

# SOLAR ENERGY ADVANCEMENTS AND THEIR ENVIRONMENTAL IMPACTS

## Abstract

The solar energy system converts solar energy into electrical energy, either directly through the use of photovoltaic panels or indirectly through the use of concentrated solar power. Solar energy is the most essential source of energy, and it has continued to gain popularity globally. Solar energy has recently experienced massive growth as a result of both technological advancements that have reduced costs and government policies that support the development and use of renewable energy sources. This is because there is an increasing demand for clean, environmentally friendly energy sources. This chapter largely tackles solar energy and covers its innovations, advancements, and prospects for the future. Energy resources can be divided into non-renewable and renewable energy sources. People are focused on using renewable energy resources to generate energy because of certain negative environmental effects like air pollution, climate change, and the depletion of natural resources. One of the most talked-about sources of sustainable energy is solar energy. The current chapter gives a general summary of the world's solar energy capacity, its classification, and advantages, and contains crucial methods for enhancing their usability, dependability, and affordability. This chapter ends by discussing potential environmental incursions in order to mitigate them with new technology advancements and ethical behaviours in future power systems. This will serve as motivation for additional research in this area.

**Keywords:** Solar energy; environmental impact; technologies; advancements

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## I. INTRODUCTION

The most plentiful source of energy on planet is likely solar energy. Solar energy is the term used to describe solar radiations that are used to produce heat and electricity.

Solar energy is a renewable resource; thus, it will never run out. Because of this, we are free to experiment and determine how to use it most effectively and efficiently. Sunlight and heat are captured and transformed into several types of energy. One of the renewable energies is solar energy, which is the transformation of solar energy. Most of the sunlight is converted to visible light and infrared radiation once it has passed through the atmosphere of the earth. These energies are transformed into electricity using solar cell panels. Due to the limitations and effects of non-renewable energy sources, people must pay attention to renewable energy sources. The increasing need for power in developing nations as a result of global warming, greenhouse gas emissions, shifting oil costs, and other factors requires innovative approaches. [1]. Therefore, the direction of energy development and the current energy structure have a significant impact on renewable energy. Solar energy, a sort of renewable energy resource, has seen vast-scale development and extensive applications as a result of limits on energy transportation [2]. Solar energy often offers several advantages over fossil fuels like coal and oil since it cleans the air, emits fewer greenhouse gases, and can be produced again during our lives [3]. The world's current situation has led to a rise in global electricity usage. Researchers have therefore concentrated on creating solar energy technologies to achieve a high degree of efficiency with a low investment cost and reduced environmental contamination [4].

In order to achieve high efficiency with little environmental contamination, researchers are making significant contributions to innovation in the solar energy area. Due to the price of the extraction and manufacturing processes, using crystalline silicon for the creation of solar cells can be expensive in the field of solar energy. Consequently, new materials for solar cell construction will include organic components in the future [5]. Organic materials are more environmentally friendly and have lower production costs, thus they can be used to make solar photovoltaic cells. According to the conventional solar cell, electricity cannot be produced without sun radiation. However, in the near future, power will be produced at night without sunlight thanks to the anti-solar cell concept [6]. Therefore, briefly explore the advancement and future of solar energy technology in this review study. Many other potential applications for solar energy in both household and commercial settings have been studied. Through intense research and development programmes, the prospects for others who are not yet commercially viable are also improving.

Environmental effects are a result of all energy generation and transmission methods [7]. Traditional producing options can harm the air, climate, water, land, wildlife, and ecosystem as well as raise unsafe radiation levels, as is evident from their consequences. Renewable technologies offer a solution to a number of social and environmental problems and are substantially safer than fossil and nuclear energy [8]. Solar power technology outperforms the potential of other renewable energy sources like wind and biomass-derived energy by several orders of magnitude [9]. Additionally, solar energy has a number of benefits that appeal to people in different parts of the world, such as lowering greenhouse gas emissions, stabilising degraded land, increasing energy independence, creating jobs, accelerating rural electrification, and raising living standards in developing nations [10].

- 1. History of Solar energy:** Since 1767, solar energy has included solar thermal energy in its history. For life to exist on Earth, the Sun is necessary. It is in charge of the water cycle, photosynthesis, and other processes. The first civilizations understood this and created methods for utilizing their energy [11]. They began as methods for capturing passive solar energy. Later methods for utilizing solar thermal energy from the sun's rays were created. To obtain electrical energy, photovoltaic solar energy was then added. Since the beginning of time, the Sun has been crucial to the growth of life. Without realizing it, the most primitive tribes have been indirectly profiting [12].

The first people to intentionally use passive sun energy were the Greeks. The Greeks started building their homes with the sun's beams in mind some 400 years before Christ. The earliest examples of bioclimatic architecture were these. The first glass homes or greenhouses were created by the Romans [13]. It was designed to capture solar heat in dwellings and make use of light.

Archimedes was the first to devise a different method of using the sun. The method involved employing mirrors to focus solar radiation at a single location. This method kept becoming better. Lavoisier built his solar furnace in 1792. It was made up of two strong lenses that focused sunlight. In the history of solar energy, photovoltaic solar energy first appeared in 1838. Modern solar systems exist now, such as solar hybrid panels. These modern systems are less expensive and more effective.

The most popular material for solar cells in the past was silicon [14]. One factor contributing to the appeal of this material is that the energy of the majority of light particles is relatively near to the energy needed by silicon's electrons to cross the energy barrier. The size of the space between silicon's conduction and valence bands is another factor.

- 2. Types of solar energy:** Solar energy systems come in a variety of forms. They are divided into two:
  - When the direct energy of the sun is converted into heat energy
  - When solar energy is transformed into electrical electricity

Furthermore, there are two distinct solar energy types that can be produced by utilizing the sun's heat:

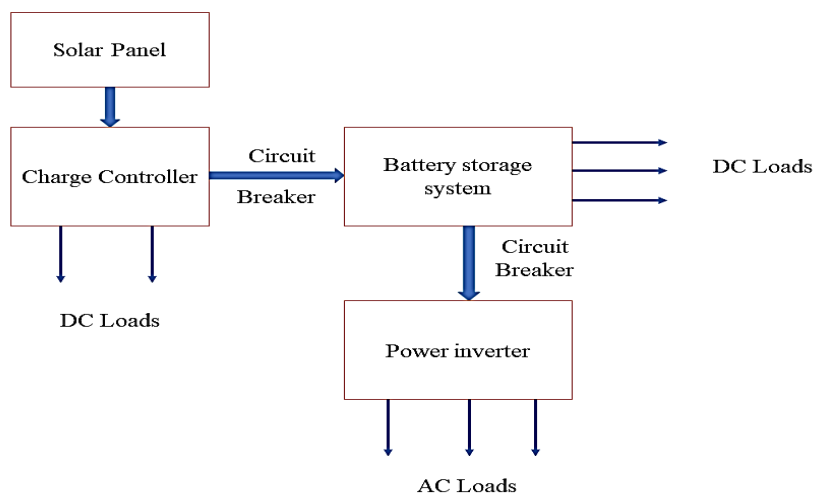
- **Passive solar energy:** It is a form of solar energy that uses no outside power. The goal is to benefit from direct sunshine. In terms of bioclimatic architecture, this idea is useful. For instance,
  - Insulated, thick walls. They keep the house cool in the summer and prevent heat output in the winter.
  - Sunlight is absorbed by dark surfaces.
- **Active solar energy:** Active solar energy is the solar energy that humans actively collect and store for later use. Active solar energy is, in other words, solar energy that has been enhanced by the use of mechanical or electrical devices [15]. It sustainably uses sunlight. For instance,

- Hydraulic pump to maintain the flow of fluid in internal circuits.
- A generator that transforms mechanical energy into electrical energy.

The two primary forms of solar energy are:

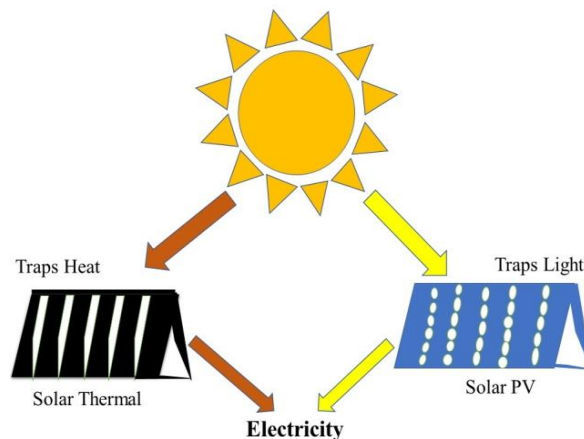
Photovoltaic solar energy  
 Thermal solar energy

- **Photovoltaic solar energy:** Photovoltaic solar systems that employ active solar system technology generate electricity. These systems can be configured for domestic use, huge industry, or urban planning projects. Electricity is generated by heat conduction in photovoltaic panels, which are used to power the suitable construction [16]. Additionally, they might be combined with other renewable energy sources like wind power.



**Figure 1: Typical photovoltaic system's block diagram**

- **Thermal solar energy:** The thermal solar energy system makes use of the sun's primary active solar system by using its energy to gather and store heat before transferring it to fluids and air to produce outcomes. To enhance heat absorption, solar panels for thermal energy can also be positioned at an angle.



**Figure 2: Difference between Solar Thermal and Solar PV**

### **3. Advantages of solar energy**

- The fact that solar energy has less of a negative environmental impact than fossil fuels is one of its main advantages.
- Solar energy also contributes to water conservation [17]. While nuclear power facilities require a lot of water for maintenance, which results in water waste, solar panel maintenance uses very little water.
- Sun panels use solar energy. Solar energy is a regenerative energy source that won't run out anytime soon. You can therefore unwind in the knowledge that you'll probably never run out of fuel to satisfy your electricity needs.
- Another piece of good news is that maintaining solar panels requires little work and has cheap maintenance costs. There is no need for extensive maintenance or cleaning.
- The likelihood of blackouts is quite low when solar panels are widely spaced throughout an area. These systems serve as the grid's energy production hubs, enhancing grid security in the event of overload or other situations that result in blackouts.
- You can use batteries to store extra power generated by your solar panels so that you can use it at night, when there isn't enough sunshine for the panels to continue producing electricity.
- You can position your solar system anywhere there is sunlight. To give places without electricity the necessary power, you can utilise these technologies.
- The benefit of solar energy that has the greatest economic impact on society is the generation of jobs. A rise in solar system demand has produced a variety of work opportunities involving installation, maintenance, cleaning, etc [18].

### **4. Disadvantages of solar energy**

- Energy efficiency is low when measured against alternative energy sources. A low correlation exists between the quantity of energy received and the quantity of electrical energy produced. Especially when contrasted with alternative energy sources like nuclear.
- The weather has an impact on performance. For instance, performance is quite bad where the sky is typically foggy.
- Restrictions all day long. Some places have shorter daylight hours. The Sun's angle with respect to the solar panel's surface is another drawback. The inclination of the sun's radiation is insufficient in some areas [19].
- Restrictions on how much energy can be stored because sometimes you can't get electricity when you need it. There are solar batteries and hot water tanks for this in a photovoltaic installation; however, the efficiency is still relatively poor.
- Some plants have the potential to have various environmental effects. Despite being regarded as clean energy, solar energy nevertheless contains elements that are bad for the environment. Impacts connected to the usage of land, water, materials, etc.

### **5. Environmental impact assessment of solar energy**

- The possible environmental effects of solar energy might differ greatly depending on the technology [20]. These effects are connected to the use of land and the destruction of habitat, the use of water, and the creation of hazardous products.

- Depending on their location, larger utility-scale solar projects can result in difficulties with habitat loss and land degradation. Water is needed for solar thermal concentration plants to cool down. These plants also need more water because it is necessary to maintain the reflectors.
- The manufacture of solar cells involves the usage of several hazardous substances. The majority of those substances are utilised to polish and clean the semiconductor surface. Compared to conventional silicon photovoltaic cells, thin-film photovoltaic cells use a variety of more harmful substances.
- Global warming emissions occur during operation. However, other phases of the solar life cycle are also connected with emissions [21]. It covers production, material transportation, installation, upkeep, decommissioning, and deconstruction.

**6. The innovations of solar energy technology:** Electricity cannot be produced after sunset, according to conventional solar cells. According to the anti-solar cell theory, solar cells might be used to produce electricity at night [20]. The anti-solar cell theory considers the earth to be a heat source and accounts for the night sky using advanced radiative cooling and radiative photovoltaic concepts [22]. Thermo-radiative cells operate on the same basic principles as traditional photovoltaics. Random photon absorption by the cell equals random emission from the cell when a p-n junction enters thermal equilibrium with its surroundings in the dark, and the Fermi level through the semiconductor remains constant. When the p-n junction is hotter than its surroundings, the device tries to cool by expelling more energy than it absorbs. The temperature remains constant when a thermal reservoir is connected to the cell. A reverse bias voltage is created across the junction when the enhanced emission lowers the carrier concentration below its equilibrium level, separating the hole and electron Fermi levels in the opposite manner [23]. When an electron and hole pair recombine but are not balanced by photon absorption, an additional electron and hole are supplied via the contacts to make up for the missing pair. When a cell is connected to a load in this case, there is a current flow [24]. The main distinction between a thermo-radiative PV cell and a conventional PV cell is :

- The current flows counter to its natural flow.
- The voltage created has a reversed sign as well.

The optical rectenna concept has been proposed as an alternative to conventional semi-conductor photovoltaic. A rectenna is a high-frequency rectifier system made up of an antenna that collects electromagnetic radiation and a diode that converts it into DC electricity. Concentrated photovoltaic (CPV) technology is a recent development in solar power technology [25]. This method uses mirrors and lenses to focus sunlight onto solar cells, which generate electricity. CPV has an advantage over non-concentrated photovoltaic systems. The fact that fewer solar cells are required to provide the same quantity of power is one of them. Temperature and sunlight intensity have a considerable impact on the solar cell's efficiency. Higher temperatures cause the solar panel's output performance to decline in contrast to lower ones. Therefore, a good cooling system is essential for getting the best performance out of solar cells and safeguarding them from deterioration and harm. Either actively or passively cooling the photovoltaic solar panel is possible [26]. In order to power the cooling system in active mode, an external power source is required; in passive mode, no external power source is required [27].

When discussing the cooling system for solar panels, a micro-heat-pipe arrays system is recommended in order to remove heat from the working temperature of solar cells. The problems of low energy output efficiency and thermal failure caused by high solar cell temperatures can be handled using the provided method [28].

Even if the adoption and use of solar power has significantly increased in recent years, there are always ways that solar-related technologies might be enhanced. To address the drawbacks of solar cells, some improvements have been made, some of which are given below:

- **Self-cooling panels:** A crucial component of how solar panels work is continuous exposure to the sun's beams. However, severe temperatures cause the majority of panels to perform less effectively. Some researchers have developed a method to enable panels to cool themselves in order to overcome this overheating issue and ensure that they can continue to work at their best even in the hottest temperatures.

Basically, the bottom of a standard solar panel has a gel sheet attached to it. This gel absorbs the night time airborne water vapour [29]. The water is then evaporated during the day as a result of the solar panel producing too much heat. The solar panel will cool off as a result of water evaporation, just like when you splash water on your skin on a hot summer day.

- **Innovation in materials:** The search for innovative components and photovoltaic cell arrangements that can improve the performance of current solar panel technology is never-ending. Perovskites, a class of semiconductors, is one example of such a substance [30]. They have the potential to be the key element in solar cells of the future. These new cells won't just be more affordable; they'll also likely be far more effective than current cells. The fact that the solar power sector is researching specific forms of synthetic perovskites is important in this regard. The type of resources extracted from the earth are not a factor in their supply because they are made in laboratories [31]. They will therefore be less expensive.
- **Solar straight from space:** The effort to create a technology that transmits solar energy directly from space to earth is in full force. American researchers made the first attempt in this direction by launching a tiny photovoltaic module.

This experiment tries to examine how solar energy is transformed into microwaves [32]. The panel features a layer intended to collect the blue light spectrum of the sun's beams, which is conceivable in the atmosphere of space, according to a clever detail the researcher has made public.

Technology, production, and methods for solar electricity are constantly changing. The industry can only maintain its momentum and bring in the era of renewable energy in this way. The fact that there are always fascinating new innovations taking place in the solar energy sector is a wonderful thing.

- **Solar desalination:** Desalination is the process of eliminating unwanted minerals from contaminated water so that it can be used for human and agricultural purposes [33]. Over time, inventors created a solar-powered device that can remove contaminants from water and transform salty water into potable water. The apparatus also disinfects and purifies water using UV light. Unfortunately, many parts of the world still lack access to clean, pure water, despite the fact that water covers 70% of the Earth's surface.
  - **Solar panels:** Anyone wishing to save money and the environment at the same time can consider solar panels as a fantastic energy source. Solar panels can be purchased for a fair price and are an investment that will save the buyer money for at least two decades [34]. More and more companies are investing in solar panels in an effort to cut costs. Solar panels have been around for a while, but because to advancements in solar energy, they are now affordable for everyone, providing power to those who have never had access to it before.
  - **Portable solar:** For safety, affordability, and efficiency, developing nations and regions that are recovering from catastrophic occurrences like floods and earthquakes are turning to alternative energy sources like solar energy [35]. Agencies like the Red Cross and the United Nations have invested millions of dollars in portable solar panels that can light and illuminate their disaster relief crews. Kits are provided with mobile solar power systems so that aid personnel can gather and store energy. In the near future, entrepreneurs will use solar-powered 3D printers to provide vital medical supplies to disaster-affected areas.
  - **Grid batteries:** The other difficulty that sustainable solar energy has is energy storage technology, in addition to the high cost of solar equipment [36]. The development of solar energy technology depends on energy storage, which is also what gave rise to the current development of grid batteries. Compared to other cells, these batteries are more effective at storing solar energy. Combining grid batteries and solar technology is the best approach to ensure a consistent electricity supply that is less expensive than fossil fuels. Solar panels can be shared with neighbours at a price that is less expensive than purchasing other forms of energy by those whose roofs aren't suitable for PV panels.
7. **Ways to improve the efficiency of solar energy:** Solar energy is currently used widely in a number of businesses because to its infinite reserves, universal accessibility, cleanliness, and many other advantages. The solar cell's efficiency is a crucial factor. Following are some crucial suggestions for increasing the effectiveness of solar electricity [37].
- Increasing the solar panel's conversion efficiency - Solar panels are the key element in turning solar energy into electricity. In recent years, scientists have been developing novel solar panel technologies. As the most current advancement in solar panels in recent years, the Nano solar panel shows a new side to development. The solar light and solar panel are vertical and have an automatic tracking system. Due to the



sunlight's shifting angle, the solar cell's generating capability will alter over time. By implementing an autonomous tracking system, the generating capacity can be increased [38].

- Create two independent devices by dividing the collecting and transformation portions. The collector is one of them; it is used to increase solar energy by sequentially collecting solar energy.
- A different converter transforms light energy into electrical energy. These mirrors were used to create this collector [39]. The converter transforms thermal energy into electrical energy, resulting in a thousand times greater generating capacity than a standard solar panel.
- The best invention in solar cell technology is the solar tree idea because there isn't enough room to place the solar panel due to the rapid increase in human population nowadays. To generate effectively, this solar tree needs very little room. The solar tree may therefore be the most appropriate for the modern world.

One of the best ways to fulfil future energy demand is through solar energy. For the first time, scientists have successfully measured in great detail the flow of solar energy into and among the many components of a photosynthetic organism [40]. This result could pave the way for the creation of solar energy technologies that are more efficient than what is now practical. Broad-spectrum solar energy can be captured by the device and converted to power using a heat-resistant gadget constructed of layers of tungsten and alumina, according to research. The dye-sensitized solar cells were made using a green polymer made from bio waste [41].

- 8. Advantages after introducing advanced technologies in solar energy:** The main problem with solar energy technology is that it is less effective than non-renewable technologies at producing electricity. A fossil fuel or nuclear power station can generate more electricity than a solar power plant. Therefore, innovation and research in the solar energy field are needed to meet the future energy demand, overcome this problem, and achieve optimum efficiency. This is not an easy process. In order to do research, scientists must study cutting-edge technologies and incur a significant upfront expenditure [42]. However, by developing solar energy and doing research in the field, we can lessen the environmental impact of non-renewable technology, improving the quality of life on Earth.

The second and third generations of solar power technology are currently being developed. For use in solar technology, further study has been done on nanomaterials. Only a small portion of the sun spectrum can be extracted with conventional silicon-based solar panels. The solar cell's efficiency can be increased by utilising a multi-junction solar cell, which can extract the entire sunlight spectrum. Electricity can be produced during overcast days and at night by adopting hybrid solar power technologies, such as solar-wind systems and solar-biomass systems [43-45]. Benefits from implementing advances in solar technology are possible. The solar spectrum can be extracted in many different ways to achieve optimal efficiency.

- Lower the start-up costs
- Get a flexible solar cell and have less of an influence on the environment.
- Capable of producing power during the day.

- In high-temperature zones, concentrated solar technology may produce power much more effectively than conventional solar technology.

According to the present findings, solar energy technologies are unable to supply enough energy to fulfill the world's steadily growing energy needs while minimizing their negative impacts on the environment and human health [46]. To overcome the aforementioned issues and achieve higher efficiency, similar to non-renewable technologies like nuclear and fossil-based energy, innovation and upgrades are required.

## 9. Environmental Impact Assessment

- **Environmental impacts from photovoltaic power generation:** When in use, photovoltaic systems are often considered to have a minimally harmful impact on the environment because they don't create any noise or chemical pollutants. It is one of the most practical renewable energy technologies to employ as an alternative to the current building cladding materials in urban areas [47].
  - **Land use:** Specific elements determine how land usage affects natural ecosystems. The geography of the landscape, the area of the PV system's coverage area, the type of land, the distance from sensitive ecosystems or scenic areas, and the biodiversity all have an impact on how land use affects natural ecosystems. Construction activities including earthmoving and transport movements are likely to have an impact on the environment and change the landscape during this phase [48]. Additionally, the installation of a PV system on formerly arable land runs the risk of destroying the biodiversity, soil productivity, the area covered by the system, the kind of the land, and the distance from delicate ecosystems and picturesque areas. Construction-related activities like earthmoving and transport movements are likely to have an impact on the environment and change the landscape. Additionally, it is possible to ruin portions of productive soil by placing a PV system on formerly arable land.
  - **Visual impacts:** The kind of the scheme and the PV systems' surroundings have a significant impact on visual intrusion. It goes without saying that the aesthetic impact of installing a PV system close to a scenic place would be very high [49]. Comparing modern buildings to historic or culturally significant buildings, there may be a favourable visual influence in the case of modules integrated into building facades. Optimum architectural solutions to lessen potential effects on building aesthetics and visual aesthetic. design and proper location of big PV installations. PV modules are assembled in large-scale systems using colour.

To reduce the negative effects on the environment caused by the manufacture of PV cells, a number of factors need to be researched:

The potential for cell layers to become thinner;  
The concentrator PV technology' full potential;  
Possibilities for more effective material use;  
Better and safer materials;  
Efficiency of module recycling technique.

- **Air pollution:** According to life cycle analyses, the manufacturing process of the system, especially when it comes to the production of power, has a significant impact on how environmentally friendly it is [50].

Modern PV systems may directly offer clean electricity that is perfectly matched to the building's demand when they are structurally integrated into buildings. In urban settings, they can also support day illumination, shadow management, and ventilation. Mirrors can be replaced with PV panels on a building's front. PV systems also help to foster a climate where additional energy-saving measures can be promoted by building promoters, owners, and users. PV energy services are especially evident in situations when only small amounts of power are needed, such as in rural electrification applications, and where consumers can directly benefit from the extraordinarily high reliability of having their own PV generator. Installing a PV generator is typically less expensive in the first scenario than extending the main grid over significant distances.

- **Noise intrusion:** There won't be much noise, as with all construction-related activities. Additionally, there will be certain employment advantages throughout the construction period and, more so for big projects, during the operational phase. It is important to urge manufacturers to create systems that are simple to recycle. The majority of environmental effects are brought on by batteries because of their heavy metal content and limited lifespan, according to a life cycle analysis of batteries for freestanding PV systems. Furthermore, its creation requires a significant quantity of energy and raw resources. A module-recycling programme can make things better in this case.
- **Environmental impacts from solar thermal electricity:** The possible environmental implications of such a concept have not been thoroughly examined due to the limited use of ST power. Even if some emissions do happen at other points in their life cycles, they are much smaller than the emissions when the system's activity stops. Materials' manufacture and processing
  - Construction
  - Land use
  - Ecosystem, flora and fauna
  - Visual impact
  - Water resources
  - Health and safety
  - Social impacts

The use of air emission or odour control equipment, design tools for the best design and siting of the installations, best practise guidelines, improved pieces of equipment, or completely innovative design are a few examples of technologies or techniques that can be used to completely eliminate or minimise potential environmental impacts from SETs. To make the best decisions, the accountable parties must take environmental considerations seriously. By evaluating the scope of potential environmental impacts and recommending appropriate mitigation measures,

an Environmental Impact Assessment (EIA) for central solar systems can substantially influence good project design and eventual public acceptance.

## II. CONCLUSION

Conventional power generation based on solar energy is often believed to be unsustainable over the long term because to the inability problems and low power efficiency. More inventions are being published globally as a result. The most vital creative possibilities involve night time electricity generation. When compared to non-renewable technologies, solar energy technologies are in a better position to meet rising energy needs based on existing technology. Innovations are therefore crucial for the solar energy business to grow as efficiently as possible. The development, evaluation of the environmental impact, and outlook for solar energy technology are therefore presented in this chapter. Last but not least, innovation is the key to solar energy technology's success in meeting the world's expanding energy needs.

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