Solar Energy

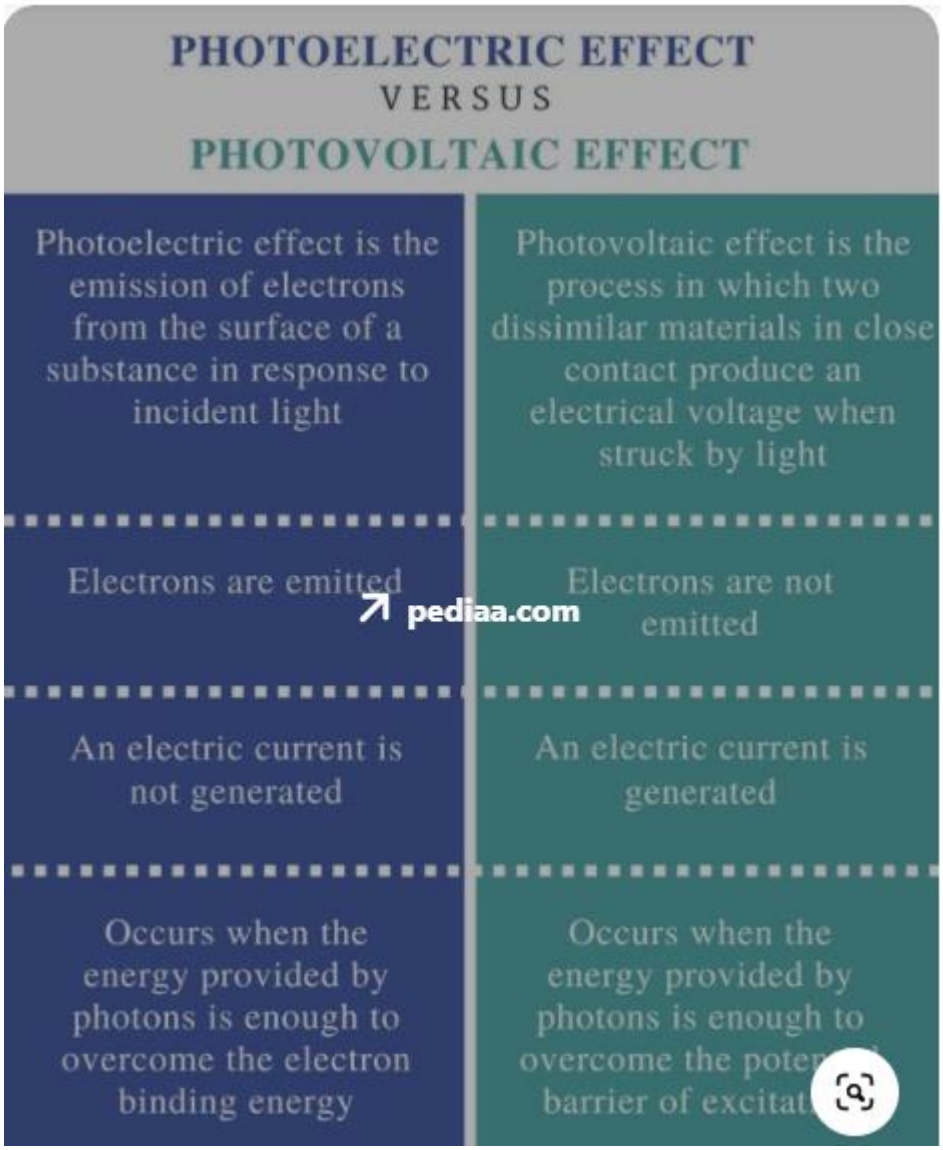
Solar power is energy from the sun that is converted into thermal or electrical energy. Solar energy is the cleanest and most abundant renewable energy source available, Solar technologies can harness this energy for a variety of uses, including generating electricity, providing light or a comfortable interior environment, and heating water for domestic, commercial, or industrial use.

Photovoltaic Effect

The **photovoltaic effect** is the generation of voltage and electric current in a material upon exposure to light. It is a physical and chemical phenomenon.

The photovoltaic effect is closely related to the photoelectric effect. In either case, light is absorbed, causing excitation of an electron or other charge carrier to a higher-energy state.

The photovoltaic effect was first discovered in 1839 by Edmond Becquerel. When doing experiments involving wet cells, he noted that the voltage of the cell increased when its silver plates were exposed to the sunlight.



Solar Technologies

There are three main ways to harness solar energy: photovoltaics, solar heating & cooling, and concentrating solar power. Photovoltaics generate electricity directly from sunlight via an electronic process and can be used to power anything from small electronics such as calculators and road signs up to homes and large commercial businesses. Solar heating & cooling (SHC) and concentrating solar power (CSP) applications both use the heat generated by the sun to provide space or water heating in the case of SHC systems, or to run traditional electricity-generating turbines in the case of CSP power plants.

How Solar Power Works?

Electrical energy can be harvested from solar power by means of either photovoltaics or concentrated solar power systems.

Photovoltaics (PV)

Photovoltaics directly convert **solar energy into electricity**. They work on the principle of the photovoltaic effect. When certain materials are exposed to light, they absorb photons and release free electrons. This phenomenon is called as the photoelectric effect. Photovoltaic effect is a method of producing direct current electricity based on the principle of the photoelectric effect.

Based on the principle of photovoltaic effect, solar cells or photovoltaic cells are made. They convert sunlight into direct current (DC) electricity. But, a single photovoltaic cell does not produce enough amount of electricity. Therefore, a number of photovoltaic cells are mounted on a supporting frame and are electrically connected to each other to form a photovoltaic module or **solar panel**. Commonly available solar panels range from several hundred watts (say 100 watts) up to few kilowatts . They are available in different sizes and different price ranges. Solar panels or modules are designed to supply electric power at a certain voltage (say 12v), but the current they produce is directly dependent on the incident light. As of now it is clear that photovoltaic modules produce DC electricity. But, for most of the times we require AC power and, hence, **solar power system** consists of an inverter too.

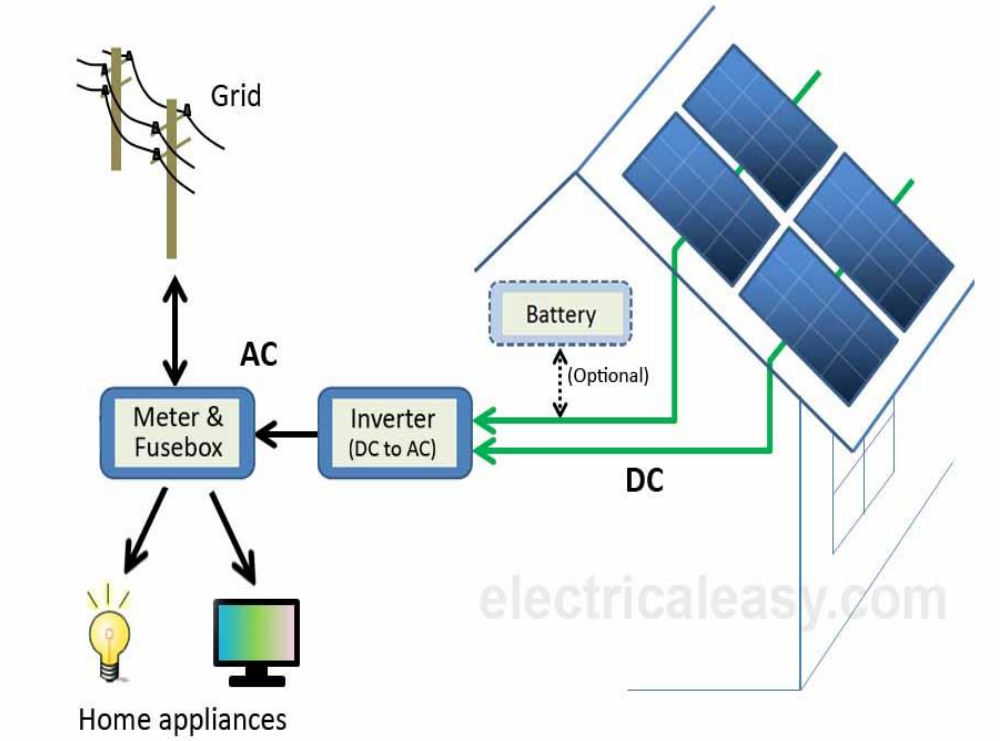
Photovoltaic Solar Power System

According to the requirement of power, multiple photovoltaic modules are electrically connected together to form a PV array and to achieve more power. There are different types of PV systems according to their implementation.

- PV direct systems: These systems supply the load only when the Sun is shining. There is no storage of power generated and, hence, batteries are absent. An inverter may or may not be used depending on the type of load.
- Off-grid systems: This type of system is commonly used at locations where power from the grid is not available or not reliable. An off-grid

solar power system is not connected to any electric grid. It consists solar panel arrays, storage batteries and inverter circuits.

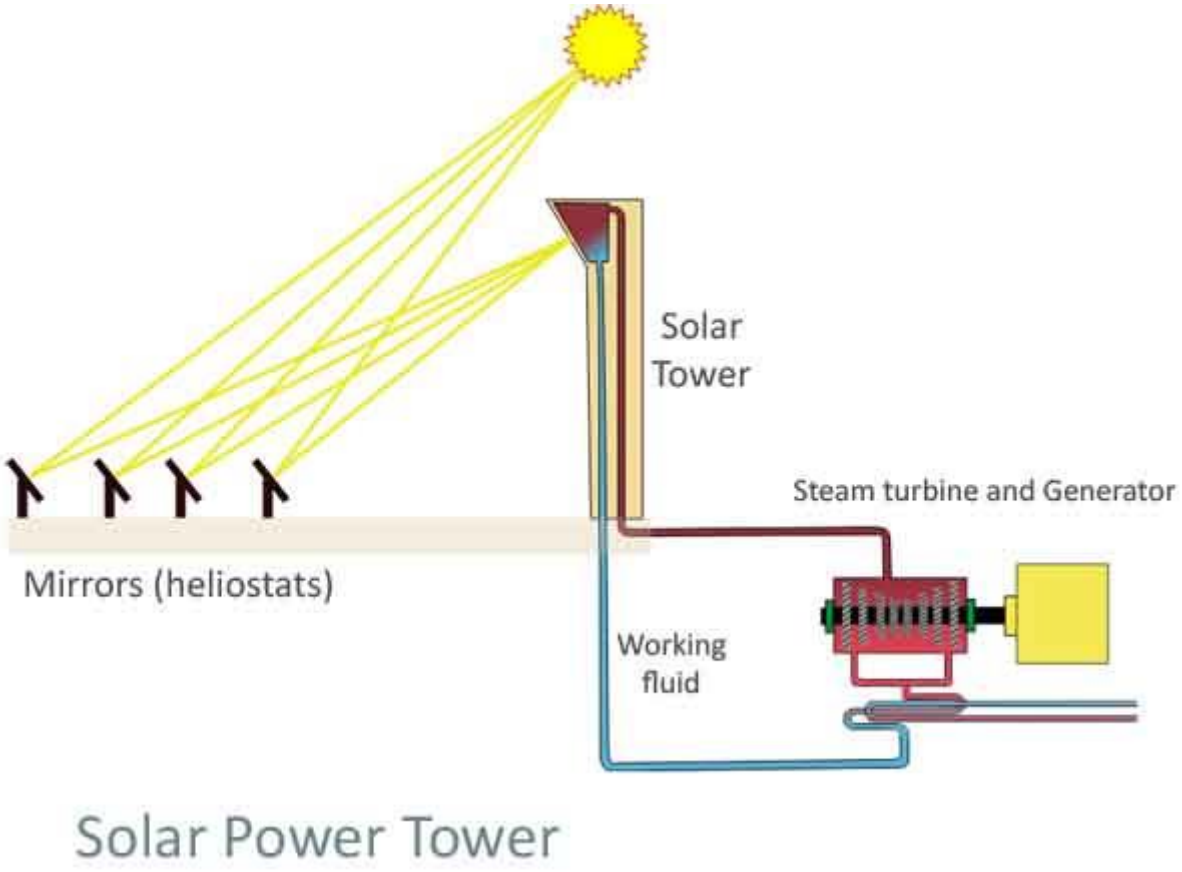
- Grid connected systems: These solar power systems are tied with grids so that the excess required power can be accessed from the grid. They may or may not be backed by batteries.



Typical grid connected PV solar system

Concentrated Solar Power

As the name suggest, in this type of solar power system, sun rays are concentrated (focused) on a small area by placing mirrors or lenses over a large area. Due to this, a huge amount of heat is generated at the focused area. This heat can be used to heat up the working fluid which can further drive the steam turbine. There are different types of technologies that are based on the concentrated solar power to produce electricity. Some of them are - parabolic trough, Stirling dish, solar power tower etc. The following schematic shows how a solar power tower works.



Importance of Solar power - unlimited source of energy

Solar power is the key to a clean energy future. Every day, the sun gives off far more energy than we need to power everything on earth. T

Limitless solar energy

The sun provides more than enough energy to meet the whole world's energy needs, and unlike fossil fuels, it won't run out anytime soon. As a renewable energy source, the only limitation of solar power is our ability to turn it into electricity in an efficient and cost-effective way.

Solar energy - a clean source No greenhouse gas emissions are released into the atmosphere when you use solar panels to create electricity. And because

the sun provides more energy than we'll ever need, electricity from solar power is a very important energy source in the move to clean energy production.

No fuel to burn

After solar panels have been installed, operational costs are quite low compared to other forms of power generation. Fuel isn't required, and this means that solar power can create large amounts of electricity without the uncertainty and expense of securing a fuel supply.

Solar Power Causes Less Electricity Loss

Electricity needs to be transported from big power plants to end-consumers via extensive networks. Long distance transmissions equal power losses. Rooftop solar power is helpful in increasing electricity efficiency, considering the short distance. Your energy becomes domestic and as a result you're in control of your own bills and energy usage. Furthermore, solar power systems are durable, thus chances of service interruption are reduced.

Solar Power Improves Grid Security

When there are many of us switching to solar power, we are less likely to experience blackouts or brownouts. Every household in the UK that have solar cells installed, functions as a small power plant. This, in turn, provides us with a greater electricity grid security, especially in terms of natural or human-caused disasters.

Solar Electricity Makes Your Home Go Off-the-Grid

The decrease in the cost of solar panels serves as a great example of why there should be an increase in the use of solar energy. Traditional electricity relies heavily on fossil fuels such as coal and natural gas. Not only are they bad for the environment, but they are also limited resources. This translates into a volatile market, in which energy prices alter throughout the day.

By investing in a 4kW solar system, which is the most common domestic size, you can, enjoy cheap electricity throughout the entire day - the sun will never increase its rates and it gives you energy security.

Solar battery storage systems can also help store electricity for nighttime and rainy

Advantages of Solar Energy

1. Renewable Energy Source

Among all the benefits of solar panels, the most important thing is that solar energy is a **truly renewable** energy source. It can be harnessed in all areas of the world and is available every day. We **cannot run out of solar energy**, unlike some of the other sources of energy.

Solar energy will be accessible as long as we have the sun, therefore sunlight will be available to us for at least 5 billion years when according to scientists the sun is going to die.

2. Reduces Electricity Bills

Since you will be meeting some of your energy needs with the electricity your solar system has generated, your **energy bills will drop**. How much you save on your bill will be dependent on the size of the solar system and your electricity or heat usage.

Moreover, not only will you be saving on the electricity bill, but there is also a possibility to **receive payments for the surplus energy** that you export back to the grid through the Smart Export Guarantee (SEG). If you generate more electricity than you use (considering that your solar panel system is connected to the grid).

3. Diverse Applications

Solar energy can be used for diverse purposes. You can generate **electricity** (photovoltaics) or **heat** (solar thermal). Solar energy can be used to produce electricity in areas without access to the energy grid, to distil water in regions with limited clean water supplies and to power satellites in space.

Solar energy can also be **integrated into the materials used for buildings**. Not long ago Sharp introduced transparent solar energy windows.

4. Low Maintenance Costs
Solar energy systems generally **don't require a lot of maintenance**. You only need to keep them relatively clean.

Most reliable solar panel manufacturers offer **20-25 years** warranty.

Also, as there are no moving parts, there is no wear and tear. The inverter is usually the only part that needs to be changed after **5-10 years** because it is continuously working to convert solar energy into electricity and heat (solar PV vs. solar thermal). Apart from the inverter, the cables also need maintenance to ensure your solar power system runs at maximum efficiency.

So, after covering the initial cost of the solar system, you can expect very **little spending on maintenance** and repair work.

5. Technology Development
Technology in the solar power industry is constantly advancing and **improvements** will intensify in the future. Innovations in quantum physics and nanotechnology can potentially increase the effectiveness of solar panels and double, or even triple, the electrical input of the solar power systems.

Disadvantages of Solar Energy

1. Cost

The **initial cost** of purchasing a solar system is fairly high. This includes paying for solar panels, inverter, batteries, wiring, and the installation. Nevertheless, solar technologies are **constantly developing**, so it is safe to assume that prices will go down in the future.

2. Weather-Dependent

Although solar energy can still be collected during cloudy and rainy days, the efficiency of the solar system drops. Solar panels are **dependent on sunlight** to effectively gather solar energy. Therefore, a few cloudy, rainy days can have a noticeable effect on the energy system. You should also take into account that solar energy cannot be collected during the night.

On the other hand, if you also require your water heating solution to work at night or during wintertime, thermodynamic panels are an alternative to consider.

3. Solar Energy Storage Is Expensive

Solar energy has to be **used right away**, or it can be **stored in large batteries**. These batteries, used in off-the-grid solar systems, can be charged during the day so that the energy is used at night. This is a good solution for using solar energy all day long but it is also quite expensive.

In most cases, it is smarter to just **use solar energy during the day** and take energy from the grid during the night (you can only do this if your system is connected to the grid). Luckily your energy demand is usually higher during the day so you can meet most of it with solar energy.

4. Uses a Lot of Space

The more electricity you want to produce, the more solar panels you will need, as you want to collect as much sunlight as possible. Solar PV panels require a lot of space and **some roofs are not big enough** to fit the number of solar panels that you would like to have.

An alternative is to install some of the panels in your yard but they need to have access to sunlight. If you don't have the space for all the panels that you wanted, you can opt for installing fewer to still satisfy some of your energy needs.

5. Associated with Pollution

Although pollution related to solar energy systems is far less compared to other sources of energy, solar energy can be associated with pollution. Transportation and installation of solar systems have been associated with the emission of greenhouse gases.

There are also some **toxic materials and hazardous products** used during the manufacturing process of solar photovoltaic systems, which can indirectly affect the environment.

Nevertheless, solar energy **pollutes far less** than other alternative energy sources.

Solar pond

A **solar pond** is a solar energy collector, generally fairly large in size, that looks like a pond. This type of solar energy collector uses a large, salty lake as a kind of a flat plate collector that absorbs and stores energy from the Sun in the warm, lower layers of the pond.[1] These ponds can be natural or man-made, but generally speaking the solar ponds that are in operation today are artificial.

How they Work

The key characteristic of solar ponds that allow them to function effectively as a solar energy collector is a salt-concentration gradient of the water. This gradient results in water that is heavily salinated collecting at the bottom of the pond, with concentration decreasing towards the surface resulting in cool, fresh water on top of the pond. This collection of salty water at the bottom of the lake is known as the "storage zone", while the freshwater top layer is known as the "surface zone". The overall pond is several meters deep, with the "storage zone" being one or two meters thick.[2]

These ponds *must* be clear for them to operate properly, as sunlight cannot penetrate to the bottom of the pond if the water is murky. When sunlight is incident on these ponds, most of the incoming sunlight reaches the bottom and thus the "storage zone" heats up. However, this newly heated water cannot rise and thus heat loss upwards is prevented. The salty water cannot rise because it is heavier than the fresh water that is on top of the pond, and thus the upper

layer prevents convection currents from forming. Because of this, the top layer of the pond acts as a type of insulating blanket, and the main heat loss process from the storage zone is stopped. Without a loss of heat, the bottom of the pond is warmed to extremely high temperatures - it can reach about 90°C. If the pond is being used to generate electricity this temperature is high enough to initiate and run an organic Rankine cycle engine.

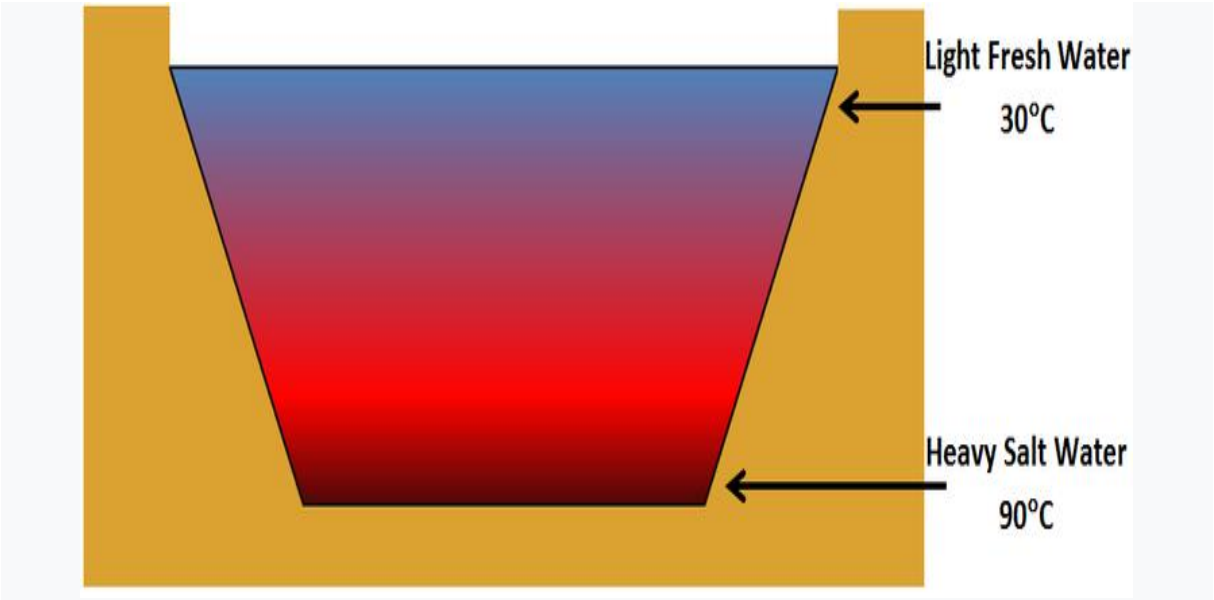


Figure 1. Diagram of a solar pond showing the temperature and saline gradient.[3]

It is vital that the salt concentrations and cool temperature of the top layer are maintained in order for these ponds to work. The surface zone is mixed and kept cool by winds and heat loss by evaporation. This top zone must also be flushed continuously with fresh water to ensure that there is no accumulation of salt in the top layer, since the salt from the bottom layer diffuses through the saline gradient over time.[2] Additionally, a solid salt or brine mixture must be added to the pond frequently to make up for any upwards salt loses.

Applications

The heat from solar ponds can be used in a variety of different ways. First, since the heat storing abilities of solar ponds are so great they are ideal for use in heating and cooling buildings as they can maintain a fairly stable temperature.[4] These ponds can also be used to generate electricity either by driving a thermo-electric device or some organic Rankine engine cycle - simply a turbine powered by evaporating a fluid (in this case a fluid with a lower boiling point). Finally, solar ponds can be used for desalination purposes as the low cost

of this thermal energy can be used to remove the salt from water for drinking or irrigation purposes.

Benefits and Drawbacks

One benefit of using these ponds is that they have an extremely large thermal mass. Since these ponds can store heat energy very well, they can generate electricity during the day when the Sun is shining as well as at night.

Despite being a source of energy, there are numerous thermodynamic limitations as a result of the relatively low temperatures achieved in these ponds. Because of this, the solar-to-electricity conversion is fairly inefficient - generally less than 2%.[1] As well, large amounts of fresh water are necessary to maintain the right salt concentrations all through the pond. This is an issue in places where fresh water is hard to come by, especially in desert environments. These ponds also do not work well at high latitudes as the collection surface is horizontal and cannot be tilted to collect more sunlight.

The largest operating solar pond for electricity generation was the

Beit HaArava pond built in Israel

India was the first Asian country to have established a solar pond in Bhuj, in Gujarat.

Solar Water Heater

What is a Solar Water Heater?

Solar water heaters or domestic solar water heater are cheap and cost-effective way to supply hot water for your home. They use solar radiation or sunshine as fuel to heat water. This method of heating water is cheaper because we don't have to pay for heat of the sun.

Working Principle

In a typical solar water heater, water is heated by the solar thermal energy absorbed by the collectors. The hot water with lower density moves upwards and cold water with higher density moves down from the tank due to gravity head. A bank of collectors can be arranged in a series – parallel combination to get higher quantity of hot water. A typical 100 litres insulated tank with a 2 m2 collector area, will supply water at a temperature of 60 - 80°C. Based on the collector system, solar water heaters can be of two types.

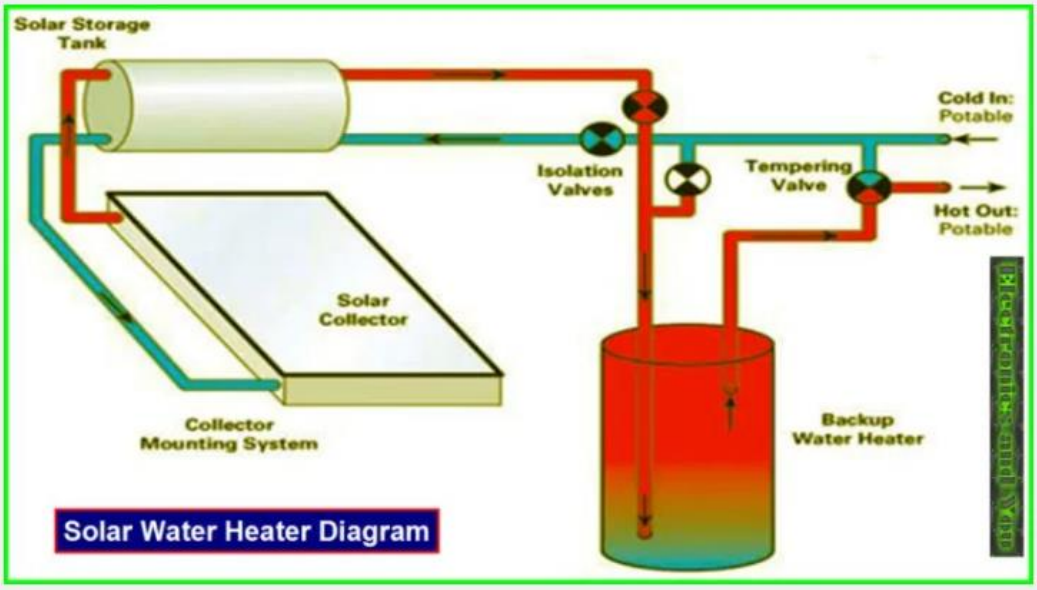
Flat Plate Collectors (FPC) based Solar Water Heaters

The solar radiation is absorbed by Flat Plate Collectors which consist of an insulated outer metallic box covered on the top with glass sheet. Inside there are blackened metallic absorber (selectively coated) sheets with built in channels or riser tubes to carry water. The absorber absorbs the solar radiation and transfers the heat to the flowing water.

Evacuated Tube Collectors (ETC) based Solar Water Heaters

Evacuated Tube Collector is made of double layer borosilicate glass tubes evacuated for providing insulation. The outer wall of the inner tube is coated with selective absorbing material. This helps absorption of solar radiation and transfers the heat to the water which flows through the inner tube.

Solar Water Heater Diagram



Solar Water Heater Diagram

Flat Plate Collector

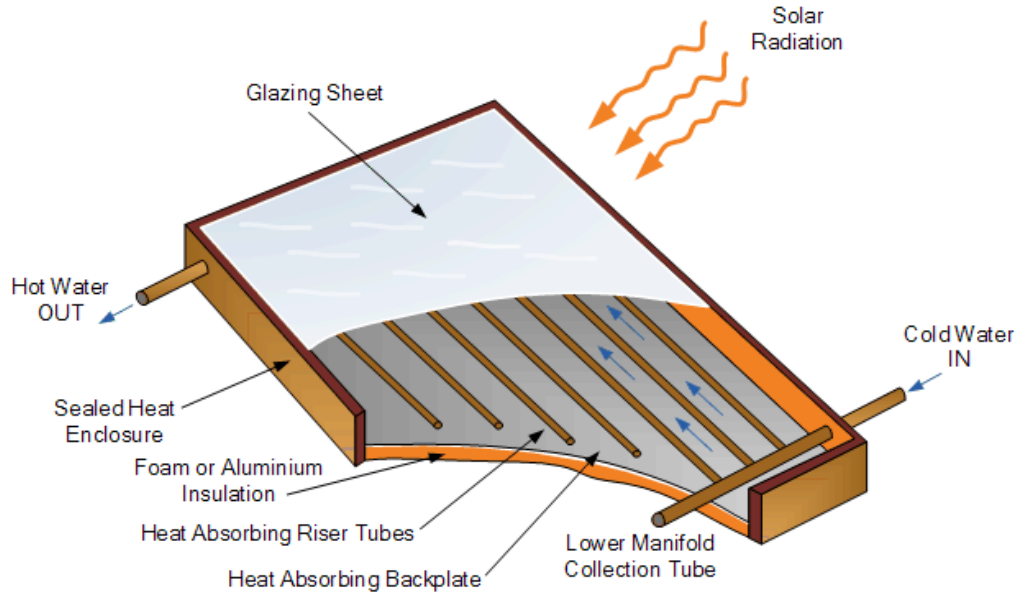
A **Flat Plate Collector** is a heat exchanger that converts the radiant solar energy from the sun into heat energy using the well known greenhouse effect. It collects, or captures, solar energy and uses that energy to heat water in the

home for bathing, washing and heating, and can even be used to heat outdoor swimming pools and hot tubs.

A solar flat plate collector typically consists of a large heat absorbing plate, usually a large sheet of copper or aluminium as they are both good conductors of heat, which is painted or chemically etched black to absorb as much solar radiation as possible for maximum efficiency. This blackened heat absorbing surface has several parallel copper pipes or tubes called risers, running length ways across the plate which contain the heat transfer fluid, typically water.

Solar Flat Plate Collector on Roof

Typical Flat Plate Collector

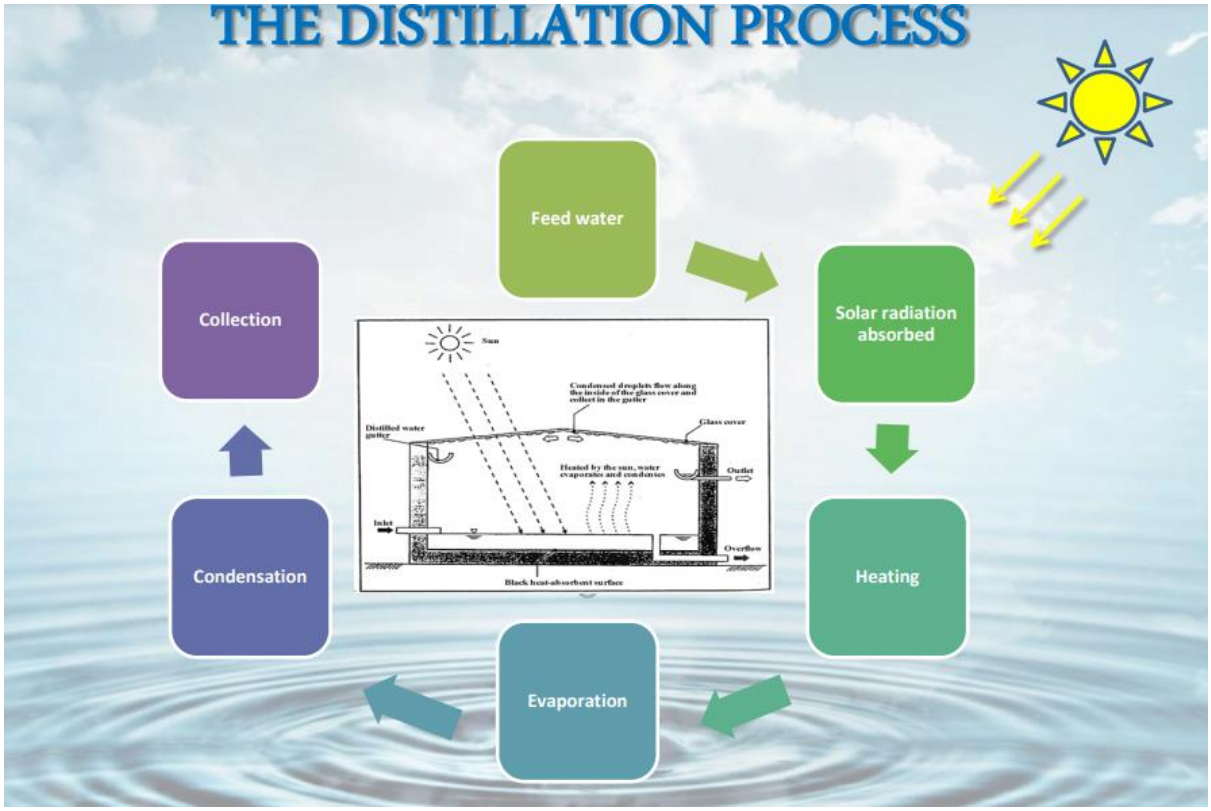


Solar Distillation

What is Solar Distillation

Solar water distillation is the process of using energy from the sunlight to separate freshwater from salts or other contaminants. The untreated water

absorbs heat, slowly reaching high temperatures. The heat causes the water to evaporate, cool, and condense into vapour, leaving the contaminants behind. **Solar stills can be** used for low capacity and self-reliant water supplying systems



Solar Cooker

A **solar cooker** is a device which uses the energy of direct sunlight to heat, cook or pasteurize drink and other food materials.

Many solar cookers currently in use are relatively inexpensive, low-tech devices, although some are as powerful or as expensive as traditional stoves, and advanced, large-scale solar cookers can cook for hundreds of people.[2] Because they use no fuel and cost nothing to operate, many nonprofit organizations are promoting their use worldwide in order to help reduce fuel costs and air pollution, and to help slow down deforestation and desertification.

Working principles

1) Concentrating sunlight: A mirrored surface with high specular reflection is used to concentrate light from the sun into a small cooking area. Depending on

the geometry of the surface, sunlight could be concentrated by several orders of magnitude producing temperatures high enough to melt salt and metal. For most household solar cooking applications, such high temperatures are not really required. Solar cooking products are typically designed to achieve temperatures of 65 °C (150 °F) (baking temperatures) to 400 °C (750 °F) (grilling/searing temperatures) on a sunny day.

2) Converting light energy to heat energy: Solar cookers concentrate sunlight onto a receiver such as a cooking pan. The interaction between the light energy and the receiver material converts light to heat and this is called conduction. This conversion is maximized by using materials that conduct and retain heat. Pots and pans used on solar cookers should be matte black in color to maximize the absorption.

3) Trapping heat energy: It is important to reduce convection by isolating the air inside the cooker from the air outside the cooker. Simply using a glass lid on your pot enhances light absorption from the top of the pan and provides a greenhouse effect that improves heat retention and minimizes convection loss. This "glazing" transmits incoming visible sunlight but is opaque to escaping infrared thermal radiation. In resource constrained settings, a high-temperature plastic bag can serve a similar function, trapping air inside and making it possible to reach temperatures on cold and windy days similar to those possible on hot days. Below is the basic science for solar panel cookers and solar box cookers. Another style of solar cooker is a parabolic solar cooker. They typically require more frequent reorientation to the sun, but will cook more quickly at higher temperatures, and can fry foods. Evacuated tube solar cookers use a highly insulated double-wall glass tube for the cooking chamber, and do not require large reflectors

Solar Greenhouse

Solar greenhouses capture the light energy of the sun and convert it into heat energy and store it. This heat is used to keep warm-weather plants from suffering during the intense cold of winter nights. Many out of season plants too are grown in a greenhouse during the winter months.

The glass or plastic in a greenhouse’s walls and roof let in the short waves of the solar light. This is then absorbed by the earth and plants in a greenhouse

and converted into heat energy. This energy cannot escape through the glass or plastic because the heat waves are longer than the light waves.

The heated floor then warms the air immediately above it. This makes the air lighter and it rises, being replaced by cooler air from the top. Through this convection method, the entire greenhouse is heated.

Working of Solar Greenhouse

In a solar greenhouse you apply the same principle, except that the greenhouse is aligned to the sun. The south and west of the greenhouse have large glass windows to the south and east. The north side has black painted stone blocks to help absorb and retain the heat. Any surface that does not have to retain heat is painted white to reflect the heat. In other words, solar greenhouses have oriented glazing to get the maximum benefit from the sun's energy. It is designed to minimize heat loss in winter and uses natural ventilation to reduce heat in summer.

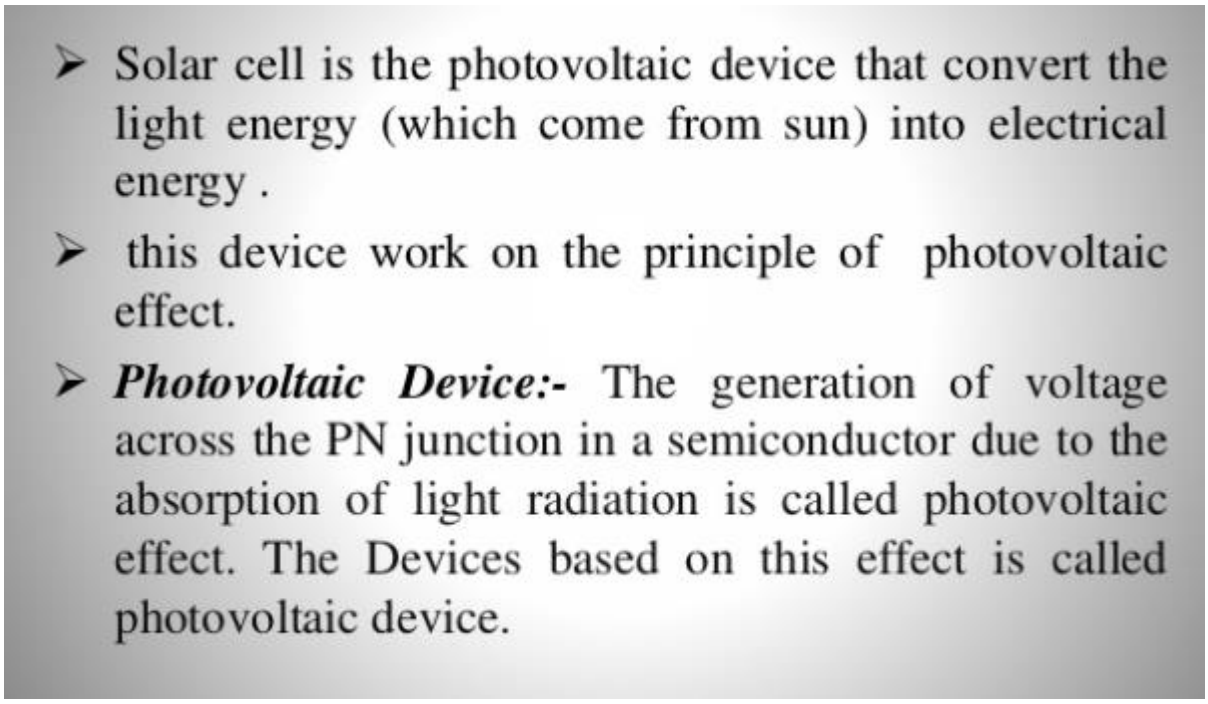
A solar greenhouse requires less artificial heating than a normal greenhouse in the harsh winter months. The amount of additional heating required will depend on the location of the greenhouse and the climate prevailing in your area.

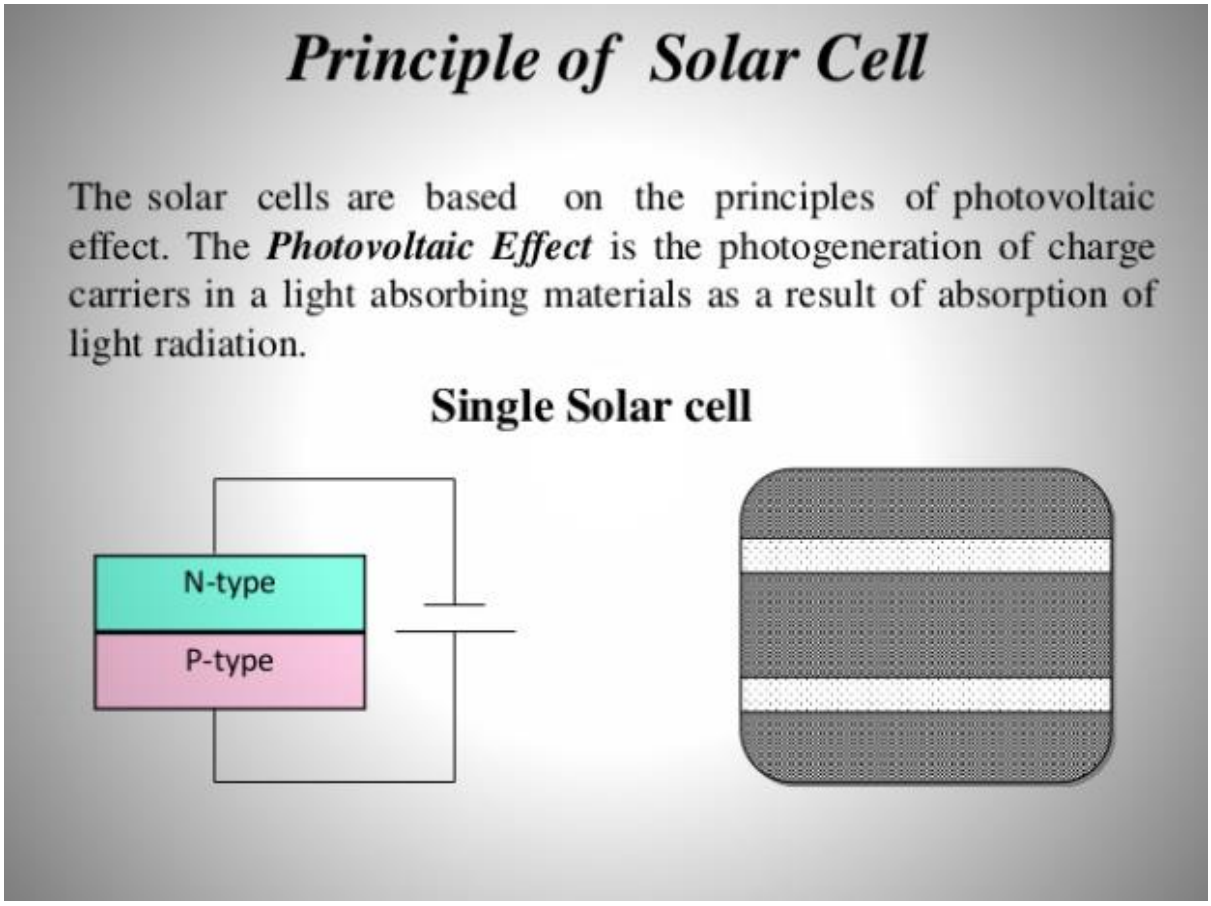
All greenhouses, solar or not, use the sun's energy to warm up the atmosphere for plants to thrive in even in the harsh winter months. The basic principle is the same for both solar greenhouses and normal ones. The sun's light energy is converted into heat energy and used to warm up the air in the greenhouse.

However, there are a few differences as well. In a solar greenhouse, the building is aligned to capture as much as possible of the sun's heat. This is done by having large glass or plastic windows to the south and east. The north

wall is made of heat absorbing material such as concrete and also has ventilation to let out excess heat in the summer months.

What is a Solar Cell?





Working Principle of Solar Cell

When light reaches the p-n junction, the light photons can easily enter in the junction, through very thin p-type layer. The light energy, in the form of photons, supplies sufficient energy to the junction to create a number of electron-hole pairs. The incident light breaks the thermal equilibrium condition of the junction. The free electrons in the depletion region can quickly come to the n-type side of the junction.
Similarly, the holes in the depletion can quickly come to the p-type side of the junction. Once, the newly created free electrons come to the n-type side, cannot further cross the junction because of barrier potential of the junction.

Similarly, the newly created holes once come to the p-type side cannot further cross the junction became of same barrier potential of the junction. As the concentration of electrons becomes higher in one side, i.e. n-type side of the junction and concentration of holes becomes more in another side, i.e. the p-type side of the junction, the p-n junction will behave like a small battery cell. A voltage is set up which is known as photo voltage. If we connect a small load across the junction, there will be a tiny current flowing through it.

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-

1. Silicon.
2. GaAs.
3. CdTe.
4. $CuInSe_2$

Criteria for Materials to be Used in Solar Cell

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

Advantages of Solar Cell

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

Disadvantages of Solar Cell

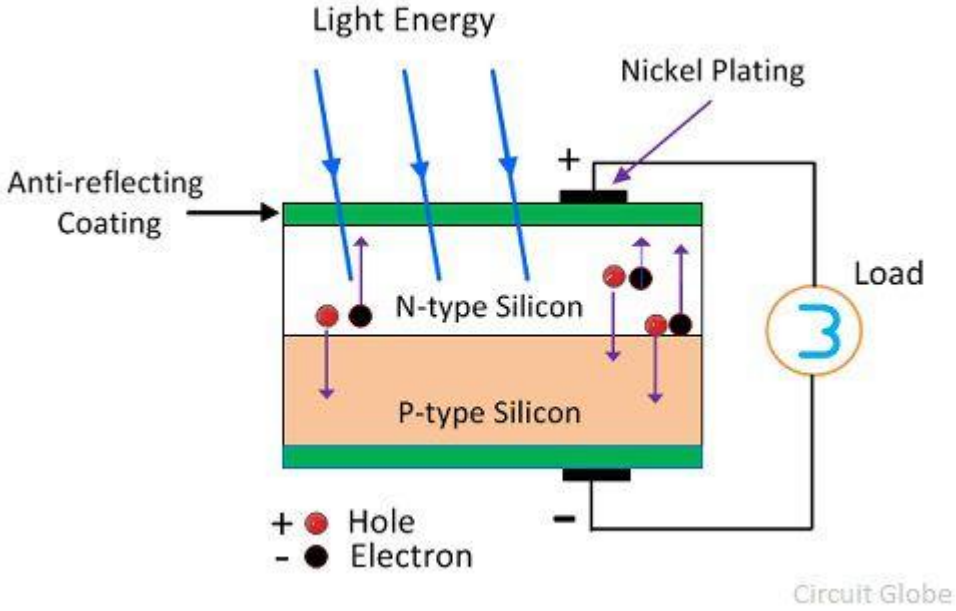
1. It has high cost of installation.
2. It has low efficiency.
3. During cloudy day, the energy cannot be produced and also at night we will not get solar energy.

Uses of Solar Generation Systems

1. It may be used to charge batteries.
2. Used in light meters.
3. It is used to power calculators and wrist watches.
4. It can be used in spacecraft to provide electrical energy.

Conclusion: Though **solar cell** has some disadvantage associated it, but the disadvantages are expected to overcome as the technology advances, since the

technology is advancing, the cost of solar plates, as well as the installation cost, will decrease down so that everybody can effort to install the system. Furthermore, the government is laying much emphasis on the solar energy so after some years we may expect that every household and also every electrical system is powered by solar or the renewable energy source.



Solar tracker

What is sun tracker?, a system that positions an object at an angle relative to the Sun. The most-common applications for solar trackers are positioning photovoltaic (PV) panels (solar panels) so that they remain perpendicular to the Sun's rays and positioning space telescopes so that they can determine the Sun's direction. PV solar trackers adjust the direction that a solar panel is facing according to the position of the Sun in the sky. By keeping the panel perpendicular to the Sun, more sunlight strikes the solar panel, less light is reflected, and more energy is absorbed. That energy can be converted into power.

Solar tracking uses complex instruments to determine the location of the Sun relative to the object being aligned. These instruments typically include computers, which can process complicated algorithms that enable the system to track the Sun, and sensors, which provide information to a computer about the Sun's location or, when attached to a solar panel with a simple circuit board, can track the Sun without the need for a computer.

What is the use of solar tracking system?

Solar trackers are devices used to orient photovoltaic panels, reflectors, lenses or other optical devices toward the sun. Since the sun's position in the sky changes with the seasons and the time of day, trackers are used to align the collection system to maximize **energy production**.