Evaluation of Energetic Matrix Scenario Between Brazil, Germany, France and UK to Attend NetZero Expectation: a Bibliometric Analysis

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This work provides a comprehensive evaluation of the energy transition scenarios of four countries Brazil, Germany, France, and the UK in the context of climate change and the urgent need for decarbonisation and their efforts to achieve NetZero goals by 2030. The study adopts bibliometric analysis as a technical procedure to identify energy transition policies, research groups, and institutions, actions of private companies, and new perspectives and trends for future studies about NetZero. The analysis highlights the emergence of new technologies such as bioenergy, hydrogen-based systems, and renewable energy storage solutions, which are essential for achieving NetZero goals. It emphasizes the need to move beyond using fossil fuels more efficiently and instead, to adopt innovative approaches to decarbonise industries and transportation. The study highlights the emergence of new technologies such as hydrogen-based systems, renewable energy storage solutions, and advanced carbon capture and utilization methods, which have the potential to accelerate the energy transition. The circular economy is also emerging as a promising avenue for reducing waste and conserving resources. The research identifies block chain technology as a potential tool for facilitating carbon offset trading, while artificial intelligence can be used to optimize energy consumption. Collaboration between governments, research institutions, and private companies is essential for driving progress in the field and achieving NetZero goals. Overall, this research provides valuable insights and a starting point for further studies on NetZero and decarbonisation.

1. Introduction

Since the beginning of "net zero" term in the 2000s, this model has grown and acquired importance around the world as a concept in renewable energy goal, with the aim of explaining energy systems that produce the same amount of energy as they consume (Liu et al., 2023; Dyudnev et al. 2021). Between 2008 and 2015, this concept began to be applied to other fields, including buildings and urban development, with the main idea that it is possible to produce as much renewable energy as is consumed in these buildings (Matana Júnior et al., 2023). In 2015, the Paris Agreement has been signed at the United Nations Conference on Climate Change (COP21) and this was an important step in the global framework against climate change. The agreement included a goal to limit global temperature rise to "less than 2 degrees Celsius above pre-industrial levels" and "efforts to limit the rise to 1.5 degrees Celsius" (Brecha et al., 2022; Schleussner et al., 2022). In 2016, the International Energy Agency (IEA) released the "Energy Policy for a Clean Future", which included the concept of "net zero" as a goal to limit greenhouse gas (GHG) emissions and protect the environment. Three years later, in 2019, the European Union announced its goal of achieving carbon neutrality by 2050, which means that its net GHG emissions will equal zero. In 2020, several countries, including UK, Japan and Canada, have announced their targets to achieve carbon neutrality by the mid to late 21st century. Since then, the "net zero" policy has been

widely discussed and implemented around the world and is considered one of the main tools for dealing with climate change and protecting the environment. France and Germany have been making efforts to achieve the carbon neutrality goals established at COP21 and the proof of this are the robust investments directed at sectors following to energy production, such as the diversification of technologies to produce renewable energy that provide greater carbon sequestration, increase the biodiversity and the reforestation (Sadhukhan, 2022). Regarding Brazil, so far, the country has not formally adhered to the IEA's "net zero" policy. However, the country has taken important steps to reduce its greenhouse gas emissions and increase its clean energy production capacity. For example, the generation of renewable electrical energy has increased significantly in recent years, especially from sources such as wind and solar energy. (Dalbem et al., 2014; Dranka and Ferreira, 2020). In addition, the country has invested in forest conservation and carbon sequestration projects (Tejada et al., 2019). Bibliometrics, a very actual method of brief and analysing, can be used for exploring the structure, characteristics and laws of a subject by studying the distribution, scalar relationship and change regulation of literature and information (Mao et al. 2018). With the help of this method, the hot spots, and trends of scientific research on the direction of the greenhouse gas emissions to achieve the "net zero" efforts could be summarized. In this work, a bibliometric analysis of selected papers, based on the keywords used ("Net Zero carbon" OR "Net-zero carbon" OR "Zero Carbon" OR "Carbon Neutrality" OR "Zero Emissions Climate Neutrality" OR "Greenhouse Gas Emissions Reduction" OR "Carbon Mitigation Strategies" OR "Climate Change Mitigation"), were retrieved from the Web of Science (WoS) database and the choice of this database was due to its multidisciplinary nature and scope. Main research topics included were energy efficiency, zero energy building, life cycle assessment, embodied energy, building simulation, and residential buildings.

1. Methodology

Bibliometric research refers to a technique that emerged at the beginning of the 20th century, as an alternative to the demand for further studies and evaluations regarding scientific production, communication, and its direction. It can be used as a quantitative tool to assess the past contribution to science by research entities and to predict their future research potential as well. Bibliometric studies aim to demonstrate the direction of science in each field of knowledge (Gautam, 2017). This work is characterized as retrospective and employs a bibliometric analysis of secondary data. This type of analysis generates a useful information for researchers to evaluate the evolution of scientific activity examining bibliographic material from an objective and quantitative perspective that demonstrates to be effective in organizing information within a specific field (Albort-Morant; Ribeiro-Soriano, 2016). Therefore, a bibliographic analysis using keywords allows the analysis of details on the main research topics contained by a delimited relationship domain of a given research area (Chen and Xiao, 2016). This work used the criteria suggested by Castillo-Vergara; Alvarez-Marin and Placencio-Hidalgo (2018): a) description of the subject of study; b) database selection and treatment; c) adjustment of search criteria; d) codification of the selected material and e) analysis of the information generated.

1.1 Database selection

The selected papers, based on the keywords used, were retrieved from the Web of Science (WoS) database and the choice of this database was due to its multidisciplinary nature and scope. According to Thelwall (2018), the tool indexes peer-reviewed academic titles, open access titles, conference proceedings, among others and it has about 12,000 scientific journals. This work analysed publications from 2000, the year in which the first result for the term "net zero" was given, until 2022. The search loop used was: TI=("Net Zero carbon" OR "Net-zero carbon" OR "Zero Carbon" OR "Carbon Neutrality" OR "Zero Emissions Climate Neutrality" OR "Greenhouse Gas Emissions Reduction" OR "Carbon Mitigation Strategies" OR "Climate Change Mitigation"). The search was only on the title, due to the specificity of the theme and the differences between "net zero" implementation policies among the countries studied. Only publication in English were requested and initially, the search sent 2,111 works, which were qualitatively analysed. Also, it was applied the "Keyword Plus" search feature, for greater robustness to the search and as a result, 577 works on the topic of interest were selected.

1.2 Coding process

Afterwards data collection, a single evidence base was created, consisting of a simple Excel file in "CSV" format, containing a complete record of the variables used for analysis: author, language, year of publication, type of research, country of origin, research field, keywords and references cited in each of the publications selected in the database selection step. To generate the thematic maps and improve the results obtained, the open access software VOSviewer (Waltman and van Eck, 2012). A frequent problem in bibliometric and systematic literature reviews is the way in which authors are identified. For example, the same author can be cited in different ways, making the process of identifying citations and collaborations difficult, causing, in some situations, problems of

double counting. To avoid this difficulty, a thesaurus file was also formatted, standardizing the authors' citation format.

2. Results and discussion

Figure 1 provides information on the distribution of publications related to a specific research topic from 2000 to 2022. A total of 2,092 articles were identified through a basic search of publications, with an average of 11 publications annually until 2010. However, from 2011, there was a 35% annual increase in the number of publications, resulting in 606 publications in 2022. The UK has the highest number of publications on the topic with 218, followed by Germany (149), the United States (68), China (53), France (45), and Brazil (25).
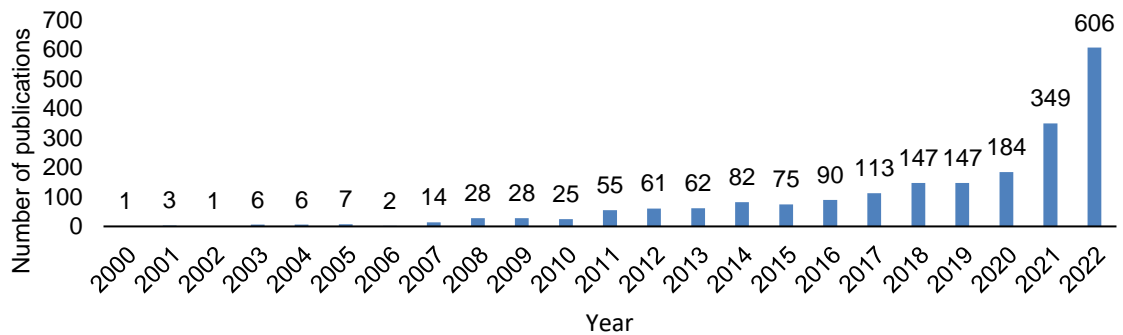

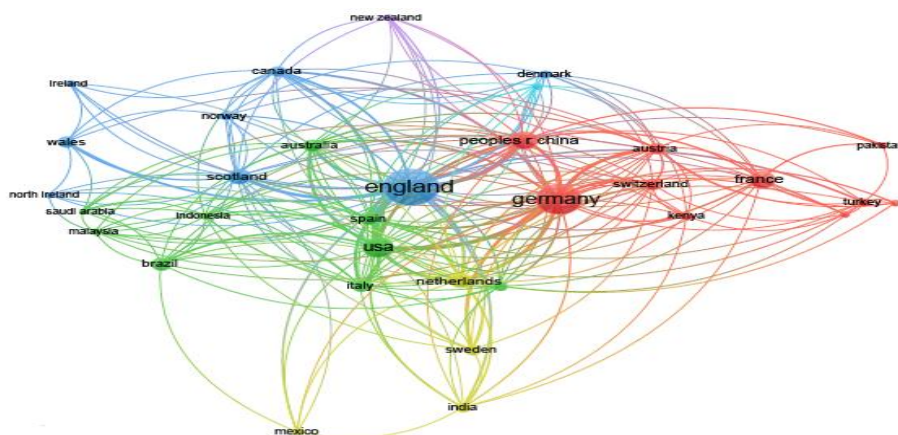Figure 1 – Number of publications (2000 a 2022)

Figure 2 – Most relevant countries on "net zero"

Figure 2 shows that the UK and Germany are the countries with the most research on this topic. In the UK, the main areas of interest are Environmental Sciences (39.5%) and Environmental Studies (29.6%). The focus is on strategies to achieve NetZero goals and the development of new technologies for generating renewable energy. In France and Germany, the main concerns are mitigating climate change and reducing greenhouse gases. In Brazil, where the country has not formally adhered to the "net zero" policy, most publications focus on developing public policies to contain climate change and reduce emissions. Climate change has become a major global concern in recent years, with governments, businesses, and individuals seeking ways to reduce greenhouse gas emissions and mitigate its impact. One of the strategies being pursued is achieving NetZero emissions, where the amount of greenhouse gases emitted is offset by their removal from the atmosphere. To achieve this goal, there is a need for the development of new technologies for generating energy from renewable sources, as well as the implementation of policies to reduce emissions. This has led to an increase in research on the topic, with various countries focusing on different aspects of the problem. France and Germany, for instance, are primarily concerned with mitigating climate change and reducing greenhouse gases, while Brazil is focused on developing public policies to contain climate change and reduce emissions. In this regard,

Table 1 shows the top three papers published from each country according to the number of citations. There are several factors that may contribute to the high number of publications on renewable energy in England and Germany. One possible reason is that both countries have implemented strong policies to promote renewable energy, which has led to significant growth in this sector. Another factor is that both countries have strong research institutions and universities with a focus on renewable energy research, which attracts talented researchers from around the world. Additionally, both countries have a history of technological innovation, which has helped to spur the development of new renewable energy technologies. Finally, there may be cultural and social factors that have encouraged people in these countries to be more environmentally conscious and interested in renewable energy.

Table 1: Paper published x number of citations

Country	Author	Year	Citations
Germany	Kabisch et al.	2016	466
Germany	Creutzig et al.	2015	377
Germany	Havlick et al.	2014	320
UK	Powlson et al.	2014	464
UK	Warren et al.	2013	217
UK	Powlson et al.	2016	215
France	Aguilera et al.	2013	262
France	Peeters & Dubois	2010	207
France	Dechezlepretre et al.	2011	200
Brazil	Soares et al.	2010	422
Brazil	Serrano et al.	2019	94
Brazil	Cifuentes et al.	2001	87
Total			**3,331**

Font: Authors.

Scientific collaboration is a strategic key to advancing research on complex issues such as climate change and achieving net-zero emissions. However, the co-authorship analysis conducted in this work revealed a low incidence of collaboration among researchers in this field. Co-authorship in the energy field is of great importance because it facilitates the exchange of knowledge, expertise, and resources among researchers. Collaborative work allows for a broader range of ideas and perspectives to be considered, leading to more innovative and effective solutions to energy challenges. By pooling resources, researchers can also access larger and more diverse datasets, which can lead to more robust and reliable research findings. Nevertheless, it is noteworthy that interest in this subject has significantly increased over the last decade, with researchers around the world awakening to the urgency of the issue. As shown in Figure 3, a small collaboration network exists between researchers, but connection rates remain low. The most commonly used keywords in publications on this topic were "energy", "emissions", "policy", and "impact". However, recent publications, particularly from 2020, have seen the emergence of new terms such as "economic-growth", "energy-consumption", and "mitigation", highlighting the growing concern of countries, including Brazil, France, the UK, and Germany, in achieving established emission reduction targets. Figure 4 illustrates the changing profile of keywords used over the last five years, as shown by the heat map of the most commonly used terms. Renewable fuels and energy innovation have become increasingly important topics in the efforts to combat climate change and achieve sustainable development. Brazil, France, the United Kingdom, and Germany are among the countries at the forefront of this movement, with a significant focus on research and development in this area. In Brazil, the focus has been on the development of biofuels, with the country being a major producer of sugarcane ethanol. Research has also been conducted on the use of biomass and wind power to generate energy. The Brazilian government has implemented policies to promote the use of renewable energy sources, and has set targets to increase the share of renewable energy in the country's energy mix. In France, there has been significant research on renewable energy technologies such as solar and wind power. The country has also made significant investments in nuclear energy, which is considered a low-carbon energy source. However, the French government has recently announced plans to reduce its reliance on nuclear energy and increase the share of renewables in its energy mix. The United Kingdom has set ambitious targets to achieve net-zero emissions by 2050, and renewable fuels and energy innovation play a critical role in achieving this goal. The country has been a leader in offshore wind power, and has also made significant investments in hydrogen fuel cell technology.

In addition, the UK government has implemented policies to support the development of renewable energy sources and encourage innovation in this area. Germany has been a leader in the development of renewable energy technologies, particularly in the area of solar power. The country has set targets to phase out nuclear power and increase the share of renewable energy in its energy mix. The German government has also implemented policies to promote the use of renewable energy sources and support research and development in this area. Overall, Brazil, France, the United Kingdom, and Germany are all making significant efforts to promote renewable fuels and energy innovation, as part of their wider efforts to address the pressing issue of climate change.

Figure 3 – Co-authorship Analysis

Figure 4 – Keywords co-occurrence analysis

3. Conclusions

In conclusion, this study highlights the urgent need to increase the use of renewable sources in the energy matrices of Brazil, Germany, France and the United Kingdom to achieve a scenario of zero emissions by 2030, even with the expected growth in energy demand.

The analysis suggests that the addition of Brazil's current installed capacity to the current electricity matrix of Germany, France and the United Kingdom, within ten years, is necessary to achieve a 70% share of renewable energies in the electricity generation matrix. The geographic and climatic conditions of the countries analyzed provide a significant potential for generating renewable energies, and there is immense potential for producing green hydrogen for energy purposes, which can help achieve the goal of "net zero" emissions by 2030. However, this study also raises important questions regarding the feasibility and economic viability of a 100% renewable electrical system by 2030 and the impact of climate change on the energy sector. Additionally, it raises the question of which other technologies may become important to meet the future energy demand of the countries until 2030. Overall, this work emphasizes the importance of considering the future we want with energy, development, and renewable sources, and the need for ongoing research and innovation efforts to address these challenges. However other bullet point needs to be still investigated between these countries such as funding sources and their impact on research output and innovation in the field of renewable energy and case studies of successful renewable energy projects and initiatives in each country, highlighting best practices and lessons learned, evaluation of public awareness and attitudes towards renewable energy in each country, and their potential impact on adoption and implementation of renewable energy technologies.

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