Renewable and Sustainable Energy Reviews xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

# Solar power utility sector in india: Challenges and opportunities

Pushpendra Kumar Singh Rathore[a,*], Shailendra Rathore[b], Rudra Pratap Singh[a], Sugandha Agnihotri[c]

[a] Gla University, 17 km Milestone, Mathura-Delhi Highway, Mathura 281406, UP, India
[b] Inverstis University, Bareilly-Lucknow Highway, Bareilly 243001, UP, India
[c] Kit, Kanpur-Allahbad Highway, Rooma, Kanpur 208001, UP, India

ARTICLE INFO

*Keywords:*
Solar
Energy
Power
India

ABSTRACT

In the last decade the demand of power in India has increased manifold, therefore Government has announced the National Solar Mission of generating 100 GW of solar power up to 2022. Around 60% of the total National Solar Mission target is allotted to the national/international large-scale solar power developers/investors. Hence, it becomes important to know the ground reality of large-scale solar PV developers/investors. This paper deeply analyzes the key barriers and bottlenecks faced by solar power developers in achieving the target and their growth. This article also suggests some motivational factors of solar energy which play an important role in attracting large solar players around the world to invest in Indian subcontinent. It concludes by highlighting some key policies of the Government that can help in addressing some identified barriers in order to ensure a secured sustainable energy future of India.

## 1. Introduction

The demand for energy in India is rapidly increasing with increasing human population, urbanization and modernization. One estimate suggests that the world population is expected to double by the middle of this century [1]. Most of the population increase will take place in developing countries like India, Brazil and China. Being a developing nation and ranked 2nd in terms of population, India's power appetite is increasing at an alarming rate. In the last 10 years, in India, the generation capacity has been doubled and at present it is around 260 GW [2]. This rapid capacity addition is insufficient to meet the power demand of the country. Further, for sustainable development our power generation must touch the figure of 300 GW and 800 GW up to 2017 and 2035 respectively [3]. India is still not able to meet its peak electricity demand despite of the fact, that in 65 years the installed capacity has been increased by more than 113 times. According to the report published by Central Electricity Authority in 2015, the peak power deficit in 2001-02 was 12.1% and at the end of 2014-15 it was reduced to 2.5%. Fig. 1 shows the gap between demand and supply of power in India in 2014-15. To overcome this situation, planned and unplanned measures were undertaken by the government and utilities to bridge this demand-supply gap. Fig. 2 shows the growth of capacity addition of power sector in the last 10 years in India. No doubt that this capacity addition has reduced the power deficit, but it leads to the emission of greenhouse gasses which affects the climate adversely. Today, India heavily relies on fossil fuel to meet its energy requirements. Around 69.5% of the total power is generated by thermal power plants [4]. In India electricity generated by burning fossil fuels contributes 37.8% of the total greenhouse gasses released in the atmosphere [5]. Burning of fossil fuels increases carbon-dioxide emission which is a major contributor to the climate change crises today [6]. In 2016, World Health Organization (WHO) has released a report in which, 11 Indian cities have occupied positions in the list of top 25 polluted cities of the world [7]. This shows that, increase in installed capacity of fossil fuel based power plants also increases the pollution level. For India to sustain strong economic growth, a significant growth in its electricity consumption is inevitable, which also does not create any harmful effect to the environment. Renewable energy sources are capable to solve the problem of sustainable development associated with fossil fuel based power plants as these energy sources are unlimited, ecofriendly and provides energy with negligible emissions of air pollutant and greenhouse gases [8]. It is clearly feasible to replace the current fossil fuel infrastructure with solar power and other renewable, and reduce $CO_2$ emissions to a level commensurate with the most aggressive climate change goal [9]. Being a tropical country and having around 300 sunny days/year, India's theoretically calculated solar energy incidence on its land area alone, is about 5000 trillion kilowatt-hours (kWh) per year (or 5 Wh/yr) [10]. To utilize this much of solar energy the government has set an ambitious target of achieving 100 GW of solar power till 2022 under Jawaharlal Nehru National Solar Mission (JNNSM). Since its

* Corresponding author.
*E-mail address:* pushpendra.rathore@gla.ac.in (P.K.S. Rathore).

http://dx.doi.org/10.1016/j.rser.2017.06.077
Received 19 September 2016; Received in revised form 22 March 2017; Accepted 22 June 2017

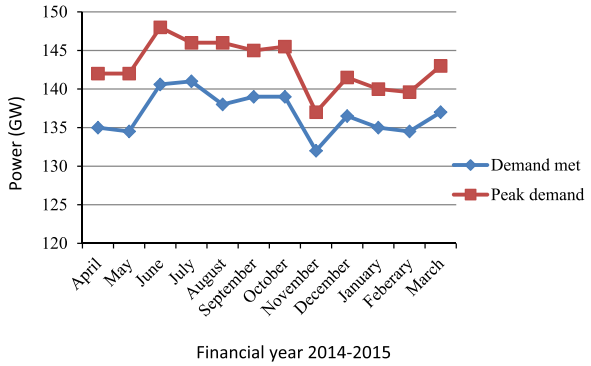


**Fig. 1.** Peak power deficit of India in the year 2014 and 2015. Sources: Central Electricity Authority, 2015.

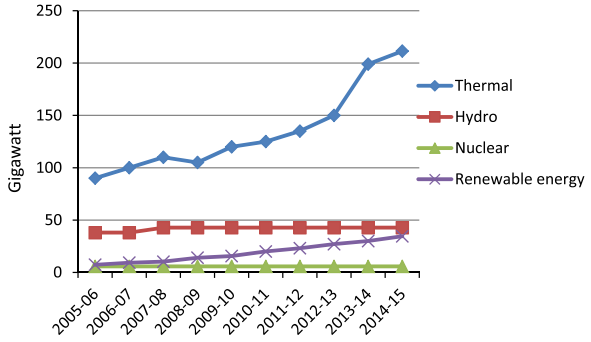


**Fig. 2.** Installed capacity of the various power sectors from 2005 to 2015. Sources: Indian central statistics office, National statistical organization, 2015.

inception, the JNNSM has seen a very slow progress in terms of installed capacity because till March 2016 the total cumulative installed capacity of the utility scale solar power projects in India is only 8118 MW [11]. But, if we see the thermal power capacity addition of the last 2 years, then it is more than the cumulative installed capacity of the solar utility sector in India [2]. Whereas, countries like China, Japan and USA has 43.53 GW, 34.41 GW and 25.62 GW of solar Power installed capacity respectively. The slow growth of the solar utility sector in India is a matter of concern because about 60% of the total target of JNNSM is allotted to solar utility sector. Now one can imagine the actual condition of the solar utility sector in India. Why this utility scale solar power sector is not growing as per the said target? Is it policy and regulatory barriers or technological barriers. Therefore, this research article is an attempt to deeply analyze various ground barriers and bottlenecks faced by the utility scale solar power developers in India. In this study, the point of view of 15 solar power developers has been taken into consideration in compiling various types of barriers faced by the developers. The author had also addressed and analyzes some motivational factors, for the solar power developers, which are associated with the Indian subcontinent. These factors will play a major role in attracting investment of the solar industry and makes India to move on the path of sustainable development by becoming one of the leading nations in solar energy especially for the growth and development of large solar power projects. In order to develop India as a hub of solar power and to achieve energy security the Government had taken various short term and long term initiatives which affects the growth and development of large scale solar power sector are also clearly mentioned in this article. At the end, the author has also shown the current status of the solar utility sector in India.

## 2. Methodology

This article discusses the barriers and opportunities faced by the solar utility sector in India. It uses certain tools for data collection from various sources, which are then analyzed for better understanding of the problem and suggesting solutions or solution approaches. One of such tools is an exploratory research tool. Exploratory research often relies on qualitative approaches such as: case studies, in-depth interviews, pilot studies, and focus groups [12]. Exploratory research tends to tackle new problems on which little or no previous research has been done. This research article deeply analyses the already published statistical reports of various Governments/private organizations of National and International repute, which are directly or indirectly associated with the growth and development of large scale solar utilities in India, to analyze the condition of the solar energy market of India for large solar utilities. During the course of study, the study team has interacted with key Government officials, the domain experts in affiliated technical and academic institutions and independent research organizations to gain perspectives of all relevant stakeholders in context with the opportunities and growth of the large solar power sector in India. In order to get more insight of the solar utility sector of India, fifteen large scale solar power developers were interviewed regarding the challenges they have faced in the Indian subcontinent, with specific focus on the constraints related to technology, financing, policies and regulations, infrastructure, and transparency and accountability.

## 3. Motivational factors for solar power sector in India

In this section we have discussed about various motivational factors that affects the growth and development of the solar power sector in India. These factors will play a major role in framing the future of the solar market in India and will definitely attract the global solar industry for investing in Indian subcontinent.

### 3.1. Availability of solar energy

The lifeline for any type of solar power establishment is the availability of solar radiation. The geographical extent of India lies between 8°4′ to 37°6′ north latitude and 68°7′ to 97°25' east longitude and it is the 7th largest country in the world, having landmass of 2.9 million $Km^2$ and hence the solar profile of India is very rich. Fig. 3 shows the annual average direct normal irradiance in most of the Indian states are around 4.5–5.0 $KWh/m^2$/Day and Fig. 4 shows that average global horizontal irradiance is around 5.0–5.5 $KWh/m^2$/Day. This much of solar energy is sufficient to produce 6,081,709 TWh/year, which puts India in the list of top five countries of the world [13].

It has been found, after analyzing these figures, that there are many regions which receive solar insulation of more than 5 $kWh/m^2$/day and therefore, these regions can constitutes solar hotspots in India. Western Ghats, Eastern Ghats, Gangetic plains, Thar deserts and Gujarat plains can be the solar hotspots in India covering around 1.89 million $km^2$ of area (~ 58% of the total land mass) [14].

### 3.2. Availability of wasteland

In evaluating the environmental impact and capital cost the amount of land area required for a particular amount of utility scale power generation, referred as solar land use energy intensity, is considered as an important parameter. A solar utility scale solar power plant has large land use energy intensity as compared to fossil based power plant [15]. For setting up a solar power plant of more than 20 $MW_{ac}$ capacity around 7.9 Acres/MW of total land area is required [16]. There is ample amount of wasteland available in the Indian subcontinent, and can be used for installation and development of utility scale solar power plant. Developing a utility scale solar power plant on wasteland doesn't create any environmental pressure on agricultural systems because wasteland is neither fit for residential purpose nor for any type of agriculture purpose. Due to