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Performance Evaluation of the Balikpapan Biodiesel Floating Storage Vessel: Analysis of Berth Occupancy Ratio, Tank Utilization, and Sustainability

Junaidi[1], A.R. Indra Tjahjani[1], I Nyoman Teguh Prasidha[1], Cahyo Setyo Wibowo[2]

[1]Master's Program in Infrastructure and Environmental Engineering, Faculty of Engineering, Universitas Pancasila, Srengseng Sawah, Jagakarsa, South Jakarta 12640, Indonesia

[2]Oil and Gas Testing Center - LEMIGAS
LEMIGAS Office Complex, Ciledug Raya, Kaveling 109 Cipulir, Kebayoran Lama, 12230, Indonesia

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ABSTRACT

Indonesia's biodiesel mandate has climbed steadily and now stands at B40, with B50 planned, which calls for a distribution system able to keep supply continuous, particularly in eastern Indonesia where onshore storage tanks remain scarce. This study evaluates the performance of the Balikpapan Floating Storage Vessel as a node for biodiesel storage and distribution from 2020 to 2025. It applies a descriptive-evaluative quantitative approach, drawing on the vessel's operational records together with national biodiesel production and distribution data. The evaluation centers on operational performance through Berth Occupancy Ratio and Tank Occupancy Rate, and on the sustainability of the vessel's role as the blend rises toward B50. The results show steadily improving performance, marked by a rise in Berth Occupancy Ratio from 44.1 to 65.9 percent and a recovery of tank utilization to 64.3 percent in 2025, following a 2023 anomaly caused by a large-capacity vessel. Projections indicate that Berth Occupancy Ratio could exceed the 75 percent threshold in 2027 as demand builds toward B50. Operating the Balikpapan Floating Storage Vessel remains worthwhile and worth optimizing while onshore tank infrastructure remains inadequate.

Corresponding author:
E-mail: (Juntambang7@gmail.com) Junaidi

INTRODUCTION

The energy transition has become a strategic global agenda as energy demand grows and pressure mounts to cut greenhouse gas emissions. Reliance on fossil fuels is seen as raising energy security risks while deepening the effects of climate change, which has pushed many countries to develop new and renewable energy as part of sustainable development (Sa'adah et al., 2017; Husada et al., 2023). Indonesia is among the countries actively developing biodiesel based on crude palm oil (CPO) because it is regarded as capable of curbing diesel imports, making better use of domestic resources, and supporting downstream development of the palm oil industry (wirawan et al., 2024; Widrian et al., 2022). The government has raised the biodiesel mandate in stages, from B20 through B30 and B35 to the B40 in force in 2025, and is now preparing the move to B50 once technical testing concludes. Each step up in blend level adds biodiesel to every liter of blended fuel, so national biodiesel demand keeps growing year after year (Amri et al., 2023; Halimatussadiah et al., 2025).

Producing biodiesel from CPO proceeds through a transesterification reaction that converts high-viscosity triglycerides into Fatty Acid Methyl Ester (FAME) with physical characteristics comparable to conventional diesel (Trisunaryanti et al., 2004; Hendro & Zahra 2024). As an ester product, biodiesel is hygroscopic and prone to oxidation, so storage conditions affect the stability of its quality while it moves through the supply chain (Wibowo et al., 2016). This property becomes an important consideration when biodiesel is held in large volumes at buffer facilities before being sent to the blending point.

Rising biodiesel demand calls for a reliable distribution system, yet current conditions in Indonesia still face logistical and infrastructure constraints. Most biodiesel plants sit in Sumatra and western Indonesia, while the strongest demand lies in Kalimantan and eastern Indonesia (Silalahi et al., 2021; Panjaitan et al., 2023). This geographic mismatch forces distribution over long distances and drives up national logistics costs (Gangwar & Sharma 2016; Omdikar et al., 2025). The challenge is compounded by limited storage tank capacity and port facilities in the east, which leaves distribution short of optimal and adds to the risk of supply delays (Surury et al., 2021). To address these constraints, PT Pertamina Patra Niaga operates the Balikpapan Floating Storage Vessel as a floating FAME storage facility that serves as a distribution hub for Kalimantan and eastern Indonesia (Dermawan et al., 2024; Awn & Chai 2018).

Using floating storage is seen as a way to improve distribution flexibility and ease the pressure on onshore tank capacity. Biodiesel supplied by biofuel producers in the western region is delivered to the vessel, then transferred to carrier ships through a ship-to-ship (STS) mechanism before being blended with diesel into Bxx. The scheme also carries high operating costs and technical risks, such as delays in cargo transfer, the inability to load and unload simultaneously, and possible weather disruptions (Yorulmaz & Susoy 2025). This issue grows more pressing because the planned move to B50 will add to the volume that must be stored and distributed, so the operating condition of the existing vessels needs to be reassessed with attention to field performance, cost, and infrastructure readiness.

Earlier studies have mostly examined biodiesel from the angle of energy policy, emission reduction, or supply chain optimization in general (Widrian et al., 2022; Suhara et al., 2024). Work that specifically evaluates the use of biodiesel floating storage in Indonesia remains limited, and few studies bring operational analysis, economic benefit, environmental impact, and sustainability

together in a single evaluation framework. The authors' earlier study assessed the readiness of the Balikpapan floating storage STS mechanism to support the B35 to B40 mandate (Junaidi et al., 2025), but it did not examine operational performance quantitatively across years or the implications of the move to B50. This study fills that gap by evaluating the vessel's operational performance from 2020 to 2025, assessing its benefits and impacts, and setting out sustainability decision criteria for the rising blend level. The aim is to analyze the operational performance of the Balikpapan Floating Storage Vessel, assess its economic benefits and environmental impact, and determine whether its continued use can support national biodiesel distribution during the transition to B50.

METHODOLOGY

The study uses a descriptive-evaluative quantitative approach to assess the use of the Balikpapan Floating Storage Vessel in biodiesel distribution across eastern Indonesia (Creswell J.W & Creswell J.D 2018) . The object of study is the floating storage vessel operating in Balikpapan waters and its chain of logistics activities, covering biodiesel intake, storage, ship-to-ship transfer, and onward distribution to delivery points in East Kalimantan, South Kalimantan, Sulawesi, and other parts of eastern Indonesia. The evaluation spans 2020 to 2025 as a historical baseline, with projections to 2027 to gauge medium-term sustainability.

The data comprise primary and secondary sources. Vessel operational data, tank capacity, intake and distribution volumes, and berthing time came from PT Pertamina Trans Kontinental and PT Pertamina Patra Niaga. Management cost data, the Mean of Platts Singapore (MOPS) reference price, national biodiesel production and distribution figures, biodiesel plant capacity, and the blending mandate stages were drawn from the Ministry of Energy and Mineral Resources (ESDM) and the Indonesian Biofuel Producers Association (APROBI). All data were validated by checking completeness, unit consistency, period alignment, and the plausibility of values. Volume data were standardized in kiloliters or liters, and cost data in rupiah. Data that were incomplete or could not be verified were noted as limitations and left out of the main calculations.

The operational performance analysis uses two indicators. The Berth Occupancy Ratio (BOR) measures how fully the vessel's operating time is used, calculated as the ratio of total facility usage time to the total available time of 672 hours per month for each vessel, as shown in Equation 1

$$BOR = \begin{pmatrix} Total\ Facility\ Usage\ Time \\ /\ Total\ Available\ Time \end{pmatrix} \times 100\% \quad (1)$$

The Tank Occupancy Rate measures how fully tank capacity is used, calculated as the ratio of the average stored biodiesel volume to the effective tank capacity, as shown in Equation 2

$$Tank\ Occupancy\ rate = \begin{pmatrix} Average\ Stored\ Bidodiesel\ Volume \\ /\ Effective\ Tank\ Capacity \end{pmatrix} \times 100\% \quad (2)$$

The sustainability analysis considers the growth of biodiesel plant capacity, the readiness of supporting infrastructure, and the trajectory of biodiesel demand against the mandate's path toward B50. The overall results were then synthesized into a decision rule on whether to maintain, optimize, or adjust the vessel's role, supported by a BOR projection based on the historical volume growth rate.

RESULT AND DISCUSSION

Vessel overview and operational capacity

The Balikpapan Floating Storage Vessel operated with a two-vessel configuration whose makeup shifted across the evaluation period as the fleet changed. Table 1 summarizes the specifications of the vessels used. From 2020 to 2022, Balikpapan waters were served by the pair MT Sengeti and MT Sele, with a combined installed capacity of about 80,521.59 kiloliters. In 2023, MT Sele was replaced by MT Gebang, and combined capacity jumped to 138,863.40 kiloliters because MT Gebang holds 97,643.50 kiloliters,

nearly two and a half times the vessel it replaced. From 2024, MT Sanga Sanga took over that role, and combined capacity returned to around 80,521.99 kiloliters (Junaidi et al., 2025).

This capacity gap matters when read alongside the volume absorption data. A large storage capacity gives more buffer room when supply arrives in bulk, but unfilled space lowers the tank utilization ratio. That is what later explains the 2023 utilization anomaly. Vessel selection is therefore not simply a matter of fleet availability; it turns on the balance between holding capacity and the fill level being targeted. Vessel operations begin with biodiesel intake through a ship-to-ship mechanism from biofuel producers' vessels. The cargo is placed in tanks as temporary storage, with attention to safety, cargo balance, and quality control. In the final stage, the biodiesel is transferred to a Pertamina vessel already loaded with diesel, so the product blends into Bxx.

History of intake and distribution volumes

Biodiesel intake to the vessel and its onward distribution as Bxx are summarized in Table 2, which also shows the vessel's share of national biodiesel volume and the mandate stage in force each year. Volume received rose from 1.22 billion liters in 2020 to 1.89 billion liters in 2025, a gain of about 54.6 percent at a compound growth rate near 9.1 percent per year. Volume distributed moved in step, from 1.19 billion liters to 1.74 billion liters (Junaidi et al., 2025).

The volume increase tracked the rising mandatory blend level, from B30 in 2020 through 2022, B35 in 2023 and 2024, and B40 in 2025. Beyond policy, surging demand from Kalimantan's mining sector added to the distribution load, since mining draws large and fairly steady volumes of blended diesel through the year. In 2024, distributed volume nearly matched received volume, a sign that the vessels were working close to a full-flow pattern with a thinning buffer stock.

The vessel's share of national volume rose to 17.4 percent in 2021, then fell fairly steadily to 12.6 percent in 2025. That decline does not mean the vessel performed worse. The absolute volume handled kept growing, but national biodiesel volume grew faster, about 12.2 percent per year against 9.1 percent for vessel intake. As production capacity in the east, Kalimantan in particular, keeps expanding, part of the supply can be handled closer to the point of need without passing through a floating storage node. Yet as long as onshore tank infrastructure is not ready, the vessel keeps its role as a distribution buffer in eastern Indonesia.

Analysis of berth occupancy ratio

Combined BOR rose from 44.1 percent in 2020 to 65.9 percent in 2025. The increase came with the growing volume handled, since added volume requires more berthing hours for ship-to-ship transfer. Across the evaluation period, utilization stayed within a healthy range. A BOR of roughly 40 to 70 percent is generally considered productive without straining the schedule, so the 65.9 percent reached in 2025 points to use that is becoming tight but is not yet saturated.

Breaking the figures down by vessel reveals a consistent pattern. MT Sengeti, the permanent vessel, ran at a fairly stable BOR of about 66 to 69 percent each year and effectively served as the operational backbone. The companion vessel showed a lower BOR that climbed step by step, from MT Sele at 32.3 percent in 2020 to 56.4 percent in 2022, then MT Gebang at 53.1 percent in 2023, and MT Sanga Sanga from 60.4 percent in 2024 to 64.8 percent in 2025. The narrowing BOR gap between the permanent and companion vessels

Table 1. Balikpapan Floating Storage Vessel Data. Source : PT Pertamina TransKontinental

No	Vessel Name	Capacity (kL)	Year
1	MT Sengeti	41,219.90	1982
2	MT Sele	39,301.69	1982
3	MT Sanga Sanga	39,302.09	1983
4	MT Gebang	97,643.50	1986

Table 2. Intake, Distribution, and Share History of the Balikpapan Floating Storage Vessel. Source : Directorate General of New and Renewable Energy and Energy Conservation, Ministry of Energy and Mineral Resources.

Year	Volume received (liters)	Volume distributed (liters)	National share (%)	Mandate
2020	1,219,967,166	1,191,970,868	14.5	B30
2021	1,619,630,299	1,213,688,320	17.4	B30
2022	1,569,044,821	1,384,223,281	15.0	B30
2023	1,663,533,662	1,648,869,216	13.5	B35
2024	1,581,189,571	1,647,332,858	12.0	B35
2025	1,885,828,021	1,741,359,861	12.6	B40

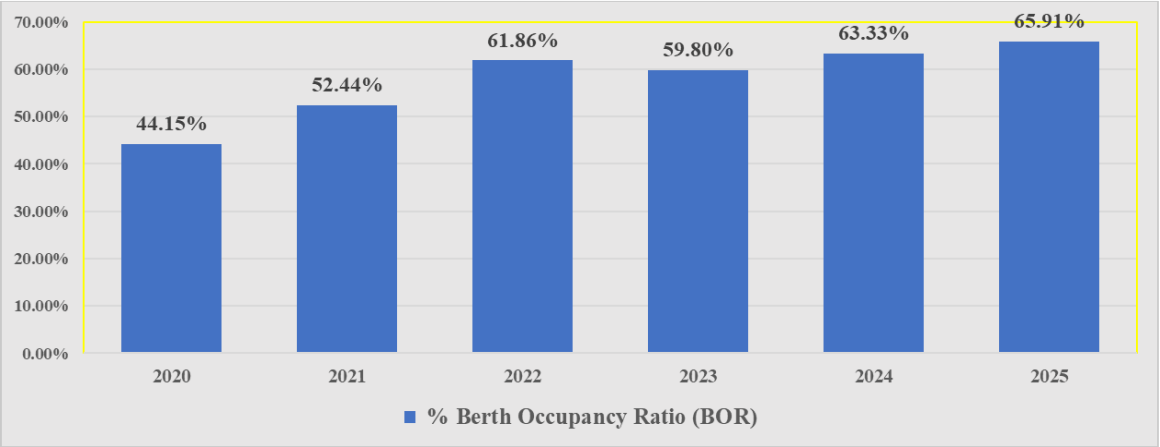


Figure 1. Trend in Berth Occupancy Ratio for floating Storage Balikpapan combined, 2020 to 2025.

in 2024 and 2025 shows the workload spreading more evenly between them. As combined BOR keeps nearing 70 percent, the room to add volume without adding vessels grows tighter. This becomes one trigger in the decision criteria, the point at which a third vessel or an onshore tank alternative needs to be considered so that service does not stall.

Analysis of tank occupancy rate

Tank utilization climbed from 40.6 percent in 2020 to 53.9 percent in 2021, held at 52.2 percent in 2022, then dropped sharply to 32.6 percent in 2023 before recovering to 53.9 percent in 2024 and reaching 64.3 percent in 2025. The sharp 2023 fall stands out as an anomaly because it occurred in a year of high intake, 1.66 billion liters.

The explanation lies in vessel capacity, not a shortfall in volume. The companion vessel in 2023 was MT Gebang at 97,643.50 kiloliters, nearly two and a half times the roughly 39,300 kiloliters of the companion vessels in other years. With the capacity denominator so much larger, the same volume yields a lower fill ratio. The per-vessel data for 2023 make this clear: MT Gebang was only about 19.2 percent full, while the smaller MT Sengeti was 78.2 percent full.

This finding brings out an important trade-off between capacity and utilization. A large vessel offers ample buffer room and the flexibility to absorb supply surges, but it depresses utilization when volume does not yet match its holding capacity. A right-sized vessel, by contrast, records high utilization but leaves little room when supply spikes.

The recovery of utilization to 64.3 percent in 2025 suggests that a mid-capacity companion vessel fits the current volume profile better. From a sustainability standpoint, the improving utilization strengthens the case that the vessel's storage space is still used efficiently, provided fleet selection matches the volume required.

Sustainability of vessel use toward the B50 blend

The sustainability of the vessel's role cannot be separated from the growth of biodiesel production capacity. National capacity grew from 12.09 million kiloliters in 2020 to 23.18 million kiloliters in 2025, a rate of about 13.9 percent per year. The most striking jump was in Kalimantan, from 2.02 million to 7.17 million kiloliters over the same period, a rise of about 254.6 percent, or a compound rate near 28.8 percent per year. Kalimantan's portion of national capacity rose from 16.7 to 30.9 percent, so a region that once depended on supply from Sumatra and Java now has its own production base, one that is growing stronger and sits close to the demand center in eastern Indonesia.

Kalimantan's capacity growth could shape the vessel's role in two directions. A closer supply source can shorten the distribution chain and reduce dependence on floating storage as a long-distance buffer. At the same time, the added production still needs storage and blending facilities before it reaches delivery points. As long as onshore tank capacity and port facilities have not grown in step with plant capacity, the vessel is still needed to bridge that gap. The idea of a buffer reserve that draws on existing storage capacity to safeguard energy supply security aligns with thinking on national strategic fuel reserves (Rahman 2011). In this context, the floating storage vessel performs a similar buffer function for biodiesel in the eastern region.

National production and distribution data reinforce this direction. National biodiesel production rose from about 6.17 million kiloliters in 2018 to 15.65 million kiloliters in 2025, while domestic consumption tracked production closely and exports shrank toward zero. Almost all output is now absorbed by the domestic market as the mandate climbs. With B40 already running in 2025 and development heading toward B50, domestic biodiesel demand will keep rising, so the need for storage and distribution facilities, including buffer nodes such as the floating storage vessel, is likely to grow rather than shrink, at least over the short to medium term (Wirawan et al., 2025). Demand pressure from the mandate therefore runs counter to the potential reduction in the vessel's role as Kalimantan's plants expand. Nearer production capacity does shorten the supply distance, but the total volume that must be stored and distributed grows larger.

Integrated data management and biodiesel resource planning will become more important for keeping the supply chain sustainable at higher blend levels (Supriyatno & Rani 2023). In addition, the higher FAME content in blends approaching B50 calls for closer attention to quality stability during storage, given biodiesel's tendency to

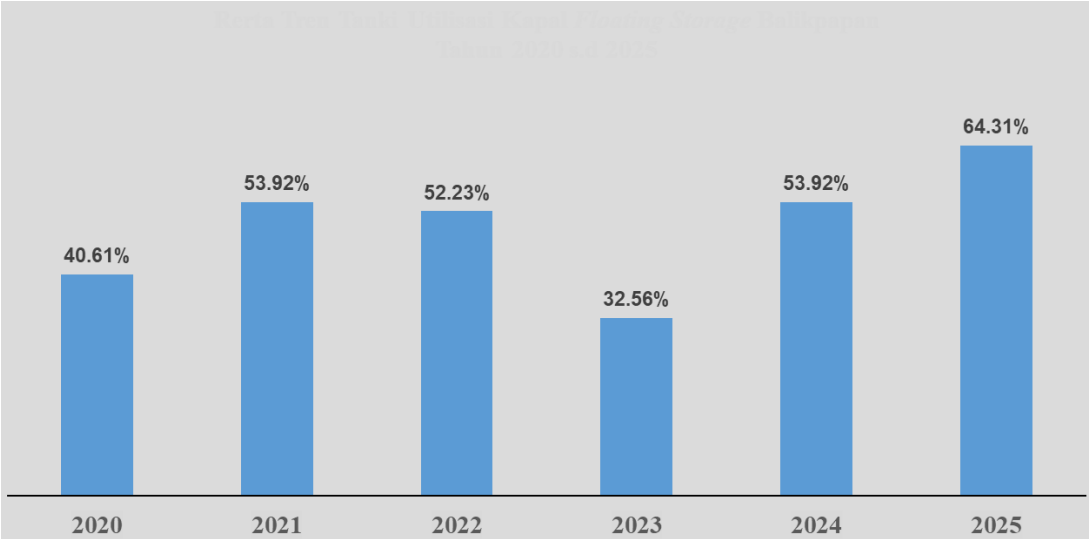


Figure 2. Tank utilization trend for Floating StorageBalikpapan, 2020 to 2025.

oxidize over long storage periods (Wibowo et al., 2016), along with accurate measurement of biodiesel content in the blend so the product keeps meeting specification (Rusli et al., 2025). This quality dimension is inherent to the vessel's function as a temporary storage node and must be maintained as the blend level rises.

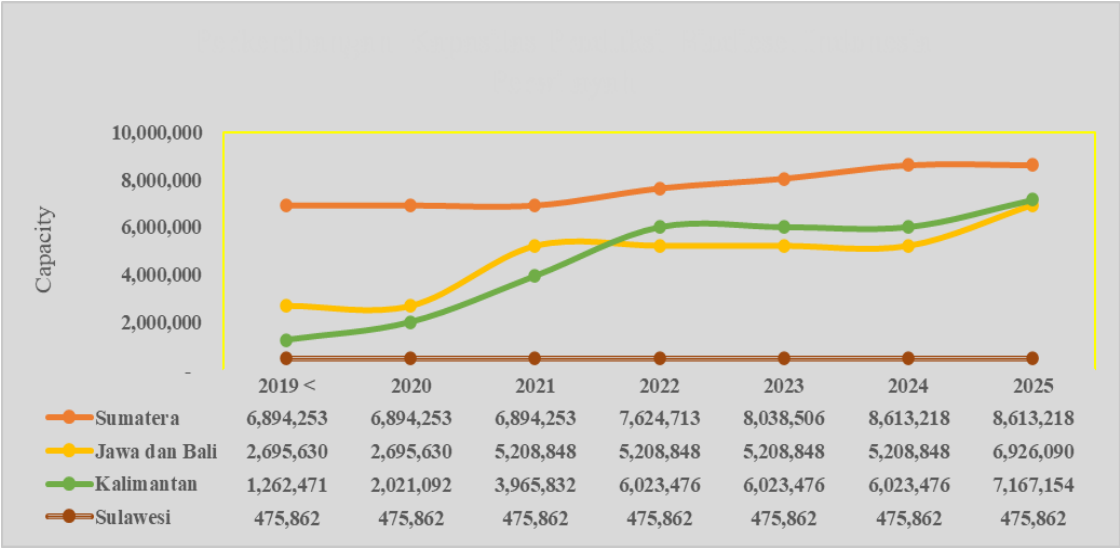
Synthesis and decision criteria

A synthesis of all indicators is summarized in Table 4. On operational performance, the volume handled grew, BOR rose from 44.1 to 65.9 percent, and tank utilization recovered to 64.3 percent after the 2023 anomaly. On economic benefit and environmental impact, cost per liter fell 22.8 percent, cumulative foreign exchange savings reached 5,658.8 million US dollars, and avoided emissions passed 25.3 million tons of CO2. On sustainability, the outcome rests on the balance between rising demand toward B50 and the readiness of onshore infrastructure.

From this summary, two decision rules emerge. First, the vessel is worth keeping as long as three conditions hold: combined BOR stays below roughly 75 percent so that service is not saturated, cost per liter remains on a declining or stable trend, and onshore tank infrastructure in eastern Indonesia cannot yet reliably hold and blend the volumes required. In 2025 all three still held, so the recommendation is to keep using the vessel. Second, a gradual shift to onshore tanks starts to warrant consideration once combined BOR consistently exceeds about 75 to 80 percent, the fast-growing Kalimantan plant capacity is matched by ready onshore tanks and ports, and cost per liter begins to climb under the burden of adding vessels. Until the onshore infrastructure preconditions are met, rushing the transition risks disrupting the continuity of supply to eastern Indonesia.

To estimate when the decision threshold is reached, a simple projection of intake volume was made, assuming growth follows the historical rate of 9.1 percent per year, as in Table 5. The projection shows combined BOR potentially reaching about 71.9 percent in 2026 and 78.4 percent in 2027. With the current two-vessel configuration, service will pass the density threshold of about 75 percent in 2027, in line with demand pressure toward B50. This is the point that triggers a decision to add vessels or shift part of the volume to onshore tanks.

A key follow-up question is which variable to change if the vessel's role needs adjusting: the capacity of each vessel or the number of vessels. The evidence across the evaluation period points to the number of vessels. Capacity per vessel is best kept in the mid class, around 39,000 to 41,000 kiloliters, and not used as the lever for adjustment. In a scale-up scenario, once BOR passes 75 percent, the better move is to add one mid-capacity vessel rather than swap in a single very large one. The 2023 lesson makes this clear: using MT



	2019 <	2020	2021	2022	2023	2024	2025
Sumatera	6,894,253	6,894,253	6,894,253	7,624,713	8,038,506	8,613,218	8,613,218
Jawa dan Bali	2,695,630	2,695,630	5,208,848	5,208,848	5,208,848	5,208,848	6,926,090
Kalimantan	1,262,471	2,021,092	3,965,832	6,023,476	6,023,476	6,023,476	7,167,154
Sulawesi	475,862	475,862	475,862	475,862	475,862	475,862	475,862

Figure 3. Growth of Indonesia's biodiesel production capacity by region

Table 3. Summary of FS Balikpapan Evaluation Indicators, 2020 to 2025, Source : Directorate General of New and Renewable Energy and Energy Conservation, Ministry of Energy and Mineral Resources and Processed Data by the Author

Indicator	2020	2021	2022	2023	2024	2025
Volume received (million liters)	1,220	1,620	1,569	1,664	1,581	1,886
Volume distributed (million liters)	1,192	1,214	1,384	1,649	1,647	1,741
National share (%)	14.5	17.4	15.0	13.5	12.0	12.6
Combined BOR (%)	44.1	52.4	61.9	59.8	63.3	65.9
Tank utilization (%)	40.6	53.9	52.2	32.6	53.9	64.3
Cost (IDR/liter)	129.9	124.8	120.5	109.6	113.4	100.3
Foreign exchange (million USD)	381	831	1,329	1,118	955	1,045
GHG (million tons CO2)	3.24	4.30	4.17	4.42	4.20	5.01
Mandate	B30	B30	B30	B35	B35	B40

Table 4. Volume and BOR Projections under a 9.1% Annual Growth Scenario. Source : Processed Data by the Author

Year	Projected volume received (million liters)	Projected BOR (%)	Utilization status
2025 (actual)	1,886	65.9	Busy but healthy
2026 (projected)	2,057	71.9	Approaching threshold
2027 (projected)	2,245	78.4	Exceeds 75% threshold

Gebang at 97,643 kiloliters drove tank utilization down to 32.6 percent because the storage space far exceeded the volume available. In a scale-down scenario, once Kalimantan's plant growth is matched by ready onshore tanks and ports, the better move is to cut the fleet from two vessels to one, keeping MT Sengeti with its steady 66 to 69 percent BOR, rather than holding two vessels at reduced loads. Most vessel costs are fixed per unit, charter above all, so removing a vessel trims cost more than simply lowering the fill level.

CONCLUSION

The operational performance of the Balikpapan Floating Storage Vessel improved steadily from 2020 to 2025. The biodiesel volume handled rose from 1.22 billion liters to 1.89 billion liters, combined BOR rose from 44.1 to 65.9 percent, and tank utilization recovered to 64.3 percent after dipping to 32.6 percent in 2023 due to the use of a large-capacity vessel. The drop in national volume share from 14.5 to 12.6 percent stemmed from faster national growth, not from weaker vessel performance.

Continuing to use the vessel remains justified as the blend level rises toward B50, but it calls for gradual adjustment. Projections show BOR could exceed 75 percent around 2027 as production capacity and demand grow. Adjustment is better focused on the number of vessels: adding a mid-class vessel of about 39,000 to 41,000 kiloliters when the load increases rather than a large-capacity one, and cutting back to a single vessel by keeping MT Sengeti if the vessel's role starts to diminish. As long as onshore tank infrastructure in eastern Indonesia remains inadequate, the floating storage vessel is best positioned as an optimized buffer rather than removed abruptly.

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DECLARATIONS

Author contributions

Junaidi: conceptualization, methodology, investigation, data curation, formal analysis, writing original draft, writing review & editing. A.R. Indra Tjahjani: Supervision (co), visualization, methodology, validation, writing review. I Nyoman Teguh Prasidha: Supervision (co), methodology, validation, writing review & editing. Cahyo Setyo Wibowo: Supervision (co), methodology, validation, writing review & editing.

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Competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. The authors' affiliations with government and academic institutions did not affect the study design, data analysis, interpretation of results, manuscript preparation, or the decision to publish.

The use of AI or AI-assisted technologies

During the preparation of this manuscript, AI -assisted technologies were used exclusively to improve the clarity, grammar, and readability of the text. The authors critically reviewed, edited, and validated all content generated with the assistance of these technologies and assume full responsibility for the accuracy, originality, and integrity of the manuscript.

GLOSSARY OF TERMS AND SYMBOLS

Terms & Symbols	Definition	Unit
BOR	Berth Occupancy Ratio, the ratio of vessel berthing time used	%
TOR	Tank Occupancy Rate, the ratio of tank capacity used	%
FAME	Fatty Acid Methyl Ester, methyl esters of fatty acids	-
CPO	Crude Palm Oil, raw palm oil	-
STS	Ship to Ship, a vessel-to-vessel cargo transfer mechanism	-
MOPS	Mean of Platts Singapore, a fuel reference price	USD/barrel
GHG	Greenhouse Gas	tons CO2
Bxx	A blend of xx percent biodiesel with diesel	-
NDC	Nationally Determined Contribution	-

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