LNG powered ships and Future Fuel Technology

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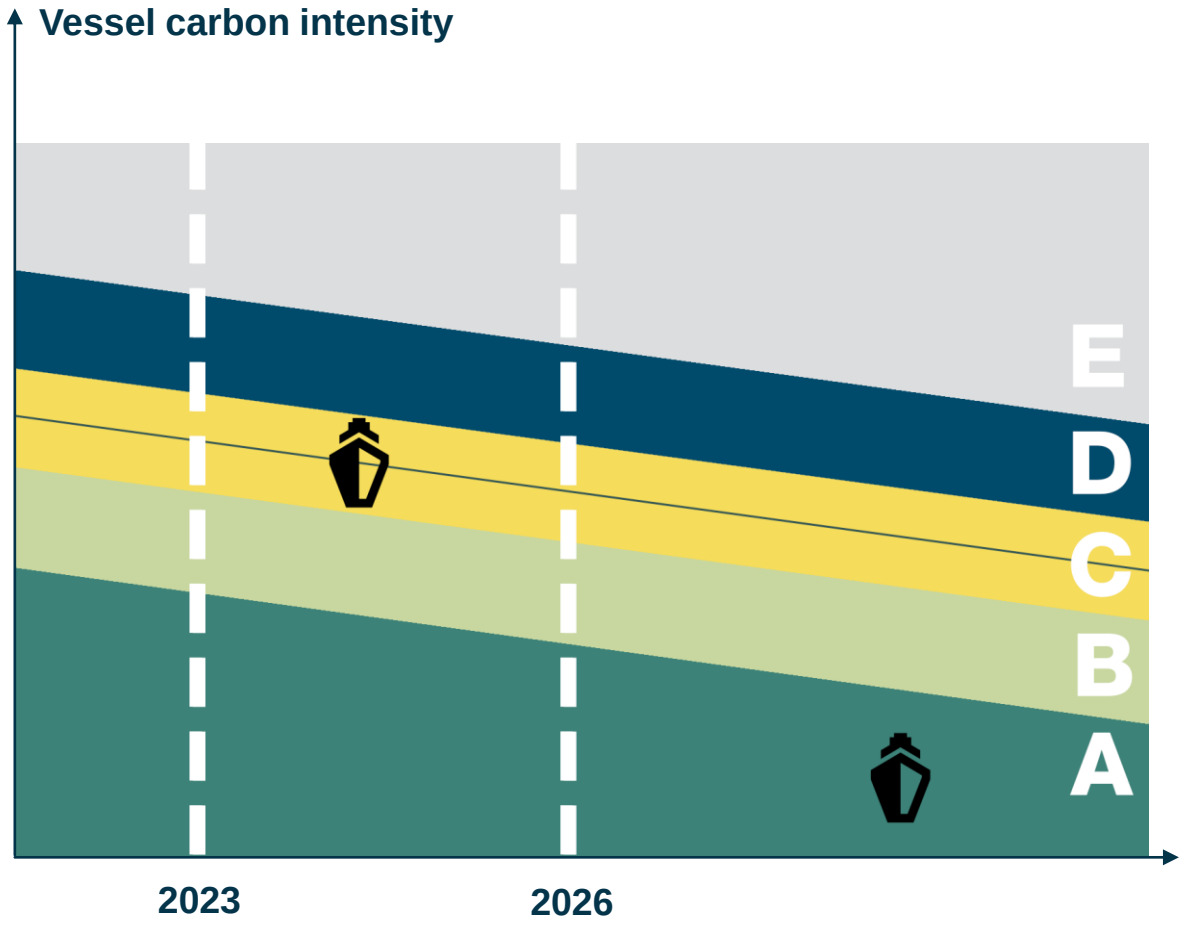
Together, we play a central role in the decarbonisation of the maritime industry

CII introduces to the maritime industry a clear rating framework for differentiating vessels based on their GHG emissions performance



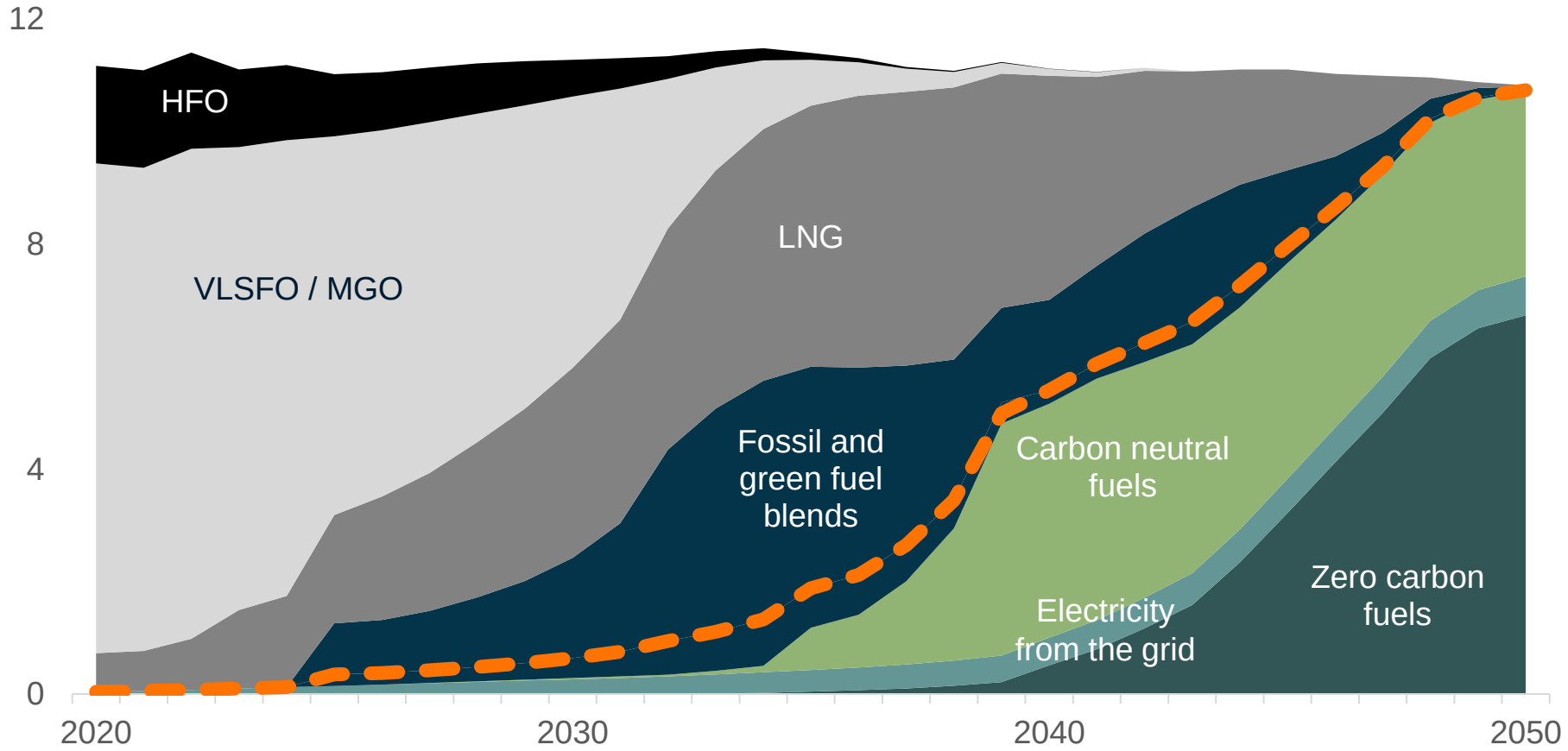
Key takeaways

- CII will **categorise ships from A to E**
- Cargo owners can easily establish their own **requirements on ratings to match own decarbonisation targets**
- If a ship wishes to **remain in the same category it will have to progressively improve GHG performance**

Transition to green fuels will be slow yet relentless. 2050 is a single vessel's lifespan away – customers need to invest in fuel flexibility to avoid risk of stranded assets

Move from a single-fuel industry to a multi-fuel one

Distribution of fuel types for Decarbonisation 2050 (1.5ºC scenario), EJ



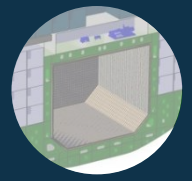
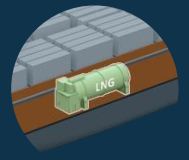
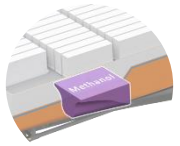
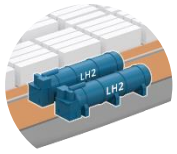
Owners will decide on technology partners now:

- Vessel life is 25-30 years
- Critical decision criteria:
  i) Multifuel capabilities for blending with green fuels
  ii) Conversion capabilities for future fuels

Carbon neutral and zero carbon fuels in maritime

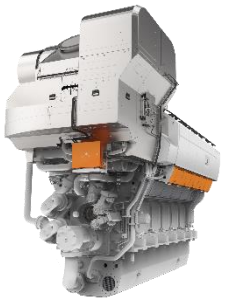
Source: DNV Maritime Forecast 2050 model, Wärtsilä internal estimates

Fuel conversions will play a vital role in the fuel transition for both existing and new vessels built during this and next decade. Fuel selection impacts the vessel structure

Fuel type	 **Heavy Fuel Oil** @ 20°C	 **Liquified Natural Gas** @ -162°C	 **Methanol** @ 20°C	 **Ammonia** @ -33°C	 **Liquid Hydrogen** @ -253°C	 **Compressed Hydrogen** @350bar	 **Marine Battery Rack**
Key considerations	▪ Standard tank arrangement	▪ Cryogenic system	▪ Mildly toxic ▪ Flexible tank arrangement	▪ Toxic ▪ Corrosive	▪ Highly reactive ▪ Cryo system	▪ High pressure ▪ Multiple tanks arrangement	▪ Marine adaptation reduces density
Fuel price factor (per GJ)	1X	0.7X [2)]	2.2X-5.4X [3)]	2.2X-4.5X [3)]	2.7X-4.5X [3)]	1.6X-2.6X [3)]	1.3X-2.3X
	Production cost estimate 2025 [1)]						
Gross tank size factor	1X [4)]	2.4X	1.7X	3.9X	7.3X	19.5X	~40X (future potential ~20X)

1) Sources: Maersk Mc-Kinney Møller Center for Zero Carbon Shipping – Industry transition strategy 2021, Wärtsilä-DNV collaboration; 2) fuel price for e-methane is expected to be in a range similar to e-methanol; 3) fuel price range spans across blue, bio and green-electro equivalent; 4) gross tank estimations based on Wärtsilä experience

Infrastructure and availability of green fuels need time to mature. Multi-fuel technology is the only viable upgrade path



Multi-fuel Engine

Technical Feasibility

Economic Viability

Our technology allows a progressive adoption of green fuels

Transition fuels ▶ **Drop-in** ▶ **Blending** ▶ **100% Pure**

Drop-in

Drop in the tank compatible bio fuels e.g. LNG and liquid bio-methane

Blending

Injecting into the engine different fuels e.g. fuel oil and green ammonia

Best TCO [1)] + **Vessel-long lifespan** + **Upgradability**

- ICE has the **lowest CAPEX**
- ICE has **predictable operational and maintenance costs**
- Independent techno-economic assessments show clearly that ICE has **the lowest TCO [1)] with alternative fuels**

Source: 1) DNVGL Maritime Forecast ed. 2020 and Lloyd's Register Techno-Economic Assessment of Zero Carbon Fuels ed. 2020

Front-runner in alternative fuel engine technology. Our portfolio goes beyond – we power vessels throughout the path towards decarbonization

		2021	2022	2023	2024	2025
Engines	Diesel					
	FAME/HVO[1)]					
	LNG					
	Bio-methane					
	Synthetic methane					
	LPG					
	Hydrogen blends					
	Hydrogen 100%					Technical concept
	Ammonia				Technical concept	
	Methanol					
Electric	Hybrid					
	Full electric				Short sea shipping / inland waterways	
Fuel cells	SOFC, PEMFC [2)]	Technology evaluation ongoing				
Energy saving devices	Propulsion energy saving devices					
	Air lubrication and flettner rotors					
	Other					

Own technology Through partnering Both in house development and partnering

1) FAME, HVO: biodiesel 2) SOFC: solid oxide fuel cell, PEMFC: proton exchange membrane fuel cell

THE NUMBER OF AVAILABLE FUELS WILL INCREASE

Green hydrogen: an essential element in most synthetic fuels. In short-sea shipping with strict emissions legislation and frequent bunker opportunities it can offset low energy density.

Green ammonia: low energy density by volume, feasible for vessels that don't have space limitations. Toxicity may be a challenge for passenger vessels, regulation may have an impact on required investment.

Green methanol: an interesting alternative with easy onboard storage, although fuel prices may be higher due to higher production energy requirements. Low energy density is compensated for by ease-of-storage.

NOTE

Every customer, business operation & region is different, which changes the propensity for various fuels

Green implies a synthetic fuel based on hydrogen produced using renewable energy, or a fuel produced from sustainable biomass

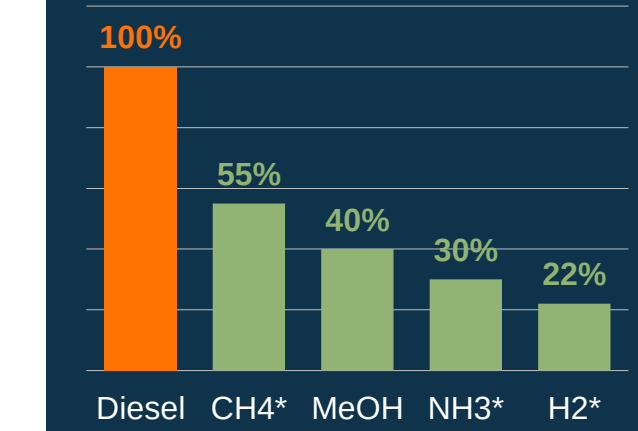
BIOFUELS ARE AVAILABLE TO SOME EXTENT TODAY

Green biomethane: likely the most economical alternative due to maturity of technology, fuel availability, existing rules & regulations, availability of feedstock, and higher carbon efficiency than biodiesel. Can be used as a drop-in alternative to natural gas.

Green synthetic methane: differs from biomethane in its production. It is synthetically produced from green hydrogen & CO2. Due to low concentration of CO2 in air, the only economically viable solution is likely to be CO2 capture from combustion of biofuels.

Biodiesels: (1st & 2nd gen) can be used in diesel engines without additional investment, provided they comply with fuel specifications. Local availability & price are the main challenges, due to competition from other industries ready to pay a premium.

VESSEL-OPERATION RANGE WITH THE SAME FUEL VOLUME & EFFICIENCIES



**in liquid form*

NOTE
The business impact from the need for more bunker space has not been considered. The implications of specific fuels must be investigated together with the customer.

FUEL-FLEXIBLE TECHNOLOGY FOR MOST FUTURE FUELS

Engine type	Diesel	LPG	LNG	FAME/ HVO*	Bio-methane	Hydrogen	Ammonia	Methanol	Synthetic methane
Diesel	●			●			●	●	
DF	●	●	●	●	●	●	●	●	●
SG		●	●		●	●	●		●
GD	●	●	●	●	●		●	●	●
LG	● (MGO only)	●		●			●	●	

● Ready solution

● Industrialisation needed

● Development needed

* FAME, HVO: biodiesel

CONTINUOUS DEVELOPMENT OF TECHNOLOGY

Our future-fuel roadmap

Verified: 2003

CH_4

Bio- or Synthetic Methane

Verified: 2015

MeOH

Methanol

Verified: 2022

NH_3

Ammonia

Verified: 2025

H_2

Hydrogen

FUEL STORAGE & SUPPLY-SYSTEMS FOR MOST FUTURE FUELS

Fuel PAC	Diesel	LPG	LNG	FAME/ HVO*	Bio-methane	Hydrogen	Ammonia	Methanol	Synthetic methane
LNGPac Stainless steel vacuum insulation		●	●		●		● **	● **	●
LNGPac Ni9 Polyurethane insulation		●	●		●				●
LH2Pac						●			
NH3Pac							●		

● Ready solution
● Minor development needed
● Development needed

* FAME, HVO: Biodiesel
** Tanks can be used as a complement, if already installed

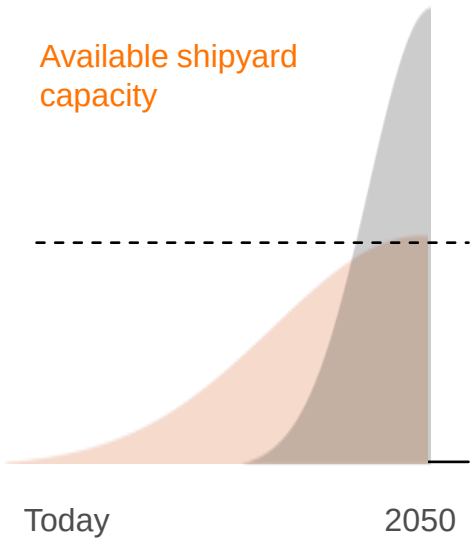
TRANSITION FUELS SUPPLEMENT THE LACK OF GREEN FUELS

- Green synthetic fuels won't be widely available to shipping industry before 2040
- Converting all IMO-class ships to carbon-neutral fuels will take many years due to limited yard capacity
- LNG can reduce GHG footprint by -5 to -21% & enable decarbonisation when mixed with biomethane* or green synthetic methane without changes to the vessel
- Introducing LNG as a transition fuel is the 1st step towards decarbonising shipping

GREEN FUEL
A synthetic fuel produced only with renewable energy or a fuel produced from sustainable biomass

NEEDED CAPACITY

Limited shipyard capacity is a risk factor



*depending on production process & feedstock of specific biomethane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