

The Evolution of Energy Transition Research in the Brics Countries: A Bibliometric Perspective

Marcelo Santana Silva¹, Luís Oscar Martins^{2*}, Fábio Matos Fernandes³, Lucas da Silva Almeida⁴, Maria Cândida Arraes de Mirnada Mousinho¹, Ednildo Andrade Torres⁵

¹Federal Institute of Education, Science and Technology of Bahia, Salvador, Brazil, ²Federal University of Reconcavo of Bahia, Feira de Santana, Brazil, ³State University of Bahia, Salvador, Brazil, ⁴Institute of Regional Development, University of Granada, 18071, Granada, Spain, ⁵Federal University of Bahia, Salvador, Brazil. *Email: luisoscar@ufrb.edu.br

Received: 18 July 2025

Accepted: 07 October 2025

DOI: <https://doi.org/10.32479/ijeeep.21340>

ABSTRACT

The energy transition has become a central global agenda in addressing climate change. Given the geopolitical and environmental relevance of the BRICS group, this study investigates the evolution of scientific production on energy transition in countries comprising the bloc, including its new members. The main research question was: What are the academic trends and contributions regarding the energy transition in BRICS, considering its expanded composition? Based on a bibliometric approach, 63 articles published between 2005 and 2025 were analyzed from the Scopus and Web of Science databases. The Bibliometrix package in R was used to map authorship patterns, collaboration networks, sources, and keywords. The results show that China, India, and Brazil lead scientific output, while the new members remain absent from the main collaboration clusters. Central themes are concentrated on public policies for renewable energy and decarbonization, reflecting theoretical maturity in the field. However, significant gaps remain regarding energy governance and the academic inclusion of African and Middle Eastern countries. The main contribution of this study lies in systematizing the intellectual structure of energy transition research within the BRICS context, highlighting asymmetries, potentialities, and future directions for scientific and policy advancement on the topic.

Keywords: BRICS, Energy Transition, Renewable Energy, Thematic Mapping, Sustainable Development.

JEL Classifications: C0; C8; F0

1. INTRODUCTION

The international scenario witnesses a progressive reconfiguration of the global order, marked by shifts in the center of gravity of power poles, which has intensified with the rise of strategically articulated voices from the Global South. In this context, the BRICS consolidates itself as a space of growing influence in the directions of global governance.

The initial idea of the BRICS was formulated by Goldman Sachs' chief economist, Jim O'Neill, in a 2001 study titled "Building Better Global Economic BRICS" (O'Neill, 2001). Initially, the category of analysis included economic-financial, business, academic, and communication means. In 2006, the concept gave

rise to a grouping related to the foreign policies of Brazil, Russia, India, and China. In 2011, during the III Summit, South Africa became part of the group, which then adopted the acronym BRICS.

In August 2023, during the 15th BRICS Summit, Saudi Arabia, Egypt, the United Arab Emirates, Ethiopia, and Iran were annexed. These five nations were selected from a list of more than 20 candidate states, revealing global interest in the proposal. With the inclusion of these new members, the bloc also began to use the acronym BRICS+ (BRICS plus) (Liu et al., 2023).

BRICS holds strategic importance in the global economic scenario. Currently, the group accounts for 37% of the world's Gross Domestic Product (GDP), 42% of the population, 45% of the labor

force, and is home to one of the largest consumer markets on the planet (Jiang et al., 2022; Sun et al., 2022).

Furthermore, although historically developed countries have been primarily responsible for global greenhouse gas (GHG) emissions, in the last four decades, some developing nations have played an increasingly significant role in intensifying the climate crisis. This is the case for the BRICS countries, as four of its members - China, India, Russia, and Brazil - are among the five largest GHG emitters on the planet. Although South Africa is not among the global leaders in emissions, it stands out as the largest emitter on the African continent. The International Energy Agency (IEA, 2023), estimates that the bloc is responsible for 45.8% of the world's CO₂ emissions.

The incorporation of six new members into the bloc, including major fossil fuel producers such as the United Arab Emirates and Iran, may generate substantial impacts on efforts to mitigate the climate crisis. Given the urgent need to reduce emissions and implement robust public policies to transform current models of energy production, distribution, and consumption, the expanded BRICS plays a strategic role. Currently, the bloc's countries account for 43.1% of global oil production and hold 44% of the world's reserves. Regarding natural gas, the expanded group concentrates 53% of reserves and 35.5% of global production (IEA, 2023).

Thus, the energy transition, characterized by the progressive replacement of fossil fuel-based energy sources with renewable and sustainable energy matrices, has been one of the main global challenges of the 21st century (Xie et al., 2023). This process is driven by the need to mitigate environmental impacts, reduce GHG emissions, and ensure energy security in a context of increasing global demand for electricity (Hassan et al., 2024).

In this context, recent years have seen a rise in academic production related to the energy transition in BRICS countries, covering issues such as energy policies, investments in clean energy infrastructure, technological challenges, and socioeconomic impacts (Sun et al., 2022; Shahbaz et al., 2016; Tugcu and Tiwari, 2016; Roberts et al., 2018). China, for instance, has led the global transition to renewable sources, with massive investments in solar and wind power, while India has implemented policies to expand solar energy use (Sharma et al., 2022). However, there are significant disparities in the pace and strategies adopted by different BRICS countries, reflecting their economic and institutional specificities (Losekann and Tavares, 2021).

Although there is considerable research on energy transition and BRICS economies, a gap remains in the literature regarding academic production on the intersection of these two themes. Bibliometric studies can help fill this gap by identifying trends, leading authors, collaboration networks, and predominant approaches in energy transition research in BRICS countries. Understanding the development of this academic production is essential for guiding evidence-based energy policies and encouraging further research.

Given this, the present study proposes the following research question: What are the main trends and academic contributions on energy transition in BRICS countries, considering its new composition? To answer this question, the general objective of this research is to analyze academic production on energy transition in BRICS countries through a bibliometric approach. Specifically, it aims to: (i) Identify the main authors, institutions, and countries publishing on the topic; (ii) map international collaboration networks and their influence on knowledge dissemination; (iii) analyze predominant themes and conceptual advances in the field; and (iv) discuss challenges and future perspectives for research on energy transition in BRICS.

The relevance of this study is justified by three main factors. First, the energy transition is an essential theme for sustainable development and carbon emission reduction, especially in emerging countries with significant economic expression like those in BRICS. Second, the inclusion of new members in the bloc brings challenges and opportunities that have not yet been sufficiently explored in the academic literature. Finally, the use of a bibliometric approach enables robust, evidence-based quantitative analysis, providing a comprehensive view of research dynamics in this area. Thus, this study aims to contribute both to academia and to the formulation of more effective energy policies in BRICS countries.

2. BRICS AND THE ENERGY TRANSITION PROCESS

The energy transition has become a central theme on the global agenda as countries seek more sustainable ways to meet their energy demands and fulfill the Sustainable Development Goals (SDGs) established by the United Nations. In this context, BRICS emerges as an important actor. For this process to occur satisfactorily, it is necessary to analyze the potentialities and constraints of each BRICS country in the energy transition, taking into account the specificities of each economy and the actions already undertaken.

Brazil presents a diversified energy matrix, with a prominent role for hydropower, which accounts for 58.9% of the electricity produced in the country (EPE, 2024). Additionally, Brazil is a world leader in the use of biofuels, such as ethanol. These characteristics provide the country with a strategic advantage in the energy transition, as the biofuel sector has proven to be a viable and sustainable alternative for reducing greenhouse gas emissions (Alves et al., 2023; Marques et al., 2020; Martins et al., 2023). However, the country still faces challenges, such as its dependence on non-renewable sources, like oil, and the need for modernization and expansion of energy infrastructure.

Russia is one of the largest fossil fuel producers in the world, with a strong emphasis on natural gas and oil. This position provides the country with economic advantages but also represents an obstacle in the energy transition, as reducing dependence on fossil fuels is one of the central objectives of this process (Lanshina et al., 2018). Nevertheless, Russia has also invested in the development

of renewable energies, such as wind and solar energy, mainly in regions far from major urban centers. However, further investments are still needed for the country to fully leverage its renewable energy potential (Titova, 2019).

China is the largest energy consumer in the world and also one of the largest greenhouse gas (GHG) emitters (Lin and Xu, 2018). However, the country has heavily invested in renewable energy, becoming a global leader in installed solar and wind energy capacity. These investments have allowed a gradual reduction in dependence on non-renewable sources, such as coal. However, China still faces challenges such as the need to modernize its energy infrastructure and improve efficiency in the sector, as rapid economic growth has led to a significant increase in energy demand (He et al., 2016; Zhang et al., 2024).

India is another BRICS country facing significant challenges in the energy transition. With a growing population and an expanding economy, the country faces an ever-increasing energy demand (Miranda et al., 2021; Altenburg and Engelmeier, 2013). Currently, India relies heavily on coal to meet its electricity demand, contributing to negative environmental and climate impacts. Despite this, the country has made efforts to increase the share of renewable energy in its matrix, such as solar power (Altenburg and Engelmeier, 2013). India has set ambitious targets for renewable energy capacity, demonstrating its commitment to the energy transition. However, challenges remain, such as the availability of financial resources and the need to establish adequate infrastructure.

South Africa faces significant challenges in its energy transition process. The country has an energy matrix highly dependent on coal (Ouedraogo, 2019; Ribeiro et al., 2024). However, the country's renewable energy sector has been supported by several government policies, including the Renewable Energy Independent Power Producer Procurement Program, which has attracted significant investments in renewable energy projects (Arndt et al., 2018; Jain and Jain, 2017; Murombo, 2022).

South Africa has great potential for the development of hydroelectric power in its region, which could contribute to diversifying its energy matrix. However, it faces economic difficulties such as capital resource shortages and the need to modernize and expand its infrastructure.

Regarding the new members, their positions on energy contributions remain unclear. According to discussions at the 15th BRICS Summit, the countries expressed interest in expanding their economic boundaries, seeking to develop their commercial, promotion, and capital access dimensions.

Saudi Arabia, one of the world's major energy producers, has historically been dependent on fossil fuels (Derouez et al., 2024). However, the Kingdom of Saudi Arabia has acknowledged the importance of diversifying its energy matrix and promoting renewable energy sources. This shift is driven by environmental concerns, energy security, and the need to capitalize on its abundant renewable energy resources (Derouez et al., 2024). Saudi Arabia's

Vision 2030 includes goals to reduce fossil fuel use and increase the adoption of renewable energy (Rezk et al., 2020). The country is also exploring hydrogen production as a renewable energy alternative (Hasan and Shabaneh, 2022).

Egypt has made efforts to increase its renewable energy capacity, particularly in solar and wind energy. The country has launched several projects to attract investments in the renewable energy sector. The Egyptian government aims to diversify its energy sources and reduce its dependence on oil and gas.

The United Arab Emirates (UAE) has significantly invested in energy transition projects in recent years, including solar power plants. The country aims to increase the share of clean energy in its total energy matrix. The UAE has also been exploring hydrogen as a future energy source (Islam and Ali, 2024).

Ethiopia stands out for its hydroelectric potential and the projects under development in this area. The country also explores wind and solar energy and intends to become a reference exporter of renewable energy in the African region (Tiruye et al., 2021).

Finally, Iran, which faces challenges related to its energy transition due to international sanctions and economic restrictions. Despite these challenges, the country has been exploring renewable energy sources, particularly wind and solar energy (Noorollahi et al., 2021; Zahedi et al., 2022). And Indonesia, which has potential for hydroelectric, geothermal and solar generation. However, its share in the bloc's energy matrix is still relatively low.

In the face of the international context marked by the challenges of the energy transition and the implications of climate change, this article is justified as a relevant contribution to the field of studies by systematically analyzing the scientific production on the topic within the BRICS framework. The choice of this political-diplomatic group is due to its growing geopolitical importance, both in energy supply and demand, which makes it essential to understand how research has evolved in this strategic context.

3. METHODOLOGY

This section details the steps followed throughout the research. Initially, we present a brief description of the bibliometric research. Next, we justify the choice of information sources and describe the steps of the coding process, the metrics and approaches used in the bibliometric analysis, as well as the software used and the criteria established to obtain the corresponding results.

3.1. Bibliometric Analysis

Bibliometric research emerged in the early 20th century as an alternative approach to deepen the understanding of scientific production and communication, as well as to guide its development. This technique serves as a quantitative tool that allows for the evaluation of the past impact of the scientific activity of research institutions, while also anticipating its future potential. In general, bibliometric studies aim to highlight the orientation of research within a specific field of knowledge (Gautam, 2017; Martins et al., 2024).

This article adopts a retrospective approach and employs bibliometric analysis of secondary data. This method provides valuable insights for researchers interested in the evolution of scientific activity. Thus, bibliometric analysis based on keywords allows for a detailed examination of the main research topics within a specific field of knowledge (Chen and Xiao, 2016; Marques et al., 2020).

3.2. Database Selection

The sample of articles analyzed in this research was selected using keywords. The repositories used were Web of Science (WoS) and SCOPUS, which include articles from reputable journals, as well as books, book chapters, and conference papers. The selection of these databases was based on their interdisciplinary nature, the breadth of their collections, and, most importantly, their relevance to the research topic.

The main keywords used were “Energy Transition,” “BRICS Countries,” and “Renewable Energy Policy.” However, to enhance the specificity of the database, additional terms were included, such as “Low-Carbon Transition,” “Decarbonization,” “Clean Energy Policy,” and “Sustainable Energy Policy,” along with the inclusion of the countries currently comprising the bloc. It is important to note that, despite the use of two repositories (WoS and Scopus), the same search pattern was applied, with only the syntax adjusted according to the standard of each repository (in relation to strings and booleans). Additionally, only articles and review articles were selected, as they align more closely with the theme discussed in this paper.

Thus, the search was conducted in “topics” (which covers the search in the title, abstract, and keywords), using the boolean operators “AND” and “OR,” according to the search specificity. Therefore, for WoS, the syntax used was:

TS = (“Energy Transition” OR “Low-Carbon Transition” OR Decarbonization) AND TS = (“BRICS Countries” OR Brazil OR Russia OR India OR China OR “South Africa” OR Egypt OR Ethiopia OR Iran OR Indonesia OR “Saudi Arabia” OR “United Arab Emirates”) AND TS = (“Renewable Energy Policy” OR “Clean Energy Policy” OR “Sustainable Energy Policy”) AND DT = (Article OR Review)

Using the same standard, the syntax used in SCOPUS was as follows:

TITLE-ABS-KEY (“Energy Transition” OR “Low-Carbon Transition” OR decarbonization) AND TITLE-ABS-KEY (“BRICS Countries” OR Brazil OR Russia OR India OR China OR “South Africa” OR Egypt OR Ethiopia OR Iran OR Indonesia OR “Saudi Arabia” OR “United Arab Emirates”) AND TITLE-ABS-KEY (“Renewable Energy Policy” OR “Clean Energy Policy” OR “Sustainable Energy Policy”) AND (LIMIT-TO (DOCTYPE, “ar”) OR LIMIT-TO (DOCTYPE, “re”))

We mapped 90 articles (35 articles from WoS and 55 articles from SCOPUS). The pre-selected articles ranged from 2005 to 2025,

distributed across 16 knowledge areas defined by SCOPUS and 13 areas according to WoS. Finally, we checked for any document duplication in the sample, as several journals are indexed in both repositories. After this procedure, we eliminated 27 duplicate articles, leaving the research base with 63 publications specifically related to the theme discussed in this study.

After reading the abstracts of all the articles, we decided not to apply any further exclusion criteria and kept the current sample, as we found that all the selected works are relevant to the topic discussed in this research.

3.3. Coding Process

After collecting and performing a preliminary reading of the articles, we created two information databases, consisting of a “BibTeX” file (from SCOPUS) and a “txt” article (from WoS), both containing the full record of variables used in the analysis: Citation information (authors, document title, year of publication, source, volume, issue, page numbers, citations, document type, and publication stage); bibliographic information (affiliations, serial identifiers, editors, original language of the document, corresponding address, and abbreviated source title); abstract and keywords (author keywords and indexed keywords); and research funding details (number, acronym, and funder). After compiling both databases, we merged them to conduct the analysis in R software.

The richness of the collected metadata contributed to a deeper understanding of the dynamics of scientific production in the field of energy transition within the context of BRICS countries, as well as the collaborative networks and the main research focuses over time.

3.4. Indicators and Bibliometric Methods Used

We employed quantitative indicators to assess the productivity of countries, authors, and journals, considering the volume of publications, the number of citations, and the frequency of keywords. These indicators allow us to measure how regularly a study or researcher is referenced in other research, establishing connections between works, authors, research groups, countries, and key terms, according to the adopted method, and structuring the analysis based on the established metrics (Cobo et al., 2011; Zupic and Čater, 2015).

The units of analysis used were countries, authors, and keywords. For each unit of analysis, we used different indicators. For countries, we employed citation analysis. For authors, the methods chosen were citation analysis and co-citation. And for keywords, we utilized co-occurrence analysis.

Citation analysis considers the number of times a work is cited as an indicator of its influence. The premise is that authors, studies, and countries with more citations have a greater impact or involvement in the research area. Co-citation analysis, on the other hand, evaluates the frequency with which two works are cited together, using this relationship as a similarity criterion and identifying groups of authors frequently referenced in certain studies (Chen and Xiao, 2016; Martins et al., 2024).

Co-occurrence analysis of keywords allows the identification of the main terms used, indicating the primary research interests up to a given point, as well as future perspectives. In this work, we used co-occurrence analysis divided by specific parameters: Driving themes, niche themes, emerging themes, and basic themes. This separation identified which topics are at the center of scientific discussions, representing consolidated and highly relevant areas (driving themes), which are highly specialized and developed by specific research groups (niche themes), those that are in the early stages of exploration or are likely to lose relevance (emerging or declining themes), and those that constitute the conceptual and theoretical foundation of the field (basic themes). This classification provides a deeper understanding of the intellectual structure of the field of energy transition in the context of BRICS countries, pointing out strategic directions for future scientific investigations and highlighting gaps that still require more attention from the academic community.

3.5. Software Used

We used the R software, through the RStudio development environment, version 4.4.3, to run our analyses. The tool was chosen due to its flexibility, efficiency, and wide range of specialized packages in information science, such as Bibliometrix and Biblioshiny. Unlike commercial tools, R is open-source, allowing for greater customization of analyses and reproducibility of results. Furthermore, its ability to handle large volumes of data and generate advanced visualizations enables a deeper exploration of collaboration networks, publication impact, and research trends. Thus, the use of R provides a robust and accessible approach for conducting detailed and high-quality bibliometric analyses.

4. RESULTS AND DISCUSSION

This section presents the analysis and relevant discussions about the 63 articles used in this study. Both quantitative and qualitative analyses of the publications, as well as critical assessments of the literature, are conducted in the following sections.

4.1. Descriptive Analysis

This section examined and detailed the bibliometric characteristics of all 63 articles selected in the sample. The aim was to reveal the status and evolution of knowledge related to the energy transition process in the BRICS countries, including its new members.

4.1.1. Number of annual publications

The sample consisted of 63 articles from the WoS and SCOPUS databases. Only articles and review articles from various areas of knowledge, from 2005 to 2025, were considered. It is important to highlight the low production of articles at the beginning of the analysis period. There was a production gap between 2006 and 2010, which was repeated between 2012 and 2014. However, from 2018 onwards, we observed a greater interest in the topic, culminating in 15 publications in 2024, with a growing trend for the coming years.

The growth in publication rates since 2018 can be attributed to the occurrence of the 10th BRICS Summit, held in Johannesburg, South Africa (Xavier et al., 2018). The meeting established the

energy research cooperation platform of the bloc, strengthening relations in this sector. Furthermore, from the end of 2023, the inclusion of new members may have encouraged the proliferation of research on energy transition-related themes.

Figure 1 illustrates this dynamic, highlighting the periods, the number of studies and the trend in research evolution.

The sample includes the participation of 193 authors, resulting in an average of 3.22 authors/article. Eight publications have only one author. About 20.6% of the studies feature international co-authorship. A total of 242 author keywords are computed, with an average of 22 citations/article. Through the trend line, it was possible to calculate the average growth rate of publications at 11.6%/year.

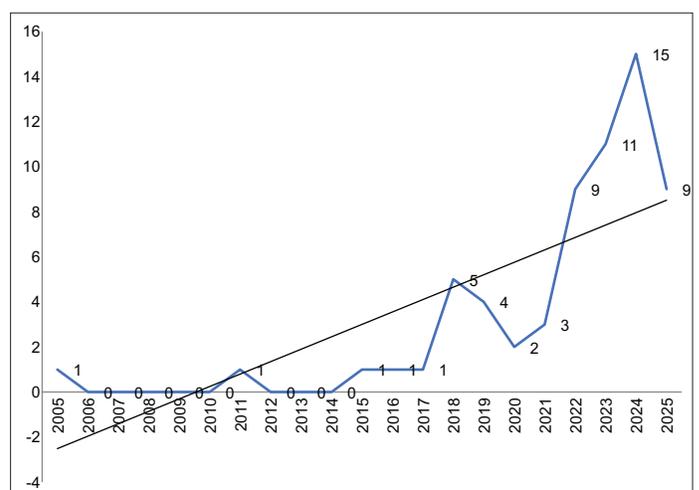
4.1.2. Origin of publications

Figure 2 illustrates the main countries where the studies were conducted, highlighting their distribution across continents. In this analysis, each publication was assigned to the country represented by the first author's institution. A total of 30 countries published articles, with four having three or more studies released.

Notably, China stands out with 27 publications. Brazil and India occupy the second position, with four publications each. Next comes Russia with three articles. China's leadership indicates the country's growing interest in diversifying its energy matrix and consolidating its transition process towards a low-carbon economy, despite still being one of the largest consumers of fossil energy sources (Lam et al., 2017; Wang et al., 2019; Miranda et al., 2021).

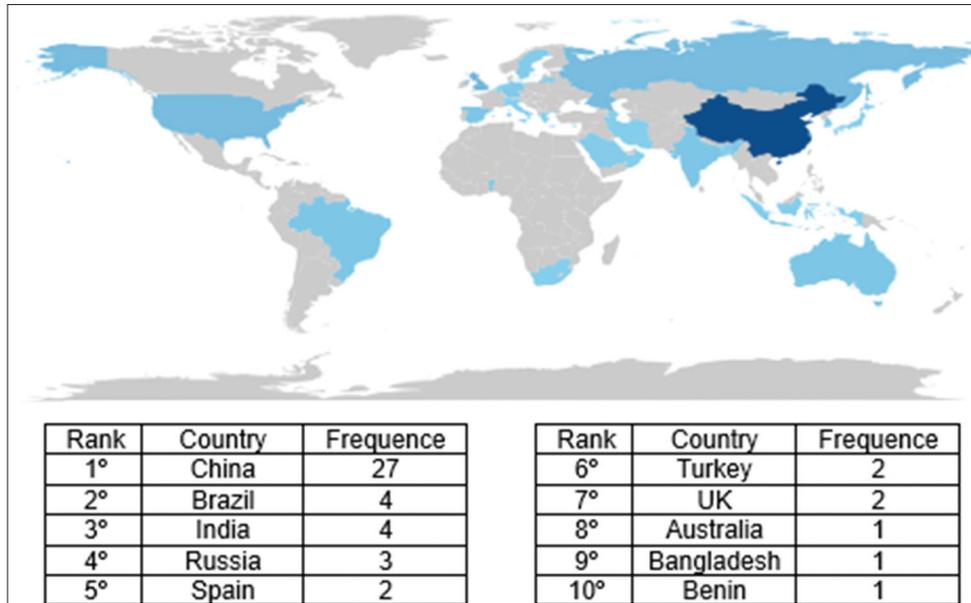
Curiously, South Africa does not stand out in scientific production on energy transition. A similar situation is observed among the new BRICS members (Egypt, Ethiopia, Iran, Indonesia, Saudi Arabia, and the United Arab Emirates), which do not appear in the list of countries with publications related to the theme of this research.

Figure 1: Articles published between 2005 and 2025 and evolution trend



Source: SCOPUS and WoS, 2025 – Prepared by the authors

Figure 2: Locations where the studies were developed



Source: SCOPUS and WoS, 2025 –Prepared by the authors

This finding may be associated with several structural, economic, and political factors. Firstly, these countries have economies heavily reliant on fossil fuels, as is the case for Iran, Saudi Arabia, and the United Arab Emirates, which may reduce the incentive for research on alternative energy sources (Tlili, 2015; Noorollahi et al., 2021). Additionally, limitations in academic and scientific infrastructure, coupled with low investments in research and development in this area, may restrict the production and dissemination of studies on the topic.

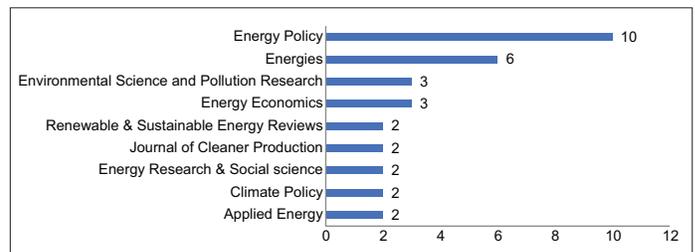
In nations such as Ethiopia, Egypt and Indonesia, more pressing socioeconomic challenges, like political instability, energy security, and access to electricity, may shift investment priorities away from energy transition research. In the case of South Africa, despite being the most industrialized country in the African continent, it still heavily depends on coal for electricity generation, which can impact the volume of studies on energy matrix diversification (Jiang et al., 2022). Finally, language barriers and the lesser integration of these countries into international research networks may hinder the indexing and visibility of studies that may already be under development on the subject.

4.1.3. Sources of publications

The list of journals included in the sample can be found in Figure 3. The analyzed articles are divided into 34 different journals. Four of these journals published approximately 35% of the total articles. This research allowed the identification of key journals, which can be considered reliable sources that add important points to research on energy transition and its relationship with BRICS.

Most of the articles were published in the journal Energy Policy (Elsevier). This journal has an impact factor of 9.3 (2024) and publishes articles both in open-access and subscription formats. It has been committed for over 50 years to disseminating research on energy efficiency, renewable energy, energy transition, and public

Figure 3: Publication sources



Source: Created by the authors

policies aimed at the energy sector—topics that are consistent with the purpose of this study.

The second prominent journal is Energies (MDPI). It is an open-access journal with an impact factor of 3.0 (2024). It has a focus similar to Energy Policy, publishing articles related to energy policy, energy efficiency challenges, and solutions for the use of renewable energies. Although the number of articles in other journals is smaller, they all share a common focus: The energy sector and the concern with energy use, conservation, and the environment.

4.1.4. Citation and co-citation analysis

According to the analysis, the publications are well distributed in terms of authors. The author who published the most specifically on the topic was Wang Y, with three articles. The other authors published up to two articles. However, the most cited author was Li L, with the article titled “Review and outlook on the international renewable energy development.”

The research discusses the situation of international energy development, focusing on the European Union, United States, Australia, India, Brazil, and China. Regarding the last three (members of BRICS), the research concludes that these nations

play a crucial role in the global energy transition, especially China and India, which lead in terms of capacity expansion, while Brazil continues to diversify its energy matrix with renewable sources such as solar, wind, and ethanol utilization (Li et al., 2022). Table 1 shows the authors, DOI of the most cited articles, total and average citations per year since the date of publication.

The relational citation analysis performed using the co-citation method allowed us to analyze and understand the structural relationships of theoretical-methodological connectivity of the research domain under study. Co-citation identifies the connection or similarity of two cited documents, through their frequency of joint occurrence in a list of references of citing authors (van Eck and Waltman, 2014).

Specifically in relation to the topic discussed in this study, the citation analysis showed a very isolated collaboration network. 12 clusters were identified, which work independently, although some research similar topics (Figure 4).

As mentioned, the network presents 12 clusters of authors, indicating different schools or areas of research on energy transition in BRICS. The sizes of the nodes reflect the frequency of co-citation; the longer the author's name, the greater his/her influence in his/her collaboration network. The lines connecting the nodes represent the strength of co-citations; in other words, thicker connections indicate that the authors are frequently cited together.

4.1.4.1. Analysis of publications from the main clusters identified in the co-citation network

The analysis of the publications of the authors highlighted in the co-citation network allows us to identify important contributions to the debate on the energy transition in the BRICS countries. Among the authors of the most influential cluster, Wang Y and Wang X stand out with works that address the impact of renewable energy, ecological governance and human development on sustainable growth.

In their research, Wang and collaborators conduct case studies on Chinese companies, highlighting their behavior in various aspects. For example, they highlight how environmental public policies encourage the financing of mergers and acquisitions (Yi et al., 2024) of Chinese companies, both nationally and internationally.

Table 1: Most global cited documents

Authors	DOI	Citations (C)	C/year
Li L, 2022	10.1016/j.enbenv.2020.12.002	242	60.50
Zhang D, 2022	10.1016/j.eneco.2022.106060	91	22.75
Cheng C, 2028	10.1016/j.rser.2018.06.033	76	9.5
Sareen S, 2018	10.1016/j.erss.2018.03.023	72	9.0
Kazimierzuk A, 2019	10.1016/j.rser.2018.12.061	69	9.86
Gatto A, 2021	10.1016/j.erss.2021.101977	68	13.6
Li W, 2019	10.1016/j.enpol.2018.12.054	63	9.0
Viswanathan B, 2005	10.1016/j.enpol.2003.11.002	61	2.9
Jiang B, 2023	10.1016/j.esr.2023.101118	48	16.0

Fonte: SCOPUS and WoS, 2025—Elaboração própria

Table 2 shows the 12 clusters and highlights the main authors and the central theme discussed by each of them.

Despite the isolation of the co-citation network, the analysis of the central themes of each cluster showed that a large part of the authors works with the impact of energy public policies on economic variables, such as energy consumption, economic growth and development, social inequality, and the energy transition process, both in BRICS member countries, especially the older members, and in developing nations. We also observed an absence of studies on energy transition in the new members.

Nevertheless, collectively, these studies provide a comprehensive view of the perspectives and challenges of the energy transition in BRICS countries. The authors argued that effective public policies, investments in production infrastructure, and financing strategies are necessary to ensure the energy transition process. The combination of these factors will enable the continuous transition to the use of renewable energy sources and lower CO₂ emissions, which can contribute to a more sustainable and robust energy model.

4.1.5. Keyword analysis

The keyword analysis identified the most recurrent words on the BRICS and energy transition theme. A total of 72 common terms were identified, subdivided into 14 clusters. According to the analysis, the keywords allowed for an understanding of the structure and evolution of the topic in the scientific field.

Table 2: Highlighted clusters and central theme discussed

Cluster	Main authors	Main theme
1	Wang X; Wang Y	Renewable energy, human development and CO ₂ emissions.
2	Li G	Impact of renewable energy support policies on promoting development.
3	Liu Z; Zhao C	Impacts of the adoption of renewable energy policies on the dynamics of carbon emissions.
4	Li X	Effectiveness of public renewable energy policies on decarbonization goals in the Chinese economy.
5	Biaou S; Assédé E	Public policies to encourage the use of bioenergy.
6	Abraham-Dukuma M	Energy transition in developing countries, especially BRICS members.
7	Du H; Brown M	Development of low-carbon economies and its relationship with inequality.
8	Cheung A; Cheung D	Impacts of public policies in different sectors on the consumption of renewable energy.
9	Bekun F; Ferreira P	Efficient use of natural resources and their impacts on energy consumption.
10	Bamisile O	Mitigation of environmental impacts and climate change and transition to a low-carbon economy.
11	Amarutha A	Effectiveness of renewable energy policies and their impacts on Indian consumption.
12	Barbosa M; Ciotta M	Impacts of promoting renewable energy policies on the energy transition process in South American countries.

Source: SCOPUS and WoS, 2025—Own elaboration

The keyword analysis was conducted according to the degree of centrality, which measures the level of connection between themes, and density, which measures the internal coherence of the term (within the cluster). High centrality means that the theme is important to the research field’s structure and has a high degree of connections. In contrast, high density indicates that the theme is at a mature stage of development, with high acceptance in the specialized literature.

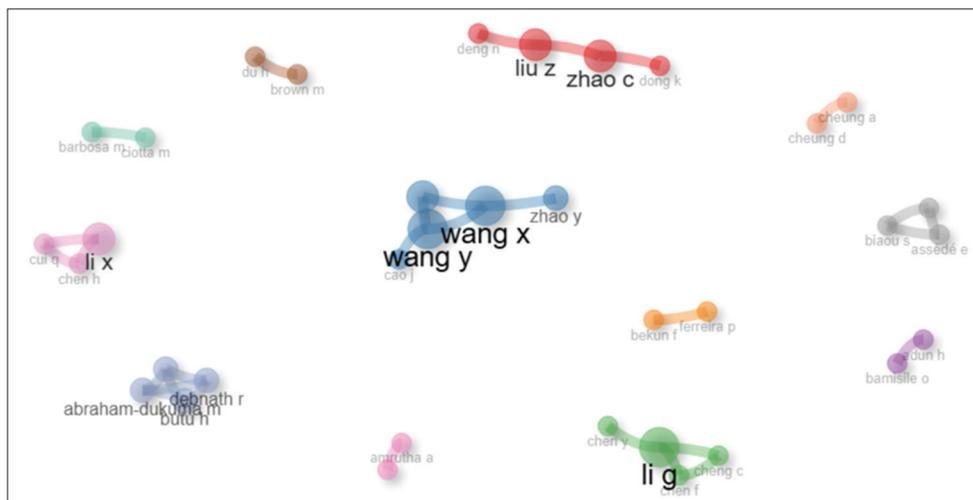
Themes with low centrality and density are considered isolated or peripheral and still emerging in terms of development, respectively. Figure 5 illustrates the main identified keywords according to their degree of density and centrality, further subdivided into motor themes (central and well-developed), niche themes (highly developed but isolated), basic or transversal themes (central but

still underdeveloped), and emerging or declining themes (poorly connected and underdeveloped).

In the upper right quadrant (motor themes) are the central and well-developed themes in the literature. They structure the knowledge field of energy transition in BRICS countries. These clusters highlight a strong emphasis on renewable energy policies, decarbonization, and energy efficiency, with a special focus on China as a central theme. The terms demonstrate the literature’s focus on public policies and incentives (such as feed-in tariffs) and how they can enable the replacement of fossil fuels with clean sources, contributing to greenhouse gas mitigation.

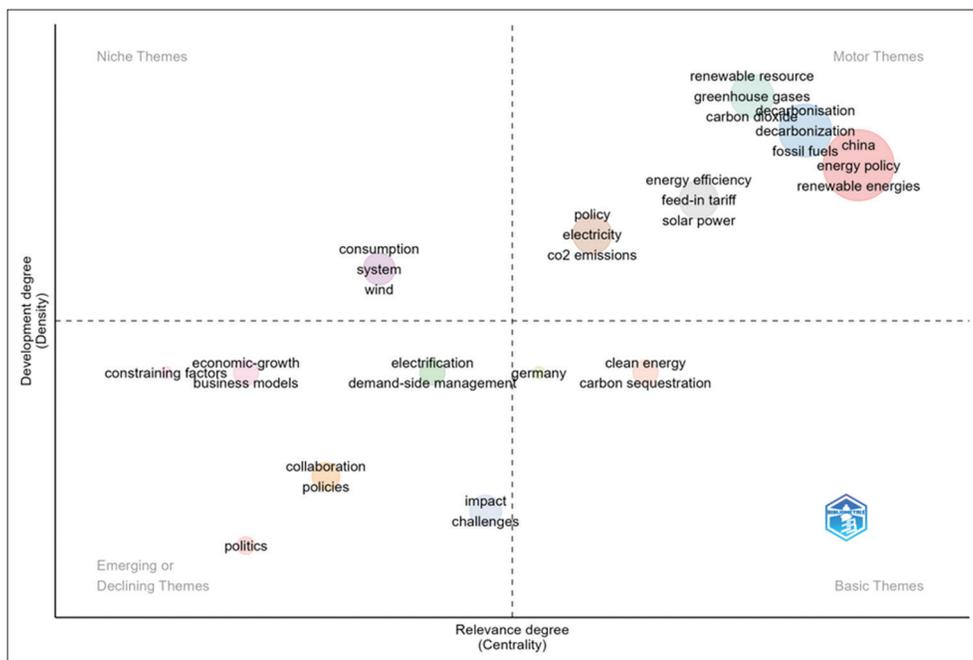
In the upper left quadrant are the so-called niche themes. The highlighted keywords were “consumption,” “system,” and

Figure 4: Co-citation network between authors



Source: SCOPUS and WoS, 2025

Figure 5: Thematic map of keywords: Conceptual framework of research on energy transition in BRICS countries



Source: SCOPUS and WoS, 2025 – Prepared by the author

“wind.” The term clusters refer to specific technical approaches to energy consumption and the integration of wind energy into energy systems. Although these are consolidated themes in methodological or empirical terms, they still do not exert a significant transversal influence in the broader debate on the energy transition process in BRICS.

The basic or transversal themes are located in the lower right quadrant. The main keywords were: “clean energy,” “carbon sequestration,” “Germany,” “electrification,” and “demand-side management.” These indicate concepts that present fundamental discussions for the consolidation of the energy transition. However, they still lack further theoretical and empirical development in the context of developing countries, especially in the case of BRICS. The emphasis on “Germany” represents a comparative reference, as seen in energy studies with a social focus, such as the article “Breaking barriers: An action framework for integrating gender into renewable energy policies in fossil-fuel-rich nations” (Heidari and Eshtiaghi, 2025), or research on spatial barriers to the implementation of renewable energies (Balagueman et al., 2023).

The lower left quadrant shows the emerging or declining terms. The most common keywords are “politics,” “collaboration,” “policies,” “impact,” “challenges,” “business models,” and “constraining factors.” The presence of these themes in this quadrant, especially “politics” and “collaboration,” which are even in the same cluster, suggests that there is still little depth in the political-institutional dimension of the energy transition in BRICS. Likewise, business models and economic growth aspects

seem to be critical points that need to be better connected to the dominant research agenda.

Table 3 shows the two main publications and associated authors for each quadrant and each key term. It also indicates the source and the year in which the articles were published, highlighting the evolution of the topics of interest in research on energy transition in BRICS.

4.2. Longitudinal Analysis

Based on the analysis of keyword co-occurrence, we identified the main themes of interest and future perspectives related to the BRICS energy transition process. By dividing the publications by quadrant (motor themes, basic themes, emerging or declining themes and niche themes), we were able to develop a time scale of interest in the themes, making it possible to identify trends in new studies. Figure 6 illustrates this perspective.

According to Figure 6, there is a clear trend for future research development in the ‘Motor Themes’ quadrant, that is, themes considered central and well-developed in the literature. Specifically, these are themes related to the development of public policies aimed at disseminating and encouraging the use of renewable energies. Publications on decarbonization and GHG reduction are also highlighted (Song et al., 2024; Yang et al., 2024; Wei et al., 2025).

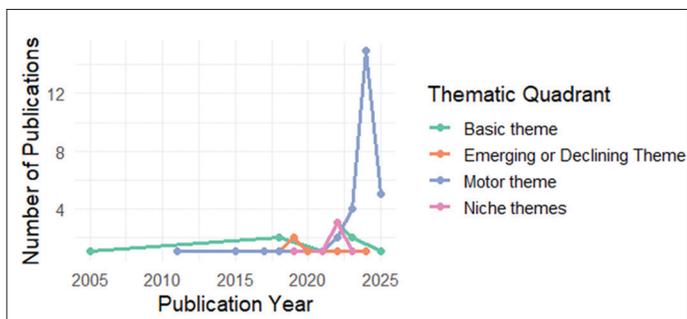
Basic themes, considered fundamental for the development of the topic but still lacking theoretical depth, also have some

Table 3: Thematic classification of the main scientific articles by quadrants of the thematic map

Title	Authors	Authors keywords	Year	Source	Thematic quadrant
Unveiling energy transition strategy: A deep dive into China’s ambitious renewable energy policy and its impact on carbon emission dynamics	Song C., Zhao C., Liu Z., Ma X., Yuan Y., Han X.	Policy input intensity, Policy modeling consistency, Renewable energy, System-Generalized method of moments.	2024	Journal of Cleaner Production	Motor Themes
The Current Status, Challenges, and Future of China’s Photovoltaic Industry: A Literature Review and Outlook	Wang F., Liu W.	Energy policies, Energy Security, Energy Transitions, Photovoltaic Industry.	2024	Energies	Motor Themes
Breaking barriers: An action framework for integrating gender into renewable energy policies in fossil-fuel-rich nations,” Heidari M.	Heidari M., Eshtiaghi M.	Decarbonization, Grounded theory, Renewable energy, SDGs, Women	2025	Energy Research and Social Science	Basic Themes
When renewable energy, empowerment, and entrepreneurship connect: Measuring energy policy effectiveness in 230 countries,” Gatto A.	Gatto A., Drago C.	Entrepreneurship boosting, Interval-based composite indicators, Renewable energy policy, Sustainable development	2021	Energy Research & Social Science	Basic Themes
The Brazilian renewable energy policy framework: instrument design and coherence	Fraundorfer M., Rabitz F.	Energy policy, instrument design, renewables.	2020	Climate Policy	Emerging or Declining Theme
What can we learn from the experience of European countries in biomethane industry: Taking China as an example?	Xue S., Zhang S., Wang Y., Wang Y., Song J., Lyu X., Wang X., Yang G.	Biogas Industry, Biomethane Industry, Energy market, Renewable energy policy.	2022	Renewable and Sustainable Energy Reviews	Emerging or Declining Theme
Policy mixes and the policy learning process of energy transitions: Insights from the feed-in tariff policy and urban community solar in Hong Kong	Mah D., Cheung D., Leung M., Wang M., Wong M., Lo K., Cheung A.	Policy learning, Renewable energy feed-in tariff, Policy mixes.	2021	Energy Policy	Niche Themes
Assessment of Clean Energy Transition Potential in Major Power-Producing States of India Using Multi-Criteria Decision Analysis	Indrajayanthan V., Mohanty N.	Fuzzy AHP, Multi-criteria decision Analysis.	2022	Sustainability	Niche Themes

Source: SCOPUS and WoS, 2025–Own elaboration

Figure 6: Future research perspectives on the energy transition process in BRICS



Source: SCOPUS and WoS, 2025–Prepared by the authors

prominence. According to the analysis, they do not have a large number of publications; however, they are always present in the time series. The most debated topics in these studies are related to the impact of renewable energy consumption in specific sectors and the response of energy consumption when incentive policies are implemented (Cheng et al., 2018; Sun et al., 2023).

‘Niche Themes’ and ‘Emerging or Declined Themes’ present distinct characteristics that deserve attention. Niche Themes correspond to highly specialized topics with high conceptual density but do not have strong connections with other central themes in the field. They are specific studies, usually conducted by specific research groups or focused on local realities, which have not yet been widely incorporated into the global energy transition debate. Despite this, they may represent potential areas of innovation or practical application in specific contexts, such as studies on the relationship between the energy transition process and sustainable development goals, or studies on a specific energy source and its possible impact on an eventual energy transition (Boute and Zhikharev, 2019; Jiang and Raza, 2023).

On the other hand, “Emerging or Declined Themes” reflect topics that are in the initial phase of theoretical development or that, on the other hand, have already lost relevance in the academic debate. In the context of the energy transition in the BRICS countries, these themes may be linked to recent discussions on energy governance, green financing mechanisms and the inclusion of African and Middle Eastern countries in the climate agenda. The low frequency of these themes throughout the time series suggests that they are still little explored in the scientific literature, but their recent emergence may indicate future trends and new research opportunities, especially considering the geopolitical and economic transformations involving the new BRICS members.

5. CONCLUSION

The present bibliometric research on energy transition in BRICS countries, based on the analysis of publications indexed in the Scopus and Web of Science databases, allowed us to identify trends, gaps, and perspectives in the field of study. The results obtained align with international literature but also present original contributions, especially when considering the new members of the bloc (Egypt, Ethiopia, Iran, Indonesia, Saudi Arabia, and the

United Arab Emirates), which are rarely explored in previous studies.

Among the findings that corroborate the literature, the centrality of themes such as “renewable energy transition,” “carbon emissions,” “economic growth,” “policy,” and “climate change” stands out, identified among the “motor themes.” These topics are widely present in recent works that analyze the interrelationship between energy transition and sustainable development, as demonstrated by (Jiang et al., 2022; Griffiths et al., 2023). The predominance of authors from China, India, and Brazil in scientific production also confirms previous bibliometric studies that point to these countries as leaders in research and development of sustainable energy solutions (Sun et al., 2023; Wang et al., 2019). The relevance of “basic themes,” such as the sectoral consumption of renewable energy and the effects of public policies on energy demand, reaffirms the multidisciplinary approach needed to face contemporary energy challenges (He et al., 2014; Liu et al., 2018).

However, the study also highlights findings that challenge the literature. The absence of some BRICS countries, such as South Africa, Egypt, Ethiopia, Iran, Saudi Arabia, and the United Arab Emirates in co-authorship networks and in central thematic clusters indicates an imbalance in the distribution of scientific production. Although these countries are geopolitically and energetically relevant, their scarce participation in academic debates on energy transition contradicts the expectation of engagement proportional to their productive capacities. Our results indicate that factors such as low scientific institutionalization, reliance on fossil fuels, and the absence of public policies aimed at research may explain this gap.

One of the main innovations of this study was the inclusion of the new BRICS members in the bibliometric analysis, which allowed for a clearer observation of the disparities in scientific involvement among the bloc’s countries. While China, India, and Brazil appear as knowledge-producing centers, the new members still do not participate significantly in the literature. This finding is relevant for thinking about international scientific cooperation policies and strengthening research capacities among BRICS countries, especially on the topic of energy transition. Moreover, the use of the thematic map tool, via Biblioshiny, enabled a refined classification of the keywords into four quadrants - motor themes, basic themes, emerging or decline themes, and niche themes - providing a dynamic analysis of thematic evolution and research focus over time.

The greatest contribution of this research, however, lies in the systematization of the main study themes on energy transition in BRICS, as well as the identification of trends and gaps for future investigations. By highlighting emerging themes - such as economic growth, sustainable financing, energy governance, and business models - the study broadens the scope of the current literature and guides new research focused on socioeconomic and institutional issues associated with energy transition. Furthermore, by demonstrating that there are countries in the bloc with little or no presence in scientific production on the subject, the research

points to the need for a more inclusive and diversified agenda, promoting the strengthening of academic production in contexts that are still peripheral in global science.

REFERENCES

- Altenburg, T., Engelmeier, T. (2013), Boosting solar investment with limited subsidies: Rent management and policy learning in India. *Energy Policy*, 59, 866-874.
- Alves, C.T., Hocevar, L.S., Martins, L.O.S., Fernandes, F.M., Coelho, R.S. (2023), Evaluation of energetic matrix scenario between Brazil, Germany, France and UK to attend net zero expectation: A bibliometric analysis. *Chemical Engineering Transactions*, 100, 583-588.
- Arndt, C., Hartley, F., Ireland, G., Mahrt, K., Merven, B., Wright, J. (2018), Developments in variable renewable energy and implications for developing countries. *Current Sustainable Renewable Energy Reports*, 5, 240-246.
- Balagueman, R.O., Assédé, E.S.P., Moumouni-Moussa, I., Soumanou, A.A., Biaou, S.S.H. (2023), Spatial disparities altered the determinants of biomass supply intention for clean energy: Policy implications. *Frontiers in Energy Research*, 11, 1239710.
- Boute, A., Zhikharev, A. (2019), Vested interests as driver of the clean energy transition: Evidence from Russia's solar energy policy. *Energy Policy*, 133, 110910.
- Chen, G., Xiao, L. (2016), Selecting publication keywords for domain analysis in bibliometrics: A comparison of three methods. *Journal of Informetrics*, 10, 212-223.
- Cheng, C., Chen, F., Li, G., Ristić, B., Mirchi, A., Qiyu, T., Madani, K. (2018), Reform and renewables in China: The architecture of Yunnan's hydropower dominated electricity market. *Renewable and Sustainable Energy Reviews*, 94, 682-693.
- Cobo, M.J., Herrera, F., Zupic, I., Čater, T., Ferreira, V.P., Martins, J., et al. (2011), Evolution of the social network of scientific collaborations. *Em Questão*, 32, 523-538.
- Derouez, F., Ifa, A., Aljughaiman, A.A., Bu Haya, M., Lutfi, A., Alrawad, M., Bayomei, S. (2024), Energy, technology, and economic growth in Saudi Arabia: An ARDL and VECM analysis approach. *Heliyon*, 10, e26033.
- Empresa de Pesquisa Energética (EPE). (2024), Balanço Energético Nacional (BEN). Rio de Janeiro: EPE. 2024. Available from: <https://www.epe.gov.br/pt/publicacoes-dados-abertos/publicacoes/balanco-energetico-nacional-ben> [Last accessed on 2025 Mar 20].
- Gautam, P. (2017), An overview of the Web of Science record of scientific publications (2004--2013) from Nepal: Focus on disciplinary diversity and international collaboration. *Scientometrics*, 113, 1245-1267.
- Griffiths, S., Sovacool, B.K., Furszyfer Del Rio, D.D., Foley, A.M., Bazilian, M.D., Kim, J., Uratani, J.M. (2023), Decarbonizing the cement and concrete industry: A systematic review of socio-technical systems, technological innovations, and policy options. *Renewable and Sustainable Energy Reviews*, 180, 113291.
- Hasan, S., Shabaneh, R. (2022), The Economics and Resource Potential of Hydrogen Production in Saudi Arabia. Riyadh, Saudi Arabia. Available from: <https://www.kapsarc.org/media/fqdnxgpy/the-economics-and-resource-potential-of-hydrogen-production-in-saudi-arabia.html> [Last accessed on 2025 Mar 20].
- Hassan, Q., Viktor, P., Al-Musawi, T.J., Mahmood Ali, B., Algburi, S., Alzoubi, H.M., Khudhair Al-Jiboory, A., Zuhair Sameen, A., Salman, H.M., Jaszczur, M. (2024), The renewable energy role in the global energy transformations. *Renewable Energy Focus*, 48, 100545.
- He, Y., Liu, Y., Wang, J., Xia, T., Zhao, Y. (2014), Low-carbon-oriented dynamic optimization of residential energy pricing in China. *Energy*, 66, 610-623.
- He, Y., Xu, Y., Pang, Y., Tian, H., Wu, R. (2016), A regulatory policy to promote renewable energy consumption in China: Review and future evolutionary path. *Renewable Energy*, 89, 695-705.
- Heidari, M., Eshtiagi, M. (2025), Breaking barriers: An action framework for integrating gender into renewable energy policies in fossil-fuel-rich nations. *Energy Research and Social Science*, 120, 103937.
- International Energy Agency (IEA). (2023), *World Energy Outlook*. Paris. Available from: <https://www.iea.org/carts> [Last accessed on 2025 Mar].
- Islam, M.T., Ali, A. (2024), Sustainable green energy transition in Saudi Arabia: Characterizing policy framework, interrelations and future research directions. *Next Energy*, 5, 100161.
- Jain, S., Jain, P.K. (2017), The rise of renewable energy implementation in South Africa. *Energy Procedia*, 143, 721-726.
- Jiang, B., Raza, M.Y. (2023), Research on China's renewable energy policies under the dual carbon goals: A political discourse analysis. *Energy Strategy Reviews*, 48, 101118.
- Jiang, Q., Rahman, Z.U., Zhang, X., Islam, M.S. (2022), An assessment of the effect of green innovation, income, and energy use on consumption-based CO₂ emissions: Empirical evidence from emerging nations BRICS. *Journal of Cleaner Production*, 365, 132636.
- Lam, L.T., Branstetter, L., Azevedo, I.M.L. (2017), China's wind industry: Leading in deployment, lagging in innovation. *Energy Policy*, 106, 588-599.
- Lanshina, T.A., "Skip" Laitner, J.A., Potashnikov, V.Y., Barinova, V.A. (2018), The slow expansion of renewable energy in Russia: Competitiveness and regulation issues. *Energy Policy*, 120, 600-609.
- Li, L., Lin, J., Wu, N., Xie, S., Meng, C., Zheng, Y., Wang, X., Zhao, Y. (2022), Review and outlook on the international renewable energy development. *Energy and Built Environment*, 3, 139-157.
- Lin, B., Xu, B. (2018), Factors affecting CO₂ emissions in China's agriculture sector: A quantile regression. *Renewable and Sustainable Energy Reviews*, 94, 15-27.
- Liu, X., Du, H., Brown, M.A., Zuo, J., Zhang, N., Rong, Q., Mao, G. (2018), Low-carbon technology diffusion in the decarbonization of the power sector: Policy implications. *Energy Policy*, 116, 344-356.
- Liu, Z., Wang, Z., Xu, M., Ma, J., Sun, Y., Huang, Y. (2023), The priority areas and possible pathways for health cooperation in BRICS countries. *Global Health Research and Policy*, 8, 36.
- Losekann, L., Tavares, A. (2021), *Transição Energética e Potencial de Cooperação Nos BRICS em Energias Renováveis e Gás Natural*. Available from: <https://repositorio.ipea.gov.br/entities/publication/8222e98b-e0c1-4c24-965c-cdb21dba40e> [Last accessed on 2025 Mar 20].
- Marques, R.S., Martins, L.O.S., Fernandes, F.M., Silva, M.S., Freires, F.G.M. (2020), Wind power and competitiveness: A bibliometric analysis. *Informação and Sociedade: Estudos*, 30(2), 1-37.
- Martins, L.O.S., De Oliveira, V.R.V., Lora, F.A., Fraga, I.D., Saldanha, C.B., Silva, D.T., Pereira, M.G.A., Silva, M.S. (2024), Geographic indications, sustainability and sustainable development: A bibliometric analysis. *Journal of Scientometric Research*, 13, 919-934.
- Martins, L.O.S., Amorim, I.R.D., Mendes, V.D.A., Silva, M.S., Mendonça Freires, F.G., Torres, E.A. (2023), Price and income elasticities of industrial electricity demand in Brazil: Estimates and implications of COVID-19. *International Journal of Energy Sector Management*, 18(4), 707-724.
- Miranda, I.T.P., Moletta, J., Pedroso, B., Pilatti, L.A., Picinin, C.T. (2021), A review on green technology practices at BRICS countries: Brazil,

- Russia, India, China, and South Africa. *Sage Open*, 11, 21582440211.
- Murombo, T. (2022), Regulatory imperatives for renewable energy: South African perspectives. *Journal of African Law*, 66, 97-122.
- Noorollahi, Y., Lund, H., Nielsen, S., Thellufsen, J.Z. (2021), Energy transition in petroleum rich nations: Case study of Iran. *Smart Energy*, 3, 100026.
- O'Neill, J. (2001), *Building Better Global Economic BRICs*. New York: Goldman Sachs Research. Available from: <https://www.goldmansachs.com/insights/goldman-sachs-research/building-better> [Last accessed on 2025 Mar 20].
- Ouedraogo, N.S. (2019), Opportunities, barriers and issues with renewable energy development in Africa: A comprehensible review. *Current Sustainable Renewable Energy Reports*, 6, 52-60.
- Rezk, H., Alghassab, M., Ziedan, H.A. (2020), An optimal sizing of stand-alone hybrid PV-fuel cell-battery to desalinate seawater at Saudi NEOM city. *Processes*, 8, 382.
- Ribeiro, J.X.F., Antwi, E., Shahreza, M.S., Oko, E., Albayati, I., Elseragy, A., Asamoah-Boateng, T., Aliyu, A.M. (2024), Renewable energy potential, production and utilisation in Africa. *Lecture Notes in Energy*, 100, 137-157.
- Roberts, R., Musango, J.K., Brent, A.C., Heun, M.K. (2018), The correlation between energy cost share, human, and economic development: Using time series data from Australasia, Europe, North America, and the BRICS nations. *Energies*, 11, 2405.
- Shahbaz, M., Rasool, G., Ahmed, K., Mahalik, M.K. (2016), Considering the effect of biomass energy consumption on economic growth: Fresh evidence from BRICS region. *Renewable and Sustainable Energy Reviews*, 60, 1442-1450.
- Sharma, G.D., Verma, M., Shahbaz, M., Gupta, M., Chopra, R. (2022), Transitioning green finance from theory to practice for renewable energy development. *Renewable Energy*, 195, 554-565.
- Song, C., Zhao, C., Liu, Z., Ma, X., Yuan, Y., Han, X. (2024), Unveiling energy transition strategy: A deep dive into China's ambitious renewable energy policy and its impact on carbon emission dynamics. *Journal of Cleaner Production*, 475, 143684.
- Sun, J., Xue, J., Qiu, X. (2023), Has the sustainable energy transition in China's resource-based cities promoted green technology innovation in firms? *Socio-Economic Planning Sciences*, 87, 101330.
- Sun, Y., Ajaz, T., Razzaq, A. (2022), How infrastructure development and technical efficiency change caused resources consumption in BRICS countries: Analysis based on energy, transport, ICT, and financial infrastructure indices. *Resources Policy*, 79, 102942.
- Tiruye, G.A., Beshu, A.T., Mekonnen, Y.S., Benti, N.E., Gebreslase, G.A., Tufa, R.A. (2021), Opportunities and challenges of renewable energy production in Ethiopia. *Sustainability*, 13, 10381.
- Titova, E.S. (2019), Biofuel application as a factor of sustainable development ensuring: The case of Russia. *Energies*, 12, 3948.
- Tlili, I. (2015), Renewable energy in Saudi Arabia: Current status and future potentials. *Environment, Development and Sustainability*, 17, 859-886.
- Tugcu, C.T., Tiwari, A.K. (2016), Does renewable and/or non-renewable energy consumption matter for total factor productivity (TFP) growth? Evidence from the BRICS. *Renewable and Sustainable Energy Reviews*, 65, 610-616.
- Van Eck, N.J., Waltman, L. (2014), Visualizing bibliometric networks. In: Ding, Y., Rousseau, R., Wolfram, D., editors. *Measuring Scholarly Impact*. Cham: Springer International Publishing. p285-320.
- Wang, F., Jiang, Y., Zhang, W., Yang, F. (2019), Elasticity of factor substitution and driving factors of energy intensity in China's industry. *Energy and Environment*, 30, 385-407.
- Wei, S., Yuan, P., Yu, R. (2025), Can renewable portfolio standard promote renewable energy capacity utilization? Empirical evidence from China. *Renewable and Sustainable Energy Reviews*, 210, 115159.
- Xavier, P.P.S., Alves, E.E.C., Steiner, A.Q., Dunda, F.F.E. (2018), Brazil-China energy cooperation: Did BRICS change anything? *Journal of China and International Relations*, 2018, 53-73.
- Xie, J., Xia, Z., Tian, X., Liu, Y. (2023), Nexus and synergy between the low-carbon economy and circular economy: A systematic and critical review. *Environmental Impact Assessment Review*, 100, 107077.
- Yang, L., Zhang, J., Li, X., Zhu, N., Liu, Y. (2024), The moderating effect of emission reduction policies on CCS mitigation efficiency. *Applied Energy*, 376, 124303.
- Yi, Z., Liu, H., Wang, Y., Chen, J. (2024), How does green finance policy affect firms' pro-environmental mergers and acquisitions? *Accounting and Finance*, 64(5), 4723-4748.
- Zahedi, R., Zahedi, A., Ahmadi, A. (2022), Strategic study for renewable energy policy, optimizations and sustainability in Iran. *Sustainability*, 14, 2418.
- Zhang, X., Khan, K., Shao, X., Oprean-Stan, C., Zhang, Q. (2024), The rising role of artificial intelligence in renewable energy development in China. *Energy Economics*, 132, 107489.
- Zupic, I., Čater, T. (2015), Bibliometric methods in management and organization. *Organizational Research Methods*, 18, 429-472.

ACKNOWLEDGEMENT

The author gratefully acknowledges financial support from the National Council for Scientific and Technological Development (CNPq), Brazil, through a Postdoctoral Fellowship (Grant No. 421143/2022-3).

We thank IFBA -Federal Institute of Education, Science and Technology of Bahia, for the financial support for this research.