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Research Article

Design Optimization and Performance Evaluation of Solar Parabolic Trough Collector: Bibliometrics Analysis Approach

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ABSTRACT

The research work highlights Bibliometrics analysis approach for research work conducted on design optimization and performance evaluation of solar parabolic trough collectors, in the last ten years, from the data obtained from dimensions.ai online database and analysis made in VOSviewer software. The research work focuses on the details of country-wise publications and citations, organization-wise publications and citations as well as journal-wise publications and their citations. The results of the research work indicated a continuous enhancement in the research activities, going on in the field.

Keywords: Bibliometrics analysis, parabolic solar troughs, optimization, analysis.

1. Introduction

One of the primary areas of focus in recent times in the field of renewable energy are solar parabolic trough collectors. Concentrated solar power technology includes parabolic troughs, which concentrate sunlight using specially curved mirror surfaces. These mirrors direct solar energy onto a receiver, creating intense heat in a fluid medium. The resulting thermal energy can be harnessed for multiple purposes; including power generation and industrial heating applications. Due to their advantages, today, troughs are considered as one of the most popular subjects of research, all around the world, and researchers are studying their different aspects, for the purpose of design optimization and analysis.

Studies have demonstrated that the choice of materials for the receiver tubes significantly impacts thermal performance. In this direction, Arun et al.(2023) conducted a comparative analysis of stainless-steel and glass-coated copper tube receivers, finding that the latter offered enhanced thermal efficiency due to better heat retention properties. Similarly, Malekan et al. (2019) explored the use of nanofluids, specifically Fe_3O_4 and CuO/Therminol 66, as working fluids, which resulted in improved heat transfer rates under magnetic fields. These advancements indicate a trend towards utilizing innovative materials and fluids to maximize the thermal performance of parabolic trough collectors.

In addition to material advancements, the optimization of the geometric design of parabolic troughs has been a significant focus. Chen et al. (2015) emphasized the importance of optimizing the energy density distribution on the receiver surface to enhance overall system efficiency. Furthermore, the integration of advanced modeling techniques has facilitated better performance predictions. For example, Wang et al. (2016) utilized simulation tools to assess the performance of parabolic trough collectors across different climatic conditions in China, highlighting the variability in efficiency based on geographic location. Such studies underscore the necessity of tailored design approaches that consider local environmental factors.

Economic considerations are also paramount in the deployment of parabolic trough technology. The levelized cost of energy (LCOE) remains a critical metric for evaluating the feasibility of solar projects. Bellos & Tzivanidis (2018) noted that parabolic trough collectors can achieve competitive LCOE figures, particularly when coupled with thermal energy storage systems, which allow for energy dispatch during non-sunny periods.. The economic viability of parabolic trough collectors is further supported by the findings of Tian et al. (2018), who explored the thermo-economic optimization of hybrid solar district heating plants that integrate flat plate collectors with parabolic

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troughs. These studies collectively highlight the importance of economic analysis in the design and implementation of solar thermal systems.

Moreover, the role of parabolic troughs in addressing energy demands in various applications has been extensively researched. Khalil et al. (2020) investigated the performance of direct absorption-based parabolic trough collectors using hybrid nanofluids, demonstrating their potential for enhanced thermal efficiency in industrial applications.

Considering above mentioned facts, the present research work is based on Bibliometrics analysis for the keywords optimization, evaluation and parabolic solar trough. During the research work, last ten years' analysis of research publications from different countries, organizations as well as different sources has been presented, followed by conclusion of the research work.

2. Bibliometrics Analysis

The present bibliometric analysis was performed using the freely available Dimensions.ai database (www.dimensions.ai). This database offers resources to support researchers across various disciplines. For conducting Bibliometrics analysis, the keywords, were fed to dimensions.ai and the results were imported to VOSviewer, from which different analyses were obtained. Details of different analysis conducted are presented under following sub-sections.

2.1 Country wise Publication and Citation Analysis

On analyzing the extracted dimensions.ai data in VOSviewer, number of publications as well as citations appeared in last ten years for different countries were obtained, the details of which are presented Table 2.1 for top twenty alternatives.

Table 2.1: Number of Publications and Citations for Different Countries in last ten years

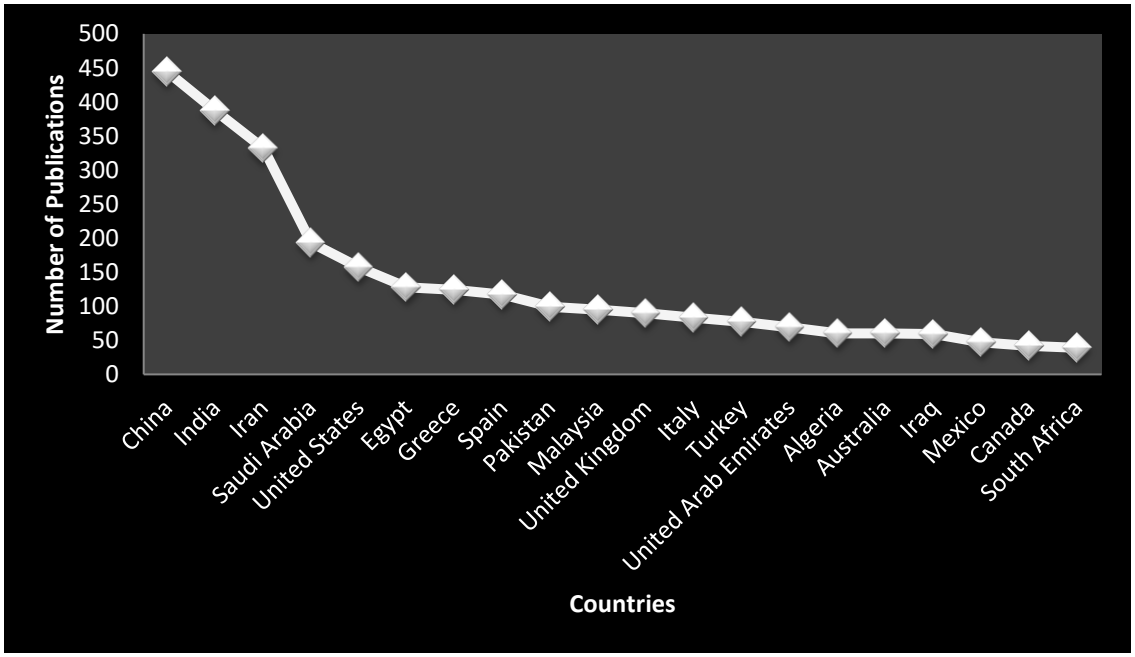
S. No	Rank	Country	Number of Publications	Rank	Country	Number of Citations
1.	1	China	444	1	China	12598
2.	2	India	387	2	Iran	11956
3.	3	Iran	332	3	India	10656
4.	4	Saudi Arabia	193	4	United States	9478
5.	5	United States	157	5	Greece	8363
6.	6	Egypt	128	6	Spain	5941
7.	7	Greece	124	7	Malaysia	5037
8.	8	Spain	117	8	Egypt	4734
9.	9	Pakistan	99	9	Saudi Arabia	4704
10.	10	Malaysia	95	10	United Kingdom	4476
11.	11	United Kingdom	90	11	Italy	4273
12.	12	Italy	83	12	Australia	4241
13.	13	Turkey	77	13	United Arab Emirates	4164
14.	14	United Arab Emirates	69	14	Pakistan	2566
15.	15	Algeria	60	15	Turkey	1859
16.	16	Australia	60	16	Canada	1601
17.	17	Iraq	59	17	Iraq	1522
18.	18	Mexico	47	18	Algeria	1313
19.	19	Canada	42	19	South Africa	1246
20.	20	South Africa	39	20	Mexico	1178

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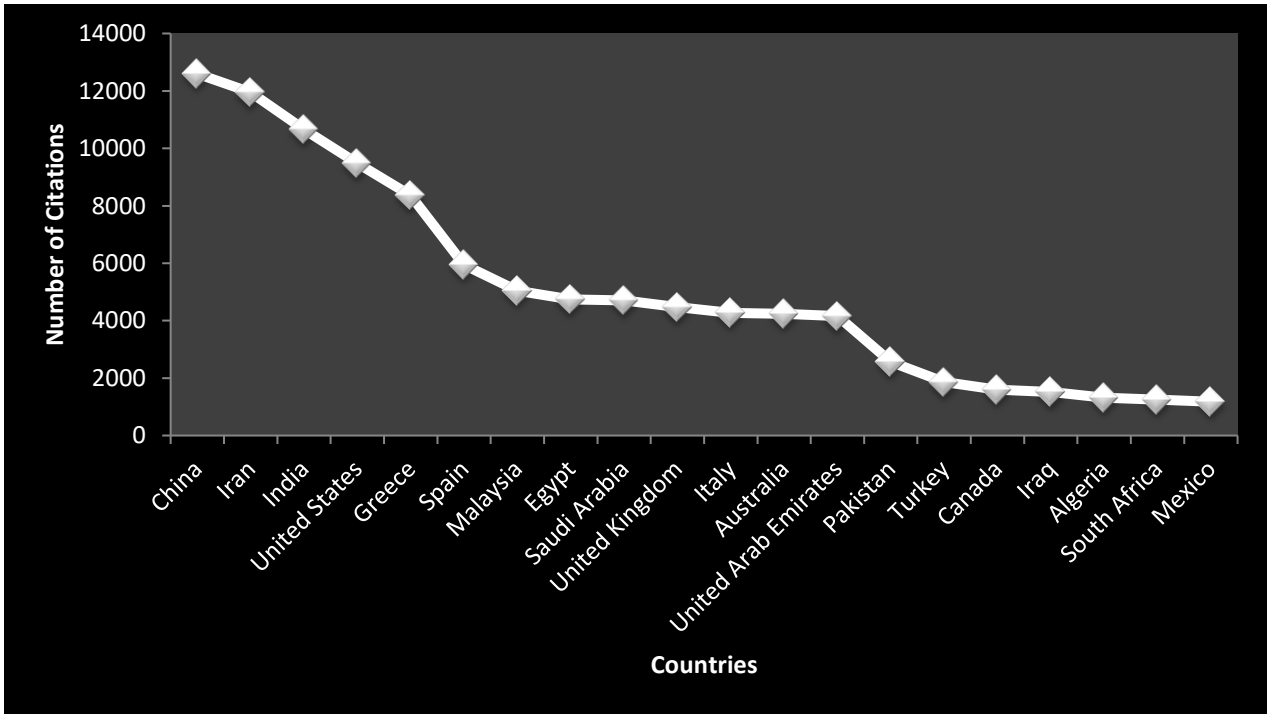
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Figure 2.1 shows the details of results in graphical format.



(a) Number of Publications from Different Countries



(b) Number of Citations from Different Countries

Figure 2.1: Details of Publications and Citations for Different Countries

The Table 2.1 and Figure 2.1 highlight the global research contributions in the field of optimization, solar parabolic troughs, and analysis, ranking countries by the number of publications and citations. China leads in both categories, with 444 publications and 12,598 citations, demonstrating its dominance in research volume and impact. India (387 publications, 10,656 citations) and Iran (332 publications, 11,956 citations) follow closely, indicating their strong involvement in solar energy optimization studies. Other notable

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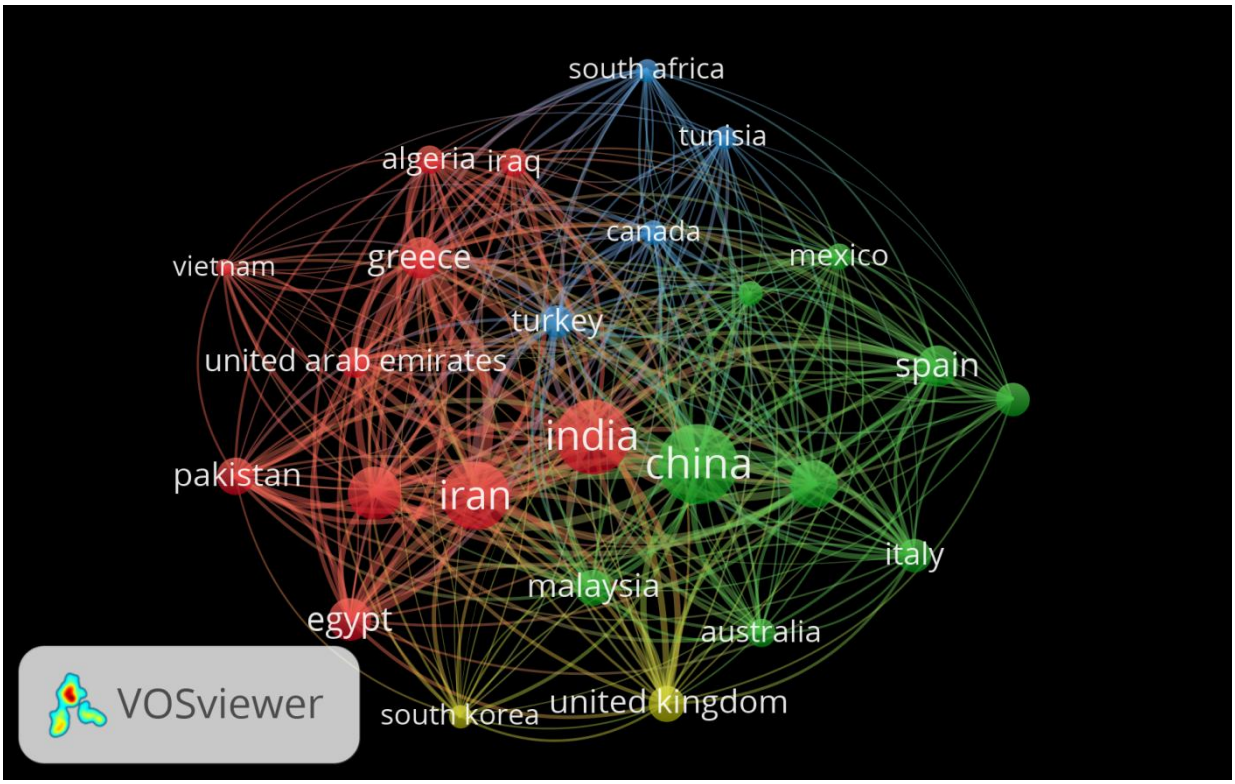
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contributors include Saudi Arabia, the United States, Egypt, Greece, and Spain, all of which have made significant advancements in this field.

When comparing research quantity vs. impact, some countries stand out for their high citation-to-publication ratio. The U.S. (157 publications, 9,478 citations) and Greece (124 publications, 8,363 citations) have relatively fewer papers but a significant impact, suggesting their research is highly influential and frequently referenced. Conversely, some countries, such as Pakistan, Turkey, and Algeria, have a decent number of publications but comparatively lower citations, implying that their research is still gaining global recognition. Iran ranks third in publications but second in citations, indicating the high quality and influence of its research output.

Emerging contributors such as Iraq, Mexico, Canada, and South Africa are making strides in this research area, although their citation numbers remain modest. This suggests that their studies are relatively newer or have yet to gain widespread recognition. The strong presence of Middle Eastern and Asian countries in both publication and citation rankings underscores the growing focus on solar energy and optimization technologies in these regions. As research continues, collaboration between high-impact countries and emerging contributors could further enhance advancements in solar parabolic trough technology. Moving one step further, on drawing network, overlay and density visualizations for above information, the following outputs were obtained.

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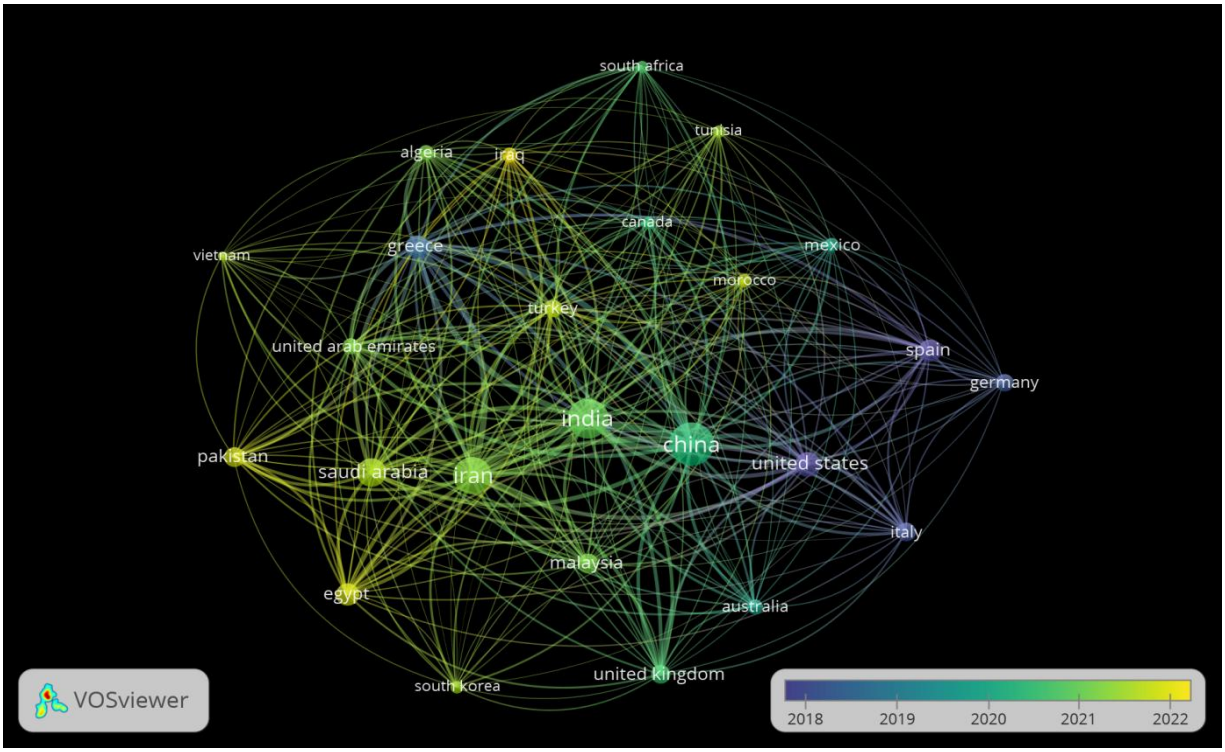


(a) Network Visualizations for Publications from Different Countries

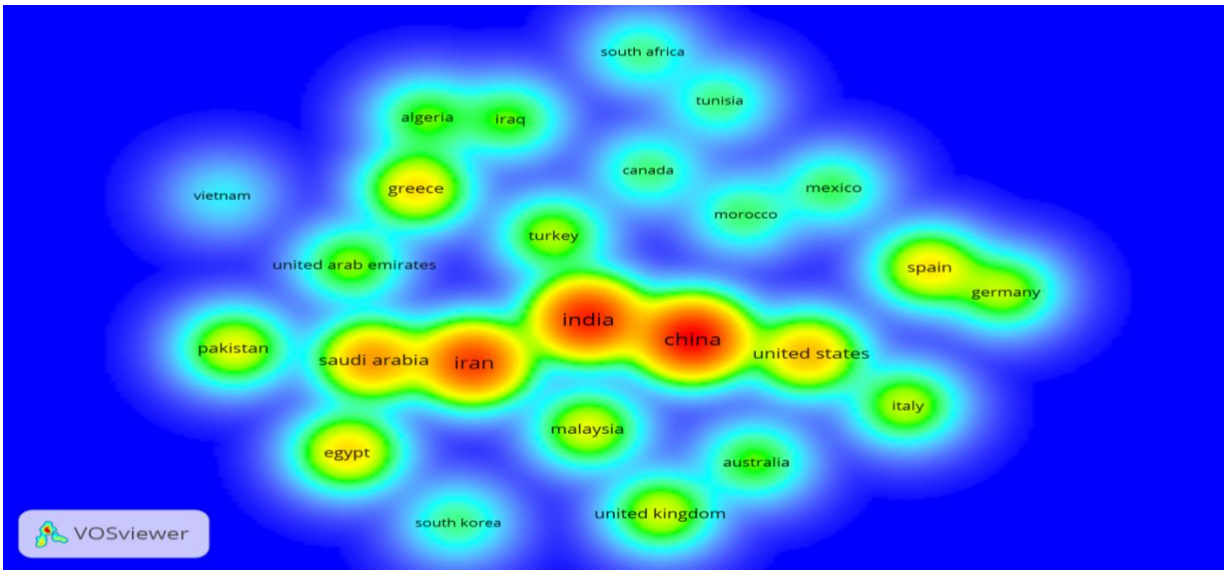
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(b) Overlay Visualizations for Publications from Different Countries



(c) Density Visualizations for Different Countries

Figure 2.2: Network, Overlay and Density Visualizations of Research Publications for Different Countries

In figure 2.2, the network visualization illustrates global research collaborations on optimization, solar parabolic troughs, and analysis, where China, India, and Iran emerge as the dominant research hubs with the highest publication output and extensive international connections. Countries are grouped into clusters based on collaboration strength, with China, Spain, Italy, and Australia forming a well-connected green cluster, while India, Iran, Pakistan, and Egypt form a red cluster representing strong Middle Eastern and South Asian cooperation. European nations (Spain, Greece, UK), North America (Canada, Mexico), and

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African countries (South Africa, Tunisia, Egypt) actively engage in global research networks. The visualization highlights the increasing interdisciplinary and cross-regional collaborations, reinforcing the importance of international cooperation in advancing solar energy optimization research.

The overlay visualization represents research collaborations over time on optimization, solar parabolic troughs, and analysis, where colors indicate publication periods (2018–2022) based on the scale at the bottom. China, India, and Iran remain the central research hubs, with extensive collaborations with other countries. Older research (2018–2019) appears in blue and purple, mainly involving Spain, Germany, Italy, and the U.S., indicating their early contributions. Recent collaborations (2021–2022) appear in yellow and green, notably involving Pakistan, Saudi Arabia, Egypt, and Iraq, suggesting an increasing research focus in these regions. The expanding connections between Europe, the Middle East, and Asia highlight the growing international interest and interdisciplinary collaborations in advancing solar energy optimization technologies.

The density visualization highlights the concentration of research publications on optimization, solar parabolic troughs, and analysis across different countries. Red and yellow areas indicate high research activity, while green and blue areas represent lower activity levels. China, India, and Iran appear as the most intense (red) regions, confirming their dominance in this field. Countries like Saudi Arabia, the United States, Egypt, and Spain also show moderate research density (yellow-green regions), indicating significant contributions. Peripheral countries such as South Africa, Tunisia, Vietnam, and Canada are in blue zones, suggesting lower but emerging research involvement. This visualization underscores strong research hubs in Asia and the Middle East, with expanding contributions from Europe, North America, and Africa.

2.2 Organization wise Publication and Citation Analysis

In the next stage, on analyzing the extracted dimensions.ai data in VOSviewer, number of publications as well as citations appeared in last ten years for different organizations were obtained, the details of which are presented Table 2.2 for top twenty alternatives.

Table 2.2: Number of Publications and Citations for Different Organizations in last ten years

S. No	Rank	Organizations	Number of Publications	Rank	Organizations	Number of Citations
1.	1	National Technical University of Athens	111	1	National Technical University of Athens	1324
2.	2	University of Tehran	86	2	University of Tehran	680
3.	3	University of Sharjah	41	3	North China electric Power University	518
4.	4	King Fahd University of Petroleum and Minerals	41	4	Anna University, Chennai	369
5.	5	Xian Jiaotong University	45	5	Xian Jiaotong University	342
6.	6	Tarbiat Modares Univesity	25	6	University of Sharjah	268

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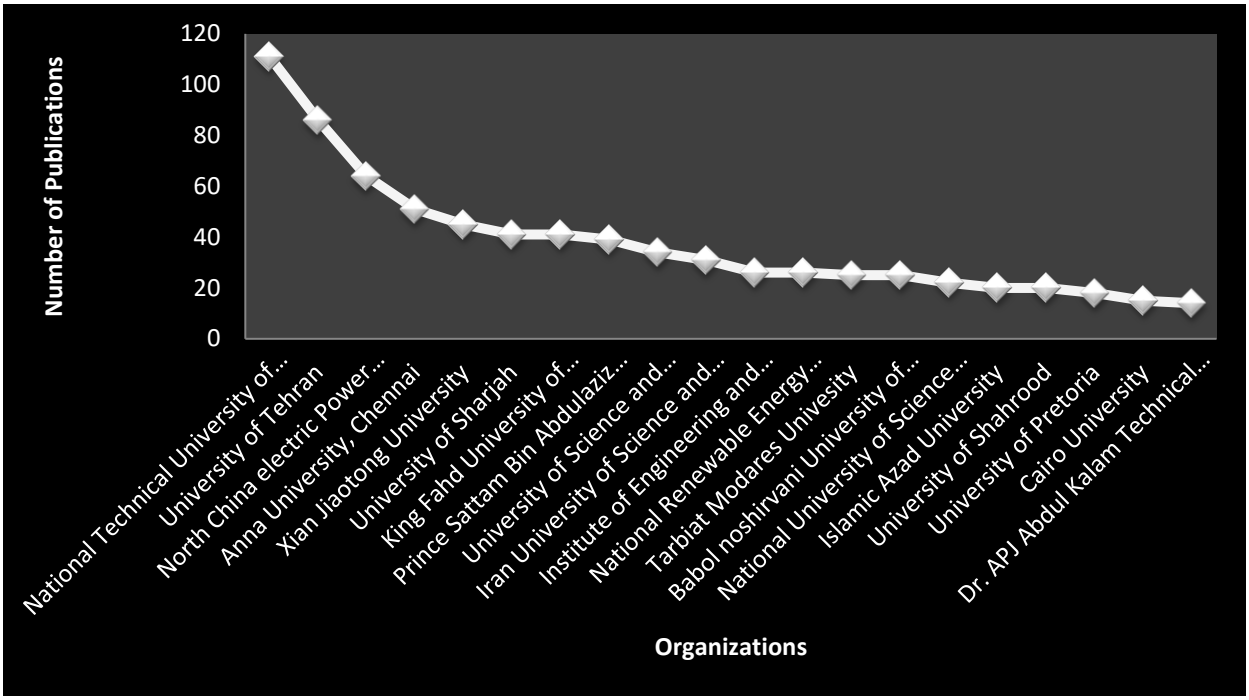
7.	7	Iran University of Science and Technology	31	7	King Fahd University of Petroleum and Minerals	244
8.	8	University of Science and Technology of	34	8	Prince Sattam Bin Abdulaziz University	195
9.	9	Anna University, Chennai	51	9	University of Science and Technology of	186
10.	10	Islamic Azad University	20	10	Iran University of Science and Technology	182
11.	11	National University of Science and Technology	22	11	Institute of Engineering and Thermophysics	178
12.	12	Prince Sattam Bin Abdulaziz University	39	12	National Renewable Energy Laboratory	176
13.	13	University of Pretoria	18	13	Tarbiat Modares Univesity	174
14.	14	University of Shahrood	20	14	Babol noshirvani University of Technology	174
15.	15	Dr. APJ Abdul Kalam Technical University	14	15	National University of Science and Technology	173
16.	16	Babol noshirvani University of Technology	25	16	Islamic Azad University	172
17.	17	Cairo University	15	17	University of Shahrood	167
18.	18	North China electric Power University	64	18	University of Pretoria	155
19.	19	Institute of Engineering and Thermo physics	26	19	Cairo University	139
20.	20	National Renewable Energy Laboratory	26	20	Dr. APJ Abdul Kalam Technical University	138

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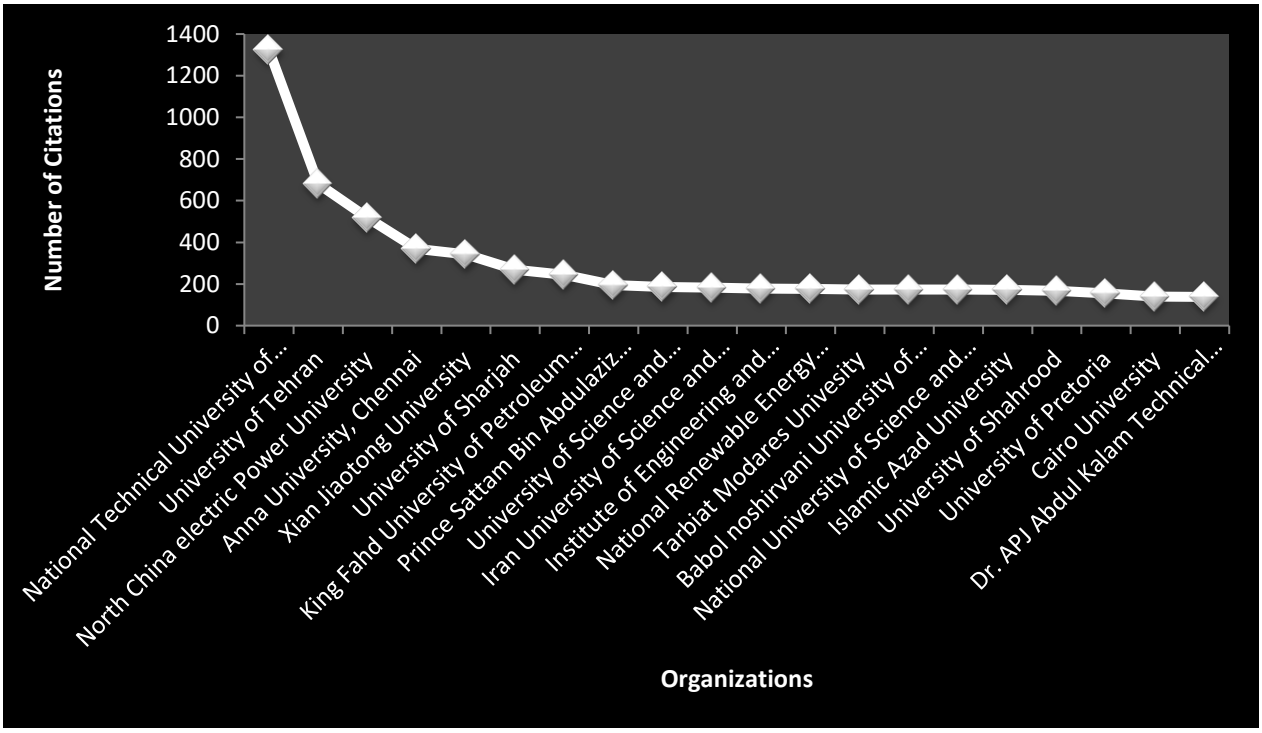
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Figure 2.3 shows the details of results in graphical format.



(a) Number of Publications from Different Organizations



(b) Number of Citations from Different Organizations

Figure 2.3: Details of Publications and Citations for Different Organizations

The Table 2.2 and Figure 2.3 presents a ranking of organizations based on their number of publications and citations related to optimization, solar parabolic troughs, and analysis. The National Technical University of Athens (Greece)

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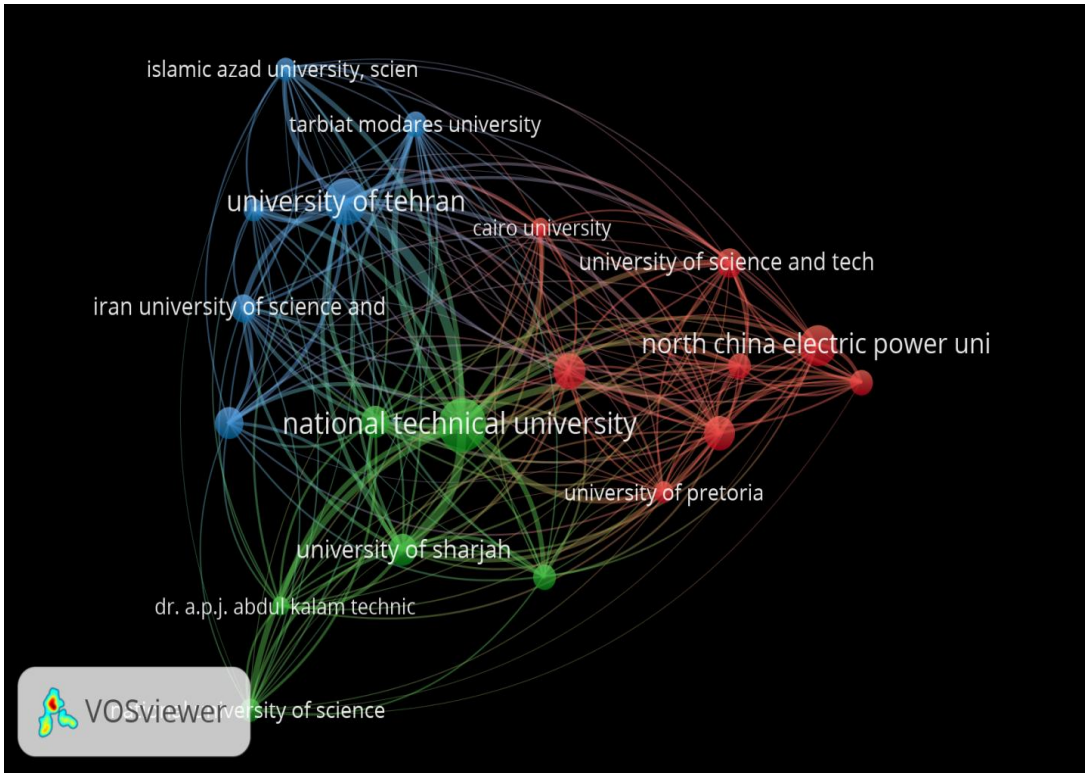
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leads in both categories, with 111 publications and 1,324 citations, indicating its dominant role in this research field. Other top contributors include the University of Tehran (Iran) with 86 publications and the University of Sharjah (UAE) and King Fahd University of Petroleum and Minerals (Saudi Arabia), each with around 41 publications. The Xian Jiaotong University (China) ranks fifth with 45 publications, highlighting China's strong research presence in solar energy technologies.

When examining research impact (citations), the National Technical University of Athens remains the most influential with 1,324 citations, followed by the University of Tehran (680 citations) and North China Electric Power University (518 citations). Some institutions, such as Anna University, Chennai (369 citations), and Xian Jiaotong University (342 citations), show a high citation-to-publication ratio, indicating high research quality and global influence. Interestingly, some universities rank high in publications but lower in citations, suggesting that their research is still gaining traction in the scientific community.

Several emerging institutions such as the University of Pretoria (South Africa), Cairo University (Egypt), and Dr. APJ Abdul Kalam Technical University (India) have a growing number of publications and citations, reflecting increasing research interest in solar parabolic trough optimization across different regions. The National Renewable Energy Laboratory (USA) and Institute of Engineering and Thermophysics (China) also feature in the citation rankings, showing strong research contributions despite fewer publications. This data highlights a global collaborative effort in advancing solar energy technologies, with institutions from Europe, Asia, and the Middle East playing a major role in shaping research on solar parabolic troughs.

Moving one step further, on drawing network, overlay and density visualizations for above information, the following outputs were obtained.

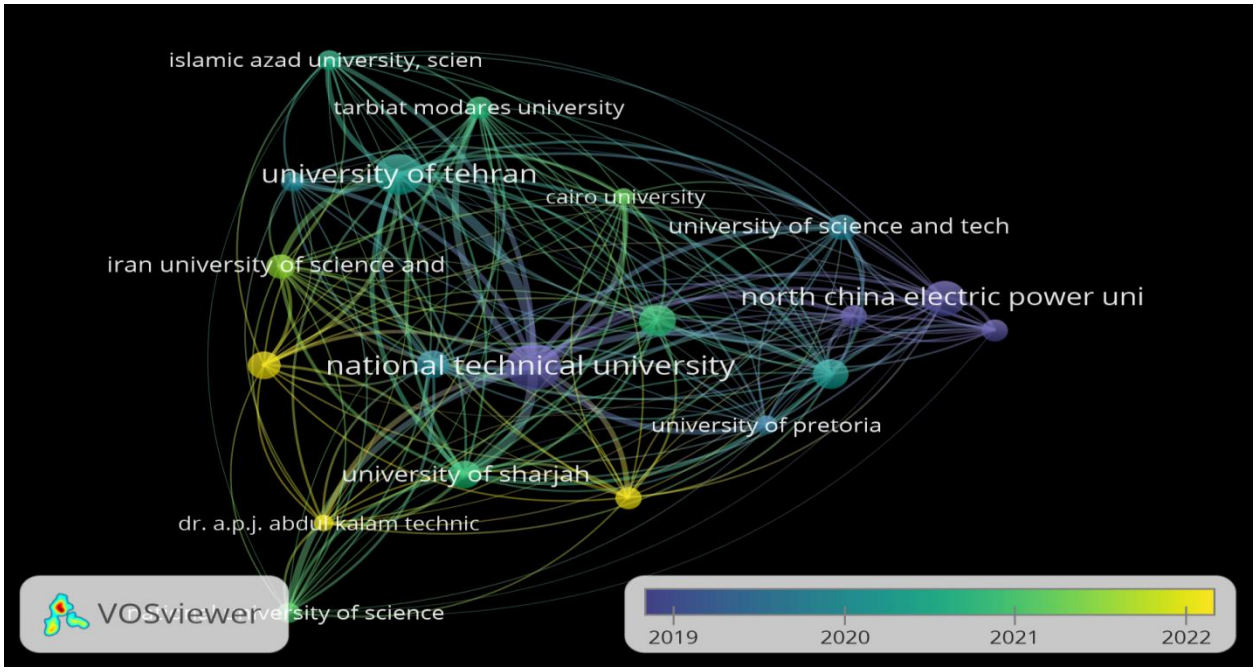


(a) Network Visualization for Publications from Different Organizations

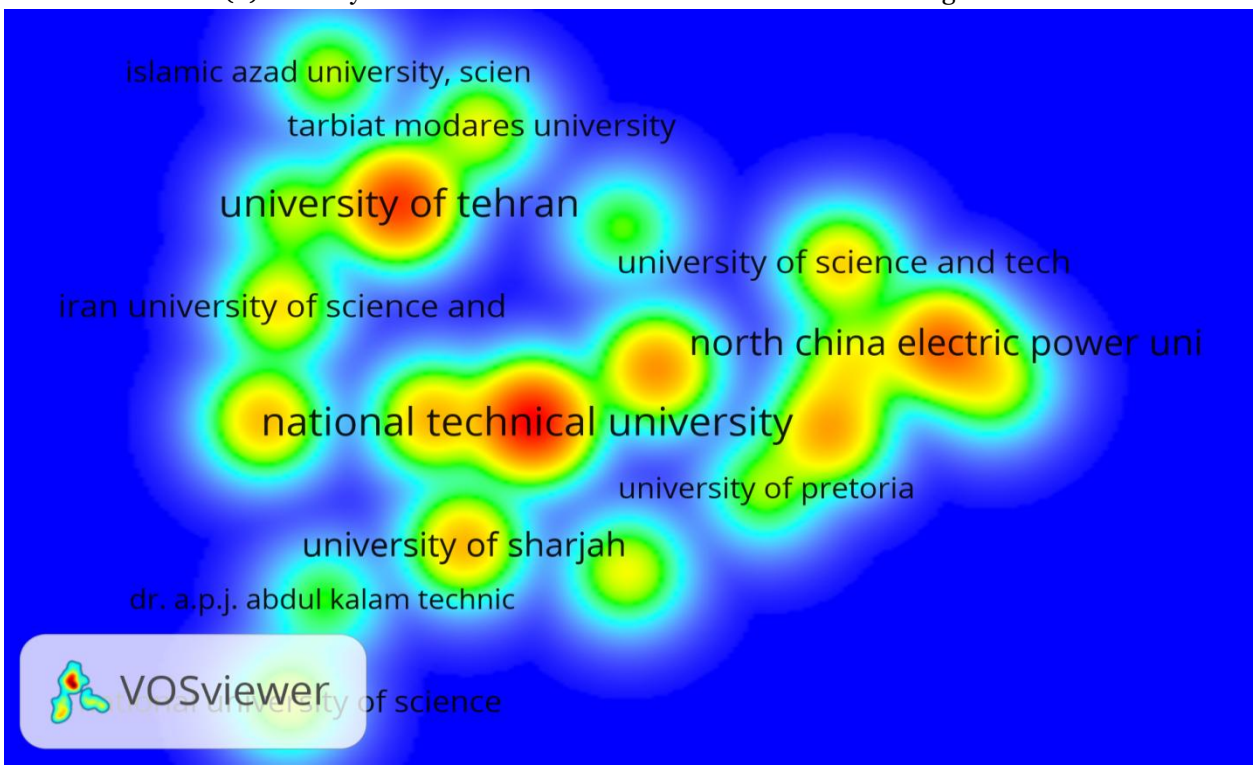
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(b) Overlay Visualizations for Publications from Different Organizations



(c) Density Visualizations for Different Organizations

Figure 2.4: Network, Overlay and Density Visualizations of Research Publications for Different Organizations

In the figure 2.4, the network visualization illustrates collaborations between different academic institutions in research on optimization, solar parabolic troughs, and analysis. Each node represents a university, and lines indicate research collaborations. The size of the nodes reflects the number of publications, while different colors represent clusters of closely collaborating institutions. The National Technical University of Athens, University of Tehran, and North China Electric Power University emerge as key research hubs with extensive connections. Iranian institutions (University of Tehran, Iran University of Science and Technology, Islamic Azad University) form a strong blue cluster,

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while Chinese universities (North China Electric Power University, University of Science and Technology) dominate the red cluster. The green cluster includes the National Technical University of Athens, University of Sharjah, and Dr. A.P.J. Abdul Kalam Technical University, indicating significant collaborations between European and Middle Eastern institutions. This visualization highlights global academic partnerships, with strong research ties between Europe, Asia, and the Middle East in advancing solar parabolic trough technology.

Similarly, the overlay visualization represents research collaborations between different universities in optimization, solar parabolic troughs, and analysis over time. The color gradient (2019–2022) at the bottom shows how research activity evolved, with older collaborations in purple and blue (2019–2020) and newer collaborations in yellow and green (2021–2022). The National Technical University of Athens, University of Tehran, and North China Electric Power University remain central research hubs with extensive global connections. Recent collaborations (yellow) are emerging from institutions like Iran University of Science and Technology, Dr. A.P.J. Abdul Kalam Technical University, and University of Sharjah, indicating increased research activity in these regions. Earlier collaborations (blue-purple) involved North China Electric Power University and Cairo University, suggesting their foundational contributions. This visualization highlights the dynamic nature of academic collaborations, with a growing emphasis on interdisciplinary and international research in solar energy optimization.

Proceeding in the similar manner, the density visualization diagram depicts research output related to "solar parabolic troughs" across various organizations, visualized using VOSviewer. The clustering of "university of tehran," "university of science and tech," "iran university of science" and "north china electric power" suggests a strong collaborative or thematic link in their publications related to this technology. "Optimization" and "analysis" are likely keywords appearing frequently within the publications of these organizations, indicating a focus on improving and understanding the performance of solar parabolic troughs. The varying color intensities represent the density of publications, with yellow areas indicating higher concentration and thus potentially significant contributions to the field of solar parabolic trough research, optimization, and analysis. This visualization allows for a quick understanding of which institutions are actively involved and potentially leading in this specific area of research.

2.3 Source wise Publication and Citation Analysis

In the next stage, on analyzing the extracted dimensions.ai data in VOSviewer, number of publications as well as citations appeared in last ten years for different Journals were obtained, the details of which are presented Table 2.3 for top twenty alternatives.

Table 2.3: Number of Publications and Citations for Different Sources in last ten years

S. No	Rank	Source	Number of Publications	Rank	Source	Number of Citations
1.	1	Renewable energy	122	1	Renewable energy	7203
2.	2	Environmental science and pollution	119	2	Renewable and sustainable energy	6985
3.	3	Solar energy	118	3	Applied energy	5280
4.	4	Applied thermal engineering	109	4	Applied thermal engineering	4776
5.	5	Energy conservation and management	99	5	Solar energy	4615

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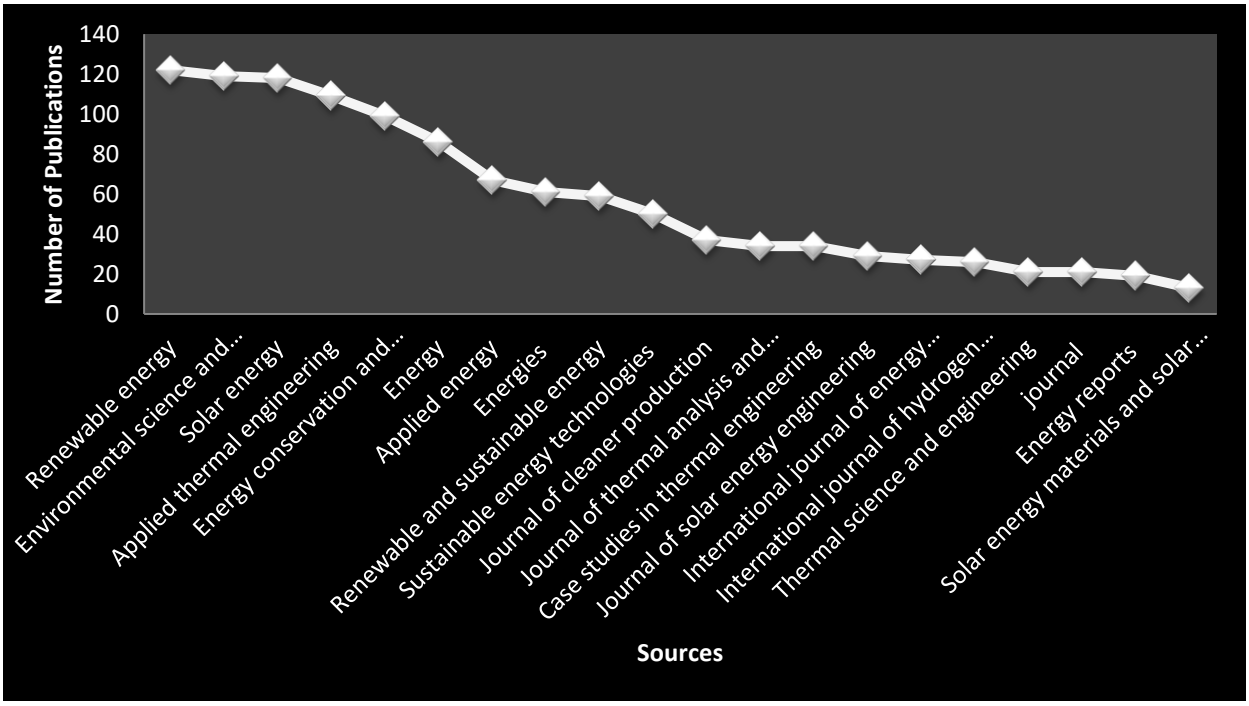
6.	6	Energy	86	6	Energy conservation and management	4526
7.	7	Applied energy	67	7	Energy	3191
8.	8	Energies	61	8	Environmental science and pollution	3052
9.	9	Renewable and sustainable energy	59	9	Sustainable energy technologies	2089
10.	10	Sustainable energy technologies	50	10	Journal of cleaner production	1999
11.	11	Journal of cleaner production	37	11	International journal of energy research	1628
12.	12	Journal of thermal analysis and calorimetry	34	12	International journal of hydrogen energy	970
13.	13	Case studies in thermal engineering	34	13	Solar energy materials and solar cells	938
14.	14	Journal of solar energy engineering	29	14	Journal of thermal analysis and calorimetry	782
15.	15	International journal of energy research	27	15	Thermal science and engineering	778
16.	16	International journal of hydrogen energy	26	16	Journal of solar energy engineering	738
17.	17	Thermal science and engineering	21	17	Energies	638
18.	18	journal	21	18	Solar energy materials and solar cells	637
19.	19	Energy reports	19	19	Case studies in thermal engineering	520
20.	20	Solar energy materials and solar cells	13	20	Energy reports	502

Figure 2.5 shows the details of results in graphical format.

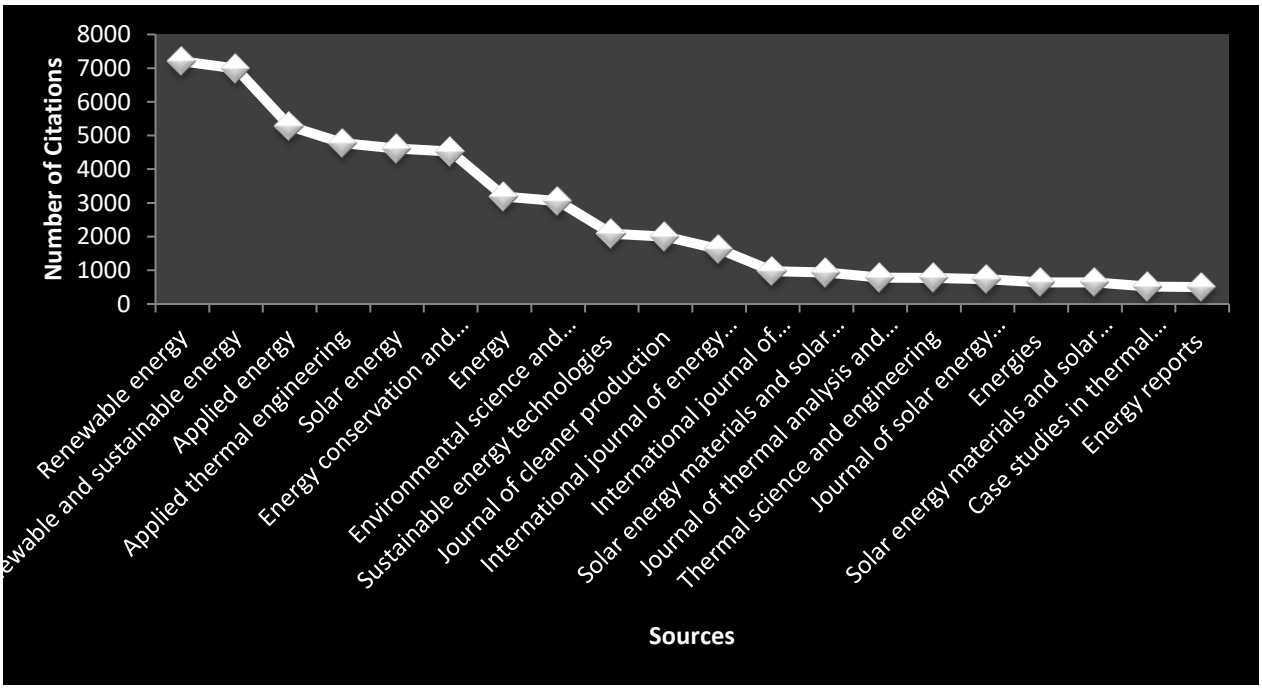
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(a) Number of Publications from Different Sources



(b) Number of Citations from Different Sources

Figure 2.5: Details of Publications and Citations for Different Sources

The Table 2.3 and Figure 2.5 ranks academic journals based on their number of publications and citations related to optimization, solar parabolic troughs, and analysis. "Renewable Energy" leads both categories, with 122 publications and 7,203 citations, making it the most prominent journal in this field. Other key journals contributing significantly to research output include "Environmental Science and Pollution" (119 publications), "Solar Energy" (118 publications),

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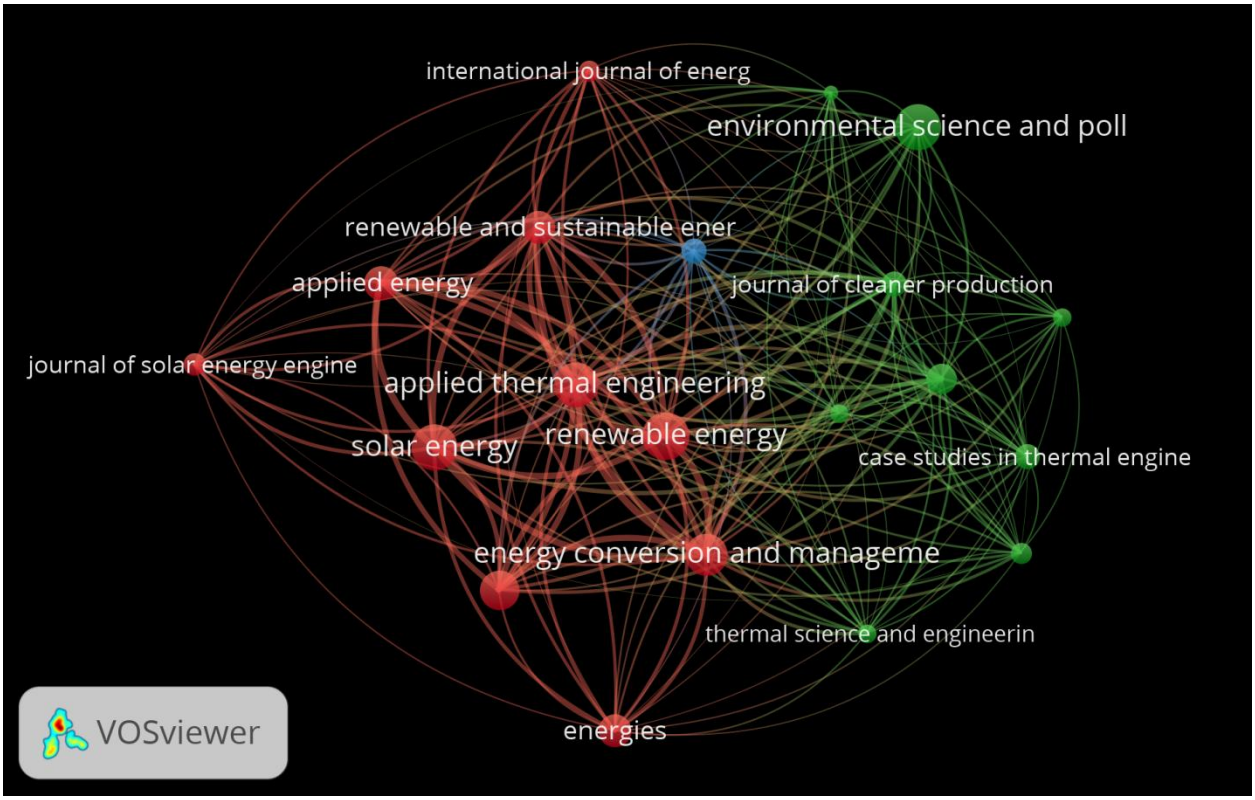
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and "Applied Thermal Engineering" (109 publications). These journals indicate a strong interdisciplinary focus, covering renewable energy, environmental science, and thermal applications in solar energy research.

In terms of impact (citations), "Renewable and Sustainable Energy" (6,985 citations) and "Applied Energy" (5,280 citations) follow closely behind "Renewable Energy," reflecting their influence in the academic community. Notably, "Solar Energy" (4,615 citations) and "Energy Conservation and Management" (4,526 citations) also receive high citations, indicating their role in advancing solar thermal system optimizations. Some journals, such as "Journal of Cleaner Production" (1,999 citations) and "International Journal of Energy Research" (1,628 citations), have fewer publications but maintain high citation counts, suggesting that their published research is of high quality and widely referenced.

Emerging journals like "Thermal Science and Engineering," "Energy Reports," and "Solar Energy Materials and Solar Cells" contribute to the field but have relatively lower publication and citation counts. This suggests a growing interest in solar parabolic trough optimization research in specialized thermal engineering and energy-related journals. Overall, the dominance of renewable energy, thermal engineering, and sustainability journals reflects the global research focus on improving solar thermal technologies through optimization and performance analysis.

Moving one step further, on drawing network, overlay and density visualizations for above information, the following outputs were obtained.

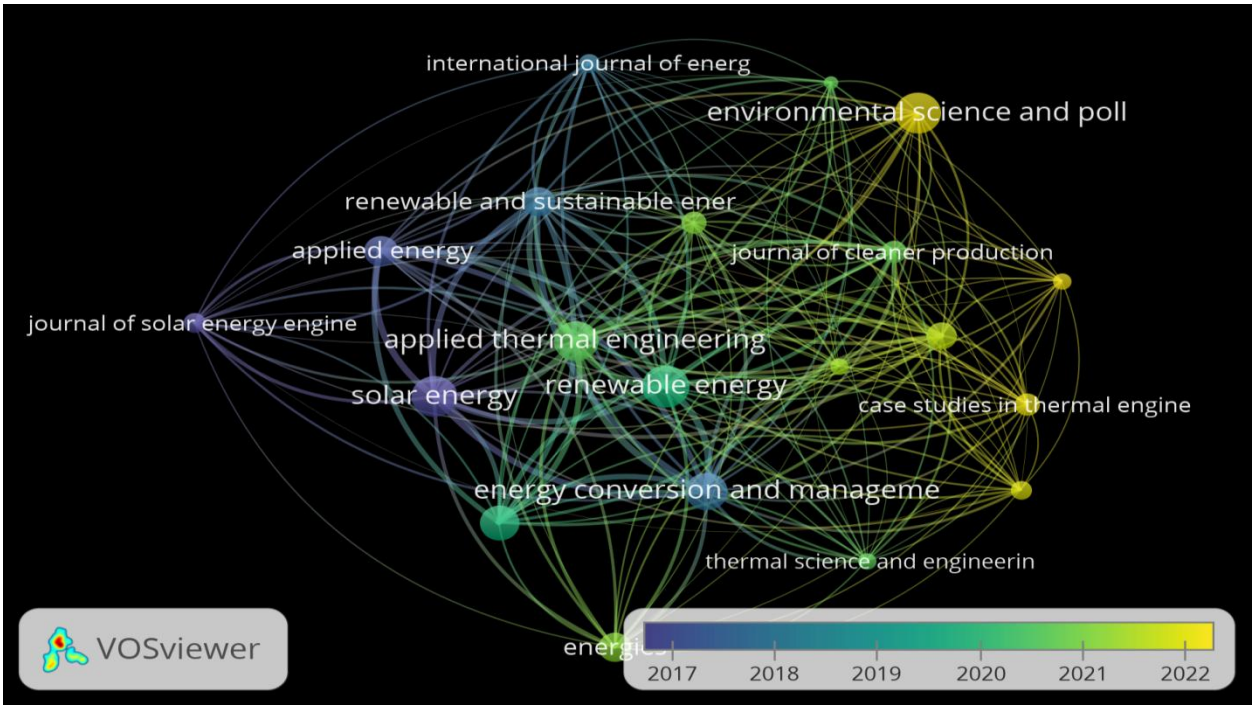


(a) Network Visualization for Publications from Different Sources

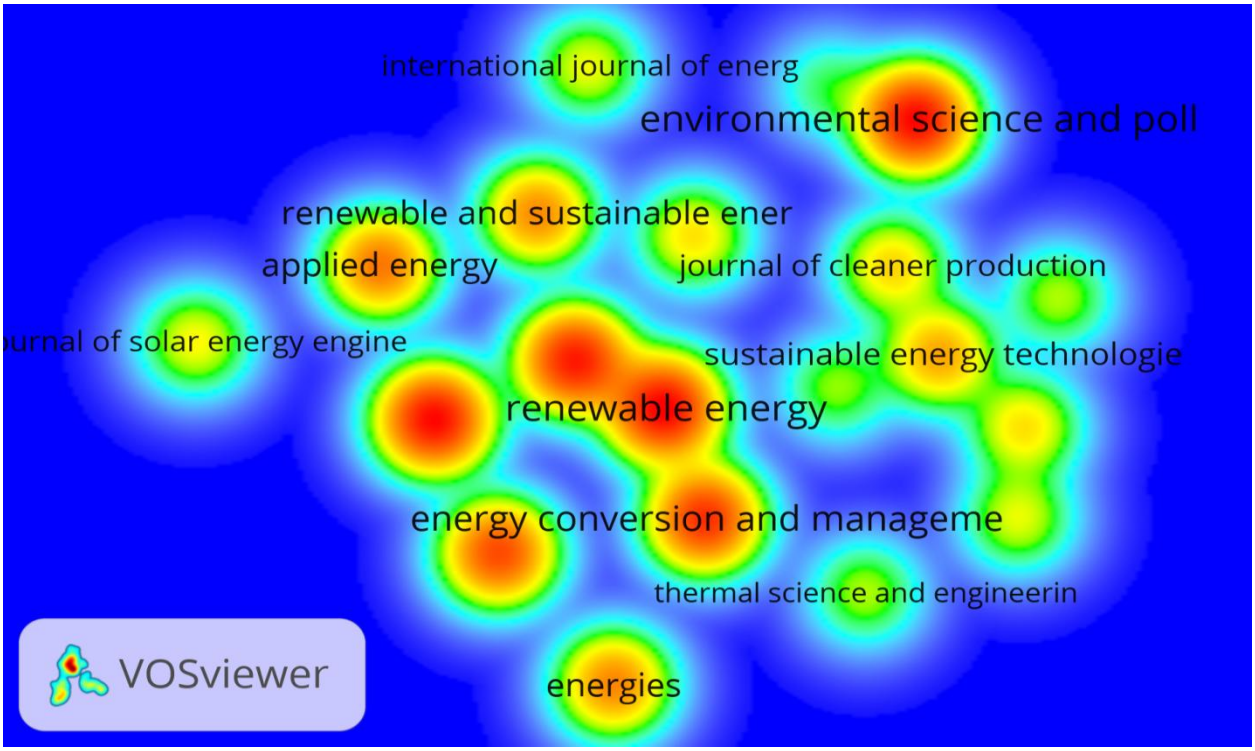
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(b) Overlay Visualizations for Publications from Different Sources



(c) Density Visualizations for Different Sources

Figure 2.6: Network, Overlay and Density Visualizations of Research Publications for Different Sources

In figure 2.6, the network visualization depicts relationships between different publications sources (likely academic journals) based on the co-citation of publications related to the topic of "solar parabolic troughs," as indicated by the earlier density visualization. The nodes represent the sources, and the lines connecting them indicate a relationship, likely the number of times publications in those sources have been cited together. The clustering of nodes, indicated by color groupings, suggests communities of sources that frequently publish and are cited together, representing

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potentially related sub-fields within solar parabolic trough research. For example, "solar energy" and "applied energy" are closely linked, showing a strong relationship in publications. This network helps visualize the interconnectedness of research and the influence of different publication sources within the field. The size of the nodes may indicate the number of publications or citations related to the topic, reflecting the relative importance of that source in the research landscape.

In the similar manner, in the overlay diagram, the color of each node now represents the average publication year of the articles in that source that are related to the topic. This allows for the observation of trends and the evolution of research focus in different journals. For example, nodes with a more yellow hue indicate sources that have published more recent articles on the topic, while bluer nodes suggest older publications. This visualization helps understand not only the relationships between sources but also how the interest and publication activity in specific areas within solar parabolic trough research have changed over time. The timeline at the bottom provides a key for the color gradient, showing the corresponding year for each color. This allows for quick identification of leading journals in specific time periods related to this research area.

Similarly, the density visualization, generated by VOSviewer, represents the concentration of publications related to a specific topic (likely "solar parabolic troughs" based on the previous images) across different publication sources (journals). The color gradient, ranging from dark blue to bright yellow, indicates the density of publications, with yellow areas representing a higher concentration and thus a greater number of publications in that journal related to the topic. The labels identify the respective journals. For example, "renewable energy" and "applied energy" show high densities, suggesting these journals have published extensively on the subject. This visualization allows for a quick assessment of which journals are most prominent and active in publishing research related to the specified topic, giving researchers an idea of where to focus their literature review or potential submission efforts. The clustering of journals suggests potential relationships or overlaps in their subject coverage.

3. Conclusion, Limitations and Future Scope of the Research

The present section presents conclusion, limitations and future scope of the research, as presented in upcoming sub-sections.

3.1 Conclusion

The following points represent the conclusion of the research work:

- Research on solar parabolic trough collectors has grown significantly in the last ten years.
- International collaboration in this field is strong, with hubs in Asia, the Middle East, and Europe.
- China, India, and Iran are leading countries in solar parabolic trough collector research publications.
- Key institutions like the national technical university of Athens and the University of Tehran are highly influential.
- *Renewable energy*, *Environmental Science and Pollution*, and *Solar Energy* are important journals in the field.

3.2 Limitations and Future Scope of the Research

Following points represent the limitations of the research:

- The study relies on a single database (Dimensions.ai), which might not include all relevant publications.
- The keyword search strategy could have missed some relevant research due to variations in terminology.
- The ten-year time frame might overlook important earlier research.
- VOSviewer has limitations in terms of analysis and visualization options.
- The study primarily uses quantitative analysis and lacks a deeper qualitative examination of the research content.
- The analysis only considers publications and excludes other research outputs like patents or conference proceedings.

Following points represent the futures scope of the research:

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- Future research could use multiple databases for a more comprehensive analysis.
- Advanced search strategies could improve the retrieval of relevant research.
- Extending the analysis to cover a longer time period could reveal long-term trends.
- Combining quantitative analysis with qualitative content analysis would provide richer insights.
- Including other research outputs would provide a more complete picture of research activity.
- Deeper analysis of researcher collaborations could identify key networks.
- Analyzing the citation network could reveal influential papers and research clusters.
- Future research could focus on specific geographic regions to understand regional strengths and collaborations

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