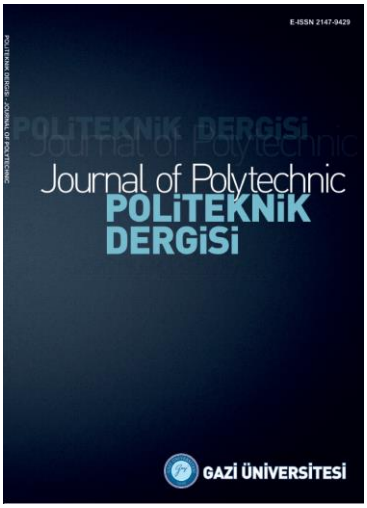

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Navigating Türkiye's energy horizon: a bibliometric exploration of academic contributions to energy, fuels, and hydrogen subjects

Türkiye'nin enerji ufkunda gezinti: enerji, yakıtlar ve hidrojen konularına akademik katkıların bibliyometrik bir incelemesi

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Navigating Türkiye's Energy Horizon: A Bibliometric Exploration of Academic Contributions to Energy, Fuels, and Hydrogen Subjects

Highlights

- *Explore academic contributions of Türkiye to energy, fuels and hydrogen topics.*
- *The oldest date is 1972 for energy&fuels and 1989 for hydrogen studies.*
- *USA and Canada are the most efficient countries for colloborations.*
- *New trends in energy&fuels: Machine learning, supercapacitor, nanoparticles, electric vehicle, graphene*
- *New trends in hydrogen: Methanolysis, multigeneration, ammonia, thermodynamic analysis, graphene.*

Graphical Abstract

Figure. Keywords for hydrogen fuel

Aim

Exploring the academic contributions of Türkiye to energy, fuels and hydrogen topic.

Design & Methodology

Bibliometric analysis is carried out for energy&fuels and hydrogen topics.

Originality

The importance of energy and fuels, which are also used as political tools, has increased with recent events and has become a threat to the national security of countries. Among the fuels, hydrogen is seen as the fuel of the future. In this study, academic trends regarding energy, fuels and hydrogen are analysed for Türkiye, as one of the critical country, is economically developing and located between Europea and Asia.

Findings

Whereas machine learning, supercapacitor, nanoparticles, electric vehicle, graphene are the new trends in energy&fuels; methanolysis, multigeneration, ammonia, thermodynamic analysis, graphene are new trends in hydrogen topic.

Conclusion

Although there is a positive correlation between some prominent and current academic topics such as "natural gas", "electric vehicles", "hydrogen production", "machine learning", "supercapacitor", "solar energy'', ‘‘graphene" and current industrial investments, it is thought that more industrial investments are needed in other prominent academic topics such as "solid oxide fuel cell", methanolysis'', ‘‘catalyst'' and etc. On the contrary, it is also observed that there is a need for more academic studies on nuclear energy and nuclear fuels compared to the actual nuclear energy investments in Türkiye.

Declaration of Ethical Standards

The authors of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

Navigating Türkiye's Energy Horizon: A Bibliometric Exploration of Academic Contributions to Energy, Fuels, and Hydrogen Subjects

Araştırma Makalesi / Research Article

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ABSTRACT

This paper aims to unveil the intellectual structure and knowledge flow within Türkiye's academic landscape, shedding light on influential research clusters and highlighting the interconnections between different research themes. The manuscript also synthesizes findings from a Web of Science database, elucidating the growth trajectories of Türkiye's contributions to the global discourse on energy, fuels, and hydrogen. Additionally, the role of interdisciplinary collaboration has been explored and the impact of Türkiye's research output on the international stage has been assessed. According to results, the oldest date goes back to 1972 for Energy&Fuels topic and 1989 for hydrogen topic. Whereas Ayhan Demirbas and Ibrahim Dincer are the most productive authors, Istanbul Technical University and Yildiz Technical University are the most productive institutions. Moreover, USA and Canada are the most efficient countries for colloborations. Last of all, while new trends in Energy&Fuels publications have been observed as machine learning, supercapacitor, nanoparticles, electric vehicle and graphene, new trends in hydrogen publications were observed as methanolysis, multigeneration, ammonia, thermodynamic analysis and graphene.

Keywords: Bibliometric analysis, academic contribution, Türkiye, energy, fuels, hydrogen.

Türkiye'nin Enerji Ufkunda Gezinti: Enerji, Yakıtlar ve Hidrojen Konularına Akademik Katkıların Bibliyometrik Bir İncelemesi

ÖZ

Bu makale, Türkiye'nin akademik ortamındaki entellektüel yapıyı ve bilgi akışını ortaya çıkarmayı, etkili araştırma kümelerine ışık tutmayı ve farklı araştırma temaları arasındaki bağlantıları vurgulamayı amaçlamaktadır. Makale aynı zamanda Web of Science veri tabanından elde edilen bulguları sentezleyerek Türkiye'nin enerji, yakıtlar ve hidrojen konusundaki küresel söyleme katkılarının büyüme yörüngelerini aydınlatmaktadır. Ayrıca, disiplinler arası işbirliğinin rolü araştırılmış ve Türkiye'nin araştırma çıktılarının uluslararası sahnedeki etkisi değerlendirilmiştir. Sonuçlara göre, enerji ve yakıtlar konusu için en eski tarih 1972'ye, hidrojen konusu için ise 1989'a kadar uzanmaktadır. Ayhan Demirbaş ve İbrahim Dinçer en üretken yazarlar olurken, İstanbul Teknik Üniversitesi ve Yıldız Teknik Üniversitesi en üretken kurumlardır. Ayrıca, ABD ve Kanada, işbirliklerinin en etkili olduğu ülkelerdir. Son olarak, Energy&Fuels yayınlarında yeni trendler makine öğrenmesi, süperkapasitör, nanopartiküller, elektrikli araç ve grafen olarak gözlemlenirken, hidrojen yayınlarında yeni trendler ise metanoliz, multijenerasyon, amonyak, termodinamik analiz ve grafen olarak gözlemlenmiştir.

Anahtar Kelimeler: Bibliyometrik analiz, akademik katkı, Türkiye, enerji, yakıtlar, hidrojen.

1. INTRODUCTION

The “energy” term is thought to date back to Aristotle [1] as a combination (originally “energeia”) of the Greek words, "en" (meaning “in”) and “ergon” (meaning “work”), as a consequence meaning “in work” [2]. With the transition of human beings' power sources from their own labor, animal muscles, wind and water to the machines (which can be called as the “Industrial Revolution")[34], the importance of the word "energy" has increased rapidly, until today. In this period, steam engines and combustion engines have been providing nonignorable services for humankind to reach today’s wealthy and raised the standard of living in the world [54]. The main fuels utilized in industries and feeding to these machines have been coal, oil, natural gas and etc. [4]. These fossil fuels and aforementioned machines have proven their reliability in time. During this duration, world economy as gross domestic product was increased sharply [6] and global energy consumption raised [7]. However, some experienced big events and crises during this period in the world changed the global energy demand sharply and caused the fluctuations in the oil prices, such as Spanish Flu, Great Depression, World

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War II, Oil Shocks in 1970s, Iran-Iraq conflict in 1979, the Gulf War in 1990, financial crisis in 2008 and finally Covid-19 Pandemic and Russian-Ukrainian War and etc. [89]. Even though these crises were temporary, in and after every crisis, new/further seekings may emerge or further innovative investments may be stimulated [10]. The best example of this is the "1970s oil crisis". After the 1973 Yom Kippur war, Organization of Arab Petroleum Exporting Countries (OAPEC) announced that it would no longer export oil to the United States and countries that sided with Israel in the war. The cost of the barrel has been increased from US$3 to US$12 [11]. The second shock was happened as tenfold rise in oil prices with the 1979 Iranian Revolution [12]. With the boosted oil prices in the world with such crises, caused stagflation and high inflation rates [13]. International Energy Agency has been established in 1974 after the economical and political crisis [14]. Boomed oil price shocks caused countries, especially those dependent on foreign energy supply, to question their energitical positions [15]. Countries reconsidered their oil consumptions [16], declared their energy plans and goals [10], interests in alternative fuels have started or expanded [17][18][19] and awareness regarding “energy efficiency” and “energy security” concepts have been raised [20][21]. Recently, it has been faced with another economic disturbance due to Covid-19 pandemic and Russian war. During the pandemic duration, oil demand [22] and industrial production [23] was extremely declined, the supply chain was disrupted. While the pandemic process was in the recovery period and energy demand had boomed due to this recovery [23], the outbreak of the Russian-Ukrainian war fueled the rising prices. Consequently, developed and especially developing countries faced with high inflation in this duration, and this effect continues today. At the moment, the evaluation of the results of this period is not easy and the foresight for near future is complex. Further raised energy prices, on-going or new conflicts and tensions between countries may create trade off between the concepts [10], “national energy security’’ and the ‘‘acceleration of energy transition(?)”(Herein it should be noted that, “energy transition” term as “replacing fossil fuels by renewable energy meaning” is disputable, since historical data shows that despite rapid growth of newer energy source, older energy source continued to grow due to continuously raised population, economic growths, energy demand and etc. [24]. It might be more accurate to describe it as "a change in the focus of attention".) Extreme energy prices and shortage of the green powers (such as experienced regional low wind power, water shortage and etc), may cause cancellations of the companies’ renewable energy investments and this may be resulted as quickly returning the fossil fuels [10][23]. However, during the pandemic period, the "importance of human health" has also come to the fore and the interest in “air pollution” and “clean energy need” has also increased [25]. As a consequence, economic, political, ecologic, military situations [26] and in detail, complex interactions of sub-headings e.g. population/economic growth, air quality, industrial policy, climate change, security of supply, customer demands, and etc. [27] will determine the future selections. Today, we are at the threshold of another step in the process where crises cause changes. Besides, for the long term, clean fuel seeking to combat with global warming and prevent air pollution will be the one of the main concerns for next decades.

One of the most hopeful alternative fuel and energy storage option for the clean air future is hydrogen. Hydrogen is the superior and ideal fuel for combustion [28], energy dense storage option for unpredictible, geographically inbalanced and intermittent renewable energy [29], versatile as its production, storage, use may be carried out by diversified methods. With the effect of the its being most abundant element in the universe [30] and its versatility, it attracts the attention of scientists and researchers [31]), and its end use causes low/no emissions. Hydrogen can be used in industrial processes such as steel, food or chemical production, generate heat and power, and produce other alternative fuels such as ammonia [32][33], metals and oil refining [34]. Its production by renewable energy systems is identified as clean with little environmental impact [35]. Its energy density is higher than batteries [36] and it is non toxic [37]. In addition to its production and storage advantages, its use for end user to produce power is clean as well. Considering combustion engines, hydrogen mixes with air and burns quickly in the combustion chamber with its high diffusion rate and high flame speed. Its auto ignition temperature and lower heating value is high [38]. Its combustion produces only NO_x and steam at the end of tailpipe [39]. Hydrogen also can be utilized by environment friendly fuel cells, with less/no vibration or noise, low maintenance requirement [40], efficient power generation, independently from Carnot efficiency [41]. Despite the aforementioned all superiorities, there are some challenges should be solved. First of all, each step from its production to end use has efficiency loss. Low efficiency results become prominent especially with the green hydrogen due to low efficiency of solar and wind power systems [28][42]. Furthermore, each step has individual challenges, for instance lack of infrastructure for large-scale production and distribution, low energy density, safety concerns, storage materials [43], high cost and etc. [44]. Today, the most of the hydrogen comes from methane based production, partial oxidation of oil and gasification of coal [45]. Reforming or gasification of fossil fuels is cheaper method but result as CO_2 emit [46]. Instead of, producing by the solar energy is attractive if the cost issue is solved. Photovoltaic water electrolysis and photocatalytic [47] water splitting methods are promising [48]. Hydrogen can be produced from hydrocarbon sources with membrane separation as well [49]. Beside these, storage of the hydrogen should be carried out as safe and efficient [50]. Its superior combustion properties come across as disadvantages for safety. Low boiling point and lightness make difficult to handle it [51] and also keep the high amount of energy[52]. Each of the commercial methods, compressed and

liquified storage has problems, such as energy consumption to fill up the cylinder with gas or keep the liquid form and boil-off losses [53], safety problems due to extremely high pressure/low temperature [30], hydrogen embrittlement in material [5455], invisible flame of the hydrogen, thanks to combustion without smoke or soot [56], environmental doubts due to hydrogen leakage affect indirectly the global warming [57]. For these reasons, material-based storage alternatives are in more investigation.

Despite all these challenges, there is a huge potential and all aforementioned varieties presents the research interests. Whereas the traces of hydrogen have gone to the 1800 century, its alternative fuel interest has been risen after oil crises [5859]. Today, countries focus on the more hydrogen fuel share in transportation and renewable energy integrated hydrogen use. Some countries set net zero goals for the next years [60]. European Union and United States set their carbon neutrality goal as before 2050, Iceland and Austria by 2040, China by 2060, Finland by 2035 [61]. European Union defines the green hydrogen as "fundamental" fo the zero pollution sustainable economy [62]. Some of the countries such as United States declared its energy strategy that gives a big importance to hydrogen and some countries and organizations such as Japan, EU, China declared their hydrogen road maps [63]. Germany, Norway, California are trying to increase FCEV car number by providing subsidies and tax benefits [64]. In addition to this, Japan is the leader country as it supplies biggest fundings regarding hydrogen fuel and hydrogen technology [65]. Moreover, some of the companies and organizations show their eagerness to the hydrogen energy with projects. Air Liquide put into the green hydrogen production as 8.2 tonnes hydrogen a day [66]. Three companies in Germany plan to operate 100 MW electrolyser in Hamburg [67].

Importance of the energy, fuels and hydrogen topics for countries is incontestable. In this study, the similar pattern [68] has been followed for academic studies, sent from Türkiye's affiliations and indexed by Web of Science as a subheading "Energy & Fuels" categorization, have been analyzed through bibliometric method. Furthermore, as a second part of the study, hydrogen was selected as a topic in the above published documents and 3003 study was separated and analyzed with the same pattern. The study was carried out for Turkey, which is located between Asia and Europe, neighboring countries with oil and natural gas reserves, economically developing, with a young population, high renewable energy opportunities and recent investments in the field of energy. The study is the first to take a snapshot of Turkey's academic contributions in the fields of energy, fuels and hydrogen in detail. It reveals academic identities, relationships and trend orientations in these subjects, and provides both guidance for those who will work in the academic field and it provides ideas for practical and industrial applications or policy makers.

1.1. Importance of "Energy and Fuels" and also "Hydrogen" topics for Türkiye

Türkiye is an economically developing country with a population of 85 million [69], surrounded by seas on three sides, located between Asia and Europe and near the Middle East which has the majority of the petroleum reserves [70]. Its economy and also energy requirement has been gradually increased in recent years. Figure 1 represents the total energy supply by source between 1990-2021 [71].

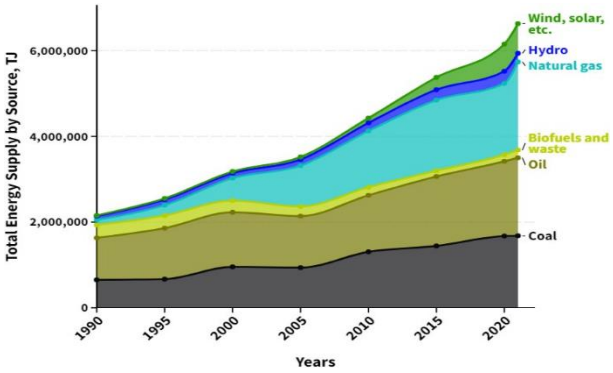

Figure 1. Total energy supply by source of Türkiye with time (adopted from [71])

According to figure, significant increase of energy amount has been observed, independently from fossil or renewable source. However, whereas renewable energy and natural gas share in the percentage are increasing, the share of oil is decreasing as a percentage. Furthermore, Türkiye is heavily dependent to fossil fuel import, such as 93% for oil and 99% for gas [72]. Transportation, heating and electricity production can be sorted as main fossil fuel consumption reasons [73]. Despite the dependence on foreign sources in the present situation, noteworthy attempts have been observed in the recent years. Serious breakthroughs and investments have been made in renewable fields such as solar, wind and hydro energy, as well as in nuclear energy. Huge renewable energy potential as solar (solar energy is also found as the best renewable energy option for Türkiye [74]) and wind, and also geothermal energy potential has been reported [75]. Beside these, Black Sea, one of the seas surrounding Türkiye has significant energy potential. Black sea has large amount of wind and wave energy [76], it is one of the biggest H2S reserve, its seawater has low salinity as an advantageous for electrolysis and it is politically almost stable [77]. It was estimated that Türkiye's share in the H2S reserve of Black Sea may be 40 to 65 times more than the discovered Tuna-1 natural gas reserve [77] which is the biggest discovered hydrocarbon reserve of Türkiye more recently. H2S has been producing continuously by sulphur reducing bacteria at mostly between the 500-2000 m [78]. This environment suffers from oxygen deficient and also toxicity. For this reason, utilizing of H2S will also beneficial for the marine ecosystem and aquatic life [79]. Decomposition of H2S to hydrogen and sulphur by electrolysis is easier than electrolysis of water

due to weaker bond between hydrogen and sulphur. Moreover, whereas separated hydrogen can be utilized as a fuel, extracted sulphur may be used in industry [80]. In addition to H2S, Türkiye has more than 70% of the reserves of boron which may be utilized in the hydrogen storage e.g. as sodium borohydride (NaBH4) and also other solid based materials in the future energy systems [81]. Furhermore, boron has superiority in fuels because of the released energy at the end of its combustion [82]. Between the fuels, hydrogen has significant importance for Türkiye. First of all, it should be noted that Türkiye has been sorted as 8. in number of publications of "hydrogen production" topic [47]. Hydrogen production capacities in Türkiye has been estimated as 2.26 megatons with hydro-based [83], 255.20 Mt with wind power [84], 559.76 kilotons with geothermal energy [85], 415.48-427.22 million tons with solar power [86]. Thanks to significant textile and agricultural activities [87], there is significant hydrogen production potential from wastes [8889]. Moreover, Türkiye has 17.480 billion tons lignite reserves and this coal can be utilized to produce hydrogen via underground gasification [9091]. In addition to these, 5% of residential natural gas consumption equivalent hydrogen can be produced by Türkiye's industrial waste heat [92]. Consequently, hydrogen takes attention amid the fuels and it will present the huge contributions to the Türkiye' s future energy policy. This study will put forward the trends of academic studies of Türkiye subjecting energy, fuels and hydrogen via bibliometric analysis.

An in-depth bibliometric analysis article focused on energy, fuels and hydrogen in the context of Türkiye holds significant importance for several reasons:

- Energy Security and Independence: Türkiye's energy demand has been steadily increasing, making it crucial to assess the country's reliance on foreign energy sources. Analyzing the existing literature helps in understanding the extent to which Türkiye is dependent on external energy suppliers and how this affects its energy security and reveals strength and limitations.
- Renewable Energy Transition: As the world shifts towards sustainable and renewable energy sources, Türkiye 's transition in this direction is vital. A bibliometric analysis can shed light on the extent of research and development in renewable energy technologies and their adoption within the country (or maybe transition know-how from fossil fuel to alternatives).
- Environmental Impact: Energy and fuels sectors are major contributors to environmental issues. Examining the research in this area can highlight the impact of Türkiye's energy choices on the environment, helping policymakers make informed decisions. This part is also important regarding emission restrictions.
- Economic Implications: Energy and fuels are integral to a nation's economy. Understanding the research landscape in this field can provide insights into the economic implications of energy choices, such as the cost-effectiveness of different sources and their impact on industries and job creation.
- Policy Formulation: Policymakers rely on data and research findings to create effective energy policies. A bibliometric analysis can identify trends and gaps in research, assisting in the development of policies that align with national goals and global energy trends.
- International Collaboration: Examining collaborative research efforts can reveal how Türkiye engages with the global energy research community. This can provide insights into potential partnerships and areas where Türkiye can benefit from international cooperation.
- Innovation and Technological Advancements: Türkiye's competitiveness in the global energy market is closely tied to its technological innovations. Analyzing the literature can help identify areas where Türkiye is excelling and where it needs to invest in research and development.
- Energy Access: Energy access is a critical aspect of development. Understanding the research landscape can help evaluate the progress made in ensuring energy access for all citizens, particularly in remote or underserved regions of Türkiye.
- Energy Efficiency: Energy efficiency is essential for reducing energy consumption and greenhouse gas emissions. A bibliometric analysis can reveal the state of research on energy-efficient technologies and practices within Türkiye.

In summary, a bibliometric analysis focused on energy and fuels in Türkiye is vital for understanding the country's energy landscape, its implications on various aspects of national development, and for guiding future policies and research priorities. This analysis can serve as a valuable resource for researchers, policymakers, and stakeholders in the energy sector, contributing to the sustainable development and energy security of Türkiye.

2. DATA COLLECTION AND METHOD

In this study, bibliometric analysis was conducted throughout Web of Science data. Bibliometrics uses mathematics and statistics to analyze books, articles, and publications with quantity, performance, and structural indicators. [93]. Thanks to the bibliometric analysis, current research area information can be gathered and trends may be revealed [94]. It identify emerging trends and provide quantitative perspective [95]. In addition to these, there are a lot of databases, such as Web of Science, Scopus, Google Scholar, PubMed, Compendex, Medline, Dimensions, Microsoft Academic, CrossRef, ResearchGate, OpenCitations and etc. Scopus offers more coverage than Web of Science [96] and the Web of Science is the more selective than Scopus [97]. Launched in 2004, Google Scholar does not need require any subscription and presents the contents as freely available [98]. However, significant amount of Google Scholar unique citations are not from journals and has lower scientific impact [99], thus less reliable [98]. Other databases have specific disadvantages, for instance Dimensions, Microsoft Academic, CrossRef, Researchgate and

OpenCitations are relatively new and there is doubt for validity of these databases and others such as Medline, PubMed, Compendix and etc. are highly specialized [98]. Among the databases, Web of Science is the first citation index for science, launched in 1964 by the Eugene Garfield as Institute for Scientific Information. Its coverage was expanded with time [100101]. Author information, affiliations, abstract, keywords, acknowledgements, funding, references and other similar informations may be obtained [102]. Web of Science Core Collection as the premier source in the platform [103] and with its respected indexes [104], Science Citation Index, Social Sciences Citation Index, Arts & Humanities Citation Index, Conference Proceedings Citation Index, Book Citation Index, Emerging Sources Citation Index, Index Chemicus, Current Chemical Reactions, it covers more than 21981 journals, over 89 million records and with 2.1 billion cited references [105]. In this study, since the most respected, selective and mature database, Web of Science data was used to carry out bibliometric analysis. Obtained data from the Web of Science was used in VOSviewer software. VOSviewer converts bibliometric data into visualizations, analyze large data with cluster and layout techniques [106].

The main flowchart of this study can be sorted as follows. First of all, data has been extracted from database in 29.10.2023. In the "document search" section, "search in" and "editions" section has been choosed as "Web of Science Core Collection" and "All", respectively. Under the "Web of Science Categories", "Energy & Fuels" was selected. 1130153 documents have been resulted. Afterthat, under the "Countries/Regions", "TURKEY" and "TURKIYE" was selected together and results were refined. The Republic of Turkey has been used the "Türkiye" name as its state name in international platforms since December 2021 and the country's name in foreign languages was changed from "Turkey" to "Türkiye" within the United Nations in 2022 [107]. Resulted 18266 documents have been exported as "Tab delimited file" with "Full Record and Cited References". Exported files have been uploaded to VOSviewer software and analyzed. Annual document number, document types, Web of Science Indexes, network of co-authorship of countries and the most used keywords, top 10 productive journal and affiliations have been demonstrated. With this way, by selecting the articles of those working in Türkiye's institutions, Türkiye's academic studies on energy and fuels were shed light. In the second part, hydrogen as one of the most important alternative fuel for Türkiye, was focused on. Selecting the "Energy & Fuels" in Web of Science Categories and "hydrogen" in Topic section, 3003 published documents have been obtained. The same analysis was carried out for hydrogen topic and results have been presented. The flowchart of the study has been illustrated in Figure 2.

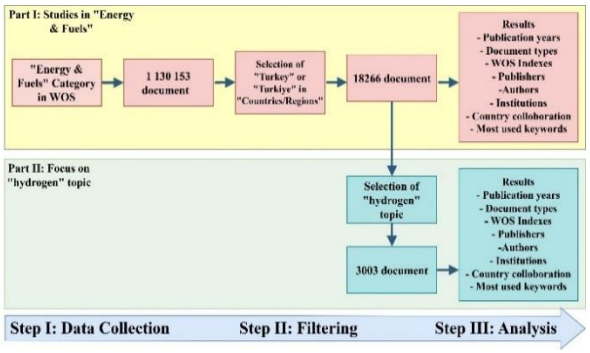

Figure 2. Flowchart of the present study

2.1. Strength and Limitations

When conducting a bibliometric analysis on the topic of energy, fuels and hydrogen in Türkiye using Web of Science (WoS) data, it's important to acknowledge certain limitations:

- Coverage Bias: Web of Science may not comprehensively cover all academic publications related to energy and fuels, potentially leading to a limited dataset. This bias can result in the omission of relevant articles published in other databases or journals not indexed by Web of Science.
- Language Bias: Web of Science primarily indexes English-language journals. This bias may exclude publications in Turkish or other languages, which are essential for a complete analysis of research in Türkiye.
- Publication Delay: Web of Science may have a time lag in indexing publications, which means that the most recent research may not be included in the analysis. This can impact the accuracy of current trends and developments.
- Subjective Keyword Selection: The quality of a bibliometric analysis heavily depends on the choice of keywords. If relevant keywords are not selected, important articles may be missed, or irrelevant ones may be included. In this context, in this article Web of Science categorization was selected as "energy & fuels" and in the second part, "hydrogen" topic was selected.
- Author Disambiguation: Web of Science may not always accurately disambiguate authors with similar names, potentially leading to incorrect authorship attributions, which can affect the accuracy of collaboration and co-authorship analysis. In this article a deep attention has been paid to this issue.
- Interdisciplinary Research: Energy and fuels research often spans multiple disciplines. Web of Science's classification system may not adequately capture interdisciplinary work, resulting in the underrepresentation of research in this area.
- Self-Citations: Researchers may excessively cite their own work, potentially inflating the importance and impact of certain articles in the analysis. This can distort the overall bibliometric results.
- Institutional Affiliation: While Web of Science includes information on institutional affiliations of authors, it may not capture collaborations involving Turkish institutions if they are not accurately recorded or updated in the database.

- Conference Proceedings and Grey Literature: Web of Science may not comprehensively cover conference proceedings or grey literature, which can be valuable sources of information, particularly in emerging or niche areas of this research or region.
- Data Accuracy and Completeness: Like any database, Web of Science is subject to errors, omissions, and inconsistencies in data. Users should be aware of the potential for data inaccuracies that could affect the analysis.

In this article, it should be underlined that to mitigate these limitations, it's advisable to complement the Web of Science data with information from other databases, such as Scopus or Google Scholar, to create a more comprehensive dataset. Additionally, manual review and validation of the retrieved articles, as well as cross-referencing with national databases and journals, can help enhance the accuracy of the bibliometric analysis.

3. RESULTS

3.1. Results of "Energy & Fuels" Categorization

In this section, results of the bibliometric analysis regarding "energy&fuels" categorization was presented. Annual document number, document types, Web of Science Indexes, journals, authors, institutions, country colloborations, the most used keywords have been analyzed.

3.1.1. Publication years of "energy & fuels" category

Figure 3. represents the count of publications for each year. According to figure, studies in "Energy &Fuels" category have been starting from the 1972. Until 1990s, slope is almost horizontal but after that, significant increase has been observed. In 2018, count has gone beyond 1000 threshold and reached to 1701 in 2022. From the beginning of 2023 to the date of carried out analysis, 1065 count has been covered for 2023. Energy and fuels are attractive topics in Türkiye as parallel to its economic and energy developments and there is remarkable increase in this period.

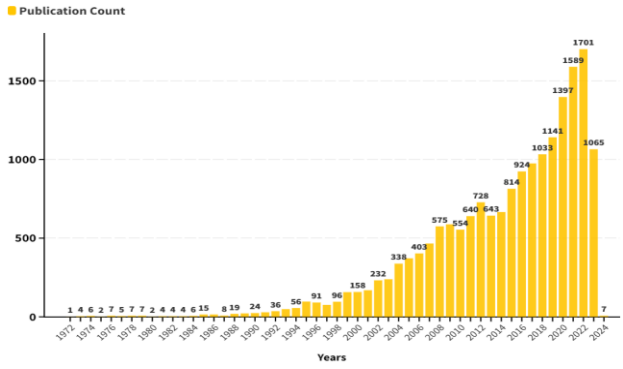

Figure 3. Number of documents per each year regarding "Energy & Fuels" category

3.1.2. Analysis of the "energy & fuels" category publications

Total 18266 publications have been selected from Web of Science Core Collection. The majority of the count in 15 publication types are articles as it consists of 83% of the total, as seen in Table 1. Article is followed by proceeding paper, review article, book chapters, early access, editorial material, correction, note, letter, retraction, retracted publication, meeting abstract, book review, biographical-item and correction, addition, respectively. Furthermore, it should be noted that the language of the most of the publications as 18257 documents is English. 7 publications have been written with German and 2 publications French. Moreover, there are difference between the mentioned 18266 publication count and total publication count presented in Table 1. In addition to this, the sum of the percentage in Table 1 exceeds the 100%. Web of Science may cover the same publication as proceeding paper and as article simultaneously if the proceeding paper was printed as article.

Table 1. Document types for "Energy & Fuels" category

Document Types	Record Count	%
Article	15173	83.067
Proceeding Paper	2744	15.022
Review Article	796	4.358
Book Chapters	285	1.56
Early Access	283	1.549
Editorial Material	168	0.92
Correction	73	0.4
Note	32	0.175
Letter	23	0.126
Retraction	7	0.038
Retracted Publication	6	0.033
Meeting Abstract	5	0.027
Book Review	3	0.016
Biographical-Item	1	0.005
Correction, Addition	1	0.005

Table 2. represents the publication count according to index coverage. Results demonstrate that the most of the publications as 15618 counts have been under Science Citation Index Expanded. Conference Proceedings Citation Index – Science (CPCI-S), Social Sciences Citation Index (SSCI), Emerging Sources Citation Index (ESCI), Book Citation Index – Science (BKCI-S), Conference Proceedings Citation Index – Social Science & Humanities (CPCI-SSH), Arts & Humanities Citation Index (A&HCI) is aligned according to count, after the SCI-Expanded, respectively. The exceeding 100% of the total percentage can be explained by the acceptance of the proceeding paper as an article.

3.1.3. Analysis of journals, affiliations, funding agencies, authors in "energy & fuels" category

According to results, there are 123 publishers. 55.2% of the record count belongs to Elsevier. It is followed by Taylor & Francis as 12.2%, IEEE as 7.5%, Wiley as 3.9%, Springer Nature as 3.7%, Mdpi as 2.4% and others has 14.7% share. Moreover, Figure 4 represents the top 10 publication titles according to publication count with journal' s impact factor. It should be noted that quartile mentioned near the journal name was thought as according to Journal Citation Reports 2022. Moreover, 2022 journal impact factor was taken for impact factors.

Table 2. Web of Science Indexes of publications for "Energy & Fuels" category

Web of Science Index	Record Count	%
Science Citation Index Expanded (SCI-Expanded)	15618	85.503
Conference Proceedings Citation Index – Science (CPCI-S)	2744	15.022
Social Sciences Citation Index (SSCI)	1020	5.584
Emerging Sources Citation Index (ESCI)	377	2.064
Book Citation Index – Science (BKCI-S)	285	1.56
Book Citation Index – Social Sciences & Humanities (BKCI-SSH)	44	0.241
Conference Proceedings Citation Index – Social Science & Humanities (CPCI-SSH)	17	0.093
Arts & Humanities Citation Index (A&HCI)	2	0.011

1739 document was published by Internatinal Journal of Hydrogen Energy (IJHE), that is qualified in 1st quartile (Q1) and ranked as 33/119 in Energy & Fuels category. Others journals have been sorted as Energy Sources Part A Recovery Utilization and Environmental Effects, Energy Conversion and Management, Energy, Fuel, Renewable Energy, International Journal of Energy Research (IJER), Applied Thermal Engineering, Renewable Sustainable Energy Reviews, Bioresource Technology. Whereas nine of the top 10 journals is in first quartile (Q1), one of them is Q3 according to Journal Citation Reports 2022.

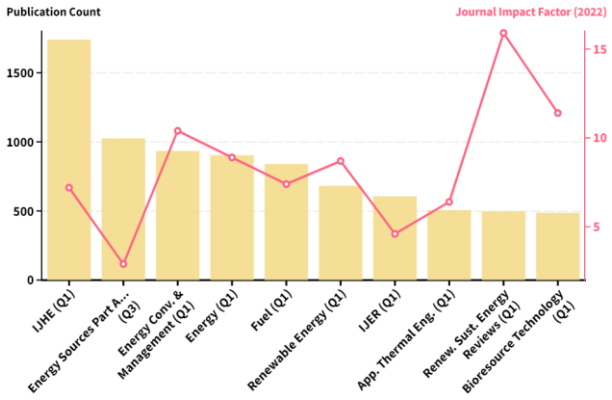

Figure 4. The most productive 10 journals in "Energy & Fuels" category

Table 3 listed the top 10 most encountered affiliation record. There are 4143 records in total. Results show that, Istanbul Technical University is leading the list with 1414 publication. The establisment date of the Istanbul Technical University goes back to 1773. Istanbul Technical University is the pioneer engineering and architectural institution with 250 years history in Türkiye. Other most productive universities considering "Energy & Fuels" category in Türkiye, are listed as Middle East Technical University with 1358 publication, Gazi University with 1082 publication, Yildiz Technical University with 1061 publication, Ege University with 700 publication, Karadeniz Technical University with 609 publication, Firat University with 473 publication, Cukurova University with 466 publication, Kocaeli

Table 3. The most 10 productive institutions in "Energy & Fuels" category

No	Institutions	Publication Count	%
1	Istanbul Technical University	1414	7.741
2	Middle East Technical University	1358	7.435
3	Gazi University	1082	5.924
4	Yildiz Technical University	1061	5.809
5	Ege University	700	3.832
6	Karadeniz Technical University	609	3.334
7	Firat University	473	2.59
8	Cukurova University	466	2.551
9	Kocaeli University	450	2.464
10	Dokuz Eylul University	423	2.316

University wth 450 publication, Dokuz Eylul University with 423 publication. The 10 affiliation constitute the 44% of total share. In addition to this, the most cited university is Gazi University with 20213 times cited. Moreover, Funding Agencies in the publications have been obtained from Web of Science. In total, 2956 funding agencies have been detected. According to Funding Agencies information, The Scientific and Technological Research Council of Türkiye (Tübitak) is the most observed funding agency in publications in "Energy & Fuels" category with 1916 count as 10.4% of total share. Other funding agencies are European Union EU with 157 counts as 0.86% share, National Natural Science Foundation of China Nsfc 137 count as 0.75% share, Turkish Academy of Sciences 137 count as 0.75% share and Yildiz Technical University 124 count 0.67% share, and others.

Table 4 demonstrates the most productive 10 authors in Türkiye for "Energy & Fuels" category. There are 21125 author records in total. Each of the top 3 author has more than 1% percentage according to publication count. The most productive author is Ayhan Demirbas. Other authors have been observed as Dincer I, Hepbasli A, Sari A, Kaygusuz K and others. Top 10 authors constitute to 9.75% of the total percentage.

Table 4. The most productive 10 authors regarding "Energy & Fuels" category

No	Authors	Publication Count	%
1	Demirbas A	365	1.998
2	Dincer I	300	1.642
3	Hepbasli A	283	1.549
4	Sari A	160	0.876
5	Kaygusuz K	140	0.766
6	Arici M	115	0.63
7	Kok MV	110	0.602
8	Colak I	109	0.597
9	Balat M	107	0.586
10	Sahin B	92	0.504

3.1.4. Analysis of co-authorship network and keywords in "energy & fuels" category

Co-authorship network of the countries with time have been visualized in Figure 5. In the analysis, maximum 25 countries per document was set. Countries has 20 or more than have been selected and by this way, number of items have been reduced to 58. Whereas the size of the node shows the document number of the country, colours indicate the position of the country from past to today as its actuality. According to results, 58 country has been grouped in 7 clusters for colloborating. Turkey has the maximum document number with biggest node. Afterthat, sorting continues with Türkiye, USA, Canada, Peoples R China and etc. The country name change in international area for foreign language is efficient to changing Turkey to Türkiye change in the results, since the Türkiye exist in current items since its average publication year is 2023. Moreover, it was observed that the actual records emerge as Türkiye (2023), Lebanon (2022), Taiwan (2021), India (2021), Serbia (2021), Poland (2021), Peoples R China (2020), Nigeria (2020), Tunisia (2020), Vietnam (2020), Czech Republic (2020) and etc.

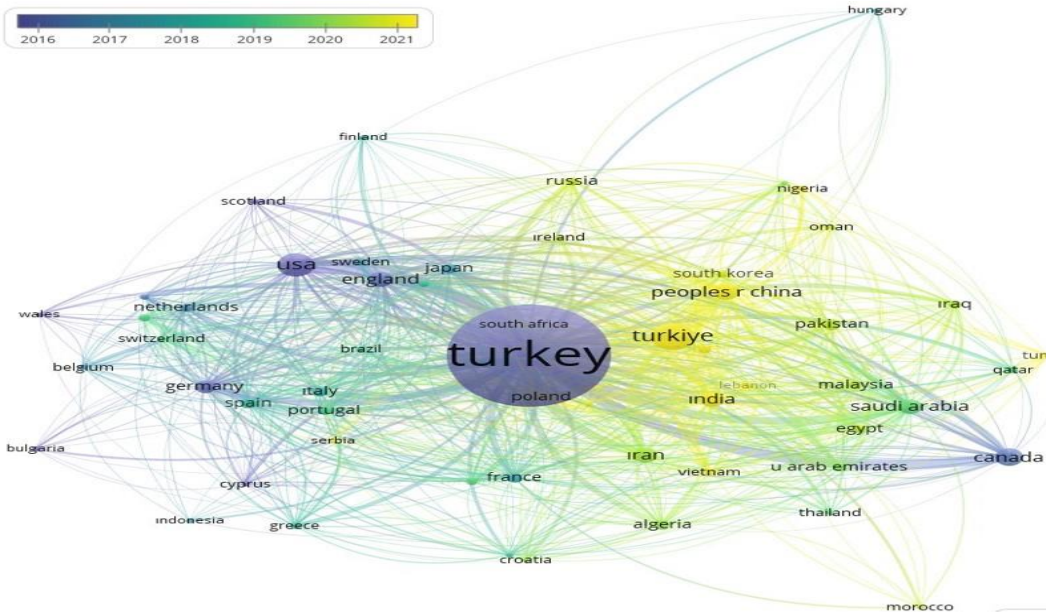

Figure 5. Co-authorship network of countries in time, for "Energy & Fuels" category

Using the VOSviewer software, the most used keywords may be obtained. Figure 6 demonstrates the co-occurrance of the author keywords. 31529 keywords have been reduced to 116 with setting the occurrences of keywords is 50 and more. The node size depicted the occurrence rate, link thickness demonstrate the how many times keywords have been used together and total link strength means that the total strength of the links of an item with other items [108]. First of all, 116 items clustered in 6 groups and the groupings have been demonstrated with different colours. The most occurred keywords are "turkey" in 671 times, "renewable energy" in 624 times, "exergy" in 622 times, "energy" in 591 times, "hydrogen" in 499 times, "biomass" in 467 times, "solar energy" in 449 times, "optimization" in 370 times, "biodiesel" in 368 times and "pyrolysis" in 345 times and etc. "Renewable energy" (also "solar energy" term related, that is important for Türkiye as identified 1527.46 kWh/m2 yearly average[109]) keyword occurred in 624 times, takes attention in sorting. In the recent years, with the incentives, renewable energy share has increased and domestic component production has improved [110]. Moreover, it was found that positive correlation between use of renewable energy and academic publications [111]. "Biomass" term ("pyrolysis" and "biodiesel" related also) can be defined as organic material utilized to obtain energy [112] and it is carbon based renewable energy source [113]. Treatment and utilization of these materials has significant importance for both energy security and environment [114]. Türkiye has significant agricultural potential with its special location and climate transitions [115]. Seeking date on biomass based energy goes back to 1980s [116] and today, waste heat&biomass based installed capacity of Türkiye has reached 2.1 GW (in 2022) [117]. However, there is still huge potential [118]. Whereas agricultural residues and available energy potential for total residues was mentioned as 75,084 kilotonne and 364,446 TJ [119], biomass gasification has been found as the best method for hydrogen production in Türkiye [120]. Top 5 keywords according to total link strength listed as "exergy", "energy", "renewable energy", "efficiency", "hydrogen". Moreover, keywords usage with time is important criteria and shows the actual/demoded words. This method gives an idea about changing topics and fields in time. The node size and link thickness are same, but colours indicate the average published year in Figure 7. Accoring to results, the most actual keywords can be listed as "machine learning" (avg. pub. year: 2021.41), "supercapacitor" (avg. pub. year: 2021.16),

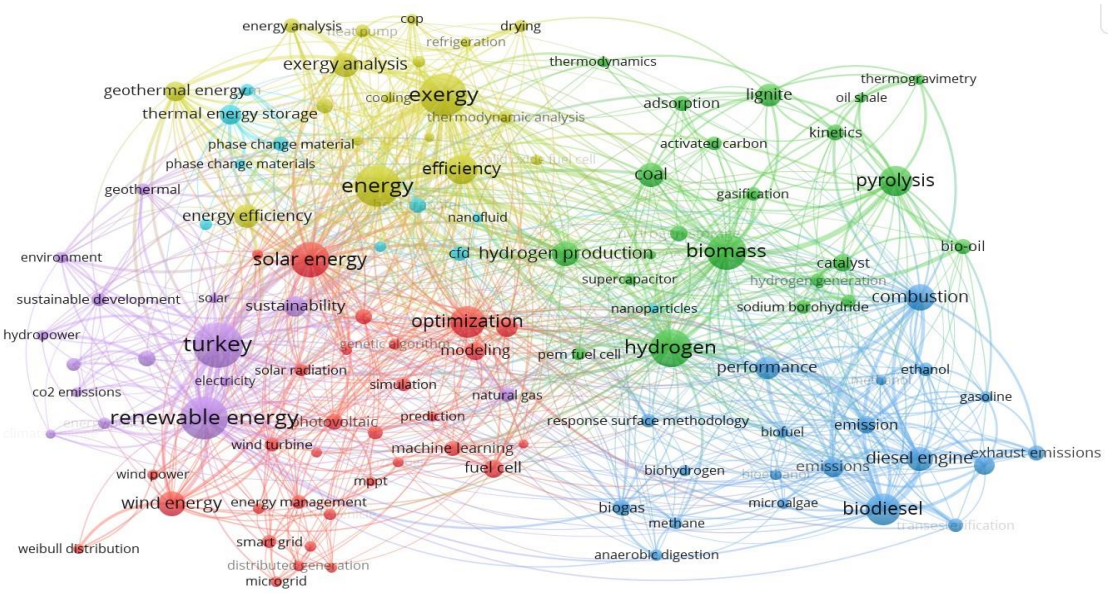

Figure 6. Network of the most used keywords for "Energy & Fuels" category

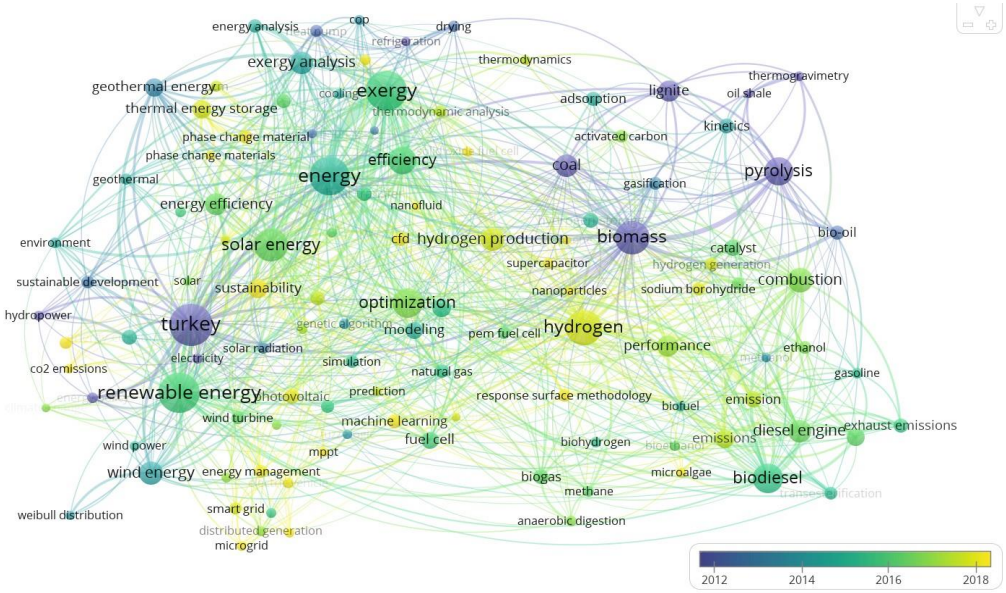

Figure 7. Network of the most used keywords for "Energy & Fuels" category in time

"nanoparticles" (avg. pub. year: 2020.07), "electric vehicle" (avg. pub. year: 2020.06) , "graphene" (avg. pub. year: 2020.02), "nanofluid" (avg. pub. year: 2019.82), "organic rankine cycle" (avg. pub. year: 2019.28) "phase change material" (avg. pub. year: 2019.11), "energy management" (avg. pub. year: 2019.16), "microgrid" (avg. pub. year: 2019.17), and etc. Hydrogen takes attention as relatively newer usage. Machine learning" takes attention as one of the most actual keyword. Artificial intelligence applications in both of the academic studies and energy sector gains more important. Recently, there are ongoing artificial intelligence actions in Türkiye, such as developing wind and air flow forecasting systems, named as RITM (Wind Monitoring and Forecasting Model) and ATHOM (Flow Forecast and Basin Optimization Model), conducted by Tübitak, demand management, Blockchain, optimization, price prediction studies conducted by an energy exchange company named as Enerji Piyasaları İşletme A. Ş. (EPİAŞ), electrical power quality and grid monitoring, load dispatch information system development, preparation of climatic maps, conducted by Turkish Electricity Transmission Corporation (TEİAŞ), a lot of projects in various areas conducted by TÜBİTAK-BİLGEM (Informatics and Information Security Research Center), ongoing projects on health and energy efficiency conducted by Erciyes Üniversity [121]. In addition to these, supercapacitors and phase change materials have been studying for energy storage applications [122] and there are supercapacitor investment

news on media in Türkiye. As an "electric vehicle" keyword, as parallel to investments on these area, academic publication number has been increasing. Türkiye has aannounced its "TOGG" brand electric vehicles in the near time [123] and electrification will play a key role for road transportation [124] or aviation[125].

3.2. Results of "Hydrogen" Topic as a subheading of "Energy &Fuels" Category

Until here, "energy & fuels" category publications whose authors are based in Türkiye have been analyzed. The number of these publications is 18266. Herein, "hydrogen" topic was selected from 18266 publication, and result is 3003 publications. Herein, 3003 documents have been analyzed with the same pathway. Publication years, publishers, document types, Web of Science Indexes, affiliations, journals, authors, country colloborations and most used keywords have been discussed.

3.2.1. Publication years of "hydrogen" topic publications

Selecting "hydrogen" topic, it was aimed that analysis to "focused onto hydrogen" studies. Figure 8 represents the publication years of "hydrogen" topic studies under "Energy & Fuels" category. Unlike the studies belongs to "energy&fuels" category in Türkiye, started from 1972, "hydrogen" topic including studies have been started from 1989. After 2000s, there are significant increase in publication count. Whereas the pause period was observed between 2009-2013, increase was continued afterthat. The max. count has reached to 326 publications in 2022. From the beginning of 2023 to the date of 29.10.2023 analysis carried out, 235 count has been recorded.

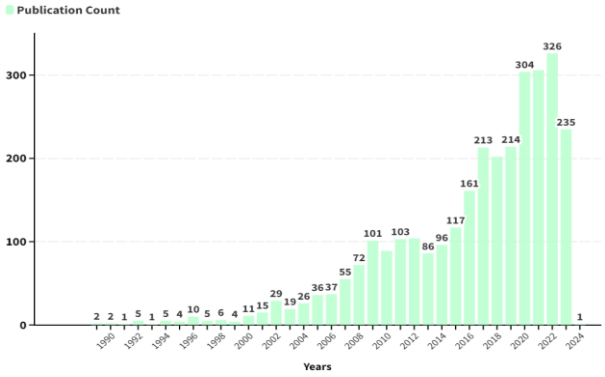

Figure 8. Number of documents per each year regarding "hydrogen" topic under "energy&fuels" category

3.2.2. Analysis of the "hydrogen" topic publications

Document types have been listed in Table 5. There are 11 document types for "hydrogen" topic. The vast majority, as 93% of total publications are article. 2794 record was found as an article. The other document types listed as 496 proceeding paper with 16.5% share, 96 review article with 3.19% share, 28 book chapters with 0.9% share, 24 editorial material with 0.79% share, and others are early acces, correction, letter, biographical-Item, retracted publication, retraction. The language of the all publications is English. The reason exceeding the 100% percentage can be said as acceptance of same proceeding papers as article.

Table 5. Document types of publications of "hydrogen" topic under "Energy & Fuels" category

Document Types	Publication Count	%
Article	2794	93.04
Proceeding Paper	496	16.517
Review Article	96	3.197
Book Chapters	28	0.932
Editorial Material	24	0.799
Early Access	22	0.733
Correction	11	0.366
Letter	2	0.067
Biographical-Item	1	0.033
Retracted Publication	1	0.033

Table 6. represents the Web of Science Indexes of records. 95.7% of the publications is covered by Science Citation Index Expanded (SCI-Expanded) with 2875 count. Other indexes listed as Conference Proceedings Citation Index – Science (CPCI-S) with 496 count as 16.5% share, Book Citation Index – Science (BKCI-S) with 28 count as 0.9% share, Emerging Sources Citation Index (ESCI) with 26 count as 0.86% share, Social Sciences Citation Index (SSCI) with 22 count as 0.73% share, Book Citation Index – Social Sciences & Humanities (BKCI-SSH) with 4 count as 0.13% share and Conference Proceedings Citation Index – Social Science & Humanities (CPCI-SSH) with 2 count as 0.06% share, respectively.

Table 6. Web of Science Indexes of "hydrogen" topic publications

Document Types	Publication Count	%
Science Citation Index Expanded (SCI-Expanded)	2875	95.738
Conference Proceedings Citation Index – Science (CPCI-S)	496	16.517
Book Citation Index – Science (BKCI-S)	28	0.932
Emerging Sources Citation Index (ESCI)	26	0.866
Social Sciences Citation Index (SSCI)	22	0.733
Book Citation Index – Social Sciences & Humanities (BKCI-SSH)	4	0.133
Conference Proceedings Citation Index – Social Science & Humanities (CPCI-SSH)	2	0.067

3.2.3. Analysis of journals, affiliations, funding agencies, authors in "hydrogen" topic publications

48 publishers have been observed for "hydrogen" topic. Elsevier published 2363 publication; it is 78.6% of the total publication count. Whereas the second is Taylor & Francis, it has 217 records as 7.22% share, third publisher is Wiley, with 118 records as 3.92% share. Other publishers have 10.1% share. Beside this, top 10 publication titles with their publication count, quartiles in "Energy & Fuels" category according to Journal Citation

Reports 2022, 2022 journal impact factors have been presented in Figure 9. As similar to "Energy & Fuels" category publications, leader journal is International Journal of Hydrogen (IJHE). International Journal of Hydrogen published 1687 study, and has 56.17% share of total publications. The information of the journal was mentioned above. The difference between the publication count of International Journal of Hydrogen Energy and others is significant. Second journal is Fuel with 145 study, third one is Energy Sources Part a Recovery Utilization and environmental effects with 134 study, fourth one is International Journal of Energy Research (IJER) with 102 study, fifth one is Energy Conversion and Management with 85 study, sixth one is Energy with 66 study, seventh one is Fuel Processıng Technology with 49 study, eighth one is Renewable Energy with 42 study, ninth one is Energy Sources with 33 study, tenth one is Bioresource Technology with 30 study. Eight journal of top 10 is in Q1, two journal is in Q3.

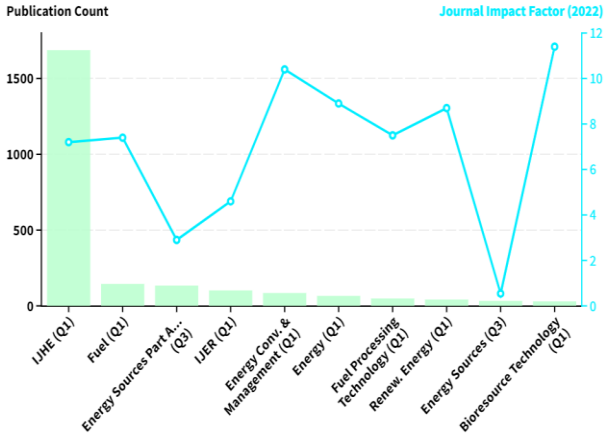

Figure 9. The most productive 10 journals for "hydrogen" topic under "Energy & Fuels" category

The most (top 10) recorded affiliations of the authors and their publication count have been demonstrated in Table 7. 1056 record has been observed, some of these in Türkiye and others are not. In Table 7, institutions not placed in Türkiye were not included in the list. Yildiz Technical University as the most encountered affiliation has 295 records, 9.8% of the total share. It should be noted that, Yildiz Technical University was ranked as 4th in "Energy & Fuels" category above. Yildiz Technical University was established in 1911 to meet technician requirement and one of the most effective institutions in Türkiye. Other institutions have been listed as Middle East Technical University with 219 records, 7.29% share, Gazi University with 214 records, 7.12% share, Dokuz Eylul University with 124 records, 4.12% share, Cukurova University with 123 records, 4% share, Erciyes University and Siirt University with 104 records, 3.46% share, Ege University with 102 records, 3.39% share and Istanbul Technical University with 95 records and 3.16% share, Nigde Omer Halisdemir University with 88 records and 2.93% share. These 10 universities constitute of the 48.8% of the total share. Moreover, Istanbul Technical University as having most observed record in "Energy & Fuels" category, now have been listed as the 9th in top 10 list. When we look the funding agencies information, 678 funding agencies exist. The most encountered funding agency is The Scientific and Technological Research Council of Türkiye (Tübitak) again, with 552 counts, 18.3% share. Turkish Academy Of Sciences is the second funding agency with 74 count and 2.46% share, third funding agency is Natural Sciences And Engineering Research Council Of Canada Nserc with 50 count and 1.66% share, fourth and fifth funding agency is European Union Eu and Yildiz Technical University with 42 count and 1.39% share.

Table 7. The most 10 productive institutions for "hydrogen" topic under "Energy & Fuels" category

No	Institutions	Publication	No
1	Yildiz Technical University	295	9.824
2	Middle East Technical University	219	7.293
3	Gazi University	214	7.126
4	Dokuz Eylul University	124	4.129
5	Cukurova University	123	4.096
6	Erciyes University	104	3.463
7	Siirt University	104	3.463
8	Ege University	102	3.397
9	Istanbul Technical University	95	3.164
10	Nigde Omer Halisdemir Unıversity	88	2.93

Table 8 indicates the most productive 10 authors for "hydrogen" topic under "Energy & Fuels" category. The observed author record is 4314. Whereas top 10 authors in the list constitute the 22.14% of the total share, total of top 3 authors exceed the 10% share of the total list with 11.2% share, according to publication count. Ibrahim Dincer is the most productive author in the list with 179 publication count as 5.96% of the all publications in the list. Other authors have been listed as Demirbas A, Eroglu I, Ozturk M, Saka C and others.

Table 8. The most productive 10 authors regarding "hydrogen" topic under "Energy & Fuels" category.

No	Authors	Publication Count	%
1	Dincer I	179	5.961
2	Demirbas A	84	2.797
3	Eroglu I	76	2.531
4	Ozturk M	71	2.364
5	Saka C	56	1.865
6	Devrim Y	41	1.365
7	Ilbas M	40	1.332
8	Sahiner N	40	1.332
9	Sen F	40	1.332
10	Hepbasli A	38	1.265

3.2.4. Analysis of co-authorship network and keywords in "hydrogen" topic publications

Changing in time co-authorship network of countries have been demonstrated in Figure 10. Per each document, up to maximum 25 countries were allowed. Minimum publication was set to 5. Colloboration of resulted 45 country was visualized. Node size indicates the publication count, link thickness indicates common publication count, colours indicate the time from past to

today as blue to yellow. According to results, 8 clusters have been emerged. According to document number, top 5 country is listed as Turkey, Türkiye, Canada, USA and Iran. Moreover, colloboration between Turkey and Canada and also Turkey and USA take attention with thick links between them. Changing from "Turkey" to "Türkiye" was observed again in this results. Moreover, the most actual country records are "Turkiye" (avg. pub. year: 2023), Malaysia (avg. pub. year: 2022), Peoples R China (avg. pub. year: 2021), India (avg. pub. year: 2021), Poland (avg. pub. year: 2021), Taiwan (avg. pub. year: 2021), South Korea (avg. pub. year: 2021), Serbia (avg. pub. year: 2021) and etc.

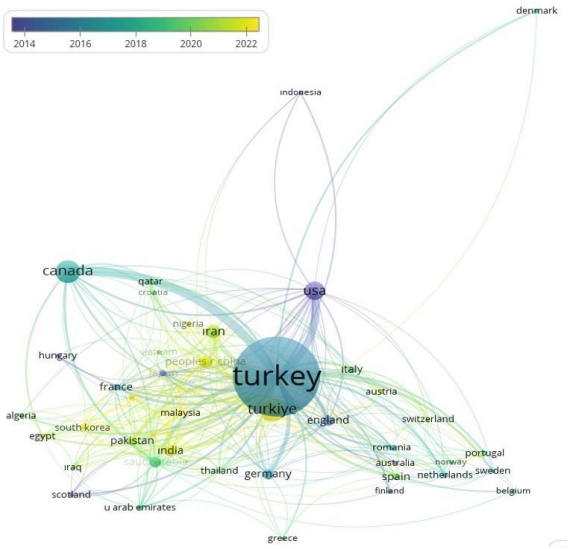

Figure 10. Co-authorship network of countries in time, for "hydrogen" topic

Figure 11 indicates the co-occurrance of keywords in the studies. 57 keywords have been obtained from 6202 record with setting the minimum occurrence as 25. Occurrence number is showed with node size. 5 different colour indicates the 5 groups. The top 10 most observed keywords are, "hydrogen" in 529 times, "hydrogen production" in 261 times, "exergy" in 184 times, "energy" in 169 times, "biomass" in 124 times, "hydrogen storage" in 122 times, "efficiency" in 117 times, "fuel cell" in 112 times, "solar energy" in 99 times and "catalyst" in 95 times. Use of keywords in time is depicted in Figure 12. Same indications are valid but the difference is colour since the changing colour from blue to yellow indicates the time from past to today. The most actual keywords in "hydrogen" topic can be listed as "methanolysis" (avg. pub. year: 2020.68), "multigeneration" (avg. pub. year: 2020.65), "ammonia" (avg. pub. year: 2020.40), "thermodynamic analysis" (avg. pub. year: 2019.88), "graphene" (avg. pub. year: 2019.52), "solid oxide fuel cell" (avg. pub. year: 2019.35), "natural gas" (avg. pub. year: 2019.33), "sustainability" (avg. pub. year: 2019.23), "optimization" (avg. pub. year: 2019.08). Results emphasized the importance of interdisciplinary interaction [126]. Graphene exists in both of two results as mentioned above. "Graphene" is versatile material that is used in a lot of diversified fields [127]. The grafen production facility with serial production capacity was announced in 2021 [128]. In addition to this, when the subject is hydrogen, despite the carried out efforts, there is a need for further acceleration. It was reported that Turkish Patent and Trademark Office has 131 patent related hydrogen (until 2021). Moreover, from 1985 to 2021, 982 master's and doctoral degrees completed [129]. In addition to these, there are some developments regarding hydrogen. TCG Pirireis (military submarine) was announced with its hydrogen and PEMFC used propulsion system and "AYN GREEN" ship that will

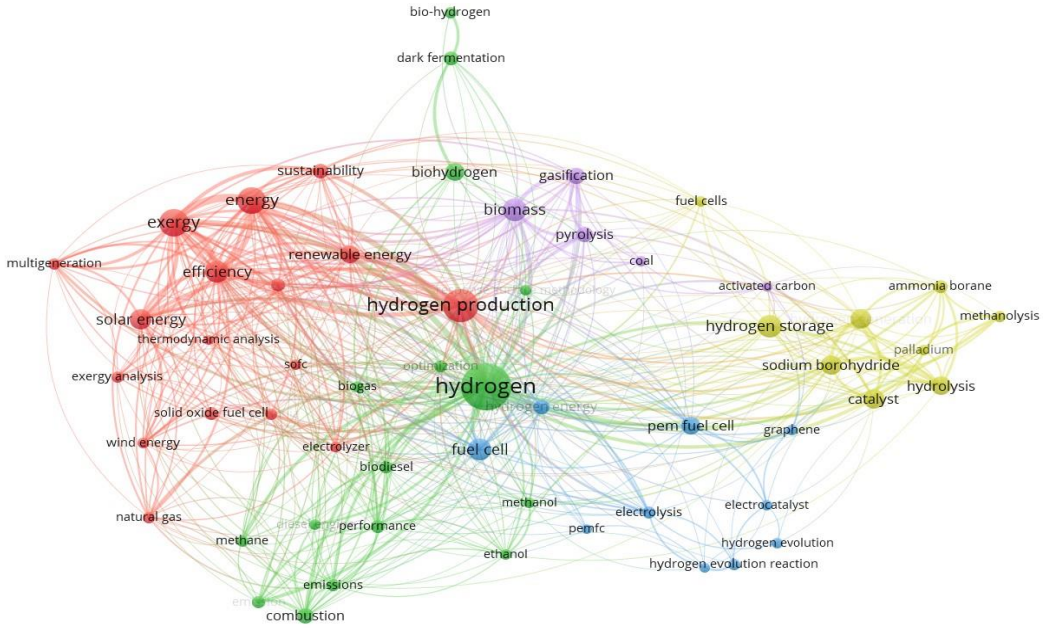

Figure 11. The most used keywords in "hydrogen" topic publications

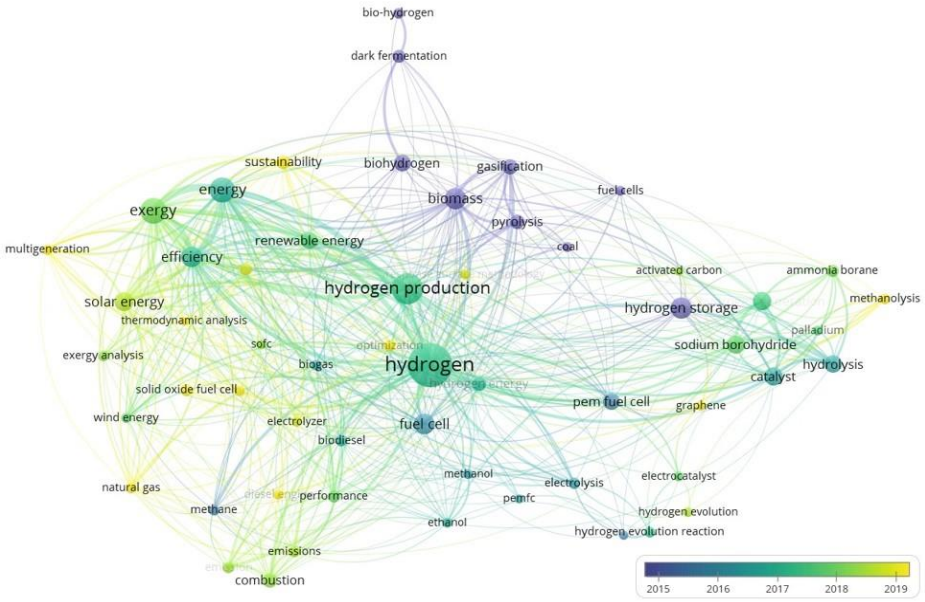

Figure 12. The most used keywords for "hydrogen" topic publications in time

work with green hydrogen will be completed in 2025 [130]. Besides, "Natural gas" and "hydrogen production" takes attention with recent investments in Türkiye. With the cooperation of Republic of Türkiye Ministry of Energy and Natural Sources, Energy Market Regulatory Authority, Yildiz Technical University and GAZBİR-GAZMER, efforts to mix hydrogen into the natural gas used in the grid have been initiated [131]. Mixing hydrogen into natural gas grid is important thanks to reduction of carbon emissions and storage of produced hydrogen [132]. In addition to increasing the capacity of evisting natural gas storage facilities, work is underway for the construction of new facilities and study for the third Floating LNG Storage and Regasification Unit System is ongoing [133]. Moreover, Türkiye boosted its petroleum and natural gas searchings and recently announced one of the largest natural gas source discovery in the Black Sea [134]. Black Sea is also important with its capacity of H_2S, that can be electrolysed and hydrogen can be separated to feed natural gas grid [135].

4. CONCLUSION

To expose Türkiye's academic contribution on energy, fuels and hydrogen topics, bibliometric analysis was carried out on two step, for Fuels&Energy category and for also hydrogen topic. Results have been mentioned below:

- The earliest publications of the Türkiye's academy under energy & fuels category date back to 1972. This date is 1989 for hydrogen topic. The publication count is increasing for both of the fields with raising importance.
- International Journal of Hydrogen Energy is the dominant journal that published studies in these areas. Despite the new colloborations between the other countries, USA and Canada are the most efficient countries in colloborations. Moreover, whereas Ayhan Demirbas and Istanbul Technical University is the most productive author and most productive institution in Energy&Fuels category, Ibrahim Dincer and Yildiz Technical University is the most productive author and most productive institution in hydrogen topic publications.
- Whereas the most used keywords in Energy& Fuels category can be listed as "renewable energy, exergy, hydrogen, biomass, solar energy, optimization, biodiesel, pyrolysis" and etc., new trends in keywords can be listed as "machine learning, supercapacitor, nanoparticles, electric vehicle, graphene".
- The most used keywords for "hydrogen" topic publications are "hydrogen production, exergy, biomass, hydrogen storage, efficiency, fuel cell, solar energy, catalyst". In addition to this, tendency in hydrogen studies turns into "methanolysis, multigeneration, ammonia, thermodynamic analysis, graphene, solid oxide fuel cell" and others.
- Although there is a positive correlation between some prominent and current academic topics such as "natural gas", "electric vehicles", "hydrogen production", "machine learning", "supercapacitor", "solar energy", "graphene" and current industrial investments, it is thought that more industrial investments are needed in other prominent academic topics such as "solid oxide fuel cell", methanolysis", "catalyst" and etc. On the contrary, it is also observed that there is a need for more academic studies on nuclear energy and nuclear fuels compared to the actual nuclear energy investments in Türkiye.

In essence, this bibliometric analysis not only encapsulates the historical evolution and current state of Türkiye's academic endeavors in energy research but also serves as a guiding beacon for future endeavors. As Türkiye navigates the complex terrain of energy transitions, the insights gleaned from this study provide a foundation upon which the nation can build a sustainable and innovative energy future.

5. NOMENCLATURE

Table 9. Nomenclature list

Abbreviation	Explanation	Abbreviation	Explanation
US	United States	SCI-E	Science Citation Index Expanded (SCI-Expanded)
NO_x	Nitrogen oxide	CPCI-S	Conference Proceedings Citation Index – Science
CO_2	Carbon dioxide	BKCI-S	Book Citation Index – Science
EU	European Union	ESCI	Emerging Sources Citation Index
FCEV	Fuel cell electrical vehicle	SSCI	Social Sciences Citation Index
MW	MegaWatt	BKCI-SSH	Book Citation Index – Social Sciences & Humanities
TJ	Terajoule	CPCI-SSH	Conference Proceedings Citation Index – Social Science & Humanities
H_2S	Hydrogen sulfide	Q	Quartile
$NaBH_4$	Sodium borohydride	H_2	Hydrogen
WOS	Web of Science		

DECLARATION OF ETHICAL STANDARDS

The authors of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

AUTHORS' CONTRIBUTIONS

Cenk KAYA: Literature research, methodology, analysis.

Veysi BAŞHAN: Methodology, analysis.

CONFLICT OF INTEREST

There is no conflict of interest in this study.

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