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Case study

The grid-connected solar energy in India: Structures and challenges

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ABSTRACT

Since Independence in 1947, the Government of India has been releasing an array of functional structures to support the growth of solar energy in the country. This paper, while unpacking and illustrating the temporal evolution of policy and institutions responsible for solar energy development, critically reviews the political economy of grid-connected solar energy in India. Findings from this study indicate that the implementation of a range of policies, programmes, and institutions, especially since the initiation of the Jawaharlal Nehru National Solar Mission (JNNSM), has been playing a prominent role in India's solar energy portfolio – building up the sector from less than 10 MW installed capacity in the 2000s to about 3000 MW in 2014. Still, solar energy is not the most popular source of renewable energy in India. The findings of this study also indicate that issues sorrounding policy, financial, and social aspects are increasingly becoming impediments to bringing a paradigm shift in the solar sector.

1. Introduction

Solar energy has assumed great importance for India due to the concerns of energy security, volatility of oil market, climate change, rural energy needs, and sustainable economic growth [1]. Since Independence in 1947, the Government of India (GoI) has been developing and initiating a wide ranging policies, regulatory instruments, and institutional structures to support the development of solar energy. However, solar energy development in India has gained momentum only after the release of the Jawaharlal Nehru National Solar Mission (JNNSM) in 2009 – a policy with a target of 20 GW solar capacity by 2022.

Since the release of the JNNSM, a large amount of literature has been analysing solar energy development in India with focus on the following areas – (i) current status and future prospects [2,3]; ii) policy and institutional support [2,4]; and (iii) challenges and opportunities [5,6]. At the same time, a considerable amount of scholarship has reviewed the historical evolution of policies and political structures [7,8], and implementation of the JNNSM [1,9]. That a rich body of literature has been produced to uncover the solar energy development in India does not necessarily mean that the issue is better understood, at least for two key reasons. First, the GoI has recently approved increasing the JNNSM's target five times to a goal of reaching 100 GW up from 20 GW by 2022. Given such political demands, it is imperative to critically (re)understand the solar energy policy governance in India. Second, it is not only essential to identify the political architecture upon which solar energy has developed in India, but also significantly important to analyse the effectiveness and efficiency of the implementation arrangements, and the underlying challenges.

The objectives of this paper are two-fold: i) to undertake a functional analysis of solar energy development between post-Independence and post-JNNSM periods; and ii) to unpack the underlying challenges for solar development, and to offer thoughts on overcoming some of the challenges. While different forms of solar energy practices are available in India – grid-connected, off-grid, decentralized systems, and other new technologies – this paper focuses on the analysis of grid-connected solar energy as it has been gaining quick momentum in the last decade. The added value of this work is that the analysis is supported with both secondary and primary data. The analysis is also first of its kind as until now there are few comprehensive studies with focus on grid-connected solar development in India.

2. Solar energy potential and status

India is strategically located with 250–300 sunny days and a

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solar radiation potential of 5000 trillion kilowatt hour per year (kWh/year), which is much higher than the annual requirement to generate sufficient solar energy from solar photo-voltaic (PV) and solar thermal technological applications [10,11]. More than 58% of the country's land area has huge potential for solar energy as the country receives a daily solar irradiance of 4–7 kW h per square metre per day (kWh/m^2/day) and sunshine of about 6–8 h a day, averaging to about 2300–3200 h per year [2,12]. While Rajasthan (with a solar irradiance of about 5.5–6.8 kWh/m^2/day), northern Gujarat (more than 5.5 kWh/m^2/day) and parts of Ladakh in the Northern India receives the highest annual global solar irradiance, the North-Eastern states receives the lowest (Fig. 1).

The regions with the highest solar energy potential also have high percentage of suitable land area available for the deployment of solar energy. About 4.89 million hectares (ha) of barren and uncultivable land is available in only Gujarat and Rajasthan [14]. The area required to meet India's current electricity energy needs through solar PV (with an efficiency of 10%) is about 3000 square kilometre (km^2) (60 km × 50 km), which is 0.1% of the country's land area [15]. It is also estimated that India can achieve complete energy security by 2031 even if 1% of the total land area is used for solar energy [16].

Despite this huge technical potential and the recent exponential growth of capacity, the 3 GW contribution of solar energy to India's total energy mix of more than 240 GW (as of December, 2014) is still negligible (Fig. 2). With an increasing domestic demand and a compounded annual growth rate (CAGR) of 7.2%, coal continues to be the most important component of India's energy mix. While concerted efforts in exploration and development of hydrocarbons has led to a significant step up in the production of oil and natural gas, imports of petroleum and gas would continue to increase substantially in absolute terms, involving a large energy import bill. The availability of hydro-electricity and additions to nuclear power generation capacity, along with the wind power generation has also increased significantly in the recent years. It is quite apparent that coal will continue to be the predominant form of energy in future.

3. Methods and analysis

The data and background for this research is mainly drawn upon the existing literature, secondary data, and ten face-to-face interviews conducted with German experts involved in India's grid-connected solar sector. All the interviews were conducted in English. For accurate rendition, with prior permission of the interviewees, most of the interviews were audio recorded. All measures were taken to ensure the anonymity of interviewees in presentation of the data.

The interviews were conducted mainly with German experts for two reasons i) the research was conducted for only three months at the German Development Institute (DIE) in Bonn, Germany; and ii) the research was supported by funding from the Federal Ministry of Education and Research (BMBF), Germany, which supports travel within Germany. Acknowledging the locational and time constraints, I hope that the results of this research still allow for the addition of a rich narrative and novel perspectives to the debates on solar energy in India.

The questionnaires used for interviews were developed based on literature review and personal experience. The questionnaire had three major sections. The first section consisted of questions relating to the profile of respondents, such as information about the respondent, his/her role in India's solar sector, the details of the institute/organization, etc. The second part of the questionnaire was designed to understand the respondents' general perspective on India's solar sector. The third section was majorly designed to comprehend the challenges and opportunities of the JNNSM, specifically in terms of grid-connected solar development. The questions covered the awareness of solar energy technologies, prospective for solar energy development in India, and perspectives towards tariff, support from the government, procurement methods, funding, etc.

The collected interview data was translated, transcribed, and analyzed using thematic analysis method and NViVo software. All through the process of analysis it was ensured that the three criteria of thematic analysis were addressed: i) the themes must reflect and respond to the research objectives ii) the themes should represent separate and distinct categories of findings; and iii) the themes should be as specific and explanatory as possible.

4. The evolution of solar energy policy governance

4.1. Pre and post reforms

While India's national energy planning post-Independence began with the formulation of the 'Electricity (supply) Act, 1948', no major initiatives for renewable energy (RE) development were undertaken until the 'oil shock' in 1970s. India's recognition for RE emerged with the 'National Fuel Policy (NFP)' released in 1973 and the 'Fuel policy committee (FPC)'committee report submitted in 1974 [17]. The 'Working Group on Energy Policy' formed in 1979 first identified the need for utilization of non-conventional energy sources. This was strengthened with the formation of the 'Department of Non-Conventional Energy Sources' (DNES) in 1982. The suggestions of the FPC came into existence through formulation of the 'Advisory Board on Energy (ABE)' in 1983. However, no tangible results were witnessed.

The liberalisation of the power sector in the 1990s, and the trifurcation of the Ministry of Energy (MoE) into the Ministry of Power (MoP), the Ministry of Coal (MoC), and the Ministry of Non-Conventional Energy Sources (MNES), renamed as the Ministry of New and Renewable Energy (MNRE) in 2006, brought significant reforms in the development of RE. The implementation of RE, which was largely through individual subsidies provided by the MNES [18], shifted to fixed tariffs and private investments via the 'Electricity Regulatory Commissions Act (ERCA), 1998', and the subsequent formation of the 'Central Electricity Regulatory Commission (CERC)' and the 'State Electricity Regulatory Commissions (SERCs)' [19]. The Electricity Act (EA) 2003 dissolved previous acts and consolidated all laws pertaining to all forms of electricity. It explicitly recognised the role of RE in grid-connected power generation. While the liberalisation in the power sector contributed significantly to the development of wind sector [more than 10,000 MW (MW) installed between 1990s and 2008], little impact was visible in the solar sector (less than 10 MW installed).

4.2. Post- National Action Plan on Climate Change (NAPCC), 2008

The NAPCC opened up new vistas for solar energy development in India through the Renewable Purchase Obligation (RPO) and Renewable Energy Certificates (REC) trading mechanism. The RPO framework formulated under the EA 2003 mandates individual states to procure at least 5% of power from RE sources by 2010 and subsequently increase by 1 percentage-on-year for the next 10 years (i.e., 15% RE share by 2020) [20]. The targets for solar RPO are 0.25% by 2012–13 and 3% by 2022.

To address mismatch between the availability of RE resources in a state with geographical and climatic limitations and the requirement to meet RPO, the REC mechanism was initiated by the CERC in 2006 and is overseen by the 'Forum of Regulators' constituted under the EA 2003 [21]. Under the REC mechanism, a state which generates RE can sell power to the one that couldn't achieve