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Green Energy: A Bibliometric Study and Challenges

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ABSTRACT: Green energy, characterized by its reliance on renewable and sustainable energy sources, has gained considerable attention in recent years as a critical solution to address climate change and reduce dependence on fossil fuels. However, despite its potential, significant challenges continue to impede its large-scale implementation. This bibliometric study aims to explore and analyze the existing literature on green energy, focusing on the key technological, economic, regulatory, environmental, and social barriers to its adoption. Using bibliometric tools, this paper examines the publication trends, influential works, and collaborative networks in the field of green energy research over the past two decades. The findings reveal that while advancements in technology and policy are evident, economic constraints, inconsistent regulatory frameworks, and public acceptance issues remain dominant themes in the discourse. Furthermore, the study highlights the need for a multidisciplinary approach to overcome these barriers and accelerate the transition to sustainable energy systems. This review provides a comprehensive understanding of the current landscape of green energy research and identifies future directions for addressing the persistent challenges in this domain.

KEYWORDS: Review, Green energy , Bibliometric, Scopus database

I. INTRODUCTION

The global transition to green energy has gained momentum as governments, industries, and societies seek sustainable alternatives to conventional fossil fuels. Green energy, derived from renewable sources such as solar, wind, hydropower, and bioenergy, plays a pivotal role in addressing pressing environmental challenges like climate change, greenhouse gas emissions, and the depletion of non-renewable resources (IRENA, 2019). As the need for cleaner, more sustainable energy sources becomes increasingly urgent, the development and deployment of renewable energy technologies have become a central focus of research, policy, and international collaboration (Sovacool et al., 2017).

Despite its significant potential, green energy adoption faces numerous challenges. These range from technological barriers, such as energy storage and grid integration, to economic and regulatory issues that can limit large-scale implementation (Lund et al., 2015). Furthermore, while green energy is often viewed as environmentally benign, concerns related to land use, resource extraction, and the impact on biodiversity must be carefully managed (Gasparatos et al., 2017). Social acceptance and public engagement are also crucial factors in the successful deployment of renewable energy projects, as community opposition and resistance can slow down progress (Devine-Wright, 2011).

This bibliometric review aims to provide a comprehensive analysis of the existing literature on green energy and its challenges. By utilizing bibliometric tools and techniques, this study examines the evolution of green energy research over the past two decades, identifying key themes, influential works, and collaborative networks within the field. The review not only highlights the current state of research on green energy but also sheds light on the persistent technological, economic, regulatory, environmental, and social obstacles that must be addressed to accelerate the global transition to renewable energy (Mekhilef et al., 2012).

In doing so, this paper contributes to a deeper understanding of the complex landscape of green energy research and offers insights into potential pathways for overcoming the challenges that lie ahead. Through the identification of trends and gaps in the literature, this review aims to inform future research and policymaking efforts aimed at fostering a more sustainable energy future.

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II. LITERATURE REVIEW

Green energy refers to energy generated from natural, renewable sources that have minimal negative impact on the environment compared to conventional fossil fuels. These sources include solar, wind, hydropower, geothermal, and biomass, all of which can be replenished naturally and produce little to no greenhouse gas emissions during operation. Green energy plays a critical role in combating climate change, reducing air pollution, and promoting energy sustainability.

According to the International Renewable Energy Agency (IRENA, 2019), green energy is essential for decarbonizing the global energy system and achieving international climate goals. It not only reduces reliance on finite fossil fuels but also contributes to energy security by diversifying the energy supply. Moreover, Sovacool et al. (2017) emphasize that green energy offers social, economic, and environmental benefits, including the potential for job creation, reduced healthcare costs due to improved air quality, and the preservation of natural ecosystems.

In essence, green energy is a cornerstone of sustainable development, offering a pathway to meet growing energy demands without compromising the health of the planet for future generations.

Green energy, which encompasses renewable energy sources such as solar, wind, hydropower, and biomass, has emerged as a critical component of strategies aimed at reducing carbon emissions, promoting sustainability, and mitigating climate change. Despite its numerous advantages over conventional fossil fuels, green energy faces several technological, economic, regulatory, environmental, and social challenges that hinder its widespread adoption and implementation. This literature review examines these challenges in detail, drawing from key studies in the field.

2.1. Technological Challenges

Technological limitations are among the most widely discussed challenges to green energy. While renewable energy technologies have made significant advances, issues related to efficiency, energy storage, and grid integration persist. Solar and wind energy are intermittent, relying on natural conditions like sunlight and wind speed, which makes it difficult to provide a stable energy supply (Mekhilef et al., 2012). The development of advanced energy storage systems, such as lithium-ion and flow batteries, is crucial for overcoming this intermittency. However, current energy storage technologies remain costly and inadequate for large-scale deployment (Luo et al., 2015).

Grid integration of renewable energy is another challenge, particularly as traditional energy grids are designed for centralized energy systems powered by fossil fuels. The decentralization of energy sources and fluctuating power outputs from renewables require upgrades in grid infrastructure and smart grid technologies to balance supply and demand efficiently (Lund et al., 2015).

2.2. Economic and Financial Barriers

The economic challenges surrounding green energy adoption are multifaceted. The upfront capital costs for renewable energy projects, such as solar and wind farms, remain high compared to fossil fuels (IRENA, 2019). Although the operational costs of green energy are generally lower, the significant initial investment required for infrastructure development, research, and technological innovation poses financial hurdles, particularly for developing nations (Gupta et al., 2020). Additionally, renewable energy markets are heavily dependent on government subsidies and incentives, which can fluctuate based on political changes, creating uncertainty for investors (Sovacool et al., 2017).

The transition from fossil fuels to green energy also has significant economic implications for industries and labor markets reliant on conventional energy sources. The reallocation of resources and the potential for job losses in traditional energy sectors may create resistance to change, further slowing down the green energy transition (Garrett-Peltier, 2017).

2.3. Policy and Regulatory Issues

Policy frameworks and regulatory support are critical for the success of green energy initiatives. However, inconsistent government policies, both at the national and international levels, remain a significant barrier. In many regions, fossil fuel industries continue to receive substantial subsidies, making it difficult for renewables to compete (Sovacool et al.,

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2017). In addition, the lack of standardized regulatory frameworks across countries creates challenges for international investment in green energy projects and hinders collaboration on large-scale energy initiatives (Baker et al., 2020).

Moreover, while some nations have adopted ambitious renewable energy targets, the implementation of these policies often falls short due to political and bureaucratic obstacles. The absence of long-term policy stability can discourage investments in renewable energy projects, which typically require long-term financial commitments (IRENA, 2019).

2.4. Environmental and Social Concerns

Although green energy is generally seen as environmentally friendly, some renewable energy technologies have their own environmental impacts. Large-scale hydropower projects, for example, have been linked to ecological disruption, habitat loss, and displacement of local communities (Kumar et al., 2011). Wind and solar energy projects also require vast land areas, which can lead to land-use conflicts and negatively impact biodiversity (Gasparatos et al., 2017). Moreover, the materials used in the production of renewable energy technologies, such as rare earth metals in solar panels and wind turbines, can lead to resource extraction and environmental degradation if not managed sustainably (Ali et al., 2017).

From a social perspective, public acceptance of green energy projects is critical to their success. Local communities often resist renewable energy installations, especially wind farms and transmission lines, due to concerns over land use, visual impact, and noise pollution (Devine-Wright, 2011). This phenomenon, known as Not In My Backyard (NIMBYism), presents significant social challenges for the expansion of renewable energy infrastructure.

2.5. Public Awareness and Engagement

Public awareness and understanding of green energy technologies play a key role in their adoption. Studies suggest that the general public's knowledge of renewable energy is often limited, and misconceptions about the reliability and cost-effectiveness of green energy persist (Wüstenhagen et al., 2007). Without widespread public support and understanding, efforts to transition to renewable energy can be delayed or face strong opposition.

Public engagement strategies that emphasize the environmental and economic benefits of renewable energy, along with transparent communication about potential local impacts, are essential for overcoming resistance and fostering a more supportive environment for green energy initiatives (Devine-Wright, 2011).

2.6. Climate and Geographic Constraints

Geographic and climate factors also present challenges to green energy deployment. Not all regions have equal access to renewable energy resources. Solar energy, for instance, is more viable in sunny regions, while wind energy is most effective in areas with consistent wind patterns (Luo et al., 2015). This geographic variability means that some regions may need to import renewable energy or rely on less efficient energy sources. Additionally, climate change itself may affect renewable energy generation by altering weather patterns, making some renewable energy sources less reliable (Pryor & Barthelmie, 2010).

2.7. Energy Transition and Fossil Fuel Dependency

The global transition to renewable energy is further complicated by the entrenched infrastructure and economic dependence on fossil fuels. Many countries, particularly those with significant fossil fuel reserves, face political and economic pressures to continue exploiting these resources (IEA, 2021). The energy transition requires phasing out fossil fuel subsidies and retraining workers in fossil fuel industries, which can be politically and economically challenging (Garrett-Peltier, 2017).

While the body of literature on green energy has expanded significantly over the past few decades, several critical research gaps persist, especially concerning the challenges hindering its widespread adoption. A bibliometric analysis of the field reveals several areas where further research is necessary to deepen understanding and inform future development:

- **Limited Focus on Developing Nations**: Much of the research on green energy is concentrated in developed countries, where the technological infrastructure and financial resources are more robust. There is a gap in

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understanding the unique challenges faced by developing nations, including economic, policy, and social factors that limit the adoption of renewable energy. Studies that address these regions' specific needs, particularly regarding affordability, energy access, and local resource potential, are lacking (Gupta et al., 2020).

- **Technological Integration and Energy Storage**: While advancements in renewable energy technologies are well-documented, research on integrating these technologies with existing energy infrastructures remains underexplored. More work is needed to address the complexities of energy storage, grid reliability, and decentralized energy systems, especially given the intermittent nature of renewables like solar and wind power (Lund et al., 2015; Luo et al., 2015). Current research offers limited practical solutions for balancing renewable energy supply and demand at scale.
- **Social Acceptance and Behavioral Factors**: Although social acceptance is acknowledged as a significant barrier to renewable energy projects, there is insufficient exploration of public engagement strategies and the psychological factors driving community resistance, such as the "Not In My Backyard" (NIMBY) syndrome. Research into effective communication and engagement techniques to increase public support for green energy projects is needed (Wüstenhagen et al., 2007; Devine-Wright, 2011).
- **Interdisciplinary Approaches to Policy and Economics**: Existing literature often examines the technological and economic aspects of green energy adoption in isolation. There is a need for more interdisciplinary research that integrates technical innovation with economic policy, regulatory frameworks, and societal impacts. In particular, studies should focus on aligning green energy policies with economic development goals and creating stable regulatory environments that promote investment (Sovacool et al., 2017).
- **Environmental and Biodiversity Impacts**: Although green energy is generally considered environmentally friendly, the environmental impacts of large-scale renewable energy installations, such as land use conflicts, habitat disruption, and resource extraction, are still under-researched (Gasparatos et al., 2017). More detailed studies on the long-term ecological consequences of renewable energy technologies, as well as sustainable resource management strategies, are required to ensure that green energy solutions do not inadvertently harm the environment.
- **Adaptation to Climate Variability**: The effects of climate change on renewable energy generation have not been adequately explored. As climate change alters weather patterns, it may impact the efficiency and reliability of green energy sources, particularly wind, solar, and hydropower. Research on how to adapt renewable energy systems to changing climatic conditions is still limited (Pryor & Barthelmie, 2010).

By addressing these gaps, future research can contribute to overcoming the persistent barriers to green energy adoption and support a more sustainable, global energy transition. A more comprehensive, multidisciplinary approach is necessary to ensure that green energy solutions are technically viable, economically feasible, and socially acceptable.

III. METHODOLOGY

3.1. Data Source

The Scopus database was chosen as the primary data source for this bibliometric analysis due to its extensive coverage and inclusion of the most up-to-date and innovative studies on consumer involvement. Scopus contains over 75 million entries, including more than 40,000 volumes, 16 million authors, and over 5,000 publishers, making it the largest collection of published papers available.

3.2. Search Strategy

To capture relevant literature on “green energy” a comprehensive search strategy was developed. The search was conducted using the "title, abstract, and keywords" search option to ensure a broad and inclusive dataset. The search terms used were:

3.3. Data Extraction and Analysis

The extracted data included information on authors, publication years, document types, countries of publication, and subject areas. The following analyses were performed:

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3.3.1 Year wise analysis
Search query: (TITLE-ABS-KEY(Green and Energy) AND PUBYEAR > 2009 AND PUBYEAR < 2025)

3.3.2 Country wise analysis
Search Query: (TITLE-ABS-KEY(Green and Energy) AND PUBYEAR > 2009 AND PUBYEAR < 2025)

3.3.4 Subject wise analysis
Search Query: (Green and Energy) AND PUBYEAR > 2009 AND PUBYEAR < 2025)

IV. ANALYSIS

4.1. Year-wise Analysis of Green Energy

Over the decades, the field of green energy research has undergone a profound transformation, characterized by a dramatic increase in the volume of scholarly publications. Beginning with a modest number of papers in the 1930s, green energy research remained relatively niche until the 1990s, when the number of publications began to rise slowly. The early 2000s marked a turning point, as the global awareness of climate change and the urgent need for sustainable energy solutions drove significant interest and investment into green energy technologies. This shift is evident in the data, with a notable acceleration in publication numbers from the early 2000s onward. For instance, the annual publication count surged from 74 in 2005 to over 2,400 in 2023, reflecting an era of unprecedented research activity. This period of rapid growth highlights not only the increasing importance of green energy but also the advancements in technology and research methodologies. The peak in recent years indicates a robust and dynamic field, with extensive contributions from researchers worldwide aiming to address pressing environmental challenges. As the world continues to prioritize sustainability, the trend suggests that green energy research will remain a critical area of focus, driving innovation and shaping the future of energy solutions.

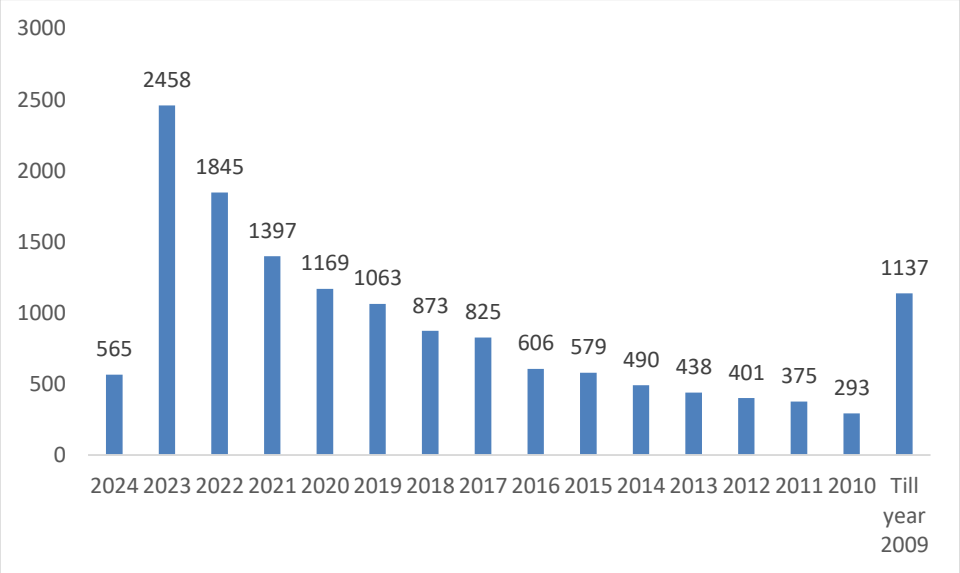

Figure no. 1: Year-Wise Trend (Year 2015 to April 2024) in Published Documents on Green Energy

4.2. Country-wise Analysis of Green Energy

In the bibliometric analysis of global publication outputs, China emerges as the foremost contributor with a substantial 3,086 publications, indicating its dominant role in the research landscape. The United States follows with 2,086 publications, showcasing its strong and sustained research activity. India ranks third with 1,070 publications, reflecting its significant growth in scholarly output. The United Kingdom and Italy also demonstrate considerable research engagement, with 1,042 and 773 publications, respectively. Germany, Australia, and Spain contribute notably with

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publication counts of 625, 584, and 472, respectively, underscoring their active participation in the global research arena. Canada and Malaysia have also made substantial contributions, with 440 and 424 publications. South Korea and Turkey, with 328 and 322 publications respectively, indicate their growing presence in international research. France and the Netherlands, with 306 and 291 publications, further illustrate their involvement in the global scholarly community. The Russian Federation, Taiwan, Saudi Arabia, Pakistan, and Japan each contribute with publication counts ranging from 261 to 284, highlighting their roles in international research endeavors. Sweden, with 220 publications, completes the top contributors, reflecting its engagement in the global research network.

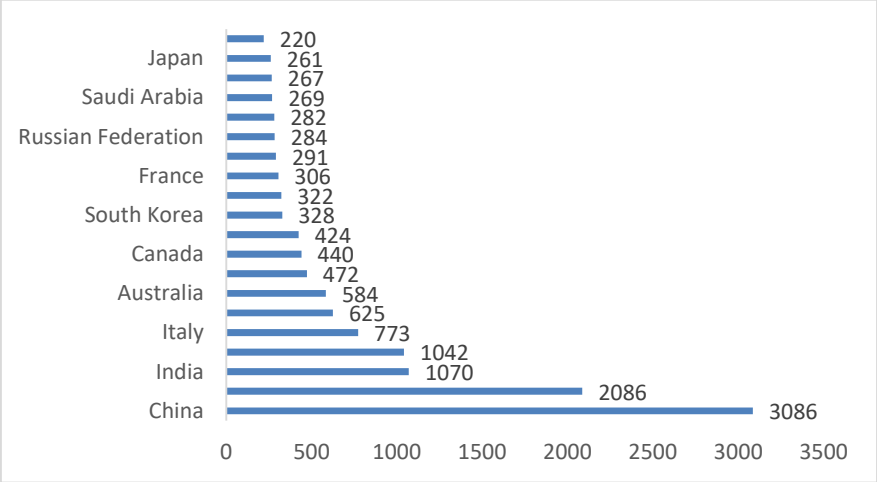

Figure no. 2: Country-Wise Trend in Published Documents On Green Energy

4.3. Author-wise Analysis of Green Energy

Table 2 shows the top writers (by number of publications) on the green energy.

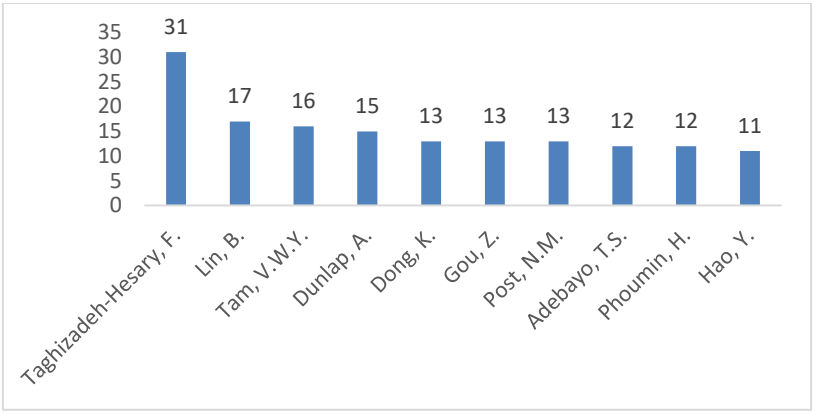

Figure no. 3: Top Ten Authors (Publication-Wise) on Green Energy

4.4. Subject-area Analysis of Green Energy

The pie chart illustrates the distribution of publications across various disciplines, highlighting the prominence of Social Sciences, which accounts for 25% of the total research output, followed by Environmental Science and Business, Management, and Accounting, each contributing 16%. Engineering and Energy-related fields represent 14% and 12% respectively, while Computer Science and Economics, Econometrics, and Finance hold smaller shares at 7% and 6%. Decision Sciences (3%) and Arts and Humanities (1%) have the least representation. This distribution underscores the

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interdisciplinary nature of research in areas like social sciences and environmental studies, particularly in bibliometric reviews focused on sustainability and green energy research.

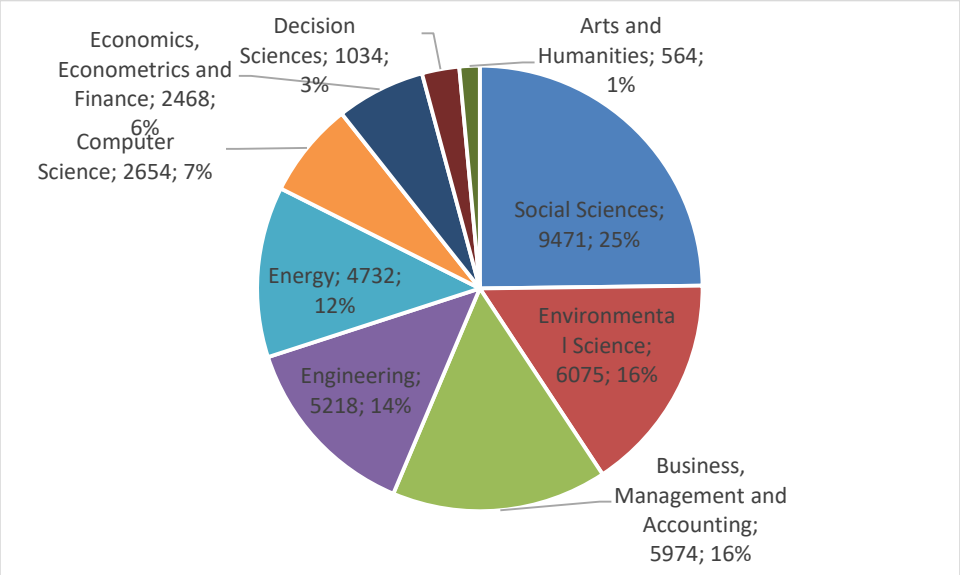

Figure no. 4 : Subject-Area Wise Trend in Published Documents On Green Energy

Table no 1: Top cited papers on "Green energy" from Scopus database from 2010 till April'2024

Sr No	Authors	Title	Year	Source title	Cited by	DOI
1	Gill S.E.; Handley J.F.; Ennos A.R.; Pauleit S.	Adapting cities for climate change: The role of the green infrastructure	2007	Built Environment	1268	10.2148/benv.33.1.115
2	Ambec S.; Lanoie P.	Does it pay to be green? A systematic overview	2008	Academy of Management Perspectives	1119	10.5465/amp.2008.35590353
3	Sanjay M.R.; Madhu P.; Jawaid M.; Senthamaraikannan P.; Senthil S.; Pradeep S.	Characterization and properties of natural fiber polymer composites: A comprehensive review	2018	Journal of Cleaner Production	1057	10.1016/j.jclepro.2017.10.101
4	Young W.; Hwang K.; McDonald S.; Oates C.J.	Sustainable consumption: Green consumer behaviour when purchasing products	2010	Sustainable Development	980	10.1002/sd.394
5	Erdoğan S.; Miller-Hooks E.	A Green Vehicle Routing Problem	2012	Transportation Research Part E: Logistics and Transportation Review	796	10.1016/j.tre.2011.08.001
6	Dangelico R.M.; Pujari D.	Mainstreaming green product innovation: Why and how companies integrate environmental sustainability	2010	Journal of Business Ethics	782	10.1007/s10551-010-0434-0

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(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

7	Alexandri E.; Jones P.	Temperature decreases in an urban canyon due to green walls and green roofs in diverse climates	2008	Building and Environment	693	10.1016/j.buildenv.2006.10.055
8	Ehrenfeld J.; Gertler N.	Industrial ecology in practice: The evolution of interdependence at Kalundborg	1997	Journal of Industrial Ecology	666	10.1162/jiec.1997.1.1.67
9	Ng E.; Chen L.; Wang Y.; Yuan C.	A study on the cooling effects of greening in a high-density city: An experience from Hong Kong	2012	Building and Environment	649	10.1016/j.buildenv.2011.07.014
10	Hartmann P.; Apaolaza-Ibáñez V.	Consumer attitude and purchase intention toward green energy brands: The roles of psychological benefits and environmental concern	2012	Journal of Business Research	628	10.1016/j.jbusres.2011.11.001
11	Imbabi M.S.; Carrigan C.; McKenna S.	Trends and developments in green cement and concrete technology	2012	International Journal of Sustainable Built Environment	624	10.1016/j.ijsbe.2013.05.001
12	Massari S.; Ruberti M.	Rare earth elements as critical raw materials: Focus on international markets and future strategies	2013	Resources Policy	602	10.1016/j.resourpol.2012.07.001
13	Scarlat N.; Dallemand J.-F.; Monforti-Ferrario F.; Nita V.	The role of biomass and bioenergy in a future bioeconomy: Policies and facts	2015	Environmental Development	595	10.1016/j.envdev.2015.03.006
14	Alshuwaikhat H.M.; Abubakar I.	An integrated approach to achieving campus sustainability: assessment of the current campus environmental management practices	2008	Journal of Cleaner Production	588	10.1016/j.jclepro.2007.12.002
15	El-Kassar A.-N.; Singh S.K.	Green innovation and organizational performance: The influence of big data and the moderating role of management commitment and HR practices	2019	Technological Forecasting and Social Change	573	10.1016/j.techfore.2017.12.016
16	Hendrickson C.T.; Lave L.B.; Matthews H.S.; Horvath A.; Joshi S.; McMichael F.C.; MacLean H.L.; Cicas G.; Matthews D.; Bergerson J.	Environmental life cycle assessment of goods and services: An input-output approach	2006	Environmental Life Cycle Assessment of Goods and Services: An Input-Output Approach	537	10.4324/9781936331383
17	Dao V.; Langella I.; Carbo J.	From green to sustainability: Information Technology and	2011	Journal of Strategic	508	10.1016/j.jsis.2011.0

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		an integrated sustainability framework		Information Systems		1.002
18	Mouzon G.; Yildirim M.B.; Twomey J.	Operational methods for minimization of energy consumption of manufacturing equipment	2007	International Journal of Production Research	505	10.1080/00020754070 1450013
19	Bhandari R.; Trudewind C.A.; Zapp P.	Life cycle assessment of hydrogen production via electrolysis - A review	2014	Journal of Cleaner Production	493	10.1016/j.jclepro.2013.07.048
20	van Vuuren D.P.; Stehfest E.; Gernaat D.E.H.J.; Doelman J.C.; van den Berg M.; Harmsen M.; de Boer H.S.; Bouwman L.F.; Daioglou V.; Edelenbosch O.Y.; Girod B.; Kram T.; Lassaletta L.; Lucas P.L.; van Meijl H.; Müller C.; van Ruijven B.J.; van der Sluis S.; Tabeau A.	Energy, land-use and greenhouse gas emissions trajectories under a green growth paradigm	2017	Global Environmental Change	491	10.1016/j.gloenvcha.2016.05.008

The analysis of highly cited publications in environmental sustainability and green technology reveals several significant academic contributions. Gill et al. (2007) offer a pioneering study on adapting urban environments for climate change through green infrastructure, a topic that has garnered 1,268 citations. This high citation count underscores the paper's influential role in shaping urban planning and environmental policy, emphasizing the importance of integrating green infrastructure to mitigate climate impacts.

Ambec and Lanoie (2008) provide a comprehensive review on the economic aspects of environmental sustainability, assessing whether adopting green practices is financially beneficial. Their work, cited 1,119 times, has become a crucial reference for both academics and practitioners exploring the cost-effectiveness of green initiatives and their impact on business performance.

Sanjay et al. (2018) present an extensive review of natural fiber polymer composites, a topic critical to advancing sustainable materials science. With 1,057 citations, their work highlights the importance of developing and understanding eco-friendly materials, driving further research in the field of sustainable materials and composites.

Young et al. (2010) investigate consumer behavior towards sustainable consumption, contributing to our understanding of green consumerism with 980 citations. Their findings offer valuable insights into consumer motivations and behaviors, aiding in the development of effective marketing strategies and policies to promote sustainable products.

Erdoğan and Miller-Hooks (2012) address the Green Vehicle Routing Problem, an important area in optimizing logistics and reducing environmental impact. Their work, cited 796 times, has been instrumental in advancing research on green logistics and transportation, influencing strategies for reducing the carbon footprint of transportation networks.

Dangelico and Pujari (2010) explore the integration of environmental sustainability into product innovation, a study that has been cited 782 times. Their research provides a framework for companies aiming to incorporate sustainable practices into their product development processes, contributing to the broader discourse on green innovation.

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Alexandri and Jones (2008) examine the cooling effects of green walls and roofs in urban environments, with 693 citations. Their research has been influential in urban design, demonstrating how green infrastructure can mitigate the heat island effect and improve urban climate resilience.

Ehrenfeld and Gertler (1997) offer a case study on industrial ecology at Kalundborg, cited 666 times. This foundational work on industrial symbiosis has provided a model for understanding how industries can collaborate to enhance sustainability and resource efficiency.

Ng et al. (2012) analyze the cooling effects of urban greening in Hong Kong, receiving 649 citations. Their study contributes to the growing body of knowledge on urban climate mitigation strategies and the benefits of green spaces in densely populated cities.

Hartmann and Apaolaza-Ibáñez (2012) investigate consumer attitudes towards green energy brands, with 628 citations. Their research sheds light on the psychological benefits and environmental concerns driving consumer preferences, informing strategies for promoting green energy adoption.

These highly cited works collectively represent significant advancements in environmental sustainability research, providing valuable insights and frameworks that continue to influence academic discourse, policy development, and practical applications in the field.

V. DISCUSSION

5.1 Challenges in Green Energy

Green energy, encompassing renewable energy sources like solar, wind, hydropower, and bioenergy, is often touted as the future of global energy supply. However, several challenges hinder its large-scale deployment and widespread adoption.

5.1(a)Technological Limitations

Many renewable energy technologies are still in developmental stages, with issues related to efficiency, storage, and integration into existing energy grids. Solar and wind power, for instance, are intermittent and depend on weather conditions, which poses challenges for maintaining consistent energy supply (Mekhilef et al., 2012). The high cost of advanced storage systems, such as batteries, and the need for substantial improvements in grid infrastructure are also significant barriers (Lund et al., 2015).

5.1(b) Economic Barriers

The transition to green energy involves substantial upfront costs. While the long-term benefits are well-recognized, the initial investment in infrastructure, research, and development is a major obstacle, especially for developing nations (IRENA, 2019). Additionally, the fluctuating costs of renewable energy technologies and their dependence on subsidies create uncertainty for long-term investments (Gupta et al., 2020).

5.1(c) Policy and Regulatory Issues

Inconsistent government policies and regulatory frameworks hamper the progress of green energy. In some regions, fossil fuels are still heavily subsidized, reducing the economic competitiveness of renewables (Sovacool et al., 2017). The lack of cohesive international policies also creates fragmentation in green energy markets, complicating cross-border investments and collaboration (Baker et al., 2020).

5.1(d) Environmental and Social Concerns

While green energy reduces carbon emissions, some technologies raise environmental concerns. For example, large-scale hydropower projects have been associated with ecological disruptions and displacement of local communities (Kumar et al., 2011). Wind and solar farms also require significant land areas, potentially impacting biodiversity (Gasparatos et al., 2017).

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5.1(e)Public Acceptance and Awareness

Social acceptance of green energy technologies can be another challenge. Misconceptions about the reliability of renewable energy, concerns over land use, and resistance to infrastructure projects in local communities (NIMBYism) often slow down deployment (Devine-Wright, 2011). Increasing public awareness and engagement is crucial for fostering a supportive environment for green energy adoption.

In conclusion, overcoming these challenges requires coordinated efforts between governments, industry, and society. A multi-faceted approach that addresses technological, economic, regulatory, and social barriers is essential for accelerating the transition to sustainable energy systems.

VI. CONCLUSION

The transition to green energy is essential for addressing global environmental challenges, mitigating climate change, and achieving a sustainable energy future. This bibliometric review has highlighted the substantial growth in green energy research, while also identifying key challenges that impede its widespread adoption. The analysis underscores several persistent gaps in the literature, particularly in areas such as technology integration, energy storage, social acceptance, and the environmental impacts of renewable energy deployment.

Despite significant advances, green energy faces technical, economic, social, and environmental barriers that must be overcome for large-scale implementation. Issues related to the reliability and scalability of renewable energy systems, the integration of these systems with existing infrastructure, and public resistance remain critical challenges. Moreover, the economic and regulatory uncertainties in many regions, especially in developing countries, further complicate the transition to renewable energy.

Future research should adopt an interdisciplinary approach, combining technological innovation with policy, economic, and social dimensions to address these challenges holistically. Greater emphasis should be placed on developing green energy solutions tailored to the specific needs of developing countries, exploring new technologies for energy storage and grid management, and enhancing public engagement to improve social acceptance.

In conclusion, while the path to a fully renewable energy system is fraught with challenges, the potential benefits of green energy far outweigh the difficulties. By addressing the identified research gaps, advancing interdisciplinary collaboration, and fostering innovative solutions, the global transition to green energy can be accelerated, paving the way for a more sustainable, resilient, and equitable energy future.

VII. LIMITATIONS AND FUTURE SCOPE

While this bibliometric review provides valuable insights into green energy research and its challenges, several limitations must be noted. The review's reliance on selected bibliometric databases may not encompass all relevant studies, potentially omitting significant research. Temporal constraints mean that recent developments may not be fully captured, and publication bias could skew the representation of findings. Additionally, the integration of interdisciplinary insights may be limited, and regional variability in green energy challenges might not be adequately addressed. The quantitative focus of bibliometric analysis might also overlook nuanced qualitative aspects of the research. Acknowledging these limitations is essential for interpreting the review's findings and guiding future research efforts.

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