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Realising the Potential of Renewable Energy as a Tool for Energy Security in Small Island Developing States

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Abstract: Small Island Developing States (SIDS) are heavily dependent on the use of imported fossil fuels to address their energy needs. This has a negative impact on the environment, SIDS budgets, and energy security. Therefore, this study aimed to investigate the role of renewable energy (RE) as a tool for energy security in SIDS. In this regard, using VOSviewer, a widely known software tool, two bibliometric analyses were performed with a focus on the literature that explores two intertwined issues: (i) the links between RE and energy security; and (ii) the implications of RE and energy security in SIDS. The results from the study show that RE can help SIDS enhance their energy security and assure long-term energy sustainability. In addition, the results show that with the reduction in the cost of batteries in the future, they will eventually replace diesel generators. Moreover, the study showed that renewable energy may assist SIDS in their long-term efforts to achieve food security. The analysis discusses the major obstacles and the potential solutions for the integration of RES into the energy generation of SIDS. The paper concludes with useful recommendations to help island nations reduce their carbon footprint.

Keywords: energy security; energy policy; energy resources; sustainability; bibliometrics

1. Introduction

Energy security is commonly defined in regards to continuous energy availability and efficiency, affordability, accessibility, sustainability, cleanliness, and reliability [1–4], and it is often linked with sustainable policies and innovations [5,6]. Although uninterrupted energy supply is essential for socio-economic growth and development [7], unfortunately, many nations still struggle with the provision of sufficient and uninterrupted energy [8]. This problem is particularly evident in the Small Island Developing States (SIDS).

SIDS possess a set of characteristics that distinguishes them from other developing countries (Table 1) and make them some of the most vulnerable countries in terms of energy needs and security. SIDS have a population of about 61.5 million people, concentrated mainly in the Caribbean (65%), the Pacific, Africa, Indian Ocean, Mediterranean, and South China Sea regions [9].

Table 1. Unique features of Small Island Developing States and their socio-economic and environmental implications.

Features	Implications
Reduced size	Limited natural and financial resources
Geographical isolation	Access to services that are difficult on occasions
Limited economic outputs	Considerable levels of poverty
Vulnerability to climate change	Higher likelihood of damages and casualties due to extreme events and displacement of populations
Food price volatility	Hardships among some groups
Dependency on fossil fuels	High prices of energy

Except for Papua New Guinea and Trinidad and Tobago, most of the SIDS lack conventional energy resources (natural gas, oil, and coal). The energy vulnerability of SIDS relates to their net energy imports, their insularity and remoteness, their peculiar geographic, demographic, environmental and socio-economic conditions [10,11], their limited natural resources, thin economies, remoteness from the main trading centres, and their high exposure to unexpected events, such as extreme weather events [12]. SIDS' economic challenges are exacerbated by the human capital emergence that leaves in search of improved living conditions in more developed countries [13]. Although being blessed with abundant solar, wind, and wave energy resources, among others, RES constitute a small share in their energy mix.

Poor socio-economic conditions and high dependence on conventional energy sources affect the capacity of SIDS to support sustainable living as envisioned in the UN's sustainable development goals (SDG). Most SIDS are unable to meet their energy requirements independently, largely relying on the importation of fossil fuels for survival [4], which puts pressure on SIDS' financial resources [11] (with some exceptions such as Trinidad and Tobago, an example of oil-exporting SIDS [14]). Half of the Pacific SIDS, for example, are considered to be highly vulnerable to oil price shocks [4]. The high transportation cost of conventional fuels means that the SIDS must pay higher energy prices. The costs of electricity and other secondary energy resources are relatively higher than in non-SIDS [4]. Similarly, petroleum products are more expensive in SIDS than in nonisland parts of the world [4]. SIDS are also subject to an irregular supply of resources. In a recent assessment to monitor the sustainability of national energy systems, only 5 SIDS were ranked among 125 countries, and just two of these ranked among the top 50 countries in terms of energy security [3,15].

In a study by Michalena and Hills [12], it was revealed that by renewable energy (RE) improvement, there will be a minor increase in RE penetration, which will lead to putting the region below global rates of RE adoption. In another respect, there was a failure by the governments to build up inward investment through development partners for RE demonstration projects. Their results also show that focus on combating global climate change has not been successful at placing RE in a local context, which contrasts with traditional Pacific communities' strong "feeling of place" and spiritual nature. Lucas et al. [10] claimed that among others, the SIDS are highly vulnerable to climate change impacts. Furthermore, SIDS are among the world's most reliant on imported petroleum goods, and the usage of RE can assist in mitigating the economic risk associated with fossil fuel price fluctuation. According to their study, there are six categories that put RE deployment in islands at risk, such as (i) insufficient data for RE development, (ii) organised regulatory frameworks, (iii) lack of financial supports, (iv) absence of human resources, (v) expensive required facilities, and (vi) socio-cultural barriers.

In another similar study, Surroop et al. [8] stated that a fundamental worldwide development concern is low access to modern energy services, generally known as energy poverty. A collection of SIDS case studies that show efforts to enhance energy availability can serve as a foundation for recommending critical electrification strategies. It is worth mentioning that the establishment of an independent regulatory body with policymaking and adjudicative capabilities, as well as a high degree of commitment from the government, were highlighted as enabling factors. Furthermore, there are some potential contributors, such as the establishment of a cost-reflective pricing structure, to the development of electricity access in the island context. In the global aspect, the most affordable RE are solar energy and wind power, and it is predicted by the experts that the costs will remain low for the up-coming years [16]. Decarbonised electricity could be generated by wind and solar energies. However, it is required to implement other technologies including energy storage, supplemental generation, demand management, and transmission expansion to fulfil the demands reliably.

Food scarcity, low-quality education, poor healthcare facilities and services, discrimination against women, and poor and ineffective governance have been identified as some of the direct implications of energy insecurity [8,17]. Due to incessant power outages and scarcity of clean cooking fuel in many SIDS, households' resort to alternative domestic sources, such as residues from agricultural products, charcoal, manure, and wood. The proliferation of these cheap, low-efficiency fuels triggers chronic respiratory problems caused by household air pollution (HAP) [18,19], which can also lead to death [8,20]. The African, Caribbean, and Pacific (ACP) SIDS host a significant proportion of energy-deprived people who still rely on traditional fuels for basic daily activities including cooking and heating [8]. Water supply systems of many SIDS increasingly require a great deal of energy to power desalination plants. Scarcity of freshwater is a major challenge, particularly in big islands with a larger number of inhabitants and substantial water demand. This increases the demand for energy and further stresses SIDS' limited resources [21].

The high exposure of SIDS to climate-change-induced natural disasters, such as sea-level rise and flooding, further affects the reliability of the electric power supply. Poor power supply is also aggravated by the SIDS' nonconnection to continental grids [10]. Transportation in SIDS is also dependent on energy imports. For instance, in the Pacific SIDS, transport represents approximately 75% of the final use of imported oil [10]. Price instability, interruptions in supply, and inefficient delivery severely affect the transportation sector [22]. The combination of high fuel costs and limited road networks in SIDS pose transportation and sustainable development challenges [23]. Crucial investments in infrastructural development are usually forfeited in the ensuing trade-off between spending on fuel imports and societal development [24].

The electricity and transportation sectors in SIDS are highly reliant on fossil fuels, making these sectors responsible for most of the emissions of greenhouse gases in these countries, which contribute to global warming. Moreover, SIDS have been in the limelight as being faced with a "moral crisis" as their combined greenhouse gases emissions are less than 1%, but they are the first victims of global warming and suffer disproportionately from extreme weather conditions such as storms and floods. Their low increase exposes them to a high risk of submergence of rising sea levels and coastal erosion. Islands such as Tuvalu, Solomon Islands, and the Maldives are currently under threat of submersion [25].

The RE developed in SIDS are mostly hydro, solar, wind, and biomass. The potential of wind resources [26], bioenergy resources, marine energy, and geothermal energy production [4,27] have been variously discussed, but available evidence remains scarce thus far of the actual status of RE in SIDS and how they are being harnessed for energy security. Studies on energy security in SIDS are still in the formative stages and are of high relevance [3].

It is believed that RE can help SIDS significantly in achieving energy security and reducing the import of fossil fuel, but it has been largely ignored by analysts and policymakers. Given the fact that most advances are moving toward a low-carbon future, RE has the potential to accelerate SIDS' energy transformation. Energy intensity trends have been unpredictable over the previous decade, and for SIDS, reductions in energy usage have not been consistent. SIDS have a wide range of initiatives, projects, and policies, and this article provides a comprehensive overview of the current state of energy efficiency in SIDS. Overall, while previous studies have primarily explored policy interventions and recommendations, this study provides a more practical plan by combining institutional arrangements and the link of RE with SIDS.

RE and energy security are widely used concepts, for which an extensive body of literature exists. To this end, bibliometrics and co-occurrence analysis can be of help in sketching and disentangling the current energy policies and sustainability drivers [26,28]. Even though many scholars have examined energy security research from distinct viewpoints and through the application of different approaches, e.g., [29–31], few of them, such as [32–34], have attempted to investigate the bibliometrics and co-occurrence analysis domain of energy security research. Nevertheless, it is vital to employ an effective strategy for analysing the existing state and upcoming trends in these domains because most study areas are dynamic as a society, and the environments change. The results of bibliometrics and co-occurrence analysis are thought to be more practical [35].

Certain valuable information about energy security research is revealed, allowing researchers to continue their research. The goal of this research is to bridge the gap between bibliometrics and co-occurrence analysis, as well as energy security research. Given the increasing number of publications on energy security, it is necessary to provide a comprehensive overview of the current state and future trends in the field. Using bibliometrics and co-occurrence analysis to analyse energy security can help provide a clearer understanding of the contribution of RE to SIDS. Accordingly, in the current study, a bibliometric/co-occurrence analysis of "renewable energy" and "energy security" was performed to provide an overview of the extent to which the use of RE may assist in energy security. Therefore, the main research problem is that SIDS have poor energy security due to their dependence on fossil fuel imports. With this problem in mind, this study aimed to investigate the role of RE as a tool for energy security in SIDS to answer the following questions:

(1) Can RE be used as a tool for energy security in SIDS?
(2) What are the feasible solutions and evidence-based approaches in accelerating the acceptance of RE in order to achieve energy security in SIDS?

Towards this end, the remainder of the paper develops as follows. Section 2 explores the methodology used for bibliometrics and co-occurrence analysis of publications focusing on general and SIDS-focused RE and energy security—it presents a set of case studies. Section 3 presents the results, followed by Section 4, which discusses the obstacles and the means to address them. Section 5 presents the conclusions.

2. Methods

In order to shed light on the prospect and deployment of RE in the SIDS, a twofold approach was used. First, using VOSviewer, a widely known software tool, two bibliometric analyses were performed with a focus on the literature that explores two intertwined issues: (i) the links between RE and energy security; and (ii) RE and energy security in SIDS. This helped with the understanding of the thematic focus of the research in this area and with the identification of the major studies that can inform this work. A bibliometric analysis is performed with a focus on the literature exploring the links between RE and climate change mitigation and energy security. Bibliometrics is a valuable set of methodologies to track and map existing publications on a specific research issue. The outputs are suitable for highlighting major thematic focuses and examining the previous studies' trends [36].

To conduct the first bibliometric analysis using VOSviewer, a search for literature at the nexus of RE and energy security was performed in the Web of Science (using the following search string: TS = ("RE" AND "energy security")) AND LANGUAGE: (English) Timespan: 1900–2021. Data were collected from the following World of Science (WoS) Indexes: SCI-EXPANDED, SSCI, A&HCI, and ESCI. The bibliometric data of 1110 articles were downloaded and used for analysis using VOSviewer. The software can be used to conduct different types of analyses. Here co-citation analysis was used to identify major resources and apply co-occurrence analysis to highlight main thematic focus areas. Co-citation shows connections between two documents that are both cited by a third document [37]. Publications that have stronger connections with other documents have been more influential in the development of the field.

A second bibliometric and co-occurrence analysis was performed. In this case, the following strings were searched: TS = (("RE" AND "energy security") AND ("Small Island Developing State *" OR "sids" OR "Bahrain" OR "Cabo Verde" OR "Comoros" OR "Guinea-Bissau" OR "Maldives" OR "Mauritius" OR "Sao Tomé and Principe" OR "Seychelles" OR "Antigua and Barbuda" OT "Bahamas" OT "Barbados" OR "Belize" OR "Cuba" OR "Dominica" OR "Dominican Republic" OR "Grenada" OR "Guyana" OR "Haiti" OR "Jamaica" OR "Saint Kitts and Nevis" OR "Saint Lucia" OR "Saint Vincent and the Grenadines" OR "Suriname" OR "Trinidad and Tobago" OR "Fiji" OR "Kiribati" OR "Marshall Islands" OR "Micronesia" OR "Nauru" OR "Palau" OR "Papua New Guinea" OR "Samoa" OR "Solomon Islands" OR "Timor-Leste" OR "Tonga" OR "Tuvalu" OR "Vanuatu" OR "American Samoa" OR "Anguilla" OR "Aruba" OR "Bermuda" OR "British Virgin Islands" OR "Cayman Islands" OR "Commonwealth of Northern Marianas" OR "Cook Islands" OR "Curacao" OR "French Polynesia" OR "Guadeloupe" OR "Guam" OR "Martinique" OR "Montserrat" OR "New Caledonia" OR "Niue" OR "Puerto Rico" OR "Saint Maarten" OR "Turks and Caicos Islands" OR "U.S. Virgin Islands")). Secondly, a case study analysis on six SIDS was performed (Figure 1).

The choice was based on: (i) the geographical distribution with a focus on main regions where SIDS are distributed and (ii) the size diversity (very small, small, and middle-sized SIDS). To the best of our knowledge, no studies have covered such a large sample of SIDS, so this study is an important contribution to the literature.

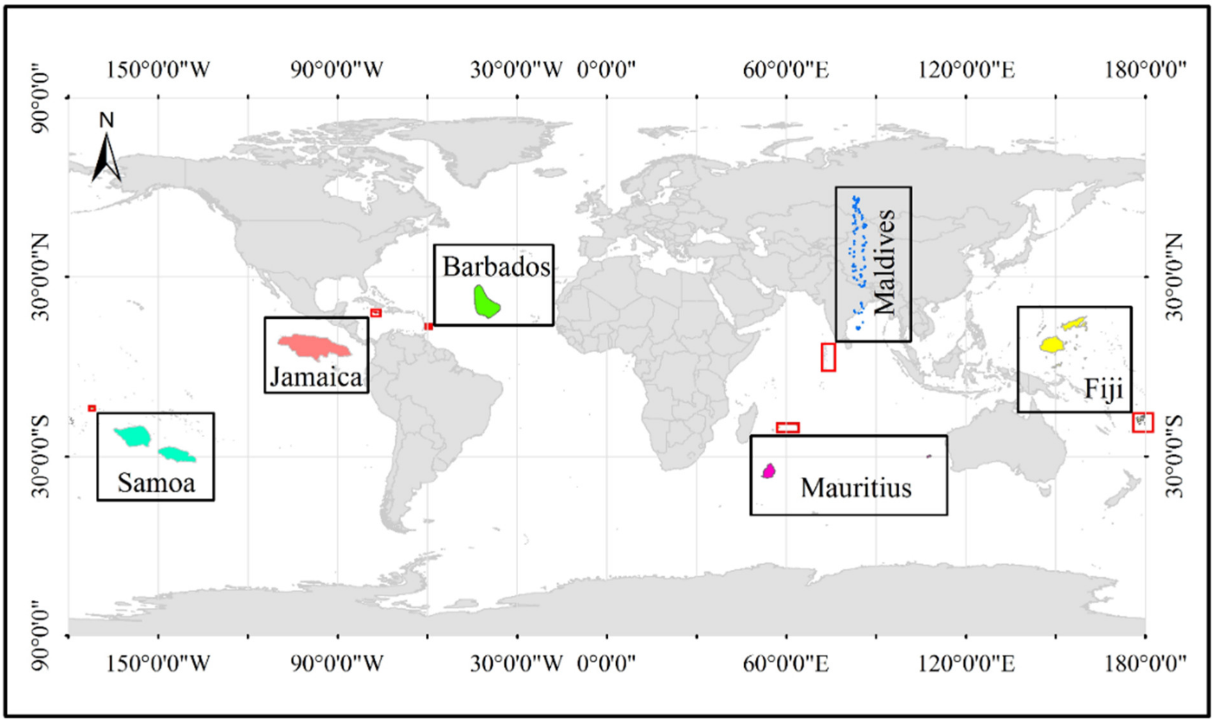

Figure 1. Locations of the sampled SIDS.

3. Results

3.1. Bibliometric Analyses

The present research examined both the overall and SIDS-focused existing scholarship on RE and energy security. The former was investigated to obtain a broader and more solid picture of the phenomenon, considering the larger corpus of literature. The latter was conducted with the aim to better highlight the publications on the energy policy dynamics related to SIDS. The results of the co-citation analysis show that the articles listed in Table 2 were more influential.

Table 2. Some influential publications in the field of energy security.

Reference	Title	Total Link Strength
Kruyt et al. (2009) [38]	Indicators for energy security	357
Winzer (2012) [39]	Conceptualizing energy security	258
Ang et al. (2015) [40]	Energy security: Definitions, dimensions, and indexes	275
Sovacool and Mukherjee (2011) [41]	Conceptualizing and measuring energy security: A synthesized approach	285
Yergin (2006) [42]	Ensuring Energy Security	154
Chester (2010) [43]	Conceptualising energy security and making explicit its polysemic nature	232
Asif and Muneer (2007) [44]	Energy supply, its demand and security issues for developed and emerging economies	108
Sovacool and Brown (2010) [45]	Competing Dimensions of Energy Security: An International Perspective	159
Intharak et al. (2007) [46]	A Quest for Energy Security in the 21st Century	156
Sovacool et al. (2011) [47]	Evaluating energy security performance from 1990 to 2010 for eighteen countries	192

These articles, e.g., [38–42] and some other important publications, such as those by Wang et al. [48] and Ibrahiem and Hanafy [49], have been reviewed to better understand the major issues discussed regarding the links between RE and energy security. The term energy security is extensively used, according to Kruyt et al. [38], but there is no agreement on its precise interpretation. They identified four aspects of energy security, which include energy availability, accessibility, cost, and acceptability, and categorised indicators for energy security using this classification. There is no single perfect indication, according to their findings, because the concept of energy security is largely context based. Applying several signs, on the other hand, leads to a more comprehensive understanding. Due to rising global demand, integrating these indications into a model-based scenario analysis revealed that the currently known fossil fuels are rapidly depleting.

Energy security and RE are top-tier issues in energy policy research. As can be seen in Table 2, the documents are listed regressively, according to their link strength. The best performing papers of this exercise scored a link strength ranging from 357 to 192. Interestingly, all of the studies that appeared in the co-citation analysis have been published in the last 15 years, with the majority of them in the last 10 years, and one work in the last 5 years. The number of yearly publications is as follows: 2015: n = 1; 2012: n = 1; 2011: n = 1; 2010: n = 2; 2009: n = 1; 2007: n = 2; 2006: n = 1.

In terms of number of publications, Energy Policy has 3 publications, followed by Renewable and Sustainable Energy Reviews and Energy, with 2 publications each. Foreign Affairs, Annual Reviews of Environment and Resource, and Asia Pacific Energy Research Centre also appear with 1 document each. In terms of authorship, the most prolific author is Benjamin K. Sovacool, who authored or was listed as the first co-author in three publications. All the other authors obtain one publication each—either as authors or coauthors. None of the authors displayed multiple affiliations.

In order to have more detailed information on the SIDS selected for the case study, a bibliometric analysis was performed on the topics of RE, energy security, and small island developing states. The words relate to all the SIDS chosen for this inquiry (n = 58).

The bibliometric search returned 19 results. All the examined papers had a spatial focus. Three works propose regional investigations: 3 in South Asia, 1 in East Asia, 2 in Southeast Asia, 1 in the Caribbean and Pacific, 1 in the Western Pacific Ocean, and 1 in Gulf Cooperation Countries (GCC). A total of 7 publications concerned domestic case studies from SIDS; Fiji with 2 works and Comoros, Cape Verde, Suriname, Jamaica, and the Maldives scoring 1 paper each. Only one publication explicitly considered SIDS broadly. Two papers did not directly deal with SIDS, but they had language and project implications and secondary analyses on SIDS; one paper focused on Denmark and the other on the EU.

According to the findings, the most trending topics are related to RE and specific sources [50], energy transition [51], energy security [52], mitigation [53], aid [54], efficiency and fuel access topics [55], consumer perception [56], sustainability and environmental preservation [57], ICT and technological innovation [58], specific projects and techniques [59], economic dynamics [60], and energy regulation and policy [61]. In terms of methodology, a wide set of techniques, including case study analysis, impact evaluation, index construction, and principal component analysis by Argentiero and Falcone [62], Karytsas and Choropanitis [63], Li et al. [64], and Luo et al. [65], were used as methods.

The most prolific authors were M. Mohsin and M. Dornan, with two items each. Apart from these authors, the bibliometric analysis did not return any outstanding authors displaying more than one publication. The paper displays the largest number of coauthors; there are six individuals (one publication). Three works were written jointly by five scholars (per each), and four were drafted from four researchers altogether (per researcher). An additional 5 papers were realised by groups made of 3 coauthors, 3 were finalised by 2 scientists each, and 3 articles were published by a single author.

The number of publications on the cross-cutting topics related to RE and energy security in SIDS reveals the newsworthiness of the tackled topic. The first publication dates back to 2009. In 2015, 2016, 2018, and 2019, two papers are recorded each year. In

2020, a publication peak (six records) is noticeable. The year 2021 registered one published article to date. These figures signal an ascending trend in terms of scholarly interest from 2015, which clearly increased in 2020. For instance, Azzuni et al. [66] investigated the impacts of transitioning from fossil fuel to a renewables-dominated energy system on energy security in Jordan. Their results reveal that availability, affordability, environment, health, and employment will be improved, whereas the diversity will remain unchanged. Therefore, Jordan can reach a 100% RE system by 2050, which will improve the country's energy security.

The largest publication outlet was Renewable and Sustainable Energy Reviews, with 6 articles, followed by Utilities Policy, where 2 papers were published. The remaining items (n = 11) were collected in 11 different journals including (i) *RE*; (ii) *Energies*; (iii) *Environmental Science and Pollution Research*; (iv) *The Journal of Cleaner Production*; (v) *Ecological Indicators*; (vi) *Asian Politics & Policy*; (vii) *Energy Economics*; (viii) *Energy Research & Social Science*; (ix) *Energy for Sustainable Development*; (x) *The Journal of the Energy Institute*; and (xi) *Pacific Economic Bulletin*.

3.2. Co-Occurrence Analyses

The output of the analysis, for a minimum occurrence threshold of six keywords, is shown in Figure 2, mapping the co-occurrence analysis on RE and energy security publications. Here, node size is an indication of the keyword's frequency of use, and the proximity of occurrence indicates that two keywords have co-occurred more frequently. It was found that the following are common topics as they have been used more frequently and have higher values of link strength (top 10): sustainability, climate change, GHGs (greenhouse gases), solar energy, wind energy, biofuels, China, biomass energy, efficiency, and bioenergy. Sustainability is strictly intertwined with RE and energy security and is fundamental to fostering connected issues such as energy resilience, vulnerability, and justice [67–69]. This is also due to the polysemic nature of energy security, even though prior scholarship, e.g., [70–72], has attempted to provide definitions and conceptualisations [42]. The achievement of energy efficiency is primarily linked to energy security and RE.

As shown in Figure 2, three major clusters can be identified in red and green—larger clusters—and blue—a smaller cluster. The largest cluster (red colour) is mainly focused on ecological issues—above all, the implications for climate change mitigation and environmental and energy sustainability. This may indicate that different scenarios for achieving energy security have major impacts on the progress towards achieving environmental sustainability, greenhouse gases and climate change mitigation targets, RE consumption and overall energy resilience, and vice-versa [73,74].

Some nonrenewable sources such as coal and natural gas can be spotted, and this may signify their importance for achieving energy security in some regions such as ASEAN and Europe. Additional geographical indications include China, Japan, Germany, Turkey, and North Africa. The first two locations refer to two East Asian ascending markets for RE, which are devoting increasing attention to energy security. Germany is a major world and European player on these themes, whereas Turkey and North Africa are regarded as major channels for both RE pipelines and energy security and supply. Energy security and environmental sustainability, as demonstrated by Murshed [75], have become important to the global policy agenda, with global economic growth strategies being reorganised to assure the reliability of energy supply while also safeguarding environmental well-being. However, one of the biggest obstacles to achieving these broad objectives is technological inefficiency. The findings of the economic analyses show that ICT trade boosts RE consumption, increases RE shares, reduces energy intensity, encourages the use of cleaner fuels, and lowers carbon emissions. Furthermore, ICT reduces carbon emissions indirectly by increasing RE usage, improving energy efficiency, and expanding access to cleaner fuels.

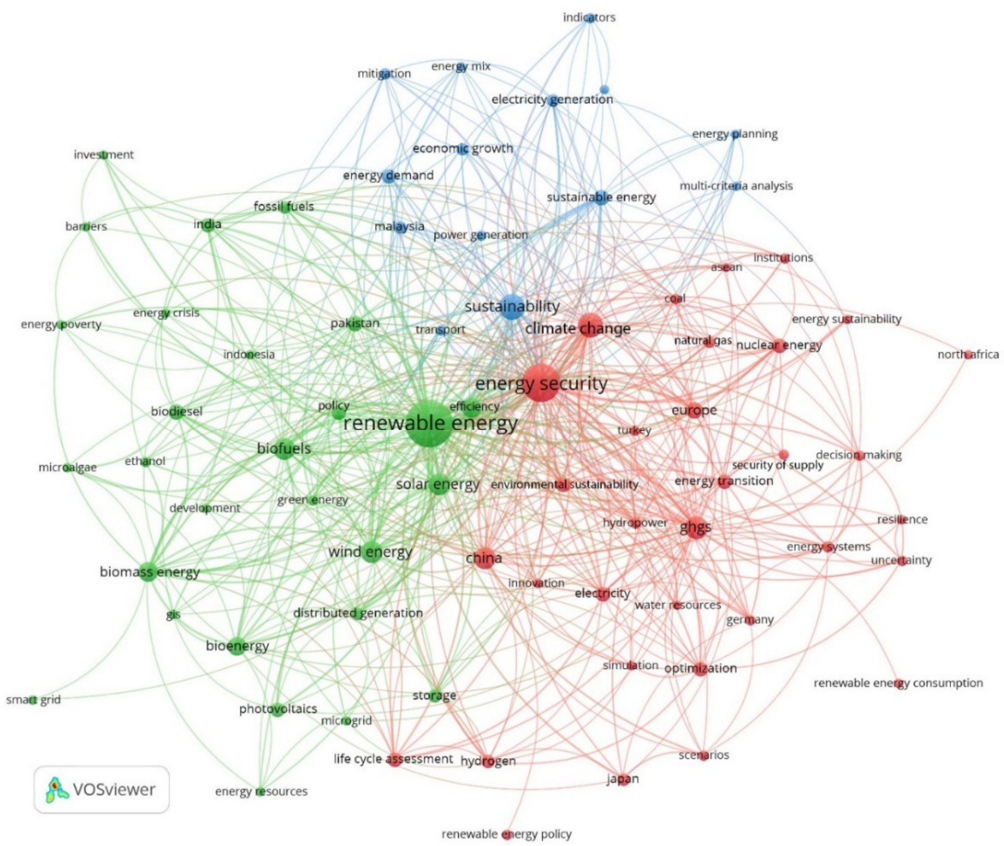

Figure 2. Co-occurrence map: RE and energy security (derived from VOSviewer).

Given the strong nexus between water and energy in some contexts and the water–energy–food nexus and their security, increasing energy security may also enhance water security [76]. The water–energy–food nexus has emerged globally, according to Sarkodie and Owusu [77], since the interrelation of these resources is critical to building conceptual tools for environmental sustainability. As a result, the water–energy–food nexus supports economic development while also enhancing life and well-being. Because of its policy consequences, scholarly study on the water–energy–food nexus is rapidly expanding nowadays. RE technologies have been identified as the cure for achieving environmental sustainability. However, while fossil fuel energy technologies compete with groundwater extraction and usage, certain renewables compete with food for land usage, requiring cost–benefit analysis. Overall, this cluster highlights the significance of optimizing energy systems to simultaneously achieve energy security and environmental sustainability [78]. As suggested by the cluster, institutions and decision-making processes would drive energy system resilience to minimise sectoral uncertainty.

The second major cluster (Figure 3, green colour) can be predominantly connected to environmental and technical topics pursuing social mandates. Smart grids and microgrids are regarded as key energy resilience strategies for overcoming energy security, access, and vulnerability, especially in remote and rural areas of the Global South to target economic, social, and environmental goals [79,80]. According to Daneshvar et al. [81] and Khalil [82], as cities are developed to become smarter, energy systems and access to them consequently becomes an even more integral part of modern living. To become more dependable and resilient, newer energy systems must also undergo transformations. Despite their reliance on natural processes, solar cells and wind energy technologies remain the strongest possibilities for new significant energy sources in smart cities. These energy sources should continue to be the foundation of smart energy systems in the future. In reality, since their emergence a few years ago, solar panels for practical uses in buildings have seen dramatic price drops around the world. Some other important issues can be highlighted based on proximate terms in this cluster. For instance, the term "storage" is closely linked to RE and infrastructure. This may indicate the significance of improvements in battery storage capacity for maximising the benefits accrued from RE [83].

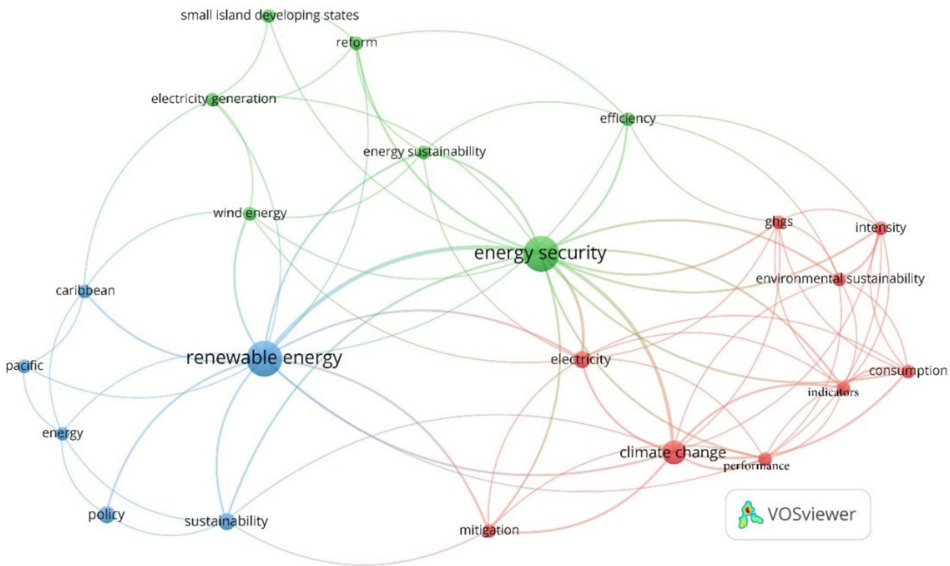

Figure 3. Co-occurrence map: RE and energy security in SIDS (derived from VOSviewer).

"Efficiency" is a frequently used term with strong and close connections to both RE and energy security. This can be interpreted as the significance of efficiency improvements for optimising the performance of RE and their contribution to energy security [84]. Three geographical terms also appear and refer to South and Southeast Asian countries sorting from this study's analyses (i.e., India, Pakistan, and Indonesia). These rank in the lower top 10 countries globally in terms of lack of access to electricity [85]. The robustness of infrastructure investments and development policies to remove energy poverty barriers and to enhance energy efficiency and RE distribution and generation are urgent and on the rise.

Finally, there is a relatively smaller cluster (Figure 3, blue colour) that contains mixed topics—mostly economic and environmental but also technical and methodological. The group includes terms such as sustainability, sustainable energy, mitigation, economic growth, energy demand, energy transport, and energy planning [86]. Another subgroup can be identified with the topics of the energy mix, electricity generation, and power generation. Two widely used techniques can be discerned, which include multicriteria analysis and indicators. Some of the major publications in this area are focused on indicators and multicriteria decision support systems (Table 2). These can be used to guide the development of sustainable and RE systems that can enhance energy security [38,87,88]. Considering the broadness of the approached issues in this third cluster, and the fact that this group only includes a unique spatial location (Malaysia), this last term is explored through specific case studies.

Making use of VOSviewer, a co-occurrence analysis was performed with the goal to corroborate the bibliometric outcomes discussed above, with a focus on SIDS. The term co-occurrence analysis is, indeed, able to render indications within the leading thematic foci and interrelations, as shown in Figure 3, following the same relations as described for general co-occurrence between RE and energy security.

The map illustrates a number of results on the reviewed research items. It is possible to detect two principal bulks of connections, having principal keywords "renewable energy" (in blue) and "energy security" (in green). A third cluster (in red) finds its dominant keyword in "climate change". This illustrates the association between the themes on the one hand and their presence in the literature on the other.

3.3. Case Study Analysis

Table 3 presents some basic characteristics of the sample, as well as the share of RE in final energy consumption. According to data from the World Bank [89], in this sample of SIDS, the percentage of consumed energy that comes from renewable sources corresponds to less than 20%, except for the Pacific Islands, whose values are around 30%.

Table 3. Characteristics of the studied SIDS.

Region	*SIDS*	*Population (Inhab.)*	*Area (km^2)*	*GDP (Billion USD)*	*Renewable Energy Consumption (% of Total Final Energy Consumption)*
Caribbean	Barbados	285,719	430	4.8	2.8
	Jamaica	2,890,299	10,990	14.8	16.8
Pacific	Fiji	905,502	18,270	5.1	31.3
	Samoa	196,440	2840	0.9	34.3
African	Mauritius	1,264,613	2040	13.3	11.5
	Maldives	436,330	300	4.6	1.0

Source: based on World Bank [89,90].

The Global Wind Atlas [91] and the Global Solar Atlas [92] are web-based tools to identify potential high-wind areas for wind power generation and to display annual average solar power potential to assist governments and investors in obtaining an initial indication of RE potential before carrying out more detailed analysis (Table 4).

Table 4. Potential for renewable energies in the sample of SIDS.

SIDS	*Wind Energy*		*Solar Energy*	
	Power Density [a] (W/m^2)	**Wind Speed [a] (m/s)**	**Photovoltaic Electricity Output (kWh/kWp per Year)**	**Direct Normal Irradiation (kWh/m^2 per Year)**
Barbados	348	7.56	1663	1777
Jamaica	354	7.09	1498	1482
Fiji	404	7.0	1269	1123
Samoa	319	6.3	1501	1543
Mauritius	418	7.7	1703	1988
Maldives	113	4.6	1599	1715

[a] Average for the 10% windiest areas at height of 100 m. Source: based on Global Wind Atlas [91] and Global Solar Atlas [92].

Among all RE, wind energy is one of the most promising options in many islands [25]. The International Electrotechnical Commission (IEC) International Standard 61400-1 [93] presents wind turbine classes according to the wind conditions of particular sites. Even though more technical details are necessary for a formal classification, the sample of SIDS would be classified as Wind Class III, with annual average wind speeds up to 7.5 m/s. Another important factor presented in Table 4 is the wind power density. This indicator represents the amount of energy available for wind turbines to convert [94]. Therefore, the higher this value is, the better the wind generation potential tends to be.

Due to the average irradiation of approximately 1055 kWh/m^2 per year, Germany is a renowned investor in RE; therefore, photovoltaic systems are among the most used sources [95–97]. Taking that into consideration, the results for the sample of SIDS are even better. In these conditions, solar energy could be harnessed through solar water heaters (SWH), solar photovoltaic (PV) systems, solar drying, and other systems [25]. According to Kuang et al. [25], the easy implementation of SWH makes it widely used in islands, and the installed capacity of a solar PV system is also flexible, enabling its implementation almost anywhere with low operational costs.

The following sections present additional information regarding RES in the SIDS sample and discuss evidence of the importance of RE for energy security.

3.3.1. Barbados

As with many other countries, Barbados defined targets to increase the use of RE and, consequently, improve its energy efficiency. By 2030, the country is expected to provide 65% of the total electricity demand from renewable sources, and solar energy is considered the most viable resource to achieve this target [98]. Since 2010, the Renewable Energy Rider programme has been contributing to the investment in solar photovoltaic systems, and a rapid increase in solar and wind harnessing is expected for the next decade [98–100]. Following the recommendations from IRENA [101], wind and solar energies are indeed the most favourable sources for this country.

3.3.2. Jamaica

Jamaica is an example of a large country in the Caribbean that has a huge and diversified amount of RE resources, such as geothermal energy, wind and hydropower energy, solar energy, and biomass [101–103]. Although Jamaica is among the islands that developed hydroelectric power more than 60 years ago, the development of its energy system since then has been based on fossil fuels [104]. Jamaica is an exception among other islands because it has a local refinery supplying most of its domestic petroleum needs, but this area also depends on the import of fossil fuels, which are characterised by high energy intensity and low energy efficiency [105]. The island had a large increase (46%) in carbon dioxide emissions between 2000 and 2005, which represented a pressing need to invest in RE technologies and, therefore, to increase national energy security and environmental sustainability [106]. Jamaica's National Energy Policy 2009–2030 acts as an important mechanism towards this need and one of its goals is the recognition of national energy potentials using developing RE, increasing energy security, and decreasing the carbon footprint. In order to ensure that, Jamaica aims to generate 30% of its energy demand from renewable sources by 2030 [103].

3.3.3. Fiji

Like many other Pacific Islands, Fiji considerably depends on imported fossil fuels—100% for transportation and 33% for electricity generation—which is an adverse condition considering increasing fuel costs [107]. As presented by Kumar [108], Fiji has had many historical events of oil supply shortage, including energy crises and war episodes, which have also contributed to high increases in energy prices. Some progress has been observed since the first National Energy Policy was established in 2006, but Fiji continues to fight challenges related to rising expenditures on imported fuels and volatility risk [109]. This represents a huge challenge for the region, given that the fluctuation in fossil fuel supply is directly connected to national energy security and corresponding costs.

3.3.4. Samoa

Like many other SIDS, Samoa also has to deal with extreme weather events, environmental degradation, and rising sea levels [110]. Considering its remoteness from large markets, investments in RE and, consequently, in energy security are even more important. According to information from IRENA [111] and Dornan [112], hydro and solar power have good potentials in Samoa, followed by wind and biomass with moderate potentials.

Samoa meets a third of its power needs through renewable sources, but the rest are met with imported diesel fuels, negatively impacting domestic energy security and prices [113]. Studies from IRENA show that besides helping to achieve a national target of 100% of RE by 2025, increased investments in RE also contribute to being less dependent on fossil fuels [113]. The water availability in Samoa is essential in supporting the high hydropower potential, but solar PV and wind power must contribute as well, accounting for almost 20% of the total electricity demand.

To help meet this local target of achieving 100% RE electricity generation by 2025, a partnership between the government of Samoa and the United Nations Development Programme (UNDP) promoted the project IMPRESS (Improving the Performance and Reliability of Renewable Energy Power System in Samoa). With the aim of supporting national efforts in RE and a cost-effective production, the project also focuses on improving energy efficiency and investing in biomass, biogas, solar, and wind energy systems [114,115].

3.3.5. Mauritius

Mauritius is an island nation that does not have any fossil fuel reserves; therefore, it relies on imports of this resource and local RE sources [116]. For electricity generation, the country imports about 77% of fuel (petroleum products) and coal, and the rest are produced from locally available renewable energies such as biomass, hydro, wind, solar, and landfill gas [117,118].

Mauritius has an urgent need to reduce its fossil fuel dependency, to invest more in RE, for both economic and environmental reasons, and to deal with increased electricity demand [117,118]. Hydroelectric power has been used for many years and corresponds to around 4% of total electricity generated [118]. Despite its advantages, such as low operational costs, this energy resource depends on rainfall for reaching maximum capacity, and the country has been facing some water stress conditions.

On the other hand, solar and wind energy are among the RE sources with the highest potential in Mauritius [119]. The local government is encouraging the use of solar energy and main applications that include SWH and PV systems. In 2014, the first solar farm was launched with a generation capacity of 15 MW, and one year later PV represented almost 1% of total electricity production [118,120]. When it comes to wind energy, Mauritius has potential sites with reliable regimes for investment, and wind power is expected to reach 8% of the contribution to total electricity generation by 2025 [117].

The Mauritius Long-Term Energy Strategy 2009–2025 aims at achieving 35% of RE electricity generation by 2025 [121], 15% more than the value from 2010 (20%). According to Khoodaruth et al. [122], this is a limited scope, and the country has potential for more, as it is feasible to aim for 100% RE by 2050.

3.3.6. The Maldives

The growing energy demand in the Maldives and environmental questions related to carbon emissions are often argued as drivers for more investments in RE technologies. Other important drivers are the financial difficulty caused by the heavy dependency on imported fossil fuels for electricity generation and the significant technoeconomic potentials considering RE [123].

The local government has been investing in sustainable energy and trying to overcome all the barriers that prevent the use of RE. Through the National Energy Policy, which discusses energy efficiency, RE, and energy security, the government set up targets for each aspect and linked them to other national policies and to Sustainable Development Goal 7, which focuses on energy [124]. Nevertheless, according to the Maldives' Renewable Energy Roadmap [125], some of these targets do not meet the most favourable economic conditions to develop RE in the country. New targets should be considered to accelerate the transition to a more RE system and to meet energy security needs.

4. Obstacles and the Means to Address Them

Lucas et al. [10] identified a scarcity of finance, poor human resources, costly infrastructure, socio-cultural impediments, and weak policy and regulatory frameworks as the main challenges for SIDS. Timilsina and Shah [126] highlight the relationships between these factors and argue that the void in technical figures, inadequate assets evaluation, and poor local capacity hamper proper policy resolutions. Dornan [127] argues that the approach of grid extension is not suitable for island countries, and the choice of this model is an obstacle for the deployment of RE. Kaler et al. [128] have identified various shortcomings such as weak institutional frameworks, poor knowledge base, limited financing, poor RE project planning, lack of local capacity, and unreadiness for regional and international cooperation as obstacles to RE deployment. The main obstacles for RE deployment in SIDS were grouped in five categories along with the major obstacles, as shown in Table 5.

Table 5. Main obstacles for RE deployment in SIDS.

Technical	Financial	Policy	Market Barriers	Misc.
Poor resource availability and data gaps in mapping RE resources	High capital costs	Regulatory and policy uncertainty	Inconsistent pricing of energy	Environmental constraints due to the presence of highly sensitive ecosystems
Inadequate infrastructure for evacuation of RE power	Inadequate funding and high cost of capital	Administrative barriers such as slow and opaque decision making	Continued subsidies for fossil fuels	Poor public acceptance and cultural barriers
Inability to absorb RE due to inflexibility and lack of capacity of the electricity grid	Lack of paying capacity for energy services by citizens	Absence of clear goals for RE deployment	Small market size and lack of structured markets	Lack of human capital and skilled workers
Poor scalability of projects	Lack of economies of scale	Poorly defined roles for government departments and weak regulation	Asymmetrical information and market power	Lack of R&D
Lack of accompanying road and transportation infrastructure for accessing remote sites	Poor incentives for RE deployment	Lack of implementing institutions with dedicated responsibilities		Poor integration of stakeholders in project development

The role of international aid for promoting RE in Pacific SIDS was analysed by Keeley [54], who concluded that well-structured action plans, effective regulation, and strong financial status of utilities are essential for attracting funding. Blechinger et al. [129] mentioned the importance of the introduction of proper regulations to accelerate the implementation of the RE potential, while Atteridge and Savvidou [130] called for strengthened local human and institutional capacities to increase the effectiveness of aid efforts. Timilsina and Shah [126] noted that cooperation between public and private sectors could intensify RE expansion. They also highlighted that long-term outlook and policies with incentives are necessary to encourage investment. Lucas et al. [10] identified the technical and financial skills that need to be developed for utilities, the private sector, government, and financial institutions to overcome challenges. Taibi et al. [131] recommended that a framework is important to deploy RE in Pacific Island countries and proposed a focused use of development finance and technical cooperation. Mofor et al. [132] recommended that increased technical conditions to control and preserve RE setups is essential and emphasised capacity-building programs. Furthermore, they support local stakeholder involvement in the development and operation of projects and regional cooperation amongst SIDS for developing RE. Although all the above measures are essential, Michalena and Hills [12] concluded that encouraging RE mechanisms such as energy governance has shown a potential to contribute to the implementation of RE in PSIDS to only a certain extent.

The solution to addressing such issues needs strong, non-government-controlled regulation. In several countries, this has already resulted in improved energy utility performance. However, it cannot tackle investment obstacles such as lack of economies of scale or general investment. Given the fixed costs associated with regulation, the construction of independent regulatory bodies in extremely small countries is also likely to be expensive, considering the possible benefits of such arrangements.

The relationship between political leaders' judgments and technical organisations' decisions in the energy sectors is a larger point. RE at the national level are useful programs because they drive public policy and show where the private sector's investment possibilities exist. Appropriate targets, on the other hand, must be backed up by advice and data from technical institutions, which include both regulatory agencies and electricity producers. This need has not been satisfied by some (but not all) of SIDS's RE objectives. In countries where there are no low-cost RE choices, RE objectives that set a goal of generating 100% of energy from renewables refer to political decision makers acting without (or despite) recommendations from technical bodies in the power sector. This lack of connection between political decision making and advice from the energy sectors is likely to be explained using targets to strengthen SIDS' negotiating position. Political leaders would be completely sensible in adopting such an approach.

5. Conclusions

SIDS are highly dependent on nonrenewable energy (mainly fossil fuels). The fluctuating price of fossil fuels combined with the high transportation cost compromise the energy supply in SIDS and often lead to energy insecurity. This paper considered RE as a medium to improve energy security in SIDS and to ensure energy sustainability. The findings show that SIDS have good potential for exploiting RE, and this offers interesting policy options. This is especially so since some SIDS were compared with Germany, which is a world leader when it comes to integration of RE, and it was concluded that SIDS have a better solar regime.

This implies that SIDS can have a bigger share of RE in the energy mix. However, there are several obstacles to the implementation of these technologies. The different obstacles are categorised into technical aspects (lack of data on resource availability, lack of infrastructure, and lack of smart grid to cope with the intermittency of RE), financial aspects (high capital cost, lack of funding, lack of economies of scale, and lack of incentive), policy aspects (inappropriate regulation and policy, poor governance and slow decision-making process, absence of RE strategy, and lack of institutions), and market size aspects (inconsistent energy price, subsidy on fossil fuels that make the RE cost less competitive, small market size, and lack of market information). The other obstacles are poor public acceptance, cultural barriers, lack of skilled human resources, and lack of research and development. More recently, COVID-19 was added to the list.

Focusing on SIDS, this study aimed to detect and describe key publication characteristics of RE and energy security. To this end, two bibliometric analyses and a co-occurrence analysis on overall trends and SIDS figures were performed. The outcomes returned important information on these energy topics. Despite the low numbers, one can notice an increasing research interest in RE and energy security in SIDS. It is also possible to ascertain selected publication characteristics, including the trendiest topics, journal collection of the publications, author characteristics, and location. Additional key aspects can be acquired from the co-occurrence analyses. In both analyses, several energy- and environment-related topics are recurrent. Some of the most connected terms include climate change and sustainability. These data can be useful for energy policy modelling and upcoming studies.

Based on the case studies analysed and the list of RE projects in SIDS, the authors propose the following additional measures to overcome the existing obstacles and to catalyse RE development in SIDS:

1. Inclusion of economic valuation of climate change mitigation in assessing RE projects;
2. Extensive resource assessment and integrated technoeconomic analysis;
3. Spatial planning for RE deployment along with simultaneous use of available land;
4. Adopting long-term RE targets while maintaining flexibility on technology;
5. Adopting a decentralised model of RE generation and distribution;
6. Development of common standards and guidelines;
7. A coordinated approach to policymaking;
8. Global cooperation for accessing innovative RE financing from private and international funding agencies;
9. Use of fiscal instruments such as tax exemption, import duty waivers on RE equipment, and long-term tax holidays;
10. Fiscal support measures such as feed-in tariffs in the short term;

11. Capacity building through technical inputs;
12. Strengthening of the existing institutional framework.

Moreover, local stakeholder involvement and increased consultative processes are needed to build greater support for the use of RE in SIDS.

In this study, several measures are proposed to overcome different obstacles and challenges to improve the integration of RE. If anything, the COVID-19 pandemic has reiterated the need to further deploy RE to reduce the dependence (and costs) associated with the use of fossil fuels. The authors propose taking the main aspects of sustainability (social, economic, and environmental) into account while assessing RE projects in order to conduct resource assessment, to come up with a strategy and the spatial planning for land use and deployment of RE, to decentralise the energy system, to develop standards, regulations, and guidelines, to come up with a coordinated policy and an institutional framework, to provide financial support through subsidies, and to involve all the stakeholders in different processes.

This paper is not exempt from limitations. Bibliometrics are useful tools to map existing scholarship and dynamics. However, a comprehensive analysis of the publications cannot be ensured. This is the case for grey literature, papers published in nonindexed journals, and papers that are published in languages other than English, which are not indexed in scholarly databases. In order to corroborate the preliminary tests, this work included two bibliometric analyses and two co-occurrence analyses. Future research could expand or differentiate the topics to focus on alternative issues and key bibliometric features or to exploit different techniques.

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