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SCHOOL OF BUILDING AND ENVIRONMENT
DEPARTMENT OF ARCHITECTURE

SAR1609 – ENERGY EFFICIENT ARCHITECTURE

UNIT – I - ENERGY EFFICIENCY IN BUILDINGS

UNIT 1 – ENERGY EFFICIENCY IN BUILDINGS

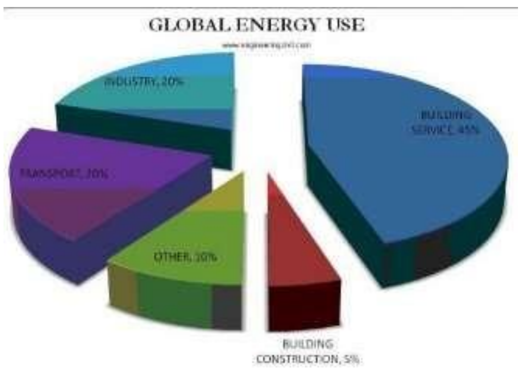
DEFINITION

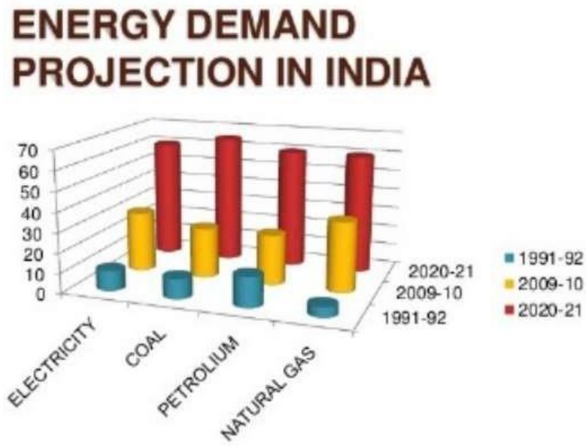
Energy efficiency simply means **using less energy to perform the same task -** that is, eliminating energy waste. Energy efficiency brings a variety of benefits: reducing greenhouse gas emissions, reducing demand for energy imports, and lowering our costs on a household and economy-wide level.

Energy efficiency - Once, it was just about using less. Now it's about creating holistic and sustainable solutions with less impact. Energy efficiency combines educating people about **consumption with new, improved, and green building construction** that **reduces urban center's environmental footprint**. Energy efficiency also relies on a greater use of **sustainable resources** like **solar and wind**. Using less energy is, of course, better, but **future energy efficiency inspires** so many more **innovations**.

NEED FOR ENERGY EFFECIENCY

Energy Efficiency helps protect the environment. When we use less energy, the less energy we need to generate at power plants, which reduces greenhouse gas emissions and improves the quality of our air. Energy efficiency helps the economy, too, by saving consumers and businesses millions of dollars in energy costs. Energy efficient solutions can reduce the energy bill for many homeowners and businesses by 20 to 30 percent.





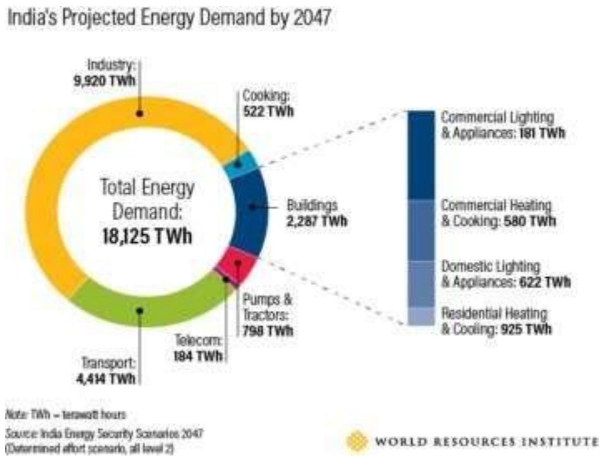
Climate change is one of the biggest threats we face today. Clearly, we need to reduce CO2 emissions globally to zero, or to less than zero, to address climate change and architecture must change to address this challenge

Buildings use more energy than either transportation or industrial sectors to heat, cool, power electronics and artificially light interiors.

Need for Energy Efficient Buildings in India

Residential and commercial structures consumed nearly a third (32 percent) of the country's total electricity in 2016, according to the latest annual energy statistics published by the Ministry of Statistics, Planning and Implementation. And as Indian cities grow, building energy demand is sure to surge.

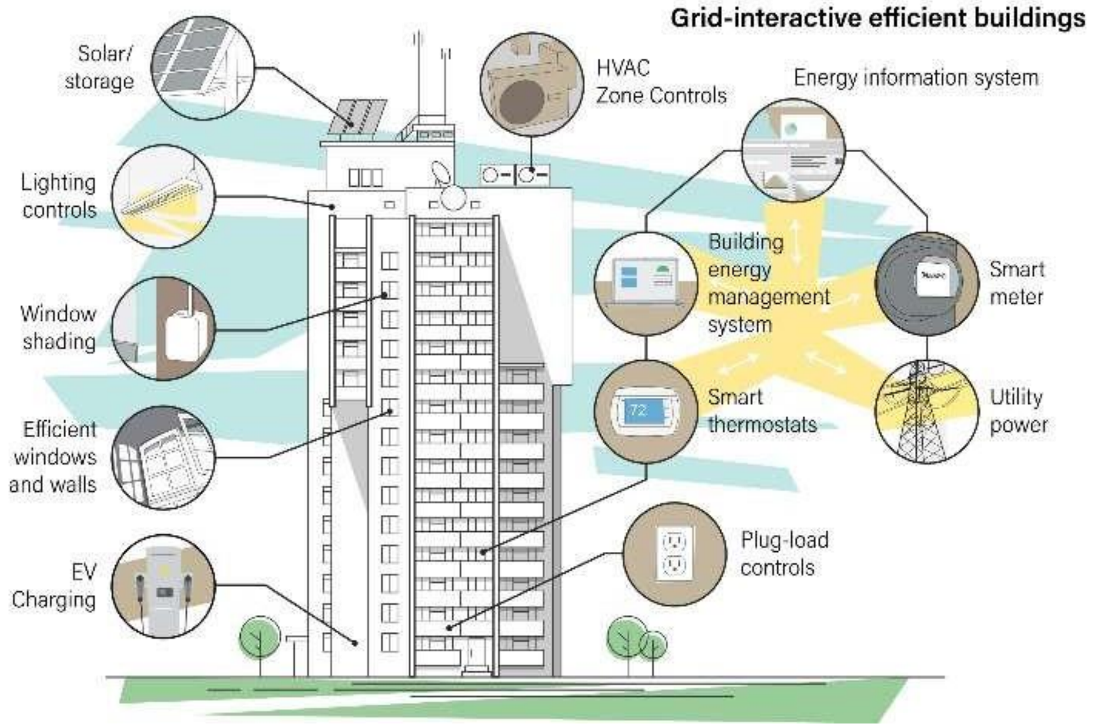
- The government's policy agency, Niti Aayog, estimates that energy demand from India's buildings will increase by more than 800 percent in 2047 compared to 2012.



India took an important step forward by launching the revised Energy Conservation Building Code (ECBC) 2017.
Developed by Ministry of Power and Bureau of Energy Efficiency, the code prescribes energy performance standards for new commercial buildings to reduce energy consumption and promote low-carbon growth.
It sets parameters for builders, designers and architects to integrate renewable energy sources in building design, with a goal of achieving a 50 percent reduction in energy use by 2030.
Buildings that meet requirements of the ECBC are between 17 to 42 percent more efficient than conventional buildings, offering enormous potential for energy savings.
A parallel effort on a code for Residential Buildings ECBC-R has also been introduced.
Buyers don't hear about benefits like easier maintenance, lower energy costs and better ventilation and insulation in hot climates. Certifying and labeling buildings based on their energy use would build trust in tenants and buyers, and stimulate the market for efficient buildings

- The energy efficiency of a building is the extent to which the **energy consumption per square meter of floor area** of the building **measures** up to established energy consumption **benchmarks** for that particular type of building under defined **climatic conditions.**
- Building energy consumption benchmarks **are representative values** for common building types against which a building's actual performance can be compared.
- These **benchmarks** are derived by **analyzing data** on different building types within a given country or place. The typical bench mark is the median level performance of all buildings in a given category and good practice represents the top quartile performance.

Comparisons with simple benchmarks of annual energy use per square meter of floor area allow the standard of energy efficiency to be assessed and the priority areas for action to be identified

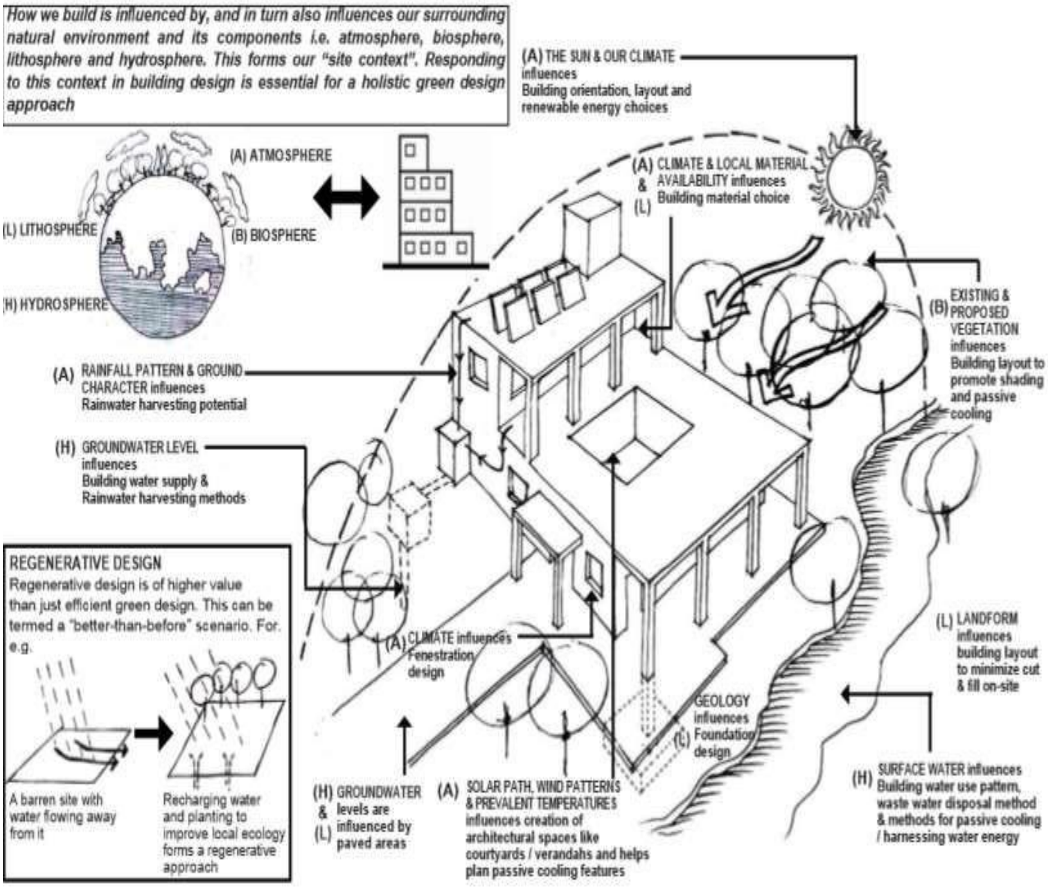


Integration of other tools (simulations, software), codes and rating systems like ECBC, LEED and GRIHA helps reduce the credibility gap between the deign intent and the actual performance.
In India, BEE (Bureau of energy Efficiency) was established on 1st March, 2002
Energy efficiency in buildings can be calculated based on two different parameters

- by quantity (BTUs, watts, etc.)
- by quality (its relative temperature or intensity)

Green buildings

Green building is an outcome of a design philosophy which focuses on;
Increasing the efficiency of resource use; energy, water, and materials while
Reducing the impact on human health and the environment during the building's lifecycle, through Better design, construction, operation, maintenance and removal
Using the five building design imperatives leads to Integrated Green Design Approach.



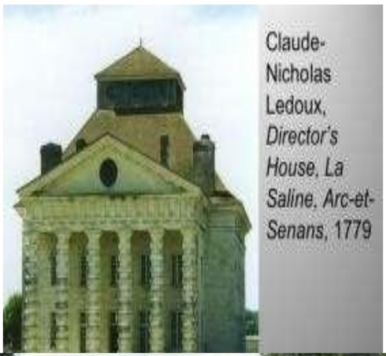
Timeline	Architectural Movement	Social Events	Effects of Social Events	Energy Efficiency in Buildings	Examples
Pre-Industrial 1500 to 1700	Vernacular Architecture	Ongoing Neolithic Revolution Renaissance architecture Agriculture as main economy	Goods produced on small scale for consumption Extensive use of wood and natural stones	Use of windmills, wind power Renewable resources were exploited for construction	St.Peters Basilica, Vatican City 
Before 20th century	Vernacular Architecture	Industrial Revolution	Steam Power Electric energy through the grid Mass production specialization Need for new spaces	Passive systems Experience of the past	The Iron Bridge by Thomas Farnalls Pritchard 
First quarter of 20th century	Modernism (Futurism)	1st World War Usage of elevator New Building	First steps of combined heating, cooling and air conditioning Materials (reinforced concrete, steel)	New systems adaptation Climate independent design	The iconic Flatiron Building, New York City  

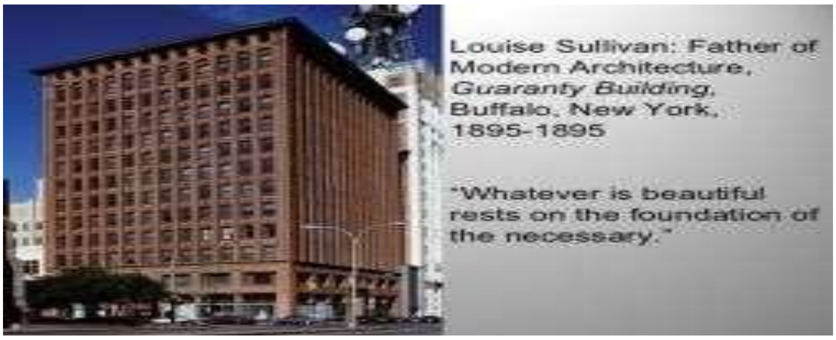
Second and third quarter of 20th century	Modernism	2nd World War Nuclear energy Space technology Establishmentof European Economic Community (EEC)	Mass production after the world war The term 'optimization' Basics of solar energy usage Basics of geothermal energy usage Basics of heat pump technologies	Systems integrations	Manufacturers Trust Company Building, NY 
20th Century (1970 to 1980)	Post Modernism	1973 Oil Crisis	Back to Climate based design Principles Passive house principles Developmengt and adaptation of computer technology	Conservation of energy	The Portland Building, USA 
20th Century (1980 to 1990)	High-Tech	Destruction of ozone layer the term 'Sustainability ' Developments of personal computers	Global development models Sun Houses Passive design principles Environmental consciousness	Sustainability and energy management	Gateway House, Hampshire 
20th Century 1990 to 2000	Deconstruction	Kyoto agreement Establishment of European Union Green Building Certification systems	Environmental consciousness Passive House standards Green Building Life Cycle Analysis Energy based simulation software Integrated design Renewable energy sources Smart Buildings	Variety of energy sources Efficiency of renewable energy sources	Fred and Ginger currently Dancing House, Prague, Czech Republic 
21st Century 2000 to 2010	Sustainability	2002, 2010 EU Energy directives Energy performance Building directives (EPBD)	Green building Certification systems Energy performance certificates Renewable energy sources New standards for energy efficiency Scenarios for climate change	Standards Reduction of emissions Energy efficency Reducing carnbon footprint	Embassy Techvillage, India's First IGBC, Platinum Certified, Milti-tenanted Business Park, Bengaluru 
21st Century 2010 to 2020	Sustainability	2002, 2010 EU Energy directives Paris agreement	High performance buildings Net zero and nearly zero buildings	Energy efficiency Clear energy	Shanghai Natural History Museum 

Day-lighting throughout history

- Daylight was the **primary source of interior lighting** in the pre-industrial world. The direct combustion of fuels (wood, coal, peat, oils) were supplementary light sources. Because of the importance of daylighting, early architecture developed with a **strong connection** between **natural lighting** and **building form** and techniques
- Daylight was still an **integral part** of **illumination systems** well into the industrial age, as a visit to any historic mill town in the United States will remind us. Early industrial buildings were daylit out of necessity rather than productivity or aesthetic considerations.
- Artificial light sources were ineffective, inefficient, and maintenance problems.

- The development of steel frame architecture allowed **building widths and heights to be increased.** It also allowed glazing areas to be increased dramatically, bringing more natural light into the interiors of these wider structures (Smithsonian Institute 2001).
- **Increases** in the amount of glazing introduced and/or aggravated many problems. **Glare** as well as building **heat loss/gain** were significantly increased.
- As industry rose to prominence and machines aided the manufacturing process, the **role of daylight changed**. Rather than simple illuminating buildings for accessibility, daylighting had to play a role in lighting the environments used by workers for the highest possible levels of productivity.
- Windows and skylights changed **from being decorative** additions to churches and other religious buildings **to being utilitarian**. Nonetheless, they still provided great amounts of natural light – one reason for the demand for Industrial Era buildings in many Western cities today.
- Throughout the **20th century**, daylighting continued to play an important role in the design of many modern buildings. The Larkin Building in Buffalo (image shown), itself a monument to commerce and administration, was designed to maximize **natural light exposure** in order to create a comfortable, productive workspace.





Hawa Mahal – Palace of Winds

- The structure was built in 1799 by Maharaja Sawai Pratap Singh
- Architect Lal Chand Ustad designed the exterior of this Jaipur palace with 953 small, intricate windows, called jharokhas. Built as a screen to shield women of the royal household from the public view as they entertained themselves by watching city-dwellers go about their daily lives, the lattice structure lets air currents flow through the jharokhas, air conditioning the entire area.
- Built in red and pink colored sand stone
- The cooling effect in the chambers, provided by the breeze passing through the small windows of the façade, was enhanced by the fountains provided at the center of each of the chambers

Khetri Mahal

The Wind Palace of Jhunjhunu gets its name from its architecture, which allows cool wind currents to blow throughout the palace. This structure is designed without any doors or windows, and uses archways and pillars instead of walls in many places to ensure a steady, continuous flow of cool air.


Amer Fort

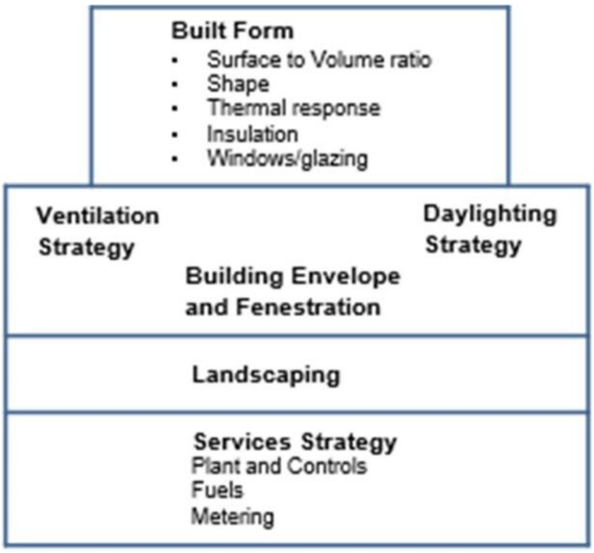
Also called Amber or Amer Palace, this fort is situated a little outside Jaipur. Influenced by both Hindu and Persian architecture, Amer Palace houses the Hall of Pleasure or Sukh Niwas. This hall was built with a channel of cool water flowing through it. The water cascade worked in combination with the cool breeze flowing into the hall, to air condition the entire space.


Design Elements / Principles

Architects can achieve energy efficiency in building by studying;

- the macro and micro climate of the site
- applying bioclimatic architectural principles to combat adverse conditions taking advantage of the desirable conditions.

The **design elements** that directly or indirectly affect the **thermal comfort** conditions and thereby the energy consumption in a building area are:



1. Site Considerations / planning

<u>Appropriate Site selection</u>

- Important design parameters :

Location of the building **determines** the **microclimate conditions** which has very important role in building energy efficiency, sun radiations, air temperature, air circulation, and humidity effects the energy costs, especially in a contour site.

- In order to provide adequate **protection** from the **prevailing wind and sun**, the orientation of buildings needs to be appropriate to the climatic conditions of the region.
- The **topography** of the location of the building is important because of the effect the **angle of incidence of solar radiation**, **slope, and orientation** of the land in terms of the use of daylight and natural ventilation, solar radiation.
- It is well known that a **south slope** is warmer and has the longest growing season in the **northern hemisphere**. When a choice of site is available, a south slope is still the best for most building types.
- In the **winter,** the south slope is the **warmest** land due to two reasons: the south slope receives the most solar energy on each square foot of land because it most directly faces the winter sun.
- The south slope will also experience the **least shading** because objects

cast their shortest shadows on south slopes

- Important parameters for site selection; the slope of the

land, the amount of incoming solar radiation, and the latitude

- The best side for a site for a building on hilly land depends on both **climate and building type**.
- Example, in **cold climates**, south slopes maximize solar collection and are shielded from

cold northern winds. Avoid the windy hilltops and low-lying areas that collect pools of cold air.

- In **hot and dry climates**, build in low-lying areas that collect cool air. If winters are very cold, build on bottom of south slope. If winters are mild, build on the north or east slope, but in all cases avoid the west slopes.
- In **hot and humid climates**, maximize natural ventilation by building on hilltops but avoid the west
- side of hilltops because of the hot afternoon sun.
- Also, the **cool low-lying areas** are appropriate especially to the north of hills. For internally dominated buildings, such as large office buildings that require little if any solar heating, the north and northeast slopes are best
- In the design of buildings, **distance between buildings** is an important designing parameter that affects utilization of solar energy and wind direction.
- The distances between buildings highly affect the **energy performance** in the usage phase of a building.
- The fact that a building remains within the **shading space** of other buildings **influences** the **utilization of solar rays** and will raise the consumption of energy. In order to utilize solar radiation;
- Besides, the **position and distance** of other buildings affect the speed and direction of wind on building, and this impacts the energy performance of building

Location weather and microclimate

- An **effective design** will take advantage of any local variations in climate, for instance by using local wind conditions to drive natural ventilation.
- Geography, topography, landscape, shelter, shading and surrounding buildings can all influence the development of built form and services, sometimes in different ways on different facades.
- These effects can be further enhanced by building arrangement and added landscape features. The **level of external pollution and noise**, particularly in urban areas, may influence the choice of ventilation system.
- In these cases, careful design can provide acceptable solutions, e.g. by placing areas requiring low noise levels furthest away from noise and pollution sources.
- Solar radiation, temperature and wind conditions can vary significantly according to topography and local surroundings.
- In **winter**, most urban microclimates are **more moderate** than those found in suburban or rural areas. They are characterized by **slightly higher temperatures** and away from tall buildings, weaker winds.
- During the day, **wide, streets, squares and non-planted areas** are the warmest part of a town.
- In **summer, green spaces** are particularly useful in modifying the environment during the late afternoon, when the buildings are very hot inside. Strong local winds can modify the temperature distribution.

Site layout and shape

- The **nature of the site** will have a strong effect on built form and orientation, as well as on services design
- Planning requirements, local and national bye-laws and fire protection

requirements may further **restrict** the building shape and orientation, affecting its services and energy performance.

- The **position** of approach roads and the requirements for vehicle parking could also influence the energy efficiency of the design.
- Often, such features can be used to advantage, e.g. by using a parking structure to form a noise barrier.

<u>Orientation</u>

- Choosing the **optimum orientation** to maximize daylight and to minimize summer heat gain and winter heat loss can have a significant impact on energy efficiency, particularly if it avoids or minimizes air conditioning.
- For example**, in hot regions**, north-facing windows suffer very little solar gain and benefits are often gained by having the major building axis pointing east/west. East or west-facing glazing is harder to shade from direct sunlight, as the sun angles are low at some times of year. South facades receive both direct and diffuse radiation and are relatively easy to control.
- In predominantly **cold regions**, buildings should be oriented to maximize solar gain; the reverse is advisable for hot regions. In regions where seasonal changes are pronounced, both the situations may arise periodically.
  For a cold climate, an orientation slightly east of south is favored (especially 15 degree east of South), as this exposes the unit to more morning than afternoon sun and enables the house to begin to heat during the day.

ORIENTATION

Winter Sun

- Sun path at a low angle, South to E-W axis
- Solar radiation will penetrate south facing facades at a low angle during winter
- Glare free daylight is most easily available on north façade as minimal solar radiation will fall at high angle
- Easy shading of south façade from high angle sun
- East and west facades continue to receive uniform, strong solar radiation at a low angle through the year
- With **careful design**, shading and deflecting devices can be incorporated to exclude the sun or redirect it into the building, just as wind can be diverted or redirected to the extent desired.
- Balconies and open terraces should be built on the south side of the house, where direct sunlight will permit their use for more hours during the day and more days during the year.
- Likewise, the garage, store rooms and other areas that are less frequently used should be situated at the northern part of the house, where they will act as buffers against cold winter winds.

<u>Location of Water bodies</u>

- **Water** is a **good modifier of micro-climate**. It takes up a large amount of heat in evaporation and cause significant cooling especially in a hot and dry climate. **In humid climates, water should be avoided as it adds to humidity.**
- The **wind pattern** near large bodies of water is generated by the **heat gain**, **heat loss, and heat storage variations** between land and water.

Water will have more stable temperatures.

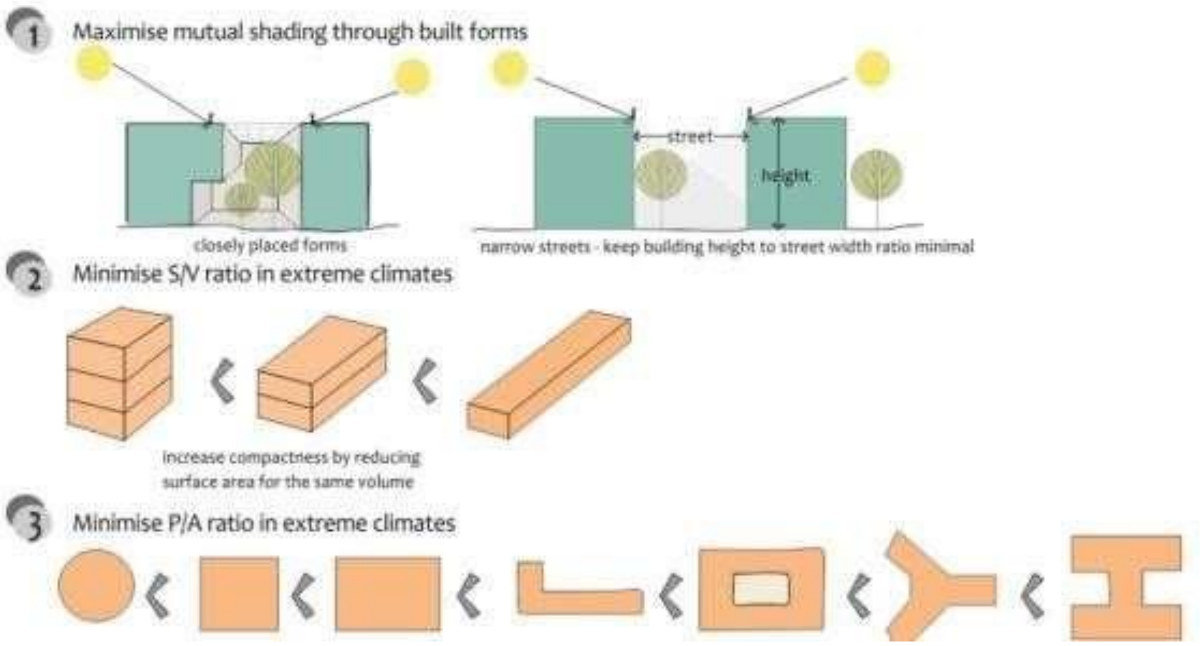
- **During the day**, the wind is usually **moving toward the land** when the land is heating up faster than the water and when the water is absorbing solar heat.
- **At night** the direction is **reversed,** with the breezes flowing from the land, as it cools, to the water, as it radiates stored heat to the night sky

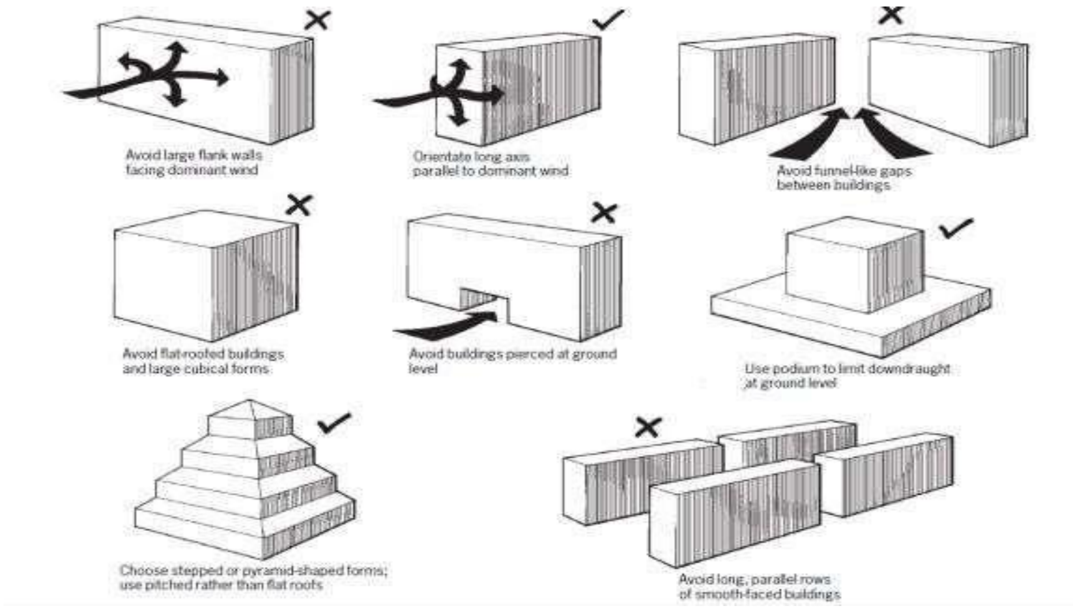
2. Built Form

<u>Surface- to-Volume ratio</u>

- For any given building volume, the **more the compact shape**, the **less wasteful** it is in **gaining or losing heat**. Hence, in hot and dry regions, cold climates, buildings are compact in form with a low S/V ration to reduce heat gain and losses respectively.
- The building form **determines** the **airflow pattern** around the building, directly affecting its ventilation.
- The **depth of a building** also determines the **requirements for artificial lighting** – greater the depth, higher the need for artificial lighting.

  Interesting fact: *Allen's rule is a biological rule formulated by Joel Asaph Allen in 1877, broadly stating that animals adapted to cold climates have shorter limbs and body appendages than animals adapted to warm climates. More specifically, it states that the body surface area-to-volume ratio for homeothermic animals varies with the average temperature of the habitat to which they are adapted (i.e. the ratio is low in cold climates and high in hot climates).*
- The **volume of space** inside a building that needs to be heated or cooled and its relationship with the **area of the envelope** enclosing the volume affect the thermal performance of the building. The parameter known as the S/V ratio is determined by the building form.



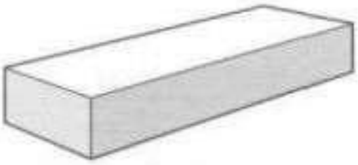


<u>Shape</u>

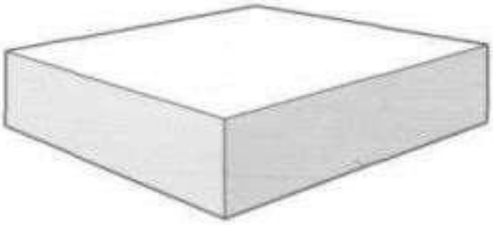
- The **shape of building** which is a considerable factor affecting heat loss and gain can be **defined** through **geometrical variables** making up building such as the proportion of building length to building depth in the plan, building height, type of roof, its gradient, front gradient.
- Heat loss-gain of building may rise and decline depending upon the proportion of the surfaces constituting environment to volume.
- Energy performance of building is affected by such factors as its form, volume surface rate and frontal motions. There is a direct relationship between the geometrical shape and energy performance of building.
- In the conducted studies, it was observed that different results were obtained in the **energy performance of the masses** which had the **same volume** but made in **different forms**.
- It was calculated that the surface area of the masses has the same volume but different forms.
- Compact building forms have a relatively small exposed surface area for a given floor area, thus reducing the influence of the external environment.
- A compact design may also benefit by requiring less space for the distribution of horizontal and vertical services, particularly for air ductwork. However, if commercial pressures and/or a compact design lead to a deep plan, i.e. over 15 m in depth, there may be a greater complexity of servicing.
- The core of the building may then require continuous electric lighting and internal activities may prompt mechanical ventilation or air conditioning. The energy efficiency benefits from natural ventilation and daylight penetration are most easily obtained up to 6 meters inwards from the windows.
- Taller constructions can increase energy consumption due to greater exposure and the need for lifts. Next figure shows examples of how building shape may effect energy efficiency

Tall, slender
- Additional exposure
- Requires lifts
- Higher heat loss

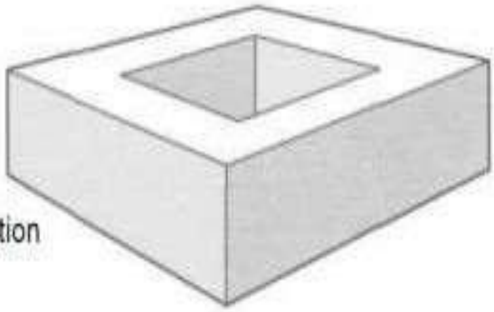
Shallow plan
- Higher heat loss
- Increased daylight
- Natural ventilation



Deep plan
- Lower heat loss
- Less daylight
- Greater use of artificial lighting
- More likely to need air conditioning



Deep plan with atrium or courtyard
(effectively shallow plan)
- Lower heat loss
- Increased daylight penetration
- Potential natural ventilation strategy



Thermal mass

Thermal mass **regulates the temperature** of the space by **controlling** the amount of **thermal energy stored** in the building.

Heavy thermal mass buildings can keep the spaces comfortable for several hours even after the HVAC system is switched off.

Heavy thermal mass also **delays the ingress of heat**, and when combined with natural ventilation and night-purge strategies, can ensure that the building is pre- cooled naturally in the morning and stays cool even after the outside temperature soars.

In warm and humid climates, low thermal mass buildings eliminate heat build-up and dissipate heat quickly to the ambient.

Mass and density of a building material affects this heat storing capacity in buildings.

Thermal response

- **Denser thermal mass** materials **store and releases** heat **better** and are more effective passive solar materials.
- Use thermal mass in climates with large diurnal temperature range.
- Select appropriate **mass colour with low reflectivity**. Dark, matt or textured surfaces absorb and re-radiate more energy than light, smooth, reflective surfaces.
- **Do not substitute** thermal mass for insulation. It should be used in conjunction with insulation.
- For heating and cooling requirements, the ground floor is the most ideal place for thermal efficiency in winter and summer.
- **Basic definitions:**
- **R Value:** is a measure of resistance to heat flow through a given thickness of material. In theory, the higher the R-value, the greater that resistance, unit is kelvin square meters per **watt** (K. m^2/W).
- **U Value:** the rate of transfer of heat through a structure (which can be a single material or a composite), divided by the difference in temperature across that structure. The units of measurement are W/m^2K.
- **BTU:** British thermal unit is a traditional unit of heat; it is defined as the amount of heat required to raise the temperature of one pound of water by one degree Fahrenheit.
- **SHGC: Solar heat gain coefficient** is the fraction of incident solar radiation admitted through a window, both directly transmitted and absorbed and subsequently released inward.
- **SHGC** is expressed as a number between 0 and 1. The lower a window's solar heat gain coefficient, the less solar heat it transmits

Insulation

- Thermal insulation in walls and roofs **reduces heat transfer** between the inside and outside and helps maintain comfortable indoor temperature.
- **Insulation helps keep indoor space cooler in summer months**
- **and warm during winters.**
- There are variety of materials to choose from including fibre glass, mineral wool, rock wool, expanded
- or extruded polystyrene, cellulose, urethane or phenolic foam boards and cotton.

- Insulation is rated in terms of R-value. Higher R-values denote better insulation

Building envelope and fenestration

- The building envelope and its components are key determinants of the amount of heat gain and loss and the wind that enters inside.
- The primary elements affecting the performance of a building envelope are;
- Materials and construction techniques
- Roof
- Walls
- Fenestration and shading
- Finishes

Building envelope and fenestration

- The building envelope should be considered as a **climate modifier** rather than solely a means of excluding external climatic conditions. The envelope generally has five main functions:
    - In cold weather, to reduce heat loss through the fabric, to maximize the benefits of solar and internal heat gains
    - reduce losses associated with uncontrolled air infiltration.
    - In warm weather, to minimize solar heat gain and avoid overheating, also to use window shading, thermal mass to reduce the heat gain.
    - To allow optimum levels of natural ventilation.
    - To allow optimum levels of daylighting.
- **Materials and construction techniques**
- Material with low embodied energy

  Embodied energy is total energy consumed in mining, processing, manufacturing, transportation and installation of each unit of a material. The higher the embodied energy of a building, the more is the emissions.

Choice of building materials is important in reducing the energy content of buildings. Strain on conventional energy can be reduced by use of low**-energy materials, efficient structural design** and **reduction in transportation energy.**

The choice of materials also helps to maximize indoor comfort.

More than 70% of total material used **in the building interiors** should be low energy.

The **biodegradability of a material refers** to its potential to naturally decompose when discarded. Organic materials can return to the earth rapidly, while others, like steel, take a longtime.

The ratings for embodied energy can be done for different materials within the same product category on a relative sale of 10. 10 rating shall be awarded to material with lowest embodied energy.

While comparing embodied energy of building materials, the total quantity by mass of the material times the embodied energy value per unit mass (energy intensity) of the material to be installed for same surface area of the building may be compared.

Thermal Insulation

What is thermal insulation?

Thermal insulation is the process of insulating material from transferring heat between the materials that are in thermal contact. Thermal insulation is measured by its thermal conductivity. This technology helps prevent heat gain/ loss through the building envelope.

This is used to save energy, protect the occupant and provide thermal comfort.

Low thermal conductive materials are used thermal insulation. Density and heat capacity are important properties of insulating materials.

Mainly provided for the floors, roof and walls in a building.

Thermal Insulation

Insulation is of great value when a building requires mechanical heating or cooling insulation helps reduce the space –conditioning loads. Location of insulation and its optimum thickness are important.

Insulation should be placed at the hotter side of the surface (in case of summer cooling, insulation should be on outer side, while in case of heating the building, insulation should be placed on the internal side).

Insulation material should be chosen keeping in mind the following parameters – thermal performance, lifetime performance, fire safety, moisture and condensation, air infiltration and environmental benefits.

During summer months in hot climates, thermal insulation must be combined with an effective ventilation strategy at night (when it is cooler) to flush out the heat.

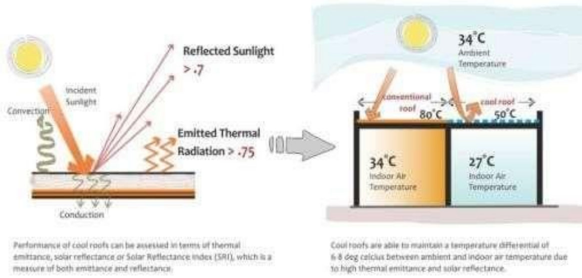
Use of 40mm thick expanded polystyrene insulation on walls and vermiculite concrete insulation on the roof can bring down space-conditioning loads of building by 15%.

Roof

The roof receives significant solar radiation and plays an important role in heat gain/losses, daylighting and ventilation. Depending on the climate needs, proper roof treatment is essential. In a hot region, the roof should have enough insulating properties to minimize heat gains. A few roof protection methods are as follows;

- A cover of deciduous plants or creepers can be provided. Evaporation from leaf surfaces will keep the room cool.
- The entire roof surface can be covered with inverted earthen pots, It is also an insulating cover of still air over the roof.
- A removable cover is an effective roof-shading device.

  A removable cover is an effective roof-shading device. This can be mounted close to the roof in the day and can be rolled up to permit radiative cooling at night. The upper surface of the canvas should be painted white to minimize the radiation absorbed by the canvas and consequent conductive heat gain through it. Effective roof insulation can be provided by using vermiculite concrete.



- Well-graded broken pieces of glossy glazed tiles (broken china mosaic)

, modified bitumen with plastic and a layer of reinforced material, RCC roof topped with

elastomeric cool roof coating or simply finished with broken white
glazed tiles.

- Slate and tile products are available with solar-reflective surfaces that offer a wide range of cool colors. Additionally, the dense, earthen composition of slate and tile products provide increased thermal mass, yielding additional energy savings
- Concrete and clay tiles may be obtained in white, increasing the solar reflectance to about 70 percent (compared to 20-30 percent range for red tile).
- Additional measures like roof insulation, vegetative roofs, and solar panels can be used to inhibit the flow of heat from roof to conditioned space within a building.
- Cool Roofs reduce annual air conditioning energy use of a single-story building by up to 15%.

Walls

- Walls are major part of building envelope and receive large amount of solar radiation.
- The heat storage capacity and heat conduction property of walls are key to meeting desired thermal comfort conditions.
- Based on heating and cooling needs of the building the following should be chosen carefully;
    - Wall thickness
    - Material
    - Finishes for the wall
    - Appropriate thermal insulation and air cavities in walls reduce heat transmission into the buildings

<u>Air cavities</u>

- Air cavities within walls or attic space in the roof ceiling combination reduce the solar heat gain factor, thereby reducing space-conditioning loads.
- The performance improves if the void is ventilated. Heat is transmitted through the air cavity by convection and radiation.
- A cavity represents a resistance to heat flow remains nearly constant.
- Ventilated air does not reduce radiative heat transfer from roof to ceiling. The radiative component of heat transfer may be reduced by using low emitivity or high reflective coating (e.g aluminum foil) on either surface facing the cavity.

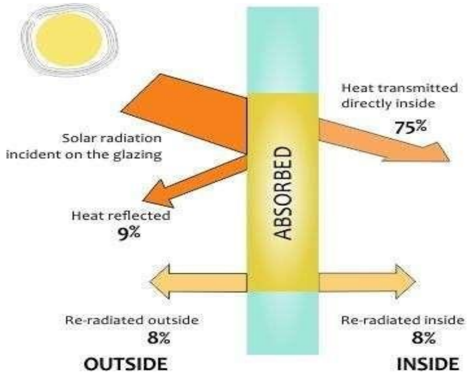
Calculation for Heat gain/loss

- **R-value** is a measure of resistance to heat flow through a given thickness of material. In theory, the higher the **R-value**, the greater that resistance **Fenestration and shading**
- Fenestrations (windows, skylights, & other openings in a building etc.) allow daylight and the prevailing wind inside the building when needed.
- These are most vulnerable to heat gain or heat losses.
- Openings at higher level help in venting out Hot air
- Moderate air velocity and flow in a room

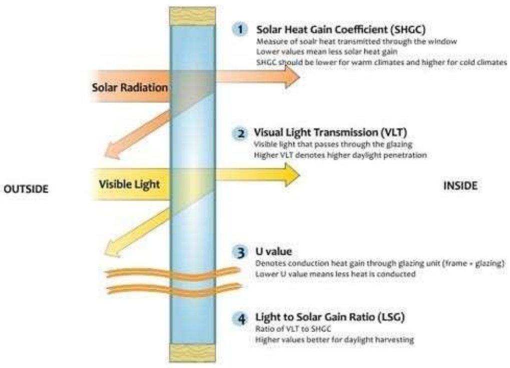
Methods to reduce heat gain through windows are:

- Orientation and size (prevalent wind direction)
- Glazing
- Internal shading devices (blinds, curtains)
- External shading devices

A



Heat transmission in a single glazing clear glass



glazing properties relevant for daylight harvesting and energy efficiency

fenestration system with low U-value and low effective SHGC can result in reduction of heating and cooling demand by 6-11% in moderate climate and between 8-16% in hot humid, hot dry, and composite climates.

These savings increase to 8-17% for moderate, and 12-26% for hot humid, hot dry, and composite climates, if high performance fenestration system, with low-e glass, frames with thermal breaks, and well-designed shading are factored in.

Using double glazing reduces the internal temperature of the glass because of reduced conduction of heat from the outdoors.

This results in better radiant temperature control and enhanced comfort. This effect can be felt in both heating and cooling, especially in spaces which have large glazed areas.

Fenestration and shading

The recommendations in IS:3362-1977 code of practices for natural ventilation of residential buildings should be satisfied in the design of windows for lighting and ventilation.

<u>Glazing Systems</u>:

Before recent innovations in glass, coatings, a typical residential window with one or two layers of glazing allowed roughly 75% - 85% of the solar energy to enter a building.

Windows admit direct solar radiation and hence promotes heat gain. This is desirable in cold climates, but critical in hot climates.

Example of Ahmedabad, if glazing is taken as 10% instead of 20% of floor area then the number of uncomfortable hours in a year can be reduced by 35%.

<u>Shading devices</u>

Heat gain through windows is determined by the overall heat loss coefficient U-Value (W/m2 K) and the solar energy gain factor, and is much higher as compared to that through solid wall.

Shading devices for windows and walls thus moderate heat gains into the building.

Shading devices are of various types:

1. Moveable opaque (roller blind, curtains, etc.) can be effective in reducing solar gains but eliminate view and impede air movement
2. Louvres (adjustable or fixed) affect the view and air movement to some degree.
3. Fixed overhangs

Moveable blinds and curtains:

- Block the transmission **of solar radiation through glazed windows,**

especially on the east and west walls.

- **In hot and dry climates,** when ambient air is hotter than room air,

they help **reduce convective heat gain**

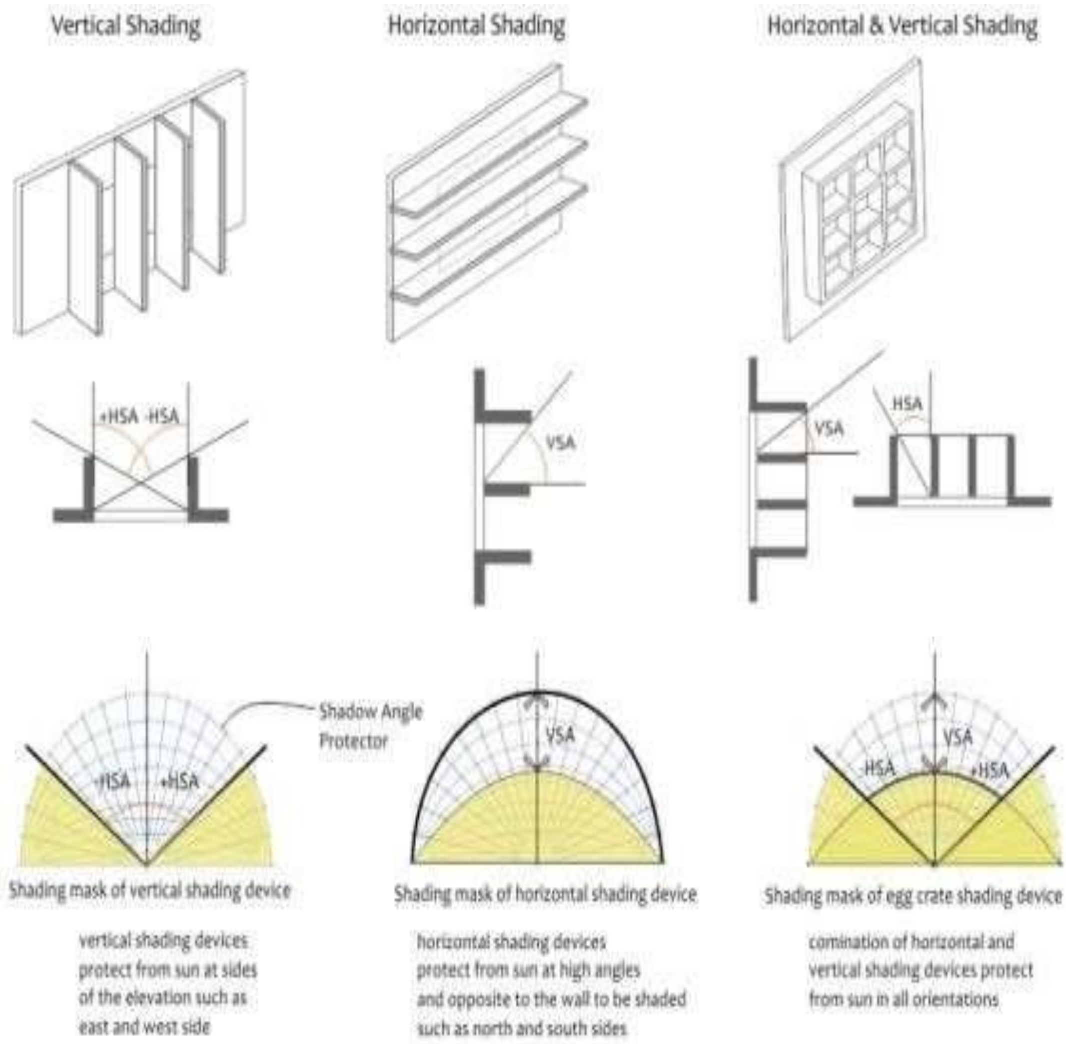
- **In warm, humid climate**, where the air flow is desirable, they **prevent ventilation**.
- **For air-conditioned buildings**, where the flow of outside air is to be blocked, they can **reduce cooling load**.

Shading devices

Advantages and disadvantages of these shading devices:

Fixed overhangs and louvers

- Overhangs on south-oriented windows provide effective shading from the high-altitude sun
- An extended roof shades the entire north or south wall from the noon sun
- East and west openings need much bigger overhangs, which may not be possible, can be achieved by porticos and verandahs or designed louvers
- Longer sides of a building should be oriented North- South which is preferred to minimize overall solar gain through the envelope.
- South-facing windows are the easiest to shade. Overhangs on south-oriented windows provide effective shading by blocking summer sun and admitting winter sun.
- Use fixed horizontal overhangs on south-facing glass. 1m shading device can reduce cooling loads substantially.
- To the greatest extent possible, limit the amount of east and west glass (minimize window area) since they are harder to shade. Consider the use of landscaping to shade east and west exposures.
- An extended roof can provide shade to the entire north and south wall from the noon sun
- Shading is generally not required at the north side. Only cutting the low evening summer sun can be achieved by vertical shades or internal blinds.
- On lower buildings, well-placed deciduous trees on the east and west will reduce
- summer overheating while permitting desirable winter solar gains
- Semi-outdoor spaces such as balconies (2.5m – 3m deep) can provide shade and protect interior spaces from overheating and climatic variations. At the same time they act as wind scoops and provide a private social space for the unit.
- If no exterior shading is possible, a lower solar heat gain coefficient for the glazing will be mandatory
- To enhance natural light utilization, passive design strategies such as light shelves are very useful for deeper and uniform distribution of light (most effective on the south side of the buildings, mostly recommended in mild climates and not for tropical or desert climate).



Shading can reduce solar gains on the building facade.
Effective shading strategies for and NZEB should aim at virtually preventing any direct solar radiation from entering the building, especially during the summer months.
Shading reduces the effective solar heat gain coefficient (SHGC) of the glazing. This means that a cheaper glass with high SHGC can be used instead of high cost, low SHGC glass.
Shading also helps in reducing glare through the windows. Users tend to pull down interior shade if there is direct solar radiation on the glass, this negates all the benefits of daylighting. Shading helps ensure glare-free daylight in the buildings.

LANDSCAPE

Factors affecting human comfort are:

- **temperature,**
- **relative humidity and**
- **wind movement.**

Combined effect of these factors creates conditions in which **thermal comfort** is experienced. The range is called **comfort zone** and varies with individuals.

- Wind and solar radiation, can be significantly **affected from landscape elements**.
- Trees can provide **solar protection** to individual houses during summer (significantly reduce energy for cooling purposes) and **evapotranspiration f**rom trees can **reduce urban temperatures.**
- Trees also help **mitigate the greenhouse effect**, **filter pollutants, mask noise, prevent soil erosion, and calm their human observers.**
- The heat in a city can be **mitigated by proper planning of vegetation belts**, diversion of winds in getting good circulation through the concrete jungle man has created.
- Vegetation controls the sun's effect by the **filtration of direct solar radiation**.
- **Wind is an effective means of dissipating heat** accumulated in the region.
- **Vegetation controls wind** through:
    - *Obstruction*
    - *Filtration*
    - *Guidance*
    - *Reflection*
    - **Precipitation** in different forms is also **influenced and controlled by the vegetation** in the region.
- As plant material **control solar radiation, wind, and precipitation and humidity**, they are effective, means of **controlling the temperature** variations both during the **day and the night.**

Plants interact with solar radiation to influence microclimate in two ways:

- Plants **absorb solar radiation and cast shade**.
- Most of the captured radiant energy is used **to evaporate water from plants**. This converts most of the captured sunlight in to latent heat and **relative humidity is increased** instead of air temperature.
- Vegetation may absorb **over 90% of light falling upon it**, reduce the wind speeds in an area to **less than 10%** of that in open.

Temperature Control-

The vegetation functions as a tool in controlling the radiation in four ways:

1. **Absorption:** About **50-60%** of the incident solar radiation is absorbed by the vegetation cover
2. **Reflection:** About **15-20%** of the absorbed radiation is reflected back by plants
3. **Radiation:** Just as absorption and reflection, plants also radiate certain amount of the solar radiation. This helps in the warming of an area under desired conditions
4. **Transmission:** The long waves are radiated back while the short waves are transmitted. Trees and shrubs create different air flow patterns, provide shading and keep the surroundings cooler in warm weather. Vegetation can be used for energy conservation in buildings in the following ways:

- Shading of buildings and open spaces through landscaping
- Roof gardens (or green roofs)
- Shading of vertical and horizontal surfaces (green walls)
- Buffer against cold and hot winds
- Changing direction of wind

Plantation also shades building surfaces and open ground, thus inducing lower surface temperatures. Since this shading is almost permanent, the low temperatures do not vary much even when exposed to harsh radiation

Green roofs or roof gardens can also be used as they help to reduce heat loads in a building. The additional thickness of the growing medium provides extra thermal insulation. These also retain moisture from rainwater further cooling the roof surface. The green cover lowers ambient temperatures through evapotranspiration.
Roof structures have to be sturdy for supporting green roofs as these impose greater dead weights than normal roofs.
Proper landscape design and vegetation can be used effectively by architects from an early design phase to lower the ambient temperature and thus reducing the resulting demand for air conditioning loads in a building.
Presence of vegetation benefits the buildings in two distinct ways.

1. The effect of shading on the walls reduces the heat gain in the building thereby enhancing comfort and reducing energy use.
2. Vegetation also reduces the heat gain in the surroundings of the buildings by shading the ground, parking lots, pavements, etc., which would otherwise heat up and cause urban heat island effect.

Trees also reduce ambient air temperature due to evapo-transpiration. A study shows that ambient air under a tree adjacent to the wall is about 2 – 2.5°C lower than that for unshaded areas.

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SCHOOL OF BUILDING AND ENVIRONMENT
DEPARTMENT OF ARCHITECTURE

SAR1609 – ENERGY EFFICIENT ARCHITECTURE

UNIT – II - SUSTAINABILITY AND MATERIALS

UNIT 2 – SUSTAINABILITY AND MATERIALS

Energy efficiency is key to ensuring a safe, reliable, affordable and sustainable energy system for the future. Efficient energy use, sometimes simply called energy efficiency, is the goal to reduce the amount of energy required to provide products and services.
Improvements in energy efficiency are generally achieved by adopting a **more efficient technology or production process** or by application of commonly accepted methods to **reduce energy losses**. There are many motivations to improve energy efficiency. Reducing energy use is also seen as a solution to the problem of **reducing greenhouse gas emissions**. Energy efficiency and renewable energy are said to be the twin pillars of sustainable energy and are high priorities in the sustainable energy hierarchy.
Recourse Consumption
Resource consumption is about the consumption of non-renewable resources. Specifically, it may refer to:

- Water consumption
- Energy consumption
- Natural gas consumption/gas depletion
- Oil consumption/oil depletion
- Logging/deforestation
- Fishing/overfishing
- Land use/land loss or
- Resource depletion and
- General exploitation and associated environmental degradation

Factors affecting the Energy use in Buildings Building Energy is a very wide field which is affected by a variety of factors on many scales.
The highest impact on energy consumption is caused by heating and cooling loads, and some of these factors are:

1. Site of the building, and the exposure of the building to the sun and how much this affects the heating and cooling loads.
2. The regional climate in which the building exists, and its influence on wind speed and direction, temperature, humidity levels and so on, and this is important to calculate the thermal comfort zone for the building which if exceeded, the users of the building will use more energy to feel comfort again.
3. Light design also affects the use of energy. Design the building to benefit from natural light.
4. Also, the material of the building highly affects the energy consumption, it is good to use **recycled materials and high-performance ones with high capacity** which able to isolate the building interior from the outside in hot and cold climates.
5. Environmental and weather conditions
6. Materials used in construction (walls, windows, doors, roof...), Walls to windows ratio
7. Exposure of building, windows...Architecture (overhangs, Trombe wall, roof shape...)
8. Application of the building.
9. Building orientation

Concept of Embodied Energy

Embodied energy is the energy consumed by all of the processes associated with the production of a building, from the mining and processing of natural resources to manufacturing, transport and product delivery.

Embodied energy **does not include the operation and disposal of the building material**, which would be considered in a life cycle approach.

Embodied energy of common materials

Generally, the more highly processed a material is the higher its embodied energy.

Material	PER embodied energy MJ/kg
Kiln dried sawn softwood	3.4
Kiln dried sawn hardwood	2.0
Air dried sawn hardwood	0.5
Hardboard	24.2
Particleboard	8.0
MDF (medium density fibreboard)	11.3
Plywood	10.4
Glue-laminated timber	11.0
Laminated veneer lumber	11.0
Plastics — general	90.0
PVC (polyvinyl chloride)	80.0
Synthetic rubber	110.0
Acrylic paint	61.5
Stabilised earth	0.7
Imported dimensioned granite	13.9
Local dimensioned granite	5.9
Gypsum plaster	2.9
Plasterboard	4.4
Fibre cement	4.8*
Cement	5.6
In situ concrete	1.9
Precast steam-cured concrete	2.0
Precast tilt-up concrete	1.9
Clay bricks	2.5
Concrete blocks	1.5
Autoclaved aerated concrete (AAC)	3.6
Glass	12.7
Aluminium	170.0
Copper	100.0
Galvanised steel	38.0

* Fibre cement figure updated from earlier version and endorsed by Dr Lawson.
Source: Lawson 1996

Materials with the lowest embodied energy, such as concrete, bricks and timber, are usually consumed in large quantities. Materials with high energy content such as stainless steel are often used in much smaller amounts. As a result, the greatest amount of embodied energy in a building can be from either low embodied energy materials such as concrete or high embodied energy materials such as steel.

Assembly	PER embodied energy MJ/m2
Elevated timber floor	293
110mm concrete slab-on-ground	645
200mm precast concrete, T beam/infill	644
Timber frame, concrete tile, plasterboard ceiling	251
Timber frame, terracotta tile, plasterboard ceiling	271
Timber frame, steel sheet, plasterboard ceiling	330
Single skin AAC block wall	440
Single skin AAC block wall gyprock lining	448
Single skin stabilised (rammed) earth wall (5% cement)	405
Steel frame, compressed fibre cement clad wall	385
Timber frame, reconstituted timber weatherboard wall	377
Timber frame, fibre cement weatherboard wall	169
Cavity clay brick wall	860
Cavity clay brick wall with plasterboard internal lining and acrylic paint finish	906
Cavity concrete block wall	465

Guidelines for reducing embodied energy

Each design should select the best combination for its application based on climate, transport distances, availability of materials and budget, balanced against known embodied energy content. The guidelines

- Design for long life and adaptability, using durable low maintenance materials.
- Ensure materials can be easily separated.
- Avoid building a bigger house than you need — and save materials.
- Modify or refurbish instead of demolishing or adding.
- Ensure construction wastes and materials from demolition of existing buildings are reused or recycled.
- Use locally sourced materials (including materials salvaged on site) to reduce transport

• Select low embodied energy materials (which may include materials with a high recycled content), preferably based on supplier-specific data.
• Avoid wasteful material use. For example, specify standard sizes wherever possible (windows, door, panels) to avoid using additional materials as fillers. Some energy intensive finishes, such as paints, often have high wastage levels so try to buy only as much as you need.
• Ensure offcuts are recycled and use only sufficient structural materials to ensure stability and meet construction standards.
• Select materials that can be reused or recycled easily at the end of their lives using existing recycling systems.
• Give preference to materials that have been manufactured using renewable energy sources. Use efficient building envelope design and fittings to minimise materials (e.g. an energy efficient building envelope can downsize or eliminate the need for heaters and coolers, water-efficient taps can allow downsizing of water pipes).
• Ask suppliers for information on their products and share this information

➔ Concept of light footprint on Environment the effect that a person, company, activity, etc. has on the environment, for example the amount of natural resources that they use and the amount of harmful gases that they produce:
Every organization should work towards a zero environmental footprint by conserving, restoring, and replacing the natural resources used in its operations.
The harmful effects of your activities on the environment You can reduce your environmental footprint by recycling as much as you can.

RECYCLABLE AND RENEWABLE MATERIALS

➔ Concept of Recyclable materials
Raw or processed material that can be recovered from a waste stream for reuse.
Recycling is the processing used materials (waste) into new products to prevent waste of potentially useful materials. Recycling is a key component of modern waste reduction and is the third component of the "Reduce, Reuse and Recycle" waste hierarchy. Recyclable materials include many kinds of glass, paper, metal, plastic, textiles, and electronics. Although similar in effect, the composting or other reuse of biodegradable waste such as food or garden waste is not typically considered recycling. Materials to be recycled are either brought to a collection center or picked up from the road side, then sorted, cleaned, and reprocessed into new materials bound for manufacturing.

Acceptable Items	Unacceptable Items
*Newspaper	*Glass
*Magazines	*Styrofoam (packing peanuts etc.)
*Glossy Ads (paperclips & staples OK)	*Food and Liquids
*Telephone Books	*Green Waste (tree limbs, grass, etc.)
*Plastic Containers (see below)	*Dirt or Rocks
*Cereal Boxes	*Aerosol Cans, Paint Cans
*Tissue Boxes	*Motor Oil, Car Batteries
*Metal Hangers	*Light Bulbs
*Paper Towel/Toilet Paper Rolls	
*Junk Mail	
*Small Appliances – examples	
Toasters,Irons,Coffee Makers,Kitchen Mixers, Pots and Pans	
*Office Paper,*Wrapping Paper	

Sustainable building materials

Sustainable building materials are materials that are ecologically responsible because their impact on the planet is not as damaging as traditional building materials.

- **Low VOC Paint** - VOC's stands for organic volatile compounds, which are chemical compounds emitted from most paints and can affect human health. Low VOC paints are usually odorless and have no chemical solvents so they will greatly improve your indoor air quality.

- **Bamboo Flooring** - Bamboo is a long lasting and rapidly renewable material that is beautiful and easy to install. Rapidly renewable materials are normally harvested within a 10-year or shorter cycle. It does not harm indoor air quality since it does not contain volatile organic compounds (VOC's)

- **Wool Carpeting -** Woven wool is a clean, environmentally friendly option for residential and commercial carpeting. Wool is a rapidly renewable material, has low VOC emissions, is fire resistant, biodegradable, compostable and adds a layer of insulation to the floor.

- **Cotton Batt Insulation -** Cotton is also a rapidly renewable material and is a natural way to provide insulation. Cotton provides high thermal resistivity values, emits no VOC's, works as a sound attenuator, is non-toxic, and 100% recyclable

- **Ecological Concrete** - Concrete is one of the most used materials in the construction industry. The problem is that generating concrete has a large impact on global warming.

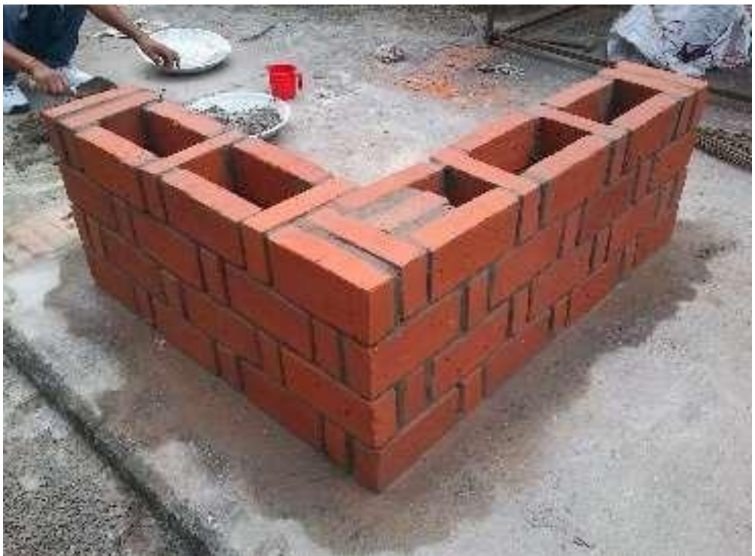
The solution is to use concrete mixtures that contain recycled materials. Recycled wood chips, crushed glass or slag can be added to the concrete mixture. Concrete has a very long life; it can be formed into any shape and is recyclable. Paper Insulation Panels These insulation panels are made from recycled newspapers and cardboards. They are an ecological alternative to using insulating foam and they are made fire-resistant by adding boric acid and calcium carbonate.

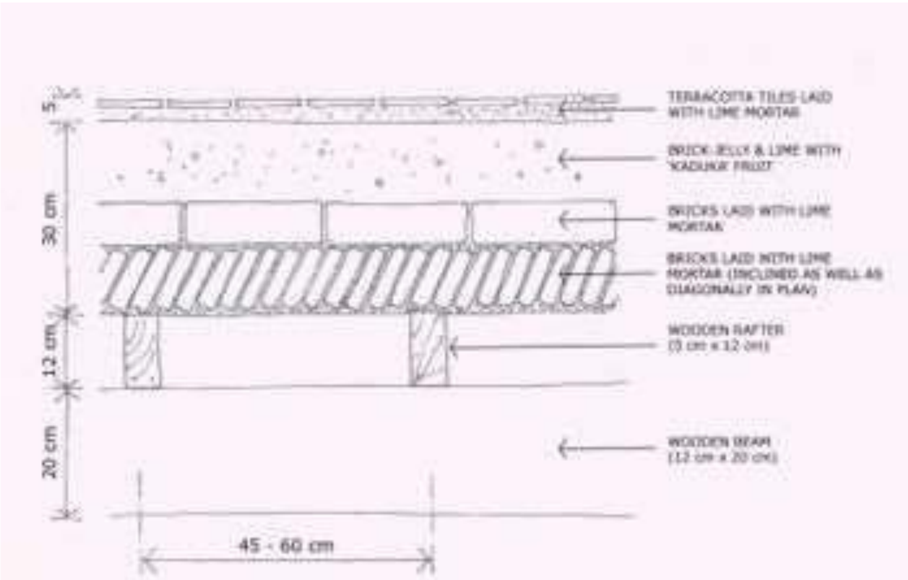
Sustainable building materials technologies can improve economic and resource efforts, increase labor productivity of building occupants and reduce harmful environmental impacts.

1. **Straw Bales -** Rather than relying on new research and technology, straw bale building hearkens back to the days when homes were built from natural, locally-occurring materials. Straw bales are used to create a home’s walls inside of a frame, replacing other building materials such as concrete, wood, gypsum, plaster, fiberglass, or stone. When properly sealed, straw bales naturally provide very high levels of insulation for a hot or cold climate, and are not only affordable but sustainable as straw is a rapidly renewable resource.
2. **Grass Crete** as its name might indicate, grass Crete is a method of laying concrete flooring, walkways, sidewalks, and driveways in such a manner that there are open patterns allowing grass or other flora to grow. While this provides the benefit of reducing concrete usage overall, there’s also another important perk — improved stormwater absorption and drainage.
3. **Rammed Earth** What’s more natural than the dirt under your feet? In fact, walls that have a similar feel to concrete can actually be created with nothing more than dirt tamped down very tightly in wooden forms. Rammed earth is a technology that has been used by human civilization for thousands of years, and can last a very long time. Modern rammed earth buildings can be made safer by use of rebar or bamboo, and mechanical tampers reduce the amount of labor required to create sturdy walls.
4. **Hempcrete** - Hempcrete is just what it sounds like – a concrete like material created from the **woody inner fibers** of the **hemp plant**. **The hemp fibers are bound with lime to create concrete-like shapes that are strong and light**. Hempcrete blocks are super-lightweight, which can also dramatically reduce the energy used to transport the blocks, and hemp itself is a fast-growing, renewable resource.
5. **Bamboo** - Bamboo might seem trendy, but it has actually been a locally-sourced building material in some regions of the world for millennia. What makes bamboo such a promising building material for modern buildings is its combination of tensile strength, light weight, and fast-growing renewable nature. Used for framing buildings and shelters, bamboo can replace expensive and heavy imported materials and provide an alternative to concrete and rebar construction, especially in difficult-to reach areas, post-disaster rebuilding, and low-income areas with access to natural locally-sourced bamboo.
6. **Recycled Plastic** - Instead of mining, extracting, and milling new components, researchers are creating concrete that includes ground up recycled plastics and trash, which not only reduces greenhouse gas emissions, but reduces weight and provides a new use for landfill-clogging plastic waste.
7. **Wood Plain** old wood still retains many advantages over more industrial building materials like concrete or steel. Not only do trees absorb CO2 as they grow, they require much less energy-intensive methods to process into construction products. Properly managed forests are also renewable and can ensure a biodiverse habitat.

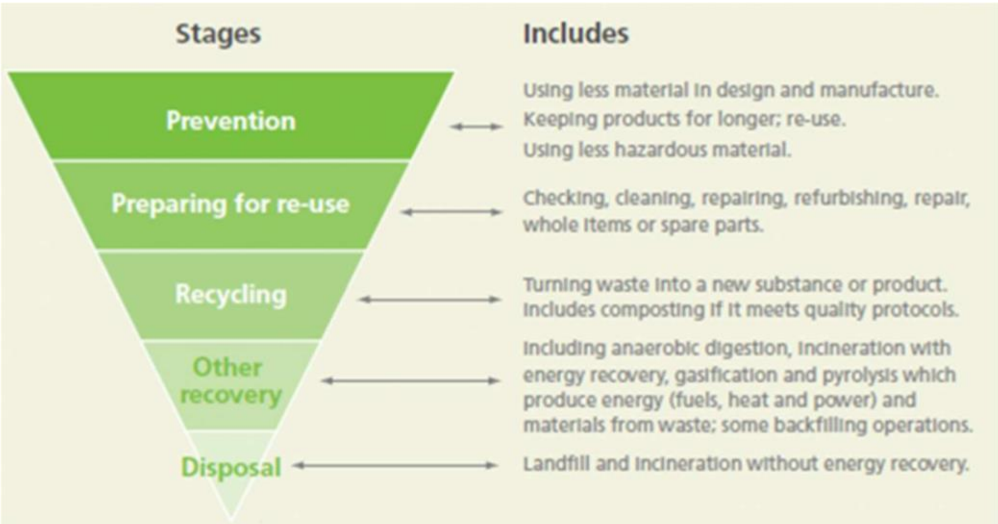
8. **Mycelium** is a crazy futuristic building material that's actually totally natural – it comprises the root structure of fungi and mushrooms. Mycelium can be encouraged to grow around a composite of other natural materials, like ground up straw, in molds or forms, then air-dried to create lightweight and strong bricks or other shapes.
9. **Ferrock** - Ferrock is a new material being researched that uses recycled materials including steel dust from the steel industry to create a concrete-like building material that is even stronger than concrete. What's more, this unique material actually absorbs and traps carbon dioxide as part of its drying and hardening process – making it not only less CO2 intensive than traditional concrete, but actually carbon neutral.
10. **Ash Crete** - Ash Crete is a concrete alternative that uses fly ash instead of traditional cement. By using fly ash, a by-product of burning coal, 97 percent of traditional components in concrete can be replaced with recycled material.
11. **Timbercrete** - Timbercrete is an interesting building material made of sawdust and concrete mixed together. Since it is lighter than concrete, it reduces transportation emissions, and the sawdust both reuses a waste product and replaces some of the energy-intensive components of traditional concrete. Timbercrete can be formed into traditional shapes such as blocks, bricks, and pavers.

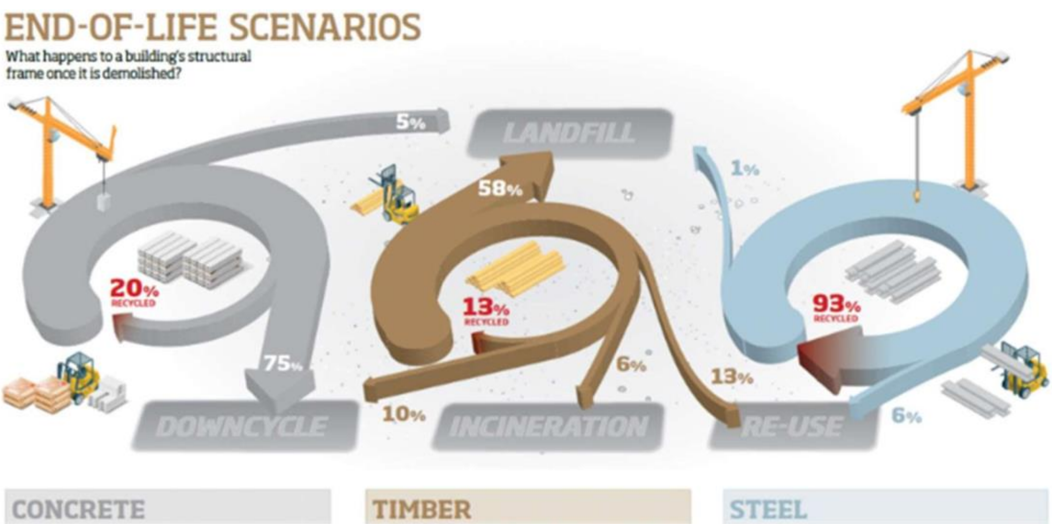
ENERGY EFFICIENT TECHNIQUES

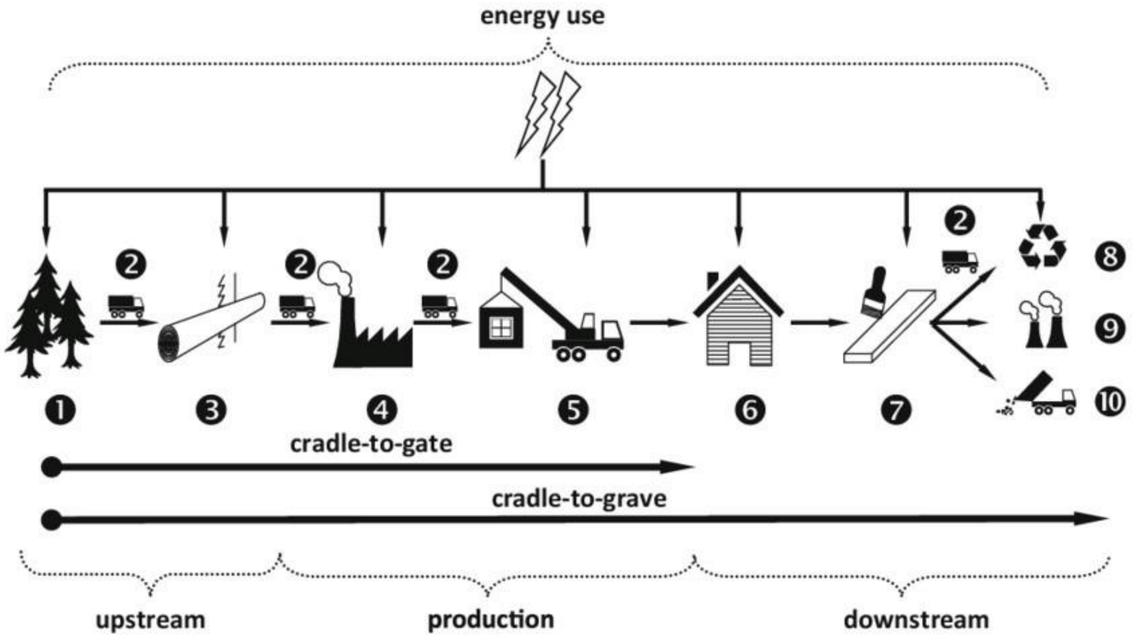




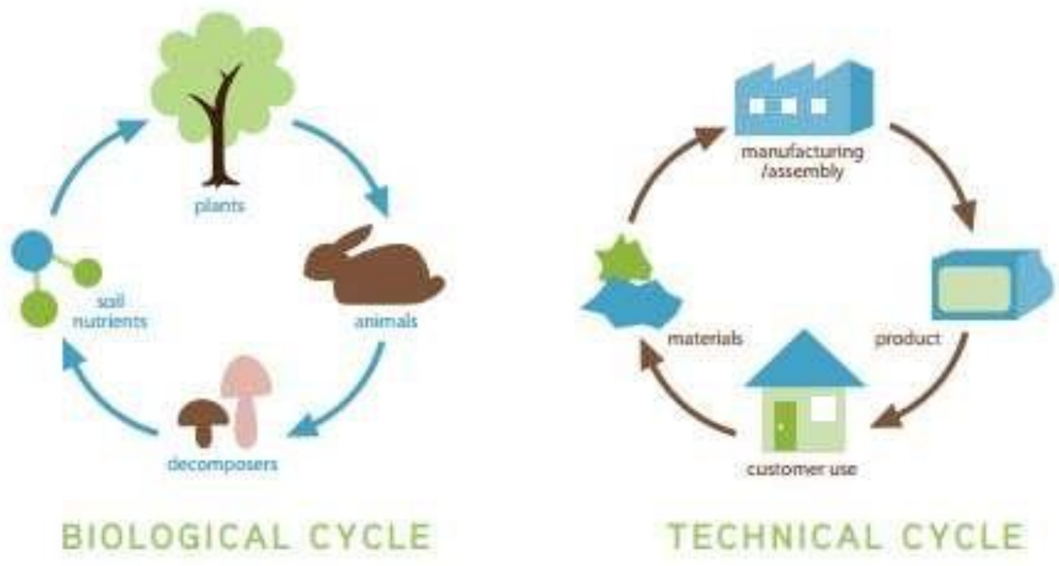
TYPICAL SECTION OF MADRAS TERRACE


Stages
Includes
Prevention
Using less material in design and manufacture.
Keeping products for longer; re-use.
Using less hazardous material.
Preparing for re-use
Checking, cleaning, repairing, refurbishing, repair, whole items or spare parts.
Recycling
Turning waste into a new substance or product. Includes composting if it meets quality protocols.
Other recovery
Including anaerobic digestion, incineration with energy recovery, gasification and pyrolysis which produce energy (fuels, heat and power) and materials from waste; some backfilling operations.
Disposal
Landfill and incineration without energy recovery.


END-OF-LIFE SCENARIOS
What happens to a building's structural frame once it is demolished?
LANDFILL
DOWNCYCLE
INCINERATION
RE-USE
5%
20% RECYCLED
75%
58%
13% RECYCLED
10%
6%
13%
1%
93% RECYCLED
6%
CONCRETE
TIMBER
STEEL



eliminate the concept of waste (cradle-to-cradle rather than cradle-to-grave). Each material in a product is designed to be safe and effective, as well as to provide quality resources for subsequent generations of products. In other words, materials



are conceived as nutrients and designed to circulate safely and productively.

SCHOOL OF BUILDING AND ENVIRONMENT

DEPARTMENT OF ARCHITECTURE

SAR1609 – ENERGY EFFICIENT ARCHITECTURE

UNIT – III - TECHNOLOGIES FOR ENERGY EFFICIENT BUILDINGS

UNIT 3 - TECHNOLOGIES FOR ENERGY EFFICIENT BUILDINGS

Renewable energy systems - Solar power

Solar power is clean green electricity sourced from sunlight. Or in some cases, from heat from the sun. Installing solar power systems in a residential setting generally means setting up a solar photovoltaic or a solar thermal system on the roof.

Definition of photovoltaic: *Photo* = "light" and *photons* = energy particles coming from sunlight; v*oltaic* = producing a voltage or volts. Abbreviation = PV

Solar energy is a renewable free source of energy that is sustainable and totally inexhaustible, unlike fossil fuels that are finite. It is also a non-polluting source of energy and it does not emit any greenhouse gases when producing electricity.

Solar electricity can supplement your entire or partial energy consumption. Using solar power means reducing your energy bills and saving money. Low maintenance and unobtrusive, installing solar panels add value to your home.

Wind power

Wind power involves converting wind energy into electricity by using wind turbines. The wind comes from atmospheric changes. These include changes in temperature and pressure which make the air move around the surface of the earth. A wind turbine captures the wind to produce energy.

Wind power is a clean energy source that can be relied on for the long-term future. A wind turbine creates reliable, cost-effective, pollution free energy. It is affordable, clean and sustainable. One wind turbine can be sufficient to generate enough electrical energy for a household, assuming the location is suitable.

Because it is a renewable resource which is non-polluting and renewable, wind turbines create power without using fossil fuels, without producing greenhouse gases or radioactive or toxic waste. Wind power is one of the best ways to combat global warming.

Hybrid systems

Hybrid systems consist of combining different types of energy production systems into a single power supply system. The most common type of hybrid system is combining a solar system with a wind generator; however, hybrid energy systems can integrate solar panels, diesel generator, batteries, and an inverter into the same system.

Solar panels create electricity from sunlight. This electricity is then stored in batteries. The inverter converts the AC electricity into a DC current.

Geothermal energy

Geothermal energy is power derived from the heat from the Earth. This can be sources such as the shallow ground to hot water and hot rock found a few kilometers beneath the Earth's surface.

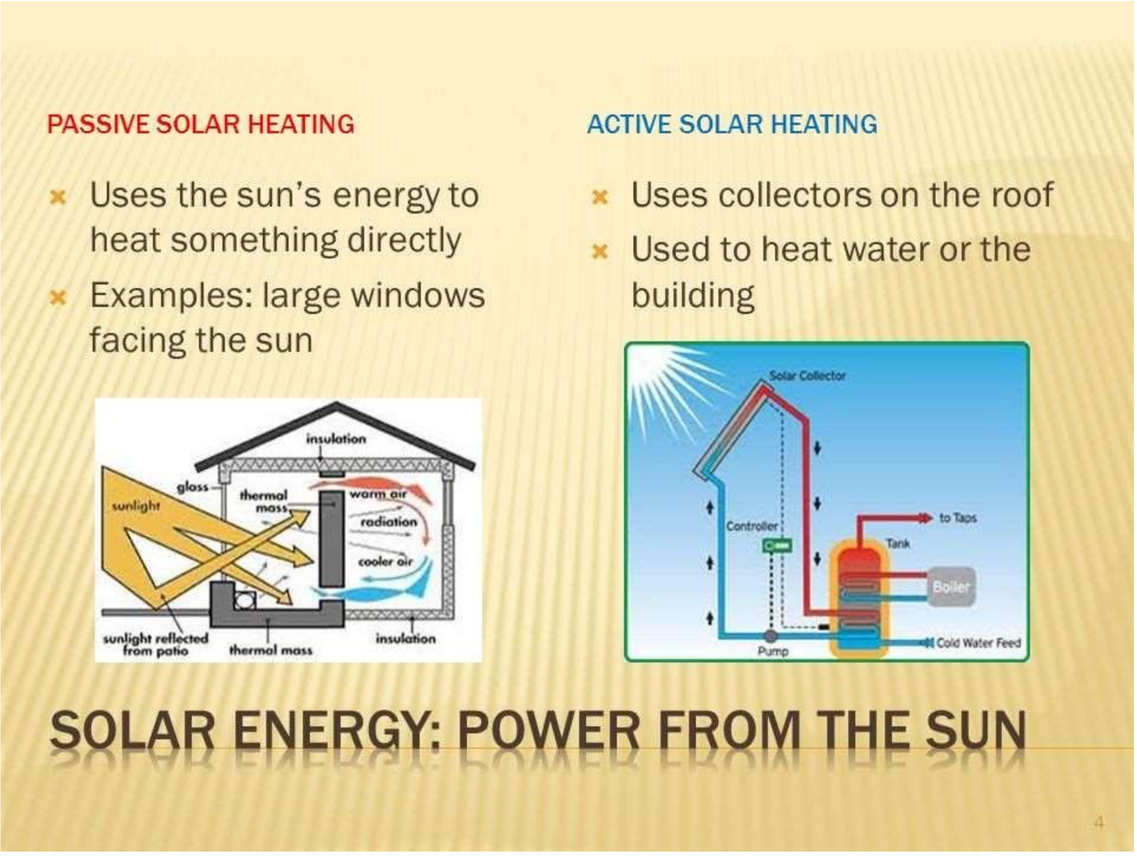
Solar energy

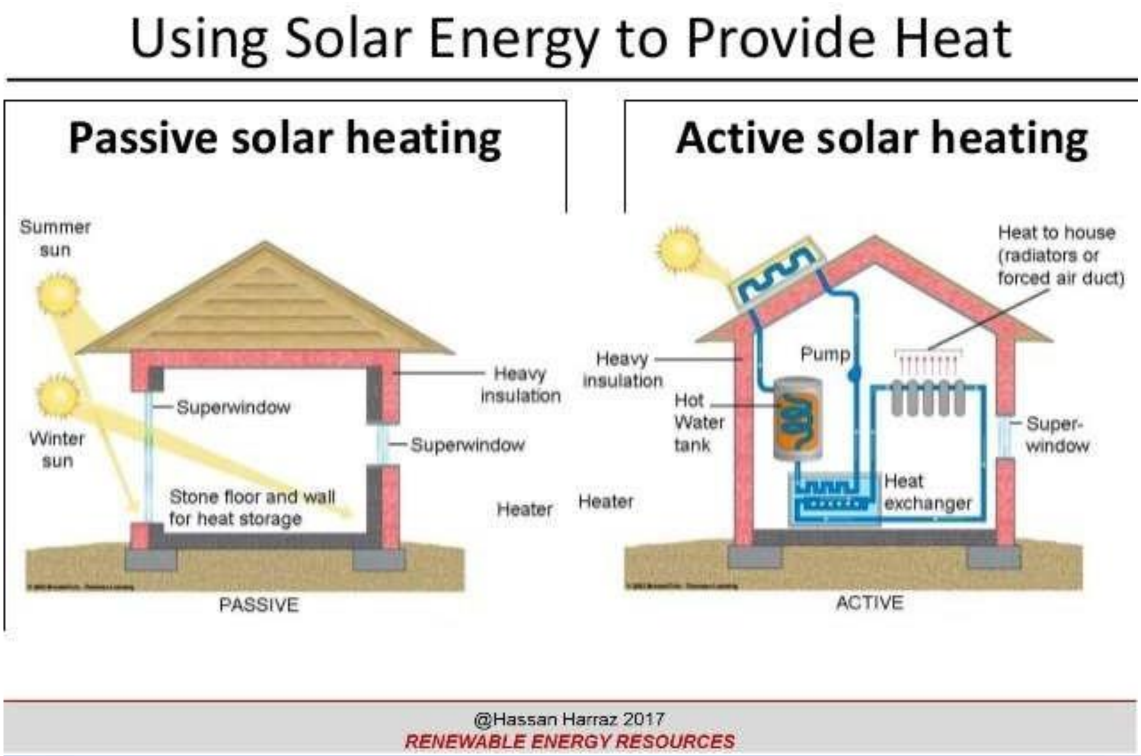
Solar energy is one of the kinds of renewable energy. Earth has been nourishing itself since centuries from sunlight. It is like an eternal source of energy so it is thought to take additional advantage by renewing it. There are two ways to obtained energy from sun; active solar energy and passive solar energy. Active solar energy method is used to utilize solar energy to a large extent and after sunset by storing.

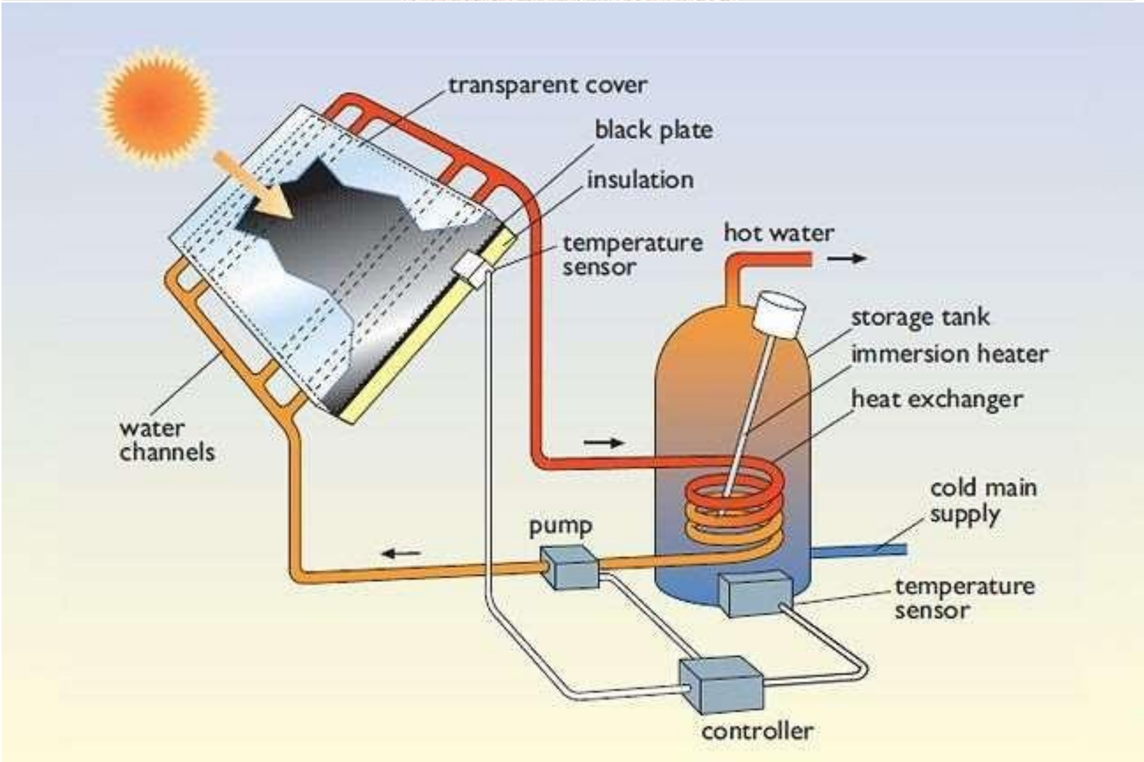
Active solar energy is obtained in two different mediums. One medium is air and the second is water or an anti-freezing solution placed in containers. Both are exposed to the sunlight to be heated. This heat either trapped in liquid or air containers. After trapping heat it is passed on to the drive, either run a device directly or to generator for storage of electricity to supply it locally. Heat trapped in air or liquid containers is distributed further using fans or pumps.

Active solar energy is more energy efficient than passive solar energy system. The reason is that in active solar system heat is stored and mechanically or electrically supply to the grid or house to meet up the demand of light.

While using the active solar energy it is very necessary to consider all the aspects in the selection of mode. Air or water based solar energy system have their own sensibilities. This selection is dependent on the location. It is the most important consideration as sunlight is the base of this mechanism. Factor comes after location is the system design whether need a big area or moderate. A key consideration is given to its use. If the full house is dependent on active solar energy or would it be partial.




Using Solar Energy to Provide Heat
Passive solar heating
Active solar heating
Summer sun
Winter sun
Superwindow
Heavy insulation
Superwindow
Stone floor and wall for heat storage
Heater
PASSIVE
Heat to house (radiators or forced air duct)
Pump
Heavy insulation
Hot Water tank
Super-window
Heat exchanger
Heater
ACTIVE
@Hassan Harraz 2017
RENEWABLE ENERGY RESOURCES


transparent cover
black plate
insulation
temperature sensor
hot water
storage tank
immersion heater
heat exchanger
water channels
cold main supply
pump
temperature sensor
controller

GEOTHERMAL ENERGY

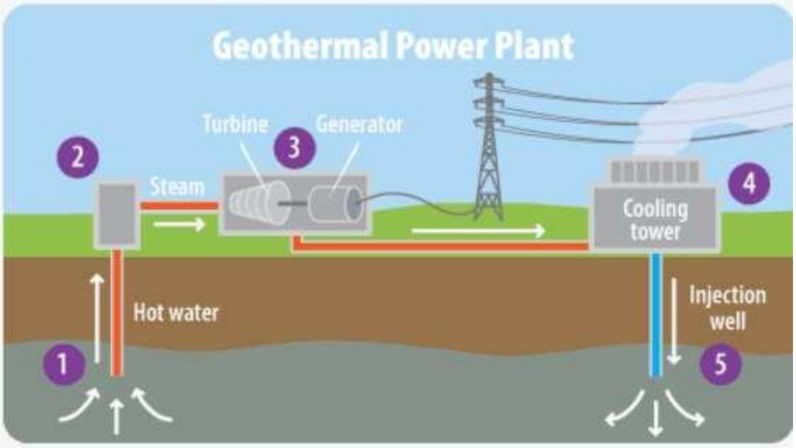
Geothermal energy is the heat that comes from the sub-surface of the earth. It is contained in the rocks and fluids beneath the earth's crust and can be found as far down to the earth's hot molten rock, magma.

To produce power from geothermal energy, wells are dug a mile deep into underground reservoirs to access the steam and hot water there, which can then be used to drive turbines connected to electricity generators. There are three types of geothermal power plants; dry steam, flash and binary. Dry steam is the oldest form of geothermal technology and takes steam out of the ground and uses it to directly drive a turbine. Flash plants use high-pressure hot water into cool, low-pressure water whilst binary plants pass hot water through a secondary liquid with a lower boiling point, which turns to vapour to drive the turbine.

Geothermal Power Plants

At a geothermal power plant, wells are drilled 1 or 2 miles deep into the Earth to pump steam or hot water to the surface. You're most likely to find one of these power plants in an area that has a lot of hot springs, geysers, or volcanic activity, because these are places where the Earth is particularly hot just below the surface.

How It Works



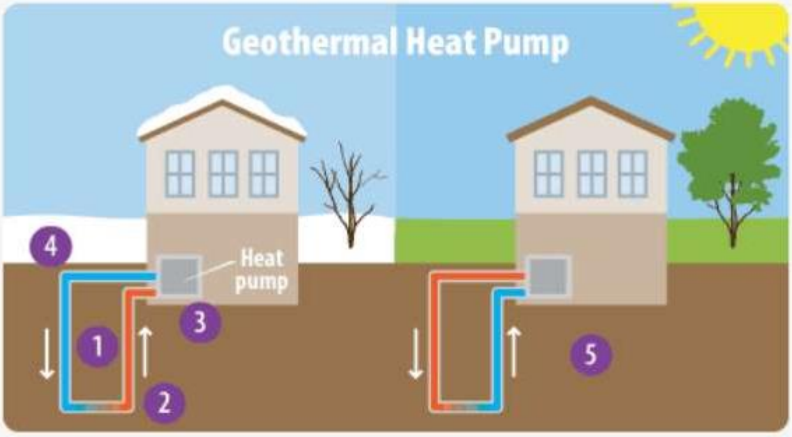
1. Hot water is pumped from deep underground through a well under high pressure.
2. When the water reaches the surface, the pressure is dropped, which causes the water to turn into steam.
3. The steam spins a turbine, which is connected to a generator that produces electricity.
4. The steam cools off in a cooling tower and condenses back to water.
5. The cooled water is pumped back into the Earth to begin the process again.

Geothermal Heat Pumps

Not all geothermal energy comes from power plants. Geothermal heat pumps can do all sorts of things—from heating and cooling homes to warming swimming pools. These systems transfer heat by pumping water or a refrigerant (a special type of fluid) through pipes just below the Earth's surface, where the temperature is a constant 50 to 60°F.

During the winter, the water or refrigerant absorbs warmth from the Earth, and the pump brings this heat to the building above. In the summer, some heat pumps can run in reverse and help cool buildings.

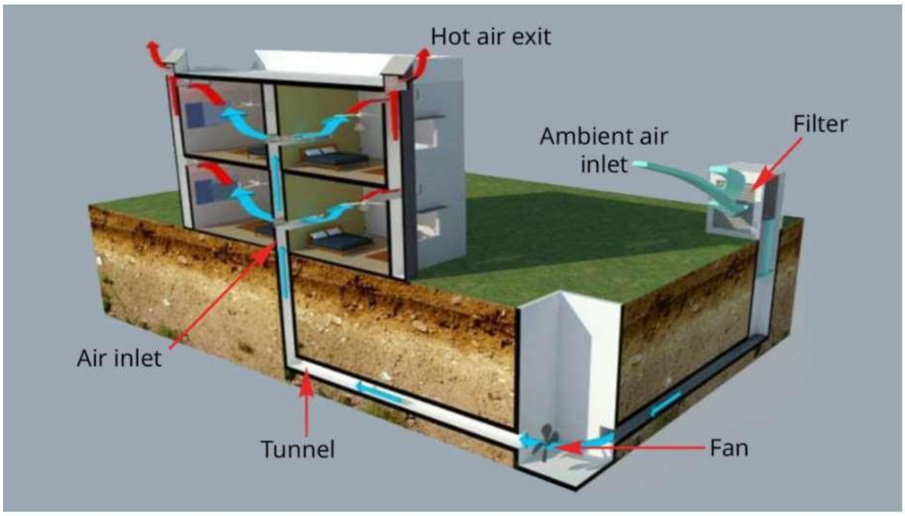
How It Works



1. Water or a refrigerant moves through a loop of pipes.
2. When the weather is cold, the water or refrigerant heats up as it travels through the part of the loop that's buried underground.
3. Once it gets back above ground, the warmed water or refrigerant transfers heat into the building.
4. The water or refrigerant cools down after its heat is transferred. It is pumped back underground where it heats up once more, starting the process again.
5. On a hot day, the system can run in reverse. The water or refrigerant cools the building and then is pumped underground where extra heat is transferred to the ground around the pipes.

EARTH AIR TUNNEL

Earth air tunnel or earth air heat exchanger is a pre-cooling or pre-heating system which consists of a pipe or network of pipes buried at reasonable depth below the ground surface. It either cools the air by rejecting heat to the ground or heats the air absorbing heat from the ground. It utilizes the fact that the deep earth temperature remains almost same as the annual average mean air temperature of the location.



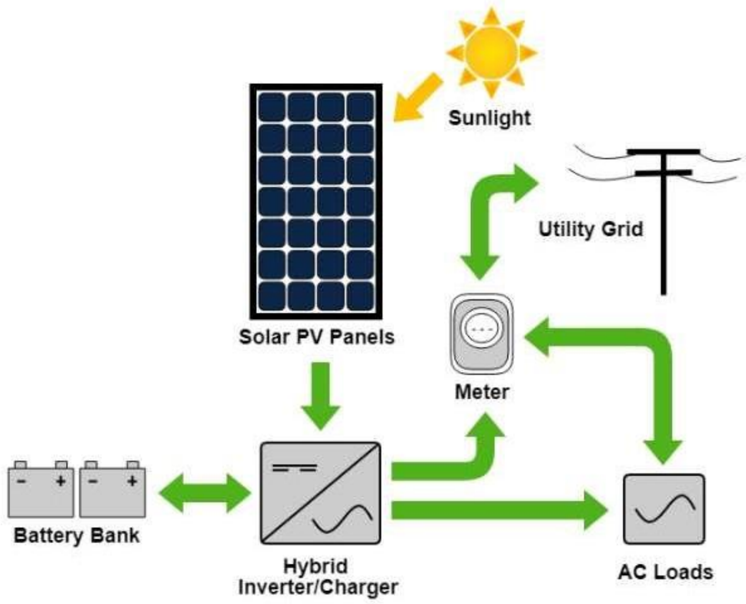
PHOTOVOLTICS

Solar photovoltaic systems, commonly referred to as solar PV systems, convert sunlight directly into electricity. This is different to the solar thermal collectors for solar water heaters. A solar PV system can help reduce carbon emissions and your electricity bill by producing sustainable electricity from the sun instead of burning fossil fuels.

Most electricity is distributed through an electrical utility provider, the company that produces and/or distributes electricity to consumers. The electricity from a variety of sources is distributed along the electrical grid and can span hundreds of miles from the power plants to homes and businesses.

This grid network is not always reliable due to overloading, severe weather, and maintenance or upgrades. Installing a PV power system allows you to create your own electricity to supply your entire home or business and can potentially eliminate the issues associated with large utility grids. The amount of electricity generated is dependent on several factors: the size and arrangement of the PV power system, the PV module type, the available sunlight, and the efficiency of the electrical components used to covert solar energy into electricity usable by your home or building.

Grid-connected PV System with Batteries

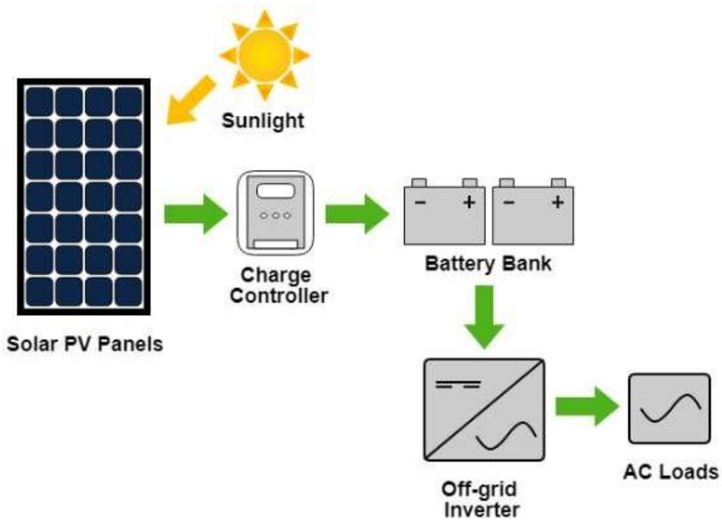


The grid-connected solar photovoltaic (PV) system is a common and cost-effective option to reduce electricity bills and emissions. It consists of PV modules, a grid connect inverter, associated mounting hardware, and electrical cables and safety devices. You can generate your own renewable energy on site, and supplement your electricity needs from the local utility grid when the PV system is not supplying enough energy. You can also export excess electricity back to the utility company when the PV system is generating more electricity than you need during daylight hours.

The way this exported electricity is metered and the rate of financial return varies by country, state, local district, and utility provider. The downside of this system configuration is that you are still connected to the grid. Depending on local regulations the system will automatically shut down if the grid becomes unavailable, meaning you will not produce any solar power during this time, and would still experience blackouts. You would also only use solar power during daylight hours with good solar irradiation, so at night and on cloudy days you would still draw power from the grid and pay an electricity bill.

A grid-connected photovoltaic (PV) system with batteries gives you the best of both worlds. The PV modules can be used to charge a battery bank during the day, and then provide this electricity to your home or business whenever it is needed (day or night). Maintaining a connection to the grid also allows for electricity to be supplied during periods of high use or when the weather is bad for extended periods. Depending on local regulations and government incentives, you may be able to export electricity from your battery bank at times when the utility provider needs it most, and attract a higher rate of return for that solar power. This system could also be configured to supply DC loads from the battery bank.

Off-grid PV System



The off-grid solar photovoltaic (PV) system can be extensively applied in remote locations, and other areas not covered by the main power grid. The PV modules generate electricity that is used to charge batteries during sunlight hours. This can then power DC loads directly or be provided to the AC load through the inverter. This system configuration provides independence from the utility grid however there are limitations on the days of autonomy and the size of the loads that can be supplied by batteries and inverters on their own.
For some applications where small amounts of electricity are required, like emergency call boxes and UPS systems, PV systems are often cost justified even when the grid is accessible. When applications require larger amounts of electricity and are located away from existing power lines, PV systems can in many cases offer the least expensive and most viable option.

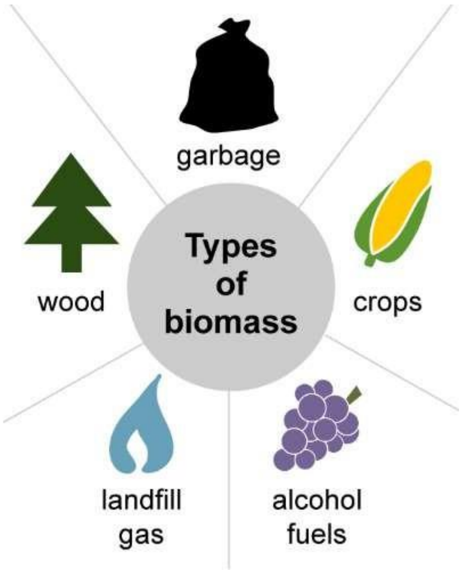
Biomass—Renewable Energy From Plants and Animals
Biomass is organic material that comes from plants and animals, and it is a renewable source of energy.
Biomass contains stored energy from the sun. Plants absorb the sun's energy in a process called photosynthesis. When biomass is burned, the chemical energy in biomass is released as heat. Biomass can be burned directly or converted to liquid biofuels or biogas that can be burned as fuels.
Examples of biomass and their uses for energy
Wood and wood processing wastes—burned to heat buildings, to produce process heat in industry, and to generate electricity
Agricultural crops and waste materials—burned as a fuel or converted to liquid biofuels
Food, yard, and wood waste in garbage—burned to generate electricity in power plants or converted to biogas in landfills
Animal manure and human sewage—converted to biogas, which can be burned as a fuel

Photosynthesis

In the process of photosynthesis, plants convert radiant energy from the sun into chemical energy in the form of glucose—or sugar.

(water)		(carbon dioxide)		(sunlight)		(glucose)		(oxygen)
$6H_2O$	+	$6CO_2$	+	radiant energy	→	$C_6H_{12}O_6$	+	$6O_2$

Source: Adapted from The National Energy Education Project (public domain)



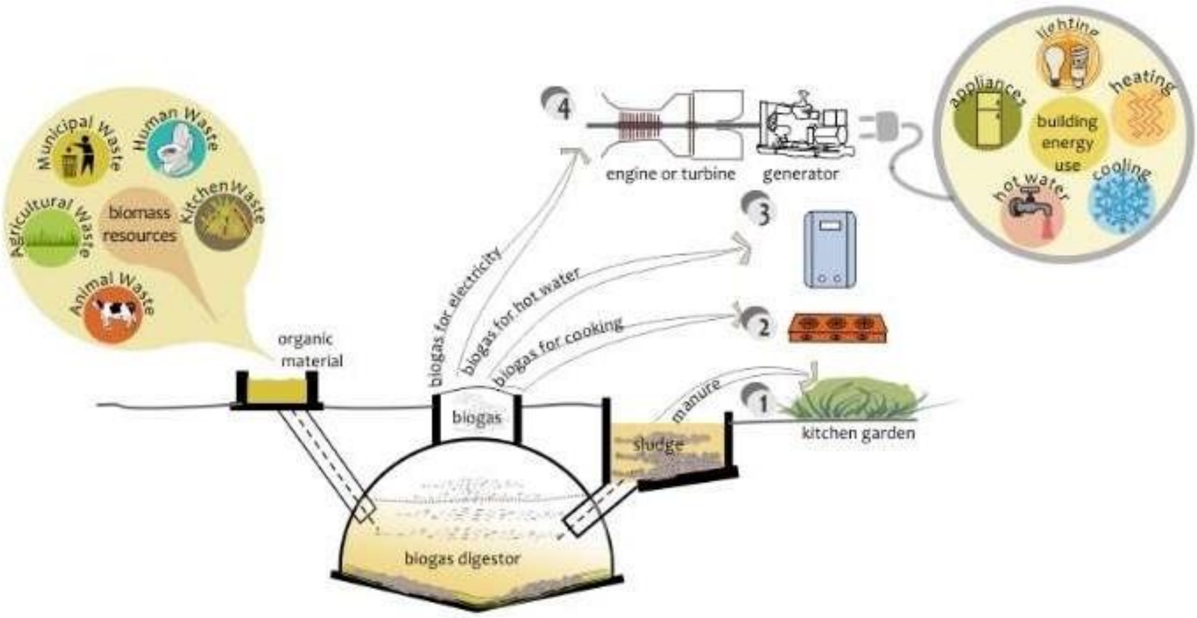
Source: Adapted from The National Energy Education Project (public domain)

Converting biomass to energy

Solid biomass, such as wood and garbage, can be burned directly to produce heat. Biomass can also be converted into a gas called biogas or into liquid biofuels such as ethanol and biodiesel. These fuels can then be burned for energy.

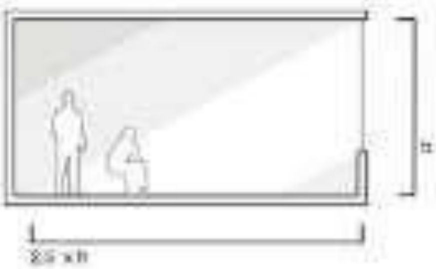
Biogas forms when paper, food scraps, and yard waste decompose in landfills, and it can be produced by processing sewage and animal manure in special vessels called digesters.

Ethanol is made from crops such as corn and sugar cane that are fermented to produce fuel ethanol for use in vehicles. Biodiesel is produced from vegetable oils and animal fats and can be used in vehicles and as heating oil.



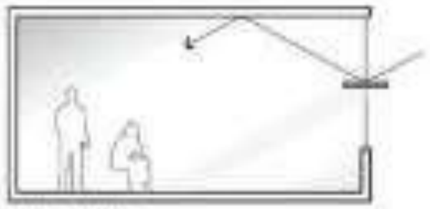
DAYLIGHTING

is a passive strategy using natural lighting to illuminate interior spaces. The benefits from daylighting range from improved aesthetic qualities, including better color balance and connection to the outdoors, to increased energy efficiency. Adding an active component can enhance the effectiveness of these strategies shown.



SIDE LIGHTING

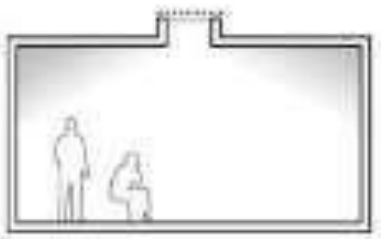
OVERHANG



LIGHT SHELF

TOP LIGHTING

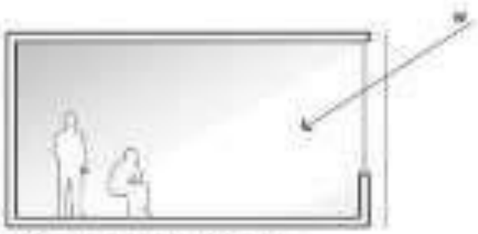
REFLECTED LIGHT



DIFFUSED LIGHT

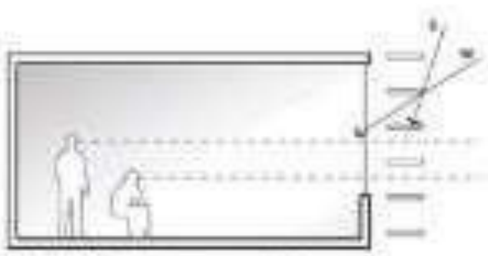
ANTI-GLARE

SUMMER VEGETATION, leaves block summer light



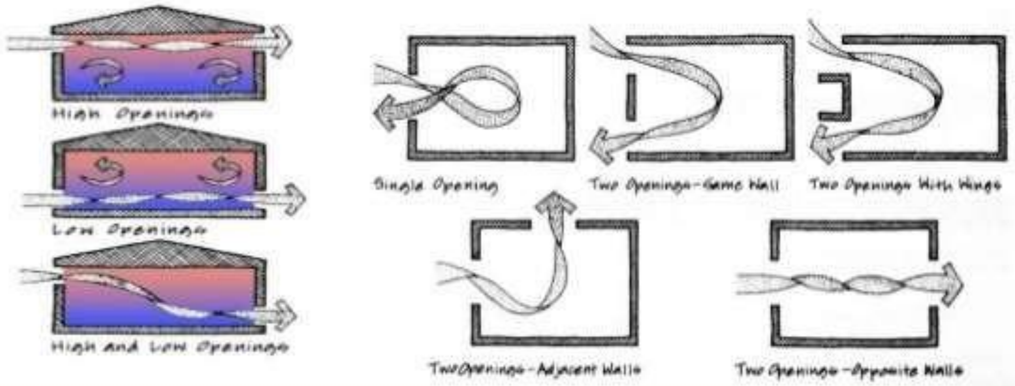
WINTER VEGETATION, bare branches allow winter light

SCREEN, diffuses light and views



LOUVERS, blocks summer light and allows winter light while maintaining views

NATURAL VENTILATION



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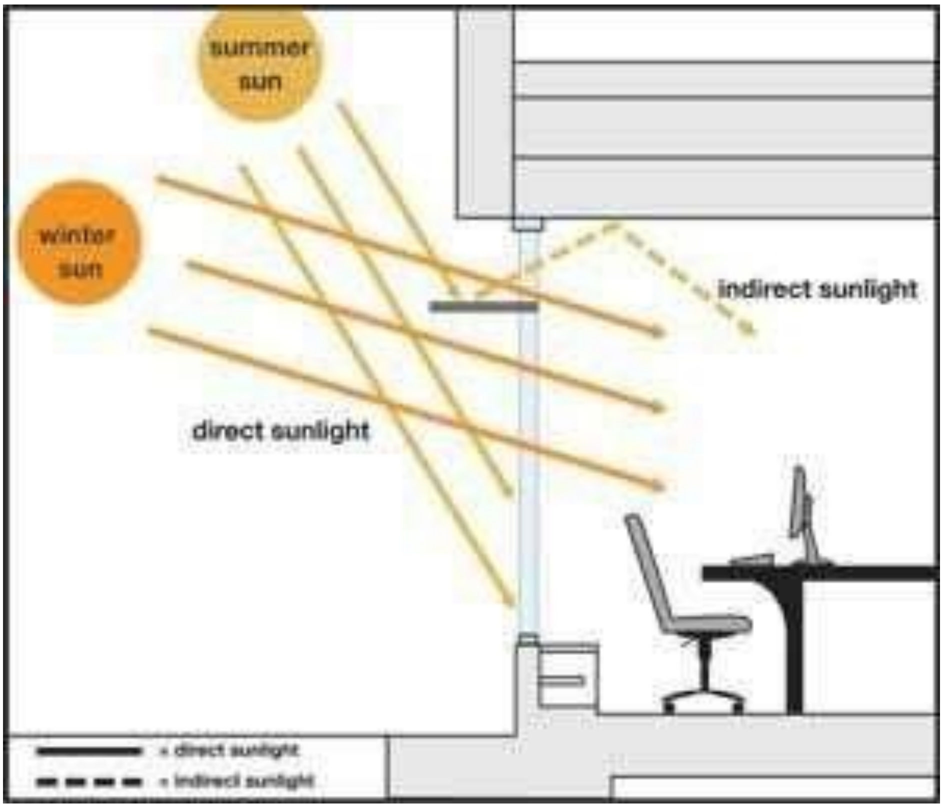
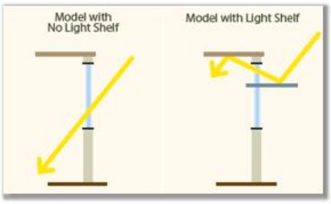
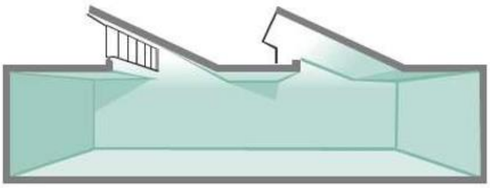


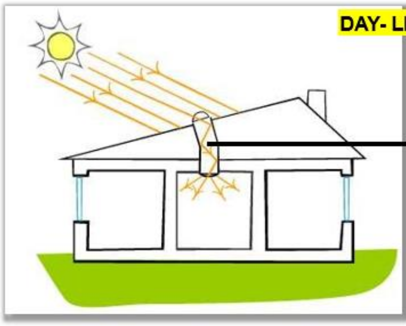
CONCEPTS OF DAY-LIGHTING

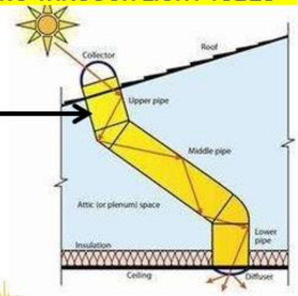
- WINDOWS
- SKYLIGHTS
- CLEARSTORIES
- ATRIUM
- SAWTOOTHS
- LIGHTSHELVES



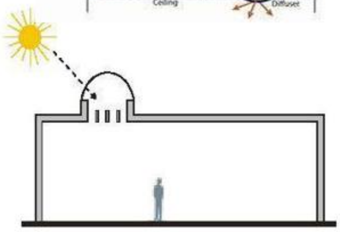


DAY- LIGHTING THROUGH LIGHT TUBES

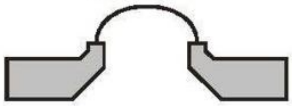




It is more energy efficient than skylight since less energy escapes from the interior due to less surface area.

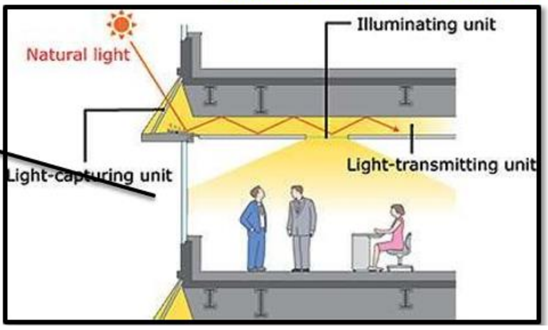


Diffuse Incoming Light for Glare Reduction



Splayed Opening on a Skylight

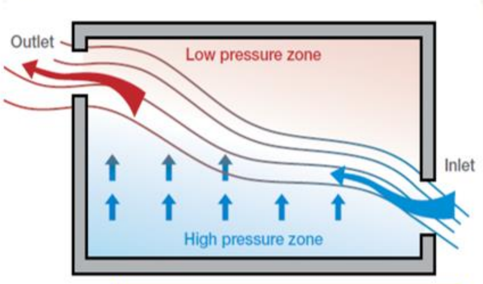
DAY-LIGHTING DUCT SYSTEM



DIFFERENT TECHNIQUES TO ACHIEVE NATURAL VENTILATION

- STACK EFFECT
- WIND TOWER
- COURTYARD EFFECT

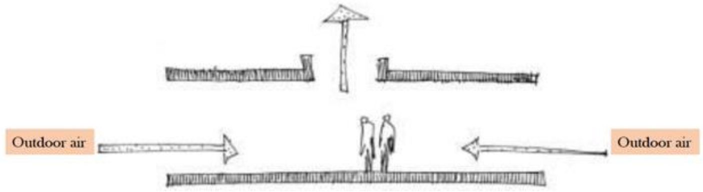
STACK EFFECT DEPENDS ON THERMAL FORCES AND DIFFERENCE IN TEMPERATURE .



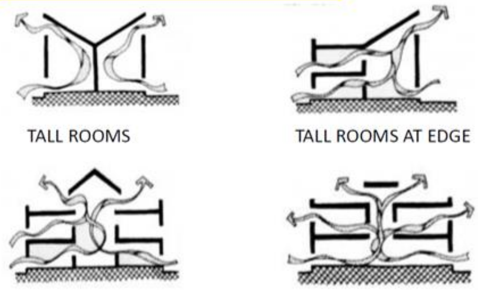
STACK EFFECT

REASON OF STACK EFFECT :-

- PRESSURE DIFFERENCE BETWEEN THE OUTSIDE AIR AND THE AIR INSIDE THE BUILDING CAUSED BY DIFFERENCE IN TEMPERATURE



STACK VENTILATION SYSTEMS



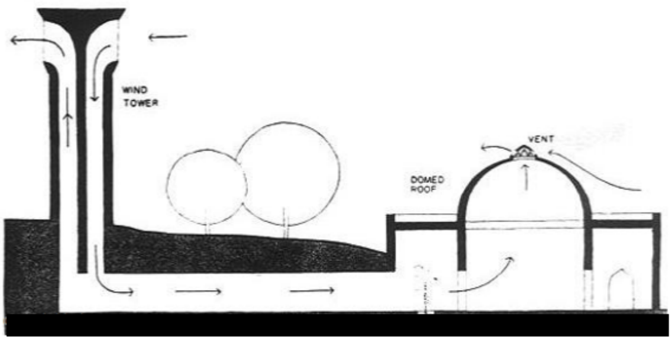
WIND TOWER

- AIR ENTERS IN WIND TOWER THROUGH OPENINGS- COOLED DOWN- BECOMES HEAVIER AND SINKS DOWN (PRESENCE OF AIR MOVEMENT)

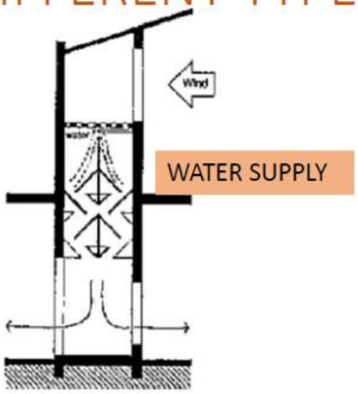
- AFTER WHOLE DAY AIR EXCHANGE – TOWER BECOMES WARM IN THE EVENING .

- TOWER WALLS ABSORBS HEAT DURING DAYTIME AND RELASES AT NIGHT WARMING COOL NIGHT AIR AT NIGHT.

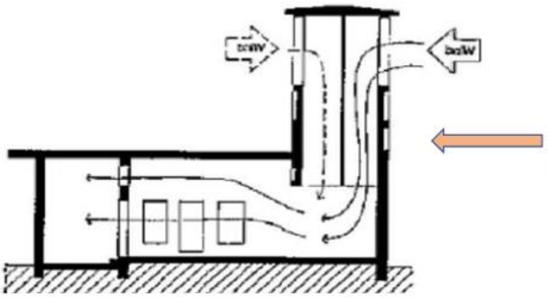
A TYPICAL WIND TOWER SECTION

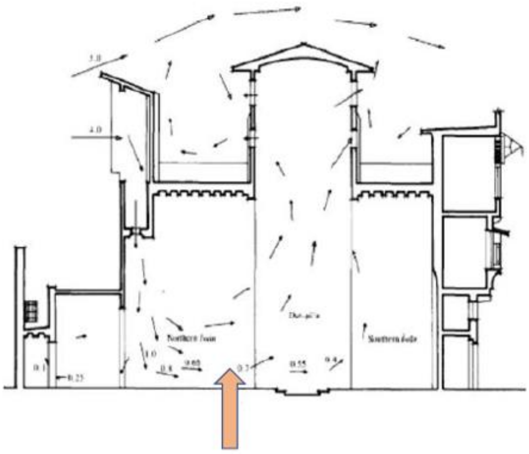


DIFFERENT TYPES OF WIND TOWERS :-



EVAPORATIVE COOLING

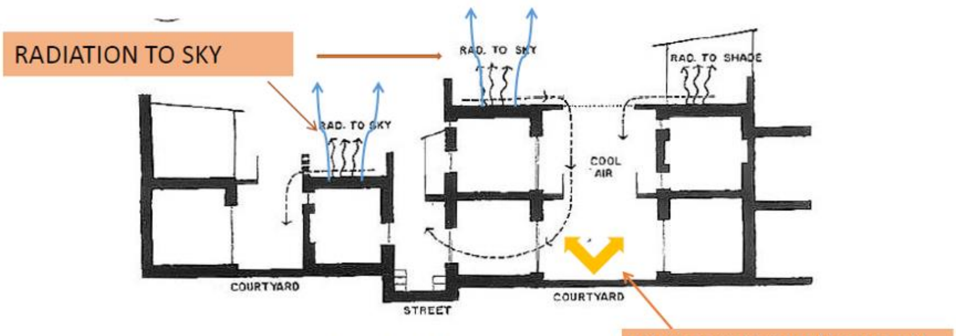




MULTI DIRECTIONAL WIND CATCHER

COURTYARD EFFECT:-

DUE TO INCIDENT SOLAR RADIATION IN A COURTYARD, AIR GETS WARMER AND RISES , COOL AIR FROM GROUND LEVEL FLOWS THROUGH THE LOWER OPENINGS

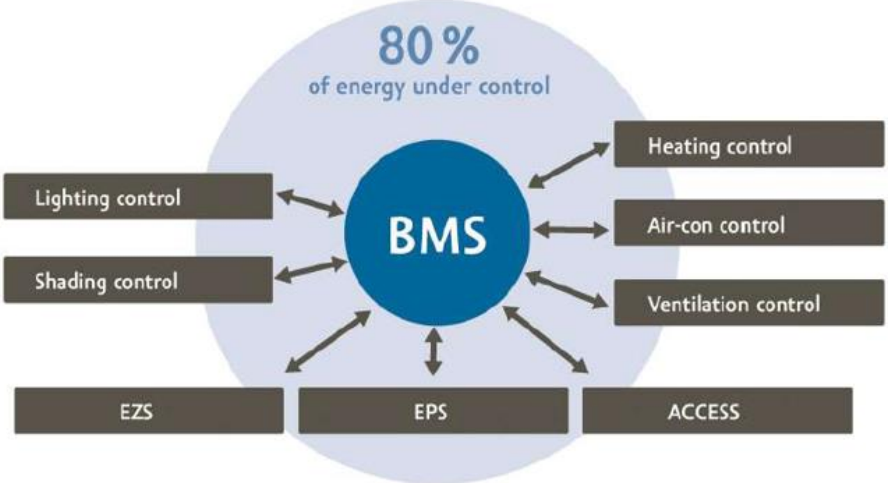


SECTION SHOWING COURTYARD EFFECT

BUILDING AUTOMATION SYSTEM
https://www.youtube.com/watch?v=OeVt4_5GLxQ

INTRODUCTION TO BUILDING AUTOMATION SYSTEMS

Definition : **Building automation** is the **automatic centralized control of a building's heating, ventilation and air conditioning, lighting** and other systems through a building management system or building automation system (BAS).



The term *building automation system*, loosely used, refers to any electrical control system that is used to control a buildings heating, ventilation and air conditioning (HVAC) system. Modern BAS can also control indoor and outdoor lighting as well as security, fire alarms, and especially everything that is electrical in the building.

A building controlled by a BAS is often referred to as an **intelligent building**, "smart building", or (if a residence) a "smart home".

Defining an intelligent building

"A building equipped with lighting, heating, and electronic devices that can be controlled remotely by Smartphone or computer." Most commercial products can provide only the ability to use a remote control and predefine behaviour of different engineering systems. It has been shown that there is no any intelligence in such Systems.

"Instead of being programmed to perform certain actions, the house essentially programs itself by monitoring the environment and sensing actions performed by the inhabitants"(e.g., turning lights on and off, adjusting the thermostat), observing the occupancy and behaviour patterns of the inhabitants, and learning to predict future states of the house.

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DEPARTMENT OF ARCHITECTURE

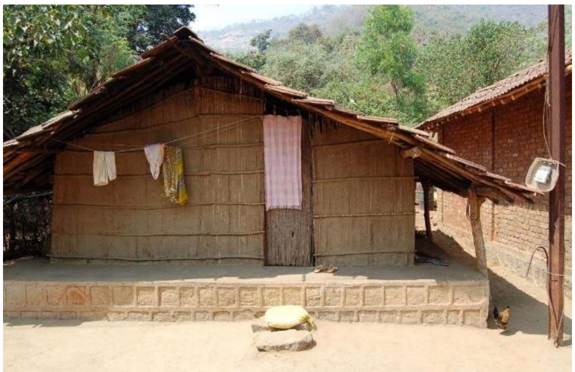
SAR1609 – ENERGY EFFICIENT ARCHITECTURE

UNIT – IV - ENERGY POLICY AND BUILDING ENERGY STANDARDS

UNIT4 - ENERGY POLICY AND BUILDING ENERGY STANDARDS

GREEN BUILDING

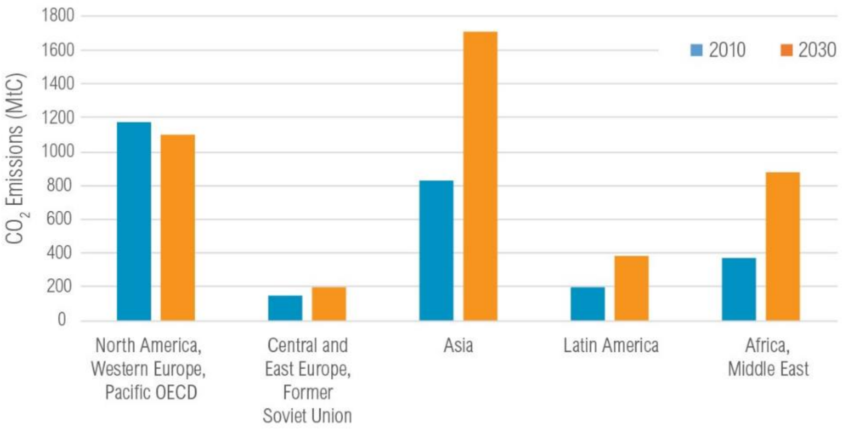
- A ‘green’ building is a building that, in its design, construction or operation, reduces or eliminates negative impacts, and can create positive impacts, on our climate and natural environment. Green buildings preserve precious natural resources and improve our quality of life. – WGBC
- Green building is a holistic concept that starts with the understanding that the built environment can have profound effects, both positive and negative, on the natural environment, as well as the people who inhabit buildings every day. Green building is an effort to amplify the positive and mitigate the negative of these effects throughout the entire life cycle of a building. -USGBC
- A green building is one which uses less water, optimizes energy efficiency, conserves natural resources, generates less waste and provides healthier spaces for occupants, as compared to a conventional building. – IGBC
- Though not rated most of the times even Vernacular buildings – buildings made of locally available materials are green.



Need for Green Building

- Natural Resources - depletion
- Resource scarcity
- Water Scarcity
- Energy Scarcity
- Create Healthy Environment
- Reduce Carbon Foot Print

Building Sector Emissions by World Region, 2010 and 2030 Projections

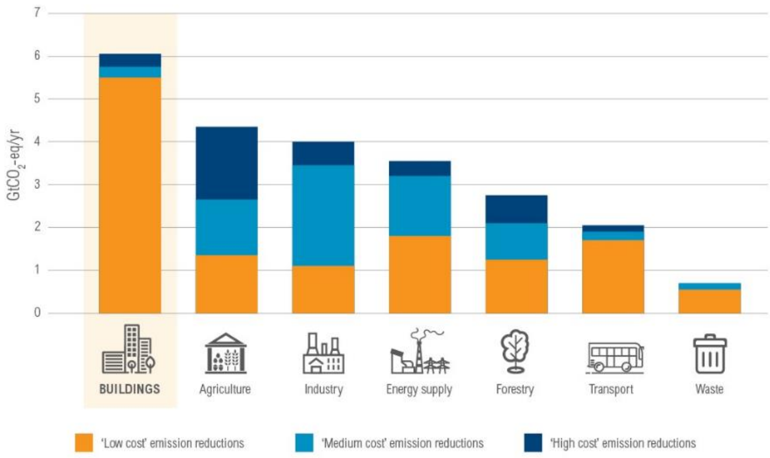


Source: du Can, Stephane de la Rue, and Lynn Price. 2008. "Sectoral Trends in Global Energy Use and Greenhouse Gas Emissions." Energy Policy (36)4: 1386–1403.

wri.org/buildingefficiency

WORLD RESOURCES INSTITUTE

Building Efficiency Is One of the Most Affordable Ways to Cut Emissions



Note: 'Low cost' emission reductions = carbon price <20 US$/t$CO_2$-eq. 'Medium cost' emission reductions = carbon price <50 US$/tCO²-eq.
'High cost' emission reductions = carbon price <100 US$/t$CO_2$-eq.
Source: IPCC. 2007. IPCC Fourth Assessment Report: Climate Change 2007: Synthesis Report. "4.3 Mitigation options." https://www.ipcc.ch/publications_and_data/ar4/syr/en/mains4-3.html

wri.org/buildingefficiency

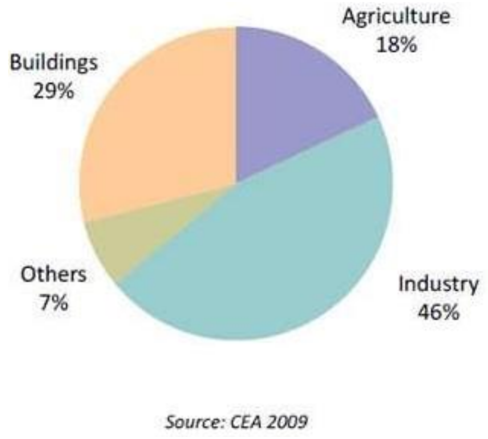
WORLD RESOURCES INSTITUTE

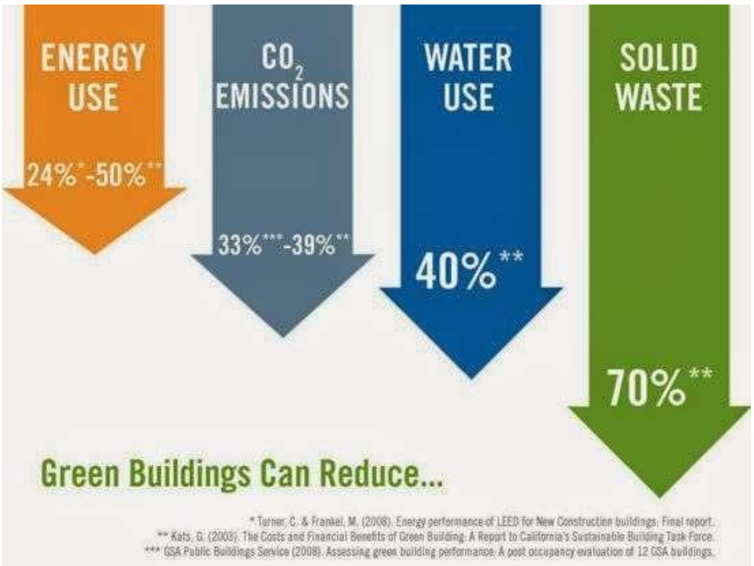
GREEN BUILDING RATING SYSTEM

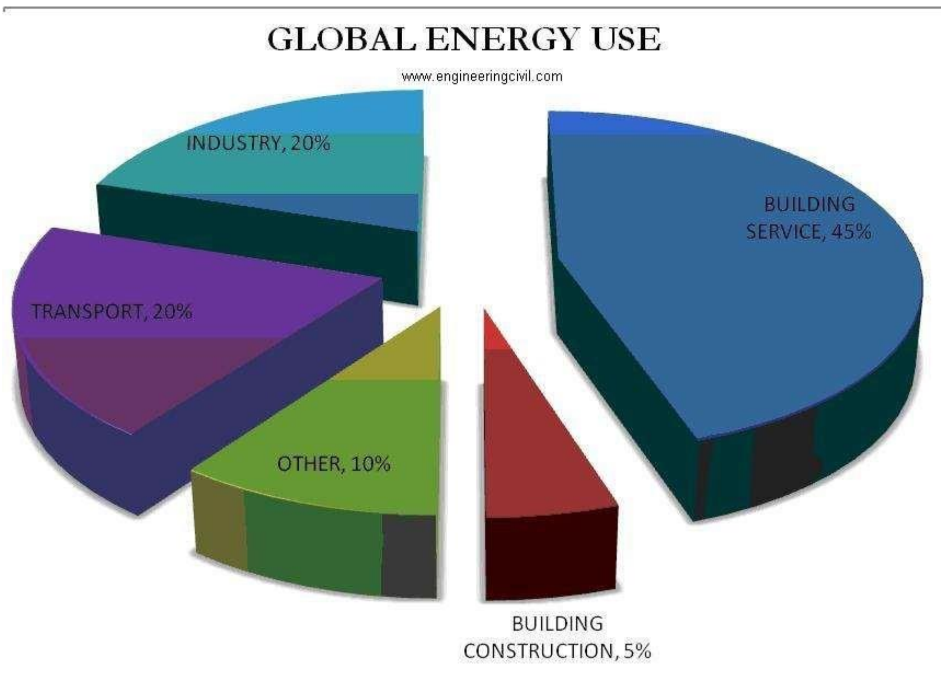
Green building rating systems have a set of pre- defined parameters for evaluating and rating building structures that are environmentally responsible and resource-efficient throughout a **building's** life-cycle from siting to design, construction, operation, maintenance, renovation and deconstruction.

NEED FOR GREEN BUILDING RATING SYSTEM

- **A body to minimise the energy consumption in the building sector**
- **Buildings consume a significant percentage (29 %)of all energy consumed in India.**







The Global Environmmental Impact of Buildings

Benefits of Green

Environmental (WGBC)

One of the most important types of benefit green buildings offer is to our climate and the natural environment. Green buildings can not only reduce or eliminate negative impacts on the environment, by using less water, energy or natural resources, but they can - in many cases - have a positive impact on the environment (at the building or city scales) by generating their own energy or increasing biodiversity.

At a global level:

- The building sector has the largest potential for significantly reducing greenhouse gas emissions compared to other major emitting sectors – UNEP, 2009. (United Nations Environment Programme)
- This emissions savings potential is said to be as much as 84 gigatonnes of CO_2 by 2050, through direct measures in buildings such as energy efficiency, fuel switching and the use of renewable energy – UNEP, 2016.
- The building sector has the potential to make energy savings of 50% or more in 2050, in support of limiting global temperature rises to 2°C (above pre-industrial levels) – UNEP, 2016.
- Green buildings achieving the **Green Star** certification in **Australia** have been shown to **produce 62% fewer greenhouse gas emissions** than average Australian buildings, and **51% less potable water** than if they had been built to meet minimum industry requirements.
- Green buildings certified by **the Indian Green Building Council** (IGBC) results in **energy savings of 40 - 50%** and **water savings of 20 - 30%** compared to conventional buildings in India.

Benefits of Green - Building level

- Green buildings achieving the **Green Star** certification in **South Africa** have been shown to save on average between **30 - 40% energy** and carbon emissions every year, and between **20 - 30% potable water** every year, when compared to the industry norm.
- Green buildings achieving the **LEED** certification in the **US** and other countries have been shown to consume **25 % less energy** and **11 % less water**, than non-green buildings.

Benefits of Green - Economically Economic

- Green buildings offer a number of economic or financial benefits, which are relevant to a range of different people or groups of people. These include **cost savings on utility bills** for tenants or households (through energy and water efficiency); **lower construction costs** and higher property value for building developers; **increased occupancy rates** or **operating costs for building owners**; and **job creation**. Since the publication of World GBC's groundbreaking 2013 report, *The Business Case for Green Building*, we have sought to strengthen the link between green buildings and the economic benefits they can offer.

- At a global level:

  Global energy efficiency measures could save an estimated **€280 to €410 billion in savings on energy spending** (and the equivalent to almost double the annual electricity consumption of the United States) – European Commission, 2015.

- At a country level:

  Canada's green building industry generated **$23.45 billion in GDP** and represented nearly **300,000 full-time jobs in 2014** – Canada Green Building Council / The Delphi Group, 2016.

  Green building is **projected** to account for more than **3.3 million U.S. jobs by 2018** – US Green Building Council / Booz Allen Hamilton, 2015.
- At a building level:

  Building owners report that green buildings - whether **new or renovated - command a 7 per cent increase in asset value** over traditional buildings – Dodge Data & Analytics, 2016.

Social Benefits of Green

Green building benefits go beyond economics and the environment, and have been shown to bring positive social impacts too. Many of these benefits are around the health and wellbeing of people who work in green offices or live in green homes.

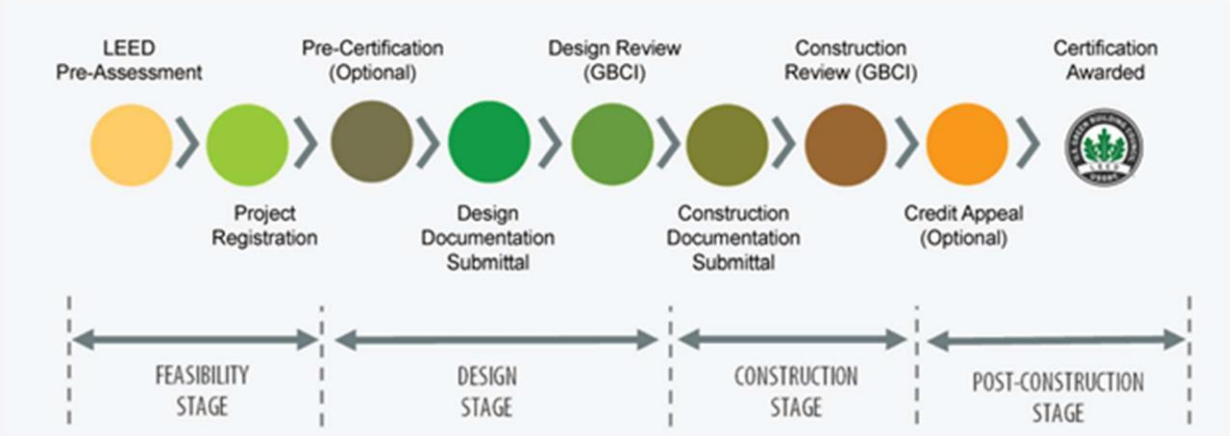
- Workers in green, well-ventilated offices record a 101 per cent increase in cognitive scores (brain function) - Harvard T.H. Chan School of Public Health / Syracuse University Center of Excellence / SUNY Upstate Medical School, 2015.
- Employees in offices with windows slept an average of 46 minutes more per night - American Academy of Sleep Medicine, 2013.
- Research suggests that better indoor air quality (low concentrations of CO_2 and pollutants, and high ventilation rates) can lead to improvements in performance of up to 8 per cent– Park and Yoon, 2011.
- World GBC and the Green Building Council of South Africa established a joint project to develop a framework to enable complex socio-economic issues to be integrated into any green building rating system in the world.

- **Environmental benefits:**

  Reduce wastage of water Conserve natural resources Improve air and water quality Protect biodiversity and ecosystems
- **Economic benefits:**

  Reduce operating costs Improve occupant productivity Create market for green product and services
- **Social benefits:**

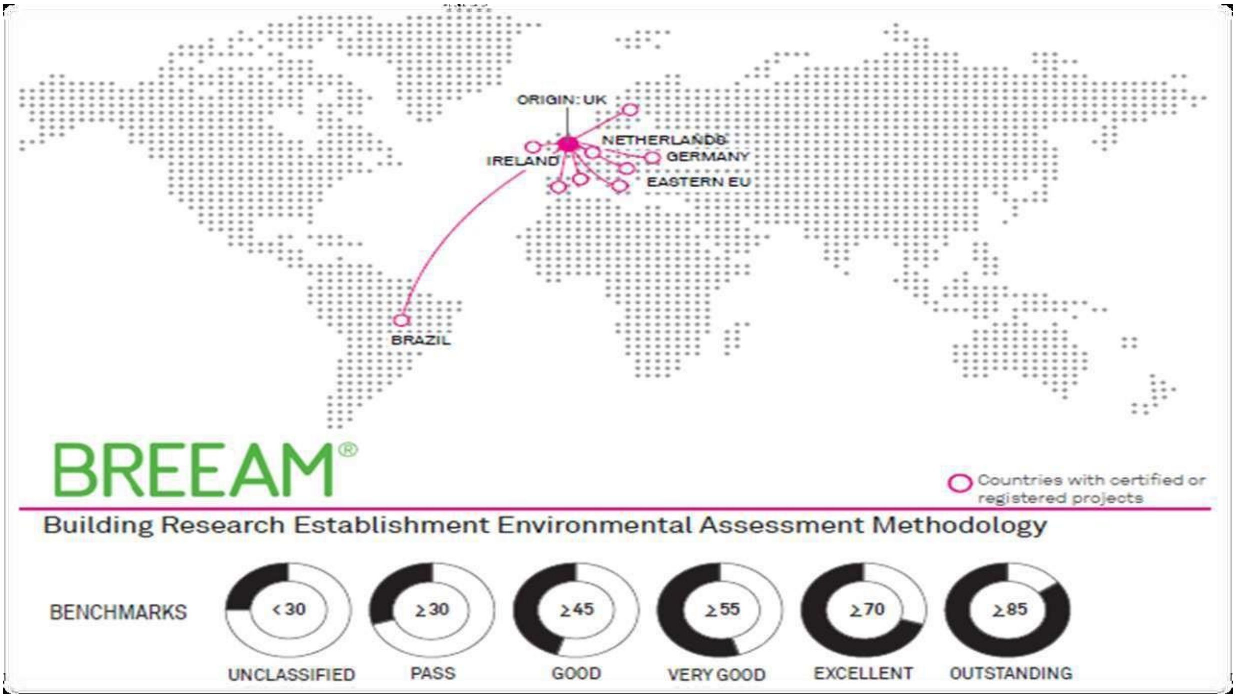
  Improve quality of life Minimize strain on local infrastructure Improve occupant health and comfort



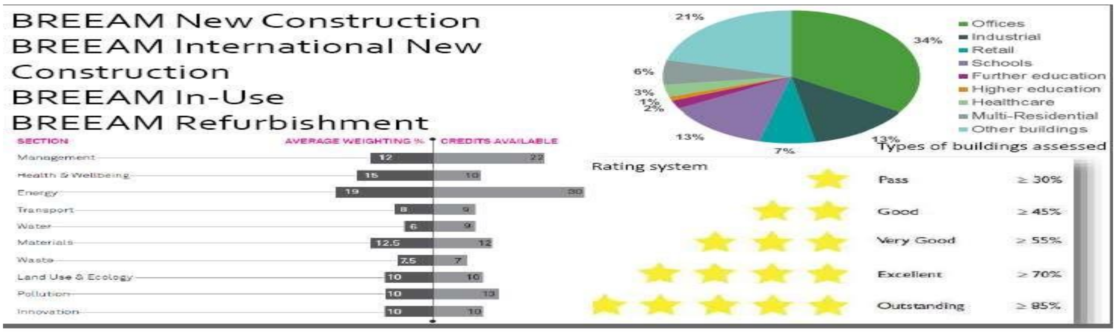
LEED rating system - Certification process

Country	Rating system
United States	Leadership in Energy & Environmental Design (LEED-United States)
	The Green Globe Rating System
	Energy Star (United States Environment Protection Agency)
Canada	Leadership in Energy & Environmental Design — Canada (LEED-Canada)
Australia	Green Star
	Australia Greenhouse Building Rating (AGBR)
United Kingdom	Building Research Environment Assessment Method Consultancy (BREEAM)
Europe	European Environment Agency rating
Hong Kong	Building Environment Assessment Method- Hong Kong (HK-BEAM)
Japan	Comprehensive Assessment System for Building Environment Efficiency (CASBEE)
Taiwan	Ecology, Energy Saving, Waste Reduction and Health (EEWH) (Taiwan)
Singapore	BCA Green Mark
Philippine	Philippine Green Building Council
South Korea	Green Building Council (Korea)
India	GRIHA
	India Green Building Council

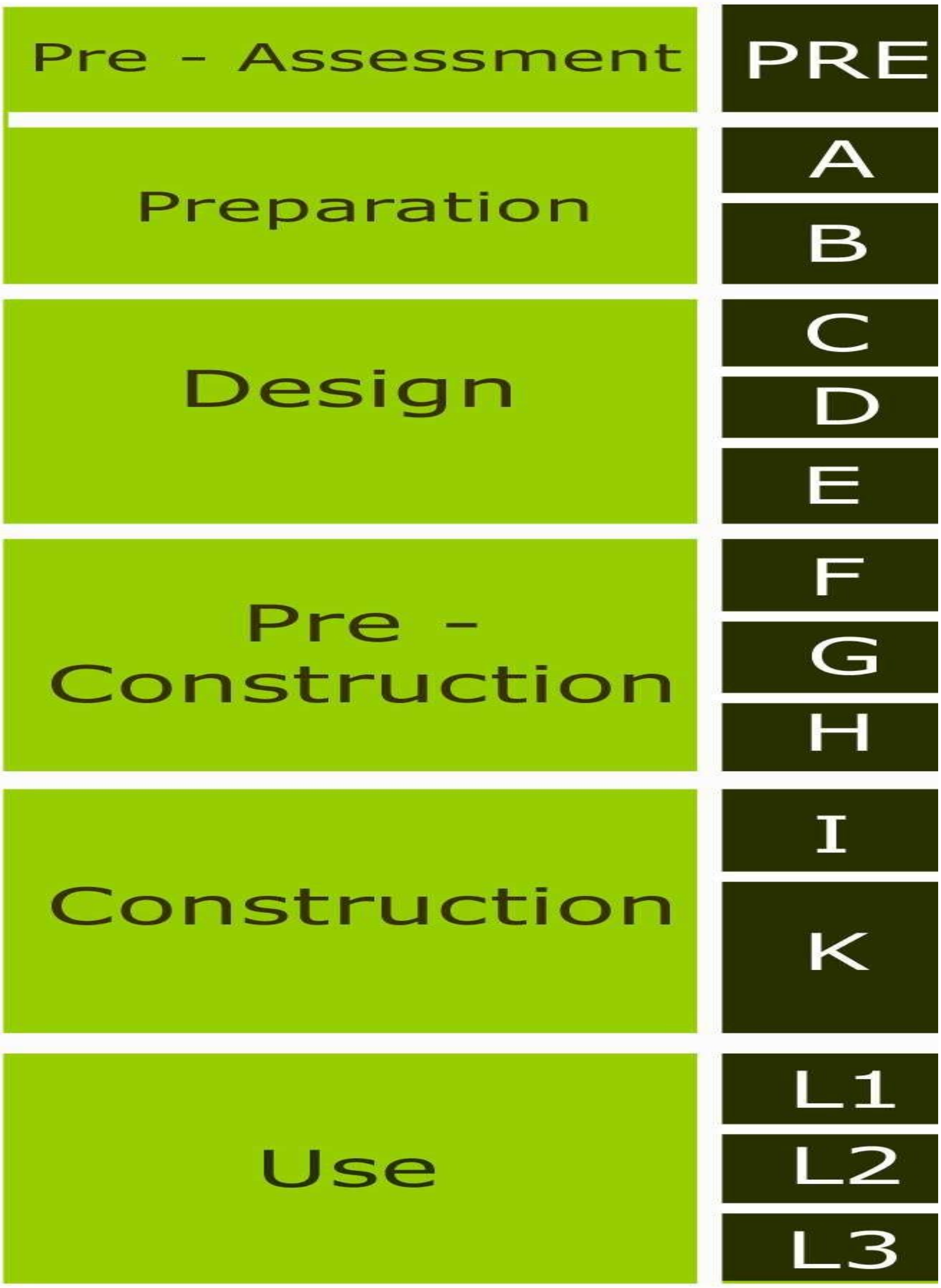
BREEAM



BREEAM CRITERIAS



BREEAM New Construction
BREEAM International New Construction
BREEAM In-Use
BREEAM Refurbishment
SECTION
AVERAGE WEIGHTING %
CREDITS AVAILABLE
Management 12 22
Health & Wellbeing 15 10
Energy 19 30
Transport 8 9
Water 6 9
Materials 12.5 12
Waste 7.5 7
Land Use & Ecology 10 10
Pollution 10 13
Innovation 10 10
21%
34%
6%
3%
1%
2%
13%
7%
13%
Offices
Industrial
Retail
Schools
Further education
Higher education
Healthcare
Multi-Residential
Other buildings
Types of buildings assessed
Rating system
Pass ≥ 30%
Good ≥ 45%
Very Good ≥ 55%
Excellent ≥ 70%
Outstanding ≥ 85%



Pre - Assessment
PRE
Preparation
A
B
Design
C
D
E
Pre - Construction
F
G
H
Construction
I
K
Use
L1
L2
L3

LEED- CREDIT CATEGORIES

• Sustainable sites credits encourage strategies that minimize the impact on ecosystems and water resources.

• Water efficiency credits promote smarter use of water, inside and out, to reduce potable water consumption.

• Energy & atmosphere credits promote better building energy performance through innovative strategies.

• Materials & resources credits encourage using sustainable building materials and reducing waste.

• Indoor environmental quality credits promote better indoor air quality and access to daylight and views.

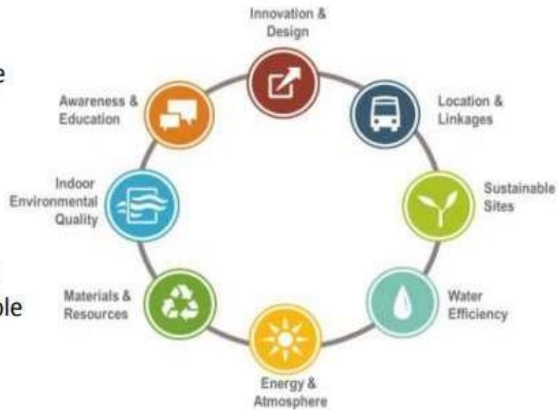
• Awareness & Education encourage home builders and real estate professionals to provide homeowners, tenants and building managers with the education and tools they need to understand and make the most of the green building features of their home.

• Innovation & Design address sustainable building expertise as well as design measures not covered under the five LEED credit categories. Six bonus points are available in this category.

• Location & Linkages encourage construction on previously developed or infill sites and promotes walkable neighborhoods with access to efficient transportation options and open space.

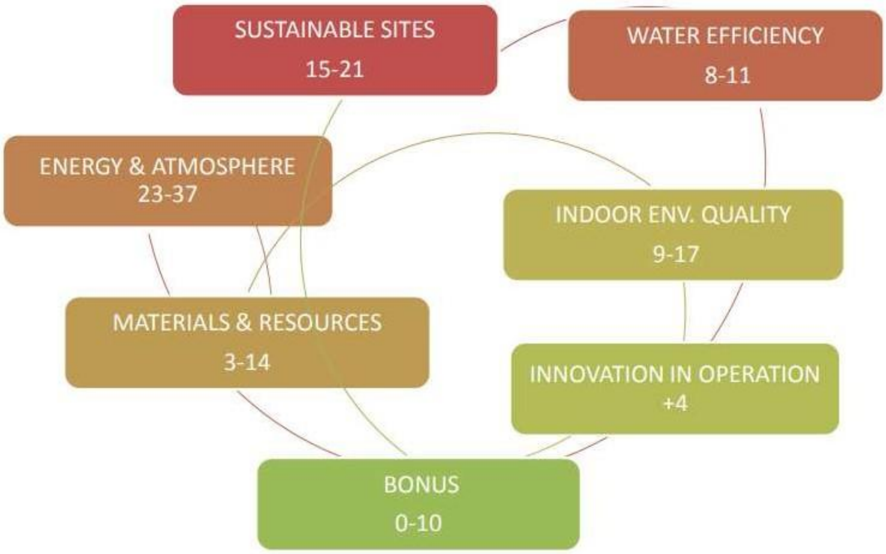
• Green infrastructure & buildings credits reduce the environmental consequences of the construction and operation of buildings and infrastructure.

•Regional priority credits address regional environmental priorities for buildings in different geographic regions. Four bonus points are available in this category.



• Awareness
homeowner
and make th
• Innovation
under the fi
• Location &
walkable ne
• Green infr
the environ
construction
infrastructu
•Regional p
environmen
geographic
in this categ

LEED



LEED For Building Design and Construction	LEED for Homes	LEED for Interior Design and Construction	LEED for Building Operation and Maintenance	LEED for Neighbourhood Development:
❖ LEED BD+C: New Construction ❖ LEED BD+C: Core and Shell ❖ LEED BD+C: Schools ❖ LEED BD+C: Retail ❖ LEED BD+C: Healthcare ❖ LEED BD+C: Data Centers ❖ LEED BD+C: Hospitality ❖ LEED BD+C: Warehouses and Distribution Centers	❖ LEED Homes: Homes and Multifamily Lowrise ❖ LEED Homes: Multifamily Midrise	❖ LEED ID+C: Commercial Interiors ❖ LEED ID+C: Retail ❖ LEED ID+C: Hospitality	❖ LEED O+M: Existing Buildings ❖ LEED O+M: Data Centers ❖ LEED O+M: Warehouses and Distribution Centers ❖ LEED O+M: Hospitality ❖ LEED O+M: Schools ❖ LEED O+M: Retail	❖ LEED ND: Plan ❖ LEED ND: Build Project

LEADERSHIP IN ENERGY & ENVIRONMENTAL DESIGN
LEED
Project Rating Systems
BD+C
ID+C
O+M
ND
HOMES
Building Design and Construction
Interior Design and Construction
Building Operations and Maintenance
Neighborhood Development
Homes
Credit Categories
Integrative Process
Location and Transportation
Materials and Resources
Water Efficiency
Energy and Atmosphere
Sustainable Sites
Indoor Environmental Quality
Innovation
Regional Priority Credits
1 CHOOSE
2 REGISTER
3 SUBMIT
4 REVIEW
5 CERTIFY
1 CHOOSE
2 REGISTER
3 SUBMIT
4 REVIEW
5 CERTIFY
LEED certification involves five primary steps
1 Determine which rating system you will use and prepare your certification application. Applications differ depending on your building type and the LEED credits you decide to pursue.
2 Register your project. The registration fee for a project is $900 for USGBC members and $1200 for non-members.
3 Submit your certification application and pay a certification review fee. Fees differ with building type and square footage.
4 Await the application review. Review processes differ slightly for each building type.
5 Receive the certification decision, which you can either accept or appeal. An affirmative decision signifies that your building is now LEED certified.
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BEPAC

- Building Environmental Performance Assessment Criteria (BEPAC) is the first comprehensive method in Canada for evaluating the environmental performance of both new and existing office buildings. BEPAC is comprised of a comprehensive set of environmental criteria, structured in five major topics: Ozone Layer Protection, Environmental Impacts of Energy Use, Indoor Environmental Quality, Resource Conservation and Site and Transportation. The credited criteria of BEPAC are organized within four modules. These modules are designed differently for the Base Building and Tenancies. Design and Management are addressed at both levels. Each module addresses the five topic areas. BEPAC criteria begin where average practice and codes leave off. The standards set in BEPAC are those which are consistent with best practice today and will lead industry towards more environmentally responsive practice in the future.

GRIHA

http://www.grihaindia.org/static/Griha%20Rating%20Booklet_Dec12.pdf

GRIHA RATINGS

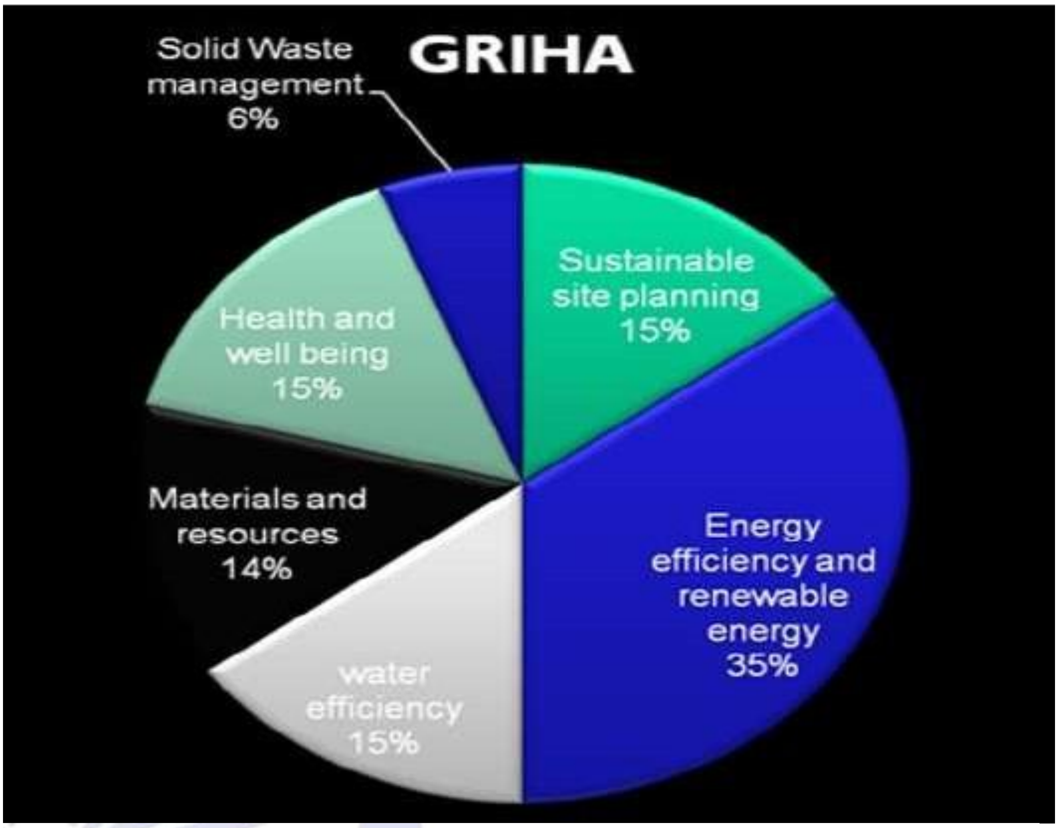
GRIHA-Green Rating for Integrated Habitat Assessment

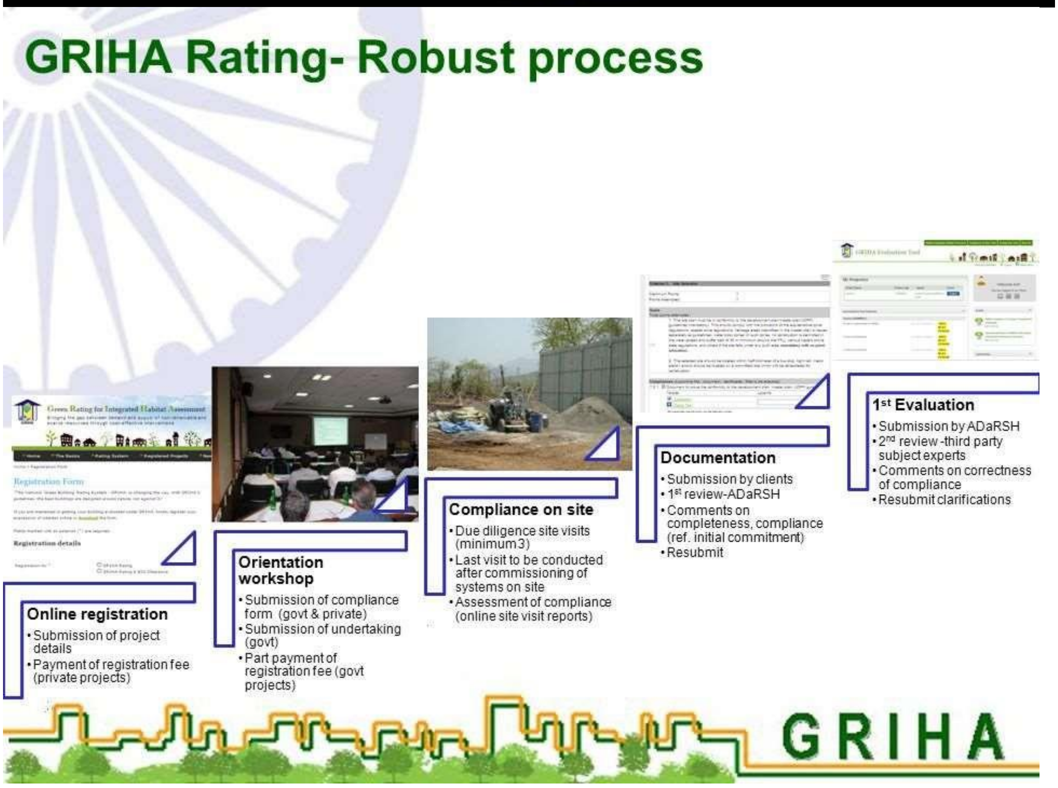
Tool to facilitate design, construction, operation of a green building ,and in turn ....measure "greenness" of a building in India

Highlights:

Set of 34 criteria

- **100 (+4 innovation points)**
- **Point system with differential weightage on various criteria (star-rating system)**
- **51 – 60** ☆
- **61 - 70** ☆ ☆
- **71 - 80** ☆ ☆ ☆
- **81- 90** ☆ ☆ ☆ ☆
- **91- 100** ☆ ☆ ☆ ☆ ☆


GRIHA
Solid Waste management 6%
Sustainable site planning 15%
Energy efficiency and renewable energy 35%
water efficiency 15%
Materials and resources 14%
Health and well being 15%


GRIHA Rating- Robust process
Online registration
• Submission of project details
• Payment of registration fee (private projects)
Orientation workshop
• Submission of compliance form (govt & private)
• Submission of undertaking (govt)
• Part payment of registration fee (govt projects)
Compliance on site
• Due diligence site visits (minimum3)
• Last visit to be conducted after commissioning of systems on site
• Assessment of compliance (online site visit reports)
Documentation
• Submission by clients
• 1st review-ADaRSH
• Comments on completeness, compliance (ref. initial commitment)
• Resubmit
1st Evaluation
• Submission by ADaRSH
• 2nd review -third party subject experts
• Comments on correctness of compliance
• Resubmit clarifications
GRIHA

GREEN BUILDINGS

- Sustainable Sites (SS)
- Water Efficiency (WE)
- Energy & Atmosphere (EA)
- Materials & Resources (MR)
- Indoor Environmental Quality (IEQ)
- Innovation in Design Process(ID)
- Regional Priority(RP)

Source:
IGBC – Indian Green Building Council

IGBC

Rating	New Construction
Certified	40-49
Silver	50-59
Gold	60-79
Platinum	80 & Above

IGBC Certification Process