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SUSTAINABILITY ORIENTED INNOVATION ANALYSIS: LOW SULFUR MARINE FUEL OIL (LS MFO) TOWARDS INDONESIA'S GREEN PORT

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Abstract

The Indonesian government has demonstrated its commitment to facilitating the transition towards zero-carbon fuel in maritime operations, along with the evolution of Indonesian ports into environmentally sustainable hubs. This commitment is exemplified through the initiation of low sulfur marine fuel oil (LS MFO) production, intended for naval armada fuel, within the port supply chain. This endeavor signifies a strategic move towards fostering greener practices within the maritime sector, aligning with global efforts to mitigate carbon emissions and promote sustainable development. The Indonesian government has demonstrated its commitment to facilitating the transition towards zero-carbon fuel in maritime operations, along with the evolution of Indonesian ports into environmentally sustainable hubs. This commitment is exemplified through the initiation of low sulfur marine fuel oil (LS MFO) production, intended for naval armada fuel, within the port supply chain. This endeavor signifies a strategic move towards fostering greener practices within the maritime sector, aligning with global efforts to mitigate carbon emissions and promote sustainable development. This analysis leads to the development of key parameters for the transformation evaluation green port framework.

Keywords: green port, LS MFO supply chain, port sustainability oriented innovation

INTRODUCTION

In today's interconnected world, no single country can independently fulfill all its requirements. Disparities in natural resource endowments, as well as variations in resource management capabilities, industrial and agricultural development, cultural advancement, and technological prowess, underscore this reality. Consequently, nations rely on international trade to bridge the gap between their needs and limitations. In the dynamic realm of port operations, this interconnected reality gains paramount significance. Ports serve as critical nodes in facilitating international trade (Badurina et al., 2017), bridging the disparities in natural resource endowments, resource management capabilities, and developmental levels among nations. Through efficient port management, countries can leverage their comparative advantages and optimize global economic interactions. Thus, ports play a pivotal role in fostering cooperation and exchange, thereby shaping the trajectory of global economic dynamics.

While there is a burgeoning body of research focusing on ports and terminals, a noticeable gap exists between theoretical insights and practical applications within conventional port literature. Much of the theoretical discourse surrounding port planning, logistics, performance, strategy, and regulations appears somewhat detached from the operational realities of contemporary ports and terminals, particularly concerning design configurations, handling systems, operational procedures, and technological advancements (Bichou, 2013). Despite the increasing attention given to the environmental impacts of ports and shipping in recent decades (Ducruet et al., 2013), there remains a critical imperative for further integration of theoretical frameworks with the operational context of modern maritime infrastructure. Notably, decarbonization stands out as a paramount concern within the maritime industry's agenda, exerting profound influence on investment priorities and strategic decision-making moving forward (Lloyd’s List, 2021).

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On this basis, the idea of an environmentally Green Port emerged. The notion of 'Green Port' development encapsulates the incorporation of environmentally sustainable practices within port activities, operations, and management. Establishing ecological/green seaports involves various measures aimed at mitigating environmental impact. These measures encompass implementing policies to reduce emissions of harmful substances into the atmosphere. This approach underscores the commitment to sustainable development within port infrastructure and operations (Badurina et al., 2017).

Sustainability-oriented innovation (SOI) emerges as a compelling theoretical framework to bridge the gap delineated above. SOI denotes deliberate alterations in an organization's ethos and principles (Adams, 2021), constituting a subset of innovation (Harsanto et al., 2022), directed towards its products, processes, practices with the aim of making social and environmental benefits beside economic gains. This conceptualization of innovation holds promise for addressing the disconnect between theoretical discourse and operational realities within port environments. By integrating SOI principles into port planning, logistics, and operations, stakeholders can work towards a more cohesive incorporation of sustainability objectives within maritime infrastructure development and management. This integration establishes a robust positive correlation between sustainability-driven innovations and fostering a green organizational identity. Such an identity, in turn, enhances the perception of environmental responsibility through demonstrated green commitments. This study offers managers valuable insights into internal factors that foster sustainable innovations and how to leverage these insights to ensure economic viability. Understanding the dynamic interplay between action, identity, and image equips policymakers with the necessary tools to formulate strategies that foster a culture of sustainability. (Taneja et al., 2023).

The World Ports Sustainability Program, established by the International Maritime Organization (IMO), endeavors to foster a collective vision of port sustainability while enhancing collaboration with supply chain partners. As a specialized UN agency entrusted with ensuring the safety, security, and environmental integrity of global shipping activities, the IMO is committed to emissions reduction and the attainment of Nationally Determined Contributions (NDCs). By 2023, the IMO has revised its Greenhouse Gas (GHG) Strategy for the shipping sector, aiming for a 70% reduction in GHG intensity by 2040, adjusted from the initial target of 80%. This necessitates a substantial enhancement in energy efficiency, considering the projected rise in trade volumes. Moreover, an interim objective is to achieve zero or near-zero GHG emissions from 5-10% of shipping energy consumption by 2030. These ambitious targets underscore the imperative for significant investments and the accelerated development of zero-emission technologies (Laffineur et al., 2023), a challenge applicable to maritime economies across the spectrum, including small and developing nations such as Indonesia.

Indonesia witnessed a steady increase in national GHG emissions from 2010 to 2018, with an annual growth rate averaging approximately 4.3% (Kementerian Keuangan Republik Indonesia, 2021). The endeavor to fulfill its NDC entails substantial climate change mitigation costs, estimated through the mitigation action costs approach. The projected cumulative expenditure for the period 2020-2030 amounts to IDR 3,779 trillion (equivalent to IDR 343.6 trillion annually). Notably, energy and transportation emerge as the primary drivers of emissions, with the NDC Roadmap forecasting expenses of Rp. 3,500 trillion for these sectors. Such projections underscore the pressing demand for robust climate change financing mechanisms to facilitate Indonesia's transition towards a low-carbon trajectory (Kementerian Keuangan Republik Indonesia, 2021).

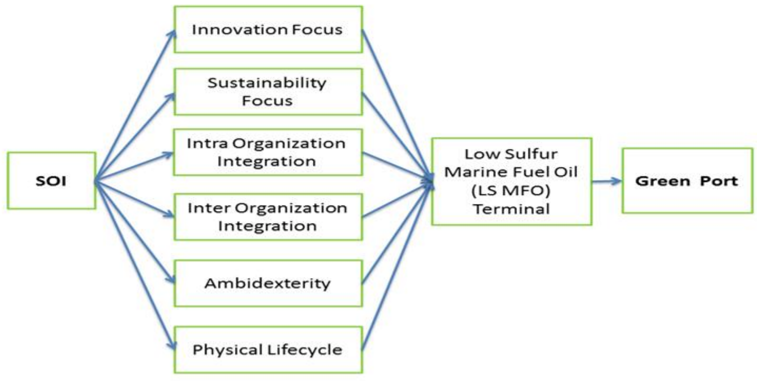
In reaffirmation of its commitment to carbon emission reduction, Indonesia renewed its NDC in July 2021. The decarbonization agenda within the shipping industry features prominently in Indonesia's NDC update, with records indicating that the national shipping sector accounted for 19 percent of carbon dioxide emissions. The country's database registers 39,510 cargo ships and 171,754 fishing boats, predominantly comprising small boat types. Notably, an estimated total of 200 thousand ships traversed Indonesia's crucial straits in 2020, with approximately 130 thousand navigating the Malacca Strait, 56 thousand the Sunda Strait, and 33 thousand the Lombok Strait annually. These extensive shipping activities have led to significant carbon dioxide emissions within Indonesia's borders. In response to this challenge, the Indonesian government has demonstrated its commitment to facilitating the transition to zero-carbon fuels in maritime operations and the conversion of Indonesian ports into environmentally sustainable facilities. This initiative includes the initiation of low sulfur marine fuel oil (LS MFO) production by Pertamina, intended for use by naval fleets within the port supply chain. The Indonesian government also has embarked on initiatives promoting the transition from oil-based fuels to gas fuels, particularly targeting small boats, as part of its broader decarbonization strategy.

This transition towards achieving a zero-emission Green Port paradigm will undergo qualitative analysis utilizing the six dimensions of Sustainability-Oriented Innovation (SOI): innovation focus, sustainability focus, intra-organizational integration, inter-organizational integration, ambidexterity, and physical life cycle (Harsanto et al., 2024). The aim and novelty is to comprehensively assess the transformative journey towards sustainable port operations. It is anticipated that the insights gleaned from this analysis will serve as valuable inputs for the development of a Port SOI model tailored to the unique context of Indonesian ports. By delving into these dimensions, this study seeks to offer practical guidance for port stakeholders in Indonesia to navigate the complexities of sustainability-driven innovation and foster a more resilient and environmentally conscious maritime infrastructure.

METHOD

This study adopts a qualitative methodology augmented by comprehensive literature reviews, necessitating a nuanced skill set encompassing topic definition, literature search and retrieval, data analysis and synthesis, and proficient academic writing and reporting, often within constrained timeframes (Cronin et al., 2008). Subsequently, this approach was applied to scrutinize the development and execution strategies for a LS MFO in connection to Belawan Port operations, employing elements of SOI. The research framework elucidating the progression of this investigation is outlined below.

Figure 1. Research Model



RESULT AND DISCUSSION

As previously elucidated, the researcher will expound upon the discussion regarding the six elements of SOI in the following sections:

1. Innovation Focus

Ports play a pivotal role in our society, but they also present significant environmental risks and stressors that can have adverse effects on neighboring natural ecosystems and human health. Notably, port systems have been identified as major energy consumers (Belcore et al., 2023), contributing to concerns about their ecological footprint. According to the Coordinating Ministry for Maritime and Investment Affairs in Indonesia, 19% of the country's CO2 emissions, as outlined in its Nationally Determined Contributions, stem from the maritime industry (Junida & Ihsan, 2021).

The International Energy Agency (IEA), in a special report, forecasts a shift in fuel consumption within Indonesian maritime shipping. While oil currently satisfies all shipping demand (123 PJ), its dominance is projected to decline to around 80% by 2030 and to one-third by 2060. Hydrogen and ammonia are anticipated to emerge as dominant energy sources for shipping, each accounting for approximately a quarter of total demand by 2060. Moreover, the prevalence of biodiesel blending in the country, meeting nearly 15% of demand, notably impacts shipping, particularly in smaller vessels that traditionally rely on diesel (IEA, 2022).

The transition to alternative energy sources in the maritime sector necessitates active involvement from various actors. These actors play a crucial role in shaping the port energy transition, influencing energy usage and practices across three intersecting domains: the port domain, maritime transportation, and inland transportation (Bjerkan et al., 2021).

As a foundational step towards transition efforts, stakeholders are pivoting from the IMO 2020 regulations, which mandate the use of compliant fuel oils with sulfur content not exceeding 0.50%. Indonesia, the target country for this program, issued Decree No. 0179.K/DJM.S/2019 by the Director General of Oil and Gas, outlining standards and quality specifications for LS MFO marketed domestically. These regulations mandate the use of low sulfur fuel for all vessels operating in Indonesian waters, irrespective of flag registration.

The imperative to adopt LS MFO is emphasized in Circular No. 35 of 2019, which underscores the health and environmental ramifications of sulfur emissions from ship fuels, particularly for communities residing near ports and coastal areas. Pertamina, recognizing this urgency, is actively engaged in mitigating pollution stemming from ship fuel emissions by producing LSFO. LSFO is tailored for marine applications, featuring a viscosity of up to 180 cSt at 50°C, specifically catering to vessels equipped with low-speed diesel engines.

Effective January 1, 2020, Indonesia has enforced mandatory compliance with low sulfur fuel regulations, aligning with IMO 2020 guidelines. Consequently, the focal point of innovation in this transition lies in the production and distribution of LFSO. Oversight of the Energy Transition for Ship and Port Infrastructure rests with key stakeholders such as the Harbormaster, Port Authority, the Port Management Unit and other stakesholders.

2. Sustainability Focus

The prominence of energy-related activities in and around ports has intensified due to the escalating significance of energy trades, heightened public environmental consciousness, and a growing industry emphasis on energy efficiency. The adoption of innovative technologies, including alternative fuels, and the proliferation of renewable energy installations within port vicinities underscore the necessity for heightened attention to energy considerations in port management (Acciaro et al., 2014).

This heightened focus has propelled efforts to transform ports into ecologically sustainable hubs, global supply-chain focal points, and maritime resource allocation centers. Such transformation necessitates a blend of incremental and radical innovation, alongside the fostering of a conducive business environment (Shi et al., 2020). Consequently, port stakeholders encounter myriad challenges in mitigating risks and averting ecosystem impacts, recognizing the interconnectedness of ports within the broader regional coastal ecosystem.

Environmental monitoring within ports must, therefore, adopt a comprehensive, holistic, multilayered approach that integrates seamlessly with the wider ecosystem. Such an approach not only aids in achieving sustainable development, a primary objective of the United Nations' (UN) 2030 agenda, but also aligns with the objectives of the Decade of Ocean Science for Sustainable Development (2021-2030) (Ferrario et al., 2022).

In line with Indonesia's commitment to achieve Net Zero Emissions (NZE) by 2060, the maritime transportation subsector has embarked on various initiatives aimed at reducing GHG emissions. These efforts encompass several strategies, including the adoption of solar photovoltaic (SBNP) cells, the implementation of efficient port operational management practices such as Onshore Power Supply facilities, exemplified by the installation at the Belawan central port. Additionally, modernization efforts entail the utilization of Vegetable Fuel (B30), energy conservation measures onboard ships and within ports, and the development of ecoports through the integration of new and renewable energy (EBT) solutions, such as solar photovoltaic systems (PLTS) and solar-powered streetlights (LPJU).

Pertamina, the national oil company, has taken strides towards promoting environmentally friendly maritime transportation fuel by initiating the production of LSFO. This initiative extends to major Indonesian ports, including Tanjung Priok, Tanjung Perak, Belawan, Makassar, Balikpapan, Batam, and Dumai. Moreover, Pertamina International Refinery has introduced innovations and new products, including LSFO with international specifications that align with environmental sustainability goals.

To bolster the sustainable adoption of low sulfur fuel and enhance fuel efficiency in ship operations, the Directorate General of Sea Transportation has devised a decarbonization mitigation plan aligned with the IMO strategy (IMO, 2023). Key elements of this plan encompass optimizing ship operations through the establishment of Short and Safe routes (Short Sea Shipping), providing Shipping Telecommunications Services (including weather information) through Vessel Traffic Service (VTS) (Kelana, et al., 2018) and Ship Reporting System (SRS), and implementing rigorous ship maintenance protocols. Notably, Inaportnet has been instrumental in streamlining ship operations management within the IT sector.

Furthermore, efforts to enhance port management efficiency include the deployment of solar cells for Aid to Navigation (AtoN), electrification of port loading and unloading equipment, and the integration of solar cells and LED lights for port facilities. These initiatives are complemented by heightened monitoring of the marine environment to foster the development of ecoports or green ports, characterized by the widespread adoption of renewable energy solutions. Collectively, these endeavors aim to achieve a 20-25% improvement in technological efficiency within the transportation sector by 2060 (Antara, 2022).

3. Intra-Organization Integration

The UN In 2015, released a seminal document titled 'Transforming our world: the 2030 agenda for sustainable development", outlining 17 Sustainable Development Goals (SDGs) accompanied by 169 targets. Among these goals, SDG 14 concern about life below water that focus on conservation and sustainability of oceans, seas, and marine resources, highlighting the significant role the maritime industry can play (Wang et al., 2020).

Aligned with its commitment to the SDGs, the IMO endeavors to advance low-carbon technologies through various mechanisms, including fostering public-private partnerships, facilitating sharing information, transfer of technology, capacity development, and technical cooperation. These efforts aim to enhance ship energy efficiency and support the implementation of the IMO Strategy through initiatives such as the Integrated Technical Cooperation Program (ITCP), the GloMEEP project, and the Maritime Technologies Cooperation Center (MTCC) network (IMO, 2023).

The IMO 2023 GHG Strategy serves as a roadmap for Member States, outlining a vision for the future of international shipping, setting ambitious targets to reduce GHG emissions, and proposing guiding principles. The strategy outlines medium and long-term steps, including likely timeframes and anticipated impacts, while also identifying barriers and recommending supporting measures such as technical cooperation, capacity building, and research and development (R&D).

The IMO 2023 GHG Strategy endeavors to diminish the carbon intensity of global maritime transport, with the ambition of achieving a minimum 40% decrease in CO2 emissions per transport operation by 2030. Furthermore, the strategy promotes the uptake of innovative technologies, alternative fuels, and energy sources characterized by zero or near-zero emissions. The objective is for these environmentally friendly alternatives to account for no less than 5% of the energy utilized by international shipping by 2030, with a subsequent aspiration to elevate this proportion to 10% (IMO, 2023).

Moreover, the UN Trade, as another prominent intra-organizational entity, delineates three principal avenues for advancing this strategy: 1) transitioning towards fuels characterized by low or negligible sulfur content, such as LSFO and liquefied natural gas (LNG); 2) implementing exhaust gas treatment systems (scrubbers) while persisting with the use of traditional high sulfur fuel; and 3) curtailing fuel consumption by enhancing energy efficiency, thereby resulting in reduced fuel emissions (United Nations, 2024).

The provision of information concerning the implementation of the global 0.50 percent sulfur limit serves to foster more equitable and efficacious participation in the global economy for developing nations like Indonesia. This necessitates the provision of comprehensive data and analysis, facilitation of consensus-building, and provision of technical assistance on matters related to trade and development.

It is imperative to acknowledge that the execution of GHG reduction measures within the maritime sector may lead to heightened maritime transport expenses, thereby augmenting trade costs among states. Such a notable escalation in maritime transport expenditures has the potential to amplify overall trade expenses, potentially instigating alterations in global trade dynamics and volumes (Halim et al., 2019). Consequently, nations, particularly developing ones such as Indonesia, necessitate assistance from international financial institutions, including world banks, to ensure the efficacy of such initiatives.

The IMO's 2023 GHG Strategy is geared towards reducing the carbon intensity of international shipping, quantified as CO2 emissions per transport operation, by a minimum of 40% by 2030, averaged across global shipping routes. Furthermore, the strategy sets forth a heightened level of ambition regarding the adoption of technologies, fuels, and/or energy sources with zero or near-zero emissions. It aims for these sustainable alternatives to comprise at least 5% of the energy consumed by international shipping by 2030, with a subsequent target of reaching 10% (IMO, 2023).

In furthering the development of this strategy, UN Trade, as another intra-organization, presents three pivotal options: a) Transitioning to fuels characterized by low or negligible sulfur content, such as LSFO and liquefied natural gas (LNG); b) Integrating exhaust gas treatment systems (scrubbers) while persisting in the utilization of conventional high sulfur fuel; and c) Reducing fuel consumption through measures enhancing energy efficiency, thereby emitting lesser fuel (United Nations, 2024). By disseminating information on the implementation of the global 0.50 percent sulfur limit, UN Trade aids developing nations like Indonesia in navigating the global economy more equitably and efficiently. It accomplishes this by providing comprehensive data and analysis, facilitating consensus-building, and extending technical assistance on matters pertaining to trade and development.

As GHG reduction measures are implemented, there is a potential escalation in maritime transport costs, impacting trade expenses between states. A notable increase in maritime transport expenditures can consequently elevate overall trade costs, potentially reshaping global trade patterns and volumes (Halim et al., 2019). Consequently, it becomes imperative for developing nations such as Indonesia to receive support from international financial institutions like world banks to ensure the collective success of this program.

4. Inter-Organization Integration

Governments play a crucial role in spearheading the formulation of explicit cluster strategies and effective policy instruments. This involves ensuring internal coherence through streamlined organizational structures and nurturing a conducive environment by investing in infrastructure and implementing soft promotional initiatives (Shi et al., 2020). Consequently, environmental sustainability has emerged as a significant concern within the port sector, engaging port authorities, policymakers, users, and local communities alike. Despite the potential of innovation to address environmental challenges, it often faces resistance. While some forms of technological or organizational innovation can be adequately assessed using closed-system theories, the intricate dynamics of seaports, particularly in relation to environmental sustainability, call for more nuanced conceptual frameworks. These frameworks need to accommodate the diverse range of stakeholders in the port industry and the complex network and vertical interactions inherent in environmental sustainability. Only innovations that dynamically align with the needs of port stakeholders and the institutional context of the port have the potential to succeed (Acciaro et al., 2014).

To date, the proactive pursuit of energy management strategies by port authorities remains limited. However, the necessity for port authorities to take an active role in managing their energy usage stems from their responsibility to oversee, organize, and promote economic operations within the port, coupled with the growing emphasis on sustainability in port management approaches. Embracing active energy management offers the potential for substantial efficiency improvements, the creation of new revenue streams from alternative sources, and ultimately, the strengthening of the port's competitive standing. As ports transition towards more sustainable models, the adoption of active energy management emerges as a pivotal element in their strategic outlook for the future (Acciaro et al., 2014).

As the shipping industry gears up to comply with global decarbonization standards, the significance of ports in this transformative process cannot be overstated. The IMO GHG Strategy serves as a directive for member states to prepare for and facilitate reductions in greenhouse gas emissions associated with shipping activities. Additionally, an IMO resolution has been adopted, urging port nations to foster voluntary collaboration with the shipping sector to mitigate ship-related GHG emissions (IMO, 2019). Hence, the role of ports in contributing to the decarbonization of shipping holds merit for a variety of reasons (Alamoush et al., 2020).

In the internal integration structure at Indonesian Ports, there are two main actors in the low sulfur fuel transition, namely the government sector and the private sector. This transition is related to the Ministries of Maritime Affairs and Investment, Transportation, Environment and Finance. Meanwhile, in operations, there is the harbormaster as the enforcer of the rules to comply with the use of LSFO, the Port Authority has the responsibility to the regulation, port control and supervision activities at commercially operated ports, as well as state-owned enterprises that work together in supporting the Net Zero Emission target in 2060 such as Pelindo as a port management unit, Pertamina as a supplier of LSFO and PLN as a supplier of electricity to replace fuel on the government side while the industrial parties involved are ship owners, shipyards that are members of INSA: Indonesian National Shipowners' Association jointly carrying out decarbonization at the port.

5. Ambidexterity

Organizational ambidexterity is essential, highlighting the simultaneous need to explore new opportunities while leveraging existing capabilities within a company for sustained success (Schnellbächer & Heidenreich, 2020). Exploration involves venturing into new options, despite the potential for unpredictable and unfavorable outcomes. Conversely, exploitation focuses on refining current capabilities, technologies, and paradigms, resulting in incremental improvements to existing products (Saleh et al., 2023).

The adoption of diverse alternative marine fuels and renewable energy sources is pivotal for maritime decarbonization. These cleaner alternatives include LNG, liquefied biogas (LBG), hydrogen, ammonia, methanol, ethanol, hydrotreated vegetable oil (HVO), fuel cells, nuclear, wind and solar power, and electricity. However, utilizing ships powered by alternative fuels introduces unique risks, such as spills, vapor dispersion, and fuel pool fires. While the likelihood of marine environmental damage from fuel leakage may be relatively low, other potential risks like methane slip-induced atmospheric contamination and unforeseen health and property hazards due to ammonia toxicity necessitate careful consideration (Wang et al., 2023).

Alternative fuels and energy sources offer promising pathways to achieve low carbon and zero carbon emissions goals, although their adoption often requires substantial technical and operational investments. However, it is imperative to recognize that while alternative shipping fuels aim to reduce carbon emissions from the shipping sector, they may overlook additional risks to the marine environment. Hydrogen, solar energy, and wind energy show potential for realizing zero-carbon shipping objectives. Yet, their complete substitution for carbon-based fuels like diesel oil and LNG presents considerable technical and economic challenges. Moreover, life cycle assessments reveal notable greenhouse gas emissions during the production or transportation of alternative fuels such as hydrogen and electricity, despite their cleaner operation as fuel sources. Additionally, biofuels, ammonia, and electricity may pose risks of acidification and eutrophication during production and disposal. Alongside environmental concerns, various alternative fuels present maritime risks for ship crews and other individuals. While factors like ship types, speeds, and routes influence the environmental impact of different alternative fuels, it is crucial to address these risks from a broader perspective (Wang et al., 2023).

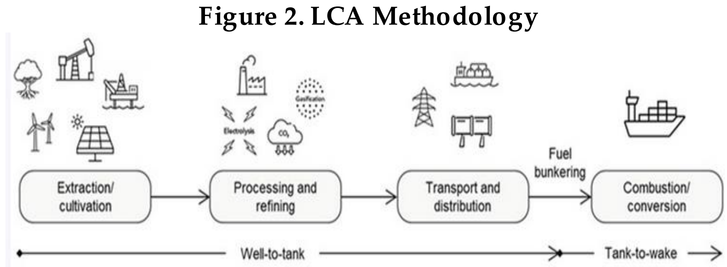
As previously discussed, the mandatory adoption of LSFO for all national and international ships entering Indonesian waters commenced on 1 January 2020. LSFO, characterized by its low sulfur content of approximately 0.5%, has garnered attention in the maritime industry and other transportation sectors as part of global efforts to mitigate environmentally harmful sulfur dioxide emissions. Sulfur dioxide is a significant contributor to air pollution, and the adoption of LSFO represents a key strategy in alleviating its adverse effects. Despite its widespread availability, the relatively higher cost of LSFO remains a challenge, exacerbated by Pertamina's limited production capacity of this low sulfur fuel. Nonetheless, Indonesia has embarked on LSFO innovation initiatives and aims to provide it for Indonesian ships, signaling the country's commitment to environmental stewardship in the maritime sector.

6. Physical life cycle

The burgeoning demand for container transport necessitates a shift towards greener practices to ensure long-term sustainability. Several innovations have emerged that align economic and environmental purpose. As notable issue is the ongoing trend of increasing ship size, which not only reduces shipping costs but also curtails fuel using and their emissions per container. Additionally, the adoption of alternative fuel blends in ship engines represents another promising avenue (Vleugel & Bal, 2015). The Life Cycle Assessment (LCA) methodology, as discussed in the 80th session of the Marine Environment Protection Committee (MEPC), encompasses the evaluation of greenhouse gas emissions from fuel production to final utilization by the ship, known as "Well-to-Wake." This assessment encompasses both the "Well-to-Tank," covering upstream emissions from primary production to fuel transport in the ship's tanks, and the "Tank-to-Wake" section, which involves downstream emissions from the ship's fuel tank to the exhaust, also referred to as "Tank-to-Propeller" (IMO, 2023).

This section explains the results of the study. Data should be presented in Tables or Figures when feasible. There should be no duplication of data in Tables and Figures. The discussion should be consistent and should interpret the results clearly and concisely, and their significance, supported by the suitable literature. This section also shows relevance between the result and the field of investigation and/ or hypotheses.

Figure 2. LCA Methodology



Source: IMO

Resolution MEPC.376 (80) was endorsed during the 80th session of the Marine Environment Protection Committee (MEPC 80), centering on the "Guidelines on Life Cycle GHG Intensity of Marine Fuels" (LCA Guidelines). These guidelines delineate methodologies for computing both well-to-wake and tank-to-wake emissions for all fuels and energy carriers, encompassing electricity, utilized aboard ships. Ongoing refinement and enhancement of these guidelines are foreseen in the forthcoming years, with a specific focus on default emission factors, sustainability benchmarks, fuel accreditation processes, and the integration of carbon capture technologies on ships (IMO, 2023).

However, the procurement of compliant low-sulfur fuels entails higher costs compared to traditional high-sulfur fuels. The price spread between these fuel types widened significantly in the latter half of 2019 in anticipation of the implementation of IMO 2020 at the outset of 2020 (United Nations, 2024). Nonetheless, ongoing innovations spearheaded by Pertamina as an LSFO manufacturer and Pelindo as a port operator, coupled with the maximization of services, are expected to enhance Cost of Service (CST) efficiency continually.

7. Sustainable Belawan Port

Belawan Port, operated by PT Pelabuhan Indonesia (Pelindo) Regional 1 Belawan, stands as a vital seaport and the western gateway of Indonesia, situated in Medan, the capital city of North Sumatra province. Positioned on the northeastern coast of Sumatra Island, it overlooks the Strait of Malacca, renowned as one of the world's busiest shipping lanes. Its strategic location renders it a crucial hub for international trade, facilitating the movement of goods entering and departing Indonesia. Belawan Port boasts modern facilities tailored to handle diverse cargo types, encompassing containers, bulk cargo, and liquid bulk cargo. With multiple terminals, berths, and warehouses, it accommodates various vessels and cargo handling operations. The port enjoys seamless connectivity to major domestic and international transportation networks, including road, rail, and air routes. Serving as a pivotal transportation conduit, Belawan Port facilitates the efficient movement of goods to and from different parts of Indonesia and neighboring countries.

At Belawan Port, Pelindo operates through its subholdings, each focusing on specific services: Pelindo Terminal Petikemas Subholding manages container services, Pelindo Multi Terminal Subholding oversees non-container cargo, and Pelindo Maritime Services Subholding provides ship-side services, equipment, and other port-related services. The port handles a diverse range of commodities, including agricultural products, minerals, manufactured goods, and petroleum products.

In 2023, PT Pelabuhan Indonesia (Pelindo) Regional 1 Belawan in North Sumatra served 3,900 ships, marking a 6% increase compared to 2022. Concurrently, there was an uptick in cargo flow, rising from 10.9 million tonnes in 2022 to 11.1 million tons in 2023 (Nasution, 2024). With this surge in activity, the demand for LSFO is expected to rise at Belawan Port in the foreseeable future. To address this, expanding capacity, enhancing efficiency, and implementing rigorous monitoring of LSFO supply and demand dynamics are crucial. The imperative for an LSFO terminal becomes increasingly pressing as Belawan Port endeavors to transition towards a sustainable Green Port model.

CONCLUSION

Indonesia is a focal point for countries aiming to adhere to zero emissions targets, particularly in the maritime sector, aligning with international standards and IMO regulations mandating the use of LS MFO since January 1, 2020. LS MFO, containing only 0.5% sulfur, complies with IMO requirements. An analysis of the situation at Belawan port reveals innovation and sustainability as key focal points. Innovation focuses on transitioning from High Sulfur Fuel Oil (HSFO) to LSFO, accompanied by necessary infrastructure upgrades. Sustainability efforts aim to establish Belawan as a Green Port, fostering energy-efficient practices in both ship and port operations. However, the success of these initiatives relies on robust intra- and inter-organizational integration. Intra-organizational collaboration involves entities like IMO, UN Conference on Trade and Development, and the World Bank, ensuring the program's collective success. Inter-organizational cooperation involves key stakeholders such as ministries, port authorities, Pelindo, Pertamina, and INSA, facilitating effective implementation. Ambidexterity analysis centers on LSFO creation and its integration into related organizations, while LCA evaluates greenhouse gas emissions from fuel production to ship utilization, encompassing both upstream and downstream emissions. Enforcing LSFO usage with continuous monitoring and innovation in ship operations promises to expedite the transition towards a Green Port in Belawan and Indonesia at large.

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