Biofuels for shipping

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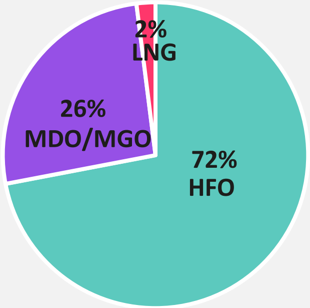
1. Background

Shipping is fueled by fossil fuels, and immediate availability of lower carbon fuels is limited

Energy consumption in shipping

- Energy consumption in shipping is almost exclusively fossil fuel based, with heavy fuel oil (HFO) and marine diesel oil/marine gas oil (MDO/MGO) responsible for the largest shares.
- Energy consumption in the sector is dominated by international shipping.
- Energy is consumed for propulsion, as well as to generate electricity for onboard use.

Share of fuel consumption by global shipping fleet (2015)[1]



Possible solutions to decarbonize

- Efficiency improvements have been achieved through slow steaming (operating ships at lower speeds) and the introduction of the Energy Efficiency Design Index (EEDI), which sets a minimum energy efficiency level for new ships.
- Fuel shifts:
  - Biofuels can reduce CO_2 emissions from shipping, depending on the feedstock type and processing. As shown on slide 7, when considering full lifecycle emissions (well-to-wake), this could range from a 100% reduction to doubling of emissions compared to fossil fuels.
  - Shore-to-ship power allows ships to turn off engines and connect to the electricity grid while in port. The emission reduction depends on the carbon intensity of the electricity grid, i.e. in the EU 40% of CO_2 is saved in ports.
  - LNG fueled ships can abate emissions by up to 21% compared to current marine fuels on a well-to-wake basis (including supply chain and fugitive emissions). The difference could be as low as 5%, depending on the engine technology and reference fuel.[2]
  - Synthetic fuels: hydrogen, ammonia and methanol produced with renewable energy are being considered as potential solutions.
  - Electric propulsion: electric ship technologies are emerging for short distance voyages. Hybrid ships are also emerging, with electric propulsion used for zero emissions operations in ports.[3]

Sources: [1] ICCT, 2017. Greenhouse gas emissions from global shipping, 2013-2015; [2] thinkstep, 2019: *Life Cycle GHG Emissions Study on the Use of LNG as Marine Fuel*; [3] Stena Line, 2018. Stena Line launches 'battery power' initiative.

1. Background

Shipping accounts for 2.6% of global CO_2 emissions and is likely to grow under a BAU scenario

Current applications and associated CO_2 emissions	• Shipping is responsible for the transport of around 80% of world trade.[1] • Direct CO_2 emissions from shipping in 2015 were 932 MtCO_2 or about 3% of global energy-related CO_2 emissions. International shipping accounted for 87% of emissions from shipping.[2] • By ton-km (t-km), shipping is one of the lowest emitting modes of freight transport. On a well-to-wheel/wake basis, oil tankers, bulk carriers and container ships have an emissions intensity of <70gCO_2/t-km. In comparison, air freight emissions can range from 400-2200gCO_2/t-km and road freight can range from 50-1400gCO_2/t-km. Rail freight can have an emissions intensity of close to zero to up to 75gCO_2/t-km.[3]
Evolutions forecast in a business-as-usual scenario	• The International Energy Agency (IEA)'s Reference Technology Scenario sees well-to-wake emissions from shipping increasing by 84% from 2014 to 2050.[4]
Obstacles to decarbonizing this application	• Alternative fuels such as biofuels have a higher cost than fossil fuels. • Limited financial incentives – energy taxes are not generally applied to fuels for international shipping, and coverage of carbon pricing on shipping emissions is limited. The EU announced that it will consider reforming taxes on maritime fuels and including the sector in the EU ETS.[5] The International Maritime Organization (IMO) considers market-based measures e.g. carbon pricing, to be a possible mid-term (2023-2030) mitigation measure.[6] • Gradual introduction of policies for the sector. International aviation and shipping are not covered by the Paris Agreement. The aviation sector adopted a global agreement on carbon-neutral growth for the sector in 2016, while the IMO adopted in 2018 an "Initial Strategy" to peak GHG emissions as soon as possible and reduce total emissions by at least 50% by 2050 compared to 2008 levels. The IMO agreed in 2019 to strengthen the EEDI requirements, with entry into force in 2022.[7]

Sources: [1] UNCTAD, 2018. Review of maritime transport 2018; [2] ICCT, 2017: Greenhouse gas emissions from global shipping, 2013-2015; [3] Smart Freight Centre, 2019: *Global Logistics Emissions Council Framework;* [4] IEA , 2017: *Energy Technology Perspectives 2017;* [5] European Commission, 2019: The European Green Deal; [6] IMO, 2018: Adoption of the initial IMO strategy on reduction of GHG emissions from ships and existing IMO activity related to reducing GHG emissions in the shipping sector; [7] IMO, 2019: UN agency pushes forward on shipping emissions reduction.

2. Description of biofuels for shipping

Overview

Description of the new solution concept	• Biofuels are energy carriers that are produced by converting primary biomass or biomass residues into liquid or gaseous fuels. • Currently, most biofuels used in shipping are various forms of biodiesel: fatty acid methyl esters (FAME) or hydro-treated vegetable oils (HVO), both of which are primarily produced from plant oil feedstocks such as rapeseed, soybean and palm oil. Waste and residue fats can also be used as feedstocks.[1] • Other biofuels could also be used for shipping e.g. biomethane and bio-methanol (refer to Source 4 for more information). However, this business case focuses on HVO and FAME which be used directly or blended with conventional fuels for use in main existing engine technologies.
Rationale for developing this solution	• Of the alternative low-carbon fuels available for shipping, HVO biofuels are the only "drop-in" fuel which can be used with existing ship engines with no or minor modifications,* or used as a blend with conventional fuels. HVO can also be distributed in most cases using existing marine fuel infrastructure. FAME diesels are not drop in fuels, but can be blended with conventional fuels in concentrations of up to 7%.[2] Maersk has operated a pilot with 20% biofuel blend.[3] Other alternative, low-carbon shipping fuels such as ammonia and hydrogen would require new engine technologies. • Battery electric ships are not a feasible solution to long-distance shipping due to weight and volume constraints and high power demand.
Assessment of technology readiness status	• HVO and FAME biodiesels are being produced at commercial scales for use in road transport.[4] • There is relatively limited operational experience with HVO as a ship fuel, with the fuel being used onboard three ferries operating in Norway.[2] The technical feasibility of FAME biodiesel blends in shipping has been demonstrated in several projects.[2] A FAME, GTL (gas-to-liquid) and enzyme shipping fuel blend is commercially available for inland shipping applications in the Netherlands.[5]

*The latest generation engines can run off multiple fuels, including conventional diesel fuels, LNG, methanol and ethanol.[4]

Sources: [1] Neste, 2016: *Neste renewable diesel handbook*; [2] DNV GL, 2019: *Assessment of selected alternative fuels and technologies*; [3] Dutch Sustainable Growth Coalition, 2019: *Maritime biofuel-pilot a great success*; [4] IEA Bioenergy, 2017: *Biofuels for the marine shipping sector*; [5] Licorne Fuel: *ChangeTL*.

2. Description of biofuels for shipping

Feedstock supply and sustainability issues

Current feedstocks

- Supply of vegetable oils for FAME and HVO is limited. These oils are also used for food, pharmaceutical and cosmetic industries. It is challenging to scale up production due to concerns over environmental and social issues:[1]
    - Land use change: biofuels production could trigger the conversion of high carbon stock land or land with high biodiversity value, e.g. primary forest, wetlands or peatlands, to agricultural lands
    - Social impacts: food crops being diverted to produce fuels can increase the price of food

Sustainable feedstocks

- The most sustainable feedstocks for biofuels are generally considered to be municipal, agricultural and/or forestry waste streams.[2]
- Sustainability certification schemes are essential to giving the market confidence in biofuel use. Current schemes need to evolve, as no single sustainability standard addresses all sustainability issues raised by industry stakeholders.[2]

Feedstock potential

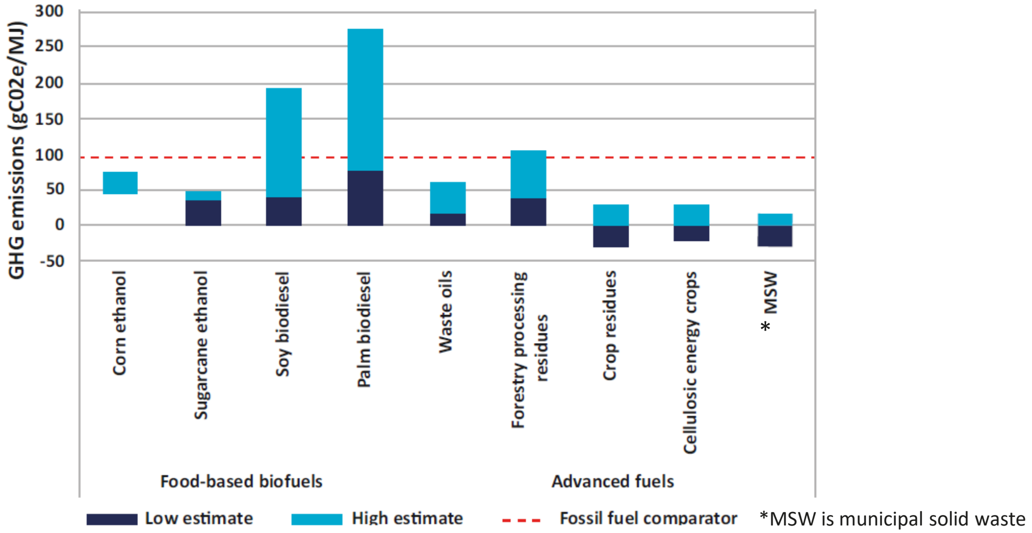
- The current supply of biofuels (for all energy uses, including bioethanol and biodiesel), can only cover 15% of energy demand from shipping.[3]
- Estimates of future sustainable bioenergy potential vary significantly. The Sustainable Shipping Initiative (SSI) suggests that availability could be in the range of 50-100 EJ by mid century.[2]
- This is unlikely to be sufficient to meeting potential demand from the shipping sector, which is projected to grow from 10 EJ today to 26-60EJ by 2050, and demand from other sectors including aviation, heavy duty road transport, and chemicals.[2]

Sources: [1] IEA Bioenergy, 2017: *Biofuels for the marine shipping sector*; [2] SSI, 2019: *The role of sustainable biofuels in the decarbonisation of shipping*; [3] ITF, 2018: *Decarbonising Maritime Transport*.

3. GHG reduction potential of biofuels for shipping

GHG emissions assessment of current and new solution

Lifecycle GHG emission reductions of biofuels (including indirect and direct land use change impacts) compared to fossil fuels vary depending on the process, feedstock and origin of the feedstock. A range of emission factors for a selection of biofuels are shown in the graph below.[1] The figure shows that biofuels derived from soy and palm could result in higher lifecycle emissions than fossil fuels. It is important to note that estimations of emissions factors can also vary significantly depending on the source.



For a comparison of GHG emissions from biofuels and other alternative fuels including hydrogen, ammonia and electricity, refer to *Mission Possible: Sectoral Focus Shipping*.

Source: [1] SSI, 2019: *The role of sustainable biofuels in the decarbonisation of shipping*.

4. Cost assessment and sensitivity analysis

- Biofuels are about 50-150% more expensive than fossil fuels that are compliant with the IMO Sulphur Cap (without need for installation of a scrubber on the ship).
- Fuel prices vary depending on location and feedstock.

Fuel	Description	IMO Sulphur Cap compliance	Price 30/1/2020 (USD per metric tonne)
IFO380	Blend of high proportion of HFO with low share of MGO	Compliant if ship is equipped with a scrubber	295[1]
VLSFO	Very low sulphur fuel oil	Compliant	475.5[1]
MGO	Marine gas oil	Compliant	492[1]
UCOME	Biofuel made from used cooking oil	Compliant	1215[2]
TME	Biofuel made from tallow	Compliant	1190[2]
SME	Biofuel made from soybean	Compliant	976[3]
FAME	Fatty acid methyl ester biofuel (feedstock unknown)	Compliant	740[3]

Rotterdam prices are shown from all fuels except SME and FAME, which are Neste's biodiesel prices (non-location specific).

For a comparison of the costs of fossil fuel shipping with biofuels and other alternative fuels including hydrogen, ammonia and electricity, refer to *Mission Possible: Sectoral Focus Shipping*.

Sources: [1] Ship & Bunker: *Rotterdam bunker prices*; [2] Greenea: *Waste-based market performance*; [3] Neste: *Biodiesel prices (SME & FAME)*.

5. New partnership opportunity

Partnerships between biofuel suppliers, ship owners/operators, ports and engine/fuel supply system manufacturers are required for long-term testing of biofuel performance in shipping and related infrastructure. This is needed to address concerns on the lack of long-term fuel test data to guarantee the safety and reliability of biofuels.[1] These partnerships can also address issues related to compatibility between different blends of biofuels and global availability.

Ship owners/operators

Partnership between ship operators and biofuel supplier, e.g. via an offtake agreement, will be important to scaling up production capacity of biofuel facilities.

Engine and fuel supply system manufacturers

Engine and fuel supply system manufacturers need to work together with biofuel suppliers to ensure that future technologies are compatible with biofuels.

Ports

Partnerships between ports and ship owners/operators, and with biofuels suppliers are required to develop fuel infrastructure and regulations. Cooperation between ports, e.g. to share knowledge and developing joint projects, can accelerate global biofuels deployment.

Biofuel suppliers

Source: [1] IEA Bioenergy, 2017: *Biofuels for the marine shipping sector*.

6. Biofuels for shipping SWOT analysis

Strengths

- Biofuels can reduce GHG emissions from shipping, depending on the feedstock type and processing.
- Biofuels can be drop-in fuels, which can be used in existing ship engines and transported and stored in existing infrastructure without requiring major changes. Biofuels can therefore potentially be scaled up to accelerate early decarbonization more rapidly than other alternative fuels.
- Shipping companies can gain reputational benefits from using biofuels.

Opportunities

- Biofuels decrease dependency on fossil fuels
- The IMO’s initial GHG strategy will consider an implementation programme for alternative low-carbon fuels and market-based measures in the medium term (2023-2030). These measures could stimulate demand for biofuels.

Weaknesses

- Biofuels are currently not cost competitive with fossil fuels.
- Limited experience in use of biofuels in shipping and lack of long-term test data on the properties and performance of biofuels in shipping.
- Commercial biofuel production facilities can currently meet a small share of fuel demand from shipping, and other sources of demand, e.g. aviation and plastics.
- Currently challenging to secure supply of sustainable feedstock.

Threats

- Competing demand for bioenergy from other sectors such as aviation and plastics.
- There is no agreed long-term pathway on the decarbonisation of the shipping sector. Some stakeholders consider biofuels to be a short-to-medium term transition fuel. Long-term decarbonisation alternatives being considered include ammonia, hydrogen fuels and battery electric shipping.
- Sustainability risks associated with the use of biofuels need to be addressed. Some stakeholders are not convinced that certification schemes can ensure sustainability.

7. Success factors

Sustainability assurances

Sustainability certification is considered by many to be a pre-requisite for biofuel use in shipping. Sustainability certification schemes should be continually revised to reflect latest knowledge on sustainability risks, including indirect land use change. The development of a single, comprehensive and peer reviewed source of emission factors for biofuels would improve the credibility of emission reduction claims.

Policy to stimulate demand

Policy is needed to drive uptake of low-carbon energy sources in shipping such as biofuels. Market-based measures such as carbon pricing could provide incentives to scale up biofuels for shipping. Regulations need to be implemented on a global scale via the IMO.

Long-term offtake agreements to secure supply and demand for biofuels

Offtake agreements between biofuels producers and shipping operators are important to enable biofuel producers to invest in development of the supply chain and technology improvements.

Commitments to reduce supply chain emissions

Companies committing to reduce their supply chain emissions—including emissions related to the shipping of goods—through initiatives such as the Science Based Targets initiative can stimulate shipping companies to increase biofuel usage.

Source: IEA Bioenergy, 2017: *Biofuels for the marine shipping sector*.

8. Biofuels for shipping: Case studies

Port authority

Port of Rotterdam Authority (Rotterdam, Netherlands)	
Context	• The port of Rotterdam is Europe's largest sea port by number of containers per year. • The total size of the port area is 127 m^2 with 30,000 sea going and 120,000 inland vessels berthed each year.
Project description & objectives	• Use of B100 biofuels for Port of Rotterdam Authority Vessels (Patrol and Incident & Fire Fighting Vessels) • Start date: March 2018 • Objective: CO_2 emission reduction • Costs: No additional investment costs.
Main technical data	• Technology: inland waterway transport engines • Fuel consumption: 2,100m^3 fuel/yr • Operational characteristics: Vessels operate in local port area and implementation has been problem-free. • Sustainability considerations: biofuels used are certified sustainable.
Benefits	• Financial benefits: none • Other benefits: Emission reductions of not only carbon but also PM and NOx • Avoided CO_2 emissions: 90-95%

Source: Communication from Port of Rotterdam Authority

8. Biofuels for shipping: Case studies

Container shipping company

A.P. Møller – Mærsk A/S (Copenhagen, Denmark)	
Context	• Maersk is an integrated container logistics company that has subsidiaries in 130 countries • Largest container ship and supply vessel operator in the world since 1996
Project 1: Biofuel pilot[1]	• Maersk container vessel mainly sailed on a 20% blend with biofuel made from used cooking oil (UCO) on Rotterdam-Shanghai route. This was the first time such a high percentage blend was used on an ocean container vessel at this scale. • Date: March – June 2019 • Collaboration with the Dutch Sustainable Growth Coalition (DSGC) including FrieslandCampina, Heineken, Philips, DSM, Shell and Unilever. • Benefits: Emission reductions of 1,500 tCO_2 and 20 tons of sulphur.
Project 2: Development of new biofuels[2]	• Established LEO coalition to develop new biofuel based on ethanol oil and lignin, a common byproduct of lignocellulosic ethanol and pulp and paper mills. • Date: from 2019 • Collaboration with researchers and customers including BMW Group, H&M Group, Levi Strauss & Co. and Marks & Spencer. • Test on vessel engines is aimed for 2020.
Project 3: Maersk ECO Delivery[3]	• Carbon footprint of cargo transported under this name is reduced via the purchase and use of biofuels in the Maersk network. • Sustainability certification verified by Roundtable on Sustainable Biomaterials • Product is available on all major trades.

Sources: [1] Bioenergy International, 2019: *Mette Maersk maritime biofuel-pilot a resounding success*; [2] Maersk, 2019: *Maersk join forces with industry peers and customers to develop LEO*; [3] Maersk: *Maersk ECO Delivery*.

8. Biofuels for shipping: Case studies

Ferry company

Fjord1 (Norway)	
Context	• Fjord1 is the largest ferry company in Norway • In 2018, it had 74 vessels and more than 20 million passengers
Project description & objectives	• 3 ferries of the Hella-Dragsvik-Vangsnes connection are operating on pure biodiesel. Fjord1 is the first ferry company in the world to use advanced biofuels in ferry operations. • Start date: January 2016 • HVO biodiesel is purchased from Finnish producer Eco-1. • Prior to operations, Fjord1 conducted extensive tests the qualify the fuel and make adjustments to the engine and other systems to accommodate the new fuel.
Benefits	• Avoided fossil fuel consumption: 1.5 million liters annually • Other benefits: biodiesel has longer durability than fossil diesel, better winter properties and give a large reduction in NOx and Sulphur emissions

Sources: Firda, 2015: *Skal drifte ferje på fornybar diesel*; ZERO, 2015: *Verdens første fergestrekning på fornybart biodrivstoff*.

9. Summary

Emissions and energy	• The shipping sector accounted for 3% (932 $MtCO_2$) of emissions in 2015. • Under the International Energy Agency (IEA)'s Reference Technology Scenario, well-to-wake emissions from shipping are expected to increase by 84% over 2014 to 2050.
Solution	• Biofuels – produced by converting primary biomass or biomass residues into liquid or gaseous fuels – are a possible solution to decarbonize the shipping sector. • Currently, most biofuels used in shipping are types of biodiesel: fatty acid methyl esters (FAME) or hydro-treated vegetable oils (HVO). Both primarily use plant oil feedstocks such as rapeseed, soybean and palm oil, but it is possible to use waste and residue fats as well.
Avoided GHG emissions and co-benefits	• Biofuel life cycle GHG emissions reductions compared to fossil fuels vary depending on the process, feedstock and origin of the feedstock. • On the one hand, the emissions reduction benefit could exceed 100% for advanced fuels made from crop residues, municipal solid waste or cellulosic energy crops. On the other hand, after including indirect and direct land-use change impacts, biofuels derived from soy and palm could result in higher life cycle emissions than that from fossil fuels.
Readiness status	• Companies are producing HVO and FAME biodiesels at commercial scale for use in road transport but there is relatively limited operational experience with their use in ship engines.
Barriers	• Biofuels are about 50-150% more expensive than fossil fuels. • There is limited feedstock supply and biofuel production capacity and other sectors, such as aviation and plastics, are also competing for bioenergy. • Concern about the sustainability risks associated with biofuel use, such as land-use change and social impacts.
Success factors	• Regulations implemented at a global scale via the International Maritime Organization. • Market-based measures such as carbon pricing to provide the financial incentive needed. • Sustainability certification schemes, which are essential to giving the shipping industry confidence in biofuel use.

10. Key sources and references on biofuels for shipping

- Bioenergy International, 2019: Mette Maersk maritime biofuel-pilot a resounding success
- DNV GL, 2019: Assessment of selected alternative fuels and technologies
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- Dutch Sustainable Growth Coalition, 2019: Maritime biofuel-pilot a great success
- Energy Transitions Commission (ETC), 2018: Mission Possible
- ETC, 2018: Mission Possible: Sectoral Focus Shipping
- European Commission, 2019: The European Green Deal
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- Greenea: Waste-based market performance
- ICCT, 2017: Greenhouse gas emissions from global shipping, 2013-2015
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- ZERO, 2015: Verdens første fergestrekning på fornybart biodrivstoff

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