Review of Sustainable Biofuel Supply Chain Model Design

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Abstract. This paper presents a bibliometric analysis and review of the progress of sustainable biofuel supply chain research. Based on a search of the Scopus database, it resulted in 208 articles published from 2013 to 2022. Bibliometric analysis examines the results by observing keywords, journal trends, and authorship. The results of the analysis of publication trends or publication developments show an increase in article publications in the field of sustainable biofuel supply chain research. Mapping science analysis forms a classification of articles to analyze research themes that have emerged over the past ten years, and to present future research.

1 Introduction

A supply chain involves a series of steps and processes to deliver products or services from suppliers to end consumers. Sustainable supply chain refers to efforts to integrate sustainable and responsible principles and practices into the entire supply chain of a company. The goal is to achieve harmony between economic, environmental, and social aspects in operational activities and business processes.

In the context of biofuels involve the principles of sustainability in the production, processing, and use of biofuels. Sustainable biofuel supply chain is a sustainable and environmentally friendly system in biofuel production that can reduce carbon emissions. One of the main challenges in biofuel production is reliance on feedstocks, such as the crops used to produce biofuels. Fluctuating market demand, climate change, and competition with other raw materials can affect it the availability and cost of raw materials. It is therefore important for each producer to control carbon emissions and increase biofuel production. A manager's main concern is to increase profits. This forces researchers to look for alternative energy resources to form a sustainable supply chain [1]. With the advancement of technology and the industrial revolution, dependence on fossil fuels has increased exponentially [2]. Among various fossil fuel substitutes, biofuels from biomass have gained worldwide attention in the last two decades. Biomass from energy and agricultural crops, as well as forest residues have major challenges and opportunities in modeling and optimizing biomass supply chains into bioenergy [3]. Therefore, there is a need for an approach, namely an optimization model that can consider these factors in determining optimal biofuel production.

M. S. Habib et.al. [4] designed a biodiesel supply chain optimization model based on animal fat waste to minimize environmental impacts and supply chain costs, and maximize social welfare. A. Garai et.al. [5] proposed an effective subsidy policy for farmers and biofuel manufacturers to increase profits in the closed loop system of herbal and medicinal supply chains. M. S. Habib et.al. [6] designed a network of animal fat-based biodiesel supply chain optimization models to minimize the total cost of biodiesel supply chain operations, and minimize carbon emissions. S. Gautam et.al. [7] developed a biofuel supply chain model by combining forest terminals and biorefineries to minimize the cost of biofuel supply chain operations. P. E. Murillo-Alvarado and E. Flores Russell [8] proposed a supply chain model for bioethanol production using agro-industrial waste to maximize economic benefits. M. S. Habib et.al. [9] formulated an animal fat-based biodiesel supply chain optimization model using Fuzzy to reduce the total cost of biodiesel supply chain.

M. Kanan et.al. [10] designed a second-generation biodiesel-based supply chain network model by considering the sustainability dimensions of economic, environmental, and social to minimize total supply chain costs and environmental emission costs. D. K. Jana et.al. [11] designed a biofuel distribution supply chain network based on life cycle energy consumption and CO_2 emissions to minimize both objective functions in an uncertain environment. T. Kalhor et.al. [12] proposed a Mixed-integer linear programming (MILP) model in managing and designing biofuel supply chain network to minimize the total supply chain cost, minimize the environmental impact derived from biofuel

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transportation and production. N. Zarrinpoor and A. Khani [13] designed a sustainable biofuel supply chain by considering economic, environmental, and social aspects to maximize profit and social.

O. Kwon and J. Han [14] and L. Moretti et.al. [15] suggested a biofuel supply chain network model to minimize fuel production costs. G. Memişoğlu and H. Üster [16] designed a biofuel supply chain network model to maximize producer profit. B. Shavazipour et.al. [17] and N. Akbarian-Saravi et.al. [18] designed a bioethanol supply chain model under uncertain conditions for profit maximization, environmental minimization, and social maximization. A hybrid dynamic system approach with mathematical programming in biodiesel supply chain was developed by A. Azadeh and H. Vafa Arani [19] to maximize profits. Y. Huang et.al. [20] designed an integrated biofuel supply chain model with stochastic programming that aims to minimize the total system cost. A. Azadeh et.al. [21], N. Kazemzadeh and G. Hu [22], and I. Awudu and J. Zhang [23] developed a biofuel supply chain model with stochastic programming to maximize profits.

By considering environmental impact factors into the biofuel supply chain, optimization models can help the managers to achieve environmental sustainability goals and reduce carbon emissions. In addition, the optimization model provides an optimal solution in corporate decision-making. For this reason, it is necessary to develop optimization models for sustainable biofuel supply chains, so to increase the sustainability, efficiency, and profitability of the biofuel industry, and reduce environmental impacts.

This paper discusses the bibliometric analysis of the sustainable biofuel supply chain so to determine the extent of publication growth and trend analysis related to this field. In chapter two, the methodology related to the stages of analysis will be explained, then in chapter three the results and discussion of article growth and trend analysis, productive journal analysis, article citation analysis, and Author's keywords. This paper examines the literature review classification scheme, analysis of previous research, gaps, and future study directions. At the end of the paper, conclusions are made.

2 Methodology

The methodology is prepared concerning the review article I. D. Wangsa et.al. [24]

2.1 Stage 1

This investigation begins with determining the topic and gathering data from the Scopus database. The following keywords were used to search for articles relevant to the research topic: Biofuel OR Bioethanol OR Biodiesel OR BioOil AND Supply chain OR Supply-chain OR Logistic AND Sustain OR Emission OR Environment OR CO_2 OR Energy. A search of the Scopus database from 2013 to 2022 yielded 1,143 relevant articles.

Table 1. Rule and Keywords.

Rule	Keywords
1	Biofuel OR Bioethanol OR Biodiesel OR BioOil
2	Supply chain OR Supply-chain OR Logistic
3	Sustain OR Emission OR Environment OR CO2 OR Energy

2.2 Stage 2

Based on the initial data stage, there are many articles that appear in various categories. From 1,143 articles, it is further refined by determining the type of document "Article", the source type "Journal", and limiting the subject area to include: Energy; Environmental Science; Engineering; Computer Science; Business, Management, and Accounting; Mathematics; Economics, Econometrics and Finance; Decision Sciences", so that 634 articles were obtained.

2.3 Stage 3

The next stage of improvement is to determine the title of the paper that is relevant to the research topic and produce 208 articles.

2.4 Stage 4

In the next stage, this paper will discuss bibliometric analysis and sustainable biofuel supply chain research trends, including: article growth and trend analysis, productive journal analysis, article citation analysis, and Author's keywords.

2.5 Stage 4

At this stage, a science mapping analysis is carried out which includes: collecting and reviewing articles, separating and tabulating with classification schemes, analysis of previous research, and future research opportunities. Based on the selected articles as many as 25 articles, it was found that there are still few studies that have not considered aspects of reducing emissions
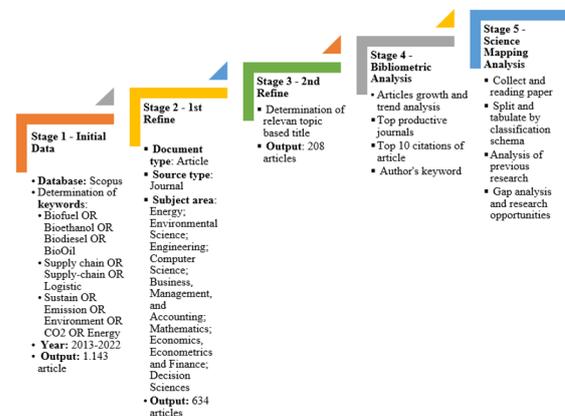

Fig. 1. Stage of analysis of biofuel sustainable supply chain

3 Result and Discussion

3.1 Article growth and trend analysis

The growth in the number of articles in annual publications based on the Scopus database of sustainable biofuel supply chain articles from 2013 to 2022 is illustrated in Figure 2. Of the total publication trends indexed by Scopus, the highest number was in 2022 with a total of 31 articles, and the lowest data was in 2015 with only 6 articles.
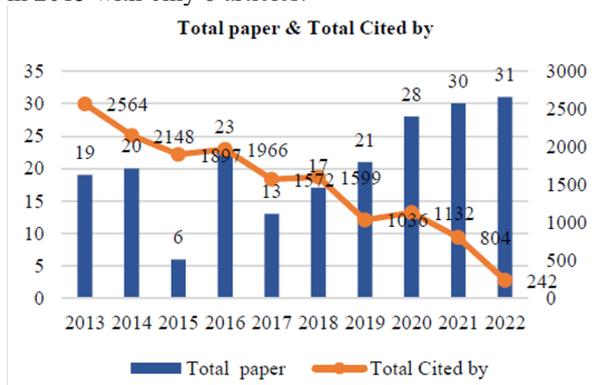

Fig. 2. Articles cited per year

From the graph above, it can be seen that the number of publications from 2013 to 2022 is 208 articles, so if averaged as many as 20-21 publications are produced annually. The results of the analysis show that the publication of articles has an upward trend every year. However, the number of cited articles experienced a downward trend with the lowest value of 242 citations in 2022

The results of the analysis of publication trends or publication developments on data taken from 2013 to 2022 show an increase in article publications in the next six years with trend $y = 1.7333x+11.267$ as shown in Figure 3. This shows that interest in sustainable biofuel supply chain research is growing and growing rapidly.
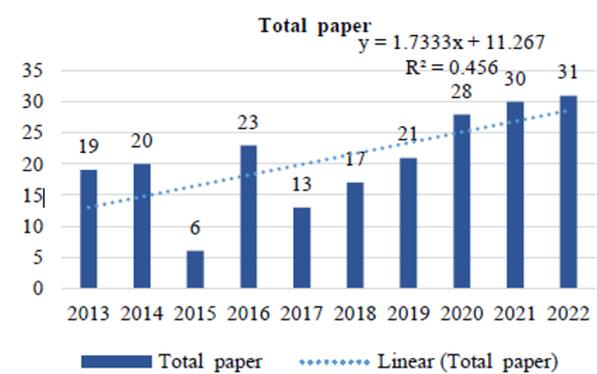

Fig. 3. Trend articles per year
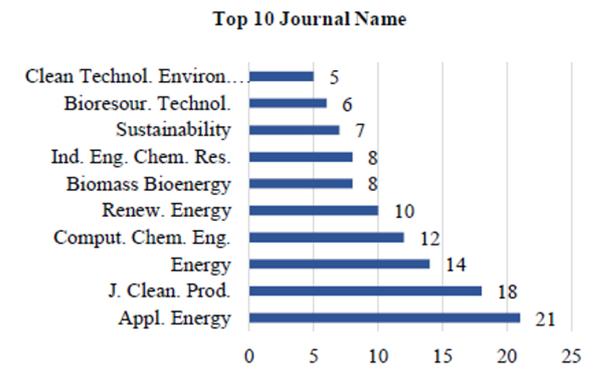
3.2 Top 10 productive journals

Fig. 4. Top 10 productive journals

Figure 4 shows the top 10 journals published in journals from 2013 to 2022, namely: Applied Energy (21 articles), Journal of Cleaner Production (18 articles), Energy (14 articles), Computers and Chemical Engineering (12 articles), Renewable Energy (10 articles), Biomass and Bioenergy (10 articles), Industrial and Engineering Chemistry Research (8 articles), Sustainability (7 articles), Bioresource Technology (6 articles), Clean Technologies and Environmental Policy (5 articles). The most published article in the journal Applied Energy is 21 articles.

3.3 Top 10 article citations

In this section, to find out articles that affect the development of sustainable biofuel supply chain publications, it is necessary to analyze the data by looking at the number of journal citations. Table 2 shows the ten most cited articles on sustainable biofuel supply chains from 2013 to 2022.

Table 2. Top 10 Citations of Articles for 2013-2022.

Rank	Article Name	Authors	Year	Journal Name	TC	C/Y
1	Optimal planning and site selection for distributed multiproduct biorefineries involving economic, environmental and social objectives	J. E. Santibañez-Aguilar et.al. [25]	2014	Journal of Cleaner Production	220	24.4
2	Design of sustainable product systems and supply chains with life cycle optimization based on functional unit: General modelling framework, mixed-integer	D. Yue et.al. [26]	2013	ACS Sustainable Chemistry and Engineering	161	16.1

	nonlinear programming algorithms and case study on hydrocarbon biofuels					
3	Models for optimization and performance evaluation of biomass supply chains: An Operations Research perspective	B. H. Ba et al. [27]	2016	Renewable Energy	143	20.4
4	An integrated optimization model for switchgrassbased bioethanol supply chain	J. Zhang et.al. [28]	2013	Applied Energy	143	14.3
5	Impact of carbon emissions in a sustainable supply chain management for a secondgeneration biofuel	W. Ahmed and B. Sarkar [29]	2018	Journal of Cleaner Production	122	24.4
6	Incorporating social benefits in multiobjective optimization of forest-based bioenergy and biofuel supply chains	C. Cambero and T. Sowlati [30]	2016	Applied Energy	116	16.6
7	Modelling different types of uncertainty in biofuel supply network design and planning: A robust optimization approach	S. Bairamzadeh et.al.[31]	2018	Renewable Energy	113	22.6
8	Stochastic production planning for a biofuel supply chain under demand and price uncertainties	I. Awudu and J. Zhang [23]	2013	Applied Energy	109	10.9
9	Two-stage stochastic programming supply chain model for biodiesel production via wastewater treatment	M. Marufuzzaman et.al. [32]	2014	Computers and Operations Research	106	11.8
10	Design of bioethanol green supply chain: Comparison between first and secondgeneration biomass concerning economic,	C. Miret et.al. [33]	2016	Computers and Chemical Engineering	105	15

	environmental and social criteria					

The paper with the most citations is the research of J. E. Santibañez-Aguilar et.al. [24] on 2014 with 220 citations in nine years or 24.44 citations per year (Cited/year). This research modelled a biomass distribution system that optimally produces multiple products using a variety of biomass feedstocks and various production technologies. The problem is solved with a MILP model to maximize net profit, minimize environmental impact and maximize the number of jobs generated by implementing a biorefinery supply chain.

The second highest cited publication was by D. Yue et.al. [25] on 2013 with 161 citations in ten years or 16.1 citations per year. This research presents an optimization framework for the life cycle design of product systems and sustainable supply chain networks under economic and environmental concerns.

The third highest cited publication was B. H. Ba et.al. [26] on 2016 with 143 citations in seven years or 20.43 citations per year. This research discusses an efficient biomass supply chain model to evaluate and optimize the required resources, associated costs, energy consumption, and environmental impacts.
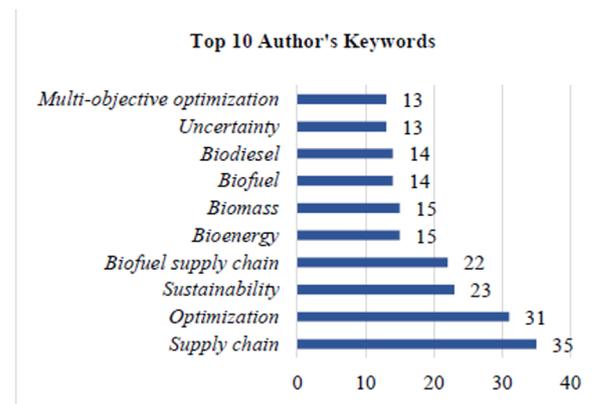
3.4 Author's keyword

Fig. 5. Top 10 Author's keyword

Figure 5 shows the top 10 most used author's keywords in sustainable biofuel supply chain articles including: Supply chain (35), Optimization (31), Sustainability (23), Biofuel supply chain (22), Bioenergy (15), Biomass (15), Biofuel (14), Biodiesel (14), Uncertainty (13), Multiobjective optimization (13). The most widely used Author's keyword analysis results are Supply chain.

Based on the results of bibliometric analysis shows that by considering various variables and limitations, optimization models can identify the optimal combination of decisions that can minimize cost, time, or other resource use in the sustainable biofuel supply chain from upstream to downstream. The objectives of designing and developing optimization models include: minimization of total costs, minimization of environmental impacts, maximization of social impacts, maximization of total profits, minimization of carbon emissions, etc. Some of the variables that are widely considered in the sustainable biofuel supply chain are economic, environmental, and social. However, variables that have not been studied by researchers are reviewed from the aspect of reducing emissions.

3.5 Literature Review Classification Scheme

Based on the results of the analysis of literature review articles, the classification scheme is presented in Figure 6.
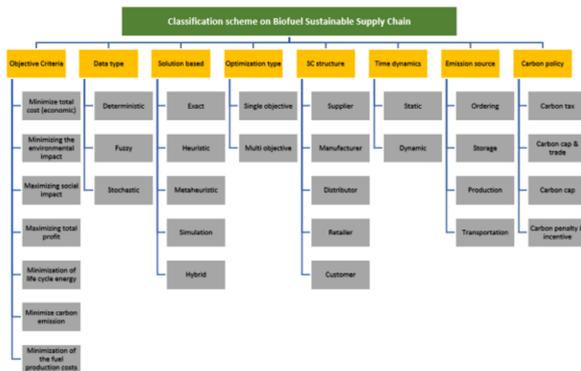

Fig.6. Literature review classification scheme

In designing biofuel supply chain models, objective functions are defined as objectives to be achieved and are usually used to minimize or maximize a performance measure. From the results of the literature review analysis, the researcher's focus is on designing a sustainable biofuel 35 31 23 22 15 15 14 14 13 13 0 10 20 30 40 Supply chain Optimization Sustainability Biofuel supply chain Bioenergy Biomass Biofuel Biodiesel Uncertainty Multi-objective optimization Top 10 Author's Keywords supply chain optimization model by setting the following goal functions: minimization of total costs, minimization of environmental impacts, maximization of social impacts, maximization of total profits, minimization of energy life cycle, minimization of carbon emissions, and minimization of fuel production costs.

Data type is a concept related to how to model or describe uncertainty in data or variables. Data types in classification schemes consist of: deterministic, fuzzy, and stochastic [34]. In data analysis, uncertainty modelling is important for understanding the characteristics of the data and selecting appropriate analysis methods.

The objective function will correlate with mathematical optimization such as linear programs, or non-linear optimization. Based on the classification scheme some of the solutions used are exact, heuristic, metaheuristic, simulation, and hybrid. The optimization types used are single-objective and multi-objective. While the dynamic time schemes are static and dynamic [34]. The biofuel supply chain structure consists of some parties, including supplier, manufacturer, distributor, retailer, and customer.

3.6 Analysis of Previous Research and Research Opportunities

The development of biofuels has made significant progress over the past few decades. Research continues to improve the efficiency of biofuel production, both in terms of bioprocessing and technology. To reduce competition for food resources, biofuel development is turning to the development of non-food feedstocks among others: lignocellulose biomass (such as plant fiber, agricultural waste, and lignocellulose waste), algae, marine biomass, and special energy crops that do not compete with food agricultural land.

The development of second-generation biofuels is the main focus of research that uses lignocellulose biomass as a feedstock that can be taken from agricultural waste, plant fibers, and other lignocellulose biomass. The production process of second-generation biofuels is more complex and involves pre-treatment of biomass, breakdown of lignocellulose components, and conversion into biofuels through processes such as fermentation, enzymatic hydraulics, and gasification. This process is used to convert biomass into biofuels. The technology used in bioprocessing allows wider use of biomass and can produce various types of biofuels such as bioethanol, biodiesel, and bio jet fuel. These developments encourage sustainability and wider adoption of biofuels as a greener alternative in the transportation sector and energy industry.

Reducing emissions in sustainable biofuel supply chains involves reducing greenhouse gas emissions produced over the entire cycle of biofuel production, processing, distribution, and use. Based on the classification scheme in the biofuel supply chain, emission reductions can be assessed from the aspect of emission sources. The source of these emissions will be seen from the activities carried out along the supply chain consisting of: ordering, storage, production, and transportation. Research of M. S. Habib et.al. [6], P. E. Murillo-Alvarado and E. Flores Russell [8], M. S. Habib et.al. [9], M. Kanan et.al. [10], D. K. Jana et.al. [11], T. Kalhor et.al. [12], N. Zarrinpoor and A. Khani [13] have assessed emission sources sourced from storage, production, and transportation activities. However, there is still little research that considers the source aspect of emissions. The source of emissions from ordering activities in the biofuel supply chain has not been studied much, this can be an input for future research.

Carbon policy in sustainable biofuel supply chains encourages innovation and research to develop more efficient and environmentally friendly technologies. Support for research and development of biofuel technologies such as biofuels from non-food biomass sources can reduce carbon footprint and improve overall sustainability. One of them is the government can implement carbon incentives and taxes to encourage the use of sustainable biofuels and reduce dependence on fossil fuels. Governments can provide subsidies or incentives to companies or individuals adopting low-carbon technologies or practices. This can take the form of tax exemptions, investment incentives, or subsidies that benefit producers and consumers of sustainable biofuels. The types of carbon policies in sustainable biofuel supply chains may vary in country or region and it can be developed continuously time by time.

Some common types of carbon policies are implemented such as: carbon tax, carbon cap and trade, carbon cap, carbon penalty and incentive. Carbon taxes are generated by industry, the energy sector, or fossil fuel consumption. The tax aims to encourage emissions reductions by making the cost of producing and consuming carbon-based energy more expensive. Research developed by M. S. Habib et.al. [6], M. S.

Habib et.al. [9], M. Kanan et.al. [10], N. Zarrinpoor and A. Khani [13], W. Ahmed and B. Sarkar [28] have considered carbon tax policies in designing sustainable biofuel supply chain models. In the emission trading system policy (cap and trade), the Government sets emission limits for companies that exceed the company's emission limit and must buy additional quotas from other companies with lower emissions. Some countries that have adopted policies encourage demand for sustainable biofuels and provide stable markets for producers.

A carbon tax on fossil fuels could be introduced to generate economic incentives to increase the use of biofuels. However, there is still a lot of research that does not take carbon policy into account. This can be used as a starting point for future study on carbon policies that involve calculating the carbon footprint from production to end usage. By establishing defined carbon footprint criteria, biofuel producers may identify areas for improvement in order to minimize emissions and increase sustainability.

4 Conclusion

Biofuels from biomass have gained prominence among various fossil fuel substitutes in the last two decades. Several studies have pushed to accelerate the commercialization of biofuel businesses over the past decade. One of them is sustainability which is becoming increasingly important in developing biofuel supply chains. This paper aims to present a literature review of research developments that are currently being carried out and developed to reduce emissions in the biofuel supply chain as an effort to support sustainability. The main outcome of this research is the mapping of biofuel supply chain classification schemes that can be used as research opportunities. As a future research opportunity, emission reductions can be studied from emission sources and by considering carbon policies that are considered capable of encouraging innovation in the use of biofuels and reducing dependence on fossil fuels.

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