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Analysis biodiesel distribution in Indonesia's Kalimantan Region: A case study on the readiness of ship-to-ship floating storage mechanisms in Balikpapan to Support the B35-B40 Biodiesel Mandate

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Abstract

The mandatory implementation of biodiesel in Indonesia has progressed from B2.5 in 2008 to B35 in 2023, with B40 targeted for 2025. However, logistical and infrastructure challenges persist, particularly in Kalimantan, where industrial demand is high but storage and distribution facilities are limited. To address this, the government has established Shipto-Ship (STS) floating storage in Balikpapan as a key distribution point. While this approach enhances distribution efficiency, it also incurs higher operational costs and environmental risks such as marine pollution. This study aims to analyze the readiness of floating storage in Balikpapan, evaluate its environmental impact, and assess the financial feasibility of transitioning to onshore storage facilities. A Systematic Literature Review (SLR) was conducted using the PRISMA 2020 framework, analyzing studies from Google Scholar, Scopus, ScienceDirect, Taylor & Francis, and Sage Journals. Findings indicate that floating storage supports biodiesel distribution but presents sustainability concerns. The cost analysis suggests that transitioning to onshore storage could reduce long-term operational expenses, while environmental assessments highlight the need for stricter regulations and monitoring to mitigate marine pollution risks. Additionally, policy recommendations emphasize enhancing biodiesel storage infrastructure and adopting cleaner distribution methods. This study underscores the strategic importance of optimizing biodiesel logistics to ensure efficient, cost-effective, and environmentally sustainable distribution in Indonesia. Future research should explore scalability, safety enhancements, and regulatory improvements for long-term biodiesel infrastructure development.

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Keywords

Biodiesel, Floating Storage, Infrastructure Readiness, Financial Model Analysis, Policy Analysis

Introduction

Energy is a strategic sector that plays a crucial role in achieving social, economic, and environmental objectives for sustainable development, as well as serving as a foundation for national economic activities [1]. With the increasing global energy demand and the depletion of fossil fuel reserves, the transition to renewable energy sources has become increasingly urgent. Indonesia, endowed with abundant natural resources, possesses significant potential for biodiesel development. Biodiesel, derived from plant-based materials such as palm oil, presents an environmentally friendly solution and holds the potential to reduce dependence on fossil fuels. Classified as biofuel, biodiesel is widely regarded as the most suitable liquid alternative to substitute fossil-based fuels due to its renewable nature and lower environmental impact. Moreover, it can often be produced using locally available resources. Among various types of biofuels, biodiesel has experienced the most advanced utilization in Indonesia [2]. The national energy policy sets specific targets for energy provision and utilization, including the achievement of an optimal primary energy mix. This policy aims to increase the share of new and renewable energy in the national primary energy mix to at least 23% by 2025 and 31% by 2050. However, the target for renewable energy contributions to the primary energy mix in 2022 was approximately 15.69%, while actual achievements only reached around 12.30%.

Several initiatives have been implemented to achieve the national renewable energy targets, including promoting the adoption of solar power technology among household consumers and increasing the utilization of biodiesel in the transportation and industrial sectors. The substitution of fossil fuels with biofuels, particularly biodiesel, in the transportation sector has emerged as a strategic effort to meet renewable energy mix targets. Notably, the increase in renewable energy contributions in 2022 compared to the previous year was primarily driven by higher biodiesel consumption, which rose from 9.5 million kiloliters to 10.5 million kiloliters, and further increased to 12.2 million kiloliters in 2023. This growth can be attributed to the gradual escalation of biodiesel blending ratios in fossil diesel, transitioning from B20 (a blend of 80% diesel and 20% biodiesel) to B35 (a blend of 65% diesel and 35% biodiesel) in February 2023. The program is expected to continue incrementally toward B40 (a blend of 60% diesel and 40% biodiesel), which is currently undergoing testing for non-automotive engines and is projected to be completed by December 2024. The implementation of the B40 program is anticipated to further increase biodiesel utilization to approximately 15.6 million kiloliters, thereby contributing significantly to the achievement of renewable energy targets.

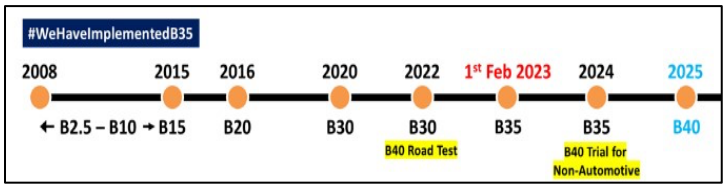

Figure 1. Map of Indonesia's Biodiesel Development Journey (Source : Indonesian Ministry of Energy and Mineral Resources) [3]

Currently, the majority of biodiesel producers in Indonesia are concentrated in the western regions, particularly on the islands of Sumatra and Kalimantan. These producers are required to meet the biodiesel demand across the entire Indonesian archipelago. To ensure the smooth execution of distribution activities, the establishment of a well-integrated distribution system is essential. Such a system is critical to maintaining the sustainability of the government's mandatory B35–B40 biodiesel program throughout Indonesia, enabling consistent supply and efficient logistical operations to support national energy targets.

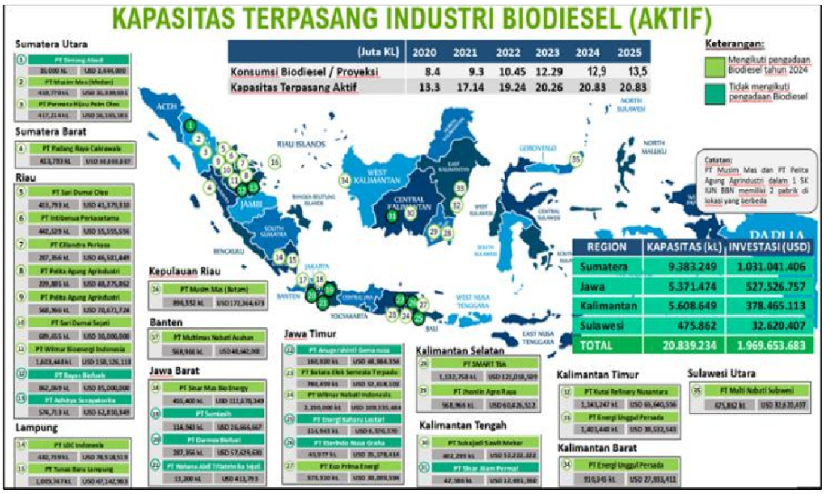

Figure 2. Map of Installed Biodiesel Industry Capacity in Indonesia (Indonesian Ministry of Energy and Mineral Resources) [3]

With the accelerated utilization of biodiesel domestically, several technical and operational issues have emerged in the field. The supply of biodiesel from biofuel companies to blending terminals frequently experiences delay due to vessel loading and unloading queues at ports or long-distance transportation, such as shipments from the western to the eastern regions of Indonesia. Furthermore, the limited storage infrastructure and facilities at blending terminals present additional challenges for distributors, particularly in the Kalimantan region.

As a solution to support the implementation of the biodiesel mandate, the government established a floating storage facility in the waters of Balikpapan, Kalimantan, in 2019, utilizing a ship-to-ship method. Floating storage involves the use of vessels or floating structures to store biodiesel at sea. This facility is managed by PT Pertamina Patra Niaga and operated by PT Pertamina Transkontinental to store biodiesel products delivered by producers near loading sites without the need for onshore storage infrastructure.

Floating storage also helps manage fluctuations in supply and demand while reducing transportation costs. The floating storage facility currently in use in Balikpapan consists of tanker vessels with a total capacity of 2 x 35,000 kiloliters. The rationale behind utilizing floating storage is the lack of sufficient tank infrastructure to store large volumes of biodiesel and the absence of supporting facilities for biodiesel receiving and blending processes in East Kalimantan. This necessity is driven by the region's high biodiesel demand, which accounts for approximately 12.5% of the national requirement.

In supporting the implementation of the B35 to B40 biodiesel mandate, it is crucial to ensure the readiness of supporting infrastructure and facilities, including the floating storage system in Balikpapan, which serves as a strategic solution for biodiesel distribution through the ship-to-ship method. Technical and operational challenges, such as limited storage capacity and uneven distribution infrastructure, necessitate a comprehensive assessment to evaluate infrastructure readiness, the impact of implementation, and the strategic measures required by the government. Therefore, this study aims to provide a holistic overview by conducting a scientific literature review to support the sustainable and optimal implementation of the biodiesel mandate program.

Method

This study adopts a Systematic Literature Review (SLR) approach following the PRISMA 2020 (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework [4][5]. PRISMA 2020 ensures a systematic, transparent, and unbiased selection of literature by structuring the identification, screening, eligibility, and inclusion processes. This approach is particularly relevant for synthesizing research on biodiesel distribution efficiency and infrastructure readiness, allowing the study to identify trends, research gaps, and strategic implications for the implementation of ship-toship (STS) floating storage mechanisms in Indonesia's biodiesel supply chain.

To further refine the research scope and ensure precise study selection, this study applies the PICOC framework shown in Table 1. The PICOC methodology allows for the systematic formulation of research objectives by defining Population, Intervention, Comparison, Outcome, and Context elements. The application of PICOC ensures that only studies directly related to biodiesel logistics, floating storage, and policy frameworks are included, preventing bias and improving research relevance.

Table 1. PICOC framework for study.

Component	Description
Population	The biodiesel distribution infrastructure in Indonesia, focusing on the floating storage facility in Balikpapan that supports the B35-B40 biodiesel mandate.
Intervention	Assessment of the effectiveness and efficiency of biodiesel storage and distribution using the Ship-to-Ship (STS) floating storage mechanism, in comparison to other storage models such as onshore tank facilities.
Comparison	Compared with onshore storage tanks or direct distribution from producers to blending terminals, evaluating logistical, economic, and environmental aspects.

Outcome	Readiness of floating storage infrastructure in supporting the B35-B40 biodiesel mandate. Evaluation of operational cost efficiency of floating storage. Compared to onshore storage facilities. Environmental impact assessment of STS-based biodiesel distribution. Policy recommendations for optimizing biodiesel distribution infrastructure.
Context	The implementation of sustainable energy policies in Indonesia, particularly in achieving the B40 biodiesel target by 2025, within the framework of an efficient and environmentally friendly biofuel distribution system.

The PICOC framework guides the systematic selection of relevant studies by narrowing the focus to biodiesel logistics, ship-to-ship floating storage, and infrastructure readiness. This structured approach ensures that the research captures the most critical and high-impact studies in the field while eliminating irrelevant or overly broad research. To identify relevant literature, a comprehensive search strategy was developed using Boolean operators (AND, OR) to structure the search strings. The following search string was applied across multiple databases to ensure a thorough review: *"("effectiveness" OR "efficiency") AND ("biodiesel distribution" OR "biofuel supply chain" OR "ship-to-ship transfer" OR "floating storage")"*

The literature search was conducted across multiple academic databases to ensure the inclusion of diverse, high quality, and relevant research. The search was performed within Google Scholar, Scopus, Sage Journals, Taylor & Francis, and ScienceDirect, covering the period from 2020 to 2025 to capture the most recent developments in biodiesel logistics, ship-to-ship floating storage, and infrastructure readiness. A total of 4,219 articles were initially identified across all sources. The majority of records were retrieved from Google Scholar (4,030 articles) due to its broad coverage of academic publications, including peer-reviewed journals and institutional repositories. Scopus contributed 45 articles, focusing on high-impact, indexed journal publications. Sage Journals and Taylor & Francis yielded 7 and 63 articles, respectively, primarily covering studies related to logistics and renewable energy policy. Lastly, ScienceDirect provided 74 articles, primarily from engineering and energy sector journals. These sources collectively provide a well-rounded representation of studies related to the effectiveness and efficiency of biodiesel distribution using ship-to-ship floating storage mechanisms.

The selection process followed PRISMA 2020 guidelines, ensuring that the review systematically identifies, screens, and includes only the most relevant studies. The PRISMA flow diagram below illustrates the process of study selection, detailing the number of articles identified, screened, excluded, and included in the final review.

Based on Figure 3, the study selection process followed the PRISMA 2020 framework, ensuring a systematic and transparent approach to identifying, screening, and including relevant literature. A total of 4,219 articles were initially identified from multiple academic databases, with 200 duplicate records removed, leaving 4,019 articles for screening. Following the title and abstract screening, 3,860 articles were excluded due to irrelevance, lack of methodological rigor, or non-open access availability. A total of

159 full-text reports were sought for retrieval, but 34 articles could not be accessed, reducing the pool to 125 articles for eligibility assessment. At this stage, 120 articles were excluded based on language, publication status, and lack of direct relevance to biodiesel distribution efficiency, ship-to ship transfer, or floating storage. Ultimately, 5 high-quality studies were selected for inclusion in the final review, ensuring that only research addressing infrastructure readiness, financial models, and operational efficiency in biodiesel distribution was considered. To ensure a rigorous and systematic selection process, this study applies clear inclusion and exclusion criteria to filter only the most relevant and high-quality studies. These criteria help maintain research validity and relevance by focusing on biodiesel distribution efficiency, ship-to-ship floating storage, and infrastructure readiness while excluding irrelevant or outdated studies. The detailed inclusion and exclusion criteria are presented in Table 2.

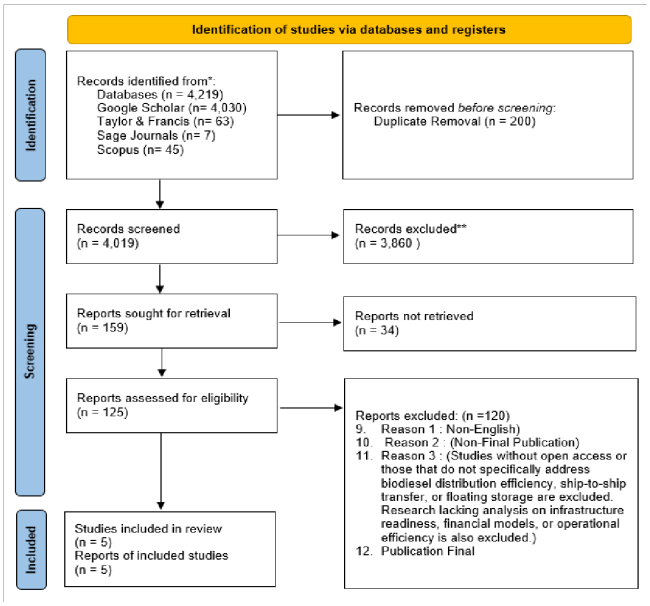

Figure 3. PRISMA flow diagram for study selection

Table 2. Inclusion And Exclusion Criteria

Criteria	Inclusion	Exclusion
Timeline	Studies published between 2020 and 2025	Studies published before 2020
Document Type	Peer-reviewed journal articles, systematic reviews	Conference papers, doctoral theses, books, and book chapters
Publication Stage	Final, published articles	Articles in progress, preprints, or non-final publications
Language	English	Non-English studies
Research Focus	Studies analyzing biodiesel distribution efficiency, ship-to-ship transfer, and floating storage, with a focus on infrastructure readiness, financial models, and operational efficiency	General studies on biofuels, energy policies, or logistics without direct relevance to biodiesel distribution efficiency, ship-to ship transfer, or floating storage

Based on Table 2, Inclusion and Exclusion Criteria, this selection framework ensures that only the most relevant and high-quality studies are included in this systematic review. The study prioritizes research published between 2020 and 2025 in peer-reviewed journals to maintain an up-to-date and evidence-based analysis of biodiesel logistics, ship-to-ship floating storage, and infrastructure readiness. The inclusion of only English-language studies ensures consistency and accessibility in interpretation. The selection focuses on research that specifically examines biodiesel storage efficiency, financial feasibility, and logistics optimization, allowing for a structured assessment of its impact on Indonesia's energy transition goals. Studies that do not explore these critical relationships or broadly discuss biofuel policies without empirical validation are excluded. To enhance the analysis, data extraction highlights key variables such as cost efficiency, logistical performance, and environmental sustainability.

Analysis and Synthesis

Indonesia's biodiesel mandate

Since its initial introduction in 2006, the utilization of biodiesel in Indonesia has experienced significant growth in terms of quality, volume, blending ratios, and the number of participating companies. This initiative was originally designed to reduce dependence on fossil fuels while simultaneously supporting energy security and environmental protection. With increasing policy support and regulatory frameworks, the mandatory biodiesel program has successfully driven the adoption of biodiesel across various sectors in Indonesia. In terms of blending ratios, biodiesel blending began at B2.5 in 2006. By 2009, with the implementation of B2.5, biodiesel consumption reached 119 thousand kiloliters (kL). Subsequently, the blending ratio was raised to B7.5 in 2012, leading to a rise in consumption volume to 1.05 million kL by 2013. In 2014, the ratio was further increased to B10, resulting in a volume of 1.8 million kL. However, in 2015, biodiesel distribution experienced a temporary decline due to a transition in financing mechanisms—from government subsidies through the state budget (APBN) to funding by the Indonesian Oil Palm Plantation Fund Management Agency (BPDPKS), which was implemented in late August 2015. This transition caused a drop in biodiesel consumption to 915 thousand kL in 2015. Despite this setback, the policy marked a crucial step toward establishing a more independent and sustainable financing model for the biodiesel program. By 2016, the government increased the blending ratio to B20, which significantly boosted biodiesel distribution, reaching approximately 3 million kL per year. This increase also reflected the government's strengthened commitment to maximizing biodiesel utilization as a blended fuel. The next substantial rise occurred in 2019 when, starting in September 2018, the government expanded incentives previously limited to the Public Service Obligation (PSO) sector to include all sectors. With broader incentives, biodiesel distribution surged to 6.4 million kL in 2019, demonstrating the positive impact of these policies on biodiesel adoption in industrial and transportation sectors.

In early 2020, the government further increased the blending ratio to B30, leading to another rise in biodiesel distribution, which reached 8.4 million kL throughout the year. With the growing national consumption of biogasoil, the demand for biodiesel as a blended fuel also saw substantial growth. Most recently, on February 1, 2023, the blending ratio was increased again to B35. This implementation resulted in a significant rise in biodiesel distribution, reaching 12.3 million kL. This achievement represents a critical milestone in Indonesia's efforts to achieve energy independence through the increased utilization of bio-based fuels (Kementerian ESDM et al., 2023).

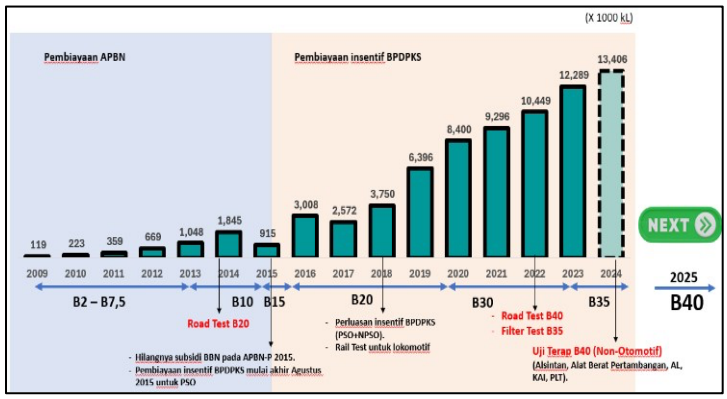

Figure 4. The Evolution of Indonesia's Biodiesel Mandate (Source : Indonesian Ministry of Energy and Mineral Resources 2024)

Indonesia has currently implemented the B35 biodiesel mandate and is set to increase the blending ratio to B40 in 2024 (Figure 4). This development positions Indonesia as the country with the highest mandatory biodiesel blending ratio globally. According to data from the Indonesian Biofuel Producers Association (APROBI), the progress of biodiesel blending programs in other countries can be observed in the Figure 5.

Country	Regulation
Argentina	B10 since April 2016, est.750 million gallons/year. Decision to underblend in 2021 due to COVID
Brazil	B2 in 2008. In 2017 increased to B8. B10 in 2019, and B12 in 2020. Has eyes on B15 in 2023.
Colombia	B10 mandate nationwide since 2018
Costa Rica	B20 mandate in place
Ecuador	B5 mandate since May 2013
European Union	New directive, RED II for 2021 – 2030 proposed biofuel reduction from 7% to 3,8% in 2030.
Norway	B3,5 as current mandate. Increased from B2,5 in 2012
Australia	Queensland: 0,5% biodiesel New South Wales: B2 mandate
Indonesia	B15 in 2015, B20 since 2016, B30 mandate since 2020, B35 mandate since 2023
Malaysia	B20 mandate postponed due to COVID.
Peru	B2 mandate in January 2019, plan to boost to B5 over the next five years
Philippines	B2 mandate, using coconut oil
South Korea	B2,5 mandate since August 2015
Thailand	B10 mandate in effect in 2018 with plan for subsidized B20 in trucks on voluntary basis
Uruguay	B6 mix in gasoil
USA	Minnesota: B20 mandate since 2008, will be fully implemented in summer months (Apr-Sep) Oregon: B5 for transportation diesel supply

Figure 5. Biodiesel Blending Development in Selected Countries (Source: APROBI, 2024)

With the increasing biodiesel blending ratios, the implementation of mandatory biodiesel programs must carefully consider technical aspects due to the unique characteristics of biodiesel. In general, biodiesel is biodegradable, free of aromatic compounds and sulfur, ensuring that its use, either pure or blended, results in lower exhaust gas emissions compared to conventional diesel fuel. Higher concentrations of

biofuel in diesel blends lead to greater reductions in greenhouse gas (GHG) emissions, making the transition to a 40% blend (B40) more environmentally beneficial. Biodiesel, being renewable and derived from vegetable oils, primarily consists of a mixture of saturated and unsaturated fatty acid methyl esters. It also acts as a mild polar solvent, enabling it to dissolve water to some extent. Additionally, biodiesel has extremely low sulfur content, contains oxygen (oxygenates), and is biodegradable. However, it exhibits oxidation stability and interacts with natural rubber and asphalt materials, while also being influenced by metals that act as oxidation catalysts. One of biodiesel's notable properties is its hygroscopic nature, which makes it prone to absorbing moisture from the environment. Water contamination is a critical issue that must be closely monitored and controlled before the fuel reaches injectors, as excessive water content can compromise performance. Water in biodiesel may originate from incomplete purification during production or be introduced through improper handling and storage procedures. Accumulated water at the bottom of storage tanks can promote microbial growth, while differences in the affinity between biodiesel and diesel fuel can lead to emulsion formation, often visible as fuel cloudiness in storage systems. Moreover, water contamination may cause corrosion in specific metal components and reduce combustion efficiency. These factors highlight the importance of addressing technical challenges associated with biodiesel storage, handling, and distribution to maintain fuel quality and ensure optimal performance.

Floating storage operations using the ship-to-ship method

To support the mandatory biodiesel program, particularly in the Kalimantan region, where storage tank facilities for biodiesel remain limited, the government, through PT Pertamina Patra Niaga, has introduced floating storage facilities for Fatty Acid Methyl Ester (FAME). Under this system, Biofuel Business Entities (BU BBN) from western Indonesia transport their biodiesel production to the floating storage units. Subsequently, PT Pertamina distributes the biodiesel to blending terminals, where it is mixed with fossil diesel to produce biodiesel blends, currently at the B35 stage. The floating storage facility for biodiesel was first operationalized in 2019, managed by PT Pertamina Transkontinental, and has continued its operations through 2024. The storage capacity of the vessels used is 2 x 35,000 kiloliters. The Ship-to-Ship (STS) method is employed for both loading and unloading processes. However, the current floating storage operations face several challenges, including adverse weather conditions, limitations in simultaneous loading and unloading processes, and risks of oil spills associated with storage and distribution mechanisms. These operational constraints highlight the need for enhanced infrastructure and protocols to improve efficiency and ensure environmental safety. An illustration of the floating storage and its operational framework is provided in the following Figure 6.

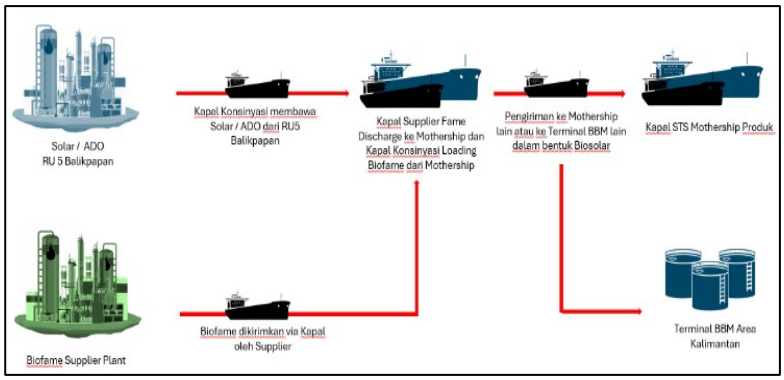

Figure 6. Biodiesel Distribution System of Floating Storage in Balikpapan (Source: PT Pertamina Patra Niaga, 2024)

The floating storage facility in Balikpapan has, to date, served as a critical blending and distribution hub for biodiesel in the Kalimantan region. Its strategic role in supporting biodiesel distribution underscores its importance in achieving the government's renewable energy targets. However, with the government's plan to increase the biodiesel blending ratio to B40, a comprehensive reassessment of the existing floating storage system is required. This reassessment must take into account current operational conditions, environmental management aspects, and the associated costs. Such an evaluation is essential to ensure the facility's capacity and efficiency align with the increased demand and operational requirements. The data presented below illustrates the percentage of biodiesel volume absorbed through the Balikpapan floating storage system, providing insights into its utilization and performance (Figure 7).

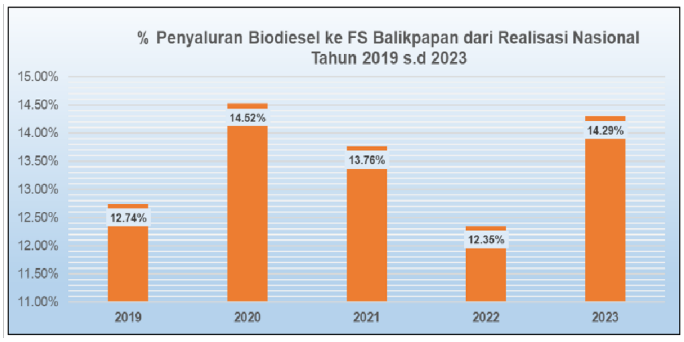

Figure 7. Biodiesel Absorption Data at Balikpapan Floating Storage (Source:Ministry of Energy and Mineral Resources, 2023)

Impact of biodiesel implementation

The implementation of the biodiesel mandate in Indonesia has generated significant positive impacts across economic and environmental dimensions. Economically, it has contributed to reducing diesel fuel imports, thereby alleviating trade balance deficits. Additionally, the program has helped stabilize Crude Palm Oil (CPO) prices, which, in turn, has improved the income and welfare of palm oil farmers. From a broader economic perspective, the biodiesel mandate has resulted in foreign exchange savings, enhanced value-added benefits through downstream processing, and created employment opportunities. Environmentally, it has played a crucial role in reducing greenhouse gas (GHG) emissions, further supporting sustainable development goals.

These outcomes underscore the multifaceted benefits of Indonesia's biodiesel program, as illustrated in Figure 8 below.

MANFAAT IMPLEMENTASI PROGRAM BIODIESEL BERBASIS SAWIT

MANFAAT	NILAI MANFAAT PROGRAM										
	B15 TAHUN 2015	B20 TAHUN 2016	B20 TAHUN 2017	B20 TAHUN 2018	B20 TAHUN 2019	B30 TAHUN 2020	B30 TAHUN 2021	B30 TAHUN 2022	B35 TAHUN 2023	B35 TAHUN 2024	B40 TAHUN 2025
Volume yang digunakan	915.460 kL = 5,76 juta BPY = 15,77 BPD	3,01 juta KL = 18,92 juta BPY = 51,84 ribu BPD	2,57 juta KL = 16,17 juta BPY = 44,31 BPD	3,75 juta KL = 23,59 juta BPY = 64,62 ribu BPD	6,39 juta KL = 41,68 juta BPY = 114,21 ribu BPD	8,4 juta KL = 52,83 juta BPY = 144,74 ribu BPD	9,3 juta KL = 58,41 juta BPY = 160,03 ribu BPD	10,5 juta KL = 66,04 juta BPY = 180,93 BPD	12,22 juta KL* = 76,90 juta BPY = 210,69 BPD	13,4 juta KL = 84,28 juta BPY = 230,90 BPD	15,6 juta KL = 98,22 juta BPY = 269,09 BPD
Penghematan devisa	USD 0,29 milyar = Rp 3,74 triliun	USD 1,02 milyar = Rp 13,6 triliun	USD 0,9 milyar = Rp 12,12 triliun	USD 1,89 milyar = Rp 26,67 triliun	USD 3,04 milyar = Rp 43,82 triliun	USD 2,64 milyar = Rp 38,04 triliun	USD 4,62 milyar = Rp 66,54 triliun	USD 8,34 milyar = Rp 122,65 triliun	USD 7,92 milyar = Rp 120,836 triliun	USD 8,06 milyar = Rp 127,45 triliun	USD 9,33 milyar = Rp 147,5 triliun
Peningkatan nilai tambah (CPO menjadi biodiesel)	Rp 1,49 triliun	Rp 4,89 triliun	Rp 3,45 triliun	Rp 5,78 triliun	Rp 9,54 triliun	Rp 10,28 triliun	Rp 11,29 triliun	Rp 13,12 triliun	Rp 15,85 triliun	Rp 18,01 triliun	Rp 20,98 triliun
Penyerapan tenaga kerja (orang)	On farm: 114.433 orang Off farm: 863 orang	On farm: 376.059 orang Off farm: 2.838 orang	On farm: 321.446 Off farm: 2.426	On farm: 478.325 Off farm: 3.609	On farm: 828.488 Off farm: 6.252	On farm: 1.071.491 Off farm: 8.085	On farm: 1.160.889 Off farm: 8.760	On farm: 1.312.500 Off farm: 9.904	On farm: 1.528.434 Off farm: 11.533	On farm: 1.675.000 Off farm: 12.639	On farm: 1.952.073 Off farm: 14.730
Pengurangan emisi GRK dan peningkatan kualitas lingkungan	2,4 juta ton CO2	7,9 juta ton CO2	6,83 juta ton CO_2	9,96 juta ton CO_2	16,98 juta ton CO_2	22,3 juta ton CO_2	24,6 juta ton CO_2	27,8 juta ton CO_2	32,6 juta ton CO_2	35,58 juta ton CO_2	41,46 juta ton CO_2

Figure 8. Biodiesel Absorption Data at Balikpapan Floating Storage (Source: Indonesian Ministry of Energy and Mineral Resources, 2023) [3]

The utilization of the floating storage facility in Balikpapan has had a substantial impact on reducing biodiesel distribution costs. Previously, biodiesel distribution extended to eastern Indonesia, incurring higher transportation expenses. With the establishment of the floating storage facility in Balikpapan, the supply of Fatty Acid Methyl Ester (FAME) biodiesel has become more cost-effective, enabling savings on transportation costs, optimizing delivery time, reducing the need for additional shipping fleets, and streamlining the B35 fuel distribution system. Moreover, the floating storage facility addresses challenges associated with the construction of onshore storage facilities, which require significant investment costs and strategically located land. As such, floating storage serves as a practical and efficient solution to support Indonesia's biodiesel distribution infrastructure.

The role and policies of the government

The implementation of Indonesia's mandatory biodiesel program is supported by regulations that serve as the legal foundation for blending biodiesel, a type of biofuel, with fossil diesel. The regulatory framework is outlined as follows:

1. Law No. 30 of 2007 on Energy: Establishes the legal framework for national energy policy, emphasizing energy security and the development of sustainable energy.
2. Law No. 39 of 2014 on Plantations: Regulates plantation management to promote sustainable agricultural practices and support the development of biofuel feedstocks.
3. Government Regulation No. 79 of 2014 on National Energy Policy: Defines Indonesia's national energy strategies, including renewable energy targets and sustainable energy utilization frameworks.

4. Government Regulation No. 24 of 2015 on Plantation Fund Management: Provides the legal basis for collecting and managing plantation funds, including financial support mechanisms for biofuel programs.
5. Presidential Regulation No. 22 of 2017 on the General National Energy Plan (RUEN): Sets forth the national roadmap for energy development, outlining policies for renewable energy integration.
6. Presidential Regulation No. 66 of 2018 (Second Amendment to Presidential Regulation No. 61 of 2015): Amends earlier regulations on the collection and use of palm oil plantation funds, reinforcing support for biodiesel program financing.
7. Minister of Energy and Mineral Resources Regulation No. 24 of 2021; Regulates the provision and utilization of biodiesel fuel within the funding framework of the Palm Oil Plantation Fund Management Agency (BPDPKS).
8. Director General of New and Renewable Energy and Energy Conservation (EBTKE) Decree No. 148.K/EK.05/DJE/2024: Establishes technical specifications and quality standards for biodiesel production and distribution.
9. Minister of Energy and Mineral Resources Decree No. 3.K/EK.05/DJE/2024: Sets the market index price (HIP) for biodiesel blended with petroleum diesel fuel, and its amendment through Ministerial Decree No. 153.K/EK.05/DJE/2024: Establishes the Market Index Price (HIP) for biodiesel blended with diesel fuel at Floating Storage or Shore Terminal Balikpapan, including additional costs based on reconciled unit costs, with a maximum surcharge of IDR. 202/liter.

Relevant case studies

Table 3. Summary of relevant literature, research gaps, and relevance to biodiesel floating storage studies

No	Article Title	Research Gap	Relevance	Source
1	Ship to Ship (STS) transfer of Cargo: latest Developments and Operational Risk	Limited studies on the environ mental impacts of nonoil STS operation s, such as biodiesel, and the management of floating storage for biodiesel, including cost aspects.	Relevant for analyzing operational l risks in cargo transfer (STS) that can be applied to research involving logistics distribution and optimization on and environmental risk mitigation.	SPOUDAI Journal of Economics and Business, 2013, Vol. 63, Issue 3-4, pp. 172–180.
2	Biofuel and Handling and Storage of Blends with Maximum m 40% Content for Diesel Engines	This book does not discuss floating storage for biodiesel, either from operation al or cost perspectives.	Relevant as it addresses technical aspects of storage, storage management, and the properties and characteristics of biodiesel	Guidelines, ESDM 2023
3	Content Handbook of Energy and Economic Statistics of Indonesia 2023	Does not specifically address biodiesel distribution in Balikpapan floating storage.	Provides general energy related data.	Indonesian Ministry of Energy and Mineral Resources 2023

4	Numerical Predictions of Ship-to-Ship Interaction in Shallow Water	The study focuses on biofuel operation s but does not address floating storage operations.	Relevant for understanding risks and maneuverability in STS operations, which can be applied to studies on operational risk management in maritime transportation or the development of technology-based training simulations.	Ocean Engineering: 2013, Volume: 72, Halaman: 386–402
5	Forecasting the Supply and Consumption of Fuel Oil in Indonesia Using a Dynamic System Model	Does not specifically address biodiesel as a biofuel.	Relevant as it discusses fuel demand forecasts until 2025.	Jurnal Ekonomi dan Pembangunan Indonesia, Vol. 17 No. 2 2017: 118–137, p-ISSN 1411-5212; e-ISSN 24069280, DOI: http://dx.doi.org/10.21002/ jepi.v17i2.661

The utilization of floating storage has been implemented as a strategy to address operational costs and provide a solution to the absence of onshore storage tank facilities, while also facilitating operational activities conducted at sea. However, based on the findings from the Literature Review (LR), there is a lack of specific and relevant discussions focusing on the application of floating storage for biodiesel. This gap highlights the need for further research to explore the operational, economic, and environmental aspects of floating storage systems in the context of biodiesel distribution and storage.

Conclusion

The findings of this study highlight the strategic importance of the floating storage facility in Balikpapan in supporting Indonesia's B35–B40 biodiesel mandate, particularly in ensuring effective distribution and storage in the eastern regions. The analysis indicates that while floating storage operations have successfully addressed logistical challenges, such as the lack of onshore storage infrastructure, they also present operational limitations and environmental risks. The study reveals that floating storage enables cost savings in transportation and enhances distribution efficiency, but the long-term sustainability of this system requires further assessment, particularly in scalability, financial feasibility, and environmental management. The evaluation of infrastructure readiness suggests that while floating storage serves as a short-term solution, transitioning to onshore storage may offer greater long-term benefits, including reduced operational costs and enhanced safety measures. Furthermore, the environmental assessment highlights the need for improved monitoring and risk mitigation strategies to prevent marine pollution and oil spills associated with ship-to ship transfers. From a policy perspective, Indonesia's existing regulatory framework provides a strong foundation for biodiesel implementation. However, additional regulations and guidelines focusing on operational safety, environmental protection,

and cost efficiency are required to support the scalability and sustainability of floating storage mechanisms. This study also identifies research gaps, particularly regarding the economic feasibility of transitioning from floating storage to onshore infrastructure, technical improvements in biodiesel handling, and simulation models for optimizing distribution logistics. Future research should explore comprehensive cost benefit analyses, innovative storage solutions, and regulatory enhancements to strengthen Indonesia's biodiesel supply chain and ensure the successful implementation of higher blending ratios in the future.

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