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Sustainable Energy Development—A Systematic Literature Review

Katarzyna Łukasiewicz [1,*], Piotr Pietrzak [1], Jakub Kraciuk [2], Elżbieta Kacperska [2] and Małgorzata Cieciora [3]

[1] Management Institute, Warsaw University of Life Sciences, 02-787 Warsaw, Poland
[2] Institute of Economics and Finance, Warsaw University of Life Sciences, 02-787 Warsaw, Poland
[3] Faculty of Information Management, Polish-Japanese Academy of Information Technology, 02-008 Warsaw, Poland
* Correspondence: katarzyna_lukasiewicz@sggw.edu.pl

Abstract: The main aim of this study is to present a systematic literature review (SLR) of the sustainable energy development (SED) and emphasize important activities relevant to this concept. The following set of research tasks was adopted to achieve the main aim: (1) presentation of the distribution of articles by year (both journal and conference papers) on the SED concept; (2) identification of the most frequently cited articles on the SED concept; (3) identification of the countries that have contributed most to the development of the SED concept through publication activities; (4) demonstration of the subject areas most frequently associated with the SED concept; (5) presentation of the various definitions of the SED; (6) identification of the most important activities carried out under the SED; and (7) presentation of future research directions for the SED. It is worth noting that the research tasks undertaken will be both quantitative and qualitative. The data search was conducted on 31 August 2022, and the selected peer-reviewed database was Scopus. The exclusion process resulted in a total of 607 journal and conference papers. The most important conclusion to be derived from this study is that there is no one unified definition of the SED. Moreover, three activities must be undertaken to realize the SED concept: (1) increasing the use of renewable energy sources in the energy mix, (2) enhancing energy efficiency, and (3) reducing emissions of greenhouse gases and air pollutants. The article also presents the authors' conceptual model that can serve as a starting point for further analyses in this area.

Keywords: sustainable energy development; systematic literature review; Scopus

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1. Introduction

Energy has always played a vital role in the lives of human beings [1]. Since the industrial revolution, it has been a "driving force for modern civilization development" [2] p. 235. At the present, the energy sector is considered to be the primary source of greenhouse gas emissions. In the case of the European Union (EU), nearly 80% of these gases are emitted from this industry [3]. A great number of authors (e.g., Bhattacharyya (1995) [4]; Kudełko and Wejer (2014) [5]; and Bielecki et al. (2020) [6]) have written about the negative externalities of the energy sector. That is why there is currently a growing emphasis on the importance of applying the concept of sustainable development (SD) to the energy sector [3]. One of the Sustainable Development Goals (SDGs)—commonly known as SDG 7—aims to ensure access to affordable, reliable, sustainable, and modern energy for all people by the end of 2030 [7].

Due to the reasons outlined, the term sustainable energy development (SED) is increasingly used in the literature (see Mak & Shearer (1996) [8]; Lin (1998) [9]; Vera et al. (2005) [10]; and Chen et al. (2022) [11]). As Tutak et al. (2020) [3] mentioned, activities pertaining to the SD of energy sector focus mostly on: (1) increasing the use of alternative, including renewable, energy sources in the energy mix [12]; and (2) enhancing energy

efficiency [13] and reducing emissions of greenhouse gases and air pollutants [14,15]. Afgan et al. (1998) [2], in this regard, still pointed to mitigation of nuclear power [16].

Since the 1990s, a remarkable number of articles have been written about the SED. It is worth noting that the prominence of conceptual and illustrative case studies demonstrates the lack of maturity of the concept of the SED. Future study should focus more on establishing the theoretical foundation for this issue. That is why the main aim of this article is to present a systematic literature review (SLR) of the SED and emphasize the important activities relevant to this concept. Special attention is devoted to the definition of the SED and its generic meaning. The following set of research tasks was adopted to achieve the main aim: (1) presentation of the distribution of articles by year (both journal and conference papers) on the SED concept; (2) identification of the most frequently cited articles on the SED concept; (3) identification of the countries that have contributed most to the development of the SED concept through publication activities; (4) demonstration of the subject areas most frequently associated with the SED concept; (5) presentation of the various definitions of the SED; (6) identification of the most important activities carried out under the SED; and (7) presentation of future research directions for the SED. It is worth noting that the research tasks undertaken will be both quantitative and qualitative.

The contribution of this study is threefold. Firstly, this SLR provides a clear picture of the state of environmental and social research on the SED. The commitment of researchers and practitioners to the potential of the SED continues to grow. Many articles in this field are being produced; nevertheless, according to the authors' best knowledge, there is a lack of comprehensive coverage of this issue. That is why the study provides an up-to-date, comprehensive SLR of 607 journal and conference papers indexed on Scopus. Secondly, this study investigates the activities that are being undertaken within the SED. This article provides a better understanding of what actions can be carried out at the level of individual countries, their groups, or international organizations to effectively implement the SED. Thirdly, the study contributes to the social or environmental literature with a discussion of the potential future research trends related to the SED. The authors believe that this study will be a helpful source of knowledge for present and future scholars interested in the SED concept.

The remainder of the paper is structured as follows. The next section provides a brief description of the methodological approach (an explanation of how the SLR was undertaken) and is followed by the research findings (both quantitative and qualitative). This is followed by a discussion (explaining what the contribution of the article to economic literature is and noting what the limitations of the research carried out are). The article ends with concluding remarks.

2. Materials and Methods

To reduce bias and add scientific value to its results, this study used a systematic approach to conduct a literature review. According to Uman (2011) [17], SLR looks at the findings of the earlier studies to identify consistent and repetitive themes. Originally used in the medical sciences in the 1970s to investigate the effectiveness of health-care interventions and, more broadly, to support the practice of evidence-based medicine [18], it has now spread to a wide range of disciplines including computer science (example of a study: [19]), engineering (example of a study: [20]), business, management and accounting (examples of studies: [21,22]), physics and astronomy (example of a study: [23]), mathematics (example of a study: [24]), and arts and humanities (example of a study: [25]).

SLR differs from traditional narrative reviews by "adopting a replicable, scientific and transparent process" [26] p. 209. Liberati et al. (2009) [27] (p. e19) pointed out the following features of an SLR:

- "a clearly stated set of objectives with pre-defined eligibility criteria for studies;
- an explicit, reproducible methodology;
- a systematic search that attempts to identify all studies that would meet the eligibility criteria; and

- systematic presentation and synthesis of the characteristics and findings of the included studies".

It is worth mentioning that a literature review can also be performed using meta-analysis. This is a collection of statistical methods that integrates the results of a large number of studies to provide an aggregate summary of knowledge in a research domain [28]. It is very important that the topic covered in the meta-analysis must be mature enough to allow researchers to include enough homogeneous empirical research in terms of subjects, interventions, and outcomes [29]. When there is not enough empirical research (as is the case of the SED), it might be better not to perform a meta-analytic review. The authors therefore decided to use SLR.

The research procedure used in this article was inspired by, among others, Reis et al. (2018) [30]; Pietrzak and Takala (2021) [31]; Corvo et al. (2022) [32]; and Bellucci et al. (2022) [33]. The authors also followed the protocol of Jesson et al. (2011) [34], which involves the following steps: (1) define a research question; (2) design a plan; (3) search for the literature; (4) apply exclusion and inclusion criteria; (5) conduct quantitative and qualitative research; and (6) discuss the results.

A SLR process is led by research questions that define the subject, object, and scope of the research [35]. Accordingly, the following research questions were identified:

RQ1. What is the academic state of the art of the research on the SED?
RQ2. What are the most important activities carried out within the SED?
RQ3. What are the future research directions related to the SED?

The data search was conducted on 31 August 2022, and the selected peer-reviewed database was Scopus. This repository was selected as the primary source of information to assure both scientific robustness and inclusivity. The authors started with the inclusion criteria by using the term "sustainable energy development" in the topic (title, abstract, or keywords). The "topic" category was chosen above the "text" category to limit the search results to publications that focused solely on investigating the SED rather than other areas of sustainable development.

As in other research that employed an SLR, the search for articles was conducted regardless of the time limitations; that was so in this paper as well, but it was limited to conference and journal papers. The chosen articles were required to be written entirely in English to prevent any misunderstandings. The exclusion process resulted in a total of 607 journal papers and conference papers from the Scopus database. On the basis of these articles, the authors have attempted to answer the three research questions (*RQ1*, *RQ2*, and *RQ3*) presented earlier. The results of the procedure used are shown in Table 1.

Table 1. SLR process.

Criteria	Filters	Number of Documents
Keyword	"Sustainable energy development"	Not applicable
Restriction	Topic (article title, abstract, keywords)	865
Document type	Journal and conference papers	633
Publication stage	Final	626
Language	English	607

Source: own study based on: [35].

3. Research Findings

3.1. Quantitative Approach

This part of the study will present results of a quantitative nature. Firstly, the authors will present the distribution of articles on the SED concept by year. Secondly, they will identify the most cited articles. Thirdly, they will identify the countries (and their research units) with the greatest contribution to the SED publication activity. Finally, they will

recognize the subject areas with which the analyzed articles correspond. Thus, the question will be answered: *What is the academic state of the art of the research on the SED? (RQ1)*

Articles and conference papers on the SED first appeared in the Scopus database in 1992. Undoubtedly, this was related to the United Nations Conference on Environment and Development (UNCED), organized in Rio de Janeiro in 1992, and the adoption of Agenda 21, containing an action plan addressed to states and international organizations. The Rio Declaration included, among others, the following determinants of sustainable development: environmental protection and its interdependence with economic development. Thus, the paradigm of sustainable development became the main motive of environmental policy and development policy (see Vinuales (2015) [36]). In the same year, two journal papers and one conference paper were published (Ebbin, Ghamarian (1992a) [37], Watkins (1992) [38], and Ebbin, Ghamarian (1992b) [39]. Until 2005, relatively few publications on the topic in question were published, while in 2006 there was a significant increase in the number of publications, initially exceeding 10, and in the following years, exceeding 20 and 30 items per year. In 2013, the European Commission published the green paper "Framework for climate and energy policy until 2030", which intensified discussions on sustainable energy development [40], and the signing of the global climate agreement at the Paris summit in December 2015 resulted in the appearance of many publications on the subject. In the Scopus database, the number of publications started to grow rapidly since 2015, reaching 80 in 2021. In the analyzed period, there were definitely more articles in scientific journals than published conference papers. As Figure 1. shows, on average, over the entire thirty-year period, more than three times more journal articles than conference papers were published.

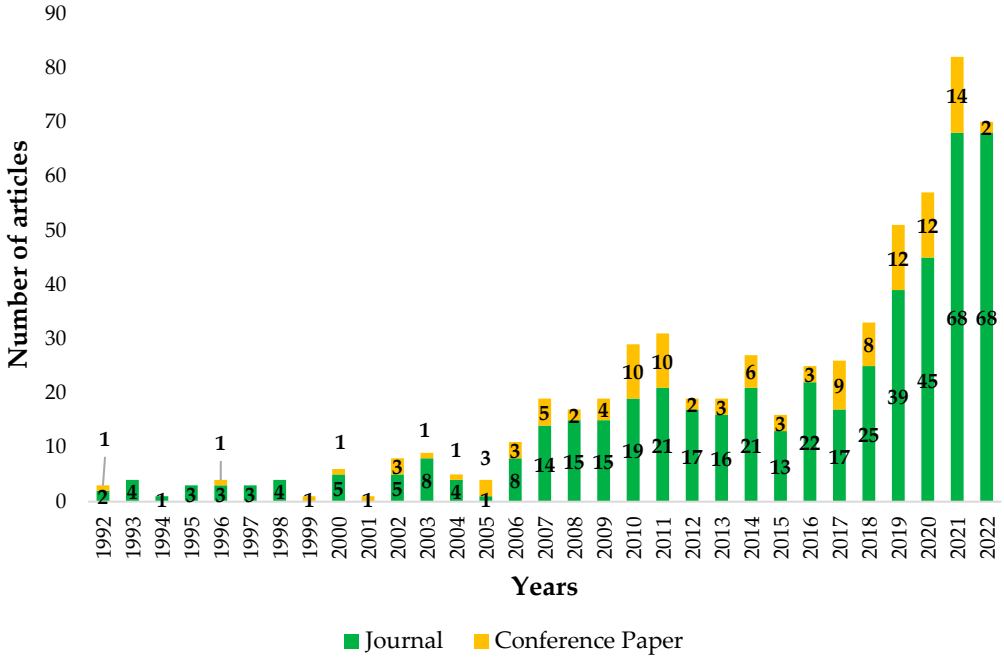

Figure 1. Distribution of articles by year. Source: own study based on: [35].

Table 2 presents the most frequently cited articles. The paper cited most often (1645 times) was a publication by Yabuuchi et al. (2017) [41] titled "P2-type $Na_x[Fe(1/2)Mn(1/2)]O_2$ made from earth-abundant elements for rechargeable Na batteries", which appeared in 2012 in "Nature Materials". The authors pointed out that rechargeable lithium batteries have risen to prominence as main devices for green development and the SED. Automobiles which are not equipped with an internal combustion engine have been launched in the market.

Table 2. Most frequently cited publications.

Citation Count	Publication Year	Authors	Document Title	*Source* (*Volume*, Pages)
1645	2012	Yabuuchi et al. [41]	"P2-type $Na_x[Fe(1/2)Mn(1/2)]O_2$ made from earth-abundant elements for rechargeable Na batteries"	*Nature Materials* (*11*(6), 512–517)
427	2009	Demirbas et al. [42]	"Potential contribution of biomass to the sustainable energy development"	*Energy Conversion and Management* (*50*(7), 1746–1760)
312	2015	Yabuuchi et al. [43]	"High-capacity electrode materials for rechargeable lithium batteries: Li_3NbO_4-based system with cation-disordered rocksalt structure"	*Proceedings of the National Academy of Sciences of the United States of America* (*112*(25), 7650–7655)
284	2007	Vera and Langlois [44]	"Energy indicators for sustainable development"	*Energy* (*32*(6), 875–882)
221	2007	Zhou et al. [45]	"A mathematical programming approach to constructing composite indicators"	*Ecological Economics* (*62*(2), 291–297)
210	2003	Meyer [46]	"European schemes for promoting renewables in liberalised markets"	*Energy Policy* (*31*(7), 665–676)
197	2008	Kajikawa et al. [47]	"Tracking emerging technologies in energy research: Toward a roadmap for sustainable energy"	*Technological Forecasting and Social Change* (*75*(6), 771–782)
196	2010	Al-Mansour and Zuwala [48]	"An evaluation of biomass co-firing in Europe"	*Biomass and Bioenergy* (*34*(5), 620–629)
191	2014	Gao et al. [49]	"Large scale production of biomass-derived n-doped porous carbon spheres for oxygen reduction and supercapacitors"	*Journal of Materials Chemistry A* (*2*(10), 3317–3324)
189	2011	Szabó et al. [50]	"Energy solutions in rural Africa: Mapping electrification costs of distributed solar and diesel generation versus grid extension"	*Environmental Research Letters* (*6*(3), 034002)

Source: own study based on: [35].

The next journal paper with the highest number of citations is titled "Potential contribution of biomass to the sustainable energy development" by Demirbas et al. (2009) [42]. This paper was published in "Energy Conversion and Management". The main aim of the study was to examine global potential and use of biomass energy and its contribution to the SED by presenting its historical evolution.

Significantly, the third most-cited article is also the one co-authored by Yabuuchi et al. (2015) [43]. This time it was published as a conference paper. The article, titled "High-capacity electrode materials for rechargeable lithium batteries: Li_3NbO_4-based system with cation-disordered rocksalt structure", was cited 312 times.

When one takes into consideration the criterion of the study regarding publication activity in the field of the SED by countries, the most indications concern China, which, as Figure 2 shows, constitutes 24% of the analyzed publications. The leading Chinese centers in this area are Chinese Academy of Sciences, Ministry of Education of China, Tsinghua University, University of Chinese Academy of Science, Nord China Electric Power University, and Wuhan University of Technology. The next country is the United States (more than 10% of publications). The main research centers dealing with the SED issues are University of Pennsylvania, University of Delaware, and United States Geological Survey. The leading countries are also Turkey, India, and Lithuania. Turkey achieved a result of 7% of publications. The leading centers in this country are Karadeniz Technical University and

Sakarya Üniversitesi. In India, a result of more 5% was achieved; the leading centers being Anna University and Indian Institute of Technology Bombay. Lithuania scored more than 5%, and the leading centers were Lithuanian Energy Institute and Vilniaus Universitetas. The sixth place was taken by Poland with approximately 5% of publications. The main research centers are Silesian University of Technology, AGH University of Science and Technology, Rzeszów University of Technology, and Cracow University of Economics. Other countries, such as Pakistan, Greece, and Brazil did not reach the level of 5%.

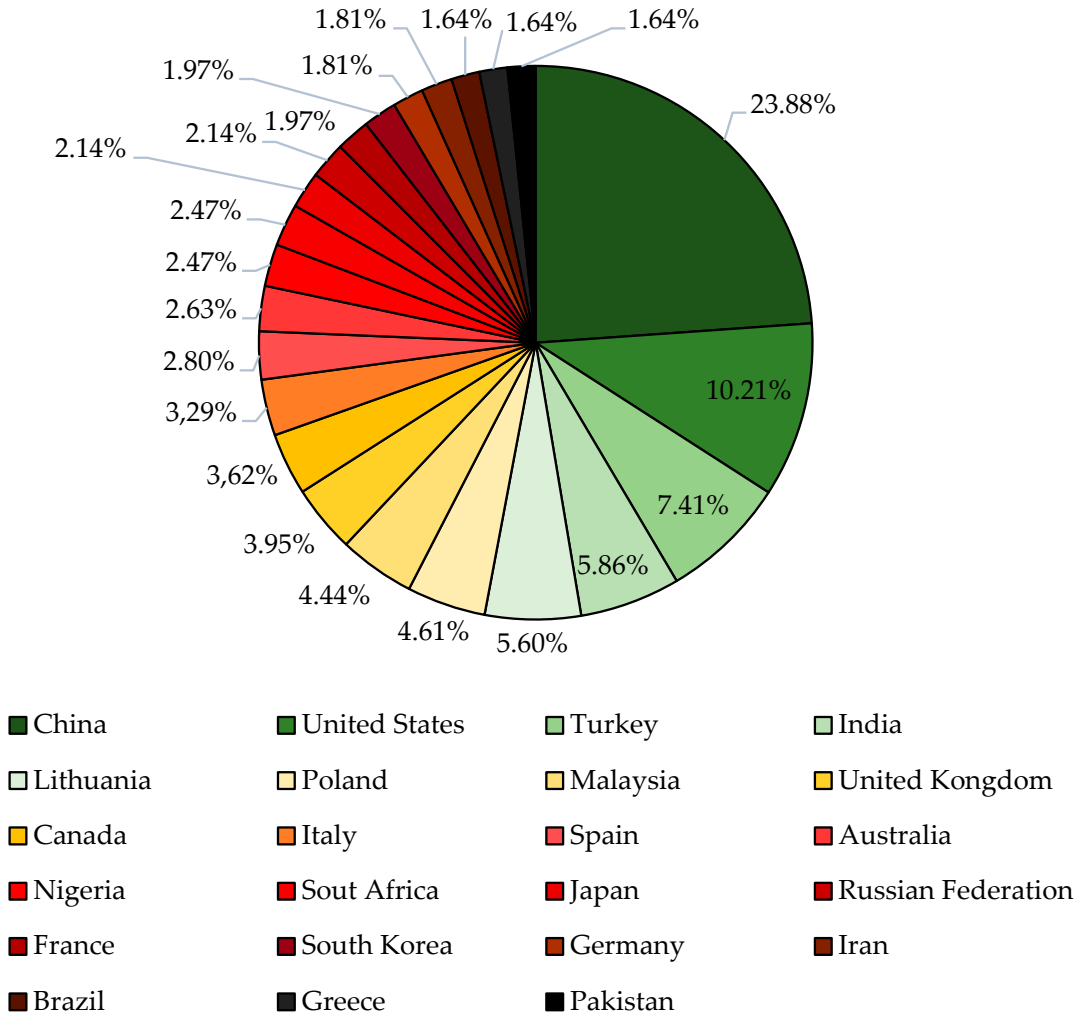

Figure 2. Share of articles per country (%). Source: own study based on: [33].

Another research criterion focuses on the research areas of the publication. The subject of the publications in the Scopus database was interdisciplinary, varied, and multi-threaded. As Figure 3 demonstrates, 22 research areas were distinguished in this criterion, including "Energy", "environmental sciences", "engineering", "earth sciences", "social sciences", "economics and finance", and "agricultural and biological sciences". There are cases where a single article represents different areas of research; therefore, the total number of publications does not add up to 607. An example of such a publication is an article by Li et al. (2022) [51], assigned to areas such as "energy", "environmental science", and "engineering". The largest share, accounting for almost 30%, was related to the subject of "energy". From the analyzed publications, we see that as many as 360 articles were assigned to this research area. This means that this subject is an important research element and is continually being developed in various research circles and published in various periodicals. Another research area concerned "environmental sciences"—its share was approximately 17% (132 publications)—and "engineering", which accounted for less than

15% of the total volume of publications (185 publications). The quite small number and percent of publications in the field of "medicine" [52]—0.3%, "psychology" [53]—0.2%, "immunology" [54]—0.1%, "neuroscience" [55]—0.1%, and "pharmacology" [56]—0.1% was quite surprising. In Figure 3., they were classified as "Others".

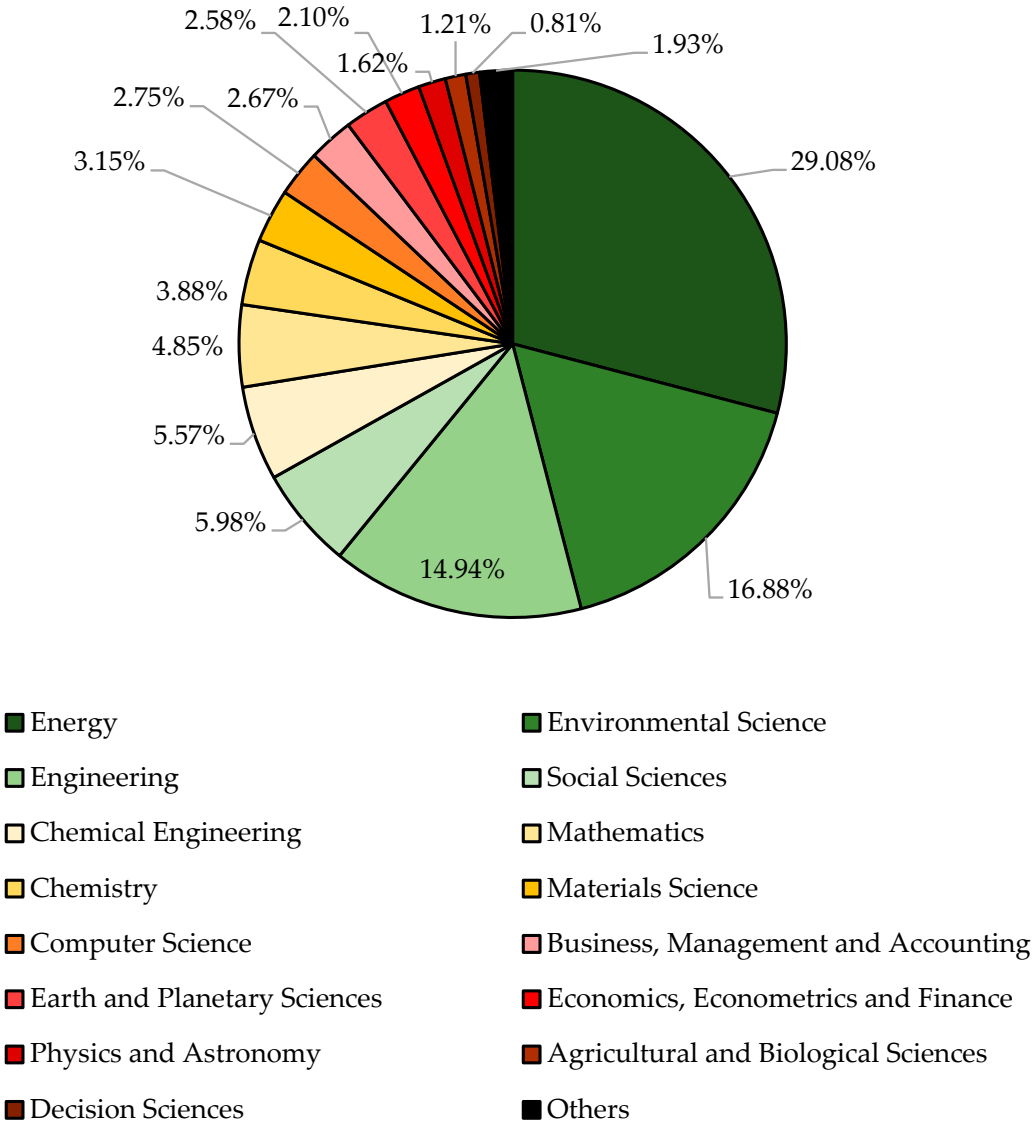

Figure 3. Share of articles per subject area (%). Source: own study based on: [33].

3.2. Qualitative Approach

In this section of the study, results of a qualitative nature will be demonstrated. The authors will present selected definitions of the SED (including their own) and identify the most important activities carried out under the SED concept. Thus, a response will be given to *RQ2*.

3.2.1. Definitions of the SED

Many authors (e.g., Afgan et al. (1998) [2]; Saha (2003) [56]; and Balat (2007) [57]) attempted to discuss the exact notion of the SED. Table 3. below presents a selection of the SED definitions. It is worth noting that the authors tracked all the publications included in the analysis. The definitions presented in Table 3 were the only ones found therein. Some authors refered to definitions presented in reports that were not the subject of this SLR. Despite their efforts, though, the term "SED" still does not have one unified definition.

Moreover, the meaning of the SED can vary depending on the context to which it is applied and the research objects. This argument emphasizes the need to define "SED". Therefore, the authors of this article hope that the systematic literature review will make a valuable contribution to the development of this field of theory.

Table 3. Definitions of the SED (Note the definitions are presented in chronological order).

Authors (Year of Publication)	Definition	Citation Count
Afgan et al. (1998) [2] p. 235	"Seven major areas are listed with specific problems and their relevance to the SED: energy resources and development; efficiency assessment; clean air technologies; information technologies; new and renewable energy resources; environment capacity; mitigation of nuclear power threat to the environment".	110
Saha (2003) [56] p. 1055	"The mission to address the issues for SED is to enhance the capacity of concerned stakeholders in developing sustainable development strategies under which energy services can be expanded and improved with a minimum compromise on environmental quality. Due weight must be given in focusing on poverty alleviation, equity and social justice".	18
Balat (2007) [57] p. 2	"Renewable energies are considered as an essential element of any strategy for SED. The poor in the developing world without access to modern energies are regarded as a major market for renewable energies".	10
Hurtado and Hunte (2007) [58] p. 266	"SED is satisfying the energy needs of the present generation without compromising future generations in satisfying these same needs. It encompasses three areas: economy, environment and society. Producing energy in a sustainable manner can be accomplished through energy efficiency and renewable sources of energy, among others".	8
Grigoroudis et al. (2013) [59] p. 205	"A vital part of sustainable development is the provision of adequate, reliable, and affordable energy, in conformity with social and environmental requirements".	8
Streimikiene et al. (2016) [60] (pp. 31–32)	"SED can be assessed by analyzing the decoupling of GDP (*Gross Domestic Product*) from energy consumption and the decoupling of energy consumption from atmospheric pollution, including GHG (*Greenhouse Gas*) emission".	26
Tiep et al. (2021) [61] p. 173	"SED is an energy system that serves the needs of the present without harming the needs of future generations. The major sources of SED are renewable such as hydroelectricity, solar energy, wind energy, wave energy, geothermal energy, bioenergy, tidal energy".	0
Ligus & Peternek [62] p. 1117	"SED has come to mean the harnessing of those energy sources that meet three requirements: (1) they are not significantly depleted by continued use; (2) they do not entail the emission of pollutants or other hazards to human or ecological and climate systems on a significant scale; and (3) they do not involve the perpetuation of significant social injustices".	12
Brodny & Tutak (2022) [63] p. 149745	"SED can be understood as socio-economic development due to energy services provided at affordable prices in a safe and environmentally friendly manner".	12
Chen et al. (2022) [11] p. 5761	"SED is a complex and multidimensional concept. It can be divided into four interrelated themes: sustainable energy supply, sustainable energy consumption, access to affordable modern energy services, and energy security".	0

Source: own study based on: [35].

It is worth noting that the definitions presented were taken only from articles meeting the criteria imposed by the authors and which are found in the Scopus database. Thus, definitions from books or chapters in monographs or reports that may seem relevant to some have been omitted. It seems that the Scopus repository did not contain papers of a theoretical nature that would explain the complexity of the SED. Therefore, on the basis of existing definitions, which are incomplete in the authors' view, they have proposed their own. Namely, the SED is a concept that is one of the pillars of sustainable development. It entails guaranteeing universal and inexpensive (affordable) access to energy, in an environmentally sound manner and in conformity with social and economic development

needs. Activities that serve to implement the SED can include increasing the use of alternative, including renewable, energy sources in the energy mix; enhancing energy efficiency; and reducing emissions of greenhouse gases and air pollutants. A graphical interpretation of this concept is shown in Figure 4.

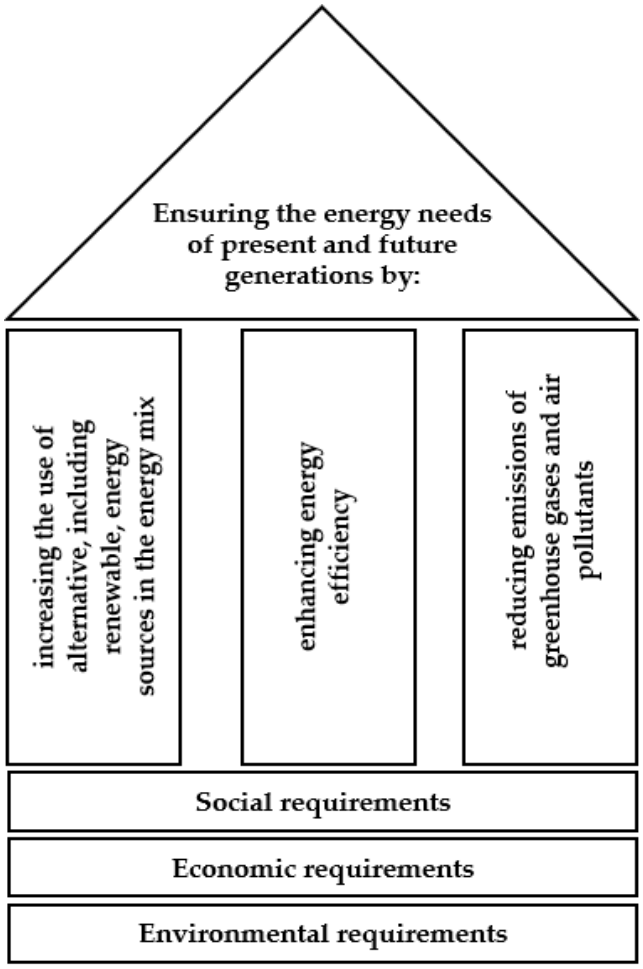

Figure 4. Graphical interpretation of the SED concept. Source: own study.

3.2.2. Use of Renewable Energy Sources in the Energy Mix

The first of the pillars of the SED is to increase the share of renewable energy sources in the energy balance. These include:

- wind energy,
- solar radiation energy,
- geothermal energy,
- hydrothermal energy,
- hydropower,
- the energy of waves, currents, and tides,
- energy obtained from biomass, biogas, agricultural biogas, and bioliquids.

Several studies, for example, Knez et al. (2022) [64]; Tamoor et al. (2022) [65]; Wang et al. (2021) [66]; and Elkadeem et al. (2022) [67] were conducted on the use of solar and wind. There also exists a considerable body of literature on biomass consumption, including Wu et al. (2022) [68]; Majchrzak et al. (2022) [69]; and Zhang et al. (2021) [70]. A number of researchers (Sari and Suwarto, Suminah, Purnomo (2022) [71]; and Wang et al. (2021) [72]) discussed the topic of the use of biogas. Finally, an interesting approach to the use of renewable energy sources in terms of hydropower was presented by Li et al. (2021) [73]; and Almeida et al. (2021) [74], among others.

It should be stressed here that EU standards require serious steps to be taken to adopt changes towards the use of RES technologies. This is due to the fact that the potential benefits of their use (presented in Table 4) are significant both for the society and the natural environment.

Table 4. Social and environmental benefits of renewable energy sources.

Type of Benefits	Examples
Social	• improvement of social welfare and, at the same time; • participation of residents in public life; • maintaining local traditions; • knowledge creation and transfer; • stimulating economic, financial, and legislative support mechanisms for actions for renewable energy in the region and creating incentive systems for energy prosumers; • ensuring equal access to renewable energy technologies as well as their products from the poly-generation energy portfolio.
Environmental	• reduction of pollution of the lithosphere, hydrosphere, and aerosphere; • the ability of self-regeneration of the regional natural environment; • regional determination of the absorptive capacity of the environment and the state of its resources (in quantitative and qualitative terms); • introduction of a reliable, comprehensive environmental assessment; • the ability to manage protected areas without harming the lives of their inhabitants

Source: own study based on: [75].

3.2.3. Improvement of Energy Efficiency

Another pillar of the SED is the promotion of measures that contribute to improving the energy efficiency of countries. In the 1970s and early 1980s, energy efficiency became the main problem of the SED. Even after the 1986 oil shock and the fall in oil prices, environmental concerns continued to increase, especially in the context of the mounting debates on global warming and climate change, which brought a new perspective to energy efficiency improvements. The latter, combined with soaring oil prices in the 2000s, brought energy efficiency to the political agenda of many countries as a top priority issue [76]. As Streimikienea and Šivickasb (2008) [77] indicated, the promotion of energy efficiency improvement along with the use of renewable energy sources became the priorities of energy policy in many industrialized countries around the world, especially in the EU countries.

Today, improving energy efficiency has become both an option and an opportunity for cities and investors, as it helps promote the competitiveness of energy systems and mitigate climate challenges. With the increasing number of political and economic threats that have occurred around the world over the past few years, uncertainty factors have increased sharply. Countries must, therefore, adapt their policies to the constantly changing external environment. As a result, economic policy uncertainty (hereafter referred to as EPU) is a topic of great concern at the moment. Not only can the EPU shock a country's economic activity and affect the energy supply and demand chain, it can also affect energy companies' investment, technological development, and energy consumption by individuals in their everyday standard activities [78].

Energy efficiency is becoming an increasingly important aspect of sustainable development that governments around the world are beginning to recognize and take into account in the planning of activities [79]. The broadly understood term *energy efficiency* is associated with the rational use of energy resources [80]. Recently, however, the meaning of this term has significantly expanded and, as indicated by Remeikiene et al. (2021) [81], in addition to the purely economic aspect of energy use, i.e., the aspect of saving resources, this concept has also started to encompass the issues of inefficient and sometimes even irrational energy consumption, which is harmful to both consumers and the environment. Energy efficiency

is a key factor in ensuring energy security and sustainable development and is strongly related to the economic development of countries [82].

Increasing energy efficiency can be achieved through the use of sustainable and interconnected energy sources. Combined heat and power CHP systems produce electricity and heat in a more energy-efficient manner compared with systems with separate production of electricity and heat. In order to improve the processes in the developed cogeneration systems, the contribution of nuclear energy is increasing, especially, as Serra et al. noticed (2009) [83] that which is obtained from small modular reactors. The use of polygeneration systems, i.e., the simultaneous, combined production of several types of energy in power stations, can also be considered a suitable alternative for achieving energy and environmental goals. Rong and Yan (2017) [84], however, indicated that polygeneration systems are increasingly used in buildings where the production of electricity, heat, and cold is combined. According to Kasaeian et al. (2020) [85], renewable energy technologies play the key role among such polygeneration systems in residential buildings.

3.2.4. Reduction of Greenhouse Gas Emissions and Air Pollutants

Most studies related to the reduction of greenhouse gases and air pollution focus on the following issues: (1) introducing innovations in the field of energy; (2) reducing CO_2 emissions from transport; (3) introducing pollution levies or taxes; (4) emissions trading; and (5) improving natural CO_2 sinks in agriculture and forestry through appropriate land use and the use of soil, plants, biomass, and wood.

Introducing innovations in the field of energy is one of the research problems discussed in many studies [86–89]. The analyses focused on the issues of reducing greenhouse gas emissions in EU countries resulting from the adopted climate and energy packages [90], where it was indicated that this is a great challenge and the goals are ambitious. Their achievement will be a great challenge for the EU countries. Reducing greenhouse gas emissions by increasing the use of renewable energy sources and improving energy efficiency will take place in various ways. Countries should introduce new concepts to facilitate the transition to sustainable energy systems [90].

Studies in this field also focused on examining the relationship between innovation and CO_2 emissions. Research by Wang and Zhu (2020) [88] on the case of China showed that innovations in renewable technologies facilitate the reduction of CO_2 emissions and are transregional in nature. Another aspect discussed in the literature is the role of transport and its innovation [86,87]. The advancement of economies towards digital technologies and the implementation of innovative solutions can significantly change the way people and goods are transported. The digital technologies used will have an impact on the demand for transport, the associated energy consumption, and the impact on the environment. This type of research was presented in the study by Noussana and Tagliapietra (2022) [87]. They showed that mismanaged investment policy may lead to opposite effects, both in terms of energy consumption and pollutant emissions. The conclusions showed that in order to fully reap the benefits of digitization, appropriate policies are needed to support the efficient and effective implementation of available technologies through optimized and shared use of alternative transport options [87]. The implementation of innovative energy technologies in road transport was discussed in the studies by, among others, Kraciuk et al. (2022) [86]. Their research showed that the introduction of innovative energy technologies in road transport, for example, battery electric vehicles (BEV), various hybrid vehicles, or autonomous vehicles are the most advantageous option from the point of view of mitigating the negative externalities generated by road transport. However, in the EU countries, these processes take place unevenly, and Sweden, the Netherlands, and Finland are the leaders in this respect [86].

One of the methods of reducing the negative effects of external environmental pollution described in the literature is the use of environmental taxes. Streimikiene et al. (2018) [91], in their research, indicated that in the EU countries, these taxes are the most important economic tool for mitigating the impact of various types of economic activity on

the environment. The purpose of their use is to create incentives to reduce the consumption of fossil fuels and to switch to renewable energy sources or the use of fuels with a lower carbon content, which would consequently result in decreasing pollution. In European countries (Denmark, France, Great Britain, Germany, and Ireland), socio-political responses to environmental tax reform (ETR) were studied. As indicated by Dresner et al. (2006) [92], the ecological tax reform was widely regarded as a desirable policy, but its implementation was limited by problems with political acceptance, including problems with awareness, trust, understanding of the goal, levels of taxation, etc. The research of Klok et al. (2006) [93] showed that the advantages and disadvantages of taxation should be presented publicly so that it is accepted by entrepreneurs and the general public. In addition, analyses conducted by Streimikiene et al. (2018) [91] showed that increasing the share of environmental taxes in GDP had a positive impact on the goals of sustainable energy development.

These taxes affect the penetration of renewable energy sources, changes in energy intensity, changes in GHG emission factors, etc. Ecological tax systems also provide incentives to implement new advanced technologies, improve products and production processes in the energy combustion sector, and increase competitiveness, environmental sustainability, and security of energy supply, and this translates into limiting air pollution, mitigating climate change, and improving the quality of life and health of humans and animals [91]. A new area of research was the impact of environmental taxes on transfers of the ecological footprint between countries [94,95]. Sun et al. (2020) [94] indicated that those countries that show an ecological deficit are in an unfavorable position, as they are forced to accelerate the consumption of their energy resources. The empirical research of Rafique et al. (2022) [95] showed that in OECD countries, economic growth increases the ecological footprint and environmental taxes reduce it.

An important tool used to reduce greenhouse gases is the EU Emissions Trading System (EU ETS). This issue was discussed by many researchers [96–98]. For example, Ciesielska-Maciągowska et al. (2021) [96] identified the challenges related to emissions trading in Poland and Central and Eastern Europe, indicating three key issues: (1) pricing models, (2) the human factor (specialized traders), and (3) flexible and intelligent organizational structure in the appropriate location (Geneva, London, and Amsterdam).

4. Discussion

This section of the paper will outline the limitations of the study conducted, identify future research directions, and present the paper's contribution to the development of the SED theory. Thus, a response will be given to *RQ3*.

4.1. Limitations

It should be noted that despite the extensive literature review based on quantitative and qualitative analysis, this study has several limitations. Firstly, a systematic review of the literature was performed on the Scopus repository, while other databases, such as Google Scholar, Web of Science—Institute for Scientific Information (ISI), were omitted, which limited the number of publications in this field. Another limitation was the search term "sustainable energy development". This affected the selection of the articles to be included in the research. This means that many valuable publications—such as Bigerna et al. (2020) [99] and Bigerna et al. (2022) [100], which undertook, for example, the issue of energy efficiency—could not be the subject of this analysis due to the absence of the phrase "SED" in the title, abstract, or keywords. Another limitation was the selection of completed journal articles and conference materials for analysis, excluding books, chapters in monographs, and reports. Finally, only works in English were included in the study, and all other publications in national languages, e.g., Chinese, Polish, or French, were excluded.

4.2. Future Research Directions

Based on the presented limitations, the authors suggest the following future research directions:

- inclusion in the analysis of other repository databases (Web of Science, Google Scholar) and inclusion of other types of publications, including reviews, monographic chapters, and books;
- inclusion in the systematic literature review of publications prepared in national languages other than English, i.e., Chinese or Polish;
- conducting a systematic literature review for other terms, such as "renewable energy sources", "energy efficiency", or "energy innovation";
- recognizing the dependencies between political and legal, economic, social, technological, and environmental factors and the SED as well as investigating how SED affects the level of safety and social well-being. Thus, the authors propose empirical verification of the conceptual model developed by them (see Figure 5).

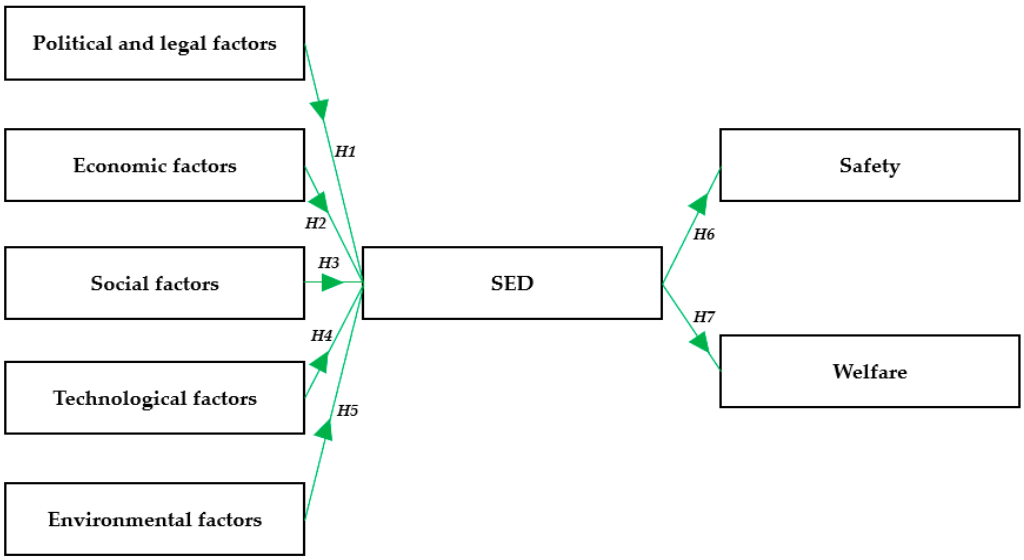

Figure 5. Graphical interpretation of the SED concept (Note that the return of the arrow indicates the direction of the "potential" relationship, while the green colour of the arrow indicates that the relationship will be positive). Source: own study.

The basis for the construction of the above model was the research of other authors (including Tutak et al., 2020 [3]). The development of the SED is closely related to economic development and the environment. In turn, the degree of involvement in the implementation of the SED may affect the level of security (including energy security), as well as social welfare. Thus, the authors propose to verify the following research hypotheses in future research:

Hypothesis 1 (H1). *Political and legal factors have a positive influence on the development of the SED.*

Hypothesis 2 (H2). *Economic factors have a positive influence on the development of SED.*

Hypothesis 3 (H3). *Social factors have a positive influence on the development of SED.*

Hypothesis 4 (H4). *Technological factors have a positive influence on the development of SED.*

Hypothesis 5 (H5). *Environmental factors have a positive influence on the development of SED.*

Hypothesis 6 (H6). *The SED has a positive effect have a positive influence on safety.*

Hypothesis 7 (H7). *The SED has a positive effect on social welfare.*

4.3. Contributions

The study that was carried out filled a knowledge gap in several dimensions. Firstly, a systematic literature review was undertaken, based on which the following research tasks were accomplished: (1) presentation of the distribution of articles by year (both journal papers and conference papers) on the SED concept; (2) identification of the most frequently cited articles on the SED concept; (3) identification of the countries that have contributed most to the development of the SED concept through publication activities; and (4) demonstration of the subject areas most frequently associated with the SED concept. Thus, the first research questions (*RQ1*) has been answered: *What is the academic state of the art of the research on the SED?* Secondly, a selection of the SED definitions was presented, which served as a basis for the development of the authors' own concept of the SED. It identifies three key activities whose fulfilment is crucial for the implementation of the SED: (1) increasing the use of alternative, including renewable, energy sources in the energy mix, (2) enhancing energy efficiency, and (3) reducing emissions of greenhouse gases and air pollutants. The second research question (*RQ2*) has, therefore, been answered: *What are the most important activities carried out within the SED?* Thirdly, future directions for SED research were proposed and the authors' conceptual model was developed. Its validation will be carried out by the authors in subsequent research projects. Hence, it was possible to find an answer to the third research question (*RQ3*): *What are the future research trends related to the SED?*

In conclusion, this paper, in the opinion of the authors, answered all the research questions set and fulfilled the main aim and objectives of the research.

5. Conclusions

On the basis of a systematic review of the literature: (1) the publication frequency and the prevailing types of publications in the field of the SED in the years 1992–2022 were analyzed; (2) the most-cited publications on the SED issues were recognized; (3) the countries that contributed most to the development of the SED concept were identified; and (4) the research areas within which the problem of the SED was discussed were defined.

The main conclusion of the study is that there is a lack of a generally accepted definition of the SED. Therefore, the authors have prepared their own definition of the SED. In their opinion, "the SED is a concept that is one of the pillars of sustainable development. It entails guaranteeing universal and inexpensive (affordable) access to energy, in an environmentally sound manner and in conformity with social and economic development needs. Activities that serve to implement the SED can include increasing the use of alternative, including renewable, energy sources in the energy mix; enhancing energy efficiency; and reducing emissions of greenhouse gases and air pollutants".

Moreover, according to the authors, many publications in the field of the SED were omitted in their quantitative and qualitative analysis. This is a consequence of the fact that the publishers, despite the fact that they raised issues closely related to the concept of the SED, did not include that term in the title, abstract, or keywords. This means that in the future, they should show greater care for the design of these elements and, thus, for the SED proposal in their studies.

The concept of the SED is very important, up-to-date, and requires further analysis and consideration. Therefore, the authors propose to validate the conceptual model presented in the article. Thanks to this, it will be possible to answer questions concerning the types of factors that have positive influence on the implementation of the SED concept as well as the types of impact that the SED has on security and social welfare.

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