WHITE PAPER

Marine biofuels

What to expect in the coming decades

July 2024

Contents

Acronyms

CII	Carbon Intensity Index
CO_2	Carbon dioxide
CO_2e	CO_2 equivalent
EEDI	Energy Efficiency Design Index
EEXI	Energy Efficiency Existing Ship Index
FAME	Fatty acid methyl esters
GHG	Greenhouse gas
HSFO	High-sulphur fuel oil
HVO	Hydrotreated vegetable oil
ILUC	Indirect land use change
IMO	International Maritime Organization
ISO	International Organization for Standardization
MEPC	Marine Environment Protection Committee
MDO	Marine diesel oil
MGO	Marine gas oil
TAN	Total acid number
TBN	Total base number
TTW	Tank-to-wake
VLSFO	Very-low-sulphur fuel oil
WAT	Wax appearance temperature
WDT	Wax disappearance temperature
WTW	Well-to-wake (lifecycle perspective)

1. Introduction

International shipping is responsible for a significant share of global CO_2 emissions and corresponding emissions of other greenhouse gases (GHG), expressed collectively as a CO_2 equivalent (CO_2e). The industry emitted an estimated 1,056 million tonnes of CO_2 in 2018, which is 2.89% of the global GHG emissions during the same year.[1] Reducing carbon intensity is crucial for sustainable maritime transportation, and it requires a transition to cleaner energy sources with lower emissions.

As world trade demand and shipping activities continue to grow, the future trajectory of GHG emissions depends on collective actions. The International Maritime Organization (IMO), which is committed to combatting climate change, is aligning with industries, agreements and development goals[2] worldwide. IMO is taking urgent action by addressing key issues and implementing reforms to achieve GHG reductions.

Recently, IMO revised its strategy. Decisions reached in mid-2023 during the 80th meeting of IMO's Marine Environment Protection Committee (MEPC), MEPC 80, aim to achieve significant reductions in CO_2e emissions related to shipping. While maintaining the goal of a 40% reduction in CO_2e emissions by 2030 compared to 2008, the revised strategy updates the target for 2050 to net zero GHG emissions.[3] To support the revised strategy, IMO is adopting short-, medium- and long-term measures.

A transition to alternative fuels is necessary to reach IMO's CO_2e reduction goals and limit GHG emissions from international shipping as soon as possible.

A number of different fuel types are being discussed as potential replacements for fossil fuels, including green and blue hydrogen, ammonia, methanol and biogas. However, as the supply infrastructure and technological readiness for these fuels remain to be developed, these fuel solutions are measures for the long term.

Among the fuel alternatives, biofuels have been identified as a low-carbon option that is relatively easy for the shipping sector to adopt as a short-term measure. Several biofuel types are already available, including fatty acid methyl esters (FAME) and hydrotreated vegetable oil (HVO). To accommodate the growing demand for sustainable fuels, the International Organization for Standardization (ISO) revised the ISO 8217 specification of the marine fuel standard in 2024, allowing the use of FAME in unlimited blend concentrations in both distillate and residual fuel grades.

Even more biofuel types are expected to become available in the near future. Yet while biofuels can contribute to reaching the IMO GHG reduction targets leading up 2050, the amounts available today are not enough to meet them. In addition, international sustainability requirements are under development to consider the full biofuel life cycle from production to use.

This paper focuses primarily on FAME and HVO, two available biofuel options that are considered favourable for the marine industry. It explores their advantages and challenges with regard to storage, treatment and operation, as well as the production processes and sustainability aspects associated with them.

1 *International Maritime Organization (IMO), 2020*

2. *Examples include United Nations Sustainable Development Goal 13 and the European Union's Fit for 55 package.*

3. *International Maritime Organization (IMO), 2023*

2. Biofuels in overview

2.1 What are biofuels?

Biofuels are fuels produced primarily with energy from renewable sources and biomass such as fats and vegetable oils. First-generation biofuels, which are the most widely available, are produced from feedstocks such as agricultural crops, vegetable oil or food waste. Second-generation biofuels are produced from non-food biomass and waste streams such as forest biomass and agricultural crop residues. Third-generation biofuels, which are still under development, derive from algae and microbes.

Today's broad range of biomass-based fuels includes FAME, HVO, pyrolysis oils and alcohols such as ethanol and methanol. FAME and HVO, like ethanol, are among the many biofuels that have been adopted for automotive use. Based on experience from the automotive industry, FAME and HVO are believed to have the greatest potential for application in marine diesel engines.

2.2 Biomass production and its impact

Although biofuels come from renewable sources, they are not without environmental downsides. One concern is the land used for growing biomass, especially when it comes to first-generation biofuels.

Biomass is generally grown on cropland that was previously used for agriculture. Competition with food production limits biofuel scalability, but it presents wider challenges as well. While the demand for biofuels has increased, the need for food and animal feed has not decreased. On the contrary, biomass production is pushing agriculture into non-cropland areas, including areas with high carbon stock, e.g. forests, wetlands and peatlands.

The shift in land use due to biomass production is called indirect land use change (ILUC). Because ILUC may cause the release of CO_2e stored in trees and soil, it risks negating the GHG savings from an increased share of biofuels in the market.[4] It is therefore important to align biomass production with the agreements and energy policies that ensure best environmental, social and economic practices.

4. European Commission (EC), 2018

2.3 Biofuels in relation to GHG emissions

The potential of biofuels to reduce full-lifecycle GHG emissions, or well-to-wake (WTW) emissions in marine terms, varies according to the biogenic nature of their carbon. Some of them, such as advanced biofuels derived from woody biomass, can reduce GHG emissions by more than 90% compared to traditional marine fuel oils.

If combined with carbon capture and storage, a sustainably produced biofuel has the potential to be a net-zero-emission fuel.[5] However, if the source of the feedstock contributes to ILUC, or if the energy used during refining has a negative impact on GHG emissions, the biofuel may have higher WTW GHG emissions. Thus, the feedstock source and the energy used in production are perhaps among the most important aspects to consider when evaluating a biofuel's sustainability profile.

Although biofuels hold promise and are seen as key in the transition towards net zero emissions, they are not considered to have full potential as carbon-neutral fuels. In addition to the sustainability factors already discussed, the production costs and the fact that biofuels are also needed in aviation and other sectors mean limited availability of biofuels to the marine industry.

2.4 Operational considerations when using biofuels

Because biofuels are very similar to today's petroleum fuels, they are often spoken of as drop-in fuels. However, the chemical and physical properties of biofuels – including FAME (a biodiesel) and HVO (renewable diesel) – differ from those of fossil fuels in certain critical areas. As a result, biofuels require careful attention in respect to fuel handling and treatment on board.

The rest of this document examines FAME and HVO specifically, elaborating on their main differences from traditional fuels. The following chapters highlight the onboard issues related to fuel line equipment, which includes tanks, pumps, separators, fuel conditioning systems and filters. In addition, they explore the effects of these biofuels on engine performance.

5. EMSA, 2023

3. FAME – fatty acid methyl esters

3.1 General characteristics of FAME

FAME is a so-called biodiesel oil. Biodiesels are derived exclusively from fats and oils such as animal fats (e.g. tallow oil), vegetable oils (e.g. palm oil, soybean oil, rapeseed oil) and used cooking oil.

More specifically, FAME comprises mono-alkyl esters produced through a transesterification process. Triglyceride from the feedstock reacts with methanol in the presence of a catalyst, which forms a mixture of FAME and glycerol.[6] FAME's physical and chemical characteristics depend on the length (number of carbons) and unsaturation level of the fatty acid molecule.

The exact chemical composition of a FAME fuel depends on both the feedstock and how the feedstock is processed. The production of FAME is a delicate, dynamic process that must be carefully controlled, as faults lead to composition changes, such as acid or glycol remaining in the FAME.

6. European Biofuels – Technology Platform, 2011

7. International Council on Combustion Engines (CIMAC), 2024

The unsaturation level of FAME molecules affects the behaviour of the fuel, such as its oxidation stability and cold flow properties. For example, oxidation is more likely to occur when the molecule chains of the feedstock have a higher level of unsaturation. Meanwhile, the cold flow properties of unsaturated FAME are generally better than those of highly saturated FAME.[7] On the other hand, FAME produced from a feedstock that contains more saturated fatty acids has a lower tendency to react with other substances.

As a biodiesel, FAME can replace MDO and MGO in low- to medium-speed diesel engines. However, it is more commonly used as a blending component. Depending on its chemical composition, FAME in neat form can be compromised by cold weather, thereby causing problems in older engine systems.

3.3 Storage and treatment of FAME on board

FAME has characteristics that necessitate careful attention when it is used as a marine fuel. Storage and treatment routines must be adapted to mitigate the possible risks.

3.3.1 Water and microbial growth

The water content in fuels can be classified as free, emulsified and soluble water. FAME's chemical composition and solvency characteristics result in a stronger affinity for water compared to petroleum-derived fuels, meaning that FAME attracts water more easily. The methyl esters absorb water and retain it in suspension within the fuel, whereas fossil fuels do not absorb or retain moisture to the same extent. Fossil fuels tend to shed water, producing a bottom layer of it in the storage tanks.

Water in the fuel often comes from water contamination. For example, water may enter the bunker tank by means of inadequate ventilation or leaking coils. FAME is also able to absorb moisture from the air (dissolving it to a level of 1000–1500 ppm) and form stable emulsions that make it prone to microbial contamination.[8]

Bacteria and fungi require moisture to grow and reproduce. Pockets of water within a tank create perfect conditions for uncontrollable growth, which may be devastating for the biofuel. By way of example, a 2014 survey performed by ECHA Microbiology Ltd. Guardian Marine Testing and Lloyds Register Marine examined samples of DMA-grade MGO containing some amount of FAME. Of the 2346 samples tested, around 45% displayed evidence of microbial growth.[9]

Microbial growth is a key challenge for FAME operation, as it poses a risk of clogging within the system. Consequently, microbial contamination can and should be controlled by minimizing water content. Water should be removed from the storage system actively and continuously, and frequent water level checks are recommended. Because condensate also contributes to higher water content, the tanks should be kept as full as possible.

Note that time is also needed for microbes to grow. Using the fuel as soon as possible is more critical for FAME than it is for fossil fuels.

Due to environmental and health concerns, reducing microbial growth with biocides is generally not recommended. Instead, thorough housekeeping of the fuel system is key. Clean tanks, continuous dewatering and control over the separation process allow FAME to be used just like any petroleum fuel.

8. *Kalligeros et al., 2013*
9. *Hill et al., 2015*

3.3.2 Oxidation risks

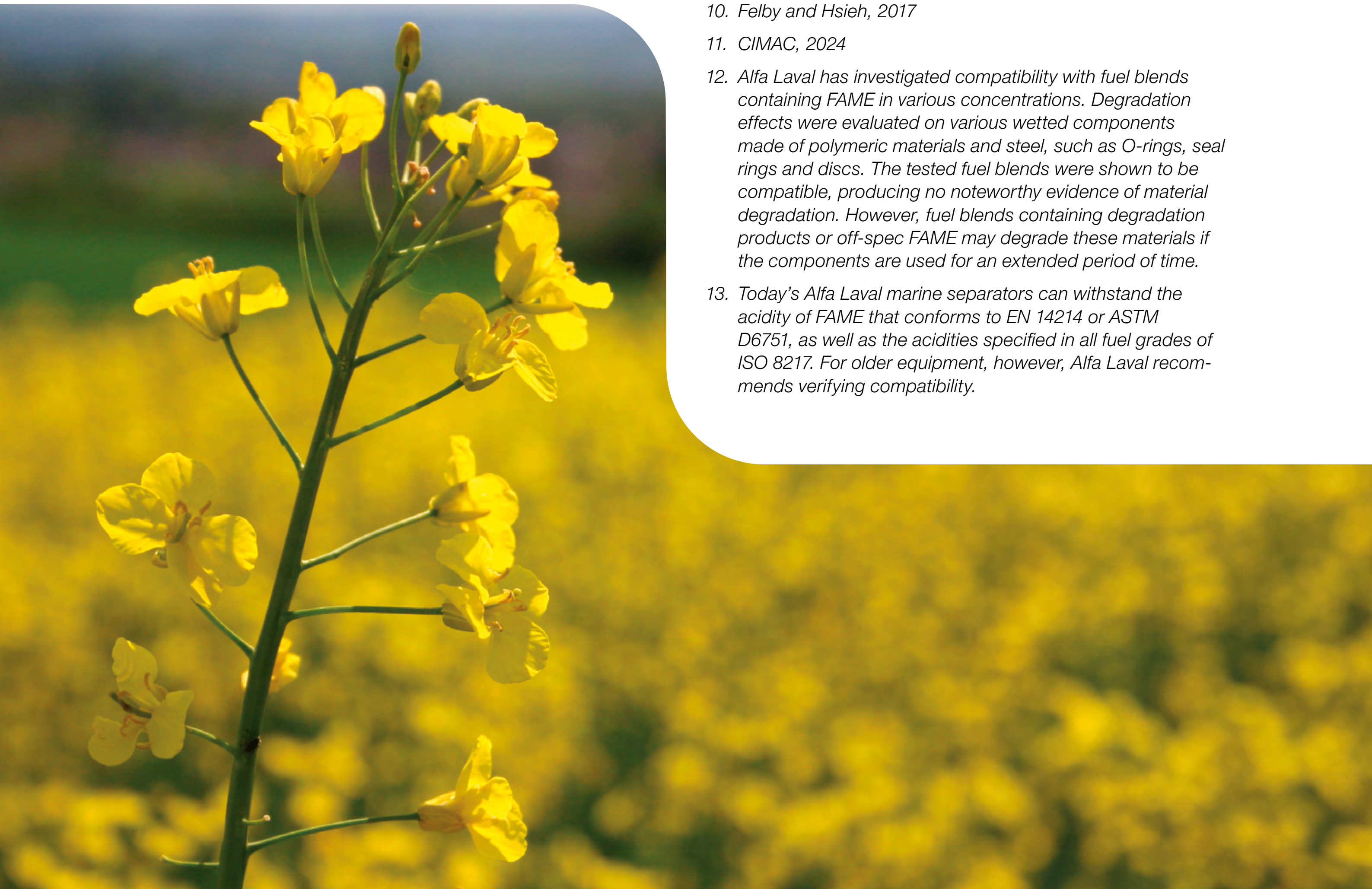
FAME's oxidation stability must also be managed. FAME is less resistant to oxidation than petroleum-derived fuels, meaning it is more prone to degrade over time and form hydroperoxides, aldehydes, carboxylic acids, alcohols and insoluble material. These degradation products may lead to issues with cold flow properties, microbial growth, separation during storage and emissions when combusted. Additionally, the formation of acid groups can affect the fuel's compatibility with metals and polymers.

Increased water content will accelerate the formation of acid products, because water facilitates the hydrolysis of esters into carboxylic acids when acids (low pH) or bases (high pH) are present.[10] Moreover, adding water to FAME can cause soapy sludge to form. Saponification occurs when free fatty acids, stemming from an incomplete reaction in the production or degradation of FAME, react with water and salts. These interactions further underline the importance of good fuel system housekeeping, water removal and timely use of the fuel.

FAME's high solvency may cause deposits within the fuel tanks and treatment systems to dislodge, creating a risk of clogging throughout the fuel line. Furthermore, it can degrade rubber parts or cause a reaction with certain metals.[11] Some materials in the fuel system may be incompatible, and the severity of this depends on the fuel's FAME concentration and the amount of exposure.[12]

In order to limit the degradation of FAME, ISO and CEN have specified oxidation stability in ISO 8217 and EN 14214, respectively. However, FAME's degradation and the resulting formation of acid products is inevitable. To avoid irreversible damage to fuel system components, corrosion must be monitored continuously, preferably by means of frequent visual inspections.[13]

In light of these concerns, a high level of caution and attention is recommended when operating on FAME for first time. Vessel operators should employ a low fuel flow, careful temperature management and other separation optimization strategies to facilitate efficient solids removal.



10. Felby and Hsieh, 2017

11. CIMAC, 2024

12. Alfa Laval has investigated compatibility with fuel blends containing FAME in various concentrations. Degradation effects were evaluated on various wetted components made of polymeric materials and steel, such as O-rings, seal rings and discs. The tested fuel blends were shown to be compatible, producing no noteworthy evidence of material degradation. However, fuel blends containing degradation products or off-spec FAME may degrade these materials if the components are used for an extended period of time.

13. Today's Alfa Laval marine separators can withstand the acidity of FAME that conforms to EN 14214 or ASTM D6751, as well as the acidities specified in all fuel grades of ISO 8217. For older equipment, however, Alfa Laval recommends verifying compatibility.

3.3.3 Wax formation

FAME has a low viscosity, comparable to that of diesel oil. However, since it contains paraffins rather than glycerines, wax formation and wax precipitation are more severe and occur at higher temperatures. The cloud point for diesel oil blends, the wax appearance temperature (WAT) for residual oil blends and the wax disappearance temperature (WDT) are dependent on the specific fuel blend and may differ greatly between blends.

The temperatures for both storage and separation should always exceed the FAME's cloud point or WAT. If wax crystals appear, the FAME must be heated to above its wax melting point in order to regain liquid properties. Normally, onboard gas oil systems have limited heating capabilities, which means the system design and ambient temperatures during sailing must be considered when selecting a suitable fuel. If the systems do not provide sufficient heating capabilities, there is a risk that any wax formed will keep the biofuel from being utilized and reaching the engine inlet as intended.

Waxes can form locally as well as generally. When stored in a double bottom tank, fuel can be cooled due to cold seawater conditions, especially when the vessel moves from summer to winter areas. These local waxes will reveal themselves later, when the tank is put in use, leading to the same problems mentioned above. While tank heating facilities can mitigate the risk, localized wax formation will always be a problem. It can best be countered by keeping FAME in areas on board where the surrounding temperature is not close to the cloud point. Although a sufficiently high storage temperature is required, note that temperatures which are too high may cause substances in the fuel to react and precipitate, resulting in a gum-like material. It is therefore important to avoid concentrated spots of higher temperature, i.e. hotspots

Vessels designed for biofuel will have their fuel and tank installations designed in a way that enables recirculation and heating. Likewise, they will have an appropriate tank coating and proper tank drainage. Fuel system designers and shipyards are expected to anticipate these needs and facilitate proper biofuel treatment.

To further help avoid issues with wax, vessel operators should make a routine of taking fuel samples from each bunker. The samples should be sent for laboratory analysis, always specifying the cold flow properties, and the new bunker should not be used until the laboratory report is received. Fuel contamination investigations have shown that fuel composition differs even among blends with the same notation, and that a proper quality surveillance program can help prevent undesired events.[14]

3.4 Combustion of FAME

When using FAME, the peak combustion temperature, which affects NOx formation, can be lowered by reducing the injection pressure and retarding injection times. The specifics of doing this should be confirmed with the engine maker.

Because FAME contains almost no sulphur, it drastically reduces emissions of SOx and particulate matter (PM).

14. CIMAC, 2013

4. HVO – hydrotreated vegetable oil

4.1 General characteristics of HVO

HVO, or renewable diesel, is derived through hydrogenation. It is also known as hydrotreated esters and fatty acids (HEFA) or hydrotreated renewable oil (HRO). HVO is produced from the same biomass as FAME, but it may also be produced from residual crops and industrial waste like wood spill.

HVO can be considered a first-generation or second-generation biofuel, depending on the biomass used. HVO made from biomass such as vegetable oils, e.g. palm oil, soybean oil or rapeseed oil, is a first-generation biofuel. HVO made from biomass such as residual crops or industrial waste is a second-generation biofuel. As a second-generation biofuel, HVO has a much smaller WTW carbon footprint compared to MGO – only 8–48 CO_2e/MJ compared to 85–87 g CO_2e/MJ.[15]

HVO, just like petroleum fuels, consists of hydrocarbons. However, the hydrocarbons in petroleum fuels are a mix, comprising both paraffins and aromatics. Because HVO is produced through hydrogenation, its hydrocarbons are mainly paraffins. This leads to new challenges when using it, such as a lower density that has an impact for marine vessels.

HVO quality is not specified in any marine fuel standard, but it is defined in the standard for automotive paraffinic diesel fuels: EN 590 B7 and EN 15940:2016 class A. Its density, 765–800 kg/m^3, is specified in EN 15940:2016+A1:2018 +AC:2019 class A. Diesel engines can run on neat HVO, which is why the automotive industry considers it drop-in fuel. On marine vessels, however, the lower density places added requirements on the fuel treatment system.

4.2 Storage and treatment of HVO on board

HVO can be stored and treated in much the same way as marine petroleum distillate. In contrast to FAME, it is not more prone to microbial growth than fossil diesel oils. Nevertheless, the low fuel density may require adjustment of the separator for efficient water removal.

4.3 Combustion of HVO

EN 15940 specifies an HVO flashpoint of 55°C, which would violate onboard safety requirements that specify a minimum flashpoint of 60°C. This issue can easily be avoided by ordering HVO with a minimum flashpoint of 60°C.

Because HVO contains neither aromatics nor sulphur, it burns cleaner than fossil diesel oil. When combusted efficiently, it results in only minor soot formation, which limits ash content and protects the quality and lifetime of the lubrication oil.

The great density difference between HVO and residual fuels, however, increases the risk of soot formation and asphaltene precipitation during a fuel changeover.

15. Fridell et al., 2019

5. The outlook for biofuels

The introduction of the 0.50% sulphur limit on 1 January 2020 brought about a major change in fuel handling on board. The announced intent to decarbonize the shipping industry by 2050, with the first major milestone in 2030, has changed the industry as a whole.

In the short term, fleets have already begun taking steps to reduce GHG emissions. Indeed, some shipowners have been forced to do so to meet the requirements of the Carbon Intensity Indicator (CII) and the Energy Efficiency Design Index (EEDI) or Energy Efficiency Existing Ship Index (EEXI) for a given vessel. Engine power limitation, or slow steaming, is the easiest option today, and it is likely that that speed limits will soon be imposed on certain vessels or in certain regions. Both measures mean longer voyage times and will eventually lead to more vessels sailing on a given route.

Ultimately, decarbonizing the shipping industry will require switching to clean and sustainable fuels. As a result of the 2020 sulphur cap, alternatives to HSFO have already become more common. However, VLSFO and MGO do not affect a vessel's carbon footprint. This point is acknowledged in IMO's default carbon factors (amount of CO_2 produced per tonne of fuel burned), which show very similar values for HSFO, VLSFO and MGO.

LNG has been seen as a clean alternative to fuel oil, producing no particulate matter, no sulphur emissions and 20% less CO_2 per unit of energy when combusted. However, the dominant component of LNG is methane, which is itself a strong GHG. Since not all methane is burned during combustion (so-called methane slip), LNG may actually be a larger contributor to global warming than fuel oil. Both IMO and the EU are currently considering the total WTW emissions for LNG, and the impact of regulation could have a severe impact on the LNG business case.

Simply put, meeting the IMO targets will require continued innovation and the introduction of other fuel alternatives, as well as constant effort to reduce onboard energy demand. Development and testing are well underway in both the automotive and marine industries, but there are still many challenges left to solve. New fuel infrastructures will need to be laid out and renewable production set up, just as vessels will need to be designed for operation on the new fuel alternatives.

Biofuels like FAME and HVO are viable alternatives in many ways. They lower emission levels significantly compared to traditional marine fuel oils, and they are easy to integrate into existing fuel infrastructure and onboard treatment plants. However, their availability to the marine industry – and their pricing – is highly dependent on global availability and competition with other sectors.

Global biofuel production remains far below the levels needed to support today's growing shipping industry, especially with the aviation and automotive industries requiring their own very large share. Likewise, much of the world's vegetable oil supply is and will be needed as a critical food source. Depending on the type of biomass used, the production of biofuels can also lead to further environmental challenges, for example through deforestation and heavy water consumption.

Technical challenges remain as well. If biofuels are the way forward, lubrication oil producers will have to adapt. Despite the high total acid number (TAN) in FAME, both FAME and HVO are sulphur-free. This requires marine engine lubrication oils with a low total base number (TBN) and high detergency, so as to lubricate the engine efficiently and prevent scuffing. The continued use of a centrifugal separator to remove contaminants (insoluble content and water) from the lubrication oil will be needed to promote engine longevity and efficiency, no matter which biofuel oil is used.

Regardless of these factors, biofuels are likely to dominate in the near future, due to their existing supply chain and the ease of integrating them into current fuel and onboard infrastructure. In the coming years, the development of additional biofuel types and their implementation on board can be expected. Furthermore, ongoing work with the short-term measures that support IMO's GHG strategy – EEDI, EEXI and CII – will likely make biofuels even more attractive.

EEDI and EEXI only account for tank-to-wake (TTW) emissions, but CII will account for WTW emissions as a result of the MEPC 80 guideline update. This marks the start of fuel lifecycle consideration with regard to emissions, and the development of a comprehensive WTW method to account for biofuel GHG emissions is expected. Likewise, IMO is developing legislation to include WTW emissions for all fuel types. This would have a positive effect on the energy efficiency calculation for most biofuels, making them even more preferable than they are today.

No matter which fuels become dominant in coming years, pilot fuels will still need to be cleaned, and lubrication and control oil must remain in good condition. Thus, at least one thing is clear when it comes to biofuels: fuel oil and lubrication oil treatment will remain a necessity.

6. Financial considerations

A cost comparison between biofuels and fossil fuel oils shows that biofuels are significantly more expensive (Figure 1). However, FAME and HVO prices are volatile (Figure 2). They are highly dependent on both region and the price of the feed stock, which is largely independent from the crude oil price.

To drive the use of biofuels in the marine market, strict legislation is needed – either in the form of regulation or in the form of economic incentives such as CO_2 taxation.

The required tank volume plays a very important part in the evaluation of alternative fuels. Even though HVO is a low-density fuel, it has a relatively high volumetric energy content (34.4 GJ/m3) and hence requires less storage space than FAME (Figure 3).

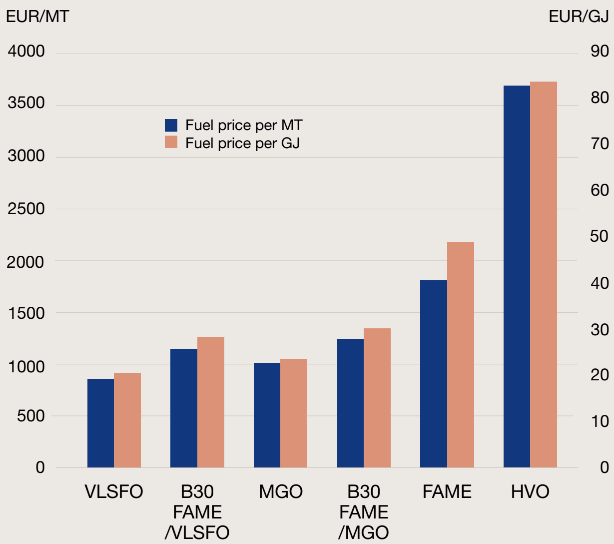


Figure 1: Cost comparison according to March 2022 fuel price level expressed as europer mass in metric tonnes and energy content in gigajoules (Biofuel Express, 2022; Neste 2022, Ship & Bunker 2022)

Fuel	Price range (USD/t MGOe)
HFO	400–500
VLSFO	450–650
LNG (grey)	500–700
Methanol (grey)	600–800
MGO	800–900
Biofuel (B24, B30)	800–900
Biofuel (B100)	1000–1500
Ammonia (grey)	1300–1500
Methanol (bio)	2450–2550
Ammonia (green)	2800–2900

Figure 2: Price levels, Q4 2023. (Data source: DNV Alternative Fuels Insight)

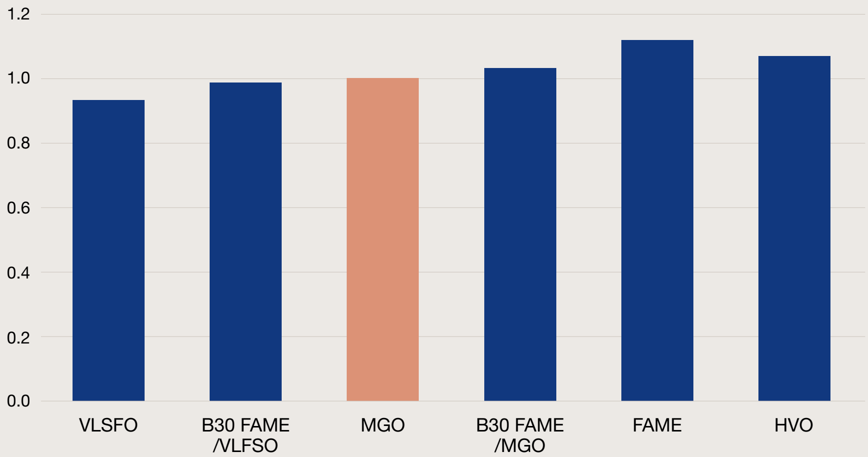


Figure 3: Volumetric comparison of fuels expressed per equivalent energy content of MGO (=1) (Neste, 2020; Ship & Bunker, 2020)

7. Summary

The Alfa Laval Test & Training Centre in Aalborg, Denmark, includes facilities for testing both gas-related solutions and biofuels. It is the world's most advanced test centre for environmental and combustion technology for the marine industry.

The marine fuel market must change for the sector to cut global GHG emissions and reach the goals of the Paris Agreement. Biofuels, such as FAME and HVO, will contribute to decarbonizing the global shipping industry and are an excellent fuel option for reducing emissions today. To be truly sustainable, however, biofuels require sustainably sourced feedstocks, produced with the smallest land use footprint.

FAME and HVO are often considered drop-in fuels. As they require little or no modification to the existing technology on board, they are a safe fuel choice when used according to the well-established safety procedures for diesel operation. Nonetheless, biofuel operation places new requirements on both equipment and operators. Special attention should be paid to a number of factors, including fuel storage and treatment.

When bunkering biofuels, the properties of each bunker should be analysed on a case-by-case basis. Fuel quality varies significantly, and fuel that is of low quality or outside the latest marine fuel standard specifications poses a great risk of equipment breakdown. Moreover, there is a risk of incompatibility when mixing biofuels with residual and/or distillate fuels.

The most common issues when running on biofuels are related to storage and a low viscosity that is very dependent on temperature. Especially for FAME, microbial growth and oxidation must also be kept under control. This puts emphasis on tank and equipment cleanliness, as well as the fuel storage time. To avoid problems, vessel operators should ensure proper housekeeping and understand the biofuel in use, including how well it matches the onboard equipment.

Biofuels can be treated in the same way as petroleum fuels. However, frequent and careful temperature checks are required. Sludge build-up, either from the fuel itself or from residues within the fuel system, may necessitate more frequent discharges or other optimization measures, such as a lower fuel flow.

The solvency properties of biofuels are reason for additional control and maintenance, as they may degrade rubber and react with certain metals.

Finally, the flashpoint of FAME and HVO must be considered, as it affects both emissions and lubrication oil quality.

Based on all these factors, FAME and HVO require thought-through solutions before uptake. Fuel treatment equipment must be verified and possibly upgraded for operation with biofuels, especially if it was not originally designed with biofuels in mind. Likewise, crews must be prepared before putting these fuels to use. Discussion with experts is advised, especially when it comes to the needs surrounding fuel treatment equipment.

Discuss your needs with Alfa Laval

Fuel flexibility will only grow more important. Now and in coming years, the design for any new vessel should consider a later switch to low- and zero-emission fuels. This is where we at Alfa Laval can help. We exist to find solutions to your technical challenges, and we invite you to discuss biofuel integration with our experts.

No matter what your current fuel plans are, you will no doubt encounter questions as the fuel transition progresses. Rest assured, we will be here to keep you informed and help you understand the latest developments. The marine industry is on a dramatic – but exciting – journey into a world of new fuels, and you are not alone.

Alfa Laval is ready to partner with you.

Property	FAME			HVO		
	Min	Max	Standard	Min	Max	Standard
Cetane number	51	–	EN 14214	70	–	EN 15940
Density @ 15°C [kg/m³]	860	900	EN 14214	765	800	EN 15940
Flashpoint [°C]	101	–	EN 14214	55.1	–	EN 15940
Viscosity @ 40°C [mm²/s]	3.5	5.0	EN 14214	2.0	4.5	EN 15940
Lubricity [µm]				–	400	EN 15940
Aromatics [% (m/m)]				–	1.1	EN 15940
Sulphur content [mg/kg]				–	5.0	EN 15940
Carbon residue on 10% distillation residue [% (m/m)]				–	0.1	EN 15940
Sulphated ash content [% (m/m)]	–	0.02	EN 14214	–	0.001	EN 15940
Water content [% m/m]	–	0.05	EN 14214	–	0.02	EN 15940
Total contamination [mg/kg]	–	24	EN 14214	–	24	EN 15940
Oxidation stability @ 110°C [h]	8.0	–	EN 14214	–	25	EN 15940
Acid value [mg KOH/g]	–	0.5	EN 14214	–	0.01	EN 15940
Cloud point [°C]				–	-10 summer -32 winter	EN 15940
Cold filter plugging point (CFPP) [°C]	–	Grade A +5 Grade B 0 Grade C -5 Grade D -10 Grade E -15 Grade F -20 Grade G -26			-10 summer -32 winter	EN 15940
Appearance @ 25°C		–		Clear and bright		EN 15940

Table 1: Fuel properties for FAME and HVO (CEN, 2019a; CEN, 2019b)

Bibliography

- ASTM International. 2020. *Standard Specification for Biodiesel Fuel Blend Stock (B100) for Middle Distillate Fuels.* ASTM D6751-20a.
- Biofuel Express. 2022. *List prices from Biofuel Express.* Available at: https://www.biofuel-express.com/hvo100/ [Accessed: 20220314].
- CEN (European Committee for Standardization). 2017. *Automotive fuels - Diesel - Requirements and test methods (Corrected version 2017-12).* EN 590:2013+A1:2017.
- CEN (European Committee for Standardization). 2018a. *Automotive fuels - Automotive B10 diesel fuel - Requirements and test methods.* EN 16734:2016+A1:2018.
- CEN (European Committee for Standardization). 2018b. *Automotive fuels - High FAME diesel fuel (B20 and B30) - Requirements and test methods.* EN 16709:2015+A1:2018.
- CEN (European Committee for Standardization). 2019a. *Liquid petroleum products - Fatty acid methyl esters (FAME) for use in diesel engines and heating applications - Requirements and test methods.* EN 14214:2012+A2:2019.
- CEN (European Committee for Standardization). 2019b. *Automotive fuels - Paraffinic diesel fuel from synthesis or hydrotreatment - Requirements and test methods.* EN 15940:2016+A1:2018+AC:2019.
- CIMAC (International Council on Combustion Engines). 2013. *Guidelines for ship owners and operators on managing distillate fuels up to 7.0 % v/v FAME (Biodiesel).* Available at: https://www.cimac.com/cms/upload/workinggroups/WG7/CIMAC_WG7_Guideline_for_Ship_Owners_and_Operators_on_Managing_Distillate_Fuels_May_2013.pdf [Accessed: 20210125].
- CIMAC (International Council on Combustion Engines). 2024. Marine-fuels containing FAME; *A guideline for shipowners & operators*. Available at: https://www.cimac.com/cms/upload/workinggroups/WG7/CIMAC_Guideline_Marine-fuels_containing_FAME_04-2024.pdf [Accessed: 20240613].
- European Biofuels – Technology Platform. 2011. *Biofuels Fact Sheet – Fatty Acid Methyl Ester (FAME).* Available at: https://www.etipbioenergy.eu/images/fame-fact-sheet.pdf [Accessed: 20210125].
- EC (European Commission). 2018. *DIRECTIVE (EU) 2018/2001 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 11 December 2018 on the promotion of the use of energy from renewable sources (recast).* Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L2001&from=EN [Accessed: 20210331].
- EMSA (European Maritime Safety Agency). 2023. *Potential of Biofuels for Shipping_rev1_Sept23.pdf.* Available at: https://www.emsa.europa.eu/publications/item/4834-update-on-potential-of-biofuels-for-shipping.html. [Accessed: 20240604].
- Felby, C. & Hsieh, C.C. 2017. *Biofuels for the marine shipping sector - An overview and analysis of sector infrastructure, fuel technologies and regulations.* International Energy Agency. Available at: https://www.ieabioenergy.com/wp-content/uploads/2018/02/Marine-biofuel-report-final-Oct-2017.pdf [Accessed: 20210126].
- Fridell, E., Hansson, J., Jivén, K. & Winnes, H. 2019. *Biofuels for low carbon shipping.* IVL Swedish Environment Research Institute. Available at: http://triplef.lindholmen.se/sites/default/files/content/resource/files/biofuels_for_low_carbon_shipping_0.pdf [Accessed: 20210125].
- Hill, G., O'Malley, L. & Williams, G. 2015. A Global Survey of the Incidence of FAME and Microbial Contamination in Marine Distillate Fuels. Available at: https://echamicrobiology.com/knowledge-hub/technical-publication/a-global-survey-of-the-incidence-of-fame-and-microbial-contamination-in-marine-distillate-fuels [Accessed: 20240711].
- IMO (International Maritime Organization). 2020. *Fourth IMO Greenhouse Gas Study.* Available at: https://wwwcdn.imo.org/localresources/en/OurWork/Environment/Documents/Fourth%20IMO%20GHG%20Study%202020%20-%20Full%20report%20and%20annexes.pdf [Accessed: 20240708].
- IMO (International Maritime Organization). 2020. *IMO working group agrees further measures to cut ship emissions.* Available at: https://www.imo.org/en/MediaCentre/PressBriefings/pages/36-ISWG-GHG-7.aspx [Accessed: 20210125].
- IMO (International Maritime Organization). 2023. Resolution MEPC.377(80): 2023 IMO strategy on reduction of GHG emissions from ships. Available at: https://wwwcdn.imo.org/localresources/en/OurWork/Environment/Documents/annex/MEPC%2080/Annex%2015.pdf [Accessed: 20240711].
- ISO (International Organization for Standardization). 2017. *Petroleum products – Fuels (class F) – Specification of marine fuels.* ISO 8217:2017, table 1 and Annex A.
- Kalligeros, S., Kotsokolos, P., Kotsifis, M., Anastopoulos, G., Lois, E. & Zannikos, F. 2013. Investigating "De Minimis" Level of Fatty Acid Methyl Esters (FAME) in Distillate Marine Gas Oil. SAE *International Journal of Fuels and Lubricants.* 6(3), 863– 869. Available at: http://www.jstor.org/stable/26273278 [Accessed 20210408].
- Neste. 2020. *Neste Renewable Diesel Handbook.* Available at: https://www.neste.com/sites/default/files/attachments/neste_renewable_diesel_handbook.pdf [Accessed: 20210326].
- Neste. 2022. *Biodiesel prices (SME & FAME).* Available at: https://www.neste.com/investors/market-data/biodiesel-prices-sme-fame [Accessed: 20220314].
- OECD (Organisation for Economic Co-operation and Development). 2019. *The Potential Contribution of Biofuels to Climate Change Mitigation in the Transport Sector: A Partial Equilibrium Analysis.* Available at: http://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=COM/TAD/CA/ENV/EPOC(2018)19/FINAL&docLanguage=En [Accessed: 20210125].
- Ship & Bunker. 2020. *Integr8: VLSFO Calorific Value, Pour Point and Competitiveness with LSMGO.* Available at: https://shipandbunker.com/news/world/662089-integr8-vlsfo-calorific-value-pour-point-and-competitiveness-with-lsmgo [Accessed:20210326].
- Ship & Bunker. 2022. *Global 20 ports average bunker prices.* Available at: https://shipandbunker.com/prices/emea/nwe/nl-rtm-rotterdam [Accessed:20220315].

This is Alfa Laval

Alfa Laval is active in the areas of Energy, Marine, and Food & Water, offering its expertise, products, and service to a wide range of industries in some 100 countries. The company is committed to optimizing processes, creating responsible growth, and driving progress – always going the extra mile to support customers in achieving their business goals and sustainability targets.

Alfa Laval's innovative technologies are dedicated to purifying, refining, and reusing materials, promoting more responsible use of natural resources. They contribute to improved energy efficiency and heat recovery, better water treatment, and reduced emissions. Thereby, Alfa Laval is not only accelerating success for its customers, but also for people and the planet. Making the world better, every day. It's all about *Advancing better*™.

How to contact Alfa Laval

Contact details for all countries are continually updated on our web site. Please visit www.alfalaval.com to access the information.

How to contact Alfa Laval

Up-to-date Alfa Laval contact details for all countries are always available on our website at www.alfalaval.com

100003528-4-EN 2407