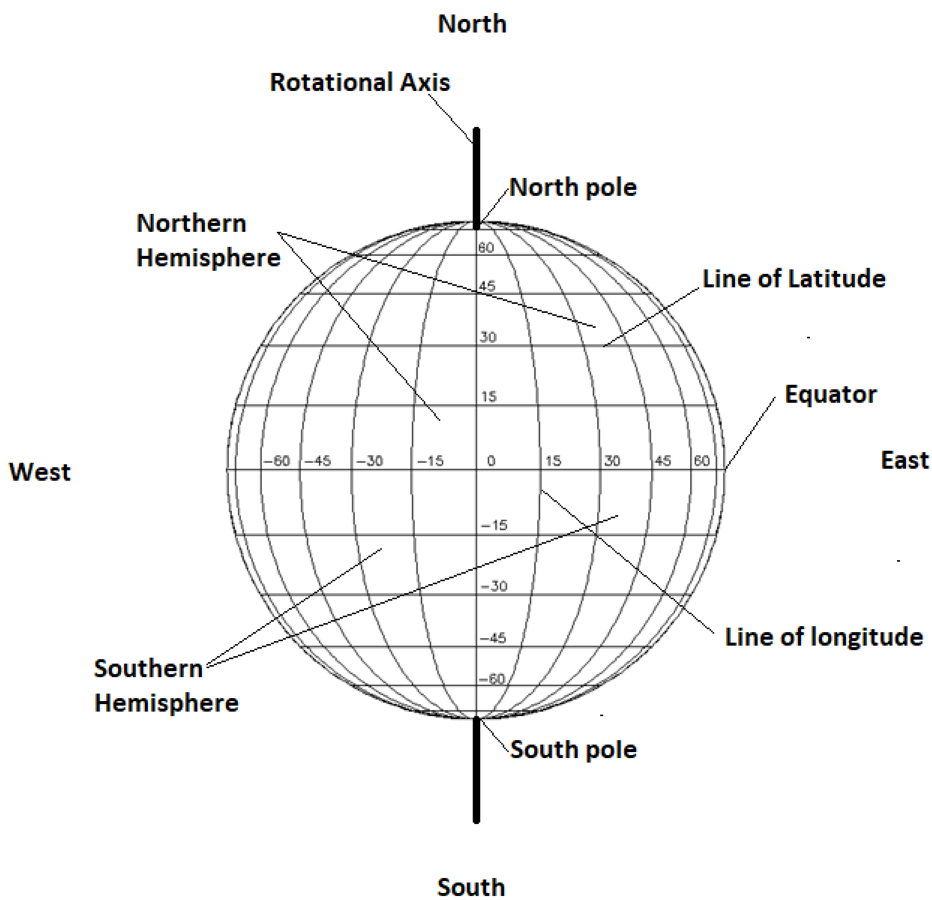
# Solar Energy

Solar energy is produced by the Sun in the form of heat and light. It is one of the most renewable and readily available source of energy on the Earth. The Earth receives solar radiation power of approximately 5.46 x $10^{21}$ MJ per year. This is 100 million times more than the total energy used by Earth's inhabitants in a year. This continuously received power from the Sun is known as incident solar radiation or insolation. This tremendous amount of energy is abundant, free of charge, almost uniformly distributed and available to all nations and inhabitants of the Earth. However, only a very small fraction of this incident solar radiation is used by the Earth's population. To use this energy efficiently we need to understand the Earth's geographic grid system and various stages of Earth's movement around the Sun.

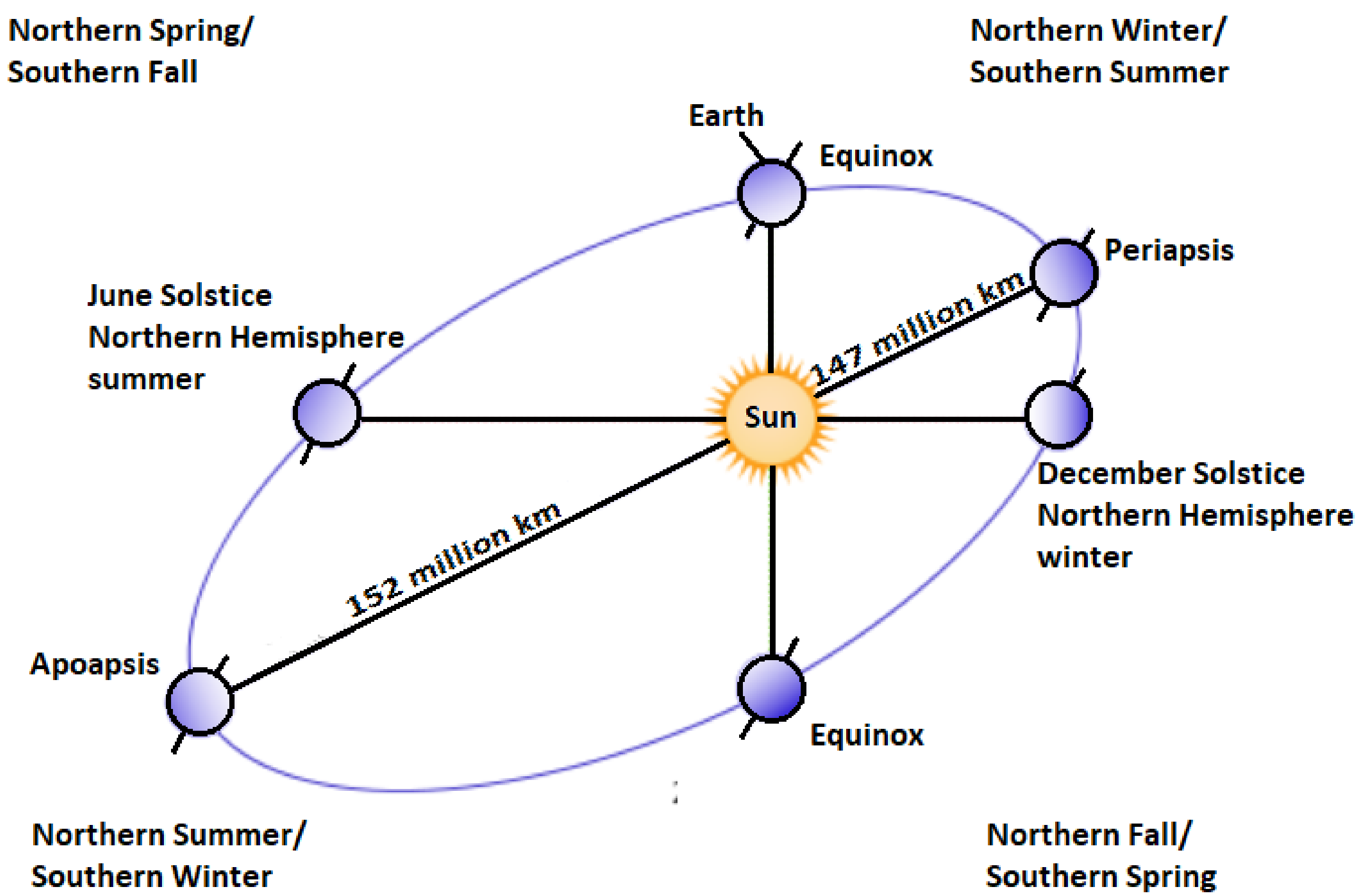
**Earth's geographic grid system and movement of the Earth around the Sun:**

Our Earth has four main cardinal directions known as North, South, East and West. North is on the top of the Earth, on the bottom there is south, on the left there is west and on the right there is east. On the Earth's surface, the imaginary line between the North and South pole which divides the Earth in to Northern and Southern hemispheres is known as equator. Upper half part of the Earth from equator to North pole is known as Northern hemisphere and below half of the Earth from equator to the South pole is known as Southern hemisphere. North pole is a point in the Northern hemisphere where Earth's axis of rotation meets with the Earth's surface. South pole is a point in the Southern hemisphere where Earth's axis of rotation meets with the Earth's surface. Horizontal mapping of lines on the Earth's surface are lines of latitude and vertical mapping of lines on the Earth's surface are lines of longitude.

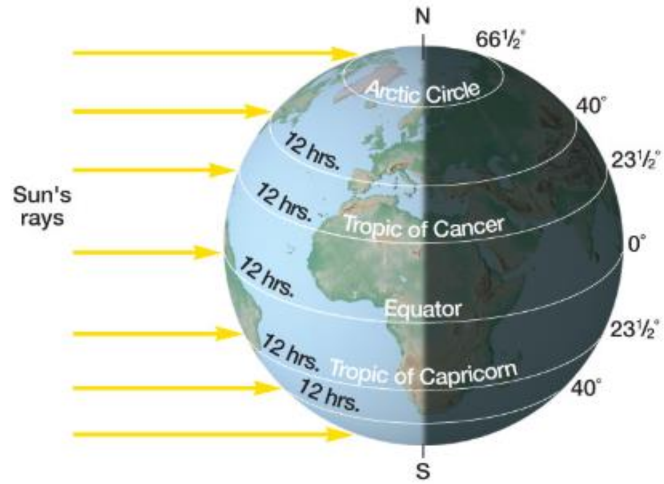



Whole year (around 365.25 days), Earth rotates around the Sun in a slightly elliptical orbit. The Earth also spins daily around its polar axis, which is directed from the North pole to the South pole. Because of Earth's spin there is a change of day and night. The polar axis is at a constant inclination of 23.45$^{o}$ to the plane of the elliptical orbit. The Earth's inclination causes the differential energy absorption by the two hemispheres of the Earth and causes the seasonal variations of solar radiation, the local temperature variations, the local wind patterns and the local seasonal weather. Because of the Earth's tilt and Earth's movement in the elliptical orbit there used to be a summer in the North hemisphere and winter in the South hemisphere at the same time. When there is a fall in the North hemisphere at the same time there is spring in the Southern hemisphere. When there is winter in the Northern hemisphere at the same time there is summer in the Southern hemisphere. When there is spring in the Northern hemisphere at the same time there is fall in the Southern hemisphere. Country in the Northern hemisphere include United States, Canada, Russia, all countries in Europe, Pakistan India, Afghanistan, etc. and country in the Southern hemisphere are Antarctica, Australia, almost all of South America.

From figures it is clear that, the countries in the Northern hemisphere like Pakistan, India etc. will be far from the Sun during the summer season and closest to the Sun during the winter season. If in summer season these countries are far from the Sun then why we have summer season or more hot? If we are far from the Sun it should be a winter season? Answer to all these questions is that our Earth is tilted and because of this tilted angle we have more hot in the summer season. And because of the Earth's tilt, the countries in the Northern hemisphere are faced directly towards the Sun

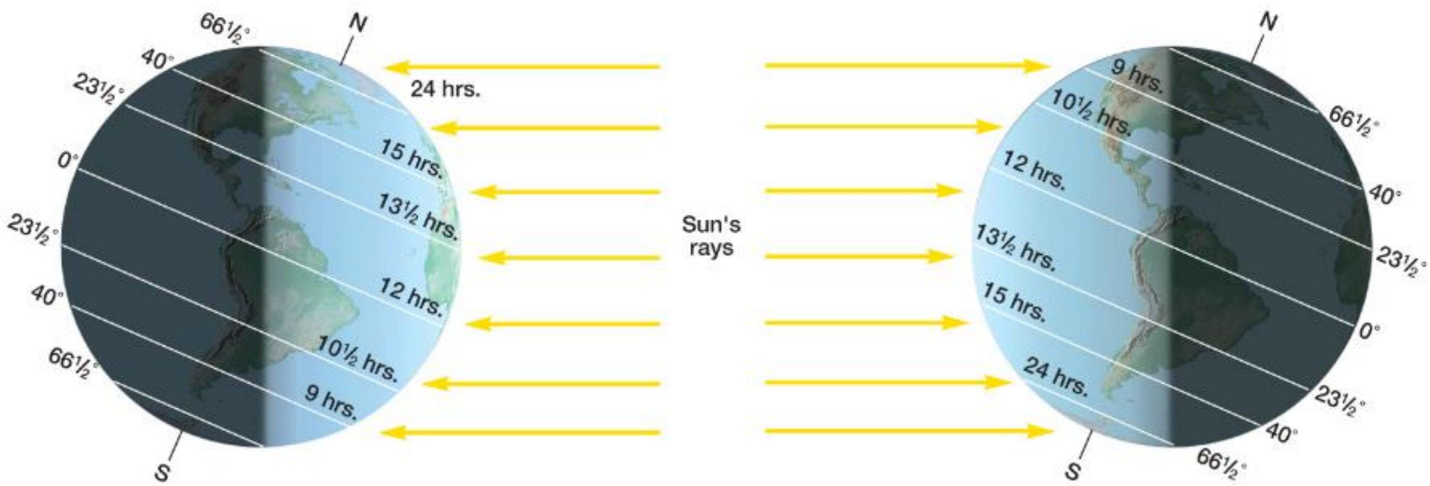



Periapsis is a point on the elliptical orbit when the Earth is closest to the Sun. This day can come anywhere from 3 January to 5 January. The length of this line is equal to 152 million km. Apoapsis is a point on the elliptical orbit when Earth is farthest to the Sun. This day can come anywhere from 3 July to 5 July. The length of this line is equal to 147 million km. There are only two times of the year when the Earth's axis is tilted neither toward nor away from the Sun, resulting in a "nearly" equal amount of daylight and darkness at all latitudes. These events are referred to as Equinoxes. Equinox means length of the day is equal to length of the night. During the equinox, the angle between the Sun's rays and equator is $90^o$. March equinox occurs somewhere between 19 March to 21 March and September equinox occurs somewhere between 22 September to 24 September.



Spring/Fall Equinox

Solstice may be roughly translated as the day when the Sun stands still in the sky. Summer solstice occurs, when the Earth is titled maximum towards the Sun and Sun’s ray falls on the North hemisphere continuously for 24 hours and there is continuously darkness for 24 hours in the South hemisphere. Summer solstice used to come anywhere between 20 June to 22 June. Winter solstice occurs, when the Earth is titled maximum away from the Sun and Sun’s ray falls on the South hemisphere continuously for 24 hours and there is continuously darkness for 24 hours in the North hemisphere. Winter solstice used to come anywhere between 21 December to 23 December.



June Solstice (Northern Hemisphere summer)

December Solstice (Northern Hemisphere winter)

According to Keppler’s laws the translational speed of the Earth is also highest during the winter. As a consequence, the winter season in the Northern hemisphere is slightly shorter and the summer season is longer than the other seasons. The opposite holds for the Southern hemisphere..

From the above discussion it is clear that, with the exception of the two equinox days, the two hemispheres of the Earth receive different amounts of solar radiation. This causes the development of the seasons and the seasonal variations of climate and weather. Given the combination of the two motions, the rotation of the Earth around its polar axis and the motion of the Earth around the Sun, the intensity of the solar energy received by any point on Earth varies significantly, but varies in a predictable way. A stationary receiver of solar energy would receive power in a periodic manner.

Cloudiness, humidity, pollution and other temporal variables that affect the insolation at a specific location provide a small amount of almost random perturbation to the local insolation. As a consequence, we know with a high degree of certainty that during the week of June and July, a solar collector in Pakistan will collect a great deal of incident solar radiation. This will be a summer time and we will be far from the Sun as compare to winter season. While during the week of December same solar collector in Pakistan will get very less incident solar radiation. After studying this we can predict easily in which season and in which time which country will get how much solar incident radiation

**Average Annual Solar Power: Solar Energy Potential**

It is apparent that the total amount of solar energy received by a collector on the surface of the Earth during a day or during a year depends on several factors, most important of which are:

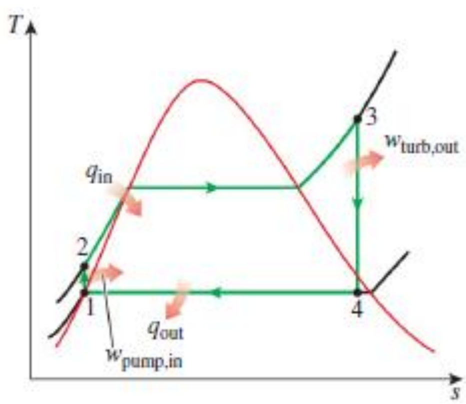
1. The geographic latitude of the location of the collector.
2. The average cloudiness or coverage of the location.
3. The day of the year.
4. The angle of the collector with the horizontal.

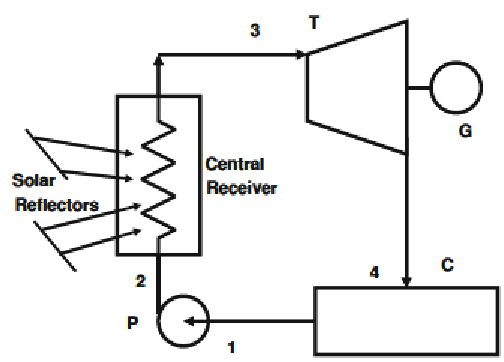
**Solar Thermal Systems**

**1. Power Cycles:** A Rankine cycle is typically used for the electricity production from solar energy. The boiler in this cycle is replaced by a system of solar collectors or reflectors that impart the solar energy to water or another working fluid, which undergoes the Rankine cycle and produces electric power in a conventional turbine. Figure below depicts the essential components of such a solar-thermal power plant, which are:

a. The pump that circulates the working fluid;
b. The system of solar reflectors and a central receiver that receives the solar energy and raise vapor;
c. The vapor turbine, usually working with steam and
d. The condenser.

.




**2. Photovoltaic cells:** Photovoltaic cells or solar cells convert the energy of the Sun directly to electricity.

**Environmental Issues of Solar Energy Utilization:**

Solar energy is one of the most benign (without any harmful effects) forms of alternative energy. Its current utilization, either as solar-thermal or as photovoltaic conversion, causes very few environmental concerns. The principal environmental advantage of solar energy is that its utilization does not involve chemical or nuclear reactions. Thus, no chemical emissions (e.g. carbon dioxide, NOx gases, etc.) and no dangerous radiation are emitted from a solar energy facility. This makes solar conversion an environmentally friendly energy source.

Manufacturing of photovoltaic cells involve the use of polluting chemicals such as sulfuric acid and cyanide. However, all the pollution associated with the production of solar cells is localized and contained at the production facility. A more significant concern in the production of the photovoltaic cells is the high amount of energy consumed during their manufacturing process currently, the energy consumed for the manufacturing of a silicon-based solar cell is equivalent to the energy the cell will produce in approximately 4 years.

Land use is another environmental effect of solar energy utilization. Solar energy is diffuse and, hence, the production of significant amounts of it requires a large land area, which is significantly more than the area used by a thermal power plant, fossil or nuclear. For this reason, inexpensive, unutilized and usually deserted areas have been chosen for the location of solar energy facilities.

A notable beneficial environmental effect of solar energy that is utilized in urban environments, e.g. photovoltaic panels or passive solar panel heating on the sides and rooftops of buildings, is that some of the incident solar radiation is utilized inside the buildings and, therefore, it is not absorbed, but reflected back to the atmosphere or scattered. Considering the overall energy balance in the vicinity of the buildings, the solar energy systems produce a small but important cooling effect in the urban environment, which results in slightly lower ambient temperatures and reduces the need for building air-conditioning.