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Can Renewable Energy Be a Driving Factor for Economic Stability? An In-Depth Study of Sector Expansion and Economic Dynamics

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Abstract

India has emerged as one of the world's most appealing locations for renewable energy development. It has set lofty renewable energy goals to reach 450 gigawatts (GW) capacity by 2030. These aims indicate India's determination to move to greener and more sustainable energy sources. India has been investing in R&D to promote technological innovation in renewable energy. This includes improvements to solar photovoltaic technology, wind energy, energy storage technologies, and smart grid systems. Innovation is critical for improving efficiency, lowering prices, and increasing the reliability of renewable energy sources. This paper aims to analyse the linkages between economic growth and renewable energy usage in India. For this, the Granger Causality technique is adopted, and it is found that no short-run causality exists among the economic growth and RE installed capacity. However, Industrial Production Granger Causes both GDP and Renewable Energy Capacity. When the stock price data of the last five years of top renewable energy companies was also collected, it was found that all the companies are showing an upward trend. While renewable energy is growing rapidly, especially solar and wind power, it is insufficient to meet the bulk of India's energy demands. Renewables contribute to reducing carbon emissions and diversifying the energy mix, but they still account for a smaller percentage compared to thermal power.

Keywords: *Renewable Energy, Thermal Energy, Sustainable growth, Solar Energy, Wind Power.*

JEL Classification: Q01, Q26, Q42, Q43

Introduction

According to major oil and gas firms, independent organisations, and governments, energy demand is expected to rise due to global population growth. Renewable energy is expected to account for 15% of world energy consumption by the mid-21st century. Renewable energy has become increasingly important in recent years due to worldwide efforts to tackle climate change and rely less on fossil fuel use. India has been actively promoting sustainable development in a variety of fields. India has set lofty goals for renewable energy generation, intending to enhance the proportion of renewable sources in its energy mix. Initiatives such as the "National Solar Mission" and the promotion of wind energy have been instrumental.

Several well-known companies have emerged as leaders in the renewable energy market, driving the transition to greener, more sustainable energy sources. The government has been working on initiatives such as the Pradhan Mantri Ujjwala Yojana to offer clean cooking fuel to homes, hence reducing indoor air pollution and boosting greener energy sources. The Smart Communities Mission is to create sustainable, technologically advanced, and citizen-friendly communities. It focuses on areas such as efficient urban mobility, waste management, and renewable energy adoption. India has also attempted to improve waste management techniques through initiatives such as the Swachh Bharat Mission. The Brundtland Report

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popularised the concept of sustainable development in the late 1980s. It is characterised as development that satisfies current demands without jeopardising the ability of future generations to satisfy their own needs. It strongly emphasises meeting necessities and offering chances for a better life. Sustainable development aims to balance environmental protection and human advancement(Khan &Varshney, 2024). India has embraced the UN's Sustainable Development Goals (SDGs) and incorporated them into its national agenda, particularly emphasising issues like gender equality, clean energy, healthcare, education, and poverty reduction(Pandey, 2024).

Furthermore, these efforts include increasing trash separation, recycling, and minimising single-use plastics to safeguard India's abundant biodiversity through protected area management, wildlife conservation projects, and promoting sustainable tourism. Under the Paris Agreement, India is committed to lowering carbon emissions while expanding forest cover. The country has invested in renewable energy and implemented energy-efficiency initiatives to meet these aims. India aspires to employ green energy to safeguard the environment, boost industries, and become more energy self-sufficient.

With significant private sector investment and a strong government mandate, India has emerged as one of the world's most appealing locations for renewable energy development. By 2050, renewable energy is expected to provide up to two-thirds of the world's energy, a significant increase over the prediction of 24% in the reference scenario. Europe: With strong renewable energy mixes and high levels of wind energy integration, Denmark and Germany are in the lead. Asia: China and India are developing quickly, with yearly growth in the solar and wind industries exceeding 30%. Americas: Brazil, the United States, and Canada present a range of contributions from renewable energy. Africa and the Middle East: Although Africa has great potential, its infrastructure still needs work. The Middle East is diversifying its energy sources (Hassan et al., 2024).

Literature Review

As the demand for clean energy continues to rise, understanding the challenges and opportunities associated with renewable energy adoption is crucial. This literature review provides an overview of the existing research in this area.

This article addresses different types of storage mediums and examines the significance of thermal energy storage (TES) systems for solar power facilities. The application, cost, and storage duration influence the choice of TES technology. The performance, economic viability, and other aspects of various TES systems, such as the oil-rock and molten nitrate salt systems, are assessed in this article. TES systems are essential to dependable and effective solar power generation (Dincer, 2002).

Apart from biomass, this report examines India's potential and present state of renewable energy sources. Using a diffusion model, it anticipates future growth trends and calculates different renewable technologies' economic feasibility and greenhouse gas savings. In addition to highlighting the possibilities of new technologies, including tidal, OTEC, solar thermal, and geothermal power, the report discusses the promising expansion of wind, solar water heaters, and photovoltaic modules (Pillai & Banerjee, 2009).

The value of thermal energy storage (TES) and concentrated solar power (CSP) in the Southwest of the United States is examined in this study. It concludes that TES can greatly raise its value by enhancing CSP's adaptability and efficiency. However, many variables, such as energy prices, ancillary service markets, and optimisation techniques, might affect the value of CSP with TES (Sioshansi& Denholm, 2010).

Everyone around the globe faces a significant challenge in reducing the contribution of fossil fuels to the global energy system, particularly through the use of 'renewable energy sources'. Solar energy technologies are fast evolving, and within the next 40 years, they could become significant worldwide energy sources (Destouni & Frank, 2010).

The possibility of solar energy in India as a remedy for the country's energy shortage is examined in this paper. It talks about the different kinds of solar energy, such as solar thermal electricity (STE), and it shows

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the policies and tactics that are being used to encourage the use of solar energy in India. The report evaluates solar energy's present state and prospects in the nation (Sharma et al., 2012).

The European Union and national governments have prioritised increasing renewable energy's proportion to the total energy supply. Estimates suggest that renewable energy sources could account for 15-20% of global energy consumption by the middle of the 21st century. Additionally, investments in renewable energy sources could increase by 2.5 times their current level. Government actions make it possible to expand investment significantly. The reduction of fossil fuels in global energy consumption is uncertain due to transnational oil companies' plans for renewables (Csomós, 2014).

Investments in renewable energy firms have increased significantly during the last decade. The government is taking several initiatives; stock markets are becoming increasingly liquid, and oil prices are increasing continuously because of this trend. It is pretty obvious that new startups in the renewable energy sector have the potential to generate large returns, and global interest in the renewables sector has grown (Inchauspe et al., 2015). Renewable power sources, particularly wind and solar, are becoming increasingly important in the energy business (Pickl, 2019).

A secure supply of energy resources is widely acknowledged as a necessary but insufficient condition for societal development. Furthermore, sustainable development necessitates a continuous supply of energy supplies that, in the long run, are conveniently and sustainably available at reasonable prices and can be used for all necessary tasks without producing negative social consequences (Dincer, 2000).

This study states that the availability of energy sources is still scarce even when renewable energy sectors are seeing a huge expansion and growth. The energy demand is quite high compared to the supply in this sector. We still need much growth in this specific sector to meet the increasing demand. Population is increasing daily; hence, the demand for energy sources is rising, which is very important for the sustainable growth of the economy (Kumar. J & Majid, 2020).

The demand for Renewable Energy sources is quite high and thus should be used along with other supplementary sources to meet the required demand. Using a hybrid system is a good solution (Kumar. J & Majid, 2020).

The efficient utilisation of energy is a prerequisite for economic development. However, excessive usage of fossil fuels hurts the environment. Because renewable energy emits few greenhouse gases, more countries are attempting to enhance their usage of renewable energies. This research shows that renewable energy does not impede economic growth in both developing and developed countries, while the consumption of renewable energy (threshold level) has little impact on economic growth in developed countries (Bhuiyan et al., 2022).

Renewable energy can help us conserve energy and improve the environment by replacing fossil fuels. Environmental difficulties have increased over the previous two to three decades; hence, the use of technology is very appropriate for better climatic conditions. As the world's population grows, so does energy consumption, requiring transitioning to alternate energy sources (Dey et al., 2022).

The article examines the evolution of wind energy in India, emphasising how it can improve energy security and encourage using renewable energy sources. It explores the possibility for further expansion, evaluates government plans, goals, and accomplishments in the wind power industry, and assesses India's development compared to other nations (Singh et al., 2022).

This study examines the functions of thermal energy storage (TES) and concentrated solar power (CSP) in a highly dependable, entirely renewable power system. It concludes that although the generation profiles of CSP and PV are similar, CSP is now more expensive. Although TES is less expensive than batteries, its integration with CSP might offer grid flexibility in some situations. Nevertheless, penetration of CSP in the modelled system is limited by high generation costs (Kennedy et al., 2022).

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This study states that using renewable energy could benefit countries' economic growth. Operative policies are essential for effectively administering renewable energy sources (Xie et al., 2023).

Environmentally friendly finance for waste-to-energy plants, sustainable water management, transportation (particularly public transit), and renewable energy sources have been encouraged. The funds produced from offering green debt instruments can be used to pay for energy-efficient buildings, resulting in a 20% increase in the share of renewable energy used overall (Dubey et al., 2023).

Economic growth shares a two-way causal link with trade and labour participation rates, while gross capital formation and foreign direct investment do not substantially affect economic growth(Jia et al., 2023).

Particularly in Asia and Europe, regional integration increases the contribution of renewable energy to sustainable development. However, the Middle East and African sub-regions exhibit negative moderation, which suggests particular regional difficulties in fusing renewable energy transitions with sustainable growth. Sustainable development is promoted by the switch to renewable energy in all 64 BRI nations, including those in Asia, Europe, the Middle East and Africa. Across the board, favourable macroeconomic circumstances, high-quality institutions, and population size support sustainable development. Nevertheless, when examining particular sub-regions, the same factors have contradictory effects, highlighting the complexity of the regional environment (Ullah et al., 2024).

The paper looks at the tactics used by global energy corporations to embrace renewable energy. It examines these tactics' social, economic, and environmental effects and offers guidance for upcoming choices in the renewable energy industry. The review seeks to make the energy future more resilient and sustainable (Odunaiya et al., 2024).

Innovative technologies that draw inspiration from renewable energy sources offer a roadmap for the future global energy revolution and have the potential to advance efforts to mitigate climate change and environmental degradation significantly. However, to achieve a sustainable energy future, governmental, technological, and financial obstacles must be removed (Gayen et al., 2024).

Data analytics has become an essential tool for promoting sustainable corporate growth in the U.S. renewable energy industry. By utilising data, organisations may improve operations, boost productivity, and support long-term environmental goals. In the renewable energy industry, the potential advantages of data-driven decision-making considerably outweigh the disadvantages, notwithstanding obstacles like data quality and regulatory compliance. Businesses can establish themselves as pioneers in the shift to sustainable energy by adopting data analytics (Atadoga et al., 2024).

Renewable Energy is considered an important source for improving the deteriorating condition of polluted environments. Companies that have been analysed are entering into this field and trying to invest in projects that can ultimately help reduce the level of physical risk, which has little role in systematic risk and complex risk (Juhola et al., 2024).

According to this article, the dependency on solar energy projects benefits "Gross State Domestic Product (GSDP)" growth. Furthermore, installing wind energy capacity has a bidirectional positive relationship with GSDP growth. As a result, renewable energy is allowing states to grow more quickly (Gupta & Guha, 2024).

The data in this study empirically supports the substantial correlation between the use of renewable energy sources and sustainable development in OECD nations. The results indicate that while a heavy reliance on non-renewable energy sources can impede the transition to a more sustainable future, increasing the use of renewable energy can considerably contribute to sustainable development goals. These findings highlight how crucial it is to switch to greener energy sources to maintain long-term environmental and economic sustainability (Güney, 2024).

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Methodology

In order to analyse India's plan for sustainable economic growth, this study aims to understand the steps taken by the government and private sector to procure and use more renewable energy sources. Further analysis is done to see the advantages and benefits the country's economy is getting in terms of economic growth. A detailed analysis of Indian companies specifically focused on generating renewable energy is done. Data on the installed capacity of these companies and the revenue generated by these companies is collected. Furthermore, to study how the companies' stocks are performing and understand the growth level of the companies focusing more on renewable energy generation, their past five years' data was collected, and the long-term trend of these companies was analysed.

Historical data on renewable energy capacity in India, annual indices of industrial production (IIP) from MOSPI, and GDP (in Rupees crore) from RBI were collected from 2009 to 2023 to establish a relation among the variables. The Granger Causality test was done among the abovementioned variables to check whether India's economic growth, renewable energy capacity of India & and Index of Industrial Production can predict each other. The conditional mean, which solely accounts for the average influence of one variable on another, is estimated in the Granger causality test, which is commonly used to determine causal links between variables (Lee & Li, 2024; Adebayo & Olanrewaju, 2024).

Let Yt, Xt and Zt represent the following variables:

- Yt: Renewable energy capacity at time t,
- Xt: Industrial production index at time t,
- Zt: GDP at time t.

The Granger causality test is performed by estimating the following vector autoregressive (VAR) models:

Renewable Energy Capacity and GDP

$$Z_t = \propto_0 + \sum_{i=1}^{p} \alpha_i \, Z_{t-1} + \sum_{i=1}^{p} \beta_i \, Y_{t-1} + \varepsilon_t$$

Here, Zt is modelled as a function of its own lagged values and the lagged values of renewable energy capacity (Yt) to test if Yt Granger causes Zt.

Industrial Production and Renewable Energy Capacity

$$X_t = \gamma_0 + \sum_{i=1}^{p} \gamma_i \, X_{t-1} + \sum_{i=1}^{p} \delta_i \, Y_{t-1} + \varepsilon_t$$

In this model, industrial production (Xt) is explained by its own lagged values and the lagged values of renewable energy capacity to test for causality from Yt to Xt.

Industrial Production and GDP

$$X_t = \lambda_0 + \sum_{i=1}^{p} \lambda_i \, X_{t-1} + \sum_{i=1}^{p} \theta_i \, Z_{t-1} + \varepsilon_t$$

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This equation tests if the GDP (Zt) Granger causes industrial production Xt, using the lagged values of both variables (Perera et al., 2024).

For further analysis, data on power stations' installed capacity (in MW) across the Mainland and Islands as of 31.07.2024 was obtained from the Central Electricity Authority of India's official website. This data provides comprehensive information on distributed power generation capacities across different regions.

- *Visualisation Tool:* A stacked bar chart was selected as the primary visualisation tool. This choice was made to effectively display the distribution of installed capacities across different categories within each region.

- *Chart Design*

    - *Bars:* Each bar in the stacked chart represents a geographical region (Mainland or Islands).

    - *Segments:* Within each bar, segments represent different types of power generation. The size of each segment correlates with the installed capacity for that type.

    - *Labels and Legends:* The chart includes labels and legends to differentiate between power generation types and regions clearly.

Data visualisation, called stacked bar charts, is used to show how different categories or attributes are distributed within a single bar(Indratmo et al., 2018). Due to the increased availability of ensemble data and the growing need for visualisation across disciplinary boundaries, ensemble visualisation has experienced tremendous growth over the past ten years (Wang et al., 2019).

Analysis and Discussion

Renewable energy is defined as energy derived from natural resources such as sunshine, wind, rain, and geothermal heat that are renewable and do not deplete when used (Guliyev & Yerdelen Tatoğlu, 2023). Since environmental problems have worsened over the last two to three decades, using renewable energy technology is crucial to enhancing the environment (Dey et al., 2022).

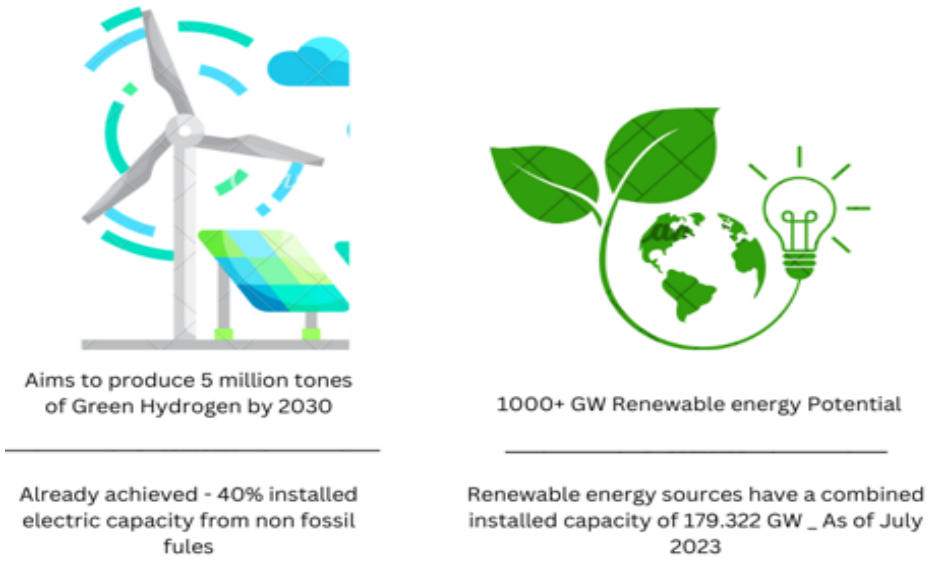

Figure 1. Global leader in Renewable Energy

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India is expeditiously becoming a global leader in renewable energy. Ample 'solar', 'wind', and 'hydro power' potential, along with a strong regulatory and administrative framework, create positive growth prospects for renewable energy projects in India. India has the world's fourth-biggest installed renewable capacity (179.322 GW as of July 2023). India has a vast and increasing population and a target of '450 GW of renewable energy magnitude by 2030 (280 GW of solar power, 140 GW of wind power, and 10 GW of biofuels)', which provides ample potential for investment and expansion.

As shown in Figure 3, India is the third largest producer of Renewable Energy. Fourth largest in wind power and solar power capacity.

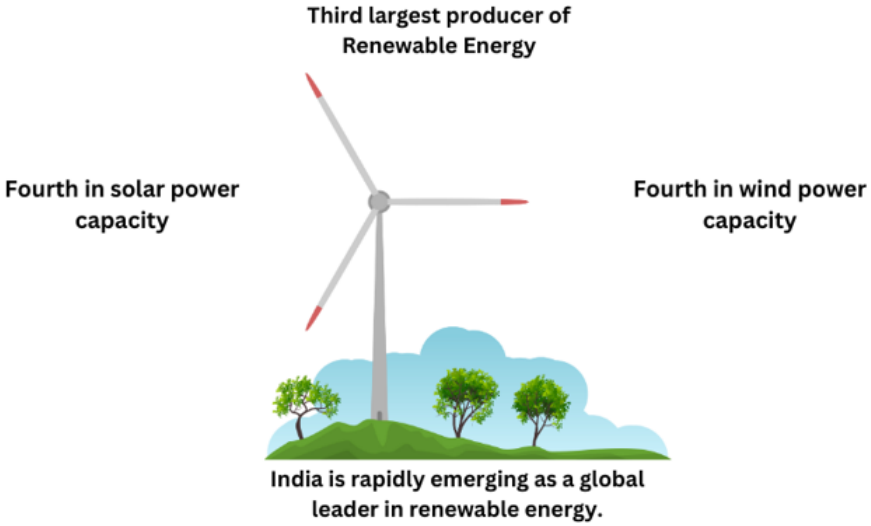

Figure 2. Position Among Other Countries

The Indian government has proactively promoted renewable energy through various policies, incentives, and programs, including subsidies, tax breaks, and renewable purchase commitments. Initiatives such as the National Solar Mission and the National Wind Energy Mission establish a framework for expanding the solar and wind energy sectors, respectively.

Like many other countries, India is attempting to improve its energy security by spreading its energy supply. Maximum usage of fossil fuels, which are mostly imported, creates economic and geopolitical problems. Renewable energy provides a domestic and sustainable alternative that reduces dependency on foreign fuels (Masoomi et al., 2023). The cost of renewable energy technologies, particularly solar and wind, has gradually decreased over time. This makes them more competitive against 'traditional energy sources' such as coal and natural gas.

As a result, renewable energy projects have become more financially viable, drawing investors and propelling the industry forward. The cost of renewable energy technologies, particularly solar and wind, has gradually decreased over time. This makes them more competitive against 'traditional energy sources' such as coal and natural gas. As a result, renewable energy projects have become more financially viable, drawing investors and propelling the industry forward. Like the rest of the globe, India has environmental issues such as air pollution and climate change. Switching to renewable energy helps to reduce greenhouse gas emissions and the effects of climate change. Additionally, renewable energy projects have a lower environmental impact than fossil fuel-based power plants, making them more socially acceptable.

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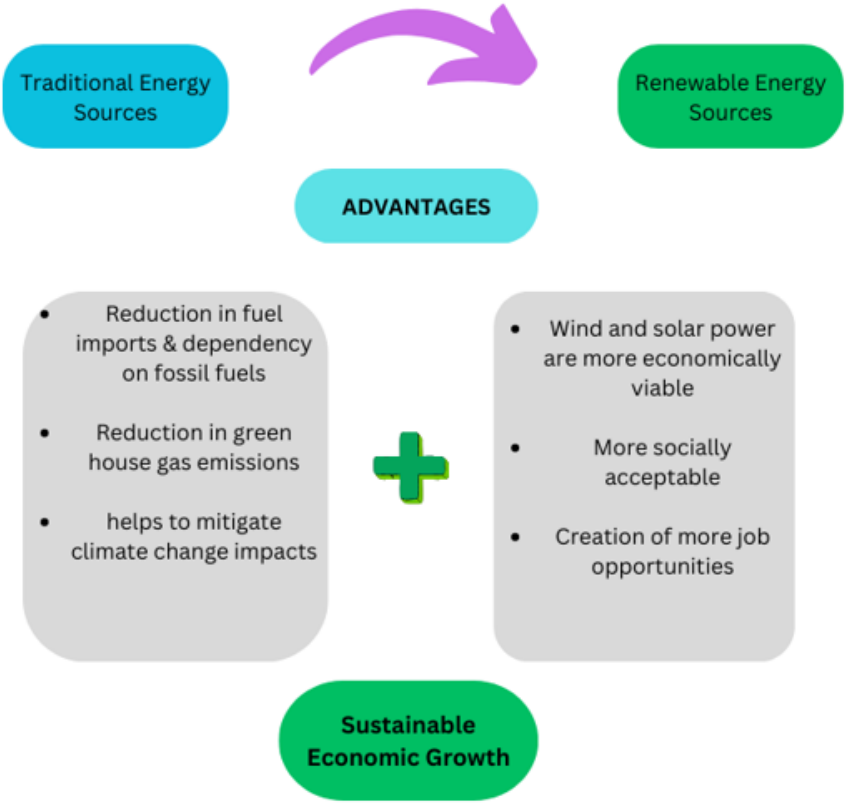

Figure 3. Advantages of Renewable Energy

The renewable energy sector provides prospects for job creation and economic development, particularly in rural communities where many of these projects are located. This is especially useful for a country like India, which has a large population and high unemployment rates in some areas. Renewable energy has become more stable and scalable due to technological advancements such as enhanced solar panel and wind turbine efficiency, energy storage solutions, and smart grid systems. These improvements have accelerated the expansion of renewable energy enterprises in India. Globally, there is an increasing emphasis on sustainability and lowering carbon footprints. Many global corporations and investors are increasingly looking for sustainable energy sources to power their businesses. As an influential figure in the global economy, India is also following these trends, propelling the augmentation of renewable energy companies to fulfil rising market demand. Nations can diversify their energy sources and lessen their reliance on imported fossil fuels to improve energy security and stability.

Less Sensitive to Market Volatility: Compared to fossil fuels, which are frequently impacted by supply-chain interruptions and geopolitical developments, the cost of renewable energy is less sensitive to fluctuations in the global market (Algarni et al., 2023).

Potential Difficulties India Is Facing in Scaling Up Renewable Energy Infrastructure

India has a number of specific obstacles in building more infrastructure for renewable energy sources and cutting costs. Because of its geographical diversity and dense population, India is a difficult place to locate sufficient resources for large-scale renewable energy projects like wind parks and solar farms.

In addition, the power grid's infrastructure is still developing, and there are difficulties in incorporating intermittent renewable energy sources. The unpredictability of solar and wind power generation can lead to

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problems with system stability and reliability, necessitating large investments in energy storage and grid enhancements.

Although renewable energy technology costs have been declining worldwide, upfront capital expenses continue to be a hurdle in India, especially for rural people and small and medium-sized organisations (SMEs). Scaling up requires having access to incentives and reasonably priced capital. Slowdowns and increased costs may result from inadequate infrastructure for producing, delivering, and installing renewable energy components. Developing a strong workforce and supply chain is crucial to India's plans to expand its renewable energy infrastructure. The potential for renewable energy in India varies by area due to sun irradiation and wind velocity variations. Research and development activities are required to overcome the technical issues associated with optimising the performance of renewable energy sources and adapting them to local conditions.

In India, large-scale renewable energy projects may have adverse effects on the environment and society, such as conflicts over land use, community uprooting, and harm to ecosystems and biodiversity. Sustainable growth requires striking a balance between developing renewable energy sources, environmental preservation, and community involvement. Considering that numerous state-owned distribution businesses in India are experiencing financial losses and heavy debt loads, there is serious concern about their financial health. Market dynamics can be distorted, and investment in renewable energy can be discouraged by tariffs and subsidies for traditional energy sources.

Even after having significant difficulties setting up units for renewable energy, there has been a significant development in this regard. Several companies are entering this field. Policies pertaining to renewable energy must consider several variables outside of energy generation, such as employment, land use, and environmental effects. Coordination with other sectors and rigorous evaluation of their possible impacts on larger societal and economic objectives are necessary for effective renewable energy policy (Sen & Ganguly, 2017).

Renewable Energy Companies in India

Renewable energy sources hold promise for addressing energy shortages in developing countries like India. India's fast-growing economy demands a significant increase in energy supply, and renewable energy can be a major contributor. Currently, renewable energy accounts for approximately 33% of India's primary energy consumption (Kumar et al., 2010). India is striving to capitalise on green energy to safeguard the environment, boost industries, and become more energy self-sufficient. With significant private sector investment and a strong government mandate, India has emerged as one of the world's most appealing locations for renewable energy development.

Table 1. Renewable Energy Companies in India

Rank	Company	Combined Installed Capacity	Revenue 2023-2024 (in USD million)
1	Adani Green Energy Limited	10934 MW	759.1
2	Sterling and Wilson Renewable Energy	10121 MW	324.6
3	ReNew Energy	10000 MW	NA
4	JSW Energy	6564 MW	178.8
5	Tata Power Renewable Energy Limited	4975 MW	257.6
6	Hero Future Energy	1200 MW	NA
7	KPI Green Energy	445 MW	168.8

(Source: [2024] Top 7 Renewable Energy Companies in India (By Capacity), n.d.)

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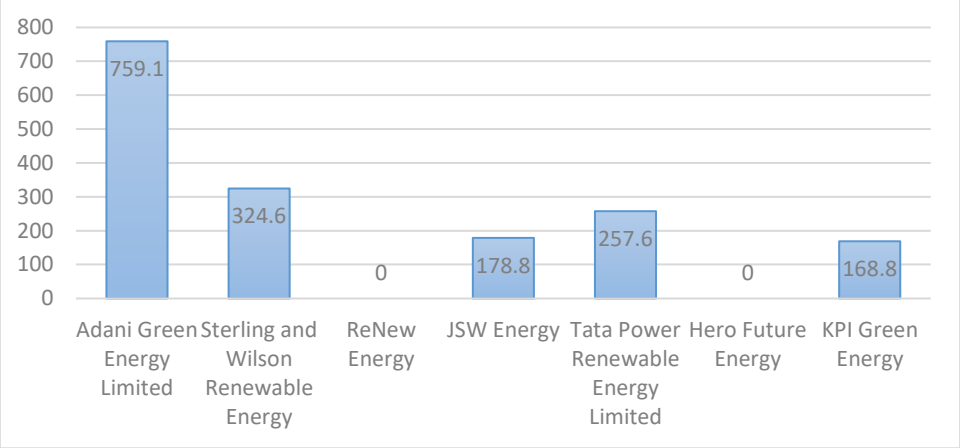

Graph 1. Revenue 2023-2024 (in USD million)

(Source: [2024] Top 7 Renewable Energy Companies in India (By Capacity), n.d.)

Shares price trend of top Renewable Energy companies

There are promising signals that financial markets are taking steps to promote sustainability. Indian stock markets have responded to the worldwide trend of sustainable business.

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Figure 4. Stock Price Trend Of Top Renewable Energy Companies In India

Note: Compiled With Eviews

India's two major stock exchanges, the Bombay Stock Exchange and the National Stock Exchange, have created sustainability-based indices. India's green bond market has risen to more than $6 billion. Green "masala bonds," are issued outside India but in rupees. Indian renewable energy firms are increasing their market share both domestically and abroad. With India's increased emphasis on renewable energy and the government's supportive policies, these companies are finding several chances to build and install renewable energy projects around the country. The confidence of investors is increasing in this sector. This investment has come from a variety of sources, including domestic and international investors, government financing, and financial institutions.

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Furthermore, companies are investing in R&D to improve their technological skills. These companies can increase renewable energy projects' efficiency, dependability, and cost by implementing creative solutions and modern technologies. As a result, their market share continues to grow, as is shown in Figure 4. The cost of renewable energy sources is comparatively less than conventional fossil fuel-based alternative sources, which is also one of the major reasons for these companies' increased market share. Dependency on fossil fuels has decreased thanks to solar energy, which has also increased economic growth and promoted environmental sustainability. India's focus on sustainable energy aligns with international efforts to tackle climate change (Meher et al., 2024).

The Indian government has been relentlessly advocating renewable energy with a range of guidelines, recognition, and initiatives. Programs like the wind energy target and the national solar mission aim to raise the proportion of renewable energy in the nation's energy mix. Investor confidence is increased, and the stock prices of renewable energy firms rise due to clear policy signals and favourable regulatory frameworks. Because of its long-term growth potential and environmental advantages, renewable energy is being increasingly regarded as a profitable business opportunity. Also, it is evident that the price of stocks in renewable energy companies is rising due to the increasing capital allocation of domestic and international investors.

Renewable Energy and Economic Growth

The relationship between economic growth and renewable energy consumption has been a significant area of investigation (Apergis & Danuletiu, 2014). There is a long-term relationship between GDP and renewable energy (RES) use in OECD nations. While low-GDP nations rely more on non-renewable energy sources, high-GDP nations often use more renewable energy sources (RES) (Guliyev & Yerdelen Tatoğlu, 2023). Examining the relevance of causation direction between the two variables is very important since it may provide valuable insights for policymakers.

Table 2. Descriptive Statistics

	GDP_AMOUNT_IN_RS__CRORE_	RENEWABLE_ENERGY_CAPACITY(MEGAWATT)	ANNUAL_INDICES_OF_INDUSTRIAL_PRODUCTION
Mean	16706377	103465.6	728.7083
Median	16240856	97837.5	731.7
Maximum	29390000	175929	860.2
Minimum	7306990	52259	622.3
Std. Dev.	6872606	41590.1	71.66068
Skewness	0.374195	0.341851	0.205509
Kurtosis	2.134312	1.769711	2.127621
Jarque-Bera	0.763877	1.155618	0.46499
Probability	0.682537	0.561127	0.792554
Sum	2.34E+08	1448518	8744.5
Sum Sq. Dev.	6.14E+14	2.25E+10	56487.79

Note: compiled with Eviews

As the test results in Table 2 depict, the mean value of the GDP is higher. The median is resistant to outliers and offers information about the distribution's central tendency, particularly when the data is skewed. SD represents the level of risk or uncertainty associated with a variable, which again is higher in the case of GDP data. Economic variables with larger standard deviations may be regarded as riskier. Positive kurtosis suggests a sharper peak. Positive skewness indicates a longer right tail, which is also more in GDP.

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Table 3. Stationarity Check

	Level	At first difference
GDP	0.3041	0.0357
RE Capacity	*0.407*	*0.01577*
Industrial Production	*0.2606*	*0.0019*

Note: compiled with Eviews

Table 3 depicts the Stationarity test results. The test was done for both series were found stationary at first difference.

Table 4. Granger Causality Test Results

Null Hypothesis:	**F-Statistic**	**Prob.**
RENEWABLE_ENERGY_CAPACITY_IN_INDIA_FROM_2009_TO_2023_IN_MEGAWATT does not Granger Cause GDP_AMOUNT_IN___CRORE_	0.80567	0.4843
GDP_AMOUNT_IN___CRORE_ does not Granger Cause RENEWABLE_ENERGY_CAPACITY_IN_INDIA_FROM_2009_TO_2023_IN_MEGAWATT	0.61832	0.5659
ANNUAL_INDICES_OF_INDUSTRIAL_PRODUCTION does not Granger Cause GDP_AMOUNT_IN___CRORE_	8.8299	0.0229
GDP_AMOUNT_IN___CRORE_ does not Granger Cause ANNUAL_INDICES_OF_INDUSTRIAL_PRODUCTION	2.6072	0.1676
ANNUAL_INDICES_OF_INDUSTRIAL_PRODUCTION does not Granger Cause RENEWABLE_ENERGY_CAPACITY_IN_INDIA_FROM_2009_TO_2023_IN_MEGAWATT	19.5712	0.0043
RENEWABLE_ENERGY_CAPACITY_IN_INDIA_FROM_2009_TO_2023_IN_MEGAWATT does not Granger Cause ANNUAL_INDICES_OF_INDUSTRIAL_PRODUCTION	2.83944	0.15

Note: compiled with Eviews

As the test results indicate in Table 4, Neither renewable energy capacity nor GDP Granger-causes the other. This suggests that changes in one variable do not significantly predict changes in the other. Variables, such as investor emotions, news about the firm, market speculation, and overall economic conditions, can affect short-term changes in the stock prices of renewable energy companies. These short movements might not always indicate developments in the GDP or underlying economic fundamentals. The p-value of 0.0229 suggests that industrial production Granger-causes GDP. This means that past industrial production values can help predict future GDP values.

The p-value of 0.1676 indicates that GDP does not Granger-cause industrial production. The p-value of 0.0043 suggests that industrial production Granger-causes renewable energy capacity. This might indicate that increased industrial activity drives the demand for and adoption of renewable energy. The p-value of 0.1500 suggests that renewable energy capacity does not Granger-cause industrial production. The results suggest a unidirectional relationship between industrial production and GDP, with industrial production being a significant predictor of GDP. There is no evidence of a direct causal relationship between renewable energy capacity and GDP or industrial production. However, the relationship between renewable energy capacity and industrial production might be more complex and influenced by other factors not captured in this analysis.

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Industries heavily consume electricity. The need for electricity and other energy sources rises along with industrial activity. In order to fulfil the expanding energy needs, this increased demand may encourage deploying renewable energy sources. Industries are frequently linked to emissions of greenhouse gases and environmental damage. Industry adoption of renewable energy to mitigate environmental impact can be attributed to the growing consciousness of climate change and the imperative for sustainable operations. The renewable energy industry generates employment in production, installation, maintenance, and research. Sustainability and corporate social responsibility (CSR) are also becoming increasingly important to many businesses. Using renewable energy can be viewed as a means of showcasing the company's dedication to these principles and enhancing its standing. The renewable energy industry generates employment in production, installation, maintenance, and research. Investments in renewable energy initiatives can promote development and economic expansion.

All Indian Installed Capacity of Energy Sources

Energy generated by heat created by the combustion of fossil fuels such as coal, oil, natural gas, or biomass is called thermal energy. It comprises power stations that produce energy using coal, gas, lignite, or diesel, sources that are not renewable, especially fossil fuels, which have a limited supply and increase greenhouse gas emissions. Energy from naturally occurring processes, such as sunshine, wind, rain, tides, waves, and geothermal heat, is called renewable energy. The energy released during nuclear fusion or fission, particularly when electricity is produced, is known as nuclear energy. Atoms split apart in power plants, a process known as fission.

Table 5. All India Installed Capacity (in MW) of Power Stations as of 31.07.2024

Region	Ownership/ Sector	Mode wise breakup						
		Thermal				Nuclear	Renewable	
		Coal	Lignite	Gas	Diesel		Hydro	RES*(MNRE)
Northern Region	State	19525.00	250.00	2878.90	0.00	0.00	6008.25	767.70
	Private	22084.33	1080.00	772.00	0.00	0.00	3241.00	39523.92
	Central	15048.62	250.00	2344.06	0.00	1620.00	11580.51	379.00
Western Region	State	21290.00	900.00	2849.82	0.00	0.00	5446.50	604.23
	Private	31762.17	500.00	4676.00	0.00	0.00	481.00	49915.99
	Central	21610.47	0.00	3280.67	0.00	3240.00	1635.00	666.30
Southern Region	State	22192.50	0.00	791.98	159.96	0.00	11827.48	637.08
	Private	13572.50	250.00	5120.24	273.70	0.00	0.00	54554.97
	Central	13952.38	3390.00	359.58	0.00	3320.00	0.00	541.90
Eastern Region	State	6970.00	0.00	80.00	0.00	0.00	3550.22	278.11
	Private	5553.00	0.00	0.00	0.00	0.00	209.00	1747.98
	Central	16166.51	0.00	0.00	0.00	0.00	1005.20	10.00
North Eastern Region	State	0.00	0.00	411.36	36.00	0.00	422.00	276.25
	Private	0.00	0.00	0.00	0.00	0.00	0.00	302.80
	Central	1242.02	0.00	1253.60	0.00	0.00	1522.01	30.00
Islands	State	0.00	0.00	0.00	84.35	0.00	0.00	5.25
	Private	0.00	0.00	0.00	35.19	0.00	0.00	29.78
	Central	0.00	0.00	0.00	0.00	0.00	0.00	5.10

Source: Central Electricity Authority. (2024). All India installed capacity (in MW) of power stations located in the regions of mainland and islands (as of 31.07.2024). Government of India.

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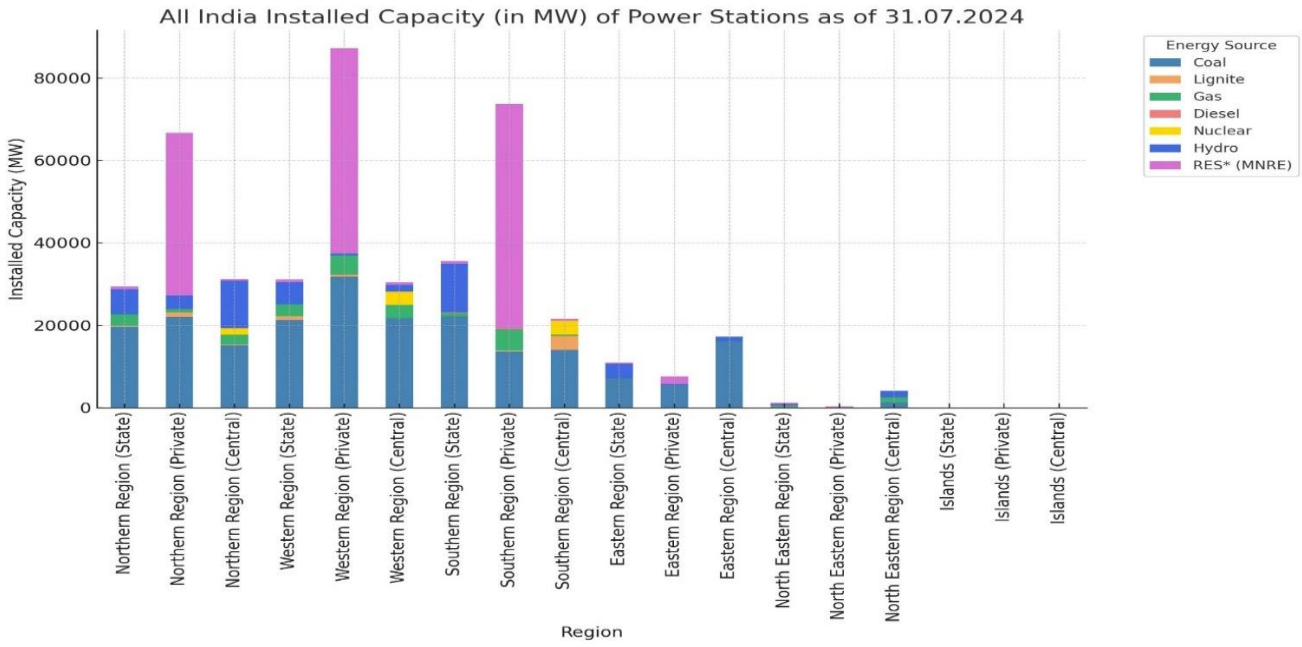
The stacked bar chart (Graph 2) visualises the installed capacity (in MW) of power stations across various regions of India as of 31st July 2024. Each bar represents the capacity contributed by different energy sources (coal, lignite, gas, diesel, nuclear, hydro, and renewable energy sources). The private sector in regions such as the Northern and Western regions has the highest installed capacity, especially in renewable energy (MNRE), showing a significant investment in non-conventional energy sources. The Southern and Western regions' private sectors contribute heavily to renewable energy, as reflected by their tall pink bars. The state and central sectors contribute more significantly to coal and hydropower than private entities, especially in the Northern and Eastern regions. Central sectors in the Northern and Western regions contribute to nuclear power, while it is absent in many other regions. The **Islands** have minimal installed capacity across all sources. The **Northeastern region** has a relatively lower capacity, with a notable contribution from gas and hydropower.

While renewable energy is becoming more important in India's energy mix and contributes to long-term sustainable development, **thermal energy,** driven by coal, gas, and other non-renewable sources, continues to meet most of the country's energy needs. This, in turn, significantly supports economic activities and industrial growth, meaning that both **thermal and renewable energy sources** play complementary roles in India's GDP growth.



Graph 2. Stacked Bar Chart of All India Installed Capacity (In MW)

Source: Visualisation Tools Used on Data By: Central Electricity Authority. (2024). All India Installed Capacity (In MW) Of Power Stations Located in The Regions of Mainland and Islands (As Of 31.07.2024). Government Of India.

Coal is still a dominant energy source in many regions, particularly in the central and state sectors. However, it is complemented by renewable energy (RES), especially in the private sector. The private sector is highly invested in renewable energy (as seen in the Southern and Western regions), signalling a shift toward sustainable energy sources. Hydropower is another significant source, particularly in state-owned utilities in regions like the Northern and Eastern regions. Nuclear energy has a relatively small but important contribution, mostly in the central sector. The Southern and Western regions stand out as the largest renewable energy producers, reflecting the region's solar and wind power potential. The Northeastern region and Islands have lower overall capacities, emphasising the need for infrastructure improvements in these areas.

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The private sector dominates renewable energy, showing how government policies and investments have encouraged private participation in green energy initiatives. The central sector has a focus on nuclear energy and coal, balancing between traditional and modern power generation. For example, regions with high coal dependency may need to shift to cleaner energy sources. Northeastern regions or Islands require more attention to meet their growing energy demands.

Further investment in renewable infrastructure in regions rich in renewables, like Southern and Western India, will enhance energy security and sustainability. Regions with untapped potential, like the Islands or the Northeastern region, can be a very good growth opportunity for private sector investments; along with it, there are a huge number of opportunities in grid modernisation or renewable projects aligned with India's climate commitments. The government can focus more on regions with low installed capacities (like the Islands) and develop infrastructure accordingly.

Having a diversified energy portfolio (coal, hydro, nuclear, and renewables) ensures energy security, reducing the risk of reliance on any single energy source. This balance is vital for future planning, especially during energy crises. India can work towards fulfilling its commitment to reducing carbon emissions and expanding renewable energy capacity. Furthermore, investment in grid infrastructure and renewable energy technologies in areas like the Northeastern region could boost both the local economy and national energy output.

India's GDP Growth Cannot Be Solely Attributed to The Growth of Renewable Energy Companies

Most of India's energy demand is still fulfilled by **thermal energy sources**, particularly coal, which plays a significant role in powering industries and supporting economic activities. India heavily relies on thermal energy, especially coal, for its electricity generation. As of 2024, more than half of the country's installed capacity for power generation comes from thermal sources. This continues to meet most industrial, commercial, and household energy needs. Major companies and government plants producing thermal energy are critical for maintaining a consistent energy supply. These include both state-run enterprises like NTPC (National Thermal Power Corporation) and private companies like Tata Power and Adani Power, which operate large thermal power plants. Power generated from thermal sources helps drive industrial output, which remains the backbone of the economy.

Thermal power plants are often more reliable for energy generation than renewables, which can be intermittent (due to weather dependency). This ensures a steady supply of electricity needed for economic stability and growth. The Indian government's focus on transitioning to greener energy sources is promising, but thermal energy remains essential to fulfil the country's large-scale energy requirements, especially in heavy industries. Government and policymakers can use this data to make informed decisions on where to invest in infrastructure.

Conclusion

Renewable energy is emerging to fulfil rising energy demand for economic growth while significantly lowering carbon emissions, as well as a potential pilot of economic growth and diversity. Furthermore, renewable energy promotes economic development while protecting the environment, resulting in sustainable economic development. Factors such as government support and active promotion, cost reduction of solar and wind power, growing demand for energy, increasing awareness of environment-related issues such as climate change and air pollution, and improvement in technologies like solar power efficiency and energy storage systems are few factors which are responsible for the growth of renewable energy companies. This ultimately helps in overall economic development. However, the Granger Causality test results indicate there is no short-run causality between renewable energy capacity in India and economic growth. However, Industrial Production Granger Causes both GDP and Renewable Energy Capacity. While renewable energy is growing rapidly, especially solar and wind power, it is insufficient to meet the bulk of India's energy demands. Renewables contribute to reducing carbon emissions and diversifying the energy mix, but they still account for a smaller percentage compared to thermal power.

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The whole world is undergoing a significant energy transition to renewable sources. This study will benefit individuals who are keen to learn about global energy trends, market dynamics, and geopolitical ramifications. This understanding is critical for navigating the intricacies of the energy transition, finding emerging opportunities, and dealing with the obstacles connected with the move to renewable energy. Furthermore, this study can be extended by creating regression models using factors that impact the usage of renewable energy sources.

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