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SOLAR POWER IN INDIA: PRESENT AND FUTURE CHALLENGES REVIEW

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Abstract:
This review assesses India's progress in solar energy integration, positioning it as a global renewable energy leader. It examines achievements in capacity installation and policy implementation, emphasizing socio-economic benefits like job creation and positive environmental impacts. Despite advancements, significant hurdles persist. Land acquisition complexities, grid integration issues, and intermittent supply demand scrutiny. Regulatory barriers also impede sectoral growth. Looking ahead, technological advancements and robust storage solutions are imperative. Socio-political factors, including public perception and governmental policies, play pivotal roles. Synthesizing diverse sources, this review offers a thorough evaluation of India's solar energy landscape, providing crucial insights for stakeholders shaping a sustainable energy future.

Keywords:
Solar power, India, renewable energy, challenges, policy, technology, sustainability, grid integration, energy transition.

Introduction:

Access to affordable electricity is a crucial determinant of urbanization, industrialization, economic prosperity, and overall societal well-being for any nation[1]. India, currently positioned as the fifth-largest electricity producer globally, boosts an installed capacity of 300 GW[2]. Within this capacity, thermal sources account for 61.32%[3], hydro contributes 14.17%[4], nuclear adds 1.91%[5], and renewable energy sources contribute approximately 14.15% (as of September 2017)[6]. Consequently, India's energy landscape predominantly relies on fossil fuels, with coal reserves alone generating roughly three-fifths of the nation's power supply[7]. This reliance, however, comes at a cost, as thermal power stations release significant volumes of harmful gases, including $N0_2$, CO2, and SO2, posing substantial risks to both public health and the environment[8]. Recognizing these challenges, the Indian government has embarked on a series of initiatives aimed at curbing the reliance on fossil-fuel-based energy and fostering the generation of renewable energy sources, with a particular emphasis on solar energy, which is abundantly available across most regions of India[9].

In the early 1980s, India demonstrated global leadership by establishing the first-ever Ministry of Non-Conventional Energy Resources[10]. This visionary moves underscored India's commitment to harnessing alternative energy sources[11]. Notably, solar and wind energy[12], which are abundant and environmentally begin, hold significant promise in India[13]. While wind energy deployment faces limitations due to variable wind speeds and unpredictability, solar energy stands out as a universally accessible and pivotal renewable resource[14]. Recent years have witnessed a noteworthy decline in the cost of solar technologies, with a promising trajectory of further reductions[15]. Presently, India boasts an installed solar energy capacity of approximately 12.2 GW, and ambitious plans are in motion to achieve a remarkable 175 GW from renewable sources by 2022[16]. This endeavor is structured to allocate 100 GW to solar power, 60 GW to wind energy, and 10 GW to biomass, along with 5 GW dedicated to small hydro projects[17]. Figure 1 provides an illustrative representation of the solar energy in India A solar energy map of India illustrates the geographical distribution of solar potential across the country, highlighting regions with abundant sunlight for energy generation. It helps investors and policymakers identify optimal locations for solar projects, promoting strategic development and sustainable energy utilization. By depicting solar intensity, it aids in maximizing energy output and fostering India's transition towards a greener future.

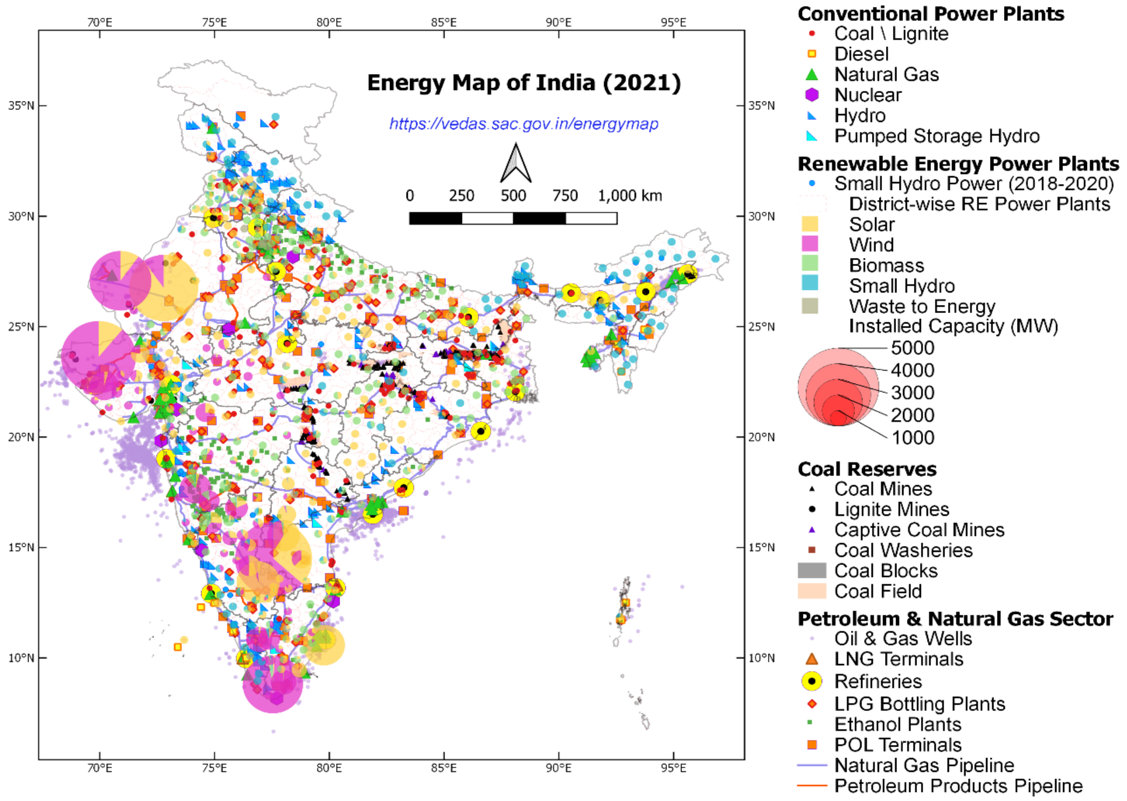

Fig 1: Solar energy Map of India

India had established a goal of achieving a solar energy capacity of 100 gigawatts by the year 2022 [18]. As of June 2023, India has achieved 70.10 GW of solar energy capacity while another 55.60 GW is under construction. The state-wise targets for renewable energy are not set by the government[19]. Solar power based electric vehicle with maximum power point tracking is discussed in various literatures[20]. The Government of India's (GOI) initiative is visually represented through the establishment of a high-capacity solar park. [21][22]. The paper additionally encompasses a catalog of beneficial software applications for the design and analysis of solar photovoltaic (PV) systems, along with their respective specifications.[23].

India has experienced two instances of achieving historically low solar power tariffs within a span of less than five months. [24]. During the Solar Energy Corporation of India Ltd. (SECI) auction held on November 23, 2020, the lowest tariff to date was recorded at Rs2/kWh. Subsequently, the lowest successful tariffs in utility-scale solar tenders experienced an average increase of 22% in comparison to the previously established record-low tariff.[25]. As depicted in Figure 2, the NSEFI Interactive renewable power capacity (in megawatts) within the state of Rajasthan is provided [26].

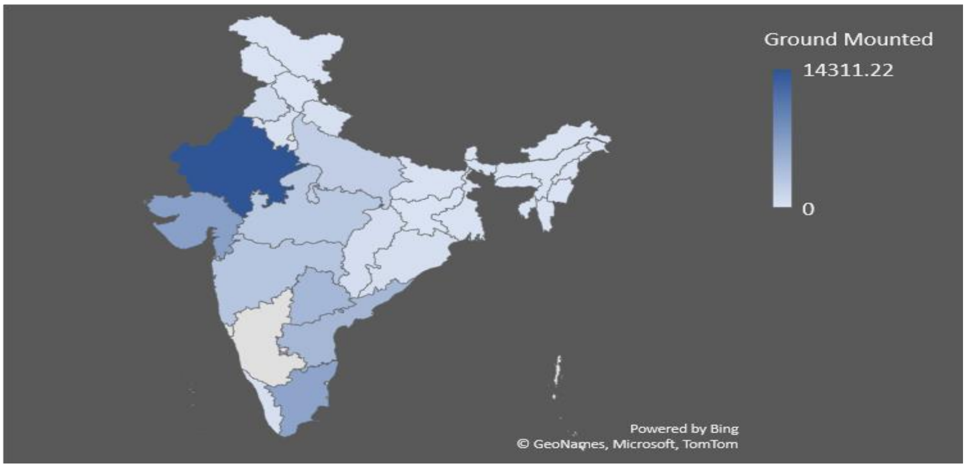

Fig 2: Installed capacity of Interactive renewable Power (MW) in Rajasthan state[26]

Overview of solar power:

Solar energy is typically transformed into electricity through the utilization of photovoltaic (PV) cells. These are solid-state devices that employ the photoelectric effect to convert light into electric power. [27]. Photovoltaic power generation encompasses the utilization of solar panels comprising multiple solar cells constructed from photovoltaic materials [28][29]. The International Energy Agency (IEA) has divided photovoltaic applications into four distinct categories: grid-connected dispersed, grid-connected centralized, and off-grid domestic and non-domestic systems [30]. Grid connected system stability analysis is shown in literature [31]. An alternative method for the efficient harnessing of solar energy is through the deployment of Concentrating Solar Power (CSP) plants.[32]. Indeed, in a Concentrating Solar Power (CSP) plant, thermal energy is collected using lenses or mirrors, and this thermal energy is then transformed into mechanical energy through a steam turbine, resulting in the production of electricity [33][34]. There exists a diverse array of Concentrating Solar Power (CSP) plant technologies, with the most advanced options being solar power towers, concentrating linear Fresnel reflectors, and sterling dishes [35]. Various techniques are used to track the sun and focus light[36]. A wide rang of installed capacity is shown in fig 3.

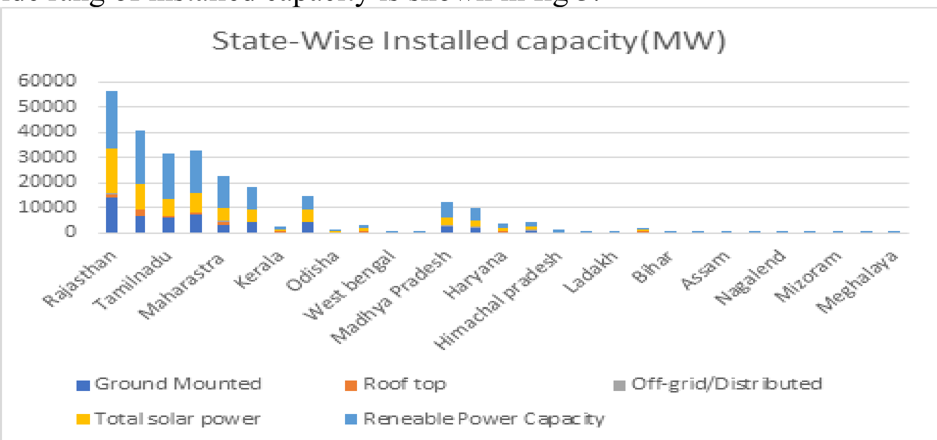

Fig 3: State-wise Installed capacity of Interactive renewable Power (MW)

Current status of solar energy in India:

Indeed, the Indian government is actively promoting the incorporation of renewable energy sources. Despite having a significantly greater potential for solar energy, India presently ranks 11th worldwide in terms of solar power generation [37]. The majority of India receives an average solar radiation of 4 to 7 kWh per square meter per day, a resource ample enough to meet the country's escalating energy demands [38]. Germany, on the other hand, obtains just 3–4 kWh/sq.m./day despite having the biggest solar power installation in the world [39][14]. In 2010, a capacity of 25.1 MW was added, followed by 468.3 MW in 2011, a more than two times increase in capacity to 1205 MW in 2012, and capacity addition of 1114 MW and 313 MW in 2013 and 2014 respectively. As of August 2015, the installed capacity for grid-connected solar power stands at 4.22 gigawatts (GW)[40]. The cost of solar energy has seen a notable reduction, dropping from Rs. 17.90 per unit in 2010 to approximately Rs. 2.44 per unit in 2017 [41]. Indeed, projections indicate that as a result of technological advancements and intensified market competition, solar power is on track to attain grid parity by the year 2017-18 [42]. Grid parity pertains to the point at which the cost of electricity generated from alternative energy sources becomes equivalent to or less than the cost of procuring power from the grid [43]. As of 2016, the Kamuthi Solar Power Project in Tamil Nadu boasts an installed capacity of 648 megawatts (MW) and holds the distinction of being the largest Solar Park in Asia [43][44]. According to latest government data Rajasthan state have the highest installed capacity of solar power in India.

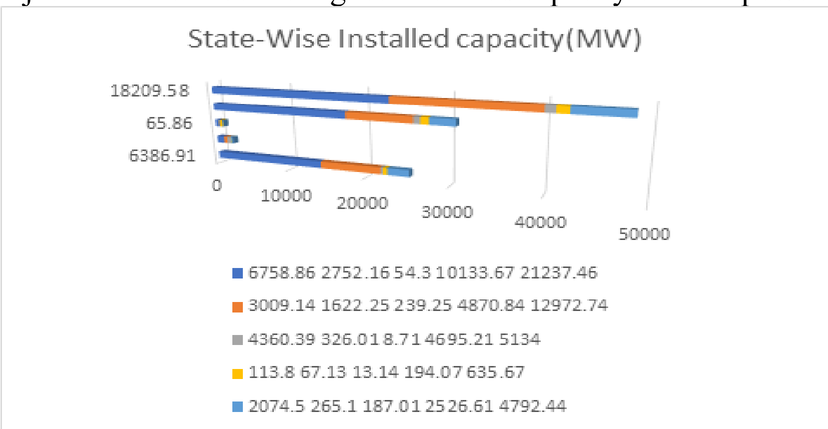

Fig 3.1: Grid/Off-Grid Installed capacity data (MW) of renewable power

The Kamuthi Solar Power Project in Tamil Nadu, India, is the largest solar park in Asia with a current installed capacity of 648 MW as of 2016[44]. According to latest government data Gujarat state have the highest rooftop installed capacity of solar power in India as shown in Fig 4.

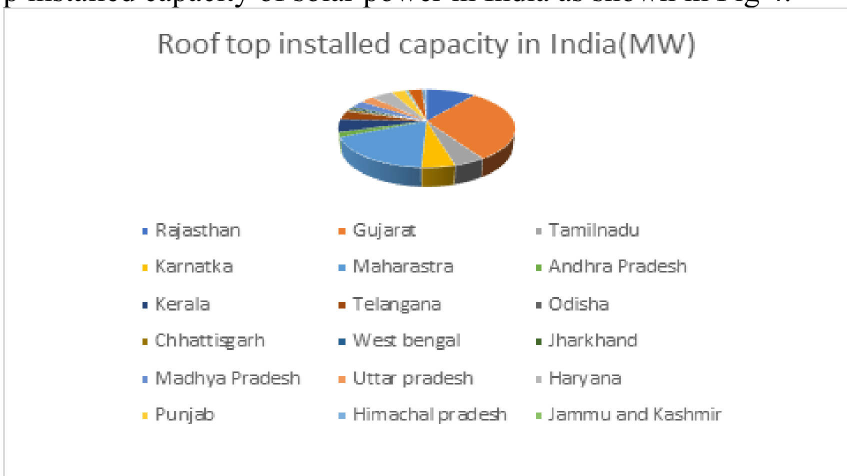

Fig 4: Roof top installed capacity in India (MW)

It is evident from the radiation pattern that most states in India have very good solar radiation throughout the year, with Rajasthan having a high radiation pattern of 6.6-6.4 kWh/m2[41]. According to latest government data Rajasthan state have the highest ground mounted installed capacity of solar power in India. Ground mounted installed capacity is 54523 MW according to government of India as shown in fig 5.

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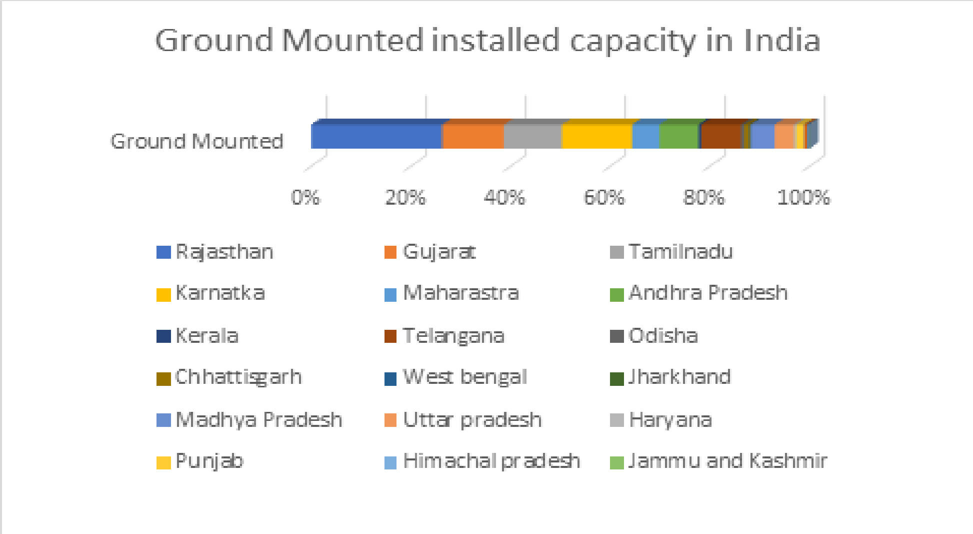

Fig 5: Ground Mounted installed capacity in India

Off Grid/ distributed installed capacity of India is 2458.05 MW and maximum is in Rajasthan that is 570.84 MW that has been shown in fig 6.

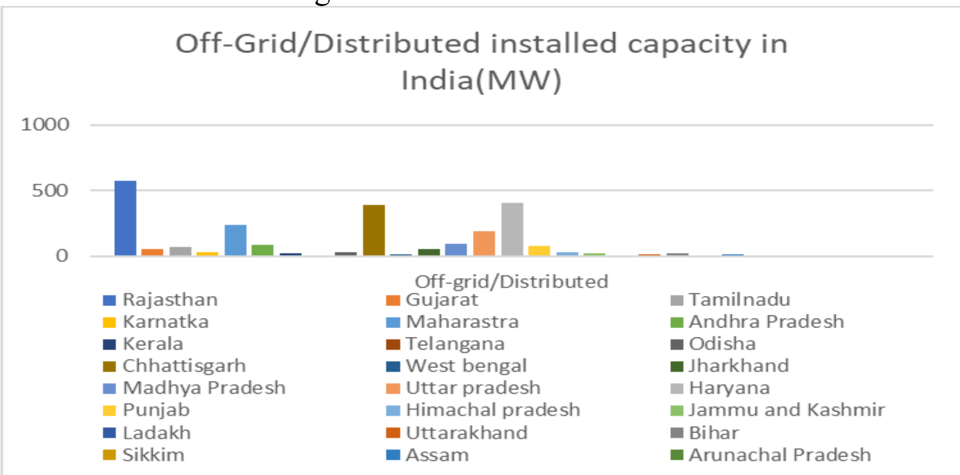

Fig 6: Off-Grid/Distributed installed capacity in India (MW)

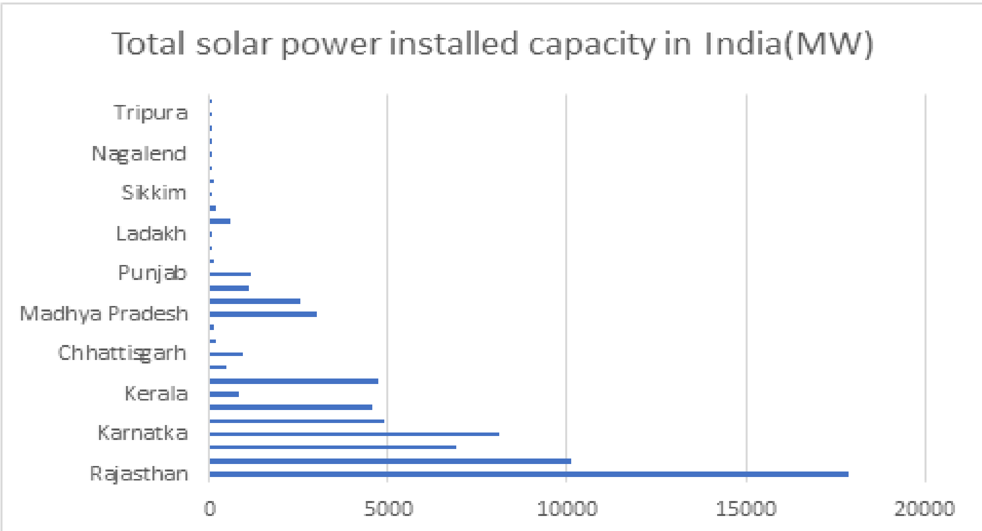

Fig 7: Total solar power installed capacity in India (MW)

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India had a total installed solar power capacity of over 54 gigawatts (GW), which is equivalent to 54523.63 megawatts (MW) as shown in fig 7.

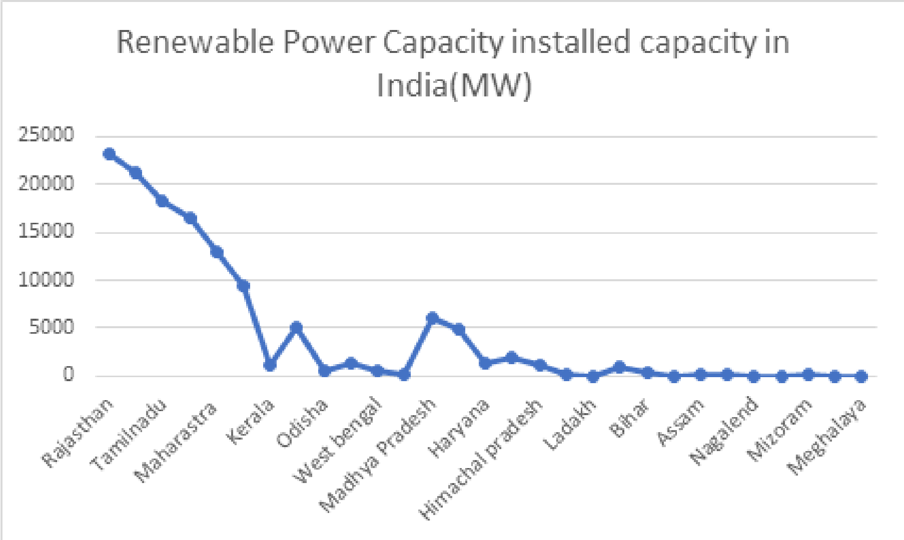

Fig 8: Renewable Power Capacity installed capacity in India (MW)

India had made significant progress in renewable energy deployment, including solar, wind, and other sources[45][31]. For the latest and most accurate information on renewable power capacity installed in India as shown in fig 7.

Government aid and services in India:

Public policies and actions:

The Electricity Act of 2003 encourages electricity generation through co-generation and renewable energy sources. The regulations for competitive procurement have been established under Section 63 of the Act [46]. If the tariff has been determined through an open, competitive bidding procedure in compliance with the rules established by the Central Government, the Appropriate Commission will approve it [47]. Increased use of power produced from non-conventional sources is required under the 2005 National power Policy. Additionally, distribution corporations are required to follow a competitive process when making purchases in this area[48]. As per the current Tariff Policy of 2006, the Appropriate Commission is obliged to establish a minimum percentage for procuring energy from non-conventional sources. This determination should take into consideration the availability of resources in the region and its potential impact on retail pricing [49].

Solar journey:

Initiated on January 11, 2009, the Jawaharlal Nehru National Solar Mission (JNNSM) aims to complete 20,000 megawatts (MW) of grid-connected solar plants by the year 2022 [53]. The mission employed a three-phase strategy, designating the first four years (2009–2013) as Phase I, the subsequent four years of the twelfth Plan (2013–17) as Phase II, and the thirteenth Plan (2017–22) as Phase III[46]. By the year 2013, this initiative aimed to integrate 1,000 megawatts (MW) of solar energy into the grid, followed by an additional 3,000 MW by 2017 [48].

The goal for 2017 may be expanded, contingent on the accessibility of international financing and the facilitation of technology transfer [54]. A five-fold increase in India's solar power capacity objective under the JNNSM to achieve 100 GW by 2022 was authorized by the Union Cabinet of India in June 2015[44]. The target encompasses 57 gigawatts (GW) from large and medium-scale grid-connected solar power facilities, along with 40 GW from rooftop solar power installations [55]. When this goal is achieved, India will rank among the top countries in the world for the production of solar energy.[56].

Over the course of its operating life, the recently created 100 GW solar objective is expected to reduce CO2 emissions by more than 170 million tonnes [57][46].

Assistance from governments:
The Indian government is offering a subsidy worth Rs. 15,050 billion to encourage the expansion of the nation's solar power potential [58]. Solar projects will receive this capital assistance in several cities and municipalities [59]. Utilizing the bundling approach with thermal electricity, solar power plants with an investment of roughly Rs. 90,000 crore will be created [58]. Large Public Sector Undertakings (PSUs) and Independent Power Producers (IPPs) will also invest. State solar policies have also been released by several state governments to advance solar energy technologies. Table 3 displays the Jawaharlal Nehru National Solar Mission (JNNSM) plan's road map for generating electricity from solar energy [60].

Table 3: The goal for JNMSM's solar energy production by 2023

Year	Rooftop Type Solar Power Project	Ground Mounted Type Solar Power Project	Total (MW)
2016	110	990	1,100
2017	200	1,800	2,000
2018	750	2,250	3,000
2019	1,300	3,700	5,000
2020	2,000	8,800	10,800
2021	4,000	15,000	19,000
2022	12,000	18,000	30,000
2023	40,000	57,000	97,000

Indian Solar Energy: Challenges and Limitations:
Solar energy in India faces several limitations and challenges[61]. Given that local meteorological conditions have a significant impact on the availability of solar radiation, one of the primary drawbacks of solar energy is that it is not available year-round in a given location [62]. Therefore, we cannot be sure whether the energy from solar will be available to us at a particular time or not[63]. In India, waste land is likewise a limited resource, and cash is hard to come by. Large land tracts are needed, although they are not always practical [64]. Currently, utility-scale solar power facilities need between one and two kilometers of land for every 20 to 60 megawatts of electricity. However, the entire amount of land needed to meet all of India's needs is equivalent to half the size of Sikkim, the second-smallest Indian state [14].

References:
[1]A. Raihan *et al.*, “Nexus between carbon emissions, economic growth, renewable energy use, urbanization, industrialization, technological innovation, and forest area towards achieving environmental sustainability in Bangladesh,” *Energy Clim. Chang.*, vol. 3, p. 100080, 2022.
[2]P. Kenganur, “Prospects for development of solar and wind projects and challenges in integrating into the grid system.” College of Management and Economics Studies, UPES, Dehradun, 2015.
[3]D. Wang, Z. Sun, J. Chen, X. Wang, X. Zhang, and W. Zhang, “Analyzing the interpretative ability of landscape pattern to explain thermal environmental effects in the Beijing-Tianjin-Hebei urban agglomeration,” *PeerJ*, vol. 7, p. e7874, 2019.
[4]Y. Meng *et al.*, “Hydropower production benefits more from 1.5 C than 2 C climate scenario,” *Water Resour. Res.*, vol. 56, no. 5, p. e2019WR025519, 2020.
[5]K.-I. Mishiba *et al.*, “Nuclear DNA content as an index character discriminating taxa in the genus Petunia sensu Jussieu (Solanaceae),” *Ann. Bot.*, vol. 85, no. 5, pp. 665–673, 2000.

[6]M. Joos and I. Staffell, "Short-term integration costs of variable renewable energy: Wind curtailment and balancing in Britain and Germany," *Renew. Sustain. Energy Rev.*, vol. 86, pp. 45–65, 2018.
[7]R. M. Elavarasan *et al.*, "A comprehensive review on renewable energy development, challenges, and policies of leading Indian states with an international perspective," *Ieee Access*, vol. 8, pp. 74432–74457, 2020.
[8]A. Shahsavari and M. Akbari, "Potential of solar energy in developing countries for reducing energy-related emissions," *Renew. Sustain. Energy Rev.*, vol. 90, pp. 275–291, 2018.
[9]S. Whitley and L. Van Der Burg, "Fossil fuel subsidy reform: From rhetoric to reality," *New Clim. Econ. London Washington, DC. Available http//newclimateeconomy. report/misc/working-papers. All rights Reserv. New Clim. Econ. c/o World Resour. Inst.*, vol. 10, p. 3, 2015.
[10] N. Golait, R. M. Moharil, and P. S. Kulkarni, "Wind electric power in the world and perspectives of its development in India," *Renew. Sustain. Energy Rev.*, vol. 13, no. 1, pp. 233–247, 2009.
[11] S. Nambiar, "India's Role in the Emerging World Order," *Jadavpur J. Int. Relations*, vol. 10, no. 1, pp. 11–21, 2006.
[12] S. Gupta, P. Singh, and R. K. Swami, "Present Wind Energy Market Scenario in India," in *Smart Energy and Advancement in Power Technologies: Select Proceedings of ICSEAPT 2021 Volume 1*, Springer, 2022, pp. 637–647.
[13] S. Sharma, S. Agarwal, and A. Jain, "Significance of hydrogen as economic and environmentally friendly fuel," *Energies*, vol. 14, no. 21, p. 7389, 2021.
[14] V. Khare, S. Nema, and P. Baredar, "Status of solar wind renewable energy in India," *Renew. Sustain. Energy Rev.*, vol. 27, pp. 1–10, 2013.
[15] R. Gross, M. Leach, and A. Bauen, "Progress in renewable energy," *Environ. Int.*, vol. 29, no. 1, pp. 105–122, 2003.
[16] N. K. Dubash, *Mapping power: The political economy of electricity in India's states*. Oxford University Press, 2018.
[17] S. C. Johnson, J. D. Rhodes, and M. E. Webber, "Understanding the impact of non-synchronous wind and solar generation on grid stability and identifying mitigation pathways," *Appl. Energy*, vol. 262, p. 114492, 2020.
[18] M. K. Hairat and S. Ghosh, "100 GW solar power in India by 2022–A critical review," *Renew. Sustain. Energy Rev.*, vol. 73, pp. 1041–1050, 2017.
[19] S. K. Sahoo, "Renewable and sustainable energy reviews solar photovoltaic energy progress in India: A review," *Renew. Sustain. Energy Rev.*, vol. 59, pp. 927–939, 2016.
[20] S. Sharma and R. K. Swami, "Solar powered electric vehicle using maximum power point tracking," 2022.
[21] R. Kumar, K. K. Samar, and S. K. Jain, "Economic Evaluation of Passive Solar Distillation System," *Int. J. Environ. Clim. Chang.*, pp. 50–53, Jan. 2022, doi: 10.9734/ijecc/2022/v12i130614.
[22] R. Kumar, S. K. Jain, and K. K. Samar, "Exergy Analysis of Passive Solar Distillation Unit in India at Udaipur," *Curr. J. Appl. Sci. Technol.*, pp. 36–43, Dec. 2021, doi: 10.9734/cjast/2021/v40i4331617.
[23] R. Jangid, J. K. Maherchandani, V. Kumar, and R. K. Swami, "Energy Management of Standalone Hybrid Wind-PV System," *Intell. Renew. Energy Syst.*, pp. 179–198, 2022.
[24] D. Deshwal, P. Sangwan, and N. Dahiya, "How will COVID-19 impact renewable energy in India? Exploring challenges, lessons and emerging opportunities," *Energy Res. Soc. Sci.*, vol. 77, p. 102097, 2021.
[25] Z. Dobrotkova, K. Surana, and P. Audinet, "The price of solar energy: Comparing competitive auctions for utility-scale solar PV in developing countries," *Energy Policy*, vol. 118, pp. 133–148, 2018.

[26] National Solar Energy Federation of india, "State-wise installed capacity of Grid/ Off-Grid Interactive Renewable Power (MW)," 2023. [Online]. Available: https://nsefi.in/figures_statistics/#
[27] G. P. Smestad, "Conversion of heat and light simultaneously using a vacuum photodiode and the thermionic and photoelectric effects," *Sol. energy Mater. Sol. cells*, vol. 82, no. 1–2, pp. 227–240, 2004.
[28] R. Kumar, S. K. Jain, and K. K. Samar, "Energy Analysis of Passive Solar Distillation Unit," *J. Exp. Agric. Int.*, pp. 24–31, Feb. 2022, doi: 10.9734/jeai/2022/v44i130785.
[29] P. N. Shukla and A. Khare, "Solar photovoltaic energy: the state-of-art," *Int. J. Electr. Electron. Comput. Eng.*, vol. 3, no. 2, p. 91, 2014.
[30] S. Mekhilef, A. Safari, W. E. S. Mustaffa, R. Saidur, R. Omar, and M. A. A. Younis, "Solar energy in Malaysia: Current state and prospects," *Renew. Sustain. Energy Rev.*, vol. 16, no. 1, pp. 386–396, 2012.
[31] R. K. Swami, P. Samuel, and R. Gupta, "Power control in grid-connected wind energy system using diode-clamped multilevel inverter," *IETE J. Res.*, vol. 62, no. 4, pp. 515–524, 2016.
[32] G. T. Machinda, S. Chowdhury, R. Arscott, S. P. Chowdhury, and S. Kibaara, "Concentrating solar thermal power technologies: a review," in *2011 Annual IEEE India Conference*, IEEE, 2011, pp. 1–6.
[33] J. K. Maherchandani, R. Tirole, and R. K. Swami, "Microgrid Energy Management Strategy for Low Dynamics Load Applications Using Simulink," in *Intelligent Computing Techniques for Smart Energy Systems: Proceedings of ICTSES 2021*, Springer, 2022, pp. 93–103.
[34] M. H. Ahmadi *et al.*, "Solar power technology for electricity generation: A critical review," *Energy Sci. Eng.*, vol. 6, no. 5, pp. 340–361, 2018.
[35] D. Mills, "Advances in solar thermal electricity technology," *Sol. energy*, vol. 76, no. 1–3, pp. 19–31, 2004.
[36] J. Sun, M. M. Hossain, C.-L. Xu, B. Zhang, and S.-M. Wang, "A novel calibration method of focused light field camera for 3-D reconstruction of flame temperature," *Opt. Commun.*, vol. 390, pp. 7–15, 2017.
[37] P. K. S. Rathore, D. S. Chauhan, and R. P. Singh, "Decentralized solar rooftop photovoltaic in India: On the path of sustainable energy security," *Renew. energy*, vol. 131, pp. 297–307, 2019.
[38] S. Mohanty, P. K. Patra, S. S. Sahoo, and A. Mohanty, "Forecasting of solar energy with application for a growing economy like India: Survey and implication," *Renew. Sustain. Energy Rev.*, vol. 78, pp. 539–553, 2017.
[39] S. Bhowmik, "Profitability of Utility-Scale Solar Power in India-Analysis of six states, possible future scenarios and implications for the 2030 solar power target," *IIIEE Master Thesis*, 2020.
[40] P. M. Salunke, H. B. Kulkarni, A. M. Waghchavare, and S. S. Kurle, "Solar energy and its applications-need, overview and future scope," *Int. Journ. Res. Appl. Sci. Eng. Technol.*, vol. 5, 2017.
[41] and the guidelines for competitive procurement have been framed under S. 63 of the A. The Electricity Act 2003 promotes electricity generation from co-generation and renewable energy sources, "A Review-Solar Power in India Present Scenerio, Challenges and Oppportunities".
[42] T. Y. Jung, D. Kim, J. Moon, and S. Lim, "A scenario analysis of solar photovoltaic grid parity in the Maldives: The case of Malahini resort," *Sustainability*, vol. 10, no. 11, p. 4045, 2018.
[43] C.-J. Yang, "Reconsidering solar grid parity," *Energy Policy*, vol. 38, no. 7, pp. 3270–3273, 2010.
[44] P. Sarangi and N. M. ICSI-CCGRT, "PROSPECTIVE OF NEW BUSINESS AVENUES FOR COMPANY SECRETARY PROFESSIONALS IN INDIA: A STUDY OF SOLAR ENERGY SECTOR".
[45] R. Kumar, "Solar Energy Schemes in India 2022," vol. 4, no. 6, pp. 1077–1078, 2022, doi: 10.1787/ec2fd78d-en.K.
[46] S. K. Chaudhary, P. Kumar, and R. Kumar, "A Review-Solar Power in India Present Scenerio,

Challenges and Oppportunities".
[47] A. Singh, "Towards a competitive market for electricity and consumer choice in the Indian power sector," *Energy Policy*, vol. 38, no. 8, pp. 4196–4208, 2010.
[48] N. K. Sharma, P. K. Tiwari, and Y. R. Sood, "Solar energy in India: Strategies, policies, perspectives and future potential," *Renew. Sustain. energy Rev.*, vol. 16, no. 1, pp. 933–941, 2012.
[49] R. Singh and Y. R. Sood, "Current status and analysis of renewable promotional policies in Indian restructured power sector—A review," *Renew. Sustain. Energy Rev.*, vol. 15, no. 1, pp. 657–664, 2011.
[50] A. Puri and M. Saxena, "India 2020: Utilities & Renewables." Deutsche Bank: India, 2015.
[51] T. Altenburg and T. Engelmeier, *Rent management and policy learning in green technology development: the case of solar energy in India*, no. 12/2012. Discussion Paper, 2012.
[52] D. Parker, "Regulation of privatised public utilities in the UK: performance and governance," *Int. J. public Sect. Manag.*, vol. 12, no. 3, pp. 213–236, 1999.
[53] A. Ummadisingu and M. S. Soni, "Concentrating solar power–technology, potential and policy in India," *Renew. Sustain. energy Rev.*, vol. 15, no. 9, pp. 5169–5175, 2011.
[54] W. H. Organization, "Report of the eighth meeting with international partners on prospects for influenza vaccine technology transfer to developing country vaccine manufacturers: Sao Paulo, Brazil, 17–18 March 2015," World Health Organization, 2017.
[55] J. R. Albert and D. S. Vanaja, "Solar energy assessment in various regions of Indian Sub-continent," *Sol. Cells Theory, Mater. Recent Adv.*, 2020.
[56] Л. Мельник, О. Дериколенко, Ю. Мазін, О. Маценко, and В. Півень, "Modern Trends in the Development of Renewable Energy: the Experience of the EU and Leading Countries of the World," *Mech. an Econ. Regul.*, no. 3 (89), pp. 117–133, 2020.
[57] N. Shah, M. Wei, V. Letschert, and A. Phadke, "Benefits of leapfrogging to superefficiency and low global warming potential refrigerants in room air conditioning," Lawrence Berkeley National Lab.(LBNL), Berkeley, CA (United States), 2015.
[58] D. Sharma[1] and P. Khurana, "SOLAR POWER: Challenges, Mission and Potential of Solar Power in India," *Target*, vol. 2010, p. 13, 2018.
[59] M. Graziano, M. Fiaschetti, and C. Atkinson-Palombo, "Peer effects in the adoption of solar energy technologies in the United States: An urban case study," *Energy Res. Soc. Sci.*, vol. 48, pp. 75–84, 2019.
[60] K. Kapoor, K. K. Pandey, A. K. Jain, and A. Nandan, "Evolution of solar energy in India: A review," *Renew. Sustain. Energy Rev.*, vol. 40, pp. 475–487, 2014.
[61] N. Rathore and N. L. Panwar, "Outline of solar energy in India: advancements, policies, barriers, socio-economic aspects and impacts of COVID on solar industries," *Int. J. Ambient Energy*, vol. 43, no. 1, pp. 7630–7642, 2022.
[62] M. Abu-Aligah, "Design of Photovoltaic Water Pumping System and Compare it with Diesel Powered Pump.," *Jordan J. Mech. Ind. Eng.*, vol. 5, no. 3, 2011.
[63] H. A. Simon, "The architecture of complexity," *Proc. Am. Philos. Soc.*, vol. 106, no. 6, pp. 467–482, 1962.
[64] G. Francis, R. Edinger, and K. Becker, "A concept for simultaneous wasteland reclamation, fuel production, and socio-economic development in degraded areas in India: Need, potential and perspectives of Jatropha plantations," in *Natural resources forum*, Wiley Online Library, 2005, pp. 12–24.