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Panteia

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Summary

The blending of biodiesel in inland navigation has both technical and economic implications. Technically, FAME (Fatty Acid Methyl Esters) in particular can lead to filter blockages, water absorption and bacterial growth, which can result in engine problems. This has hurt the reputation of biodiesel in the industry, especially with incidents in the winter of 2019-2020 where experiences with FAME led to a negative perception of biodiesel. However, with proper maintenance (i.e., good-housekeeping), periodic tank cleaning and the use of appropriate coatings and fuel filters, these problems are largely manageable. HVO (Hydrotreated Vegetable Oil) offers a more technically reliable alternative and can be used without engine modifications, but is more expensive than FAME and fossil diesel.

Economically, the higher price of biodiesel, especially HVO, is a major stumbling block. HVO100 is currently €160-180 more expensive per 1,000 litres than fossil diesel, and without subsidies or compensation, many companies see no financial incentive to switch. In addition, there is uncertainty about the availability of biodiesel, with some bunker companies stating they cannot supply sufficient supplies in the event of a large-scale switch. This leads to reluctance within the industry.

Do companies have a legitimate excuse not to switch? Partly. The combination of higher costs, technical risks and negative past experiences makes many inland navigation operators procrastinate. However, practical examples show that the technical problems are largely solvable and that successful deployment is possible with the right preparation. A pilot with the vessel MTS Vlissingen has shown that sailing on 100% FAME is possible with minimal modifications, while an ongoing study by TNO is testing eight vessels with blends up to 30% FAME. The results of this test are expected by the end of 2025. It will play an important role in determining the feasibility and reliability of biodiesel in inland navigation. Until then, the discussion remains open and it is too early to make a final judgement.

Rationale for assignment

This document has been written by **Panteia** on behalf of the **REDII Ports** project which is funded by the **Interreg North Sea Programme**. This programme was set up to accelerate the implementation of renewable energy sources in ports and shipping. The project focuses on overcoming technical, economic and regulatory barriers to integrating biofuels, green hydrogen and other renewable energy carriers in maritime transport. Within this framework, the **Port of Zwolle** is exploring the feasibility of biodiesel blending for inland shipping. Port of Zwolle has initially approached clients in the port to stimulate the use of HVO or FAME. As companies are reluctant to try this, Port of Zwolle has asked us to write a report which could help to stimulate the use of alternative fuels.

With this project, we seek to make a practical overview of the effects of biodiesel blending on vessels that traditionally run on fossil diesel. There are several concerns within the sector regarding potential technical issues, fuel availability and cost implications. Previous experiences, particularly with FAME (Fatty Acid Methyl Ester), have raised questions about fuel stability, filter clogging and microbial growth. This led to a cautious approach from many operators. However, emerging studies and real-life pilots suggest that with proper fuel management and (minor) technological adjustments, these challenges can be mitigated. Additionally, HVO (Hydrotreated Vegetable Oil) presents a more stable alternative but comes at a higher price.

We try to clarify whether companies have valid reasons to hesitate in adopting biodiesel or if concerns stem from a lack of knowledge and experience.

Our main research questions include:

- What are the technical implications of biodiesel blending for vessels currently running on fossil diesel?
- To what extent do fuel stability and maintenance requirements influence the perception of biodiesel?
- What is the economic feasibility of biodiesel adoption in inland shipping, considering cost differences and potential financial incentives?
- How have companies that successfully implemented biodiesel addressed technical and operational challenges?

1 Policy context

Currently, the Dutch inland navigation sector emits 1.6m tonnes of CO_2 annually. This is the equivalent of 550,000 passenger cars. To put this figure into perspective, we can plot this amount of emissions against total freight transport (incl. road and rail), giving the inland navigation sector a 13% share of CO_2 emissions. The share of the inland navigation sector in the entire CO_2 emissions of the transport sector (including air freight) in the Netherlands is less than 5%. In contrast, the inland navigation transports around 31% of all goods in the Netherlands[1].

Nonetheless, the 2021 European Climate Act (2021/1119)[2] sets the goal of becoming climate neutral by 2050. This target requires a 55% reduction in greenhouse gas emissions by 2030 compared to 1990, the so-called 'Fit for 55'. To make these targets feasible, a higher share of renewable energy sources is needed in several sectors, including the inland navigation sector. One of the government instruments to meet the targets in the European Climate Act is the so-called 'Renewable Energy Directive III' (REDIII). REDIII's predecessor is 2018's REDII[3]. REDII prescribed a target of at least 32% renewable energy by 2030. After examination by the European Commission, this target proved insufficient to meet long-term climate goals. As a result, the European Commission, using its legislative power, presented a new proposal for REDIII[4]. Subsequently, REDIII was presented in the EU Official Journal on 31 October 2023[5] (see table 1).

1 https://persportaal.anp.nl/artikel/8291729d-1ba5-4ed8-a62b-9777b8079ee7/steeds-meer-monitoring-emissies-binnenvaart

2 https://eur-lex.europa.eu/legal-content/NL/TXT/?uri=CELEX:32021R1119

3 https://eur-lex.europa.eu/legal-content/NL/TXT/?uri=CELEX:32018L2001

4 https://eur-lex.europa.eu/legal-content/NL/TXT/?uri=CELEX:52021PC0557

5 https://eur-lex.europa.eu/legal-content/NL/TXT/?uri=OJ:L_202302413

Table 1 Time-line relevant events by year

Year	Event
1990	Baseline year for the EU's climate targets.
2018	Introduction of Renewable Energy Directive II (REDII), setting a 32% renewable energy target by 2030.
2019-2020	Unannounced introduction of biofuels in inland navigation caused operational issues (e.g., blocked filters, engine shutdowns).
2021	European Climate Act (2021/1119) is introduced, setting the goal of climate neutrality by 2050.
2023 (October 31)	Renewable Energy Directive III (REDIII) is published in the EU Official Journal.
2024 (February)	Dutch Ministry of Infrastructure and Water Management (IenW) informs stakeholders about a delay in REDIII implementation.
2025 (January 1)	Original deadline for the Netherlands to announce the REDIII implementation schedule.
2026 (January/February)	New deadline for REDIII implementation.
2050	EU Climate Neutrality Target (Net Zero emissions).

Bron: Panteia

EU member states are obliged by the EU to implement REDIII. Under the new rules, EU member states can choose between 1) a binding 2030 target of 14.5% GHG intensity reduction in transport by using renewable energy; 2) a binding 2030 target of at least 29% renewable energy within end-use energy consumption in the transport sector. In February 2024, the Ministry of Infrastructure and Water Management (IenW) informed stakeholders of the amended schedule for REDIII implementation. The implementation schedule was to be announced on 1 January 2025, but this was moved to January/ February 2026. In practice, this means that the implementation of REDIII requires amendments to the Environmental Management Act (Wet milieubeheer), the Energy Transport Decree (Besluit energie vervoer) and the Energy Transport Regulations (Regeling energie vervoer). The current vision of the new government focuses on steering towards reducing chain emissions rather than increasing the share of renewable energy. Nevertheless, biofuel deployment is expected to be an important (intermediate) solution to the 'Net Zero' goal for 2050.

Although the European climate goals require increased use of renewable fuels, the inland navigation sector has so far been exempt from blending obligations. Therefore, the inland navigation sector is not accustomed to the (mandatory) use of biofuels. Short-term introduction, without announcement, led to several problems in the winter period 2019-2020, including blocked filters and shutdowns of engines. It is clear that a substantial proportion of the reports submitted to the Biofuels Hotline ('Meldpunt Biobrandstoffen') related to the product ChangeTL[6], which falls outside the applicable specifications (EN590) for diesel fuel. This involved only a small number of reports. However, the problems have caused an image problem for biofuels in the sector.

[6] Mix of 20% FAME and 80% GTL, which did not meet EN590 specifications for diesel fuel.

Therefore, this study aims to assess the technical, economic and practical implications of biofuel blending for inland navigation, addressing whether concerns in the sector are justified and what lessons can be drawn from successful applications.

2 What is biodiesel and how does blending work?

Biodiesel is a renewable fuel made from organic materials such as vegetable oils, animal fats and waste products. It is viewed as a more sustainable alternative to fossil diesel and can be blended with conventional diesel to reduce carbon emissions. There are two primary types of biodiesel used in inland navigation: ***FAME*** (Fatty Acid Methyl Ester) and ***HVO***[7] (Hydrotreated Vegetable Oil). FAME is produced through *transesterification*[8]: a process in which oils and fats react with methanol to form methyl esters. It is derived from feedstocks such as rapeseed oil, used cooking oil and animal fats[9]. Nevertheless, FAME has a high viscosity, absorbs water and can induce microbial growth[10]. This makes it necessary to limit the blend ratio to a maximum of 7% (B7) to make it work for most (old) engines. On the other hand, HVO is produced through *hydrogenation*, which removes oxygen from oils and fats. It is derived from similar feedstocks but has properties closer to fossil diesel, including a higher cetane number and better stability at low temperatures. HVO can be used in blends up to 100% (HVO100) without engine modifications.

Biodiesel can be blended with conventional fossil diesel. In fact, the reason is nearly always to reduce greenhouse gas emissions. This process can be done in several ways. One method is ***pre-blending*** at refineries, where biodiesel is mixed with conventional diesel before distribution to ensure consistent quality and compliance with fuel standards such as EN590[11]. Another method is ***in-line blending***, where biodiesel is added directly to the diesel fuel stream during distribution. Some ships also have onboard blending capabilities.

The percentage of biodiesel blended with fossil diesel varies. The most common blend is B7, which consists of 7% FAME and 93% fossil diesel and is suitable for most engines without modifications. Higher blends, such as B20 to B30 (20-30% FAME and 70-80% fossil diesel), can further reduce emissions but may require fuel system modifications.

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[7] I am aware that from a theoretical point of view, HVO is not a biodiesel. But since HVO can be used in diesel engines, without the risks of corrosion or problems often associated with traditional biodiesel (e.g., FAME), I do classify it as biodiesel.

[8] See p. 15: Alt-fuels-for-Marine-and-Inland-Waterway-JRC-3.pdf

[9] This mainly concerns 'animal by-products' from slaughter.

[10] See next section.

[11] The EN590 standard (also called 'specification') defines and describes all the technical parameters that diesel must meet across Europe. This is important for engine manufacturers so they know what quality they need to tune their engines to. It is also important for end-users so that they can be sure that they can fill up with or have a consistent quality of diesel delivered into their diesel tank anytime, anywhere in Europe.

HVO100, which consists entirely of hydrotreated vegetable oil, can be used as a direct replacement for fossil diesel without any engine modifications.

3 Technical impact on vessel engines

As mentioned in the introduction, biodiesel has suffered a loss of reputation in the inland waterway sector. Currently, people are working hard to rectify this damage. Suppliers of biodiesel are cautiously reaching out to inland shippers again. After all, the fright was due to reports from skippers stating that there were engine problems after using biodiesel[12]. However, these noises should not be completely ignored. This section provides some reasons for this.

One of the biggest concerns is the tendency of biodiesel (especially FAME) to oxidise over time. This oxidation leads to the formation of peroxides and other compounds that can affect fuel quality. When biodiesel is stored for long periods, particularly in the presence of air, these oxidation products can damage engine components, clog fuel filters and reduce combustion efficiency[13]. The biodiesel can be stored in the right conditions for more than two months without loss of quality. After this time, the fuel should be monitored closely to ensure it remains within specifications.

Secondly, biodiesel (especially FAME) tends to absorb water. Absorbing water can lead to contamination of the fuel system. The presence of water in the system can cause microbial growth, which can block filters. Engine components can also corrode and affect the quality of the fuel itself. This risk is greater if longer-stored biodiesel is used and/ or the fuel is exposed to many different temperatures[14]. In addition to water-related problems, biodiesel (especially FAME) does not perform well at low (outdoor) temperatures. At low temperatures, biodiesel can become viscous or gel-like. This may be the cause of some engine problems that skippers had reported. Gel-like biodiesel can cause the engine to fail to start and stop supplying fuel to the injectors. This problem can especially occur in the Netherlands during the cold winter months. The degree of solidification depends on several parameters, including the type of biodiesel and the blend[15].

Thirdly, there may be so-called compatibility issues between biodiesel and engine materials. Not all ship engines are built for biodiesel or biodiesel blends. Especially the higher blends towards the B20 and B30 can cause problems without retrofitting the

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[12] The 'Meldpunt' received 27 reports from 2018 to 2021. Most of the reports were about engine failing, followed by poor engine operation and decreasing engine speed.

[13] Florentinus A., Hamelinck C., van den Bos A., Winkel R., Cuijpers M., 2012. Potential of biofuels for shipping - Final Report. Prepared by Ecofys for European Maritime Safety Agency (EMSA).

[14] McGill R., Remley W., Winther K., 2013. Alternative Fuels for Marine Applications. Technical report. A Report from the IEA Advanced Motor Fuels Implementing Agreement.

[15] FAME can start solidifying at temperatures below 10 degrees Celcius, depending on the fatty acid profile of the feedstock used. Higher concentrations of biodiesel (e.g. FAME100) are more likely to solidify than lower blends with fossil diesel.

engine. More specifically, the following parts can wear out or break down: rubber seals, gaskets and hoses. This in turn can lead to fuel leaks, system failures and other safety hazards. Several companies specialise in doing risk analysis in this area[16].

Finally, it is clear from the literature and externally consulted experts that sterol glycerides (SGs) and saturated monoglycerides (SMGs) in particular can be linked to filtration problems[17]. In the UK, a strict limit value has therefore been implemented on these parameters with encouraging results. Currently, in the Netherlands, there is only a recommendation to limit SMGs and SGs - for summer grade fuel this is at 90 ppm (SMGs) and for winter grade at 55 ppm's.

4 Biodiesel and engines: potential solutions

In the previous section, we have seen some of the problems surrounding biodiesel for the engine. In this section, we will see that a lot can be done to avoid the risks of complications (such as engine failure). Vessel failures can pose major safety risks. If a vessel comes to a halt on a busy waterway, such as the Rhine, it may get in the way of other traffic. A vessel may also drift which can lead to collisions or damage to riverbanks and other infrastructure. Furthermore, engine failure can pose safety risks to personnel, have financial consequences and even lead to environmental disasters. So, measures are highly recommended and do not require very large investments. Most of the measures require so-called 'good housekeeping' and demand greater awareness among suppliers, bunker operators and skippers.

First of all, it is important to realise that fuel management can do a lot to promote fuel quality and thus prevent technical problems. The tanks in which fuel is stored should be made of the right material. One of the best choices is to opt for stainless steel. This, among other things, is resistant to corrosion. For existing tanks, a suitable coating can be chosen[18]. Several companies, including Iris, specialise in coatings. Epoxy Phenolic coating, for example, is well suited for biodiesel, as is Epoxy Novalac[19]. But even if a skipper has a coating in the storage tank, it is not exempt from periodic cleaning. The problems that can occur in traditional tanks can also occur to a lesser extent in coated tanks. So, periodic cleaning falls under good housekeeping.

Furthermore, tanks should be properly sealed to minimise condensation. As indicated earlier, water can promote microbial growth which can lead to filter blockages[20]. Finally, placing storage tanks in the shade is recommended, likewise equipping tanks with

[16] See e.g., Using biodiesel in marine diesel engines: new fuels, new challenges
[17] For example, read our previously published report: blg-1125107.pdf
[18] See: Homepage - Iris
[19] See: Epoxy Novolac Coating | Five Star Products
[20] For more in-depth knowledge on tank installations, see: BRL SIKB 7800

heating systems. However, this is beyond the scope of this assignment. This aspect applies not only to skippers, but also to fuel suppliers and bunker operators.

Furthermore, barge operators can replace certain fuel system components. Rubber components can be replaced with biodiesel-resistant materials. One well-known material is Viton[21]. Furthermore, fuel pumps and injectors often need to be modified. This is because FAME has a higher viscosity than fossil diesel and a different combustion behaviour. In other words, viscosity means that biodiesel (especially FAME) is viscous, making it difficult to flow through small openings and thus difficult or impossible to squeeze into the fuel pumps and injectors. This leads to less efficient combustion, which can reduce its range.

Also, FAME has a lower energy density than fossil diesel. This means that more fuel has to be consumed to cover the same distance. Even with engine and fuel system modifications, FAME's energy density remains. Despite technical modifications, FAME delivers about 13% less energy per litre compared to fossil diesel. The energy density of FAME is 37.2MJ/kg or 32.6MJ/l volumetric energy density; the energy density of fossil diesel is 42.9MJ/kg or 35.2MJ/l. The energy density of HVO is a lot higher than FAME, at 44.1MJ/kg. The volumetric energy density is also a lot higher than FAME, at 34.4MJ/l[22].

Therefore, another interesting option is to use an alternative fuel, namely HVO. This is because HVO is chemically identical to fossil diesel. As a result, relatively many already existing diesel engines are already compatible using HVO. It also does not necessarily require a coating in the fuel tank, as HVO has no aggressive properties that can be harmful to materials. For example, Catterpillar guarantees that all Catterpillar engines built after 1990 may run 100% on HVO[23].

5 Costs

One question that can be asked is whether it is a legitimate reason for inland waterway operators not to switch to biodiesel because of the financial cost. First, it is worth noting that even within the industry itself there is some confusion about the *availability* of biodiesel. Some bunker operators indicate that they will not be able to supply enough biodiesel if many ships switch to biodiesel, while others indicate that they will be able to supply a sufficient amount[24]. Uncertainty about biofuel availability is especially true for HVO. In fact, the aviation sector is not looking at FAME at all, but mainly at sustainable aviation fuel (SAF). If the aviation sector switches to SAF, the question is whether there will be enough HVO available for the inland shipping sector. This is because SAF is largely made with the raw materials also used for HVO. It is therefore

[21] See: Viton™ in Industrial Machinery | Viton™ Fluoroelastomers
[22] See: FACT SHEET
[23] See: Caterpillars mogen draaien op HVO100 | Schuttevaer.nl
[24] E.g., see: Vraag naar HVO100 niet gestegen in de binnenvaart door oproep CEO Bauer van HGK | Schuttevaer.nl

advisable for suppliers, bunkering companies and inland waterway operators to enter into more discussion on this. Supply and demand should be better matched[25].

In addition, the price of biodiesel depends on several factors. By nature, feedstock prices are highly variable. Both HVO and FAME are produced from oils and fats. The price of these feedstocks can vary due to many factors. These include weather conditions, geopolitical developments and trade restrictions. As described earlier, HVO and FAME are each produced in a special way. These processes require high energy and water costs. This is especially true for HVO.

To come back to the question of whether it is a legitimate reason not to switch to biodiesel because of the costs, at the moment the answer is 'yes, but...'. The price of biodiesel, especially HVO100, is higher than traditional diesel. There are voices from the industry saying that if the price difference between HVO100 and traditional gasoil is not compensated, few companies will switch. Those switching now will pay the price difference and have to compete against companies that continue to use the cheaper diesel. In the truck sector, we see transport companies giving the option of 'climate-neutral' transport. This could also be an interesting option for the inland shipping sector.

Currently, per 1000 litres, the price difference between HVO100 and fossil diesel is between EUR 160 and 180, but the price fluctuates from week to week[26]. One week it can differ 120 euros, another week 160 euros and again 200 euros the next week. A barge holds thousands of litres of fuel, making the price per tonne-kilometre quite high compared to fossil diesel. The short-term solution to close the price gap lies in the hands of politicians. Politicians must ensure that there is sufficient supply. In the long run, market mechanisms of supply and demand will ensure higher volumes at a falling price as demand increases. But in the beginning, supportive incentives are needed from politicians. Consider the provision of subsidies. HVO and FAME are already exempt from taxation in, among others, the Netherlands and Germany.

6 Real-life examples

In the introductory text, we saw that there were several reports of engine failures and other malfunctions after skippers switched to blends of biodiesel. It should be noted that no baseline study was conducted. So we do not know whether the engines were properly cleaned beforehand, whether the filters were already outdated, in short, we know virtually nothing about the initial condition of these vessels. Hence, it is unfounded to conclude on the basis of these reports that biodiesel or blends thereof do not work for inland navigation. Over time, Panteia and other organisations have proposed pilots to test biodiesel in practice. By conducting real-world trials, one can

[25] Another non-financial expense is the environmental impact of biofuel feedstock production. Specifically, problems may arise due to lack of agricultural land for the production of the feedstock if multiple modes and sectors switch to biofuels. This is true not just for first-generation biofuels, but also for some second-generation biofuels, including FAME.

[26] See: Overzicht Fieten Olie Adviesprijzen (euro 95, super 98, diesel, adblue, HVO 100) - Fieten Olie

check under largely controlled conditions whether biodiesel is really that dangerous. This way, a baseline measurement of its condition can be made. Meanwhile, several of such initiatives have already been put into practice, some of which we still have to wait for the results. In this section, I would like to highlight some of these initiatives around biodiesel and inland navigation.

A pilot was completed in 2023 in which the vessel 'MTS Vlissingen' has been running on 100% FAME for 9 months[27]. This vessel is part of VT Group's fleet. They collaborated with FinCo Group for this pilot. FinCo Group is an independent supplier of renewable energy solutions. In turn, FinCo purchased part of the biodiesel from Argent Energy. With FAME, CO_2 reductions of up to 89% can be achieved[28]. FinCo Group has knowledge of the modifications required to make a vessel ready to run on 100% FAME. FinCO Group indicates that minimal modifications are needed for this. A lot of technical knowledge was gathered during this pilot. This is useful because the use of biodiesel is still in its infancy in the inland shipping sector. Especially the effect of various (weather) conditions needs to be better mapped. This pilot shows that it is possible to switch to 100% FAME with minimal modifications to a ship. We estimate the cost to be between €10,000 and €50,000[29].

Perhaps the most interesting research on FAME in inland navigation is currently ongoing. Eight vessels are currently running a one-year study under the supervision of TNO on different FAME blends up to B30. This research is commissioned by the Ministry of Infrastructure and Water Management on Panteia's recommendation in its director role. This trial should reveal in what compositions and under what conditions blends up to B30 work best for inland vessels. It also looks at the concentration of sterol glycerides and saturated monoglycerides that can cause filtration problems. A monitoring form is completed every time ships bunker. In this way, information is collected on oil change intervals, engine running hours, volumes bunkered and frequencies with which filters need to be changed. It also tests the fuel filters for deposits or contamination. Since a previous trial in which KBN was involved, which ended in some engine problems, did not map the initial situation, this study does. The outcome will include knowledge of what technical and operational measures are needed to operate trouble-free on FAME. In addition, the trial should show whether a specific fuel quality standard is needed for a particular blend for inland navigation. The inland shipping sector is closely involved in the study with the cooperation of KBN, NOVE/Foundation VOS, VEMOBIN, MVO and VT-group, as well as engine suppliers and the insurance industry. The results of this pilot are expected by the end of 2025[30].

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[27] Read more: VT en FinCo ronden biodiesel pilot af: 100% FAME slaagt voor test binnenvaart - Duurzaam Ondernemen

[28] This means that biodiesel is not the solutions for emission-free shipping. Although 89% reduction is a good step, Europe needs to move towards 100% reduction. In the mid-term, biofuels seem a good solution, but in the long-term, electric propulsion, hydrogen and/or nuclear energy on ships should be considered.

[29] With possible additional maintenance costs per year: €5,000 - €20,000. Partly due to having to replace parts (e.g., filters) more often and cleaning the tanks more often.

[30] For more information, see: Binnenvaart test FAME voor snelle CO_2-reductie | TNO