

Solar Energy Policy for India: An Overview

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Abstract—India's energy crisis can be resolved by using reliable sources of renewable resources, such as solar energy with minimum adverse ecological effects. Several photovoltaic projects have been sanctioned based on rooftop models and land-based solar parks to address energy security concerns. India's strategy focusing on increasing the installation of new solar plants, lead to the vast expansion of the renewable energy market. This paper explores the Indian government policies, current approaches, significant achievements and a scenario for solar power in India. It also summaries various technological options, research, awareness and outreach activities for the deployment of solar energy. These supportive policies provide tax exemptions, attractive tariff plans, and economic incentives which contribute to the sustainable development of the nation.

Index Terms—Energy parks, government initiatives, renewable energy policy, solar PV systems, tariff rates.

NOMENCLATURE

ARUN	Atal Rooftop User Navigator.
CEA	Central Electricity Authority.
CERC	Central Electricity Regulatory Commission.
CREDA	Chattisgarh State Renewable Energy Development Agency.
CUF	Capacity utilization factor.
Discoms	Distribution companies.
FAME	Faster Adoption Manufacture Electric.
GAIL	Gas Authority of India limited.
GHG	Green House Gas.
GRPV	Grid connected rooftop solar photovoltaic.
GW	Giga Watt.
IEEFA	Institute for Energy Economics and Financial Analysis.
IREDA	Indian Renewable Energy Development Agency.
IREDA	The Indian Renewable Energy Development Agency.
ISTS	Inter state transmission system.
JNNSM	Jawaharlal Nehru National Solar Mission.
KW	Kilo watts.
MNRE	Ministry New Renewable Energy.
MPUVL	Madhya Pradesh Urja Vikas Limited.

NAPCC	National Action Plan on Climate Change.
NCEF	National Clean Energy Fund.
NISE	National Institute of Solar Energy.
NREP	National Rural Electrification Policies.
NSEFI	National Solar Energy Federation of India.
NTPC	National Thermal Power Company.
PSU	Public Sector Unit.
PV	Photo Voltaic.
RECs	Renewable Energy Certificates.
RPO	Renewable Purchase Obligation.
RTS	Roof Top Solar.
SECI	Solar Energy Corporation Indian.
SPIN	Solar Photovoltaic Installation Network.

I. INTRODUCTION

AN energy policy is a plan of action for a country in which the government resolves issues of energy security by establishing industry for production, distribution and its consumption for achieving sustainable growth. Energy policy features may be comprised of regulations, foreign agreements and investment opportunities. It behaves crucially in addressing the effect of global warming and energy supply problems [1].

Solar is among the fastest rising energy sources in the world. Solar energy is the energy that is produced from the sun's radiation process. Numerous countries compete to claim their supremacy in the solar energy sector as a leading nation. Solar to energy conversion efficiency has increased over the last few years. It all depends on the location of countries and the availability of optimal irradiation. In addition to China, the US, India, and several smaller countries also enjoy strong sunshine almost all year long. Such a large output of solar energy by using solar farms may be the answer to meeting the demands of energy on this planet.

India boasts a precious resource in solar energy. There are about 250–300 sunshine days yearly with regular solar radiation of 200 MW/km². Solar is a significant energy source in India, but presently limited in use. It can deliver a better supply of power, especially in isolated or far away areas [2] and enhance the safety of India's power supply. The intensity of solar radiation varies geographically from the west in Rajasthan which annually has the maximum radiation energy, compared with northeastern areas, which receive less. India has an acceptable solar radiation level which annually obtains the equivalent sun's energy of over 5000 trillion kWh. The incident solar radiation varies from 4 to 7 kWh/m²/day, having 2300 to 3200 sunshine hours yearly, depending on the region. The overall sun's radiation ranges between 1600 to 2200 kWh/m² for a year, which is equivalent to the amount of

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tropical and subtropical radiation received. The corresponding energy production is around 6000 million GWh every year [3].

In this paper, an attempt has been made to discuss various policy options for the encouragement of solar PV installation in India. The various incentives and solar tariff scenarios are also illustrated based on current trends. However, although the study takes into account solar energy policy and tariff scenarios in India, policy makers in other countries can also take advantage of the findings of this study while formulating policies and incentive schemes for their respective countries.

II. OVERVIEW OF ENERGY POLICIES IN SELECTED COUNTRIES

Many policies for the feed-in tariff, selection standards, tax benefits, pricing legislation, incentives, allocation requirements, trading schemes, etc. have been framed and adapted to encourage the utilization of green energy [4]. The key aim of these guidelines is to decrease the dependence on fossil fuels and promote novel renewable projects. This has a good impact on the growth of energy and also reduces ecological imbalance. Various countries have formulated such policies and they are being developed in the global market.

- China has become the world leader in solar industry. The Government provides low-interest loans to firms to purchase equipment, tax reduction on the manufacturing process, easy access to low-cost capital, land transfer refunds, electricity price refunds and motivation to the entrepreneurs. The Government has also facilitated investments for research and improvement in solar power technology demonstrations [5].
- The goal of the United States of America is to endorse the diversification of energy production by the use of renewable resources to minimize the state's dependency on fossil fuels. Many state laws encourage utilities to swap clean energy certificates to help utilities fulfill their renewable energy obligations [6].
- Canada stresses growing dependency on localized rural energy sources; especially photovoltaic roofing, to reduce

environmental effects by reducing carbon emissions from greenhouse gases. The Government is promoting solar development as a result of its deteriorating pricing structure. [7].

- Germany established a feed-in tariff mechanism in the country for the remuneration of produced energy. Different rates are established for the various power capacity of the generated system to stimulate strong price reduction. Tariffs are fixed for an operational duration of 20 years [8].
- Australia is at the crossroads to fulfil its potential energy needs in an increasingly carbon-restricted multilateral policy setting. Despite major government funding initiatives, renewable energy is rising at a slower pace as coal-fired power stations produce cheaper domestic electricity [9].
- Malaysia's government has formulated environmentally sustainable energy policies to ensure energy protection and sustainability. The key aim is to support the practical usage of resources and to deter inefficient, non-productive habits of energy use [10].

Countries throughout the continents are racing towards building the world's biggest solar farms. As a result, the list of big solar utility projects worldwide is getting larger [11]. Some large operational solar power plants, with installed capacity in the world (Fig. 1) are:

- *Tengger Desert Solar Park, China* – This 1547 MW solar plant project was built in Zhongwei, Ningxia. It covers an area of 1200 km of the 36700 km Tengger desert region. In China, the park is known as “The Great Wall of Solar”. It generates more than 15 GW of electricity and provides renewable energy to more than 600000 households.
- *The Mohammed Bin Rashid Al Maktoum Solar Park, Dubai* – This 2450 MW solar plant has a planned production capacity of 5000 MW by 2030. It is likely to be the biggest solar project at a single site in the world to combine CSP and photovoltaic technology for 950 MW capacity [12].



Mohammed Bin Rashid Al Maktoum Soar Park, Dubai



Waldpolenz Solar Park, Germany



Noor Solar Park, Morocco



Longyangxia Dam Solar Park, China



Datong Solar Power plant, China



Tengger Desert Solar Park, China

Fig. 1. Large solar photovoltaic farms throughout the world.

- *Noor Solar Park, Morocco* – This solar park is called Ouarzazate solar power station and has a capacity of 1117 MW. It is located in the Drâa-Tafilalet province of Morocco. It is the biggest concentrated solar power project in the world. With an added 72 MW photovoltaic facility, the whole project is expected to produce 1117 MW capacity after completion.
- *Longyangxia Dam Solar Park, China* – This solar plant is situated next to a hydropower plant on the Yellow River in the province of Qinghai, China. The solar power plant is combined with the hydroelectric power station, enabling the control of the output to offset the intermittent generation of solar power until it is connected to the grid. This helps to conserve the water. 300 hectares of solar panels with a capacity of 850 MW have been installed. It is projected to produce 220GWh of electricity each year for 100000 households.
- *Waldpolenz Solar Park, Germany* – This is the most extensive photovoltaic thin film (PV) power grid in the world. It was built on the military airbase in the east of Leipzig, Germany. The solar plant has a 40-megawatt power capacity built utilizing thin-film module technologies [13]. For the first time, solar modules using thin-film technology were used, to annually provide 40000 MWh electric power.
- *Datong Solar Power plant, China* – This solar power plant has a builtin capacity of 1 GW with a combined total of 3 GW. This Chinese plant, on completion, could become the world's largest solar-based plant. It will be able to produce 870 million watts solar electricity overall, equivalent to 120 million watts of monthly electric power.

III. OVERVIEW OF THE RENEWABLE ENERGY (SOLAR ENERGY) SCENARIO IN INDIA

India's potential and its policy initiatives are designed to enhance the capacity of renewable energy to meet the national energy needs in an economically, environmentally and socially sustainable way in order to become a part of the global clean energy map. India's energy market is expanding rapidly in the world, as per a study by the Institute for Energy Economics and Financial Analysis (IEEFA). India had targeted an ambitious goal of building an additional 175 Gigawatt

(GW) installed capacity by 2022 through renewable energy. It will consist of producing 100 GW from solar, 60 GW from wind, 10 GW from biomass and 5 GW from small hydropower plants. From this target, there is a further objective of producing 100 GW through solar photovoltaic (PV) systems, and 40 GW of rooftop solar (RTS) photovoltaic (PV) systems. The renewable energy installed capacity is about 86.75 GW out of which 34.40 GW capacity is from solar power. The growing demands for electricity and supporting steps to meet these supply requirements backed by favorable government policies have attracted many foreign investors to invest money in different renewable energy generation projects in India [2]. Fig. 2 shows the yearly variation of cumulative capacity of renewable energy in India.

During the current year, the Indian market for solar energy has reached 8263 MW compared to 9782 MW of last year's installation, whereas the rooftop facilities consist of 1665 MW capacity as compared to last year's capacity of 6608 MW. Fig. 3 shows the yearly variation of cumulative capacity of solar energy installed.

On the clean energy front, India has reached a milestone. In the past few years, renewable power (solar and wind) have increased their proportional share. The electricity output has reached a 21% threshold, and the share of the total capacity of power installed from renewable sources has also achieved 36%.

Many new solar rooftop installations have been built on residential, commercial, industrial and agricultural buildings in recent years, due to the recognition and favorable government schemes. These are integrated infrastructure projects that may or may not provide a two-way net metering supply which reduces the pressure on the central or local infrastructure. Furthermore, the growing concern for the environment among people due to harmful pollution caused by the depleting fossil fuels encourages them to use solar energy goods to meet their energy needs. In rural areas, government facilities have included solar lanterns that decrease the requirement for kerosene oil and solar lighting systems for homes and streets. Solar cookers to minimize the consumption of wood or coal use, solar water heaters, dryers for agricultural and animal products, solar water pumps for irrigation purposes, solar greenhouses for vegetation, etc. are being promoted to

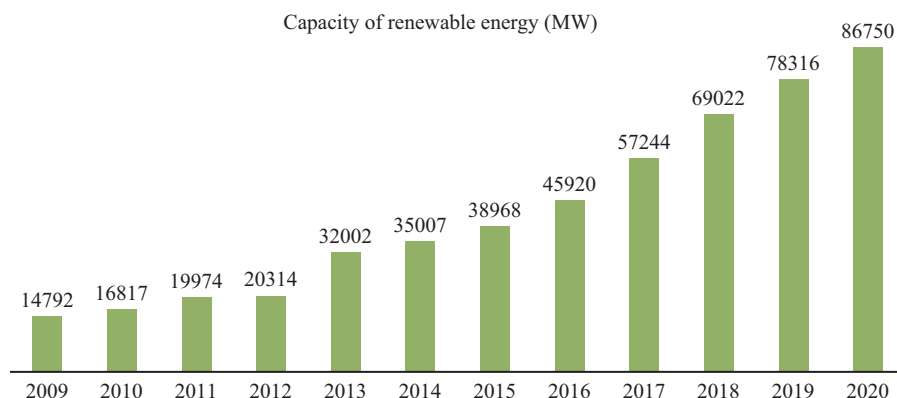


Fig. 2. Yearly variation of cumulative capacity in MW of renewable energy installed in India.

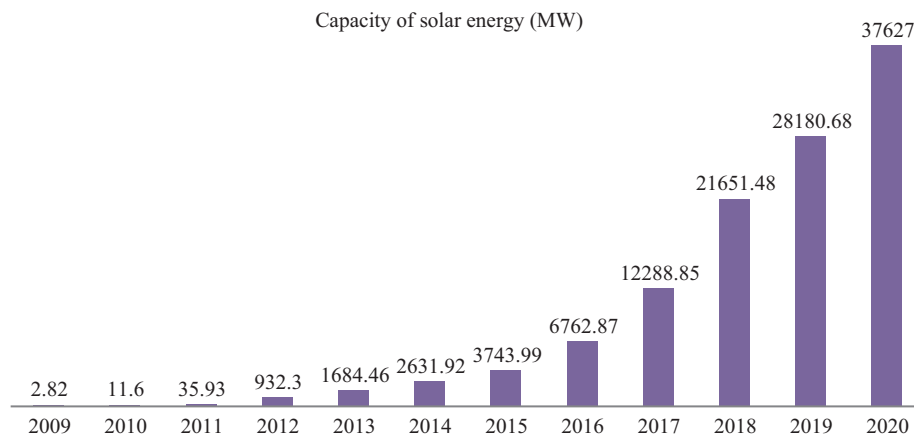


Fig. 3. Yearly variation of cumulative capacity in MW of solar energy installed in India.

increase the use of solar energy. This growth and production of solar power raises the standard of living of the country's population, saves the environment and contributes to economic development.

The declining principal cost of constructing solar projects has led to the dramatic dropping of solar tariffs in the past few years, and this segment has seen extraordinary development. Although the solar photovoltaic production itself has experienced overall growth, the roof top solar photovoltaic section is estimated to gain traction in future years. From the 40 GW power capacity to be generated by 2022, around 37 GW of solar power has already been produced through August 2020. Thus, by 2022 the milestone goal of 100 GW solar power capacity could be comfortably achieved. Among these, the largest share is land-mounted solar parks with a capacity of 27930 MW followed by 21141 MW of rooftop solar projects. The smallest share consists of stand-alone or off-grid solar projects with a capacity of 919 MW in villages and areas without access to the grid supply.

This value is primarily because of a few distribution companies (Discoms) exhibiting reluctance to encourage solar photovoltaic systems on the rooftop, fearing revenue loss. These results also predict the technological and organizational difficulties of these systems. In addition, monetarily supporting these projects are not readily available owing to the smaller range of solar rooftop projects and payment security problems. The solar rooftop plants, however, are very advantageous for the various Discoms who are cautious of them.

The consumers who pay the maximum electricity bills are the industries, for Discoms. They are now transitioning to open-access in most situations for short-term schemes to buy cheap power, independent of the roofing utility, as the key-anchor party to install solar roofing systems in their approved areas. Most consumers have an open-access approach to the transmission and distribution (T&D) system in order to procure electric power. Distribution utilities that incur a strong technical and commercial aggregate (AT&C) have declined due to the vast numbers of customers in rural areas, who don't pay their electricity bills will become most exaggerated by this transition, when they lose a substantial proportion of their source of income. Discoms often believe that the fees

charged by open-access users are not appropriate for them to cross-subsidize (as they are exempted from such charges).

IV. POLICIES & INITIATIVES TO PROMOTE SOLAR ENERGY IN INDIA

In recent years the Government has introduced many electricity policies for the need and priority of promoting renewable energy [3].

A. Electricity Act 2003

This act gives a basis for the overall development of India's electricity market. This allows provisions for privileged tariffs and renewable energy alternative quotas. Compulsory renewable energy procurement for circulation permits which facilitate the connectivity with the grid have also been introduced.

B. National Electricity Policy 2005

This policy provides permits for privileged tariffs on energy generated from renewable resources. The purpose of the policy is to provide everyone with the right to use electricity and to raise the minimum availability per capita by 2012 to 1000 kWh per annum.

C. National Tariff Policy 2006

This is the Renewable Purchase Obligation (RPO) mechanism to set the least amount of the proportion for the states' procurement of electricity from renewable electricity sources. Among other renewable energies, it also offers a special solar tariff.

D. Integrated Energy Policy, 2006

This integrated policy proposed a precise emphasis on the production of renewable energies and establishes clear capability goals.

E. National Rural Electrification Policies (NREP), 2006

NREP-2006's targets included providing all households with access to electricity by the end of 2009, efficient and stable electricity supply at fair prices, and the least amount of daily lifeline usage of single units per household as a fair value by

2012. Off-grid technologies anchored in stand-alone renewable energy systems, such as solar photovoltaic, can be utilized for electricity supply in villages/houses where connectivity to the grid is not practically possible or economical. The scheme has an objective of supplying electric power to all the houses in the country and the last stage of a lifeline of daily usage of 1 unit (kWh) per household [14]. The policy also states that the photovoltaic solar off-grid response can be utilized whenever it is not possible to provide the grid power supply. The proposal also covers the possibility of installing off-grid solar photovoltaic solutions where the grid power supply is not feasible.

F. Semiconductor Policy (2007)

The Semiconductor Policy is intended for uplifting the production of semiconductors and ecosystems, of which solar photovoltaic is also an element. It provides a 20 per cent financial support for SEZ manufacturing plants and 25 per cent for the manufacture of plants which are outside Special Economic Zones. Nevertheless, the subsidy is conditional upon the project's net present value (NPV) being at least US\$ 212 million (Rs 10000 million).

G. National Action Plan on Climate Change (NAPCC), 2008

To combat climate change, the Government of India has introduced a project style action strategy for sustainable expansion under NAPCC. The first goal was to accelerate the production of solar electricity. It estimates the RPO at not only 5% of the overall grid procure, but also shows a 10-year 1% rise in RPO year-on-year.

H. Solar PV generation-based incentive scheme

MNRE developed a strategy in January 2008 for incentives based on the generation for both solar thermal and solar photovoltaic installations connected to the grid. The scheme has been extended to all current approved firms for state and central power production and to private and public power sector PV producers.

I. Generation Based Incentives (GBIs) for Solar

The installation of GBI was less than 33 kW for limited solar grid projects. The goal of the GBIs is to bridge the gap between the basic tariff of INR 5.5 and the Central Electricity Regulatory Commission (CERC) as a financial opportunity.

1) Jawaharlal Nehru National Solar Mission (JNNSM), 2010

This is popularly known as the National Solar Mission, which is a part of India's National Climate Change Action Plan (NAPCC). In 2014, the Indian Government overhauled the Solar Mission. It targets solar electricity power installed for 100 GW by 2022 [15]. The Government has introduced a range of initiatives to boost renewable energy to meet this ambitious target.

J. Clean Energy Cess, 2010

Clean Energy Cess imposed the INR 50 levy for each ton of coal consumed in the region. The cessation recognized the National Clean Energy Fund (NCEF) to support renewable energy proposals. The Indian Renewable Energy Development

Agency (IREDA) contributes nearly 40% for the overall cost of renewable energy proposals.

K. Joint Liability Group (JLG) for Off-grid Installations

By synthesizing the market and collective capacity, an assembly of 4–10 entrepreneurs may join locally, as the JLG are helping to make loans available for non-agricultural ventures that would be important to microgrid systems.

L. Corporate Social Responsibility (CSR)

CSR has been initiated to promote the involvement of the private segments for the growth of the nation and the accomplishment of social targets. CSR gives funding to account for 2 per cent of their investments from off-grid ventures in the top 500 companies.

M. Renewable Energy Certificates (RECs), 2011

RECs are based on the market system that has been launched to maximize the capability of renewable energy sources. It decreases the inter-state disparities in the generation of renewable power and the duty of the appropriate institutions to comply with their RPOs at a segregated solar and non-solar price.

N. State-level initiative policies

Electricity Boards of State and respective state-level government agencies for renewable energy are vital in state-level policy implementation. Independently, along with the efforts of the central Government, the state governments promote solar energy through its specific policies such as:

1) Sustainable Rooftop Implementation for Solar Transfiguration of India (SRISTI) scheme 2017

In this program, central financial assistance would be provided to the residential sectors. The focus will be on increased involvement of DISCOMs. A subsidy of up to 40% will be given for constructing rooftop solar systems with capacities of 3 KW to 10 KW [16]. Performance-based benefits will be given to DISCOMs on the basis of total capacity over and beyond base capacity reached in the financial year.

2) Pradhan Mantri Sahaj Bijli har Ghar (PM-SAUBHAGVA) Yojna 2017

Under this scheme, the Government is promoting the electrification of all eligible households in rural and urban areas using solar energy. This scheme was initiated by the state authority of Manipur.

3) KisanUrja Suraksha Evam UtthaanMahabhiyan (KUSUM) yojna 2018

The objective of this scheme provides financial support and water security to farmers. It includes the construction of solar pumps, the solarization of current grid-connected farm pumps and the installation of grid-connected renewable energy plants. The scheme is being introduced by government departments. The farmers will be able to use the generated energy to meet their irrigation requirements, and the excess available energy could be sold to DISCOM. As a result, providing additional income for farmers also helps the state meet its targets and sustainably saves the environment from carbon dioxide emissions.

O. Sun One World One Grid' (OSOWOG) plan 2020

Recently the Indian Government has announced “One Sun One World One Grid” (OSOWOG) proposal for connecting solar energy supply across borders. The vision behind this mantra is “The Sun Never Sets” and is adaptable at any geographical location, worldwide, at any given moment. Through this initiative, the government plans to synergize over 140 countries, across the far east and the far west regions, to create consensus, initiate energy policy imperatives and set up a foundation for such global cooperation. This will help to make another leap in creating a sustainable network of integrated clean energy services that are seamlessly exchanged for mutual benefit and global sustainability. An interconnected grid would share renewable energy resources of all countries with each other for meeting their electricity demand, including peak demand and also for rationalizing their tariffs [17]. This will draw developers around the world and help to address socio-economic problems and contribute to decreased project expenses, better productivity and improved capacity use for all participating agencies.

P. Other Initiatives by the Government of India

Several schemes, namely (i) Defence scheme (ii) Central Public Sector Undertakings (CPSUs) scheme (iii) Bundling scheme (iv) Canal bank/ Canal top scheme (v) VGF Scheme (vi) Solar park scheme and (vii) Solar rooftops, have been initiated/launched by the Ministry, under NSM, are under implementation.

Through its policies, the Government has made efforts to increase the capacity to meet the national demand for energy in socially, economically and environmentally sustainable ways [18]. In addition, it has introduced a variety of policies for the country's overall growth. Some are as follows:

1) Suryamitra program

This program was launched for creating a qualified technical workforce of persons all over the country. People have been determined as qualified to operate effectively at any level in the protection, planning, construction, pre-and post-commissioning, service and maintenance of solar energy-based projects [20].

2) Rooftop grid engineer course

This training course was conducted by the National Institute of Solar Energy (NISE), New Delhi at different state technological universities in the country. The goal of these courses is to provide students with an understanding of the basic concepts of Grid-connected rooftop solar power plants and their efficient operation at any point of plant design, installation, and pre-and post-commissioning. They will understand the various certifications & national and state policies of Rooftop SPV plants, run and manage a rooftop solar photovoltaic system, including conducting project management to install a solar photovoltaic roofing system, understanding the formalities needed by the authority for applications, applications, applications, licenses, interconnections, assessments, certifications, commissioning, etc. to promote SPV power plants.

3) Waiver of inter-state power transmission charges

The Government has waived the charges for interstate electricity transmission and damages for solar and wind power generation projects to be empowered by March 2022. No additional fee would then be charged for the transfer of electricity through an interstate transmission grid for the distribution and purchasing of power [21]. This gives a boost to cleaner energy resources.

4) S-Wurja Application

A free app called S-Wurja was developed by the National Institute of Wind Energy. It is available on the Google play store and Apple app store. It is a green energy tool which can be used to segregate micro-level data related to solar energy and wind energy characteristics in any location using inIndia.al

5) FAME program

India's Government is providing funds to smart cities for the procurement of electric vehicles to be used for mass transportation as part of a pilot project under the faster implementation and manufacture of electric vehicles (FAME) program in India.

6) Lowest per unit cost of solar power

When the national solar project was initiated in 2010, the solar power cost was Rs.17 per unit compared with the current Rs.2.44 per unit auction. This cost-cutting break was made feasible by competitive bidding based on tariffs; efforts were undertaken by India's (SECI), central and state governments' solar energy cooperation through tenders [22]. The Ministry of New and Renewable Energy (MNRE) has furthermore made a significant contribution to the promotion of solar energy through various initiatives and events for public awareness.

Role of MoP: The Ministry of Power (MoP) has waived interstate transmission system (ISTS) charges and losses on all solar and wind projects installed before June 30 2023. ISTS charges will be suspended for a period of 25 years from their date of commissioning for transmission as well as for the sale to companies with a renewable purchasing commitment.

Role of MNRE: The Ministry of new and renewable energy (MNRE) has also contributed a lot in encouraging the use of solar energy by organizing different campaigns for creating public awareness. The Ministry of New and Renewable Energy (MNRE) has promoted various initiatives to improve renewable energy in the fields of lighting, cooking and motivating energy in rural areas as well as in urban, industrial and commercial applications. To make the most through the use of solar energy, the ministry is making every effort to raise knowledge of the advantages of solar power in the rural and urban areas.

V. GUIDELINES FOR INSTALLATION OF A GRID-CONNECTED SOLAR PHOTOVOLTAIC SYSTEM

The deployment efficiency of the solar plant should be determined based on the energy requirements and the electrical charges connected to the devices and their uses. It is also worth remembering previous monthly bills showing power usage and power availability. The capacity allowed is the peak power of up to 1000 KW.

1) Site details should be known, such as available area, geographical location, solar radiation, shade-free premises, distance from nearby distribution transformer, high tension feeders, lines, etc.

2) The proposed solar PV capacity in KW should not exceed the sanctioned load of the service connection or be less than 40% of the rating of the distribution transformer. The voltage levels permitted are:

- (a) 230 V (Single Phase): up to 3 kWp max.
- (b) 400 V (Three Phase): Above 3 to 112 kWp max
- (c) 11 kV HT: Above 112 to 300 kWp
- (d) 33 kV HT: Above 300 kWp

3) The solar inverter to be used should satisfy the technical standards and specifications determined by Central Electricity Authority (CEA). As it handles the regulatory requirements of the quality of power injected into the grid, it should be of a certified make & type also be provided with automatic isolation protection equipment.

4) The existing service connection should be supportive of the newly added solar system in terms of current capacity, phase connection, type of operation transformer and safety requirement.

5) The distribution transformer information should be understood in such a way as to measure the technical feasibility of the proposed solar PV plant. The overall solar photovoltaic power, including the proposed new power, must not exceed 30 percent of the transformer capacity of the distribution [23].

6) The Solar Power Developer will have completed the plant in 180 days for rooftop systems and six months from the date of approval for ground-mounted systems. In case of delay, the consumer shall have to obtain a further extension from the Distribution authority for 2 (two) months only and then the approval granted will lapse automatically.

7) The link should be at the most massive load level for optimum gain and minimal current imbalance in the case of net solar at single Phase.

8) The design and construction of the SPV rooftop should be fitted with adequately rated protective devices to detect any irregularities in the network and to isolate the SPV from the grid. The inverters used should automatically meet the required quality specifications and should be certified by the correct authority for their efficiency; the safety logic should be checked before the commissioning of the plant.

9) Automatic isolation or insulation security of SPV should be ensured, with no grid supply and conditions of low or overvoltage and should be within the necessary response time. Good rated fuses and quick-acting circuit breakers shall be provided on the input and output side of the inverters and disconnect/isolate switches to isolate the DC and AC system for maintenance. The customer will compensate for all internal earthing protection and self-protective systems, DC ground fault surge, transients etc [24].

10) In the case of the CAPEX model of the system, the consumer has self-ownership while in the RESCO model, the ownership is by a third party.

11) The user shall, within the limits defined in the agreement or approved by the Central Electricity Authority, limit the harmonic generation.

12) To measure export power separately, a single bi-directional service link meter should be installed. Also, a solar generation meter should be installed next to a bidirectional meter to measure gross solar output PV generation.

13) Consumers would be excluded from banking, cross-subsidy, wheeling and energy taxes, and have no real estate tax responsibility.

14) The billing process is expected to be annual from April to March. Any unadjusted energy credits shall be charged at the rate shown by the MPERC.

15) The scheme shall be introduced electronically in order to ensure maximum transparency; the grant shall be made available online via NEFT/RTGS on the user's account after verification of the plant's results after the plant has been commissioned.

VI. SOLAR PV PROJECTS STATUS IN INDIA

A. Development of Solar Parks

The Solar Park Scheme aims to provide a considerable boost to the production of solar energy by serving as a flagship demonstration facility to attract project developers and investors, encouraging additional similar projects, stimulating economies of scale for cost savings, technological upgrades, and achieving large-scale savings in greenhouse gas (GHG) emissions. Design of the Ultra and Mega Solar Power Projects Solar Parks range from 20000 MW to 40000 MW. Around 42 aggregate-capacity solar parks of 23499 MW have been authorized in 17 country states. Table I shows a list of solar parks installed in different states with their maximum capacities [19]. Land of approximately 139115 acres was established, and 76436 acres of land was acquired in various solar parks. Earlier, the Pavagada solar park in Karnataka was the largest solar park being fully operational with a capacity of 2050 MW, but now, Bhadla solar park in Rajasthan with 2245 MW capacity has become the largest solar park in the world. At the same time, Asia's most significant single sight solar power plant is the Rewa solar plant in Madhya Pradesh

TABLE I
SOLAR PARKS INSTALLED IN DIFFERENT STATES OF INDIA WITH THEIR MAXIMUM CAPACITY

No.	State	Largest capacity solar park in MW	No. of parks	Total capacity in MW
1	Andhra Pradesh	1500	5	4160
2	Arunachal Pradesh	30	1	30
3	Gujarat	700	3	6200
4	Jharkhand	150	1	150
5	Karnataka	2000	1	2000
6	Kerala	200	1	200
7	Madhya Pradesh	750	5	2750
8	Maharashtra	500	7	1950
9	Manipur	20	1	20
10	Meghalaya	20	1	20
11	Mizoram	20	1	20
12	Nagaland	23	1	23
13	Odisha	275	2	375
14	Rajasthan	680	6	4331
15	Tamil Nadu	500	1	500
16	Uttar Pradesh	440	4	570
17	West Bengal	200	1	200
Total			42	23499

with a capacity of 750 MW. Fig. 4 shows the various solar parks commissioned in different states with their approved and installed capacities.

Out of 175 GW targets, about 86.3 GW have been installed from renewable energy generation plants. The current solar capacity is more than 34 GW. Different states have installed significant solar capacities; their contribution is indicated in Fig. 5 [25]. Karnataka has the highest capacity of 7.28 GW followed by Rajasthan (4.84 GW), Tamil Nadu (3.79 GW), Telangana (3.62 GW), Andhra Pradesh (3.56 GW) and so on.

- In Chhattisgarh, the state renewable energy department and the state health department collaborated to install, operate and maintain 900 health care centers across the state using solar photovoltaic systems. Energy-efficient appliances such as LED lights, freezers, baby warmers, vaccine refrigerators, computers, centrifuges, fans, microscopes, etc., are used. This benefits 80000 patients per day.
- Chattisgarh state has commissioned 135.19 MW of solar power. It has installed about 51000 solar energy-driven pumps for irrigation as off-grid projects. Many schools and college buildings have built rooftop solar systems to support the 50 MW grid power target. The cities of Raipur and Bilaspur were developed as solar cities.
- The Government of Gujarat has initiated a solar power proposal for farmers SuryashaktiKissan Yojana allowing

them to produce electric power for their own consumption, sell the excess energy to the grid and receive extra money. Solar panels will be given to farmers with an existing electricity connection, as per their load requirements. The State and Central Government are offering 60 per cent subsidy on the project cost [26]. Solar water pumps may soon replace conventional water pumps.

- The state of Maharashtra has the highest farm top solar potential with 21.1 GW
- In West Bengal, the solar-powered drip irrigation has transformed agriculture in remote villages.
- In Madhya Pradesh state Indian Renewable Energy Development Agency Limited (IREDA) and The World Bank have funded two large solar power plants in the state. Rewa Ultra Mega solar power plant having a capacity of 750 MW and Mandsaur solar project with 250 MW have been commissioned.
- Madhya Pradesh Urja Vikas Nigam Limited (MPUVL) has created India's first-ever innovative data room with the support of the SBI technical assistance program. This helped the project developers in obtaining details, such as site coordinates, estimated site capacity, indicative array layout, and electricity bills for each proposed site [27]. By gaining access to such information, bidders or project developers obtained more clarity on the site, and the result was a better tariff estimation.

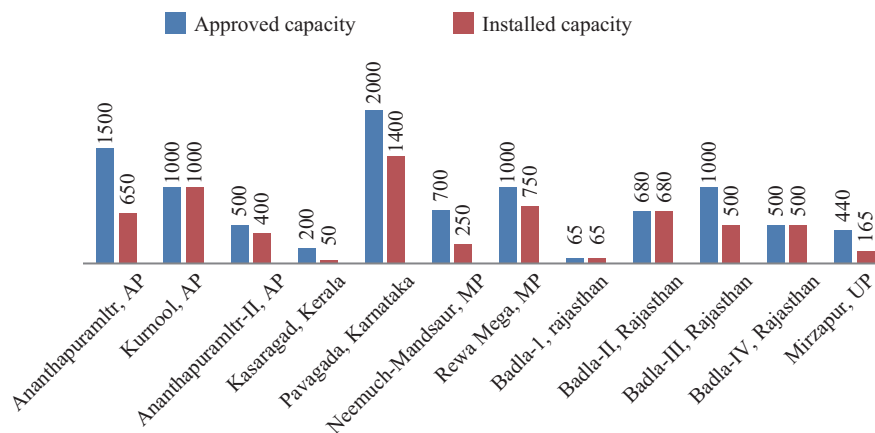


Fig. 4. Solar parks commissioned in different states of India with their approved & commissioned capacities.

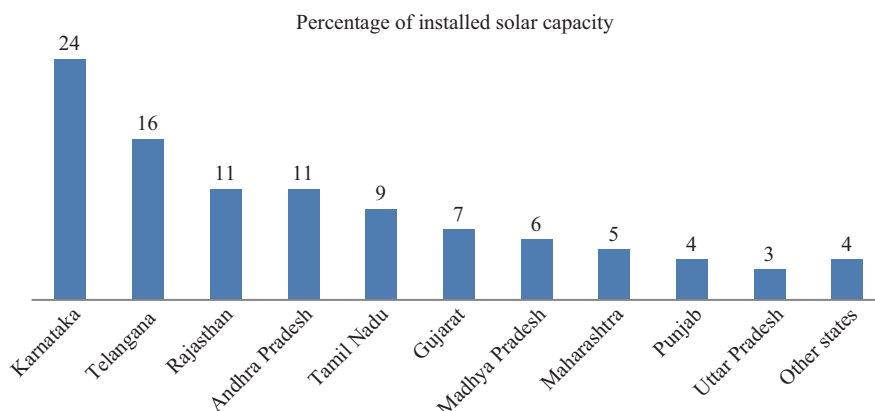


Fig. 5. Percentage of installed solar capacities of the top 10 states in India.

- In Gujarat, a 1 MW canal top solar power plant is installed at the Sardar Sarovar canal for power generation. It produces 1.6 million units of solar electricity annually and protects approximately 90 lakh liters of water from evaporation. The solar modules mounted above the canal stay cooler as compared to land mounted ones; thus, they generate more energy. Coverings over the channels save land for agriculture and water for irrigation and also provides local production of power.
- In Kerala, a 500 KW floating solar power plant is installed on the Banasura Sagar reservoir. The plant consists of 1938 panels mounted over hollow cement floaters over 1.25 acres of water. High-efficiency solar panels with a 11 kV substation, 500KVA transformer, 17 inverters, supervisory control and a data acquisition (SCADA) system for monitoring and control of power production and a securing system all become an integral part of the floating solar plant. Due to the moderating influence of the water bodies on the temperature of the device, floating solar plants had a higher performance relative to ground-mounted installations.

Table II shows a list of some solar power projects installed in the various states of India. Fig. 6 shows photographs of the largest solar power plants in India with an installed capacity.

Rooftop SPV: A rooftop SPV system connected to the grid distribution system and feeding the power in substations or load centers eliminates transmission and distribution losses. Also, with grid-connected systems, the cost of batteries for storing energy is eliminated. These are the vital reasons for promoting grid-interactive rooftop SPV systems for captive power generation. Roof spaces can also be leased out (roof leasing) for generating solar power either for the captive requirement or for transmitting back to the grid. In addition to the rooftop or ground-mounted solar plants, different solar applications, such as floating solar plants, solar installations over water canals, solar trees, and solar roadways, are also in the experimentation stage, which could further transform the solar industry [29].

Consumers can use either a net meter or a gross meter link for the grid connectivity of these systems. Under a net meter link, Discoms can charge customers for energy consumed from the grid and the roofing solar panel; this could be viewed as

TABLE II
SOME SOLAR POWER PROJECTS ALREADY COMMISSIONED IN INDIA

No.	Name of Project	Location	State	Area in acres	Capacity in MW	Commission year
1	Badla solar park	Phalodi, jodhpur district	Rajasthan	14000	2255	September 2018
2	Pavagada solar park	Tumakuru district	Karnataka	13000	2050	January 2018
3	Rewa ultra mega solar plant	Rewa	Madhya Pradesh	1875	1000	March 2016
4	Kurnool ultra mega solar park	Kurnool	Andhra Pradesh	5932.32	1000	July 2017
5	Ananthapuram ultra mega solar park	Nambula, pulakunta	Andhra Pradesh	7924.76	1000	March 2018
6	Charanka solar park	Charanka, patan district	Gujarat	4900	790	March 2016
7	Kamuthi solar project	Ramanthapuram	Tamil Nadu	2500	648	September 2016
8	NTPC solar power plant	Mandsaur	Madhya Pradesh	615	250	March 2018
9	Kasaragad project	Ambalathara	Kerala	300	200	March 2017
10	Welspun solar project	Neemuch	Madhya Pradesh	365	151	March 2013
11	Sakri solar project	Dhule district	Maharashtra	650	130	March 2013
12	Renew dichpally solar park	Dichpally	Telangana	725	143	September 2017
13	Bhagwanpur solar project	Bhagwanpur	Madhya Pradesh	650	130	September 2014
14	Mirzapur solar plant	Dadar kalan village	Uttar Pradesh	380	75	March 2018
15	Ujjain solar park	Ujjain	Madhya Pradesh	150	65	March 2016



Badla solar park, Rajasthan 2255 MW



Pavagada solar park, Karnataka 2050MW



Ananthapuram ultra mega solar park,
Andhra Pradesh 1000 MW



Rewa Ultra mega solar plant, Madhya
Pradesh 750 MW

Fig. 6. Photographs of the largest solar power plants in India with an installed capacity.

part of the payment of the system to the developer. Under a gross meter connection, Discoms can charge consumers for their use and pay for electricity exported to the grid; charging for the system could be included as part of the payment, and be part of a roof-lease contract, where the developer and Discom pay the owner for the use of his roof.

Figure 7 shows a utility-based model for a grid-connected rooftop model with a net metering connection.

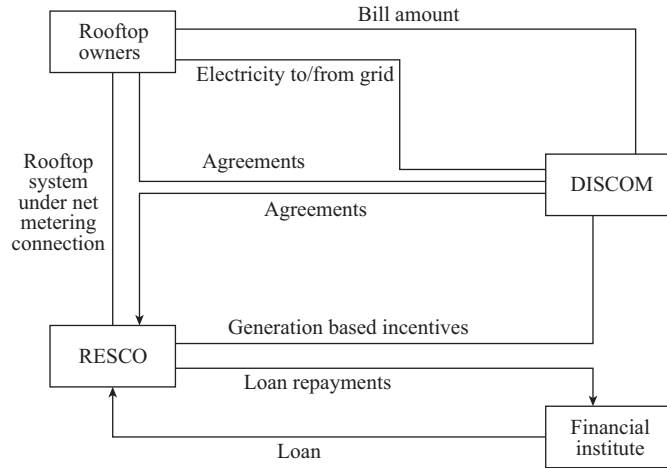


Fig. 7. Utility-based model for a grid-connected rooftop model with a net metering connection.

B. Significant Achievements in the Solar Sector

- Round-the-clock power supply to more than 10000 remote villages and hamlets, including those on the islands of Sunderbans, Bastar, Andaman and Nicobar, Jammu and the Kashmir region of Ladakh and Northeast electrified by solar energy.
- Infosys campus in Bangalore generates 100 million units meeting 43% of electricity requirements from solar energy. They have also installed 100 MW capacity solar rooftop plants in the cities of Pune, Chennai and Hyderabad.
- Installing of grid-tied solar plant and numerous off-grid purposes for complete solar powering of Konark sun temple and Konark town in the Puri district of Orissa state. 10 MW grid-connected projects for electricity needs of all households in Konark city Konark temple are fulfilled with solar energy.
- Introduced the ARUN (Atal Rooftop Solar User Navigator) mobile app to make it easier for recipients to send requests and to provide information.
- Solar Photovoltaic Installation (SPIN), a new online tool for tracking and implementing the Rooftop Program (RTS), was developed.
- In Bhopal city, a 750 KW solar power plant was installed along the upper lakeside for supplying power to a water pumping station having two 750hp pumps lifting raw water to its filtration plant. This would generate around 13000 units of electricity and save Rs.40 lakhs annually.
- The Indian Solar Energy Corporation (SECI) has declared that it has successfully installed the country's second-largest solar photovoltaic rooftop power plant at GAIL's

Petrochemical Complex in Uttar Pradesh. The solar plant of 5.76 MWp would generate approximately 793000 units of electricity per year for the captive use of GAIL. The plant is expected to reduce carbon dioxide emissions by about 6000 tons per year and contribute to India's COP21 commitment goals [28].

- The State Government of Chattisgarhis is providing a 40% subsidy to customers for installation of 1 kW to 3 KW residential rooftop solar systems and a 20% subsidy on those above 3 KWp to 10 KWp rooftop systems under the Capex model. This was possible as the Chattisgarh State Renewable Energy Development Agency (CREDA) revealed Rs 40000 per kW rate for the capacity range between 1 kW to 10 kW for mounting of the grid-tied solar rooftop photovoltaic (GRPV) project of the MNRE program.
- The Rewa solar power project was awarded by the President of the World Bank Group for its creativity and excellence. It is the first clean energy initiative to provide rail cooperation outside the state of Madhya Pradesh to Delhi Metro.

VII. SOLAR TARIFF IN INDIA

So far, the highest ever total of 9362.64 MW capacity has been added recently taking the cumulative achievement to 21651.46 MW. Advancement of Solar Parks and Ultra Mega Solar Power Projects have improved the capacity from 20000 MW to 40000 MW Rooftop projects of around 1063.63 MWp capacity have been installed along with new projects of 2009 MWp capacity have been sanctioned. All these achievements decreased the solar tariff to the lowest level of Rs.2.44/kWh at the Bhadla Phase-III Solar Park in Rajasthan, which is bringing it closer to grid parity. New innovative approaches, such as floating solar plants, mechanized wind-solar hybrid, and solar power are being attempted.

The tariff rates vary due to the changing interest rates, module costs, capacity utilization factors across states, additional taxes or duties and project returns. Thus, the latest solar tariff in India is Rs. 2.5 per unit which is even lower than the rate of per unit power (Rs. 3/KWh) supplied by a conventional thermal power plant as indicated in Fig. 8. The National Thermal Power Company (NTPC), India's largest coal plant operator is progressively facilitating solar energy by building its own low-cost renewable portfolio. This will prove to be a solution for the unequal treatment of electricity in the country and will help to achieve "one government, one grid, one renewable, one price," according to the National Solar Energy Federation of India (NSEFI). In the latest bids held by the Solar Energy Corporation of India (SECI) many international and national power-producing companies, such as ReNew Power, Greenko Group, SB Energy, AMP Energy, Eden Renewables, Azure Power, Tata Power, Adani Group, Ayana Power, Avada Energy and Mahindra Susten companies, participated.

When the national solar mission was declared in the year 2010, the cost of solar electricity was Rs.17 per unit relative to the current bid of Rs.2.44 per unit. This breakthrough cost-cutting was made possible by competitive tariff-based bidding

TABLE III
CHRONOLOGY OF LOWERING OF SOLAR TARIFFS

No	Period	Scheme	Solar park	State	Capacity (MW)	Company won tender	Lowest tariff in (Rs./KWh)
1	Nov 15	National Solar Mission (NSM)	Gani solar park (Kurnool)	Andhra Pradesh	100	SunEdison	4.63
2	Jan 16	NSM policy	Bhadla II solar park	Rajasthan	100	Fortum	4.34
3	Feb 17	State scheme	Rewa solar park	Madhya Pradesh	750	ACME	3.30
4	April 17	NSM policy	Kadapa solar park	Andhra Pradesh	250	Solairedirectengie	3.15
5	May 17	Viability Gap Funding (VGF)	Bhadla IV solar park (Adani park)	Rajasthan	250	Phelan, Avaada	2.62
6	May 17	VGF scheme	Bhadla III solar park (SauryaUrja Park)	Rajasthan	500	ACME	2.44
7	Jun 20	SECI scheme	Non solar park	Across India	1200	Solar pack	2.36

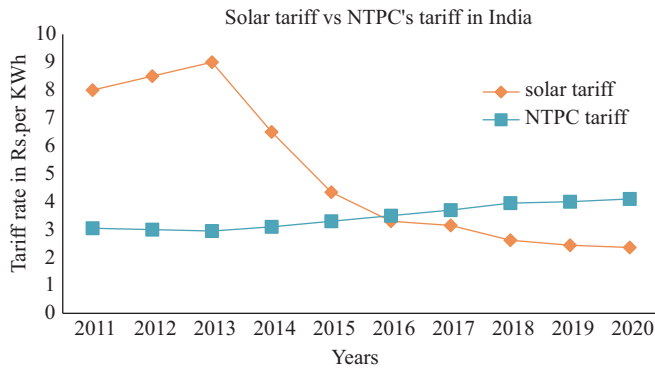


Fig. 8. Tariff of solar power compared to conventional thermal power.

activities conducted by India's Solar Energy Cooperation (SECI), central and state governments by bids.

The Central Electricity Regulatory Commission (CERC) has given new tariff regulations for renewable energy projects from July 01, 2020, to March 31, 2023. The project-specific tariff will apply to solar, floating solar, solar thermal, wind, and biogas power projects. Also included are the municipal solid waste, renewable hybrid, and renewable projects with storage. The useful life period for a solar power project is 25 years, considering a debt and equity ratio of 70:30 and the return on equity of 14% with a depreciation rate of 4.67% per year for the first 15 years and the remaining depreciation spread evenly for the remaining useful life of the project. The operation and maintenance (O&M) expenses for the financial year (FY) 2020–21 will be increased at the rate of 3.84% per year for the tariff period. Also, a late payment surcharge of 1.50% per month will be levied by the generating company if the payment is delayed beyond 45 days from the date of the presentation of the bill. The Commission will determine what will be the only project-specific capital costs, considering the existing market trends. The minimum CUF for solar power projects should be 21%, 23% for solar thermal and 19% for floating solar projects. The maximum auxiliary consumption for approval of solar power projects should be 0.75%, 10% for solar thermal and 0.75% for floating solar projects.

VIII. CHALLENGES AND POLICY IMPLICATIONS

There are few initiatives to finance entrepreneurs with low interest in the development of solar projects, land availability

purchases and the production of solar goods. The cost of installation of solar power plants and the associated transmission and distribution losses are high.

Customers face delays in approval of plant setups, requests for net metering and signing of Power Purchase Agreements. The payment of subsidies provided by the Government may not be distributed in due time.

Manufacturers depend primarily on export markets that consume solar PV cells and modules at higher costs, thereby improving their revenue. This results in decreased supply to the fast-growing local market. High-quality inverters and other items are also manufactured from other countries. There are also cost increases due to taxes and duties levied on products.

There is a need for concentrated, collaborative and goal-driven research and development. Improved funding of utilities, models and arrangements to stimulate the PV industry and the use of PV goods is required. There is a lack of stronger industry-government collaboration on technology to achieve size advantages.

There is a lack of information and market awareness of new policies and their benefits among people living in rural areas of the nation. This is due to illiteracy and poor financial conditions. Proper training of human resources and workshops are needed to ensure the growth and adoption of technology.

In urban areas and metropolitan cities, land space is scarce for solar project development as cities are crowded with high and enormous sized buildings. A dedicated land area near substations for the complete installation of solar and storage equipment is required.

IX. FUTURE OUTLOOK

India is deeply committed to accomplish the determined target of 175 GW from renewable resources by 2022. Already by 2020, the installed renewable capacity has reached 87 GW from which 37 GW is through solar energy. Thus the milestone goal of 100 GW solar power capacity by 2022 can easily be achieved with 34 GW of projects in progress and many new upcoming tenders.

India is reducing its greenhouse emissions and plans to generate 40% of its built energy power from non-fossil fuels by 2030. This will lead to a significant change from coal-fired generation to clean energy sources. India's green room for electricity is distributed through solar and wind power

businesses, hybrid vehicles and storage projects. It is expected to remain an attractive destination for renewable energy investments internationally, with the Government setting aggressive goals and implementing a series of reforms to raise market interest.

The Government has taken several measures to attract international investment in this field to support renewable energy. It has helped in this process by improving the macro-economic fundamentals, maintaining political stability and providing a variety of fiscal benefits. The Government has proposed some welcome measures, such as tax cuts for the development of mega-manufacturing plants for solar panels, lithium storage batteries, electric cars and charging facilities.

It also focuses on improving the grid to allow the smooth and enhanced deployment of renewables. The vulnerability to investors can be minimized by enhancing transmission infrastructure, relaxing land acquisition requirements, ensuring no flip flops after contracts have been signed and re-examining aggressive tariff limits at reverse auctions. India's distribution companies (discoms) will fulfill their renewable procurement commitments (RPO-promises to purchase a certain amount of their electricity needs from renewable energy producers) and pay investors on schedule.

Because of competitive tariff-based bidding efforts undertaken by solar energy cooperation, central and state governments, the solar tariff has decreased to Rs.2.5 per unit from Rs.17 per unit in 2010 when the national solar mission was initiated.

MNRE also plays a vital role in endorsing solar energy creating general alertness and initiatives to improve renewable energy in the fields of lighting, cooking, heating, drying, irrigation and motivating energy in rural areas as well as in urban, industrial and commercial applications.

The Government also focuses on developing technical skills and knowledge of the people to raise their standard of living, protecting the environment and contributing to the economic development of the nation.

X. CONCLUSION

Policies for growth of renewable solar energy, challenges and attitude in India have been discussed in this study. Following are the critical conclusions from this analysis.

1) The Indian Government has made a set of regulations to encourage consumers to become producers of energy. These prosumers promote renewable resources and become savers of the environment rather than becoming destroyers.

2) The outlook for connecting solar energy goals to current missions on Make in India, Smart City Project and Virtual India is recommended as a pledge for the growth and transformation of the country's entire energy system. The Government has launched many skill development programs, such as the Suryamitra program and Rooftop grid engineer course for creating a qualified technical workforce of persons all over the country. People were trained for efficiently working at every stage of safety, designing, installation, pre and post-commissioning, operation & maintenance of solar energy-related projects.

3) Many regulations including exemption from tax legislations, allowances, attractive tariff grants, knowledge awareness, renewable energy standards, economic incentives, technological research and development, etc., provide important encouragement and interest in developing and using clean energy technologies.

4) The state governments have framed many supportive policies and developed solar PV projects to increase the production of electricity in the state using solar energy. A large amount of unused rooftop spaces in government, institutional, industrial, commercial and residential buildings are being utilized for installing grid-connected rooftop solar PV projects, supporting the country to achieve its target.

5) Solar energy generation is a climate-friendly alternative that contributes to a substantial reduction in carbon dioxide emissions without consuming any fuel during service. The proposed priorities for the future should be the implementation of grid-ready off-grid networks for rural and remote areas and the establishment of grid-connected by-laws for new grid buildings, such as "Rooftop ready".

6) There is a breakthrough reduction in the cost of the tariff, which has been made possible by competitive bidding efforts undertaken through tenders and various public awareness campaigns and events by government authorities for promoting solar energy.

7) Establishing solid foundations have been accomplished through net metering strategies and updating the DISCOMS incentive program. This results in a decrease in electricity bills by selling at a cheaper cost, in proportion to the higher wattage produced by solar panels, to maximize the contribution of homeowners in energy savings.

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