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VIDEO LECTURER

PHYSICS DEPARTMENT

Name of Paper :- Renewable Energy Sources-I

PHY-356(D)

Topic:- An Introduction to Energy Sources

Energy: Definition, Classifications of energy sources

➢India's energy generation capacity of About 70% from fossil fuels, with coal 40% crude oil and natural gas at 24% and 6%

➢India is largely dependent on fossil fuel imports to meet its energy demands — by 2030, India's dependence on energy imports is expected to exceed 53% of the country's total energy consumption.

➢The growth of electricity generation in India has been hindered by domestic coal shortages and as a consequence, India's coal imports for electricity generation increased by neraly 20% in last 10 years. Due to rapid economic expansion, India has one of the world's fastest growing energy markets and is expected to be the second-largest contributor to the increase in global energy demand by 2035, accounting for nearly 20% of the rise in global energy consumption.

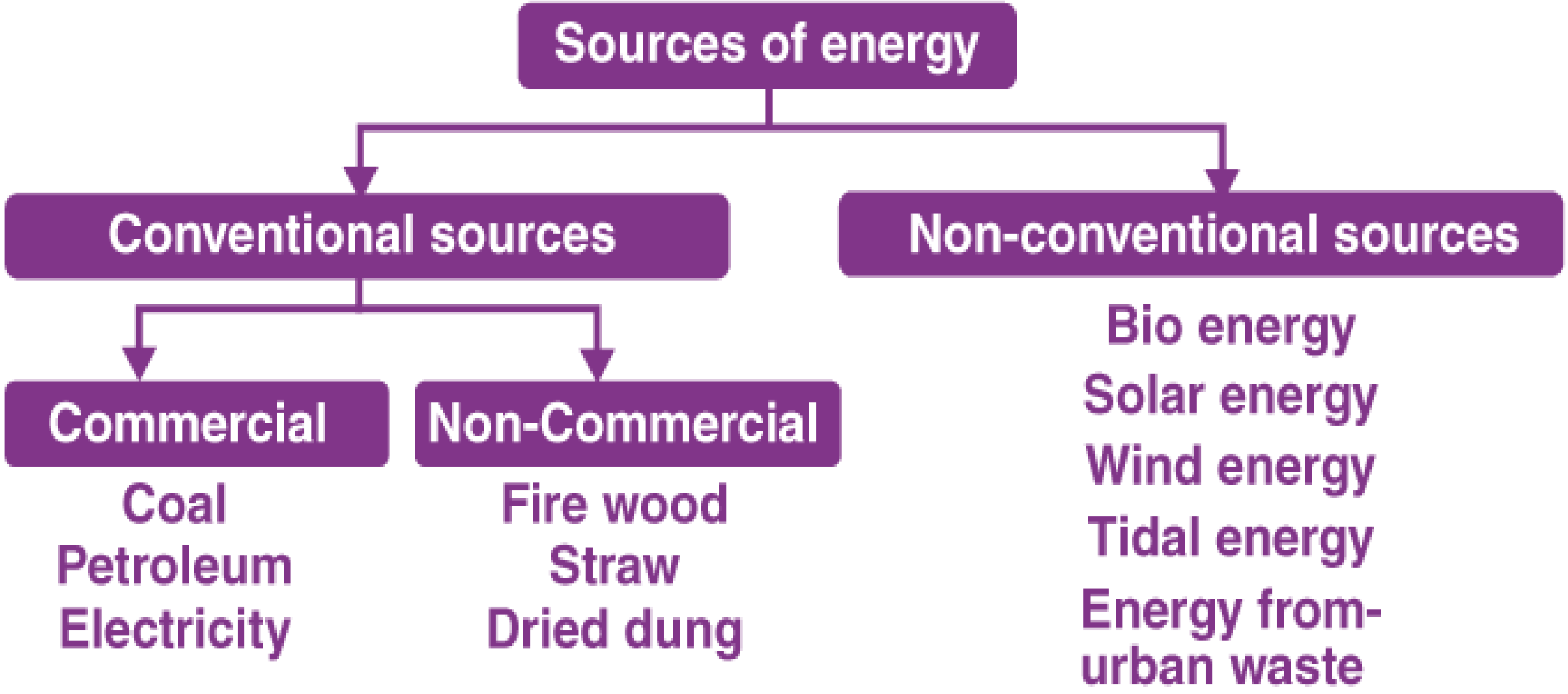
➢Given India's growing energy demands and limited domestic fossil fuel reserves, the country has ambitious plans to expand its renewable and nuclear power industries. India has the world's fifth largest wind power market and plans to add about 20GW of solar power capacity by 2022. India also to increase the contribution of nuclear power to overall electricity generation capacity from 4.2% to 9% within 25 years.

Energy: Definition, Classifications of energy sources

- Types of Energy Basically energy can be classified into two types: Potential and Kinetic Energy Potential Energy Potential energy is stored energy and the energy of position (gravitational). It exists in various forms.
- Kinetic Energy Kinetic energy is energy in motion- the motion of waves, electrons, atoms, molecules and substances. It exists in various forms.
- Various Forms of Energy Chemical Energy Chemical energy is the energy stored in the bonds of atoms and molecules. Biomass, petroleum, natural gas, propane and coal are examples of stored chemical energy. Nuclear Energy Nuclear energy is the energy stored in the nucleus of an atom - the energy that holds the nucleus together.
- The nucleus of a uranium atom is an example of nuclear energy. Stored Mechanical Energy is energy stored in objects by the application of a force. Compressed springs and stretched rubber bands are examples of stored mechanical energy. Gravitational Energy Gravitational energy is the energy of place or position.
- Water in a reservoir behind a hydropower dam is an example of gravitational energy. When the water is released to spin turbines, it becomes rotational energy.
- Radiant Energy Radiant energy is electromagnetic energy that travels in transverse waves. Radiant energy includes visible light, x-rays, gamma rays and radio waves.
- Solar energy is an example of radiant energy. Thermal Energy Thermal energy (or heat) is the internal energy in substances- the vibration and movement of atoms and molecules within substances. Geothermal energy is an example of thermal energy. Electrical Energy Electrical energy is the movement of electrons. Lightning and electricity are examples of electrical energy. Motion The movement of objects or substances from one place to another is motion.

Conventional and non-conventional sources of energy

- The word energy is defines that capacity or ability do work. It is measured the total amount of work that body can do.
- Energy exits in many forms including Mechanical energy (kinetic and potential), Thermal (or) Heat energy ,Chemical energy, Electrical energy, Nuclear energy, Electromagnetic energy and Gravitational energy.
- Motion is associated all forms of energy . For eg. Any object or body is in motion K.E.is associated with it.
- According principle of conservation of energy. And first law of thermodynamics energy can neither be created nor destroyed.
- There are two Primary Sources of energy like **Conventional Sources of energy and non-conventional Sources of energy.**
- Conventional Sources of energy is also know as **non-renewable Sources of energy.**
- Conventional Sources of are in **limited** quantity and consumed by human being many years.
- These non-renewable Sources of energy are decaying matter which take hundreds of years.


Sources of energy
Conventional sources
Non-conventional sources
Commercial
Non-Commercial
Coal
Petroleum
Electricity
Fire wood
Straw
Dried dung
Bio energy
Solar energy
Wind energy
Tidal energy
Energy from-
urban waste

Coal



- petroleum, and natural gas are called **Fossil fuel.**
- **Coal** Is indeed vital source of energy
- It is considered as the backbone of the energy sector for its use in industry, for transportation and electric power generation.
- Since the advent of industrialization coal has been most common source of energy.
- Formation of coal takes place when dead plants matter decays which convert into coal by pressure and heat over millions of years.
- Coal is a complex mixture of compounds of carbon, hydrogen and oxygen. Small amounts of nitrogen and Sulphur compounds are also present in coal.
- It is mainly available in Bihar, West Bengal, Orissa and Madhya Pradesh.
- **There are 4 Type of coal depending on (%) Carbon content** Peat 60**%** Lignite (soft coal) 70**%** Bituminous (house hold coal) 80**%** Anthracite (hard coal) 90 **(%).**
- It is clear that peat is the most inferior quality of coal. Whereas anthracite is the most superior quality of coal. Bituminous is most commonly used in households and industry.

Natural gas and Oil

- Nowadays oil is consider liquid gold.
- Oil is made up of large number of tiny animals and plants which when die get trapped at the bottom of the sea under multiple layers of sand and mud.
- It is widely used in trains, ships, automobiles and planes.
- Natural gas is one of the most crucial sources of energy in the world.



- Natural gas formed when several layers under surface of earth
- It consists about 95% Methane and rest ethane and propane. It occurs deep under the crust of the earth either alone or a long with oil.
- It is a product of petroleum mining.
- The gas is available in Tripura, Jaisalmer, off-shore areas of Bombay High and in the Krishna – Godavari delta.
- It is used as a domestic and industrial fuel.
- The natural gas is now also available as CNG (Compressed Natural Gas) a substitution of petrol in automobiles.

Electricity



- Electricity is a form of energy which is flow of electrons (electrical charge) one direction .
- It is common source of energy.
- It is widely used in commercial and domestic purposes.
- Electricity can be produced using fossil fuels (coal petroleum) nuclear power and renewable alternative (solar wind or hydropower).
- It is utilized in electrical appliance including refrigerator air conditioner TV, washing machine
- It is a product of petroleum mining.

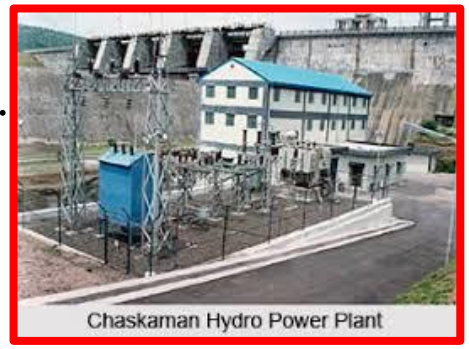
Thermal Power



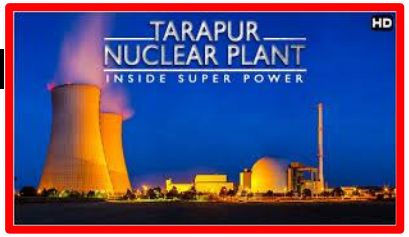
- Thermal power is generated at various power stations by means of oil and coal.
- It is generated using thermal generators and specifically designed furnace.
- The thermal power plant burns fuels for boiling water and making steam.
- The Steam produced then it spins a turbine connected to a generator that weave electricity .

Hydroelectric Power

- The hydroelectric power is produced by constructing dams above the flowing rivers like Damodar Valley Project , Bhakra Nangal Project and Koyana dams project.
- flowing water creates energy that can be capture and eventually turn into electricity.
- When water is released form reservoir then flow through the turbine.
- Turbine spin the water and activate the generator which produced the electricity


Chaskaman Hydro Power Plant

Nuclear Power



- The nuclear plants use uranium and plutonium as fuel which is less expensive than coal
- The majority of nuclear power is produced via nuclear fission, nuclear fusion.
- The energy released by the complete fission of one Kg of Uranium (U^{235}), is equal to the heat energy obtained by burning 4500 tonnes of coal (or) 220 tons of oil.
- However there are some limitations in the use of nuclear energy namely high capital cost of nuclear power plants, limited availability of raw materials, difficulties associated with disposal of radio active waste and shortage of well trained person to handle the nuclear power plants..

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Non-conventional sources of energy

- The sources of energy which are being produced continuously in nature and are in exhaustible are called renewable , **non-conventional** sources are also known as **renewable** sources of energy.
- This non-conventional sources do not polluted the environment natural surrounding, required less expenditure.

Some of these sources are **Solar energy Wind energy, Tidal energy,**





- **Wind energy** is generated by harnessing the power of wind and mostly used in operating water pumps for irrigation purposes.
- A wind mill converts the kinetic energy of moving air into mechanical energy that can be either used directly to run the machine or to run the generator to produce electricity.
- China 1st , 2nd U.S., 3rd Germany and India is the 4th -largest country in the generation of wind power.
- **Tidal energy** is generated by exploiting the tidal waves of the sea is known as tidal energy. This source is yet to be tapped due to the lack of cost-effective technology.
- Basically in a tidal power station water at high tide is first trapped in a artificial basin and then allowed to escape at low tide.
- The escaping water is used to drive water turbines, which in turn drive electrical generators.

Solar Energy

- Energy from the sun is called solar energy. The Sun's energy comes from nuclear fusion reaction that take place deep in the Sun.
- Hydrogen nucleus fuse into helium nucleus. The energy from these reactions flow out from the sun and escape into space. being a tropical country, india receives huge potential of solar energy. States like Andhra Pradesh, Bihar, Gujarat, Haryana, Madhya Pradesh, Maharashtra, Orissa, Punjab, Rajasthan, and West Bengal have great potential for tapping solar energy due to their location. indias solar energy are in the form of photo voltaic cell, solar panels and solar lanterns. it provides solution for energy in community and individual levels in remote and inaccessible areas.

Importance Non-conventional sources of energy

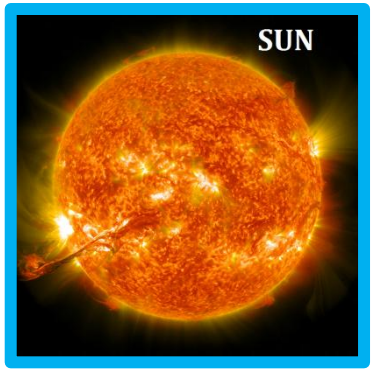
- Due to increase in use of fossil fuels and rapid depletion of natural sources have led to development of alternative of solar energy which is renewable and **environment friendly**.
- The demand of energy is increase continues due to rapid industrialization and increase in population.
- Hence Conventional Sources of energy will not sufficient to meet the growing demand.

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- The demand of energy is increase continues due to rapid industrialization and increase in population.
- Hence Conventional Sources of energy will not sufficient to meet the growing demand.
- Conventional Sources of energy are non-renewable and these are bound to finish up to one day.
- Conventional Sources of energy also cause pollution therefore their use degrades environment.
- Large hydro project resources affect wildlife cause deforestation and cerates various social problem.
- Solar energy is some times called radiant energy. These are different kinds of radiant energy emitted by sun. The most important are light infrared rays. Ultra violet rays, and X- Rays.

Sun

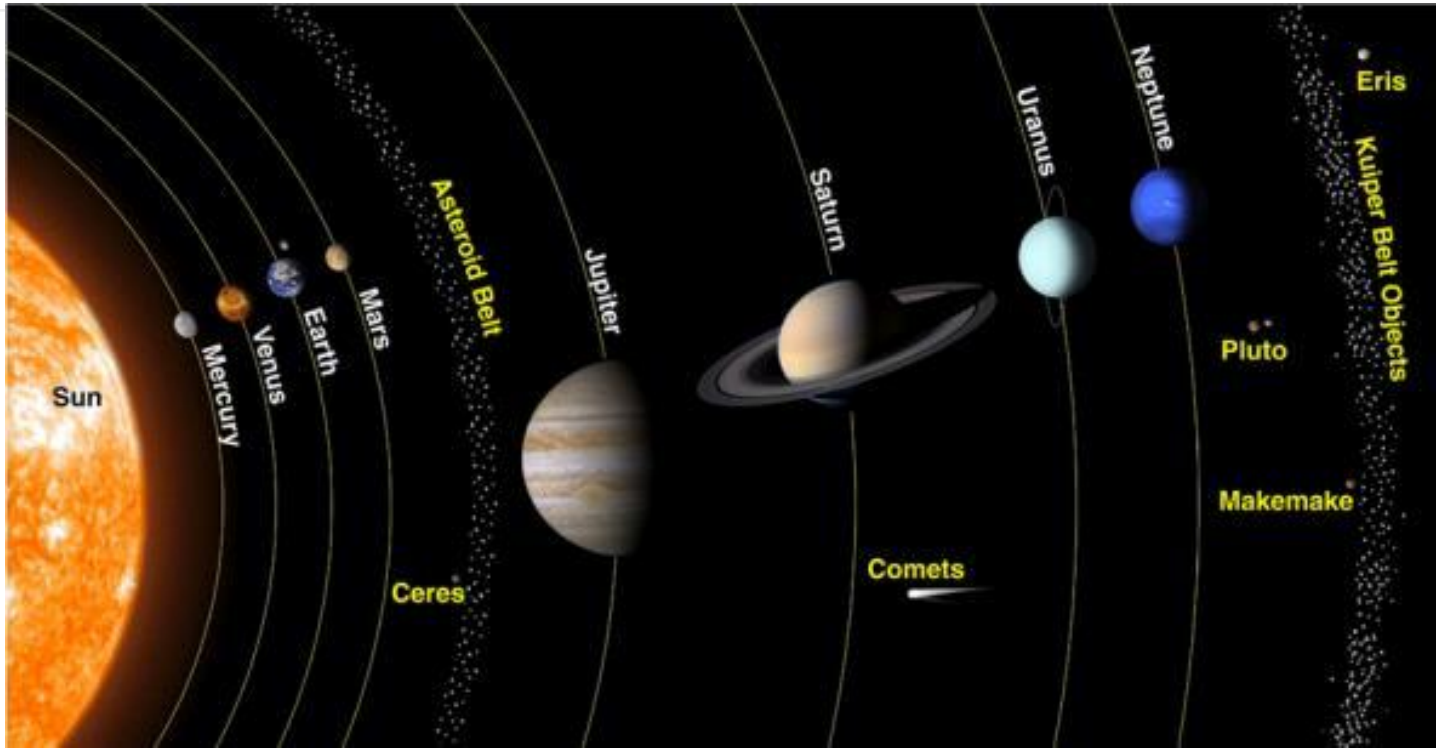
- The **Sun**, like all stars, is an **enormous ball** of **extremely hot**, largely **ionized gas**, shining under its own power The Sun is located at the center of our solar system. The Sun is a 4.5 billion-year-old yellow star a hot glowing ball of hydrogen and helium at the center of our solar system.
- The Sun does not have a solid surface like Earth.
- At the inner core of the Sun contains gravitational force which creates due to a pressure which generates nuclear fusion that turns to convert hydrogen into helium.
- The sun is a large sphere of very hot gases. It's diameter is **1.39×10^9 m**. While that of the mass **is 2×10^{30} Kg.**
- The mean distance between the two is **1.5×10^8 KM**. The beam radiation received from the sun on the earth is reflected in to space, nearly 15% radiation is absorbed by the earth atmosphere and the rest of it absorbed by the earth's surface.
- The mean radius of the sun is **432,450 miles (696,000** kilometers) which makes its diameter about **864,938** miles (**1.392** million km).
- The sun contains **99.8 %** of the mass of the entire solar system.
- Sun is the dominant source of radiative energy in the solar system.
- The Sun is a dynamic star, constantly changing and sending energy out into space.



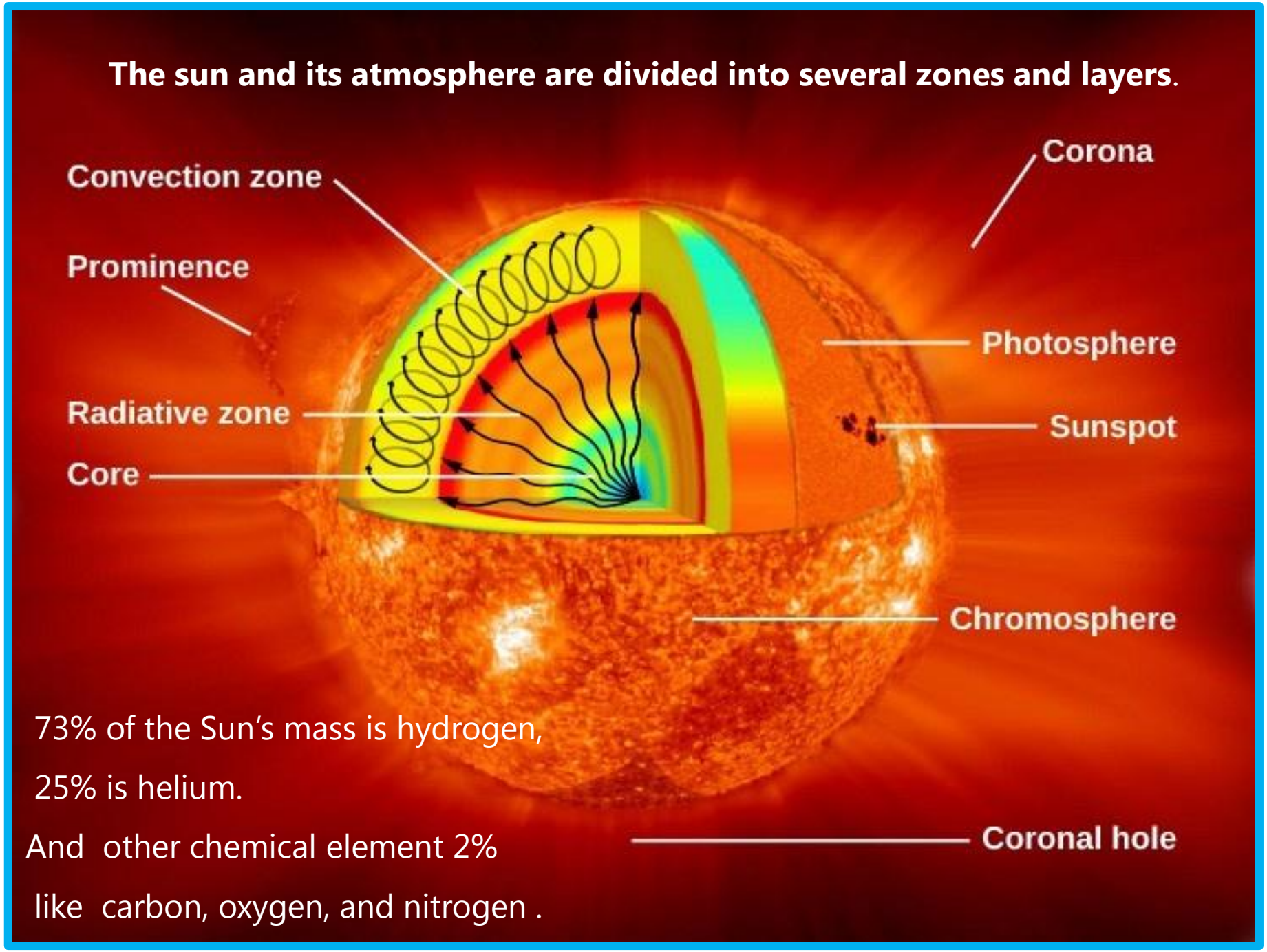
About **73% of the Sun's mass is hydrogen**, and another 25% is helium.

Table The Abundance of Elements in the Sun

Element	Percentage by Number of Atoms	Percentage By Mass
Hydrogen	92.0	73.4
Helium	7.8	25.0
Carbon	0.02	0.20



The sun and its atmosphere are divided into several zones and layers.



73% of the Sun's mass is hydrogen,

25% is helium.

And other chemical element 2%

like carbon, oxygen, and nitrogen .

The solar interior, from the inside out, is made up of the core, radiative zone and the convective zone.

The solar atmosphere above that consists of the photosphere, chromosphere, and the corona (solar wind is an outflow of gas from the corona).

Photosphere The photosphere is the bright outer layer of the Sun that emits most of the radiation.

The photosphere is an extremely uneven surface.

The effective temperature on the outer side of the photosphere is 6000°C.

Chromosphere Just above the photosphere is the chromosphere.

It is relatively a thin layer of burning gases.

The chromosphere is a bit cooler — 4,320 ◌̊C.

Sunspot

A dark patch on the surface of the Sun is known as a sunspot.

Sunspots appear as dark areas because they are about 500-1500°C cooler than the surrounding chromosphere.

The individual sunspot has a lifetime ranging from a few days to a few months.

Each spot has a black centre or umbra, and a lighter region or penumbra, surrounding it.

It has been suggested that the Sun is 1% cooler when it has no sunspot and that this variation in solar radiation might affect the climates of the Earth.

Solar Wind

➢The solar wind is a stream of energised, charged particles, like electrons and protons, flowing outward from the Sun at speeds as high as 900 km/s and at a temperature of 1 million degrees (Celsius).It is made of plasma (ionised atoms).

➢**Effects of solar wind**

➢As the solar wind approaches a planet that has a **well-developed magnetic field** (such as **Earth, Jupiter** and **Saturn**), the particles are **deflected**.

➢This region, known as the **magnetosphere**, causes the particles to travel around the planet rather than bombarding the atmosphere or surface.

➢The magnetosphere is roughly shaped like a hemisphere on the side facing the Sun, then is drawn out in a long trail on the opposite side.

➢The boundary of this region is called the **magnetopause**, and some of the particles are able to penetrate the magnetosphere through this region by partial reconnection of the **magnetic field lines**.

➢The **solar wind is responsible for the overall shape of Earth's magnetosphere**.

➢Moreover, planets with a weak or non-existent magnetosphere are subject to **atmospheric stripping** by

Corona

A corona is a distinctive atmosphere of plasma that surrounds the Sun and other celestial bodies.

The Sun’s corona extends millions of kilometers into space and is most easily seen during a total solar eclipse.

Sun’s Corona visible during Total Solar Eclipse

Plasma

Plasma is one of the four fundamental states of matter, the others being solid, liquid, and gas.

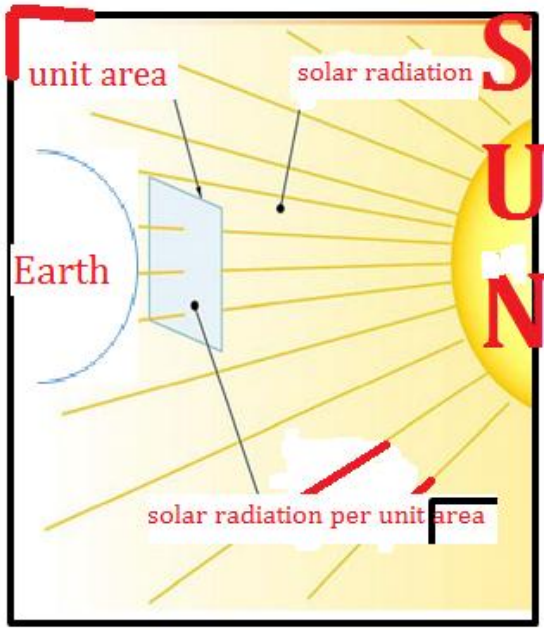
Plasma is ionised gas (atoms and molecules are converted into ions typically by removing one or more electrons from the outer shell)

Lightning and electric sparks are everyday examples of phenomena made from plasma.

Neon lights could more accurately be called ‘plasma lights’, because the light comes from the plasma inside of them.

Solar Constant

- The amount of solar energy received per second by one square meter area on near earth's space and perpendicular to the sun's direction at the mean distance of the earth from the sun.
- Sun is emitted solar radiation interns energy distributed uniformly in 3d in space.
- When the sun is closest to the earth, on January 3, the solar heat on the outer edge of the earth's atmosphere is about 1400 W/m^2; and when the sun is farthest away, on July 4, it is about 1330 W/m^2.
- Due to Earth moves round the sun therfour some times distance between earth and the sun is large and some time less.
- So that we take mean distance and space is perpendicular to the sun's direction as show[illegible]
- **Solar constant =Solar energy received /area into time**
- Approximate value of solar constant 1.4 kilowatt/m^2 or
- 1400kJ/s/m^2 or 1400 watt/m^2
- we can estimate the solar energy received on earths surface.
- We can calculated the tempters of sun



ELECTROMAGNETIC SPECTRUM

- The electromagnetic spectrum encompasses all types of radiation.
- The part of the spectrum that reaches Earth from the sun is between 100 nm and 1 mm.
- This band is broken into three ranges: ultraviolet, visible, and infrared radiation. Ultraviolet contains wavelengths between 100-400 nm. Visible light falls within the range of 400-700 nm, and infrared light contains wavelengths from 700 nm to over 1 mm [1]. In the visible light spectrum, the colors are determined by the length. Longer wavelengths appear red while shorter wavelengths are blue/violet as they range closer to the ultraviolet spectrum [5].The electromagnetic spectrum describes all of the kinds of light, including those the human eye cannot see. most of the light in the universe is invisible to our eyes.
- The light is made up of the individual colors of the rainbow, represents only a very small portion of the electromagnetic spectrum.
- The types of light include **radio waves, microwaves, infrared radiation, ultraviolet rays, X-rays and gamma rays** all of which are impossible to see human eyes.

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The Electromagnetic Spectrum

The electromagnetic spectrum contains different types of transverse waves. All of these waves can undergo interference, be reflected, refracted, diffracted and polarised, and travel at the speed of light, 2.998×10^8 m/s, in a vacuum.

Type	Radio Waves	Microwaves	Infrared (IR)	Optical (visible) Light	Ultraviolet (UV)	X-rays	Gamma Rays
Wavelength (m)	$>1 \times 10^{-1}$	$1 \times 10^{-1} - 1 \times 10^{-3}$	$1 \times 10^{-3} - 7 \times 10^{-7}$	$7 \times 10^{-7} - 4 \times 10^{-7}$	$4 \times 10^{-7} - 1 \times 10^{-8}$	$1 \times 10^{-8} - 1 \times 10^{-13}$	$<10^{-11}$
Longer Wavelength ←							→ Shorter Wavelength
Lower Frequency ←							→ Higher Frequency
Frequency (Hz)	$<3 \times 10^9$	$3 \times 10^9 - 3 \times 10^{11}$	$3 \times 10^{11} - 4 \times 10^{14}$	$4 \times 10^{14} - 8 \times 10^{14}$	$8 \times 10^{14} - 3 \times 10^{17}$	$3 \times 10^{17} - 3 \times 10^{19}$	$>3 \times 10^{17}$
Energy (J)	$<2 \times 10^{-24}$	$2 \times 10^{-24} - 2 \times 10^{-22}$	$2 \times 10^{-22} - 3 \times 10^{-19}$	$3 \times 10^{-19} - 5 \times 10^{-19}$	$5 \times 10^{-19} - 2 \times 10^{-17}$	$2 \times 10^{-17} - 2 \times 10^{-14}$	$>2 \times 10^{-14}$
How Are They Made?	By oscillating electrons in aerials	Directly produced by electron tube oscillators	By oscillating molecules in hot objects, such as LEDs, flames and stars	Emitted by the sun and other very hot objects, such as light bulbs and laser pointers	Emitted by the sun and other extremely hot objects, such as sparks and UV lamps	By firing electrons at a metal target	Emitted during radioactive decay
Applications	Television, radio, communications	Radar, cooking, satellite communications, mobile phones	Night vision, heat used in toasters and grills, remote controls, thermal imaging	Seeing, communications, optical fibres, DVD players, laser printers	Sunbeds, invisible security marking, sterilisation	X-ray photography, CT scanning, airport security, cancer treatment	Irradiation of food, security, cancer treatment, sterilisation
Dangers	Not thought to be hazardous	Heats water within the body, can damage or kill cells	Felt as heat, can cause skin damage and burns	Can damage the eyes	Can cause sunburn, damages eyes, causes cancer	Damages eyes and cells, causes cancer	Damages eyes and cells, causes cancer
How Are They Detected?	Resonance in electronic circuits using an aerial	Resonance in electronic circuits, heating effect on water	Thermometer, thermopile, heating effect on skin	Photographic film, the eye, photodetectors	Photographic film, sunburn, photodetectors	Photographic film, fluorescence	Photographic film, Geiger-Müller tube

daydream

Solar Radiation at the Earth's Surface (Terrestrial radiations)

•It is the electromagnetic radiation which originates from earth and its atmosphere.

•Terrestrial Radiation is a longer wavelength which is totally infrared.

•When the terrestrial solar radiation reaches the earth's surface,it is broken into two components i.e.diffuse radiation and beam radiation.

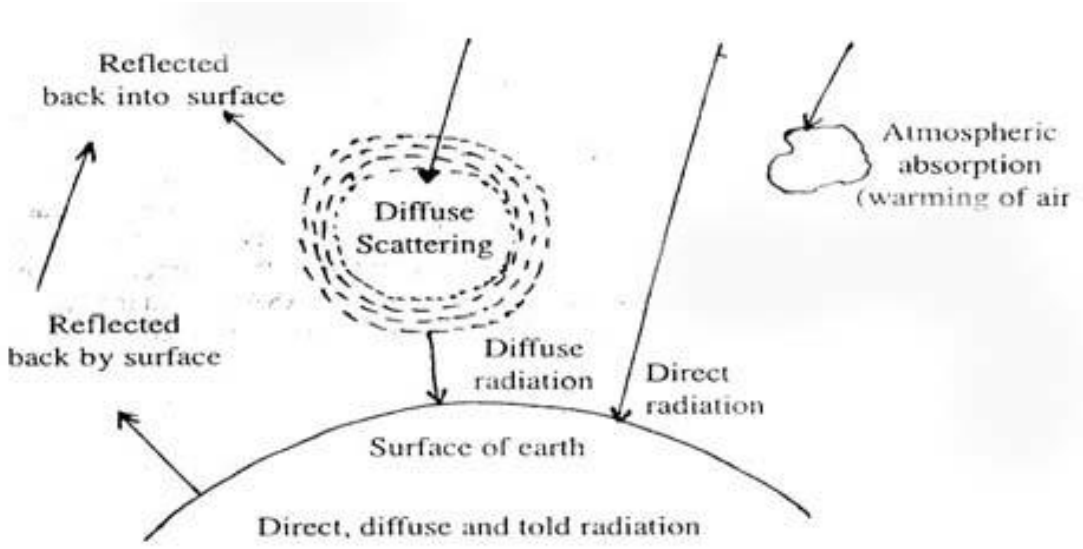
•**Beam Radiation or direct** is the solar radiation which moves through the atmosphere in a straight without (change in direction) being scattered, reflected or absorbed by particles in the air.)

•**Diffuse Radiation** is the solar radiation which is being scattered, reflected or absorbed by the particles (direction has been changed) while passing through the atmosphere but ultimately reaches the earth's surface.

•Total or global solar radiation all solar radiation

•Incident on a surface. including scattered, reflected and direct.

The sum of the beam and diffuse radiation **total or global radiation.**

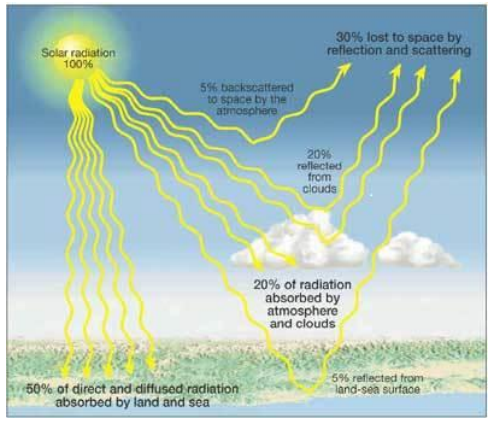


• It does not have Unique direction.

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Solar Radiation at the Earth's Surface (Terrestrial radiations)

- Solar radiation incident on the Earth's atmosphere is relatively constant
- Due to atmospheric effects radiation at the Earth's surface varies including absorption and scattering local variations in the ***atmosphere***, such as water vapor, clouds, pollution, latitude of the location and the season of the year and the time of day.
- The above effects have several impacts on the solar radiation received at the Earth's surface.
- The solar radiation that penetrates the earth's atmosphere like exosphere, thermosphere, mesosphere, stratosphere, troposphere reaches to earth's atmosphere the differs in both amount and character from the radiation at the top of the atmosphere.
- In the first place. partly radiation is reflected back(20%) into the space, especially by clouds. And partly absorbed by molecules in the air(20%)
- Further more, 50% of direct and diffused radiation the radiation absorbed by land and sea.
- In addition, 5% reflected from land sea surface and 5 % backscattered by atmosphere.
- In addition, 30% lost to space reflection and scattering



Extraterrestrial Radiation:

Solar Radiation outside the at the Earth's atmosphere (Extra Terrestrial Radiations)

- Extraterrestrial Radiation. Solar radiation incident outside the earth's atmosphere is called extraterrestrial radiation.

  On average the extraterrestrial radiation incident on the earth's atmosphere 1361 Watts/meter^2 (W/m^2).

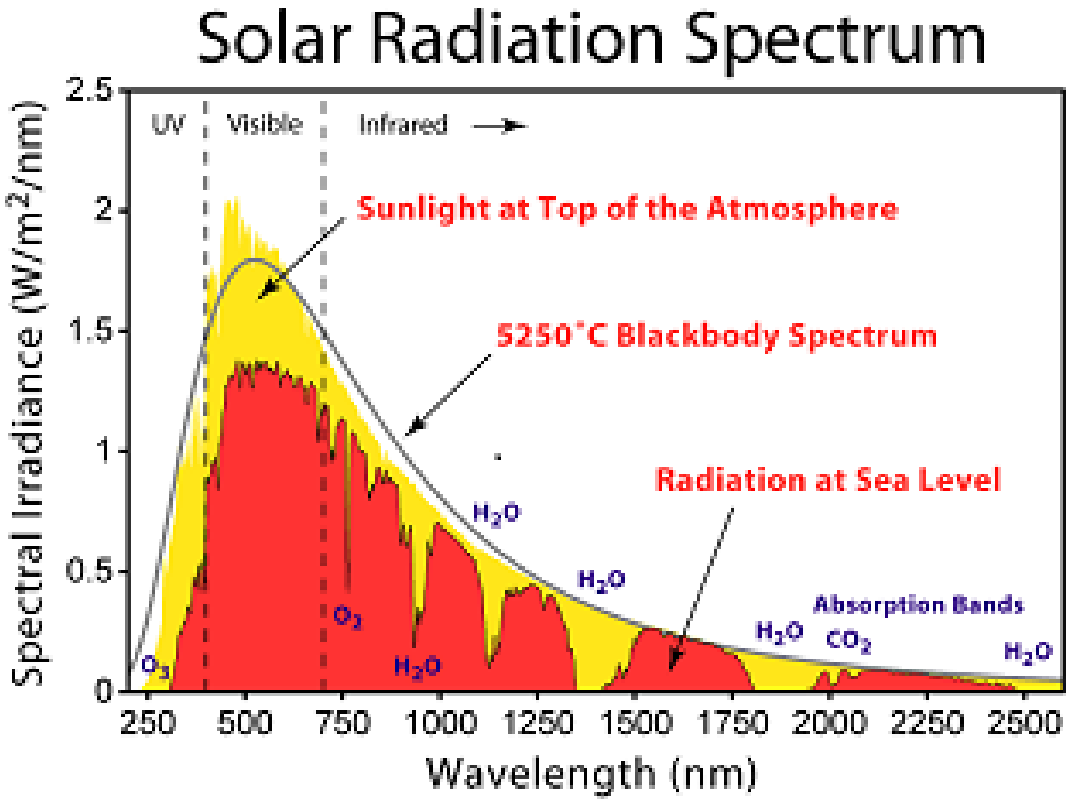
•The extraterrestrial radiation is 1367 watts/m^2.

•Due to the change in distance between earth and sun, there is a seasonal variation in the extraterrestrial rate.

Solar Radiation various portion of the spectrum in this Fig Area under the entire curve is the solar radiation.

Visible part of the solar radiation sp. Carries about Half of its total energy.

Intensity is max in the green portion of visible sp. i.e. 0.48micro met

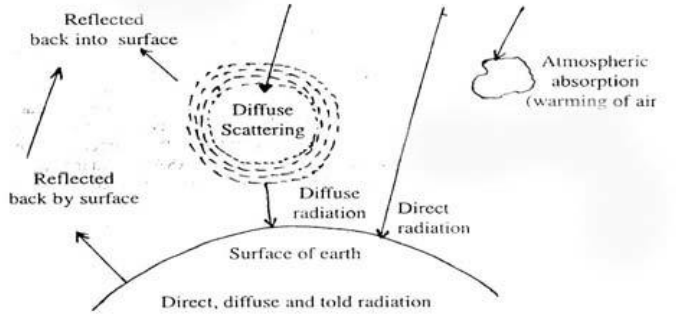


Solar Radiation that has not been absorbed or scattered and reaches the ground directly from the sun is called **“Direct Radiation” or Beam Radiation.**

Diffuse radiation are that Solar Radiations received from the sun after its direction has been changed due to reflection and scattering by the atmosphere

diffuses radiation comes to the earth from all parts of the sky.

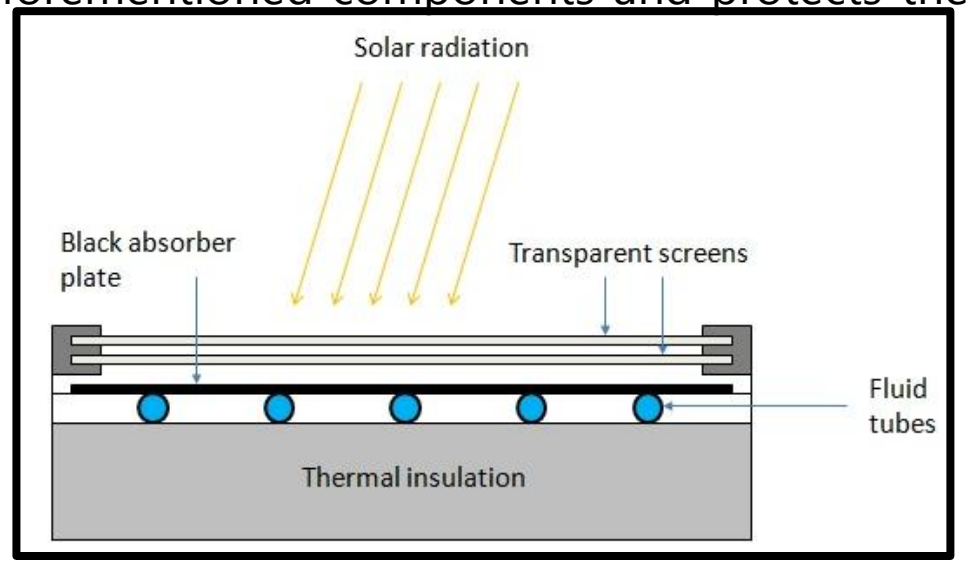
The sum of the beam and diffuse radiation **total or global radiation.**



FLAT PLATE COLLECTORS

- The term ‘flat plate’ is slightly misleading in the sense that the surface may not be truly flat-it may be combination of flat, grooved or of other shapes as the absorbing surface, Collectors is device which absorb solar incoming radiation convert into heat, and transfer this heat to fluid like air water and oil.
- The flat plate collectors forms the heat of any solar energy collection system
- It designed for operated in the low temperature range from ambient to 60^0 c or the medium temperature, form ambient to 100^0c.
- flat plate collector delivers heat at a relatively low cost for a long duration. The flat plat collectors is basically a heat exchanger
- Flat plate collectors is used to convert at much solar radiation as possible into heat at the highest attainable temperature with the lowest possible investment in material and labour.

- **Absorber plate:** It is a flat conducting plate to which the tubes, fins, or passages are attached. It may be a continuous or discrete plate. The plate is usually coated with a high absorbtance and low remittance layer. As fig
- **Cover plate**: One or more sheet of glass or other radiation-transmitting material forms the cover plate. The cover plate serves two purposes, i.e. first one minimization of convective heat loss and second blocking of IR radiation.
- **Heat removal passages**: These are tubes, fins, or passages which conduct or direct the stream of water from the inlet to the outlet of the collector.
- **Headers or manifolds**: These are the pipes to admit and discharge water that is meant to be heated.
- **Insulation:** Insulations such as Rockwool or Glass wool are fitted in the back and sides of the collector to prevent heat loss from the collector.
- **Casing**: The casing surrounds the aforementioned components and protects them from dust, moisture and any other material.



- The principal behind a flat collector is very simple. If a metal sheet is exposed to solar radiation, the temperature will rise until the rate at which energy is received is equal to the rate at which heat is lost from the plate; this temperature is termed as the 'equilibrium' temperature.
- If the back of the plate is protected by a heat insulting material, and the exposed surface of the plate is painted black and is coved by one or two glass sheets then the equilibrium temperature will be much higher than that for the simple exposed sheet.
- This plate may be covered into a heat collector by adding a water circulating system, either by making it hollow or by soldering metal pipes to the surface and transferring the heated liquid to a tank for storage.
- These collectors are simply metal boxes that have some sort of transparent glazing as a cover on top of a dark-coloured absorber plate.
- The sides and bottom of the collector are usually covered with insulation to minimize heat losses to other parts of the collector.
- Solar radiation passes through the transparent glazing material and hits the absorber plate. This plate heats up, transferring the heat to either water or air that is held between the glazing and absorber plate.
- Sometimes these absorber plates are painted with special coatings designed to absorb and retain heat better than traditional black paint. plates are usually made out of metal that is a good conductor -like copper or aluminum.

Some advantages of the flat-plate collectors are that they are:
Easy to manufacture
Low cost
Collect both beam and diffuse radiation
Permanently fixed (no sophisticated positioning or tracking equipment is required)
Little maintenance

Disadvantages of Concentrated Solar Collectors

1.High Costs: The average production cost of concentrated solar thermal energy is much higher than other renewable resources. Though during the past few years, the average cost has dropped to $0.20/kWh. Still, the costs are high as in comparison, the average production cost solar PV is in the range of $0.05 to $0.10/kWh. The average cost of solar PV production will drop even further in the future.

2.Future Technologies can potentially make CSP obsolete: Solar energy is witnessing new innovations quite frequently. Companies all over the world are experimenting to find more efficient and cost-effective ways to produce solar energy by making technological breakthroughs. Especially, Chinese solar companies are dominating the solar market by providing low-cost energy using advanced methods. These new innovations may potentially make concentrated solar technology outdated.

3.May Aggravate Water Shortage: CSP plants use significant amounts of water, and that may pose a major problem in dry regions. Using non-water cooling increases the cost of CSP projects quite a bit. Though using seawater has been suggested; still, its feasibility remains to be seen.

4.Environmental Issue: Using massive arrays of mirrors may negatively impact the wildlife in the dry regions, especially endangering the rare species. For example, there have already been conflicts in California on this issue with project Developers reducing the size of their plants and bearing the additional cost to move wildlife.

5.As concentrated solar collectors can focus only on direct solar radiation, their performance is poor during cloudy days.

6.The cost of building and maintaining concentrated solar collectors is high.

7.Concentrated solar collectors are practical for implementation only in areas with high direct insolation, such as arid and desert

Advantages of Concentrated Solar Collectors

1.Zero Fuel Cost: Concentrated solar collectors do not need any fuel like most other renewable energy sources. This is undoubtedly a significant advantage over fossil fuels, the cost of which is going up rapidly every year. Due to this reason, electricity prices are also increasing fast in more parts of the world faster than general inflation.

2.Can Produce Both Electricity and Heat: Concentrating solar collectors deliver heat at a much higher temperature. Due to higher temperatures, it is possible for the power generation equipment to generate both electricity and heat.

3.Round-the-Clock Availability of Electricity: Concentrated solar collectors make it possible to produce electricity 24-hours a day by storing the energy. Other forms of Renewable energy, like wind energy, are intermittent.

4.No Carbon Emission: Concentrated solar collectors do not cause any carbon emission, which is a great advantage.

5.Job Creation: Concentrated solar power production can create more permanent jobs and boost the economy as compared to other types of renewable energy resources.

6.Economy of Scale: The effects of a significant economy of scale can be observed when shifting to large

The different types of collector geometries are shown in figure 4.29.

The first type shown in figure 4.29(a) is a flat-plate collector with adjustable minors at the edges to reflect radiation on to the absorber plate, It is simple in design, has a concentration ratio a little above unity and is useful for giving temperatures about 20°C or 30°C higher than those obtained from a flat-plate alone.

A compound parabolic concentrating collector (CPC) is shown in figure. The concentrator consists of curved segments which are parts of two parabolas. Like the first type, this collector is also non-imaging. The type concentration ratio is moderate and imaging. The concentration ration is moderate and generally ranges from 3 to 10. The main advantage of the compound parabolic collector is that it has a high acceptance angle and consequently requires only occasional tracking. In addition, its concentration ratio is equal to the maximum value possible for a given acceptance angle.

The next type collector (figure 4.29(c)) is a cylindrical parabolic collector in which the image is formed on the focal axis of the parabola. Many commercial versions of this type are now available.

Concentratin

Unlike the cylindrical parabolic collector in which the concentration has to rotate in order to track the sun, the type shown in figure 4.29(d) has a fixed concentrator and a moving receiver. The concentrator is an array of long, narrow, flat mirror strips fixed along the cylindrical surface. The strip produce a narrow line image which follows a circular path as the sun moves. This path is on the same circle on which the mirror strips are fixed. Thus, the receiver has to be moved along the circular path in order to track the sun.

er, similar to a boiler tube. T

Concentration is also achieved by using lenses. The most commonly used device is the Fresnel lens shown in figure 4.29(e). The one shown in the figure is a thin sheet, flat on one side with fine longitude grooves on the other. The angles of these grooves are such that radiation is brought to a line focus. The lens is usually made of extruded acrylic plastic sheets. Line focussing collectors like the one shown in figure 4.29(c,d,e). Usually have concentration rations between 10 to 80 and yield temperature between 150 to 400.

In order to achieve higher concentration ratios and temperatures it becomes necessary to have point focussing rather than line focussing. A sketch is shown in figure4.29(f). Such collectors can have concentration ratios ranging from 100 to a few thousand and have yielded temperatures upto 2000°. However, from the point of view of the mechanical design, there are limitations to the size of the concentrator and hence the amount of energy which can be collected by one dish. Commercial versions have been built with dish diameter up to 17m. In order to collect larger amounts of energy at one point, the central receiver concept has been adopted. In this case, beam radiation is reflected from a number of independently controlled mirrors called ‘Heliostats’ to a central receiver located at the top of a tower.

“Rabl” has show that for a given acceptance angle ($2\theta_a$) the maximum possible concentration ratio of a two-dimensional (line-focus) concentrator is

One of the major goals of sustainable energy systems is to provide clean, affordable, accessible energy with benign environmental impact. Development of reliable energy systems without toxic byproducts to preserve the environment while powering the future is urgently needed. This need has led to the design and implementation of power generating systems using photovoltaics (PV) and energy storage devices. Currently, there is an excess increase in the fossil fuels cost due to increase in consumption of electric grid energy and its inability to meet up with the demand. Optimizing the generation, storage and use of electric power by using renewables (PV) and storage devices will enhance efficient, effective and reliable power consumption. This chapter proposes an efficient approach for the integration of renewable energy systems (PV) and energy storage devices as well as their safety and tradeoffs in the environment.

Solar radiation is a radiant energy emitted by the Sun as a result of its nuclear fusion reactions. Spectral characteristics of solar radiation, both external to the Earth's atmosphere and at the ground, can be seen in Figure 1. Over 99% of the energy flux from the Sun is in the spectral region of 0.15–4 μm, with approximately 50% in the visible light region of 0.4–0.7 μm. The total amount of energy emitted by the Sun and received at the extremity of the Earth's atmosphere is constant, that is, 1370 W/m^2/s. The amount of energy received per unit area of the Earth's surface is 343 W/m^2/s. The standard spectrum for space applications is referred to as AM_0. It has an integrated power of 1366.1 W/m^2. Two standards are defined for terrestrial use: (1) the $AM_{1.5}$ global spectrum is designed for flat plate modules and has an integrated power of 1000 W/m^2 and (2) the $AM_{1.5}$ direct spectrum is defined for solar concentrator work. It includes the direct beam from the Sun and the circumsolar component in a disk of 2.5° around the sun. The direct and circumsolar spectra have an integrated power density of 900 W/m^2 (Figure 1).

Introduction to Photovoltaic effect

➢The photovoltaic effect was discovered in 1839 by the French physicist, Alexandre Edmond Becquerel.

➢ While experimenting with metal electrodes and electrolyte, he discovered that conductance increases with illumination.

➢Willoughby Smith discovered the photovoltaic effect in selenium in 1873. Albert Einstein described the phenomenon in 1904.

➢The first silicon monocrystalline solar cell was constructed in 1941. In 1951, the first germanium solar cells were made.

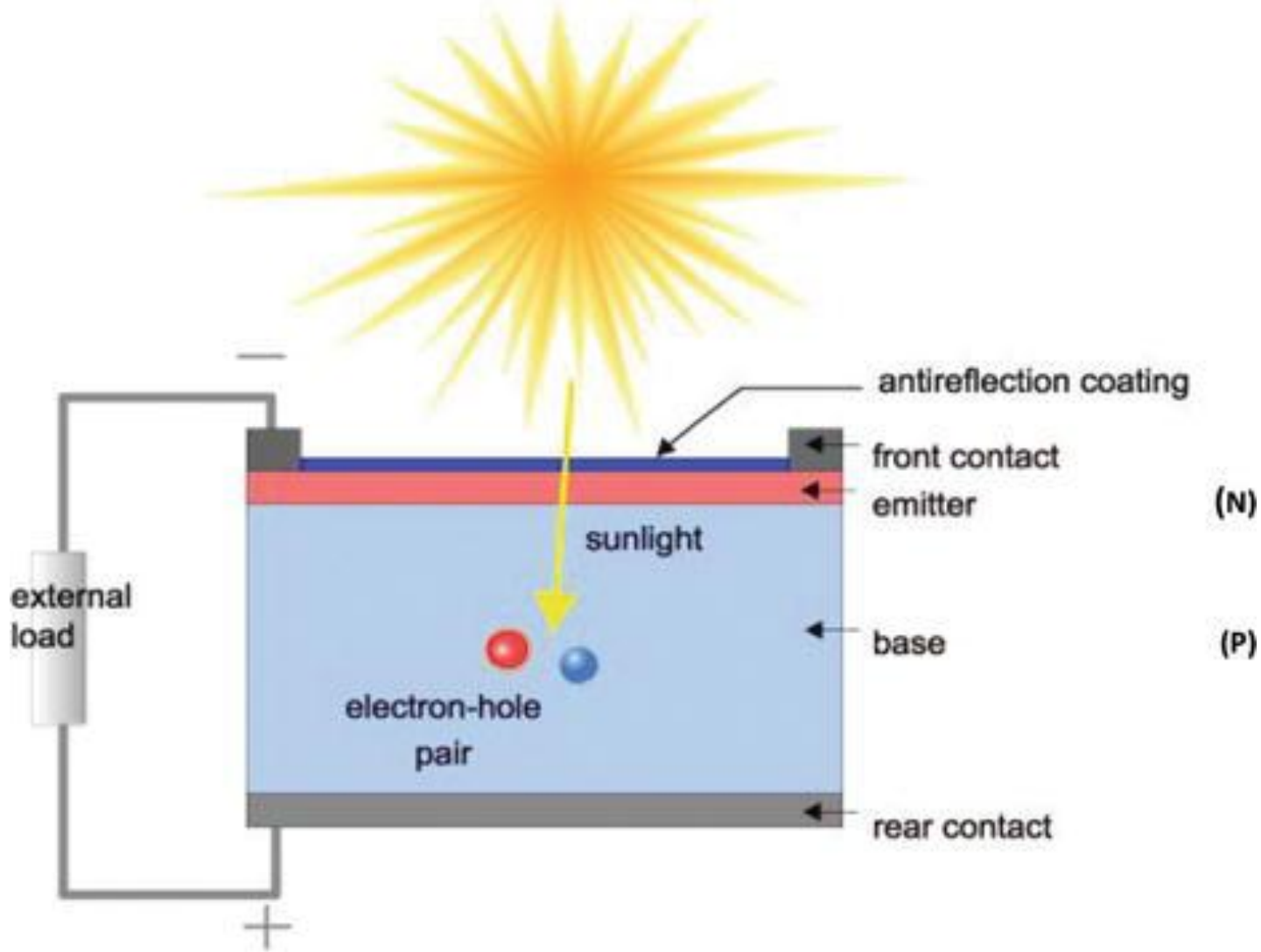
➢Bell's Laboratories published the results of the solar cell operation with 4.5% efficiency.

➢ The efficiency was increased to 6% within a few months. In 1957, Hoffman Electronics introduced a solar cell with 8% efficiency.

➢ A year later, in 1958, the same company introduced a solar cell with 9% efficiency. The first radiation-proof silicon solar cell was produced for the purposes of **space technology** in the same year.

➢In 1960, Hoffman Electronics introduced another solar cell with **14%** efficiency. In 1977, the world production of photovoltaic modules exceeded **500 kW**.

➢In 1984, ARCO Solar introduced the first **amorphous modules**. In 1985, researchers at the University of **New South Wales in Australia constructed a solar cell with more than 20% efficiency**. In 1996, BP Solar purchased APS


antireflection coating
front contact
emitter
(N)
sunlight
external
load
base
(P)
electron-hole
pair
rear contact

➢When a solar cell is illuminated by sunlight, photon energy of the incident light is converted to direct current electricity through the process of photovoltaic effect of the solar cell.

Incident light causes electron–hole pairs to be generated in the semiconductor, and there is an increase in the concentration of minority carriers (electrons in the p-type region and holes in the n-type region) in the depletion region.

This increase in the concentration of minority carriers results in the flow of the minority carriers across the depletion region into the quasineutral regions.

These photo-generated carriers cause the flow of photo-generated current. When the junction is in the open-circuit condition, no net current can flow inside the p-n junction; thus, the current resulting from the flux of photo-generated and thermally generated carriers is balanced by the opposite recombination current .

If a load is connected between the electrodes of the illuminated p-n junction, some fraction of the photo-generated current will flow through the external circuit. The potential difference between the n-type and p-type regions will be

Basic structure of a solar cell

Anti-reflecting coating (ARC), which is a very important part in solar cell fabrication. It is usually sprayed over bare silicon cell because silicon has a high surface reflection.

Front contacts that are necessary to collect the current generated by a solar cell. They are usually made of metals.

An emitter that absorbs the incoming photons and transports their energies to the excited state of charge carries. Pentavalent-doped silicon (n-type) has a higher surface quality than trivalent doped silicon (p-type), so it is placed at the front of the cell, where majority of the light is absorbed.

In p-n junction, in its simplest form, the base (p-type) region is joined at a junction with emitter (n-type) region leading to majority electrons in the n-type side close to the junction to diffuse of to the p-type side and majority hole from the p-type to diffuse n-type side.

Rear contact is a less important than the front contact because it is much way from the junction and does not need to be transparent

SOLAR PV

Solar Photovoltaic (PV) is a technology that converts sunlight (solar radiation) into direct current electricity by using semiconductors. When the sun hits the semiconductor within the PV cell, electrons are freed and form an electric current.

Solar PV technology is generally employed on a panel (hence solar panels). PV cells are typically found connected to each other and mounted on a frame called a **module.** Multiple modules can be wired together to form an **array,** which can be **scaled up or down to produce** the amount of power needed.

PV cells can be made from various semi-conductor materials. The most commonly used material today is **silicon** but other materials, such the ones listed below, are being tested and used to increase the efficiency of converting sunlight to electricity.

- Monocrystalline Silicon

Photovoltaics is **the direct conversion of light into electricity at the atomic level**. Some materials exhibit a property known as the photoelectric effect that causes them to absorb photons of light and release electrons.

The photovoltaic conversion is based on the photovoltaic effect, that is, on the conversion of the light energy coming from the sun into electrical energy. To carry out this conversion, devices called solar cells are used, constituted by semiconductor materials in which a constant electric field has been created artificially (by means of a pn junction). In this chapter the basics of photovoltaic generation are presented, starting from the fundamentals of the photovoltaic effect, the basic structure and behavior of the solar cell, cell types, the photovoltaic module and a brief introduction to the applications in photovoltaic systems with the estimation of the energy generation of grid connected photovoltaic systems.

What is a Solar Cell?

A **solar cell** (also known as a photovoltaic cell or PV cell) is defined as an electrical device that converts light energy into electrical energy through the photovoltaic effect. A solar cell is basically a p-n junction diode. Solar cells are a form of photoelectric cell, defined as a device whose electrical characteristics – such as current, voltage, or resistance – vary when exposed to light.

Individual solar cells can be combined to form modules commonly known as solar panels. The common single junction silicon solar cell can produce a maximum open-circuit voltage of approximately 0.5 to 0.6 volts. By itself this isn't much – but remember these solar cells are tiny. When combined into a large solar panel, considerable amounts of renewable energy can be generated.

What is photovoltaic (PV) technology and how does it work? PV materials and devices convert sunlight into electrical energy. A single PV device is known as a cell. An individual PV cell is usually small, typically producing about 1 or 2 watts of power. These cells are made of different semiconductor materials and are often less than the thickness of four human hairs. In order to withstand the outdoors for many years, cells are sandwiched between protective materials in a combination of glass and/or plastics.

To boost the power output of PV cells, they are connected together in chains to form larger units known as modules or panels. Modules can be used individually, or several can be connected to form arrays. One or more arrays is then connected to the electrical grid as part of a complete PV system. Because of this modular structure, PV systems can be built to meet almost any electric power need, small or large.

PV modules and arrays are just one part of a PV system. Systems also include mounting structures that point panels toward the sun, along with the components that take the direct-current (DC) electricity produced by modules and convert it to the alternating-current (AC) electricity used to power all of the appliances in your home.

The largest PV systems in the country are located in California and produce power for utilities to distribute to their customers. The Solar Star PV power station produces 579 megawatts of electricity, while the Topaz Solar Farm and Desert Sunlight Solar Farm each produce 550 megawatts.



Photovoltaic Array

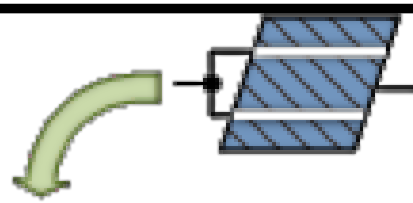
The Solar Photovoltaic Array

If *photovoltaic solar panels* are made up of individual photovoltaic cells connected together, then the **Solar Photovoltaic Array**, also known simply as a **Solar Array** is a system made up of a group of solar panels connected together.

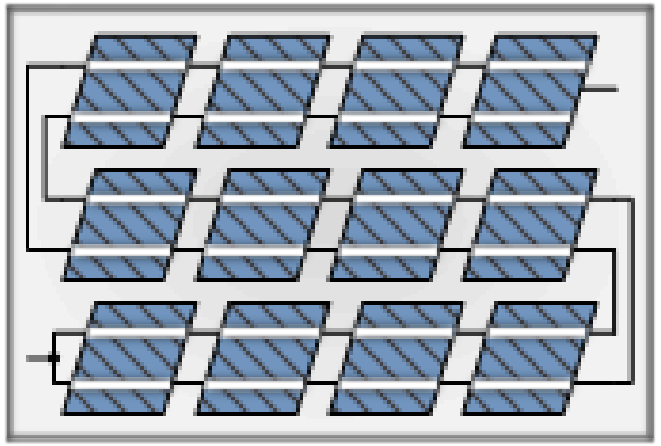
A *photovoltaic array* is therefore multiple solar panels electrically wired together to form a much larger PV installation (PV system) called an array, and in general the larger the total surface area of the array, the more solar electricity it will produce.

A complete photovoltaic system uses a photovoltaic array as the main source for the generation of the electrical power supply. The amount of solar power produced by a single photovoltaic panel or module is not enough for general use.

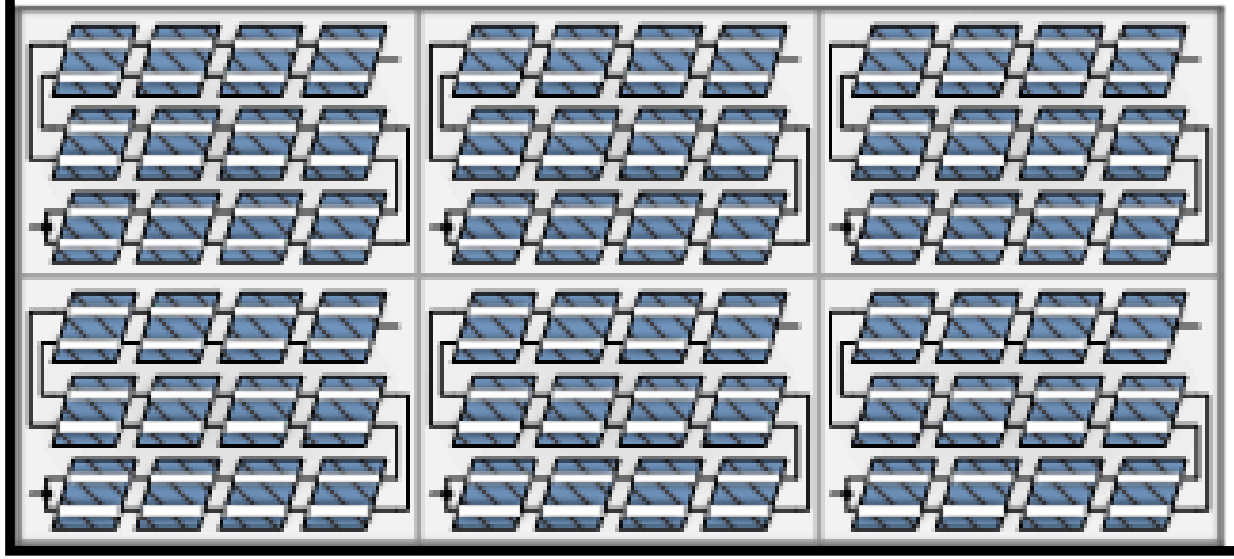
Most manufactures produce a standard photovoltaic panel with an output voltage of **12V or 24V**. By connecting many single PV panels in series (for a higher voltage requirement) and in parallel (for a higher current requirement) the **PV array will produce the desired power output**.



PV Cell – a single Solar Cell



PV Panel - a collection of single solar cells connected together



PV Array - a number of individual PV panels electrically connected together

A Photovoltaic Solar Array

- Photovoltaic cells and panels convert the solar energy into **direct-current (DC) electricity.** The connection of the solar panels in a single photovoltaic array is same as that of the PV cells in a single panel.
- The panels in an array can be electrically connected together in either a series, a parallel, or a mixture of the two, but generally a **series** connection is chosen to give an increased **output voltage**. For example, when two solar panels are wired together in series, their voltage is **doubled** while the current remains the **same.**
- The size of a photovoltaic array can consist of a few individual PV modules or panels connected together in an urban environment and mounted on a rooftop, or may consist of many hundreds of PV panels interconnected together in a field to supply power for a whole town or neighbourhood.
- The flexibility of the modular photovoltaic array (PV system) allows designers to create solar power systems that can meet a wide variety of electrical needs, no matter how large or small.
- It is important to note that photovoltaic panels or modules from different manufacturers should not be mixed together in a single array, even if their power, voltage or current outputs are nominally similar.
- This is because differences in the **solar cell I-V characteristic curve** as well as their spectral response are likely to cause additional mismatch losses within the array, thereby reducing its overall efficiency

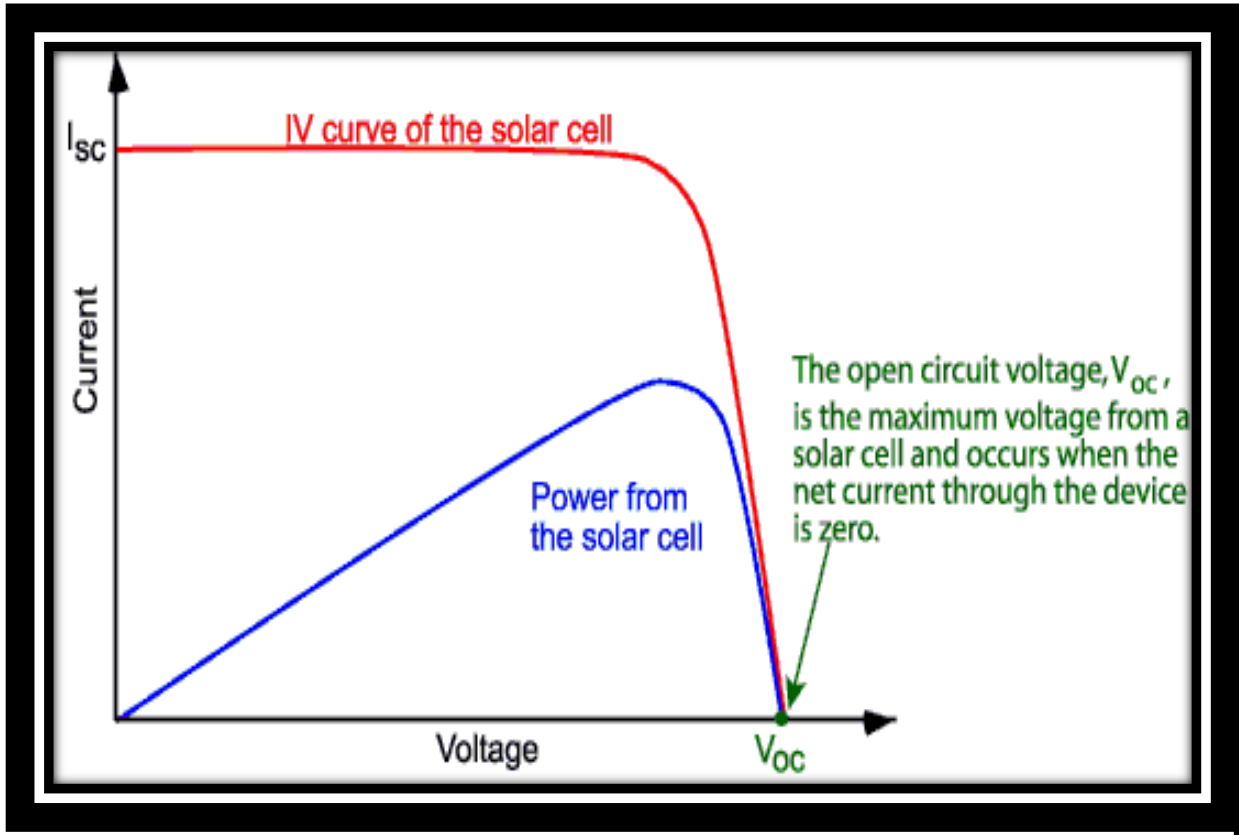
The Electrical Characteristics of a Photovoltaic Array

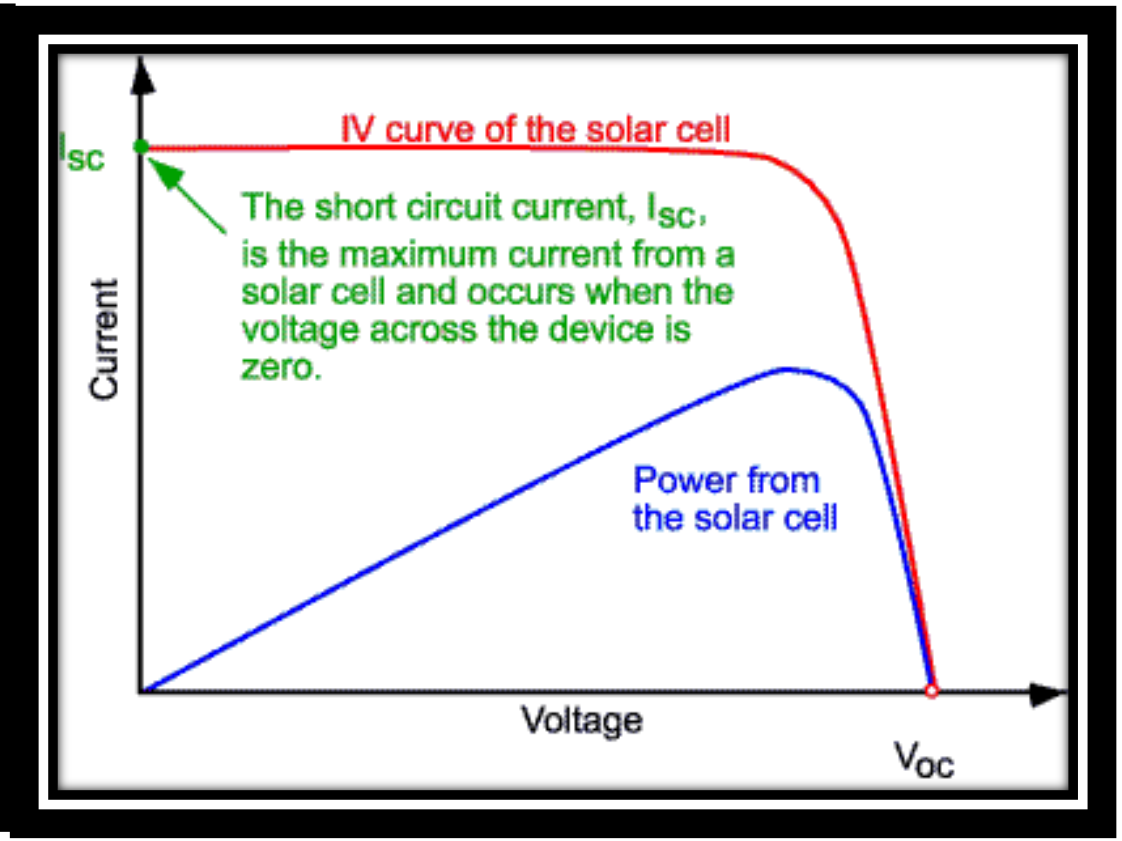
The electrical characteristics of a *photovoltaic array can be* summarized in the relationship between the output current and voltage. The amount and intensity of solar insolation controls the amount of output current (I), and the operating temperature of the solar cells affects the output voltage (V) of the PV array. Photovoltaic panel (I-V) curves that summarise the relationship between the current and voltage

V_{OC} = open-circuit voltage: – This is the maximum voltage that the provides when the terminals are not connected to any load (an open circuit condition). This value is much higher than V_{max} which relates to the operation of the PV array which is fixed by the load. This value depends upon the number of PV panels connected together in series.

The open-circuit voltage, V_{OC}, is the maximum voltage available from a solar cell, and this occurs at zero current. The open-circuit voltage corresponds to the amount of forward bias on the solar cell due to the bias of the solar cell junction with the light-generated current. The open-circuit voltage is shown on the IV curve below.

I_{SC} = short-circuit current – The maximum current provided by the PV array when the output connectors are shorted together (a short circuit condition). This value is much higher than Imax which relates to the normal operating circuit current. Or The short-circuit current is the current through the solar cell when the voltage across the solar cell is zero (i.e., when the solar cell is short circuited). Usually written as I_{SC}, the short-circuit current is shown on the IV curve below


I_{sc}
IV curve of the solar cell
Current
Power from
the solar cell
The open circuit voltage, V_{oc}, is the maximum voltage from a solar cell and occurs when the net current through the device is zero.
Voltage
V_{oc}


I_{sc}
IV curve of the solar cell
The short circuit current, I_{sc}, is the maximum current from a solar cell and occurs when the voltage across the device is zero.
Current
Power from
the solar cell
Voltage
V_{oc}

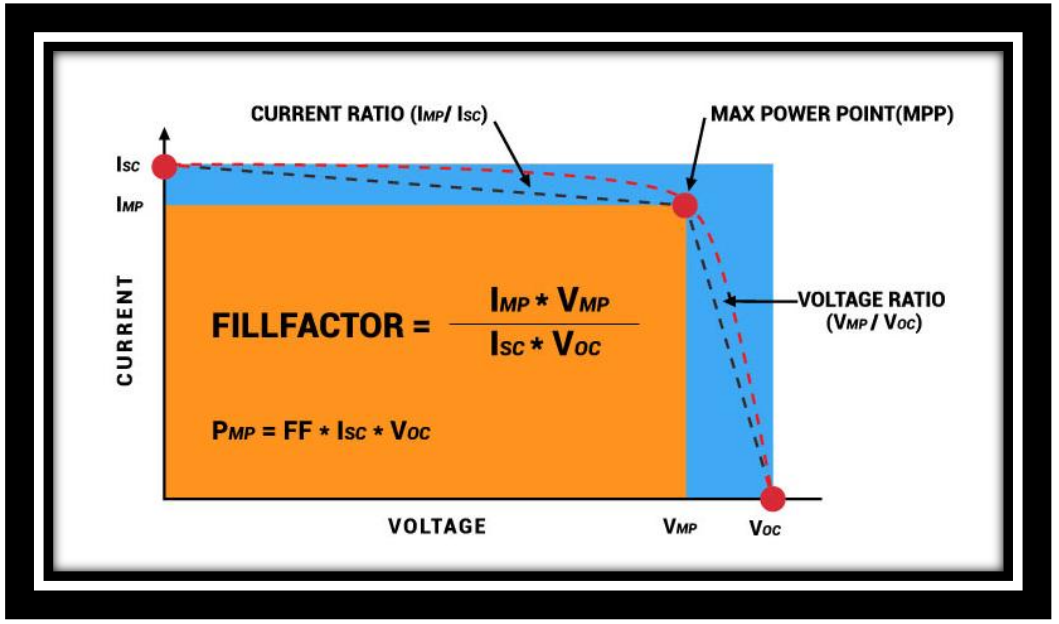
What is the meaning of Fill factor and efficiency of solar cell?

Fill factor meaning with formula:

The Fill Factor (FF) is typically a measure of the Efficiency of a solar cell. The short-circuit current and the open-circuit voltage are the maximum current and voltage respectively from a solar cell.. The "fill factor", more commonly known by its abbreviation "FF", is a parameter which, in conjunction with V_{oc} and I_{sc}, determines the maximum power from a solar cell. FF is the ratio of maximum power (P_{max}) to the product of V_{OC} & I_{SC}, i.e. The fill factor is the relationship between the maximum power that the array can actually provide under normal operating conditions and the product of the open-circuit voltage times the short-circuit current, (Voc x Isc) This fill factor value gives an idea of the quality of the array and the closer the fill factor is always less than 1 (unity), t Typical values are between 0.7 and 0.8.

$$Fill\ ..\ factor\ \ (FF\ ) = \frac{V_m \times I_m}{V_{oc} \times I_{sc}} Or\ \frac{Max\ ..Useful\ .power\ .}{ideal\ .power}$$

$$V_m \times I_m = FF \times V_{oc} \times I_{sc}$$



The Fill Factor of Solar Cells:

The Fill factor (FF) of a solar PV module is usually about 80% for silicon cells.

And solar cells made from GaAs can give a maximum FF of 89%

efficiency of Solar Cell: **% eff = percent efficiency** – The efficiency is the most commonly used parameter to compare the performance of one solar cell to another. Efficiency is defined as the ratio of maxmum output power extracted from the solar cell to input power given to solar cell. from the sun the efficiency depends on the spectrum and intensity of the incident sunlight and the temperature of the solar cell. Therefore, conditions under which efficiency is measured must be carefully controlled in order to compare the performance of one device to another.

$$Efficience \quad ..of \ ..solar \ \ ..cell \ .(\eta) = \frac{P_{\max}}{P_{in}}$$

$$(\eta) = \frac{V_m \times I_m}{p_{input}} we \ ..know \ \ ..that \ \ ..V_m \times I_m = FF \times V_{oc} \times I_{sc}$$

$$(\eta) = \frac{FF \times V_{oc} \times I_{sc}}{p_{input}}$$

The efficiency of solar cell is very low the best silicon solar cell produced in the lab is 20% commercial cell have the efficiency 12to 14 %

P_{max} = maximum power – This relates to th

$$\text{Efficiency } (\eta) = \frac{P_{max}}{P_{in}}$$

Efficiency	Fill Factor
It is the ratio of the highest power that a solar PV panel can generate under standard testing conditions to the input power	It is the ratio of maximum power to the theoretical power.
$\text{Efficiency } (\eta) = \frac{\text{Fill Factor (FF)} \times V_{OC} \times I_{SC}}{P_{in}}$	$\text{Fill Factor (FF)} = \frac{P_{max}}{P_t}$
You can maximize a solar PV panel's Efficiency through an increased Fill Factor (FF), V_{OC}, and I_{SC}.	iii. The maximum achievable power (theoretical) depends on several factors, such as the silicon type employed to build solar PV modules. Any deviation from the anticipated value in Fill Factor could be evidence of the module being faulty.

Factors Affecting the Performance of Solar Power System

CLEANLINESS OF SOLAR PANEL SURFACE, LOCATION FOR SOLAR POWER SYSTE, performance of solar panels performance of solar power system roof orientation for solar panels, shading for solar panels weather performance for solar power system

The efficiency of solar panels has dramatically increased over the past decade. While with time the cost of solar panels has fallen more than 80% over the last eight years making solar panels a very lucrative investment.

When you plan to buy a Solar Power System, many companies will promise many things about efficiency, savings and long term advantages with different solar technologies.

Many people are unaware of what factors affect the output of Solar Power System. Hence SolarSmiths today is going to take you in-depth about factors that influence solar energy production. Understanding these factors will help you to become a smart buyer who can make correct decisions.

Let's understand the factors that affect the output of Solar Power System:

1.Weather Change

Lot of us assumes that high temperature leads to high solar panel efficiency, but it is just a myth.

As heat exposure can prematurely degrade solar cells as for daily production, high temperatures lead to a drop in voltage and a drop in overall power.

Solar cells perform better in the cold rather than in hot climates, such as if solar panels are exposed to 25˚C, which can be significantly different from the real outdoor situation.

Hence whatever single temperature rises above 25˚C the solar panel output decays by about 0.25% for amorphous cells and about 0.4-0.5% for crystalline cells.

Thus, in hot summer days, panel temperature can easily reach 70˚C or more where the panels will put out up to 25% less power compared to what they rate for at 25˚C.

Therefore in most of India when the temperature is High about 45 ˚C and high demand for electricity in April/May/June, a 100W panel will produce only 75W.

2.Shading

Shading is same as a clog in the pipe of running water, as it restricts the water in same pipe way solar cell is shaded, when the shadow falls on even a small part of the solar panel the current through the entire string is reduced.

The cells within a panel are mostly connected wired in series, and the shaded cells affect the current flow of the whole **solar power system** If the affected panel is wired in series (in a string) with other panels, then the output of all those panels will be affected by the partial shading of one panel. In such a situation, an obvious solution is to avoid wiring panels in series if possible.

3.Roof Orientation

The positioning of the solar panel must be facing a south direction for those living in the Northern Hemisphere and the sun is always along the southern part of the sky. Hence it is generally the best practice to position solar panels facing south to capture the maximum amount of sunlight overall.

The south-facing solar panels should be tilted between a 30- and 40-degree angle so that behind this angle specificity is to ensure sunlight hits panels at a perpendicular angle, which produces the most energy. An edge along these lines also helps snow to slide off of solar panels more quickly during winter in the northern latitudes.

The angle of inclination of the solar panels should be actively adjusted according to changes in seasons, latitude and longitude and sunshine hours.

4.Cleanliness of Solar Panel Surface

The cleanliness of the solar panel surface is directly connected to photoelectric power conversion. Due to polluted environment, rainfall, snow, dust, sandstorms are few factors can play a role in reducing the efficiency of solar module hence ensure cleaning frequency of the solar panels according to the local labour cost.

In most places, there`s more pollution in the winter; hence spring is the best time to do an annual cleaning. While once solar panels are cleaned once or twice a year they will produce 3.5% and 5.1% more electricity compared to un cleaned.

5.Location

Not all places have the same abundance of annual sunshine. To decide the amount of solar radiation received in your home isolation is a tough job in designing a cost-effective solar array for your usage.

Insolation is identified by elements such as local weather, the time of year, and most importantly, the latitude of your **home** or **company**.

Depending upon the season there will be a different climate in different locations; hence your solar panel's production numbers will be different according to the season remember to consider annual production.

Materials Used in Solar Cell

The materials which are used for this purpose must have band gap close to 1.5ev. Commonly used materials are-

- Silicon.
- GaAs.
- CdTe.
- $CuInSe_2$

Criteria for Materials to be Used in Solar Cell

- Must have band gap from 1ev to 1.8ev.
- It must have high optical absorption.
- It must have high electrical conductivity.
- The raw material must be available in abundance and the cost of the material must be

Advantages of Solar Cell

No pollution associated with it.
It must last for a long time.
No maintenance cost.

Disadvantages of Solar Cell

It has high cost of installation.

It has low efficiency.

During cloudy day, the energy cannot be produced and also at night we will not get solar energy.

Uses of Solar Generation Systems

It may be used to charge batteries.

Used in light meters.

It is used to power calculators and wrist watches.

It can be used in spacecraft to provide electrical energy

Solar cells, also called photovoltaic cells, convert the energy of light into electrical energy using the photovoltaic effect. Most of these are silicon cells, which have different conversion efficiencies and costs ranging from amorphous silicon cells (non-crystalline) to polycrystalline and monocrystalline (single crystal) silicon types.

Unlike batteries, solar systems do not use chemical reactions, nor do they require fuel. In addition, solar cells don't have moving parts like electric generators. Domestic solar systems convert around 20% of the sunlight the receive into electricity, while more expensive commercial systems can convert up to 40%. However, with technological advances the solar efficiency of these panels is expected to rise.

The largest formation of solar cells are called arrays, which are made up of thousands of individual cells and can be put together into solar farms to convert sunlight into power for large scale commercial, industrial and residential use.