



# Energy consumption and environmental degradation nexus: A systematic review and meta-analysis of fossil fuel and renewable energy consumption

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## ABSTRACT

This study examines the energy consumption and environmental degradation nexus at a disaggregated (i.e., fossil fuel energy and renewable energy) level by investigating bibliometric indicators on a global scale. For this purpose, the study considers a number of studies published between 1980 and 2021 that were selected on the Web of Science (WoS) database based on relevant keywords. A bibliometric analysis was done through VOS-viewer from a comparative perspective. Thus, 17,298 studies on fossil fuel energy consumption & environmental degradation and 62,002 studies on renewable energy consumption & environmental degradation were identified. Bibliometric indicators and network visualizations were used to present the results, which show: (i) the topic of disaggregated energy consumption and environmental degradation has been a problem since 1991; (ii) the number of renewable energy-related studies has exceeded the number of fossil fuel-related studies regarding environmental degradation; (iii) many of the studies in both disaggregated groups fall under the categories of energy fuels, environmental sciences, and green sustainable science technology, respectively; (iv) most of the studies have been published by Elsevier; (v) most of the researchers are from the United States of America (USA), whereas those from China and Pakistan have recently come to the fore. Hence, this study assesses the emerging trends in the literature on the energy consumption and environmental degradation nexus at a disaggregated level. Moreover, potential issues to be included by future studies are suggested.

## 1. Introduction

Energy has often been one of the most vital issues for economic parties including countries, policymakers, economies, and people. The main reason for this fact is that it is inevitable to use energy to meet needs, such as heating, lighting, transportation and production (Zhong et al., 2020). For this reason, energy production and energy production sources are highly important.

Fossil fuel sources - including coal, oil and natural gas - have been the main energy sources in energy production for a long time. While the share of natural gas has been increasing, the share of coal and oil has been gradually decreasing (British Petroleum-BP, 2022; Energy Information Administration-EIA, 2022). On the other hand, renewable energy sources have been used in energy production since 1965. In this group, geothermal, biomass, and hydro are the leading sources that are

used to produce energy. Other renewable sources, such as wind and solar, have also been used recently with an increasing contribution to energy production. Recently, wind, hydro, and solar sources have taken place among the most used sources in energy production (BP, 2022).

However, energy production is one of the most important causes of environmental degradation (Mukhtarov, 2022). It is a fact that demand and supply of energy increases as the world population increases (Mutezo and Mulopo, 2021). Consequently, environmental degradation has been accelerating due to the fact that fossil fuel sources (especially, coal and oil) still have an important share in total energy production in some countries, such as China and India, causing a significant amount of carbon dioxide (CO<sub>2</sub>) emissions. On the other hand, it is not an easy task for policy makers to restructure the existing energy production structure from fossil fuel sources to renewable sources because of environmental concerns. (BP, 2022; Oliveira and Moutinho, 2021). In fact, the

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relationship between energy consumption and environmental degradation can be viewed from two different perspectives. While energy consumption (especially using fossil fuel energy) promotes serious environmental degradation, an increase in renewable energy consumption contributes positively to the reduction of environmental degradation.

Studies in the current literature point out a nexus between energy consumption and environmental degradation (e.g., [Adebayo et al., 2021a](#); [Kartal, 2022](#)). There is often a bidirectional nexus between energy consumption and environmental degradation. An increase in energy consumption leads to an increase in environmental degradation through CO<sub>2</sub> emission. Nowadays, the nexus between energy consumption and environmental degradation is among the top priorities to be studied ([Anuar et al., 2021](#)). In line with the increasing energy consumption and environmental degradation, research on the nexus has been increasing recently with the determination of a net-zero emissions goal for countries.

As the public interest in environmental degradation increases, studies examining environmental degradation from different perspectives increase. For example, environmental degradation ([Zyoud et al., 2017](#)), CO<sub>2</sub> emissions ([Kartal, 2022](#); [Khan et al., 2019](#)), environmental pollution ([Shen et al., 2019](#)), air quality ([Li et al., 2020](#)), and environmental sustainability ([Solarin and Bello, 2020](#)) are some of these concepts in the current literature. Similarly, studies on energy consumption are also increasing (e.g., [Kartal, 2022](#), [Kartal et al., 2022](#), [Kılıç Depren et al., 2022](#), [Kirikkaleli and Darbaz, 2021](#)). In addition, there are studies which include some bibliometric studies. For instance, [Mao et al. \(2018\)](#) included the period 1998–2017 by covering 9514 studies; [Hu and Milner \(2020\)](#) investigated the period 1996–2019 by including 320 articles; [Anuar et al. \(2021\)](#) covered the period 2000–2020 by including 1372 articles; [Hou and Wang \(2021\)](#) uncovered the period 1990–2019; [Wang et al. \(2022\)](#) studied 1990–2021 period by including 1433 articles; and [Oliveira and Moutinho \(2021\)](#) examined 111 articles for the period 2008 January–2021 May. Moreover, [Omran et al. \(2022\)](#) studied the period 1995–2022 by focusing on buildings, before the end of the year 2022.

When evaluating all this literature, it can be seen that despite many studies about the nexus between energy consumption and environmental degradation, there is not an up-to-date study covering the most recent and large data in examining the nexus at a disaggregated level through a bibliometric analysis, which is important in investigating the progress of the relevant literature. Hence, there is a need for a new study that includes the most recent and large data interval to examine the nexus on a global scale by covering many more studies and applying a more comprehensive approach. Thus, it is determined that there is a gap in the current literature, which this study can fill.

By considering the significant nexus between energy consumption and environmental degradation and the gap in the current literature mentioned above, this study applies a bibliometric review that considers studies in the current literature to investigate the nexus and explores which direction studies in this field have been taking. In line with the aims of the study, the WoS database was used to search for studies on energy consumption and environmental degradation for the period 1980–2021 by applying some keywords. Also, a bibliometric analysis was conducted on the selected studies to investigate clusters and links, and to quantify the effect of the studies on the subject in the respective period. Hence, this study (i) examines the progress of the research on energy consumption and environmental degradation nexus by performing a bibliometric analysis and presents a visualization map about the progress of the nexus on a global scale. A bibliometric analysis examines the studies that make use of the selected relevant keywords according to document types, source types, years of publication, languages, subject areas, and other details like these ([Depren et al., 2018](#)). Also, bibliometric analysis has widely been used in recent years ([Liu et al., 2021](#)); (ii) reviews the identified studies in terms of the clusters comprising co-occurrence networks. Hence, the analysis considers the keywords of the publications and examines which keywords,

as well as words other than keywords, appear in titles, abstracts, and articles; (iii) produces a synthesized analysis of the study trends on energy consumption and environmental degradation by geographical distribution of publications and authorship.

The main novelty of the study is to investigate the nexus between energy consumption and environmental degradation at a disaggregated level on a global scale. Secondly, the study performs a bibliometric analysis to make a comprehensive examination. Thirdly, the study uses a very large time interval that is between 1980 and 2021. By considering that the year 2022 is not over yet, it was excluded from this study. Following the approach mentioned above, this study identifies the research hotspots in investigating the progress of the nexus at a disaggregated level and quantifies the influential aspects of the articles and research journals published on the topic to determine which authors and journals are the most prolific and dominant within the collected data. Finally, it suggests future research perspectives according to the extant literature. Thus, this study makes a comprehensive analysis and offers a clear picture of the energy consumption and environmental degradation nexus.

There are a total of five sections. After the introduction, Section 2 reviews the relevant literature by presenting a summary. Section 3 explains the methodology that is followed for empirical examination in the study. Section 4 presents the empirical results, and discussion, and implications. Finally, Section 5 presents the conclusion including limitations and suggestions for future studies.

## 2. The systematic literature review

### 2.1. Fossil fuel energy consumption and environmental degradation

For many years, fossil fuel sources were the main sources of energy production until renewable sources emerged. Until recently coal and oil have been used more extensively than natural gas. Because concern regarding the environment has been increasing, the studies in the literature have focused on the changes in the use of energy sources.

Some studies in the literature examined the nexus between fossil fuel (coal) energy consumption and environmental degradation. [Rafindadi et al. \(2014\)](#) studied the nexus in the selected Asia-Pacific countries for the period 1975–2012 via a cross-sectional analysis and panel regression models. [Pata \(2018\)](#) focused on the nexus in Turkey for the period 1971–2014 by performing Autoregressive Distributed Lag (ARDL). [Cheng et al. \(2021\)](#) examined the nexus in China for the period 1969–2019 by applying the Bootstrap Fourier Granger Causality Test in Quantiles. Similarly, [Gani \(2021\)](#) uncovered the nexus in fifty-nine countries using coal, seventy-seven countries using gas, and ninety-six countries using oil for the period 2012–2016 performing the panel data analysis. [Yuping et al. \(2021\)](#) investigated the Argentina case for the period 1970–2018 by using ARDL and Gradual shift causality methods. According to these studies, fossil fuel energy consumption from coal is among the causes of environmental degradation.

Also, some studies examined the nexus between fossil fuel (oil) energy consumption and environmental degradation. [Lim et al. \(2014\)](#) explored the nexus in the Philippines for the period 1965–2012 by applying Johansen co-integration and Granger-causality tests. [Saboori et al. \(2017\)](#) investigated the nexus in three East Asian oil-importing countries (namely, South Korea, Japan, and China) for the period 1980–2013 by performing the Granger causality test, Johansen cointegration test, generalized impulse response functions, and variance decompositions. In searching for a similar nexus, [Kartal \(2022\)](#) studied the top-five carbon-producing countries (namely, USA, Russia, Japan, India, and China) for the period 1965–2019 by using Multivariate Adaptive Regression Splines (MARS). Based on these studies, fossil fuel energy consumption from the oil source is one of the causes of environmental degradation.

In addition, the nexus between fossil fuel (natural gas) energy consumption and environmental degradation were examined in the current

literature. Das et al. (2011) investigated the nexus in India for the period 1967–2010 by performing an autoregressive integrated moving average model. Alkhatlan and Javid (2013) studied the nexus in Saudi Arabia for the period 1980–2011 by applying ARDL. Bimanatya and Widodo (2018) uncovered the nexus in Indonesia for the period 1965–2012 by using Johansen cointegration and Granger causality tests based on the Vector Error Correction Model (VECM). In search of a similar nexus, Yuping et al. (2021) uncovered the nexus in Argentina for the period 1970–2018 by performing ARDL and Gradual shift causality methods and Kartal (2022) examined the top-five carbon-producing countries for the period 1965–2019 via the MARS approach. Depending on these studies, fossil fuel energy consumption from the natural gas source causes environmental degradation; however, it is less harmful compared to coal and oil. Also, natural gas can be used to decrease CO<sub>2</sub> emission according to the studies of Dong et al. (2018) that focused on 14 Asia-Pacific countries for the period 1970–2016 via augmented mean group (AMG) estimates.

Moreover, Ramzan et al. (2022) investigated the cost of non-renewable (i.e., fossil fuel) energy consumption on the environment for Pakistan for the period 1960/Q1–2019/Q4 by using non-parametric causality-in-quantiles (NCQ) approach. They highlighted the importance of reducing the use of fossil fuel resources by switching to renewable energy consumption.

## 2.2. Renewable energy consumption and environmental degradation

While fossil fuel sources were used extensively for energy production, renewable sources emerged and began to be used around 1965s (BP, 2022). In early times, geothermal, biomass, and hydro sources were used mainly before 1973. However, other renewable sources like wind and solar began to be used later around the 1990s. With the increasing awareness about the negative effects of fossil fuel sources on the environment, the number of studies on renewable energy consumption in mitigating adverse effects on the environment has been increasing significantly (Ahmad et al., 2020; Streimikiene and Akberdina, 2021).

Yazdi and Shakouri (2014) examined the nexus between renewable energy consumption and environmental degradation, which is proxied by CO<sub>2</sub> emission most of the time, in Iran for the period 1975–2011 by Granger causality approach based on error correction model (ECM). Bekhet et al. (2017) studied the nexus in Gulf Cooperation Council (GCC) countries (namely, Bahrain, Oman, Qatar, and Saudi Arabia) for the period 1980 and 2011 by using the ARDL approach. On the other hand, Mao et al. (2018) examined the progress of the literature on biomass energy and environment nexus for the period 1998–2017 by applying a bibliometric analysis. Raza and Shah (2018) uncovered the effect of renewable energy on environmental degradation in G7 countries by using dynamic ordinary least squares (DOLS), fixed effect ordinary least squares (FEOLS), and fully modified ordinary least squares (FMOLS). Also, Sarkodie (2018) investigated the nexus in 18 African countries for the period 1971–2013 by performing the Westerlund error-correction model, panel cointegration test, and panel causality test. Besides, Alola et al. (2019) uncovered the nexus in the three largest countries in Europe, which are France, Germany, and the United Kingdom, for the period 1990–2016 by applying DOLS and FMOLS approaches. Sharif et al. (2019) investigated the effect of renewable energy consumption for 74 nations for the period 1990–2015 by using FMOLS and heterogeneous panel causality techniques. Zafar et al. (2019) studied the nexus in G-7 and N-11 countries for the period 1990–2016 via Lagrange Multiplier (LM) bootstrap panel cointegration approach.

The studies which focused on the nexus in the year 2020 are as follows: For example, Adebayo et al. (2020) analyzed the nexus in MINT countries (i.e., Turkey, Nigeria, Indonesia, and Mexico) for the period 1980–2018 by the Dumitrescu-Hurlin panel causality test. Koç and Buluş (2020) examined the nexus in South Korea for the period 1971–2017 by using the ARDL approach. By applying a similar method, Leal and Marques (2020) investigated the nexus in the 20 highest carbon-

emitting countries in OECD for the period 1990–2016. Also, Raza et al. (2020) examined BRICS (i.e., South Africa, Russia, India, China, and Brazil) and Next-11 countries by FMOLS and heterogeneous panel causality techniques. Sharif et al. (2020) uncovered the same nexus in top-10 polluted countries for the period 1990–2017 through Quantile-on-Quantile regression (QQR) and Granger causality in quantiles (GCQ) methods.

In the year 2021, various studies were published on the study of the nexus. For instance, Adebayo et al. (2021a) examined the nexus in Thailand for the period 1990–2018 by using ARDL, DOLS, FMOLS, and Wavelet Coherence (WC). Adebayo et al. (2021b) studied the nexus in Chile for the period 1990–2018 by applying nonlinear ARDL. Jiang et al. (2021) investigated 154 countries in different income groups for the period 1995–2017 via panel smooth transition regression (PSTR) model. Also, Shan et al. (2021) examined the nexus in Turkey for the period 1990–2018 by performing bootstrap ARDL. Zhan et al. (2021) explored the nexus in Pakistan for the period 1995–2017 by employing the quantile ARDL method. Moreover, Ullah et al. (2021a) examined the effect of renewable energy consumption for top-15 renewable energy consumption (REC) economies for the period 1996–2018 by panel analysis, while Ullah et al. (2021b) investigated the same effect for 122 countries by PSTR approach.

Furthermore, earlier this year, that is 2022, Ahmed et al. (2022) examined Pakistan case by applying Augmented ARDL, while Fakher et al. (2022) considered the effect of renewable energy consumption for selected low- and high-income economies for the period 1996–2020 using continuously updated fully modified and continuously updated bias corrected estimators and Dumitrescu & Hurlin causality method. Besides, Awosusi et al. (2022) studied the nexus in BRICS countries for the period 1992–2017 by employing method of moments-quantile-regression (MMQR), DOLS, and FMOLS methods. Chien et al. (2022) analyzed the top Asian countries by applying the cross-sectional ARDL method. Kartal (2022) examined the nexus in the top five carbon-producing countries for the period 1965–2019 by applying the MARS approach. Kartal et al. (2022) investigated the USA case for the period 1989/1–2021/9 by using WC, GCQ, QQR, and quantile regression (QR) approaches. Murshed et al. (2022) studied G-7 countries for the period 1995–2016.

All the studies mentioned above mainly prove that renewable energy consumption from different sources, such as hydro, wind, and solar, makes a positive (i.e., decreasing) contribution to reducing environmental degradation by limiting CO<sub>2</sub> emissions.

## 2.3. Literature on the methodology

In the current literature, there are a lot of studies that examined the nexus between energy consumption and environmental degradation at disaggregated and aggregated levels. In these studies, the nexus was examined by using various empirical methods, such as AMG estimates, ARDL [classical, bootstrap, cross-sectional, non-linear, quantile], autoregressive integrated moving average model, causality test [Dumitrescu-Hurlin, gradual shift, granger (based on ECM & VECM), panel], cointegration test (Johansen, panel), cross-sectional analysis, DOLS, FEOLS, FMOLS, GCQ, generalized impulse response functions, heterogeneous panel causality, LM bootstrap panel cointegration approach, MARS, MMQR, NCQ, panel regression, panel smooth transition regression, PSTR, QR, QQR, variance decompositions, VECM, WC, and Westerlund ECM. Evidently, some of these methods, such as ARDL and its versions, were frequently used, whereas some others, such as MARS, were rarely applied.

## 2.4. Evaluation of the literature

As summarized in the literature review, various studies in the current literature examined the nexus between energy consumption and environmental degradation. A review of the current literature provides some

conclusions. First, there is an important number of studies dealing with the nexus between renewable energy sources and environmental degradation. Second, although renewable energy sources have been gaining more and more popularity, fossil fuel sources still play a dominant role in the production of energy causing negative environmental impacts.

On the other hand, there is no study that uncovers the nexus by including the most available data and using software, such as VOSviewer, to make a comparative and comprehensive bibliometric analysis. Therefore, this study focused on investigating the nexus between energy consumption and environmental degradation at a disaggregated level by applying a bibliometric analysis, using the most available data excluding the year 2022 during when the study was conducted. Hence, it can be expected that the results of the study can provide implications for future research.

### 3. Materials and methods

In this section, we provided the database, time period, and methodology to analyze a comprehensive assessment of energy consumption and environmental degradation. Also, VOSviewer software, version 1.6.17 was used for analysis. Moreover, the required information and raw data for assessment were sourced from the WoS Core Collection database. Although it is acknowledged that there are other databases, such as Scimedirect and Scopus, the WoS database was used because it is the most inclusive database of scientific documents.

In this study, the six-step approach was followed for a bibliometric analysis and the proposed research framework is presented in Fig. 1.

The first step was to determine the scope of the study. The second and third steps of the study were to download the publication raw data from the WoS database by using the pre-determined keywords that were highly related to the topics examined. The fourth step was to perform a bibliometric analysis. The fifth step was to present the comparison of the results. Finally, the sixth step was to give the conclusion and implications as well as the limitations of the study and some suggestions for future studies.

WoS database was used to search for the keywords, titles, and abstracts related to fossil fuel energy consumption & environmental degradation and renewable energy consumption & environmental degradation for the period 1980–2021. The year 2022 was not included

because the study was done before the end of the year. Hence, the data cover the publications until the end of 2021 to avoid misrepresenting the progress of the literature on the nexus between energy consumption and environmental degradation.

Two different datasets were obtained from the database by using the following keywords:

- Fossil Fuel Energy: “Fossil Fuel”, “Fossil Fuels”, “Fossil Sources”, “Coal Consumption”, “Crude Oil Consumption”, “Petroleum Consumption”, “Natural Gas Consumption”, “Non-Renewable Energy”, “Non-Renewable Energy Consumption”, “Fossil Energy”, “Fossil Energy Consumption”,
- Renewable Energy: “Renewable Sources”, “Solar Energy”, “Wind Energy”, “Hydro Energy”, “Waste Energy”, “Wood Energy”, “Bio-fuel”, “Biomass”, “Geothermal”, “Non-Fossil Energy”, “Non-Fossil Energy Consumption”, “Renewable Energy”, “Renewable Energy Consumption”,
- Environmental Degradation: “carbon decarbonization”, “carbon dioxide emission”, “carbon emission”, “carbon free”, “carbon neutrality”, “carbon notr”, “CO<sub>2</sub>”, “CO<sub>2</sub> emission”, “CO<sub>2</sub> zero emissions”, “environmental change”, “environmental degradation”, “environmental deterioration”, “greenhouse gas”, “greenhouse gas emission”, “net zero carbon emission”, “net zero CO<sub>2</sub> emission”, “net zero emission”, “net zero greenhouse gas”, “net zero greenhouse gas emission”, “net-zero-CO<sub>2</sub>”, “net-zero-CO<sub>2</sub>-emissions”.

Every keyword in each topic was combined with the “OR” statement. Furthermore, the consumptions of fossil fuel energy and renewable energy queries were combined with the query of environmental degradation with the “AND” statement to reach relevant publications. There are 17,298 publications in the first query on fossil fuel energy consumption and environmental degradation, and 62,002 publications in the second query on renewable energy consumption and environmental degradation.

Although it is acknowledged that there is also a literature on nuclear energy, considering that it is unclear whether nuclear energy belongs to either renewable or fossil fuel energy, it was not included in this study.

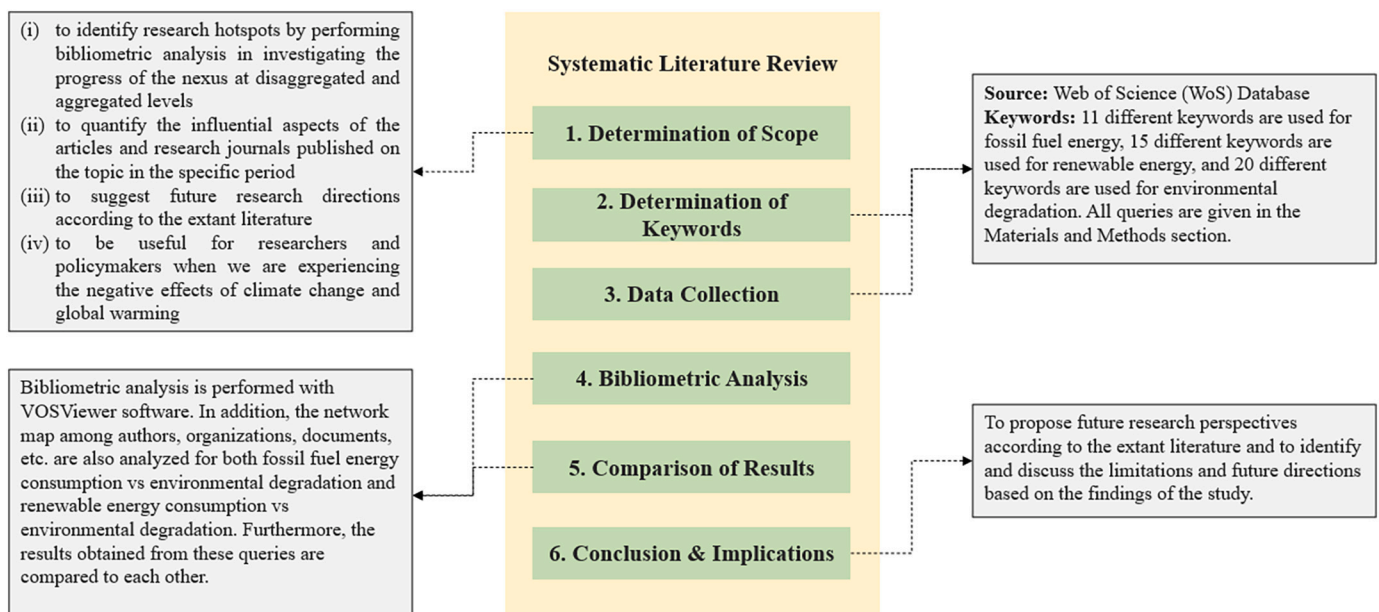


Fig. 1. The proposed research framework.

#### 4. Bibliometric analysis and visualization

Before starting the bibliometric examination of the dataset, the descriptive statistics of the two queries are given in this section. The number of publications is given in Fig. 2.

The “Fossil & Environment” label represents the first query, while the “Renewable & Environment” label represents the second query. The gap between the number of publications about fossil fuel energy consumption and environmental degradation, and that about renewable energy consumption and environmental degradation has increased since 2005. The number of publications on the renewable energy consumption and environmental degradation nexus has reached 7543 in 2021, whereas 2071 studies have been published about the fossil fuel energy consumption and environmental degradation nexus. This statistic shows that the importance of renewable energy consumption has an increasing trend year by year.

The publications were categorized based on the topics of the studies on the WoS database, and one publication can go under more than one category. Based on this categorization, the top-five WoS categories of the two queries are shown in Fig. 3.

The major two WoS categories of publications are Energy Fuels and Environmental Sciences in both queries. Moreover, the number of publications by authors, the distribution of publishers, and the percentage of publications by the authors' countries are given in Fig. 4 and Fig. 5, respectively.

Ciais, P. and Wang, Y. are the authors who have the highest number of publications on fossil energy consumption & environmental degradation, and renewable energy consumption & environmental degradation, respectively. Moreover, Elsevier and Springer Nature are the top-two publishers on fossil fuel energy consumption and environmental degradation, while Elsevier and IEEE are the top-two publishers on renewable energy consumption and environmental degradation. Furthermore, the percentage of the publisher IEEE on the topic of renewable energy consumption and environmental degradation stands out. When the countries of the authors are analyzed, it is seen that the USA and China are the top-two countries in both query results.

##### 4.1. Fossil fuel energy consumption and environmental degradation

The results of the query contain the keywords of the publications on fossil fuel energy consumption and environmental degradation that were analyzed from many different perspectives. The connection among the authors, their organizations, and their countries were examined by a co-authorship analysis. In addition, the network map of the co-occurrence of different keywords in a publication and the connection

among the cited documents, journals, authors, organizations, and countries were examined by a co-citation analysis.

Contrary to Fig. 6, there are no clear clusters and the number of connections among the organizations is too complex to visualize based on Fig. 7. However, Chinese Academy of Sciences (chinese acad sci), the University of California Berkeley (univ calif berkeley), and Tsinghua University (tsinghua univ) are the universities that have a relatively higher number of connections than other organizations. In addition, the University of Chinese Academy of Sciences (univ chinese acad sci), and Beijing Institute of Technology (beijing inst technol) have a relatively higher number of publications after 2017, which stands out in Fig. 6.

The USA and China are the most dominant countries that have a high number of publications on the fossil fuel energy consumption and environmental degradation nexus as shown in Fig. 8. Also, the authors from these countries are working with different authors from many different countries, which can be seen in the number of connections among these countries. Moreover, the number of publications started to increase after 2017 for authors from Iran, Pakistan, Saudi Arabia, Libya, Qatar, and the United Arab Emirates.

A variety of keywords used in studies have changed over time as shown in Fig. 9. In early 2012, the terms “Carbon sequestration”, “methane”, ‘nitrous oxide’, ‘biofuels’, and ‘carbon cycle’ were frequently used in the studies about fossil fuel energy consumption and environmental degradation. However, after 2017, the terms ‘economic growth’, ‘energy management’, ‘GDP growth’, and ‘ecological foot-prints’ were frequently used with fossil fuel energy consumption and environmental degradation. In addition, the most frequently used terms with ‘economic growth’ were ‘renewable energy’, ‘CO<sub>2</sub> emission’, “China”, and “climate change”. Furthermore, “climate change”, “life cycle assessment”, “CO<sub>2</sub> emissions”, and “renewable energy” were the terms that were more frequently used with other keywords in this study.

Journal of Cleaner Production, Energy Policy, Renewable & Sustainable Energy Review, Energy, and Environmental Science and Pollution Research are the most cited journals about fossil fuel energy consumption and environmental degradation. Also, the number of connections among these journals is relatively higher than others (Fig. 10).

##### 4.2. Renewable energy consumption and environmental degradation

The second part of the results determines the connection map among authors, organizations, and countries using the query containing the keywords of the publications on renewable energy consumption and environmental degradation. Also, the network map of the co-occurrence of different keywords in a publication and the connection among the

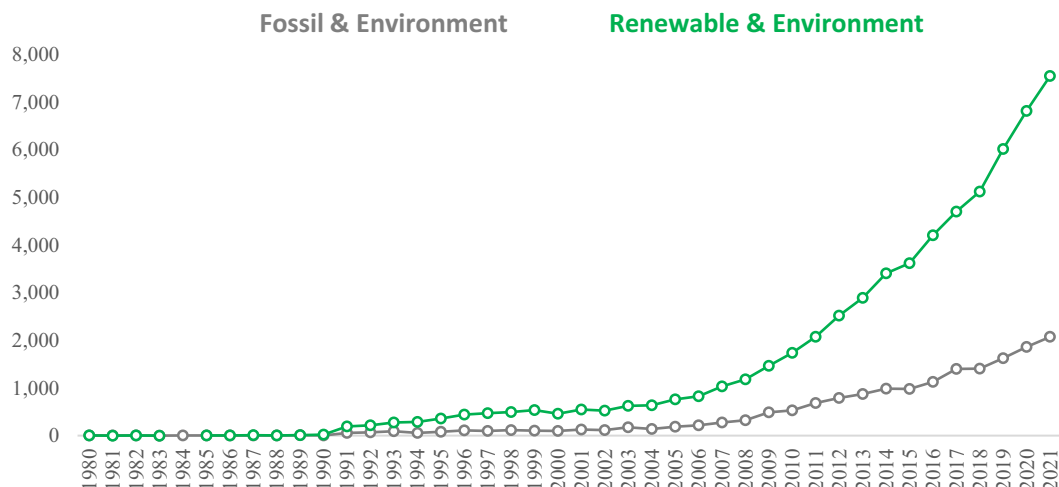


Fig. 2. The number of publications of two different topics by years.

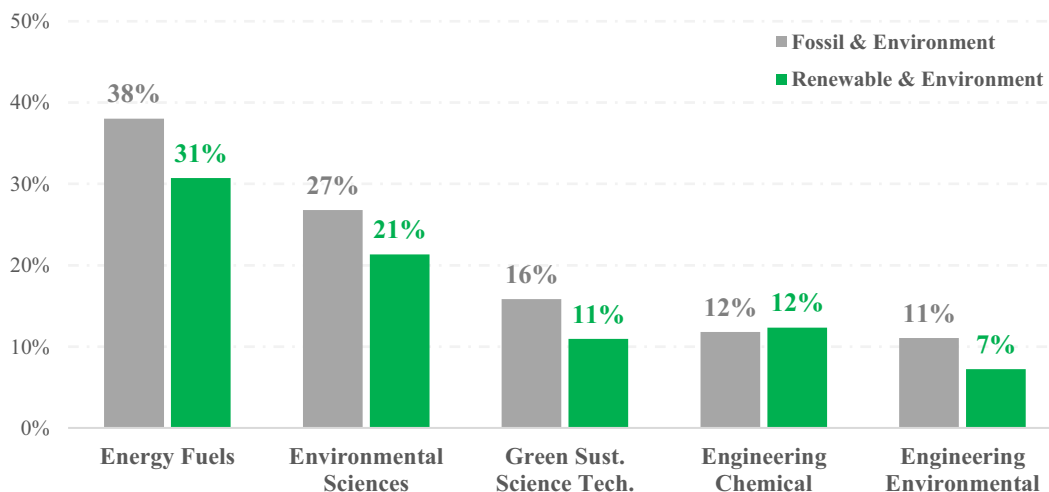


Fig. 3. The top-five WoS categories of publications.

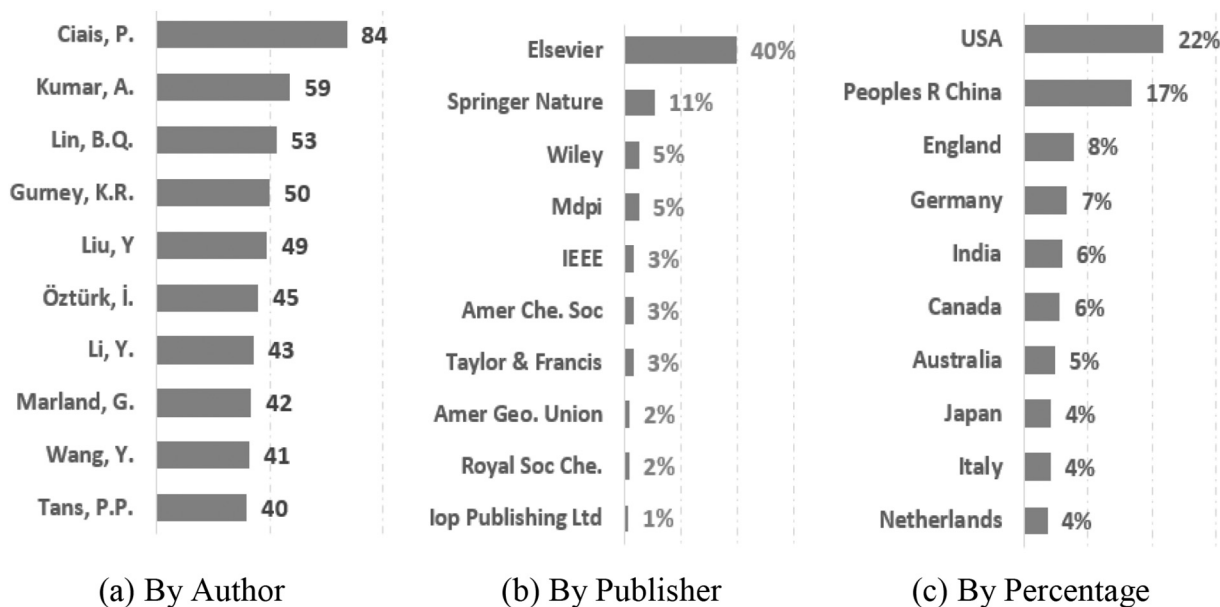


Fig. 4. The number of publications in fossil fuel energy consumption and environmental degradation.

cited documents, journals, authors, organizations, and countries were examined by a co-citation analysis.

Contrary to Fig. 11, there are six clear clusters and the number of connections among the organizations is too complex in Fig. 12. Similar to Fig. 7, Chinese Academy of Sciences (chinese acad sci), the University of California Berkeley (univ calif berkeley), and Tsinghua University (tsinghua univ) are the universities that have relatively higher connections to other organizations. In addition, Beijing Institute of Technology (beijing inst technol) has a relatively higher number of publications after 2019 (Fig. 12).

The USA and China are the most dominant countries that have a high number of publications on the renewable energy consumption and environmental degradation nexus, which is similar to the same analysis of the fossil fuel energy consumption and environmental degradation nexus as shown in Fig. 13. Also, the authors from these countries are working with different authors from many different countries, which can be seen in the number of connections (lines) among these countries. Moreover, the number of publications started to increase after 2017 for authors from Pakistan, Iran, Saudi Arabia, Libya, Qatar, the United Arab Emirates, and Turkey.

Various keywords used in studies have changed over time as shown in Fig. 14. In early 2012, the terms “microbial biomass”, “elevated CO<sub>2</sub>”, and “soil respiration” were frequently used in the studies about renewable energy consumption and environmental degradation. However, after 2016, the terms “economic growth”, “energy consumption”, “environmental Kuznets curve”, and “renewable energy consumption” were frequently used with renewable energy consumption and environmental degradation. In addition, “renewable energy”, “climate change”, “biomass”, and “bioenergy” are the terms that are more frequently used with other keywords in the study.

The journals, Renewable & Sustainable Energy, Energy, Soil Biology & Biochemistry, Energy Policy, and Renewable Energy are the most cited journals about renewable energy consumption and environmental degradation. Also, the number of connections among these journals is relatively higher than others. Moreover, Soil Biology & Biochemistry was the most-cited journal in 2010, while Renewable & Sustainable Energy was the most-cited journal in 2018 (Fig. 15).

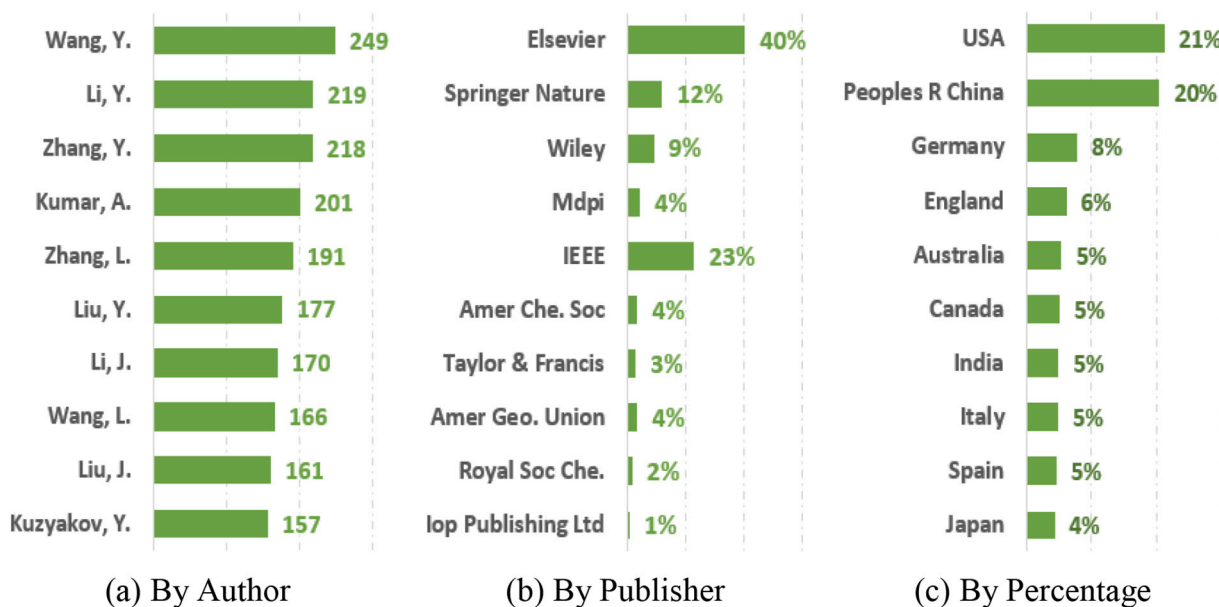


Fig. 5. The number of publications on renewable energy consumption and environmental degradation.

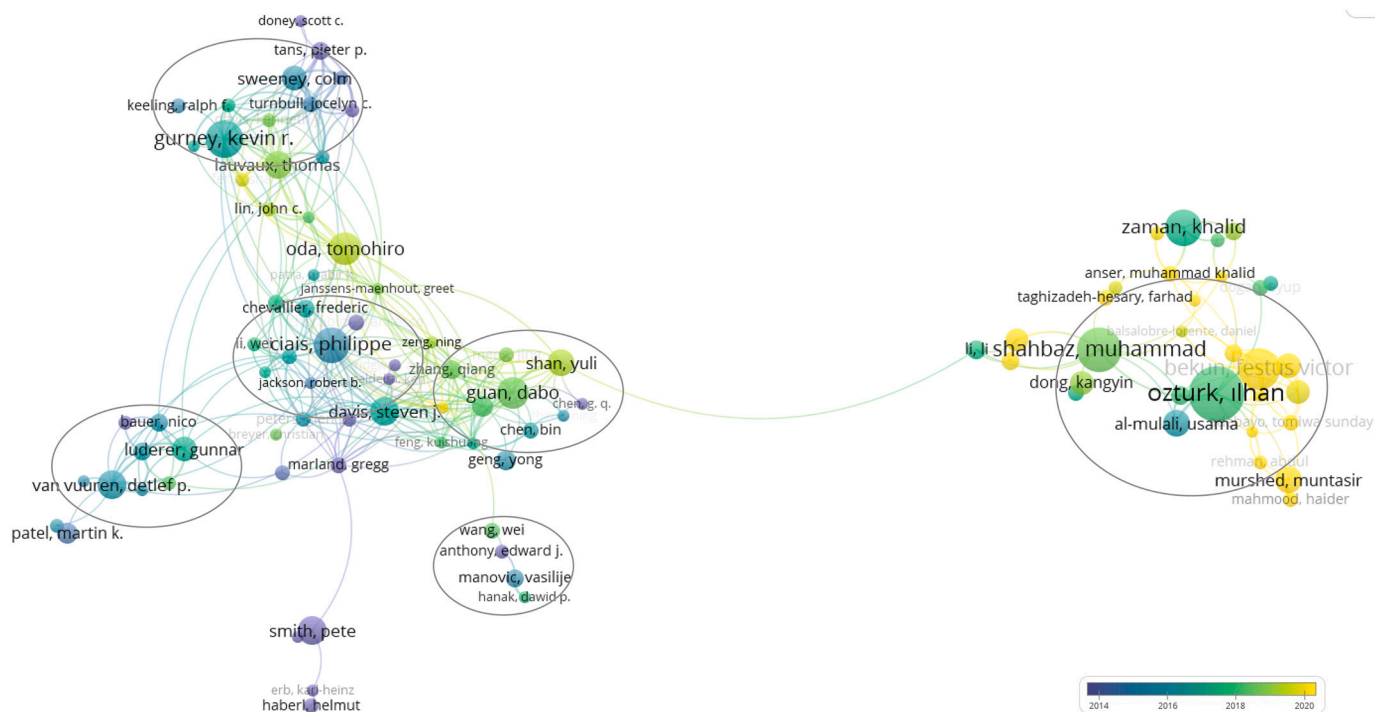
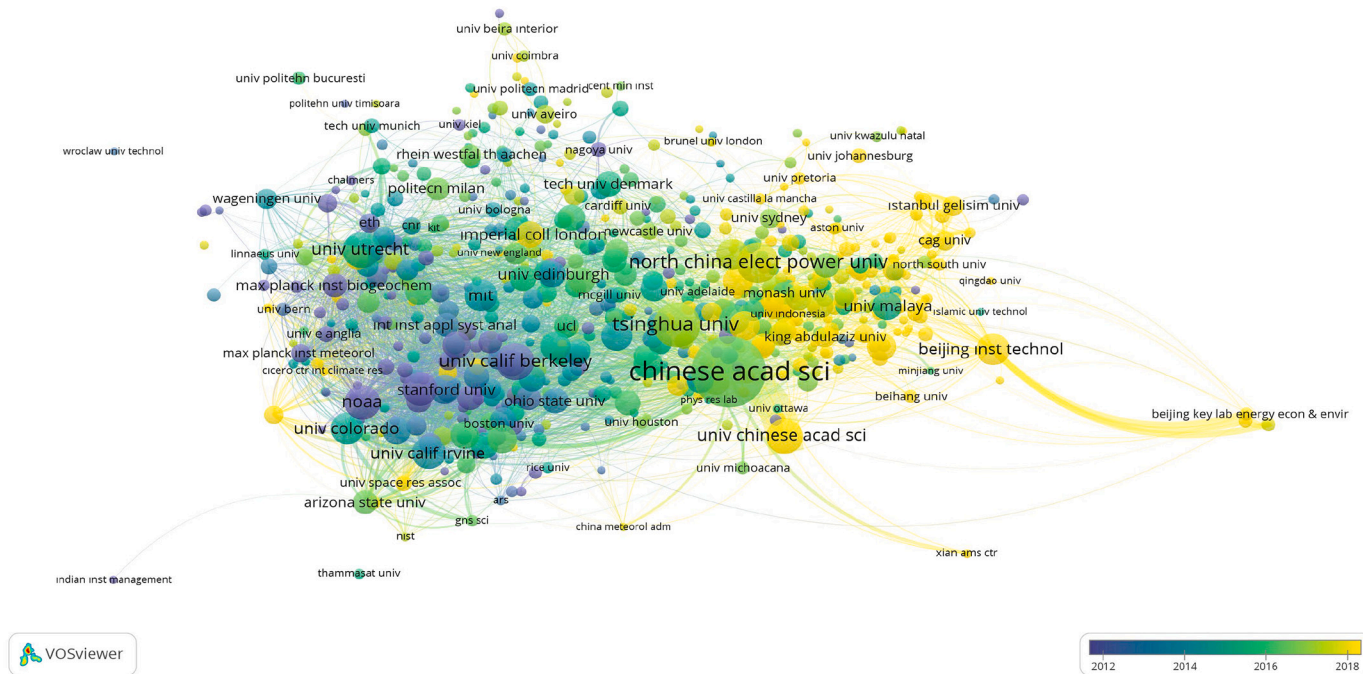


Fig. 6. The network map of publications on fossil fuel energy consumption and environmental degradation according to the co-authors' studies. The minimum number of documents of an author is set to 10 to reach a clearer network map. There are five clusters of authors who are mainly working together. Also, Gurney, K. R., Ciais, P., Van Vuuren, D., Manovic, V., Öztürk, İ., and Muhammad, S. are the centers of the clusters, which means that these authors are working with other authors frequently and have a relatively higher number of publications. Moreover, the right side of Fig. 6 shows that the publications of these authors were published after 2018.

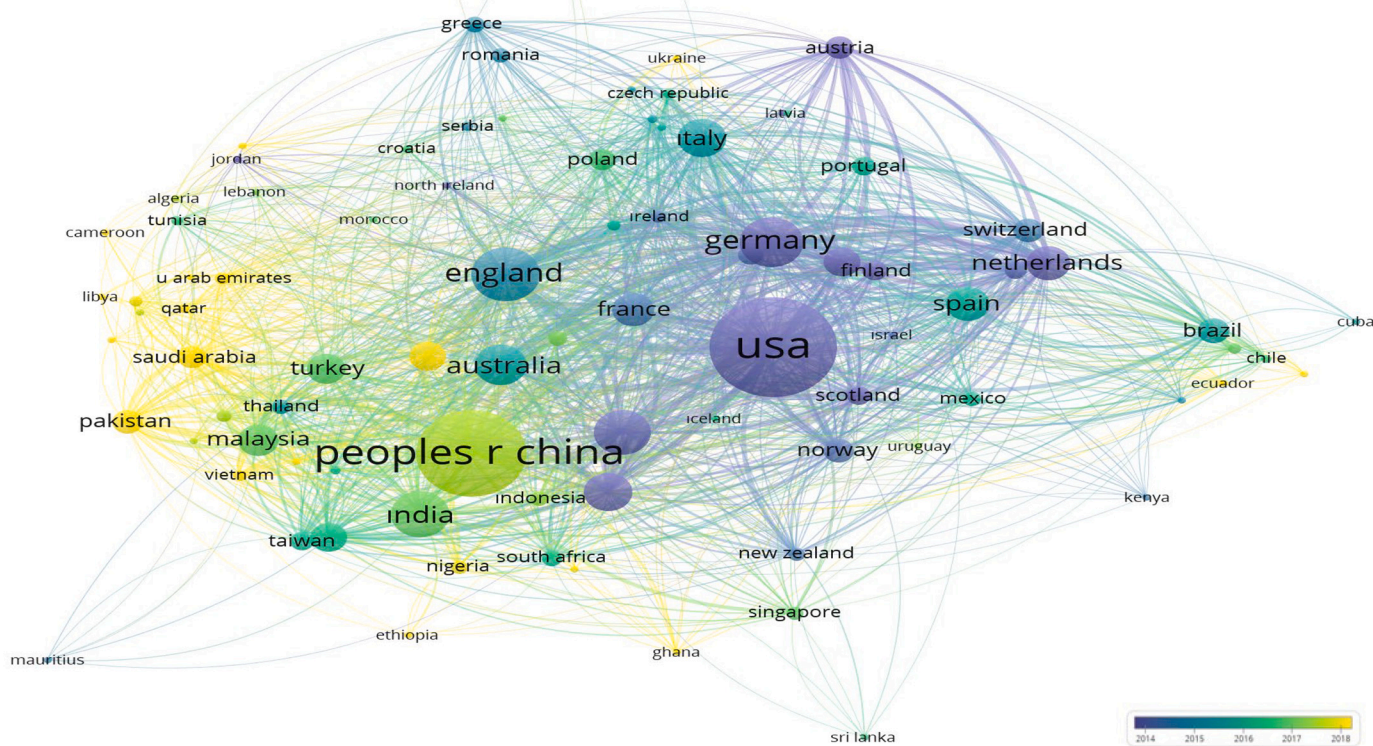
4.3. Discussion and implications

In this study a bibliometric analysis was applied to examine the energy consumption and environmental degradation nexus at a disaggregated level on a global scale. The bibliometric analysis results show that (i) studies about the energy consumption and environmental degradation nexus at a disaggregated level have received increasing attention since 1991; (ii) there have been many more studies on

renewable energy consumption than on fossil fuel consumption; (iii) most of the studies in both disaggregated groups (i.e., renewable energy & environmental degradation and fossil fuel energy & environmental degradation) are found under the categories of energy fuels, environmental sciences, and green sustainable science technology in the order mentioned; (iv) Elsevier is the most leading publisher by which most of the studies were published; (v) most researchers are from the USA, whereas China and Pakistan have come to the fore recently. Hence, the



**Fig. 7.** The network map of publications on fossil fuel energy consumption and environmental degradation according to the author's organizations. The minimum number of documents of an organization is set to 10 to reach a clearer network map.



**Fig. 8.** The network map of publications on fossil fuel energy consumption and environmental degradation according to the authors' countries. The minimum number of documents of a country is set to 10 to reach a clearer network map.

bibliometric analysis results present important findings about what emerging trends are and how the nexus between energy consumption and environmental degradation has been progressing at a disaggregated level. The results obtained in this study are parallel with the studies in the current literature, such as [Adebayo et al. \(2021a\)](#), [Adebayo et al. \(2021b\)](#), [Awosusi et al. \(2022\)](#), [Kartal \(2022\)](#), [Kartal et al. \(2022\)](#), and

[Kirikkaleli et al. \(2022\)](#), which also highlights the importance of the impact of energy consumption on environmental degradation.

Considering the main the characteristics of the studies conducted between 1980 and 2021 as well as the findings obtained from the bibliometric analysis, it may be recommended in future studies to:

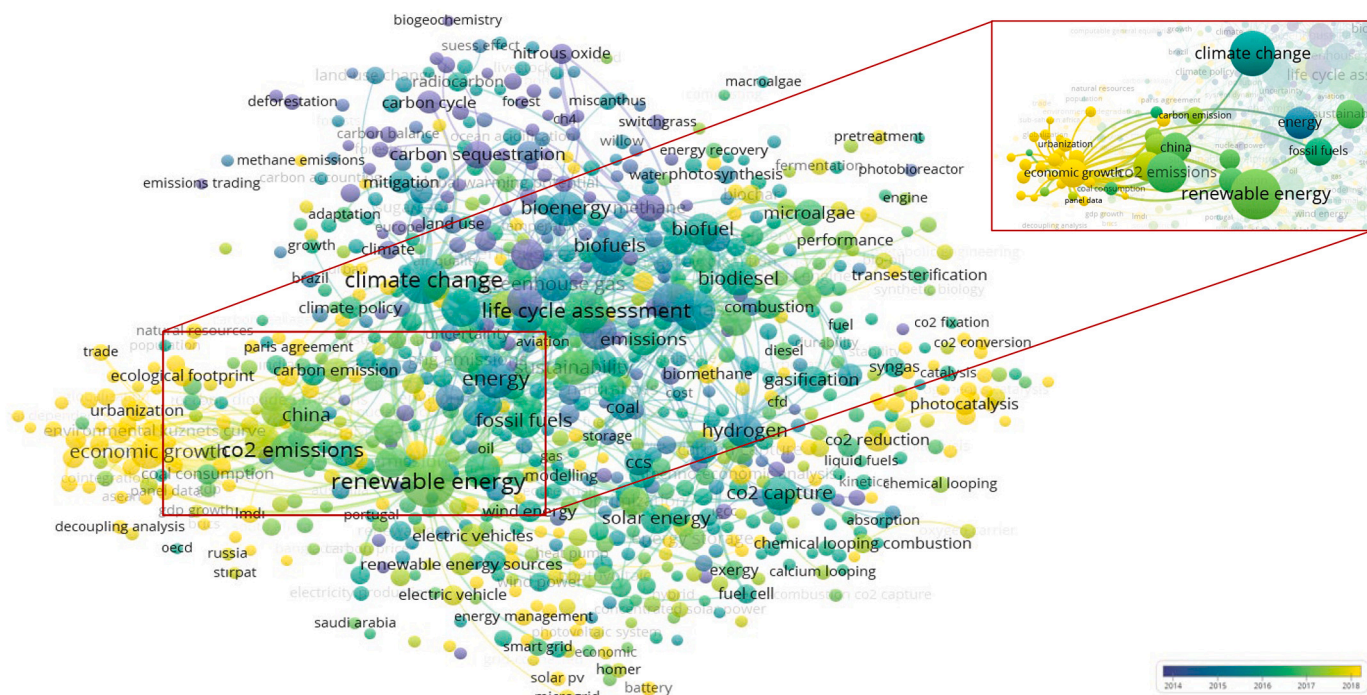


Fig. 9. The network map of keywords used for fossil fuel energy consumption and environmental degradation. The minimum number of occurrences of a keyword is set to 10 to reach a clearer network map.

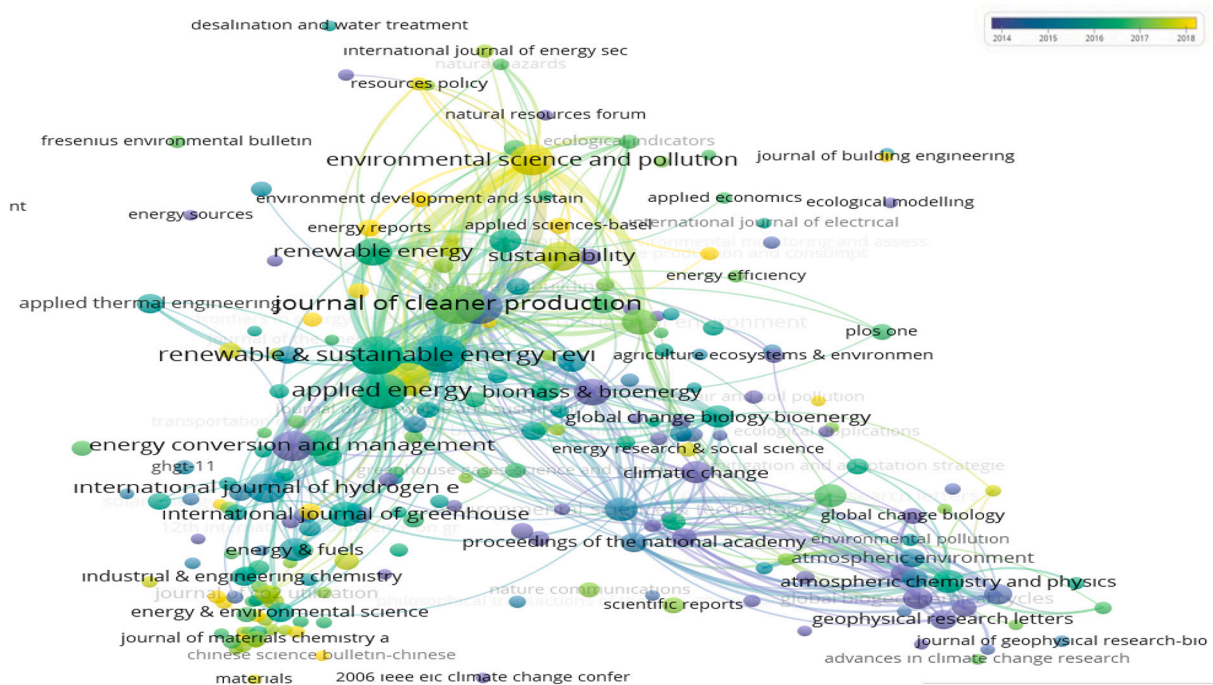


Fig. 10. The network map of the cited journals about fossil fuel energy consumption and environmental degradation. The minimum number of occurrences of a journal is set to 20 to reach a clearer network map.

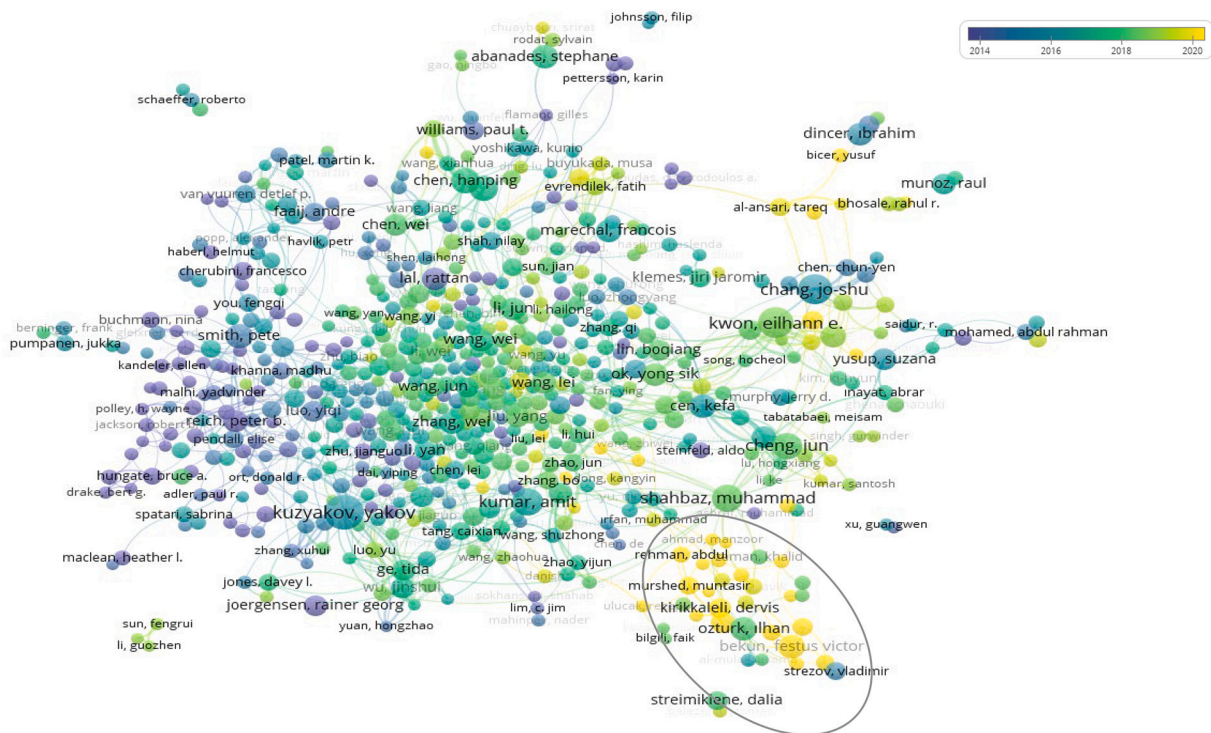
1) continue to study on renewable sources to enable transition from fossil energy to renewable energy to reduce the adverse effects on the environment by reducing degradation.

Although the number of studies on renewable energy and renewable sources is increasing, unfortunately, the use of fossil resources still remains an important issue for some countries, such as China and India. For this reason, it is important to continue studies on renewable sources

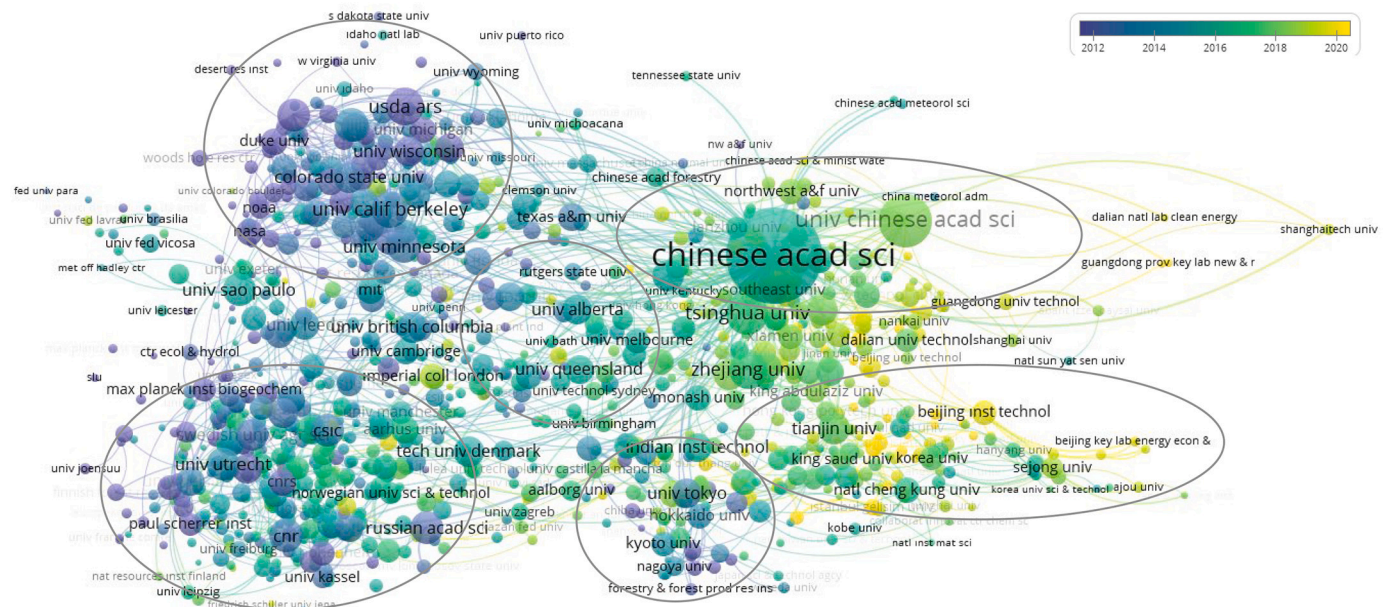
in order to support the transition from fossil resources to renewable sources.

2) focus on energy fuels and environmental sciences to decrease negative effects of energy consumption on the environment.

While examining the nexus between energy consumption and environmental degradation from various perspectives, it is still important to



**Fig. 11.** The network map of publications on renewable energy consumption and environmental degradation according to the co-authors' studies. The minimum number of documents of an author is set to 15 to reach a clearer network map. Contrary to the network map visualization of renewable energy consumption and environmental degradation based on the co-authors' studies, it was revealed that there is no clear clustering structure (Fig. 11). Also, it was seen that Öztürk, İ., Kirikkaleli, D., and Bekun, F.V. are the authors working on this topic after 2018. Kuzuyakov, Y., Zang, W., and Shahbaz, M. have a relatively higher number of connections than others.



**Fig. 12.** The network map of publications on renewable energy consumption and environmental degradation according to the authors' organizations. The minimum number of organizations of an author is set to 15 to reach a clearer network map.

focus on energy fuels and environmental science categories because they include both energy consumption and environmental degradation where the nexus occurs the most.

3) consider recent theoretical developments in related topics, such as urbanization, CO<sub>2</sub> emissions, ecological footprint, load capacity

factor, institutional quality, and political stability while examining the energy consumption and environmental degradation nexus.

Although it is still valuable to consider the well-known and most common factors, it is also important to follow how the literature evolves. In the recent literature, a variety of indicators, such as institutional

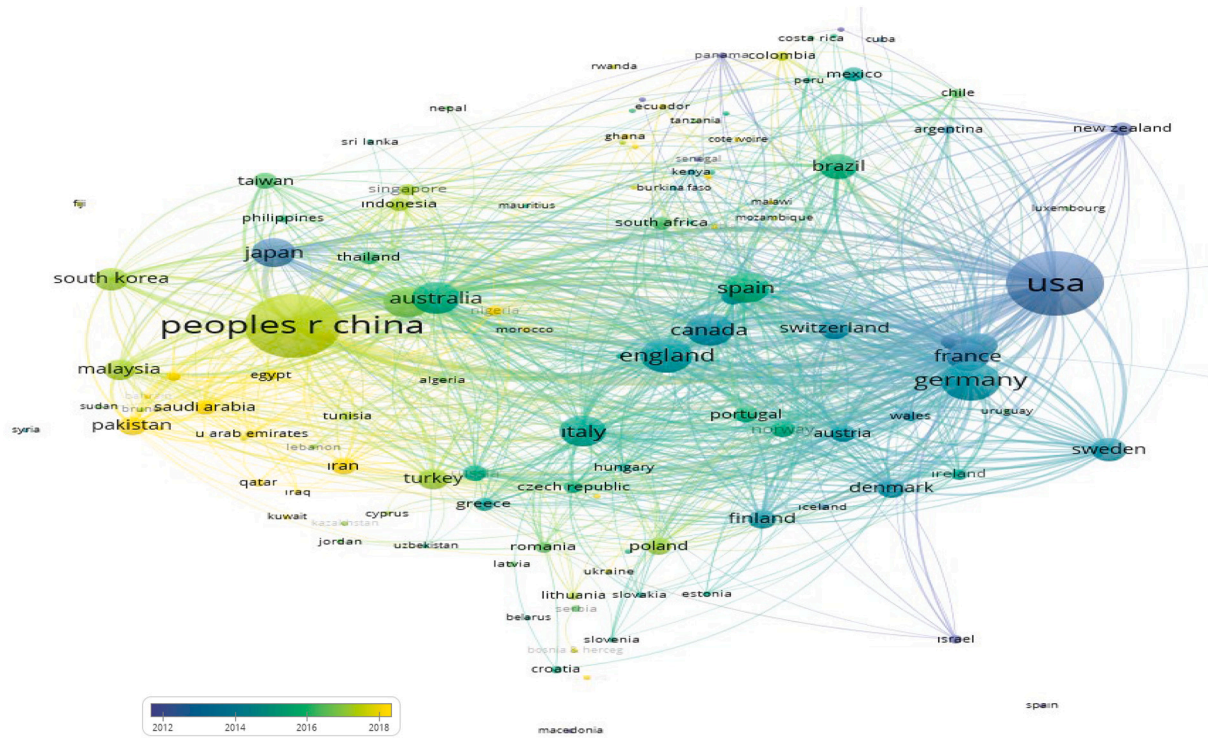


Fig. 13. The network map of publications on renewable energy consumption and environmental degradation according to the authors' countries. The minimum number of documents of a country is set to 10 to reach a clearer network map.

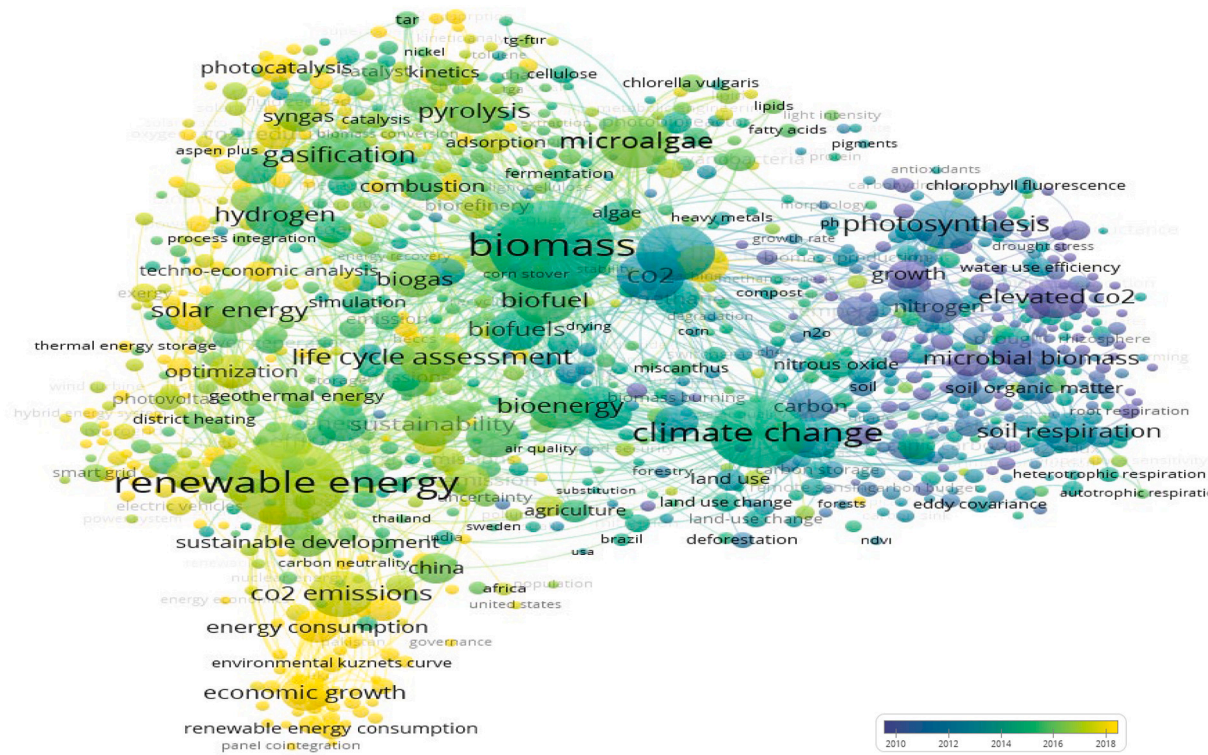


Fig. 14. The network map of keywords for about renewable energy consumption and environmental degradation. The minimum number of occurrences of a keyword is set to 20 to reach a clearer network map.

quality and political stability, have been used as explanatory variables. Moreover, indicators, such as ecological footprint and load capacity factor, have been used as a proxy for environmental degradation in

addition to CO<sub>2</sub> emission. For this reason, future studies should consider the most recent theoretical developments when examining the nexus between energy consumption and environmental degradation.

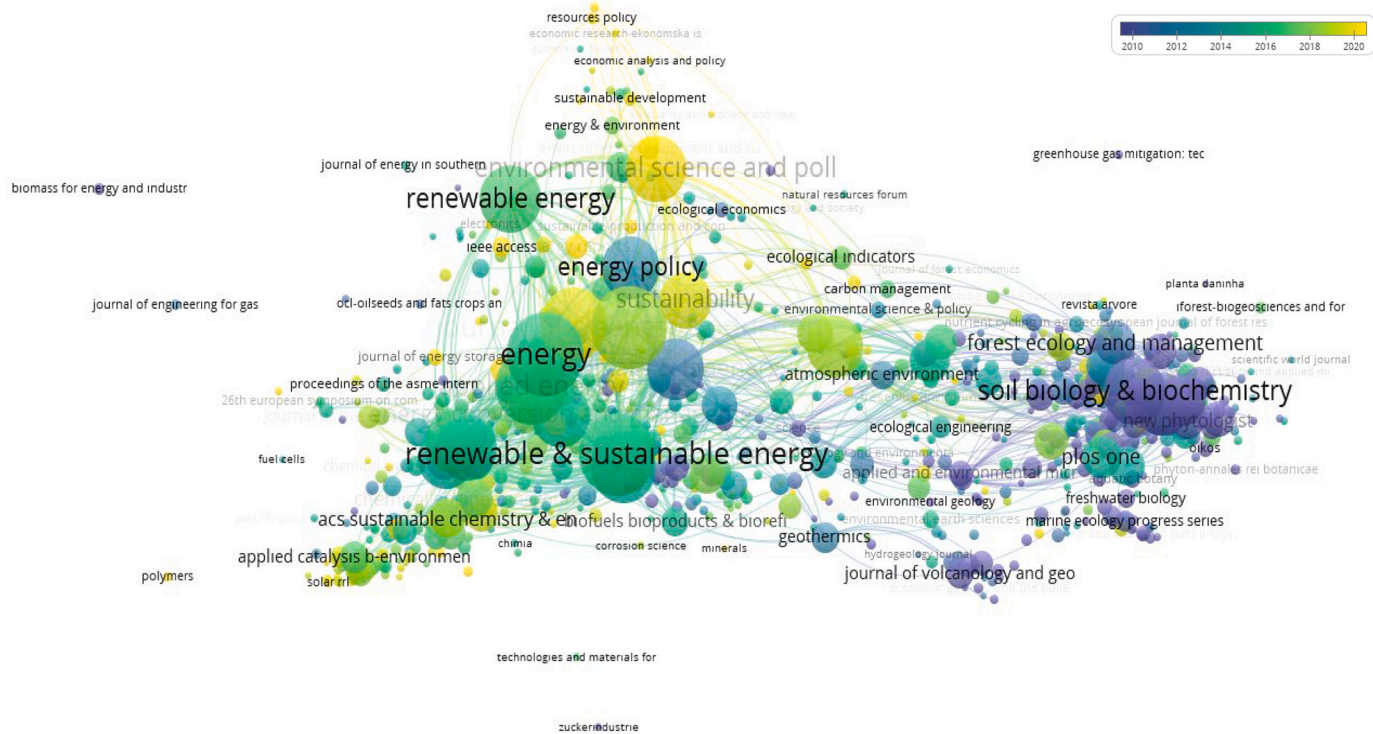


Fig. 15. The network map of the cited journals about renewable energy consumption and environmental degradation. The minimum number of occurrences of a journal is set to 20 to reach a clearer network map.

- 4) collaborate with the researchers from the USA and China to support the development of the literature.

The bibliometric analysis results show that the researchers from the USA and China have an important share in the whole population. Considering this fact, it is important to collaborate with the researchers from the USA and China in future studies because they are the people who shape the literature and developments.

- 5) follow the developing literature and the leading journals published by Elsevier and Springer.

The bibliometric analysis results present that both Elsevier and Springer are the leading publishers, while journals, such as Renewable & Sustainable Energy Reviews, Renewable Energy, Energy Policy, Environmental Science & Environmental Pollution, which are published by these publishers have a leading role. Thus, it is crucial for policymakers as well as researchers to follow up the most recent literature and journals that are provided by these publishers.

### 5. Conclusion

This study examines the nexus between energy consumption and environmental degradation at a disaggregated level on a global scale by using a bibliometric analysis, which is the main novelty of the study. In this context, 17,298 studies on fossil fuel energy consumption & environmental degradation, and 62,002 studies on renewable energy consumption & environmental degradation, published between 1980 and 2021 in the WoS database, were defined by using keywords and analyzed in order. The following results were found based on a bibliometric analysis:

First, the energy consumption and environmental degradation nexus has been an important and evolving topic since 1991. However, this topic attracted attention among scholars in the 2000s and most of the studies have been published as articles in journals. Second, the number

of renewable energy-related studies grows much faster than the number of fossil fuel-related studies in the area of environmental degradation. Third, many of the studies in both disaggregated groups are found under the categories of energy fuels, environmental sciences, and green sustainable science technology, respectively. Fourth, Elsevier and Springer are the publishers, by which most of the studies were published. Fifth, the USA is the country that publishes most of the studies about the nexus, whereas China and Pakistan have come to the fore in recent times. Hence, this study assesses the emerging trends in the literature on the energy consumption and environmental degradation nexus.

By considering the bibliometric analysis results, the following issues were suggested to be considered in future studies: (1) continuing to study on renewable sources to enable transition from the fossil energy to the renewable energy to reduce the adverse effects on the environment by reducing degradation; (2) focusing on energy fuels and environmental sciences to reduce the negative effects of energy on the environment; (3) considering the most recent theoretical developments, such as urbanization, CO<sub>2</sub> emissions, ecological footprint, load capacity factor, institutional quality, and political stability while examining the energy consumption and environmental degradation nexus; (4) collaborating with the researchers from the USA and China to support the development of the literature; (5) following the recent literature and leading journals published by Elsevier and Springer.

However, this study has some limitations that can be improved by future studies: (1) Although this study considers the studies indexed in the WoS, which is one of the largest databases, it does not include all the studies that have been published in other databases, such as Science-direct and Scopus; (2) This study uses some keywords in the queries to identify relevant studies on energy consumption and environmental degradation. Therefore, there may be some studies that were not included in this study as no single search query is expected to be perfect to capture 100% of studies in related fields. (3) This study focuses on studies identified using certain keywords to exclude irrelevant search results. However, there may be other researches published in the area without including these keywords.

By considering the limitations of the study, it can be recommended that future studies cover more databases, such as Scienedirect and Scopus, which are also important databases. Also, more keywords can be used in queries and new keywords not used in this study can be added. Moreover, future studies can include data for the year 2022 after the end of the year. Furthermore, future studies can include COVID-19 pandemic as a very recent phenomenon.

### Disclosure statement

The authors certify that they have NO affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

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### Availability of data and materials

The data that support the findings of this study are available in Web of Science database, of which is extracted by VOSviewer tool.

### Ethics approval and consent to participate

Not applicable.

### Consent for publication

The authors are willing to permit the Journal to publish the article.

### Authors' contributions

The authors have contributed equally to this work. All authors read and approved the final manuscript.

### Declaration of Competing Interest

The authors declare that they have no competing interests.

### Data availability

Data will be made available on request.

### Acknowledgments

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