Bio/Renewable Fuels Technology Development for Wärtsilä

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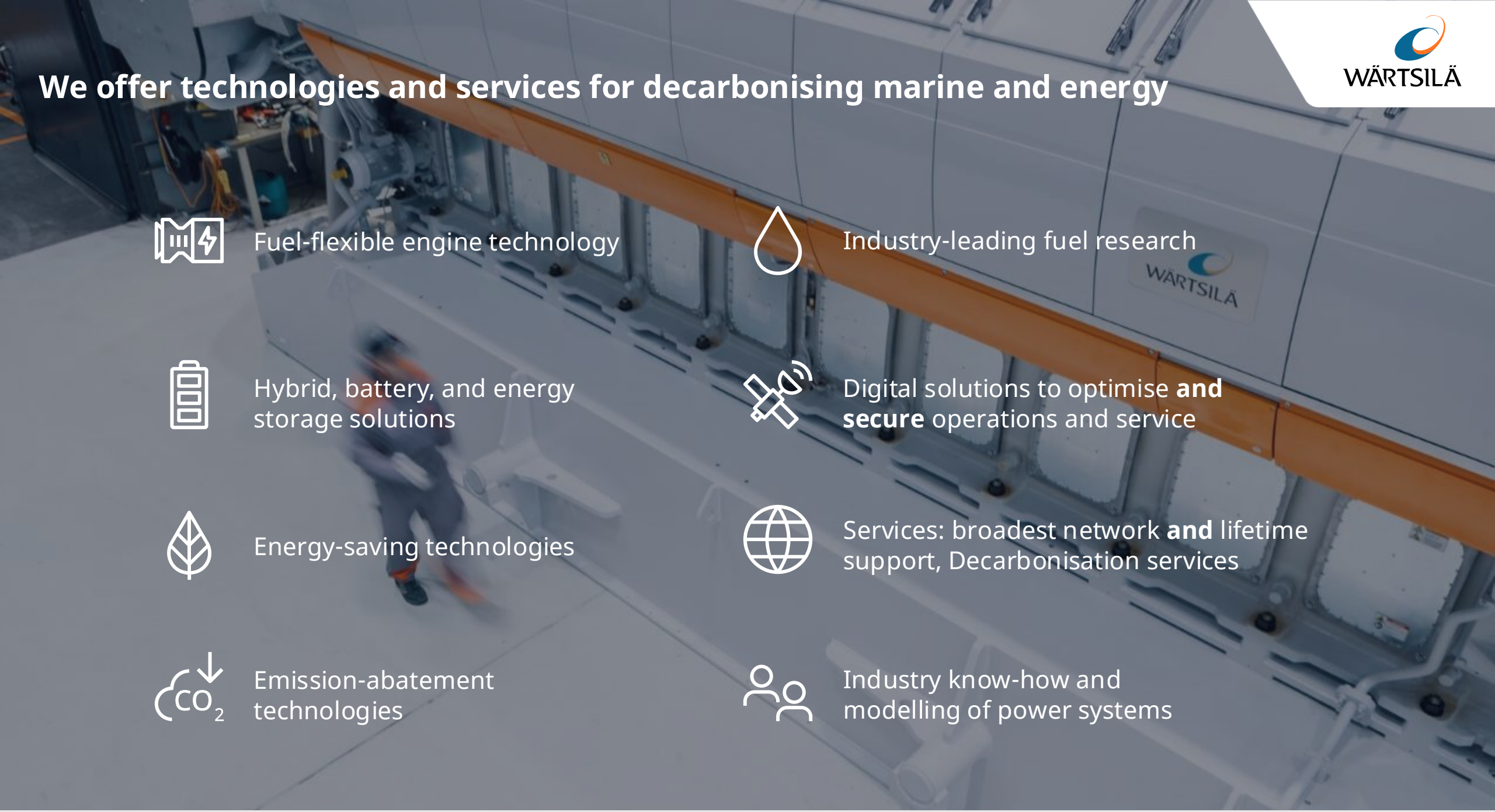
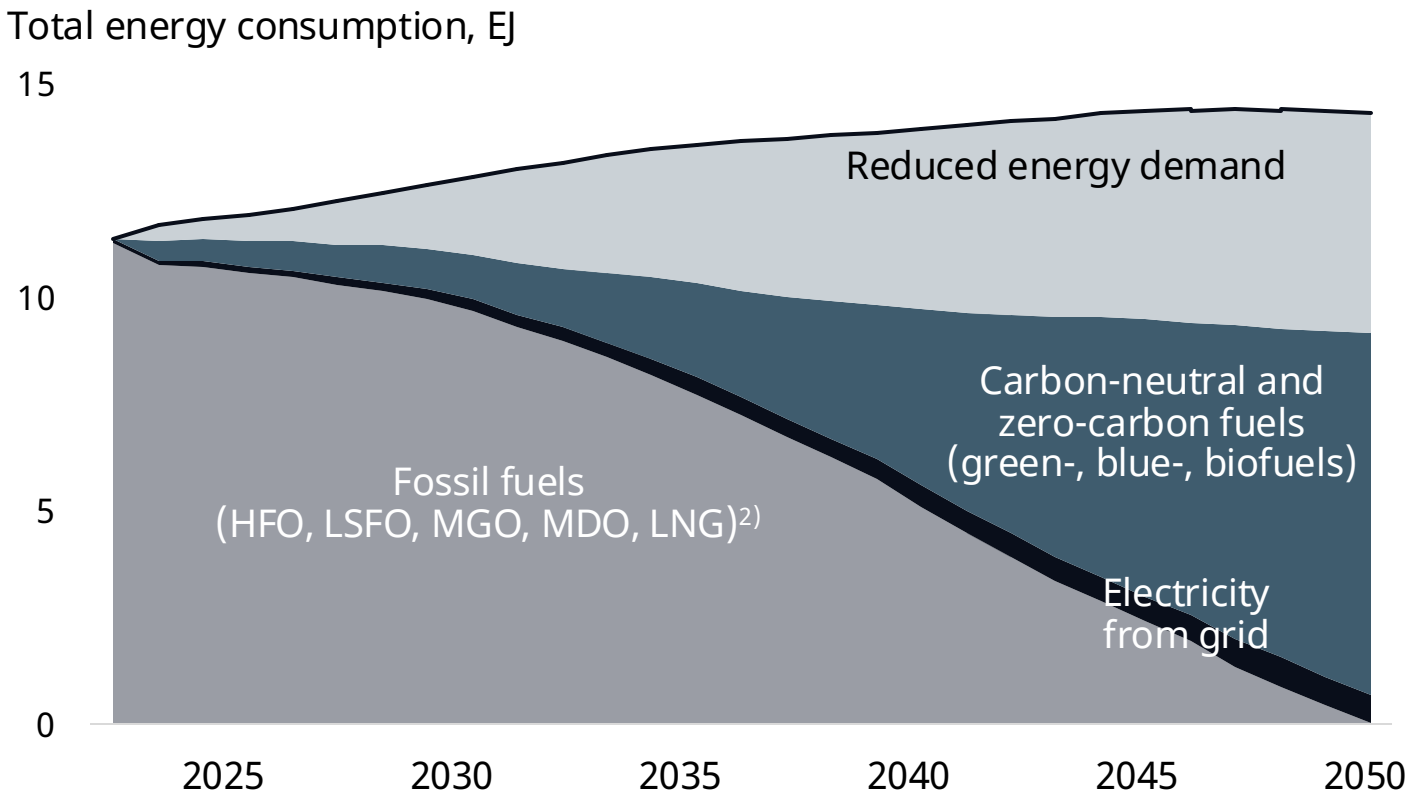
We offer technologies and services for decarbonising marine and energy



- Fuel-flexible engine technology
- Industry-leading fuel research
- Hybrid, battery, and energy storage solutions
- Digital solutions to optimise **and secure** operations and service
- Energy-saving technologies
- Services: broadest network **and** lifetime support, Decarbonisation services
- Emission-abatement technologies
- Industry know-how and modelling of power systems

Our engines can burn fuels regardless of their source, enabling a flexible pathway towards IMO net-zero targets

Sustainable fuel uptake scenario for net-zero in 2050[1)]

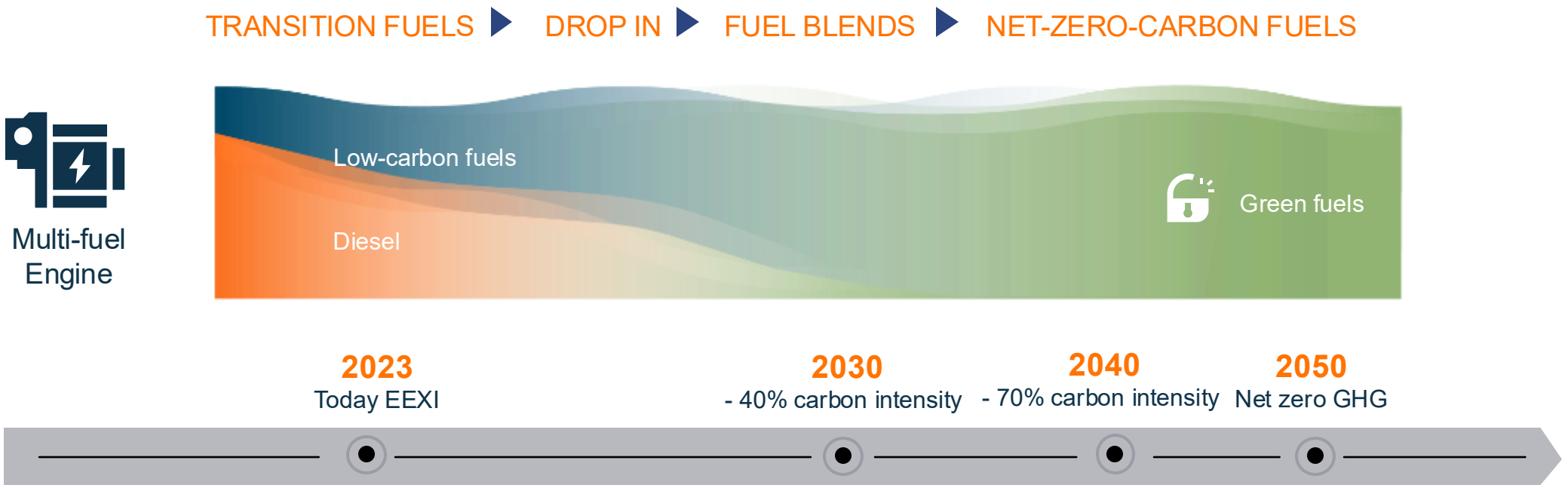


- ✓ **Green fuels**
  Produced from hydrogen made through electrolysis using renewable energy
- ✓ **Blue fuels**
  Produced using fossil fuels, with carbon captured and stored during the fuel production process
- ✓ **Biofuels**
  Produced from non-edible crops or natural products such as wood, or agricultural residues
- ✓ **Blending of fuels**
  Green, blue and biofuels can be blended with fossil fuels for a gradual emission reduction

1) Source: DNV Maritime Forecast 2050; 2) HFO – Heavy Fuel Oil; LSFO – Low Sulphur Fuel Oil; MGO – Marine Gas Oil; MDO – Marine Diesel Oil

Certainty in transition

Infrastructure and availability of green fuels need time to mature - current Wärtsilä multi-fuel technology offer a future proofed upgrade path



Natural gas , LBG , liquid bio-methane

Natural gas: Composition

Example of natural gas composition (Spain)

Methane	91,44 % mole
Ethane	5,35 % mole
Propane	1,22 % mole
Butane	0,41 % mole
Pentane	0,03 % mole
Hexane / heavier HC’s	0,02 % mass
Carbon dioxide	0,54 % mole
Water	0,00 % mole
Nitrogen	0,99 % mole

- Trace amounts of chlorine, fluorine, ammonia, hydrogen sulphide, particles.

- Composition of natural gas can vary significantly depending on natural gas origin and treatment process.

Biogas upgrading

Raw biogas is produced through the breakdown of organic matter in the absence of oxygen, which is referred to as Anaerobic Digestion. (AD)

TYPICAL COMPOSITION:

- 50-70% Methane
- 30-50% Carbon dioxide
- < 0.1% Oxygen
- < 0.1% Nitrogen
- Hydrogen sulphide, water and small amounts / traces of harmful and aggressive elements depending on feedstock.
- NOT a suitable fuel quality for the engines!

Biomethane is produced by separating and cleaning the raw biogas.

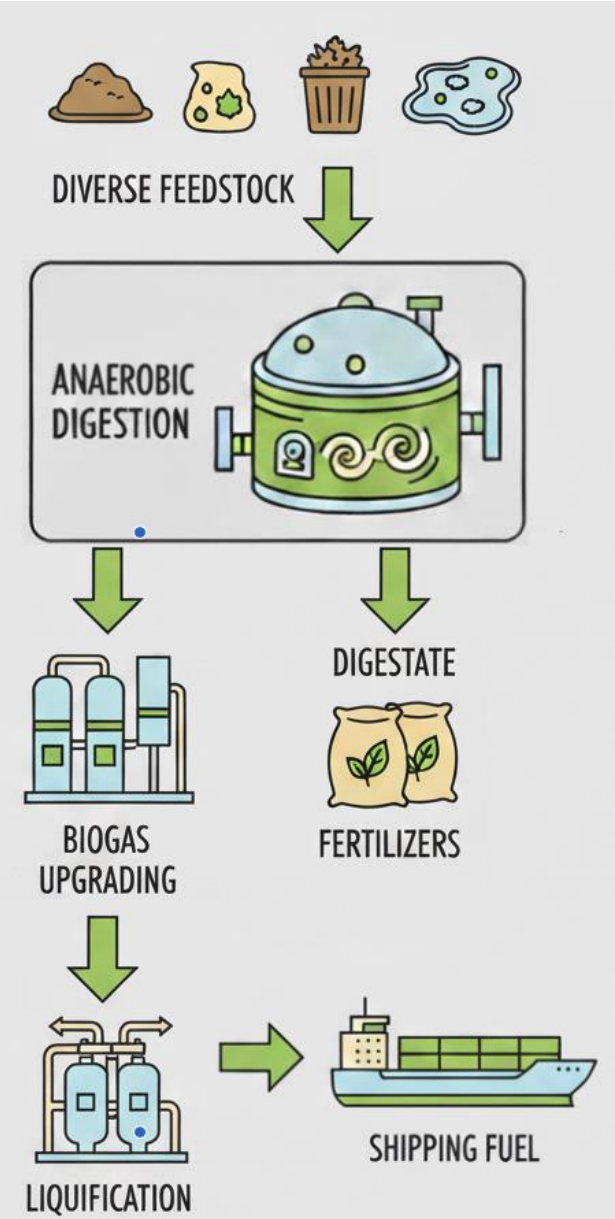
TYPICAL COMPOSITION:

- 99,9% Methane
- 0.1% Carbon dioxide
- < 0.1% Oxygen
- < 0.2% Nitrogen
- < 5mg/m^3 Hydrogen sulphide

- Methane slip during manufacturing process is < 0.1%
- Activated carbon removes H_2S, also other impurities like siloxanes are removed.
- Good gas quality for the engines!

Biogas Pros and Cons

Pros	Cons
+ > 90% GHG reduction	- De-centralised and small-scale production
+ Least harmful fuel for human health, ecosystems, resources and the environment in general	- High initial investment cost
+ Future proof, LNG vessels can transition to bio as it becomes more available	- Feedstock limits
+ Utilise existing LNG infrastructure	- Lack of standards ensuring fuel quality
+ Synergy with local waste management, production can be setup near by ports.	- Retrofit of existing ships CAPEX intensive
	- LNG infrastructure under development



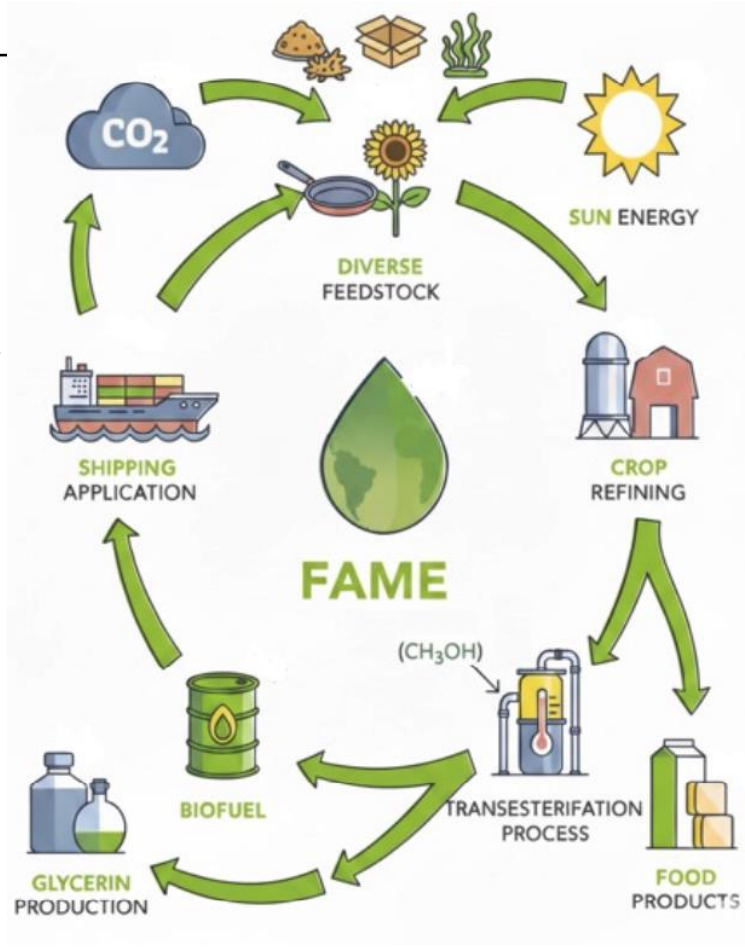
Liquid Biofuels

Liquid bio fuels: General

- Categorization within Wärtsilä
  - Straight (SVO) / pure (PVO) vegetable oils
  - Biodiesel (FAME) and its blends with fossil fuels
  - Paraffinic renewable diesel fuel from synthesis / hydrotreatment (HVO) and blends with fossil fuels
  - Processed fuels belonging to HFO substitutes, like VLSFO/FAME or VLSFO/HVO blends.

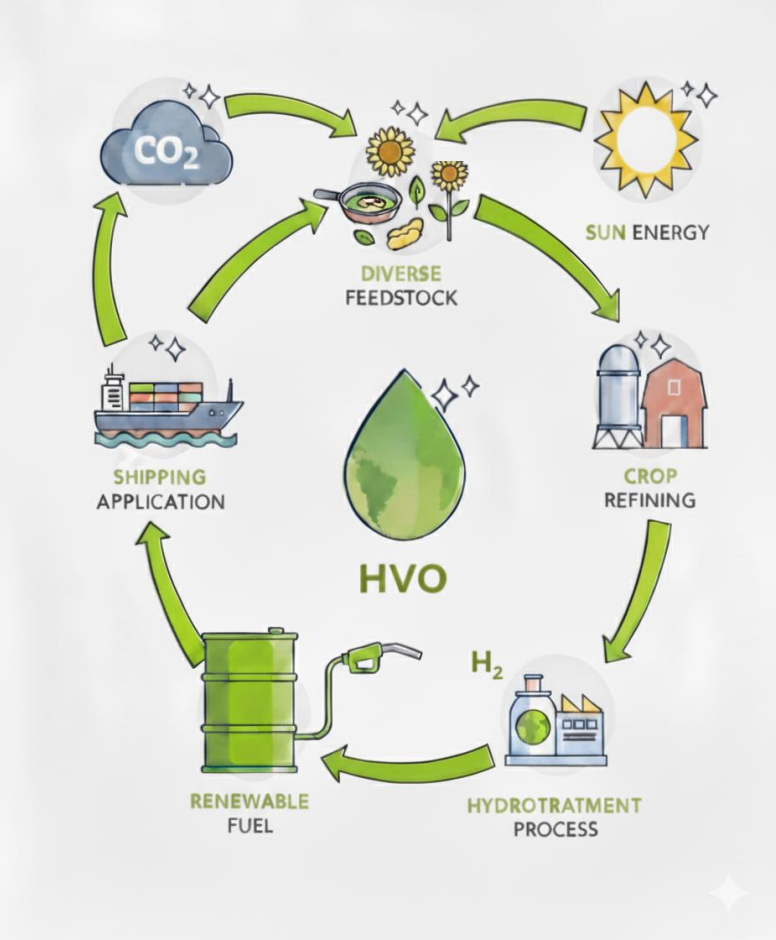
Biodiesel (FAME) : Pros and Cons

Pros	Cons
+ Sulphur oxide emissions close to zero	- Contains less energy (~13%) than fossil diesel
+ Lower particulate emissions	- Water separation from biodiesel is more challenging
+ Reduction in CO_2 emissions (from well to tank)	- Solvent characteristics may degrade rubber and attack certain metals and can lead to loosening of old deposits from fuel system causing e.g. filter clogging. Tank cleaning prior to use to be considered.
+ Biodiesel mixes well with petroleum diesel	- Can foster the risk of microbial activity
+ Can be used in the existing engines w/o modifications	- Long term storage period limited (Acid number increases, oxidation takes place)
+ The EN 14214:2012 standard is available	- Cold flow properties may be a problem (mainly a quality issue)



Renewable diesel (HVO): Pros and Cons

Pros	Cons
+ Sulphur oxide emissions closed to zero	- Flash point limit min. 55 °C SOLAS/ Class require min. 60 °C. Fuel purchaser shall require that flash point of delivered fuel is > 60 °C.
+ Low particulate emissions	- Price higher than FAME
+ Reduction in CO_2 emissions (from well to tank)	- Production volumes still low and competition with other segments
+ HVO mixes well with fossil fuels (HFO & MGO)	
+ Can be used in the existing engines w/o modifications	
+ The EN 15940:2016 standard is available	



Liquid biofuels: Experience

Renewable diesel (HVO)

- Neste My tested in a Laboratory engines
- BioVerno tested in a Laboratory engine.
- Documented long-term field experience does not exist.
- Gas-to-Liquid (GTL) synthetic diesel manufactured with Fischer-Tropsch process is from quality point of view similar compared to Neste My & BioVerno but not a renewable fuel if fossil natural gas is used as a feedstock.

Biodiesel (FAME)

- Biodiesel B100 tested in a Laboratory engine
- Documented long-term field experience for 100% FAME does not exist.
- 5 – 30% biodiesel / fossil diesel blend used in various countries. No big drawbacks recorded so far.

Press releases Ethanol

The Raízen and Wärtsilä study aims to build and implement a fleetwide decarbonisation plan (source: Wartsila)

Partnership aims to expedite ethanol uptake in marine segment

19 Feb 2024 by Riviera News

Brazilian energy firm Raízen and Wärtsilä have signed an agreement to advance bioethanol uptake

MM would use a Wärtsilä 32 ethanol multi-fuel engine in its fleet of platform supply vessel newbuilds (source: CMM)

Deal with Wärtsilä sets stage for first ethanol-powered PSV newbuilds in Brazil

29 Aug 2024 by John Snyder

Brazil's CMM has inked a memorandum of understanding with the Finnish engine maker that will see Wärtsilä 32 multi-fuel engines incorporated in a series of ethanol-powered PSVs

Brazil revolutionizes with a new ethanol plant in Pernambuco and aims for global leadership in the energy transition

Written by Caio Aviz

Published 19/09/2025 às 23:47

Renewable Biofuels

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Aerial view of the Suape 2 Thermal Power Plant, in Pernambuco, where the world's first large-scale ethanol-powered thermoelectric plant will be tested.

Ethanol: A Viable Alternative Fuel Option for Shipping

- **Global Ethanol Production ~100 M tonnes/yr**
  Approximate annual ethanol output worldwide, indicating ample supply potential for shipping.

- **CO_2 Reduction Potential ~80%**
  Lifecycle GHG emission cut using sustainable ethanol vs. fossil marine fuel (on routes like Brazil–Europe).

- **Technology readiness today**
  Existing methanol engines can be easily adapted to burn ethanol, and future engines are being developed for EtOH as primary fuel.

- **Rising interest**
  Until recently, ethanol was largely overlooked in maritime decarbonisation debates, but this is changing

Renewable ethanol: Pros and Cons

Pros	Cons
+ Well-to-wake CO_2 emissions 50–80% reduction with nearly zero SO_x/PM emissions.	- Ethanol has ~40% less energy than traditional marine fuel (but higher than MeOH)
+ Produced worldwide at scale, with established distribution networks and already shipped and stored in many ports	- Fuel Storage & Handling needs special consideration as well as fuel systems and some engine components. (same as for MeOH)
+ Modern dual-fuel methanol engines can run on ethanol with minor modifications	- Ethanol's low flashpoint (~13°C) classifies it as a flammable liquid, requiring special handling.
+ Ethanol industry can scale up production quickly if demanded	- Competes with road transport for supply
+ Lower toxicity and higher energy than methanol	- Ethanol's green benefits depend on feedstock and production methods. There are lingering concerns about **food vs. fuel** and land-use change.

Internal combustion engines will power maritime decarbonisation

Net-zero targets will require a fundamental shift towards sustainable fuels, and multi-fuel engines provide the most flexible pathway