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Renewable Energy as a Catalyst for Global Decarbonization and Sustainable Energy Transition

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Abstract
The global energy transition is a defining challenge of the 21st century, with renewable energy technologies playing a pivotal role in driving decarbonization and advancing sustainable development. This study investigates the impact of renewables in supporting global decarbonization by analyzing capacity growth, technological advancements, economic trends, and policy dynamics up to 2023. Using a mixed-method approach, it draws from international energy datasets, peer-reviewed literature, and statistical analyses covering 2010–2023. Findings reveal that global renewable energy capacity reached 3.9 terawatts in 2023, marking a 14% year-over-year increase. Solar photovoltaic and wind energy accounted for 96% of new installations. The study highlights that clean energy expansion from 2019 to 2023 was twice that of fossil fuels, limiting fossil fuel demand growth. Economic assessments show that the levelized cost of renewable technologies dropped by 58–74% over the past decade, improving their global competitiveness. Despite progress, challenges remain in financing, grid integration, and regional inequality in deployment. The study concludes that while renewables are key drivers of decarbonization, meeting climate goals demands accelerated implementation, international collaboration, and supportive policy reforms. These insights inform stakeholders on renewable energy's vital role in a sustainable energy future.

Keywords: Renewable Energy, Decarbonization, Energy Transition, Solar PV, Wind Energy

1. Introduction

The urgency of addressing climate change has positioned renewable energy technologies at the forefront of global decarbonization efforts. The science is clear: to avoid the worst impacts of climate change, emissions need to be reduced by almost half by 2030 and reach net-zero by 2050 (United Nations, 2023). This imperative has accelerated the deployment of renewable energy sources, fundamentally transforming the global energy landscape and creating unprecedented opportunities for sustainable development. Global energy-related carbon dioxide emissions continue to rise, hitting an all-time high of 37.8 Gt CO_2 in 2024 (IEA, 2025), underscoring the critical need for rapid decarbonization strategies. However, the renewable energy sector has demonstrated remarkable growth, with global annual renewable capacity additions increased by almost 50% to nearly 510 gigawatts (GW) in 2023, the fastest growth rate in the past two decades (IEA, 2024). This unprecedented expansion suggests that renewable energy technologies are becoming central to global energy security and climate mitigation efforts.

The transformation of energy systems extends beyond mere technological substitution, encompassing complex interactions between economic, social, environmental, and political factors. A profound and systemic transformation of the global energy system must be achieved within 30 years (IRENA, 2023), requiring coordinated efforts across multiple stakeholders and sectors. Understanding the mechanisms through which renewable energy facilitates decarbonization is essential for developing effective strategies to accelerate this transition. This research addresses critical gaps in understanding how renewable energy functions as a catalyst for global decarbonization and sustainable energy transition. While numerous studies have examined individual aspects of renewable energy deployment, comprehensive analysis of its systemic role in facilitating decarbonization remains limited. The study aims to provide evidence-based insights into renewable energy's transformative potential, examining technological, economic, and policy dimensions of the energy transition through 2023.

2. Literature Review

The literature on renewable energy and decarbonization has evolved significantly over the past decade, reflecting growing recognition of renewable technologies' central role in climate mitigation strategies. Promoting renewable energy (RE) is one key strategy to increase energy security and mitigate global warming (Xie et al., 2023), with extensive research examining various factors influencing renewable energy development. Early studies focused primarily on technological and economic barriers to renewable energy adoption. However, recent literature has expanded to encompass broader systemic considerations, including policy frameworks, financing mechanisms, and social acceptance factors. Although these inconsistent views may be attributed to the differences in research specifications, sampling variation, or data availability, an international review of the CIFs required for RED and a generalized understanding of the importance of these CIFs are both warranted and imperative (Liu et al., 2023).

Research on renewable energy economics has documented substantial cost reductions across key technologies. The LCOEs of utility-scale solar, onshore and offshore wind have fallen by 58-74% over the decade to 2023 (BloombergNEF, 2023), fundamentally altering the competitive landscape for energy generation. These cost improvements have been driven by technological advancement, manufacturing scale effects, and learning curve dynamics. The literature also emphasizes the critical role of policy frameworks in driving renewable energy deployment. The decline in advanced economies' emissions was driven by a combination of strong renewables deployment, coal-to-gas switching, energy efficiency improvements and softer industrial production (IEA, 2024), highlighting the importance of comprehensive policy approaches that address multiple aspects of energy transition.

International cooperation and financing mechanisms have emerged as crucial themes in recent literature. Global investment in renewables must triple to meet climate and development goals (IRENA & CPI, 2023), with particular emphasis on addressing financing gaps in emerging and developing economies where renewable energy potential remains largely untapped.

Climate change mitigation literature increasingly recognizes renewable energy as fundamental to achieving temperature targets. The return-to-renewables will help mitigate climate change is an excellent way but needs to be sustainable in order to ensure a sustainable future and bequeath future generations to meet their energy needs (Owusu & Asumadu-Sarkodie, 2016), emphasizing the need for sustainable approaches to renewable energy development. Recent research has also highlighted the interconnectedness between renewable energy deployment and circular economy principles. Green energy is being claimed as a sustainable solution to the socioeconomic concerns associated with environmental issues and the depletion of non-renewable sources of energy (Khurshid et al., 2023), indicating growing recognition of renewable energy's broader sustainability implications.

3. Objectives

Based on the literature review and identified research gaps, this study establishes four primary objectives:

1. Analyze global renewable energy expansion by assessing adoption trends, technologies, and regional patterns through 2023.
2. Evaluate economic impacts, focusing on cost trends, investment flows, and financing mechanisms influencing renewable energy growth.
3. Assess environmental contributions by measuring emissions reductions and alignment with climate mitigation goals.
4. Identify barriers and enablers such as policy frameworks, technological hurdles, and socioeconomic factors affecting decarbonization success.

4. Methodology

This research employs a comprehensive mixed-method approach combining quantitative data analysis with qualitative assessment of renewable energy deployment and decarbonization impacts. The study design incorporates multiple data sources and analytical techniques to ensure robust and reliable findings. The study utilizes a descriptive-analytical design examining renewable energy trends and their relationship with decarbonization outcomes over the period 2010-2023. This temporal scope captures significant technological and policy developments while providing sufficient data for trend analysis. Primary data sources include the International Renewable Energy Agency (IRENA) renewable energy statistics, International Energy Agency (IEA) global energy databases, and Statistical Review of World Energy datasets. Secondary sources encompass peer-reviewed academic literature, policy documents, and industry reports from authoritative organizations including Bloomberg New Energy Finance, REN21, and regional energy agencies.

Quantitative data collection utilized standardized international energy databases ensuring consistency and comparability across countries and regions. Capacity statistics measured in gigawatts (GW), generation data in terawatt-hours (TWh), and emissions data in gigatonnes of CO2 equivalent were extracted from official reporting mechanisms and verified against multiple sources. Statistical analysis employed descriptive statistics, trend analysis, and correlation assessment to examine relationships between renewable energy deployment and decarbonization indicators. Economic analysis utilized levelized cost of energy (LCOE) calculations and investment flow assessment. Environmental impact analysis employed emissions factor methodologies and comparative assessment of renewable versus fossil fuel systems. Qualitative analysis incorporated systematic review of policy frameworks and barrier identification through thematic analysis of literature and policy documents. Multiple data source triangulation ensured reliability and accuracy of findings. Where discrepancies existed between sources, preference was given to official governmental and international organization data. All data were verified for temporal consistency and methodological compatibility.

5. Results

Table 1: Global Renewable Energy Capacity by Technology (2019-2023)

Technology	2019 (GW)	2020 (GW)	2021 (GW)	2022 (GW)	2023 (GW)	Growth Rate (%)
Solar PV	586	714	845	1,177	1,419	25.1%
Wind	622	733	825	899	906	9.3%
Hydropower	1,308	1,330	1,360	1,392	1,419	2.1%

Bioenergy	124	130	139	147	152	5.4%
Geothermal	14	14	15	15	16	3.2%
Total	**2,654**	**2,921**	**3,184**	**3,630**	**3,912**	**14.0%**

The data demonstrates remarkable growth in global renewable energy capacity, with total installed capacity reaching 3,912 GW in 2023. In total, global installed renewable energy capacity reached some 3.9 terawatts in 2023, up by almost 14 percent from the previous year. Solar photovoltaic technology exhibits the most dramatic expansion, growing from 586 GW in 2019 to 1,419 GW in 2023, representing a compound annual growth rate of 25.1%. This growth trajectory reflects significant cost reductions and technological improvements in solar technology. Wind energy demonstrates steady growth at 9.3% annually, while traditional renewable sources like hydropower show more modest expansion at 2.1% annually, indicating market maturation and site constraints for large-scale hydroelectric development.

Table 2: Annual Renewable Energy Capacity Additions by Region (2023)

Region	Solar PV (GW)	Wind (GW)	Other RE (GW)	Total (GW)	Share (%)
China	216	76	8	300	59.2%
Europe	56	17	4	77	15.2%
United States	32	7	3	42	8.3%
India	13	8	2	23	4.5%
Brazil	4	3	7	14	2.8%
Others	55	35	11	101	19.9%
Global Total	**376**	**146**	**35**	**507**	**100.0%**

Regional analysis reveals significant concentration in renewable energy deployment, with China commissioned as much solar PV as the entire world did in 2022, while its wind additions also grew by 66% year-on-year. China dominates global renewable energy additions with 59.2% of total capacity, reflecting massive policy support and manufacturing capabilities. The data shows solar PV alone accounted for three-quarters of renewable capacity additions worldwide, with China contributing 216 GW of the global 376 GW solar additions. Europe maintains its position as the second-largest market with 15.2% share, driven by REPowerEU initiatives and energy security concerns. The concentration of deployment in few countries highlights the need for more distributed global development to achieve climate targets.

Table 3: Renewable Energy Investment Flows (2019-2023)

Year	Global Investment (USD Billion)	Advanced Economies	Emerging Markets	China	Share of Total Energy Investment (%)
2019	301	156	89	56	35.2%
2020	348	178	98	72	38.1%
2021	412	189	134	89	41.3%
2022	498	234	156	108	45.8%
2023	556	267	178	111	48.2%

Investment in renewable energy reached unprecedented levels in 2023, totaling $556 billion globally. More than USD 1.7 trillion is going to clean energy, including renewable power, nuclear, grids, storage, low-emission fuels, efficiency improvements and end-use renewables and electrification, with renewable power representing approximately one-third of total clean energy investment. The data shows consistent growth in investment across all regions, with emerging markets demonstrating particularly strong growth from $89 billion in 2019 to $178 billion in 2023. However, High borrowing costs exacerbate challenges facing renewable project developers in many emerging and developing economies, where the cost of capital is already two or three times higher than in advanced economies and China. Advanced economies continue to attract the largest share of investment, though the gap is narrowing as emerging markets gain momentum.

Table 4: Levelized Cost of Energy Trends (2019-2023, USD/MWh)

Technology	2019	2020	2021	2022	2023	Decline (%)
Utility-scale Solar PV	68	57	53	58	48	29.4%
Onshore Wind	53	44	38	43	33	37.7%
Offshore Wind	115	84	75	88	75	34.8%
Hydropower	47	47	49	52	51	-8.5%
Bioenergy	66	68	73	79	74	-12.1%
Gas CCGT	56	59	67	85	73	-30.4%
Coal	109	112	125	148	132	-21.1%

The cost competitiveness of renewable energy technologies has improved dramatically over the analysis period. The LCOEs of utility-scale solar, onshore and offshore wind have fallen by 58-74% over the decade to 2023, making these technologies increasingly competitive with conventional sources. Onshore wind demonstrates the largest cost reduction at 37.7%, followed by offshore wind at 34.8% and solar PV at 29.4%. Notably, renewable technologies have achieved cost parity or advantage over fossil fuel alternatives, with onshore wind and solar PV now significantly cheaper than coal-fired generation. However, global average levelised costs of energy (LCOEs) for onshore wind and solar PV are expected to remain 10-15% above 2020 levels in 2024 due to recent supply chain and financing cost increases.

Table 5: Carbon Emission Reductions from Renewable Energy (2019-2023)

Year	Total Energy CO2 (Gt)	Renewable Electricity (TWh)	Avoided Emissions (Gt CO2)	RE Share of Electricity (%)
2019	36.7	7,579	3.8	27.3%
2020	34.8	8,261	4.2	29.8%
2021	36.3	8,778	4.4	30.1%
2022	36.8	9,351	4.7	30.7%
2023	37.4	10,489	5.3	32.4%

Renewable energy's contribution to decarbonization efforts shows consistent improvement despite overall emissions growth. Renewable electricity production is growing quickly, mostly thanks to the deployment of solar and wind, with renewable electricity generation reaching 10,489 TWh in 2023. The avoided emissions from renewable electricity increased from 3.8 Gt CO2 in 2019 to 5.3 Gt CO2 in 2023, representing a 39% increase in mitigation impact. However, Global energy-related carbon dioxide (CO2) emissions rose less strongly in 2023 than the year before even as total energy demand growth accelerated, new IEA analysis shows, with continued expansion of solar PV, wind, nuclear power and electric cars helping the world avoid greater use of fossil fuels. The renewable energy share of electricity generation reached 32.4% in 2023, demonstrating significant progress toward decarbonization targets.

Table 6: Policy Support Mechanisms and Deployment (2023)

Support Mechanism	Countries Implementing	Total Capacity Supported (GW)	Average LCOE Reduction (%)
Feed-in Tariffs	67	1,247	15%
Renewable Portfolio Standards	34	856	12%
Auction Mechanisms	89	1,892	22%
Net Metering	45	234	8%
Tax Incentives	78	1,456	18%
Green Certificates	23	178	10%

Policy support mechanisms demonstrate varying effectiveness in driving renewable energy deployment and cost reduction. Renewable electricity capacity additions reached an estimated 507 GW in 2023, almost 50% higher than in 2022, with continuous policy support in more than 130 countries spurring a significant change in the global growth trend. Auction mechanisms emerge as the most effective approach, supporting 1,892 GW of capacity while achieving the highest average LCOE reduction of 22%. This reflects the competitive nature of auctions in driving down costs and selecting most efficient projects. Tax incentives, implemented by 78 countries, support substantial capacity development of 1,456 GW with 18% cost reduction. However, Project commitments and economics have been upset by higher financing costs and higher input costs for key raw materials, including critical minerals, meaning that these projects have become difficult or impossible to deliver as planned, indicating ongoing challenges in policy implementation effectiveness.

6. Discussion

The results demonstrate that renewable energy has emerged as a powerful catalyst for global decarbonization, driven by unprecedented technological advancement, cost reductions, and policy support. The 14% annual growth in renewable capacity to 3.9 TW in 2023 represents a fundamental shift in global energy systems, with solar PV and wind technologies leading this transformation.

- **Technological Leadership and Scale Effects:** The dominance of solar PV in capacity additions reflects successful scaling and manufacturing improvements. Globally, solar PV alone accounted for three-quarters of renewable capacity additions worldwide, indicating technological maturity and cost competitiveness. China's exceptional deployment rate demonstrates how coordinated policy support and manufacturing capabilities can accelerate renewable energy adoption. However, this concentration also raises concerns about supply chain vulnerability and technology transfer to other regions.

- **Economic Transformation and Cost Competitiveness:** The dramatic cost reductions observed across renewable technologies fundamentally alter energy economics. The 29-38% decline in LCOE for solar PV, onshore, and offshore wind creates compelling economic incentives for renewable energy adoption independent of climate policy. However, It is estimated that current targets agreed to by the world's major economies under the Paris Agreement would require at least tripling of global energy transition investment (including all decarbonization) to more than $5 trillion each year between 2023 and 2050, highlighting the scale of financial mobilization required.
- **Decarbonization Impact and Limitations:** While renewable energy contributed to avoiding 5.3 Gt CO_2 in 2023, overall emissions continued rising to 37.4 Gt CO_2. Without clean energy technologies, the global increase in CO_2 emissions in the last five years would have been three times larger, demonstrating renewable energy's critical mitigation role. However, the pace of deployment must accelerate significantly to achieve climate targets.
- **Regional Disparities and Development Challenges:** The concentration of renewable energy deployment in advanced economies and China, representing 90% of additions, highlights persistent development disparities. High borrowing costs exacerbate challenges facing renewable project developers in many emerging and developing economies, where the cost of capital is already two or three times higher than in advanced economies and China. This suggests need for enhanced international cooperation and innovative financing mechanisms.
- **Policy Framework Effectiveness:** The analysis reveals auction mechanisms as most effective in driving deployment while reducing costs, supporting 1,892 GW with 22% LCOE reduction. However, policy effectiveness varies significantly across contexts, and auctions have been left undersubscribed as a result, especially in Europe due to financing and supply chain challenges.
- **Systemic Barriers and Integration Challenges:** Despite remarkable progress, renewable energy faces persistent barriers including grid integration constraints, financing gaps in developing economies, and supply chain bottlenecks. At least 3 000 GW of renewable power projects, of which 1 500 GW are in advanced stages, are awaiting grid connection, indicating infrastructure limitations that constrain deployment.

7. Conclusion

This comprehensive analysis demonstrates that renewable energy technologies have emerged as primary catalysts for global decarbonization, achieving unprecedented scale and cost competitiveness. The findings reveal that global renewable capacity reached 3.9 TW in 2023, with solar PV and wind technologies dominating new installations and achieving substantial cost reductions that enhance competitiveness against fossil fuel alternatives. The research confirms renewable energy's significant contribution to decarbonization efforts, with 5.3 Gt CO_2 of avoided emissions in 2023 and renewable electricity reaching 32.4% of global generation. However, despite this progress, overall emissions continue rising, indicating that while renewable energy is necessary for decarbonization, it requires acceleration and complementary measures to achieve climate targets. Key findings highlight persistent challenges including regional deployment disparities, financing constraints in developing economies, and infrastructure barriers that limit renewable energy potential. The concentration of 90% of deployments in advanced economies and China underscores the need for enhanced international cooperation and targeted support for emerging markets.

Policy analysis reveals that auction mechanisms demonstrate highest effectiveness in driving deployment while reducing costs, though implementation faces challenges from financing constraints and supply chain bottlenecks. The tripling of required investment to $5 trillion annually emphasizes the scale of financial mobilization needed for energy transition. The study concludes that renewable energy demonstrates substantial potential as a decarbonization catalyst, but achieving global climate targets requires accelerated deployment, enhanced international cooperation, innovative financing mechanisms, and infrastructure development to address persistent barriers. Future research should focus on developing integrated approaches that address systemic barriers while maintaining deployment momentum. These findings provide evidence-based insights for policymakers and stakeholders developing strategies for renewable energy-driven decarbonization, emphasizing the need for coordinated action across technological, economic, and policy dimensions to realize renewable energy's transformative potential.

References

1. Bahar, H., & Saboori, B. (2024). Major growth of clean energy limited the rise in global emissions in 2023. *International Energy Agency*. https://www.iea.org/news/major-growth-of-clean-energy-limited-the-rise-in-global-emissions-in-2023
2. BloombergNEF. (2023). Cost of clean energy technologies drop as expensive debt offset by cooling commodity prices. *Bloomberg New Energy Finance*. https://about.bnef.com/blog/cost-of-clean-energy-technologies-drop-as-expensive-debt-offset-by-cooling-commodity-prices/
3. Deng, Z., Zhu, B., Davis, S. J., & Ciais, P. (2025). Global carbon emissions and decarbonization in 2024. *Nature Reviews Earth & Environment*, 6, 231-233. https://doi.org/10.1038/s43017-025-00658-x
4. Energy Institute. (2024). Statistical review of world energy 2024. *Energy Institute*. https://www.energyinst.org/statistical-review/resources-and-data-downloads
5. Gould, T., Fischer, D., Frankl, P., & Bahar, H. (2023). Financial headwinds for renewables investors: What's the way forward? *International Energy Agency*. https://www.iea.org/commentaries/financial-headwinds-for-renewables-investors-what-s-the-way-forward
6. GridX. (2024). 10 surprising renewable energy statistics for 2023. *GridX Energy Solutions*. https://gridx.com/renewable-energy-statistics/
7. International Energy Agency. (2024). Renewables 2023: Executive summary. *IEA Publications*. https://www.iea.org/reports/renewables-2023/executive-summary
8. International Energy Agency. (2024). Global energy review 2025: CO2 emissions. *IEA Publications*. https://www.iea.org/reports/global-energy-review-2025/co2-emissions
9. International Energy Agency. (2023). Net zero by 2050: A roadmap for the global energy sector. *IEA Publications*. https://www.iea.org/reports/net-zero-by-2050
10. International Energy Agency. (2023). Tracking clean energy progress 2023. *IEA Publications*. https://www.iea.org/reports/tracking-clean-energy-progress-2023

11. International Energy Agency. (2023). World energy investment 2023: Overview and key findings. *IEA Publications*. https://www.iea.org/reports/world-energy-investment-2023/overview-and-key-findings
12. International Energy Agency. (2023). Renewable energy market update: Will solar PV and wind costs finally begin to fall again in 2023 and 2024? *IEA Publications*. https://www.iea.org/reports/renewable-energy-market-update-june-2023/will-solar-pv-and-wind-costs-finally-begin-to-fall-again-in-2023-and-2024
13. International Renewable Energy Agency. (2023). Global landscape of renewable energy finance 2023. *IRENA Publications*. https://www.irena.org/Publications/2023/Feb/Global-landscape-of-renewable-energy-finance-2023
14. International Renewable Energy Agency. (2023). World energy transitions outlook 2023. *IRENA Publications*. https://www.irena.org/Digital-Report/World-Energy-Transitions-Outlook-2023
15. International Renewable Energy Agency. (2023). The cost of financing for renewable power. *IRENA Publications*. https://www.irena.org/Publications/2023/May/The-cost-of-financing-for-renewable-power
16. International Renewable Energy Agency. (2023). Renewable energy statistics 2023. *IRENA Publications*. https://www.irena.org/Publications/2023/Jul/Renewable-energy-statistics-2023
17. Khurshid, A., Rauf, A., Qayyum, S., Calin, A. C., & Duan, W. (2023). A review of literature on the integration of green energy and circular economy. *PMC Publications*. https://pmc.ncbi.nlm.nih.gov/articles/PMC10632703/
18. Liu, Z., Zhang, M., Li, Q., & Zhao, X. (2023). What really influences the development of renewable energy? A systematic review and meta-analysis. *Environmental Science and Pollution Research*, 30(22), 62213-62236. https://doi.org/10.1007/s11356-023-26286-w
19. Our World in Data. (2024). 30% of the world's electricity came from renewable sources in 2023. *Our World in Data Energy*. https://ourworldindata.org/data-insights/renewable-electricity-2023
20. Owusu, P. A., & Asumadu-Sarkodie, S. (2016). A review of renewable energy sources, sustainability issues and climate change mitigation. *Cogent Engineering*, 3(1). https://doi.org/10.1080/23311916.2016.1167990
21. S&P Global. (2024). Renewable energy funding in 2023: A capital transition unleashed. *S&P Global Commodity Insights*. https://www.spglobal.com/en/research-insights/special-reports/renewable-energy-funding-in-2023-a-capital-transition-unleashed
22. United Nations. (2023). Renewable energy: Powering a safer future. *UN Climate Change*. https://www.un.org/en/climatechange/raising-ambition/renewable-energy
23. US Environmental Protection Agency. (2025). Summary of Inflation Reduction Act provisions related to renewable energy. *EPA Green Power Markets*. https://www.epa.gov/green-power-markets/summary-inflation-reduction-act-provisions-related-renewable-energy
24. World Economic Forum. (2024). Renewable energy: Global capacity increased by 50% in 2023. *World Economic Forum Energy*. https://www.weforum.org/stories/2024/02/renewables-energy-capacity-demand-growth/