



UNIT II

Solar Energy Collection & Storage and Applications



UNIT-II

SOLAR ENERGY COLLECTION, STORAGE AND APPLICATIONS

Sensible heat storage:

The use of sensible heat energy storage materials is the easiest method of storage. In practice, water, sand, gravel, soil, etc. can be considered as materials for energy storage, in which the largest heat capacity of water, so water is used more often. In the 70's and 80's, the use of water and soil for cross-seasonal storage of solar energy was reported. But the material's sensible heat is low, and it limits energy storage.

Latent heat-storage:

Latent heat-storage units are storing thermal energy in latent (= hidden, dormant) mode by changing the state of aggregation of the storage medium. Applicable storage media are called "phase change materials" (PCM).. Commonly salt crystal is used in low-temperature storage, such as sodium sulfate decahydrate /calcium chloride, sodium hydrogen phosphate 12-water. However, we must solve the cooling and layering issues in order to ensure the operating temperature and service life. Medium solar storage temperature is generally higher than 100 °C but under 500 °C, usually it is around 300 °C. Suitable for medium temperature storage of materials are: high-pressure hot water, organic fluids, eutectic salt. Solar heat storage temperature is generally above 500 °C, the materials currently being tested are: metal sodium and molten salt. Extremely high temperature above 1000 °C storage, fire-resistant ball alumina and germanium oxide can be used.

Chemical, thermal energy storage:

Thermal energy storage is making the use of chemical reaction to store heat. It has the advantage of large amount in heat, small in volume, light in weight. The product of chemical reaction can be stored separately for a long time. It occurs exothermic reaction when it is needed. It has to meet the needs of below conditions to use chemical reaction in heat reserve: good in reaction reversibility, no secondary reaction, rapid reaction, easy to separate the resultant and reserve it stably. Reactant and resultant are innocuous, unflammable, large in heat of reaction and low price of reactant. Now some of the chemical endothermic reaction could meet the needs of above conditions. Like pyrolysis reaction of $\text{Ca}(\text{OH})_2$, Using the above endothermic reaction to store heat and release the heat when it is necessary. But the dehydration reaction temperature in high atmospheric pressure is higher than 500 degrees. It is difficult to use solar energy to complete dehydration reaction. We can use catalyst to decrease the reaction temperature, but still very high. So it is still in testing time of heat reserve in chemistry.

Plastic crystal thermal energy storage:

In 1984, the U.S. market launched plastic crystal materials for home heating. Plastic crystal's scientific name is Neopentyl Glycol (NPG), it and the liquid crystal are similar to three-dimensional periodic crystals, but the mechanical properties are like plastic. It can store and release thermal energy in the constant temperature, but not to rely on solid-liquid phase change to store thermal energy, it stores the energy through the plastic crystalline molecular structure occurring solid - solid phase change. When

plastic crystals are at constant temperature 44°C, it absorbs solar energy and stores heat during the day, and releases the heat during the night.

Solar thermal energy storage tank:

Solar pond is a kind of a certain salt concentration gradient of salt ponds, and it can be used for acquisition and storage of solar energy. Because of its simple, low cost, and it is suitable for large-scale application so it has attracted people's attention. After the 60's, many countries have started study on solar pond, Israel has also built three solar pond power plants.

Solar Collectors

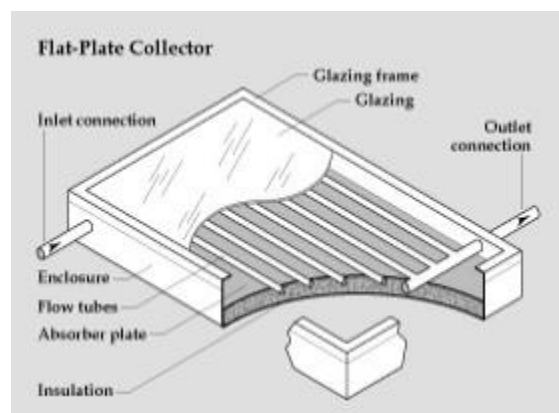
Solar collectors are the key component of active solar-heating systems. Solar collectors gather the sun's energy, transform its radiation into heat, then transfer that heat to water, solar fluid, or air. The solar thermal energy can be used in solar water heating systems, solar pool heaters, and solar space-heating systems. There are several types of solar collectors:

- Flat-plate collectors
- Evacuated-tube collectors

Residential and commercial building applications that require temperatures below 200°F typically use flat-plate collectors, whereas those requiring temperatures higher than 200°F use evacuated-tube collectors.

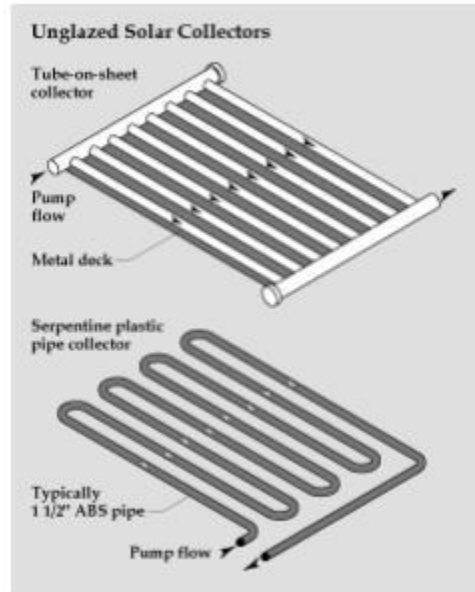
Flat-plate collectors

Flat-plate collectors are the most common solar collector for solar water-heating systems in homes and solar space heating. A typical flat-plate collector is an insulated metal box with a glass or plastic cover (called the glazing) and a dark-colored absorber plate. These collectors heat liquid or air at temperatures less than 180°F. Flat-plate collectors are used for residential water heating and hydronic space-heating installations.



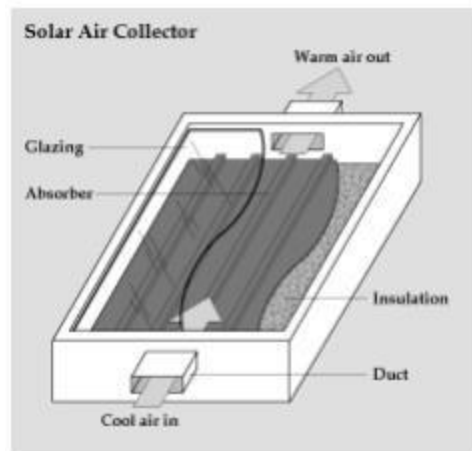
Liquid flat-plate collectors heat liquid as it flows through tubes in or adjacent to the absorber plate. The simplest liquid systems use potable household water, which is heated as it passes directly through the collector and then flows to the house. Solar pool heating This home in Nevada has an integral collector

storage (ICS) system to provide hot water.also uses liquid flat-plate collector technology, but the collectors are typically unglazed as in figure below.



Unglazed solar collectors typically used for swimming pool heating.

Air flat-plate collectors are used primarily for solar space heating. The absorber plates in air collectors can be metal sheets, layers of screen, or non-metallic materials. The air flows past the absorber by using natural convection or a fan. Because air conducts heat much less readily than liquid does, less heat is transferred from an air collector's absorber than from a liquid collector's absorber, and air collectors are typically less efficient than liquid collectors.



Air flat-plate collectors are used for space heating.

Evacuated-tube collectors

Evacuated-tube collectors can achieve extremely high temperatures (170°F to 350°F), making them more appropriate for cooling applications and commercial and industrial application. However, evacuated-tube collectors are more expensive than flat-plate collectors, with unit area costs about twice

that of flat-plate collectors. Evacuated-tube collectors are efficient at high temperatures. The collectors are usually made of parallel rows of transparent glass tubes. Each tube contains a glass outer tube and metal absorber tube attached to a fin. The fin is covered with a coating that absorbs solar energy well, but which inhibits radiative heat loss. Air is removed, or evacuated, from the space between the two glass tubes to form a vacuum, which eliminates conductive and convective heat loss. A new evacuated-tube design is available from the Chinese manufacturers, such as: Beijing Sunda Solar Energy Technology Co. Ltd. The "dewar" design features a vacuum contained between two concentric glass tubes, with the absorber selective coating on the inside tube. Water is typically allowed to thermosyphon down and back out the inner cavity to transfer the heat to the storage tank. There are no glass-to-metal seals. This type of evacuated tube has the potential to become cost-competitive with flat plates.

Concentrating collectors

Unlike solar (photovoltaic) cells, which use light to produce electricity, concentrating solar power systems generate electricity with heat. Concentrating solar collectors use mirrors and lenses to concentrate and focus sunlight onto a thermal receiver, similar to a boiler tube. The receiver absorbs and converts sunlight into heat. The heat is then transported to a steam generator or engine where it is converted into electricity. There are three main types of concentrating solar power systems: parabolic troughs, dish/engine systems, and central receiver systems.

These technologies can be used to generate electricity for a variety of applications, ranging from remote power systems as small as a few kilowatts (kW) up to grid-connected applications of 200-350 megawatts (MW) or more. A concentrating solar power system that produces 350 MW of electricity displaces the energy equivalent of 2.3 million barrels of oil.

Trough Systems

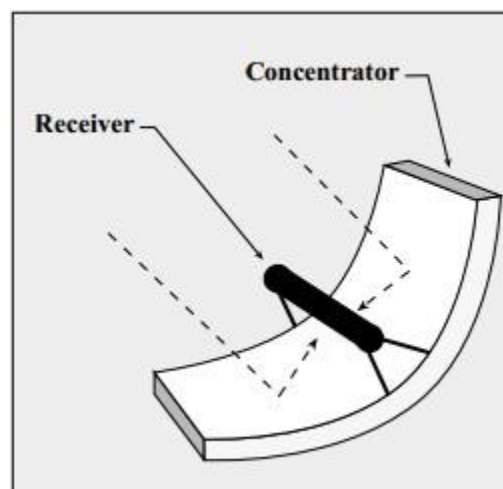


Fig. 1 A parabolic trough

These solar collectors use mirrored parabolic troughs to focus the sun's energy to a fluid-carrying receiver tube located at the focal point of a parabolically curved trough reflector (see Fig. 1 above). The energy from the sun sent to the tube heats oil flowing through the tube, and the heat energy is then used to generate electricity in a conventional steam generator. Many troughs placed in parallel rows are called a "collector field." The troughs in the field are all aligned along a north-south axis so they can track the sun from east to west during the day, ensuring that the sun is continuously focused on the receiver pipes. Individual trough systems currently can generate about 80 MW of electricity. Trough

designs can incorporate thermal storage—setting aside the heat transfer fluid in its hot phase—allowing for electricity generation several hours into the evening. Currently, all parabolic trough plants are "hybrids," meaning they use fossil fuels to supplement the solar output during periods of low solar radiation.

Dish Systems



Fig.2 Dish Systems

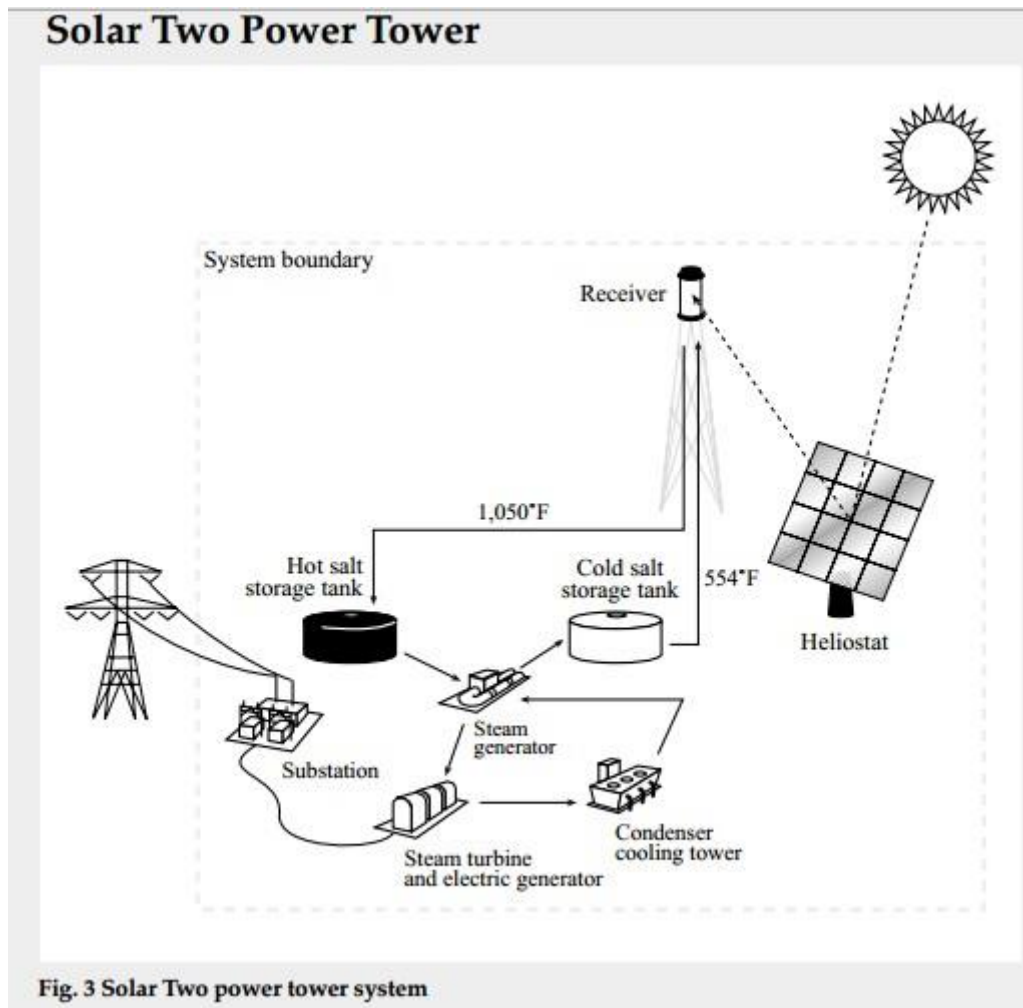
Dish systems use dish-shaped parabolic mirrors as reflectors to concentrate and focus the sun's rays onto a receiver, which is mounted above the dish at the dish center. A dish/engine system is a standalone unit composed primarily of a collector, a receiver, and an engine (see Fig.2 above). It works by collecting and concentrating the sun's energy with a dish-shaped surface onto a receiver that absorbs the energy and transfers it to the engine. The engine then converts that energy to heat. The heat is then converted to mechanical power, in a manner similar to conventional engines, by compressing the working fluid when it is cold, heating the compressed working fluid, and then expanding it through a turbine or with a piston to produce mechanical power. An electric generator or alternator converts the mechanical power into electrical power.

Dish/engine systems use dual-axis collectors to track the sun. The ideal concentrator shape is parabolic, created either by a single reflective surface or multiple reflectors, or facets. Many options exist for receiver and engine type, including Stirling cycle, microturbine, and concentrating photovoltaic modules. Each dish produces 5 to 50 kW of electricity and can be used independently or linked together to increase generating capacity. A 250-kW plant composed of ten 25-kW dish/engine systems requires less than an acre of land. Dish/engine systems are not commercially available yet, although ongoing demonstrations indicate good potential. Individual dish/engine systems currently can generate about 25 kW of electricity. More capacity is possible by connecting dishes together. These systems can be combined with natural gas, and the resulting hybrid provides continuous power generation.

Central Receiver Systems

Central receivers (or power towers) use thousands of individual sun-tracking mirrors called "heliostats" to reflect solar energy onto a receiver located on top of a tall tower. The receiver collects the sun's heat in a heat-transfer fluid (molten salt) that flows through the receiver. The salt's heat energy is then used to make steam to generate electricity in a conventional steam generator, located at the foot of the tower. The molten salt storage system retains heat efficiently, so it can be stored for hours or even days before being used to generate electricity. Therefore, a central receiver system is composed of five main components: heliostats, receiver, heat transport and exchange, thermal storage, and controls (see Fig. 3). Solar One, Two, "Tres" The U.S. Department of Energy (DOE), and a consortium of U.S. utilities and industry, built this country's first two large-scale, demonstration solar power towers in the desert near Barstow, California. Solar One operated successfully from This concentrating solar power system uses mirrors to focus highly concentrated sunlight onto a receiver that converts the sun's heat into energy. Receiver and generator Concentrator Individual dish/engine systems currently can generate about 25 kW of electricity.

Power tower plants can potentially operate for 65 percent of the year without the need for a back-up fuel source. Solar Two—a demonstration power tower located in the Mojave Desert—can generate about 10 MW of electricity. In this central receiver system, thousands of sun-tracking mirrors called heliostats reflect sunlight onto the receiver. Molten salt at 554°F (290°C) is pumped from a cold storage tank through the receiver where it is heated to about 1,050°F (565°C). The heated salt then moves on to the hot storage tank. When power is needed from the plant, the hot salt is pumped to a generator that produces steam. The steam activates a turbine/generator system that creates electricity. From the steam generator, the salt is returned to the cold storage tank, where it is stored and can be eventually reheated in the receiver. By using thermal storage, power tower plants can potentially operate for 65 percent of the year without the need for a back-up fuel source. Without energy storage, solar technologies like this are limited to annual capacity factors near 25 percent. The power tower's ability to operate for extended periods of time on stored solar energy separates it from other renewable energy technologies. Hot salt storage tank Steam generator 1,050°F Cold salt storage tank Condenser cooling tower 554°F System boundary Substation Steam turbine and electric generator



Applications of Solar Energy

Solar energy can supply and or supplement many farm energy requirements. The following is a brief discussion of a few applications of solar energy technologies in agriculture.

Crop And Grain Drying

Using the sun to dry crops and grain is one of the oldest and mostly widely used applications of solar energy. The simplest and least expensive technique is to allow crops to dry naturally in the field, or to spread grain and fruit out in the sun after harvesting. The disadvantage of these methods is that the crops and grains are subject to damage by birds, rodents, wind, and rain, and contamination by wind blown dust and dirt. More sophisticated solar dryers protect grain and fruit, reduce losses, dry faster and more uniformly, and produce a better quality product than open air methods.

The basic components of a solar dryer are an enclosure or shed, screened drying trays or racks, and a solar collector. In hot, arid climates, the collector may not even be necessary. The southern side of the enclosure itself can be glazed to allow sunlight to dry the material. The collector can be as simple as a glazed box with a dark coloured interior to absorb the solar energy that heats air. The air heated in the

solar collector moves, either by natural convection or forced by a fan, up through the material being dried. The size of the collector and rate of airflow depends on the amount of material being dried, the moisture content of the material, the humidity in the air, and the average amount of solar radiation available during the drying season.

There is a relatively small number of large solar crop dryers around the world. This is because the cost of the solar collector can be high, and drying rates are not as controllable as they are with natural gas or propane powered dryers. Using the collector at other times of the year, such as for heating farm buildings, may make a solar dryer more cost effective. It is possible to make small, very low cost dryers out of simple materials. These systems can be useful for drying vegetables and fruit for home use.

Space And Water Heating

Livestock and dairy operations often have substantial air and water heating requirements. Modern pig and poultry farms raise animals in enclosed buildings, where it is necessary to carefully control temperature and air quality to maximize the health and growth of the animals. These facilities need to replace the indoor air regularly to remove moisture, toxic gases, odors, and dust. Heating this air, when necessary, requires large amount of energy. With proper planning and design solar air/space heaters can be incorporated into farm buildings to preheat incoming fresh air. These systems can also be used to supplement

Solar Energy Applications for Agriculture

Natural ventilation levels during summer months depending on the region and weather. Solar water heating can provide hot water for pen or equipment cleaning or for preheating water going into a conventional water heater. Water heating can account for as much as 25 percent of a typical family's energy costs and up to 40 percent of the energy used in a typical dairy operation. A properly-sized solar water heating system could cut those costs in half.

There are four basic types of solar water-heater systems available. These systems share three similarities: a glazing (typically glass) over a dark surface to gather solar heat; one or two tanks to store hot water; and associated plumbing with or without pumps to circulate the heat-transfer fluid from the tank to the collectors and back again.

(a) Drain down systems pump water from the hot water tank through the solar collector, where it is heated by the sun and returned to the tank. Valves automatically drain the system when sensors detect freezing temperatures.

(b) Drain back systems use a separate plumbing line filled with fluid, to gather the sun's heat. These systems operate strictly on gravity. When the temperature is near freezing, the pump shuts off and the transfer fluid drains back into the solar storage tank.

(c) Anti-freeze closed-loop systems rely on an antifreeze solution to operate through cold and winter months. Anti-freeze solutions are separated from household water by a double-walled heat exchange.

(d) Bread box batch systems are passive systems in which the storage tank also functions as the collector. One or two water tanks, painted black, are placed in a well-insulated box or other enclosure that has a south wall made of clear plastic or glass and tilted at the proper angle. This allows the sun to shine directly on the tank and heat a batch of water. An insulated cover can provide freeze protection.

Greenhouse Heating

Another agricultural application of solar energy is greenhouse heating. Commercial greenhouses typically rely on the sun to supply their lighting needs, but are not designed to use the sun for heating. They rely on gas or oil heaters to maintain the temperatures necessary to grow plants in the colder months. Solar greenhouses, however, are designed to utilize solar energy both for heating and lighting. A solar greenhouse has thermal mass to collect and store solar heat energy, and insulation to retain this heat for use during the night and on cloudy days. A solar greenhouse is oriented to maximize southern glazing exposure. Its northern side has little or no glazing and is well insulated. To reduce heat loss, the glazing itself is also more efficient than single-pane glass, and various products are available ranging from double pane to cellular glazing. A solar greenhouse reduces the need for fossil fuels for heating. A gas or oil heater may serve as a back-up heater, or to increase carbon dioxide levels to induce higher plant growth.

Passive solar greenhouses are often good choices for small growers, because they are a cost-efficient way for farmers to extend the growing season. In colder climates or in areas with long periods of cloudy weather, solar heating may need to be supplemented with a gas or electric heating system to protect plants against extreme cold. Active solar greenhouses use supplemental energy to move solar heated air or water from storage or collection areas to other regions of the greenhouse.

Remote Electricity Supply (Photovoltaic)

Solar electric, or photovoltaic (PV), systems convert sun light directly to electricity. They work any time the sun is shining, but more electricity is produced when the sun light is more intensive and strikes the PV modules directly (as when rays of sunlight are perpendicular to the PV modules). They can also power an electrical appliance directly, or store solar energy in a battery. In areas with no utility lines, PV systems are often cheaper and require less maintenance than diesel generators, wind turbines, or batteries alone. And where utilities charge for new lines, a PV generating system is often much cheaper for the land owner than paying for a new line. PV allows for the production of electricity—without noise or air pollution—from a clean, renewable resource. A PV system never runs out of fuel. Solar electric power comes in very handy on farm and ranches, and is often the most cost-effective and low maintenance solution at locations far from the nearest utility line. PV can be used to power lighting, electric fencing, small motors, aeration fans, gate-openers, irrigation valves, switches, automatic supplement feeders. Solar electric energy can be used to move sprinkler irrigation systems. PV systems are also extremely well-suited for pumping water for livestock in remote pasture, where electricity from power lines is unavailable. PV is often much less-expensive than the alternative of extending power lines into these remote areas.

Water Pumping

Photovoltaic (PV) water pumping systems may be the most cost-effective water pumping option in locations where there is no existing power line. They are exceptionally well-suited for grazing operations to supply water to remote pastures. Simple PV power systems run pumps directly when the

sun is shining, so they work hardest in the hot summer months when they are needed most. Generally, batteries are not necessary because the water is stored in tanks or pumped to fields and used in the day time. Larger pumping systems may include batteries, inverters, and tracking mounts to follow the sun. When properly sized and installed, PV water pumps are very reliable and require little maintenance. The size and cost of a PV water pumping system depends on the quality of solar energy available at the site, the pumping depth, the water demand, and system purchase and installation costs. PV systems are very cost-effective for remote livestock water supply, pond aeration, and small irrigation systems. For example, a system that includes a 128 watt PV array and a submersible pump can produce 750-1000 gallons of water per day from 200 foot drilled well.



UNIT III

Wind Energy

