UNIT-II

SOLAR ENERGY COLLECTION, STORAGE AND APPLICATIONS

Sensible heat storage:

The use of sensible heat energy storage materials is the easiest method ofstorage. In practice, water, sand, gravel, soil, etc. can be considered asmaterials for energy storage, in which the largest heat capacity of water, sowater is used more often. In the 70’s and 80’s, the use of water and soil forcross-seasonal storage of solar energy was reported. But the material’s sensibleheat 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. Applicablestorage media are called "phase change materials" (PCM).. Commonly saltscrystal 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 operatingtemperature and service life. Medium solar storage temperature is generallyhigher than 100 ℃but under 500 ℃, usually it is around 300 ℃. Suitable formedium temperature storage of materials are: high-pressure hot water, organic fluids, eutectic salt. Solar heat storage temperature is generally above 500 ℃,the materials currently being tested are: metal sodium and molten salt.Extremely high temperature above 1000 ℃storage, fire-resistant ball aluminaand germanium oxide can be used.

Chemical, thermal energy storage:

Thermal energy storage is making the use of chemical reaction to store heat. Ithas the advantage of large amount in heat, small in volume, light in weight. Theproduct of chemical reaction can be stored separately for a long time. It occursexothermic reaction when it is needed. it has to meet the needs of belowconditions to use chemical reaction in heat reserve: good in reaction reversibility, no secondary reaction, rapid reaction, easy to separate the resultant andreserve it stably. Reactant and resultant are innoxious ,uninflammable, large in heat of reaction and low price of reactant. Now some of the chemicalendothermic reaction could meet the needs of above conditions. Like pyrolysis reaction of $Ca(OH)_2$, Using the above endothermic reaction to store heat andrelease the heat when it is necessary. But the dehydration reaction temperaturein high atmospheric pressure is higher than 500 degrees. I t is difficult to usesolar energy to complete dehydration reaction. We can use catalyst to decreasethe reaction temperature, but still very high. So it is still in testing time of heat14reserve 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 liquidcrystal are similar to three-dimensional periodic crystals, but the mechanicalproperties are like plastic. It can store and release thermal energy in theconstant temperature, but not to rely on solid-liquid phase change to storethermal energy, it stores the energy through the plastic crystalline molecularstructure occurring solid - solid phase change. When plastic crystals are atconstant temperature 44c, it absorbs solar energy and stores heat during theday, 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 itcan be used for acquisition and storage of solar energy. Because of its simple,low cost, and it is suit to large-scale applied so it has attracted people's attention.After the 60’s, many countries have started study on solar pond, Israel has alsobuilt three solar pond power plants.

Solar Collectors

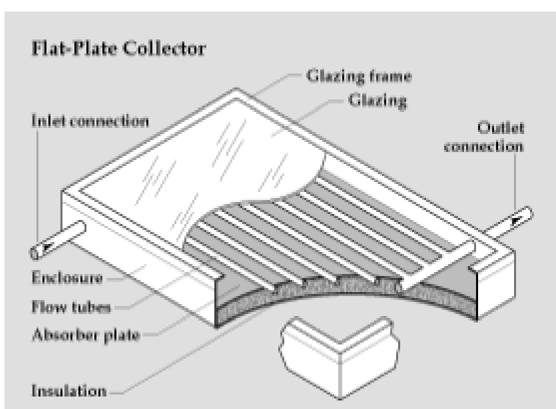
Solar collectors are the key component of active solar-heating systems. Solar collectors gather the sun's energy, transformits radiation into heat, then transfer thatheat to water, solar fluid, or air. The solar thermal energy can be used in solar waterheating systems, solar pool heaters, andsolar space-heating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

- Flat-plate collectors
- Evacuated-tube collectors

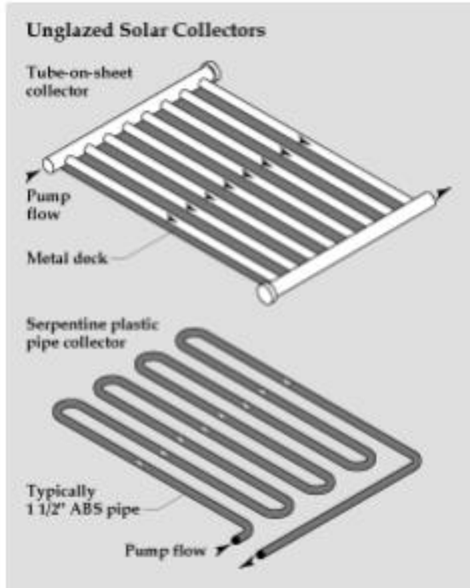
Residential and commercial building applications that require temperatures below 200°F typically use flat-plate collectors, whereas those requiring temperatures higher than 200°F use evacuated-tube collectors.

Flat-plate collectors

Flat-plate collectors are the most common solar collector for solar water-heating systemsin 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.

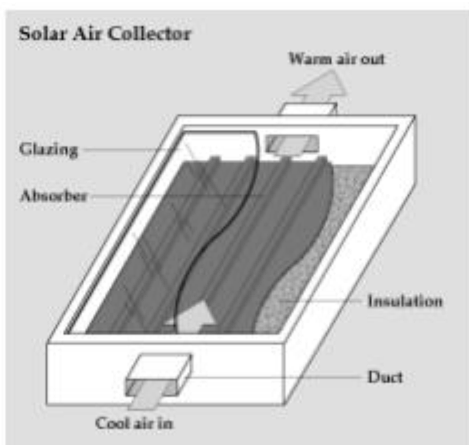


Liquid flat-plate collectors heat liquid as it flows through tubes in or adjacent to the absorber plate. The simplest liquid systems use potable household water, which is heated as it passes directly through the collector and then flows to the house. Solar pool heating This home in Nevada has anintegral 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 lessefficient 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, whichuse light to produce electricity, concentrating solar power systems generate electricity with heat. Concentrating solarcollectors use mirrors and lenses to concentrate and focus sunlight onto a thermalreceiver, similar to a boiler tube. Thereceiver absorbs and converts sunlight into heat. The heat is thentransported to asteam generator or engine where it is converted into electricity. There are threemain types of concentrating solarpower systems: parabolic troughs, dish/engine systems, and central receiver systems.

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

Trough Systems

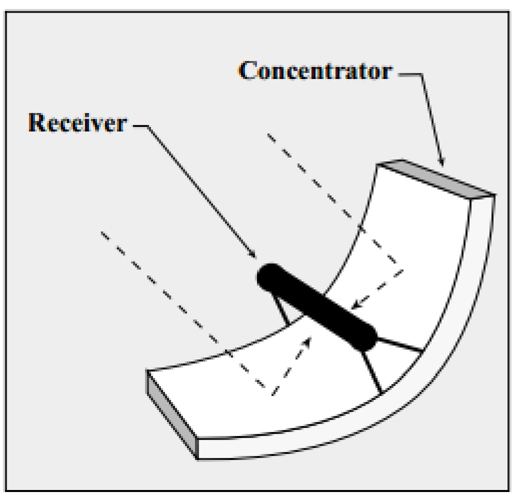


Fig. 1 A parabolic trough

These solar collectors use mirrored parabolic troughs to focus the sun's energy toa fluid-carrying receiver tube located atthe focal point of a parabolically curved trough reflector (see Fig.1 above). Theenergy from the sun sent to the tube heatsoil flowing through the tube, and the heatenergy is then used to generate electricityin a conventional steam generator. Many troughs placed in parallel rows arecalled a "collector field." The troughs inthe field are all aligned along a northsouth axis so they can track the sun fromeast to west during the day, ensuring thatthe sun is continuously focused on thereceiver pipes. Individual trough systemscurrently can generate about 80 MW ofelectricity. Trough designs can incorporatethermal storage—setting aside the heattransfer fluid in its hot phase—allowingfor electricity generation several hoursinto the evening. Currently, all parabolic trough plants are"hybrids," meaning they use fossil fuels tosupplement the solar output during periods of low solar radiation.

Dish Systems

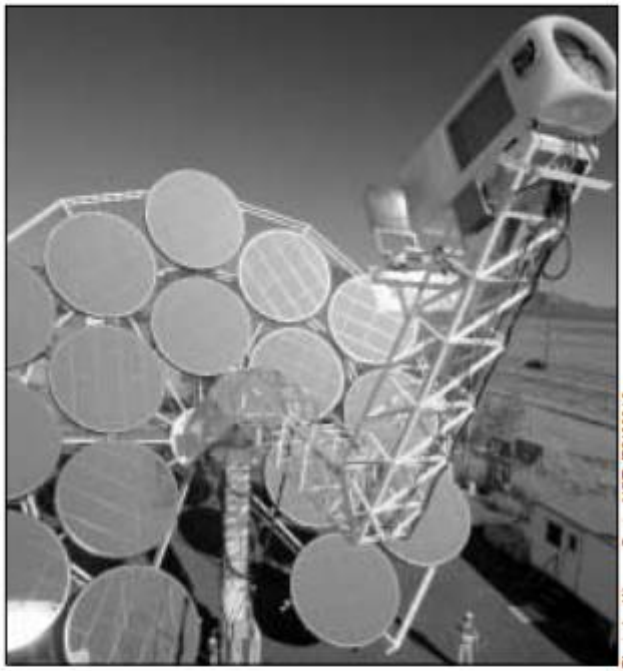


Fig.2 Dish Systems

Dish systems usedish-shaped parabolic mirrors asreflectors to concentrate and focusthe sun's rays ontoa receiver, which ismounted above thedish at the dish center. A dish/enginesystem is a standalone unit composed primarily ofa collector, areceiver, and anengine (see Fig.2 above). It works bycollecting and concentrating the sun's energy with a dishshaped surface onto a receiver thatabsorbs the energy and transfers it to theengine. The engine then converts thatenergy to heat. The heat is then convertedto mechanical power, in a manner similarto conventional engines, by compressingthe working fluid when it is cold, heatingthe compressed working fluid, and thenexpanding it through a turbine or with apiston to produce mechanical power. Anelectric generator or alternator converts the mechanical power into electricalpower.

Dish/engine systems use dual-axis collectors to track the sun. The ideal concentrator shape is parabolic, created either by asingle reflective surface or multiple reflectors, or facets. Many options exist forreceiver and engine type, including Stirling cycle, microturbine, and concentrating photovoltaic modules. Each dishproduces 5 to 50 kW of electricity and canbe used independently or linked togetherto increase generating capacity. A 250-kWplant composed of ten 25-kW dish/enginesystems requires less than an acre of land.Dish/engine systems are not commercially available yet, although ongoingdemonstrations indicate good potential.Individual dish/engine systems currentlycan generate about 25 kW of electricity.More capacity is possible by connectingdishes together. These systems can becombined with natural gas, and the resulting hybrid provides continuous powergeneration.

Central Receiver Systems

Central receivers (or power towers) usethousands of individual sun-tracking mirrors called "heliostats" to reflect solarenergy onto a receiver located on top of atall tower. The receiver collects the sun'sheat in a heat-transfer fluid (molten salt)that flows through the receiver. The salt'sheat energy is then used to make steam togenerate electricity in a conventionalsteam generator, located at the foot of thetower. The molten salt storage systemretains heat efficiently, so it can be storedfor hours or even days before being usedto generate electricity. Therefore, a centralreceiver system is composed of five maincomponents: heliostats, receiver, heattransport 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 andindustry, built this country's first twolarge-scale, demonstration solar powertowers in the desert near Barstow, California. Solar One operated successfully fromThis concentrating solar power system uses mirrors tofocus highly concentrated sunlight onto a receiver thatconverts the sun’s heat into energy.ReceiverandgeneratorConcentratorIndividualdish/engine systemscurrently cangenerate about25 kW of electricity.

Power tower plantscan potentiallyoperate for 65percent of the yearwithout the needfor a back-up fuel source.Solar Two—a demonstration powertower located in the Mojave Desert—can generate about 10 MW of electricity.In this central receiver system, thousands of sun-tracking mirrors calledheliostats reflect sunlight onto thereceiver. Molten salt at 554ºF (290ºC) ispumped from a cold storage tankthrough the receiver where it is heatedto about 1,050ºF (565ºC). The heated saltthen moves on to the hot storage tank.When power is needed from the plant,the hot salt is pumped to a generatorthat produces steam. The steam activates a turbine/generator system thatcreates electricity. From the steam generator, the salt is returned to the coldstorage tank, where it stored is and canbe eventually reheated in the receiver. By using thermal storage, power towerplants can potentially operate for 65percent of the year without the need fora back-up fuel source. Without energystorage, solar technologies like this arelimited to annual capacity factors near25 percent. The power tower's ability tooperate for extended periods of time onstored solar energy separates it fromother renewable energy technologies.Hot saltstorage tankSteamgenerator1,050˚FCold saltstorage tankCondensercooling tower554˚FSystem boundarySubstationSteam turbineand electric generator

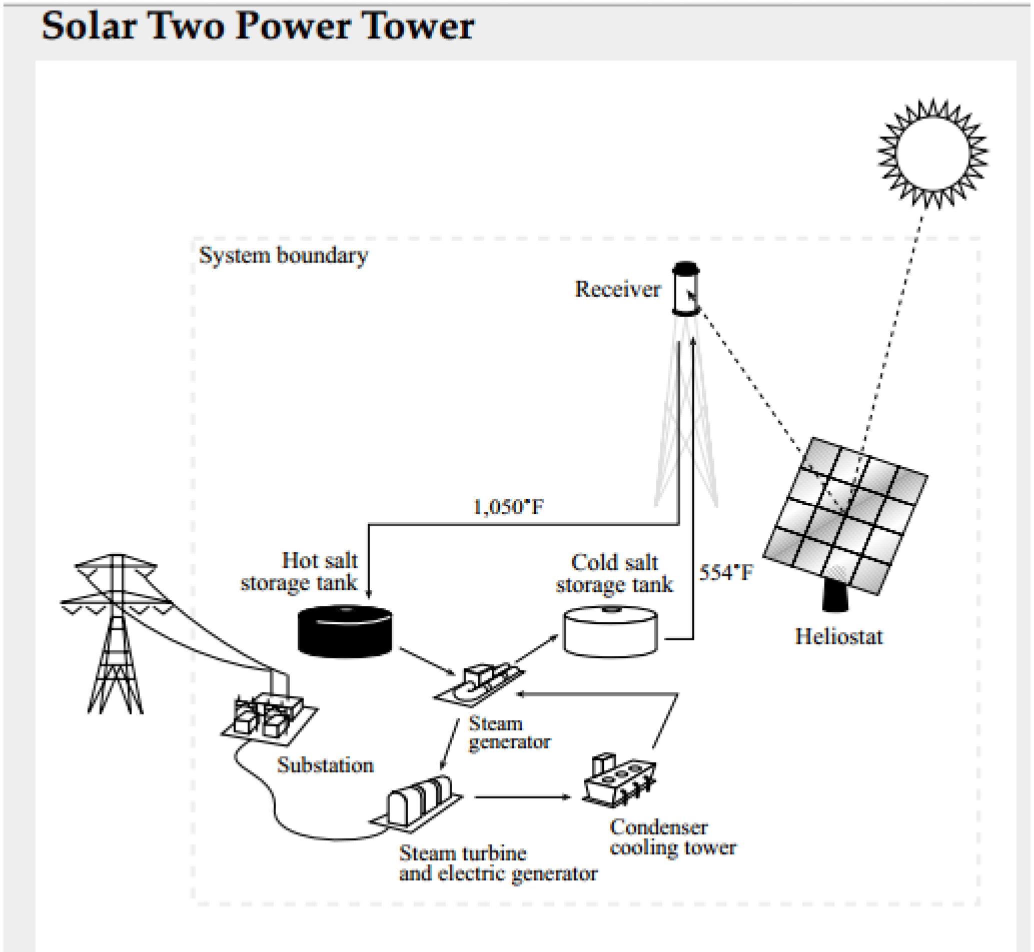


Fig. 3 Solar Two power tower system

Applications of Solar Energy

Solar energy can supply and or supplement many farm energy requirements. Thefollowing is a brief discussion of a few applications of solar energy technologies inagriculture.

Crop And Grain Drying

Using the sun to dry crops and grain is one of the oldest and mostly widely usedapplications of solar energy. The simplest and least expensive techniques is to allow cropsto 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 bybirds, rodents, wind, and rain, and contamination by wind blown dust and dirt. Moresophisticated solar dryers protect grain and fruit, reduce losses, dry faster and moreuniformly, 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 orracks, 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 thematerial. The collector can be as simple as a glazed box with a dark coloured interior toabsorb the solar energy that heats air. The air heated in the solar collector moves, eitherby natural convection or forced by a fan, up through the material being dried. The size ofthe 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 solarradiation available during the drying season.

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

Space And Water Heating

Livestock and diary operations often have substantial air and water heating requirements. Modern pig and poultry farms raise animals in enclosed buildings, where it is necessary tocarefully control temperature and air quality to maximize the health and growth of theanimals. These facilities need to replace the indoor air regularly to remove moisture, toxicgases 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 farmbuildings 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 preheatingwater going into a conventional water heater. Waterheating can account for as much as 25 percent of a typical family's energy costs and up to40 percent of the energy used in a typical dairy operation. A properly-sized solar waterheatingsystem could cut those costs in half.

There are four basic types of solar water-heater systems available. These systems sharethree similarities: a glazing (typically glass) over a dark surface to gather solar heat; oneor two tanks to store hot water; and associated plumbing with or without pumps tocirculate 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 thesystem when sensors detect freezing temperatures.

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

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

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

Greenhouse Heating

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

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

Remote Electricity Supply (Photovoltaic)

Solar electric, or photovoltaic (PV), systems convert sun light directly to electricity. Theywork any time the sun is shining, but more electricity is produced when they sun light ismore intensive and strikes the PV modules directly (as when rays of sunlight areperpendicular to the PV modules). They can also power an electrical appliance directly, orstore solar energy in a battery. In areas with no utility lines, PV systems are often cheaperand 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 cheaperfor 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 invery handy on farm and ranches, and is often the most cost-effective and lowmaintenancesolution at locations far from the nearest utility line. PV can be used topower lighting, electric fencing, small motors, aeration fans, gate-openers, irrigation valveswitches, automatic supplement feeders. Solar electric energy can be used to movesprinkler irrigation systems. PV systems are also extremely well-suitedfor pumping water for livestock in remote pasture, where electricity from power lines isunavailable. 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 pumpingoption in locations where there is no existing power line. They are exceptionally wellsuitedfor grazing operations to supply water to remote pastures. Simple PV powersystems run pumps directly when the

sun is shining, so they work hardest in the hotsummer months when they are needed most. Generally, batteries are not necessarybecause the water is stored in tanks or pumped to fields and used in the day time. Largerpumping 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 littlemaintenance. The size and cost of a PV water pumping system depends on the quality ofsolar energy available at the site, the pumping depth, the water demand, and systempurchase and installation costs, PV systems are very cost-effective for remote livestockwater supply, pond aeration, and small irrigation systems. For example, a system thatincludes a 128 watt PV array and a submersible pump can produce 750-1000 gallons ofwater per day from 200 foot drilled well**.**