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SCHOOL OF BUILDING AND ENVIRONMENT
DEPARTMENT OF CIVIL ENGINEERING

UNIT – I - INTRODUCTION TO CLIMATE AND ORIENTATION - SCIA1202

Weather:

Weather only describes the particular day‘s surrounding environment atmosphere conditions of these variables in a given region. **Ex:** Temperature, rainfall, humidity, sky condition

Weather has only limited predictability. Meso scale convective systems are predictable over a period of hours only; Synoptic scale cyclones may be predictable over a period of several days to a week. Beyond a week or two individual weather systems are unpredictable.

Climate:

Climate is the average weather in a place over many years usually over a 30-year interval. It is measured by assessing the patterns of variation in temperature, humidity, atmospheric pressure, wind, precipitation, atmospheric particle count and other meteorological variables in a given region over long periods of time. Climate varies from place to place, depending on latitude distance to the sea, vegetation, presence or absence of mountains or other geographical factors.

Climate varies also in time, from season to season, year to year, decade to decade or on much longer time-scales as the Ice Age. Statistically significant variations of the mean state of the climate or of its variability, typical persisting for decades or longer are referred to as ―Climate change‖

FACTORS THAT DETERMINE CLIMATE:

Air temperature: ^{0}C

Air temperature is a measure of the energy of motion of the air‘s gas molecules. The factors most responsible for the heating and cooling of the atmosphere are radiation arriving from the sun and radiation flowing from earth. The air is made up of individual molecules just like any other physical material. When exposed warm or hot temperatures, these molecules expand as they dry out. When this happens, the air becomes less able to hold moisture or water vapors. When air becomes cold, its molecules contract, which allow them to better hold onto moisture. As a result rain, sleet or snow occurs when the temperature are cooler, while hot dry air produces little to no precipitation.

Wind near the surface of the earth:

Monsoon winds are good examples as they affect the climate of the countries over which they blow. Monsoons are sudden seasonal reversals in wind direction. They bring heavy rain. The strongest monsoons occur in southern Asia, Australia and Africa.

The climates of these countries are affected by these monsoons as heavy rain occurs during the monsoon period. The global winds (particularly, Hadley cell, ferner cell and Polar cell) regulate the global weather, help in moving the ocean currents which affect the climate of many countries and sometimes signal an El Nino formation which also affect the climate of many continents.

Precipitation: mm

Changes in rainfall and other forms of precipitation will be one of the most critical factors determining the overall impact of climate change. Rainfall is much more difficult to predict than temperature but there are some statements that scientists can make with confidence about the future. A warmer atmosphere can hold more moisture, and globally water vapour increases by 7% for every degree centigrade of warming.

There's evidence to show that regions that are already wet are likely to get wetter, but details on how much wetter and what impacts there will be on a local scale are more difficult to ascertain. The dry regions of the subtropics are likely to get drier and will shift towards the poles. For much of Europe, wetter winters are expected, but with drier summers over central and southern Europe.

It is likely that in a warmer climate heavy rainfall will increase and be produced by fewer more intense events. This could lead to longer dry spells and a higher risk of floods. So far, any impact that climate change may have had generally on regional rainfall cannot be distinguished from natural variations. However, for some specific cases a signal is starting to emerge.

Humidity: %

Humidity is the amount of water vapor in the air and can be described in different ways. Humidity is a key player in the weather.

Water vapor in the air, the humidity, plays an important part in global climate. Like carbon dioxide, water vapor is a greenhouse gas. Climate scientists have found that carbon- dioxide human activities is adding to the air is causing the Earth's average climate to warm. This, in turn, is almost surely affecting other aspects of global climate, and could have even bigger effects in the future.

As the climate warms, the humidity can increase. Since water vapor is a greenhouse gas, it should increase warming as it increases. Measuring how much global humidity is increasing and figuring out how it will increase, and the effects of such an increase are major challenges for climate scientists. (**Related: NASA report on warming and humidity)**

Absolute humidity (AH): is the mass of water vapor divided by the mass of dry air in a volume of air at a given temperature. The hotter the air is, the more water it can contain.

Relative humidity (RH): is the ratio of the current absolute humidity to the highest possible absolute humidity (which depends on the current air temperature). A reading of 100 percent relative humidity means that the air is totally saturated with water vapor and cannot hold any more, creating the possibility of rain. This doesn't mean that the relative humidity must be 100 percent in order for it to rain -- it must be 100 percent where the clouds are forming, but the relative humidity near the ground could be much less.

Wet bulb temperature (WBT): The lowest temperature that can be obtained by evaporating water into the air at constant pressure. The name comes from the technique of putting a wet cloth over the bulb of a mercury thermometer and then blowing air over the cloth until the water evaporates. Since evaporation takes up heat, the thermometer will cool to a lower temperature than a thermometer with a dry bulb at the same time and place. Wet bulb temperatures can be used along with the dry bulb temperature to calculate dew point or relative humidity.

Dry Bulb Temperature (DBT): The temperature of the air measured by the ordinary thermometer is called as the dry bulb temperature of air.

Cloud type and amount:

Climates have always been signs of the weather to come. Scattered white cumulus clusters sailing across a field of blue promise a dry summer afternoon. Massive dark thunderheads portend crop-damaging wind and rain. A blanket of light gray signals a temperate winter's night. A high sheet of see-through wisps signals a change in the weather tomorrow or the next day.

Their most important roles in climate are to modulate Earth's basic radiation balance and to produce precipitation. The law of conservation of energy requires that the energy absorbed by the Earth from the sun balance the energy radiated by the Earth back into space. Clouds both reflect incoming sunlight and inhibit the radiation of heat radiation from the surface, thereby affecting both sides of the global energy balance equation.

Clouds also produce precipitation from water vapor, releasing heat to the atmosphere in the process (evaporation of water vapor from the surface cools it, so that these two processes serve to transfer heat from the surface to the atmosphere). Thus, any changes in clouds will modify the radiative energy balance and water exchanges that determine the climate. The trouble is that clouds are produced by the climate, specifically the atmospheric motions (winds) that are produced by the radioactive and latent heating influenced by clouds. This connected loop of relations is called a feedback loop. The ways that clouds respond to changes in the climate are so complex that it is hard to determine their net effect on the energy and water balances and to determine how much climate might change.

Solar radiation:

Solar radiation powers the climate system. There are three fundamental ways to change the radiation balance of the Earth:

1. by changing the incoming solar radiation (e.g., by changes in Earth‘s orbit or in the Sun itself);
2. by changing the fraction of solar radiation that is reflected (called _albedo‘; e.g., by changes in cloud cover, atmospheric particles or vegetation); and

3. by altering the long wave radiation from Earth back towards space (e.g., by changing greenhouse gas concentrations).

Climate, in turn, responds directly to such changes, as well as indirectly, through a variety of feedback mechanisms.

Because the Earth is a sphere, more solar energy arrives for a given surface area in the tropics than at higher latitudes, where sunlight strikes the atmosphere at a lower angle. Energy is transported from the equatorial areas to higher latitudes via atmospheric and oceanic circulations, including storm systems. Energy is also required to evaporate water from the sea or land surface, and this energy, called latent heat, is released when water vapor condenses in clouds (see Figure 1).

Atmospheric circulation is primarily driven by the release of this latent heat. Atmospheric circulation in turn drives much of the ocean circulation through the action of winds on the surface waters of the ocean, and through changes in the ocean‘s surface temperature and salinity through precipitation and evaporation.

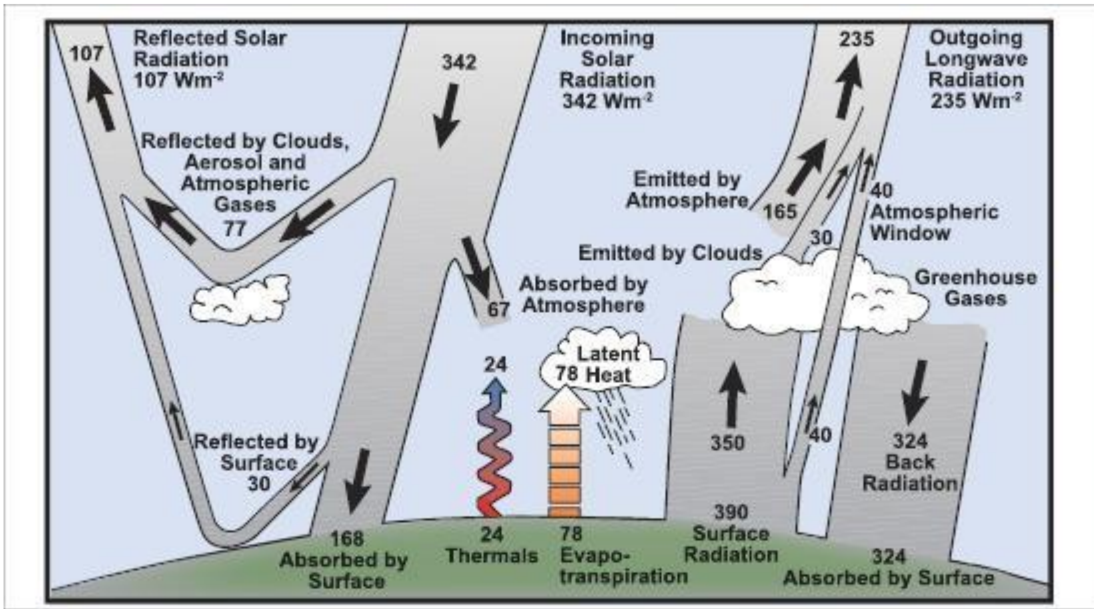


Figure 1 Solar Radiation

Structure of the Earth/Tilt of the Earth's Axis:

In early January each year, Earth reaches its closest distance to sun. At this time, the northern hemisphere experiences winter while the southern hemisphere experiences summer. The Earth travels to its farthest point from the sun at the beginning of July each year, when it is summer in the Northern Hemisphere and winter in the Southern Hemisphere.

While it is true that Earth does have a perihelion, or point at which it is closest to the sun, and an aphelion, its farthest point from the sun, the difference between these distances is too minimal as to have any significant impact on the Earth‘s seasons and climate

it‘s easy to figure out that the Earth‘s orbit around the sun is not so much elliptical (oval) as it is circular, and that the Earth‘s distance from the sun remains relatively constant throughout its annual orbit.

The Earth is constantly changing its position with the sun. That‘s because the Earth tilts in relation to the sun. That is what creates the differences in the seasons and the annual warming and cooling cycles of the Earth‘s Northern and Southern Hemispheres.

The Earth is tilted 23.5 degrees on its axis, a straight line through the planet from the North Pole to the South Pole. The Earth spins around, or rotates, on this axis as it orbits the sun. The key here is that as the Earth orbits the sun, different regions on Earth tilt both towards and away from the sun, depending on the region‘s respective hemisphere. This causes the sun‘s light and energy to hit the different regions of the Earth at different angles throughout the course of one orbit, or one full year.

Earth‘s coldest temperature averages about minus 60°F (-45°F to -97°F) and its hottest temperature averages about 130°F-plus. While these extremes make most life impossible to naturally exist or thrive, they occur only in remote areas of the planet, such as the Antarctic (coldest average temperatures) or the Sahara Desert (hottest). Still, these temperatures are relatively warm (or cool) compared to other planets..

Atmospheric circulation:

THE HYDROLOGIC SYSTEM includes the entire cycle (hydrologic cycle) of water movement on the Earth (be it on the surface or in the air). The driving force behind this cycle is the energy input from the sun.

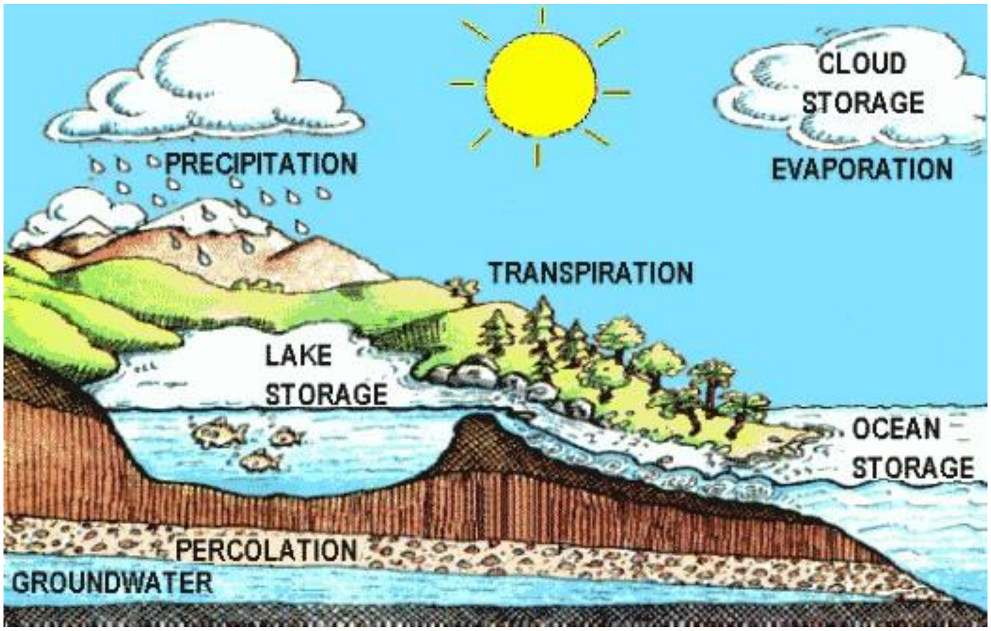


Figure-2 as shown in above diagram shows the various pathways of (1) water to the oceans (rivers, glaciers, precipitation); (2) water into the atmosphere by evaporation (from falling rain, rivers & lakes, soil, the oceans, transpiration by plants); and (3) onto the landmasses (by rain, snow). Water movement/transport occurs through movement of clouds, by rivers, ocean circulation, groundwater flow, and evaporation.

The bulk of the water is contained in the oceans, which contain about 30000 times more water than atmosphere and continents combined, cover approximately 70% of the Earth's surface and are on average 3800 m deep. The remainder of the water is found in ice caps & glaciers (3%), groundwater (1%), and rivers and lakes (0.01%). The latter two reservoirs constitute the terrestrial fresh water supply. Thus, only a very small fraction of the overall water supply is suitable and available for human use. The water transfer between these reservoirs is accomplished by the processes of evaporation, transpiration, precipitation, and flow of water (following gravity).

Every year about 30000 to 40000 cubic kilometers (a cube 30-35 km in size) of water move across the surface of the continents to the oceans, profoundly shaping the surface of the continents. Evaporation by the sun effects lifting of water into the atmosphere, and the counterforce to this process is gravity that forces rain to fall back on the earth and causes water move back to the oceans in streams (river systems), on the way eroding soils, cutting canyons, and transporting solids (silt, sand, clay) and dissolved salts to the oceans. The transfer of water vapor from the oceans to the atmosphere goes hand in hand with the transfer of tremendous amounts of thermal energy to the atmosphere and is very important for atmospheric circulation (see below). For this reason atmospheric circulation and winds can be considered part of the hydrologic cycle.

<u>COMPONENTS OF CLIMATE</u>:

Its components

The climate system is an interactive system consisting of five major components:

1. The atmosphere,
2. The hydrosphere,
3. The cryosphere,
4. The land surface and
5. The biosphere (forced or influenced by various external forcing mechanisms, the most important of which is the Sun)

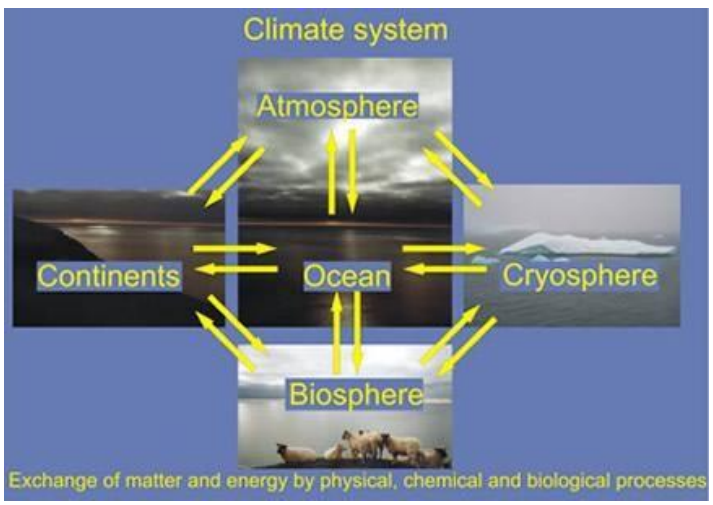


Figure-3 Components of Climate

1. The atmosphere:

The *atmosphere* is the most unstable and rapidly changing part of the system. Its composition, which has changed with the evolution of the Earth, is of central importance to the problem assessed in this Report. The Earth‘s dry atmosphere is composed mainly of nitrogen (N_2, 78.1% volume mixing ratio), oxygen (O_2, 20.9% volume mixing ratio, and argon (Ar, 0.93% volume mixing ratio). These gases have only limited interaction with the incoming solar radiation and they do not interact with the infrared radiation emitted by the Earth.

However there are a number of trace gases, such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and ozone (O_3), which do absorb and emit infrared radiation. These so called greenhouse gases, with a total volume mixing ratio in dry air of less than 0.1% by volume, play an essential role in the Earth‘s energy budget.

Moreover the atmosphere contains water vapour (H_2O), which is also a natural greenhouse gas. Its volume mixing ratio is highly variable, but it is typically in the order of 1%. Because these greenhouse gases absorb the infrared radiation emitted by the Earth and emit infrared radiation up- and downward, they tend to raise the
temperature near the Earth‘s surface.

Water vapour, CO_2 and O_3 also absorb solar short-wave radiation. The atmospheric distribution of ozone and its role in the Earth‘s energy budget is unique. Ozone in the lower part of the atmosphere, the troposphere and lower stratosphere, acts as a greenhouse gas. Higher up in the stratosphere there is a natural layer of high ozone concentration, which absorbs solar ultra-violet radiation.

2. The Hydrosphere:

The hydrosphere is the component comprising all liquid surface and subterranean water, both fresh water, including rivers, lakes and aquifers, and saline water of the oceans and seas. Fresh water runoff from the land returning to the oceans in rivers influences the ocean‘s composition and circulation.

The oceans cover approximately 70% of the Earth‘s surface. They store and transport a large amount of energy and dissolve and store great quantities of carbon dioxide. Their circulation, driven by the wind and by density contrasts caused by salinity and thermal gradients (the so- called thermohaline circulation), is much slower than the atmospheric circulation.

Mainly due to the large thermal inertia of the oceans, they damp vast and strong temperature changes and function as a regulator of the Earth‘s climate and as a source of natural climate variability, in particular on the longer time-scales.

3. The Cryosphere:

The cryosphere, including the ice sheets of Greenland and Antarctica, continental glaciers and snow fields, sea ice and permafrost, derives its importance to the climate system from its high reflectivity (albedo) for solar radiation, its low thermal conductivity, its large thermal inertia and, especially, its critical role in driving deep ocean water circulation. Because the ice sheets store a large amount of water, variations in their volume are a potential source of sea level variations

4. The land surface:

Vegetation and soils at the land surface control how energy received from the Sun is returned to the atmosphere. Some is returned as long-wave (infrared) radiation, heating the atmosphere as the land surface warms. Some serves to evaporate water, either in the soil or in the leaves of plants, bringing water back into the atmosphere. Because the evaporation of soil moisture requires energy, soil moisture has a strong influence on the surface temperature.

The texture of the land surface (its roughness) influences the atmosphere dynamically as winds blow over the land‘s surface. Roughness is determined by both topography and vegetation. Wind also blows dust from the surface into the atmosphere, which interacts with the atmospheric radiation.

5. The biosphere

The marine and terrestrial biospheres have a major impact on the atmosphere‘s composition. The biota influence the uptake and release of greenhouse gases. Through the photosynthetic process, both marine and terrestrial plants (especially forests) store significant amounts of carbon from carbon dioxide. Thus, the biosphere plays a central role in the carbon cycle, as well as in the budgets of many other gases, such as methane and nitrous oxide.

Other biosphere emissions are the so-called volatile organic compounds (VOC) which may have important effects on atmospheric chemistry, on aerosol formation and therefore on climate. Because the storage of carbon and the exchange of trace gases are influenced by climate, feedbacks between climate change and atmospheric concentrations of trace gases can occur.

The influence of climate on the biosphere is preserved as fossils, tree rings, pollen and other records, so that much of what is known of past climates comes from such biotic indicators.

Interactions among the components:

Many physical, chemical and biological interaction processes occur among the various components of the climate system on a wide range of space and time scales, making the system extremely complex. Although the components of the climate system are very different in their composition, physical and chemical properties, structure and behavior, they are all linked by fluxes of mass, heat and momentum: all subsystems are open and interrelated.

As an example, the atmosphere and the oceans are strongly coupled and exchange, among others, water vapour and heat through evaporation. This is part of the hydrological cycle and leads to condensation, cloud formation, precipitation and runoff, and supplies energy to weather systems. On the other hand, precipitation has an influence on salinity, its distribution and the thermohaline circulation. Atmosphere and oceans also exchange, among other gases, carbon dioxide, maintaining a balance by dissolving it in cold polar water which sinks into the
deep ocean and by out gassing in relatively warm upwelling water near the equator.

Some other examples: sea ice hinders the exchanges between atmosphere and oceans; the biosphere influences the carbon dioxide concentration by photosynthesis and respiration, which in turn is influenced by climate change.

The biosphere also affects the input of water in the atmosphere through evapotranspiration, and the atmosphere‘s radioactive balance through the
amount of sunlight reflected back to the sky (albedo).

<u>SITE CLIMATE:</u>

Site climate conditions are usually estimated based on historical weather data and computer models. The term "site climate" is also used to describe local climate at a research site, such as a field research station.

The term "site climate" is used mainly in the wind energy industry to describe typical variations in wind speed and potential power output at a current or planned wind generator site.

Local factors which affect the site climate:

Many factors influence site climate, such as the surrounding topography, direction of exposure (if the site is on a hill, for example), and tree cover.

Topography:

It concerns with slope, orientation, exposure, elevations, hills or valley, at or near the site

Ground Surface:

The surface is with natural or man -made , its reflectance, permeability and the soil temperature, a s these affect vegetarian an d this in turn affects the climate.

Three Dimensional objects:

It is such as trees, or tree belts, fences, walls and buildings, as these may influence air movement, may cast at shadow and may sub-divide the area into smaller units with distinguishable climatic features.

Climate Classification

The **Köppen Climate Classification System** is the most widely used system for classifying the world's climates. Its categories are based on the annual and monthly averages of temperature and precipitation. The Köppen system recognizes five major climatic types; each type is designated by a capital letter.

A - **Tropical Moist Climates**: all months have average temperatures above 18° Celsius.

B - **Dry Climates**: with deficient precipitation during most of the year.

C - **Moist Mid-latitude** Climates with Mild Winters.

D - Moist Mid-Latitude Climates with Cold Winters.

E - **Polar Climates**: with extremely cold winters and summers.

Tropical Moist Climates (A)

Tropical moist climates extend northward and southward from the equator to about 15 to 25° of latitude. In these climates all months have average temperatures greater than 18° Celsius. Annual precipitation is greater than 1500 mm. Three minor Köppen climate types exist in the A group, and their designation is based on seasonal distribution of rainfall.

Af or tropical wet is a tropical climate where precipitation occurs all year long. Monthly temperature variations in this climate are less than 3° Celsius. Because of intense surface heating and high humidity, cumulus and cumulonimbus clouds form early in the afternoons almost every day. Daily highs are about 32° Celsius, while night time temperatures average 22° Celsius.

Am is a tropical monsoon climate. Annual rainfall is equal to or greater than Af, but most of the precipitation falls in the 7 to 9 hottest months. During the dry season very little rainfall occurs.

The tropical wet and dry or savanna (Aw) has an extended dry season during winter. Precipitation during the wet season is usually less than 1000 millimeters, and only during the summer season.

Dry Climates (B)

The most obvious climatic feature of this climate is that potential evaporation and transpiration exceed precipitation. These climates extend from 20 - 35° North and South of the equator and in large continental regions of the mid-latitudes often surrounded by mountains.

Minor types of this climate include:

BW - dry arid (desert) is a true desert climate. It covers 12% of the Earth's land surface and is dominated by xerophytic vegetation. The additional letters h and k are used generally to distinguish whether the dry arid climate is found in the subtropics or in the mid-latitudes, respectively.

BS - dry semiarid (steppe). Is a grassland climate that covers 14% of the Earth's land surface. It receives more precipitation than the BW either from the intertropical convergence zone or from mid-latitude cyclones. Once again, the additional letters h and k are used generally to distinguish whether the dry semiarid climate is found in the subtropics or in the mid-latitudes, respectvely.

Moist Subtropical Mid-Latitude Climates (C)

This climate generally has warm and humid summers with mild winters. Its extent is from 30 to 50°

of latitude mainly on the eastern and western borders of most continents. During the winter, the main weather feature is the mid-latitude cyclone. Convective thunderstorms dominate summer months.

Three minor types exist:

Cfa - humid subtropical; **Cs** - Mediterranean; and **Cfb** - marine.

Moist Continental Mid-latitude Climates (D)

Moist continental mid-latitude climates have warm to cool summers and cold winters. The location of these climates is pole ward of the C climates. The average temperature of the warmest month is greater than 10° Celsius, while the coldest month is less than -3° Celsius. Winters are severe with snowstorms, strong winds, and bitter cold from Continental Polar or Arctic air masses. Like the C climates there are three minor types: Dw - dry winters; Ds - dry summers; and Df - wet all seasons.

Polar Climates (E)

Polar climates have year-round cold temperatures with the warmest month less than 10° Celsius. Polar climates are found on the northern coastal areas of North America, Europe, Asia, and on the landmasses of Greenland and Antarctica.Two minor climate types exist.

ET or ***polar tundra*** is a climate where the soil is permanently frozen to depths of hundreds of meters, a condition known as permafrost. Vegetation is dominated by mosses, lichens, dwarf trees and scattered woody shrubs.

EF or ***polar ice caps*** has a surface that is permanently covered with snow an

ice. Climatic Region Descriptions

The following discussion organizes the climatic regions of the world into eight different groups. Categorization of these climates is based on their Köppen classification and seasonal dominance of air masses.

Tropical Wet, Tropical Wet and Dry, Subtropical Desert and Steppe, Mid-Latitude Desert and Steppe, Mid-Latitude Wet, Mid-Latitude Winter-Dry, Mid-Latitude Summer-Dry, Polar Tundra & Polar Ice Cap

CHARACTERISTICS OF DIFFERENT CLIMATES

Warm-humid climate

Hot-dry desert, or semi-desert climate — subgroup: hot-dry maritime desert climate
Composite or monsoon climate (combination of 1 and 2) — subgroup: tropical upland climate
These groups are referred to throughout the text. Detailed description of each zone is given below

Warm-humid climates are found in a belt near the Equator extending to about 15°N. and S. Examples of cities in this zone: Lagos, Dar-es-Salam, Mombasa, Colombo, Singapore, Jakarta, Quito and Pernambuco. Figure 18 shows a climate, graph for Mombasa.

There is very little seasonal variation throughout the year, the only punctuation being that of periods with more or less rain and the occurrence of gusty winds and electric storms.

Air temperature, i.e. DBT, in the shade reaches a mean maximum during the day of between 27 and 32°C, but occasionally it may exceed the latter value. At night the mean minimum varies between 21 and 27°C. Both the diurnal and annual ranges of temperature are quite narrow. Humidity, i.e. RH, remains high, at about 75% for most of the time, but it may vary from 55 to almost 100%. Vapor pressure is steady in the region of 2500 to 3000 N/m^2.

Precipitation is high throughout the year, generally becoming more intense for several consecutive months. Annual rainfall can vary from 2000 to 5000 mm and may exceed 500 mm in one month, the wettest month. During severe storms rain may fall at the rate of 100 mm/h for short periods.

Sky conditions are fairly cloudy throughout the year. Cloud cover varies between 60 and 90% Skies can be bright, a luminance of 7000 cd/m^2 or even more when it is thinly overcast, or when the sun illuminates white cumulus clouds without itself being obscured. When heavily overcast, the sky is dull, 850 cd/m^2 or less.

Solar radiation is partly reflected and partly scattered by the cloud blanket or the high vapor content of the atmosphere, therefore the radiation reaching the ground is diffuse, but strong, and can cause painful sky glare. Cloud and vapor content also prevents or reduces outgoing radiation from the earth and sea to the night sky, thus the accumulated heat is not readily dissipated. Wind velocities are typically low, calm periods are frequent, but strong winds can occur during rain squalls. Gusts of 30 m/s have been reported. There are usually one or two dominant directions.

Vegetation grows quickly due to frequent rains and high temperatures and it is difficult to control. The red or brown laterite soils are generally poor for agriculture. Plant-supporting organic substances and mineral salts are dissolved and washed away by rain-water. The subsoil

water table is usually high and the ground may be waterlogged. Little light is reflected from the ground. Special characteristics: high humidity accelerates mould and algal growth, rusting and rotting. Organic building materials tend to decay rapidly. Mosquitoes and other insects abound. The thunder-storms are accompanied by frequent air-to-air electrical discharges.

Warm-humid island climate

Islands within the equatorial belt and in the trade-winds zone belong to this climate type. Typical examples are the Caribbeans, the Philippines and other island groups in the Pacific Ocean.

Seasonal variations are negligible.

Air temperature, i.e. DBT, in the shade reaches a day-time mean maximum between 29 and 32°C and rarely rises above skin temperature. Night-time mean minima can be as low as 18°C, but it is normally between this figure and 24°C. The diurnal range is rarely more than 8 degC and the annual range is only about 14 degC. Humidity, i.e. the RH, varies between 55 and almost 100%, the vapour pressure being between 1 750 and 2 500 N/m^2.

Hot-dry desert climate

Precipitation is high, 1250 to 1800 mm per annum, and 200 to 250 mm in the 27 wettest month. Up to 250 mm may fall in a single storm of a few hours' duration. Spray is driven nearly horizontally on windward coasts.

Sky conditions are normally clear or filled with white broken clouds of high brightness, except during storms, when the skies are dark and dull. Clear blue skies are of low luminance, between 1700 and 2500 cd/m^2. Solar radiation is strong and mainly direct, with a very small diffuse component when the sky is clear, but varies with the cloud cover. Winds: the predominant trade-wind blows at a steady 6 to 7 m/s and provides relief from heat and humidity. Much higher velocities occur during cyclones (see below).

Vegetation is less luxuriant and of a lighter green colour than in the warm-humid zones. It varies with the rainfall. Sunlight reflected from light colored coral, sand and rock can be very bright. The soil is often dry with a fairly low water-table.

Special characteristics are the tropical cyclones or hurricanes with wind veloci-ties from 45 to 70 m/s, which constitute a serious seasonal hazard the high salt content of the atmosphere encourages corrosion in coastal areas. These climates occur in two belts at latitudes between approximately 15 and 30° north and south of the Equator. Examples of settlements in this zone: Assuan, Baghdad, Alice Springs, and Phoenix. Figure 19 shows a climate graph for the last-named.

Two marked seasons occur: a hot and a somewhat cooler period. Air temperature, i.e. DBT, in the shade rises quickly after sunrise to a day-time mean maximum of 43 to 49°C. The ever-recorded maximum temperature of 58°C was measured in Libya in 1922. During the cool season the mean maximum temperature ranges from 27 to 32"C. Night-time mean minima are between 24 and 30"C in the hot season and between 10 and 18'C in the cool season. The diurnal range is very great: 17 to 22 degC.

Humidity, i.e. the RH, varies from 10 to 55%, as the wet-bulb depression is large (rapid evaporation). The vapour pressure is normally between 750 and 1 500 $N/m^{2.}$ Precipitation is slight and variable throughout the year, from 50 to 155 mm per annum. Flash- storms may occur over limited areas with as much as 50 mm rain in a few hours, but some regions may not have any rain for several years.

Sky conditions are normally clear. Clouds are few due to the low humidity of the air. The sky is usually dark blue, with a luminance of 1700 to 2500 cd/m^2. and further darkened during dust or sand-storms to 850 cd/m^2 or even less. Towards the end of the hot period, dust suspended in the air may create a white haze, with a luminance of 3500 to 10000 cd/m^2, which produces a diffuse light and a painful glare. Solar radiation is direct and strong during the day, but the absence of cloud permits easy release of the heat stored during the day-time in the form of long-wave radiation towards the cold night sky. Diffuse radiation is only present during dust haze periods.

Winds are usually local. The heating of air over the hot ground causes a tempera-ture inversion, and as the lower warm air mass breaks through the higher cooler air, local whirlwinds are often created. Winds are hot, carrying dust and sand — and often develop into dust-storms.

Vegetation is sparse and difficult to maintain because of the lack of rain and low humidities. The soil is usually dusty and very dry. Strong sunlight illuminating a highly reflective light coloured and dry ground can create a luminance of 20000 to 25000 cd/m^2. Soils dry quickly after rain and would generally be fertile if irrigated. The subsoil water-table is very low.

Special characteristics: during certain months dust and sand-storms may he frequent. The high day-time temperatures and rapid cooling at night may cause materials to crack and break up.

Hot-dry maritime desert climate

Maritime desert climates occur in the same latitude belts as the hot-dry desert climates, where the sea adjoins a large land mass. These are regarded to be amongst the most unfavorable climates of the earth. Typical examples are Kuwait, Anto-fagasta and Karachi.

There are two seasons: a hot one and somewhat cooler one.

Air temperature, i.e. DBT, in the shade reaches a day-time mean maximum of about 38°C, but in the cool season it remains between 21 and 26°C. The night-time mean minimum temperatures of the hot season range from 24 to 30°C and of the cool season from 10 to 18 °C. The diurnal mean range varies between 9 and 12 degC, the larger diurnal variation occurring during the cool season.

Humidity, i.e. the RH, is steadily high, between 50 and 90%, with vapour pressures of 1500 to 2500 N/m^2, as the strong solar radiation causes strong evaporation from the sea. The moisture is, however, not precipitated but remains suspended in the air, creating intensely uncomfortable conditions.

Precipitation, as in other desert regions, is very low.

Sky conditions are as for hot-dry desert climates, a little more cloud may occur in the form of a thin, transparent haze, which is likely to cause glare.

Solar radiation is strong, with a higher diffuse component than in desert climates, due to the thin clouds and suspended moisture.

Winds are mostly local, coastal winds, caused by the unequal heating and cooling of land and sea surfaces. These tend to blow off the sea towards the land during the day and in the reverse direction during the night.

Vegetation is sparse, not more than some dry grass. The ground and rocks are brown or red; it is dry and dusty throughout the year. Ground glare can be intense.

Special characteristics: dust and sand-storms may occur. The salt laden atmosphere accelerates corrosion.

Composite or monsoon climate

These climates usually occur in large land masses near the tropics of Cancer and Capricorn, which are sufficiently far from the Equator to experience marked seasonal changes in solar radiation and wind direction. Examples of cities with composite climates: Lahore, Mandalay, Asuncion, Kano and New Delhi. The latter is shown as an example in Figure 20.

Two seasons occur normally. Approximately two-thirds of the year is hot-dry and the other third is warm-humid. Localities further north and south often have a third season, best described as cool-dry.

Air temperature, i.e. DBT, in the shade is as follows:

Seasons	hot-dry	warm-humid	cool-dry
Day-time mean max.	32-43°C	27-32°C	up to 27°C
Night-time mean min.	21-27°C	24-27°C	4-10°C
Diurnal mean range	11-22 degC	3-6 degC	11-22 degC

Humidity, i.e. the RH, is low throughout the dry periods at 20 to 55%, with a vapour pressure of 1300 to 1600 N/m^2. During the wet period it rises to 55 to 95%, with a vapour pressure of 2000 to 2500 N/m^2.

Precipitation: the monsoon rains are intense and prolonged; occasionally 25 to 38 mm can fall in an hour. Annual rainfall varies from 500 to 1300 mm with 200 to 250 mm in the wettest month. There is little or no rain during the dry seasons.

Sky conditions markedly vary with the seasons. The sky is heavily overcast and dull during the monsoons, and clear, with a dark blue colour, in the dry seasons. Towards the end of the hot-dry seasons the sky becomes brighter with frequent dust haze. The intensity of sky glare varies accordingly.

Solar radiation alternates between conditions found in the warm-humid and the hot-dry desert climates. Winds are hot and dusty during the dry period. Directional changes in the prevailing winds at the beginning of the warm-humid season bring rain-clouds and humid air from the sea. Monsoon winds are fairly strong and steady.

Tropical upland climate

Vegetation, which is sparse — characteristic of a hot-dry region — with brown and red barren ground, changes rapidly and dramatically with the rain. The landscape becomes green and fertile within a few days. Plants grow quickly. In the cooler period vegetation covers the ground, but diminishes as the temperature rises. The soil is damp during the rains but it dries out quickly. There is a risk of soil erosion during monsoons. In the dry season strong ground glare may be experienced.

Special characteristics: seasonal changes in relative humidity cause rapid weakening of building materials. Dust and sand-storms may occur. Termites are common. Occasional condensation problems.

Mountainous regions and plateaux more than 900 to 1200 m above sea-level experience such climates, between the two 20°C isotherms. Examples of cities in such regions: Addis Ababa, Bogota, Mexico City and Nairobi.

Seasonal variations are small in upland climates near the Equator, but when further away from the Equator, the seasons follow those of the nearby lowlands.

Air temperature, i.e. the DBT, in the shade decreases with altitude. At an altitude of 1800 m the day-time mean maxima may range from 24 to 30`C and the night-time mean minima are around 10 to 13°C. At some locations it may fall below 4°C and ground frost is not uncommon. The diurnal range is great. The annual range depends on latitude: at the Equator it is slight; but at the tropics of Cancer and Capricorn it may be 11 to 20 degC.

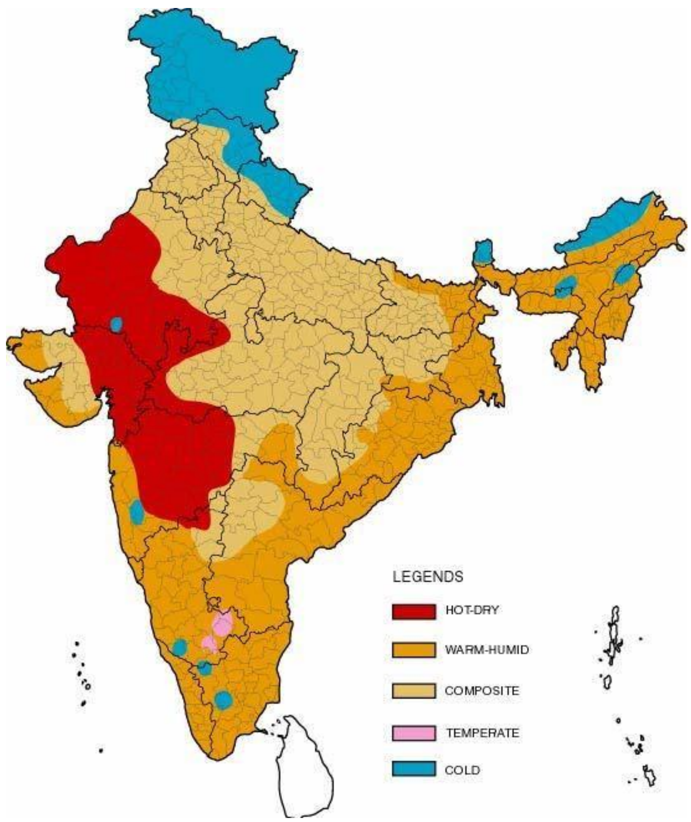
Humidity, i.e. the RH, varies between 45 and 99% and the vapour pressure between 800 and 1600 N/m^2. Precipitation is variable, but rarely less than 1000 mm. Rain often falls in heavy concentrated showers, reaching an intensity of 80 mm per hour.

Sky conditions are normally clear or partly cloudy, to the extent of about 40%. During the monsoon rains the sky is overcast — and the clouds are heavy and low. Solar radiation is strong and direct during the clear periods, stronger than at the same latitude, but at sea-level. Ultra-violet radiation especially is stronger than at lower altitudes. It becomes more diffuse as cloud cover increases.

Winds are variable, predominantly north-east and south-easterlies, but may be drastically deflected by local topography. Wind velocity rarely exceeds 15 m/s.

Vegetation is green although not very luxuriant during the wet season but it may wither in the dry season, when the ground can turn brown or red. The soil may be damp in the rains but dries quickly. Special characteristics: heavy dew at night. Strong radiation loss at night during the dry season, which may lead to the formation of radiation fog. Thunder-storms with a fair proportion of electric discharges — air to ground. Hail may also occur.

CLIMATIC ZONES IN INDIA



Source: National Building Code 2005, Part 8

Regions having similar characteristic features of climate are grouped under one climatic zone. According to a recent code of Bureau of Indian Standards, the country may be divided into five major climatic zones:

Hot & Dry (mean monthly temperature >30 and relative humidity <55%);

Warm & Humid (mean monthly temperature >25-30 and relative humidity >55-

75%); Temperate (mean monthly temperature 25-30 and relative humidity <75%);

Cold (mean monthly temperature <25 and relative humidity – all values);

Composite (This applies, when six months or more do not fall within any of the other categories).

Brief Description

Buildings in different climatic zones require different passive features to make structures energy- efficient. Some features that can be adopted in particular zones are listed below.

Introduction - Climatic Zones of India

Regions having similar characteristic features of climate are grouped under one climatic zone. According to a recent code of Bureau of Indian Standards, the country may be divided into five major climatic zones: Hot & Dry (mean monthly temperature >30 and relative humidity <55%); Warm & Humid (mean monthly temperature >25-30 and relative humidity >55-75%); Temperate (mean monthly temperature 25-30 and relative humidity <75%); Cold (mean monthly temperature <25 and relative humidity – all values); Composite (This applies, when six months or more do not fall within any of the other categories).

Brief Description

Buildings in different climatic zones require different passive features to make structures energy- efficient. Some features that can be adopted in particular zones are listed below.

Hot and dry

Hot & Dry (mean monthly temperature >30 and relative humidity <55%); The hot and dry zone lies in the western and the central part of India; Jaisalmer, Jodhpur and Sholapur are some of the towns that experience this type of climate.

In such a climate, it is imperative to control solar radiation and movement of hot winds. The design criteria should therefore aim at resisting heat gain by providing shading, reducing exposed area, controlling and scheduling ventilation, and increasing thermal capacity. The presence of ―water bodies‖ is desirable as they can help increase the humidity, thereby leading to lower air temperatures. The ground and surrounding objects emit a lot of heat in the afternoons and evenings. As far as possible, this heat should be avoided by appropriate design features.

Some of the design features for buildings in this climate are:

- ❖ Appropriate orientation and shape of building
- ❖ Insulation of building envelope
- ❖ Massive structure
- ❖ Air locks, lobbies, balconies, and verandahs
- ❖ Weather stripping and scheduling air changes
- ❖ External surfaces protected by overhangs, fins, and trees
- ❖ Pale colours and glazed china mosaic tiles
- ❖ Windows and exhausts
- ❖ Courtyards, wind towers, and arrangement of openings
- ❖ Trees, ponds, and evaporative cooling

Warm and humid

Warm & Humid (mean monthly temperature >25-30 and relative humidity >55-75%); The warm and humid zone covers the coastal parts of the country, such as Mumbai, Chennai and Kolkata. The main design criteria in the warm and humid region are to reduce heat gain by providing shading, and promote heat loss by maximizing cross ventilation. Dissipation of humidity is also essential to reduce discomfort.

Some of the design features for buildings in this climate are:

- ❖ Appropriate orientation and shape of building
- ❖ Roof insulation and wall insulation
- ❖ Reflective surface of roof
- ❖ Balconies and verandahs
- ❖ Walls glass surface protected by overhangs, fins, and trees
- ❖ Pale colours and glazed china mosaic tiles
- ❖ Windows and exhausts
- ❖ Ventilated roof construction, courtyards, wind towers, and arrangement of openings
- ❖ Dehumidifiers and desiccant cooling

Moderate

Temperate (mean monthly temperature 25-30 and relative humidity <75%);Pune and Bangalore are examples of cities that fall under this climatic zone. The design criteria in the moderate zone are to reduce heat gain by providing shading, and to promote heat loss by ventilation.

Some of the design features for buildings in this climate are:

- Appropriate orientation and shape of building
- Roof insulation and east and west wall insulation
- Walls facing east and west, glass surface protected by overhangs, fins, and trees
- Pale colours and glazed china mosaic tiles
- Windows and exhausts
- Courtyards and arrangement of openings

Cold

Cold (mean monthly temperature <25 and relative humidity – all values);

Generally, the northern part of India experiences this type of climate. The design criteria are to resist heat loss by insulation and controlling infiltration. Simultaneously, heat gain needs to be promoted by admitting and trapping solar radiation within the living space.

Some of the design features for buildings in this climate are:

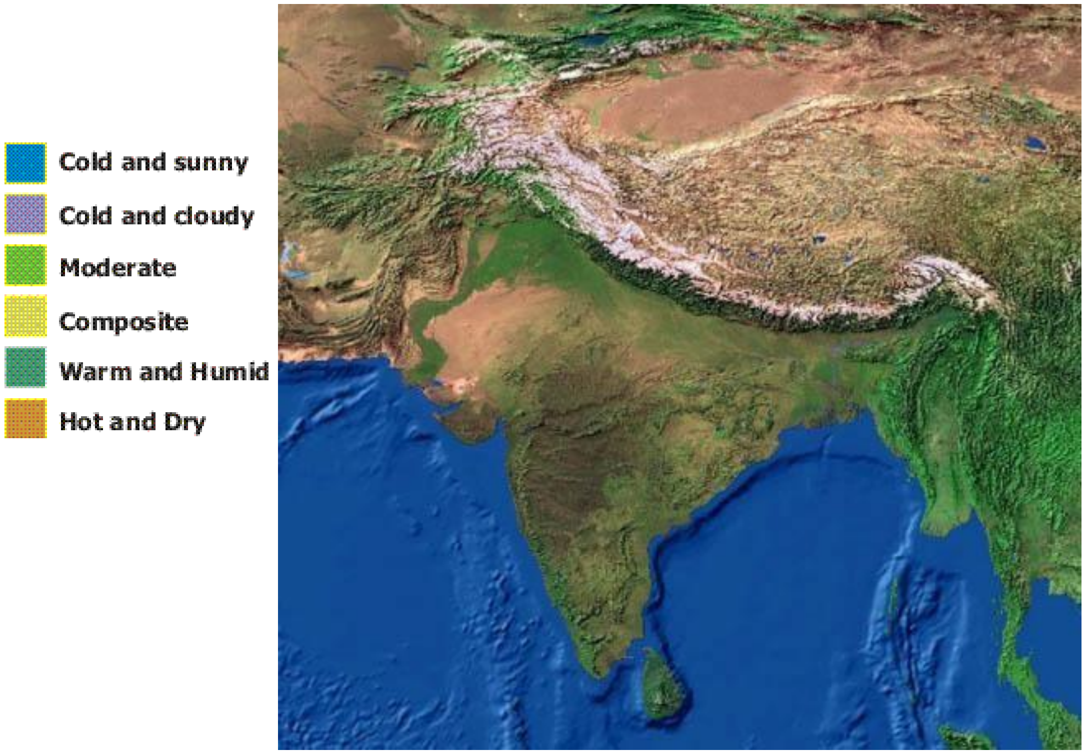
- Appropriate orientation and shape of building
- Use of trees as wind barriers
- Roof insulation, wall insulation, and double glazing
- Thicker walls
- Air locks and lobbies
- Weather stripping
- Darker colours
- Sun spaces, greenhouses and trombe walls

Composite

Composite (This applies, when six months or more do not fall within any of the other categories). The composite zone covers the central part of India, such as New Delhi, Kanpur and Allahabad. The design criteria are more or less the same as for hot and dry climate except that maximizing cross ventilation is desirable in the monsoon period.

Some of the design features for buildings in this climate are:

- Appropriate orientation and shape of building
- Use of trees as wind barriers
- Roof insulation and wall insulation
- Thicker walls
- Air locks and balconies
- Weather stripping
- Walls, glass surfaces protected by overhangs, fins, and trees
- Pale colours and glazed china mosaic tiles
- Exhausts
- Courtyards, wind towers, and arrangement of openings
- Trees and ponds for evaporative cooling
- Dehumidifiers and desiccant cooling



ORIENTATION:

Orientation refers to the position and direction of a building on site, with respect to the path of the sun. Orientation strongly relates a building to the natural environment— the sun, wind, weather patterns, topography, landscape, and views. Decisions made in site planning and building orientation will have impacts on the energy performance of the building over its entire life cycle.

Energy conservation strategies relating to building orientation are:

- Maximizing north and south façade exposure for daylight harvesting to reduce lighting electrical loads
- Using southern exposure for solar heat gain to reduce heating loads in the heating season*
- Using shading strategies to reduce cooling loads caused by solar gain on south façades*

Turning long façades toward the direction of prevailing breezes to enhance the cooling effect of natural ventilation

- Turning long façades in the direction parallel to slopes to take advantage of cool updrafts to enhance natural ventilation
- Shielding windows and openings from the direction of harsh winter winds and storms to reduce heating loads
- Orienting the most populated building spaces toward north and south exposures to maximize day lighting and natural ventilation benefit
- Determining building occupant usage patterns for public, commercial, institutional, or residential buildings, and how occupants will be affected by the building orientation, by time of day, on different exposures

FACTORS AFFECTING THE ORIENTATION:

The orientation of a building is influenced by following numerous environmental and built factors,

Sensory

- Thermal—solar exposure, wind direction, temperature
- Visual—varying daylight qualities in different locations and at different times of day
- Acoustical—direction of objectionable noises
- Environmental—smoke, dust, odors

Psychological

- Views
- Privacy
- Street activity

Local development patterns

- Street direction
- Spatial organization, land use, urban design
- Zoning
- Accessibility requirements—main/secondary entrances, parking

Other considerations

- Aesthetic
- Direction of storms
- Site conditions—topography, geotechnical, wetlands
- Site vegetation—mature trees
- View corridors, scenic easements

Designing for Building Orientation

- The designer must consider and prioritize all factors and site conditions affecting building orientation. For example, a building might have to take heed of multiple orientation factors depending on functional requirements: designing for cooling load or heating load. To take advantage of north–south day lighting, the building may be oriented along an east–west axis. But this may be counter to street lines and other site considerations. Orientation of the building entrance may have to respect street access, activity zones, and local urban design guidelines.
- For most regions, optimum façade orientation is typically south.* South-facing* glass is relatively easy to shade with an overhang during the summer to minimize solar heat gain. Light shelves also can work well with the higher sun in the southern exposure. North- facing* glass receives good daylight but relatively little direct isolation, so heat gain is less of a concern.
- East and west window orientations and horizontal orientation (skylights) all result in more undesired heat gain in the summer than winter. East and west sun glare is also more difficult to control for occupant comfort because of low sun angles in early morning and late afternoon.
- Wind will affect tall buildings more than low structures. Design for wind direction—admitting favorable breezes and shielding from storms and cold weather winds. Wind information is often available from airports, libraries, and/or county agricultural extension offices. In cold climates, locate pedestrian paths and parking lots on south and east sides of buildings to enable snow melting, but in southern climates locate these on the less sunny east or north sides of the building.

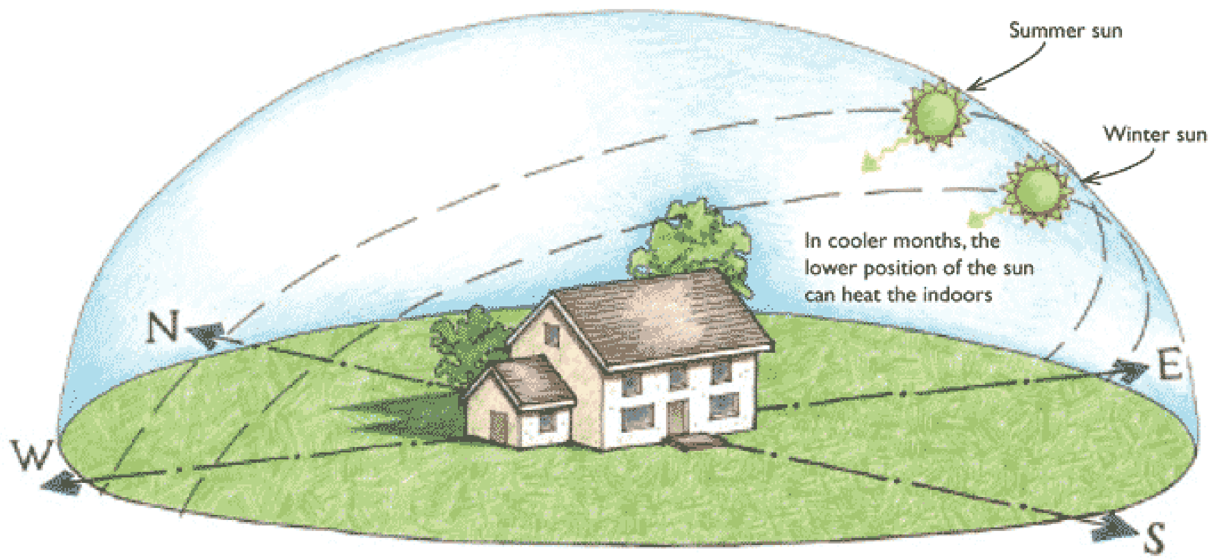


FIGURE-4 ORIENTATION OF THE BUILDING

- In temperate and northern climates, locate deciduous trees for south-side shading in the cooling season; in the heating season, the dropped leaves will permit desired solar gain. In urban settings, orientation may be strongly determined by local regulation, view easements, and urban design regulations. Be aware of unique local and site-specific conditions, such as lake or coastal exposures, effect of mountainous conditions, and special scenic easements.
- To minimize heat losses and gains through the surface of a building, a compact shape is desirable. This characteristic is mathematically described as the ―surface-to-volume‖ ratio of the building. The most compact orthogonal building would be a cube. This configuration, however, may place a large portion of the floor area far from perimeter day lighting. Contrary to the cube, a building massing that optimizes day lighting and ventilation would be elongated along its east–west axis so that more of the building area is closer to the perimeter. Although this may appear to compromise the thermal performance of the building, the electrical load and cooling load savings achieved by a well-designed day lighting system will more than compensate for the increased surface losses.

Orientation criteria for Tropical climate:

In cold and temperate climates, long rectangular buildings, with their longer walls facing the winter sun are excellent solutions in terms of energy efficiency.

Obviously, in hot and tropical climates, the basic rule is different, and direct sun-exposure of the building should be avoided. In hot humid climates the long axis of the house should be oriented for cross-ventilation as well as for sun-protection...

Orientation and shape

Well oriented home, with a proper shape and properly placed windows can cut your energy bills by 30 percent or more.

We shouldn‘t forget the very basics about the sun‘s path in the sky: sun rises in the east and sets in the west and is higher in the summer sky and lower in winter. These basic facts, and the several particulars of each site and climate, should be taken into account when building a new home.

Hot climates

In hot climates (either humid or dry) with no winter heating needs, orientation should exclude sun exposure, and look for exposure to cooling breezes.

Orientation

In temperate and cold climates, in the north hemisphere, the longer walls of the building should face south (the north, in southern hemisphere countries). Southern exposure is crucial to get maximum solar benefits (Northern exposure in southern hemisphere courtiers).

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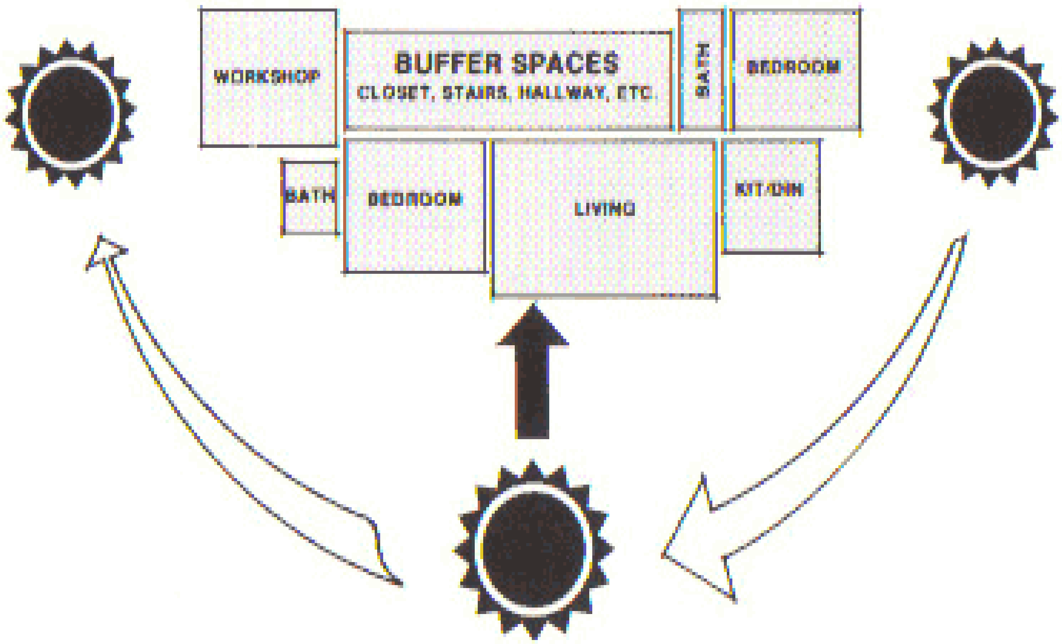
Image: a suggestion of



Building shape and axis

Rectangular-compact buildings, with their longer walls facing the winter low sun (to profit from it), are excellent solutions. In this case, the longer axis of the building (its ridge line) is oriented east/west.

Such orientation and shape allow maximum winter solar gains and will reduce unwanted summer sun (that will strike the east and the west sides of the house).

Most frequently used rooms facing the winter's low sun

The most used areas of the house should be located on the winter side of the building (cold and temperate climates), where sunlight can enter through conveniently located windows, high clerestories windows, or skylights.

South-exposure should incorporate well sized overhangs and the shadow of trees, to limit sun radiation in the hotter months.

Less frequently used rooms on the east/west short side of the house

Other rooms and divisions (namely garages, storage rooms, laundry rooms...) should be located on the home's east/west and shorter sides, where they can act as an extra thermal buffer. Avoid glass in the east and west sides of the house, since it is a common cause of unwanted energy losses and glare.

Shading the house & landscape

Landscape features such as trees, hills or the predominant orientation of the winds are also important while considering the energy needs. Study on the prevailing winds and their patterns in order to use windbreaks or walls to direct breezes into the house or to channel cold winter winds away from it is necessary. In the summer, when the sun is higher in the sky, trees with adequate tree-top can help to shade the building and keep it cooler.

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SCHOOL OF BUILDING AND ENVIRONMENT
DEPARTMENT OF CIVIL ENGINEERING

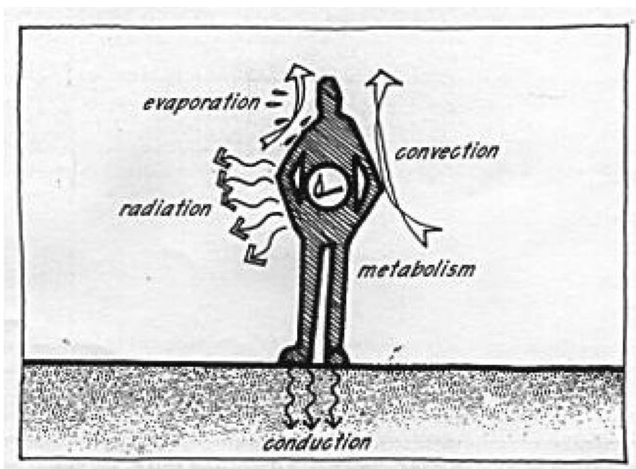
UNIT – II - THERMAL SENSATION AND TRANSFER OF HEAT IN BUILDINGS- SCIA1202

Thermal sensation:-The sense of temperature

In cool environments, hands and feet feel colder than other body parts. The head, insensitive to cold but sensitive to warm, feels warmer than the rest of the body in warm environments. Overallsensation and comfort follow the warmest local sensation (head) in warm environments and the coldest (hands and feet) in cool environments.

There has been limited research on how people respond, physiologically and subjectively, to thethermal non-uniformities encountered in buildings, vehicles, and the outdoors. Such non uniformities (in air temperature, air movement, radiation, and conduction to surfaces) affect the skin temperatures of the body's various parts, affecting a person's overall thermal sensation and comfort in complex ways. Even in spatially and temporally uniform environments, the body's skin temperatures are distributed non-uniformly, as are local sensations and local comfort.

BODY HEAT BALANCE:



Heat Balance

Constant internal temperature requires a balance. Even in a thermoneutral environment, basalmetabolism produces 1 kcal_kg-1_h-1. The specific heat of human tissue only requires 0.83 kcal_kg-1 to raise internal temperature by 1°C. Therefore, without heat loss processes, internal temperature would elevate by 1°C_h-1 even at rest

The heat produced must be dissipated to the environment, or a change in body temperature will occur. The deep body temperature is about 37°C, whilst the skin temperature can vary between 31°C and 34°C under comfort conditions. Variations occur in time, but also between parts of the body, depending on clothing cover and blood circulation. There is a continuous transport of heat from deep tissues to the skin surface, from where it is dissipated by radiation, convection or (possibly) conductionand evaporation.

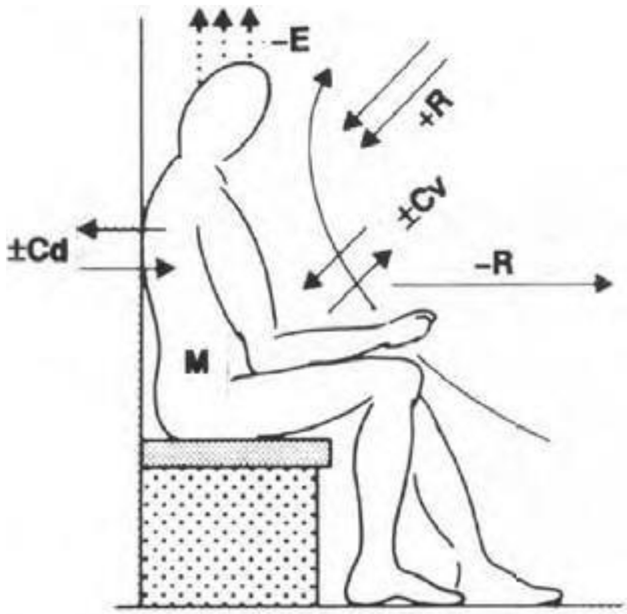
The body's heat balance can be expressed as

$$\mathbf{M \pm R \pm Cv \pm Cd - E = \Delta S\ (W)\quad 1.1)}$$

where M = metabolic rate,Cv = convection; R = net radiation; Cd = conduction E = evaporation heat loss ,ΔS = change in heat stored

If ΔS is positive, the body temperature increases, if negative, it decreases.

The heat dissipation rate depends on environmental factors, but the body is not purely passive, it is homoeothermic: it has several physiological regulatory mechanisms.



To warm conditions (or increased metabolic heat production) the body responds by vasodilation: subcutaneous blood vessels expand and increase the skin blood supply, thus the skin temperature, which in turn increases heat dissipation. If this cannot restore thermal equilibrium, the sweat glands are activated, the evaporative cooling mechanism will operate. Sweat can be produced for short periods at a rate of 4 L/h, but the mechanism is fatigable.

Thermal comfort is a term used by the American Society of Heating, Refrigerating and Air- Conditioning Engineers, an international body. It is defined as the state of mind in humans that expresses satisfaction with the surrounding environment (ANSI/ASHRAE Standard 55[1]). Maintaining this standard of thermal comfort for occupants of buildings or other enclosures is one of the important goals of HVAC (heating, ventilation, and air conditioning) design engineers.

Thermal comfort is affected by heat conduction, convection, radiation, and evaporative heat loss. Thermal comfort is maintained when the heat generated by human metabolism is allowed to dissipate, thus maintaining thermal equilibrium with the surroundings. It has been long recognised that the sensation of feeling hot or cold is not just dependent on air temperature alone.

Humans are homeothermic (i.e. body temperature is maintained independent of environmental temperature

Body temperature often described as either: – **‘Core’** (typically 36.1-37.8°C) ,**‘Shell’** (ideally 33°C but up to 42°C in contracting muscle)

Body heat content usually exceeds 1500 kcal

• Metabolic heat production _70-1500 kcal_h-1, so heat transfer with the environment is essential.

• However, this operates both ways and overall heat balance can be expressed as: Metabolic Rate ± Radiation ± Convection ± Conduction – Evaporation

Factors of comfort

The variables that affect heat dissipation from the body (thus also thermal comfort) can be grouped into three sets:

- **Environmental**: air temperature, air movement, humidity, radiation
- **Personal**: metabolic rate (activity), clothing
- **Contributing factors**: food and drink, acclimatization, bodyshape, subcutaneous fat, age and gender, state of health

Body Mechanism to regulate its temperature

The human body regulates temperature by keeping a tight balance between heat gain and heat loss. Your temperature regulation system is more analogous to the operation of a home furnace, as opposed to the function of an air conditioner. Humans regulate heat generation and preservation to maintain internal body temperature or core temperature. Normal core temperature at rest varies between 36.5 and 37.5 °Celsius (°C), which is 97.7 to 99.5 °Fahrenheit (°F). Core temperature is regulated by the hypothalamus (in the brain), which is often called the body’s thermostat. The hypothalamus responds to various temperature receptors located throughout the body and makes physiological adjustments to maintain a constant core temperature. For example, on a hot day, temperature receptors located in the skin send signals to the hypothalamus to cool the body by increasing the sweat rate.

During all types of exercise the body's ability to thermoregulate is challenged. Heat is produced as a bi-product of metabolism (metabolism is defined as all of the reactions that occur in the human body). However, the human body is only 25% efficient, therefore you lose approximately 75% of energy as heat. During exercise, heat is produced mainly from working muscle contractions and core temperature can go above 40 °C (104 °F).

Mechanism of Body to lose heat

As previously discussed, the body regulates temperature like a furnace. It is constantly producing heat and then dispersing it through various processes. Heat can be lost through the processes of conduction, convection, radiation, and evaporation. Conduction is the process of losing heat through physical contact with another object or body. For example, if you were to sit on a metal chair, the heat from your body would transfer to the cold metal chair. Convection is the process of losing heat through the movement of air or water molecules across the skin. The use of a fan to cool off the body is one example of convection. The amount of heat loss from convection is dependent upon the airflow or in aquatic exercise, the water flow over the skin. Radiation is a form of heat loss through infrared rays. This involves the transfer of heat from one object to another, with no physical contact involved. For example, the sun transfers heat to the earth through radiation. The last process of heat loss is evaporation. Evaporation is the process of losing heat through the conversion of water to gas (evaporation of sweat). The primary heat loss process for aqua enthusiasts is convection, however, in an outdoor pool on hot day evaporation will also play a primary role in heat loss.

Water content in the body

Water makes up approximately 60% of your total body composition. In addition, 73% of lean body mass or muscle is composed of water. It is the essential nutrient for survival and is required for all cell functions. Water is also an important constituent in thermoregulation, because it is a major component of blood volume. It is mainly lost through sweat, respiration, and waste. However, when the body is dehydrated, most of the water lost is from the blood.

Sweat Basics

The average person has 2.6 million sweat glands. Sweat is made up of water and electrolytes such as sodium, chloride, and potassium. When the hypothalamus senses an increase in core temperature it will act by increasing blood flow to the skin, stimulating the sweat glands. The result is an increase in the rate of water lost through sweating.

During low- to moderate-intensity exercise of less than one hour, there are minimal electrolyte losses because the body reabsorbs most of the electrolytes from the sweat. However, during moderate- to high-intensity exercise of greater than one hour, the electrolyte loss in sweat becomes significant and the sweat rate is too fast for re-absorption of electrolytes.

Water loss during exercise

During high-intensity exercise, a person can lose up to 2.0 liters of water per hour! However, 1.0 liter of water per hour is more common. Sweat rate can vary depending on the environmental temperature, humidity, type of clothing worn during exercise, intensity of exercise, fitness level of the individual and acclimation of the individual to the environment. Replacing fluids during and after exercise is very important for staying hydrated and preventing dehydration. Signs of dehydration include dark colored urine (urine should be the color of water with a splash of lemon), muscle cramps, decreased sweat rate, and increased fatigue.

Best way to stay hydrated

According the American College of Sports Medicine (ACSM), before, during and following exercise, water or a carbohydrate/electrolyte drink is recommended to stay hydrated. The drink of choice should be cold in temperature and taste good to the individual. If it’s more palatable to the person, more will be ingested!

ACSM makes the following general recommendations for the amount and type of fluid that should be ingested before, during and after exercise:

Approximately 24 hours before exercise, an individual is recommended to consume fluids and foods to promote hydration. Fruits, vegetables, and carbohydrates are examples of foods that promote hydration. In addition, avoid too much alcohol and caffeine, as these fluids can cause water loss and promote dehydration.

- Two hours before exercise, 16 ounces (2 cups) of fluid should be ingested to promote hydration and allow time for excretion of excess water.

During exercise of less than an hour, it is recommended to ingest water every 15 minutes

- To prevent dehydration. Electrolyte loss is negligible; therefore a carbohydrate drink is not necessary.
- During exercise of greater than an hour, it is recommended to ingest a carbohydrate and electrolyte drink every 15 minutes.
- Never restrict fluids during exercise!
- After exercise ingest a carbohydrate and electrolyte solution. The carbohydrate will replenish glycogen stores (muscle carbohydrate stores) and the electrolytes will replenish sodium, chloride, and potassium lost in sweat. In addition, avoid carbonated drinks, as they make you feel full and decrease fluid intake.

Effective Temperature.

It is defined as the temperature of a still, saturated atmosphere, which would, in the absence of radiation, producethe same effect as the atmosphere in question. **It thus combines the effect of dry air temperature and humidity**. It became the most widely used index for the next 50 years, but it is now superseded.

Wet bulb globe temperature (WBGT)

It indicates the combined effect of air temperature, low temperature radiant **heat, solar radiation and airmovement.**

Operative temperature (OT)

It is defined as the temperature of a uniform, isothermal "black" enclosure in which man would exchange heat by radiation and convection at the same rate as in the given non-uniform environment

DETERMINATION OF THERMAL COMFORT TEMPERATURE

The major aim of comfort research is to find comfort temperature for an individual or group. However, 6 major variables determine how warm or cold a person feels.

Environmental factors

- air temperature
- air speed
- humidity
- mean radiant temperature

Individual factors

- activity
- clothing insulation

Thermal Comfort Indices and Standards

The combined effects of environmental and individual factors can be represented on a psychrometric chart. Basically, the psychrometric chart gives air temperature (dry bulb) along the X axis at 0% RH and then curves of equal humidity.

The ranges of indoor temperature, humidity, and air movement, under which most persons enjoy mental and physical well-being. Also known as comfort standard.

THE COMFORT ZONE

It is the combinations of temperature and humidity where people report comfort.

If conditions are to the right of the comfort zone then need to increase cooling say be increasing wind. If conditions are to the left of the comfort zone then need to increase heating say by increasing sun. Superimposed on this chart are lines of effective temperature i.e. lines of equal thermal sensation.

- **Comfort Indices (ET)** - ET is "an arbitrary index which combines into a single number the effect of dry-bulb temperature, humidity, and air motion on the sensation of warmth or cold felt by the human body".

Standard Effective Temperature (SET) - For sedentary activity (1.1 met), light clothing and low air speed SET = ET* SET = ET* extended to incorporate different

levels of activity and clothing SET is the temperature of an isothermal environment which has air and mean radiant temperature equal to each other, RH of 50%, still air, and in which a person with a standard level of clothing insulation would have the same heat loss at the same mean skin temperature and the same skin wettedness as the person has in the actual environment with the clothing insulation under consideration. The activity level is assumed to be the same in both environments. SET calculation involves: For a given level of activity, clothing, and air speed - psychrometric chart--lines of constant SET. It has also been suggested that SET links directly to sensation rather than air temperature. SET is the most comprehensive comfort index, yet while in its restricted form (sedentary activity--effective temperature (ET)) it has been adopted by ASHRAE in its comfort standard, in its more general form it has yet to be widely used.

COMFORT STANDARDS

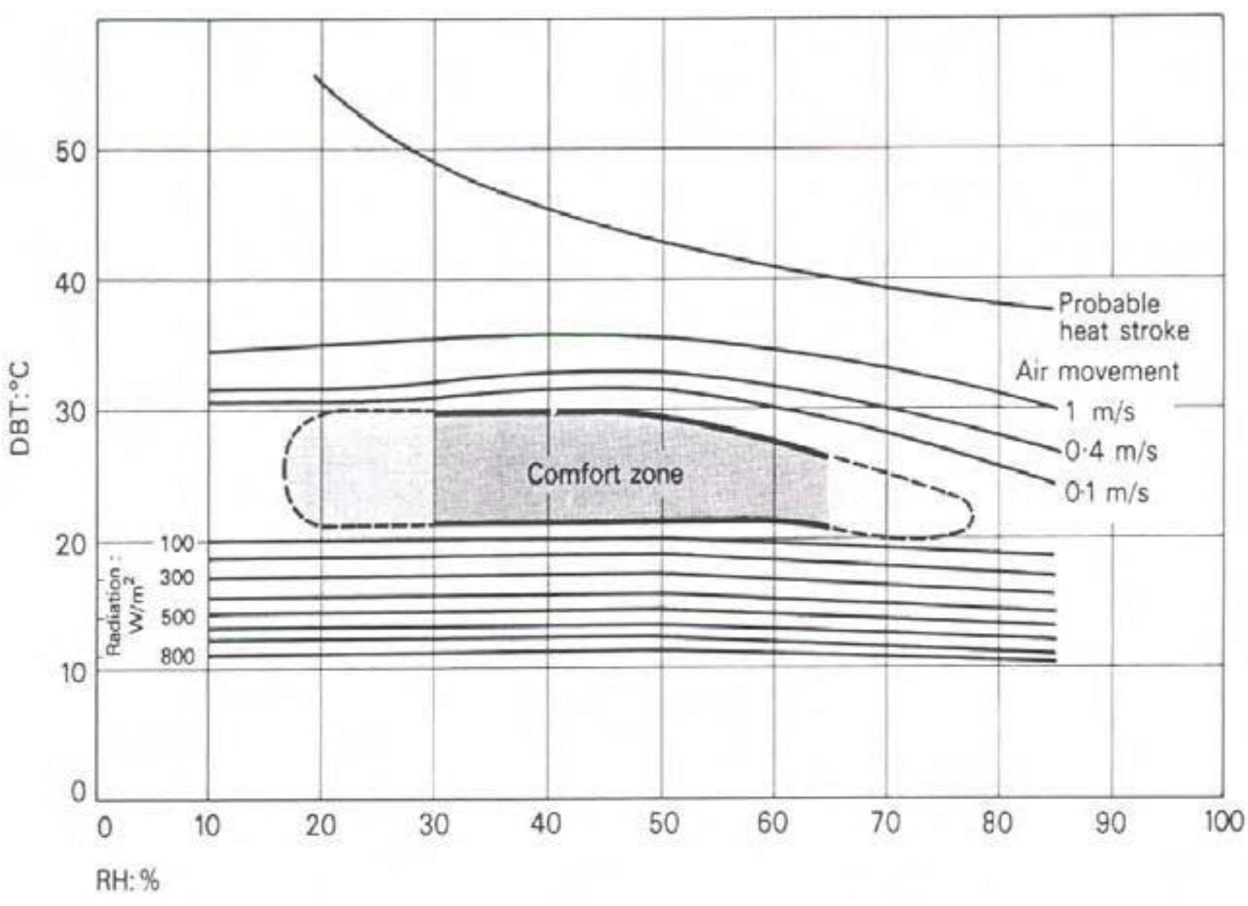
ASHRAE 55-1981

- Activity - 1.2 met, mainly sedentary
- Winter - 0.9 clo (sweater, long sleeve shirt, heavy slacks), air flow -0.15 m/s (30 fpm)
- Optimum operative temperature = 22.7ºC (71ºF) (globe temperature, MRT)
- Summer - 0.5 clo (light slacks, short sleeves or blouse), air flow -0.25 m/s (50 fpm)
- For each increased degree Kelvin up to maximum 28ºC at 0.8 m/s air, need to increase air motion by 0.275 m/s. OR by 30 fpm for every degree Fahrenheit up to 82.5ºF at 160 fpm. Optimum operative temperature = 24.4ºC (76ºF) With minimum clothes (0.05 clo) top = 27.2ºC (81ºF)

Olgyay was the first to outline the comfort zone in architectural terms, i.e. the range of environmental conditions within which the average person would feel comfortable. He did this in graphic form, with DBT on the vertical axis and RH on the horizontal. The aerofoilshaped zone at the centre of this graph is the comfort zone. Fig.34 shows his original bioclimatic chart, together with its playful interpretation and Fig.35 is a chart converted to metric units and adjusted for warm climates.

He subsequently drew lines above the comfort zone, showing how air movement at different velocities could extend the upper boundary of the comfort zone (or: if the DBT is above the comfort limit, what air velocity would be required to restore comfort). Below the comfort zone families of lines indicate various levels of radiation that would compensate for the lower than comfortable temperatures. This chart became quite popular amongst architects. Whilst the various single-figure indices would concealthe magnitude of individual variables, this chart allows the manipulation of these variables, showing the contribution of each separately. The prevailing climatic conditions can then be plotted on the same chart, which will allow a diagnosis

of the climatic problem.



It is interesting to note that the latest version of the ASHRAE Code (Standard 55-2004) *reverts to the 12 g/kg upper limit of humidity, and that it abolishes the lower limit (Fig.38 f). Now there is no lower limit. It has beensuggested that this lower limit (4 g/kg) had been imposed for non- thermal reasons, so it should not be included in a thermal comfort standard. These reasons were excessive drying out of the skin, and especially of the mucous membranes. The view we accept is that if the concern is human well-being, (whether it is labelled thermal comfort on just comfort in general) then such reasons justify the inclusion of lower limits.*

TRANSFER OF HEAT:

Difference between heat and temperature:

Temperatureis a measure of the amount of energy possessed by the molecules of a substance. It manifests itself as a degree of hotness, and can be used to predict the direction of heat transfer.

The usual symbol for temperature is *T*. The scales for measuring temperature in SI units are the Celsius and Kelvin temperature scales.

Heat, on the other hand, is energy in transit. Spontaneously, heat flows from a hotter body to a colder one. The usual symbol for heat is Q. In the SI system, common units for measuring heat are the Joule and calorie.

Difference between thermodynamics and heat transfer

Thermodynamics tells us:

- how much heat is transferred (dQ)
- how much work is done (dW)
- final state of the system

Heat transfer tells us:

- how (with what **modes**) dQ is transferred
- at what **rate** dQ is transferred
- temperature distribution inside the body

Heat transfer complementary Thermodynamics

Heat transfer is a discipline of thermal engineering that concerns the generation, use, conversion, and exchange of thermal energy and heat between physical systems. Heat transfer is classified into various mechanisms, such as heat conduction, convection, thermal radiation, and transfer of energy by phase changes.

Modes of Heat Transfer

The fundamental modes of heat transfer are:

Conduction or diffusion

The transfer of energy between objects that are in physical contact

Convection

The transfer of energy between an object and its environment, due to fluid motion

Radiation

The transfer of energy to or from a body by means of the emission or absorption of electromagnetic radiation

Mass transfer

The transfer of energy from one location to another as a side effect of physically moving an object containing that energy

Thermal Conductivity, k

As noted previously, thermal conductivity is a thermodynamic property of a material. From theState Postulate given in thermodynamics, it may be recalled that thermodynamic properties of puresubstances are functions of two independent thermodynamic intensive properties, say temperatureand pressure. Thermal conductivity of real gases is largely independent of pressure and may beconsidered a function of temperature alone. For solids and liquids, properties are largelyindependent of pressure and depend on temperature alone.

Heat Transfer in the Human Body

The principles of heat transfer in engineering systems can be applied to the human body in order to determine how the body transfers heat. Heat is produced in the body by the continuous metabolism of nutrients which provides energy for the systems of the body.[17]

The human body must maintain a consistent internal temperature in order to maintain healthy bodily functions. Therefore, excess heat must be dissipated from the body to keep it from overheating. When a person engages in elevated levels of physical activity, the body requires additional fuel which increases the metabolic rate and the rate of heat production. The body must then use additional methods to remove the additional heat produced in order to keep the internal temperature at a healthy level.

Heat transfer by convection is driven by the movement of fluids over the surface of the body. This convective fluid can be either a liquid or a gas. For heat transfer from the outer surface of the body, the convection mechanism is dependent on the surface area of the body, the velocity of the air, and the temperature gradient between the surface of the skin and the ambient air.[18] The normal temperature of the body is approximately 37°C. Heat transfer occurs more readily when the temperature of the surroundings is significantly less than the normal body temperature. This concept explains why a person feels "cold" when not enough covering is worn when exposed to a cold environment. Clothing can be considered an insulator which provides thermal resistance to heat flow over the covered portion of the body.[19] This thermal resistance causes the temperature on the surface of the clothing to be less than the temperature on the surface of the skin. This smaller temperature gradient between the surface temperature and the ambient temperature will cause a lower rate of heat transfer than if the skin were not covered.

In order to ensure that one portion of the body is not significantly hotter than another portion, heat must be distributed evenly through the bodily tissues. Blood flowing through blood vessels acts as a convective fluid and helps to prevent any buildup of excess heat inside the tissues of the body. This flow of blood through the vessels can be modeled as pipe flow in an engineering system. The heat carried by the blood is determined by the temperature of the surrounding tissue, the diameter of the blood vessel, the thickness of the fluid, velocity of the flow, and the heat transfer coefficient of the blood. The velocity, blood vessel diameter, and the fluid thickness can all be related with the Reynolds Number, a dimensionless number used in fluid mechanics to characterize the flow of fluids.

Latent heat loss, also known as evaporative heat loss, accounts for a large fraction of heat loss from the body. When the core temperature of the body increases, the body triggers sweat glands in the skin to bring additional moisture to the surface of the skin. The liquid is then transformed into vapor which removes heat from the surface of the body.[20] The rate of evaporation heat loss is directly related to the vapor pressure at the skin surface and the amount of moisture present on the skin.[18] Therefore, the maximum of heat transfer will occur when the skin is completely wet. The body continuously loses water by evaporation but the most significant amount of heat loss occurs during periods of increased physical activity.

PERIODIC HEAT FLOW

In nature the variation of climatic conditions produces a non- steady state. Diurnal variations produce an approximately repetitive 24-hour cycle of increasing and decreasing temperatures. The effect of this on a building is that in the hot period heat flows from the outdoors into the building, where some of it is stored, and at night during the cool period the heat flow is reversed: from the building to the outside. As this cycle is repetitive, it is described as periodic heat flow. The diurnal variations of external and internal temperatures is a periodic cycle. In the morning, as the outdoor temperature increases, heat starts entering the outer surface of the wall. Each particle in the wall will absorb a certain amount of heat for every degree rise in temperature, depending on the specific heat of the wall material. Heat to the next particle will only be transmitted after the temperature of the first particle is increased. Thus the corresponding increase in the internal temperature will be delayed.

The outdoor temperature reaches its peak and starts decreasing, before the inner surface temperature has reached the same level. From this moment the heat stored in the wall will be dissipated partly to the outside and only partly to the inside. As the outdoor air cools, an increasing proportion of this stored heat flows outwards, and when the wall temperature falls below the indoor temperature the direction of the heat flow is completely reversed.

The two quantities characteristic of this periodic change are the time lag (φ) and the decrement factor (ù). Decrement factor is the ratio of the maximum outer and inner surface temperature amplitudes taken from the daily mean. The Division of Building Research i s currently reexamining and appraising the methods employed in predicting the thermal energy exchange between the indoor and the outdoor environment through the enclosing walls and roofs of buildings, Summer conditions which give r is e to periodic flow are of special in t e r e s t , and heat exchange between the ground surface and the outdoor environment is also of' concern. Although the path of the thermal energy exchange between -in doors and outdoor may be broken into p a r t s for special study, these are actually inter-related and in a rigorous treatment must be considered together , It became necessary in dealing with the exchange between exterior surfaces and the outdoor environment to consider also c e r t a in aspects of the heat flow through the building enclosure itself , One aspect of t h is , the ease of periodic heat flow i n walls and roofs, and of methods by which it may be calculated is now considered, Certain aspects of the thermal exchange between the exterior surface of a building and the outdoor environment were dealt within DBR Report Moo 1210 It is not apparent that the material contained i n this report will be of sufficient interest to others to warrant publication, Opinions on this, together with any criticism and other comments are invited, two methods of calculating the periodic heat flow through solid walls or roofs are described.

Matrix methods and vector methods

The matrix method gives the accurate value of heat flow through a solid wall whether homogeneous or multilayer. One of the advantages of this method is the ease with which different surface heat transfer coefficients can be accounted for. A much simpler vector diagram method is presented for calculating the complex thermal impedance of a wall or roof. The errors which occur with this method are chiefly due to representing a continuous wall by a lumped resistance capacitance network. 'The lumping error for a "T" network representation of a homogeneous wall is evaluated analytically: the same method can be applied to more complex circuits.

The heat flow through the walls o r roof of a building rarely reaches a steady state, so for an accurate calculation of heating o r cooling load it is necessary t o take account of the heat storage capacity of the wall or roof. Nackey and Wright (1, 2) have reported an accurate and approximate method for calculating the periodic heat flow through .homogeneous and multilayer walls. Their work was based on the following assumptions:

(1) Periodic sol - air temperature

(2) Constant indoor air temperature

(3) The outdoor air film coefficient of heat transfer

(4) The indoor air film coefficient of heat t r a n s f e r

(5) One dimensional heat flow through the wall.

Periodic sol - air temperature

Sol-air temperature (Tsol-air) is a variable used to calculate cooling load of a building and determine the total heat gain through exterior surfaces.

$$T_{\text{sol}-\text{air}} = T_o + \frac{(a \cdot I - \Delta Q_{ir})}{h_o}$$

where

a = solar radiation absortivity of a surface [-]

I = global solar irradiance [W/m²]

ΔQ_{ir} = extra infrared radiation due to difference between the external air temperature and the apparent sky temperature. = $F_r * h_r * \Delta T_{o-sky}$ [W/m²]

Constant indoor air temperature

It is not always true that environmental quality for preservation has to be sacrificed for energy saving: we know of no evidence that allowing a drift to lower winter temperature does harm. The period of summer temperature above the standard specification can be reduced by careful attention to lighting efficiency and to the thermal and humidity capacity of the building envelope and interior structures. Our research effort should be directed towards highly buffered building design, design of buildings and sites which optimise solar gain, and efficient use of light, both natural and artificial.

TIME LAG AND DECREMENT FACTOR

Thermal mass:

Thermal mass is a concept in building design which describes how the mass of the building provides "inertia" against temperature fluctuations, sometimes known as the thermal flywheel effect. For example, when outside temperatures are fluctuating throughout the day, a large thermal mass within the insulated portion of a house can serve to "flatten out" the daily temperature fluctuations, since the thermal mass will absorb thermal energy when the surroundings are higher in temperature than the mass, and give thermal energy back when the surroundings are cooler, without reaching thermal equilibrium. This is distinct from a material's insulative value, which reduces a building's thermal conductivity, allowing it to be heated or cooled relatively separate from the outside, or even just retain the occupants' thermal energy longer.

Materials commonly used for Thermal mass:

Water, clay, concrete, Bricks, Rammed earth, Natural rocks and stones

Time lag:

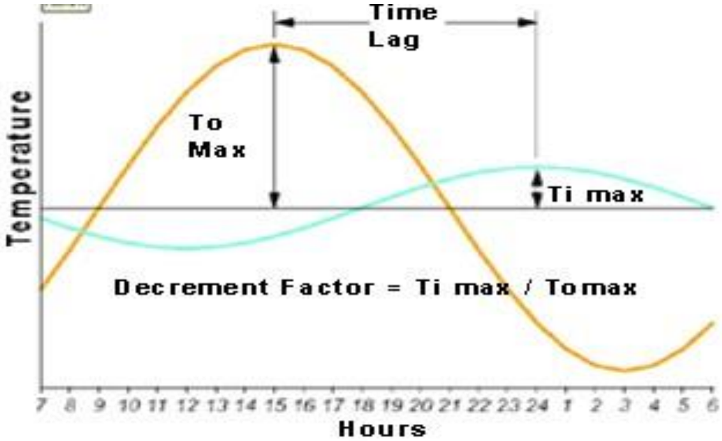
The time delay due to the thermal mass is known as a time lag.

Decrement Factor:

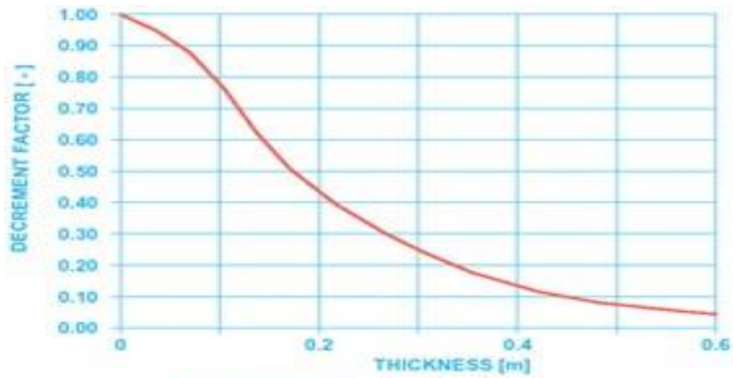
The thicker and more resistive the material, the longer it will take for heat waves to pass through.

The reduction in cyclical temperature on the inside surface compared to the outside surface is known as decrement.

Thus, a material with a decrement value of 0.5 which experiences a 20 degree diurnal variation in external surface temperature would experience only a 10 degree variation in internal surface temperature.



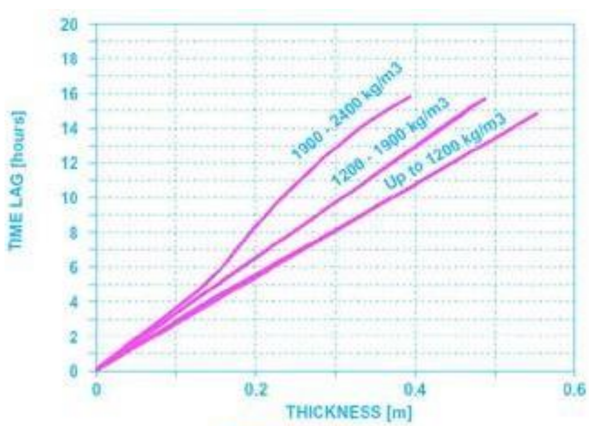
Thermal Mass Introduces Time Lag Decrement Factor



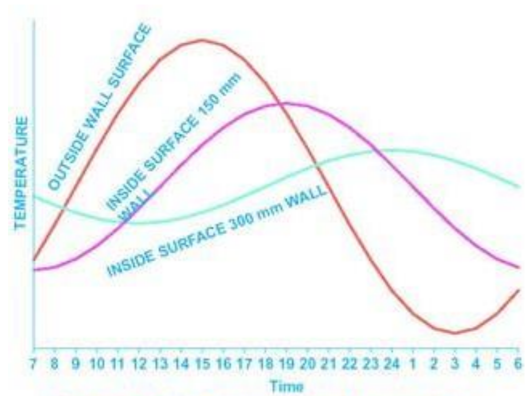
DECREMENT FACTOR

This effect is particularly important in the design of buildings in environments with a high diurnal range. In some deserts, for example, the daytime temperature can reach well over 40 degrees. The following night, however, temperatures can fall to below freezing. If materials with a thermal lag of 10-12 hours are carefully used, then the low night-time temperatures will reach the internal surfaces around the middle of the day, cooling the inside air down. Similarly, the high daytime temperatures will reach the internal surfaces late in the evening, heating the inside up.

In climates that are constantly hot or constantly cold, the thermal mass effect can actually be detrimental. This is because both surfaces will tend towards the average daily temperature which, if it is above or below the comfortable range, will result in even more occupant discomfort due to unwanted mean radiant gains or losses. Thus in warm tropical and equatorial climates, buildings tend to be very open and lightweight. In very cold and sub-polar regions, buildings are usually highly insulated with very little exposed thermal mass, even if it is used for structural reasons.



TIME LAG



Wall Surface Temperature Fluctuation

THERMAL GLASS:

With increasing environmental awareness as well as the rising costs of energy, more emphasis is now being placed on ways to save energy in all types of domestic, commercial and public buildings. Government regulations specifying minimum requirements for the energy efficiency of new homes are being gradually tightened to achieve zero carbon by 2016. At the same time, it is important to improve the existing housing stock so requirements for refurbishments such as replacement windows are also being tightened.

Energy-efficient glass can play an important role in achieving these targets for thermal insulation of homes. By replacing your existing single glazed window glass with Pilkington energiKare™ thermally insulated windows, you could reduce the amount of energy lost through your windows by up to 75% and lower your heating bills by up to 20% each year. Significant savings can also be achieved by upgrading double glazed windows which were installed before regulations were significantly tightened in 2002.

Heat loss is normally measured by the thermal transmittance or U value, usually expressed in W/m2K and, in its most basic terms, the lower the U value, the greater the thermal insulation. However, the amount of free heat energy from the sun, the solar gain or g-value can also have a big impact. Window Energy Ratings, which take account of solar gain, were introduced by the British Fenestration Rating Council (BFRC) in 2006 and they can provide a good indicator of how energy-efficient windows for homes can be. The Window Energy Ratings Scheme is based on a scale of A through to G, with A-rated windows being the most energy-efficient. Thermally insulated glass units or double glazed units incorporate low-emissivity glass such as Pilkington K Glass™ and can significantly improve the overall thermal performance of a window. Therefore the thermal insulation value is just one aspect of how much energy can be saved.

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SCHOOL OF BUILDING AND ENVIRONMENT
DEPARTMENT OF CIVIL ENGINEERING

UNIT – III – BUILDING ENVELOPE– SCI1202

A **building envelope** is the physical separator between the conditioned and unconditioned environment of a **building** including the resistance to air, water, heat, light, and noise transfer.

- Building envelope refers to the exterior façade, and is comprised of opaque components and fenestration systems.
- Opaque components include walls, roofs, slabs on grade and opaque doors.
- Fenestration systems include windows, skylights, ventilators and floors that are more than one-half glazed.

The building envelope is all of the elements of the outer shell that maintain a dry, heated, or cooled indoor environment and facilitate its climate control. Building envelope design is a specialized area of architectural and engineering practice that draws from all areas of building science and indoor climate control.

The many functions of the building envelope can be separated into three categories.

Support (to resist and transfer structural loads)
Control (the flow of matter and energy of all types)
Finish (to meet human desires on the inside and outside)

The control function is at the core of good performance, and in practice focuses, in order of importance, on rain control, air control, heat control, and vapor control.

Importance of the Simulation of Buildings:

Every building is different in many ways:

- Location/exterior environment
- Construction/building envelope
- HVAC system

- Building envelope/construction determines how a building will respond to the exterior environment

- Thermal simulation requires information about the physical make-up of the building, where various constructions are located and how they are oriented, how the building is subdivided into zones, etc.

- Thermal simulation requires information on the building envelope to properly analyze the building from an energy perspective

BUILDING ENVELOPE ESSENTIAL FOR:

Water and water vapor control

Control of rain is most fundamental, and there are numerous strategies to this end, namely, perfect barriers, drained screens, and mass / storage systems.

One of the main purposes of a roof is to resist water. Two broad categories of roofs are flat and pitched. Flat roofs actually slope up to 10° or 15° but are built to resist standing water. Pitched roofs are designed to shed water but not resist standing water which can occur during wind-driven rain or ice damming. Typically residential, pitched roofs are covered with an underlayment material beneath the roof covering material as a second line of defense. Domestic roof construction may also be ventilated to help remove moisture from leakage and condensation.

Walls do not get as severe water exposure as roofs but still leak water. Types of wall systems with regard to water penetration are *barrier*, *drainage* and *surface-sealed walls*. Barrier walls are designed to allow water to be absorbed but not penetrate the wall, and include concrete and some masonry walls. Drainage walls allow water that leaks into the wall to drain out such as cavity walls. Drainage walls may also be ventilated to aid drying such as rainscreen and pressure equalization wall systems. Sealed-surface walls do not allow any water penetration at the exterior surface of the siding material. Generally most materials will not remain sealed over the long term and this system is very limited, but ordinary residential construction often treats walls as sealed-surface systems relying on the siding and an underlayment layer sometimes called housewrap.

Moisture can enter basements through the walls or floor. Basement waterproofing and drainage keep the walls dry and a moisture barrier is needed under the floor.

Air control

Main : Air barrier

Control of air flow is important to ensure indoor air quality, control energy consumption, avoid condensation (and thus help ensure durability), and to provide comfort. Control of air movement includes flow through the enclosure (the assembly of materials that perform this function is termed the air barrier system) or through components of the building envelope (interstitial) itself, as well as into and out of the interior space, (which can affect building insulation performance greatly). Hence, air control includes the control of wind washing (cold air passing through insulation) and convective loops which are air movements within a wall or ceiling that may result in 10% to 20% of the heat loss alone.

The physical components of the envelope include the foundation, roof, walls, doors, windows, ceiling, and their related barriers and insulation. The dimensions, performance and compatibility of materials, fabrication process and details, connections and interactions are the main factors that determine the effectiveness and durability of the building enclosure system.

Common measures of the effectiveness of a building envelope include physical protection from weather and climate (comfort), indoor air quality (hygiene and public health), durability and energy efficiency. In order to achieve these objectives, all building enclosure systems must include a solid structure, a drainage plane, an air barrier, a thermal barrier, and may include a vapor barrier. Moisture control (e.g. damp proofing) is essential in all climates, but cold climates and hot-humid climates are especially demanding

Thermal envelope

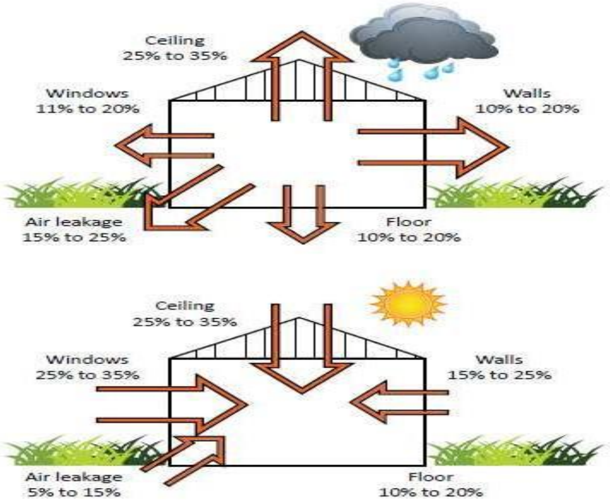
The *thermal envelope*, or heat flow control layer, is part of a building envelope but may be in a different location such as in a ceiling. The difference can be illustrated by understanding that an insulated attic floor is the primary thermal control layer between the inside of the house and the exterior while the entire roof (from the surface of the shingles to the interior paint finish on the ceiling) comprises the building envelope. Building envelope thermography involves using an infrared camera to view temperature anomalies on the interior and exterior surfaces of the structure. Analysis of infrared images can be useful in identifying moisture issues from water intrusion, or interstitial condensation.

Purpose of Building Envelope:

- Groups of Surfaces (Zones) and Overall Building Characteristics
- Walls, Roofs, Ceilings, Floors, Partitions, etc.
- Materials and Groups of Materials (Constructions)

Mandatory requirements & Specific Matters:-

- Maximum fenestration,
    - U – factor
    - SHGC
    - Air leakage
- Recessed lighting,
- Fire places.



The matters which are restricted by the building envelopes are:

Minimum setback from Front Street:

The minimum front setback from the street frontage is 5 meters, unless specified on plan. Unless indicated by a setback profile code on the plan, the minimum setback on a corner lot from a side street is 2 meters.

Unless noted on the plan, the minimum front setback on a splayed corner between two Street frontages is on an arc between the setback of the main and second street frontage, Commencing at the points that are perpendicular to the points where the street alignment Commences to arc. Front entrances are to be easily accessible from the main street frontage.

Site coverage - Buildings must not occupy more than 60 per cent of the lot, regardless of the extent of building outlined by the envelope through setback profiles and plans. In calculating site coverage, eaves, fascia and gutters not exceeding 600mm in total width, and unroofed swimming pools, terraces, patios, decks and pergolas may be disregarded.

Building height – Maximum building height as shown in side and rear setback profiles specified on the plan. Maximum building heights between specified points on a setback profile lie on a straight line drawn between the two specified points within a profile. Maximum building heights between profiles lie on a straight line drawn between the closest parts of the two profiles.
Building height may be increased by the amounts shown in Tables 1 and 2 on sloping sites with a crossways or lengthways slope.

TABLE 1: EXTRA BUILDING HEIGHT IN ADDITION TO HEIGHTS DEFINED IN SIDE AND REAR PROFILES – UPWARD SLOPES* **			
RISE OF UPWARD SLOPES	**1 - 3m setback from boundary**	**3.01m – 5m setback from boundary**	**5.01m from boundary to midpoint of lot**
5-10 degrees	No additional height	Add 0.5m to height set by standard profile	Add 0.5m to height set by standard profile
10.01 to 15 degrees	Add 0.5m	Add 1m	Add 1m
5 degrees or more and slope faces between 20 degrees east and 20 degrees west of true south	No additional height	No additional height	No additional height

TABLE 2: EXTRA BUILDING HEIGHT IN ADDITION TO HEIGHTS DEFINED IN SIDE AND REAR PROFILES – DOWNWARD SLOPES*			
FALL OF DOWNWARD SLOPES	**1 - 3m setback from boundary**	**3.01m – 5m setback from boundary**	**5.01m from boundary to midpoint of lot**
5 -15 degrees	Add 0.5m to height set by standard profile	Add 1m to height set by standard profile	Add 1m to height set by standard profile

* Height limits between measurement points are defined by the shortest line between two measurement points.

** Height allowances do not apply to lots adjoining lots not part of the same agreement or restriction.

Side and rear setbacks – Maximum extent of building is indicated on plan and in profiles. The following may encroach into the specified setback distances by not more than 500mm.

- Porches and verandahs
- Masonry chimneys
- Sunblind's
- Screens provided to protect a neighboring property from overlooking
- Flues and pipes
- Domestic fuel tanks and water tanks
- Heating and cooling equipment and other services.

The following may encroach into the specified setback distances:

- Landings with an area of not more than 2 square metres and less than 1 metre high.
- Unroofed stairways and ramps
- Pergolas
- Shade sails

- Eaves, fascia, gutters not more than 600mm in total width
- Carports, walls and buildings within the Boundary Wall Zone.

<u>Walls on boundaries:</u>

Unless in a party wall profile or otherwise specified on plan, walls within 1 metre of a boundary are restricted to a maximum length of 12 metres and must be located within the Boundary Wall Zone (BWZ) shown in a profile.

Unless specified on plan, the BWZ spans the length of the side boundary between the front and rear setbacks permitted by the envelope.

Maximum wall height in the BWZ is restricted to 3.2 metres, or 3.6 metres if the wall is 7 metres or less in length.

Building height within the BWZ must not exceed 3.6m.

Walls less than 1m from the boundary must be within 200 millimetres of the boundary.

Carports may be built within 1 metre of the boundary if the side of the carport facing the boundary is open.

Solar access to north-facing habitable room windows

Solar access to existing north-facing habitable room windows on lots not part of this restriction are not dealt with by this building envelope.

<u>Overshadowing of recreational private open space</u> **–**

Overshadowing of private open space is limited by minimum rear setbacks and maximum building heights. Overshadowing of recreational private open space for lots not part of this restriction is not dealt with by this building envelope.

<u>Overlooking</u> – Non-overlooking zones on the plan and profiles indicate walls or roofs that must not contain habitable room windows or raised open spaces that provide a direct line of sight into a habitable room window or secluded private open space on an adjoining lot, unless the window or raised open space is at an angle of 90 degrees or more to the property boundary and at least 3 metres from the boundary.

Raised open spaces covered by the non-overlooking zone are those with a floor level of 2 metres or more above natural ground level. Overlooking of lots not part of this restriction is not dealt with by this building envelope.

Daylight to new habitable room windows: - Walls containing habitable room windows must be set back from the boundaries of the lot to allow a horizontal distance of at least 1 metre clear to the sky from the boundary.

Habitable room windows must face an outdoor space or light court with a minimum area of 3m2 and minimum dimension 1m clear to the sky, not including land on an adjoining allotment, or a verandah on the lot if it is open for at least one-third of its perimeter, or a carport on the lot if it has two or more of its sides open or is open for at least one-third of its perimeter.

A side of a carport or verandah is considered to be open if its roof covering adjacent to that side is not less than 500mm from another building on the lot or the boundary of an adjoining lot.

INTERPRETATION MATTERS

The following matters are to be taken into account in applying the specific matters above to a proposed dwelling.

1. Ground level after engineering works associated with subdivision is to be regarded as natural ground level.

2. In the case of conflict with the plan or profile diagrams, the specifications in the above text prevail.

3. Definitions of terms are as follows:

In the Building Act 1993:

- Building
- Lot

In Part 4 of the Building Regulations 1994:

- Clear to the sky
- Street
- Height
- Private open space
- Recreational private open space

- Raised open space
- Secluded private open space
- Setback
- Site coverage
- Window
- Single dwelling
- North (true north)

<u>Additional definitions are:</u>

<u>Adjoining Lot</u> – Any lot which shares a common boundary other than a lot which meets the subject lot at a single point or at one corner

<u>Direct line of sight</u> – Any line of sight from a window to a neighboring lot which is contained within the space enclosed by a vertical plane measured at an angle of 45 degrees from each side of the window, and a horizontal plane 1.7m above the floor level of the habitable room, a horizontal distance of 9m from the window, and ground level. In the case of a direct line of sight from a raised open space, the line of sight is any line measured from a height of 1.7m above the floor level and along the perimeter of the raised open space to any point within a horizontal distance of 9m from the raised open space and extending 45 degrees beyond any point where the perimeter of the raised open space meets a wall of the building.

<u>Front Street</u> - The front setback applies to the street frontage that allows the most direct access to the front door.

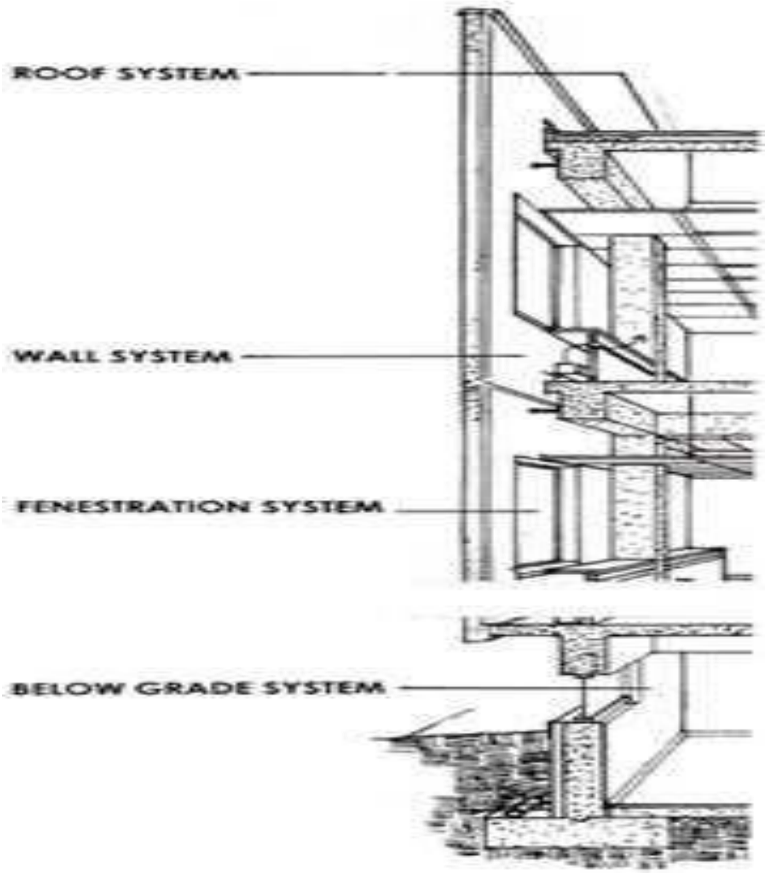
<u>Slope</u> – The average fall or rise from the lot boundary away from the boundary to the midline of the lot, which is a line drawn equidistant from two opposite boundaries.

<u>Upward slope</u> – The centre point of the natural ground level of a cross section of the lot is higher than the natural ground level of the lot boundary. May also be referred to as a positive (+) slope.

<u>Downward slope</u> – the centre point of the natural ground level of a cross section of the lot is lower than the natural ground level of the lot boundary. May also be referred to as a negative (-) slope.

<u>Lengthways slope</u> – the slope falls or rises along the long axis of the lot, which is usually from front to rear.

BUILDING ENVELOPE SYSTEM:



Fenestration

- Fenestration (architecture), refers to the design, construction, or presence of openings in a building. Fenestration includes windows, doors, louvres, vents, wall panels, skylights, storefronts, curtain walls, and slope glazed systems
- Fenestration is a fundamental element of architectural design defining both outside appearance and interior atmosphere of a building.
- The arrangement, proportioning, and design of windows and doors in a building
- An opening in a surface (as a wall or membrane)
- The operation of cutting an opening in the bony labyrinth between the inner ear and
- tympanum to replace natural fenestrae that is not functional

Introduction to fenestration

- Majority of heat transfer in the tropics is through thermal radiation
- Solar radiation incident on building apertures is in the form of
    - Beam

- Diffused (i.e. skylight)
- Reflected radiation

- Visible light is a component of solar radiation
- The national building code of 1983 requires habitable rooms to have one or more
- Windows or skylights, not otherwise provided with light and ventilation.

Size of apertures

The building code further requires the combined area of a room's skylights and windows to be no less than 10% of its floor area, at least half of which should be operable to facilitate ventilation.

Apertures should be uniformly distributed throughout a room for good daylighting

- Skylights provide more uniform lighting than windows.
- Locating windows as high as possible within a room improves distribution

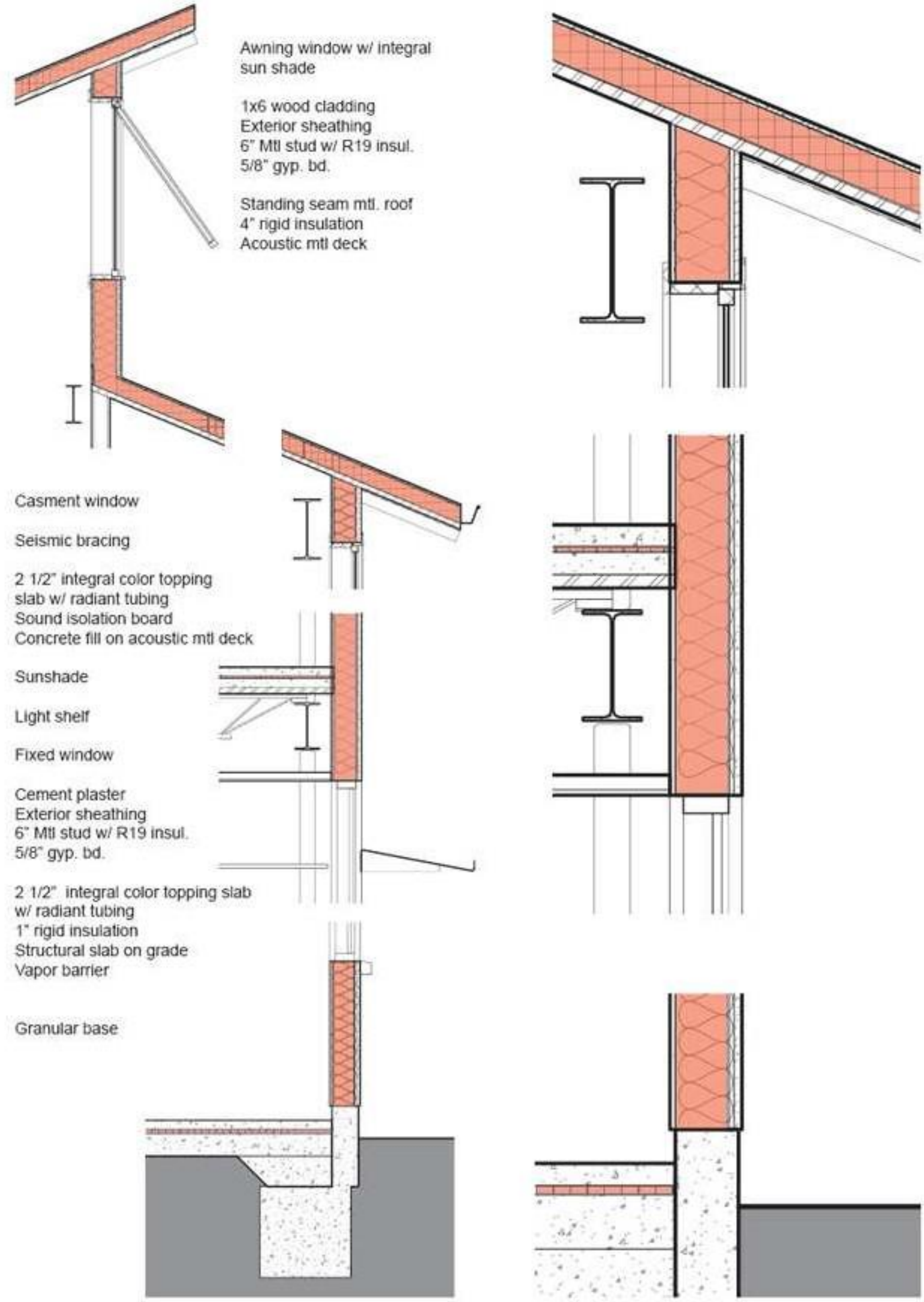
In the humid tropics, solar heat-gain (SHG) increases as apertures get larger, even if natural lighting is used to supplement electric lighting.

WINDOW:-

A **window** is an opening in a wall, door, roof or vehicle that allows the passage of light and, if not closed or sealed, air and sound. Modern windows are usually glazed or covered in some other transparent or translucent material. Windows are held in place by frames.

Many glazed windows may be opened, to allow ventilation, or closed, to exclude inclement weather.Windows often have a latch or similar mechanism to lock the window shut.

Types include the eyebrow window, fixed windows, single-hung and double-hung sash windows, horizontal sliding sash windows, casement windows, awning windows, hopper windows, tilt and slide windows (often door-sized), tilt and turn windows, transom windows, sidelight windows, jalousie or louvered windows, clerestory windows, skylights, roof windows, roof lanterns, bay windows, oriel windows, thermal, or Diocletian, windows, picture windows, emergency exit windows, stained glass windows, French windows, and double- and triple paned windows.


Awning window w/ integral sun shade
1x6 wood cladding
Exterior sheathing
6" Mtl stud w/ R19 insul.
5/8" gyp. bd.
Standing seam mtl. roof
4" rigid insulation
Acoustic mtl deck
Casment window
Seismic bracing
2 1/2" integral color topping slab w/ radiant tubing
Sound isolation board
Concrete fill on acoustic mtl deck
Sunshade
Light shelf
Fixed window
Cement plaster
Exterior sheathing
6" Mtl stud w/ R19 insul.
5/8" gyp. bd.
2 1/2" integral color topping slab w/ radiant tubing
1" rigid insulation
Structural slab on grade
Vapor barrier
Granular base

Windows and the sun

Sun incidence angle

Historically, windows are designed with surfaces parallel to vertical building walls. Such a design allows considerable solar light and heat penetration due to the most commonly occurring incidence of sun angles. In passive solar building design, an extended eave is typically used to control the amount of solar light and heat entering the window(s).

An alternative method is to calculate an optimum window mounting angle that accounts for summer sun load minimization, with consideration of actual latitude of the building. This process has been implemented, for example, in the Dakin Building in Brisbane, California—in which most of the fenestration is designed to reflect summer heat load and help prevent summer interior over-illumination and glare, by canting windows to nearly a 45 degree angle.

Solar window

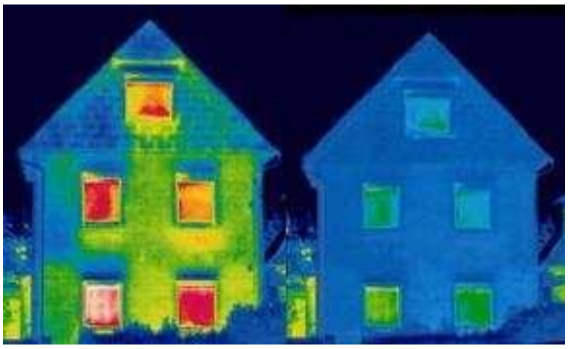
Photovoltaic windows not only provide a clear view and illuminate rooms, but also convert sunlight to electricity for the building. In most cases, translucent photovoltaic cells are used. Recently, hybrid-type transparent solar concentrator systems have been developed,which resulted in the industrial production of solar windows. These ClearVue solar PV windows also feature superior thermal insulation and solar control properties.

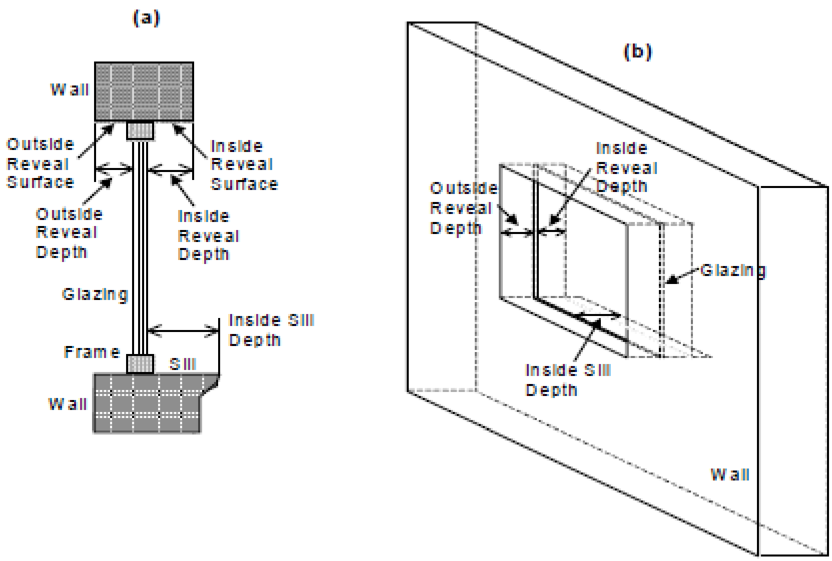
Passive solar

Passive solar windows allow light and solar energy into a building while minimizing air leakage and heat loss. Properly positioning these windows in relation to sun, wind, and landscape—while properly shading them to limit excess heat gain in summer and shoulder seasons, and providing thermal mass to absorb energy during the day and release it when temperatures cool at night—increases comfort and energy efficiency. Properly designed in climates with adequate solar gain, these can even be a building's primary heating system.

Window coverings

A window covering is a shade or screen that provides multiple functions. For example, some window coverings control solar heat gain and glare. There are external shading devices and internal shading device.Low-e window film is a low-cost alternative to window replacement to transform existing poorly-insulating windows into energy-efficient windows. For high-rise buildings, smart glass can provide an alternative.





Material	Thermal resistance	Durability	Maintenance	Cost	Recycled content	Comment
Wood	very good	variable	high	high	low	shrinks and swells with humidity changes
uPVC ("vinyl")	very good	very good*	very low	average	very low	has a life span of 50 years in average
Aluminum	bad**	good	very low	low	typically > 95%	used in most cheap structures
Wood-Aluminium	very good	good	very low	high	high	used in modern buildings
Steel	medium	superior	very low	high	> 98%	typically welded at corner joints
Fiberglass	very good	very good*	very low	high	medium	

- Outside reveal defined by window vertices
- WindowFrameAndDivider specifies details of frame, sill, inside reveal, etc

GLAZING:

The vast majority of new windows, curtain walls and skylights for commercial building construction have insulating glazing for energy efficiency and comfort

Typical glazing characteristics

The transmission, absorption and reflection of solar radiation by glass depends on

- The angle of the beam
- Thickness
- Refractive index

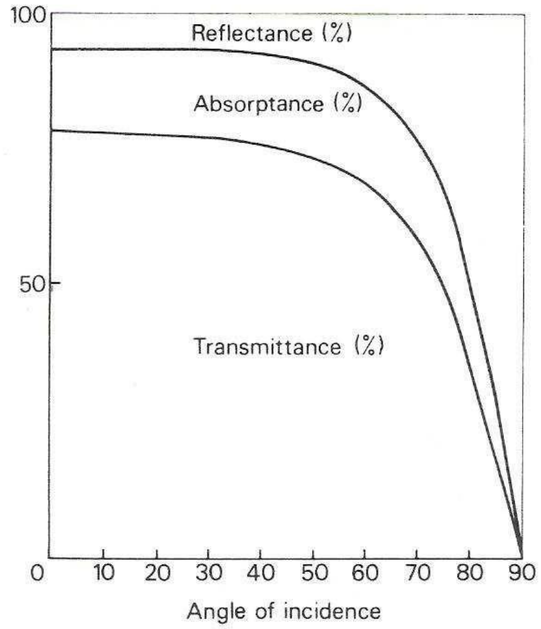


Fig. 1. T, A, R characteristics for 4-6 mm clear glass: KL = 0.16, μ = 1.52.

- Absorption/extinction coefficient (K) of the glass

Glazing and filling

Low-emissivity coated panes reduce heat transfer by radiation, which, depending on which surface is coated, helps prevent heat loss (in cold climates) or heat gains (in warm climates).

High thermal resistance can be obtained by evacuating or filling the insulated glazing units with gases such as argon or krypton, which reduces conductive heat transfer due to their low thermal conductivity. Performance of such units depends on good window seals and meticulous frame construction to prevent entry of air and loss of efficiency.

Special glazing

Double glazing is not cost – effective in the humid tropics Solar control glasses are classified as

- Heat-absorbing
- Heat –reflecting
- Heat- reflecting polyester film over clear glass
- Photo- chromatic glasses

Glazing which transmits more heat than light should be avoided in the tropic

SHADING:

- Operable shading is more effective than fixed shading, if used to reduce glare and intense solar radiation.
- Shading is more efficient when located outdoors
- Large overhangs reduce indoor lighting levels, through lighting levels are more uniform.
- The size and configuration of shading devices should be determined with use of sun charts.

Shading devices can be categorized as

- Overhangs
- Fins
- Baffles
- Combinations of two or more

Shading devices do not have to be monolithic.

OPAQUE CONSTRUCTION BUILDING
ENVELOPE SEALING

Air sealing:

- Air will leak through a building envelope that is not well sealed

Leakage of air (causes):

- Decreases the comfort of a residence by allowing moisture, cold drafts, and unwanted noise to enter lower indoor air quality by allowing in dust air borne pollutants.

25% to 40% of the energy used for heating and cooling in a typical residence

Amount of air leakage:

Depends on two factors

1. Number and size of air leakage paths through the building envelope
2. Difference in air pressure between the inside and outside
    - Wind
    - Indoor
    - Outdoor temperature differences (stack effect)
    - Chimney and flue exhaust fanss
    - Equipments with exhaust fans (dryers, central vacuums etc)
    - Ventilation fans (bath, kitchen etc)

To prevent air leakage:

Best to seal the building envelope during construction prior to installation of the dry well

Test: a “blower door” test (good way of to identify air leakage paths)

Materials used: caulks, foams, weather stripping, gaskets, door sweeps.

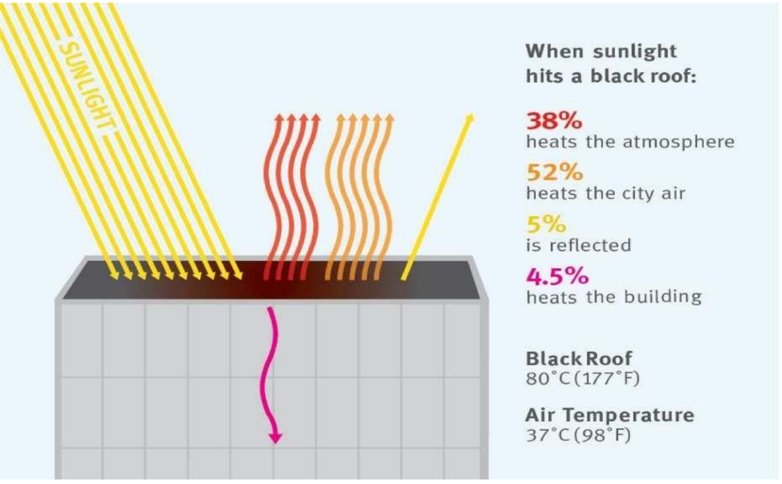
Advantages:

- Improved comfort
- Improved indoor air quality
- Increased construction quality
- Lower energy bills
- Fewer condensation problems
- Reduced obsolescence

PRESCRIPTIVE REQUIREMENTS

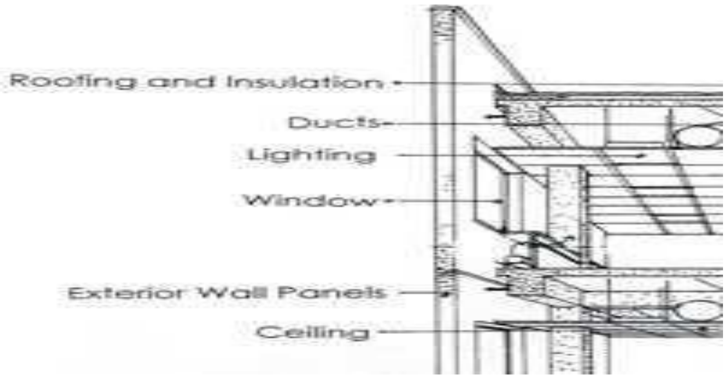
1. Exterior roofs and ceilings
    - Insulation
    - Substantial contact
    - Insulation above suspended ceilings
    - Insulation protection
2. Cool roofs
    - Reflectance
    - Absorptance
    - Emissivity
3. Opaque walls
4. Vertical fenestration
5. Skylights

ROOF:



A **roof** is part of a building envelope. It is the covering on the uppermost part of a building or shelter which provides protection from animals and weather, notably rain or snow, but also heat, wind and sunlight. The word also denotes the framing or structure which supports that covering.

The characteristics of a roof are dependent upon the purpose of the building that it covers, the available roofing materials and the local traditions of construction and wider concepts of architectural design and practice and may also be governed by local or national legislation. In most countries a roof protects primarily against rain. A verandah may be roofed with material that protects against sunlight but admits the other elements. The roof of a garden conservatory protects plants from cold, wind, and rain, but admits light.



Function of Roof

- Insulation
- Drainage
- Solar roofs

Insulation:

Because the purpose of a roof is to protect people and their possessions from climatic elements, the insulating properties of a roof are a consideration in its structure and the choice of roofing material.

Some roofing materials, particularly those of natural fibrous material, such as thatch, have excellent insulating properties. For those that do not, extra insulation is often installed under the outer layer. In developed countries, the majority of dwellings have a ceiling installed under the structural members of the roof. The purpose of a ceiling is to insulate against heat and cold, noise, dirt and often from the droppings and lice of birds who frequently choose roofs as nesting places.

Concrete tiles can be used as insulation. When installed leaving a space between the tiles and the roof surface, it can reduce heating caused by the sun.

Forms of insulation are felt or plastic sheeting, sometimes with a reflective surface, installed directly below the tiles or other material; synthetic foam batting laid above the ceiling and recycled paper products and other such materials that can be inserted or sprayed into roof cavities. So called Cool roofs are becoming increasingly popular, and in some cases are mandated by local codes. Cool roofs are defined as roofs with both high reflectivity and high thermal emittance.

Drainage:

The primary job of most roofs is to keep out water. The large area of a roof repels a lot of water, which must be directed in some suitable way, so that it does not cause damage or inconvenience. Flat roof of adobe dwellings generally have a very slight slope. In a Middle Eastern country, where the roof may be used for recreation, it is often walled, and drainage holes must be provided to stop water from pooling and seeping through the porous roofing material.

Similar problems, although on a very much larger scale, confront the builders of modern commercial properties which often have flat roofs. Because of the very large nature of such roofs, it is essential that the outer skin be of a highly impermeable material. Most industrial and commercial structures have conventional roofs of low pitch. In general, the pitch of the roof is proportional to the amount of precipitation. Houses in areas of low rainfall frequently have roofs of low pitch while those in areas of high rainfall and snow, have steep roofs. The longhouses of Papua New Guinea, for example, being roof- dominated architecture, the high roofs sweeping almost to the ground. The high steeply-pitched roofs of Germany and Holland are typical in regions of snowfall. In parts of North America such as Buffalo, USA or Montreal, Canada, there is a required minimum slope of 6 inches in
12 inches, a pitch of 30 degrees.

The pitch of the roof is in part determined by the roofing material available, a pitch of 3/12 or greater slope generally being covered with asphalt shingles, wood shake, corrugated steel, slate or tile.

The water repelled by the roof during a rainstorm is potentially damaging to the building that the roof protects. If it runs down the walls, it may seep into the mortar or through panels. If it lies around the foundations it may cause seepage to the interior, rising damp or dry rot.

Solar roofs:

Newer systems include solar shingles which generate electricity as well as cover the roof. There are also solar systems available that generate hot water or hot air and which can also act as a roof covering. More complex systems may carry out all of these functions: generate electricity, recover thermal energy, and also act as a roof covering.

Solar systems can be integrated with roofs by:

- Integration in the covering of pitched roofs, e.g. solar shingles.
- Mounting on an existing roof, e.g. solar panel on a tile roof.
- Integration in a flat roof membrane using heat welding, e.g. PVC.
- Mounting on a flat roof with a construction and additional weight to prevent uplift from wind.

Roof components

- Automobile roof
- Bituminous waterproofing
- Roofing felt
- Tensile architecture
- Tented roof
- Thin-shell structure

COOL ROOF:

Reflective surfaces are surfaces that can deliver high solar reflectance (the ability to reflect the visible, infrared and ultraviolet wavelengths of the sun, reducing heat transfer to the surface) and high thermal emittance (the ability to radiate absorbed, or non-reflected solar energy).Reflective surfaces are a form of geoengineering.

The most well-known type of reflective surface is the *cool roof*. While cool roofs are mostly associated with white roofs, they come in a variety of colors and materials and are available for both commercial and residential buildings. Today's "cool roof" pigments allow metal roofing products to be EnergyStar rated in dark colors, even black.

Roofs are covered with a reflective coating that has a high emissivity property that is very effective in reflecting the sun’s energy away from the roof surface.

These “cool roofs” are known to stay 10 C to 16 C cooler than a normal roof under a hot summer sun.

This quality greatly reduces heat gain inside the building and the needs to be met by HVAC system.

A cool roof reflects and emits the sun's heat back to the sky instead of transferring it to the building below.

"Coolness" is measured by two properties, solar reflectance and thermal emittance. Both properties are measured from 0 to 1 and the higher the value, the "cooler" the roof

Benefits of cool roofs:

Cool roofs, in hotter climates, can offer both immediate and long-term benefits including:

- Savings of up to 15% the annual air-conditioning energy use of a single-story building
- Help in mitigating the urban heat island effect
- Reduced air pollution and greenhouse gas emissions, as well as a significant offsetting of the warming impact of greenhouse gas emissions.
- Improved occupant comfort.
- Comply with codes and green building programs.

Properties

There are two properties that are used to measure the effects of cool roofs:

- Solar reflectance, also known as albedo, is the ability to reflect sunlight. It is expressed either as a decimal fraction or a percentage. A value of 0 indicates that the surface absorbs all solar radiation, and a value of 1 represents total reflectivity.
- Thermal emittance is the ability to emit absorbed heat. It is also expressed either as a decimal fraction between 0 and 1, or a percentage.

Types of cool roof

Cool roofs fall into one of three categories: roofs made from cool roofing materials, roofs made of materials that have been coated with a solar reflective coating, or green roofs

Cool roofs

White thermoplastic membrane roofs, are inherently reflective, achieving some of the highest reflectance and emittance measurements of which roofing materials are capable. A roof made of white thermoplastic, for example, can reflect 80 percent or more of the sun's rays and emit at least 70% of the solar radiation that the roof absorbs. An asphalt roof only reflects between 6 and 26% of solar radiation.

Coated roofs

An existing (or new) roof can be made reflective by applying a solar reflective coating to its surface. The reflectivity and emissivity ratings for over 500 reflective coatings can be found in the Cool Roofs Rating Council.Green roofs

Green roofs provide a thermal mass layer which helps reduce the flow of heat into a building. The solar reflectance of green roofs varies depending on the plant types (generally 0.3– 0.5).Green roofs may not reflect as much as a cool roof but do have other benefits such as evapotranspiration which cools the plants and the immediate area around the plants, aiding in lowering rooftop temperatures but increasing humidity, naturally. Moreover, some Green roofs need maintenance such as regularly watering.

OPAQUE WALLS

Defined as all other constructions by their individual material layers and the thermos physical properties (eventual from standard libraries) of the material-layers.

WALL – BUILDING ENVELOPE

A **wall** is a structure that defines an area, carries a load, or provides shelter or security. There are many kinds of walls:

- Defensive walls in fortification
- Walls in buildings that form a fundamental part of the superstructure or separate interior sections, sometimes for fire safety
- Retaining walls, which hold back earth, stone, or water
- Walls that protect from oceans (seawalls or rivers levees)
- Permanent, solid fences
- Border barriers between countries

- Brick wall
- Stone wall
- Glass wall (only when most of the wall, in smaller amounts it is called a window)
- Doors are mobile walls on hinges which open to form a gateway

Defensive wall - The word wall originally referred to defensive walls and rampart

Building wall - Building walls purposes are to support roofs, floors and ceilings, enclose a space as part of the building envelope, along with a roof to give buildings form, and to provide shelter and security. In addition, the wall may house various types of utilities such as electrical wiring or plumbing.

Curtain wall - In architecture and civil engineering, *curtain wall* refers to a building facade that is not load-bearing but provides decoration, finish, front, face, or historical preservation.

Mullion wall - Mullion walls are a structural system that carries the load of the floor slab on prefabricated panels around the perimeter.

Party wall - Party walls are walls that separate buildings or units within a building. They provide fire resistance and sound resistance between occupants in a building.

Infill wall - An infill wall is the supported wall that closes the perimeter of a building constructed with a three-dimensional framework structure.

Fire wall - Fire walls resist spread of fire within or sometimes between structures to provide passive fire protection. A delay in the spread of fire gives occupants more time to escape and fire fighters more time to extinguish the fire. Such walls have no windows, and are made of non- combustible material such as concrete, cement block, brick, or fire rated drywall—and have wall penetrations sealed with special materials. A doorway in a firewall must have a rated fire door.

Shear wall - Shear walls resist lateral forces such as in an earthquake or severe wind. There are different kinds of shear walls such as the steel plate shear wall.

Knee wall - Knee walls are short walls that either support rafters or add height in the top floor rooms of houses. In a one-and-one-half story house, the knee wall supports the *half story*.

Cavity wall - Cavity walls are walls made with a space between two "skins" to inhibit heat transfer.

Pony wall – Pony wall is a general term for short walls, such as:

A half wall that only extends partway from floor to ceiling, without supporting anything

- A stem wall—a concrete wall that extends from the foundation slab to the cripple wall or floor joists
- A cripple wall—a framed wall from the stem wall or foundation slab to the floor joists

Solar energy - A trombe wall in passive solar building design acts as a heat sink.

SKYLIGHTS:

Skylights are light transmitting fenestration (elements filling building envelope openings) forming all, or a portion of, the roof of a building's space for daylighting purposes.

Skylighting types include roof windows, unit skylights, tubular daylighting devices (TDDs), sloped glazing, and custom skylights. Uses include:

- daylighting elements used to allow direct and/or indirect sunlight, via toplighting.
- providing a visual connection to the outdoor environment to interior occupants.
- sustainable building — passive solar heating, and with operable units; ventilation for passive cooling and fresh air exchange.

Fixed unit skylight

A fixed skylight consists of a structural perimeter frame supporting glazing infill (the light-transmitting portion, which is made primarily of glass or plastic). A fixed skylight is non-operable, meaning there is no ventilation.

Operable skylight

An operable (venting) unit skylight uses a hinged sash attached to and supported by the frame.

When within reach of the occupants, this type is also called a roof window.

Retractable skylight

A retractable skylight rolls - on a set of tracks - off the frame, so that the interior of the facility is entirely open to the outdoors, i.e., not impeded by a hinged skylight. The terms retractable skylight and retractable roof are often used interchangeably, though skylight implies a degree of transparency.

Windows, doors, and skylights – VERTICAL FENESTRATION

Collectively known as fenestration, windows, exterior doors, and skylights influence both the lighting and the HVAC requirements of a building.

In addition to design considerations (the placement of windows and skylights affects the amount of available natural light), materials and installation can affect the amount of energy transmitted through the window, door, or skylight, as well as the amount of air leakage around the window components.

New materials, coatings, and designs all have contributed to the improved energy efficiency of high-performing windows, doors, and buildings.

Some of the advances in windows include: multiple glazing, the use of two or more panes of glass or other films for insulation, which can be further improved by filling the space between the panes with a low-conductivity gas, such as argon, and low-emissivity (low-e) coatings, which reduce the flow of infrared energy from the building to the environment.

In residential buildings, using optimum window design and glazing specification is estimated to reduce energy consumption from 10 to 50 percent below accepted practice in most climates; in commercial buildings, an estimated 10 to 40 percent reduction in lighting and HVAC costs is attainable through improved fenestration.

Points to be consider on Vertical Fenestration:

- Skylights admit harsh direct overhead sunlight and glare either horizontally (a flat roof) or pitched at the same angle as the roof slope.
- In some cases, horizontal skylights are used with reflectors to increase the intensity of solar radiation (and harsh glare), depending on the roof angle of incidence.

- When the winter sun is low on the horizon, most solar radiation reflects off of roof angled glass (the angle of incidence is nearly parallel to roof-angled glass morning and afternoon).
- When the summer sun is high, it is nearly perpendicular to roof-angled glass, which maximizes solar gain at the wrong time of year, and acts like a solar furnace.
  - Skylights should be covered and well-insulated to reduce natural convection (warm air rising) heat loss on cold winter nights, and intense solar heat gain during hot spring/summer/fall days

  The equator-facing side of a building is south in the northern hemisphere, and north in the southern hemisphere.

- Skylights on roofs that face away from the equator provide mostly-indirect illumination, except for summer days when the sun rises on the non-equator side of the building (depending on latitude).
- Skylights on east-facing roofs provide maximum direct light and solar heat gain in the summer morning.
- West-facing skylights provide afternoon sunlight and heat gain during the hottest part of the day.
- Some skylights have expensive glazing that partially reduces summer solar heat gain, while still allowing some visible light transmission. However, if visible light can pass through it, so can some radiant heat gain (they are both electromagnetic radiation waves.
- Partially reduce some of the unwanted roof-angled-glazing summer solar heat gain by installing a skylight in the shade of deciduous (leaf-shedding) trees, or by adding movable insulated opaque window covering on the inside or outside of the skylight.
- This would eliminate the daylight benefit in the summer. If tree limbs hang over a roof, they will increase problems with leaves in rain gutters, possibly because roof-damaging ice dams, shorten roof life, and provide an easier path for pests to enter your attic.
- Leaves and twigs on skylights are unappealing, difficult to clean, and can increase the glazing breakage risk in wind storms.
- "Saw tooth roof glazing" with vertical-glass-only can bring some of the passive solar building design benefits into the core of a commercial or industrial building, without the need for any roof-angled glass or skylights.
- Skylights provide daylight. The only view they provide is essentially straight up in most

applications. Well-insulated light tubes can bring daylight into northern rooms, without using a skylight. A passive-solar greenhouse provides abundant daylight for the equatorside of the building.

- Infrared thermography color thermal imaging cameras (used in formal energy audits) can quickly document the negative thermal impact of roof-angled glass or a skylight on a cold winter night or hot summer day.

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SCHOOL OF BUILDING AND ENVIRONMENT
DEPARTMENT OF CIVIL ENGINEERING

UNIT – IV - ENERGY CONSEVATION IN BUILDINGS THROUGH VENTILATION AND LIGHTING – SCI1202

Ventilation

It is the process by which fresh air is introduced and ventilated air is removed from an occupied space. The primary aim of ventilation is to preserve the qualities of air. Sometimes, ventilation may also be used to lower the temperature inside an occupied area.

Fresh Air - Fresh air provides the steady supply of rich oxygen and it is free from pollutants.

There are two types of ventilation – natural and mechanical ventilation

a) Natural ventilation

Natural ventilation is the process of supplying and removing air by means of purpose-provided aperture (such as openable windows, ventilators and shafts) and the natural forces of wind and temperature-difference pressures.

Natural ventilation may be divided into two categories:

i) ***Controlled natural ventilation*** is intentional displacement of air through specified openings such as windows, doors, and ventilations by using natural forces (usually by pressures from wind and/or indoor-outdoor temperature differences). It is usually controlled to some extent by the occupant.

ii) ***Infiltration*** is the uncontrolled random flow of air through unintentional openings driven by wind, temperature-difference pressures and/or appliance-induced pressures across the building envelope. In contrast to controlled natural ventilation, infiltration cannot be so controlled and is less desirable than other ventilation strategies, but it is a main source of ventilation in envelope-dominated buildings.

b) Mechanical ventilation

Mechanical or forced ventilation is the process of supplying and removing air by means of mechanical devices, such as fans. It may be arranged to provide either supply, extract or balanced ventilation for an occupied space.

There are also specialised areas in which ventilation is vital, such as ventilation for industrial processes, mines, tunnels and underground development. Fans and blowers cause the movement of air within buildings and through enclosures. By doing so, they can generate large pressures. If more air is exhausted from a building than is supplied, a net negative pressure is generated and vice versa.

If air is forced through the ducts that leave the building enclosure or pass outside the primary air barrier system (e.g., the very bad practise of placing ductwork in vented attics or crawlspaces) any leaks in the ductwork (and all ducts have some leakage, most ductwork is very leaky) will result in a net exhaust of air, and hence a net negative inward pressures on the building enclosure. The reverse can happen if leaky ducts outside the air barrier are under a net suction pressure. Bathroom exhaust fans, clothes dryers, built-in vacuum cleaners, dust collection systems, and range hoods all exhaust air from a building. This creates a negative pressure inside the building. If the enclosure is airtight or the exhaust flow rate high, large negative pressures can be generated.

These negative pressures have the potential to cause several problems:

- by driving inward air leakage through the enclosure, outdoor air may transport moisture into the enclosure during hot humid outdoor weather conditions
- the negative pressures can cause back drafting of combustion appliances.
- the efficiency of most air handling devices will decrease with increasing back pressures.

Traditional methods for aiding ventilation

There are three common methods of traditional ventilation : courtyard, wind catcher and ventilation shaft

1. **Courtyard**

A **courtyard** or **court** is an enclosed area, often surrounded by a building or complex, that is open to the sky. Such spaces in inns and public buildings were often the primary meeting places for some purposes, leading to the other meanings of court.

Courtyards have historically been used for many purposes including cooking, sleeping, working, playing, gardening, and even places to keep animals.

- Due to incident solar radiation in a courtyard, the air gets warmer and rises.
- Cool air from the ground level flows through the louvered openings of rooms surrounding a courtyard, thus producing air flow.

At night, the warm roof surfaces get cooled by convection and radiation.

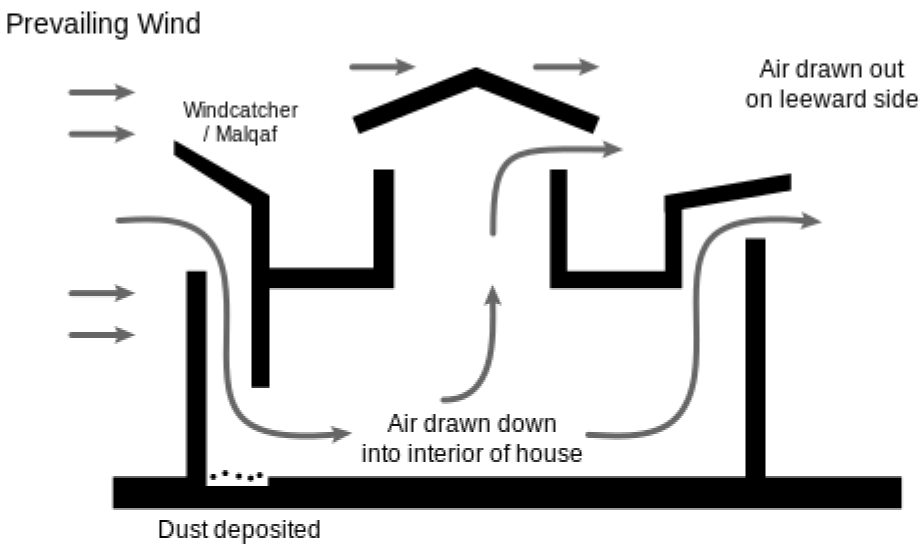
- If this heat exchange reduces roof surface temperature to wet bulb temperature of air, condensation of atmospheric moisture occurs on the roof and the gain due to condensation limits further cooling.
- If the roof surfaces are sloped towards the internal courtyard, the cooled air sinks into the court and enters the living space through low-level openings, gets warmed up, and leaves the room through higher-level openings.
- However, care should be taken that the courtyard does not receive intense solar radiation, which would lead to conduction and radiation heat gains into the building.

Courtyards

2. Wind catcher

A wind catcher is a traditional Persian architectural element to create natural ventilation in buildings.[3]Wind catchers come in various designs: uni-directional, bi-directional, and multi-directional. Wind catchers remain present in many countries and can be found in traditional Persian-influenced architecture throughout the Middle East.

The wind catcher can function in three ways: directing airflow downward using direct wind entry, directing airflow upwards using a wind-assisted temperature gradient, or directing airflow upwards using a solar-assisted temperature gradient.



Function of Wind catcher

- **Downward airflow due to direct wind entry**

One of the most common uses of the wind catcher is to cool the inside of the dwelling; it is often used in combination with courtyards and domes as an overall ventilation and heat-management strategy. It is essentially a tall, capped tower with one face open at the top. This open side faces the prevailing wind, thus "catching" it, and brings it down the tower into the heart of the building to maintain air flow, thus cooling the building interior.

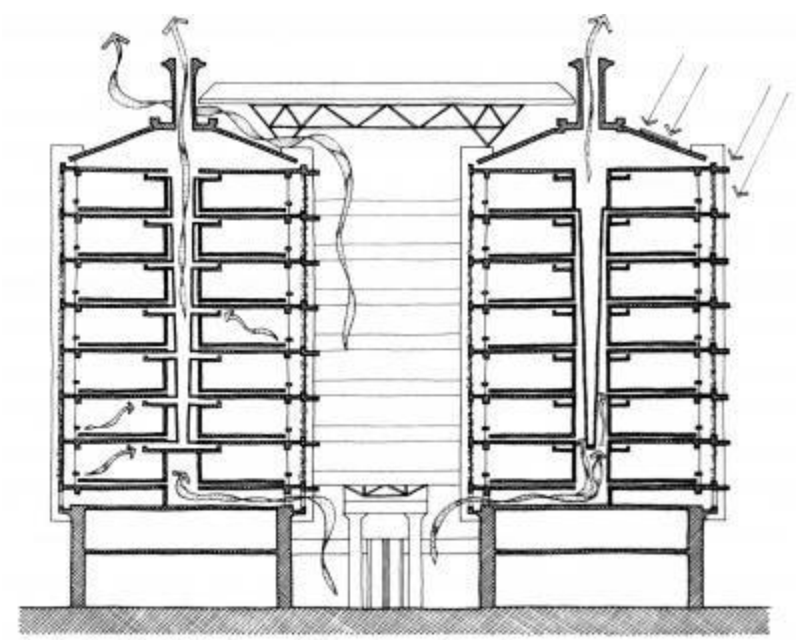
- ***Wind-assisted temperature gradient***

Wind catchers are also used in combination with underground canal. In this method, the open side of the tower faces away from the direction of the prevailing wind (the tower's orientation can be adjusted by directional ports at the top). By keeping only this tower open, air is drawn upwards.

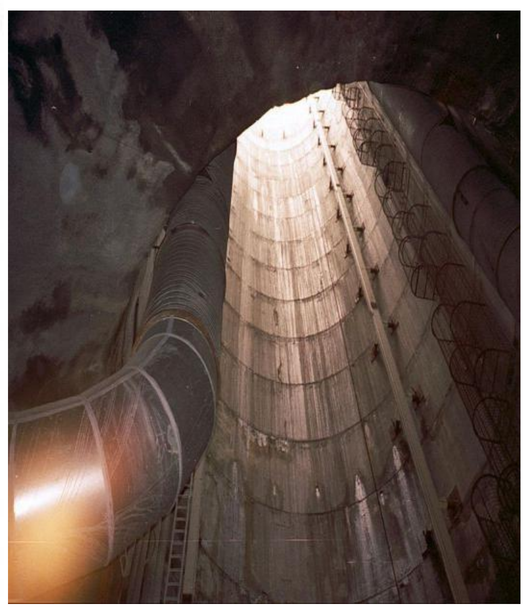
- ***Solar-produced temperature gradient***

In a windless environment or waterless house, a windcatcher functions as a solar chimney. It creates a pressure gradient which allows hot air, which is less dense, to travel upwards and escape out the top.

3. **Airshaft**



Section, Eastgate Building, Harare, Zimbabwe, Pearce Partnership

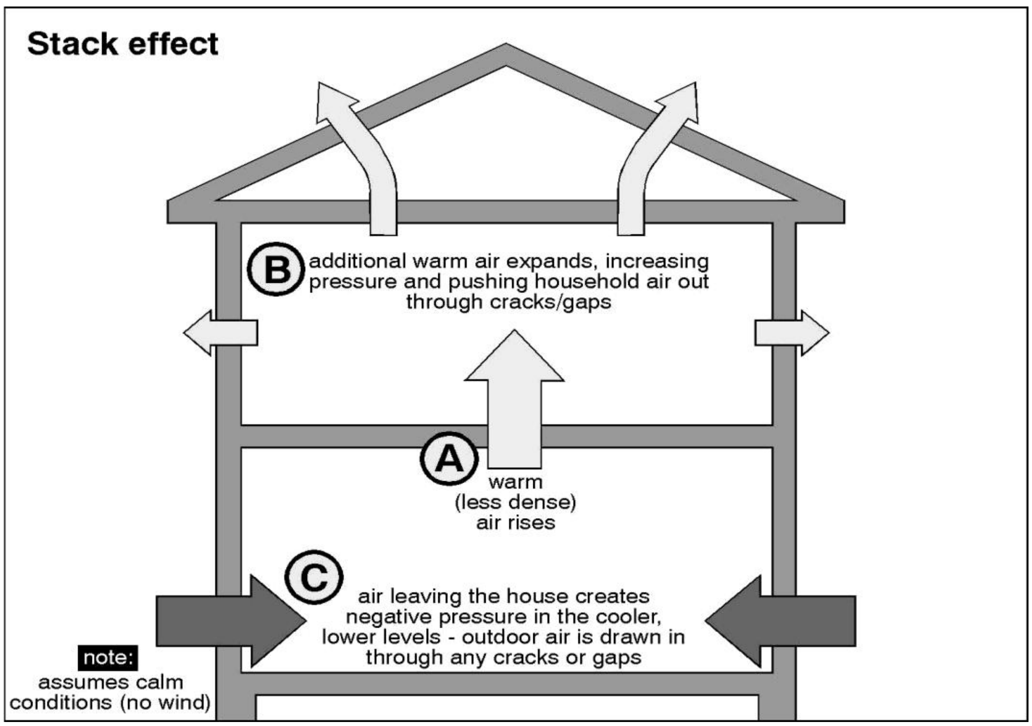


It is the vertical space within a tall building which permits ventilation of the building's interior spaces to the outside. The floorplan of a building with an airshaft is often described as a "square donut" shape. Alternatively, an airshaft may be formed between two adjacent buildings. Windows on the interior side of the donut allow air from the building to be exhausted into the shaft, and, depending on the height and width of the shaft, may also allow extra sunlight inside.

Ventilation shaft in a multistorey building Ventilation shaft in a tunnel

Stack effect

Since buildings are not totally sealed (at the very minimum, there is always a ground level entrance), the stack effect will cause air infiltration. During the heating season, the warmer indoor air rises up through the building and escapes at the top either through open windows, ventilation openings, or unintentional holes in ceilings, like ceiling fans and recessed lights. The rising warm air reduces the pressure in the base of the building, drawing cold air in through either open doors, windows, or other openings and leakage. During the cooling season, the stack effect is reversed, but is typically weaker due to lower temperature differences.



There is a pressure difference between the outside air and the air inside the building caused by the difference in temperature between the outside air and the inside air. That pressure difference (ΔP) is the driving force for the stack effect and it can be calculated with the equations presented below. The equations apply only to buildings where air is both inside and outside the buildings. For buildings with one or two floors, h is the height of the building. For multi-floor, high-rise buildings, h is the distance from the openings at the neutral pressure level (NPL) of the building to either the topmost openings or the lowest openings.

$$\Delta P = C\,a\,h\left(\frac{1}{T_o} - \frac{1}{T_i}\right)$$

where:

ΔP = available pressure difference, in Pa
C = 0.0342

a = atmospheric pressure, in Pa

h = height or distance, in m

T_o = absolute outside temperature, in K

T_i = absolute inside temperature, in K

Mechanism for Air movement through Buildings:

There are three primary mechanisms which generate the pressure differences required for air flow within and through buildings :

1. wind,
2. stack effect or buoyancy, and
3. mechanical air handling equipment and appliances.

For air flow to occur, there must be both:

1. a pressure difference between two points, and
2. a continuous flow path or opening connecting the points.

Air movement through the buildings

Successful design of naturally ventilated building requires a good understanding of the air flow patterns around it and the effect of the neighboring buildings. The objective is to ventilate the largest possible part of the indoor space. Fulfillment of this objective depends on window location, interior design and wind characteristics.

As wind approaches the face of a building the airflow is slowed, creating positive pressure and a cushion of air on the building's windward face. This cushion of air, in turn, diverts the wind toward the building sides. Airflow as it passes along the sidewalls separates from building wall surfaces and, coupled with high-speed airflow, creates suction (negative pressure) along these wall surfaces. On the building leeward side a big slow-moving eddy is created. Suction on the leeward side of the building is less than on the sidewalls (Figure 1).

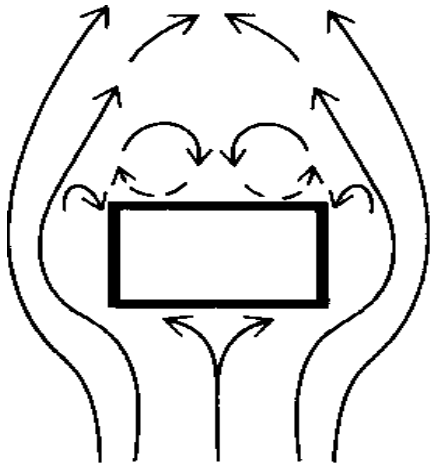


FIGURE 1

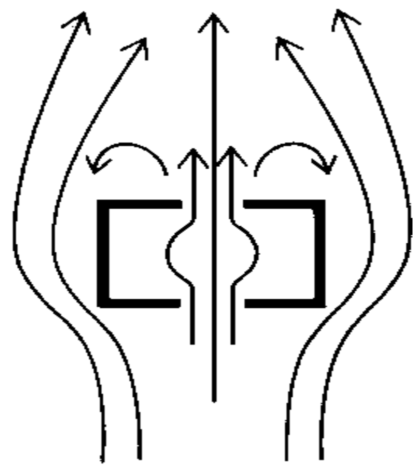


FIGURE 2

If windows are placed in both windward and leeward faces, the building would be cross ventilated and eddies will develop against the main airflow direction (Figure 2).

Ventilation can be enhanced by placing windows in sidewalls due to the increased suction at this location; also, greater air recirculation within the building will occur due to air inertia (Figure 3). Winds often shift direction, and for oblique winds, ventilation is best for rooms with windows on three adjacent walls (Figure 4) than on two opposite walls (Figure 5).

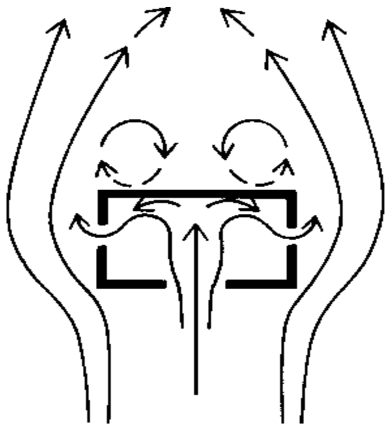


FIGURE 3

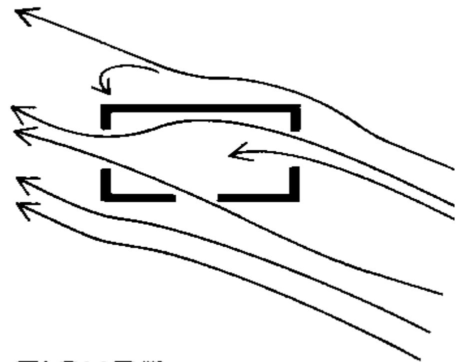


FIGURE 4

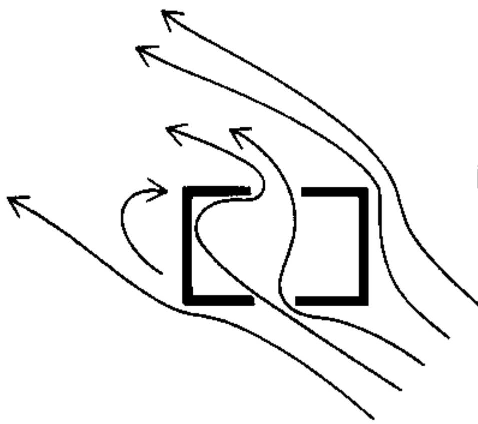


FIGURE 5

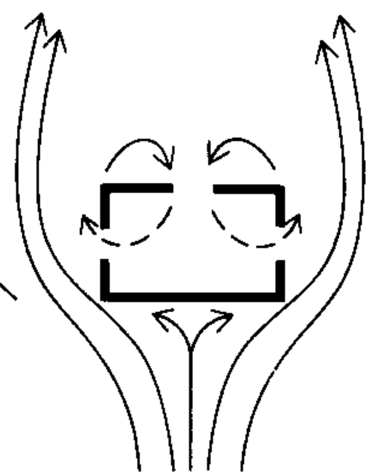


FIGURE 6

However, if wind is from the one windowless side, then ventilation is poor, since all openings are in suction (Figure 6).

If the building configuration only allows for windows in one wall, then negligible ventilation will occur with the use of a single window, because there is not a distinct inlet and outlet. Ventilation can be improved slightly with two widely spaced windows. Airflow can be enhanced in these situations by creating positive and negative pressure zones by use of architectural features such as wing walls (Figure 7). Care must be exercised in developing these features to avoid counteracting the natural airflow, thereby weakening ventilation (Figure 8).

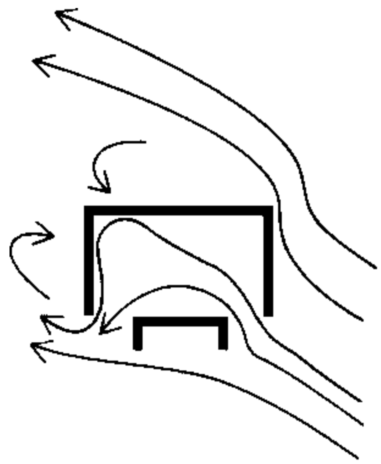


FIGURE 7

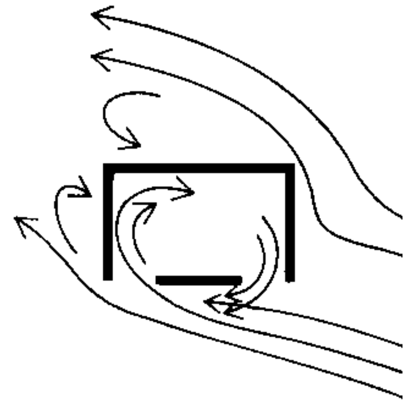


FIGURE 8

As airflow passes through a well-ventilated room, it forms an "air jet." If the windows are centered in a room, it forms a free jet (Figure 9). If, however, the openings are near the room walls, ceiling, or floor, the air stream attaches itself to the surface, forming a wall jet (Figure 10). Since heat removal from building surfaces is enhanced with increased airflow, the formation of wall jets is important in effecting rapid structure cooling. To improve the overall airflow within a room, offsetting the inlet and outlet will promote greater mixing of room air (Figure 11).

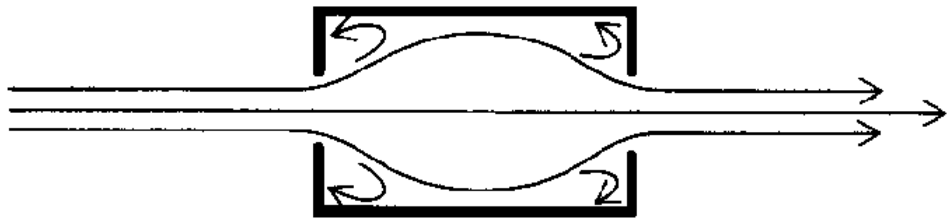


FIGURE 9

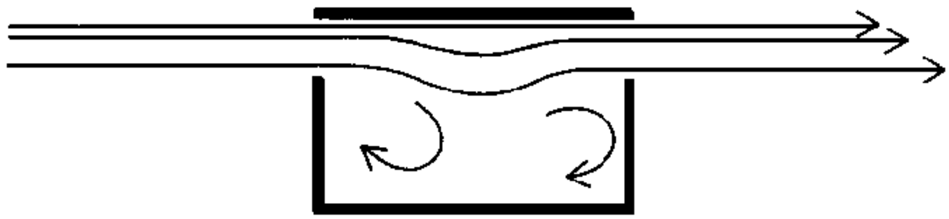


FIGURE 10

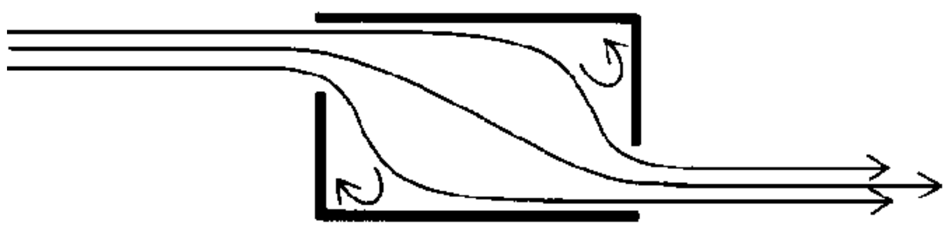
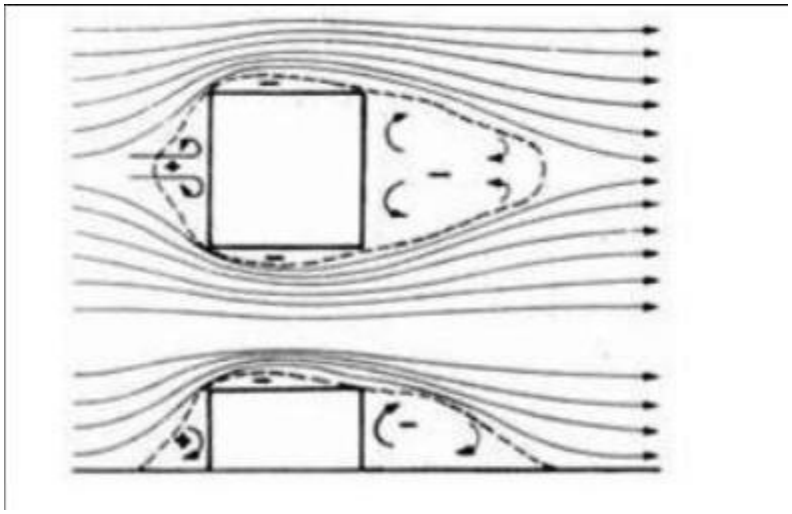


FIGURE 11

Air movement around the building

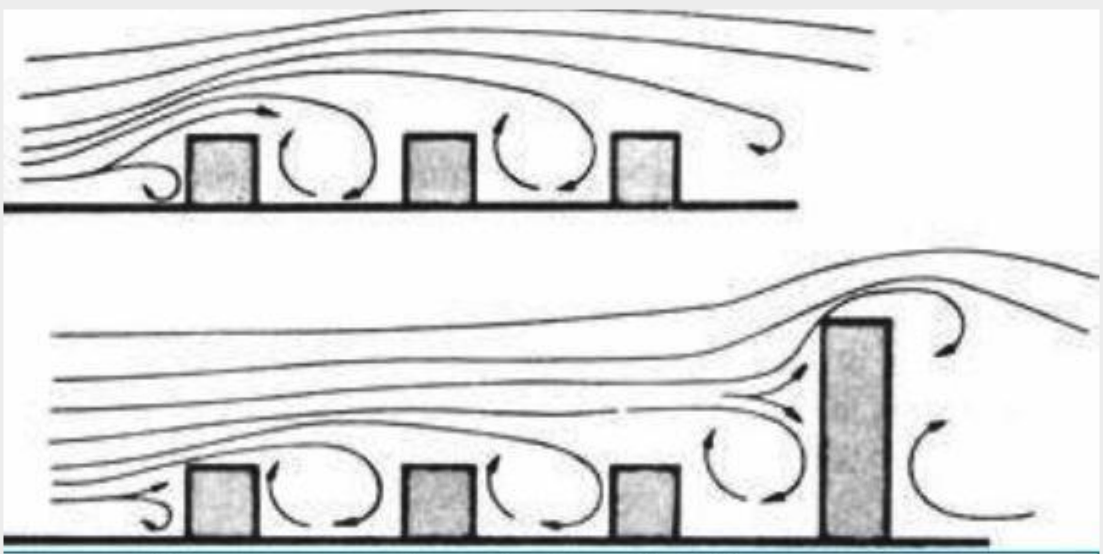
Thermal forces are rarely sufficient to create appreciable air movements. The only natural force that can be relied on is the dynamic effect of winds as shown in fig.



Air flow around the buildings in plan

1. **Air stream separation at the face of buildings**

The effect of tall blocks in mixed developments is shown in figure. Figure shows how the air stream separates on the face of a tall block, part of it moving up and over the roof part of it down, to form a large vortex leading to a very high pressure build-up. An increased velocity is found at ground level at the sides of the tall block. This could serve a useful purpose in hot climates, although if the tall block is not fully closed but is permeable to wind, these effects may be reduced.

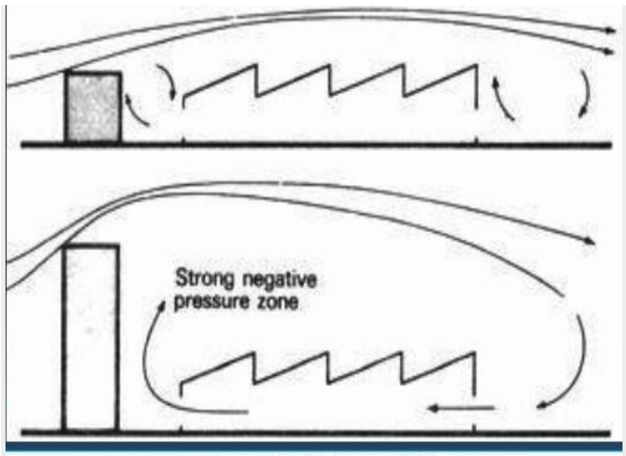


Air stream separation at the face of buildings

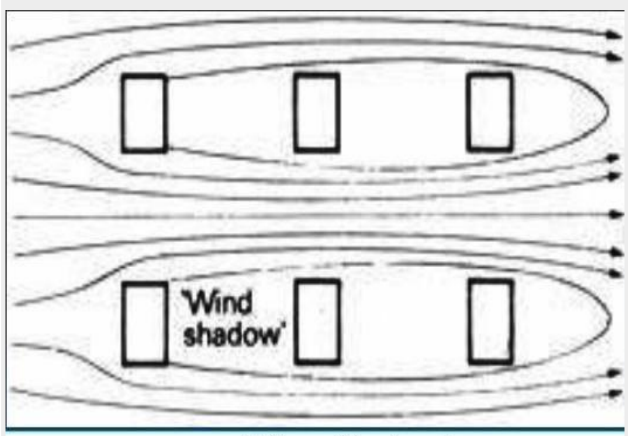
2. **Reverse flow behind a tall block** If a low building is located in the wind shadow of a Tall block , the increase in height of the obstructing block will increase the air flow Through the low building in a direction opposite to that of the wind. The lower (return-) wing of a Large vortex would pass through the building.

3. **Air flow: grid-iron lay-out**

   if in a rural setting in open country, single storey buildings are placed in rows in a grid-iron pattern, stagnant air zones leeward from the first row will overlap the second row. A spacing of six times the building height is necessary to ensure adequate air movement for the second row. Thus the 'five times height' rule for spacing is not quite satisfactory



Reverse flow behind a tall block



Air flow: grid-iron lay-out

4. **Air flow: checkerboard lay-out :**
   In a similar setting, if the buildings are staggered in a checker-board pattern, the flow field is much more uniform, stagnant air zones are almost eliminated.

Lighting Types:

Ambient lighting

Accent lighting

Task lighting

Aesthetic Lighting

Natural lighting

i. Ambient lighting:

A hidden source of light that washes a room with a glow. It flattens an interior and creates very little shadow. A wall sconce is an example of ambient lighting. So are those Japanese paper shades you find in stores. Use of a dimmer also can provide ambient light.

ii. Accent lighting:

Directional lighting or lighting that adds interest or highlights a certain object or unusual architectural feature in a room. A bulb and some kind of shield to direct the light are all that's needed for this type of lighting. Halogen spotlights and table lamps with opaque shades are good ways to achieve accent lighting.

iii. Task lighting:

Task lighting is just that; lighting that's used to perform daily activities such as reading, cooking, shaving, putting on makeup, etc. It needs to be glare-free. Effective task lighting enhances visual clarity and keeps the eyes from getting tired.

Different banks of task light are useful in the kitchen -- near the stove and chopping areas are places for this type of lighting. Task-lighting sources are never seen and any task light should have a reflective shield. Ambient lighting and task lighting go hand in hand. Pools of light created by several spots produce a lovely effect.

iv. Aesthetic lighting:

Lighting itself can be a work of art. A neon sculpture would be purely decorative and an example of aesthetic lighting. A spotlight illuminating a statue on a pedestal or portrait on the wall is also artistic. This type of lighting also needs to be used along with other lighting types.

v. Natural lighting:

Sunlight, candlelight and firelight; this is light that moves and is sometimes referred to as kinetic. The quality of natural light, sunlight in particular, depends on many things -- time of day, weather, what season it is. Fall has a different light than summer, for instance. The setting sun gives a different kind of light than midday sun.

Exterior Building grounds lights:

Outdoor lighting can make a home look warm and inviting or majestic and regal depending on the type and placement of the lights. At the same time outdoor lighting can light driveways and pathways for guests while providing security and a deterrent to intruders. Choosing the right outdoor lighting for your home is easier to do when you have a basic understanding of the different types of outdoor lighting fixtures available. Then you can decide what lights will work best for your purpose.

There are five different types of outdoor lighting options to choose from. Each creates a certain effect and will work best in particular types of situations. The most important thing to remember when choosing outdoor lights is that light is fluid and the way it is encased and directed will have a major impact on the way the light is diffused and therefore how well it realizes your goals.

i. Path Lights or Spot Lights:

Path lights are the most commonly used outdoor lights. Placed along the sides of a walkway, path or driveway, path lights are low to the ground and spread the light down and out so that you can see where you are walking and not stray off the path. You don’t need as many lights as you might think and using too many can make your driveway look like the local airport.

Path lights work as well in the back yard as they do in the front yard and provide a warm, soft light without producing glare. Solar powered path lights are a popular option as they do not require any additional wiring or power to operate which can save on your power bill.

ii. Down lights or Flood Lights:

Motion detector lights that are placed on the house or garage are down lights. They are placed high and pointed down toward the ground and are most often used for security purposes. Down lights are very bright and create a glare so if you are using them to create natural lighting you may want to place the lights in a tree or in some other way shield they so the light is diffused and you can't see the bulb.

iii. Up Lights:

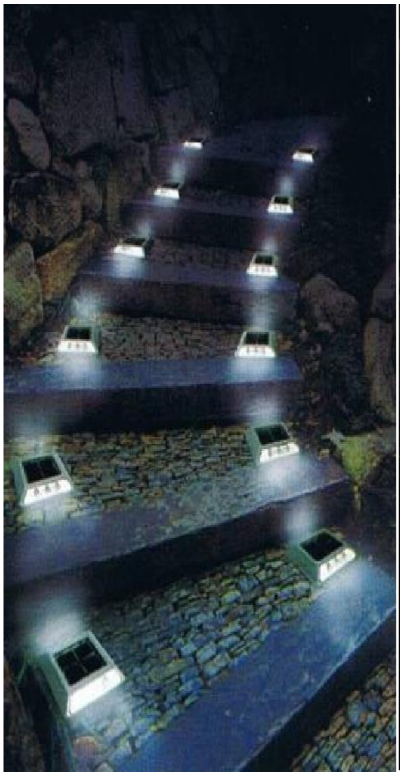
Up lights are most often spot lights that are placed on the ground and pointed upward toward a tree or fountain or anything you wish to use as a focal point with your outdoor lighting. The ambient light of up lights create can also be useful for patios and walkways as well depending on how they are placed.

iv. Backlights :

Backlights are an outdoor lighting option and are used to enhance your landscape in some artistic manner. For example, a backlight might be placed behind a plant in such a way as to cast a shadow on a wall while bringing attention to the plant. Backlights create drama and are usually placed behind an object and out of sight.

v. Specialty Lights:

specialty lights have become a popular option in outdoor lighting when creating an outdoor living space on a deck or patio. They include string lights, torches, underwater lights, lanterns and the like and are used to create mood and ambiance wherever they are placed.



Path light ***Down lights***

Uplights *Speciality lights*

Backlight

Types of lights

There are four basic types of lights:

1. Incandescent,
2. Fluorescent,
3. High-intensity discharge, and
4. Low-pressure sodium

1. Incandescent Light

Light is produced by a tiny coil of tungsten wire that glows when it is heated by an electrical current. They have shortest lives and they are Inefficient

2. **Fluorescent lights**

- It is filled with an argon or argon-krypton gas and a small amount of mercury.
- Fluorescent lamps last about 10 times longer than incandescent bulbs
- Fluorescent lights need ballasts (i.e., devices that control the electricity used by the unit) for starting and circuit protection
- Compact Fluorescent lamps (CFL) can replace incandescents that are roughly 3 to 4 times their wattage. They last 10 to 15 times as long. Cost from 10 to 20 times more than comparable incandescent bulbs. One of the best energy efficiency investments available.

3. **High-intensity discharge light**

High-intensity discharge (HID) lamps provide the highest efficacy and longest service life of any lighting type

a. **mercury vapor**
b. **metal halide**, and **high-pressure sodium**

They also require ballasts, and they take a few seconds to produce light when first turned on because the ballast needs time to establish the electric arc

4. **Low-pressure sodium light**

- Low-pressure sodium (LPS) lamps have a borosilicate glass gas discharge tube (arc tube) containing solid sodium, a small amount of neon, and argon gas in a Penning mixture to start the gas discharge.

- Very efficient lamp
- Powerful lamp for use of large areas
- Despite a warm up time of 5-10 minutes it restarts immediately if there is a brownout
- Lumen output does not drop with age (such as in LEDs or incandescents)

- Worst color rendering of any lamp
- Sodium is a hazardous material which can combust when exposed to air

Study of interiors in lighting and their effects:

Begin by planning the building such that every regularly occupied work or Living space has access to a window, skylight, or other source of natural light. Give high priority to windows that provide a view.

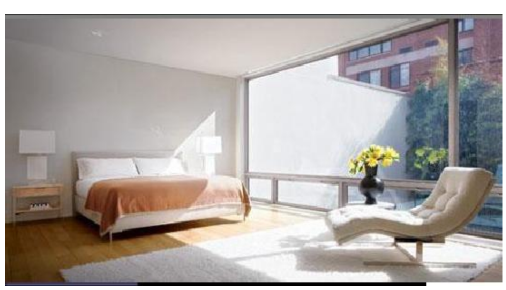
1. Remember that the effective day lighted area extends into the building only about 2 times the width of a window and about 2 to 2.5 times its height.

2. Minimize the size of the east and west sides of the building and maximize. The south and north sides of the building. Because of the seasonally varying Paths of the sun in the sky, it is difficult to design east- and west- facing windows. North-facing windows in the northern hemisphere present no solar Heating problems, and south-facing windows are the easiest to protect with Passive elements like overhangs, awnings, and light shelves.

3. If a large area of the building is not near a window, investigate top-light skylights in one-story buildings or the top floor of multistory buildings. Simple Top-light skylights should occupy 3% to 5% of the total roof area in order to provide adequate levels of interior lighting.

4. Protect the interior from too much natural light 2.5 times or higher the Level of ordinary electric light — by employing appropriate window glass, Exterior shading devices, interior shading devices, or a combination of these.

5. Provide an electric lighting system and/or automatic lighting controls to permit harvesting of the energy savings. The best way is to dim the electric lights rather than switch them on and off. Modern fluorescent dimming systems allow day lighting controls and fundamentally energy-efficient fluorescent and compact fluorescent lighting



The day lighting area for the bed room

Exit sign:

- An **exit sign** is a device in a public facility (such as a building, aircraft or boat) denoting the location of the closest emergency exit in case of fire or other emergency.
- Electrically powered exit signs normally use incandescent bulbs.
- Most **LED** and some **CFL** exit signs can meet ECBC requirement.
- Due to their low power consumption, LED exit signs can be purchased with built-in backup power supplies (i.e., batteries).
- With an estimated service life of 10 years or more, LEDs require significantly fewer lamp replacements than exit signs equipped with either incandescent lamps or CFLs.

Exit

Introduction to Energy conservation

- It refers to reducing energy consumption through using less of an energy service. Energy conservation differs from efficient energy use, which refers to using less energy for a constant service.
- **Energy conservation** includes any behavior that results in the use of less energy.
- It focuses on the behavior of people.
- One example is using day lighting through windows rather than turning on the lights. Another example is, driving less is an example of energy conservation.
- Driving the same amount with a higher mileage vehicle is an example of energy efficiency.
- Energy conservation and efficiency are both energy reduction techniques.
- **Energy efficiency** involves the use of technology that requires less energy to perform the same function. It focuses on the equipment or machinery being used. Eg. LED light bulbs throughout the house

Energy Conservation in Lighting System (Lighting Control)

The mandatory requirements for lighting mostly relate to interior and exterior lighting controls:

i. Lighting controls allow lighting to be turned down or completely off when it is not needed – the simplest way to save energy.

ii. It includes on-off controls, dimming controls, and systems that combine the use of both types of equipment.

iii. Controls include time clocks, occupant and motion sensors, automatic or manual day lighting controls, and astronomical time switches (the automatic switches that adjust for the length of the day as it varies over the year).

iv. They perform two basic functions:1) they turn lights off when not needed, and 2) they modulate light output so that no more light than necessary is produced.

v. Use a time scheduling device to control lighting systems according to predetermined schedules.

vi. Control the lights in response to the presence or absence of people in the space.

vii. Switch or dim electric lights in response to the presence or absence of daylight illumination in the space.

viii. Gradually adjust electric light levels over time to correspond with the depreciation of light output from aging lamps.

ix. Minimum one control device per 250 m^2 coverage area is required for the total area upto 1000 m^2.

x. Minimum one control device per 1000 m^2 coverage area is required for the total area more than 1000 m^2.

xi. Lighting for all exterior applications shall be controlled by a photosensor or astronomical time switch that is capable of automatically turning off the exterior lighting when daylight is available or the lighting is not required.

xii. Display or accent lighting greater than 300 m2 (3,000 ft2) area shall have a separate control device.

xiii. Lighting in cases used for display purposes greater than 300 m2 (3,000 ft2) area shall be equipped with a separate control device.

xiv. Hotel and motel guest rooms and guest suites shall have a master control device at the main room entry that controls all permanently installed luminaires and switched receptacles.

xv. Supplemental task lighting including permanently installed under-shelf or under cabinet lighting shall have a control device integral to the luminaires or be controlled by a wall-mounted control device.

xvi. Lighting for non-visual applications, such as plant growth and food-warming, shall be equipped with a separate control device.

xvii. Lighting equipment that is for sale or for demonstrations in lighting education shall be equipped with a separate control device accessible only to authorized personnel

Energy Conservation in Ventilation System

Maximum possible use should be made of wind-induced natural ventilation. This may be accomplished by following the design guidelines

i. Adequate number of circulating fans should be installed to serve all interior working areas during the summer months in the hot dry and warm humid regions to provide necessary air movement at times when ventilation due to wind action alone does not afford sufficient relief.
ii. The capacity of a ceiling fan to meet the requirement of a room with the longer dimension D meters should be about 55D m3/min.
iii. The height of fan blades above the floor should be (3H + W)/4, where H is the height of the room, and W is the height of the work plane.
iv. The minimum distance between fan blades and the ceiling should be about 0.3 meters.
v. Electronic regulators should be used instead of resistance type regulators for controlling the speed of fans.
vi. When actual ventilated zone does not cover the entire room area, then optimum size of ceiling fan should be chosen based on the actual usable area of room, rather than the total floor area of the room. Thus smaller size of fan can be employed and energy saving could be achieved.
vii. Power consumption by larger fans is obviously higher, but their power consumption per square meter of floor area is less and service value higher. Evidently, improper use of fans irrespective of the rooms dimensions is likely to result in higher power consumption. From the point of view of energy consumption, the number of fans and the optimum sizes for rooms of different dimensions are taken from ECBC.

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SCHOOL OF BUILDING AND ENVIRONMENT
DEPARTMENT OF CIVIL ENGINEERING

UNIT – V - ENERGY EFFICIENT BUILDINGS AND TECHNOLOGIES – SCIA1202

Energy efficient buildings (new constructions or renovated existing buildings) can be defined as buildings that are designed to provide a significant reduction of the energy need for Space conditioning ie .heating and cooling, independently of the energy and of the equipments that will be chosen to heat or cool the building.

Needs for Energy Efficiency in Existing Buildings:

i. Environmental needs :

- Enhance and protect biodiversity and ecosystems
- Improve air and water quality
- Reduce waste streams
- Conserve and restore natural resources

ii. Economic needs :

- Reduce operating costs
- Create, expand, and shape markets for green product and services
- Improve occupant productivity
- Optimize life-cycle economic performance

iii. Social needs :

- Enhance occupant comfort and health
- Increase aesthetic qualities
- Minimize strain on local infrastructure
- Improve overall quality of life

Renewable Energy systems:

Renewable energy is energy which comes from natural resources such as sunlight, wind, rain, tides, and geothermal heat, which are renewable (naturally replenished). About 16% of global final energy onsumption comes from renewables, with 10% coming from traditional biomass, which is mainly use for heating, and 3.4% from hydroelectricity.

New renewables (small hydro, modern biomass, wind, solar, geothermal, and biofuels) accounted for another 3% and are growing very rapidly. The share of renewables in electricity generation is around 19%, with 16% of global electricity coming from hydroelectricity and 3% from new renewables. Renewable energy replaces conventional fuels in four distinct areas: electricity generation, hot water/ space heating, motor fuels, and rural (off-grid) energy services.

The conversion of solar radiation in to heat for technological, comfort heating and cooking purposes. Solar thermal heating is applied to water, air or structural materials. Conversion of light to heat can be achieved through passive systems or active systems (mechanically transferring heat by means of a working fluid such as oil, water or air).

The following renewable energy systems are adopted in buildings:

A) Passive solar heating
B) Passive solar cooling
C) Active solar heating
D) Active solar cooling
E) Photovoltaic system

Passive Solar Design:

Passive solar design refers to the use of the sun‘s energy for the heating and cooling of living spaces. In this approach, the building itself or some element of it takes advantage of natural energy characteristics in materials and air created by exposure to the sun. Passive systems are simple, have few moving parts, and require minimal maintenance and require no mechanical systems.

Design considerations for Passive solar systems:

- The building should be elongated on an east-west axis.
- The building‘s south face should receive sunlight between the hours of 9:00 A.M. and 3:00 P.M. (sun time) during the heating season.
- Interior spaces requiring the most light and heating and cooling should be along the south face of the building.
- Less used spaces should be located on the north.
- An open floor plan optimizes passive system operation.
- Use shading to prevent summer sun entering the interior.

Passive Solar Heating System:

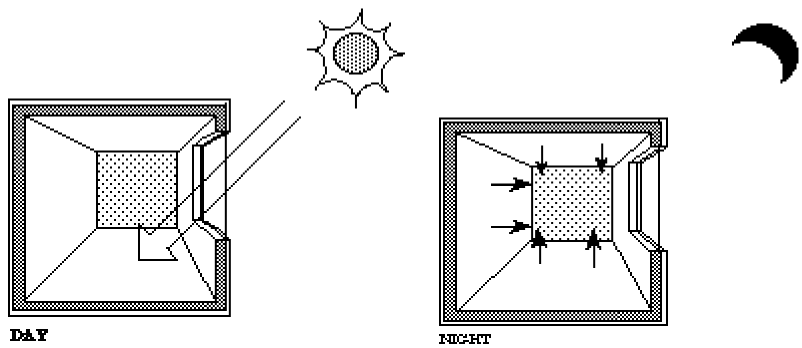
Two primary elements of passive solar heating are required:

i. South facing glass
ii. Thermal mass to absorb, store, and distribute heat

There are three approaches to passive systems – **direct gain, indirect gain, and isolated gain.** The goal of all passive solar heating systems is to capture the sun‘s heat within the building‘s elements and release that heat during periods when the sun is not shining (night time). At the same time that the building‘s elements (or materials) are absorbing heat for later use, solar heat is available for keeping the space warmth and comfortable (not overheated).

Direct Gain

In this system, the actual living space is a solar collector, heat absorber and distribution system. South facing glass admits solar energy into the house where it strikes directly and indirectly thermal mass materials in the house such as masonry floors and walls. The direct gain system will utilize 60 – 75% of the sun‘s energy striking the windows.



Thermal mass in the interior absorbs the sunlight and radiates the heat at night.

In a direct gain system, the thermal mass floors and walls are functional parts of the house. It is also possible to use water containers inside the house to store heat. However, it is more difficult to integrate water storage containers in the design of the house.

The thermal mass will temper the intensity of the heat during the day by absorbing the heat. At night, the thermal mass radiates heat into the living space.

Design considerations Direct gain system:

- A heat load analysis of the house should be conducted.
- Do not exceed 150 mm of thickness in thermal mass materials.
- Do not cover thermal mass floors with wall to wall carpeting; keep as bare as functionally and aesthetically possible.
- Use a medium dark color for masonry floors; use light colors for other lightweight walls; thermal mass walls can be any color.
- For every square foot of south glass, use 150 pounds of masonry or 4 gallons of water for thermal mass.
- Fill the cavities of any concrete block used as thermal storage with concrete or other high mass substance.
- Use thermal mass at less thickness throughout the living space rather than a concentrated area of thicker mass.
- The surface area of mass exposed to direct sunlight should be 9 times the area of the glazing.

- Sun tempering is the use of direct gain without added thermal mass. For most homes, multiply the house square footage by 0.08 to determine the amount of south facing glass for sun tempering.

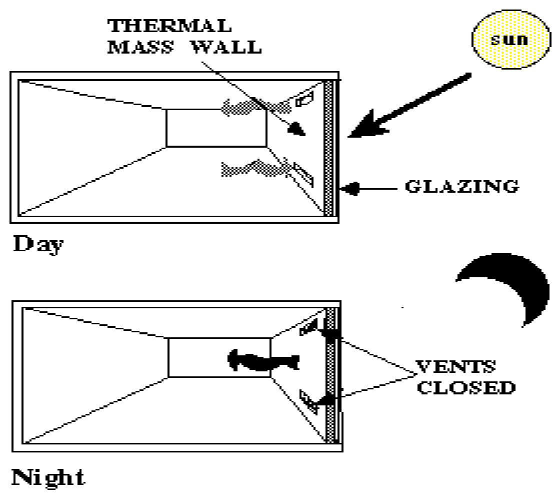
Indirect Gain

In an indirect gain system, thermal mass is located between the sun and the living space. The thermal mass absorbs the sunlight that strikes it and transfers it to the living space by conduction. The indirect gain system will utilize 30 – 45% of the sun's energy striking the glass adjoining the thermal mass.

There are two types of indirect gain systems:

- Thermal storage wall systems (Trombe Walls)
- Roof pond systems

Thermal storage wall systems:The thermal mass is located immediately behind south facing glass in this system.



Thermal Mass Wall or Trombe Wall Day and Night Operation

Operable vents at the top and bottom of a thermal storage wall permit heat to convect from between the wall and the glass into the living space. When the vents are closed at night radiant heat from the wall heats the living space.

Roof pond systems

- Six to twelve inches of water are contained on a flat roof.
- This system is best for cooling in low humidity climates but can be modified to work in high humidity climates. (Effectively provides heat in southern latitudes during the heating season for one story or upper stories of buildings.)
- Water is usually stored in large plastic or fiberglass containers covered by glazing and the space below is warmed by radiant heat from the warm water above.
- These require somewhat elaborate drainage systems, movable insulation to cover and uncover the water at appropriate times, and a structural system to support up to 65 lbs/sq ft dead load.Design considerations of Indirect gain system for thermal storage walls
- The exterior of the mass wall (toward the sun) should be a dark color.
- Use a minimum space of 4 inches between the thermal mass wall and the glass.
- Vents used in a thermal mass wall must be closed at night.
- A well insulated home (7-9 BTU/day-sq. ft.-degree F) will require approximately 0.20 square feet of thermal mass wall per square foot of floor area or 0.15 square foot of water wall.
- If movable night insulation will be used in the thermal wall system, reduce the thermal mass wall area by 15%.
- Thermal wall thickness should be approximately 10-14 inches for brick, 12-18 inches for concrete, 8-12 inches for adobe or other earth material and at least 6 inches for water.

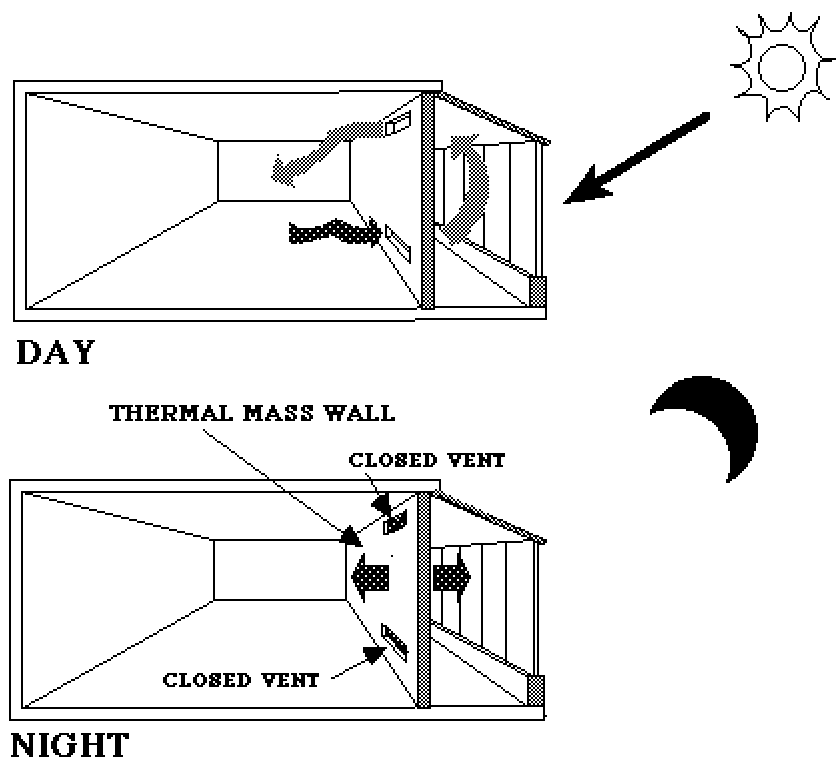
Isolated Gain

An isolated gain system has its integral parts separate from the main living area of a house. Examples are a sunroom and a convective loop through an air collector to a storage system in the house. The ability to isolate the system from the primary living areas is the point of distinction for this type of system.

The isolated gain system will utilize 15 – 30% of the sunlight striking the glazing toward heating the adjoining living areas. Solar energy is also retained in the sunroom itself.

Sunrooms (or solar greenhouses) employ a combination of direct gain and indirect gain system features. Sunlight entering the sunroom is retained in the thermal mass and air of the room. Sunlight is brought into the house by means of conduction through a shared mass wall in the rear of the sunroom, or by vents that permit the air between the sunroom and living space to be exchanged by convection.

The use of a south facing air collector to naturally convect air into a storage area is a variation on the active solar system air collector. These are passive collectors. Convective air collectors are located lower than the storage area so that the heated air generated in the collector naturally rises into the storage area and is replaced by return air from the lower cooler section of the storage area. Heat can be released from the storage area either by opening vents that access the storage by mechanical means (fans), or by conduction if the storage is built into the house.



Day and Night Operation of a Sunroom Isolated Gain System

The sunroom has some advantages as an isolated gain approach in that it can provide additional usable space to the house and plants can be grown in it quite effectively.

The convective air collector by comparison becomes more complex in trying to achieve additional functions from the system. This is a drawback in this area where space heating is less of a concern than in colder regions where the system would be used longer. It is best to use a system that provides more than one function if the system is not an integral part of the building. The sunroom approach will be emphasized in this information since it can provide multiple functions.unrooms

Sunrooms can feature sloped and/or overhead glass, but is not recommended for the Austin area. A sunroom will function adequately without overhead or sloped glazing. Due to long hot summers in this area, it is important to use adequate ventilation to let the heat out. Sloped or overhead glazing is also a maintenance concern. Due to the intensity of weather conditions for glazing facing the full .i.ventilation: passive design and brunt of the sun and rain, seals between the gazing panels need to be of extremely high material and installation quality.

A thermal wall on the back of the sunroom against the living space will function like the indirect gain thermal mass wall. With a thermal wall in the sunroom, the extra heat during the day can be brought into the living space via high and low vents like in the indirect gain thermal wall.

More elaborate uses of the heated air generated in the sunspace can be designed into this system, such as transferring the hot air into thermal mass located in another part of the house.

Design considerations for Isolated Gain of sunrooms:

- Use a dark color for the thermal wall in a sunspace.
- The thickness of the thermal wall should be 8-12 inches for adobe or earth materials, 10- 14 inches for brick, 12-18 inches for (dense) concrete.
- Withdraw excess heat in the sunroom (if not used for warm weather plants) until the room reaches 45 degrees and put the excess heat into thermal mass materials in other parts of the house.
- For a sunroom with a masonry thermal wall, use 0.30 square feet of south glazing for each square foot of living space floor area.
- If a water wall is used between the sunroom and living space instead of masonry, use

0.20 square feet of south facing glass for each square foot of living area.

- Have a ventilation system for summer months.
- If overhead glass is used in a sunroom, use heat reflecting glass and or shading systems in the overhead areas.

Passive Solar Cooling System

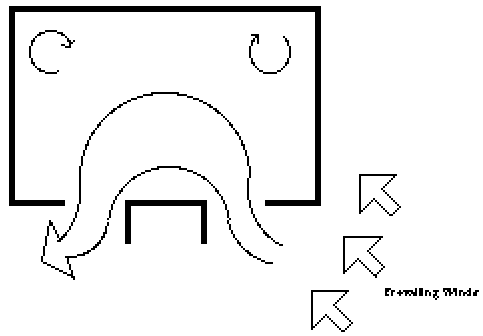
Ventilation & Operable Windows

A primary strategy for cooling buildings without mechanical assistance (passive cooling) in hot humid climates is to employ natural ventilation. (The Fan and Landscape sections also address ventilation strategies.) In the Austin area, prevailing summer breezes are from the south and southeast. This matches nicely with the increased glazing on the south side needed for passive heating, making it possible to achieve helpful solar gain and ventilation with the following strategies:

- Place operable windows on the south exposure.
- Casement windows offer the best airflow. Awning (or hopper) windows should be fully opened or air will be directed to ceiling. Awning windows offer the best rain protection and perform better than double hung windows.
- If a room can have windows on only one side, use two widely spaced windows instead of one window.

Wing Walls

Wing walls are vertical solid panels placed alongside of windows perpendicular to the wall on the windward side of the house.



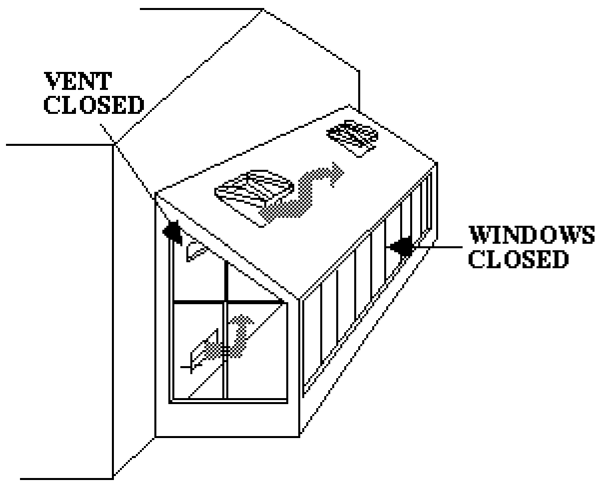
Top View of Wing Walls Airflow Pattern

Wing walls will accelerate the natural wind speed due to pressure differences created by the wing wall.

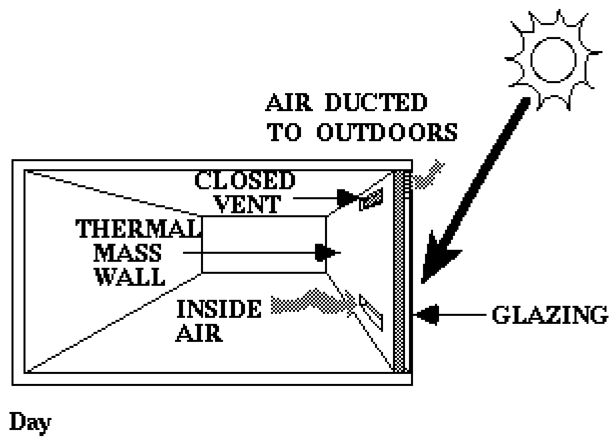
Thermal Chimney

A thermal chimney employs convective currents to draw air out of a building. By creating a warm or hot zone with an exterior exhaust outlet, air can be drawn into the house ventilating the structure.

Sunrooms can be designed to perform this function. The excessive heat generated in a south facing sunroom during the summer can be vented at the top. With the connecting lower vents to the living space open along with windows on the north side, air is drawn through the living space to be exhausted through the sunroom upper vents. (The upper vents from the sunroom to the living space and any side operable windows must be closed and the thermal mass wall in the sunroom must be shaded.)

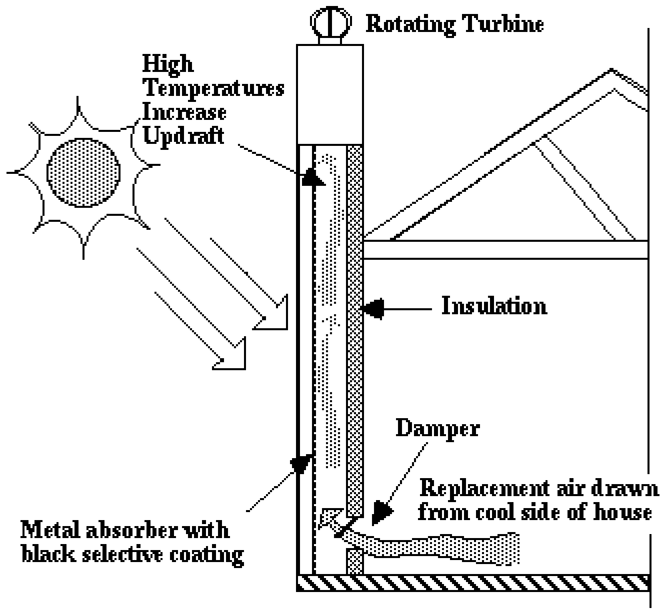


Summer Venting Sunroom



Summer Venting Thermal Mass Wall

Thermal mass indirect gain walls can be made to function similarly except that the mass wall should be insulated on the inside when performing this function.



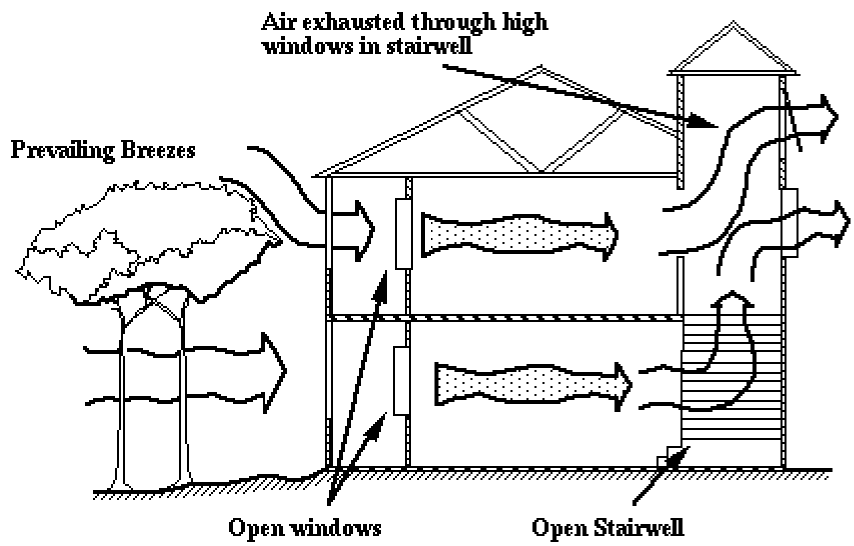
Thermal Chimney

Thermal chimneys can be constructed in a narrow configuration (like a chimney) with an easily heated black metal absorber on the inside behind a glazed front that can reach high temperatures and be insulated from the house. The chimney must terminate above the roof level. A rotating metal scoop at the top which opens opposite the wind will allow heated air to exhaust without being overcome by the prevailing wind.

Thermal chimney effects can be integrated into the house with open stairwells and atria. (This approach can be an aesthetic plus to the home as well.)

Other Ventilation Strategies

- Make the outlet openings slightly larger than the inlet openings.
- Place the inlets at low to medium heights to provide airflow at occupant levels in the room.



Thermal Chimney Effect Built into Home

- Inlets close to a wall result in air -washing| along the wall. Be certain to have centrally located inlets for air movement in the center areas of the room.

- Window insect screens decrease the velocity of slow breezes more than stronger breezes (60% decrease at 1.5 mph, 28% decrease at 6 mph). Screening a porch will not reduce air speeds as much as screening the windows.

- Night ventilation of a home should be done at a ventilation rate of 30 air changes per hour or greater. Mechanical ventilation will usually be required to achieve this

- High mass houses can be cooled with night ventilation providing that fabric furnishings are minimized in the house.

- Keep a high mass house closed during the day and opened at night.

Solar active thermal Systems

Active solar design uses outside energy and equipment—like electricity and solar panels—to help capture and utilize the energy of the sun. Passive solar design doesn‘t use any outside energy or require much special equipment, but simply takes advantage of existing natural phenomena, like the direction of the sun or the insulating properties of concrete.

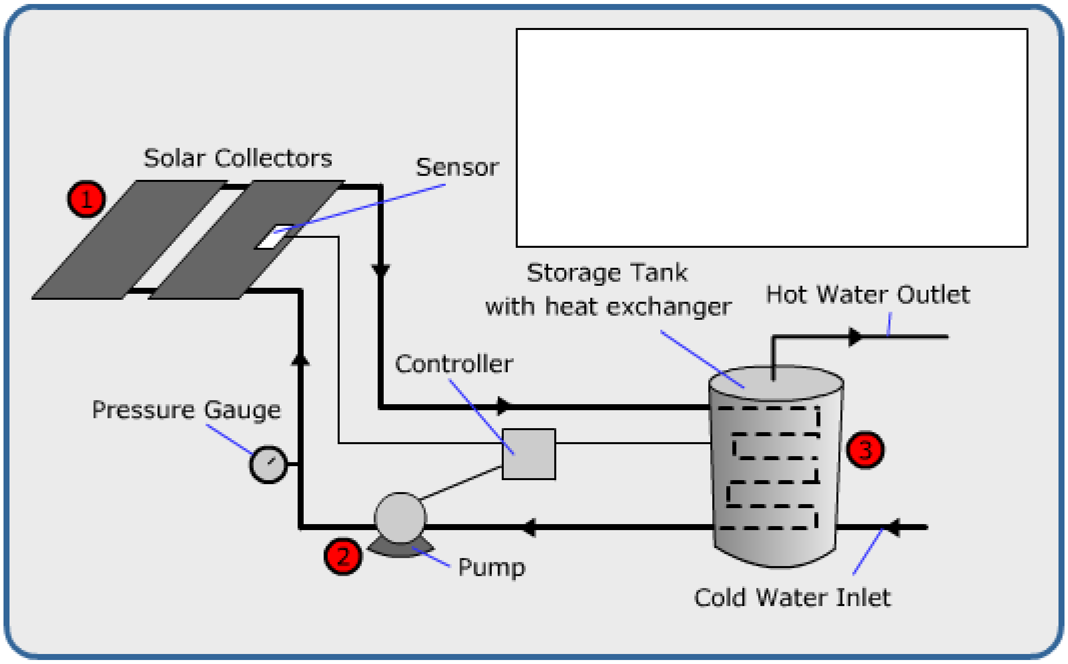
Solar Active Heating System

Active solar heating systems are comprised of collectors, a distribution system and a storage device.

Active solar heating systems operate as follows:

- Flat plate collectors are usually placed on the roof or ground in the sunlight. The top or sunny side has a glass or plastic cover to let the solar energy in. The inside space is a black (absorbing) material to maximize the absorption of the solar energy.
- Cold water is drawn from the storage tank by pump #1 and is pumped through the flat plate collector mounted on the roof of the house.

  The water absorbs the solar energy and is returned back to the tank.
- Warm water from the tank is pumped by pump #2 though the heating coil.
- The fan blows air (from the room) over the heated coil, and the heated air then passes into the room and heats the room.
- Cold air sinks to the bottom and is recirculated over the heating coil.



Active solar heating system

1 Solar collectors the flat panels mounted on roof to collect and absorb the solar radiation or energy and transfers into a fluid

2 Solar pumps or fans transfer and distribute the solar heat in a fluid from the collectors directly or indirectly throughout the house

An energy storage system that stores and provides heat when the sun is not shining.

Solar Active Cooling System:

It can be necessary to provide cooling to buildings during warm weather, or where there are significant thermal gains (such as solar gain, people and equipment). This cooling is sometimes referred to as comfort cooling. Cooling may also be necessary for refrigeration or for some industrial processes.

Active cooling

Active cooling can be provided by:

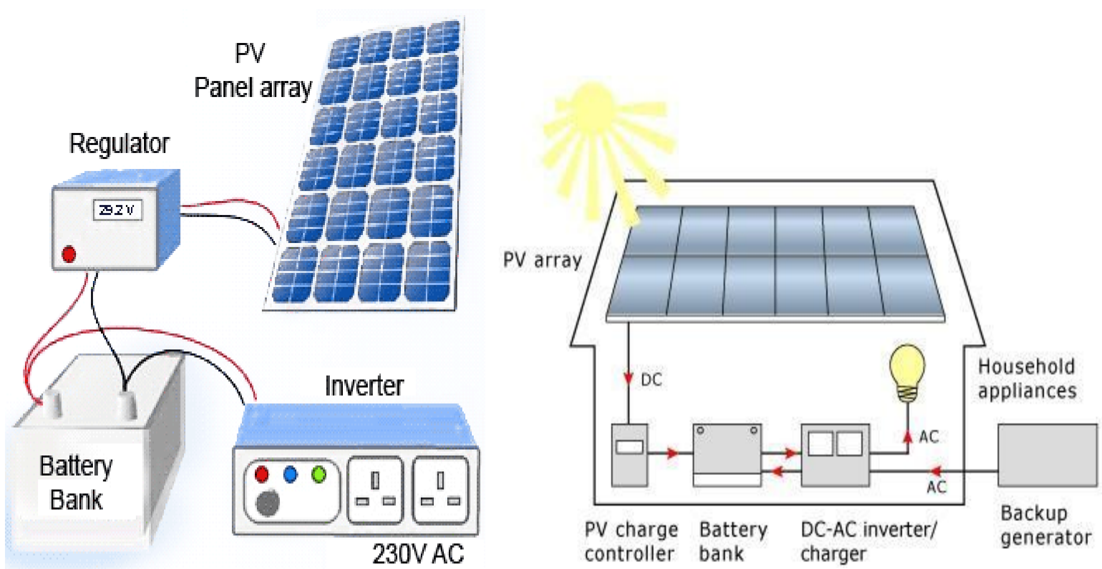
- Earth-to-air heat exchanger (ground coupling), which draws ventilation supply air through buried ducts or tubes (sometimes referred to as earth tubes). As the temperature of the ground below 3m is practically constant, it can be use to substantially reduce ambient air temperature fluctuations, with the incoming air being heated in the winter and cooled in the summer. See Earth-to-air heat exchanger for more information.

- Open or closed loop water to air heat exchangers, which exploit the relatively stable temperature of the earth to provide water that can cool in the summer and heat in the winter. See Ground energy options for more information.
- Mechanical or forced ventilation, driven by fans. This might be cooled below outside air temperature by the use of refrigerants, or by thermal mass, such as thermal labyrinths, or by night time purging. See mechanical ventilation for more information.
- Chilled water. Chilled water is typically provided by chiller units using refrigeration or compression refrigeration. It can then be used to provide cool air, in air handling units (to be ducted around the building), chilled beams, chilled ceilings and so on. Chiller units use are frigerant that boils at a low temperature and pressure, removing heat from the chilled water, and then condenses to release that heat, which is rejected to the outside (or recovered). See Refrigerants for more information. NB The use of chilled water to cool the building fabric itself is sometimes described as 'active thermal mass'. Refrigerants can be used to provide cooling directly to spaces in variable refrigerant flow(VRF) systems. This is based on the flow of refrigerant between an external condensing unit and multiple internal evaporators (typically fan coil units). See variable refrigerant flow for more information.
- Evaporative cooling can be provided by simple systems, such as misting fans and by spraying water over the roof of a building, or by more complex packaged units that draw hot, dry air through a continually dampened pad and supply cool, humid air to the building. Indirect evaporative cooling can be provided by the incorporation of heat exchangers, by the use of cooling towers, or by spraying water over the cooling coils of conventional chiller units. Typically, evaporative cooling is best suited to hot, dry climates. See evaporative cooling for more information.
- Ice can be used as an effective means of thermal storage, storing ‗coolth' in colder parts of the day to provide cooling during warmer parts of the day. See Thermal storage for cooling for more information.

Active cooling might be provided as part of a heating, ventilation and air conditioning system (HVAC) which may also include air filtration and humidity control. The cooling process itself can result in dehumidification, as cool air is less able to ‗hold' moisture than warm air. The term air conditioning is sometimes take to mean control over air temperature and humidity, rather than just temperature control in the case of comfort cooling.

Photovoltaic system:

Solar panels collect the sun's energy and convert it into direct current (DC) electricity. A solar inverter converts the DC electricity from the panels into the type of electricity we use at home: alternating current (AC). This electricity can be directly used for any application and will cost nothing. If the panels do not generate enough power, the solar inverter is capable of extracting additional power from the grid.

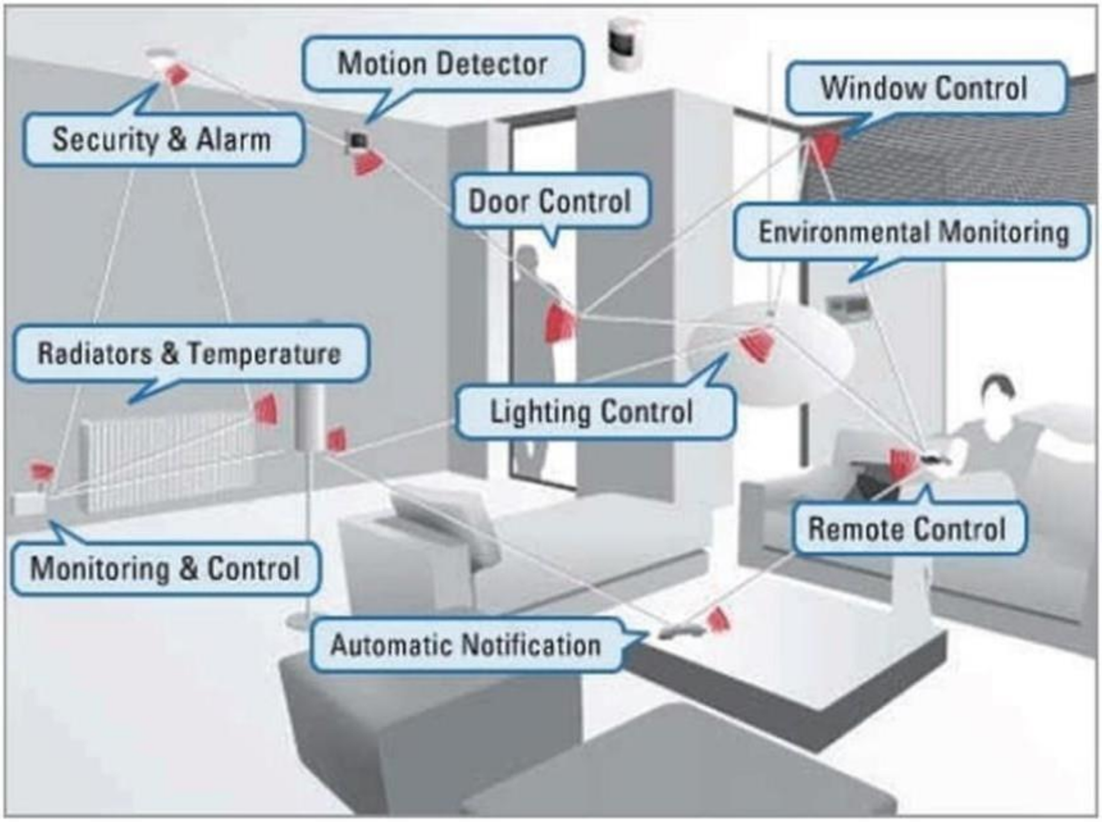


Photovoltaic power system

This way it can progressively become more independent from conventional energy by expanding the solar installation when convenient. The use of a battery pack will allow to create an uninterrupted power supply system (**UPS**).

Building Management System:

Building Energy Management Systems (BMS or BEMS) are computer-based systems that help to manage, control and monitor building technical services (HVAC, lighting etc.) and the energy consumption of devices used by the building. They provide the information and the tools that building managers need both to understand the energy usage of their buildings and to control and improve their buildings' energy performance.



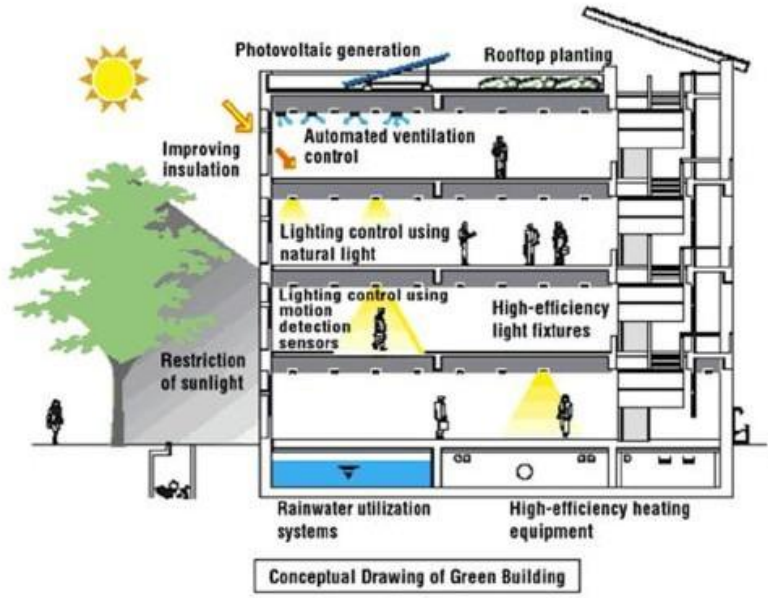
A very basic BMS consists of software, a server with a database and smart sensors connected to an Internet-capable network. Smart sensors around the building gather data and send it to the BMS, where it is stored in a database. If a sensor reports data that falls outside pre-defined conditions, the BMS will trigger an alarm.

Introduction to Green Buildings Concepts:

The Green Building Movement in India has been spearheaded by IGBC (part of CII) since 2001, by creating National awareness**.** Green concepts and techniques in the residential sector can help address national issues like water efficiency, energy efficiency, reduction in fossil fuel use in commuting, handling of consumer waste and conserving natural resources.

Green Building Concept

- Sustainable site planning
- Building Design optimization
- Energy performance optimization
- Renewable energy utilization
- Water and Waste management
- Solid waste management
- Sustainable building material and construction technology
- Health, well being and environmental quality



The concept of Green Building concentrates mainly on five points:

a) Site Selection and Planning

b) Water efficiency

c) Energy Efficiency

d) Materials and Resources

e) Indoor Environmental Quality

f) Innovation and Design Process

- Increasing the efficiency with which buildings use energy, water and materials
- Reducing building impacts of human health and the environment, through better site selection, design, construction, operation, maintenance, and removal throughout the complete life cycle.

Against this background, the Indian Green Building Council (IGBC) has launched **IGBC Green Homes Rating System** to address the National priorities. By applying IGBC Green Homes criteria, homes which are sustainable over the life cycle of the building can be constructed. This rating programme is a tool which enables the designer to apply green concepts and criteria, so as to reduce the environmental impacts, which are measurable.

Green buildings ratings for certification:

Green building rating system is a tool which enables the designer to apply green concepts and criteria, so as to reduce the environmental impacts, which are measurable.

IGBC has developed the following 9 green building rating systems in India:

i. IGBC Green Homes
ii. IGBC Green New Buildings
iii. IGBC Existing Buildings
iv. IGBC Green Townships
v. GBC Green Factory Buildings
vi. IGBC Green SEZ
vii. IGBC Green Schools
viii. IGBC Green Landscaping
ix. IGBC Green Mass Rapid Transit System

IGBC Green Homes is the first rating programme developed in India, exclusively for the residential sector. Green homes can have tremendous benefits, both tangible and intangible. The most tangible benefits are the reduction in water and energy consumption right from day one of occupancy. The energy savings could range from 20 - 30 % and water savings around
30 - 50%. Intangible benefits of green homes include: enhanced air quality, excellent daylighting, health & well being of the residents, safety benefits and conservation of scarce national resources. Green Homes rating system can also enhance marketability of a project.

National Priorities to be considered in Green Building Rating System:

The Green Homes Rating System addresses the most important National priorities which include water conservation, handling of house-hold waste, energy efficiency, reduced use of fossil fuels, lesser dependence on usage of virgin materials and health & well-being of residents.

a. **Water Conservation:**

   Most of the Asian countries are water stressed and in countries like India, the water table has reduced drastically over the last decade. Green Homes Rating System encourages use of water in a self-sustainable manner through reducing, recycling and reusing strategies. By adopting this rating programme, green homes can save potable water to an extent of 30 – 50%.

b. **Handling of House-hold Waste:**

   Handling of waste in residential buildings is extremely difficult as most of the waste generated is not segregated at source and has a high probability of going to land-fills. This continues to be a challenge to the municipalities which needs to be addressed. IGBC intends to address this by encouraging green homes to segregate the house hold waste.

c. **Energy Efficiency:**

   The residential sector is a large consumer of electrical energy. Through IGBC Green Homes rating system, homes can reduce energy consumption through energy efficient-lighting, air conditioning systems, motors, pumps etc., The rating system encourages green homes which select and use BEE labeled equipment and appliances. The energy savings that can be realized by adopting this rating programme can be to the tune of 20 – 30%.

d. **Reduced Use of Fossil Fuels:**

   Fossil fuel is a slowly depleting resource, world over. The use of fossil fuel for transportation has been a major source of pollution. The rating system encourages the use of alternate fuels for transportation and distributed power generation.

e. **Reduced Dependency on Virgin Materials:**

The rating system encourages projects to use recycled & reused material, and discourages the use of virgin wood, thereby, addressing environmental impacts associated with extraction and processing of virgin materials. Reduced usage of virgin wood is also encouraged.

f. **Health and Well-being of Residents:**

Health and well-being of residents is the most important aspect of Green Homes. IGBC Green Homes Rating System ensures minimum performance of day lighting and ventilation aspects which are critical in a home. The rating system also recognizes measures to minimize the indoor air pollutants.

The various levels of rating awarded are:

Certification Level	Individual Residential Unit	Multi-dwelling Residential Units	Recognition
Certified	38 – 44	50 – 59	Best Practices
Silver	45 – 51	60 – 69	Outstanding Performance
Gold	52 – 59	70 – 79	National Excellence
Platinum	60 - 75	80 – 100	Global Leadership

IGBC Green Homes° Project Checklist

Unit Units

Site Selection and Planning			
SAP Mandatory Requirement 1	*LocalBu“dding Regulations*	*Require d*	*Require d*
SAP Mandatory Requirement 2	*So“d Erosion Contml*	*Require d*	*Require d*
SSP Credit 1	Basic House-hold Amenities	1	2
SSP Credit 2	Natural Topography or Vegetation : 15%, 25%	2	4
SSP Credit 3	Heat Island Effect, Non Roof: 50°%, 75%	NA	2
SSP Credit 4	Heat Island Effect, Roof: 50°%, 75%	4	4
SSP Credit 5	Parking Facilities for Visitors: 10°%	NA	1
SSP Credit 6	Electric Charging Facility for Vehicles: 5%	NA	1
SSP Credit 7	Design for Differently Abled	1	2
SSP Credit 8	Basic Facilities for Construction Workforce	1	2
SSP Credit 9	Green Home Guidelines, Design & Post Occupancy	NA	1
	\\ a ter Fffivienvj		
WE Mandatory Requirement 1	*Raimvater Harvesting, Roof& Non-mof, 25%*	*Require d*	*Require d*
WE Mandatory Requirement 2	*Water E icient Plumbing Fixnires*	*Require d*	*Require d*
WE Credit 1	Landscape Design: 20°%, 40%	2	4
WE Credit 2	Management of Irrigation Systems	1	1
WE Credit 3	Rainwater Harvesting, Roof & Non-roof: 50°%, 75%	4	4
WE Credit 4	Water E&cient Plumbing Fixtures: 25%, 35%	4	4
WE Credit 5	Waste Water Treatment and Reuse: 100°% & 50%, 95%	NA	4
WE Credit 6	Water Metering **Energy Efficiency**	NA	1
EE Mandatory Requirement 1	*CFC-free Equipment*	*Require d*	*Require d*
EE Mandatory Requirement 2	*Minimum Energy Performance*	*Require d*	*Require d*
EE Credit 1	Enhanced Energy Performance : 3%, 6%, 9%, 12%, 15%,18%, 21%, 24%, 27%, 30°% (or) 2%, 4%, 6%, 8%, 10%,12%, 14%, 16%, 18%, 20°%	10	10
EE Credit 2	On-site Renewable Energy: 5%, 10°%, 15% (or)	6	6

	2.5%. 5%. 7.5%		
EE Credit 3	Solar Water Heating System : 50%, 95% (or) 25%, 50%	4	4
EE Credit 4	Energy Saving Measures in Other Appliances & Equipment	2	2
EE Credit 5	Distributed Power Generation	NA	2
EE Credit 6	Energy Metering	NA	1
		22	25
Materials & Resources			
MR Mandatory Requirement 1	*Separation ofHouse-hold Waste*	***Require d***	***Require d***
MR Credit 1	Organic Waste Management, Post Occupancy : 95% (or) 50%, 95%	2	4
MR Credit 2	Handling of Construction Waste Materials : 50% (or) 50%, 95%	1	2
MR Credit 3	Reuse of Salvaged Materials : 2.5%, 5% (or) 1%, 2%	2	4
MR Credit 4	Materials with Recycled Content : 10%, 20%	2	2
MR Credit 5	Local Materials : 25%, 50%	2	2
MR Credit 6	Rapidly Renewable Building Materials & Certified Wood : 50%, 75%	4	4
IEQ Mandatory Requirement 1	*Tobacco Smoke Control*	***Require d***	***Require d***
IEQ Mandatory Requirement 2	*Minimum Day 50%*	*Required*	*Require d*
IEQ Mandatory Requirement 3	*Fresh Air Ventilation*	***Require d***	***Require d***
IEQ Credit 1	Enhanced Daylighting : 75%, 95%	4	4
IEQ Credit 2	Enhanced Fresh Air Ventilation	2	2
IEQ Credit 3	Exhaust Systems	2	2
IEQ Credit 4	Low VOC Materials, Paints & Adhesives	2	2
IEQ Credit 5	Building Flush-out	1	1
IEQ Credit 6	Cross Ventilation : 50%, 75%	4	4
		15	15
ID Credit 1	Innovation & Design Process	4	4
ID Credit 2	IGBC Accredited Professional	1	1

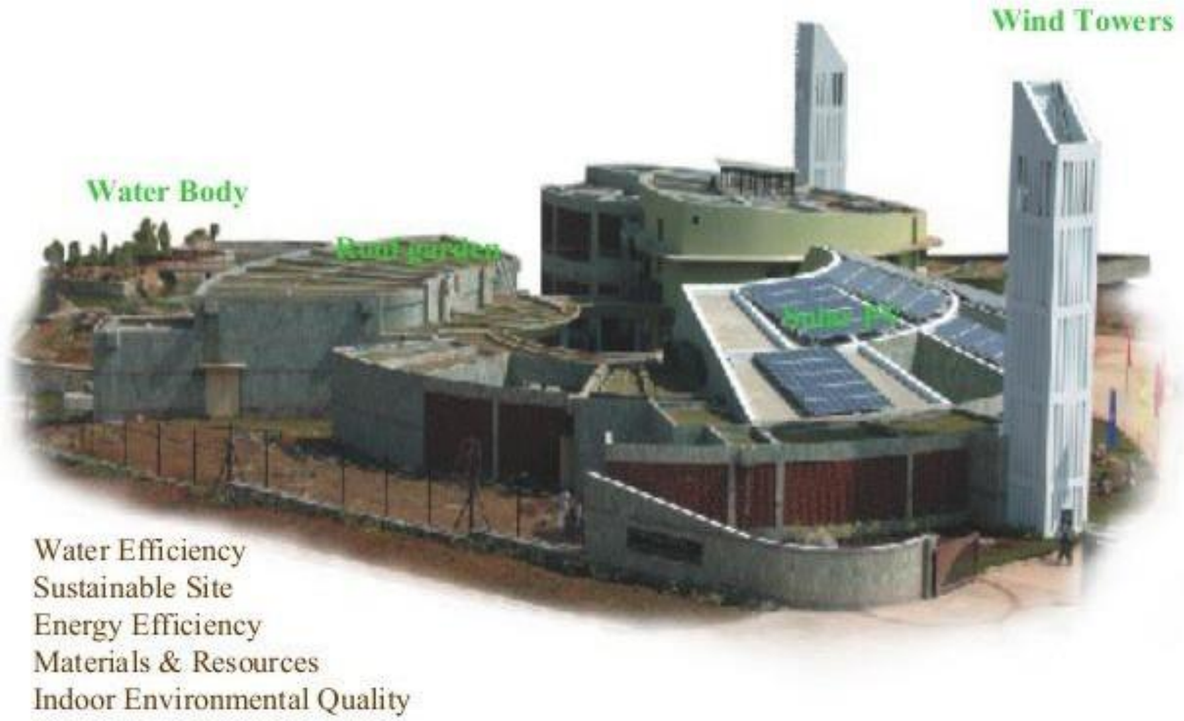
Case studies:

I. CII Sohrabji Godrej Green Business Centre

CII - Sohrabji Godrej Green Business Centre (CII Godrej GBC), cozily nestled close to Shilparamam, is the first LEED Platinum rated green building in India. The building is a perfect blend of India's rich architectural splendor and technological innovations, incorporating traditional concepts into modern and contemporary architecture. Extensive energy simulation exercises were undertaken to orient the building in such a way that minimizes the heat ingress while allowing

natural daylight to penetrate abundantly. The building incorporates several world- class energy and environmentfriendly features, including solar PV systems, indoor air quality monitoring, a high efficiency HVAC system, a passive cooling system using wind towers, high performance glass, aesthetic roof gardens, rain water harvesting, root zone treatment system, etc. The extensive landscape is also home to varieties of trees, most of which are native and adaptive to local climatic conditions. The green building boasts a 50% saving in overall energy consumption, 35 % reduction in potable water consumption and usage of 80% of recycled / recyclable material. Most importantly, the building has enabled the widespread green building movement in India.

GREEN BUSINESS CENTER



Green features and sustainable technologies in Sohrabji Godrej Green Business Centre

Energy Efficiency

State-of-the- art Building Management Systems (BMS) were installed for realtime monitoring of energy consumption. The use of aerated concrete blocks for facades reduces the load on air-conditioning by 15-20%.

Double-glazed units with argon gas filling between the glass panes enhance the thermal properties.

1. **Zero Water Discharge Building**

All of the wastewater, including grey and black water, generated in the building is treated biologically through a process called the Root Zone Treatment System. The outlet-treated water meets the Central Pollution Control Board (CPCB) norms. The treated water is used for landscaping.

2. **Minimum Disturbance to the Site**

The building design was conceived to have minimum disturbance to the surrounding ecological environment. The disturbance to the site was limited within 40 feet from the building footprint during the construction phase. This has preserved the majority of the existing flora and fauna and natural microbiological organism around the building. Extensive erosion and sedimentation control measures to prevent topsoil erosion have als been taken at the site during construction.

3. **Materials and Resources**

80% of the materials used in the building are sourced within 500 miles from the project site. Most of the construction material also uses post-consumer and industrial waste as a raw material during the manufacturing process. Fly-ash based bricks, glass, aluminum, and ceramic tiles, which contain consumer and industrial waste, are used in constructing the building to encourage the usage of recycled content. Office furniture is made of bagassebased composite wood. More than 50% of the construction waste is recycled within the building or sent to other sites and diverted from landfills.

4. **Renewable Energy**

20% of the building energy requirements are catered to by solar photovoltaics. The solar PV has an installed capacity of 23.5 kW.

5. **Indoor Air Quality**

Indoor air quality is continuously monitored and a minimum fresh air is pumped into the conditioned spaces at all times. Fresh air is also drawn into the building through wind towers.

The use of low volatile organic compound (VOC) paints and coatings, adhesives, sealants, and carpets also helps to improve indoor air quality.

Other Notable Green Features

■ Fenestration maximized on the north orientation

■ Rain water harvesting

■ Water-less urinals in men‘s restroom

■ Water-efficient fixtures: ultra low and low-flow flush fixtures

■ Water-cooled scroll chiller

■ HFC-based refrigerant in chillers

■ Secondary chilled water pumps installed with variable frequency drives (VFDs)

■ Energy-efficient lighting systems through compact fluorescent light bulbs (CFLs)

■ Roof garden covering 60% of building area

■ Large vegetative open spaces

■ Swales for storm water collection

■ Maximum day lighting

■ Operable windows and lighting controls for better day lighting and views

■ Electric vehicle for staff use ■ Shaded carpark

Cost and Benefits

This was the first green building in the country. Hence, the incremental cost was 18% higher. However, green buildings coming up now are being delivered at an incremental cost of 6-8%. The initial incremental cost gets paid back in 3 to 4 years.

Benefits achieved so far:

■ Over 120,000 kWh of energy savings per year as compared to an ASHRAE 90.1 base case

■ Potable water savings to tune of 20-30% vis-à-vis conventional building

■ Excellent indoor air quality

■ 100% day lighting (Artificial lights are switched on just before dusk)

■ Higher productivity of occupants.

Measurable Results in CII Sohrabji Godrej Green Business Centre:

- **energy savings** : 55% reduction, with ASHRAE 90.1 as the baseline 120,000 kWh / year
- **Reduction in CO_2 emissions** : 100 tons / year (building is functional since January 2004)
- **Water savings** 35% reduction in potable water consumption
- **Envelope thermal transfer value** U-value of double glazing: 1.70 Watt/m2 °K U-value of solid wall: 0.57 Watt/m2 °K U-value of roof: 0.294 Watt/m2 °K
- **Air conditioning system efficiency** 0.8 kW/ton (watercooled scroll chiller system with CoP: 4.23 at ARI condition) Installed two 25 TR chillers
- **Energy efficiency index (EEI)** 84 kWh/m2/year

II. Anna Centenary Library building, Chennai:

The pictures of Anna Library is shown below:


ANNA CENTENARY LIBRARY

Anna Centenary Library building houses a total area of 30,950 square meters (333,140 square feet) and has a capacity to accommodate 1.5 million books. At any given point, the library can accommodate 1200 people, not including an auditorium that can separately seat 1280 people. The project achieved the LEED Gold rating given by Indian Green Building Council under New Construction rating.

Reading areas which are facing North and East are located next to structurally glazed facades which provide abundance of daylight. The Southwest side of the building has thermal buffer zones of service cores and a 9 floor high atrium with an outward sloping glass wall which protect the building from the heat gain. Roof overhangs, Pergolas, and metal louvers are also used to lower heat and glare.

In order to lower heat island effect of the building, the library terrace area is painted with high albedo paints and the Auditorium terrace and Library terrace level at 1st, 2nd and 3rd floor are covered with green roof. The soil used on these surfaces has been collected during the excavation of the project, where top 20 cm (nearly 8 inches) of the soil has been saved for landscaping applications.

The project used building materials with recycled content value of 12 % by cost of the total material cost, and 75 % of the construction waste were reused within the site or sent for recycling. 77 % of the building materials were sourced locally to support the regional economy and reduce the environmental impact.

Although there are many features which lower the building‘s energy consumption such as LED and CFL lighting, high efficiency motors, pumps and fans, and systems which enable monitoring and control of lighting and ventilation, the building achieves 17.5 % less consumption compared to an ordinary building of equivalent size.

The library has rain water sump and percolation pits which are used for rain water harvesting and increase in ground water table. A collection well/sand filter is provided at the lowest point of the site, which helps to remove the sediments from storm runoff moving out of the site.

The Anna Centenary Library has onsite sewage treatment plant of to treat the wastewater produced from the building, and only treated waste water is used for landscape irrigation and toilet flushing requirements. The water consumption in irrigation is lowered with high efficiency landscape drip and sprinkler system, which combined with water efficient fixtures use 64 % less water compared to a standard building.

The quality of indoor air is ensured with usage of low VOC products (Paints, Adhesives and sealants), CRI certified carpet and MDF & plywood free from urea formaldehyde resins are used in the building. Only eco friendly house keeping chemicals are allowed inside the building premises, and the chemical rooms inside the building are provided with deck to deck partitions and negative differential pressure of 5 pas is maintained.

Further awareness regarding green living among the public is promoted through use of areas where different materials can be stored for recycling, graphics, posters, as well as an artificial tree in the heart of the Children's Area that promotes the message of nature conservation.

III. ITC Green Center

It is located at the city of gurgoan, Haryana was opened in 2005. This building received the LEED platinum certification. This building recycles and reuses all the water that lands on it, results in zero water discharge. This building uses insulated glasses that keeps the heat out and allows the natural light to transmit into the building. This building saves the energy and water by 51 percent and 40 percent respectively. This building has saved Rs.1 crore in power cost annually. The construction of this building uses certified woods. This building uses CO2 Monitoring system to improve the quality of the air to provide the fresh air.