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Right Time to Reap Benefits from Residential Solar Rooftop PV in India - A Venture of Millions

P.R. Arora

Research Scholar

Abstract- Make your home solar is going to be reality within few years. Rooftop PV has been developed by Germany, Spain and Italy with the encouragement Feed- in -Tariff system for early attaining towards grid parity. The rates of solar PV has been drastically reduced in recent years and approaching towards the grid parity. There has been increasing trend of grid connected residential rooftop PV worldwide due to merits. In India the grid parity for residential rooftop PV is likely to be achieved within three to four years. Installation of rooftop PV at residential buildings will be able to meet present deficit of electricity in cities and towns and future demand of electricity. Therefore, time has come to encourage and motivate the peoples of India for installation of rooftop PV at their residence to meet the demand of electricity in urban areas. Central and the State Governments have a major role in development of rooftop PV at the residential buildings in urban areas.

Index Terms- Feed -in - Tariff, Grid parity, Land resource, Net metering, Solar resource

Abbreviations- BoS -Balance of System, Discom - Distribution Company, EPIA- European Photovoltaic Industry Association, GW- Giga watt, KW - kilowatt, KWh- Kilowatt- hour, MNRE- Ministry of New and Renewable Energy, MU- Million Units, MW- Megawatt, MWp - Megawatt peak, RTPV- Rooftop Photovoltaic

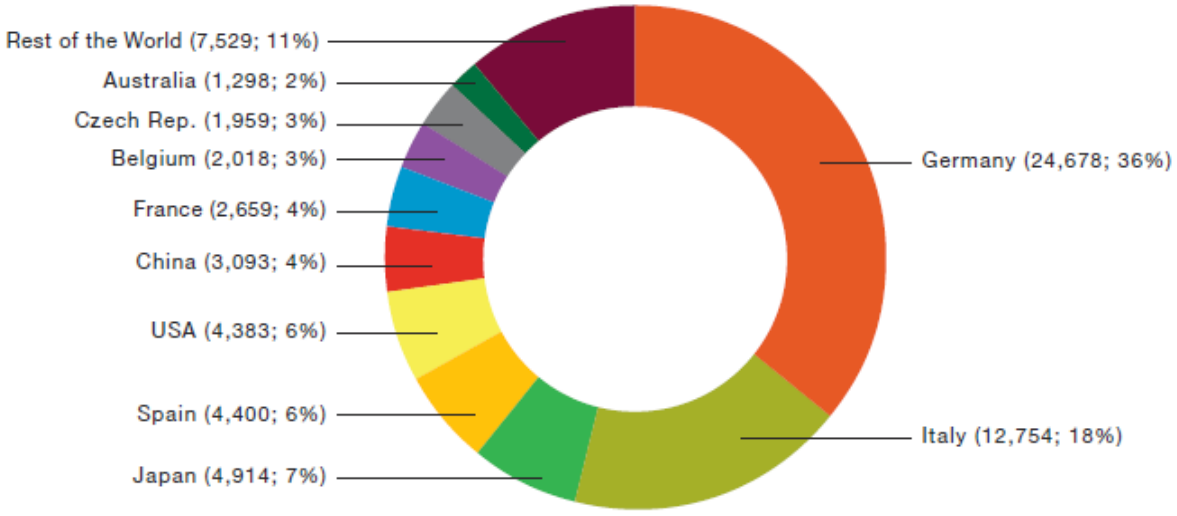
I. Introduction

In India, there is deficit of electricity in base load and peak load hours. As per actual power supply conditions during 2011-12, base load requirement was 937,199 (MU) against the availability of 857,886 MU, a 8.5% deficit. During peak loads, the demand was for 130 GW against availability of 116 GW, a 10.6% shortfall [(1)]. The 17th electric power supply survey of India claimed that over the period 2010-2011, the industrial demand accounted for 35% of power requirement, domestic household use accounted for 28%, agricultural 21%, commercial 9%, public lighting and other miscellaneous applications accounted for rest [(2)]. With an economy projected to grow 8-9% per annum, rapid urbanization and improving standards of living for millions Indian households, the demand is likely to grow significantly. Presently, several cities and towns in the country are experiencing a substantial growth in peak electricity demand as a result most of the cities/ towns are facing severe electric shortages [(3)]. The utilities are facing difficulty in meeting the increasing power demand in cities, the load shedding is implemented and electricity is not available for several hours. Solar rooftop PV with grid connected is right choice to meet the demand of cities and reduction in pollution in the cities causing due to diesel generating sets. Solar rooftop PV is a matured technology and the craze has been increasing worldwide. Japan, USA and Germany were the early leaders in adopting rooftop PV systems, while Italy, Australia and China have seen strong growth in recent times. In India, Jawaharlal Nehru Solar Mission put a target 20,000 MW by 2022 for grid connected solar Power Plants including rooftop PV. There are so many advantages of Rooftop PV, mainly it does not require land and water, utilizes the roof of buildings. Limited land in India is also a major constraint for setting up utility scale PV power plants. Rooftop PV shall be installed at the roof of millions buildings/ houses, it shall develop entrepreneurship and employment to the millions. It will brain ware of millions of peoples of the country; peoples will become conversant with generation, consumption of electricity and pollution. There is great role of MNRE and State Governments in adoption of residential rooftop PV.

II. Total Generation from PV

Figure 1 shows, PV generation capacity in Megawatt and % share of generation of top ten countries of the world. At the beginning of 2012, Germany and Italy alone represent more than 50% of world installed capacity [(4).]

Figure 1, Global Cumulative Installed Capacity Share 2011(MW :%)

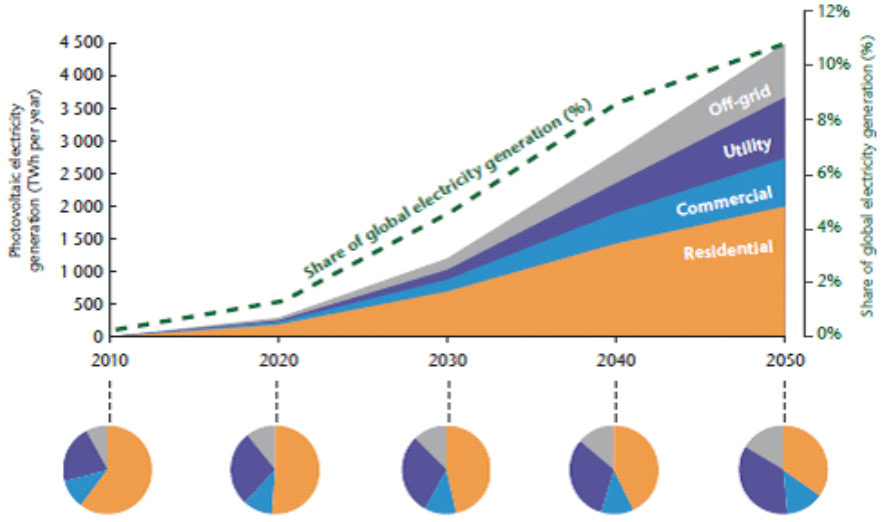


Source: EPIA May 2012

III. PV MARKET

There are four end- use sectors with distinct market for PV, Residential systems (typically up to 20 KW systems on individual buildings/ dwellings), Commercial Systems (typically up to 1MW systems for commercial office buildings, schools, hospitals, and retail), Utility scale systems (starting at 1MW, mounted on buildings or directly on ground) , Off-grid applications (varying sizes) [5]. The relative share of four market segments (residential, commercial, utility and off-grid) is expected to change significantly over time. The residential sector has the highest potential, it has maximum around 60%. After residential segment, utility segment is one of the biggest segments and followed by off-grid and commercial segments. The relative shares of PV deployment among the different sectors will vary by country and according to the requirement of individual country. As per figure2, by 2050 PV will provide around 11% of global electricity production.

Figure 2, Evolution of photovoltaic electricity generation by end -use sectors



Source: IEA Technology Roadmap for Solar Photovoltaic energy, 2010

IV. BRIEF ON SOLAR ROOFTOP PV

Solar rooftop PV is a matured technology and generates electricity during sunshine. Rooftop PV is a distributed form of generation of electricity. Germany is a leading country in rooftop system, represent largest segment by far, 85% of installed capacity in 2010 [6]. The rooftop PV is composed of PV modules and the balance of system (BoS). The PV module is the interconnected array of PV cells. The items covered under balance of system are structure for installation, racks, invertors, transformer and misc electrical items. Presently, the capital cost of rooftop PV is a major barrier in its adoption in India.

Generation from RTPV has several advantages, mainly no additional land, transmission network and water is required.

Potential of Solar Rooftop PV in India

The solar rooftop PV segment in India has not yet developed, it has a strong growth potential, and it is difficult to assess the exact potential for RTPV in India. Total commercial rooftop area of major cities Delhi, Mumbai, Kolkata, Bangalore, Chennai, Pune and Hyderabad for PV installation is 5.13 million m^2 when extrapolated to 2009, this total rooftop area have a PV potential of 513.3 MWp [(7)]. Figures of major cities indicates that India have unlimited rooftop area on the residential and commercial buildings of urban areas. Day by day this rooftop area has been increasing with the urbanization.

Characteristic of Rooftop PV

The PV works during sun shine of the day, 9AM to 5PM. Generation from PV varies from season to season, PV generates 25% higher in summer season than winter season and it generates 50% higher in summer season than monsoon season. The generation from PV is maximum in summer when the requirement of electricity is maximum, it generates less in winter when requirement is less. It generates very less in monsoon season when requirement is very much less. Solar power can effectively used for power consumption during sunshine hours. There are 24 hours in a day, and availability of the sun shine is more than 8hours per day, therefore, 30 % energy requirement of the day (0 hours to 24 hours) is available during sunshine. The electricity generated may be used during sunshine or may be fed to the grid when not required.

Capital Cost of Solar Rooftop PV:-

The capital cost of a rooftop PV system is composed of PV module cost and balance of system (BoS) cost. The BoS cost includes items, such as cost of structural system (e.g. structural installation, racks, site preparation and other attachments), the electrical system costs (e.g. the inverter, transformer, wiring and other electrical installations cost).

It was only few years ago, PV electricity was four to five times more expensive than the fossil fuels [(8)]. Continuing decreasing cost of solar rooftop PV and increasing cost of fossil fuels, grid parity could occur within three to four years in several states of India where high solar resource is available and prevailing high tariff of electricity. The grid parity is expected to be achieved in 2019-20 in the states where moderate solar resource is available and prevailing lower tariff of electricity.

Advantage of Solar Rooftop PV:-

Solar Rooftop PV can be accommodated on roof or open ground and in variable capacities from few watts to several MW. When the load is less the power is surplus, this surplus power can be fed to the grid and in case power requirement is much, the same can be drawn from grid. The main advantages of Rooftop Solar PV are as under.

- Space for mounting structures already exists, no additional land is required.
- The distribution network already exists and no new connection is required.
- A wide range of size can be accommodated from KW for residential and MW for commercial and industrial purposes.
- The cost of residential rooftop PV is within the limit of many home owners.
- The power generated is used at the same place, therefore, involvement of transmission and distribution is very much less, the excess electricity generated is fed in the system of utility and the electricity required can be drawn from the utility. Ultimately, selling the electricity when not required in day hours of sunshine to the utility and purchasing when required.
- The arrangement can be made for backup/ storage when utility supply fails.
- The house owner becomes conscious about the generation and consumption of electricity.
- It will develop large numbers of entrepreneurs.
- A large number of jobs shall be created.

V. METERING

Metering depends upon the tariff, the rate the unit charged by utility is same as of units generated by rooftop PV, and then net metering is employed. If the rate of units generated by rooftop solar PV is higher than the units supplied by the utility, then gross metering system is employed.

Net Metering-

In the day hours the domestic load is less, therefore, electricity is fed to grid and when the load is more than the capacity of solar PV, the electricity is drawn from the grid. The grid supply act as a back up to the rooftop PV, we use the grid supply in night hours, cloudy days when no sunshine and requirement is more than the capacity of solar rooftop PV. It is clear that electricity is fed to the grid when generation is more from residential rooftop PV and electricity is drawn when requirement is much than generation from rooftop PV. For maintaining the account of electricity transaction, a bi – directional meter is installed which can record power flow in both directions. Thus, the meter gives two readings detailed as under.

- Electricity drawn from the grid.
- Electricity supplied to the grid.

The rates of electricity drawn from utility, the bill is raised for the power supplied from utility and credited for the electricity fed to the grid at decided rate. If the rates of electricity supplied to grid and received from the grid are same, and house owner wants to earn money, then a house owner will have to install the roof top PV of higher capacity. Suppose a house hold has consumption is 200 KWh per month and house owner will have to generate more than 200 KWh per month for income.

Gross Metering System (Feed -in- Tariff System):-

Gross metering system employ two meters, for metering the total electricity produced (consumed by the customer and fed to the grid) by the rooftop PV. Second meter is consumer meter that indicates total electricity consumed by consumer. Therefore, the system records the energy produced by the rooftop PV and the total energy consumed by the consumer. This system is employed for encouragement of rooftop system in the country

and for early grid parity. As a result, higher tariff is given for generation and lower tariffs are charged for consumption. Such tariff is used in Germany, Spain and Italy.

VI. Government Support

Looking to the growth and requirement of residential solar rooftop PV, Central/ State governments need to encourage, provide subsidies and soft loans, deciding tariff, development of mechanism for grid integration and educate the peoples about the advantages of RTPV.

MNRE

MNRE has vital role for development of RTPV in the country and arrange capital subsidy and soft loans to the consumers.

Role of State Governments

After the MNRE, the responsibilities lies with State Governments to develop RTPV in their State, making decision for tariff and strengthening of discoms for incorporating the electricity generated from RTPV. State Governments have to decide the tariff system, feed- in - tariff system or net metering system. For encouragement, State government may give option for both tariff, net metering system (State government may offer additional subsidy other than MNRE) or feed -in -tariff system. Before implementation of RTPV in State, the strengthening of the discoms shall be required such as construction of smart grids for receiving the generation from RTPV, arranging meters and their calibration, billing system, timely recovery of revenues.

VII. Urban Population

The economic growth is leading to urbanization along with the increasing in demand of electricity. As per table 1, trends of population projections of Government of India, 2006, shows total population of the country and urban share of population. There has been rising trend in urban population, 27.8% in 2001, 30% in 2011, 31.1% in 2016, 32.3% in 2021, and 38.2% in 2026. As per UN projections (UN-2006), the Indian urban population would be 41% by 2030. If the same trends follow the urban population would be 50% by 2050.

Table 1, Population of India and urban share of population

	Population	Urban share
	Million persons	% Share
2001	1,029	27.8
2011	1,193	30.0
2016	1,269	31.1
2021	1,340	32.3
2026	1,400	38.2

Source- Population projections (Government of India, 2006)

In India urban population leads a highly intensive life style characterized with high usage of modern sophisticated items, such as air conditioners, refrigerators, washing machines, geysers and cooking appliances etc [9]. Per capita consumption of electricity in urban areas is very high in comparison to the rural areas.

The construction of residential and commercial buildings are rapidly taking place with increase in population in urban areas, therefore, area of rooftop has been regularly increasing with the construction of buildings.

VIII. Projected Generation Capacity from Residential Solar Rooftop PV

Domestic consumption of electricity accounted 28% in 2010 -11 of total consumption in India, and the domestic consumption is going to increase to 34% by 2021-2022. There are large numbers domestic consumers having floor/ roof available with them. Rooftop PV can replace grid during sunshine period i.e. more than 8 hours per day. By 2017-18, the forecasted levelized tariff based of the cost to serve at INR Rs. 9.29/KWh vis - a- vis a levelized tariff of rooftop PV at Rs. 8.31/KWh [10]. The cost of generation from rooftop PV shall be less than the utility, the domestic consumers will turn towards rooftop PV. Domestic consumers having high consumption (monthly consumption of electricity is above 200 units per month) will turn to rooftop PV in the initial stage due to high tariff charges from utility and amount of the bill of utility would be much more than the electricity generated from rooftop PV. Consumers having less consumption (monthly consumption of electricity is up to 200 units per month) will turn at later stage, when utility electricity is very much costly to rooftop PV. Domestic consumers having high and less consumption will adopt rooftop PV in different phases. The load of domestic consumers generally ranges between 1KW to 5KW in India. Domestic consumers are less in the category 5KW to 20 KW, we may consider this category as 10 KW category. Suppose domestic consumers of urban area adopt for solar rooftop PV in phased manner, projected generation capacity comes to 4500 MW, as per table 2.

Table 2, Projected generation capacity from Residential Solar rooftop PV

S no.	Year	Category Capacity in KW/ installation	No. of domestic consumers adopt Rooftop PV in urban area (assumed)	Total capacity	Total Cumulative capacity
	2016-17	10 KW (above 5KW to 20KW)	30,000	300MW	300 MW
2.	2017-18	5KW	1,00,000	500 MW	800 MW
3.	2018-19	4KW	2,00,000	800 MW	1600 MW
4.	2019-20	3 KW	3,00.000	900 MW	2500 MW
5.	2020-	2 KW	5,00,000	1000	3500 MW

	21			MW	
6.	2021-22	1KW	10,00,000	1000MW	4500 MW

Source: Table has been prepared on the basis of assumption for adoption of rooftop PV

Assumption has been made for adoption of roof top PV for each category, adoption in each category shall take place in all the block years, but for simplification and presentation, it has been taken in a particular block year. For example, 5KW category adoption by domestic consumers have been assumed 1, 00,000 in the block year 2017-18. In fact all total adoption will not take place in the block year 2017-18 but it shall be adopted from the year 2017-2018 to 2021-22. For simplification and representation, it has been taken in block year 2017-18. In beginning, high consumption domestic consumers will turn for adoption of rooftop PV and later it shall be adopted by less consumption domestic consumers and, therefore, categories have taken in descending order. Table 2 shows, 2130,000 household of urban area (on the basis of assumption) shall be involved in adoption of rooftop PV in India up to 2021-2022. Germany connected its one-millionths PV system to the grid in late 2011, and continued to lead total installed and operating PV capacity [(11)].The generation from residential Rooftop PV in India shall be 7.9 Terawatts, by end of 2021-22, which one could not think earlier.

IX. Limitations of Utility Scale Solar PV Plants

PV generating power plants can be set on utility scale in order of 1 MW or above. The amount of land required for utility scale solar power plants, utilizing solar modules 15% efficiency in tropical regions is approximately 1 hectare/ MW [(12)] . 1 Km^2 land is required for 100 MW power plant and such large area could pose a strain on India's available land resource. The projected capacity from residential rooftop PV is 4500 MW up to 2021-22 as per table 2, the land required shall be around 45 Km^2 for utility scale PV solar power plant. In addition to the requirement of land, there shall be need to develop transmission and distribution network.

X. Land Resource in India

India accounts for only about 2.4% of world's geographical area and 4% of its water resources, but has to support about 17% of world's human population and 15% of livestock. Increasing human and animal population has reduced availability of land over the decades. Per capita availability of land has declined from 0.89 hectare in 1951 to 0.32 hectare in 2001 and is projected further side down to 0.20 hectares in 2035 [(13)].

XI. Discussions and Conclusions

Population and the share of urban population in India have been regularly increasing. The urban population which was 27.8% in 2001and is to reach 41% by 2030 as per UN-2006, population projection in India. Per capita consumption of electricity of urban population is very much higher in comparison to rural population. There is already deficit of electricity in urban areas and this deficit will increase year by year.

Continuing decreasing cost of residential solar rooftop PV and increasing cost of fossil fuels, grid parity could occur within three to four years in several states of India where high solar resource is available and prevailing high tariff of electricity. The grid parity is expected in 2019-20 in the states where moderate solar resource is available and prevailing lower tariff of electricity.

Utility scale PV power plant requires huge land, about 1 Km^2 area for 100 MW capacities. Projected generation capacity from residential solar rooftop PV of Indian urban area is 4,500 MW by 2022 as per table 2, and for installation of utility scales PV plant having generating capacity of 4,500 MW will require 45 Km^2 of land.

Land resource in India is very limited and per capita land has been regularly shrinking, per capita land was 0.89 hectare in 1951 and reduced to 0.32 hectare in 2001and is further projected to 0.20 hectare in 2035.

From above discussions, it is clear that there has been increasing demand of electricity in urban areas, residential rooftop PV shall be economical than the grid supply after achieving grid parity within three to four years. Utility scale PV plant requires huge land and this huge land requirement restrict us to install Utility scale PV plant in the country. One of the most positive aspects of rooftop PV is that, it does not require land which is very much precious. Unlimited and unused rooftop area is available on residential buildings of India.

Residential rooftop PV will involve millions of household for generation of electricity; it will create entrepreneurship and jobs to millions. It will brain ware millions of people in the country.

Looking to above factors, encouragement and motivation is needed for adoption of residential rooftop PV in India. The Central and State Government need to come forward for providing capital subsidies, generation based incentive and arranging soft loans.

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AUTHORS

First Author – Pramod Ranjan Arora, Retired Superintending Engineer, Rajasthan Rajya Utpadan Nigam Ltd.