International Journal of Economic, Business, Accounting, Agriculture Management and Sharia Administration (IJEBAS)

International Journal of Economic, Business, Accounting, Agriculture Management and Sharia Administration (IJEBAS Journal) | ISSN (e): 2808-4713
Volumes 5 No. 1 (2025)

ECONOMIC AND FINANCIAL FEASIBILITY ANALYSIS OF B50 BIODIESEL IMPLEMENTATION IN INDONESIA

Dyah Ratna Paramith*
School of Business and Management Institut Teknologi Bandung

Received	: 27 December 2024	Published	: 26 February 2025
Revised	: 12 January 2025	DOI	: 10.54443/ijebas.v5i1.2500
Accepted	: 29 January 2025	Link Publish	: https://radjapublika.com/index.php/IJEBAS

Abstract

B50 biodiesel implementation in Indonesia is an important step towards energy security, reducing dependence on fossil fuels, and promoting sustainability in the palm oil industry. This research attempts to analyze the economic and financial viability of B50 biodiesel by examining supply-demand dynamics, cost structures, investment requirements, and market pricing mechanisms. Furthermore, it analyzes the impact of B50 on the domestic palm oil industry, the prospects for export activity, and how financially sustainable are its implementations. The methods mixed were employed, using qualitative and quantitative analysis. Data were obtained from government reports, industry publications, expert interviews, and econometric modeling. The study analyzes past biodiesel policies, the regulatory framework, and how these factors influence subsidies and incentives in making B50 commercially viable. With respect to the economic aspect, production costs, profitability projections, and risk assessment were performed to achieve a conclusive financial assessment. The research argues that the B50 option will greatly reduce foreign exchange outflow, enhance energy security, and present challenges in terms of supply chain stability, pricing, and market competition. The report underscores the need for policy intervention to put in place better infrastructure, financing regime, and regulatory framework to counter these risks. International trade policies, including the EUDR, create future export challenges for Indonesian palm oil, thereby necessitating proper strategizing concerning the adjustment of domestic consumption and production planning. Lastly, the study concludes that the government support with joint cooperation from the industries will determine the economic and financial viability of B50 biodiesel. Recommended policies include better utilization of degraded lands, improved productivity of smallholders, and ensuring financial incentives for stakeholders. This study is aimed at adding to the ongoing debate regarding sustainable energy policies, which will, with this study, serve as one of the main early references for future biodiesel development strategies in Indonesia.

Keywords: ***Biodiesel, B50 Policy, Palm Oil Supply-Demand, Energy Security, Financial Feasibility, Sustainability, Biofuel Investment***

INTRODUCTION

Petrodiesel and petroleum-based products are heavily exploiting petroleum resources. Very intensive energy demand has been generated due to the fast increasing industrialization, fast increasing transportation, fast increasing urbanization, and a fast-growing population. This scenario is causing a quick exhaustion of non-renewable fossil resources by keeping human civilization on the border of the energy crisis. In addition, since the combustion of fossil fuels increases emissions of greenhouse gases and hence is a major contributor to global warming, it has been implicated very much in environmental deterioration. Fuels are the backbone of modern living-from cooking to running heavy machines-and fossil fuels form the bulk of these sources. Fuel is absolutely essential for society's continuity and development. Studies predict that by the year 2030 there will be an energy demand crisis and there will not be any fossil fuel left for human use by the year 2060. Considering the present degenerative scenario, the scientific community is looking for alternate energy sources and has now diverted its focus toward the renewability of these energy sources and environmental friendly development. Researchers are now advancing the techniques of exploiting renewable and green energy resources-sun, wind, hydro, ocean, tidal-for energy generation, but none of them can meet the criteria for substitution as conventional fossil fuels. Hence there is an urge for a viable renewable green fuel to survive in the present deteriorating scenario. Biofuels, biodiesel which comprises bioethanol, biodiesel, and biogas, are emerging as frontrunners to satisfy future

demands. For over two decades, biodiesel has considered itself a potent substitute for fossil fuel due to its very comparable properties to petrodiesel. Advantages that biodiesel enjoys over petrodiesel and that are relevant to compression ignition engine design considerations are low viscosity, high flash point, high cetane number, good lubricity, biodegradable, non-toxic, and less greenhouse gas emissions. It also has lower ignition delay time and increased combustion efficiency, which adds to the advantages for good engine life. Therefore, biodiesel is being seriously considered by scientists, while various researchers are working toward making it sustainable for mass consumption.

Biodiesel is the alcoholic esters of the mixtures of fatty acids, commonly known as FAME (fatty acid methyl esters) which are prepared from vegetable oils, microalgae lipids, animal fats, and sewage sludge by several processes of which transesterification is the most convenient and widely used method. In transesterification, the triglyceride molecule is allowed to react with methanol with the help of a catalyst. Both homogeneous and heterogeneous transesterifications as well as enzyme-catalyzed transesterifications are reported for biodiesel production. Except for renewability and environmentally friendliness, cost-effective and sustainable are also important issues to consider in the search for alternative fuel for future use. These are heavily relative to feedstock availability and cost. Different oil feedstocks such as soybean oil, sunflower oil, palm oil, jatropha oil, pongamia oil, yellow oleander oil, castor oil, neem oil, rubber oil, along with animal fat, microalgal lipid, sewage sludge, and waste cooking oil (WCO) are used for biodiesel production.

Indonesia, as the world's largest palm oil producer, manages an extensive plantation area of 16.8 million hectares, yielding approximately 46 million tons of crude palm oil (CPO) in 2022. With its ambitious Golden Indonesia 2045 Vision, the country aims to double its CPO production to 100 million tons. However, achieving this target presents significant challenges, not only in ensuring food and energy sovereignty but also in maintaining sustainable export growth and aligning with the Sustainable Development Goals (SDGs).

In the context of food and energy security, securing the domestic supply of raw materials for cooking oil and biofuel (B50) has become a national priority. The mandatory biodiesel program, which mandates the progressive increase in biodiesel blending up to 50% (B50), plays a crucial role in reducing Indonesia’s dependence on fossil fuels. This policy was primarily driven by global crude oil price fluctuations. According to World Bank (2023), the real crude oil price surged from USD 46.86 per barrel in 2016 to USD 74.23 per barrel in 2023, significantly straining Indonesia’s state budget (APBN) through fuel subsidies. The B50 mandate not only mitigates this burden but also reinforces Indonesia’s commitment to renewable energy adoption.

Indonesia’s palm oil export landscape has undergone substantial shifts. Despite being the leading global supplier, Indonesia’s market share in the global vegetable oil trade has declined from 38.47% in 2015 to 32.54% in 2022 (UNCOMTRADE 2023). This decrease is primarily attributed to rising domestic consumption, driven by Indonesia’s downstream industrial policies. According to Indexmundi (2023), Indonesia accounted for 26.02% of global palm oil consumption in 2023, making it the world’s largest consumer. The downstream industry (hilirisasi) strategy implemented by the Indonesian government follows three key pathways: increasing the use of palm oil in food processing industries (oleofood), expanding palm-based chemicals for pharmaceuticals, cosmetics, and detergents (oleochemicals), and supporting renewable energy initiatives through biodiesel development (biofuel).

The introduction of the European Union Deforestation-Free Regulation (EUDR) presents both challenges and opportunities for Indonesia’s palm oil sector. The regulation, aimed at ensuring supply chains are free from deforestation, poses a significant trade barrier for Indonesian palm oil exports to Europe. On one hand, the B50 policy helps absorb excess domestic palm oil supply, potentially mitigating the impact of reduced European demand due to EUDR restrictions. On the other hand, prioritizing biodiesel production may reduce crude palm oil (CPO) exports, impacting government revenue from export duties and levies.

To sustain its global leadership and meet the Golden Indonesia 2045 targets, Indonesia must adopt a balanced approach by enhancing sustainability practices to meet international environmental standards, ensuring market access in Europe and other regions, boosting domestic value-added industries through continued downstream expansion in oleofood, oleochemicals, and biofuel sectors, diversifying export markets beyond Europe by targeting growing demand in China, India, and Africa, and optimizing biodiesel policies to strike a balance between domestic energy security and export revenue preservation. In summary, while Indonesia's B50 biodiesel mandate and downstream policies strengthen its domestic palm oil industry, strategic measures are essential to navigate evolving global trade regulations, maintain export competitiveness, and achieve long-term sustainability.

LITERATURE REVIEW

Basic Oleochemical Industry

The oleochemical industry is one of the important ones along the palm oil value chain, where various intermediate products are manufactured from the crude palm oil (CPO) and palm kernel oil (PKO) that are the primary raw materials in this industry. These intermediates include fatty acids, fatty alcohols, fatty amines, methyl esters, and glycerol, all of which are important inputs in the downstream industries of pharmaceuticals, toiletries, and cosmetics (Depperin 2009; ICN 2009; Gumbira-Sa'id 2010). The growing application of these products is one highlight showing the multipurpose nature of palm oil-derived chemicals, secondly in food and also non-food applications.

Indonesia produced a record 54.8 million tons of palm oil in 2023, increasing approximately 7 percent from the previous record of 51.2 million tons in 2022. Crude palm oil (CPO) accounted for 50.1 million tons, while crude palm kernel oil (CPKO) contributed 4.7 million tons. This continuous increase in production signifies Indonesia's leadership as the world's largest producer of palm oil and showcases the growth of the sector in spite of the constraints posed by global market trends. On the other hand, palm oil consumption in Indonesia increased in volume to 23.2 million tons in 2023, an increase of 10.7 percent over the 20.9 million tons consumed in 2022. Food consumption remains the largest share of domestic use, with a consumption volume of 10.2 million tons in 2023, a nominal 3.6 percent increase from 9.9 million tons in 2022. However, the most significant rise occurred in biodiesel, with 10.6 million tons being consumed in 2023-an impressive leap of 20.4 percent from the 8.8 million tons consumed in 2022. This sudden surge in biodiesel consumption goes on to prove the success of Indonesia's biofuel policies aimed at reducing dependence on fossil fuels and providing sustainable energy solutions. The oleochemical industry utilized 2.3 million tons of palm oil in 2023, a growth of 3.7% over the two million tons used in 2022. This growth is indicative of the increasing industrial demand for palm oil derivatives.

Current Condition of Basic Oleochemical and Biodiesel Industry

The government sees the industries of Basic Oleochemical and Chemurgi in Indonesia as among the key upstream areas in need of development as part of an industrial strategy. These industries are being prioritized according to the National Industrial Development Master Plan (RIPIN) 2015–2035) in developing three major upstream agro-industries: oleofood, oleochemical, and chemurgi (bio-based chemical industries). These industries are very important to help the country grow its bio-based economy while allowing greater value-added processing of palm oil and its derivatives, thus reducing its dependence on imported chemical and fuel products.

The oleofood industry aims for commercialization by concentrating on the high-value conversion of palm oil derivatives into food ingredients such as olein, stearin, glycerol, PFAD, cocoa butter substitutes, margarine, shortening, and specialty fats. Beyond the primary products, other products targeted for development include tocopherol, beta-carotene, organic acids, and alcohols from the waste of the palm oil industry. These innovations will meet the growing demand for healthier food products and functional food ingredients while enhancing Indonesia's presence in the global food supply chain.

Biodiesel Production Technology

When we talk about biodiesel production, we have to talk about the major chemical reaction called transesterification whereby glycerin is separated from vegetable oils or fats giving rise to two primary products: methyl esters (better known as biodiesel or mono-alkyl esters) and glycerin, which is an attractive by-product for many industries such as pharmaceuticals, cosmetics, and food production. Vegetable oils (palm oil, soybean oil, rapeseed oil, sunflower oil), animal fats, and even recycled cooking oils or used fats are the most widely accepted feedstocks for biodiesel production. It is, therefore, particularly advantageous to consider the use of waste oils for biodiesel since they will help sustainability, cut down pollution, and conserve virgin vegetable oil resources. Apart from the feedstocks, biodiesel produksi will need an alcohol component, which is typically methanol, although ethanol, isopropanol, or butanol may also be utilized under specified conditions.

Current Condition of Basic Oleochemical and Biodiesel Industry

In recognition of its fundamental role in accelerating the Indonesian agro-industrial sector, the Basic Oleochemical and Chemurgi Industry has been classified as one of the priority upstream industries needing development in Indonesia. The government, via its RIPIN 2015-2035 Industrial Development Plan, provides a strategic pathway for improving the oleofood, oleochemical, and chemurgi industries by relying on the country’s abundant palm oil resources. These industries are expected to drive economic development, reduce dependency on fossil-based products and enhance sustainability through bio-based innovations.

Concept of Increasing Palm Oil Productivity

In implementing the B50 biodiesel program, Indonesia requires approximately 61 million tons per year of crude palm oil (CPO) for stable domestic food supplies and export commitments. The current CPO production, as per GAPKI, is only 54.8 million tons in 2024, which means that improving production and productivity is paramount. Solutions to mitigate this gap must essentially adopt a holistic approach towards the palm oil industry, where mainly intensification strategies in oil palm plantations guised as the last possible options may fit, given the vast agricultural potential that Indonesia possesses.

Development of Biodiesel Policy Implementation in Indonesia

With the setting of biodiesel in Indonesia, since 2014 the incremental adjustments in the mandatory biodiesel blend have been moving forward. The acceleration of the biodiesel mandate by the government under Regulation of the Minister of Energy and Mineral Resources No. 12/2015 started from B10 in 2014, B15 in 2015, B20 in 2016, and B30 in 2020. Implementing B35 as of February 1, 2023, means 35% of the fuel mix in diesel engines consists of biofuel derived from palm oil, while the remaining 65% comes from conventional diesel. This is one of the great strides toward energy security and independence in consonance with the government's vision on an equitable and just energy transition. According to Coordinating Minister for Economic Affairs, Airlangga Hartarto, "the Mandatory Biodiesel Program is not just about reducing fossil fuel dependence; it is also about being part of the whole process of building the economy for sustainable energy solutions."

METHOD

Research Scope

This study takes a macroeconomic approach at the national level, using 2020 as the base year, as it marks the beginning of the B30 policy implementation. The analysis projects trends and outcomes through 2045, aligning with Indonesia’s Golden Vision target. The research activities are being conducted in Bogor and Jakarta over a five-month period, from September 2024 to January 2025, ensuring a comprehensive evaluation of economic and policy impacts.

Data Collection Methods

The present study combines primary and secondary data for thorough analysis. Primary data is collected through Focused Group Discussions (FGDs) with key stakeholders; this gives additional insights from industry experts, policymakers, and relevant institutions involved in biodiesel and palm oil. Perspectives provided in the FGDs on contemporary issues, market conditions, and policy implications of the B50 biodiesel implementation in Indonesia are quite pertinent.

Data Analysis Methods

The data and information collected are systematically processed and analyzed using both qualitative (descriptive) and quantitative approaches. The descriptive analysis focuses on three key areas: (1) a comprehensive review of biodiesel implementation, (2) the environmental, social, and economic impacts of B50 implementation, and (3) potential legal disputes or countermeasures from international trade partners.

RESULTS AND DISCUSSION

Analysis of Biodiesel Implementation Problems in the Transportation and Power Generation Sectors

The Challenges of Transportation Industry

Using biodiesel in transportation carries with it some technical problems since there are some vehicle types that cannot convert from conventional to biodiesel very easily. One of the most important transitions to biodiesel happens when engine specifications must be adapted by vehicle manufacturers to allow an optimum performance with higher biodiesel blends. A significant technical concern associated with biodiesel is clogging filters, which results from the gel or sludge formation within the fuel system. This affects the efficiency of fuel flow, leaving much to be desired in the functional capacities of critical components such as the fuel pump and the injector. The majority of the time, the power of the vehicle is compromised, pulling it down with less fuel efficiency.

Progress in Biodiesel Implementation and Future Perspectives

From the initial B2.5 (2.5% biodiesel blend) introduced in 2008, Indonesia steadily increased biodiesel mandatories, reaching B35 (35% biodiesel blend) in 2023. The implementation of B35 is a big step towards a

greater shift to biodiesel in the country which is backed up with extensive road tests, filter evaluations, and vehicle compatibility assessments. One of these is the B30 road test, which includes diesel-engine vehicles conducted in 2019 and provided valuable information related to performance in real-world conditions. Other subsequent prototype trials such as B40 road tests and B35 filter tests in 2022 were key in assessing the feasibility of newer biodiesel blends.

B40 application trials extended beyond transportation to several non-automotive industries, including mining heavy equipment, agricultural machinery, power plants, and maritime and railway fleets, with promising results. The successful implementation of trials for B35 and B40 has strengthened optimism toward the eventual application of B50 biodiesel (50% blend), which is anticipated once complete test trials are done and production capacity secured mainly on supply of crude palm oil (CPO).

On the one hand, B50 biodiesel's prospects are rather bright, but on the other hand, it has several technological, supply chain logistical, and economic hurdles to cross. The fact remains that, with continuous development and intervention in the infrastructure sector, Indonesia is preparing its position to evolve and work into becoming stronger as a country that can position itself as one of the leaders in the sustainable biofuel production arena, while simultaneously enforcing the country's commitment to energy security, environmental sustainability, and economic resilience.

Power Generation Sector

There are many technical complications associated with biodiesel utilization in the power generation sector, number one being modification in a power plant configuration, which would optimize for combustion efficiency. Most commonly modification would be in the burner section. Additional heaters in the biodiesel storage tanks, agitation mechanisms, and specialized swirlers would be useful in designing a burner for biodiesel to facilitate efficient air-fuel mixing for combustion. Perhaps more importantly, it will be increased viscosity and flashpoint, which make it more difficult to burn than conventional diesel, leading to electricity generation inefficiencies (Laila, 2017; Hamid & Yusof, 2010). It must reach the auto-ignition point as rapidly as possible with a rapid and complete intake of fuel-air mixture for effective energy production. Prolonged combustion leads to inefficient utilization of fuel and increased waste, which has consequences on the operational efficiency and cost effectiveness. In addition to this, biodiesel combustion temperatures are lower than those of diesel. Therefore, it would take longer heating times to produce the saturated or superheated steam for driving turbines and generating electricity.

Based on the Regulation of Minister of Energy and Mineral Resources No. 12 of 2015, biofuels are made compulsory in the power generation sector which meant that diesel-fueled power plants had to use B30 diesel by 2016. This guideline did not go as planned. Some diesel power plants in western Indonesia adopted B30 but not in eastern areas for not enough supply chain. Most importantly, Pertamina-the state company for the flow of the national fuel-is still not yet able to distribute B30 to all diesel-fueled power plants in the country. Also, the PLN is required to consume B30. Other sectors, especially PSO transport, are still using B20. It is only in 2020 that the transition to B30 should be implemented in all sectors (Raksodewanto et al., 2018).

Besides logistical constraints and supply chain issues, what has affected the transition process towards B30 is biodiesel's lower calorific value compared to diesel. Empirical data show that biodiesel consumption sometimes exceeds that of diesel by 2-3%, leaning toward the operational load of a plant. The higher the load, the smaller the difference in terms of fuel consumption. This translates into an increased burden in terms of operational and maintenance costs. During the early phase of adoption, many components required a change in material to be compatible with biodiesel, especially those made of rubber. Furthermore, biodiesel's property of dissolving combustion residues has led to the frequent replacement of fuel filters, meaning an extra maintenance cost (Raksodewanto et al., 2018).

PT PLN (Persero) has performed biodiesel application in three different types of power generation plants comprising gas-fired power plants (PLTG), diesel-fired power plants (PLTD), and gas-engine power plants (PLTMG). However, it has brought really operational issues regarding the Fatty Acid Methyl Ester (FAME) content of biodiesel, which does not suit well with gas turbines as it has risks to degrade materials. Besides that the use of biodiesel gives around 3% more Specific Fuel Consumption (SFC) than conventional High-Speed Diesel (HSD), which means it is going to cost more for fuel. Moreover, maintenance costs have risen as well due to the need for very often service and replacements of components. Thus, PLN is going to be given exemptions for a gradual transition to biodiesel. It derives from the distinct aspects necessary for power generation through biodiesel, especially those concerning metals in biodiesel, which declare corrosive agents damaging the turbine

components. Challenges above have technological innovations, better fuel standardization, and policy support strategies to entrench biodiesel fitting in lastingly as well as effectively into the power generation infrastructure in Indonesia without compromising reliability and cost-effectiveness.

Analysis of Financing and Foreign Exchange Savings Aspects

For biodiesel to be made compulsory, it requires a sizable monetary investment to close the price differential between importing fossil diesel and biodiesel produced domestically, taking into account the costs for transportation of biodiesel producers to Pertamina. In the absence of proper subsidies or incentives, biodiesel remains uneconomical for most users, especially when global crude oil prices fall or crude palm oil (CPO) prices rise. As Indonesia steps into higher blends of biodiesel such as B35 and above, the significance of financial aid becomes even more intense, not only for enabling price differentials, but also as capital toward infrastructure upgrades and new technological innovations to facilitate large-scale application.

Indonesians need to invest heavily to make biodiesel mandatory because the price differential against imported fossil diesel is very large, considering the cost of transport from biodiesel producers to Pertamina. It's confinement without subsidies or incentives: biodiesel is not economically feasible for most end users when world crude oil prices drop or crude palm oil (CPO) increases. The higher blend lift biodiesel, say B35 and over, makes the financial support requirement all the more severe, not only in offsetting price differentials, but also in the investments in necessary infrastructure upgrades and new technological innovations required for large-scale adoption.

Biodiesel use would have to be made compulsory at a significant financial cost to the user, covering the price gap between imported fossil diesel and domestically produced biodiesel, including transport of biodiesel producers to Pertamina. And without sufficient subsidies or incentive programs biodiesel is not going to be cost-effective for most final users, particularly when global crude oil prices decline or crude palm oil (CPO) price increases. As for more and more Indonesian applications in higher biodiesel blends such as B35 and above, financial support becomes even more critical not only to redress price differentials but also to invest into infrastructure improvements and new technological innovations that will be increasingly requisite for large-scale application.

In addition to the funding requirement for making biodiesel mandatory-from the cost differences compared to imported fossil diesel, including transport from biodiesel producers to Pertamina-biodiesel remains economically unfeasible for most end users in the absence of sufficient subsidies or incentive programs when world crude oil prices fall or the price of crude palm oil (CPO) is high. Increased blending with biodiesel, e.g. B35 and beyond, makes ever more compelling demand for financial support, not only to offset price differentials, but also as investments in the requisite technology and infrastructure upgrades necessary for large-scale deployment.

Compulsory biodiesel will require a very big financial input to cover the price difference from imported fossil diesel to home-produced biodiesel, including the transport cost from biodiesel producers to Pertamina. On this score, without adequate subsidies or incentive programs, biodiesel remains economically unviable for most end users, especially when world crude oil prices fall or crude palm oil (CPO) rises. As Indonesia shifts into further higher biodiesel blends like B35 and above, so the need for funding support increases even more for redressing price differentials and also for investment in necessary infrastructure upgrades and new technological innovations that are increasingly required for large-scale adoption.

Mandatory biodiesel requires a large financial burden to be apportioned among cost differentials from imported fossil diesel to locally produced biodiesel, including transportation of biodiesel producers to Pertamina. Without sufficient subsidies or grants, biodiesel remains economically unfeasible for end users, particularly at times when international crude prices drop, or crude palm oil (CPO) increases. Increased blending with biodiesel such as B35 and beyond puts even more compelling demand for financial support-not only to offset price differentials but also as investments in the necessary infrastructure improvements and new technological innovations that will be increasingly requisite for large-scale application.

An important milestone in biodiesel funding was marked in 2015, when the biofuels subsidy was removed from the Revised State Budget, thus transferring the financial liability to the Palm Oil Plantation Fund Management Agency (BPDPKS). Starting August 2015, BPDPKS was appointed the new incentive provider for the Public Service Obligation (PSO) biodiesel program, thus ensuring financial sustainability in the use of biodiesel for domestic consumption. The year 2018 marks another huge milestone; this time it included the expansion of BPDPKS incentives to cover Non-Public Service Obligation (NPSO) sectors, including non-automotive industries. This was further enhanced with a locomotive rail trial in accordance with Presidential

Regulation Number 66 of 2018, which amended Presidential Regulation No. 61/2015, thus creating an improved framework of Indonesia as a biodiesel policy.

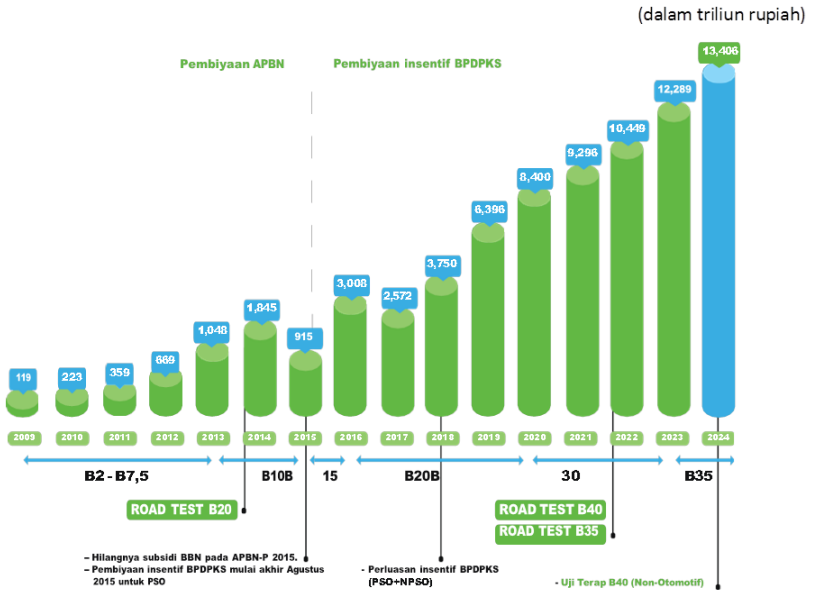

Figure 24. Linimasa Pengembangan Biodiesel (Ditjen EBTKE- ESDM, 2024)

And so far for five years, the increasing palm biodiesel blending rate has led to much foreign exchange saving from reduced fossil diesel imports. The amount saved increased from IDR 3.7 trillion in 2015 to IDR 26.7 trillion in 2018, and continued to grow towards IDR 121.5 trillion in 2023. The falling trends in fossil diesel imports have contributed to the tightening of the oil and gas trade balance deficit in Indonesia, making biodiesel strategically positioned to optimize energy security as well as economic resilience for this nation. In the future, biodiesel policies need to be financially sustainable since this would require a balance between economic viability and different subsidy schemes with respect to long-term energy diversification strategies.

Environmental Aspect Analysis

Indonesia has made a strong commitment to the global community, particularly through the Paris Agreement, to actively reduce carbon emissions. As part of this commitment, the country has set an ambitious Nationally Determined Contribution (NDC) target, aiming to cut emissions by 29 percent through domestic efforts and up to 41 percent with international support by 2030. One of the key strategies to achieve this goal is the substitution of fossil diesel with palm-based biodiesel, which has been shown to reduce greenhouse gas (GHG) emissions by approximately 40 to 70 percent. Data from the Ministry of Energy and Mineral Resources (MEMR) and the Oil Palm Plantation Fund Management Agency (BPDPKS) indicate that the implementation of the biodiesel mandate between 2015 and 2023 has significantly contributed to emission reductions, rising from 2.4 million tons of CO_2 equivalent in 2015 to 32.7 million tons of CO_2 equivalent in 2023.

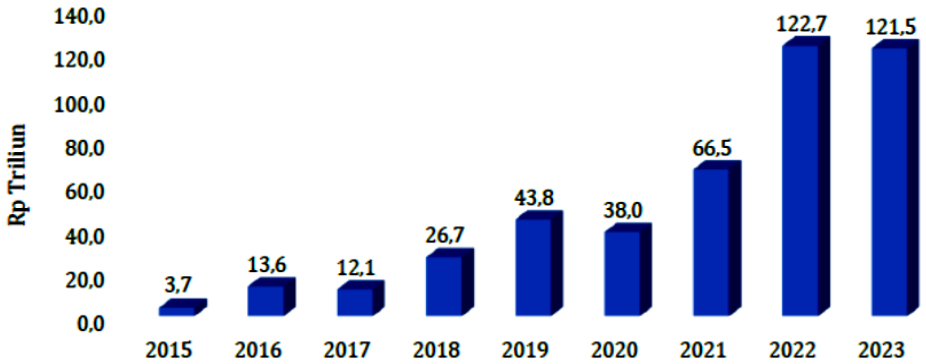

Figure 25. Penghematan devisa solar impor akibat kebijakan mandatori biodiesel di Indonesia (BPDPKS, 2024)

Figure 26. Penurunan emisi GRK yang meningkat akibat kebijakan mandatori biodiesel di Indonesia (BPDPKS, 2024)

Its biodiversity conservation gained from the development of biodiesel. However, biodiesel development was not really limited to environmental benefits only. It has achieved another milestone in reducing dependence on imported fossil fuels significantly and saving cost for the country through much foreign exchange. However, while the biodiesel policy has positive value in reducing emissions and ensuring energy security, it implicitly contains some serious environmental challenges. Increased demand for crude palm oil as feedstock for biodiesel production translates to deforestation and biodiversity loss. According to a study on Biofuels Development and Indirect Deforestation, between 2014 and 2022, 4.25 million hectares expanded oil palm plantations matched with the surging demand for biodiesel. This increase in plantation expansion was most significant coming after 2016, when the government decided to infuse incentives and subsidies to palm oil through BPDPKS.

The pace at which this country grows has placed it under increasing international scrutiny over deforestation, land-use change, and biodiversity conservation. The country's image in global environmental governance is in jeopardy, especially with the strict sustainability regulations like EUDR, which would definitely affect the access of Indonesian palm oil to key export markets. Still, developing Indonesia's biodiesel industry requires an argument over economics and environmental responsibility in the near future. Stronger sustainability measures, stricter land-use policies, and transparent monitoring mechanisms would be the prerequisites for ensuring that such a program meets climate goals and manages land sustainably.

SWOT Analysis of Biodiesel Implementation

Comprehensive SWOT analysis conducted for the implementation of biodiesel in Indonesia, which covers the general analysis of strengths, weaknesses, opportunities, and threats to mandatory biodiesel programs from B20 to B35 during the years 2018 to 2023

Analysis of Internal Factors

Internal factors in the analysis represent the strength and weaknesses of biodiesel utilization in Indonesia.

Strengths:

1. Abundant raw materials: Indonesia has a consistent supply of crude palm oil (CPO) for the production of biodiesel. It is the world's largest producer of palm oil. CPO consumption in requirement of biodiesel ranged from 8.87% to 21.26% of total CPO production from 2018 to 2023.
2. A large domestic market: The fast-growing population and increasing energy demand in Indonesia open great opportunities for uses of biodiesel, especially in vehicles, power plants, and industries.
3. Strong supportive Government Policies: This biodiesel program is very much empowered by national policy instruments such as the phased mandatory blend requirement until total achievement in 2025 (Permen ESDM 2015). It also enforces sanction compliance among non-compliant entities as provided by Ministerial Regulation No. 41 of 2018.
4. Commitment to greenhouse gas reduction: The national action plan greenhouse gas reduction-RAN-GRK-is its support to adoption of renewable energy in transport and other sectors as provided under Presidential Regulation No. 61 of 2011.

5. Modern biodiesel production technology: Indonesia has successfully rolled out B35 with no operational major disruptions, thereby indicating strong technical expertise in palm oil-based biodiesel production.

Weakness

1. Very high production costs: Even with all the raw materials available, the prices of CPO now are very much higher than that of fossil diesel, thus making it subsidized by the government to be competitive with biodiesel.
2. Food crisis: Thus, increasing demand by CPO for biodiesel will be concluded as fewer for food production. Whereas the implementation of a B30 caused much supply disruption and made an increase in prices of cooking oil since the year 2021.
3. Limited infrastructure: The biodiesel production, distribution, and processing infrastructures are not uniform across Indonesia, so there must be more investment in logistics and storage.
4. Fuel quality problem: The oxidation stability of biodiesel is poorer as compared to fossil diesel and it also solidifies at low temperatures, causing engine startup problems in vehicles. It often requires retrofitting some existing diesel engines for better compatibility with higher blends of biodiesel.

External Factor Analysis

External factor analysis is an opportunity (opportunities) or threat (threats) of using biodiesel.

Opportunity factors

1. The implementation of mandatory biodiesel will increase the domestic absorption of CPO and reduce the supply of CPO in the international market, thereby encouraging an increase in world CPO prices, which in turn will affect the increase in TBS and CPO prices domestically, as well as increase the export value per unit of palm oil and its derivatives.
2. Biodiesel production from palm oil can be the answer to export restrictions that occur with various arguments particularly from the countries of European Union to produce biodiesel from palm oil internally, to fuel the domestic needs.
3. The imposition of mandatory use of biodiesel can cut into diesel usage, which partly still has to be imported. This is bound to save foreign currency and enhance energy independence (Figure 24) .
4. Crude oil reserves as fossil fuels are energy sources limited in nature; hence, with unending exploitation, one day this energy resource would rather be rare and hence costly than another. Contrastingly, the energy demand is also going up with economic and industrial development. This means in the long run, biodiesel demand all over the world will further grow and create a huge market opportunity for the biodiesel industry in Indonesia.

Threat factors

1. The International community often utilizes environmental and social issues to impose various pressures on palm oil commodities, thereby diminishing the international trading standing of Indonesia. Palm oil production is oftentimes related to deforestation and biodiversity loss; clearing land through burning increases GHG emissions due to carbon smoke emitted in the air, thereby further aggravating environmental quality. The expansion of palm oil plantations is reputedly disregarding or extinguishing customary rights so that indigenous peoples lose access to these important resources, such as water, forests, and land for hunting or farming; such conflicts over land between local communities and indigenous peoples are oftentimes brought to the attention of the international community for purposes of putting pressure on Indonesia.
2. The fluctuation of CPO price: Whenever CPO price increases internationally, the costs of production for biodiesel would go up, thereby increasing the burden of the government subsidy.
3. World fossil oil price fluctuations: With low fossil oil prices, biodiesel production becomes less competitive.
4. The future orientation of photovoltaic and nuclear power plants, coupled with the advancement of electric means of transportation, could pose threats to biodiesel development.

Concerning the state of biodiesel usage in Indonesia, this has probably great merits in the shifting of energy from renewable sources to improving the country's energy security. Some challenges such as sustainability issues, cost efficiency, and infrastructure need to be addressed immediately to reap the best benefits from an ongoing biodiesel program. Biodiesel production from palm oil for domestic use has a promising contribution to

the renewable energy transition in Indonesia. However, this will only be achievable by mitigation of challenges related to environmental issues, cost-efficiency variants, and infrastructure development. That can happen through collaborative effort involving the extent of which government, industry, and society are prepared to invest in the sustainable and competitive application of biodiesel from palm oil. There is a technical issue in the use of biodiesel, thus requiring collaboration between biodiesel producer and vehicle manufacturers and the authorities. It is through improving the quality of biodiesel, adjusting engine technology, and good education and maintenance that renewable energy transitions with biodiesel development will be successful without significant impacts.

CONCLUSION

Since its launch in 2009, the government biodiesel policy is regarded as one of the components of the national energy mix to stimulate energy independence and reduce greenhouse gas emissions. This particular mandate has now been progressively ramped up, as the B40 would be mandated for 2025 and the B50 for 2026. Within this context, a thorough study of the supply and demand for palm oil becomes pertinent in order to ensure that the policy does not infringe upon food security, domestic industrial needs, or export performance.

1. The Development Dynamics System is the Palm Oil Supply-Demand Model, which serves as a yardstick for judging the viability of the B50 biodiesel policy. Serious validity test showed MAPE values of below 5%, which thus made it reliable to use for policy review.
2. The key factors that control palm oil supply include productivity and land availability, while the palm oil demand is significantly influenced by (a) mandatory biodiesel policy, (b) domestic household cooking oil consumption, (c) non-cooking oil food consumption, (d) oleochemical industry, and (e) export demand.
3. According to the Palm Oil Supply-Demand Model's projections, two major implications arise:
    a. An assessment under the current policy framework reveals that the B50 mandate (effective 2026) and domestic cooking oil needs would become satisfied. Meanwhile, there will be declining palm oil exports, and supply for other domestic non-cooking food uses and oleochemicals will be curtailed. Realistically, one can also say that achieving Indonesia's Golden Vision 2045 target of producing 100 million tons of palm oil annually will not be feasible based on existing conditions.
    b. The production target of 100 million tons by 2045 will thus necessitate such strategic policy measures- productivity enhancement and optimal use of abandoned land. There are many benefits of following this approach: (1) sustainable and balanced increased productivity, (2) compliance with government commitments to climate change mitigation by way of moratorium on peatland and forest conversion, (3) unlocking an estimated 2.7 million ha of unproductive and abandoned plantations, (4) mitigating possible social conflict, and (5) building greater resilience to climate variability, incuding El-Nino.The suggested combination strategy would ensure biodiesel and cooking oil target achievement without compromising domestic and export supply.
4. Maximizing the production of biodiesel not only serves to safeguard Indonesia's renewable energy mix but also helps to reduce greenhouse gas emissions, conserve foreign exchange on fuel imports, and counteract the threat of non-tariff trade barriers against developed countries, particularly those presented by the European Union Deforestation-free Regulation (EUDR).
5. The task of making biodiesel commercially available will require considerable investment in both production and distribution infrastructure as well as research and development (R&D). Strengthening biodiesel technology will be critical in ensuring a higher product quality, better engine compatibility, increased competitiveness, and ultimately wider market acceptance. If these challenges have been successfully addressed, Indonesia may be able to position itself in the world arena as a leader in sustainable palm oil and biodiesel production.

REFERENCES

Abimanyu, A. S., & Muhammad, A. 2022. Pra Rancangan Pabrik Biodiesel Dari Minyak Kelapa Sawit Dan Metanol Dengan Kapasitas 100.000 Ton/Tahun. Universitas Islam Indonesia.

Anonim. 2023. Peluang dan Tantangan Teknis Implementasi Biodiesel Dalam Upaya Peningkatan Bauran Energi Terbarukan di Indonesia. https://megashift.fisipol.ugm.ac.id/ 2023/09/11

Bappenas (2019) Background Study: Visi Indonesia Emas 2045. Kementerian Perencanaan Pembangunan Nasional/Badan Perencanaan Pembangunan Nasional, Jakarta

Barcelos, E., Rios, S.D.A., Cunha, R.N., Lopes, R., Motoike, S.Y., Babiychuk, E., Skirycz, A. and Kushnir, S., 2015. Oil palm natural diversity and the potential for yield improvement. Frontiers in plant science, 6, p.190.

Basiron, Y., 2007. Palm oil production through sustainable plantations. European Journal of Lipid Science and Technology, 109(4), pp.289-295.

Bogheiry, Ali; Thaha, M; Rahmah L. 2023. Global dependence analysis on Indonesian palm oil production and its effect on environmental security using the copenhagen school approach. J. World Sci. 2(3):466–482. doi:10.58344/ jws.v2i3.243.

Bou Dib J, Krishna VV, Alamsyah Z, Qaim M (2018) Land-use change and livelihoods of non-farm households: The role of income from employment in oil palm and rubber in rural Indonesia. Land Use Policy 76:828-838. doi:https://doi.org/10.1016/j.landusepol.2018.03.020

BPS (2023) Indonesia Oil Palm Statistics 2022. BPS-Statistics Indonesia, Jakarta

BPS (2024) Luas Panen dan Produksi Padi di Indonesia 2023 (Hasil Kegiatan Pendataan Statistik Pertanian Tanaman Pangan Terintegrasi dengan Metode Kerangka Sampel Area). Direktorat Statistik Tanaman Pangan, Hortikultura, dan Perkebunan, Badan Pusat Statistik, Jakarta

BPDPKS. 2024. Manfaat Implementasi Program Biodiesel Berbasis Sawit Periode 2015-2023.

Chiriacò MV, Galli N, Santini M, Rulli MC (2024) Deforestation and greenhouse gas emissions could arise when replacing palm oil with other vegetable oils. The Science of the Total Environment 914:169486. doi:https://doi.org/10.1016/j.scitotenv.2023.169486

Chong, C. T., Ng, J.H., Ahmad, S., & Rajoo, S. 2015. Oxygenated palm biodiesel: Ignition, combustion and emissions quantification in a light-duty diesel engine. Energy Conversion and Management, 101, 317–325. https://doi.org/https://doi.org/10.1016/j.enconman. 2015.05.058

Chrisendo D, Siregar H, Qaim M (2022) Oil palm cultivation improves living standards and human capital formation in smallholder farm households. World Development 159:106034. doi:10.1016/j.worlddev.2022.106034

Chowdhury. S., Romsha, Singh., Saket, Shrivastava., Jitendra, S., Sangwai. 2023. Biodiesel Production. 205-232. doi: 10.1002/9781119785712.ch8

Corley, R.H.V. and Tinker, P.B., 2015. The oil palm. John Wiley & Sons.

Dimawarnita, F., Kartika, I.A. and Hambali, E., 2021, May. Sustainability of biodiesel B30, B40, and B50 in Indonesia with addition of emulsifier. In IOP Conference Series: Earth and Environmental Science (Vol. 749, No. 1, p. 012026). IOP Publishing.

Ditjenbun (2023) Statistical of estate crops volume I 2022 - 2024. Secretariate of Directorate General of Estates, Indonesian Ministry of Agriculture, Jakarta

EPA. (2020). Renewable Fuel Standard Program. United States Environmental Protection Agency. Retrieved from https://www.epa.gov/renewable-fuel-standard-program/overview-renewable-fuel-standard

Fakultas Ekonomi dan Bisnis UGM. 2024. Tantangan Sawit Nasional di Tengah Kampanye Negatif dan Perang Dagang. Berita FEB-UGM, 03-10-2024 (https://feb.ugm.ac.id/id/berita).

Farobie, O. and 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

Febriansyah, H. and Anggundari, W.C., 2022. Analisis Stakeholders dalam Pengembangan dan Penerapan Standar Biodiesel. In Pertemuan dan Presentasi Ilmiah Standardisasi, 2021, pp.125-134.

Fitriliana, Fitriliana., Syaifuddin, Yana., Maryam, Maryam., Rahmi, Rahmi., Rita, Nengsih., Cut, Rusmina., Sufitrayati, Sufitrayati., Asnariza, Asnariza. (2023). Peluang Investasi dan Pengembangan Energi Biomassa: Perspektif Pemanfaatan dan Daya Saing Pengembangannya. Jurnal serambi engineering, doi: 10.32672/jse.v8i3.6505

Gujarati, D.N. and Porter, D.C. (2009) Basic Econometrics. 5th Edition, McGraw Hill Inc., New York.

Gultom, G.A., Krisnamurti, B., and Saragih, B. 2023. Pengaruh Harga Internasional, Ekspor, Harga TBS, Dan Volume Produksi Biodiesel Terhadap Harga CPO Domestik. Forum Agribisnis. 13(2): 152-163. https://doi.org/10.29244/fagb.13.2.152-163.

Hamid,S.T., & Yusuf, R. 2010. Preparasi Karakteristik Biodiesel Dari Minyak Kelapa Sawit. MAKARA of Technology Series, 6(2). https://doi.org/10.7454/mst.v6i2.64

Harahap, F., Silveira, S., & Khatiwada, D. 2019. Cost competitiveness of palm oil biodiesel production in Indonesia. Energy, 170, 62–72. https://doi.org/10.1016/j.energy.2018.12.115

Hariyadi, T.P., 2024. Analisis Potensi dan Evaluasi Emisi Biodiesel dari Palm Oil Mill Effluent (POME). Jurnal Al-Azhar Indonesia Seri Sains Dan Teknologi, 9(2).

Indrawan N, Thapa S, Rahman SF, Park J-H, Park S-H, Wijaya ME, Gobikrishnan S, Purwanto WW, Park D-H (2017) Palm biodiesel prospect in the Indonesian power sector. Environmental Technology & Innovation 7:110-127. doi:https://doi.org/10.1016/j.eti.2017.01.001

INSA. 2018. Pemerintah Pangkas Proses Distribusi Bahan Baku Biodiesel.

Jelsma I, Schoneveld GC, Zoomers A, van Westen ACM (2017) Unpacking Indonesia's independent oil palm smallholders: An actor-disaggregated approach to identifying environmental and social performance challenges. Land Use Policy 69:281-297. doi:10.1016/j.landusepol.2017.08.012

Kementerian Perdagangan. 2023. Sistem Pemantauan Pasar dan Kebutuhan Pokok: Perkembangan Harga Minyak Goreng Nasional.

Kementerian Perindustrian Republik Indonesia. 2021. Tantangan Dan Prospek Hilirisasi Sawit Nasional: Analisis Pembangunan Industri. Jakarta (ID): Kementrian Perindustrian Republik Indonesia.

KLHK (2024) Laporan Inventarisasi Gas Rumah Kaca (GRK) dan Monitoring, Pelaporan, Verifikasi (MPV) Tahun 2023. Direktorat Inventarisasi GRK dan Monitoring, Pelaporan, Verifikasi; Direktorat Jenderal Pengendalian Perubahan Iklim; Kementerian Lingkungan Hidup dan Kehutanan

Krishna VV, Kubitza C (2021) Impact of oil palm expansion on the provision of private and community goods in rural Indonesia. Ecol Econ 179:106829. doi:10.1016/j.ecolecon.2020.106829

Kurniawati, A.S., Pratiwi, A.I., Ariyani, N.R., Septiani, M. and Sasongko, N.A., 2022, November. Utilization of palm oil based biofuel to support sustainable energy transition in Indonesia. In IOP Conference Series: Earth and Environmental Science (Vol. 1108, No. 1, p. 012038). IOP Publishing.

Laila, L. 2017. Kaji Eksperimen Angka Asam dan Viskositas Biodiesel Berbahan Baku Minyak Kelapa Sawit dari Pt Smart Tbk. Jurnal Teknologi Proses Dan Inovasi Industri, 2(1). https://doi.org/10.36048/jtpii.v2i1.2245

Li TM (2024) Securing oil palm smallholder livelihoods without more deforestation in Indonesia. Nature Sustainability 7:387-393. doi:10.1038/s41893-024-01279-w

Manik Y, Leahy J, Halog A (2013) Social life cycle assessment of palm oil biodiesel: a case study in Jambi Province of Indonesia. The International Journal of Life Cycle Assessment 18:1386-1392. doi:10.1007/s11367-013-0581-5

Maqoma, R. I. 2022. Apa itu COP27? Ini penjelasan istilah-istilah rumit dalam konferensi iklim tahunan dunia. The Conversation. https://theconversation.com/apa-itu-cop27-ini-penjelasan-istilah-istilah-rumit-dalam-konferensi-iklim-tahunan-dunia-193744

Menteri Energi dan Sumber Daya Mineral Republik Indonesia. 2017. Keputusan Menteri Energi dan Sumber Daya Mineral Republik Indonesia Nomor: 3756K/10/MEM/2017.

Mokhtar, Sukmono A., Setiapraja H., Ma'ruf M., Yubaidah S., Haryono I., Rochmanto B., Soewono R.T., Adhi Sukra K.F., Thahar A., Manurung E., Wibowo C.S., Widodo S., Supriyadi F., Abriyant R.Y., Suntoro D., Faridha, Reksowardojo I.K. Towards nationwide implementation of 40% biodiesel blend fuel in Indonesia: a comprehensive road test and laboratory evaluation. Biofuel Research Journal 39 (2023) 1876-1889. DOI:10.18331/BRJ2023.10.3.2.

Muhammad M, Hasudungan HWV (2024) Analyzing the market conditions and long-term dynamics in the biodiesel industry. Biofuels:1-10. doi:10.1080/17597269.2024.2371241

Mulyasari G, Djarot IN, Sasongko NA, Putra AS (2023) Social-life cycle assessment of oil palm plantation smallholders in Bengkulu province, Indonesia. Heliyon 9. doi:10.1016/j.heliyon.2023.e19123

Murphy, D.J., 2014. The future of oil palm as a major global crop: opportunities and challenges. Journal of oil palm research, 26(1), pp.1-24.

Naylor RL, Higgins MM (2018) The rise in global biodiesel production: Implications for food security. Global Food Security 16:75-84. doi:https://doi.org/10.1016/j.gfs.2017.10.004

Nugrahapsari, Rizka Amalia; Harianto; Nurmalina, Rita; Fariyanti A. 2024. The Changing Role and Its Determinants of the Leading Vegetable Oil Exporting Countries. J. ISSAAS 30(1):125–141.

Obidzinski K, Andriani R, Komarudin H, Andrianto A (2012) Environmental and Social Impacts of Oil Palm Plantations and their Implications for Biofuel Production in Indonesia. Ecology and Society 17

Ogunkunle, O., & Ahmed, N. A. 2021. Overview of Biodiesel Combustion in Mitigating the Adverse Impacts of Engine Emissions on the Sustainable Human–Environment Scenario. Sustainability, 13(10), 5465. MDPI AG. Retrieved from http://dx.doi.org/10.3390/ su13105465

Oliphant E, Simon AC (2022) The cost of sustainable palm oil: Should an Indonesian smallholder pursue RSPO-certification? World Development Perspectives 26:100432. doi:https://doi.org/10.1016/j.wdp.2022.100432

Pusdatin. 2024. Analisis Kinerja Perdagangan Komoditas Kelapa Sawit. Pusat Data dan Sistem Informasi Pertanian Sekretariat Jenderal Kementerian Pertanian, 2024.

Qaim M, Sibhatu KT, Siregar H, Grass I (2020) Environmental, Economic, and Social Consequences of the Oil Palm Boom. Annual Review of Resource Economics 12:321-344. doi:10.1146/annurev-resource-110119-024922

Rahmanulloh, A., & McDonald, G. (2019). Indonesia Biofuels Annual Report 2019. In Global Agricultural Information Network (GAIN) Report.

Raksodewanto, A.A., Abrori, M., & Hariana. 2018. Penggunaan Biodiesel B30 Untuk Sektor Pembangkit Listrik Dalam Rangka Penghematan Devisa. Seminar Nasional Sains dan Teknologi Fakultas Teknik Universitas Muhammadiyah Jakarta , 17 Oktober 2018.

Saadun N, Lim EAL, Esa SM, Ngu F, Awang F, Gimin A, Johari IH, Firdaus MA, Wagimin NI, Azhar B (2018) Socio-ecological perspectives of engaging smallholders in environmental-friendly palm oil certification schemes. Land Use Policy 72:333-340. doi:https://doi.org/10.1016/j.landusepol.2017.12.057

Sahara, Dermawan A, Amaliah S, Irawan T, Dilla S (2022) Economic impacts of biodiesel policy in Indonesia: a computable general equilibrium approach. Journal of Economic Structures 11:22. doi:10.1186/s40008-022-00281-9

Santika T, Wilson KA, Law EA, St John FAV, Carlson KM, Gibbs H, Morgans CL, Ancrenaz M, Meijaard E, Struebig MJ (2020) Impact of palm oil sustainability certification on village well-being and poverty in Indonesia. Nature Sustainability. doi:10.1038/s41893-020-00630-1

Schoneveld GC, van der Haar S, Ekowati D, Andrianto A, Komarudin H, Okarda B, Jelsma I, Pacheco P (2019) Certification, good agricultural practice and smallholder heterogeneity: Differentiated pathways for resolving compliance gaps in the Indonesian oil palm sector. Global Environmental Change 57:101933. doi:https://doi.org/10.1016/j.gloenvcha.2019.101933

Saputra, W., Ichsan, M.., Permatasari, A., and Syakira, T. 2021. Pandangan Pemangku Kepentingan Terhadap Risiko Ekonomi Dan Lingkungan Dalam Kebijakan Biodiesel Di Indonesia. Spos Indonesia.

Sawit Indonesia. 2024. EUDR akan Diterapkan Awal Januari 2025 Akan Menghambat Ekspor Sawit. Sawit Indonesia, 1 Maret 2024.

Senatore, A., Cardone, M., Rocco, V., & Prati, M. V. 2004. A Comparative Analysis of Combustion Process in D.I. Diesel Engine Fueled with Biodiesel and Diesel Fuel. In Alternative Diesel Fuels (pp. 40–45). https://doi.org/https://ieeexplore.ieee.org/servlet/ opac?bknumber=8522095

Sibhatu KT (2023) Oil palm boom: its socioeconomic use and abuse. Frontiers in Sustainable Food Systems 7. doi:10.3389/fsufs.2023.1083022

Sinaga,V.S. dan R. M. E. Foekh, 2021. Kebijakan Uni Eropa Red II dan Delegated Act terhadap Perdagangan Produk Kelapa Sawit Indonesia. Jurnal Bina Mulia Hukum Volume 6, Nomor 1, September 2021.

Souza, S.P., Seabra, J.E. and Nogueira, L.A.H., 2018. Feedstocks for biodiesel production: Brazilian and global perspectives. Biofuels, 9(4), pp.455-478.

Suwarno, Windratmo. 2019. Kebijakan Sawit Uni Eropa dan Tantangan bagi Diplomasi Ekonomi Indonesia. Jurnal Hubungan Internasional Vol. 8, No. 1 / April - September 2019.

Susila, W.R., and Munadi, E., 2008. Dampak Pengembangan Biodiesel Berbasis Cpo Terhadap Kemiskinan Di Indonesia. Informatika Pertanian, 17(2):1173-1194.

U.S. Energy Information Administration (EIA). (2023). Gasoline and Diesel Fuel Update. https://www.eia.gov/petroleum/gasdiesel/

Voice of America-Indonesia. 2024. Indonesia Prihatin Soal Regulasi UU Deforestasi Uni Eropa yang Dinilai Mendiskriminasi Industri Minyak Sawit. Reuters 03-10-2024.

Wardany, S. El, & Mohareb, H. 2021. Libya Protests Block Oil Exports, Risking Recent Stability. Bloomberg. https://www.bloomberg.com/news/articles/2021-09-08/libya-protesters- halt-tanker-loading-at-key-oil-port

Watts JD, Pasaribu K, Irawan S, Tacconi L, Martanila H, Wiratama CGW, Musthofa FK, Sugiarto BS, Manvi UP (2021) Challenges faced by smallholders in achieving sustainable palm oil certification in Indonesia. World Development 146:105565. doi:https://doi.org/10.1016/j.worlddev.2021.105565

Yasinta T, Karuniasa M (2021) Palm oil-based biofuels and sustainability In Indonesia: assess social, environmental and economic aspects. IOP Conference Series: Earth and Environmental Science 716:012113. doi:10.1088/1755-1315/716/1/012113