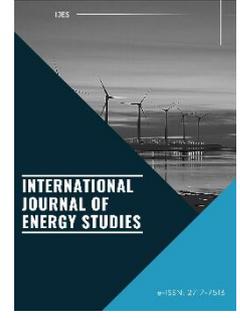


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Absorption cooling systems: Bibliometric analysis

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Highlights

- Provides a bibliometric overview of absorption cooling research (1980–2024).
- Examines publication growth, leading countries, and key journals.
- Identifies frequent keywords and thematic clusters in the field.

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ABSTRACT

Aim: This study aims to determine collaborations, authors, journals, keywords, and trending topics related to absorption cooling in science and engineering. **Materials and methods:** A PRISMA-based flowchart similar to the systematic method was used for bibliometric analysis. Web of Science (WoS) database was used to obtain data. Bibliometrix software and WoS analysis were used for data analysis. **Result:** 4552 articles were reached between 1980 and 2024 (22.07.2024). The articles have an annual growth rate of 11.16% from 1980. The article written by “Krause et al. 2016 [42]” is the most cited publication. The most used author’s keywords were “solar cooling,” while the most used keyword plus was “performance.” In recent years, “Energy storage density” and “4e analysis” have become trends in the author’s keywords and keywords plus, respectively. The most productive author in the field has been “DINCER I.” According to the number of articles produced by the institutions, the most productive institution was “UNIVERSITY OF TEHRAN”. The most effective journal in the field was found to be “Applied Thermal Engineering”. According to the countries’ annual publication output, “CHINA” ranked first. It has been observed that a significant part of the journals in the field are in the “Energy Fuels” and “Thermodynamics” WoS categories. **Conclusions:** Bibliometric data has been obtained to guide future researchers who will work on this issue.

Keywords: Absorption cooling, Absorption refrigeration, Absorption chiller, Bibliometric, Scientometric

1. INTRODUCTION

The absorption cooling system generally consists of a generator, absorber, evaporator, condenser, pump, and expansion valve (Figure 1). There is a solution for mixing fluid in the system. One of the mixing fluids is the refrigerant, which undertakes the cooling task, while the other fluid is the absorber, which absorbs the refrigerant. The system works as follows (Figure 1): The strong solution in the absorber is sent to the generator by increasing its pressure with the help of the pump. Here, the refrigerant evaporates with the heat provided from outside and separates from the absorber. The remaining weak solution returns to the absorber. The refrigerant passes to the condenser, releases heat, and turns into the liquid phase. The high-pressure refrigerant, which passes into the liquid phase in the condenser, passes through the expansion valve, its pressure is reduced and enters the evaporator. It evaporates with the heat it receives from the cooled environment in the evaporator, returns to the absorber at low pressure, and combines with the absorber. Thus, the cooling cycle is continuously renewed. Here, heat energy is the key point in separating these two fluids from each other and is the most important point in distinguishing absorption cooling from other cooling technologies. If there is a cheap and continuously available heat source (such as waste heat, geothermal energy, or solar energy) where cooling will be done, absorption cooling systems will be an excellent alternative to other cooling systems. Another advantage is that a pump is used instead of a compressor, especially for pressurization. However, the fluid pairs must use cause minimal damage to nature and the ozone layer [1]. However, the absorption cooling system is large and expensive and has a low coefficient of performance (COP) is the most significant factor that prevents it from becoming widespread [2].

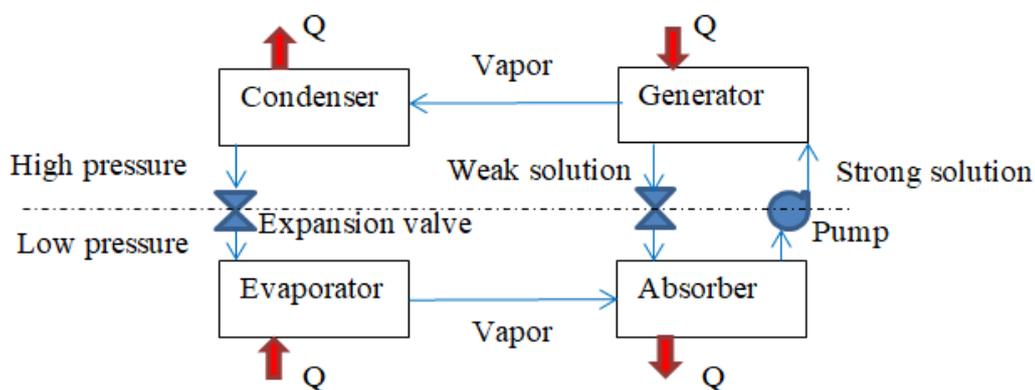


Figure 1. Absorption cooling system

Bibliometric analysis (scientometric, science mapping, information analytics) a specific subject regarding its scientific impact and relationships using bibliometric data with mathematical and

statistical methods [3]. Bibliometric studies take a panoramic view of the subject and provide clues on conducting subsequent studies [4]. Bibliometric software, which has emerged with the advancement of technology, enables rapid analysis of extensive bibliometric data [5, 6]. There are many studies on absorption cooling. In this section, review articles written in the field will be discussed. Review articles written in the field have generally been written using the traditional (narrative) review method such as Ayou and Coronas [7], Bravo et al. [8]. There are traditional review methods such as the critical method [9] and systematic parametric review [10]. Reviews using the traditional (narrative) review method: Kim and Infante Ferreira [11] examined different solar-powered cooling technologies. Ibrahim et al. [12] examined solar absorption cooling systems. They also examined thermal energy storage methods for integration into the cooling system and control strategies for optimum performance. They gave information about the programs used for simulation. As a result of the review, it was found that solar energy absorption cooling with hot water thermal storage is the most used system. Bonomolo et al. [13] examined the integration of solar cooling systems in buildings in the Sunbelt region. Verma et al. [14] a literature review was conducted on increasing the performance of absorption refrigeration systems (ARSs). In the study, different methods used to improve the COP of ARSs based on cycle layout modification and working fluid pair selection were examined. Raut and Kalamkar [15] conducted a literature study on the storage of latent heat energy in solar thermal water-lithium bromide vapor absorption cooling systems. Phase-changing substances were also examined. Mustafa et al. [16] reviewed solar absorption cooling systems. The literature is divided into theoretical and experimental studies and explained in detail. Mukhtar and Ghani [17] examined hybrid ejector-absorption cooling systems. Lahoud et al. [18] examined single-effect solar absorption chillers and looked at the example of Lebanon. Talpada and Ramana [19] examined the performance of new working pairs and nanoparticles in absorption cooling systems. Hara Chakravarty et al. [20] the integration of renewable energy processes in a vapor absorption chiller was reviewed. Lima et al. [21] absorption cooling systems using different ammonia-based absorbents as refrigerants were investigated. Literature data were obtained from the Scopus database. Valiyandi and Thampi [22] examined different technologies used to improve the performance of diffusion absorption refrigeration systems (DARS). Jiao and Li [23] examined solar energy cooling systems working with photovoltaic-thermal collectors. Reviews using a comprehensive method, one of the traditional review methods: Alhuyi-Nazari et al. [24] examined the applications of geothermal sources for absorption chillers in buildings. It is concluded that the performance of geothermal-sourced absorption chillers depends on different factors, such as the system's configuration,

operating conditions, and the mass flow rate of the geofluid and applied components. Mungyeko Bisulandu et al. [25] conducted a literature review of thermal resources used in DARS. The study examined thermal resources under the main headings of solar energy, waste heat, and geothermal. Abdullah and Alzahrani [26] examined the large-scale solar-based absorption cooling system. LiBr-H₂O was selected as the working fluid. As a result of the energy and exergy analysis of the system, parametric analysis was performed. Jiang et al. [27] examined nanofluids in absorption refrigeration systems. Sui and Wu [28] investigated membrane-based absorbers/desorbers for absorption cooling systems. Villarruel-Jaramillo et al. [29] examined solar cooling technologies and polygeneration plans. Potential industrial applications were also looked at. It has been stated that the sectors with the most significant potential in this field are the food, beverage, and mining industries. Wen et al. [30] comprehensively summarized previous studies on simultaneous liquid flow, heat, and mass transfer in a falling-film liquid desiccant dehumidification and absorption cooling system based on CFD technology. Review or research article using the bibliometric analysis: Zhai et al. [31] reviewed membrane-based absorption cooling and heating. They used the traditional scanning method but included bibliometric analysis in the second part of the study, which they divided into eight sections. In the bibliometric analysis, 89 articles obtained from the WOS database were analyzed in the VOS viewer program by selecting the years 1970-2020. The result of bibliometric analysis reported that the membrane-based absorption cycle is a developing technology and has attracted increasing attention in recent years. Bravo et al. [8] carried out a bibliometric analysis of solar cooling technologies. In the study, data obtained from the Scopus database were analyzed using the VOSviewer program. Solar thermal cooling of buildings is a trend, followed by photovoltaic solar cooling. Saikia et al. [32] carried out a bibliometric analysis of solar cooling technologies. 3639 documents downloaded from the WOS database were analyzed using Bibliometrix, VOSviewer programs, and the Python tool. As a result of the study, they reported that solar thermal cooling technology is at the forefront, but photovoltaic-driven cooling systems will be examined more in the future.

The literature review found no bibliometric studies on absorption cooling systems. This study will be the first. This study aims to answer the following questions in order to determine the area of absorption cooling studies in science and engineering literature and to have a broad perspective on absorption cooling in science and engineering:

- (1.) What are the descriptive data of absorption cooling studies in science and engineering?
- (1.1.) What are the values related to the number of studies?

- (1.2.) What are the values related to the number of authors?
- (2.) What is the social and intellectual structure of absorption cooling studies in science and engineering?
 - (2.1.) What are the literature's most effective articles, sources, and keywords?
 - (2.2.) What are the keywords' social network structure and trends?
 - (2.3.) What is the international collaboration network structure?

The study was considered important because it can bring different perspectives to collaborations, authors, journals, and topics related to absorption cooling in science and engineering.

2. MATERIALS AND METHODS

A PRISMA-based flowchart similar to the systematic review method [33] was used for bibliometric analysis. The flowchart is data collection, pre-processing, loading, analysis, and visualization, respectively (Figure 2).

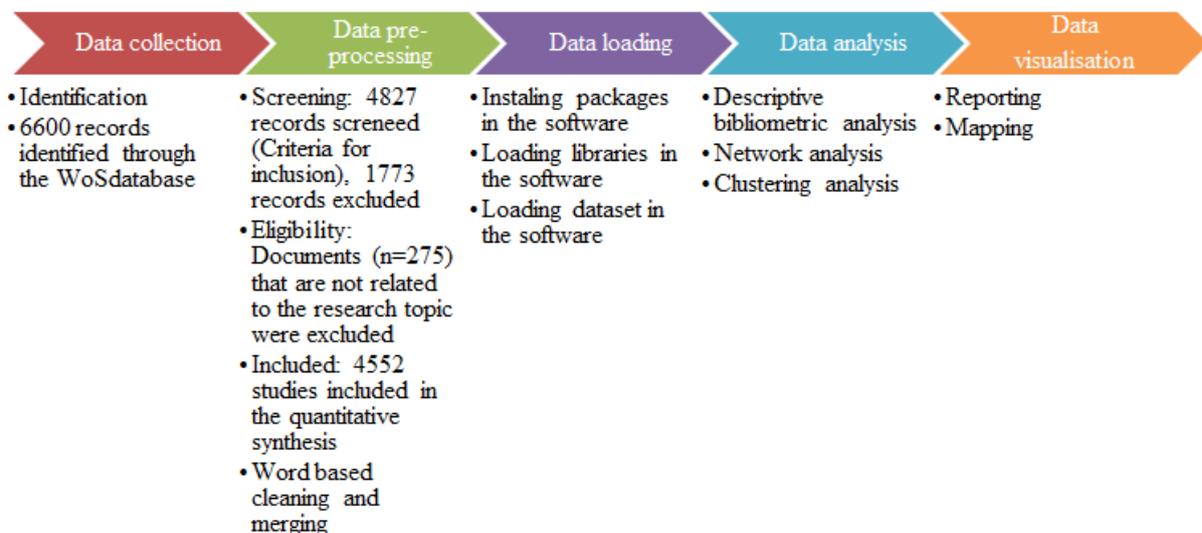


Figure 2. A flowchart for Bibliometric analysis

There are different scientific databases for bibliometric analysis. The most commonly used are Web of Science (WoS), Scopus, Google Scholar, and Science Direct [34]. Journal and scientific structure may differ depending on the database to be selected, so the selection is biased [35,36]. When looking at databases, WoS is known for its large publication and citation capacity, quality journals, and easy access to bibliometric information [37, 38, 39]. On the other hand, the WoS database, which includes journals included in the Science Citation Index Expanded, Social

Sciences Citation Index, Arts & Humanities Citation Index, and Emerging Sources Citation Index, is a reliable scientific platform [40]. Considering these features, the WoS database was used in our study.

2.1. Data Collection

Different words were used as parameters to obtain data with the help of search operators provided by the WoS database. The main parameter representing absorption cooling, which is the subject of the study, was selected as the word "absorption" as a result of the preliminary research. However, since it is used in many general-purpose topics, it was not deemed appropriate to use it alone. The word "cooling" was chosen as a result of the experiments. Different words give the concept of cooling (cooling, chiller, refrigeration). Therefore, these words were also included in the research. As a result, 6728 studies were reached, but some words that could distort the subject's essence were used from previous studies [32] and reduced to 6600 studies. Parameters used:

TS=("absorp* cool*" or "absorp* refrige*" or "absorp* chill*" or "Absorp* air condit*" or "solar cool*" or "solar refrige*") NOT TS=("stars" OR "galax*" OR "planet*" OR "spectr*" OR "quantum" OR "peerovskite*" OR "hot *carrier" OR "aerosol*" OR "cool roof*" OR "clouds" OR "plasm*" OR "urban heat island" OR "laser" OR "anneal*" OR "photonic")

The topic field (TS) was selected as the parameter usage area. The subject field contains information such as title, abstract, and keywords. On 22.07.2024, 6600 studies were obtained by entering the parameters into the WoS database.

2.2. Data Pre-Processing

Data were pre-processed with screening, eligibility, included, cleaning, and merging stages. Each of these stages contributed to refining the dataset to ensure its relevance, consistency, and suitability for bibliometric analysis. In the screening stage, the included criteria were selected as publication type, publication language, and index type and applied in order. "Article" was selected as the publication type in order to include only peer-reviewed original research papers and to exclude reviews, meeting abstracts, and editorial materials, which are not suitable for performance and content-based bibliometric evaluations. This filtering yielded 4953 publications. Next, "English" was selected as the publication language. This decision aimed to ensure a linguistically homogeneous dataset and to prevent inconsistencies in keyword usage caused by multilingual entries. After this step, 4874 publications were retained. Subsequently, index type was specified. Only publications indexed in "Science Citation Index Expanded (SCI-EXPANDED)" and

“Emerging Sources Citation Index (ESCI)” were included, as these indexes represent high-quality and peer-reviewed literature with broader visibility and citation potential in the academic community. At the end of this step, 4827 publications remained in the dataset. In the eligibility stage, the filtered data were exported in plain text format from WoS and transferred to the Bibliometrix R-package environment for further refinement. At this stage, the filter functions in Bibliometrix were used to remove certain inconsistencies. First, entries with irregular or hybrid language designations, such as “SLOVENE ENGLISH,” were eliminated to maintain uniformity. Then, document types that were not aligned with the scope of original research output—such as data papers, early access items, proceedings papers, and retracted publications—were also excluded from the dataset. These types of records are often incomplete or non-final versions and can bias bibliometric indicators if included. Finally, 4552 publications were included in the study in the included phase. These records represent a refined and high-quality dataset composed of peer-reviewed English-language articles indexed in SCI-EXPANDED or ESCI. The final dataset met the criteria for reliable bibliometric analysis.

2.3. Data Loading

The obtained data was loaded in “plain text file” format.

2.4. Data Analysis

The open-source R package Bibliometrix software [5] was used for the bibliometric analysis of the data in the study. Apart from this, WoS analysis was used for the subject area.

2.5. Data Visualisation

Data obtained from the Bibliometrix program are presented through reporting and mapping.

3. RESULTS AND DISCUSSION

3.1. Descriptive Results

As a result of the analysis, 4552 articles were reached between 1980 and 2024. The articles have an annual growth rate of 11.16% from 1980. The average age of the articles included in the study is 9.03. The number of single-authored articles is 265, and the number of authors is 215. The international co-authorships are 22.5%. There are 7545 different author’s keywords in the articles from 430 sources, and the average number of citations per document is 24.46. General descriptive results are given in Table 1. The annual production of publications is shown in Figure 3. A wavy

curve is seen in annual publication production until 2004, while an increase is seen especially after 2008. Between 1980 and 2004, the number of publications remained below 50 per year, generally showing minor fluctuations. From 2008 onward, a steady growth trend became evident, reaching over 200 publications annually by 2016. The most rapid growth occurred between 2016 and 2021, peaking at 386 articles in 2022. A slight decline is observed in 2024 due to the year being incomplete at the time of data collection.

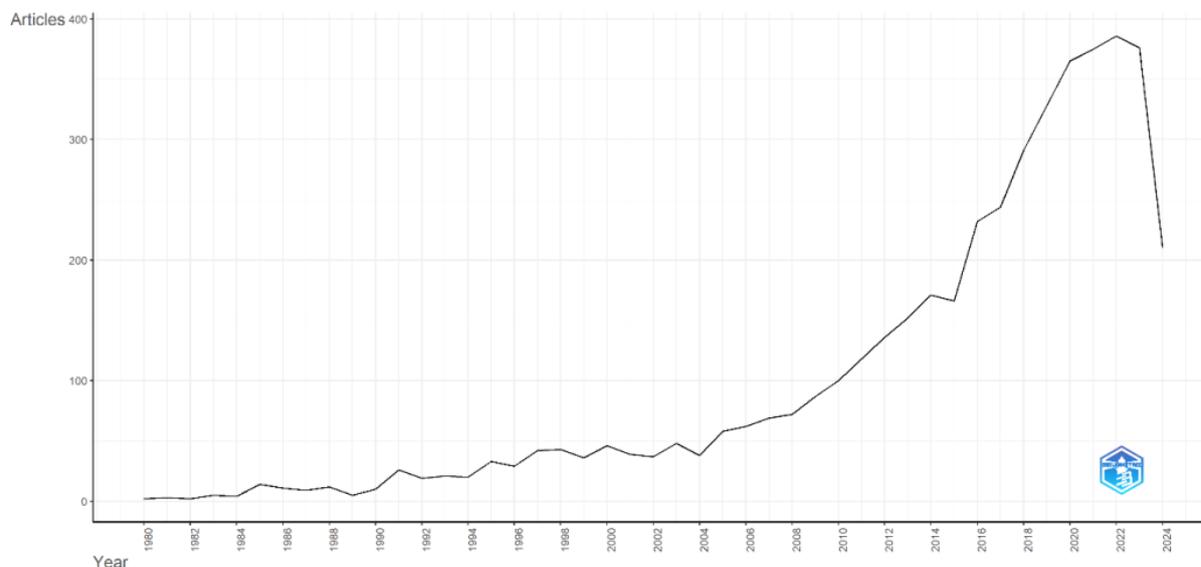


Figure 3. Annual scientific production

Table 1. Main information

Description	Results	Description	Results
MAIN INFORMATION ABOUT DATA		AUTHORS	
Timespan	1980:2024	Authors	8435
Sources (Journals, Books, etc)	430	Authors of single-authored docs	215
Documents	4552	AUTHORS COLLABORATION	
Annual Growth Rate %	11.16	Single-authored docs	265
Document Average Age	9.03	Co-Authors per Doc	3.62
Average citations per doc	24.46	International co-authorships %	22.5
References	74440	DOCUMENT TYPES	
DOCUMENT CONTENTS		Article	4552
Keywords Plus (ID)	3241		
Author's Keywords (DE)	7545		

3.2. Social And Intellectual Results

A three-field plot was used to observe absorption cooling articles in science and engineering between 1980 and 2024 (Figure 4).

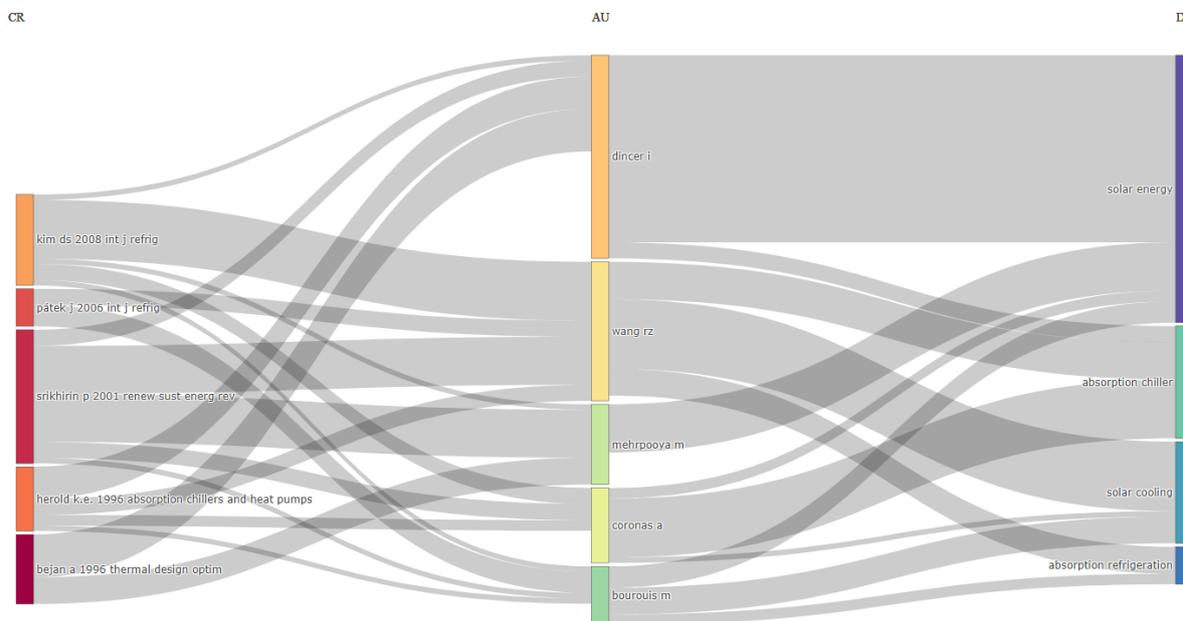


Figure 4. Three-field plot (CR: references, Au: Authors, DE: Author’s keywords)

The visualization based on the Sankey diagram shows the publication components and their relationships using three basic features (authors, keywords, journals) [33, 41]. The five most effective units were selected for each. The first five most effective authors used the reference “Srikkhirin et al. 2001 [1]” the most, and this source is also the most cited article among review studies in the subject area in the WoS database. When the authors were examined, it was seen that “dincer i” and “wang rz” were effective in the field. Effective authors in the field mostly preferred the keywords “solar energy” and “absorption chiller”.

Table 2 lists the most cited articles and shows which publications have attracted the most attention in the literature. The article “A pressure-amplifying framework material with negative gas adsorption transitions” by Krause et al. [42] is the most cited publication (Table 2). Studies have shown different uses of absorption cooling technology in the fields of science and engineering.

Table 2. Most global cited documents

Paper	Total Citations
KRAUSE S, 2016, NATURE “A pressure-amplifying framework material with negative gas adsorption transitions” [42]	447
BRÜCKNER S, 2015, APPL ENERG “Industrial waste heat recovery technologies: An economic analysis of heat transformation Technologies” [43]	355
FLORIDES GA, 2003, ENERG CONVERS MANAGE “Design and construction of a LiBr–water absorption machine” [44]	310
CHOW TT, 2002, ENERG BUILDINGS “Global optimization of absorption chiller system by genetic algorithm and neural network” [45]	248
MARNAY C, 2008, IEEE T POWER SYST “Optimal Technology Selection and Operation of Commercial-Building Microgrids” [46]	242

3.2.1. Keywords and thematic analysis

There are two types of data in the word analysis. These are keywords plus and author's keywords. Keywords Plus is as effective as the author's keywords in showing the knowledge structure of scientific fields, but they are less comprehensive in representing the article's content [47]. In order to better understand the field text, both the author's keywords and keywords plus were examined separately. First, the word cloud was examined. The frequency and effect of the word are taken as the basis for creating the word cloud. The first 50 words were taken as the basis for the analysis. Figure 5 was created using the author's keywords. When Figure 5 was examined, it was seen that the author's keywords "solar cooling", "absorption chiller" and "absorption refrigeration" were prominent. Figure 6 was created using keywords plus. When Figure 6 was examined, it was seen that the keywords plus "performance", "optimization" and "energy" were prominent. The top ten author's keywords and keywords plus rankings according to frequency values alone are given in Table 3. When Table 3 is examined, two words in the top ten in both groups are "exergy" and "optimization".

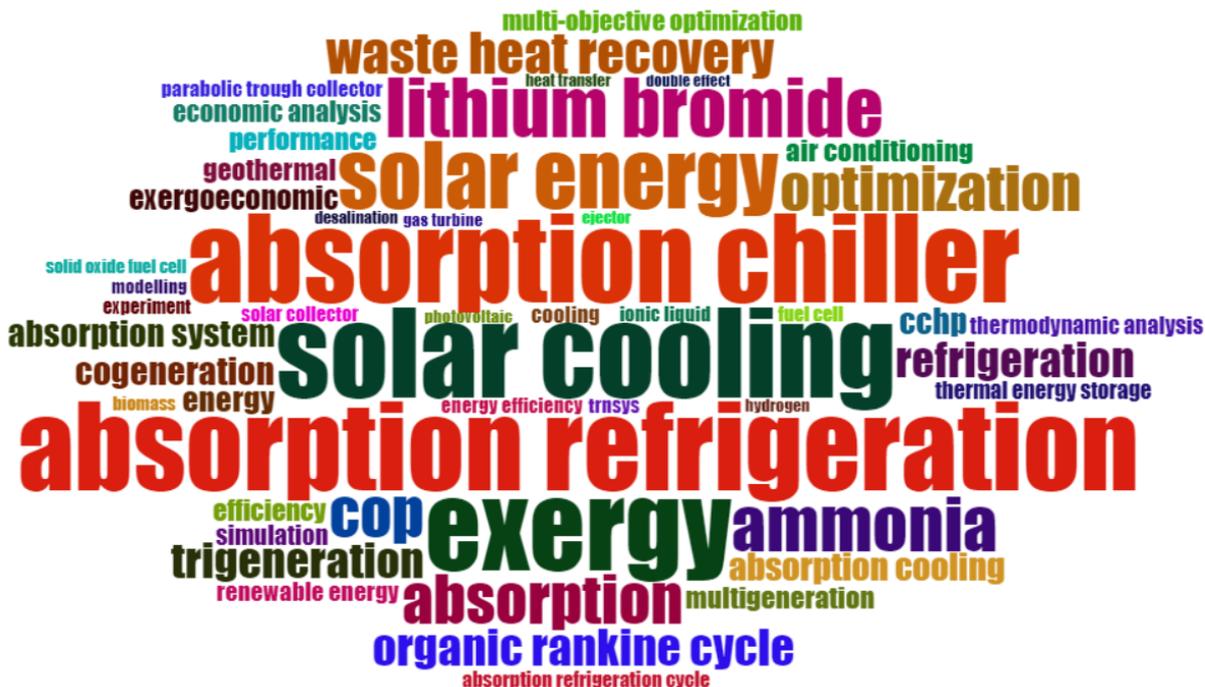


Figure 5. Word cloud (n=50) of author's keywords



Figure 6. Word cloud (n=50) of keywords plus

The word cloud can provide the general structure, but it is insufficient because it represents the cumulative increase [48], so a trend topic analysis was performed. Keyword trends, also known as trend topic analysis, show us how the literature has changed over the years and in which years the

words were used and were trending [33]. Since it is created using the words used in titles, abstracts, and keywords, it shows us how important these fields are. Researchers can easily reach the publications they seek using words [49]. The trends of absorption cooling studies in science and engineering between 1980 and 2024 are given in Figures 7 and 8.

Table 3. Most frequent words

Author’s keywords		Keywords plus	
Words	Freq	Words	Freq
solar cooling	430	performance	1594
absorption chiller	422	optimization	1135
absorption refrigeration	421	energy	866
exergy	412	cycle	635
solar energy	319	system	617
lithium bromide	283	design	595
ammonia	258	exergy	571
absorption	234	simulation	506
cop	233	driven	414
optimization	220	thermodynamic analysis	412

In the trend topic analysis, as the concepts move to the upper right corner, it is understood that they have been used more in recent years [48]. The Author’s keywords were used for Figure 7, the annual minimum frequency was 5, and the number of words per year was 3 in creating the figure. When Figure 7 is examined, it is seen that the Author’s keywords “Energy recovery” and “Water” have maintained their popularity for a long time. However, in recent years it has been observed that the Author’s keywords “Energy storage density”, “Freshwater production”, “arc” and “machine learning” have become trends.

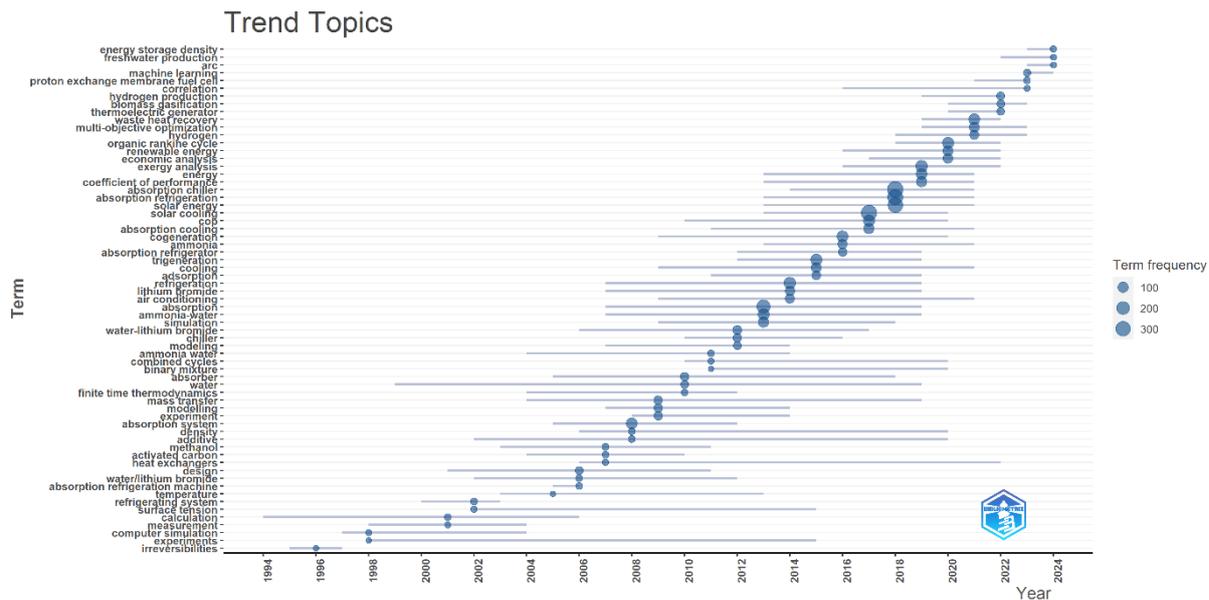


Figure 7. Trend topics for Author’s keywords

For Figure 8, keywords plus were used, the annual minimum frequency was five, and the number of words per year was 3 in creating the figure. When Figure 8 is examined, it is seen that the keywords plus “Thermodynamic model” have maintained their popularity for a long time. However, in recent years, it has been observed that the keywords plus “4e analysis”, “Small-capacity” and “Multigeneration” have become trends.

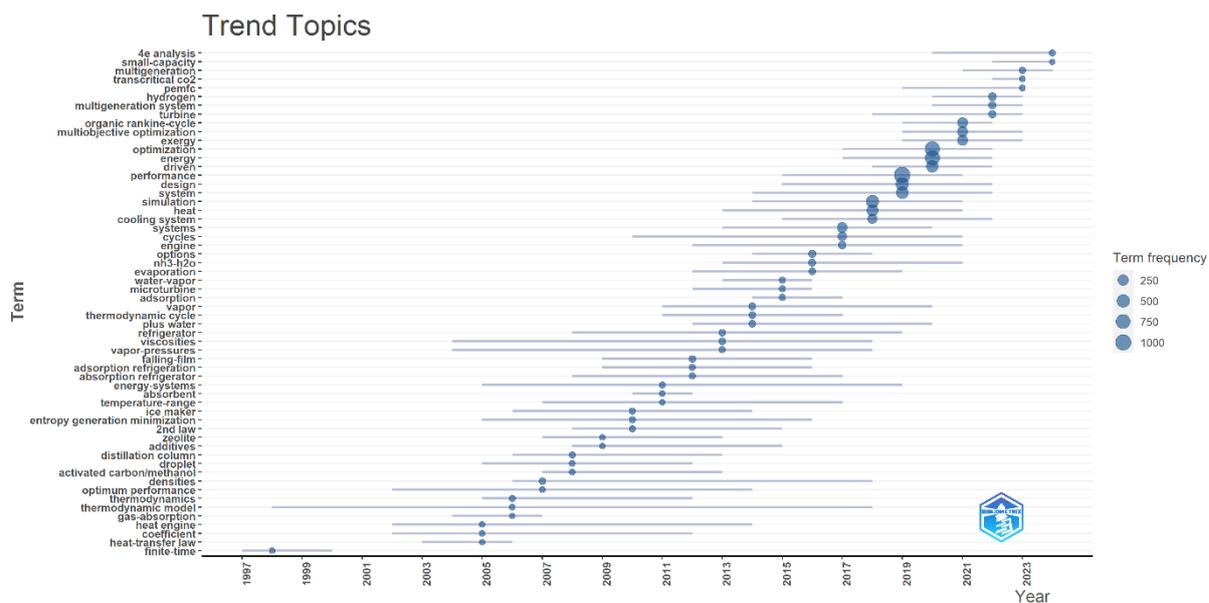


Figure 8. Trend topics for Keywords plus

Thematic mapping was used for the conceptual structure of the study area [50]. There are two parameters in the thematic map: the horizontal axis represents centrality (x-axis), and the vertical axis represents density (y-axis); these two parameters represent the keyword network and the thematic map consists of four sections [48]. Here, the upper right side represents “Motor Themes”; the keywords in this group are more common among themselves [51], and this makes them more developed [52]. This section tells us that the most effective publications in the field are made on these keywords. The themes in the upper left corner are highly developed and isolated themes (“Niche Themes”). The themes here have developed internal connections among themselves, but there are insignificant external connections and, therefore, have only marginal meanings [52]. This section shows us interesting topics that are uncommon in the literature. The lower left section shows newly emerging or disappearing themes (“Emerging or Declining Themes”), which have relatively fewer internal or external ties to other themes [48]. Therefore, they can be considered less important in the field under investigation [52]. The lower right section is the “Basic Themes,” which are important in the field but not sufficiently developed [48]. This section represents areas as strong as motor themes but not yet so strong.

In creating the thematic map, the number of words was 1000, the minimum cluster frequency (per thousand docs) was 5, the number of labels was 3, the label size was 0.3, the community repulsion was 0, and the clustering algorithm “Walktrap” was used. Figure 9 shows the thematic map created from the author’s keywords. Here, the upper right side is the “Absorption chiller”, “Exergy” and “Solar energy” clusters, which are the motor themes, but some of them are also included in the basic themes (Figure 9). In Figure 9, the “Ionic liquids”, “Solubility” cluster and the “Experiment”, “Heat transfer”, “Mass transfer” clusters in the upper left corner belong to the niche themes. In the lower-left section of Figure 9, the emerging or declining themes include “Solar cooling,” “Thermal energy storage,” and half of the “Trmsys” cluster. In the lower right section of Figure 9, the basic themes are “Absorption refrigeration”, “Lithium bromide” and “amonia” clusters, which are important for the development of absorption cooling technology in the field of science and engineering, but are not sufficiently developed. Apart from this, half of the other two clusters we have just mentioned are also in this basic themes (Figure 9).

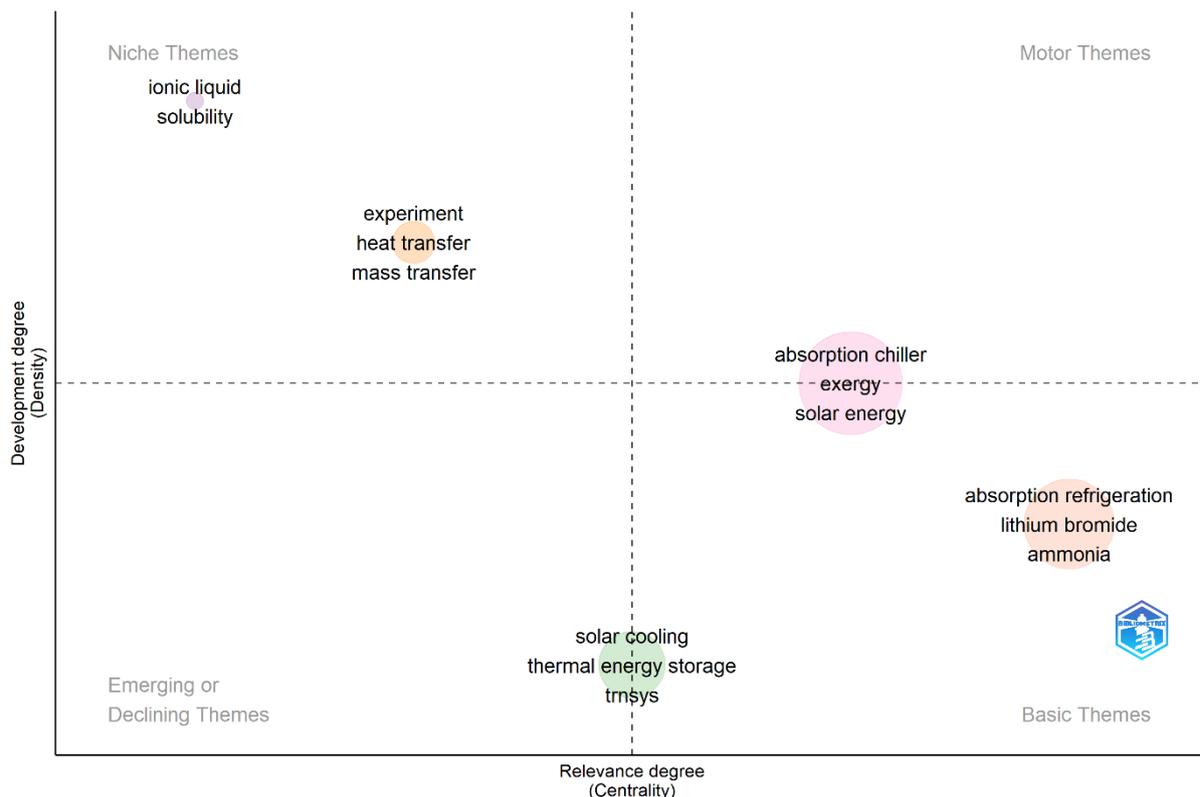


Figure 9. Thematic map of the author’s keywords

Figure 10 shows the thematic map created from keywords plus. Here, the “Performance”, “Optimization” and “Energy” cluster on the upper right side are the motor themes (Figure 10). In Figure 10, the “Ionic liquids”, “Solubility” and “Heat-capacities” cluster in the upper left corner is the niche themes. In Figure 10, the “Water”, “Temperature” and “Lithium bromide” are the emerging or declining themes in the lower left section. In the lower right part of Figure 10, the basic themes of “Cycle”, “System” and “Simulation” are important for the development of absorption cooling technology in the field of science and engineering, but they are not sufficiently developed.

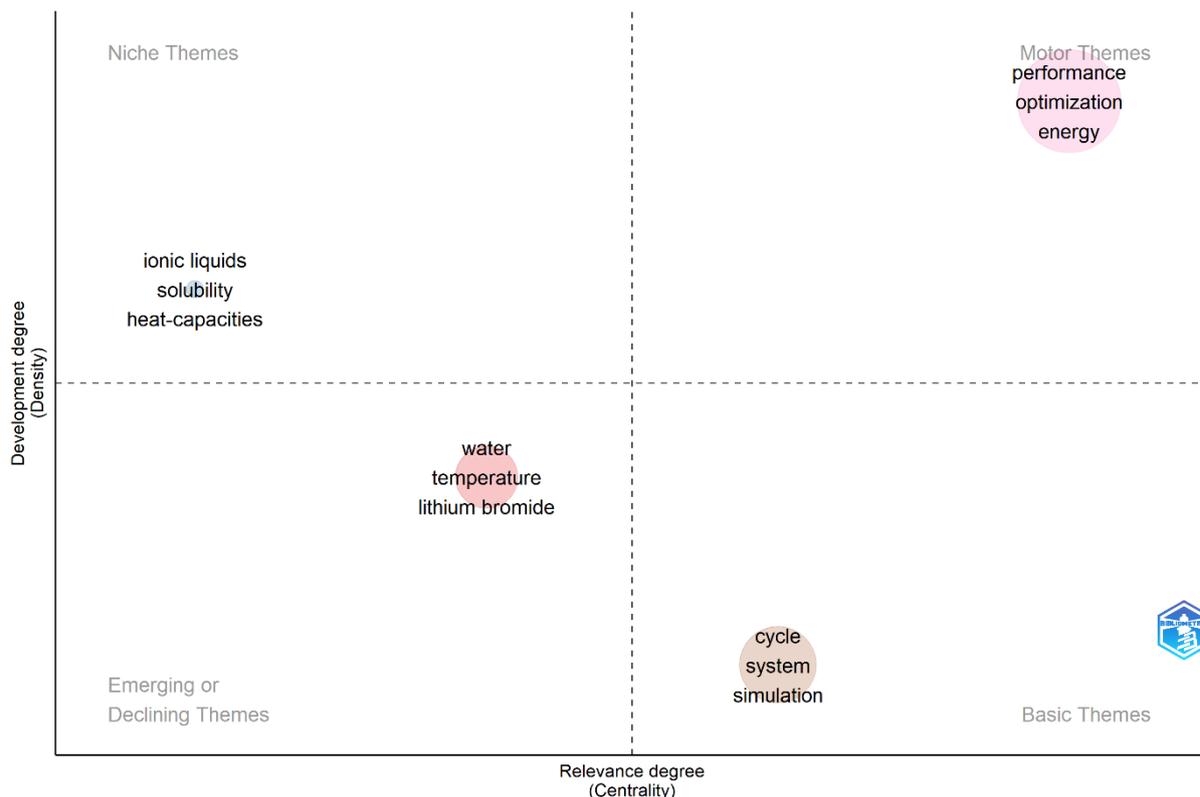


Figure 10. Thematic map of keywords plus

3.2.2. Author analysis

The ten most productive authors in the field are given in Table 4. Here, the most productive author is DINCER I. In Table 4, the articles fractionalized values are above 10, which shows us how many publications the authors have with co-authors.

Table 4. Most relevant authors

Authors	Articles	Articles Fractionalized
DINCER I	94	36,78
WANG RZ	62	18,82
CORONAS A	51	13,20
MEHRPOOYA M	46	15,38
BOUROUIS M	41	12,15

3.2.3. Affiliations

The ten most productive institutions are given in Figure 11 according to the number of articles produced by the institutions. The most productive institution with 162 publications was “UNIVERSITY OF TEHRAN”.

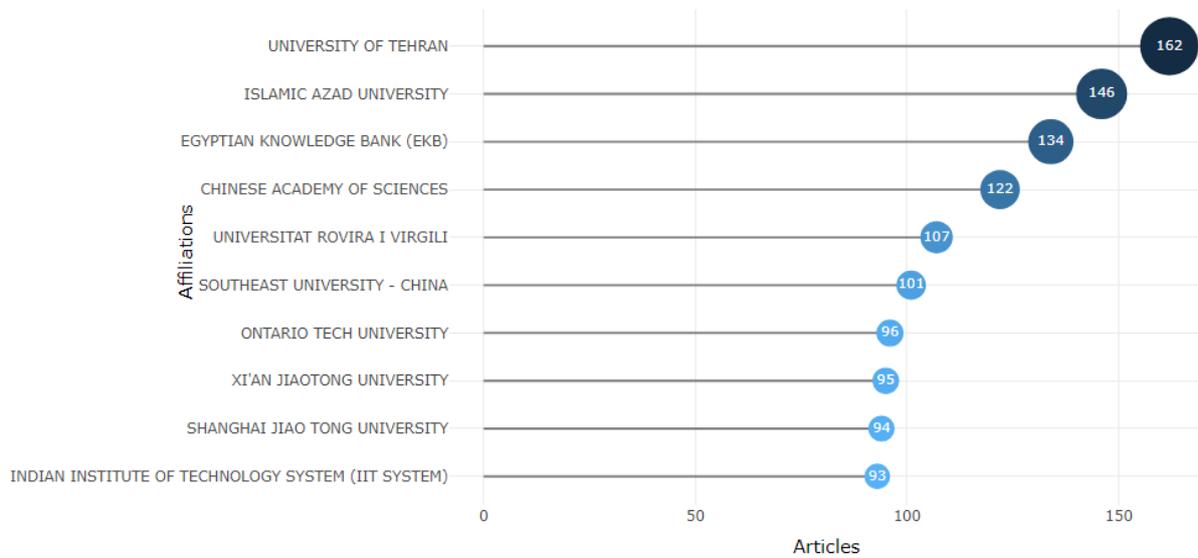


Figure 11. Most relevant affiliations

3.2.4. Sources

The journals in the downloaded dataset were examined (Table 5). Table 5 lists the five most effective journals. According to Table 5, most of the articles reached are in the journal “Applied Thermal Engineering” (n=487). The journal specializes in thermal engineering, including components, devices, and equipment, renewable and clean-energy technologies, components through to system design, and economic assessments. It publishes quality and effective articles in energy and heat (CiteScore: 11.3, Impact Factor: 6.1) [53].

Table 5. Most relevant sources

Sources	Articles
APPLIED THERMAL ENGINEERING	487
ENERGY CONVERSION AND MANAGEMENT	476
ENERGY	344
INTERNATIONAL JOURNAL OF REFRIGERATION-REVUE	233
INTERNATIONALE DU FROID	188
APPLIED ENERGY	188

3.2.5 Country analysis

According to the annual publication output of the countries, CHINA ranked first (Table 6). Table 6 shows that the ten most productive countries are mainly in regions with high solar energy and are developed or developing countries.

Table 6. The most productive countries

Region	Freq	Region	Freq
CHINA	2033	SAUDI ARABIA	339
IRAN	966	ITALY	302
INDIA	542	TURKEY	288
USA	491	MEXICO	278
SPAIN	471	UNITED KINGDOM	244

3.3. Web Of Science (WOS) Analysis Results

Unlike bibliometric analysis, the WoS analysis results of 4827 articles obtained from the WoS database are given. Table 7 is the category formed by assigning the journals included in the Web of Science core collection to at least one category. It was observed that a significant portion of the journals in which the obtained articles were published were in the WoS categories of “Energy Fuels” and “Thermodynamics.”

Table 8 shows the results of the Citation Topics Meso analysis. This table provides us with the core of the citation topics, regardless of the subject and content of the document. It represents the areas where authors cite each other's articles and evaluates the relationship between the documents. According to Table 8, authors mostly cited each other in the field of "Thermodynamics."

Table 7. Web of Science categories

Web of Science Categories	Record Count	% of 4.827	Web of Science Categories	Record Count	% of 4.827
Energy Fuels	3094	64.098	Green Sustainable Science Technology	441	9.136
Thermodynamics	2438	50.508	Chemistry Physical	242	5.013
Engineering Mechanical	1253	25.958	Construction Building Technology	192	3.978
Mechanics	1213	25.129	Environmental Sciences	191	3.957
Engineering Chemical	535	11.083	Engineering Civil	152	3.149

Table 8. Citation topics meso

Citation Topics Meso	Record Count	% of 4.827	Citation Topics Meso	Record Count	% of 4.827
7.70 Thermodynamics	3992	82.701	5.77 Applied Physics	42	0.870
2.89 Ionic, Molecular & Complex Liquids	155	3.211	7.139 Energy & Fuels	31	0.642
4.18 Power Systems & Electric Vehicles	114	2.362	4.84 Supply Chain & Logistics	29	0.601
6.115 Sustainability Science	98	2.030	2.241 Membrane Science	25	0.518
5.56 Quantum Mechanics	68	1.409	2.62 Electrochemistry	20	0.414

3.4. Discussion

When the 7545 author's keywords and 3241 keywords plus found in the sources obtained in our study were examined, it was seen that different words were used for the same phenomenon. Words used differently for similar phenomena were combined by creating a txt. file. Too many words brought limitations, so similar words with a frequency of at least three were brought together based on the first 100 most used words. In selecting the word to represent, the most used word for the same phenomenon, the word with the highest frequency, was taken. Word combinations were made for both groups (author's keywords, keywords plus). In the word analysis, the original structure and the modified structure were compared, and it was seen that the modified structure represented the field better. For example, the author's keywords "absorption chiller" and "absorption chillers" represent the same phenomenon. However, since their spelling is different, the program analysis them as different phenomena, so these two words were combined and used in the word "absorption chiller". Similarly, the words "absorption cooling", "absorption cooling system" or "absorption refrigeration", "absorption refrigeration system". Apart from this, the words "absorption chiller", "absorption cooling" and "absorption refrigeration" actually represent a similar phenomenon. However, it was not preferred to combine them because the authors in the field preferred these concepts with a minimal difference, so it was thought that the author preferences would not be hindered in reflecting the technical term development and concept preference in the field. In the bibliometric analysis they conducted in the field of solar cooling technology, Saikia et al. [32], unlike us, changed all the words "Absorption cycle", and "Absorption system", including the words mentioned above, to "absorption" and used them in the evolution of highly occurred keywords analysis. As a result, the word "absorption" came to the fore, while the other words were not included in the analysis. In the same study, the first 100 of

the original author's keywords used by the authors are given; most of the keywords in the list are similar and compatible with our study. This is because solar energy has been researched extensively as a heat source in absorption cooling technology. In our study, "solar cooling" came first, and "solar energy" came fifth among the author's keywords, which shows that solar energy is at the forefront in studies on absorption cooling. Similarly, Ibrahim et al. [12] solar energy cooling with absorption coolers is similar to the result of the traditional review study. The study found that solar absorption cooling with hot water thermal storage is the most used system worldwide. In their traditional review study on absorption cooling systems in 2020, Nikbakhti et al. [2] stated that the two most prominent main working fluid pairs in absorption cycles are LiBr-H₂O and H₂O-NH₃. In our study, among the author's keywords, "lithium bromide" came in sixth place, and "ammonia" came in seventh place, which showed that the authors mostly worked on these fluids. The reviews on absorption cooling systems have generally been made on specific areas; when looking at Srihirin et al. [1] suggestions covering the general area, it was stated that it is necessary to develop new working fluids, increase absorber performance, and invent new advanced cycles. In our study, the keywords plus "performance" came first, and "cycle" came fourth, which showed their representation of the field of study and also drew attention to the subject of "ionic liquids" and "solubility" working fluids in the niche theme on the thematic map. The fact that only two of the same words appear in Table 3 and the other words are different does not create the perception that the author's keywords and keywords plus are completely different from each other because the first ten rankings are given in the list when the entire list is looked at, all the words in the table are in both lists. The words author's keywords and keywords plus are similar, but their rankings in the lists are different because their frequency of use is different. In a different study conducted to compare the author's keywords and keywords plus, it was stated that both showed similar research tendencies; however, while keywords plus terms emphasized research methods and techniques, the author's keywords tended to focus on a specific subject [47]. Similarly, when Table 3 is examined, it was seen that the author's keywords better represented the subject of study, while keywords plus better represented the study method. Since the bibliometric analysis has not been done in the field of absorption cooling before when two bibliometric studies [8, 32] conducted in the field of solar cooling are examined in terms of being a similar subject, there are similar results, but there are differences. One of the reasons for this is that different technologies are used in the field of solar cooling other than absorption cooling. Our data in these two studies are closer to the Saikia et al. [32] study, which is thought to be because Saikia et al. [32] uses the WoS database, and Bravo et al. [8] uses the Scopus database. In addition, Saikia et

al. [32] chose a more general subject while Bravo et al. [8] chose a more specific subject, and it was seen that the choice of subject is also important for bibliometric analysis. Tables 7 and 8 emphasize the importance of demonstrating the relevance of the obtained data to the targeted research field. WoS category analysis provides a tool for verifying this relevance. If categories are concentrated outside the expected domains based on prior knowledge, the choice of keywords and search operators should be reconsidered. Otherwise, the results may misrepresent the field. Conducting WoS category analysis helps prevent such discrepancies and ensures the robustness of the findings. The thematic map results, particularly the identification of “absorption chiller,” “exergy,” and “solar energy” as motor themes, confirm the centrality of efficiency analysis and renewable integration in the field. These clusters represent mature research areas driving innovation. In contrast, the “Ionic liquids” and “Solubility” niche themes suggest underexplored yet technically promising topics that could contribute to environmental sustainability by improving fluid compatibility and thermal properties. Furthermore, emerging themes such as “machine learning” and “4E analysis” reflect a methodological evolution in the field, where computational tools and comprehensive assessment frameworks are gaining momentum. These findings can guide funding agencies and researchers towards both established and novel domains within absorption cooling.

4. CONCLUSION

This study presents the first bibliometric analysis of absorption cooling systems within the science and engineering literature. A total of 4552 articles published between 1980 and 2024 were analyzed using the Bibliometrix (R) package and Web of Science (WoS) tools. By analyzing authorship patterns, keywords, collaboration networks, and thematic structures, the development of the field was systematically mapped.

The field has shown a steady and significant increase in publication volume, particularly after 2008, with an annual growth rate of 11.16%. This surge aligns with the global rise in attention toward sustainable, renewable-based cooling technologies in response to energy crises and climate change. The prominence of author keywords like "solar cooling," "absorption chiller," and "absorption refrigeration" suggests continued interest in low-emission thermal systems.

The most cited article, "A pressure-amplifying framework material with negative gas adsorption transitions" by Krause et al. (2016), and the dominance of journals such as Applied Thermal

Engineering and Energy Conversion and Management confirm the field's grounding in thermodynamic performance optimization. The most productive author, Dincer I., and leading institutions such as the University of Tehran demonstrate geographic and institutional contributions, with China emerging as the most prolific country in annual output.

Trend analysis and thematic maps revealed both current focal points and underexplored areas. Motor themes such as "absorption chiller," "exergy," and "solar energy" indicate well-established domains. Basic themes like "absorption refrigeration," "lithium bromide," and "ammonia" are foundational but may benefit from renewed attention, particularly regarding environmental compatibility and performance. Niche themes, including "ionic liquids" and "solubility," suggest promising yet underrepresented areas of research. The emergence of keywords such as "energy storage density," "machine learning," and "4E analysis" highlights the integration of artificial intelligence and broader energy assessment frameworks in recent years.

Furthermore, the study addresses an evident gap in the literature: although numerous traditional reviews exist on solar and absorption cooling systems, no comprehensive bibliometric mapping had been published. This study provides not only descriptive insights but also strategic implications by identifying trending topics, declining research areas, and collaborative potentials.

Recommendations and Limitations: Future studies could expand this analysis by including additional databases such as Scopus and integrating other document types like conference papers or review articles. Special attention should be paid to unifying terminology in the field, as variations in keywords hinder discoverability and thematic clarity. The integration of absorption systems with other renewable-based cycles (e.g., trigeneration, multigeneration) and the development of environmentally benign working fluids are key areas for innovation.

In conclusion, this bibliometric analysis serves as a roadmap for researchers, funding agencies, and policy-makers by highlighting both mature and emerging areas in absorption cooling technology. It offers a structured, data-driven foundation for future research aiming to enhance system performance, sustainability, and technological integration.

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DECLARATION OF ETHICAL STANDARDS

The authors of the paper submitted declare that nothing which is necessary for achieving the paper requires ethical committee and/or legal-special permissions.

CONTRIBUTION OF THE AUTHORS

Ramazan Yılmaz: Performed the bibliometric data collection and analysis.

Erhan Kırtepe: Wrote the manuscript and interpreted the bibliometric results.

CONFLICT OF INTEREST

There is no conflict of interest in this study.

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