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ROLE OF RENEWABLE ENERGY IN REDUCING CARBON EMISSIONS AND PROMOTING SUSTAINABLE ENVIRONMENTAL DEVELOPMENT

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ABSTRACT

Climate change, environmental degradation, energy insecurity and increasing global energy demand have created an urgent need to transform the existing energy system. Conventional dependence on coal, petroleum and natural gas remains a major source of greenhouse gas emissions, air pollution and ecological damage. Renewable energy provides an important pathway for addressing these challenges because solar, wind, hydropower, biomass and geothermal resources can generate energy with substantially lower operational carbon emissions than fossil fuels. This research paper examines the role of renewable energy in reducing carbon emissions and promoting sustainable environmental development, with particular emphasis on recent global developments and the Indian context. The study adopts a descriptive and analytical research methodology based primarily on secondary data from international organisations, government publications and recent research literature. The analysis indicates that renewable energy is becoming central to the global energy transition. In 2024, renewables accounted for approximately one-third of global electricity generation, while renewable capacity additions reached a record level of more than 580 GW. India has also achieved substantial progress, reaching 50% of installed electricity capacity from non-fossil sources in June 2025 and continuing its policy drive towards 500 GW of non-fossil capacity by 2030. The paper argues that renewable energy contributes not only to carbon mitigation but also to energy security, technological innovation, employment generation, rural development, improved air quality and long-term economic resilience. However, intermittency, energy storage, transmission infrastructure, land-use concerns, financing constraints and supply-chain dependence remain significant challenges. The study concludes that renewable energy should be integrated with energy efficiency, storage, smart grids, green hydrogen, sustainable transport and responsible land-use planning to achieve meaningful sustainable development.

Keywords: Renewable Energy, Carbon Emissions, Climate Change, Sustainable Development, Solar Energy, Wind Energy, Energy Transition, India, Green Economy, Environmental Sustainability

1. INTRODUCTION

Energy is fundamental to economic development, industrialisation, transportation, agriculture, communication and modern living. However, the conventional energy system has historically depended heavily on fossil fuels. Coal, oil and natural gas have enabled rapid economic growth, but their extensive use has also generated significant environmental costs. Fossil-fuel combustion releases carbon dioxide (CO_2), methane and other pollutants, contributing to global warming, air pollution, ecosystem degradation and climate-related risks.

The transition towards renewable energy has therefore become an important component of international climate and development policy. Renewable energy refers to energy obtained from naturally replenishing resources such as sunlight, wind, flowing water, biomass and geothermal heat. Unlike fossil fuels, renewable resources are not depleted through normal energy use and generally produce much lower greenhouse-gas emissions during operation.

Recent developments demonstrate the speed of this transition. In 2024, renewable sources accounted for about 32% of global electricity generation. Solar photovoltaic and wind generation experienced particularly rapid expansion, while renewables and nuclear power together provided around 40% of global electricity generation. The International Renewable Energy Agency reported that global renewable power capacity increased by approximately 582 GW during

2024, taking total installed renewable capacity to about 4,443 GW.

Renewable energy is consequently no longer simply an environmental alternative to fossil fuels. It has become an important economic and strategic component of national energy systems. Falling technology costs, improvements in efficiency, government incentives and increasing private investment have accelerated deployment.

The Indian context is particularly important. India has a rapidly growing population, expanding industrial activity and increasing electricity demand. At the same time, it faces substantial pressure to reduce emissions while maintaining economic growth. The country has committed to achieving 500 GW of non-fossil electricity capacity by 2030 and reaching net-zero emissions by 2070. By June 2025, India had already achieved 50% of installed electricity capacity from non-fossil sources, several years ahead of its original 2030 milestone.

The central argument of this paper is that renewable energy can contribute to sustainable environmental development through three interconnected pathways: reducing carbon-intensive energy production, improving environmental quality and supporting an economically resilient low-carbon development model.

3. Literature Review

The literature on renewable energy and environmental sustainability has expanded considerably as governments, businesses and researchers have focused on climate change mitigation and energy transition.

Recent international evidence demonstrates that renewable energy is becoming a major source of electricity growth. The International Energy Agency (IEA) reported that clean energy sources accounted for more than 80% of the growth in global electricity generation during 2024. Renewables alone accounted for almost three-quarters of the overall increase in electricity generation. Solar PV increased generation by approximately 480 TWh, while wind generation increased by around 180 TWh.

This expansion is significant from an emissions perspective because renewable electricity can displace electricity generated by coal and natural gas. The IEA has also observed that global electricity emissions intensity declined by about 3% in 2024, reflecting the increasing contribution of renewable and other low-emission energy sources.

Cost competitiveness has further strengthened the case for renewable energy. According to the IEA, onshore wind and solar PV remained among the most competitive options for new electricity generation in 2024. This suggests that environmental objectives and economic interests are increasingly aligned.

However, the literature also indicates that renewable energy deployment does not automatically guarantee sustainable development. Large-scale renewable projects may create land-use conflicts, biodiversity concerns, visual impacts and social displacement if planning processes are inadequate. Solar-panel and battery manufacturing also requires minerals, energy and industrial infrastructure. Therefore, a sustainable energy transition must consider the entire life cycle of renewable technologies.

Another important issue is intermittency. Solar and wind generation vary according to weather and time of day. This creates challenges for grid management, especially as their share increases. Energy storage, demand response, transmission expansion and hybrid renewable systems are consequently becoming essential components of modern electricity systems.

In India, government data show a rapid increase in renewable capacity. During financial year 2024–25, India added 29.52 GW of renewable energy capacity, bringing total installed renewable capacity to approximately 220.10 GW by March 2025. Solar energy accounted for the largest component of new capacity, with 23.83 GW added during the year.

The literature therefore supports a broad conclusion: renewable energy is essential for decarbonisation, but its environmental and developmental benefits depend on appropriate policies, infrastructure, technology, financing and institutional governance.

4. Renewable Energy and Carbon Emission Reduction

The most direct contribution of renewable energy to climate mitigation is the substitution of fossil-fuel-based electricity generation.

Coal-fired power plants are particularly carbon-intensive. When solar, wind or hydropower replaces coal-generated electricity, emissions associated with fuel combustion can be significantly reduced. Renewable energy therefore addresses emissions at their source rather than attempting to compensate for emissions after they occur.

The global electricity sector illustrates this transition. In 2024, renewables supplied about one-third of global electricity, while coal continued to provide approximately 35%. The rapid increase in renewable generation has limited the need for additional fossil-fuel generation in many electricity systems.

The IEA estimates that electricity-generation emissions were approximately 13.8 billion tonnes of CO_2 in 2024. Although power-sector emissions still increased slightly

during that year, the growth was considerably constrained by the expansion of clean energy.

The importance of renewable energy is even clearer when considering future electricity demand. The IEA projects that renewable energy could supply approximately 43% of global electricity generation by 2030 under its Renewables 2025 outlook. Renewables are expected to meet more than 90% of the increase in global electricity demand during 2025–2030.

This trend indicates that renewable energy can perform a dual function: meeting increasing energy demand while limiting the need for additional fossil-fuel generation.

5. CONTRIBUTION OF MAJOR RENEWABLE ENERGY SOURCES

5.1 Solar Energy

Solar photovoltaic technology has become one of the fastest-growing renewable technologies. Its advantages include modularity, declining costs, scalability and suitability for both large power plants and distributed rooftop systems.

Solar power can contribute to sustainable development in urban as well as rural areas. Rooftop systems allow households, institutions and businesses to generate electricity locally, reducing transmission losses and potentially lowering electricity expenditure.

India has experienced particularly rapid solar growth. During FY 2024–25, solar capacity increased by 23.83 GW, while cumulative installed solar capacity reached 105.65 GW by March 2025.

5.2 Wind Energy

Wind power is another major source of low-carbon electricity. Wind turbines generate electricity without combustion and therefore have very low operational carbon emissions.

India possesses substantial onshore wind resources, particularly in states such as Gujarat, Tamil Nadu, Karnataka, Maharashtra and Rajasthan. Wind-solar hybrid projects can improve generation profiles by combining two variable sources.

5.3 Hydropower

Hydropower provides renewable electricity while offering an important advantage over some variable renewable sources: reservoir-based projects can provide dispatchable electricity and grid-balancing services.

However, hydropower projects can affect river ecosystems, fisheries, forests and local communities. Sustainable hydropower development therefore requires careful environmental assessment and appropriate rehabilitation and compensation mechanisms.

5.4 Biomass and Bioenergy

Biomass can convert agricultural residues, organic waste and other biological materials into useful energy. In agricultural economies such as India, biomass energy can create an additional value stream from agricultural residues.

Properly managed biomass can contribute to waste reduction and rural income generation. However, unsustainable biomass harvesting can cause deforestation, soil degradation and competing land-use pressures. Sustainable sourcing is therefore essential.

6. RENEWABLE ENERGY AND SUSTAINABLE ENVIRONMENTAL DEVELOPMENT

Sustainable development extends beyond carbon reduction. It requires environmental protection, economic opportunity and social well-being.

6.1 Reduction in Air Pollution

Fossil-fuel combustion releases particulate matter, sulphur dioxide, nitrogen oxides and other pollutants. Replacing coal and oil with renewable electricity can reduce these emissions, improving air quality and public environmental health.

This is especially important in rapidly growing cities and industrial regions where air pollution creates substantial economic and social costs.

6.2 Energy Security

Renewable resources reduce dependence on imported fossil fuels. Countries that import large quantities of oil, gas or coal can improve energy security by developing domestic solar, wind, hydropower and biomass resources.

For India, this dimension is strategically important because increasing electricity demand and fossil-fuel imports can expose the economy to international commodity-price fluctuations.

6.3 Employment Generation

The renewable energy sector creates employment across manufacturing, engineering, construction, installation, operations, maintenance, finance and research.

The development of domestic manufacturing capacity can also generate industrial opportunities. India has increasingly linked renewable energy expansion with domestic manufacturing and the broader objective of energy self-reliance.

6.4 Rural Development

Distributed renewable energy can provide electricity to remote communities and agricultural areas. Solar pumps, mini-grids and rooftop systems can support irrigation, food processing, cold storage, small businesses and rural enterprises.

Consequently, renewable energy can act as an instrument of rural economic transformation rather than simply an electricity-generation technology.

6.5 Sustainable Industrial Development

Renewable electricity is also important for decarbonising industries. Green hydrogen, produced using renewable electricity, has potential applications in steel, fertilisers, chemicals, shipping and other difficult-to-electrify sectors.

India's National Green Hydrogen Mission is intended to develop India as a major producer and user of green hydrogen, linking renewable electricity development with industrial decarbonisation.

7. GLOBAL TRENDS IN RENEWABLE ENERGY DEVELOPMENT

The scale of recent renewable deployment is historically significant. IRENA reported that renewables accounted for more than 90% of global power-capacity expansion in 2024. Total installed renewable power capacity reached approximately 4,443 GW at the end of the year.

Solar PV was the principal contributor to this expansion. In 2024, solar accounted for approximately 452 GW of new renewable capacity, or about 78% of total renewable additions. Wind contributed approximately 114 GW.

These trends demonstrate that the renewable-energy transition is increasingly driven by both environmental policy and economic competitiveness.

Nevertheless, the current rate of deployment remains below what is required for the internationally discussed goal of tripling global renewable capacity by 2030. IRENA has indicated that annual renewable additions would need to accelerate substantially to remain aligned with that objective.

Therefore, the challenge is no longer whether renewable technologies can be deployed at scale. The central question is whether governments, markets and institutions can expand them rapidly enough while maintaining system reliability and environmental integrity.

7. RENEWABLE ENERGY DEVELOPMENT IN INDIA

India represents an important case because the country must simultaneously pursue economic development, energy access and climate mitigation.

India's renewable-energy capacity increased significantly during FY 2024–25. According to the Ministry of New and Renewable Energy, total installed renewable energy capacity reached 220.10 GW by March 2025, following an annual addition of 29.52 GW.

The country's progress accelerated further during 2025. Government data indicate that India achieved 50% of cumulative installed electricity capacity from non-fossil sources in June 2025, five years ahead of its original NDC milestone. By 31 December 2025, total installed electricity capacity had reached 513.73 GW, with 266.79 GW from non-fossil sources.

By March 2026, India's installed renewable-energy capacity had reached approximately 274.68 GW, including solar, wind, bioenergy, small hydro and large hydro. Total non-fossil capacity reached 283.46 GW.

These figures demonstrate that renewable energy is becoming structurally important within India's electricity system.

The country's 500 GW non-fossil capacity target for 2030 is supported by several policy mechanisms, including renewable-energy procurement, competitive bidding, transmission development, green-energy corridors, storage initiatives and support for emerging technologies. However, India still faces the challenge of reducing the carbon intensity of electricity generation because coal remains a major component of the power system. The IEA reported that coal supplied nearly three-quarters of India's electricity in 2024, despite the country's rapid growth in renewable capacity.

This illustrates an important distinction between **capacity transition** and **generation transition**. Installing renewable capacity does not immediately eliminate fossil-fuel generation. Storage, transmission, demand management and flexible generation are necessary for renewable capacity to produce deeper reductions in actual emissions.

8. CHALLENGES IN RENEWABLE ENERGY ADOPTION

Despite its benefits, renewable energy faces several challenges.

8.1 Intermittency

Solar and wind generation vary with weather and time. Large-scale deployment therefore requires energy storage, grid flexibility and forecasting systems.

8.2 Energy Storage

Battery storage can shift electricity from periods of high renewable generation to periods of high demand. Pumped-storage hydropower and other storage technologies can complement batteries.

8.3 Transmission Infrastructure

Renewable resources are not always located near demand centres. New transmission networks are therefore essential to transfer electricity efficiently.

8.4 Land and Biodiversity

Large renewable projects can require significant land. Poorly planned development may conflict with agriculture, forests, wildlife habitats and community interests.

8.5 Financing

Although renewable costs have declined, large projects still require substantial upfront capital. Financing conditions can be especially challenging in developing economies.

8.6 Supply-Chain Dependence

Solar modules, batteries, inverters, rare minerals and other components involve complex global supply chains. Building domestic manufacturing capacity is therefore important for long-term energy security.

8.7 Waste Management

Solar panels, wind-turbine components and batteries eventually reach the end of their useful lives. Recycling and circular-economy systems must develop alongside deployment.

9. FINDINGS

The analysis produces several important findings.

First, renewable energy has become a major driver of global electricity expansion. Record renewable capacity additions demonstrate that the transition is no longer a marginal phenomenon.

Second, renewable energy contributes directly to carbon-emission reduction by displacing fossil-fuel electricity generation. The increasing renewable share has helped reduce the carbon intensity of global electricity.

Third, solar and wind are currently the principal engines of renewable expansion because of technological improvements, declining costs and scalability.

Fourth, renewable energy supports sustainable development beyond climate mitigation. It can improve air quality, strengthen energy security, create employment and support rural economic development.

Fifth, India has made substantial progress in renewable capacity and has already achieved 50% non-fossil installed electricity capacity, demonstrating significant policy and investment momentum.

Sixth, installed capacity alone is not sufficient to achieve deep decarbonisation. India's continued dependence on coal-fired electricity demonstrates the importance of storage, transmission, demand management and grid flexibility.

Seventh, renewable-energy policy must move from a narrow focus on capacity addition towards a broader focus on system integration, environmental sustainability and lifecycle management.

10. CONCLUSION

Renewable energy represents one of the most important pathways for addressing the interconnected challenges of climate change, environmental degradation and energy insecurity. The evidence examined in this paper demonstrates that renewable technologies have moved rapidly from alternative energy sources to mainstream components of modern electricity systems.

Global renewable capacity reached approximately 4,443 GW at the end of 2024, while renewable sources supplied about one-third of global electricity generation. The continued expansion of solar and wind is particularly significant because these technologies can be deployed rapidly and at different scales.

The environmental contribution of renewable energy extends beyond reducing CO_2 emissions. Renewable deployment can improve air quality, reduce dependence on imported fuels, strengthen energy security, support technological innovation and generate new economic opportunities.

India's experience demonstrates the potential of renewable energy to support both environmental and developmental objectives. The country achieved 50% of installed electricity capacity from non-fossil sources in June 2025 and is pursuing 500 GW of non-fossil capacity by 2030. However, the continued importance of coal in electricity generation shows that the next stage of the transition must focus on actual generation displacement rather than capacity additions alone.

The future of sustainable energy therefore depends on an integrated approach. Renewable generation must be combined with energy storage, transmission expansion, smart grids, energy efficiency, green hydrogen, electric mobility and circular-economy practices. Equally important, renewable projects must be developed in ways that protect biodiversity and respect local communities.

Ultimately, renewable energy should not be viewed merely as a mechanism for replacing fossil fuels. It should be understood as a foundation for a broader transformation of energy, industry, transport and society. When supported by appropriate institutions, technology and inclusive policies, renewable energy can help create an economy that is cleaner, more resilient, energy-secure and environmentally sustainable.

REFERENCES

1. Chowdhury, M. S. A., Rahman, M. A., Gracy, S. H. R., Govindappa, S., Kumar, A., & Rahman, M. (2024). *Role of English language in international trade and economic development*. *Migration Letters, 21*(S7), 1607–1612. https://migrationletters.com/index.php/ml/article/view/9073
2. Chowdhury, M. S. A., Hasan, M. M., Rahman, M., & Rafi, M. (2026). *The environment of women's reputation in Pride and Prejudice by Jane Austen*.

International Journal of Business, Arts and Scientific Study, *7*(1).

3. Chowdhury, M. S. A. (2021). *Smart classroom and students' achievement during the Covid-19: Prospects and challenges post Covid situations*. *International Journal of Business, Arts and Scientific Study (IJBASS)*, *2*(2), 60–66.
4. Mir, S. A., Chowdhury, M. S. A., Hasan, M. M., & Haq, M. K. (2026). Business beyond borders: FinTech, blockchain, and the new trading era. *International Journal of Advanced Research & Higher Studies (IJARHS), 5*(1). https://doi.org/10.70818/ijarhs
5. Sheriff, A. M., Chowdhury, M. S. A., & Hasan, M. M. (2026). *Global fintech platforms: Innovations and business models – An empirical analysis*. *Journal of Sustainable Learning and Development, 6*(1).
6. Chowdhury, M. S. A. (2025). Eco-respectability and women empowerment: Class, gender, and environmental space in Jane Austen's *Emma*. *International Journal of Environmental Sciences, 11*(22S), 1018–1023.
7. Chowdhury, M. S. A., *et al.* (2024). Representation of social class, intellectual independence, and gender roles in *Emma* by Jane Austen. *Migration Letters, 21*(S3), 1135–1139.
8. Chowdhury, M. S. A., & Sofi, N. U. D. (2024). Women's liberation in Jane Austen's *Sense and Sensibility*: Balancing emotion and independence. *International Journal of Innovation Studies, 8*(2), 341–347.
9. Chowdhury, M. S. A., & Sofi, N. U. D. (2024). Representation of social class, intellectual independence, and gender roles in *Emma* by Jane Austen. *Migration Letters, 21*(S3), 1135–1139.
10. Chowdhury, M. S. A. (2026). *Microeconomic transformations in local communities: A critical analysis of labor market effects*. *International Journal of Advanced Research & Higher Studies, 5*(1). https://doi.org/10.70818/ijarhs
11. Chowdhury, M. S. A., & Sofi, N. U. D. (2024). *Challenging patriarchy: The quest for equality in Jane Austen's Pride and Prejudice*. *Library Progress International, 44*(3), 10817–10820.
12. Hasan, M. M., Chowdhury, M. S. A., Haque, M. F., Surjamokhey, S. Y., & Ahmed, T. (2025). *The presence of local leaders of Alamdanga on social media and the influence on public opinion during election: An analysis*. *Journal of South Asia (JOSA)*, *1*(2).
13. Chowdhury, M. S. A. (2026). Bangladesh's journey from economic basket case to middle-income complexities. *International Journal of Scientific Research & Engineering Trends, 12*(3). DOI:10.5281/zenodo.20305442
14. Chowdhury, M. S. A. (2026). Social realism and class conflict in the works of Aravind Adiga and Rohinton Mistry. *International Journal of Scientific Research & Engineering Trends, 12*(3). DOI:10.5281/zenodo.20305759
15. Chowdhury, M. S. A., *et al.* (2020). Integrated democracy as a weapon of interpersonal skill in Walt Whitman's poetry. *International Journal of Business, Arts and Scientific Study, 1*(1).