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Article

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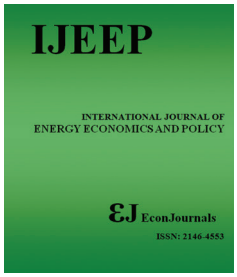

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A Bibliometric Review to Understanding the Supply Chain of Renewable Energy

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ABSTRACT

This bibliometric analysis investigates the evolving research landscape in renewable energy supply chains. The study uses VOSviewer software to examine influential articles, authors, countries, journals, and keywords from 2015 to 2023. Notably, 2019 marked a significant shift with a surge in publications and citations, suggesting a transition toward more impactful and higher-quality research. In subsequent years, they have witnessed fluctuations in citation counts, potentially reflecting changes in research focus and publication quality. Geographically, the United States and China stand out as leading contributors, with the United Kingdom, Germany, Italy, and Iran also making substantial contributions. The analysis of journals and publishers reveals variations in research impact and influence, with Elsevier emerging as a significant publisher. The keyword analysis underscores the prevalence of "Supply chains," "renewable energy resources," and "biomass' as central themes. This study offers valuable insights into the research trends and dynamics in the renewable energy supply chain field.

Keywords: Renewable Energy, Supply Chain, Bibliometric Review
JEL Classifications: Q21, D2, Q2

1. INTRODUCTION

As an indispensable catalyst for global economic progress and societal well-being, energy faces an unsustainable trajectory in its production and consumption methods (Yüksel, 2008) (Cerdeira Bento and Moutinho, 2016). The regulation of greenhouse gas emissions has become imperative, urging a concentrated focus on energy efficiency across production, distribution, and consumption systems (Wang et al., 2014). Expanding electricity supply infrastructures in developing nations is widely acknowledged as pivotal for raising living standards and fostering sustained economic growth (Warsame et al., 2023) (Sarkodie and Adams, 2018). This recognition has spurred a growing consensus among policymakers and investors globally regarding the critical role of electricity. Consequently, promoting renewable energies emerges as a strategic pathway toward sustainable development, addressing climate change concerns and meeting rising energy demands (Warsame, 2023; Ohlan, 2015). The swift integration of renewable energy technologies offers a promising route to clean energy systems, significantly reducing environmental impacts tied to fossil fuel consumption and serving as a strategy for climate change mitigation (Warsame, 2023). Moreover, adopting renewable energies is pivotal in advancing countries' ambitions for energy independence (Azevedo et al., 2019).

Recent global discourse underscores the intricate relationship between climate change and the evolving landscape of energy sources, particularly renewable energy. The convergence of these factors significantly impacts global energy usage (Al Jaber et al., 2014). The World Bank's report, "Climate Impacts on Energy Systems," reveals the direct implications of climate change on energy systems, encompassing its effects on energy supply, demand, infrastructure, endowments, and transportation. The report also illuminates the indirect impacts of climate change

through its influence on other economic sectors, shaping energy systems. This comprehensive analysis emphasizes the intricate interplay between climate change and energy, necessitating strategic interventions and adaptability within energy frameworks to counter and mitigate the widespread effects of climate change on energy systems globally (Ebinger, 2011).

Despite this, renewable energy and sustainable supply chain management are crucial players in the global energy industry. Sustainable supply chain management targets eco-friendly and efficient supply chains, while renewable energy gains prominence due to the decreasing use of fossil fuels and their harmful greenhouse gas emissions, making it a more cost-effective choice than conventional sources (Osman et al., 2023). To navigate this complex landscape, experts often employ system dynamics to model and simulate intricate situations involving multiple players and interconnected systems (Cucchiella and D'Adamo, 2013).

The primary goals in sustainable supply chain management involve evaluating performance and integrating operations, considering environmental, social, and economic factors. This comprehensive approach is particularly pivotal in the energy sector as it significantly impacts economic development (Shekarian et al., 2022). A sustainable supply chain requires aligning resources, flows, and stocks with a clear sustainability plan, necessitating greater attention and collaboration among all stakeholders involved in the renewable energy process to establish a more environmentally friendly and efficient energy value chain (Hilmola et al., 2005) (Sahoo et al., 2022).

Extensive scholarly investigations have made substantive contributions across diverse academic domains. However, examining bibliometric studies concerning the renewable energy supply chain posed a challenging task. In November 2023, researchers conducted a thorough search within the SCOPUS database using the same parameters as the primary data inquiry, including the specific keyword "bibliometric," to refine the search and identify studies relevant to bibliometric analysis within this particular context.

Despite the vast expanse of available academic literature, the initial search yielded surprisingly limited results, presenting only three relevant studies. Unfortunately, two of these findings were confined to specific fields and offered minimal value to the researchers' objectives. However, a study by Azevedo et al. (2019) aligned partially with the research focus. Yet, its temporal scope was confined solely to research conducted between 2005 and 2018, necessitating a reevaluation of the research methodology.

In pursuing a broader and more updated perspective on the renewable energy supply chain, the researchers resolved to expand their search criteria. The revised parameters will encompass studies conducted from 2015 to 2023 to capture the latest developments and trends in this dynamic field. This expanded, and more contemporary inquiry aims to provide a comprehensive understanding of the bibliometric landscape surrounding renewable energy supply chains.

2. METHODOLOGY

In this research, the authors employ science mapping to explore existing renewable energy supply chain knowledge. Science mapping involves analyzing academic works through bibliometric techniques (Morris and Van Der Veer Martens, 2008). One specific aspect of bibliometric analysis is the identification and visualization of evolving scientific ideas and their interconnections over time (Cobo et al., 2011; Small, 1997). This analysis can be conducted at various levels, such as keywords, authors, publications, journals, institutions, and countries (Small, 1999).

Small (1999) outlines seven key steps in science mapping analysis: data collection, preprocessing, network extraction, normalization, mapping, analysis, and visualization. However, some of these steps may be integrated, as modern software tools can perform them concurrently with minimal effort, as seen in the VOSviewer software, which handles network extraction, normalization, mapping, analysis, and visualization almost instantly after configuring the required parameters. Some researchers propose simplifying the process into three main steps: data acquisition, preparation, and analysis (Fabrikant et al., 2010). Here, we outline the steps the researchers took in gathering and analyzing data for their study.

2.1. Search Criteria

Researchers can access bibliographic sources, such as Google Scholar, SCOPUS, and the Institute for Scientific Information (ISI) Web of Science (WoS), to collect data for bibliometric analysis (Small, 1999). For this review, SCOPUS was chosen due to its extensive coverage of publications and journals in the social sciences compared to WoS (Hallinger and Kovačević, 2019). Google Scholar was not utilized due to the challenges of obtaining bibliometric data from its database and its less stringent indexing rules.

The first step of the study involves defining the terms and keywords to gather information about the renewable energy supply chain. These keywords should be descriptive and account for word derivatives and variations. SCOPUS, the world's top indexer for high-quality reference articles, was used to search for relevant articles.

The objective was to identify the most pertinent articles from the initial search results. The search was conducted in November 2023, yielding 1161 documents published between 2015 and 2023. Only English-language journal articles and conference papers were included in the search results. CSV files were exported for all initial search results, encompassing author names, citation information, document titles, publication years, source titles, volume, page numbers, citation counts, source types, DOIs, abstracts, keywords, and conference details.

2.2. Data Collection and Cleaning

After retrieving data from the database, the researchers exported Comma-Separated Values (.csv) files as previously described. Due to limitations on the SCOPUS website, only the bibliometric data for the first 2000 entries could be exported. Since the analysis

focused on the top 100 most-cited articles, the remaining entries were not considered.

The data cleaning process involved identifying and rectifying missing or incorrect entries. Ensuring all required fields were complete and the data within each area matched the corresponding field title was essential. Entries with inaccuracies or omissions were removed, and the cleaned data was then saved in a separate Microsoft Excel (.xls) file. To facilitate analysis, this new file was converted to a Text (tab-delimited) format for easy importation into VOSviewer.

2.3. Bibliometric Analysis

Bibliographic networks, including keyword maps, co-author networks, citation and co-citation networks, and bibliographic link networks, are commonly employed in scientific mapping (Cobo et al., 2011). In this study, the researchers utilized a keyword map, co-authors from various countries, and a bibliographic link network. Additionally, an analysis of publications, citations, and prominent journals where the top 100 most-cited papers on the renewable energy supply chain were published was included to enhance the results' comprehensiveness.

Various software tools are available for scientific mapping, such as INSPIRE (van Eck and Waltman, 2010), HistCite (Garfield et al., 2003), VantagePoint (Porter, 2004), CoPalRed (Porter, 2004), CiteSpace II (Chen, 2006), and Gephi (Cobo et al., 2011). In this study, VOSviewer, accessible at www.vosviewer.com, was employed to visualize bibliometric maps and networks. Additionally, the data from VOSviewer was used to create graphs in Microsoft Excel.

Bibliometric maps can be presented using different methods based on distance, graphs, or time (Cobo et al., 2011). Regardless of the visualization method used, maps consist of "nodes" (representing entities) and "edges" (connecting these entities). In distance-based visualization, the proximity of nodes indicates the strength of their connection. In graph-based visualization, edges represent relationships; the entities are unrelated if a connection is absent. Timeline-based or temporal analysis organizes nodes vertically based on specific periods, with horizontal distance indicating the relationship between entities.

VOSviewer employs a distance-based method for displaying bibliometric networks but also allows for the representation of edges if desired. When interpreting the bibliometric maps in this study, consider three key aspects: (1) Node size reflects entity frequency. (2) Proximity between nodes indicates stronger connections. (3) The thickness of lines connecting nodes signifies the presence of both of these characteristics.

3. RESULTS AND DISCUSSION

3.1. Citation by Years

The figure 1 states the supply chain of renewable energy publications and their citations from 2015 to 2023 present an intriguing insight into the evolution of this field. One noticeable trend is the fluctuation in the number of publications and citations. In 2017 and 2019, they witnessed a surge in publications, hitting 165 and 109, respectively. This increase might signify a growing interest and investment in renewable energy supply chain research during these years. However, while the number of publications was high in 2017, the total citations were relatively lower compared to 2019, where a similar number of publications accrued significantly more citations. This contrast suggests that although there were fewer publications in 2019, the quality and impact of the research were higher, leading to increased citations.

Moreover, the data reflects a general downward trend in the total number of citations from 2015 to 2023, with a notable drop after 2019. While the number of publications remained relatively steady in the subsequent years, the citations decreased. This decline might indicate a shift in the quality of research or changes in the focus of the studies within the renewable energy supply chain. However, the most recent data for 2023 shows a sudden surge in the number of citations despite a decrease in the number of publications compared to the previous year. This anomaly could imply an emergence of highly impactful research, possibly indicating a new direction or significant breakthroughs in the field, leading to a higher citation rate despite fewer publications. Overall, the contrasting patterns between the number of publications and their corresponding citations reveal fluctuations in research quality, focus, and impact within the renewable energy supply chain field over these years.

3.2. Countries

Figure 2 presents a compelling overview of the top countries engaged in research and publication regarding the supply chain of renewable energy. The United States is a frontrunner in this field, with 212 publications showcasing a robust interest and significant contribution to advancing renewable energy supply chain knowledge. China closely follows, with 193 publications, signifying its active involvement and growing emphasis on sustainable energy supply chain research. Both nations are firmly committed to advancing renewable energy through academic discourse and innovation.

While the United States and China lead the pack, other countries like the United Kingdom, Germany, Italy, and Iran also showcase commendable involvement in this domain, with publications ranging from 102 to 64. As figure 3 depicts these nations have a solid foundation in renewable energy and actively contribute to the discourse. Meanwhile, India, Netherlands, Australia, and Malaysia, with publications from 62 to 44, display a lower but still noteworthy presence in this field. Each country brings unique perspectives and expertise to the conversation, enriching the global understanding of renewable energy supply chains. The variation in publication numbers reflects diverse approaches, investment levels, and focus areas within the supply chain of renewable energy across these nations.

3.3. Journals

The dataset focusing on various journals within the renewable energy supply chain domain provides a comprehensive view of their publication volume, citation metrics, and other indicators. A distinct variation is observed across the journals regarding their publication volume and the resultant citation numbers. For instance, "Energy Policy" stands out with a relatively lower

Table 1: Top-most frequently cited sources

Journals	TP	TC	CPP	Cite Score	SNIP	SJR	H-Index	Publisher
Journal of cleaner production	75	2527	33.7	89	2.379	1.981	268	Elsevier
Sustainability (Switzerland)	45	582	12.9	75	1.198	0.664	136	MDPI
Applied energy	39	1873	48.0	91	2.758	2.907	264	Elsevier
Energies	37	325	8.8	77	1.025	0.632	132	MDPI
Renewable energy	25	504	20.2	91	2.146	1.815	232	Elsevier
Energy	23	564	24.5	92	2.132	1.989	232	Elsevier
International journal of hydrogen energy	21	632	30.1	89	1.423	1.318	248	Elsevier
Energy policy	15	889	59.3	91	2.155	2.292	254	Elsevier
Energy conversion and management	12	421	35.1	90	2.286	2.514	232	Elsevier
Computers and chemical engineering	11	171	15.5	84	1.468	0.897	152	Elsevier
Environmental science and pollution research	11	172	15.6	84	1.214	0.944	154	Springer
International Journal of Life Cycle Assessment	11	162	14.7	88	1.395	1.135	123	Springer
Renewable and sustainable energy reviews	11	155	14.1	94	3.631	3.232	378	Elsevier

Figure 1: Publications by yearly

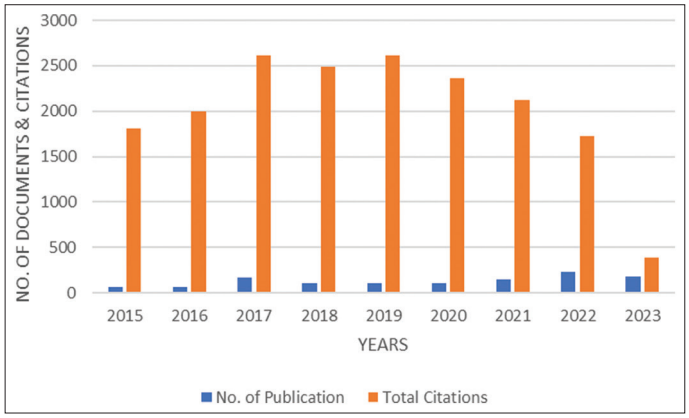
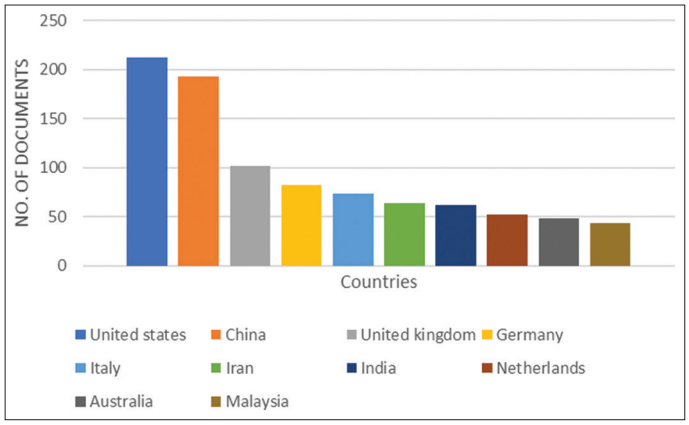


Figure 2: The contribution of numerous nations



publication count of 15 but a substantially higher total citation count of 889. This showcases a significantly high citation per publication ratio of approximately 59, signifying the impact and quality of the research articles published in this journal. On the other hand, journals such as "Energies" and "Renewable Energy" have a moderate number of publications but demonstrate an influential cite score, both publishing around 25 articles and accumulating more than 500 citations, portraying a high impact in renewable energy supply chain research.

Additionally, , the dataset in table 1 presents interesting differences among publishers and their respective journals. Elsevier appears to be a prominent publisher in this field, housing multiple journals such as "Journal of Cleaner Production," "Applied Energy," and "Renewable and Sustainable Energy Reviews," among others. These Elsevier-published journals generally exhibit competitive citation metrics, high Cite Scores, and relatively high SJR (SCImago Journal Rank) and H-Index values, signifying their significant influence and contribution to the scholarly discourse within renewable energy supply chain studies. Contrarily, journals under MDPI and Springer, while contributing to the research output, tend to have lower citation counts and impact metrics than many Elsevier journals. This variation across publishers indicates differing levels of impact and influence within the scholarly landscape of renewable energy supply chain research, with Elsevier standing out as a dominant force.

3.4. Citation Network

The dataset provided encompasses a rich array of authors and their characteristics within the renewable energy supply chain field. It exhibits a multitude of variables, such as the clustering of authors, link weights, total link strength, and citation counts. Notably, a diverse range of clustering is evident among these authors, which suggests different groups or collaborative networks within the field. For instance, researchers like Zhang J., Li Y., and Zhang Y. have notably high citation counts of 4178, 4609, and 3960, respectively, indicating significant influence and impact within the scholarly landscape of renewable energy supply chain research. These authors likely contribute to pivotal studies and possess a strong presence in the academic discourse.

On the contrary, some authors have relatively lower citation counts and collaborative links, potentially indicating a developing or less-established presence within the field. For example, Spinelli R., Tatari O., and Sokhansanj S. have lower citation counts of 170, 2744, and 1485, respectively, suggesting a lesser impact or contribution than those with higher citation counts. The distribution of authors within different clusters and the wide variation in citation counts imply a diverse landscape in the expertise and influence of these researchers within the renewable energy supply chain. This may point to a mix of established, influential figures and emerging scholars, each contributing to this field's overall growth and development through their respective research and collaborations.

The dataset in figure 4 showcases a spectrum of authors with varying degrees of impact and collaboration, which is crucial in highlighting the dynamic nature of research within the renewable

energy supply chain domain. The differences in citation counts and clustering indicate the presence of both established and emerging researchers, each contributing to their capacity to advance knowledge and practices within this critical area of study.

3.5. Keywords

The researchers also analyzed to identify the central themes addressed by the 100 most-cited articles. This was accomplished using VOSviewer to examine the frequency of co-occurrence of words, including those selected by the authors and those from the journals. Figure 4 presents the outcomes, revealing that the information in these publications can be categorized into three primary clusters. These clusters, in order of their size, are characterized by the most significant keywords "Supply chains," "renewable energy resources," and 'biomass."

"Supply chains" emerges as the most frequently occurring term, appearing 674 times in Cluster 1, comprising 57 keywords. Notably, this keyword stands out as the most commonly used term across the entire map, underscoring its paramount importance in discussions about supply chains. It exhibits strong associations with renewable and alternative energy concepts, both within Cluster 1. It also demonstrates robust linkages with keywords from Clusters 2 and 3, such as biomass and renewable energy resources, with link strengths of 145 and 242, respectively.

The term "biomass" is encountered 186 times within Cluster 2, containing 37 keywords. It ranks as the third most frequently used term in the entire analysis. Results indicate that biomass exhibits substantial associations with supply chains and renewable energies, as evidenced by link strengths of 145 and 57, respectively, both

Figure 3: The contribution network of numerous nations

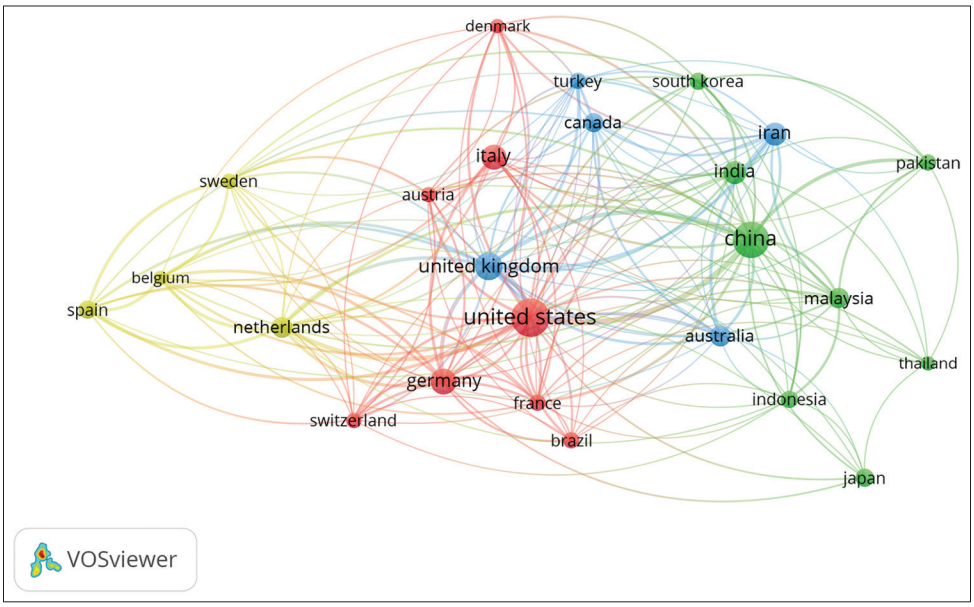


Figure 4: Collaborative network connections among renowned authors

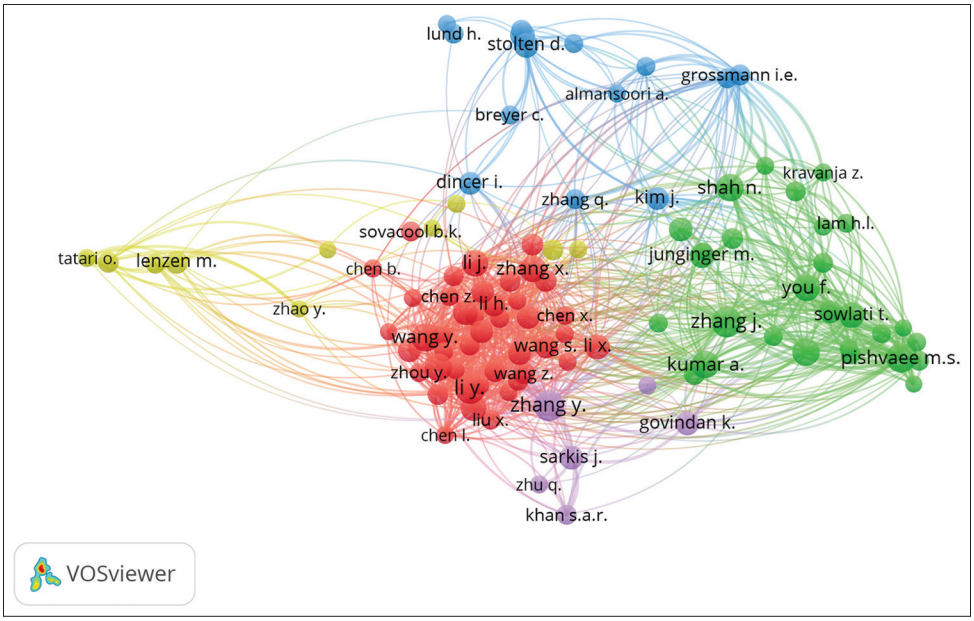
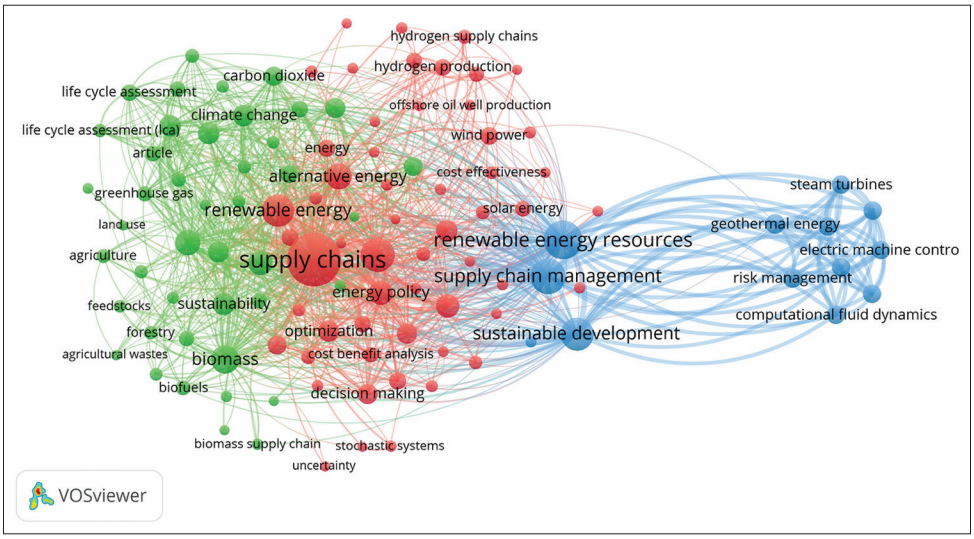


Figure 5: Matching network for the most common keywords



of which are located within Cluster 1. Furthermore, "biomass" displays robust connections with several keywords from the third cluster, establishing significant ties with sustainable development and supply chain management, each bearing link strengths of 46 and 41, respectively.

In Cluster 3, the phrase "renewable energy resources" is encountered 357 times among 13 keywords. This term exhibits strong linkages with supply chains and management, as evidenced by link strengths of 242 and 142, respectively. It is also the second most frequently used term overall. However, its connections with other concepts are weaker than the principal terms in the first and second clusters. Notably, it lacks substantial associations with keywords outside its cluster. Additionally, relationships among the keywords within this cluster appear to be weak, with four keywords, including "renewable energy resources," "supply chain management," "sustainable development," and "coal," forming a distinct subgroup separate from the remaining keywords in the cluster.

Figure 5 illustrates the proximity of the first and second clusters, indicating the close interrelation between the keywords within these clusters compared to those in other clusters. This suggests a stronger focus on supply chains, a topic more prominently featured in the fields of market and economy.

4. CONCLUSION

The bibliometric analysis focusing on the renewable energy supply chain presents a comprehensive landscape of the evolving discourse and research trends within this domain. The VOSviewer software research approach provided insight into the most influential articles, authors, countries, journals, and keywords prevalent in the academic discourse on renewable energy supply chains. The study spanned from 2015 to 2023, outlining significant fluctuations in the volume of publications and citations. The year 2019 stands out as a period marked by a substantial increase in the number of publications and a significantly higher citation count, indicative of a shift towards more impactful and higher-quality research within the field. However, the subsequent years displayed a noticeable decline in the overall number of citations, suggesting changes in research focus or varying qualities of publications that affected their impact. Moreover, the sudden surge in citations in 2023, despite a decrease in the number of publications, suggests the emergence of highly influential research, possibly indicating critical breakthroughs or a shift in research emphasis.

The geographical distribution of publications highlights the prominent involvement of leading countries, with the United States and China leading in producing research in renewable energy supply chains. These nations contribute significantly to the academic conversation, demonstrating a substantial commitment to advancing sustainable energy through scholarly contributions. Other countries like the United Kingdom, Germany, Italy, and Iran also make noteworthy contributions, each adding a unique perspective and expertise to the global discourse. The varied publication figures across nations reveal diverse approaches, levels of investment, and areas of focus within the supply chain of renewable energy, enriching the understanding and discussion on a global scale.

Furthermore, the analysis of journals and publishers revealed significant variations in the impact and influence across different platforms. Journals like "Energy Policy," "Energies," and "Renewable Energy" exhibited varying publication volumes and citation metrics, indicating a spectrum of research quality and influence. Elsevier, known for its high-impact journals, stands out among publishers, holding significant impact and contributing substantially to the scholarly landscape in this field. The diverse citation networks and clustering among authors in the supply chain of renewable energy signal a mix of established researchers and emerging scholars. Some authors exhibit high citation counts, pointing to their significant influence within the domain, while others, with lower counts, signify a developing presence or less-established influence. The varying degrees of impact and collaboration contribute to the dynamic and multifaceted nature of research within the renewable energy supply chain field.

Additionally, the analysis of keyword maps emphasizes the prominent themes in the most-cited articles, indicating the prevalence of "Supply chains," "renewable energy resources," and "biomass" as the primary focal points. The strong interconnections among these key terms, precisely the closeness between the "Supply chains" and "biomass" themes, reveal their significant linkages in research discourse. "Renewable energy resources," while featuring highly in citations, exhibit weaker connections with other keywords outside its cluster, indicating a more standalone presence. The adjacency of the first and second clusters signifies a closer link between the economic and market-oriented keywords, emphasizing a heightened interest in supply chains associated with these fields.

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