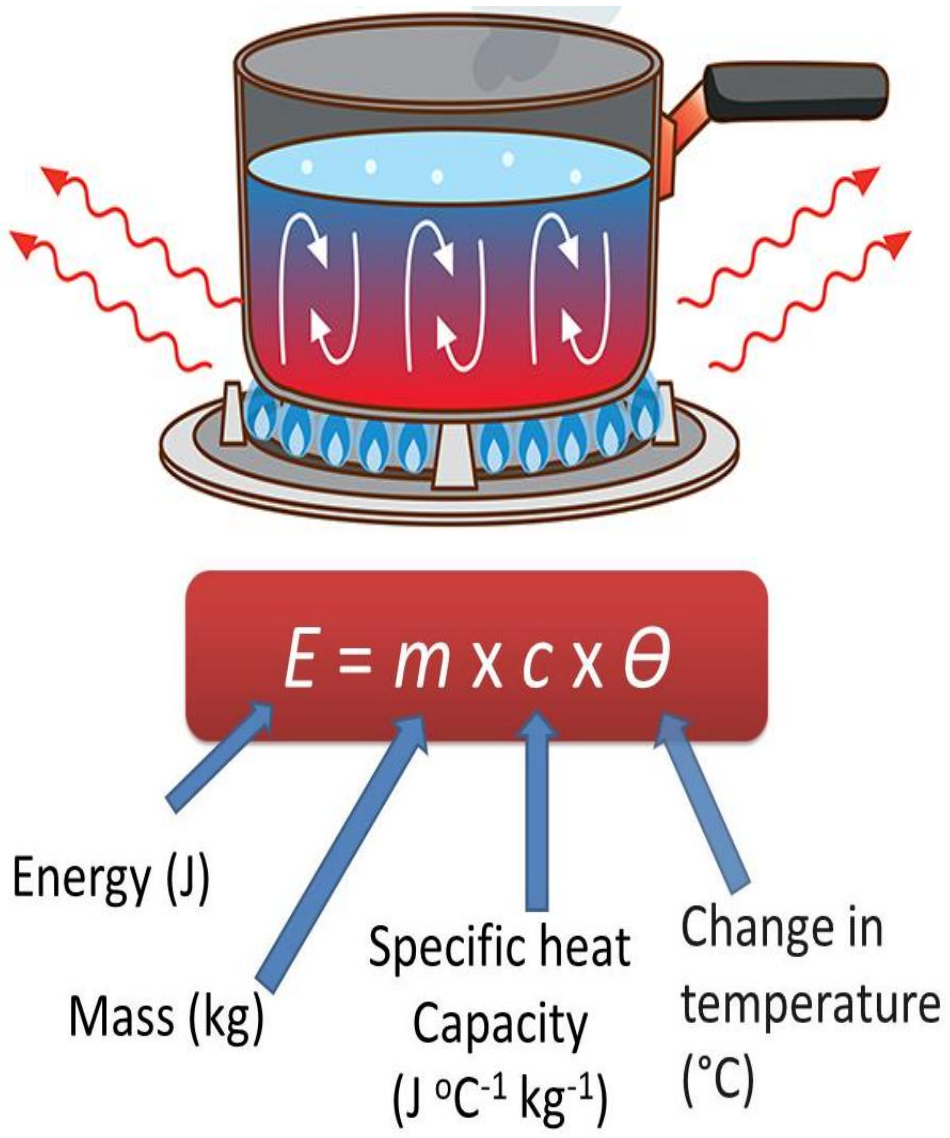
Example:

Metals generally have high thermal conductivity, while materials like wood, fiberglass, and expanded polystyrene have low conductivity.

THERMAL PROPERTIES OF BUILDING MATERIALS

Specific Heat Capacity (c)

- **Specific heat** is a measure of the **amount of heat energy** required to **raise the temperature** of a unit mass of a substance by **one degree Celsius or Kelvin**.
- Substances with higher specific heat require more energy to change temperature, while those with lower specific heat heats up or cools down more quickly.
- This property is crucial in fields like thermodynamics and engineering, influencing the design of systems for efficient heat exchange and storage in various industrial and environmental applications.



water's specific heat capacity = 4.184 J/g°C
vegetable oils specific heat capacity = 2 J/g°C

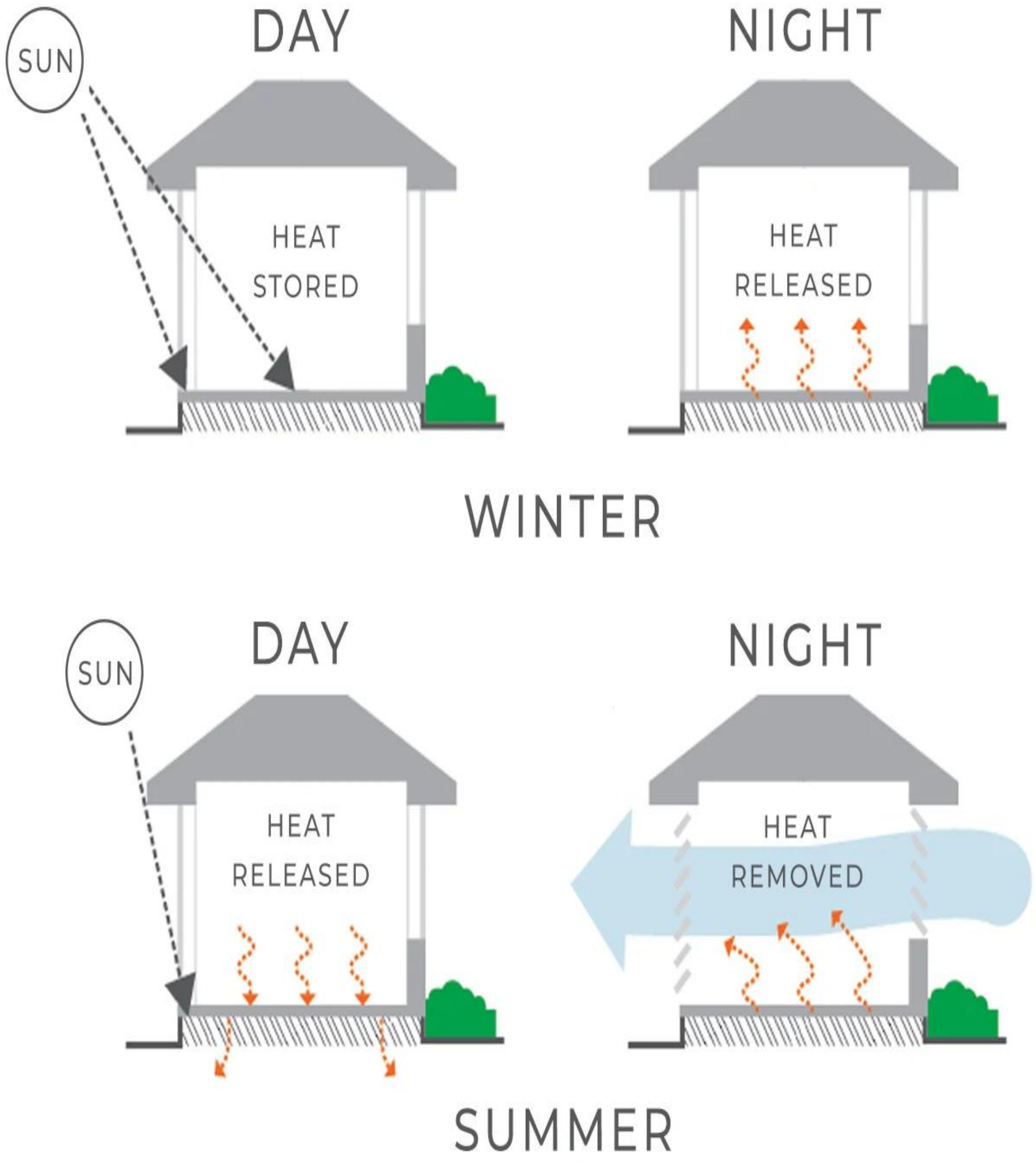
THERMAL PROPERTIES OF BUILDING MATERIALS

Thermal mass

- Thermal mass refers to the **ability of a material to absorb, store, and release heat energy**.
- Materials with high thermal mass can absorb heat during the day and release it slowly at night, helping to stabilize indoor temperatures.

Example:

- Concrete and stone have high thermal mass, while lightweight materials like wood and insulation have low thermal mass



THERMAL PROPERTIES OF BUILDING MATERIALS

Thermal Diffusivity (α):

- Thermal diffusivity is a **measure** of how **quickly heat diffuses through a material**.
- It's calculated by dividing thermal conductivity by the product of density and specific heat capacity.

Examples:

Cooking:

When cooking, materials with **high thermal diffusivity**, like **aluminum**, are used for cookware because they heat up and cool down quickly, allowing for better temperature control.

Building Materials:

Materials with **low thermal diffusivity**, like **insulation**, help maintain a stable temperature inside a building.

Electronics Cooling:

In electronics, materials with **high thermal diffusivity** are used to dissipate heat from components, preventing overheating.

THERMAL PROPERTIES OF BUILDING MATERIALS

Thermal Resistance (R):

- Thermal resistance is the measure of a **material's opposition to heat flow**.
- It quantifies how effectively a material resists the transfer of thermal energy.
- **Higher** thermal resistance means a material is a **better insulator**, while **lower** thermal resistance indicates **better heat conduction**.
- Mathematically thermal resistance can be calculated by:

$$R = \Delta T / Q$$

R is thermal resistance

ΔT is the temperature difference across the material

Q is the rate of heat transfer (heat flow) through the material

HEAT TRANSFER

IN

BUILDING STRUCTURES

MODE OF HEAT TRANSFERS

What affects the Thermal indoor environment?

- The thermal indoor environment can be affected by both internal and external sources.
- The heat exchange between the building and its environment occurs mainly in three ways:
    - *Conduction*
    - *Convection*
    - *Radiation*

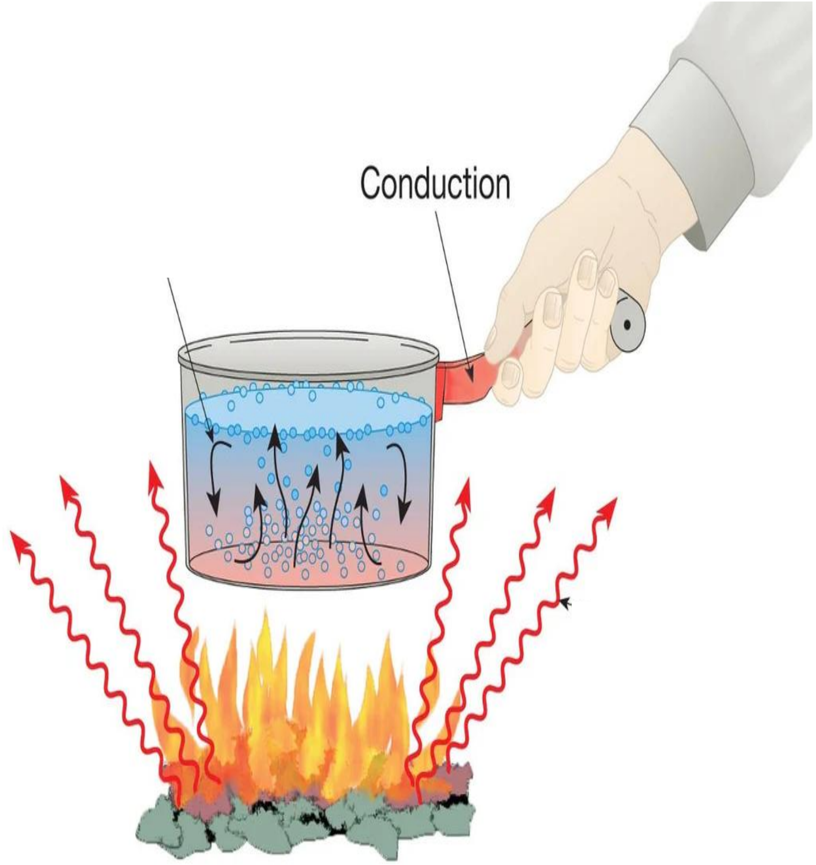
CONDUCTION

Definition: Conduction is the transfer of heat through a solid material from one particle (molecule) to another without the movement of the material as a whole.

How it works: It occurs due to direct contact between particles. The heat energy is transferred through vibrations and collisions of particles.

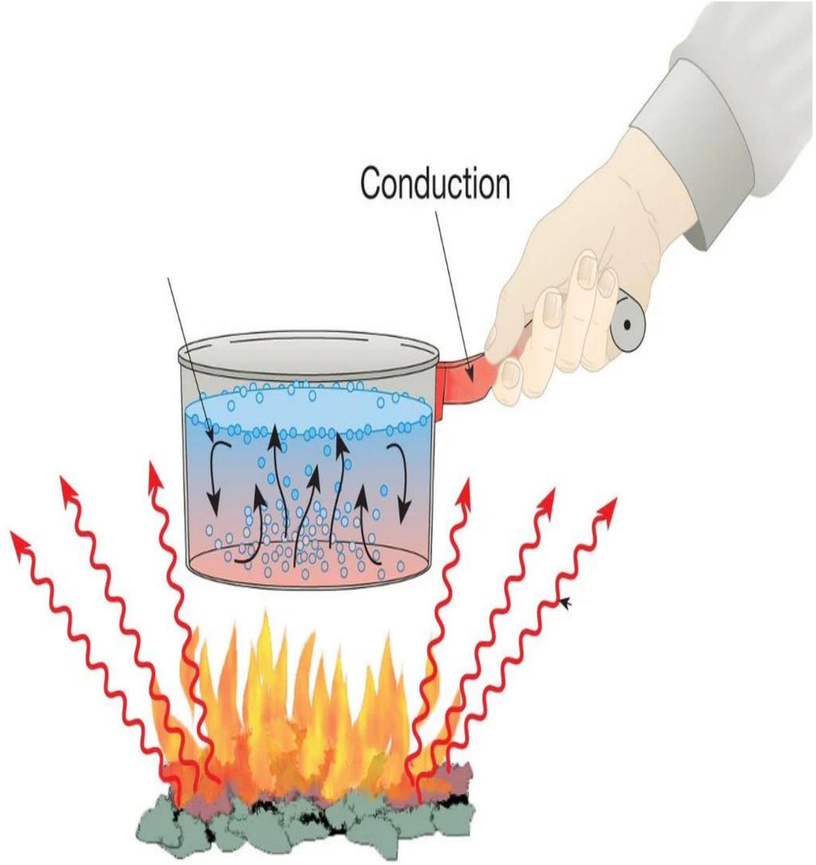
Example:

- ❖ A metal spoon becomes hot from its tip to handle when placed in a pot of boiling water.
- ❖ Ironing clothes — heat transfers from the hot iron to the fabric by conduction.
- ❖ A soda can sitting in hot sun when touched will feel hot.



CONDUCTION (Contd.)

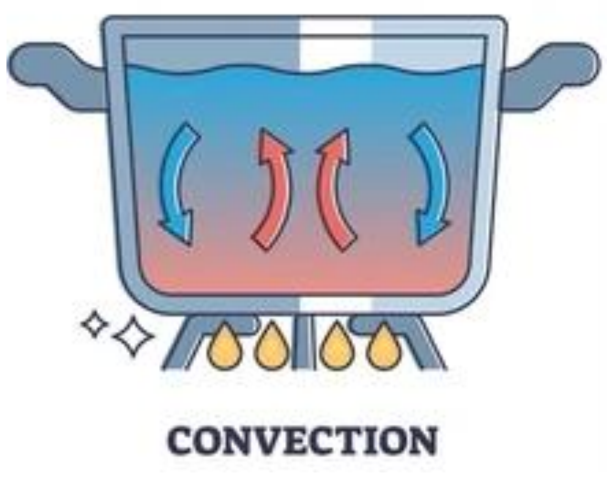
- Heat flows from one object to the other, when they are in contact with each other.
- In solids, molecules are closely arranged so that they cannot move freely.
- When one end of the solid is heated, molecules at that end absorb heat energy and vibrate fast at their own positions.
- These molecules in turn collide with the neighboring molecules and make them vibrate faster and so energy is transferred.
- The process of transfer of heat in solids from a region of higher temperature to a region of lower temperature without the actual movement of molecules is called conduction.



CONVECTION:

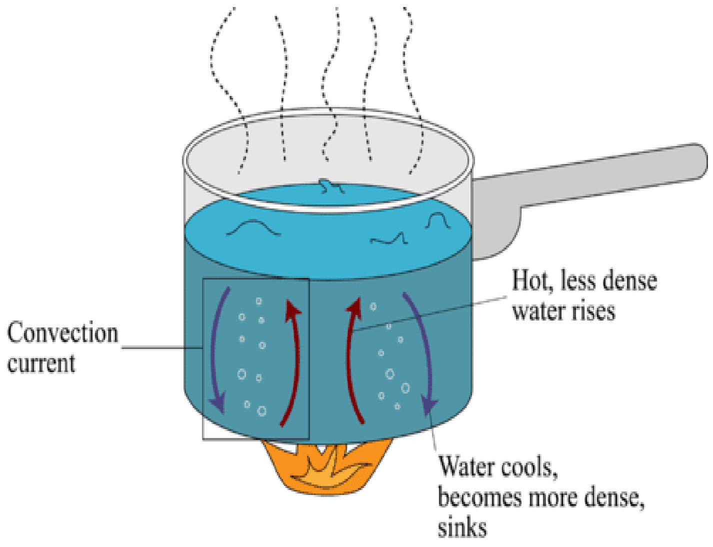
Definition:

The thermal energy is carried along with a fluid, such as air or liquid, when it is heated and moves away from the point of origin.



How it works:

Hot fluid rises (because it becomes less dense), and cooler fluid sinks, creating a **convection current** that circulates heat.



Example:

- ❖ Boiling water in a pot — water at the bottom heats up, rises, and is replaced by cooler water from the top.
- ❖ In a room heated by a heater — warm air rises and cold air moves down to be heated.

CONVECTION (Contd.)

- Convection is the flow of heat through a fluid from places of higher temperature to places of lower temperature by movement of the fluid itself.
- When fluids (liquid and gas) are heated, the molecules closer to the source of heat get heated first and expand, thereby decreasing the density of the liquid.
- The lighter molecules rise up and the cooler and heavier molecules come down.
- Thus, convection is the transfer of heat due to the actual movement of particles.

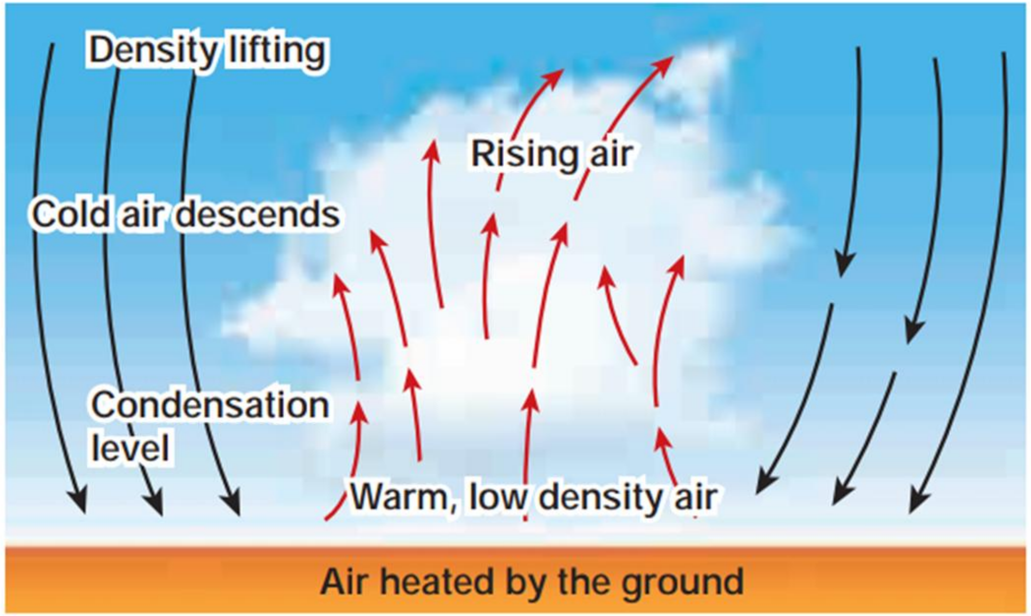
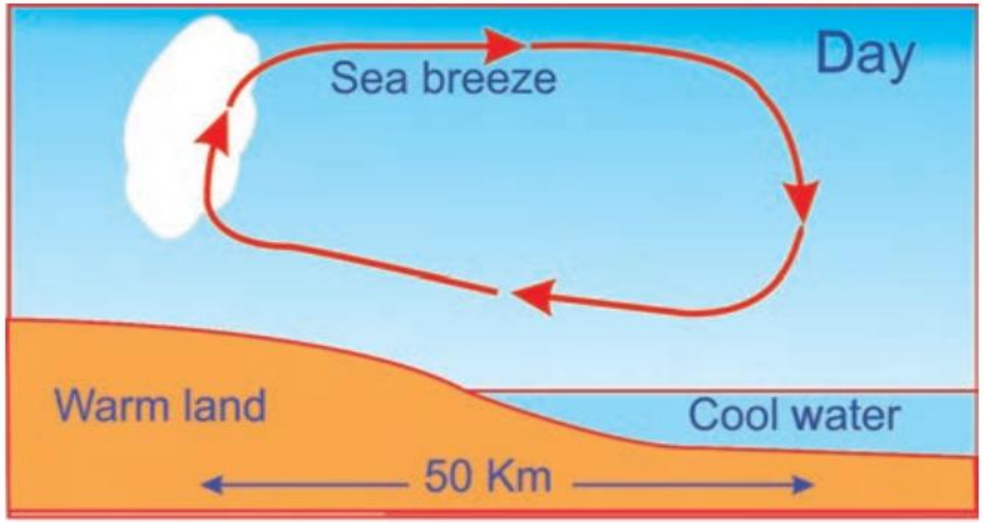


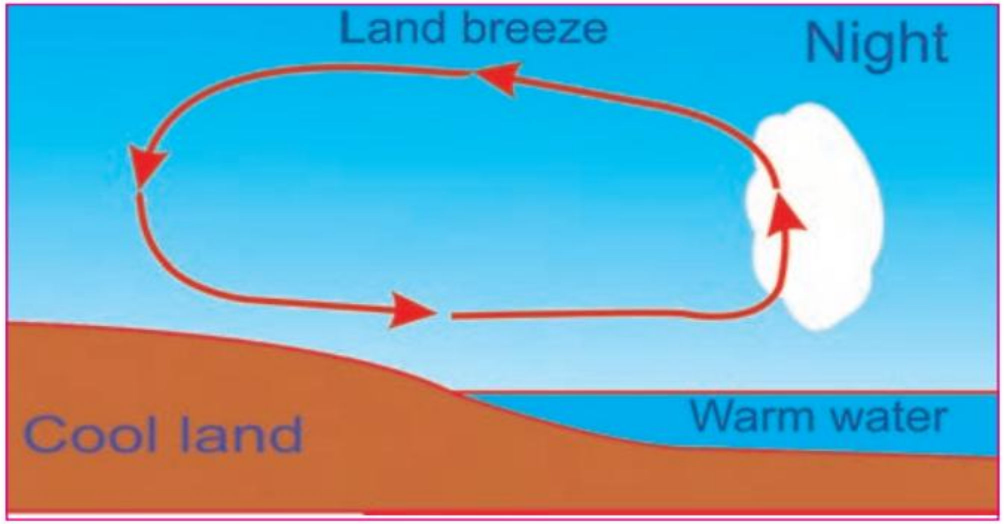
Figure 1.3 Convection in air

Hot fluid rises (because it becomes less dense), and cooler fluid sinks, creating a convection current that circulates heat

Convcetion (Contd.,) Example

- Winds are caused by convection currents.
- During the day, the land warms up more than the sea.
- The warm air over the land rises and the cold air from the sea moves in to replace it.
- So during the day, breeze blows from the sea to the land. This is sea breeze.
- At night, the land cools down faster than the sea.
- The warmer air over the sea rises.
- Cold air over the land moves in to replace it .
- So during the night, breeze blows from the land on to the sea.
- This is land breeze.





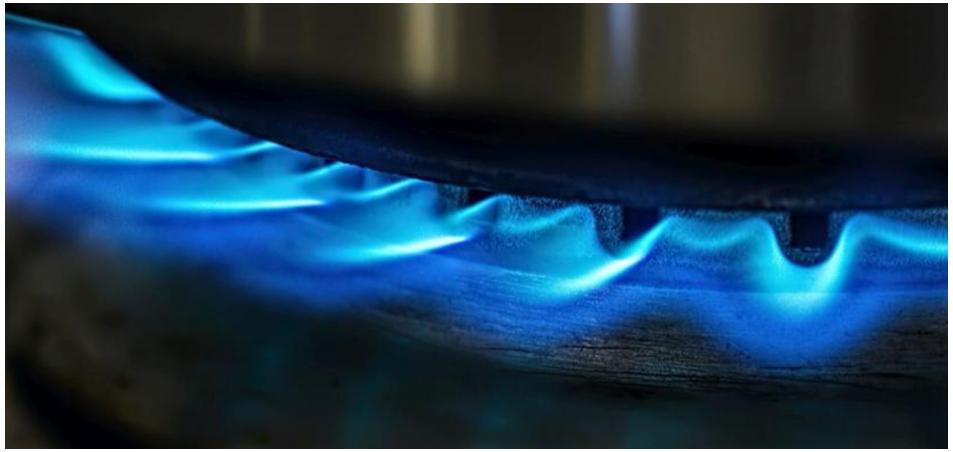
RADIATION

Definition: Radiation is the transfer of heat energy through **waves** without needing a medium (can even occur in a vacuum).

How it works: Heat is emitted in the form of radiation and does not require any contact or medium.

Example:

- ❖ The Sun heating the Earth through the vacuum of space.
- ❖ Feeling warmth on your skin while standing near a campfire.



RADIATION (Contd.,)

- Radiation is a method of heat transfer that does not require particles to carry the heat energy.
- In this method, heat is transferred in the form of waves from hot objects in all direction.
- Radiation can occur even in vacuum whereas conduction and convection need matter to be present.
- Radiation consists of electromagnetic waves travelling at the speed of light.
- Thus, radiation is the flow of heat from one place to another by means of electromagnetic waves.

Example

- Transfer of heat energy from the sun reaches us in the form of radiation.
- Some objects absorb radiation and some other objects reflect them.

Figure 1.6 Black and shiny metal surface.

Radiation in daily life

i. White or light colored cloths are good reflectors of heat. They keep us cool during summer.

ii. Base of cooking utensils is blackened because black surface absorb more heat from the surrounding.

iii. Surface of airplane is highly polished because it helps to reflect most of the heat radiation from the sun.

HEAT TRANSFERS – IN BUILDINGS

Incident Solar Radiation: Sunlight strikes the wall.

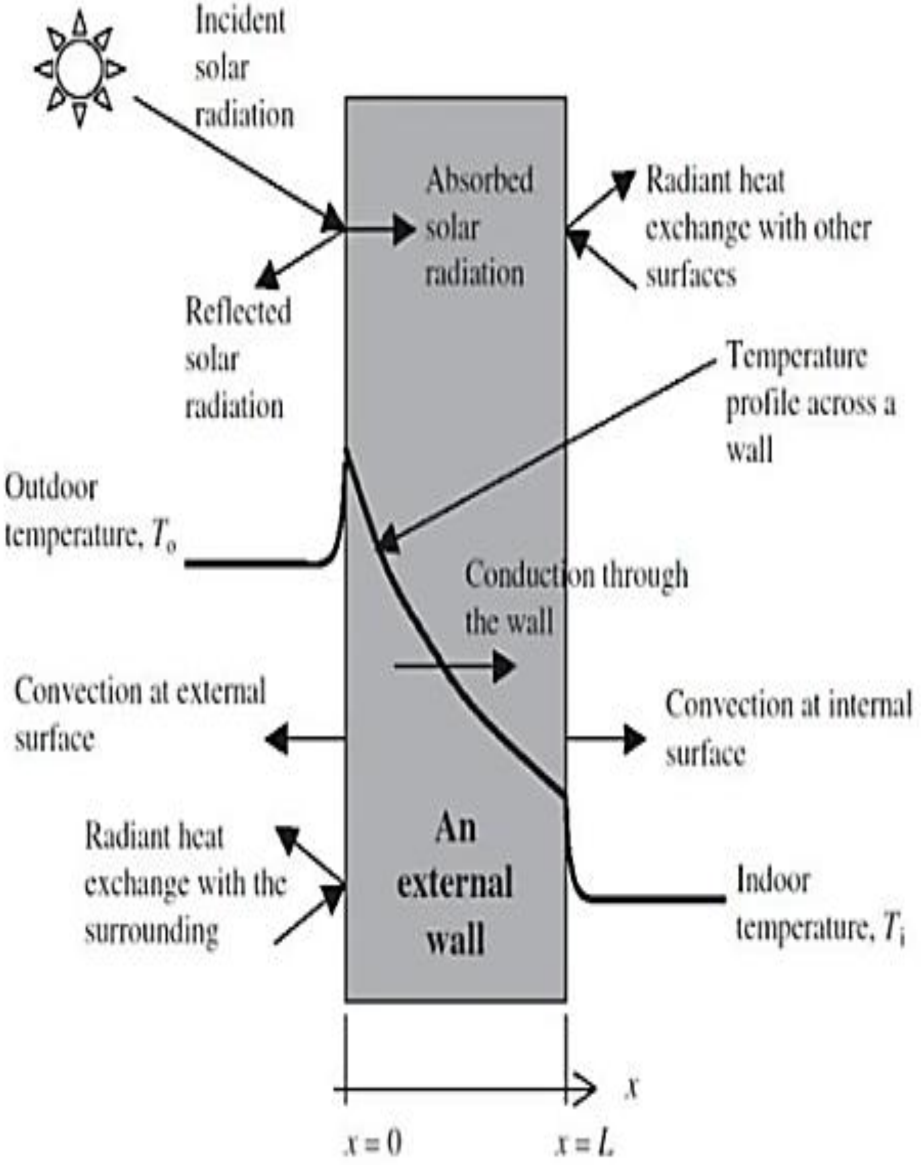
Reflected Solar Radiation: Some of the solar radiation is reflected back into the environment.

Absorbed Solar Radiation: A portion of solar energy is absorbed by the wall, raising its temperature.

Outdoor Temperature (*To*): The ambient air temperature outside.

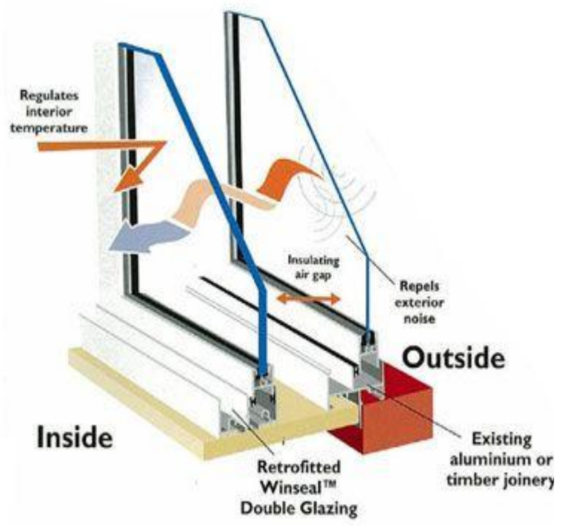
Convection at External Surface: Heat is exchanged between the wall and the outdoor air by convection.

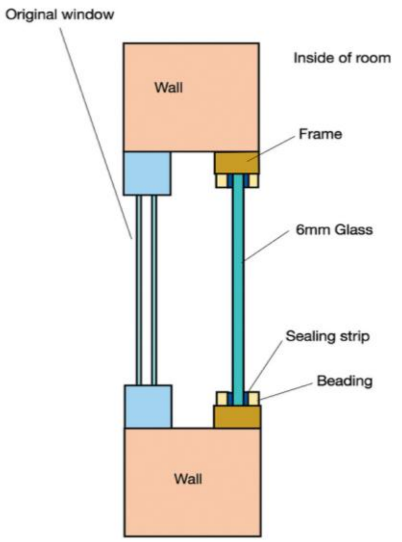
Radiant Heat Exchange with Surroundings: The wall can emit and absorb thermal radiation with the environment (e.g., sky, ground).



HEAT TRANSFERS – IN WINDOWS

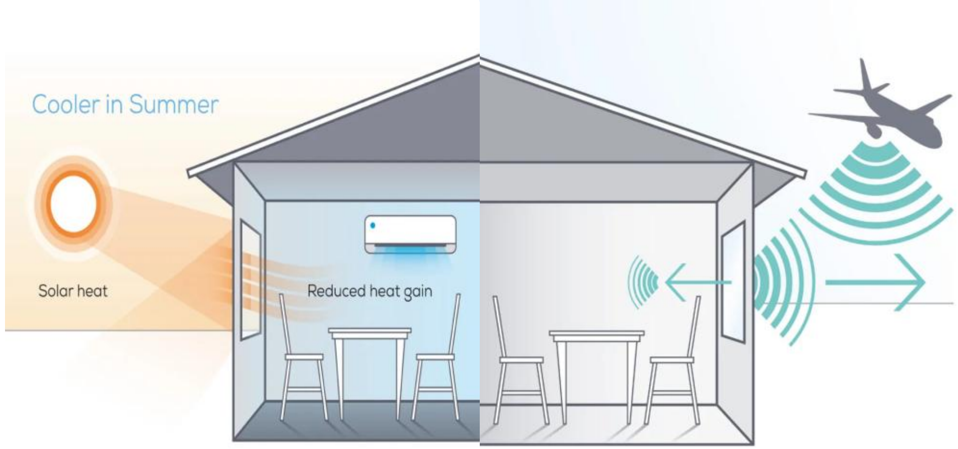
- Windows can lose heat in several ways, especially through radiation, conduction, and convection.
- In a **single window system** once the heat is absorbed from the inner surface of the building heat directly escapes outside as radiation.
- In a **double window system** (double glazing windows) has two panes of glass with a gap in between. Heat from the inner environment of the building hits the inner pane of the glass while some of this heat is passed to the outer pane.



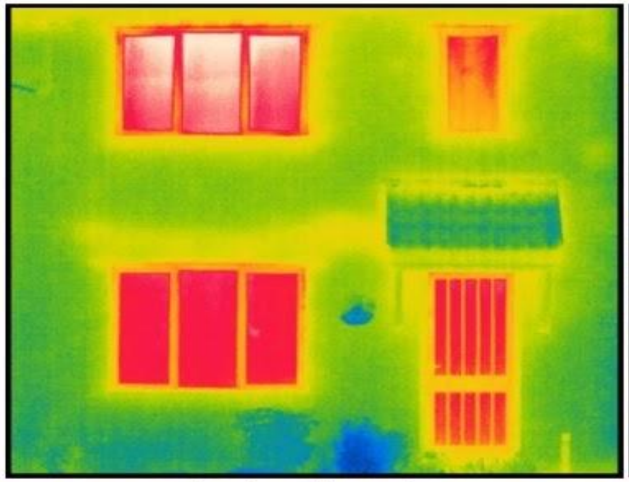


What happens in the gap between the two panes?

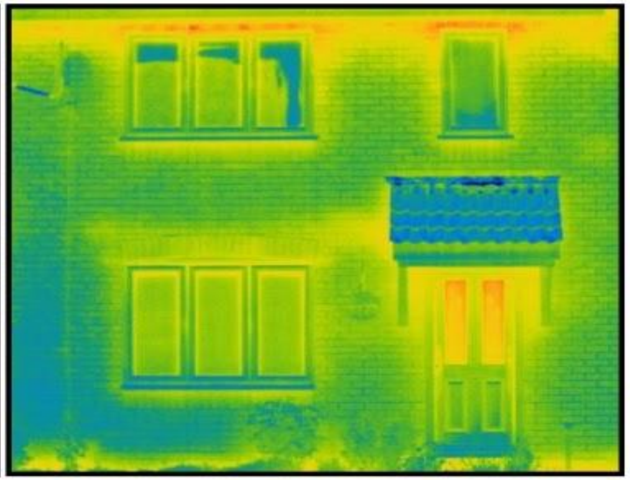
- Warm air touches the inner glass and rises.
- Cooler air present near the outer pane sinks to replace the warm air.
- This creates a **convection current**, slowly moving heat to the outer pane.



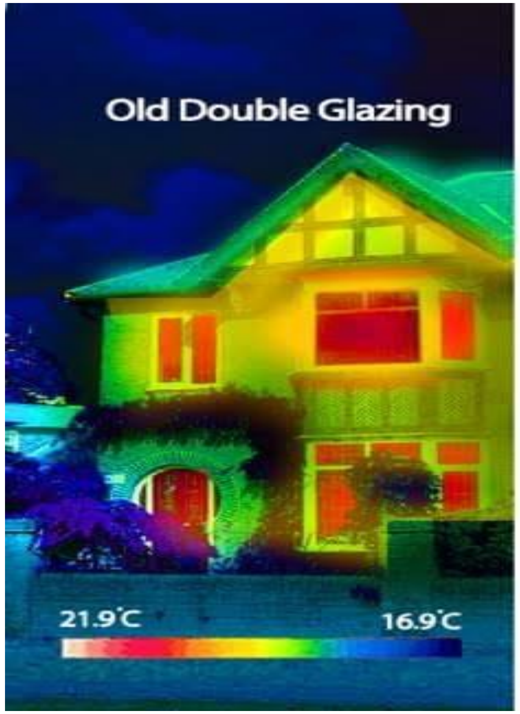
HEAT TRANSFERS – IN WINDOWS

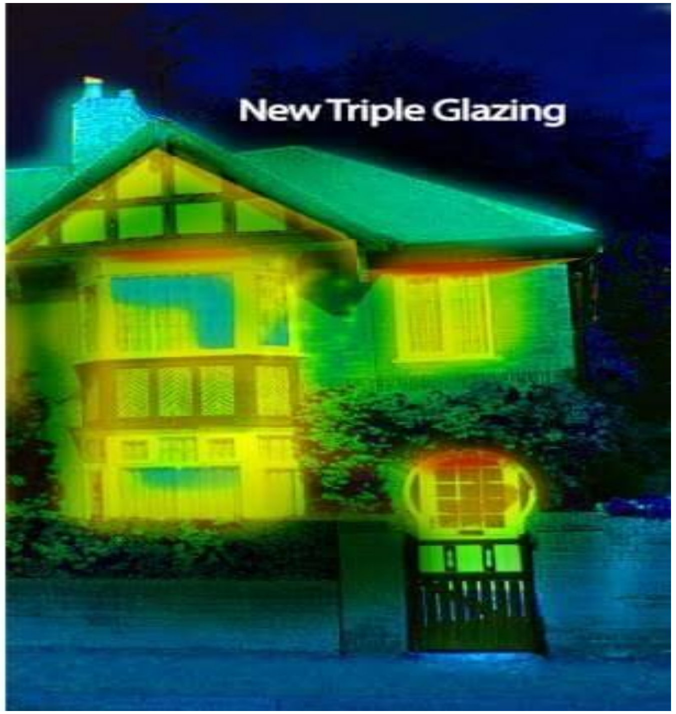


Single Glazed Timber Windows

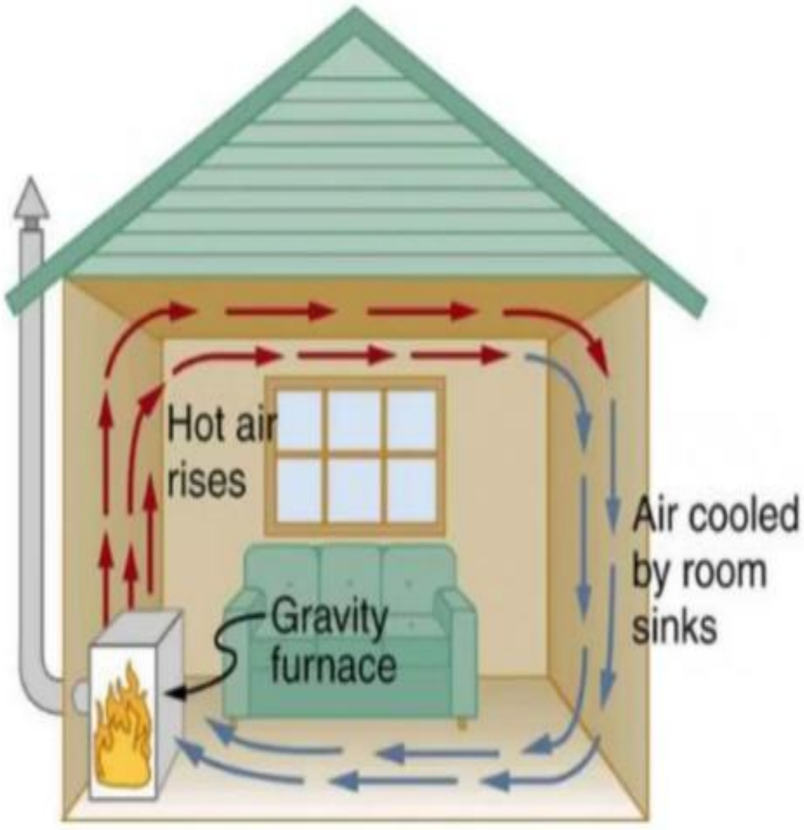


After New Double Glazing



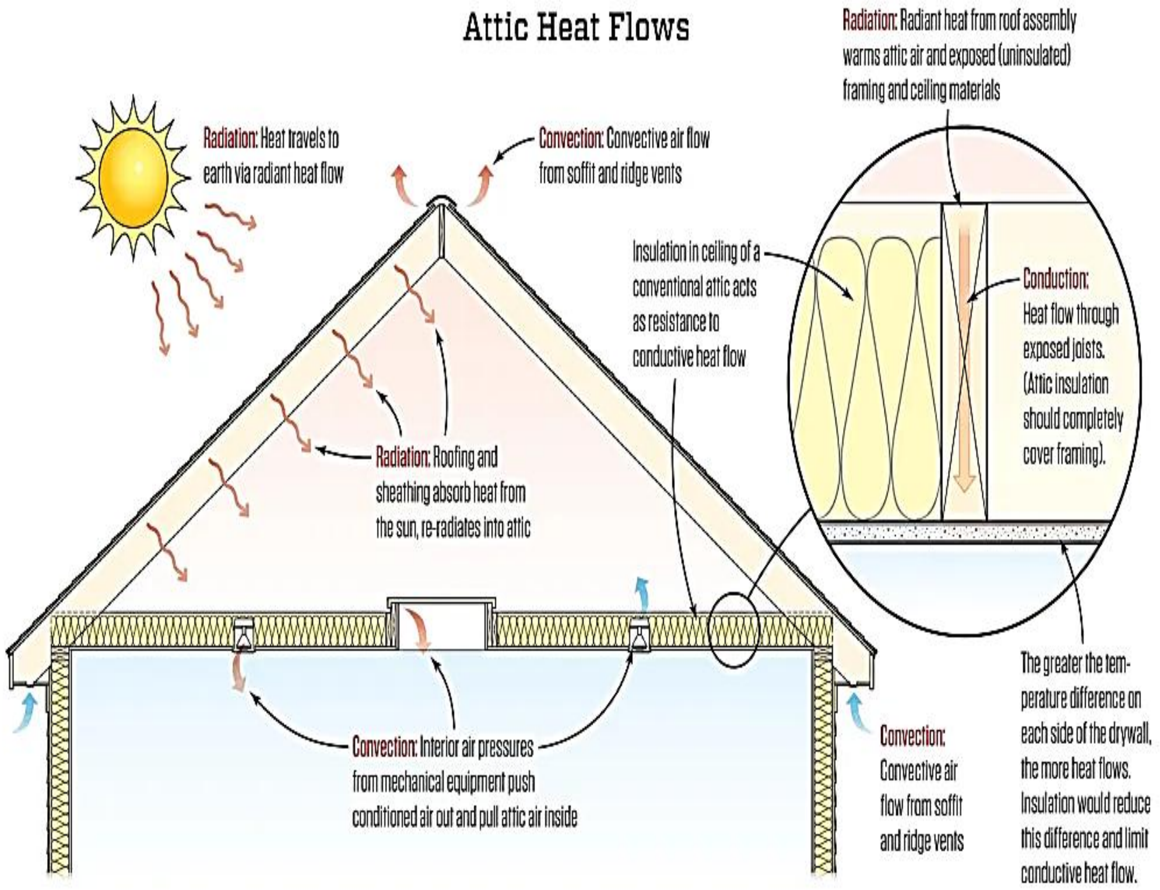


HEAT TRANSFERS – THROUGH BUILDING ROOMS



- The furnace heats the air in the room.
- Hot air rises because it's lighter (less dense).
- As the warm air rises, it spreads heat around the space — this is called a convection loop.
- When the warm air reaches cooler areas like ceilings or outside walls, it cools down.
- As it cools, the air becomes heavier (denser) and falls back down to the floor.
- This falling cool air goes back toward the furnace to be reheated, and the loop continues.

MODE OF HEAT TRANSFERS – IN ATTIC



Radiation :

Sun to Roof (Outside):

The sun emits radiant heat, which travels through air and heats the roof surface.

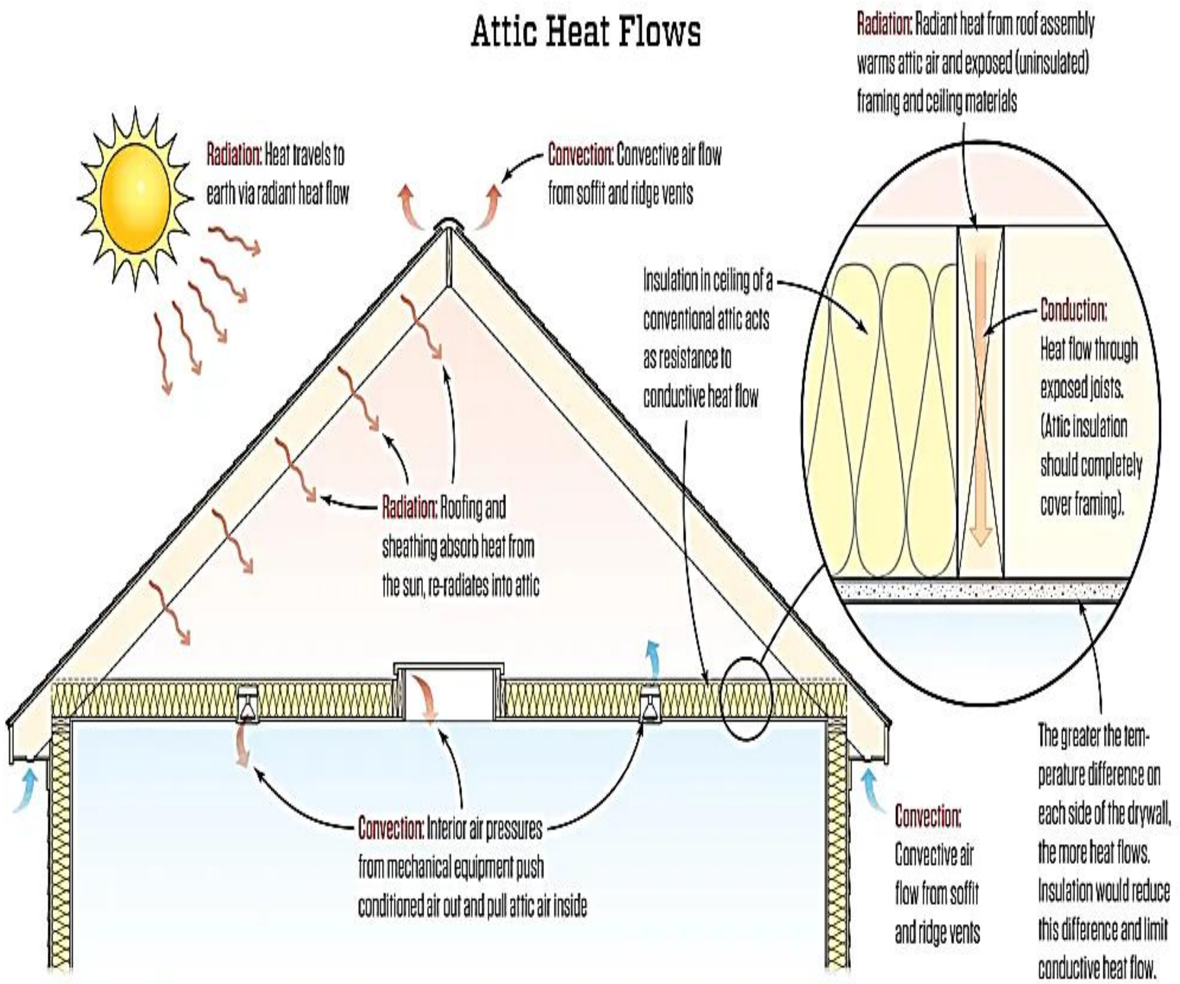
Roof to Attic (Inside):

The roofing and sheathing absorb this heat and then re-radiate it inward, warming the attic air and the internal surfaces like framing and ceiling materials.

Impact:

This process increases the temperature of the attic air and the structural materials inside.

MODE OF HEAT TRANSFERS – IN ATTIC



Conduction:

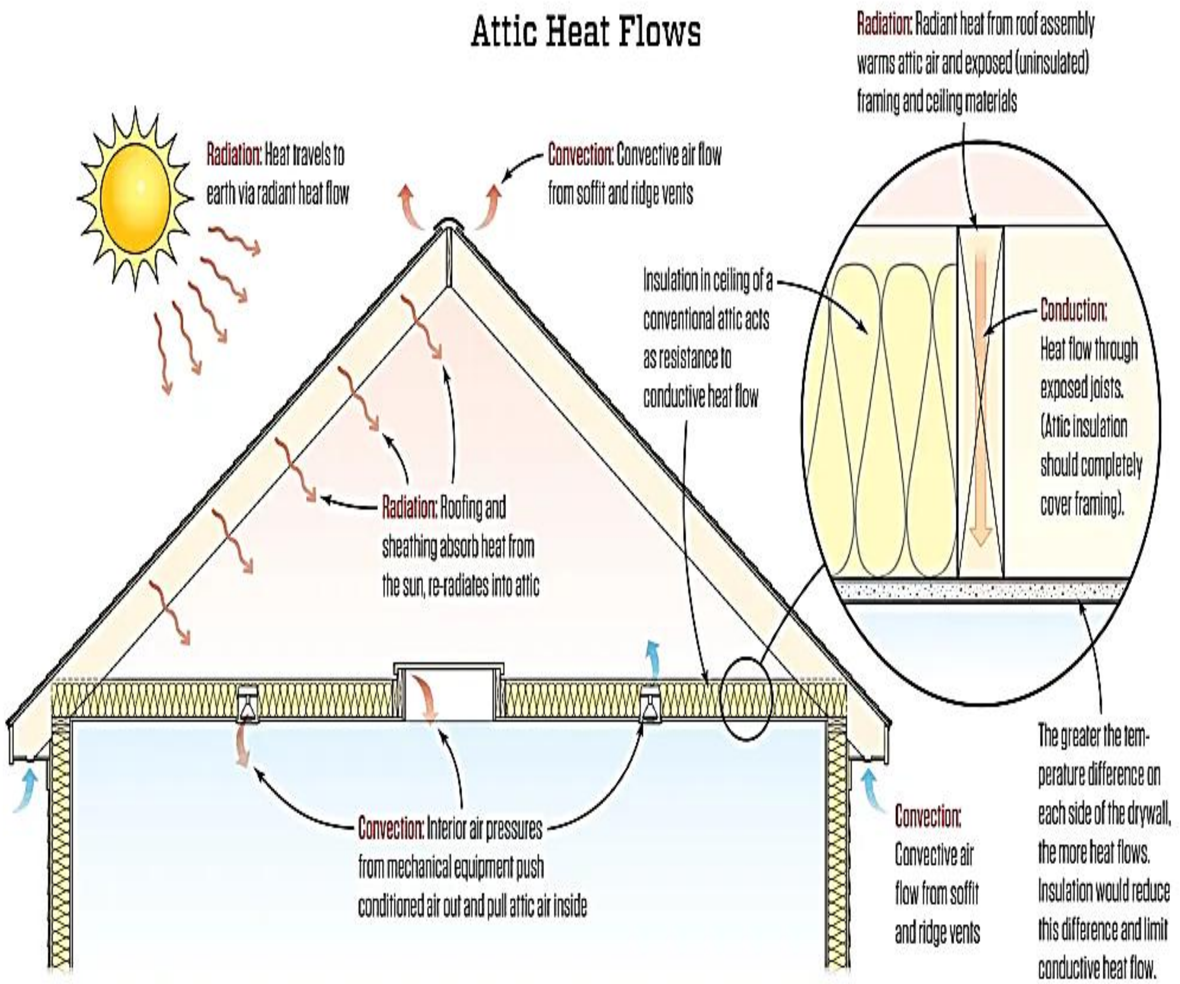
Through Framing:

Heat flows by **conduction** through **exposed joists** (wood framing) and ceiling materials.

Insulation Role:

- ✓ Insulation resists this heat flow.
- ✓ If **insulation doesn't cover the framing properly**, heat flows more easily through these gaps.
- ✓ More **temperature difference = more conductive heat flow**.

MODE OF HEAT TRANSFERS – IN ATTIC



Convection:

Outside Vents:

Warm air rises and **exits via ridge vents**, while cooler air **enters from soffit vents**, creating a **convective airflow** loop through the attic.

Inside the House:

Mechanical systems (like AC) and **air pressure differences** can pull hot attic air into the living space and push out conditioned (cool) air, especially if the attic is not sealed well.

MODE OF HEAT TRANSFERS – IN ATTIC-SUMMARISED

Radiation (Heat from the Sun)

•Sunlight hits the roof.

•The roofing material absorbs this heat.

•Then it re-radiates the heat inside the attic.

•This makes the air and the wooden frame inside warm.

OVERALL HEAT TRASNFER PROCESS

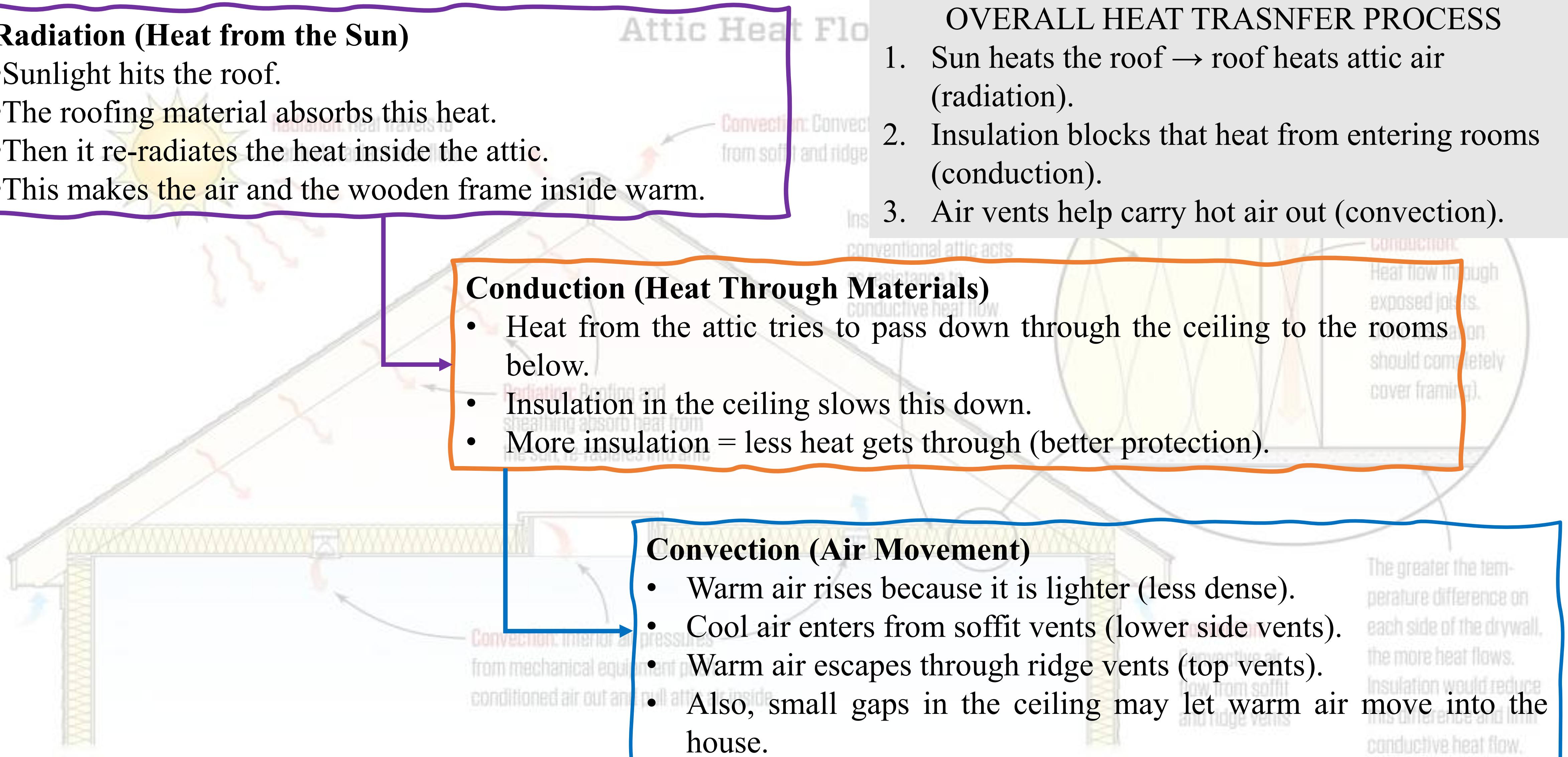
1. Sun heats the roof → roof heats attic air (radiation).
2. Insulation blocks that heat from entering rooms (conduction).
3. Air vents help carry hot air out (convection).

Conduction (Heat Through Materials)

- Heat from the attic tries to pass down through the ceiling to the rooms below.
- Insulation in the ceiling slows this down.
- More insulation = less heat gets through (better protection).

Convection (Air Movement)

- Warm air rises because it is lighter (less dense).
- Cool air enters from soffit vents (lower side vents).
- Warm air escapes through ridge vents (top vents).
- Also, small gaps in the ceiling may let warm air move into the house.



Energy Balance for heating and cooling of buildings

Energy Balance for heating and cooling of buildings

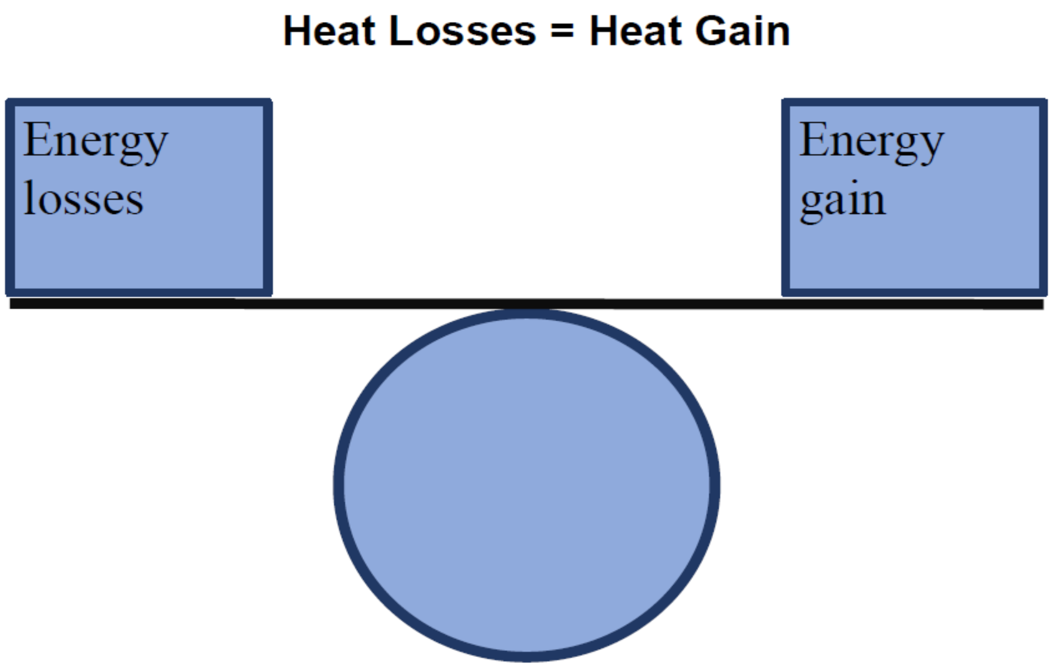
- An energy balance for building heating and cooling refers to **maintaining equilibrium** between the **heat gained and the heat lost within the structure**, which directly influences indoor temperature and overall energy usage.
- In buildings, the heat energy transfer occurs due to basic three mechanisms such as **conduction, convection and radiation**.

For example:

- If the temperature is higher, the person will feel very hot and there will be a necessity to provide extra cooling unit.
- If the temperature is lower, the person will feel very cold and there will be a necessity provide extra heating.

Energy Balance for heating and cooling of buildings

- In order to maintain constant temperature, the energy loss and gain should be equal in a building.



Heat Gain > Heat Loss → indoor temperature increases.
Heat Gain < Heat Loss → indoor temperature drops.
Heat Gain = Heat Loss → indoor temperature remains constant

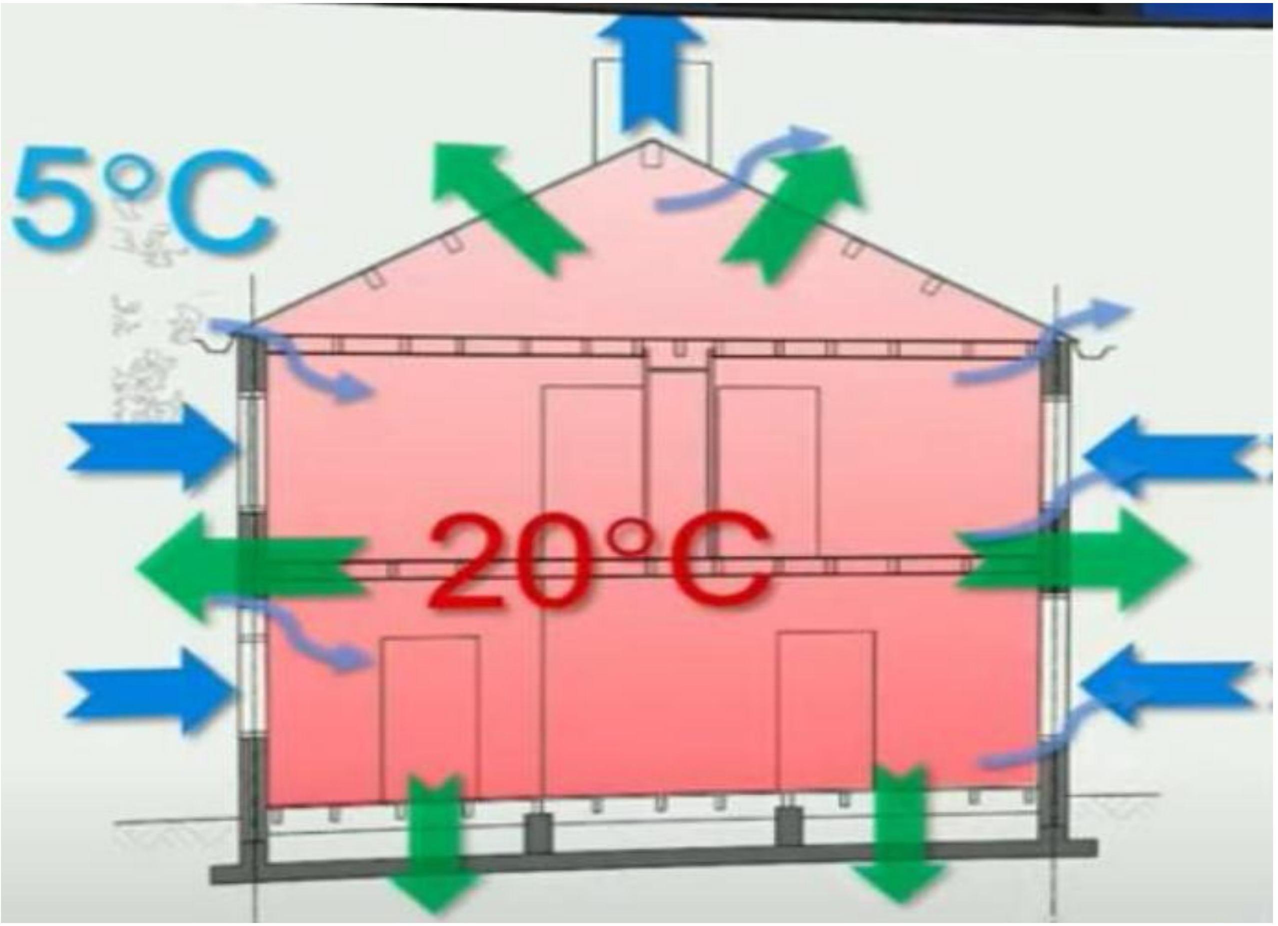
Energy Balance during winter season

- During winter season, to maintain constant temperature inside a building, the heat loss occurring should be maintained by heat gain in the building.
- In the bucket, if you want to maintain the water level then what ever amount of water coming out of the holes in the bucket should be compensated by pumping equal amount of water inside the bucket.

Heat losses in the buildings

Let us consider there is a 15°C temperature difference between building and the environment. This difference in temperature causes heat losses through

- ✓ Roof
- ✓ Walls
- ✓ Window
- ✓ Floor



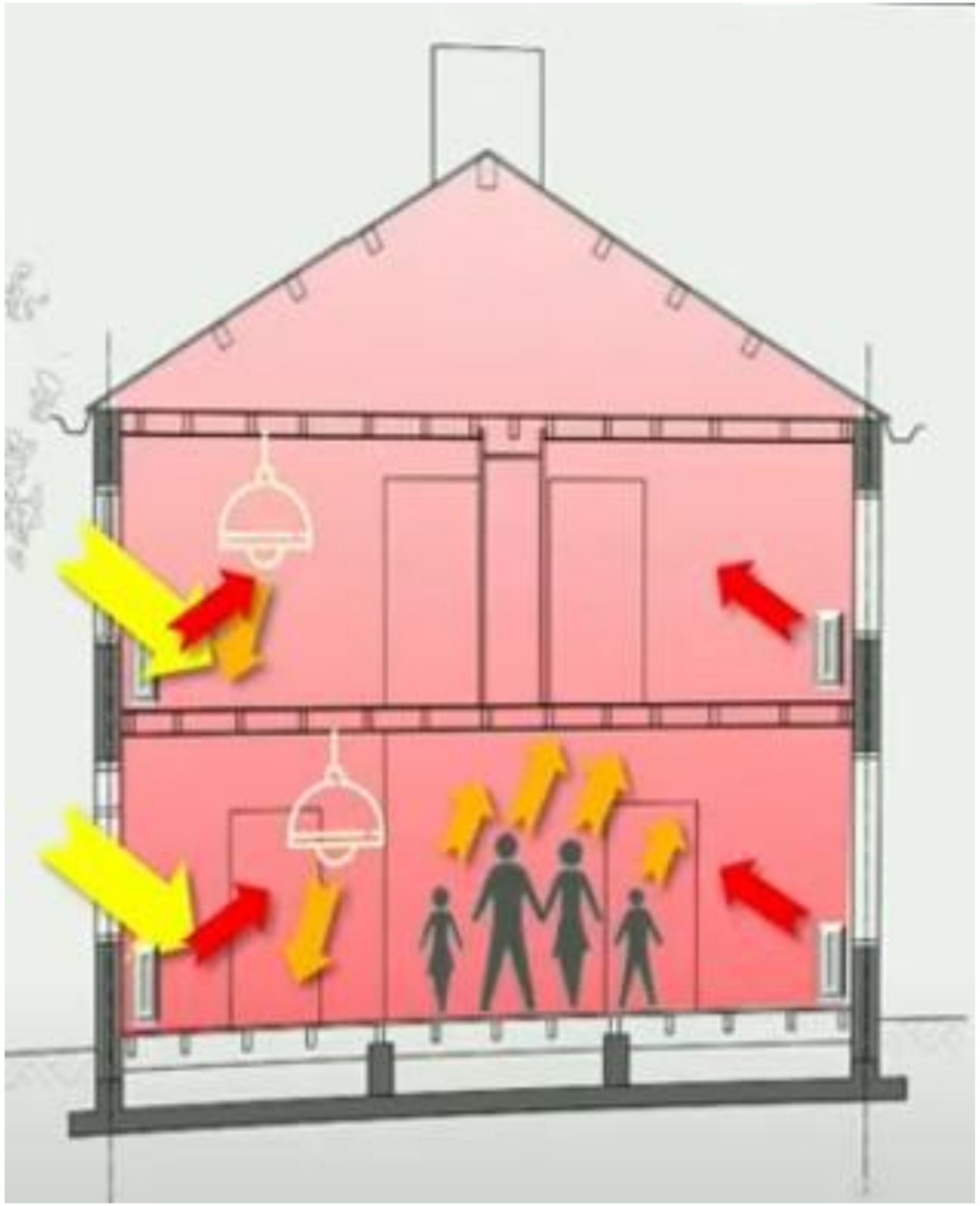
How heat is gained in the buildings?

In a building the amount of heat gained will happen in any of the following ways:

Solar heating - Radiation from the sun. Depends upon the weather and climate conditions, window size, sun shading properties and orientation.

Internal heat loads - Includes heat released from the humans and electrical appliances. Depends upon the number of persons, number of lamps, number and type of electrical appliances.

Heating unit - Radiators used for rising the temperature of the room.



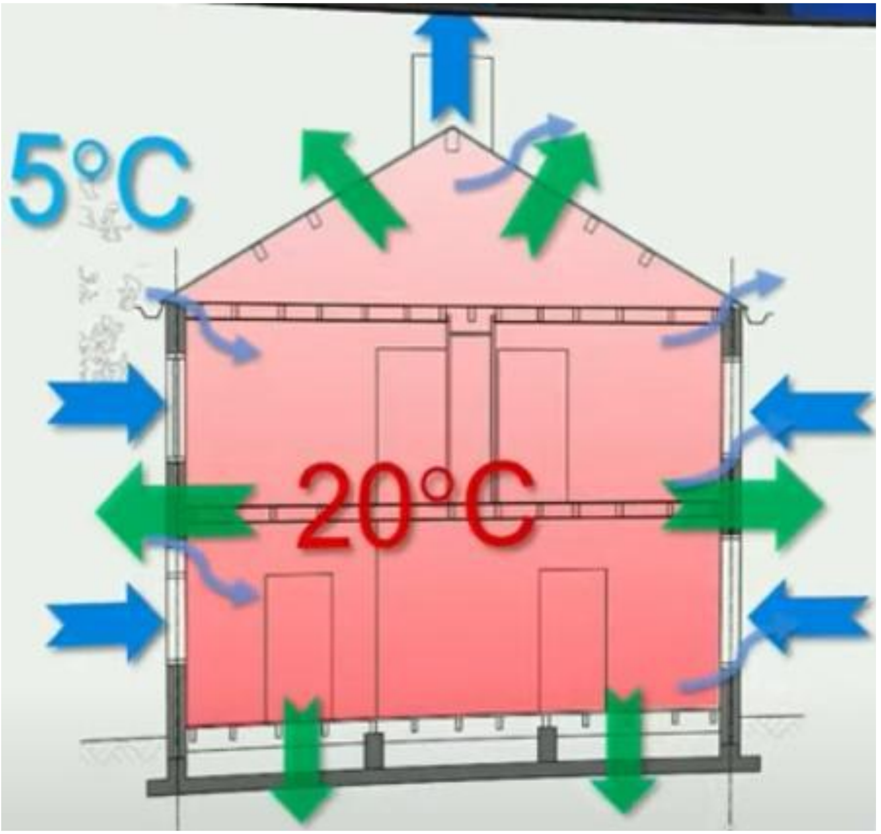
How heat is lost in the buildings?

In general, the heat losses in the building can be categorize in to

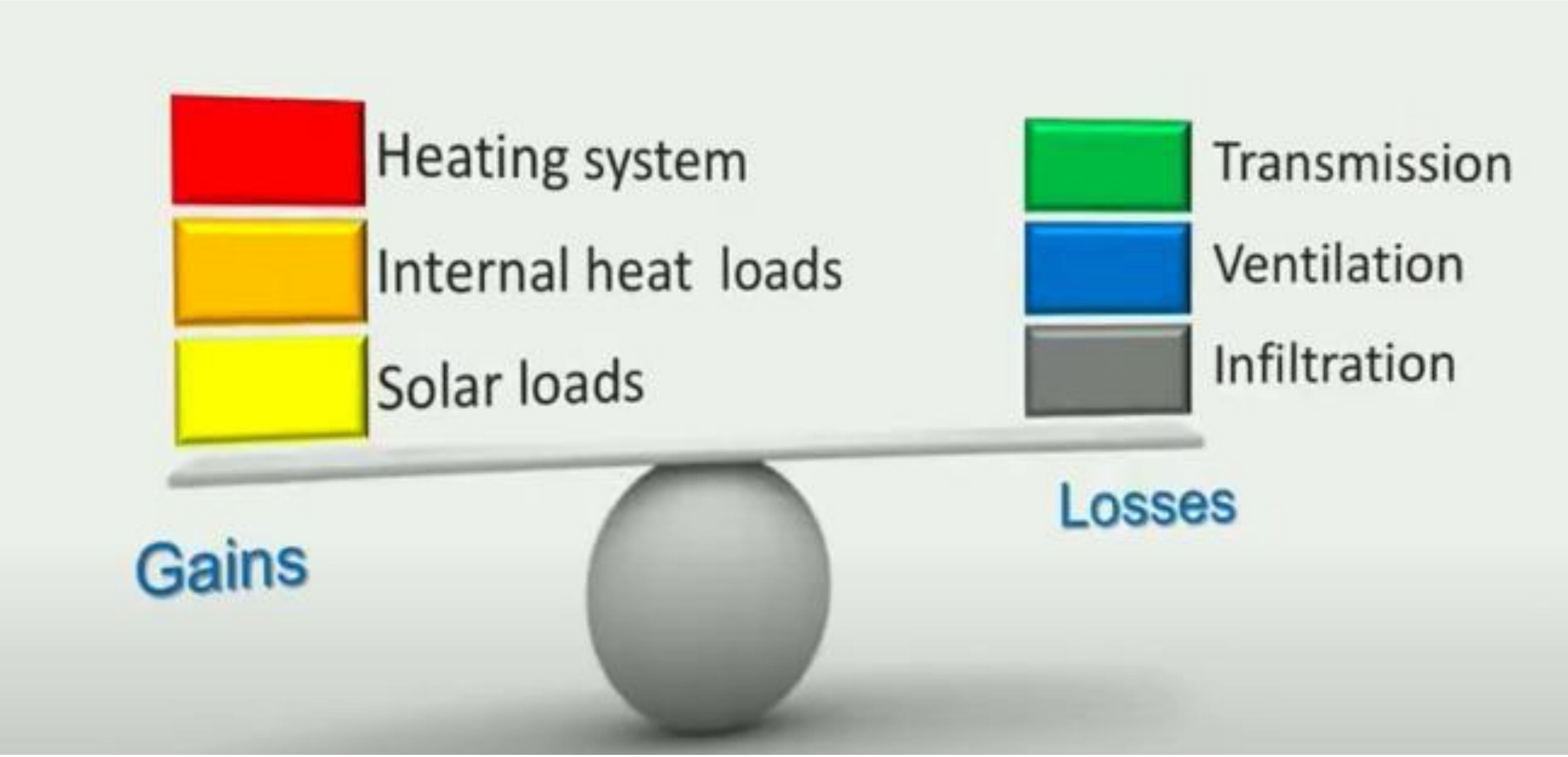
Heat loss due to transmission- depends upon difference in temperature and thermal properties of building material

Heat loss due to ventilation- occurs via circulation of cold air inside the building through ventilations and the exit of warm air outside the building (chimney).

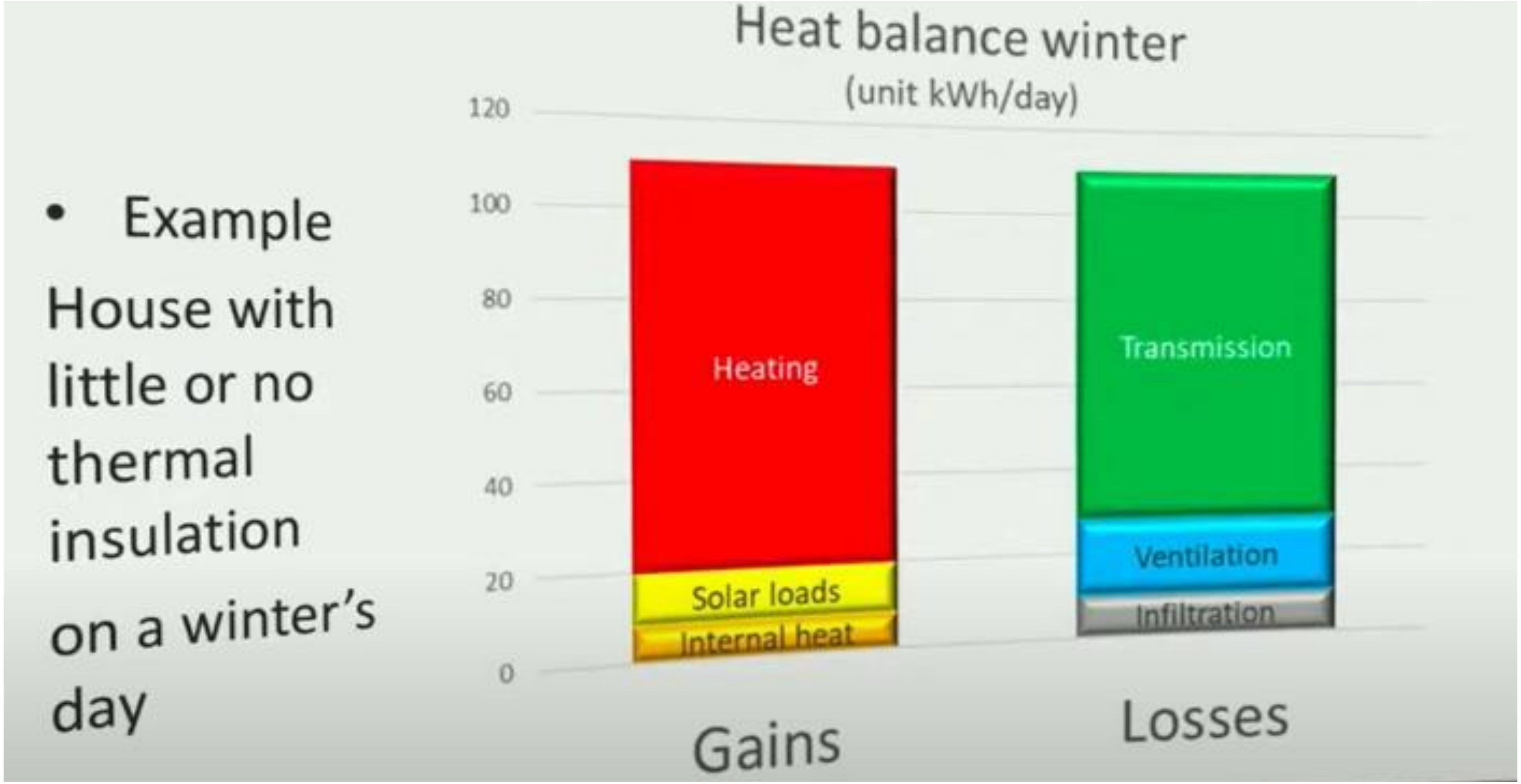
Heat loss due to infiltration- occurs due to the leaks in windows, cracks in buildings - occurs due to the discontinuity in the building joints.



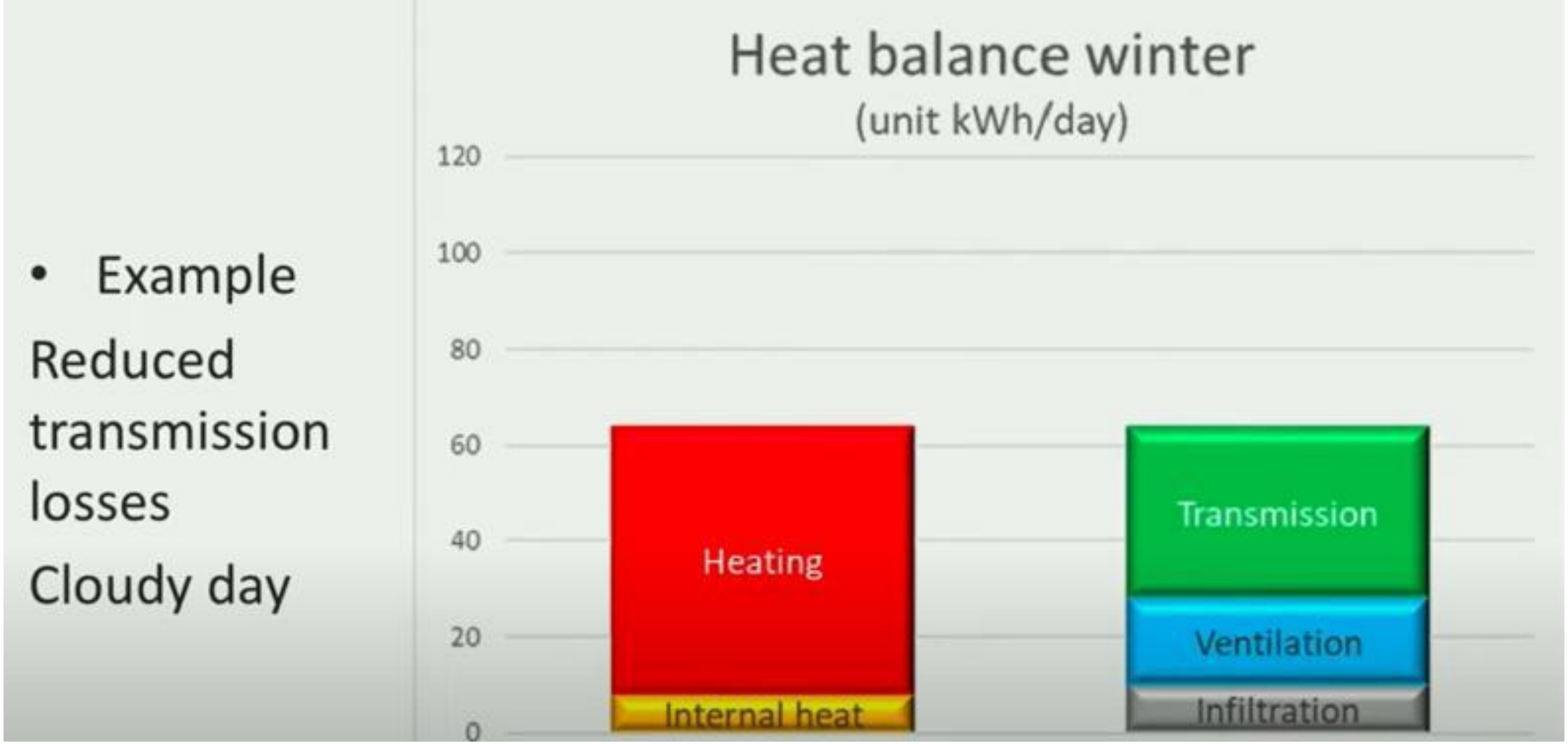
Energy balance in buildings



Heat gain in the buildings during winter season



Heat gain in the buildings during cloudy days



Strategies to make energy efficient buildings in cold areas.

Strategy 1

Increase the passive gain, by that way we can reduce the usage of separate heater unit.

Strategy 2

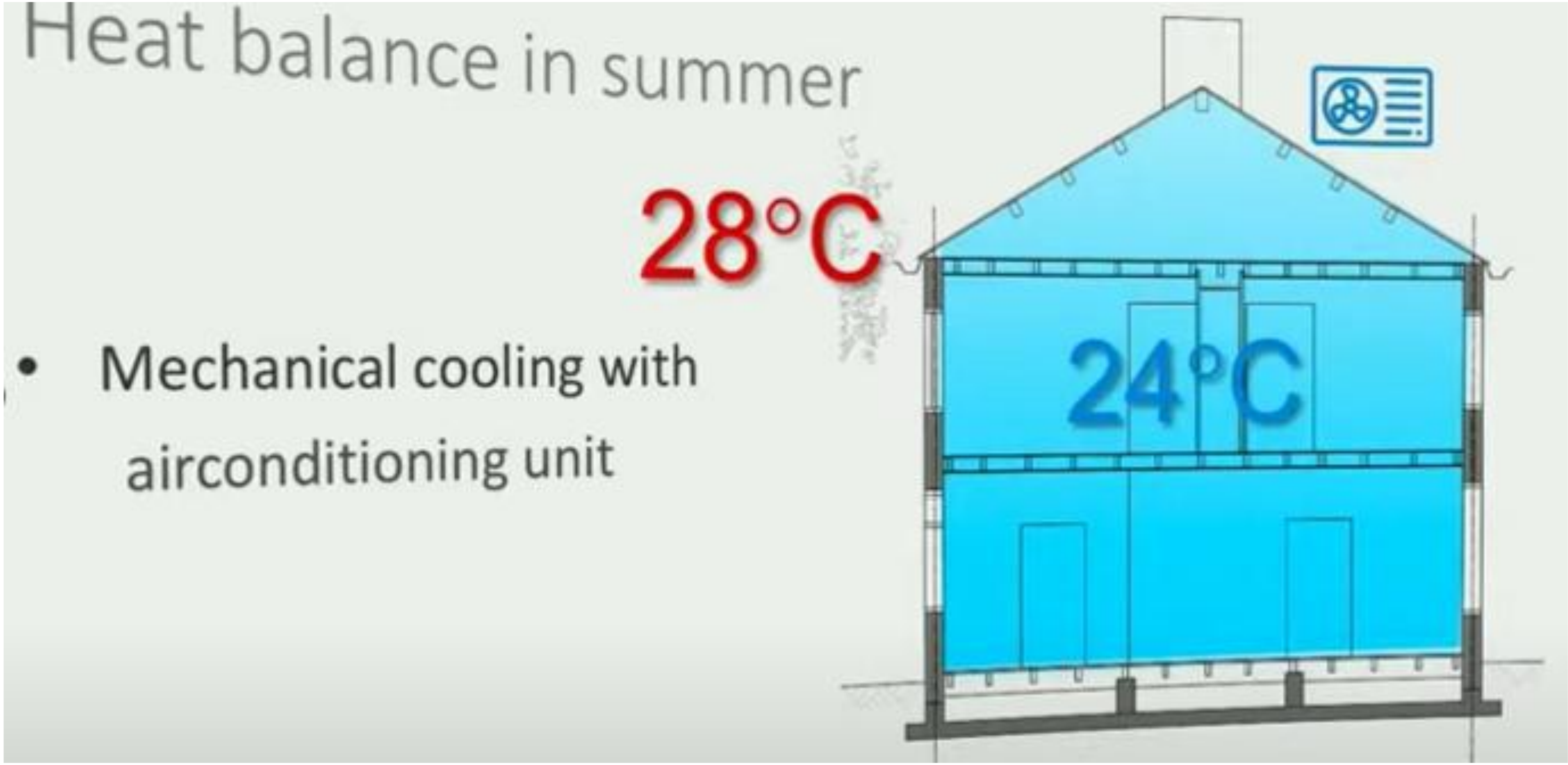
Reduce the heat losses so that the hot air tries to get trapped inside the building.

Heat balance during summer season

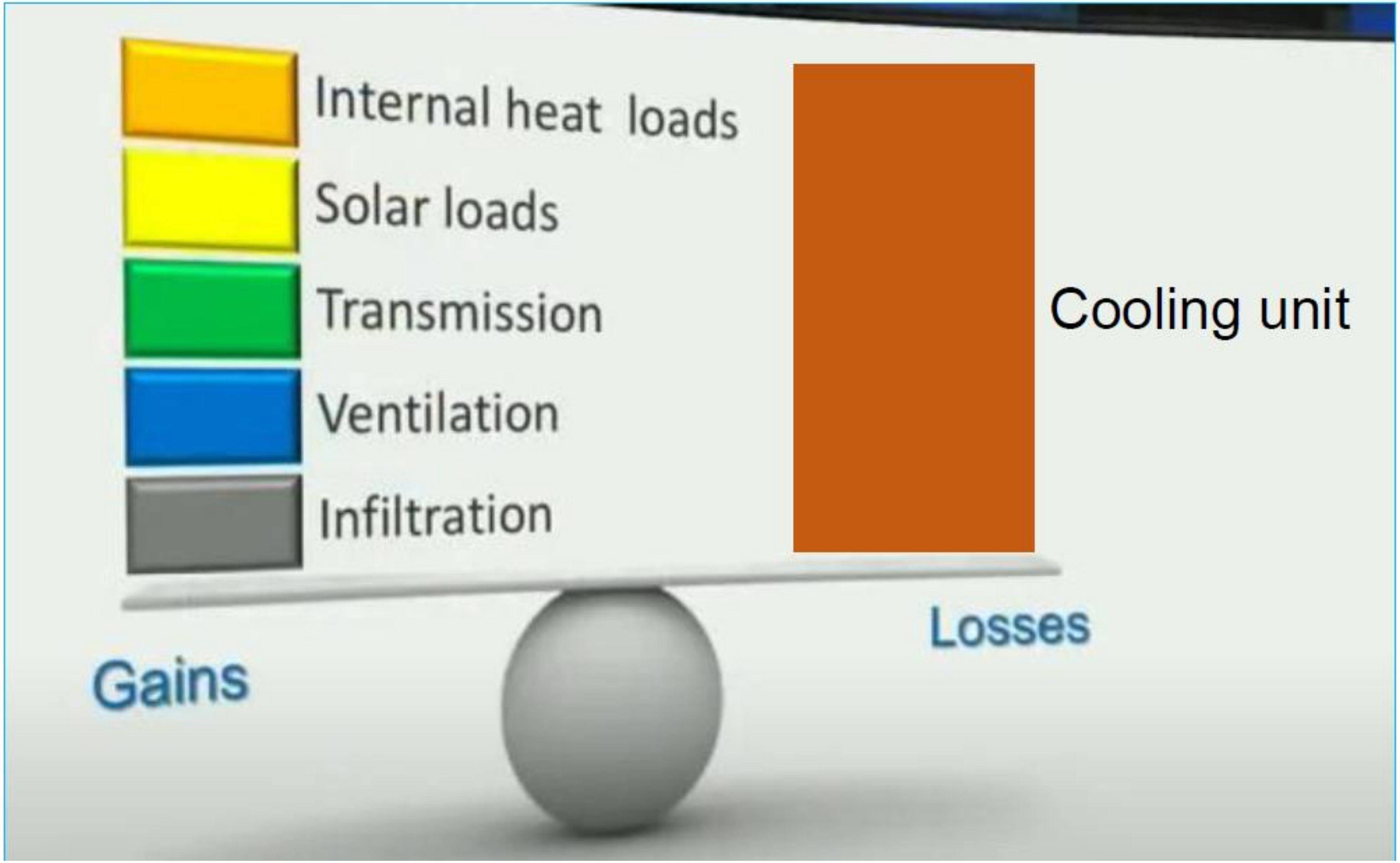
- During the summer season, to maintain a constant indoor temperature, the heat gain should be balanced by heat loss within the building, it is similar to water analogy shown in the Figure.
- The boat is occupied by water due to hole in the bottom surface , if you want to float the boat, you need to pump out the water entering inside the boat.
- Similarly, during summer season, to maintain constant temperature, we need to remove the heat gained by using cooling units like Ac's.

Imagine a room:
Gains 3000 W from sun, appliances, and warm air
Air conditioner removes the gained heat of 3000 W

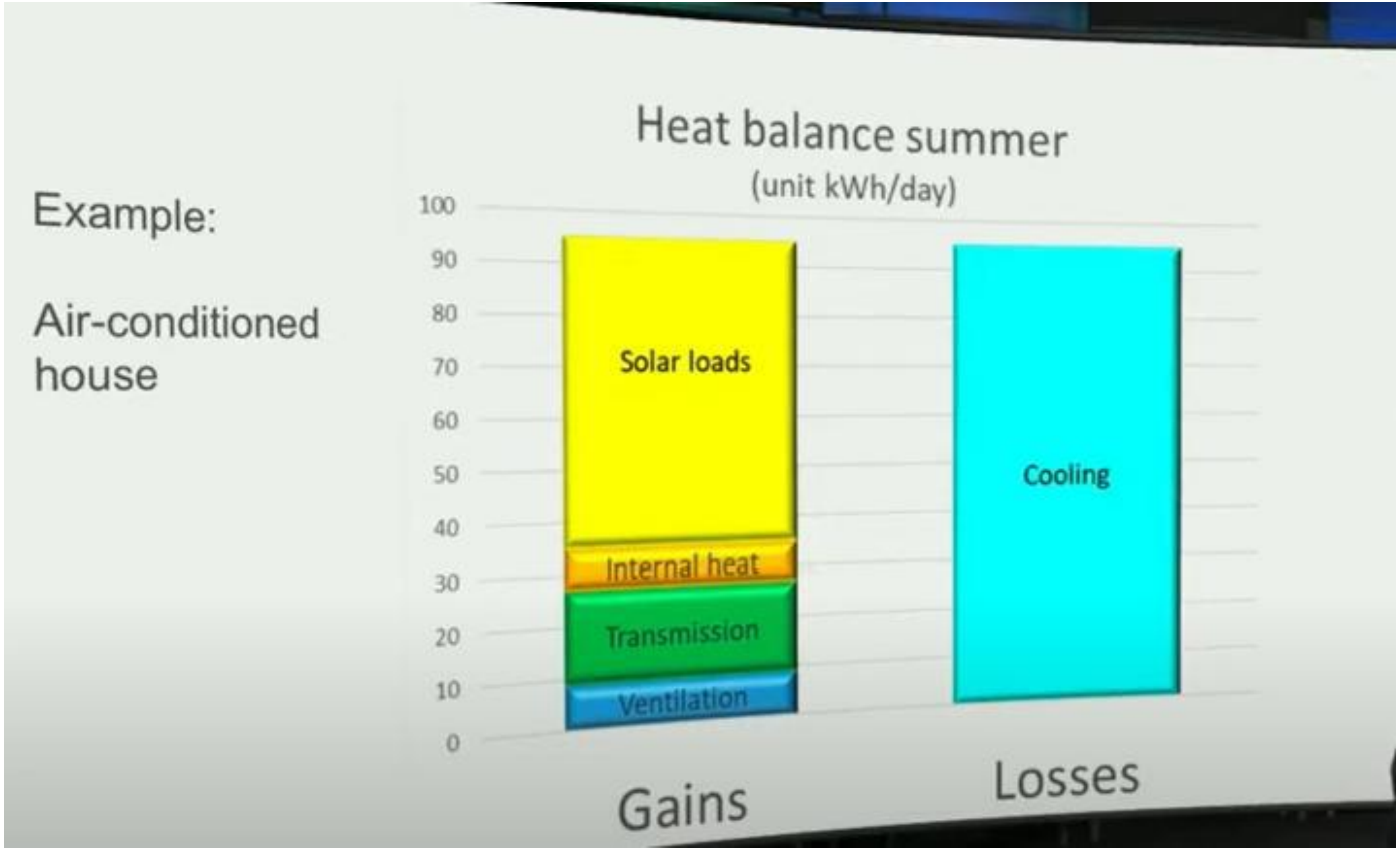
Heat balance during summer season



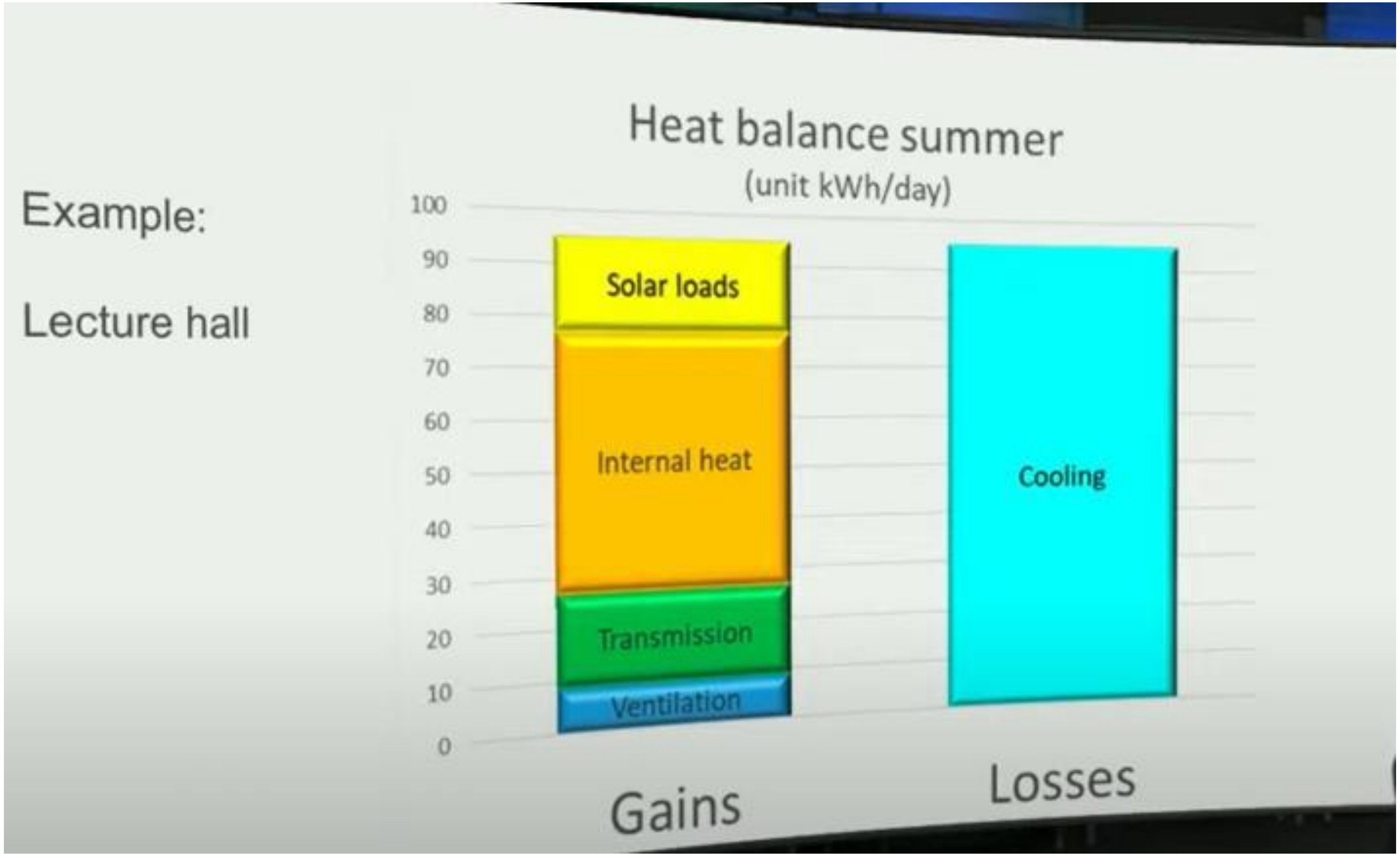
Heat balance during summer season



Heat balance during summer season



Heat balance during summer season

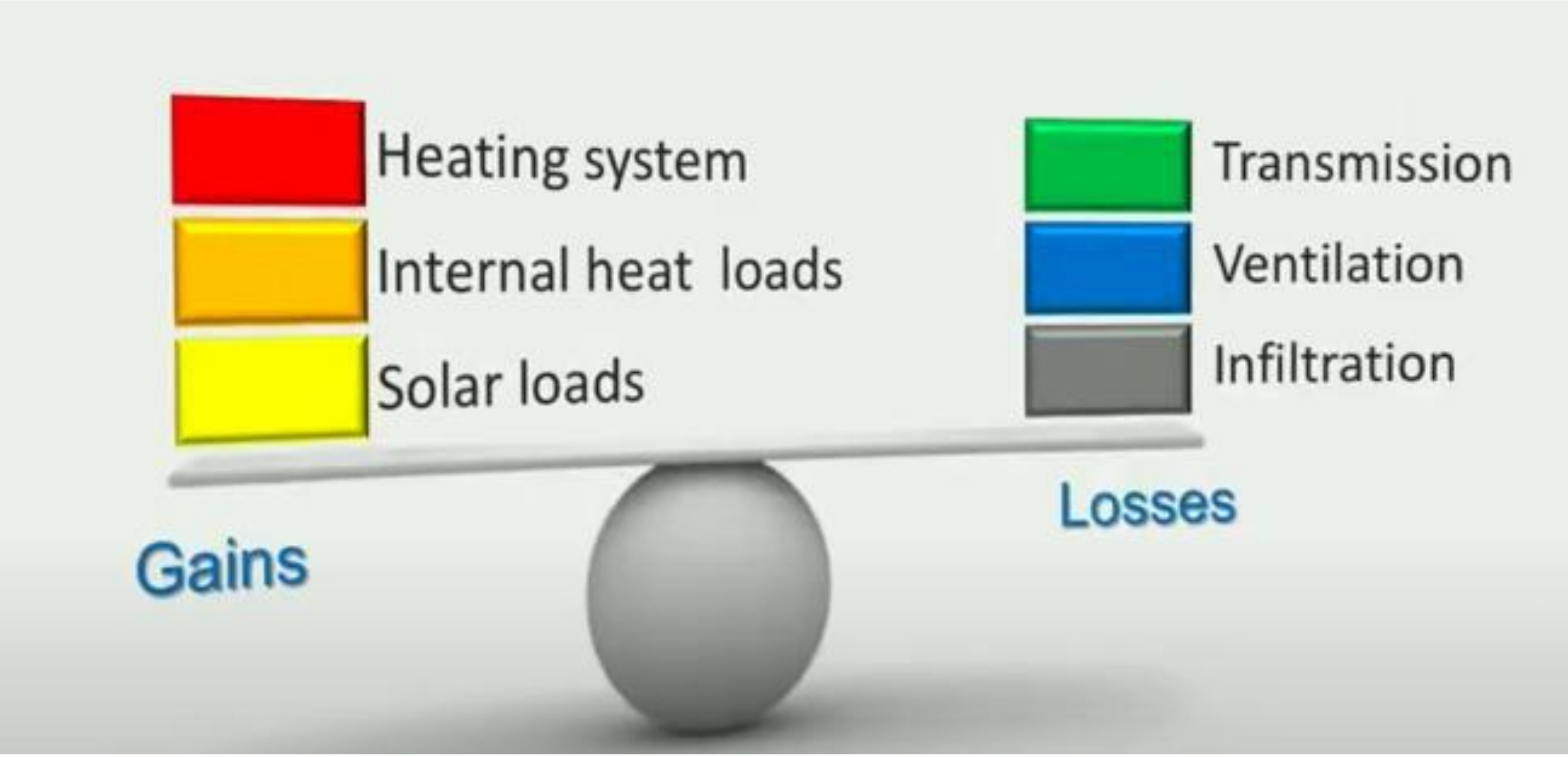


Strategies to make energy efficient buildings in cold areas.

Strategy 1

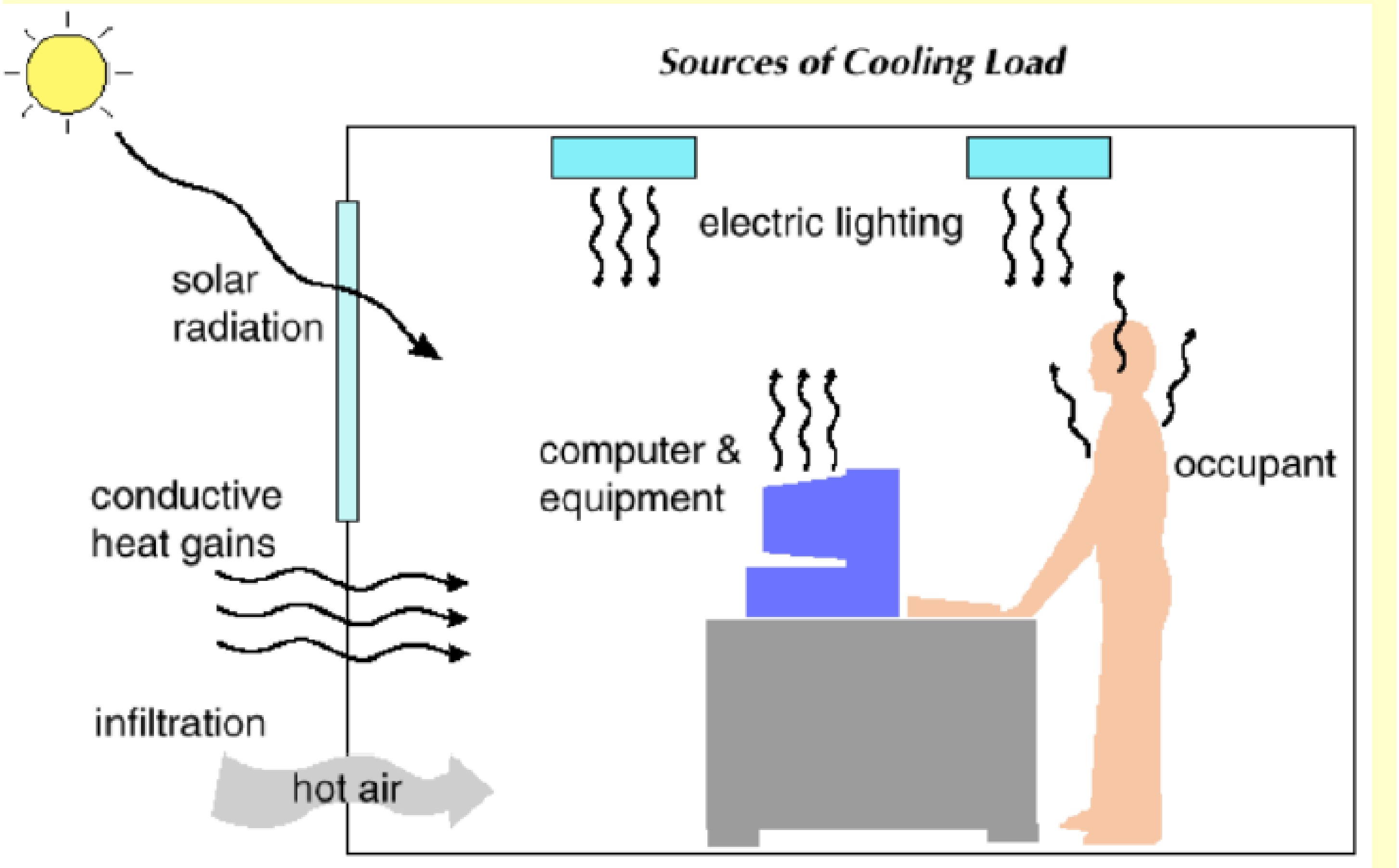
Reduce the heat gain, by that way we can reduce the usage of separate cooling unit.

Energy balance in buildings



Heat Gain > Heat Loss → indoor temperature increases.
Heat Gain < Heat Loss → indoor temperature drops.
Heat Gain = Heat Loss → indoor temperature remains constant.

Estimation of heating and cooling loads



What is a Cooling Load?

- The cooling load refers to the amount of heat energy that needs to be removed from a space to maintain a specified indoor temperature.
- The knowledge about cooling load is required for designing air conditioning system – to ensure a comfortable indoor environment during summer seasons.

What Impacts the Cooling Load?

Several factors can influence the cooling load:

- External Factors: These include the surrounding temperature difference, solar gain (heat from the sun penetrating the building), and relative humidity.
- Internal Factors: Inside the building, heat sources such as occupants, electronic devices, lighting, and machinery contribute.
- Building's Construction: Materials used, insulation efficiency, type of windows, and building orientation can all alter the cooling load.

Why we need to calculate the cooling load and why it is so important?

Determining the cooling load is crucial for:

- ❑ Energy Efficiency: An accurate cooling load calculation ensures the HVAC system operates with minimal energy wastage.
- ❑ System Sizing: It prevents the installation of undersized (leading to an insufficient cooling process) or oversized (leading to cost inefficiencies) HVAC systems.
- ❑ Occupant Comfort: Accurate calculations ensure that HVAC systems maintain a comfortable environment for occupants.

Formula used for calculating cooling load

$$Q = U\,A(T_o - T_i) + Q_{int} + Q_{sol} + Q_{vent}$$

Where:

Q is the total cooling load in Watts.

U is the overall heat transfer coefficient in W/m^2K.

A is the surface area of the building component in m^2.

$\mathbf{T_i}$ is the desired indoor temperature in °C.

$\mathbf{T_o}$ is the outside temperature in °C.

Q_{int} represents the internal heat gains in Watts.

Q_{sol} stands for the solar gains in Watts.

Q_{vent} indicates the ventilation heat gains or losses in Watts due to air changes.

The ventilation heat loss or gains (Q_{vent}) can be further expressed as

$$Q_{vent} = \rho \times Cp \times V \times (T_o - T_i)$$

Where:

ρ is the density of air, approximately 1.225 kg/m^3 at sea level.

C_p is the specific heat capacity of air, approximately 1005 J/kg°C.

V is the volume of air exchanged per hour in m^3/h.

Example

Building Overview:

- A two-story building with four rooms.
- Elements include walls, roof, windows, and a door.

Heat gain through walls :

- **Surface Area:** 200 m^2
- **Material:** Brick with plaster
- **Heat Transfer Coefficient (U):** 1.5 W/m^2K

- $Q_{wall} = U * A * (T_o - T_i)$
- $Q_{wall} = 1.5\ W/m^2K * 200\ m^2 * (35°C - 24°C)$
- $Q_{wall} = 3300\ W$

Heat gain through Roofs

- **Surface Area:** 100 m²
- **Material:** Concrete slab with insulation
- **Heat Transfer Coefficient (U):** 0.7 W/m²K

- $Q_{roof} = U * A * (T_o – T_i)$
- $Q_{roof} = 0.7\ W/m^2K * 100\ m^2 * (35°C – 24°C)$
- $Q_{roof} = 770\ W$

3. Heat gain due to solar energy through windows

- **Surface Area:** 20 m²
- **Material:** Double-glazed glass
- **Heat Transfer Coefficient (U):** 2.8 W/m²K
- **Solar Transmission Coefficient (STC):** 0.65
- **Solar Radiation:** 500 W/m²

Conduction:

$Q_{window\_conduction} = U * A * (T_o – T_i)$

$Q_{window\_conduction} = 2.8\ W/m^2K * 20\ m^2 * (35°C – 24°C)$

$\underline{Q_{window\_conduction} = 616\ W}$

Solar Gain via radiation

- Q_{window_solar} = STC * Solar Radiation * A
- Q_{window_solar} = 0.65 * 500 W/m² * 20 m²
- Q_{window_solar} = 6500 W

Total for Windows:

- $Q_{window\_total} = Q_{window\_conduction} + Q_{window\_solar}$
- Q_{window_total} = 7116 W

4 Heat gain through Door

- **Surface Area:** 2 m^2
- **Material:** Wood
- **Heat Transfer Coefficient (U):** 2.5 W/m^2K

- $Q_{door} = U * A * (T_o – T_i)$
- $Q_{door} = 2.5\ W/m^2K * 2\ m^2 * (35°C – 24°C)$
- $Q_{door} = 55\ W$

5. Heat gain through ventilation

Air change rate: 0.7 (changes per hour)

Volume = 500m^3

Final volume per seconds = $\frac{(0.7*500)}{(3600)}$ = 0.0972 m^3/s

Calculation:

$Q_{vent} = \rho * Cp * V * (T_o - T_i)$

$Q_{vent} = 1.225\ kg/\ m^3 * 1005\ J/kg^0C * 0.0972\ m^3/s * (35^0C - 24^0C)$

$Q_{vent} = 1316.76\ W$

6. Internal Heat Sources

- **Occupants:** 750 W
- **Lighting:** 300 W
- **Electronic Equipment:** 2300 W
- **Other Appliances:** 200 W
- **Total for Internal Sources:**
- $Q_{internal} = Q_{occupants} + Q_{lighting} + Q_{electronics} + Q_{appliances}$
- $Q_{internal} = 3550\ W$

Combining all elements:

$Q_{total} = Q_{wall+}\ Q_{roof+}\ Q_{window\_total+}\ Q_{door}\ +Q_{vent}\ +Q_{ineternal}$

Q_{total} = 3300 W + 770 W + 7116 W + 55 W + 1316.76 W + 3550 W

Q_{total} = 16,107.76 W

To maintain the desired indoor temperature, the HVAC (Heating, Ventilation and Air Conditioning) system needs to counteract a total heat gain of 16,107.76 W

Low and Zero Energy Buildings

Low and zero energy buildings are designed to significantly reduce energy consumption and often generate their own renewable energy to offset the energy used Zero energy buildings, also known as net zero energy buildings (NZEB'S) aim to produce as much energy as they consume over a year through a combination of energy efficiency measures and on-site renewable energy generation Low energy buildings, on the other hand, focus on achieving substantial energy savings through efficiency improvements, often exceeding building code requirements

Low energy buildings-Benefits

Energy Efficiency Focus

- Low energy buildings prioritize energy efficiency in their design and construction, often incorporating features like high levels of insulation, airtight construction, and high performance windows and doors.

Reduced Energy Demand

- By minimizing energy loss and optimizing energy usage, low energy buildings significantly reduce the overall energy demand for heating, cooling, and other building functions.

Reduced Carbon Footprint

- Lower energy consumption translates to a smaller carbon footprint, contributing to environmental sustainability.

Examples

- Low energy buildings may include features like passive solar design, heat recovery ventilation, and geothermal heat pumps.

Zero Energy Buildings (or) Net Zero Energy Buildings (NZEBs)

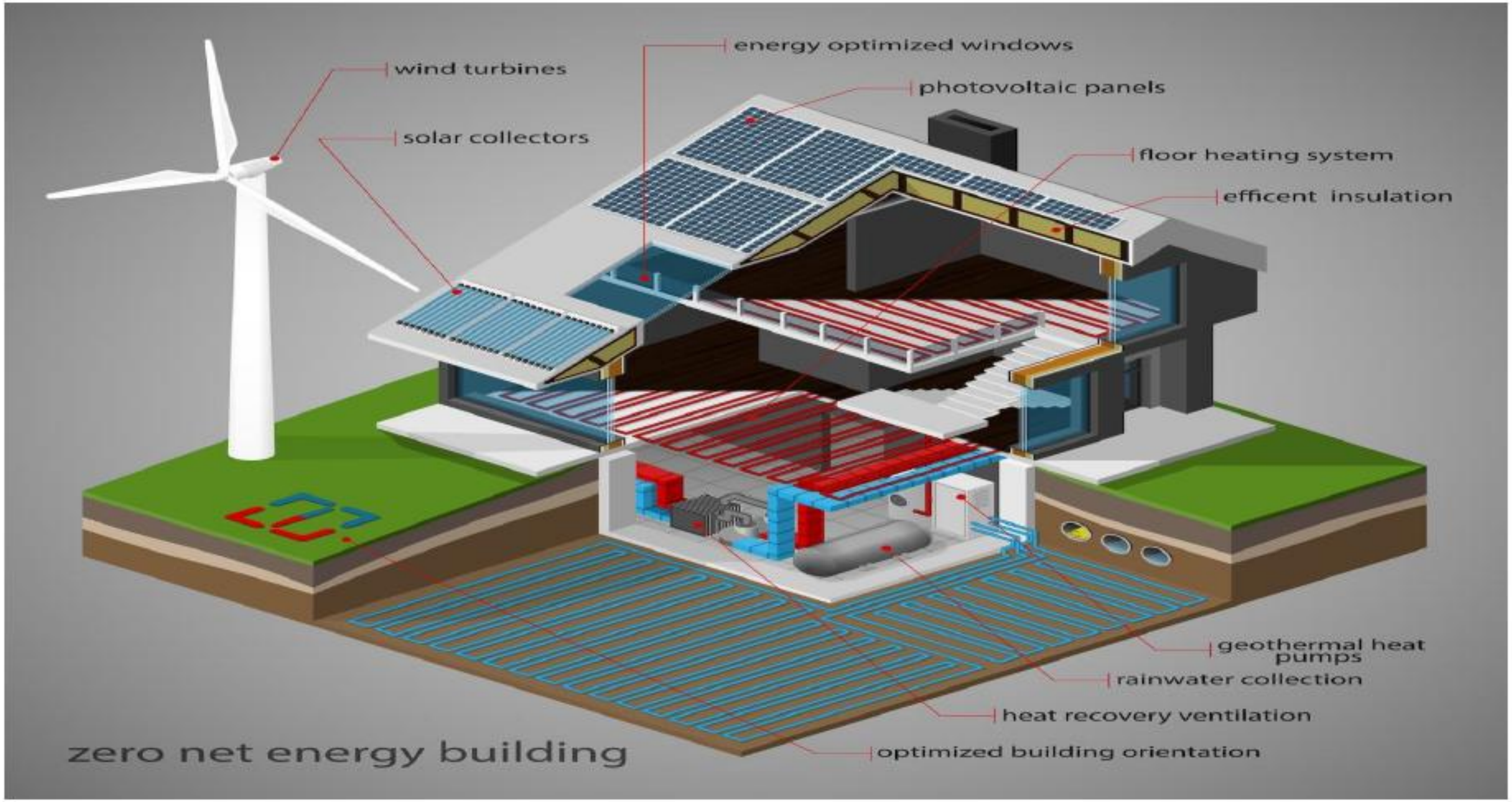


Fig.1 Net Zero Energy Building

Zero energy or Net Zero energy buildings

Net Zero Energy Goal

- NZEBs strive to **balance their energy consumption** with on site renewable energy production, aiming for a net zero energy balance over a year (producing as much energy as it consumes over a year).

Renewable Energy Integration

- NZEBs typically **incorporate renewable energy** systems like solar photovoltaic (panels, wind turbines, or solar thermal systems to generate electricity or heat.

Energy Efficiency is Crucial

- While renewable energy is essential, NZEBs also prioritize energy efficiency to **minimize the size and cost of renewable energy systems**.

Benefits:

- NZEBs offer reduced energy costs, increased comfort, positive environmental impact, and improved energy security.

Net Zero Energy Buildings Design Consideration

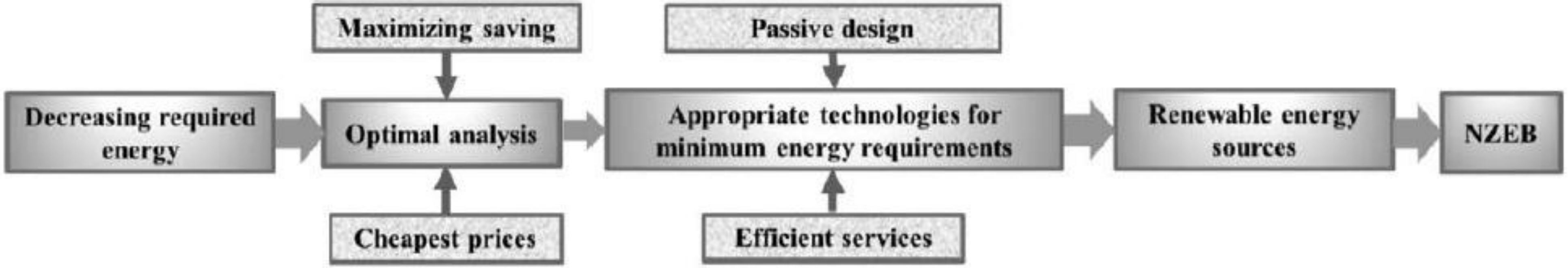


Fig.2 Net Zero Energy Buildings Design Consideration

Key differences between Low and Net Zero Energy Buildings

Energy Production:

While both low and NZEBs types of buildings prioritize energy efficiency ,NZEBs go a step further by actively generating their own energy from renewable sources.

Net-Zero Balance: - A building or system produces as much energy as it consumes over a year.

NZEBs aim for a net-zero energy balance, meaning they off sett their energy consumption with on-site renewable energy production.

Cost Considerations:

NZEBs may have higher up-front costs due to the integration of renewable energy systems, but they can offer long-term cost savings on energy bills and potentially qualify for incentives.

Key differences between Low and Net Zero Energy Buildings

Conclusion:

In essence ,both low and zero energy buildings represent a shift towards more sustainable and energy-efficient building practices, with NZEBs representing a more advanced stage of energy independence and environmental responsibility.

Key Design Strategies for Low and Zero Energy Buildings

Energy Efficiency

Buildings are designed to be highly energy efficient, using advanced insulation, high performance windows, efficient HVAC systems, and efficient lighting and appliances.

Passive Design Techniques

Natural light, ventilation, and shading are utilized to minimize energy demand for heating, cooling, and lighting.

Renewable Energy Generation

On site renewable energy sources, like solar panels or wind turbines, are incorporated to meet or exceed the building's energy needs.

Key Design Strategies for Low and Zero Energy Buildings

Smart Energy Management Systems

Systems are employed to monitor and control energy usage and optimize renewable energy production

Sustainable Materials

Materials with low embodied carbon and recycled content are used.

Adaptive Reuse

Existing structures are retrofitted to improve energy efficiency and incorporate renewable energy systems.

GLOBAL ENERGY SCENARIO

GLOBAL ENERGY SCENARIO

1. OVERVIEW

- The global energy scenario is shaped by numerous factors: increasing demand, technological advancements, climate concerns, and geopolitical developments. As the world population approaches 8 billion, the demand for energy continues to grow, especially in developing nations where industrialization, urbanization, and improved living standards are accelerating.

- **Global Energy Demand**: The world’s energy consumption has increased significantly, growing by around 2% per year since the early 2000s. The demand for energy is largely driven by Asia, especially China and India.

- **Geopolitical Factors**: Energy plays a critical role in global geopolitics. Countries with major energy resources like Saudi Arabia and Russia have substantial global influence. Oil and gas have historically been the primary geopolitical tools in international relations.

2. SOURCES OF ENERGY (GLOBAL SHARE)

2.1 Fossil Fuels (Oil, Coal, Natural Gas)

- **Oil**:

➢ **Key uses**: Primarily for transportation and industry (petrochemicals, aviation, etc.).

➢ **Geopolitical importance**: Countries like the Middle East (Saudi Arabia, Iran) and Russia are major suppliers.

➢ **Challenges**: While oil remains a significant energy source, its environmental impact (emissions) and price volatility have led to a global push toward diversification.

- **Coal**:

➢ **Largest share**: Coal remains the world's largest energy source for electricity generation, contributing roughly 26% of global energy use.

➢ **Pollution concerns**: Coal combustion is a major source of greenhouse gas emissions and other pollutants, making it a focal point in climate change debates.

➢ **Regional differences**: In Asia, particularly China and India, coal is essential for industrialization, but these countries are also increasing their renewable energy investments.

- **<u>Natural Gas</u>**:

➢ **Cleaner fossil fuel**: Compared to oil and coal, natural gas is **less carbon-intensive**. It's considered a transition fuel towards cleaner energy.

➢ **Uses**: Power generation, industrial processes, and increasingly for **heating**.

➢ **Expansion**: The **shale gas boom** (US) has transformed global markets, making natural gas more abundant and affordable.

2.2. Renewable Energy

- **<u>Hydropower</u>**:

➢ **Mature technology**: Hydropower, primarily large dams, contributes a significant portion of renewable energy (16% of global electricity).

➢ **Geographical distribution**: Major hydropower plants are found in China, Brazil, and Canada.

➢ **Challenges**: Environmental impact of large dams, displacement of local populations, and climate change effects on water availability.

- **<u>Solar Energy</u>**:

➢ **Rapid growth**: Solar power is among the fastest-growing energy sectors, with global solar capacity growing by over 20% annually.

➢ **Global leaders**: China, Germany, and India lead solar installations, with China having over 1,000 GW of capacity installed by 2024.

➢ **Technological advancements**: The cost of solar panels has fallen by over 90% in the past decade, making it a viable energy solution globally.

- **<u>Wind Energy</u>**:

➢ **Onshore vs. Offshore**: While onshore wind has been around for decades, offshore wind is becoming a significant contributor in regions like Europe and the US.

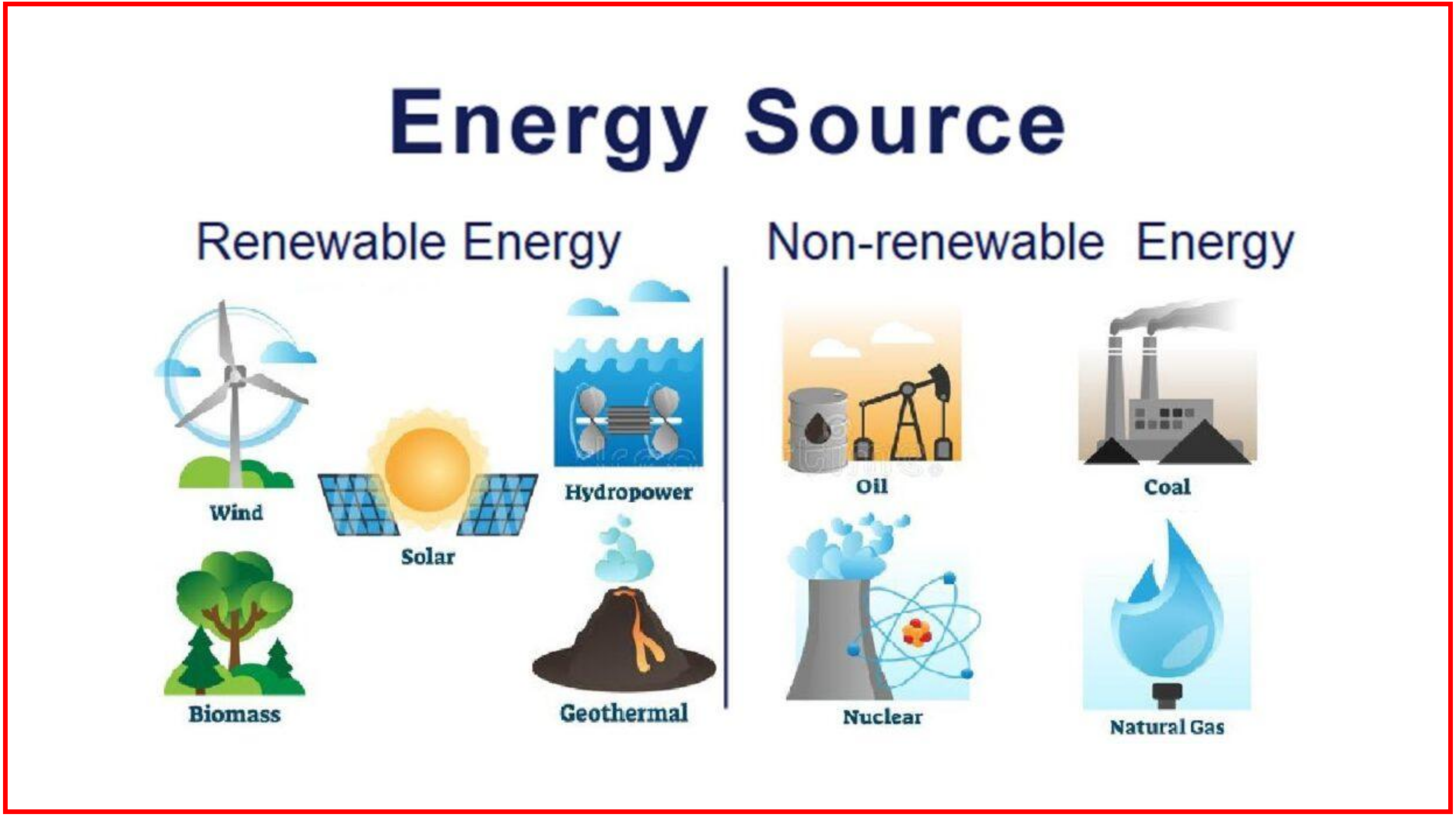
➢ **Cost-effectiveness**: Wind is now competitive with fossil fuels in many markets due to technological innovations in turbine efficiency and size.

2.3. Nuclear Energy

- **Low-carbon energy**: Nuclear power remains one of the few large-scale sources of carbon-free electricity.
- **Current issues**: The high upfront costs, nuclear waste management, and safety concerns (e.g., Fukushima, Chernobyl) continue to limit nuclear’s growth.
- **Future potential**: Next-gen reactors and innovations in small modular reactors (SMRs) may make nuclear energy safer and more economically feasible in the future.

3. ENERGY DEMAND TRENDS

- **Rising demand in Asia**: Countries like China and India are expected to account for half of the global energy demand by 2040. In China, energy consumption has nearly doubled since 2000, and India is projected to become the world’s largest importer of energy by 2030.
- **Energy use per capita**: Developed nations consume significantly more energy per capita than developing nations. However, as these nations industrialize, their per capita consumption is set to increase.
- **Electrification**: Electricity is the fastest-growing energy form due to increased use in transportation (electric vehicles), industry, and digital technologies.


Energy Source
Renewable Energy
Non-renewable Energy
Wind
Solar
Hydropower
Biomass
Geothermal
Oil
Coal
Nuclear
Natural Gas

4. ENERGY ACCESS

- Over **770 million people** still lack **access to electricity**, primarily in **sub-Saharan Africa** and **rural Asia**.
- The push for **universal energy access** focuses on **off-grid** solutions (solar home systems, microgrids) in developing nations, which can offer **clean and affordable energy**.

5. CLIMATE CHANGE AND SUSTAINABILITY

- **Net-zero by 2050**: The global community is committed to **limiting global temperature rise** to **1.5°C**. To achieve this, the energy sector must **decarbonize** by 2050.
- **Challenges**: Transitioning from fossil fuels to renewables requires significant infrastructure investment, policy adjustments, and international cooperation.
- **Decarbonization strategies**: Carbon capture and storage (CCS), biofuels, and **electrification of transportation** are key areas of focus.

6. TECHNOLOGICAL TRENDS

- **Energy Storage**: As renewable energy like solar and wind is intermittent, **battery storage** technologies are crucial for providing reliable power. Tesla, BYD, and others are driving innovations here.
- **Smart Grids**: The integration of digital technologies (AI, IoT) into power grids allows for real-time management of supply and demand, making the grid more efficient, flexible, and resilient.
- **Hydrogen Economy**: Green hydrogen produced by renewable electricity is being touted as a clean energy carrier, especially for sectors like heavy industry and long-distance transportation.

7. GEOPOLITICAL AND ECONOMIC FACTORS

- **Energy security**: Nations are increasingly concerned with energy independence. Countries like the US, China, and Russia focus on securing resources to minimize vulnerability to supply disruptions.
- **Global Energy Investment**: In 2023, global investments in clean energy exceeded $1.7 trillion (BloombergNEF). Countries are investing in clean energy technologies to meet climate goals while ensuring future energy security.

INDIAN ENERGY SCENARIO

INDIAN ENERGY SCENARIO

1. OVERVIEW

- India is a key player in the global energy market due to its large population (1.4 billion) and rapid economic growth. The Indian economy is set to become the **world's third-largest** by 2030, driving substantial increases in energy demand.
- **Energy Consumption Growth**: India's energy consumption has grown by an average of **4.3% annually** over the past decade, with electricity demand growing by 6–7% annually.

2. CURRENT ENERGY SOURCES (INDIAN SCENARIO)

2.1. Coal

- ➢ **Largest energy source**: India is the world's second-largest consumer of coal, with around **50%** of its energy mix coming from coal.
- ➢ **Challenges**: Coal mining and usage contribute to significant air pollution (especially in cities like Delhi), and the country faces growing pressure to reduce carbon emissions.

2.2. Oil & Gas

- **Dependence on imports**: India imports around **85% of its crude oil**. Rising global oil prices and supply chain disruptions (e.g., the Russia-Ukraine conflict) pose risks to energy security.
- **Natural Gas**: India is increasingly investing in LNG terminals and developing its domestic gas resources, including coalbed methane (CBM) and shale gas.

2.3. Renewables

- India is a global leader in solar energy, with more than 40 GW of installed capacity and ambitious targets to reach 175 GW by 2022 and 500 GW by 2030.
- The country also has rich wind resources, especially along its coasts, and is exploring offshore wind technology.

2.4. Nuclear Energy

- **Limited share**: Nuclear energy accounts for **around 2%** of India's total installed capacity, but there are plans to **expand** this to **22 GW by 2031**.
- India is focusing on **thorium reactors**, as thorium is more abundant and safer compared to uranium-based reactors.

3. POWER SECTOR

- India has made tremendous progress in **electrification**, with **99.99% of villages** now having access to electricity (per government data).
- **Grid Integration**: Despite rapid renewable growth, **grid stability** remains a challenge due to the intermittent nature of solar and wind power.

4. ENERGY ACCESS & EQUITY

- **Challenges remain**: While electrification has been achieved, issues like **power quality** and **24x7 access** persist, especially in rural areas.
- **Clean cooking fuels**: Over **90 million households** now have access to **LPG** through government programs like **PM Ujjwala Yojana**.

5. POLICY AND REGULATION

- **National Electricity Policy 2021**, **Draft Energy Policy**, **Hydrogen Mission**.
- **Renewable Energy targets**: 175 GW (2022), 500 GW (2030).
- **Perform Achieve Trade (PAT)** scheme for energy efficiency.
- **Faster Adoption and Manufacturing of Electric Vehicles (FAME)** scheme.
- Carbon trading and Green Hydrogen incentives introduced.

6. CHALLENGES

- **Energy security**: High import dependence on oil and gas.
- **Grid integration**: Managing variable renewables.
- **Air pollution**: Power plants and vehicles contribute significantly.
- **Financial stress**: DISCOM losses, tariff distortions.
- **Technological gaps**: In domestic manufacturing, storage, and smart systems.

7. OPPORTUNITIES AND TRENDS

- **Solar dominance**: India is among the cheapest solar producers globally.
- **Green Hydrogen**: India plans to be a global hub.
- **Battery storage & EVs**: Huge market potential.
- **International cooperation**: ISA, G20, COP summits, and global alliances.

8. FUTURE OUTLOOK OF GLOBAL AND INDIAN ENERGY SCENARIO

A. Global:

- Shift toward **net-zero** by 2050 is driving investment.
- Renewables and storage will dominate new capacity.
- Fossil fuel use may peak by late 2020s.

B. India:

- Energy demand to **double by 2040** (IEA).
- Massive scope for **renewables, energy efficiency, and green jobs**.
- Transition challenges: balancing development and decarbonization.

FUTURE BUILDING DESIGN ASPECTS

FUTURE BUILDING DESIGN ASPECTS

1. Sustainability and Environmental Performance

- **Aim:** Reduce environmental impact and achieve long-term energy and resource efficiency.

- **Detailed View:**

➢ **Net-Zero Buildings**: Designed to produce as much energy on-site (via renewables) as they consume annually. Example: solar-powered homes with battery storage.

➢ **Carbon-Neutral Buildings**: Offset carbon emissions by using low-emission materials and renewable energy or investing in carbon offsets.

➢ **Circular Design**: Building components are designed for reuse, disassembly, and minimal waste.

➢ **Eco-Friendly Materials**: Materials like cross-laminated timber (CLT), recycled steel, or algae-based insulation reduce embodied carbon.

2. Smart and Responsive Buildings

- **Aim:** Use of automation, sensors, and data to enhance efficiency and comfort.

- **Detailed View:**

➢ **IoT Integration**: Sensors track occupancy, temperature, lighting, humidity, and adjust systems automatically.

➢ **Building Automation Systems (BAS)**: Control HVAC, lighting, and security systems to reduce operational costs.

➢ **AI and Machine Learning**: Learn usage patterns and optimize operations (e.g., AI controlling HVAC during off-peak hours).

➢ **Digital Twin**: A virtual, real-time model of a building used to simulate and monitor systems, improve maintenance, and optimize energy.

3. Advanced Construction Methods and Materials

- **Aim:** Speed, accuracy, sustainability, and material innovation.

- **Detailed View:**

➢ **3D Printing**: Concrete 3D printers build structural components on-site, reducing material waste and labor costs.

➢ **Modular Construction**: Factory-built sections of buildings transported and assembled onsite; ideal for rapid and scalable development.

➢ **Self-Healing Materials**: Concrete infused with bacteria or polymers that seal cracks autonomously.

➢ **Smart Materials**: Glass that adjusts transparency (electrochromic), phase change materials that store/release heat.

4. Human-Centered and Health-Focused Design

- **Aim:** Promote physical and mental well-being of occupants.

- **Detailed View:**

➢ **Biophilic Design**: Incorporates nature (plants, daylight, natural textures) to reduce stress and increase productivity.

➢ **Air & Light Quality**: Emphasis on proper ventilation, air purification, and circadian lighting (lighting that mimics natural day-night cycles).

➢ **Wellness Standards**: Certifications like WELL and Fitwel prioritize comfort, nutrition, fitness, mental health.

➢ **Post-COVID Safety**: Touchless controls, antimicrobial surfaces, and better airflow zoning to prevent spread of disease.

5. Urban Integration and Community-Oriented Design

- **Aim:** Strengthen social connectivity and urban resilience.

- **Detailed View:**

➢ **Vertical Cities**: High-rises functioning as cities—housing, workspaces, recreation in one vertical footprint.

➢ **Transit-Oriented Design**: Developments planned around public transportation hubs to reduce private car use and traffic.

➢ **Mixed-Use Planning**: Buildings combine residential, commercial, and public services to support vibrant, 24/7 communities.

➢ **Inclusive Design**: Spaces for all demographics (elderly, disabled, children); universal access and social equity embedded in design.

6. Resilience, Safety, and Disaster Preparedness

- **Aim:** Design for durability, adaptability, and emergency response.

- **Detailed View:**

➢ **Climate Resilience**: Adapt structures to local risks (e.g., elevated buildings in flood zones, wind-tolerant shapes in hurricane areas).

➢ **Multi-Hazard Design**: Integration of systems to handle earthquakes, wildfires, floods, and pandemics.

➢ **Autonomous Systems**: Buildings with their own energy, water, and food supply (useful during natural disasters or grid failures).

➢ **Emergency Planning**: Escape routes, panic rooms, smart alarms, and adaptable space usage during crises.

7. Regulatory, Economic, and Ethical Considerations

- **Aim:** Ensure design is compliant, cost-effective, and ethically responsible.

- **Detailed View:**

➢ **Green Certifications**: LEED, BREEAM, and WELL promote measurable benchmarks in energy use, health, and sustainability.

➢ **Life-Cycle Costing**: Instead of only upfront costs, designers evaluate long-term maintenance, energy, and disposal costs.

➢ **Incentives & Policies**: Tax rebates, grants, or relaxed zoning laws for green or affordable housing projects.

➢ **Ethical Sourcing**: Materials obtained without child labor, environmental harm, or exploitation. Transparency in supply chain is key.

8. Emerging and Experimental Concepts

- **Aim:** Push boundaries of traditional architecture and adapt to extreme conditions.

- **Detailed View:**

➢ **Regenerative Buildings**: Go beyond reducing harm; they actively improve their environment (e.g., buildings that clean the air or regenerate water).

➢ **Space Architecture**: Structures that support human life in zero gravity, with airtight habitats, closed-loop life systems, and radiation shielding.

➢ **AR/VR in Design**: Use of Virtual Reality (VR) for immersive walkthroughs; Augmented Reality (AR) to overlay digital information on physical spaces.

➢ **Hybrid Realities**: Integration of physical and digital experiences (e.g., smart glass with embedded screens, interactive walls, metaverse-compatible rooms).

Unit-1-Energy Transfer in Buildings **9 Hour**

Concepts of thermal comfort and energy efficient buildings, Conventional versus Energy Efficient Buildings-Climate and its influence in building design for energy requirement- Thermal properties of building materials, Heat transmission in building structures, Energy balance for cooling and heating of buildings- Estimation of heating and cooling loads, Low and zero energy buildings- Global and Indian energy scenario-Future building design aspects.