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LIQUEFIED NATURAL GAS TRADE: SCIENTIFIC MAPPING

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ABSTRACT

Energy has been an important part of the world agenda in recent years, both economically and politically. In the 21st century, with the growing awareness of climate change and the role of fossil fuels on the greenhouse effect, the world has been searching for cleaner energy sources; in this context, liquefied natural gas (LNG) stands out as an important alternative. Many countries want to solve their energy problems and explore sustainable ways of foreign trade. Declining global oil reserves and high oil prices increase the global demand for LNG with its advantages such as cost, ease of transport and sustainability.

This study conducts a bibliometric analysis of the foreign trade of LNG, highlighting the significance of the subject. The bibliometric analysis outlines the academic perspective on LNG imports and exports, providing a valuable framework for researchers and policymakers interested in this area. The objective of this study is to identify general trends within the sector and to facilitate decision-making processes. On May 31, 2024, a search was performed in the Web of Science (WoS) database using three different keywords: “Liquefied natural gas” (topic) and either “import” or “export” (topic). This search yielded a total of 273 publications, with no date restrictions applied. The analysis of these publications examines trends across various categories, including authors, sources, countries, and keywords. This bibliometric analysis enhances our understanding of the dynamics of LNG trade and identifies future research directions by creating a scientific map of this research area. The analysis reveals that

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the significance and interest in the case continue to grow, as evidenced by an increase in publications on LNG imports and exports from 1994 to 2024.

Keywords: Liquefied natural gas, import, export, bibliometric analysis

SIVILAŞTIRILMIŞ DOĞAL GAZ TİCARETİ: BİLİMSEL HARİTALAMA

ÖZ

Enerji, son yıllarda hem ekonomik hem de politik olarak dünya gündeminin önemli bir parçası olmuştur. 21. yüzyılda, iklim değişikliği ve fosil yakıtların sera etkisi üzerindeki rolü konusunda artan farkındalıkla birlikte, dünya daha temiz enerji kaynakları arayışına girmiştir; bu bağlamda, sıvılaştırılmış doğal gaz (liquefied natural gas-LNG) önemli bir alternatif olarak öne çıkmaktadır. Birçok ülke enerji sorunlarını çözmek ve dış ticaretin sürdürülebilir yollarını keşfetmek istemektedir. Azalan küresel petrol rezervleri ve yüksek petrol fiyatları, maliyet, taşıma kolaylığı ve sürdürülebilirlik gibi avantajları nedeniyle LNG'ye olan küresel talebi artırmaktadır.

Bu çalışma, LNG dış ticaretinin bibliyometrik analizini yaparak konunun önemine dikkat çekmektedir. Bibliyometrik analiz, LNG ithalat ve ihracatına ilişkin akademik bakış açısını ana hatlarıyla ortaya koyarak, bu alanla ilgilenen araştırmacılar ve politika yapıcılar için değerli bir çerçeve sunmaktadır. Bu çalışmanın amacı, sektördeki genel eğilimleri belirlemek ve karar alma süreçlerini kolaylaştırmaktır. 31 Mayıs 2024'te, Web of Science (WoS) veri tabanında üç farklı anahtar kelime kullanılarak bir arama yapılmıştır: "Sıvılaştırılmış doğal gaz" (konu) ve "ithalat" veya "ihracat" (konu). Bu aramada, tarih kısıtlaması uygulanmayan toplam 273 yayın bulundu. Bu yayınların analizi, yazarlar, kaynaklar, ülkeler ve anahtar kelimeler dahil olmak üzere çeşitli kategorilerdeki eğilimleri incelemektedir. Bu bibliyometrik analiz, LNG ticaretinin dinamiklerine ilişkin anlayışımızı geliştirmekte ve bu araştırma alanının bilimsel bir haritasını oluşturarak gelecekteki araştırma yönlerini belirlemektedir. Yapılan analizler, LNG ithalat ve ihracatına ilişkin yayınların 1994-2024 yılları arasında artış göstermesinin de gösterdiği üzere, konuya olan ilginin ve önemin artarak devam ettiğini ortaya koymaktadır.

Anahtar Kelimeler: Sıvılaştırılmış doğal gaz, ithalat, ihracat, bibliyometrik analiz

1. INTRODUCTION

Energy accessibility and climate resilience are increasingly critical factors in the global energy landscape. Two key elements shaping this issue are accessibility and environmental sustainability. Addressing these challenges requires substantial technological and economic investments, yet they are pivotal in shaping current energy supply trends. These factors should not be viewed in isolation, as developing regions must meet their energy demands while minimizing environmental impact. From this perspective, the role of natural gas is vital today and will become even more significant in the coming years. As a cleaner alternative to other hydrocarbons, natural gas plays a crucial role in the transition to a sustainable energy future. The liquefaction of natural gas enhances both efficiency and reliability in its delivery from producer to consumer. For these reasons, LNG has garnered significant attention. Over the past two decades, LNG trade volumes have more than tripled, now accounting for nearly 50% of global natural gas trade (Filimonova et al., 2022; Nikhalat-Jahromi et al., 2017; Peng et al., 2021;).

LNG is natural gas that has been cooled to below -160°C and transported in liquid form using specially designed vessels. One of its primary advantages over pipeline gas is its flexibility; LNG can be imported from multiple supplying countries, thereby enhancing supply security. As global demand for LNG continues to rise, technological advancements are expected to enhance the cost-effectiveness of the LNG supply chain, though these advancements may not be groundbreaking. Moreover, LNG's role in energy supply extends beyond simply meeting resource availability or responding to exceptional circumstances, such as conflicts, that affect supply-demand balance. Political factors also play a significant role in shaping energy supply options. The growing recognition that natural gas, a fossil fuel, has a lower environmental impact compared to oil and coal is gaining global acceptance (Al-Haidous et al., 2022; Coyle et al., 2003; Gianone and Imre, 2022; Nikhalat-Jahromi et al., 2017; Passos et al., 2024; Yafimava, 2023;).

Given LNG's potential as a sustainable energy source, its global acceptance is becoming increasingly inevitable. In 2022, coal-fired power plants were responsible for 73% of global greenhouse gas emissions related to electricity and heat production. Transitioning from coal to natural gas offers a significant opportunity for economically viable emission reductions in the short and medium term (Zakeri et al., 2022). Despite the growing production of wind and solar energy, the share of renewable energy in the global energy and electricity mix has only marginally increased. The reduction rate of the carbon factor remains

insufficient to meet the $<2^{\circ}\text{C}$ global warming target, leading to continued carbon emission growth in 2023. Notably, natural gas, as an energy source, is meeting the rising global demand for energy. Among G20 countries, significant growth is observed in the United States (electricity production) and Australia (LNG production) by 2023. Conversely, decreases have been recorded in Europe, Japan, South Korea, and Canada. While non-OECD countries are experiencing a robust recovery, China, Russia, and India have shown significant growth, whereas Argentina and Brazil have seen declines. In 2023, the global LNG market entered a crucial phase marked by modest growth and dynamic shifts due to geopolitical and economic factors. The number of importing markets has increased with four new entrants—Germany, Hong Kong, the Philippines, and Vietnam—while the number of exporting countries remains stable, with only modest increases in liquefaction capacity.¹ The market grew by approximately 2%, down from a nearly 6% growth rate in 2022, reaching 401 million tons. This growth was driven by Asia and the Americas, while demand in Europe remained stable (Enerdata, 2024; GIIGNL, 2024). Gao et al. (2024), in their study on the evolution of hub economies in LNG trade, highlighted Japan and South Korea as the primary economies characterized by high import power and nodal degree. China, India, and Spain are noted as later entrants, while Qatar, Nigeria, Algeria, The United States (US), Russia, and Australia are identified as the leading exporters. In terms of supply, Qatar has steadily increased its production capacity since the late 1990s, becoming the leading exporter, although Australia overtook Qatar to become the largest exporter in 2020. In addition, the contribution of shale gas in the US export race should not be overlooked.

It seems that the US will continue to maintain its remarkable position in LNG exports. Hartley and Medlock (2023) reveal that US LNG export projects are doing more spot trading and that the advantage of “Market Liquidity, Low Investment Costs, Portfolio Traders and Transportation Costs” facilitates this situation. Here, the term 'portfolio traders' is not used much and it is an interesting title for this topic, which makes us feel the need for an extra explanation. Hartley and Medlock (2023) state that some LNG suppliers constitute important

¹ LNG importing countries can be listed as follows: Asia-China, Japan, South Korea, India, Taiwan, Thailand, Pakistan, Bangladesh, Singapore, Indonesia, Malaysia, Philippines, Hong Kong, Vietnam; Europe-France, Spain, Netherlands, United Kingdom, Italy, Turkey, Belgium, Germany, Poland, Portugal, Lithuania, Greece; Americas- Chile, Argentina, Puerto Rico, Dominican Republic, Jamaica, Colombia, Brazil, Mexico, El Salvador, Panama, United States, Canada; Middle East & Africa- Kuwait, United Arab Emirates, Jordan, Egypt. LNG exporting countries are as follows: The United States, Australia, Qatar, Russia, Malaysia, Egypt, Algeria, Indonesia, Oman, Canada, Nigeria, Papua New Guinea, Norway, Angola, United Arab Emirates (UAE), Brunei, Peru, Iran, Trinidad & Tobago (GIIGNL, 2024).

customers for US LNG exports and define themselves as “portfolio traders” due to their long-term contractual agreements. Portfolio traders supplying LNG emerge as important actors in this reciprocal trade. The study reveals that US LNG export projects have an opportunity and stronger incentives to produce without reducing output, to remain flexible about where and when to ship cargoes and to take advantage of arbitrage opportunities provided by spot price movements that are not perfectly correlated. Furthermore, thanks to new liquefaction facilities and Europe's shift away from Russian gas, the US is increasing its LNG exports and strengthening its position as the world's largest LNG exporter. In 2022, LNG exports increased by 9% due to the loss of Russian gas in the European market and the commissioning of new facilities. In 2024, the US is expected to become the world's largest LNG exporter with 113 billion cubic meters (IEA, 2019).

On the other hand, while sustainable energy security and energy supply stand out as key factors driving the rise of LNG, uncertainties remain regarding the potential adverse impacts of increased natural gas production in the United States on greenhouse gas emissions. Gilbert and Sovacool (2017) found that the climate impacts of U.S. LNG exports to Asia, particularly to China, Japan, India, and South Korea, could vary significantly. In contrast, Roman-White et al. (2019) offered a more moderate interpretation of these effects, demonstrating that U.S. LNG exports, when used for electricity generation in European and Asian markets, would not increase emissions from a life-cycle perspective compared to regional coal extraction and electricity generation. Similarly, Abrahams et al. (2015), through their analyses, examined the impacts of increasing U.S. LNG exports on global greenhouse gas (GHG) emissions and demonstrated that transportation distance is not a significant factor in terms of greenhouse gases. Moreover, they highlighted that LNG exports have the potential to reduce life-cycle greenhouse gas emissions originating from electricity generation and industrial heating.

It is also observed that the United States has increased its export capacity, encompassing regions in South and North America as well as certain parts of Europe, thereby gaining influence in trade relations. In this context, it is noted that the intensity of production emissions and the volume of LNG trade among these economies significantly affect the redistribution of LNG-related embodied methane (CH₄) emissions. Preventing adverse climate outcomes from this redistribution depends on the proper implementation of targeted energy and climate policies initiated by core economies, which have the potential to significantly reduce CH₄ emissions (Gao et al., 2024).

Kasumu et al. (2018) evaluated the life-cycle greenhouse gas emissions of LNG trade for electricity generation at the country level and demonstrated that natural gas imports provide environmental benefits for Canada. Moreover, LNG plays a critical role in decarbonizing maritime transportation. Its high energy density, low CO₂ content, and near-negligible emissions of sulfur, nitrogen oxides, and particulates make LNG the optimal alternative fuel for complying with current and future maritime regulations and reducing greenhouse gas emissions (GIIGNL, 2024; Iannaccone et al., 2020; Kumar et al., 2011). As an expected outcome of these circumstances, the anticipated 50% increase in renewable capacity by 2023 underscores the continuing need for flexible gas-fired generation assets. The demand for natural gas rises as efforts toward a low-carbon economy intensify; however, whether natural gas and renewable energy sources can fully substitute for each other remains uncertain. Renewable energy policies tend to reduce LNG trade volumes, suggesting a partial substitution relationship between renewable energy and natural gas (Najm and Matsumoto, 2020). While renewable energy can replace natural gas in electricity generation, it does not serve as a perfect substitute due to differences in scale. The rise of energy transition policies has reduced LNG trade in OECD economies. In this context, where less developed economies lag behind in the energy transition, the findings of Najm and Matsumoto (2020) suggest that policymakers should consider the nature of economic structures among trading partners when formulating energy regulations and carbon reduction targets. However, in the current global context, it is also essential to acknowledge that extraordinary situations, such as wars, can accelerate this process. In this context, the observed upward trend in Europe's LNG trade, driven by the impact of the Russia-Ukraine war, suggests that LNG will maintain its advantageous position in this substitution process, at least in the short term (Akar and Ekiz, 2024).

When examining the development of the LNG industry over the past thirty years, it is evident that large gas fields, such as those in Japan and South Korea, which are inaccessible by pipelines, have been successfully integrated into the market. Markets previously dominated by pipeline gas suppliers have been diversified, creating a competitive environment and enhancing energy supply security for many consumer countries. This demonstrates the critical role of LNG supply chains. As a result, geopolitical and political constraints on global gas supply have also been reduced (Mokhatab et al., 2013).

Despite significant fluctuations in the LNG sector in 2022, the market entered a recovery phase in 2023. Global net LNG imports rose by 2.1% compared to 2022, reaching

401 million tons. However, ongoing drought conditions in the Panama Canal continue to disrupt canal operations and affect global shipping routes. Furthermore, attacks in the Red Sea have added further complications to global LNG logistics, resulting in a sharp decline in the number of LNG carriers passing through the Suez Canal in early 2024 compared to the same period in 2023 (Enerdata, 2024; IEA, 2019). Nevertheless, the continued expansion of LNG trade has made global LNG import competition more complex and difficult to analyze. While research in this area remains limited, Zhu et al. (2023) explored developments from 2000 to 2020 by constructing a global LNG import competition network using complex network analysis methods. Their findings indicate that global LNG import competition is widespread and intense, with competition unevenly distributed across Asia, Europe, and between these two regions.

As competition increasingly shifts towards Asia, Japan has lost its leading position despite facing intense competition. Meanwhile, China has become a more significant player, intensifying competition with other importers. The European Union has also increased and diversified its LNG imports by reducing reliance on Russian gas, leading to a 62% increase in the LNG trade balance compared to 2022. In Europe, the natural gas supply deficit is expected to grow due to declining reserves in the Netherlands and the North Sea. This gap is expected to be filled by both LNG and pipeline gas imports. Russia continues to maintain a strong position among the leading countries in the global LNG trade balance and significant developments in the gas market. However, net LNG imports in Asia have decreased, primarily due to reduced imports from China and India. Australia continues to expand its LNG exports. China is on track to become the world's largest importer of LNG and pipeline gas by 2024. Nonetheless, it is predicted that domestic production will struggle to meet the growing demand. LNG imports from other developing Asian countries are also rising sharply (ACER, 2024; Enerdata, 2024).

The current bibliometric study on LNG import and export analysis aims to map the scope and development of literature in this field. It begins with an introductory section that discusses the existing literature on LNG and its fundamental concepts. The study then evaluates the current position of the leading countries in LNG trade, considering the environmental impacts of LNG exports and imports from a broad perspective. Following the introduction, the methodology section outlines the bibliometric analysis methods and findings. The limitations of the study are discussed in a dedicated section. Finally, the discussion and conclusion section provides a general evaluation of the findings based on the

literature and offers policy recommendations. Overall, this study aims to offer a comprehensive overview of the literature on LNG imports and exports. It seeks to provide valuable insights into current trends, key researchers, and the most influential publications for those working in this field and anyone interested in the subject.

Bibliometric analysis plays a significant role across various research areas by uncovering the descriptive, social, and intellectual structures within the data. This type of analysis, which can give a general view of an area in the form of scientific mapping, is valuable in guiding researchers and providing ideas to policy makers. The current study aims to contribute to the literature by identifying the main trends in LNG trade through bibliometric analysis and supporting future planning. By doing so, it is expected to gain a better understanding of the dynamics of LNG trade, thus making an important contribution to identifying future research directions. Therefore, it is crucial to emphasize the encouragement of this type of research (Atabay and Güzeller, 2021).

2. METHOD

2.1. Query

The WoS database was searched on 31 May 2024 using 3 different keywords. The query used in the search is; ('liquefied natural gas (topic)' and 'import' or 'export' (topic)). The result of the search without any time interval was 273 publications. In terms of the number of publications, there are many different applications in literature. For example, Lamhour et al. (2023) performed their analyses on 114 publications. In the second example; Castagna et al. (2024) performed a bibliometric analysis on 140 publications. In the third example, Ejaz et al. (2022) analysed 1917 publications.

2.2. Analysis Tool

The data obtained using the WoS database were analysed using the Bibliometrix library of the R programming language. This library, written by Aria and Cuccurullo (2017), provides tools for quantitative research. Orăştean and Mărginean (2023), Forliano et al. (2021) and El Bouazzaoui et al. (2024) also used the Bibliometrix library of the R programming language in their academic studies.

2.3. Data Quality

The WoS database can be used for bibliometric analysis of scientific publications. Hamidi et al. (2024), Eduljee et al. (2022) and Di Cosmo et al. (2021) used data from the WoS database in their bibliometric studies. The structure of the WoS database lends itself to bibliometric analysis of scientific studies.

2.4. Similar Studies and Why Bibliometric Analysis?

A search of the WoS database using the keywords LNG and bibliometric yields 7 publications using bibliometric analysis. These LNG-focused studies include, in brief: (1) Mohiuddin et al. (2024) global ship emissions, (2) Huffman et al. (2024) comparative analysis of LNG and 'liquefied petroleum gas' transport risks, (3) Borri et al. (2020) recent trends in energy storage, (4) Xu et al. (2024) determining the technological trajectory of natural gas transport, (5) Tadros et al. (2023) examining green shipping regulations, technologies and future trends, (6) Ampah et al. (2021) evaluating alternative clean marine fuels, and (7) Li et al. (2020) mapping the scientific background of Sam Mannan, who worked on LNG. As can be seen from these examples, LNG literature has been approached from different angles using bibliometric analysis, which provides scientific mapping and shows trends in the field. The primary advantage of this method is its analysis of existing literature, illustrating the connections between studies on LNG trade and enriching the academic conversation in this area.

3. ANALYSIS and FINDINGS

3.1. Descriptive Statistics

Pant et al. (2024) present the descriptive statistics of the publications obtained in their bibliometric study. In this context, Table 1 shows the descriptive statistics of the publications obtained as a result of the query. It shows that there are 273 publications on LNG imports and exports for the period 1994-2024. These publications are distributed over 178 sources and the annual growth rate of publications is 7.6 percent. There are 753 authors in these publications and the number of 'single author papers' is 55. The authors used a total of 840 keywords in their studies. The rate of international co-authorship in publications is 22.34%.

Table 1. Descriptive statistics

Description Descriptive Statistics	Results	Description	Results
MAIN INFORMATION ABOUT DATA		AUTHORS COLLABORATION	
Timespan	1994:2024	Single-authored docs	62
Sources (Journals, Books, etc)	178	Co-Authors per Doc	3.02
Documents	273	International co-authorships %	22.34
Annual Growth Rate %	7.6	DOCUMENT TYPES	
Document Average Age	7.33	Article	205
Average citations per doc	15.61	article; book chapter	2
References	9504	article; early access	2
DOCUMENT CONTENTS		article; proceedings paper	3
Keywords Plus (ID)	454	Editorial Material	3
Author's Keywords (DE)	840	Proceedings Paper	45
AUTHORS		review	13
Authors	753		
Authors of single-authored docs	55		

Source: Created by the author.

3.2. Three-Field Analysis

Three-field analysis can be used in bibliometric studies (Ayan et al., 2022). This analysis basically shows the degree of relationship between three main elements (Atabay and Güzeller, 2021: 600). Figure 1 shows a three-field analysis in terms of the source of the publication, the author of the publication and the keyword used in the publication.

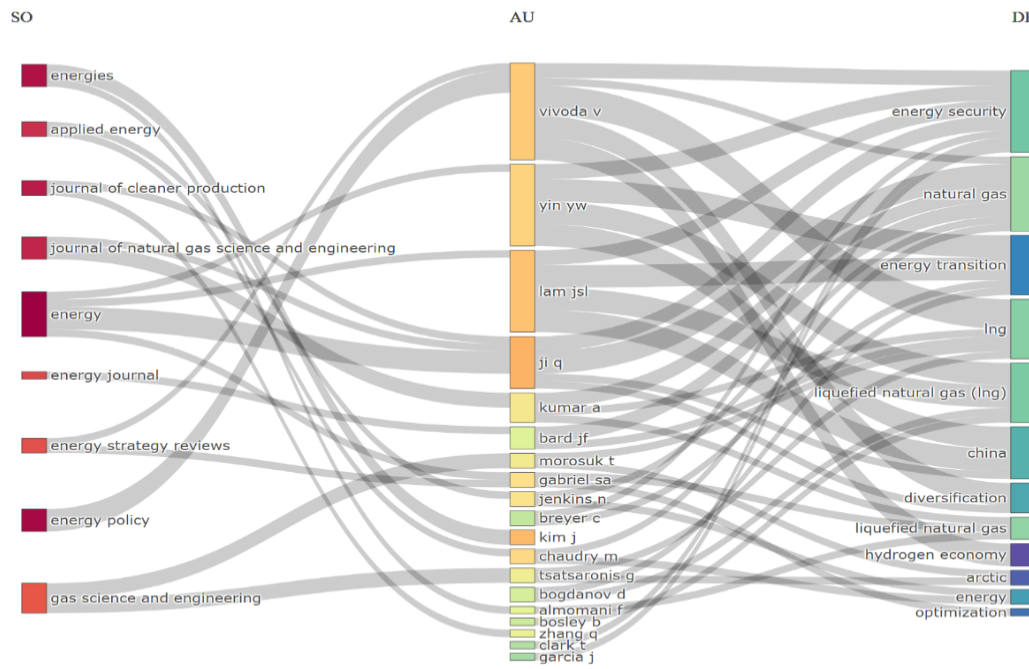


Figure 1-fields diagram

Figure 1 shows a graph with three fields, and in the analysis of this graph the 'number of articles' value for all three fields was taken as 20 (default value). Looking at the analysis carried out, it can be seen that energy journals are the most favored in the studies. When looking at the topic in terms of clean energy, it is important that a journal that focuses on clean energy, such as 'journal of cleaner energy', is included in the list. Vivoda V. stands out as one of the most influential authors in the field and this author is associated with both 'energy strategy reviews' and 'energy policy' journals. In addition, the author uses the keywords 'energy security', 'natural gas', 'LNG', 'diversification' and 'hydrogen economy' in his publications. Apart from the author mentioned above, 'Lam JSL', 'Yin YW' and 'Ji Q' are among the important authors in terms of 'liquefied natural gas' import and export literature.

The influential authors in this field have mostly used 'energy security', 'natural gas', 'energy transition', 'lng' and 'liquefied natural gas' and 'china' as keywords.

3.3. Source and Citation Analysis

Table 2 shows the sources with the highest number of publications on the subject, the sources with the highest number of local citations (only publications obtained as a result of the search are evaluated) and the local impact of the sources. These shows which publishers attract more attention. Here, the journals 'energy' and 'energy policy' have the highest number of publications. Again, the journal 'energy policy' has the highest citation value in terms of local sources. With an H-index of 12%, the journal 'energy' seems to have the highest impact. Regarding the first 2 ranks, it can be seen that the journals 'energy' and 'energy policy' are in the first 2 ranks in 3 different categories. These journals focus on studies related to the subject (LNG)

Table 2 Popular sources

Most Relevant Sources		Most Local Cited Sources		Sources' Local Impact			
Sources	Articles	Sources	Articles	Element	H_Index	TR	PY_Start
Energy	16	Energy Policy	414	Energy	12	868	2003
Energy Policy	16	Energy	296	Energy Policy	11	548	2000
Energies	11	EnergyEcon	204	Journal Of Natural Gas Science and Engineering	6	116	2014
Journal of Cleaner Production	7	Appl Energy	173	Applied Energy	5	471	2011
Journal Of Natural Gas Science and Engineering	6	Int J Hydrogen Energy	123	Energies	5	145	2012
Applied Energy	5	Renew Sust Energ Rev	109	Journal of Cleaner Production	5	124	2018
Journal Of World Energy Law & Business	5	Energy J	85	Eurasian Geography and Economics	4	53	2007

Eurasian Geography and Economics	4	J Clean Prod	83	Energy Strategy Re-views	3	135	2012
Energy Journal	3	Energy Convers Management	61	Energy Economics	2	46	2019
Energy Strategy Reviews	3	J Nat Gas Sci Eng	61	Energy Journal	2	11	2017

Source: Created by the author.

3.4. Most Globally Cited Documents

Table 3 lists the most cited publications, and these citations also include (global) citations outside the publications that are the subject of the research. This section provides descriptive information on the 10 publications that have received the most attention in literature. In this way it is possible to see the leading publications that have gained a place in literature. In the research; an environmentally friendly fuel for a sustainable environment, renewable energy supply, energy transport routes, LNG infrastructure for China, energy in Malaysia, energy demand forecasting, natural gas demand, world gas model, gas supply security indicators and the commercial potential of Barents Sea energy resources.

Table 3. Most globally cited documents

Author	Paper	Total Citations	TR per Year	Normalized TR
Kumar et al. (2011)	Appl Energy	376	26.86	4.25
Bogdanov and Breyer (2016)	Energy Convers Manage	247	27.44	10.64
Thomas and Dawe (2003)	Energy	238	10.82	1.95
Lin et al . (2010)	Energy	169	11.27	4.02
Sulaiman et al. (2011)	Biomass Bioenergy	167	11.93	1.89
Geem and Roper (2009)	Energy Politics	149	9.31	4.97
Shaikh et al. (2017)	Energy	120	15.00	9.62
Egging et al. (2010)	Energy	94	6.27	2.24
Cabal (2010)	Energy Politics	92	6.13	2.19
Dore (1995)	Arctic	78	2.60	1.00

Source: Created by the author.

3.5. Trending Topics of Words

The Trend Topic analysis shows how the literature has changed over the years, using all publications returned as a result of the query. This analysis can also be performed as a title, abstract or keyword plus analysis. The purpose of this analysis is to ensure that the correct keywords, titles or abstracts are used in the studies. In this way, it is possible for authors to adapt to the literature in the relevant field in a shorter period of time.

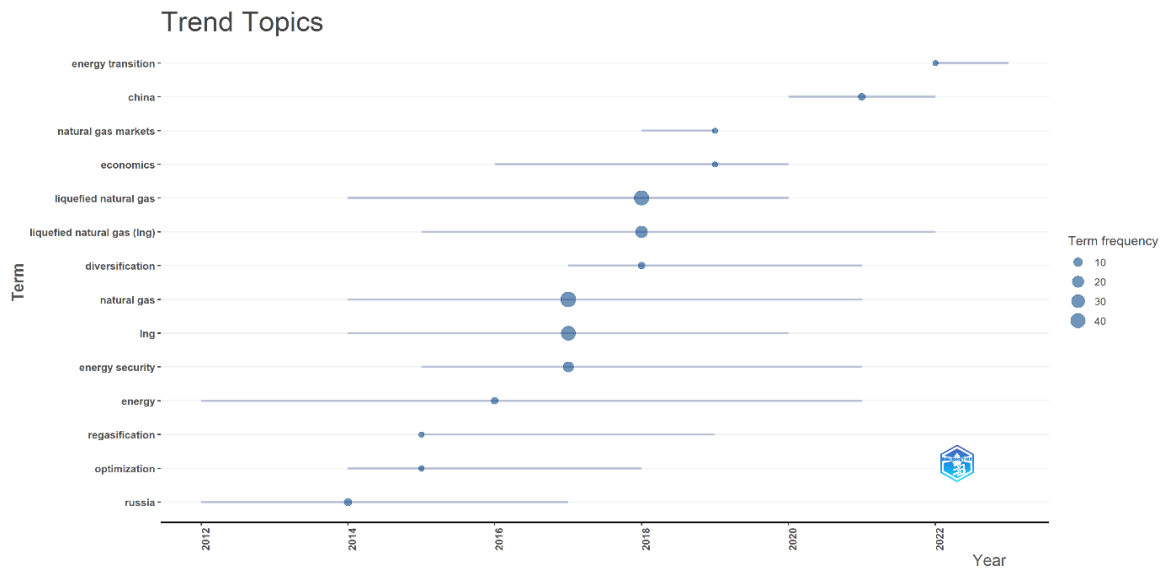


Figure 2. Words that are trending topics by Year

Figure 2 shows the trend of topic words according to author keywords of publications over the years. In the analysis, the value of 'minimum word frequency' was 5 and the value of 'number of words per year' was 3 (default values). The analysis covers publications received between 1994 and 2024. There are words in the studies that have remained popular for many years, such as 'liquefied natural gas', 'lng' and 'natural gas'. There are also terms that have become more prominent recently, such as 'energy transition'. For a more effective research process, it may be useful for researchers to monitor the trending words in recent years for their future studies and to design their studies accordingly.

3.6. Co-occurrence Network

The keywords used in publications can be the basis of academic studies using bibliometric methods (Wang et al., 2024). Co-occurrence analysis shows the words used together in the studies and author keywords were used in this analysis. The keyword co-

occurrence analysis used 'Walktrap' as the clustering algorithm and 'association' as the normalisation method. The label size was set to 3 and the edge size to 5. The terms 'liquefied natural gas' and 'liquefied natural gas (LNG)' were considered synonymous in the analysis.

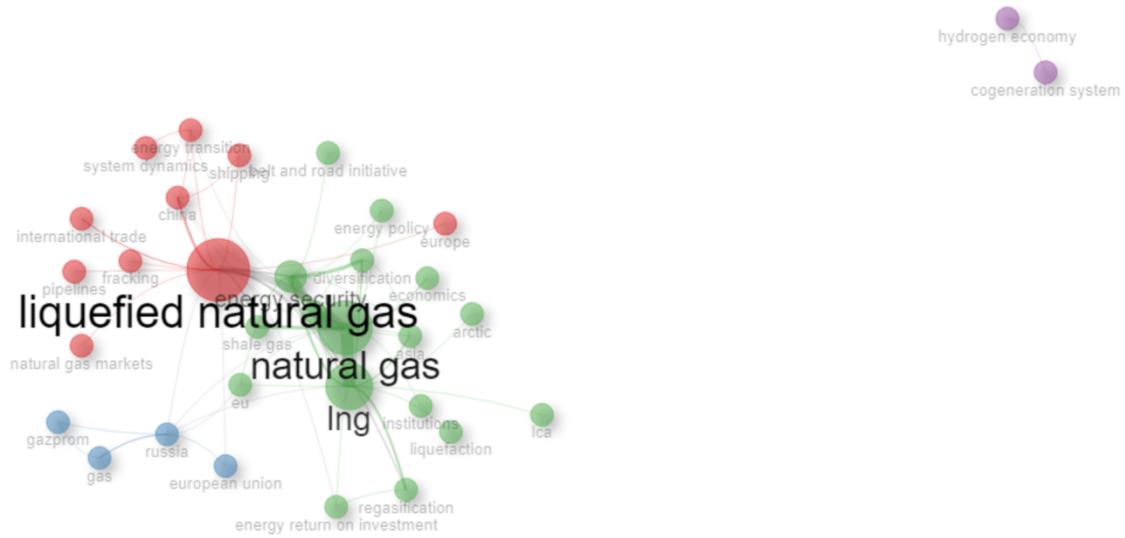


Figure 3. Co-occurrence network

There are 4 clusters in Figure 3 and the groups have 10, 4, 17 and 2 elements respectively. Within the groups, 'liquefied natural gas', 'natural gas' and 'LNG' are used more than the others. These leading terms are followed by terms such as European Union, Russia, China, energy transition and international trade. The third cluster is under the heading 'natural gas' and has the highest number of items.

3.7. Collaboration Network

Collaboration networks can display collaborations under different headings. These collaborations can be authors, countries or institutions. The 'Walktrap' clustering algorithm and the 'Association' normalisation method were used to generate Figure 4. As a result of the analysis using these methods, 10 clusters emerged.

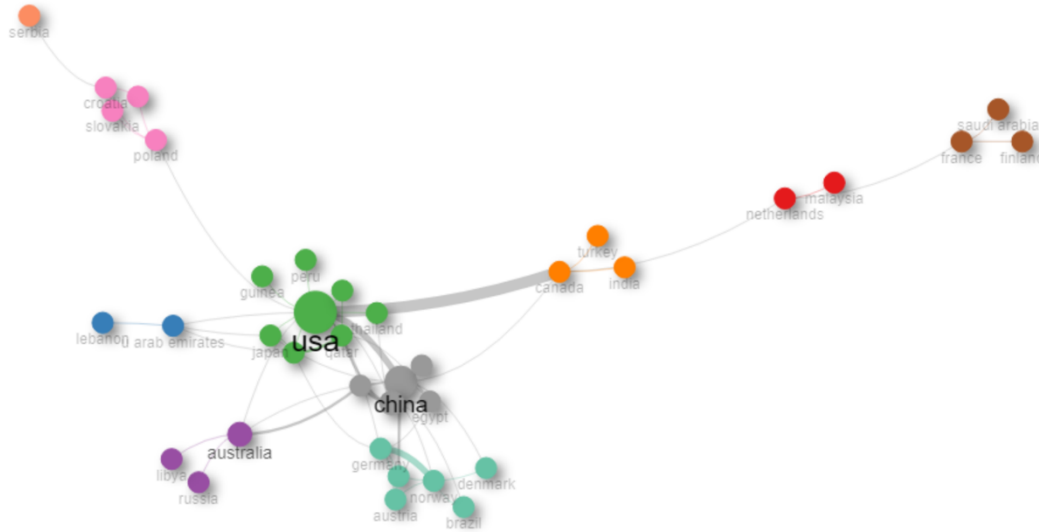


Figure 4. Collaboration Network -Country

Figure 4 shows the results of the collaboration network analysis by country. It can be seen that many countries cooperate in publications on LNG imports and exports. The size of the node is related to the number of publications and it can be seen that the US and China have more publications. These two countries are the most influential countries in the network. The lines between countries indicate the level of international collaboration. The higher the degree, the thicker the lines. In this context, there is significant collaboration between the USA - Canada and China-USA.

Table 4 presents the inter-institutional cooperation in the import and export studies related to LNG. In this collaborative effort, 14 different groups have been formed, and each group works together. An analysis of these groups by the number of members reveals that the largest groups consist of 4 members each. By examining the table, we can identify which institutions are engaged with the topic and are open to collaboration. While most of these institutions are universities, the list also includes financial support organizations such as the Qatar Foundation.

Table 4. Collaboration network-institutions

Node	Cluster	Betweenness	Closeness	Pagerank	Node	Cluster	Betweenness	Closeness	Pagerank
Qatar University	1	14	0.1	0.037	Indian Institute of Technology System (IIT System)	7	1	0.5	0.037
Hamad Bin Khalifa University-Qatar	1	0	0.067	0.028	Indian Institute of Technology (IIT) - Madras	7	0	0.333	0.025
National University of Singapore	1	0	0.063	0.016	University of Alberta	7	0	0.333	0.014
Qatar Foundation (QF)	1	0	0.067	0.028	University of Texas System	8	0	0.5	0.031
Chinese Academy of Sciences	2	0	0.25	0.033	University of Texas Austin	8	0	0.5	0.031
University Of Chinese Academy of Sciences, CAS	2	0	0.25	0.033	University of Calgary	8	0	0.5	0.014
Southwestern University of Finance and Economics - China	2	2	0.333	0.027	China University of Petroleum	9	0	1	0.026
University of Edinburgh	2	0	0.2	0.008	University Of International Business and Economics	9	0	1	0.026
Egyptian Knowledge Bank (EKB)	3	14	0.1	0.042	Russian Academy of Sciences	10	0	1	0.026
University of Cologne	3	0	0.067	0.018	Kola Science Center of The Russian Academy of Sciences	10	0	1	0.026
Arab Academy for Science, Technology, and Maritime Transport	3	0	0.063	0.011	University of London	11	0	1	0.026
Cairo University	3	0	0.067	0.026	Queen Mary University London	11	0	1	0.026
Rice University	4	0	0.333	0.02	China University of Geosciences	12	0	0.5	0.028
University of Western Australia	4	1	0.5	0.037	Ministry Of Natural Resources of The People's Republic of China	12	0	0.5	0.028
Curtin University	4	0	0.333	0.02	United States Department of Energy (DOE)	12	0	0.5	0.02
Cardiff University	5	1	0.5	0.037	University Of Queensland	13	0	1	0.026

Imperial College London	5	0	0.333	0.02	Australian National University	13	0	1	0.026
University Of Oxford	5	0	0.333	0.02	Technical University of Berlin	14	0	1	0.026
University Of Maryland College Park	6	0	1	0.026	Norwegian University of Science and Technology (NTNU)	14	0	1	0.026
University System of Maryland	6	0	1	0.026					

Source: Created by the author.

4. LIMITATIONS AND RECOMMENDATIONS

This study has some limitations and suggestions for future similar studies. The study used publications from the WoS database. Future studies could include databases such as Scopus. This study provides an overview of the literature on LNG imports and exports. The study aims to provide important information to those who will conduct research on the area. However, shortcomings such as insufficient use of keywords in the publications used in the analysis will prevent the results from being fully explanatory. In cases where such shortcomings can be overcome, bibliometrics is a good method of analysis. Because it lends itself to interdisciplinary work. It is suitable for providing a broad overview of the topics covered and can be applied in different disciplines.

5. DISCUSSION and CONCLUSION

In the context of modern geopolitical dynamics, international hydrocarbon trade is becoming increasingly complex. This complexity drives global trends that require the development of new solutions and adaptations to the changing external environment. Key factors contributing to the growth of the global gas market include the shift toward environmentally friendly energy sources, greater opportunities for LNG transportation compared to pipeline gas—which involves geopolitical risks—and the ability to meet gas supply demands during peak periods. The simplicity and efficiency of natural gas liquefaction technologies have played a significant role in advancing international gas trade. However, research shows that the main reasons for differences in natural gas consumption vary across countries. The key factors are production-import-export scales, consumption structure ratio, energy intensity, economic growth, demographic effects and the equilibrium effect. It should

be noted here that the scale effect of LNG increases the global trade volume of LNG by making a marginal contribution to total imports and exports (Chen et al., 2019; Vazhenina, 2020).

LNG is also an important energy option that offers the potential for savings in fuel consumption, which is beneficial for the environment. With lower emissions compared to other fossil fuels, natural gas is gaining significance and is recognized as a key resource for achieving a cleaner world. In this context, LNG is becoming an increasingly prominent fuel globally, as evidenced by its rising usage. LNG plays a crucial role in the global low-carbon transformation and has gained popularity, with a notable increase in LNG trade since 2015. As a result, LNG has assumed a leading role in the development of regional gas markets, emerging as a competitive commodity worldwide under the influence of globalization (Alzayed et al., 2022; Dubov et al., 2019; Filimonova et al., 2022; Hou et al., 2024; Hu et al., 2017; Jin et al., 2022).

Chen et al. (2016) conducted a study on LNG trade competition networks and the competitive dynamics in this sector from 2005 to 2014. They identified Qatar, Australia, Malaysia, Algeria, and Nigeria as among the top 10 most competitive countries in LNG exports, contributing to a highly competitive environment. Notably, Qatar has taken on a dominant role in the global LNG market, engaging in numerous competitive relationships. This dominance is attributed to the challenges posed by traditional energy sources, which are reaching their limits. Producers and consumers alike are grappling with issues related to pricing, costs, environmental concerns, and geopolitical factors. Additionally, rising demand paired with limited supply has brought "energy security" to the forefront, highlighting interconnected challenges. When considering these factors along with advancements in technology, it can be argued that Qatar's position as a market leader in LNG liquefaction capacity has driven a significant increase in LNG projects worldwide (Sakmar and Kendall, 2009).

However, several factors are expected to significantly impact LNG trade and its competitive dynamics in the future. These include the role of the U.S. in the global natural gas market, the entry of shale gas into international markets, and some European countries' preference to re-export their LNG due to economic challenges. The offer of LNG as an alternative option in international trade has emerged as a primary driver of growth in the global gas market. This has resulted in a situation where natural gas prices vary based on transportation costs worldwide. Approximately a decade ago, LNG accounted for only 30% of

total natural gas trade. Since then, LNG utilization has increased due to the planning and construction of numerous new projects. In a study by Du and Paltsev (2014), it was estimated that the volume of LNG trade would reach between 340 and 360 million tons in 2021, an increase from approximately 240 million tons in 2013. It is now evident that these forecasts have materialized. Over the past 50 years, LNG trade has grown at an average rate of 11%, rising from 2.6 million tons in 1971 to 372.3 million tons in 2021. By 2021, the cumulative number of LNG deliveries exceeded hundreds of thousands, with shipments made to more than forty different markets worldwide. The number of LNG importing markets has nearly quintupled since the 1990s, with the most significant growth occurring between 2009 and 2016 (Du and Paltsev, 2014; GIIGNL, 2024).

LNG transportation model analyses are essential for optimizing trade strategies between countries and ensuring the security of energy imports and exports. However, current understanding of port-level trade patterns remains limited. Peng et al. (2021) examined global LNG transportation networks for the 2013–2017 period using collected ship trajectory data. The study found that the LNG transportation network is characterized by closer connections, with Singapore, Ras Laffan, and Khawr Fakkan playing significant roles in this context. Furthermore, it was observed that the global LNG trade network has developed several closely connected trading communities since 2013, with ports within these communities becoming geographically concentrated. The findings also revealed that the global LNG trade network is divided into three main regions. One region includes ports in the Middle East, Australia, Singapore, East Asia, and Southeast Asia; another comprises ports in the Middle East, East Africa, the Mediterranean, and the rest of Europe; and the last region, a relatively independent trading zone, consists of ports in the Americas. In their study on new trade routes for LNG, Filimonova et al. (2022) assert that Europe represents the most significant potential market for LNG and that LNG shipments to Europe impact the gas supply security of developing countries. Qatar, Egypt, and Norway are highlighted as key potential suppliers. The study aims to identify optimal trade routes and assist LNG suppliers in accessing new markets. Norway and Belgium, Egypt and Spain, as well as Norway and Russia, are identified as having the highest potential for connections to Singapore.

On the other hand, Memon et al. (2014) predicted that Australia would become the fastest-growing LNG producer in the future. They estimated that, by 2030, Australia would be the second-largest exporter, following Qatar, and would account for 25% of global LNG production. Feng et al. (2017) highlighted the volatile nature of international trade by

comparing the flexibility of LNG trade to the regionalization of the natural gas market. They noted that countries such as India, Spain, the Netherlands, Singapore, and Italy may increase their LNG imports from the United States, while the United Kingdom might export LNG to Japan, and France could export to South Korea. This dynamic allows governments to identify new trading partners as needed and adjust their energy strategies by leveraging existing relationships.

LNG is a significant energy source that plays a crucial role in electricity generation due to its flexible pricing. Predictions indicate that the global demand for LNG is on the rise and will likely continue to grow. This trend can be attributed to several factors, including the depletion of global oil reserves and the advantages LNG offers over other energy resources, such as lower costs, easier transportation, and greater sustainability, especially in light of high oil prices. As more countries begin to consume LNG, this trend is expected to positively influence technological advancements in the energy sector. Consequently, LNG is anticipated to contribute significantly to the growth of the natural gas industry. Its key benefits include being an accessible resource that can be transported economically over long distances to meet energy demands (Memon et al., 2014; Vazhenina, 2020).

This study focuses on the significance of LNG trade and employs bibliometric analysis to examine trends in this field. The rapid increase in scientific outputs highlights the necessity of using scientific mapping methods across various branches of science. Traditional methods struggle to provide a clear overview of the growing number of publications, making this modern approach essential. By addressing these challenges, researchers can better understand the intellectual structure of the LNG trade and its associated fields. But it will also provide convenience for policy makers (Aria and Cuccurullo, 2017). In this study for scientific mapping; WoS database was searched on May 31, 2024 using 3 different keywords. The query used in the search was; ('liquefied natural gas (topic)' and 'import' or 'export' (topic)). As a result of the search without any time interval, 273 publications on foreign trade in the LNG sector were reached. With the publications obtained, it is aimed to provide a general view of LNG energy trade. The research is useful for researchers and policymakers who want to work on the subject and is important in terms of providing a view of the sector. In the analysis for this purpose; R programming language Bibliometrix library was used as in the study conducted by Aria et al. (2021).

The bibliometric analysis reveals that publications on LNG imports and exports from 1994 to 2024 are increasing at an annual rate of 7.6%, indicating the topic's ongoing

popularity. There are currently 753 researchers in this field, with only 55 working individually. Additionally, the rate of international collaboration in these publications is 22.34%, highlighting opportunities for joint efforts and international cooperation. "Energy" and "Energy Policy" are among the leading journals for both publications and citations. In terms of countries, the USA and China are the most significant. Additionally, 39 different organizations are open to collaboration and conduct studies in this field.

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Data Link as follows:

<https://www.webofscience.com/wos/woscc/summary/d63a2dd1-6d7b-4071-bcd6-216b0a4b345f-ed55ed07/relevance/1>

ETHICAL DECLARATION

In the writing process of the study titled “Liquefied natural gas trade: Scientific mapping”, there were followed the scientific, ethical and the citation rules; was not made any falsification on the collected data and this study was not sent to any other academic media for evaluation.

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