

Solar Energy Harnessing in India: An Overview

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Abstract— Owing to India's growing economy, the energy demand is ever increasing, but there is a severe shortage of supply. Increasing concern over environmental pollution caused by fossil fuels has triggered exploration of non-renewable energy resources. Out of such alternate energy sources, solar energy has garnered much interest all over the world due to its easy availability and abundance. In this paper, the benefits and importance of solar energy is highlighted. An overview of potential of solar energy harnessing in India, its present status, barriers and challenges, and the supportive government policies and future prospective is presented.

Keywords— Government policies: India: renewable energy: Solar energy: solar power.

I. INTRODUCTION

Development of any country is directly related to its energy resources present since energy is the backbone of economy. [1] Energy is the primary and most universal measure of development of a nation. As conventional energy sources are depleting day by day and insufficient to meet today's population needs, utilization of alternative energy sources is the only solution. The increased power demand, depleting fossil fuel resources and growing environmental pollution have led the world to think seriously for other alternative sources of energy. Basic concepts of alternative energy resources are related to the issues of sustainability, renewability and pollution reduction. Thus, it is essential for today's world to concentrate on renewable energy sources in order to satisfy the demand and conserve our finite natural resources for the generations to come.

There are many forms of renewable energy – hydroelectric, wind energy, solar, biomass, etc. Most of these renewable energies depend directly or indirectly on sunlight. Wind and hydroelectric power are the direct result of differential heating of the Earth's surface which leads to air moving about (wind) and precipitation forming as the air is lifted. Solar energy is the direct conversion of sunlight using panels or collectors. Biomass energy is stored sunlight contained in plants. The renewable source of energy that we take into study is the solar energy which is obtained from the sun and can never be exhausted. Sun's irradiance reaches the earth in abundance which can be saved properly and can be used as a better alternative for non-renewable energy sources.

Solar energy technologies are classified as active or passive depending on the methodology involved in harnessing solar power. Active technology includes use of photovoltaic systems to generate electricity and solar thermal energy systems for heating water to drive turbines and generate electricity. Passive technology involves designing buildings so as to utilize sunlight to the maximum extent. In this paper, we have focused on exploitation of active solar technology in India.

India is the world's third largest producer and third largest consumer of electricity.[2] The national electric grid in India

has an installed capacity of 364.96 GW as of 30 November 2019 [3] out of which 63.1% energy is from fossil fuels, 13.8% from hydro, 1.9% from nuclear, 8.6% from solar, 10.2% from wind, and, 2.6% from biomass sectors. [4] India is the first and only country to have set up a Ministry of New and Renewable Energy (MNRE) as early as in 1980's. The mission of this Ministry is to generate more and more power using renewable energy sources and gradually reduce dependency on fossil fuels and hence establish energy security and self-sufficiency. It has given a special importance to solar energy sector. Even though coal based thermal power plant is still the cheapest means of power generation, technological improvements and decreasing cost of solar panels has opened up the possibilities of change in the scenario in the future. In this paper, we have summarized the recent developments and future of solar energy in India.

II. POTENTIAL FOR SOLAR ENERGY IN INDIA

Among the various renewable energy resources, solar energy has the highest potential in India. Being close to the equator and having tropical climate, clear sunny weather is experienced 250 to 300 days a year in most parts of our country. The solar radiation received per year varies from 1600 to 2200 kWh/m². The map of India depicting average solar radiation received per day is shown in Fig. 1. This when harnessed completely can generate about 6,000 million GWh of electricity per year. The National Action Plan on Climate Change also points out: "India is a tropical country, where sunshine is available for longer hours per day and in great intensity. Solar energy, therefore, has great potential as future energy source. It also has the advantage of permitting the decentralized distribution of energy, thereby empowering people at the grassroots level". [5]

III. BENEFITS OF SOLAR ENERGY

Solar energy is a clean, renewable resource that is continuously supplied to the earth by the sun. It can be installed virtually anywhere; in a field to on a building.

1. *Zero energy-production costs:* Solar energy plants do not require any outside supply to work, so its maintenance and energy production costs are practically zero. Once the panels

are installed, they generate energy with little maintenance and no harmful wastes.

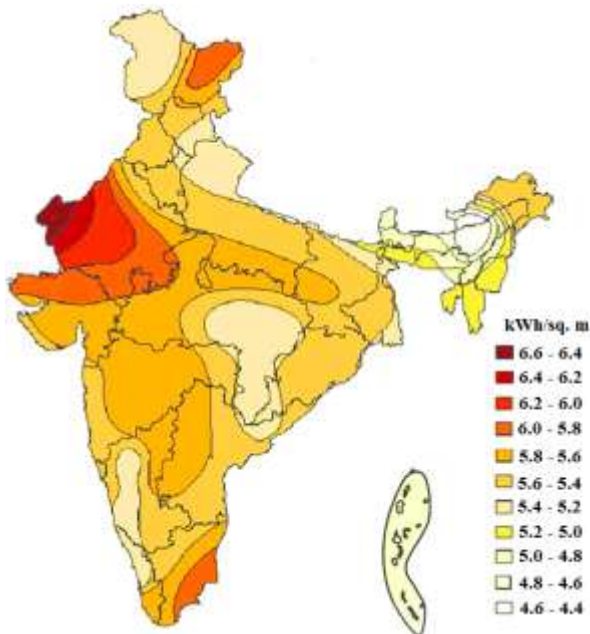


Figure 1: Map of India Average Daily Solar Radiation in units of kWh/m².
[Source: <http://www.cercind.gov.in>]

2. *Low transmission losses:* With the individual installation of photovoltaic panels on rooftops, the need to transport energy is drastically reduced, increasing the efficiency of the electrical system.

3. *Versatile installation:* The most interesting advantage is the possibility of providing electricity in remote locations, where the cost of installing electrical distribution lines is too high or unfeasible. Solar panels can be virtually installed anywhere and everywhere the sun shines.

4. *No adverse impact on the environment:* Solar power is pollution free and causes no emission of greenhouse gases after installation. Solar power does not need water to produce energy. Solar power does not pollute waterways or atmosphere like fossil fuel power plants, which are a huge contributors to water and air pollution by using significant amounts of water for cooling the system and emitting harmful gases during energy production processes. The water that is discharged contains toxic pollutants that are dangerous to human health.

5. *Energy security to the country:* No dependency on foreign resources for electricity generation.

6. *Economic impact:* With India being a growing economy, power consumption is only going to rise. So adoption of solar energy is the ideal way forward to manage balance between economic growth and sustainable environment. Additionally, with the advent of Electric Vehicles, using renewable energy in the charging infrastructure will further boost the growth of the industry and hence the economy. Solar energy creates more job opportunities at the installation site.

7. *Easy installation:* Installation is easier and consumes lesser time compared to other renewable power plants.

8. *Long term durability:* Since solar panels involve no moving parts, they last longer and are more reliable compared

to other renewable energy sources.

IV. CURRENT STATUS OF SOLAR ENERGY IN INDIA

Solar power is expanding in India at a fast pace both in terms of technology and installation. India has world's third fastest expanding solar power program, standing next to only USA and China. The country's solar installed capacity reached 31.696 GW as of 31 October 2019.[6] Since 2010, the cumulative solar photovoltaic installation capacity has grown enormously from 161 MW to 28,181 MW as shown in Fig. 2. Solar power generated in India year-wise is shown in Fig. 3. State-wise cumulative installation of solar power is shown in Fig. 4.

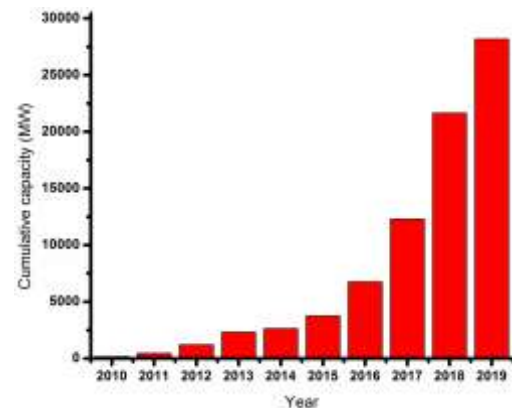


Figure 2: Cumulative solar photovoltaic installation capacity (MW) in India [3]

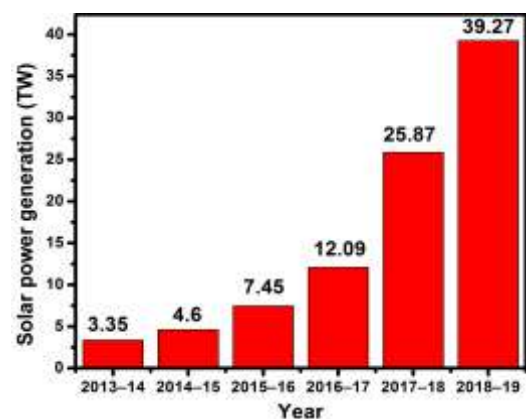


Figure 3: Year-wise solar power generation in India [5]

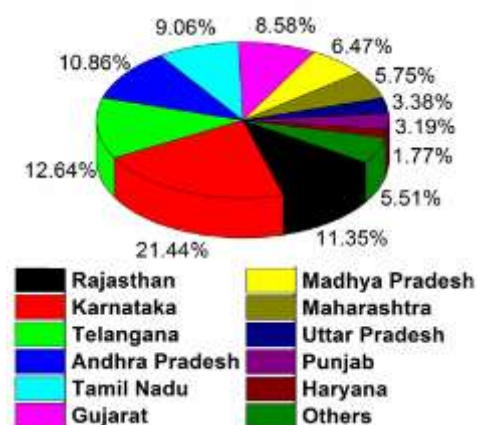


Figure 4: State-wise cumulative solar installation in MW as on 31 March 2019 [6]

The Indian government had set an initial target of 20 GW capacity of solar power for 2022, which was achieved four years earlier itself. [7]. The target was increased to 100 GW by 2022 in the year 2015 with an investment of US\$100 billion. [8] This increase in solar power is supplemented by a steep drop in the cost of production of solar electricity as well. The cost of solar power generation per kW has come down from 12.16 in 2010 to 4.00 in 2019. India ranks first in the world in terms of the lowest capital cost per MW to install the solar power plants. [9]

Solar energy is harnessed in India is in three forms –

- i. *Large scale grid connected or Ground based solar plants* which mostly refer to huge number of solar panels installed in a large land area such as solar parks.
- ii. *Rooftop solar power generation* which is 70% industrial or commercial.
- iii. *Off-grid solar power for local needs* which includes solar, solar home lighting systems, solar street lights, solar cooker, etc.

Total installed capacity of these three forms of solar energy is shown in Table 1. India has established more than 42 solar parks in which electricity is generated from solar energy with the help of a large number of photovoltaic cells connected in the form of a grid. The major solar power parks in India along with their peak power (DC) generation capacity are shown in Table 2. The Indian government has initiatives to increase off-grid solar by distributing solar lanterns, increasing solar street lighting installations and distributing and popularizing the use of solar cookers.

TABLE 1: Photovoltaic (PV) installed capacity by application (MW) as of 31/7/2019 [5]

Application	Capacity (MW)
Ground mounted	27,930.32
Rooftop	2,141.03
Off-grid	919.15
TOTAL	30,990.50

TABLE 2: Major solar large grid power projects in India [5]

Plant	State	Peak power (MW)
Pavagada Solar Park	Karnataka	1400
Kamuthi Solar Power Project	Tamil Nadu	648
Gujarat Solar Park-1	Gujarat	221
Welspun Solar MP project	Madhya Pradesh	151
ReNewPower, Nizamabad	Telangana	143
Sakri solar plant	Maharashtra	125

V. RENEWABLE ENERGY POLICY FRAMEWORK

The Government of India as well as most of the State Governments has put in place exclusive policies to promote renewable energy in general and solar energy in particular. [10-14]

1. As per the *Electricity Act 2003*, the government of India strives to promote electricity generation from co-generation and renewable energy sources. The act accelerated the process of renewable energy development in the country.
2. The *National Electricity Policy 2005* was a watershed policy that gave a fillip to rapid increase in renewable energy installations. It stipulates that progressively the share of electricity from non-conventional sources would

need to be increased. It also mentions that the electricity generated from such sources could be purchased by the government from private companies through a competitive process.

3. The *Tariff Policy of 2006* has stated that the appropriate Central government Commission shall fix a minimum percentage for purchase of energy from non-renewable sources taking into account availability of such resources in the region and its impact on retail tariffs.
4. *Solar Atlas*: In June 2015, India began a ₹40 crore project to measure solar radiation. The Ministry of New and Renewable Energy (MNRE) has installed fifty-one solar radiation resource assessment stations across India by to create a database of solar-energy potential. Data is collected and reported to the Centre for Wind Energy Technology (C-WET) to create a solar atlas. This data is utilized in setting up solar power plants.
5. *Jawaharlal Nehru National Solar Mission (JNNSM)*: The subsidies and incentives provided by the Government and since 2010 under JNNSM have been instrumental in adoption of solar energy. This mission was launched in 11 January 2009 with the target for Grid Connected Solar Projects of 20,000 MW by 2022. The Mission had adopted a three-phase approach with the three phases spanning from 2009-13, 2013-17 and 2017-22. The target was achieved 4 years ahead. This mission encouraged private companies to generate solar power by reducing the import duty on solar panels by five percent. This is expected to reduce the cost of a rooftop solar-panel installation by 15 to 20 percent. [15]
6. *Indian initiative of International solar alliance (ISA)*: In January 2016, Prime Minister Narendra Modi and French President François Hollande laid the foundation stone for the headquarters of the International Solar Alliance (ISA) in Gwal Pahari, Gurgaon. This alliance comprising over 120 countries lying wholly or partially between the Tropic of Cancer and the Tropic of Capricorn will focus on promoting and developing solar energy and solar products. ISA aims to achieve a reduction in production and development cost of solar power which will result in its widespread use in poor and remote regions. [15]
7. *Initiatives taken by Central Government*: Indian government has taken several Initiatives and provided subsidies to promote the growth of solar power generation. Some such initiatives are: Viable gap funding, opportunity to claim depreciation by solar power generating companies, capital subsidies to rooftop solar power plants, issuing tradable renewable energy certificates (REC), Assured Power Purchase Agreement (PPA) to guarantee purchase of solar power by government, waiving off of Interstate transmission system (ISTS) charges and losses during the period of PPA, upto 70% and 30% subsidy for the hill states and other states respectively for the installation of rooftop solar units, etc. [15]

VI. BARRIERS AND CHALLENGES OF SOLAR ENERGY GENERATION

Even though the government has ambitious targets for

solar energy generation in the country, there are various barriers and challenges related to solar energy in India, which have been pointed below. [16]

- The main disadvantage of solar energy is its unavailability for all 24 hours. The weather conditions are major factor on availability of solar radiation.
- Large land area is required for solar power plants, which sometimes is not feasible. For example, the amount of land required for utility-scale solar power plants is currently approximately one square kilometer for every 20–60MW generation
- 100 GW of solar power generation would mean about 10.5% share for solar power in total generation of power in India. Such large share of intermittent sources requires huge investments in the power grid infrastructure for transmission, smart supply and demand management.
- To achieve a capacity of 60 GW for utility scale projects by 2022, there would be a requirement of investment of 2,80,000 crores. The government currently expects a big share of this to come from international sources. But an international fund for solar projects in India is very less.
- Storage problem is also very serious. Suppose if the demand of power is not so high then the electricity produced by the solar plant will have to be stored somewhere to supply when demanded. Therefore, storage technology in terms of economical and efficient batteries needs to be developed on priority.
- Temperature and dust problems affect the reliability of solar panels. In remote areas with high temperatures, it is being found that we are not getting the required units of power. The panels do not yield their optimal usage. Dust is a problem, especially in Rajasthan, where the dust conditions are really bad and require frequent cleaning around two times a month, which then increases the operational costs. The alluvial dust (present in plains of north India and delta regions of south India) turns into mud when water is poured is difficult to clean while sandy dust (present in Rajasthan and Gujarat) can be washed away easily with water.

VII. CONCLUSION

India is poised for significant growth power generation through renewable energy sources. The government policy in the last two decades has provided the centre stage for exploitation of renewable energy sources in general and solar energy in particular. Being close to the equator, India is in favorable geographical location and enjoys abundant supply of solar radiation, almost throughout the year.

However, if India has to reach the full potential in harnessing solar energy, it has to overcome several barriers, which may pose challenges to the stakeholders. Need to attract foreign investors and development of economical storage technologies are the primary issues we need to tackle. In addition, there are many technical problems, such as high temperatures in several places and harsh environment, which may pose problems for the longevity of solar installations. All stakeholders need to put collective efforts to overcome these challenges and reach the planned targets for solar energy generation.

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