

Application of Solar Energy in India

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Abstract - The term "solar energy" describes the radiant energy that the sun emits, which may be captured and transformed into useful forms of power like heat or electricity. Because of its sustainability and abundance, this renewable energy source is a major priority in the fight against climate change and the decrease in dependency on fossil fuels. Solar energy has emerged as a pivotal player in the global energy landscape, offering sustainable solutions to address both environmental challenges and energy security concerns. This paper provides an in-depth exploration of solar energy, including its technological advancements, economic impacts, policy frameworks, and prospects.

Keywords—Solar Energy, Climate change, technological advancements, economic impacts, policy frameworks, prospects

I. INTRODUCTION

We cannot just rely on conventional energy sources to meet our demands, hence the production of power from renewable energy sources is imperative. One of the most significant renewable energy sources utilized globally is solar energy (1). Utilizing the solar energy that reaches Earth, solar panels aid in the production of electricity through solar radiation (2). We use this power in our homes, businesses, offices, educational institutions, and so forth. Solar panels are composed of solar cells connected in series, which are assembled into solar modules that are connected in parallel. Every solar cell is composed of semiconductors such as germanium, silicon, and so forth. Every solar cell function as a PN junction, and the photovoltaic effect causes current to flow when photon particles strike the panel's surface. Since the solar panels' output is dc by nature, it can be linked to an inverter to change it from DC to AC, which can then be utilized to power our home's electrical equipment. Extra AC power can be supplied (3). The majority of the world's needs for electricity, heat, and cooling may theoretically be met by solar energy. As solar photocatalytic detoxifying technology advances, solar energy may also be able to address our environmental issues (4). While concentrated solar power systems first convert solar energy into thermal energy and then use a thermal engine to further convert that thermal energy into electrical energy, photovoltaic systems immediately turn solar energy into electrical energy (5). Photovoltaic (PV) cells can be used to directly generate electricity from solar energy, or concentrated solar power (CSP) technology can be used to generate electricity indirectly. Improvements have been

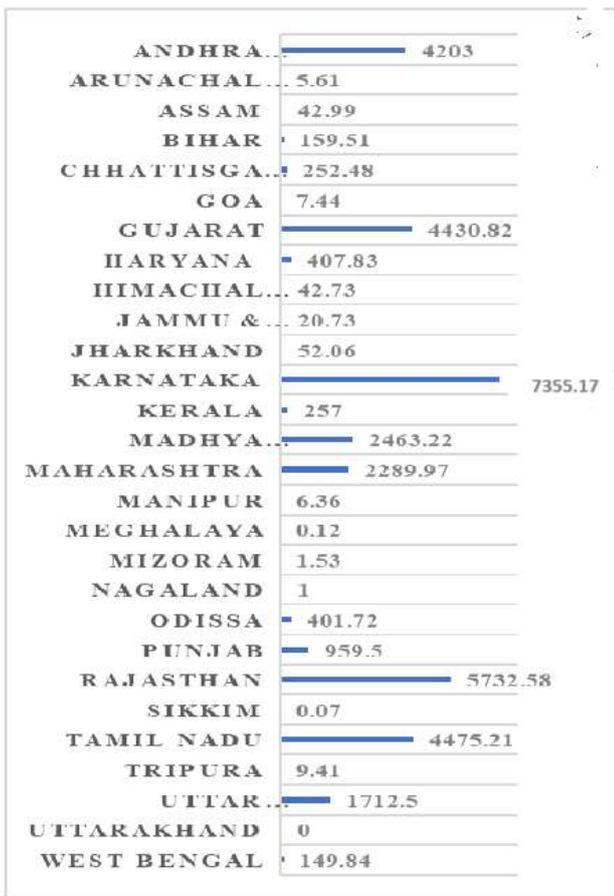
made to increase the PV's efficiency. Solar cells, which can currently achieve up to about 34.1% in multi-junction PV cells. Utilizing concentrated solar systems to generate electricity has a bright future as well, with the CSP in particular standing out for its high capacity, effectiveness, and the capacity to store energy (6). Light, sometimes referred to as electromagnetic radiation, is what the sun emits and is called solar radiation. While sunlight eventually reaches every location on Earth, the amount of solar radiation that reaches each location varies. Photovoltaic systems employ an electronic method to directly generate electricity from solar radiation. They may power a wide range of devices, from road signs and calculators to big, commercial buildings and residences (7). According to data from the International Energy Agency (IEA), solar array installations will provide about 45% of global energy consumption in 2050. It was discovered that solar thermal technology is becoming remarkably common in industrial settings. An alternative for producing energy, processing chemicals, or even space heating is solar thermal. It is applicable to the food, non-metallic, building, chemical, textile, and even business-related industries. In contrast, solar electricity is widely used in the building, water desalination, telecommunication, and agricultural sectors to run lights, pumps, engines, fans, freezers, and water heaters (8). The earth's troposphere warms because of the usage of fossil fuels because they release greenhouse gases like carbon dioxide (CO₂) and methane (CH₄) that prevent long-wave terrestrial radiation from escaping into space. To minimize the use of fossil fuels and increase the use of clean, renewable, and ecologically friendly energy sources. Due to its abundance and more uniform dispersion in the environment than any other renewable energy source, including wind, geothermal, hydro, wave, and tidal energy, solar energy ranks first among these sources. Future research directions are provided for temperature collectors (9). Both the ecology and the economies of developing nations can profit from solar energy equipment. By using alternative energy sources, solar power, especially as it becomes more cost-competitive with other energy sources, has the potential to improve the lives of millions of impoverished people in developing nations. Technologies that underpin various solar-powered devices, assesses the global scenario of installed generation systems for costs of deployment, maintenance, and operation, and economic policies (10). Significant advancements in three technologically different methods to solar energy utilization—solar electrical, solar thermal, and solar fuels technologies—as well as lingering issues and related research prospects are assessed. The astounding

advancements that have been realized in Cost savings and the commercial use of solar energy technology highlight the advantages of R&D spending and show how innovation must continue in order to generate new developments in the sector (11).

II Exploration of Solar Energy

India has been emphasizing solar energy more and more as a crucial part of its energy plan for several convincing reasons.

India is ideally situated to produce solar energy due to its year-round abundance of sunlight. India's southern states (Tamil Nadu, Maharashtra, Rajasthan, and Gujarat) have exceptionally high levels of sun radiation (12) (13).



Capacity in MW (13).

India's energy demand is rising due to the country's fast urbanization and population growth. To meet this need sustainably and without significantly relying on fossil fuels, solar energy offers an option (8).

The National Solar Mission (NSM) is one of the many programs the Indian government has started to promote solar energy. NSM aims to reach 100 GW of solar power capacity by 2022, with the goal of reaching 450 GW by 2030. This includes rooftop and utility-scale installations (13).

Investment in the solar power industry has been stimulated by policies such as tax breaks, subsidies, and advantageous

tariffs. The installation of rooftop solar systems by residential, commercial, and industrial customers is additionally encouraged by net metering regulations (12)(14).

To improve its solar energy capabilities, India has worked with nations and international organizations. Global promotion of solar energy and the facilitation of technology transfer and capacity building are the goals of initiatives such as the International Solar Alliance (ISA), which was founded by France and India(12).

III Technological Advancements

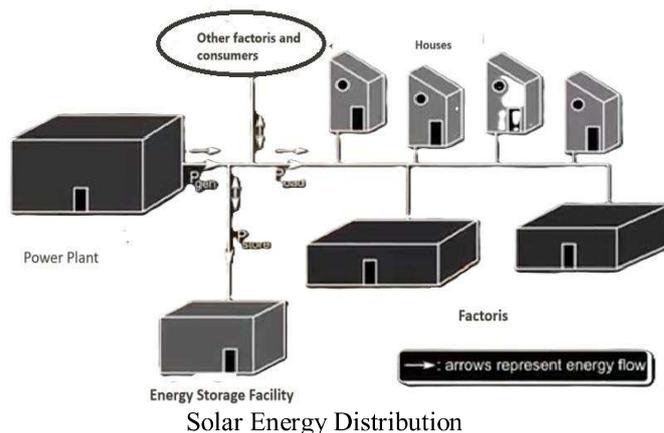
The global deployment of solar power has expanded, costs have decreased, and efficiency has improved thanks in large part to technological developments in solar energy. The following are some significant technological developments in the solar energy industry:

Over time, solar photovoltaic (PV) panels have become more and more efficient. Beyond conventional silicon-based cells, other materials have demonstrated potential in increasing efficiency, such as perovskite solar cells.

The efficiency of thin-film solar cells has increased, and they are lighter, more flexible, and employ semiconductor materials in layers that are far thinner than those of standard silicon cells.

By absorbing sunlight on the front and reflecting light on the back, these panels can produce power from both directions, increasing total energy output.

As opposed to fixed-angle installations, these systems allow the solar panels to be oriented differently throughout the day to optimize their exposure to sunlight and increase energy capture (12)(13)(14).



III Economic Impacts

In India, solar energy has a big economic influence on a lot of different sectors and helps with overall development. Here are a few crucial elements:

Numerous jobs in production, installation, maintenance, and research have been created by the solar industry. By 2030, solar energy is predicted to provide over 24 million new

employments. To give workers the skills they need for the solar business, training programs are being put in place.

India can lessen its need on imported fossil fuels, enhancing energy security and stabilizing the economy, by utilizing solar energy. Having a varied energy portfolio makes one more resilient to changes in the price of energy globally.

By utilizing solar energy, homes and companies can drastically reduce their electricity expenses, which boosts disposable income and economic expenditure. By lightening the load on the grid during peak hours, distributed solar power can save infrastructure expenditures.

Significant foreign direct investment (FDI) has been drawn to the Indian solar business, promoting both scientific advancement and economic expansion. The solar supply chain promotes local manufacturing, which boosts economic growth (e.g., inverter and panel manufacture) (13).

IV Policy Frameworks

India has created a thorough system of policies to support solar energy with the goals of enhancing energy security, lowering carbon emissions, and fulfilling its climate pledges. Key elements of this framework are as follows:

The National Solar Mission (NSM) was started in 2010 with the goal of making India the world leader in solar energy by 2022 with the deployment of 100 GW of solar power (modified to 300 GW by 2030). solar thermal technology, grid-connected solar electricity, and off-grid solar uses.

Adoption and investment in the solar industry are encouraged by financial incentives for solar installations.

Creation of huge solar parks to encourage scale economies. The national goal of the government is to establish solar parks.

Incentives for producers of solar-related components as well as subsidies for both commercial and residential solar systems. For solar installations, there are GST (Goods and Services Tax) exemptions and reductions.

Requires that electricity distribution companies procure a percentage of their total energy purchased from different energy sources with solar being one of them.

Support from organizations like the Indian Institute of Science and other research agencies for R&D in solar technology to increase efficiency and lower prices (12)(13).

V Challenges

Notwithstanding the strong foundation, there are still difficulties with financing, acquiring land, and maintaining grid stability. It is anticipated that future regulations will concentrate on improving energy storage options, expanding domestic production, and combining solar energy with other renewable energy sources. All things considered, India's framework for solar energy policies is dynamic and ever-

evolving, catering to new opportunities and problems in the renewable energy industry (5).

Reduction of greenhouse gas emissions and environmental footprint. Land use considerations and biodiversity impacts and challenges of intermittency and grid integration (7).

Both large-scale projects and household installations may encounter obstacles because to high initial capital costs and limited financing options (6).

The large-scale integration of solar energy may not be supported by the current grid infrastructure, which could cause stability problems (11).

Despite the advancements in technology, continuous research and development remain essential for increasing productivity and cutting expenses (12).

VI Prospect

The unpredictable nature of solar energy and how it integrates into the grid, the lack of land required for large-scale installations, and financial constraints are major problems. However, India's commitment to boosting solar energy output and tackling these problems bodes well for the industry's future growth and contribution to sustainable development.

Growing microgrids and rooftop solar arrays can strengthen local economies and lessen need on centralized power.

Maintaining participation in international alliances, such as the International Solar Alliance, can help with financing and knowledge transfer.

A more hospitable environment for investment and project execution can be produced by simplifying rules and implementing supportive policies.

Innovation and project development can be accelerated via public-private sector collaboration.

As sustainability becomes more and more important, solar energy will be essential to meeting India's climate targets and lowering the country's reliance on fossil fuels.

The solar industry is experiencing a growing need for trained personnel, and investing in workforce training can assist satisfy this demand (12)(13).

Conclusion

These developments keep solar energy more competitive with other energy sources and contribute to its growing global adoption, particularly in nations like India where solar energy is essential for sustainably satisfying energy demands. In India, solar energy has significant economic benefits that include cost savings, job creation, energy security, and rural development. In conclusion, despite certain obstacles, solar energy has a bright future in India thanks to government assistance, technological breakthroughs, and rising public awareness of the need for sustainable energy sources. In order to examine the growth of renewable energy sources during the last several years, this study provides a thorough assessment of various

renewable energy sources. This study makes it abundantly evident that renewable energy sources will play a major role in providing us with the electricity we need to lead modern, healthy lives.

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