energies

Review

Charting the Global Energy Economy Research: Trends, Gaps, and Paradigm Shifts

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Abstract

The review provides the results of the analysis of research publications in the field of energy economy on a global scale. The review aims to test three hypotheses and build and analyze the main trend lines and clusters to determine the direction of movement of new knowledge in the energy economy research. This review delves into the multifaceted nature of energy transitions, highlighting the pivotal role of policy frameworks, financial instruments, and technological innovation. By examining the socio-economic implications of renewable energy deployment and addressing the challenges associated with energy storage and grid integration, this study contributes to the ongoing discourse on sustainable energy development. The review used scientometric, correlation, and bibliometric methods of analysis. Artificial Intelligence was used to process 411,396 units of information (a special prompt was created). There is a new scientific result: (a) research hypotheses 1 and 3 were accepted, research Hypothesis 2 was rejected; (b) new trend lines showed the directions where the global energy economy is heading; (c) new clusters showed the top five leading countries and top 10 keywords in the field of energy economy; (d) leading journals in the studied area were found. The review indicated an underrepresentation of specialized journals in this field among the top journals. The review also showed that several keywords characterizing the sixth technological paradigm are missing from the top 10 keywords. This result suggests that these research areas were underrepresented in citation-based bibliometric data in energy in 2021–2024. The review is useful to identify promising and problematic areas for future research in the global energy economy.

Keywords: energy; energy economy research; energy efficiency; knowledge economy; sixth technological paradigm; innovations; sustainable development; economics; economic and social effects

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1. Introduction

This review continues the authors' previous publication on the influence of knowledge and innovation on energy development [1]. In the mentioned paper [1], the authors analyzed the problems of Polish energy, including renewable energy. The analysis was carried out from the point of view of the knowledge economy. The current work retains economic approaches to the study of the energy sector. Here, the main trends and clusters in the field of energy economy have been built and studied. The first difference between this paper and the previous one [1] is the global approach, since the previous focus was on local energy in Poland. Further, in the previous publication, research in the Polish energy sector was analyzed [1]. The new article focuses on analyzing research in the energy sector economy. The second difference is the change in the focus of our research. Both differences are implemented based on the knowledge economy, which occupies a central place in modern economic research, including the energy sector [2–11]. The knowledge economy is "production and services based on knowledge-intensive activities that contribute to an accelerated pace of technical and scientific advancement" [5].

Knowledge is an essential and effective resource in the modern economy that helps enterprises increase revenues through market growth [8]. The knowledge economy relies on intellectual resources, including innovation, scientific knowledge, and information [12]. In other words, "a key component of the knowledge economy is a greater dependence on intellectual capabilities than on physical costs or natural resources" [5]. Therefore, the knowledge economy helps to accelerate the implementation of innovations and create new value for customers [8].

Currently, civilization is meeting with the sixth technological paradigm [13–16]. The use of artificial intelligence [16,17], digitalization of management processes [15], and the processing of big data [1,17] contribute to increasing the technological and economic efficiency of civilization. The characteristics of the sixth technological paradigm require new knowledge, which is generated from scientific research and reflected in scientific publications [1,4,11,17].

Energy is one of the key industries that determines the development of the sixth technological paradigm [18,19]. The knowledge economy, based on access to new information [4,5,7,12] and active interaction between various sectors of the economic complex, is becoming a driving force for creating and implementing innovations in the energy sector [1,7,18–20]. For example, recent data indicate that transferring technology and knowledge is vital for energy efficiency and sustainability [20].

Scientific publications play an essential role in the dissemination of new knowledge and the implementation of innovations. They record the results of scientific research. Scientific publications facilitate the exchange of ideas and the generation of new hypotheses. They also form the basis for creating networks for interdisciplinary and international cooperation [13–16,18,19]. The publication of scientific articles in reputable scientific journals stimulates cooperation between scientists and industry, especially in the energy sector [1]. Journals indexed in databases recognized by the scientific community, such as Scopus and Web of Science, play an important role in the knowledge economy [1,5,17]. For the scientific community, publications in such journals become the basis for creating global scientific networks and integrating knowledge with real technologies [1,13–17,20]. The energy sector needs such integration since economic decisions can be considered an ideological component of innovations in the knowledge economy [1,17]. It seems logical that the growth (fall) in the number of scientific publications on the "economy" in the world will lead to the growth (fall) in the number of publications on the "energy economy" in the world.

Figure 1 shows the results of scientometric and correlation analyses [1,17] for the keyword "economy." The scientometric analysis was performed based on the search results for scientific publications in the Scopus database from 2015 to 2023 (393,040 search results, https://www.scopus.com/term/analyzer.uri, accessed on 30 October 2024). The keyword "economy" was chosen due to the importance of the ideological component of innovation [1,17] in the energy sector.

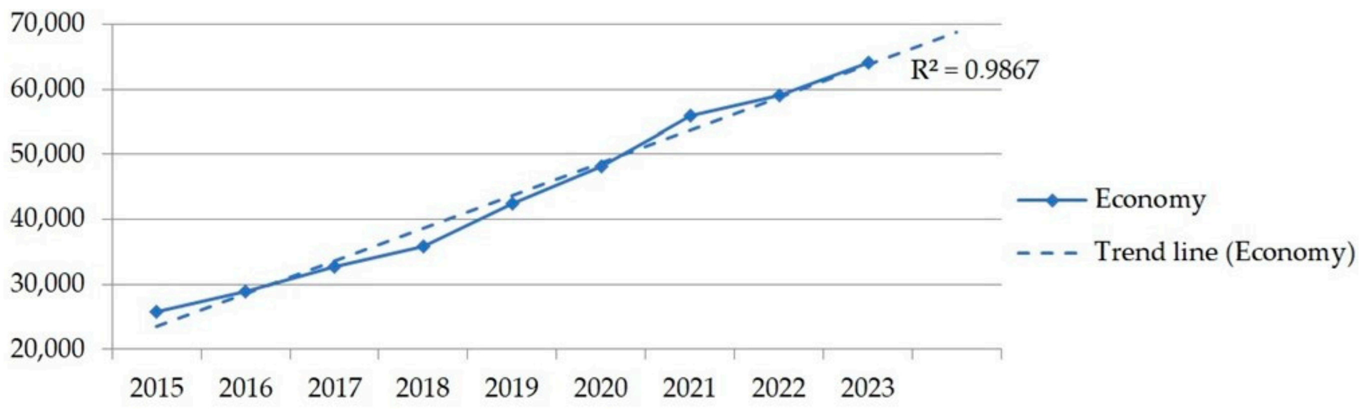


Figure 1. The number of publications on the keyword "economy" in the world.

Visually, Figure 1 demonstrates an increasing trend line with R^2 = 0.9867. This value indicates a growing interest in this topic among scientists worldwide.

The correlation coefficient R^2 = 0.9867 indicates an extremely high degree of linear dependence between the variables under consideration. A R^2 value close to 1 means that 98.67% of the variation in the dependent variable is explained by changes in the independent variable within the model. This value indicates an almost perfect fit of the data with the trend line.

The increasing trend line visualized in Figure 1 confirms the presence of a strong positive correlation. This correlation means that an increase in the values of the independent variable leads to a proportional increase in the values of the dependent variable. The high R^2 coefficient also emphasizes the stability of the model and its high predictive ability. However, it should be noted that statistical dependence does not always mean causation. Therefore, the value of R^2 = 0.9867 confirms the existence of a strong positive linear relationship between the variables. It is possible to conclude that the stable growth in the number of publications on "economy" leads to a stable growth in the number of publications in the field of "energy economy" worldwide.

Search Hypothesis 1: *The global trend line for the number of publications in the field of energy economy is steadily increasing from 2015 to 2023.*

Search Hypothesis 2: *The growth in the number of publications in the field of energy economy does not have abnormal deviations from the straight trend line.*

Search Hypothesis 3: *The transition to a sustainable energy future requires a multifaceted approach, combining technological advancements, supportive policies (including economic), and societal shifts.*

The purpose of the review is to test three research hypotheses and shed light on the global trend lines and clusters in the field of energy economy. The time frame of the study was from 2015 to 2023. Therefore, all extreme events (COVID-19, full-scale war in Ukraine, etc.) affect the final result.

The scientific novelty of the study is the acceptance of both proposed research hypotheses, the new application of AI tools to solve a specific research problem, and the construction and analysis of trend lines and clusters describing the state of the global energy economy on a stable section of the trend line with high predictive potential. The main conclusions expressed in the review: (1) The trend line of interest of scientists in research in the energy economy is steadily directed upward, i.e., the number of publications in this area is moving up (growing); (2) The share of research in the field of energy economy was moving upward until 2021. In 2021, it reached a state of stability and moved almost parallel to the abscissa axis from 2021 to 2024; (3) The top five countries that lead the scientific community in energy economy research are China, India, the USA, the United Kingdom, and Italy; (4) The top five scientific journals that lead the scientific community in energy economy research are *Sustainability* (Switzerland), *Journal of Cleaner Production, E3S Web of Conferences*, *Energies*, and *Energy*. Most citations are in the *Journal of Cleaner Production*, *Sustainability* (Switzerland), *Energy*, and *Energies*; (5) The top 10 keywords showing the most cited areas of research in energy economy are "sustainable development," "economic analysis," "energy efficiency," "energy utilization," "economic and social effects," "economics," "carbon dioxide," "renewable energies," "alternative energy," and "renewable energy resources." Based on the review results, the goals of future research are planned; (6) The main directions of future research are shown.

The article is structured as follows: Introduction (presents the relevance of the problem, hypotheses, scientific novelty, and practical significance); Materials and Methods (describes the main steps of the study); Results and Discussion (the authors test three hypotheses and discuss the results obtained); and Conclusions (the authors confirmed the research hypotheses, summarized the main results of the bibliometric analysis, identified key trends and clusters in the field of energy economics, and outlined the limitations and directions for future research).

2. Materials and Methods

This manuscript continues to publish the results of a previously initiated general study in the scientific fields of "energy" [1] and "economy" [17]. This part of the general study was conducted from 7 May to 18 December 2024. This part was carried out in several stages.

In the first stage, a general assessment of the research area was performed through a classical literature review, scientometric analysis (qualitative study), and correlation analysis (quantitative study). Scientometric analysis was performed based on the results of a search for scientific publications by the keyword "economy" in the Scopus database from 2015 to 2024 (445,480 search results, https://www.scopus.com/term/analyzer.uri, accessed on 30 October 2024).

In the second stage, research hypotheses 1 and 2 were tested. First, scientometric and correlation analyses of scientific publications in the field of global energy economy were performed. Scientometric analysis was performed by searching scientific publications in the Scopus database from 2015 to 2023. For this purpose, publications related to the energy sector "energy" were selected from 393,040 search results for the keyword "economy." A total of 46,964 search results were used to construct a trend line of publications in the field of energy economy in the world. To compare trend lines and their sections, the article systematically uses the standard linear trend model in the following form:

$$y = a \cdot x + b, \quad (1)$$

where x—year (time indicator), y—number of publications or share of publications, and a—coefficient reflecting the slope.

R^2—determination coefficient assessing the degree of conformity of empirical data to a given linear relationship.

Then, the authors constructed a graph reflecting the share of publications (%) on the topic of "energy economy" relative to the number of publications on the subject of "economy" in the world. This graph of the relative weight of publications in the field of global energy economy was divided into two trend lines: 2015–2021 and 2021–2023. The trend line section after 2021 was selected for further study of trends and clusters in the field of energy economy worldwide.

During the fourth stage, the trend line in the field of energy economy (2021–2024) was analyzed to study the top five positions among the following:

- Countries by the number of publications;
- Scientific journals by the number of publications;
- Scientific journals by the number of citations.

The number of citations of scientific articles is an essential indicator of the influence and significance of the research. The more citations an article has, the more interest it generates in the scientific community. In simple terms, we can say that the number of citations reflects the innovative, breakthrough, revolutionary nature of the published information.

Citations can also indicate the quality and reliability of the research since the more reputable scientists refer to an article, the more likely it is to contain valuable information. Thus, the number of citations plays an important role in the scientific community, helping to track influential articles, reputable journals, and modern trends in research areas.

To process a large array of bibliometric data (7825 scientific documents containing 411,396 citation records), an artificial intelligence (AI) system was used with a multi-step prompt (Appendix A). The model was based on the GPT-4o architecture and could statistically process data. The analysis included (1) sequential structuring of raw publication metadata in Excel tables; (2) sorting and systematization of data by publication sources; (3) calculation of statistical indicators: the mathematical expectation of the number of citations per article M(x), the standard deviation for the sample and the general population S(x), $S(x-1)$; and (4) ranking of journals by citation indicator. Quality control included checking for outliers, merging duplicate journal titles, and uniform processing criteria for all data subsets. This methodology ensured transparency, reproducibility, and statistical reliability when analyzing citation dynamics in energy economics.

Research Hypothesis 3 was tested using data from 2021 to 2024. At this stage, bibliometric analysis was used for the keywords "econom*" and "energ*". Bibliometric analysis (qualitative study) was performed based on the search results for scientific publications in the Scopus database from 2021 to 2024 (407,552 search results, https://www.scopus.com/ accessed on 10 December 2024, analysis tool—VOSviewer, version 1.6.19, ©2009–2023 Nees Jan van Eck and Ludo Waltman). The main clusters for the keywords "econom*" and "energ*" were built and analyzed.

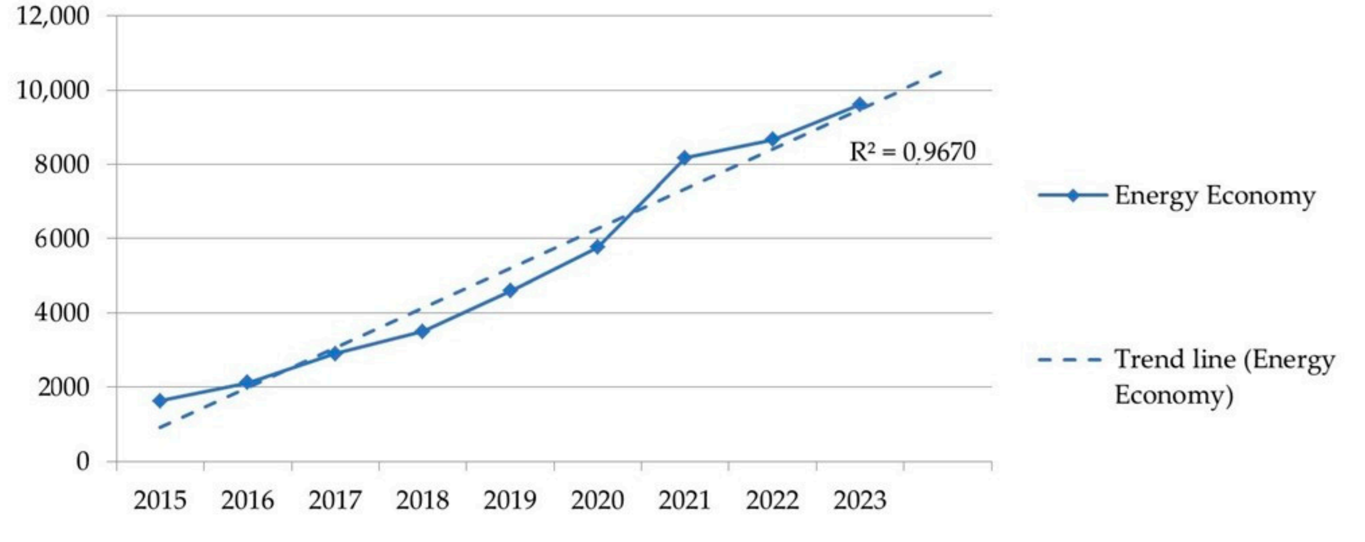
Finally, the authors discussed the results.

3. Results and Discussion

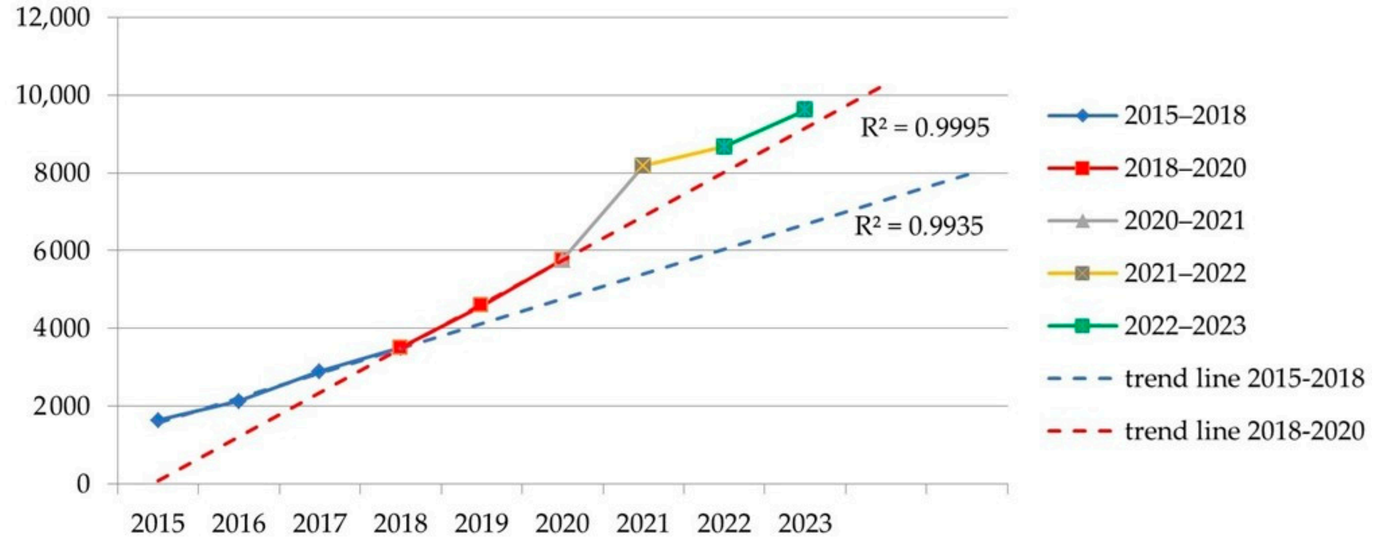
3.1. Testing Research Hypothesis 1

Figure 2 shows the results of scientometric and correlation analyses of publications in the field of energy economy worldwide. The scientometric analysis was performed based on the results of a search for scientific publications in the Scopus database from 2015 to 2023 (46,964 search results).

Visually, Figure 2a demonstrates an increasing trend line with R^2 = 0.9670. This value indicates a growing interest in this topic among scientists worldwide. The correlation coefficient R^2 = 0.9670 indicates an extremely high degree of linear dependence between the variables under consideration. A R^2 value close to one means that 96.70% (Figure 2) of the variation in the dependent variable is explained by changes in the independent variable within the model. This value indicates an almost perfect fit of the data with the trend line. The increasing trend line visualized in Figure 2 confirms the presence of a strong positive correlation. This trend means that an increase in the values of the independent variable leads to a proportional increase in the values of the dependent variable. The high R^2 coefficient also emphasizes the stability of the model and its high predictive ability. At the same time, it should be remembered that statistical dependence does not always mean causation. Therefore, the value R^2 = 0.9670 confirms the existence of a strong positive linear relationship between the variables. It is possible to conclude and accept research Hypothesis 1 that the global trend line of the number of publications in the field of energy economy shows stable growth.



(**a**)



(**b**)

Figure 2. The number of publications in the field of the global energy economy. (**a**) General view of the trend line. (**b**) Trend lines in the form of separate sections.

In turn, Figure 2b shows a more interesting picture. First of all, Figure 2b shows five sections of a straight line with different slopes (statistical characteristics are summarized in Table 1).

Table 1. Statistical characteristics of straight lines in Figure 2.

Time Limits	Regression Equation	R^2	A
2015–2023	y = 1073.1x − 147.11	0.9670	1073.1
2015–2018	y = 637.3x + 945	0.9935	637.3
2018–2020	y = 1134.5x − 1055.8	0.9995	1134.5
2020–2021	y = 2410.0x − 8694	1.0000	2410.0
2021–2022	y = 490.0x + 4746	1.0000	490.0
2022–2023	y = 950.0x + 1066	1.0000	950.0

Table 1 shows the overall slope of the trend line of the global energy economy equal to 1073.1 with a correlation coefficient of R^2 = 0.9670. Dividing the overall dependence (Figure 2a) into separate sections (Figure 2b) led to higher values of the correlation coefficient for each section (Table 1). Table 1 shows a weaker increase in publications in the 2015–2018 section compared to the overall trend line (slope). This was the period before the COVID-19 pandemic. In the 2018–2020 section, Table 1 shows an increase in publications comparable to the overall trend line. This was the period of the COVID-19 pandemic. In this section, the slope is higher than in the 2015–2018 section by almost two times. This fact can be interpreted as the absence of a negative impact of the COVID-19 pandemic on the publication activity of scientists in the field of energy economy.

The slope in the 2020–2021 section is two times higher than in the previous section. A higher slope value than the general trend line also characterizes the 2020–2021 section. In the next section (2021–2022), the slope decreases almost five times compared to the previous one. During this period, civilization emerged from the pandemic, and the decline in publication activity cannot be associated with this event. Further, in the 2022–2023 section, the slope increased two times compared to the 2021–2022 section. The slope value approached the slope value of the general trend line. In general, changes in the slope value in 2018–2023 (Table 1) can be associated with armed aggression in Ukraine. The world was preparing for energy independence and increased the intensity of research. This hypothesis is not the purpose of this review. It can be tested at the next stage of the study.

Changes in the slope of the trend line in individual sections by 2–5 times can be considered anomalies in the publication activity of scientists in the field of energy economy. The final section (2022–2023) is characterized by a slope approximately equal to the slope of the general trend line (2015–2023). Thus, the first research hypothesis is accepted, and the second is rejected.

It is interesting to compare the number of scientific publications in the energy economy and the economy field. The result will show both the general interest of economists in energy economics and the trend line of such interest.

Figure 3 shows the share of publications (%) in the field of energy economy relative to the number of publications on the topic of "economy" in the world. A total of 445,480 search results of scientific publications in the Scopus database from 2015 to 2024 were used to plot the graph.

Figure 3 shows a graph representing two trend lines with a break in 2021. A steadily increasing trend line up to 2021 is described by the regression equation y = 1.2881x + 4.7997 with R^2 = 0.9730. This value indicates a growing interest in this topic among scientists worldwide. This line likely reflects innovation's outpacing growth at the intersection of economics and energy against the background of economic research. This outcome may result from changes in energy technologies [18,19] and economic science, as in the ideological component of innovation [5,13,17]. The correlation coefficient R^2 = 0.9730 indicates an extremely high degree of data consistency with the trend line, which means minimal scattering of points around the trend line. The visually increasing trend line in Figure 3 (blue) confirmed the presence of a positive relationship. As the values of the independent variable increased, the dependent variable also increased.

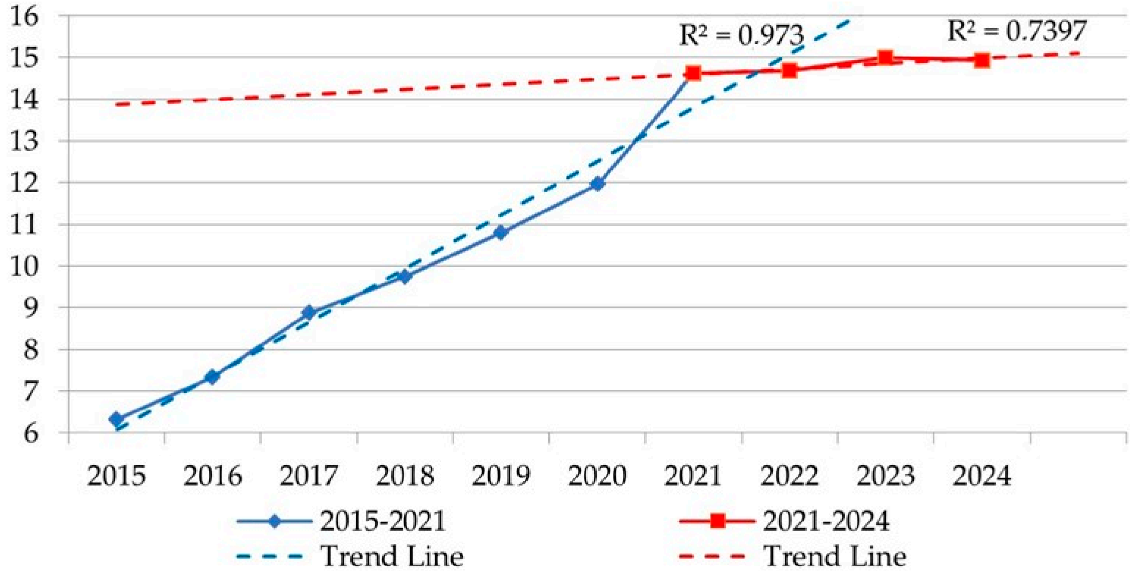


Figure 3. Share of publications (%) in the field of energy economy relative to publications on the topic of "economy" in the world.

Further, after 2021, we see a trend line almost parallel to the abscissa axis (Figure 3). This trend line is described by the regression equation y = 0.1241x + 13.75 with R^2 = 0.7397. This value indicates a slowdown in the growth rate of research in this area. So, publications on the topic of energy economy have reached an equilibrium point among other areas of economic science. This observation may result from the completion of transformations in energy technologies [18,19] and transformations in economic science, as in the ideological component of innovation [5,13,17]. The correlation coefficient R^2 = 0.7397 indicates a high degree of linear dependence between the variables under consideration. The R^2 value of 0.7397 means that about 73.97% of the variation in the dependent variable is explained by changes in the independent variable. This value indicates a positive correlation between the variables and suggests that the linear trend model describes the observed data well. However, about 26.03% of unexplained variation remains, which may be due to the influence of other factors not included in the current model or random fluctuations. Thus, Figure 3 shows the stabilization of the share of publications in the field of energy economy concerning the total number of publications on the topic of "economy" in the world (2021). This stable section of the graph after 2021 was adopted to study the clusters and top five positions in the global energy economy.

3.2. Analysis of the Top 5 Positions in the Field of Energy Economy (2021–2024)

3.2.1. Top 5 Leading Countries in the Global Market of Scientific Products (Energy Economy)

Figure 4 shows the number of publications in the Scopus database in the field of energy economy for the top five leading countries (231,511 search results from 2021 to 2024).

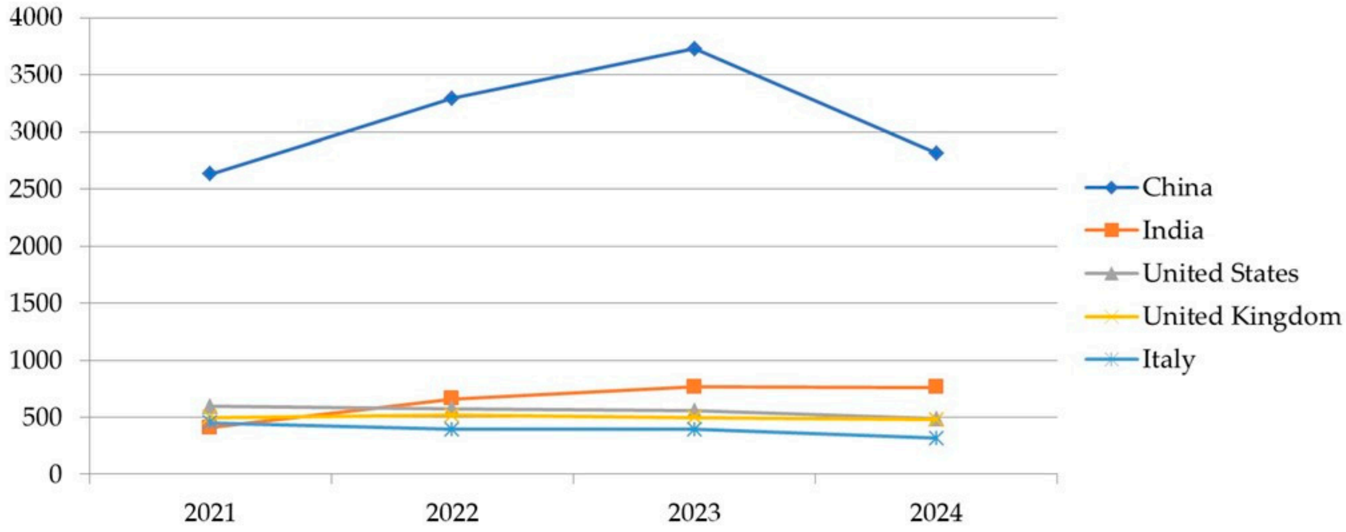


Figure 4. Top 5 leading countries by the number of publications in the Scopus database in the field of energy economy.

Figure 4 shows that China is the absolute leader in the number of publications. It is followed by countries such as India, the United States, the United Kingdom, and Italy. China is ahead of the other top countries by 2000–2500 publications annually.

In China, the number of publications in the field of energy economy increases sharply from 2021 to 2023. In 2024, the decline in the number of publications is disproportionately high (Figure 4).

In India, the number of publications in the field of energy economy is gradually increasing from 2021 to 2024. In the other top leading countries, it has remained virtually unchanged. A slight decline in the number of publications in Italy can be compensated by the end of the year (Figure 4).

Thus, Figure 4 demonstrates the clear quantitative dominance of Chinese scientists in the global market of scientific products in the field of energy economy.

3.2.2. Top 5 Leading Journals by the Number of Publications in the Global Market of Scientific Products (Energy Economy)

Figure 5 shows the number of publications in the Scopus database in the field of energy economy for the top five leading journals (231,511 search results from 2021 to 2024).

Figure 5 shows that the absolute leader in the number of publications is the journal "Sustainability" (Switzerland). This journal is ahead of the other top journals by 500–1500 publications annually.

Also, Figure 5 shows that scientific publications in the field of energy economy were not published in journals with an economic profile. Two of the top five journals are journals on energy: "Energies" (fourth position) and "Energy" (fifth position). The first three top scientific publications are weakly related to the energy economy, judging by their titles. The specialized journal "Energy Economics" is in seventh position in the rating. This scientific fact may indicate problems with publishing research results in specialized scientific journals in the studied field. For example, such problems may be a small number of specialized journals, a long period of the editorial process, an unreasonably high APC, etc. Thus, Figure 5 demonstrates the clear quantitative dominance of the scientific journal "Sustainability" (Switzerland) in the world market of scientific products in the field of energy economy. Figure 5 may indicate an underrepresentation of specialized journals in this field among the top journals. This fact may require further study of the structure of submissions or editorial dynamics.

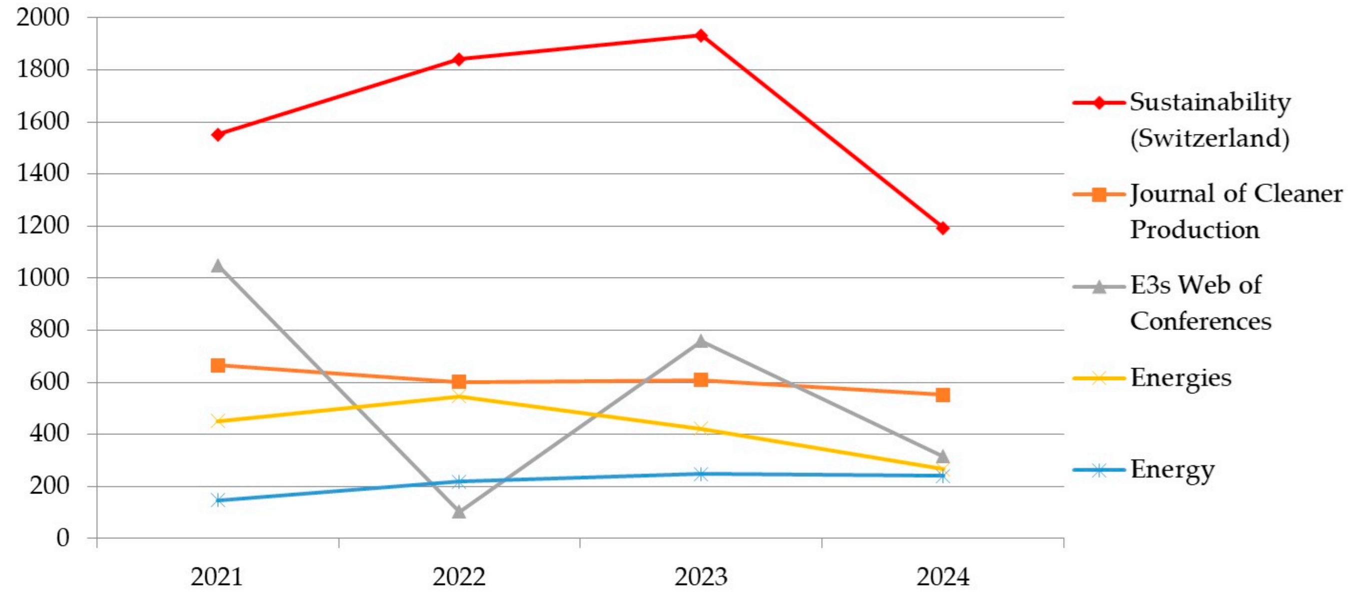


Figure 5. Top 5 leading journals by the number of publications in the Scopus database in the field of energy economy.

3.2.3. Top 5 Leading Journals by the Number of Citations in the Global Market of Scientific Products (Energy Economy)

Figure 6 shows the top five leading journals and the number of citations of previously published papers in the field of energy economy in these journals (394,300 search results from 2021 to 2024).

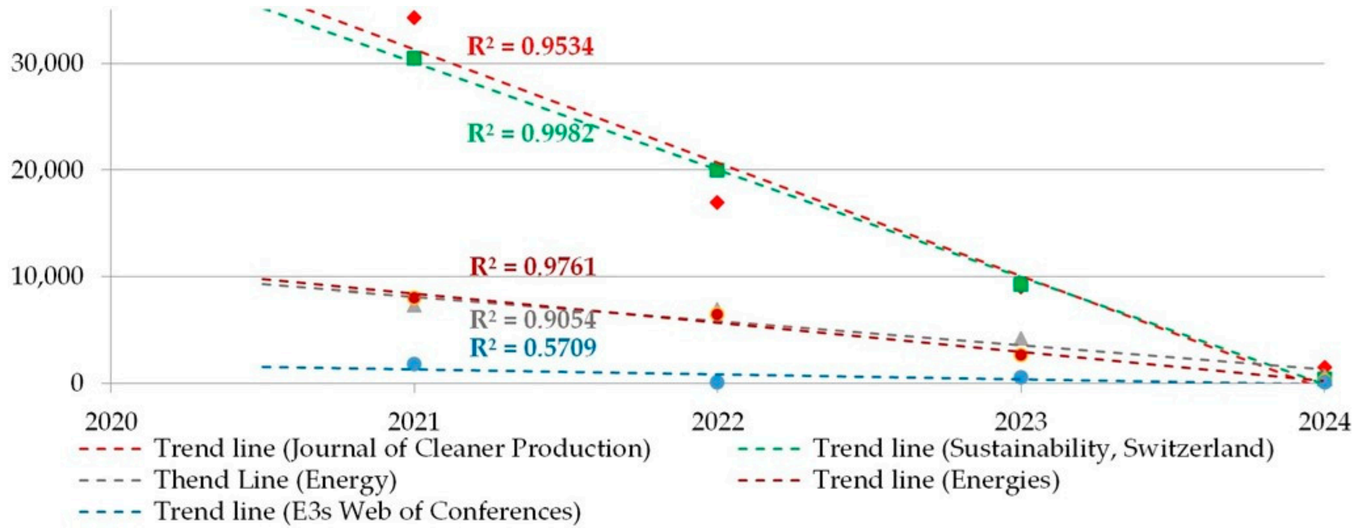


Figure 6. Top 5 leading journals and the number of citations of previously published publications in the field of energy economy.

Figure 6 shows that the articles published in the journals "Journal of Cleaner Production" and "Sustainability" (Switzerland) received the most citations. The number of citations of articles decreases in direct proportion from 2021 to 2024. The value of the correlation coefficient R^2 demonstrates a strong positive relationship between the variables and confirms the statistical significance of the dependence.

Articles published in the journals "Energy" and "Energies" received approximately three times fewer citations (Figure 6). In these journals, the number of citations of articles also decreases in direct proportion from 2021 to 2024.

The value of the correlation coefficient R^2 demonstrates a strong positive relationship between the variables and confirms the statistical significance of the dependence. Publications in the scientific journal "E3S Web of Conferences" have a very low number of citations (Figure 6). In addition, the value of the correlation coefficient $R^2 = 0.5709$ indicates that the model explains the data only partially. Although a linear dependence is present, it is not extremely strong, which requires a cautious approach when interpreting the results. This indicator demonstrates that changes in the independent variable have a noticeable but incomplete effect on the dependent variable.

The highest value of the correlation coefficient is shown by the journals "Sustainability" (Switzerland), "Energies," "Journal of Cleaner Production," and "Energy" (Figure 6). These journals provide predictable growth in publication citations over three years.

Thus, the least authoritative of the top five scientific publications is "E3s Web of Conferences". This publication has the lowest number of citations and the weakest predictive potential. The journals "Journal of Cleaner Production", "Sustainability" (Switzerland), and "Energies" are the most authoritative in terms of citation counts among the top five scientific journals publishing articles in the field of energy economy. They have a high predictive potential.

The statistical characteristics of the trend lines are summarized in Table 2.

Table 2. Statistical characteristics of trend lines in Figure 6.

Journal	Regression Equation	R^2	A
Journal of Cleaner Production	$y = -10620.0x + 2 \times 10^7$	0.9534	−10620.0
Sustainability (Switzerland)	$y = -10078.0x + 2 \times 10^7$	0.9982	−10078.0
Energy	$y = -2273.8x + 5 \times 10^6$	0.9054	−2273.8
Energies	$y = -2725.7x + 6 \times 10^6$	0.9761	−2725.7
E3S Web of Conferences	$y = -468.3x + 947{,}752$	0.5709	−468.3

Table 2 shows the differences in the slope of the trend lines for different journals. According to Table 2, the journals "Journal of Cleaner Production" and "Sustainability" (Switzerland) provide the fastest growth in publication citations.

Then, the authors analyzed 411,396 pieces of information using artificial intelligence. Table 3 shows the results of processing the array of articles on energy economy for 2024 using a prompt (Appendix A). The "M(x)" column ranks the obtained data.

Table 3. Top 5 journals by the criterion "Number of citations per paper" for 2024.

№	Journal Title	Number of Citations	Number of Papers	M(x)	S(x)	S(x − 1)
1	Journal of Cleaner Production	1451	551	2.6334	3.9561	3.9525
2	Energy	600	240	2.500	4.277	4.2681
3	Energies	227	266	0.9925	2.0113	2.0075
4	Sustainability (Switzerland)	414	1194	0.7286	1.2554	1.2548
5	E3s Web of Conferences	41	315	0.1302	0.8132	0.8119

Table 3 shows that in 2024, the two most cited journals were the *Journal of Cleaner Production* and *Energy*. The mathematical expectation M(x) of the number of citations for publications in these journals is more than two citations per publication.

The second echelon regarding paper citations comprises the *Energies* and *Sustainability* (Switzerland) journals in 2024. As of the analysis date, M(x) of the number of citations was slightly less than 1.0.

The third position is occupied by the publication E3S Web of Conferences. M(x) of the number of citations is slightly more than 0.13. Journals that are not included in the top five journals by the number of citations are not shown in Table 3.

Table 3 helps experts in the energy economy choose the optimal publication trajectory. Statistical indicators allow both to compare the citation rate of journal publications with each other and with a given number μ.

The comparison of M(x) was performed for 2021–2023. Higher M(x) values characterize the obtained data. These data are similar to the data presented in Table 3. So, the list of the top five journals with the highest number of citations for 2021–2024 is provided in Table 3.

3.3. Testing Research Hypothesis 3

Research Hypothesis 3 was tested using bibliometric analysis based on 407,552 search results. The search used the keywords "econom*" and "energy*" from 2021 to 2024. The 2000 most cited articles showed the result of the final analysis.

Query: "econom*" AND "energ*".

Total number of articles in the Scopus database: 407,552.

Period of analysis: 2021–2024 (December 10).

Areas: economics, econometrics, and finance; energy.

Number of articles after the first limitation: 67,925.

Dataset for analysis: 2000 from 67,925 (2000 more cited in the dataset).

Total number of keywords in VOSviewer: 13,892.

Keywords for analysis in the first stage—289 (not less than 21 occurrences in search results).

Keywords for analysis in the second stage—top 10 keywords.

Keyword map in the first stage—Figure 7.

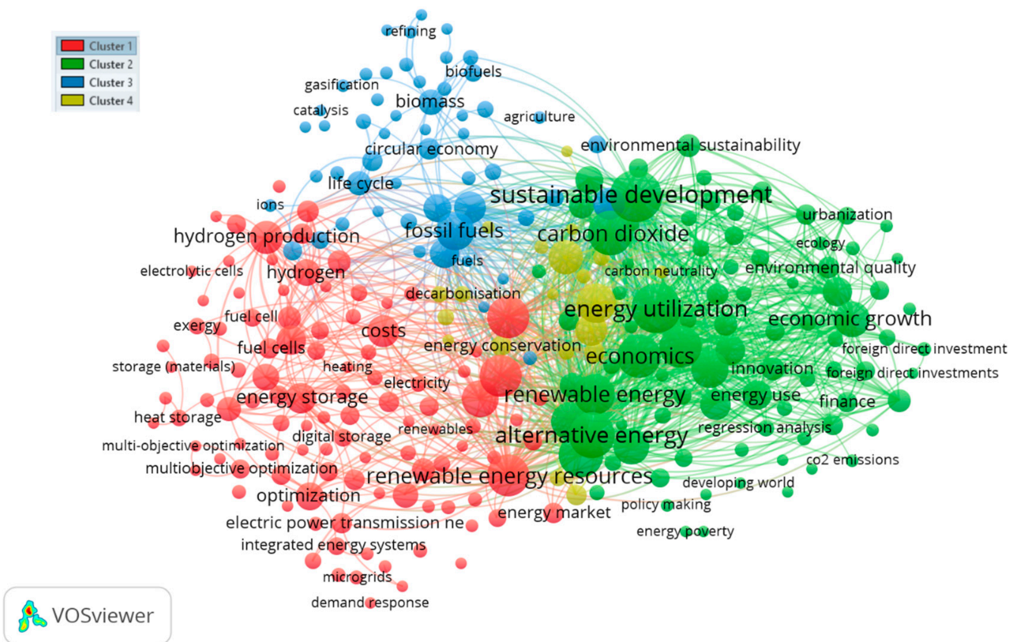


Figure 7. Query "econom*" and "energ*": keyword map (https://www.scopus.com/ accessed on 10 December 2024, analysis tool—VOSviewer).

Country map in the first stage—Figure 8.

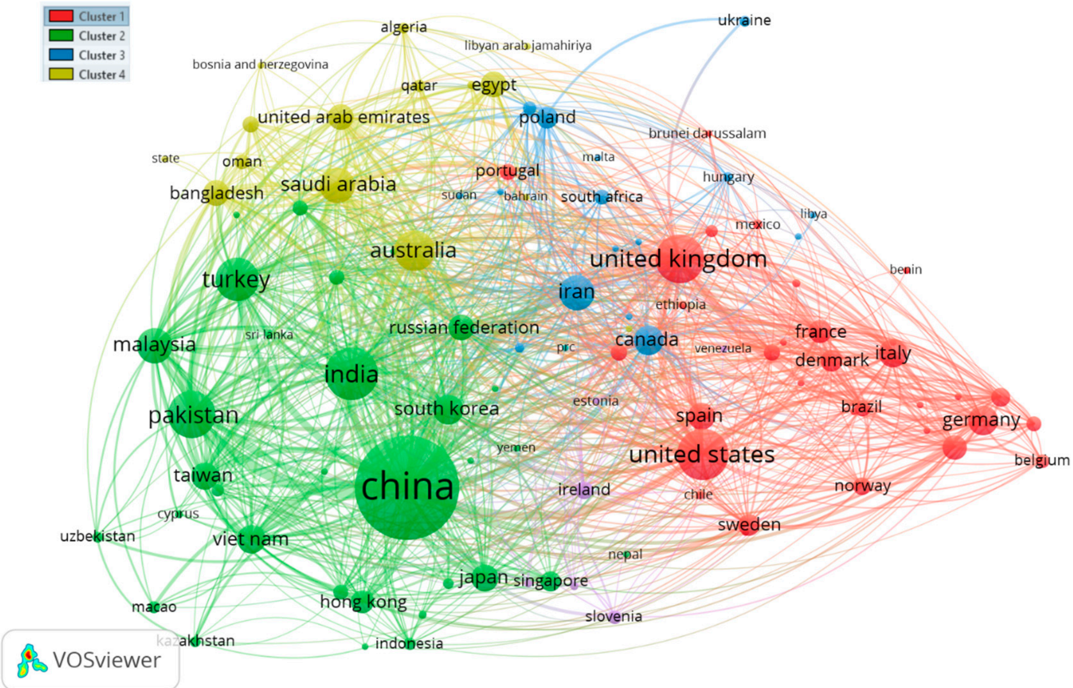


Figure 8. Query "econom*" and "energ*": countries map (https://www.scopus.com/ accessed on 10 December 2024, analysis tool—VOSviewer).

Keyword map in the second stage—Figure 9.

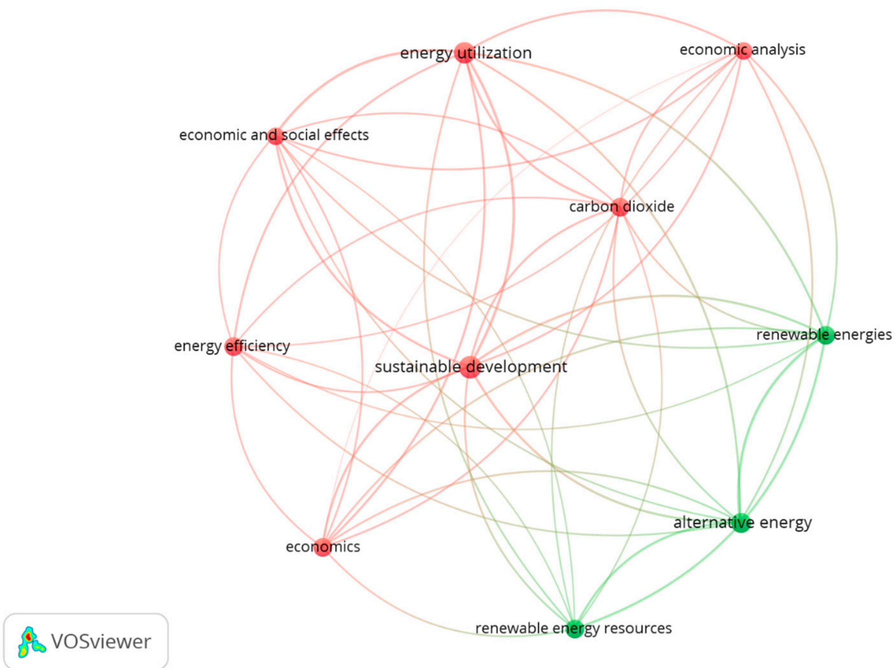


Figure 9. Query "econom*" and "energ*": keyword map. Top 10 keywords (https://www.scopus.com/ accessed on 10 December 2024, analysis tool—VOSviewer).

Key elements in Figure 7.

Figure 7 illustrates the interconnected landscape of research on sustainable energy, highlighting key themes and frequently co-occurring terms within the academic literature. At the center of the network are concepts such as "sustainable development," "carbon dioxide," "renewable energy," and "energy utilization," indicating their foundational role across various subfields. Surrounding these core terms are more specialized topics, including technological innovations like hydrogen production and energy storage, and broader themes such as economic growth, environmental quality, and policymaking. The density and linkage of terms suggest a high level of interdisciplinarity in the field, with strong ties between environmental, economic, and engineering-oriented research. This visualization effectively maps how diverse research efforts advance the global discourse on sustainable energy and climate solutions.

The red cluster emphasizes scientific and technological aspects, centering around "energy storage," "hydrogen production," and "optimization." This cluster connects to specific terms like "fuel cells," "exergy," "multi-objective optimization," and "heat storage," highlighting the importance of advanced energy technologies and strategies in achieving energy efficiency and storage solutions.

The green cluster dominates the visualization and focuses on concepts central to sustainable development, including "economic growth," "economics," "environmental sustainability," and "energy utilization." These terms are interwoven with topics like "carbon dioxide," "environmental quality," and "urbanization," suggesting a strong link between economic and environmental considerations in energy systems.

The blue cluster focuses on "biomass" and "fossil fuels" with associated terms like "gasification," "biofuels," and "circular economy." It reflects exploring alternative energy sources and their role in transitioning from fossil fuel reliance.

The yellow cluster serves as a bridge between scientific and policy-oriented topics. with key terms like "alternative energy," "renewable energy," and "carbon neutrality." This cluster indicates a connection between renewable energy technologies, broader sustainability goals, and environmental responsibility.

Key elements in Figure 8.

Figure 8 displays a co-authorship network among countries, illustrating the collaborative research landscape. The size of each country's node indicates its overall research output or influence within the network, while the lines connecting them represent collaborative relationships. The clustering of countries into distinct colored groups suggests the presence of regional or historically formed research alliances and communities.

The red cluster is dominated by Western countries like the United States, the United Kingdom, and Germany, which are closely linked to each other and form another major hub of activity or influence. This cluster highlights the interconnected nature of research and collaboration among developed nations in Europe and North America and their ties with countries such as Brazil and Spain. The red cluster corresponds to the results of scientometric analysis in the field of energy economy for the top five leading countries (Figure 4).

In this network, China stands out as the most prominent node, with a central position in the green cluster, suggesting its pivotal role in analyzing the topic through research output, collaboration, or influence. Surrounding China in this cluster are other Asian countries such as India, Pakistan, Malaysia, and countries like Turkey, indicating a strong regional connection or shared thematic focus. The green cluster corresponds with the results of scientometric analysis in the field of energy economy for the top five leading countries (Figure 4).

The blue cluster, meanwhile, includes countries such as Poland and Ukraine, representing a separate yet interlinked group with moderate activity or regional influence. However, Poland has more universities than Canada, which is in the blue cluster. Poland appears weaker than Canada. Several problems of universities in Eastern European countries have been proven earlier [1,17,21]. A new problem has been added to these problems in Poland. This problem is the weak position in the world market of scientific products in the field of energy economy (Figure 8). This problem confirms the importance of additional local research into the issues at the intersection of Polish energy and economic sciences [1,17] in the future.

The yellow cluster features countries in the Middle East, such as Saudi Arabia and the United Arab Emirates, as well as parts of Africa and smaller nations with specific ties to other regions.

Key elements in Figure 9.

The red cluster centers around terms like "sustainable development," "energy utilization," "carbon dioxide," and "economic analysis." These nodes suggest a focus on integrating energy efficiency and economic analysis within the broader context of sustainable development. Key connections among these terms highlight the interplay between energy use, economic factors, and social effects, underscoring the importance of evaluating energy systems' economic and social implications in achieving sustainability goals.

The green cluster is anchored by terms such as "renewable energies," "alternative energy," and "renewable energy resources." This cluster emphasizes the transition to renewable energy solutions and their role in mitigating carbon emissions while fostering sustainability.

The connections between the green and red clusters illustrate the close relationship between renewable energy adoption and sustainable development objectives. Overall, this network depicts the interconnectedness of economic, environmental, and energy-related topics, showing how they collectively contribute to the discourse on sustainability and renewable energy advancements.

Thus, the bibliometric analysis revealed a complex relationship and mutual influence of the top 10 keywords in the research area. Figure 9 explains the top five list of journals that publish research results in the field of energy economy (Figure 5).

An analysis of the top five cited articles for the above-mentioned search query showed the following features.

Authors [22] present a comprehensive review of hydrogen energy systems. The study explores various hydrogen production, storage, and application technologies to highlight their potential as a clean energy carrier. Achieving carbon neutrality hinges on developing "green hydrogen," produced through renewable energy sources like solar or wind power. However, challenges remain concerning hydrogen production and infrastructure efficiency, and scalability. Zhao et al. [23] identify key strategies and countermeasures for China to achieve carbon neutrality, including energy transition, industrial restructuring, and technological innovation. While renewable energy sources play a crucial role, addressing carbon emissions embedded within manufacturing processes and infrastructure is equally important. Rosenboom et al. [24] advocate for bioplastics as a sustainable alternative to conventional plastics derived from fossil fuels. Bioplastics offer a closed-loop solution within a circular economy, with the potential for biodegradation and reduced environmental impact. However, challenges exist regarding production scalability, cost-effectiveness, and ensuring bioplastics are biodegradable.

The paper [25] emphasizes the urgent need to address climate change and the crucial role that renewable energy can play in mitigating its impacts. The authors discuss various renewable energy technologies, their potential to reduce greenhouse gas emissions, and the barriers and challenges to their widespread adoption. The paper also highlights the importance of comprehensive policy and regulatory frameworks and the potential socio-economic benefits of transitioning to a renewable energy-based economy.

The paper [26] further emphasizes the role of hydrogen in the energy transition, highlighting its potential for decarbonizing hard-to-abate sectors such as transportation and industry.

As the analysis of these articles shows, the study focuses on technologies, not the economic problems of their implementation. This fact is somewhat logical since the economy is an element of innovation support [17], not an independent direction. This statement is confirmed by analyzing the array of articles linking the economy and energy.

The journals that published these papers [22–26] are missing from Figures 5 and 6. These five papers are among the 2000 most cited publications. Figures 5 and 6 cover all publications in the field of energy economy. The citation analytics for Figure 6 were performed using AI (Appendix A). Thus, the fact that the journals that published the papers [22–26] are missing from Figures 5 and 6 and Table 1 does not contradict the previously noted trends and clusters.

The development of the energy economy has become a critical focus in global research, addressing financial, technological, and social dimensions. This review highlights the contributions of recent studies to understanding the complex interplay of renewable energy adoption, sustainable practices, and economic growth.

Publications not included in the top five by the number of citations cover various research areas at the intersection of the economy and energy. Some of these publications are analyzed below.

The article [27] comprehensively analyzes academic research trends related to the smart transformation of the global energy sector. Research has extensively examined the role of financial instruments in facilitating the transition to green energy. A bibliometric analysis of scientific publications from 1954 to 2023 emphasizes the importance of financial tools in advancing green energy adoption [28]. Similarly, a study on India's progress toward the Sustainable Development Goals (SDGs) demonstrates how economic investments in renewable energy contribute to broader socio-economic objectives [29]. The study [30] underscores the critical role of sustainable agriculture in addressing global challenges, promoting environmental stewardship, supporting socio-economic progress, and renewable energy (in biofuel production), aligning with the SDGs.

The critical role of renewable energy in addressing global environmental challenges is highlighted in various studies. The author of [31] addresses how social sciences intersect with climate change, offering unique perspectives on this global challenge. Research on renewable energy adoption reveals its concentration in the power sector, with limited yet moderate growth in transport and heating [32]. Increased renewable energy production significantly reduces CO_2 emissions, affirming its importance in mitigating environmental pollution [33,34]. Similarly, research finds that renewable energy consumption positively correlates with GDP per capita and foreign direct investment but is negatively associated with CO_2 and domestic gas emissions [35]. Findings in a study [36] reveal that environmental and energy security are more closely linked than either is with economic security.

Technological advancements have been pivotal in transforming the energy economy. Research on blockchain and AI highlights their ability to optimize energy consumption and support decentralized energy markets [37]. Additionally, home energy management systems in Italy demonstrate potential for enhancing residential energy efficiency and achieving net-zero targets by 2030 [38]. Entrepreneurs and start-ups face unique challenges in the renewable energy sector, including regulatory barriers [39] and investment risks [40]. The article [41] finds that increased exposure to climate change risks correlates with decreased firm value in the energy sector. However, the integration of eco-friendly strategies and green branding is shown to enhance competitiveness and support sustainable development [42]. At the same time, innovative solutions, such as using biofuels and waste in Ukraine, present opportunities for sustainable energy development [43,44]. The article [45] examines global research trends in household energy efficiency and renewable energy adoption. The article [46] examines Poland's strategic initiatives and progress in expanding offshore wind energy within the Baltic Sea.

Policy frameworks play a pivotal role in shaping the energy economy. Analyses of Ukraine and Latvia's renewable energy policies highlight the effectiveness of feed-in tariffs and net metering in encouraging household solar energy adoption despite challenges in financial sustainability [47,48]. The article [49] examines how local government policies influence citizens' decisions to reside in specific areas, focusing on the role of green policy leadership. Study [50] also emphasizes the importance of aligning energy initiatives with public expectations for successful implementation and sustained support. The research [51] highlights the importance of integrating environmental assessments into energy policymaking to ensure a balanced energy security approach, considering economic and ecological factors. The article [52] examines the development and challenges of renewable energy in Ukraine, focusing on public demand and governmental strategies.

The intersection of energy policies with social equity and public health is explored in depth. Localized electricity pricing models in Ukraine demonstrate the potential for promoting social equity and environmental sustainability [53]. Additionally, the public health benefits of renewable energy adoption are emphasized, with waste-to-energy systems and biofuels identified as significant contributors to sustainable energy development in Ukraine [43,54,55]. The study [56] critically examines integrating environmental objectives into economic recovery initiatives, particularly post-crisis redevelopment efforts.

The development of the energy economy is deeply intertwined with consumer behavior, which shapes energy consumption patterns, the adoption of renewable energy technologies, and the effectiveness of energy policies. The authors of research [57] investigated the factors influencing young consumers in Georgia to participate in various sharing economy models, including car-, ride-, accommodation-, tool-, meal-, tech-, and fashion-sharing. They found that environmental awareness was a key motivator for car-sharing participation, with a more significant impact on users than providers. According to [58], awareness and understanding of environmental issues positively impact sustainable behavioral intentions among young individuals in Jaipur, India.

The interplay between economic security and energy taxation has been a focal point in energy economy research. Studies reveal that transport and energy taxes positively influence biofuel production and consumption, with varying impacts depending on the tax structure [59–61]. Furthermore, localized analyses highlight the importance of energy consumption data in evaluating shadow economies and the effectiveness of environmental taxes in promoting decarbonization [62–64].

A review of sources on the topic of the study once again showed the interest of scientists from Eastern European universities in the problems at the intersection of energy and economic sciences [1,17,43,46–48,52–55]. There is a similar interest in another post-communist country, Georgia [57]. Returning to the knowledge economy approach [1,8,12], we can note problems with using AI in Eastern Europe [17,65–67]. This direction may become the goal of future research.

This body of research underscores the transformative potential of renewable energy, supported by financial tools, technological innovation, and robust policy frameworks. By addressing economic, environmental, and social dimensions, these studies provide actionable insights for advancing the energy economy, fostering sustainability, and ensuring energy security.

After summarizing the results mentioned above, we accept research Hypothesis 3 based on the following theses:

1. Effective policy frameworks and financial instruments are essential for accelerating the transition to a low-carbon economy. Governments can be pivotal in creating sup-

portive policies, such as feed-in tariffs, tax incentives, and carbon pricing mechanisms. Additionally, financial institutions can fund renewable energy projects and innovative technologies. International cooperation and knowledge sharing are also crucial for driving global progress in sustainable energy development.

2. Energy transitions have significant socio-economic implications. While renewable energy deployment can create jobs and stimulate economic growth, ensuring equitable access to clean energy and addressing potential social and environmental impacts is important. Careful planning and inclusive policy frameworks are essential to minimize negative consequences and maximize the benefits of energy transitions.
3. The transition to a sustainable energy future requires a multifaceted approach, encompassing technological innovation, policy frameworks, and behavioral changes. Renewable energy sources such as solar, wind, and bioenergy are crucial for reducing greenhouse gas emissions and mitigating climate change. However, challenges with energy storage, grid integration, and policy implementation persist. Further research and development are needed to enhance the efficiency and cost-effectiveness of energy technologies.

4. Conclusions

This review led to the acceptance of research Hypothesis 1 and research Hypothesis 3. Research Hypothesis 2 was rejected. Also, the scientific result of this review is as follows:

1. A steadily growing trend line of the number of publications in the field of energy economy (Figure 2). The trend line demonstrates a growing interest in research in the field of energy economy and has a high predictive potential (R^2 = 0.9670). Thus, the interdisciplinary "energy economy" research field is moving towards stable growth. This fact means that this research field is promising in the near future.
2. A broken line reflecting the proportion of publications in the field of energy economy against the background of the total number of publications in the field of economy (Figure 3). This broken line consists of two sections. The first section is described by a steadily growing trend line from 2015 to 2021 (R^2 = 0.9730). The second section is represented by a virtually horizontal trend line from 2021 to 2024 (R^2 = 0.7397). The second trend line demonstrates stability in the relationship between "energy economy" and "economy" from 2021 to 2024. Thus, the interdisciplinary research area of "energy economy" is in a stable equilibrium within economic research. This fact means there are clusters of intensive research in this interdisciplinary area.
3. The high predictive potential of the horizontal trend line made it possible to study the energy economy area in more detail from 2021 to 2024. The review showed the following:
    - Four clusters showed a keyword map based on the analysis of the 2000 most cited publications for the keywords "econom*" and "energ*" (Figure 7). Figure 9 shows the top 10 keywords in the research area. Thus, the interdisciplinary research area "energy economy" is described by such keywords as "sustainable development," "economic analysis," "economics," "economic and social effects," "energy efficiency," "energy utilization," "carbon dioxide," "renewable energies," "alternative energy," and "renewable energy resources." This observation means that research and publications using these keywords can lead to high citation rates;
    - Keywords related to the features of the sixth technological paradigm (use of AI, digitalization of management processes, big data processing) are absent from the top 10 keywords in the above clusters. This result suggests that these

research areas were underrepresented in citation-based bibliometric data in energy in 2021–2024;

- Figure 4 shows the top five leading countries by the number of publications in the studied area: China, India, USA, U.K., and Italy. The results of the cluster analysis adjusted this list. Four geographic clusters showed Italy is not among the top five countries based on the 2000 most cited publications (Figure 8). Four geographic clusters showed the priority influence on the world market of scientific products in the field of research of such countries as China, India, the USA, the U.K., Pakistan, and Turkey (Figure 8). That is, Italian scientists create a flow of thematic publications. However, these publications, for the most part, do not carry breakthrough, revolutionary information. Figures 4 and 8 demonstrate the evident quantitative and qualitative dominance of Chinese scientists in the world market of scientific products in the energy economy. In turn, the blue cluster showed the problems of Eastern European universities in this interdisciplinary field of research (Figure 8);
- The top five scientific journals with the maximum number of publications in the research area are *Sustainability* (Switzerland), *Journal of Cleaner Production*, *E3S Web of Conferences*, *Energies*, and *Energy* (Figure 5). Figure 5 demonstrates the evident quantitative dominance of the scientific journal "Sustainability" (Switzerland) in the world market of scientific products. This observation means that the top five journals have the maximum impact on the interdisciplinary research area of "energy economy" regarding the number of publications;
- The specialized scientific journal *Energy Economics* is in seventh place in the world ranking. So, Figure 5 demonstrates the presence of hidden problems concerning specialized journals. This fact means that specialized scientific journals in the field of energy economy perform poorly in the functions of specialized scientific journals;
- The four scientific journals with the maximum number of citations in the research area are the *Journal of Cleaner Production*, *Sustainability* (Switzerland), *Energy*, and *Energies* (Figure 6). Given their high predictive power, the journals "Sustainability" (Switzerland), "Energies", and "Journal of Cleaner Production" are the most authoritative in terms of citation counts. This observation means that these journals have the most significant impact on the interdisciplinary research field of "energy economy" regarding the number of citations of published papers.

4. A special prompt was created to analyze the number of citations since standard tools do not allow analyzing a citation array of 411,396 information units. Table 3 shows the number of citations per paper. The analysis will enable scientists to choose their publication trajectory based on journals with the maximum number of publications, authors from leading countries, and the criterion "number of citations per paper." AI has provided new capabilities for processing data arrays that exceed the capabilities of standard tools such as Scopus Analyzer and VOSviewer. Using a multi-step prompt based on the GPT model provided a structured transformation of unformatted citation data into standardized statistical indicators for more than 400 thousand information units. Although the method has shown high analytical potential, it requires further development of the prompt structure and verification of the output data. In the future, it is advisable to compare the citation analysis results obtained using AI with the results based on classical bibliometric or machine models, which can increase the reliability and reproducibility of scientific assessments.
5. The results of this review can be used as a basis for several applied and academic areas. First, the review results help scientists align their publication strategies with global

scientific trends. The results can guide scientists when choosing relevant and cited topics and highly cited scientific journals in energy economics. Second, universities and public research policy bodies can use these results to understand their global market positioning better. This is an essential step in identifying opportunities for international collaboration. Third, the results obtained can be useful for policymakers and managers in the energy sector. They could use our results to select innovation development and strategic management areas in the energy sector. Fourth, editorial boards and publishers of specialized journals can use the results when assessing their editorial policies. Finally, the analytical framework and AI-based methods prepared in our review can be adapted to evaluate other interdisciplinary areas. This is a scalable model for analyzing trends and influences in the global research market.

6. The limitation of this review is the use of only the Scopus database for analysis of the top five journals by the number of publications and the number of citations. The Scopus scientometric database is one of the most recognized and widely used databases indexing articles from high-quality scientific journals that meet strict peer-review criteria. This fact makes Scopus a reliable source for publication analysis, which is especially important in research into the interaction of science and industry, including in the energy sector. Scientific journals indexed in Scopus serve as a basis for creating global scientific networks and integrating knowledge with real technologies, which is especially important for our work. These limitations can become areas of future research. Studying the hidden problems of specialized journals can be the goal of future research. It is also interesting to analyze keywords and their citation in 2024–2025 and to study the interdisciplinary field of energy economy for Eastern European countries.
7. Future research is seen in the following directions:
    - Research and development to improve the efficiency and cost-effectiveness of energy technologies;
    - Effective policy frameworks and financial instruments to accelerate the transition to a low-carbon economy;
    - Transition to a sustainable energy future. Challenges with energy storage and grid integration;
    - Ensuring a balance between the widespread deployment of renewable energy sources and the need to ensure their technological maturity and economic viability;
    - Careful planning and inclusive policy frameworks to maximize the benefits and minimize the negative impacts of energy transitions;
    - Investigation of areas of insufficient attention and areas related to the sixth technological paradigm (use of AI, digitalization of management processes, big data processing).

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Appendix A

Multi-step prompt for processing an array of articles on energy economics.

The processing was carried out using the artificial intelligence model GPT-4o.

Step 1.

"The attached text describes 7825 scientific documents (articles, reviews, conference papers, etc.). The description of each document includes the following data: author(s); the title of the document; year; EID; Name of the source; volume, issues, pages; number of citations; the source and type of the document; DOI; open access (open access); short description (abstract); author's keywords.

Create an Excel table from this data for all 7825 scientific documents. Let the new Excel table consist of the following columns: author(s); the title of the document; the title of the source; the number of citations; the DOI; and the author's keywords.

Leave the data language in the new Excel table as in the original data. Name the new Excel table "2024" and give the option to download."

Step 2.

Please sort all documents in the table "2024" into groups according to the column "Name of the source" in alphabetical order. Each group contains documents published in the same source.

Merge duplicate records for the journals "Sustainability (Switzerland)" and "Energies" for each journal separately.

Within each group, rank the documents by the number of citations (Number of citations). In total, this is 411,396 units of information (citations).

Name the table "2024-groups-and-ranking" and allow downloading.

Step 3.

Act like an experienced and qualified mathematician with a specialization in statistics. Please process the table "2024-groups-and-ranking". Calculate statistical indicators for column "D" (Number of citations):

- Mathematical expectation, M(x)
- Standard deviation for the sample, S(x)
- Standard deviation for the general population, S(x − 1).

Calculate statistical indicators for column "D" from line 2 to line 7826 with an accuracy of 4 decimal places. Be careful and precise.

After the bottom document, in column "C," add three lines:

- Mathematical expectation, M(x)
- Standard deviation for the sample, S(x)
- Standard deviation for the general population, S(x − 1).

Enter the obtained values of statistical indicators and round them to 4 decimal places. Please separate the integer and fractional parts of the comma.

Name the table "2024-statistics" and allow downloading.

Step 4.

Merge duplicate rows for the journals "Sustainability (Switzerland)" and "Energies".

Reformat the table "2024-statistics". Prepare a new table: Name of the source; Number of citations; Number of documents; M(x); S(x); S(x − 1). Call it "2024-citations". Write each source group name only once in the column "Name of the source." Merge duplicate groups with the same name. In the column "Number of documents," write the sum of documents in this source group.

In each source group, process the number of document citations (data in column D). For each source group of the table "2024-statistics", calculate the Mathematical expectation. M(x) for the number of citations and write it in the column M(x). Also, calculate the Standard deviation for the sample, S(x) for the number of citations, and write it in the S(x) column. Also, calculate the Standard deviation for the general population, S(x − 1) for the number of citations, and write it in the S(x − 1) column.

Check all statistical results for anomalies. Ensure there are no duplicate journal titles, missing data, or outliers. After checking, confirm the correctness of the final ranking.

Rank the data in the table "2024-citations" by the Mathematical expectation value. M(x). The largest value is at the top of the table "2024-citations".

Save the table "2024-citations" and let me download it.

References

1. Okulich-Kazarin, V.; Artyukhov, A.; Skowron, Ł.; Wołowiec, T. The Crossroads of the Knowledge Economy and Renewable Energy: Recommendations for Poland. *Energies* **2024**, *17*, 6116. [CrossRef]
2. Diessner, S.; Durazzi, N.; Hope, D. Skill-Biased Liberalization: Germany's Transition to the Knowledge Economy. *Politics Soc.* **2022**, *50*, 117–155. [CrossRef]
3. Moisio, S.; Rossi, U. The Value of the Urban Field in Technology-Driven Knowledge Economies: The Role of the State. *Environ. Plan. F* **2024**, *3*, 227–246. [CrossRef]
4. Lee, T.; Van der Heijden, J. Does the Knowledge Economy Advance the Green Economy? An Evaluation of Green Jobs in the 100 Largest Metropolitan Regions in the United States. *Energy Environ.* **2019**, *30*, 141–155. [CrossRef]
5. Powell, W.W.; Snellman, K. The Knowledge Economy. *Annu. Rev. Sociol.* **2004**, *30*, 199–220. [CrossRef]
6. Salvador, E.; Comunian, R. Why and How Higher Education Is So Important for Cultural and Creative Industries' Sustainable Development? *Ind. High. Educ.* **2024**, *38*, 6–13. [CrossRef]
7. Lee, J.; Jeong, S.; Jung, H.J. Interfirm Knowledge Sharing for Energy Efficiency. *Prod. Oper. Manag.* **2023**, *32*, 2510–2528. [CrossRef]
8. Mustika, H.; Eliyana, A.; Agustina, T.S.; Anwar, A. Testing the Determining Factors of Knowledge Sharing Behavior. *Sage Open* **2022**, *12*, 21582440221078012. [CrossRef]
9. Bonoli, G.; Emmenegger, P. (Eds.) *Collective Skill Formation in the Knowledge Economy*; Oxford University Press: Oxford, UK, 2022; p. 384. [CrossRef]
10. Sun, J.; Wu, X. Digital Economy, Energy Structure and Carbon Emissions: Evidence from China. *Sage Open* **2024**, *14*, 21582440241255756. [CrossRef]
11. John, L.; Rempala, K. The Ethics of Knowledge Production and the Problem of Global Knowledge Inequality. *Philos. Soc. Crit.* **2024**, *0*, 01914537241239096. [CrossRef]
12. World Bank. *Building Knowledge Economies: Advanced Strategies for Development*; World Bank Publications: Washington, DC, USA, 2007; pp. 4–12.
13. Grishnova, O.; Berezhna, I.; Mikhurinskaia, E.; Berezhnoy, A. The Economic Crisis of 2020 and the Sixth Technological Order: Interconnection and Patterns. *Bull. Taras Shevchenko Natl. Univ. Kyiv Econ.* **2021**, *3*, 25–34. [CrossRef]
14. Knell, M. Nanotechnology and the Sixth Technological Revolution. In *Technological Innovations. Multinational Corporations and the New International Competitiveness*; Springer: Dordrecht, The Netherlands, 2011; pp. 175–194. [CrossRef]
15. Alekseieva, K.; Novikova, I.; Bediukh, O.; Kostyuk, O.; Stepanova, A. Technological Orders' Change Caused by the Pandemics: Digitalization in the Internationalization of Technology Transfer. *Probl. Perspect. Manag.* **2021**, *19*, 261–275. [CrossRef]
16. Volk, S.C.; Schäfer, M.S.; Lombardi, D.; Mahl, D.; Yan, X. How Generative Artificial Intelligence Portrays Science: Interviewing ChatGPT from the Perspective of Different Audience Segments. *Public Underst. Sci.* **2025**, *34*, 132–153. [CrossRef]
17. Okulich-Kazarin, V.; Artyukhov, A.; Skowron, Ł.; Wołowiec, T.; Bokhonkova, Y. Science and Innovation Management: Sustainable Development Goals 8 and 9 as Challenges for Poland. *Sustainability* **2024**, *16*, 9668. [CrossRef]
18. Yi, S.; Dan, L. Impact of Energy Enterprise Exports on Technological Innovation: PSM Analysis Based on Chinese Industrial Enterprise Database. *Sci. Technol. Soc.* **2022**, *27*, 524–542. [CrossRef]
19. Alam, M.S. Bringing Energy Back into the Economy. *Rev. Radic. Polit. Econ.* **2009**, *41*, 170–185. [CrossRef]

20. Ghazal, R.; Karimi, M.S.; Khezri, M.; Javaheri, B.; Bilan, Y. Unraveling the Environmental Kuznets Curve: The Influence of Economic Diversity. Energy Efficiency. and Industrial Dynamics on Carbon Emissions in Developing Economies. *Energy Environ.* **2024**. [CrossRef]
21. Okulich-Kazarin, V.; Zhurba, M.; Shorobura, I.; Bokhonkova, Y.; Serbin, Y. Three Characteristic Features of the East European Educational Services Market. *Univ. J. Educ. Res.* **2020**, *8*, 1549–1556. [CrossRef]
22. Yue, M.; Lambert, H.; Pahon, E.; Roche, R.; Jemei, S.; Hissel, D. Hydrogen Energy Systems: A Critical Review of Technologies. Applications. Trends and Challenges. *Renew. Sustain. Energy Rev.* **2021**, *146*, 111180. [CrossRef]
23. Zhao, X.; Ma, X.; Chen, B.; Shang, Y.; Song, M. Challenges Toward Carbon Neutrality in China: Strategies and Countermeasures. *Resour. Conserv. Recycl.* **2022**, *176*, 105959. [CrossRef]
24. Rosenboom, J.G.; Langer, R.; Traverso, G. Bioplastics for a Circular Economy. *Nat. Rev. Mater.* **2022**, *7*, 117–137. [CrossRef]
25. Olabi, A.G.; Abdelkareem, M.A. Renewable Energy and Climate Change. *Renew. Sustain. Energy Rev.* **2022**, *158*, 112111. [CrossRef]
26. Kovač, A.; Paranos, M.; Marciuš, D. Hydrogen in Energy Transition: A Review. *Int. J. Hydrogen Energy* **2021**, *46*, 10016–10035. [CrossRef]
27. Chygryn, O.; Bektas, C.; Havrylenko, O. Innovation and Management of Smart Transformation Global Energy Sector: Systematic Literature Review. *Bus. Ethics Leadersh.* **2023**, *7*, 105–112. [CrossRef]
28. Krause, J.; Myroshnychenko, I.; Tiutiunyk, S.; Latysh, D. Financial Instruments of the Green Energy Transition: Research Landscape Analysis. *Financ. Mark. Inst. Risks* **2024**, *8*, 198–212. [CrossRef]
29. Singh, S.N.; Pandey, A. Accomplishing Sustainable Development Goals in India: A Systematic Literature Review. *Financ. Mark. Inst. Risks* **2023**, *7*, 80–87. [CrossRef]
30. Huzenko, M.; Kononenko, S. Sustainable Agriculture: Impact on Public Health and Sustainable Development. *Health Econ. Manag. Rev.* **2024**, *5*, 125–150. [CrossRef]
31. Bhandari, M.P. The Fundamental Principles of Social Sciences. *Bus. Ethics Leadersh.* **2023**, *7*, 73–86. [CrossRef]
32. Chygryn, O.; Shevchenko, K. Energy Industry Development: Key Trends and the Core Determinants. *SocioEcon. Chall.* **2023**, *7*, 115–128. [CrossRef]
33. Skowron, Ł.; Chygryn, O.; Gąsior, M.; Koibichuk, V.; Lyeonov, S.; Drozd, S.; Dluhopolskyi, O. Interconnection Between the Dynamic of Growing Renewable Energy Production and the Level of CO2 Emissions: A Multistage Approach for Modeling. *Sustainability* **2023**, *15*, 9473. [CrossRef]
34. Kwilinski, A.; Dobrovolska, O.; Wołowiec, T.; Cwynar, W.; Didenko, I.; Artyukhov, A.; Dluhopolskyi, O. Carbon Dioxide, Nitrous Oxide, and Methane: What Types of Greenhouse Gases Are Most Affected by Green Investments and Renewable Energy Development? *Energies* **2024**, *17*, 804. [CrossRef]
35. Artyukhova, N.; Tiutiunyk, I.; Bogacki, S.; Wołowiec, T.; Dluhopolskyi, O.; Kovalenko, Y. Scenario Modeling of Energy Policies for Sustainable Development. *Energies* **2022**, *15*, 7711. [CrossRef]
36. Mentel, G.; Vasilyeva, T.; Samusevych, Y.; Vysochyna, A.; Karbach, R.; Streimikis, J. The Evaluation of Economic, Environmental and Energy Security: Composite Approach. *Int. J. Glob. Environ. Issues* **2020**, *19*, 177. [CrossRef]
37. Kuzior, A.; Sira, M.; Brozek, P. Using Blockchain and Artificial Intelligence in Energy Management as a Tool to Achieve Energy Efficiency. *Virtual Econ.* **2022**, *5*, 69–90. [CrossRef] [PubMed]
38. Gualandri, F.; Kuzior, A. Home Energy Management Systems Adoption Scenarios: The Case of Italy. *Energies* **2023**, *16*, 4946. [CrossRef]
39. Myroshnychenko, I.; Podosynnikov, S.; Halynskyi, D.; Ushkalov, M.; Chuhai, O. Regulatory Barriers for Entrepreneurship and Start-Ups in Renewable Energy: Bibliometric Analysis. *SocioEcon. Chall.* **2024**, *8*, 181–210. [CrossRef]
40. Dobrovolska, O.; Ortmanns, W.; Podosynnikov, S.; Halynskyi, D.; Miniailo, A. Start-Ups and Entrepreneurship in Renewable Energy: Investments and Risks. *Financ. Mark. Inst. Risks* **2024**, *8*, 213–240. [CrossRef]
41. Naseer, M.; Bagh, T.; Iftikhar, K. Firm's Climate Change Risk and Firm Value: An Empirical Analysis of the Energy Industry. *Financ. Mark. Inst. Risks* **2023**, *7*, 1–11. [CrossRef]
42. Starchenko, L.; Lyeonov, S.; Vasylieva, T.; Pimonenko, T.; Lyulyov, O. Environmental Management and Green Brand for Sustainable Entrepreneurship. *E3S Web Conf.* **2021**, *234*, 00015. [CrossRef]
43. Ziabina, Y.; Iskakov, A.; Senyah, M.M. Waste Management System: Key Determinants of Green Development and Energy Balance Transformation. *SocioEcon. Chall.* **2023**, *7*, 161–172. [CrossRef]
44. Ziabina, Y.; Khomenko, L.; Osei Owusu, E.K. Analysis of Accidental Transmission Impacts in the Chain "Waste Management System–Public Health". *Health Econ. Manag. Rev.* **2023**, *4*, 74–82. [CrossRef]
45. Sotnyk, I.; Kurbatova, T.; Trypolska, G.; Sokhan, I.; Koshel, V. Research Trends on Development of Energy Efficiency and Renewable Energy in Households: A Bibliometric Analysis. *Environ. Econ.* **2023**, *14*, 13–27. [CrossRef]
46. Kuzior, A. Development of Offshore Wind Energy in Poland. *AIP Conf. Proc.* **2024**, *3033*, 020021. [CrossRef]
47. Sotnyk, I.; Kurbatova, T.; Blumberga, A.; Kubatko, O.; Kubatko, O. Solar Energy Development in Households: Ways to Improve State Policy in Ukraine and Latvia. *Int. J. Sustain. Energy* **2022**, *41*, 1623–1649. [CrossRef]

48. Sotnyk, I.; Kurbatova, T.; Kubatko, O.; Baranchenko, Y.; Li, R. The Price for Sustainable Development of Renewable Energy Sector: The Case of Ukraine. *E3S Web Conf.* **2021**, *280*, 02006. [CrossRef]
49. Oe, H.; Yamaoka, Y.; Sartamorn, S. Research on Residents' Intention to Settle and the Mediating Effect of Green Policy Leadership. *Health Econ. Manag. Rev.* **2023**, *4*, 48–57. [CrossRef]
50. Kolosok, S.; Vasylieva, T.; Lyeonov, S. Machine Analysis of the UK Electrical Energy Initiatives Based on the E-Petitions to the UK Government and Parliament. *CEUR Workshop Proc.* **2021**, *2870*, 1562–1573.
51. Vasylyeva, T.A.; Pryymenko, S.A. Environmental Economic Assessment of Energy Resources in the Context of Ukraine's Energy Security. *Actual Probl. Econ.* **2014**, *160*, 252–260.
52. Kuzior, A.; Lobanova, A.; Kalashnikova, L. Green Energy in Ukraine: State. Public Demands, and Trends. *Energies* **2021**, *14*, 7745. [CrossRef]
53. Mentel, G.; Vasilyeva, T.; Samusevych, Y.; Pryymenko, S. Regional Differentiation of Electricity Prices: Social-Equitable Approach. *Int. J. Environ. Technol. Manag.* **2018**, *21*, 354. [CrossRef]
54. Badreddine, A.; Larbi Cherif, H. Public Health Improvement by Reducing Air Pollution: A Strategy for the Transition to Renewable Energy. *Health Econ. Manag. Rev.* **2024**, *5*, 1–14. [CrossRef]
55. Matvieieva, Y.; Sulym, V.; Rosokhata, A.; Jasnikowski, A. Influence of Waste Incineration and Obtaining Energy from It to the Public Health for Certain Territories: A Bibliometric and Substantive Study. *Health Econ. Manag. Rev.* **2023**, *4*, 71–80. [CrossRef]
56. Bardy, R.; Rubens, A. Weighing Externalities of Economic Recovery Projects: An Alternative to Green Taxonomies that is Fairer and More Realistic. *Bus. Ethics Leadersh.* **2022**, *6*, 23–34. [CrossRef]
57. Zhghenti, T.; Kapanadze, L. Sustainable Innovation in the Digital Age: Analyzing the Motivations of the Young Generation in Joining the Sharing Economy. *SocioEcon. Chall.* **2024**, *8*, 1–11. [CrossRef]
58. Mehta, A.; Sharma, M.; Gupta, N. Determinants Responsible for Sustainable Consumption Behavior Among Youths. *SocioEcon. Chall.* **2024**, *8*, 240–252. [CrossRef]
59. Bilan, Y.; Samusevych, Y.; Lyeonov, S.; Strzelec, M.; Tenytska, I. The Keys to Clean Energy Technology: Impact of Environmental Taxes on Biofuel Production and Consumption. *Energies* **2022**, *15*, 9470. [CrossRef]
60. Samusevych, Y.; Lyeonov, S.; Artyukhov, A.; Martyniuk, V.; Tenytska, I.; Wyrwisz, J.; Wojciechowska, K. Optimal Design of Transport Tax on the Way to National Security: Balancing Environmental Footprint. Energy Efficiency and Economic Growth. *Sustainability* **2023**, *15*, 831. [CrossRef]
61. Kuzior, A.; Samusevych, Y.; Lyeonov, S.; Krawczyk, D.; Grytsyshen, D. Applying Energy Taxes to Promote a Clean. Sustainable and Secure Energy System: Finding the Preferable Approaches. *Energies* **2023**, *16*, 4203. [CrossRef]
62. Sedmíková, E.; Vasylieva, T.; Tiutiunyk, I.; Navickas, M. Energy Consumption in Assessment of Shadow Economy. *Eur. J. Interdiscip. Stud.* **2021**, *13*, 47–64. [CrossRef]
63. Dobrovolska, O.; Günther, S.; Chernetska, O.; Dubrova, N.; Kachula, S. Environmentally Related Taxes and Their Influence on Decarbonization of the Economy. *Environ. Econ.* **2024**, *15*, 174–189. [CrossRef]
64. Yoshimori, M. Global Cooperation for Reducing Carbon Emissions: The Role of Carbon Taxes. *Financ. Mark. Inst. Risks* **2024**, *8*, 69–79. [CrossRef]
65. Okulich-Kazarin, V.; Artyukhov, A.; Skowron, Ł.; Artyukhova, N.; Wołowiec, T. Will AI Become a Threat to Higher Education Sustainability? A Study of Students' Views. *Sustainability* **2024**, *16*, 4596. [CrossRef]
66. Sert, M.F.; Yıldırım, E.; Haşlak, İ. Using Artificial Intelligence to Predict Decisions of the Turkish Constitutional Court. *Soc. Sci. Comput. Rev.* **2022**, *40*, 1416–1435. [CrossRef]
67. Molina, O.; Butollo, F.; Makó, C.; Godino, A.; Holtgrewe, U.; Illsoe, A.; Junte, S.; Larsen, T.P.; Illésy, M.; Pap, J.; et al. It Takes Two to Code: A Comparative Analysis of Collective Bargaining and Artificial Intelligence. *Transf. Eur. Rev. Labour Res.* **2023**, *29*, 87–104. [CrossRef]