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Renewable Energy as a Mitigation Strategy for Climate Change: Pathways, Challenges, and Policy Implications

Selung Konai Emmanuel[1], Waikhom Dorendrajit Singh[2], Maibam Kamal Hassan[3]

[1,2,3]Research Scholar, Department of Geography, Dhanamanjuri University, Manipur

Abstract
The transition of fossil fuel-based energy systems to renewable energy has become a key strategy to reduce greenhouse gas emissions and enhance low-carbon development. This study examines renewable energy and its role in the climate change mitigation process by examining environmental, economic and social benefits, pathways and transitions, including policy implications in global and Indian contexts. The study followed qualitative, descriptive and systematic review methods, guided by PRISMA 2020, with secondary data from academic and institutional sources as relevant. Global electricity generation, according to the findings, shows significant growth over the period of 2015 to 2025. Among the renewable sources, hydropower takes the largest share with 4,434.97 TWh in 2025, indicating expansion from 3,882.13TWh from 2015. Solar and wind also experienced rapid expansion, producing 2,778.64 TWh and 2, 713.14 TWh in 2015 from 256.01 TWh and 829.08 TWh in 2015 respectively. The results indicate that the total capacity of renewable energy has increased from 81.31 GW in 2014–15 to 220.10 GW in 2024–25 in India. Solar energy was the largest component with a total of 66.78 GW and the highest CAGR of 38.77% compared to 7.92% for wind, 2.60% for bioenergy and 2.31% for small hydropower. The study further demonstrates the potential of renewable energy in GHG reduction, energy security, job creation, economic development, public health and sustainable environment management. Intermittency, high initial investment costs, inadequate grid infrastructure, policy uncertainty and technological limitations, however, remain as significant barriers. Therefore, the present study gives importance to stable policies, financial incentives, grid modernisation, energy storage, technological innovation, international cooperation and institutional capacity-building as essential measures for accelerating a resilient, low-carbon and sustainable energy transition.

Keywords: Renewable energy; climate change; greenhouse gas emissions; sustainability; energy transition; low-carbon development

1. Introduction:

Climate change refers to long-term alterations in the Earth's climatic systems, particularly the warming of the atmosphere, oceans, and land surfaces caused by increased concentrations of greenhouse gases (GHGs) in the atmosphere(The Climate Dictionary, 2024). Anthropogenic activities, such as the combustion of fossil fuels, deforestation, industrialisation, and unsustainable land-use practices, have resulted in accelerated global warming and intensified climate-related disasters such as droughts, floods, heatwaves, rising sea levels, and biodiversity loss (Yoro & Daramola, 2020). According to the United Nations Environment Program, global greenhouse gas emissions reached alarming levels in recent decades, with the energy sector accounting for the largest share of carbon dioxide (CO_2) emissions (Environment, 2019). Figure 1 shows the global emission trend of the world from 2000 to 2024 (Ritchie et al., 2023). It shows the overall increase in co2 across the globe between 2000 and 2024. The magnitude of emissions varies among different countries and regions; however, the increasing trend in emissions suggests the continued dependence on fossil fuels to meet the global energy demand. This observed trend indicates the necessity for a transition towards low-carbon energy. The greenhouse gases defined by the Kyoto Protocol are carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), and the fluorinated gases such as hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and Sulphur hexafluoride (SF6) (KYOTO PROTOCOL) The severity of climate change has increased to a great extent, and this has led to intensified global efforts in limiting the dependency on fossil fuels by transitioning towards sustainable energy systems. And so, renewable energy has now emerged as the most feasible and effective strategy in mitigating climate change, as it provides optimal energy with minimal carbon emissions (Owusu & Asumadu-Sarkodie, 2016). Renewable energy sources such as solar, wind, hydropower (Ngobeh et al., 2023), geothermal and biomass(Fridleifsson, 2001; Surewer et al., 2024) are naturally replenished and contribute to the reduction of global carbon emissions while also supporting economic growth in a sustainable way.

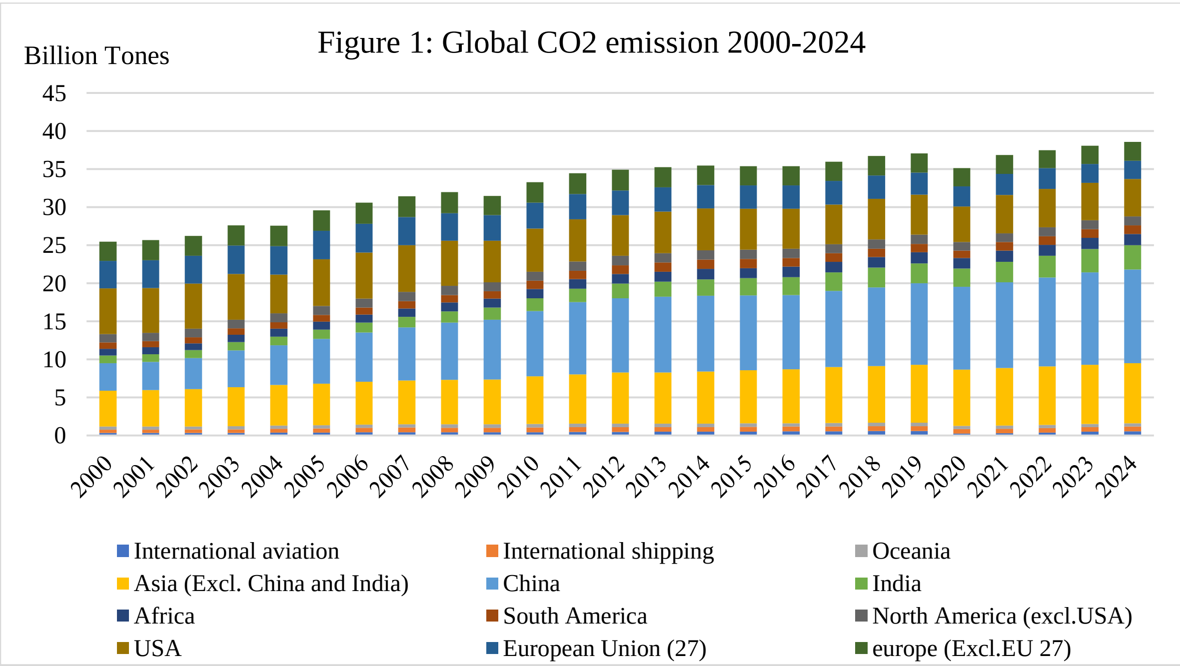


Figure 1: Global CO2 emission 2000-2024

Source: Our World in Data (Ritchie et al., 2023)
(https://ourworldindata.org/co2-and-greenhouse-gas-emissions)

Technologies associated with renewable energy have gained tactical and strategic importance for their significant contributions to sustainable energy supply, employment generation, technological innovation, economic resilience and, most importantly, their contributions to environmental wellness. (Candra et al., 2023). For developing countries like India, characterised by rapid urbanisation, population growth (Ahmed, 2024) and industrial expansion, the transition towards renewable energy systems is significantly important. Expanding renewable energy infrastructure can help reduce fossil fuel dependence, improve energy access, and support long-term sustainable development in developing countries (Adeosun et al., 2023). There is progress in global renewable energy development; however, despite all this development, multiple challenges continue to stand against the global energy transition. These include technological limitations, intermittency of renewable resources, inadequate transmission infrastructure, financial barriers, and inconsistent policy frameworks across countries and regions(M.Saleh & I.Hassan, 2024). Furthermore, disparities in technological capabilities and investment capacities between developed and developing nations create unequal opportunities for renewable energy expansion(Li et al., 2022)..

In the Indian context, the increasing use of fossil fuels has damaged both the local and global environment(Kumar et al., 2010; Kumar. J & Majid, 2020). Therefore, there has been increasing demand for the adoption of renewable energy. This is because of the increasing CO2 emissions (Figure 1) and the need for balanced economic development along with sustainable environmental management. Against this backdrop, the present study examines renewable energy as a significantly critical mitigation strategy for climate change. This study emphasises synthesising the contemporary literature and policy recommendations to assess the environmental, economic and social implications of renewable energy adoption. It also identifies important barriers and challenges associated with renewable energy transitions and lays out strategically important policies for low-carbon emissions.

2. Literature Review:

2.1 Renewable Energy and Climate Change Mitigation: The study mainly focused on the research papers published during the last two decades. The emphasis on the papers included recent studies that primarily focused on examining renewable energy adoption in developing countries and emerging economies. Multiple studies have identified renewable energy as a concrete strategy for reducing carbon emissions, while it has a crucial role in supporting sustainable development. Candra, Chammam, Alvarez, Muda and Aybar(2023) studied the interconnection of renewable energy consumption with economic growth and greenhouse emissions in middle-income and high-income countries (Candra et al., 2023). They analysed the relationship by using the structural Vector Auto Regression (SVAR) model. Their study's final result showed that renewable energy positively affected economic growth and also simultaneously helped reduce carbon dioxide emissions. The study further demonstrated that an increase in renewable energy production advocates generating employment, poverty reduction and upliftment of a sustainable environment. Abidi and Nsaibi (2024), in their research work, investigated the effectiveness of renewable energy in mitigating climate change and its adaptation strategy by collecting data from 58 countries spanning from 1990 to 2022 by employing the ARDL model(Abidi & Nsaibi, 2024). Their results demonstrated that the use of renewable energy resulted in the reduction of greenhouse gases and also led to a decrease in temperature anomalies. Yoro and Daramola (2020) investigated the role of industrialisation and urbanisation in anthropogenic greenhouse emissions; carbon dioxide emissions resulted from fossil fuel combustion (Yoro & Daramola, 2020). They further identified that technologies for renewable energy adoption, energy efficiency improvement, and carbon capture provided a viable solution for climate change mitigation.

2.2 Renewable Energy and Sustainable Development:

Renewable energy not only contributes to climate change mitigation, but it also provides a pathway to sustainable development by advocating environmental protection, economic growth and welfare for society. Gao, Fan, and Liao (2018) critically reviewed the significance of Germany's energy transition strategy as a framework for promoting renewable development(Gao et al., 2018). The authors highlighted the significance of assistance from the government and incentives, which play a greater role in the mitigation of intermittency in energy production. Kumar and some other authors, Ashwani Kumar, Kapil Kumar, Kaushik, Sharma and Mishra (2010), provided a comprehensive analysis of the available renewable resources of India and provided important knowledge in balancing the rising demand and also mitigating environmental degradation(Kumar et al., 2010). They further indicated the potential of renewable energy in the improvement of energy access and reduction of dependence on fossil fuel consumption, which are imported from outside. Nathwani and Kammen (2019) indicated the need for access to affordable clean energy for improving global living standards and reducing poverty in terms of energy holding(Nathwani & Kammen, 2019). Their study also highlighted renewable energy production as a supporting tool for inclusive development for facilitating more access to modern energy systems in the underdeveloped regions. They further added that the affordability of energy services for every citizen across the globe requires massive diffusion and technological development, offering point-of-use options connecting with new business models. The authors also highlighted the necessity of integrating social innovations and flexible governance approaches with the emerging technologies.

2.3 Renewable Energy and Policy Framework:

A strong policy framework plays a crucial role in the promotion of renewable energy production and adoption. Mathur and Shekhar (2020) examined the alternative mitigation scenarios for India's energy sector by using the MARKAL energy system model (Mathur & Shekhar, 2020). They highlighted three broad categories for India, which included decarbonization of electricity, electrification of end-uses and improvement in energy efficiency. They concluded that early action could potentially prevent India from carbon lock-in and leapfrog to renewables from coal in the power sector. However, they also highlighted the challenges and barriers to be addressed for undertaking large-scale uptake of low-carbon technologies in India. Dharmala and some other scholars analysed the linkages between air pollution and climate change policies in the transportation sector, where they teamed into five and modelled five scenarios which included fuel efficiency, electrification, alternative fuels, modal shifts and modernisation in transport demand(Dharmala et al., 2022). They explored the best policy that shares synergetic effects in carbon dioxide reduction (CO2) and particulate matter (PM2.5) emissions. They highlighted the effectiveness of all the measures in reducing air pollutants and CO2 emissions. Gebreslassie(2021) explored the challenges of locally developing and manufacturing solar and wind energy technologies necessary policies that facilitate energy technologies localisation (Gebreslassie, 2021). Their research work results highlighted the importance of investment capital, a developed solar and wind supply chain, and availability of a skilled workforce in the development and manufacturing of solar and wind energy technologies in a region.

2.4 Renewable energy policy and transition in India:

India plays a greater role in the global energy transition because of its significant contributions to national and international climate action(Prajapati et al., 2026). For India, meeting the increasing energy demand requires a transition from fossil fuels to renewable energy. This will also provide greater initiative in mitigating climate change in India. The Indian power sector has been constantly giving its effort in a transformative journey to accomplish this objective by bringing renewable energy from different sources. In order to boost India's clean energy and in the hope of limiting dependence on fossil fuels, the Ministry of New & Renewable Energy has introduced several initiatives to increase renewable energy technologies

and their widespread adoption. PMSurya Ghar: Muft Bijli Yojana for rooftop solar electrification (2017), the Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan (PM-KUSUM) for solar pumps, the National Green Hydrogen Mission for green hydrogen production, etc. are some of the significant initiatives launched by the ministry in line with the energy transition in India. Moreover, the ministry launched the Viability Gap Funding (VGF) Scheme for 1000 MW offshore wind energy projects. For the development of the tribal population with the aim of its empowerment, under PM JANMAN and DA JGUA, MNRE introduced the New Solar Power Scheme for Tribal and PVTG Habitations. Additionally, the National Bioenergy Programme has been revised to update Central Financial Assistance (CFA), strengthening the country's renewable energy mix (https://mnre.gov.in/en/renewable-energy-statistics/)
Overall, the literature review demonstrated the significance of renewable energy and its crucial role in climate change mitigation, sustainable development and economic growth. The review of literature, however, identified certain barriers in terms of financial assistance, infrastructure, policy formulation and technological limitations.

Source: Author's compilation from Literature Review

Table 1: Summary of the literature review of the study

Authors name	Focus area	Methods	Significant Findings
Candra et al. (2023)	Renewable energy, economic growth and greenhouse gas emissions in MICs and HICs.	Structural Vector Auto Regression (SVAR) Model	Renewable energy production positively influences economic growth, supporting employment generation while also reducing CO2 emissions(Candra et al., 2023)
Abidi & Nsaibi (2024)	Effectiveness of Renewable Energy in climate mitigation in 58 countries	Autoregressive Distributed lag (ARDL) Model	Significant reduction of greenhouse gas emissions and temperature anomalies and contribution to energy security and economic resilience(Abidi & Nsaibi, 2024).
Dharmala et al. (2022)	Transportation and climate Change mitigation in India	Scenario -based policy modelling	Fuel efficiency, electrification, alternative fuels, modal shifts and modernisation in transport demand helped in significant reduction of CO2 and particulate matter (PM2.5) emissions(Dharmala et al., 2022).
Kumar et al. (2010)	Renewable energy status and potential in India	Descriptive and policy analysis	Adoption of renewable energy techniques and taking care of carbon emissions, air cleaning ensured a sustainable future(Kumar et al., 2010).
Mathur & Shekhar (2020)	India's Energy Sector under alternative mitigation scenarios	MARKAL energy system model	Early action on Decarbonization of electricity, electrification and energy efficiency can help reduce carbon lock-in and uplift climate change mitigation in India(Mathur & Shekhar, 2020).

Yoro & Daramola (2020)	CO2 emissions, Global warming and resultant effects	Analytical review	Carbon capture techniques are essential for mitigating fossil fuel combustion, which is the major source of global warming(Yoro & Daramola, 2020)
Gao et al. (2018)	Energiewende of Germany and Taiwan's energy transition	Critical policy review	Renewable promotion schemes and electricity liberalisation play an important role in an interconnected continental energy system to mitigate intermittency(Gao et al., 2018)
Gebreslassie (2021)	Development of solar and wind energy technologies in Ethiopia	Policy analysis	The strong necessity of capital investment, technology transfer, availability of skilled workforce for sustainable development and affordable and sustainable energy access(Gebreslassie, 2021).
Nathwani & Kammen (2019)	Universal clean energy access	Policy-oriented review	Improvement in living standards and reduction in global energy poverty requires affordable renewable and clean energy(Nathwani & Kammen, 2019)
Owusu & Asumadu-Sarkodie (2016)	Renewable energy sources, sustainability issues and climate change mitigation.	Comprehensive literature review	Renewable energy technologies have a significant role in climate change mitigation and sustainable development(Owusu & Asumadu-Sarkodie, 2016).
Rial (2024)	Biofuels and climate change mitigation	Review analysis	Biofuels have significant mitigation potential in a clean environment and sustainable energy future(Rial, 2024).
Saidi & Omri (2020)	Reduction of CO2 in OECD countries	Econometric analysis	Nuclear and renewable energy play a significant role in CO2 emissions reduction in the long term(Saidi & Omri, 2020).
Sumi & Tamim (2025)	Integration of renewable energy in sustainable development pathways in climate change mitigation	Conceptual and policy review	Renewable energy systems lower greenhouse gas emissions and pollution, improving the quality of the environment and human health, also lessening dependence on fossil fuels(Sumi & Tamim, 2025).
Krey & Clarke (2011)	Renewable energy's role in climate mitigation scenarios	Scenario synthesis review	The role of renewable energy is significantly crucial in achieving global climate mitigation targets and long-term low-carbon transitions(Krey & Clarke, 2011).

Fawzy et al. (2020)	Climate change mitigation strategies	Systematic review	Conventional mitigation technologies are not sufficient to mitigate climate change; therefore, alternative routes such as renewable energy adoption, afforestation and energy efficiency are also significant in climate change mitigation(Fawzy et al., 2020).
Yue & Gao (2018)	Contributions of both natural system and human activities to greenhouse gas emissions.	Environmental assessment review	Greenhouse gas emissions responsible by human activities put extra pressure on the self-balanced earth(Yue & Gao, 2018).

The existing literature extensively discusses the environmental and economic benefits of renewable energy. However, multiple significant research gaps remain unexplored. Several papers reviewed primarily focused on developed countries, while a few studies examined the long-term effectiveness of the potential of renewable energy systems in developing countries. The literature concentrated mainly on socio-economic inequalities, energy poverty and also institutional limitations. A substantial proportion of the literature emphasised the technical and environmental issues of renewable energy adoption but failed to provide interdisciplinary analysis of the social, political and governance-related dimensions in association with energy transition. Policy inconsistency, public acceptance, regional disparities and implementation barriers needed deeper investigation for overall sustainable development. Several papers evaluated the contributions made by renewable energy to greenhouse gas reduction; however, there remained limited comparative analysis of the available renewable energy technologies in terms of efficiency, affordability, sustainability, and adoption capacity under varying spatial and climatic conditions. In the Indian context, the majority of the existing papers focused on sector-specific policies or simply individual renewable technologies instead of providing a comprehensive study of renewable energy in the context of climate mitigation strategy. Further, there existed limited literatures which analyze recent global findings together with policy and developmental challenges of India. Therefore, the present study aims to address these gaps by analysing a comprehensive and policy oriented-review of renewable energy and its role in the climate change mitigation process. The main focus of this study is on the pathways, challenges, sustainability implications and policy frameworks that are at par relevant to both global and Indian contexts.

3. Objective of the Study:

The study focused on two main objectives. The focused objectives of this study are provided below:

1. To study the renewable energy’s role in climate change mitigation.
2. To examine the environmental, economic, and social benefits of renewable energy adoption.

4. Materials and Methods:

4.1 Research Design: This study adopts a qualitative, descriptive, and systematic review-based research design to analyse the contribution of renewable energy in mitigating climate change. The systematic qualitative review was guided by the principles of PRISMA 2020, ensuring transparency in methodology and minimising selection bias. The main idea for the induction of a qualitative approach was aligned with the aims to critically analyse the existing knowledge of renewable energy technologies, climate change mitigation strategies, sustainable development and policy interventions. The descriptive nature of the study is incorporated in order to undergo systematic interpretation of global and Indian renewable energy trends, barriers, benefits and policy frameworks. The systematic review-based research design focused on identifying recurring themes and patterns, knowledge gaps and policy implications in existing research papers.

4.2 Sources of Data: This study solely relied on secondary data collected from credible academic, institutional and international sources. Relevant sources were retrieved from internationally recognised databases and repositories including Web of Science, Scopus, Google Scholar, SpringerLink and JSTOR. In addition, reports and publications from international organisations and government institutions including the Intergovernmental Panel on Climate Change (IPCC), International Energy Agency (IEA), United Nations Development Programme (UNDP), United Nations Environment Programme (UNEP) and other Government policy reports were reviewed. The study also incorporated statistical data and graphical information from "Our World in Data" and IEA renewable energy databases to support discussions regarding global greenhouse gas emissions and renewable energy generation trends. The statistical information from the Ministry of New and Renewable Energy (MNRE) and the Central Electricity Authority (CEA) were also reviewed to analyse India's Cumulative installed capacity of RE and RES and Cumulative Installed Capacity under RES from 2014-15 to 2024-25

4.3 Literature Selection Criteria: The review for this paper primarily aimed for recent studies published between 2010-2025. This included the incorporation of recent technological developments aligned with renewable energy and climate change mitigation strategies, as well as policy-oriented arguments related to climate change mitigation. The literature selected was based on relevance, credibility and contribution to the objectives of the study. The papers primarily included peer-reviewed journal articles, review articles, policy reports and international publications on climate action and renewable energy adoption. The literature was selectively taken to cover the thematic principles of the study. It includes renewable technologies, climate change mitigation strategies, greenhouse emissions, sustainable development, energy transition policies, low-carbon pathways, etc.

4.4 Data Analysis Method: The collected literature for this study and secondary data used here were analysed using thematic content analysis, a process which involved identifying recurring concepts, themes, findings and relevant policies related to renewable energy and climate change mitigation. The major themes organised from the reviewed literature were categorised as (i) renewable energy and climate change mitigation, (ii) renewable energy and sustainable development, (ii) renewable energy and policy frameworks and (iv) renewable energy policy and transition in India. Additionally, the global and Indian renewable-energy statistics were also descriptively interpreted, including trends in renewable electricity generation, installed renewable energy capacity and other selected institutional reports.

5. Types of Renewable Energy and Their Climate Mitigation Potential:

Renewable energy systems include energy sources such as biomass, hydropower, geothermal, solar energy, wind energy, and marine energies(Panwar et al., 2011). It has a greater role in the protection of the environment and climate change mitigation(Arroyo M. & Miguel, 2020; Umeh et al., 2024). Its deployment leads to a reduction in socioeconomic inequalities while various local communities gain greater access to clean and cost-effective energy (Umeh et al., 2024). Some of the Renewable Energies and their mitigation potential are discussed below.

5.1 Solar Energy: Solar energy is one of the fastest-growing renewable energy sources globally. It harnesses sunlight through photovoltaic (PV) systems and solar thermal technologies to generate electricity and heat. Solar power produces minimal greenhouse gas emissions during operation and offers enormous potential for decentralised energy generation (Krey & Clarke, 2011). The declining cost of solar technologies has accelerated global adoption, particularly in developing countries. Large-scale solar deployment contributes significantly to reducing fossil fuel dependence and improving energy access in remote regions.

5.2 Wind Energy: Wind energy is considered one of the cleanest and most environmentally sustainable energy sources because it generates electricity without emitting greenhouse gases or harmful pollutants during operation (Owusu & Asumadu-Sarkodie, 2016). Wind turbines convert kinetic energy from wind into electricity and can be deployed both onshore and offshore. Wind energy has become increasingly cost-competitive and plays an important role in reducing carbon emissions from the electricity sector. In many countries, wind power now represents a major component of national renewable energy strategies.

5.3 Hydropower: Hydropower is one of the oldest and most widely utilised renewable energy technologies. It generates electricity by converting the kinetic energy of flowing water into mechanical energy. Hydropower systems are highly efficient and capable of producing large quantities of electricity with relatively low operational emissions (Kumar et al., 2010). In addition to electricity generation, hydropower contributes to water management, irrigation, and flood control. However, large-scale hydropower projects may also create ecological and social challenges, including habitat disruption and population displacement.

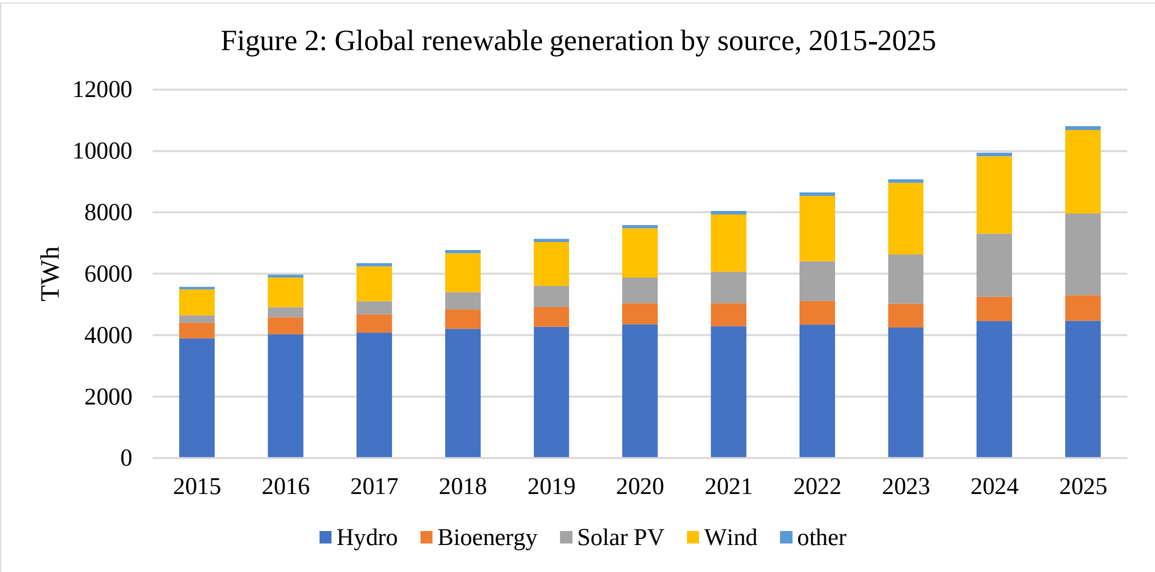
5.4 Biomass Energy: Biomass energy is derived from organic materials such as agricultural residues, forestry waste, and biodegradable municipal waste. Biomass can be converted into electricity, heat, or biofuels through various technological processes(Schuck, 2006). The utilisation of renewable organic matter reduces waste accumulation and makes biomass a best option for climate mitigation when sustainably managed(Rial, 2024). Its innovations mainly focus on the optimisation of available technologies such as gasification and biochemical processes. (Surewer et al., 2024) This innovative process enhances energy yields and facilitates diversifying biomass applications. However, there is a risk of deforestation and land degradation if unsustainable biomass production is practised.

5.6 Geothermal Energy: Geothermal energy utilises heat from the Earth’s interior to generate electricity and provide heating services. Unlike solar and wind energy, geothermal energy is not significantly affected by weather conditions, making it a reliable and stable energy source. Geothermal systems produce very low greenhouse gas emissions and can provide continuous base-load power generation (Abidi & Nsaibi, 2024). However, geothermal energy development is geographically limited to areas with suitable geological conditions.

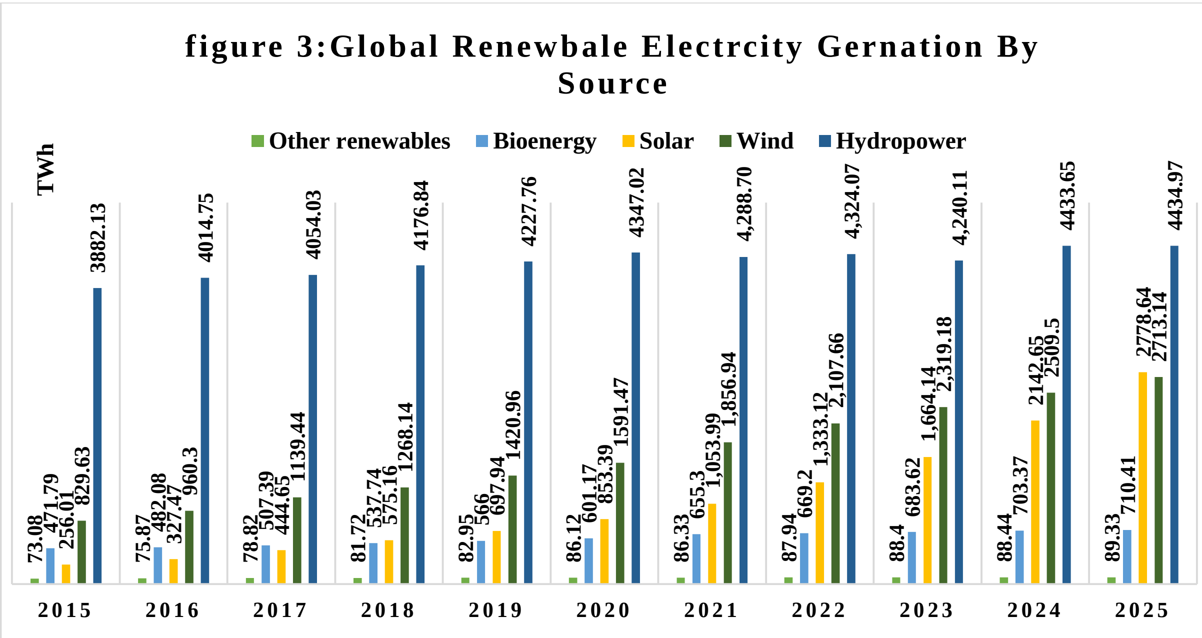
6. Global and Indian renewable trends:

6.1 Global energy generation by source:

Figure 2 shows the global energy generation by source. The data is generated from global renewable generation by source from 2015 to 2025. Here, the chart shows a significant increase in overall energy production over the period, from 5500 TWh in 2015 to around 10800 TWh in 2025. Regarding the renewable energy sources, the chart indicates major expansion and diversification of their generation. It is observed in Figure 2 that among the renewable energy sources, hydropower remained the largest source, producing 3899 TWh to 4470 TWh over the period, indicating a gradual increment. Bioenergy also shows gradual development in its production, sharing 509 TWh to 840 TWh throughout the period. Solar energy, on the other hand, experienced significant growth, approximately from 245 TWh in 2015 to 2653 TWh. In fact, it has risen as the fastest-growing energy source among renewable energy. Wind power also presents substantial expansion, with its production increasing from 835 TWh in 2015 to 2723 TWh in 2025. Other renewable sources such as geothermal, tidal and wave remained comparatively low compared to other major renewable energy sources, with 91 in 2015 to 121 TWh in 2025. In fact, the overall energy expansion doubled between 2015 and 2025, with solar and wind proving rapid growth while hydropower remained the largest share.



Source: (Global Renewable Generation by Source, 2015-2025 – Charts – Data & Statistics)
Note: Other includes geothermal, tidal and wave



Source: Ember (2026) – with major processing by Our World in Data (Electricity Production by Source, n.d.) Note: Other resources include geothermal, wave and tidal

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Figure 3 shows global electricity generation by renewable energy resources from 2015 to 2025, and the information is obtained from Our World in Data. It is evident from the chart that hydropower dominates in electricity production and remained the largest source of electricity, producing 3882.13TWh in 2015 to 4434.97 TWh. Wind power shows strong growth, indicating a production of electricity from 829.63 TWh in 2015 to 2713.14TWh in 2025. Solar energy also shows substantial production, from 256.01 TWh in 2015 to 2778.64 TWh in 2025. Bioenergy shows a steady increment from 471.79 TWh to 710.41 over the period from 2015 to 2025. However, other resources, including geothermal, wave and tidal, remained relatively small in their share.

6.2 India's Renewable Energy capacity:

There is a report of increasing India's total RE capacity from 81.31GW in 2014-15 to 220.10 GW in 2024-25 (Table 2). The report shows that large expansion comes from RES, which shows expansion from 40.04 GW in 2014-15 to 172.37 in 2024-25, while the table reports expansion of large Hydro from 41.27 GW in 2014-15 to 47.73 GW in 2024-25. The total installed capacity reported in Table 2 is 220.1 GW. The transformation within the RES is given in Table 3. In 2014-15, wind alone held 23.44 GW (58.54%), sharing the highest installed total RES* capacity. However, by 2024-25, the situation reversed as the report shows solar occupying 66.78 GW, sharing 61.29% of the total RES* capacity. The report shows solar with the highest CAGR at 38.77%, compared to 7.92% for wind, 2.60% for bioenergy and 2,31% for small hydro (Table 3).

Table 2: India's Cumulative installed capacity of RE and RES since 2014-15

Financial year	RES* (GW)	Large Hydro (GW)	Total RE (GW)
2014–15	40.04	41.27	**81.31**
2015–16	47.09	42.78	**89.87**
2016–17	58.56	44.48	**103.04**
2017–18	70.65	45.29	**115.94**
2018–19	79.41	45.4	**124.81**
2019–20	88.26	45.7	**133.96**
2020–21	95.8	46	**142.01**
2021–22	109.89	46.72	**156.61**
2022–23	125.16	46.85	**172.01**
2023–24	143.64	46.93	**190.57**
2024–25	**172.37**	**47.73**	**220.1**

Source: Ministry of New and Renewable Energy (MNRE) and Central Electricity Authority (CEA). Note: RES*- Comprising of Solar, Wind, Bio-Power and Small Hydro Power, RE – Large Hydro + RES

Table 3: India's Cumulative Installed Capacity under RES since 2014-15 (in GW)

year	small hydro powr	wind power	biopower		solar power	total RES* Capacity
			BM power/Congen.	waste to energy		
2014-15	4.06	23.44	8.31	0.24	3.99	40.04

2015-16	4.27	26.78	8.67	0.25	7.12	47.09
2016-17	4.38	32.28	8.84	0.28	12.78	58.56
2017-18	4.49	34.15	9.36	0.31	22.35	70.65
2018-19	4.59	35.63	9.78	0.32	29.10	79.41
2019-20	4.68	37.63	9.88	0.35	35.6	88.26
2010-21	4.79	39.25	10.15	0.39	41.24	95.8
2021-22	4.85	40.36	10.21	0.49	54.00	109.89
2022-23	4.94	42.63	10.25	0.55	66.78	125.16
2023-24	5.00	45.89	10.36	0.59	81.81	143.64
2024-25	5.10	50.04	10.74	0.84	105.65	172.37
Gr (2014-15 to 2024-25)	25.62%	114.21%	29.24%	250.00%	2547.87%	330.49%
CAGR (2014-15 TO 2024)	2.31%	7.92%	2.60%	13.35%	38.77%	15.72%

Source: Ministry of New and Renewable Energy MNRE) and Central Electricity Authority (CEA). Note: *RES comprises of Solar, Wind, Small Hydro Power & Bio-Power, Gr=Growth (%) CAGR=Compound Annual Growth Rate

7. Benefits of Renewable Energy:

Renewable energy has a significant contribution towards reducing greenhouse gas and has been at the forefront in fighting global warming. RE also contributes to climate change mitigation by replacing fossil fuel-based energy, thereby providing a significant contribution to meeting international goals of the Paris Agreement(Fawzy et al., 2020). Renewable energy further enhances energy security by diversifying energy supply sources and positively contributing to reducing dependence on imported fossil fuels (Saidi & Omri, 2020). Additionally, industries that work on renewable energy production open opportunities for employment generation in terms of manufacturing, installation, operation, maintenance, and research sectors. The renewable energy sector emerged as a major source of green jobs worldwide, providing a wider platform for inclusive and economic growth(Candra et al., 2023). On the other hand, fossil fuel combustion contributes to polluting the air, and this leads to major diseases such as respiratory disorders, cardiovascular diseases, and premature deaths (Dharmala et al., 2022). However, renewable energy systems abate the presence of air pollutants in the atmosphere and contribute to the improvement of public health outcomes. It also remarkably contributes to the improvement of land degradation, conserving natural resources at a glance while maintaining balanced ecology, and this leads to overall sustainable development(Sumi & Tamim, 2025). It further acts as a substitute for the Sustainable Development Goals (SDGs), while contributing to clean energy, climate action and sustainable livelihoods for many communities.

Table 4: Benefits of Renewable Energy and Their Impacts

Benefits of Renewable Energy	Major Impacts
Reduction of Greenhouse Gas Emissions	Decreases atmospheric CO_2 levels and mitigates global warming and climate change(Fawzy et al., 2020).

Energy Security and Independence	Reduces dependence on imported fossil fuels and enhances national energy stability(Saidi & Omri, 2020).
Economic Growth	Stimulates industrial development, technological innovation, and sustainable economic expansion(Candra et al., 2023)..
Employment Generation	Creates green jobs in manufacturing, installation, operation, and maintenance sectors(Candra et al., 2023).
Public Health Improvement	Reduces air pollution and lowers the incidence of respiratory and cardiovascular diseases(Dharmala et al., 2022).
Environmental Protection	Minimises environmental degradation, ecosystem damage, and fossil fuel extraction impacts(Sumi & Tamim, 2025).
Climate Change Mitigation	Renewable energy significantly contributes to climate change mitigation and sustainable development(Owusu & Asumadu-Sarkodie, 2016).

Source: authors compilation from literature review

8. Challenges of Renewable Energy Transition:

Renewable energy transition adoption in developing countries faces various challenging issues in terms of intermittency, investment cost, financial constraints, infrastructure and grid modernisation, policy barriers and institutional constraints. Intermittency remains a major challenge in renewable energy generation. Renewable energy sources, mainly solar and wind energy, and their generation are influenced by weather conditions, and therefore their production varies over time. This poses a significant challenge in maintaining electricity power by their production, including grid reliability. Technologies like batteries and pumped hydro storage are crucially significant for energy storage and may help in addressing intermittency challenges(Krey & Clarke, 2011). Financial investment also poses significant challenges to developing infrastructure related to the production of renewable energy. This challenge has significantly become a constraint to developing countries in large-scale renewable energy supply. The suggested solution for this may include reaching international financing, green bonds, and climate funds for better investment in renewable energy production.(Gebreslassie, 2021). Grid modernisation and smart grid technologies are also very important for improving renewable energy integration. Inconsistency in policy frameworks, delays in bureaucratic decisions, and inadequate regulatory support often pose challenges to renewable energy expansion. Stable long-term policies and financial incentives are essential for encouraging private-sector participation (Gao et al., 2018). Developing countries remain facing frequent technological limitations, a lack of skilled human resources, and weak institutional capacities. Effective knowledge transfer, research collaboration, and technological innovation are significantly necessary to overcome these barriers (Gebreslassie, 2021)

Table 5: Constraints in Renewable Energy Transition and the pathways to overcome

Constraints in Renewable Energy Transition	Proposed way of solving
Intermittency and Reliability Issues	Energy storage technologies such as batteries and pumped hydro storage(Krey & Clarke, 2011)
High Initial Investment Costs	Access to international financing, green bonds, and climate funds(Gebreslassie, 2021)

Infrastructure and Grid Limitations	Grid modernisation and smart grid technologies(M.Saleh & I.Hassan, 2024)
Policy and Regulatory Barriers	Stable long-term policies and financial incentives(Gao et al., 2018).
Technological and Institutional Constraints	Effective knowledge transfer, research collaboration, and technological innovation(Gebreslassie, 2021)

Source: Author's Compilation from Literature Review

9. Government policies supporting energy transition in India:

The cumulative installed capacity of RE has reached about 180 GW as of 2024-2025 (table), and it has roughly shared about 43% of the total power generation capacity. The expansion is largely driven by the share of solar and wind energy, and they are greatly supported by policies such as Renewable Purchase Obligations (RPOs), Production Linked Incentive (PLI) schemes, and Green Energy Open Access Regulations(Kumbhar et al., 2026). With the new developments in India's clean energy transition and climate action targets, India has achieved 300 GW of installed electricity generation capacity based on non-fossil fuels, as per the report dated 31st July 2026 (India Achieves Landmark 300 GW Non-Fossil Fuel Power Capacity, 2026), over 60% of the 500 GW target to be achieved by 2030. Some of the significant policies supporting the Indian renewable energy transition are discussed below:

9.1 National Solar Mission: This mission promotes ecologically sustainable growth while also addressing India's energy security challenge(Jawaharlal Nehru National Solar Mission (JNNSM) | India Science, Technology & Innovation - ISTI Portal, n.d.). It has adopted a 3-phase approach, and it has set the target of 20,200 MW of Grid connection and 2000 MW of Off-grid capacity by 2022. The Union Government has further revised the set target of grid-connected solar power projects to 100,000 MW by the year 2021-22.

9.2 PM-KUSUM: This policy supports the deployment of solar pumps and grid-connected renewable power plants on barren and agricultural lands, strengthening rural livelihoods and reducing the agricultural sector's reliance on fossil fuels. Reduction in the use of diesel promotes clean, renewable energy in the field of farming while also generating farmers' income through solar power generation, where surplus electricity is sold (PM-KUSUM Scheme, n.d.)

9.3 PM Surya Ghar: Muft Bijli Yojana: PMSurya Ghar: Muft Bijli Yojana is the world's largest domestic rooftop solar policy with the target of electrifying one crore households with solar energy by 2027(Renewable Energy Statistics 2024-25, n.d.). It promotes both sustainability and increased energy affordability, enabling million families to generate clean energy at the grassroots level. This scheme also sets the goal of establishing one solar-powered model village in every district.

9.4 Renewable Purchase Obligation: The Government of India has taken the initiative to generate 175 GW of electricity from renewable energy resources by 2022, 100 GW and 75 GW from solar and wind energy, respectively. India has committed to install 40 GW of rooftop photovoltaic (RPV) capacity by 2022, and the distribution companies (DISCOMs) are mandated to buy 10.5% of their total power purchase from solar power by 2022 as a part of renewable purchase obligations (RPOs) mandate(Mundra et al., 2020). The Government of India has introduced RPO targets for all the states and power companies and large industries. Renewable purchase obligation (RPO) is made mandatory by the State Electricity Regulatory Commission (SERC) to promote renewable energy. This legal mandate has helped fight climate change by creating a guaranteed, green energy market, ultimately contributing to the reduction of fossil fuel use and greenhouse gas emissions.

9.5 Green Energy Corridor: Green Energy Corridor is another significant programme supporting large-scale integration of renewable energy into the national grid, one of India's plans to achieve 500 GW of non-fossil power capacity by 2030(INTEGRATION OF NON-FOSSIL FUEL POWER GENERATING INTO NATIONAL GRID, n.d.)

9.6 National Green Hydrogen Mission: This mission has a significant contribution to India's transition towards a low-carbon and sustainable economy by producing green hydrogen using renewable energy sources through water electrolysis(Unlocking India's Green Hydrogen Production Potential, 2025). The mission sets its goal of achieving, by 2030, the development of 5 million metric tonnes (MMT) of green hydrogen annually, 125 GW of renewable energy capacity, Rs 8 lakh crore investment, and over 6 lakh jobs creation, and reduction of fossil fuel imports worth more than 1 lakh crore. Additionally, to contribute significantly to global climate mitigation efforts, it targets to diminish nearly 500 MMT of greenhouse gases annually

10. Pathways for climate change mitigation and sustainable development:

Climate change mitigation focuses on cutting down greenhouse gases emissions. This can be successfully done by utilising low-carbon fuels and also related technologies. It also includes a reduction in terms of service demand and energy consumption by shifting towards efficient ways to meet the same services with less energy utilisation(Chaturvedi & Shukla, 2014). The interconnected process must be implemented to abate climate change, boost energy transition and enhance sustainable development substantially. These pathways must include transformative efforts in terms of technology, efficient policy implementation, economic investment, and institutional development. Social participation should also be taken into consideration to contribute to collective work with the mentioned pathways in facilitating the transition towards non-fossil fuels. The findings of the study highlighted several important policy implications for governments, policymakers, and international institutions. First, governments should establish stable and long-term renewable energy policies that provide clear investment signals for private and public stakeholders. Feed-in tariffs, renewable energy subsidies, tax incentives, and carbon pricing mechanisms can accelerate clean energy deployment. Secondly, investment in energy infrastructure and grid modernisation is essential for integrating renewable energy into existing energy systems. Smart grids, energy storage systems, and advanced transmission networks can improve reliability and efficiency. Third, international cooperation and financial support are necessary for developing countries in renewable energy transitions. Climate finance mechanisms, technology transfer programs, and research collaborations can help address financial and technological disparities. Fourth, policymakers should promote research and innovation in renewable energy technologies, energy storage systems, and low-carbon industrial processes. Investment in research and development can reduce technology costs and improve energy efficiency. Finally, renewable energy policies should be integrated with broader sustainable development strategies, including poverty reduction, public health improvement, and employment generation.

Table 4. Policy Recommendations for Accelerating Renewable Energy Transition

Policy Recommendation	Purpose	Expected Outcome
Introduce Stable Renewable Energy Policies	Ensure long-term investment confidence and policy consistency	Increased private and public investment in renewable energy projects
Expand Financial Incentives and Subsidies	Reduce the financial burden of renewable energy adoption	Faster deployment of renewable energy technologies
Strengthen Grid Infrastructure	Improve transmission and distribution systems for renewable integration	Enhanced grid reliability and efficient energy distribution
Promote Energy Storage Technologies	Address intermittency challenges associated with solar and wind energy	Improved energy reliability and continuous power supply
Increase Research and Development (R&D) Investment	Encourage innovation in renewable technologies and energy efficiency	Technological advancement and cost reduction
Implement Carbon Pricing and Carbon Taxes	Discourage fossil fuel use and promote low-carbon energy systems	Reduction in greenhouse gas emissions
Enhance International Cooperation	Support technology transfer, climate finance, and knowledge sharing	Accelerated renewable energy adoption in developing countries
Develop Skill Training and Capacity-Building Programs	Improve technical expertise and workforce readiness	Creation of skilled labour and green employment opportunities
Support Decentralised Renewable Energy Systems	Expand energy access in rural and remote areas	Improved energy equity and rural development
Introduce Feed-in Tariffs and Net Metering Policies	Encourage renewable electricity generation by consumers and industries	Increased adoption of rooftop solar and distributed generation
Integrate Renewable Energy into National Development Plans	Align energy transition with sustainable development objectives	Balanced economic growth and environmental sustainability
Promote Public Awareness and Environmental Education	Increase public acceptance and understanding of renewable energy benefits	Greater community participation in clean energy initiatives
Strengthen Environmental Regulations	Ensure sustainable implementation of renewable energy projects	Reduced environmental risks and better ecological conservation
Facilitate Green Financing Mechanisms	Mobilise climate finance, green bonds, and sustainable investments	Increased funding availability for clean energy infrastructure

Source: Author's Compilation

10. Conclusion:

The present review study illustrates the significant role of renewable energy in the pathway for the climate change mitigation process and sustainable development. The findings of the study highlight the global CO2 emissions increasing substantially between 2000 and 2024, the major contributors being China and India (Figure 1). On the other hand, the study demonstrates substantial growth in global renewable energy generation, particularly in solar and wind energy (Figure 2). This indicates the significantly increasing role of renewable energy sources towards low-carbon energy transitions. In the Indian context, the total renewable energy capacity increased from 81.31 GW in 2014–15 to 220.10 GW in 2024–25(Table 2). Solar energy is emerging as the fastest-growing renewable source, reaching 66.78 GW. Solar energy emerged as the dominant component, reaching 66.78 GW and recording the highest CAGR of 38.77%, compared with 7.92% for wind, 2.60% for bioenergy, and 2.31% for small hydropower. The study further highlights that renewable energy can contribute to greenhouse gas emission reduction, energy security, economic growth, employment generation, public health and environmental protection. However, the transition continues to face challenges including intermittency of renewable resources, high initial investment costs, inadequate grid infrastructure, policy and regulatory uncertainty, and technological and institutional limitations. Overcoming these barriers requires an integrated approach involving stable and long-term policies, financial incentives, grid modernisation, energy-storage systems, research and technological innovation, international cooperation, and institutional capacity-building. In the Indian context, continued implementation of renewable-energy programmes and stronger integration of renewable energy with national development objectives can further accelerate the energy transition. Overall, renewable energy has considerable potential to support climate change mitigation while promoting sustainable economic and environmental development. A coordinated approach combining technological, economic, policy and social measures is essential for achieving a resilient, low-carbon and sustainable energy future.

11. Limitations of the Study:

Despite undergoing a comprehensive review of available literature on renewable energy to find out its role in climate change mitigation, this study has certain limitations. The entire study is based on data from secondary sources such as journal articles, national and international reports, etc. Field surveys, interviews, experiments and primary data collection were not conducted for this study. The findings entirely relied on the reliability and interpretations of previous studies by adopting a qualitative and descriptive approach. Moreover, this study does not use advanced quantitative models and other advanced techniques for analysing the findings in measuring the impact on climate change mitigation, although statistical trends and empirical findings from the published papers were analysed. The study is based on discussing the renewable trends of India in particular and while also analysing the trends related to global renewable energy. Therefore, it does not include a comparative study of other developing and developed countries. Despite all these limitations, the study provides significant understanding and awareness pertaining to environmental, socio-economic and policy dimensions of renewable energy and also emphasises the role of renewable energy in climate change mitigation and development in a sustainable way.

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