The Bioscan
AN INTERNATIONAL QUARTERLY JOURNAL OF LIFE SCIENCES
21(2): S.I (2), 296-307, 2026
www.thebioscan.com

Thematic Structure of Renewable Energy Integration in Sustainable Development

Parveen Kumar Sharma[1*], Prof. Hemraj Verma[2]
[1]*Research Scholar,
School of Liberal Arts and Management, DIT University, Dehradun.
Email: Shivam99063@gmail.com
[2]Dean & Professor,
School of Liberal Arts and Management, DIT University, Dehradun.
Email: drhemraj.verma@dituniversity.edu.in

DOI: https://doi.org/10.63001/tbs.2026.v21.i02.S.I(2).pp296-307

KEYWORDS:
Renewable energy, Sustainable development, Digitalization, Green energy, Social development, Economic development

Received on:
21-03-2026

Accepted on:
09-04-2026

Published on:
19-04-2026

ABSTRACT

The purpose of this study is to analyze the thematic structure of renewable energy integration, identify development patterns, and propose a research roadmap for BRICS nations in renewable energy sector. The research uses bibliometric analysis to achieve an aim of the research. The keywords utilized "Renewable energy," "Sustainable development," "Digitalization," "Green energy," and "Social and Economic development," which were employed to retrieve relevant research from the Scopus database. The core collection of Scopus yielded 448 renewable energy research articles published between 1994 and 2023, which were analyzed using the bibliometric analysis program in VOS viewer. The findings revealed that the keywords that performed best were "energy" and "renewable," with circles denoting related topics. Nearly, 58.3% of the 448 papers from 1439 different authors were included in the study. The most fruitful co-authorships were those that connected the top ten writers of the paper. The findings also revealed that the challenges like high costs, technological hurdles, and regulatory barriers persisted in the renewable energy sector.

INTRODUCTION

Energy plays a pivotal role in steering economic growth, exhibiting a direct and foreseeable correlation between the two. It stands as a scarce and indispensable resource crucial to economic activities, particularly in nations at varying stages of development (Rahman et al., n.d.). Zooming out to a broader perspective on the energy landscape, there is a definite divide in the energy sector between the two main players: renewable and non-renewable sources. The sun, wind, water, and heat from the Earth all serve as natural resources that constantly replenish renewable energy. Examples include geothermal energy, biomass, hydroelectric power, solar energy, and wind energy. On the other hand, non-renewable energy, which includes fossil fuels like coal, oil, natural gas, and nuclear energy, is like a limited treasure chest that gradually runs out over time. The concept of renewable energy, dating back to an era preceding contemporary climate concerns, demands a thorough exploration of its historical context. The term itself has surfaced in scientific literature since the early 1900s, creating a dichotomy between renewable and finite fossil fuel sources (Bell, 1906; Clarke et al., 1909). Notably, early deliberations distinguished between "inexhaustible" resources like wood and animal power and "renewable" sources such as solar, wind, tidal, and hydropower (Clarke et al., 1909). More research is needed to achieve the best balance between renewable energy, economic expansion, and environmental objectives. (Sinha et al., n.d.) and (Chopra, S. K. (1987), n.d.) discovered that effective intervention design is necessary for integrated energy planning in local economic development plans.

Modern economists underscore the profound impact of energy across multiple facets of economic development, encompassing consumption, supply, demand, and living standards (Alabi et al., 2017; Emir & Bekun, 2019). The transition to renewable energy sources has a substantial influence on the environmental, social, and economic spheres and produces several advantages in a range of industries. By diversifying energy sources, this move improves energy security, creates jobs in the renewable energy sector, and lowers prices for businesses and consumers by

advancing clean energy technology (Harjanne et al., 2018). In addition, it draws capital, stimulates creativity, and advances technology. In terms of social effect, renewable energy boosts local economies, expands access to electricity in underprivileged populations, and improves public health by reducing pollutants in the air and water. It benefits the environment by reducing greenhouse gas emissions, protecting natural resources, and fostering biodiversity. In addition, renewable energy promotes resource efficiency and waste reduction in line with the circular economy's tenets. In the end, its tangible aid in accomplishing the Sustainable Development Goals highlights its critical role in promoting sustainable development routes around the globe.

A significant amount of literature has been examined to understand the integration of renewable energy sources and their effects on development, even if it cannot be said that every study conducted in this area has been assessed. The merits, limitations, and applicability of the evaluation techniques used in various publications were examined, which assisted researchers in choosing the best techniques for assessments of the integration of renewable energy sources. A literature search was done using the following keywords in English and some other languages: "Renewable energy," "Economic and Sustainable development," "Social and Environment development," and "Green and Digitalization" to locate pertinent papers. The websites "Google," "Google Scholar," "Science Direct," "Mandley," and "Web of Science" were the most frequently accessed sources. Following a review of relevant articles' references to find additional literature, all pertinent English- and some other language-speaking publications were filtered to include only those discussing renewable energy integration and their influence on development.

Research on the creation of renewable energy integration was not performed specifically for bibliometric analysis. As a result, this study combined bibliometric analysis and systematic review to establish a theme structure and publication patterns. As a result, this study investigated publications that were indexed by Scopus and released throughout the last 29 years (1994–2023), with a focus on those that investigated the integration and interaction of renewable energy. The structure and patterns in thematic academic studies were found by carefully examining the published results, which also served as a guide for further research on the subject.

Table 1 - Criteria for admission and rejection

Admission criteria	Rejection criteria
• Major subjects include renewable energy and sustainable development. • English-language journal article	• Not the article's primary focus • Book chapter, book review, proceedings article, and editorial

Source: Author's Computation.

Three research questions (RQ) were suggested by this study based on the analysis that was presented:

RQ 1: Is it possible to use renewable energy to further advance the economic development of the BRICS nations?

RQ 2: Which nation, Journal and organization make the largest contributions to the Renewable energy publication?

RQ 3: How do publishing themes related to renewable energy trend?

Comprehensive literature evaluation and bibliometric analysis, this work is fascinating because the data set used can predict publishing patterns in the future for renewable energy integration for sustainable development. Bibliometric analysis (BA) with network analysis, scientific mapping, and performance analysis; systematic literature review (SLR) with content analysis. The basis of conducting this study lies in the concept of performing a systematic literature review and bibliometric analysis. Given that a significant portion of research in this field focuses on China and India, Research Question 1 investigates how the BRICS nations can enhance their economies through the utilization of renewable energy. This question aligns with the analytical content of the systematic literature review. Research Questions 2 aims to map out nations, organizations, and publications supporting renewable energy, with a focus on assessing their performance through bibliometric analysis. In Research Question 3, the importance of bibliometric analysis in scientific mapping is highlighted, specifically in mapping themes within publications related to renewable energy.

METHODS

Study design

The study design involved the utilization of both a Systematic Literature Review (SLR) and bibliometric analysis to delineate the bibliometric profile. In certain publications, this approach was referred to as Systematic Literature Network Analysis (SLNA). The search process, including identification, source filtering, and screening, is illustrated in Figure 1. To uncover trends, patterns, and visualize metadata, bibliographic analysis was conducted. The first step in the process was to identify key terms for the investigation. Data was then extracted in CSV format. To verify the CSV data, we utilised VOS viewer and Microsoft Excel. We also worked besides numbers by using content studies. Graphs and charts were used to present our findings. We were able to organise and improve the data with the aid of Microsoft Excel. We utilised goggle scholar for content analysis, VOS viewer to create maps, and Publish or Perish to verify the accuracy of the quotes and scores. With several perspectives, content analysis techniques, and quotation checks, we ensured that the research was examined from every angle.

Data search and identification

The study's data came from the Scopus database, which was examined on January 6, 2024. The publications that examined the development and integration of renewable energy and were published throughout the last 30 years (1994–2024) served as the source of data. In the meanwhile, the Scopus database contained many highly regarded international scientific publications, ensuring that the strict peer-review procedure preserved the articles' caliber. As such, the information used was reliable. Renewable energy was the keywords utilized to find papers that fit the objectives of this study.

- To study the link between renewable energy and economic development of the BRICS nations.
- To Analyze the journal and organization with largest contributions to the Renewable energy publication

The study focused on identifying key keywords to define the research topic. Data was collected and exported in CSV format, allowing for efficient organization and analysis. Microsoft Excel was used for data organization, sorting, filtering, and

correction. VOS viewer was used to create detailed visualization maps for understanding bibliometric networks. The methodological approach was comprehensive, incorporating both quantitative and qualitative analyses. Content analysis was applied to examine data, identifying patterns and meanings that quantitative methods might overlook. Publish or Perish was used to verify citation accuracy, ensuring source credibility. Scholarly tools were employed for in-depth content analysis. Results were presented using graphs, charts, and pictures, making the findings accessible and easy to understand. Microsoft Excel was used for data selection and correction, improving data quality. VOS viewer generated visual maps to clarify complex relationships within the data. This systematic and multi-faceted approach ensured a thorough review of the research material, resulting in a robust and multidimensional analysis.

Statistical Analysis

Table 2 presents the top sixteen publications in this study that address the relationship between renewable energy and social, economic, and environmental development, as well as their impact on sustainable and green development in the context of digitalization. Several variables were covered by the investigation, such as themes, journals, organizations, key concepts, analytical techniques, methodologies, and future projects. These publications were probably chosen for inclusion based on how much they added to our knowledge of the connections between renewable energy and more general development objectives.

RESULTS AND DISCUSSIONS

Table 2: Top Sixteen research papers of all the four themes of literature review which are highly cited.

Author	Objective	Data and variables	Methodology	Findings
Sinha et al. (1994)	To investigates the India's rural energy planning using systematic literature review technique.	Data from the 7th Five-year plan and economic surveys and the variables are integrated energy sources like biomass, biogas, etc. and technologies	Systematic literature review	The integrated energy planning, as opposed to integrated energy sources and technologies had required good intervention design to be a part of the local economic development plan.
Das et al. (1995)	To examine the overall cost of wood fuel while accounting for the restricted supply of wood fuel	Renewable energy sources and cost efficiency and data from WDI.	Non-linear programming model.	The best approach to encourage the adoption of upgraded wood stoves in rural India was not to directly subsidies them.
Rozakis et al. (1997)	To investigate the localized energy source combinations for producing electricity in a Greek island region.	Hydro, wind, and conventional power generation and data from WDI.	Integrated system using the "F-Can" computer model.	The energy sources included in the integrated system under consideration had been biomass, hydro, wind, and conventional power generation.
Chakraborty (1999)	To examine the socio-economic aspects of PV power plants in Sagar Island, West Bengal.	Data from the world bank and different economic and sustainable variables.	A multi-phase sampling technique was decided to pick the sample independently of those who use solar electricity and diesel generator power.	The use of electricity from PV power plants has enhanced welfare and decreased reliance on kerosene.
Sinha et al. (2000)	To study the socioeconomic effects of stand-alone PV systems in the Sundarbans islands of India.	Wind energy, thermal energy, PV and GDP. DATA from various agencies and surveys.	ARDL Model.	The adoption of photovoltaic (PV) systems increased welfare levels in entertainment, health, and education, and the demand for various capacities increased due to improved operating and maintenance practices, accessible credit options, and high-quality system components.
Mihalak Akon et al. (2002)	To study the viability of utilizing energy from renewable sources in the South Argman Sea region, namely on the Greek islands.	Renewable energy, co2 emission and GDP from agencies of Greek islands. Data from WDI.	FLMOS technique.	The predictions for energy conservation placed a strong emphasis on encouraging combined heat and power systems and wise energy use across the board.
Kai et al. (2004)	To study the possibility of clean energy sources to create a regional energy system on Yakushima Island.	Renewable sources, Co2 emission and water productivity in the Yakushima Island from world bank.	FLMOS technique.	The family fuel energy could be substituted without having an adverse effect on the environment and the island's hydroelectric power

				generation had been adequate to supply all energy needs.
Sbia et. al;(2014)	To investigates the links between carbon emissions, economic expansion, clean energy, FDI, and trade openness in the United Arab Emirates (UAE), spanning the period from 1975Q1 to 2011Q4	FDI, energy consumption, use of green energy, CO2 emissions, and economic growth leading to trade openness. Data from 1975 to 2011from the world bank.	Autoregressive Distributed Lag (ARDL) model.	Trade openness moderates this relationship, facilitating the transfer of energy-efficient technologies. The relationship was dynamic, with FDI and energy consumption influencing each other. Increased trade openness contributes to a more integrated economy. Clean energy consumption positively impacts economic growth, enhancing economic development.
Sebri, et. Al; (2014).	To investigate the causal relationships among trade openness, CO2 emissions, renewable energy usage, and economic growth: New data from the BRICS nations.	Economic growth, renewable energy consumption, trade openness and carbon dioxide emissions from world bank indicator.	A multivariate framework and the ARDL bounds testing technique were used to study co-integration and a vector error correction model.	Renewable energy was necessary to support economic growth in the BRICS nations.
Al-Mullai (2015)	To examine the GDP of 82 developing nations that was affected between 1990 and 2009 by both renewable and non-renewable energy.	Sources of non-renewable and renewable energy, GDP and Co2 emission of 82 developing regions from world bank from 1990 to 2009.	FMOLS approach.	The co-integration result validated the variables' long-run relationship. The expected outcome also showed that both non-renewable and renewable energy sources supported economic advancement potential. However, compared to renewable energy, it was demonstrated that non-renewable energy resources responded to the economic sector.
Banday and Aneja (2018)	To investigate how the G7 economies' GDP, CO2 emissions, and energy resources related to each other between 1971 and 2014.	GDP, CO2 emissions, and energy resources in the G7 economies from 1971 to 2014 from world bank and IEA.	Panel ARDL.	Both GDP and energy resource utilization increased the potential for CO2 emissions.
Singh, A. K. et. al, (2019)	To examine the link between personal, economic, and social growth and the environmental sustainability index (ESI) for 22 Asian economies from 1990 to 2012.	They selected seven primary components and twenty-five environmental performance sub-indicators and data from WDI.	The composite z-score method and using linear, log-linear, and nonlinear regression models.	Among Asian nations, Malaysia had the most ecologically sustainable economy, albeit there was considerable fluctuation over time and within sectors.
Alola et al. (2022)	To study the effects of non-renewable energy efficiency and the use of renewable energy on the sustainability of the environment in India from 1965 to 2018.	Trade liberalization, the selling off ecological assets, and atmospheric pollution from CO2 emissions (world bank).	ARDL Framework.	Trade and financial growth had a detrimental effect on sustainability; these factors had positively impacted it by raising the load capacity factor. Due to factors including trade liberalization, the selling off ecological assets, and atmospheric pollution from CO2 emissions, India's ecological footprint has outgrown its bio-capacity by 171%.
Hwang, Y. K. (2023).	A field investigation of 18 Latin American and Caribbean countries was conducted to look at the potential synergies between the digital economy and the move to renewable energy sources	GDP, co2 emission, natural resource, renewable energy transition index, digital index, inflation, globalization index (all from world bank).	Principal factor analysis (PFA), Hausman test, and co-integration test.	The transition to renewable energy has a significant threshold effect on both environmental sustainability and economic development, depending on income and carbon emissions levels.

	in order to foster green economic growth.			
Rasouli Nezhad and Hesary (2023)	To investigate the connections among the top 10 economies that support green finance, energy efficiency, CO2 emissions, and the green energy index (GEI).	Development of green energy projects that lack funding, particularly during the COVID era. Green bonds were proven to be an effective strategy for promoting green energy projects and lowering CO2 emissions.	Regression's random impact on the population, wealth, and technology model.	They discovered that, particularly in developing nations with limited resources, a 1% increase in the consumption of green energy might result in 1.26% economic growth. Studies have demonstrated a causal link between the use of green energy and economic growth in OECD nations. Green financing may also aid in the development of green energy projects that lack funding, particularly during the COVID era.
Jyoti and A K Singh (2023)	To look at the causal link between digitalization and economic development as well as the interaction between digitalization alongside additional factors and socioeconomic development.	Information communication technology index for 109 nations between 2010 and 2020 for 12 variables from world bank.	Using correlation coefficient analysis using panel data and A log-linear regression model, the Granger causality test was utilized.	Digitalization has transformed many processes, notably knowledge, data, learning, entertainment, text, devices, pictures, factors of production, money, and market. The industrial sector has profited immensely from these changes.

Source: Author's Calculation.

Renewable Energy and Economic Development:

Early studies (1987–2000) highlighted the potential of renewable energy planning for cost-effective and sustainable solutions, considering regional differences in resource availability, climate, and socioeconomic situations (Banerjee, S., Jash, T., & Das, T. K. (1997), n.d.; Chopra, S. K. (1987), n.d.; Das, T. K., & Banerjee, S. (1995). Energy Technology, n.d.; Chakrabarti et al., n.d.; Sinha et al., n.d.).The creation of jobs, energy independence, innovation, lower costs, better health, energy access, empowerment, community development, reducing the effects of climate change, and preservation of natural resources are some of the economic advantages. Low greenhouse gas emissions, fighting climate change, less air pollution, resource conservation, and biodiversity protection are all achieved by renewable energy sources. But there are obstacles like intermittent, cost, and grid upgrading. Integrated energy planning is crucial for rural energy needs, but it must be flexible and consider local context. Solar systems have a beneficial socioeconomic influence on rural welfare, leading to increased income, better health, education, and environmental advantages. (Aliabadi et al., n.d.; Saqib et al., n.d.; Singh, Jyoti, and, et al., n.d.) This led to a shift away from a centralized energy strategy and towards local authorities adopting renewable energy sources.

More research has been conducted on the complex links between emissions, economic growth, and renewable energy from 2014 to 2023. Literature shows a positive relationship between GDP growth and renewable energy use, while others emphasize the impact of specific circumstances and governmental initiatives (Sebri et al., 2013). The Global Sustainable Development Index (GSDI) provides a framework for evaluating energy changes' contribution to sustainable development. Renewable energy has the potential to promote sustainable growth and rural empowerment, but its effects are complex and require careful assessment of local contexts and legislative frameworks (Bhattacharya et al., n.d.; Leal et al., n.d.). A non-linear programming technique was utilized by (Das et al., n.d.) To lower wood fuel costs while taking restricted availability into consideration. The ineffectiveness of West Bengal's IREP programmed was discovered by (Banerjee, S., Jash, T., & Das, T. K. (1997), n.d.), underscoring the necessity of flexible energy planning that considers regional features like socioeconomic situations, climatic conditions, and resource availability. Systems with big tray sizes and small batteries had a significant amount of energy seat, according to Shrestha and Goel's (1998) results, while systems with tiny batteries and small tray sizes lost load hours.

To optimize energy flows while taking system economics and efficiency into account, Mourelatos et al. (1998) used the linear programming technique to study how Greece's energy planning was impacted by the CO2 reduction strategy. Byrne et al. (1998) demonstrated that there was no discernible cost difference between small-scale home solar systems and traditional gasoline generator sets. Neij (1998) suggested that policy instruments might have enhanced the diffusion and uptake of renewable energy technologies based on his experience curve analysis of the likelihood of renewable energy technology diffusion and adoption. In the Uttara Kannada District of Karnataka, India, sector-specific disaggregated data on energy consumption was gathered by Ramachandra et al. (2000). While Mihalak Akon et al. (2002) looked at the feasibility of using renewable energy sources in the South Argman Sea region, Manolakos et al. (2001) examined an electronic programme for developing hybrid renewable energy systems. A bottom-up modelling technique was employed by Ghosh et al. (2002) to assess the possibility of lowering carbon dioxide emissions in the electrical industry. Family fuel energy might be replaced, according to Kai et al.'s 2004 evaluation of the viability of using clean energy sources to establish a regional energy system on Yakushima Island. Pata et al. (2023) raise the possibility that greater efforts may be necessary to meet carbon neutrality targets.

The influence of Renewable energy on Sustainable Development.

Renewable energy is pivotal for sustainable development as it offers a clean, abundant energy source that meets current

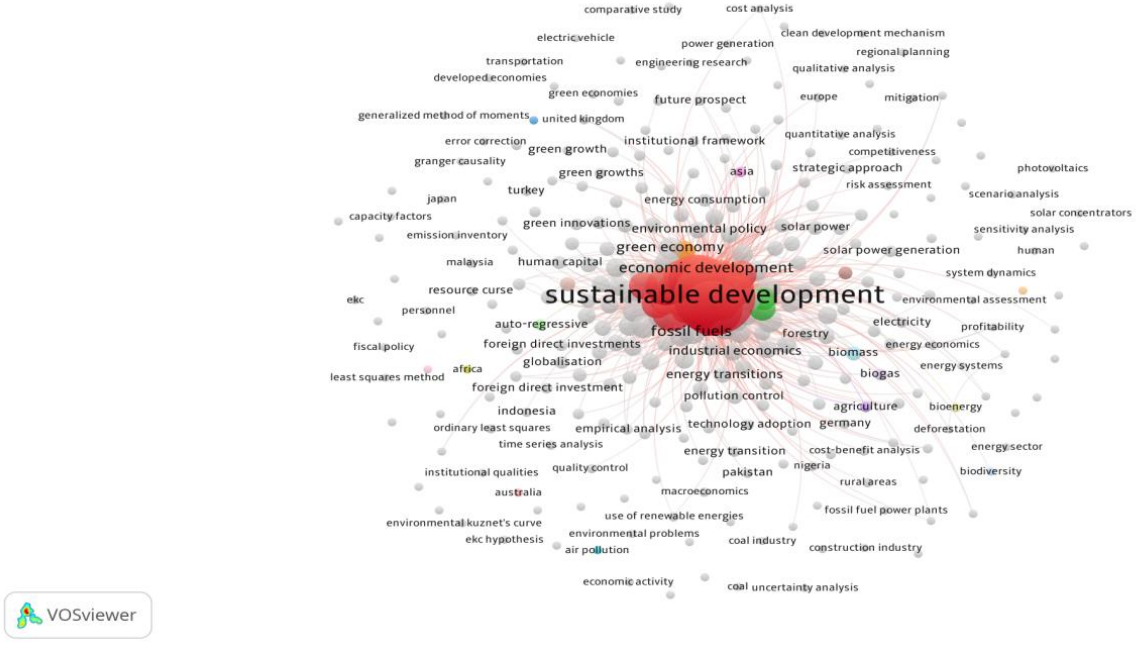
demands without compromising the future (Byrne et al., n.d (2023) By fostering energy independence, renewable energy reduces reliance on fossil fuel imports, enhances economic resilience, and spurs innovation and job creation (Malik et al., n.d.; Rozakis, S., Soldatos, P. G., Papadakis, G., Kyritsis... -, n.d.; Sarafidis et al., n.d.). Environmentally, it significantly lowers greenhouse gas emissions and conserves natural resources, contributing to climate change mitigation and ecological balance. Socially, renewable energy improves access to essential services like healthcare and education, particularly in underserved regions, and enhances public health by reducing pollution (Ghosh, S. (2002)., n.d.; Harjanne et al., 2018). Despite challenges such as high initial costs and regulatory barriers, the long-term benefits of renewable energy—economic growth, environmental sustainability, and improved social equity—are compelling, underscoring the need for continued investment and policy support to realize a sustainable future.

Output of Publications and Trend of Growth

One key measure of the development patterns in scientific research is the volume of publications. The frequency with which papers are referenced by other authors serves as a gauge for publishing quality. A temporal picture of the volume of publications on renewable energy that have been published and cited is shown in Figure 2.

Figure 1: Keyword and Co -Keyword Citation Bursts Analysis

A publication's main ideas were represented in its keywords, which were nouns or phrases. An article's scientific effect may be gauged by how frequently it is referenced in other articles. One criterion used to evaluate the caliber of research articles in scientific, technological, and social science publications was citation analysis. 1500 keywords were used in this study, according to the bibliometric data, and a minimum of 4 and a maximum of 20 keywords were considered for analysis. Using VOS viewer, co-occurrence of terms was examined to highlight research hotspots in the field of renewable energy. After setting the co-occurrence threshold of the keywords at 20, 396 objects were visualized (Figure 1).



Co-keyword network visualization on renewable energy research.

The size of the circles in Figure 1 indicates how frequently a term appears. More keywords that have been co-selected in the publications on renewable energy are indicated by bigger circles. The strongest keywords were "energy" and "renewable." The relative intensity and topic similarity of the two keywords were shown by their distance. Circles with the same colour cluster indicated that these articles had a related subject. Figure 1's co-keyword network made 147 different groups easy to see. Each stood for a subdomain within the renewable energy area. By examining each main cluster's main node circles, appropriate labels might be assigned to each of the six main clusters. Particularly, as demonstrated by the red cluster (Figure 1, cluster 1, upper right, 133 items), terms that appear to be connected to the topic of "Renewable energy" include sustainability, biomass, biogas, solar, governance, economic, green, innovation, Co2 emission, technology, rural, finance growth, etc. Keywords like CO2 emissions, Brazil, green, China, consumer behavior, and energy utilization are concentrated in the red cluster (Figure 3, cluster 1, bottom right, 130 items), which is centered on the primary domain of "renewable energy integration of sustainable development." Subsequently, terms related to the concept of "sustainability," such as "human," "strategic approach," "recycling," and "sustainable," were centered on the yellow cluster (Figure 1, cluster 2, upper left, 8 items). Keywords related to development themes were found in the blue cluster (Figure 1, cluster 3, center left, 7 items), including cost-benefit analysis and emission. Keywords related to "energy for sustainable" such as "Japan," "Mexico," "energy," "performance," "integration," etc. were included in a second purple core cluster (Figure 1, cluster 4, 6 items). The final sapphire blue cluster (cluster 6, 4 items) in the center of Figure

1 collected terms related to low carbon, technology, and other related topics, mostly around "green sustainability."

Table for the keywords

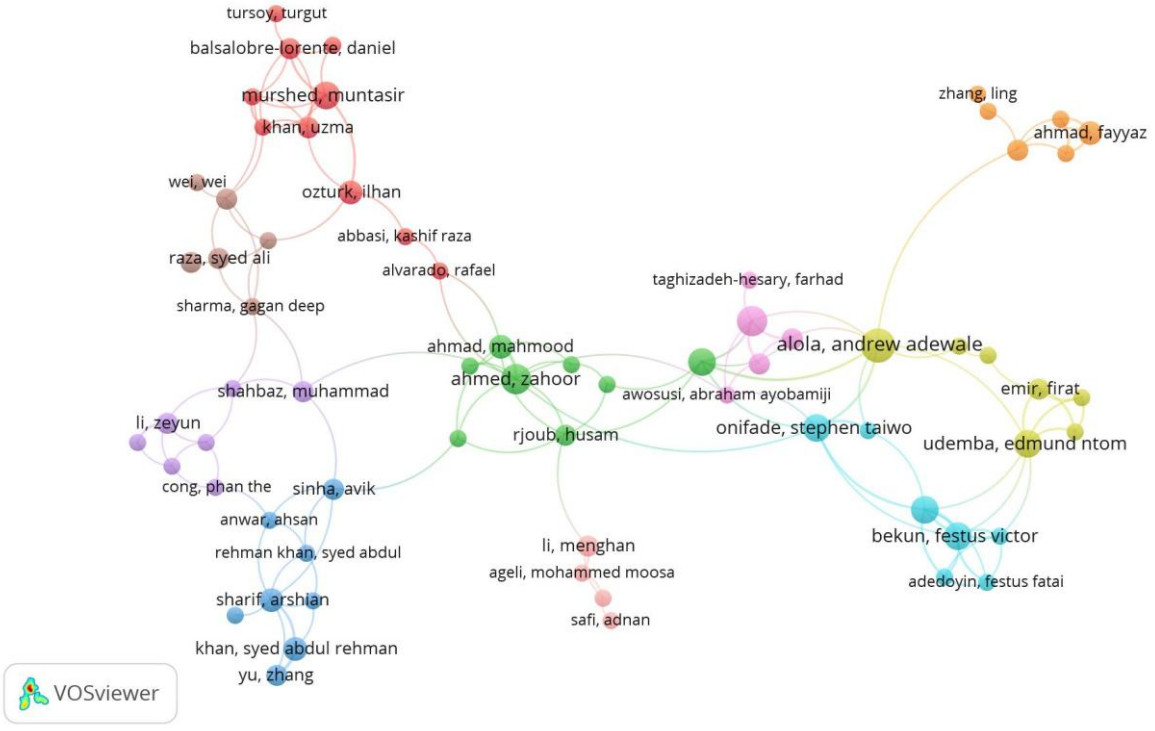
Table 3: Top 10 keywords used in Research on Renewable energy and Sustainable Development

RO	Keywords	Cluster	Links Total Link Occurrences APY Strength			
Top 1	Sustainable development	2	315	415	414.00	2022
Top 2	Economies	2	390	226	226.00	2019
Top 3	Alternative energy	3	318	174	174.00	2011
Top 4	Environmental economics	2	256	170	170.00	2018
Top 5	Renewable energy	1	298	135	135.00	2008
Top 6	Renewable energy resources	2	257	130	130.00	2016
Top 7	Sustainability	3	288	129	129.00	1990
Top 8	Renewable energies	4	317	126	126.00	2016
Top 9	Economic growth	3	299	105	105.00	2016
Top 10	Energy utilization	2	208	105	105.00	2017

Source: Author's Computation.

Note: RO: ranking order; cluster number (in Figure 1; APY: average publication year in Figure 1

Figure 2 Co-authorship analysis



The function module of the VOS viewer's co-authorship visualization was utilized to examine the patterns of collaboration among authors, organizations, and nations that write on sustainable development and renewable energy. Figure 2 shows a visual mapping of the authors' collaboration network in the smart cities study topic, based on 448 papers provided by 1439 distinct authors. It was not possible to combine works written by authors under various identities unless they employed a distinct digital identification method, such as ORCID.

Based on statistical analysis, it was found that 58.3% of the authors (n = 109/1439) were credited in two publications about smart cities, 23.6% (n = 34/1439) in at least three publications, 11.8% (n = 17/1439) in four publications, and 6.3% (n = 9/1439) in five or more publications. The threshold value of two was used while generating author data based on the co-authorship map to make it simple to identify the well-known writers (n = 109) who have written about sustainable development and renewable energy. Nonetheless, a portion of the 109 authors lacked connections to other authors inside the network. Only 107 items were examined.

Figure 2 shows the collaboration cluster of the writers as 10 distinct colours, while the lines among the authors show their

linkages of cooperation. Principal academic relationships and outstanding researchers may be found in the network among these groupings. For example, Figure 2 shows a cluster containing the strong-link researchers "abbas, Shujaat", "Adebayo, Tomiwa Sunday", "Ahmed, Zahoor", "Alola, Andrew Adewale", and "bekun, Festus victor." "Song, Hoebing", "Vasilakos, Athanasios v.", "Ning, Zhaolong", "Foschini, Luca", "Ahmad, Awais", "Paul, Anand", "Chilamkurti, Naveen", "Lloret, Jaime", "Choo, Kim-Kwang Raymond", "Song, Hoebing" and "Ahmed, Syed Hassan" were the primary researchers in the network. One of these primary researchers was connected to other researchers.

Table for the top 10 co-authorship

Table 4. The top 10 co-authorships linked document-productive authors.

RO a	Authors	Links	Citation	Total strength	Documents	Year
Top 1	Alola, Andrew Adewale	10	307	10	10	2012
Top 2	Ahmed, Zahoor	12	506	12	12	2010
Top 3	Abbas, Shujaat	9	34	9	9	2021
Top 4	Gyamfi, bright Akwasi	13	431	13	13	2010
Top 5	bekun, Festus victor	12	446	12	12	2011
Top 6	Onifade, Stephen Taiwo	10	406	10	10	2015
Top 7	Udema, Edmund Ntom	10	81	10	10	2019
Top 8	Murshed, Muntasir	9	203	9	9	2016
Top 9	Adebayo, Tomiwa Sunday	8	150	8	8	2016
Top 10	Ahmad, Mahmood	9	322	9	9	2015

Source: Data from Scopus and analysis in Vos-viewer

Table 4 shows that all ten of the authors with the strongest co-authorship connections produced articles after 2010. This suggests, at least in part, that the dominant field of sustainable development research maintained its strong growth status.

The countries on the co-authorship network visualization map were produced using VOS viewer and the bibliographic data gathered from the Scopus core collection. A country's minimum document threshold was set at two during the mapping of Figure 3. Out of the 85 nations listed, 59 were used for visualization.

Figure 3 countries and regional analysis

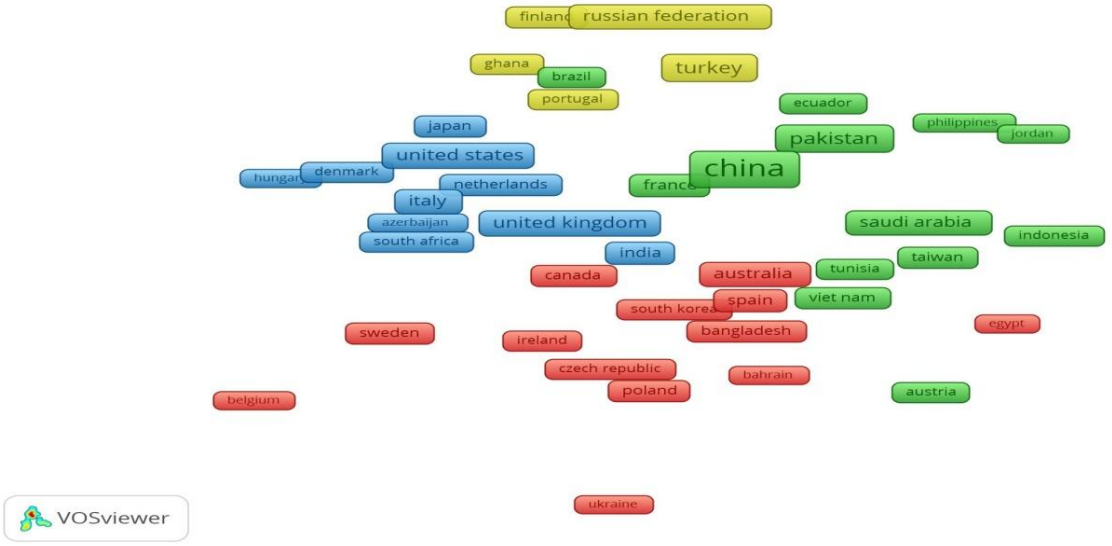


Table 5. For the top 10 countries and regional analysis

S.no	Countries	Documents	Citations	Total Link strength
01	China	177	7336	224
02	Turkey	53	2876	114
03	Pakistan	47	2772	105
04	Russian federation	23	953	65
05	Malaysia	27	1159	63
06	Saudi Arabia	25	1224	63

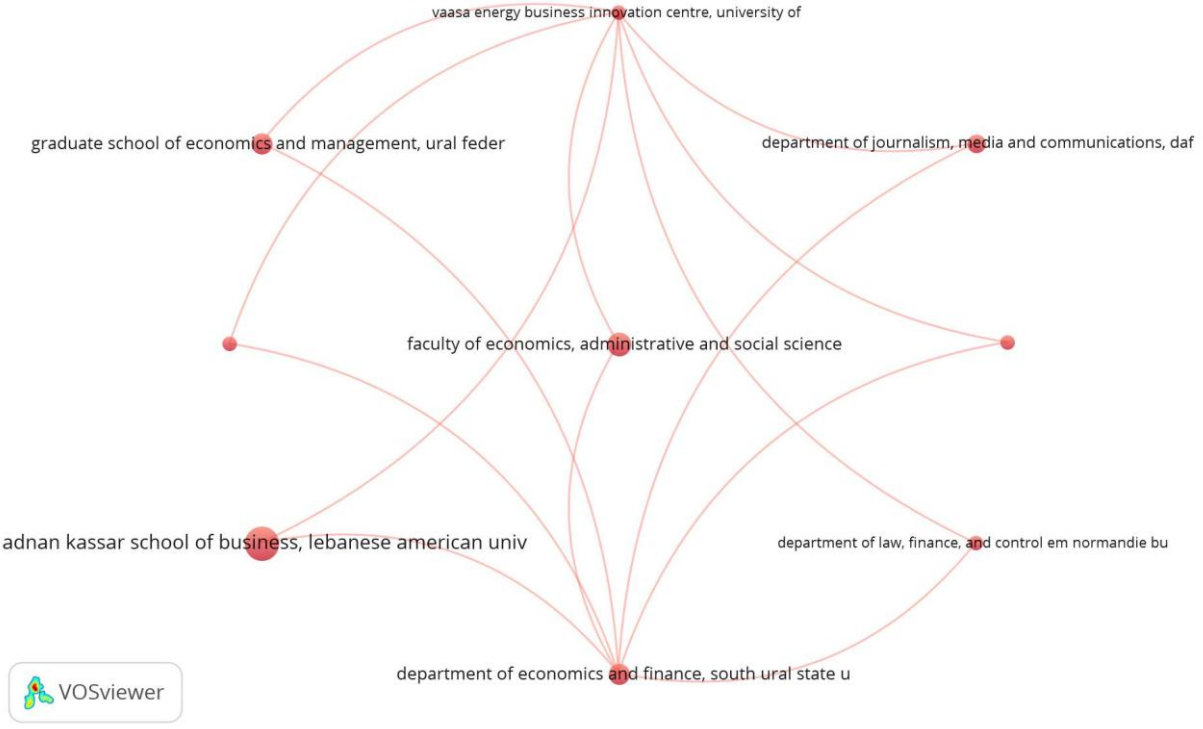
07	United Kingdom	37	1363	56
08	France	16	547	41
09	Australia	24	600	37
10	India	20	598	36

Source: Data from Scopus and analysis in Vos-viewer.

Table 5 delivers an overview of research collaboration and productivity in different nations. It examines metrics most likely collected from a certain field of study or database. The "Documents" column shows how many documents (articles, papers) a nation has published; China tops the list with 177. The "Citations" column illustrates the influence of this research; once again, China has the largest number (7336), indicating that their work is frequently cited by other researchers. Collaborating with researchers worldwide is shown by the "Total Link strength" column. Here, China exhibits both their high productivity and a good degree of cooperation (224).

In comparison to China, India's research output is lower (20 documents), and its citation count is lower (598). Their overall link strength (36), however, still shows some signs of international coordination. Another intriguing example is France. Even while France produces a lot less documents (16) than China, they yet collaborate at a high rate (41) compared to their production. This implies that although French research may be more concentrated, it makes advantage of solid international collaborations. It's crucial to keep in mind that these outcomes might vary based on the research topic selected. Furthermore, many citations and documents do not always indicate higher-quality research. Equally significant are the research's actual quality and impact. On the other hand, a high "Total Link strength" indicates a thoroughly researched study.

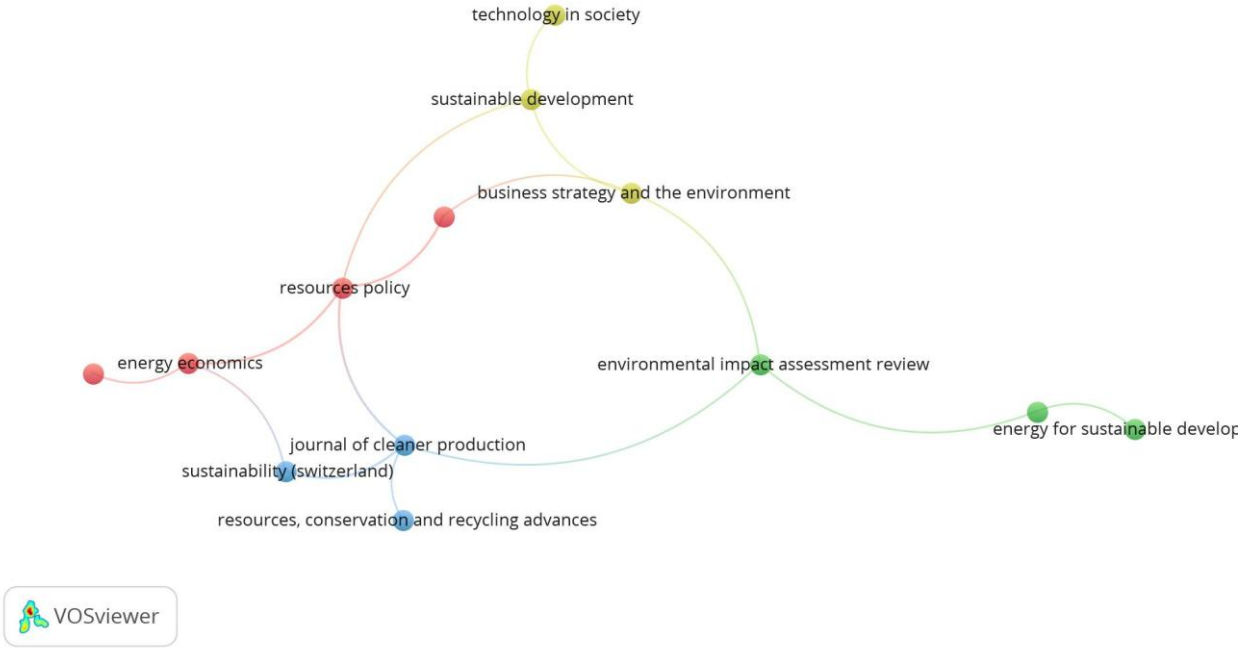
Figure 4 Visual map of research on renewable energy



Different colours correspond to the nine clusters that were created by dividing 1290 representative organizations into groups in Figure 4. The line connecting the two nodes shows the academic relationship between the two organizations, while the size of the node or circle indicates the number of publications. The bond is stronger the shorter the line. As a result, Figure showed that the red cluster (middle right) had the greatest number of members (57) among the organizations that conducted research on sustainable development and renewable energy. The Adnan Kesar School of Business led this red cluster in publication creation, while South Ural State's Department of Economics and Finance grabbed the top.

Figure 5 Journal publications on the renewable energy

There were 1439 articles overall across 86 distinct journals. While several journals encouraged a broad range of study topics and the interdisciplinary nature of studies on sustainable development and renewable energy, 37.97% (n = 36) of the journals had only published two papers. Furthermore, the visualization map of journal articles was created using VOS viewer (Figure 10) to provide a more direct representation of the journal finds.



The subdomains of renewable energy research are shown by the colour of the nodes, and the number of journal articles is indicated by the size of the nodes, as Figure 5 clearly shows. About thirty-six of the eighty-six journals were chosen for study in order to look into the relationship and cluster of the most productive journal because the threshold was set at nine. After examining Figure 5, the following conclusion was made: Energy economics, corporate strategy, the environment, and resource policy ranked second in one cluster of highly productive journal journals, followed by the Journal of Cleaner Production and so on. There is an extensive web of journal ties inside each cluster.

MAJOR CONCLUSIONS

Renewable energy is a sustainable solution for both the environment and the economy, reducing carbon emissions and reducing dependence on fossil fuels ("Renewable Energy, Energy Efficiency, Policy and the Environment Efficiency," 1998). Green finance, particularly for developing countries, is crucial for attracting private capital and cutting carbon emissions (Sharma & Choubey, 2022). To harness renewable energy's full potential, effective policies, innovative financing tools, and dedication to technological progress are needed. Renewable energy stands as a champion for both environmental sustainability and economic growth. Intergovernmental Panel on Climate Change research recognizes its critical role in reducing carbon emissions and combating global warming. Studies like (Hwang, Y. K. (2023), n.d.; Singh et al., n.d.) delve deeper, utilizing indexes like the Renewable Energy Transition Index (RETI) to showcase the region's progress.

A study that used 1500 keywords examined the phrases that appeared more than once in research publications about renewable energy. The keywords that performed best were "energy" and "renewable," with circles denoting related topics. In studies on renewable energy and sustainable development, the following ten keywords are most frequently used: green sustainability, energy utilization, alternative energy, environmental economics, and sustainable development. Analysis of cooperation patterns among authors, organizations, and countries writing on sustainable development and renewable energy was done using the co-authorship visualization available in the VOS viewer. Nearly, 58.3% of the 448 papers from 1439 different authors that were included in the study were given credit. The most fruitful co-authorships were those that connected the top ten writers of the paper. Studies on sustainable development have remained the leading subject, and after 2010, all ten writers with the strongest co-authorship ties produced papers. In the BRICS countries, the link between sustainable development and renewable energy is nuanced and dependent on regional factors. Both the use of fossil fuels and carbon emissions might be decreased by using renewable energy. To reconcile environmental goals, fair development, and economic progress, however, strong policy frameworks are required. While other emerging nations like China, Bangladesh, and Africa have effectively adopted policies, countries like India are using renewable energy to achieve their environmental targets. By increasing efficiency and integrating ICT, digitalization may accelerate economic success while reducing greenhouse gas emissions and climate concerns. It also gives a chance for synergistic growth with renewable energy. Authors, organizations, and nations work together extensively on research on renewable energy and sustainable development, including reoccurring topics like energy use and green sustainability. In Conclusion, it is a tale of two forces, intertwined and inseparable: renewable energy, the champion of a cleaner world, and digitalization, the engine of economic prosperity. Embracing their combined power, we can forge a

future were sustainability and growth dance in perfect harmony, painting a brighter tomorrow for all.

Policy implication:

Renewable energy is a promising solution for a sustainable future, promoting economic growth and environmental sustainability. However, it requires a coordinated approach. In summary, the following points highlight the significance of cooperation and information exchange among the BRICS countries to expedite the shift to sustainable energy sources and proficiently tackle worldwide energy challenges.

- Establish collaborative research initiatives focused on renewable energy technologies.
- Facilitate technology transfer and knowledge exchange among BRICS nations.
- Coordinate research agendas to address common challenges and leverage collective expertise.
- Support continuous innovation and technological advancements in renewable energy.
- Allocate funding and resources for joint research projects and innovation hubs.

Competing interest and Data availability statement

The author(s) declare that there are no competing financial or non-financial interests that could have influenced the work reported in this study. Publicly available datasets were analyzed in this study. The data supporting the findings of this research are available from the Scopus database. These data can be accessed through institutional subscription or directly from the official Scopus website.

REFERENCE

1. Aliabadi, D. E., Chan, K., … N. W.-A. at S., & 2023, undefined. (n.d.). Future renewable energy targets in the EU: Impacts on the German transport. Papers.Ssrn.Com. Retrieved December 22, 2023, from https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4418865
2. Banerjee, S., Jash, T., & Das, T. K. (1997). Integrated... - Google Scholar. (n.d.). Retrieved December 22, 2023, from https://scholar.google.com/scholar?hl=en&as_sdt=0%2C5&q=Banerjee%2C+S.%2C+Jash%2C+T.%2C+%26+Das%2C+T.+K.+%281997%29.+Integrated+rural+energy+planning+programme+in+West+Bengal.%E2%80%AFSESI+Journal%2C%E2%80%AF7%281%29%2C+1-6.&btnG=
3. Bhattacharya, M., Paramati, S., Ozturk, I., energy, S. B.-A., & 2016, undefined. (n.d.). The effect of renewable energy consumption on economic growth: Evidence from top 38 countries. Elsevier. Retrieved December 22, 2023, from https://www.sciencedirect.com/science/article/pii/S0306261915013318
4. Byrne, J., Shen, B., policy, W. W.-E., & 1998, undefined. (n.d.). The economics of sustainable energy for rural development: a study of renewable energy in rural China. Elsevier. Retrieved December 22, 2023, from https://www.sciencedirect.com/science/article/pii/S0301421597000992
5. Chakrabarti, S., Chakrabarti, S., … A. M.-… R. U.-I., & 2001, undefined. (n.d.). A study on the impact of the use of electricity on socio-economic activities and environmental awareness of the inhabitants of Sagar Dweep, an island in West. Isical.Ac.InS Chakrabarti, S Chakrabarti, A Majumder, R MukherjeeEconomic Research Unit-Indian Statistical Institute, 2001•isical.Ac.In. Retrieved December 22, 2023, from http://www.isical.ac.in/~eru/erudp/2003-10.pdf
6. Chopra, S. K. (1987). Integrated Rural Energy Planning... - Google Scholar. (n.d.). Retrieved December 22, 2023, from https://scholar.google.com/scholar?hl=en&as_sdt=0%2C5&q=Chopra%2C+S.+K.+%281987%29.+Integrated+Rural+Energy+Planning+Programme-Design+Programme+Contents+Implementation.%E2%80%AFUrja%2C+XXI+%282%29&btnG=
7. Das, T., Energy, S. B.-, & 1995, undefined. (n.d.). Energy technology choice in rural India. Elsevier. Retrieved December 22, 2023, from https://www.sciencedirect.com/science/article/pii/0360544295000085
8. Das, T. K., & Banerjee, S. (1995). Energy technology... - Google Scholar. (n.d.). Retrieved December 22, 2023, from https://scholar.google.com/scholar?hl=en&as_sdt=0%2C5&q=Das%2C+T.+K.%2C+%26+Banerjee%2C+S.+%281995%29.+Energy+technology+choice+in+rural+India.%E2%80%AFEnergy%2C%E2%80%AF20%287%29%2C+683-685&btnG=
9. Ghosh, S. (2002). Electricity consumption and economic... - Google Scholar. (n.d.). Retrieved December 22, 2023, from https://scholar.google.com/scholar?hl=en&as_sdt=0%2C5&q=Ghosh%2C+S.+%282002%29.+Electricity+consumption+and+economic+growth+in+India.%E2%80%AFEnergy+policy%2C%E2%80%AF30%282%29%2C+125-129&btnG=
10. Harjanne, A., policy, J. K.-E., & 2019, undefined. (2018). Abandoning the concept of renewable energy. Elsevier. https://doi.org/10.1016/j.enpol.2018.12.029
11. Hwang, Y. K. (2023). The synergy effect through combinati... - Google Scholar. (n.d.). Retrieved December 22, 2023, from https://scholar.google.com/scholar?hl=en&as_sdt=0%2C5&q=Hwang%2C+Y.+K.+%282023%29.+The+synergy+effect+through+combination+of+the+digital+economy+and+transition+to+renewable+energy+on+green+economic+growth%3A+Empirical+study+of+18+Latin+American+and+caribbean+countries.+Journal+of+Cleaner+Production%2C+418%2C+138146.&btnG=
12. Leal, P., Marques, A., Energy, J. F.-I. J. of, & 2018, undefined. (n.d.). How economic growth in Australia reacts to CO2 emissions, fossil fuels and renewable energy consumption. Emerald.ComPH Leal, AC Marques, JA FuinhasInternational Journal of Energy Sector Management, 2018•emerald.Com. Retrieved December 22, 2023, from https://www.emerald.com/insight/content/doi/10.1108/IJESM-01-2018-0020/full/html
13. Malik, S., management, P. S.-E. conversion and, & 1997, undefined. (n.d.). Data extrapolation techniques for energy systems planning. Elsevier. Retrieved December 22, 2023, from https://www.sciencedirect.com/science/article/pii/S0196890496000921
14. policy, L. N.-E., & 1997, undefined. (n.d.). Use of experience curves to analyse the prospects for diffusion and adoption of renewable energy technology. Elsevier. Retrieved December 22, 2023, from https://www.sciencedirect.com/science/article/pii/S0301421597001353
15. Rozakis, S., Soldatos, P. G., Papadakis, G., Kyritsis,... - Google Scholar. (n.d.). Retrieved December 22, 2023,

from https://scholar.google.com/scholar?hl=en&as_sdt=0%2C5&q=Rozakis%2C+S.%2C+Soldatos%2C+P.+G.%2C+Papadakis%2C+G.%2C+Kyritsis%2C+S.%2C+%26+Papantonis%2C+D.+%281997%29.+Evaluation+of+an+integrated+renewable+energy+system+for+electricity+generation+in+rural+areas.%E2%80%AFEnergy+policy%2C%E2%80%AF25%283%29%2C+337-347.++&btnG=

16. Saqib, N., Abbas, S., Ozturk, I., … M. M.-G., & 2024, undefined. (n.d.). Leveraging environmental ICT for carbon neutrality: Analyzing the impact of financial development, renewable energy and human capital in top polluting economies. Elsevier. Retrieved December 22, 2023, from https://www.sciencedirect.com/science/article/pii/S1342937X23002782
17. Sarafidis, Y., Diakoulaki, D., Papayannakis, L., Energy, A. Z.-R., & 1999, undefined. (n.d.). A regional planning approach for the promotion of renewable energies. Elsevier. Retrieved December 22, 2023, from https://www.sciencedirect.com/science/article/pii/S0960148198008088
18. Schumacher, E. (2011). Small is beautiful: A study of economics as if people mattered. https://books.google.com/books?hl=en&lr=&id=IKo3ALhVFKcC&oi=fnd&pg=PR2&dq=Schumacher,+E.+F.+(1973).%E2%80%AFSmall+is+beautiful:+A+study+of+economics+as+if+people+mattered.+Random+House.+&ots=izdJRPl37U&sig=NVwfLXiKjfjyQ_kgqKdvKpClL5g
19. Sebri, B., Salha, O., Sebri, M., & Salha, O. Ben. (2013). On the causal dynamics between economic growth, renewable energy consumption, CO2 emissions and trade openness: Fresh evidence from BRICS countries. Elsevier. https://www.sciencedirect.com/science/article/pii/S1364032114004857
20. Sharma, M., & Choubey, A. (2022). Green banking initiatives: a qualitative study on Indian banking sector. Environment, Development and Sustainability, 24(1). https://doi.org/10.1007/s10668-021-01426-9
21. Singh, A., Jyoti, B., … S. K.-I. J. of, & 2021, undefined. (n.d.). Assessment of global sustainable development, environmental sustainability, economic development and social development index in selected economies. Researchgate.NetAK Singh, B Jyoti, S Kumar, SK LenkaInternational Journal of Sustainable Development and Planning, 2021•researchgate.Net. Retrieved December 22, 2023, from https://www.researchgate.net/profile/Sanjaya-Lenka/publication/350427726_Assessment_of_Global_Sustainable_Development_Environmental_Sustainability_Economic_Development_and_Social_Development_Index_in_Selected_Economies/links/6066e370a6fdccad3f666a08/Assessment-of-Global-Sustainable-Development-Environmental-Sustainability-Economic-Development-and-Social-Development-Index-in-Selected-Economies.pdf
22. Singh, A., Jyoti, B., and, V. M.-E. E., & 2023, undefined. (n.d.). Policy implications from selected countries for a sustainable future of the society through green entrepreneurship and economic development. Igi-Global.ComAK Singh, B Jyoti, VK MishraEntrepreneurship Ecosystems and Their Opportunities and Challenges, 2023•igi-Global.Com. Retrieved December 22, 2023, from https://www.igi-global.com/chapter/policy-implications-from-selected-countries-for-a-sustainable-future-of-the-society-through-green-entrepreneurship-and-economic-development/330744
23. Sinha, C., Venkata, R., Policy, V. J.-E., & 1994, undefined. (n.d.). Rural energy planning in India: designing effective intervention strategies. Elsevier. Retrieved December 22, 2023, from https://www.sciencedirect.com/science/article/pii/0301421594901694
24. Weekly, L. A.-E. and P., & 1981, undefined. (n.d.). Financing New and Renewable Sources of Energy. JSTORL AliEconomic and Political Weekly, 1981•JSTOR. Retrieved December 22, 2023, from https://www.jstor.org/stable/4369837
25. Zouros, N., Contaxis, G., Policy, J. K.-E., & 2005, undefined. (n.d.). Decision support tool to evaluate alternative policies regulating wind integration into autonomous energy systems. Elsevier. Retrieved December 22, 2023, from https://www.sciencedirect.com/science/article/pii/S0301421504000187