BIBLIOMETRIC ANALYSIS OF THE CURRENT STATE OF RESEARCH IN THE FIELD OF ENERGY CLUSTERS AT THE INTERNATIONAL LEVEL

Anna HORZELA-MIŚ

Faculty of Organisation and Management, Silesian University of Technology; anna.horzela@polsl.pl,
ORCID: 0000-0003-2345-9861

Introduction: At each stage of the research development cycle for a specific discipline or sub discipline, taking into account the global nature of the knowledge dissemination process and the dynamics of change, researchers ask themselves questions about potential areas of research, the degree of intensity of research conducted so far, leading research centers and scientists in a given research field. Bibliometric is a tool that allows to answer the above questions. The bibliometric analysis allows us to discover the current state of a research field, identify the principal authors, articles, and topics, and propose future research lines to develop it further.
Aim of the paper: The aims of the article is to present the results of bibliometric analysis of scientific research on issues of energy cluster, published between 1914 and 2022 in the Web of Science Core Collection and Scopus database.
Materials and methods: The articles were analyzed quantitatively, and by word and author co-occurrence. The author also showed in the paper among other things: documents per years by sources, documents by country or territory, the most popular publishers, document types or years with the highest number of published papers on energy clusters. Keywords analysis of bibliometric data indexed in this two databases is the main research method applied to conduct the study. The method of systematic literature review is used to outline the theoretical background of the study.
Results and conclusions: This study shows that interest in energy clusters has been growing steadily over the years in many scientific fields. Conducted bibliometric analysis has shown that the greatest interest, where energy clusters gain importance, are scientific articles (almost 80%), in which the Journal of Chemical Physics has a clear advantage. The analysis in the future should be expanded to include additional indicators. Therefore, the presented analysis is preliminary and should be the subject of further research.

Keywords: bibliometric method, energy cluster, research, Scopus, Web of Science Core Collection.

1. Introduction

Given the global nature of the knowledge dissemination process and the dynamics of change, at each stage of the research development cycle for a specific discipline or sub-discipline, researchers ask themselves questions about potential areas of research and the degree of its intensity. Bibliometrics is a tool that helps to answer the above questions. It is a set of research techniques for the quantitative analysis of publications, including scientific publications and patent documents.

The purpose of the article is to present the results of bibliometric analysis on the issue of energy cluster. The presentation of the results of the analysis focuses on scientific publications on energy cluster in 1914-2022 in one of the largest world scientific bases, i.e. Web of Science Core Collection and Scopus. Keyword analysis of bibliometric data indexed in this database is the main research method used to conduct research. Articles published in 1914-2022 were analysed quantitatively and according to the co-occurrence of words and authors. Further analysis allowed the identification of leading research centers publishing articles on energy cluster and selected key authors dealing with the studied subject. The work also analyses the period in which energy cluster topics were most popular and the areas that most often relate to the studied issue. The Web of Science Core Collection and Scopus databases also allowed to point out the type of publication and specific titles of publishers with the largest number of publications with the keyword energy cluster. The first part of the paper describes the research method from a theoretical perspective.

2. Methodology

Bibliometrics is a set of research techniques used for quantitative analysis of publications, including scientific publications and patent documents (Klincewicz, Zemigala, 2012). Bibliometric analysis also assumes the quantification of documentary information streams and the use of quantitative indicators of various databases reflecting the state of science or its specific fields (Marszakowa-Szajkiewicz, 2009). Bibliometrics or, more broadly, scientometrics, can also be treated as a separate research discipline in scientometrics, dealing with research into the development of science as an information process. Typical practical applications of bibliometrics include analysis of research and development activities, performed due to the needs of persons managing entities in the R&D sector and formulating scientific or innovation policy (Klincewicz, Zemigala, 2012). Figure 1 shows the types of issue discussed.

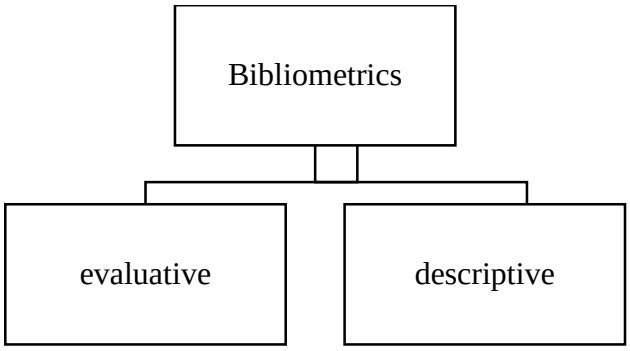

Figure 1. Types of bibliometrics. Adapted from: "*Bibliometrics in technology management and research.*" by K. Klincewicz, M. Zemigala, M. Mijal (2012), Ministry of Science and Higher Education, Warsaw, p. 14.

Evaluative bibliometrics focuses on the assessment of research centers or selected researchers and is based primarily on indexes of study citations. Descriptive bibliometrics is used in the analysis of trends published in scientific research, identification of relevant researchers or research centers (Zemigala, 2014).

Bibliometric analysis uses bibliographic indicators to analyze the most critical literature in a particular field of research (Santos et al., 2011). Bibliometric analysis allows to discover the current state of the research field, identify the main authors, articles and topics, and propose future research directions for its further development (González-Serrano et al., 2020). In bibliometric and scientometric research, great importance is attached to the analysis of networks, for example documents, keywords, authors or magazines (Franceschini et al., 2016; Albareda, Hajikhani, 2019). Clustering and mapping techniques are often used to study such networks (Bartolacci et al., 2020). The purpose of these techniques is to provide insight into the network structure. These techniques are helpful in finding answers to the questions (Waltman et al., 2010):

- What are the main topics or main research fields within a certain scientific area?
- How do these topics or areas relate to each other?
- How has a particular scientific field developed over the years?

The most important advantages of bibliometric analysis include (Ejdys, 2016):

- Obtained results are simple to interpret.
- They present quantitative data that is precise and consistent.
- They allow testing of both small and very large data sets.
- They are non-invasive – they can be made repeatedly based on available bases.
- They are based on publications and citations.
- They have a small interval between the time of conducting analysis and receiving their results.
- They allow analysis to be carried out by persons not involved in the research (Klincewicz et al., 2012).

This article includes bibliometric analysis of information on scientific publications from 1914-2022 (as of November 25, 2022) available in one of the largest scientific publications in the world in terms of the number of scientific databases, i.e. Web of Science Core Collection and Scopus. The study analyses all articles published in the index of Web of Science Core Collection™ (SSCI, SCI-Expanded, A & HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH and ESCI) on the subject of energy cluster in all available areas. The data from Web of Science Core Collection were compare with data from Scopus because there are some of the most accepted databases for collecting and analysing scientific articles.

The article uses descriptive bibliometrics. Scientific publications were searched for in the subject line, which includes the abstract, title, keywords of authors and keywords suggested by the database. The search word was energy cluster. The conclusions resulting from the analysis should be treated with great caution and the following analysis should be seen as one of the possible perspectives of researching scientific activity on energy cluster and should be supplemented with a more detailed analysis of data from both the Web of Science Core Collection, Scopus and other available, recognized world bases.

The analysis focused on data on scientific activity and related indicators, such as the number of scientific publications in individual years, the most popular areas in which publications on energy cluster were noted, type of publication and the most frequently appearing titles, authors of publications and centers that most often publish energy cluster-related materials. The article attempts to apply bibliometric analyzes to the concept of energy cluster and discusses the main limitations associated with conducting this type of analysis.

3. Results

3.1. Web of Science Core Collection

The Web of Science Core Collection database lists a total of 210,771 scientific papers related to the term "Energy cluster". Narrowing the search to Author keywords or title or abstract, 104 736 results were obtained. The database shows that the dominant form of presentation is the article (87 334 articles), proceedings papers (20 745), review articles (2554 works) and early access - 492. In the Web of Science Core Collection database there are also other types of publications such as chapters in books, editorials, notes, discussions, etc., but their number is small. Figure 2 presents the most popular publication types for the studied concept.

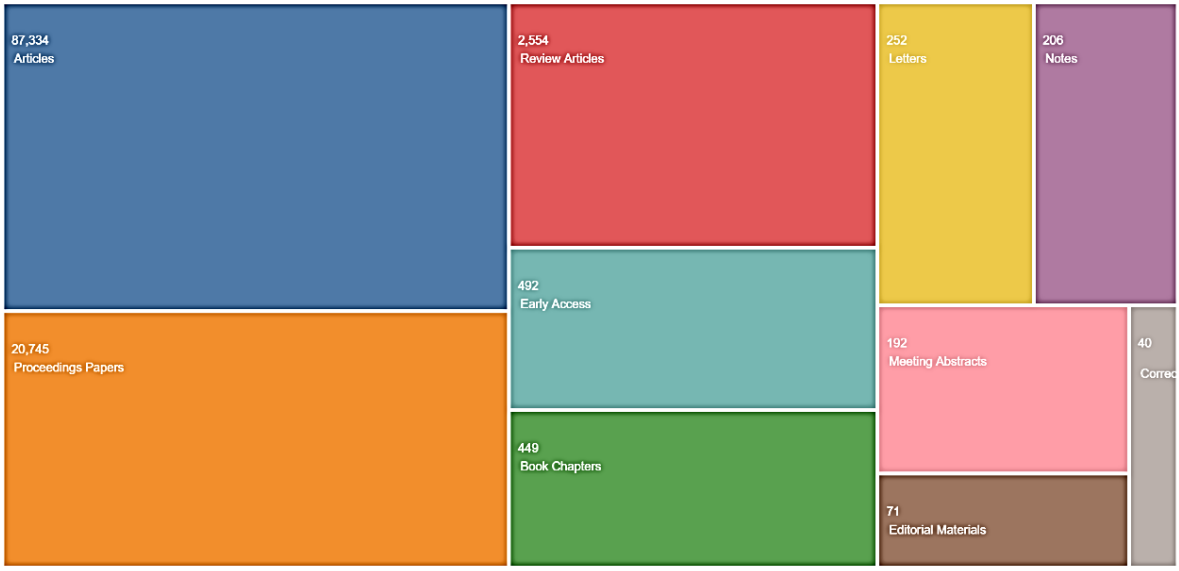

Figure 2. Document types.

Adapted from: "Web of Sciece".

Considering the areas in which the above-mentioned papers were most frequently published, according to the Web of Science Core Collection division, the most frequent areas include:

- Chemistry Physical.
- Physics Atomic Molecular Chemical.
- Materials Science Multidisciplinary.
- Physics Applied.
- Enineering Electrical.
- Physics Condensed Matter.
- Astronomy.
- Computer Science.

When performing a bibliometric analysis of the term energy cluster, it is also worth taking a detailed look at how interest in this area has evolved over the years. Figure 3 presents the development of the term energy cluster between 1998 and 2022.

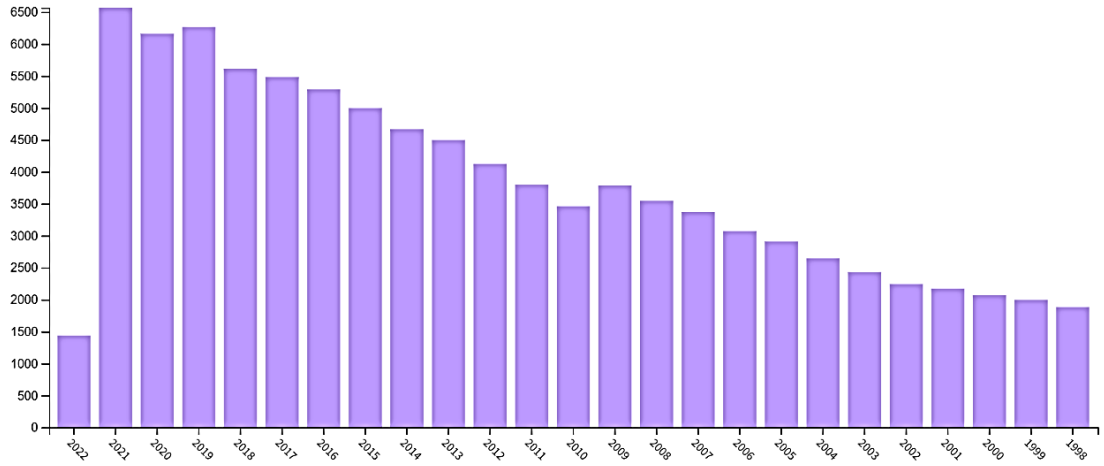

Figure 3. Publication years.

Adapted from: "Web of Sciece".

According to Figure 3, we can observe an upward trend. In the following analyzed years, the number of publications related to the concept of Energy cluster is constantly increasing. Since 1991 the number of articles has exceeded 1000, since 2000 – 2000 works, 2006 – 3000 works, 2012 – 4000 works, 2016 – 5000, 2019 – 6000 works. Thus, it can be concluded that the researched topic has a great and not waning interest among researchers. In the following years, the continuing trend proves the timeliness of the concept of Energy cluster in the world science, especially in the field of chemistry and physics.

Publications related to the Energy cluster are most often published by publishing houses such as: Elsevier (over 20 thousand publications), Amer Chemical Soc (over 10 thousand publications), Springer Nature, IEEE, AMER Inst Physics. The detailed characteristics of the 20 most popular publications along with the number of publications are presented in Figure 4.

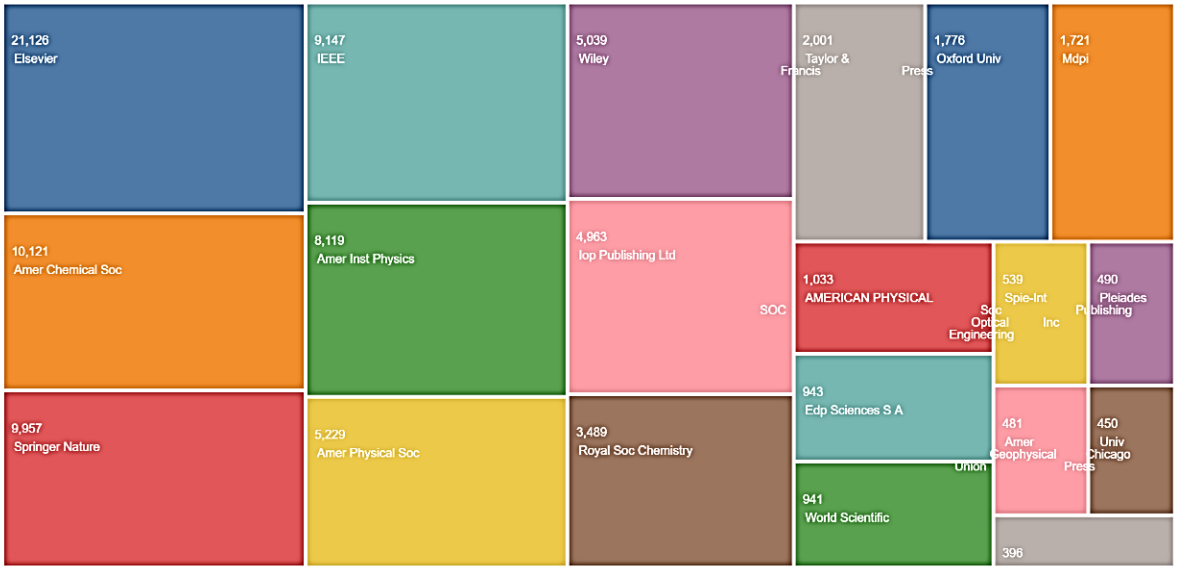

Figure 4. Publishers.

Adapted from: "Web of Sciece".

Considering the journals in which authors most often publish articles related to energy cluster, we can distinguish:

- Journal of Chemical Physics – 5755 articles.
- Physical Review – 2934 articles.
- Journal of Physical Chemistry – 2794 articles.
- Physical Chemistry – 1715 articles.
- Astrophysical Journal – 1580 articles.

The largest number of authors are from research centers in the USA, Peoples R China, Germany, Japan, India, France, England and Spain. Analyzing the individual scientific achievements in the field of Energy cluster, several prominent authors can be identified: Zhang Y with 450 publications, Wang Y with 389 publications, Wang J with 346 publications, Li Y with 318 publications, and Li J and Zhang J with 318 publications each. The detailed characteristics of the authors who most frequently undertook Energy cluster papers along with the number of publications are presented in Figure 5.

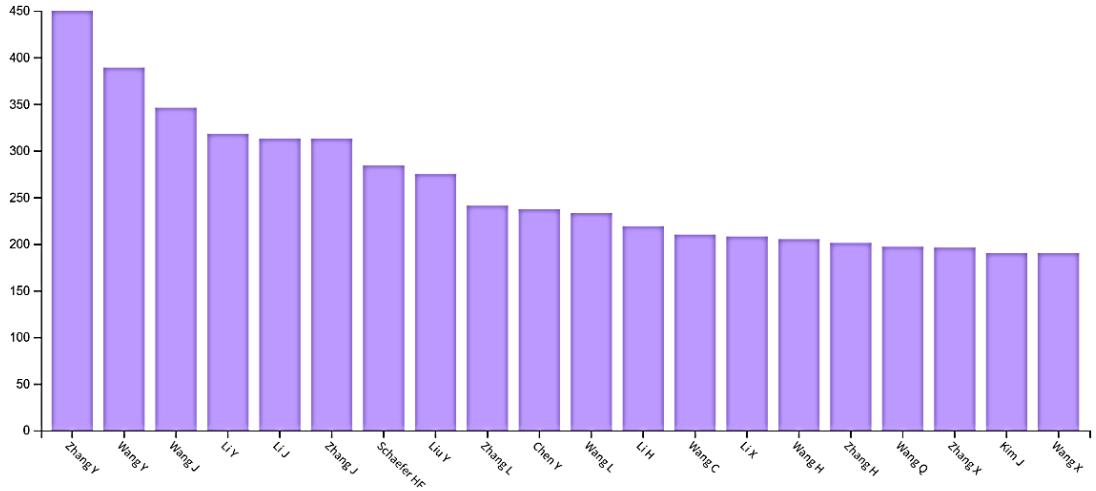

Figure 5. Authors.

Adapted from: "Web of Sciece".

3.2. Scopus

The Scopus database yielded 907,444 papers related to the term energy cluster, which is more than 4 times higher than the results from the Web of Science Core Collection database. As in the case of the first analysis, also in the Scopus database, the search was limited to a few categories, namely Author keywords or title or abstract. The total number of results obtained was 125 210. When analyzing the types of publications, the vast majority, nearly 80%, are articles. This is followed by Conference Papers - 16.6%. Types of all publications along with their percentage share are presented in Figure 6.

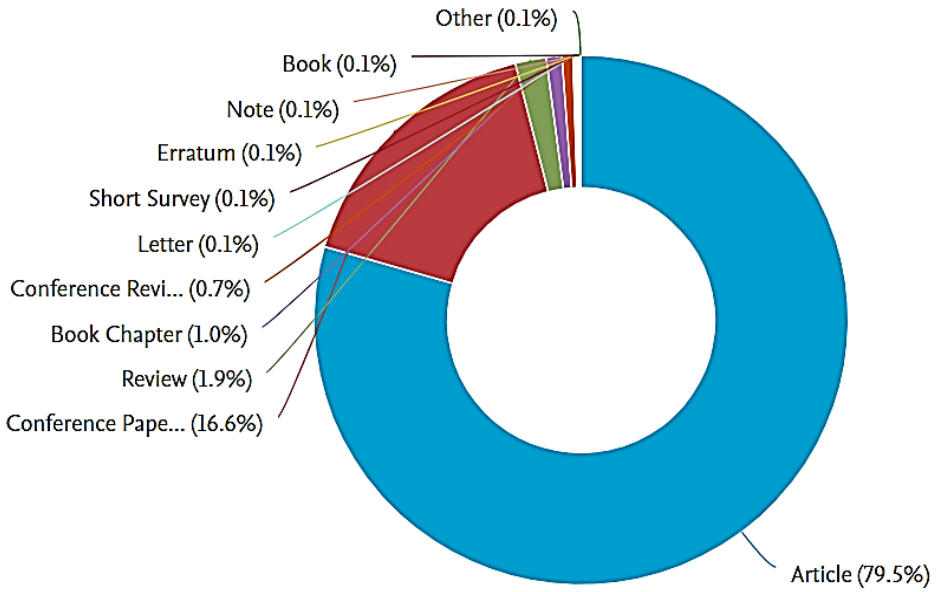

Figure 6. Document types.

Adapted from: "Scopus".

Considering the countries where the authors were most likely to publish papers on the Energy cluster concept similarly to the first analysis, these countries include mainly: the USA (over 32 thousand publications), China (over 20 thousand publications), Germany, India, Japan, United Kingdom, France. Figure 7 shows the 10 most active countries along with the number of publications.

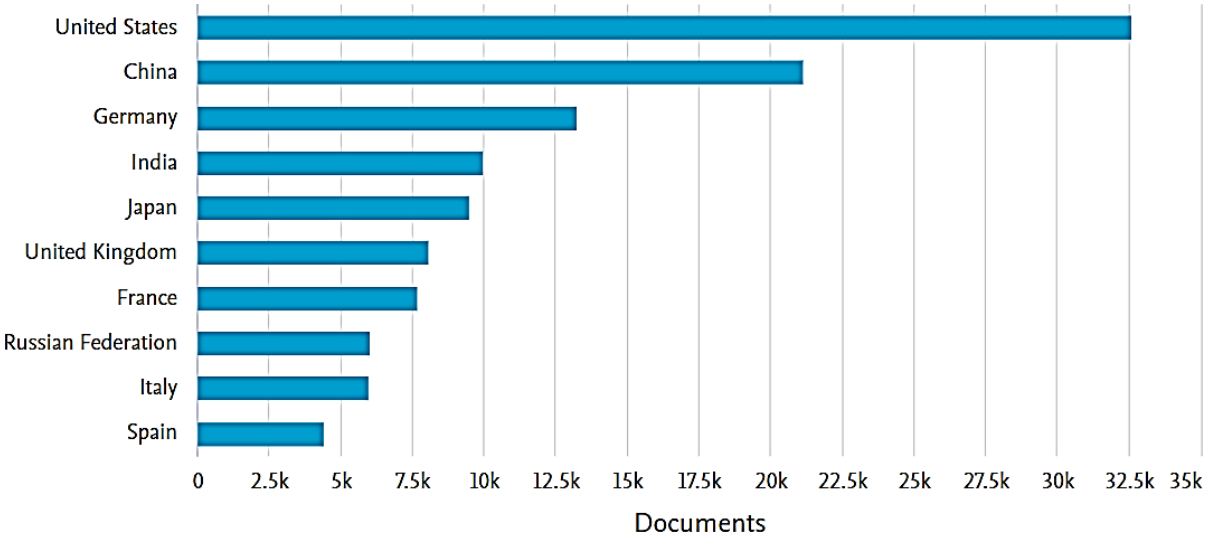

Figure 7. Documents by country or territory.

Adapted from: "Scopus".

The most published areas were Physics and Astronomy (60,221 papers), Chemistry (40,460 papers), Materials Science (27,211 papers), Engineering (25,263 pace), and Computer Science (20,584 papers). Figure 8 shows the percentage of top areas in which Energy cluster papers were produced.

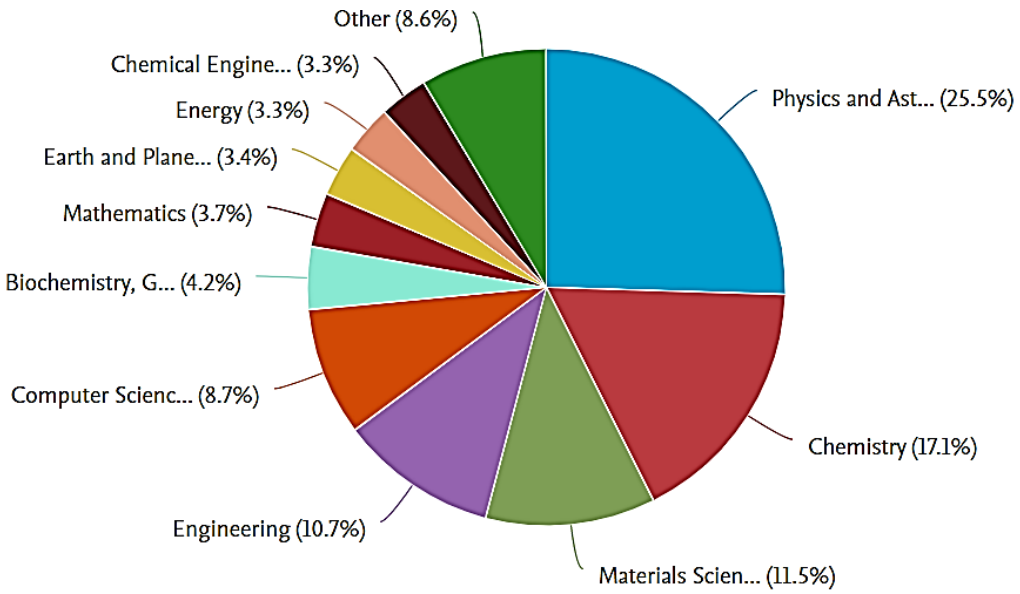

Figure 8. Document by subject area.

Adapted from: "Scopus".

Comparing the results obtained from both databases, one can notice differences in the authors of individual publications. Figure 9 presents the authors who have most frequently published works on energy cluster according to the Scopus database. The authors with the most frequent publications include: Schaefer H.F. (328 publications), Barlett R.J.(251 publications), Yamad I. (187 publications), Dixon D.A. (162 publications), Wales D.J. (158 publications).

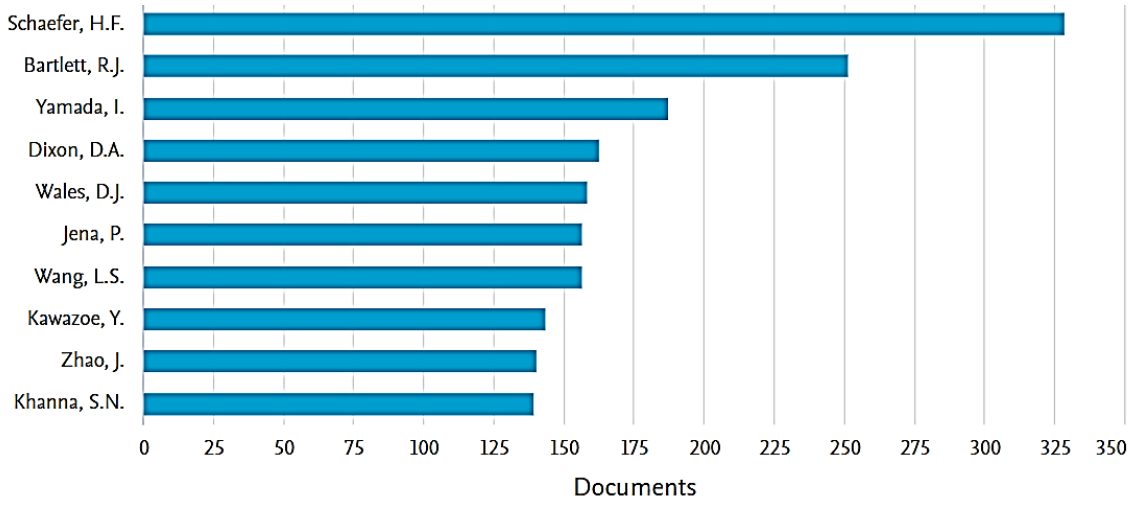

Figure 9. Document by author.

Adapted from: "Scopus".

The highest number of publications was in 2021 - 7146 scientific papers. According to Figure 10, the data in Figure 3 were confirmed, namely the trend of publications is increasing. In 2014, the number of publications exceeded 5 thousand. In the last decade, a great interest in the Energy cluster topic can be observed. This is certainly related to the development of the main objectives of the energy cluster, i.e. ensuring local energy security, improving the local environment and increasing the competitiveness and economic efficiency of the local economy.

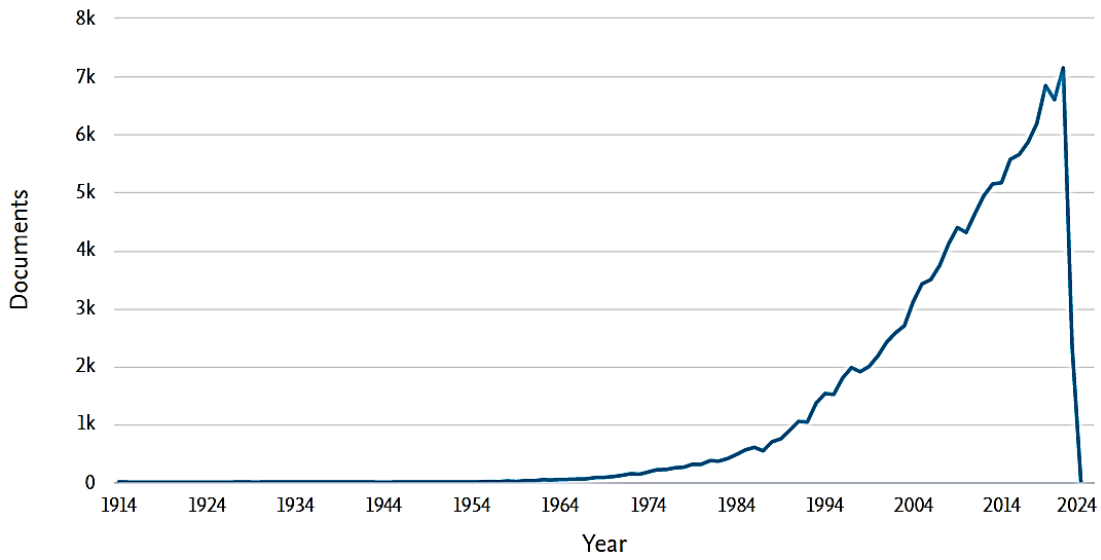

Figure 10. Publication years.

Adapted from: "Scopus".

Considering the journals in which the keyword Energy cluster appears most often, the results are similar to the Web of Science Core Collection database. Figure 11 shows the top 5 most popular journals along with the number of publications in each year. The highest number of papers was for Journal of Chemical Physics - 6644, Journal of Physical Chemistry A - 2938, Physical Rewiev B Condensed Matter And Materials Physics, 2324,Chemical Physics Letter 1751, Physical Chemistry Physics 1714, Astrophysical Journal - 1578.

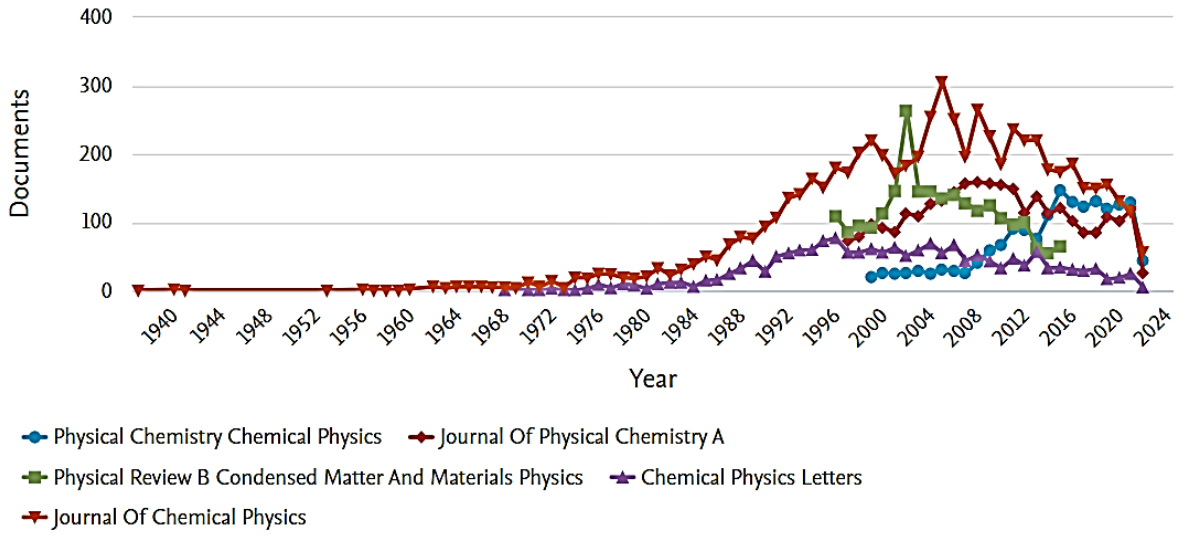

Figure 11. Documents per years by source.

Adapted from: "Scopus".

The Scopus database also provides a list of keywords related to the study term. Therefore, words related to Energy cluster may include: Energy efficiency, density functional theory, Energy utilization, wireless sensor networks, cluster asalysis, sensor nodes, molecular dynamics, binding energy. The remaining keywords and their network are presented in Figure 12.

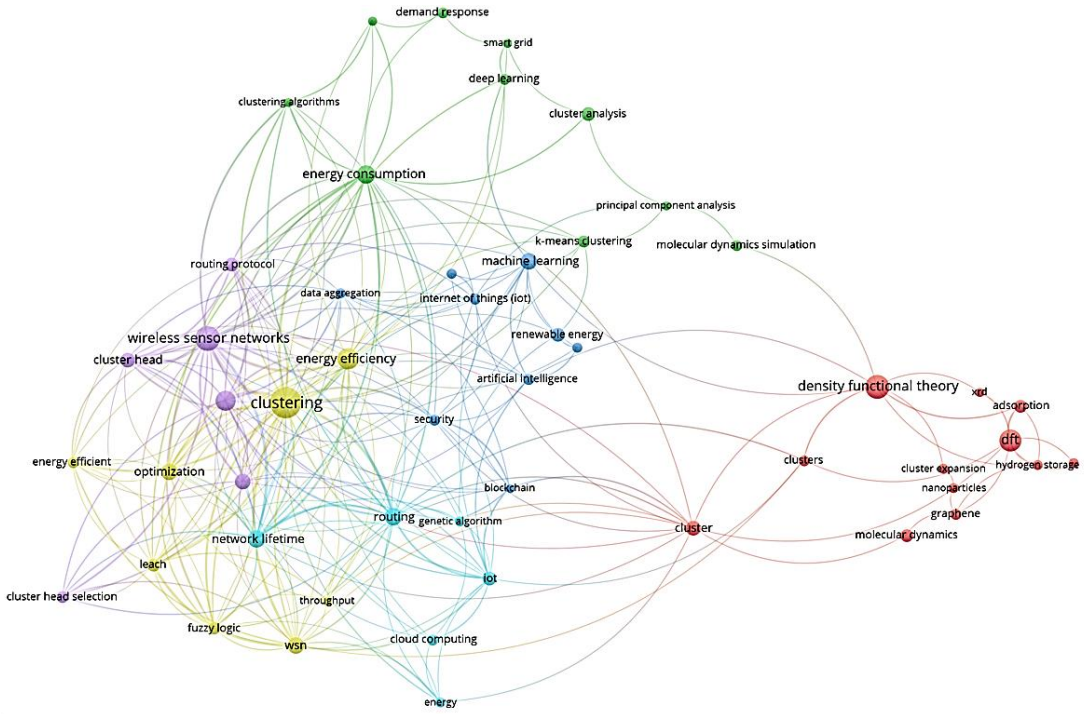

Figure 12. Map of co-occurrence of keywords for the term Energy cluster.
Source: Own work.

4. Conclusion

This study shows that interest in energy clusters has been growing steadily over the years in many scientific fields. The energy market in Poland is gradually evolving towards the promotion and intensive development of civic energy translating into various regional and local initiatives and activities (Sołtysik et al., 2018). One of the visible trends of the global economy, which enables efficient management of raw materials and local energy potential, is the development of distributed energy. Forecasts show that these sources can be an important formula for supplementing energy supply in less urbanized areas. The place for the development of these sources are energy clusters. They give the opportunity to build new areas of activity for local entrepreneurs, as well as to accelerate economic growth in the areas covered by the cluster. Thanks to the cooperation of various entities in the energy cluster there is a platform for creating new areas of profit for its participants.

Conducted bibliometric analysis has shown that the greatest interest, where energy clusters gain importance, are scientific articles (almost 80%), in which the Journal of Chemical Physics has a clear advantage. Taking into account the number of publications, a steady increase in their number is noticeable, in 2021 their number exceeded 6,000. Most authors come from the USA, China and Germany, who publish mainly in the areas of Physics and Astronomy, Chemistry, Material Science, Engineering and Computer Science. It is worth noting that the two databases,

Scopus and Web of Science, use different indexing algorithms and different sets of publications, which may affect the differences in the results of bibliometric analysis. Here are some factors that influence the differences in citations of leading authors in the two databases:

1. Indexing coverage. Both databases have their own criteria for selecting journals, conferences and publications to be indexed. There are differences in territorial and subject coverage, meaning that certain publications may be present in only one of the databases and others in both.
2. Journals unique to one database. There are journals and publications that are exclusively indexed in one database, but not the other. This means that researchers publishing in such journals will be visible as lead authors only in that particular database.
3. Indexing algorithms. Scopus and Web of Science use different algorithms to index and evaluate the quality of publications. This can affect which publications are considered important and which citations are given more prominence.
4. Indexing lag time. The two databases have different lag times for indexing new publications. This can result in leading authors of some recent papers not yet being included in bibliometric data.
5. Differences in data availability. Often, differences in citations are also due to the fact that different institutions or countries have access to only one database, which affects authors' preferences in choosing where to publish.

It is worth noting that both databases, Scopus and Web of Science, strive to provide the most comprehensive and accurate information possible, but differences in how they operate and collect data can lead to differences in the results displayed, including citations of leading authors in a given field. Despite these potential repetitions, bibliometric analysis is still a useful tool for assessing the impact of scientific publications and identifying important research topics.

The analysis in the future should be expanded to include additional indicators, especially regarding citations and collaborations, as well as the national dimension of publishing activity in energy clusters. The present study is mainly based on data from the Web of Science Core Collection and Scopus, but eventually these databases should be used more widely. The study can also be extended to other internationally known databases. The advantage of these databases is that they provide access to publications and knowledge from all over the world, although there are still many journals that are not included in the above-mentioned databases and therefore the picture obtained on their basis is not complete (especially since these databases include mainly English-language publications). In order to make a comparison with Polish authors and publishers, it is also necessary to look at the indicators available in Polish scientific databases. Therefore, the presented analysis is preliminary and should be the subject of further research.

Acknowledgements

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