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REVIEW ON SOLAR ROOFTOP DEVELOPMENT, POLICIES AND CHAALLENGS IN INDIA

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Abstract — *Today solar photovoltaic rooftop for production of electricity has emerged as a potential green technology to address climate change issues by reducing dependability on conventional fossil fuel based electricity. With a strong commitment to increase the renewable sources based energy capacity around 170 GW by 2022, India has a target to install around 100 GW of solar energy capacity. Among this around 40 GW would be the share of grid connected solar PV rooftop. This review paper is about information on growth in solar energy, solar rooftop policy matters and challenges in India. The current Indian goals, issues & challenges in achieving them and trends in further development are discussed here.*

Keywords- *Solar rooftop, Solar energy, Photo Voltaic Cell*

I. INTRODUCTION

The climate change threats are driving our dependence on pollution free sources of energy to minimize greenhouse gas emissions. No doubt solar PV energy is one of the cleanest sources of electricity and is being considered as next to fossil fuel based conventional electricity systems. World cumulative installed solar energy capacity of 3.7 GW in 2004 has reached 177 GW in 2014 i.e., increasing almost 50 times in ten years [1]. Global investment in Renewable Energy (RE) has been growing steadily and increased five times since 2004, from $62 bn to $316 bn in 2014 in ten years [2]. The share of investment in the solar rooftop and other solar PV projects is increasing more rapidly and was 12% higher than in the previous year and became 67.4 bn in 2015, thus making it one of the fastest growing industries worldwide. International Energy Agency (IEA) Technology Roadmap: Solar PV Energy envisions total production of SPV electricity to increase to 16% in 2050 (in place of 11% projected earlier) with China and India having major shares [3]. Looking inwards, India is having fourth largest electricity generation capacity in the world after US, China and Russia. Its Renewable Energy (RE) share increased to 13.16% in 2015 with solar energy having a share of 11.62% in it. Between 2005 and 2015 the renewable grid connectivity has increased from 6.2 GW to around 36 GW for both solar and wind. As on June 2016 renewable based capacity became 43,727 MW in the total installed capacity of 303,100 MW [4].

- **Historical developments in solar PV in India**

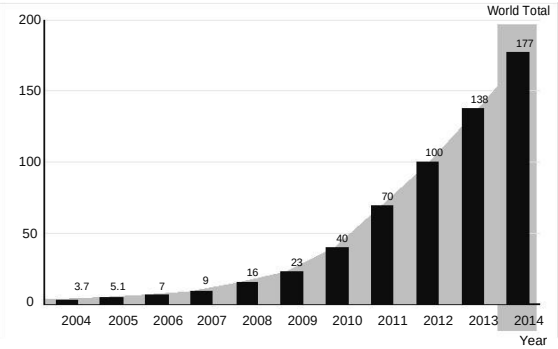
Solar Photovoltaic (SPV) Program of India was conceived in 1970s in response to the world oil crisis, as one of the largest national programs in the world. The SPV research & development in the country began in late 1970s and a programme for energy development was launched in early 1980s with three main objectives; (i) research on solar cell materials, development of production and manufacturing capabilities of SPV module, and (iii) promotional measures and incentives for installation of SPV electricity. The manufacturing base was strengthened and over 300,000 smaller systems aggregated to 22 MW have been installed until 1995 making India third largest Solar PV user. Export had a share of almost 46% in 2002 [5]. Remaining catered to telecommunication towers, street lighting, agricultural water pumping and others [6]. Solar Home Systems (SHS) were encouraged. First major PV plant connected to the grid was set up in Jamuria, Asansol district; West Bengal of 1 MW capacity. Though distributed SPV in rural & remote areas and for strategic applications remained one of the key programs.

In 2010 Jawaharlal Nehru National Solar Mission (JNNSM) was introduced as part of National Action Plan on Climate Change 2008 giving a target to install 20 GW solar capacity by 2022. The mission is to be implemented in three phases namely; Phase I (2010 to 12), II (2013 to 17) and III (2017 to 22). Under phase I of JNNSM one of the component related to solar rooftop is 'Rooftop PV and Small Scale Generation Program (RPSSGP) aimed to encourage development of rooftop or ground-mounted solar systems with maximum capacity size of 2 MW [7]. A total of 100 MW is targeted under this scheme. Projects under the RPSSGP scheme -remain mostly ground-mounted with negligible share of solar rooftop. Grid connected solar power plants capacity was assessed at 45.5 MW in July 2011.

Being a tropical country, India is solar rich country having on average 300 sunny days in a year. India has higher solar irradiance compared to many other countries and solar electricity potential is between 4 and 7 kWh per sq. m per day in its most parts. Government of India has revised Solar Mission in 2014 with a target of 100 GW installed capacity of solar electricity by 2022. Out of which 40 GW is now projected to come through grid connected rooftop solar systems.

- **Solar rooftop PV**

A solar photovoltaic (SPV) power plant consists of different components i.e., photovoltaic modules, mounting system, dc to ac converter and electrical connections. The Roof Top PV (RTPV) systems are smaller PV systems in comparison to land mounted ones, installed on rooftops of residential, commercial or industrial building complexes. It comprises of solar inverter, meters for regulating electricity generated and various components for modification of electrical output and input rate in kWp (peak kilowatts, the expected electrical power from a system when sun is overhead) [8]. The electricity generated from such systems could either be entirely fed into the grid at regulated feed-in-tariffs (FiT), or used for self consumption with the net metering approach. A net metering mechanism allows for a two-way flow of electricity wherein the consumer is billed only for the 'net' electricity (total consumption to own PV production) supplied by the DISCOM. Such RTPV systems could be installed with one integrated net meter or two separate meters, one for export to grid and one for self consumption. Full potential of non-grid RTPV is yet to be utilized as the cost continues to be high. With part financial support provided by the state to promote their use, such systems are considered most appropriate for rural and remote areas. In the regions of power shortages, performance reliability of non-grid RTPV can also be improved with at least 1 h of back-up battery and this helps in bringing down the cost. The growth trend of total global installed SPV capacity from 2004 to 2014 is shown in Fig. 1.



II. SOLAR ENERGY DEVELOPMENT AND POLICIES IN INDIA

Policy infrastructure in renewable energy sector in India took shape when Commission of Alternate Sources of Energy (CASE) was created in 1981 in the Department of Science & Technology. It became independent Department of New Energy Sources (DNES) in 1982 and full fledged Ministry in 1992. Ministry's guidelines to various States to purchase RE power at Rs. 2.25 per unit with 5% annual escalation with 1993 as base year triggered early development of RE sector especially the wind energy. The government has announced several policies to promote solar energy. Direct and indirect tax benefits such as sales tax, excise duty exemptions and custom duty exceptions have been given. Project developers were exempted from income tax on all earnings from a project in its first 10 years of operation and accelerated depreciation (AD) for solar energy producers to claim 80 per cent of the costs in the first year itself. Policies and acts impacting direct solar energy development 2000 onwards are discussed below.

Electricity Act 2003, This Act provides a framework for overall growth of electricity sector in India. Provisions for preferential tariff and quotas for integration with renewable energy have been made. Mandatory Procurement of RE power for Distribution Licensees and facilitation of grid connectivity were incorporated. Based on optimal utilization of resources including renewable sources of energy, it suggested that a policy for permitting standalone systems would be prepared.

National Electricity Policy 2005, The policy allowed preferential tariff for electricity produced from renewable energy sources. In order to reach the areas where no grid connectivity was there it aimed to provide access to electricity to all, 'Power to all by 2012' and increase minimum per capita availability to 1000 kWh per year by 2012. Tariff Policy 2006, The mechanism of Renewable Energy Portfolio (RPO) to fix a minimum percentage of purchase of energy consumption by the States from renewable energy sources and giving special tariff for solar energy among others were its main contribution. Integrated Energy Policy 2006, this integrated policy document while giving overall policy guidelines for action recommended special focus on RE development and set specific targets for capacity addition.

National Action Plan on Climate Change (NAPCC) 2008, Government of India enunciated mission mode action plans for sustainable growth under NAPCC to address climate change. Its first mission was intensification of solar energy development. It also advised that RPO's be set at 5% of total grids purchase, and be increased by 1% each year for 10 years. Generation based Incentives (GBI) for Solar e Introduced in 2009 for small grid solar projects below 33 kV, GBIs are provided for bridging the gap between a base tariff of INR 5.5 (by 2010e2011, with an annual escalation of 3 per cent) and the tariff determined by the Central Electricity Regulatory Commission (CERC) as a fiscal incentive.

Jawaharlal Nehru National Solar Mission (JNNSM) 2010. The mission gave specific targets of 20,000 MW of grid-connected and off-grid solar power capacity by 2022 with 2000 MW as share of off-grid capacity. Renewable Energy Certificates (RECs). A market based mechanism, RECs was introduced in 2011 to enhance renewable energy capacity by leveling the inter-state divergences of renewable energy generation and the requirement of the obligated entities to meet their RPOs with differentiated price for solar and non-solar.

Clean energy cess introduced in 2010 to levy the amount of INR 50 to every tonne of national or imported coal used in the country. A National Clean Energy Fund (NCEF) created from the cess aims to fund clean energy projects and provide up to 40 per cent of the total costs of RE projects through the Indian Renewable Energy Development Agency (IREDA). The cess has now been increased to INR 400 per tonne of coal used. Joint Liability Group (JLG) for Off-grid installations by synthesizing business and social potential a small group of 4 to 10 local entrepreneurs as JLG to avail loans for non-farming activities which could be applied for micro-grid installations. Corporate Social Responsibility (CSR) to encourage the private sector participation in the national growth and for meeting social goals such as pollution free generation the CSR funds are channelized by top 500 companies as 2 per cent of their profits towards off-grid solutions. The overview of RTPV policies of selected states in india is shown as per below Table 1.

Table 1

Overview of RTPV policies of selected states in India.

Sr. no.	State	Policy guidelines	Target segment
1.	Andhra Pradesh	Scheme of Net metering with excess energy sold to utility at average pooled purchase cost (APPC), 20% subsidy of capital cost up to 3 kW in domestic sector	All 3 phase service consumers Single phase consumers are not eligible
2.	Chhattisgarh	Gross & Net metering. FiT INR 4.35/kWh. Energy banking allowed	Residential, Commercial & Industrial
3.	Gujarat	Gross metering at INR 9.63/kWh with accelerated depreciation INR 10.75/kWh with no depreciation Roof owners get lease rental and project developer get FiT for 25 years 5 MW rooftop PPP model is now being extended to 5 more cities.	Government, Residential, Commercial, Industrial, Institutional Buildings
4.	Karnataka	Gross & Net metering at INR 9.56 without subsidy INR 7.20 with subsidy	All Consumers 1 to 5 kW in single phase 230 V 5 to 50 kW in 3 phase 415 V 50 kW to 1 MW in 11 kW line
5.	Kerala	Net metering State subsidy of Rs. 39000/per system for the approximate cost of the plant of Rs. 2.5 lakh Rs. 10,000/kW capital subsidy for smaller units	All consumers
6.	Rajasthan	Net metering, Tariff based competitive bidding INR 7.50/kWh without accelerated depreciation INR 6.63/kWh with depreciation.	All consumers
7.	Tamil Nadu	Net metering Self consumption and energy banking for one year Generation based incentive of INR 2/kWh for first 2 years, INR 1/kWh for next 2 years and 0.5/kWh for Subsequent 2 years	50 MW for domestic Customers 300 MW for government buildings and rural & urban lighting <10 kW in 240 V 5 to 15 kW in 415 V 100 kW in 11 kV
9.	West Bengal	Net metering Tariff applicable to net energy supply Energy banking allowed for one year	All consumers
10.	Haryana	Gross & Net metering (off-grid & grid connected) Energy banking allowed for one year	All consumers

III. CURRENT CHALLENGES IN SOLAR ROOF TOP

International Energy Agency [3] analyses suggest that the Amendments in the Acts, Tariff Policy 2006, State-level policies and a greater participation of the private sector have played a key role in the overall growth of RE installed capacity in India. However as India is moving ahead to achieve the target of 175 GW of RE by 2022 and 100 GW solar based installed power capacity, new challenges are being faced in RTPVs target of 40 GW at different stages of installation and use. Several policy analyses have been made [9 to11]. The Climate Group [9] while suggesting that performance of commercial and industrial sector would play a greater role towards meeting the target, strongly recommends greater partnership of private sector so as to double the current capacity. Net metering and a package of incentives to utilities are no doubt necessary foundations. Means of covering Investors risk and greater consumer awareness can be the basic building blocks. Skill development, maximizing rooftop spaces and mandates to support the adoption of rooftop solar can lead to a sustained growth. The study recommends that mandates would have highest contribution in driving the movement. The main barriers faced during large scale deployment of RTPV include lack of awareness among consumers about the system, lack of manufacturing facilities, lack of skilled workforce, high upfront cost and lack of business models and regulatory challenges.

- **Challenges in regulatory framework**

From the analysis of different countries it is evidenced that regulations need to change from time to time to make RTPV a success. With this in view the regulatory framework in India from solar has been continuously evolving. The solar energy cost declined from INR 17/kWh in 2011 for meeting solar RPO obligations of various states to INR 4.63/kWh in 2015 as lowest though solar bidding route for a plant in the state of Andhra Pradesh. Model net metering guideline to allow deemed RPO for utilities against the electricity consumption from net-metering based solar rooftop-only against self consumption by consumers is defined as obligated entities [12]. For better forecasting of solar/wind generation for the purpose of grid integration, Renewable Regulatory Fund (RRF) regu-lations in 2010 as per the provisions of the Indian Electricity Grid Code Regulations, 2010 were introduced [11]. However, present regulations on connectivity do not recognize rooftop connectivity at low voltage (say 230/415V). Regulations to remove prevailing cross subsidy (subsidizing a particular group of consumers and recovering the cost by charging higher price from another group) so that tariff can become more attractive and execution guidelines for energy account-ing process and Time of Day (TOD) settlement to connect at HT lines level and LT level consumers need to be evolved.

India's 'Smart Cities' project launched in 2014, envisages solar energy to make 10% contribution in the total electricity of selected cities. Amendment in building by-laws for making provision of rooftop solar can give it a boost. New constructions would take place and to make new buildings 'Rooftop ready', with proper zoning and utilization of car park areas are to be addressed by the urban planners, along with regulation of favorable mandates for retrofitting in old buildings. From a study of solar energy potential of Nashik city in Maharashtra state it emerged that grid connectivity is going to be major issue in solar energy contribution for smart cities [13].

- **Outlook for RTPV in residential, commercial and industry sectors**

Solar PV Rooftop market potential for India has been assessed as 124 GW by taking the total area under urban settlements as 77,370 km2 [14]. The residential sector has a share of 38%, commercial/institutional 4% and industry 3% of the total usable area for RTPV, remaining 55% is other area. Emergence of domestic sector as the second largest energy consuming sector after industries is seen in India in the last few years. The electricity consumption in residential sector grew from 32 GkWh in 1990 to 198 GkWh in 2013. It is expected to increase to 1270 GkWh in 2040 [15]. In growing cities as the number of households is increasing, the residential sector electricity needs are growing rapidly. It is anticipated that about 30% of the solar rooftop target capacity of 40 GW can be met from the residential sector provided integration with grid is made. There are 331 million households according to 2011 census. On average a 3 kW system per household will require approximately 4 million RTPV households, which is less than 0.01% of the total. The scenario analysis suggests aggressive market supports with tax incentives and consumer centric regulations such as; amendment in building by laws for considering solar rooftop structure as temporary structure so that it does not need fresh approval for raising height of the building by local municipalities will be important drivers for achieving the goal.
Most cities in India have flat structure low height buildings with lesser number of high rise buildings at present. Distribution Companies (DISCOMS) can facilitate by providing grid interconnection and reduction in electricity bills by selling at lower rate in proportion to higher wattage achieved from solar installation. As for the multi-storey housing complexes new models may emerge. A study in Tamil Nadu suggests third party lease model that has responsibility of building up structure, selling and buying electricity and transferring it to households is most suited [16]. Business models for both grid connected and off-grid RTPV are being developed. Power Trading Corporation in India has signed a MoU with Solar Energy Corporation of India to purchase and sale of power generated from 3000 MW solar projects on a long-term basis. Power Financing Corporation of India and Infrastructure Leasing & Financial Services (IL&FS) Infra-structure Development Corporation Limited are actively involved in developing Green Energy Corridors for grid transmission of RE.

IV. CONCLUSION

Solar energy production does not emit greenhouse gases and is a climate friendly option. During operation a solar plant contributes to significant reduction of CO2 emissions without consuming any fuel. In India, a country having practiced decentralized system for so long, a new thrust to grid connected solar electricity has been given and solar rooftop has emerged as an achievable goal for residential, commercial and industrial sectors. The National Solar Mission targets 100 GW of solar electricity capacity by 2022 with 40 GW as RTPV. To fulfill these impressive targets technology and investment have to be in the top gear.

A review of global experience in RTPV installation in top solar countries has been made. It indicated dominance of feed-in-tariff and direct capital subsidy mode until 2011. But in the year 2012 it was observed that self consumption mode of implementation increased from 3.4 per cent to 12 per cent. Soft loans, tax credits, role of municipalities and market based mechanisms have played dominant roles in encouraging peoples' participation. Residential and commercial sectors top in numbers in RTPV installation in most countries.

Policies for growth of rooftop solar, challenges and outlook in India have been discussed. Government of India is leading by example through installation of solar rooftops widely on government buildings, airports, railways network, educational institutions, residential sector and commercial complexes. Though high growth is expected and cost wise it can reach parity with coal based power generation very soon, it is to be noted that unlike thermal power plants, RTPV generation is consumers dominated and therefore peoples' participation and acceptance are critical issues for its success. At the national level, manufacturing capacity, investment in R&D, investor friendly environment, skill development, low voltage grid connectivity of variable solar resource and regulatory decisions are major challenges to be resolved. As the penetration of RTPV has to increase boost to manufacturing capabilities not only in solar modules but also in inverters and batteries is must. In skill development providing skills for jobs of engineers, manufacturers, suppliers, repairs, maintenance, testing facilitators are some of the important challenges before the state agencies.

While strong foundations are being built in India through net metering policies and revising package of incentives; at city level greater role of municipalities in amendment of building by-laws for considering solar rooftop structure as temporary structure so that it does not need fresh approval for raising height of the building and role of DISCOMS in providing reduction in electricity bills by selling at lower rate in proportion to higher wattage achieved from solar installation so as increase home owners' contribution in energy security for 24 by 7 power for all are being considered. Provisions are also needed for soft loans, tax credits in property and investment. An outlook for linking of solar energy targets with the current missions on ‘Make in India’, ‘Smart city mission’ and ‘Digital India’ as a promise for developing capabilities and transformation of entire power system in the country is recommended. Development of off-grid systems that are ‘Grid ready’ for rural and remote areas, and making by-laws for new buildings for grid connected as ‘Rooftop ready’ should be the suggested goals for the future.

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