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Shining a Light on the Future: Present Scenario of Solar Energy, Opportunities and Obstacles of Solar Energy Start-ups in Uttar Pradesh

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Abstract : Energy is the driving force behind all activities and plays a crucial role in creating wealth. Currently, our energy supply is heavily reliant on fossil fuels, leading to harmful effects on the environment such as atmospheric pollution, ozone layer depletion, and the greenhouse effect. In order to secure a better future for generations to come, it is imperative to focus on sustainable development that nurtures the environment. This paper will concentrate on the current scenario of the solar energy and the future of startups in this sector, as solar power is the most abundant, practical, and cost-effective among other renewable energy sources. According to the United Nations Development Programme's 2000 World Energy Assessment, the potential of solar energy is several times larger than the world's total energy consumption. India, in particular, has great potential in solar energy due to its high direct normal irradiance, making it a key player in the renewable energy market. The solar energy industry in India is rapidly evolving, presenting significant opportunities for new businesses and entrepreneurs due to the government's ambitious targets and supportive regulations. However, some obstacles to the widespread adoption of solar PV technology include dependence on sunlight duration and intensity, lack of awareness in rural areas, high installation costs, disposal of toxic chemicals used in solar cells, inconsistent performance in different weather conditions, and the need for alternative power sources for continuous supply.

Keywords – Sustainable Development, Renewable Energy, Entrepreneurs, Clean Energy, Non-fossil fuels, Solar Energy Start-ups.

INTRODUCTION

Energy is the driving force behind all types of activities and plays a crucial role in generating wealth. As human life advances, the need for energy is growing significantly. Economic activities of all kinds are expanding due to population growth. The world is moving towards a technological revolution to facilitate multidimensional development. With billions of population increase in just one generation, the supply of energy must also increase in proportion to consumption. Energy is essential for various economic activities such as production, distribution, innovation, consumption, mining, and construction. Currently, the majority of energy supply relies on fossil fuels, but this trend must be reversed as the harmful effects on the environment are becoming increasingly severe. It is important to prioritize sustainable development to ensure the well-being of future generations and the environment. Available energy resources are depleting over time, and preventing an energy crisis is one of the major challenges of the 21st century. Therefore, the most effective way to meet current and future energy demands is to embrace renewable energy sources, which are abundantly available in our environment. As a result, policy-making is now focused on managing the environmental and social impacts caused by the detrimental effects of fossil fuels by adopting renewable energy sources. This is due to the fact that fossil fuels are limited in availability and will eventually be exhausted, they produce greenhouse gases and pollute the environment, while renewable energy sources are inexhaustible, freely available, and environmentally friendly. Approximately half of the carbon emissions in India are generated by the power sector. As a result, renewable energy sources are gaining attention and importance from governments, scientists, experts, and investors worldwide. There are various renewable energy sources, such as hydro power, wind power, biogas, and solar power. This paper specifically focuses on solar energy with special reference to Uttar Pradesh because solar power is the most abundant, feasible, practical, and economical source of energy among all renewable sources. Solar energy can be defined as energy generated from solar radiation.

Solar energy has the potential to provide energy security and independence to everyone, as it can be produced anywhere without the need for a grid transmission line or dependence on the government and utilities. Solar system installation reduces electricity bills as people can generate and sell their electricity to the grid. Solar photovoltaics (PVs) require low maintenance and typically have a lifespan of 25 years. Asian countries, due to their geographical locations, receive more sunshine throughout the year compared to other countries, making them ideal candidates for utilizing solar energy. **[22]** Solar PV has the highest capital cost among all renewable energy sources, but the lowest long-term operational cost. It produces direct current (DC) without the need for water to move turbines, does not contribute to noise pollution, and has low maintenance costs. **[33]**

LITERATURE REVIEW :

Zekai Sen (2004) concludes in his paper that solar energy is essential in reducing dependence on fossil fuels. He suggests that the oil price fluctuations in the 1970s led to increased research and development in the solar energy sector. The economic activities of a country play a crucial role in shaping its future, and the supply of energy is a crucial factor in this path. Countries that are self-sufficient in their energy supply have the advantage of unrestricted growth. Singh S. et al. (2010) argue that the quality of energy consumption determines the economic development of a region. Assessing the economic potential of renewable energy is important because economic conditions fluctuate rapidly over time. Sharma A. (2011) believes that energy is the main ingredient for the wealth and growth of a nation. He also acknowledges that while solar energy installation may be relatively costly initially, the long-term returns without higher maintenance costs justify the investment. M. Ragheb (2011) proposes in his paper that Nikola Tesla invented an apparatus to utilize radiant energy and filed a patent for it, which he claims was the inception of solar energy. The author argues that solar thermal power plants are more advantageous than solar photovoltaic plants. Sharma et al. (2012) assert that India has the capacity to generate a massive supply of renewable energy. They emphasize that the power sector contributes significantly to the carbon emissions of the country and scaling up the quantity of solar energy could help mitigate the environmental effects of air pollution. Jones et al. (2012) explore that the development of photovoltaics after World War 2 popularized the use of solar energy. They also researched that the ideas to exploit solar energy originated in ancient Greece and Rome, with subsequent advancements in France and America. Kapoor et al. (2014) argue that India is privileged with higher direct normal irradiance. They also note that despite the focus on renewable energy sources since the 1950s, major development in the solar sector took place after 2009. Palit D. et al. (2015) highlight the installation of microgrids in rural areas, which has helped improve the education and health sectors. **[27]** Singh, B.R. et al. (2016) suggest that India's per capita power consumption is significantly lower than the world average. They also suggest that India's vast wasteland areas can be utilized for generating solar energy without encroaching on agricultural or residential land. Kannan et al. (2016) emphasize in their review that the exponential growth in population within a single generation is accompanied by increased industrial revolution and economic activities, which create a high demand for energy. They focus on the repercussions of current fossil fuel usage to address the rising energy demand and suggest shifting towards abundant renewable energy sources in our environment. Barai R.M. (2017) emphasizes the importance of renewable energy sources in achieving sustainable development goals. The annual solar energy emissions from the sun far exceed the total global energy demand for a year, showcasing the significance and potential of solar energy. Kabir et al. (2018) explain in their paper that with advanced technology, the sun has the capability to meet the entire global energy demand. They particularly highlight the impact of solar energy on transforming transport systems, as it does not require transportation by vehicles unlike other energy sources. While government initiatives and incentives are aiding the development of the solar sector, factors such as the higher cost of solar panels, inverters, and batteries need to be taken into consideration. Ugli et al. (2019) emphasize the need for land space to harness solar energy, stating that approximately 1 square kilometer of land area is required to capture 1 GW of solar energy. Yadav P. et al. (2019) assert that sustainable energy is crucial in addressing the trilemma of economic growth, social development, and environmental protection. They also advocate for the installation of mini-grids in rural areas to fulfill electricity demands of households, primary health centers, schools, and other institutions. Ray & Roy (2022) note that India is currently connected to neighboring countries such as Bhutan, Nepal, and Bangladesh through a single power grid for electricity import and export. Additionally, Gulf countries like Kuwait, Bahrain, Saudi Arabia, and UAE are interconnected in a grid, indicating the feasibility and practicality of the 'One Sun One World One Grid' initiative from both technical and economic standpoints. **[31]** Singh A. et al. (2022) found that in India, solar and wind projects are easily considered "green" because they help in reducing greenhouse gases, which leads to exemptions from regulatory authorities who would otherwise review the social, economic, and natural values of the land. However, without careful planning, these land-intensive renewable energy (RE) projects could negatively impact local communities, contribute to food scarcity, and harm biodiversity. The current total wasteland area in India is around 56 million hectares, out of which the total wasteland area in Uttar Pradesh is 1.698416 million hectares.**[36]** Vanak & Nair (2023) suggest that cooperation among various inhabitants of our ecosystem is crucial, and transitioning to green energy should not come at the cost of vital ecological resources such as open natural ecosystems. Hence, governments and policymakers should be cautious when classifying wastelands for construction projects to preserve these natural ecosystems from unnecessary conversion and disruption of their physical characteristics.**[46]** Rao M. (2023) reminds us that 600 square kilometers of land in Kutch, Gujarat, and 950 square kilometers in Jaisalmer, Rajasthan were classified as wasteland suitable for energy projects. However, environmental specialists raised concerns, claiming that these lands have high biodiversity and wildlife value.**[1]**

RELEVANCE AND IMPORTANCE OF THE SOLAR ENERGY :

The relevance and importance of solar energy is undeniable, especially in the context of India's commitment to generating 500 GW of renewable energy by 2030, with a significant portion expected from solar and wind projects. The "One Sun One World One Grid" initiative aims to connect the world through a single grid, initially focusing on transmitting solar power and later expanding to include

other renewable sources. This ambitious plan addresses the challenge of solar energy generation at night by ensuring continuous availability of sunlight across the connected grid.

India's vision to become a developed nation by 2047 includes targets for energy independence and achieving net zero carbon emissions by 2070. This underscores the essential role of solar power in reducing dependence on fossil fuels and combating environmental degradation, ozone depletion, and increasing energy demands.

Physical Infrastructure of the solar sector of India:

India still faces supply chain disruptions in the solar sector due to the reliance on imports from China for a major part of solar equipment, including cells, modules, glass, encapsulate film, back sheets, aluminum framing, and machinery needed for cell and module production. However, the Government of India is optimistic about creating a self-reliant ecosystem in the solar sector for energy generation. Several institutions have been established by the government to work towards achieving policy goals. The Ministry of New and Renewable Energy (MNRE) is the central authority responsible for various functions related to the renewable energy sector. Under the authority of the ministry, five bodies have been set up to implement programs for different objectives:

- National Institute of Solar Energy: Located in Gurugram, it is a focal point for technical research and development in the solar energy sector.
- Solar Energy Corporation of India (SECI): This is the implementing and executive arm of the Government of India for the development of the renewable energy sector in the country.
- Indian Renewable Energy Development Agency Limited (IREDA): Established as a non-bank financial institution, IREDA promotes, develops, and extends financial assistance for setting up renewable energy projects. **[24]**

Digital Infrastructure:

- National Portal for Rooftop Solar: This portal aims to simplify the procedure of installing rooftop solar systems, providing information about the project, and ensuring proper dispersion of subsidies.
- HRD Portal: An online platform that accepts applications for short-term training and skill development in the renewable energy sector.
- Concessional Custom Duty Certificate (CCDC Solar Portal): User interactive online portal to assist solar power manufacturers.
- Research and Development Portal: An online platform for the submission of renewable energy-related R&D proposals.
- PM KUSUM Portal: This portal monitors and implements the PM KUSUM scheme for farmers.
- Akshaya Urja Portal: Provides information about state-wise power potential, monthly installed capacity, and power generation of renewable energy sources.

India’s Solar Energy Potential:

Narendra Modi, the Prime Minister of India, is considered the chief architect of the International Solar Alliance (ISA), which was established after the Paris Declaration in 2015 to promote solar energy. The alliance brought together 121 nations to commit to solar energy promotion. To inspire the globe to promote the solar sector, the headquarters of ISA was set up in Gurugram, Haryana. India possesses significant direct normal irradiance, providing potential to lead the renewable energy market. With an average annual temperature ranging from 25.1 ℃ to 27.51 ℃ and receiving almost 3000 hours of sunshine throughout the year, India holds immense solar energy potential. The country has emerged as a global leader in renewable energy, demonstrating its commitment to sustainable energy for sustainable development.

The National Institute of Solar Energy (NISE) has assessed the country’s solar potential to be about 748 GW, assuming 3% of the wasteland area to be covered by Solar PV modules. The Indian government has set ambitious targets to tap into this potential, with a revised goal to achieve 500 GW of renewable energy by 2030.

India has achieved the 5th rank in the world in solar power deployment. According to the Ministry of New and Renewable Energy (MNRE), the solar power capacity of India increased by 7526.15 MW in the financial year 2023-24, between April and January, totaling 74306.52, which is approximately 30 times more than the capacity in 2014.

Different sources of solar energy:
- Ground Mounted Solar Plant: 57.82 GW
- Grid Connected Solar Rooftop: 11.08 GW
- Hybrid Projects (Solar Component): 2.57 GW
- Off-Grid Solar: 2.84 GW

Table 1: All India total Solar energy generation:

Period	Total energy BU (billion units)	Total renewable energy (Million Units)	Solar energy (MU)	% of RE of total energy generation
Apr 2022 - Jan 2023	NA	316754.86	82214.50	21.31 %
April 2023 - Jan 2024	1453.04	309661.84	93328.05	30.14 %

Source : MNRE data

In 2023, the Renewable Project Monitoring Division of the Central Electricity Authority published a report claiming that renewable energy generation in India during January 2023 had increased by 34.87% compared to January 2022. Solar power generation during the same period saw a 40.52% increase compared to January 2022. The report also stated that 121.55 GW (29.53%) of energy was generated from renewable sources, with 63.89 GW coming from the solar sector alone. **[24]**

Table 2 : Top 10 solar projects of India:

Bhadla solar park (S.P.), Rajasthan	2245 MW
Pavagada solar park, Karnataka	2050 MW
Kurnool Ultra Mega S.P. Andhra Pradesh	1000 MW
NP Kunta, Andhra Pradesh	978.5 MW
Charanka Solar Park, Gujrat	615 MW
Reva Ultra Mega S. P. Madhya Pradesh	750 MW
Kamuthi Solar Park, Tamil Nadu	NA
Ananthapurm- II, Andhra Pradesh	446 MW
Galiveedu Solar Park, Andhra Pradesh	NA
Mandsaur solar farm, Madhya Pradesh	250 MW

Source: IB.solar.com

Gujarat leads the Indian states in solar-generated electricity capacity. The highest intensity of radiation falls on different parts of Rajasthan, Gujarat, Madhya Pradesh, Andhra Pradesh, and the Ladakh region, while the northeastern parts of the country receive the least amount of radiation. Rajasthan has the added advantage of vast wasteland in the form of the Thar desert, which is able to generate 142 GW power. Madhya Pradesh and Maharashtra each have a 60 GW power generation capacity through sunshine. Punjab and Haryana lack wasteland area due to extensive agricultural activities; therefore, canal and rooftop solar systems are appropriate in these regions.

According to the Ministry of Power, India's per capita power consumption has reached 1255 kWh in 2021-22, while the average per capita power consumption in developed nations is around 15000 kWh.

Uttar Pradesh Solar Energy Policy 2022:

The vision of the policy includes providing reliable and sustainable generation of solar energy in Uttar Pradesh and reducing dependence on fossil fuel-generated electricity. The policy also targets spreading awareness among the public and bringing investment opportunities in the solar sector for private participants. Uttar Pradesh is growing as an industrial hub. Therefore, the power demand of

the state is continuously increasing because energy is a significant factor in economic development. The state needs to generate additional electricity to cover its demand and reduce the financial burden of importing electricity. Being an agrarian state, the availability of land for solar projects is comparatively less in UP.

A subsidy of ₹2.5 crore per MW is given for projects above 5 MW power storage capacity. A 40 MW solar plant is being installed in Ayodhya Dham, covering 165 acres of land, under the Solar City program. 58 solar trees are installed in Ayodhya at different locations, with LED lights, shade, and branch-like design. In order to achieve net zero carbon emissions by 2070, 17 different government departments are required to pass all their projects based on some predefined environmental standards set at the international level, to avoid negative footprints of developmental projects in the long term.

The UP government targets to generate 22000 MW electricity from solar projects by 2027, of which 14000 MW will be from solar parks, 4500 MW from residential rooftops, 1500 MW from non-residential rooftops, and 2000 MW from PM Kusum Yojana. The policy also suggests installing solar projects on the sides of expressways, railway tracks, and on the top of any water body. The owners of the rooftop solar systems will benefit from facilities such as net metering, net billing, and gross metering. The state government also provides a subsidy of ₹15000/kW up to a maximum of ₹30000 for rooftop solar system installation. In UP, the Bundelkhand region is attracting numerous solar projects because the land in the region is unproductive for agricultural purposes, reducing the price of land significantly compared to other parts of the state. In Uttar Pradesh, Banda district is considered the most suitable location for solar projects. A solar park of 4000 MW capacity will be installed in Bundelkhand to make it an industrial city like Noida and greater Noida.

Solar Energy Potential in Uttar Pradesh: India is committed to achieving net zero carbon emissions by 2070. One of the milestones to achieve this is to generate 500 GW energy through non-fossil fuel sources by 2030. India's installed RE capacity was 120.9 GW as of 30 December 2022. Uttar Pradesh is India's fourth-largest state and contributes to 16.2% of India's population. The state's climate and power sector initiatives are bound to have a significant impact on the national targets. Uttar Pradesh has the potential to generate about 22.83 GW (3.04% of the country's potential) energy. According to the reply of the Environment Minister in Rajya Sabha, the total wasteland area in India was 557665.51 square km in 2021, with Uttar Pradesh sharing 8537.06 square km of vast area. This land needs to be properly exploited to meet RE energy demands. Uttar Pradesh has a total installed capacity of 29,858 MW from all energy sources. Around 72% of the installed capacity comes from thermal plants, which include coal, gas, and diesel. **[39]** According to the data of the Ministry of New and Renewable Energy (MNRE), the total installed solar power capacity of Uttar Pradesh as of 31-01-24 was 2782.83 MW.

Table 3: Solar energy generation in Uttar Pradesh over the last decade:

Year (As on)	Ground mounted (MW)	Rooftop (MW)	Off grid (MW)	Total (MW)
31-03-23	NA	NA	NA	2515.22
31-03-22	1851.50	258.78	134.15	2244.43
31-03-21	1455.25	257.25	123.77	1836.27
31-03-20	949	146.10	113.42	1208.52
31-03-19	844	116.10	87.33	1047.43
31-03-18	638.26	56.15	60.81	755.22
31-03-17	336.73		52.08	388.81
31-03-16	143.50		41.59	185.09
31-03-15	71.26		30.89	102.15
31-03-14	21.08		24.60	45.68
	NA			

Source: MNRE website data

Table 4 : Major CPSU (Central Public Sector Undertaking) plants of Uttar Pradesh and their capacity (Apr 2023- Jan 2024)

CPCU	Installed capacity (MW)	Generation MU(million units)
Unchahar solar	10	10.72
Singrauli solar	15	16.5
Dadri solar	5	4.74
Auraiya	40	54.30
Gurhah	75	6.83
Pearson Solar Power	75	122.54

Source : MNRE data

Solar Energy Investments in UP and the Achievements of UPNEDA:

In 2023, Uttar Pradesh hosted the Global Investor's Summit, which captured investments of ₹35 lakh crore. The solar power sector alone received ₹8.28 lakh crore of this total investment. UPNEDA claims that almost 125 projects worth ₹1 lakh crore have already commenced on the ground, with over 5000 acres of land allotted for solar plants. Companies like Bundelkhand Solar Energy Limited (BSEL), TUSCO, LSPDCL, and others have been allotted lands for their projects. Currently, solar power projects generating 2155 MW of power have been installed, and this energy is directly being sold to private firms, companies, malls, and plazas.

Under the Decentralized Distribution Generation scheme (DDG), remote and forest areas are being energized with solar packs. In 2023, 7000 households benefited from this scheme. Additionally, medical colleges and educational institutes in different districts, such as Lucknow, Kanpur, and Gorakhpur, are being equipped with rooftop solar plants, generating around 30 MW of energy. Furthermore, Ayodhya, as a model Solar City, is operating solar boats, solar trees, solar power-based cold storage, and solar charging EV stations.

To achieve sustainable energy goals, the state aims to generate 40% of its total energy demands from solar and other renewable energy sources in the upcoming years. Approximately 60% of the total solar energy in the state is extracted from the Bundelkhand region due to the availability of cheap wasteland and favorable radiation.

UPNEDA has plans to set up 4 large solar projects worth ₹ 35000 crore in Bundelkhand and Eastern UP. Additionally, a 3600 MW capacity off-stream close loop pump storage project has been sanctioned in Sonbhadra district. [39] This project, costing around ₹ 17000 crore, will be constructed by the Greenko Group. Furthermore, a floating solar park on Matatila dam in Lalitpur, generating 1000 MW of energy, has been allotted to TUSCO Limited at an estimated cost of ₹6500 crore. Bundelkhand Solar Energy Limited (BSEL) also has plans to set up a 1200 MW solar power park in Jalaun district, with an investment of ₹4800 crore. The state government will provide a subsidy for this project amounting to ₹20 lakh/MW or 30% of the total cost, whichever is less. ACMI Cleantech Solutions Private Limited will construct two off-stream closed-loop pumps in Prayagraj and Meerganj area. Additionally, the state government proposed to build a 50 MW floating solar park in the Bhakhira Bird Sanctuary. Under the Ultra Mega Renewable Energy Power Parks Scheme, the Ministry of New and Renewable Energy (MNRE) has approved 3 solar parks in Uttar Pradesh, which will be built by TUSCO Limited.

Table 5: Proposed projects of TUSCO Limited:

Project	Capacity	Commissioning period
Jhansi Solar Park	600 MW	May 2025
Lalitpur Solar Park	600 MW	May 2025
Chitrakoot Solar Park	800 MW	May 2025

According to Bundelkhand Saur Urja Limited web portal, BSUL is working on four proposed projects in the Bundelkhand region:

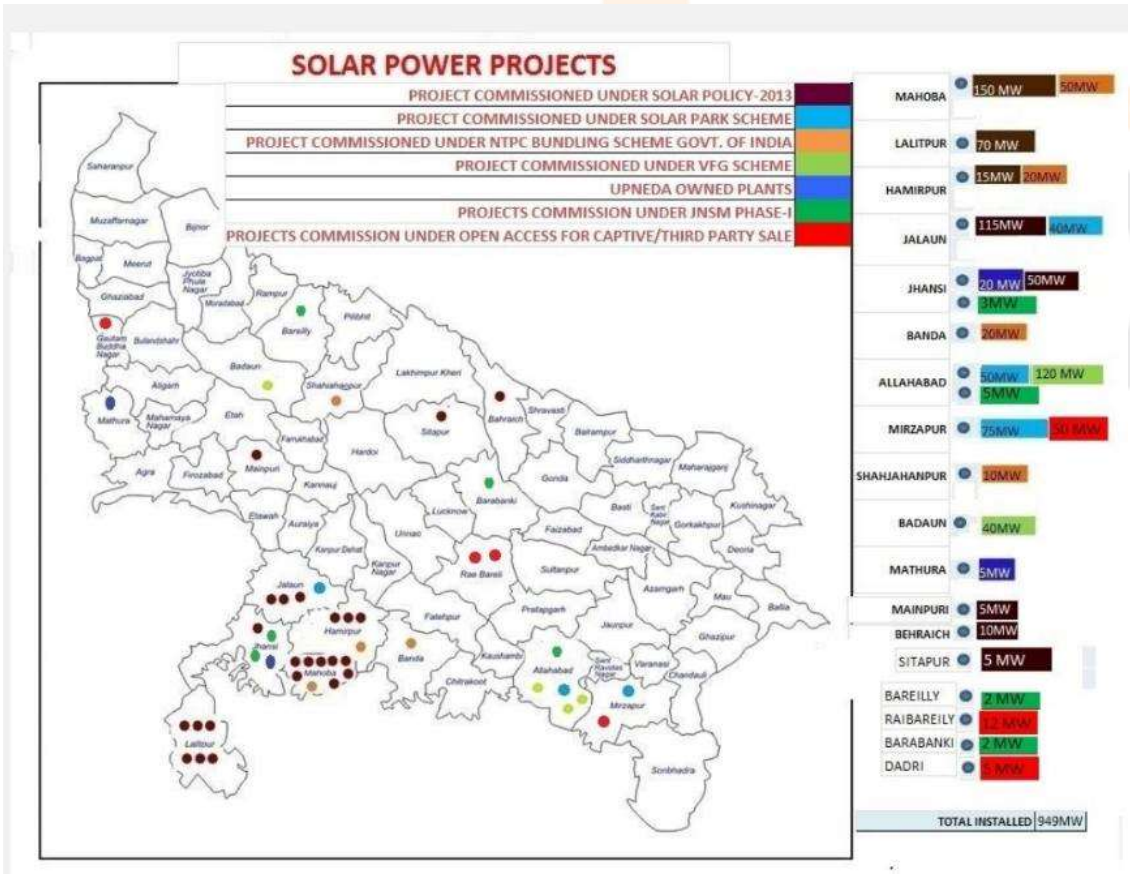
Table 6: Proposed projects of BSUL:

Project	Location	Power capacity	Electricity generation (MU)
Kalpi Solar Power Project	Jalaun	65 MW	148
Madhogarh Solar Power Project	Jalaun	45 MW	91 MU
Mirzapur Solar Power Project	Mirzapur	100 MW	202.49 MU
Jalaun Solar Park	Jalaun	1200 MW	2996 MW

Source: BSULindia.com

Despite several accomplishments, it's important to note that by December 2022, UP had only achieved 23% of its target of generating 10697 MW power. One of the major obstacles in reaching the solar power target is the lack of available land. The need for a large amount of land for big projects causes significant delays. However, the state government has initiated the creation of a land bank where suitable lands for such projects will be leased for a period of 30 years. UPNEDA will evaluate the land's characteristics, such as solar radiation levels, slope, elevation, distance to the substation, and proximity to water bodies. Government entities can lease land for ₹1/hectare per year, while private parties can lease land for ₹15000/hectare per year.

Source: UPNEDA Portal (the image is not updated recently)



Investment Scope - Leading to Economic Development:

Economic growth is the byproduct of wise investment, leading to prosperity. Over the last few years, there has been a surge in investment in the renewable energy sector, which bodes well for the predicted growth of the Indian economy and fulfills mankind's environmental responsibilities. Solar energy aligns with the government's agenda of sustainable growth and energy security, reducing the burden of importing fuels from foreign countries and offering economic advantages. The renewable energy sector also presents significant employment opportunities, addressing the unemployment gap in the country.

In order to further stimulate investment in the solar energy sector, the Indian government has liberalized the Foreign Direct Investment (FDI) policy, allowing 100% FDI in the renewable energy sector through the automatic route. **[16]** The report published by the Indian Brand Equity Foundation (IBEF) in collaboration with the Ministry of Commerce and Energy, based on the information from the Ministry of New and Renewable Energy (MNRE) and the Central Electrical Authority (CEA), states that the addition of 13.5 GW of renewable energy in 2023 corresponded to an investment of ₹74000 crore.

In the Interim Budget 2024-25, there was a significant increase in the funds allocated for solar power grid infrastructure, rising from ₹4970 crore in the previous year to ₹8500 crore. Additionally, the government allocated ₹17490 crore to the Green Hydrogen Mission and the Strategic Intervention for Green Hydrogen Transition (SIGHT) program, demonstrating a commitment to boosting the clean energy sector.

The report also highlights the signing of a Memorandum of Understanding (MoU) between the government of Rajasthan and NTPC Green Energy, amounting to ₹1.6 lakh crore, with the aim of achieving a target of 31825 MW of clean energy generation.

India saved US$ 4.2 billion in fuel costs in the first half of 2022 through solar power generation. Furthermore, in December 2023, Andhra Pradesh announced ₹6600 crore for the development of renewable energy infrastructure, including solar projects, solar plants, substation enhancement, and contracts for solar energy projects by the Solar Energy Corporation of India (SECI).

The India Brand Equity Foundation predicts an investment of US$ 15.5 billion in solar PV projects and US$ 2.7 billion in battery manufacturing. Additionally, the Gujarat government partnered with Torrent Power for an investment of ₹47350 crore in renewable energy, green hydrogen, and electricity distribution. During the same period, Tata Power announced an investment of ₹70000 crore to develop a 10 GW solar and wind power capacity in Tamil Nadu.

The installed solar energy capacity of India has grown 26 times in the last 9 years, totaling 73.32 GW as of December 2023. The Production Linked Incentive (PLI) scheme for manufacturing high-efficiency solar PV modules is supported by a fund of ₹19500 crore. AmpIn Energy Transition announced a significant investment of ₹3100 crore to generate clean energy and establish an integrated manufacturing facility for solar cells and modules in the eastern region, including Bihar, West Bengal, Odisha, and Jharkhand. Reliance Industries is also set to invest ₹75000 crore in green energy production. MNRE proposed a unit with a generation capacity of 13000 MW and a battery storage facility of 12000 MWh in Ladakh, requiring substantial investment. **[15]**

The government aims to establish a green city in every state dominated by solar energy to meet its energy demands. IBEF estimates that India's renewable energy sector will receive an investment of US$ 80 billion in the next four years. Currently, projects worth US$ 196.98 billion are ongoing in India's renewable energy sector. Additionally, according to the Department for Promotion of Industry and Internal Trade (DPIIT), the non-conventional energy sector of India received FDI inflow of US$ 15.36 billion between April 2000 and September 2023.

Since 2014, more than US$ 70 billion has been invested in this sector, reflecting the increasing attraction of investors towards clean energy projects. R.K. Singh, the minister for New and Renewable Energy and Power, noted that for the specific period of April 2020-September 2023, the renewable energy sector received an infusion of US$ 6.1 billion in FDI equity.

Major initiatives of the government to attract domestic and foreign investment in the renewable energy sector include establishing an Ultra Mega Solar Park, a Project Development Cell for investment promotion, and constructing new transmission lines under the Green Energy Corridor Scheme. **[12]**

Scope of Solar Energy Start-ups in India:

The solar energy sector in India presents significant opportunities for startups due to the increasing investment and the potential for multifaceted growth. The sector is a key player in the renewable energy space, and with objectives such as energy independence and achieving net-zero carbon emissions, there is a need for innovative approaches to build a robust infrastructure. Favorable government policies and substantial funding provide a conducive environment for the expansion of startups. Investment is crucial for the development, maintenance, operation, and commissioning of large-scale solar projects, creating a demand for various complementary products and services throughout the project lifecycle. Startups play a vital role in providing these products and services, showcasing their capacity for innovation.

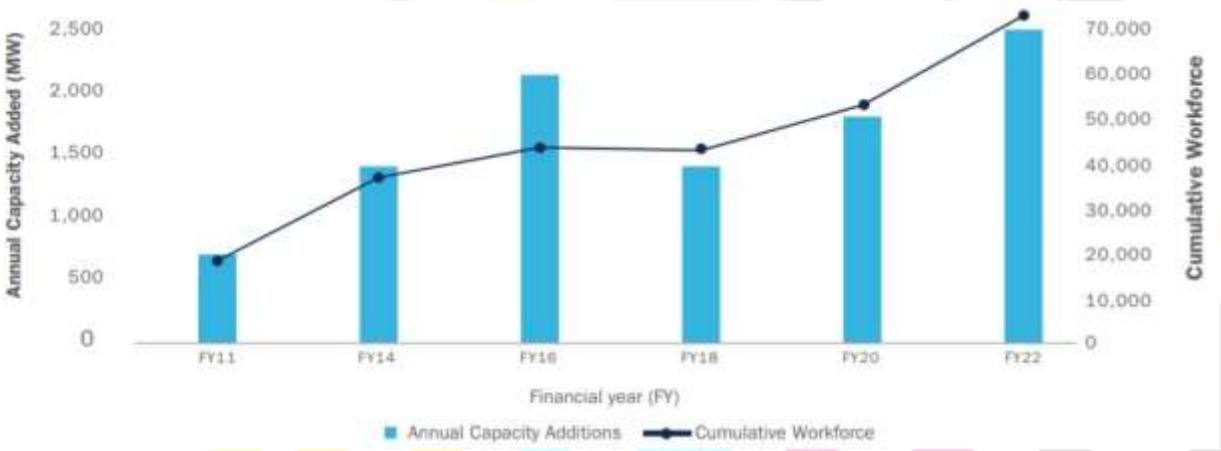
The solar energy sector in India has seen the establishment of numerous startups to meet growing consumer demand. The Start-up India portal records over 1200 DPIIT-recognized startups in the Renewable Solar Energy sector, with 21 investors, 335 incubators, 54 accelerators, and 112 mentors supporting the sector nationwide. In Uttar Pradesh alone, there are 134 solar energy startups, 38 incubators, 4 accelerators, and 10 mentors.[11] This growth trend is expected to continue, given the universal applicability of solar energy across sectors such as agriculture, health, education, transportation, and electricity. [18] The solar energy sector offers a range of startup opportunities, addressing various needs and niches. Examples of potential startup ideas within this sector include: solar panel manufacturing, solar installations and maintenance services, solar energy storage solutions, financing services for solar installations, off-grid solar products and services, solar-operated appliances, solar energy auditing and monitoring, solar consultancy, solar panel cleaning solutions, solar content creation and blogging, and solar energy training institutes. [3]

India's Solar Energy Employment Prospects:

As India strives to achieve 50% of its power generation from non-fossil fuel sources by 2030, there will be a surge in employment opportunities. In February 2022, the Council on Energy, Environment and Water (CEEW), in collaboration with two other agencies – the National Resources Defense Council of India (NRDC) and the Skill Council for Green Jobs (SCGJ) under the Ministry of Skill Development and Entrepreneurship, published a report titled "India's Expanding Clean Energy Workforce, 2022 Update." The report revealed that in the 2022 fiscal year, India added 13.9 GW of solar energy capacity. During the same period, the country hired 52700 new workers in project development roles within the solar and wind energy sectors. Of this workforce, about 99% (i.e., 52100 workers) were employed in the solar energy sector. The actual number of jobs, including indirect and induced employment, is expected to be much higher than this. According to the report, as of fiscal year 2022, the cumulative number of workers employed in the solar energy sector was 138015. [6]

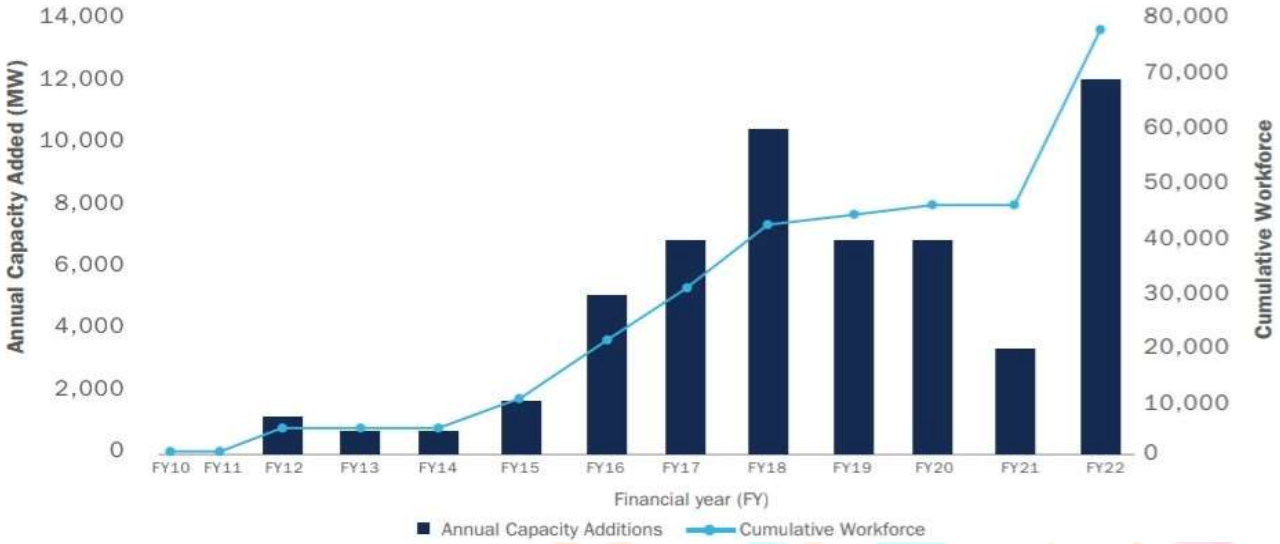
The report suggests that the solar sector has the potential to create 3.4 million temporary and permanent jobs by 2030. Solar power is expected to offer the highest job opportunities in the renewable energy sector. However, a significant portion of these jobs may be temporary, as many workers are laid off after the completion and commissioning of solar projects. Another report by the International Renewable Energy Agency titled "Renewable Energy and Jobs Annual Review 2023" revealed that from 2012-2022, out of the total 13.7 million jobs in the global energy sector, 4.9 million were in the solar energy sector. This report estimated the total number of direct solar jobs in India to be around 201400, with an additional 80800 jobs in off-grid settings. The number of jobs in the utility-scale solar sector was 72700, and in the rooftop solar sector, it was 65400. [17]

Figure: Workforce additions in rooftop solar in FY22 increased 6 fold over FY21:



Source: CEEW-NRDC Analysis, 2022

Figure : New workforce additions in utility-scale solar segment in FY22 increased 16 fold over FY21



Source: CEEW-NRDC Analysis, 2022

Nature and the Requirements of the Job Opportunities:

The goal to maximize the share of renewable energy sources in overall power generation creates numerous job opportunities. This will require the development of energy storage systems on a larger scale to avoid voltage fluctuations in the grid. Therefore, large-scale battery manufacturing is essential. The National Green Hydrogen Mission also creates hundreds of thousands of jobs in the sector. The transition to electric vehicles in transportation necessitates the establishment of charging stations, including battery swapping facilities, and the operation and maintenance of these stations. Extensive establishment of solar PV module manufacturing, trading, repairing, and other technical solutions for solar equipment is needed. The construction of green buildings, in line with eco-friendly structures, designs, and the management of complementary materials involved in the process, will also create employment opportunities. Additionally, a larger number of workers will be required for project deployment, construction, and power generation for big and mega projects. [7]

Skill Development and Capacity Building:

In addition to workers in conventional energy sectors, such as coal mines, the renewable energy sector requires a certain level of knowledge and skills. The Skill Council for Green Jobs (SCGJ) is a government body that develops strategies, plans, skill development programs, and interventions to meet the emerging demands of the workforce, including E-mobility, green hydrogen, biofuels, and energy storage, among others. The council is also preparing to incorporate vocational courses in the green business sector in schools, universities, and other higher institutes to align with the New Education Policy 2020. As of 2022, more than 86000 Suryamitras (solar technicians) have been trained by the council and certified by the government of India. An e-learning management system has been developed by the council to assist remote learning and a job portal for the placement and employment of trained candidates. [24]

The Ministry of New and Renewable Energy (MNRE) supports educational institutes and other organizations to conduct short-term training programs focusing on skill development at all levels, for example, Suryamitra, Vayumitra, Varunmitra. The ministry also conducts various programs to promote the RE sector:
- National Renewable Energy Science Fellowship Scheme for researchers with innovative ideas in the RE sector.
- National Renewable Energy Fellowship for MSc/MTech/Ph.D. degrees.
- Support for higher educational institutes for laboratory upgradation

Major Challenges in the Solar Sector:

Despite the increasing popularity of solar energy, there are several challenges that need to be addressed. Start-ups in the solar energy sector encounter various obstacles. Some of the major barriers include:

Financial Constraints:
According to a PRS Legislative Report published by the standing committee on energy in 2022, research conducted on the financial barriers in the development of the solar sector has revealed the following: [29]

- There is a significant gap between the required investment and actual investment for renewable energy capacity, which limits the commissioning of solar projects. Only ₹75000 crore was invested in the last few years against the required investment of ₹1.5-2 lakh crore.
- Banks have a reluctant attitude towards renewable energy projects.
- The lending capacity of IREDA for large-scale projects is limited due to its low capital base. The Capital Adequacy Ratio of the institute has declined from 23% in 2014-15 to 17% in 2020-21, reducing its borrowing capacity.
- Renewable energy developers face challenges in generating revenues due to delays in payments by discoms.
- High dependence on imports of solar PVs from China creates uncertainty in pricing and timely availability of modules.

Operational and Maintenance Challenges:
- Accumulation of dust, bird droppings, atmospheric particulate matter, dry leaves, etc., on solar panels leads to a decrease in energy production.
- According to CEEW, approximately 3-4 liters of water are needed to clean a panel on normal land area and 7-8 liters of water in arid zone areas. Therefore, 24000 liters of water would be required to clean a 1 MW solar farm. This practice does not align with sustainability.
- The use of detergents and chemicals is prone to creating ground contamination. Hard water results in glass residue deposit on panels, and the installation of water softening plants adds to the financial burden on project developers.
- Large solar projects like solar parks are highly labor-intensive. Managing risks and worker safety from hazards like electrical shock remains crucial.
- The shortage of skilled labor increases the cost of production.
- The sector has a longer return on investment. **[35]**

Policy Barriers:
In India, awareness about the benefits, importance, and potential of solar power is poorly spread, restricting the acceptance of solar energy on a larger scale. Solar systems are comparatively cost-intensive compared to other energy generation technologies. This requires a substantial amount of funds to establish a start-up in the sector, and therefore, most people hesitate to invest in it. With a poor position in semiconductor manufacturing, India imports most of the solar cells from other countries, leading to a substantial increase in the overall cost of solar panels. Inverters and batteries are crucial parts of utilizing energy from solar panels, creating additional costs in these projects. As a result of the high initial cost, even middle-class individuals find it difficult to invest in solar systems. The government provides subsidies, but the policy requires the customer to bear the total cost until the installation is done, and then the subsidy is deposited in the beneficiary's account. Most start-ups have to deal with these policy barriers. Some of the barriers are:

- Bureaucratic barriers to getting licenses and permits.
- Due to corruption and political influence, the execution of the law does not always consider the practical requirements.
- Impractical and unrealistic regulations might put unnecessary barriers on the way of developers and investors.
- Unreasonable time constraints on project development and execution may act as a roadblock.

Technical Challenges:
The radiation of the sun is not evenly spread across different regions of the earth. Places near the Equatorial belt do not receive proper duration and intensity of sunshine, while places near the North and South Equator have abundant sunshine.**[4]** Solar cells do not convert their light source into energy at 100% efficiency. These points can negatively influence entrepreneurs to invest their money in a project related to the solar sector.

Land Related Challenges:
Large solar parks can affect the food security of the region by changing the land use pattern, resulting in the loss of natural vegetation, topsoil, and displacement of manpower. The solar parks also impact the process of photosynthesis and the soil's ability to store carbon due to reduced sunlight reaching the ground. Additionally, solar panels can cause an average 3°C rise in below-ground temperatures, rendering the land unusable for other purposes.

In India, approximately 58% of the land receives almost 5 kWh/meter square/day, making it ideal for solar energy production. However, setting up solar parks requires vast land areas, with 4-5 acres needed to generate 1 MW of electricity. Unplanned implementation of these projects could lead to the loss of cultivable land and other socio-economic impacts. While the government offers subsidies and incentives for developing solar projects in wastelands and barren areas, developers often prefer land near urban areas with existing infrastructure. In Europe, subsidies and incentives for solar projects on agricultural land are restricted, preventing the exploitation of cultivable land for profit. **[41]**

Future Prospects:

To optimize land use, research in Germany and the USA is focusing on "dual-use farming," where crops are grown beneath solar panels. Studies suggest that crops can thrive in this environment, sometimes yielding better results than in full sun. Planting native seeds under solar farms can also increase land efficiency by reducing panel degradation. This concept, also known as agrophotovoltaics, is being promoted by the National Renewable Energy Laboratory (NREL). **[20]**

Solar manufacturing companies are working on reducing the size of solar panels and increasing energy density. Innovative projects, such as solar roads and space-based solar energy collection, are under research and development. India's rapid economic growth presents opportunities for job creation in the renewable energy sector. Institutes like IIT Bombay – National Center for Photovoltaic Research and Education (NCPRE) have introduced new courses and mentorship programs to advance technological knowledge and promote indigenous technology development.

It is crucial to establish a robust training and skill development ecosystem to prepare a skilled workforce for the renewable energy industry. This includes gender-focused skilling courses to increase participation of women in the clean energy sector, application-oriented courses relevant to emerging industries, and upskilling of the current workforce to adapt to the transition from conventional to clean energy. **[24]**

Discussion:

A large area of land is needed for solar power generation. Approximately 4-5 acres of land are required to build a 1 MW solar power plant. This challenge can be addressed by increasing rooftop systems, utilizing metro stations' roofs, canal solar plants, and floating solar plants. In India, the government promotes the use of space on canals, deserts, water bodies, highway and railway sides for setting up solar projects, yet there are no subsidies or incentives provided for using these spaces. As a result, the potential for power generation from these areas remains untapped. Government bodies should offer incentives and assistance to both public and private enterprises to make use of these available spaces, which will also help preserve agricultural land and natural habitats. To reduce land conversion for solar projects, the government should conduct a drone analysis of the rooftop potential of cities and promote policies to utilize this space for increased energy production.

One of the major reasons why entrepreneurs hesitate to invest in wastelands is the additional capital and operational expenses required due to the geographical and land terrain challenges. Infrastructural facilities such as transmission lines, internal roads for accessibility, and water bodies are often lacking in wasteland areas, which leads developers to avoid incurring the substantial cost increases and prefer land parcels near urban areas. To address this issue, solar park bidding should be site-specific, taking into account factors such as topography and infrastructural costs. Restoring landscape and vegetation after the completion of mega projects can help retain local populations and different habitats. The tariff agreement should be determined in proportion to the investment involved in using wasteland. The government should consider providing incentives to project owners based on the units of energy generated.

Conclusion:

Solar energy, being an inexhaustible source, holds the potential to meet the world's entire energy demand if the right technologies for capturing and supplying its energy are available. It's aSdvantageous that most wastelands receive highly favorable irradiance from the sun. Promoting the use of degraded land for solar parks is crucial. The vast degraded wastelands across India have the potential to generate around 1789 GW of solar and wind energy, which is four times greater than the 2030 goal. Rooftop spaces in built areas, water bodies like canals and reservoirs, and spaces around national and state highways have a high potential of around 550 GW, which can significantly reduce land requirements. **[8]**
Biomass-derived fuels and solar energy can be used synergistically to reduce the overall carbon footprint associated with energy generation. **[36]** Solar policies should include representatives from all stakeholders in the solar sector, including consumers, DISCOMs, solar plant developers, and regulatory commissions. This will ensure proper coordination among all parties and avoid conflicts. The UPNEDA's corpus fund should be transparent and accessible to the public in order to increase the officials' accountability and timely delivery of initiatives. Regular inspections and assessments of energy targets are required for successful policy implementation.

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