The Current Landscape and future dimensions of the renewable energy finance: A bibliometric analysis and scientific mapping

Mustafa Raza Rabbani

Department of Economics and Finance, College of Business Administration

University of Bahrain, Bahrain.

Harald Kinateder

School of Business, Economics and Information Systems, University of Passau,

94030 Passau, Germany.

Tonmoy Choudhury

School of Business, King Fahad University Petroleum and Minerals,

Dhahran, Kingdom of Saudi Arabia.

Abstract

The article provides a detailed survey of renewable energy finance by using bibliometric analysis and scientific mapping. The study used a widely accepted Scopus database covering the period from 2000 to 2021. We applied network analysis tools to identify eight main clusters defined by the different dimensions of renewable energy finance and their geographical and technical scope. Our main objective is to provide a complete overview of renewable energy finance and future research dimensions. The study provides the discussion on influential aspects such as top authors contributing to the discipline, top journals, leading countries, institutions, and finally an overview of the most cited articles in sustainable energy finance. Finally, a meta-analysis was performed to compute the summary effect size of each research stream by using a random effect model. In the end, the study proposes future research directions based on the review and identified research gaps.

Keywords: Bibliometric; Energy market; Finance; Green bond; Renewable; VOSViewer.

JEL Classification: G2; Q2; Q42; Q48; Q55.

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Highlights

- Use of Bibliometric analysis to provide a detailed survey of the academic literature on renewable energy finance.
- The literature in renewable energy finance has been growing since the year 2000 and it is diverse.
- From 2010 onwards, the literature on renewable energy and economic development started to become more influential.
- Future research directions are identified, and it includes the use of Fintech in renewable energy finance, the regulatory framework in renewable energy finance, the economic feasibility of renewable energy in the emerging markets, Impact of private and public finance on renewable energy development and, Renewable energy finance and sustainable development goals.

1. Introduction

Energy consumption, greenhouse emission, and resulting global warming have emerged as the most pressing problem for the current generation of scientists and policy makers (Tolliver et al., 2020). In response to these concerns, countries all across the globe are looking to try alternative sources of energy and tap into superior renewable energy sources (Cihat et al., 2021). Renewable energy sources have significantly reduced greenhouse gas emissions. energy imports and the use of fossil fuels which is the largest source of carbon dioxide across the globe (Ahmad & Zhang, 2021; Croutzet & Dabbous, 2021). Renewable energy has significant socio-economic benefits and transition to renewable sources can completely transform the environment (Ji et al., 2021). Transitions to renewable sources of energy are generally done by respective governments but enhanced need and volume of the need require increased participation from the financial institutions and financial market (Radpour et al., 2021). Transitioning to renewable energy sources needs capital-intensive costs and requires active participation from financial institutions and financing becomes a key issue (D. Zhang et al., 2016). Financial institutions have a huge role to play in providing the financing of these infrastructure projects on the way to the transition to renewable energy sources (Tietjen et al., 2016).

Moving to renewable energy sources has so far been the most effective tool to mitigate the risk associated with climate change (Kirillova et al., 2021; Meza et al., 2019). Renewable energy is defined as the energy sources that are naturally replenishing on a human timescale (Say et al., 2018). It includes the sources that are virtually inexhaustible in duration but limited in the duration of energy that is available per unit of time such as energy from sunlight, wind, rain, tides, rain, waves, and geothermal heat (US Energy Information Administration 2018). Among the several benefits of sustainable energy few of them includes, it reduces greenhouse and

another harmful gas emission (Fouquet & Johansson, 2008; Oikonomou et al., 2009), it reduces air pollution (Blazy et al., 2021; Crook et al., 2011) and creates employment opportunities (Böhringer et al., 2013; Mu et al., 2018; Ziegelmann et al., 2000). Renewable energy is one of the important factors in the United Nations 17 Sustainable Development Goals (UN-SDG) (Bigerna et al., 2021; Buonocore et al., 2019). It is one of the key factors contributing to sustainable development goals (Zhiznin et al., 2019). It has already gained momentum and in 2016, 176 countries that account for more than 98% of the world population have pledged to achieve the sustainable energy goal (Bigerna et al., 2021)

Various studies have shown that investment in renewable energy projects is a highly profitable venture and it gives around a 15 percent return annually (Olave-Rojas & Álvarez-Miranda, 2021; Taghizadeh-Hesary & Yoshino, 2020). The maximum contribution comes from the private sources in the renewable energy sector (IRENA and CPI, 2018). Around 87% of total renewable energy finance between 2013 and 2014 amounting to USD 223 Billion and 270 Billion between 2015-2016 comes from the private sector (IRENA and CPI, 2018). Around 2/5th of the private investment comes from the project developers. The share of project finance in the new investments has increased significantly from 16% in 2004 to around 52% in 2015 whereas, other sources such as institutional account for less than 5% of the new investment in renewable energy financing (OECD, 2016). Several incentives like tax refunds, grants, and loan schemes are provided by the respective governments to promote renewable energy investment (Ahmed et al., 2019; Huang et al., 2012).

To cut the long story short, the economies all across the globe are making a move and looking for an option to make a transition to renewable energy sources (Chang et al., 2016; Ongoma, 2018). Countries have already taken steps in this direction and implemented various effective

policies for renewable energy development ranging from setting power purchase agreements (PPA) and providing a legislative framework of providing incentives for less pollution and imposing high taxes on fuel and energy sources (Apostoleris et al., 2018). Many countries have brought in the carbon credit policy where it intends to emit carbon-di-oxide or equivalent amounts of other greenhouse gases from the atmosphere (Falconett & Nagasaka, 2010; Lewis, 2010; Virupaksha et al., 2019).

There are already a few literature reviews and bibliometric analyses on sustainable energy finance, for example, Elie et al., (2021) provide the bibliometric analysis of different sources of renewable energy finance. This is more of a survey study focusing on the different types of financing methods utilized in energy finance by taking only 407 articles for bibliometric coupling. The study lacks a comprehensive survey of the reviewed articles, and it focuses merely on the specific aspect of renewable energy finance. In a similar study Aleixandre-Tudó et al., (2019), provide the Meta-analysis of the relevant literature and outline the future research direction in renewable energy finance research. There is no credible study providing an extensive literature survey on renewable energy finance and focusing on the financing issues in the overall energy market. The present study identifies this gap and provides the current overview of the existing literature on the financing issues in the energy market and gives the future dimension of the research in renewable energy finance.

This study contributes to the literature of sustainable and renewable energy finance in the following ways; First, it conducts the Scientometric analysis of the available literature on sustainable energy finance and identifies the leading authors, institutions, countries, and journals.

Second, it conducts the comprehensive literature survey and explores the conceptual structure of the field, and provides the existing literature in dominant research streams as- 1.

In the end, the study proposes future research questions which will be helpful to the future academic research community, policy makers, and regulators in the field of sustainable energy finance. The remaining paper is organized as follows.

In the second section, we provide the methodology used for the study. Section three presents the results of the study and section four will provide the future research directions and section five will present the conclusion of the study.

2. Data and Methodology

Based on the previous analytical observation and stylized facts, we provide the Current landscape and future dimensions of renewable energy (RE) finance. To do so, we use scientific mapping and bibliometric analysis to see how data can be further grouped into different subsystems. The data used in this study is obtained from the Scopus database because Scopus is the largest abstract and citation database for the peer-reviewed literature. The bibliometric analysis investigates the cross science of quantitative analysis of all knowledge carriers with mathematical and statistical methods. It is a comprehensive method that constitutes the mathematical and statistical methods and philosophy and pays attention to quantification. Many bibliometric indicators are used in this study including the total number of publications in a year, most prolific authors, most cited articles, most cited authors, the annual citation structure, co-citation analysis, and co-citation network of authors, institutions, affiliations, etc. The study also used scientific mapping of data using VOS viewer and R-studio software to provide visual

representations of the structure and dynamics of scholarly knowledge in the field of renewable energy finance.

The study used the research protocol developed by Van Oorschot et al., (2018), for innovation literature, Fahimnia et al., (2015), for green supply chain management, and Epicoco et al., (2014) for mapping green chemistry communities. We used the four-step protocol and selected the items based on the criteria as mentioned in Fig. 1.

<insert Figure 1>

First, we select the items based on the keywords used in the various academic literature on renewable energy finance on the extended Scopus database. We used the main keywords in this study (renewable energy market, and finance) to achieve the objective of the study, which is to explore the Current landscape and future dimensions of renewable energy finance. The keywords related to renewable and sustainable energy were selected based on the extensive review of the literature and were renewable energy in combination with (renewable AND energy) OR (renewable AND sources) OR bio AND energy) OR (bio AND source) OR (solar AND energy) OR (solar AND power) OR (renewable AND electricity). Similarly, the keywords for renewable energy finance were considered and forced those keywords to be present with the search field (Title, Abstract, Keyword) in each retrieved document. More specifically, we used a combination of words such as, (finance* OR funding OR investor). The combinations of words enable us to restrict our analysis focusing on the supply of funds for renewable energy and thereby avoiding unrelated studies with not much related to renewable energy financing. Our search was not

limited to a specific period rather we took all the studies appearing up to 11th October 2021. We include the articles only written in the English language as English only appears to comprehensively cover the scope of the subject under study. At this stage, it appeared to be 3169 articles.

Secondly, we refined our search without keywords and extensive manual check; eliminated the articles which appeared only in the keyword plus, which further eliminated the 1621 articles and by manually reading, analyzing, and evaluating the titles, keywords, and abstracts to retain the articles which are concentrating on the 'renewable energy finance'. These refinements resulted in 1548 articles in our final sample.

Thirdly, we compute the descriptive statistics (Table 1) using the R-Studio to show the general characteristics of the data. The descriptive statistics include the number of documents published per year, average years from publication, most relevant authors, most local cited authors, most relevant affiliations, most relevant sources, most local cited sources, source dynamics, and word cloud.

Finally, we combine bibliometric analysis with scientific mapping to examine the current state and future dimensions of research in renewable energy finance. Following Donthu et al., (2021), we use the bibliographic coupling to establish the similarity relationship between the documents. We also performed co-citation and co-occurrence to know the frequency with which two documents are cited together by other documents and to know the semantic proximity or an idiomatic expression respectively (Donthu et al., 2021; Kumar et al., 2020).

3. Results of the Bibliometric analysis and discussion

This section provides the results of the bibliometric analysis. In this section, we provide a detailed discussion on sample characteristics, annual scientific publications, publication growth, most prolific journals, most prolific authors, most influential documents, most important sources, most relevant affiliation, most relevant countries, most frequent words, co-citation analysis, and cartography analysis. A detailed discussion is provided on the identified research streams followed by the future research direction.

3.1 sample characteristics

The objective of selecting a sample is that it should be large enough to represent the universe properly (Wi niewski et al., 2009). The selected sample must be large enough to provide the required reliability, statistical stability, and accuracy required for the subject under study (Hansen, 1982). Selecting a sample is one of the most characteristic features of any bibliometric study (Bajaj et al., 2021). We have made all the possible precautions in selecting our sample for the present study. Table 1 provides the sample characteristics of the data collected for the study. With 1548 articles published between 2000 to 2021 having 454 sources which constitute 1548 articles and 123 reviews. The average citations per year per document is 4.127 whereas, the average citations per document is 21.48, implying the high importance of publication in this area. There are 71752 references, 4045 authors, and 2.61 authors per document.

<insert Table 1>

3.2 Annual Scientific publications

The annual scientific publication provides the publication trend on the subject under study over the years. Figure 2 provides the annual scientific publication over the years between 2000 to

2021. It is observed from the figure that the publication has grown exponentially over the years. Although the first article on the subject under study appeared as early as 1964, it gained momentum only in the 1990s among the global academic community. Only 11 articles appeared in the year 2000 and increased to 13 in 2001 and again dropped to only 3 articles in 2002. The year 2005 recorded 5 articles published in the domain of sustainable energy finance and onwards it is an increasing trend. The study in the early period of the study mainly focused on the financial incentives to support renewable energy systems (Haas et al., 2001), overcome the financial barriers to promote renewable energy (Haas et al., 2001; Herrick, 2003), computing the cost of renewable energy consumption and production (Enzensberger et al., 2003; Stavy, 2002; Weisser, 2004) and, renewable energy investment challenges in the developing countries (Käkönen & Kaisti, 2012; Leblanc, 2008; Meng et al., 2014), COP 21 (Batten et al., 2018). In the later part of the last decade (2010's) the study on renewable energy finance mainly focuses on the use of technology like Blockchain (Tsao & Thanh, 2021; Werapun et al., 2020), Fintech (Croutzet & Dabbous, 2021), and artificial intelligence (do Amaral Burghi et al., 2020; Y.-C. Yang et al., 2020) in the renewable energy finance.

<insert Figure 2>

3.3 Most relevant journals and authors

It is important in bibliometric research to find out the most relevant sources of the subject under study to give readers a blueprint of the most credible journals in terms of the number of publications and citations received by the scientific community (Khan et al., 2020; Paltrinieri et al., 2020; Tijjani et al., 2020). It can be observed from Table 2 below that the energy policy

published by Elsevier is the most prolific journal as far as publications in renewable energy finance are concerned, it has published a maximum of 175 articles and received a maximum citation of 4682 followed by the renewable energy, another journal from Elsevier publication group has published 135 articles during this period with 1508 citations.

<insert Table 2>

Table 3 lists the top 20 authors based on Total Citations received by their publications, number of papers, publication starting year, their h-index, m-index, and g-index. The h-index is a metric to evaluate the number of publications, citations, and overall impact in the scientific community. It represents that an author has n papers that have been cited at least n times (G Abramo et al., 2010). M-index is defined as the result of the division of h-index with a total active year of the author, while g-index is the number where top g articles are cited at least g square times (Giovanni Abramo et al., 2013).

The most cited author in the field of renewable energy finance is Rangwitz M., who has the most impactful publications in the field. The most cited article by the author is Sensfub et al., (2008), this article examines the price effect of renewable electricity generation in the spot market in Germany. The article has so far received so far more than 500 citations on Scopus and around 1000 citations on google scholar. The author has so far received an H index of 7 and g-index of 8 and over 865 total citations. The second most cited author is SCHMIDT TS, who has received an h-index and g-index of 6 with total citations of 236. He has so far published 6 articles in the field of renewable energy finance. The publication history of SCHMIDT TS includes Malhotra et al., (2017), Schmidt et al., (2013), and Schneider et al., (2010) among a few of the impactful publications. His major focus remains to scale up the financing options for renewable energy sources. The other authors include Zhang, Y., Chen, Y., Diner, H., and Li, Y, etc.

<insert Table 3>

3.3 Most relevant affiliation

Figure 3 shows the most contributing affiliations/organizations actively involved in the study & analysis of the implementation of financing in the renewable energy domain. University of California, USA has published a maximum number of articles, having the core theme of renewable energy and financing issues related to renewable. Few of the important studies are conducted an economic performance of renewable energy in projects in California states (Sivaraman & Moore, 2012), tradable renewable energy credits in California (Hilton & Marriott, 2010), renewable energy, and social capitalism issues in California and China comparison (Clark II & Li, 2010). The second-best article is published with the Islamic Azad University, Iran. The articles such as Eslami & Nahani, (2021), Khoshnevis Yazdi & Shakouri, (2017), and Qerimi et al., (2020) are some of the articles with affiliation from Islamic Azad University, Iran focusing on the issues such as economic growth and renewable energy (Khoshnevis Yazdi & Shakouri, 2017), factors affecting renewable energy investment in Iran (Cheraghi et al., 2020). Griffith University from Australia and North China Electronic University hold a combined third position with 14 publications each.

<insert Figure 3>

3.4 Most influential documents

The documents which are quite influential around renewable energy and financing issues, and allied fields are those which have been referred by fellow authors to expand the body of knowledge. A list of the top 20 most influential papers in this area is presented in table 4. The papers with the central theme of renewable energy finance and factors affecting the decision-making process in renewable energy investment have witnessed the most citations. Financing has been the major problem for renewable energy projects and different factors determine the choice of the financing options (Blume-Werry et al., 2021; Cheraghi et al., 2020; Makki & Mosly, 2020; Mohammadi & Yavari, 2017). For example, the articles Sensfuß et al., (2008) in the year 2008 has received a maximum number of citations with an average annual citation of 49. This paper provides detailed investigations of the price effect of renewable energy generation. Similarly, the paper on renewable energy stock and other indices is examined by various authors with different themes (Ferrer et al., 2018; Hemrit & Benlagha, 2021; S. Tao et al., 2021). Recently there have been several impactful publications examining the role of the COVID-19 pandemic on renewable energy financing (Bigerna et al., 2021; Shekhar et al., 2021; Tsai, 2021; Tu et al., 2021).

<insert Table 4>

3.5 Keyword Occurrences Map

A keyword occurrence map clarifies the research trend in renewable energy finance by looking at the most frequently used keyword by authors, in the title, and the abstract. This map helps in identifying the leading areas of research status, and the emerging avenues of scientific inquiry in specific areas of research. We have used the VOSviewer software application, the similar methods are used by (Ding & Yang, 2020; Jeong & Koo, 2016; Nájera-Sánchez, 2020), to establish the emerging trends and thematic evolution of the research streams.

We conducted keyword and keyword occurrence analysis to explore the underlying themes of financing renewable energy projects. The most frequent keywords with their total link strength are shown in table 5, the words such as energy policy, alternative energy, renewable energies, investments, renewable sources, renewable energy source, solar energy, wind energy, commerce, economics, finance. These keyword occurrences are in line with the advancement in finance and economics research in the renewable energy area. Financing is key to any renewable energy project as it is very much linked with sustainable development goals. Figure 4 depicts the word cloud depicting using the R-Studio software. Word cloud is a visual representation of text data. In other words, it is also known as the collection or cluster of words depicted in different sizes. The cloud is represented by the tag of a single word. The size of each word represents the importance of words in the cloud. In figure 4, the biggest size of the tag is an investment, which represents that investment appears the greatest number of times in the keyword and title search (Donthu, Kumar, Pattnaik, et al., 2021; Khan et al., 2020; Paltrinieri et al., 2020).

<insert Table 5>

For the creation of this map, the minimum number of occurrences of a keyword was kept at 5, out of 1547 keywords only 95 meet the cut-off criteria. It means that only topics with these keywords are evolving, and future research can be undertaken to further establish the area.

<insert Figure 4>

The keyword occurrence map is presented in fig 5, the map is made of 3 clusters with 1074 links and 2317 total link strengths. The size of the nodes shows the frequency of occurrence of a keyword while in the line connecting them is the relationship between the keywords.

The first cluster represented by green color has 36 items in it and the most frequent items are renewable energy, energy policy, commerce, cost, investment, profitability, financial development, energy utilization. It is consistent with the articles published on financial instruments to address renewable energy instruments (Bürer & Wüstenhagen, 2009; Shrimali, 2021a), barriers to investment in renewable energy (Ragosa & Warren, 2019; Sardianou & Kostakis, 2020), economic analysis of renewable energy projects (Nelson et al., 2021; Touili et al., 2018), techno-economic potential of renewable energy projects (Lemence & Tamayao, 2021).

The red-colored cluster is also made of 36 keywords, the keywords having a maximum frequency in this cluster are renewable energy investment, energy policy, solar energy, financial development, economic growth, energy-efficient, sustainability, and risk assessment. This cluster exhibits the fact that research studies are being conducted to assess the risk associated with the financing of renewable energy projects (Firouzi & Meshkani, 2021; Hossain et al., 2021; Zhou et al., 2021), investor perspective on renewable energy finance (Dinica, 2006), sustainability and competitiveness in renewable energy finance (Subhadra, 2010; Wüstenhagen, 2003).

The third cluster shown with blue color is made up of 23 items, this cluster has combined the keywords focusing on renewable energy, commerce, solar energy, and energy utilization. The studies such as Oh et al., (2020), focus on the economic effects of the renewable energy expansion policy, and Raucci et al., (2019), technical and economic evaluation of renewable energy production.

<insert Figure 5>

3.6 Citation Network of authors

The citation network is a directed network that represents the citation of one author's work by another and symbolizes the information sharing & flow and overall scientific research impact in the subject (N Donthu, Kumar, Pattnaik, et al., 2021). A citation network of authors is created using VOSviewer and presented in fig 6, the criteria are defined as a minimum number of documents of an author at 2 and their documents should have received a minimum number of 5 citations.

<insert Figure 6>

The citation map created, consists of 3 clusters as shown in fig 6. The red cluster is made up of 38 items and the leading authors in this grouping are Wang, I., Zhang, D., Wang, S., Dincer, H., Ali, Q. and Breyer C. These authors are cited each other work in renewable energy finance they have researched out mainly the legitimate side of investments in renewable energy projects. They investigated the nexus between economic policy uncertainty and renewable energy consumption(Lv & Spigarelli, 2016; K. Q. Zhang et al., 2021; Y. Zhang et al., 2021).

The second cluster consists of 40 authors and is represented with green color in the network map. Dinner, H., Wang, S., Chen, Y., Ozturk, I. are prominent authors in this cluster. These researchers are connected and cite each other’s works in renewable energy finance and corporate investing patterns in renewable energy projects(L. Wang et al., 2021; S. Wang et al., 2019; Y. Wang et al., 2021).

The Blue colored cluster is made up of 38 authors, this cluster is dominated by Wang, Y., Chang, K., Gosens, J., Cao, H., etc. The authors collaborated to examine renewable energy investment,

rationality, capital structure, and implications with firm-level evidence (D. Zhang et al., 2016; H. Zhang et al., 2018).

3.6 Co-citations Analysis of Cited Reference

Co-citation analysis helps gauge the impact of scientific literature in the subject of study, two documents are said to be co-cited if they are cited together in third documents (N Donthu, Kumar, Pattnaik, et al., 2021). The co-citation network is created with VOSviewer software, the min no of citation of a cited reference is kept at 5, out of 72226 references only 231 meet the threshold. It shows the fact that there are very few papers that are cited together in the research domain of renewable energy finance.

The co-citation of the cited references network map is created and presented in fig 7, the map is divided into 7 clusters with 2672 links and a link strength of 3777.

The cluster presented with red color has 139 references which are cited together and connected to other clusters in the network. This cluster is combining the citations on the research theme of strategic choice of the renewable energy investment, conceptual framework of the renewable energy investment, etc. Optimal investment strategies for solar energy based systems (Pfeiffer & Mulder, 2013; Song et al., 2019; Wüstenhagen & Menichetti, 2012).

Green cluster is made up of 60 common references and based on the theme of financial development and deployment of energy technologies, valuation approaches in renewable energy investments, financing solar thermal technologies, the role of financial efficiency in renewable energy demand, the effect of financial development on renewable energy consumption, the

model for the development of a business strategy for renewable energy technology services (Kazak et al., 2020; Lee, 2021; Qin et al., 2021; Safi et al., 2021).

The third cluster is represented by blue color in the network map and made up of 58 references, the prominent theme in this cluster is about financial development and energy consumption, Co2 and energy consumption in emerging economies, how much does financial development contribute to the renewable energy growth, the dependence between oil and renewable energy prices (Dornan, 2015; Sadorsky, 2012; Shah et al., 2018).

The fourth cluster in the network consists of 31 references and is represented by a yellow color, this cluster is focusing on the strategic choice for the renewable energy investment (Song et al., 2019), practical approaches to renewable energy investment (Hürlimann et al., 2019).

<insert Figure 7>

3.8 Co-citation of cited authors

The co-citation network of authors is represented in fig 8. The network is created using VOSviewer software by keeping the minimum number of citations of an author 20. This threshold criterion is met by only 764 authors out of 68026. The node in the network shows the authors, while the line connecting the nodes shows the relationship strength among authors. The co-citation network is made of 5 clusters with 128695 links and total link strength of 829605. The link strength shows the intensity of relationship and collaboration among authors researching renewable energy finance.

The largest cluster (red) has 299 items, Sovacool, B. K., Wustenhagen, R., Popp, D., Lund, H., Fama, E. F., and Pauly J. P., etc. are prominent authors in this cluster and have strong linkage with other clusters. The results of this co-citation analysis of authors are consistent with the

analysis of the co-citation of references. This cluster is more about exploring technological advancements like Fintech-based P2P lending, Crowdfunding, and venture capital financing in renewable energy financing (Vasileiadou et al., 2016). The research in this cluster also focuses on the risk perception of investors on renewable energy investments (Chassot et al., 2014).

The green-colored cluster emerged as the second-largest cluster in the network, it consists of 244 authors, leading authors in this cluster are Abbas, W., Adaramola, M. S., Zhang, X., Kumar, S., Breyer C., etc. These authors have collaborated and investigated the economic feasibility of renewable energy in emerging markets. The research streams emerging from this cluster are about renewable energy sources to an urban building in developing countries and challenges, opportunities, and techno-economic feasibility simulation (Kumar & Ravikumar, 2016).

The third cluster (blue) is based on 200 authors, some of the leading authors in this cluster are Shahbaz, M., Murshed, M., Apergis, N., Sinha, A., Sadorsky, P., Khan, Z., Ahmad, K., etc. These authors are examining the effect of financial development on renewable energy demand, the relationship between financial development and energy consumption (Lahiani et al., 2021; Shahbaz et al., 2021). The studies in this cluster also investigated the influences of renewable electricity generation, technological innovation, financial development, and economic growth on ecological footprints, impact f foreign direct investment on renewable electricity production and consumption (Bouyghrissi, Murshed, et al., 2021; Murshed, Abbass, et al., 2021; Murshed, Ahmed, et al., 2021; Murshed, Elheddad, et al., 2021).

The fourth cluster in this network is represented by yellow color and consists of 20 authors. The authors with maximum co-citations in this cluster are Zhang, D., Yilmaz, K., Uddin, G.S., Managi, S. The theme in this cluster revolves around the asymmetric connectedness and spillover between the energy and financial market (Emeara et al., 2021; Ji et al., 2021; Rehman

et al., 2021; Shrimali, 2021b). Various studies in this cluster included studies on the asymmetric and extreme influence of energy price changes on renewable energy stock performance (Xia et al., 2019), asymmetric and quantile-based regression modeling on crude oil prices, and clean energy stock indices (Dawar et al., 2021).

<insert Figure 8>

4. Future research directions

Based on the extensive review and bibliometric analysis, it is observed that the renewable energy finance domain is well researched and researchers from across the globe are contributing to this important issue. Still, there are a few areas that need to be explored further to get new insight and provide future researchers, regulators, and government clear direction and vision to work further. The following Table (No. 6) summarizes the emerging research areas to be explored further in the renewable energy finance domain.

Theme	**Sub Themes**	**References**
Use of Fintech in renewable energy finance	Does the use of Fintech promote renewable energy finance?	(Liu et al., 2021)
	Use of Fintech in unlocking green finance initiatives for financing renewable energy projects.	(Nassiry, 2018)
	Connectedness between green finance, green energy, fintech environment protection.	(Yang et al., 2021)
	Can Fintech development pave the way for the low carbon economy: Empirical	(Tao et al., 2022)

	evidence.	
	Development in Fintech for achieving the SDG through renewable energy finance.	Author's suggestion
Economic feasibility of renewable energy in the emerging markets	Economic feasibility analysis of renewable energy projects in emerging market economies.	(Ahmad & Zhang, 2021)
	Feasibility study of renewable energy projects using dynamic modeling.	(Sierra Rodriguez et al., 2020)
	Examining the Economic feasibility of renewable energy projects using a quantile-based approach.	(Polemis & Spais, 2020)
	Techno-economic feasibility study of Fintech and renewable energy integration.	(Croutzet & Dabbous, 2021)
	Comparative analysis of economic feasibility of different types of renewable energy projects.	(L Elie et al., 2021)
	Examining risk dimensions of renewable energy projects with other asset classes.	(Wu et al., 2012)
The regulatory framework in renewable energy finance	Policy and regulatory framework for the promotion of renewable energy finance.	(Gboney, 2009)
	Review of existing policies encouraging renewable energy finance.	(Ciarreta et al., 2017; Pezon, 2017)
	The nexus between governance and	(Carafa, 2015)

	renewable energy finance.	
	Renewable energy support, policy framework, and financial performance nexus.	(Bouyghrissi, Berjaoui, et al., 2021)
	The nexus between regulatory framework, renewable energy consumption, and economic growth.	(Qayyum et al., 2021)
Impact of private and public finance on renewable energy development	Measuring risk, return, and cost of capital for renewable energy investments.	(Luc Elie et al., 2021)
	Heuristics and intuitive decision-making and behavioral economics in renewable energy finance.	(Wu et al., 2012)
	Factors determining the cross-border private and public investment in renewable energy projects.	(Maula, 2012)
	Role of public policies in promotion of public investment in renewable energy finance.	(Sung et al., 2019)
	Public finance model of renewable and nonrenewable energy and sustainable development goals.	Author's suggestion
Renewable energy finance and sustainable	Key challenges for the renewable energy finance and sustainable development goals.	(Schwerhoff & Sy, 2017)
	The nexus between green finance,	(Böhringer et al.,

development goals.	sustainable development goals, and financial development.	2013)
	Energy selection model and sustainable development goals	(Bykzkan et al., 2018)
	Impact of renewable energy and green finance on sustainable development goals.	(Tu et al., 2021)
	Green bonds, social impact Sukuk, and Islamic social finance for financing renewable energy projects.	(Smaoui & Ghouma, 2020).

5. Conclusion

We combined bibliometric, Scientometric, and meta-analysis for the study and our results show that the literature in renewable energy finance has been growing since the year 2000 and it is diverse. The paper provided a detailed survey of the available literature on renewable energy finance using bibliometric analysis and scientific mapping to conclude.

The results obtained by the path analysis are consistent with the previous results and show how the literature first focuses on the policies that have been developed by the respective governments to promote renewable energy and its financing through public and private financing options. From 2010 onwards, the literature on renewable energy and economic development started to become more influential in the literature. The recent studies show how renewable energy projects are sustainable and help in achieving the economic growth of the country. Moreover, the studies on developing countries and renewable energy finance are impactful and appear in the themes.

The study identifies five main themes as the use of Fintech in renewable energy finance, the regulatory framework in renewable energy finance, the economic feasibility of renewable energy in the emerging markets, the impact of private and public finance on renewable energy development and, Renewable energy finance and sustainable development goals for discussion and drawing the future research questions.

Given this wide area of future research dimensions in renewable energy investment, we hope that the readers will find this paper a useful and inspiring starting point to embark on the research at the intersection of energy investment, energy policy, finance, and behavioral sciences. We are confident that the study will provide valuable insight on how to reach the optimal investment level needed to successfully manage the tradition into a renewable energy future.

Finally, this work has some limitations that could serve as the foundation for future research. We used the Scopus database for retrieving data for our analysis purpose, using other databases could give entirely different research patterns in CSR in the banking literature.

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Appendices

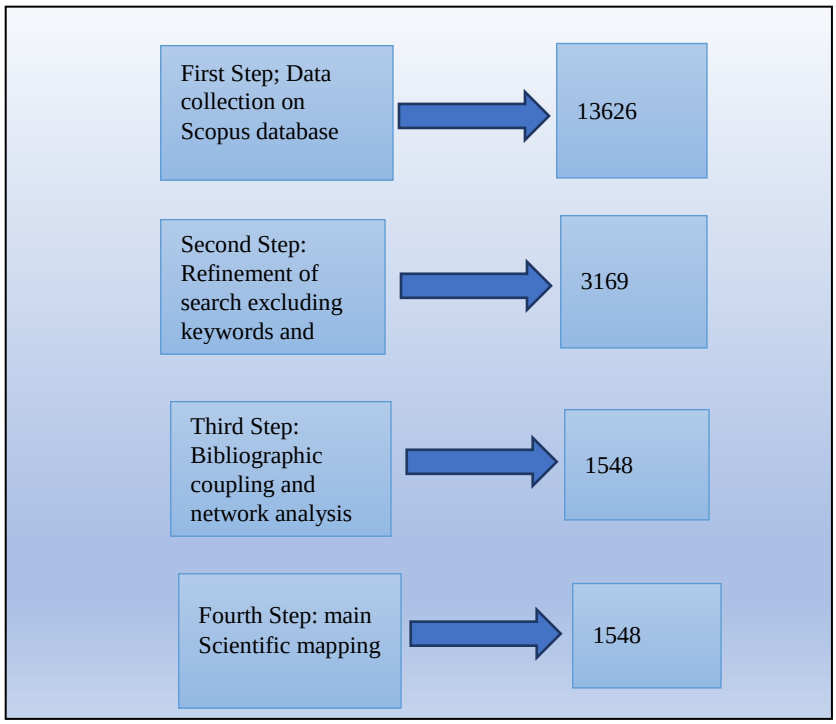

Figure 1:Four step data collection and filtering procedure

Figure 1 shows the four steps for the data collection and filtering process. It is observed that the first step includes retrieving data from the Scopus database. The second step includes data refinement, the third step includes bibliographic coupling and network analysis, and the fourth step includes scientific mapping.

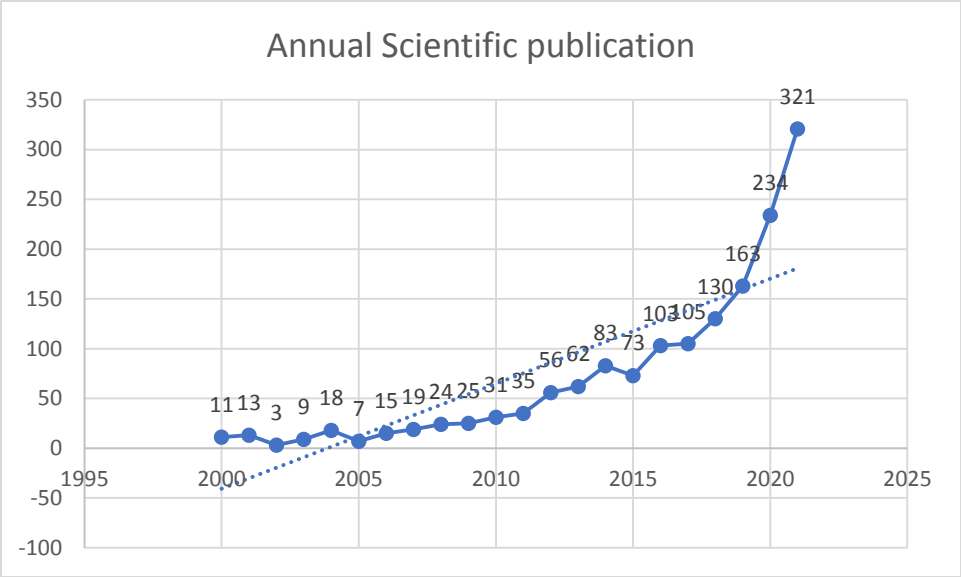

Figure 2: Annual Scientific publication on the topic renewable energy finance.

Figure 2 depicts the annual scientific publication over the years between 2000 to 2021. It has grown from 11 documents on renewable energy finance in the year 200 to 321 documents in the year 2021.

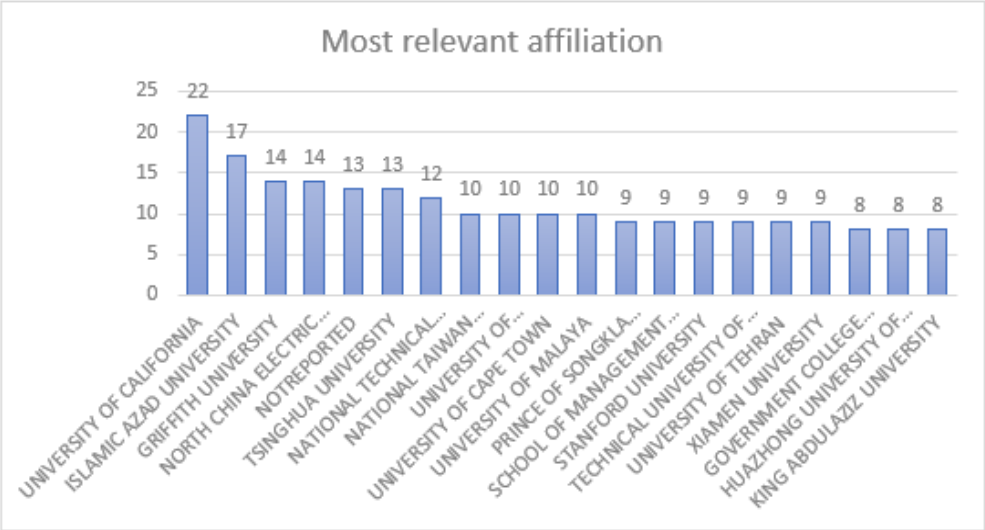

Figure 3: Most relevant affiliation

Figure 3 depicts the most relevant affiliation publishing research articles on renewable energy finance. It is observed that most articles are produced with the University of California affiliation. Followed by the Islamic Azad University and Griffith University.

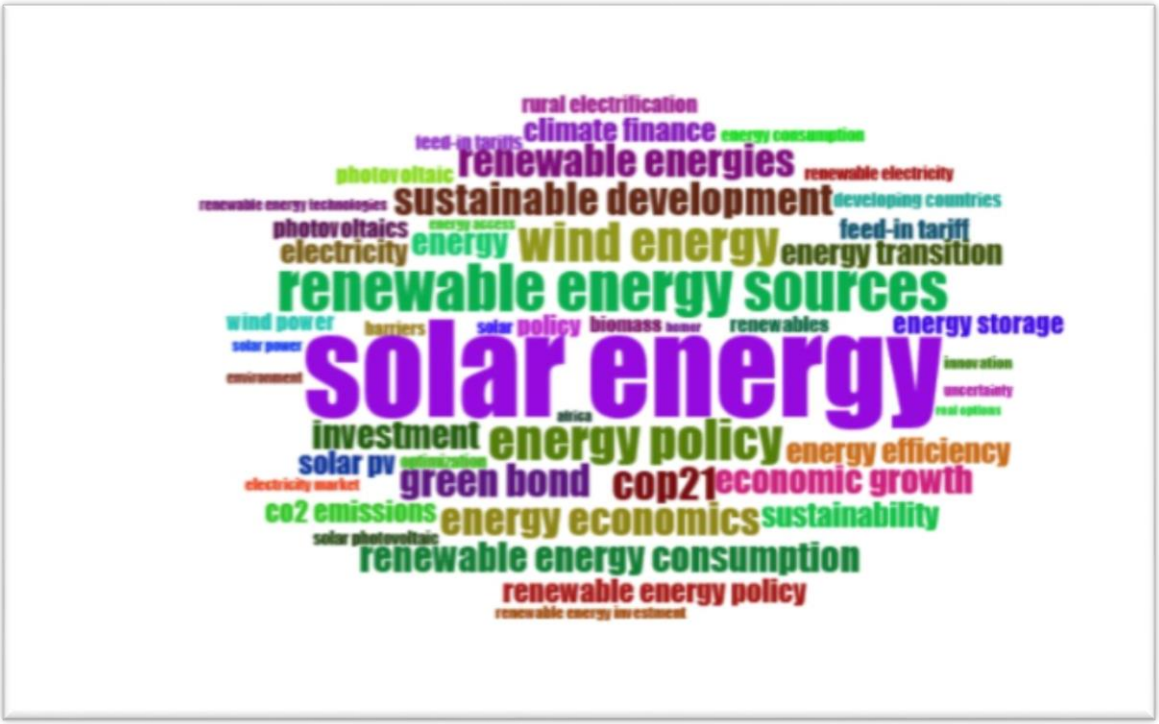

Figure 4: Word cloud - Visual reorientation of the text data.

Figure 4 depicts the word cloud retrieved by using Biblioshiny software. The figure shows the most widely used keywords by the authors. The most widely used keywords include solar energy, renewable energy sources energy policy, COP21, renewable energy consumption, etc. The figure also shows some of the methods of renewable energy finance such as green bonds etc.

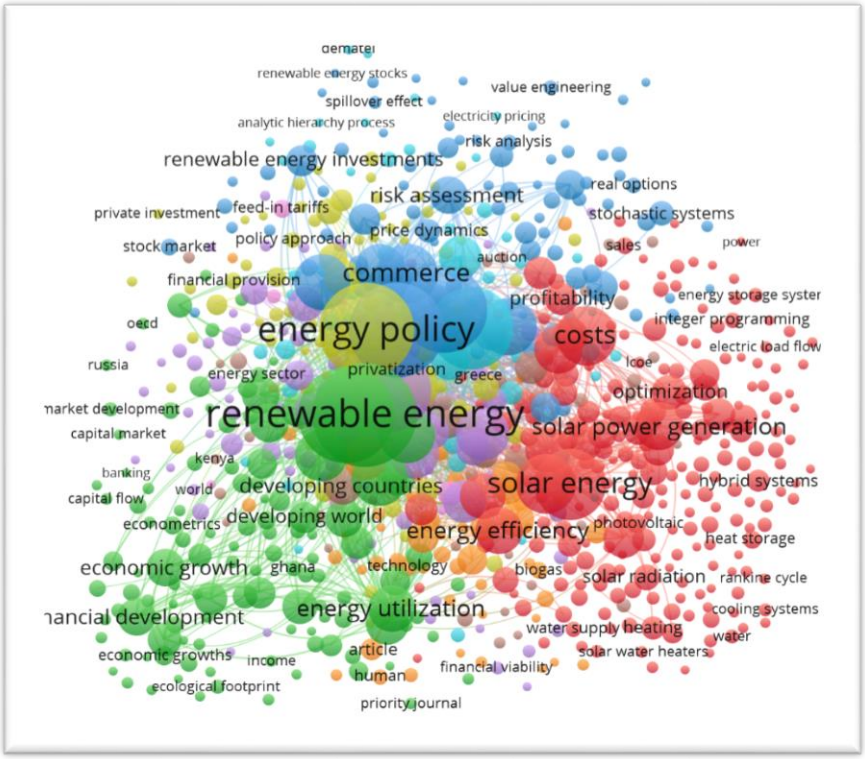

Figure 5: Keyword Occurrences map in renewable energy finance.

Figure 5 shows the keyword occurrences retrieved by using VOSViewer. The keywords such as renewable energy, energy policy, COP21, energy economics, green bond, etc. are the most frequently used keywords in the renewable energy finance literature.

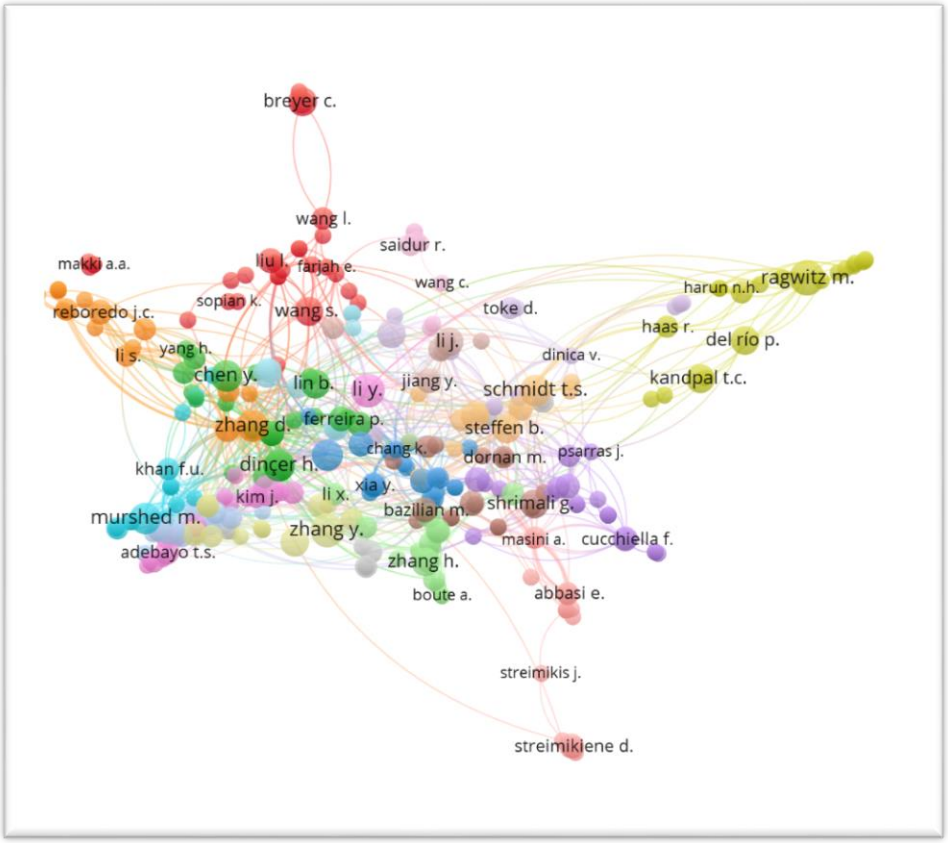

Figure 6: Citation network of authors

The citation network of authors shows the citing behavior of the scholarly publication in the field of renewable energy finance. The nodes represent the citation network of one author with the other. Zhang, D. appears to have the greatest number of collaborations in the network with different authors.

Figure 7: Co-citations of cited reference

Figure 7 depicts the frequency by which two documents are cited together by other documents. It is observed that the paper by Wustenhagen R., is frequently cited with the Rebaredo, j., etc.

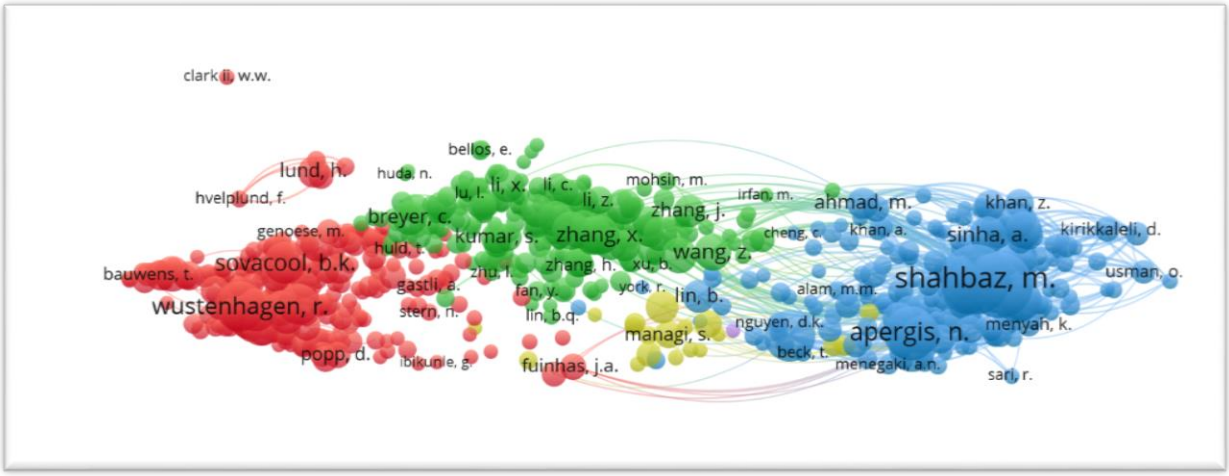

Figure 8: Co-citation of the cited authors.

Figure 8 depicts the co-citation of cited references where at-least one document of each author is cited together in a paper. It can be observed that the papers of each Wustenhagen, R., Sovakool, B. K., Popp, U., and Bauwens, T., are cited together. The authors such as Agergis, N., Shahbaz, M., Sinha, A., and Khan, Z. are cited together.

Table 1: Main Information

Description	**Results**
Timespan	2000:2021
Sources (Journals, Books, Etc)	454
Documents	1548
Average Years From Publication	4.41
Average Citations Per Documents	21.48
Average Citations Per Year Per Doc	4.127
References	71752
Document Types	
Article	1548
Document Contents	
Keywords Plus (Id)	5951
Author's Keywords (De)	3987
Authors	
Authors	4045
Author Appearances	4721
Authors Of Single-Authored Documents	234
Authors Of Multi-Authored Documents	3811
Authors Collaboration	
Single-Authored Documents	254
Documents Per Author	0.383

Authors Per Document	2.61
Co-Authors Per Documents	3.05
Collaboration Index	2.95

Table 1 shows the main information about the data. It is observed that the 1548 documents were retrieved from the 454 sources between 2000 to 2021. There are 71752 references and the average citations received by the articles includes 4.127 citations per year per document. Whereas the articles in renewable energy finance are cited 21.48 times.

Table 2: Most Relevant Sources

Sources	Articles	Citations
Energy Policy	175	4682
Renewable Energy	135	1508
Energies	78	427
Energy Economics	44	1296
Journal Of Cleaner Production	43	802
Energy	39	1508
Applied Energy	38	1069
Environmental Science And Pollution Research	37	338
Sustainability (Switzerland)	37	368
Renewable And Sustainable Energy Reviews	29	2476
International Journal Of Energy Economics And Policy	27	890
Energy Research And Social Science	25	294
Energy For Sustainable Development	21	324
Energy Conversion And Management	17	285
Solar Energy	13	324

Table 2 depicts the most relevant sources. Energy policy has produced the most number of articles, followed by renewable energy and energies.

Table 3: Most Prolific Author (PY_start: Production Start Year, TC: Total Citations, NP: No. of Papers)

AUTHOR	H_INDEX	G_INDEX	M_INDEX	TC	NP	PY_START
RAGWITZ M	7	8	0.438	865	8	2006
LI J	2	3	0.5	16	5	2018
LI Y	5	7	0.833	142	7	2016
ZHANG Y	3	7	0.75	89	7	2018
CHEN Y	3	6	0.231	152	6	2009
DINER H	4	6	1.333	73	6	2019
SCHMIDT TS	6	6	0.5	236	6	2010
WANG Q	4	6	0.333	203	6	2010
WANG Y	3	6	0.75	59	6	2018
YKSEL S	4	6	1.333	73	6	2019
ZHANG D	4	6	0.667	280	6	2016
ZHANG H	4	5	0.4	203	5	2012
BREYER C	4	5	0.667	285	5	2016
DEL RO P	4	5	0.25	83	5	2006
KANDPAL TC	4	5	0.222	46	5	2004
LI Z	3	5	0.375	35	5	2014
LIN B	5	5	0.625	302	5	2014
MURSHED M	5	5	5	66	5	2021
OZTURK I	5	5	0.714	458	5	2015

SHRIMALI G	2	5	0.333	40	5	2016

Table 3 depicts the most prolific authors contributing to the renewable energy finance literature. It is observed that Ragwitz, M., has produced a maximum of 8 documents with the highest h-index, followed by the LI, J., and Li, Y., etc.

Table 4: Most influential documents

Paper	Journal	Year	Total Citations	TC per Year
MILLS D.	SOL ENERGY	2004	621	34.5
SENSFU F.	ENERGY POLICY	2008	512	36.5714
RI M.	SOL ENERGY	2007	495	33
COUTURE T.	ENERGY POLICY	2010	464	38.6667
FRONDEL M.	ENERGY POLICY	2010	317	26.4167
MARTINOT E.	ANNU REV ENERGY ENVIRON	2002	291	14.55
PATA UK.	J CLEAN PROD	2018	275	68.75
BRER MJ.	ENERGY POLICY	2009	257	19.7692
AL-MULALI U.	NAT HAZARDS	2015	256	36.5714
WIGINTON LK.	COMPUT ENVIRON URBAN SYST	2010	253	21.0833
WSTENHAGEN R.	ENERGY POLICY	2012	247	24.7
WALKER G.	GLOBAL ENVIRON POLIT	2007	228	15.2
FOUQUET D.	ENERGY POLICY	2008	223	15.9286
CHARFEDDINE L.	RENEW ENERGY	2019	209	69.6667
REICHE D.	ENERGY POLICY	2004	205	11.3889
LESSER JA.	ENERGY POLICY	2008	199	14.2143
MASINI A.	ENERGY POLICY	2012	187	18.7
MUSALL FD.	ENERGY POLICY	2011	185	16.8182
OWEN AD.	ENERGY POLICY	2006	185	11.5625

KLESSMANN C.	ENERGY POLICY	2011	184	16.7273

Table:4 depicts the most influential documents. It is observed that the paper by Mills, D., published in solar energy is the most influential document with a total of 621 citations and 34.5 citations per year.

Table 5: Top 20 most frequent keywords

Words	**Occurrences**
Energy Policy	531
Alternative Energy	462
Renewable Energies	432
Investments	366
Renewable Resource	358
Renewable Energy Resources	347
Solar Energy	214
COP21	200
Energy Economics	182
Green Bond	175
Solar Power	175
Sustainable Development	163
Economics	158
Hydrogen	158
Climate Finance	147
Investment	140
Energy Efficiency	131
Carbon Dioxide	130
Energy Resource	120
Energy Market	118

Table 5 depicts the most common keyword used by the authors. It is observed that the most common keyword by the authors includes renewable energy sources, solar energy, COP21, energy economics, green bond, etc.