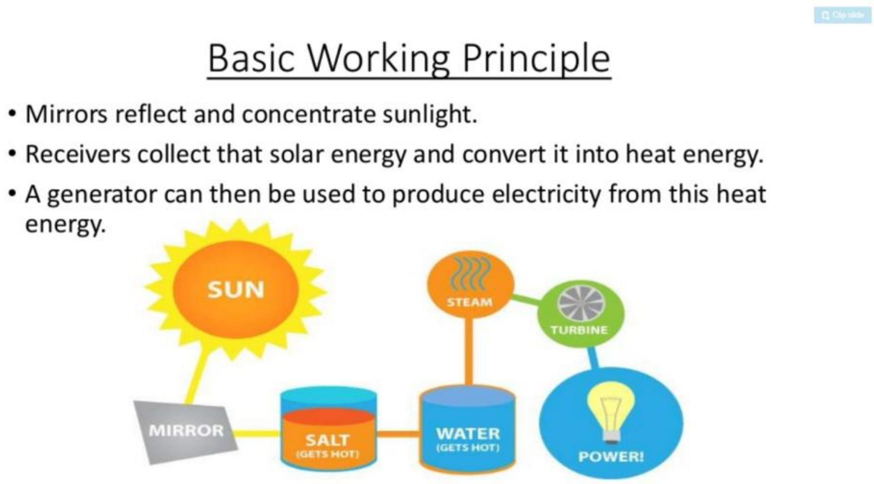
UNIT-V

SOLAR THERMAL POWER PLANTS

Solar thermal power/electric generation systems collect and concentrate sunlight to produce the high temperature heat needed to generate electricity. All solar thermal power systems have solar energy collectors with two main components: *reflectors* (mirrors) that capture and focus sunlight onto a *receiver*. In most types of systems, a heat-transfer fluid is heated and circulated in the receiver and used to produce steam. The steam is converted into mechanical energy in a turbine, which powers a generator to produce electricity. Solar thermal power systems have tracking systems that keep sunlight focused onto the receiver throughout the day as the sun changes position in the sky. Solar thermal power plants usually have a large field or array of collectors that supply heat to a turbine and generator.

Solar thermal power systems may also have a thermal energy storage system component that allows the solar collector system to heat an energy storage system during the day, and the heat from the storage system is used to produce electricity in the evening or during cloudy weather. Solar thermal power plants may also be hybrid systems that use other fuels (usually natural gas) to supplement energy from the sun during periods of low solar radiation.



Types of concentrating solar thermal power plants

There are three main types of concentrating solar thermal power systems:

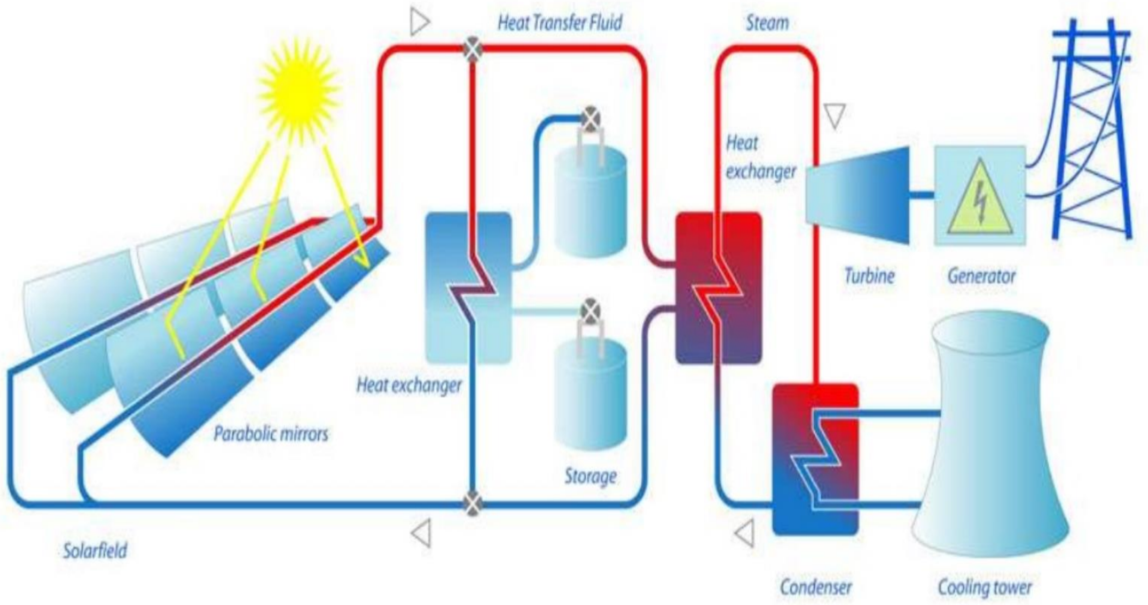
- **Linear concentrating systems, which include parabolic troughs and linear Fresnel reflectors**
- **Solar power towers**
- **Solar dish/engine systems**

Parabolic troughs

A parabolic trough collector has a long parabolic-shaped reflector that focuses the sun's rays on a receiver pipe located at the focus of the parabola. The collector tilts with the sun to keep sunlight focused on the receiver as the sun moves from east to west during the day.Because of its parabolic shape, a trough can focus the sunlight from 30 times to 100 times its normal intensity (concentration ratio) on the receiver pipe, located along the focal line of the trough, achieving operating temperatures higher than 750°F.

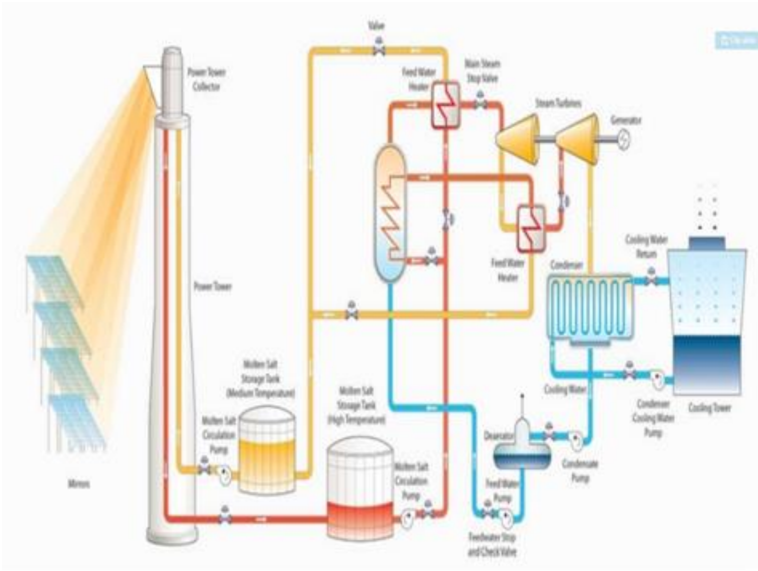
The working fluid is molten salt. This is heated higher than 750°F and it is moving to the heat exchanger. The water is converted as steam by observing the heat from the molten salt in heat exchanger. This steam is moving inside of the turbine and it will be converted as mechanical energy. This mechanical energy is converted into electrical energy by using generator.

- A parabolic trough consists of a linear parabolic reflector that concentrates light onto a receiver positioned along the reflector's focal line.
- The receiver is a tube positioned directly above the middle of the parabolic mirror and filled with a working fluid.
- The reflector follows the sun during the daylight hours by tracking along a single axis.
- A working fluid (e.g. molten salt) is heated to 150–350 °C (423–623 K (302–662 °F)) as it flows through the receiver and is then used as a heat source for a power generation system.



Solar power tower systems

- Power towers (also known as 'central tower' power plants or 'heliostat' power plants).
- These designs capture and focus the sun's thermal energy with thousands of tracking mirrors (called heliostats) in roughly a two square mile field.
- A tower resides in the center of the heliostat field. The heliostats focus concentrated sunlight on a receiver which sits on top of the tower.
- Within the receiver the concentrated sunlight heats molten salt to over 1,000 °F (538 °C).
- The heated molten salt then flows into a thermal storage tank where it is stored, maintaining 98% thermal efficiency, and eventually pumped to a steam generator.
- The steam drives a standard turbine to generate electricity.



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heliostat (from [*helios*](), the Greek word for *sun*, and *stat*, as in stationary) is a device that includes a mirror, usually a plane mirror, which turns so as to keep reflecting sunlight toward a predetermined target

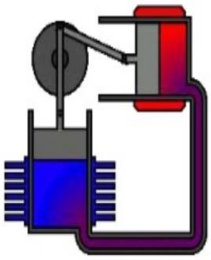
Solar dish/engine system

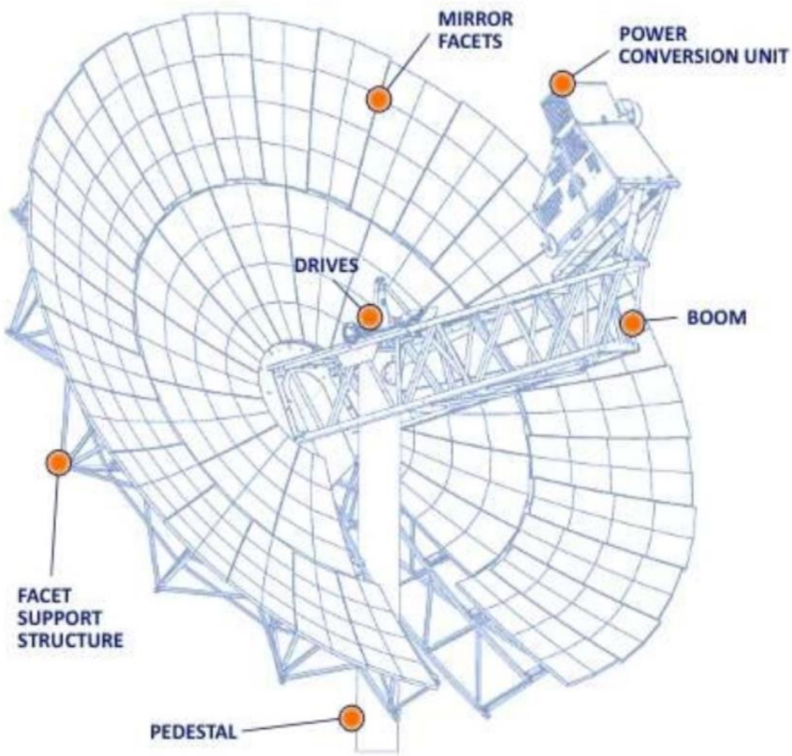
The system consists of a stand-alone parabolic reflector that concentrates light onto a receiver positioned at the reflector's focal point.

The working fluid in the receiver is heated to 250–700 °C (523–973 K (482–1,292 °F)) and then used by a Stirling engine to generate power.

Parabolic-dish systems have the highest efficiency of all solar technologies provide solar-to-electric efficiency between 31–32%.

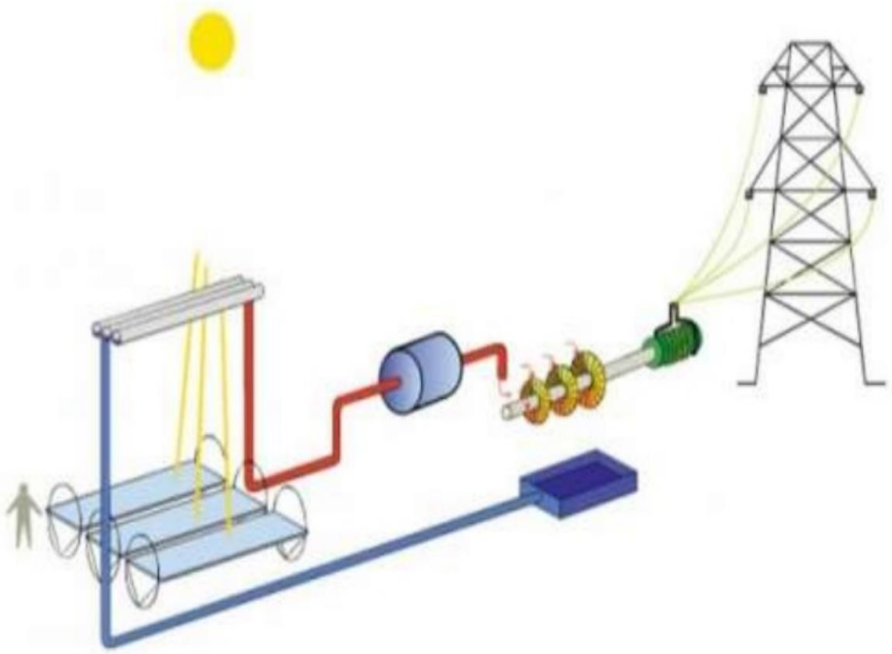
Stirling Engine →





Compact linear Fresnel reflector

- Linear Fresnel reflectors use long, thin segments of mirrors to focus sunlight onto a fixed absorber located at a common focal point of the reflectors.
- These mirrors are capable of concentrating the sun's energy to approximately 30 times its normal intensity.
- This concentrated energy is transferred through the absorber into some thermal fluid.
- The fluid then goes through a heat exchanger to power a steam generator.



A linear Fresnel reflector power plant uses a series of long, narrow, shallow-curvature (or even flat) mirrors to focus light onto one or more linear receivers positioned above the mirrors. On top of the receiver a small parabolic mirror can be attached for further focusing the light. These systems aim to offer lower overall costs by sharing a receiver between several mirrors (as compared with trough and dish concepts), while still using the simple line-focus geometry with one axis for tracking. This is similar to the trough design (and different from central towers and dishes with dual-axis). The receiver is stationary and so fluid couplings are not required (as in troughs and dishes). The mirrors also do not need to support the receiver, so they are structurally simpler. When suitable aiming strategies are used (mirrors aimed at different receivers at different times of day), this can allow a denser packing of mirrors on available land area.

Enclosed parabolic trough

The enclosed trough architecture encapsulates the solar thermal system within a greenhouse-like glasshouse. The glasshouse creates a protected environment to withstand the elements that can reduce the reliability and efficiency of the solar thermal system. Lightweight curved solar-reflecting mirrors are suspended within the glasshouse. A single-axis tracking system positions the mirrors to track the sun and focus its light onto a network of stationary steel pipes, also suspended from the glasshouse structure.Steam is generated directly using oil field-quality water, as water flows along the length of the pipes, without heat exchangers or intermediate working fluids. The steam produced is then fed directly to the field's existing steam distribution network, where the steam is continuously injected deep into the oil reservoir. Sheltering the mirrors from the wind allows them to achieve higher temperatures and prevents dust from building up as a result from exposure to humidity.[11] GlassPoint Solar, the company that created the Enclosed Trough design, states its technology can produce heat for EOR for about $5 per million British thermal units in sunny regions, compared to between $10 and $12 for other conventional solar thermal technologies.

Enclosed troughs are currently being used at the Miraah solar facility in Oman. In November 2017, GlassPoint announced a partnership with Aera Energy that would bring parabolic troughs to the South Belridge Oil Field, near Bakersfield, California.

Advantages of Solar Thermal Energy

- No Fuel Cost
- Predictable, 24/7 Power
- No Pollution and Global Warming Effects
- Using Existing Industrial Base

Disadvantages of Solar Thermal Energy

- High Cost
- Future Technology has a high probability of making CSP Obsolete
- Ecological and Cultural Issues
- Limited Locations and Size Limitations
- Long Gestation Time Leading to Cost Overruns

SOLAR POND

- One way to tap solar energy is through the use of solar ponds.
- Solar ponds are large scale energy collectors with integral heat storage

for supplying Thermal energy

It can be used for various applications, such as process heating, water desalination, refrigeration, drying and power generation..

A solar pond is a body of water that collects and stores solar energy. Solar energy will warm a body of waters but the water loses its heat unless some method is used to trap it.

•A basin filled with brine (i.e. a water/salt mixture) functions as collector and heat storage.

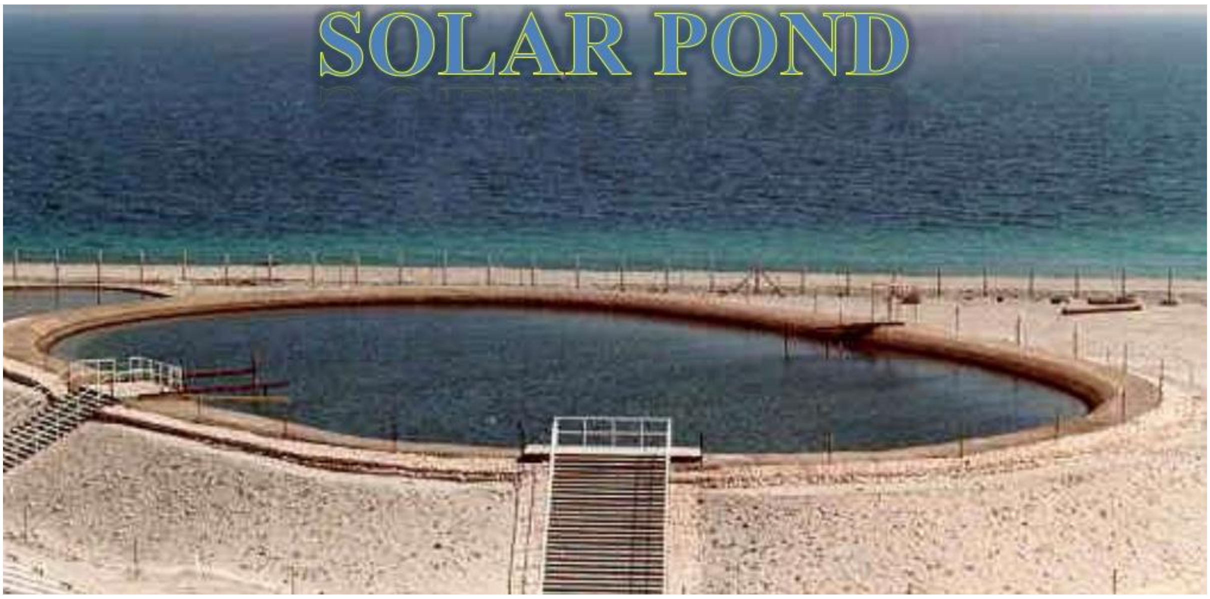
•The water at the bottom of the solar pond serves as primary heat storage from which heat is withdrawn.

•The deeper water layers and the bottom of the solar pond itself serve as absorber for the impinging direct and diffuse solar radiation.

•Due to the distribution of the salt concentration within the basin, which increases towards the bottom of the basin, natural convection and the ensuing heat loss at the surface due to evaporation, convection and radiation is *minimized.*

•This is why heat of an approximate temperature between 80 and 90 °C (approximate stagnation temperature 100 **OC)** can be extracted from the bottom.

•Heat can then be used for power generation**.**



The colder water, which is heavier, moves down to replace the warm water, creating a natural convective circulation that mixes the water and dissipates the heat. The design of solar ponds reduces either convection or evaporation in order to store the heat collected by the pond. They can operate in almost any climate.

A solar pond can store solar heat much more efficiently than a body of water of the same size because the salinity gradient prevents convection currents. Solar radiation entering the pond penetrates through to the lower layer, which contains concentrated salt solution. The temperature in this layer rises since the heat it absorbs from the sunlight is unable to move upwards to the surface by convection. Solar heat is thus stored in the lower layer of the pond.

WORKING PRINCIPLE

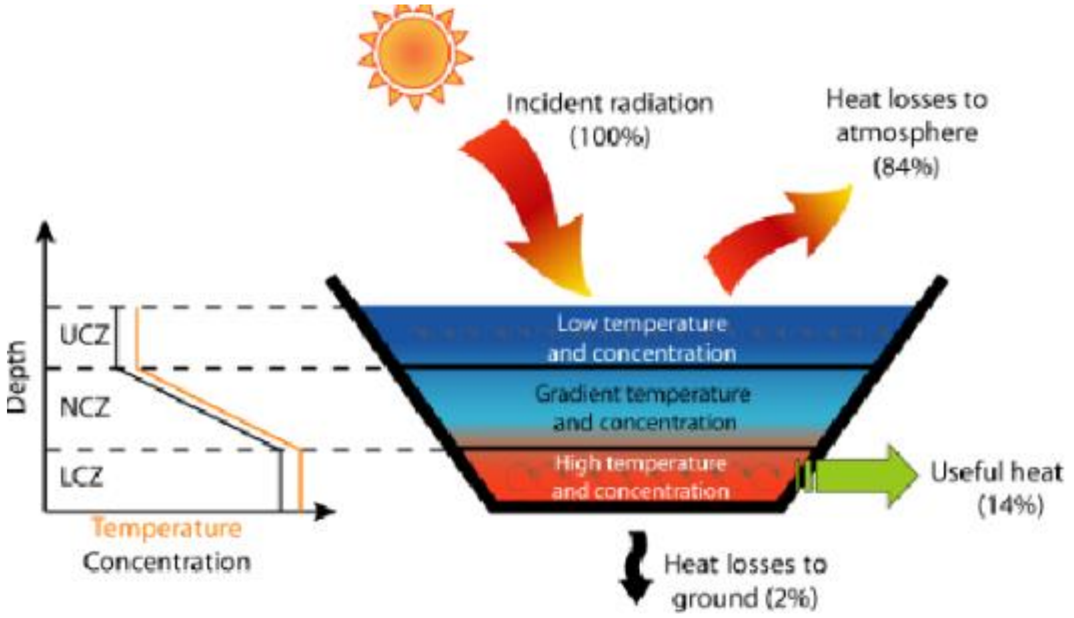
The solar pond works on a very simple principle. It is well-known that water or air is heated they become lighter and rise upward. Similarly, in an ordinary pond, the sun's rays heat the water and the heated water from within the pond rises and reaches the top but loses the heat into the atmosphere.

The net result is that the pond water remains at the atmospheric temperature. The solar pond restricts this tendency by dissolving salt in the bottom layer of the pond making it too heavy to rise.

- The more specific terms salt-gradient solar pond or non-convecting solar pond are also used. The solar pond, which is actually a large area solar collector is a simple technology that uses a pond between one to four metres deep as a working material.
- The solar pond possesses a thermal storage capacity spanning the seasons. The surface area of the pond affects the amount of solar energy it can collect.The dark surface at the bottom of the pond increases the absorption of solar radiation. Salts like magnesium chloride, sodium chloride or sodium nitrate are dissolved in the water, the concentration being densest at the bottom (20% to 30%) and gradually decreasing to almost zero at the top. Typically, a salt gradient solar pond consists of three zones. An upper convective zone of clear fresh water that acts as solar collector/receiver and which is relatively the most shallow in depth and is generally close to ambient temperature.
- A gradient which serves as the non-convective zone which is much thicker and occupies more than half the depth of the pond. Salt concentration and temperature

increase with depth.

A lower convective zone with the densest salt concentration, serving as the heat storage zone. Almost as thick as the middle non-convective zone, salt concentration and temperatures are nearly constant in this zone.



When solar radiation strikes the pond, most of it is absorbed by the surface at the bottom of the pond. The temperature of the dense salt layer therefore increases. But the salt density difference keeps the ‘layers’ of the solar pond separate. The denser salt water at the bottom prevents the heat being transferred to the top layer of fresh water by natural convection, due to which the temperature of the lower layer may nse to as much as 95°C.

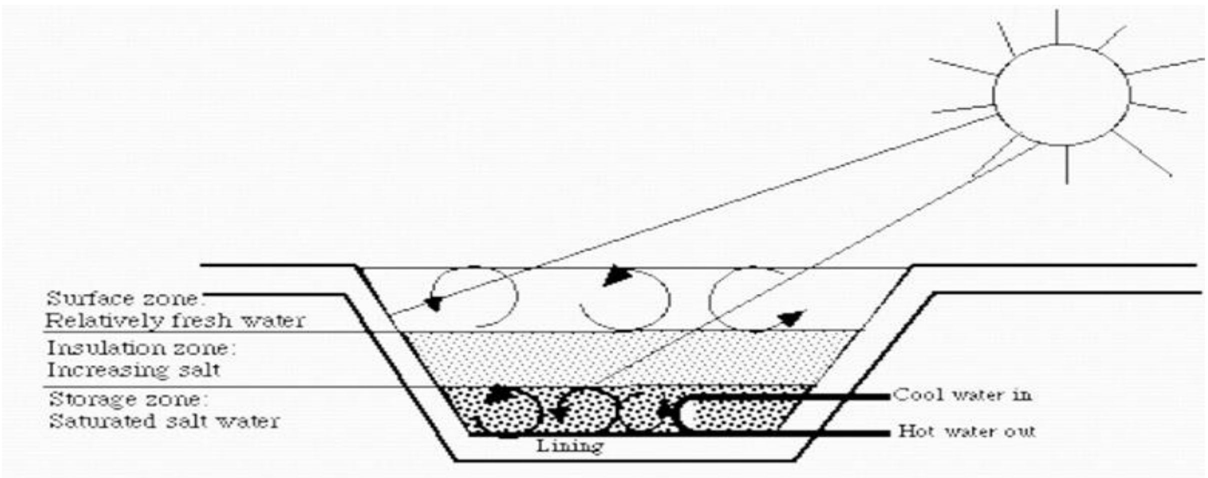
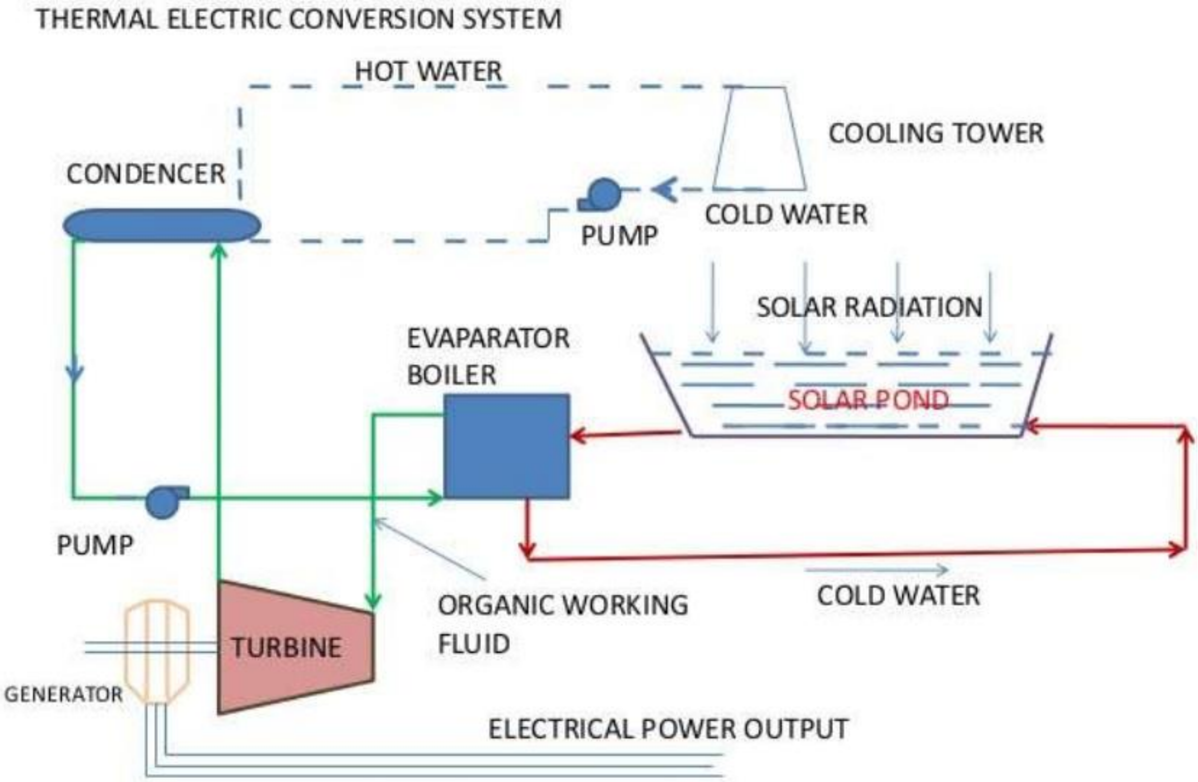


Diagram of the different layers of a Solar Pond



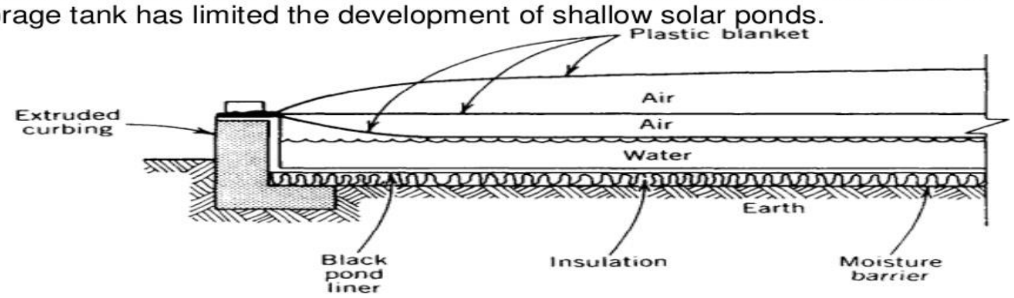
FLOW DIAGRAM OF SOLAR POND ELECTRIC POWER PLANT

TYPES OF SOLAR PONDS

- **CONVECTING SOLAR PONDS**

❑ A well-researched example of a convecting pond is the shallow solar pond. This pond consists of pure water enclosed in a large bag that allows convection but hinders evaporation.

❑ The bag has a blackened bottom, has foam insulation below, and two types of glazing (sheets of plastic or glass) on top. The sun heats the water in the bag during the day. At night the hot water is pumped into a large heat storage tank to minimize heat loss. Excessive heat loss when pumping the hot water to the storage tank has limited the development of shallow solar ponds.



• NON-CONVECTING SOLAR PONDS

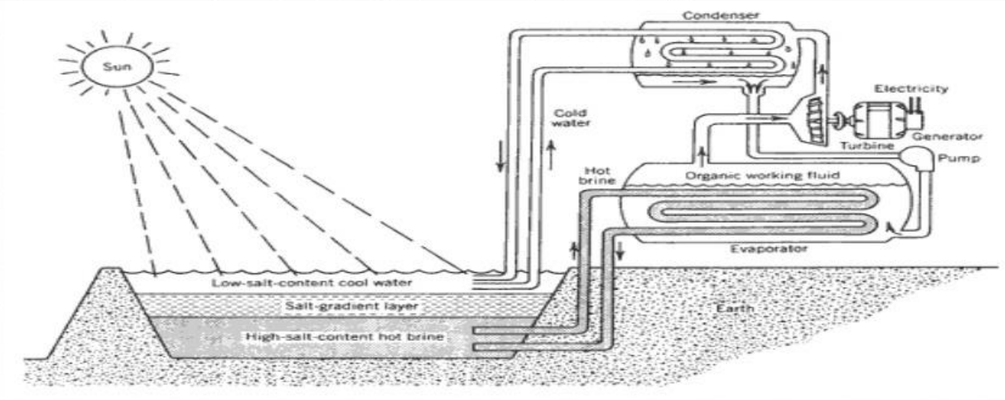
- The main types of nonconvecting ponds is salt gradient ponds. A salt gradient pond has three distinct layers of brine (a mixture of salt and water) of varying concentrations. Because the density of the brine increases with salt concentration, the most concentrated layer forms at the bottom. The least concentrated layer is at the surface. The salts commonly used are sodium chloride and magnesium chloride. A dark-colored material usually butyl rubber lines the pond.

- As sunlight enters the pond, the water and the lining absorb the solar radiation. As a result, the water near the bottom of the pond becomes warm up to 93.3°C. Even when it becomes warm, the bottom layer remains denser than the upper layers, thus inhibiting convection. Pumping the brine through an external heat exchanger or an evaporator removes the heat from this bottom layer. Another method of heat removal is to extract heat with a heat transfer fluid as it is pumped through a heat exchanger placed on the bottom of the pond.

APPLICATIONS

- Process heat

  Studies have indicated that there is excellent scope for process heat applications (i.e. water heated to 80 to 90° C.), when a large quantity of hot water is required, such as textile processing and dairy industries. Hot air for industrial uses such as drying agricultural produce, timber, fish and chemicals and space heating are other possible applications



A visual Demonstration of how a Solar Pond is used to Generate Electricity

- Desalination

  Drinking water is a chronic problem for many villages in India. In remote coastal villages where seawater is available, solar ponds can provide a cost-effective solution to the potable drinking water problem. Desalination costs in these places work out to be 7.5paise per litre, which compares favourably with the current costs incurred in the reverse osmosis or electrodialysis/desalination process.

- Refrigeration

  Refrigeration applications have a tremendous scope in a tropical country like India. Perishable products like agricultural produce and life saving drugs like vaccines can be preserved for long stretches of time in cold storage using solar pond technology in conjunction with ammonia based absorption refrigeration system.

ADVANTAGES

- Low investment costs per installed collection area.
- Thermal storage is incorporated into the collector and is of very low cost.
- Diffuse radiation (cloudy days) is fully used.
- Very large surfaces can be built thus large scale energy generation is possible.
- Expensive cleaning of large collector surfaces in dusty areas is avoided .