WHEN TRUST MATTERS

# BIOFUELS IN SHIPPING

## Current market and guidance on use and reporting

WHITE PAPER


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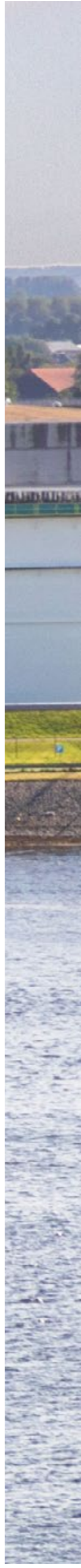
# Content





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# 1 Executive Summary

With the decarbonization of shipping in increasing focus, the use of biofuels[1] is on the rise.

Decarbonization targets have been set by the International Maritime Organization (IMO), and greenhouse gas (GHG) regulations are adding to the cost of using conventional fossil fuels, incentivizing shipowners to explore different ways to reduce emissions.

Building on previous research, this paper incorporates the latest developments with global biofuel supply, and its uptake in shipping, while also providing a technical overview of best practices for the use of the biofuels FAME and HVO on ships. The report also contains an overview of how biofuels can be used for compliance with key GHG regulations.

In 2023, global production of liquid biofuels (ethanol, FAME, and HVO primarily) and biogases reached about 111 million tonnes of oil equivalent (Mtoe)[2] and 41 Mtoe respectively. Out of this, we estimate that about 15% (liquid biofuels)[3] and 65% (biogases) of total global production was based on advanced feedstocks (i.e. non-food and non-feed feedstocks). A very small share of total liquid biofuels production is consumed by ships: around 0.7 Mtoe in 2023, which amounted to about 0.6% of global supply. The vast majority (about 98.9%) is consumed by road transport, with aviation accounting for about 0.5%.

While shipping's share remains low, this still represents strong growth on previous years. This is reflected by the increasing number of ports offering biofuel bunkering. Through a systematic review of public information, DNV has identified more than 60 different ports where a biofuel bunkering has taken place since 2015.

Based on interviews with eight different biofuel suppliers, we have identified three key factors influencing the maritime biofuel market going forward: the voluntary market, GHG regulations in shipping, and supply-side constraints. Today, the voluntary market is the single most important demand-driver for biofuels within the international shipping market, with societal demand leading to pressure from cargo owners to seek emissions reductions. However, in the future, additional biofuel demand is expected to be unlocked by GHG regulations such as FuelEU Maritime and IMO mid-term GHG measures. On the other hand, supply-side constraints such as sustainable feedstock scarcity, competition with other sectors, and logistical challenges, will negatively impact the size of the marine biofuel market.

A diverse range of biofuels exists, each with varying potential for maritime applications. Currently, products of FAME and HVO (commonly known as biodiesel and renewable diesel, respectively) are the most established for use in shipping, each possessing distinct properties and characteristics.

To gain insights into the technical and operational aspects of biofuel use in shipping, we collected feedback from 12 shipping companies through a series of interviews and surveys. The technical compatibility of FAME and HVO with onboard systems varies from ship to ship, making it essential to assess each case individually. FAME, in particular, poses some challenges compared to standard oil fuels, especially for stability (degradation), corrosivity, and cold flow properties.

The recently updated ISO 8217 standard (ISO 8217:2024) now includes FAME and synthetic or renewable paraffinic diesel fuels up to 100%. It is crucial for relevant parties to incorporate this latest standard and possibly additional criteria to accommodate expected operating conditions. Verifying fuel quality, ensuring compatibility with onboard systems, and monitoring performance are essential, especially given the presence of off-specification fuels increasingly being marketed as biofuels.

Nonetheless, industry feedback indicates that operations generally proceed without significant problems when using both blends and pure products, provided the transition is well-planned and executed.

In general, use of eligible biofuels can give significant benefits with respect to the IMO's Carbon Intensity Indicator (CII) regulation, the EU Emissions Trading System (ETS), and the EU's FuelEU Maritime regulation. For CII (interim approach), use of biofuels is rewarded by a reduction in $CO_2$ emissions. For EU ETS, a $CO_2$ conversion factor of zero can be used, while for FuelEU Maritime, biofuels can reduce well-to-wake GHG intensity. It is also expected that biofuels will be credited with GHG reduction for the upcoming IMO mid-term GHG measures.

To prove eligibility with each regulation, the relevant biofuels must be documented to meet sustainability and GHG saving requirements. Today, this is achieved via a Proof of Sustainability (PoS) or similar document. Currently, the IMO accepts PoS documenting compliance with international certification schemes like International Sustainability and Carbon Certification (ISCC) and Roundtable on Sustainable Biomaterials (RSB), while several others, such as Better Biomass, are also accepted by the European Commission.

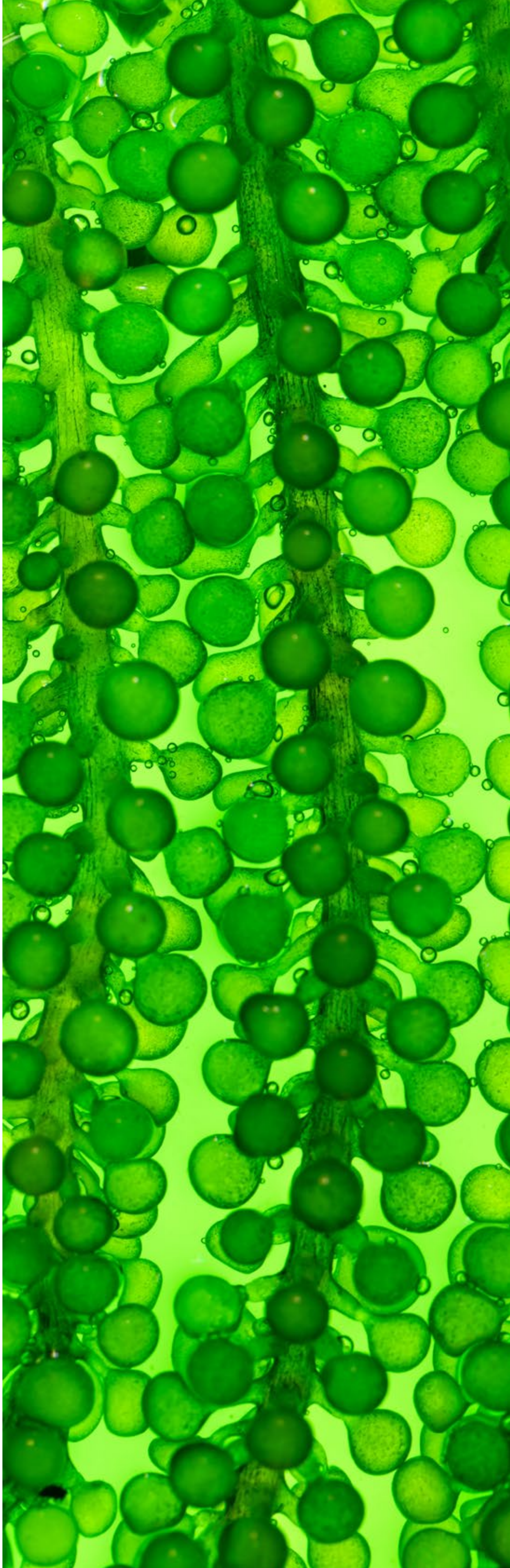
Maritime decarbonization is a complex puzzle and increased use of biofuels can help to drive emissions reduction. While shipping's share of global biofuel supply is currently low, regulatory incentives and the development of best practices for the use of biofuel on ships can support significant growth in their use in the coming years.

# 2 Introduction

With the phase-in and entry into force of new GHG regulations, operating on conventional fossil fuels is expected to have a significant added cost in the future. From 2024, shipping was included in the EU ETS, while FuelEU Maritime entered into force at the beginning of 2025, setting limits on GHG intensity of energy used on ships. In 2027, the IMO's mid-term measures, including both a GHG fuel standard and an economic element, will enter into force. Consequently, we expect the volume of biofuels and other low GHG intensity fuels bunkered by vessels worldwide to increase. To ensure safe introduction of biofuels on vessels, it is important to apply best practices to minimize potential risk of damage to equipment and loss of power on the vessel.

This white paper incorporates the latest developments on biofuels supply and uptake in shipping, maritime GHG regulations for biofuels, and best practices for use on ships, building on previous DNV studies on biofuels and other relevant literature, see for example, (DNV, 2023; 2024a; EMSA, 2023; 2022; IEA, 2024b). To better understand the perspective of key stakeholders in the marine biofuel value chain, we collected feedback from eight biofuel suppliers and 12 shipping companies via interviews and surveys. Feedback from biofuel suppliers primarily focused on the maritime market for biofuels and future developments including competition with other markets (e.g. road and aviation). Shipping companies gave feedback on their experiences so far operating on biofuels, including potential issues and challenges.

**The following key topics are covered in the paper:**
- global supply and end users of biofuels, including current uptake in shipping (Chapter 3)
- technical and operational considerations for use of FAME and HVO on ships (Chapter 4)
- relevant GHG regulations and reporting requirements related to use of biofuels in shipping (Chapter 5)



# 3 Global supply of biofuels and uptake in shipping

In this chapter, we look at the current global supply and end use of liquid and gaseous biofuels. We then focus on the uptake within the maritime industry and discuss factors that influence the marine biofuel market.

## 3.1 Global supply of biofuels and feedstocks used

As illustrated in Figure 3-1, the principal biofuels produced today are ethanol, biogases (including bio-methane), Fatty Acid Methyl Ester (FAME), and Hydrotreated Vegetable Oil (HVO). In addition, there are smaller volumes of aviation biofuel (biojet), bio-methanol, and bio-LPG being produced. In total, liquid biofuel production amounted to about 111 million tonnes of oil equivalent (Mtoe) in 2023 (of which ethanol accounts for more than 50%), while gaseous biofuel production was about 41 Mtoe.

A wide variety of different feedstocks can be used to produce biofuels. In Table 3-1 we describe the most commonly used feedstocks for biofuel production today for different biofuel types.

In Figure 3-2, we illustrate the estimated break-down of biofuel production (in terms of energy content of the fuel) and feedstock type for i) ethanol, ii) FAME, HVO, and biojet, and iii) biogases. The values are indicative only and quantify the significant differences between biofuel product and feedstocks used for production. We have categorized feedstocks into advanced (non-food and non-feed feedstocks) and conventional (based on agricultural main products), consistent with the EU's Renewable Energy Directive (RED). Based on the results, we can estimate an advanced biofuel production of about 18 Mtoe (ethanol, FAME, HVO, and biojet) and at least 26 Mtoe (biogases) in 2023.

The type of feedstock used for biofuel production can have a significant impact on lifecycle GHG emissions, water and soil,

FIGURE 3-1

**Global supply of biofuels in 2023[4], based on data from IEA (2024a; 2024b); (GENA Solutions & Methanol Institute, 2024); (Argus Media, 2022)**

Units: Million tonnes of oil equivalent (Mtoe)

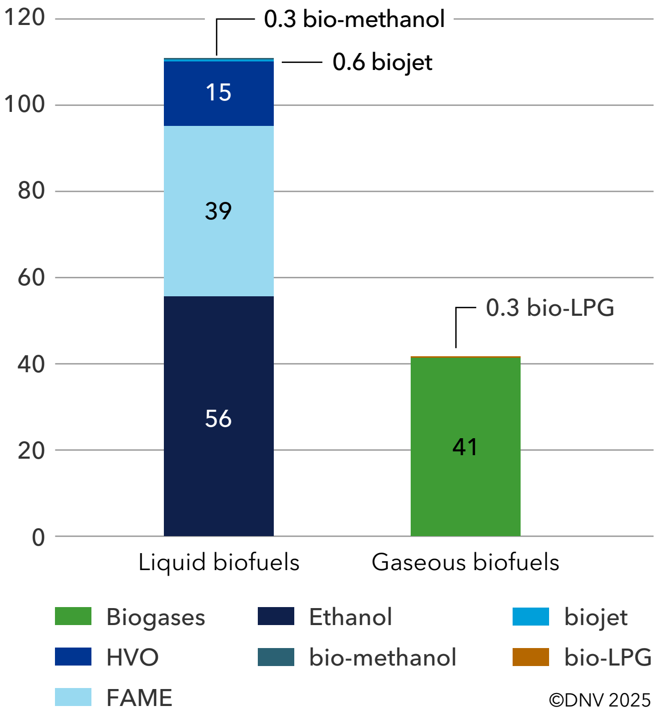



TABLE 3-1

**Type of feedstock currently applied for production of biofuels (IEA, 2024b; 2020)**

| Biofuel-type | Applied feedstocks for production |
|---|---|
| Ethanol | Mainly sugars (including sugarcane and sugar beets) and starches (including maize, wheat, rice, and other coarse grain). Only a very limited amount was produced from non-crop sources such as agricultural residues (e.g. sugar bagasse), forestry residues, and municipal solid waste. |
| FAME, HVO, and biojet | Mainly vegetable oils such as soybean oil, rapeseed oil, palm oil, and others. A significant share is also produced from residue oils, including used cooking oil, animal fats, palm oil mill effluent and other residue oils. Only a very limited amount is produced from other sources such as agricultural residues, forestry residues, and municipal solid waste. |
| Biogases | Mainly from animal manure, municipal solid waste, and municipal wastewater. A significant share is also from crops. |

biodiversity as well as land use and deforestation (including indirect land-usage change, 'ILUC'). Existing regulatory standards tend to favour biofuels made from non-food and non-feed feedstocks (advanced) rather than from agricultural main products (often termed conventional feedstocks). There are, however, differences between regions. For example, according to the U.S. Environmental Protection Agency (EPA), sugarcane ethanol meets the sustainability criteria for advanced biofuels with a threshold of at least 50% lifecycle GHG reductions (EPA, 2024). The EU's RED, on the other hand, is more restrictive and considers only ethanol made from non-food and non-feed feedstock sources such as straw and bagasse as advanced biofuel. RED applies GHG saving criteria[5] ranging from 50% to 65% for biofuels used in the transportation sector, depending on the date the biofuel production installation became operational (EC, 2023). Under Carbon Intensity Indicator (CII) rating requirements, the IMO has adopted a well-to-wake (WtW) GHG reduction requirement of 65% relative to Marine Gas Oil (MGO) for biofuels, and sustainability criteria set by international certification schemes such as ISCC are recognized. However, this is considered an interim approach until a more comprehensive method is developed to calculate a fuel's emission factor based on the IMO lifecycle assessment (LCA) guidelines.[6]

## 3.2 End use of biofuels

Today, the vast majority of all liquid biofuels are consumed in the transportation sector, and more specifically, road transportation. In several countries (e.g. USA, Brazil, Indonesia, Norway), there are biofuel blending requirements for diesel and gasoline used by cars and trucks. Many such blending requirements have been in place for decades, leading to a well-established market for biofuels within road transportation. In other transportation sectors, such as shipping and aviation, uptake of biofuels is increasing but remains far below that of road transport. In 2023, uptake of biofuels amounted to about 0.6 Mtoe in aviation, while in shipping it was around 0.7 Mtoe (IEA, 2024b). Respectively, this made up about 0.5% and 0.6% of total liquid biofuel consumption.

End use of biogases is more diversified than liquid biofuels. Biogases are primarily used for electricity and heat purposes (see Figure 3-3), however, there is also significant use within industry and the transportation sector. For use in the transportation sector, biogas needs to be upgraded to biomethane and compressed or liquefied.

FIGURE 3-2

**Share of biofuel production (in terms of energy content) by feedstock type. Estimated shares are indicative and based on IEA (2024b). For biogases, feedstock shares are based on 2018 data from IEA (2020)**

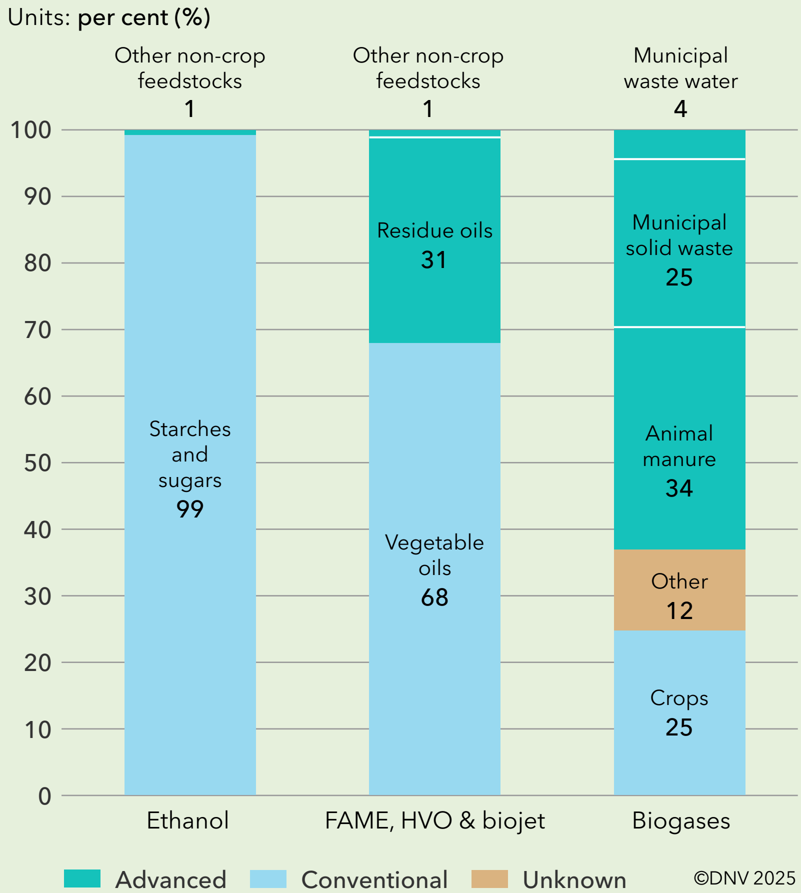
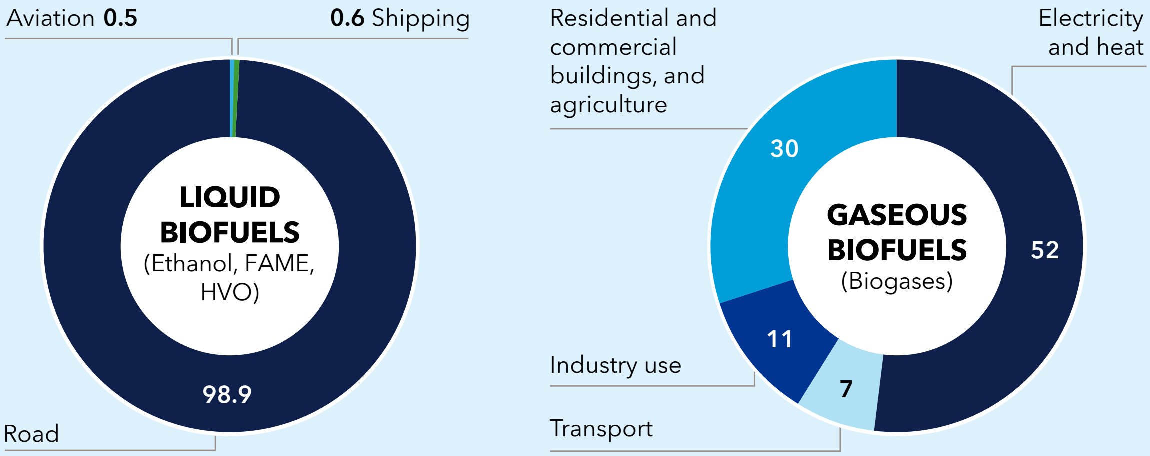


FIGURE 3-3

**End-use sectors for liquid biofuels (left) and gaseous biofuels (right) in 2023, based on IEA (2024b)**

Units: per cent (%)

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## 3.3 Uptake in shipping

In 2023, the total biofuel consumption in shipping (both domestic and international) amounted to about 0.7 Mtoe (IEA, 2024b). To put this in perspective, this is equivalent to about 0.3% of the total energy use of the marine shipping sector.

### 3.3.1 Biofuel types and blends

The two primary biofuel types applied by ships today are FAME and HVO (commonly known as biodiesel and renewable diesel, respectively). Based on a review carried out by DNV of publicly reported biofuel bunkering operations globally, as well as interviews with owners and fuel suppliers, FAME is the most prevalent out of the two. Besides FAME and HVO, a limited amount of ethanol (4,137 tonnes) was also reported consumed by major ships in 2023 (IMO, 2024). There have also been many reported bunkering operations of bio-LNG[7], and since 2023 ships have also bunkered bio-methanol.[8]

The highest volume of biofuel is consumed by ships via fuel blends, consisting of both a biofuel fraction (FAME or HVO primarily) and a conventional oil-based fuel fraction (distillate fuels or residual fuel). The most common blends range from 20% (B20) to 30% (B30) biofuel content by volume. For example, B24 biofuel accounted for 518,000 tonnes or 99% of the bio-blended fuel bunkered in Singapore in 2023.[9] In Rotterdam, B30 biofuel is reportedly the most common blend sold[10]. Although B24 and B30 account for the largest volumes of biofuel delivered to ships, there are many examples of vessels bunkering other fuel blends, including B5, B10, B20, B50, B80, and B100.

Currently, as per MARPOL[11] Annex II and the IBC[12] code, biofuel blends containing FAME delivered by bunkering barges or vessels classified as oil tankers are restricted to a maximum biofuel share of 25% (by volume). That is one of the reasons why, for example, in Singapore, the vast majority of biofuel bunkered in 2023 was B24. For bunkering of higher FAME biofuel content blends from bunkering ships (e.g. B30, B50, B100), IMO Type 2 chemical tankers are needed. This is considered a bottleneck for the uptake of biofuels containing FAME biodiesel, especially for blends with 25% or higher biofuel content. In Rotterdam, a high percentage of biofuel bunkering operations is made by inland waterway barges. These barges are subject to different regulations compared to bunkering vessels or barges operating in international waters and may therefore carry higher blends (including B30) without additional requirements.

Fuels containing HVO, either as a stand-alone product or in fuel blends also containing fuel oil or distillates, are considered petroleum distillates, and as such can be carried on bunker vessels classified as oil tankers.

### 3.3.2 Bunker sales and prices in Singapore and Rotterdam

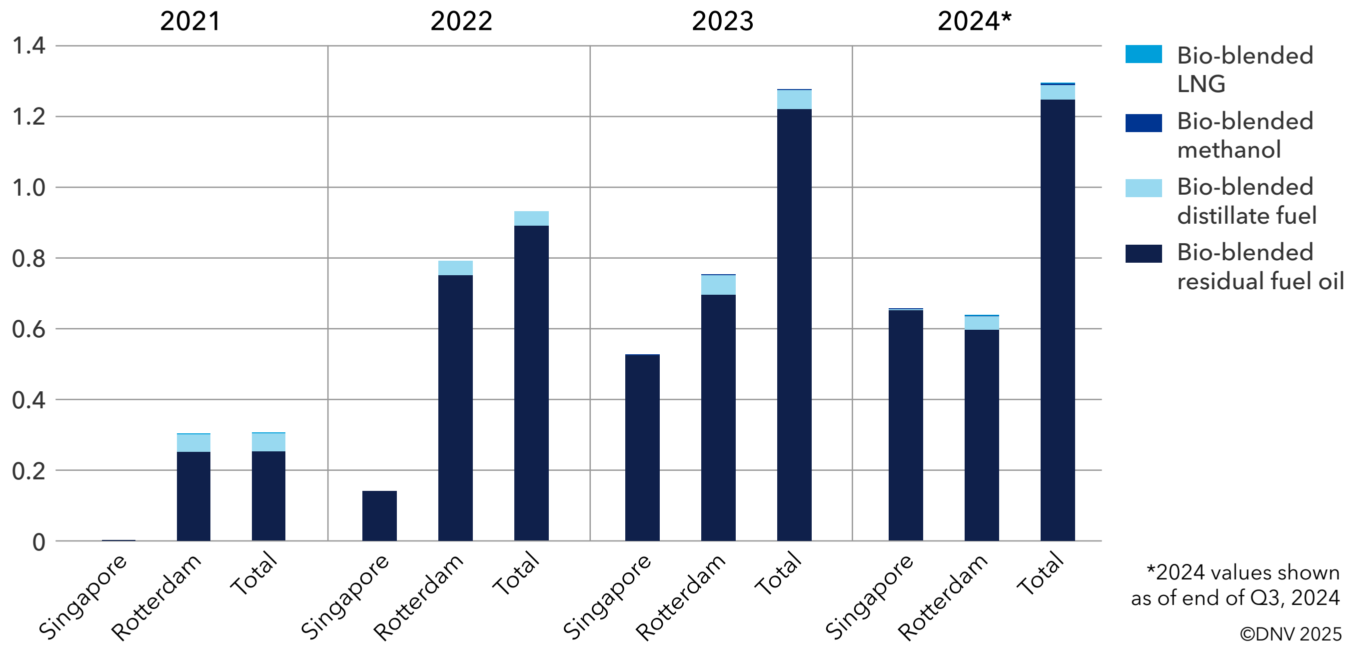
Figure 3-4 shows the reported sale of bio-blended fuel[13] in the two largest bunkering hubs globally from 2021 to 2024; Singapore and Rotterdam. As shown in the graph, the sale of bio-blended fuel has increased dramatically from about 300,000 tonnes in 2021 to more than 1.3 million tonnes in 2024 (as of Q3, 2024). Bio-blended residual fuel oil accounts for the largest share of bio-blended fuel, followed by bio-blended distillate fuel. Bio-blended methanol and bio-blended LNG accounted for about 4,600 tonnes and 1,000 tonnes, respectively, of bio-blended fuel sales in 2024. We estimate that, roughly speaking, Singapore and Rotterdam accounted for about half of all biofuels supply to shipping in 2023 (only accounting for biogenic fuel)[14].

Figure 3-5 shows historic fuel prices for Very Low Sulphur Fuel Oil (VLSFO) and advanced biofuels (including B30 and B24 blends) in key bunkering hubs (Amsterdam-Rotterdam-Antwerp [ARA] and Singapore) between 2023 and 2025. The bunkering price of advanced FAME (B100) biofuel within ARA, has been fluctuating between about 1,000 and 1,520 USD/tonne VLSFO-eq. since the beginning of 2023,

FIGURE 3-4

**Reported bunker sales of bio-blended fuel from Singapore and Rotterdam (Port of Rotterdam, 2024; MPA Singapore, 2024)**

Units: million tonnes



translating to a price premium of about 520 to 1,000 USD/tonne VLSFO-eq. relative to VLSFO (ARA). B30 (ARA) and B24 (Singapore) FAME VLSFO biofuel blends, meanwhile, have been trading between 710 and 880 USD/tonne VLSFO-eq. and 690 to 1,000 USD/tonne VLSFO-eq., respectively, within the same period. For B30 (ARA) FAME VLSFO blend, this equates to a pure FAME price of about 1,200 to 1,800 USD/tonne VLSFO, which is comparatively higher than the price range for FAME (B100) in ARA.

### 3.3.3 Availability of biofuels in ports worldwide

Besides Rotterdam and Singapore, there are several other major bunkering ports that have reported bunkering of biofuels, including Fujairah[15], Zhoushan[16], Antwerp-Bruges[17], Busan[18], Hong Kong[19], and Gibraltar[20]. Through a systematic collection of public data on biofuel bunkering in different ports, primarily from news articles and press releases, DNV has mapped out: i) ports worldwide where at least one biofuel bunkering operation (either pure biofuel, or biofuel blends) has taken place and ii) ports where fuel suppliers have explicitly stated that they can offer biofuel bunkering. The results are illustrated in Figure 3-6, indicating that biofuel bunkering availability is quite geographically diverse, but concentrated in Europe and East Asia. In total, we identified more than 60 different ports where a biofuel bunkering operation has taken place since 2015. If we include locations where suppliers claim they can deliver biofuels, this brings the total up to almost 90 different ports.

### 3.3.4 Key factors influencing the maritime biofuel market

To gain insight on factors influencing the maritime biofuel market, we conducted eight interviews in 2024 (Q4) with biofuel suppliers based in North and South America, Europe, and East Asia. During the interviews, we asked ten or more questions relating to future expectations for the maritime biofuel market, competition with other sectors, feedstock availability, and other relevant topics.

Through the interviews, we identified three key factors that are set to shape the maritime biofuel market in the future: the voluntary market for biofuels, GHG regulations, and supply-side constraints (see Figure 3-7). The voluntary market for biofuels has been the most important driver for certain ship types (e.g. containerships) to date and is largely pushed by cargo owners. However, this may change in the future as new GHG requirements come into force. Supply-side constraints for shipping due to competition with other end users of biofuel, scarce supplies of biofuel produced from sustainable feedstocks, and logistical challenges are also important factors to consider.

**Voluntary market for marine biofuels**

The voluntary market for biofuels in shipping is primarily characterized by commercial service offerings allowing cargo owners to pay a higher price for ocean freight in return for reduced scope 3 GHG emissions[21]. Examples of such services are: MSC Biofuel Solution (MSC)[22], Act with CMA CGM+ (CMA CGM)[23], Ship Green (Hapag-Lloyd)[24], ONE LEAF+ (Ocean Network Express)[25], Maersk ECO Delivery

FIGURE 3-5

**Price of VLSFO and biofuels (including B30 and B24 blends) in key bunkering hubs (Amsterdam-Rotterdam-Antwerp [ARA] and Singapore) between 2023 and 2025. Based on price statistics provided by Argus Media, which can be found on DNV's Alternative Fuels Insight platform (afi.dnv.com)**

Units: Fuel price (USD/tonne VLSFO-eq.)

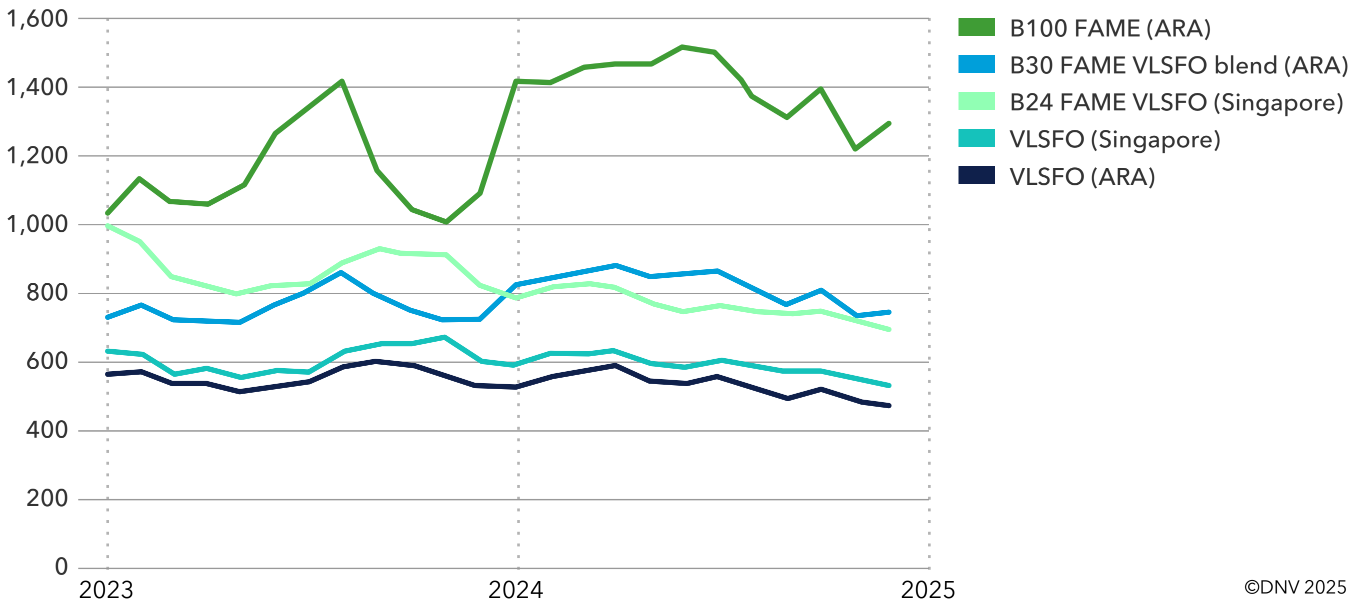


FIGURE 3-6

**Map of locations where biofuel bunkering operations have taken place since 2015 (green) or where biofuel suppliers have indicated that biofuels are available (blue). Each dot represents one port. Bunkering of FAME, HVO, bio-LNG, and bio-methanol is included**




Source: DNV; as of December 2024

Ocean (A.P. Moller – Maersk)[26], Reduced Carbon Service (Wallenius Wilhelmsen)[27], and Sail for Change (UECC)[28]. Some of these services are not only restricted to biofuels, but also other fuel types that may lower the GHG footprint of shipping. We estimate that these companies accounted for almost 1 million tonnes of bio-blended fuel consumption in 2023[29], making up a large share of shipping's total demand for biofuels. Some shipping companies are starting to make use of biofuel insetting as a means of reducing Scope 3 GHG emissions for their clients. This means that instead of only offering green transportation services for vessels where biofuel is physically used as a fuel, green transportation services can be offered based on certificates (see information box at end of chapter).

The importance of the voluntary market was echoed by several of the fuel suppliers we talked to. This voluntary market largely depends on the willingness of cargo owners to pay an additional transportation fee for reducing Scope 3 GHG emissions. As a result of this, it is now primarily restricted to the container shipping and car carrier trades, where cargo owners are pursuing Scope 3 GHG emissions reductions.

In the future, we are likely to see more voluntary initiatives and more ship types using biofuels voluntarily. For example, a RoPax service has started to offer passengers the option of paying a premium on ticket prices to enable use of biofuels, see Viking Lines[30]. In early 2024, the logistics provider Scanlog signed a deal to use bio-LNG for reducing Scope 3 emissions associated with transportation of coffee for a client[31]. Another noteworthy development is that ZEMBA, as a first-of-a-kind buyers' group within the maritime sector, has finalized a tender process which will see 20,000 tonnes of bio-LNG bunkered in the period 2025–2026[32].

As of December 2024, there were 65 green shipping corridors initiatives[33] that may promote increased use of biofuels (including bio-LNG, bio-methanol, and FAME/HVO) across multiple ship types.

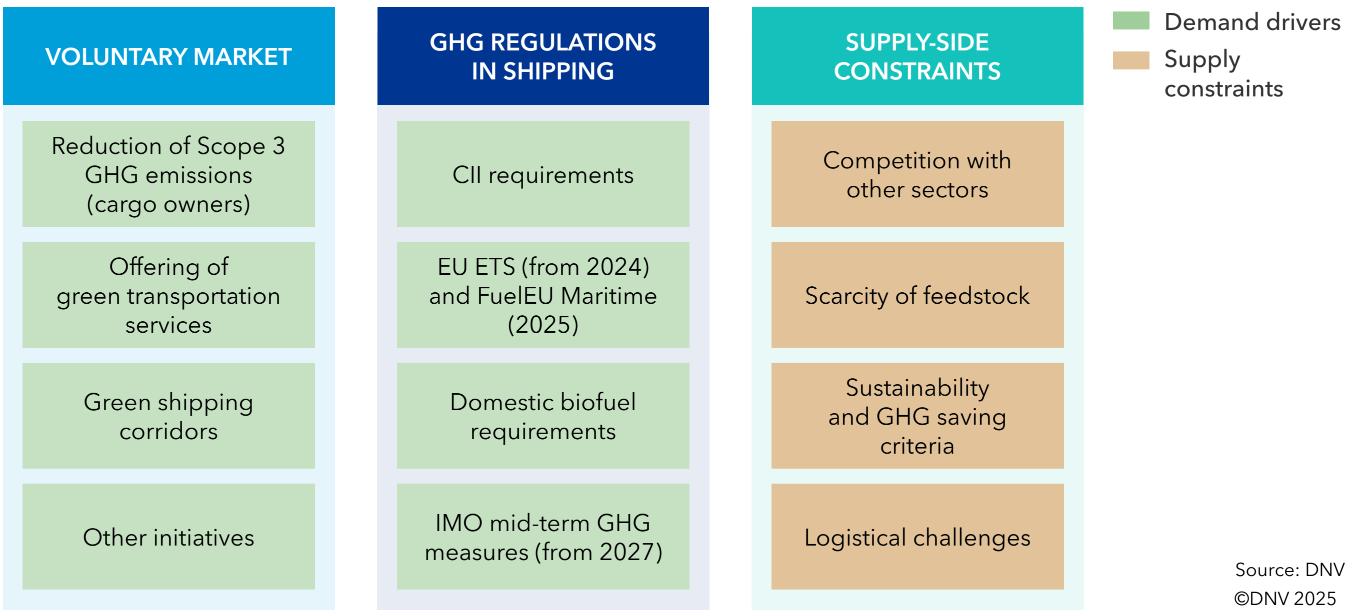
**GHG regulations in shipping**

So far, the regulatory push from international GHG policy measures (IMO and EU) to use biofuels has been limited, and not as significant as the voluntary market. Although owners have incentives to use biofuels to meet CII requirements and reduce costs associated with EU ETS compliance (for vessels trading in EU/EEA), these requirements by themselves do not necessarily justify the added cost of using biofuels. It is expected, however, that with the entry into force of new regulations, namely FuelEU Maritime in 2025 and IMO mid-term measures in 2027, demand will be boosted significantly. In anticipation of this, some biofuel supply agreements have already been agreed as preparation for FuelEU Maritime[34]. As a result of FuelEU Maritime's pooling mechanism, some owners are also considering selling excess compliance units generated from the use of biofuels[35].

In the longer term, demand increases depend on which decarbonization pathways shipowners choose. Compared to other transport sectors such as aviation, shipping has more prospective long-term fuel alternatives (e.g. ammonia, hydrogen, methanol, methane). One major biofuel supplier pointed out that the adoption of new GHG regulations promoting the use of biofuels may not necessarily reduce the size of the voluntary market. The reason for this is the concept of 'additionality'[36], where the voluntary market should contribute to additional GHG reduction on top of compliance-driven actions. In this case, GHG regulations and the voluntary market could both contribute, in combination, to the continued development of the marine biofuel market.

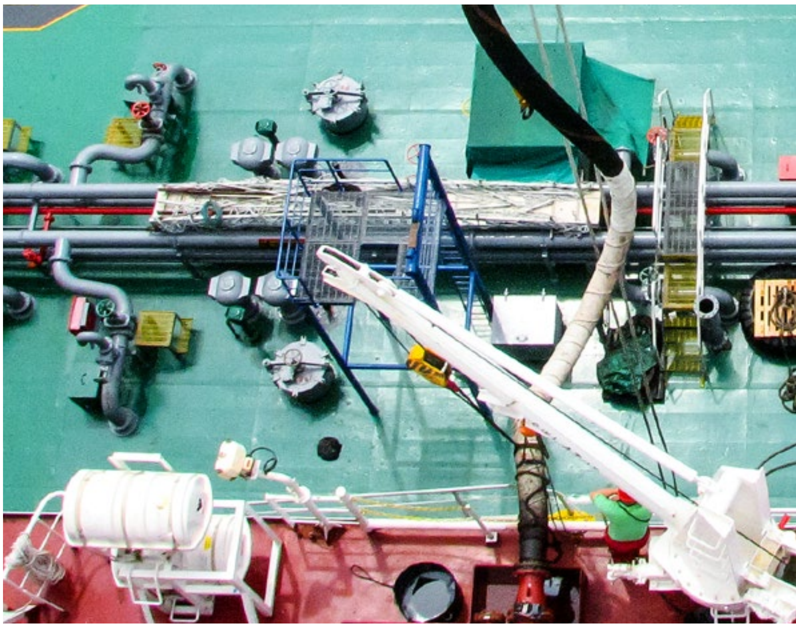
FIGURE 3-7

**Key factors influencing the marine biofuel market identified via interviews with biofuel suppliers**




Source: DNV

In some countries and states, domestic policies significantly contribute to the use of biofuels. For example: from 1 October 2023, Norway implemented requirements effectively phasing in 6% advanced biofuel for all domestic shipping[37]. For several years, Indonesia has mandated bunker suppliers to sell B30 biofuel blends to the domestic shipping market[38]. Since 2009, Washington state in the USA, has mandated that state agencies use bio-blended diesel to operate all vessels[39].

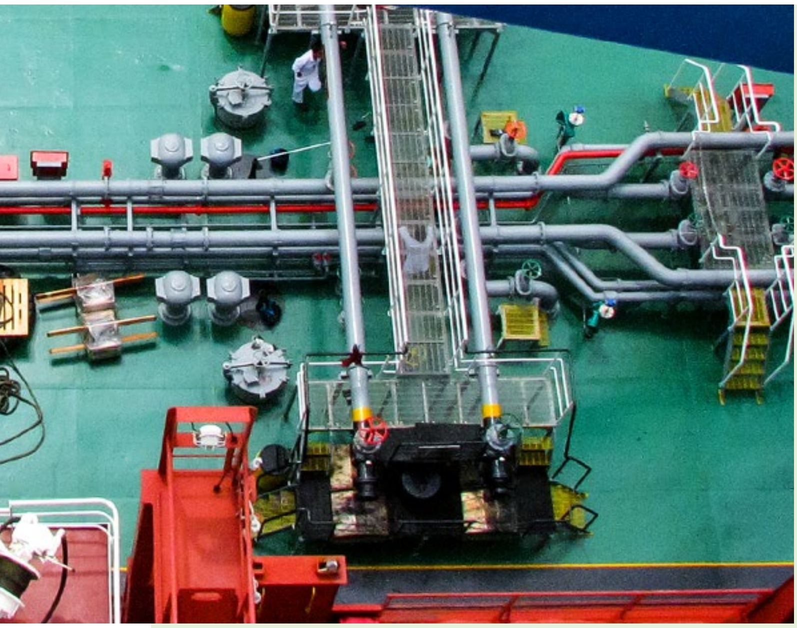


**Supply-side constraints**

From the interviews, we found four key supply-side constraints that impact the market for biofuels in shipping. These constraints relate to logistics, competition with other end-use sectors, and scarcity of eligible marine biofuels:

- **Scarcity of feedstocks:** At some point in the future, feedstock availability is expected to be an important limiting factor for advanced biofuel production. This is especially the case for waste sources such as used cooking oil (UCO). To mitigate this, some suppliers are investigating new feedstock types (e.g. alternative waste feedstocks). Besides using more feedstock, an important way to scale up production is to optimize existing assets.
- **GHG saving and sustainability criteria:** The EU GHG regulations for shipping incorporate sustainability standards for biofuel, which promote use of advanced biomass sources. For example, FuelEU Maritime specifically requires that biofuels are not produced from food and feed crops (otherwise, the fuel should be considered as a fossil fuel using the default values of the least favourable fossil-fuel pathway). It is still unclear what sustainability and GHG saving criteria will be applied by the IMO mid-term measures when they enter into force in 2027. Some biofuel suppliers have pointed out that stringency of biofuel sustainability standards has a major impact on the volume of eligible biofuels available for shipping.
- **Logistics:** The volume of biofuels used in shipping today is too low for the establishment of a dedicated infrastructure for the supply of bio-blended fuels. This barrier may become less important as biofuel uptake in shipping increases. In some regions, there are still concerns among owners and operators of port infrastructure regarding the carriage of FAME. Therefore, identifying tanks and barges willing to accept FAME can be a hurdle in some ports. HVO, on the other hand, has much wider acceptance. In China (mainland), there is currently a lack of a clear regulatory framework for physical blending of fuel oil and FAME, which effectively increases distribution costs of bio-blended fuels. When resolved, one of the interviewed biofuel suppliers expects marine biofuel uptake in China to increase[40]. For bunkering of higher FAME biofuel content from bunkering ships, such as B30, B50, and B100, IMO Type 2 (chemical) tankers are needed. This is considered a bottleneck for the uptake of biofuels containing FAME, especially when it comes to blends with 25% or higher biofuel content. Ongoing discussions in the IMO could lead to a relaxation of this requirement in the future.
- **Competition with other sectors:** Several of the biofuel suppliers interviewed view aviation as a more attractive emerging market for biofuels. The main reason is the higher margins enjoyed by aviation fuel compared to marine bunker fuel due to higher quality requirements and complex production methods. An additional factor is that while GHG regulations for ships tend to be fuel-agnostic (i.e. not pre-selecting fuel type or other measures needed to be compliant), regulations and targets for aviation are not. An example is the ReFuelEU Aviation regulation[41], which sets requirements on the share of Sustainable Aviation Fuel (SAF) blended into conventional aviation fuel supplied at airports in the EU. Some suppliers expect that shipping's use of non-biogenic fuels with potentially lower GHG footprints than current marine fuel oil (e.g. LNG, e-fuels) may limit demand for biofuels. Road transportation is by far the most important biofuel market today. While increased electrification may limit biofuel uptake in some countries for passenger cars in the future, this may be offset by increased demand from road segments which are harder to electrify, such as long-distance heavy-duty trucks.

Cargo owners are increasingly compelled by customers and investors to reduce Scope 3 emissions and pursue decarbonization within their operations.



## Biofuel insetting service

Cargo owners are increasingly compelled by customers and investors to reduce Scope 3 GHG emissions and pursue decarbonization within their operations. Consequently, numerous cargo owners have begun embedding decarbonization objectives into their corporate strategies. Some are setting ambitious goals to achieve a carbon-neutral or carbon-positive status by 2040, or potentially even by 2030.

This shift is likely to increase expectations for the shipping industry to enhance transparency and adhere to more rigorous GHG emissions reporting requirements across the logistics chain. The usage of biofuel is therefore an effective way to reduce GHG emissions in the ocean freight industry instantly. Switching from fossil-fuel-powered shipping transport to sustainable biofuel will make an important difference to Scope 3 emissions for many cargo owners.

Applying an insetting service and using a book-and-claim chain-of-custody system disconnects the transport and fuel from the cargo and service offered, allowing green services to be offered based on certificates, not the actual fuel. It allows the shipping company to decouple or disconnect the emission attributes from the physical fuel and forwards them to their clients in the form of verified certificates. This is applicable when the shipping company offers a low emission service to a client, but the actual vessel does not have the chance to bunker biofuel as it is not readily available in all geographies.

Biofuel insetting therefore offers a strategic pathway for shipping companies to contribute to global sustainability goals while enhancing their business practices. The cargo owner, who is willing to invest in the premium fuel, can claim to own the GHG reduction on Scope 3 emission uniquely with a verified certificate. This ensures that there will be no double booking of emissions.

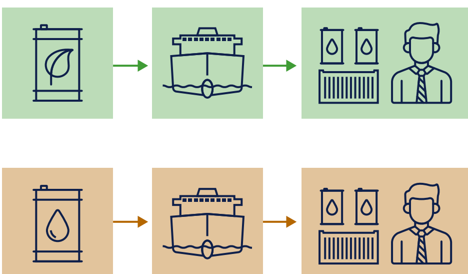
To manage complexity and ensure trust, DNV offers a robust tailor-made biofuel insetting verification service. The verification service covers all steps – from emission baseline, the inset process and system validation, sustainable fuel bunkering, carbon account validation, inset verification, issuance of verification statement, and support regarding the green claim for Scope 3 accounting. See Biofuel insetting: a strategic approach to decarbonization in maritime transport for more information.

FIGURE 3-8

**Book-and-claim principles**

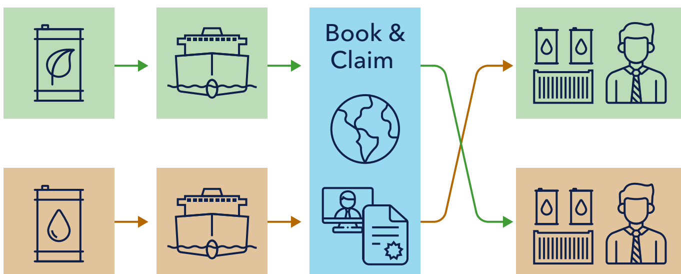
**Traditional shipping service**

**Direct physical link** between transport and service allowing **green services** only to be offered **where biofuel is used**.



**Book & Claim service**

**Disconnected link** between transport and service allowing **green services** to be offered **based on certificates**, not on the actual fuel used.



# 4 Technical and operational considerations for FAME and HVO

A key reason why biofuels are seen as an attractive decarbonization pathway in shipping is their ability to be used by existing vessels without modifications (i.e. drop-in capability with existing conventional engine and fuel technology). This holds true for instance for bio-LNG since it has practically identical properties as fossil LNG. For biodiesels and bioliquids intended to replace distillates and fuel oils, the drop-in capability can vary significantly and depends on factors such as the feedstock used to produce the biofuel, the production process, and the level of refining and upgrading. It is therefore important for potential users to evaluate each biofuel type on a case-by-case basis to ensure that the fuel specification and quality are compatible with the intended applications. Otherwise, there is a risk of damage to equipment and loss of power on the vessel.

A diverse range of biofuels exists, each with varying potential for maritime applications. Among these, FAME and HVO have emerged as the most established for use in shipping. Consequently, this chapter focuses primarily on liquid biofuels, specifically products of FAME and HVO as outlined in ISO 8217:2024. It is emphasized that FAME and HVO are fundamentally different fuels with distinct properties. The chemistry and composition of FAME differ significantly from those of hydrocarbon-only fuels such as HVO and other traditional fossil marine fuels.

To gain insights into the technical and operational aspects of biofuel use in shipping, we engaged with 12 industry players using FAME or HVO. These included shipping companies and cruise lines based in Europe, North America, and East Asia. Our discussions covered practicalities and formalities related to bunkering, such as fuel specifications, documentation, and fuel analysis. Additionally, we addressed technical topics, including onboard preparations and modifications prior to the introduction of HVO or FAME, verification with equipment manufacturers, onboard inspections and maintenance, and potential challenges resulting from the use of the new fuel.

## 4.1 Fuel properties

FAME, often referred to as biodiesel, is produced from fats, oils, and greases (FOGs) through a process called transesterification. Depending on the feedstock used for production (see Section 3.1), the characteristics of FAME products can vary. Despite the potential variations, the following key points generally apply to FAME.

- Slightly lower energy content per unit mass compared to MGO, resulting in a lower volumetric energy density.
- Comparable cetane number to MGO, indicating good ignition properties.
- Higher flash point than MGO, making FAME less flammable.
- Reduced cold flow performance, potentially problematic in low temperatures.
- Good lubricity properties.
- Reduced oxidation stability compared to MGO, with increased acidity (leading to higher viscosity and deposits) and higher risk of fuel degradation. As such, FAME is less suitable for long-term storage.
- Its hygroscopic nature makes it prone to absorbing water, which may affect stability and result in microbiological growth.

HVO, commonly referred to as renewable diesel or paraffinic diesel, is derived from FOGs through a hydrotreatment process. This process produces paraffinic hydrocarbons that are compatible with most existing fuel systems and engines. Although the properties of HVO may also exhibit variations, the following key points typically apply:

- Energy content per unit mass comparable to MGO.
- High cetane number compared to MGO, resulting in shorter ignition delay.
- Flash point can vary but is generally comparable to MGO.
- Good tolerance to cold temperatures (depending on low-temperature upgrading method).
- Low lubricity due to low to non-existing sulfur content.
- Can have slightly lower density and viscosity than MGO.
- Robust storage stability and minimal concerns regarding microbial growth or materials compatibility.

It is important to note that fuel properties will vary across the different biofuel products and blend-in ratios. Table 4-1 provides a comparison of selected fuel properties of pure HVO and FAME, highlighting how their characteristics typically differ from those of MGO.

**Off-specification biofuels**
It is advisable to exercise caution against biofuels not complying with ISO 8217 and especially biofuels that have not been thoroughly verified and tested in operational settings. Recent events demonstrate that novel biofuels, or blends thereof, might show compliance with the specified limits as given in ISO 8217:2024 but at the same time may not fulfil the requirements of Clause 5 of ISO 8217[42]. For instance, Cashew Nutshell Liquid (CNSL) is a product not included in ISO 8217:2024. It may require extra caution due to the mixed results observed with such fuels when used on board, including issues such as fuel sludging, fuel injector failure, corrosion of engine parts, filter clogging, fuel system deposits, corrosion of turbocharger nozzle rings, and damage to Selective Catalytic Reactor (SCR) units. Additionally, CNSL contains reactive phenolic com-

pounds, which can lead to polymerization, resulting in the formation of gums and fuel deposits. Due to its high acid values, CNSL is also highly corrosive.

CNSL is derived as a byproduct of the cashew nut industry and serves as a cost-effective yet non-standard alternative fuel. FAME and HVO, as addressed in ISO 8217, have become widely recognized and accepted by the industry. However, there are no specifications from a recognized authority for CNSL. Avoiding off-spec biofuels is essential to minimize the risk of technical problems on board.

## 4.2 Fuel standards and testing

Until 2024, there was no widely accepted fuel standard for HVO and FAME, other than the inclusion of biofuel blends with a FAME content of up to 7% in ISO 8217:2017 and 'de minimis' levels since 2010. It is important to note that energy-rich or paraffinic diesel fuels, such as HVO, GTL (gas to liquid), and BTL (biomass to liquid), have been permitted in previous versions of ISO 8217. These are classified as petroleum distillates and do not affect the classification of blends that include paraffinic diesel fuel. While ISO 8217:2017 has served as a foundation, it has been essential for the involved parties to agree on additional properties.

An updated version of the standard, ISO 8217:2024 was recently published. Charter parties need to be revised to include this latest standard and possibly additional test criteria for biofuels. Additionally, it is worth noting that engine manufacturers may have their own standards that should also be considered.

The biofuel specification intended for use is normally shared with the engine and equipment manufacturers to confirm its compatibility before testing the biofuel for the first time. It is also noted that some parties share the ship's specifications with the biofuel supplier to investigate compatibility with the onboard systems. As a standard practice, ISO 8217 is referenced as the specification for ordering biofuel, with additional properties, such as those related to cold flow, occasionally specified.

A supplier pre-test of the biofuel to be bunkered is typically requested well in advance of the bunkering process, along with a Proof of Sustainability (PoS) document. Additionally, most perform drip and bunker sampling to verify the fuel before it is used on board. It is also noted that some have expanded their procedures to include fuel sampling and analysis at regular intervals, after the fuel has been on board for a certain amount of time, or in case of suspected fuel degradation.

TABLE 4-1

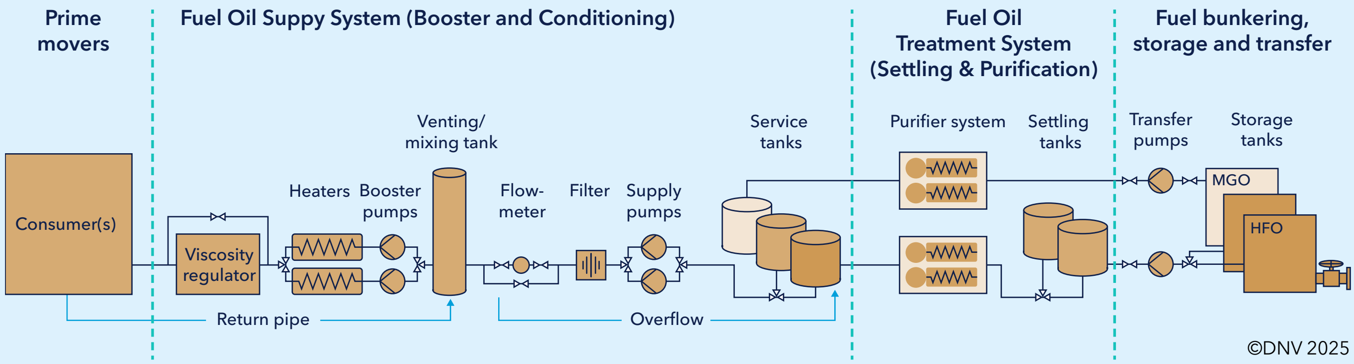
**Comparison of selected fuel characteristics for pure FAME and HVO, using MGO as the baseline**

| (Baseline: MGO) | FAME | HVO |
|---|---|---|
| **Energy content** | Lower | Comparable |
| **Cetane number** | Comparable | Higher |
| **Density** | Comparable | Slightly lower |
| **Viscosity** | Slightly higher | Slightly lower |
| **Material compatibility** | Incompatible with certain materials* | Comparable |
| **Flash point** | Higher | Comparable |
| **Lubricity** | Good** | Poor |
| **Cold flow properties*** ** | Poor | Good / Comparable |
| **Storage stability** | Poor | Good / Comparable |

*Corrosive activity varies with quality indicators such as acidity; **FAME maintains good lubricity despite having a very low sulfur content; ***Cloud Point (CP), Pour Point (PP), and Cold Filter Plugging Point (CFPP)

FIGURE 4-1

**This high-level illustration depicts a typical fuel oil system for ships, divided into four subsystems**






### 4.2.1 ISO 8217:2024

The recently published ISO 8217: 2024, titled 'Products from Petroleum, Synthetic, and Renewable Sources – Fuels (Class F) – Specifications of Marine Fuels,' has been revised as follows:

- Table 1 – Distillate and bio-distillate Marine Fuels, now allow up to 100% FAME (DF-grades).
- Table 3 – Bio-residual Marine Fuels now allow up to 100% FAME.
- Marine fuels containing 100% FAME shall meet EN 14214 (except for sulfur, cloud point [CP] and cold filter plugging point [CFPP]) or ASTM D6751 (except for sulfur requirement) and ISO 8217:2024 Table 1.
- Marine fuel consisting of 100% paraffinic diesel fuel (HVO) shall meet EN 15940 (except EN 15490:2023 Tables 2 and 3) and ISO 8217:2024 Table 1 (important since EN15940 has a minimum flashpoint of 55°C).

It is important to emphasize that the only biofuels now covered by the ISO 8217:2024 standard are FAME and synthetic or renewable paraffinic diesel fuels (HVO, GTL, BTL and PTL [power to liquid]). No other biofuel types are covered.

Fuel testing companies provide specialized test programmes for biofuels. These programmes can include extended testing of various parameters, such as cold flow properties, microbial growth, water content and acidity (beyond Acid Number) which are considered not to be adequately addressed in ISO 8217:2024.

## 4.3 Technical and operational considerations

HVO and FAME possess distinct properties, whereof some may present challenges for onboard system components.

HVO is recognized as a drop-in fuel and can by practical means serve as a substitute for fossil diesel grades. Compared to MGO, HVO has a similar flashpoint, good cold temperature tolerance, robust stability and oxidation properties, and is generally comparable in terms of microbial growth or materials compatibility. Although HVO is a high-quality product, some adjustments may be needed before it can be used due to potentially lower density, viscosity, and lubricity.

FAME comes with relatively good combustion and lubricity properties. Still, it poses some challenges compared to standard oil fuels, particularly in terms of stability (degradation), corrosivity, and cold flow properties.

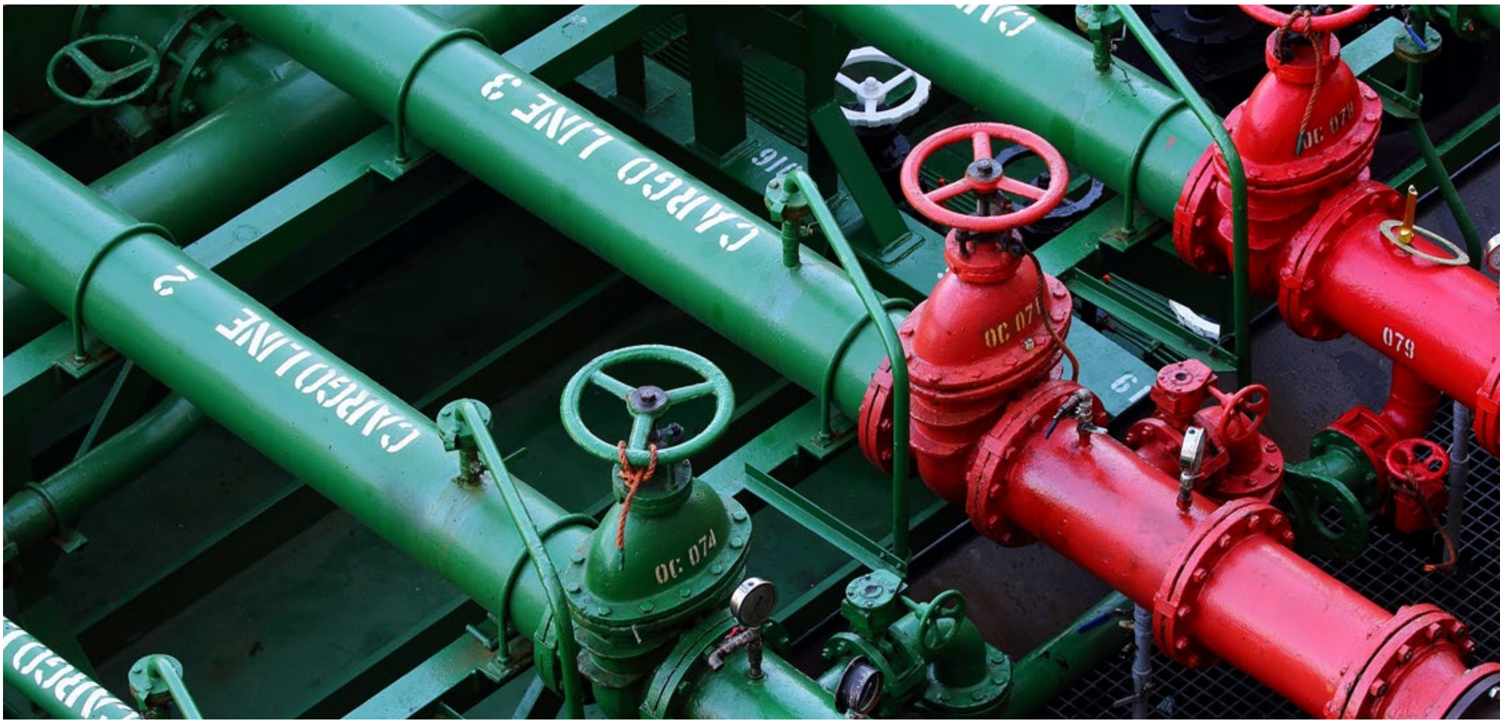
Despite these challenges, and occasional issues, feedback from the industry indicates that most operations proceed without significant problems, even when using pure HVO or FAME. This is contingent upon conducting preparations and compatibility investigations to facilitate the use of new fuels. The following section reviews a typical fuel oil system found on ships, divided into four subsystems, and examines operational and technical topics to highlight potential challenges related to compatibility with onboard systems. The fuel oil system is illustrated in Figure 4-1.

### 4.3.1 General considerations

Some challenges are not specific to a single subsystem and can be considered general considerations for multiple subsystems or the entire fuel oil system. This subsection explores such topics in more detail.

**Flashpoint**

No fuel oil with a flashpoint below 60°C shall be used as fuel for ships, as defined in SOLAS Chapter II-2/B/4. The flash-




point of FAME is typically significantly higher than this limit. In contrast, HVO has a flashpoint comparable to MGO, but it can sometimes fall below or just above the SOLAS limit, posing a risk of non-compliance.

It is important to note that auto-diesel in the EU is subject to lower regulatory flashpoint limits, typically ranging from 52 to 55°C. Therefore, any risk of a non-compliant flashpoint may arise from using such fuel as a blending stock rather than from the HVO or FAME themselves. It is also noted that fuel oil with a flashpoint of not less than 43°C may be used in emergency generators.

ISO 8217:2024 has adopted the minimum flashpoint limit of 60°C according to SOLAS. In any case, the flashpoint must be confirmed to exceed 60°C in the Bunker Delivery Note and through fuel analysis. If a low flashpoint is detected, the standard onboard procedures for oil fuels must be followed.

**Material compatibility and corrosion**
FAME can degrade due to various chemical and biological processes, including oxidation. Upon oxidation, FAME can form hydrogen peroxides, which subsequently lead to the creation of organic acids, aldehydes, carboxylic acids, and alcohols. This process is indicated by a sharp increase in the Acid Number (AN). Increased water content accelerates the formation of these acidic products.

The elevated acidity of FAME can result in the corrosion of materials such as brass, bronze, copper, lead, tin, and zinc, as well as unprotected steel in tanks, piping, valves and machinery components that come in contact with FAME, such as fuel injection equipment and pumps. This corrosion ultimately reduces the lifespan of machinery and equipment.

FAME may also cause degradation and increased wear of certain types of elastomers and rubber compounds used in hoses, gaskets, seals, diaphragms and O-rings, which can eventually lead to leaks. Therefore, it is recommended that engine and equipment manufacturers are consulted regarding material compatibility.

A relevant parameter for monitoring oxidation of FAME is the AN. While it indicates the presence of acidic compounds, values below the ISO 8217 limits do not guarantee the absence of problems linked to acidic compounds. According to ISO 8217:2024, there is no established correlation between the AN and the corrosivity of the fuel. There is, however, a correlation between inorganic acids (strong acids) in a fuel and the corrosive activity. This is measured by the Strong Acid Number (SAN). Note that engine manufacturers recommend keeping the acid number for FAME fuels at a minimum. Fuel analysis is recommended if acidic fuel is suspected or in case of extended onboard storage of FAME.

HVO is considered to have material compatibility similar to conventional petroleum diesels in terms of components, tanks, and materials used in storage, transfer, and handling equipment (EMSA, 2023).

**Cold flow properties**
Products of HVO typically exhibit good tolerance to cold temperatures. The cold flow properties of FAME depend on the fatty acid composition, with saturated esters exhibiting poor behaviour at low temperatures. As a result, FAME may have poor cold flow properties. The cold flow properties can be measured using the same methods as for conventional fuels, with Cloud Point (CP), Pour Point (PP), and Cold Filter Plugging Point (CFPP) being the most important metrics.

It is noted that recommendations exist to maintain the fuel temperature at least 10°C above the PP and 5°C above the CFPP during transfer. In particular, this is important when handling FAME. For conventional oil fuels, the recommendation has been to keep the storage temperature 2 to 5°C above the CP, 10°C above the PP, and 10°C above the CFPP.

Note that for residual oil blends, Wax Appearance Temperature (WAT) and Wax Disappearance Temperature (WTD) have been recommended as test parameters in addition to PP.

Our survey findings indicate that the cold flow properties of both FAME and HVO have not been problematic. Furthermore, only a small number of respondents specify cold flow requirements when ordering the fuel. However, it is essential to understand the impact of cold flow properties and agree on operability properties based on the anticipated conditions. This is especially important when operating in cold climates.

**Filter monitoring**
It is recommended that filters are monitored after introducing biofuel, particularly those without differential pressure alarms. While occurrences of clogged filters have been noted, they are not considered a significant issue.

**Inspection and maintenance**
Few respondents have reported changes in inspection or maintenance routines after permanently introducing the biofuel. Some have implemented stricter inspection intervals but confirm that no new checkpoints have been added. Feedback from collected responses indicate that during initial trials, more care was exercised, and the frequency of regular inspections was increased. These inspections included activities such as fuel sampling, high-pressure pump inspections, monitoring of engine and separator performance, filter checks, cylinder oil drain tests, ring wear measurements, combustion chamber inspections, and pressure measurements. Some respondents have even reported enhanced performance and cleaner systems following the use of FAME.

## 4.3.2 Fuel oil system – specific considerations

### 4.3.2.1 Bunkering, storage and transfer

**Mixing of fuels and tank arrangement**
FAME is a more effective solvent compared to hydrocarbon diesel fuels, resulting in a notable cleaning effect. Depending on the blending ratio and the extent of fouling in tanks and fuel systems, FAME can effectively loosen or dissolve accumulated deposits and sediments left behind by conventional fuels over time. To avoid significant issues in the piping systems, such as filter clogging, it is essential to ensure that any residual wax, sludge, or oil is completely removed from the fuel tank. Therefore, it is recommended that tanks are thoroughly emptied, cleaned, and dried prior to introducing the FAME product. HVO, being a hydrocarbon fuel, does not have the same solvent effect and should, in this context, be handled similarly to hydrocarbon-only diesels such as MGO. For ships using HVO, feedback shows that commingling is kept to a minimum, and mixing with residual fuel grades is avoided. Additionally, no tank cleaning has been necessary when switching between MGO and HVO.

It is advised to avoid mixing fuels of different types or sources unless absolutely necessary. If mixing is unavoidable, the ratio should not exceed 90:10, with the standard guideline being 80:20. This means biofuels should not be mixed with other fuels on board, whether they are fossil-based or other biofuels. Implementing this recommendation in practice can be challenging. Additional factors come into play, such as whether the fuel is bunkered from the same location and if it is sourced from the same supplier and with the same blend. In the case of FAME, feedback from the industry reveals significant variations in management practices regarding commingling. According to the responses collected, some report being meticulous about emptying and cleaning tanks, ensuring that commingling never occurs. Others, however, neither clean nor adhere to specific limits on commingling. These same sources typically note that the fuel comes from the same supplier, that they consume the fuel fairly quickly (typically within 3 months), and routinely conduct analyses of fuel quality. It is therefore essential that measures align with the actual conditions during bunkering and on board the ship, and that each case is evaluated individually. When using biofuels and mixing is unavoidable, it is recommended to include a compatibility test between the existing fuel and the new biofuel.

**Stability**
HVO is chemically stable under normal ambient temperatures and recommended usage. Its oxidation stability is comparable

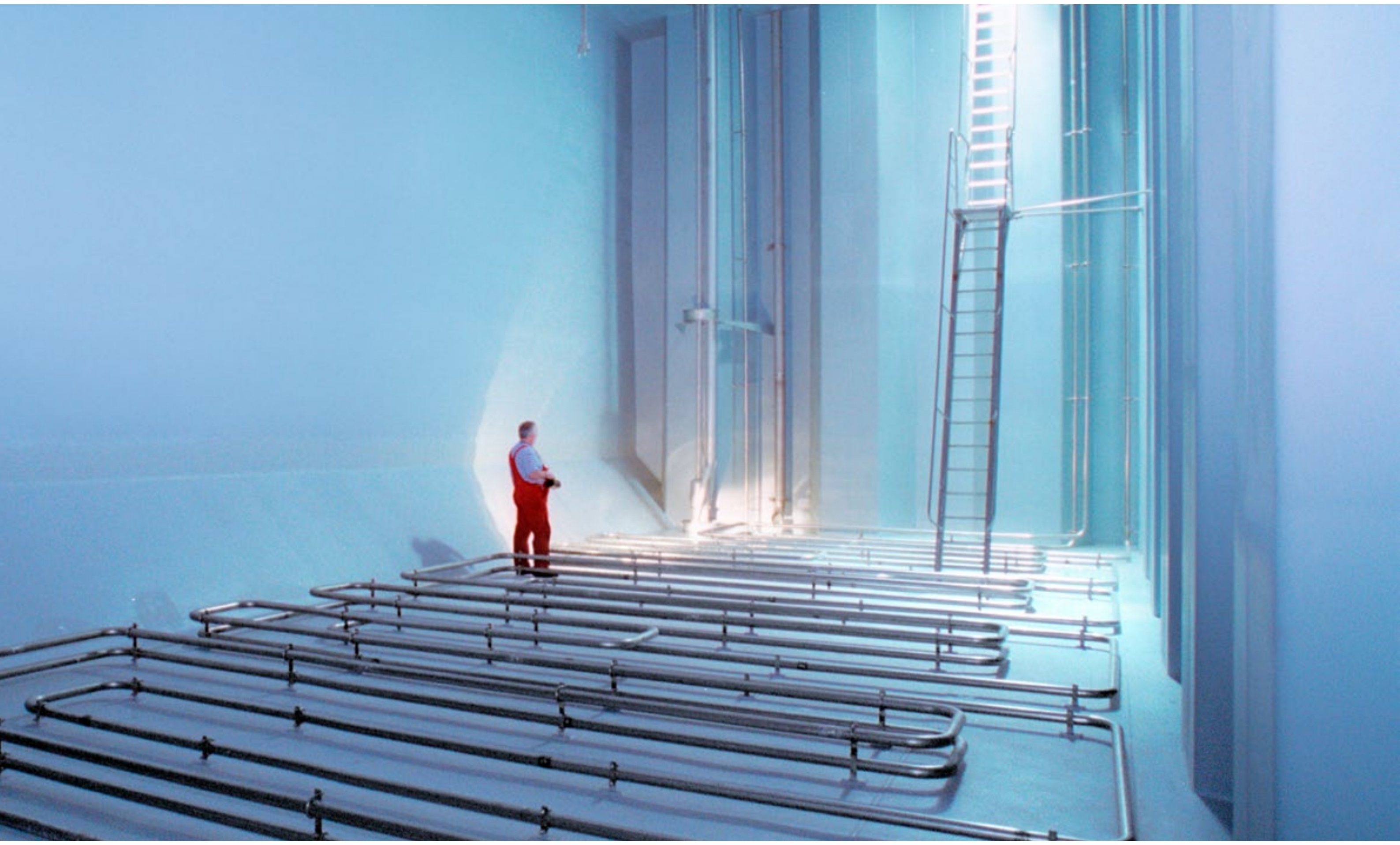
## Cold flow properties

**Cold filter plugging point (CFPP):** Highest temperature at which a given volume of distillate fuel fails to pass through a standardized filtration device in a specified time, when cooled under standardized conditions

**Pour point (PP):** Lowest temperature at which a fuel will continue to flow when it is cooled under specified standard conditions

**Cloud point (CP):** Temperature at which a cloud of wax crystals first appears in a transparent liquid when it is cooled under specified conditions

Source: ISO 8217



to conventional petroleum diesel, indicating that similar storage conditions apply to HVO. The overall oxidation stability of fuels depends on factors like initial fuel quality, additives, and exposure to contaminants, heat, air and light.

FAME generally has lower oxidation and thermal stability than petroleum diesel grades like MGO. It degrades through chemical and biological processes, including oxidation, reverse trans-esterification, hydrolysis, thermal polymerization, and microbial growth (EMSA, 2023). Lower long-term stability is a significant issue with FAME, as oxidation can lead to degradation and the formation of deposits in the fuel over time, depending on storage conditions. This degradation may cause the fuel to become increasingly acidic and viscous, eventually leading to the production of solid deposits that can impair engine operation. Such deposits could block filters and pipes, resulting in fuel starvation and various engine problems. If FAME is stored under favourable conditions, the fuel quality can remain good even after six months, although degradation has been reported after just three months.

It is also important to note that FAME can form deposits or sediments when in contact with certain metals like copper, lead, tin, or zinc. Unlike oil-based fuels, FAME can hold high levels of water in suspension. The presence of water in FAME can promote hydrolytic reactions that break down the FAME, resulting in the formation of free fatty acids. When these fatty acids react with salt and water, they can create a soapy sludge.

**Microbiological growth**

Microbiological growth can occur in conventional MGO. Ships that have experienced issues with microbiological growth in MGO are likely to face similar problems with biofuels unless their tanks have been cleaned and proper housekeeping measures are implemented, such as preventing water ingress.

FAME is particularly susceptible to microbial growth, which can cause clogging in filters and piping. It is crucial to avoid water in the fuel to minimize this issue. If microbiological growth is detected, thorough cleaning and steaming of the fuel tanks will typically be necessary. HVO is comparable to MGO in terms of microbial growth, and no additional precautions should be necessary.

Microbiological activity, including bacteria, yeast, and fungi (BYF) consists of living organisms that may exist in various stages within FAME. These stages range from dormant to active multiplication. The presence of water is a significant factor that enables these microorganisms to thrive. Therefore, it is recommended to emphasize water drainage in biofuel tanks, along with the purification of biofuel in fuel separators.

Higher temperatures can also promote bacterial growth, so it is advisable to keep storage temperatures low if possible. Tank heating should only be performed when necessary to maintain minimum cold flow properties. Additionally, prolonged storage of FAME on board can increase the risk of microbial growth.

### 4.3.2.2 Fuel treatment

**Density and purification**
Fuel separators might need adjustments to accommodate fuels with densities different from those originally used. These adjustments can be made digitally in some systems, while others may require mechanical modifications. HVO has a lower density compared to traditional diesel fuels, which could affect the efficiency of the fuel separators and necessitate modifications. In contrast, the density of FAME is comparable to that of MGO.

For traditional fuels, operating water is typically added to soften the fuel. Adding water to soften FAME is not needed, nor desirable, as it may contribute to the formation of soapy sludge.

The survey results indicated that there were no significant challenges related to the purification of FAME. However, in a few rare cases, a control system upgrade was necessary to facilitate operations with FAME. For HVO, adjustments to older purifiers have been necessary to accommodate the changed density, such as replacing gravity discs to match the properties of HVO.

**Tank drainage**
Focus should be maintained on regularly draining water from fuel tanks containing biofuel, especially FAME. Potential accumulation of sludge in the tanks should also be monitored and drained.

### 4.3.2.3 Fuel supply

**Viscosity**
HVO can have a lower viscosity than distillate fuels, making proper viscosity control essential. Low viscosity (below 2 cSt) can lead to leakages at pipe connections and within engine systems, including injector pumps. Worn fuel injection pumps may struggle to build sufficient pressure due to internal leakage. Additionally, a viscosity below 1.5 cSt has been linked to increased wear on gear pumps. FAME generally has a slightly higher viscosity than traditional diesel fuel. Significantly higher viscosity at injection can create challenges with fuel atomization and combustion in diesel engines.

Typically, the viscosity of fuel supplied to engines is controlled using a viscometer, provided it can accurately detect very low viscosities. In terms of viscosity, engine manufacturers permit the use of FAME and HVO, as long as the requirements at the engine inlet are met. Based on the responses collected, we have not identified any operational issues related to this matter.

It should be noted that ISO 8217:2024 includes minimum (2 cSt) and maximum (6 cSt) viscosity criteria similar to that of distillate fuels.

**Energy content and density (fuel consumption)**
The Lower Calorific Value (LCV) of FAME is typically lower than that of MGO and VLSFO, while the LCV of HVO is comparable. Therefore, considering only LCV and density, one might expect higher fuel consumption when using products of FAME. This aligns with industry comments noting an increase in fuel consumption.

It is noted that the energy content test specification stated in ISO 8217:2017 was not valid for FAME or FAME blends. ISO 8217:2024 is updated in this regard, specifying LCV measurement according to ASTMD 240. Engine manufacturers highlight that it is important to adjust the engine according to the correct energy content to operate efficiently.

The LCV of FAME blends naturally decrease as the proportion of FAME increases, given that 100% FAME has a lower LCV compared to standard fuel oils. This reduction in energy content necessitates an increase in fuel consumption to maintain a given engine load. Engines that do not automatically adjust the injection quantity may be affected by this change in energy density. Electronically controlled engines can potentially manage this through autotuning features, provided the correct LCV is defined in the engine control system. Conversely, mechanically controlled engines may require slight modifications. Furthermore, if engine power limitation (EPL) has been implemented on mechanically controlled engines, the maximum power output may be further reduced when using a fuel with a lower LCV.

**Lubricity**
Biofuels, particularly HVO, can have very low sulfur content, which can lead to lubricity issues. Low lubricity may result in increased wear on components such as pumps and fuel injectors. Note that even though FAME can have very low sulfur content it provides good lubricity (EMSA, 2022); (CIMAC, 2024).

It is important to verify the lubricity and viscosity of HVO, as they may be lower than those of traditional distillate fuels. Additives may need to be incorporated to enhance lubricity.

For HVO, the standard EN 15940 specifies a maximum wear scar diameter of 400 micrometres as the lubricity criterion. In comparison, for FAME, the standard ISO 8217:2024 establishes a maximum wear scar diameter of 520 micrometres. Each engine manufacturer provides specific lubrication recommendations that should be strictly followed.

**Evaporation temperature**
Certain biofuels have a higher evaporation temperature, which increases the risk of accumulation in the lube oil of

4-stroke engines. To mitigate this risk, it is recommended that lube oil analyses be conducted more frequently.

**$NO_x$**

Before the adoption of MEPC.1/Circ.795/Rev.7 'Unified Interpretations to MARPOL Annex VI,' an exemption from the flag state was required to test biofuels for compliance with MARPOL Annex VI Regulation 13. However, with the approval of this Unified Interpretation (UI) during MEPC 78, biofuels can now be used without flag-state approval, provided that $NO_x$ requirements are met. It should be noted that the conditions specified by the UI apply only if the vessel's flag state has adopted the UI.

Besides $NO_x$ limitations, it is important to note that the fuel oil quality requirements included in MARPOL Annex VI Regulation 18 also apply for biofuels.

MEPC.1/Circ.795/Rev.8 states that "a fuel oil which is a blend of not more than 30% by volume of biofuel or synthetic fuel should meet the requirements of regulation 18.3.1 of MARPOL Annex VI". This means that for a marine diesel engine capable of operating on a biofuel blend of up to 30%, such fuels are considered 'similar' to fossil fuels, and no specific actions are required.

MEPC.1/Circ.795/Rev.7 'Unified Interpretations to MARPOL Annex VI' allows marine diesel engines that can operate on biofuel blends exceeding 30% without altering their $NO_x$ critical components or settings, as specified in the engine's approved Technical File, to use such fuel oils without any additional formalities.

A self-check following the Onboard Verification Procedure (OVP) outlined in the engine-specific Technical File is sufficient to demonstrate that biofuels do not "cause the engine to exceed the applicable $NO_x$ emission limit". Any changes to $NO_x$ critical components or settings listed in the OVP must be submitted for approval by the intellectual property holder of the $NO_x$ Technical File.

## 4.4 Summary and recommendations

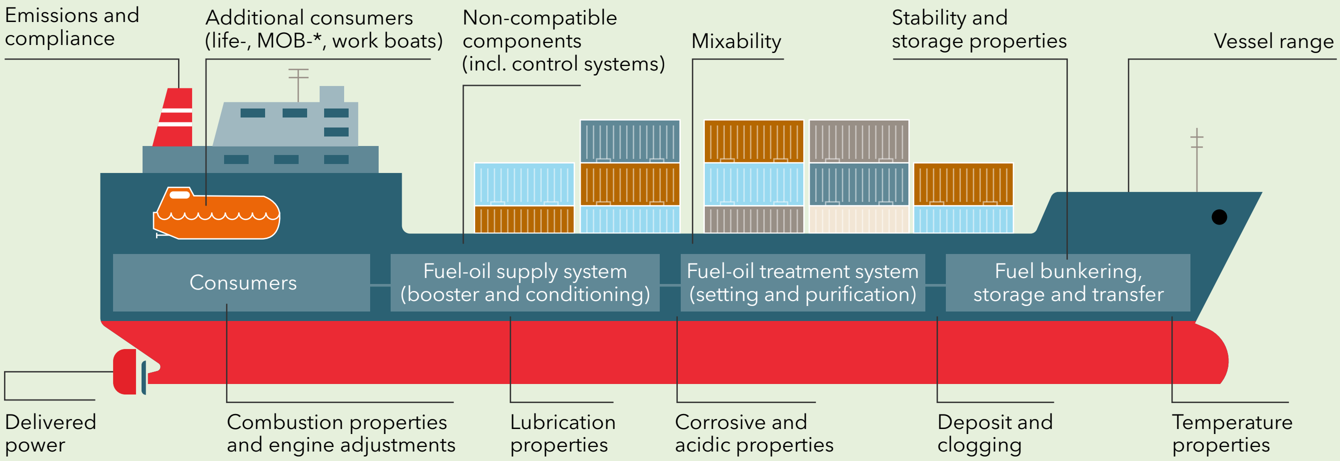
It is emphasized that FAME and HVO are fundamentally different fuels with distinct properties. Their technical compatibility with onboard systems varies not only from each other but also from ship to ship, necessitating individual assessments. Nevertheless, industry feedback indicates that operations generally proceed without significant problems, provided the transition is well-planned and executed. Figure 4-2 highlights key factors relevant to a ship during this process. Using the four subsystems illustrated in the same figure, Table 4-2 goes further into detail and summarizes technical and operational considerations for each subsystem.

Biofuels can, in many cases, be a feasible and practical solution for meeting requirements to reduce GHG emissions. With the growing emphasis on sustainability, it may be beneficial to maintain transparency with charterers by indicating whether a ship is equipped and ready to operate on biofuels. This can be demonstrated through DNV's biofuel class notation.

The following summary, provided in Table 4-2, should be considered general advice, as the considerations for introducing HVO or FAME will vary from ship to ship. It is always recommended to verify the details with the original equipment manufacturer and possibly conduct a risk assessment prior to introducing the new fuel.

FIGURE 4-2

**Essential factors to consider before and during the use of biofuels on ships. These topics may affect one or multiple onboard systems and are not specific to any particular fuel or blend. The four fuel oil subsystems are further detailed in Table 4-2, which provides general advice for FAME and HVO**






*MOB boat: man overboard rescue boat

TABLE 4-2

**Summary of general and subsystem-specific factors to consider before and during the use of FAME and HVO on ships. The general considerations may be relevant for several sub-systems**

<table>
<tr><th>Sub-system</th><th>FAME</th><th>HVO</th></tr>
<tr><td rowspan="2">General considerations</td><td>• Materials compatibility: Verify the compatibility of metals, elastomers, and rubber compounds, and replace them if needed.<br>• Cold flow properties: Verify according to expected operating conditions due to poor low temperature tolerance.</td><td>• Flash point: To be confirmed within applicable limit (60°C).</td></tr>
<tr><td colspan="2">• Filters: To be monitored according to established routines during normal operation, with extra attention during initial trials.<br>• Fuel mixing: Avoid or minimize mixing to the extent possible.<br>• Fuel specification: Utilize recognized standards and specify additional requirements based on expected operating conditions. Avoid off-spec fuels.<br>• Fuel analysis: Request supplier pre-test and conduct drip or bunker sampling to verify fuel quality.</td></tr>
<tr><td rowspan="2">Storage and transfer</td><td>• Stability: Monitor temperature and avoid water ingress and contaminants.<br>• Storage time: To be monitored. Fuel analysis may be relevant if storage is prolonged (typically beyond 3 months, depending on various factors).</td><td>–</td></tr>
<tr><td colspan="2">• Prepare tanks: Empty, clean and dry to the extent possible prior to introducing the new fuel. Maintain proper housekeeping measures.<br>• Thermal management: Monitor fuel temperature to accommodate for cold flow properties.</td></tr>
<tr><td rowspan="2">Treatment and purification</td><td>• Purification: Review compatibility and adjust according to fuel specification.</td><td>• Purification: Review compatibility and adjust according to fuel specification. Note that the density of HVO is lower than that of MGO.</td></tr>
<tr><td colspan="2">• Thermal management: Monitor fuel temperature to accommodate for cold flow properties.<br>• Tank drainage and preparation: Empty, clean and dry to the extent possible. Regular draining of water and potential sludge.</td></tr>
<tr><td>Fuel supply</td><td>• Viscosity: Ensure proper viscosity control. FAME may have slightly higher viscosity than MGO.</td><td>• Viscosity: Ensure proper viscosity control. HVO may have slightly lower viscosity than MGO.</td></tr>
<tr><td rowspan="2">Consumers</td><td>• Fuel consumption: Increased consumption may result from a lower LCV.<br>• Lubricity: Verify according to Original Equipment Manufacturer's (OEM) recommendations. Lubricity is considered good despite its low sulfur content.</td><td>• Lubricity: Verify according to Original Equipment Manufacturer's (OEM) recommendations. HVO has low lubricity due to low sulfur content.</td></tr>
<tr><td colspan="2">• LCV: Adjust according to energy content to ensure efficient operation (power output, limiters, and EPL may be affected if changes in LCV are not accounted for).<br>• Internal leakages: May become evident due to factors such as low viscosity (HVO), incompatible materials (FAME), or worn pump and injection components.</td></tr>
</table>

# 5 Biofuel as a GHG compliance measure

As illustrated in Chapter 3, the uptake of biofuels in shipping has increased significantly since 2021. However, it still makes up a very low share (0.3%) of the total energy use of the marine shipping sector. This increasing trend is expected to continue as more GHG regulations (IMO and EU) incentivizing use of biofuels and other low GHG intensity fuels enter into force. In this chapter, we first describe and illustrate the impact of biofuel use on GHG compliance status under different GHG policy measures. Second, we outline documentation requirements to give proof of the biofuel's GHG credentials under the same GHG policy measures.

## 5.1 Impact on GHG compliance status

In general, use of biofuels can give significant benefits with respect to Carbon Intensity Indicator (CII), EU Emissions Trading System (EU ETS), and FuelEU Maritime[43] requirements. However, to reap the reward of these benefits, the relevant biofuels must be documented to meet sustainability and GHG saving requirements.

In Table 5-1, we summarize the impact of biofuels on GHG compliance status along with sustainability and GHG saving requirements for different IMO and EU regulatory policy measures.

The exact benefit of using biofuels depends on factors such as certified GHG saving and share of biofuel in fuel blend (see information box on page 28 for an example of how biofuel can impact key GHG metrics used by IMO CII, EU ETS, and FuelEU Maritime requirements).

TABLE 5-1

**Regulatory status of biofuels with respect to different IMO and EU GHG regulations**

| | Policy measure | Impact on GHG compliance status from use of biofuels | Sustainability and GHG saving criteria |
|---|---|---|---|
| IMO | EEDI/EEXI | **No effect.** The EEXI and EEDI is a design requirement using the carbon content of the standard reference fuel used in the test report of the $NO_X$ Technical File. | – |
| IMO | DCS (interim approach)[44] | **Reduction of the annually reported $CO_2$ emissions.** A $CO_2$ conversion factor equaling the well-to-wake (WtW) GHG emissions factor can be used for the biofuel. In case of blends, energy weighted average factor is used. | **Sustainability:** Must be certified and fulfil sustainability criteria set by international certification schemes such as International Sustainability and Carbon Certification (ISCC) and Roundtable on Sustainable Biomaterials (RSB). Other schemes can also be accepted by flag administrations.<br>**GHG saving requirement:** Must provide a WtW GHG reduction of at least 65% compared to the WtW GHG emissions of fossil MGO (94 $gCO_2eq/MJ$). |
| IMO | CII (interim approach)[44] | **Reduction of the annually reported CII.** | |
| EU | EU MRV | **No effect.** Emission factors as per Regulation (EU) 2015/757 of the specific biofuel type are to be applied in the calculation and reporting of GHG emissions. | – |
| EU | EU ETS | **Reduction of the annually reported $CO_2$ emissions and required number of EU emission allowances.** Blend components are considered separately with applicable emission factors. | **Sustainability:** Must fulfil sustainability criteria according to EU RED and certified by certification schemes recognized by the EU. This includes ISCC EU, Better Biomass, RSB and others[45]. Unlike EU RED, there is no cap on Annex IX B biofuel feedstocks (e.g. animal fats and used cooking oil).<br>FuelEU Maritime specifically requires that the biofuels are not produced from food and feed crops.<br>**GHG saving requirement:** Biofuel must be produced with a GHG saving from 50% to 65%[46] (relative to a fossil-fuel comparator of 94 $gCO_2eq/MJ$). |
| EU | FuelEU Maritime | **WtW GHG emissions reduced.** WtW GHG emission values for the specific biofuel is to be used. | |
| IMO (pending adoption) | IMO mid-term GHG measures | **Expected that use of biofuels will reduce WtW GHG emissions[47].**<br>The reduction will depend on the emission values for the specific biofuel. | **To be determined** |

## Impact of using biofuels on key GHG metrics

The case considers a fuel blend consisting of FAME and fossil MGO (see key fuel parameters for both fuels given in Table 5-2). It is assumed that the FAME biodiesel fulfils relevant sustainability criteria set by recognized certification schemes and has a GHG saving of 65%, fulfilling GHG saving criteria from both the IMO (as specified in the circular on biofuels under CII)[48], as well as FuelEU Maritime and EU ETS. It is also possible to achieve higher GHG savings with FAME than we use in this example.

Table 5-3 shows the impact of using different fuel blends containing FAME biodiesel and MGO on key GHG metrics. Each fuel blend (e.g. B10), indicates the percentage share of FAME biodiesel in the fuel blend by volume. The results for EU ETS and FuelEU Maritime are only valid for a vessel on a voyage within EU/EEA. EU allowances (EUAs) are tradeable permits that represent the right to emit one tonne of $CO_2$ under EU ETS.

As seen from the Table 5-3, depending on fuel blend, significant reductions in CII, required number of EUAs, and WtW GHG intensity can be achieved by using biofuel compared to running on 100% MGO:

- Reduction when using B100 amounts to 56% (CII) and 62% (FuelEU Maritime WtW GHG intensity). The main reason why the relative reduction is lower for CII is because of the interim approach in which, effectively, WtW GHG emissions are accounted for biofuels, but only tank-to-wake (TtW) $CO_2$ emissions are accounted for MGO.
- Since a $CO_2$ emission factor of zero can be used for EU ETS, we see a high reduction in the required number of EUAs needed for compliance, up to 100% when using B100. From 2026, the reduction decreases slightly, due to the fact that non-$CO_2$ GHGs also need to be accounted for ($N_2O$ and $CH_4$).

TABLE 5-2

**Key fuel parameters for MGO and FAME[49]. It is assumed that the FAME applied has a GHG saving of 65%**

| | Parameter | MGO | FAME (GHG saving: 65%) |
|---|---|---|---|
| **Fuel properties** | Lower heating value (MJ/g) | 0.0427 | 0.037 |
| | Density ($kg/m^3$) | 0.86 | 0.89 |
| **CII** | Emission factor, Cf ($gCO_2/g$) | 3.206 | 1.22 |
| **EU ETS** | TtW $CO_2$ intensity ($gCO_2/MJ$) | 75.08 | 0.00 |
| | TtW GHG intensity ($gCO_2eq/MJ$) | 76.23 | 1.33 |
| **FuelEU Maritime** | WtW GHG intensity ($gCO_2eq/MJ$) | 90.77 | 34.38 |

TABLE 5-3

**Reduction of key GHG metrics when applying different blends of FAME and MGO. All percentage reductions are relative to applying 100% MGO fuel. The results for EU ETS and FuelEU Maritime are only applicable for a vessel on a voyage within EU/EEA. It is assumed that the FAME applied has a GHG saving of 65%**

| | | | Reduction by GHG metric (relative to using 100% MGO) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | **MGO (ref.)** | **B10** | **B20** | **B24** | **B30** | **B50** | **B100** |
| **CII** | CII ($gCO_2$/capacity-mile) | | 0% | 5% | 10% | 12% | 16% | 27% | 56% |
| **EU ETS** | Required no. of EUAs | 2024–2025 | 0% | 9% | 18% | 22% | 28% | 47% | 100% |
| | | From 2026 | 0% | 9% | 18% | 22% | 27% | 46% | 98% |
| **FuelEU Maritime** | WtW GHG intensity ($gCO_2eq/MJ$) | | 0% | 6% | 11% | 14% | 17% | 29% | 62% |

## 5.2 Documentation requirements

To reap the full regulatory benefits from use of biofuels, it must be documented that the applied biofuel meets sustainability and GHG saving requirements outlined in Table 5-1. As the responsible party for regulatory compliance with DCS, CII, FuelEU Maritime, MRV and EU ETS requirements, it is important that the shipping company acquires the required documentation from the fuel supplier and submits it to the verifier.

As illustrated in Figure 5-1, along with the Bunker Delivery Notes (BDNs) and annual reports (DCS, MRV, and FuelEU Maritime), the shipping company also needs to submit a Proof of Sustainability (PoS) or similar document to the verifier (see information box on page 30 describing PoS).

As an interim approach, the IMO accepts PoS documenting compliance with international certification schemes like International Sustainability and Carbon Certification (ISCC) and Roundtable on Sustainable Biomaterials (RSB)[50]. The European Commission accepts PoS documenting compliance with several certification schemes covering RED, such as ISCC EU, Better Biomass, RSB and others[51].

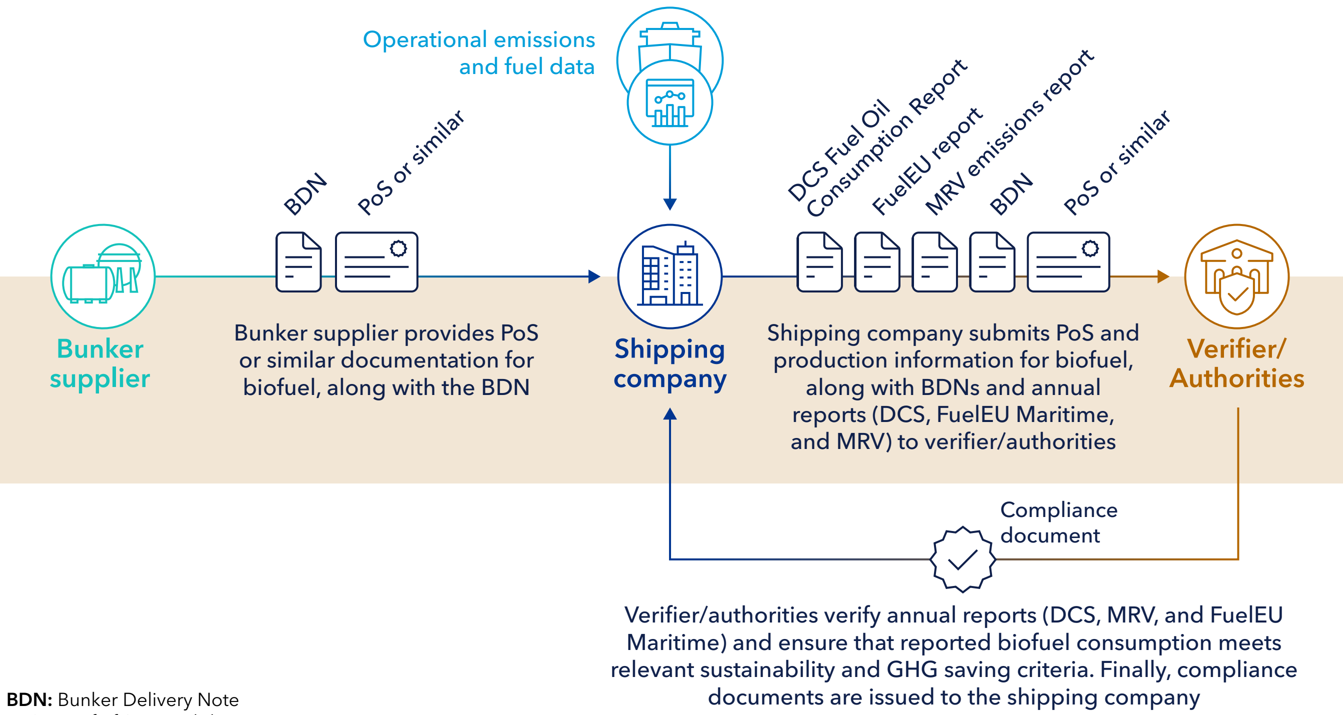
In case it cannot be documented that the biofuel delivered to a ship and consumed on board complies with sustainability and GHG saving criteria, this will significantly reduce or eliminate any compliance status benefit gained:

To reap the full regulatory benefits from use of biofuels, it must be documented that the applied biofuel meets sustainability and GHG saving requirements

- CII: the fuel should then be assigned a Cf equal to the Cf of the equivalent fossil-fuel type.
- EU ETS: the fuel will be treated as a fossil fuel, and the emission factors for biofuels as per Regulation (EU) 2015/757 of the specific biofuel type are to be applied in the calculation and reporting of GHG emissions.
- FuelEU Maritime: the fuel should be considered as a fossil fuel using the default values of the least favourable fossil-fuel pathway.

FIGURE 5-1

**Documentation requirements for use of biofuels in shipping. Along with the Bunker Delivery Notes (BDNs) and annual reports (DCS, MRV, and FuelEU Maritime), the shipping company also needs to submit a Proof of Sustainability (PoS) or similar document to the verifier**




**BDN:** Bunker Delivery Note
**PoS:** Proof of Sustainability

After a successful verification of annual reports (DCS, FuelEU Maritime, and MRV), the verifier/authority issues a compliance document to the shipping company.

When reporting use of biofuels as part of DCS, FuelEU Maritime, or MRV annual reports, additional reporting data fields are required. As per DNV's Operational Vessel Data (OVD) standard[52], these are the additional reporting fields for biofuel:

- Lower Calorific Value (LCV) for the biofuel component in MJ/g. LCV may be different under FuelEU Maritime and MRV compared to DCS. For FuelEU Maritime and MRV emission reports, the LCV should align with the EU RED (Annex III)[53].
- The GHG emission intensity value for the biofuel component in $gCO_2eq/MJ$. This value may be different under FuelEU Maritime compared to DCS. The GHG emission intensity value should be aligned with the PoS or equivalent documentation.
- For blends, the mass of each fuel component within the blends is needed.
- Reference to recognized certification scheme (ISSC, RSB, etc.) or unique number of the PoS.

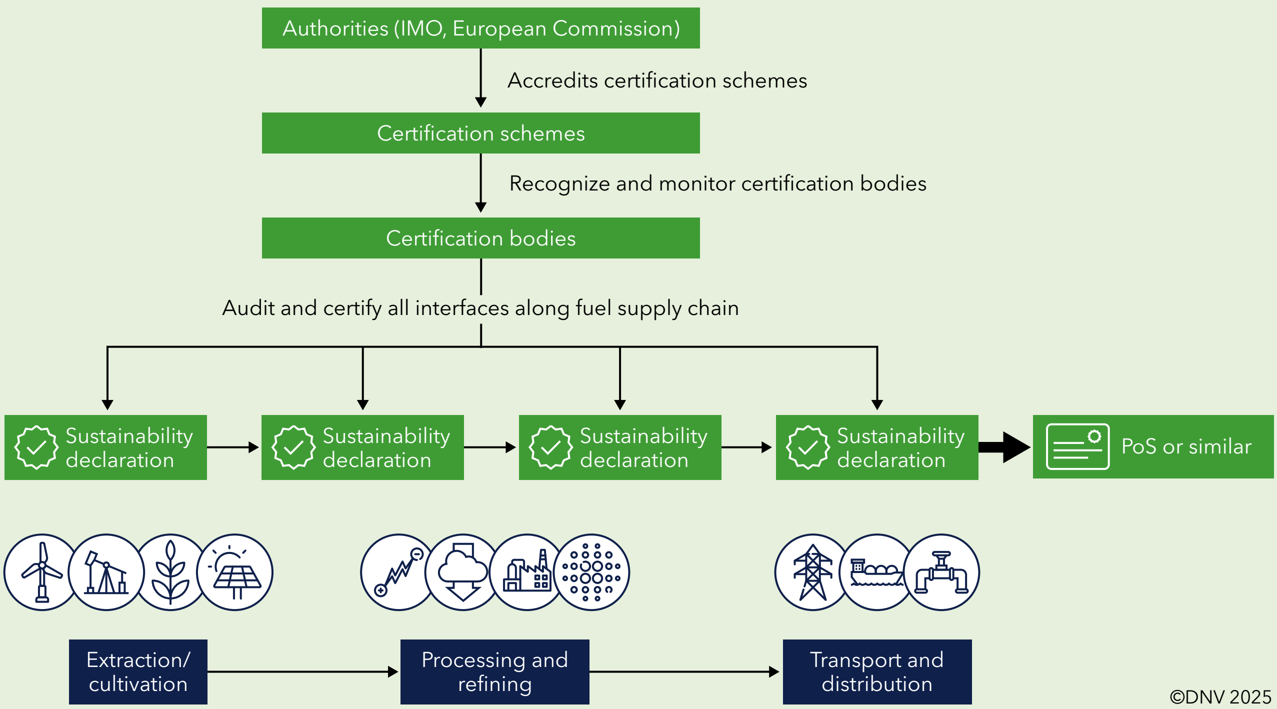
## Proof of Sustainability (PoS) document

The PoS document is a declaration by the bunker supplier, or other operator in the fuel supply chain, stating the origin of the fuel, the total GHG emissions during the production, and whether it fulfils any sustainability requirements. The PoS document issued by the bunker supplier is audited by a certification body according to the requirements of a certification scheme, to ensure that the bunker supplier maintains a mass balance of sustainable materials and that the claim in the PoS document is issued only to one user (see Figure 5-2).

To allow use of the PoS document by both the fuel supplier and the end user of the fuel within EU regulations and schemes, the European Commission is developing the Union Database (UDB). The UDB is intended to become a reliable system that supports parallel claims of renewable energy while preventing companies from double booking the same batch of renewable fuel in multiple greenhouse gas schemes (Dutch Emissions Authority, 2024). Until the UDB is fully operational, the European Commission has stated that in case the PoS document is not available for shipping companies, an equivalent proof-of-compliance documentation can be considered for acceptance by the authorities (EC, 2024). The requirements for equivalent proofs of compliance are still under development.

FIGURE 5-2

**Illustration of certification framework for low GHG intensity fuels**



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# Endnotes

1 Biofuels are made by converting organic matter (also known as biomass or feedstock) into a fuel product. While $CO_2$ is emitted when combusting most biofuels, this is negated by the fact that biomass absorbs $CO_2$ from the atmosphere during growth, giving biofuels the potential to be carbon-neutral.

2 Mtoe = million tonnes oil equivalent

3 Primarily HVO and FAME produced from residue oils.

4 For bio-methanol, we use production capacity in 2023 reported by GENA Solutions & Methanol Institute (2024) as proxy for supply. Due to scarce data, bio-LPG supply is based on forecasted value for 2022.

5 Relative to a fossil-fuel comparator of 94 $gCO_2eq/MJ$.

6 See INTERIM GUIDANCE ON THE USE OF BIOFUELS UNDER REGULATIONS 26, 27 for more details.

7 See, for example, Largest ship-to-ship LBM bunkering executed by STX Group, Hapag-Lloyd and Titan Clean Fuels - STX Group, Gasum Provides Bio-LNG to Equinor | Rigzone

8 See, for example, NEWS - Enabling Singapore's 1st bio-methanol bunkering operations | Royal Vopak

9 Argus Media: Bunkering sector needs deeper dive into B24 bio bunker fuel market | Manifold Times

10 INSIGHT: What to Look Out for When Buying Biofuel Bunkers - Ship & Bunker

11 International Convention for the Prevention of Pollution from Ships

12 International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk

13 Bio-blended fuel includes both the biogenic and petroleum-based component of fuel blends. As such, the reported sale of pure biofuel is lower than what is given in the figure.

14 We make this estimate by first calculating the pure biofuel bunker sales in each port, by assuming that the weighted average biofuel blend sold in Singapore and Rotterdam was 24% and 30%, respectively, by volume. Then, we divide by the total amount of pure biofuel bunkered by ships in 2023 (about 0.7 Mtoe).

15 Port of Fujairah Joins Biofuel Bunker Market - Ship & Bunker Port of Fujairah Joins Biofuel Bunker Market - Ship & Bunker

16 Zhoushan | Bunker

17 First methanol bunkering with deepsea vessel Ane Maersk at Port of Antwerp-Bruges

18 Yang Ming and KPI OceanConnect complete B30 HSFO biofuel bunkering in Busan | Manifold Times

19 Hong Kong Makes Progress in Developing Biofuel Bunker Blend Market - Ship & Bunker

20 Peninsula joins growing group of bio-bunker suppliers with 1st delivery in Gibraltar | S&P Global Commodity Insights

21 Scope 3 emissions are all indirect greenhouse gas (GHG) emissions that occur in the value chain of a company, both upstream and downstream, and are not included in Scope 1 and Scope 2 emissions. This includes GHG emissions from the transportation and distribution of products.

22 MSC Biofuel Solution | MSC

23 CMA CGM | Take control of your environmental performance with ACT with CMA CGM+

24 Ship Climate-Friendly with Ship Green - Hapag-Lloyd

25 Ocean Network Express Launches Green Shipping Solution – ONE LEAF+ | ONE Singapore

26 ECO Delivery | Transportation Services| Maersk

27 Fueling a decarbonized future: the new energies taking us towards net-zero 2040- Wallenius Wilhelmsen

28 UECC hoists Sail for Change initiative

29 Based on public information from each company's respective sustainability or annual report.

30 See Reduced emissions | Viking Line Group

31 Löfbergs reduces carbon footprint with 100% fossil fuel-free sea transport - World Coffee Portal

32 Gasum to supply Hapag-Lloyd with waste-based bio-LNG in accordance with winning ZEMBA tender | Gasum

33 Green shipping corridors are specific maritime routes where zero-emission ships and other emissions reduction initiatives are implemented and supported through a combination of public and private actions. Green Shipping Corridor tracker, there were at least 64 Green Shipping Corridors as of August 2024.

34 See, for example, Trafigura strikes biofuels deal with John Fredriksen venture in drive to tackle upcoming EU rules | TradeWinds
UECC hoists Sail for Change initiative

35 See, for example, Gasum and Wasaline team up to build out FuelEU Maritime pooling service | TradeWinds (tradewindsnews.com)

36 Defining Additionality in the Voluntary Book-and-Claim Market in Deep-Sea Shipping | Global Maritime Forum

37 Omsetningskrav for biodrivstoff til sjøfart - miljodirektoratet.no

38 Indonesia has been supplying bio-bunker blends for more than half a decade – Pertamina

39 https://des.wa.gov/sites/default/files/2022-06/2020BiodieselUseReport.pdf

40 For example, the city of Zhoushan has applied for an exemption, allowing physical blending of B24 FAME biodiesel, see Zhoushan Municipal Development and Reform Commission's reply to Proposal No. 83007 of the Third Session of the Eighth CPPCC

41 ReFuelEU Aviation - European Commission

42 CTI-Maritec. "Bunker Flash: CNSL BioFuel Blended in Marine Fuel." Issued on 21 November 2024.

43 For a more detailed analysis on how biofuels can be used by vessels to ensure compliance with FuelEU Maritime, see (DNV, 2024b).

44 This is considered an interim approach, until a more comprehensive method is developed to calculate a fuel's emission factor based on the IMO LCA guidelines. See interim guidance on the use of biofuels under regulations 26, 27 for more details.

45 See Voluntary schemes for a complete list of EU-approved biofuel certification schemes.

46 Depending on date biofuel production facility became operational; before 5 October 2015: 50%, between 6 October 2015 and 31 December 2020: 60%, after 1 January 2021: 65%.

47 The GHG strategy states that the IMO GHG reduction ambitions should take into account WtW emissions. This can be done in diverse ways, either by setting a requirement on the total WtW GHG intensity of energy used, or by using tank-to-wake (TtW) GHG emissions, but adjusted based on well-to-tank (WtT) emissions and other sustainability aspects.

48 Interim guidance on the use of biofuels under regulations 26, 27

49 Based on FuelEU Maritime regulation, RED, and own calculations.

50 This is considered an interim approach until a more comprehensive method is developed to calculate a fuel's emission factor based on the IMO LCA guidelines. See interim guidance on the use of biofuels under regulations 26, 27 for more details.

51 See Voluntary schemes for a complete list of EU-approved biofuel certification schemes.

52 OVD is a widely used data standard for reporting log abstracts and other operational data from vessels.

53 See DIRECTIVE (EU) 2023/2413 Directive - EU - 2023/2413 - EN - Renewable Energy Directive - EUR-Lex

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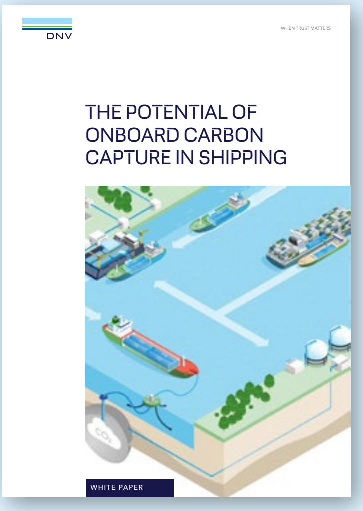


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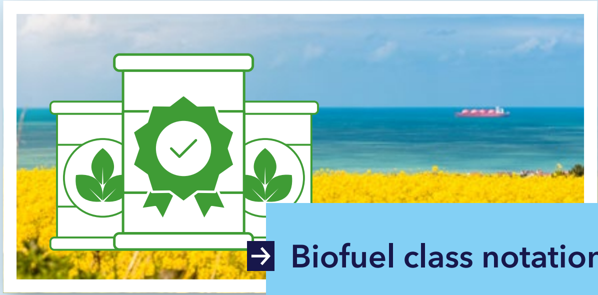

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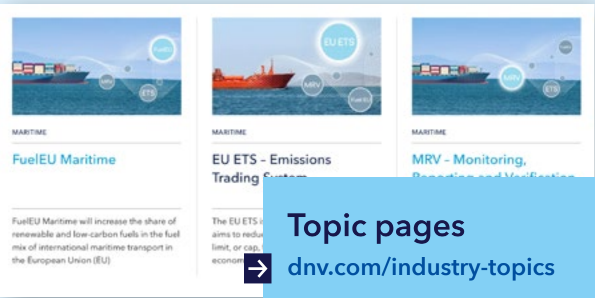


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