Research Landscape of Energy Transition and Green Finance: A Bibliometric Analysis

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Abstract

This study utilizes bibliometric analysis to examine historical and present research patterns in the realms of energy transition and green finance and to forecast potential future domains. Using the bibliometric method, 328 scholarly articles from the Web of Science database were evaluated. This paper identifies influential publications, maps the research landscape, and forecasts emerging tendencies through co-citation and co-word analyses. Co-citation analysis found three main clusters, whilst co-word scrutiny revealed four main clusters. Despite the growing significance of research on energy transition and green finance research, further in-depth investigation is necessary to offer a thorough depiction of the research domain. This research represents a pioneering endeavour in the utilization of bibliometric analysis to investigate the interrelationship between two items. It offers valuable insights into the rapidly expanding field of energy transition and green finance, effectively highlighting its contours and indicating potential future developments.

Introduction

The rapid industrial expansion brings noteworthy environmental issues, including elevated pollution and resource scarcity (Ikumapayi et al., 2023; Tao et al., 2022). Environmental issues now pose significant threats to human well-being (Sharma et al., 2021). As we address pressures such as resource scarcity, social advancement, and ecological protection, rational energy utilization becomes crucial for global sustainability, further emphasizing the necessity of energy transition due to the depletion of traditional reserves (Liu et al., 2017; Wang et al., 2021b). Under such circumstances, energy transition implies the transition from fossil fuel-dependent energy sources to those that produce zero carbon emissions (An et al., 2022). The emergence of clean and low-carbon energy has captured growing attention (Zou et al., 2016). Currently, the global landscape is amidst a period of energy revolution and transition, where the international focus on energy is progressively shifting from traditional fossil fuels like petroleum and gas to encompass renewable energy and energy efficiency (Zhao et al., 2022). For instance, the United States plans a 50% greenhouse gas reduction by 2030; Japan targets a 46–50% emission cut by 2030 from 2013 levels; Canada strengthens contributions for a 40–45% reduction from 2005 by 2030; the European Union aims for a 55% emission cut by 2030 and net zero by 2050; China announces to control coal-fired power generation projects; South Africa shifts emissions peak to 2025 (Earth.Org, 2021).

In contrast to the mature market of traditional energy, renewable energy is constrained by technological limitations and financial barriers (Peimani, 2018). Traditional finance prioritizes profit maximization, focusing on risk-return optimization and disregarding externalities. Due to substantial initial investments and extended payback periods, businesses and financial entities often exhibit scepticism towards pro-social or pro-environmental ventures (Tao et al., 2022). As societal awareness of corporate externalities grows, value maximization gradually integrates considerations for diverse stakeholders, including society and the environment. Opportunities in clean technology and other environmentally favourable domains attract heightened investor interest (Liu et al., 2022a; Liu et al., 2022b). In response, green finance is an innovative financial instrument bridging finance and the environmental sector (Elheddad et al., 2021;
Rasoulinezhad & Taghizadeh-Hesary, 2022). Employing financial services, green finance decreases the support for heavy pollution and energy-intensive companies, promotes eco-conscious enterprises, lessens energy consumption intensity and consequently fosters harmonized advancement encompassing economic growth and environmental protection (Wang et al., 2021b).

Practically, the significance of green finance's potential contribution to developing renewable energy is increasingly highlighted (Rasoulinezhad & Taghizadeh-Hesary, 2022). While the effect of green finance on mitigating emissions is widely acknowledged, its precise role in supporting the energy transition remains underexplored. Moreover, existing research related to green finance and renewable energy predominantly relies on theoretical deductions, with only a handful of recent and fragmented preliminary empirical studies. The existing body of research in the fields of energy transition and green finance exhibits a lack of coherence, which serves as the motivation of this paper. At the stage of transitioning towards renewable energy sources, it is important to consolidate existing knowledge to find the most salient issues.

To effectively set green finance policies and track enhancements on energy transition, it is crucial to comprehend recent trends in literature. This study employs bibliometric analysis to assess related literature spanning 2012 to 2023, addresses knowledge gaps and offer insights into the field's evolution, aiding researchers, policymakers, and industry professionals to effectively apprehend the status quo and future direction within the energy transition-green finance relationship. Unlike prior studies that mainly concentrate on individual themes, it pioneers the use of bibliometric analysis to explore the correlation between two items. This research aims to comprehensively understand energy transition and green finance research by accomplishing two research objectives:

1. To identify influential past research works and current prevalent themes in energy transition and green finance using co-citation analysis.
2. To uncover thematic structures, dominant topics, and emerging areas in energy transition and green finance research, with the goal of predicting future trends and potential focus areas using co-word analysis.

**Literature Review**

Green finance constitutes a pivotal financial mechanism closely tied to environmental conservation (Wang et al., 2023a). Energy transition initiatives can be propelled through the advancement of green finance (Rasoulinezhad & Taghizadeh-Hesary, 2022). Theoretical studies have explored the correlation between green finance and energy transition through case studies from various countries. In the context of China, Lee (2020) examines the green finance-sustainability linkage and reveals a favourable effect on green energy projects. Drawing from the case of Costa Rica, Goldstein (2001) emphasizes the necessity of global green economic reforms, functioning as a potent catalyst to boost green energy investment and reduce environmental pollution. Prakash and Sethi (Prakash & Sethi, 2021) suggest green bonds as the means to bridge the financing gap for India to meet sustainable development goals. Ainou et al. (2023)
recommend enhancing Morocco’s energy transition through increased use of renewables and efficient technologies, achieved by implementing green investment projects.

Energy transition and green finance relationship can be influenced by other factors, for example, financial market mechanisms and government policies (Wang & Zhi, 2016). Meo and Karim (2022) use quantile regression to verify that market conditions and mechanisms are instrumental in establishing a favourable association between green financing and carbon dioxide (CO2) emissions reduction. By the daily data from December 2008 to December 2019, Nguyen et al. (2021) demonstrate the influence of investment time and frequency horizons on green finance’ impact on the promotion of clean energy.

However, some scholars have identified the inefficiency issues of green finance on energy transition. For example, Hafner et al. (2020) show green finance inefficiency in the United Kingdom due to weak financial infrastructure. Gibon et al. (2020) reveal that suboptimal fund allocation practices counteract the intended positive impact of green financing. Considering the multifaceted determinants shaping the association between green finance and energy transition, a rationale exists for delving deeper into their intricate interrelationship, which serves as the motivation for this paper.

Although previous studies have explored how green finance stimulates energy transition, they are topic-limited. Besides, the literature on energy transition and green finance is more theoretical and qualitative in interpretation, while quantitative research techniques have made fewer contributions in the past. The bibliometric analysis proposes a systematic research framework with delineating pivotal scholarly publications, mapping a cognitive structure of knowledge, and prognosticating nascent trends by co-citation and co-word analyses. This framework assists researchers in exploring theories and addressing research gaps to address the inter-relationship between energy transition and green finance. Practitioners can also utilize it to formulate practical plans, comprehend stakeholder dynamics, address diverse developmental needs, and tackle potential future issues.

Methods

Bibliometric Approach

Bibliometric analysis, through examination of existing publications encompassing authors, keywords, publishing locations, sources, etc., enables the comprehensive evaluation of the status within a specific research area (Almas et al., 2022; Fauzi, 2023a). This analytical approach facilitates an assessment of the developmental trajectory and potential of a designated topic (Yan et al., 2022). Currently, within diverse research fields, the employment of bibliometric analysis has been instrumental in uncovering the evolution of literature focused on a target theme, alongside an exploration of publishing sources and collaborative relationships among authors and countries/regions (Wider et al., 2023; Zakaria et al., 2023). The primary strength of bibliometric analysis lies in the transformation of intangible scientific literature into a structured and manageable entity (Fauzi et al., 2023b; Yao et al., 2022). Co-citation and co-word analysis deepen structural evaluation and future direction mapping (Fauzi, et al., 2022b)
Co-citation analysis hinges upon tallying concurrent citations and utilizes co-citation counts to assess similarities among documents, journals, and authors (Fauzi, 2023a). The examination of research themes involves the organization of scholarly literature, thereby unveiling coherence and evolutionary trends (Fauzi, et al., 2022a; White & McCain, 1998). Prominent publications derive their significance from quantified co-cited counts and link strength (Bashar et al., 2021). The frequency of keywords in articles is calculated by co-word analysis (Verma et al., 2023). It explores the interactions among keywords, thereby indicating influential topics (Su & Lee, 2010). By extracting from titles, keywords or abstracts, co-word analysis assesses trend evolution and concept connections (Baker et al., 2020; Zhang et al., 2019).

Research design and data collection procedure

The study starts by carefully selecting literature that aligns with the specified search criteria. Subsequently, a comprehensive examination of both quantitative and qualitative aspects of the literature is conducted. This analytical process aims to derive meaningful results and draw appropriate conclusions.

The first step involves collecting data from the Web of Science (WOS) database. The process and parameters used for the literature search and screening are detailed in Table 1. WOS databases are selected for bibliometric analysis due to their superior quality and extensive content (Yadav & Banerji, 2023). These databases hold the distinction of being the most popular and reliable repositories of scholarly publication and citation data, offering extensive access to highly regarded research from around the world (Birkle et al., 2020; Martín-Martín et al., 2021). As mentioned in the "WOS Database" section, it refers to a comprehensive examination of all WOS databases. The "Time Period" covers all works from database inception until August 11, 2023. In the "Search Field" section, the search encompasses title, abstract, and keywords. The "Search Keywords" column reveals those articles containing the keywords ("energy transition*" or "green energy*" or "renewable energy*" or "alternative energy*" or "low-carbon energy*" or "environmentally friendly energy*" AND "green finance*" or "sustainable finance*" or "environmental finance*") were the main focus. The "Citation Topics Meso" column indicates that the study included all meso-level topics associated with the keywords. "Document Type" considered all document types, whereas "Languages" suggests that all languages were considered. This comprehensive procedure yielded 328 articles for further analysis.
In the second phase, a quantitative bibliometric analysis was conducted to clarify research on energy transition and green finance. This phase encompasses two two-stages: (1) an analysis of annual publication trends, and (2) a scientific mapping process. Within the scientific mapping step, version 1.6.18 of the bibliometric software VOSviewer was utilized. Network analysis was executed based on co-citation and keyword co-occurrence here, aiming to investigate the network of research collaborations and illuminate the latest academic trends. VOSviewer, an open-source tool, offers sufficient functions for visualizing bibliometric networks and scientifically depicting literature (Yao et al., 2022). It involves clustering scattered knowledge across diverse fields based on similarities and relevancies. Within the visual network, nodes represent specific entities, such as references and keywords. Nodes with high similarity are clustered together and differentiated from other clusters by color, while nodes with lower similarity are separated whenever possible (Eck & Waltman, 2010).

Finally, in the third stage, this study encompassed a qualitative thematic analysis of the literature, presented through tables and narrative summaries. Thematic analysis necessitated authors’ comprehensive reading of texts to become familiar with their substantive content and to assign a representative name to each identified cluster (Mashari et al., 2023).

Result and Discussion

This section encompasses statistical analysis of publication trends, co-citation analysis, and co-word analysis.

Publication Trends and Descriptive Analysis
Web of Science search retrieved 6,871 citations for selected articles (N = 328), with 5,647 without self-citations. The H-index stood at 44, with an average of 20.95 citations per article. The compilation of 328 articles shows a rise in demand for studies related to energy transition and green finance. Although this research started in 2012, it wasn't until 2019 that significant advancements were made. Since that time, the volume of pertinent publications has grown dramatically. Figure 1 depicts article publications and citations from 2012 to August 11, 2023.

**Co-citation Analysis**

This study employs document co-citation analysis over author co-citation analysis. The choice of document analysis aligns with the study's aim to map the intellectual framework of a specific field because author co-citation analysis risks misinterpreting findings due to authors' involvement in multiple research fields, as suggested by Hota et al. (2020). Co-citation analysis used 62 as the threshold, yielding a total of 62 cited references. Figure 2 displays network analysis, while Table 2 showcases the top ten co-cited references. Zhang et al. (2021) were cited 56 times, Meo and Karim (2022) were cited 39 times, and Taghizadeh-Hesary and Yoshino (2019) were cited 57 times.
Table 2
Top 10 documents ranked by co-citation and total link strength.

<table>
<thead>
<tr>
<th>No.</th>
<th>Documents</th>
<th>Citation</th>
<th>Total link strength</th>
</tr>
</thead>
</table>

Source: VOSviewer analysis on author interpretation

Co-citation analysis reveals three distinct clusters, each with a unique thematic emphasis. These clusters represent publications with thematic affinities and connections. Clusters with shared topics are noted by nodes of the same colour. Each cluster is identified and defined as follows:

- **Cluster 1 (Red)** includes 28 publications with the title “Green finance, emissions and sustainable development”. To address the dynamic shifts in global climate, tackle energy use and emissions
issues, and realize the ecologically comprehensive advancement of sustainable development objectives (SDGs), green finance acts as a mechanism for fostering the expansion of green productivity (Lee & Lee, 2022). It has emerged as a pivotal strategy for facilitating credit provisioning within the energy conservation and environmental protection industry, which eventually catalyzes effectuating energy transition (Jin et al., 2021). It also enhances the investment efficiency of renewable energy companies with over-investment (He, 2019a). A notable equilibrium relationship exists between carbon intensity, green finance and alternative energy consumption across a long term, wherein the primary influences on alternative energy consumption are green finance and carbon intensity (Ren et al., 2020). Decreasing industrial pollution and CO2 emissions through green finance enhances environmental quality and facilitates the attainment of environmental sustainability (Zhou et al., 2020).

- Cluster 2 (Green) contains 18 publications with the title “Impacting factors on green finance-emissions connection”. Factors influencing the energy transition-green finance relationship can be categorized into three classifications: market conditions, scientific technology and social factors. Meo and Karim's (2022) research verifies that the intensity of the green finance-emissions connection varies with countries due to market conditions related to green finance, such as bearish or bullish trends, along with country-specific market conditions. Li et al. (2021) further find that the Covid-19 pandemic recession in the market disturbs the effects of green finance with private participation in investment in renewable energy. For scientific technology, fintech leads in green finance by utilizing big data and artificial intelligence to cut industrial emissions and boost environmental investments (Muganyi et al., 2021). Furthermore, Akomea-Frimpong et al. (2022) regard social factors, encompassing environmental and climate change policies, interest rate dynamics, religious orientations, risk assessments, and concerns for social inclusivity and equity, as contributors to the establishment of green finance policies by banking institutions. Additionally, green regulations enhance the connection between green finance and renewable energy investments, while oil price fluctuations and geopolitical risks negatively impact investment trends in clean energy sources (Li et al., 2022b).

- Cluster 3 (Blue) contains 16 publications with the title “Green finance instruments”. Green finance exerts its influence on energy transition through a diverse array of financial instruments. The challenges in developing green energy projects, such as insufficient long-term financing, low return rates, multiple risks, and limited market player capacity, can be addressed through practical measures. These strategies encompass the involvement of financial institutions that promote environmentally friendly investments, the utilisation of spillover tax which can boost project returns, the establishment of green credit guarantee programmes to mitigate credit risk, the creation of community-based trust funds, and the addressing of green investment risks through financial and policy de-risking (Taghizadeh-Hesary & Yoshino, 2019, 2020). In addition, Mohsin et al. (2021) propose the promotion of green bonds within the renewable energy sector, achieved by constructing a low-carbon finance index utilizing a comprehensive range of energy, environmental, and financial indicators. Regarding the instrument of green investment, Alemzero et al. (2021) suggest amplifying regional investments in renewable energy and energy infrastructure.
Table 3 summarizes the co-citation analysis, which includes cluster labels, the number of publications, and representative publications.

<table>
<thead>
<tr>
<th>Cluster</th>
<th>Label</th>
<th>Number of publications</th>
<th>Representative publications</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Red)</td>
<td>Green finance, emissions and sustainable development</td>
<td>28</td>
<td>(Lee &amp; Lee, 2022), (Jin et al., 2021), (He et al., 2019a), (Ren et al., 2020), (Zhou et al., 2020)</td>
</tr>
<tr>
<td>2 (Green)</td>
<td>Impacting factors on green finance-emissions connection</td>
<td>18</td>
<td>(Meo &amp; Karim, 2022), (Li et al., 2021), (Muganyi et al., 2021), (Akomea-Frimpong et al., 2022), (Li et al., 2022b)</td>
</tr>
<tr>
<td>3 (Blue)</td>
<td>Green finance instruments</td>
<td>16</td>
<td>(Taghizadeh-Hesary &amp; Yoshino, 2019), (Taghizadeh-Hesary &amp; Yoshino, 2020), (Mohsin et al., 2021), (Alemzero et al., 2021)</td>
</tr>
</tbody>
</table>

Source: VOSviewer analysis on author interpretation

Co-occurrence of keyword

Each identified keyword appeared at least 8 times and 65 keywords were determined as the final selection for co-word analysis. Co-word analysis unveiled that "green finance" appeared 211 times, making it the most used keyword. "Renewable energy" and "CO2 emissions" were second and third, with 137 and 68 occurrences, respectively. The top 15 co-occurring keywords are shown in Table 4. Figure 3 shows the result of the co-word analysis, which is composed of four separate but seemingly connected clusters. The following traits of each cluster are assessed and discussed:
### Table 4  
**Keyword co-occurrence analysis top 15 keywords**

<table>
<thead>
<tr>
<th>Rank</th>
<th>Keyword</th>
<th>Occurrences</th>
<th>Total link strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Green finance</td>
<td>211</td>
<td>866</td>
</tr>
<tr>
<td>2</td>
<td>Renewable energy</td>
<td>137</td>
<td>602</td>
</tr>
<tr>
<td>3</td>
<td>CO2 emissions</td>
<td>68</td>
<td>404</td>
</tr>
<tr>
<td>4</td>
<td>Economic-growth</td>
<td>64</td>
<td>382</td>
</tr>
<tr>
<td>5</td>
<td>Consumption</td>
<td>59</td>
<td>366</td>
</tr>
<tr>
<td>6</td>
<td>China</td>
<td>71</td>
<td>332</td>
</tr>
<tr>
<td>7</td>
<td>Impact</td>
<td>46</td>
<td>256</td>
</tr>
<tr>
<td>8</td>
<td>Growth</td>
<td>50</td>
<td>247</td>
</tr>
<tr>
<td>9</td>
<td>Innovation</td>
<td>38</td>
<td>208</td>
</tr>
<tr>
<td>10</td>
<td>Sustainable development</td>
<td>37</td>
<td>194</td>
</tr>
<tr>
<td>11</td>
<td>Efficiency</td>
<td>30</td>
<td>159</td>
</tr>
<tr>
<td>12</td>
<td>Investment</td>
<td>29</td>
<td>151</td>
</tr>
<tr>
<td>13</td>
<td>Cointegration</td>
<td>24</td>
<td>131</td>
</tr>
<tr>
<td>14</td>
<td>Carbon emissions</td>
<td>19</td>
<td>117</td>
</tr>
</tbody>
</table>

- **Cluster 1** (Red) contains 22 keywords and is titled **“Chinese economic growth and environmental sustainability”**. The complex interplay between economic growth and environmental sustainability, particularly in China, is a significant trend shaping the global landscape. Empirical evidence has revealed the relationship between growth, driven by urbanization, trade, and financial development, and its effects on CO2 emissions and energy consumption (Abid et al., 2022). China’s growing economy has led to increased consumption, particularly of non-renewable energy sources, resulting in higher emissions (Chen et al., 2023b). The connection between the push for technology-driven solutions and the rapid transition towards renewable energy development is apparent. This transition is driven by both environmental concerns and the need for trade and economic advancement. China, similar to other nations, confronts the task of effectively balancing its substantial economic expansion with the imperative of maintaining environmental sustainability (Chen et al., 2023a). The nation’s efforts to achieve carbon neutrality demonstrated through emission reduction commitments, align with the broader global trend (Wei et al., 2022).

- **Cluster 2** (Green) contains 22 keywords and is titled **“Sustainable finance in the energy transition”**. There is currently a noticeable convergence between climate change imperatives and economic strategies in the contemporary global landscape. In light of the evident consequences of changing
weather patterns and environmental deterioration, there is a growing emphasis on energy transition (Bashir et al., 2023), which entails the transition from fossil fuel-dependent energy sources to those that produce zero carbon emissions (An et al., 2022). The central focus of this transition is the efficacy of sustainable finance, which has emerged as a crucial instrument in expediting our progress towards an environmentally conscious economy (Mirza et al., 2023). The emergence of green bonds as a financial mechanism exemplifies the market's proactive response to the urgent challenges posed by climate change (Mendez & Houghton, 2020). These instruments demonstrate the convergence of financial flows with the objectives of promoting low-carbon and climate-resilient development, particularly through their focus on climate and environmental projects (Hafner et al., 2020). The increasing inclination towards investing in renewable energy signifies not only a moral dedication but also an acknowledgement of the advantages in terms of performance and risk reduction (He, 2019b). The market is increasingly recognizing that the pursuit of sustainability does not necessarily conflict with the goals of efficiency and profitability (Rasoulinezhad & Taghizadeh-Hesary, 2022). On the contrary, these objectives can be mutually beneficial and interdependent. Policies are increasingly reinforcing this pattern, establishing a context in which climate finance has transitioned from being a specialized area to becoming an integral component of the global investment strategy (Akomea-Frimpong et al., 2022; Kempa & Moslener, 2017).

Cluster 3 (Blue) contains 12 keywords and is titled “Green finance in sustainable governance”. In recent times, there has been a notable convergence of governance, management, and sustainable development, with a particular focus on the diverse field of green finance (Wang et al., 2023b). Green finance encompasses various financial instruments and mechanisms, including green bonds, which are specifically designed to provide funding for projects that yield favourable environmental outcomes cc. These projects primarily focus on green energy initiatives and innovations aimed at enhancing energy efficiency. With the increasing urgency of addressing climate change, stakeholders across various sectors have started to closely examine the factors that influence environmental performance. The audit findings have highlighted a significant requirement to incorporate energy efficiency into organizational governance, going beyond mere operational obligations (Li et al., 2022b). In contrast to traditional financial mechanisms, which typically overlooked the environmental consequences of funded projects, the contemporary concept of green finance aims to ensure that the funds mobilized not only generate financial profits but also make a significant contribution to sustainable development (Zhang et al., 2022). Therefore, the responsibility lies in guaranteeing the smoothness of this integration, rendering it a matter of both management and governance.

Cluster 4 (Yellow) contains 9 keywords and is titled “Economic growth and carbon emissions in the COVID-19 landscape”. During the exceptional circumstances of the COVID-19 pandemic, significant transformations were witnessed in various sectors of the global economy. Scholars have directed their attention towards examining the interdependent connection between economic growth and carbon emissions. Researchers have discovered intriguing patterns by utilizing panel-data models, a methodology that incorporates both temporal dynamics and cross-sectional variations across countries or sectors (Wang et al., 2021a). Cointegration tests, a statistical methodology utilized to
detect enduring associations between variables, have unveiled a strong correlation between economic activities and their corresponding environmental footprints (Nketiah et al., 2022). Certain industries, particularly those that heavily depend on physical presence such as tourism and manufacturing, experienced a temporary decline in growth as a result of the pandemic-induced lockdowns (Barua, 2020). Consequently, there was a simultaneous decrease in carbon emissions (Chu et al., 2021). Nevertheless, as economies began to recover, emissions also experienced a resurgence, albeit with variations observed among different sectors (Bi, 2023). This discovery highlights a fundamental dilemma: the difficulty of disentangling economic growth from the deterioration of the environment.

Table 5 summarizes co-word analysis for energy transition and green finance literature, including cluster labels, the number of keywords, and representative keywords.

<table>
<thead>
<tr>
<th>Cluster</th>
<th>Label</th>
<th>Number of keywords</th>
<th>Representative Keywords</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Red)</td>
<td>Chinese economic growth and environmental sustainability</td>
<td>22</td>
<td>Carbon neutrality, China, CO2 emissions, consumption, countries, economic-growth, emissions, empirical-evidence, energy-consumption, environmental sustainability, financial development, growth, impacts, nexus, nonrenewable energy, panel, quality, renewable energy development, technology, trade, transition, urbanization.</td>
</tr>
<tr>
<td>2 (Green)</td>
<td>Sustainable finance in the energy transition</td>
<td>22</td>
<td>Climate change, climate finance, economy, efficiency, energy, energy transition, finance, green bond, impact, innovation, investment, market, performance, policies, power, renewable energy investment, risk, sustainable finance.</td>
</tr>
<tr>
<td>3 (Blue)</td>
<td>Green finance in sustainable governance</td>
<td>12</td>
<td>Climate-change, determinants, energy efficiency, environmental performance, governance, green bonds, green energy green finance, green innovation, management, sustainable development.</td>
</tr>
</tbody>
</table>

Source: VOSviewer analysis on author interpretation

Implications
This paper examines the current status of the energy transition-green finance association and yields illumination into the intricacies inherent in the body of literature through the application of bibliometric analysis. It provides comprehensive conceptual mapping, enhancing understanding of connections between prominent topics (Fauzi, et al., 2022a).

**Theoretical Implications**

The findings offer profound theoretical insights regarding the research dynamics and academic collaboration within the field of the energy transition-green finance connection by quantitative examination of literature data. Firstly, the paper provides a new perspective on the application of bibliometric analysis. Diverging from previous literature which focuses on singular thematic exploration, this research represents a pioneering endeavour in the utilization of bibliometric analysis to investigate the interrelationship between two items. Understanding the energy transition-green finance association can validate or refine existing theories and aid in predicting future trends.

Secondly, the co-citation analysis unveils the developmental trajectory and evolution of knowledge. The application of green finance to energy transition is proposed under sustainable development, closely tied to the imperative of reducing carbon emissions and addressing climate issues (Ren et al., 2020; Zhou et al., 2020). Furthermore, market conditions, technology and government policies have an impact on the intensity of this relationship (Akomea-Frimpong et al., 2022; Muganyi et al., 2021; Meo & Karim, 2022). Various instruments have been created, such as green bonds and green credits, to leverage the potential of green finance on energy transition (Mohsin et al., 2021; Taghizadeh-Hesary & Yoshino, 2020).

Thirdly, the analysis of keyword co-occurrence underscores the significance of evaluating energy transition and green finance across various countries or periods. For example, China faces the challenge of balancing its significant economic growth with the crucial need to uphold environmental sustainability, and align with the broader global trend (Chen et al., 2023a; Wei et al., 2022). This insight can guide researchers in delving into remediation studies aimed at minimizing environmental impacts, thereby securing the sustainable development of the economy.

Moreover, this paper verifies COVID-19's impact on carbon emissions and economic expansion. Many manufacturing activities were halted during the pandemic, leading to a significant reduction in both economic growth and carbon emissions (Barua, 2020; Chu et al., 2021). Following the end of the pandemic, although the economy begins to recover, there is also a rebound in carbon emissions (Bi, 2023). Therefore, further research is needed to explore how green finance can facilitate energy transition while maintaining economic growth.

**Practical Implications**

Pragmatically, the study exerts substantial influence across various industries and societal aspects. Firstly, the research findings can serve as crucial references for the government in formulating financial and energy policies. In the face of climate change, government policies are of paramount importance for both economic and environmental sustainability by guiding and regulating different parties (Bashir et al.,
This contributes to the development of policy strategies that support sustainable energy growth and moving towards a low-carbon economy. For example, the government can formulate relevant policies to contribute to the reduction of sulfur dioxide and wastewater emissions (Zhang et al., 2021b). The state can also establish green regulations frameworks to strengthen the relationship between green financing and renewable energy investment (Li et al., 2022b), safeguarding the interests of investors and maintaining market stability.

Moreover, the paper adds the growth of financial institutions in green finance. Based on findings, financial institutions can adjust their business strategies and introduce green finance products related to energy transition, such as green bonds, green credits, etc., to attract clients interested in investing in sustainable energy (Li et al., 2022b; Su et al., 2022). This requires financial institutions to possess specialized knowledge and collaborate with other stakeholders to achieve the dual goals of sustainable finance and energy transition.

Furthermore, the study has implications for corporate strategies and investment decisions. Companies can gain a more profound understanding of green finance's beneficial impact on energy transition, as well as identify potential challenges that may arise during the transition process. This aids companies in formulating development pathways that are not only strategic but also sustainable (Li et al., 2022a). Incorporating green finance and energy transition into long-term planning allows companies to select suitable green finance instruments that align with their specific needs, supporting financing for energy transition projects. This necessitates companies to foster adaptability to refine strategies in response to dynamic changes in both the market and the environment. Then, corporations can make a meaningful contribution towards enhancing value across environmental, societal, and economic dimensions.

Lastly, the findings support Sustainable Development Goals (SDGs). SDGs encompass the attainment of affordable, reliable, sustainable and modern energy production, including reducing reliance on finite resources, minimizing environmental pollution, and combating climate change and its impacts (SDGs 7 and 13). Furthermore, green finance contributes to make cities and human settlements inclusive, safe, resilient and sustainable by driving the adoption of renewable energy and enhancing efficiency (SDG 11) (Department of Economic and Social Affairs of United Nation, 2015). Supported by this study, we can propel the economy, society and environment sustainability, creating a better living environment for both current and future generations.

However, the journey toward an energy transition-green finance relationship has its distinct challenges, including risks on green technologies, relatively lower rate of return, lack of understanding by investors, regulatory uncertainty and limited access to finance (Taghizadeh-Hesary & Yoshino, 2019, 2020). Addressing these challenges requires collaborative efforts from governments, financial institutions, businesses, and various sectors of society. This entails creating supportive policies, awareness campaigns, standardized reporting frameworks, and innovative financing mechanisms to incentivize green finance and facilitate energy transition. In conclusion, studying green finance's energy transition impact not only aids in guiding policy formulation and business decisions but also contributes to driving
tangible progress in sustainable development and environmental preservation. Such research provides essential insights and guidance to various stakeholders for achieving a cleaner and more sustainable energy future.

**Conclusion, Limitations and Future Avenues**

This study presents a comprehensive bibliometric review of energy transition and green finance using a quantitative method to uncover recent and emerging trends. Literature related to the energy transition-green finance association emerged in 2012 and experienced a substantial increase starting in 2019. By co-citation analysis, past and current trends are classified into three clusters: "Green finance, emissions and sustainable development," "Impacting factors on green finance-emissions connection," and "Green finance instruments." These historical themes depict the background of green finance supporting energy transition, such as addressing climate change and emissions reduction. Simultaneously, in the co-word analysis, the generated clusters are related to emerging trends in green finance and energy transition, such as economic growth and environmental sustainability. The co-occurrence of keywords also suggests that future research should focus on topics such as formulating international policies, enhancing management and governance, and leveraging green finance for a mutually beneficial energy transition and economic development.

This research still has some limitations. Initially, bias in bibliometric analysis poses concerns. These biases encompass institutional bias, self-citation, and language bias (Bullock et al., 2018). Recent papers need time for citation accumulation. Current relevant papers may lack impact compared to older ones, which accumulate more citations due to extended depository presence. Thus, their influence may be unassessed currently. Additionally, citation impact mainly hinges on first authors in co-citation and other cited-based bibliometric analyses, like direct citation analysis and co-authorship (Zhao, 2006). These initial authors might co-author other impactful papers but are underrepresented in the present analysis. Besides, data source limitations arise. Although Web of Science stands as a reputable and reliable source of publications which ensures article quality, various databases, like Scopus and Dimension, might yield different results (Pranckutė, 2021). Another limitation involves subjective determination in the interpretation of clusters. The author's inductive approach, based on co-citation and co-word analyses, may influence outcomes. Cluster finalization hinges on the authors' judgment, potentially causing bias (Wider et al., 2023).

To address these issues, future research could utilize systematic review and meta-analysis to accommodate bibliometric limitations, explore more databases and conduct qualitative inquiries for deeper insights into green finance' influences on energy transition. Interdisciplinary collaboration among fields such as finance, energy, environmental science, engineering, social sciences and law can facilitate a comprehensive understanding of this domain and more effectively leverage green finance for energy transition advancement. Embracing the challenges and prospects of energy transition empowers researchers to contribute to addressing climate issues and achieving economic and environmental sustainably advancement.
Declarations

Ethical Approval
Not Applicable

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

JH and WW prepared concept of the study and literature review and conducted data collection. WW conceptualized and conducted data processing. All authors participated in discussion and interpretation of data processing results. All authors participated in manuscript editing and approved the final manuscript.

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Availability of data and materials

The raw data supporting the conclusion of this article will be made available by the corresponding author, without undue reservation.

References


Figure 1

Number of publications and citations, 2012 to August 11, 2023

(Source: Web of Science)
**Figure 2**

Co-citation analysis (VOSviewer visualization)
Figure 3

Co-word analysis on energy transition and green finance (VOSviewer visualization)