Unit I

INTRODUCTION: SOLAR RADIATION: Role and potential of new and renewable sources, the solar energy option, Environmental impact of solar power, structure of the sun, the solar constant, sun-earth relationships, coordinate systems and coordinates of the sun, extraterrestrial and terrestrial solar radiation, solar radiation on titled surface, instruments for measuring solar radiation and sunshine, solar radiation data, numerical problems. Photo voltaic energy conversion – types of PV cells, I-V characteristics

SOLAR ENERGY COLLECTION: Flat plate and concentrating collectors, classification of concentrating collectors, orientation and thermal analysis, advanced collectors.

Outcome: Distinguish various types of solar thermal collectors

Renewable energy

Renewable energy sources are those that can be replenished over time, such as solar, wind, water, and biomass. They offer a number of advantages over traditional energy sources, such as lower emissions, greater security, and the potential to create jobs.

Role of new and renewable sources

Renewable energy sources can play a significant role in meeting the world's growing energy needs. They can help to reduce greenhouse gas emissions, improve energy security, and create jobs.

- Reduce greenhouse gas emissions: Renewable energy sources produce no greenhouse gases, which are a major contributor to climate change. This makes them an important part of the solution to climate change.
- Improve energy security: Renewable energy sources are not subject to the same price volatility as fossil fuels. This makes them a more secure source of energy, especially for countries that are reliant on imports of fossil fuels.
- Create jobs: The renewable energy sector is a growing sector, and it is creating jobs in a variety of fields. This is good news for the economy, and it can help to reduce unemployment.

Potential of new and renewable sources

The potential of new and renewable sources is vast. They have the potential to meet a significant portion of the world's energy needs.

- Solar energy: Solar energy is the most abundant renewable energy source. It can be used to generate electricity, heat water, and power vehicles.

- Wind energy: Wind energy is another abundant renewable energy source. It can be used to generate electricity and pump water.
- Hydropower: Hydropower is a renewable energy source that has been used for centuries. It can be used to generate electricity and irrigate land.
- Biomass energy: Biomass energy is a renewable energy source that comes from organic matter. It can be used to generate electricity, heat water, and power vehicles.

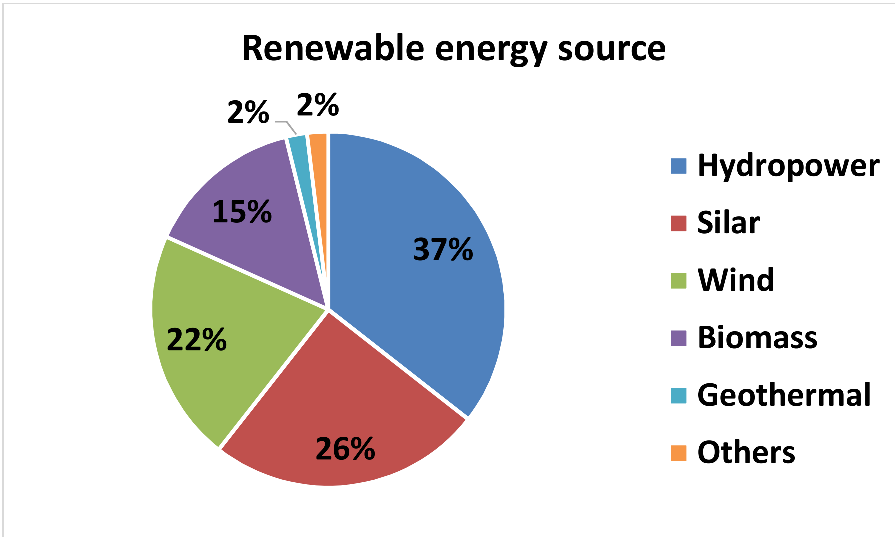


Figure 1: The following figure shows the global share of renewable energy in electricity generation.

As we can see, hydro accounted for the largest share of renewable energy in electricity generation in 2023, at 37%. Solar was the second largest source, at 26%, followed by wind at 22% and biomass at 15%.

The global share of renewable energy in electricity generation is expected to continue to grow in the coming years. The International Energy Agency (IEA) projects that renewable energy will account for 40% of global electricity generation by 2030.

This growth is being driven by a number of factors, including the falling cost of renewable energy technologies, the increasing demand for clean energy, and the need to reduce greenhouse gas emissions. Energy Matters

Conclusion

Renewable energy sources offer a number of advantages over traditional energy sources. They are cleaner, more secure, and have the potential to create jobs. The potential of renewable energy is vast, and it is an important part of the solution to climate change.

Environmental impact of solar power

Solar power is widely regarded as a clean and environmentally friendly source of energy. However, it's important to consider the environmental impact of solar power across its life cycle, including manufacturing, installation, operation, and end-of-life disposal. Here are some key aspects of the environmental impact of solar power:

- Greenhouse Gas Emissions: Solar power generation produces minimal greenhouse gas emissions during operation compared to fossil fuel-based energy sources. The primary emissions associated with solar power come from the manufacturing process, including the production of solar panels and related components. However, these emissions are significantly lower compared to the emissions from fossil fuel power plants.
- Resource Consumption: The production of solar panels requires the extraction and processing of raw materials, such as silicon, aluminum, glass, and various metals. The extraction of these materials can have environmental impacts, including habitat disruption, energy consumption, and water usage. However, the resource consumption and environmental impacts of solar panel manufacturing are generally lower compared to the extraction and processing of fossil fuels.
- Land Use: Solar power plants, whether large-scale utility plants or smaller rooftop installations, require land for their installation. While solar panels themselves have a small physical footprint, utility-scale solar farms can occupy significant land areas. Careful planning and siting of solar installations can help minimize land use conflicts and preserve ecosystems.
- Water Usage: Solar power generation typically requires minimal water for operation. However, water may be required during the manufacturing process for cooling and cleaning purposes. The water consumption associated with solar panel manufacturing is relatively low compared to many other industrial processes. In regions with water scarcity, the water usage during manufacturing may need to be carefully managed.
- Waste and Recycling: Solar panels have a long operational lifespan, typically ranging from 25 to 30 years or more. At the end of their life, solar panels can be recycled to recover valuable materials like silicon, glass, and metals. Proper recycling and disposal practices are essential to minimize the environmental impact of decommissioned solar panels. Efforts are underway to develop more efficient and scalable recycling technologies for solar panels.
- Ecosystem Impacts: Solar power installations, particularly large-scale solar farms, can affect local ecosystems during the construction phase. Habitat disruption, loss of vegetation, and changes in local biodiversity can occur if not properly planned and managed. However, compared to the ecosystem impacts associated with fossil fuel extraction and combustion, solar power installations generally have a lower overall environmental footprint.
- Air and Water Pollution: Solar power generation does not produce air pollutants, such as sulfur dioxide, nitrogen oxides, or particulate matter, during operation. This contributes to improved air quality and reduces the impact on human health. Solar power plants do not generate wastewater or contribute to water pollution during operation, further minimizing environmental impacts.

Sun, Physical Description and Reactions

Nature of Sun

Sun is a medium sized yellow star that may be considered as a sphere of intensely hot gaseous matter with an average diameter of 1.39×10^9 m at an average distance of 1.495×10^{11} m (or 1 Astronomical unit) from the earth. The sun coalesced from a cloud of gas and dust formed 4.5 billion years ago. Earth goes around the sun in an elliptic orbit as shown in Fig. 2.1, not to scale. The earth is closest to the sun at 1.471×10^{11} m, the perihelion around January 2 each year; it is farthest at 1.526×10^{11} m around July 2 each year.

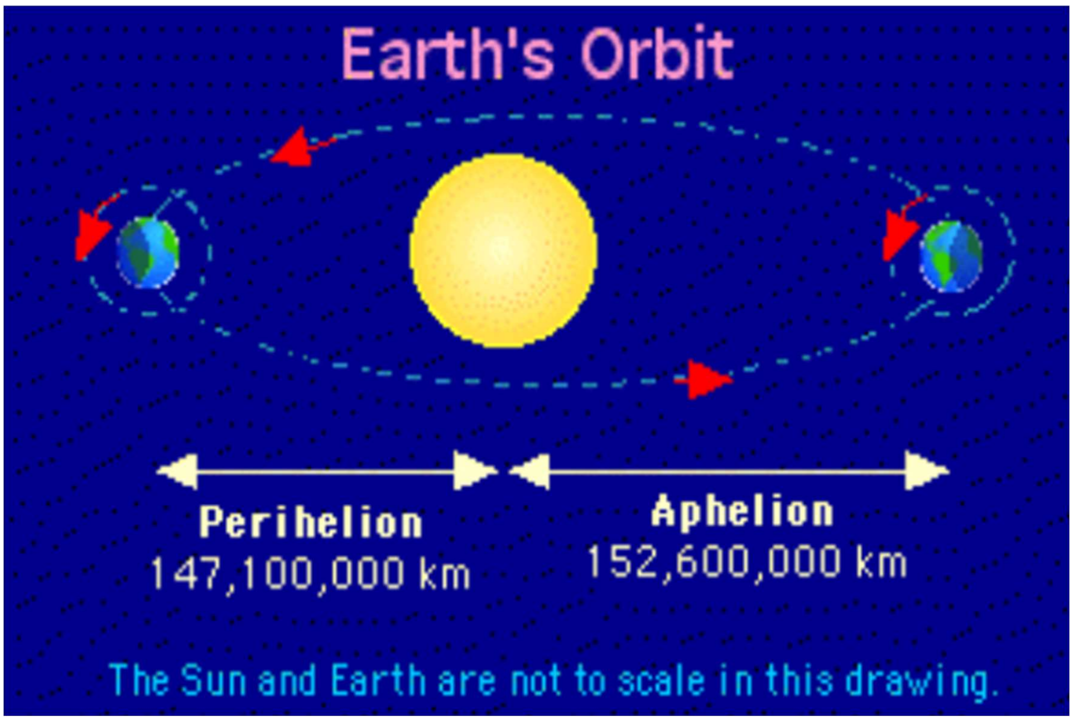


Figure 2: The Perihelion and the Aphelion

Energy is produced in the sun (and other stars also) by continuous fusion in which four nuclei of hydrogen fuse in a series of reactions.

$4\ {}_1H^1 \rightarrow 2He^4 + 2(+1e^0)$

This reaction results in a mass decrease of about 0.0276 amu, corresponding to 25.7 MeV. The heat produced in these reactions maintains temperatures of the order of several million degrees in the core region of the sun and serves to trigger and sustain succeeding reactions.

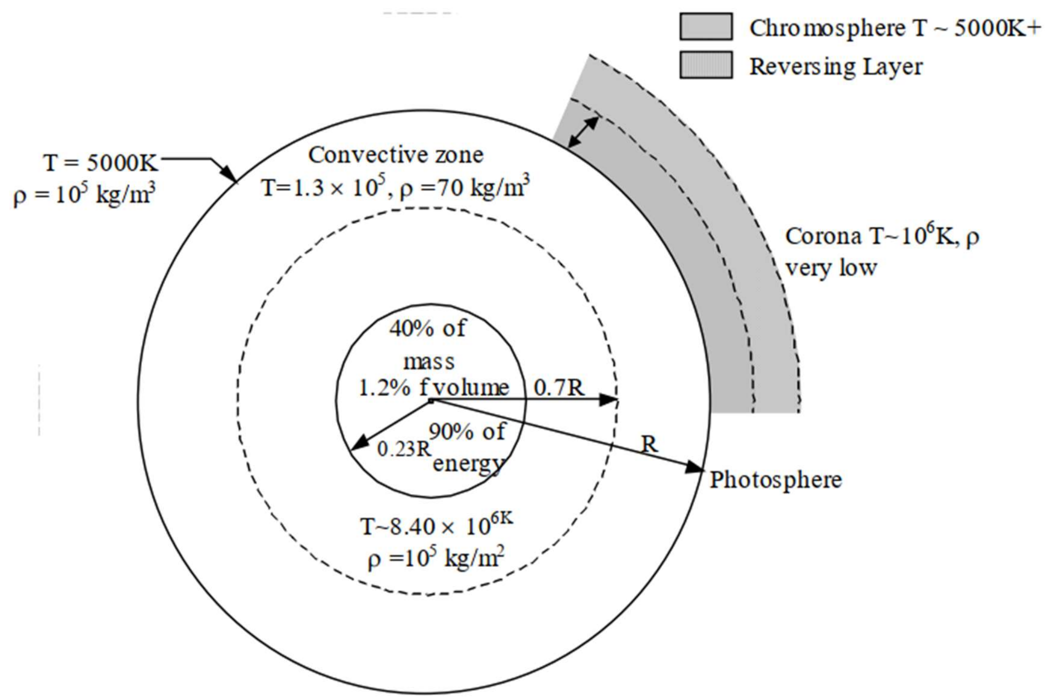


Figure 3: Sun and its important zones

The Sun is made up of about 2 x 10^{30} kilograms of gas. It is composed of about 75% hydrogen and 25% helium. About 0.1% is metals made from hydrogen via nuclear fusion. It has been estimated that the sun has used up about half of its initial hydrogen available 4.5 billion years ago, i.e., the time of formation.

A simple schematic of the sun is shown in Fig. 2. With reference to Fig. 2, 90 % of the energy is generated in the region $0 < r < 0.23$ *Rsun* , where *Rsun* is the radius of the sun. The temperature at 0.7 *Rsun* is of the order of 130 x 103 K. From the region r > *Rsun*, convection process begins and is referred to as the convective zone. The upper layer of the convective zone is the photosphere, which is the source of most solar radiation. Other layers following the reversing layer (a layer of relatively cooler gases of several hundred km deep), are, chromosphere (has a depth of 10, 000 km with some what higher temperature and lower density) and lastly, the corona, of very low density and at a temperature of 10^6 K. Solar radiation is the composite result of several layers which absorb and emit at various wave lengths. For, thermal purposes it is adequate to consider the sun to be a blackbody at an effective temperature of 5762 K. This information is adequate for many solar energy calculations.

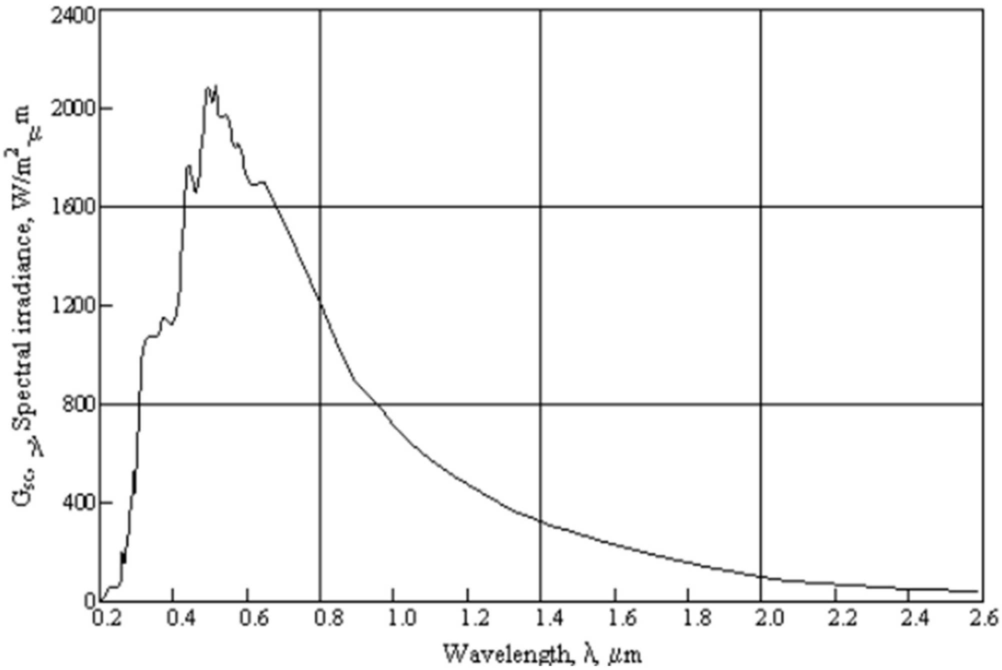


Figure 4: Spectral distribution of solar radiation.

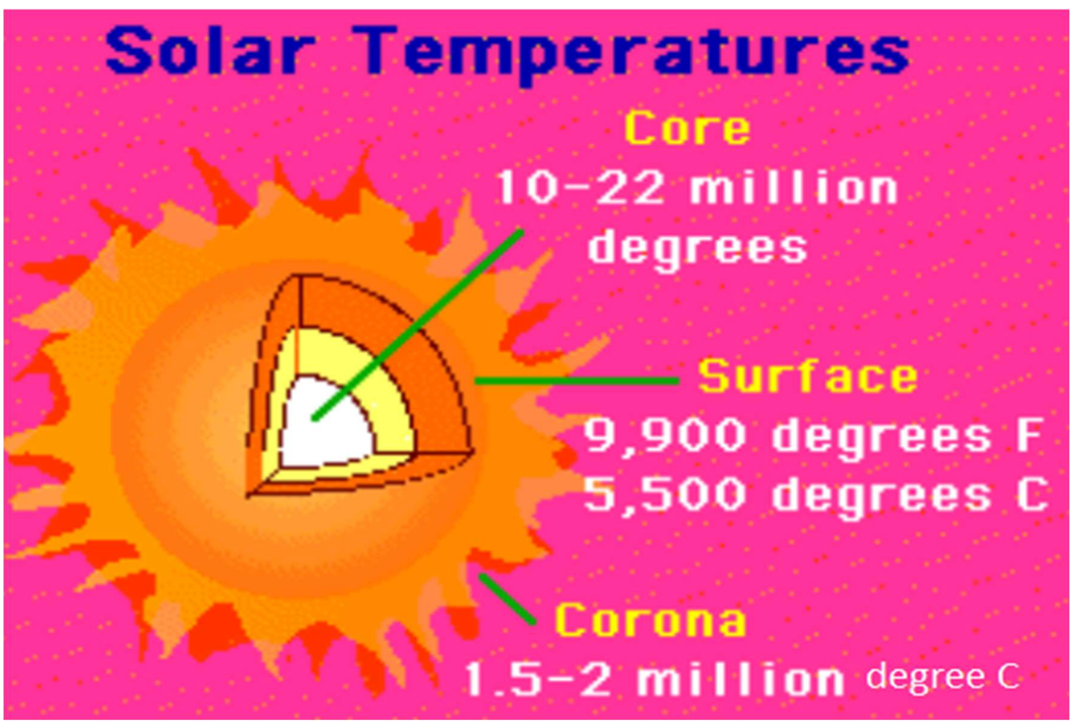


Figure 5: Temperatures at different layers in the sun.

The details of the sun's temperature are depicted in Fig. 4. The Sun's core can reach $5.5x10^6$ °C to $12.5x10^6$ °C. The estimates vary, the higher one going up to $40x10^6$ °C. The surface temperature is approximately 5,500°C. The outer atmosphere of the sun goes up, to $1.5x10^6$ °C to 2 $x10^6$ °C degrees. The effective temperature of the sun is determined by measuring how much energy much energy (both heat and light) it emits.

Green Energy

- Energy resources that are renewable
- Can be naturally replaced
- Clean, Safe and not harmful to the environment.

Type of Green Energy

- Solar
- Water
- Wind
- Geothermal
- Biomass

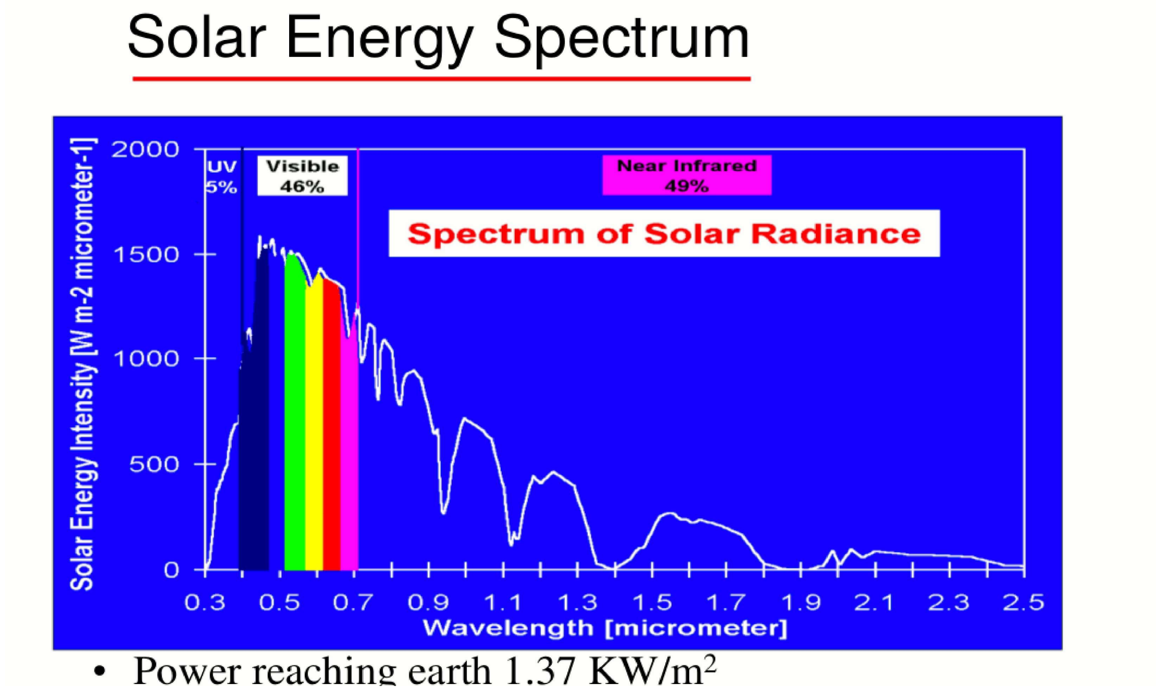
Solar thermal energy applications

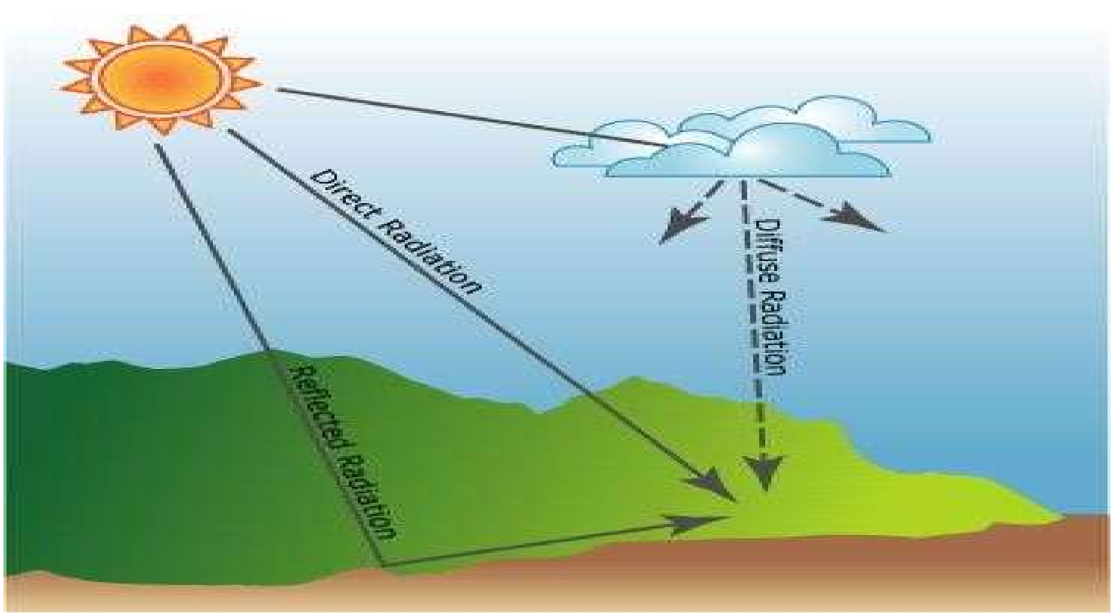
- Water heating
- Solar drying
- Solar Cooking
- Desalination / Distillation
- Solar Pasteurisation
- Solar thermal energy in architecture

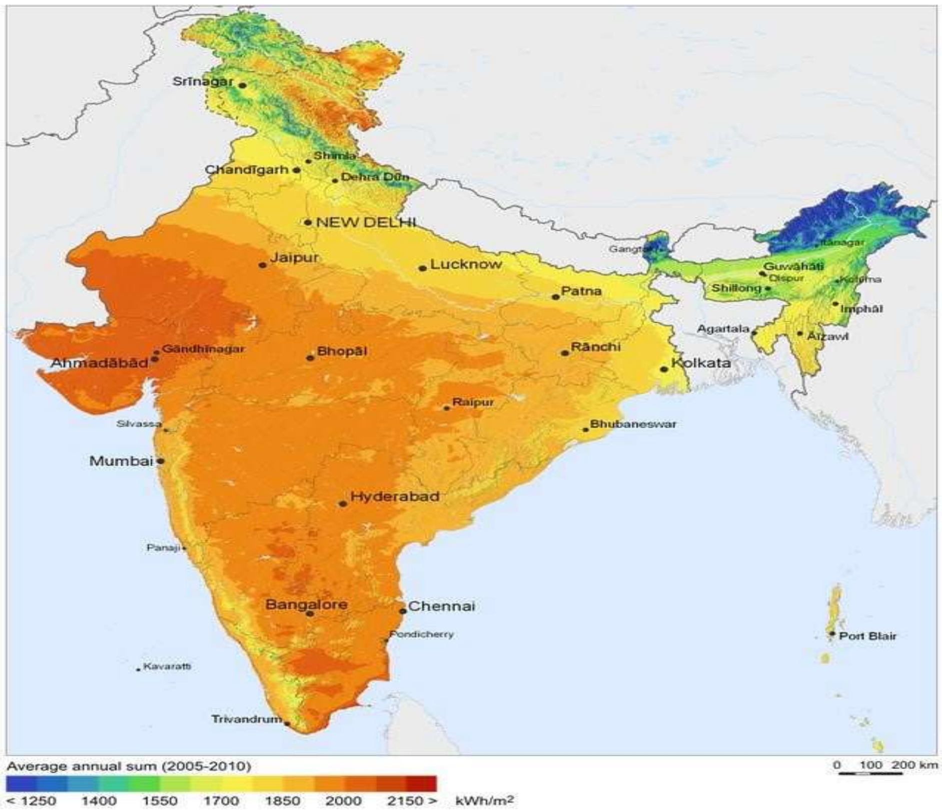
Principle of Solar Thermal effect

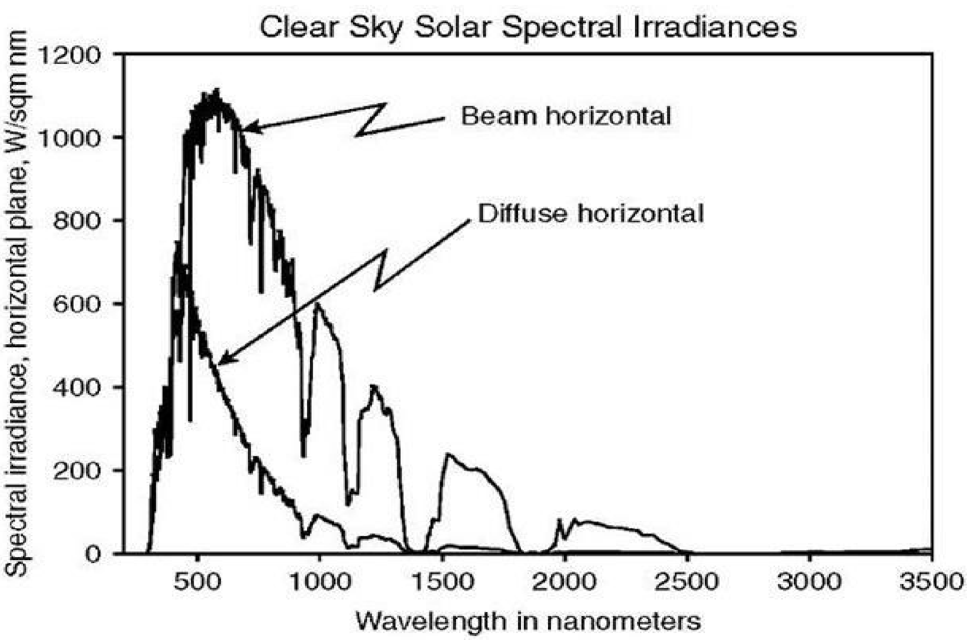
- Solar thermal energy (STE) is a form of energy and a technology for control and make use of natural resources of solar energy to generate thermal energy or electrical energy.

Available Radiation





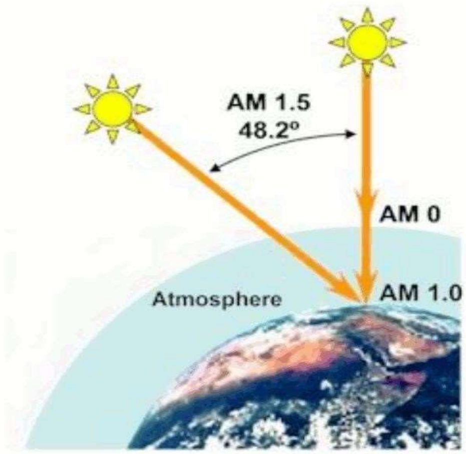

Srinagar
Shimla
Chandigarh
Dehra Dun
NEW DELHI
Jaipur
Lucknow
Patna
Guwahati
Shillong
Imphal
Agartala
Aizawl
Ahmadābād
Gāndhinagar
Bhopāl
Rānchi
Kolkata
Raipur
Bhubaneswar
Silvassa
Mumbai
Hyderabad
Panaji
Bangalore
Chennai
Pondicherry
Port Blair
Kavaratti
Trivandrum
Average annual sum (2005-2010)
0 100 200 km
< 1250 1400 1550 1700 1850 2000 2150 > kWh/m2

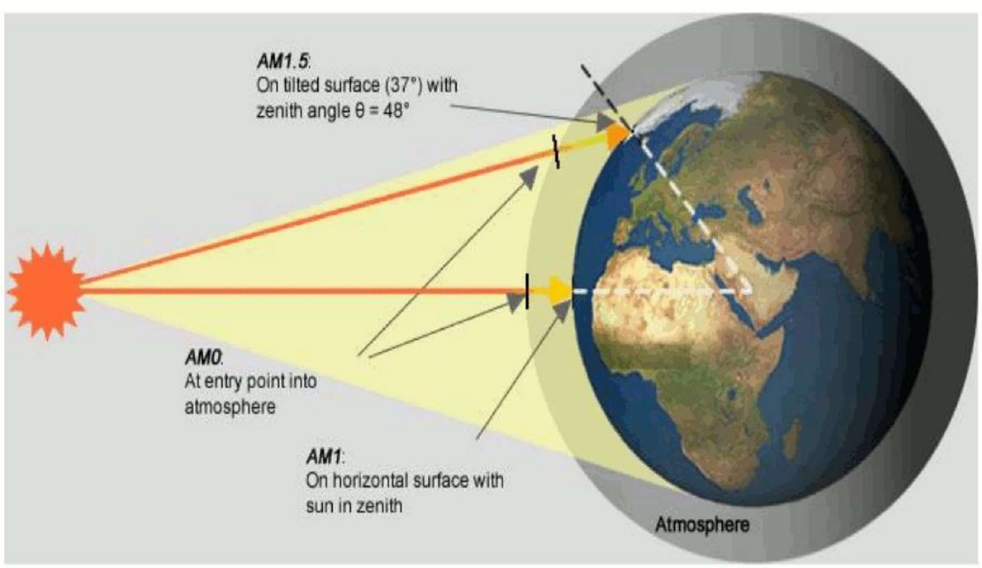

Clear Sky Solar Spectral Irradiances
Spectral irradiance, horizontal plane, W/sqm nm
1200
1000
800
600
400
200
0
Beam horizontal
Diffuse horizontal
500 1000 1500 2000 2500 3000 3500
Wavelength in nanometers

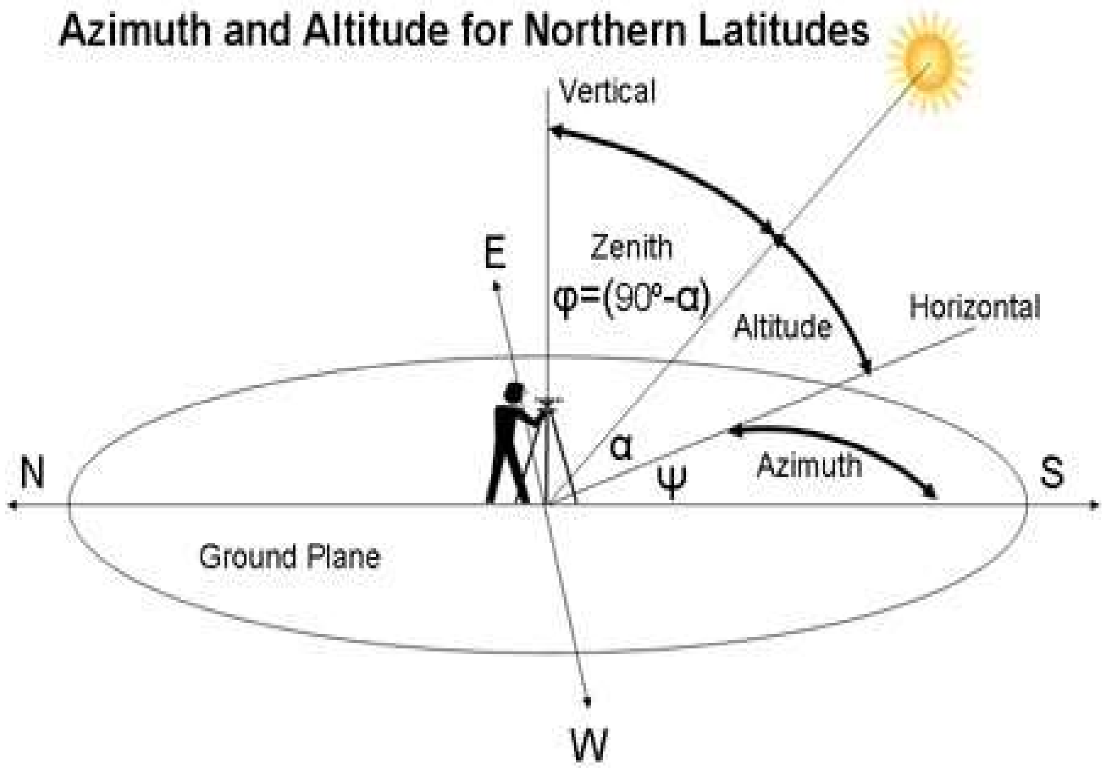
Factors which affects solar energy

Geographic location
Time of day
Season
Local landscape Weather conditions
Geographic location

Air Mass

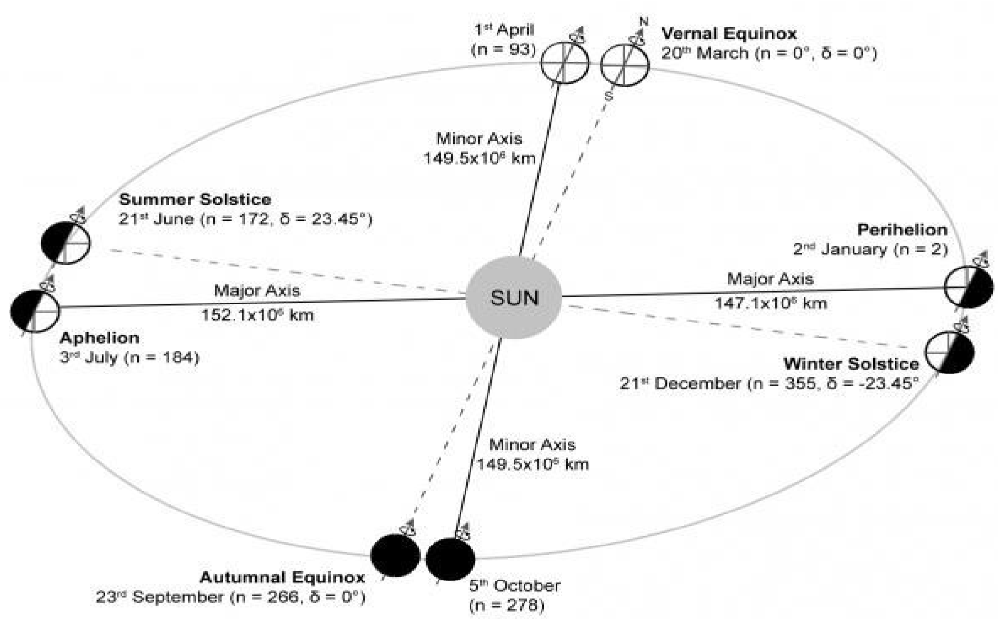


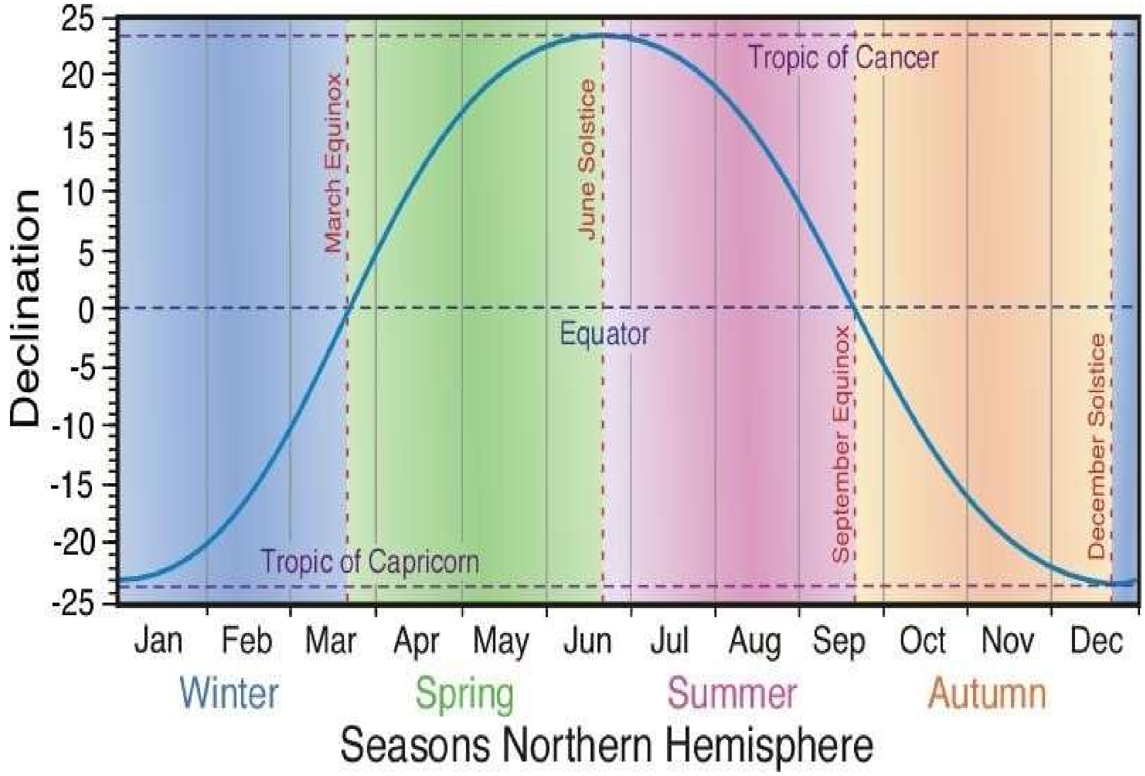




Declination

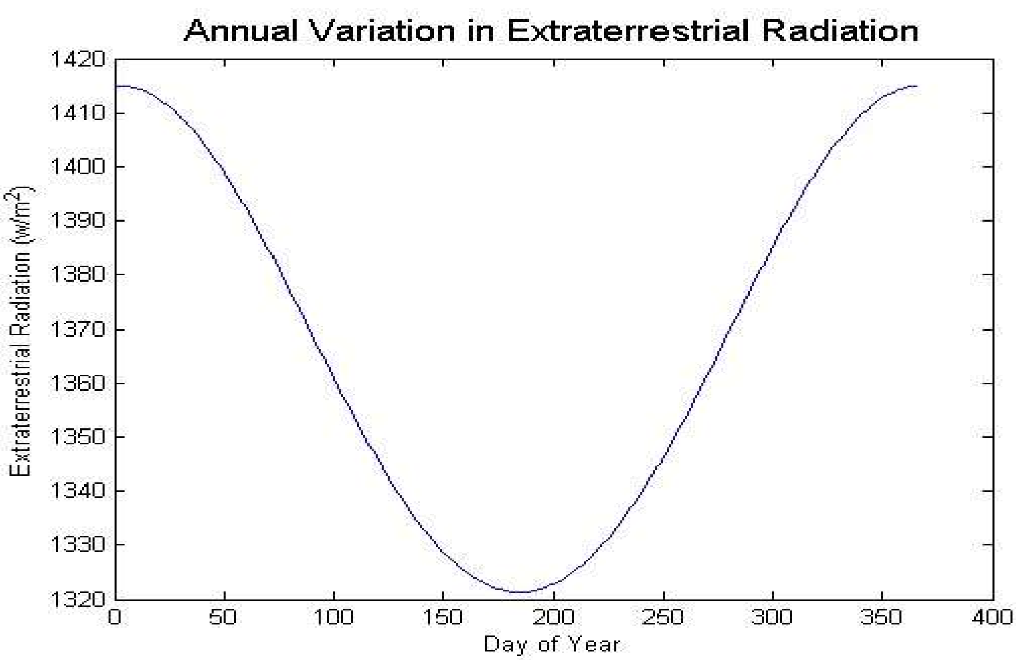
Declination=23.45*Sin((360/365)*(284+n))



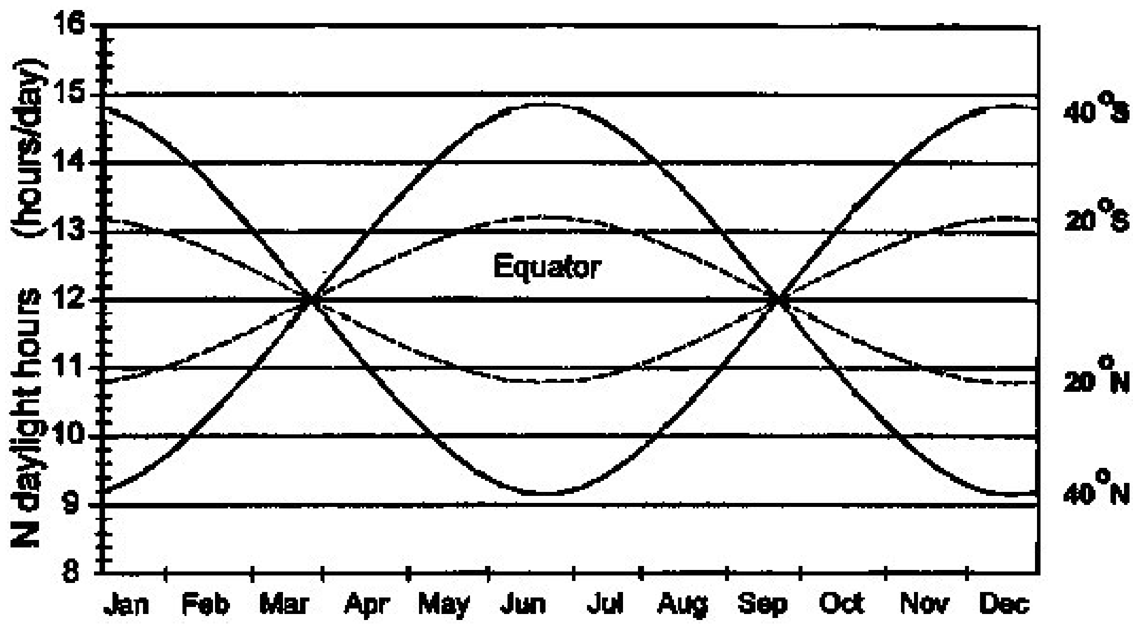


Extra teristerial radiation

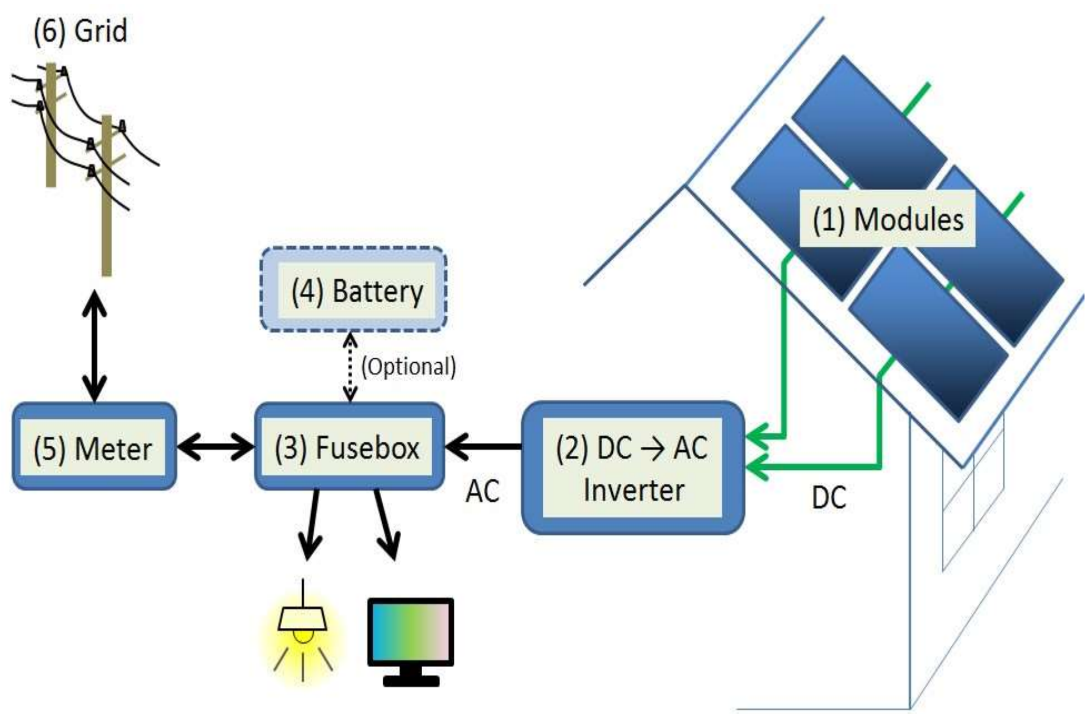
Iext=Isc[1.0+0.33cos(360n/365)]



Variation of daylight hour



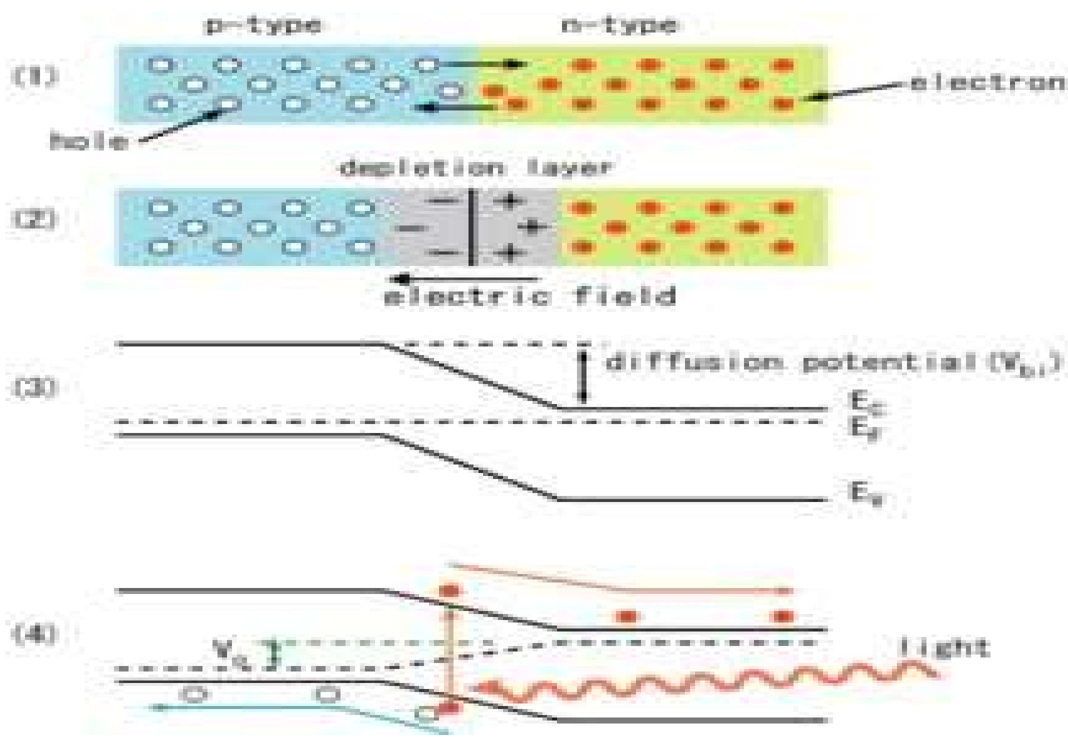
Solar Photo Voltaic



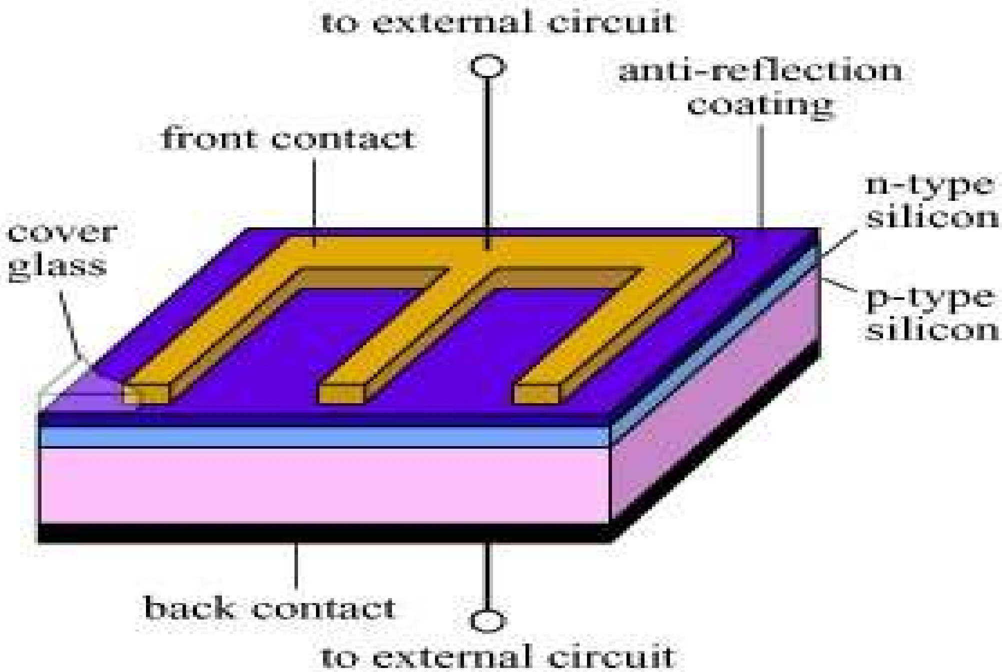
Type of PV Cell

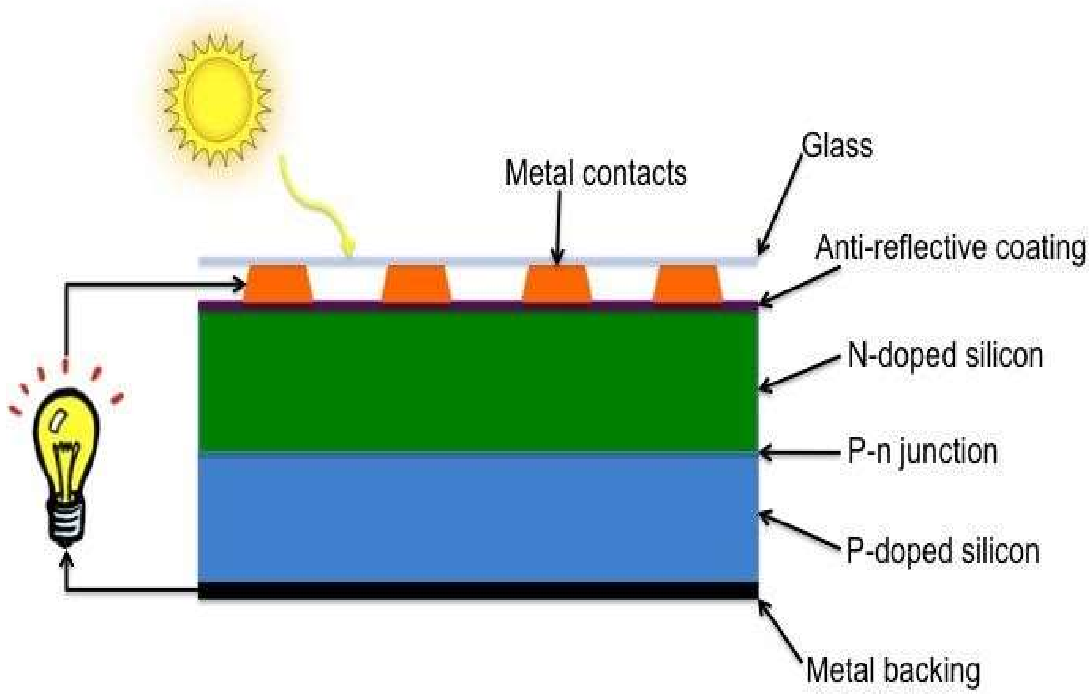
- Single Crystal Solar Cell
- Thin Film Solar Cell
- Amorphous Si Solar Cell
- Tandem Solar Cell
- Concentrating Solar Cell

Working Principle

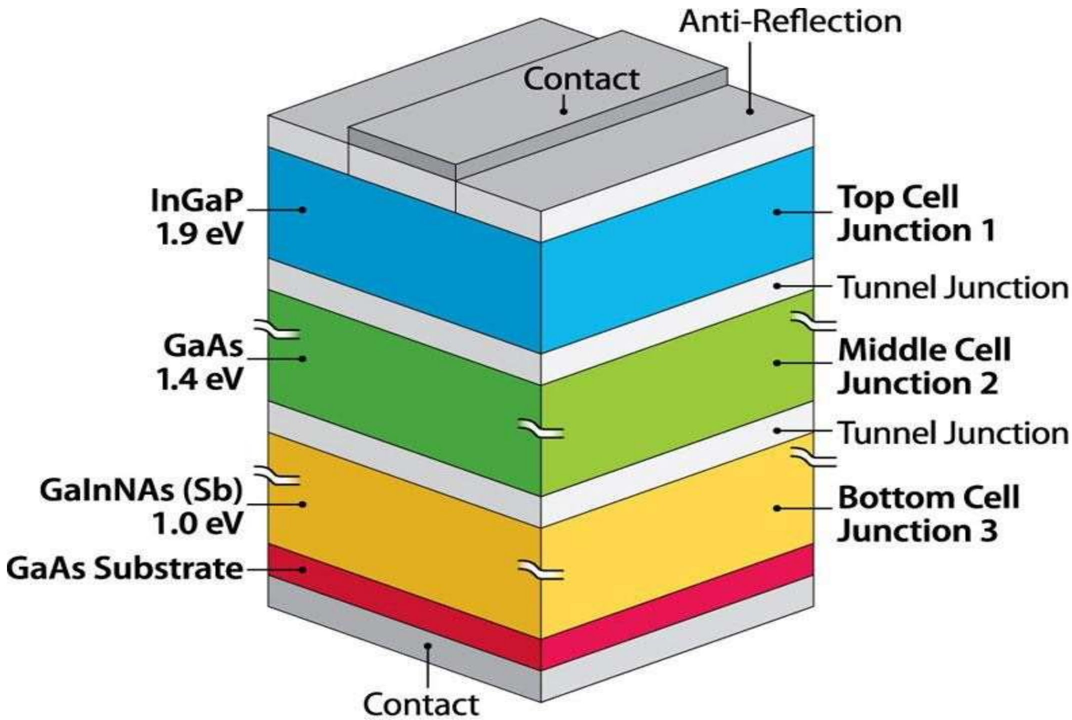


c-Si Solar Cell

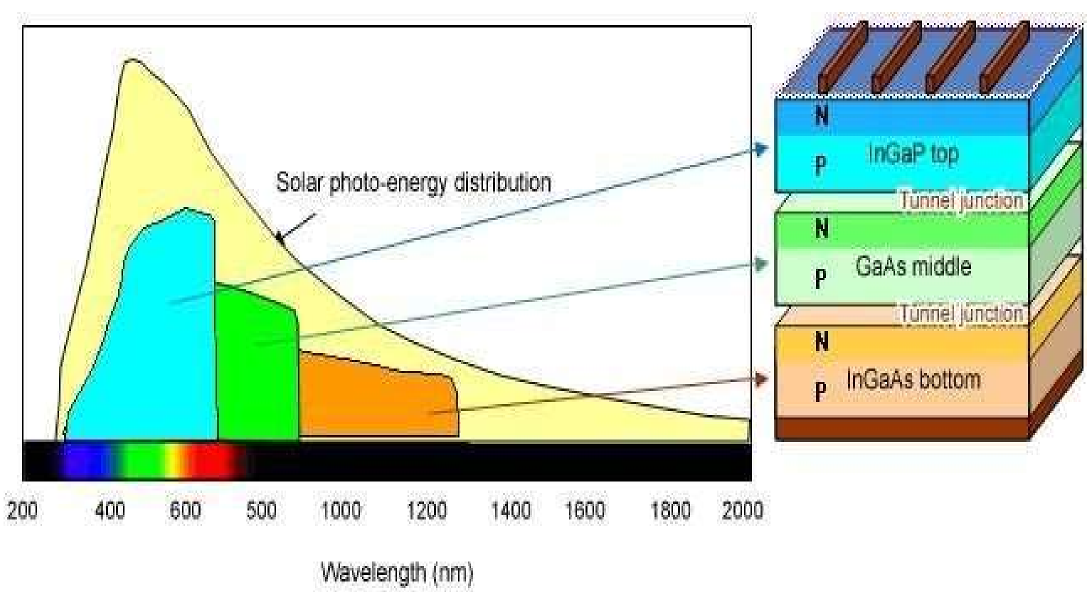




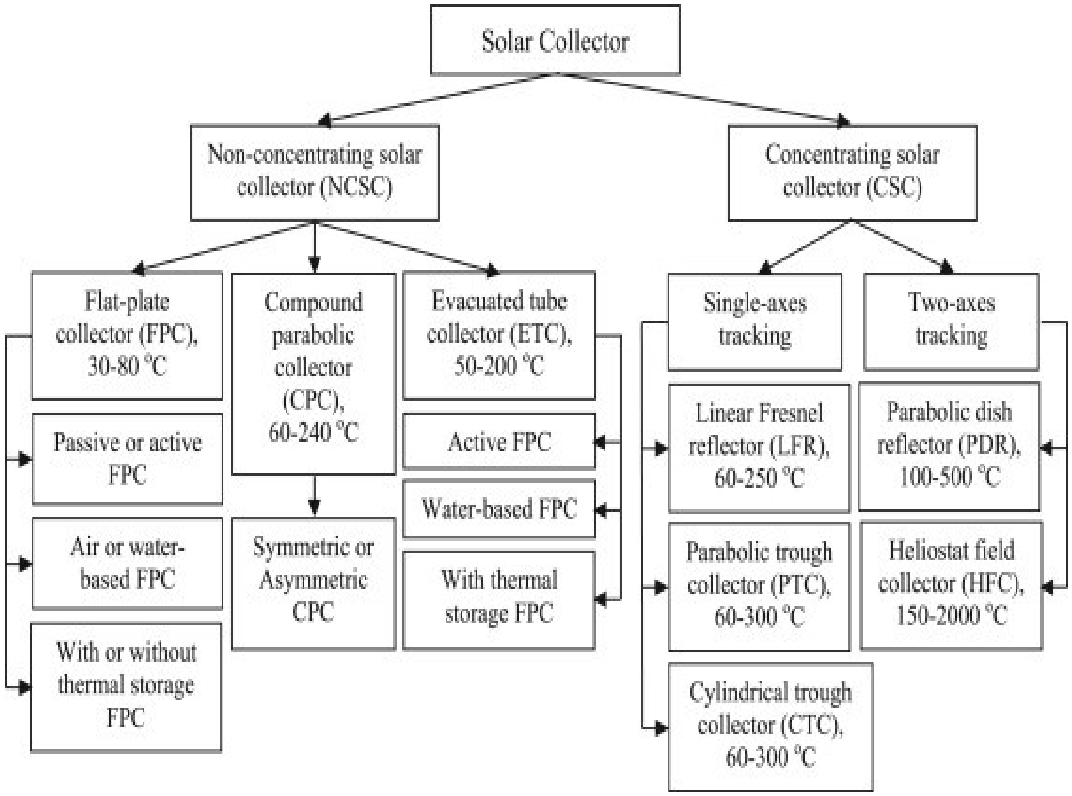
Tandem Solar Cell



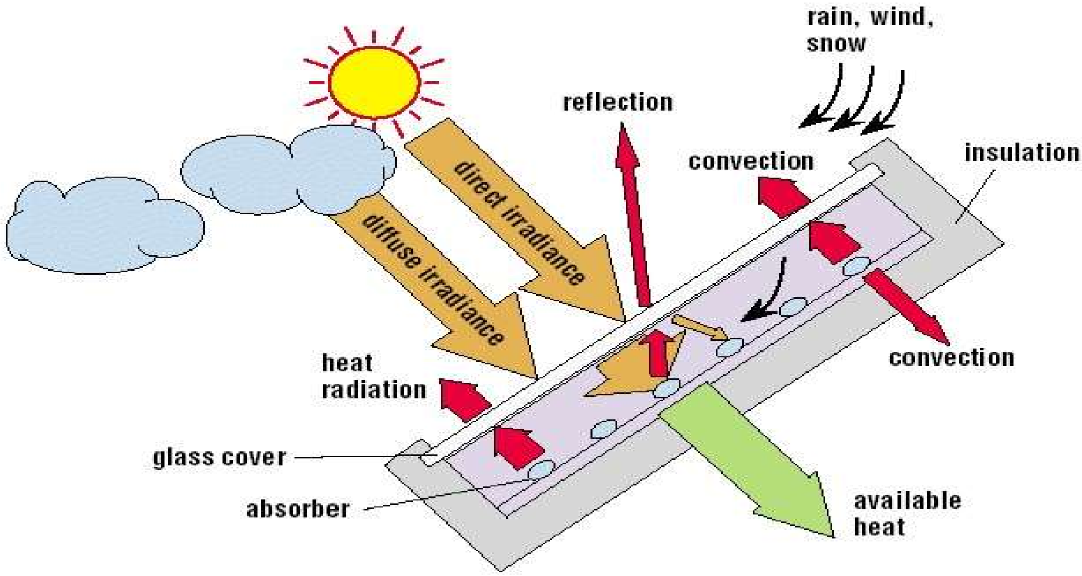
Wavelength Distribution of Solar Photo-Energy and Wavelength Sensitivity of Triple-Junction Compound Solar Cell



Classification of solar collector

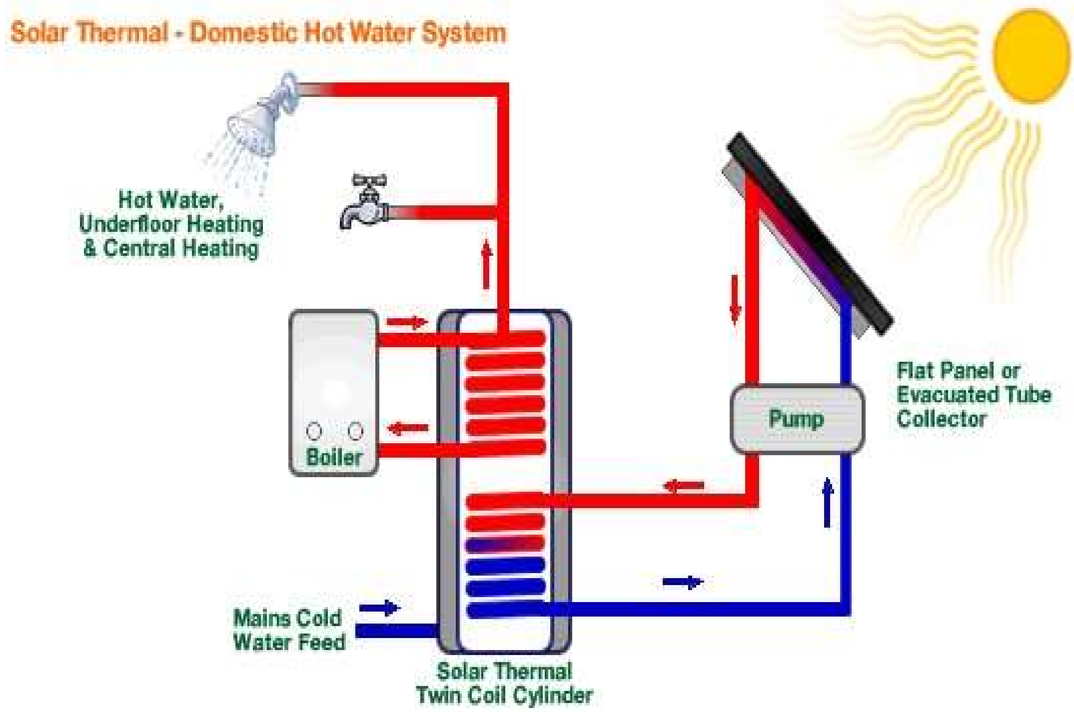


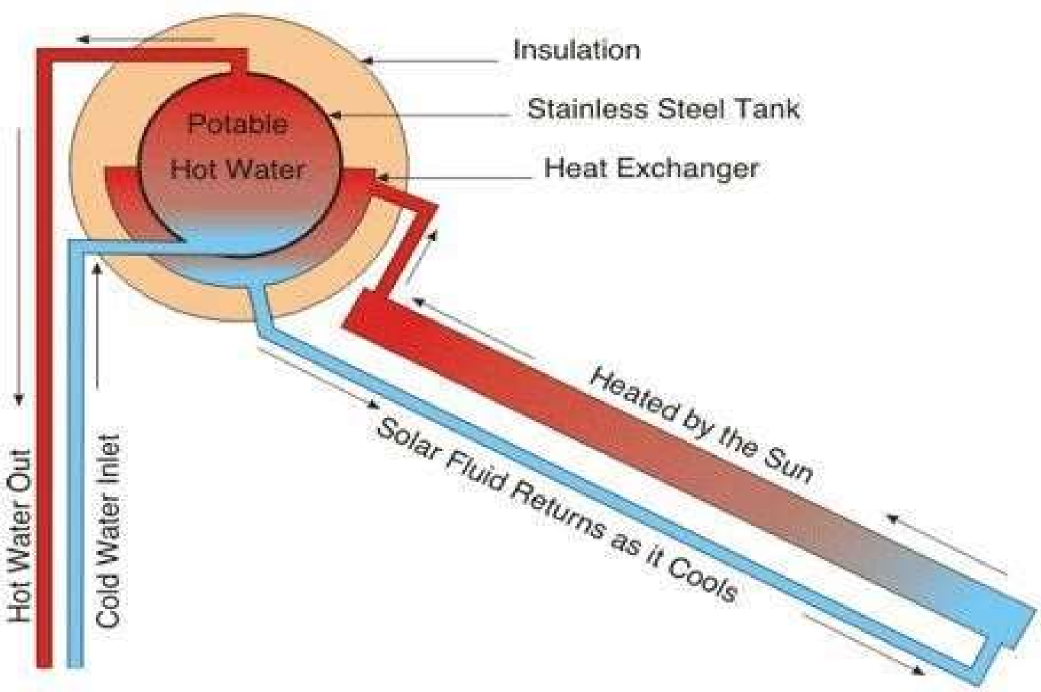
Solar Thermal Principle



Flat Plate Solar Collectors

Thermo syphon


Solar Thermal - Domestic Hot Water System
Hot Water,
Underfloor Heating
& Central Heating
Boiler
Pump
Flat Panel or
Evacuated Tube
Collector
Mains Cold
Water Feed
Solar Thermal
Twin Coil Cylinder


Insulation
Stainless Steel Tank
Heat Exchanger
Potable
Hot Water
Heated by the Sun
Solar Fluid Returns as it Cools
Hot Water Out
Cold Water Inlet

SUMMARY

- The characteristics desired of an ideal energy source have been identified. The principal features are, perennial nature, non-polluting and uniform availability.
- Thermodynamic viewpoint iterates the need to match the source of energy with the application.
- The energy from the sun by continuous fusion reaction of Hydrogen combining to form Helium in the sun produces the energy.
- Sun can be considered as a black body at an effective temperature of 5762 K emitting energy continuously.
- Most of the solar radiation reaching the earth's surface is in the wave length range of 0.29 μ to 4.0μ.

Question Bank

Short

1. What is terrestrial solar radiation?
2. Give different types of Concentrating type collectors.
3. Discuss about solar constant.
4. Define solar constant.
5. Explain the variation in sun declination in a year.
6. What are the factors influencing diffuse radiation on earth surface?
7. Define photosynthesis efficiency.
8. What is latitude, longitude and prime meridian?
9. Discuss the features of Solar Photo Voltaic system.
10. Discuss the main applications of Solar Photo Voltaic system?
11. Discuss the limitations of solar photovoltaic system.
12. What are the major components of photovoltaic systems?
13. Explain about extraterrestrial and terrestrial solar radiation.
14. Discuss about the role and potential of new and renewable sources of energy.

Long

1. Explain the construction and principle of operation of a sunshine recorder.
2. Explain the working of photo voltaic energy conversion system.
3. Discuss about concentrated collectors and advanced solar energy collectors.
4. With a neat diagram explain any two instruments used for measuring solar radiation.
5. Enumerate the different types of concentrating type collectors.
6. Explain in detail the factors responsible for variation in extraterrestrial radiation.
7. Compute the radiation striking on a inclined surface.
8. Explain with a simple sketch, construction and working of pyreheliometer.
9. What are the relative advantages of concentrating collectors over flat plate collectors?

10. Explain how diffuse radiation can be measured and factors affecting accuracy of measurement.
11. What are PV cells and explain briefly how they can be used for energy conversion?
12. What are the major advantages of solar cells over conventional power generation?
13. Briefly discuss I-V characteristics of PV cells.
14. Why orientation is needed in concentrating type collectors? Describe the different methods of sun tracking.
15. Estimate the rate at which the sun emits energy. What fraction of this energy is intercepted by the earth and what is the amount intercepted?
16. How does a Photo Voltaic cell works? Explain with suitable diagram.
17. Enumerate the different types of concentrating type collectors. Describe a collector used in power plant for generation of electrical energy.18. Explain the working of pyranometer with the help of a neat sketch.
19. What are the main components of a flat plate solar collector, explain the function of each
20. Explain the Angstrom compensation pyrheliometer, with the help of a neat sketch.
21. What are the advantages and disadvantages of concentrating collectors over flat plate collectors?
22. Explain the working of Flat plate collector with the help of a neat sketch.