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Research Article

# An Evaluation of Global Publications of Geothermal Energy Research: A Bibliometric Review

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## ABSTRACT

The study examines global "Geothermal Energy" research on a set of quantitative and qualitative metrics to understand the status of research in the subject at a global level. The study analysis is based on publication data on the subject, comprising a total of 492 publications as indexed in the Web of Science database covering the period 2014-2024. The study provides a window of annual scientific production, the most productive authors, journals, keywords, trends, hot topics, organizations, countries, thematic and conceptual country collaboration maps, and highly cited references in the context of collaborative research. The study finds that the number of publications in this field has increased steadily, with the most significant growth occurring in the past decade. Dincer I, is the most proactive author, with an *h*-index of 5 and 261 citations. The most frequently used keywords in "energy" are 73 (7%), followed by "performance" at 69 (6%). The most productive trends in the hotspot "fluid" and "geochemistry" and constraints" are, respectively, term frequency. The top journals in this field include Energies (58), Citescore (6.2), and impact factor (3.0). China has leading organizations in the field of geothermal energy research. This study has evaluated the growth and impact of geothermal energy research across the globe from 2014 to 2024. The study also helps the researchers and relevant stakeholders with a starting point to further maximize research and research networks in critical and advanced areas of research in the field of geothermal energy research.

**Keywords:** Geothermal Energy, Bibliometrix, Scientometrics, Bibliometrics, Energy Research.

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## INTRODUCTION

Geothermal energy isthermal energy extracted from the earth'scrust. It combines energy from the formation of the planet and fromradioactive decay. Geothermal energy has been exploited as a source of heat and or electric power for millennia. Geothermal heating, using water fromhot springs, for example, has been used for bathing sincePalaeolithic times and forspace heating since roman times.Geothermal power generation of electricity from geothermal energy has been used since the 20th century. Unlike wind and solar energy, geothermal plants produce power at a constant rate, without regard to weather conditions. Geothermal resources are theoretically more than adequate to supply humanity's energy needs. Most extraction occurs in areas neartectonic plate boundaries. The cost of generating geothermal power decreased by 25% during the 1980s and 1990s technological advances continued to reduce costs and thereby expand the amount of viable resources. In 2021, the US department of energy estimated that power from a plant "built today" costs about $0.05/kWh. In 2019, 13,900Megawatts (MW) of geothermal power was available worldwide. An additional 28 gigawatts provided heat for district heating, space heating, spas, industrial processes, desalination, and agricultural applications as of 2010. As of 2019 the industry employed about one hundred thousand people.

## REVIEW OF LITERATURE

Li and X (2025) studied on global geothermal energy application research covering 2259 records during (1990-2022) This study employed the significant increase, collaborative authorship, institutions, collaboration aspects and frequently used keywords in geothermal energy application research. Among the geothermal energy related bibliometric studies, Wang *et al*., (2025) analyzed global research output to provide a detailed analysis of sub fields of geothermal gas research. Ravi, S., & Sharma, R (2024) they investigated global research assessment of green technology using web of science database. Bibliometric tools were employed to explore annual growth and radio growth rate of publication, documents type, language, relative growth rate and doubling

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time, author productivity, degree of collaboration, institutions, In another study, Ghalambaz and Sheremet (2023) has examined global publications data on Solar Thermal Energy Storage (STES) during 1982-2022, to analyse the most productive authors, organizations, and the leading countries and collaboration aspects of frequency used keywords in solar thermal energy storage. Wang and Liu (2019) examined Zero Energy Building (nZEB) research on measure such as Italy, the USA and Spain are the top three countries by the number of nZEB publications. The most productive journals, organizations, the leading experts, the multi stage optimization method for cost-optimal and nearly zero-energy building solutions in line with the zero energy building research.

## OBJECTIVES OF THE STUDY

This study, we have employed scientometric approaches to analyse statistically and qualitatively research publication outputs on geothermal energy research during 2014-2024. This study seeks to provide a holistic and comprehensive overview of geothermal energy research area by measuring the annual growth of publications:

- How have the annual scientific production trend from 2014 to 2024.
- Which publication types and journals are most prominent in the research area.
- who are the feminist authors, countries, and institutions in the field of geothermal energy research output.
- Which countries collaborative the most and what are the authorship patterns in the research publications.
- Which research publications are highly cited in the research area?
- What are the most co-cited references in the research publications?
- What are the most frequently used trend keywords by authors in the field of geothermal energy.

## METHODOLOGY

This study employed scientometric analysis to investigate the geothermal energy research during 2014-2024. The study methodically searched through the Clarivate analytics web of science core collection database (www.webofscience.com), this database highly regarded repository for bibliometric and scientometric studies due to its expensive coverage of scientific literature. To search strategy utilizing Boolean logical search operators "OR" and "AND" was used to search criteria were structured as follows: Topic "Geothermal energy" and customize publication index: 2014 - 2024, this search executed on January 10, 2025, yielded 492 publications aligning with the study's primary objectives. This study constructing various Bibliometric open source software tools, Specifically, R-Studio Package Bibliometrix app for Biblioshiny (v4.0.0) (Aria & Cuccurullo, 2017) was employed to generate diverse visualizations and analyses, such as network maps and citation metrics.

### Search query

The following search query was run in the advanced search box of the Web of Science database to retrieve bibliographic data. TS=("Geothermal energy") as shown in the Figure 1.

## RESULTS AND DISCUSSION

### Descriptive analysis

The global research output in "geothermal energy" (492 publications) published during 2014-2024, most of the documents were published in scientific journals and feminist authored by 1818 researchers, with an annual growth rate of (56.48%) single – authored documents comprised a significant portion of the publications, with 29 totals, there was an international co-authorship rate of (30.49%) this study extracted keywords Plus ID 1027 and 1496 authors' keywords from the documents, providing valuable insights into the topics and themes covered in this extensive body of research (Table 1).

### Annual scientific Production

In all, a total of 492 publications were contributed. The annual scientific production was observed to be (Figure 2).

### Most productive authors in geothermal energy

In all, a total of 1622 authors had participated in global "Geothermal energy" research during the period 2014-2024,

**Table 1: Geothermal energy research: description information about the study 2014-2024.**

| Description | Results |
|---|---|
| Timespan | 2014-2024 |
| Sources (Journals, Books, etc.) | 144 |
| Documents | 492 |
| Annual Growth Rate % | 56.48 |
| Document Average Age | 4.35 |
| Average citations per doc | 23.66 |
| References | 22465 |
| Keywords Plus (ID) | 1027 |
| Author's Keywords (DE) | 1496 |
| Authors | 1818 |
| Authors of single-authored docs | 26 |
| Single-authored docs | 29 |
| Co-Authors per Doc | 4.4 |
| International co-authorships % | 30.49 |

this study identified the top 15 authors local impact by h-index in the research filed of geothermal energy research output and various index of their research, out of the 15 authors, three hailed from the h- index, g-index, m-index and total citations, Dincer I author local impact by h-index 5 and citation is with 261, and second author is 87 citation remaining author followed by the as per the Table 2.

## Treemap of high-frequency keywords

Treemap is a visual tool that provides an overview of an author's keywords, allowing readers to identify hot topics or the author's evolving patterns of prevailing themes. Cobo *et al.*, (2011) and Xie *et al.*, (2020) have noted the usefulness of the tree map in identifying the most frequency and vital keywords used by an author. The study, we have employed out of 535 author's keywords, the top 50 authors are displayed in Figure 3. The figure's rectangles' dimensions correspond to the keyword's frequency, with larger rectangles representing more frequency keywords. According to the results "energy" was the most frequently occurring keyword with a frequency of (73 times 7%), followed by "Performance" (69 times, 6%) "Systems" (56 times, 5%) "optimization" (51 times, 5%) and "resources" (47 times, 4%), these results provide insight into the author's research interests, emphasizing geothermal energy research output.

## Temporal evolution of keywords frequencies

The Sankey diagram segments the timeframe into distinct temporal intervals, revealing the dynamic evolution of keywords with in the domain of geothermal energy research output (Figure 1) between 2014 and 2024, exclusive prominence was accorded to "reference service" as the primary research keywords, From the three–fields plot in Figure 4 we can see that in the data records on "geothermal energy research journal output is a highest in the field of three field plot.

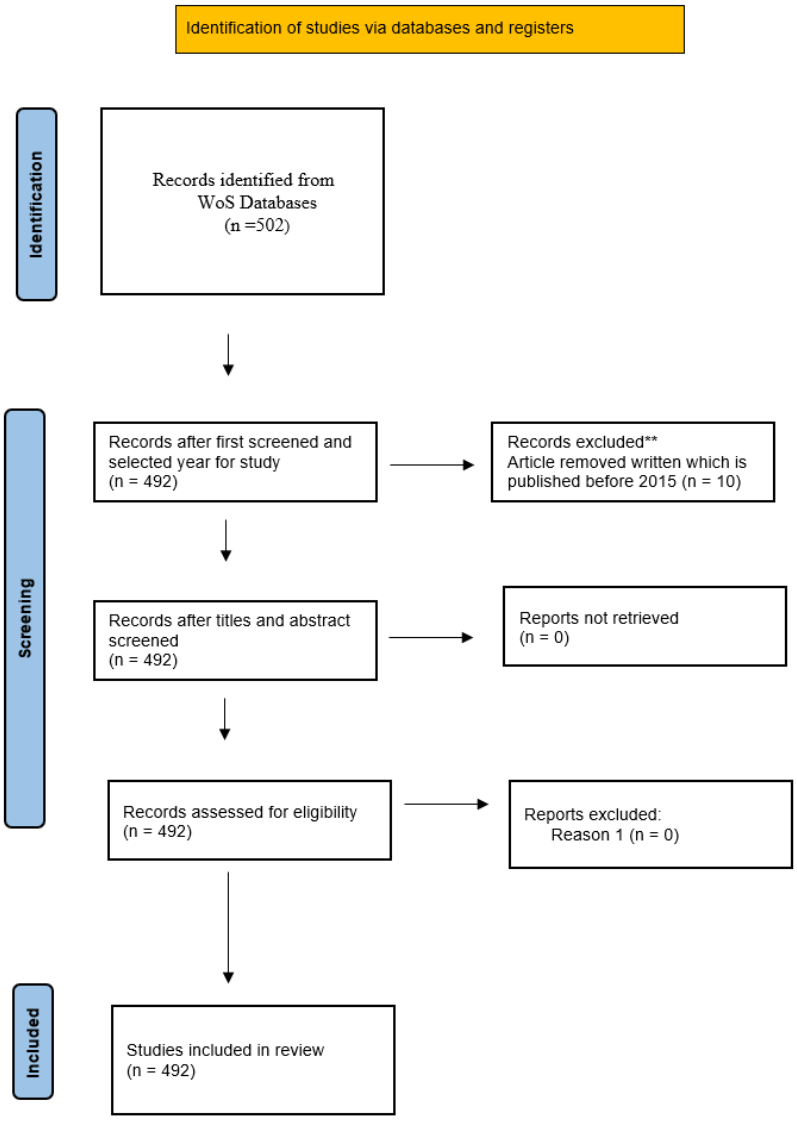


**Figure 1:** PRISMA flow diagram for data extraction process in Geothermal Energy.

## Trends hot topics

The graphical representation in Figure 5 indicates a hierarchical pattern of research topics prominent among researchers over the years. These research areas were closely connected to geothermal energy research. The Primary focus of the research was on geothermal energy research, and this subject matter was the most discussed and widely explored theme. From 2014-2024 based on these findings, it can be "fluid" "Geochemistry" and "constraints" are respectively term frequency, Organic ranking cycles is the last frequency of the geothermal energy research.

## Most productive journals in geothermal energy

Journals have long served as important channels for disseminating prior knowledge playing a vital role in the geothermal energy research filed. A total of 492 records were published from 2014 to 2024, with the majority appearing in journals. A comprehensive analysis of these sources revealed that 90 journals made significant contributions to the research filed. Table 3 highlights the top 15 journals that were productive in publishing research articles." Energies" was the most prolific of all, having published 58 articles, cite score (6.2), Impact Factor (3.0), Switzerland on geothermal energy research output since its inception in SJR 0.65. Followed by "Renewable Energy" 43 articles, the other top performing Cite score journals included "Renewable & Sustainable Energy Reviews" (31.2) cite score. As for the top Impact Factor (IF) journals "Renewable & Sustainable Energy Reviews" in 16 and another top SJR ranking is "Applied Energy" 2.82, It is worth nothing that least journals publishing "Geoenergy Science and Engineering" the findings can inform researchers, scholars, and practitioners in choosing suitable journals to publish their work and stay up- to date with the latest development in the field.

## Most productive organizations in geothermal energy

The study involvement of 672 affiliations in 492 publications related to geothermal energy research output, top affiliations produced these publications from ten countries: the China University Petroleum, China University of Geosciences, Afyon Kocatepe University, University Tehran, Agh university science and technology, Jilin University, University of Chile, Figure 6. shows that the most prolific affiliation of geothermal energy research output accounted for 672 publications approximately, The China University Petroleum emerged as the affiliation with the most publications, with 19 articles. Second the China University of Geosciences with another most publications, with 16 articles. Afyon Kocatepe University and University Tehran the most affiliation of respectively and other affiliation dominated one by one.

## Most productive countries in geothermal energy

The importance of geothermal energy research has been the subject of research and publications for several decades, with over 50 countries contributing to the body of knowledge of the topic between 2014 and 2024. Table 4 of a recent study presents the top 15 countries ranked by the number of Total Citations (TC) and Average Article Citations (AAC) offering insight into the quantity and impact of the research produced. The China leads the pack with the highest number of research outputs, with a TC of 3153 and AAC of 24.8. This indicates a high level of research activity focused on geothermal energy research output by China. USA comes in second with a TC of 907, and AAC of 25.2 followed by the Iran, with a TC of 697, AAC of 53.6. However, when considering the lowest level of research activity focused on geothermal energy research output in Switzerland with a TC of

**Table 2: Geothermal energy research: most productive author's local impact by h–index.**

| Name of the authors | *h*_index | *g*_index | *m*_index | TC | NP | PY_start |
|---|---|---|---|---|---|---|
| Dincer I | 5 | 5 | 0.5 | 261 | 5 | 2016 |
| Li Y | 5 | 7 | 0.8 | 85 | 7 | 2020 |
| Manzella A | 5 | 5 | 0.45 | 333 | 5 | 2015 |
| Tomaszewska B | 5 | 6 | 0.62 | 115 | 6 | 2018 |
| Baba A | 4 | 4 | 0.66 | 109 | 4 | 2020 |
| Bujakowski W | 4 | 4 | 0.5 | 104 | 4 | 2018 |
| Davidsdottir B | 4 | 4 | 0.36 | 305 | 4 | 2015 |
| Dezayes C | 4 | 4 | 0.66 | 35 | 4 | 2020 |
| Falcone G | 4 | 4 | 0.5 | 127 | 4 | 2018 |
| Kumar R | 4 | 5 | 0.66 | 164 | 5 | 2020 |
| Noorollahi Y | 4 | 4 | 0.44 | 136 | 4 | 2017 |
| Ozturk M | 4 | 5 | 0.44 | 168 | 5 | 2017 |
| Raymond J | 4 | 5 | 0.44 | 35 | 5 | 2020 |
| Shi Y | 4 | 4 | 0.44 | 159 | 4 | 2020 |
| Soltani M | 4 | 4 | 0.44 | 417 | 4 | 2019 |

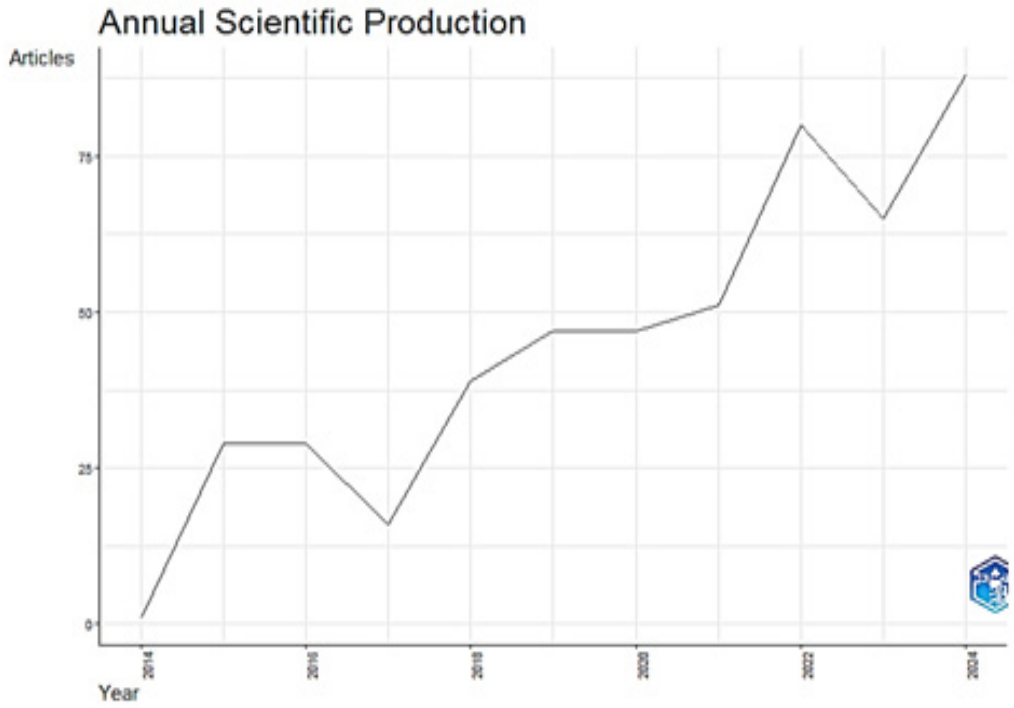


**Figure 2:** Annual Scientific Production in geothermal energy research.

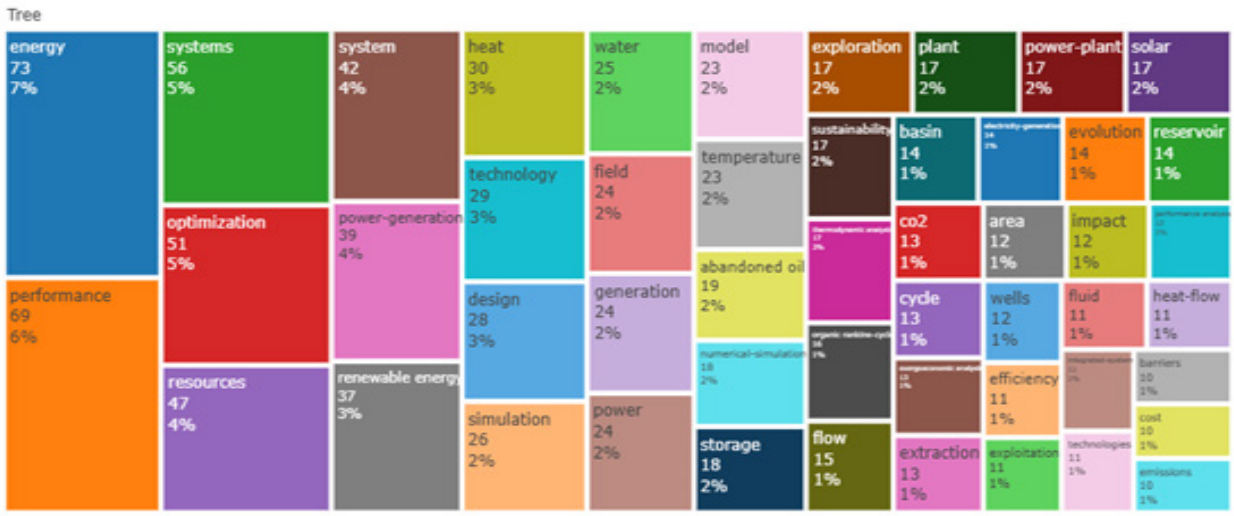


**Figure 3:** Treemap showing most appeared author's keywords in geothermal energy (Bibliometrix).

215 and an AAC of 35.8. The study demonstrates the on-going importance of geothermal energy research output and the global interest in furthering our understating of the subject.

## Thematic Map

Figure 7 shows a thematic map of document keywords to assess the current status and future trends in a research filed of geothermal energy research. The map is divided into four quadrants with different meanings according to the density and centrality of terms (2021). Density measure the affinity between topic and centrality measures the correlation between terms. Quadrants emerging or Decaling Themes, basic themes, Niche Themes, and Motor Themes represent driving, specialized, emerging or disappearing, and underlying themes, respectively (Esfahani *et al.*, 2019). The analysis of the thematic map of keywords show that "thermodynamic analysis" "organic ranking–cycle" "exergoeconomic analysis" "technology barriers climate–change" "Performance simulation" and "energy systems optimization" are central and relevant topics (Basic Themes), while "rock ash degradation", "co2 emissions natural–gas tests" thermo physical properties conductivity corrosion" but low density (Niche Themes), emerging or Decaling Themes,


**Figure 4:** Word frequency in geothermal energy research.

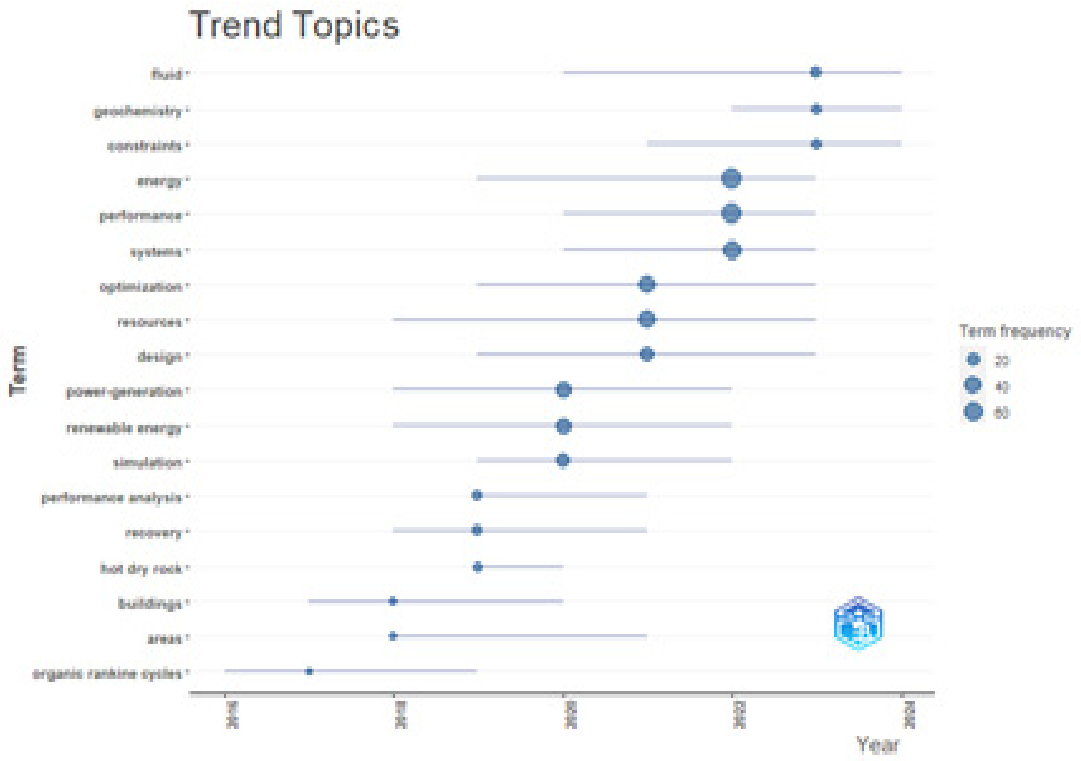


**Figure 5:** Trends topic on geothermal energy research.

Niche Themes, "Australian strathbogie grantle crack density" respectively, research focuses on the application performance simulation field and improve efficiency and safety in industry.

## Conceptual Structure Map: Factorial Analysis

From the factorial analysis in Figure 8. We can see the topics investigated in different research clusters. Although there is no clear connection between the topics researched in the present study.

## Country Collaboration Map

In addition to analysing countries' contributions (Figure 9) provides a visualization of international research collaboration on geothermal energy research output. The darker and thicker lines on the map indicate a higher frequency of collaboration, with blue representing the countries involved in the collaboration. The Canada and USA are shown to have the highest frequency of collaboration, followed by from Germany to Netherlands, from China United Kingdom, from Germany to the United Kingdom, from Italy to Netherlands, are respectively. The study demonstrates

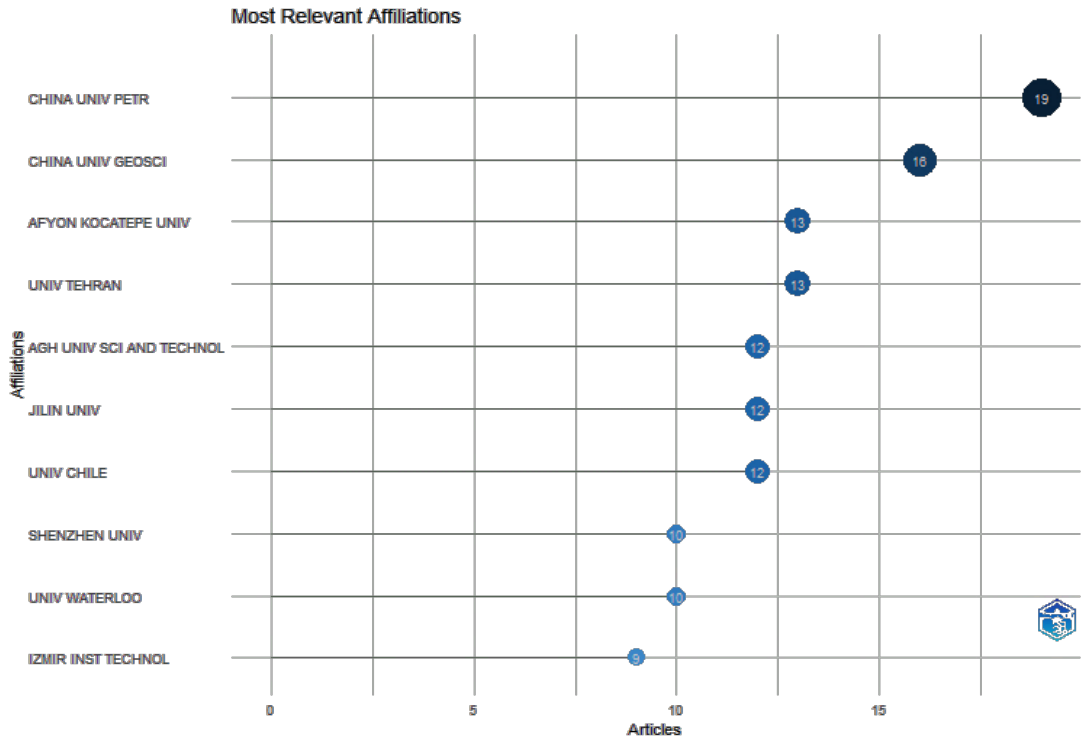


**Figure 6:** Most productive research organisations in geothermal research.

**Table 3: Most productive journal in geothermal energy research.**

| Sl. No. | Name of the journal | TP | Cite score | Country | SJR 2023 |
|---|---|---|---|---|---|
| 1 | Energies (IF=3.0) | 58 | 6.2 | Switzerland | 0.65 |
| 2 | Renewable energy (IF=9.0) | 43 | 18.4 | UK | 1.92 |
| 3 | Renewable & sustainable energy reviews (IF=16.3) | 40 | 31.2 | UK | 3.6 |
| 4 | Geothermics (IF=3.5) | 35 | 7.7 | UK | 0.99 |
| 5 | Energy (IF=9.0) | 17 | 15.3 | UK | 2.11 |
| 6 | Geothermal energy (IF=2.9) | 12 | - | United States | 0.75 |
| 7 | Sustainability (IF=6.8) | 12 | 3.3 | Switzerland | 0.67 |
| 8 | Applied energy (IF=10.1) | 11 | 21.2 | UK | 2.82 |
| 9 | Energy conversion and management (IF=9.9) | 11 | 19.0 | UK | 2.55 |
| 10 | Applied thermal engineering (IF= 6.1) | 8 | 11.3 | UK | 1.49 |
| 11 | International journal of hydrogen energy (IF=8.1) | 8 | 13.5 | UK | 1.51 |
| 12 | Journal of cleaner production (IF=9.8) | 7 | 20.4 | UK | 2.06 |
| 13 | Energy policy (IF=9.3) | 6 | 17.3 | UK | 2.39 |
| 14 | Environmental science and pollution Research (IF=8.7) | 6 | - | Germany | 1.01 |
| 15 | Geoenergy science and engineering | 6 | - | Netherlands | 0 |

*SJR=SCImago journal ranking.

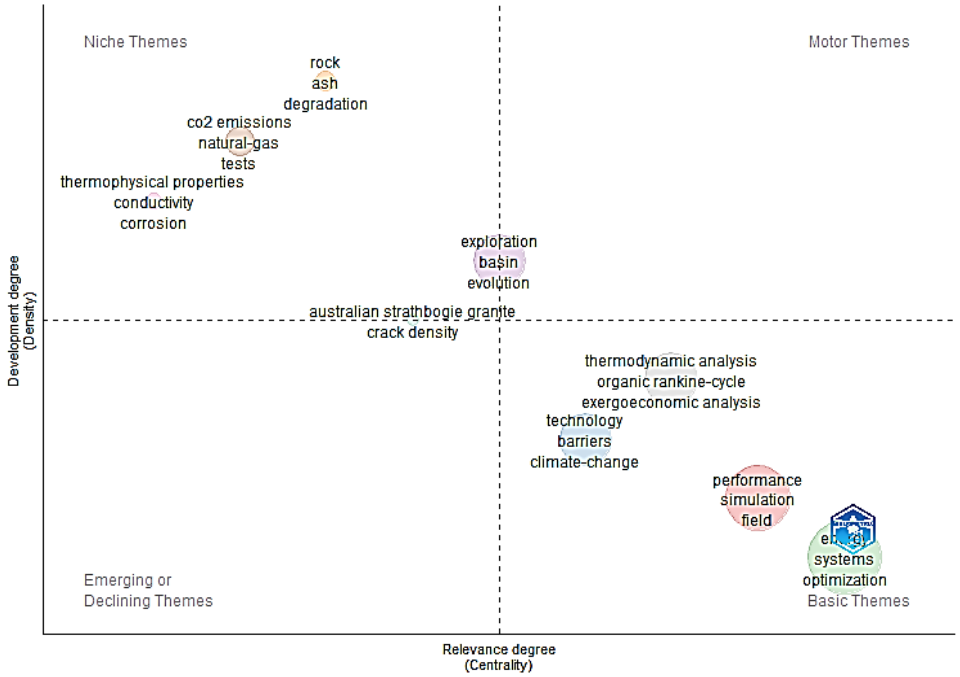


**Figure 7:** Thematic Map of Geothermal Energy research output.

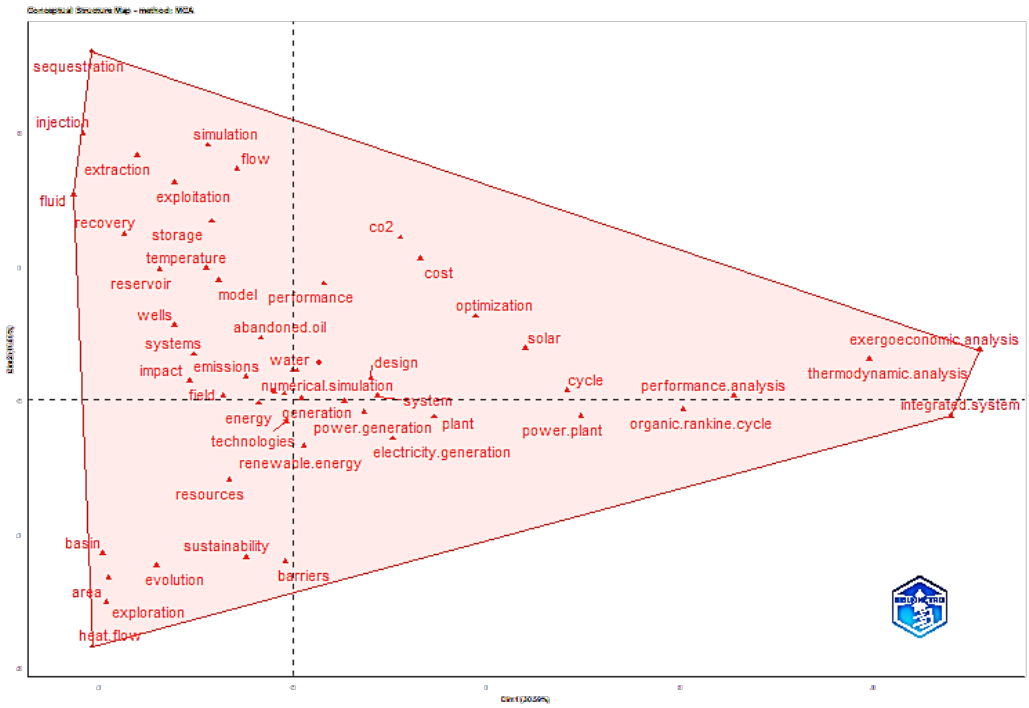


**Figure 8:** Conceptual Structure Map: Factorial Analysis.

the on-going importance of geothermal energy research output and the global interest in furthering our understanding of the subject.

Examining highly cited references is crucial as they indicate a particular field's fundamental knowledge base. Table 5 highlights the top 10 highly cited references researcher have cited in the realm of geothermal energy research output. The most cited reference, with a count of 308, was published by "Zhu Jl, 2015, in the Energy." This paper provided a comprehensive overview of the ever-evolving concept of geothermal energy research making it an essential resource for researchers in this filed. The second most highly cited references, with a count of 232 was published by" Anderson A, 2019, Applied Energy" and followed by the third most highly cited reference, with a citation count of 220 was published by "Shortall R, 2015, Renewable and sustainable energy reviews." These references delved into the quality of consumer services and the implications for the future. Overall, these highly

**Table 4:** Top 15 most productive research countries in geothermal energy research.

| Sl. No. | Country Name | Total Citations | Average Article Citations |
|---|---|---|---|
| 1 | China | 3153 | 24.8 |
| 2 | USA | 907 | 25.2 |
| 3 | Iran | 697 | 53.6 |
| 4 | Turkey | 638 | 26.6 |
| 5 | Italy | 569 | 31.6 |
| 6 | Canada | 536 | 19.9 |
| 7 | Germany | 458 | 19.1 |
| 8 | United Kingdom | 445 | 22.2 |
| 9 | Iceland | 371 | 41.2 |
| 10 | Netherlands | 369 | 41 |
| 11 | Australia | 355 | 71 |
| 12 | Spain | 290 | 29 |
| 13 | Poland | 247 | 13.7 |
| 14 | Egypt | 219 | 36.5 |
| 15 | Switzerland | 215 | 35.8 |

**Table 5:** Highly cited references in geothermal energy research.

| Sl. No. | Name of the Paper | Total Citations | TC per Year | Normalized TC |
|---|---|---|---|---|
| 1 | Zhu Jl, 2015, Energy, DOI: 10.1016/j.energy.2015.08.098 | 308 | 28 | 5.80 |
| 2 | Anderson A, 2019, Applied energy, DOI: 10.1016/j.apenergy.2019.04.102 | 232 | 33.14 | 5.34 |
| 3 | Shortall R, 2015, Renewable and sustainable energy reviews, DOI: 10.1016/j.rser.2014.12.020 | 220 | 20 | 4.14 |
| 4 | Moya D, 2018, Renewable and sustainable energy reviews, DOI: 10.1016/j.rser.2018.06.047 | 217 | 27.12 | 4.09 |
| 5 | Soltani M, 2021, Renewable and sustainable energy reviews, DOI: 10.1016/j.rser.2021.110750 | 199 | 39.8 | 9.04 |
| 6 | Li Kw, 2015, Renewable and sustainable energy reviews, DOI: 10.1016/j.rser.2014.10.049 | 194 | 17.63 | 3.65 |
| 7 | Hou Jc, 2018, Renew energy, DOI: 10.1016/j.renene.2018.02.115 | 167 | 20.87 | 3.14 |
| 8 | Limberger J, 2018, Renewable sustainability energy review, DOI: 10.1016/j.rser.2017.09.084 | 165 | 20.62 | 3.11 |
| 9 | Sun Fr, 2018, Energy conversation and Management, DOI: 10.1016/j.enconman.2018.08.094 | 157 | 19.62 | 2.96 |
| 10 | Soltani M, 2019, Sustainable cities and society, DOI: 10.1016/j.scs.2018.09.036 | 155 | 22.14 | 3.57 |

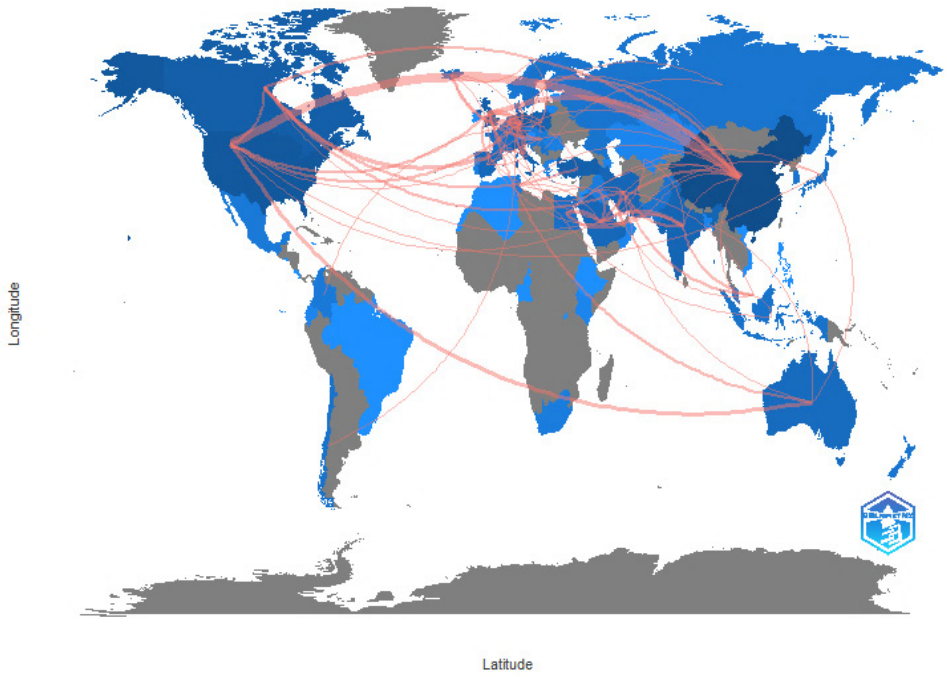


**Figure 9:** Country Collaboration Map.

cited references reveal the critical aspects that researchers in geothermal energy research consider while conducting their research, providing a window into the field's current state.

## CONCLUSION

This study, we have employed the bibliometric methods to analyse a total of 492 global publications on geothermal energy research. The data for the study was scoured from web of science core collection database covering the period 2014-2024. Finding from the bibliometric analysis provide an overview of the extent of research activates in the area of geothermal energy research; identify the key actors as well as the major research areas in the field. In addition, the contribution of annual scientific production, the most productive authors, trends hot topics, journals, organizations, countries, reference, was evaluated along with their citation impact. The collaborative linkages among the keywords were also analyzed. The relationship networks of tee map, thematic map, conceptual map and country collaboration map were analyzed. The study also helps with the researchers and relevant stakeholders, a starting point to further maximize research and research networks in critical and advanced areas of research in the field of geothermal energy research.

## CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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