**Title: SUSTAINABLE PRACTICES: SOLAR ENERGY**

Authors:

Dr. Thoudam Regina (Assistant Professor, Gargi College, Zoology Department, mobile:9958652213, mail ID:thoudamregina@gmail.com)

Mahima (B.Sc Zoology Honours, Gargi College, Zoology Department, mobile:8168929281, mail ID: mahimadalal890@gmail.com)

**INTRODUCTION:**

Due to the enormous rise in atmospheric pollution and global warming, there is now an environmental threat. Ecology, climate, and population health will all suffer catastrophic effects if this keeps happening with no meaningful improvement. The level of energy consumption directly affects the world population in the process of economic growth and efficiency improvement. The use of technology that is environmentally friendly, a promotional increase in energy efficiency, a decrease in overall energy consumption, and a concomitant decrease in hazardous substances produce significant but fundamental effects. For this reason, considering the facts, saving fossil fuels, and eliminating dangerous substances, we can considerably reduce costs by gradually switching from natural energy to renewable energy sources like solar energy (1). Despite being the planet’s most abundant energy source, sunlight is quite weak at the surface of the planet. Nevertheless, the sun is still a very potent energy source. Sunlight that can cause chemical reactions, produce heat, or produce electricity is known as solar energy (2).

The main reason of this is the massive radial radiation spreading from the far-off Sun. Up to 54% of the incoming sunlight is absorbed or scattered by Earth’s atmosphere and clouds, which contributes a negligible additional loss. About half of the sunlight that reaches the earth is visible light, the other half is infrared radiation, with trace amounts of ultraviolet and other electromagnetic radiation. (3)

World energy needs, both present and future, are far exceeded by the entire amount of solar energy incident on Earth. All future energy demands could potentially be met by this extremely diffused source if it is appropriately harnessed. Given its limitless supply and non-polluting nature in comparison to the finite fossil fuels, coal, oil, and natural gas, solar energy is predicted to become a more appealing renewable energy source in the twenty-first century. Sunlight has a vast potential because it provides Earth with energy equivalent to 200,000 times the world’s daily electric generating capacity. While solar energy is free in and of itself, its widespread use is unfortunately restricted by the high cost of gathering, converting, and storing it. Though the former is simpler to achieve, solar radiation can be transformed into either thermal energy or electrical energy.



Photovoltaic solar panel system

<https://betterenergy.org/blog/system-design-for-a-high-renewables-future/>

**ELECTRICITY GENERATION BY SOLAR ENERGY**

Solar energy technologies can be broadly classified into two categories: photovoltaics (PV) and concentrating solar-thermal power (CSP).

**1. Photovoltaics solar thermal energy**

The term “photovoltaic” refers to both light and electricity, so the first stage in converting solar energy is installing these solar cells. A tiny semiconductor wafer consisting of two silicon layers makes up each solar cell. These days, silicon is a chemical element that occurs naturally and is among the best semiconductors. Silicon semiconductors can function as insulators and conductors. The P-type and N-type are the names of the two positively and negatively charged silicon layers, respectively. While P-side semiconductors absorb additional electrons in the electric field, N-type semiconductors readily send away electrons. Thus, the development of an electric field on the solar panel is enhanced by this positive and negative layer. As everyone knows, photons are tiny packets of energy that are carried by the sun and land on Earth. The photons in the sunshine frighten the electrons within these PV cells, causing them to activate and begin flowing when they meet the already-formed electric field. The electric current is further created by these free electrons that begin to flow on the electric field. Normally, the electrical energy obtained from solar radiation using PV cells is referred to as direct current (DC) electricity. Unfortunately, we cannot use this created electrical energy to power buildings or residences; instead, we must convert it into Alternating Current (AC) electricity. Specialized solar inverters must be installed to further convert DC into AC. These inverters can be set up in modern solar systems to function as one of the systems. They can be concealed below the panels and attached as micro inverters.  Household appliances can immediately start using the 120 volts AC electricity that the inverter converts from DC. Prior to entering the electric grid, the power generated by solar radiation first goes through the home’s electrical panel (4).

**2. Concentrating solar thermal power**

To convert solar energy from the sun into heat, CSP uses a mirror arrangement to focus solar light onto a receiver. After then, the heat is transformed into steam, which powers a turbine to generate electricity. Thermal energy storage devices can be used by CSP plants to hold onto power until they need it, such as at times when there is little or no sunshine. What distinguishes CSP as a versatile renewable energy source is its capacity to store energy. Additionally, CSP systems can be integrated with other power sources to build hybrid power plants. Thermal-fired power stations, for instance, that run on fuels like coal, natural gas, and biofuel can be linked with CSP.



**Solar Thermal Power Plan**

[**https://www.energy.gov/eere/solar/concentrating-solar-thermal-power-basics**](https://www.energy.gov/eere/solar/concentrating-solar-thermal-power-basics)

**2.1 Types of CSP technology**

CSP technology come in four varieties:

2.1.1 Parabolic Trough: Solar energy is concentrated using parabolic trough systems, which focus the light onto a receiver pipe using curved, trough-shaped reflectors. Usually, the pipe is filled with thermal oil, which is heated and used in a steam generator’s thermal power block to produce energy.

2.1.2 Power tower systems: These systems leverage heliostats, which are mirrors that track the sun and direct its energy towards a receiver at the summit of a tower. Steam is produced inside the receiver by heating a fluid, usually molten salts, and using that steam to power a turbine generator.

2.1.3 Systems using linear fresnel lenses: Several collectors are arranged in rows. The sun is reflected onto the receiver pipe above by the mirrors, which are placed flat on the ground. Fresnel systems, like trough and tower systems, can directly produce steam or incorporate storage into a power block.

2.1.4 Systems of parabolic dishes: A tracking device that tracks the sun’s path is attached to a receiver that receives solar energy reflected from a parabolic-shaped dish that works as a concentrator. A heat engine then produces energy from the gathered heat. Because of the dish’s ability to reach extremely high temperatures, the device may be suitable for use in solar reactors (5).

**3. Solar reflector:**

Solar technology use reflectors to focus sunlight onto the solar panels. A protective layer and a silver coating are applied on glass, which serves as the basic material. They increase solar panels' energy output since they reflect the entire solar spectrum. To generate high temperatures, concentrated solar power plants use concentrating, or focusing, collectors to focus sunlight from a large area onto a small, blackened receiver. This significantly increases the light’s intensity. The arrays of precisely positioned mirrors or lenses can concentrate enough sunlight to heat a target to at least 3,600 °F (2,000 °C). After that, this heat can be used to run a boiler, which produces steam for a steam turbine power plant. It is possible to concentrate a lot of solar radiation onto blackened pipes that circulate water and heat it directly by arranging the movable mirrors in that way.

**APPLICATIONS OF SOLAR ENERGY**

The ability to help enterprises overcome a variety of obstacles and promote sustainable development has made solar energy extremely important. Due to its advantages for the environment, financial savings, and developments in technology, solar energy is becoming more and more popular for industrial application. The use of solar energy for industrial purposes depends on several variables, including geographic location, energy demand, regional regulations, and the availability of financial incentives. The industrial sector is anticipated to use solar energy more frequently as costs come down and solar technology develops, which will help create a more environmentally friendly and sustainable energy landscape. Solar energy has several applications, such as:

**1. Power Generation**: To supply industries with electricity, large-scale solar power plants referred as solar farms or solar parks—are being created. Photovoltaic panels, which are the basis of these power plants, directly convert sunlight into electricity. Drilling, pumping, refining, and transportation are just a few of the tasks that companies frequently use energy for. Firms can meet a portion of their energy needs by installing solar panels on-site, decreasing their dependency on conventional fossil fuel-based power sources.

**2. Water Heating System Using Sunlight**

An apparatus that aids in heating water by harnessing solar energy is a solar water heating system. This energy has no cost at all. Water is heated by solar energy, or the sun’s beams. The temperature can be reached to 60–80 degrees Celsius with ease (6). Solar-powered water heater for home use, solar water heaters with capacities between 100 and 300 litres are appropriate. Larger systems can be found in hotels, hospitals, canteens, restaurants, and guest homes, among other places. For domestic use, 100-liter solar water heaters can take the place of an electric geyser and potentially save up to 1500 units of electricity yearly. Utilizing 1000 solar water heaters with a 100 litre capacity each can help save about 1 MW of peak demand. 1.5 tons of carbon dioxide emissions can be avoided annually with 100-litre solar water heaters. In a solar water heaters operation sunlight strikes the collector panel, which is a part of the solar water heating system. Within the collectors, a black absorbing surface known as an absorber collects solar radiation and distributes the heat energy to the water that passes through it. A tank that is insulated to stop heat loss holds the heated water. Water automatically circulates from the tank through the collectors and back to the tank thanks to the thermosiphon system. There are two types of solar water heaters based on the collector system: The components of a solar water heater are an insulated storage tank to hold hot water and a collector to gather solar energy.

**3. Cooling**

Solar cooling is a method that transforms solar heat into effective cooling for air conditioning and refrigeration systems. To produce chilled water or conditioned air for use in the building, thermally driven cooling uses solar thermal energy that is collected and utilized by the process. Typically, a solar cooling system consists of three parts. A refrigeration or air-conditioning plant for creating cooling, a solar collector for capturing solar energy and converting it to heat, and a heat sink for heat rejection are a few examples (7).

Solar thermal and electrical cooling systems are the two primary categories of solar cooling systems. Solar collectors can be used to transform solar radiation into thermal energy, which can then be used to carry out the cooling process for the first category. Several techniques, including absorption, adsorption, ejector, Rankine, and desiccant systems, can be utilized to cool the produced thermal energy. The sorption chillers can be powered by concentrating solar collectors such parabolic dish collectors, linear Fresnel collectors, and parabolic trough collector or stationary collectors like flat plate, evacuated tube, and Photovoltaic thermal (8).

 **4. Water desalination system**

The sun distillation process is the most advanced and commonly used method for desalinating saltwater, particularly in dry regions. Saline water has been utilized for solar distillation for many years. The need for more widespread use of water desalination technology is not just caused by the scarcity of fresh water. The quality of accessible fresh water supplies has considerably declined in many regions of the world as a result of increased pollution of rivers, lakes, and, in some cases, ground water. The most efficient and popular method of turning brackish water into potable water is using a solar still. It is simple to construct using readily available, locally maintained materials. To increase the efficiency of the solar distillation systems, several enhancing strategies have been researched. Active and passive stills might both use adjustments. Among these changes for passive systems is the addition of fins, corrugated absorber plates, additional condensers, internal reflectors, step-wise basins, dye, wick, and wicks (9).

**5. Agriculture**

The use of solar energy has the potential to revolutionize the agricultural industry by providing value in several ways, including the preservation of valuable water resources, the reduction of reliance on the grid, long-term power cost savings, and even the creation of a new source of income (10). There is a growing demand for the use of solar energy in a larger range of applications across various functions, even though it has been used in agriculture since the dawn of civilization. By reducing dependency on fossil fuels and cutting operating expenses, solar energy may power irrigation systems, agricultural machinery, and other farming processes.

**6. Mining**

At isolated locations, mining companies are depending more and more on solar energy to power their operations. Mining operations require dependable lighting, communication, and surveillance systems in order to run safely and continuously around-the-clock. Morningstar controllers were chosen by mining project managers due to their exceptional quality, exceptional service, and availability. The crushing and grinding processes have the main contribution to the total CO2 emissions in mining. Some scientist highlighted the issue of mineral depletion with a special focus on the role of energy in the mining industry. Some work in this field concludes that energy is a fundamental factor in the mining industry (11).

**7. Oil Industry**

The use of high-grade solar energy is also required in global oil business. The oil sector has a solid foundation for the efficient use of high-grade prospective solar energy. As part of the initial crude oil treatment process in the state of the oil fields for its subsequent transportation to ORP, the temperature is to be between 50 and 600 C to be easily obtained by different solar engineering systems. In the current state of oil fields, primary oil treatment is an expensive and incredibly time-consuming operation. In addition to these products emitting pollutants into the atmosphere, mazut or gas expenditure is required for the completion of this procedure (1).

Solar energy has been incorporated into the oil business over the past ten years as major oil firms have made investments in renewable energy. Solar energy was once viewed as a rival energy source that may displace or cut into the global share of fossil fuels as a source of alternative energy. The oil business, however, has begun investing heavily in solar energy and adapting to the winds of change. The topic of solar energy is debated in terms of its potential to replace or supplement oil (12).

An excellent prospect for the future growth of the renewable energy sector is the use of solar energy in the oil sector. These possibilities include the application of solar thermal and photovoltaic technologies. By using solar energy, the sector will use fewer fossil fuels overall and leave a smaller ecological footprint. Solar energy will assist the sector in partially satisfying its energy needs in regions with a dearth of conventional fuels like natural gas (13).

**8. Manufacturing**

With solar PV panels serving as the most notable example, the phrase “solar manufacturing” refers to the production and assembly of parts for the whole solar value chain. Wafers, cells, glass, backsheets, and frames are just a few of the many subparts that make up a PV panel. Inverters, wiring, combiner boxes, racking and tracking structures, to name just a few manufactured items, are needed for solar energy systems in addition to panels. And that’s just for PV. Heliostat, receiver, and thermal storage system production is necessary for CSP systems. Industries like cement, steel, and chemicals that need a lot of energy to manufacture their products can use solar energy to offset some of their electricity needs (14).

**9. Energy storage**

Although there is an endless source of clean energy from the sun, it can be difficult to capture. Thankfully, there are several options for business and residential storage that provide tested answers for storing solar energy, and new technologies are being created every day. Grid-scale battery storage will probably soon be accessible, but for commercial uses, mechanical storage options offer efficient ways to capture solar energy when it is required most. The greatest solution for household solar is battery storage, which is readily available in a variety of reasonably priced models. Together, these options offer a potent portfolio for storing solar energy and make a strong case for expanding solar deployment in industrial and residential settings (15).

**10.** **Off grid application:**

Renewable solar energy is a well-known energy source as more people become aware of its affordability and sustainability. Solar energy is created by solar panels by absorbing and converting solar radiation. People that switch to solar energy have the option of either an off-grid or a grid-tied solar installation (16).

Solar system owners who are grid-tied can rely on the power grid along with the rest of the city, whereas those who are off the grid are responsible for supplying power to their homes on their own. This sort of solar power, in contrast to a grid-tied system, uses batteries to store the electricity generated by the solar panels. Although living off the grid can be unsettling, many homes should benefit from it. Off-grid solar energy systems are dependable during power outages because they store energy and are constantly prepared for calamities. In the event of any unforeseen accidents, a residence with an off-grid solar power system can delay having to face blackouts. Industrial applications that are off the grid or in isolated areas where traditional power sources are not readily available or are expensive to maintain can also benefit from the use of solar energy. Solar energy can be used to offer a dependable source of energy in remote oil exploration and extraction sites were connecting to the grid may be difficult or expensive. A reliable power supply for essential processes can be made possible by energy storage systems coupled with solar panels (17).

**11.** **Grid support system:**

Utilising solar energy has the potential to considerably improve the dependability of the electrical system. By producing electricity from several sources, solar energy may reduce reliance on a single source of energy and increase the grid’s resilience. Solar energy may also provide ancillary grid services like frequency control and voltage support to maintain the grid’s stability and dependability. For instance, by adjusting solar energy output to match demand, solar inverters can help control grid frequency. This will reduce the possibility of blackouts and other disturbances, which may occur if the frequency of the grid becomes unstable. Solar energy may also be used to power the grid, negating the need for huge transmission and centralized power plants. As a result, the likelihood of grid failures brought on by disruptions in the infrastructure supporting centralized power generation or transmission may e reduced. In addition, solar electricity can be utilized in conjunction with energy storage systems like batteries to produce backup power during periods of high demand or grid failures. Because of this, even during periods of high demand or system failures, a consistent and stable supply of electricity can be maintained. As a result, solar energy may significantly contribute to improving grid dependability by expanding the range of available energy sources, providing auxiliary grid services, and reducing reliance on centralized power generation and transmission infrastructure. As solar energy continues to gain popularity as a source of renewable energy, its importance in improving grid resilience is anticipated to grow. Solar energy is used by some sectors to send surplus electricity back to the grid, stabilizing the energy supply and generating income through feed-in tariffs or other incentive schemes (18).

**12. Building Integration:**

Solar energy must be incorporated into the design of structures to ensure their sustainability, energy efficiency, and resilience. To reduce their reliance on non-renewable energy sources, reduce operating costs, and improve indoor environments, architects and builders can use photovoltaic panels to harvest solar energy. As a backup source of electricity during blackouts, solar energy integration into building design may help increase resilience. Considering the benefits of solar energy and incorporating it into their designs is essential for architects and builders as the need for sustainable building design keeps growing. By doing this, they might create structures that are not only functional and aesthetically pleasing, but also environmentally sound and sustainable. Industrial buildings can incorporate solar panels into their architecture, which has advantages for energy production and shade (19).

**13.** **Water pumping:**

Water from underground sources can be raised using solar-powered pumps, which eliminates the need for grid electricity or diesel generators and lowers operating expenses. Solar-powered water pumps function by converting photons from the sun into electricity to power the pump. It uses solar panels to gather photons from the sun and create direct current, which powers the motor that pumps water away from its source. If the pump motor needs alternating current rather than direct current, an inverter is needed. Components of a system for a solar-powered water pump include:

12.1 Photovoltaics systems

Solar panels, often known as the solar photovoltaic system, utilize the sun’s photons to transform them into electricity in three simple processes. Photons from the sun are captured by solar cells and transformed into direct current electricity. An inverter changes direct current electricity into alternating current electricity. To run the water pump, this electricity is utilized. In Electric water pump, the water pump motor draws water from any nearby source, whether it be an underground well or another water source that can be used for irrigation, domestic consumption, or other uses. In Inverter, the inverter transforms the electricity from the original DC to usable AC since water pumps require AC electricity. A water tank for storing water that can be used when sunlight isn’t available is frequently part of the water pumping system. In controls for pumps, the water pump is controlled by the controllers, which also enable on/off switching. They can prolong the water pump’s lifespan by shielding it from electrical malfunctions or motor damage if it continues to run when a water source runs dry. The best water delivery is achieved via controllers (20).

**14. Environmental mitigation**

It is crucial to cut greenhouse emission and stop climate change to protect animal, human and ecosystem.  Additionally, utilizing solar energy can reduce water usage and improve air quality. Sites must be chosen, built, and managed to minimize impacts to nearby animals, wildlife habitat, soil resources, and water supplies since ground-mounted PV and concentrating solar-thermal power facilities require the use of land. The U.S. government’s Solar Energy Technologies Office (SETO), Department of Energy funds research to better understand how solar energy installations, animals, and ecosystems interact and to find solutions that have the greatest environmental advantages. Solar developers generally assess several sites, site designs, and operating plans during the siting and permitting of solar projects. They do this by abiding by the pertinent federal, state, and local regulations, consulting with the appropriate authorities, conducting impact assessments, and taking mitigation measures. The improvement of the siting and permitting process as well as the maintenance of healthy local ecosystems are two goals that solar developers, regulators, host communities, and other stakeholders are interested in achieving. Stakeholders can enhance decision-making, lower soft costs, or non-hardware costs, and aid SETO in achieving its objectives by expanding the number of resources and field-tested solutions that are available (21). In addition to greenhouse gas emissions and habitat destruction, extraction of natural resource can have a severe influence on the environment. Industries based on such extraction may show they care about the environment by using solar energy in their operations and lowering their carbon footprint.

**15. Hybrid solar system:**

The hybrid solar system incorporates a battery backup to store the power in addition to being net metered to the grid. A hybrid solar inverter produces electricity using the energy that solar panels collect. The power backup capability of a hybrid solar system is its most significant advantage. It implies that, even in the event of a power outage, you can continue to use electricity uninterrupted. The surplus electricity produced by the solar system during peak hours is stored with the use of a battery backup. In a system that is battery-ready, a hybrid solar inverter is more frequently used than a traditional battery inverter. A charger and a connection are included with the contemporary hybrid solar inverter. A hybrid solar inverter costs more than a typical battery inverter because of its advantages. A more dependable and adaptable energy supply can be provided by hybrid systems that integrate solar energy with traditional power sources, including natural gas generators. Reducing fuel use and emissions is possible with this strategy. There are four components to the hybrid solar system: In Solar Panel, DC electricity is produced using solar panels to transform solar energy. The solar system’s most important component is the solar panel. In the Hybrid Inverter, it is a solar system’s second crucial element. To power household appliances later, the hybrid inverter regulates the voltage and converts DC to AC voltage. A fuse, Surge protection devices, and miniature circuit breaker are all included in the direct current delivery box for security (DCDB). Multiple solar panel wires are joined together by the DCDB into a string with positive and negative outputs (22). In Control for charging, by managing how much power is supplied to the battery, the charging controller lengthens battery life.



Hybrid Solar System

<https://mechanicaljungle.com/what-is-hybrid-solar-system/>

**COMMUNITY RELATIONS**

Putting communities first when creating energy projects would not only result in better outcomes for the communities but also reduce risk and boost profitability. A few million dollars to hundreds of millions of dollars must be invested in large capital projects like solar farms. Due to their cost advantage and almost zero emissions, they also present an opportunity to address many of the equality issues mentioned above. The success of these projects depends on managing risk. Strong environmental, social, and governance criteria are being used by investors more and more as risk indicators. However, individuals frequently ignore how these three pillars are interconnected and just pay attention to one, which restricts their ability to reach their full potential. Environmental, social, and governance measures are frequently politicized as well; some jurisdictions have banned them while others have made them a priority. There appears to be a problem with the tension between state legal obligations, risk management, and best practices. Integrating solar energy into operations can have beneficial social effects in areas where extraction of valuable resources occurs close to local communities. It can result in the creation of jobs, the upgrading of skills and infrastructure, and the strengthening of ties between the business community and the local populace (23).

**ENERGY EFFICIENCY**

Energy-efficient technologies like LED lighting, sensors, and automation systems can be powered by solar energy, increasing the general effectiveness of any operations. When combined with storage, solar energy may supply backup power for nights and outages and function at similar efficiency on both small and big sizes. Solar energy can also help to lower electricity costs, contribute to a resilient electrical grid, create jobs, and stimulate economic growth. In comparison to other battery types (such as lead-acid or nickel-cadmium), lithium-ion solar batteries recharge quickly and operate at the best efficiency. They have a round-trip efficiency of more than 96%, which indicates that less than 4% of the electricity they store is used for charging themselves.

**RESEARCH AND DEVELOPMENT AND INNOVATION**

The goal of PV research and development is to lower the overall cost of solar energy. Government-funded research into solar energy has spawned new enterprises and jobs. By lessening the consequences of climate change, the sector’s continuous growth has a substantial impact on the environment. Research can support solar sector growth and produce more energy that is more efficient. Because of research, sustainable energy has gotten more affordable during the previous few decades. Technology for solar panels is always being developed and improved. Since the creation of the first solar panel, we have made significant progress. Significant advancements in efficiency, energy storage, wearable solar technology, and many other areas have occurred in recent years. The good news is that solar panels and other technologies are becoming more affordable. CSP and PV are the two most popular solar technologies. Solar PV systems turn solar energy into electricity by collecting the sun’s light. Utilizing the sun’s heat to run heaters and turbines is known as concentrated solar power. These two technologies have both advanced due to research and development. The research and development divisions of oil firms investigate new technology to improve operations. Investing in solar energy research and innovation can result in the creation of cutting-edge solutions for managing resources and energy needs (24).

**LONG TERM SUSTAINABILITY**

Compared to fossil fuels, solar energy is intrinsically more environmentally friendly and sustainable. Sunlight is the largest and most sustainable resource on earth, utilizing it by converting it into electrical energy is one of the most sustainable sources of energy. Growth that satisfies current needs without endangering the ability of future generations to meet their own is considered sustainable. Solar energy may be continuously used without affecting its future supply. By diversifying their energy sources and incorporating renewable energy sources like solar into their overall business strategies, industries will also position themselves for long-term sustainability as the globe moves towards cleaner energy sources.

**COST SAVINGS**

The ability of solar energy to lower energy costs for low-income households is one of the most important advantages of this technology. These households can reduce their monthly energy costs by producing their own electricity, and they can use the money they save to pay for other requirements like food and housing. Because solar energy has lower operating and maintenance costs than conventional power sources, it can result in long-term cost benefits.

**CONCLUSION**

The numerous uses of solar energy have shown that it has a great potential to fundamentally alter how we generate and use energy in a variety of fields. The energy landscape has changed because of the move toward decentralized energy production, enabling people to actively participate in the transition to sustainable energy. Additionally, the use of solar energy in agriculture through technologies like solar-powered irrigation systems and crop drying has improved production while also having a favorable effect on rural populations by supplying dependable energy sources that improve livelihoods and food security. Costs are continuing to rise along with technology.

Solar energy integration in residential and agricultural settings holds enormous promise for a more resilient and sustainable future as technology improves and costs continue to fall. Beyond specific industries, the contribution of solar energy to large-scale power production and grid stability cannot be disputed. Utility-scale solar farms have become important players in the world's energy mix, supplying clean electricity to suit the needs of cities and businesses. Energy storage technology, such batteries, which store surplus energy produced during sunny times for use during cloudy days or at night, have advanced because of the integration of solar power into the grid.

Solar power's position as a cornerstone of the transition to renewable energy is being further cemented by this innovation in energy storage, which is transforming solar energy into a dependable energy source. Finally, the diverse uses of solar energy highlight its potential to transform how we create, use, and think about energy, bringing us closer to a more sustainable and ecologically conscious future. These applications range from small homes to large power networks.

**Reference**

1.Mammadov F. Application of solar energy in the initial crude oil treatment process in oil fields. Journal of Energy in Southern Africa. 2006; volume 17 (2): 27-30.

2. Ashok S. Everything about solar energy [cited 2023 Aug 29]. Available from: <http://energyprofessionalsymposium.com/>Solar Energy.

3.What Is Solar Energy? How Is It Produced? When Was It Discovered? And Other Details [cited Dec 12, 2022]. Jagran Josh. Available from:  <https://www.jagranjosh.com/general-knowledge/what-is-solar-energy-1670835359-1>

4.How does solar work. Solar energy technologies office. Available from: ([https://www.energy.gov/eere/solar/how-does-solar work#:~:text=Solar%20technologies%20convert%20sunlight%20into,in%20batteries%20or%20thermal%20storage](https://www.energy.gov/eere/solar/how-does-solar-work#:~:text=Solar%20technologies%20convert%20sunlight%20into,in%20batteries%20or%20thermal%20storage)).

5. Concentrating Solar Thermal Power Basics, Solar Energy Technologies Office. Available from:(<https://www.energy.gov/eere/solar/concentrating-solar-thermal-power-basics#:~:text=CSP%20technologies%20use%20mirrors%20to,an%20engine%20to%20generate%20electricity>).

6. Concentrating Solar Thermal Power Basics. Solar Energy Technologies Office. Available from: (<https://www.nrel.gov/research/re-solar-water-heating.html>).

7. Maidment G.G, Paurine A. Comprehensive Renewable Energy. Volume 3, Elsevier Ltd. London; 2012

8. Youssef E, Abdellah E.F. [Solar and Photovoltaics Energy Utilization and Sustainability](https://www.sciencedirect.com/science/article/pii/B9780323939409000025). [Reference Module in Earth Systems and Environmental Sciences](https://www.sciencedirect.com/referencework/9780124095489/reference-module-in-earth-systems-and-environmental-sciences), Elsevier Ltd, Morocco; 2023

9. Baily EE, Shalaby SM,    Kabeel AE, Fathy AM. Cost analysis for several solar desalination systems. Desalination. 2016 (384):12-30

10. Applications of Solar Energy in Agriculture. Available from: (<https://www.dynamicslr.com/solar-energy-applications-in-agriculture/#:~:text=Solar%20energy%20is%20applicable%20in,for%20irrigation%20and%20many%20others> )

11. Behar O, Pena R, Kouro S, Kracht W, Fuentealba E, Moran L. et al. The use of solar energy in the copper mining processes: A comprehensive review. Cleaner Engineering and Technology. 2021;4.100259

12. Cenk T, Mazda I, Celal H.C, Yildiray P, Raul M, Aysegul B, Jose M et al. Technical and Economical Aspects of Use of Solar Energy in Oil & Gas Industry in the Middle East Paper presented at the SPE International Heavy Oil Conference and Exhibition, Kuwait City, Kuwait, 2018. Paper Number: SPE-193768-MS

13. Absi HM, Qattan AA, Otaibi AA. Application of solar energy in the oil industry- Current status and future prospects. [Renewable and Sustainable Energy Reviews](https://www.sciencedirect.com/journal/renewable-and-sustainable-energy-reviews). 2015 (43): 296-314

14. Solar manufacturing. The Office of Energy Efficiency and Renewable Energy. Available from: (<https://www.energy.gov/eere/solar/solar-manufacturing#:~:text=Solar%20manufacturing%20refers%20to%20the,glass%2C%20backsheets%2C%20and%20frames>

15.Solar Integration: Solar Energy and Storage Basics. Solar energy technologies office. Available from: <https://www.energy.gov/eere/solar/solar-integration-solar-energy-and-storage-basics>

16. Off-Grid or Stand-Alone Renewable Energy Systems. Available from:

(<https://www.energy.gov/energysaver/grid-or-stand-alone-renewable-energy-systems>).

17. Benefits of off-grid solar systems [cited May 03, 2019]. Available from: (<https://www.greenjournal.co.uk/2019/05/5-benefits-of-off-grid-solar-systems-infographic/>

18. How solar power and the grid work together. Available from: <https://palmetto.com/learning-center/blog/how-solar-power-and-the-grid-work-together>

19. Integrating solar energy with building design: A guide for architects and builders. Available from: <https://thesolarlabs.com/ros/integrating-solar-energy-with-building-design-a-guide-for-architects-and-builders/>

20. Solar Pumping Explained: What Are Solar Pumps & How They Work?

Available from: <https://healingwaters.org/how-do-solar-powered-water-pumps-work/>

21. Solar Energy, Wildlife, and the Environment. [Solar Energy Technologies Office](https://www.energy.gov/eere/solar). Available from:  [https://www.energy.gov/eere/solar/solar-energy-wildlife-and environment#:~:text=As%20a%20renewable%20source%20of,water%20use%20from%20energy%20production](https://www.energy.gov/eere/solar/solar-energy-wildlife-and-environment#:~:text=As%20a%20renewable%20source%20of,water%20use%20from%20energy%20production)

22. Hybrid Solar System: Working, Price, Types, Pros, and Cons. Available from: <https://www.solarsquare.in/blog/hybrid-solar-inverter/>

23.Community Solar basis. Available from: <https://www.energy.gov/eere/solar/community-solar-basics>

24. Solar Energy Research and Development. Available from: <https://www.dynamicslr.com/solar-energy-research-development/>