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Climate Change Mitigation through Renewable Energy: Challenges, Opportunities, and Global Perspectives

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ABSTRACT

Climate change has become a critical global challenge due to increasing greenhouse gas emissions, rising temperatures, and environmental degradation caused mainly by fossil fuel consumption. This study explores the role of renewable energy in reducing carbon emissions and mitigating climate change impacts on a global scale. The research examines the contribution of renewable energy sources, including solar, wind, hydropower, biomass, and geothermal energy, toward achieving a sustainable and low-carbon energy system. The study reviews existing literature on renewable energy adoption, technological innovation, green finance, energy policies, and their relationship with carbon-emission reduction. The findings indicate that renewable energy expansion has significantly contributed to reducing greenhouse gas emissions, improving energy security, and supporting sustainable development. However, challenges such as infrastructure limitations, investment requirements, policy barriers, and differences in technological capacity among countries continue to influence the pace of energy transition. The study highlights that effective climate policies, increased renewable energy investments, and international cooperation are essential for achieving global decarbonisation goals. It concludes that renewable energy represents a fundamental pathway for limiting global warming, protecting ecosystems, and ensuring long-term environmental and economic sustainability.

Keywords: *Renewable Energy, Carbon Emissions, Climate Change Mitigation, Sustainable Development.*

1. Introduction

Climate change has become one of the most pressing global challenges of the twenty-first century, affecting environmental sustainability, economic development, and human well-being. The increasing concentration of greenhouse gases, particularly carbon dioxide (CO_2), in the atmosphere has largely resulted from the extensive consumption of fossil fuels for electricity generation, industrial production, transportation, and urbanization. These emissions have intensified global warming, leading to rising temperatures, changing rainfall patterns, frequent natural disasters, melting glaciers, sea-level rise, and biodiversity loss. As a result, governments, international organizations, and policymakers have recognized the urgent need to reduce carbon emissions while maintaining economic growth and energy security [1].

Renewable energy has emerged as a sustainable alternative to conventional fossil-fuel-based energy systems because it produces electricity with minimal carbon emissions and reduces environmental degradation. Sources such as solar, wind, hydropower, geothermal, and biomass have gained significant attention due to technological advancements, declining production costs, and supportive government policies [2]. Their growing adoption has strengthened global efforts to achieve carbon neutrality and fulfill international climate commitments, including the Paris Agreement and the Sustainable Development

Goals [3-6]. However, several challenges, including energy storage, transmission infrastructure, investment requirements, and policy implementation, continue to influence the pace of renewable-energy expansion. Therefore, examining the role of renewable energy in reducing carbon emissions and mitigating climate change is essential for developing effective strategies that promote sustainable development, environmental protection, and long-term global energy security [7].

II. Review of Literature

Osman et al. (2023) reviewed the contribution of renewable energy to climate-change mitigation and reported that fossil fuels remained the dominant source of global greenhouse gas and carbon dioxide emissions. They found that declining costs of solar, wind, biomass, and other renewable technologies had accelerated their adoption. The review also highlighted varying environmental impacts and climate-related vulnerabilities across renewable sources. The authors concluded that renewable energy could decarbonize most of the electricity sector by 2050, significantly reduce carbon emissions, and support the global target of limiting temperature rise to 1.5°C.

Güneş et al. (2023) investigated the impact of global energy transformation on climate change using panel data from 26 world regions during 2005–2022. Their findings indicated that renewable energy, alternative energy, technological innovation, and climate-related financial development had significantly reduced climate change, whereas fossil fuel consumption had intensified it. The authors concluded that expanding renewable energy infrastructure and implementing effective decarbonisation policies were essential for mitigating global warming and achieving long-term environmental sustainability.

Bhatt (2023) examined the contribution of global partnerships and sustainable development initiatives to climate change mitigation and biodiversity conservation. The study found that the Sustainable Development Goals had strengthened climate resilience, forest protection, and renewable energy adoption. It also highlighted increasing forest loss, biodiversity decline, and rising global temperatures despite ongoing efforts. The author concluded that integrating sustainable development with renewable energy sources such as solar, wind, hydropower, geothermal, and bioenergy had been an effective strategy for reducing carbon emissions and mitigating climate change.

Khan et al. (2022) examined the impact of renewable energy consumption, electricity production, and economic activity on global carbon-emission risks using data from 219 countries between 1990 and 2020. The findings indicated that greater renewable energy use had significantly reduced environmental degradation and carbon emissions. However, the effectiveness of renewable energy varied across countries because of differences in income levels, technological advancement, foreign investment, and economic structure. The authors concluded that renewable energy was a key factor in mitigating carbon risks while supporting sustainable development.

Dalei (2022) investigated the role of renewable energy policies in promoting sustainable energy security and mitigating climate change. The study found that renewable energy had become a reliable and environmentally friendly energy source, with its long-term success depending on effective policy frameworks. Using the Driving Forces–Pressure–State–Impact–Response framework, the research highlighted the importance of policy interventions in addressing climate-related challenges. The author concluded that strong renewable energy policies were essential for enhancing energy security and supporting global sustainable development.

Zhang et al. (2022) examined the relationships among technological innovation, green finance, renewable energy consumption, environmental pollution, and climate change using data from 49 countries during 2007–2019. The findings showed that technological innovation and green finance had significantly

increased renewable energy adoption while reducing carbon emissions and climate-related risks. The authors concluded that strengthening green finance and promoting technological innovation were crucial for accelerating the clean energy transition, enhancing environmental sustainability, and mitigating climate change.

Yang et al. (2022) investigated the impact of renewable energy investment on carbon dioxide emissions across 13 countries between 2010 and 2019. The findings revealed that the environmental benefits of renewable energy investment depended on both its scale and allocation. While technological improvements had reduced emissions, expanded economic activity had partly offset these gains. The study also showed that greater investment in wind energy lowered carbon emissions more effectively than investments in solar or bioenergy. The authors concluded that strategic allocation of renewable energy investments was essential for maximizing climate change mitigation.

Jaumotte et al. (2021) evaluated climate mitigation strategies for achieving net-zero emissions through a combination of carbon pricing, green infrastructure investment, and renewable energy subsidies. Their findings indicated that early green fiscal spending had stimulated economic growth while supporting the transition to a low-carbon economy. The study also showed that long-term economic costs remained relatively modest. The authors concluded that integrated green policy measures could effectively reduce emissions, promote sustainable development, and strengthen economic recovery during the clean energy transition.

Barthelmie and Pryor (2021) reviewed global wind energy resources, industry developments, and their contribution to climate change mitigation. The study found that wind energy capacity had expanded rapidly while generation costs had declined substantially, enabling wind power to supply an increasing share of global electricity. The authors projected that further expansion of wind energy could significantly reduce greenhouse gas emissions and help limit global warming. They concluded that accelerating wind-energy deployment would be essential for achieving long-term climate goals and supporting the global transition to clean energy.

Prasad et al. (2020) reviewed the contribution of bioenergy to the transition from fossil fuels toward low-carbon energy systems. The study highlighted that bioenergy had supported decarbonisation, improved energy security, and promoted sustainable economic development while reducing dependence on conventional fuels. The authors also emphasized that technological advancements and supportive energy policies had strengthened the role of bioenergy in climate change mitigation. They concluded that bioenergy represented a vital component of the renewable energy mix for achieving long-term environmental sustainability and reducing carbon emissions.

Sarkodie et al. (2020) investigated the influence of renewable energy, income growth, foreign direct investment, and governance on greenhouse gas emissions in 47 Sub-Saharan African countries during 1990–2017. The findings revealed that increased renewable energy consumption significantly reduced greenhouse gas emissions, while economic growth and other interactive factors sometimes increased environmental pressures. The authors concluded that the effectiveness of renewable energy in climate mitigation depended on its contribution to the energy mix, technological progress, and the implementation of appropriate national policies.

Johnsson et al. (2019) examined fossil-fuel and renewable-energy demand patterns by comparing fossil-fuel-rich countries with nations having limited domestic reserves. The study found that countries with abundant fossil resources had shown higher fossil-energy consumption but slower renewable-energy expansion, creating challenges for climate mitigation. The authors emphasized the importance of reducing

fossil-fuel dependence, increasing investment in clean technologies, and adopting carbon capture strategies. They concluded that rapid transformation of energy systems and coordinated policy actions were essential for achieving global climate targets and limiting warming below 2°C.

III. Major Findings from Study

Author(s) & Year	Study Focus	Methodology / Data Used	Major Findings	Conclusion
Osman et al. (2023)	Role of renewable energy in global climate-change mitigation	Review of renewable energy sources including solar, wind, biomass, hydropower, and geothermal energy	Fossil fuels contributed significantly to greenhouse gas and CO_2 emissions. Declining renewable energy costs accelerated adoption, while different renewable sources showed varying environmental impacts.	Renewable energy could decarbonize a major portion of the electricity sector by 2050 and support limiting global temperature rise to 1.5°C.
Güneş et al. (2023)	Impact of global energy transformation on climate change	Dynamic panel data analysis of 26 world regions (2005–2022) using system-GMM, pooled OLS, and random-effects models	Renewable energy, alternative energy, technological innovation, and climate finance reduced climate change impacts, while fossil fuel consumption increased environmental degradation.	Expansion of renewable energy infrastructure and decarbonisation policies were necessary for reducing global warming.
Bhatt (2023)	Role of sustainable development initiatives in climate action and biodiversity conservation	Analysis of SDGs, forest assessments, biodiversity reports, greenhouse gas inventories, and renewable energy statistics	Sustainable Development Goals strengthened climate resilience, forest conservation, and renewable energy adoption. Forest loss and biodiversity decline remained major concerns.	Integrating renewable energy with sustainable development strategies was effective for reducing emissions and protecting ecosystems.
Khan et al. (2022)	Effects of renewable energy consumption and economic activity on carbon risks	Panel data of 219 countries (1990–2020) using GMM and quantile regression techniques	Renewable energy consumption reduced environmental degradation and carbon emissions, although impacts differed across income groups and economic structures.	Renewable energy played a significant role in reducing carbon risks while supporting sustainable development.
Dalei	Renewable	Driving Forces–	Effective renewable	Strong policy

(2022)	energy policies and sustainable energy security	Pressure–State–Impact–Response (DPSIR) framework analysis	energy policies improved energy security, climate resilience, and sustainable development outcomes.	frameworks were essential for expanding renewable energy and reducing climate change impacts.
Zhang et al. (2022)	Relationship between technological innovation, green finance, renewable energy, and climate change	Simultaneous-equation models using data from 49 green bond-issuing countries (2007–2019)	Technological innovation and green finance increased renewable energy adoption and reduced carbon emissions and climate risks.	Strengthening green finance and innovation was important for clean energy transition and climate mitigation.
Yang et al. (2022)	Effectiveness of renewable energy investment in reducing CO_2 emissions	Data from 13 countries (2010–2019) using mediation models	Renewable investment reduced emissions through technological improvements, but economic expansion sometimes increased emissions. Wind energy investment showed stronger emission reduction effects.	Strategic allocation of renewable energy investments was necessary to maximize climate benefits.
Jaumotte et al. (2021)	Climate mitigation strategies and low-carbon economic transition	Economic modelling of carbon pricing, green infrastructure investment, and renewable energy subsidies	Green fiscal investment supported economic growth and reduced transition costs toward a low-carbon economy.	Integrated green policies could achieve emission reduction while maintaining economic stability.
Barthelmie and Pryor (2021)	Contribution of wind energy to climate change mitigation	Review of global wind resources, industry trends, and future projections	Wind energy capacity increased rapidly, electricity costs declined, and wind power contributed significantly to reducing greenhouse gas emissions.	Accelerated wind-energy deployment was essential for achieving long-term climate targets.
Prasad et al. (2020)	Role of bioenergy in low-carbon energy transition	Review of bioenergy technologies, policies, and sustainability aspects	Bioenergy improved energy security, supported decarbonisation, and provided alternatives to fossil fuels.	Bioenergy was an important component of renewable energy systems for achieving sustainable development.
Sarkodie et al. (2020)	Effects of renewable	Dynamic heterogeneous	Renewable energy significantly reduced	Renewable energy effectiveness

	energy, economic growth, FDI, and governance on emissions	estimation using data from 47 Sub-Saharan African countries (1990–2017)	greenhouse gas emissions, whereas economic growth and other factors sometimes increased environmental pressures.	depended on energy mix, technological advancement, and policy implementation.
Johnsson et al. (2019)	Fossil fuel dependency and renewable energy transition	Comparative analysis of fossil-fuel-rich and fossil-fuel-limited countries	Fossil-fuel-rich countries showed higher fossil energy demand and slower renewable adoption, creating climate challenges.	Reducing fossil fuel dependence, investing in clean technologies, and adopting carbon capture were necessary for achieving climate targets.

IV. Conclusion

The study concluded that renewable energy had played a significant role in reducing carbon emissions and addressing global climate change challenges. The expansion of solar, wind, hydropower, biomass, and geothermal energy had contributed to cleaner energy production, reduced dependence on fossil fuels, and supported sustainable development [8-12]. The reviewed studies highlighted that technological innovation, green finance, effective policies, and international cooperation had strengthened renewable energy adoption worldwide. However, challenges such as infrastructure limitations, investment requirements, energy storage issues, and regional differences continued to affect the pace of energy transition. Therefore, accelerating renewable energy deployment and improving policy frameworks were essential for achieving global climate goals. A coordinated approach involving governments, industries, and international organizations could promote a low-carbon future, enhance energy security, and support long-term environmental sustainability while limiting the adverse impacts of climate change.

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