

Study the Global Transition to Renewable Energy and Technological Innovations in Solar Energy Storage.

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Abstract: The contemporary world, as we know it today, would not have been possible without energy. Energy is critical to a nation's development and success. In today's world, energy is so crucial that it affects our lives and livelihoods at the most fundamental levels. Currently, the world economy is dominated by the use of fossil fuels. To maintain its industrial complex, humanity relies mostly on oil, natural gas, coal, and nuclear energy. Impending climate change, environmental degradation, and the point at which conventional energy sources are depleted force the global industry to consider renewable energy sources, which may be the determining factor in economic advancement and efficiency in the long run. The sun is an infinite source of energy that can meet all of humanity's energy needs. The sun's energy can be used directly or turned into electricity. Solar energy can be used to generate electricity directly or indirectly through photovoltaic (PV) cells and concentrated solar power (CSP) technology. Electricity generation from concentrated solar technologies, particularly CSP, has a promising future due to its high capacity, efficiency, and energy storage capability. Solar energy has practical use in agriculture, particularly for water treatment and irrigation. Solar energy is utilized to power automobiles as well as for home heating and cooking. Solar energy's future seems promising due to technological advancements and environmental benefits. The main challenge for solar energy is its unavailability throughout the year, high capital costs, and lack of materials for PV cells. These issues can be addressed by building an effective energy storage system as well as low-cost, efficient, and abundant PV solar cells.

Keywords: Concentrating solar power, efficient energy storage system, photovoltaic cells, power tower, solar energy, solar power technologies.

Introduction: The sun, as we all know, is a vast source of energy that has just lately been harnessed. It provides enormous resources for generating clean, non-polluting, and sustainable electricity, resulting in zero global warming emissions. In recent years, it has been discovered that the power of the sun may be collected and stored for worldwide usage, eventually replacing traditional energy sources. As the globe shifts its focus towards greener energy, solar energy has grown in importance. In contrast to finite fossil fuels, solar energy is a renewable, free source of energy that is both sustainable and endless. It is a non-polluting form of energy that does not release greenhouse gases such as H₂O (water vapor), CO₂ (carbon dioxide), and so on when producing power. Solar power systems provide enormous environmental benefits as compared to traditional energy sources, and so greatly contribute to the sustainable development of human activities.

Solar energy can be transformed into heat, electricity, or solar fuels. For example, photosynthesis is a natural process that converts sun energy into solar fuel. Photosynthesis is a chemical process that allows

plants to store solar energy in the form of carbohydrates, which are used as fuel. Furthermore, the protons and electrons generated during photosynthesis can be further metabolized to form H₂ and CH₄. Approximately 11% of solar energy is used in natural photosynthesis of biomass, which is the greatest Use of solar energy. However, only 100TW of this energy is transferred to photosynthesis, which is insufficient for human energy use.[1] Despite the low energy efficiency, there are known methods for increasing solar fuel production efficiency. The solar conversion efficiency of the photosynthesis process is measured in terms of quantum efficiency, which is defined as the percentage of absorbed photons that produce stable photoproducts; in contrast, commercial solar photovoltaic (PV) cells, for example, are measured directly in terms of power.[2] However, in both PV cells and the photosynthesis process, the energy is stored in chemical bonds and obeys the laws of thermodynamics that not all of the energy in each received photon can be captured. Use it productively. Photons are absorbed by chlorophyll in natural photosynthesis, and heat is discharged to the lower absorption band, which is identical to how PV cells release any energy above the band gap as heat. The current usage of solar energy is quite limited, with 0.015% used to generate electricity, 0.3% for heating, and 11% used in natural photosynthesis of biomass, as previously stated. On the other hand, fossil fuels account for around 80% to 85% of world energy consumption. The difficulty with fossil fuels is that their reserves are finite and environmentally unfavourable due to CO₂ emissions. For example, every tonne of coal burned emits one tonne of carbon dioxide into the air. This release of carbon dioxide is extremely harmful to the ecosystem and is the primary cause of global warming, the greenhouse effect, climate change, and ozone layer depletion.[3] As a result, humans must seek alternate energy sources to ensure a clean and sustainable future. Solar energy is the most effective renewable energy source due to its large scale, widespread availability, versatility, and environmental benefits.[4] As previously said, solar energy can generate both heat and power, making it extremely versatile in a variety of industries. The heat generated by solar thermal sources is utilized for space heating, chemical processing, food preparation, and textile manufacturing. Solar-generated power Energy is used in telecommunications, transportation, water heating and treatment, agriculture, and the building industry.[5]

Sustainability and Environmental Impact of PV Manufacturing:

Solar-powered electricity generation:-

Solar energy can generate electricity either directly through PV cells or indirectly through concentrated solar power (CSP).

Photovoltaic (PV) A PV cell is a component of a PV system that generates electricity using the PV effect. The PV effect is described as the creation of electric voltage between two electrodes connected to a solid or liquid system by shining a light on it. Almost all PV cells contain a PN junction through which a photovoltage is applied. The cost-effectiveness and efficiency of solar PV cells are determined by the material used. The optimum solar cell material must meet the following parameters [6-7]: •

- The material used for manufacturing the solar cells should have a band gap between 1.1 and 1.7 eV.
- The material should have a direct band structure.
- The material should be readily available and nontoxic.

- The material should be suitable for large reproduction.
- The material should have good PV conversion efficiency.

The material should have a long-term stability factor PV cells can be classified into three major generations: first-generation, second-generation, and third-generation cells.

a. PV cells manufactured of crystalline silicon are considered first-generation cells. These cells could be monocrystalline or polycrystalline silicon with high grain sizes.

b. Second-generation PV cells. Thin-film cells are classified as second-generation PV cells. These cells are less expensive than first-generation cells due to reduced silicon material requirements but have a smaller market share due to poorer efficiency. There are several types of thin-film cells. Amorphous silicon (AS) solar cells are made by decomposing silane gas in a plasma-enhanced chemical reactor and depositing the cells on a substrate.

c. Third-generation PV cells. Third-generation PV cells improve on second-generation PV cells, aiming for improved performance. Efficient and environmentally friendly. The primary advantage of these cells is their low cost.

Concentrated solar power (CSP) or solar thermal technologies use concentrated sun radiation to generate steam or hot air. This steam or hot air is then used to generate energy through a traditional power cycle.[8] The four types of CSP technology utilized now are as follows [9]:

- Parabolic troughs,
- Power towers,
- Dish/engine systems, and Linear Fresnel reflectors

Direct Applications of Solar Energy:-

Apart from generating electricity, solar energy is used for a variety of different applications. Some direct uses of solar energy are as follows:

Agriculture.

In desert regions where water for agriculture is scarce, the sun desalination method has been used to turn brine into fresh water for agricultural purposes. In this technique, brine is collected in a basin and evaporated using solar radiation. This freshwater can be used for agricultural purposes.[10] Water pumps powered by solar PV cells have been successfully deployed in Algeria's Sahara region. These pumps were proven adequate for the aforementioned purposes.[11]

Solar vehicles: To promote sustainable mobility and reduce environmental effects of fossil fuels, research is underway to produce solar-powered vehicles. Because of the ever-increasing expense of fossil fuels and developments in PV cells, the future of solar-powered vehicles appears to be bright.[12] Given current PV efficiency, a solar car with an 8 m² footprint may generate 1600 to 2400 W or 2 to 3 horsepower; consequently, even at midday, a solar vehicle can only produce 11 horsepower. It appears difficult to envision a solar-powered automobile shortly. However, growing worries about the environmental implications of fossil fuels and their costs are adding to a lot of emphasis on research in this sector. [13-14] Solar vehicles have challenges such as high beginning costs, limited speed range, and low efficiency (only 17%).

Cooking:

Many countries use firewood as a cooking fuel. In India, for example, wood provides 47% of the energy for cooking. In several African countries, the ratio exceeds 75%. Replacing this energy with solar cooking can assist the environment by conserving trees. A solar cooking system has been built, complete with energy storage. It consists of flat plate collectors, reflectors, and a working fluid that typically distributes heat from the collectors to cooked products.[15]

Water Treatment:

Photocatalysis has shown remarkable success in grading organic contaminants in water and air over the last two decades. The thin-film fixed-bed reactor (TFFBR) is an early solar reactor that utilizes a light-concentrating mechanism for the photocatalysis of water.[16] The technical obstacle to commercializing catalytic water treatment is now the post-treatment recovery of catalyst particles.[17]

Solar energy in space: Solar energy can power satellites orbiting the Earth. These satellite power stations can transform solar energy into electricity using PV and other solar technologies. This electricity can be transformed into a microwave beam using a microwave generator and antenna onboard the satellite. Photocatalysis has shown remarkable success in grading organic contaminants in water and air over the last two decades. Satellite antennas can send a thin-film fixed-bed beam to an Earth-based receiving antenna. In this technique, the microwave beam can be turned back into electricity on Earth. The satellite system's power can be sent anywhere on Earth.[18] The satellite wireless power transfer system's DC-to-DC efficiency at 5.8 Hz was measured to be 45%. This efficiency is due to the development of effective DC-RF converters and rectennas for this frequency.

Challenges and Opportunities in Scaling up Solar Power Storage:

Because of its abundance and environmentally friendly nature, solar energy is our most sustainable energy source. As PV solar cells continue to improve and produce electricity at competitive rates both for domestic and industrial uses, they are expected to be optimized and recognized as the predominant energy source by 2022. Worldwide use of the improved solar technologies of the future is expected to surpass the use of conventional electric generation technologies by the end of 2032. The future of solar energy depends upon its economic feasibility, environmental impact, and advancement in technology. For solar power to be a dependable energy source in the future, solar energy technologies must overcome certain challenges. These challenges are studied and discussed below

Technical difficulties: One of the PV cells' technical difficulties is that they need to increase their efficiency to compete with other energy sources. It is necessary to guarantee a plentiful supply of the ingredients used to manufacture cells, such as silicon and CdTe. It is necessary to create a billing and metering system that is easy to use. Thermal losses in CSP technologies must be minimized and high-heat-capacity heat-transferring fluids must be identified. For solar water heating to be widely used, the system must be approved under current building codes, appliance safety requirements, and other requirements.

Environmental challenges: The primary benefit of solar energy systems is their little impact on the environment. Systems driven by solar energy are significantly superior to those fueled by traditional fossil fuels.[19] It has been discovered that compared to traditional systems, home solar water heating systems emit 80% fewer greenhouse emissions. Compared to a traditional electric power plant system,

solar space heating results in a 40% reduction in greenhouse gas emissions.[20] We can stop the degradation of our water resources and air pollution from harmful gases like CO₂, SO₂, and others by moving from traditional energy sources to solar energy technology.

solar energy is the most practical energy source going forward. Solar technology appears to be a very promising means of producing electricity. The efficiency of multi-junction photovoltaic cells has been astounding. The technologies of CSP. Solar energy can provide the energy needs of vital businesses such as water treatment, agriculture, the automotive and food preparation sectors, and the automobile industry, in addition to producing electricity.

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