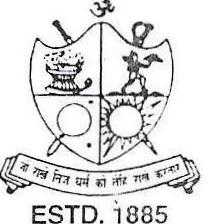
# F.E.T. R.B.S. COLLEGE AGRA

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**A REPORT**

**ON**

**Solar Energy**

**SUBMITTED TO: SUBMITTED BY:**

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**CH -3rd Year**

**0700451008**

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**CHEMICAL 3rd YEAR**

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**ABSTRACT**

Solar energy is the light and radiant heat from the Sun that influences Earth's climate and weather and sustains life. Solar power is the rate of solar energy at a point in time; it is sometimes used as a synonym for solar energy or more specifically to refer to electricity generated from solar radiation. Since ancient times solar energy has been harnessed for human use through a range of technologies. Solar radiation along with secondary solar resources such as wind and wave power, hydroelectricity and biomass account for most of the available flow of renewable energy on Earth.

Solar energy technologies can provide electrical generation by heat engine or photovoltaic means, daylighting, hot water, and space heating in active and passive solar buildings; potable water via distillation and disinfection, space cooling by absorption or vapor-compression refrigeration, thermal energy for cooking, and high temperature process heat for industrial purposes

**INTRODUCTION**

The word solar stems from the Roman word for the god of the sun, Sol. Therefore, the word solar refers to the Sun and “solar power” is power from the Sun.

When we say something is solar powered, we mean that the energy it uses for power came directly from solar energy or sunlight energy. The sun provides Earth with 2 major forms of energy, heat and light. Some solar powered systems utilize the heat energy for heating while others transform the light energy into electrical energy (electricity).

There are many practical applications for solar power that are in use today. Passive solar home designs utilize heat energy. By slanting windows in a house and facing them to the south you can control the heat energy that enters the house. During the winter when the Sun is low in the sky it shines into the window to warm and illuminate the house. During the summer when the Sun is high in the sky the slant of the windows keeps the sunshine out so that the house stays cooler.

There are vehicles that run on solar power. Some have PV panels as a direct power source that convert light energy into electricity to power their motors. Since those cars will not run when the sun is not available it is

more practical to have a car powered by batteries that can be recharged with solar energy.

In countries and locations where traditional power sources are not available it is more economical to power a house with solar energy. To these people, solar is not an alternative energy; it is their primary energy source.

**🡪ENERGY FROM SUN**

The Earth receives 174 petawatts (PW) of incoming solar radiation (insolation) at the upper atmosphere. Approximately 30&percnt; is reflected back to space while the rest is absorbed by clouds, oceans and land masses. The spectrum of solar light at the Earth's surface is mostly spread across the visible and near-infrared ranges with a small part in the near-ultraviolet.

The absorbed solar light heats the land surface, oceans and atmosphere. The warm air containing evaporated water from the oceans rises, driving atmospheric circulation or convection. When this air reaches a high altitude, where the temperature is low, water vapor condenses into clouds, which rain onto the earth's surface, completing the water cycle. The latent heat of water condensation amplifies convection, producing atmospheric phenomena such as cyclones and anti-cyclones. Wind is a manifestation of the atmospheric circulation driven by solar energy. Sunlight absorbed by the oceans and land masses keeps the surface at an average temperature of 14 °C. The conversion of solar energy into chemical energy via photosynthesis produces food, wood and the biomass from which fossil fuels are derived.[5]Yearly energy resources & annual energy consumption (TWh)

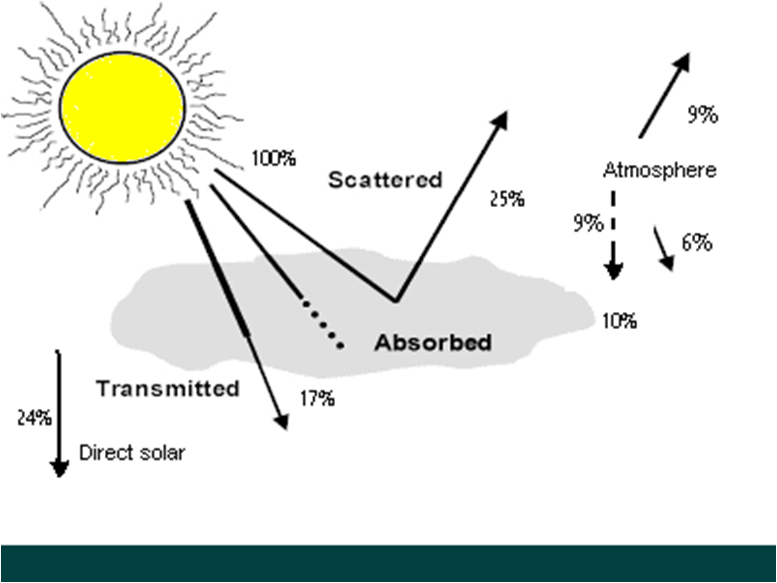
Solar energy absorbed by atmosphere, oceans and Earth[6] 751,296,000.0

Wind energy (technical potential) 221,000.0

Electricity (2005) -45.2

Primary energy use (2005) -369.7

Solar radiation along with secondary solar resources such as wind and wave power, hydroelectricity and biomass account for 99.97&percnt; of the available renewable energy on Earth. The total solar energy absorbed by Earth's atmosphere, oceans and land masses is approximately 3,850 zettajoules (ZJ) per year. In 2002, this was more energy in one hour than the world used in one year. Photosynthesis captures approximately 3 ZJ per year in biomass. The amount of solar energy reaching the surface of the planet is so vast that in one year it is about twice as much as will ever be obtained from all of the Earth's non-renewable resources of coal, oil, natural gas, and mined uranium combined.



From the table of resources it would appear that solar, wind or biomass would be sufficient to supply all of our energy needs, however, the increased use of biomass has had a negative effect on global warming and dramatically increased food prices by diverting forests and crops into biofuel production. As intermittent resources, solar and wind raise other issues.

**HISTORY**

**🡪The First Solar Motor**

The earliest known record of the direct conversion of solar radiation into mechanical power belongs to Auguste Mouchout, a mathematics instructor at the Lyce de Tours. Mouchout began his solar work in 1860 after expressing grave concerns about his country's dependence on coal. "It would be prudent and wise not to fall asleep regarding this quasi-security," he wrote. "Eventually industry will no longer find in Europe the resources to satisfy its prodigious expansion. Coal will undoubtedly be used up. What will industry do then?" By the following year he was granted the first patent for a motor running on solar power and continued to improve his design until about 1880. During this period the inventor laid the foundation for our modern understanding of converting solar radiation into mechanical steam power.

Mouchout's initial experiments involved a glass-enclosed iron cauldron: incoming solar radiation passed through the glass cover, and the trapped rays transmitted heat to the water. While this simple arrangement boiled water, it was of little practical value because the quantities and pressures of steam it produced were minimal. However, Mouchout soon discovered that by adding a reflector to concentrate additional radiation onto the cauldron, he could generate more steam. In late 1865, he succeeded in using his apparatus to operate a small, conventional steam engine.

By the following summer, Mouchout displayed his solar motor to Emperor Napoleon III in Paris. The monarch, favorably impressed, offered financial assistance for developing an industrial solar motor for France. With the newly acquired funds, Mouchout enlarged his invention's capacity, refined the reflector, redesigning it as a truncated cone, like a dish with slanted sides, to more accurately focus the sun's rays on the boiler. Mouchout also constructed a tracking mechanism that enabled the entire machine to follow the sun's altitude and azimuth, providing uninterrupted solar reception. After six years of work, Mouchout exhibited his new machine in the library courtyard of his Tours home in 1872, amazing spectators. One reporter described the reflector as an inverted "mammoth lamp shade...coated on the inside with very thin silver leaf" and the boiler sitting in the middle as an "enormous thimble" made of blackened copper and "covered with a glass bell."

Anxious to put his invention to work, he connected the apparatus to a steam engine that powered a water pump. On what was deemed "an exceptionally hot day," the solar motor produced one-half horsepower. Mouchout reported the results and findings to the French Academy of Science. The government, eager to exploit the new invention to its fullest potential, decided that the most suitable venue for the new machine would be the tropical climes of the French protectorate of Algeria, a region blessed with almost constant sunshine and entirely dependent on coal, a prohibitively expensive commodity in the African region.

Mouchout was quickly deployed to Algeria with ample funding to construct a large solar steam engine. He first decided to enlarge his invention's capacity yet again to 100 liters (70 for water and 30 for steam) and employ a multi-tubed boiler instead of the single cauldron. The boiler tubes had a better surface-area-to-water ratio, yielding more pressure and improved engine performance.

In 1878, Mouchout exhibited the redesigned invention at the Paris Exposition. Perhaps to impress the audience or, more likely, his government backers, he coupled the steam engine to a refrigeration device. The steam from the solar motor, after being routed through a condenser, rapidly cooled the inside of a separate insulated compartment. He explained the result: "In spite of the seeming paradox of the statement, [it was] possible to utilize the rays of the sun to make ice." Mouchout was awarded a medal for his accomplishments.

**🡪The Tower of Power**

During the height of Mouchout's experimentation, William Adams, the deputy registrar for the English Crown in Bombay, India, wrote an award-winning book entitled Solar Heat: A Substitute for Fuel in Tropical Countries. Adams noted that he was intrigued with Mouchout's solar steam engine after reading an account of the Tours demonstration, but that the invention was impractical, since "it would be impossible to construct [a dish-shaped reflector] of much greater dimensions" to generate more than Mouchout's one-half horsepower. The problem, he felt, was that the polished metal reflector would tarnish too easily, and would be too costly to build and too unwieldy to efficiently track the sun.

Fortunately for the infant solar discipline, the English registrar did not spend all his time finding faults in the French inventor's efforts, but offered some creative solutions. For example, Adams was convinced that a reflector of flat silvered mirrors arranged in a semicircle would be cheaper to construct and easier to maintain. His plan was to build a large rack of many small mirrors and adjust each one to reflect sunlight in a specific direction. To track the sun's movement, the entire rack could be rolled around a semicircular track, projecting the concentrated radiation onto a stationary boiler. The rack could be attended by a laborer and would have to be moved only "three or four times during the day," Adams noted, or more frequently to improve performance.

Confident of his innovative arrangement, Adams began construction in late 1878. By gradually adding 17-by-10-inch flat mirrors and measuring the rising temperatures, he calculated that to generate the 1,200Ã» F necessary to produce steam pressures high enough to operate conventional engines, the reflector would require 72 mirrors. To demonstrate the power of the concentrated radiation, Adams placed a piece of wood in the focus of the mirrored panes where, he noted, "it ignited immediately." He then arranged the collectors around a boiler, retaining Mouchout's enclosed cauldron configuration, and connected it to a 2.5-horsepower steam engine that operated during daylight hours "for a fortnight in the compound of [his] bungalow."

Eager to display his invention, Adams notified newspapers and invited his important friends--including the Army's commander in chief, a colonel from the Royal Engineers, the secretary of public works, various justices, and principal mill owners--to a demonstration. Adams wrote that all were impressed, even the local engineers who, while doubtful that solar power could compete directly with coal and wood, thought it could be a practical supplemental energy source.

Adams's experimentation ended soon after the demonstration, though, perhaps because he had achieved his goal of proving the feasibility of his basic design, but more likely because, as some say, he lacked sufficient entrepreneurial drive. Even so, his legacy of producing a powerful and versatile way to harness and convert solar heat survives. Engineers today know this design as the Power Tower concept, which is one of the best configurations for large scale, centralized solar plants. In fact, most of the modern tower-type solar plants follow Adams's basic configuration: flat or slightly curved mirrors that remain stationary or travel on a semicircular track and either reflect light upward to a boiler in a receiver tower or downward to a boiler at ground level, thereby generating steam to drive an accompanying heat engine.

**🡪Collection without Reflection**

Even with Mouchout's abandonment and the apparent disenchantment of England's sole participant, Europe continued to advance the practical application of solar heat, as the torch returned to France and engineer Charles Tellier. Considered by many the father of refrigeration, Tellier actually began his work in refrigeration as a result of his solar experimentation, which led to the design of the first non-concentrating, or non-reflecting, solar motor.

In 1885, Tellier installed a solar collector on his roof similar to the flat-plate collectors placed atop many homes today for heating domestic water. The collector was composed of ten plates, each consisting of two iron sheets riveted together to form a watertight seal, and connected by tubes to form a single unit. Instead of filling the plates with water to produce steam, Tellier chose ammonia as a working fluid because of its significantly lower boiling point. After solar exposure, the containers emitted enough pressurized ammonia gas to power a water pump he had placed in his well at the rate of some 300 gallons per hour during daylight. Tellier considered his solar water pump practical for anyone with a south-facing roof. He also thought that simply adding plates, thereby increasing the size of the system, would make industrial applications possible.

By 1889 Tellier had increased the efficiency of the collectors by enclosing the top with glass and insulating the bottom. He published the results in The Elevation of Water with the Solar Atmosphere, which included details on his intentions to use the sun to manufacture ice. Like his countryman Mouchout, Tellier envisioned that the large expanses of the African plains could become industrially and agriculturally productive through the implementation of solar power.

In The Peaceful Conquest of West Africa, Tellier argued that a consistent and readily available supply of energy would be required to power the machinery of industry before the French holdings in Africa could be properly developed. He also pointed out that even though the price of coal had fallen since Mouchout's experiments, fuel continued to be a significant expense in French operations in Africa. He therefore concluded that the construction costs of his low-temperature, non-concentrating solar motor were low enough to justify its implementation. He also noted that his machine was far less costly than Mouchout's device, with its dish-shaped reflector and complicated tracking mechanism.

Yet despite this potential, Tellier evidently decided to pursue his refrigeration interests instead, and do so without the aid of solar heat. Most likely the profits from conventionally operated refrigerators proved irresistible. Also, much of the demand for the new cooling technology now stemmed from the desire to transport beef to Europe from North and South America. The rolling motion of the ships combined with space limitations precluded the use of solar power altogether. And as Tellier redirected his focus, France saw the last major development of solar mechanical power on her soil until well into the twentieth century. Most experimentation in the fledgling discipline crossed the Atlantic to that new bastion of mechanical ingenuity, the United States.

**🡪The Parabolic Trough**

Though Swedish by birth, John Ericsson was one of the most influential and controversial U.S. engineers of the nineteenth century. While he spent his most productive years designing machines of war--his most celebrated accomplishment was the Civil War battleship the Monitor--he dedicated the last 20 years of his life largely to more peaceful pursuits such as solar power. This work was inspired by a fear shared by virtually all of his fellow solar inventors that coal supplies would someday end. In 1868 he wrote, "A couple of thousand years dropped in the ocean of time will completely exhaust the coal fields of Europe, unless, in the meantime, the heat of the sun be employed."

Thus by 1870 Ericsson had developed what he claimed to be the first solar-powered steam engine, dismissing Mouchout's machine as "a mere toy." In truth, Ericsson's first designs greatly resembled Mouchout's devices, employing a conical, dish-shaped reflector that concentrated solar radiation onto a boiler and a tracking mechanism that kept the reflector directed toward the sun.

Though unjustified in claiming his design original, Ericsson soon did invent a novel method for collecting solar rays--the parabolic trough. Unlike a true parabola, which focuses solar radiation onto a single, relatively small area, or focal point, like a satellite television dish, a parabolic trough is more akin to an oil drum cut in half lengthwise that focuses solar rays in a line across the open side of the reflector. This type of reflector offered many advantages over its circular (dish-shaped) counterparts: it was comparatively simple, less expensive to construct, and, unlike a circular reflector, had only to track the sun in a single direction (up and down, if lying horizontal, or east to west if standing on end), thus eliminating the need for complex tracking machinery. The downside was that the device's temperatures and efficiencies were not as high as with a dish-shaped reflector, since the configuration spread radiation over a wider area--a line rather than a point. Still, when Ericsson constructed a single linear boiler (essentially a pipe), placed it in the focus of the trough, positioned the new arrangement toward the sun, and connected it to a conventional steam engine, he claimed the machine ran successfully, though he declined to provide power ratings.

The new collection system became popular with later experimenters and eventually became a standard for modern plants. In fact, the largest solar systems in the last decade have opted for Ericsson's parabolic trough reflector because it strikes a good engineering compromise between efficiency and ease of operation.

For the next decade, Ericsson continued to refine his invention, trying lighter materials for the reflector and simplifying its construction. By 1888, he was so confident of his designs practical performance that he planned to mass-produce and supply the apparatus to the "owners of the sun burnt lands on the Pacific coast" for agricultural irrigation.

Unfortunately for the struggling discipline, Ericsson died the following year. And because he was a suspicious and, some said, paranoid man who kept his designs to himself until he filed patent applications, the detailed plans for his improved sun motor died with him. Nevertheless, the search for a practical solar motor was not abandoned. In fact, the experimentation and development of large-scale solar technology was just beginning.

**🡪Moonlight Operation**

Eneas's company folded. In his opinion, the lessons of Mouchout, Adams, Ericsson, and Eneas proved the cost inefficiency of high-temperature, concentrating machines. He was convinced that a non-reflective, lower-temperature collection system similar to Tellier's invention was the best method for directly utilizing solar heat. The inventor also felt that a solar motor would never be practical unless it could operate around the clock. Thus thermal storage, a practice that lent itself to low-temperature operation, was the focus of his experimentation.

To store the sun's energy, Willsie built large flat-plate collectors that heated hundreds of gallons Henry E. Willsie began his solar motor construction a year before of water, which he kept warm all night in a huge insulated basin. He then submerged a series of tubes, or vaporizing pipes, inside the basin to serve as boilers. When the acting medium--Willsie preferred sulfur dioxide to Tellier's ammonia--passed through the pipes, it transformed into a high-pressure vapor, which passed to the engine, operated it, and exhausted into a condensing tube, where it cooled, returned to a liquid state, and was reused.

In 1904, confident that his design would produce continuous power, he built two plants, a 6-horsepower facility in St. Louis, Mo., and a 15-horsepower operation in Needles, Calif. And after several power trials, Willsie decided to test the storage capacity of the larger system. After darkness had fallen, he opened a valve that "allowed the solar-heated water to flow over the exchanger pipes and thus start up the engine." Willsie had created the first solar device that could operate at night using the heat gathered during the day. He also announced that the 15-horsepower machine was the most powerful arrangement constructed up to that time. Beside offering a way to provide continuous solar power production, Willsie also furnished detailed cost comparisons to justify his efforts: the solar plant exacted a two-year payback period, he claimed, an exceptional value even when compared with today's standards for alternative energy technology.

Originally, like Ericsson and Eneas before him, Willsie planned to market his device for desert irrigation. But in his later patents Willsie wrote that the invention was "designed for furnishing power for electric light and power, refrigerating and ice making, for milling and pumping at mines, and for other purposes where large amounts of power are required."

Willsie determined all that was left to do was to offer his futurist invention for sale. Unfortunately, no buyers emerged. Despite the favorable long-term cost analysis, potential customers were suspicious of the machine's durability, deterred by the high ratio of machine size to power output, and fearful of the initial investment cost of Willsie's ingenious solar power plant. His company, like others before it, disintegrated.

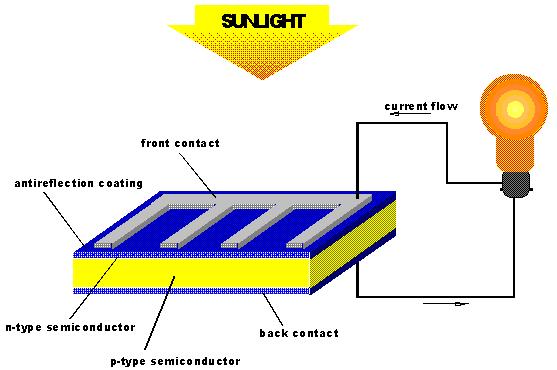
Europe's colonial holdings, and the upper regions of Africa were soon engulfed. Shuman's solar irrigation plant was destroyed, the engineers associated with the project returned to their respective countries to perform war-related tasks, and Frank Shuman died before the armistice was signed.

Whether or not Shuman's device would have initiated the commercial success that solar power desperately needed, we will never know. However, the Sun Power Co. can boast a certain technical maturity by effectively synthesizing the ideas of its predecessors from the previous 50 years. The company used an absorber (though in linear form) of Tellier and Willsie, a reflector similar to Ericsson's, simple tracking mechanisms first used by Mouchout and later employed by Eneas, and combined them to operate an engine specially designed to run with solar-generated steam.

**APPLICATIONS OF SOLAR ENERGY**

**🡪PHOTOVOLTAIC ENERGY**

Photovoltaic energy is the conversion of sunlight into electricity. A photovoltaic cell, commonly called a solar cell or PV, is the technology used to convert solar energy directly into electrical power. A photovoltaic cell is a nonmechanical device usually made from silicon alloys.



Sunlight is composed of photons, or particles of solar energy. These photons contain various amounts of energy corresponding to the different wavelengths of the solar spectrum. When photons strike a photovoltaic cell, they may be reflected, pass right through, or be absorbed. Only the absorbed photons provide energy to generate electricity. When enough sunlight (energy) is absorbed by the material (a semiconductor), electrons are dislodged from the material's atoms. Special treatment of the material surface during manufacturing makes the front surface of the cell more receptive to free electrons, so the electrons naturally migrate to the surface.

When the electrons leave their position, holes are formed. When many electrons, each carrying a negative charge, travel toward the front surface of the cell, the resulting imbalance of charge between the cell's front and back surfaces creates a voltage potential like the negative and positive terminals of a battery. When the two surfaces are connected through an external load, electricity flows.

The photovoltaic cell is the basic building block of a photovoltaic system. Individual cells can vary in size from about 1 centimeter (1/2 inch) to about 10 centimeter (4inches) across. However, one cell only produces 1 or 2 watts, which isn't enough power for most applications. To increase power output, cells are electrically connected into a packaged weather-tight module. Modules can be further connected to form an array. The term array refers to the entire generating plant, whether it is made up of one or several thousand modules. The number of modules connected together in an array depends on the amount of power output needed.

The performance of a photovoltaic array is dependent upon sunlight. Climate conditions (e.g., clouds, fog) have a significant effect on the amount of solar energy received by a photovoltaic array and, in turn, its performance. Most current technology photovoltaic modules are about 10 percent efficient in converting sunlight. Further research is being conducted to raise this efficiency to 20 percent.

The photovoltaic cell was discovered in 1954 by Bell Telephone researchers examining the sensitivity of a properly prepared silicon wafer to sunlight. Beginning in the late 1950s, photovoltaic cells were used to power U.S. space satellites (learn more about the history of photovaltaic cells). The success of PV in space generated commercial applications for this technology. The simplest photovoltaic systems power many of the small calculators and wrist watches used everyday. More complicated systems provide electricity to pump water, power communications equipment, and even provide electricity to our homes.

Some advantages of photovoltaic systems are:

Conversion from sunlight to electricity is direct, so that bulky mechanical generator systems are unnecessary.

PV arrays can be installed quickly and in any size required or allowed.

The environmental impact is minimal, requiring no water for system cooling and generating no by-products.

Photovoltaic cells, like batteries, generate direct current (DC) which is generally used for small loads (electronic equipment). When DC from photovoltaic cells is used for commercial applications or sold to electric utilities using the electric grid, it must be converted to alternating current (AC) using inverters, solid state devices that convert DC power to AC.

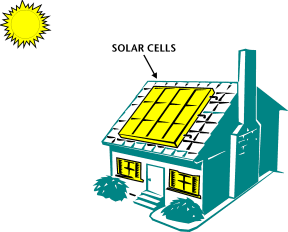
Historically, PV has been used at remote sites to provide electricity. In the future PV arrays may be located at sites that are also connected to the electric grid enhancing the reliability of the distribution system.

**🡪SOLAR THERMAL HEAT**

Solar thermal(heat) energy is often used for heating swimming pools, heating water used in homes, and space heating of buildings. Solar space heating systems can be classified as passive or active.

Passive space heating is what happens to your car on a hot summer day. In buildings, the air is circulated past a solar heat surface(s) and through the building by convection (i.e. less dense warm air tends to rise while more dense cooler air moves downward) . No mechanical equipment is needed for passive solar heating.

Active heating systems require a collector to absorb and collect solar radiation. Fans or pumps are used to circulate the heated air or heat absorbing fluid. Active systems often include some type of energy storage system.



Solar collectors can be either nonconcentrating or concentrating.

1) Nonconcentrating collectors – have a collector area (i.e. the area that intercepts the solar radiation) that is the same as the absorber area (i.e., the area absorbing the radiation). Flat-plate collectors are the most common and are used when temperatures below about 200o degrees F are sufficient, such as for space heating.

2) Concentrating collectors – where the area intercepting the solar radiation is greater, sometimes hundreds of times greater, than the absorber area.

**🡪SOLAR WATER HEATER.**

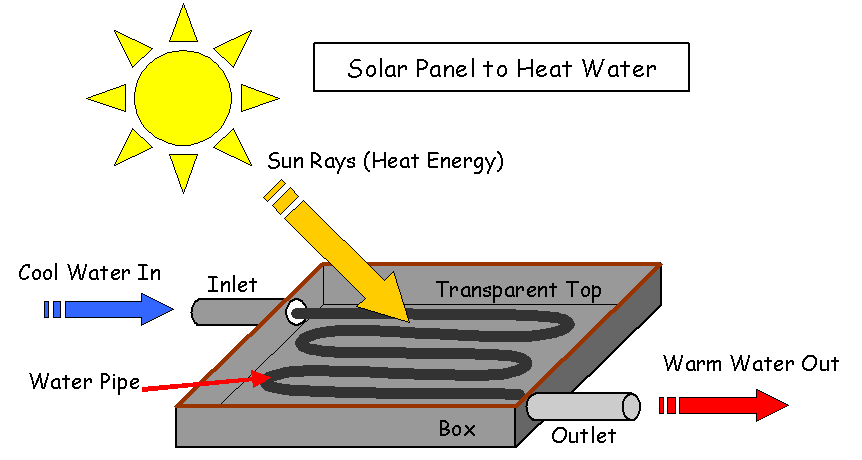
A solar water heater uses the sun's energy rather than electricity or gas to heat water, thus reducing your monthly utility bill. When installed properly, solar water heaters are more economical over the life of the system than heating water with electricity, dedicated heat pumps, heat recovery units or propane.

In Florida, three types of solar systems are used: pumped, integral collector storage (ICS), and thermo-siphon. The direct circulation system circulates potable water from the water storage tank through one or more collectors and back into the tank. The solar collector is the main component of the solar system. It is usually a metal box with insulation and a black absorber plate that collects solar radiation and heats the water. The circulating pump is regulated by either an electronic controller, a common appliance timer, or a photovoltaic (PV) panel.

n integral collector storage systems, the solar water storage system is built into the collector. The potable water in the collector unit is heated by the sun and delivered by city or well water pressure to an auxiliary tank (which contains non-solar back-up heating) or directly to the point of use.

A thermosiphon solar water heating system has a tank mounted above the collector (normally on the roof) tothe tank provide a natural gravity flow of water. Hot water rises through piping in the collector, which is mounted below**;** heavier cold water sinks to the lowest point in the system (the collector), displacing the lighter hot water which rises to the tank.

The ICS and thermosiphon systems are simple since they use no pumps or controllers and water always flows through the collector.



As sunshine strikes the collector, the water inside it is heated. If the circulating pump is regulated by a PV panel, the pump starts turning as the PV panel is activated by the same sunshine. This direct current (DC) motor pump moves water from the tank through the collector and back to the tank. As the sun's intensity changes throughout the day, the circulating pump also changes its speed accordingly. By the end of the day, the water in the tank has been circulated many times through the collector and has been heated to usable hot water temperatures.

If the circulating pump is regulated by an electronic differential controller, a sensor at the outlet of the collector and a sensor at the bottom of the tank (Figure 1) activate the circulating pump when the water in the collector is about 15-200 F warmer than the water at the bottom of the tank. The pump then circulates water from the collector and the tank. This process continues as long as the water temperature at the collector outlet is about 50 F higher than that in the bottom of the tank. If the temperature difference decreases further, the controller automatically shuts off the pump.

Common appliance timers also may control system operation. The timer is set to operate during a period of the day when solar radiation is available to heat the potable water. It is important that the timers used in these systems incorporate battery back-up in the event of power failures. In order to avoid loss of energy from the tank during overcast days, the collector feed and return lines are both connected at the bottom of the storage tank. During normal operation, natural stratification allows the warmer water to rise to the top part of the tank.

During periods of insufficient sunshine or high hot water demand, a backup electrical element in the storage tank heats the water. The check valve prevents heat loss when the circulating pump is off. The circulating pump consumes only a small amount of electricity - around $5 to $10 worth per year, or in the case of PV - none.

**🡪SOLAR COOKER**

Solar cookers use sunlight for cooking, drying and pasteurization. They can be grouped into three broad categories: box cookers, panel cookers and reflector cookers.The simplest solar cooker—the box cooker first built by Horace de Saussure in 1767. A basic box cooker consists of an insulated container with a transparent lid. It can be used effectively with partially overcast skies and will typically reach temperatures of 90–150 °C. Panel cookers use a reflective panel to direct sunlight onto an insulated container and reach temperatures comparable to box cookers. Reflector cookers use various concentrating geometries (dish, trough, Fresnel mirrors) to focus light on a cooking container. These cookers reach temperatures of 315 °C and above but require direct light to function properly and must be repositioned to track the Sun.

The solar bowl is a concentrating technology employed by the Solar Kitchen in Auroville, India, where a stationary spherical reflector focuses light along a line perpendicular to the sphere's interior surface, and a computer control system moves the receiver to intersect this line. Steam is produced in the receiver at temperatures reaching 150 °C and then used for process heat in the kitchen.

A reflector developed by Wolfgang Scheffler in 1986 is used in many solar kitchens. Scheffler reflectors are flexible parabolic dishes that combine aspects of trough and power tower concentrators. Polar tracking is used to follow the Sun's daily course and the curvature of the reflector is adjusted for seasonal variations in the incident angle of sunlight. These reflectors can reach temperatures of 450–650 °C and have a fixed focal point, which simplifies cooking. The world's largest Scheffler reflector system in Abu Road, Rajasthan, India is capable of cooking up to 35,000 meals a day. 

**🡪SOLAR VEHICLES**

Development of a solar powered car has been an engineering goal since the 1980s. The World Solar Challenge is a biannual solar-powered car race, where teams from universities and enterprises compete over 3,021 kilometres (1,877 mi) across central Australia from Darwin to Adelaide. In 1987, when it was founded, the winner's average speed was 67 kilometres per hour (42 mph) and by 2007 the winner's average speed had improved to 90.87 kilometres per hour (56.46 mph). The North American Solar Challenge and the planned South African Solar Challenge are comparable competitions that reflect an international interest in the engineering and development of solar powered vehicles.

Some vehicles use solar panels for auxiliary power, such as for air conditioning, to keep the interior cool, thus reducing fuel consumption.

In 1975, the first practical solar boat was constructed in England. By 1995, passenger boats incorporating PV panels began appearing and are now used extensively. In 1996, Kenichi Horie made the first solar powered crossing of the Pacific Ocean, and the sun21 catamaran made the first solar powered crossing of the Atlantic Ocean in the winter of 2006–2007. There are plans to circumnavigate the globe in 2010.

Helios UAV in solar powered flight

In 1974, the unmanned Sunrise II plane made the first solar flight. On 29 April 1979, the Solar Riser made the first flight in a solar powered, fully controlled, man carrying flying machine, reaching an altitude of 40 feet (12 m). In 1980, the Gossamer Penguin made the first piloted flights powered solely by photovoltaics. This was quickly followed by the Solar Challenger which crossed the English Channel in July 1981. In 1990 Eric Raymond in 21 hops flew from California to North Carolina using solar power. Developments then turned back to unmanned aerial vehicles (UAV) with the Pathfinder (1997) and subsequent designs, culminating in the Helios which set the altitude record for a non-rocket-propelled aircraft at 29,524 metres (96,860 ft) in 2001. The Zephyr, developed by BAE Systems, is the latest in a line of record-breaking solar aircraft, making a 54-hour flight in 2007, and month-long flights are envisioned by 2010.



A solar balloon is a black balloon that is filled with ordinary air. As sunlight shines on the balloon, the air inside is heated and expands causing an upward buoyancy force, much like an artificially-heated hot air balloon. Some solar balloons are large enough for human flight, but usage is generally limited to the toy market as the surface-area to payload-weight ratio is relatively high.

Solar sails are a proposed form of spacecraft propulsion using large membrane mirrors to exploit radiation pressure from the Sun. Unlike rockets, solar sails require no fuel. Although the thrust is small compared to rockets, it continues as long as the Sun shines onto the deployed sail and in the vacuum of space significant speeds can eventually be achieved.

The High-altitude airship (HAA) is an unmanned, long-duration, lighter-than-air vehicle using helium gas for lift, and thin-film solar cells for power. The United States Department of Defense Missile Defense Agency has contracted Lockheed Martin to construct it to enhance the Ballistic Missile Defense System (BMDS). Airships have some advantages for solar-powered flight: they do not require power to remain aloft, and an airship's envelope presents a large area to the Sun.

**🡪AGRICULTURE & HORTICULTURE**

Agriculture seeks to optimize the capture of solar energy in order to optimize the productivity of plants. Techniques such as timed planting cycles, tailored row orientation, staggered heights between rows and the mixing of plant varieties can improve crop yields. While sunlight is generally considered a plentiful resource, the exceptions highlight the importance of solar energy to agriculture. During the short growing seasons of the Little Ice Age, French and English farmers employed fruit walls to maximize the collection of solar energy. These walls acted as thermal masses and accelerated ripening by keeping plants warm. Early fruit walls were built perpendicular to the ground and facing south, but over time, sloping walls were developed to make better use of sunlight. In 1699, Nicolas Fatio de Duillier even suggested using a tracking mechanism which could pivot to follow the Sun. Applications of solar energy in agriculture aside from growing crops include pumping water, drying crops, brooding chicks and drying chicken manure.

Greenhouses convert solar light to heat, enabling year-round production and the growth (in enclosed environments) of specialty crops and other plants not naturally suited to the local climate. Primitive greenhouses were first used during Roman times to produce cucumbers year-round for the Roman emperor Tiberius. The first modern greenhouses were built in Europe in the 16th century to keep exotic plants brought back from explorations abroad. Greenhouses remain an important part of horticulture today, and plastic transparent materials have also been used to similar effect in polytunnels and r ow covers.



**🡪WATER TREATMENT**

Solar distillation can be used to make saline or brackish water potable. The first recorded instance of this was by 16th century Arab alchemists. A large-scale solar distillation project was first constructed in 1872 in the Chilean mining town of Las Salinas. The plant, which had solar collection area of 4,700 m², could produce up to 22,700 L per day and operated for 40 years. Individual still designs include single-slope, double-slope (or greenhouse type), vertical, conical, inverted absorber, multi-wick, and multiple effect. These stills can operate in passive, active, or hybrid modes. Double-slope stills are the most economical for decentralized domestic purposes, while active multiple effect units are more suitable for large-scale applications.



Solar water disinfection (SODIS) involves exposing water-filled plastic polyethylene terephthalate (PET) bottles to sunlight for several hours. Exposure times vary depending on weather and climate from a minimum of six hours to two days during fully overcast conditions. SODIS is recommended by the World Health Organization as a viable method for household water treatment and safe storage. Over two million people in developing countries use SODIS for their daily drinking water.

Small scale solar powered sewerage treatment plant

Solar energy may be used in a water stabilisation pond to treat waste water without chemicals or electricity. A further environmental advantage is that algae grow in such ponds and consume carbon dioxide in photosynthesis.

**🡪SOLAR LIGHTING**

The history of lighting is dominated by the use of natural light. The Romans recognized a right to light as early as the 6th century and English law echoed these judgments with the Prescription Act of 1832. In the 20th century artificial lighting became the main source of interior illumination but daylighting techniques and hybrid solar lighting solutions are ways to reduce energy consumption.

Daylighting systems collect and distribute sunlight to provide interior illumination. This passive technology directly offsets energy use by replacing artificial lighting, and indirectly offsets non-solar energy use by reducing the need for air-conditioning. Although difficult to quantify, the use of natural lighting also offers physiological and psychological benefits compared to artificial lighting. Daylighting design implies careful selection of window types, sizes and orientation; exterior shading devices may be considered as well. Individual features include sawtooth roofs, clerestory windows, light shelves, skylights and light tubes. They may be incorporated into existing structures, but are most effective when integrated into a solar design package that accounts for factors such as glare, heat flux and time-of-use. When daylighting features are properly implemented they can reduce lighting-related energy requirements by 25&percnt;



Hybrid solar lighting is an active solar method of providing interior illumination. HSL systems collect sunlight using focusing mirrors that track the Sun and use optical fibers to transmit it inside the building to supplement conventional lighting. In single-story applications these systems are able to transmit 50&percnt; of the direct sunlight received.

Solar lights that charge during the day and light up at dusk are a common sight along walkways.[citation needed]

Although daylight saving time is promoted as a way to use sunlight to save energy, recent research has been limited and reports contradictory results: several studies report savings, but just as many suggest no effect or even a net loss, particularly when gasoline consumption is taken into account. Electricity use is greatly affected by geography, climate and economics, making it hard to generalize from single studies.[36]

**🡪SOLAR ENERGY STORAGE.**

Storage is an important issue in the development of solar energy because modern energy systems usually assume continuous availability of energy.[122] Solar energy is not available at night, and the performance of solar power systems is affected by unpredictable weather patterns; therefore, storage media or back-up power systems must be used.

Thermal mass systems can store solar energy in the form of heat at domestically useful temperatures for daily or seasonal durations. Thermal storage systems generally use readily available materials with high specific heat capacities such as water, earth and stone. Well-designed systems can lower peak demand, shift time-of-use to off-peak hours and reduce overall heating and cooling requirements.

Phase change materials such as paraffin wax and Glauber's salt are another thermal storage media. These materials are inexpensive, readily available, and can deliver domestically useful temperatures (approximately 64 °C). The "Dover House" (in Dover, Massachusetts) was the first to use a Glauber's salt heating system, in 1948.



Solar energy can be stored at high temperatures using molten salts. Salts are an effective storage medium because they are low-cost, have a high specific heat capacity and can deliver heat at temperatures compatible with conventional power systems. The Solar Two used this method of energy storage, allowing it to store 1.44 TJ in its 68 m³ storage tank with an annual storage efficiency of about 99&percnt;.

Off-grid PV systems have traditionally used rechargeable batteries to store excess electricity. With grid-tied systems, excess electricity can be sent to the transmission grid. Net metering programs give these systems a credit for the electricity they deliver to the grid. This credit offsets electricity provided from the grid when the system cannot meet demand, effectively using the grid as a storage mechanism.

Pumped-storage hydroelectricity stores energy in the form of water pumped when energy is available from a lower elevation reservoir to a higher elevation one. The energy is recovered when demand is high by releasing the water to run through a hydroelectric power generator.

**CONCLUSION**

**Argument that sun provides power only during the day is countered by the fact that 70% of energy demand is during daytime hours. At night, traditional methods can be used to generate the electricity.**

**Goal is to decrease our dependence on fossil fuels.**

**Currently, 75% of our electrical power is generated by coal-burning and nuclear power plants.**

**Mitigates the effects of acid rain, carbon dioxide, and other impacts of burning coal and counters risks associated with nuclear energy.**

**pollution free, indefinitely sustainable**

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