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Energy transition in India: Prospects and challenges

Gayathri Mahesh[1] Anand NeelaKantan[2] Anjali S Nambiar[3]

[1] PG Scholar, Christ college, Irigalakuda (Autonomous), Calicut University

[2] PG Scholar, Dr. Janaki Ammal Campus Kannur university

[3] PG Scholar, University college, Thiruvananthapuram, Kerala University

Abstract

India is focusing on a shift towards sustainable development while meeting its growing energy demands. This study examines the transition to renewable energy in India between 2015 and 2024. The analysis reveals that both renewable and non-renewable energy generation have increased but renewable energy has grown at a faster pace. A comparative analysis on Kerala's renewable energy status relative to major Indian states highlights that despite expenditure from the state government there is underutilization of the state's renewable resource potential. Geographical disparities, infrastructural gaps still remain as a key challenge. The research underscores the relevance of public-private partnerships, strategic policy implementation, and region-specific planning to achieve India's ambitious clean energy goals. To meet its sustainable development goals, India should enhance its reliance on renewable energy and should invest more on it.

Key Words: *Energy transition, Sustainable development, Renewable energy, Non-renewable energy*

1. Introduction

The energy sector in India include all industries and infrastructure involved in the production, distribution, and consumption of energy. India is a nation with growing population and in the path of development, hence the nation requires a greater need for the energy sector and its growth. The main key Components of India's Energy Sector are Power Generation, Electricity Transmission and Distribution (T&D), Oil and Natural Gas, Coal Mining and Renewable Energy Development. In Power Generation, Coal is the dominant source, accounting for 50-55% of India's electricity generation. And India is one of the largest producers and consumers of coal global Renewable Energy like solar, wind, hydro-power, biomass, and small hydro are also sources of electricity generation. Electricity Transmission and Distribution (T&D) is Managed by public and private utilities like Power Grid Corporation of India (transmission), State Electricity Boards (SEBs), and DISCOMs (distribution companies). Oil and Natural Gas public sector companies like ONGC, Indian Oil Corporation, Bharat Petroleum, Hindustan Petroleum of India imports over 80% of its crude oil needs. Coal Mining plays as a key for powering thermal power plants.

As there are many sources of energy there are renewable as well as non-renewable energy, as the world is facing the pressing issue of climate change, air pollution and energy security. According to S&P Global Commodity Insights' Energy and Climate Scenarios, India is expected to reach an upper-middle-income status by the mid-2030s, alongside an urban surge exceeding 40 percent. However, this economic growth's quality depends on tackling high pollution levels. Data from IQAir reveals that 17 of the world's 20 most polluted cities are in India, with coal still dominating the energy mix at 48 percent.

The nation must therefore accelerate Sustainable development by transition to clean energy to mitigate both air pollution and climate change. Sustainable development is defined as "meeting the needs of present without compromising the ability of future generations to meet their own needs" by Brundtland commission. Hence, this transformation from these non-renewable energy to renewable energy is key to attain sustainable form of development.

As the nation identified the importance of sustainable development, India aligns its national development agenda with the United Nations Sustainable Development Goals (SDGs), a set of 17 global goals adopted in 2015 which is aiming to be achieved by 2030. India's approach includes national policies, state action plans, and regular progress monitoring through the NITI Aayog. India undergoes this major energy transformation by moving from a fossil-fuel-

heavy system toward a cleaner, more sustainable, and secure energy future. This transition is driven by the need to ensure energy security, reduce carbon emissions, support economic growth, and meet climate commitments. Against this background, this study looks into the transition of India's energy sector with particular reference to Kerala's case with the following broad objectives.

Objectives

- To study the transition of India's energy sector to Renewable Energy for Sustainability from 2015 to 2024
- To understand Kerala's Renewable Energy position in comparison to major Indian states
- To look into the challenges in India's Energy Transition

Literature review

Animesh Pal (2013) in his paper deals with growth, policies and challenges of power sector in India. The development of the power sector has long been associated with economic growth and national development. According to Bhattacharyya (2011), energy availability is directly linked to industrial productivity and the standard of living. Several studies, highlight that achieving large-scale capacity additions, such as the 100,000 MW target set for India's 12th Five Year Plan, requires both massive capital investments and robust policy frameworks. However, public financing requires a greater reliance on private investments and public-private partnerships (World Bank, 2012). This paper states that coal and gas continue to dominate India's energy mix, but the urgency for renewable integration has grown with global climate commitments. The need for efficient project execution and regulatory reforms is emphasized by Rathi (2015), who argues that bureaucratic delays and poor coordination often hinder infrastructure development. Finally, scholars like Ghosh (2016) advocate for a balanced energy portfolio combining fossil fuels, hydro, and renewables, underpinned by cost-effective, sustainable technologies to support inclusive and environmentally responsible growth.

Nagaraju Kaja (2017) found out that developing countries, including India, are witnessing rapid growth in energy demand, driven by economic expansion and population increases. Nagaraju Kaja, in his study highlights the alarming rise in energy usage in India's residential and commercial buildings, with projections showing a more than fourfold increase between

2005 and 2030.The study further points out that despite national policies like the National Mission on Enhanced Energy Efficiency (NMEEE, 2009), the implementation of energy conservation strategies remains weak. Similarly, Bureau of Energy Efficiency (BEE) reports underscore that building energy efficiency is a low-hanging fruit, yet underutilized due to inadequate regulatory mechanisms and lack of incentive structures. Moreover, paper stress the importance of integrating energy-efficient technologies during the design and construction phases of buildings, especially in rapidly urbanizing nations like India. There is a consensus that unless energy conservation becomes an enforceable and incentivized norm, India's energy demand in the building sector will continue to escalate unsustainably.

Chauhan and Indu (2020) extensively studied the relationship between energy consumption and economic growth, especially in the context of developing economies like India. The study highlights the increasing global emphasis on managing energy use efficiently in the face of environmental concerns such as climate change, fossil fuel depletion, and ecological imbalance. Earlier studies, such as those by Stern (2004) and Ozturk (2010), affirm that energy is not only a facilitator of economic activity but also a limiting factor when over-dependence on conventional sources leads to environmental degradation. In the Indian context, the shift in policy focus towards diversifying the energy mix—particularly through renewables—has been well documented by the Planning Commission (2013) and further supported by empirical work from Bhattacharyya and Timilsina (2010). The study underscores the urgency of transition to an alternative energy sources that minimize environmental and health impacts while supporting inclusive growth.

Stuti Haldar, Ananya Peddibhotla, Amir Bazaz (2023) states that the intersection of energy transitions and social justice has gained significant academic attention as countries like India commit to ambitious clean energy targets. Haldar et al. (2021) provide a critical review of existing literature on energy transitions in India, highlighting the gap in scholarship concerning justice-oriented perspectives. While global energy justice literature—predominantly Western—has extensively examined policy, economics, and technology (Jenkins et al., 2016), it often neglects the socio-political nuances specific to the Global South. In the Indian context, where fossil fuels currently dominate electricity generation, the move toward renewable energy raises concerns about distributive justice, especially for rural and marginalized communities (Sovacool & Dworkin, 2015). Haldar et al argue that unequal access to resources, decision-making processes, and transition benefits risks exacerbating existing inequalities, particularly for vulnerable groups such as women, children, and

informal sector workers. Using the triumvirate framework of energy justice—distributive, recognition, and procedural—the authors systematically analyse how justice concerns are embedded within India's energy transition literature. Their work fills a crucial gap by contextualizing justice within local socio-economic realities, thus providing a foundation for more inclusive and equitable energy policies. This aligns with recent calls for "just transitions" that prioritize both climate action and social equity.

Matthew D Leonard, Efstathios E Michaelides, Dimitrios N Michaelides mentions the ways to accomplish the substitution of coal with renewable energy sources, most notably wind and solar. The large-scale substitution of coal with wind and solar significantly shifts the demand for the rest of the power producing units. When the contribution of wind and solar exceeds approximately 25% of the total annual energy produced, there are time periods within a year when excess electricity is produced that must be wasted/dissipated. This presents a severe constraint for the substitution of coal-generated electricity with renewables. Extensive calculations are made for: (a) the solar and wind rated power that are necessary for the substitution of part or all the power currently supplied by a coal-fired power plant; and (b) the storage requirements for this substitution. The calculations also reveal that the substitution of coal with the renewable energy sources may be optimized for minimum energy storage capacity.

Methodology

This study adopts a mixed-methods approach, combining quantitative analysis and qualitative analysis. The study is based on secondary data sources collected from;

- Government reports: MNRE, NITI Aayog, Ministry of Power, MOSPI
- International agencies: IEA
- Academic journals: Kerala Economy (GIFT).

The data collected were tabulated and analysed by using growth rate and ratio analysis. In the following section the transition of India's energy sector is discussed.

Transition of India's energy sector to renewable energy

With the world's largest population, India is experiencing a rapid surge in energy consumption and demand. The nation's economic progress is closely tied to the energy sector, as India stands as the third-largest producer and consumer of energy globally. India's rapid

urbanization and economic growth have led to a sharp rise in energy demand. Meeting this increasing need—essential for powering industries, transportation, and households—comes with its own set of challenges. India is committed to ensuring accessible and dependable energy across all sectors while prioritizing green energy initiatives and sustainable development. There are substantial financial allocations for achieving renewable energy targets, reducing carbon emissions, and enhancing energy security.

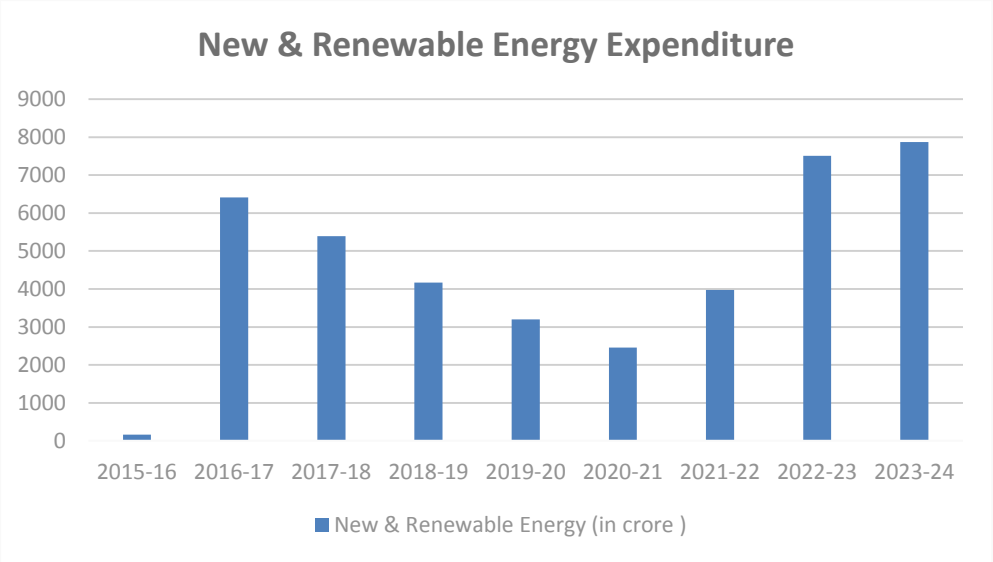
The New and Renewable Energy sector in India has been steadily evolving since 1982, following the establishment of the Department of Non-conventional Energy Sources (DNES) under the Ministry of Energy. With the transition from the Five-Year Plans to the NITI Aayog framework, government spending on renewable energy witnessed a significant rise. In 2015–2016, the expenditure stood at Rs.165.44 crore. This expenditure recorded a sharp increase in 2016–2017, but in the subsequent years, spending gradually declined, dropping from Rs.6414.46 crore to Rs.2459.13 crore by 2020–2021 (Table 1.1). This reduction was largely attributed to the economic impact of the global COVID-19 pandemic, often referred to as the "Great Lockdown," which also strained India's economy. However, from 2021–2022 to 2023–2024, the government's expenditure rebounded, growing at a rate of 40.73%. Over the period from 2015 to 2024, the compound annual growth rate (CAGR) of government spending on new and renewable energy has been calculated at 50.07%.

Table 1.1 Energy Expenditure of Union Government (in crore)

Year	Energy	New & Renewable Energy
2015-16	37469.27	165.44
2016-17	43441.09	6414.46
2017-18	44203.94	5392.25
2018-19	44165.87	4169.63
2019-20	60428.51	3200.82
2020-21	52480.96	2459.13
2021-22	26911.32	3972.66
2022-23	47954.51	7504.12
2023-24	39716.94	7869.10

Source: Union Budget,Government of India, various years (https://www.indiabudget.gov.in/)

Figure 1.1



Renewable and non-renewable energies are still demanded and generated by the nation. As our economy is growing day by day the need for energy is really high. The complete shift of energy generation to renewable energy is in a growing stage. When we analyses the growth of renewable energy generation, it is increasing yearly. And the generation of non-renewable energy is also increasing yearly. But this growth is increasing at a decreasing rate. Which means comparatively the growth rate of renewable energy is having an increasing trend than that of non-renewable energy.

From 2015 to 2024, renewable energy generation in India increased from 187.16 Billion Units (BU) to 359.89 BU, which is nearly doubled. Between 2015-2016 and 2018 -2019, the growth rate of renewable energy showed an increasing trend (Figure 1.1). The growth rate declined considerably during the lockdown due to COVID -19. After the pandemic the growth rate has reached to its positive trend.

From 2015 to 2024, non-renewable energy generation in India increased from 981.2 BU to 1374.23 BU, representing a growth of less than double over the period. Between 2015–2016 and 2018–2019, the growth rate of non-renewable energy showed a declining trend. This was followed by a negative growth during 2019–2020 and 2020–2021, with rates of -1.87% and -1.25%, respectively (Table 1.2). After this period, the growth rate began to rise slightly. Overall, the total growth in non-renewable energy generation during this time frame stands at

40.05%. Here coal is still the major source of energy in India used for electricity and industry.

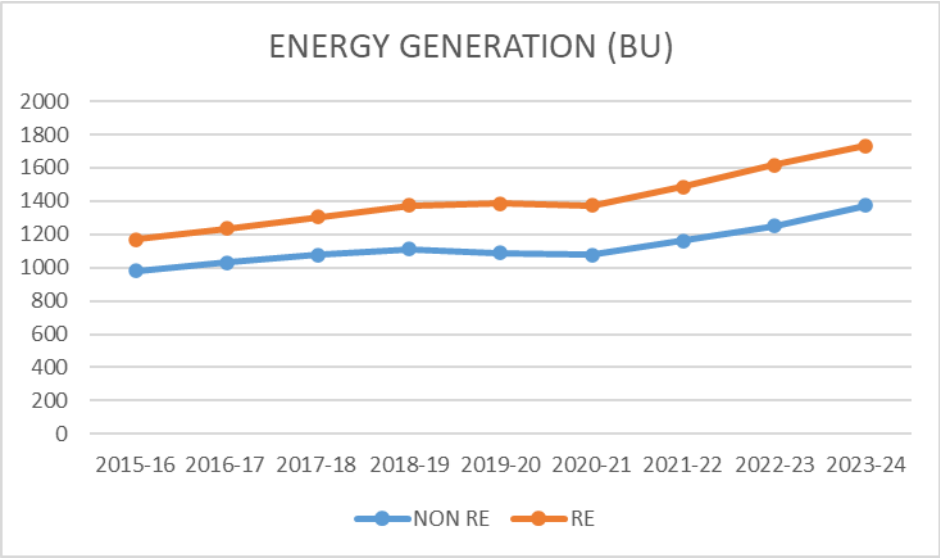
Table 1.2 Renewable and non-renewable energy generation (in Billion Units)

Year	Non-RE	Growth Rate	RE	Growth Rate
2015-16	981.2		187.16	
2016-17	1032.14	5.19	203.93	8.96
2017-18	1075.4	4.19	227.94	11.77
2018-19	1110.03	3.22	261.65	14.79
2019-20	1089.22	-1.87	294.11	12.40
2020-21	1075.54	-1.26	297.55	1.17
2021-22	1161.82	8.02	322.54	8.40
2022-23	1251.98	7.76	365.66	13.37
2023-24	1374.23	9.76	359.89	-1.58

Source-Ministry of new and renewable energy (MNRE)

**RE – Renewable energy*

Figure 1.2



From the analysis, we come to the conclusion that the renewable as well as the non-renewable energy expenditure are increasing yearly. Along with this increase there is also a growth in the energy generation. But the renewable energy is having an average growth rate of 9.66, which is much greater than the average growth rate 4.25 per cent of non-renewable energy. Hence the nation is in the phase of drastic energy transformation.

The Government of India has put in place a wide range of subsidies and incentives to encourage the transition towards cleaner energy. These measures aim to attract investment, reduce costs, and make renewable energy more accessible across the country. For instance,

up to 100% Foreign Direct Investment (FDI) is permitted under the automatic route for renewable energy projects. To make projects more financially viable developers benefit from a waiver of inter-state transmission charges for solar and wind power projects commissioned by June 2025, The government has also set clear Renewable Purchase Obligations (RPOs) to ensure a consistent demand for clean energy. Along with this large-scale Ultra Mega Renewable Energy Parks have been established to provide ready land and transmission infrastructure to developers. Schemes like PM-KUSUM, Solar Rooftop Phase II, and the CPSU Scheme Phase II support both decentralized and grid-connected installations are also introduced. The MNRE provides direct financial incentives for green Hydrogen production through National Green Hydrogen Mission. To ensure that renewable power can be efficiently evacuated, the Green Energy Corridor project is expanding transmission lines and substations. Moreover, Research and innovation are promoted through the Renewable Energy Research and Technology Development Programme, which offers substantial funding support to research institutions, start-ups, and private companies. Together, these initiatives reflect India's strong commitment to making renewable energy a cornerstone of its future energy mix.

Kerala's renewable energy position _ An interstate comparison

India being a country with diverse geographical conditions is the third largest country in energy generation. Spanning from the sun-drenched deserts of Rajasthan and the wind-rich coastlines of Tamil Nadu and Gujarat, to the hydropower potential of the Himalayan states and the coal-rich eastern belt of Jharkhand and Chhattisgarh, each region offers distinct natural endowments. This geographical and resource diversity is the reason for inter-state differences in energy generation capacities. Some states have started giving focus to renewable energy and few other states are still reliant on fossil fuels. Hence analysing the state wise potential is essential.

While comparing states on the basis of energy generation during 2023-24, Rajasthan, Gujarat, Karnataka, Himachal Pradesh, and Tamil Nadu are the top five states in energy generation during 2023-24. When we consider these states, the percentage of energy expenditure to the states total expenditure 2025-26 (estimated) is between 0.0001% and 1.509%. The state with greater share is Rajasthan, they spend 1.509% of total expenditure for renewable energy (Table 2.1). Other states like Karnataka, Himachal Pradesh, and Tamil Nadu are only contributing less than that of Kerala government renewable energy expenditure. Here Kerala

spends its 0.009% of total expenditure for renewable energy, which is greater percentage share than many leading states.

Table 2.1 New and renewable energy as a percentage of total state expenditure in 2025-26 (in crore)

States	New and renewable energy expenditure (crore)	Total expenditure (crore)	Percentage
Rajasthan	5728.37	3,79,617	1.509
Gujarat	842.74	3,32,150	0.254
Karnataka	15	3,83,075	0.004
Himachal Pradesh	3.2	52,709	0.006
Tamil Nadu	0.31	4,39,293	0.0001
Kerala	19.47	1,98,582	0.009

Source- State budget documents, 2025-26, various states

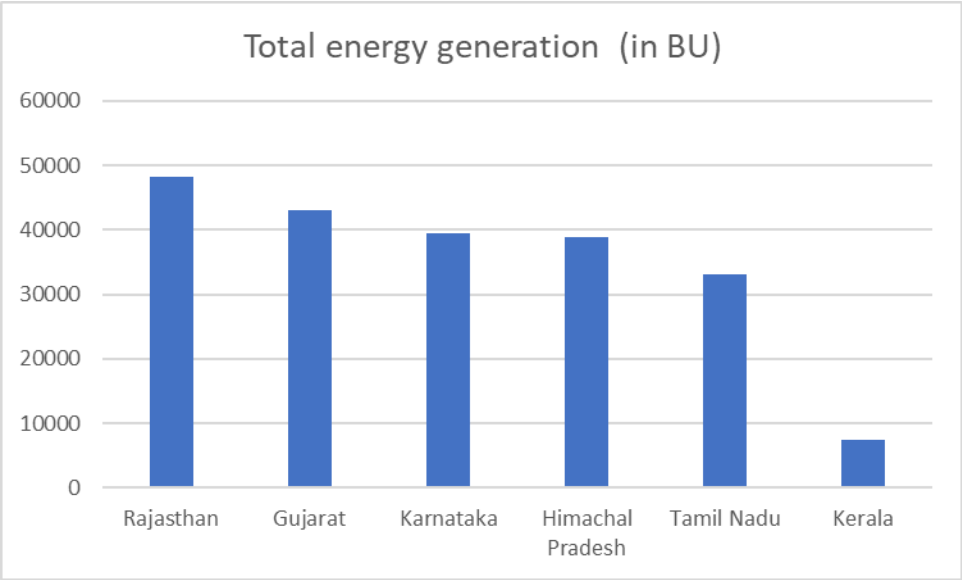
While comparing states on the basis of energy generation during 2023-24, Rajasthan, Gujarat, Karnataka, Himachal Pradesh, and Tamil Nadu are the top five states in energy generation during 2023-24. Rajasthan lies in the top with a total energy generation of 48164.86 BU with a major share in solar power (38365.21 BU). While Kerala's total energy generation is 7359.96 BU with a major share from large hydro power (5155.72 BU). In the case of small hydro power, Himachal Pradesh lie on the top with 2526.98 BU and Kerala is having 716.31BU of small hydro power (Table 2.2). Gujarat is leading in the case of wind power with 24794.50 BU and Kerala is only generating 214.53 BU of wind energy. Karnataka leads in the case of bio power generating 2801.51BU. While Kerala is generating 78.12BU only. In the case of solar power, Rajasthan leads with 38365.21 BU while Kerala is generating only 1195.28BU. Himachal Pradesh is leading in large hydro power with 36365.85BU while Kerala is generating 5155.72BU.

Table 2.2 State wise energy generation during 2023 – 2024 (in Billion Units)

States /UTs	Small Hydro Power	Wind Power	Bio Power	Solar Power	Large Hydro	Total
Rajasthan	7.45	8390.67	387.55	38365.21	1013.97	48164.86
Gujarat	217.68	24794.5	2.13	13468.91	4556.33	43039.55
Karnataka	1370.76	10950.2	2801.51	15404.09	8973.17	39499.72
Himachal Pradesh	2526.98	…	…	59.54	36365.85	38952.37
Tamil Nadu	206	16908.08	751.75	11737.48	3563.28	33166.59
Kerala	716.31	214.53	78.12	1195.28	5155.72	7359.96

Source- Renewable energy statistics 2023-24 (www.mnre.gov.in)

Figure 2.1



This data shows there is no direct correlation between the government expenditure and renewable energy generation. But the main factor which accelerate this growth in generation is the public privet partnership. States with largest energy generation like Rajasthan collaborated with Tata Powers Investment, UAE partnership and Central Public Sector Enterprises have encompassed significant investments and capacity additions across various renewable energy domains. Most of the states promote PPP partnership for investments and development in renewable energy.

Kerala's topography is having a diverse nature. And these diversities provide the state a greater capacity to achieve renewable energy than installed capacity in energy generation. Kerala's major source of renewable energy is hydro. But the state lacks to reach the resource potential of 3673 MW. And only reached Hydro energy installed capacity of 1964.15 MW. The second largest source, small hydro's resource potential is 647.15 but its installed capacity is only 276.52 MW. Kerala is having a high resource potential in solar energy due to its geographical location. But we have only utilised 25.19% of solar energy. Like the top five states Kerala also need to spend on renewable energy generation based on its topographical potential. The data proves there is not much correlation between the state's expenditure and generation of renewable energy, as Public privet partnership and topographical potential of states plays a major role in energy generation.

The analysis of state-wise energy generation for 2023–24 highlights the significant disparities across Indian states, shaped by their unique geographical features and natural resource availability. States like Rajasthan, Gujarat, Karnataka, Himachal Pradesh, and Tamil Nadu have effectively harnessed their renewable energy potential, emerging as leaders in energy generation through focused investment and infrastructure development. In contrast, Kerala, despite its diverse topography and considerable renewable resource potential—especially in hydro and solar energy—lags behind in fully realizing this capacity.

To move forward, Kerala must address the gaps in resource utilization through robust policy implementation, financial incentives, and technological adoption. Doing so will not only enhance the state's energy security and sustainability but also contribute meaningfully to India's broader renewable energy goals.

Concluding observations

India's energy sector is undergoing a significant transformation driven by rising energy demands, environmental concerns, and a global push towards sustainability. While the country continues to rely on non-renewable sources like coal, the shift to renewable energy is gaining momentum. The analysis reveals that energy expenditure is increasing on both renewable and non-renewable energy. Along with it, total energy generation is also increasing. Evidence shows that the proportion of renewable energy is increasing more rapidly than non-renewable energy showing a drastic shift towards cleaner energies. All the states are improving their renewable energy and they are focusing on their topographical specialists to generate this renewable energy. When we analyse the top states, they are only contributing a less amount for these renewable energy generation but still they are the greatest renewable energy producers. Here we came to a conclusion that there is no correlation between the state Governments expenditure and generation of renewable energy. Public private partnership plays a crucial role in bridging this expenditure gap which can't be met by State Government. Kerala is contributing a greater share of expenditure for renewable energy but still the state has a long way to go. And the data have also proven that the states like Rajasthan, a state with large deserts mainly focused on the solar energy, Gujarat dominates wind energy, Karnataka is ahead in bio-energy and Himachal Pradesh tops in both large and small hydro energy. All these top five states are mainly spending on renewable energy, which is supported by their topography.

Policy suggestions

India should continue its focus on renewable energy to meet its target of net zero emissions in the coming years. To unlock the full potential of sub national governments like Kerala should focus more on the renewable energy sector. Despite notable expenditure on renewable initiatives, Kerala and similar states still contribute marginally to actual generation capacity. Bridging this gap requires a multifaceted strategy.

First, fostering Public-Private Partnerships (PPP) can accelerate the development and implementation of large-scale solar and hydro projects by leveraging both public funding and private sector efficiency. Additionally, community engagement and awareness campaigns are essential to promote decentralized renewable solutions such as rooftop solar installations, micro-hydro systems, and biomass energy. Investments in modern infrastructure, such as smart grids and advanced transmission systems, will ensure better integration and management of variable renewable energy sources. Furthermore, this create employment opportunities but also ensure the long-term sustainability and maintenance of renewable energy assets.

By aligning policy efforts with these strategic suggestions, states like Kerala can significantly enhance their renewable energy generation capabilities. Understanding regional trends in generation and expenditure can guide policymakers to make data-driven decisions, ensuring that India remains on a steadfast path toward a sustainable and globally competitive clean energy future.

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