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Article

Energy Sector's Green Transformation towards Sustainable Development: A Review and Future Directions

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Abstract: The energy sector's green transformation recently gained major scientific attention, due to the role of the energy sector in the economy. The energy sector, similarly to the other economic sectors, faces sustainable development (SD) challenges. This review paper's goal is to explore the areas of the green energy sector transformation towards SD context distinguished in the scientific literature review. The adopted method in this paper is bibliometric research of the scientific publications indexed in Scopus. There were two original queries formulated, and their results were analyzed in the VOSviewer program in the form of bibliometric maps and tables. A comparison of the proposed original queries' results points to the importance of the journal subject area indexed in the Scopus database. There are publications important for the energy sector green transformation not included in the energy subject area in this database. The vast number of publications dealing with cross-disciplinary subjects revolving around green transformation in the energy sector is the cause of the multiple side topics covering the areas of the SD. The study identifies keyword-specified areas around the topic of green transformation towards SD in the energy sector. In this study, the limitations of the employed methods and the theoretical, methodical, and empirical implications of the research were presented. Presented results can inspire other researchers who are looking for a research gap or describing the state of the art. The future possible research avenues were also addressed.

Keywords: bibliometric review; energy sector; green jobs; green economy; green transformation; sustainable development

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1. Introduction

The idea of Sustainable Development (SD) is no longer only a theoretical concept discussed in the category of an undefined future [1,2]. Still, at the core of the concept is such resource management that meets the needs of present generations without limiting their satisfaction by future generations [3,4], and consequently, there is an emphasis on the fact that future generations have the same rights as present generations in terms of their development [5]. At the same time, it can be observed that changes are constantly taking place around the formulated social [6,7], economic [8,9], and environmental [10,11] challenges that are supposed to lead to sustainable development. In addition, it can be seen that SD is a key pillar of the implemented development policies of many countries and international communities [12,13]. The SD is also implemented in the practice of operating various types of organizations. As a result, researchers identify activities aimed at SD in both public entities [14,15] and businesses [16–18]. At the same time, it should be pointed out that, regardless of the level of aggregation of the considerations undertaken (micro- or macroscale), it is increasingly common in the pursuit of SD to adopt and monitor various types of measurable indicators closely linked to the objectives aimed at SD [19–21]. Indicators of this type should be reliable to support the private sector in the pursuit of

SD [22]. At present, the SD goals in the scope of Agenda 2030 are of key importance [23,24]. Such measures make it possible, in the opinion of the authors of this article, not only to identify the direction of the changes taking place but also to measure their scale and transfer the policies created internationally or nationally to the local level.

The sectoral approach has an important place in the scientific discourse related to the issue of SD [25,26]. In this type of approach, pre-subject researchers analyze selected sectors of the economy from the point of view of ongoing changes aimed at the SD [27–29]. These studies also point out the importance of individual sectors of the economy for the future development of the go-economy consistent with the idea of the SD. Particular importance is given to the energy sector in this discourse. Researchers in their scientific reflections even point to the strategic and undeniable role of the energy sector in the functioning and further development of modern economies [30–32]. Such a role results from the historical fate of economic development as a result of which it is impossible to imagine modern social and economic life without constant access to energy resources and electricity [33]. Nevertheless, next to this, it is impossible not to notice that in the literature there is increasingly a discussion of the problem of undertaking analysis in a much broader context than sectoral. Hence, in the discussion, there are an increasing number of statements indicating that the sectoral approach in the context of implementing various types of climate change adaptation initiatives causes imbalances and may delay sustainable development [34,35]. Such an approach also, in the opinion of the authors of this article in the context of scientific analysis, may contribute to the lack of knowledge of the full picture of the research problem in question, as it represents a rather narrow view of it. Such a thesis will be verified in the research presented in this article.

Due to the aforementioned strategic role of the energy sector, its transformation towards SD [36,37] and the decarbonization challenges behind it [38,39] occupy an important place in the literature. Some of the researchers working on this issue explicitly indicate that this type of transition should be called a green transition [40,41]. The main rationale behind such naming of this process is the fact indicating that the transformation of the energy sector towards SD occurs as a result of increasing the use of those renewable sources as energy sources at the expense of abandoning the use of energy resources from non-renewable sources [42]. The process of green transformation itself is, of course, much more complex, one could even point out that it is multidimensional [43,44]. It involves, for example, the issue of maintaining continuity of electricity supply [45], the issue of costs of such transformation [46] both on the side of energy suppliers and consumers, the issue of environmental impact [47,48], or even, as noted by the authors of this article, the issue of shaping appropriate competencies of employees in the greening energy sector, known in the literature as green competencies [49,50], or creating green jobs [51–53].

The aforementioned multidimensionality of the scientific considerations undertaken in the field of greening of the energy sector, and, above all, their lack of order became the reason for the authors of this article for the analyses made and further presented. The authors recognize that at the current stage of undertaken considerations around the green transformation of the energy sector, it becomes necessary to organize the existing knowledge to isolate the currently most frequently cited issues. In addition, the authors wish, based on their analysis, to identify interesting research threads that may gain popularity in the coming years and become key issues in the field of greening the energy sector.

The aim of this paper is to present the areas of the green energy sector transformation towards SD context distinguished in the scientific literature review. The literature review is complemented by the bibliometric research of the scientific publications indexed in Scopus. Then the scientific contribution of this paper is to demonstrate the bibliometric data analysis related to the identified areas of the green energy sector transition. This paper is based on the structure of the obtained bibliometric data from two original queries' results. The adopted method of bibliometric data analysis with the VOSviewer programme (version 1.6.19; Centre for Science and Technology Studies, Leiden University, Leiden, The Netherlands) compares two sets of results in the graphical form of bibliometric maps. This research provides bibliometric data analysis by utilizing mapping tools and identifying the research gap.

The article has five interrelated sections, which aim to achieve the stated research objective. The first part, the Section 1, presents the location of the issue in the literature, the motives behind undertaking the research, and the purpose of the research. In turn, the Section 2 presents a description of the research methodology. An important element of the methodology presented is the indication of the stages of the research and their location in time [54]. These are essential elements that affect the results obtained. In the Section 3, there are described study results of the undertaken bibliometric analyses. The Section 4, following the logic of the scientific argument, consists of a discussion of the results and proposed methods and their limitations. The Section 5 of the article is dedicated to theoretical and practical implications. This part simultaneously concludes the article and presents indications of future research directions related to the issue of green transformation of the energy sector.

2. Materials and Methods

The subject of this research were scientific publications collected in the Scopus scientific database, which is "a multidisciplinary abstract and citation database with powerful discovery and analytical tools" [55]. The popularity and trust of that database among researchers were the primary reasons for this database choice [56,57]. This research's main limitation is the fact that some of the newer journals are not indexed in the Scopus database [35,58]. However, the "literature collected in this database consists of the peer-reviewed publications organized as a digital collection of books, journal articles, and conference proceedings, etc." [2]. The information related to those publications indexed in the database is called bibliographic metadata [59,60].

This study is based on the procedure scheme presented in Figure 1 in detail. The methodology consists of main three intertwined stages: extraction, screening, and analysis [54]. The conceptualization of the research was the first step of the study. This step was crucial due to the keywords selection is important for the further analysis of the green energy sector transformation subject [35,61]. Authors noticed the possibilities and limitations of methods usually selected by the researchers who aim to explore the literature database.

The outcome of the first step in Figure 1 was the database and method of analysis selection. The second step of the research was data extraction and initial analysis in the Scopus database (Figure 1) by the formulated queries presented in Table 1. The two sets of results were identified in the procedure and analyzed separately. The presented procedure aims to present the dynamics of the scientific interest in the green energy sector transformation visible in the bibliometric maps revealing the subject areas and trends [62,63].

Table 1. Search queries syntax details.

Symbol	Query Syntax	No. Results (18 February 2023)
Q1	TITLE-ABS-KEY (({sustainable development} OR sustainability) AND ((green) AND (transformation OR transition)) AND ({energy sector})) AND (LIMIT-TO (PUBSTAGE, "final")) AND (EXCLUDE (PUBYEAR, 2023)) AND (LIMIT-TO (LANGUAGE, "English"))	96
Q2	TITLE-ABS-KEY (({sustainable development} OR sustainability) AND ((green) AND (transformation OR transition)) AND ({energy sector})) AND (LIMIT-TO (PUBSTAGE, "final")) AND (EXCLUDE (PUBYEAR, 2023)) AND (LIMIT-TO (LANGUAGE, "English")) AND (LIMIT-TO (SUBJAREA, "ENER"))	54

Source: Authors' elaboration.

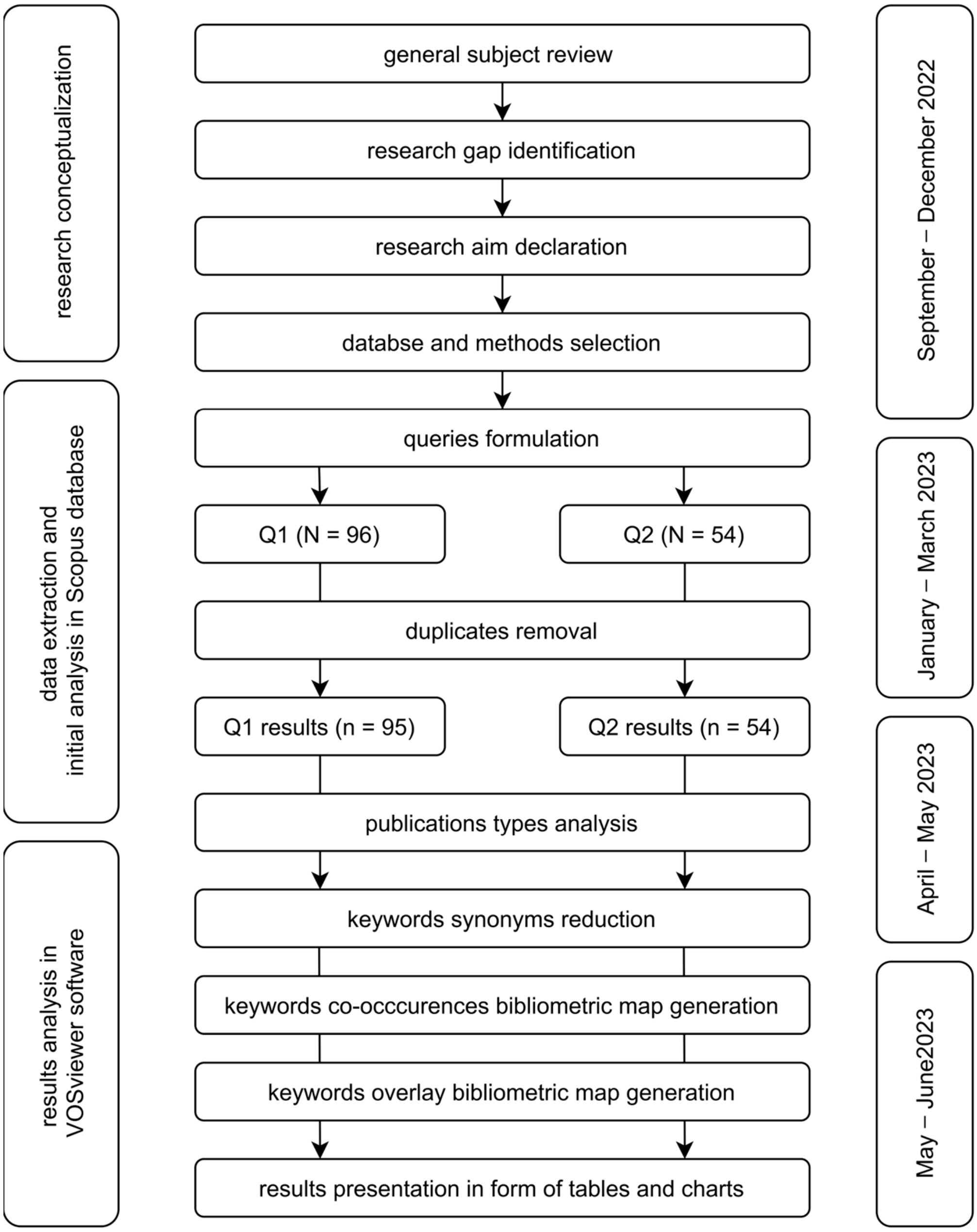

Figure 1. Methodology Scheme. Source: Authors elaboration.

The method adopted in this research is a bibliometric variation of the systematic literature review to explore and present areas of the green energy sector transformation towards SD context. There is also a classical review method dedicated to the selected papers' overall presentation required in the Sections 1, 3 and 4 of this paper. In the employed method, the two original queries (Table 1) were formulated based on the keywords to create a comprehensive query syntax to compare two results sets. The keyword "sustainable development" and its synonym "sustainability" together with "green" or "transformation" of the "energy sector" were searched in Q1 and Q2. The other elements of syntax are the effects of applied search filters in the Scopus database [64]. The queries presented in Table 1 were created from the refined results sidebar after each query was executed. This very last element differentiates formulated queries. Q1 is not limited to the energy subject area as Q2 with the last syntax element expressed as: AND LIMIT-TO (SUBJAREA, "ENER"). Presented in Table 1 queries represent the explorative approach of the performed research, due to the query syntaxes.

The presented queries have syntax corresponding with the databases by the used operators and they are very similar; in addition, the order of the queries represents the steps of the database exploration [65,66]. The Q2 results presented in Table 1 are a subset of the results obtained from Q1. Due to the ongoing indexation and research, the newest publications from 2023 were not distinguished from the explored database [67,68]. The period limitation was not only a limitation proposed in the queries syntax, but the limitation to the final published version and limitation to the English language of publication were also applied.

Based on the results presented in Tables 2 and 3, the charts presenting the number of publications in Scopus were generated on the Scopus website by the selection of the results analysis option [35,69]. Search results obtained in Q1 were limited to the "energy" subject area presented in Table 3 and are results of Q2.

Table 2. Search criteria used in the initial research of Q1 results.

Criteria	Details
Database	Scopus
Search area	Article title *, Abstract, Keywords
Topics	Sustainability and green transformation in the energy sector
Time span	2005–2022
Subject area	All scientific areas (95)
Document type	Article (56), conference paper (18), book chapter (10) review (10), short survey (1)
Language	English (95)
Publication stage	Final (95)

* Each publication title indexed in the Scopus database. Source: Authors' elaboration.

Table 3. Search criteria used in the initial research of Q2 results.

Criteria	Details
Database	Scopus
Search area	Article title *, Abstract, Keywords
Topics	Sustainability and green transformation in the energy sector
Time span	2015–2022
Subject area	Energy (54)
Document type	Article (35), conference paper (9), review (7), book chapter (2), short survey (1),
Language	English (54)
Publication stage	Final (54)

* Each publication title indexed in the Scopus database. Source: Authors' elaboration.

Presented results were also checked qualitatively by the authors of this research to check duplicates; in effect, from 96 results of Q1, 95 results were further analyzed in VOSviewer bibliometric software, version 1.6.19. Because the results of Q2 results are a subset of Q1 results, among the Q2 results there were no duplicates. The research procedure as presented in Figure 1 was continued onwards through the bot sets of results obtained from Q1 and Q2.

To extend the research, the VOSviewer program (version 1.6.18) was employed. The results obtained from Q1 and Q2 from the studied periods were downloaded each time as a set of files in .csv format, and during the export form the Scopus database was marked. Further analyses were carried out on the full metadata. Each query's results were analyzed in VOSviewer and presented in graphical forms as bibliometric maps. The choice of the keywords type (all, author, or indexed keywords) and the number of keywords co-occurrences determines the result obtained in its graphical presentation and bibliometric map clarity [70]. Therefore, the indexed keywords with a minimum number of 5 keyword co-occurrences were set for each bibliometric map. The keywords automatically generated by the VOSviewer were downloaded as the .txt file and opened again as a .xlsx file to merge synonyms, replace plural by singular form, unify the abbreviation with the full word versions, and select one version of English (between American and British). In the final dialogue box in the VOSviewer program, the keywords deselected were countries, and geographical names and keywords duplicates were removed. There is also a good practice of bibliometric research to remove all own names of countries, organizations, or geographical objects [2]. The modified .xlsx files were used to generate bibliometric maps for each query data set.

The results presented as a bibliometric map allow quantitative and qualitative comparison between Q1 and Q2 results. The VOSviewer allows researchers to define new research gaps so far not covered by published papers and indicate the directions of further scientific development [71].

3. Results

Queries Q1 and Q2 (Table 1) were used for studying the Scopus database. The initial number of the obtained results of each query is presented in Table 1. The comparison between results for general Q1 and energy sector-specified Q2 queries is presented in detail in this section.

The query Q1 (Table 1) was repeated on 18 June 2023 in a Scopus database exploration with the original ninety-five results (one duplicate was excluded). Due to the ongoing indexation of the documents and publications in the Scopus dataset, the year range to analyze, 2005–2022, was automatically selected due to Q1 syntax. Then, Q1 results were analyzed online on the Scopus database website by opening "analyze search results". This analysis is presented in Figure 2, where the dynamic of the document number is visible in the analyzed period 2005–2022.

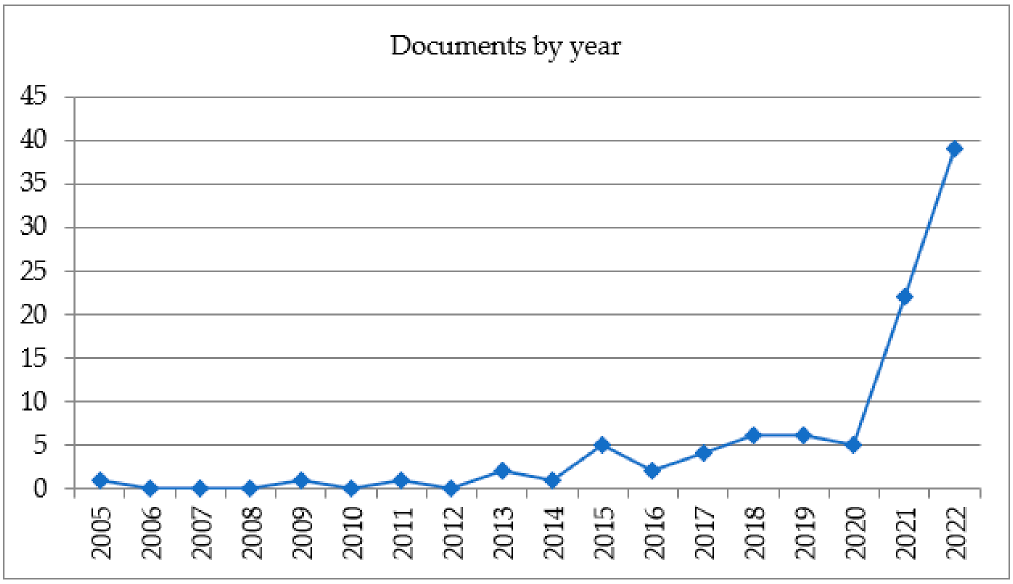

Figure 2. Q1 results analysis. Source: Authors' elaboration based on Scopus database.

The same procedure of online research results analysis on the Scopus website was applied to Q2 results. In effect, the dynamics of publications in the energy sector was presented in Figure 3. There is a different period automatically selected covering 2015–2022 due to the years of publications indexed in Scopus and Q2 syntax (Table 1).

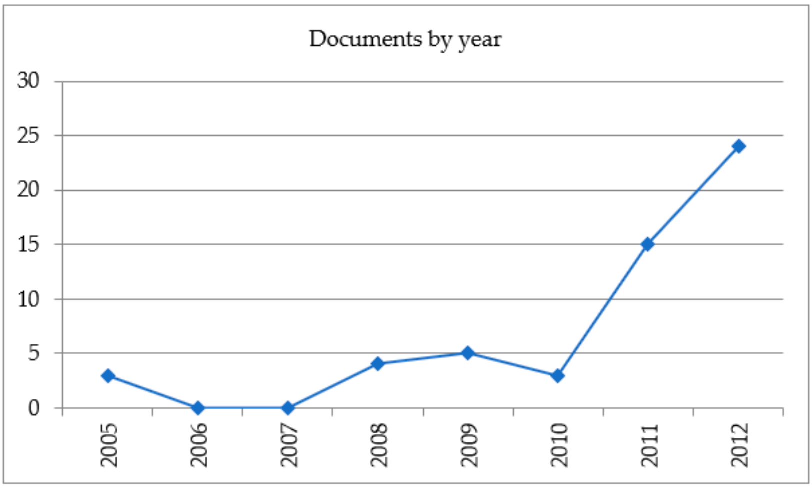

Figure 3. Q2 results analysis. Source: Authors' elaboration based on Scopus database.

There are similar dynamics in a change of publication number visible in Figures 2 and 3 despite different distinguished years of analysis. There is visible growth in both figures, which occurred after 2020 in the subject of transformation towards the green energy sector. Similarities between figures are caused by the fact that Q2 results are a subset of Q1 results. Figures 2 and 3 present the exploration of the scientific literature indexed in the Scopus database, presented in detail in Tables 2 and 3, respectively. Analysis of the scientific literature reveals patterns and areas related to the green energy sector transformation toward SD.

Figure 4 shows a bibliometric map of co-occurrences of indexed keywords related to the explored subject of the energy sector green transformation towards sustainable development based on the Q1 results.

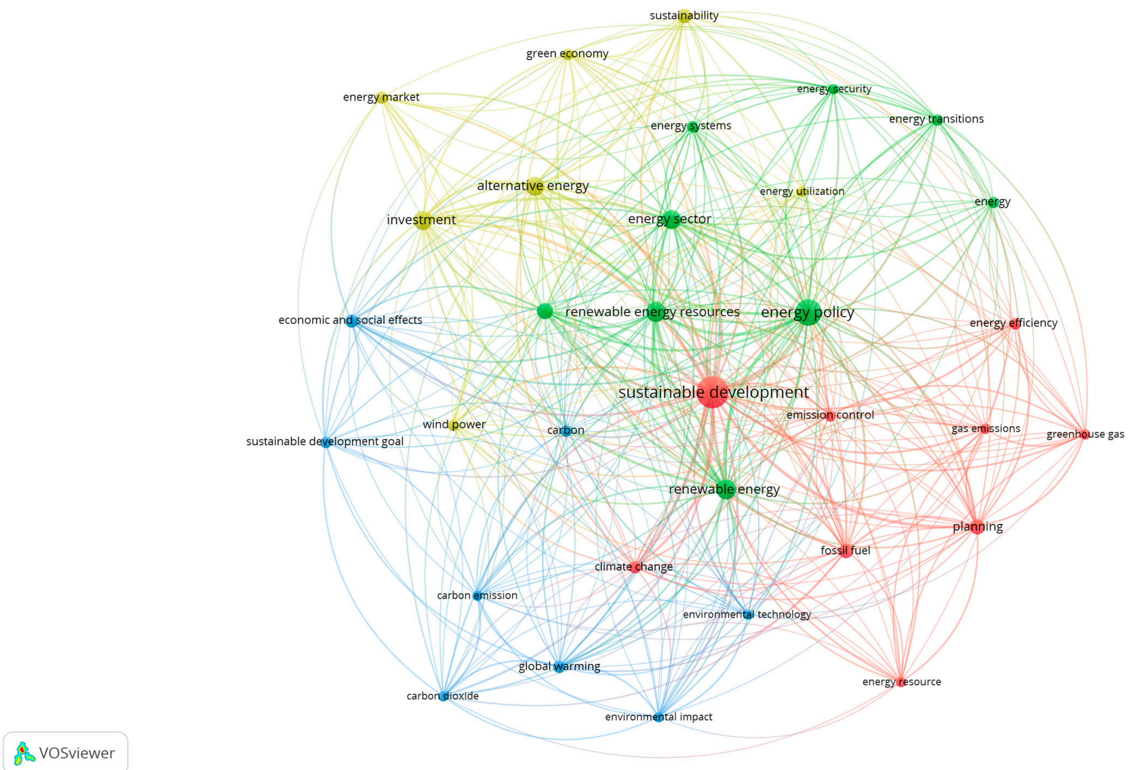

Figure 4. Bibliometric map of keywords co-occurrences results from Scopus based on original Q1. Source: Authors' elaboration performed in the VOSviewer (version 1.6.19).

Although the green energy sector transformation was explored by the Q1 query syntax, the keyword "transformation" or change is not present in Figure 4. The keywords which were selected and used by the VOSviewer program are collected in Table 4. Keywords are separated by semicolons, and the number of co-occurrences is indicated by the symbol "O" in parentheses. The symbols listed in parentheses include the number of links (L) and the total link strength (TLS), which were calculated using VOSviewer software. In Table 4 there are clusters identified by colors, as in Figure 4. Despite the original writing form, the keywords in Table 4 are written in small letters as in the VOSviewer program. The order of clusters presented in Figure 4 and Table 4 is caused by the number of keywords identified by the VOSviewer; however, the order presented in Table 4 keywords is alphabetical.

Table 4. Clusters of keywords co-occurrences are presented in Figure 4 for Scopus Q1.

Cluster	Color	Keywords
1	Red	climate change (O = 7, L = 22, TLS = 42); emission control (O = 6, L = 25, TLS = 36); energy efficiency (O = 6, L = 16, TLS = 28); energy resource (O = 5, L = 19, TLS = 33); fossil fuel (O = 9, L = 25, TLS = 61); gas emissions (O = 5, L = 20, TLS = 36); greenhouse gas (O = 5, L = 20, TLS = 36); planning (O = 11, L = 27, TLS = 67); sustainable development (O = 47, L = 32, TLS = 232)
2	Green	economics (O = 12, L = 30, TLS = 80); energy (O = 6, L = 16, TLS = 26); energy policy (O = 31, L = 32, TLS = 168); energy sector (O = 16, L = 28, TLS = 87); energy security (O = 5, L = 22, TLS = 40); energy systems (O = 6, L = 23, TLS = 40); energy transitions (O = 6, L = 22, TLS = 43); renewable energy (O = 19, L = 31, TLS = 133); renewable energy resources (O = 18, L = 31, TLS = 105)
3	Blue	carbon (O = 6, L = 20, TLS = 26); carbon dioxide (O = 5, L = 21, TLS = 38); carbon emission (O = 5, L = 23, TLS = 38); economic and social effects (O = 8, L = 23, TLS = 47); environmental impact (O = 5, L = 23, TLS = 41); environmental technology (O = 5, L = 20, TLS = 36); global warming (O = 7, L = 23, TLS = 53); sustainable development goal (O = 6, L = 18, TLS = 31)
4	Yellow	alternative energy (O = 16, L = 29, TLS = 84); energy market (O = 7, L = 16, TLS = 30); energy utilization (O = 5, L = 20, TLS = 30); green economy (O = 6, L = 21, TLS = 38); investment (O = 16, L = 28, TLS = 93); sustainability (O = 9, L = 22, TLS = 39); wind power (O = 6, L = 22, TLS = 39)

Symbols: O = number of occurrences, L = number of links, TLS = total link strength calculated in VOSviewer. Source: Authors' elaboration in VOSviewer (version 1.6.19).

The Identified clusters (Table 4) are related to the different areas of the scientific interest of the analyzed publications' authors. First is the red cluster, which presents the environmental perspective on emissions caused by the energy sector. Therefore, in this cluster, "climate change", "fossil fuel", and "greenhouse gas" keywords are listed. Second, the green cluster in Table 4 consists of keywords related to the strategic perspective of the energy sector transition. In this cluster there are keywords "energy policy" or "energy security" revolve around "renewable energy" and "renewable energy sources". Third, a blue cluster is focused on the impact of the changes in the energy sector; the changes combine two previous perspectives, environmental and economic [72,73]. That is why in this cluster keywords such as "global warming", "carbon", "carbon dioxide", and "carbon emission" are collected along with "environmental technology" and "economic and social effects". The last subnetwork was visible in Figure 4, and Table 4 is marked in the yellow color cluster where "alternative energy" and "energy market" provide the context for "investment" in "green economy" to achieve "sustainability".

Calculated values of keywords occurrences, number of links, and total link strength indicate surprising characteristics because there is no clear relation between them. Most often, co-occurring keywords with the highest O value do not have the highest number of links (L) or total link strength (TLS). TLS values are higher for the keywords' places centrally [74] in Figure 4.

It should be noted that the individual clusters are not thematically uniform when it comes to keywords. In addition to issues directly related to the SD (keyword "sustainability" in a yellow cluster or "sustainable development" in a red cluster), there are also economic issues (represented by the "green economy" keyword), climate change and emissions issues, or numerous cross-disciplinary issues referring to the energy sector. The first cluster, the red one, is built from nine nodes, of which the keyword "sustainable development" is the largest node identified during the analysis (the most frequent word co-occurring 47 times). The green cluster is also built from the same number of nodes, where keywords are revolving around energy sector issues with economic issues. In this cluster, the most frequent word is "energy policy", with 31 co-occurrences. The blue cluster has eight nodes, while the keyword most frequently occurring is "economic and social effects" (eight co-occurrences). In addition, note here the reference to Sustainable Development Goals. In the fourth yellow cluster, "alternative energy" and "investment" are the most frequent keywords, both co-occurring in this subnetwork 16 times.

The results presented in this section have over five co-occurrences of keywords due to the selection of this minimum value in the VOSviewer program. The minimum number of five co-occurrences for the analysis of both sets of data was the result of research intentions to compare obtained results from Q1 and Q2 in graphical forms.

Figure 5 presents the graphical results of Q2 used for the Scopus literature exploration. In Figure 5, the minimum five co-occurrences of keywords are represented as nodes in the network. The edges of the network represent the explored co-occurrences between keywords in data obtained from Scopus. The keywords used in the Scopus Q2 were collected in Table 5 and are separated by semicolons. The keywords are written in small letters in Table 5, despite their original writing due to the VOSviewer procedures.

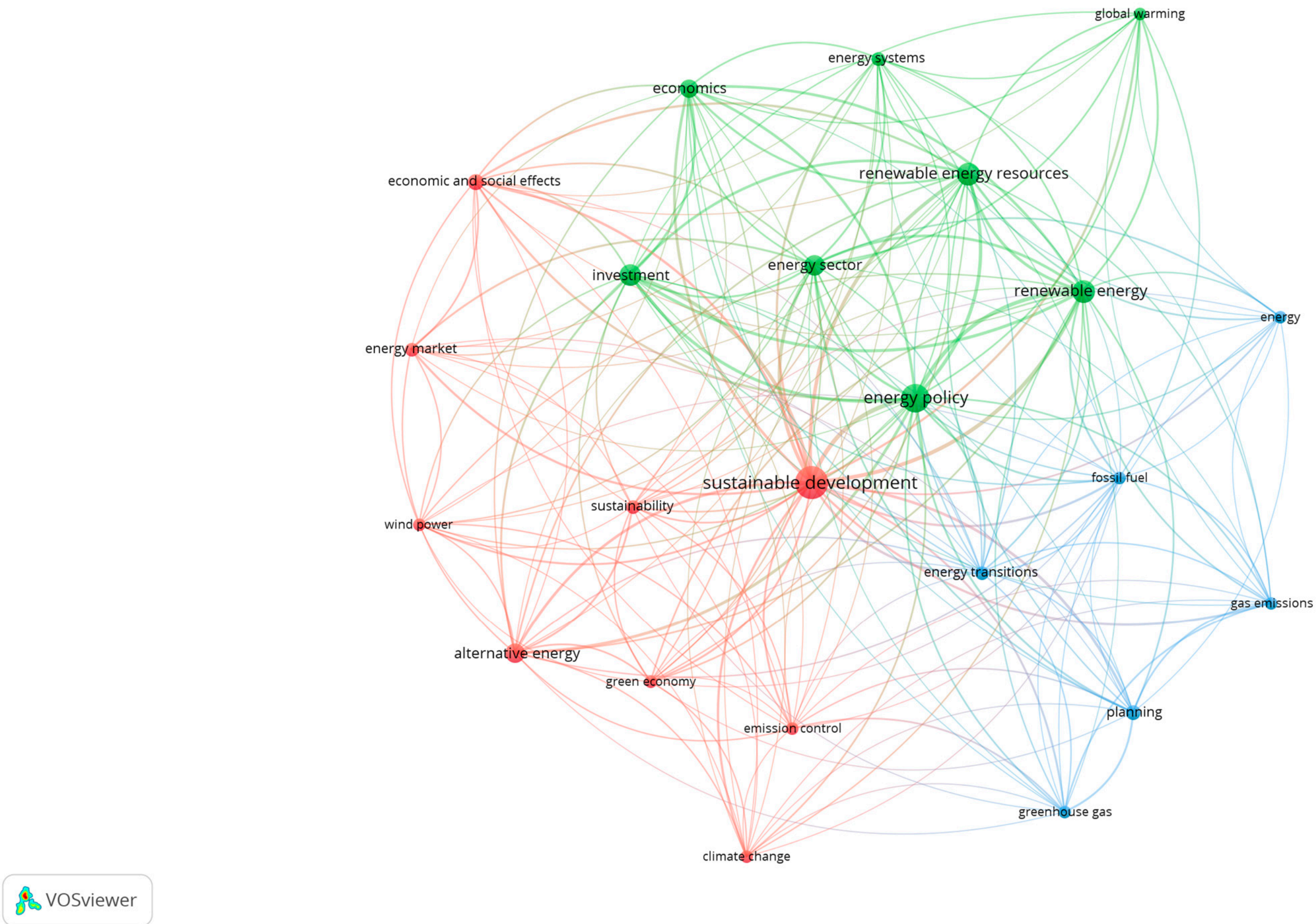

Figure 5. Bibliometric map of keywords co-occurrences results from Scopus based on original Q2. Source: Authors' elaboration performed in the VOSviewer (version 1.6.19).

Table 5. Clusters of keywords co-occurrences are presented in Figure 5 for Scopus Q2.

Cluster	Color	Keywords
1	Red	alternative energy (O = 11, L = 18, TLS = 50); climate change (O = 5, L = 16, TLS = 25); economic and social effects (O = 8, L = 16, TLS = 38); emission control (O = 5, L = 17, TLS = 26); energy market (O = 6, L = 14, TLS = 26), green economy (O = 5, L = 16, TLS = 31); sustainability (O = 6, L = 18, TLS = 30); sustainable development (O = 33, L = 22, TLS = 151); wind power (O = 5, L = 15, TLS = 26)
2	Green	economics (O = 10, L = 19, TLS = 56); energy policy (O = 24, L = 22, TLS = 115); energy sector (O = 13, L = 22, TLS = 71); energy systems (O = 6, L = 17, TLS = 33); global warming (O = 5, L = 12, TLS = 29); investment (O = 14, L = 20, TLS = 73); renewable energy (O = 16, L = 20, TLS = 95); renewable energy resources (O = 15, L = 21, TLS = 78)
3	Blue	Energy (O = 5, L = 13, TLS = 21); energy transitions (O = 6, L = 19, TLS = 39); fossil fuel (O = 5, L = 19, TLS = 35); gas emissions (O = 5, L = 15, TLS = 30); greenhouse gas (O = 5, L = 15, TLS = 29); planning (O = 7, L = 16, TLS = 37)

Symbols: O = number of occurrences, L = number of links, TLS = total link strength calculated in VOSviewer. Source: Authors' elaboration in VOSviewer (version 1.6.19).

In Table 5, there are three clusters automatically identified and ordered by the VOSviewer program. The clusters are represented by the same colors in Figure 5 and Table 5. The first cluster is marked in color red in Figure 5 and consists of co-occurring keywords related to the SD consequences of the green energy sector transition.

Similar to the analysis presented as a bibliometric map in Figure 4, the individual clusters in Figure 5 are not thematically uniform. The clusters are cross-disciplinary. Moreover, it should be noted that the keywords presented in Table 5 can also be found in Table 4. This similarity is because all the items generated in the Scopus database using query Q2 were simultaneously part of the narrower query Q1. This resulted in fewer keywords meeting the accepted threshold of five co-occurrences, which also translated into the fact that only three clusters were formed. In the red cluster, as in Table 4, the node with the highest number of occurrences was the keyword "sustainable development". In the green cluster, on the other hand, the "energy policy" node dominated. In the blue cluster, on the other hand, the most frequently co-occurring keyword was "planning". It should be pointed out that the obtained results presented in Table 5 differ from those obtained in Table 4 in the number of co-occurrences and the assignment of some of the keywords to a given cluster.

Keywords placed centrally in Figure 5 are also presented in Table 5, and their centrality is proved by the TLS values, "sustainable development" (TLS = 151) and "energy policy" (TLS = 115).

There is a significantly lower number of bibliometric map nodes in Figure 5 than in Figure 4. To illustrate the thematic evolution of interest in the green energy sector transformation the overlay analysis was performed and presented in Figures 6 and 7.

The overlay analysis presented in Figures 6 and 7 indicates which keywords were in scientists' focus over time and are still in use. The years are represented by the various color ranges. In blue, green, and yellow, the topics studied over the examined months in the years 2019–2021 are depicted. This relatively up-to-date timeframe for the analyses was obtained due to the articles selected for the analyses being selected as a result of a query that sought information on the green transition in the energy sector in the publication title, abstract, and keywords. Darker colors are used to mark the older publications, while light colors represent the newest publications.

The overlay analyses do not require further presentation in Tables because their content is covered by Tables 4 and 5, respectively. Figure 6 presents a more complete reference to the current issue in the form of keywords revolving around the subject of green transformation in the energy sector than Figure 7. This is due to the broader spectrum of the study caused by the inclusion of the analyses publications not indexed in the subject area "energy". The evolution of scientific interest in the subject pointed out that authors in their scientific studies aimed recently at presenting the issue of green transformation in the energy sector by general reference to "sustainability", and they paid attention to the issue of "global warming". Scientists were pointing out the relationship between the current state of the energy sector and its impact on the environment [75,76]. Other recently popular subjects are energy security, renewable energy, and green economy, because the energy sector is key to the transformation of the hitherto brown economy [77,78]. The "investments" are needed to change the current energy system [79,80], and next to the Sustainable Development Goals (described in Agenda 2030), the transformation of the energy sector [81,82], as well as the sources of generated energy in general, occupy an important place in the context of changes aimed at global sustainability in the energy sector.

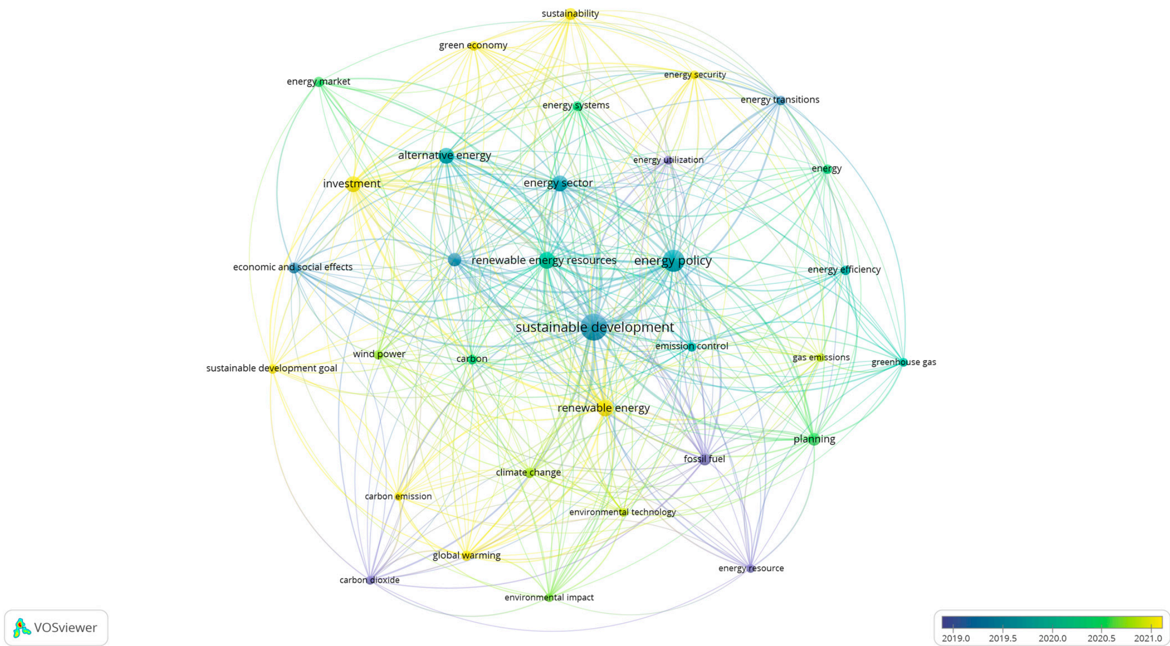

Figure 6. Bibliometric map of keywords overlay results from Scopus based on original Q1. Source: Authors' elaboration performed in the VOSviewer (version 1.6.19).

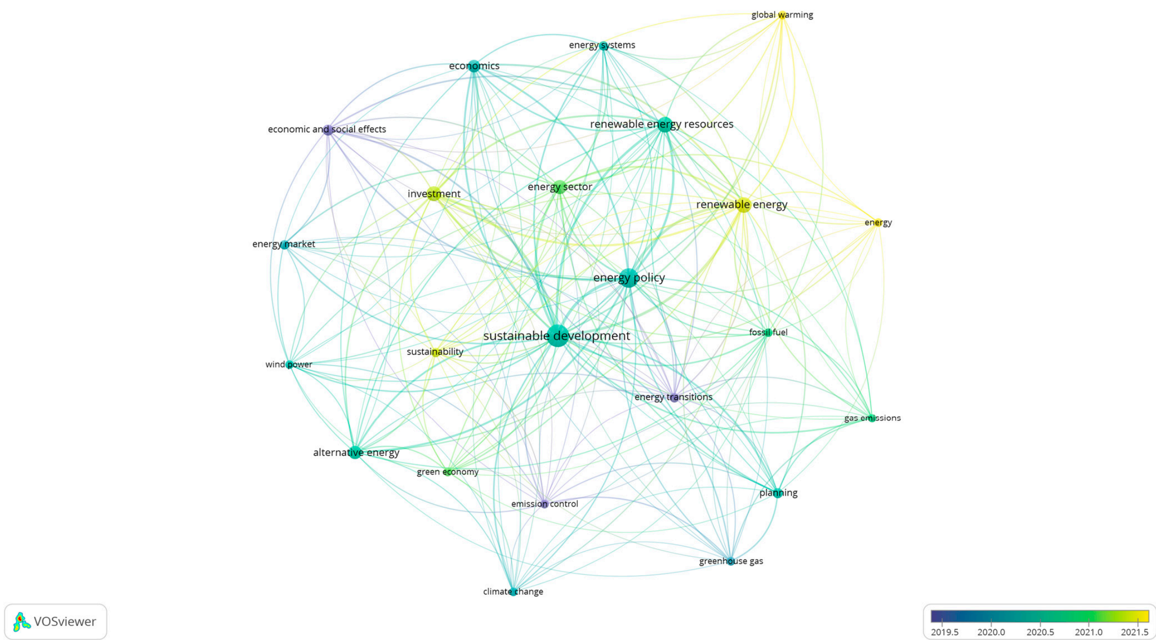

Figure 7. Bibliometric map of keywords overlay results from Scopus based on original Q2. Source: Authors' elaboration performed in the VOSviewer (version 1.6.19).

4. Discussion

Transformation of the energy sector towards the green energy sector has been mainly considered in this study, which aimed to explore the subject of scientific literature. Despite the used query syntaxes, there were no nodes in Figures 4 and 5 representing "green transition" or "transformation". However, among the results presented in the form of bibliometric maps, there are SD areas related to the green transformation in the energy sector. The exploration of the Scopus-indexed literature is important for understanding the processes of the energy transition and achieving the Sustainable Development Goals in the energy sector [83,84].

The multidimensional nature [85] of these transformations is evident in the disparity between Q1 and Q2 queries. Narrowing down the scope of analysis results in the loss of valuable information present in articles published outside the energy-related subject area. However, this approach highlights the existence of scientific papers from other fields that address the issues of green transformation [86,87] in the energy sector [2,33]. The observed discrepancy between Q1 and Q2 suggests that the topic of green transition was initially discussed in non-energy-related journals. Notably, the first article on green transformation in the energy sector appeared in 2005 [88], inducing then-growing interest in industry-specific journals.

Despite the growing popularity of Green Jobs (GJs), they have not been prominently featured in bibliometric maps or identified as frequently occurring terms in titles, abstracts, and keywords [89]. However, it is important to recognize that GJs are a direct outcome of the green economic transformation, which is acknowledged in research findings. The authors anticipate that in future analyses, the research popularity of GJs in this field may lead to their inclusion as a prominent term [51]. The green transformation necessitates the reskilling of existing energy sector workers to acquire green competencies, thereby facilitating the transition from traditional jobs to GJs.

In addition to the creation of new GJs, the energy sector undergoes a transformation from traditional practices to green practices [90,91]. The analysis of bibliometric maps indicates that the green transformation in the energy sector is multifaceted, with a broad transformational aspect and a narrow focus on the transition itself. Researchers have adopted different approaches to these transformations, emphasizing sustainable development. Some scientific papers highlight a gradual and multidimensional green transformation [92], while others focus on unidimensional changes during the transition when the other papers opened a discussion about transformation and transition differences [93,94].

Surprisingly among the identified keywords, there is a lack of those indicating energy sector regulations. Compliance with regulations and policies related to the SD also helps business to attend to the energy sector green transformation and is also potentially reducing costs and increasing profits. The lack of certain keywords can be seen as a research limitation. In this study, another limitation is that only the frequency and popularity of certain keywords in scientific publications are presented without the positive or negative meaning. The method used in this paper primarily focuses on keyword co-occurrences and their presentation, and while it is a useful approach, keyword analysis can sometimes overlook the broader context of the single publication.

The main limitation is caused by the selection of the single database explored in this research, which was Scopus. In addition, in this research, indexed keywords were analyzed, and therefore results from other popular among scientists' databases such as Web of Science or Google Scholar would cause the problem of different indexation conditions. There are other differences between gathered metadata other than Scopus databases, and the publications are grouped in different collections, referred to as subject areas. The publications are indexed in multiple databases, so the comprehensive analysis based on the vast collection would demand decision-making about which source is primary and which publication to choose for further analysis.

One of the inherent limitations of the present investigation pertains to the design of the query and the selection of keywords. The problem of the searched keywords identification is either caused by the query syntax or the rarity of those words in the examined database [2]. In this particular study, the researchers employed the term "energy sector" as the basis for their queries. However, an alternative approach could have involved utilizing the more generic term "energy". Nevertheless, adopting such a broad approach would have yielded an excessively wide-ranging scope of investigation. Furthermore, incorporating different keywords would have introduced an additional differentiating factor, alongside the assignment of the journal to a specific domain.

The choice of conjunction operator is another significant methodological implication that warrants attention. By employing the logical operator 'and', the researchers would have effectively reduced the number of publications retrieved, whereas the 'or' operator would have augmented the search outcomes [95]. This underscores the criticality of appropriately constructing queries in Scopus, taking into careful consideration the chosen operators and the syntax employed in query formulation. Such meticulous attention to query construction is imperative to ensure the accuracy and reliability of search results. In this paper there is a specific limitation related to the VOSviewer program which recognizes or reverts the capital letters of abbreviations to small letters. Therefore, attention is required to revise each keyword.

5. Conclusions

The energy sector is pivotal for each country's economy and influences all other economic sectors [56]. On the other hand energy sector fuels the economy of each country [2]. The interest in the subject of green energy sector transformation has been presented as visible growth of publication numbers in the Scopus database. In the VOSviewer program, the subject evolution has been explored in the SD perspective [78,96]. The bibliometric analyses of the green transformation in the energy sector are still rare due to the complexity and the number of scientific publications, and this paper covers this research gap.

The aim of this paper to present the areas of the green energy sector transformation towards SD context distinguished in the scientific literature review was accomplished using VOSviewer software. The main reason for choosing VOSviewer over the other bibliometric programs is its ability to support original query syntaxes and the possibility to replace overlapping keywords in the analysis procedure. Additionally, VOSviewer also characterizes by a developed graphical presentation of performed analyses.

The results presented in this research proved that transformations in the energy sector extend beyond technical aspects such as energy sources and technology. They also encompass economic, political (energy security), and social dimensions. The results of the sectoral analysis indicate that energy sector transformation has multiple dimensions and outcomes, correlated with areas of the SD [97]. One of the issues most often raised in publications is energy security [2]. Energy security includes ensuring electricity availability, uninterrupted energy supply, achieving energy independence, and diversifying energy sources [98,99].

The bibliometric analysis illustrates the evolution of the energy sector's green transformation towards SD presented in the scientific literature. This has been achieved by the presentation of the significant keywords. The visualization of the researched subject constitutes the scientific contribution of this paper along with a detailed tabular description of the obtained results. Another scientific input is a detailed description of procedures that assure the reproducibility of the research by other authors.

The scientific contribution of this article lies in providing a general pattern of the significant keywords repeated between results of the used queries. The evolution of the keywords presented in graphical form can be considered an indication of the emerging trends in scientific literature. Theoretical implications of the identified co-occurring keywords are important for business in the SD context.

The energy sector transformation review can be useful for management processes in organizations of this sector. It can help managers to plan business policy, to develop strategy, and make decisions about prices, staffing, and marketing. Managers can identify trends and respond to the changes in the energy sector, which can overall improve the performance of the business. The information can help to reduce the energy sector's negative impact on the natural environment and become more sustainable.

The methodological implication used in this research is the merging keywords procedure used in the VOSviewer keywords analysis. A VOSviewer thesaurus file can be used to merge different variants of keywords; however, the file has to be proposed and constructed by the authors. This process of merging similar keywords or their abbreviations and different forms (American or British English, singular or plural) can result in a greater number of keyword co-occurrences appearing in the bibliometric map. The keywords co-occurrence map in effect of the merging process can become richer, have more keywords, and simultaneously be more readable as there are fewer synonyms or linguistic versions of the same keyword. Researchers can therefore draw inspiration from the analyses performed. This option in VOSviewer not only allows the existing keyword database to be explored from the database metadata but also enables the creation of customized keyword queues tailored to a specific perspective.

The authors recommend focusing on the scope of research rather than narrowing it down to specific categories, as journals are connected to broader subject areas. Additionally, they suggest exploring alternative databases and utilizing bibliometric tools with enhanced features for a more comprehensive analysis of scientific literature. Future research can be extended with another popular bibliometric software [2,100]. In the future, in-depth bibliometric research combined with a classical literature review can consider the general pattern for renewable and non-renewable energy sources. This has the potential to open doors for the application of additional quantitative approaches, such as conducting a meta-analysis on the factors found in existing literature regarding the progress of the energy sector's shift towards SD, specifically focusing on its green transformation [101]. Therefore, possible research avenues of extended research can focus on the energy carriers' types or forecasting methods.

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