Green Project Management and Clean Energy: Emerging Trends and Business Challenges

Gerencia de Proyectos Verdes y Energías Limpias: Tendencias Emergentes y Desafíos Empresariales

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Abstract

Introduction: The transition to a sustainable energy model has positioned green projects and clean energy as global priorities. This study presents a bibliometric analysis of trends and challenges in this domain, offering a comprehensive view of the research landscape from 2002 to 2024.
Objective: To analyze research trends on green projects and clean energy worldwide, using a bibliometric approach to identify predominant study lines and key contributors.
Methodology: Using Scopus data, 122 documents from 96 sources authored by 344 contributors were analyzed. The study assessed scientific productivity, leading sources, prominent authors, key institutions, and emerging keywords.

Results: The findings reveal an annual growth rate of 7.59% in scientific output, with China leading global productivity, followed by India and the United States. The Journal of Cleaner Production and Resources Policy were identified as the most influential journals, while IBN Tofail and WSB universities emerged as key institutional contributors. Taghizadeh-Hesary F was recognized as the leading author. Keywords such as "sustainable development," "renewable energy," and "green projects" dominate the scientific discourse, aligning closely with global sustainability goals.
Conclusions: This study underscores the critical role of clean energy in combating climate change and facilitating the global energy transition, providing valuable insights for researchers, policymakers, and project managers.

Keywords
Sustainable development, renewable energy, Ecological projects, energy policy, climate change

Resumen

Introducción: La transición hacia un modelo energético sostenible ha situado los proyectos verdes y las energías limpias como prioridades globales. Este estudio realiza un análisis bibliométrico de las tendencias y desafíos en este ámbito, proporcionando una visión integral del panorama investigativo entre 2002 y 2024
Objetivo: Analizar las tendencias de investigación sobre proyectos verdes y energías limpias a nivel global, utilizando un enfoque bibliométrico para identificar líneas de estudio predominantes y autores destacados.
Metodología: Basado en datos de la base Scopus, se analizaron 122 documentos de 96 fuentes, con contribuciones de 344 autores. Se evaluó la productividad científica, las principales fuentes, autores destacados, instituciones líderes y palabras clave emergentes
Resultados: Los hallazgos revelan un crecimiento anual del 7,59% en la producción científica, con China liderando la productividad global, seguida de India y Estados Unidos. Las revistas Journal of Cleaner Production y Resources Policy sobresalen por su influencia, mientras que las universidades IBN Tofail y WSB emergen como actores clave. Taghizadeh-Hesary F se posiciona como el autor más relevante. Las palabras clave predominantes, como "desarrollo sostenible", "energías renovables" y "proyectos verdes", reflejan la convergencia de la investigación científica con los objetivos de sostenibilidad global
Conclusiones: Este análisis subraya el papel crítico de las energías limpias en la lucha contra el cambio climático y la transición hacia un futuro sostenible, ofreciendo perspectivas valiosas para investigadores, formuladores de políticas y gestores de proyectos.

Palabras clave
Desarrollo sostenible, energías renovables, proyectos ecológicos, política energética, cambio climático

I. INTRODUCTION

The climate crisis, evidenced by extreme weather events such as prolonged droughts, intense storms, and record-breaking heatwaves, has gained relevance in the contemporary global context [1]. These events pose significant challenges to sustainability, demanding urgent efforts to reduce the negative environmental impacts of energy generation [2]. Likewise, growing urbanization and population growth increase pressure on infrastructure and natural resources, further complicating the environmental outlook [3].

In this context, renewable energy-based projects have become a central pillar in mitigating climate change and promoting sustainability. These initiatives aim to reduce greenhouse gas emissions through the adoption of clean technologies and renewable energy sources, generating additional benefits in terms of social and economic development, such as job creation, technological advancement, and improved quality of life [4], [5], [6].

Key technologies include biomass, geothermal, hydroelectric, solar, and wind energy, each with advantages and limitations determined by factors such as resource availability, existing infrastructure, and governmental policies [7], [8].

Despite these variations, all these technologies share the goal of reducing dependence on fossil fuels and fostering sustainable energy systems [9]. In this way, clean energy represents an opportunity to modernize energy infrastructure and build a more sustainable future for current and future generations [10].

The development and adoption of renewable technologies are driven by scientific advances, increased environmental awareness, and pressure from governmental and social actors to reduce carbon emissions [11]. Within this framework, it is essential to comprehensively analyze current developments, technological trends, and the most effective energy practices. This study conducts a bibliometric analysis that identifies the main research topics, recent advances, and efficient management strategies in the field of sustainable energy, using an internationally recognized database [12], [13], [14].

The aim of this analysis is to stimulate an informed debate on how to facilitate the energy transition toward cleaner and more sustainable energy sources. It seeks to provide a solid foundation for strategic decision-making by researchers, policymakers, investors in green technologies, and project managers [15]. Ultimately, this work is expected to help pave the way toward an equitable and sustainable global energy system.

II. LITERATURE REVIEW

Climate change, exacerbated by rising global temperatures, presents significant challenges worldwide. These challenges manifest in extreme weather events that simultaneously affect multiple sectors and regions, complicating mitigation and adaptation strategies. The literature review addresses various aspects related to urbanization, energy transition, sustainable development, and the political and economic barriers that influence the adoption of clean energy.

Global warming has intensified the frequency and severity of extreme weather phenomena, impacting critical infrastructure and vulnerable communities [16]. The relationship between climate change and urban development is complex, requiring an integrated approach that considers both mitigation and adaptation [17]. Recent studies emphasize the need for an energy transition that prioritizes renewable sources and sustainable technologies to reduce dependence on fossil fuels [18].

Rapid urbanization in emerging economies has significantly increased the demand for natural resources, contributing to a greater ecological footprint [19]. Sustainable urban management is crucial to addressing these challenges, promoting practices that minimize environmental impact. Furthermore, the integration of advanced technological solutions in urban design can enhance city resilience to climate change [20].

Public policy plays a fundamental role in promoting renewable energy. Governments must implement regulatory frameworks that incentivize investment in clean technologies and foster innovation in the energy sector [21]. International collaboration is also essential for sharing knowledge and resources that facilitate the global energy transition.

Urbanization, Development, and Ecological Footprint

Accelerated urbanization and population growth have increased pressure on natural resources, resulting in a greater ecological footprint—particularly in emerging economies such as China [22]. The sustainable management of resources in urban areas is crucial to mitigating the negative effects of uncontrolled urban growth [23].

The increase in demand for basic services in urban areas intensifies pressure on water, energy, and transportation systems, contributing to rising greenhouse gas emissions and exacerbating climate change [24]. The integration of sustainable technologies in urban infrastructure is essential to mitigate these effects.

Energy efficiency in buildings, through green construction technologies, and effective waste management are key aspects to reducing the environmental impact of cities [25]. Additionally, citizen participation in urban planning ensures that strategies reflect community needs, promoting sustainable development [26].

Recent studies indicate that sustainable cities can achieve significant reductions in carbon emissions through the implementation of electric mobility solutions and smart traffic management systems [27]. Urban planning must also consider the development of green spaces, which not only improve air quality but also provide social and economic benefits [28]. Urban resilience to natural disasters is another critical aspect. Cities must adopt planning approaches that include early warning systems and effective evacuation strategies [29].

The literature suggests that urban policies should be dynamic and adaptive, allowing adjustments in response to environmental and social changes [30]. The integration of information and communication technologies in urban management can enhance the efficiency of services and improve emergency response capabilities [31].

Energy Transition and Technological Challenges

The energy transition toward a model based on renewable sources is crucial for addressing climate change and ensuring long-term sustainability. This process involves a profound transformation of traditional energy systems, which rely on fossil fuels, toward a more sustainable model. The growing demand for energy, particularly in emerging economies, intensifies the need for advanced technologies to diversify and decarbonize energy sources [32].

One of the main challenges is the integration of clean energy technologies into existing infrastructures, such as power grids. Renewable energy sources, such as solar and wind, exhibit variability in their generation, which requires improvements in storage capacities and intelligent grid management [33]. The implementation of smart grids and advanced storage systems, such as lithium-ion batteries, is essential to store energy during periods of high production and release it when demand is higher.

The energy transition also requires constant innovation in carbon capture and storage (CCS) technologies, which could play a crucial role in mitigating greenhouse gas emissions [34], [35]. However, the development of these technologies faces significant technical and economic challenges. The efficiency and economic viability of current CCS solutions require substantial improvements for large-scale implementation [36].

Digitization plays a fundamental role in the energy transition. The use of emerging technologies such as the Internet of Things (IoT), artificial intelligence, and big data analysis optimizes the management of energy systems, enabling a more efficient allocation of resources and greater integration of renewable energy sources [37]. These advancements facilitate the adaptation of infrastructures to new energy realities, although they require training of specialized human capital.

Renewable Energy and Sustainable Development

Renewable energies are key to sustainable development, not only for their ability to reduce greenhouse gas emissions but also for promoting energy independence and serving as a driver of economic growth. Recent studies indicate that renewable energies are essential to achieving global climate goals, especially in reducing the carbon footprint [38]. The expansion of technologies such as solar, wind, hydroelectric, and biomass has shown great potential in terms of job creation, energy cost reduction, and increased energy security [39].

The role of renewable energies in sustainable development transcends climate change mitigation by improving energy access in remote regions and promoting a circular economy. In developing countries, adopting renewable solutions can help reduce energy poverty and create sustainable infrastructures that support social and economic progress [40].

The transition towards renewable energies presents significant challenges in terms of investment and infrastructure adaptation. Financing these projects remains a key barrier, especially in developing countries with economic difficulties and a lack of political incentives. However, subsidy policies and innovative financial mechanisms, such as green bonds and socially responsible investment funds, are helping to overcome these challenges.

In the long term, promoting renewable energies not only contributes to environmental sustainability but also promotes social justice. Equitable access to clean energy can alleviate socioeconomic inequalities and promote a fairer distribution of energy resources globally [41].

Political and Economic Barriers to the Adoption of Clean Energy

The adoption of clean energies faces significant political and economic barriers that limit their global expansion. Despite the growing consensus on the need for a transition toward more sustainable energy sources, these obstacles hinder the effective implementation of policies and investment in clean technologies. The lack of a robust regulatory framework and resistance from traditional sectors are key factors limiting progress toward a sustainable energy future.

From a political perspective, one of the main challenges is the lack of will and leadership to implement energy policies that favor renewable energies. In many countries, especially those with economies dependent on fossil fuels, there is strong resistance to change due to economic and political interests linked to the oil, gas, and coal industries [42]. Subsidies for fossil fuels discourage investment in clean technologies by making renewable energy less competitive in terms of prices [43]. Additionally, the lack of coherence and continuity in energy policies, caused by changes in government and political priorities, generates uncertainty that hampers long-term investments in the clean energy sector [44].

Economic barriers are equally decisive. Although the costs of renewable technologies have decreased, initial investments in infrastructure and project financing remain high, limiting access to the energy transition, especially in emerging economies [45]. In many developing countries, the lack of access to adequate financing, both public and private, prevents large-scale deployment of clean energy projects. Moreover, economic volatility and financial risks associated with the energy transition create doubts among investors, delaying the adoption of renewable energies [46].

Another significant economic barrier is the lack of tax incentives and financial support mechanisms that facilitate access to clean technologies. Without public policies that offer tax exemptions, subsidies, or incentives for research and development of renewable energies, both companies and governments may be reluctant to bear the initial costs, even when the long-term return on investment is evident.

The transition towards a cleaner energy model also requires adapting existing infrastructures. The investments needed to modernize power grids, introduce energy storage technologies, and promote energy efficiency in buildings require significant efforts from both governments and the private sector.

In many countries, the shortage of specialized talent in renewable energies and emerging technologies hinders the development and expansion of the sector. The lack of educational programs, technical training, and international collaboration networks limits countries' ability to advance in the adoption of clean energy [47].

In general, overcoming these political and economic barriers requires a comprehensive approach that combines consistent public policies, financial incentives, and a clear commitment from governments and industry to reduce dependence on fossil fuels and promote investment in clean technologies.

III. METHODOLOGY

The present study focuses on current trends in green projects aimed at clean energy, a critical area for global sustainability and minimizing environmental impact. By analyzing scientific publications produced in recent years, the main lines of research, technological innovations, and management strategies in the field of sustainable energy have been identified. The objective is to map the state of the art, highlighting both consolidated and emerging areas that promise to advance towards more sustainable energy solutions.

Based on the above explanations, the following variables have been established with their descriptors (Table 1).

TABLE 1. STANDARDIZATION OF KEYWORDS

Variable	Descriptor
Proyectos Verdes	"green projects" "sustainable projects"
Energía Limpia	"clean energy" "alternative energy" "renewable energy"

Soruce: Authors(2024).

Based on the identification of these elements, the following search equation was formulated in the Scopus database:With the data obtained from Scopus, a data analysis process was carried out using R Studio software with its Bibliometrix package and VOS Viewer software to perform co-authorship network analysis and keyword analysis, integrating metrics such as publication density and citation index. This approach was complemented by a qualitative analysis of the most influential articles, which included a detailed review of the theoretical and methodological frameworks used by the authors. To perform the analysis of co-authorship networks and keyword analysis, integrating metrics such as publication density and citation index. This approach was complemented by a qualitative analysis of the most influential articles, which included a detailed examination of the theoretical and methodological frameworks used by the authors.

IV. RESULTS AND DISCUSSION

This section presents the results obtained from the detailed bibliometric analysis, followed by an in-depth discussion of the main trends, technological advances, challenges, socioeconomic impacts, and political barriers faced by the transition towards a sustainable energy system based on clean energies (Table 2).

TABLE 2. GENERAL SEARCH DATA

MAIN INFORMATION ABOUT DATA	
Timespan	2002:2024
Sources (Journals, Books, etc)	96
Documents	122
Annual Growth Rate %	7,59
Document Average Age	5,12
Average citations per doc	20,93
References	5334
DOCUMENT CONTENTS	
Keywords Plus (ID)	781
Author's Keywords (DE)	399
AUTHORS	
Authors	344
Authors of single-authored docs	22
AUTHORS COLLABORATION	
Single-authored docs	22
Co-Authors per Doc	3,02
International co-authorships %	24,59
DOCUMENT TYPES	
Article	83
Book	1
book chapter	6
conference paper	25
Note	2
Review	5

Source: Authors using R software based on Scopus information (2024).

Table 2 identifies the general elements associated with scientific production in the field of knowledge, showing a growth of 7.59% in recent years, with a total of 122 sources and 344 authors contributing to the publications. Similarly, the growth in scientific output can be seen more clearly in Figure 1, highlighting the years 2020 (16), 2022 (23), and 2023 (26) articles per year, during which a notable increase in publications related to the research topic was observed. These years account for 53.28% of all the research conducted.

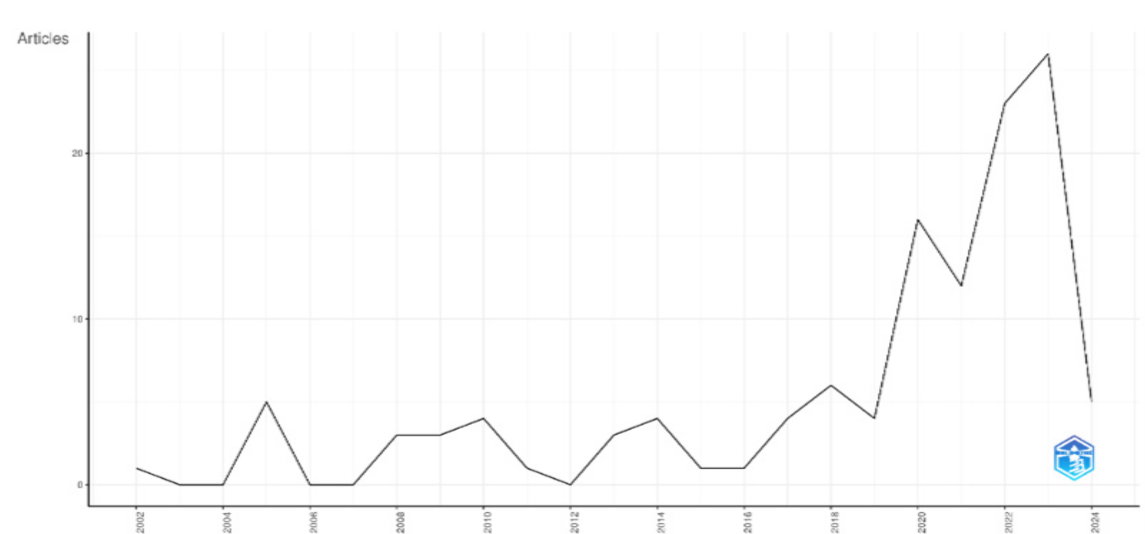

Figure 1. Annual Scientific Production. Source: Author based on Scopus information. (2024).

Next, the most relevant sources are displayed based on the frequency of publication on the topic and through the percentiles shown by Bradford's Law. This law classifies journals into three performance zones, each with an increase in the number of journals and a similar proportion of articles [48]. Tabla 3 shows the percentages corresponding to each Zone of

Bradford's Law. It is worth noting that Zone 1 is the one that concentrates the most publications with 33.61% (41) titles in 15 journals. Similarly, Figure 2 shows the most representative journals according to this law.

TABLA 3. LEY DE BRADFORD

Zona	No. Revistas	No. Títulos	Porcentajes
Zona 1	15	41	33,61%
Zona 2	41	40	33,61%
Zona 3	40	40	32,79%

Source: Authors based on Scopus information. (2024).

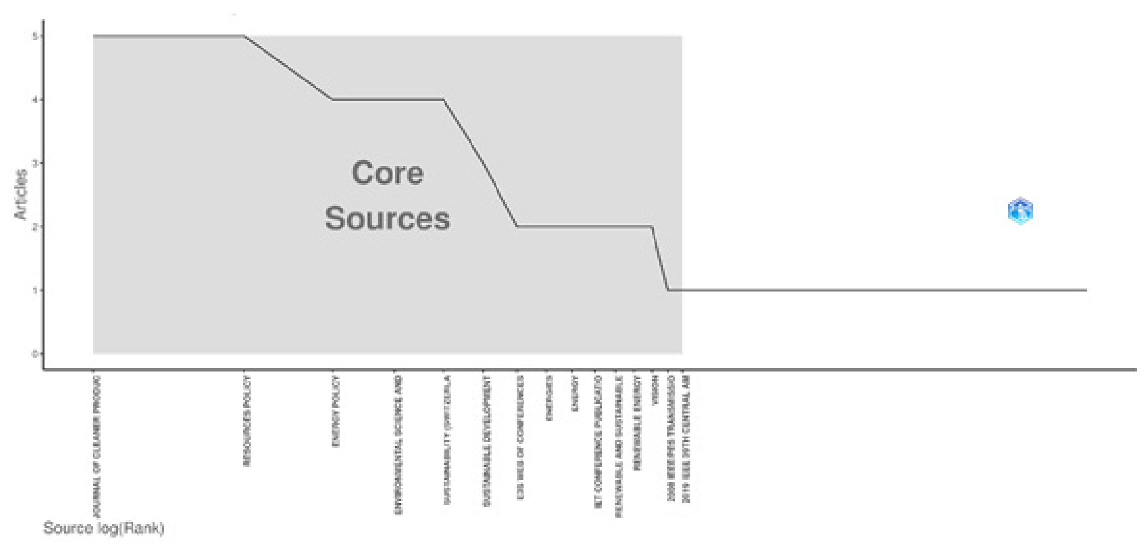

Figure 2. Bradford's Law. Source: Authors based on Scopus information. (2024).

In line with the above, Figure 3 shows that Journal of Cleaner Production and Resources Policy lead the field with 5 publications each, followed by Energy Policy, Environmental Science and Pollution Research, and Sustainability (Switzerland) with 4 publications each.

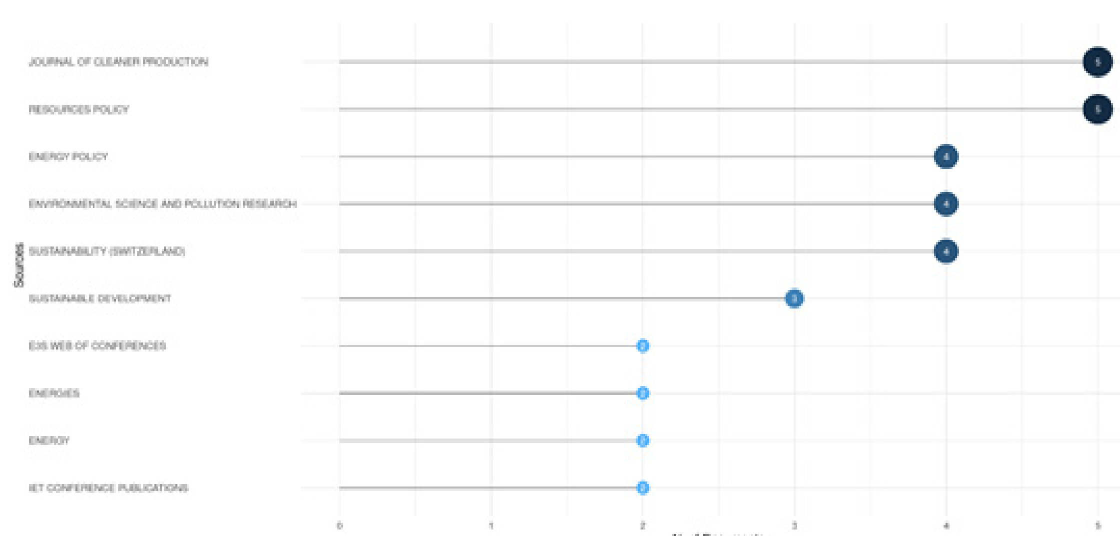

Figure 3. Most Relevant Sources. Source: Authors using R software based on Scopus information. (2024).

In the case of one of the most relevant sources identified, Journal of Cleaner Production is an international, transdisciplinary journal focused on research and practices related to cleaner production, the environment, and sustainability.

On the other hand, in terms of countries, China stands out as the leading contributor in terms of scientific productivity, with 50 contributions, followed by India with 28, the United States with 26, Italy with 16, Portugal with 16, Malaysia with 12, and Indonesia with 12, among others. This can be seen in Table 4.

TABLE 4. SCIENTIFIC PRODUCTION BY COUNTRY

Country	Freq
CHINA	50
INDIA	28
USA	26
ITALY	16
PORTUGAL	16
MALAYSIA	12
UKRAINE	12
INDONESIA	10
JAPAN	10
SWEDEN	10

Source: Author based on Scopus information (2024).

As can be seen, publications from China represent 14.66% of the total found. Recent studies show that investment in green industries has been increasing, and the nation is now the world's leading destination for green investments. According to these studies, China has committed to achieving carbon neutrality by 2060, which requires significant investments in environmentally friendly projects [49]. However, due to financial limitations that can seriously hinder its ability to invest in green technology, Chinese companies are constrained in their capacity for green innovation [50].

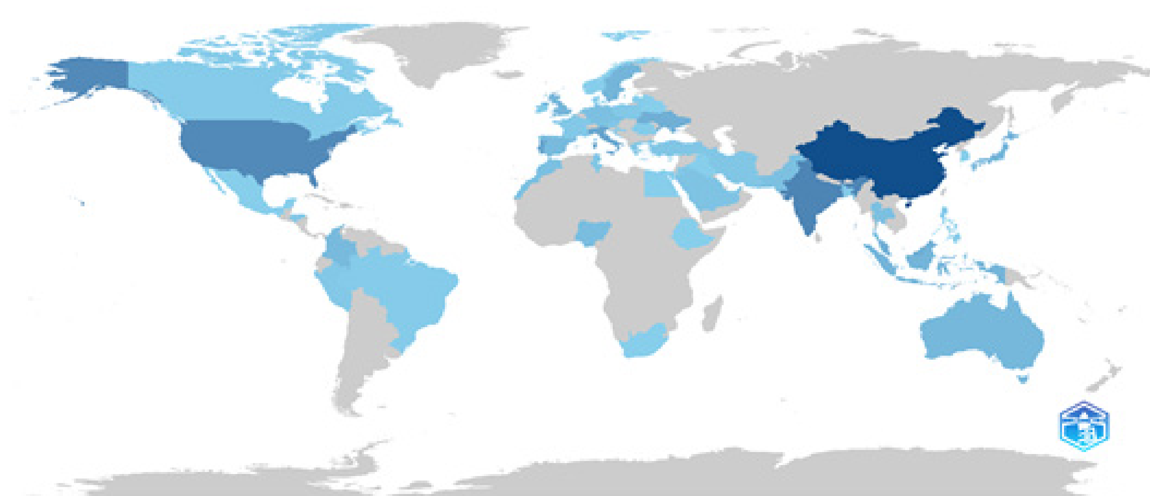

Figure 4. Scientific Production by Country. Source: Authors based on Scopus information. (2024).

Recent studies show that investment in green industries has been increasing, and the nation is now the world's leading destination for green investments. According to these studies, China has committed to achieving carbon neutrality by 2060, which requires significant investments in environmentally friendly projects [49]. However, due to financial constraints that can seriously hinder its ability to invest in green technology, Chinese companies face limitations in their capacity for green innovation [50].

Figure 5. Most Relevant Affiliations. Source: Author based on Scopus information.2024).

To measure researcher productivity, the frequency index is used as a reference; Figure 6 shows the leadership of Taghizadeh-Hesary F., with five (5) contributions, followed by Kwilinski A., Rasoulinezhad E., and Yoshino N., each with three (3) contributions. For the purposes of this research, Lotka's Law is applied to map the production curve across the number of authors, providing a clearer understanding of author impact within the knowledge area [51].

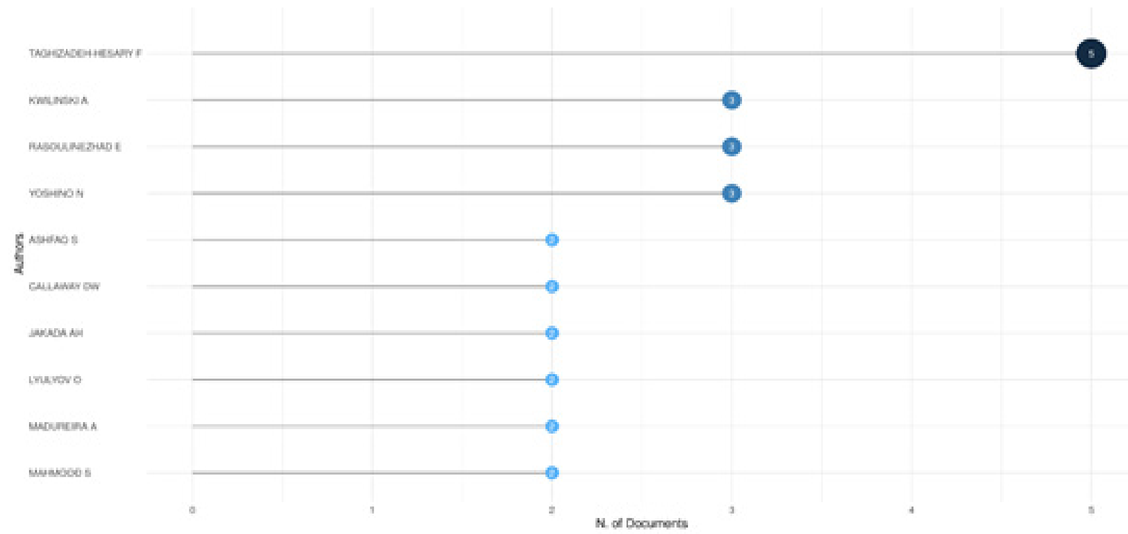

Figure 6. Most Relevant Authors. Source: Author using R software based on Scopus information.2024)

Table 5 shows that 94.8% of the authors have made only one contribution, followed by 4.10% who have made at least two, and 1.20% who have made more than three. From this, it can be inferred that the majority of authors researching this topic are transient.

TABLE 5. LOTKA'S LAW

Documents written	N. of Authors	Proportion of Authors
1	326	0.948
2	14	0,041
3	3	0.009
5	1	0.003

Source: Authors using R software based on Scopus information. (2024).

On the other hand, Table 6 shows the twenty-two most cited articles related to the study topic; the three most representative are: YU C-H, 2021, ENERGY POLICY; TAGHIZADEH-HESARY F, 2020, ENERGIES; and RASOULINEZHAD E, 2022, ENERGY EFFIC.

TABLE 6. MOST CITED ARTICLES

Paper	DOI	Total Citations	References
YU C-H, 2021, ENERGY POLICY	10.1016/j.enpol.2021.112255	675	[50]
TAGHIZADEH-HESARY F, 2020, ENERGIES	10.3390/en13040788	472	[52]
RASOULINEZHAD E, 2022, ENERGY EFFIC	10.1007/s12053-022-10021-4	472	[53]
ZHANG YF, 2023, ENVIRON SCI POLLUT RES	10.1007/s11356-023-27870-w	223	[54]
YOSHINO N, 2019, ECON MODEL	10.1016/j.econmod.2018.11.018	199	[55]
STRIELKOWSKI W, 2020, ECONOMIC RES EKON ISTRAZ	10.1080/1331677X.2020.1734854	167	[56]
SUREEYATANAPAS P, 2018, J CLEAN PROD	10.1016/j.jclepro.2018.04.206	161	[57]
MNGUMI F, 2022, ENVIRON SCI POLLUT RES	10.1007/s11356-022-19839-y	156	[58]
HALLIRU AM, 2020, J CLEAN PROD	10.1016/j.jclepro.2020.124247	150	[59]
SHANG Y, 2023, RESOUR POLICY	10.1016/j.resourpol.2023.103359	143	[60]
GUILD J, 2020, JOURNAL OF SUSTAIN FINANCE INVEST	10.1080/20430795.2019.1706312	137	[61]
DU J, 2023, ENERGY ECON	10.1016/j.eneco.2023.106595	129	[62]
LIU H, 2020, ENERGY POLICY	10.1016/j.enpol.2020.111709	115	[63]
FARINELLI U, 2005, J CLEAN PROD	10.1016/j.jclepro.2004.12.013	101	[64]

GU A, 2020, ECOSYST HEALTH SUSTAIN	10.1080/20964129.2020.1747947	87	[65]
KWILINSKI A, 2023, LAND	10.3390/land12020511	84	[66]
GONG Y, 2020, ENERGY POLICY	10.1016/j.enpol.2020.111687	59	[67]
ZAMAN S, 2022, ENERGY POLICY	10.1016/j.enpol.2022.112793	54	[68]
OLAOFE ZO, 2018, ENERGY	10.1016/j.energy.2018.07.185	39	[69]
DOMENECH B, 2015, RENEWABLE SUSTAINABLE ENERGY REV	10.1016/j.rser.2015.06.017	27	[70]
MOUSSA RR, 2018, AIN SHAMS ENG J	10.1016/j.asej.2018.09.001	26	[71]
LANGE M, 2018, MAR POLICY	10.1016/j.marpol.2018.01.008	26	[72]

Source: Authors using R software based on Scopus information. (2024).

Finally, the cluster analysis conducted using VOS VIEWER, shown in Figure 7, reveals the most impactful terms grouped by co-occurrence. It highlights keywords such as “sustainable development,” “renewable energy,” “green projects,” “renewable energy resources,” “global warming,” and “landfill.” These are some of the key terms associated with the knowledge area of new trends in green projects towards clean energy.

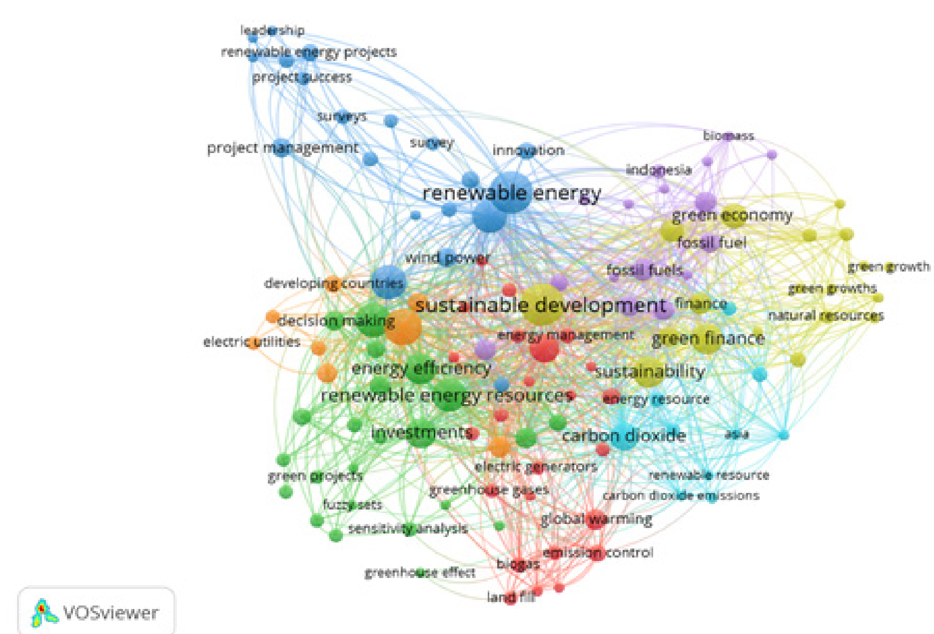

Figure 7. Keyword Co-occurrence. Source: Author using VOSviewer software based on Scopus information (2024).

V. CONCLUSIONS

The bibliometric analysis developed in this research reveals important trends and patterns in green projects focused on clean energy. From the 122 articles analyzed in this bibliometric study, based on information obtained from Scopus on new trends in green projects towards clean energy, the conclusions outlined below can be established.

The highest publication peaks were observed in the years 2020, 2022, and 2023, where 53.28% of all published works are concentrated, demonstrating a growing interest in the field and reflecting the global urgency to find sustainable solutions. Additionally, the scientific production analyzed from 2002 to 2024 shows a growth rate of 7.59%, demonstrating the dynamism and continued relevance of this topic within the scientific community, as well as the increasing attention that clean energy is receiving in the global research agenda.

The geographical distribution of publications highlights the prominence of countries such as China, India, and the United States, which lead research on clean energy, concentrating 68.90% of all the publications found. This geographical concentration reflects the interest and resources dedicated by these countries to research in renewable energies and sustainability. Furthermore, there is a growing importance of other developing countries that are also contributing to advancements in this field.

The journals that publish the most on this topic are Journal of Cleaner Production and Resources Policy, each leading the field with 5 publications. Following them are Energy Policy, Environmental Science and Pollution Research, and Sustainability (Switzerland), each with 4 publications. The rest of the publications are spread across various journals, highlighting the importance of these platforms in disseminating knowledge in the field of energy sustainability and their key role in advancing energy sciences. The prevalence of journals specialized in sustainability underscores the interrelation between energy research and global environmental concerns.

Regarding academic institutions, the most significant contributions to the research topic come from IBN Tofail Universityand WSB University, each with six (6) contributions. Additionally, Kassel University, Southwestern University of Finance and Economics, and Technical University of Athens stand out, each with five (5) contributions. Together, these institutions represent 9.78% of all the publications analyzed. Their commitment to research on clean energy is evident, and their role in generating innovative knowledge reinforces the importance of institutional collaboration in this field.

In terms of authorship, the researchers with the most publications on the topic are Taghizadeh-Hesary F., with five (5) works, followed by Kwilinski A., Rasoulinezhad E., and Yoshino N., each with three (3) publications. This study also highlights that only 3.02% of researchers in this field participate in international co-authorships, underscoring the importance of promoting transnational collaboration to address the global challenges related to the energy transition.

The most recurrent keywords in the analyzed articles are “sustainable development,” “renewable energy,” “green projects,” “renewable energy resources,” “global warming,” and “landfill.” These terms reflect the central topics in the clean energy field, with an emphasis on climate change, natural resource management, and sustainable development. These topics are not only fundamental to the transition towards cleaner energy but also highlight the need for a holistic approach to the study of green energy projects.

This bibliometric study provides a solid foundation for future research on renewable energies. It is recommended to focus on specific topics, such as the use of cutting-edge technologies, the evaluation of energy regulations, and the investigation of the financial sustainability of environmentally friendly initiatives. As patterns are tracked over time, longitudinal research can help detect significant changes in the objectives and methods used in the clean energy field.

To accelerate the global transition towards cleaner and more sustainable energy, it is essential to investigate international collaboration and interdisciplinarity. Cooperation between different disciplines and countries can facilitate the development of innovative solutions and accelerate the adoption of clean technologies on a global scale. As the world moves towards a low-carbon economy, research areas that address these issues will be essential to ensure that the energy transition is successful and fair for all.

CRediT AUTHORSHIP CONTRIBUTION STATEMENT

H. Hernandez-Palma: Conceptualization; Conducted the formal research process, specifically performing experiments or data collection. **D. Novoa-Pérez:** Methodology development and design; Preparation, creation, and presentation of the published work. **K. Brochado-Ariza:** Verification of the reproducibility and replicability of results; Writing – Original Draft.

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