The Profile of Studies on Renewable Energy in Sustainable Supply Chain

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Abstract. Over the years, has been growing policies aiming to reduce the greenhouses gases emissions – GHG, which lead for the searching of sustainable alternative solutions. One way mitigates the GHG emissions is the use of renewable energy sources. Nevertheless, for the use of such resources there are a series of processes inherent to the energy production and consumption, being the supply chain one of the principals. Based on this, the main objective of present article is to map the role of renewable energies inside the context of sustainable supply chain, observing how the studies have been developed, looking for the main researchers, organizations and collaboration networks, being at final a mapping of the 15 most cited studies in area. The research was carried out with the papers published at Web of Science database, using VantagePoint software to quantify the information's, including the evolution of studies over time until 2019. It was possible to perceive that the research has been growing since 2010, moreover, subjects related to biomass, biofuels and photovoltaic energy were the most recurrent at the most cited. However, within this framework, the theme presented itself as new and that there are still great potentials to be explored.

Keywords: Renewable energies, supply chain, sustainable.

1 Introduction

Nowadays, the concern about the global warming and carbon emission is increasing more over [1], [2]. It is scientific knowledge that the global warming is caused by GHG emissions, mainly for carbon dioxide (CO_2), which is also generated by fossil fuel combustion processes [3]–[5]. According to Fang et al [6], the industrial sector contributes

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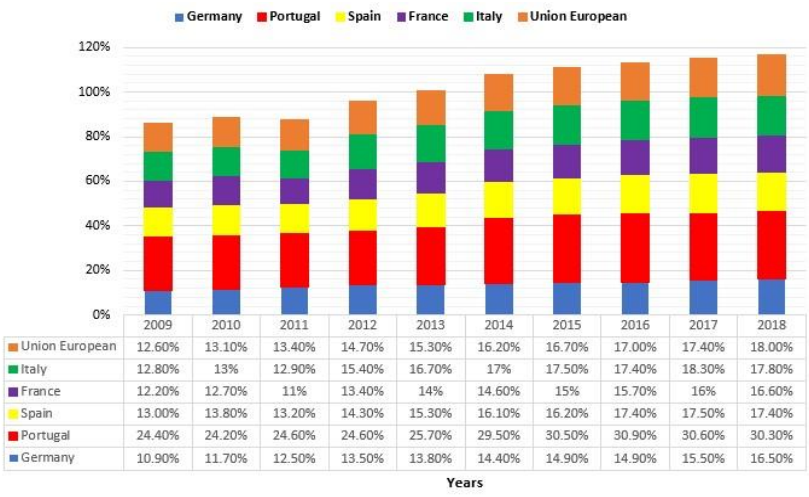
with one-half of the global energy consumption. Within this context, the supply chain it is a process that involves different layers (from raw material, to manufacturing and delivering the products for clients – sometimes, even the recycling and disposal) and process (as manufacturing, transportation, storage and so on) that are intensive in energy consumption.

Therefore, one of the solutions that has been studied and implement over the years is the use of renewable energies [7], [8], that covers a wide use of different resources, such as, photovoltaic energy [9], hydrogen [10], wind energy [11], biogas for cogeneration [12] and many others [13]–[15].

According to Eurostat data (September of 2020) [16] in Fig. 1, the energy balance of renewable sources has increased by almost 6% in all European Union in the last 10 years, highlighting Portugal as one of main growing countries from renewable sources. Another important fact to highlight, is the growth of renewable energies in emerging countries, such as Brazil, with according to data from the Ministry of Mines and Energy [17], renewable energy sources, which include hydro, wind, solar and bioenergy, reached 46.1% of participation in the 2019 total energy demand matrix, increasing 0.6 percentage point in relation to the 2018 indicator.



	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Union European	12.60%	13.10%	13.40%	14.70%	15.30%	16.20%	16.70%	17.00%	17.40%	18.00%
Italy	12.80%	13%	12.90%	15.40%	16.70%	17%	17.50%	17.40%	18.30%	17.80%
France	12.20%	12.70%	11%	13.40%	14%	14.60%	15%	15.70%	16%	16.60%
Spain	13.00%	13.80%	13.20%	14.30%	15.30%	16.10%	16.20%	17.40%	17.50%	17.40%
Portugal	24.40%	24.20%	24.60%	24.60%	25.70%	29.50%	30.50%	30.90%	30.60%	30.30%
Germany	10.90%	11.70%	12.50%	13.50%	13.80%	14.40%	14.90%	14.90%	15.50%	16.50%

Fig. 1. Energy balance from renewable sources for European Union and other countries (2020) (Source: Eurostat adapted by the authors [16]).

Furthermore, an increasing the consumption of renewable energy can also decrease the dependence on fossil energy sources, promoting a sustainable development [18], [19]. However, for sustainable development it is necessary attend to social and environmental scenario, where in most of the time they are not even take account [20].

Still within the concept of sustainable development, an area that has grown up the studies is the design of sustainable supply chains. In general, the design of supply chains

ISBN 978-9930-541-79-1

is crucial to integrate several flows of raw materials, goods, and products at the end of their useful lives, that are some relevance for industrial processes [21].

As global demand has accrete dramatically (according to data from Energy Information, 30% of energy consumption will increase between 2020 and 2050) [22], the business sector has focused much of the efforts with the economic aspect, often leaving aside social and environmental aspects [23].

It is important to emphasize that quantifying these aspects is not always easy, bringing greater complexities in the development of mathematical models that support decision making regarding the design of supply chains [24]. In this sense, some authors point out that the incorporation of environmental and social aspects is a challenge in the area for the next years [25], [26], making it possible to visualize the recent efforts of researchers that have brought these dimensions for the literature [27]–[29].

With this, researchers observed that improvements can be achieved by two different ways: advanced programming research and operational strategies [30]. Based on this, this article aims to understand the role of renewable energy within the context of sustainable supply chain, performing the following questions, (i) Who are the main researchers in the field? (ii) How countries and institutions have worked to promote these studies? and (iii) How have studies grown in area and what are the most relevant thematic areas in this subject? Raising these questions, the next sections will discuss the methodological procedures to answer that, as well the results and discussion followed by conclusion.

2 Methodological Procedures

The methodological procedures used in this study involves a qualitative analysis of the literature and, the use of statistical techniques. Through a datamining process, the articles were obtained from the Web of Science (Wos) database, due to its scope and coverage [31]. Table 1 shows the parameters of search performed.

Table 1. Description of search in the Web of Science database

Criterion	Description
Topic 1	TS1 = (“SUPPLY CHAIN*” OR “SUPPLY NETWORK*”)
Topic 2	TS2 = (“SUSTAINAB*”)
Combination	TS3 = (“TS1” AND “TS2”)
Data base	Web of Science
Refinement	Only Articles
Data	March 20, 2020 - 16:20 GMT-3

In a first time, the study had not included any keyword related to renewable energy sources, since decided to gather all the papers published about the subject and then, select for a frame of analysis. By doing that, the associated error was reduced with the

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elimination of papers that could be related to the theme but does not use a specific keyword as the indexation terms.

Therefore, with the results from the search performed accordingly Table 1, was selected those papers that had keywords related to any kind of renewable energy. In Table 2 are listed the main categories used to select those papers. It is important to point that were found 260 keywords related to renewable energy.

Table 2. Categories and some keywords used for cutout in Wos database

Category	Keywords
Energy	Energy Renewable Energy Energy Efficiency Energy Consumption Exergy Sustainable Energy Electricity
Renewable Energy	Wind Energy Solar Energy Wind and Solar Power Solar Photovoltaic Off-Grid Solar Thermal Energy
Bioenergy	Biomass Bioenergy Biofuel Palm Oil Biogas Ethanol Forest Biomass Woody Biomass
Supply Chain	Biomass Supply Chain Bioethanol Supply Chain Hydrogen Supply Chain Biorefinery Supply Chain Thermal Coal Supply Chain
Systems	Biocatalysis C-Si Photovoltaic Panel Hybrid Generation Heat Recovery Hydrogen System
Others	Biomethane Cellulosic Biofuels

Another way to visualize the quantification of words is by the graph illustrate in Fig. 2, where is possible to view the frequency of each category of words referring to

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renewable energies, in which the largest amount is represented by biomass followed by biofuel, ethanol, solar, photovoltaic and hydrogen.

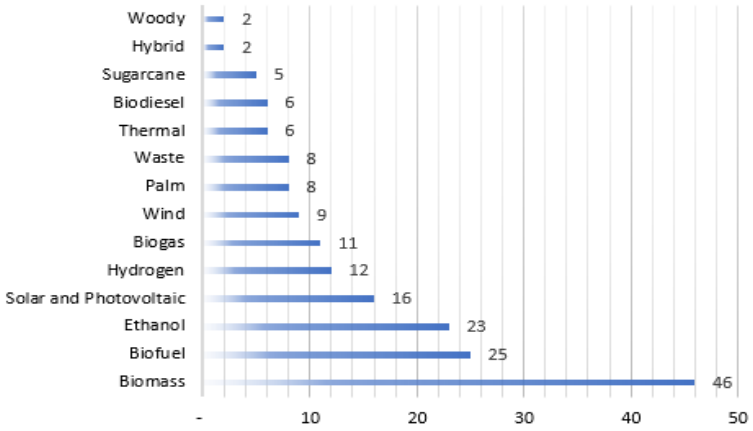

Fig. 2. Most recurrent words of 260 for clipping inside the Wos database from Table 1 (Source: The authors)

After this step of segregating words related to renewable energies, the study was carried out from VantagePoint, in which the main results and discussions will be presented in the next section.

3 Results and discussion

As discussed in the methodological procedures, the first step was to perform the search according to the criteria presented in Table 1. Where in all time (1900-2019), 9558 studies were found, being 6984 indexed scientific articles (Table 3).

Based on these results, the database for this study was created, focusing on the 6984 indexed journals. Therewith, the next step is understanding the role of renewable energies within this context. For this, the keywords that involved areas and categories related to renewable energy sources were cutout according to the search criteria established by Table 2, In which a total of 547 studies were found.

The first result analyzed was how the studies that relate renewable energy in sustainable supply chain have been developed over the years (Fig 3). In Fig. 3 the green line shows the records in function of the years and the blue one is the tendency line. Fig. 3 shows that the interest in this subject is recent (first paper published in 2002), with an accentuated growth from 2010.

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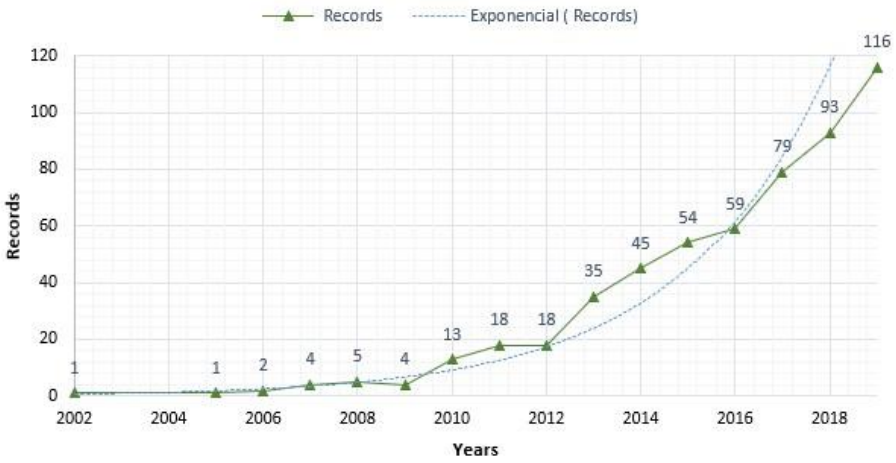

Fig. 3. Evolution of sustainable supply chain and renewable energies records in function of years (Source: VantagePoint and the authors)

The second analysis sought to understand the collaboration network among the main authors. A total of 1777 authors were found, which the 10 largest authors in the database were (records) respectively; You, FQ (12), Bezzo, F (7), Faaij, APC (7), Junginger, M (7), Ponce-Ortega, JM (7), Zhang, J (7), Cucchiella, F (6), D'Adamo, I (6), Lam, HL (6) and Osmani, A (6). The collaboration network is presented by Fig. 4, in which it is possible to observe, at least, 10 contribution networks composed by 3 authors or more.

To clarify the visualization of the main authors that publish about sustainable supply chain and renewable energy, Table 3 lists 28 authors with at least 4 publications. Where can be seen some collaboration network, among the main authors, You, FQ is between two networks, being made up of Yue, Dj and Ponce-Ortega, JM, besides this, it stands out Cucchiella and D'Adamo working together, Lam, Zhang, Y and Khan, SAR, among other authors with great importance in the area.

The next analysis carried out was to understand the main organizations and institutions that have published most in the thematic area of this article. The main results led to: Imperial College of Science, Technology and Medicine (with 16 records), University of Padua (14), Iran University Science and Technology (12), University of Utrecht (11), Wageningen University (11), University of Groningen (10), Northwestern University (9), Oak Ridge National Laboratory (9), University of California (9), University of Manchester (9).

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Table 3. The 28 more recurrent authors with most records in database for sustainable supply chain and renewable energy (Source: The authors)

Position	Author	Records
1º	You, FQ	12
2º	Bezzo, F	7
	Faaij, APC	7
	Junginger, M	7
	Ponce-Ortega, JM	7
	Zhang, J	7
3º	Cucchiella, F	6
	D'Adamo, I	6
	Lam, HL	6
	Osmani, A	6
4º	Azapagic, A	5
	Dale, VH	5
	Hilliard, MR	5
	Khan, SAR	5
	Pishvaee, MS	5
	Santibanez-Aguilar, JE	5
	Sarkar, B	5
	Shah, N	5
5º	Efroymson, RA	4
	Elkamel, A	4
	Garcia, DJ	4
	Gonela, V	4
	Guillen-Gosalbez, G	4
	Jaber, MY	4
	Jeswani, HK	4
	Murphy, RJ	4
	Yue, DJ	4
	Zhang, Y	4

The main Brazilian institutions that appear in the database are Federal Fluminense University – UFF (4), Federal University of Rio de Janeiro – UFRJ (3), São Paulo University – USP (3) and Federal Technological University of Paraná – UTFPR (2).

Regarding the countries that published the most about the subject, we highlight the top 10:USA (with 145 records), UK (67), Italy (63), Netherlands (45), Germany (34), China (30), Australia (26), Canada (25), Brazil (24) and Malaysia (24). Fig. 5 shows the map of countries with different colors for the number of publications.

It is also important to note that, it is well known that some countries on the African continent, the Middle East, and a small number of countries in Latin America have not contributed to the research area. However, it is a topic that been studied widely in a global scale.

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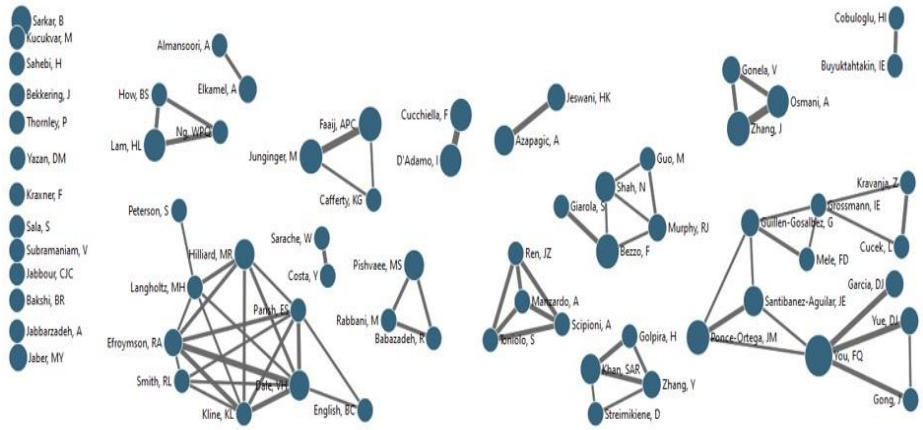

Fig. 4. Collaboration networks and micro-networks between the various authors found in the database (Source: VantagePoint and the authors).

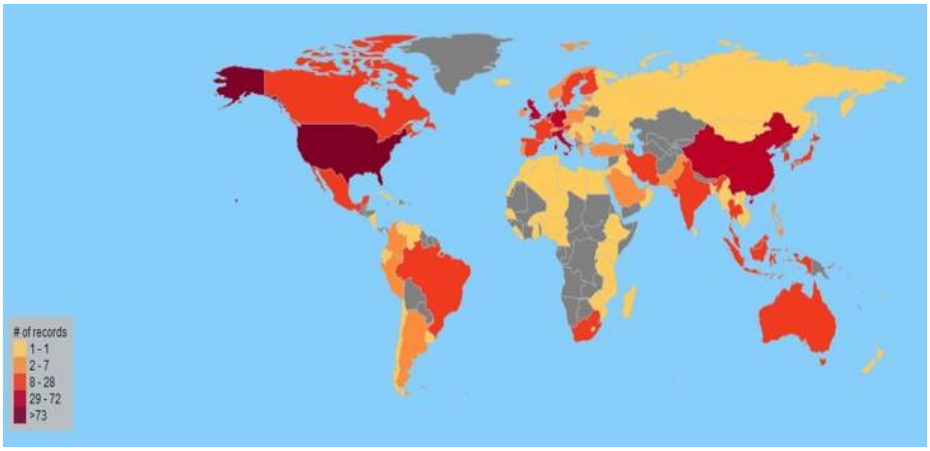

Fig. 5. Global map presenting the number of records for countries (Source: Vantage-Point and the authors).

After analyzing the main authors involved and their networks, organizations and countries, the next step was to understand what the main areas of research are related to sustainable supply chains and renewable energies (Fig. 6). As expected the main results are related to the areas energy, engineering and technology, as follow: Energy & Fuels (with 221 records), Engineering (213), Environmental Sciences & Ecology (201), Science & Technology - Other Topics (157), Biotechnology & Applied Microbiology (70), Agriculture (57), Business & Economics (46), Thermodynamics (33), Computer Science (28) and Operations Research & Management Science (27).

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In addition, it was observed the appearance of other areas not very close to renewable energies but that involve decision-making process, leading to a conclusion that the different industrial segments are looking for sustainable alternatives to minimize the environmental impacts in the supply chain.

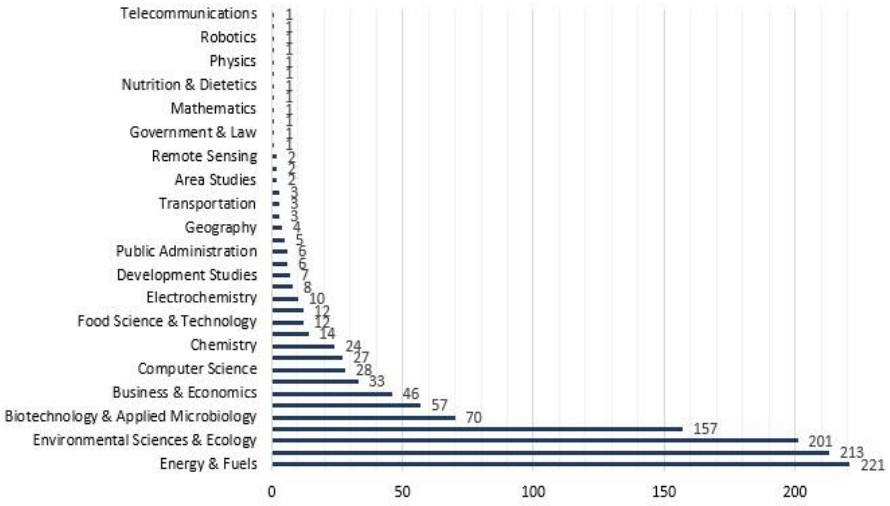

Fig. 6. Research areas and the number of records (Source: The authors)

Finally, the last analysis consisted of understanding which keywords are most present in the studies, Fig. 7 shows the words with the highest record within the base of data. As can be seen, the most frequent words are bioenergy, biofuel, bioethanol, biogas, renewable energy, palm oil, among others. It is possible to view different sources of energy presents that more recurrent.

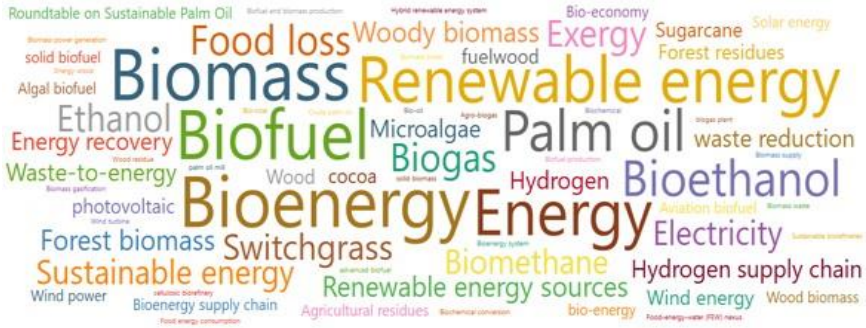

Fig. 7. Word cloud with the most frequently keywords in database (Source: VantagePoint and the authors).

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Finally, a mapping with the 15 most cited works in the area is presented according to Table 4, which represents a total of approximately 2.74% of all works. Scientific publications were ordered by citation recurrence and categorized by author (year), objective of the work, source of energy, supply chain and which sustainable criteria were presented.

Table 4. Mapping of the most cited works in area (Source: The authors)

Author	Objective	Energy Source	Supply Chain	Sustainable Criteria
You et al. (2011) [32]	Design of cellulosic ethanol supply chain under sustainable criteria	Biomass (switchgrass and miscanthus)	Cellulosic ethanol supply chain	• Emissions of GHG • Job creation Cost
Yue, You and Snyder (2014) [33]	Describes the key challenges and opportunities in optimization of biomass-to bioenergy supply chains	Biomass (algae) (agricultural/forest)	Biofuel/bioenergy supply chain	• Emissions of GHG • Emissions of CO_2 • Job creation Cost
Gold and Seuring (2011) [34]	Literature review about bio-energy production	Biomass	Bio-energy supply chain	• Emissions of CO_2 • Transport Traffic congestion Cost
Choudhary and Shankar (2012) [35]	STEEP-fuzzy AHP-TOPSIS based framework for evaluation and selection of locations for TPPs	Coal	TPP supply chain**	• Environmental impact • Cost
Goodrich et al. (2013) [36]	Analysis of manufacturing costs for wafer-based monocrystalline PV module supply chain	PV	PV module supply chain	• Cost • Energy Efficiency
Ahmad and Tahar (2014) [37]	Review and selection of a RE source in Malaysia	Hydropower, Wind, PV, Biogas and Biomass	Energy generation supply chain	• Emissions of CO_2 • Environmental impact • Job creation • Public acceptance • Cost
Mccormick and Kaberger (2007) [38]	Analysis, and discussion of barriers for bioenergy in the EU	Biomass and Biogas	Bioenergy supply chain	• Emissions of GHG • Job creation Cost
Scott et al (2012) [39]	Review of problems in bioenergy sector using MCDM	Biomass, PV Wind, Hydrogen	Biomass/Biofuel Supply Chain	• Emissions of GHG • Emissions of CO_2 • Environmental impact • Job creation • Public acceptance • Cost
Zangh et al (2013) [40]	Mathematical model to determine the optimal supply chain/logistics decisions of SBSC	Biomass (Switchgrass)	Bioethanol Supply Chain	• Energy consumption • Cost
Cucchiella and D'Adamo (2013) [41]	Literature review of supply chain and RE	Biomass, hydrogen, PV and Wind power.	RE supply chain/supply chain management	• Emissions of GHG • Job creation

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				Cost
Corsano et al. (2011) [42]	MINLP optimization model for a sustainable design and behavior analysis of sugar/ethanol supply chain (SC).	Biomass (Sugarcane)	Sugar/ethanol supply chain	• Cost • Environmental impact
Cucchiella et al. (2015) [43]	Environmental and economic analysis of building integrated photovoltaic systems in Italian regions	PV	PV supply chain**	• Emissions of CO_2 • Energy Efficiency • Energy consumption • Cost
Stokes et al. (2011) [44]	Quantifying the life-cycle energy consumption and associated air emissions from water supply, treatment, and distribution	Natural Gas	Water distribution and treatment supply chain	• Emissions of CO_2 • Emissions of GHG • Energy consumption
Chiaroni et al. (2014) [45]	Debate concerning self-consumption to support the economic sustainability of photovoltaic facilities	PV	PV supply chain	• Cost • Energy Efficiency
Khan et al. (2018) [46]	Examine the relationship between green logistics operations and energy demand, economic growth and environmental sustainability for 43 countries	Biomass	Industrial/biofuel supply chain management	• Emissions of CO_2 • Emissions of GHG • Cost

*TPP – Thermal Power Plant, PV – Photovoltaic, RE – Renewable Energy, EU – Europe Union, MCDM – Multi-Criteria Decision-Making, SBSC – switchgrass-based bioethanol supply chain.
** Supply chains not explicit by the authors

Most of the authors found in the database as the main ones listed of the most cited, being them, You, Lam, Yue, Zangh, Cucchiella, D'Adamo and Khan. Moreover, biomass and photovoltaic was the most recurrent source energy, cost and emissions of CO_2 and GHG was sustainable criteria more recurrent and biofuel and bioenergy was supply chain most recurrent.

4 Conclusion

This paper showed that the renewable energies theme in supply chain still young, being started to have grown from 2010, which can be noted in the most cited works (where only one is before 2010). Furthermore, it was seen that a lot of countries and institutions of all words is searching solutions to implement renewable energies in supply chain, justified by the global map of publications, where only a small portion of the Middle East and some countries on the African continent did not respond. Another important conclusion is to see how the different industrial sectors have implemented

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research in this area, which includes sector ranging from the pharmaceutical to food for example. Inside the area, the themes that presented high research were related to biomass, biofuels, and bioenergy, followed by photovoltaic, wind energy and biogas, however, many studies involved other areas was founded in database such as thermal, cogeneration, hybrid system, but not presenting the same recurrence as the main. Regarding the observed sustainable criteria, much is looked at the cost and GHG emissions, however, the social factors were the least pointed out. This study demonstrated the effectiveness of the VantagePoint for the presentation of results from the database, in addition, as limitations of this research, we have the low number of mapped articles (about 2.74% of the entire database) and not considering studies from the database from 2020 (considering that it is the current year). As a suggestion for futures works, a greater analysis of scientific articles could more clearly validate the information taken from the database, in addition to a more critical assessment for the social and environmental scenarios.

Acknowledgment

The authors would like to thank CNPq by the scholarship awarded, IFRJ for the availability of VantagePoint software and the project “Ciudades Inteligentes, totalmente integrales, eficiente y sostenibles (CITIES), n. de processo: 518RT0557”.

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ISBN 978-9930-541-79-1