Renewable and Sustainable Energy Reviews 69 (2017) 239–247

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

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

India's on-grid solar power development: Historical transitions, present status and future driving forces

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ARTICLE INFO

Keywords:
On-grid solar electricity
Sustainability transitions
Renewable electricity
India

ABSTRACT

India with a fast growing demand for electricity and increasing consideration to emissions reduction is investing strongly in renewable electricity generation. Among renewables, the Central and State Governments have set aspirational targets for on-grid solar electricity and legislated several supporting policies to realise these targets. As a result of the favourable political environment, the development of on-grid solar, in terms of the rate of growth in installed capacity, has been increasing in the recent years, and it is expected to continue in the future. This paper aims to investigate the impact of historical transitions of India's electricity sector on the ongoing development of on-grid solar electricity and to explore the prospect of solar sector development in the future. First of all, we investigate how the historical transformation of governmental intervention's approach intertwined with the gradual shift of the source of generation has paved the way for the current achievements in on-grid solar electricity. Second, we envision the future challenges and opportunities for the development of solar sector by looking ahead and discussing the continuity of government's support and the prospective competitions between different sources. We conclude the paper with some required steps to be taken in order to secure the achievement of the targets in solar electricity in the future.

1. Introduction

India as the second most populous country is currently experiencing a steep economic growth and subsequently, a rapidly growing energy demand. In 2012, the country was ranked as the third and fifth highest country in global energy and electricity consumption respectively [1]. Urbanisation, economic development of society, the expansion of industry and the development of new services have contributed to a sharp increase in electricity demand. The demand is expected to rise even further in the near future (see Figs. 1 and 2). To cover this growing demand, 20 GW of new generation capacity will be required annually by 2020 [2]. The (on-grid) installed capacity from different sources has been increased appreciably in the past couple of years. Despite the high level of electricity generation, the country still suffers from about 10% generation deficit of total electricity demand, which puts almost 300 million people with no access to electricity [3,4].

The country's required electricity is generated in different methods: on-grid which is the main method for urban areas as well as widely used for agriculture and industry, off-grid which is more common for rural areas and captive power plants which are mostly used for industries. Electricity is also being generated from different conventional and unconventional sources. In 2014, from the total installed capacity of 255 GW [6], the share of conventional sources is about 70%, where coal alone accounts for about 84% of it. Large hydroelectric and renewables take the second and third rank of the largest installed capacity respectively (see Table 1).

The importance of renewable energy in developing countries and, more specifically, in India's electricity sector, has become significantly higher in recent years (see Table 2). On-grid renewables are seen as a new way to address the concerns about the gap between demand and supply, energy security, energy equity with safe and convenient access and the global commitment to emissions reduction [7–9]. In spite of

Abbreviations: CERC, Central Electricity Regulatory Commission; FIT, Feed-in Tariff; GoI, Government of India; JNNSM, Jawaharlal Nehru National Solar Mission; MNRE, Ministry of New and Renewable Energy; MoP, Ministry of Power; NAPCC, National Action Plan on Climate Change; NHPC, National Hydroelectric Power Corporation; NTPC, National Thermal Power Corporation; PoI, Parliament of India; PSU, Public Sector Unit; REC, Renewable Energy Credit; RPO, Renewable Purchase Obligation; SEB, State Electricity Board; SERC, State Electricity Regulatory Commission; SOE, State-Owned Enterprise; TP, National Tariff Policy 2006

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http://dx.doi.org/10.1016/j.rser.2016.11.032
Received 24 October 2015; Received in revised form 18 July 2016; Accepted 1 November 2016

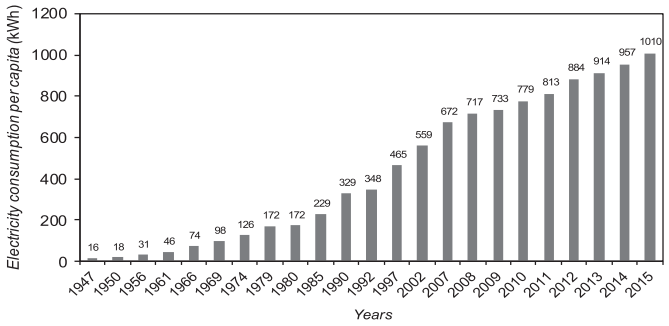

Fig. 1. Growth of electricity consumption per capita in India 1947–2015 [3].

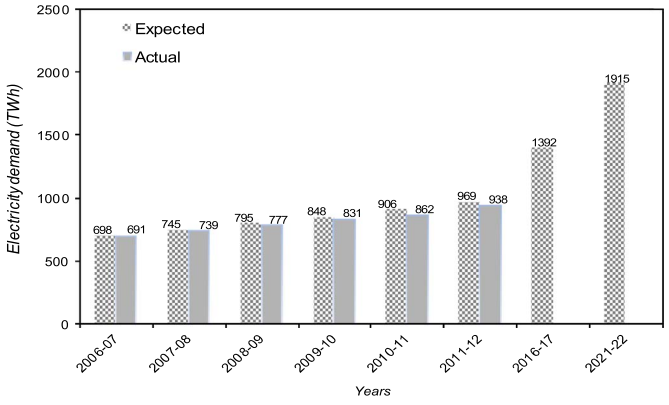

Fig. 2. The expected and actual electricity demand in India 2006–2022 [5].

Table 1
The share of different sources in India's on-grid installed capacity in 2014 [4].

Fuel source	Installed capacity (MW)	Share (%)
Coal	153,571	60
Gas	22,971	9
Oil	1,200	< 1
Hydro	40,799	16
Nuclear	4,780	2
Renewables	31,692	12
Total	255,013	100

Table 2
The growth of different on-grid renewable options in MW [15,16].

Renewable	1992	2002	2007	2012	2014	2015[a]
Wind power	38	1667	7094	17352	20298	25188
Small hydro	79	1438	1975	3395	3774	4188
Solar power	0.6	1	2	941	2208	5248
Biomass power and cogeneration-bagasse	–	390	1140	3135	3797	4761
Waste to energy (urban and industrial)	–	–	43	89	99	127
Total	118	3496	10253	24912	30176	39511

[a] Up to January 2016.

small share for renewables (12% of total installed capacity), India is considered generally as a successful example among developing countries in renewable electricity in terms of the annual growth of investment and installed capacity [10–13]. This growth has not been uniform across different States. India has 29 States and 7 union territories with a shared social, economic, and political background. However, they have different behavioural patterns and priorities, disparate availability of potential renewable sources, flexible policies and regulations, built infrastructures and available networks. Across the country, eight States, including Tamil Nadu, Andhra Pradesh, Karnataka, Gujarat, Maharashtra, Rajasthan, Himachal Pradesh, and Jammu & Kashmir, account for 80–90% of existing total renewable capacity in the country. Among them, Rajasthan and Gujarat are top two States with the highest installed capacity for on-grid solar (PV), and Tamil Nadu and Gujarat are two top States for wind power [14].

In 2011, the growth of renewable investment was (about 62%) higher compared to 2010. Most of this investment has come to wind ($5.9 billion) and solar ($4.7 billion) sectors as they have been the top priorities of the government [17]. Wind has the highest capacity of on-grid electricity, and solar has the highest annual rate of growth since 2012. Wind electricity is a closer option to grid parity which makes it more affordable compared to solar electricity. However, most of appropriate sites for wind farms have been exploited which may limit the rapid expansion of wind energy in future to some extent. On the other hand, solar electricity benefits from large potential solar radiation (annual average 19–22 MJ m^{-2} per day [18]) and available lands which are mainly unexploited. The price of solar technology is also falling which makes it more competitive in the near future.

Considering the growing importance of solar electricity in India, this paper aims to review the development of India's on-grid solar electricity. Several previous researches have studied the development of the Indian renewable electricity sector in general, and solar electricity in particular, from different perspectives [19–22]. We differentiate our review from the previous studies by investigating the development of solar electricity as the continuation of historical transitions in the whole electricity sector. India's electricity sector has experienced at least two major transitions so far: the first is a transition from a State-owned sector to a State-influenced liberalised sector and the second is a transition from conventional to renewable sources of energy for electricity generation. These historical transitions with several institutional and structural changes have laid the ground for on-grid solar electricity development. The paper seeks to answer: how has the ongoing development of solar electricity been built upon the privatisation of electricity sector and the empowerment of renewable energy in the past? Moreover, it intends to discuss: how will the future look for on-grid solar electricity based on the prospect of its driving forces?

The main method used in this paper is the review of documents with a theoretical heuristic and supported by three groups of facts: raw facts, stylised facts and inferred facts.

1. 'Raw facts' are the data collected from the review of the documents. They are the numbers or exact qualitative statements (which are cited to their references). The documents are scholarly articles and reports that have been published in academia, international energy organisations [11,23–25] and the Indian government bodies (e.g. Ministry of Power [26], Planning Commission [27], Central Electricity Authority [3], Government of India [28–30]). Some data required for this review (data associated with the very recent developments) are collected during the 1st Re-Invest Summit, which was held in New Delhi, February 2015.[1]
2. The collected data are categorised and structured in a stylised manner with a theoretical heuristic in sustainability transitions field [31,32]. The theory is not explained here as it is out of the scope of the review paper and has been discussed before [33,34]. It generates 'stylised facts'. They are qualitative storylines (instead of rigid raw data) for a better interpretation of data to readers.
3. And at the end, the inferences about the prospect of solar sector and its challenges are made by looking over the whole storyline as well as by using the recent discussion in the 1st Re-Invest Summit around the future of the Indian electricity sector. They are 'inferred facts'.

The rest of the paper is structured as follows. In Sections 2 and 3,

[1] http://www.re-invest.in/