

Nuclear Energy and the Sustainable Development Goals: A Bibliometric Perspective on Global Research Trends

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RESUMO

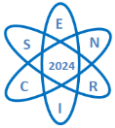
This bibliometric analysis investigates research on environmental sustainability in the context of nuclear energy, based on publications sourced from the Web of Science database. The study examines metrics such as country, year, journal, Sustainable Development Goals (SDGs), and influential authors. Findings reveal Italy as the leading contributor, followed by Austria, Germany, Brazil, and Australia, underscoring a significant European focus on nuclear energy and sustainability. Brazil's involvement suggests a growing interest from developing nations, underscoring the global scope of this research. The analysis identifies key publication years, including 2012, 2013, 2020, 2022, and 2023, reflecting links to global events and shifts in climate policy; notably, 2022 was chosen due to the lack of earlier specific publications in this field. The sustained output from 2012 to 2023 highlights consistent academic interest in integrating nuclear energy with environmental sustainability. This research aligns closely with SDG 13, "Climate Action," underscoring the critical role of nuclear energy in reducing carbon emissions. Other pertinent SDGs include SDG 6, "Clean Water and Sanitation," SDG 7, "Affordable and Clean Energy," and SDG 14, "Life Below Water," reflecting the interdisciplinary nature of this research, which addresses critical areas in energy, water resources, and marine sustainability. Overall, this analysis emphasizes the global and interdisciplinary nature of nuclear energy research, highlighting its pivotal role in advancing environmental sustainability and supporting SDG targets, particularly in climate change mitigation.

1. INTRODUCTION

Bibliometrics has become an indispensable tool for the quantitative analysis of scientific output, enabling the assessment of progress and trends across various domains of knowledge [1], [2], [3]. Within the framework of the Sustainable Development Goals (SDGs), bibliometric analysis provides valuable insights into how research aligns with global objectives, such as climate change mitigation, access to clean energy, and environmental preservation [4], [5]. In the nuclear, this analysis is particularly pertinent, given the strategic role that nuclear energy plays in the transition towards a more sustainable future.

Utilising the Web of Science (WoS) database, which offers extensive coverage of high-quality scientific publications [6], [7], [8], alongside VOSviewer software for the visualisation and analysis of networks, allows for a comprehensive understanding of the connections between nuclear research and the SDGs [9]. This approach facilitates the identification of collaboration patterns, key areas of study, and the influence of specific countries and authors in advancing sustainable nuclear practices. By mapping the nuclear field through these resources, it is possible not only to quantify scientific output but also to uncover the interdisciplinary dynamics that drive sustainable development in this critical sector.

Environmental sustainability and nuclear energy are increasingly intertwined within the global discourse on sustainable development [10]. This study conducts a detailed bibliometric



analysis of research publications to explore the relationship between nuclear energy and environmental sustainability. The analysis considers the geographical distribution of research, publication trends over time, alignment with the United Nations SDGs, publication and citation trends, co-authorship networks among authors, and international collaboration between countries.

2. METHODOLOGY

All documents were selected from the Web of Science (WoS) - Core Collection (Clarivate Analytics) in August 2024. This database was chosen for its comprehensive and reliable international repository of academic articles. Keywords such as "Sustainable Development Goal" and "Nuclear Field" were used, along with filters for the years 2015 to 2024, document type (articles), and the English language.

The study examines publication trends, citation patterns, and the distribution of research across various countries and scientific journals. Additionally, it analyzes the alignment of these publications with specific SDGs and identifies the most influential authors in this domain. The primary Sustainable Development Goals of interest include SDG 13 (Climate Action) and SDG 7 (Affordable and Clean Energy).

3. RESULTS

Figure 1 illustrates publication trends (depicted by light purple bars), showing a steady increase up to 2021, peaking at six publications. Post-2021, there is a decline, with reduced numbers in 2023 and a lower projection for 2024. Citations (represented by the dark blue line) exhibit a similar trend, rising continuously from 2019 to peak in 2021 with approximately 140 citations. From 2022 onwards, citations begin to decrease, mirroring the decline in publications.

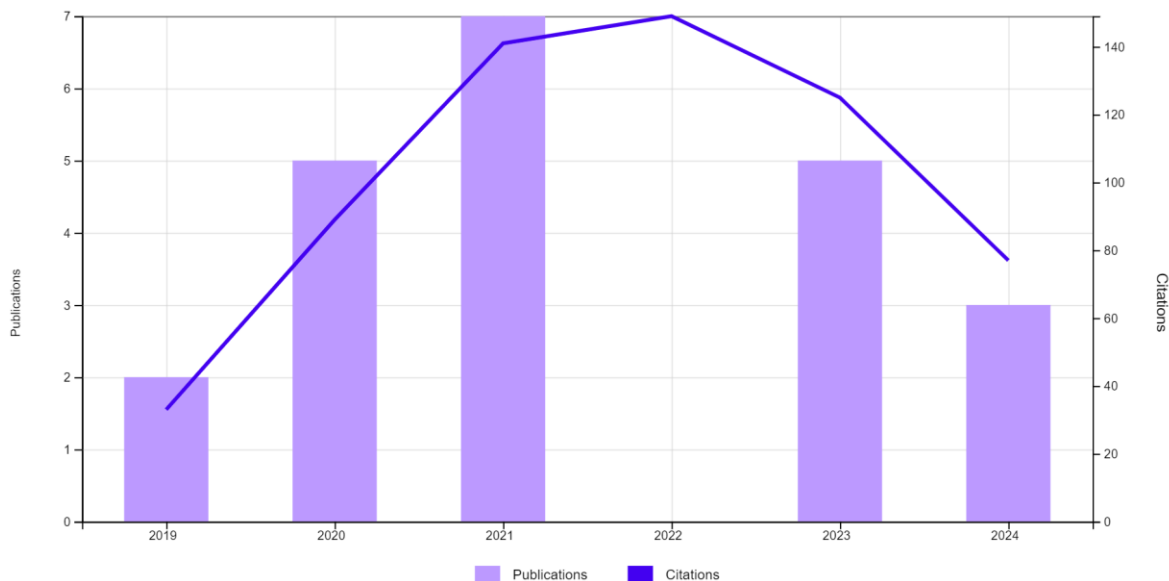
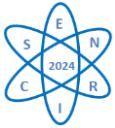


Fig. 1. Publication trends.

In 2020 and 2021, there was notable growth in both publications and citations, indicating increased interest and impact in research during this period. However, a decline in both metrics post-2021 suggests potential exhaustion of topics or a shift in research focus. There



is a clear correlation between the number of publications and citations, with higher publication output leading to greater visibility and citation rates.

Figure 2 depicts a dense co-authorship network, with nodes representing authors and lines indicating their collaborative relationships. The thickness of the lines reflects the frequency of these collaborations; thicker lines denote more frequent collaborations. Central authors such as Mikael Odenberger, Lisa Goransson, Johan Rootzen, and Alla Toktarova are prominent, suggesting their crucial role in facilitating research partnerships. These central figures have numerous connections, indicating their leadership in collaborative projects. Additionally, the network shows sub-groups of closely connected authors, highlighting specific research teams or laboratories that frequently collaborate on scientific publications.

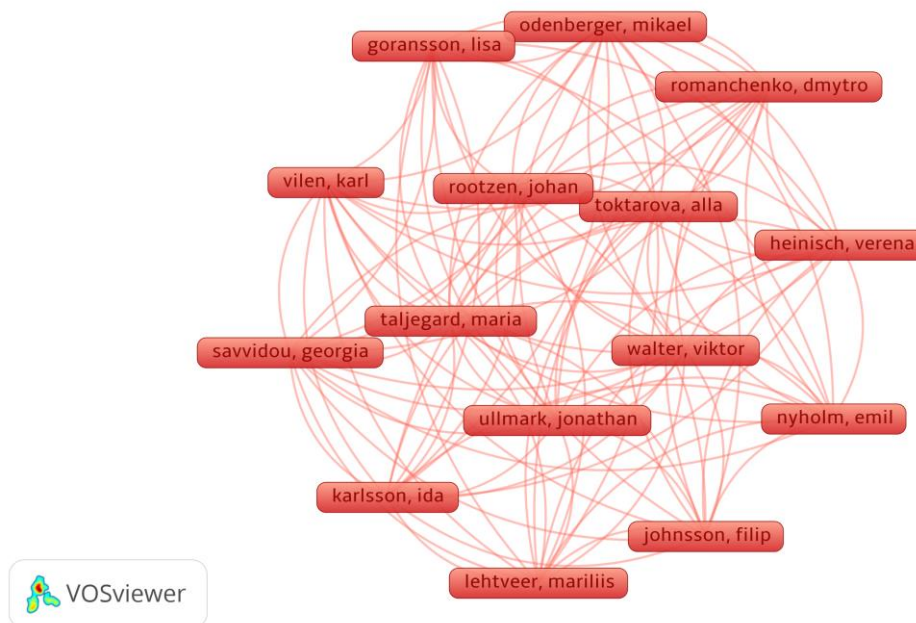


Fig. 2. Co-authorship and authors network visualisation.

China and India emerge as the most central and influential countries in the co-authorship network, highlighted in yellow, reflecting their substantial role in international scientific collaborations. China, prominently positioned at the centre, demonstrates extensive connections with other nations. The United States, Netherlands, Indonesia, and Germany are also significant contributors, though less influential than China and India. Brazil, Canada, and Turkey, while less prominent, still play important roles. The network illustrates global collaboration across continents, including Asia, Europe, North America, and South America. Countries such as Ukraine, Scotland, and Lebanon, while involved, have less impact, and Bangladesh, Poland, and Italy show lower co-authorship densities (Figure 3).

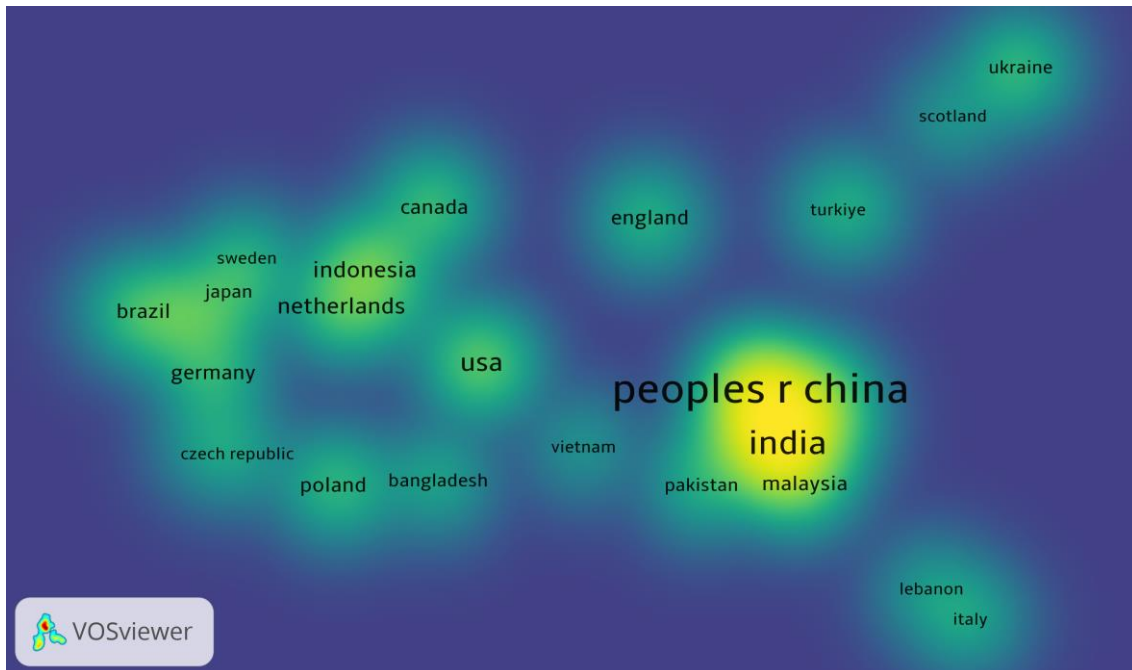
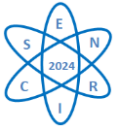


Fig. 3. Co-authorship and country density visualisation.

This underscores the critical role of international collaboration in scientific research, with China and India emerging as leading global contributors in co-authorship. It illustrates the geographical distribution of collaborations, revealing how various countries are interconnected, thereby advancing scientific progress through global cooperation. This depiction also highlights the increasing influence of emerging nations, such as China and India, in generating scientific knowledge through collaborative efforts with other countries.

The VOSviewer analysis of citation types and source units reveals key insights into the academic landscape of nuclear energy and environmental sustainability (Figure 4). Setting a minimum document threshold of three across a sample of 50 sources, three sources met the citation threshold, underscoring their influence within the field.

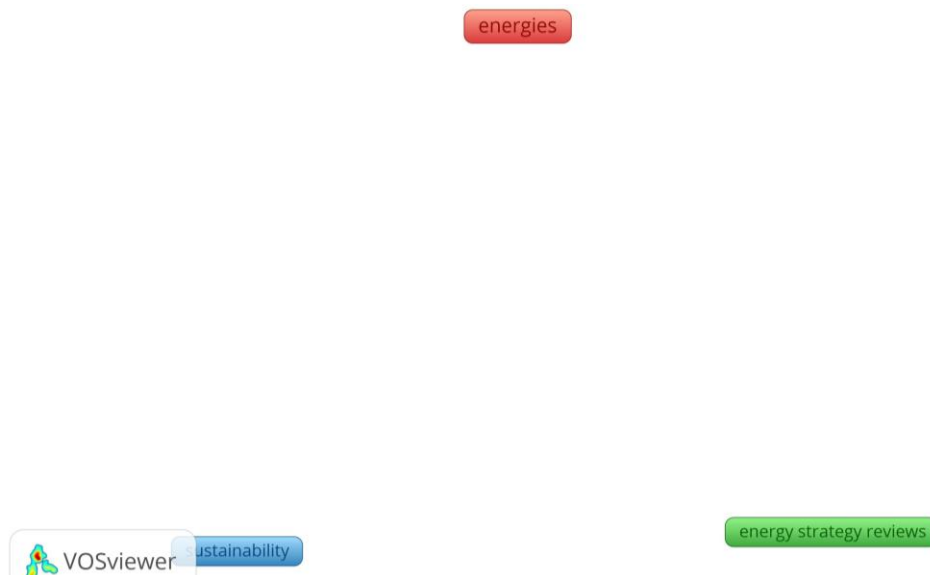


Fig. 4. Citation and Sources visualisation.



The analysis identified three primary journals central to the publication of studies: *Energies*, *Energy Strategy Reviews*, and *Sustainability*, with 5, 3, and 3 documents, respectively. These journals reflect a broad interdisciplinary approach, with *Energies* leading in impact, accumulating 61 citations, followed by *Sustainability* with 26, and *Energy Strategy Reviews* with 4. The significant citation count for *Energies* highlights its prominent role as a foundational source in this research domain, suggesting a strong academic endorsement and an established repository of knowledge on sustainable energy strategies. These findings underscore the concentrated influence of these sources and affirm their essential role in advancing research on nuclear energy's intersection with sustainability.

4. CONCLUSION

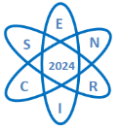
This bibliometric analysis underscores the critical and growing global academic focus on the nexus between nuclear energy and environmental sustainability. The alignment with SDGs, particularly SDG 13, highlights nuclear energy's pivotal role in mitigating climate change.

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