Biofuels (drop-in)

Overview

- Background and key characteristics
- Drop-in biofuel production value chains
- Feedstocks and energy sources
- Production technologies
- Onshore requirements
- Onboard requirements
- Regulations, standards and guidance
- Environmental impact
- Cost overview
- Barriers and risks
- Summary

Key concept reminder

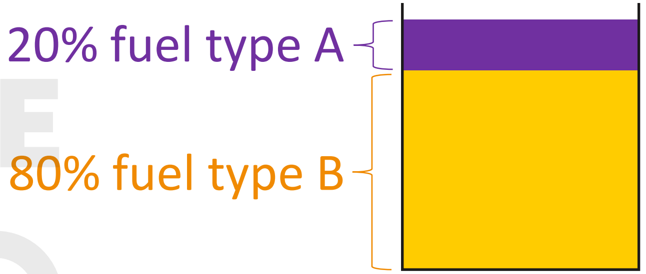
‘Drop-in’ fuel

- A ‘drop-in’ substitute refers to a fuel that can be directly used in place of an existing fuel with minimal alterations to the equipment using the fuel.
- In some cases, an alternative fuel may not be useable in its 100% pure form and may require ‘blending’ to produce a drop-in solution.

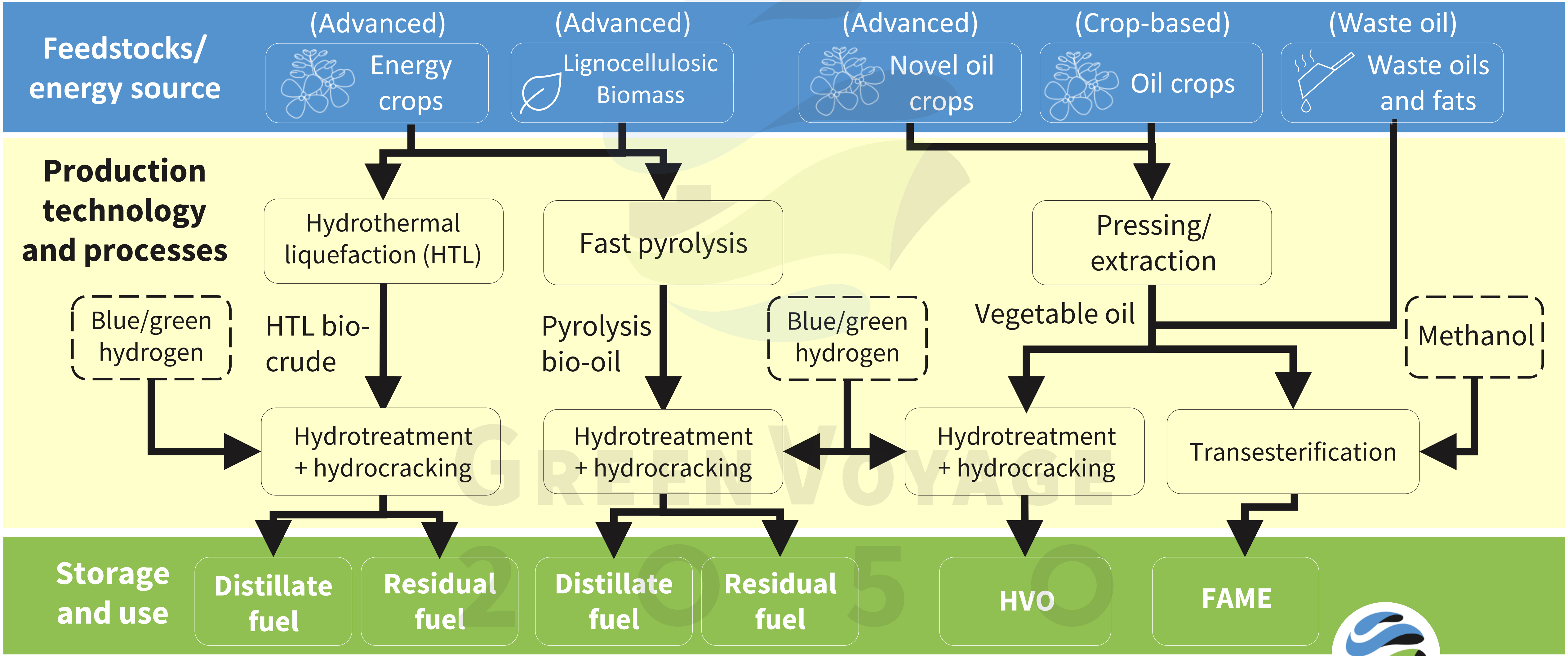
Fuel blends and blending limits

- ‘Blending’ refers to mixing an amount of one type of fuel with another type, expressed as a percentage (%) of the total mixture.
- Usually describes the amount of an **alternative fuel** added to a **traditional fuel**.
- Maximum limits on how much alternative fuel can be added are often dictated by quality standards, technical requirements and the properties of the alternative fuel.
- Blending is carried out prior to bunkering (not onboard the vessel).

Example: 20% blend by volume



Drop-in biofuel production value chains



Drop-in biofuel applications and blending – distillate alternatives

(HTL)	(Pyrolysis)	(Hydro-processing)	(Transesterification)

Storage and use

Distillate fuel	Residual fuel	Distillate fuel	Residual fuel	HVO	FAME
Up to 100%*				Up to 100%[1]	Up to 7%[1]
				MGO	MGO

*higher blend
=
more upgrading and processing
=
Higher processing cost

Typical distillate fuel vessel type
Source: Stena Line

Key points:

- FAME has a specified blending limit dictated by ISO 8217 standard (however, engine manufacturers permit higher blends).
- HVO has been trialled at a range of blends, but limitations, if they exist, are not yet widely understood.
- HTL/pyrolysis fuel oils will be limited primarily by the cost of achieving high blending limits.

[1] ICCT Working paper 2020-21- The Potential of Liquid Biofuels in Reducing Ship Emissions

Drop-in biofuel applications and blending - residual alternatives

	(HTL)		(Pyrolysis)		(Hydro-processing)	(Transesterification)
Storage and use	Distillate fuel	Residual fuel	Distillate fuel	Residual fuel	HVO	FAME
		Up to 100%			Uncertain	Uncertain

*higher blend
=
more upgrading and processing (but less than for MGO)
=
higher processing cost

HFO

HFO

Typical residual fuel vessel type
Source: Maersk

Key points:

- No widely-agreed limit for HVO or FAME, but trials at 20% blends are known to be in progress.
- HTL/pyrolysis fuel oils will be limited primarily by the cost of achieving high blends.

Feedstocks and energy sources

Current availability	Oil crops	Waste oils and fats	Lignocellulosic Biomass	Novel oil crops

Key Points

- Crop-based feedstocks such as palm oil and soybean are widely available, but in some geographies, such as Europe, their use is limited by policy and is expected to decrease as it is not viewed as a long-term solution (due to ILUC).
- Used waste oils and fats have high GHG savings but limited potential globally, and the maritime sector will face competition for supply from other transport sectors such as road and aviation.
- Lignocellulosic biomass (forestry and agricultural residues, woody and grassy energy crops, municipal wastes) has much greater long-term potential
- Other solutions to increase feedstock supply include use of novel oil crops (such as camelina and carinata) which could reduce land competition through winter growing, use of degraded land.

Widely Available

Availability Constrained

Availability Very Restricted

Production technologies

Production technology and processes

Hydrothermal liquefaction (HTL)
HTL bio-crude
Hydrotreatment + hydrocracking

Fast pyrolysis
Pyrolysis bio-oil
Hydrotreatment + hydrocracking

Blue/green hydrogen

Pressing/ extraction
Vegetable oil
Hydrotreatment + hydrocracking
Transesterification

Methanol

Readiness

Bio-crude production: TRL 5-6
Upgrading: TRL3-4

Fast pyrolysis: TRL 8
Upgrading: TRL 5-6

TRL 9

TRL 9

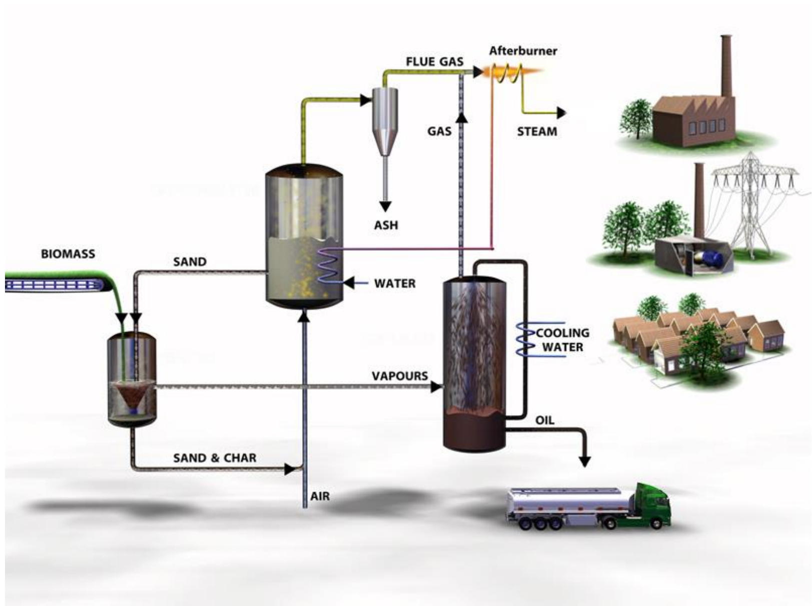
Example feedstocks

Used cooking oil Source: Neste

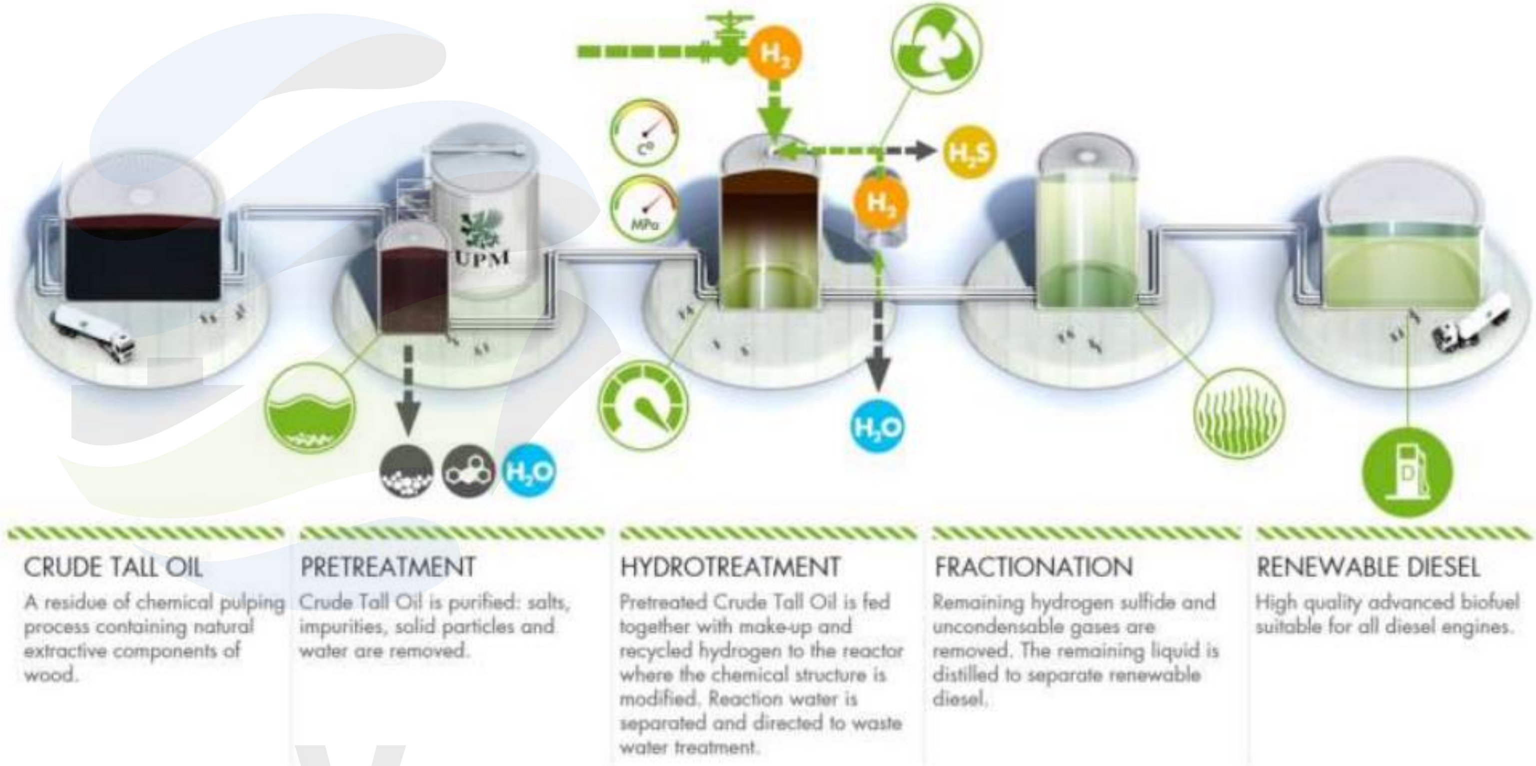
Forest residues Source: GoodFuels

Energy crops Source: USDA

Production technologies



Fast pyrolysis plant, BTG Source: BTG



HVO production process Source: UPM Biofuels

Onshore requirements

Storage and use | Drop-in biofuels

Storage

- Pyrolysis and HTL fuels – may require additional investment for acid-proofing but this could be mitigated through upgrading and blending.
- HVO – very good storage stability, not prone to oxidation or microbiological growth, suitable for long storage durations. No significant modifications required to traditional storage infrastructure.
- FAME – prone to oxidation (which can degrade fuel quality) and to leaving deposits (which can clog elements like filters). Relatively short degrading time means it should not be stored for long periods (max 6 months)[1]. Risk of microbial growth due to water absorption. Additional investment for control of storage conditions may be required.
- Blending limits will also apply to fuels in storage.

[1] IBIA, 2016 from ICCT

Onshore requirements

Storage and use | Drop-in biofuels

Transportation

- HVO can be transported in same way as standard diesel.
- FAME requires more onerous controls on conditions for transportation, loading and unloading (such as avoiding water contamination).
- Loading and unloading equipment for HTL and pyrolysis oils requires acid-proofing, which may need additional investment depending on level of upgrading and/or blending.

Bunkering

- All biofuel blends can be used in current bunkering methods, although some modifications to the equipment may be necessary in line with storage upgrade requirements (e.g. acid-proofing for HTL and pyrolysis fuel oils depending on upgrading and/or blending).

Onboard requirements

Storage

- FAME – potential additional storage controls and practices needed. FAME can lift deposits during early use, potentially blocking elements such as filters. Oxidation instability and risk of microbial growth can also cause issues for vessels with long periods in between bunkering. Some onboard fuel storage may also be designated for highly infrequent use (such as emergency power generation and auxiliary engine or lifeboat supply) and should therefore not use high FAME concentrations.
- No significant additional requirements for storage of HVO onboard.
- Increased viscosity and quantities of micro-carbon residuals from use of HTL/pyrolysis fuels could impact onboard filtration and pumping systems.

Storage and use | Drop-in biofuels

Onboard requirements

Handling

- ISO standard on marine fuels permits use of biomass-based hydrocarbon fuels and the use of FAME up to a stipulated blending limit of 7%.
- Some other additional standards and specifications are relevant to use on board (such as European and American standards on handling practices of FAME due to its high oxygen instability.
- Clear policies and guidance for handling, storage and use will need to be developed for use of biofuel alternatives if they are not simply supplied as a blended product.

Storage and use

Drop-in biofuels

Onboard requirements

Propulsion (1)

- FAME – potential engine refurbishment/upgrade work needed (e.g. fuel supply hoses, filters). Manufacturer tests have found no negative effects of using FAME in marine engines up to 10% blends.
- The use of a traditional residual fuel with a FAME blending component has been successfully trialled, and will be made available for use in the near future.
- HVO – no engine upgrades required.
- HTL and pyrolysis fuels – may lead to increased risk of fuel injector and injection system component wear.
- Use of a drop-in residual alternative to HFO has been trialled both in laboratory tests in 2018 and onboard during 2019 and 2020. Further trials and investigations into use of the fuel at a larger scale are ongoing.

Storage and use | Drop-in biofuels

Onboard requirements

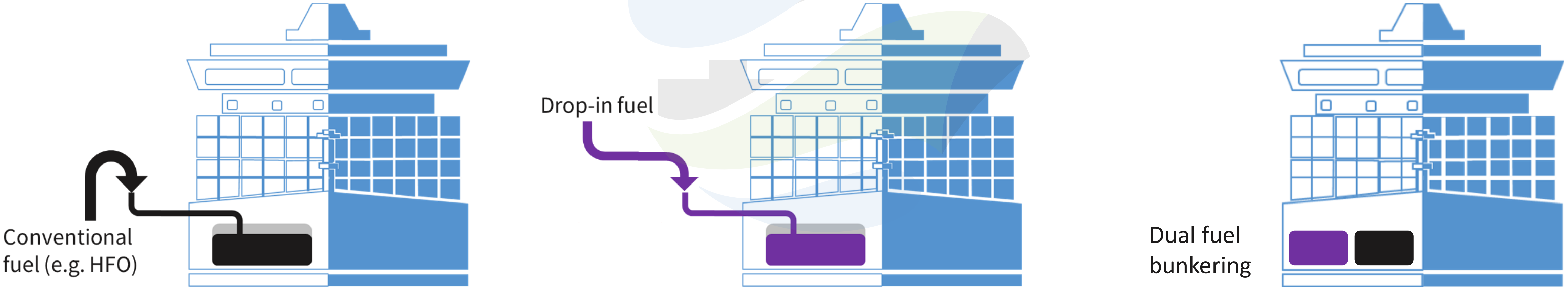
Propulsion (2)

- Engines using new biofuel blends would require certification in accordance with MARPOL Annex VI Regulations. It is likely to be very challenging on a practical level to recertify all engine types that are currently deployed and in-use.

Storage and use | Drop-in biofuels

Biofuel propulsion options

- As discussed in the onboard requirements section, biofuels are a ‘drop-in’ solution (either in pure form or as a blend) and as such they can be used in existing engines, albeit with the potential modifications discussed.



- Dual fuel bunkering can also be used, with separate tanks designated for biofuels and traditional fuels, allowing a vessel to use either option depending on location.
- While using biofuels with existing engines may be technically possible, there are likely to be other barriers or difficulties in doing so, such as the need to recertify engines to use the fuels.
- We will look at these wider barriers later in the session.

Regulations, standards and guidance

Body/Organisation	Documentation	Status/Comment
IMO	MARPOL Annex VI (Regulation 18)	States that any fuel not derived from petroleum refining must not cause engines to exceed sulphur content or NOx emission limits.
European Committee for Standardisation (CEN)	EN 14214 Liquid petroleum products - Fatty acid methyl esters (FAME) for use in diesel engines and heating applications	European standard specification for FAME fuel.
ISO	ISO 8217:2017 Petroleum products — Fuels (class F) — Specifications of marine fuels	Allows up to 7% FAME blend for distillate grades, and extends fuel definition to include hydrocarbon fuels from renewable biomass sources (such as HVO, HTL and pyrolysis fuel oils)

Examples of vessels using drop-in biofuels

Stena Immortal Source: Stena Bulk

~50,000dwt MR tanker operated using 100% advanced biofuel produced from cooking oil and forestry residue feedstocks.

MS For-Ever Source: Interreg Danube

90m inland container vessel trialled with 30%, 50% and 100% blends of advanced biofuel from 'sustainable waste streams'.

MS Polarlys Source: Bioenergy International

Trial of HVO that is 'free of palm oil' in cruise ship (gross tonnage 11,341t, length 123m).

Environmental impacts (GHG emissions)

	HTL fuel oil	Pyrolysis fuel oil	HVO	FAME
Emission reduction drivers	• Hydrogen production method • Feedstock type	• Hydrogen production method • Feedstock type	• Hydrogen production method • Feedstock type (waste oils/fats)	• Feedstock type
Reduction in well-to-wake GHG emissions*	80% to 82%[1]	77% to 80%[2]	53% to 89%[3]	53 to 89%[3]

* per unit energy of fuel, as 100% blends vs RED II Comparator
# considering achievable blending limits and feedstock availability

[1] *E4tech analysis:* De Jong et al. (2015), Short term techno-economic feasibility of renewable jet fuel production. *Excl. transport and distribution and refueling. Feedstock: Forest residues.*
[2] *E4tech analysis: IRENA, 2016. Innovation Outlook: Advanced Liquid Biofuels. Excludes downstream transport and distribution and refueling. Assumed feedstock: Forest residues.*
[3] *RED II typical values for rapeseed (lower bound) and waste cooking oil (upper bound) feedstocks.*

Environmental impacts (air quality)

	HTL fuel oil	Pyrolysis fuel oil	HVO	FAME
Reduction in SOx emissions*	Up to 100% (assuming low sulphur in feedstock)	Up to 100% (assuming low sulphur in feedstock)	100%[1]	99% to 100%[2]
Reduction in NOx emissions*	Uncertain, depends on fuel properties	Uncertain, depends on fuel properties	0% to 20%[1]	0%[2]
Reduction in PM emissions*	~0%[3]	~0%[3]	Generally reduced	Generally reduced

*as 100% blends vs MGO, positive values reflect lower emissions.

[1] ICCT Working Paper 2020-21: The potential of liquid biofuels in reducing ship emissions. Data derived from lab testing.
[2] ICCT Working Paper 2020-21: The potential of liquid biofuels in reducing ship emissions. Data derived from life-cycle assessment modelling.
[3] E4tech analysis

Fuel cost overview

Production route	HTL fuel oil	Pyrolysis fuel oil	HVO	FAME
Key drivers (Expected trend: positive/negative/either)	• HTL CapEx • Hydrogen cost	• Fast pyrolysis CapEx • Hydrogen cost	• Feedstock cost • Hydrogen cost	• Feedstock cost
Current production cost (per GJ fuel)	**51 – 98 USD**	**31 – 45 USD**	**24 – 39 USD**	**20 – 35 USD**
Current production cost vs HFO market price (per GJ fuel)	Additional 38 – 91 USD[1]	Additional 18 – 39 USD[1]	Additional 11 – 33 USD[1]	Additional 7 – 29 USD[1]
Potential cost reduction (% reduction vs current cost)	Up to 72%	Up to 36%	Low	Low

Source: E4tech analysis: IRENA, 2016. Innovation Outlook: Advanced Liquid Biofuels. & ICCT – The potential of liquid biofuels in reducing ship emissions, 2020
[1]: based on HFO market price of 250 – 500 USD/tonne.

Barriers and risks

Category	Barrier / Risk	Rating
Policy	Lack of certainty on future government and inter-government support for biofuels compared to other alternative fuels.	High – ongoing uncertainty can lead to inaction within fuel supply industries.
Commercial/ economic	Volatility or uncertainty of feedstock (and therefore production) costs.	Low (HTL/pyrolysis), high (HVO/FAME) – risk can be mitigated through use of supply contracts, market hedging practices etc.
	Feedstock competition (leading to decreased availability and increased price).	Low (HTL/pyrolysis), high (HVO/FAME) – high risk for parties with long-term contracts but potential to mitigate through actions such as setting clear policies on feedstock use.
	Potentially poor production economics for HTL and pyrolysis routes.	Low/medium – high CapEx and high costs of higher levels of upgrading suitable for higher fuel blends, which has potential to become prohibitively expensive. Given size of upgrading plants that would be required, feedstock unavailability and lack of large offtake contracts are barriers to their deployment at scale.

Barriers and risks

Category	Barrier / Risk	Rating
Regulatory	Existing equipment would require recertification.	Medium – depending on the type and blend, existing engines may need to be recertified to use some biofuel options, which would be challenging on a practical basis. Assurance would need to be sought that engine warranties would not be invalidated.
	Lack of standards for raw or upgraded HTL and pyrolysis fuel oils	Low/medium – standards are of high importance although use of them will be familiar to relevant parties once they are developed.
Sustainability	Significant differences in sustainability impacts between different feedstocks	High – sustainability concerns likely to limit use of some feedstocks in some countries. For other feedstocks, agreed sustainability schemes required to minimize impacts and give confidence

Drop-in biofuels summary (1)

Key points

- With the ability to be used as 'drop-in' fuels or to be blended with existing fossil fuels, biofuels have a **strong potential use case for short-term deployment** to realise net GHG emission reductions quickly.
- The extent to which they can be directly used as drop-in fuels **depends on:**
  - The ability to blend the fuel.
  - In general there is currently a reasonable amount of uncertainty and lack of standardisation surrounding blending limits (e.g. inconsistencies between manufacturers and lack of standards).
  - However, the technical feasibility of using higher blends of some biofuel options is becoming clearer with pilot programmes and trials.
  - Other barriers to short-term deployment, such as practical challenges of recertifying existing engines and the onboard retrofit and adaptation required to use some biofuel types.
- The sustainability of biofuels is **heavily dependent on the type of feedstock** used.

Drop-in biofuels summary (2)

Key points

- Near term biofuels deployment will depend on policy measures to overcome the increased costs of biofuels use.
- In the mid to long term, achieving higher biofuels deployment will rely on continued policy support, as well as reducing conversion costs for HTL and pyrolysis oils, and increasing access to sustainable feedstocks for HVO and FAME.
- There is likely to be competition for oil-based feedstocks for HVO and FAME in the near term, given demands from road transport and aviation. In the longer term, competition could emerge from across the economy for lignocellulosic feedstocks for HVO and pyrolysis oils. It is possible that governments and regulatory bodies may respond to concerns over feedstock competition through intervention or prioritisation efforts, ensuring that feedstocks are used for applications that have the fewest alternative fuel options available, such as aviation.