International Journal of Innovative Research and Scientific Studies, 8(6) 2025, pages: 2281-2294

IJIRSS International Journal of Innovative Research & Scientific Studies

ISSN: 2617-6548

URL: www.ijirss.com

Optimization, exergy, and innovation in PTC systems: A scientometric review

Mthimunye Thabiso Vincent[1*], Mukumba Patrick[2], KeChrist Obileke[3]

[1,2,3]Department of Physics, Science and Agriculture, University of Fort Hare, Private Bag X 1314, South Africa.

Corresponding author: Mthimunye Thabiso Vincent (*Email: ttvmthimunye@gmail.com*)

Abstract

This paper examines the research patterns and trends of the parabolic trough collectors around the world from 2014 to 2025. Data (keywords in articles) was collected from the Scopus academic Journal. A co-word analysis was conducted to measure the correlation among the extracted keywords. The thematic mapping of research topics identifies optimization, exergy analysis, and the organic Rankine cycle as the most mature and influential themes within the PTC and concentrated solar power (CSP) literature. The study results show that the comprehensive analysis of the parabolic trough solar collector research landscape from 2014 to 2024 demonstrates a field characterized by significant growth, interdisciplinary collaboration, and evolving thematic focus. The sustained increase in scholarly output and the prominence of key research themes such as optimization, exergy analysis, and advanced heat transfer fluids reflect the domain's maturation and dynamism.

Keywords: Exergy, Innovation, Optimization, PTC systems, Scientometric review.

DOI: 10.53894/ijirss.v8i6.10108
Funding: This study received no specific financial support.
History: Received: 8 July 2025 / **Revised:** 12 August 2025 / **Accepted:** 14 August 2025 / **Published:** 19 September 2025

Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: All authors contributed equally to the conception and design of the study. All authors have read and agreed to the published version of the manuscript.
Transparency: The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.
Acknowledgements: We want to express our sincere appreciation to the RNA Renewable Energy (Wind) of the Department of Research and Innovation at the University of Fort Hare, DSI, and Eskom for their support.
Publisher: Innovative Research Publishing

1. Introduction

Using statistical techniques to evaluate several facets of published works, such as authorship, citation patterns, and theme trends, bibliometric studies are quantitative analyses of academic literature [1]. Bibliometric studies assist scholars in comprehending the impact and influence of scholarly works within particular domains by utilizing methods like network visualization, citation analysis, and co-citation analysis [2]. In addition to helping institutions assess research productivity and collaboration trends, this approach helps identify important authors, seminal publications, and new research subjects [3]. Furthermore, bibliometrics is crucial in guiding funding choices and strategic planning for academic programs by identifying the research landscape's strengths and weaknesses.

Co-words analysis is a bibliometric technique that examines the co-occurrence of keywords in academic literature to map the intellectual structure of a research field. This method reveals thematic connections and trends, providing insights into the evolution of knowledge across various disciplines [4]. The following sections outline the key aspects of co-words analysis based on recent studies. Co-word analysis involves collecting data from academic publications, focusing on the frequency of keyword pairs [5]. Techniques such as hierarchical clustering and factor analysis are often employed to identify relationships and thematic clusters within the data [6, 7].

In chronic heart failure research, co-word analysis identified key themes such as "Cardiac Resynchronization" and "Echocardiography," revealing a structured network of knowledge [6]. The field of international management science demonstrated rapid thematic changes, highlighting the dynamic nature of research trends [8]. In science education, co-word analysis tracked the evolution of scaffolding research, identifying significant keywords and trends over two decades [9].

Co-word analysis has uncovered emerging research areas, such as technological innovation in hotels, which is categorized into distinct clusters [10]. The technique is versatile and applicable across various fields, including medicine, education, and management, thus facilitating a comprehensive understanding of research landscapes [9].

While co-words analysis provides valuable insights into research trends and thematic structures, it may also overlook nuanced qualitative aspects of research that are not captured through keyword frequency alone. This limitation suggests the need for complementary qualitative analyses to enrich understanding.

2. Methodology

This study employs a bibliometric approach to analyze the global research landscape on parabolic trough collectors (PTCs) between 2014 and 2024. Bibliometric analysis is a quantitative method used to evaluate patterns in scholarly communication, focusing on metrics such as publication frequency, author productivity, and keyword trends. Data for this analysis were retrieved from the Scopus database, utilizing a structured search query that combined relevant keywords such as “parabolic trough collector,” “solar energy,” “optimization,” and “thermal efficiency.” The dataset was filtered to include only peer-reviewed journal articles within subject areas such as Engineering, Energy, Environmental Sciences, and Materials Science.

The core analytical technique employed was co-word analysis, which identifies and quantifies the co-occurrence of keywords within the literature. This technique is instrumental in mapping a research field's intellectual structure and thematic evolution. Keywords were extracted from article titles, abstracts, and author-provided descriptors. Network analysis tools were then used to generate visual representations, including thematic maps, Sankey diagrams, and bubble timelines. These collectively illustrate research themes' maturity, centrality, and connectivity over time. Additional analyses included trend topic tracking, author productivity over time, and citation impact metrics, allowing for a multidimensional exploration of the PTC scholarly ecosystem. This combined methodological approach provides macro- and micro-level insights into solar thermal research's progression and future trajectory.

3. Results and Discussions

The field of solar energy has seen significant advancements over the past decade, with parabolic trough solar collectors (PTCs) emerging as a leading technology for large-scale solar thermal applications. This analysis examines the research landscape of PTCs from 2014 to 2024, focusing on publication trends, key subject areas, and research themes such as heat transfer, efficiency, and optimization.

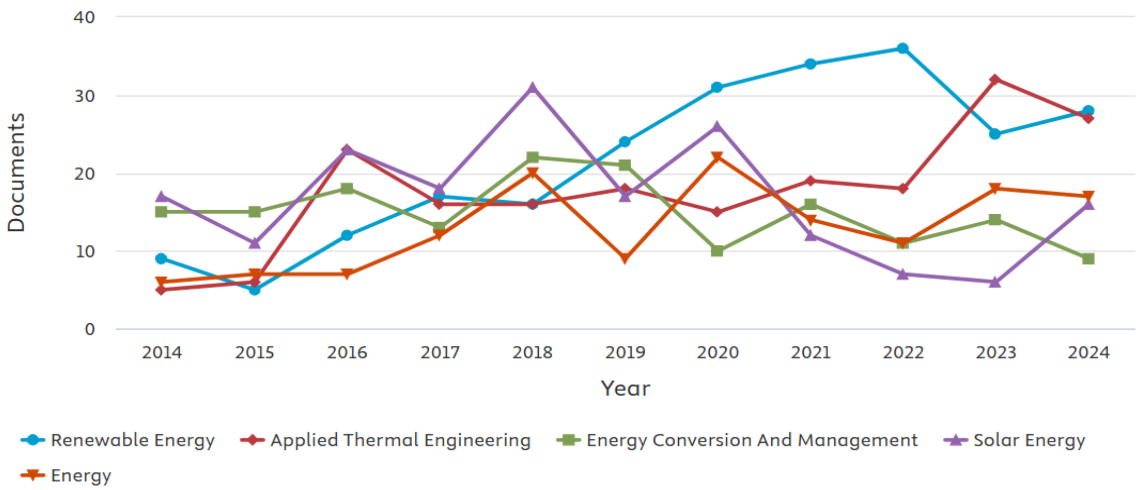

Figure 1.
Comparison of the documents per year by source.

The graph presents annual publication counts for each journal over 11 years. The y-axis indicates the number of documents, while the x-axis represents the publication year. A general upward trend in the total number of publications indicates growing academic interest and investment in PTC research. The most significant peaks occur in Renewable Energy (2022) and Applied Thermal Engineering (2023), both exceeding 30 documents in those years.

An analysis of publication trends across key journals reveals varying patterns of research activity related to parabolic trough collectors (PTCs). *Renewable Energy* (blue line) demonstrates a steady increase in scholarly output from 2014, culminating in a peak in 2022 with over 35 publications, followed by a modest decline in 2023 and 2024. *Applied Thermal Engineering* (red line) shows a pronounced surge in publications beginning in 2021, reaching its highest point in 2023, indicative of a growing emphasis on the engineering dimensions of PTC systems. In contrast, *Energy Conversion and Management* (green line) exhibits relative stability over the examined period, with minor fluctuations, suggesting sustained but moderate academic interest. *Solar Energy* (purple line) displays considerable variability, with an early peak in 2016, followed by a gradual decline and eventual stabilization at lower levels post-2020. Lastly, *Energy* (orange line) reflects moderate growth characterized by periodic fluctuations, with significant peaks in 2019 and 2023.

The data reflects the dynamic nature of PTC research, with journals responding to evolving scientific, technological, and societal priorities. The increasing prominence of Renewable Energy and Applied Thermal Engineering suggests a growing integration of PTC research with broader renewable energy systems and applied engineering challenges. Meanwhile, the steady output in Energy Conversion and Management points to ongoing interest in system-level efficiency and management

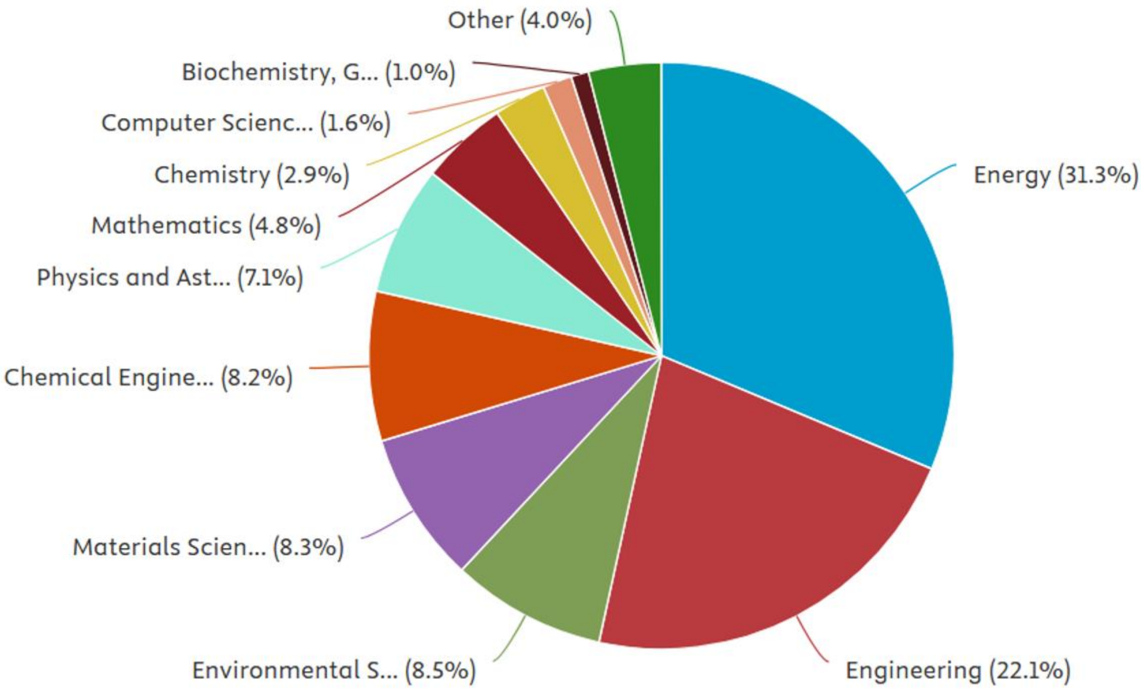

Figure 2.
Documents by subject area.

The largest share of research is concentrated in the Energy field (31.3%), followed by Engineering (22.1%). This distribution is expected, as PTCs are primarily developed and optimized for energy generation, particularly in solar thermal power plants. The significant representation of engineering underscores the focus on system design, mechanical optimization, and practical implementation.

A notable proportion of research related to parabolic trough collectors (PTCs) is distributed across *Environmental Science* (8.5%), *Materials Science* (8.3%), and *Chemical Engineering* (8.2%), reflecting the inherently interdisciplinary nature of this field. Contributions from *Environmental Science* encompass analyses of environmental impacts, sustainability assessments, and lifecycle evaluations of solar thermal systems. *Materials Science* is critical in developing high-performance absorber coatings, glass covers, and structural components to improve PTC systems' efficiency and longevity. *Chemical Engineering* contributes through investigations into heat transfer fluids, thermodynamic behavior, and process integration strategies.

Foundational support is also provided by disciplines such as *Physics and Astronomy* (7.1%), *Mathematics* (4.8%), and *Chemistry* (2.9%). Research in *Physics and Astronomy* enhances the understanding of solar radiation behavior, optical properties, and thermal dynamics. *Mathematics* is instrumental in modeling, simulation, and performance optimization, while *Chemistry* contributes to the synthesis and characterization of advanced materials and coatings.

Emerging contributions are observed from *Computer Science* (1.6%) and *Biochemistry, Genetics, and Molecular Biology* (1.0%), indicating growing interest in applying computational modeling, artificial intelligence, and bio-inspired materials or mechanisms. Other fields (4.0%) also demonstrate occasional yet meaningful intersections with PTC research, underscoring its broad scientific and technological relevance.

The subject area distribution demonstrates that PTC research is highly multidisciplinary, drawing on engineering, energy systems, environmental assessment, and materials innovation expertise. The prominence of energy and engineering highlights the applied nature of the field. At the same time, significant contributions from environmental and materials sciences reflect the ongoing need for sustainable and technologically advanced solutions.

The involvement of supporting sciences ensures that theoretical and computational advances continue to inform practical developments. Computer science and mathematics roles will likely grow as computational and data-driven methods become more prevalent.

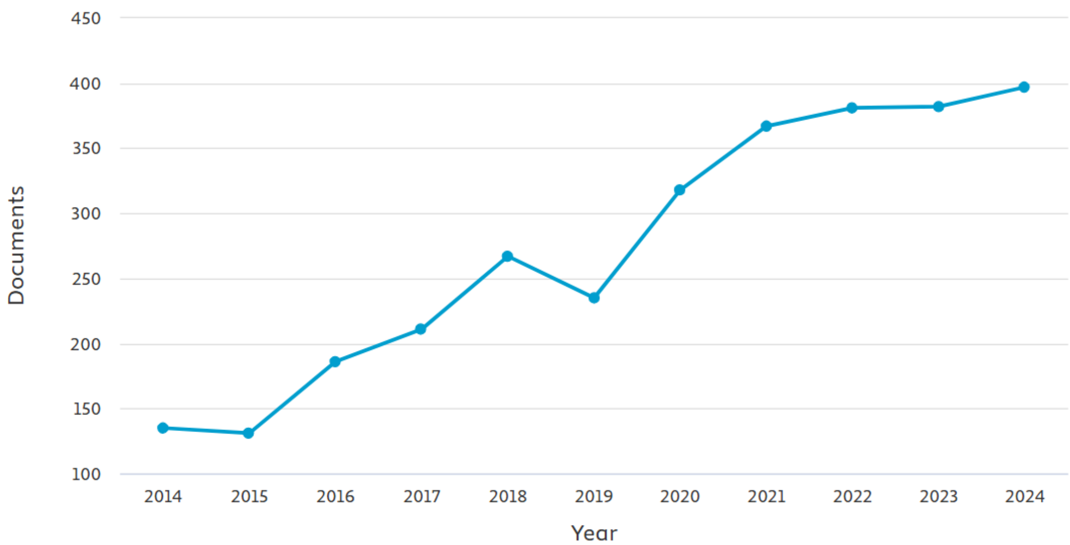

Figure 3.
Illustrates the annual number of documents published between 2014 and 2024.

The line graph illustrates the annual number of documents published between 2014 and 2024, revealing a clear upward trend that indicates sustained growth in scholarly output over these 11 years. From 2014 to 2017, the number of documents published increased modestly; starting at approximately 135 papers in 2014, there was a slight dip in 2015. However, this decline was temporary, as publication numbers rose consistently thereafter, reaching around 210 by 2017. This period of steady growth was followed by a sharper increase between 2017 and 2018, when document output rose from about 210 to over 260. Although a slight decline occurred in 2019, with production dropping to roughly 240 documents, 2020 marked a significant recovery as publications surged past 300. From 2020 onwards, the growth trajectory became more pronounced and steadier, with document production increasing to approximately 365 in 2021 and continuing to grow marginally in subsequent years. By 2024, the output peaked at around 400 documents, demonstrating a plateauing growth pattern that suggests the field is maturing while maintaining consistently high levels of academic activity.

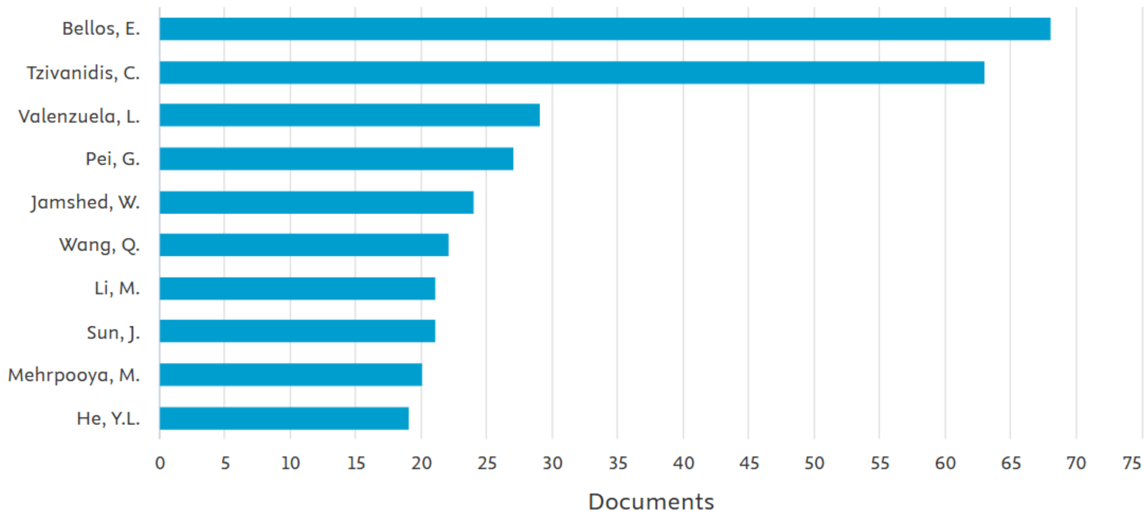

Figure 4.
Comparison of the document counts for 15 authors.
Source: Bellos, et al. [11]; Valenzuela and Montecinos [12]; Wang, et al. [13]; Li Min, et al. [14]; Sun and Perona [15], Mehrpooya [16], and He, et al. [17]

The horizontal bar graph presents the top 10 most prolific authors regarding the number of documents published. This metric serves as an indicator of individual research productivity within the relevant scholarly domain.

Bellos, et al. [11] emerges as the most prolific author, with approximately 70 published documents, reflecting sustained and substantial engagement in scholarly research over an extended period. Closely following is Bellos, et al. [11], who has contributed slightly more than 65 documents. The proximity in publication volume between these two authors may indicate frequent collaboration or shared affiliation within the same research networks or institutions.

Valenzuela and Montecinos [12] have each authored between 30 and 35 documents, positioning them as notable contributors to the field, albeit with a lower output than the leading authors. Jamshed, W. follows with just under 30 publications, suggesting consistent involvement in research activities.

The remaining contributors — Wang, et al. [13], Li Min, et al. [14], Sun and Perona [15], Mehrpooya [16], and He, et al. [17] — each demonstrate a moderate but steady level of productivity, with 20 to 25 documents attributed to their authorship. This consistent output indicates active participation in collaborative research initiatives and ongoing scholarly projects**.**

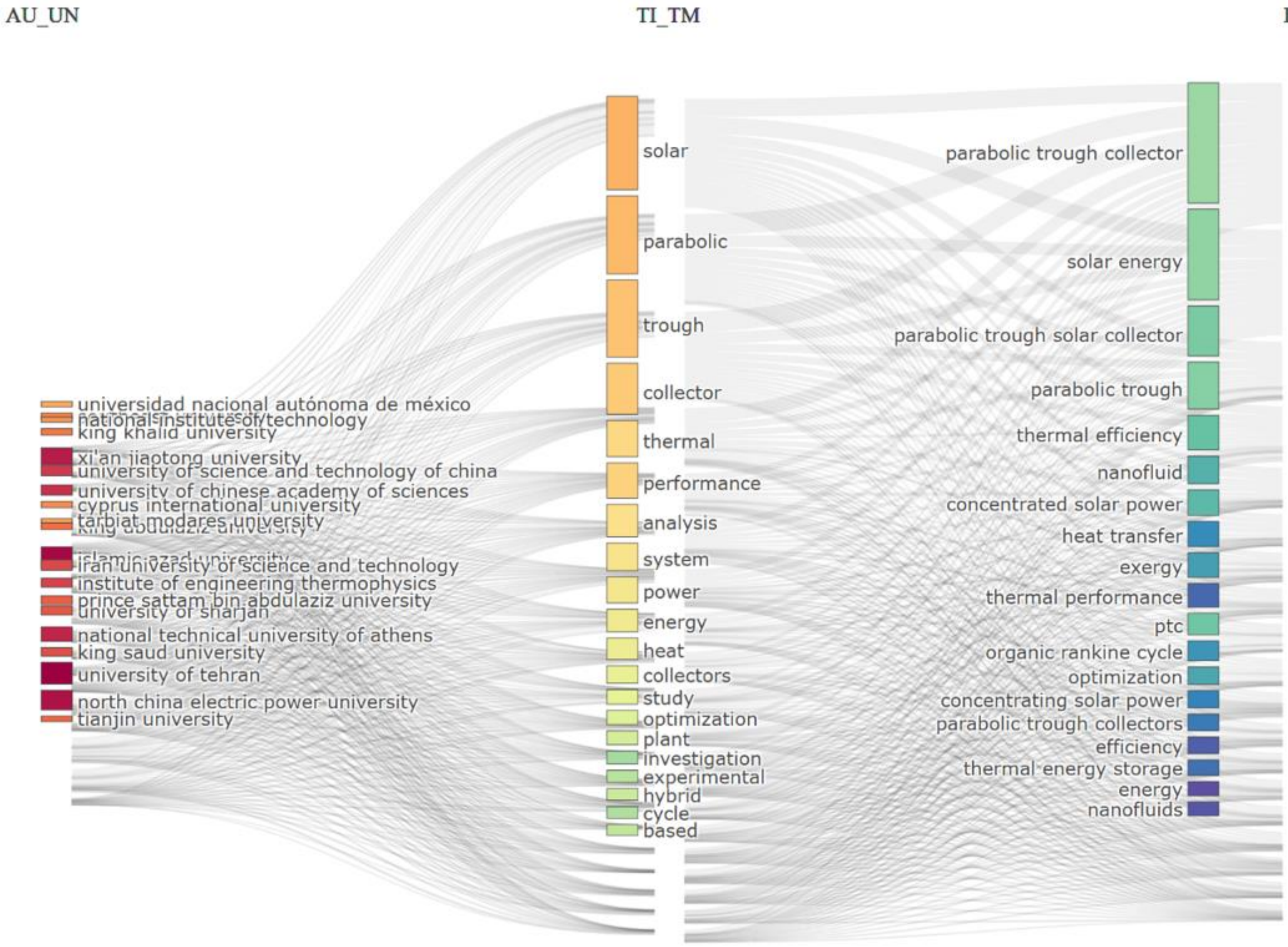

Figure 5.
Three-field plot.

A bibliometric Sankey diagram was constructed to examine the relationship among commonly occurring title terms (TI_TM), author affiliations (AU_UN), and subject descriptors (DE) within the literature on parabolic trough solar energy systems. Visualization provides insight into the thematic structure of the field, key institutional contributors, and the conceptual classifications guiding ongoing research.

Analysis of frequently used title terms reveals that the field is dominated by foundational concepts such as *"solar," "parabolic,"* and *"trough,"* which appear with the highest frequency. These terms underscore the central focus of the literature on parabolic trough collectors as a subset of solar thermal technologies. Additional high-frequency terms include *"system," "power," "energy," "collector," "analysis,"* and *"performance,"* which reflect a strong orientation toward system-level evaluations, energy conversion performance, and operational analysis.

Emerging trends are also apparent through the presence of terms such as *"optimization," "cycle," "hybrid,"* and *"experimental,"* which indicate a growing research interest in performance enhancement, integration with other cycles (e.g., Organic Rankine Cycle), and empirical validation of novel configurations.

The central section of the Sankey diagram highlights the institutions that are most actively contributing to research in this domain. The University of Tehran and Islamic Azad University are leading, each demonstrating strong linkages to a wide range of keywords and descriptors, suggesting a diverse research portfolio. Chinese institutions such as North China Electric Power University, Xi'an Jiaotong University, and the University of Science and Technology of China also emerge as significant contributors, reflecting national investment in solar energy technologies and a robust academic response.

European and Middle Eastern institutions, including the National Technical University of Athens, Iran University of Science and Technology, and the University of Sharjah, are also prominently represented, suggesting a geographically diverse but technically convergent research network.

Descriptors linked to these institutions and title terms reveal the research's scientific classification and thematic direction. The most frequent descriptors—such as *"parabolic trough collector," "solar energy," "thermal efficiency," "optimization,"* and *"organic Rankine cycle"*—indicate a clear focus on performance analysis, thermodynamic optimization, and hybridization strategies.

The presence of descriptors like *"nanofluid," "exergy,"* and *"thermal performance"* points to the field's increasing integration of advanced materials, detailed energy/exergy analyses, and a broader systems-engineering perspective.

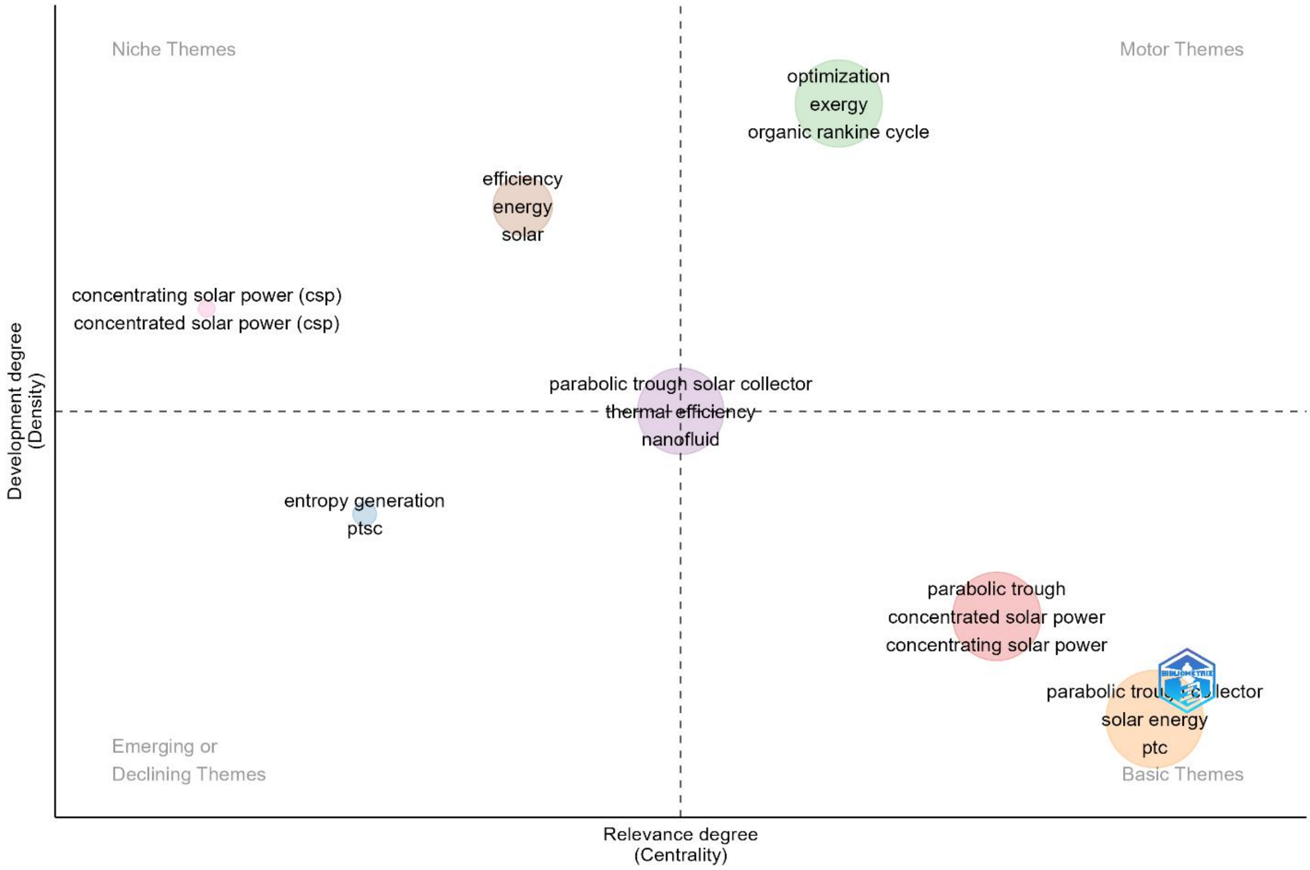

Figure 6.
Presented is a thematic map, frequently employed in bibliometrics.

The image presented is a thematic map, frequently employed in bibliometric and scientometric studies to illustrate the structural organization and developmental progression of research themes within a particular domain. This map is structured around two key dimensions: density, which reflects the level of internal development of a theme (vertical axis), and centrality, which indicates the theme's relevance and connectivity to other themes within the broader research field (horizontal axis).

The thematic map is divided into four quadrants, each representing a distinct category of thematic significance: Upper Right Quadrant (Motor Themes), Upper Left Quadrant (Niche Themes), Lower Left Quadrant (Emerging or Declining Themes, and Lower Right Quadrant (Basic Themes. This typology provides valuable insights into thematic clusters' maturity, influence, and strategic positioning within the research landscape.

The thematic map reveals various research themes' structural positioning and developmental maturity within parabolic trough collectors (PTCs) and concentrated solar power (CSP) systems.

Themes in the upper right quadrant—notably *optimization*, *exergy*, and *organic Rankine cycle*—are characterized by high centrality and density. This positioning indicates that these topics are conceptually well-developed and central to the research agenda. Their prominence suggests that studies on optimization techniques, exergy analysis, and integration of organic Rankine cycles are pivotal in enhancing the efficiency and performance of solar thermal systems. These themes likely represent the core drivers of innovation in the field.

In contrast, the upper left quadrant contains themes such as *efficiency*, *energy*, and *solar*, which, although well-developed, exhibit relatively low centrality. This implies that while these areas are methodologically and conceptually mature, they tend to occupy more specialized or isolated niches within the broader research landscape. Their influence may be limited to specific subfields rather than being widely integrated across the domain.

The lower left quadrant houses underdeveloped and peripheral themes such as *entropy generation* and *PTSC* (likely referring to *parabolic trough solar collector*). These topics exhibit low density and centrality, indicating that they may represent emerging research areas still in their formative stages or declining subjects that have diminished in relevance over time.

Themes in the lower right quadrant, including *parabolic trough*, *concentrated solar power*, *concentrating solar power*, *parabolic trough collector*, *solar energy*, and *PTC*, are foundational to the field. Their high centrality reflects their strategic importance and broad relevance. Yet, their lower density suggests that these core concepts still require deeper exploration and further theoretical or empirical development to reach maturity.

Finally, a cluster of themes located near the intersection of the axes, such as *parabolic trough solar collector*, *thermal efficiency*, and *nanofluid*, occupies a central transitional space. These themes are relevant and moderately developed, signifying active and evolving research areas. Their position implies they are at the forefront of technological advancements, particularly enhancing thermal performance and incorporating advanced working fluids such as nanofluids into solar thermal applications.

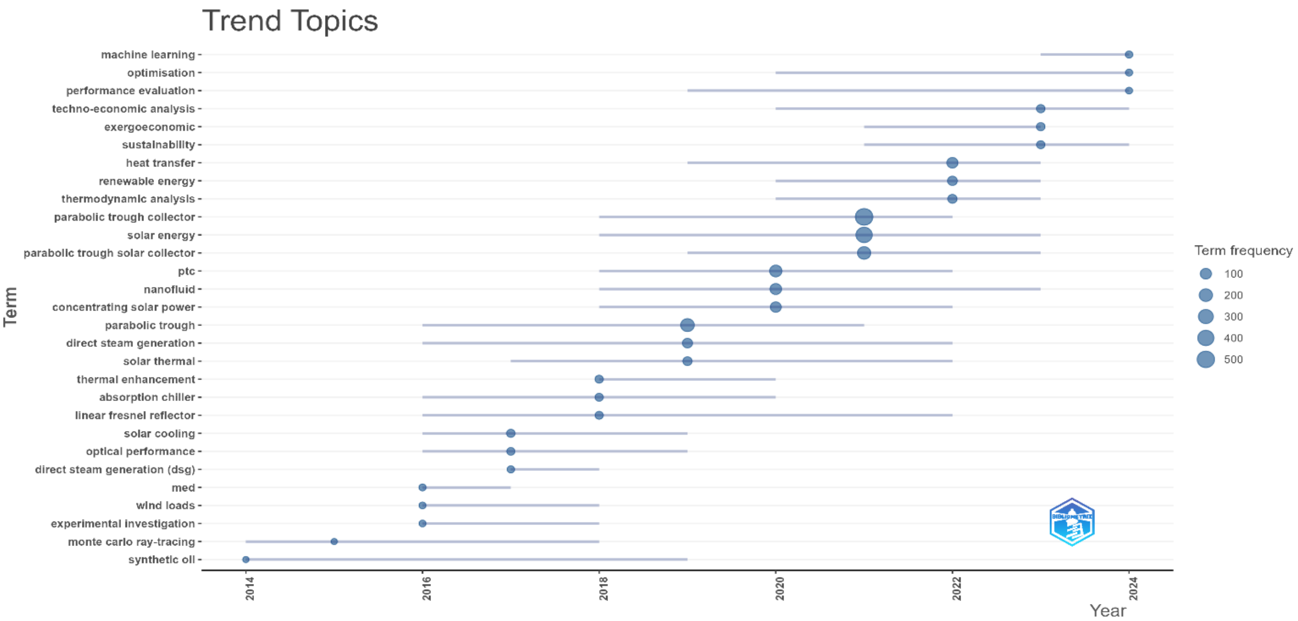

Figure 7.
Represents trending topics.

The bubble timeline graph presented above visualizes the temporal evolution and relative frequency of key research terms in the field of parabolic trough collectors (PTC) and concentrated solar power (CSP) technologies between 2014 and 2024. The x-axis represents time (years), while the y-axis lists the individual research terms. The size of each bubble corresponds to the term frequency, reflecting how often each term appeared in scholarly outputs during the specified time frame. This form of analysis helps identify both historical and emerging research trends.

The terms appearing prominently toward the latter half of the timeline (post-2020) with large bubbles include Machine learning, Optimization, Performance evaluation, Techno-economic analysis, and Sustainability. These topics represent emerging or rapidly growing areas of interest, highlighting a shift in the research landscape toward data-driven optimization, system-level analysis, and sustainability assessment in solar thermal applications. The prominence of *machine learning* signals a contemporary trend toward integrating artificial intelligence into CSP systems' modeling, prediction, and control.

Several terms have appeared consistently across multiple years and are represented by medium to large bubbles, indicating their centrality and sustained interest. These include a parabolic trough collector, solar energy, thermodynamic, renewable, and exergoeconomic analysis.

These terms are reflective of fundamental research pillars in the domain. Their continuous presence suggests ongoing investigations into thermal efficiency, system configurations, and energy economics, all of which are critical for improving the viability and performance of CSP technologies.

Specialized terms such as nanofluid, PTC, parabolic trough solar collector, direct steam generation, concentrated solar power, and linear Fresnel reflector reflect a technological and experimental focus within the field. Notably, the term *nanofluid* has gained significant traction, indicating increasing interest in enhanced heat transfer fluids to improve collector efficiency. Similarly, *direct steam generation* and *parabolic trough* frequently appear, reinforcing the industry's continued focus on improving heat absorption and conversion mechanisms.

Terms such as Monte Carlo ray-tracing, Synthetic oil, Experimental investigation, Wind loads, and MED (multi-effect distillation) show limited temporal presence or smaller bubble sizes, indicating they are either niche topics, highly specialized areas, or possibly declining research interests. These topics may still be significant in specific subdomains (e.g., modeling or hybrid applications), but they do not appear to dominate the broader research conversation.

The timeline suggests a thematic evolution from foundational and experimental topics (2014–2018) to more sophisticated and systems-level concerns (2019–2024). Early emphasis on collectors, thermal modeling, and simulation has expanded to encompass: Integrated system optimization, AI-assisted control and diagnostics, Sustainability and life-cycle performance**,** and Economic feasibility assessments. This trend indicates increasing research maturity and a shift toward real-world applicability and scalability of solar thermal technologies.

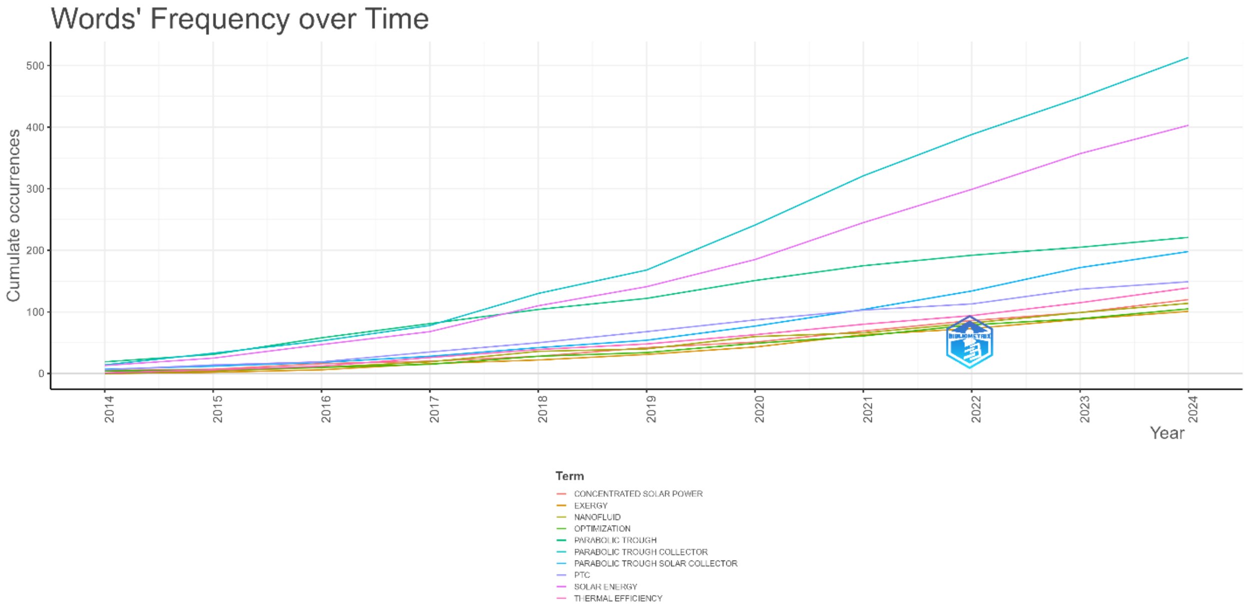

Figure 8.
Represents the words' frequency over time.

The "Words' Frequency over Time" graph presents the cumulative occurrences of selected keywords in academic literature from 2014 to 2024. The analysis of this data provides insights into the evolving focus and research trends within the field of solar thermal technologies, particularly parabolic trough collectors and associated systems.

The pronounced rise in "Exergy" and "Optimization" frequency underscores a shift towards performance analysis and system enhancement in solar thermal research. The increased attention to "Nanofluid" highlights the field's pursuit of innovative materials to improve thermal properties and overall system efficiency. Meanwhile, the steady growth of foundational terms such as "Parabolic Trough Collector" and "Thermal Efficiency" reflects the ongoing importance of core concepts and technologies.

The data suggests that the research community is increasingly prioritizing topics related to system optimization, exergy analysis, and advanced working fluids. This trend is likely driven by the need for higher efficiency, cost-effectiveness, and sustainability in solar thermal power generation. The persistent relevance of basic terms further indicates that foundational research remains essential for technological advancement and practical implementation despite the emergence of novel themes. In conclusion, the graph demonstrates a dynamic and expanding research environment, with a clear trajectory towards optimization and innovation in parabolic trough collector technologies and their applications.

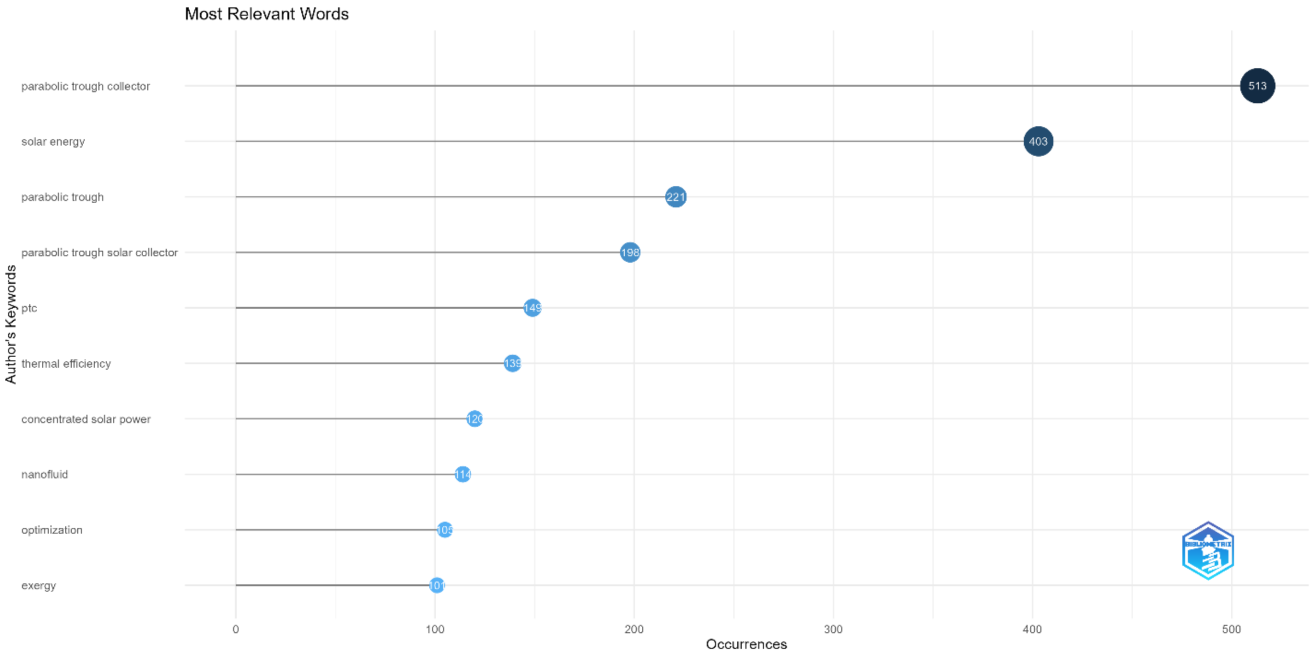

Figure 9.
Shows the most relevant words.

The figure presents a horizontal bar chart illustrating the frequency of occurrence for key author keywords in the academic literature concerning parabolic trough collectors and related solar energy technologies. The x-axis represents the number of occurrences, while the y-axis lists the keywords. The data provides a quantitative overview of the thematic focus within the field.

The term *"parabolic trough collector"* emerges as the most frequently cited keyword, with 513 mentions, highlighting its central and foundational position within the research landscape. This frequency underscores the technological core of much of the scholarly output in the field. Closely following is *"solar energy,"* with 403 occurrences, reflecting the broader renewable energy context in which parabolic trough technology is applied. The frequent appearance of terms such as *"parabolic trough"* (221 mentions) and *"parabolic trough solar collector"* (198 mentions) further emphasizes the specificity and sustained research interest in this concentrated solar power technology. These terms illustrate the thematic concentration on parabolic trough systems as a dominant subfield within solar thermal research.

The term "PTC," an abbreviation for parabolic trough collector, appears 141 times, indicating the widespread use of the full term and its acronym in scholarly communication. Additionally, the occurrences of "thermal efficiency" (83) and "concentrated solar power" (78) reflect a strong research emphasis on performance assessment and the integration of parabolic trough collectors into larger solar power systems. Emerging and specialized topics such as "nanofluid" (71 occurrences) highlight a growing interest in advanced heat transfer fluids to enhance system performance. Furthermore, the significant presence of "optimization" (70 occurrences) and "exergy" (61 occurrences) underscores the increasing importance of system optimization and thermodynamic analysis in recent studies, pointing to a trend toward improving efficiency and sustainability within the field.

The high frequency of terms directly related to parabolic trough collectors demonstrates that this technology remains a primary focus within solar thermal research. The prominence of "solar energy" and "concentrated solar power" indicates that research is often situated within the broader context of renewable energy systems and their deployment at scale. The notable presence of "thermal efficiency," "optimization," and "exergy" reflects a research trend toward maximizing performance and improving the sustainability of these systems.

Including "nanofluid" among the most relevant keywords suggests a recent shift towards exploring innovative materials to enhance heat transfer and overall system efficiency. This aligns with global trends in solar thermal research, where material science and engineering are increasingly intersecting with traditional energy studies.

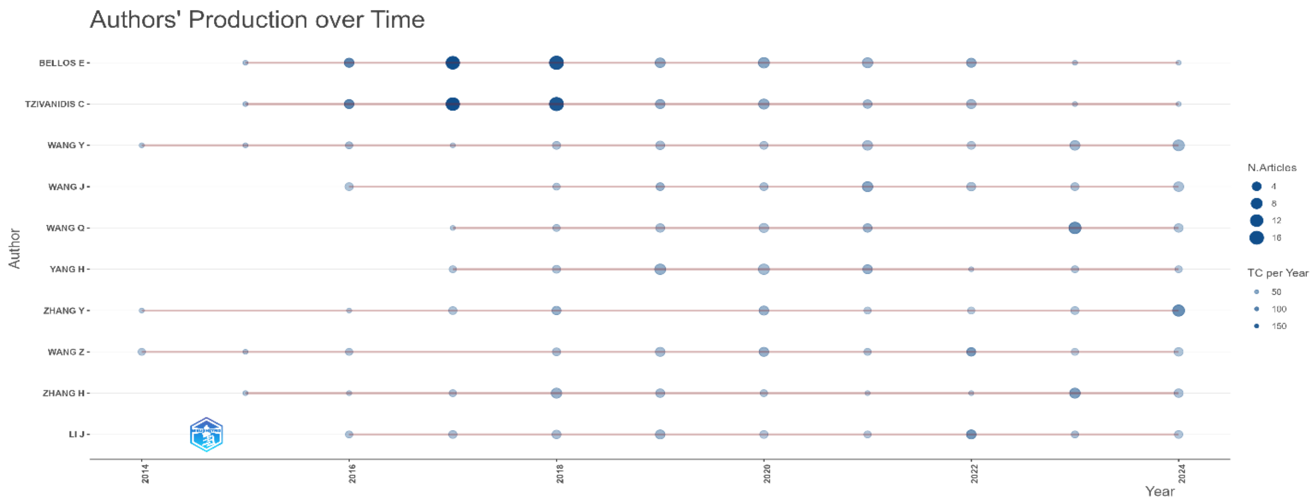

Figure 10.
Shows the authors' production over time.
Source: Bellos, et al. [11]; Valenzuela and Montecinos [12]; Wang, et al. [13]; Li Min, et al. [14]; Sun and Perona [15], Mehrpooya [16], He, et al. [17] and Bellos and Tzivanidis [18]

The graphical representation above depicts the annual research output and citation impact of key authors contributing to the field of parabolic trough collectors (PTC) and concentrated solar power (CSP) from 2014 to 2024. Each point on the timeline represents published articles by an individual author in a given year. The size of the circles indicates the number of articles published per year (N. Articles). At the same time, the shade of blue represents the total citations (TC) per year, with darker hues corresponding to higher citation counts.

Among the listed authors, Bellos, et al. [11], and Bellos and Tzivanidis [18] stand out as the most prolific, consistently publishing from 2016 through 2022. Notably, these authors exhibit high productivity, with several years showing between 8 and 12 publications, and maintain high citation rates, indicating significant influence and recognition within the academic community.

Authors such as Wang, et al. [19] have also maintained steady output, though at a slightly lower volume. Their contribution spans multiple years, suggesting consistent engagement in solar thermal research. However, their impact on citations per year appears more moderate, reflecting either a narrower research scope or less widespread academic dissemination.

A cluster of authors—including Wang, et al. [19] and Li Min, et al. [14]—have published more frequently in the later years of the timeline, particularly between 2020 and 2023. Although their publication counts per year remain modest, the emergence of these authors may reflect a new wave of scholarship focused on evolving subfields such as thermal enhancement, machine learning applications, or hybrid systems within CSP technologies.

Citation density per year, indicated by the tone of each bubble, provides additional insight into the quality and reach of the publications. Bellos and Tzivanidis [18] again dominate this dimension, with consistently darker markers in multiple years, suggesting sustained academic impact and relevance.

Authors such as Wang, et al. [13] show relatively lighter hues, pointing to either recent publications that have not yet accrued significant citations or publications in niche areas with limited readership.

The overall distribution of scholarly activity from 2014 to 2024 indicates that research in parabolic trough and solar thermal systems has experienced a steady increase in author participation and output, especially after 2016. This growth coincides with global policy shifts toward renewable energy and increased funding in solar research, potentially explaining the uptick in academic contributions and diversified authorship.

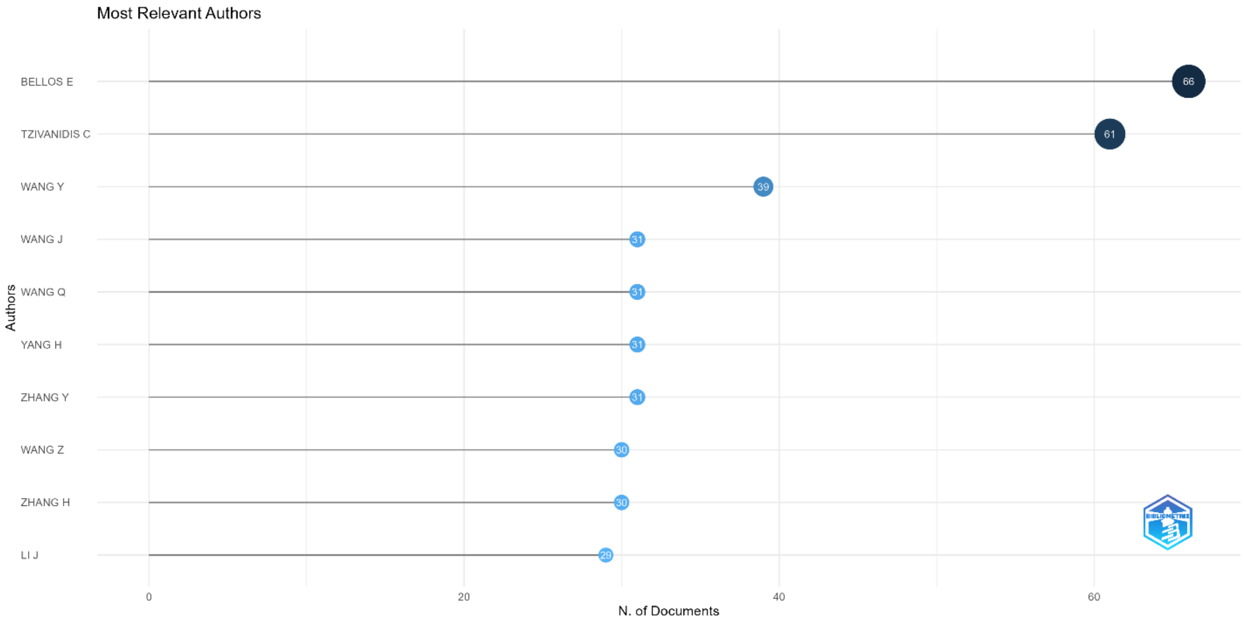

Figure 11.
Shows the most relevant authors.
Source: Bellos, et al. [11]; Valenzuela and Montecinos [12]; Wang, et al. [13];; Wang, et al. [19] and Li Min, et al. [14] Bellos and Tzivanidis [18] and Wang, et al. [13]

The chart presented above identifies the most prolific authors within the research domain of parabolic trough collectors (PTC) and concentrated solar power (CSP), based on the number of documents published. The horizontal axis represents the total publication count, while the authors are listed along the vertical axis. The size and color intensity of the data points visually reinforce the publication volume.

The authors Bellos and Tzivanidis [18], stand out with the highest publication counts—66 and 61 documents respectively. This substantial output underscores their sustained and leading role in shaping the research trajectory of PTC and CSP technologies. Their high productivity signifies strong individual scholarly engagement and suggests their central involvement in collaborative projects and likely affiliation with high-output institutions or research clusters.

Following the leading contributors, Wang Y. emerges as the third most relevant author with 39 publications, indicating consistent scholarly engagement. A group of authors—Wang, et al. [13] and Wang, et al. [19] —each contributed 30 to 31 publications. This group represents a robust core of researchers who have made significant, albeit slightly less prolific, contributions to the field. Their uniform output suggests involvement in ongoing research programs, potentially focused on experimental validation, performance modeling, or hybrid system integration in solar thermal technologies.

Wang, et al. [19] and Li Min, et al. [14] round out the list with 30 and 29 publications, respectively. While their total document count is modest compared to the top two contributors, their presence within the top ten most relevant authors highlights their growing visibility in literature. Their inclusion may signify either recent increases in output or contributions in rapidly evolving thematic areas such as nanofluid application, machine learning integration, or techno-economic analysis.

Although publication volume is not a sole indicator of academic impact, it remains a key metric for identifying influential researchers and research hubs. The dominance of a small number of authors suggests a degree of concentration in scholarly output, which may correlate with institutional leadership, access to research funding, or participation in international collaborations. Furthermore, the recurrence of these authors across other bibliometric indicators (e.g., citation impact, temporal productivity) reinforces their foundational role in advancing CSP and PTC research.

4. Discussion

The analysis of publication trends from 2014 to 2024 reveals a significant expansion and evolution in parabolic trough solar collector (PTC) research. The marked increase in publications, particularly within engineering and renewable energy journals, underscores the technological advancements and growing global emphasis on sustainable energy solutions. This upward trajectory is anticipated to persist, driven by intensifying international commitments to clean energy and climate change mitigation.

The distribution of subject areas within PTC research highlights the inherently interdisciplinary nature of the field. While energy and engineering disciplines predominate, substantial contributions from environmental sciences, materials science, chemistry, and physics are integral to comprehensive progress. This multidisciplinary engagement is essential to tackle the complex challenges of improving efficiency, ensuring sustainability, and scaling solar thermal technologies for widespread application.

A closer examination of publication volume over the past decade indicates robust growth, with only minor fluctuations observed around 2018–2019. These temporary dips appear as anomalies, as evidenced by a strong and sustained recovery from 2020 onward. This pattern likely reflects renewed interest, increased funding, and institutional support, reinforcing the vitality of the research domain.

Authorship patterns reveal a skewed distribution, where a small cohort of researchers, most notably Bellos and Tzivanidis, produce nearly twice the number of publications compared to their peers within the top ten authors. Such concentration of scholarly output is characteristic of many scientific fields. It suggests that these key contributors play pivotal roles in steering research directions and shaping the development of PTC technologies.

The thematic mapping of research topics identifies optimization, exergy analysis, and the organic Rankine cycle as the most mature and influential themes within the PTC and concentrated solar power (CSP) literature. Established yet more specialized themes, such as efficiency and energy, remain relevant, whereas topics like entropy generation appear to be emerging or gaining prominence. Foundational themes—including parabolic trough collectors, solar energy, and CSP—remain critical but require further development to reach higher maturity levels. Notably, the intersectional focus on thermal efficiency and nanofluids emerges as a promising frontier, likely to drive significant innovations in system performance.

Trend topic analysis further illustrates the dynamic and evolving nature of the field. While core themes such as parabolic trough collectors and solar energy maintain their foundational status, novel areas, including machine learning, techno-economic analysis, and nanofluid applications, are gaining traction. This blend of enduring relevance and emergent focus areas reflects the field's adaptability and depth in addressing contemporary challenges related to energy efficiency, sustainability, and integration of advanced technologies.

Keyword frequency analysis corroborates these findings, demonstrating a robust and evolving research landscape. There is a clear emphasis on system design, efficiency enhancement, and integrating optimization techniques and advanced materials within broader solar power frameworks. This thematic diversity indicates a future research trajectory centered on technological innovation and enhanced performance.

Finally, the temporal analysis of author productivity highlights both dominant contributors and a growing cohort of emerging researchers. While a few individuals exert significant influence through prolific output and citation impact, the increasing participation of a broader research community signals the maturation and expansion of the field. This diversification indicates deepening core knowledge and exploring interdisciplinary applications to advance solar thermal technologies.

In summary, the collective insights from publication trends, thematic mapping, and authorship patterns reveal a vibrant, interdisciplinary, and progressively sophisticated research landscape in parabolic trough solar collector technology. The field is well-positioned to evolve in response to global energy demands and technological opportunities.

5. Conclusion

In conclusion, the comprehensive analysis of the parabolic trough solar collector research landscape from 2014 to 2024 demonstrates a field characterized by significant growth, interdisciplinary collaboration, and evolving thematic focus. The sustained increase in scholarly output and the prominence of key research themes such as optimization, exergy analysis, and advanced heat transfer fluids reflect the domain's maturation and dynamism. The concentrated contributions of leading authors and emerging researchers' expanding participation further underscore the field's vitality and potential for innovation. As global priorities emphasize sustainable and efficient energy solutions, parabolic trough collector research is poised to be critical in advancing concentrated solar power technologies. Future investigations integrating emerging methodologies and materials are expected to drive continued system performance, scalability, and environmental sustainability improvements.

References

[1] K. Lee and S. Lee, "Knowledge structure of the application of high-performance computing: A co-word analysis," *Sustainability,* vol. 13, no. 20, p. 11249, 2021. https://doi.org/10.3390/su132011249

[2] O. Alipour, F. Soheili, and A. A. Khasseh, "A co-word analysis of global research on knowledge organization: 1900-2019," *Knowledge Organization,* vol. 49, no. 5, pp. 303-315, 2022. https://doi.org/10.5771/0943-7444-2022-5-303

[3] J.-J. Nájera-Sánchez, E.-M. Mora-Valentín, M. Ortiz-de-Urbina-Criado, and P. Moura-Díez, "Mapping the conceptual structure of environmental management: a co-word analysis," *Business: Theory and Practice,* vol. 20, pp. 69-80, 2019. https://doi.org/10.3846/BTP.2019.07

[4] H. Khaldi and V. Prado-Gascó, "Bibliometric maps and co-word analysis of the literature on international cooperation on migration," *Quality & Quantity,* vol. 55, no. 5, pp. 1845-1869, 2021. https://doi.org/10.1007/s11135-020-01085-4

[5] J. L. A. Sánchez, F. G. C. Soto, P. E. R. La Rosa, D. F. M. Palma, G. A. C. Campos, and A. J. R. Cadillo, "Big data research in the business, management and accounting field: Revealing the thematic structure based on co-word analysis," *Iberoamerican Journal of Science Measurement and Communication,* vol. 4, no. 1, pp. 1-8, 2024. https://doi.org/10.47909/ijsmc.116

[6] A. A. Khasseh, P. Hasanzadeh, A. R. Isfandyari-Moghaddam, F. Soheili, and A. Mousavi Chelak, "Mapping the intellectual structure of chronic heart failure: A co-word analysis," *Journal of Scientific Research,* vol. 10, no. 1, pp. 101–109, 2021.

[7] R. Yin *et al.*, "Hotspot for study in UML of China: Co-word analysis," in *2009 International Conference on Management of e-Commerce and e-Government*, 2009. https://doi.org/10.1109/ICMECG.2009.92

[8] H. Yue, "Visualization the subject structure of international management science by co-word analysis," in *2011 International Conference on Information Management, Innovation Management and Industrial Engineering*, 2011, vol. 3, https://doi.org/10.1109/ICIII.2011.314.

[9] T.-C. Lin, K.-Y. Tang, S.-S. Lin, M.-L. Changlai, and Y.-S. Hsu, "A Co-word analysis of selected science education literature: Identifying research trends of scaffolding in two decades (2000–2019," *Frontiers in Psychology,* vol. Volume 13 - 2022, 2022. https://doi.org/10.3389/fpsyg.2022.844425

[10] C. Fernandes and R. Pires, "Exploring the conceptual structure of the research on innovation in hotels through co-word analysis)," *Administrative Sciences,* vol. 11, no. 3, p. 78, 2021. https://doi.org/10.3390/admsci11030078

[11] E. S. Bellos, Zafar, L. S. Sundar, A. K. Tiwari, H. M. Ali, M. Sheikholeslami, and H. Babar, "Recent advances on the fundamental physical phenomena behind stability, dynamic motion, thermophysical properties, heat transport, applications, and challenges of nanofluids," *Physics Reports,* vol. 946, pp. 1-94, 2022.
[12] J. P. Valenzuela and C. Montecinos, "Structural reforms and equity in Chilean schools." Oxford UK: Oxford University Press, 2017.
[13] Q. H. Wang, K. Kalantar-Zadeh, A. Kis, J. N. Coleman, and M. S. Strano, "Electronics and optoelectronics of two-dimensional transition metal dichalcogenides," *Nature Nanotechnology,* vol. 7, no. 11, pp. 699-712, 2012.
[14] L. D. Li Min, Pradip *et al.*, "Coronavirus disease 2019 (COVID-19) pandemic and pregnancy," *American Journal of Obstetrics and Gynecology,* vol. 222, no. 6, pp. 521-531, 2020.
[15] J. Sun and P. Perona, "Where is the sun?," *Nature Neuroscience,* vol. 1, no. 3, pp. 183-184, 1998.
[16] M. A. Mehrpooya, Majid, "Large-scale liquid hydrogen production methods and approaches: A review," *Applied Energy,* vol. 212, pp. 57-83, 2018.
[17] Y. L. He, Qing, K. H. Luo, Q. Kang, Q. Chen, and Q. Liu, "Lattice boltzmann methods for multiphase flow and phase-change heat transfer," *Progress in Energy and Combustion Science,* vol. 52, pp. 62-105, 2016.
[18] E. Bellos and C. Tzivanidis, "Alternative designs of parabolic trough solar collectors," *Progress in Energy and Combustion Science,* vol. 71, pp. 81-117, 2019.
[19] Q. Y. Wang, Xueming, W. Jiang, and C. Ji, "Experimental study on heat storage and corrosion properties of ternary carbonate salt-based ZnO nanofluids for solar thermal energy storage," *Journal of Thermal Analysis and Calorimetry,* vol. 147, no. 23, pp. 13935-13947, 2022.

Metadata	Description	Missing Counts	Missing %	Status
AB	Abstract	0	0.00	Excellent
AU	Author	0	0.00	Excellent
DT	Document Type	0	0.00	Excellent
SO	Journal	0	0.00	Excellent
LA	Language	0	0.00	Excellent
PY	Publication Year	0	0.00	Excellent
TI	Title	0	0.00	Excellent
TC	Total Citation	0	0.00	Excellent
C1	Affiliation	3	0.10	Good
DI	DOI	133	4.47	Good
DE	Keywords	134	4.50	Good
ID	Keywords Plus	184	6.18	Good
RP	Corresponding Author	242	8.13	Good
CR	Cited References	2978	100.00	Completely missing
WC	Science Categories	2978	100.00	Completely missing

TITLE-ABS-KEY ((("Parabolic Trough Solar Collector" OR "Parabolic Trough" OR "Solar Trough Collector" OR "Parabolic Solar Trough" OR "Solar Thermal **Trough**" OR "Linear Parabolic Collector" OR "Line-Focus Parabolic Collector" OR "Concentrated Solar Trough Collector" OR ptc) AND (experiment OR "heat transfer" OR application OR "working fluid" OR optimization OR design OR performance OR "Solar Collectors" OR "simulation performance" OR "numerical simulation" OR " techno-economic analysis"))) AND PUBYEAR > 2013 AND PUBYEAR < 2025 AND (LIMIT-TO (SUBJAREA , "ENGI") OR LIMIT-TO (SUBJAREA , "ENER") OR LIMIT-TO (SUBJAREA , "BIOC") OR LIMIT-TO (SUBJAREA , "MATE") OR LIMIT-TO (SUBJAREA , "ENVI") OR LIMIT-TO (SUBJAREA , "PHYS") OR LIMIT-TO (SUBJAREA , "CENG")) AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (EXACTKEYWORD , "Parabolic Trough Collectors") OR LIMIT-TO (EXACTKEYWORD , "Solar Collectors") OR LIMIT-TO (EXACTKEYWORD , "Solar Energy") OR LIMIT-TO (EXACTKEYWORD , "Parabolic Trough Collector") OR LIMIT-TO (EXACTKEYWORD , "Collector Efficiency") OR LIMIT-TO (EXACTKEYWORD , "Parabolic Trough") OR LIMIT-

TO (EXACTKEYWORD , "Parabolic Trough Solar Collectors") OR LIMIT-TO (EXACTKEYWORD , "Solar Heating") OR LIMIT-TO (EXACTKEYWORD , "Solar Power") OR LIMIT-TO (EXACTKEYWORD , "Energy Efficiency") OR LIMIT-TO (EXACTKEYWORD , "Optimization") OR LIMIT-TO (EXACTKEYWORD , "Thermal Energy") OR LIMIT-TO (EXACTKEYWORD , "Thermal Efficiency") OR LIMIT-TO (EXACTKEYWORD , "Performance") OR LIMIT-TO (EXACTKEYWORD , "Thermal Performance") OR LIMIT-TO (EXACTKEYWORD , "Parabolic Trough Solar Collector") OR LIMIT-TO (EXACTKEYWORD , "Concentrating Solar Power") OR LIMIT-TO (EXACTKEYWORD , "Solar Thermal Energy") OR LIMIT-TO (EXACTKEYWORD , "Solar Concentrators") OR LIMIT-TO (EXACTKEYWORD , "Computational Fluid Dynamics") OR LIMIT-TO (EXACTKEYWORD , "PTC") OR LIMIT-TO (EXACTKEYWORD , "Concentration (process)") OR LIMIT-TO (EXACTKEYWORD , "Thermal Power") OR LIMIT-TO (EXACTKEYWORD , "Heating") OR LIMIT-TO (EXACTKEYWORD , "Energy Utilization") OR LIMIT-TO (EXACTKEYWORD , "Parabolic Trough Concentrators") OR LIMIT-TO (EXACTKEYWORD , "Power Generation") OR LIMIT-TO (EXACTKEYWORD , "Thermal-efficiency") OR LIMIT-TO (EXACTKEYWORD , "Numerical Model") OR LIMIT-TO (EXACTKEYWORD , "Heat Transfer Performance") OR LIMIT-TO (EXACTKEYWORD , "Nanofluid"))