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A Perspective Study and Remarks of Solar Energy System in India

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Abstract – The fact that electricity generation and energy consumption are the key assessment of countries' development, there is constantly a link between the availability of energy resources and the growth in the economic dimension of a country. Besides, the way of life of an individual relies upon the per capita energy utilization. Thinking about India's desire to make sure the energy security, sustainable energy sources like solar, wind, tidal and biomass contributes significant job in the energy blend of the nation. The advancement in power generation began in the later 19th century and many power stations have been charged by the ministry of power (MoP) with the association of central electricity authority (CEA) after independence. At present, 65 % to 70 % of global energy requirements are satisfied by the thermal power plants which enhance the demand on fossil fuels and thereby impacting the ecological corruption through the emission of green house gases. Sun powered new energy has been recognized as one of the key sustainable sources to replace the conventional fossil fuel generation and decrease the carbon impression in India. Indian government has initiated the establishment of 100 GW on-grid and off-grid solar power plants by 2022 under Jawaharlal Nehru National Solar Mission (JNNSM), trusting the huge available potential across the country. Accomplishing this task is a great deal of challenge for the community. In this proposed study, authors surveyed the economy of solar energy potential, technological advancements and capacity inclusion in India comparing the global existence. Also this paper is organized in an approach to declare the necessities, accessible source, present situation, challenges and opportunities, targets of the solar energy sources in India.

Keywords: Sustainable energy, solar energy, fossil fuel, challenges and opportunities, green house gas

1. Introduction

Because of the modernization of human culture, the interest for electrical energy has expanded exponentially. The power derived from the sun and wind becomes the hopeful and smart solutions by all accounts and is receiving more considerations in research and industrial networks [1]. Concern towards the sustainable development and secure for energy, alternate resources are receiving the critical significance in India including worldwide [2, 3]. Amidst all the green energy resources, solar power fills in as a viable technology for the large scale of

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power infiltration and creates hope in the diverse applications. Solar energy technologies are the inexhaustible assets in account of their ever-increasing yield efficiency and capability to be employed in assortment of areas [4]. Unlike other conventional energy sources, India is bestowed with an enormous potential of solar irradiance. It is predicted that almost 55 % - 60 % of the nation receives an annual average solar insolation of 5 kWhr/m^2/day which helps to cater the growing electricity demand in a decentralized, productive and convenient way. As per the statistics and report of National Institute of Solar Energy (NISE), sun powered energy has an estimated potential of 748.98 GW_{peak} throughout the country. Interestingly, it becomes easier in accessing and makes the sun-based resource available even in remote locations of India. After the instigation of JNNSM, solar power has acquired the genuine importance widely and from then on, the growth is scaling up [5]. The power shared from the solar energy was 3 MW in 2008 which slowly mounted to 3.74 GW by 2015. The target was driven to set an installed capacity of 100 GW to be achieved by 2022. A few investigations pointed out the hindrance behind the objective set by JNNSM. Nevertheless, government and its administrative wings worked over the years to conquer the obstacles and acknowledge the opportunity in the exceptional growth towards 100 GW achievements. If this circumstance prevails, India's market of coal share certainly falls from 75 % to 55 % nearing by 2040 and on the contrary, renewable resource will have domination in the contribution graph approaching 60 % of share as it is 30% currently. It is prognosticated that the carbon emissions from the power sector may radiate around 80 g CO_2/kWh while it is 515 g CO_2/kWh as on date [6].

Table 1. Global solar PV and solar thermal power installed capacity [7]

Top ten - Solar PV installed countries (GW)										**World Total (GW)**
China	US	Japan	Germany	**India**	Italy	UK	Australia	France	Republic of Korea	
176.1	62.4	56	45.3	**32.9**	20.1	13	11.1	9	7.9	**505**
Top ten - Solar thermal power installed countries (MW)										**World Total (MW)**
Spain	US	South Africa	Morocco	**India**	China	UAE	Saudi Arabia	Egypt & Algeria	Iran	
2,304	1,738	400	366	**225**	220	100	50	20+20	17	**5,460**

Courtesy: Renewables 2019 Global Status Report [7]

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In support of aforesaid, International Energy Agency (IEA) also reported that the demand for fossil fuel may increase by more than 50 % by 2030 and the bureau predicted that the solar thermal power and solar photovoltaic (PV) system will bring about 11 % and 16 % of global energy consumption by 2050 respectively. The global cumulative PV installed capacity is 505 GW and solar power thermal capacity rounded to 5.46 GW during the year-end of 2018 as shown in Table 1.

The research put forth in this study attempts to portray the need of renewable forum for the future society and unsafe circumstances owing to the continuous exposure of green house gas emissions for the humankinds. Further the paper reveals the space for solar energy in driving towards the fulfillment of impending requirements. In the sections to come, major energy resources in India followed by the decades of development in solar energy are conferred initially, strategy imposed by the government, challenges and opportunities, future plans with concluding remarks at the end of the article, will be the complete organizing structure.

2. Energy resources in India

Energy is an innovation from the nature itself which goes as an essential hotspot for improving the standard of our lives [8]. The trends over the demand for fossil fuel are expanding every day and this pattern will be proceeded up in the coming scenarios globally. The major assets of energy in India are thermal power, nuclear, hydro and renewable energy resources. 17,450 TWhr was the global electricity generation in the year 2005, wherein coal and gas contributes to the maximum around 60 %, each of atomic energy and hydro power shares 16 % individually. To end with the renewable resources, only 2 % of the total power was contributed from solar, wind, small hydro and geothermal altogether [9, 10]. The impression was changed by the renewable in 2015 with a contribution of 23.5 % of total power (24,097.72 TWhr). Presently, India turns out to be the 3rd biggest among the world nations in the generation of power through sustainable energy resources and achieves 19 % of installed capacity only from the inexhaustible resources among the cumulative capacities in the country.

There is an enormous potential equal to 900 GW can be likely to access from the renewable resources. For this reasons, regional and central government regulatory bodies together with national institutes of solar, wind, biomass affords modernized plans and scientific assistance to overcome the issues in accessing the available potentials [11, 12].

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3. Solar energy status and state of affairs in India

Being a tropical nation, India has an immense solar vitality. Its topography permits the most provinces to get an infinite amount of sunlight consistently [2]. Nationwide inference through satellite and subsequent corroboration by ground data analysis ensures that the Indian territories are receiving an equivalent electrical energy of 5,00,000 TWhr approximately, with the largest part receiving 4–7 kWhr/m^2 per day. Rajasthan and Gujarat are the two states in India characterized with extreme global irradiance throughout the year [13]. Solar photovoltaic (PV) and solar thermal power are the broader classifications of sun based energy. Solar PVs are further classified into crystalline and thin film solar cells. The former one occupies 90 % of market whereas the later one resides in the minority segment of PV showcase, with most innovates outdated. Solar PVs has its own benefits and faults; however, PV technology is the only way to decarbonize the energy systems [14]. Since India stands third largest associate after USA and China in CO_2 emissions. It is realized from the study that lifetime CO_2 emission of a PV power plant is much lower than the emission of power generated by fossil fuel plant [15]. This is also due to the reality that most CO_2 will be given off from the solar power plant during the developing stage itself. Figure 1 obviously confirms the life cycle emissions of conventional and renewable energy sources, equivalent to tons of CO_2 per GWhr. Profusion of solar insolation, remote area or countryside electrifications and progression in the markets has prompted the significant approaches and policies in solar energy system over the years [16, 17].

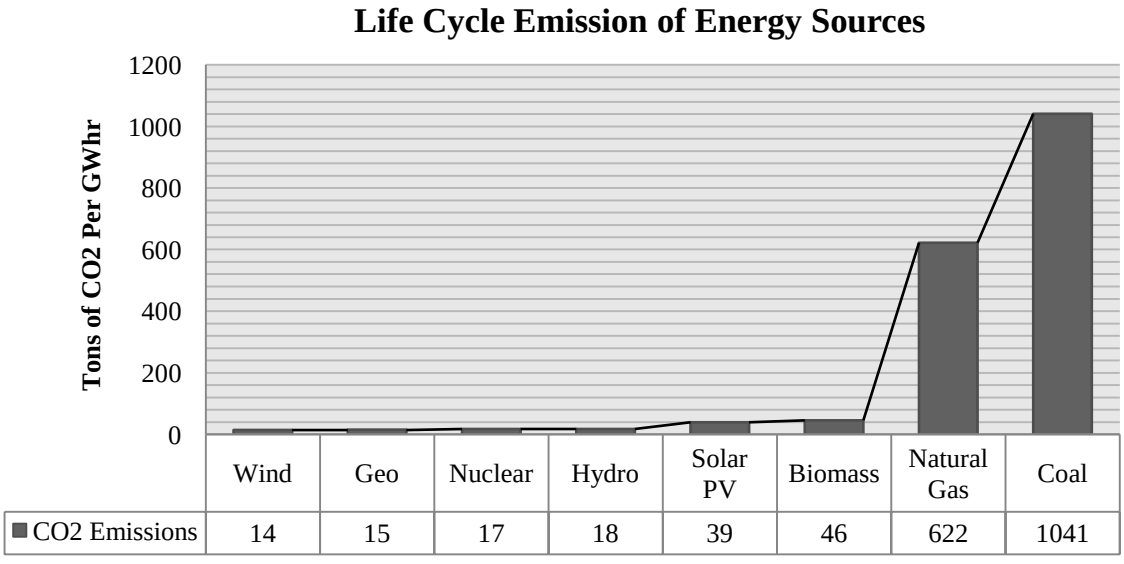

Figure 1. Life cycle emission of energy sources

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The historical progress in the development was invigorated after the country's independence, through its Five Year Plan (FYP). A planning commission was formed to look after the regular updates and implementation of schemes. The instigation of first FYP was made in 1950s, despite the fact that sun based energy was accepted as a technology in their 3rd FYP i.e., (1961-1966). It was originally in the sixth FYP (1980-1985), the commission explicitly proposed the significance of sun powered vitality and deputes the department of Non-Conventional Energy Resources with an aim to offer fund and subsidy to explore and exhibit the field of renewable energy technology [18]. Nationwide programs are conducted and sorted out with a goal to improve the productivity of the solar cells for the maximum power generation. There was a striking improvement in the solar power during the 7th and 8th FYP which paves the rural electrification for 10,000 remote villages. The 9th FYP involves a great deal in the production and sale of solar power at sensible tariffs to any outsiders in the country from the private sectors. During its 10th FYP (2002-2007), central government has come up with an expectation of 140 MW all the way through integrated cycles, village energy security and furthermore for the research in material innovations conceded by the Council of Scientific and Industrial Research (CSIR). Containment of green house gas emission is the aspiration of 11th and 12th FYP and significantly it is greeted by the population. The objective of 13th FYP leads to the installation of 20 GW energy security scheme in 3 phases under JNNSM [18]. National Institute of Solar Energy (NISE), Department of Science and Technology (DST), CSIR and centrally funded research institutes are continuously undertaking the huge ventures in research based activities. There has been a colossal development for the solar PV system in the present decade having an aggregate of 505 GW as on December 2018 but it was 5.1 GW in 2005. India holds the fifth place with a contribution of 32.9 GW installed capacity and China drives the graph with maximum installations (176.1 GW). The solar thermal collectors reached 5,460 MW global capacity by the year end of 2018, wherein India's position was five with 225 MW installations [7, 19].

In evident of the available potential, Indian government has set-mark a huge target for harvesting the renewable energy. "175 GW by 2022" becomes the renewable slogan, which comprises of 60 GW from the wind, 5 GW of small hydro, 10 GW of biomass energy and 100 GW alone from the solar power plant [12, 20]. The annual average solar insolation in India is exposed in Figure 2. This paper therefore sought to survey the worldwide significance of solar

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power and India's insistence to build up the business sectors. Still 97 % of the preferable zones are needed to be addressed for the current obstacles and shifting towards the market growth.

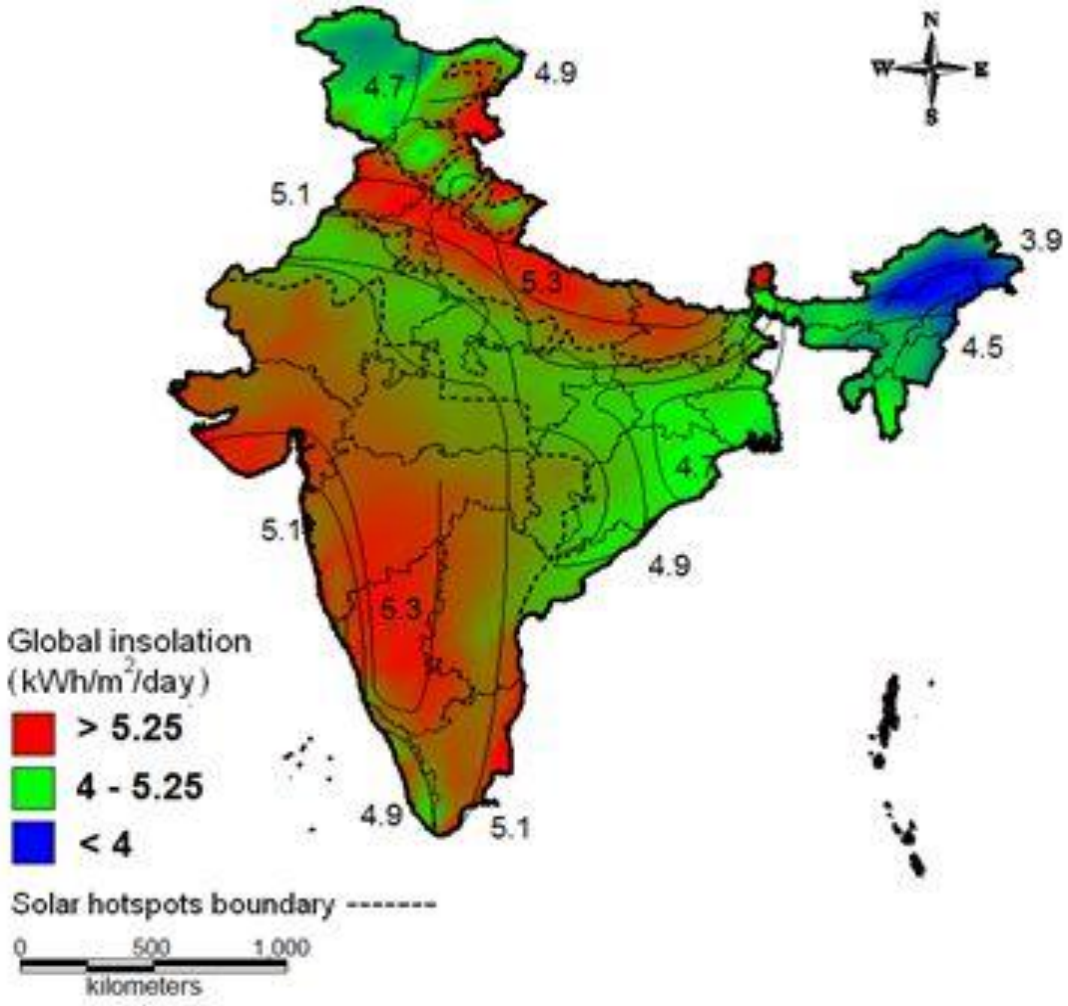

Figure 2. Annual average solar irradiance in India with hot spot boundary (Courtesy, IISC Bangalore)

4. Challenges and barriers for the deployment of solar energy

The plenitude of the potential single-handedly cannot develop the solar power generation. A number of factors end up being an obstacle to instigate the solar plant and drive them at their rated capacity. The different moves that should be accomplished to achieve target expansions are given under following captions.

4.1 Financial Barriers

Preliminary expenditure spend towards the solar PV installations directs dissuasion among the investors and made them to give up the idea [21]. Lack of financing mechanism is the

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hindrance to the advancement of solar PV installations. Interestingly, research demonstrates that the speculation essential for the PV installations are intended for developing the nation under different factors. Despite the fact that PV installations are less expensive in the developing nations, factors like auxiliary equipment cost, manpower, safe ventures and so forth have a prompt role up to the last part. Some exploration proposes that there are worries among specialists over the procedure of auction-based PV acquirement as the task may lead to low quality ventures [26,27,28]. Intervention of business sectors retreats the price and quite often directs the developers to abandon the project. In spite of various tax benefits proposed on solar powered innovations, tariffs are still an obstacle for the low cost developments. The cost of a solar based PV system accounts the expense of panels, energy storage unit, power converters and so forth. This will further add the investments and by this means dispirit the customer interests towards the technology. The national banks represent a major source for financing the solar power projects in India but these banks debt at a much higher rate when comparing with other developed nations [1].

4.2 Technical Barriers

Regardless of the fact that the sun powered PV technology has taken a colossal jump with regards to the innovations, it hasn't demonstrated itself to be more efficient. Even though the government is initiating so many policies and the system is progressing towards the achievement, conversion efficiency of the solar PV technology remains the prevalent challenge in the development of solar energy systems [20]. Subsequent impediment is that the solar PV system can hardly provides instantaneous response to the load demand but it will not occurs in conventional power plants which craft them progressively powerful. This drawback in renewable system can be met with the help of energy storage unit under standalone mode which can able to supply the demand for several autonomy days without expanding the cost and size of the plant. Ample assortments of PV innovations are accessible in the market, whereas in any case, competency is extensively low in judging against the conventional power plants. A few investigations additionally portrays that the intermittent nature of solar irradiance, influence of panel under partial shading conditions, component efficiency and failure affects the performance of the entire PV system. Imbalance in panel output due to the high temperature effect results in hotspot which abruptly reduces the efficiency of solar PV system [22].

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4.3 Environmental and social barriers

Although solar energy comes under the clean and vital resources of electric power, some literatures point outs the ecological allegation caused by the manufacturing process of PV panels over the years. Besides, many studies reveal the environmental after-effect and impact occurs during the way towards the assembling of PV boards. This may happens due to the harmful mix up of the chemical extracts like cadmium telluride and copper indium selenide in the innovation of solar thin film technologies. E-waste also will turnout in the long run exercise of PV panels and batteries, moreover its recycling stays a big challenge to the environment and mankind [23].

The awareness towards the renewable energy has been still low for the nations like India having an incredible populace. The proposed initiative, underlying process and capital investments eventually makes to surrender the recommendations. Confusions and vulnerability in technology, fiscal plans and cost benefits will certainly moves the technology towards the back. Ministry of New and Renewable Energy (MNRE) is frequently conducting the "Information and Public Awareness Program" to disperse the facts and benefits of the inevitable energy resource, job opportunities, logical advancements and special endeavors in the solar energy sectors [24].

4.4 Regulatory issues

The club needs the regulatory issues imposed for the solar power to have a fundamental comprehension of the plan, improvement and execution of sustainable power system. Appraisal of weather forecast, assessing the complimentary government policies, cost recuperation plans for interfacing the remote site into the framework, cost analysis and administering of net-metering are the explicit factors which propose the solar energy market development in India [25].

5. Strategic steps and suggestions

Solar technologies in India are well positioned to meet the growing energy demand for the next few years as the solar potential availability is boundless with the smart policy support and technology frameworks. Aforesaid in the earlier section, countrywide energy demand is receiving higher and higher everyday and so as to fulfill the needs, Indian policy makers at the national and regional level need to mobilize the cost effective group effort of different levels of

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the government. Accomplishing a 100 % inexhaustible renewable based system ought to be an objective for strategy developers in the coming year. Simultaneously, the strategy can be implemented in a cost-effective way compared to conventional fossil fuel systems. Over the earlier two decades, a few strategies have been brought to hasten the development of solar energy and thereby reduce the reliance on the existing power plant for the needs of the nation. Since India is populated more in the rural part, the policies are framed in such a way to electrify the villages and conceding adequate facilities through the resources. The concept of rural electrification significantly helped the government to achieve the target. Pertaining to the report of government, 100 % rural electrification was achieved. But some autonomous report submitted by the secret agencies disclosed that the figures are not realistic and most villages are still unelectrified.

Of the substantial quantity of approaches, none have focused to the core in the development of solar based PV network other than JNNSM. Put for a 10 year period with unprecedented goal, this approach to solar energy development has been extremely doing well in boosting the installations throughout the country. By the end of 2018, the overall installed capacity of on-grid and off-grid solar PV plant in the country was 26 GW under this mission. Assortments of plans are executed under JNNSM with an aim to deploy the available resources to surpass the target of 100 GW. In alongside to state wise schemes for JNNSM, central government also additionally strides in achieving the phenomenal target. Public sectors and several ministries have been given mandates to actualize the grid and off grid solar PV forum on municipalities and civic societies which further motivates the private developers and common people to establish the PV environments in their arena.

Table 2. Barriers and recommendations for solar energy generation

Challenges	Variables	Recommendation
Land	• Lack of land availability • Complex zone areas • Lack of data, title, ownership in solar prone zone	• Power generation from PV consumes a lot of surface area. • Housetop is the measure to overcome the land related barriers. • Building integrated solar plant has a solution using thin film technology.

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Economy	• Risks under pre-investment • Cost of supporting accessories and battery • Generation expenditures	• Banks should be more flexible in offering loan for the lenders for PV installations • Credit security system can be initiated for ease in access of money from third party and pay back by the borrowers in default
Policy and regulatory	• Issues in transparency of policy • Insufficient legal support for several policies	• Legal guidelines and adequate support should be given for the private investors • Creating awareness and provide ample information like net metering, PV markets, subsidy, service and maintenance among the consumers
Technology	• Conversion efficiency • Intermittent nature of source and storage problems	• Focus towards concentrated solar PV system in a way to enhance the performance • Research in huge venture should be undertaken by solar missions and the institutes of national importance

In addition to large scale power generation, confined generation of solar power from rooftop PVs, floating PVs, solar pumps and lanterns are likewise being treated as a solution for long standing energy issues. With huge water bodies encompassing India, floating PVs can be used not only to engage the offset land accessibility but it gives an answer for temperature rise issues in PV panel with the progression of water as a natural coolant, yielding high energy output. The regular flow of water over the surface of the PV board takes away the dust or unwanted sediments which is generally causing the poor conversion efficiencies. While the wealth of the water bodies around the nation can helps in facilitating the solar power plant installations, the absence of water in areas where the PV plants are sited causes a significant issues as normal cleaning and upkeep is not feasible. Another hindrance to the expansion of solar market is the imposition of protection tariffs on import of components and resources for solar PV plants. This has dispirited the investors and developers to step into the solar energy market.

The recommendations exemplified in Table 2 helps to overcome the impediment faced by the sun powered technology. The topographical position of India's land mass retrieves surplus solar irradiance wherein the states such as Rajasthan, Gujarat and Maharashtra receive the maximum which has enough assistance to achieve the objectives of 2022. Housetop generation provides response for the scarcity of land which contributes both electricity and thermal power giving

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consumers the chance to become independent, pecuniary benefits etc. Solar energy can be a best option for fossil fuels provided by implementing stringent policies for housetop production and adhering to those policies. The stockholders and investors should have awareness about budgetary guide for MSME's (Micro, Small and Medium Enterprises) so as to overcome the financial constraints and barriers. While tending to address the problems of solar power generation, it is must to address the possibilities and benefits of solar power generation. Energy security is a factor that can undermine the development of any nation. Solar energy environment is the only solution for secured energy and course of action for the developing countries.

6. Conclusions

India is confronting an emergency crisis due to the transition headed for urbanization and shortage of electricity for the millions of household over the past decade. The total power requirement is expected to be inflating around 400 GW by the year end of 2020. To meet the surplus demand and to keep progress in the energy market, there is a huge need for capacity additions. The progress towards the sustainable environment repays the energy demand as well as minimizes the green house emission by the factor of 5 to 50 % within a year. Because of the immense potential and inalienable qualities of solar power, the commission has given greater emphasis on promoting the solar frameworks, since only less than 3 % of total potential is used as on date. Striving targets of solar power can be justified by the active strategies of the state and central government. On the top, government is putting a considerable degree of push on "Made in India" to cut down the expense of solar power technology. Prediction and estimation of solar power was one of the restricting parts earlier, yet the situation is evolving. The authors in this proposed review have significantly analyzed the difficulties in the zones of available resources, policy developments, financial requirement and consumer awareness. The paper also talks about the vital activities that must be taken to address the current difficulties and turns them into chances.

- ✓ Despite of acceleration in the development of solar energy, huge steps have not been taken for housetop power generations.
- ✓ Technological advancements, solution for long standing issues in land availability and finance will literally be the hindrance for solar PV installations.

- ✓ Educational initiatives, research centers and schools were established with an intention to explore the innovations and skills in the field of sustainable energy resources.
- ✓ JNNSM is the most productive strategy proposed by the policy makers with an aim to promote the energy production.

The pinnacle of policies around the nation has empowered its prosperity. With an identity as a tropical country, India has a large market base with smart and inventive schemes and becomes the pioneer contributor in global energy market.

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