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The Role of Renewable Energy in Driving Economic Transformation and Sustainable Development in Saudi Arabia

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ABSTRACT

This study explores the impact of renewable energy on economic transformation and sustainable development. A comprehensive literature review was conducted using the Scopus database, focusing on articles, reviews, and book chapters published between 2014 and 2023. The search employed keywords such as “renewable energy,” “development,” “economy,” and “sustainable development,” with filters applied for language, subject area, geography, and document type. The analysis reveals that adopting renewable energy reduces ecological footprints and greenhouse gas emissions, promoting environmental sustainability. Specific renewable energy sources, particularly wind energy, are identified as effective catalysts for sustainable economic development. The study highlights the role of renewable energy consumption in supporting economic growth, tourism, and GDP growth. The significance of hydrogen as a clean energy carrier, along with its production from renewable sources, is also emphasized. The findings underscore the crucial role of renewable energy technologies in driving economic transformation and sustainable development by enhancing environmental sustainability, stimulating economic growth, creating employment opportunities, and facilitating the transition to a low-carbon economy. However, challenges persist, requiring supportive policies, financial inclusion, and technological advancements to optimize the benefits of renewable energy adoption. Future research should expand geographical coverage, improve data quality, standardize methodologies, explore socio-political dimensions, assess distributional impacts, and promote interdisciplinary collaboration to effectively address the complex challenges associated with renewable energy and economic development.

Keywords: Renewable Energy, Economic Transformation, Sustainable Development, Environmental Sustainability, Low-Carbon Economy

JEL Classifications: Q01, Q42, O44, Q56, F21

1. INTRODUCTION

In recent years, renewable energy has been more important in driving economic change and promoting sustainable development in recent years (Fang et al., 2022). Amid increasing worries about addressing climate change and achieving the United Nations' Sustainable Development Goals (SDGs), the adoption and use of renewable energy technology have become very important (Madurai Elavarasan et al., 2021). According to (Li et al., 2023), the impact of renewable energy on several aspects of economic growth and environmental sustainability provides useful insights into the possible benefits and challenges associated with this

transformation. Studies undertaken in several countries, including MINT nations (Mexico, Indonesia, Nigeria, and Turkey), BRICS countries (Brazil, Russia, India, China, and South Africa), and Saudi Arabia, have repeatedly shown the beneficial effects of shifting to renewable energy sources. The research conducted by (Adebayo et al., 2023; Ibrahim et al., 2022; Kahouli et al., 2022; Manigandan et al., 2022) emphasise the capacity of renewable energy to decrease greenhouse gas emissions and improve environmental sustainability.

Traditionally, plans for economic expansion have mainly depended on fossil fuels, resulting in negative ecological repercussions

(Yang et al., 2021). However, recently, the adoption and use of renewable energy technologies have emerged as crucial drivers for economic transformation (Gielen et al., 2019). As countries worldwide strive to reduce their reliance on fossil fuels and address the issues posed by climate change, the shift towards renewable energy sources has gained increased importance (Olabi and Abdelkareem, 2022). Numerous investigations have delved into the impact of renewable energy on various dimensions of economic advancement. Research findings consistently demonstrate that the adoption of renewable energy contributes to bolstering economic development and fostering international sustainable development across a spectrum of nations, encompassing both developed and developing economies (Rehman Khan et al., 2023; Dar et al., 2022).

Moreover, renewable energy sources play a crucial role in promoting sustainable development by addressing environmental, social, and economic challenges (Zafar et al., 2020). Prior research indicates that adopting renewable energy technologies such as solar, wind, and hydropower has positive benefits on environmental sustainability (Rahman et al., 2022). This is primarily achieved by reducing greenhouse gas emissions and mitigating the impacts of climate change (Ogbolumani and Nwulu, 2024). According to (Baloch et al., 2022), the use of renewable energy has the capacity to improve the quality of life for millions of people, particularly in developing countries, by providing them with clean and inexpensive electricity. Furthermore, the transition to renewable energy sources has the potential to drive economic expansion and provide new job opportunities (Sarwar, 2022). This transformation promotes investment, creativity, and the rise of new enterprises focused on the development and implementation of renewable energy technology (Dar et al., 2022). However, to harness the full potential of renewable energy for sustainable development, it is imperative to address the challenges associated with integrating them into existing energy systems. This entails establishing appropriate policies and regulations to facilitate the growth of the renewable energy sector.

The primary aim of this research is to investigate the impact of renewable energy on driving economic transformation and fostering sustainable development. The article aims to explore how the uptake and use of renewable energy technology may enhance economic development and promote environmental sustainability.

1. How can renewable energy technologies contribute to economic transformation by encouraging economic development and boosting industrial advancement?
2. How do renewable energy sources help achieve SDGs such as providing affordable and clean energy, promoting economic growth and decent work, and advancing environmental sustainability?

2. RESEARCH METHODOLOGY

In February 2024, we extensively searched the Scopus database to find academic papers, reviews, and book chapters related to renewable energy production and its economic consequences. The search focused on items released from 2014 to 2023. We narrowed down our search to English language papers by using specific keywords like “renewable energy,” “development,”

and “economy” AND “Sustainable development”. We refined our emphasis by using filters related to topic areas such as Environmental Sciences, Energy, Engineering, Social Sciences, Economics/Econometrics/Finance, and Business/Management/Accounting. We focused on Saudi Arabia geographically. We focused on articles and reviews that were in the final stage of publication. The search approach originally found 6415 documents. The materials were screened according to predetermined criteria to evaluate their relevance to the subjects of renewable energy and economic issues. We examined the whole texts of the studies and selected 62 that fulfilled our specific inclusion and exclusion criteria for our analysis.

We retrieved relevant information from the chosen studies using a standardised method. We were able to gather data on the technique used, geographic scope, factors examined, and results concerning several facets of renewable energy implementation. The issues considered were the accompanying costs and benefits, together with the implications on economic growth. We categorised the research based on their analytical methodologies and geographical locations due to their variety. We were able to evaluate data methodically by categorising it and then synthesise conclusions across many dimensions using a narrative approach. The components included variables affecting the adoption of renewable energy, policy efficacy, costs and benefits of renewable energy projects, and the overall economic impacts of expanding renewable energy sources. Figure 1 below illustrate the inclusion and exclusion criteria of PRISMA statement 2020.

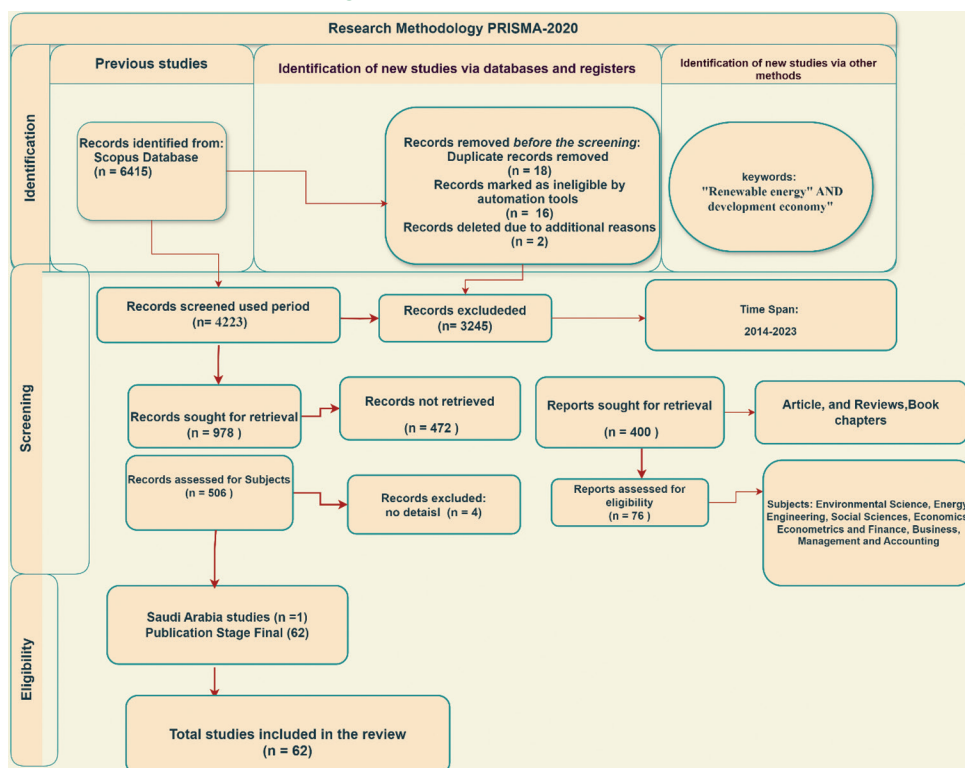
3. DESCRIPTIVE

The Table 1 summarises the bibliometric data for the research on renewable energy’s influence on economic transformation and sustainable development. The collection contains 62 papers from 27 journals, books, and other publications from 2014 to 2023. The research subject has grown in interest at 44.22%/year during the

Table 1: Main information

Description	Results
Main information about data	
Timespan	2014:2023
Sources (Journals, Books, etc.)	27
Documents	62
Annual growth rate %	44.22
Document average age	2.81
Average citations per doc	49.79
References	4121
Document contents	
Keywords Plus (ID)	518
Author’s Keywords (DE)	236
Authors	
Authors	3
Authors of single-authored docs	0
Authors collaboration	
Single-authored docs	0
Co-Authors per Doc	3
International co-authorships %	50
Document types	
Article	59
Review	3

Figure 1: PRISMA statement 2020



given timeframe. Documents average 2.81 years old, suggesting that majority of the research is recent. The research has a high average citation count of 49.79/document, indicating its academic impact. The materials include 4,121 references, suggesting a strong literature base.

The database (Keywords Plus) allotted 518 keywords and the writers contributed 236. This multidisciplinary study covers renewable energy, economic transformation, and sustainable development using a variety of concepts. All papers have several authors, with an average of 3 co-authors, indicating a cooperative research strategy. Half of the papers had international co-authorships, indicating a global perspective and teamwork on the research goal. Most of the publications (59) are articles, while 3 are reviews. This distribution prioritises original research and empirical evidence, with fewer articles providing full field descriptions. The Table 1 shows a fast-growing study topic based on bibliometric data. The study focuses on collaborative, multinational investigations to understand the complex relationships between renewable energy, economic change, and sustainable development.

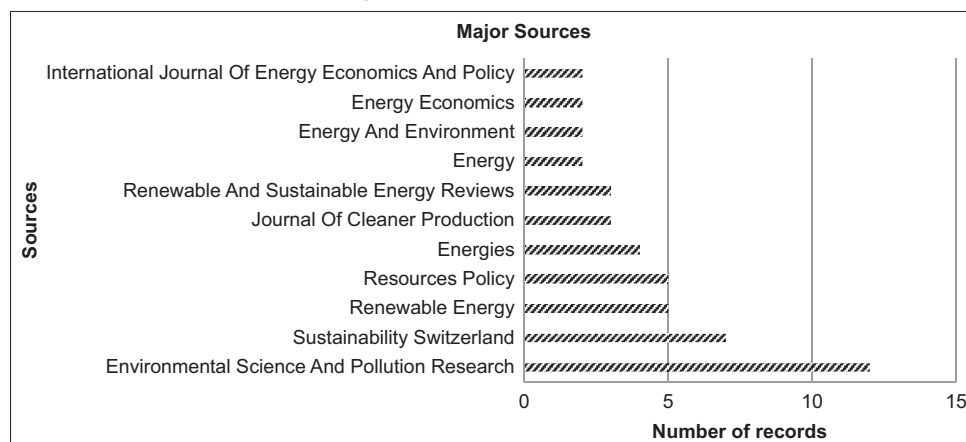
In addition, Figure 2 displays a ranking of the leading sources (journals) that have published papers pertaining to the study purpose of examining the impact of renewable energy on promoting economic transformation and sustainable development. The journal "Environmental Science and Pollution Research" has the highest number of articles, with a total of 12. It is followed by the journal "Sustainability Switzerland," which has 7 articles. The journals "Renewable Energy" and "Resources Policy" have each contributed 5 papers, while the journal "Energies" has published 4 articles. The journals "Journal of Cleaner Production" and "Renewable and Sustainable Energy Reviews" have both published a total of 3 papers apiece. Four more sources, namely

"Energy," "Energy and Environment," "Energy Economics," and "International Journal of Energy Economics and Policy," have each provided two articles to the dataset.

The diversity of sources emphasises the interdisciplinary character of the study goal, including environmental science, sustainability, energy technology, policy, and economics. The fluctuating quantity of articles produced by each site indicates varied degrees of attention and specialisation. The picture offers valuable insights into the primary factors that propel research on renewable energy, economic change, and sustainable development. It highlights the intricate and interrelated issues involved with this subject.

Furthermore, Figure 3 illustrates a bar graph depicting the yearly output of research-related papers from 2014 to 2023. The salient characteristic is the substantial surge of publications published in 2023, totaling 27 articles, which indicates a growing interest in the subject matter. In the previous years, there has been a reasonably stable level of output, with little growth seen in recent years. In 2022, there were a total of 12 articles, while in 2021 and 2020, there were 5 articles each. In 2017, there were 5 articles, which is more than the years before and after. In 2016, there were two articles, whereas in 2014, there was just one piece.

Figure 3 depicts a consistent and noticeable increase in the quantity of published papers throughout time, with a particularly significant surge in 2023. This phenomenon may be ascribed to several causes, including the pressing need to address climate change, the decreasing costs associated with renewable energy technology, and the worldwide effort to transition to a low-carbon economy. The rising volume of research indicates a growing acknowledgement of the significance of renewable

Figure 2: Most relevant sources

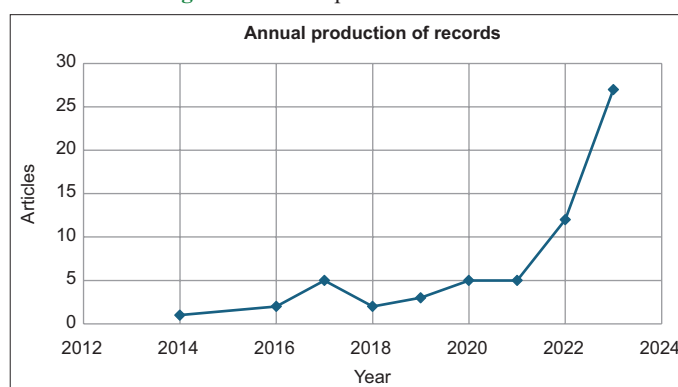
energy in propelling economic change and promoting sustainable development.

4. RESULTS

The study used scientific mapping techniques to precisely identify, depict, and outline the conceptual framework and content of material about renewable energy and development economy, as found in research publications investigating the relationship between social media and body image from 2019 to 2023. This programme is the first attempt to use bibliometric science mapping methods to analyse the intricacies of body image across genders in the field of social media studies. Our results are likely to attract researchers who are interested in gaining a thorough grasp of the study environment related to social media and body image. We used VOS viewer software to graphically show the occurrences of main key phrases across writers for analysis of the data. This method allowed us to analyse the recurring themes and main subjects included in the literature, leading to a better comprehension of the connections and developments in renewable energies (Andersen and Swami, 2021; Al Husaeni et al., 2023; Qureshi and Khan, 2022). In addition to this for the themes identification we utilise the RStudio biblioshiny technique (Jiaqing et al., 2023).

In addition, the table presents a co-word network analysis of significant phrases and their interactions in the research objective of investigating the impact of renewable energy on economic transformation and sustainable development. The study employs the metrics of betweenness, closeness, and PageRank. The term “sustainable development” has the highest betweenness centrality (175.719), indicating its significant role in connecting different fields of network study. A betweenness centrality value of 146.154 suggests that the concept of “economic development” has a crucial role in connecting various study aims. Additionally, “economic development” (79.269), “alternative energy” (52.436), and “carbon dioxide” (33.722) are also noteworthy in terms of betweenness centrality. These terms highlight the interconnections between the research aim and its economic, environmental, and energy aspects.

The closeness centrality measures the proximity of a phrase to all other terms in the network. The highest proximity centrality scores

Figure 3: Annual production of articles

are seen for the terms “sustainable development” (0.019), “economic development” (0.018), and “economic growth” (0.017), indicating their utmost relevance and strong connections to other research topics. Page Rank is a centrality statistic that ranks ideas based on the amount and quality of links. The PageRank scores of “sustainable developments” (0.071), “economic development” (0.056), and “economic growth” (0.048) are the highest, indicating their significant relevance in the research network. In addition, the terms “carbon dioxide,” “carbon emission,” “environmental protection,” and “energy consumption” highlight the environmental focus of the research aim, particularly the importance of renewable energy in addressing climate change and promoting sustainability. Additional terms such as “investments,” “finance,” and “policy making” highlight the economic and policy impacts of renewable energy deployment on economic transformation and sustainable development.

The co-word network analysis reveals that the research objective is centred on sustainable development, economic development, and economic growth. Furthermore, it emphasises the interconnectedness of environmental, energy, and economic elements, as well as the significance of investments, finance, and policy in achieving SDGs and transitioning to renewable energy. Table 2 and Figure 4 illustrate the key term occurrences.

Furthermore, the co-occurrence network in Figure 4 represents the fundamental ideas and their interconnections in the research objective of investigating the impact of renewable energy on economic transformation and sustainable development. The

network consists of nodes that represent words and edges that represent the co-occurrence of these words in examined texts. The primary focus of the network is “sustainable development,” emphasising its significance and strong connections to other areas of research. The nodes “economic and social effects,” “economic growth,” “alternative energy,” and “economics” are intricately linked to “sustainable development,” highlighting their interconnectedness in the study’s objective.

Additional noteworthy groupings of nodes consist of renewable energy sources (“renewable energy resources,” “renewable energy consumption”), environmental factors (“carbon dioxide emission,” “environmental protection”), investment and policy (“investments,” “energy policy”), and specific geographical emphasis (“Pakistan,” “Malaysia,” “middle east”). The network also connects “energy use,” “energy efficiency,” and “sustainable economic development,” highlighting the

significance of energy in promoting sustainability. Terms such as “panel data” and “regression analysis” provide econometric techniques for examining the relationship between renewable energy and economic development. The co-occurrence network graphically highlights the major elements of the research aim and their interactions. The interconnections between sustainable development and economic, social, and environmental factors, as well as renewable energy, policy, and investment, are essential for achieving a more sustainable future.

Renewables energise and economic transformation.

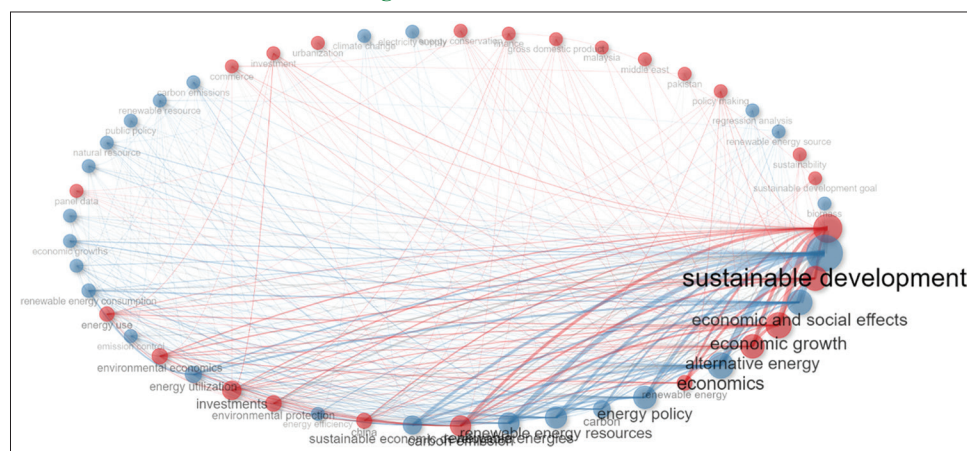
Nations are progressively prioritising the use of renewable energy technology to achieve sustainable economic development and reduce the negative environmental impacts of traditional fossil fuel energy systems (Sueyoshi et al., 2022). Extensive research has shown the capacity of renewable energy to boost economic development, encourage investments, provide job opportunities, and reduce carbon emissions (Sen and Ganguly, 2017). Collectively, several studies highlight the positive impact of renewable energy technology on economic change (Berka and Creamer, 2018). In addition, (Danish et al., 2020) noted a decrease in the ecological footprint linked to the use of renewable energy in BRICS nations, indicating a positive effect on environmental quality and the advancement of sustainable development objectives. Similarly, (Manigandan et al., 2022) highlight the need of using renewable energy sources to improve environmental well-being by reducing emission levels in BRICS nations. The findings suggest that shifting towards renewable energy has the potential to separate economic growth from environmental harm, thereby aiding in achieving SDGs.

Furthermore, several investigations have shown the capacity of renewable energy to support low-carbon economies and enable long-term sustainable development. According to (Zeqiraj et al., 2020) a direct correlation between the use and generation of renewable energy, which contributes to the development of a low-carbon economy in nations in the long run. Also, (Yue et al., 2022) saw renewable energy sources as a viable way to decrease global carbon emissions and promote long-term sustainable development. The results emphasize the crucial significance of renewable

Table 2: Key term occurrences

Term	Betweenness	Closeness	Pagerank
Economic development	146.154	0.018	0.056
Carbon dioxide	33.722	0.016	0.042
Economic growth	79.269	0.017	0.048
Alternative energy	52.436	0.017	0.043
Renewable energy	3.569	0.013	0.022
Carbon emission	14.13	0.015	0.034
China	4.301	0.014	0.022
Environmental protection	4.543	0.014	0.023
Investments	19.125	0.016	0.031
Environmental economics	2.744	0.013	0.021
Energy use	4.198	0.014	0.022
Panel data	0.565	0.012	0.011
Commerce	0.635	0.012	0.012
Investment	0.042	0.012	0.012
Urbanization	0	0.01	0.004
Energy conservation	0.043	0.011	0.007
Finance	1.486	0.013	0.013
Gross domestic product	0.015	0.011	0.008
Malaysia	0	0.01	0.004
Middle east	0	0.01	0.004
Policy making	0	0.012	0.011
Sustainability	0	0.011	0.005
Sustainable development goal	0	0.011	0.006
Sustainable development	175.719	0.019	0.071

Figure 4: Thematic clusters



energy in helping nations shift towards more environmentally friendly economies and achieving SDGs. In addition, financial development and investments are crucial for promoting the use of renewable energy and stimulating economic change (Liu et al., 2023). Financial development has a notable favourable impact on the shift to renewable energy in developing economies in the extended period. Enhancing financial institutions and attracting investments may accelerate the adoption of renewable energy technology, thereby strengthening economic development initiatives (Alsagr and van Hemmen, 2021).

On the other hand, many studies have investigated the effectiveness and possibilities of various renewable energy sources in promoting economic change in different countries. According to (Baloch et al., 2022), wind energy is the most efficient renewable energy source for fostering sustainability and economic growth in developing countries. Additionally, wind energy as the best renewable energy source for promoting sustainable and economic growth (Zhao et al., 2022a). The results emphasise the need of using specialised renewable energy technology that are customised to the resources and circumstances specific to each nation. However, the importance of renewable energy in improving socio-economic well-being and achieving SDGs is also vital. According to (Omri and Belaïd, 2021) renewable energy helps reduce the negative effects of CO₂ emissions on human development and economic growth in transitioning countries. Using renewable energy on advancing sustainable development objectives related to the environment, society, and economy. The results suggest that using renewable energy might improve social welfare and promote a peaceful equilibrium between economic progress and environmental sustainability (Hannan et al., 2021). Table 3 is illustrating the studies that are reviewing the literature on renewable energy and SDGs.

However, supportive policies and technology improvements are essential to overcome the hurdles associated with transitioning to renewable energy and fully reap its advantages. (Fashina et al., 2018) noted that renewable energy resources have enormous potential to stimulate economic development by providing and producing energy, but they are often not fully used. In addition, (Guang-Wen et al., 2023) found that using renewable energy decreases carbon dioxide emissions, but making the financial system more equitable may unintentionally raise emission levels in certain nations. The need of enacting supporting policies, strengthening financial institutions, and promoting technology advances to overcome obstacles and accelerate the shift to renewable energy (Vanegas Cantarero, 2020).

The results provide strong evidence of the substantial potential of renewable energy technology to stimulate economic change in various nation contexts. The use of renewable energy shows potential for stimulating economic development and industrial advancement by promoting sustainable development, reducing carbon footprints, attracting investments, and facilitating long-term economic growth. To maximise the advantages of renewable energy, it is crucial to enact supporting legislation, promote financial growth, and drive technical advancements. Implementing these steps is essential for fully using the potential

of renewable energy and experiencing its significant influence on global economies.

4.1. SDGs

The shift to renewable energy sources is acknowledged as a crucial approach for promoting the SDGs established by the United Nations, especially in the areas of affordable and clean energy (SDG 7), and economic growth (SDG 8), and climate action (SDG 13) (Shayan et al., 2022). Many prior studies have shown the positive effects of using renewable energy on environmental sustainability and decreasing ecological footprints. According to (Adebayo et al., 2023), relationship between the utilisation of renewable energy and environmental standards in MINT nations, such as Mexico, Indonesia, Nigeria, and Turkey. In addition, (Ibrahim et al., 2022) showed that renewable energy may enhance environmental sustainability in BRICS nations (Brazil, Russia, India, China, and South Africa), particularly when combined with regulatory quality and green technologies. However, (Kahouli et al., 2022) found a negative long-term correlation between renewable energy and ecological footprint in Saudi Arabia. The substantial opportunity of using renewable energy sources to improve environmental health by lowering emission levels in BRICS nations (Manigandan et al., 2022).

Furthermore, researchers have investigated the efficiency and potential of specific renewable energy sources in advancing sustainable development across diverse country contexts. For example, (Baloch et al., 2022), identified wind energy as the most effective renewable energy source for promoting sustainable and economic growth in Pakistan and other developing countries. In addition, (Zhao et al., 2022b) also determined that wind energy is the best renewable energy source for advancing sustainable and economic development, particularly in Pakistan. These results emphasise the need of using specific renewable energy technologies that are customised to the individual resources and circumstances of each nation. However, researchers emphasise the importance of renewable energy in promoting economic growth and sustainable development. The renewable energy consumption has a major role in boosting economic development and promoting international tourism in industrialised nations (Rehman Khan et al., 2023). Also, the vital role of biofuels, such as renewable energy projects, in driving global economic growth and GDP advancement in 10 nations (Dar et al., 2022). The critical need of Gulf nations focusing on renewable energy measures to drive sustainable economic development (Sarwar, 2022).

However, Recent research have explored the possibility of hydrogen as a sustainable energy carrier, focusing on its generation from renewable sources and wastewater. The hydrogen's crucial position as a primary fuel in upcoming energy carrier materials and diverse industrial uses, underscoring its increasing importance in the transition to a sustainable energy future (Qazi, 2022). In addition, (Patil et al., 2022) demonstrated the efficiency and cost-effectiveness of a designed urea electrolyzer for hydrogen generation. This development facilitates the establishment of clean renewable energy infrastructure by offering a practical and cost-effective way to produce hydrogen from sustainable sources. Also, formic acid to be a viable H₂ energy carrier

Table 3: Studies examining the role of renewable energy in achieving sustainable development goals

Author	Research focus	Settings	Outcomes
Danish et al., 2020	Ecological footprint	BRICS countries	Renewable energy improves sustainability and environmental quality by reducing ecological impact.
Zeqiraj et al., 2020	Low-carbon economy	EU countries	Long-term, renewable energy use and production boost low-carbon economy.
Alsagr and van Hemmen, 2021	Financial development and renewable energy	Emerging markets	Financial development boosts long-term renewable energy transition.
Baloch et al., 2022	Renewable energy efficiency	Pakistan and developing countries	The most efficient renewable energy source for sustainability and economic growth is wind.
Omri and Belaïd, 2021	Renewable energy and socio-economic welfare	Transitional economies	Renewable energy reduces CO ₂ 's negative effects on human and economic development.
Hannan et al., 2021	Renewable energy and sustainable development goals	Global	Renewable energy helps achieve sustainable development objectives in the environment, society, and economy.
Yue et al., 2022	Renewable energy and sustained growth	Global	Renewable energy is considered a possible strategy for decreasing global carbon emissions and achieving continuous long-term growth.
Fashina et al., 2018	Renewable energy potential	Uganda	Renewable energy resources have great potential to boost economic development but are not fully used for energy services and manufacturing.
Dar et al., 2022	Biofuel and economic growth	Ten countries	Biofuels, along with renewable energy initiatives, are crucial for meeting the worldwide demand and are closely tied to economic expansion and GDP advancement.
Zhao et al., 2022	Renewable energy determinants	Pakistan	Wind energy is the most suitable renewable energy source for promoting sustainable and economic growth.
Adebayo et al., 2023	Renewable energy and environmental quality	MINT countries	Utilising renewable energy positively impacts environmental quality.
Murshed et al., 2022	Renewable energy transition	Argentina	Boosting the percentage of renewable power in the overall electricity production helps decrease carbon dioxide emissions and promote sustainable development objectives.
Kahouli et al., 2022	Renewable energy and ecological footprint	Saudi Arabia	A significant and lasting negative association exists between the use of renewable energy and ecological impact in the long run.
Manigandan et al., 2022	Renewable energy and sustainable development goals	BRICS countries	Utilising renewable energy sources may significantly improve environmental health by lowering pollution levels.
Saqib et al., 2023	Renewable energy and carbon footprints	E-7 countries	- The use of renewable energy is held up as the panacea for reducing carbon emissions over the time under study.
Vanegas Cantarero, 2020	Renewable energy and sustainable economic growth	Gulf countries	Gulf nations need to focus on renewable energy projects to achieve sustainable economic development.
Guang-Wen et al., 2023	Renewable energy and sustainable development	Next 11 countries	Energy productivity and renewable energy adoption reduce carbon dioxide emissions, while inclusive financial systems enhance them.

because of its large volumetric H₂ storage capacity, low toxicity, and low flammability. Formic acid has characteristics that make it an attractive choice for the economical and easy storage and transportation of hydrogen, effectively tackling issues related to its distribution and storage (Dutta et al., 2022). The need to reduce costs, decarbonise, and enhance the durability of hydrogen storage systems to maximise the potential of renewable energy-based hydrogen production systems. The storage systems need to be compatible with long-distance distribution networks and have enough fuelling stations to guarantee the efficient and widespread use of hydrogen as a clean energy source (Ahmed et al., 2022). Table 4 is illustrating the details of authors, research focus, settings and outcomes on renewable energy, sustainability, and sustainable development.

Moreover, the complex connection among foreign direct investments (FDI), renewable energy, and environmental sustainability is significant for the sustainable development. The findings of (Shinwari et al., 2022) found that Chinese Foreign Direct Investment (FDI) in Belt and Road Economies showed

a stronger environmental focus than investments from other nations, confirming the halo effect theory. In addition, solar power offers a greener option to coal-based power production in China, with reduced non-renewable energy prices and carbon emissions (Wu et al., 2021). However, the contrasting impacts of renewable and non-renewable energy sources on CO₂ emissions in MENA nations. Renewable energy improves environmental quality, whereas non-renewable energy worsens it (Omri and Belaïd, 2021). The industry sector was recognised as the main contributor to environmental deterioration, highlighting the need of implementing sustainable industrial practices. Besides this, (Qyyum et al., 2022), explored the possibility of producing biohydrogen from industrial wastewater via fermentation and emphasised the effective use of pilot-scale bioreactors. They emphasised the need for more pilot-scale experiments using high-strength wastewater to enhance performance. This method, while not completely renewable, offers a possible route to stabilising worldwide temperatures and highlights the need of exploring various techniques to accomplish SDGs.

Table 4: The nexus of renewable energy, sustainability, and sustainable development

Authors	Research Focus	Settings	Outcomes
Adebayo et al., 2023	Renewable energy and environmental quality	MINT countries (Mexico, Indonesia, Nigeria, and Turkey)	Positive correlation between renewable energy and environmental requirements
Ibrahim et al., 2022	Renewable energy and environmental sustainability	BRICS nations (Brazil, Russia, India, China, and South Africa)	Renewable energy improves environmental sustainability, especially with good regulations and green technology.
Kahouli et al., 2022	Renewable energy and ecological footprint	Saudi Arabia	Long-term negative link between renewable energy and eco-footprint
Manigandan et al., 2022	Renewable energy and environmental health	BRICS nations	Significant potential for renewable energy to reduce emissions and enhance environmental health.
Baloch et al., 2022	Renewable energy efficiency and sustainable development	Pakistan and other developing countries	The best renewable energy source for sustainability and economic development is wind energy.
Zhao et al., 2022	Renewable energy and sustainable development	Pakistan	The finest renewable energy source for sustainability and economic growth is wind.
Rehman Khan et al., 2023	Renewable energy and economic development	Industrialized nations	Renewable energy usage boosts economic growth and international tourism.
Dar et al., 2022	Biofuels and economic growth	10 nations	Biofuels, like renewable energy initiatives, drive global GDP growth.
Sarwar, 2022	Renewable energy and sustainable economic development	Gulf nations	Gulf states must prioritise renewable energy for sustained economic growth.
Qazi, 2022	Hydrogen as a sustainable energy carrier	Global	Hydrogen's importance as a fuel in future energy carriers and industrial purposes
Patil et al., 2022	Hydrogen production from renewable sources	Global	A hydrogen-generating urea electrolyzer's efficiency and cost.
Dutta et al., 2022	Formic acid as a hydrogen energy carrier	Global	Formic acid is a promising H ₂ energy carrier owing to its huge volumetric H ₂ storage capacity, low toxicity, and low flammability.
Ahmed et al., 2022	Hydrogen storage systems for renewable energy	Global	Formic acid is a promising H ₂ energy carrier owing to its huge volumetric H ₂ storage capacity, low toxicity, and low flammability.
Shinwari et al., 2022	Foreign direct investments and environmental sustainability	Belt and Road Economies	China's FDI was more environmentally focused than others.
Wu et al., 2021	Solar power sustainability	China	With lower non-renewable energy costs and carbon emissions, solar power is greener than coal.
Omri and Belaïd, 2021	Renewable and non-renewable energy impacts on CO ₂ emissions	MENA nations	Renewable energy enhances the environment, whereas non-renewable energy degrades it. Industry is the major cause.
Qyyum et al., 2022	Biohydrogen production from industrial wastewater	Global	Promoted pilot-scale bioreactors for fermenting industrial wastewater into biohydrogen.

Finally, renewable energy sources' diverse benefits to SDGs pertaining to cheap and clean energy, decent employment and economic development, and environmental sustainability. However, the limitations and the need for supporting policies, financial inclusion, and technology advances to fully benefit from renewable energy. To accelerate SDG achievement, governments and stakeholders must prioritise renewable energy technology development and deployment and investigate novel solutions like hydrogen generation and storage.

5. CONCLUSION

This research aims to investigate the impact of renewable energy on economic growth and its contribution to promoting SDGs. Research consistently shows that incorporating renewable energy technologies can greatly help in accomplishing the United Nations' SDGs, specifically related to accessible and clean energy (SDG 7), promoting decent work and economic growth (SDG 8), and

tackling climate change (SDG 13). The study's results emphasise the beneficial effects of implementing renewable energy on environmental sustainability, such as decreasing ecological footprints and greenhouse gas emissions. The report highlights the positive impact of using renewable energy on improving environmental quality and lowering emission levels in different country groupings including MINT, BRICS, and Gulf states. The findings highlight the crucial importance of renewable energy in reducing the negative environmental impacts of economic activity and advancing SDGs. The findings emphasise the efficacy and potential of certain renewable energy sources, such wind power, in promoting sustainable economic progress. Also, the need of optimising the use of renewable energy technology according to the specific resources and situations to achieve sustainable economic development.

Furthermore, renewable energy is crucial for stimulating economic growth and development by improving economic advancement, promoting international tourism, and boosting GDP in different

countries. The results highlight how the shift to renewable energy may provide new economic prospects, promote development, and contribute to achieving SDG 8, which emphasises decent work and economic prosperity. The importance of hydrogen as a clean energy carrier, produced from renewable sources and wastewater, is vital for sustainable economic growth. The importance of developing new solutions and technologies for clean energy production and storage is emphasised. This will help in achieving SDG 7 for affordable and clean energy and promoting environmental sustainability in line with SDG 13.

On the other hand, the complex interconnection between foreign direct investments, renewable energy, and environmental sustainability is being examined. The need of responsible investment strategies and integrating cleaner energy options to reduce the negative environmental impact of economic activities and promote sustainable development is emphasised by these observations. Challenges remain, requiring supporting policies, financial inclusion, and technical advancements to maximise the benefits of shifting to renewable energy sources. It is crucial to prioritise environmental factors in all sectors, especially in industry, and to investigate innovative approaches for generating clean energy to achieve SDGs.

Finally, to advance the area, future research should aim to expand geographical coverage, improve data accuracy and availability, and develop uniform procedures. Exploring social and political aspects, performing thorough studies, and examining the impact of energy storage and hydrogen on enabling renewable energy integration are important areas for future research. Evaluating the distributive impacts of adopting renewable energy, creating thorough frameworks, and promoting multidisciplinary cooperation are crucial for addressing the complex difficulties associated with renewable energies and economic progress. Scholars may enhance our understanding of how renewable energy affects economic growth and sustainability by exploring potential future paths, eventually promoting the shift towards a low-carbon, sustainable future.

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