

Chapter I

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I Introduction: What is Solar Energy

Solar energy or energy from the Sun sustains the very life on this planet, that is the Earth. Or indeed, on the entire solar system in whatever form.

♣ Forms of Sustainability on the Earth

The Sun

- provides light and heat in various forms
- warms the seas or oceans
- sustains weather conditions and patterns
- maintains the Earth's atmosphere
- provides energy to plants and all forms of greenery
- sustains the planet's climate the year around

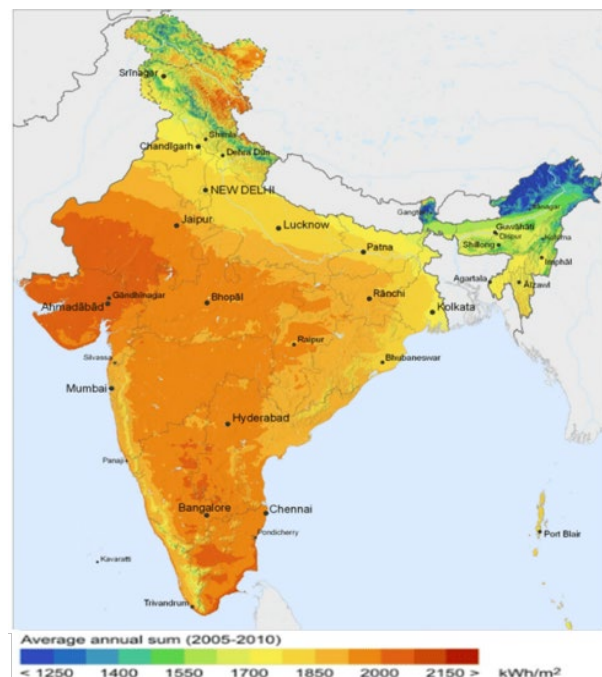
♣ History of Solar Energy

Although it may not be exactly traced back, in theory solar energy is believed to have been used by humans as early as the 7th century BC. History suggests that humans utilised sunlight to ignite fires with the help of a magnifying glass or reflective materials. Later, in the 3rd century BC, the Greeks and Romans were known to harness solar power with mirrors to light torches for religious ceremonies.

♣ Solar Energy Potential

● The Indian Sunshine

With about 300 'clear' sunny days, India's theoretical solar power reception on just the land surface area is nearly 5,000 Peta Watt-hour (1 Peta = 10^{15}) or 5,000 trillion kWh [1 'unit' of electricity as metered in a premises is 1 kWh] equivalent to 600 Tera watt of power. This is far more than the current total annual consumption of electricity of consumers in India, being about 8,000 MWh. A pictorial view of relative sunshine or solar energy availability over the country is shown alongside revealing the most advantageous location of areas along the western coast with the state of Gujarat offering the most potential for solar energy¹.



¹The state is also recognised to have realised electrical energy from the Sun the most, compared to all other states in India.

- **Advantages of Solar Energy**

- ❖ **Renewal Source**

Energy from the Sun or Solar Energy is going to last for at least 5 billion years.

- ❖ **Clean Source**

Solar Energy provides a clean source of energy resulting in NO pollution.

- ❖ **Silent Operation**

A solar power system is completely silent, producing no noise pollution.

- ❖ **Availability**

The energy is easily available right on one's roof top .

- ❖ **Low Maintenance**

The generation unit requires little maintenance.

- ❖ **Cutting Electricity Bill**

Except for initial investment the energy generated is 'free'.

- ❖ **Accessibility**

A solar power system can be installed even at remote, far-flung places.

- **Applications of Solar Energy**

Solar energy is mainly applicable to

- provide illumination in all forms anywhere as required
- allow heating for various purposes
- manifest as photosynthesis for plants' growth
- provide generation of electricity
- make possible cooking in general
- provide natural ventilation in buildings

- **Types of Solar Energy**

Energy from the Sun can be exploited broadly in two forms

A. Direct

and

B. Indirect

The main difference between the two schemes is the means in which solar energy is utilised functionally, without or with any intervention.

- ♣ **Terms Associated with Solar Energy**

- **Solar Radiation**

Solar radiation is the energy emitted by the Sun, which is sent to the Earth in all directions through space. Emitted by the surface of the Sun, this energy influences atmospheric and climatological processes. It is also, directly and indirectly, responsible for common phenomena, such as plant photosynthesis, keeping the planet at a temperature compatible with life and wind formation, which is essential for manifestation as wind power.

Solar radiation can be captured and turned into useful forms of energy, such as heat and electricity, using a variety of technologies.

• Types of solar radiation

Depending on the form in which solar radiation reaches the Earth, it can be in one or other types.

- Direct solar radiation: This type of radiation penetrates the atmosphere and reaches the Earth's surface without dispersing on the way.
- Diffused solar radiation: This is the radiation that reaches the Earth's surface after having undergone multiple deviations in its trajectory, for example by gases in the atmosphere.
- Reflected solar radiation: This is the fraction of solar radiation that is reflected by the Earth's surface or atmosphere and 'lost' in space.

Each one of these has its own significance when used in varied applications.

• Solar Irradiance

This is defined as "the rate of solar radiation falling on a given surface area at a given instant of time" and is a measure of solar energy reaching the surface.

Irradiance is measured in kW/m^2 .

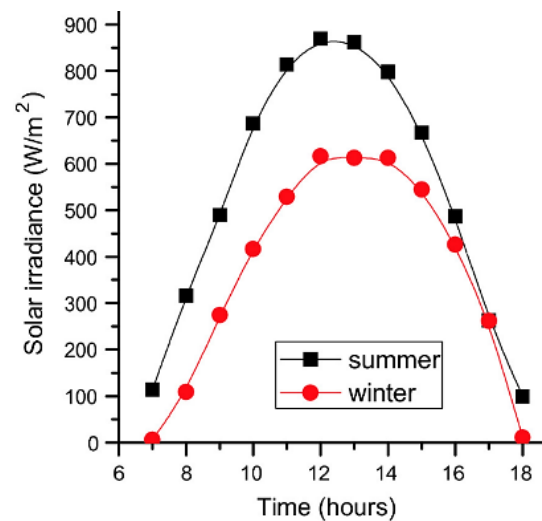
Note that irradiance will vary with time over the hours of sunlight during the day depending on the position of the Sun in the sky in a particular place or city.

Also, the irradiance with time over the day hours will depend on the season, that is during summer or winter as shown alongside.

The graph is "bell shaped" as expected, applicable to a particular place, but the values of irradiance in kW/m^2 would vary.

This shows that maximum utilisation of solar energy would be realised during summer for any application.

An illustrative variation of irradiance during four distinct months of a year is depicted in Fig.1.1.



Open Lowland Site, sunny days only, 1995

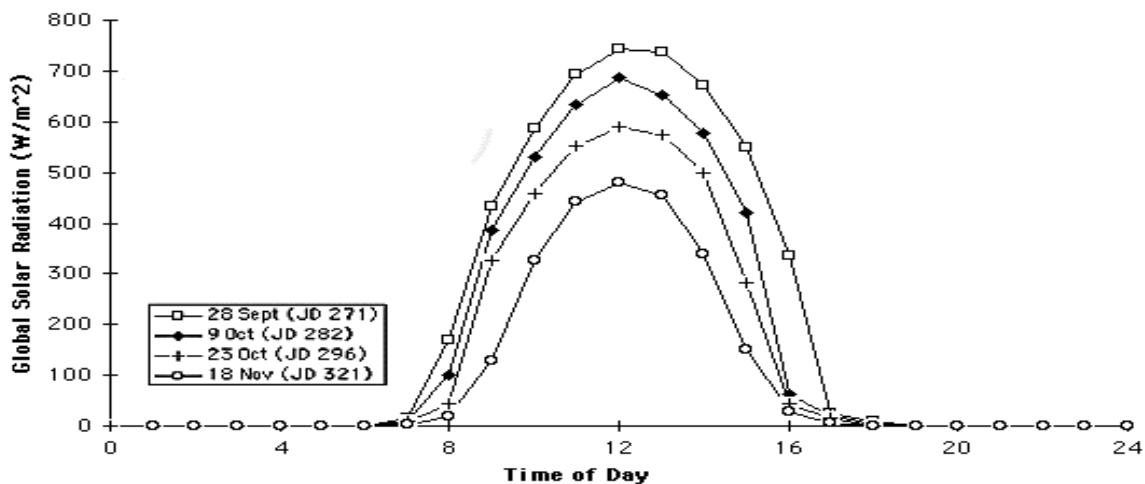


Fig.1.1 : Typical irradiance over twenty-four hours on specific days in four months

The peak irradiance (or radiation) occurs around noon to 1 pm with a morning ramp-up and a decline as the Sun goes down.

Approaching winter, as the days get shorter the total irradiation falls as would be expected.

- **Irradiation**

This is defined as the 'amount' of solar energy *over time* and thus represents total *energy* received on a surface area.

Irradiation is measured as $\text{kWh/m}^2/\text{day}$, that is, solar energy expressed as kilowatt-hour per square metre of a surface per day.

- **Deflection**

The amount of light (or solar energy) lost when the given surface on the Earth is not facing the Sun squarely as the latter moves across the sky is called deflection. This feature is particularly relevant when solar energy is used for electricity generation.

- ♣ **The Sun's Position in the Sky**

For nearly all applications of solar energy it would be advantageous to study the Sun's position in the sky on any day and at a given time.

Two coordinates describe the position of the Sun in the sky.

- **Azimuth**

This describes the direction from east to west in degrees. By convention North is taken to be the datum, at 0° , East as 90° , South as 180° and West as 270° , and so accounted where required.

- **Altitude**

This describes how high the Sun is from horizon to zenith, also measured in degrees.

A pictorial image of the two coordinates is given in Fig.1.2.

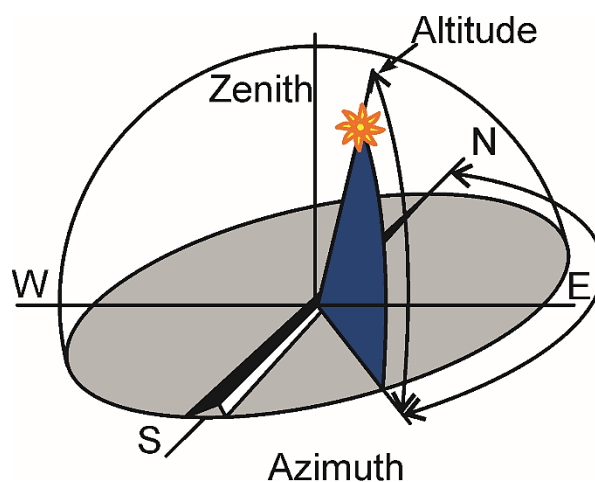


Fig.1.2 : Coordinates defining position of the Sun in the sky

- **The Sun Path Diagram**

A Sun path diagram plots the position of the Sun throughout the year. This plays an important role in the design and installation of many applications using solar energy, esp. to optimise the performance of solar panels by determining the best angle to exploit solar

irradiance and avoid hinderances in the path of the sunshine such as trees and other buildings located around.

A typical such diagram is shown in Fig.1.3.

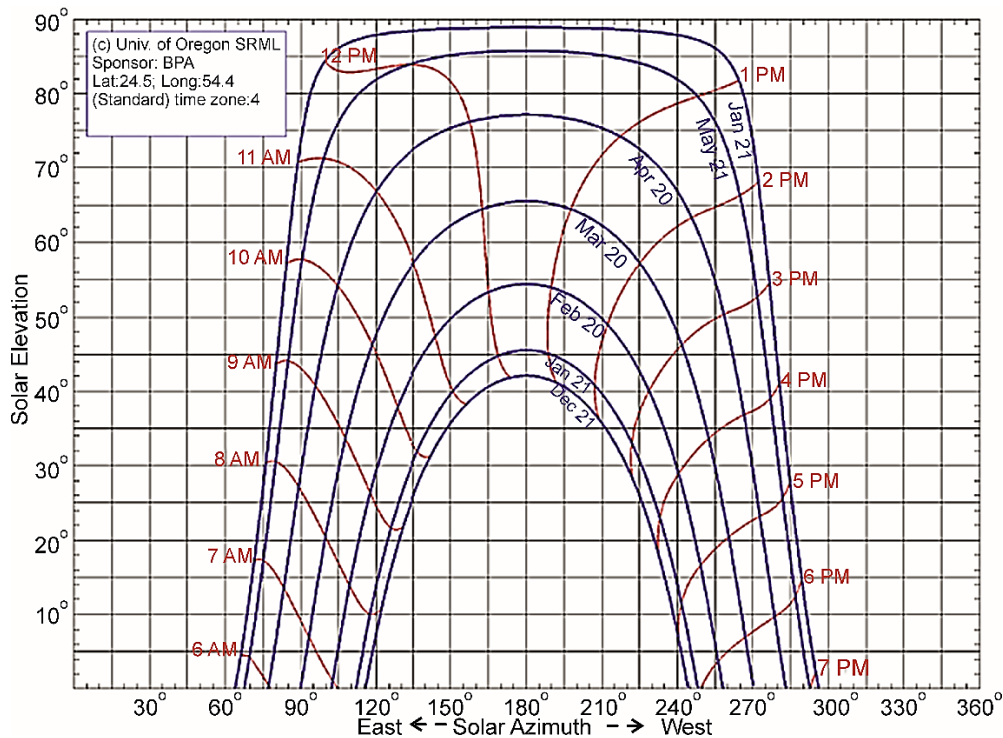


Fig.1.3 : A typical Sun path diagram

● Latitude

An important parameter associated with solar radiation over the Earth's surface is the "latitude" of the place of interest. It is measured in degrees with respect to datum, usually the horizontal surface of a rooftop, etc.

✎ Significance of Latitude

The most significant role played by latitude is when installing solar panels for generating electricity using solar energy. The panels would be best located at an angle approximately equal to the angle of latitude of the city or place; for example, in Hyderabad the angle of latitude being 17° , the panels are oriented at this angle with respect to the roof surface to exploit maximum irradiation from the Sun esp. during winter when the Sun's trajectory is low from east to west².

In contrast, the panels would be positioned almost flat on a roof surface in Kanyakumari, the bottom most city in India, which has a latitude of 8° .

As expected, the latitude of the Equator is 0° ; that of north pole is 90° and of Srinagar in between is about 34° .

²This aspect is discussed in detail later.