Environmental Science and Pollution Research
https://doi.org/10.1007/s11356-022-24973-8

RESEARCH ARTICLE

Uncovering four domains of energy management in palm oil production: a sustainable bioenergy production trend

Mohammed Hammam Mohammed Al-Madani[1] · Yudi Fernando[1,2] · Ming-Lang Tseng[3,4,5,6] · Ahmed Zainul Abideen[7]

Received: 11 April 2022 / Accepted: 21 December 2022

Abstract

This study aims to identify current and future research trends in sustainable bioenergy production. The systematic review is conducted using a social network analysis method. The data were collected from the Web of Science and Scopus database (2010–2021). Out of the 1747 articles reviewed, 100 were found to be relevant for thematic analysis. The results uncovered four domains of palm oil biodiesel production for sustainable energy management: (1) renewable energy, (2) biodiesel, (3) bioenergy, and (4) life cycle assessment. This study has proposed a sustainable bioenergy production framework based on the four main domains. The framework sheds light on the future of sustainable bioenergy production. The findings indicate the potential growth of the research topic, including sustainable bioenergy, palm oil biodiesel, energy management, and carbon emissions reduction. Future research must incorporate the energy management framework to design a sustainable energy management ecosystem strategy. In addition, the industry must comply with the international sustainability standard and sustainable development goals to manage the energy supply chain and consistency of palm oil biodiesel production.

Keywords Sustainable biodiesel production · Content analysis · Energy efficiency · Energy practice · Renewable energy · Social network analysis

Introduction

Sustainable energy substitutes are required to complement the finite conventional energy supply and lessen the effects of global warming (Makarfi and Ganda 2018). Fossil fuel consumption is prevalent, which leads to an increase in greenhouse gas emissions that must be reduced to prevent irreparable harm (Hassan et al. 2015). In order to avoid an energy deficit and vulnerability, responsible enterprises have started looking at the potential of embracing renewable energy (Fernando et al. 2022a). However, fossil fuels remain a vital part of the petrochemical sector and an energy source. Although energy derived from fossil fuels can no longer be the main energy source, clean energy alternatives must be developed to ensure environmental sustainability and energy security.

Responsible Editor: Ta Yeong Wu

✉ Ming-Lang Tseng
tsengminglang@gmail.com

Mohammed Hammam Mohammed Al-Madani
almadani4545@yahoo.com

Yudi Fernando
yudi@ump.edu.my; yudi.fernando@binus.ac.id

Ahmed Zainul Abideen
abideen.m@gmail.com

[1] Faculty of Industrial Management, Universiti Malaysia Pahang, 26300 Pahang, Malaysia

[2] Management Department, BINUS Online Learning, Bina Nusantara University, 11530 Jakarta, Indonesia

[3] Institute of Innovation and Circular Economy, Asia University, Taichung, Taiwan

[4] Department of Medical Research, China Medical University Hospital, China Medical University, Taichung, Taiwan

[5] Ramon V. Del Rosario College of Business, De La Salle University, Manila, Philippines

[6] UKM-Graduate School of Business, Universiti Kebangsaan Malaysia, Selangor, Malaysia

[7] Faculty of Transport and Logistics, Muscat University, Muscat, PO Box 550, PC 130, Sultanate of Oman

Published online: 30 December 2022

The massive increase in global warming, the burning of fossil fuels, and sustainable development are all related to the disruption of the ecological balance, the pollution of the environment, and the consumption of fossil fuels. Bioenergy has received significant attention from researchers and legislators due to its advantages and evident contribution to environmental conservation (Hoang et al. 2021). Crude oils like gasoline and diesel have traditionally served as the primary energy and fuel sources. Biodiesel fuels made from soya or palm oil have recently gained popularity as competitive alternatives to petroleum-based diesel fuels (Popa 2021). Even though petroleum-based fuels are often used, biodiesel fuels are becoming increasingly popular in the power and transportation sectors.

Biodiesel that is environmentally friendly and sustainable has a significant impact on how clean energy is implemented in the industry (Tseng et al. 2021; Yavari and Ajalli 2021). The chemical structure of a biodiesel molecule is identical to that of gasoline when oxygen atoms are removed. The higher cetanes, better energy density, and substantially reduced sulphur content of biodiesel make it a more significant fuel in terms of fuel standards. As a result, biodiesel can be immediately used in the gasoline sector (Chen et al. 2019). As an alternative to gasoline, biodiesel is a well-known bioenergy source. The biodiesel sector has continued to grow since biofuel has received approval from more than 60 countries across the world (Yusoff et al. 2021). The rapid expansion of the world economy and the constant advancement of industrialisation has increased the need for energy worldwide. Constant use of fossil fuels has negatively influenced natural resources, the energy market, and the environment (Zhu et al. 2016). As a result, it is crucial to address the development of biofuels and support sustainable biodiesel production.

There has been a demand to produce biodiesel fuels that are sustainable and environmentally friendly (Konur 2021). As crude oil yields keep rising, the growth of alternative energy becomes more apparent. The most alluring and practical answer became biodiesel production from renewable oils. Significant amounts of C, H, and O are present in biodiesel, particularly in the form of long-chain saturated or unsaturated esters with a molecular structure between C12 and C24. It can significantly help with the energy problem while preserving the ecological carbon balance (Huber et al. 2006). Throughout its life cycle, CO_2 emissions can be reduced by up to 90% by switching to biodiesel from traditional petrochemical fuel (Pourzolfaghar et al. 2018). Biodiesel has gained market share because of its positive environmental effects (Jain et al. 2021).

The life cycle assessment evaluates the amount of energy. For instance, when the feedstock is consumed, gas emissions and waste are produced during the product's life cycle. A substance's life cycle energy is the entire amount of non-renewable energy used in its production, transfer, and acquisition. When manufacturing biodiesel, each type of oil has a unique life cycle. The biodiesel life cycle ensures that the product is known systemically throughout the manufacturing process, from the extraction of raw materials into the production system to the manufacturer's final disposition (Esmaeili 2022). For example, producing 1 MJ of mineral fuel requires 1.2 MJ of fossil fuels, but only 0.311 MJ of energy is required to make 1 MJ of biodiesel. In light of this, the biodiesel life cycle reveals that it can produce more energy than fossil fuels generate by more than a factor of three (Chatterjee et al. 2012).

Palm oil-based biodiesel is expected to contribute more to bioenergy production and solve the energy crisis that endangers the future of diesel. It is in light of the possibility that gasoline and diesel may be produced less in the near future. What accounts for the highly delayed acceptance of palm oil as a renewable source of green energy in the energy management movement? Global biodiesel demand surged 23% between 2005 and 2015, making the market expand seven times. The biodiesel industry expanded quickly, and crude oil prices were high, but since mid-2014, oil prices have dropped significantly (Naylor and Higgins 2017). Another key reason for employing palm oil as a renewable energy source is the nation's policy. For instance, the EU tightened requirements in 2009 with the Renewable Energy Directive, which mandated that 10% of all transportation energy must come from renewable sources. Additionally, the EU has implemented trade restrictions to protect domestic biodiesel producers, such as a 3.5% import tax on biodiesel blends B30 and less and a 6.5% import tax on B30-B100 fuels (Naylor and Higgins 2017).

Similarly, Indonesia's national energy policy aims to employ 5% more biofuels in transportation by 2025. The main driving force behind this strategy was reducing the nation's reliance on fossil fuels while giving its thriving and developing oil palm industry an additional outlet. In addition to the financial burden of subsidising the use of palm oil in biodiesel, there are additional problems, such as land removal, fires on high-carbon soils, and disagreements over land rights (Wright et al. 2017). Similar to Indonesia, Malaysia has developed its biodiesel industry within its sizable oil palm sector. The Malaysian government adopted biofuel regulations to achieve B7, B10, and 93% petro-diesel. However, because conventional fuel is so economical, increasing biodiesel subsidies to producers and blenders would strain the nation's finances. The biodiesel mandates have occasionally been delayed (Naylor and Higgins 2017).

Understanding energy management that focuses on a biodiesel feedstock is crucial. Energy supply, energy conversion, and energy use are all associated with energy control (Örs 2020). Energy and material flow through systems to be monitored, calculated, registered, reviewed, analyzed, managed, and steered to consume lesser power to achieve the highest output (Lawrence et al. 2019). When it is well-managed, palm oil provides adequate resources of renewable energy. This study examines literature, particularly biodiesel, and its relationship with energy

management. It has functioned as an alternative fuel to reduce air pollution and fuel costs. In addition, because of palm oil accessibility, simplicity in production, and advantages for the environment, biodiesel is one of the most promising renewable fuels (Erdiwansyah et al. 2019).

Although palm oil has been extensively explored in the literature, it is critical to conduct a comprehensive study on how it plays a critical role as a source of sustainable energy management. Scholars have investigated palm oil's substantial social and environmental consequences in biodiesel and the potential environmental effects of land conversion and cultivation (Rulli et al. 2019). Previous studies on palm oil's function in biodiesel production and land-use shift (Bicalho et al. 2016), properties of pure palm oil biodiesel and market standards (Mekhilef et al. 2011). Other studies focused on regulatory framework and industry roadmap model for generating electricity from sustainable oil palm biomass (Umar et al. 2018). Larsen et al. (2018) explored theories of hybrid public–private governance for palm oil supply chains.

In other studies, Erdiwansyah et al. (2019) suggested that alternative fuels, such as alcohol and biodiesel, have been recommended as crucial to decrease greenhouse gas emissions and toxic pollutants from combustion chambers. Despite countless attempts and triumphs in energy management, there are still a few systematic viewpoints in the palm oil sector's energy management study. The current review aims to fill this research gap with the content analysis methodology. The perspectives explored in this study aim to present the course for palm oil studies, define the problems, and extend the energy management literature on palm oil. Keyword co-occurrence and bibliographic data are the main components of content analysis.

This study provides a complete overview of palm oil's current developments and scientific understanding while examining literature gaps. The study simplifies the literature for authors to interact and expand on the palm oil industry's renewable energy research. This contribution is a dynamic review of the literature on palm oil in journal databases from early publications. Several studies have been conducted on this topic, but further studies are still needed to enhance biofuel literature and provide trends and gaps. To achive the research objectives, this study has attempted to deploy bibliometric analysis on palm oil articles. The findings show patterns, gaps, and a visual image of the growth of the research field. The study helps to review and reveal the main themes of palm oil literature as the source of alternative fuel and how to manage energy effectively. To comprehend the growing sphere of palm oil biodiesel, this study aims to answer the following questions:

- What are the key themes of the palm oil literature on the industry, management decisions, and energy management? This study question helps to clarify both dominant topics and gaps in the research field.
- What is the role of energy management in palm oil studies, and which journals publish the key publications for this framework? The response to this question provides an overview and an interpretation of the essential publication in the palm oil field. It is making it more accessible for those interested in palm oil studies to understand the latest developments in the field.
- Which countries, organizations, and sources have contributed most to research into palm oil? The response to this question will indicate which country has more awareness and interest. However, more attention is needed from growing economies and countries to identify potential study opportunities and challenges.
- What are the most common terms for palm oil co-occurrence from the management perspective and throughout fields of study? This element makes it possible to understand the most commonly used words in palm oil and its main components that apply to progress palm oil research forward and acquire a comprehensive framework.
- What is the future of palm oil research? The answer to this question can identify the future research direction.

This study increases the reach of relevant material on palm oil research. Though addressing the study issues, there is minimal research focusing on palm oil studies and tying them to energy management. This study is unique because it provides an energy management framework and a clearer understanding of clean energy's future research path. Although Archer et al. (2018) argued that life cycle analysis in palm oil biodiesel has contributed to sustainability practice, it has not shed much light on its energy management. Mahlia et al. (2019) investigated the origins of palm oil, how it is processed, the bioproducts produced from this biomass, and the oil palm biomass-based power plant. However, it was little managerial implication for energy research.

Moreover, Mazivila (2018) used non-destructive analytical procedures described in the scientific literature and found that various biodiesel feedstock, such as palm oil, were present in the diesel–biodiesel blend. The literature also includes reviews on palm oil (Nambiappan et al. 2018), discussing productivity, labor shortage, technology adoption, and sustainability that concern the palm oil industry. Another recent review by Zahan and Kano (2018) looked into palm oil and its by-products as an input to biodiesel production. This study has studied the properties of biodiesel palm oil and has shown similar properties to conventional petro-diesel. As a result, we argue that this study not only reviews previous palm oil studies but also includes information about palm oil as a renewable energy source for energy management. Finally, we present an analysis of an exclusive study that covers previous studies on palm oil while providing a connection to energy management that is still lacking in the available literature.

The following section discusses the literature on palm oil, biodiesel palm oil, and energy management. A review of the processes and methods used accompanies it. The findings are subsequently discussed and analysed. Finally, the study ends with discussion, conclusion, and suggestions for future analysis.

State-of-the-art conceptualization

The palm oil biodiesel sector has sparked a lot of debate. Some experts suggest that palm oil is better than biodiesel crops such as soya beans. Palm oil is one of the most efficient oil crops regarding land efficiency, output, and consumption (Nambiappan et al. 2018; Yavari and Ajalli 2021). Palm oil, for example, yields the most oil per hectare, averaging 4–5 t per hectare per year, outperforming soybean, and rapeseed oil by about 10 and 6 times, respectively (Szulczyk and Atiqur 2018). Furthermore, palm biodiesel is a clean and efficient alternative to the widely utilized traditional diesel. Furthermore, the combustion of palm-based biodiesel does not increase the amount of CO2 in the environment (Erdiwansyah et al. 2019). CO2 is one of the greenhouse gases responsible for increased global heat. As a result, using palm oil biodiesel instead of conventional diesel as motor fuel would have a comparatively more enormous global benefit (Erdiwansyah et al. 2019).

Additionally, palm oil biodiesel provides fewer engine emissions (Mekhilef et al. 2011). The non-toxicity, biodegradability, acceptable viscosity, high flash point, high lubricating qualities, and high octane count of palm biodiesel fuel make it an environmentally and eco-friendly energy source (Pandey and Sharma 2018). Furthermore, biodiesel can aid in the reduction of greenhouse gas emissions. Finally, a thriving biodiesel industry can boost employment in rural areas.

On the other hand, critics of palm biodiesel have raised concerns about deforestation, land use shifts, food versus fuel, and tree carbon storage. For example, rainforests store more carbon per hectare than palm oil. As plantation owners convert forests to oil plantations, palm oil trees store less carbon. Furthermore, palm oil mill effluents are pumped into ponds by palm oil mills (POME). Because effluents include much organic content, bacteria break them down into methane gas, a solid GHG gas (Prapaspongsa et al. 2017). As a result, palm oil mills would need to treat their effluent, collect the methane gas, and either flare it or create household energy to increase their GHG efficiency.

On the other side, establishing palm oil plantations by destroying existing rainforests produces additional greenhouse gas emissions. Therefore, increased focus should be placed on protecting the productivity of existing farmed land while also increasing power production by utilising biomass from palm oil. Furthermore, in cases where energy production necessitates burning biomass residue, the utilization of biomass ash would be critical for restoring soil nutrients on plantations (Reijnders 2006).

Biomass from palm fresh fruit bunches

Biomass can be extracted from living plants or animals and used to generate energy or fuel (Suksong et al. 2020). Biomass has several advantages. Biogas, for example, is created by fermentation biomass such as palm shells and fiber after oil extraction and can be used to generate power or combustion applications. The biomasses from palm oil include shell and fibre, empty fruit bunches (EFB), and palm oil mill effluent (POME). For every ton of fresh fruit bunches processed, approximately 0.20 t of crude palm oil are produced.

Meanwhile, biomass produced an average of 190 kg of fiber and shell, 230 kg of empty fruit (EFB), and 600–700 kg of palm oil mill effluent per ton of FFB (Phuang et al. 2022). However, before biomass can be utilized as an energy source, it must undergo treatment. On the other hand, biofuel, a renewable energy source, can be produced after undergoing conversion and appropriate treatment. In Malaysia, for example, the palm oil industry generates a surplus of waste used to obtain energy for internal use (Popa 2021).

Biomass conversions enable the production of biofuels, which are regarded as the primary source of domestic renewable energy. For example, palm oil, sugar, rice, and wood companies in Malaysia have used biomass to generate electricity for in-house applications (Mahlia et al. 2019). Furthermore, palm oil mills use mesocarp fiber and palm kernel shells as biomass sources in their electrical boilers. Therefore, palm oil has the potential to be a renewable energy source. In addition, palm waste, such as shell, fiber, and empty fruit, can be mixed and treated to generate steam for electricity generation., Lower emissions from palm oil biomass have long-term implications for this renewable energy source (Farid et al. 2019).

Biofuels

Biofuels are characterized as energy sources derived from living organisms. Biofuels may be produced directly from the waste of a living organism. As with palm oil, it can be turned into biofuels, such as biodiesel, which can replace traditional diesel to a large extent without significant engine modifications (Singh et al. 2020). Another type of fuel that can be extracted from palm oil is briquettes. Under high temperatures and pressure, they can be produced from empty fruit bunches and palm kernel oil. There are numerous proven advantages, such as zero carbon emissions, cost-effectiveness, and long burning times. Briquettes also

grant the palm oil industry credit under the Kyoto Protocol framework for mitigating global warming (Shuit et al. 2009).

The quality of biofuels depends on the fermentation technologies. There are several types of biofuel generation. Food crops are used to produce first-generation biofuels. The non-food feedstock can be processed to produce biofuels. It is classified as a second-generation biofuel. The third generation of biofuels is from food waste biomass and algae (Singh et al. 2020). Studies have shown the potential of getting hydrogen gas from biomass through gasification technology (Ahmad et al. 2019). However, the energy transition is still to develop in the following years.

Using renewable energy sources (RES) as a substitute for fossil fuels is the first step toward achieving a carbon–neutral society. For example, hydrogen has the potential to be used as a renewable energy source to generate electricity in automobiles. Hydrogen fuel has been shown to provide zero automobile emissions while improving engine performance (Kovač et al. 2021). Therefore, energy management benefits from developing gasification technology for palm oil biomass, such as discarded fruit bunches, palm oil fibers, and palm oil kernel shells (Hossain et al. 2016).

Palm oil biodiesel

Fossil fuel supply concerns society, decision-makers, and academicians, especially as conventional oil reserves are expected to last five decades or less (Foo 2015). Consequently, regulatory agencies are becoming more concerned about developing, maintaining, and protecting renewable energy sources. Renewable energy improves energy security and management and contributes to global warming reduction. Furthermore, renewable energy facilitators can lessen the volatile fluctuation of fossil fuels. Moreover, renewable energy can lower entire supply chain costs (Cantarero 2020; Silalahi et al. 2020). Countries rich in biomass, such as palm oil, have therefore invested in research to produce renewable energy sources, such as biodiesel, as an energy security measure for conserving the environment (Nutongkaew et al. 2019). To be considered a reliable renewable energy source, palm oil biodiesel must be cost-competitive, economically practical, and environmentally beneficial.

Biodiesel is a biodegradable and clean energy source. In addition, biodiesel offers the advantage of having a low emission profile. Palm oil and palm kernel oil are key oils with a higher energy output than most other oils. Palm oil and palm kernel oil are converted into raw palm oil, refined into refined palm oil, and biodiesel palm oil (Szulczyk and Atiqur 2018). Refined palm oil can be used in different applications, but this study only deals with palm biodiesel as one of its key uses. Regarding environmental considerations, palm oil helps energy management and stability. Besides that, life cycle studies on palm oil have shown that the yield ratio of palm oil energy is 3.53 higher than most rapeseed oil and soybean oil, which are about 1.4 and 1.3, respectively (Queiroz et al. 2012).

One specific application of palm oil in biodiesel production for combustion engines is marine engines, vehicles, and industrial engines (Amini et al. 2017; Arumugam and Ponnusami 2019). Biodiesel has several advantages: the low sulfur profile, high storage period, low density, zero aromatic hydrocarbons, low cetane number, and friendly to the environment (Erdiwansyah et al. 2019; Noor et al. 2018; Wang et al. 2016). Furthermore, because of shorter injection delays and enhanced air–fuel mixing, sustainable palm oil biodiesel is highly promising in terms of energy security and clean combustion (Kovač et al. 2021). Finally, palm oil biodiesel holds the potential to conserve the environment by lowering emissions while simultaneously functioning as a renewable energy source (Erdiwansyah et al. 2019).

Palm oil diesel and energy management

It is necessary to manage an adequate supply of renewable energy through clean technology (Fernando et al. 2021a, b; Fernando and Hor 2017). The continued rise in the consumption of petroleum fuels and the associated emissions of hazardous gases could result in adverse economic and environmental concerns in the coming decades (Abukhadra et al. 2018). According to the World Energy Forum assessments, the anticipated reserves for conventional fossil fuels will be depleted in less than ten decades. Therefore, the importance of renewable and clean energy has drawn the interest of energy and environmental organisations as a viable solution to the challenges of energy shortages and the destructive emissions of fossil fuels. Biodiesel and biofuels have been recommended as efficient and environment-friendly alternatives (Lee et al. 2011).

However, to qualify as a sustainable energy source, the palm biodiesel industry needs to look after its energy use at all palm oil production stages. The energy input must not surpass the energy output from the biodiesel palm. Many issues need to be resolved, such as the high price of palm oil, the low price of conventional diesel, the farming and production activities adopted, and the energy use from the initial phase to palm biodiesel production (Kamahara et al. 2010). Therefore, integrating the palm biodiesel production facility with the palm oil production plant is necessary. Via integration, transporting palm oil to biodiesel production facilities would save energy. In producing electricity or steam, biomass should be wholly exploited. In addition, biogas needs to be collected and used from the effluent of palm oil and isolate the fertiliser for further use. Biogas can provide energy for the whole plant, eliminate the amount of by-product waste, and improve the efficiency of GHG emissions (Ng et al. 2013).

The systematic procedures

This study aims to answer the five study questions stated in the introduction with the bibliometric mapping and clustering method suggested by Mirkouei et al. (2017). The systematic review expands the biodiesel literature by reviewing emerging developments and trajectories in the Web of Science and Scopus database. Books were omitted, and the concentration was solely on comprehensive research and systematic review articles. This study focuses on the theoretical understanding of palm oil reviews concerning energy production and a technological trend that has received little attention in sustainability and environmental management. The methods used were directed to employ Web of Science and Scopus as the key input for the insights in the analysis. Web of Science and Scopus are abundant sources for bioenergy-oriented articles and trans-disciplinary literature. Figure 1 illustrates the detailed steps undertaken for content analysis. The following sub-sections cover content analysis, social network analysis, and analytical processes.

Content analysis

The content analysis relies on keywords in the literature to classify topics, connections, and parameters. It is carried out by reviewing the frequency of keywords in the literature (Khudzari et al. 2018). The keywords describe the parameters in the databases of palm oil, biofuel, biodiesel, and energy management. Thus, a precise performance is produced, and unrelated subjects are omitted. The obtained data indicates whether the database is connected to the study by selecting the predetermined keywords in the two databases. In addition, the study shows what databases and journals contribute more in bibliographic knowledge to the literature on palm oil biodiesel.

A bibliographical review is the best methodology for studying palm oil, biofuels, and energy management because they are complex and cross-disciplinary (Khudzari et al. 2018). For instance, carbon emissions, biofuel, and energy management have complex environmental management issues. Therefore, investigating the keywords' co-occurrence correlation to find clusters of the words is highly recommended (Wang et al. 2017). However, social network analysis is being used to define trends and interpret views of the subject to improve the study's accuracy. Therefore, the next section explains the software used for the analysis.

Social network analysis

The VOSviewer version 1.6.8 was used to conduct bibliometric analysis. It can be utilized to discover literature trends and gaps in databases. The method used works well for bibliometric clustering. Furthermore, the software is as

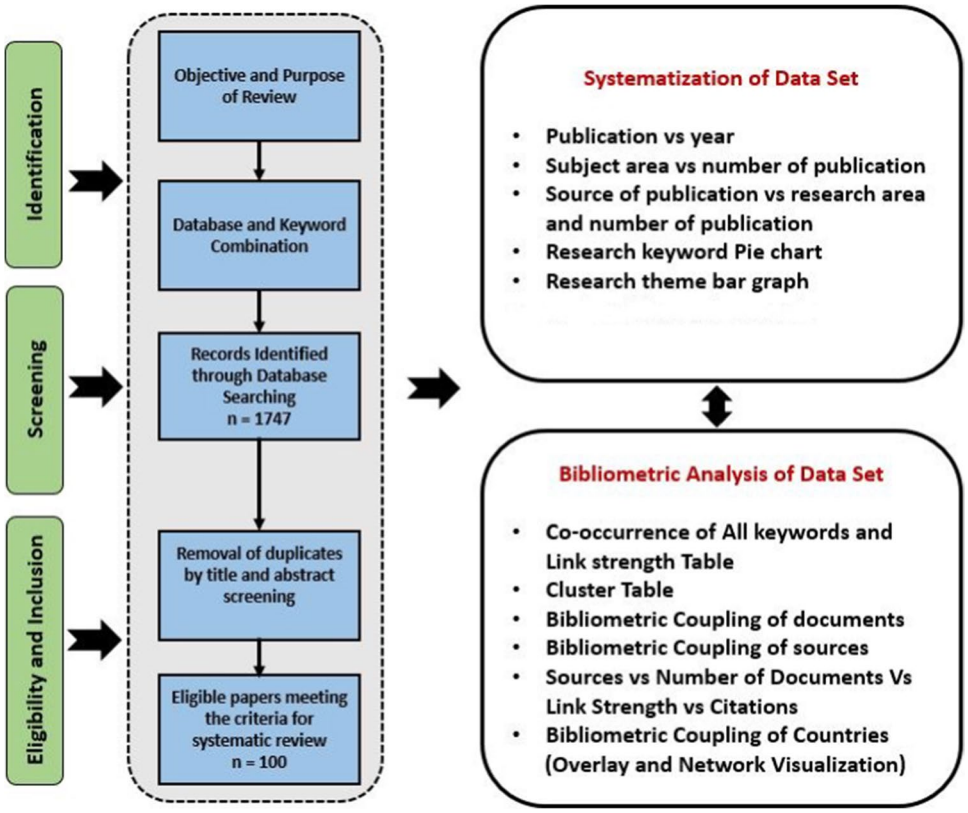

Fig. 1 Research process

simple as downloading articles in the preferred format from databases such as Web of Science and Scopus and uploading the files into the software without further processing. Social network analysis (SNA) was used to analyse the files and determine the clusters of thematic words based on keyword co-occurrence (Lee et al. 2017). There are two parts to SNA. The first covers social actors, and the second covers scholar's interactions (Zou et al. 2017). As a result, SNA supports the strategy used in this research to determine palm oil topics, examine researchers' country of origin, study country-wise citations, and journal co-citations (Perianes-Rodriguez et al. 2016).

Data uploaded to the software is visualised using routing, clustering, and normalization techniques. The platform uses standardization, mapping, and clustering techniques and offers data visualisation opportunities. The OpenNLP Toolkit is used by VOSviewer software for labelling verbs, nouns, and adjectives. The program has an option that only picks the significant endings so that the general sentences can be omitted from the keyword network. A relevancy score for each keyword is measured, and visualisation is shown in circles representing the publishing scale in the field of interest. Finally, the closer the nodes are, the greater the likelihood of co-citation (Perianes-Rodriguez et al. 2016).

Research procedure

This section discusses the steps taken and stages for content analysis. The research procedure shows in Fig. 1. Shaharudin et al. (2019) and Abideen et al. (2020) have previously used the research procedure. At first, we ran a keyword search in the Scopus database to find all palm oil and energy management publications irrespective of the field of study. The keyword search code was as follows: (TITLE (palm AND oil) AND TITLE-ABS-KEY (energy) OR TITLE-ABS-KEY (bioenergy)) AND PUBYEAR > 2009, which gave 1747 data sets. The Scopus database was selected because it has the highest number of datasets compared to any other database. We used the PRISMA method to find the most relevant datasets. Only Scopus was used to reduce the work required to eliminate duplicates and irrelevant data sets. This study attempted to study all the palm oil-related datasets that discuss energy management and filter the data sets related to bioenergy. Publications concerning palm oil and energy management were extracted from the Scopus database from 2010 to 2021. A detailed review of article titles and abstracts was performed to scrutinize further the most relevant datasets for the content and bibliometric analysis. Only Journal articles were filtered for the study by excluding the conference proceedings, books, and book chapters. Later, all the duplicates were excluded. Finally, this research investigated 100 data sets related to energy management in the palm oil industry, which is the study's core focus.

A systematic review was conducted on the acquired data set to snowball them into various understandable, descriptive graphs and tables. This process assisted in understanding the inferences and implications of the research (Al-Madani et al. 2022). After a detailed systematic review, the data sets were uploaded into VOSviewer software to analyse the research clusters, link strengths, and relevance or strength of the research topic (Shaharudin et al. 2019). The trend in the publication was framed to understand the importance given to the research area and other developments over the years (Fig. 2). For example, there is a massive increase in the energy extraction from palm oil since the world is moving towards finding ways to generate renewable energy sources, reduce waste, and maintain environmental sustainability. The data set was further analyzed and divided into several subject areas to understand the most published research cluster. Consequently, more publications show clustering in "Environmental science," "Energy," and "Engineering" subject areas (Fig. 3).

The dataset was further analyzed to retrieve the list of published sources and the volume (Table 1). This study reviewed each article and mentioned the research themes associated with those publications. The journal Bioresource Technology, for example, publishes research themes on biohazards and bio-wastes. However, the Journal of Cleaner Production has covered many areas and published the highest number of articles on environmental sustainability, effective and sustainable resource usage, energy generation, and waste management.

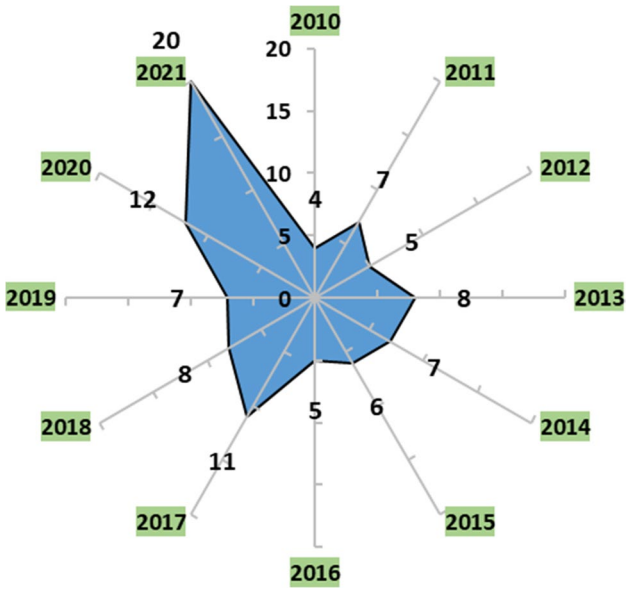

Fig. 2 Year vs number of publications

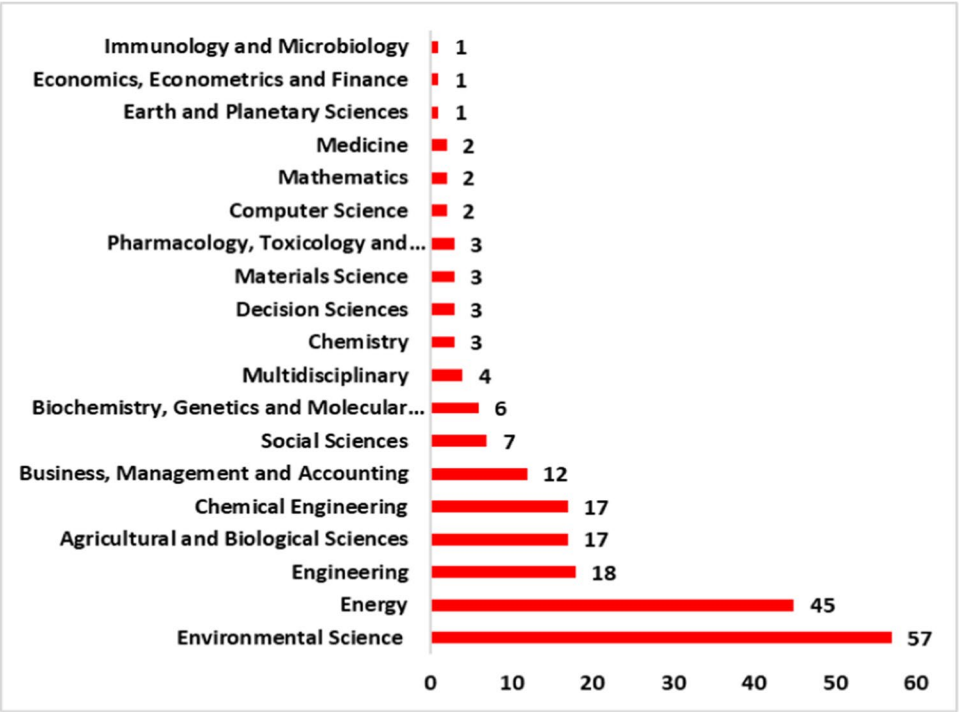

Fig. 3 Subject area vs number of publications

This study discovered major research topics that previous researchers had focused on during a detailed and thorough reading of each article's title, abstract, and available full text in the data set. We have calculated the percentage of selected research topics and created a pie chart to display them in Fig. 4. Most research has been focused on biomass (23%) and bioenergy generation (18%), respectively. Waste management also has been a primary research agenda. However, we discovered that sustainability (14%), waste management (14%), renewable energy (13%), and environmental-related sustainability (10%) contributed to the research field.

The data set was further divided into three main research themes in which the previous literature has been published. Finally, we calculated the number of articles that directly address these themes over the past 10 years to understand the research importance the community's given to each theme. This idea is portrayed in Fig. 5.

Bibliometric analysis

Co-occurrence of all keywords

The bibliometric coupling is basically conducted to understand the network links between research clusters and research topics and their relevance and intensity (Waltman et al. 2010). Using the Vosviewer software, the data set was analyzed further to run the co-occurrence mapping of all keywords. The initial criteria for a minimum number of occurrences of keywords were set to 5. There were 108 keywords found out of 1494 in the data set. The has been presented using a network node-link diagram (Fig. 6).

The primary sources of bio-based waste for energy generation are palm oil and mill effluents. Palm oil research issues that have received much attention include renewable energy, biodiesel, life cycle assessment, carbon emissions, sustainability, and energy policy. Through co-occurrence analysis, four clusters are discovered for all keywords. These findings answer the primary research question by identifying the major topics linked to palm oil studies in energy management. Based on these findings, biodiesel is the most dominating cluster (cluster 1). Therefore, biodiesel and bioenergy are the most essential cluster and extensively discussed keywords in biofuels, energy, and engineering literature. Furthermore, biodiesel research is linked to palm oil and renewable energy research (cluster 2), energy efficiency and production research (cluster 3), and greenhouse gas emissions (cluster 4).

This finding is corroborated by the large number of palm oil-related studies discovered in the literature (Mahmud and Cho 2018; Marin-Burgos and Clancy 2017; Mat et al. 2017; Nutongkaew et al. 2019). Cluster 1 shows the major research areas, which include bioenergy, carbon footprint, environmental management, and energy usage. There is an ongoing discussion on the palm oil biodiesel cluster among global scholars, particularly on land use changes and biofuels' effects. At the same time, the industry promotes biodiesel palm oil to prevent climate change and ensure energy stability. Therefore, it helps develop global sustainable strategies. The fourth topic covered in the literature was bioenergy and

Table 1 A comparison between publication source, number, and research area

No	Source of publication	Number of publication	Research area
1	Bioresource Technology	9	Bio-waste management, biomass, palm oil mill effluent
2	Journal > of > Cleaner Production	8	Sustainability, > resource > allocation, deforestations, land use, energy management
3	Biomassand > Bioenergy, Environmental Science and Pollution Research, International Journal of Life Cycle Assessment, Renewable and Sustainable Energy Reviews, Renewable Energy	4	Biomass, > biowaste management, environmental sustainability
4	Water Science and Technology, Chemical Engineering Transactions	3	Agricultural innovation, fertilizer
5	Energy, Sustainability (Switzerland), Materials, Waste Management and Research	2	Renewable > energy, sustainable > production, > biodiesel production
6	Food Research, Scientia Agricola, ARPN Journal of Engineering and Applied Sciences, Forests, Production Planning and Control, Geoforum, Land Use Policy, Biofuels, Bioproducts and Biorefining, Journal of Hazardous Materials, PLoS ONE, Bioresources and Bioprocessing, Journal of Environmental Engineering and Landscape	1	Economic sustainability, land use, palm production and harvesting, energy management
6	Management, Proceedings of Institution of Civil Engineers: Waste and Resource Management, Agricultural Water Management, Energy and Environment, Environmental Progress and Sustainable Energy, Sustainable Energy Technologies and Assessments, Sustainability Science, Energy, Sustainability and Society, ARPN Journal of Engineering and Applied Sciences, Periodica Polytechnica Social and Management Sciences, Sustainable Production and Consumption, Sadhana—Academy Proceedings in Engineering Sciences, International Journal of Supply Chain Management, Forests, Production Planning and Control, Geoforum, Resources, Conservation and Recycling, Environmental Pollution, Environmental Research Letters, Land Use Policy, Applied Mathematical Modelling, PLoS ONE, Biofuels, Bioproducts and Biorefining, Journal of Hazardous Materials Technology and Engineering, Agricultural Systems.International Journal of Recent Environmental Technology and Innovation, American Journal of Applied Sciences, Bioresources and Bioprocessing, Molecules, Journal of Environmental Management, Journal of Environmental Engineering and Landscape Management, Proceedings of Institution of Civil Engineers: Waste and Resource Management, Journal of Oleo Science, Energy Conversion and Management, Industrial Crops and Products, Journal of Oil Palm Research	1	Economic sustainability, land use, palm production and harvesting, energy management

energy policy. Scholars in this cluster have focused on different fields, such as management practices, ecosystems, energy crops, biodiversity, and energy policy (Loh 2017; Somnuek and Slingerland 2018). Scholars have also focussed on life cycle assessment criteria in their agenda. They have analysed life cycle evaluations from land-use shifts, circular economies, greenhouse gases, and storage. The results are consistent with the environmental performance of biodiesel palm oil, land use reform, fuel production, and engine combustion literature (Castanheira and Freire 2017; Maharjan et al. 2017; Prapaspongsa et al. 2017). Previous literature has shown that palm oil biodiesel is a renewable energy source. Consequently, energy management strategies could include palm oil biodiesel as a low-carbon source to reduce carbon emissions (Bentivoglio et al. 2018; Sakdasri et al. 2017). A detailed list of keywords according to their respective clusters is displayed in Table 2.

Journal and article linkage and relevance

This study conducted a bibliometric analysis to find out the relevance and link strength of the documents by keeping

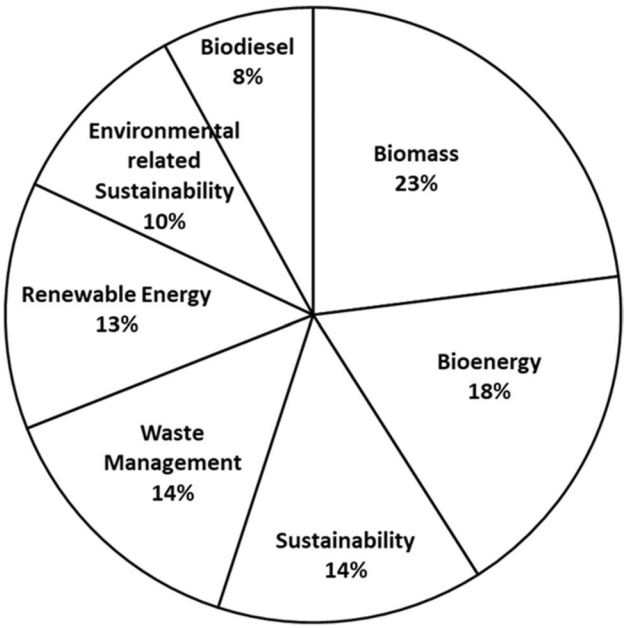

Fig. 4 Percentage distribution of major research topics

the minimum number of citations per document as 10 in the criteria for search. As a result, 56 sets out of 100 articles were acquired, as shown in Fig. 7. Similarly, the analysis was done on the journal sources by fixing the minimum number of source documents as one and citation as 1. Forty-nine out of 61 sources were acquired from the threshold level, as shown in Fig. 8.

*Journal of Cleaner P*roduction and *Biosource Technology* have published and linked with the greatest relevance to other sources. Therefore, Table 3 was tabulated to see the actual number of documents and citations and link strength meeting the analysis criteria to get a more detailed picture.

Relevance between countries

The criteria for this analysis were set to set the maximum number of countries per document at 20. The minimum number of documents per country was set at 2. Finally, the minimum number of citations per country was set at 2. A total of 17 countries' names were finalized out of an initial 36 that met the criteria. A density visualization of the results is shown in Fig. 9. Australia, Netherlands, Brazil, and United Arab Emirates have recently published a lot and Malaysia and Indonesia have published the maximum.

The results from VOSviewer show its efficiency as a tool for clustering publications, especially when compiling publication content and themes. Using VOSviewer offers useful knowledge graphics and easy-to-understand clustering content visualization. The software can also be used to accurately classify the density of keyword incidents at a total level. VOSviewer is also very helpful in finding differences in analysis or searching for certain trends and topics between several data. The visualization function can calculate the density of keywords in publications, even at an aggregate level. Studying the clusters obtained after

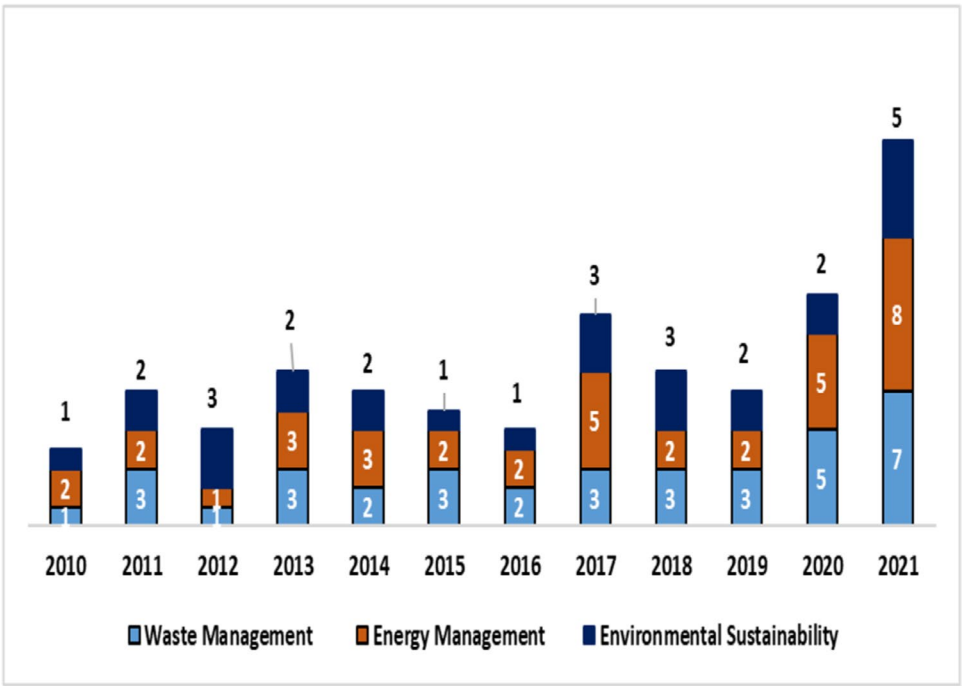

Fig. 5 Major research theme vs year of publication

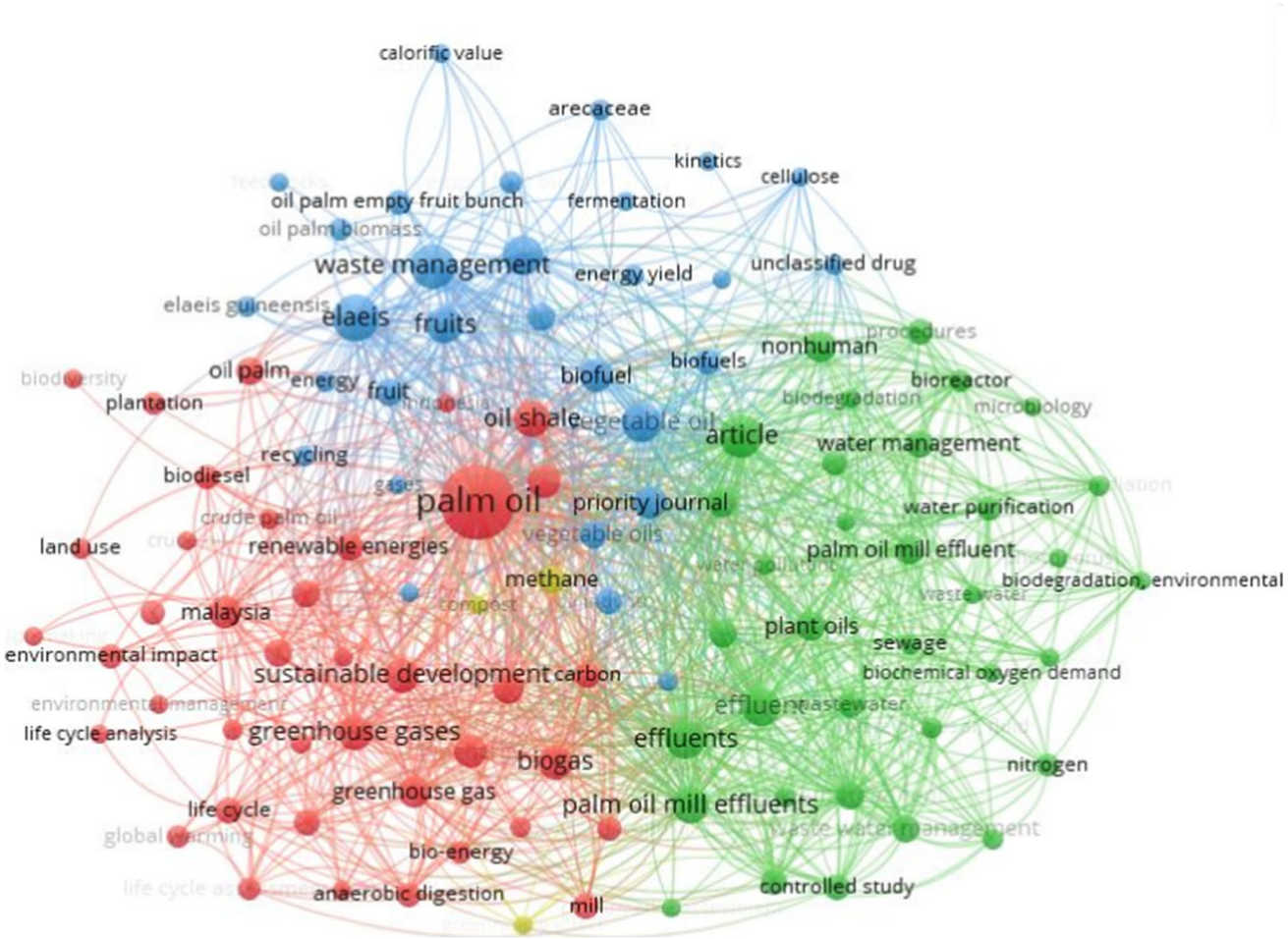

Fig. 6 Keyword occurences (bibliometric coupling)

Table 2 Cluster table for all keywords coupling

Cluster 1	Cluster 2	Cluster 3	Cluster 4
Bioenergy	Biodegradation	Biomass	Combustion
Biodiesel	Bioreactors	Energy efficiency	Greenhouse effect
Biogas	Bioremediation	Energy yield	Methane
Carbon dioxide	Effluent treatment	Recycling	
Carbon footprint	Industrial waste	Vegetable oils	
Climate change	Performance assessment		
Emission control	Water pollution		
Energy management	Wastewater management		
Environmental impact			
Global warming			
Greenhouse gas			
Life cycle analysis			
Renewable energy			
Sustainability			

extracting the data was extremely beneficial. It can show research gaps and changes in trends over a particular topic or field of study. This software provides a guide for future researchers interested in certain topics to conduct dynamic research.

Discussion

Environmental consciousness is critical for firms to add to their business strategies and gain a competitive advantage in the long run (Fernando et al. 2022b). It is also

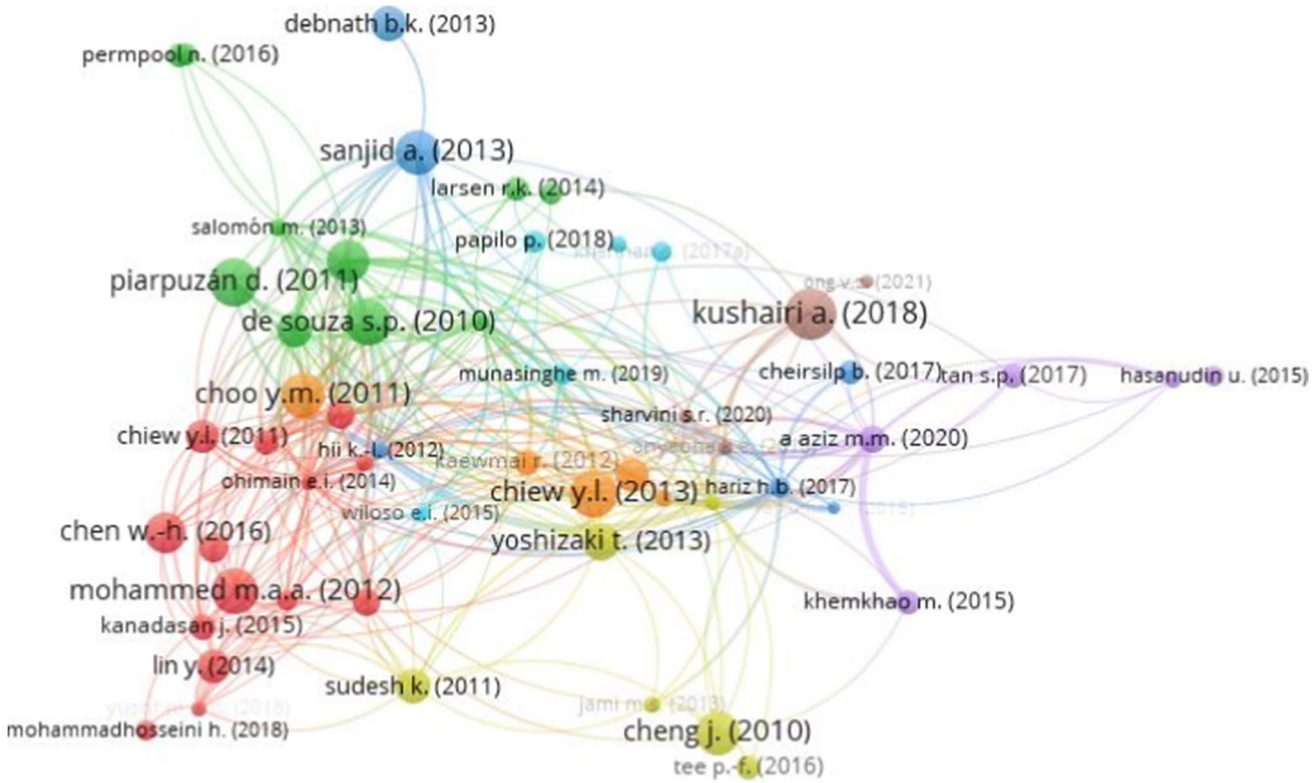

Fig. 7 Bibliometric coupling of documents sources

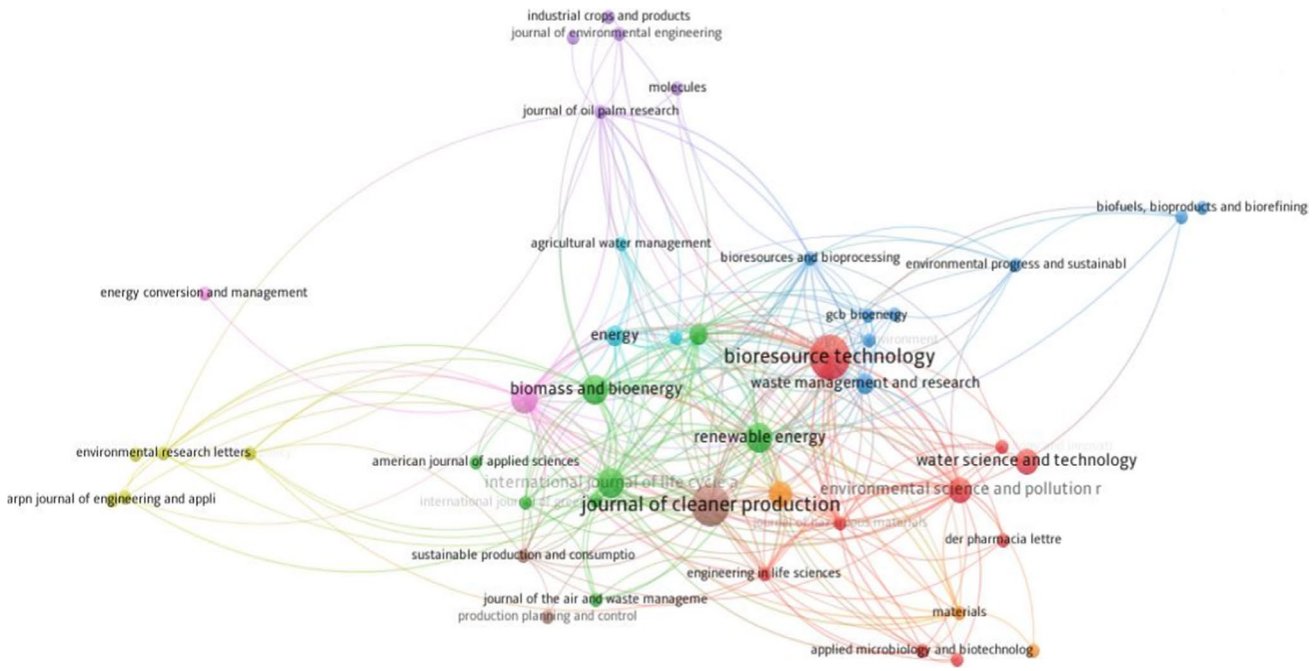

Fig. 8 Bibliometric coupling of journal sources

Table 3 Sources vs number of citations vs documents vs relevance strength

Sources	Number of documents	Citations	Total link strength
Renewable and Sustainable Energy Reviews	4	288	153
Renewable Energy	4	161	135
International Journal of Life Cycle Assessment	4	190	131
BioSource Technology	9	531	98
Environmental Science and Pollution Research	3	76	95
Journal of Cleaner Production	8	204	85
Biomass and Bioenergy	4	307	84
Journal of Hazardous Materials	1	11	74
Sustainability MDPI	2	23	67
Engineering in Life Sciences	1	17	47
BioSources and Bioprocessing	1	1	45
Chemical Engineering Transactions	3	14	35
Journal of Palm Oil Research	1	136	35
Sustainable Energy Technologies and Assessment	1	16	34
Waste Management and Research	2	20	31
Energy Sustainability and Society	1	7	26
Materials	1	36	26
Sustainable Production and Consumption	1	22	26

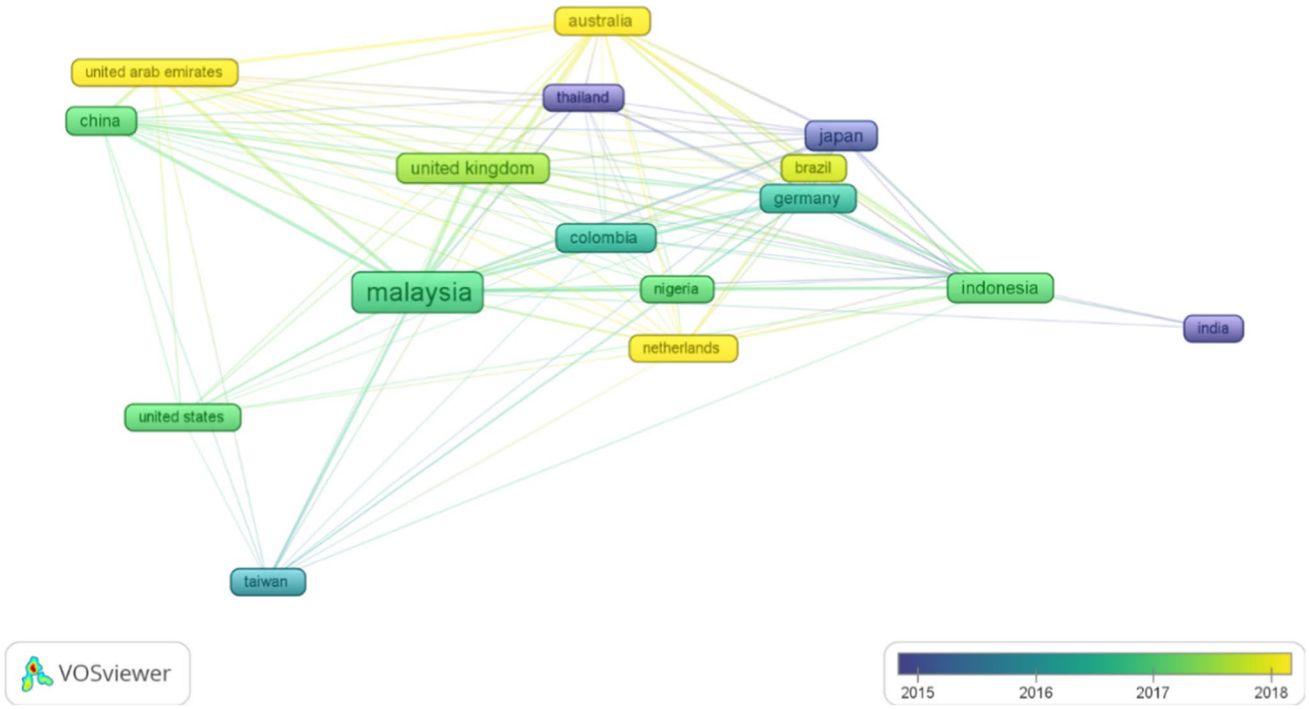

Fig. 9 Density visualization of countries

advantageous to have a green credential from the environmental protection perspective in the global market (Fernando et al. 2021a, b). The discussion and conclusion section aims to find a response to RQ5. RQ5 is focused on the potential biodiesel future research. After examining the literature, there are various implications for palm oil biodiesel studies. In addition, through social network research, the findings of palm oil biodiesel have provided

clear and easy guidance on which journals and databases contribute the most to this field of study. ScienceDirect (Elsevier) is a key platform for palm oil biodiesel literature in engineering, technology, or environmental research. Moreover, most energy-oriented articles related to palm oil biodiesel are found in ScienceDirect (Szulczyk and Atiqur 2018).

The results also showed important information regarding which journal contributes the most to palm oil biodiesel literature. The *Cleaner Production Journal* is a cross-cited journal by other journals such as science, engineering, and environment. Other journals published about palm oil biodiesel include *Energy Conversion Management*, *Energy Policy*, and the *Resources Journal.* However*, the Journal of Cleaner Production* remains the dominant contributor. When it comes to citation aspects, most of the citations on palm oil biodiesel also come from the *Journal of Cleaner Production* (ScienceDirect). In addition, while management and social science publications had a minor contribution, they still played a role in the growth of palm oil biodiesel research. We found that Web of Science and Scopus' indexed databases covered a wider area, including management and social science journals. It has contributed to handling managerial issues and behavioural sciences.

The largest producers and exporters of palm oil are Malaysia and Indonesia. They have implemented policies for the sustainable manufacturing of biodiesel. For instance, Malaysia's National Biofuel Policy (NBP) and Biofuel Industry Act (BIA) seek to develop biofuels environmentally and socially responsibly. As a preventative strategy to lessen dependency on dwindling oil supplies, provide security against fluctuating and rising oil prices and mitigate GHG emissions from conventional fuels. Ninety-two companies received licenses in response to these measures, with an annual aim of 10 million tons of palm oil biodiesel production (Farobie and Hartulistiyoso 2022). According to a literature review and projected future trends, palm oil biodiesel has four times the energy efficiency of soybean biodiesel, even under more favourable conditions for soybean biodiesel development (Queiroz et al. 2012).

Palm biodiesel represents foreign currency benefits for the country and the growth of jobs in rural areas and industry. In addition, biodiesel contributes to environmental sustainability and global warming mitigation. Furthermore, the growing biodiesel industry also supports agricultural employment. In addition to its contribution to the supply of food and energy, palm oil advances the sustainability and economic growth of the nations that produce it. The Malaysian government decided to boost palm oil production with a milestone of 26.6 million tonnes by 2035 to strengthen the economy. As of April 2017, 440,262 individuals in Malaysia were directly employed by the oil palm sector. By providing a key source of income, biodiesel laws and palm farming both directly and indirectly boost employers' socioeconomic position by raising their living standards (Nambiappan et al. 2018).

Biomass by-products from palm oil production, such as palm kernel shells, empty fruit bunches, and palm oil mill effluent, are also viable sources for decreasing GHG emissions while reducing solid waste and water pollution. Scholars focus on bioenergy and its therapies, evident from the bioenergy and energy policy literature in cluster 4. Therefore, employing biomass as a sustainability approach to maximise profits while avoiding potentially adverse environmental consequences (Tapia and Samsatli 2020). However, it has a significant amount of GHG production in the palm oil business. We argue that the GHG issue can be reduced by encouraging mills to handle their POME and prevent the release of methane.

Additionally, alternate uses for this biomass, such as manufacturing cellulosic ethanol, butanol, or bioelectricity, add value to the palm oil supply chain. It can also be looked into in the future as part of research initiatives. Consequently, biomass reduces GHG emissions even further and boosts the palm oil industry's productivity in terms of GHG emissions (Szulczyk and Atiqur 2018). Figure 8 shows the feasible research gaps and future research trends derived from the insights of this study.

Due to its versatility, efficiency, and low cost, palm oil is the most widely used raw material in vegetable oil production. However, the rise in industrial palm oil production has had significant environmental and socioeconomic implications, fueling arguments over the long-term viability of palm oil. Discourses can impact environmental policy and affect production, consumption, and trade relations. This study opens up many research gaps based on the findings and observations. There is a significant need to conduct further research on sustainable ecosystem management strategies (RQ1), energy management and policy (RQ2), more ASEAN (Indonesian and Malaysian) based case studies and fieldwork (RQ 3), rural development and livelihood prospects (RQ 4), and sustainable bioenergy processing methods (RQ 5). Most clusters focus on transforming palm oil biomass into biofuel (Fig. 10). Furthermore, the sustainable bioenergy domain should be given prioritised to some research areas, such as energy uncertainties and disruptions, alternative fuel production, storage, consumption, and recovery.

Furthermore, it is critical to investigate GHG, low carbon emissions, carbon footprint studies at various levels, and the value chain's life cycle. The biggest producers of palm oil are Indonesia and Malaysia, and more fieldwork, case studies, and evidence-based evaluations are needed to acquire ideas for worldwide applicability. Furthermore, this is the perfect location to confirm the prospects for rural livelihood improvement because of improved governance and technical advances in the biomass preparation cycle along this

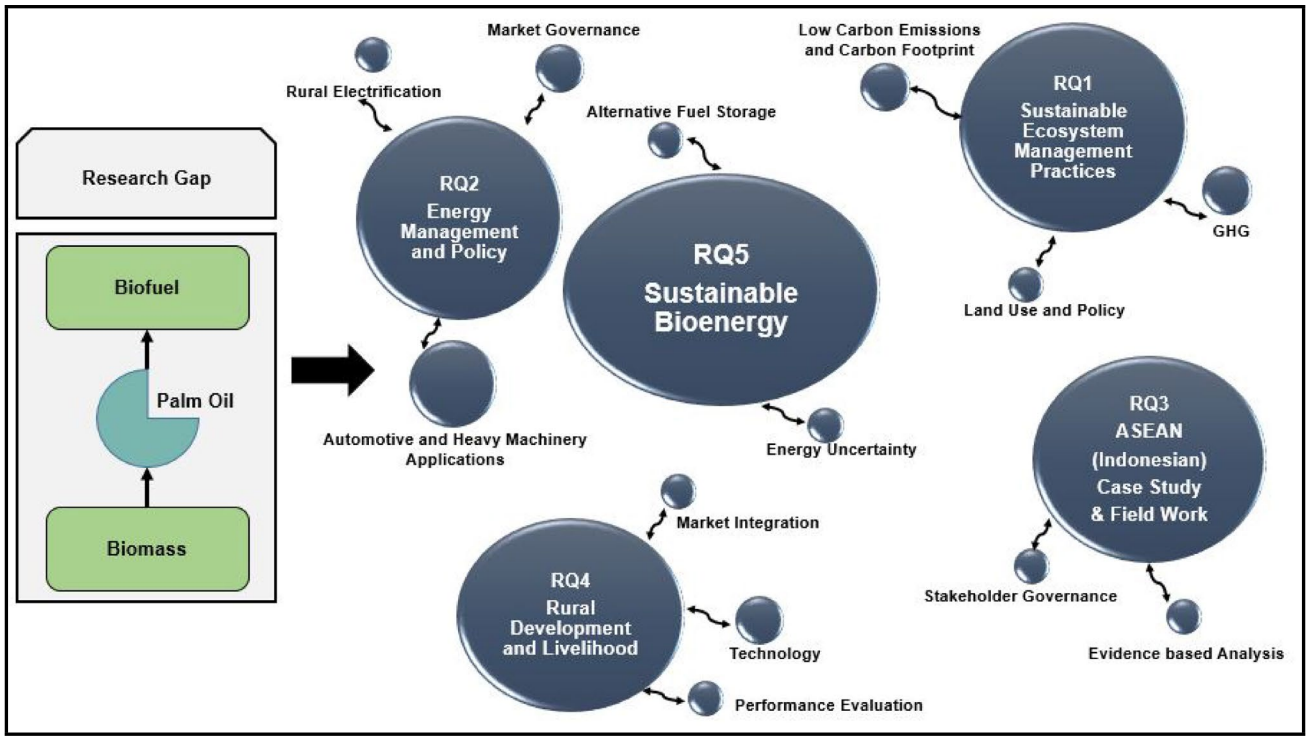

Fig. 10 Future research scope gaps based on research question and corresponding inferences

bioenergy journey. Ultimately, to establish new projects in the renewable energy market, the separate global scale of sophisticated energy management policy guidelines must be framed, particularly for this biomass to biofuel production. This study illustrated the connections and interactions between various research areas (smaller circle) and the relevant broad research scope (bigger circle) in Fig. 10.

Conclusion

Alternative fuel management is a significant challenge for countries with abundant fossil fuel supplies. Since the surge in fossil fuel prices, relying on renewable energies has been an energy-saving option. Furthermore, the public has become aware of the environmental issues caused by non-renewable fuels and is increasingly interested in renewable energy sources. Furthermore, practitioners and researchers urgently need to identify biodiesel palm oil's true environmental impact. As a result, several countries have proposed energy policies to include palm oil in their mix of renewable energy targets. However, there are still obstacles, such as tough global competition, feedstock problems, food versus fuel warfare, biodiversity, restricted land use, and deforestation. A contemporary issue is the European countries' ban on using palm oil in their energy mix due to deforestation. Therefore, the palm oil sector would only flourish if sustainable and energy management were followed. Another way for the palm oil industry toward sustainability is through having advanced farming systems and legislation to restrict forest destruction and limit GHGs emissions.

Furthermore, being accredited by international and local institutions is urgently needed for palm oil producers since its visibility in the food and energy market is better than other oils, such as soybean. Lastly, further studies are needed on palm oil biodiesel as an alternative fuel. Future research should also consider policy alignment with renewable energy incentives and conventional fuel subsidy reforms.

Author contribution Literature review screening, data collection, analysis, and first manuscript draft were performed by Mohammed Hammam Mohammed Al-Madani. First version writing and final version editing, improving the writing language and content of the manuscript were performed by Yudi Fernando. First version writing and final version editing were performed by Ming-Lang Tseng. First version writing and final version editing were performed by Ahmed Zainul Abideen. All authors commented on versions of the manuscript. All authors read and approved the final manuscript.

Funding This study is funded by the Division of Research and Innovation, Universiti Malaysia Pahang (RDU1903126; PDU203220; UIC211502; RDU212701). This study is partially supported by the National Science and Technology Council, Taiwan (NSTC 111–2221-E-468–008-MY3).

Data availability Not applicable.

Declarations

Ethical approval and consent to participate Not applicable.

Consent for publication Not applicable.

Conflict of interest The authors declare no competing interests.

References

Abideen AZ, Mohamad FB, Fernando Y (2020) Lean simulations in production and operations management–a systematic literature review and bibliometric analysis. J Model Manag. https://doi.org/10.1108/JM2-05-2019-0103

Abukhadra MR, Dardir FM, Shaban M, Ahmed EA, Soliman MF (2018) Spongy Ni/Fe carbonate-fluorapatite catalyst for efficient conversion of cooking oil waste into biodiesel. Environ Chem Lett 16(2):665–670. https://doi.org/10.1007/s10311-017-0695-2

Ahmad FB, Zhang Z, Doherty WOS, O'Hara IM (2019) The outlook of the production of advanced fuels and chemicals from integrated oil palm biomass biorefinery. Renew Sustain Energy Rev 109:386–411. https://doi.org/10.1016/j.rser.2019.04.009

Al-Madani MHM, Fernando Y, Tseng ML (2022) Assuring energy reporting integrity: Government policy's past, present, and future roles. Sustainability 14(22):15405

Altarazi YS, Yusaf T, Yu J, Gires E, Ghafir MFA, Lucas J (2022) A review of engine performance and emissions using single and dual biodiesel fuels: Research paths, challenges, motivations and recommendations. Fuel 326:125072

Amini Z, Ilham Z, Ong HC, Mazaheri H, Chen WH (2017) State of the art and prospective of lipase-catalysed transesterification reaction for biodiesel production. Energy Convers Manag 141:339–353. https://doi.org/10.1016/j.enconman.2016.09.049

Archer SA, Murphy RJ, Steinberger-Wilckens R (2018) Methodological analysis of palm oil biodiesel life cycle studies. Renew Sustain Energy Rev 94:694–704. https://doi.org/10.1016/j.rser.2018.05.066

Arumugam A, Ponnusami V (2019) Biodiesel production from Calophyllum inophyllum oil a potential non-edible feedstock: an overview. Renew Energy 131:459–471. https://doi.org/10.1016/j.renene.2018.07.059

Bentivoglio D, Finco A, Bucci G (2018) Factors affecting the indonesian palm oil market in food and fuel industry: Evidence from a time series analysis. Int J Energy Econ Policy 8(5):49

Bicalho T, Bessou C, Pacca SA (2016) Land use change within EU sustainability criteria for biofuels: the case of oil palm expansion in the Brazilian Amazon. Renew Energy 89:588–597. https://doi.org/10.1016/j.renene.2015.12.017

Cantarero MMV (2020) Of renewable energy, energy democracy, and sustainable development: a roadmap to accelerate the energy transition in developing countries. Energy Res Soc Sci 70:101716. https://doi.org/10.1016/j.erss.2020.101716

Castanheira ÉG, Freire F (2017) Environmental life cycle assessment of biodiesel produced with palm oil from Colombia. Int J Life Cycle Assess 22(4):587–600. https://doi.org/10.1007/s11367-016-1097-6

Chatterjee R, Sharma V, Kumar S (2012) Life cycle assessment of energy performance of biodiesel produced from Jatropha curcas. J Renew Sustain Energy 4(5):053110. https://doi.org/10.1063/1.4754156

Chen S, Zhou G, Miao C (2019) Green and renewable biodiesel produce from oil hydrodeoxygenation: strategies for catalyst development and mechanism. Renew Sustain Energy Rev 101:568–589. https://doi.org/10.1016/j.rser.2018.11.027

Erdiwansyah MR, Sani MSM, Sudhakar K, Kadarohman A, Sardjono RE (2019) An overview of Higher alcohol and biodiesel as alternative fuels in engines. Energy Rep 5:467–479. https://doi.org/10.1016/j.egyr.2019.04.009

Esmaeili H (2022) A critical review on the economic aspects and life cycle assessment of biodiesel production using heterogeneous nanocatalysts. Fuel Process Technol 230:107224. https://doi.org/10.1016/j.fuproc.2022.107224

Farid MAA, Hassan MA, Othman MR, Shirai Y, Ariffin H (2019) Sustainability of oil palm biomass-based products. Chapter 10 in lignocellulose for future bioeconomy, chapter 10. Elsevier, pp 207–242. https://doi.org/10.1016/B978-0-12-816354-2.00012-8

Farobie O, Hartulistiyoso E (2022) Palm oil biodiesel as a renewable energy resource in Indonesia: current status and challenges. Bioenerg, Res 15:93–111. https://doi.org/10.1007/s12155-021-10344-7

Fernando Y, Hor WL (2017) Impacts of energy management practices on energy efficiency and carbon<emissions, reduction: a, survey, of, Malaysian, manufacturing, firms. Resour Conserv Recycl 126:62–73. https://doi.org/10.1016/j.resconrec.2017.07.023

Fernando Y, Rozuar NHM, Mergeresa F (2021a) The blockchain-enabled technology and carbon performance: Insights from early adopters. Technol Soc 64:101507. https://doi.org/10.1016/j.techsoc.2020.101507

Fernando Y, Tseng ML, Sroufe R, Abideen AZ, Shaharudin MS, Jose R (2021b) Eco-innovation impacts on recycled product performance and competitiveness: Malaysian automotive industry. Sustain Prod Consum 28:1677–1686. https://doi.org/10.1016/j.spc.2021.09.010

Fernando Y, Tseng ML, Aziz N, Ikhsan RB, Wahyuni-TD IS (2022a) Waste-to-energy supply chain management on circular economy capability: an empirical study. Sustain Prod Consum 31:26–38. https://doi.org/10.1016/j.spc.2022.01.032

Fernando Y, ShaharudinAbideen MSAZ (2022b) Circular economy-based reverse logistics: dynamic interplay between sustainable resource commitment and financial performance. Eur J Manag Bus Econ. https://doi.org/10.1108/EJMBE-08-2020-0254

Foo K (2015) A vision on the opportunities, policies and coping strategies for the energy security and green energy development in Malaysia. Renew Sust Energ Rev 51:1477–1498. https://doi.org/10.1016/j.rser.2015.07.041

Hassan SN, Sani YM, Abdul Aziz AR, Sulaiman NMN, Daud WMAW (2015) Biogasoline: an out-of-the-box solution to the food-for-fuel and land-use competitions. Energy Convers Manag 89:349–367. https://doi.org/10.1016/j.enconman.2014.09.050

Hoang AT, Tabatabaei M, Aghbashlo F, Carlucci AP, Olcer AI, At Le, Ghassemi A (2021) Rice bran oil-based biodiesel as a promising renewable fuel alternative to petrodiesel: a review. Renew Sust Energ Rev 135:110204. https://doi.org/10.1016/j.rser.2020.110204

Hossain MA, Jewaratnam J, Ganesan P (2016) Prospect of hydrogen production from oil palm biomass by thermochemical process – A review. Int J Hydrog Energy 41(38):16637–16655. https://doi.org/10.1016/j.ijhydene.2016.07.104

Huber GW, Iborra S, Corma A (2006) Synthesis of transportation fuels from biomass: chemistry, catalysts, and engineering. Chem Rev 106(9):4044–4098. https://doi.org/10.1021/cr068360d

Jain SK, Kumar S, Chaube A (2021) Biodiesel promotion policies: a global perspective in biodiesel fuels, vol 1, chapter 17. CRC Press, pp 343–353

Kamahara H, Hasanudin U, Widiyanto A, Tachibana R, Atsuta Y, Goto N, Daimon H, Fujie K (2010) Improvement potential for net energy balance of biodiesel derived from palm oil: a case study

from Indonesian practice. Biomass Bioenerg 34(12):1818–1824. https://doi.org/10.1016/j.biombioe.2010.07.014
Khudzari JM, Kurian J, Tartakovsky B, Raghavan GV (2018) Bibliometric analysis of global research trends on microbial fuel cells using Scopus database. Biochem Eng J 136:51–60. https://doi.org/10.1016/j.bej.2018.05.002
Konur O (2021) Biodiesel and petrodiesel fuels: science, technology, health, and the environment in biodiesel fuels, vol 1, chapter 1. CRC Press, pp 3–36
Kovač A, Paranos M, Marciuš D (2021) Hydrogen in energy transition: A review. Int J Hydrog Energy 46(16):10016–10035
Larsen RK, Osbeck M, Dawkins E, Tuhkanen H, Nguyen H, Nugroho A, Gardner TA, Wolvekamp P (2018) Hybrid governance in agricultural commodity chains: insights from implementation of 'No Deforestation, No Peat, No Exploitation' (NDPE) policies in the oil palm industry. Clen Prod J 183:544–554. https://doi.org/10.1016/j.jclepro.2018.02.125
Lawrence A, Nehler T, Andersson E, Karlsson M, Thollander P (2019) Drivers, barriers and success factors for energy management in the Swedish pulp and paper industry. Clen Prod J 223:67–82. https://doi.org/10.1016/j.jclepro.2019.03.143
Lee S, Posarac D, Ellis N (2011) Process simulation and economic analysis of biodiesel production processes using fresh and waste vegetable oil and supercritical methanol. Chem Eng Res Des 89(12):2626–2642. https://doi.org/10.1016/j.cherd.2011.05.011
Lee CT, Hashim H, Ho CS, Van Fan Y, Klemeš JJ (2017) Sustaining the low-carbon emission development in Asia and beyond: Sustainable energy, water, transportation and low-carbon emission technology. Clean Prod J 146:1–13. https://doi.org/10.1016/j.jclepro.2016.11.144
Loh SK (2017) The potential of the Malaysian oil palm biomass as a renewable energy source. Energy Convers Manag 141:285–298. https://doi.org/10.1016/j.enconman.2016.08.081
Maharjan S, Wang WC, Teah HY (2017) Life cycle assessment of palm-derived biodiesel in Taiwan. Clean Technol Environ Policy 19(4):959–969. https://doi.org/10.1007/s10098-016-1290-0
Mahlia TMI, Ismail N, Hossain N, Silitonga AS, Shamsuddin AH (2019) Palm oil and its wastes as bioenergy sources: a comprehensive review. Environ Sci Poll Res. https://doi.org/10.1007/s11356-019-04563-x
Mahmud MI, Cho HM (2018) A review on characteristics, advantages and limitations of palm oil biofuel. Int J Glob Warm 14(1):81–96. https://doi.org/10.1504/IJGW.2018.10009446
Makarfi IY, Ganda ET (2018) Bio-oil as a potential source of petroleum range fuels. Renew Sustain Energy Rev 81:69–75. https://doi.org/10.1016/j.rser.2017.07.036
Marin-Burgos V, Clancy JS (2017) Understanding the expansion of energy crops beyond the global biofuel boom: evidence from oil palm expansion in Colombia. Energy Sustain Soc 7(1):1–21. https://doi.org/10.1186/s13705-017-0123-2
Mat YMH, Mamat R, Najafi G, Ali OM, Yusop AF, Ali MH (2017) Potentials of palm oil as new feedstock oil for a global alternative fuel: a review. Renew Sustain Energy Rev 79:1034–1049. https://doi.org/10.1016/j.rser.2017.05.186
Mazivila SJ (2018) Trends of non-destructive analytical methods for identification of biodiesel feedstock in diesel-biodiesel blend according to European Commission Directive 2012/0288/EC and detecting diesel-biodiesel blend adulteration: a brief review. Talanta 180:239–247. https://doi.org/10.1016/j.talanta.2017.12.057
Mekhilef S, Siga S, Saidur R (2011) A review on palm oil biodiesel as a source of renewable fuel. Renew Sustain Energy Rev 15(4):1937–1949. https://doi.org/10.1016/j.rser.2010.12.012
Mirkouei A, Haapala KR, Sessions J, Murthy GS (2017) A review and future directions in techno-economic modeling and optimisation of upstream forest biomass to bio-oil supply chains. Renew Sustain Energy Rev 67:15–35. https://doi.org/10.1016/j.rser.2016.08.053
Nambiappan B, Ismail A, Hashim N, Ismail N, Shahari DN, Idris NA, Omar N, Salleh KM, Hassan NA, Kushairi A (2018) Malaysia: 100 years of resilient palm oil economic performance. Oil Palm Res J 30(1):13–25. https://doi.org/10.21894/jopr.2018.0014
Naylor RL, Higgins MM (2017) The political economy of biodiesel in an era of low oil prices. Renew Sustain Energy Rev 77:695–705. https://doi.org/10.1016/j.rser.2017.04.026
Ng RT, Ng DK, Tan RR (2013) Systematic approach for synthesis of integrated palm oil processing complex. Indus Eng Chem Res 52(30):10221–10235. https://doi.org/10.1021/ie400846g
Noor CM, Noor M, Mamat R (2018) Biodiesel as alternative fuel for marine diesel engine applications: a review. Renew Sustain Energy Rev 94:127–142. https://doi.org/10.1016/j.rser.2018.05.031
Nutongkaew P, Waewsak J, Riansut W, Kongruang C, Gagnon Y (2019) The potential of palm oil production as a pathway to energy security in Thailand. Sustain Energy Technol Assess 35:189–203
Örs İ (2020) Experimental investigation of the cetane improver and bioethanol addition for the use of waste cooking oil biodiesel as an alternative fuel in diesel engines. J Brazilian Soc Mech Sci Eng 42:1–14. https://doi.org/10.1007/s40430-020-2270-1
Pandey KM, Sharma D (2018) Ecological friendly functional fluids and lubricant techniques in machining processes: a review. 1(2):182–196. https://doi.org/10.1504/IJHM.2018.092730
Perianes-Rodriguez A, Waltman L, Van Eck NJ (2016) Constructing bibliometric networks: a comparison between full and fractional counting. Informetrics J 10(4):1178–1195. https://doi.org/10.1016/j.joi.2016.10.006
Phuang ZX, Lin Z, Liew PY, Hanafiah MM, Woon KS (2022) The dilemma in energy transition in Malaysia: a comparative life cycle assessment of large scale solar and biodiesel production from palm oil. Clean Prod 350:131475. https://doi.org/10.1016/j.jclepro.2022.131475
Popa, VI (2021) Biomass and sustainability. In sustainability of biomass through bio-based chemistry, chapter 1. CRC Press, pp 1–33
Pourzolfaghar H, Abnisa F, Daud WM, Aroua MK (2018) Atmospheric hydrodeoxygenation of bio-oil oxygenated model compounds: a review. J Anal Appl Pyrolysis 133:117–127. https://doi.org/10.1016/j.jaap.2018.04.013
Prapaspongsa T, Musikavong C, Gheewala SH (2017) Life cycle assessment of palm biodiesel production in Thailand: impacts from modelling choices, co-product utilisation, improvement technologies, and land use change. J Clean Prod 153:435–447. https://doi.org/10.1016/j.jclepro.2017.03.130
Queiroz AG, França L, Ponte MX (2012) The life cycle assessment of biodiesel from palm oil ("dendê") in the Amazon. Biomass Bioenerg 36:50–59. https://doi.org/10.1016/j.biombioe.2011.10.007
Reijnders L (2006) Conditions for the sustainability of biomass based fuel use. Energy Pol 34(7):863–876. https://doi.org/10.1016/j.enpol.2004.09.001
Rulli MC, Casirati S, Dell'Angelo J, Davis KF, Passera C, D'Odorico P (2019) Interdependencies and telecoupling of oil palm expansion at the expense of Indonesian rainforest. Renew Sustain Energy Rev 105:499–512. https://doi.org/10.1016/j.rser.2018.12.050
Sakdasri W, Sawangkeaw R, Ngamprasertsith S (2017) An entirely renewable biofuel production from used palm oil with supercritical ethanol at low molar ratio. Brazilian J Chem Eng 34(4):1023–1034. https://doi.org/10.1590/0104-6632.20170344s20150660
Shaharudin MS, Fernando Y, Jabbour CJC, Sroufe R, Jasmi MFA (2019) Past, present, and future low carbon supply chain management: a content review using social network analysis. J Clean Prod J 218:629–643. https://doi.org/10.1016/j.jclepro.2019.02.016

Shuit SH, Tan KT, Lee KT, Kamaruddin A (2009) Oil palm biomass as a sustainable energy source: a Malaysian case study. Energy 34(9):1225–1235. https://doi.org/10.1016/j.energy.2009.05.008

Silalahi FTR, Simatupang TM, Siallagan MP (2020) Biodiesel produced from palm oil in Indonesia: current status and opportunities. AIMS Energy 8:81–101. https://doi.org/10.3934/energy.2020.1.81

Singh D, Sharma D, Soni SL, Sharma S, Kumar Sharma P, Jhalani A (2020) A review on feedstocks, production processes, and yield for different generations of biodiesel. Fuel 262:116553

Somnuek S, Slingerland M (2018) Can good agricultural practices sustain oil palm yields for bioenergy production in northeast, thailand? Exp Agric 4(6):915–930. https://doi.org/10.1017/S0014479717000497

Suksong W, Tukanghan W, Promnuan K, Kongjan P, Reungsang A, Insam H, Sompong O (2020) Biogas production from palm oil mill effluent and empty fruit bunches by coupled liquid and solid-state anaerobic digestion. Bioresource Technol 296:122304. https://doi.org/10.1016/j.biortech.2019.122304

Szulczyk KR, Atiqur RKM (2018) The potential and environmental ramifications of palm biodiesel: evidence from, Malaysia. J Clean Prod 203:260–272. https://doi.org/10.1016/j.jclepro.2018.08.241

Tapia JFD, Samsatli S (2020) Integrating fuzzy analytic hierarchy process into a multi-objective optimisation model for planning sustainable oil palm value chains. Food Bioprod Process 119:48–74. https://doi.org/10.1016/j.fbp.2019.10.002

Tseng ML, Tran TPT, Ha HM, Bui TD, Lim MK (2021) Sustainable industrial and operation engineering trends and challenges towards Industry 4.0: a data driven analysis. J Indus Produc Eng 38(8):581–598. https://doi.org/10.1080/21681015.2021.1950227

Umar MS, Urmee T, Jennings P (2018) A policy framework and industry roadmap model for sustainable oil palm biomass electricity generation in Malaysia. Renewable Energy 128:275–284. https://doi.org/10.1016/j.renene.2017.12.060

Waltman L, Van Eck NJ, Noyons EC (2010) A unified approach to mapping and clustering of bibliometric networks. J Informetrics 4(4):629–635. https://doi.org/10.1016/j.joi.2010.07.002

Wang Y, Liu H, Lee CFF (2016) Particulate matter emission characteristics of diesel engines with biodiesel or biodiesel blending: a review. Renew Sustain Energy Rev 64:569–581. https://doi.org/10.1016/j.rser.2016.06.062

Wang L, Zhao L, Mao G, Zuo J, Du H (2017) Way to accomplish low carbon development transformation: a bibliometric analysis during 1995–2014. Renew Sustain Energy Rev 68:57–69. https://doi.org/10.1016/j.rser.2016.08.021

Wright T, Rahmanulloh A. Abdi A (2017) Indonesia Biofuels Annual Report Jakarta.,URL: https://gain.fas.usda.gov/RecentGAINPublications/Biofuels Annual_Jakarta_Indonesia_6–20–2017.Pdf

Yavari M, Ajalli P (2021) Suppliers' coalition strategy for green-Resilient supply chain network design. J Ind Prod Eng 38(3):197–212. https://doi.org/10.1080/21681015.2021.1883134

Yusoff MNAM, Zulkifli NWM, Sukiman NL et al (2021) Sustainability of palm biodiesel in transportation: a review on biofuel standard, policy and international collaboration between Malaysia and Colombia. Bioenergy Res 14:43–60. https://doi.org/10.1007/s12155-020-10165-0

Zahan KA, Kano M (2018) Biodiesel production from palm oil, its by-products, and mill effluent: a review. Energies 11(8):2132. https://doi.org/10.3390/en11082132

Zhu H, Luo W, Ciesielski PN, Fang Z, Zhu JY, Henriksson G, Hu L (2016) Wood-derived materials for green electronics, biological devices, and energy applications. Chem Rev 116(16):9305–9374. https://doi.org/10.1021/acs.chemrev.6b00225

Zou H, Du H, Wang Y, Zhao L, Mao G, Zuo J, Huisingh D (2017) A review of the first twenty-three years of articles published in the Journal of Cleaner Production: with a focus on trends, themes, collaboration networks, low/no-fossil carbon transformations and the future. J Clean Prod 163:1–14. https://doi.org/10.1016/j.jclepro.2017.04.157