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SOLAR POWER: A LADDER TO ACHIEVE SUSTAINABLE DEVELOPMENT IN INDIA

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ABSTRACT:

Shifting of power generation methods is primary need for sustainable development and therefore the energy sector faces significant pressure to shift towards a low carbon mix. Solar power is solution as it address dual challenges of energy security and environment sustainability. This study investigates how solar power should be given preference over the power generation by Coal and its role as a transformative driver in meeting India's growing energy demand while aligning with national commitments to the Sustainable Development Goals. Government is taking great initiatives for production of solar power and in this study the positive results have been found. We used Excel tools to examine growth rate of Solar Power in country over years. We concluded that solar power growth rate is comparatively higher than coal power which ultimately proves this study.

Keywords: Solar Power, Sustainable Development Goals, Growth Rate, Renewable energy, Coal

I. INTRODUCTION

India is steadily advancing toward its global climate commitments under the Paris Agreement, which include the target of installing 500 gigawatts (GW) of renewable capacity by 2030 and achieving net-zero carbon emissions by 2070 (IBEF, 2025). By February 2025, the country had crossed the milestone of 100 GW of installed solar power capacity. Over the last decade, India's solar sector has experienced remarkable growth of nearly 3450%, expanding from just 2.82 GW in 2014 to 100 GW in 2025 (Sreejith,2025). Solar energy has emerged as the leading driver of renewable growth, contributing about 47% of the nation's total installed renewable capacity. The year 2024 alone witnessed a record addition of 24.5 GW of solar power, more than doubling the installations achieved in 2023 (MNRE,2025a). Energy plays a pivotal role in shaping the economic and developmental trajectory of nations. Broadly, energy sources are categorized into renewable and non-renewable forms, each with distinct implications for sustainability. In the Indian context, coal remains the primary non-renewable source, yet its extensive use is associated with significant environmental costs, including air pollution, greenhouse gas emissions, and ecosystem degradation. Conversely, renewable sources such as solar, wind, hydro, and biomass provide cleaner and more sustainable alternatives. Among these, solar energy has emerged as a critical component of India's energy transition, offering solutions to the setbacks posed by coal-based thermal power plants, including high emission levels, excessive water consumption, and long-term ecological harm. The expansion of solar infrastructure thus reflects not only an environmental imperative but also a strategic pathway for achieving sustainable energy security in India. Between 2024 and 2030, solar photovoltaic (PV) technology is anticipated to account for approximately 80% of the global increase in renewable energy capacity (IEA,2024). This expansion will be driven both by the commissioning of utility-scale solar projects and by the accelerated deployment of rooftop PV systems across the commercial and residential sectors.

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By the end of the decade, solar PV is projected to become the predominant renewable energy source worldwide, surpassing wind power and hydropower, the latter of which currently represents the largest share of renewable electricity generation (IEA,2024)

Table 1: Largest Solar Plants in India

PROJECT NAME	LOCATION	CAPACITY (MW)	KEY DETAILS
Bhadla Solar Park	Rajasthan	2245	Largest solar park in the world, spread across 14,000 acres in the Thar Desert.
Pavagada Solar Park	Karnatka	2050	Also known as "Shakti Sthala," it is the second-largest solar park in India.
Kurnool Ultra Mega Solar Park	Andhra Pradesh	1000	Commissioned in 2017, this park is located over 5,932 acres.
Rewa Ultra Mega Solar Park	Madhya Pradesh	750	Made headlines for supplying power to the Delhi Metro.
Kamuthi Solar Power Project	Tamil Nadu	648	One of the world's largest single-location solar farms, completed by Adani Group in 2017.
Charanka Solar Park	Gujrat	500+	Located in Patan district, this park is built on otherwise unused land

Source: *(Freyr Energy, 2025)*

II. PRIOR LITERATURE

India's energy transition presents a complex challenge where coal continues to hold a central role despite the rapid growth of renewable energy (RE). **Tongia & Gross (2019),** emphasize that while both coal and RE are essential to meet the country's surging power demand, structural issues in the Indian power sector hinder their complementary growth. They note that local air pollution is a more pressing concern than climate change in the near term, with stricter environmental regulations likely to force inefficient plants offline. Instead of envisioning an immediate coal phase-out, the authors argue that cleaner and more efficient coal technologies offer a more realistic pathway. Their analysis draws on government and regulatory data, Brookings India's internal projections, and plant-level competitiveness assessments using scenario. The conclusion highlights that, given India's rising energy needs, coal use will likely expand more in absolute terms than renewable energy, even as RE capacity grows. **Sharma et al. (2012),** investigated the development of India's solar energy sector, focusing on strategies, policies, perspectives, and future opportunities. Their work assessed national initiatives, financial schemes, and policy frameworks introduced to advance solar technologies, with particular emphasis on the Jawaharlal Nehru National Solar Mission. They evaluated the country's solar resource potential, technological improvements, and investment patterns, while also highlighting challenges such as high installation costs, weak infrastructure, and policy inconsistencies. The study concluded that with stronger institutional backing and effective execution, solar energy could play a pivotal role in driving India's sustainable energy transition. **Majid et al. (2020),** studied how renewable energy sources contribute to the energy demand in India. Even though India has achieved a fast and remarkable economic growth, energy is still scarce. Strong economic growth in India is escalating the demand for energy, and more energy sources are required to cover this demand. At the same time, due to the increasing population and environmental deterioration, the country faces the challenge of sustainable development. The gap between demand and supply of power is expected to rise in the future and therefore one should work in direction

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towards solar power or other renewable energy. **Prehoda et al. (2017),** examined the health benefits of replacing coal-based electricity generation with solar photovoltaic (PV) power in the United States. Their analysis showed that transitioning from coal to solar PV would have significantly reduced mortality caused by coal-related pollutants such as fine particulate matter, sulfur dioxide, and nitrogen oxides. The research also highlighted the economic value of avoided deaths, framing solar adoption not only as an environmental and energy policy issue but also as a major public health intervention. Overall, the findings demonstrated that substituting coal with solar PV could have saved tens of thousands of lives in the U.S. while simultaneously reducing healthcare costs and improving societal well-being.

Objectives

1. To analyze the emission of carbon from Coal and Solar power generation in India.
2. To examine the growth in production of electricity by Solar Plant in India.
3. To analyze Government policies on Solar Power and Sustainable Development.

III. RESEARCH METHODOLOGY

The present study is based on secondary data related to the emission of carbon from Coal and Solar power generation in India from 2009 to 2003, Growth in Electricity generated by Solar Plant in India from 2000 to 2024 and State-wise (Location based) installed capacity of Renewable Power as on 31.07.2025 which was compiled from Ember, CEA &Ministry of Power (MoP) and Adviser (P&C)& Ministry of New and Renewable Energy,2025 respectively. Microsoft Excel was used to calculate compound annual growth rate of available data base.

IV. RESULTS AND DISCUSSION

1. The Emission of carbon from Coal and Solar power generation in India.

The table 2 showed the growth in power generation from coal and solar plants in India during the period 2010–2023. Electricity generation from coal increased rapidly from 597.60 GWh to 1346.80 GWh in 2010 and 2023 respectively. The annual growth rate fluctuated between years, with the highest growth of 10.63% in 2013, while a slight decline of –0.15% was observed in 2020. The compound annual growth rate (CAGR) for coal was recorded at 2.23%, which shows emission increased over the period of time. On the other side Solar Power generation started at a low level of 0.01 GWh in 2010 and rose to 5.39 GWh in 2023. In the initial years, solar energy recorded very high growth rates such as 100% in 2010, 75% in 2011, and 50% in 2012 due to its small base. However, after 2021, the growth slowed down significantly, with a negative growth of –16.14% in 2022. As a result, the compound annual growth rate for solar was calculated at –12.21%, which shows Solar Power produced less CO2 as compared to Coal. This will help India in achieving zero Carbon footprint and also help in promoting green energy for better and Sustainable future.

Table 2: Carbon emission from Coal and Solar in India from 2009 to 202

(in million metric tons of carbon dioxide equivalent)

YEAR	COAL	Growth Rate	SOLAR	Growth Rate
2009	5680.5	-	0	-
32010	597.60	4.94	0.01	100.00
23011	650.73	8.16	0.04	75.00

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2012	728.15	10.63	0.10	60.00
2013	782.51	6.95	0.16	37.50
2014	874.37	10.51	0.23	30.43
2015	924.16	5.39	0.31	25.81
2016	983.70	6.05	0.55	43.64
2017	1020.03	3.56	1.02	46.08
2018	1095.16	6.86	1.73	41.04
2019	1093.56	-0.15	2.20	21.36
2020	1042.33	-4.91	2.79	21.15
2021	1160.33	10.17	3.25	14.15
2022	1256.14	7.63	4.52	28.10
2023	1346.80	6.73	5.39	16.14
CAGR	**-**	**2.23%**	**-**	**-12.21%**

Source**:** *Ember(2024)*

2.Growth in Electricity generated by Solar Plant in India

Table 3 showed, during the years 2000 to 2008, electricity generation by Solar plant remained almost stagnant at only 2 to 3 GWH. The growth rate was recorded as 0%, which showed that there had been no major increase in electricity generation capacity. In 2009, electricity generation of Solar plant rose to 8 GWH along with 62.5% growth rate. During the year 2010, saw a sharp rise to 54 GWH, with a growth rate of 85.19%. By 2011, electricity generation increased to 1,410 GWH with a growth of 96.17%. This marked the beginning of large-scale expansion in electricity generation. Between 2012 and 2018, electricity generation increased consistently every year. Growth rates during these years remained very high between 28% to 65%. From 2019 to 2023, the pace of growth slowed but continued to remain positive. Electricity generation rose from 51,386 GWH. In 2019 to 118,528 GWH in 2023. Growth rates during these years ranged from 12% to 27%, which indicated a phase of stability and maturity in the sector. In 2024, electricity generation reached 475,000 GWH along with the growth of 75.05%. This sharp rise suggested the introduction of mega projects, technological breakthroughs, major policy support and various Government initiatives and policies.

Table 3: Trends in the growth of Electricity produced by Solar Plant in India from 2000 to 2024

YEAR	Electricity generated (in GWH)	Growth rate	YEAR	Electricity generated (in GWH)	Growth Rate
2000	2	0.00	2013	4099	65.60
2001	2	0.00	2014	5789	29.19
2002	3	33.33	2015	10401	44.34
2003	3	0.00	2016	18867	44.87
2004	3	0.00	2017	26331	28.35
2005	3	0.00	2018	40357	34.75
2006	3	0.00	2019	51386	21.46
2007	3	0.00	2020	62042	17.18
2008	3	0.00	2021	75646	17.98
2009	8	62.50	2022	103581	26.97
2010	54	85.19	2023	118528	12.61

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2011	1410	96.17	2024	475000	75.05
			CAGR	**67.49%**	-

***Source*:** *CEA &Ministry of Power (MoP)*

Table 4 showed, State-wise (Location based) installed capacity of Renewable Power as on 31.07.2025. During the FY25, total of 119016.54 MW power generated by Solar plants in India. Rajasthan produced 32317.19 MW, Gujrat produced 21904.55 MW, Maharashtra produced 13336.82 MW, Tamil Nadu produced 10823.98 MW and Karnataka produced 10060.84 MW. These are top five states in producing Solar power. This was all due to abundant Sunlight, Vast land area, Government initiative and policies and financial incentives. On the other hand, Nagaland produced 3.17 KW, Meghalaya produced 4.28 KW, Lakshadweep produced 6.57 KW, Sikkim produced7.56 and Ladakh produced 11 KW. These states contribute low Solar Power in India. The reason behind lower Solar Power was monsoon cover and cloud cover, dense vegetation and hilly Terrain, and lack of Government policies and incentives.

Table4: State-wise (Location based) installed capacity of Renewable Power as on 31.07.2025.

S.no	States'	Ground Mounted Solar	RTS (including PM-Surya Ghar Yojana)	Hybrid Solar Comp.	Off-grid Solar/ KUSUM	Solar Power Total
		(MW)	(MW)	(MW)	(MW)	(MW)
1	Andhra Pradesh	5006.34	428.6		88.34	5523.28
2	Arunachal Pradesh	1.27	6.68		6.9	14.85
3	Assam	126	107.9		9.44	243.34
4	Bihar	196.06	193.8		21.28	411.14
5	Chhattisgarh	998.91	146.2		390.73	1535.84
6	Goa	1.95	57.7		1.49	61.14
7	Gujarat	15025.13	5835.3	871.11	173.01	21904.55
8	Haryana	267.76	889.6		1019.65	2177.01
9	Himachal Pradesh	203	62.9		34.58	300.48
10	Jammu & Kashmir	2.49	42.2		29.8	74.49
11	Jharkhand	21	93.04		86.32	200.36
12	Karnataka	9054.03	755.4	212.25	39.16	10060.84
13	Kerala	323.21	1444.2		24.93	1792.34
14	Ladakh	6	5			11.00
15	Madhya Pradesh	4865.23	627.7		102.04	5594.97
16	Maharashtra	7982.71	3745.4		1608.71	13336.82
17	Manipur	0.6	10.2		6.08	16.88
18	Meghalaya		0.21		4.07	4.28
19	Mizoram	22	3		6.39	31.39
20	Nagaland		1		2.17	3.17

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21	Odisha	574.5	106.8		42.34	723.64
22	Punjab	886.27	503.4		81.76	1471.43
23	Rajasthan	27821.74	1710	1980	805.45	32317.19
24	Sikkim	0.52	5.12		1.92	7.56
25	Tamil Nadu	9621.08	1132.5		70.4	10823.98
26	Telangana	4360.49	633.5		8.71	5002.70
27	Tripura	5.57	12.2		11.34	29.11
28	Uttar Pradesh	2776.34	382.5		324.72	3483.56
29	Uttarakhand	541.05	273.71		20.96	835.72
30	West Bengal	240.35	67.13		13.14	320.62
31	Andaman & Nicobar Islands	25.05	5.6		0.27	30.92
32	Chandigarh	6.34	71.7		0.81	78.85
33	Dadra & Nagar Haveli and Daman & Diu	14.3	105.6			119.90
34	Delhi	9.84	341.3		1.46	352.60
35	Lakshadweep	2.45	1.6		2.52	6.57
36	Puducherry	1.03	67.8		0.18	69.01
37	Others				45.01	45.01
TOTAL		**90990.61**	**19876.49**	**3063.36**	**5086.08**	**119016.54**

Source: *Adviser (P&C), Ministry of New and Renewable Energy,2025*

3. India's Progress on Renewable energy and The Sustainable Development Goals (SDGs): Solar Energy

- **PM Surya Ghar: Muft Bijli Yojana:**

This scheme helps residential households install rooftop solar systems to get free or low-cost electricity. This scheme aims to benefit one crore households and also expected to save the Government Rs. 75000 Cr. Annually in electricity cost. PIB Delhi,2024

SDG 1: No Poverty: By drastically reducing household electricity expenses, the scheme frees up income for other basic needs, which helps in reducing poverty.

SDG 7: Affordable and Clean Energy: This scheme provides financial assistance and making solar power accessible to the wider population, including lower-income households. It significantly increases the share of renewable energy in the nation's energy mix.

SDG 11: Sustainable Cities and Communities: Promotes decentralized renewable energy generation within urban and rural communities, making cities more sustainable and resilient to power failure.

SDG 13: Climate Action: Facilitates a significant shift from non -renewable such as coal to clean energy at the household level which helps in reducing carbon emissions by 720 million tonnes (PIB Delhi,2024) and contribute to India's climate targets.

- **PM-KUSUM Scheme:**

This program will help farmers in installation of 17.50 lakh solar Agriculture pumps of Capacity up to 7.5 HP for replacement of existing diesel and solarizing of 10 lakh grid-connected agricultural pumps. (GoI,2024)

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SDG 7: Affordable and Clean Energy: This scheme helps the agricultural sector to switch from diesel to clean solar power.

SDG 2: Zero Hunger: By providing a reliable and subsidized clean power source for irrigation leads to enhancing agricultural productivity and improves water management create better food security.

SDG 13: Climate Action: Reduces carbon emissions caused by diesel-powered pumps, helping mitigate climate change.

SDG 8: Decent Work and Economic Growth: This scheme helps in boosting farmers' income by reducing diesel costs. In some cases, farmers can also sell surplus power back to the grid, creating an additional revenue stream.

- **Production Linked Incentive (PLI) Scheme for High-Efficiency Solar PV Modules**

This initiative incentivizes domestic manufacturing of high-efficiency solar PV modules with outlay of Rs. 24,000 Cr. (MNRE, 2025b)

SDG 9: Industry, Innovation, and Infrastructure: This directly supports the development of a resilient domestic solar manufacturing industry. It encourages innovation by promoting advanced, high-efficiency technologies and helps in creating a sustainable ecosystem for the solar industry.

SDG 8: Decent Work and Economic Growth: The expansion of a domestic manufacturing base creates numerous direct and indirect jobs, contributing to productive employment and economic growth.

SDG 12: Responsible Consumption and Production: By boosting local manufacturing, the scheme helps reduce reliance on imported solar components and fosters a more self-reliant and sustainable production model.

- **Grid -Connected Rooftop Solar Programme (Phase-II):**

This program promotes grid-connected 4000 MW rooftop solar installations through central financial assistance for residential consumers. MNRE,2022

SDG 7: Affordable and Clean Energy: This increases the overall installed capacity of solar power by focusing on the residential sector. This improves grid stability and reduces peak load demand

V. CONCLUSION

The findings of this study highlight that coal has long played a vital role in ensuring India's energy security, providing a stable and large-scale source of power generation. However, critical analysis of this dependency reveals significant environmental, social, and economic costs associated with continued reliance on coal, including pollution, resource depletion, and barriers to long-term sustainability. In contrast, literature supporting solar power demonstrates its immense potential in terms of abundance, cost-effectiveness, and environmental benefits. The data analyzed in this study confirm that solar energy not only meets growing energy demands but also contributes directly to the goals of sustainable development. Thus, while coal has been central to India's growth, a strategic transition toward solar energy is essential to secure a cleaner, more resilient, and sustainable future.

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