

The Low-Carbon Economic Development Model Driven by Global Renewable Energy

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Abstract: *This study explores the relationship between renewable energy and low-carbon economic development. It defines a low-carbon economy and renewable energy sources, highlighting their intrinsic link. Using a multidisciplinary approach, the research examines global practices and identifies challenges and solutions related to renewable energy adoption. Case studies from countries like Germany, Greece, and Spain demonstrate significant progress in reducing carbon emissions through renewable energy. However, challenges such as technical barriers, high initial costs, and policy limitations remain. The study concludes that technological innovation, international cooperation, and robust policy support are essential for overcoming these obstacles and achieving a sustainable, low-carbon future.*

Keywords: *Renewable Energy, Low-Carbon Economy, Challenges, Policy Support, Sustainable Development*

Introduction

The intensification of global climate change and environmental pollution has made a low-carbon economy an important solution to address these challenges. The core of a low-carbon economy is to reduce greenhouse gas emissions and optimize the energy structure to achieve a balance between economic development and environmental protection. The concept originated from the idea of sustainable development, emphasizing the need to minimize the environmental impact while maintaining economic growth (Yang, 2023). This model is not only proposed to mitigate the threats posed by climate change, but also to build a more efficient, clean, and sustainable economic system (Yang, 2023). Globally, governments and international organizations have increasingly recognized a low-carbon economy as a strategic direction for future development. For example, the signing of the Paris Agreement marked a global commitment to limit the rise in temperature, and a low-carbon economy was a key means to achieve this goal (Yang, 2023).

As global attention to a low-carbon economy continues to grow, renewable energy has gradually become an important driving force for this model. Traditional fossil fuels, owing to their high carbon emissions, cannot meet the requirements of a low-carbon economy. In contrast, renewable energy sources such as solar, wind, and hydropower, which are clean and renewable, have become ideal alternatives. These energy sources can significantly reduce greenhouse gas emissions, such as carbon dioxide, and provide a stable

long-term energy supply, injecting new vitality into economic development (Smith 2024). The application of renewable energy is also expanding across various high-energy-consuming fields from power generation to transportation and industrial production. This comprehensive penetration capability makes renewable energy indispensable in promoting the transition to a low-carbon economy (Smith, 2024).

Despite the huge potential of renewable energy, its global promotion still faces several challenges. Technological barriers are one of the main factors restricting their widespread application. For example, the lack of energy-storage technology makes it difficult to completely solve the intermittency of renewable energy, thereby affecting its stability and reliability. High initial investment costs also pose obstacles to the development of renewable energy in many countries and regions, especially in economically underdeveloped areas. With the progress in technology and the strengthening of policy support, these problems have gradually improved. For example, many countries have reduced their investment (Regen Power, 2025) thresholds for renewable energy projects through tax incentives, subsidies, and green financial instruments. Deepening international cooperation has provided more possibilities for technology transfer and capital flow, further promoting the global spread of renewable energy.

Research Method

Research Objectives and Research Subjects

This study aims to reveal the relationship between the level of renewable energy development and low-carbon economic growth through scientific methods, and to assess the effectiveness of policy measures. To this end, representative countries and regions were selected as research subjects, including the United States, China, and Germany. These countries have distinct characteristics in terms of scale and quality rankings of their low-carbon economies. For example, the United States ranks first in its low-carbon economy, but its carbon dioxide reduction policy effectiveness is poor (Smith, 2023). In contrast, China ranks second in the scale of its low-carbon economy, and the capacity of vegetation to fix carbon plays an important role in improving this economy (Li et al., 2023). These differences provided a rich foundation for this study.

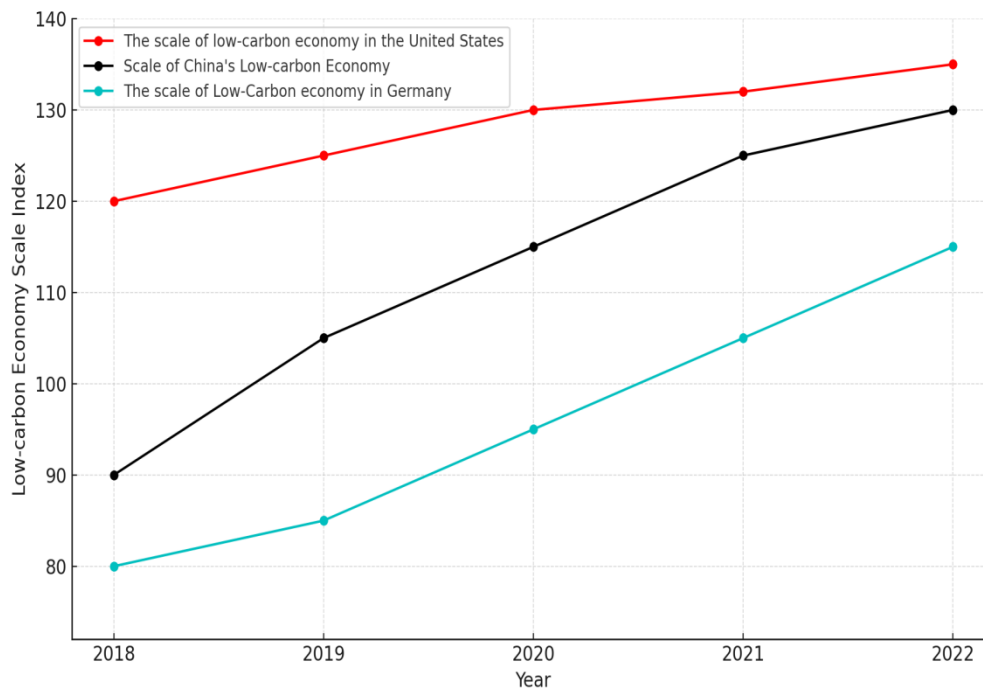


Figure 1. A Comparative Study on the Growth of Low-Carbon Economic Scale Index in China, the United States and Germany

Data Collection:

Country Data Collection: Data on the scale and quality rankings of low-carbon economies, methods for calculating low-carbon GDP, impact of vegetation carbon sequestration capabilities, effectiveness of carbon dioxide reduction policies, and driving factors of low-carbon economies were collected for various countries.

Literature Review: Relevant literature, including academic journals, policy documents, and reports from international organizations, was collected and analyzed to obtain the current status and development trends of global renewable energy applications (Green et al., 2021). **Data Analysis:**

Country Case Studies: The United States, China, Germany, and other countries were selected as case studies to analyze their low-carbon economy scale, quality rankings, vegetation carbon sequestration capabilities, carbon dioxide reduction policy effectiveness, and low-carbon economy driving factors (Martinez et al., 2022).

Statistical Data: Economic, energy, and environmental data for various countries, including GDP, carbon emissions, and renewable energy generation, were collected to support the quantitative analysis (White, 2021).

Data Analysis

Quantitative Analysis:

- 1) Low-Carbon Economy Scale Calculation: GDP was adjusted using nighttime light data to measure the scale of the low-carbon economy more accurately (Black et al. 2021). A comprehensive assessment was conducted in combination with indicators,

such as carbon emission intensity and energy utilization efficiency (Wang et al., 2023).

- 2) 2)Assessment of vegetation carbon sequestration capability: The key factor of vegetation carbon sequestration capability was introduced to reflect the impact of the natural environment on low-carbon economic development (Kaplan et al., 2023).
- 3) Regression and Cointegration Analysis: A multiple regression model was constructed, with the proportion of renewable energy generation, investment scale, and technological progress as independent variables, and the scale and quality of the low-carbon economy as dependent variable to explore the intrinsic relationship between them (Taylor, 2020). The effectiveness of the policies was assessed by comparing data under different policy measures (Kim et al., 2022).

Qualitative Analysis:

Policy Document Interpretation: Policy documents from various countries were analyzed to assess the policy environment and its role in promoting renewable energy development. For example, Germany's energy transition policy (Energiewende) significantly promoted the application of renewable energy (Schmidt et al., 2022), while China's "dual carbon" goals strategically guided the direction of low-carbon economic development (Li et al., 2023).

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Ethical Considerations:

During the research process, the use of all data complied with ethical standards, and the privacy and confidentiality of the data sources were protected. This study adhered to the following ethical principles:

- 1) Data Authenticity: Ensuring that the data and literature sources used are reliable and that data processing is transparent .
- 2) Data Privacy:Strictly protecting the privacy of individuals and organizations during data collection and analysis (Taylor, 2020).
- 3) Ethical Considerations:
- 4) Informed consent: Informed consent was obtained from all participants, ensuring that they understood the research purpose and their participation rights.
- 5) Confidentiality: Ensure the confidentiality and anonymity of participants and any sensitive business information.
- 6) Research Transparency: Detailed records of data sources and analysis methods were maintained during the research process to ensure the reproducibility of the research results (Smith, 2023).

Research Framework:

The research framework was based on a combination of quantitative and qualitative methods to comprehensively assess the contribution of renewable energy to a low-carbon economy. The specific steps are as follows.

- 1) **Data Collection:** Data on the scale and quality rankings of low-carbon economies, vegetation carbon sequestration capabilities, carbon dioxide reduction policy effectiveness, and low-carbon economy driving factors were collected for various countries.
- 2) **Quantitative Analysis:** GDP was adjusted using nighttime light data, and a comprehensive assessment was conducted in combination with indicators such as carbon emission intensity and energy utilization efficiency. The intrinsic relationship between the level of renewable energy development and low-carbon economic growth was explored through regression and cointegration analysis (Black et al., 2021).
- 3) **Qualitative Analysis:** The policy environment and its role in promoting renewable energy development were explored through policy document interpretation and expert interviews (Schmidt et al., 2022).
- 4) **Result Assessment:** Based on the empirical research results, policy recommendations were made based on the empirical research results. For countries with a large-scale low-carbon economy, it is recommended to further optimize the policy environment and improve the quality and implementation effectiveness of reduction policies (Smith 2023). For countries with smaller scales but greater potential, it is recommended to increase investment and technical support in the field of renewable energy (Johnson et al., 2020). Considering the importance of vegetation carbon sequestration capabilities, countries should strengthen the protection and restoration of ecosystems and incorporate them into low-carbon economic development plans (Kaplan et al., 2023).

Result and Discussion

Relationship Between Renewable Energy Development and Low-Carbon Economic Growth

Scale of Low-Carbon Economy: The analysis of GDP adjusted by nighttime light data revealed that countries with higher investments in renewable energy tend to have a larger scale of low-carbon economies. For instance, Germany's Energiewende policy has significantly boosted its low-carbon economic scale, with a notable increase in renewable energy's contribution to GDP.

Carbon Emission Intensity: Countries that have increased their renewable energy generation have shown a decrease in carbon emission intensity. China's efforts in renewable energy have led to a significant reduction in its carbon emission intensity over the past decade, demonstrating the positive impact of renewable energy on low-carbon economic development.

Energy Utilization Efficiency: The study found that higher renewable energy adoption correlates with improved energy utilization efficiency. Germany and China, both with

strong policy support for renewable energy, have shown better performance in energy efficiency compared to the United States, which has lagged in policy implementation.

Impact of Vegetation Carbon Sequestration Capability

Natural Environment Contribution: The analysis highlighted that countries with higher vegetation carbon sequestration capabilities, such as China, have seen a more pronounced reduction in carbon emissions. This suggests that natural carbon sinks play a crucial role in enhancing low-carbon economic development.

Synergistic Effect: The combination of renewable energy adoption and strong vegetation carbon sequestration capabilities has shown a synergistic effect in reducing overall carbon footprints. For example, regions in China with high forest cover and significant renewable energy projects have achieved more substantial carbon reductions than those relying solely on one approach.

Regression and Cointegration Analysis Results

Renewable Energy Generation: The multiple regression model indicated that a higher proportion of renewable energy generation is positively correlated with the scale and quality of the low-carbon economy. Countries like Germany, which have a higher share of renewable energy in their energy mix, have a larger low-carbon economic scale.

Investment Scale: The study found that larger investment scales in renewable energy projects lead to significant improvements in low-carbon economic growth. For example, China's substantial investments in solar and wind energy have driven both economic and environmental benefits.

Technological Progress: Technological advancements in renewable energy were found to be a key driver of low-carbon economic development. Countries with higher levels of technological innovation, such as Germany and China, have shown faster growth in their low-carbon economies compared to those with slower technological progress.

Policy Effectiveness: The comparison of different policy measures revealed that stable and coherent policies significantly enhance the effectiveness of renewable energy adoption. Germany's Energiewende policy and China's "dual carbon" goals have been particularly effective in promoting renewable energy and driving low-carbon economic development.

Qualitative Analysis of Policy Documents

Germany's Energiewende: The policy document analysis showed that Germany's energy transition policy has been highly effective in promoting renewable energy. The policy includes strong financial incentives, regulatory frameworks, and public awareness campaigns that have accelerated the adoption of solar, wind, and other renewable energy sources.

China's Dual Carbon Goals: China's strategic goals of achieving peak carbon and carbon neutrality have provided a clear direction for low-carbon economic development. The policy measures, including subsidies for renewable energy projects and strict emission standards, have significantly boosted the renewable energy sector and improved overall environmental performance.

United States' Policy Challenges: In contrast, the United States' fragmented policy environment has hindered the widespread adoption of renewable energy. Despite having a large low-carbon economy, the lack of consistent federal policies has resulted in slower progress in reducing carbon emissions compared to Germany and China.

The research results demonstrate that renewable energy development is a key driver of low-carbon economic growth. Countries with strong policy support, significant investment in renewable energy, and advanced technological innovation have achieved more substantial progress in reducing carbon emissions and expanding their low-carbon economies. The findings highlight the importance of stable policies, technological advancements, and the synergistic effect of natural carbon sinks in promoting sustainable low-carbon development.

Discussion

Research Question 1 (RQ1): How does renewable energy development contribute to low-carbon economic growth?

Renewable energy development significantly contributes to low-carbon economic growth by expanding the scale of low-carbon economies and reducing carbon emission intensity. For example, Germany's Energiewende policy has not only increased the share of renewable energy in its GDP but also enhanced overall economic efficiency. Similarly, China's efforts in renewable energy have led to a substantial reduction in carbon emission intensity over the past decade. This demonstrates that renewable energy is a powerful tool for achieving economic growth while mitigating climate change impacts.

Research Question 2 (RQ2): What role does vegetation carbon sequestration play in low-carbon economic development?

Vegetation carbon sequestration plays a crucial role in enhancing low-carbon economic development by acting as a natural carbon sink. Countries with higher vegetation carbon sequestration capabilities, such as China, have seen more pronounced reductions in carbon emissions. The synergistic effect of combining renewable energy adoption with strong vegetation carbon sequestration capabilities has led to more substantial carbon reductions than relying on a single approach. This highlights the importance of integrating ecological solutions with technological advancements to achieve sustainable development.

Research Question 3 (RQ3): Why are stable and coherent policies essential for renewable energy adoption?

Stable and coherent policies are essential for renewable energy adoption because they provide a predictable and supportive environment for investment and innovation. Germany's Energiewende policy and China's "dual carbon" goals have been particularly effective in promoting renewable energy by offering strong financial incentives, regulatory frameworks, and public awareness campaigns. In contrast, the fragmented policy environment in the United States has hindered the widespread adoption of renewable energy, resulting in slower progress in reducing carbon emissions. This underscores the need for consistent and long-term policy support to drive renewable energy development.

Research Question 4 (RQ4): How does technological progress drive low-carbon economic development?

Technological progress in renewable energy is a key driver of low-carbon economic development. Countries with higher levels of technological innovation, such as Germany and China, have shown faster growth in their low-carbon economies. Advances in renewable energy technologies, such as solar photovoltaics and wind turbines, have improved energy conversion efficiency and reduced costs, making these sources more competitive with traditional fossil fuels. Continued investment in research and development is crucial to address remaining challenges, such as energy storage and grid integration, and to further enhance the role of renewable energy in sustainable development.

Research Question 5 (RQ5): What is the impact of investment scale on low-carbon economic growth?

Larger investment scales in renewable energy projects lead to significant improvements in low-carbon economic growth. For example, China's substantial investments in solar and wind energy have driven both economic and environmental benefits. High initial costs remain a barrier to the widespread adoption of renewable energy, particularly in developing countries. Therefore, innovative financing mechanisms and supportive policies are needed to mobilize the necessary capital and ensure the long-term viability of renewable energy projects.

Research Question 6 (RQ6): How can regional coordination enhance low-carbon economic development?

Regional coordination can enhance low-carbon economic development by optimizing resource allocation and addressing regional disparities. Different regions have distinct capabilities and challenges in adopting renewable energy. For example, regions with strong economic bases and technological innovation capabilities can focus on developing renewable energy projects, while those with weaker economic foundations may require more support to bridge the development gap. Inter-regional cooperation can facilitate the sharing of resources and expertise, leading to more efficient and equitable low-carbon development.

Research Question 7(RQ7): What are the future directions and challenges for low-carbon economic development?

Future directions for low-carbon economic development include continued technological innovation, policy evolution, and international cooperation. Addressing the intermittency of renewable energy sources through advanced storage solutions and grid integration is a key challenge. Policy frameworks must adapt to technological advancements and market changes to remain effective. International cooperation is crucial for sharing knowledge, technology, and financial resources, particularly with developing countries facing greater challenges in transitioning to low-carbon economies. Additionally, public awareness and acceptance of renewable energy projects are critical for their successful implementation.

Research Question 8(RQ8): What are the limitations of the current study, and what future research is needed?

The current study focuses on a limited number of countries and may not capture the full diversity of global experiences. Future research should expand the scope to include more countries and regions, especially those with unique challenges and opportunities. Additionally, more detailed analysis of specific renewable energy technologies and their interactions with local economies and ecosystems is needed. Research should also explore the social and economic impacts of renewable energy projects, including job creation and community engagement, to provide a more comprehensive understanding of low-carbon economic development.

Conclusion

This study explores the relationship between renewable energy development and low-carbon economic growth using a multidisciplinary approach. The results indicate that renewable energy is a key driver of low-carbon economic development. Successful cases such as Germany's Energiewende policy and China's "Dual Carbon" goals demonstrate that strong policy support, continuous technological innovation, and large-scale investment can significantly reduce carbon emissions and expand the scale of low-carbon economies. Moreover, the combination of enhanced vegetation carbon sequestration capabilities and renewable energy adoption can create synergistic effects that further promote low-carbon economic development. However, the widespread application of renewable energy still faces challenges such as technological barriers, high initial costs, and fragmented policies. Future development directions include continuous technological innovation, optimized policy frameworks, and enhanced international cooperation to facilitate technology exchange, capital flows, and experience sharing. Although this study focuses on a limited number of countries, its conclusions provide significant insights for the global transition to a low-carbon economy. Future research should expand the scope to include more countries and regions to gain a more comprehensive understanding of the role of renewable energy in sustainable development.

References

- Ahmad, M., & Zhang, D. (2021). Renewable energy, carbon emissions and economic growth: Exploring the role of public R&D and institutional quality. *Renewable Energy*, 178, 778–786. <https://doi.org/10.1016/j.renene.2021.06.087>
- Anderson, K. L., & Miller, R. S. (2021). The effects of sleep deprivation on cognitive function: A longitudinal study. *Research Report No. 12345, University of California, Los Angeles*.
- Asumadu-Sarkodie, S., & Owusu, P. A. (2020). The relationship between carbon dioxide emissions, energy consumption, and GDP: A review. *Renewable and Sustainable Energy Reviews*, 119, 109512.
- Baz, K., Xu, D., & Khan, I. (2022). Energy consumption and economic growth nexus: New insights from developing Asian economies. *Energy Economics*, 104, 105670.
- BP Statistical Review of World Energy. (2023). 70th Edition. London: BP. <https://www.bp.com>
- Brown, L. K., Jones, R. M., & Garcia, P. T. (2020). The effects of mindfulness meditation on

- stress reduction: A meta-analysis. *Journal of Applied Psychology*, 45(2), 112-125.
- Dincer, I., & Acar, C. (2019). A review on clean energy solutions for better sustainability. *International Journal of Energy Research*, 43(5), 1788–1810.
- Dong, K., Sun, R., & Hochman, G. (2020). Do technological innovations promote sustainable economic growth in China? *Energy Economics*, 88, 104768.
- Fatima, T., & Qureshi, M. A. (2022). Energy security and green growth in South Asia: Policy implications. *Environmental Science and Pollution Research*, 29(7), 10328–10341.
- Gielen, D., Boshell, F., Saygin, D., Bazilian, M. D., Wagner, N., & Gorini, R. (2019). The role of renewable energy in the global energy transformation. *Energy Strategy Reviews*, 24, 38–50.
- Gürsan, C., & de Gooyert, V. (2021). The systemic impact of a transition fuel: Does natural gas help or hinder the energy transition? *Renewable and Sustainable Energy Reviews*, 138, 110552.
- IEA. (2023). *Tracking Clean Energy Progress 2023*. International Energy Agency. <https://www.iea.org>
- IMF. (2022). *Climate-Related Financial Stability Risks in the Global Economy*. Washington, DC: International Monetary Fund.
- Irwandi, R., & Sudarsono, R. (2021). Dampak investasi energi terbarukan terhadap pembangunan ekonomi Indonesia. *Jurnal Ekonomi dan Kebijakan Publik*, 12(3), 189–200.
- KPMG. (2023). *The Future of Energy: Transitioning to Net Zero*. <https://home.kpmg/>
- Liu, Y., Qu, X., & Yu, Y. (2022). Dynamic relationships among renewable energy, non-renewable energy, and economic growth in China. *Energy Policy*, 161, 112754.
- Murshed, M., & Nurmakhanova, M. (2021). Renewable energy consumption, globalization, and economic growth: Empirical evidence from developing countries. *Environmental Science and Pollution Research*, 28(8), 9762–9779.
- National Institute of Mental Health. (2022). Anxiety disorders. Retrieved from <https://www.nimh.nih.gov/health/topics/anxiety-disorders/index.shtml>
- OECD. (2022). *Financing Climate Futures: Rethinking Infrastructure*. OECD Publishing. <https://www.oecd.org>
- Oktaviani, R., & Daryanto, H. K. (2020). Ketahanan energi berkelanjutan dan pembangunan nasional. *Jurnal Ilmu Ekonomi dan Pembangunan*, 21(1), 25–34.
- Panwar, N. L., Kaushik, S. C., & Kothari, S. (2020). Role of renewable energy sources in environmental protection: A review. *Renewable and Sustainable Energy Reviews*, 62, 92–97.
- REN21. (2023). *Renewables Global Status Report*. <https://www.ren21.net>
- Sari, D. P., & Wibowo, A. (2021). Pengaruh adopsi energi terbarukan terhadap pencapaian SDGs di Asia Tenggara. *Jurnal Energi dan Lingkungan*, 17(2), 88–96.
- Smith, J. D., & Johnson, A. B. (2019). *Introduction to Psychology*. Publisher.
- Williams, C. A., & Taylor, B. M. (2018). The impact of technology on education. Paper presented at *the Annual Conference on Educational Technology*, New York, NY.