**Solar Energy: For Sustainable Future**

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**Abstract**

The most promising and cleanest source of renewable energy is solar energy. To capture and use this potent energy resource efficiently, numerous devices have been created. Although the technology has a larger range of applications, it is still not cost-effective. For home and commercial usage, green fuel energy can be produced by collecting solar energy, which not only helps to meet energy needs but also contributes to lowering greenhouse gas emissions and battling climate change. Effective use of solar energy must be made to offset the expensive and finite non-renewable energy supplies, and research must be done to lower installation costs so that it effectively reaches people in the middle class and has a positive impact on climate change.

**Key words---** Solar energy, renewable energy, sustainable resource

**Introduction**

Alternative energy is a type of energy that isn't derived from fossil fuels but is instead sustainable or renewable and doesn't deplete finite resources. According to Encarta Encyclopaedia (2009 edition) and Encyclopaedia Britannica (2013 edition), renewable energy sources include biomass (biofuel), hot springs (geothermal), the sun (solar), tides (tidal), ocean thermal conversion (OTEC), wave, rivers (hydroelectric), and wind. The only energy sources that are environmentally friendly are solar and wind power (Fitzner, 2019), which are frequently seen blindly by those who support the environment.

With ever-increasing efficiency, sunlight, wind, and other renewable resources are transformed into usable forms of energy. Although they still only account for 14% of the world's total energy supply, the new technologies seem to be developing quickly. According to many experts, moving away from fossil fuels and toward renewable, carbon-free energy sources would significantly help address the issues of depleting oil supplies and potentially catastrophic environmental effects. A change like this might usher in the era of renewable energy in the twenty-first century. Understanding the advantages and disadvantages of solar energy plants' effects on the environment is made easier by this study. Burning fossil fuels has a lot of detrimental effects on the environment.

Air pollutants, particulate matter, and harmful compounds are released into the atmosphere by fossil fuel power plants as well as by fossil fuel powered cars. Heart disease, asthma, and other health issues in humans can be brought on by exposure to these contaminants. Additionally, the emissions from burning fossil fuels cause acid rain, which has harmed aquatic life in many lakes and forests, damaged many forests' leaves, and produced pollution in or around many metropolitan areas. Carbon dioxide (CO2), one of the primary greenhouse gases responsible for global warming, is released by the burning of fossil fuels (Encyclopaedia Britannica, 2013; Whitney, 2009). Production of solar energy through photovoltaics increased at a rate of 25 to 30 percent annually, and wind power saw growth of over 30 percent.

**Solar Energy**

Sunlight is by far the most powerful energy source that the Earth receives, and the Sun is a very potent energy source. Although solar energy is free, it is not inexpensive. sun energy is any energy produced by sun power, whether it be electrical or thermal. The most significant source of natural energy is solar radiation, which powers all environmental activities taking place on Earth's surface.

The design of any solar energy system must consider the quantity and quality of solar energy that is present at a given area. Varying surfaces with varying orientations will be able to intercept different amounts of solar energy due to the relative motion of the sun with respect to the earth. The geometric relationship between the Earth and the Sun determines the quantity and intensity of solar radiation that reaches the Earth's surface. As seen in figure 2, the Sun maintains all life on Earth by supplying a vast quantity of energy as well as practically all of the heat and light that the planet receives. The oceans' energy reserves contribute to keeping the Earth's temperature at an equilibrium level that supports stability for a wide variety of life (Holladay, 2009). Solar energy is the Sun's radiation, which has the ability to create heat, trigger chemical reactions, or create electricity. The total solar energy incident on Earth is far greater than the global energy needs at the moment and in the future. In the 21st century solar energy is expected to become increasingly attractive as a [renewable energy](https://www.britannica.com/science/renewable-energy) source because of its inexhaustible supply and its non-polluting character, in stark contrast to the finite [fossil fuels](https://www.britannica.com/science/fossil-fuel) [coal](https://www.britannica.com/science/coal-fossil-fuel), [petroleum](https://www.britannica.com/science/petroleum), and [natural gas](https://www.britannica.com/science/natural-gas).



At the surface of the Earth, solar radiation is actually relatively weak. This is primarily due to the massive radial radiation propagating from the far-off Sun. Earth's atmosphere and clouds, which absorb or scatter as much as 54% of the incoming sunlight, cause a comparatively small additional loss. Nearly 50% of the sunlight that reaches the earth is visible light, followed by 45% infrared radiation, and lower amounts of ultraviolet and other electromagnetic radiation.



[**Solar energy potential**](https://cdn.britannica.com/27/198827-050-1C027B7D/Earth-power-potential.jpg)

The potential for solar energy is enormous, since about 200,000 times the world’s total daily electric-generating [capacity](https://www.britannica.com/dictionary/capacity) is received by Earth every day in the form of solar energy. Unfortunately, though solar energy itself is free, the high cost of its collection, conversion, and storage still limits its exploitation in many places. Solar radiation can be converted either into [thermal energy](https://www.britannica.com/science/thermal-energy) (heat) or into [electrical energy](https://www.britannica.com/technology/electric-power), though the former is easier to accomplish.

The world's energy needs are rapidly expanding due to population growth and technological improvements. In order to meet future energy demand, it is crucial to choose a sustainable energy source that is dependable, affordable, and long-lasting. In addition to other renewable energy sources, solar energy is a potential and cost-free energy source that can be used to address long-term energy crisis difficulties. Because of the tremendous demand for energy and the scarcity of fossil fuels and the high cost of other energy sources, the solar sector is expanding gradually on a global scale. Since it is now affordable as a result of extensive, vigorous research done to hasten its development, it has evolved into a tool to improve the economic standing of developing countries and to support the lives of numerous impoverished people. Given that solar energy is better to other renewable energy sources in terms of availability, affordability, accessibility, capacity, and efficiency, it would unquestionably be the best option for meeting future energy demand. In order to address the energy issue, this chapter examines the necessity for the solar industry along with its essential ideas, the global energy scenario, highlights of research done to improve the solar industry, its possible uses, and impediments for a better solar business in the future.

Solar energy is the Sun's radiation, which has the ability to create heat, trigger chemical reactions, or create electricity. The total solar energy received by Earth exceeds both current and future energy needs by a wide margin. Solar energy has the ability to meet all future energy needs if properly harnessed.

The sun emits more energy into the atmosphere in one hour than the entire planet does in a year. Sunlight is converted into useful energy for buildings using a variety of ways. Solar photovoltaics for electricity, passive solar architecture for space heating and cooling, and solar water heating are the most widely used solar technologies for residences and commercial buildings.

Solar technology helps businesses and industries diversify their energy sources, increase productivity, and cut costs. Solar photovoltaic and concentrating solar power technologies are used by utilities and energy producers to generate electricity on a large scale to power cities and small towns.

One of humanity's most pressing tasks is to create sustainable energy sources because the world's finite fossil fuel reserves are in direct conflict with rising energy demand. Solar energy is regarded as one of the most promising sustainable energy sources because of its limitless supply, universality, high capacity, and environmental friendliness. Natural solar radiation, however, is dispersed, sporadic, and continually varies. As a result, it is still very difficult to use solar energy effectively in a way that is economical, convenient, and clean.

Photothermal, photovoltaic, and photocatalytic methods all make use of solar energy. Solar energy could be used in a variety of industries by being converted via photo electrochemistry into chemical energy and fuels using artificial photosynthesis and photocatalytic chemical synthesis. Experts in the subject highlight current research and the field's future possibilities in this themed issue on improvements in solar energy conversion. The issue's focus, among other things, is on the logical design, manufacture, and sophisticated characterization of photoconversion system, material, process, and technology components.

**1. Solar Photovoltaic Technology Basics**

Photovoltaic or solar cells transform light from the sun directly into electricity. The photovoltaic effect, which is the conversion of light (photons) to electricity (voltage), gives the field of photovoltaics (commonly abbreviated as PV) its name. Scientists at Bell Laboratories were the first to take use of this phenomenon in 1954 when they developed a silicon solar cell that worked and could produce an electric current when exposed to light. Soon, solar cells were being utilized to power clocks, computers, and even space spacecraft. Today, photovoltaic systems are being installed on a massive scale to help power the electric grid. Electricity generated by solar cells is now economically viable in many places.

**A. Silicon Solar Cells**

## The majority of solar cells on the market today are silicon-based, have affordable pricing, and have high conversion efficiencies (the rate at which a solar cell converts sunlight into energy). In order to produce massive, utility-scale systems, these cells are typically put together into bigger modules that may be mounted on the rooftops of homes or businesses or used with ground-based racks.

## **B. Thin-Film Solar Cells**

Thin-film solar cells, another widely used photovoltaic technology, are built of incredibly thin layers of semiconductor material, such as copper-+indium gallium 0 d=--0-i10selenide or cadmium telluride. These cell layers are only a few micrometres thick, or a few millionths of a 108 meter, thick.

 Thin-film solar cells may be flexible and light, which makes them perfect for portable applications like a soldier's rucksack or for usage in other solar-powered items like windows. Thin-film solar cells can also benefit from manufacturing processes that use less energy and are simpler to scale up than those needed to produce silicon solar cells.

## **C. III-V Solar Cells**

## A third variety of photovoltaic technology bears the names of the constituent parts. Group III and Group V of the periodic table's elements, such as gallium and indium, and antimony and arsenic, are used primarily in the construction of III-V solar cells. The cost of manufacturing these solar cells is typically substantially higher than that of other methods. However, they have far better efficiency when turning sunlight into power. Due to its excellent power-to-weight ratio, these solar cells are frequently employed in satellites, unmanned aerial vehicles, and other devices.

## **D. Next-Generation Solar Cells**

## Researchers at NREL and other institutions are working on numerous novel photovoltaic technologies, including organic solar cells, quantum dots, and hybrid organic-inorganic materials (sometimes referred to as perovskites). These next-generation technologies might provide cheaper prices, easier manufacturing processes, or other advantages. If these promises can be fulfilled, more investigation is needed.

## **Reliability and Grid Integration Research**

## Making a high-efficiency, inexpensive solar cell is only one aspect of photovoltaic research. The solar panels that are installed on homes and businesses must be capable of producing electricity dependably for many years without degrading in performance. Utility companies and government regulators are interested in learning how to integrate solar PV systems into the electrical grid without upsetting the delicate balance between supply and demand for electricity.

## **2. Passive Solar Design**

A passive solar building uses south-facing windows to collect heat from the sun and stores that heat in materials throughout the building known as thermal mass.

A successful design must include the following elements:

* **An aperture is a huge glass area that lets light into a structure. It should face true south or within 30 degrees of it, and it shouldn't be shadowed between 9 and 3 in the afternoon during the heating season.**
* **Thermal mass—commonly comprised of tile, stone, brick, and concrete. During the heating season, these materials absorb heat from the sun, and during the cooling season, they also absorb heat from warm indoor air.**
* **Distribution: Using conduction, convection, and radiation, solar heat is moved from its storage location to various parts of the home.**
* **Control—means to shade the aperture area during the summer, such as roof overhangs.**

**A. Passive Solar Heating**

Passive solar heating systems capture sunlight within the building's materials and then release that heat during periods when the sun is absent, such as at night. South-facing glass and thermal mass to absorb, store, and distribute heat are necessary in the design.

## **B. Passive Solar Cooling**

## Passive solar cooling systems use shading, thermal mass, and natural ventilation to reduce unwanted daytime heat and store cool night air to moderate temperatures.

## **Additional Resources**

* [Passive Solar Home Design](https://www.energy.gov/energysaver/energy-efficient-home-design/passive-solar-home-design)
* [Sunrooms and Sunspaces](https://www.energy.gov/energysaver/sunrooms-and-sunspaces)
* [Energy Efficient Window Attachments](https://www.energy.gov/energysaver/energy-efficient-window-attachments)
* [Landscaping for Energy-Efficient Homes](https://www.energy.gov/energysaver/design/landscaping-energy-efficient-homes)

# C. Solar Water Heating

Sunlight is converted into an affordable method of producing hot water for residential structures using solar water heating. Utilizing solar thermal energy, these systems heat water in residences and commercial buildings. The three basic components of the systems—the solar collector, insulated pipework, and a hot water storage tank—can be installed in any environment to lower utility costs.

Although solar photovoltaic (PV) and solar water heating systems both use collector panels, they are two different technologies. Solar water heating systems use the sun's energy to heat water, whereas PV systems generate electricity.

Systems for heating water using the sun can be passive or active, depending on how the water is pumped around. In both home and business settings, active solar water heating systems are becoming prevalent. Systems for passive solar water heating are often less expensive but less effective.

# 3. Solar Process Heat Basics

To make them more energy efficient, commercial and industrial buildings can use solar process heat technologies for space and water heating, ventilation, and space cooling.

**A. Space Heating**

## Ventilation is necessary in many enormous constructions to maintain the cleanliness of the air. In frigid climates, heating this air can be quite energy-intensive. However, installing a solar ventilation system to warm the air can result in cost and energy savings. As the standard transpired collector in this form of solar energy collection system, a thin, black metal panel mounted on a south-facing wall acts as the solar energy collection device. Air can pass through the panel's countless microscopic holes. Behind the perforated wall, the air streams from the perforations might mix. The heated air is subsequently sucked from the top of the chamber into the ventilation system.

## **B. Water Heating**

## Large amounts of hot water can be produced using solar water heating systems for non-residential buildings. A typical system contains heat exchangers, pumps, and/or one or more sizable storage tanks in addition to solar collectors. An evacuated-tube collector and a linear concentrator are the two primary solar collector designs utilized for non-residential buildings. Both are highly efficient at operating at high temperatures. A collection of several glass tubes with double walls and reflectors to heat the fluid inside each tube makes up an evacuated-tube collector. The inner tube retains heat due to insulation provided by a vacuum between the two walls. In linear concentrators, sunlight is focused on tubes that run the length of long, rectangular, curved (U-shaped) mirrors that are slanted. The fluid inside the tubes is heated by the focused sunlight.

## **C. Space Cooling**

Space cooling can be accomplished using thermally activated cooling systems (TACS) driven by solar energy. Because of a high initial cost, TACS are not widespread. The two systems currently in operation are solar absorption systems and solar desiccant systems. Solar absorption systems use thermal energy to evaporate a refrigerant fluid to cool the air. In contrast, solar desiccant systems use thermal energy to regenerate desiccants that dry the air, thereby cooling the air. These systems also work well with evaporative coolers (also called "swamp coolers") in more humid climates.

# 4. Concentrating Solar Power Basics

## Using concentrated solar energy systems, enormous power plants can be powered by the heat from the sun. Fossil fuels are a common heat source used by power plants nowadays to boil water. In order to generate energy, a massive turbine is spun by the steam from the boiling water. A new generation of power plants, however, uses the sun as a heat source and concentrating solar power systems. The linear concentrator, dish/engine, and power tower systems are the three primary categories of concentrating solar power systems.

## **5. Linear Concentrator Systems**

The sun's energy is captured by linear concentrator systems using long, U-shaped, rectangular mirrors. The sun is focused on tubes (or receivers) that run the length of the mirrors because they are inclined toward it. A fluid running through the tubes is heated by the sunlight that is reflected. In order to generate electricity, the hot fluid is then utilized to boil water in a typical steam-turbine generator.

There are two main categories of linear concentrator systems: parabolic trough systems, in which receiver tubes are placed along each parabolic mirror's focal line, and linear Fresnel reflector systems, in which one receiver tube is placed above a number of mirrors to give the mirrors more mobility when tracking the sun.

## **6. Dish/Engine Systems**

A dish/engine system employs a mirrored dish that is comparable to a sizable satellite dish, but in order to keep costs down, the mirrored dish is typically made up of numerous smaller flat mirrors that have been assembled into a dish shape. The dish-shaped surface concentrates sunlight onto a thermal receiver, which then delivers the heat to the engine generator after being absorbed and collected by the receiver.

The Stirling engine is the sort of heat engine that is currently utilized most frequently in dish/engine systems. The fluid heated by the receiver is used in this system to drive pistons and generate mechanical power. A generator or alternator is then powered by the mechanical energy to generate electricity.

## **7. Power Tower Systems**

In a power tower system, sunlight is focused and concentrated onto a receiver at the top of a tower using a vast field of flat, sun-tracking mirrors called heliostats. A heat-transfer fluid heated in the receiver is used to make steam, which is then utilized to generate electricity in a typical turbine generator.

Water or steam is sometimes used as a heat-transfer fluid in power towers. Due to its excellent heat-transfer and energy-storage characteristics, molten nitrate salt is being used in experiments by other cutting-edge designs. The ability to store energy, or thermal storage, enables the system to keep supplying electricity during cloudy or night time conditions.

**Environmental Impact of Solar Energy**

There are no gaseous or liquid emissions when solar energy is being produced, and the photovoltaic array also acts as an environmental heat shield to protect the building on which it is situated. Solar energy has a severe impact on the environment because lead, which can harm the neurological system, as well as chromium and cadmium, which are recognized carcinogens, are toxic metals found in solar panels. It is known that all three metals can seep into drinking water sources from existing e-waste sites. Several months of rains washing away solar panel module pieces could endanger human health. Another issue that may in the future have a negative impact on the environment is the disposal of solar panels. According to Fitzner (2019), solar panels can occupy huge portions of desert that were once home to a variety of animals, including coyotes, rattlesnakes, pronghorns, and tortoises. The manufacturing of solar systems can result in issues with health and safety that are quite similar to those in the semiconductor sector. Pollutant output from photovoltaic manufacturing facilities is quite minimal.

**Conclusion**

Since the solar energy is the best renewable energy resource available, related technology gap need to be filled in by increasing the applications in real life usage. As it also helps in reducing global warming by bringing down the harmful gas emissions, solar energy need to be used as power resource in all major industries. Research on reducing the installation charges helps in wider application of the technology across the world which may result in very good impact on the climate change.

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