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GLOBAL ENERGY TRANSITION: AN ANALYSIS OF RENEWABLE ENERGY CONSUMPTION AND CO_2 EMISSION TRENDS

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ABSTRACT
The global energy system is undergoing a significant transition as countries strive to achieve sustainable economic growth while addressing climate change and reducing greenhouse gas emissions. Renewable energy has emerged as a key component of this transition, supported by technological advancements, declining costs, and increasing investments in clean energy infrastructure. This study examines the changing pattern of the global energy transition by analysing trends in the electricity generation mix, renewable energy consumption, clean energy investment, and carbon dioxide (CO_2) emissions. The study is based on secondary data collected from the Energy Institute Statistical Review of World Energy, the International Energy Agency (IEA), and other international energy reports. Descriptive statistics, percentage analysis, and trend analysis are employed to evaluate changes in global energy patterns over time. The findings reveal a gradual decline in the share of coal in electricity generation, accompanied by rapid growth in solar, wind, and bioenergy. Clean energy investment has increased substantially, reflecting the global commitment to achieving carbon neutrality and sustainable development. However, despite the rapid expansion of renewable energy, global CO_2 emissions remain high because of increasing energy demand and continued dependence on fossil fuels. The study concludes that accelerating renewable energy deployment, strengthening clean energy investment, and improving energy efficiency are essential to reducing carbon emissions and supporting the global transition towards a sustainable and low-carbon energy system.

KEYWORDS: *Global Energy Transition, Renewable Energy Consumption, Electricity Generation Mix, Clean Energy Investment, CO_2 Emissions, Sustainable Development, Climate Change.*

INTRODUCTION

The global energy sector is undergoing a profound transformation as countries seek to balance economic growth, energy security, and environmental sustainability. Rising energy demand, rapid industrialization, urbanization, and population growth have substantially increased the consumption of fossil fuels, making the energy sector the largest contributor to anthropogenic carbon dioxide (CO_2) emissions. The continued dependence on coal, oil, and natural gas has intensified concerns over climate change, global warming, air pollution, and environmental degradation. Consequently, accelerating the transition from fossil fuel-based energy systems to cleaner and renewable energy sources has become a central objective of international climate and energy policies.

Renewable energy technologies, including solar, wind, hydropower, and bioenergy, have experienced remarkable growth during the past two decades. Technological innovation, declining production costs, supportive government policies, and international commitments under the Paris Agreement have significantly expanded renewable energy deployment worldwide. Despite this progress, fossil fuels continue to dominate the global energy system, indicating that the transition towards a low-carbon economy remains incomplete. The pace of renewable energy adoption varies considerably across countries owing to differences in economic development, energy infrastructure, investment capacity, and policy frameworks.

Recent global energy statistics further highlight both the progress and the challenges of the ongoing energy transition. According to the International Energy Agency (IEA), global energy demand increased by **2.2% in 2024**, while global electricity demand grew by **4.3%**, nearly twice the average annual growth observed over the previous decade. The expansion of renewable energy and nuclear power accounted for more than **80% of the increase in global electricity generation**, with solar photovoltaic energy recording the fastest growth among all electricity generation technologies. Nevertheless, energy-related CO_2 emissions reached approximately **37.8 billion tonnes in 2024**, reflecting the continued influence of fossil fuel consumption and the growing demand for electricity across emerging and developing economies.

The global electricity generation mix is also changing steadily. Coal remains the largest source of electricity generation, although its share has gradually declined over time. At the same time, renewable energy has expanded rapidly, with solar and wind emerging as the fastest-growing sources of electricity generation. In 2024, renewable energy accounted for approximately one-third of global electricity generation, while renewable energy together with nuclear power contributed nearly two-fifths of total global electricity production, marking an important milestone in the global transition toward cleaner energy systems.

Investment patterns provide additional evidence of this structural transformation. Global investment in clean energy technologies has increased substantially and now exceeds investment in fossil fuels. The IEA estimates that worldwide investment in clean energy reached approximately **US$2 trillion in 2024**, nearly twice the amount invested in fossil fuel supply. This shift reflects growing confidence in renewable energy technologies and demonstrates increasing public and private commitment to achieving long-term climate and sustainable development goals.

Although numerous studies have examined the relationship between energy consumption and CO_2 emissions, relatively few have integrated recent global trends in the energy mix, renewable energy consumption, clean energy investment, and CO_2 emission patterns within a single analytical framework. Understanding these interconnected trends is essential for evaluating the progress of the global energy transition and identifying the challenges that remain in reducing carbon emissions.

Against this background, the present study analyses the changing global energy landscape by examining trends in electricity generation from different energy sources, renewable energy consumption, clean energy investment, and CO_2 emission patterns using recent international data. The study provides a comprehensive assessment of the ongoing global energy transition and discusses its implications for environmental sustainability and climate change mitigation. The findings contribute to the growing literature on energy economics by offering updated empirical evidence that can assist researchers, policymakers, and international organizations in designing effective strategies to accelerate the transition toward a low-carbon and sustainable energy future.

REVIEW OF LITERATURE

REN21 (2024) examined the global progress of renewable energy deployment and found that renewable energy capacity continued to expand rapidly due to technological advancements, supportive government policies, and declining costs. However, the report highlighted that fossil fuels still dominate the global energy system, making the pace of energy transition insufficient to achieve international climate targets. The study recommended accelerating renewable energy investments and strengthening policy support to facilitate a sustainable global energy transition.

International Energy Agency (2024), in the *World Energy Investment Report*, reported that global investment in clean energy exceeded investment in fossil fuels for the first time. The study found that annual clean energy investment reached nearly US$2 trillion, driven primarily by increased spending on renewable energy technologies, electricity grids, energy storage, and electric vehicles. The report emphasized that continued investment is essential to achieving net-zero emissions and ensuring long-term energy security.

Ember (2024) analysed global electricity generation and observed that renewable energy sources accounted for a record share of global electricity production. The report found that solar power experienced the fastest growth among all electricity generation technologies, while coal remained the single largest source of electricity generation. The study concluded that sustained growth in renewable electricity is essential for reducing global carbon emissions.

Ritchie, Hannah and Roser, Max (2023) examined long-term trends in global energy consumption and carbon emissions. Their analysis showed that renewable energy consumption has increased substantially during the last two decades; however, global CO_2 emissions continue to remain high because overall energy demand has increased simultaneously. The study emphasized that renewable energy expansion must be accompanied by improvements in energy efficiency and reductions in fossil fuel dependence.

Pata, Ugur Korkut (2023) investigated the relationship between renewable energy consumption and environmental quality. The study concluded that increasing renewable energy consumption significantly reduces carbon emissions in the long run while promoting sustainable economic development. It recommended expanding

renewable energy infrastructure and strengthening environmental policies to accelerate the transition toward a low-carbon economy.

Balsalobre-Lorente, Daniel et al. (2022) analysed the impact of renewable energy consumption, economic growth, and technological innovation on environmental sustainability. The study found that renewable energy contributes significantly to reducing CO_2 emissions, whereas excessive fossil fuel consumption increases environmental degradation. The authors emphasized that technological innovation and clean energy investment are critical drivers of sustainable development.

Nathaniel, Solomon P. and co-authors (2021) examined the relationship between energy consumption and carbon emissions across developing and developed economies. Their findings indicated that renewable energy consumption improves environmental quality, while fossil fuel dependence continues to increase carbon emissions. The study recommended enhancing international cooperation and increasing investment in renewable energy technologies.

Research Gap

The existing literature has extensively examined renewable energy consumption, energy transition, and carbon emissions. However, most previous studies have focused on individual countries or regional economies, with limited attention given to a comprehensive analysis of recent global trends in electricity generation, renewable energy consumption, clean energy investment, and CO_2 emissions within a single framework. Furthermore, rapid developments in renewable energy technologies and changing global investment patterns require updated empirical evidence. Therefore, the present study fills this gap by providing a comprehensive analysis of the global energy transition using recent international data, highlighting changes in the energy mix, renewable energy consumption, clean energy investment, and CO_2 emission trends.

Significance of the Study

The transition from fossil fuel-based energy systems to renewable energy has become one of the most important global priorities for achieving sustainable development and mitigating climate change. Understanding recent trends in renewable energy consumption, electricity generation, clean energy investment, and CO_2 emissions is essential for evaluating the effectiveness of current energy policies and identifying future challenges.

This study contributes to the existing literature by providing an updated and comprehensive assessment of the global energy transition using internationally recognized data sources. The findings offer valuable insights into the changing composition of the global electricity generation mix, the growth of renewable energy, and the relationship between energy transition and environmental sustainability.

The study is expected to benefit policymakers, researchers, energy planners, and environmental organizations by providing evidence that can support the formulation of effective renewable energy policies, encourage clean energy investment, and strengthen strategies for reducing greenhouse gas emissions. Furthermore, the findings may serve as a useful reference for future academic research on global energy transition, sustainable development, and climate change mitigation.

Objectives of the Study

1. To analyse the changing pattern of the global electricity generation mix.
2. To examine the trend in global renewable energy consumption.
3. To analyse global investment in clean energy and fossil fuel energy.
4. To examine the trend of global CO_2 emissions.
5. To discuss the implications of the global energy transition for environmental sustainability.

METHODOLOGY

Data Sources

This study is based entirely on secondary data obtained from internationally recognized and reliable sources. Data on the global electricity generation mix by energy source, renewable energy consumption, carbon dioxide (CO_2) emissions, and global energy investment were collected from the Energy Institute Statistical Review of World Energy (2024), the International Energy Agency (IEA), and the World Energy Investment Report. These databases provide comprehensive and internationally comparable information on global energy production, consumption, investment, and environmental indicators.

The study examines the changing pattern of the global electricity generation mix from 2002 to 2025, renewable energy consumption from 1965 to 2022, global clean energy investment, and trends in global CO_2 emissions over the study period.

Analytical Framework

The study adopts a **descriptive and trend analysis** approach to examine the ongoing global energy transition. Descriptive statistical techniques were used to summarize and present the data through tables and graphical illustrations. Trend analysis was employed to identify long-term changes in the composition of the global energy mix, renewable energy consumption, clean energy investment, and CO_2 emission patterns.

The analysis focuses on the changing contribution of major energy sources, including coal, natural gas, nuclear energy, hydropower, solar energy, wind energy, bioenergy, oil, and other renewable sources. Particular attention is given to the growth of renewable energy and the gradual transition from fossil fuel-based energy systems toward cleaner and more sustainable energy sources. Furthermore, the study compares trends in clean energy investment and fossil fuel investment to assess the direction of global energy financing. Changes in renewable energy consumption are also analysed to evaluate their contribution to the global energy transition and their implications for environmental sustainability. The trend in global CO_2 emissions is examined to understand whether the expansion of renewable energy has contributed to reducing carbon emissions.

The findings are interpreted in the context of global climate change mitigation, sustainable development, and international energy transition initiatives. The descriptive approach adopted in this study provides a comprehensive understanding of recent developments in the global energy sector and offers valuable insights for policymakers, researchers, and energy planners.

(Trend Analysis)

Table 1.Energy Sources In The World (Percentage)

Year	Coal	Gas	Nuclear	Hydro	Solar	Wind	Bioenergy	Other Renewables	Oil	Total
2002	38.51	19.52	16.54	16.53	0.01	7.22	0.33	0.99	0.34	100
2003	39.68	19.67	15.82	15.97	0.01	7.09	0.39	1.03	0.34	100
2004	39.18	20.16	15.69	16.36	0.02	6.67	0.50	1.08	0.34	100
2005	39.66	20.38	15.13	16.30	0.02	6.43	0.58	1.17	0.33	100
2006	40.29	20.77	14.73	16.25	0.03	5.68	0.72	1.20	0.33	100
2007	41.00	21.43	13.78	15.74	0.04	5.55	0.88	1.26	0.32	100
2008	40.35	21.63	13.51	16.44	0.06	5.24	1.12	1.32	0.34	100
2009	39.99	21.92	13.39	16.51	0.10	4.89	1.41	1.44	0.35	100
2010	39.95	22.70	12.83	16.30	0.15	4.55	1.65	1.55	0.33	100
2011	40.73	22.24	11.89	16.07	0.29	4.84	2.03	1.59	0.32	100
2012	39.97	22.97	10.84	16.44	0.43	4.96	2.39	1.68	0.32	100
2013	40.83	21.87	10.60	16.56	0.58	4.66	2.81	1.78	0.32	100
2014	40.57	21.94	10.56	16.50	0.84	4.31	3.06	1.89	0.33	100
2015	38.74	23.09	10.58	16.36	1.08	4.28	3.50	2.03	0.34	100
2016	37.99	23.49	10.46	16.45	1.35	3.95	3.95	2.01	0.35	100
2017	38.05	23.28	10.25	16.20	1.78	3.49	4.54	2.07	0.35	100
2018	38.05	23.26	10.07	16.04	2.19	3.07	4.86	2.11	0.35	100
2019	36.73	23.55	10.33	16.01	2.66	2.80	5.38	2.19	0.35	100
2020	35.39	23.42	10.03	16.52	3.24	2.70	6.04	2.30	0.36	100
2021	36.26	22.79	9.85	15.22	3.74	2.75	6.65	2.40	0.34	100
2022	35.80	22.60	9.20	14.90	4.50	3.10	6.80	2.70	0.40	100
2023	35.40	22.20	9.10	14.30	5.60	3.40	6.90	2.70	0.40	100
2024*	35.00	22.00	9.00	14.00	6.80	3.80	6.90	2.20	0.30	100
2025*	34.50	21.80	9.00	13.80	7.50	4.10	6.90	2.10	0.30	100

Source : BP energy outlook

The table shows the changing pattern of global electricity generation by source from **2002 to 2025**. Coal remained the dominant source of electricity generation throughout the period, although its share gradually declined from **38.51% in 2002** to around **34.50% in 2025**. The share of natural gas remained relatively stable at around **22–23%**, while nuclear energy declined from **16.54%** to about **9.00%**. Hydropower also experienced a slight decrease over the study period. In contrast, renewable energy sources such as **solar, wind, and bioenergy** recorded significant growth. Solar energy increased from **0.01% in 2002** to **7.50% in 2025**, while bioenergy and

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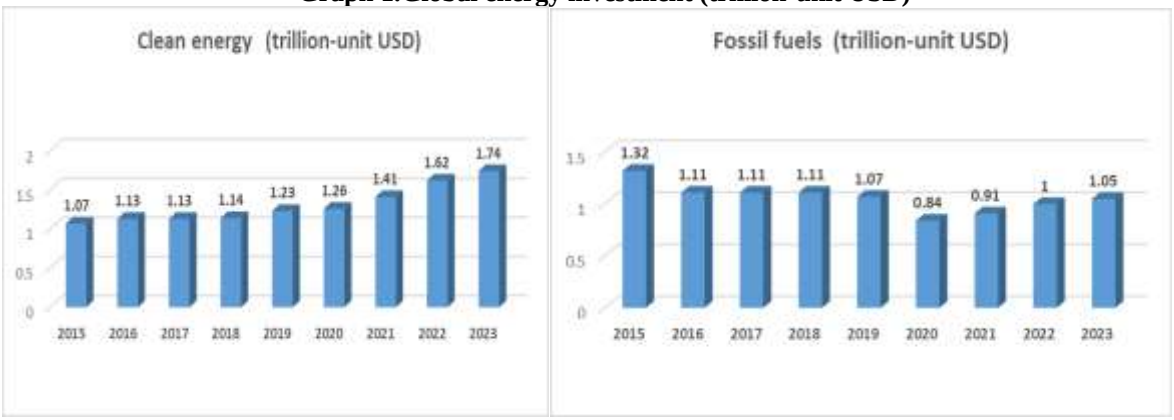
wind also expanded steadily. Oil contributed only a very small share throughout the period. Overall, the data indicate a gradual global transition from conventional fossil fuels toward cleaner and renewable energy sources, reflecting increasing emphasis on sustainability, technological advancement, and climate change mitigation.

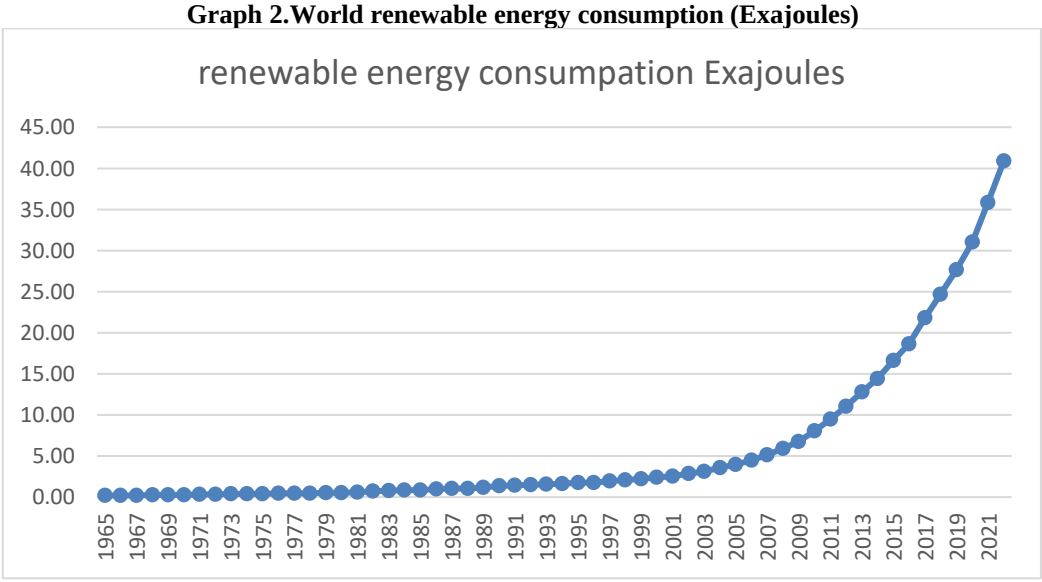
Graph 1.Global energy investment (trillion-unit USD)



Sources : IEA international energy agency and World energy Investment

As we can see the above the tables represent the investment on fossil fuel and clean energy source year wise in the world. The clean energy investment shows a generally increasing trend, with the highest Annual Average Growth Rate (AAGR) in 2022 (14.8%). The compound annual growth rate (CAGR) for clean energy is positive (6.22%), indicating a steady increase over the period. Then Fossil fuels investment has varied, with a notable decrease in 2016 (-16.2%) and a subsequent recovery The AAGR for fossil fuels has been negative overall, indicating a declining trend, except for a growth in 2021 and 2022. The CAGR for fossil fuels is negative (-2.81%), suggesting an overall decline in investment This table suggests a shift towards cleaner energy sources and a declining trend in fossil fuel investment, aligning with global efforts to transition towards more sustainable energy systems. The positive CAGR for clean energy indicates a consistent growth pattern, while the negative CAGR for fossil fuels signals a reduction in their relative share in the energy mix.

Graph 2.World renewable energy consumption (Exajoules)



Source : BP Energy Outlook

The graph illustrates the global consumption of renewable energy, measured in exajoules, from 1965 to 2022. The trend shows a slow and nearly flat increase in renewable energy consumption from 1965 until the early 2000s. During this period, renewable energy's contribution to the global energy mix was relatively minimal, reflecting the dominance of fossil fuels and limited investment in renewable technologies. However, from the mid-2000s onwards, there is a noticeable upward trajectory in renewable energy consumption. This growth accelerates significantly after 2010, indicating the global shift towards renewable energy sources like wind, solar, and bioenergy, driven by increasing environmental concerns, technological advancements, and supportive government

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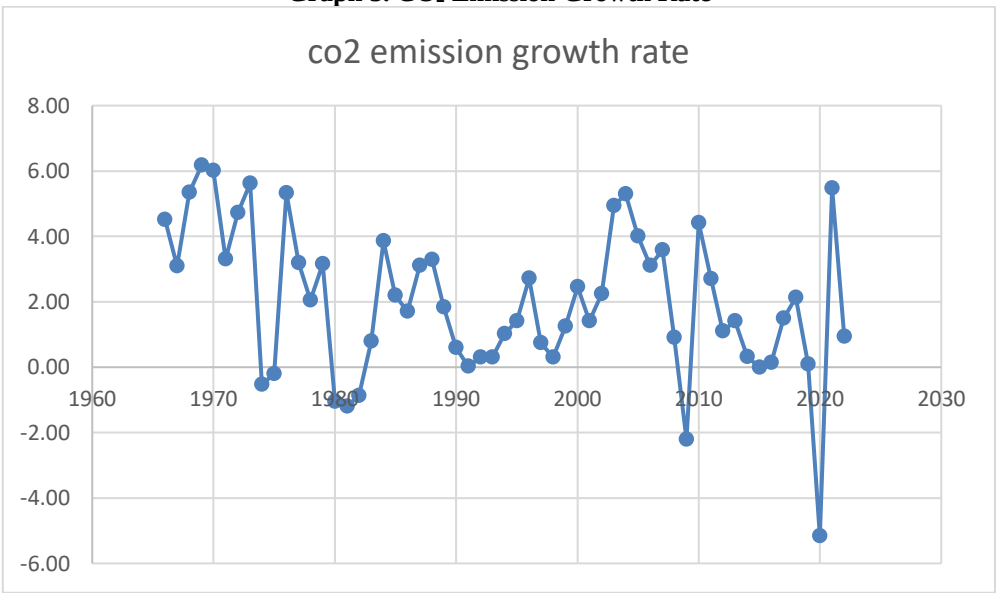
policies. The most dramatic surge is observed after 2015, with renewable energy consumption skyrocketing, almost doubling between 2015 and 2022. By 2022, renewable energy consumption exceeds 40 exajoules, marking a sharp rise compared to the previous decades. This reflects the global energy transition away from fossil fuels, as countries ramp up efforts to combat climate change and meet international sustainability targets. The steep curve in recent years underscores the rapid adoption and scaling of renewable energy technologies across the world.

Graph 3. CO_2 Emission Growth Rate



Source : BP energy outlook

The graph depicts the growth rate of CO2 emissions from 1960 to 2030, highlighting significant fluctuations in emission trends over the years. In the 1960s and early 1970s, the growth rate of CO2 emissions was relatively high, peaking at over 6%, driven by rapid industrial expansion. However, this trend saw a sharp decline in the mid-1970s, dipping into negative growth, likely due to the global oil crisis and economic slowdown during that period.

From the late 1970s through the 1990s, the growth rate remained volatile, with periods of moderate increases and declines. This era reflects global economic transitions, technological advancements, and environmental policies beginning to take shape. The early 2000s saw another surge in CO2 emission growth, driven by industrialization and increased energy demand, especially in developing nations. A significant dip is observed around 2008, coinciding with the global financial crisis, which temporarily reduced emissions due to slower economic activity. In the 2010s, the CO2 growth rate showed heightened volatility, with sharp increases and decreases. Around 2020, the growth rate dropped dramatically, reaching its lowest point, likely as a result of the COVID-19 pandemic and the ensuing global lockdowns that curtailed industrial activity and transportation. Post-2020, a strong rebound is observed, but with continued fluctuations, indicating ongoing uncertainty as nations navigate economic recovery while addressing environmental challenges. The period from 2020 to 2030 suggests an unstable trajectory, reflecting the balance between economic growth and sustainability efforts.

MAJOR FINDINGS

The major findings of the study are as follows:

1. The global electricity generation mix has undergone a gradual transformation over the study period, with renewable energy sources gaining a larger share while the dependence on fossil fuels has slowly declined.
2. Coal continues to be the largest source of global electricity generation; however, its contribution has shown a gradual decline due to increasing environmental concerns and the expansion of renewable energy technologies.
3. Renewable energy sources, particularly solar, wind, and bioenergy, have experienced remarkable growth during the study period, reflecting technological advancements, declining production costs, and supportive government policies.

4. Global renewable energy consumption has increased significantly over the past decades, indicating continuous progress toward a cleaner and more sustainable energy system.
5. Investment in clean energy has increased substantially and now exceeds investment in fossil fuel energy in many parts of the world, demonstrating the growing global commitment to low-carbon development.
6. Despite the rapid expansion of renewable energy, global CO_2 emissions remain at high levels because of increasing energy demand, industrialization, and continued dependence on fossil fuels.
7. The study indicates that renewable energy alone is insufficient to achieve significant emission reductions unless accompanied by improvements in energy efficiency, technological innovation, and effective environmental policies.
8. The findings highlight that accelerating the global energy transition is essential for achieving sustainable development and international climate goals.

SUGGESTIONS

Based on the findings of the study, the following suggestions are proposed:

1. Governments should strengthen policies that promote renewable energy generation through financial incentives, subsidies, and supportive regulatory frameworks.
2. Greater investment should be directed towards solar, wind, hydropower, bioenergy, and energy storage technologies to accelerate the transition to a low-carbon energy system.
3. Countries should gradually reduce dependence on coal and other high-carbon fossil fuels by promoting cleaner and more sustainable energy alternatives.
4. Public and private investment in clean energy infrastructure, electricity transmission networks, and smart grid technologies should be increased.
5. International cooperation should be strengthened to facilitate technology transfer, climate finance, and renewable energy development, particularly in developing countries.
6. Governments should encourage energy efficiency measures across industrial, commercial, and residential sectors to reduce overall energy consumption and carbon emissions.
7. Research and innovation in renewable energy technologies should receive greater financial support to improve efficiency and reduce production costs.
8. Policymakers should adopt integrated energy and environmental policies that balance economic development with climate change mitigation and environmental sustainability.
9. Public awareness programmes should be expanded to encourage the adoption of renewable energy technologies and sustainable energy consumption practices.
10. Continuous monitoring of global energy transition indicators should be undertaken to evaluate progress towards achieving the Sustainable Development Goals (SDGs) and net-zero emission targets.

CONCLUSION

The global energy transition represents one of the most significant structural changes in the modern energy sector. The findings of this study demonstrate that renewable energy has expanded considerably over the past two decades, supported by technological innovation, declining costs, increasing clean energy investment, and favourable policy initiatives. Solar and wind energy have emerged as the fastest-growing renewable energy sources, while the share of coal in electricity generation has gradually declined.

Despite these positive developments, fossil fuels continue to dominate the global energy system, resulting in persistently high levels of carbon dioxide emissions. The increasing global demand for energy has offset many of the environmental benefits associated with renewable energy expansion. Consequently, achieving international climate objectives will require not only accelerated deployment of renewable energy but also significant improvements in energy efficiency, technological innovation, and effective climate policies.

Overall, the study concludes that the global transition toward sustainable energy is progressing steadily but remains insufficient to achieve long-term carbon neutrality goals. Continued investment in clean energy, strengthened international cooperation, and comprehensive policy reforms will be essential to reducing greenhouse gas emissions and ensuring a secure, sustainable, and environmentally resilient global energy future.

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