# Transitioning to Sustainable Energy: The Role and Future of Renewable Energy Sources in India's Power Sector

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## Abstract:

Renewable energy around the globe has become essential for sustainable development and India is at the forefront of this transformation. Energy is crucial for any developing economy and India is no exception to this. However, the dependence on non-renewable sources leads to significant environmental and health challenges. For instance, air pollution, to which coal mining contributes 40%, accounts for 8-10% of healthcare costs and over $90 billion annually. Given that 74% of the nation's energy currently comes from fossil fuels, addressing environmental concerns is paramount as India continues its rapid development (Subhashish Dey, 2022).

The National Electricity Plan is an answer to this issues which aims to ensure widespread electricity access, it also mitigating environmental impact. This involves strongly promoting renewable energy sources, with solar, wind, biomass, and hydropower playing pivotal roles in shaping a sustainable energy future. This research paper will investigate into the status of renewable energy in India, explore the challenges it faces, and analyse its potential future contributions to the Indian economy through a comprehensive SWOT analysis.

## 1) Introduction

India faces increasing energy demand for economic development, but is responsible for 6.65% of global carbon emissions (Charles Rajesh Kumar. J, 2020). Despite its National Electricity Plan, India contributes to 7.3% of global emissions and is the third-largest emitter of carbon dioxide. With 74% of energy demand coming from coal and oil, India faces health and environmental challenges (Charles Rajesh Kumar. J, 2020). Air pollution contributes to 8-10% of healthcare costs, and India's dependence on oil and natural gas puts pressure on foreign exchange reserves and trade balance. Coal mining in India leads to environmental degradation, deforestation, and water pollution. Transitioning to cleaner energy sources could lead to economic dislocation and social and economic issues.

India is transitioning to renewable energy technologies to achieve sustainable growth and prevent climate change. The country generates 203.18 GW of renewable energy, accounting for 46.3% of its total electricity generation capacity (Charles Rajesh Kumar. J, 2020). Solar power is the leading contributor, accounting for 92.12 GW. Hydropower and Solar Photovoltaic are the largest contributors, employing the most individuals. Wind Power generates 52,000 jobs, Liquid Biofuels provide 35,000, and Solid Biomass 58,000. To promote renewable energy, a combination of push policies and pull mechanisms, investment opportunities, job creation for unskilled workers, technicians, and contractors, and technological and financial initiatives are necessary.

### 1.1) Global need of renewable energy

The global demand for renewable energy is crucial due to climate change and energy demand. Currently, renewable energy accounts for 29% of global electricity generation, with solar and wind contributing 10% and 7%, respectively. To meet the Paris Agreement's target of limiting global warming to 1.5°C, renewable energy must make up 70-85% by 2050.

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### 1.3) How renewable energy sources contribute to the energy demand in India

India's rapid economic growth is escalating energy demand, necessitating more energy sources to meet this demand. The country faces challenges of sustainable development due to increasing population and environmental degradation. The gap between demand and supply of power is expected to widen in the future. India's renewable energy sector has seen significant progress since 2014-15, with solar and wind power accounting for over 46% of the country's total electricity generation capacity. Solar power, with 92.12 GW, is leading the way in cleaner, non-fossil fuel-based energy sources. The government aims to achieve 500 GW of renewable energy by 2030 (Subhashish Dey, 2022). Renewable energy sources contributed 359.89 BU in 2023-24, representing 20.75% of total energy generation.

## 2) Literature Review

1) (Subhashish Dey, 2022) Renewable energy present status and future potentials in India: An overview. The study evaluates the energy mix evolution in relation to a country's development level, based on real GDP per capita. India is the fourth most attractive renewable energy market globally, with the government committed to increasing clean energy use and promoting green energy. The study suggests increased investment in renewable energy output, energy efficiency, economic growth, and carbon emissions as significant factors of renewable energy consumption. The relationship between renewable energy and sustainable development is discussed, with renewable energy output, energy efficiency, economic growth, and carbon emissions being significant factors.
2) (Sunita Pachar, 2021) Implication of Renewable Energy in Sustainable Development in India: Future Strategy. Renewable energy (RE) has significant potential for sustainable development in India, as the country's growing economy requires a 3-4 times higher energy supply than currently consumed. The research paper discusses RE sources, drivers,

challenges, and policies. It concludes that RE can fulfill India's energy demand with the latest technologies, improving quality of life and creating domestic jobs. RE can also reduce environmental pollution, carbon emissions, and nonrenewable energy scarcity. It positively impacts economic growth, job creation, and welfare. The paper recommends strategic policy in sustainable energy sources.

3) (Charles Rajesh Kumar. J, 2020) Renewable energy for sustainable development in India: current status, future prospects, challenges, employment, and investment opportunities. India's renewable energy strategy aims to boost economic development, improve energy security, and combat climate change. With government support and favorable economic conditions, India has become a top leader in renewable energy markets. The government has implemented policies to attract foreign investments, accelerating the sector and creating jobs. The paper presents India's achievements, prospects, challenges, investment opportunities, and obstacles faced by the renewable sector, providing recommendations for policymakers, innovators, investors, industries, stakeholders, researchers, and scientists.

## 3) Objectives of the study

1. To assess the current status and growth potential of renewable energy sources in India.
2. To analyze the challenges faced by India in scaling up renewable energy financing.
3. To identify and recommend strategies for increasing the utilization of renewable energy in India

## 4) Hypotheses

1. H0: There is no significant effect of fossil fuel usage on the environment
2. H0: Renewable energy sources have no positive impact on the environment.

## 5) Data Collection

- The research paper is based on secondary data i.e. articles, relevant websites and reports.

### 6.1) Current achievements in renewable energy

India's renewable energy sector has seen significant growth in 2024, with significant strides in solar and wind energy installations, policy advancements, and infrastructural improvements. With a commitment to achieving 500 GW of non-fossil fuel-based energy capacity by 2030, India is emerging as a global leader in clean energy. As of 20th Jan 2025, India's total non-fossil fuel-based energy capacity reached 217.62 GW. In 2024, India added 24.5 GW of solar capacity and 3.4 GW of wind capacity, reflecting a two-fold increase in solar installations and a 21% rise in wind installations compared to 2023. Solar energy remains the dominant

contributor to India's renewable energy growth. Last year saw the installation of 18.5 GW of utility-scale solar capacity, a nearly 2.8x increase compared to 2023. Rajasthan, Gujarat, and Tamil Nadu emerged as the top-performing states, contributing 71% of India's total utility-scale solar installations. The rooftop solar sector also experienced significant growth in 2024, with 4.59 GW of new capacity installed, marking a 53% increase from the year 2023. The PM Surya Ghar: Muft Bijli Yojana, launched in 2024, played a crucial role in this expansion, facilitating 7 lakh rooftop solar installations within ten months. Additionally, the off-grid solar segment recorded a 182% increase, adding 1.48 GW in 2024, furthering India's energy access goals in rural areas. India added 3.4 GW of new wind capacity in 2024, with Gujarat (1,250 MW), Karnataka (1,135 MW), and Tamil Nadu (980 MW) leading the way. These states accounted for 98% of the new wind capacity additions, highlighting their continued dominance in wind power generation (Charles Rajesh Kumar. J, 2020).

India's renewable energy sector has seen revised tariff policies, waived charges, and finalized policies, including a national lab policy for testing, standardization, and certification. The Surya Mitra program trains college graduates in solar panel installation, commissioning, operations, and management, making the sector more attractive for investors.

### 6.2) Sectoral review of renewable energy sources

#### Hydropower

As of 2023, India's hydropower capacity stands at approximately 46,865 MW, representing roughly 11% of the country's total power generation capacity; with an estimated economically viable hydroelectric potential of 148,701 MW, indicating a significant room for further development in the sector. Additional smaller hydroelectric power units with a total capacity of 4,683 MW (1.3% of its total utility power generation capacity) have been installed. India's hydroelectric power potential is estimated at 148,700 MW at 60% load factor.

#### Sea wave power

According to studies, India has a significant sea wave power potential, with estimates suggesting a total capacity of around 40,000 MW along its coastline, with the western coast generally having higher wave energy potential compared to the east coast, primarily due to more stable waves and less cyclone activity; the average potential along the Indian coast is estimated to be around 5-10 kW/m.

#### Tidal power

Hydro power is a reliable, commercially developed renewable energy resource that uses controlled water flow to generate electricity. Tidal energy, derived from oceanic tides, is a

cheaper, easily available, and environmentally friendly source. India has a potential of 8000 MW of tidal energy, which can be harnessed in tidal streams, barrages, and lagoons. Tidal energy can be used for domestic, off-grid generation, depending on property type (Subhashish Dey, 2022).

**Wind energy**

Wind energy is a clean energy source increasingly used in the UK, contributing to the National Grid through wind turbines. It converts mechanical energy into electric energy, a form of solar energy. The world's largest windmill is typically in China, with a capacity of 6000 MW. Wind power installations in India increased by 31% in the 2019-20 financial year, reaching 2.07GW, a 31% increase from 1.58GW in 2018. Wind energy has lower environmental effects compared to fossil fuels.

**Solar energy**

Sunlight is an abundant and renewable energy resource, with solar energy reaching the Earth's surface in just one hour. This energy can be used for various purposes, including heating, photovoltaic, thermal, and artificial photosynthesis. In the UK, solar energy is increasingly popular as a renewable source. Active solar energy includes photovoltaic systems, concentrated solar power, and solar water heating, while passive solar energy includes building orientation, thermal biomass, and natural air circulation. The Earth receives 174,000 TW of solar radiation, which is absorbed by the Earth's land surface, oceans, and rivers. The total solar energy absorbs approximately 385,000 EJ per year. As of November 30, 2021, the UK has a solar installed capacity of 48.556 GW. Solar energy is widely used in water heating, cooking, and electricity production, such as photovoltaic cells (Subhashish Dey, 2022).

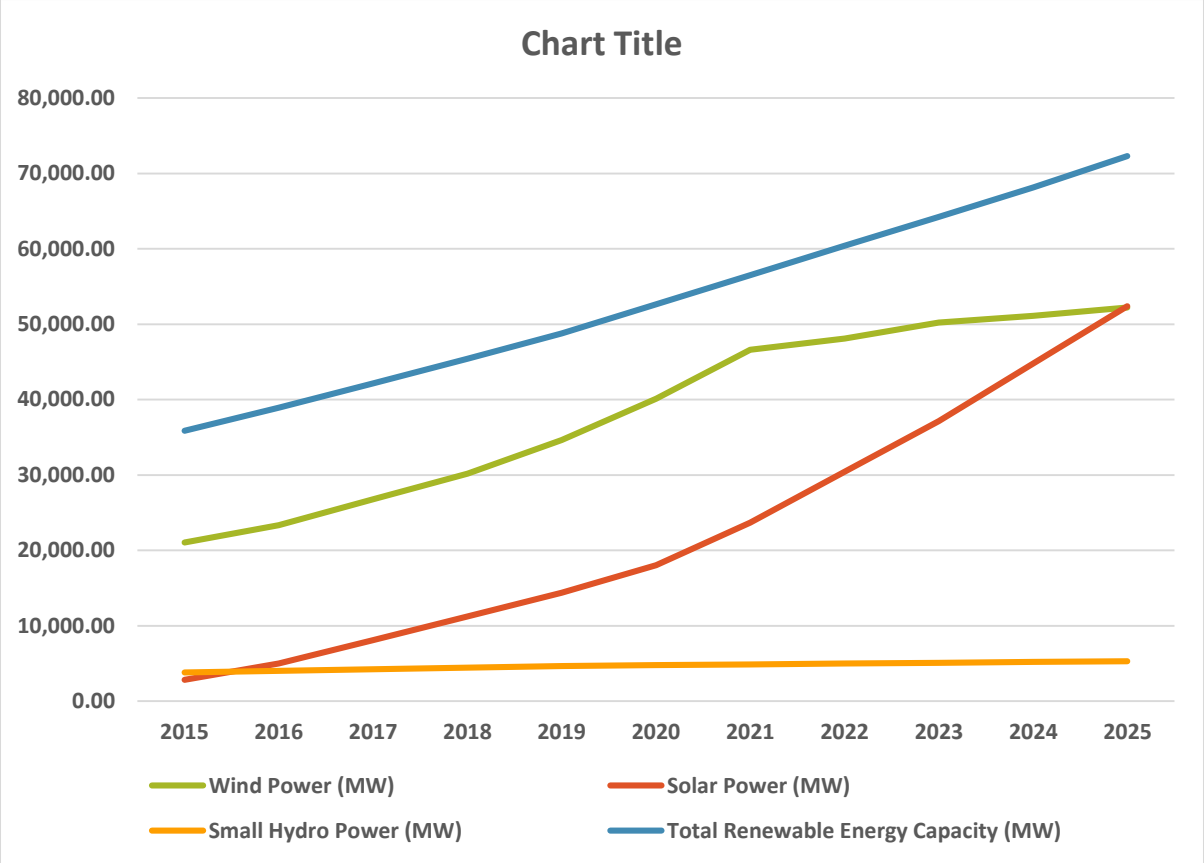
**Geothermal energy**

Geothermal energy, a thermal geological energy, is a renewable source that harnesses natural heat below the earth's surface to heat homes and generate electricity. It is of negligible importance in the UK compared to countries like Iceland, where geothermal heat is more readily available. Geothermal energy is based on the geothermal gradient, which depends on the temperature difference between the planet's core and its surfaces. The earth's internal heat is generated from radioactive decays. Geothermal energy is low-cost, easily available, sustainable, trustworthy, and clean. The Vindhyachal Thermal Power Station in Madhya Pradesh is the largest thermal power plant in India. The International Geothermal Association reports that 24 countries produce 10,715 MW of geothermal power globally (Subhashish Dey, 2022).

**Nuclear energy**

Nuclear power, a low-carbon energy technology, has experienced a slowdown since the 1970s-1990s, with a sharp dip following the 2011 Fukushima disaster. India produced 43 TWh in 2020-21, contributing 3.11% of total power generation. To address climate problems, focusing on a carbon-free future and transitioning from fossil fuels to nuclear and renewable energy can reduce accidents, air pollution, and health impacts. Countries like France, USA, China, Russia, and Canada also produce nuclear power (Subhashish Dey, 2022).

| Year | Wind Power (MW) | Solar Power (MW) | Small Hydro Power (MW) | Total Renewable Energy Capacity (MW) |
|---|---|---|---|---|
| 2015 | 21,042.58 | 2,821.91 | 3,803.68 | 35,849.59 |
| 2016 | 23,354.35 | 4,993.27 | 4,021.79 | 38,915.45 |
| 2017 | 26,777.40 | 8,123.63 | 4,239.90 | 42,157.87 |
| 2018 | 30,200.45 | 11,254.00 | 4,446.28 | 45,408.37 |
| 2019 | 34,623.50 | 14,384.36 | 4,664.39 | 48,769.59 |
| 2020 | 40,125.87 | 18,043.00 | 4,770.74 | 52,627.57 |
| 2021 | 46,628.24 | 23,701.63 | 4,877.09 | 56,485.57 |
| 2022 | 48,109.47 | 30,455.32 | 4,984.44 | 60,418.03 |
| 2023 | 50,227.24 | 37,139.12 | 5,090.83 | 64,227.42 |
| 2024 | 51,097.53 | 44,767.92 | 5,196.27 | 68,116.37 |
| 2025 | 52,207.06 | 52,401.04 | 5,301.71 | 72,312.89 |




Source: Ministry of New and Renewable Energy, India

**Interpretation:**

From 2015 to 2025, total renewable energy capacity doubled, rising by 101.7% from 35,849.59 MW to 72,312.89 MW. Solar power saw the most rapid growth of 1,757%, increasing from 2,821.91 MW to 52,401.04 MW, making it the largest contributor (72.5%) by 2025. Wind power grew by 148%, from 21,042.58 MW to 52,207.06 MW, though its share declined slightly to 72.2% due to Solar's faster rise. Small hydro power grew modestly by 39%, from 3,803.68 MW to 5,301.71 MW, with its share dropping from 10.6% in 2015 to 7.3% in 2025. The data highlights a clear transition towards solar-dominated renewable energy, driven by technological advancements and policy support.

**Renewable energy: SWOT analysis**


**6.3) Scaling Up: Renewable energy financing landscape in India**

India has significantly increased its renewable energy capacity, reaching 190 GW as of June 2024. The country aims to achieve 500 GW of non-fossil fuel power capacity by 2030 and net zero emissions by 2070. To achieve these goals, India needs to rapidly scale up investments in the renewable energy sector, estimated to be over $300 billion. This requires tapping into a diverse range of domestic and international sources, addressing key financing challenges, and tapping into a more diverse range of domestic and international sources.

**6.4) Initiatives to encourage investments in the renewable sector**

The Indian government has been actively encouraging investments in the renewable energy sector, allowing foreign direct investment (FDI) up to 100% under the automatic route. This has attracted $3.8 billion in FDI in the solar energy sector over the past three financial years.

The government has waived inter-state transmission system charges for solar and wind power projects to be commissioned by June 30, 2025. To further boost the sector, the government plans to add 50 GW of renewable energy capacity annually over the next five years and set a trajectory for renewable purchase obligation up to 2029-30. Standardization of bidding guidelines and the implementation of production-linked incentive schemes for solar PV manufacturers are expected to drive growth in the sector. The government is also focusing on reducing PPA counterparty risk by making energy purchases through highly rated central public sector enterprises. Schemes such as the Liquidity Infusion Scheme, Electricity (Late Payment Surcharge and Related Matters) Rules, 2022, and the Revamped Distribution Sector Scheme have been announced to increase the overall health of the sector, especially in the distribution space.

The 2024-25 Interim Budget has allocated $1.2 billion to solar power grid projects, an increase from $568 million in FY24. Viability gap funding will be provided for offshore wind energy for an initial capacity of 1 GW. India needs an investment of $293 billion between 2023 and 2030 to achieve its current solar and wind energy targets. To match the International Energy Agency's net zero pathway, India must secure an extra $101 billion in funding for developing solar, wind, storage, and transmission infrastructure.

**6.5) Financing sources for renewable energy projects**

India's renewable energy financing has primarily come from private non-banking financial companies (NBFCs), with public NBFCs and public sector banks also joining the market. The positive environmental and socio-economic impact of renewable energy has attracted long-term investors. From 2019-2021, foreign banks and financial institutions provided 50% of the debt raised by India's renewable energy projects. As of March 2022, eight major sovereign wealth and pension funds have taken direct equity stakes in Indian renewable energy companies. Indian renewable energy companies are increasingly utilizing domestic and international bond markets, with Greenko, ReNew Power, Adani Green Energy Limited, and Azure Power being top issuers of green bonds. India made its debut in the sovereign green bond space in 2021, issuing sovereign green bonds worth Rs 80 billion in January 2023 and Rs 200 billion in four tranches of Rs 50 billion in 2023-24.

**6.6) Challenges in scaling up renewable energy financing**

India's renewable energy projects face several risks, including delays in payments from discoms, challenges in land acquisition and infrastructure availability, rising interest rates, and contract renegotiations. As of June 2024, overdue payments to power producers amount to $10.42 billion, putting pressure on developers. Project delays and cost overruns have also

contributed to these risks. Expected equity returns for renewable projects have fallen due to payment delays, generation underperformance, and cost pressures. Rupee depreciation is an added risk for projects with foreign currency debt exposure. Banks face sectoral exposure limits and provisioning norms, constraining lending to renewables

**6.7) Strategy for increased utilization of renewable energy**

To increase the proportion of renewable energy in the overall energy mix, recommendations include raising awareness for decentralized energy systems, encouraging private sector participation in generating grid-quality power from renewable sources, providing a suitable policy package for private sector involvement, promoting a renewable energy movement through cooperatives and community-based networks, fostering entrepreneurship in the renewable energy sector, viewing renewable energy development as a tool for social justice, providing equal opportunities in institutional support, financial mobilization, and tariff structuring, creating a Renewable Energy Act to address renewable energy issues, increasing research and development efforts to bring renewable energy technology to the level of conventional energy systems, establishing a National Renewable Energy Development Corporation to plan and coordinate renewable energy development, and imposing a sustainability tax on non-renewable power units to create a fund for renewable investments.

## 7) Limitations of the study

This research on India's renewable energy leverages reliable data, yet variations in collection methods between regions and over time could introduce inconsistencies. The paper offers a valuable overview of renewable energy sources; however, more in-depth examination of individual sources is needed to provide a clearer understanding of their full economic impact on the nation.

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## Website Link

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- https://powerline.net.in/2024/07/01/scaling-up-renewable-energy-financing-landscape-in-india/
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