

Photovoltaic Power Generation in Indian Prospective Considering Off-grid and Grid-Connected Systems

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Abstract- Electricity plays a vital role in the progress of any developed and developing nation across the world. The maximum capacity of electricity is supplied by fossil fuel-based centralized power generating stations. The inadequacy of fossil fuels and their harmful effects on the environment leads the research towards energy generation from renewable sources. Wind, solar, biogas, small hydro, etc. are the potential resources of renewable energy. The existing installed solar PV capacity in India is 21.6 GW. Solar has the maximum potential out of the 900 GW estimated potential of renewable energy in India. This paper highlights the progress and efforts made in the field of solar energy in India. The current status of solar energy generation under the Jawaharlal Nehru National Solar Mission (JNNSM) is reviewed thoroughly to justify the utilization of solar potential. The government initiatives, tariff policies, and solar energy incentives are presented in terms of different support programs, funding schemes, and subsidies. As a consequence, the future targets are being achieved by establishing solar parks and rooftop solar systems with the help of net metering concept. Moreover, some success stories as an eye-opener in the field of solar are also depicted.

Keywords National Solar Mission, Photovoltaic, Solar Policy, Solar Incentive, Solar Target

1. Introduction

Electricity is a principal aspect for the social, economic and industrial growth of any developed and developing nation. It is estimated that the energy consumption of the world will be two-thirds more than today's consumption in next two decades. India is the fastest developing nation having a huge demand for electricity for their economic and infrastructure growth. The centralized electricity generation system of India is heavily dependent on fossil fuels like coal, oil, nuclear etc. for decades. It worth noted that the conventional energy resources are depleting at a faster rate and unable to supply the required amount of energy. The growing demand and environmental concerns are major forces behind the renewable energy startup program. The ultimate goal for India is to develop and deploy new and renewable energy resources for supplementing the clean and

green energy to fulfill their energy needs. India has approximately 900 GW renewable energy potential in the form of wind, solar, bio and hydro energy [1, 2]. Solar has maximum estimated potential in the opulently solar blessed country among all renewable because of India's geographical position. India lies in the tropical regions of northern hemisphere between 8°4' to 37°6' north latitude and 68°7' to 97°25' east longitude, where solar rays have more density and that makes the sense for solar energy harnessing throughout the year. Therefore, solar power is omnipresent in this country and more than 300 bright sunny days are available for solar power generation. As a consequence, Indian Territory receives around 5000 trillion kWh solar energy annually and the solar energy of per day varies in the range of 4-7 kWh/m² [3-6]. Therefore, around 750 GW solar potential is available after the assumption of only 3% waste

land across the country, so the solar has the potential to meet the peak load demands during peak hours.

The cumulative achievement of grid-tied renewable energy capacity in MW as per Ministry of New and Renewable Energy (MNRE) for Indian context is shown in Fig.1. More than 50% of the total renewable power installed is supplied by wind energy but the solar power installed capacity has shown a tremendous growth in the last five years as shown in Fig. 2. The installed solar capacity has grown eight times in last one decade [8]. This growth has provided a great motivation in the field of solar energy. Thus, Government of India (GOI) has planned a cumulative target of 100 GW solar power generations out of 175 GW renewable targets up to 2022.

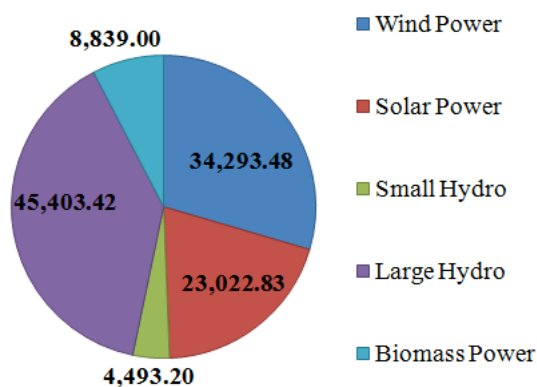


Fig. 1. Cumulative Achievements of Grid-tied Renewable Energy Capacity (MW) as on 31st July 2018 [19]

This target seems to be a difficult one but several state electricity authorities are witnessing great results in ultra mega solar projects and grid-tied rooftop solar systems due to the concept of net metering [8]. After witnessing this type of results in ultra mega solar projects and rooftop grid-tied systems, the government has claimed for world climate support in the submission of united national framework submission on climatic changes. Therefore, the government has announced a 40% renewable energy penetration into the grid by the year 2030 [1].

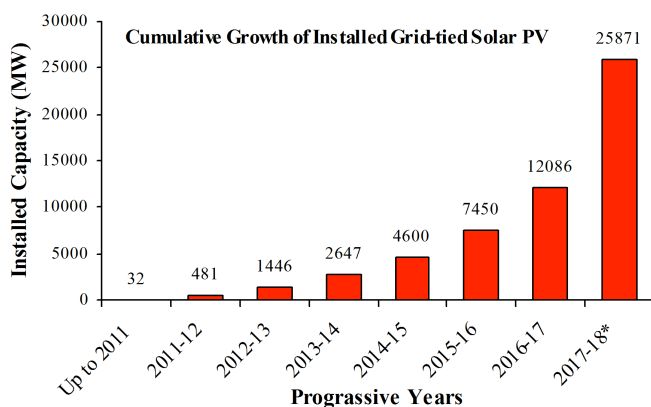


Fig. 2. Evolution of Grid-tied Solar Power Installed Capacity (MW) [19]

Indian government established a separate nodal ministry for renewable energy-related matters. It was renamed as MNRE in October 2006. The efforts made by MNRE have been remarkable in different areas such as grid-interactive renewable power generation, rural electrification,

development of decentralized energy systems etc. They are also supporting some programs like solar parks, Akshay Urja shops, UDAY scheme, hybrid vehicles etc. The role of this ministry starts increasing when security concerns are increasing due to uncertainty in the supply and prices of fossil fuels. The ministry has announced JNNSM in January 2009 for generating more and more power from the solar systems. The main objective of this mission is to establish India as an economic developed energy efficient country by promoting the different programs related to solar energy [1-6].

This paper aims at the planning of solar energy generation for economic growth of the country, which is purely based on energy security and future perspective. The targets and achievements under different phases of JNNSM are thoroughly examined for updating the targets. Different incentives under support programs for solar energy generation are also included. The subsidy schemes for different solar projects under MNRE and state authorities are also included for promoting solar energy.

This paper presents the current status of solar energy and its future prospective scenario based on their cumulative growth and technology developed. Section 2 will discuss solar energy portfolio in India including their recent growth statistics. Incentives from the different support programs and policies are covered under section 3. The future perspective and the motivational success stories are covered under section 4 and 5 respectively. Finally concluding remarks are presenting in section 6.

2. Solar Energy Portfolio in India

Prior to the Electricity Act 2003, the power generation, transmission, and distribution were mainly guided by the Indian Electricity Act, 1910 and carried by state electricity authorities. Some political and economic problems in tariff determination enacted the Electricity Regulatory Act 1998. The Electricity Act 2003 was introduced for further strengthening the development of the power sector and enhancing the trading scenario. Private players were also allowed to invest in the electricity sector to introduce the competition among different agencies so that the overall development of the electricity sector can take place. This act denies the license related policies for power generation except for hydropower. As per Electricity act, the power generation companies have to generate a minimum of 10% power from the renewable sources [11-14]. Therefore, India has taken the biggest renewable energy extension programme for coming years to fulfill clean and pollution free energy dream of the nation. Energy demand and economy of India are growing simultaneously at a faster rate to meet the modernization and renovation of infrastructure.

India has already 69.02 GW installed capacity of renewable energy out of 343.89 GW installed capacity as on 31st May 2018. Renewable energy is promoted to cover different aspects such as energy security, environmental protection, climatic changes etc. Solar energy has a higher potential to feed the power to the rural and urban areas since; there is no need for a separate transmission system. The stand-alone solar systems were installed in the last decade, mainly in the form of solar pumps, street lighting, and home

lighting systems for some remote areas. Although the standalone systems had great success off-grid systems were unable to lift the burden from the power utilities. Therefore the government has decided to promote grid-tied solar photovoltaic systems to reduce the burden from the power utilities. MNRE had launched JNNSM in the year 2010 for promoting the solar power by providing subsidies and incentives with the help of some agencies [8].

2.1. Jawaharlal Nehru National Solar Mission

This mission was launched by MNRE in the year 2010 for supplying green and clean energy to the nation. The initial target was 20000 MW grid-tied solar powers by 2022. The cumulative target of solar power generation is revised from 20 GW to 100 GW by the cabinet on 17th June 2015. The revised target includes 60 GW large/medium scale land-based solar power plants and 40 GW rooftop solar power systems. Apart from the 100 GW power generation, there were some other objectives such as the installation of 20 million solar lightening systems by 2022, development of 20 million square meters solar thermal collector area, the establishment of some good conditions for solar cells/modules manufacturing and achievement of grid parity by helping research and development section. The complete mission has to be completed in three phases and further divided into batches and tranches for simple executions. There must be an evolutionary process in between the phases to protect the government from the subsidy exposure in case of inflation or cost reduction [11-13].

2.2.1. Grid-tied Solar System

India is the world’s third largest country in terms of power generation and fourth largest in terms of power consumption. The national grid has 343.89 GW installed capacity including 20.07% renewable but still the demand-supply gap is wide enough. This gap can be narrowed down by supply power from the sun during peak hours of the load curve. Therefore the peak demand can be meet through grid-tied solar power system [1-6].

Phase-I of JNNSM (2010-13): The first phase of this mission was focusing off-grid applications and some lower hanging solar thermal units. The Phase-I of JNNSM comprises of two components which are (i) 1000 MW grid-tied solar photovoltaic system integrated with 33kV line or above, and (ii) 100 MW rooftop systems integrated with utility below 33 KV line. This phase consists of three stages namely, (i) Migration scheme, (ii) Phase-I, Batch-I, and (iii) Phase-I, Batch-II.

Migration Scheme: The ongoing projects were transferred under this scheme to speed up their progress. Total 16 such projects of 84 MW capacities came under this scheme for long-term provisions. The central electricity regulatory commission (CERC) decided the average tariff of Rs 17.91/kWh for solar photovoltaic (SPV) system and Rs 15.31/kWh for solar thermal systems.

Batch-I & Batch-II: There are certain limits for project capacities under this phase. The maximum capacities for

SPV and ST systems of Batch-I are 5 MW and 100 MW respectively. Thirty SPV projects and seven ST projects were selected to achieve these targets. The solar projects allocation scheme was fixed through reverse bidding. Bids were invited for the auction of 150 MW SPV system and 470 MW ST systems in August 2010 under Batch-I. The maximum installation capacity limits are increased from 5 MW to 20 MW for the SPV system in Batch-II. Twenty-eight SPV projects were selected for an aggregate capacity of 350 MW. Overall 523 MW SPV systems and 202.5 MW ST systems were commissioned during Phase-I. The average tariff for both SPV and ST systems are shown in Table 1. The total power generated from the commissioned plants of the first phase was purchased by NTPC Vidyut Vyapar Nigam Limited (NVTN) and being sold through a bundling mechanism to the state electricity companies.

Table 1. Average Tariff under Phase-I [12-13]

Stages of Phase-I	Average Tariff for SPV System US\$/(\$/Unit)	Average Tariff for ST System US\$/(\$/Unit)
Migration Scheme	0.24/17.91	0.21/15.31
Phase-I, Batch-I	0.16/12.16	0.16/11.48
Phase-I, Batch-II	0.12/8.77	-

Phase-II of JNNSM (2013-17): The Phase-I had a great success in off-grid solar power applications and grid-tied solar systems. The achievements of Phase-I are greater than their targets. This momentum needs to be carried forward in Phase-II for some more grid-tied solar systems with the help of different schemes such as Viability Gap Funding (VGF), Bundling etc. Data published in the annual report of MNRE has been prepared and presented in Table 2. At the end of Phase-II, India achieved more than its targets as shown in Table 2. Different targets and their achievements are shown in Table 2 for all three phases of JNNSM. As of 30th June 2017, the Grid-tied solar systems have 13114.82 MW installed capacity throughout the country.

2.1.2 Off-grid Solar Systems

A key prospect of solar energy lies in the Off-grid and decentralized systems. The home lighting system, solar street lights, solar water pumps, and solar lanterns are few examples of the Off-grid solar system. Mainly they are useful in remote areas, where grid connectivity is neither possible nor economical. Solar based applications are quite feasible in remote areas with cost-effective solutions. These applications are very useful in rural areas to fulfill energy needs for lighting and irrigations purposes because they are directly serving the poor peoples of this country. JNNSM has directed certain guidelines for the installation of Off-grid systems. MNRE has approved 12 laboratories across the country for testing the off-grid applications. The ministry had made a provision of 30% subsidy on the capital cost of the system and also assigns Indian Renewable Energy Development Agency (IREDA) Ltd. to provide a loan at 5% annual rate. Ministry has introduced a process of accreditation to encourage some partner agencies to reach out

Table 2. Targets and achievements under Jawaharlal Nehru National Solar Mission [1]

Type of Application	Phase-I Target (2010-13)	Achievement of Phase-I (2010-13)	Phase-II Target (2013-17)	Achievement of Phase-II (2013-17)	Phase-III Target (2017-22)
Grid-tied solar power (Plants, rooftop and distribution plants)	1100 MW	1686.44 MW	10000 MW	12288.83 MW	100000 MW
Stand-alone solar applications (Home lighting systems, street lighting, and lanterns)	200 MW	252.5 MW	1000 MW	1000 MW	2000 MW
Solar Thermal Collectors (Solar heating and cooling systems, industrial heat processes etc.)	7 million square meter area	7.01 million square meter area	15 million square meter area	15 million square meter area	20 million square meter area

to the peoples of rural areas in order to spread out the information. Currently, some small and market-based schemes have achieved narrow penetration in this section, but the government has started some financial incentive schemes to promote these applications. The national solar mission plans to electrify 1000 villages under the ongoing program of village electrification with the help of MNRE. Since these lighting systems are very much equipped with remote and tribal areas, therefore 90% subsidy is provided. Fig. 3 shows the year-wise installation of home lighting systems over the last six years. A total of 1396036 numbers of home lighting systems were installed in India [1].

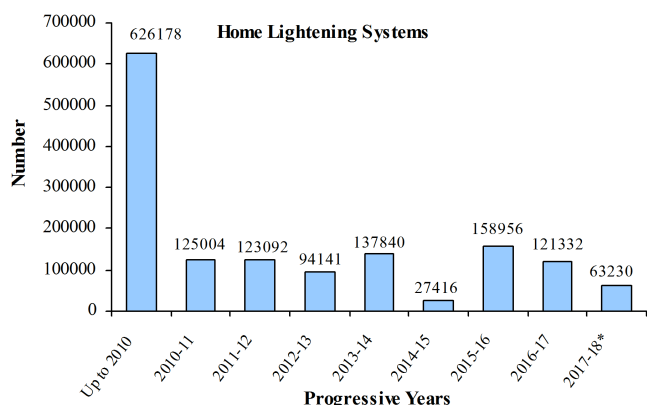


Fig. 3. Number of Installed Home lightening Systems [19]

Around 252 MW was achieved against a target of 200 MW during the first phase of JNNSM. Fig. 4 shows the total number of solar street lights installed during the last six year across the country through different schemes by MNRE. More than four lakh solar street lights were installed during the last six years across the country to brighten the rural and urban streets during the night.

The huge geographical area of this country demands high capacity transmission lines which are very costly. Many farmers are still depending on diesel pumps because of no grid connectivity. Still, more than 20% of power is consumed by the agricultural pumps across the country. DISCOMS are distributing lakhs of connections every year for agricultural pumps under different subsidized schemes. The burdens of subsidies are growing day by day on power utilities. They are looking for some alternatives to feed water for the agricultural works. The solar pump is the most popular off-grid application to supply water for

irrigation as well as drinking purposes through the solar system arrangement. More than 65% population are living in rural areas and heavily depending on the agricultural activities for their income [13].

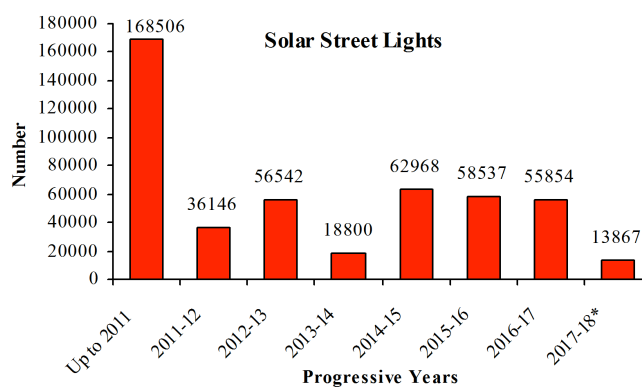


Fig. 4. Numbers of Installed Solar Street Lights [19]

Even some parts of the country are isolated from the grid connectivity where peoples are facing drinking water problems. Therefore solar pumps are becoming living changing prospects for those peoples. Fig. 5 shows the growth of the solar pump installed during the last five years. Hence, more than one lakh solar pumps are already installed across the country.

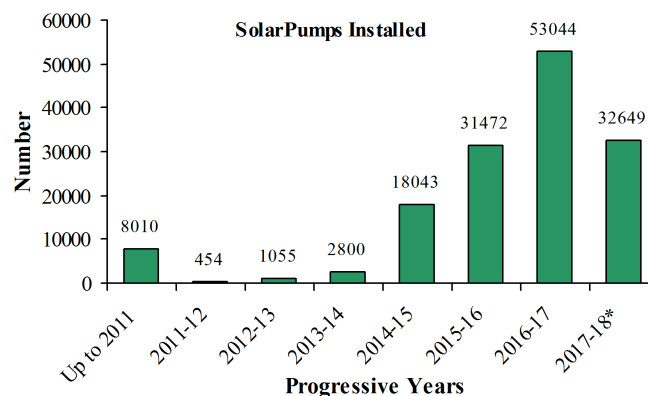


Fig. 5. Number of Installed Solar Water Pumps [19]

2.1.3 Domestic Manufacturing

Manufacturing of solar cells/ modules is also one of the objectives of this mission. More than 85% of solar modules are imported from other countries annually.

However 30% domestic manufactured content was necessary requirements for the development of solar thermal projects during the first phase. Hence, the solar cells and modules manufacturing is growing at the faster rate shown in Fig. 6. Domestic manufactured crystalline silicon cells were mandatory for all projects related to solar thermal but other technological based cells/modules can be imported if required. The growths of domestic cells/modules are increasing and hence can fulfill the complete demand in future. Total solar module manufactured capacity is estimated around 6000 MW in the country at present [10-13].

Adani group is the largest solar module manufacturer in the country having manufactured 1200 MW capacity solar modules in the year 2016. The ministry and industry are very much positives about the manufacturing of solar cells/Modules with 5-6 GW capacity by domestic players. MNRE has endorsed some association for the manufacturing of solar cells/Modules as shown in Table 3.

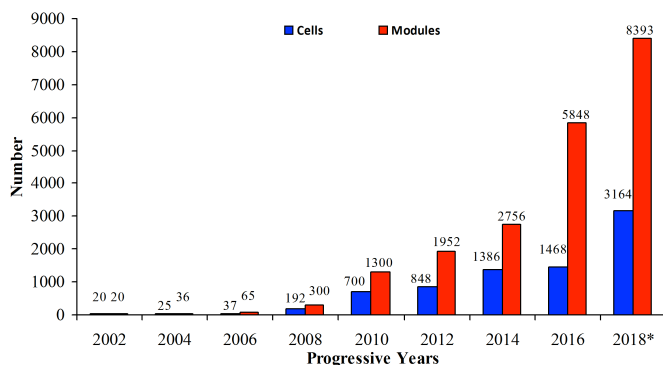


Fig. 6. Year-wise Solar Cells and Modules Manufacturing Capacity (MW) [19]

The national solar mission has already shown a glimpse of hope to fulfill energy demand by using solar

energy harnessing methods. State wise installations of off-grid solar power installed applications are presented in Table 4. The total solar installed capacity of every state has been tabulated in Table 4. The solar energy targets were revised in 2015 after the ministry has taken some stride forward towards their commitment to climatic changes by reducing the emission of greenhouse gases.

2.1.4 Solar Tariff and Solar Cells/Modules Price

CERC provides a certain solar tariff for next 25 years, which will be reviewed every year by CREC. Solar tariff is falling down freely after hitting a new low of Rs. 2.44/unit in latest auction of Bhadla Solar Power Project. International companies from the countries like Japan, South Africa, France, USA, Singapore etc. are also showing great interest in the auctions for investment in solar energy [17, 18]. South African solar giant Phelan Energy Group is also invested in Indian solar market and won a bidding for 100 MW solar power projects at Rs. 2.62/unit in Rajasthan [19]. Recently one of the Indian company Acme solar has won the bidding for 200 MW solar plant capacity in Rajasthan at Rs. 2.44/Unit [1]. This is the biggest step towards the mission of clean and affordable power. The average bidding prices for solar power sale in India falls from Rs. 12.16/unit to Rs. 2.44/Unit in the last seven years as shown in Fig. 7.

The per unit (kWh) price of electricity has reduced considerably in last few years as the manufacturing of solar modules/cells is increasing at a great pace in India, therefore Engineering, Procurement, and Construction (EPC) prices have been reducing at a very fast rate in the last couple of years. Fig. 8 represents the Module prices and EPC prices for the last nine quarters [19].

Table 3. Solar Associations Endorsed by MNRE for Solar Cells/Modules Manufacturing [1,19]

Sr. No.	Name of Association	Location
1	National Solar Energy Federation of India (NSEFI)	702, Chiranjeev Tower, Nehru Place, Opp. Eros Hilton Hotel, New Delhi
2	Indian Solar Manufacturers Association (ISMA)	81/2, Ist Floor, Sri Aurobindo Marg, Near Hero Honda Showroom Adhchini, New Delhi
3	Solar Energy Society of India (SESI)	2nd Floor, Central Board of Irrigation and Power (CBIP), Malcha Marg, Chanakyapuri New Delhi
4	All India Solar Industries Association(AISIA)	602, Western Edge-I, Western Express Highway, Borivali (East). Mumbai, Maharashtra
5	Confederation of Indian Industry(CII) Renewable Energy	India Habitat Centre (IHC) Confederation of Indian Industry CII Central Office Mantosh Sondhi Centre 23 Institutional Area Lodi Road, New Delhi
6	Federation of Indian Chambers of Commerce & Industry (FICCI) Renewable Energy	Federation House Tansen Marg, New Delhi
7	Solar Thermal Federation of India (STFI)	T-301, Ashoka Mall, 21/2, Bund Garden Road, Opp. Hotel Sun and Sand, Pune, India
8	Solar Power Developers Association (SPDA)	T-11, 3rd Floor, Vasant Square Mall, Sector B, Pocket-5 Vasant Kunj, New Delhi
9	Karnataka Renewable Energy System Manufacturers Association (KRESMA)	No 4, 80 ft Ring Road, Next to BDA Complex, Nagarabhavi, 2nd Stage, Bangalore
10	Rajasthan Solar Association (RSA)	602, Trinita Mall, Swej Farm New Sanganer Road Jaipur

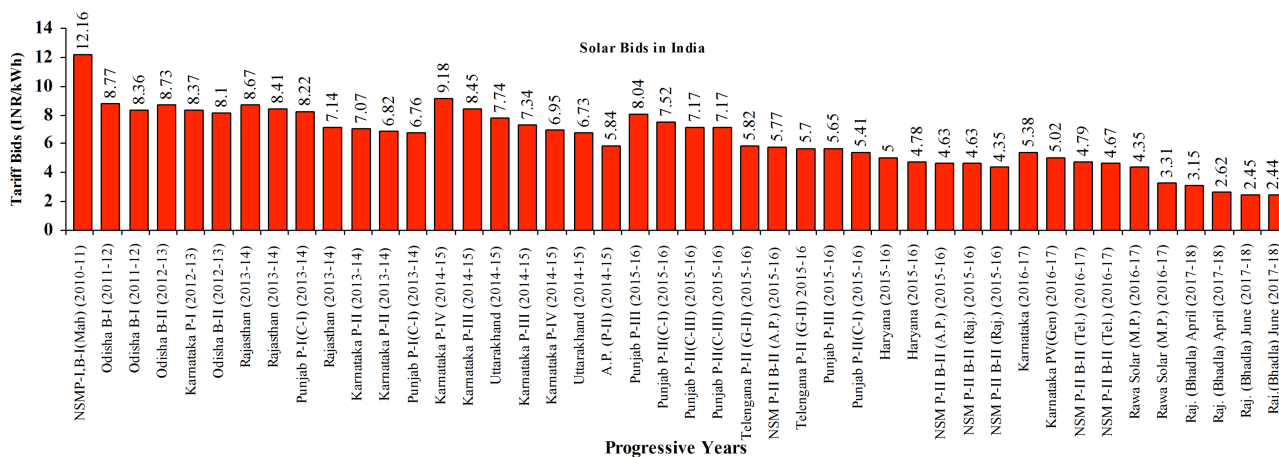


Fig. 7. Year wise Average Bids/tariff in India through Reverse Auctions [18]

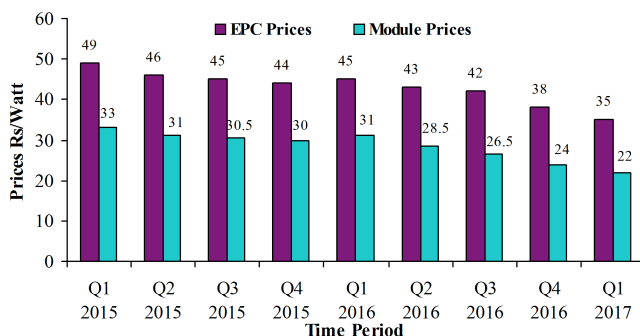


Fig. 8. Quarterly Module prices and EPC prices for the last nine quarters [25]

Table 4. State-Wise Solar Potential, Installed Power Systems, Installed Capacity and Revised Targets [1, 19]

Indian State/UT	Solar Potential (GWP)	Installed Solar Power Systems					Solar Installed Capacity State wise as on 31-12-2017 (MW)	Tentative Solar Power Targets Till 2022 (MW)
		No. of Lanterns Installed	No. of Home Light Systems Installed	No. of Street Lights Installed	No. of Solar Pumps Installed	Stand Alone Plant Capacities (MW)		
Telangana	20.41	0	0	351	424	6643	2990.07	-
Rajasthan	142.31	225851	166978	6852	41377	10850	2310.46	5762
Andhra Pradesh	38.44	51360	22972	7812	19526	3785.595	2165.21	9834
Tamil Nadu	17.67	16818	273015	39235	4459	12752.6	1819.42	8884
Karnataka	24.70	7334	52638	2694	4118	7754.01	1800.85	5697
Gujarat	35.77	31603	9253	2004	8010	13576.6	1344.69	8020
Madhya Pradesh	61.66	529101	4016	9378	5584	3654	1210.11	5675
Punjab	2.81	17495	8626	42758	1857	2066	905.64	4772
Maharashtra	64.32	239297	3497	10420	3315	3857.7	763.08	11926
Uttar Pradesh	22.83	104791	235909	185091	10877	10041.46	550.38	10697
Uttarakhand	16.80	93927	91595	21905	26	2365.03	246.89	900
Haryana	4.56	93853	56727	22018	1243	2321.25	203.85	4142
Chhattisgarh	18.27	3311	7754	2042	26673	28660.04	179.38	1783
Bihar	11.20	210391	12303	955	1882	4168.6	141.52	2493
Kerala	6.11	54367	41912	1735	818	15825.39	88.20	1870
Odisha	25.78	99843	5274	5834	8570	567.515	79.51	2377
Delhi	2.0	4807	0	301	90	1269	58.02	2762
West Bengal	6.26	17662	145332	8726	653	1730	39.84	5336
Jharkhand	18.18	138723	9450	787	3598	3639.9	23.27	1995
Assam	13.76	13379	6926	318	45	1605	11.78	663

Tripura	2.08	64282	32723	1199	151	667	5.09	105
Arunachal Pradesh	8.65	14433	18945	1671	22	650.1	4.39	39
Jammu and Kashmir	111.05	51224	65319	5806	39	7719.85	2.36	1155
Himachal Pradesh	33.84	33909	29342	58718	6	1905.5	1.48	776
Manipur	10.63	4787	3900	1888	40	1241	1.33	105
Goa	0.88	1093	393	707	15	32.72	0.71	358
Nagaland	7.29	6766	1045	6235	3	1506	0.50	61
Mizoram	9.09	9589	6801	5056	37	2019	0.20	72
Meghalaya	5.86	24875	7844	4900	19	1084.5	0.06	161
Sikkim	4.94	23300	15059	504	0	850	0.01	36
Andaman and Nicobar	0.79	6296	468	390	5	167	104.1	27
Chandigarh		1675	275	898	12	730		153
Lakshadweep		5289	600	2465	0	2190		4
Puducherry		1637	25	417	21	121		246
Others		0	125797	24047	9150	0		23885
NABARD	0	0	116226	0	4012	0		
Total	748.94	2328865	1477189	471220	147527	181901.36	17052.37	99534

2.2. Qualification Testing by Using National and International Standards

MNRE has started different institutes for guiding solar programs and policies through some standard procedures. National Institute of Solar Energy (NISE) has PV module test laboratory for photovoltaic modules and their components as per national and international standards. This laboratory is accredited by national

accreditation board for testing and calibration laboratories (NABL) with standard IS/IEC 17025: 2005. They are offering different services like performance, quality, electroluminescence, thermography and potential degradation analysis [20]. These tests are performed at IEC standard 60904-3 i.e. 25°C temperature, 100mW/m² light intensity and AM 1.5 spectrum. The PV testing facility at NISE is certified by ISO-17025. Different testing standards with their testing specifications are shown in Table 5 with their testing time.

Table 5. Qualification Testing of PV Module as per IS/IEC Standards [15, 19]

Sr. No.	National and International Standard Number	Type of the Product	The title for the National/ International Standard	Testing Time
1.	IEC 61215/ IS 14286	Silicon wafer-based Crystalline terrestrial PV modules	Silicon crystalline terrestrial PV module - Design and their type	Four Months
2.	IEC 61646/ IS 16077	SiGs, CdTe based thin-film terrestrial PV modules	Thin-film terrestrial PV module – Design and their type	Four Months
3.	IS/IEC 61730 (Part-1)	Silicon wafer and thin-film-based PV module	PV module safety qualification Part 1 - Construction requirements	One Month
	IS/IEC 61730 (Part-2)	Silicon wafer and thin-film-based PV module	PV module safety qualification Part 2 - Testing requirements	One Month
4.	IS 16221 (Part-1)	Power converters for solar PV system	Safety of converters used in PV systems Part 1- General necessities	25-30 Days
	IS 16221 (Part-2)	Power converters for solar PV system	Safety of converters used in PV systems Part 2- Particular necessities for grid-tied inverters	
5.	IEC 61701	Silicon wafer and thin-film-based PV module	Salt mist type corrosion testing of PV modules	One Month
6.	IEC 62804	Silicon wafer and thin-film-based PV module	PV module’s sensitivity testing for a degradation test	25-30 Days
7.	IS 16169	Grid-tied solar PV inverters	Islanding detection and prevention measures for grid-tied solar PV inverters	
8.	IS 16270	Battery Storage	General requirements for solar PV applications and their testing	Depends on the type of test

It has been recommended by MNRE to check the quality certification and type approval before deployment of solar panels.

3. Incentives for Solar Energy

Several incentive policies and support programs are currently working in India for the promotion and support of solar energy mission [14]. These programs and policies are equally supported by central government and state governments. Several funding schemes and subsidies are explained in details.

3.1 Support Programs

The national mission for utilization of solar energy is quite impossible without proper planning and support programs to implement the targets. Initially, it was only about 20000 MW solar energy target and have to be completed in three phases from 2010 to 2022. But the consistent effort of the central government has lifted the targets by consulting with some funding agencies and stakeholders. Different support programs have been already launched under various central schemes to achieve the target of 100 GW by the year 2022 [19].

3.1.1 Viability Gap Funding (VGF) Scheme

The government has drafted a scheme to support those projects, which are economically acceptable but financial not possible. Ministry of finance administered this scheme by granting yearly funds. It was launched in 2004 for supporting some public cum private partnership projects. This scheme provides a 20% grant of the total cost to the infrastructure related projects. The capital grant is provided as a subsidy to attract private players for participation in the reverse bidding process and selected on the bases of competitive bidding. Financial institution of the project will lead the charge of monitoring and evolution processes so that the public money can be utilized in a better way. The solar projects which are working under VGF scheme are as follows:

- 750 MW ground-mounted solar photovoltaic projects (JNNSM Phase-II, Batch-I) are implementing by Solar Energy Corporation of India (SECI) under this VGF scheme. Seven different states are having different projects under the VGF scheme. After their crystal clear selection and grant process, 680 MW capacities could be achieved for the financial corral and commissioned for operation [19].

- 2000 MW capacity solar photovoltaic projects (JNNSM Phase-II, Batch-III) are implementing by SECI under VGF scheme in seven states/UT's across the country. Producers would be paid a tariff of Rs 4.43/unit, which is decided by reverse bidding auctions. The produced power would be sold to state electricity companies at Rs 4.50/unit including trading charges [20].

- 5000 MW capacity solar photovoltaic projects (JNNSM Phase-II, Batch-IV) will be implementing by SECI under VGF scheme in four trenches of 1250 MW each. The four trenches (2015-19) would be completed in four financial

years. The produced power purchase at Rs. 4.43/unit by SECI and would be sold at Rs. 4.50/unit to the state DISCOM's [18].

- Central Public Service Company (CPSU) and central government have launched the 1000 MW grid-tied SPV system (JNNSM Phase-II) in 2015 under the VGF scheme. It may be either land-based or rooftop project owned by government/CPSU. The developed Power may be used for self-purpose or third party sale/ DISCOM's sale at a viable tariff. The Ministry has allocated 1037.26 MW solar power capacity to 16 different CPSU's/Government organizations within the allocated funds of Rs 1000 crore [21].

3.1.2 State Specific Bundling Scheme

It was started for grid integration of solar power projects during the first phase of JNNSM. Highly expensive solar power projects were connected to unallocated coal plants of NTPC under Bundling scheme. The solar project's installation under bundling scheme came a long way and helped to promote the solar by reducing their average cost after bundling with unallocated power [1].

- Integration of 1000 MW grid connected solar projects were implemented through this mechanism by NRVV. SPV and ST power plants aggregate 978 MW installed capacity and 84 MW was added under migration scheme. The power was purchased by NRVV through reverse bidding and sold to different state companies for distribution. Average cost is reduced by bundling solar power with an unallocated quota of coal power from NTPC. A total of 718 MW solar powers. The average tariff for both SPV and ST power systems are shown in Table 1 under Phase-I [1].

- After getting the response from different states, MNRE has decided to implement 3000 MW solar projects through NRVV under the second phase of JNNSM. These projects will be implemented by the joint venture of state and central agencies in the solar parks. MNRE starts developing 25 solar parks to enhance solar capacity in various states. The land and connectivity are provided by state or Solar Park Implementation Agency (SPIA) by providing details regarding allotment, rates, possessions etc [21]. The entire quantity can be on/off the solar park and may be shared.

3.1.3 Renewable Purchase Obligation (RPO)

RPO is a major scheme to promote renewable energy generation in the country. This mechanism mandates that state and private distributors need to purchase a certain limit of power from renewable sources. RPO is defined in two categories i.e. solar and non-solar. Each and every state needs to be defined by their solar power generation as a part of RPO under solar obligation [17-19]. The RPOs are applied on distribution consumers, open access consumers, and captive consumers. Their target is achieved by three different ways as (i) Establish your own renewable generation plant (ii) Purchase renewable energy from any other renewable company and (iii) Through energy exchange program of

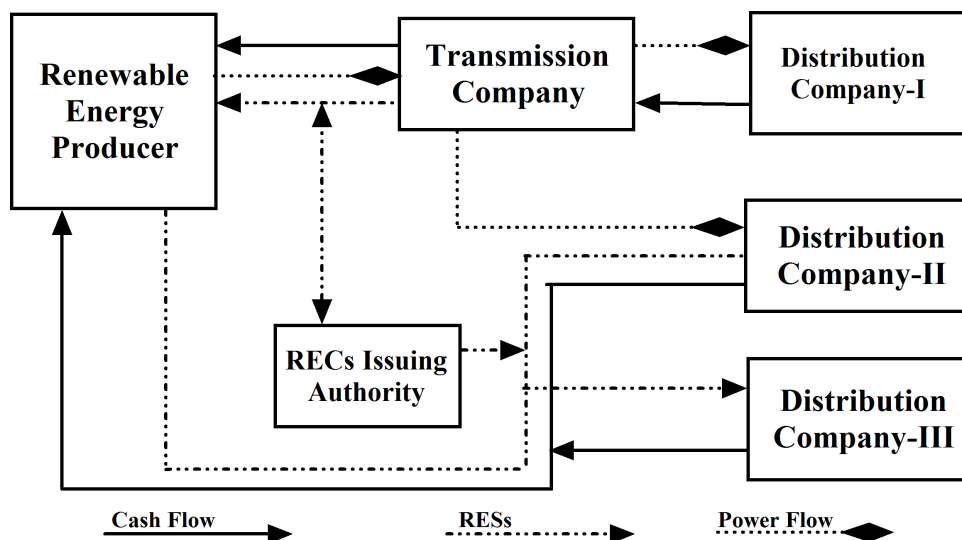


Fig. 9. The flow of Power and different Green Energy Attributes in Indian Scenario [21]

purchasing Renewable Energy Certificate (REC). In December 2010, the REC policy had been started by Indian Government to support the green energy sector, so that they can earn more tariff over their conventional cumulative price. REC policy created a pseudo linked mechanism inside the market by granting a REC per MWh of renewable energy from their generators so that they can contribute to the grid. They have sufficient green energy so that they can trade of their extra power to renewable deficient utilities. The RECs have been purchased by energy deficient entities to meet their renewable targets imposed by the government. Mostly REC policy is beneficial for renewable energy companies [1]. Renewable energy and RECs are selling by renewable energy producer to the transmission and distribution companies separately based on their arrangement. Fig. 9 shows the complete block diagram of the power flow, cash flow, and RECs as per their mutual agreement.

3.1.4 Ujwal DISCOM Assurance Yojna (UDAY) Scheme

The government of India has started UDAY scheme to find a permanent solution to support financial and operational reforms of DISCOMs. It was started in November 2015 by Ministry of Power, Coal & New and Renewable Energy. The main intent was, to provide financial balance in their distribution system. Already, 27 states have joined this scheme to balance their financial mess. Over 75% debt of DISCOMs shall take by state governments as of September 2015 for a period of two years [1]. The fiscal deficits of the states will not be included the debts taken by respective states. The future losses of the DISCOMs can be included in a graded manner by the states. Some other financial institutions will also support these states to encourage the states. Therefore Cooperative and competitive federalization can be achieved by using this scheme. The Aggregate Technical and Commercial (AT&C) losses are reducing at a faster rate in the last two years and reached a level of 20%. Thus, DISCOM's are now more than capable of supplying

continuous electricity across the country and also able to support the mandate solar energy generations in their zone of production [23].

3.1.5 Akshay Urja Shops

Aditya solar shops were started in 1995 by the ministry and later renamed as Akshaya Urja Shops. The main objective of this scheme was to establish a shop in every district for sale and service of solar energy based products so that a network can be created throughout the country. Only State Nodal Agencies (SNAs) were allowed to establish these shops during the 9th plan period but after that plan, the private players are also allowed to set up these shops [1]. There are certain guidelines for the establishment of these shops regarding location, quality, services, goods etc. There is the provision of soft loan for 85% of the capital cost at the rate of 7% per year and provided by the cooperative/public sector bank. More than 400 shops are currently working in different districts under the name "Akshay Urja Shops". Finally, the ministry has decided to discontinue Akshay urja shops after completion of the 12th plan [19].

3.1.6 Surya Mitra Scheme

Growing nature of solar sector is creating employment opportunities for the youth. NISE is organizing various "Surya Mitra" skill development programs with the help of state nodal agencies and sponsored by MNRE. The main aim of this scheme is to develop technical skills like Installation, operation, and maintenance of the solar system among the youths of the country. They are also trying to prepare the youths for some entrepreneurship in the solar sector [22]. The candidates from the rural background having some diploma in Electrical, Mechanical and Electronics are eligible and preferred for this three-month training program. Every batch is having 30 sets and this course is running at free of cost. Currently, 192 Surya Mitra institutes are working across the country [19, 23].

3.1.7 Atal Jyoti Yojna

MNRE has started this scheme for distribution and installation of solar street lights across rural and semi-urban areas of Assam, Bihar, Jharkhand, Uttar Pradesh and Odisha where the electrification was very less. These street lights are very useful in providing convenience by lighting the roads and markets. MNRE is supplying 75% budgets for the solar street lighting system under this scheme and the remaining 25% budgets is provided by Member of Parliament Local Area Development Scheme (MPLADS) from their local budget. MNRE has appointed Energy Efficiency Services Limited (EESL) for the implementation of this scheme. This scheme has 154 MWp installed capacity in the form of decentralized and off-grid solar applications as on 31st December 2016. The ministry has sanctioned 44,213 solar street lights, 7,161 solar water pumps, 477 small solar plants, 25,900 solar home systems, and 5,00,000 solar lamps under this scheme in the financial year 2016-17 across various states of the country [1, 19].

3.1.8 Deen Dayal Upadhyaya Gram Jyoti Yojana

This scheme was specially designed for continuous power supply to rural India. Formally it was Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) and later renamed as Deen Dayal Upadhyaya Gramin Jyoti Yojna (DDUGJY). The government plans to invest Rs. 756 billion for feeder separation of the rural transmission system and infrastructure strengthening of distribution system including metering facilities. Ministry has sanctioned 921 projects under DDUGJY for 1,21,225 un-electrified and 5,92,979 partially electrified villages. The electrification of remote villages is also supported by MNRE through cost-effective solutions using solar energy under this scheme. Central/state government are installing stand-alone solar PV projects with battery backup in the form of mini/microgrid mode for village electrifications. The projects under this scheme are designed in such a manner that each and every household should get minimum of 1 kWh/day as per National Electricity Policy, 2005. If the minimum amount of energy is not achievable in cost-effective manners through renewable then the solar energy can be used for basic lighting systems as per decided by the respective authorities. CFA provides 90% of the total capital cost of solar energy generating systems for rural electrification [1, 19].

3.2 Subsidies

The reliability of the supply is also quite low due to increased power cuts across the cities. Therefore, people have started looking for some alternative solutions for a continuous supply of power. Solar energy is the foremost contenders for reliability and continuous power supply. High capital cost on the installation of the solar system

was a major barrier in the future of solar energy. Therefore the government has started several subsidies under the JNNSM in 2010 for installation of solar systems across the country [1].

3.2.1 Capital Subsidy Scheme for Small Solar Systems

The government has started a subsidy scheme for individuals/organizations to install solar lighting system and small solar PV system at reduced capital cost. This scheme was implemented by IREDA and financed by the National Bank for Agriculture and Rural Development (NABARD). There are certain steps for purchasing solar systems through subsidy/loans provided by NABARD. This scheme was modified in 2012 to restrict the subsidy up to 40% on capital cost. In March 2015 NABARD has stopped the subsidies. In January 2016 the government has started an ambitious rooftop subsidy scheme. In this regard, the cabinet committee of economics approved INR 50 billion for funding 30% of the capital cost of a rooftop system. The government has also made a priority list. Public institutions, schools, hospitals etc. are at the top of the priority list and residential projects are at the bottom of the list. Even the subsidies for residential projects are becoming less and hard to get [4-9].

3.2.2 Subsidy on Off-grid Solar Applications

The ministry has planned certain targets for decentralized and off-grid solar applications. They are providing 30% subsidy on the capital cost of the system in the range of Rs. 21 to Rs. 120 per watt as per the system configuration and module category. NABARD, commercial banks, and regional rural banks are also providing a 40% subsidy on off-grid solar applications under the financing program [1].

4. Future Perspective of Solar Energy

India is a tropical country having 748.5 GW solar potential including 3% of wasteland across the country. The abundance of solar energy in Indian conditions and the technology development uplift the targets after every revision. The solar energy has the ability to become the future perspective of the power sector as it is pollution free and less costly [24-27].

4.1 Future Targets

The government has put certain targets for future to meet the energy demands by fulfilling climatic conditions. The yearly target of the rooftop, as well as ground, mounted solar system has been depicted in Fig. 10. Rooftop systems are on priority in the coming years because of availability of areas in urban areas. The rooftop solar system has a target of 40 GW out of 100 GW total solar energy target [21].

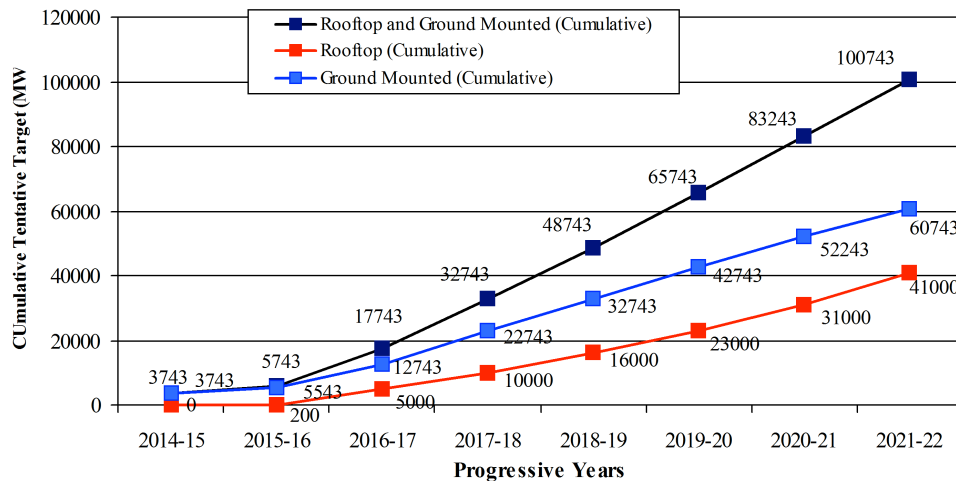


Fig. 10. Year-wise Cumulative Tentative Target of 100 GW Solar Power Achieved by 2022

4.2 Solar Parks and Ultra Mega Solar Power Projects

Distribution of small capacity solar power projects will lead towards higher cost because of higher transmission cost. The site development costs, transmission line costs, land possession difficulties, water and infrastructure problems reduce the significance level of small and scattered projects. Hence, the government has planned solar parks and ultra mega solar power projects of 500

MW capacities or more, based on the success of “Charanka Solar Park” in Gujarat. A financial support of Rs. 81 billion has been sanctioned for 40,000 MW capacity solar parks by the year 2020. The installation of grid-tied solar power will be achieved with the help of solar generation on large scale through solar parks. The infrastructure of 34 solar parks of 20100 MW capacities has already sanctioned by center and state governments as shown in Table 6.

Table 6. List of Solar Parks across the Country with their Location and Capacity [1, 19]

Sr. No.	State	Name of the Developer Company	Capacity (MW)	Location	Approval Date
1.	Andhra Pradesh	AP Solar Power Corporation Pvt. Ltd.	1500	Vill.-N.P. Dist.-Ananthapuram	28/11/2014
2.		JVC of SECI	1000	Vill.-Rama Chandraya Palli, Dhondiam & Vaddirala Dist.-Kadapa	28/07/2015
3.		AP Power Generation Corporation Limited	1000	Vill.-Gani & Sakunala, Dist.-Kurnool	28/11/2014
4.		New & Renewable Energy Development Corporation Andhra Pradesh Limited	500	Vill.-Talaricheruvu & Aluru Dist.-Ananthapuramu	14/01/2016
5.	Arunachal Pradesh	Arunachal Pradesh Energy Development Agency (APEDA)	30	Town-Tezu Dist.-Lohit	29/04/2015
6.	Assam	JVC of APDCL, APGCL	80	Town-Amguri Dist.-Sibsagar	28/08/2015
7.	Chhattisgarh	Chhattisgarh Renewable Energy Development Agency	250	Dist.-Rajnandgaon & Janjgir Champa	29/09/2015
8.	Gujarat	Gujarat Power Corporation Limited	700	Vill.-Radhanesda Dist.-Banskantha	01/12/2014
9.		Gujarat Power Corporation Limited	500	Vill.-Harsad and Navapara Dist.-Banskantha	-----
10.	Haryana	Saur Urja Nigam Haryana Ltd. (SUN Haryana)	500	Vill.-Bugan, Baralu & Daukhera Dist.- Hisar, Bhiwani Mahendergarh	15/01/2016
11.	Himachal Pradesh	HP State Electricity Board Limited	1000	Spiti Valley Dist.-Lahaul & Spiti	09/04/2015
12.	Jammu & Kashmir	J & K Energy Development Agency (JKEDA)	100	Vill.- Mohargarg & Badla Brahmana	29/09/2015

				Dist.- Samba	
13.	Karnataka	Karnataka Solar Power Development Corporation Private Limited	2000	Vill.-Ballasamudra, Tirumani, Rayacherlu & Kyataganacherlu Dist.-Nagalamadike Hobli, Pavagada Taluk & Tumkur	19/03/2015
14.	Kerala	Renewable Power Corporation of Kerala Limited	200	Vill.- Paivalike, Meenja, Kinnoor, Kraindalam & Ambalathara Dist.-Kasargode	19/03/2015
15.	Madhya Pradesh	Rewa Ultra Mega Solar Limited	750	Vill.-Badwar, Itar Pahad, Ramnagar, Barseta Dist.-Rewa	01/12/2014
16.			700	Dist.- Neemuch & Mandsaur	08/06/2016, 15/01/2016 & 6/10/2015, 29/09/2015
17.			1050	Dist.- Agra & Shajapur	08/06/2016
18.			250	Dist.- Rajgarah & Morena	08/06/2016, 15/01/2016
19.	Maharashtra	M/S Pragat Akshay Urja Limited	500	Vill.- Taluka Sakri Dist.-Dhule	29/09/2015
20.		Maharashtra State Electricity Generating Company Limited (MAHAGENCO)	500	Vill.- Dondaicha, Dist.- Dhule	17/12/2015
21.		M/S K. P. Power Pvt. Limited	500	Vill.- Taluka Patoda Dist.- Beed	17/12/2015
22.	Meghalaya	Meghalaya Power Generation Corporation Ltd (MePGCL)	20	Vill.- Suchen & Thammar Dist.- East & West Jaintia	04/09/2015
23.	Mizoram	Zoram Energy Development Agency (ZEDA)	20	Dist.-Vankal, Mizoram	-----
24.	Nagaland	Directorate of New & Renewable Energy, Nagaland	23	Vill.- Ganeshnagar, Zhadimja & New Peren Dist.-Dimapur, Kohim & Peren	29/04/2015
25.	Odisha	Green Energy Development Corporation of Odisha Limited	1000	Dist.- Bouch, Balasore, Deograh, Kalahandi, and Keonjhar	28/10/2015
26.	Rajasthan	Rajasthan Solar Park Development Company	680	Vill.- Bhadla, The.- Bap Dist.- Jodhpur	02/12/2014 & 19/06/2015
27.		Surya Urja Company of Rajasthan Limited	1000	Vill.- Bhadla, The.- Bap Dist.- Jodhpur	12/12/2014
28.		M/S Essel Surya Urja Company of Rajasthan Limited	750	Teh.- Phalodi, Dist.- Jodhpur The.- Pokaran, Dist.- Jaisalmer	30/11/2015-16/NSM, 17/12/2015
29.		M/S Adani Renewable Energy Park Rajasthan Limited	500	Vill.- Bhadla, The.- Bap Dist.- Jodhpur	29/09/2015
30.			421	Vill.- Dawada, Rasla & Nedan Dist.- Jaisalmer	01/02/2016
31.	Rajasthan Solar Park Development Company Ltd.	1000	Vill.-Nokh Dist.- Jaisalmer	-----	
32.	Uttar Pradesh	Lucknow Solar Power Development Corporation Limited	440	Dist.- Allahabad, Mirzapur, Jalaun & Kanpur	17/12/2015
33.	Uttarakhand	State Industrial Development Corporation Uttarakhand Limited (SIDCUL)	50	Vill.-Sitarganj & Khurpia Farm Dist.- U.S. Nagar	16/12/2015
34.	West Bengal	West Bengal State Electricity Distribution Company Limited	500	Dist.- Purab Medinpur, Paschim Medinpur & Bankura	02/12/2014
35.	Tamil Nadu	Yet to be Finalized	500	Dist.- Ramanathapuram	14/07/2015
Total			20514		

Note: (-----), means data is not available

4.3 Solar PV Projects on Canal Bank and Canal Top

Utilization of space near canal banks and on the canal tops is the main motive behind this scheme. The government of India has approved “Pilot-cum-Demonstration Project for Development of Grid Connected Solar PV Power Plants on Canal Banks and Canal Tops” under JNNSM [23]. The government has set up a target of 100 MW under (50 MW canal tops and 50 MW for canal banks) this project by keeping the availability of land in the mind. All states and UT’s are eligible for this scheme if they are working in the power system and having a canal for irrigation. All state electricity companies/government and state PSU’s and government organizations can take this project provided that they have some experience in power system operation. Solar Energy Corporation of India (SECI) will manage this scheme and handle the fund-related matters. The subsidies are provided by CFA under the guidelines of MNRE. CFA provides Rs. 3 crore per MW for canal tops solar projects and Rs. 1.5 crore per MW for canal banks solar projects. CFA of Rs. 225 crore is providing for 100 MW solar Project in two years from sanctioning date. Around 40% financial assistance has given at the time of sanctioning the project and the remaining 60% amount provides at the time of commissioning the project [1]. The detailed information about canal top and canal-based solar PV projects is shown in Table 7.

5. The motivation for an Eye Opener

Several successful examples and innovative stories are strengthening the future of solar energy in India. There are so many live examples of determination and courage for the change in the field of renewable energy. Some of the successful and inspirational stories in the field of solar energy are presented here to explore this modern energy concept [1].

➤ SELCO solar light Pvt. Ltd. was founded by Dr. Harish Hande to provide energy services to the poor peoples of India for their basic needs. He was inspired by the peoples of the Dominican Republic as they were using solar lighting system in 1993. Then he thought about, bringing the solar lighting system to the rural areas of India. Therefore he started his focus on solar lighting system during his Ph.D. time at the University of Massachusetts in 1993. He started his experiment in remote areas to know about the issues and challenges related to the solar lighting system. After his experiment, he was pretty sure about the success of solar in India and started such initiatives in this field. He adopted the financial structure that follows their income pattern so that the payback and their income were synchronized. Currently, SELCO is popular for providing solar energy services to the rural areas of India. SELCO has made better lives of 120000 peoples through its direct benefits of solar systems. Their success story has also broken the myths that villagers cannot maintain the technology. SELCO has 25 energy centers across Gujarat and Karnataka including 175 workers.

Table 7. State-wise Allocation of 50 MW Canal top and 50 MW Canal Bank based Solar PV Projects [1, 24]

Sr. No.	Implementing Agency/Company	Allocated State	Project Type	Allocated Capacity (MW)	Commissioned As on 31/12/2017 (MW)
1.	New & Renewable Energy Development Corporation of Andhra Pradesh (NREDCAP)	Andhra Pradesh	Canal Top	1	1
2.	Andhra Pradesh Power Generation Corporation Limited (AP-GENCO)		Canal Bank	5	5
3.	Sardar Sarovar Narmada Nigam Limited (SSNNL)	Gujarat	Canal Top	10	10
4.	Sardar Sarovar Narmada Nigam Limited (SSNNL)		Canal Bank	15	15
5.	Krishna Bhagya Jala Nigam Limited (KBJNL)	Karnataka	Canal Top	10	-----
6.	Kerala State Electricity Board Limited (KSEB)	Kerala	Canal Top	2	2
7.	Kerala State Electricity Board Limited (KSEB)		Canal Bank	1	1
8.	Punjab Energy Development Agency (PEDA)	Punjab	Canal Top	20	5
9.	Uttarakhand Jal Vidyut Nigam Limited	Uttarakhand	Canal Top	1	-----
10.	Uttarakhand Jal Vidyut Nigam Limited		Canal Bank	19	-----
11.	Uttar Pradesh Irrigation Department	Uttar Pradesh	Canal Top	6	-----
12.	West Bengal State Electricity Distribution Company Limited (WBSEDCL)	West Bengal	Canal bank	10	10
Total				100	49

Note: (-----), means data not provided by MNRE

➤ Indira Nagar is a small hamlet having 13 houses and 190 inhabitants in Tonk district, Rajasthan. Most of the peoples are either laborer in a nearby town or farmer having small land. Minda NexGen Tech Ltd. has started a 240-watt solar based microgrid for providing electricity to the villagers [26, 27]. Their main aim was to supply electricity for lighting and education purposes. The peoples of this village have started several works like stitching, fertilizer mixing, utensil washing, and pulse grinding after this microgrid establishment in the village. Prior to these initiatives, they were using only kerosene oil lamps during nights. This plant was based on Built, operate and maintain scheme by collecting Rs.150 from every house monthly. This rent was just equivalent to the cost of three-liter kerosene oil used monthly by every household. Every house has two 1.5 watt LED bulbs and one 6.6 volts charging point for mobiles.

➤ Gram power initiates a prepaid electricity system for rural India to provide sustainable energy in a reliable manner. Gram power has established local micro-grid using renewable-based captive generation for supplying local energy demands. The work line of this project is very simple and related to the prepaid meters for proprietary grid communication monitoring. The load limits are configured for every meter with overload detection and self-recovery scheme. The generated power sold wisely to the consumers via local entrepreneur in prepaid mode at retail price. The smart meter calculates the hour of consumption of particular equipment and charged according to in prepaid type mode.

6. Conclusion

The solar energy sector has growing strength to strength from last five years. MNRE has appointed many agencies for different roles and support programs to achieve the solar energy targets by the year 2022. Many schemes and policies are working across the country for support and motivation in the field of solar energy. The effort has been made to highlight the targets in solar energy and their planning with the help of some supporting programmes. The JNNSM and its policies are discussed for the exploration of complete solar scenario across the country. Different solar energy incentives and the support programs with their policies are highlighted for the commercial, domestic and institutional regions. This paper is a collective effort to present solar energy status and prospectus for the scientist and engineers so that they can further enhance this field by analyzing and developing different technologies. Therefore the continuous effort of researchers and scientists has found a way to increase the efficiency of solar cells through some modifications in the modular structure of polymer used in solar cells. These structures consist of an electron acceptor and donor material to enhance its efficiency over 30%.

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