Law Colloquy Journal of Legal Studies (LCJLS)
Volume 1, Issue IV
January 2022

Solar Energy Production in India: An Analysis

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Abstract

One of the major environmental issues of our day is the changing global warming. The only way to avoid or mitigate this crisis is to reduce greenhouse gas emissions. Many different policies have been implemented around the world to curb greenhouse gas emissions and thereby reduce environmental damage. Many developed countries have taken different steps to reduce carbon dioxide emissions to a sustainable degree. One of the most significant sources of greenhouse gas emissions is the electric power market. Various initiatives have been implemented in the electricity industry around the world to reduce greenhouse gas emissions. The use of renewable energy as a source of electrical power is one of the most important strategies adopted by the power industry in recent years in many parts of the world. Solar is one of the most lucrative and operationally feasible renewable energy options, as well as one of the most powerful power sources in the renewable energy market.

This paper emphasis on the Solar energy production, which is indigenous and distributed and has a low marginal cost of generation. The contention made in the paper is that how solar energy can be a help to improve energy efficiency by diversifying supply, reducing reliance on imports, and reducing fuel price volatility. Solar energy production in India can also be a useful tool for boosting regional economic development, especially in many underdeveloped states that have the greatest potential for developing solar power systems, which are renewable and limitless sources of energy. It will ensure a steady supply of electricity to support domestic industrial growth. As a result, photovoltaic power systems will play a significant role in future energy not only in India but across the world. Lastly, it suggested many awareness programmes for solar energy.

Keywords: *Solar energy, India, photovoltaic power, environmental issues, environmental law.*

Introduction

One of the major environmental issues of our day is the changing global warming. The only way to avoid or mitigate this crisis is to reduce greenhouse gas emissions. Many different policies have been implemented around the world to curb greenhouse gas emissions and thereby reduce environmental damage. Many developed countries have taken different steps to reduce carbon dioxide emissions to a sustainable degree. One of the most significant sources of greenhouse gas emissions is the electric power market. Various initiatives have been implemented in the electricity industry around the world to reduce greenhouse gas emissions. The use of renewable energy as a source of electrical power is one of the most important strategies adopted by the power industry in recent years in many parts of the world. Solar is one of the most lucrative and operationally feasible renewable energy options, as well as one of the most powerful power sources in the renewable energy market.

Solar energy is typically produced using solar photovoltaic (SPV) or focused solar power techniques (CSP). According to the 'International Energy Agency,' CSP and SPV would account for around 11 percent and 16 percent of global electricity demand, respectively, by 2050. According to some sources, solar energy will be the primary source of power by 2025, with most solar projects taking place in India and China. Solar power plants use either SPV or CSP to convert solar energy into electrical energy. The CSP system uses lenses and monitoring devices to focus illumination from a wide field onto a narrow beam. In the case of SPV, photovoltaic effects are used to transform sunlight energy into electrical energy. The first SPV factory, with a capacity of 1 MW, was installed by "Arco Solar" in Lugo, California, in 1982.

The need for India to increase energy provision for its rapidly increasing population and economy presents a daunting challenge, which is seen as both a great opportunity and a need for the country to increase the share of renewables in its overall energy mix. India is currently the world's sixth-largest electricity-generating nation, with a total capacity of 177 GW, of which 65 percent comes from thermal, 21% from hydro, 3% from nuclear, and the remaining 11% from renewable energy sources.

Around the same time, rural areas need electricity access, and fossil fuel import reliance must be reduced. India's strategy is to address its energy needs in a responsible, long-term, and environmentally friendly way. The implementation of solar energy technology in the country was listed as a National Mission in the National Action Plan on Climate Change (NAPCC) in June 2008. The "Jawaharlal Nehru National Solar Mission" was authorized by the Indian government in November 2009. (JNNSM). The mission's goal is to build and install renewable energy technology in the country to reach grid parity by 2022. Due to rising electricity demand and minimal environmental effects, solar energy options have played an increasingly important role in recent years. Solar energy is a renewable, secure, easy-to-

maintain, and long-term power source. Several power policies have discussed the importance and necessity of promoting clean energy in recent years. The Electricity Act of 2003, for example, delicensed stand-alone generation and delivery networks in remote areas. The National Rural Electrification Policy of 2005 and the National Rural Electrification Policy of 2006 both emphasize the importance of electrification in rural areas. According to the New Tariff Policy (2006), a certain proportion of electricity must be imported from such sources, as determined by the Regulatory Commission. Later sections go into the specifics of the Indian government's directive to encourage green energy.

The 'Central Electricity Regulatory Commission' launched the Renewable Energy Certificate (REC) scheme to make the renewable energy procurement process easier for obligate agencies and state utilities. The property rights to renewables generation's social, financial, and other non-power groups are known as RECs. Buyers benefit from REC's flexibility in (a) procuring renewable power through different regional regions, and (b) adding renewable attributes to electricity use at a provider of choice. A generator can generate electricity from renewable sources in any part of the country using the REC technique.

The solar power's huge capacity, ease of availability, and other inherent characteristics, the Indian government has placed a greater focus on its promotion in the Indian power scenario. India is currently ranked among the top ten countries in the world for solar power investment, capacity expansion, and job growth. After the successful implementation of the solar mission, solar power can also provide a better economic scenario for all states in India, especially for some underdeveloped states where solar power generation capacity is high but not yet exploited.

Solar Energy in India: Past & Present

India is one of the top countries with high Direct Normal Irradiance (DNI), which is affected by spatial position, sun movement, the tilt of the Earth's rotational axis, and atmospheric attenuation from suspended particles. India has a major solar energy capacity of about 5000 trillion kWh per year (Pandey & Singh), according to estimates. Solar radiation incident in India ranges from 4–7 kWh per day, with annual radiation of 1200–2300 kWh per square meter. It has 250–300 bright sunny days a year and 2300–3200 hours of sunshine.

After nearly three decades, of Independence the 6th FYP (1980–85) was the first to discuss solar energy and its application. Solar energy development was particularly appealing because it could satisfy the energy needs of decentralized rural areas as well as future industrial applications. The Department of Non-Conventional Energy Sources (DNES) was founded as a Ministry of Energy unit on September 6, 1982. This department aimed to provide funds for

improving research, growth, and demonstrations in the field of Renewable Energy Technologies (RET), which included all major RES such as solar, wind, biomass, and geothermal energy, among others. CASE initiated a subsidy-based scheme to manufacture and sell 10,000 solar cookers in 12 states and one union territory. Besides, the Solar Thermal Energy Centre (STEC) was developed with the primary goal of driving solar-thermal R&D, research, and demonstration activities to assist devices and systems in reaching commercial output.

The Government of India supported and initiated private sector involvement in the 9th FYP (1997–2002) intending to mobilize additional capital for the power sector, specifically generation, transmission, and distribution. Under this initiative, Independent Renewable Power Producers (IRPP) were given the freedom to sell (renewable) power to any third party in the country through existing transmission lines of the State Electricity Boards (SEBs) in exchange for fair fees. All obstacles in this regard had to be overcome for IRPPs to contribute to the promotion of power generation from non-conventional energy sources. Subsidies were introduced in solar energy programs.

The Ministry of Non-Conventional Energy Sources (MNES) was in charge of negotiating incentives with relevant departments and ministries, as well as justifying the solar programs and subsidies in addition to other subsidy programs such as LPG, kerosene, and so on. This program also saw the advancement of solar photovoltaic cell technology, which was completed under the Department of Scientific Industrial Research's "Program Aimed at Technological Self-Reliance" (PATSER). PATSER wanted to help businesses by developing and demonstrating a variety of indigenous innovations (Kapoor et al.).

Solar power was thought to be essential in achieving energy independence that was renewable and could help the country minimize GHG emissions in the 11th FYP (2007–2012). With the growing threat of climate change and as a responsible developing country, India initiated the Jawaharlal Nehru National Solar Mission (JNNSM) in January 2010 as part of its National Action Plan on Climate Change (NAPCC). India hopes to encourage solar energy in a major way through this mission to reduce GHG emissions and map out viable options for ensuring energy protection by 2022.

Electricity Act 2003, National Electricity Policy 2005, Tariff Policy 2006 and its revision in 2011, National Action Plan on Climate Change 2008, Semiconductor Policy 2007, and Karnataka Semiconductor Policy 2010 are some of the governments of India's steps to promote solar energy in the country since 2000. Also, until April 2014, 14 states have declared their solar policies (Khare 2013).

The solar sector has seen tremendous growth in recent years, the cumulative installed solar capacity had increased by more than eight times in the last 4 years from 2.630 GW (2013–

2014) to 22 GW (2017–2018). By the end of 31st December 2018, the installed capacity in solar power amounted to 25.2122 GW. In the year 2014, the world largest solar park was the

Topaz solar farm in California with a 550 MW facility and by the year 2015, another operator in California, Solar Star, edged its capacity up to 579 MW but by 2016, India's Kamuthi Solar Power Project in Tamil Nadu has topped the table with a capacity of 648 MW which was established set up by the Adani Green Energy, a part of the Adani Group, in Tamil Nadu by February 2017, the Longyangxia Dam Solar Park in China was the new leader, with 850 MW of capacity which soon changed as India's Bhadla Solar Park which is at Bhadla, Jodhpur, Rajasthan, and has a total capacity of 2,245 MW Currently, tops the list with all this there are 600 MW operating units and 1400 MW units under construction in India. The MNRE has approved around 41 solar parks in 21 states in the country which will have more than around 26,144 MW cumulative capacities. The Kurnool solar park in Andhra Pradesh was set up with 1000 MW capacity and with 2000 MW the largest solar park of Pavagada (Karnataka) was completed in 2019 making it the World's second-largest photovoltaic solar park after 2245 MW Bhadla Solar Park which is at Bhadla, Jodhpur, Rajasthan, and has a total capacity of 2,245 MW.

Regulatory Framework governing the solar sector and Role of RPO & REC

With the establishment of the Commission of Alternate Sources of Energy (CASE) in the Department of Science and Technology in 1981, India's policy infrastructure in the renewable energy field began to take shape. In 1982, it became an autonomous Department of New Energy Sources (DNES), and in 1992, it was elevated to the status of a full-fledged Ministry. The Ministry of New and Renewable Energy (MNRE) is the Government of India's nodal ministry for all new and renewable energy issues. The ministry's overall goal is to produce and implement modern and clean technologies to supplement the country's energy needs.

There is no specific Legislations regarding solar energy, though there are policies and regulations on both level central as well as state and government initiatives which cover the major aspects covering the solar sector under the renewables.

After the launch of the Jawaharlal Nehru National Solar Mission (JNNSM) in 2010, the Indian SPV market grew significantly. Ground-mounted, rooftop, and storage system SPVs make up the majority of grid-connected SPVs. The overall installed capacity increased from 40 MW in 2010 to 2686 MW as of 30 June 2014, thanks to structural structures, national and local supporting processes, and tailored policies, including adequate subsidies and financing

arrangements. In Phase, I of the JNNSM, a total capacity of 1686 MW was provided, and in Phase II, an additional capacity of 1000 MW was added. As of June 2015, the gross installed capacity of

grid-connected SPV was 4060.65 MW (MNRE, 2015), from both federal and state-level initiatives. The government is taking a variety of steps to achieve this target, which is described below:

- The National Tariff Policy has a renewable purchasing obligation (RPO) for solar electricity.
- Subsidies for off-grid applications, GBI for bundled electricity, and Viability Gap Funding (VGF) for grid-connected solar power projects are all available through numerous initiatives announced from time to time.
- Developing ultra-mega solar power schemes and solar parks, as well as 1 MW solar parks on canal banks and solar-powered irrigation pumps, set capable of powering 1 lakh pumps.
- Import duty/excise duty exemptions, accelerated depreciation, and a tax holiday are also available to solar power plant developers.

The first phase of the program presented the government with learning opportunities, such as lower tariffs if the ability to be allocated is significant, seasoned businesses are involved in large projects, and the transmission and evacuation mechanism remains a major problem. Aside from prompt payment and guarantee of continuity from the lender's perspective, domestic manufacturing units need further R&D assistance because the bulk of the machinery is imported, increasing the overall price.

Legal and Institutional Framework

A. **The Electricity Act** of 2003, which came into effect in June 2003, is the most relevant piece of clean renewable energy legislation. The act directs the Government of India to formulate policies and directs State Electricity Regulatory Commissions (SERCs) to take action to encourage alternative and non-conventional energy sources within their jurisdiction. It urges the promotion of cogeneration and the generation of electricity from renewable energy sources by establishing appropriate steps for grid connectivity and the selling of electricity to any user, as well as specifying a percentage of overall electricity usage in the distribution licensee's region for the purchasing of electricity from such sources. Furthermore, EA 2003 specifies the establishment of a National Electricity Policy (NEP), a National Tariff Policy, and a strategy for the

implementation of power systems to maximize the use of all resources, including renewable energy sources.

B. **National Electricity Policy 2005**: Aims to maximize the value of renewable energy resources while lowering capital costs, promoting competition, and including the private sector. The percentage for non-conventional power procurement should be applied to the tariffs set by the SERCs. As required by SERCs, the share of electricity generated from non-conventional sources must gradually increase. Distribution firms must buy these items in a fair bidding mechanism(Kapoor et al.).

C. **The National Tariff Policy of 2006** specifies that a certain proportion of green energy procurement is made mandatory. SERCs should also decide on a preferential tariff to enable green energies to participate, and renewable energy procurement should be done by competitive bidding. In 2011 the modification to Tariff Policy 2011 was made which includes:

- SERCs would set a special RPO for Obligated Entities to buy electricity from Solar Energy Sources.
- By the end of 2012–13, solar RPO will have increased to 0.25 percent, and by 2022, it will have increased to 3 percent. Fuel purchases from non-conventional sources of energy would occur in roughly equal proportions across states.
- One of the methods to meet such a goal may be the Renewable Energy Certificate (REC) Mechanism.

D. **National action plan on climate change (NAPCC) – 2008**, It establishes a national target for RE purchases, which will rise from 5% of overall grid purchases in 2010 to 15% by 2020, with an annual growth of 1% for the next ten years. Different SERCs in different states can set higher targets on their own. It also authorizes appropriate authorities to grant certificates that buy renewable energy over the national grid, which could be tradable, to allow utilities that fall short of their renewable energy procurement obligations to fulfill their obligations (RPO)

E. **NAPCC 2008**: The Government of India's National Action Plan on Climate Change establishes eight key national missions that will continue through 2017, including a variety of steps to combat global warming. According to one of the missions, a dynamic minimum renewable purchasing standard (DMRPS) should be established, with annual escalation until a predetermined amount is achieved. It set a goal of purchasing 5%

renewable energy in FY 2009-10, with a 1% growth per year to achieve 15% renewable energy penetration by 2020.

F. **RPO (Renewable Purchase Obligation) and REC (Renewable Energy Certificate):** Solar energy has the highest capacity of all renewable energy options in the world. Clear, sunshine weather can be seen in most parts of India 250 to 300 days per year. The annual radiation ranges between 1600 and 2200 kWh/m2, which is equivalent to that obtained in tropical and sub-tropical areas. The annual equivalent energy capacity is about 6,000 million GWh. "India is a tropical region, where sunlight is possible for longer hours per day and in high intensity," according to the National Action Plan on Climate Change. As a result, solar energy has a lot of promise as a possible energy source. It also has the benefit of allowing for decentralized energy sharing, which empowers people at the grassroots level." The Government of India initiated the National Solar Mission intending to establish India as a global leader in solar energy by providing the policy conditions for its rapid adoption across the world. The Ministry of New and Renewable Energy has undertaken an exercise to monitor and assess problems in the fulfillment of the Solar Power Purchase Obligation and implementation of the Solar REC system in India, in light of the current efforts of the Central and State Governments, as well as various agencies, to promote solar energy. This will aid numerous stakeholders in comprehending the problems and opportunities that solar power production presents. Monitoring Solar RPO Compliance and reviewing core issues relevant to the regulatory environment for solar in various Indian states are also part of the plan.

SERCs mandate service companies to purchase a certain amount of their overall power needs from renewable energy sources. The states have already set their RPOs, which range from 2% to 14% of their overall electricity demand to be fulfilled by renewable energy. The REC process was adopted in 2010 to allow and accept interstate renewable energy transactions to resolve the discrepancy between the supply of renewable energy supplies and the obligation of obligated agencies to fulfill their RPO across States.

In India, some states, such as Rajasthan and Tamil Nadu, have a high potential for renewable energy sources, and state commissions have set higher RPOs. Well above the RPO level set by the State Commissions, there are ways to tap into the capacity in certain states. The high cost of generation from renewable energy sources, on the other hand, discourages local distribution licensees from buying electricity produced from renewable energy sources above the RPO level set by the State Commission. The definition of a Renewable Energy Certificate (REC) takes on new meaning in this sense obligation to buy. This definition aims to resolve the disconnect

between the supply of clean energy sources and the obligation of obligated institutions to achieve their renewable energy targets.

Green Tags, Renewable Obligation Certificates and Tradable Renewable Certificates are all technically similar terms for RECs. The idea has been used to promote a robust and credible market for trading the green qualities of electricity in countries such as the United Kingdom, the United States, Australia, Japan, the Netherlands, Denmark, and Poland, to provide an additional source of revenue to renewable energy generators (Goyal & Jha).

Salient Features of REC Framework

- The Renewable Energy Certificate (REC) mechanism is a market-based tool that promotes renewable energy and makes renewable purchase obligations easier (RPO)
- The Renewable Energy Certificate (REC) process aims to resolve the discrepancy between the supply of RE services in the state and the duty of obligated agencies to fulfil the renewable procurement obligation (RPO).
- The cost of generating power from alternative energy sources is divided into two categories: the cost of generating electricity equal to traditional energy sources and the cost for environmental attributes.
- Renewable energy generators will have two options: a) sell renewable energy at a preferential cost, or b) sell power production and environmental qualities associated with RE generation separately.
- Renewable Energy Certificates can be used to swap environmental attributes (REC).
- Solar certificates will be granted to qualified entities for electricity generation based on solar as a clean energy source, and non-solar certificates will be issued to eligible entities for electricity generation based on renewable energy sources other than solar.
- According to the information supplied by the Power Exchanges, the Central Agency would delete the RECs sold in Power Exchanges from its data. The Central Agency would extinguish the certificates in the order of first-in-first-out.
- Under the forbearance and floor prices, REC will be traded. This forbearance as well as the floor price CERC, in consultation with others, will decide FOR (Forum of Regulators) from the central agency from time to time (Goyal & Jha).

Benefits of REC Mechanism

- **Interstate Transmission**: RECs provided for a certain amount of energy obtained by renewable energies do not require long-distance scheduling. Just RECs must be passed to the obligated bodies, and such energy can be used locally. Transmission of energy from renewable

sources situated outside of the States can be uneconomical and technologically problematic due to the renewable duty imposed by preferential tariffs.

- **Promotion of stand-alone systems:** Since the selling of RECs would not necessitate electricity delivery, the increased revenue from REC sales may serve to increase the competitiveness of

standalone systems. Transmission of power from such areas could not be cost-effective in a typical scenario.

- **Competition in the Electricity Market**: By separating RECs from electrical energy, near-cost-effective renewable energy can compete in the power exchange. The revenue generated by RECs could help to offset the cost disadvantage that such renewable energy technologies face.
- **Alternative to Fulfilling Renewable Purchase Obligation:** The tradability of RECs at the national level will enable obligated entities/distribution licensees to meet their obligations despite natural diversity. RECs from generators in other states may be obtained. A state's limited capital endowment can only allow for a lower renewable commitment.
- **Attract Investment:** The REC sector will provide ideal conditions for the production of sustainable energy-based electricity generation. The unbundling of RECs from electrical resources allows the latter to compete successfully in a competitively traded power market. This will also allow investors in clean energy technology to use power futures to mitigate their chances of rising electricity prices. This, in conjunction with RECs, would have sufficient risk hedging and, as a result, stimulate clean energy investment.

Prospects of Solar Energy

Placed with dual energy and environmental pressures, India has no choice but to work toward growing the position of clean energy in future energy systems. The JNNSM's goal is to make India a global leader in solar energy by establishing the policy conditions that will enable it to spread as rapidly as possible across the world.

According to the International Energy Agency (IEA), by 2050, SPV and CSP would account for about 16 percent and 11 percent of global electricity demand, respectively. Solar energy has now been the world's fastest-growing source of electricity, according to an IEA survey from 2017, India has the largest solar energy capacity among all the renewable energy sources, and it ranks fifth in the world for solar energy generation. Given the promise of solar energy, India's government has initiated the Jawaharlal Nehru National Solar Mission (JNNSM), which aims to generate 20,000 MW of solar energy by 2022. Gujarat, a leader in solar power policy, plans to generate 1,000 MW of solar energy and announced an Rs. 130 billion solar power program

in July 2009, to produce 20 GW of solar power by 2020 (Singh, and Singh, 2016). Currently, the Thar area of Rajasthan is home to some of the country's best solar projects, with nearly 2,100 GW of power produced.

Solar energy has many benefits, including the fact that it is infinite and does not pollute the atmosphere. Furthermore, as the cost of installing solar panels decreases, demand rises. It is encouraging to learn that the Government of India's dedicated Ministry of New and Renewable Energy (MNRE) has launched a scheme to build Ultra Mega Renewable Energy Power Parks (UMREPPs) under the current Solar Park Scheme. Furthermore, India's success in the solar power sector is steadily promising, with some of the key milestones mentioned below:

In India, milestones in the field of solar energy include:

2010 – 25.1 MW of solar energy generated;

2011 – 468.3 MW of solar energy produced;

2015 – 4229.36 MW of solar energy produced;

2017 – 10,000 MW of electricity produced; and

2022 – 1,00,000 MW of electricity to be produced.

According to a recent survey by the press information bureau, India's overall accomplishments in the solar power market are higher than those of other clean energy sources. The combined achievement in the solar power sector increased by 9.237 percent between 2014 and 2018, while the change in the wind power sector was just 1.663 percent. In addition, India aims to generate 100 GW of solar energy by 2022. India also benefits from the International Solar Alliance (ISA), the first international intergovernmental organization under which India and several other countries have signed a framework agreement. Because of its numerous uses, the solar energy market is rapidly expanding, and many recent advances in terms of energy efficiency and cost reduction have been made. Solar panels are becoming lighter, more compact, and available everywhere as energy-efficient and cost-effective materials are created. A lot can be achieved in the field of solar energy in India with the proper introduction of newer technology and its successful implementation. In most parts of India, post-harvest losses of agricultural products are a major concern. An indirect solar dryer for drying agricultural products was planned, manufactured, and its efficiency was evaluated to reduce post-harvest losses. The dryer was created locally from locally available components and was cost-effective. Such a low-cost, locally built solar dryer could be extremely beneficial to India's rural farmers. Similarly, solar-powered water pumping systems have proven to be a cost-effective and dependable solution to diesel and manually driven pumps (Eker, B), increasing agricultural

production around the world. Solar-powered pumps have also been shown to be an effective and environmentally sustainable way for people living in rural areas to fulfill their domestic and commercial needs. Developers recently built a low-cost solar-powered water pump (under $50) for the

citizens of KohDambang, Cambodia, to fulfill their irrigation and household needs. Since irrigation is a major constraint in agriculture for most rural farmers, a low-cost solar pump may be a viable alternative for them to increase agricultural productivity.

The "Made in India" campaign, which promotes domestic production, helped to propel solar installation capability to new heights. India currently has the fifth-largest installed solar power in the world. Solar energy had reached 25,212.26 MW by the end of December 2018, exceeding the estimate of 2022, and a further 22.8 GW of power had been tendered out or is currently being implemented.

MNRE is planning to auction off the remaining solar energy capacity next year for the years 2018–2019 and 2019–2020, to add 100 GW of capacity by March 2020. As a result, the two-year deadline for project execution will be maintained. Tariffs may be set by a fair bidding mechanism (reverse e-auction) to substantially reduce tariffs. In July 2018, the lowest solar tariff was identified as INR 2.44 per kWh. Solar tariffs in India were INR 18 per kWh in 2010. About 100,000 lakhs (10,000 million) acres of land had been designated for many proposed solar parks, with over 75,000 acres acquired. As of November 2018, there were 47 solar parks with a combined capacity of 26,694 MW. Solar plants with a total capacity of 4195 MW have been installed in numerous solar parks (floating solar power).

For the time being, large-scale, ground-mounted solar projects are driving India's solar industry. Utility-scale solar plants accounted for 82.3 percent of India's installed solar capacity as of September 2019. About 28.9 GW of ground-mounted solar power and 2.2 GW of rooftop solar power are deployed in the region. This pattern is expected to continue since many utility-scale schemes are in the works. The government uses a reverse bidding process to award ground-mounted solar plants, which often come under the Solar Parks and Ultra Mega Solar Power Projects program. In India, rooftop solar is yet to gain traction. Commercial and retail customers account for most rooftop solar installations. Though there is no question that India will match or exceed the National Solar Mission's 60 GW ground-mounted solar goal by 2022 (if not exceed it), meeting the 40 GW rooftop solar target remains a challenge.

This process could be accelerated if India's metering infrastructure were modernized quickly. In India, net metering was first implemented in 2012 to make it easier to connect small home systems to the grid and to encourage residential rooftop installations. Almost all states have now issued rules requiring the installation of net metering infrastructure. However, there is still a problem with implementation. In India, taxes, import duties, and organizational hurdles have made 2018 a "slow year" for solar. According to the National Solar Energy Federation of India (NSEFI latest)'s projections, the country's newly installed solar capacity in 2019 was nearest to Solar Power Europe's low scenario, as seen in the graphs below. Nonetheless, India continues

to expand and is projected to become the world's second-largest PV market in the next five years, with nearly 90 GW of new capacity added between 2019 and 2023. The Indian government recently approved a total of 1.7 billion dollars in financing for phase 2 of its grid-connected rooftop solar network, which is expected to speed up installation.

Challenges faced by renewable energy in India

The MNRE has been working hard to improve the solar market, and its efforts have been successful in identifying numerous roadblocks.

- **Obstacles to policy and regulation**

In the solar industry, there is no detailed policy statement (regulatory framework). Where there is a need to encourage the growth of specific green energy technologies, strategies may be declared that are incompatible with renewable energy production plans. Since each state defines its RPOs (Renewable Purchase Obligations), each state's regulatory structure and procedures vary, putting investments in this sector at greater risk. Buyers will also purchase ready-made projects. This is a pit that consumers fall into to save money on taxes. Since they are excluded from income tax, foreign investors are unable to participate. An RPO is described differently in each state's regulatory strategy and structure. For different renewable sources, the RPO percentage defined in the regulatory structure is not specific.

- **Institutional obstacles**

Institutes, departments, and other players working under the MNRE have limited inter-institutional cooperation. This lack of collaboration, teamwork, and delays are stifling progress in renewable energy growth. Investors are less interested in investing in this business because of the delays in executing policies due to inadequate coordination. There are no suitable or well-established research centers for the construction of green infrastructure. There are no customer service centers to assist investors with solar energy programmers.

- **Technological obstacles**

  Environmental risks, natural disasters, preparation, infrastructure breakdown, and benefit loss all lead to dynamic risk threats that any sustainable project installation faces. On December 11th, 2017, the MNRE released a policy on the standardization of renewable energy projects (testing, standardization, and certification). In comparison to multinational practices, they are only at a basic standard. Processes for quality assurance are also in their infancy. Each renewable energy progress is built on clear action plans for production criteria, testing, and certification.

  Other Key challenges facing the growth and development of solar energy in India include:

- Solar PV is also years away from real cost-effectiveness and being able to perform on the same scale as other electricity generation innovations in terms of cost and T&D losses. T&D losses, which are estimated to be about 40%, rendering solar energy production extremely unfeasible. The government, on the other hand, is encouraging R&D by creating research centers and financing such initiatives. The government has partnered with world-renowned universities to reduce the cost of installing solar power systems and is working on upgrading substations and transmission and distribution lines to reduce T&D losses.
- **Land Scarcity:** Land supply per capita in India is very limited, and land is a scarce resource. Land set aside near substations for the exclusive installation of solar cells will have to deal with other land-based needs.
- Considering India's limited financial capabilities, funding projects such as the National Solar Mission is a challenge. The Finance Ministry has expressed reservations about financing a large-scale program like NSM. Manufacturers are mostly based on export markets, which purchase Solar PV cells and modules at a higher cost, allowing them to increase revenues. Many new manufacturers have established partnerships with foreign players in Europe and the United States, putting export demand first. This might lead to a shortage of goods for the rapidly expanding local market.
- The need for concentrated, collaborative, and goal-driven R&D to help India achieve technology leadership in PV, as well as a lack of stronger industry-government collaboration.
- To boost the PV industry and the usage of PV goods, better financing infrastructure, models, and arrangements are needed.
- Human capital planning and training to promote market growth and PV adoption.
- The importance of inter-industry collaboration in extending the PV supply chain, exchanging technological knowledge through conferences and meetings, partnering with BOS (balance of

systems) suppliers, and collecting and publishing reliable market statistics, patterns, and forecasts.

- The need to raise market understanding of technology, its economics, and its proper use.
- The complexity of the subsidy system, as well as the participation of so many entities such as MNRE, IREDA, SNA, the power board, and the electricity regulatory commission, makes solar PV project implementation challenging.
- The Generation Based Incentive scheme needs a lengthy process for land allotment and PPA signing.

It is suggested that solar energy goals be linked to current missions such as "Make in India," "Smart City Project," and "Digital India" as a pledge for improving capabilities and transforming the country's entire power grid. Future priorities should include the creation of 'Grid ready' off-grid services for rural and remote areas, as well as the adoption of 'Rooftop ready' by-laws for modern grid-connected buildings. It will only be a matter of time before India becomes a global leader in solar energy if these initiatives are carried out as planned.

Conclusion and recommendations

There is a serious power shortage in India. It needs major capacity expansions to satisfy the demands of its rapidly expanding economy. Solar energy production, which is indigenous and distributed and has a low marginal cost of generation, will help to improve energy efficiency by diversifying supply, reducing reliance on imports, and reducing fuel price volatility. Solar energy production in India can also be a useful tool for boosting regional economic development, especially in many underdeveloped states that have the greatest potential for developing solar power systems, which are renewable and limitless sources of energy. It will ensure a steady supply of electricity to support domestic industrial growth. As a result, photovoltaic power systems will play a significant role in future energy not only in India but across the world.

Policy and regulation

In its legislative structure for solar energy, the MNRE should provide a detailed action plan or strategy for the promotion of the solar industry. Within a set timeline, the action plan should be prepared in coordination with the country's SERCs, and the policy/action plan can be implemented. The federal and state governments should have a "Must run status" in their policies and strictly adhere to it to maximize the use of solar energy. In India, RECs can only be traded on a stock exchange. Trading over the counter (OTC) or off-exchange has the

potential to increase market participation. A REC forward curve would provide market participants with additional pricing information.

Financing the Solar sector

The government should focus on R&D and set aside a surplus fund for this purpose. In 2017, an INR 445 crore budget was allocated, down from an INR 272.85 crore budget in 2016. The original allocation for 2017–2018 was INR 144 crore, which was decreased to INR 81 crore in the updated figures. Even if the decreased funds could not be entirely used, there is a pressing need for ongoing oversight of R&D and budget allocation. The introduction of the Goods and

Service Tax (GST) in 2017 exacerbated market efficiency, resulting in cost increases and posing a challenge to the profitability of existing programs, eventually impeding goal achievement. These GST questions must be resolved.

Improvement in manufacturing/technology

The nation should shift its industrial base to the domestic market. It imports 90% of its solar cells and modules from Malaysia, China, and Taiwan, so developing a strong domestic manufacturing base is critical. It is essential to develop a robust manufacturing strategy. This will help lower capital costs which could be sold all over the world. To establish rapid use of solar power, encourage the sharing of ideas between business, academia, and policymakers from around the world.

Renewable energy hybridization

For efficient use of transmission networks and land, the country should concentrate on hybrid power projects. India should propose incorporating battery storage into hybrid ventures to help optimize supply and electricity at affordable costs while also reducing variability. Develop mandatory guidelines and rules for hybrid systems, which are currently lacking in recently announced legislation (wind-solar hybrid policy on 14.05.2018). The efficiency of renewable energy can be improved by combining two or more renewable systems with traditional power source battery storage.

Solar Energy Awareness

Solar energy also has a long way to go in terms of social acceptance in urban India. The most important element in the widespread and uniform use of solar energy is public awareness. Solar

energy and its environmental advantages should be made known to the general public. The government should hold regular awareness programs across the world, especially in villages and remote areas like the islands. The government should create more educational/research institutions to aid in the dissemination of information about new technologies in society. People should be educated in innovative methods that can benefit the city daily.

The solar industry faces significant challenges. Others are intrinsic to all renewable technologies, while others are the product of a warped regulatory system and sector. The implementation of technology is hampered by the lack of robust policies and regulatory mechanisms. To attract investors to the solar energy industry, clear policies and legal procedures are needed. Because of a lack of consistent policies, the approval of private sector proposals is taking longer. The

government should take steps to entice private investors. R&D can be used to overcome insufficient technology and the lack of facilities needed to develop green technologies. More funding should be available from the government to promote science and advancement in this field. Since there is insufficiently qualified staff to prepare, show, sustain and run solar energy structures, organizations should be pragmatic in their workforce preparation. When compared to domestically made machinery, imported equipment is more expensive.

References

1. B.Eker, "Solar powered water pumping systems". Trakia Journal of Sciences, vol.3,

2. B.R. Singh and O.Singh, ",Future Scope of Solar Energy in India". Proceedings of International Seminar on Sources of Planet Energy, Environmental & Disaster Science: Challenges and Strategies,2016.

3. Development of Renewable Energy in India: An Industry Perspective, in Renewable Energy Policy and Politics: A Handbook of Decision-Making

4. Global trends in renewable energy investment 2018, Bloomberg new energy

5. Government of India. Annual Report 2009–10. New Delhi, India: Ministry of New and Renewable Energy, Government of India; 2010

6. Government of India. National Electricity Policy 2005. Available: http://www.powermin.nic.in

7. Karan Kapoor, Krishan K. Pandey, A.K. Jain, Ashish Nandan , Evolution of solar energy in India: A review

8. Karan Kapoor, Krishan K. Pandey, A.K. Jain, Ashish Nandan , Evolution of solar energy in India: A review

9. Ministry of Power. Available: http://www.powermin.nic.in

10. MNRE. Annual Report, New Delhi; 2006

11. Mohit Goyal , Rakesh Jha, Introduction of Renewable Energy Certificate in the Indian scenario

12. Pandey S, Singh VS. "Determinants of success for promoting solar energy in India," Renewable Sustainable Energy Review

paper_2017.pdf.

13. Press Information Bureau, Government of India, Ministry of New and Renewable Energy, New Delhi,2018.

14. REMAP, renewable energy prospects for India (2017), The International renewable energy agency (IRENA). Available at

https://www.irena.org/media/Files/IRENA/Agency/Publication/2017/May/IRENA_REmap_India_and Sustainable Energy

15. "Technology Roadmap: Solar Photovoltaic Energy, 2014", International Energy Agency (IEA), (2018). Available at http://www.iberglobal.com/files/2018/renewable_trends.pdf
16. Vikas Khare (2013) Status of solar wind renewable energy in India Renewable