



ADVANCES IN BIOFUELS FOR MARINE APPLICATIONS

The marine sector is shifting away from petroleum diesel fuels and towards biofuels to achieve decarbonisation. Dr Raj Shah, Val Corrente, Mathew Stephen Roshan and Gavin Thomas explore how the future of biofuels is predicted to rely on algal feedstocks that are genetically engineered for efficient biofuel production

The combustion of petroleum-based fuel releases greenhouse gases and pollutants that contribute to climate change.

It is imperative to develop alternatives to fossil fuels to mitigate the adverse effects of climate change.

The marine sector produces approximately 900 million metric tons of carbon dioxide per year. This accounts for about 3% of total global greenhouse emissions annually (Figure 1).

To address the growing threat of the climate crisis, the International Maritime Organization (IMO) is encouraging the marine sector to reduce its greenhouse gas emissions.

Marine engines are more versatile than engines in other sectors, like aviation. So the marine sector is the ideal candidate for a shift towards alternative fuels [1].

Multiple alternative fuels have been considered, including hydrogen and ammonia.

Hydrogen produces zero carbon emissions. But it requires extreme safety precautions for storage and transportation [2].

Ammonia is also a low-carbon fuel. But it poses significant safety concerns because of its toxicity [2].

Both hydrogen and ammonia require new infrastructure and alternate engine designs to be compatible in marine vessels. Biodiesel, however, is a viable solution as a drop-in fuel to phase out petroleum-based fuels because it is compatible with existing marine engines.

Biodiesels, fuels derived from biological sources like vegetable oils and animal fats, are a promising alternative to petroleum fuels.

Biodiesel blends can decrease greenhouse gas emissions by up to 80% compared to conventional marine fuels [2].

Currently, the biodiesel fuels FAME (fatty acid methyl ester) and HVO (hydrotreated vegetable oil) are the two most used biofuels in shipping [1]. Both are drop-in fuels that can be used in vessels designed for conventional petroleum fuel [3].

Liquefied biogas, however, must be used on LNG-capable vehicles.

In 2023, only 0.3% of marine energy was from biofuels [3].

The future of biodiesel use in the marine sector will require adjustments to existing marine technology.

Application of biodiesel in marine vessels

Most marine vessels currently use diesel engines that can easily operate with alternative fuels with little to no change to the fuel system.

FAME and HVO, for example, can effectively be used in compression ignition engines, which are often used in marine vessels [2].

However, changing the fuel system to accommodate the use of alternatives with different compositions and properties than conventional diesel fuels may necessitate significant changes to the engine and the on-board fuel storage and delivery systems.

Bio-methanol and bioethanol are versatile options for marine applications [1]. Advanced biofuels (HVO and DME) have the best fuel system compatibility because their density is often comparable to conventional marine fuels. Therefore there is minimal risk of losing cargo space when switching to complex biofuels [1].

One means of introducing advanced biofuels is by blending them with traditional marine diesels. These blends are named based on the volumetric percent of biodiesel in the blend (Figure 2).

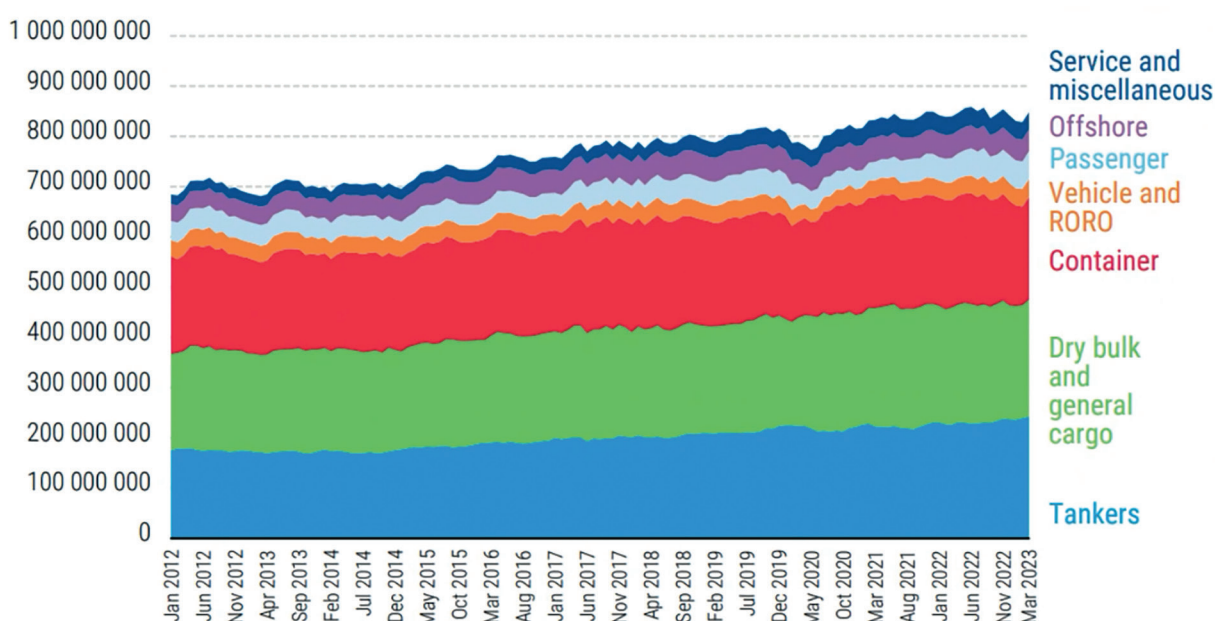


Figure 1: Total carbon dioxide emissions (tons) by vessel type from January 2012 to March 2023 [1]

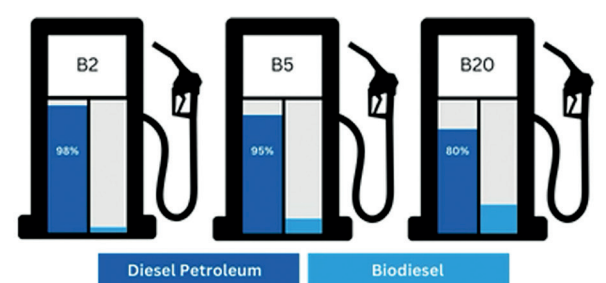


Figure 2: Biofuel blends are named based on the percentage of biodiesel in the fuel [4]

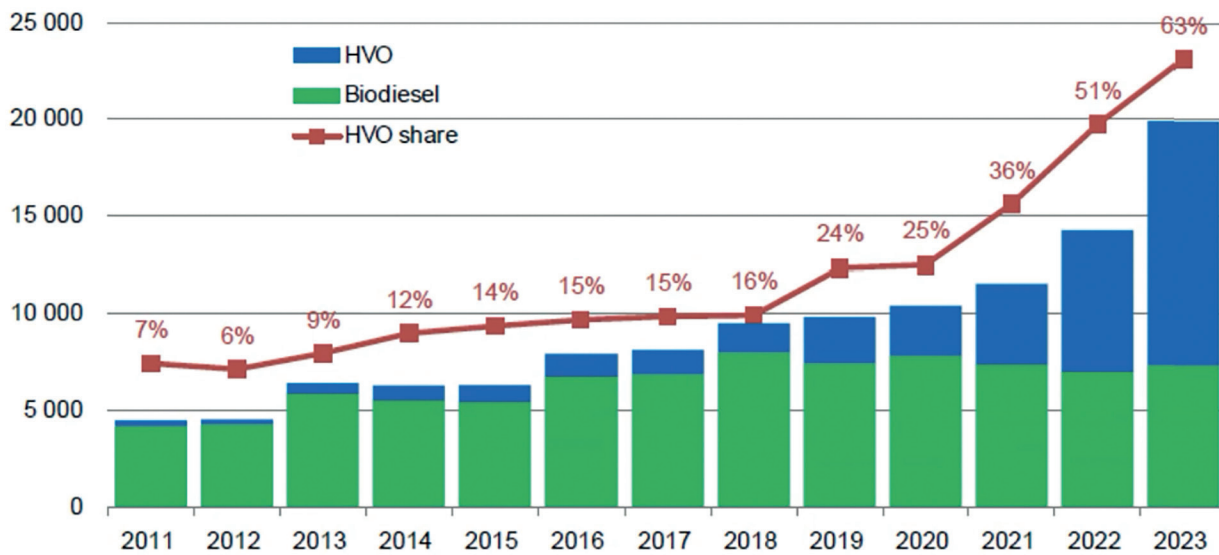


Figure 3: Production of biodiesel and HVO in the US (1,000 tons) [1].

Other alternative fuels may cause a loss of cargo space because they necessitate additional infrastructure for storage or safe operation.

For example, LNG and hydrogen require cryogenic tanks. This can increase shipping costs and increase the number of journeys needed to transport the same cargo, potentially increasing emissions [1].

Liquid natural gas (LNG) is gaining popularity for ferries and cruise ships due to lower emissions compared to petroleum-based fuels [1].

LNG is considered a transition fuel because its fossil-based origin is not sustainable for long-term use [1].

Fuel infrastructure and onboard delivery systems are adaptable to advanced biofuels [1]. The largest container shipping lines are currently transitioning to methanol. But these new methanol-powered vessels can only operate at their full potential if fuel production and bunkering are updated at the same pace [1].

HVO diesel is the most prominent drop-in biofuel today.

Biomethane is also increasingly popular for vessels that operate on fossil liquified gas because liquid biogas has proven to be a drop-in gas [1].

Advanced biofuels, despite their favourable compatibility with existing marine fuel systems, introduce a host of technical challenges.

Challenges of biodiesel in marine applications

Biodiesel can be used in compression ignition engines often used in maritime vessels, but it requires larger storage infrastructure.

Biodiesel has a 10-12% lower energy density than traditional marine diesel. This results in increased fuel consumption and decreased range per fuel load [2].

While biodiesel requires more strict fuel management, it may not always necessitate larger storage.

Oxidative stability, hygroscopicity, cold-flow rheology and material compatibility are important factors limiting the adoption of biodiesel in the marine sector.

Biodiesel blends with greater biofuel content often stray further

Table 1: Characteristics of biodiesel compared to traditional marine diesel [2]

Parameter	Biodiesel (B20)	Biodiesel (B100)	Petroleum Diesel
Energy density (MJ/L)	31.5-32.2	31.5-32.2	35.8
Cetane number	50-60	50-60	40-50
Combustion efficiency	Improved due to higher cetane number	Enhanced due to reduced ignition delay	Standard
Storage stability	Moderate concerns due to oxidation risks	Significant concerns due to high risk of microbial growth	Generally stable
Oxygen concentration	2-3 weight%	10-12 weight%	Not applicable
Particulate matter emission reduction	40% reduction	Not applicable	Baseline
Carbon monoxide emission reduction	50% reduction	Not applicable	Baseline
Fuel consumption increase	3-5% increase	Higher due to lower energy density	Baseline
Viscosity	~1.9-6.0 cSt at 40°C	Higher (may complicate flow management)	Lower

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from the characteristics of petroleum fuel.

A B20 blend can be used in marine engines with minimal modifications. While B100 requires more modifications because of its increased viscosity and reduced volatility [2].

Biodiesel blends with low biodiesel content are a useful tool to achieve decarbonisation and improved air quality if adopted across the marine sector.

The chemical and physical properties of HVO are nearly identical to those of diesel fuel. So it can be safely mixed with diesel [1].

Conventional biodiesel, like FAME, has been the dominant alternative fuel source for the past decade. But HVO production has surpassed that of biodiesel in recent years (Figure 3).

There are several barriers to the introduction of biofuels in the marine industry.

The cost of biofuel production, scaling production, lack of international standards and infrastructure, lack of fuel supply, potential incompatibility of biofuel blends with existing engines and concerns regarding the stability of drop-in biofuels are considered the main barriers to biofuel use [1]. Long term continuous use of biofuels can adversely affect vessel operations [5].

These effects can be mitigated by using biodiesel quickly and frequently draining water from the fuel tank.

Storing biodiesel for brief periods of time helps to prevent fuel degradation and biofouling. And water drainage from fuel tanks can limit microbial growth [5].

Due to the many technical and economic barriers to adopting biofuels in marine shipping, it is imperative to holistically analyse the costs and benefits of a shift towards alternative fuels.

To evaluate the opportunity biodiesel presents to the marine shipping sector, the total cost of its adoption and a comprehensive understanding of the impact of its long-term use must be considered.

The Global Center for Maritime Decarbonisation (GCMD) tested the continuous use of 24% FAME and very low sulphur fuel oil (VLSFO) [5].

Fifty-five days after switching from VLSFO to B24, there were no significant adverse effects on the fuel delivery system [5]. No significant changes in pump pressure, filter changeover frequency, or residue accumulation in the filters observed.

Additionally, fuel consumption remained nearly constant. This was likely because the net calorific value of VLSFO and B24 were comparable at 41.1 MJ/kg and 40.2 MJ/kg, respectively [5].

This suggests that B24 can safely be implemented as a transition fuel as the marine sector becomes less dependent on petroleum fuels. B24, however, will likely not become the sole fuel source used in marine shipping. So, it is necessary to understand other alternatives.

In addition to FAME biodiesel blends, there are other alternative fuels that can be implemented with minimal changes to existing fuel systems.

Bio-oil, bio-DME, and bio-alcohols are relatively homogenous. They therefore require fewer complex upgrades to stabilise them for marine use [1].

One metric to quantify the properties of fuel is the cetane number. This is a measure of combustion quality.

The cetane number of biodiesels often ranges from 50-65. While the cetane number of petroleum diesel is about 40-50 [2].

A higher cetane number indicates improved ignition quality and may reduce roughness and some emissions [2].

Bioalcohols have low cetane numbers, so they are difficult to ignite in compression ignition engines. A low cetane value necessitates modifications to the ignition system to achieve reliable combustion [1].

High pressure injection systems and dual-fuel strategies have been investigated to counteract poor ignition associated with low cetane values [1]. These combustion characteristics can have broader impacts on vessel operations and even on marine ecosystems.

The differing combustion characteristics of biofuels from petroleum diesel offers environmental benefits but can also introduce concerns about storage stability.

The elevated oxygen concentration of biodiesel facilitates cleaner combustion. But it increases the risk of oxidation in fuel systems [2].

Biodiesel's properties offer reduced emissions and enhanced combustion. And its composition offers further environmental advantages.

In addition to its vulnerability to oxidation, biodiesel is susceptible to degrade while being stored.

Storage stability of biodiesel is of particular concern in marine applications. Water contact may result in fuel breakdown and microbial proliferation. And this can compromise engine performance [2].

However, these environmental benefits also come with operational disadvantages. Overall, biodiesel's minimal carbon dioxide emissions and reduced environmental toxicity make it an enticing choice.

The characteristics of biodiesel are compared to petroleum diesel in Table 1.

Production and properties of biodiesel

Biodiesel is sourced from a variety of biological materials.

Each feedstock necessitates unique processing to convert it into biofuel. And each resulting biofuel varies in chemical properties compared to biofuels derived from other sources (Figure 4).

Despite the differing processes by which each feedstock is converted to biofuel, many organic materials undergo the same reaction mechanism.

Biodiesel production typically consists of esterification between alcohol and carboxylic acid to produce an ester and water [6]. This reaction mechanism is depicted in Figure 5.

Biofuels from each unique feedstock have unique chemical compositions that impact their functions.

Biodiesel properties depend on the fatty acid profile of the

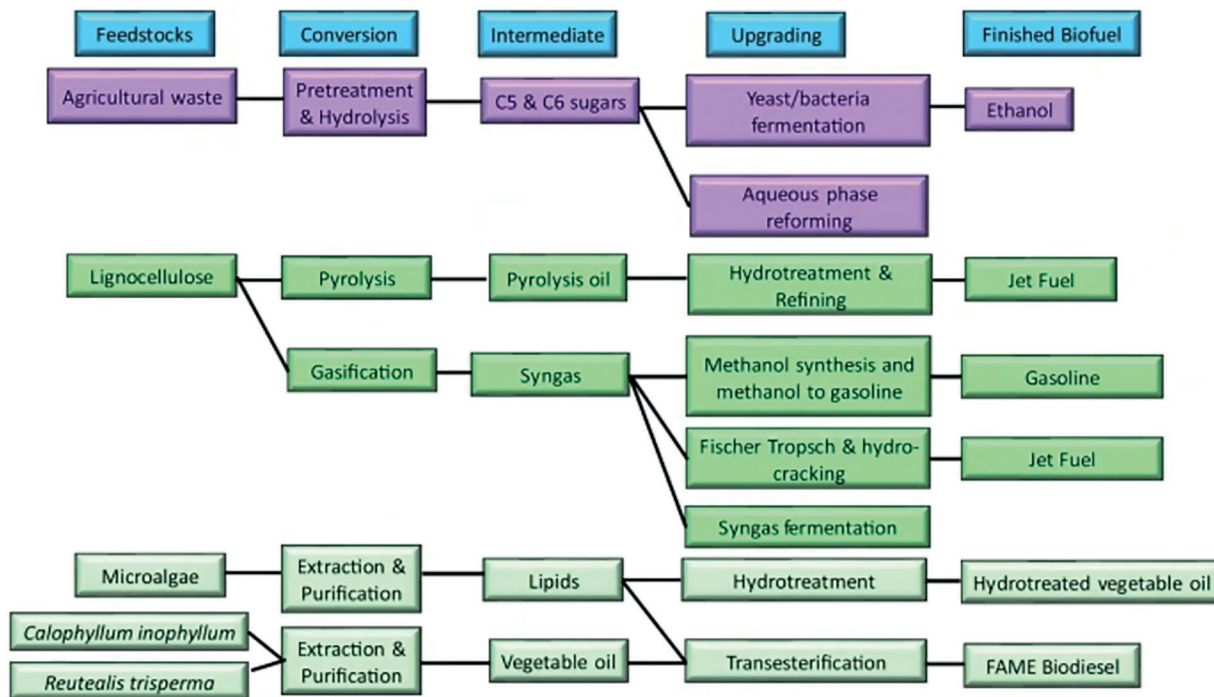


Figure 4: Some biofuel options, their feedstocks, and processing methods [6]

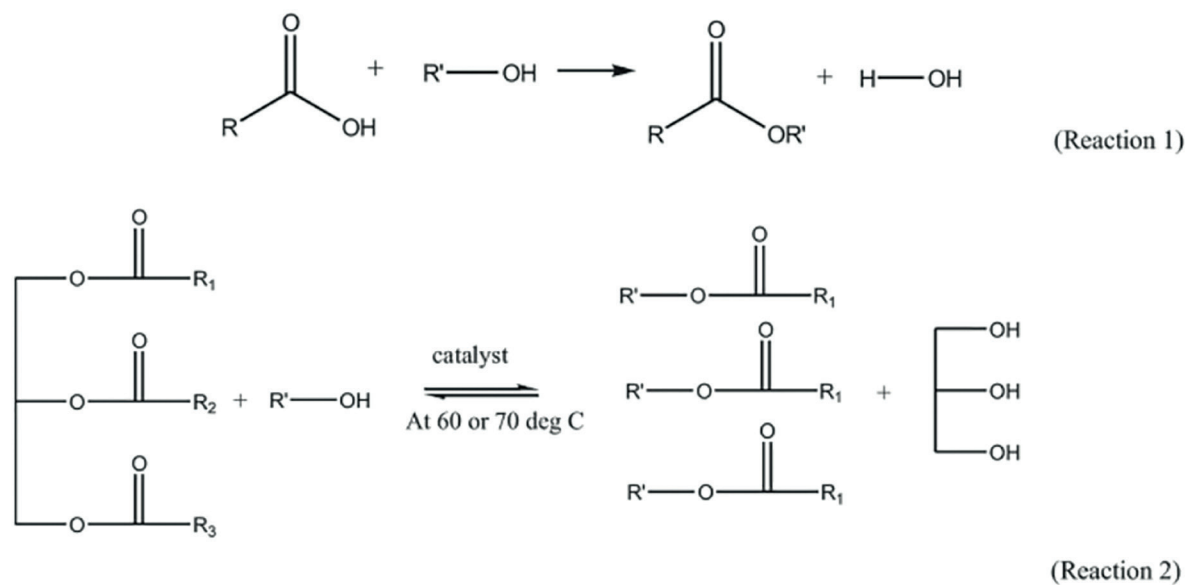


Figure 5: Typical reaction mechanism of biodiesel production [6]

Table 2: Environmental impacts of biodiesel and petroleum diesel [2]

Category	Parameter	Biodiesel (B20)	Biodiesel (B100)	Petroleum diesel
Carbon footprint	Greenhouse gas emissions reductions (well-to-wheel)	15-20%	Up to 80%	Baseline (0%)
	Carbon dioxide emissions reductions	Up to 25%	Up to 74% [12]	Baseline (0%)
	Particulate matter emissions reductions	Up to 60%	Up to 90%	Baseline (0%)
	Nitrous oxide emissions reductions	5-10%	Up to 30%	Baseline (0%)
Lifecycle analysis	Carbon intensity (g CO ₂ /kWh)	Up to 80% lower	Up to 80% lower	Baseline (higher carbon intensity)
	Fuel consumption reduction in fishing fleet	Up to 20%	Not applicable	Baseline (0%)
	Greenhouse gas emissions reduction in research vessels	30% reduction over lifecycle	Not applicable	Baseline (0%)

vegetable oil from which it is derived.

Unsaturated fatty acids are susceptible to oxidation [7]. Oxidation increases the number of heteroatoms in the fatty acid chain, decreasing biodiesel efficiency [6].

Therefore, the stability of biodiesel is impacted by its interactions with atmospheric oxygen, light and temperature, storage conditions, and sediment formation [7].

Blending with petroleum diesel prolongs the stability of biodiesel. But it may also accelerate deposit formation [6].

When oxidised, biofuels may form carboxylic acid, alcohol and aldehydes [6]. These contaminants clog fuel injector pins and fuel filters (Figure 6).

Carboxylic acid sinks to the bottom of the fuel tank and blocks the filter when it enters the fuel pipe, stopping the engine [8].

Removing water from diesel and adding antioxidants are the most prudent solutions to carboxylic acid contamination [8].

Oxidation jeopardises the stability of a biofuel in storage. But the exposure of the fuel to air or light is not the only concern when introducing biofuels to existing marine fuel systems.



Figure 6: Carboxylic acid deposits in a fuel filter [8]

Material incompatibility has been observed between biofuels and existing marine engines and fuel systems.

Methanol is corrosive and has a high heat of vapourisation that requires the implementation of compatible materials and cooling mechanisms to prevent degradation and promote efficient combustion [1].

The corrosive properties of biodiesel are intensified by water. They cause increased deterioration of engine components.

Biodiesels are hygroscopic and typically maintain 1,200-1,500 ppm water [9].

As with mitigating carboxylic acid formation, removing water from the fuel is imperative to prevent unwanted chemical reactions.

Additionally, appropriate materials and coatings must be developed to endure the corrosive impacts of biodiesel.

The chemical properties of biodiesel can compromise engine seals and gaskets. So different materials and design specifications are necessary [2].

Despite the risks of oxidation and corrosion, biofuels can help improve vessel operations due to their low sulphur content.

The sulphur content of conventional marine diesel can adversely affect vessel operation and the local marine ecosystem. Sulphur removal can decrease the lubricity of petroleum diesel, and biodiesel blends are commonly used to restore the lubricity of the fuel [10].

Mixtures of 5 to 10% biodiesel, without conventional lubricity additives, demonstrate lubricity values like that of conventional diesel [10].

Improved lubricity decreases wear on pumps and sliding engine components.

Environmental impacts of biodiesel

Biodiesel-operated marine vessels demonstrate reduced emissions compared to those operated with petroleum fuels.

Biodiesel can liberate oxygen atoms from their chemical composition during combustion. This will increase combustion efficiency [11]. It also reduces particulate matter, carbon monoxide and hydrocarbon emissions [11].

Additionally, biodiesel blends have been shown to significantly reduce soot emissions [11]. However, increased brake-specific fuel consumption was observed while using these blends. This was because of the reduced calorific value of biodiesel compared to petroleum diesel.

Biodiesel can mitigate damage to marine ecosystems caused by marine shipping.

The low sulphur content of biodiesel mitigates acid rain and ocean acidification. This is essential to maintaining the health of ocean ecosystems.

The use of biodiesel instead of traditional marine fuels can reduce sulphur oxide emissions by 90%, preventing damage to marine ecosystems [2].

Biodiesel has faster biodegradability and lower sulphur content than petroleum diesel.

Biodiesel spills decompose four times faster than traditional diesel. It provides an ecological advantage but also raises concern about long-term fuel stability [2].

There are significant emission reductions throughout the lifecycle of biodiesel.

The carbon intensity of biodiesel, including feedstock cultivation, fuel production and consumption, is significantly lower than that of fossil fuels.

Producing biodiesel from algal oil can provide a net carbon reduction of up to 80% [2].

Vessels employing biodiesel blends in the fishing sector have demonstrated up to 20% reduction in fuel consumption and emissions during operation. This leads to decreased operating costs and improved sustainability [2].

The environmental impacts of biodiesel and petroleum diesel are compared in Table 2.

Increased nitrous oxide emissions are of concern when using biofuels.

Blending methanol with water is one possible solution to reduce nitrous oxide emissions [1].

Additionally, exhaust gas recirculation is a common technique to decrease peak combustion temperatures and reduce nitrous oxide emissions by recycling a fraction of the exhaust gas into the combustion chamber [2].

Despite the potential for increase nitrous oxide emissions, the potential environmental impacts of biofuels are overwhelmingly positive compared to petroleum diesel.



Figure 7: The biodiesel cycle [15]

Adapting marine technology and infrastructure

In addition to integrating biodiesel with petroleum diesel, alternative engine systems have been developed to integrate electric power from renewable sources.

Hybrid propulsion systems integrate traditional diesel engines with electric power. This increases fuel efficiency and decreases emissions.

Integrating biofuel generators with wave energy converters can result in a 20% enhancement in energy output [2].

Systems that integrate biodiesel with energy storage technology can enhance operational efficiency by using biodiesel for peak power requirements and relying on stored energy during periods of low demand. Storage and refueling infrastructure needs adapting in addition to engine technology to accommodate biofuels.

Technological advancements to marine engines can alleviate the performance discrepancies between petroleum diesel and biodiesel.

Alcohol-based fuels often require dual-fuel engine systems or additives to enhance their ignition characteristics [1]. Nano-enhanced additives integrate metallic nanoparticles or graphene oxide to augment fuel fluidity and thermal stability, which improves cold-flow performance [2].

Dual-fuel engines efficiently transition between biodiesel and conventional diesel. Dual-fuel engines operating with biodiesel mixes can improve engine performance and prolong the lifespan of marine engines by minimising damage caused by high sulphur concentrations in conventional fuels [2].

Biofuels with simple molecules, like methanol (biomethanol), and methane (liquefied biogas), behave similarly to their fossil counterparts. They therefore operate effectively with their respective dual-fuel engines [1].

However, biodiesel (FAME) and renewable diesel (HVO) are more complex. These complex fuel alternatives propose challenges with cold flow properties, long-term storage, material compatibility and high acidity [1].

Additionally, dual-fuel engines can require additional fuel storage and potentially decrease cargo space [1]. These complex biofuels create further technical challenges.

Biodiesel is less stable and less reliable in cold temperatures than conventional marine fuels.

Biodiesel can deteriorate in six to 12 months. This results in increased acidity and the accumulation of deposits that interfere with fuel filters and injectors [2].

Adapted storage solutions for biodiesel include temperature-regulated tanks and the addition of antioxidants to the fuel.

Biodiesel can have inconsistent combustion properties in harsh maritime environments with significant temperature fluctuations due to its elevated viscosity can result in gelling and obstruction of fuel systems.

As a result, biodiesel blends can reduce power production by 5-10% in extreme conditions [2].

Cold flow improvisers and insulated fuel systems can alleviate the challenges of biodiesel's cold flow characteristics. But these adaptations are costly [2].

Biodiesel fuel gelling and wax crystallisation can occur at low temperatures due to the elevated saturated fatty acid composition of biodiesel relative to diesel fuels.

The use of thermal management systems, like fuel preheaters and insulated fuel conduits, facilitate optimal fuel flow [2].

Gasoline tanks with insulated linings facilitate in maintaining ideal temperatures to prevent gelling. Additionally, piping systems with 15% larger diameters can accommodate the higher viscosity of biodiesel and reduce clogging [2].

The higher viscosity of biodiesel compared to petroleum diesel also necessitates an increase in injection pressure to improve combustion [10].

Sophisticated fuel injection systems are already used in marine engines to assist accurate fuel flow regulation [2].

In addition to design changes, the differing properties of biodiesel from petroleum diesel require changes in maintenance and engine calibration.

Maintenance procedures must also be modified when using biodiesel. Intervals between inspection and maintenance may need to decrease by 10-15% to address the wear patterns of biodiesel. This could cause a 15% increase in maintenance expenses to enhance engine longevity [2].

The removal of water from biofuel and biodiesel blends, as mentioned previously, is an important part of maintenance when using alternative fuels.

Engines must be recalibrated to accommodate the reduced energy density of biodiesel for the system to achieve its desired performance [2].

Table 3: Challenges of adopting biodiesel and proposed solutions [2]

Challenge	Analysis	Proposed solutions	Impact of solutions
Cold flow issues	Fuel gelling and clogging at low temperatures.	Blend biodiesel with low-pour-point fuels and use cold flow additives.	Enhanced reliability of biodiesel in colder climates. Reduced engine blockages.
Storage stability	Oxidative degradation and microbial growth reduce fuel quality.	Implement storage systems with moisture control and antioxidants.	Improved fuel shelf life and reduced maintenance costs.
Infrastructure costs	High capital investments are required for vessel retrofits and refuelling stations.	Encourage public-private partnerships and government subsidies.	Increased adoption of biodiesel and reduced financial burden on stakeholders.
Renewable energy integration	Technical challenges in optimising hybrid systems with biodiesel.	Enhance compatibility between biodiesel generators and renewables.	Enhanced energy efficiency and reduced reliance on fossil fuels.
Compatibility with marine engines	Biodiesel blends may increase wear and tear on traditional marine engines.	Invest in materials research to improve biodiesel compatibility with existing engines.	Extended engine lifespan and improved performance with biodiesel blends.

The principal challenges of adopting biodiesel in the marine sector are summarised in Table 3 along with their proposed solutions and impacts.

Despite the challenges and additional costs introduced by biodiesel, biofuels continue to gain popularity globally.

Meeting the global demand for biofuels

To achieve decarbonisation, the marine sector is expected to rely on alternatives to petroleum fuel.

The marine sector is especially challenging to electrify. So biofuels are prudent [7].

Currently, there are no alternative fuels produced in sufficient quantities to meet the total demand of the marine shipping industry [1]. Production of alternative biofuels is often costly and/or inefficient, which ultimately increases the production cost [1].

There are an array of economic hurdles preventing the widespread adoption of biofuels in the marine sector.

A robust, widespread supply chain for marine biofuels isn't fully established; unlike conventional fuels [1].

Biofuels are often more expensive to produce and scale up than fossil fuels [1]. Some biofuels can blend with diesel, and high concentrations or pure use might require costly engine modifications or new technologies [2].

Inconsistent fuel specifications and management practices create risks. They require case-by-case evaluation [1].

Current solutions to these barriers include chemical additives to fuels, new engine designs and biodiesel fuel blends. These challenges demand costly investments, research and global collaboration across the marine sector.

Refuelling infrastructure must also adapt to support the shift away from fossil fuels. Many European ports have established biodiesel refuelling stations [2].

Integrating biodiesel into current fuel systems can be accomplished with minimal retrofitting expenses, estimated at 2-5% of total shipbuilding costs [2].

Despite the progress made towards phasing out petroleum diesel, biodiesel still presents many engineering challenges.

Marine industries around the world are innovating solutions to the costs incurred by switching to biodiesel.

Incorporating biodiesel into shipping supply chains can increase operational costs by 10-15%. This is mainly due to the necessary infrastructure enhancements and storage systems, so shipping companies are establishing multi-fuel bunkering stations that allow vessels to refuel with both biodiesel and conventional fuels [2].

Biofuel use in the marine industry is currently concentrated in Europe and East Asia. There are more than 60 global ports equipped for biodiesel bunkering [3].

From 2021 to 2024, total sales of biodiesel blends in Singapore and Rotterdam increased by about 1,300,000 tons [2]. The most sold biodiesel blends in these cities were B24 and B30, respectively. These biofuel blends primarily use FAME and VLSFO [3].

The expansion of biodiesel in the marine sector is also limited by feedstock constraints.

Insufficient feedstock is one limitation to scaling up biofuel production.

One major concern of increasing biofuel production is that the energy sector competes with the food industry for biomass feedstock [1].

First-generation biofuels are produced from biomass that is also used for food. For example, FAME is derived from feedstocks including rapeseed oil, soybean oil, tallow and used cooking oil [13].

The lifecycle of a first-generation biodiesel is represented in Figure 7. First generation biofuels are likely to increase greenhouse gas emissions compared to the fossil fuels they are intended to replace because the crops used for biofuels will drive indirect land-use change [14].

Second generation biofuels are produced from non-food biomass. While third-generation biofuels are primarily derived from algae and cyanobacteria.

Algae-derived biodiesel mitigates the feedstock constraints of traditional biodiesel production.

The cultivation of algae can produce more than 20,000 L of biodiesel per hectare annually. While soybean and palm oil only produce 400 L per hectare and 6,000 L per hectare, respectively [2].

The future of biodiesel is predicted to rely on marine algae as a fuel source.

Lastly, fourth-generation biofuels employ genetically engineered organisms for enhanced sugar utilisation and lipid synthesis to increase the efficiency of biofuel production.

Biofuels are predicted to fill the gap during a transition away from

fossil fuels, rather than being a long-term replacement.

As biofuels have increased in popularity, first and second-generation biofuels have failed to meet the growing demand [14].

Algal feedstocks offer great promise. And fourth-generation biofuels derived from genetically modified algae should be the primary focus for exploring sustainable feedstocks.

Conclusion

Despite the several engineering challenges introduced to the marine sector by biodiesel, it is a promising alternative to petroleum diesel.

Biodiesel provides immediate scalability. It is therefore compatible with current marine infrastructure. So, it is the most prudent solution for short-term decarbonisation initiatives.

The marine sector produces approximately 3% of carbon dioxide emissions per year. So it is crucial to reduce the greenhouse gas emissions of marine operations.

Long term, significant adjustments need to be made to marine engines and refuelling infrastructure to transition away from fossil fuels and towards biodiesel.

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Biographies

Dr Raj Shah is director at Koehler Instrument Company in New York, where he has worked for over 25 years. He is an elected Fellow or Chartered professional with numerous organisations, including ASTM, IChemE, STLE, NLGI, the Energy Institute, the Royal Society of Chemistry, and the Chartered Management Institute, among others, and is an ASTM Eagle Award recipient. He coedited the bestseller *Fuels and Lubricants Handbook* and holds a PhD in Chemical Engineering from Penn State. Dr Shah is an adjunct professor in materials science and chemical engineering at Stony Brook University, serves on multiple academic advisory boards, and has authored over 725 publications during more than three decades in the energy industry.

Mr Val Corrente is a graduate from Worcester Polytechnic Institute with a master of science in chemical engineering and a concentration in bioengineering. Val's academic and research experience includes biochemical engineering, environmental remediation and process scale-up, with a strong foundation in analytical and biological laboratory techniques. Val has conducted research in plant and fungal systems for remediation of heavy metals, employing transport modelling to evaluate contaminant uptake and design scalable remediation strategies. In addition to academic



Val Corrente

research, Val has experience in industrial laboratory quality assurance and undergraduate instruction. Val's interests focus on applying chemical engineering principles to biotechnology, environmental sustainability and engineered biological systems

Mr Mathew Stephen Roshan is a chemical and molecular engineering undergraduate student at Stony Brook University where Dr's Shah and Mittal are on the external advisory board of directors and where he is a research assistant at the Advanced Energy Research and Technology Center performing research on carbon capture and hydrogen storage. He also works as an intern under Dr Raj Shah studying tribology, alternative energy and fuels at Koehler Instrument Company and is a member of the SBU chapter of the American Institute of Chemical Engineers (AIChE).



Mathew Roshan

Mr Gavin Thomas is part of a thriving internship program at Koehler Instrument Company in Holtsville, NY and is a recent graduate of the Chemical and Molecular Engineering program at Stony Brook University. He also works as a process engineer at Mill-Max in Oyster Bay, NY where he becomes hands-on with various production processes to ultimately improve safety, efficiency and cost-effectiveness.



Gavin Thomas

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Author Contact Details

Dr. Raj Shah, Koehler Instrument Company

- Holtsville, NY 11742 USA
- Email: rshah@koehlerinstrument.com
- Web: www.koehlerinstrument.com

