
# TECHNICAL INFORMATION

# INTRODUCTION OF MARINE BIOFUELS



Welcome to Innospec's two-part series of technical bulletins looking at Biofuels. Over the next two months you will gain insights collected from a broad range of industry bodies and experts, including Innospec. We will explore the reason for widespread demand and usage, the pros and cons of biofuels in terms of regulatory compliance, operational realities and challenges surrounding their long-term usage.

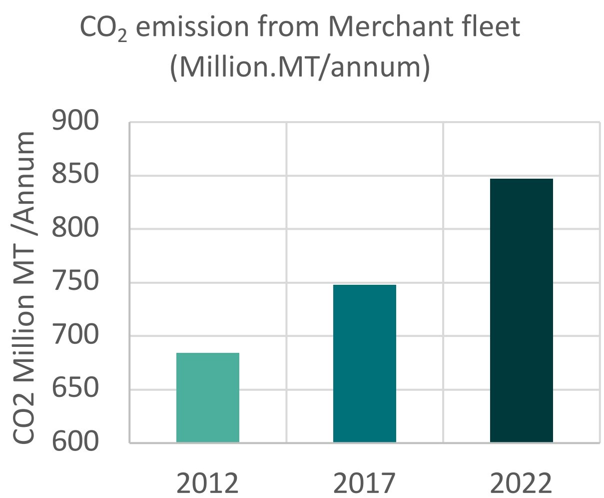
Innospec's direct-to-fuel products date back to 2005 with the first Biostable additive package. For almost two decades Innospec have worked together with refineries, biofuel manufacturers and end users to resolve issues related to the application of biofuels

Although this is a well-established technology in automotive sector, it remains a new and developing sector for maritime, which is full of opportunities and challenges. We encourage you to visit our website and reach out to our fuel experts to learn more.

**WHY BIOFUELS?**

Despite unprecedented effort in recent years, global shipping $CO_2$ emissions grew by 3%, close to pre-pandemic levels. New regulations such as CII, EU-ETS, driven by the IMO objective to reduce greenhouse gas Emissions, lends itself in the short term to exploring alternative fuels.

The push to find clean energy to fuel the Merchant fleet is on. Biofuels are but one of many solutions, but there are several reasons why Biofuel is considered one of the front runners in this race, as you will find out.




**THE LONG STORY OF BIOFUEL, IN SHORT:**

Biofuels have been around since the earliest mass production cars. The first diesel engine ever invented by Rudolf Diesel in the 1890s could run on a variety of fuels, including vegetable oil. However, the availability of cheap Petroleum derived fuels in huge volumes created limited interest in alternatives.

*During World War II, when petroleum fuel supplies were interrupted, vegetable oil was used as fuel by several countries. After the war ended and petroleum supplies were again cheap, vegetable oil fuel was once again forgotten.*

*In 2004, biofuels returned as countries looked to reduce their dependency on imported fossil fuels and reduce air pollution. In 2008 "food vs. fuel" debate suspended support for biofuel use until climate change increased demand for low $CO_2$. and Biofuels became an option again…*

## Biofuel Composition : What's Inside?

Biofuels have significantly lower sulphur, hydrocarbon, particulate and $CO_2$ (well-2-wake) emissions than petroleum equivalents. As such they are a viable alternative to MGO, VLSFO or ULSFO. However, not all biofuels are created equal. The quality and origin of the feedstocks used in the final fuel blend impact their characteristics, quality and emissions.

Historically Biofuels have been defined by two categories:

1$^{st}$ Generation: Fuels directly related to biomass sources considered edible e.g. Crops
2$^{nd}$ Generation: Fuels produced from cellulosic waste e.g. Forestry residues & organic waste.

Summarised below are three of the most common sources of biofuel used worldwide, including their pros & cons:

| 1$^{st}$ Generation | | 2$^{nd}$ Generation |
|---|---|---|
| Straight Vegetable Oil<br>SVO | Fatty Acid Methyl Ester<br>FAME (B100) | Hydrotreated Vegetable Oil<br>HVO (R100) |
| $CO_2$ Neutral<br>Good Lubricity Properties<br>Low PM Emissions<br>Low $SO_x$ Emissions | Widely Available<br>Drop-in<br>Good Lubricity Properties<br>Lower Cost<br>Good Miscibility with Residuals | Performs Similarly to MGO<br>Drop-in<br>Good Oxidation Stability<br>Low Susceptibility to Microbe Contamination |
| Poor Oxidation Stability<br>High Viscosity / Pour-point<br>Feedstock Variety<br>Increased Engine fouling<br>Negative Impact on Lube Oil<br>Engines Require Modification | Poor Oxidation Stability<br>Poor Cold Flow Properties<br>High Risk of Microbial Contamination<br>Potential Increased NOx Emissions | Cost & Availability<br>Poor Lubricity Properties<br>Poor Cold Flow Properties<br>Potential for Poor Miscibility |

## Biofuel cost vs benefit: Is it Worth it ?

- Biodiesel pricing is very volatile and can also vary dramatically by location. It can cost up to 3 times the fossil fuel equivalent.
- In Q1 2024 the indicative biofuel price in Europe was $1270. In Q1 2023 the price was $1820 (Ref: chemanalyst.com)
- Drop-in fuel - No CAPEX needed

## Why Does the Quality of FAME Vary?

The physical & chemical characteristics of FAME are highly dependent on the feedstock of oil used during production. The co-mingling of multiple feedstocks is often common practice; however, the resulting properties of this process is unpredictable.

This unpredictable nature can also be noticed in one feedstock alone as the crops required to manufacture FAME are often grown seasonally, therefore producers will purchase different batches throughout the year based on price & availability, co-mingling them in storage tanks.

As shown below in *Figure 3* many varieties of oil feedstock exist for FAME production, of which the chemical composition for each differs greatly. These properties in turn determine the physical characteristics of the finished Biofuel e.g. Cold Flow Handling, Oxidation Stability, Lubricity.

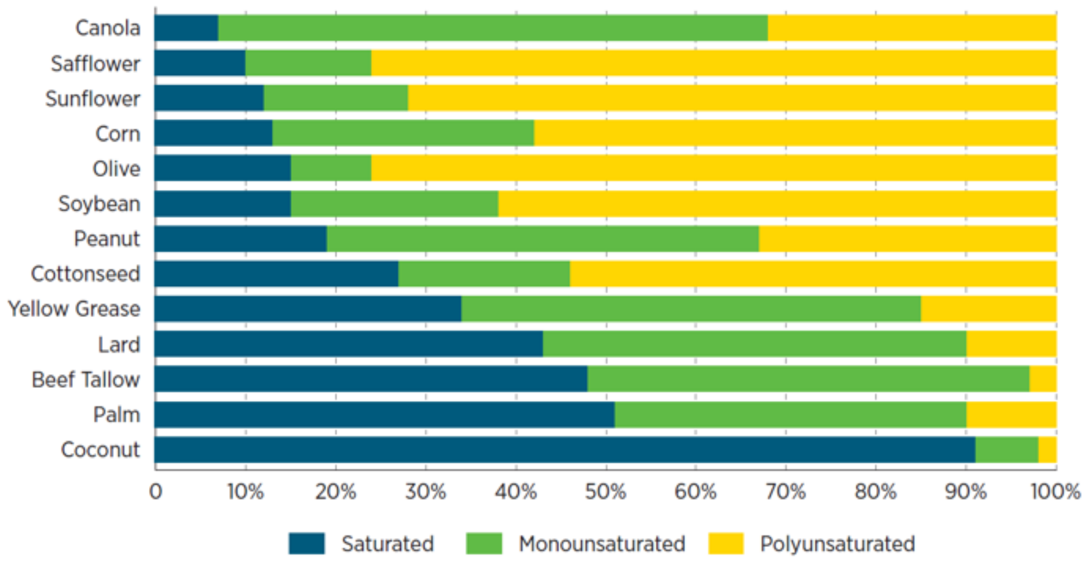
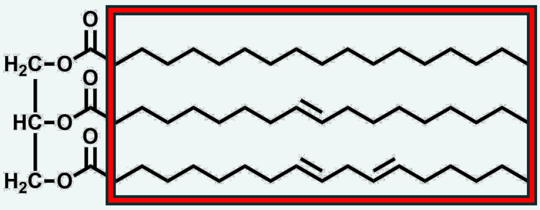



**Figure 3 - SOURCE:** Biodiesel Handling and Use Guide *(Fifth Edition)* • November 2016

## The Chemistry Behind Biofuels

As **FAME** does not naturally occur in the quantities able to meet the transport industry's demand, it is instead manufactured via the transesterification of vegetable oils and animal fats.

During transesterification, triglyceride molecules react with an alcohol in the presence of a catalyst, producing fatty esters and glycerol. The properties of the finished FAME are dependent on the long chain fatty acid portion of the FAME molecule as shown below:



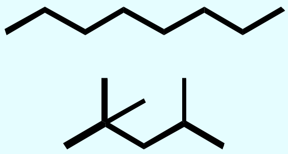

Stearic Ester

Oleic Ester

Linoleic Ester

Similarly, **Hydrotreated Vegetable Oil** can be produced from various waste streams that contain triglycerides & fatty acids; however, the extra step of hydrocracking is performed. This process strips oxygen, sulfur and aromatic hydrocarbons from the fuel, producing a paraffinic liquid that shares similar chemical properties to traditional fossil diesel.

During this process, a mixture of paraffins are yielded; n-Paraffins & iso-Paraffins. The proportion between these two types of molecule are the driving force that determine the physical properties of the finished fuel e.g. Cold Flow Properties



n-Paraffin

iso-Paraffin

| Property | Saturated Fatty Acids | Unsaturated Fatty Acids | Non-Isomerised HVO | Isomerised HVO |
|---|---|---|---|---|
| **Chain Type** | Linear Chain | Branched Chain | Linear Chain | Branched Chain |
| **Physical Appearance** | Solid at Ambient | Liquid at Ambient | Liquid at Ambient | Liquid at Ambient |
| **Pour Point** | Higher than Unsaturated | Lower than Saturated | Higher than Isomerised | Lower than Non-Isomerised |
| **Oxidation Stability** | Poor, More stable than Unsaturated | Poor, Less Stable than Saturated | Stable | Stable |
| **Typical Cetane Values** | 50-60 | 50-60 | >70 | >70 |
| **Lubricity** | Good | Good | Poor | Poor |

# What are the Engine Performance Issues with Biofuel Usage?

Renewable components are a recent addition to the marine fuel pool (Per ISO8217:2017, distillate marine grade fuels can already contain 7% FAME i.e. DFA), however they have been in widespread use across other industries for many years.

## ENGINE PERFORMANCE

The addition of certain biofuel components will have an impact on engine performance over time. Renewable stocks and certain FAME fuels have an increased deposit forming tendency which means that injectors and fuel pumps become restricted or blocked over time.

## POWER LOSS

As seen in Figure 1, an engines power can decrease over time whilst running blends containing biofuel, especially in fuels containing higher concentrations.

At time T we were able to apply Innospec's technology to recover engine performance to the original condition.

Power losses will result in higher fuel consumption and a less efficient combustion, ultimately increasing emissions.

## EMISSIONS

Renewable fuels provide a much better combustion efficiency in comparison to existing marine grade fuels, however they do tend to burn hotter and contain less energy, therefore they are known to increase unwanted Nitrous Oxides ($NO_X$) emissions.

## $NO_X$

The International Maritime Organisation (IMO) recently introduced the UI (Unified interpretation), which allows up to 30% FAME within marine grade fuel whilst remaining compliant with MARPOL ANNEX 6. It is widely understood that the addition of most biofuel components increases $NO_X$ Emissions, hence why they are controlled.

## Hydrocarbon (HC)

Due to the improved combustion efficiency given by the inclusion of FAME, the presence of Hydrocarbons in the exhaust reduces significantly.

## Particulate Matter (PM)

Another byproduct of better combustion is a significant reduction in Soot, black smoke and particulate matter in these fuels.

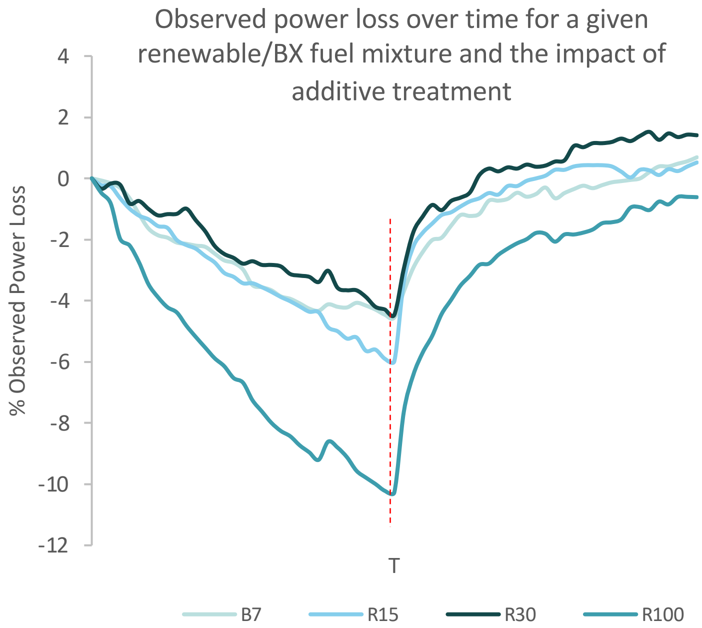



*Figure 1. Innospec engine testing*

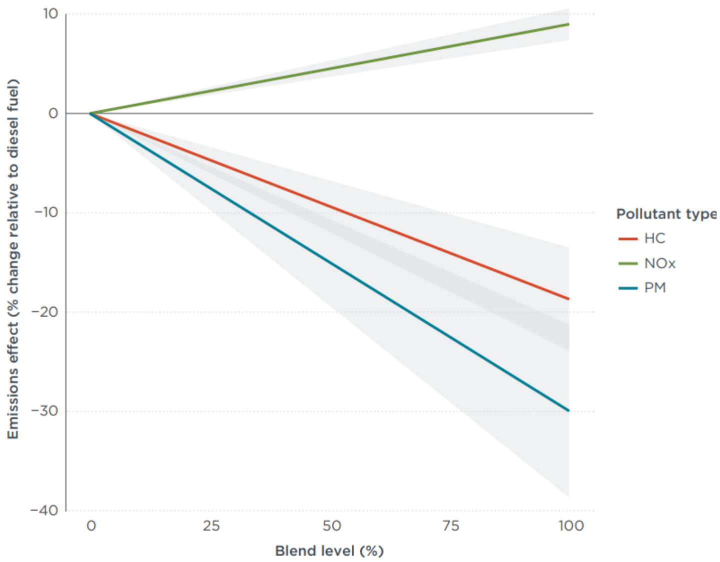
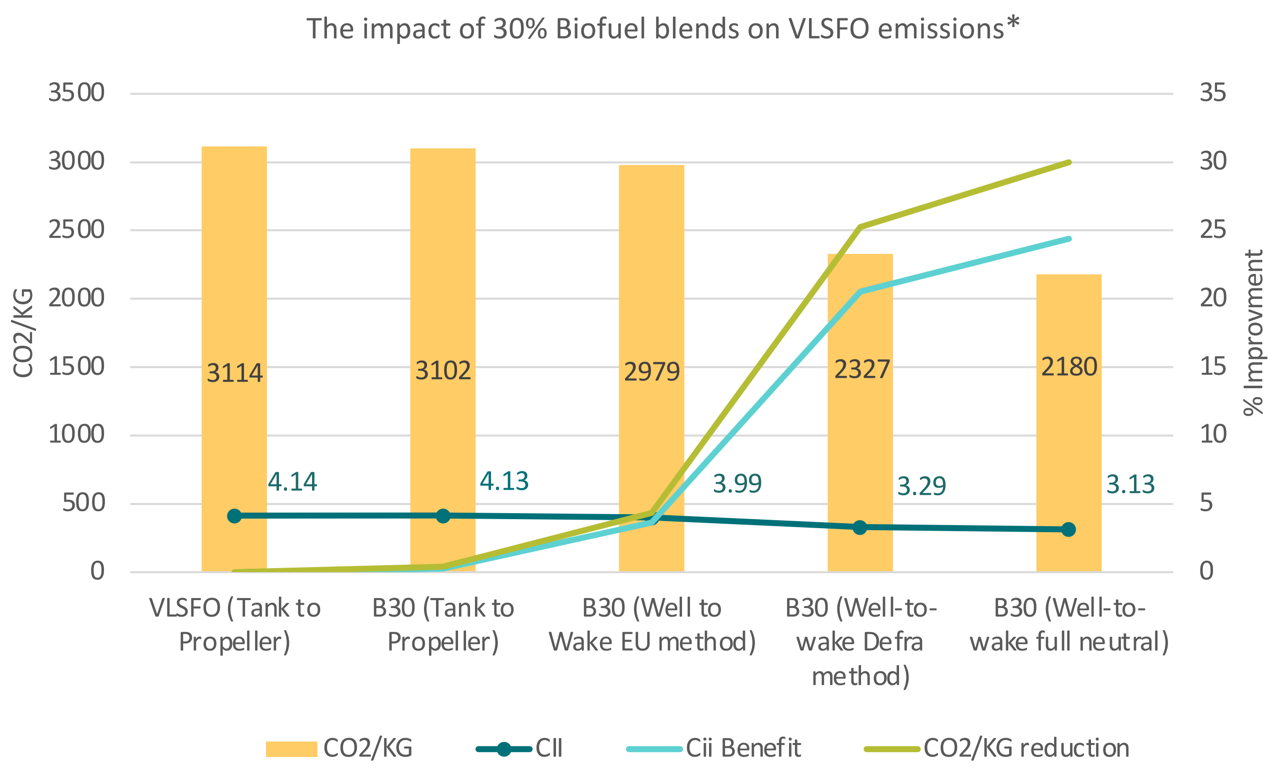



*Figure 2. ICCT, The effect of FAME by % on the emissions from diesel, HC (Hydrocarbons), NOx (Oxides of Nitrogen), PM (Particulate Matter).*

## Understanding the effect on Carbon Dioxide Emissions when using Biofuel

The assessment of the benefits of Biofuels is complex and confusing. In theory a 30% reduction in total emissions is achievable when using a 30% of fully Carbon neutral Biofuel in the fuel mixture. However, Carbon Dioxide is emitted when manufacturing Biofuels. For example, emissions from farm vehicles when growing the crops, or in the transportation of the Biofuel to its point of use. It is always worth keeping this point in mind when considering the environmental benefits of the fuels and assessing emission data, which is shown below.

The below graph shows the benefits on Carbon emissions and CII rating depending on the Carbon Dioxide emissions of the Biofuel used to determine the benefit. To the left of the graph is VLSFO for reference, and to the right is a B30 when the 30% Biofuel is considered Carbon Neutral.




If we consider B30 as a fully Carbon neutral fuel can provide considerable well-to-wake benefits, potentially reducing total $CO_2$/Kg emissions from 3114 kg/MT of fuel, to 2180 kg/MT of fuel. In the example above the CII rating is improved by 25%!!

## What blends are likely to appear in the Market?

Hundreds sea trials have been conducted worldwide on bio and alternative fuels. Combined with our knowledge of these fuels from other markets, this has given us a wealth of knowledge on what to expect in both the short & long-term.

### Residual Bx Blends (FAME)

Globally residual Bx fuels are being trialed using a FAME percentage between 10-50%, however the blends with the better price to emissions gain fall between 25-30% (Often referred to as B25 & B30).

Biofuels up to B30 meet the requirements of Reg. 18.3.2 of MARPOL Annex VI., not causing an engine to exceed the applicable NOx emission limit. If higher concentrations are used then NOx emissions could increase due to higher cylinder temperatures. Meaning the fuel would breach these MARPOL regulations.

FAME proves easy to blend with conventional residual & distillate fuels with a vessels main engine requiring no retrofitting for consumption. This makes FAME a suitable 'drop-in' solution in the short term.

### Distillate Rx Blends (HVO / Renewable Diesel)

HVO shares similar characteristics with MGO, and compared to FAME, not only provides better energy content but is more resistant to oxidation having been hydrotreated during production.

HVO can be potentially blended into either distillate or residual streams, but the cost of the material is higher than that of FAME, and availability tends to be lower. Therefore HVO is more likely to be blended with higher quality conventional fuel e.g. Distillates.

Below is some information produced by Neste – a leading producer of HVO. This compares the heating value of regular Diesel fuel to HVO (Neste Renewable Diesel) and FAME.

| | | Diesel fuel (typical summer grade without biocomponent) | Neste Renewable Diesel | FAME |
|---|---|---|---|---|
| Density | $kg/m^3$ | 835 | ~780 | ~880 |
| Heating value | MJ/kg | 43.1 | 44.1 | 37.2 |
| Heating value | MJ/l | 36.0 | 34.4 | 32.7 |
| • difference to diesel fuel | | | -5 % | -9 % |
| Heating value, 10 vol-% blend | MJ/l | | 35.8 | 35.7 |
| Heating value, 30 vol-% blend | MJ/l | | 35.5 | 35.0 |

**SOURCE:** https://www.neste.com/sites/default/files/attachments/neste_renewable_diesel_handbook.pdf

## Can these blends be harmful to my Vessel?

### Maintenance & Storage

Filter blocking, corrosion, bacteria formation, cold weather blockages, deposit & sludge formation are some of the issues that increase within the fuel system as the biofuel content increases. Effectively reducing the safe storage time and increasing maintenance costs.

### Unstable Biofuels mainly arise due to the following effects

- Incompatible Materials Blended
- Prolonged & Improper Storage Conditions
- Oxidation via Thermal Aging
- Contamination – Bacterial, Water, Chemical

Fuel Injectors with heavy deposits

'White grease' suffocating fuel filters

Sludge created by bio-fuel build-up being scraped from the bottom of a tank.

Bacterial contamination on fuel pumps

Please contact your local sales representative for more information.
email: CSC.americas@innospecinc.com CSC-emea@innospecinc.com CSC.asiapacific@innospecinc.com
For technical support or questions please email: marine.technical@innospecinc.com

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