India's Renewable Energy Growth Over Time Using Pivot Tables

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Abstract

India has made significant progress in expanding its renewable energy capacity in recent years, aiming to move toward a more sustainable and low-carbon power sector. This paper examines the growth of renewable energy generation in India over time, focusing on key contributors such as solar, wind, hydro, and biomass. Using government-sourced time-series data, the study highlights how renewable energy generation has evolved, revealing patterns of growth, stagnation, and seasonal shifts in production. The data-driven insights help to understand India's shifting energy mix, with solar energy emerging as a major contributor in recent years. The study provides a clearer understanding of how renewable energy development aligns with national goals and global sustainability targets. The findings may support future policy planning, infrastructure investment, and energy forecasting for a cleaner and more reliable power system in India.

Keywords: Big Data Analytics, Renewable Energy, Time Series Analysis, Solar Energy, Wind Energy, Seasonal Patterns, India

1. Introduction

India emerge as a global reader in its energy transition, as it balances rapid economic growth with the urgent need to reduce greenhouse gas emissions and ensure energy sustainability. As of early 2025, India's total installed power generation capacity stands at approximately 430 GW, of which over 180 GW (around 42%) is contributed by renewable energy sources. This includes solar energy (77 GW), wind power (45 GW), large hydro (47 GW), and bioenergy (11 GW). Solar and wind power, in particular, have shown remarkable growth due to consistent policy support, falling technology costs, and increased private sector participation. In line with the Paris Agreement, India has committed to achieving 500 GW of non-fossil fuel capacity by 2030 and meeting 50% of its electricity requirements from renewable sources by that year. Furthermore, the country aims to

achieve net-zero carbon emissions by 2070, making renewable energy a central pillar of its climate strategy. Some Government initiatives such as the National Solar Mission, Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME), PM-KUSUM, and the Green Hydrogen Mission have further accelerated the shift toward a cleaner energy future.

Despite this progress, the pace and distribution of renewable energy generation vary significantly across sources and regions. While solar energy has experienced exponential growth, other sectors such as biomass and small hydro have shown relatively slower expansion. Additionally, seasonal factors, policy shifts, and infrastructure challenges affect consistency in generation energy. Understanding these variations and tracking how renewable energy generation has evolved over time is critical for evaluating the real world impact of these efforts and designing future interventions.

This study uses official time-series data on power generation from various renewable sources in India to examine the country's progress over recent years. By mapping trends in solar, wind, hydro, and biomass generation, the research aims to highlight areas of growth, stagnation, and fluctuation. These insights are valuable for policymakers, energy planners, and researchers working toward a sustainable, low-carbon energy system that aligns with India's long-term developmental and environmental goals.

2. Review of Literature

Previous studies have explored renewable energy trends in India, often focusing on individual sources or regional case studies.

- **Bhattacharya et al. (2020)** examined the policy drivers behind India's solar power growth, emphasizing the role of the National Solar Mission.
- **Chaudhary and Narayan (2019)** analyzed wind energy patterns and identified monsoon dependence as a key challenge for grid integration.
- **Ghosh and Dutta (2021)** reviewed biomass utilization, noting slow growth due to logistical and economic constraints.
- **International Renewable Energy Agency (IRENA, 2022)** highlighted India's global position in renewable capacity expansion, ranking third worldwide in new installations.

This study adds to the literature by combining multiple renewable sources into a single time-series analysis, integrating both annual and seasonal perspectives.

3. Materials and Methods This study is based on secondary data obtained from official government records of monthly renewable energy generation in India. The dataset covers the period 2014–2015 to 2022–

2023 and includes generation figures (in Million Units - MU) for major renewable sources: solar, wind, biomass, bagasse, small hydro, and others.

3.1 Data Preparation and Cleaning

The raw Excel dataset required preprocessing to remove empty rows, merge split headers, and standardize date formats. Missing values were addressed through forward fill where appropriate. Units of generation were retained in MU for uniformity.

3.2 Data Structuring

The dataset was reshaped into a structured table containing the fields:

- Year (financial year)
- Month (April to March)
- Source (e.g., Solar, Wind, Biomass)
- Generation (MU)

3.3 Data Analysis Tools

- **Microsoft Excel**: Used for data cleaning, creating pivot tables, and generating the annual and monthly visualizations.
- **Pivot Tables & Pivot Charts**: Created to summarize generation by year and by month for each energy source.
- **Stacked Area Chart**: Depicts the overall growth in renewable energy generation over years, highlighting source-wise contributions.
- **Stacked Column Chart**: Shows seasonal patterns and monthly variation in generation across sources.

3.4 Analytical Focus:

- Annual growth trends for each source and total renewable generation.
- Seasonal/Monthly variations in source performance.
- Identification of sources driving the most significant growth.

4. Results and Discussion

4.1 Annual Trends:

The stacked area chart reveals a consistent upward trend in total renewable generation from **2014–15 to 2022–23**. Solar energy exhibits the sharpest growth, especially from 2017–18 onward, surpassing wind as a major contributor in recent years. Wind generation also shows an upward trajectory but with relatively stable seasonal

cycles. Biomass, bagasse, small hydro, and other renewables maintain modest contributions, indicating limited expansion compared to solar and wind.

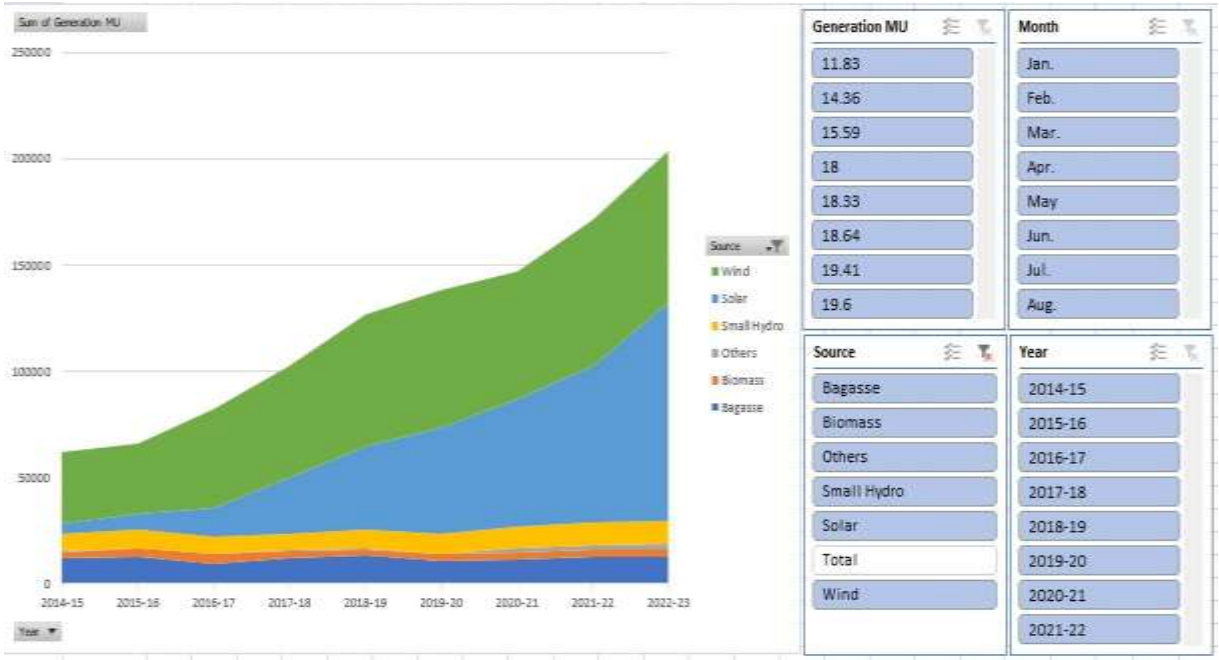

Fig. 1 Annual Trends of Renewable Power Generation

4.2 Monthly/Seasonal Trends :

The stacked column chart demonstrates pronounced seasonal variations. Wind power peaks between June and September, corresponding to monsoon wind patterns. Solar generation is more evenly distributed but slightly lower during monsoon months due to cloud cover. Biomass and small hydro exhibit relatively stable month-to-month output. These patterns suggest that India's renewable energy mix is strongly influenced by seasonal climatic factors, requiring complementary planning between sources.

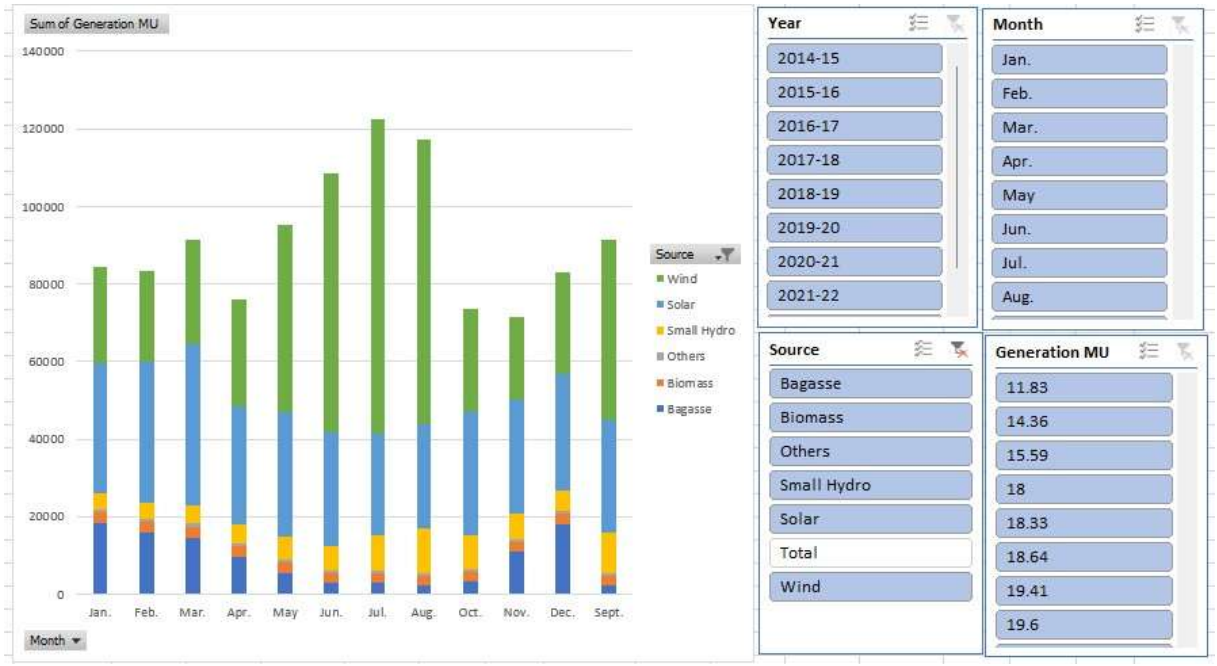

Fig. 2 Monthly Trends of Renewable Power Generation

Key Observations:

- Solar and wind together account for the majority of renewable growth.
- Seasonal variability emphasizes the need for grid balancing and energy storage solutions.
- Slower growth in biomass and small hydro indicates a potential area for policy intervention.

5. Conclusion

The study shows that India's renewable energy generation has grown significantly over the past decade, driven largely by solar and wind expansion. Solar has emerged as the fastest-growing source, benefiting from policy incentives, falling costs, and large-scale project deployment. Wind generation remains a strong contributor but exhibits more seasonal fluctuation. Biomass, small hydro, and other sources contribute modestly and have not experienced comparable growth.

These findings highlight the importance of diversifying renewable sources to balance seasonal variability, investing in storage technologies, and continuing policy support for emerging sectors. The data underscores that India is on track toward its renewable energy targets, but achieving **500 GW of non-fossil capacity by 2030** will require sustained investment and strategic deployment.

6. References

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