

TEK Talks - Wärtsilä

Shaping the decarbonisation
of marine and energy

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GM Research Coordination & Funding
Sustainable Fuels & Decarbonisation
Wärtsilä





190 years of innovation

1834

Our story begins when a sawmill is established in a Finnish village, Wärtsilä.

1995

Our pioneering dual-fuel engine can switch between fuels during operation.

2015

Guinness World Records names Wärtsilä 31 as the most efficient 4-stroke diesel engine in the world.

2023

As we stand among TIME's 100 most influential companies, our story continues with world's firsts:

- 4-stroke engine-based ammonia solution for marine.
- Wärtsilä engine runs on 25 vol% hydrogen blend.

1950s

Our first marine engines.

1970s

The first-ever 4-stroke engine operating on heavy fuel oil.

We enter the energy sector.

2012

World's first hybrid system on-board a vessel.

2021

Our first methanol engines.

Uniquely positioned to drive global transformation in our industries

1 in 3 of the world's vessels

are equipped with Wärtsilä solutions. That's over 30,000 ships.

Over 180 countries

where Wärtsilä energy installations provide reliable power.

50% of sales come from services

and 90% of our lifecycle customers renew their service agreement.

A global team of experts fuelling change since 1834



17,800
people



280+
locations



130
nationalities



79
countries



6,015
net sales, MEUR



52%
service sales
of total



Figures from 2023



Accelerating the green transition by identifying environmentally and economically sustainable value chains

Where are we heading and how?

Is regulation a threat or an opportunity for Wärtsilä?

Our decarbonisation targets for 2030

- | Provide a product portfolio which will be ready for zero-carbon fuels
- | Become carbon neutral in our own operations



Håkan Agnevall,
President & CEO

Market forces speeding up decarbonisation of marine and energy



Growing recognition of need for sustainability

- Maritime transports 80% of global trade
- Growing energy demand
- New policies & regulations



Technology development

- Rapid growth of renewables
- Fuel-flexible technologies and sustainable fuels
- Other solutions cutting emissions, such as abatement and battery technology



Increased connectivity & data

- Installations and systems grow in data and complexity
- Holistic optimisation of each system

Decarbonising the energy industry with renewables and balancing power

1
Adding more renewables into the power mix.

Decrease running hours of inflexible power plants.

2
Adding flexible engine power plants & storage to balance the intermittency of renewables.

Continue adding renewables supported by flexibility.

3
Phasing out non-flexible power plants running on coal.

Utilise Power-to-X and flexible balancing engine power plants to provide carbon-neutral long-term storage.

4
Accessing sustainable fuels and converting all remaining power plants to run on them.

5
A 100% renewable energy future is here
It is based on renewables, energy storage, and balancing engine power plants running on sustainable fuels.

Decarbonising the marine ecosystem requires collaboration and connectivity



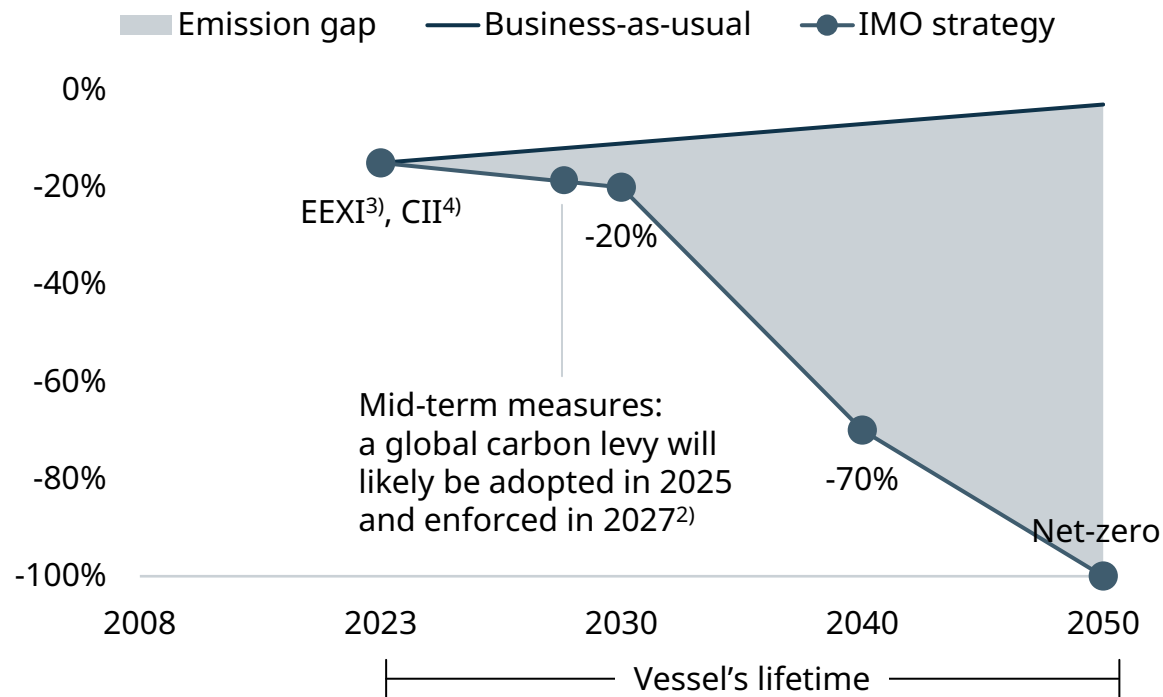
Fuel distributors
Fuel producers
OEMs
Ports
Regulators
Shipyards
Ship financing
Ship operators
Ship owners

After IMO net-zero commitment last year, the regulatory focus has moved to “mid-term measures”

For vessels operating in EU waters, fuel cost may double due to emission fees by 2030, compared to 2023

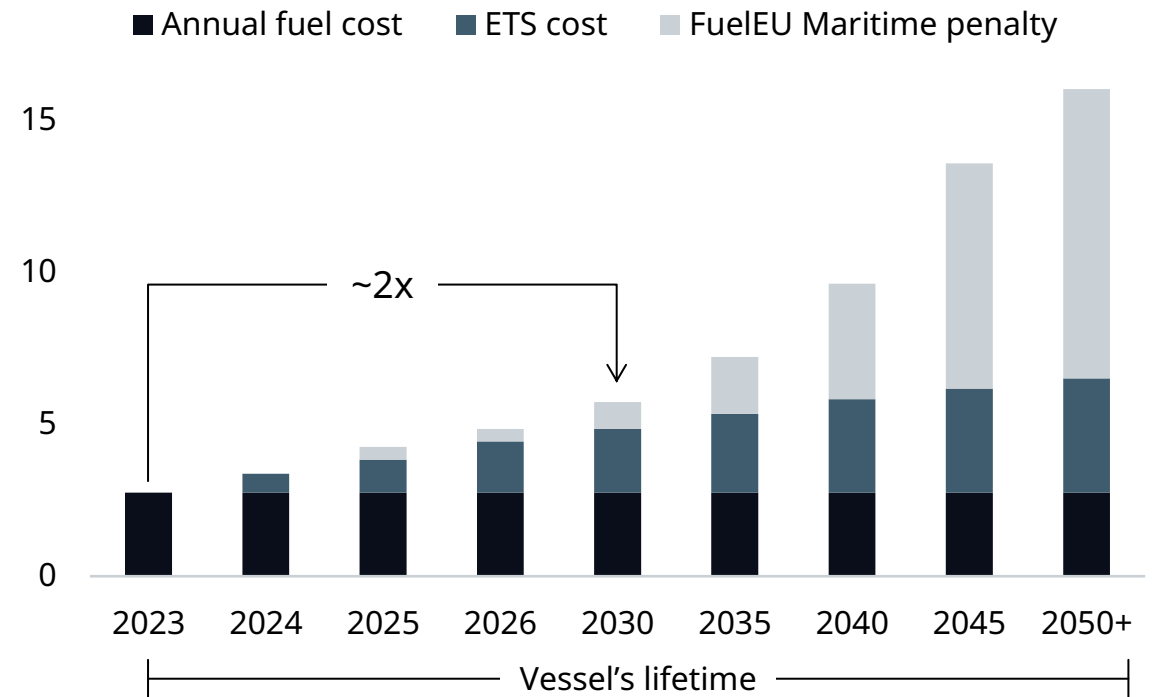
IMO GHG Strategy¹⁾

GHG emission reduction % vs 2008



EU Fit-for-55

Fuel-related costs for Handymax bulker operating in EU, MEUR³⁾



1) Source: IMO; data refers to well-to-wake Green House Gases (GHG) emissions; 2) E.g., goal-based marine fuel standard, GHG emissions pricing mechanism; 3) Assuming 5 000 tons/year VLSFO (Very Low Sulphur Fuel Oil) consumption subject to EU Fit-for-55, VLSFO at EUR 550/ton; EU ETS allowances from EUR 100/ton today to EUR 230/ton in 2050 (source: Transport & Environment NGO)

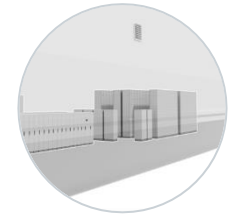
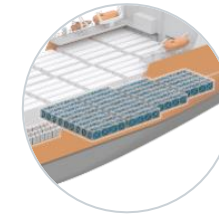
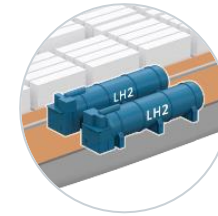
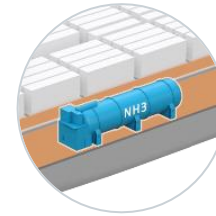
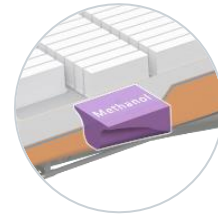
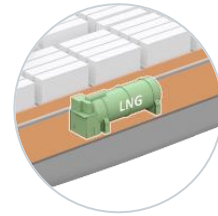
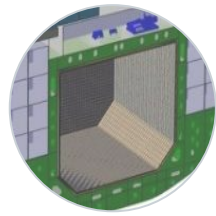
Decarbonisation can be reached through different pathways; net-zero targets will require a fundamental shift towards sustainable fuels

Decarbonisation pathways

Burn less fuel ¹⁾		Clean up emissions ¹⁾	Use alternative energy sources	
Vessel efficiency	Operational efficiency	Emission abatement	Sustainable fuels	Electrification
<ul style="list-style-type: none"> Reduction of GHG emissions and fuel cost E.g., energy efficiency improvement of engine, propulsion, hull, other systems 	<ul style="list-style-type: none"> Reduction of GHG emissions and fuel cost E.g., speed reduction, route optimisation, onboard energy management 	<ul style="list-style-type: none"> Significant reduction of GHG emissions through onboard carbon capture, regardless of the fuel CO2 offloading infrastructure, onboard storage and value chain needed 	<ul style="list-style-type: none"> Significant / total reduction of GHG emissions Technology available; infrastructure and supply under development 	<ul style="list-style-type: none"> Zero GHG emissions through battery-electric propulsion Viable on short ranges due to low energy density
Approximate greenhouse gas (GHG) emission reduction potential				
25%		70%	100%	100%

1) These pathways shall be combined with the utilisation of alternative fuels to support long term IMO targets

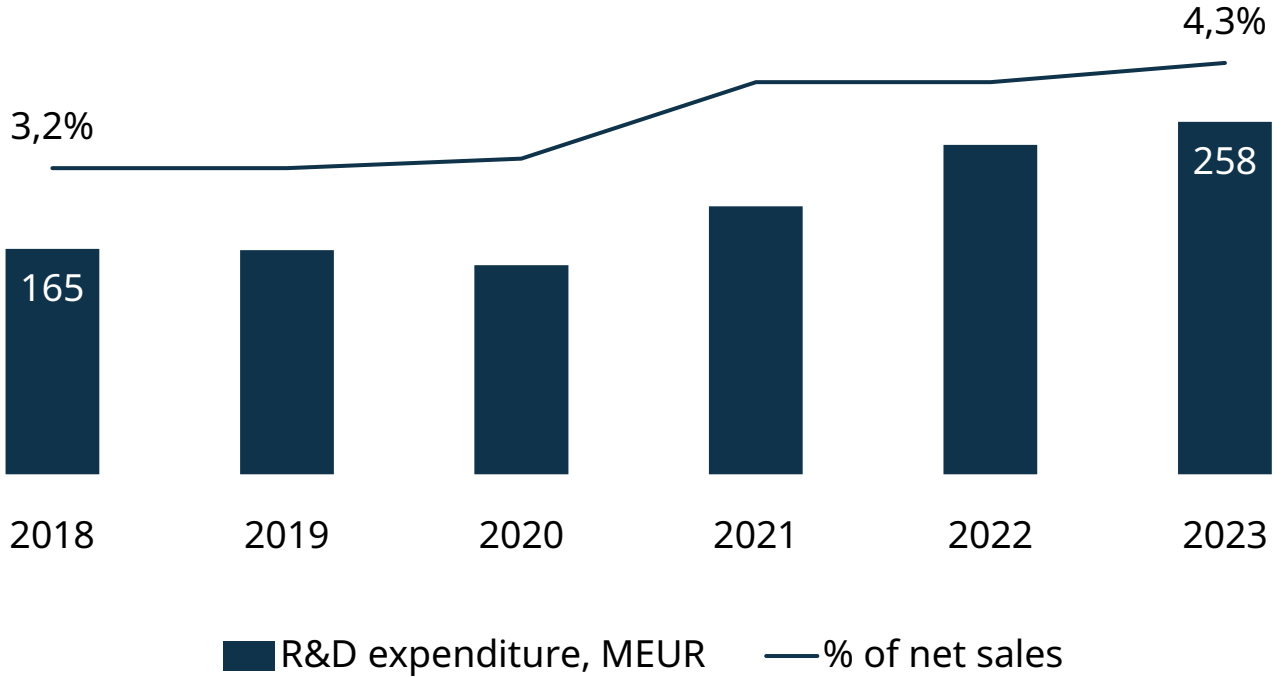
Cost of emissions will close the price gap between fossil and sustainable fuels; fuel selection impacts the vessel structure



Fuel type	Low Sulphur Fuel Oil @ 20°C	Liquefied Natural Gas @ -162°C	Methanol @ 20°C	Ammonia @ -33°C	Liquid Hydrogen @ -253°C	Compressed Hydrogen @ 350bar	Marine Battery Rack
Fuel price factor (per GJ) ¹⁾	1x	1.1x – 4.6x ²⁾	2.6x – 5.5x ³⁾	2.4x – 4.3x ⁴⁾	3.6x – 4.6x ⁴⁾	2.1x – 3.1x ⁴⁾	2.0x – 5.3x ⁸⁾
Fuel price factor in 2035, incl. carbon tax ^{1) 5)}	1x	0.8x – 1.4 ²⁾	0.8x – 1.6x ³⁾	0.7x – 1.2x ⁴⁾	1.2x – 1.5x ⁴⁾	0.6x – 1.0x ⁴⁾	0.8x – 2.0x ⁸⁾
Gross tank size factor ⁶⁾	1x	1.7x – 2.4x ⁷⁾	1.7x	3.9x	7.3x	19.5x	~40x (~20x potential)

1) Fuel production cost estimate for 2025 and 2035; source: Maersk Mc-Kinney Møller Center for Zero Carbon Shipping – NavigaTE 2023; 2) Price range spans between fossil & electro- methane; 3) Price range spans between bio- & electro- methanol; 4) Price range spans between blue- & electro- ammonia/hydrogen; 5) Assuming 100% consumption subject to EU Fit-for-55, EU allowances at EUR 159/ton (source: Transport & Environment NGO); 6) Gross tank estimations based on Wärtsilä data; 7) 1.7x membrane tanks, 2.4x type C tanks; 8) Shore energy price EUR 0.1-0.27/kWh

To support our decarbonisation technology development, we increased our R&D spending from historical average of ~3% of net sales to ~4%



~2,900
patents and applications
since 2013

43%
of which are classified as
technologies that reduce or
eliminate GHG emissions

Which are the energy converters of the future?



We develop our engine technologies in four R&D facilities located in Europe

Sustainable Technology Hub, Vaasa, Finland

- Top level research laboratories
- University collaboration
- Integrated with production and services remote monitoring

Turku, Finland

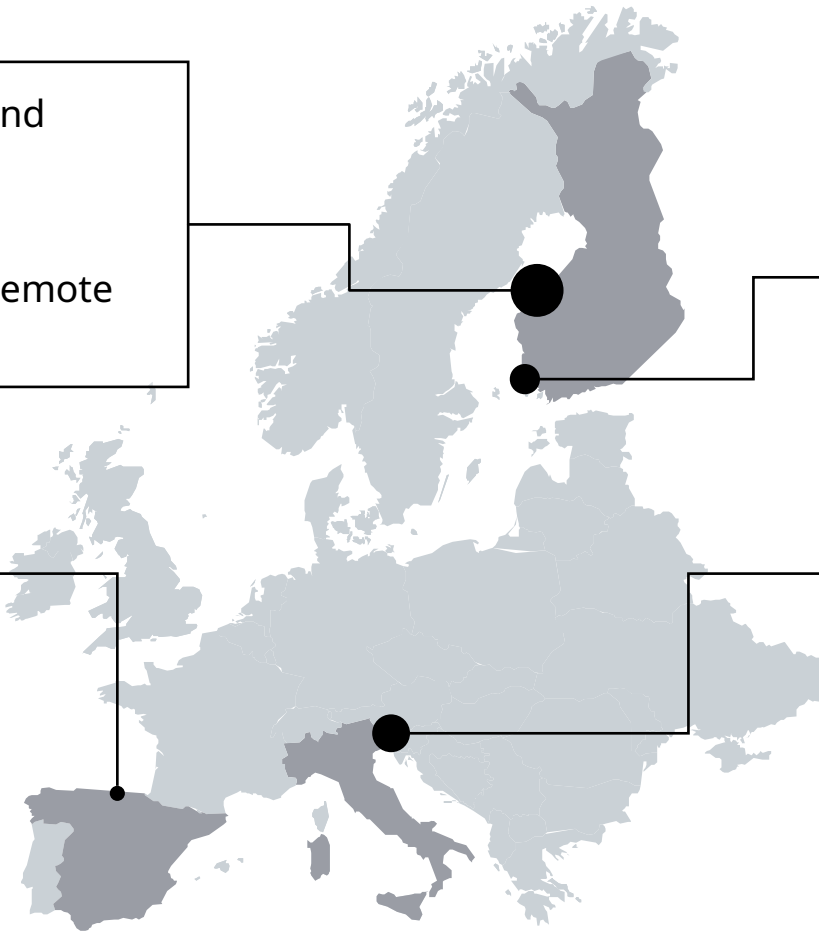
- University collaboration
- Connection to marine cluster

Bermeo, Spain

- Top level hydrogen test facility
- Gas pipeline connection
- Local funding for energy production

Trieste, Italy

- 2-stroke engines testing
- University collaboration
- Connection to marine cluster



STH

This is Sustainable Technology Hub

Welcome to an ecosystem of collaboration



Wärtsilä Sustainable Technology Hub in Vaasa Finland

- Hub for decarbonizing Marine and Energy
- 3400 employees
- 90 000 m2 brand new facility with state of the art modern technology development, testing and production equipment
- Energy self-sufficient building, ready for carbon neutrality
- R&D Centre for future fuels and 4-stroke engines
- Services; Remote monitoring centre, Technical Services, Training centre
- The heart of the Energy Vaasa ecosystem
- Partner campus to facilitate open innovation with customers, partners, academia (ZEM and WISE Veturi programs etc.)
- 1,000 monthly visitors

Approx 50

nationalities represented among personnel

99%

of manufacturing for export

3,400+

employees



Innovation and R&D investments as change drivers

€260 m R&D investment

representing 4.3% of our net sales.

2,900 patents & applications

of which 43% are classified as technologies that reduce or eliminate GHG emissions (since 2013).

> 1,000 ideas & inventions

from our colleagues through the internal innovation program.

Two Veturi programs on-going

(ZEM = Zero Emission Marine and WISE = Wide Intelligent Sustainable Energy)



We lead in fuel flexibility and fuel efficiency, having the industry's most comprehensive offering for alternative fuels

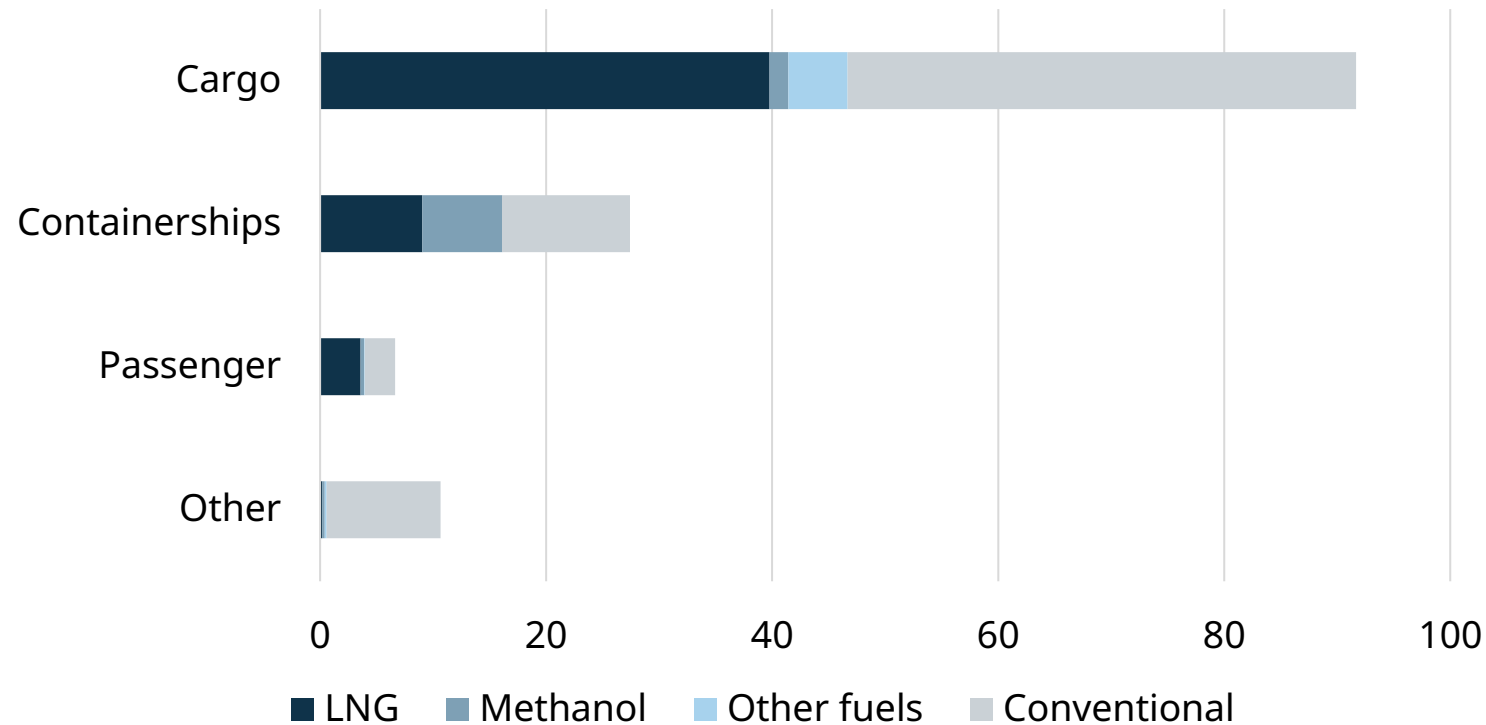
	Fuels ¹⁾	2015	2022	2023	2024	2025
LNG	LNG Diesel	Over 15 years of experience on field in Marine, over 30 years in Energy				
Methanol	Methanol Diesel	▪ First retrofit	▪ Sales release	▪ First delivery		
Ammonia	Ammonia Diesel			▪ Sales release		▪ First delivery
Hydrogen	Hydrogen	15% ²⁾ hydrogen blends possible on LNG DF engines				▪ 100% hydrogen ³⁾
Fuel supply system		Over 13 years of experience on field in LNGPac		▪ MethanolPac first delivery ▪ AmmoniaPac sales release		▪ AmmoniaPac first delivery



Timeline may be subject to change based on market demand and other factors; hydrogen technology development (both blending and pure hydrogen) is ongoing, with focus on Energy market; 1) Multi-fuel engines can switch seamlessly between alternative and conventional fuels anytime; all fuels can be fossil, bio or synthetic; 2) Based on fuel volume; 3) Technology concept

Across the markets, LNG is still the most popular alternative fuel choice, followed by methanol; uncertainty remains over long-term fuel mix

Fuel uptake by segment, mCGT on orderbook



~50%

of total shipbuilding orderbook is set to run on alternative fuels

~55%

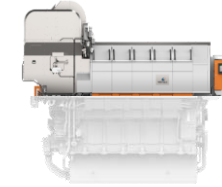
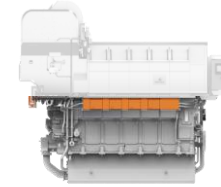
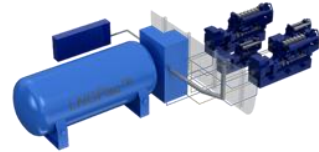
of passenger vessels are set to run on LNG

~60%

of containerships on orderbook are alternative fuel capable, out of which ~45% are set to run on methanol

Source: Clarksons Research May 2024, vessels above 2000 GT; mCGT = Compensated Gross Tonnage, millions; 'Other fuels' includes ammonia, biofuels, ethane, LPG, hydrogen and nuclear; hydrogen fuel cell pilots not included; segment 'Other' includes offshore, fishing vessels, dredgers, yachts, tugs, etc.

Our engines have built-in upgradability to future fuels, with significant part commonality between different fuel versions and a modular design



LNG DF ¹⁾ engine to run on:	Fuel System	Engine base	Engine top
▪ Bio/Synthetic diesel	▪ No changes	▪ No changes	▪ No changes
▪ Bio/Blue/Green methane	▪ No changes	▪ No changes	▪ No changes
▪ Ammonia	▪ Replace with AmmoniaPac	▪ No changes	▪ Change fuel injection system and power pack ²⁾
▪ Methanol	▪ Replace with MethanolPac	▪ No changes	▪ Change fuel injection system and power pack ²⁾
▪ Hydrogen blend ³⁾	▪ Move to alternative fuel handling system	▪ No changes	▪ No changes

↓

Replacement of fuel handling and storage system has bigger impact in terms of CapEx, cargo space and vessel range

↓

Upgrading a multi-fuel engine to a new fuel requires limited investment thanks to high modularity and part commonality

1) DF – Dual Fuel; 2) I.e., piston, cylinder liner, connecting rod; 3) Up to 15% on fuel volume

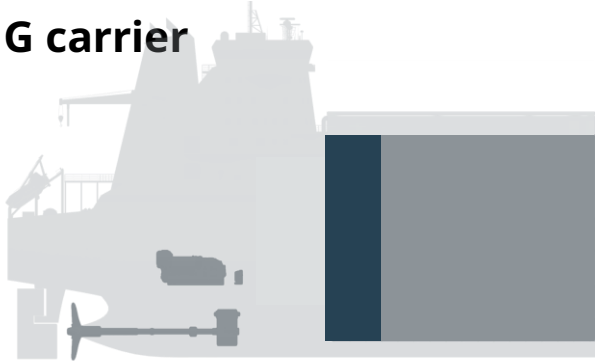
Hybrid-Electric will challenge 2-stroke as prime-mover for LNG carriers, enabling higher efficiency and increased cargo capacity

Wärtsilä Hybrid-Electric LNG carrier

~185k cbm capacity

3x 4-stroke spark-gas gensets
2x 4-stroke dual fuel gensets
2 MWh batteries

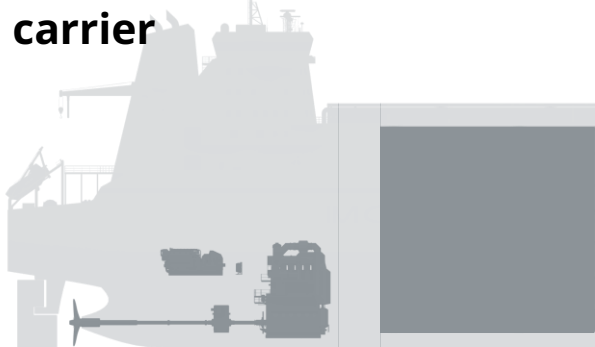
■ Extra cargo capacity



Conventional 2-stroke LNG carrier

174k cbm capacity

2x 2-stroke main engines
4x 4-stroke aux engines



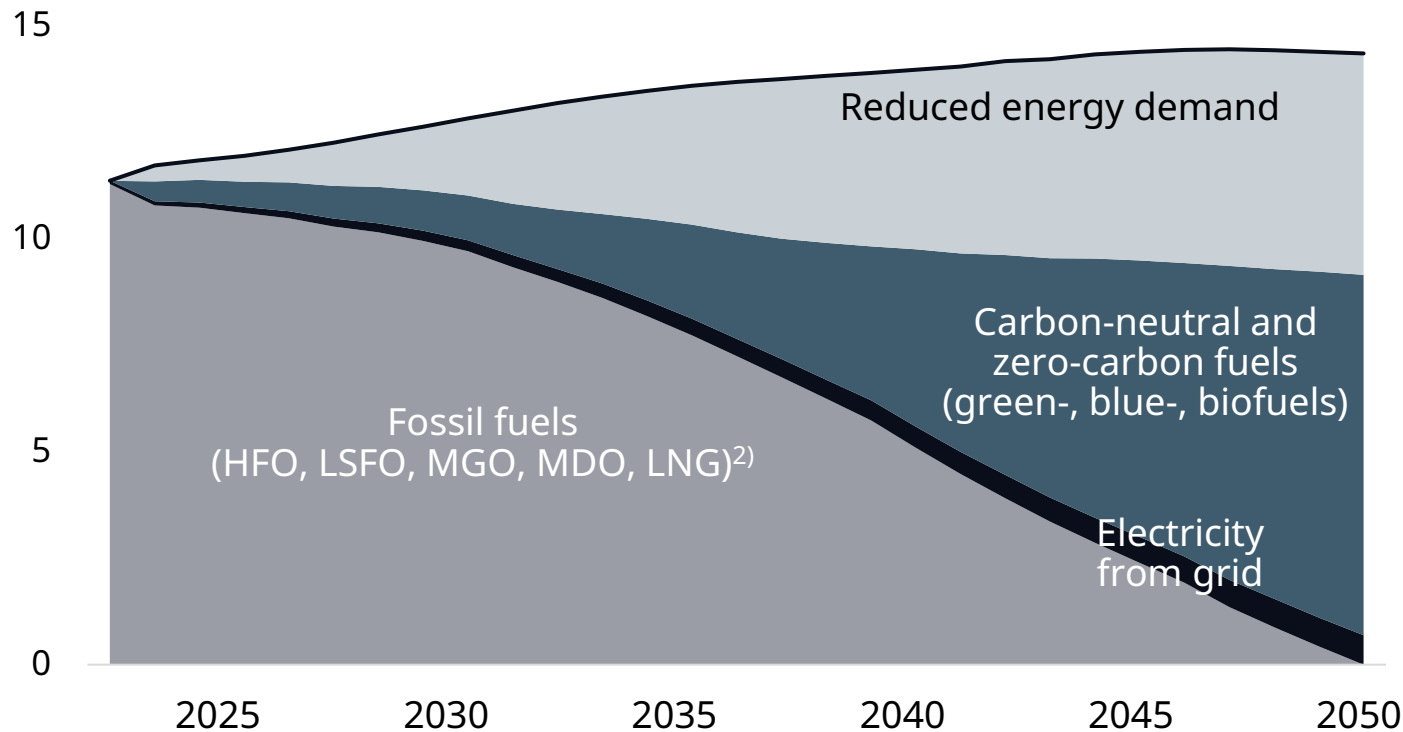
- ✓ **Launched at Gastech in 2023**
with Shell and Hudong-Zhonghua Shipbuilding
- ✓ **6% extra cargo capacity**
with same ship dimensions
- ✓ **>10% lower fuel consumption and emissions**
with optimal efficiency across all speeds
- ✓ **20% lower maintenance costs**
with fewer engine running hours
- ✓ **Superior redundancy, uptime, flexibility**
as it can operate with fewer engines
- ✓ **Future proof**
as it can integrate alternative power sources

Values refer to a comparison with a conventional 174k cbm LNGC (2x 2-stroke low pressure DF main engines, 4x 34DF 4-stroke aux engines), calculated on full year cycle real operating profile with average speed of 15 knots in laden and 13.5 knots in ballast; cargo increase confirmed by Hanwa Ocean and Hudong-Zhonghua shipyards in their general arrangements and outline specifications

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 2050¹⁾

Total energy consumption, EJ



- ✓ **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

LNG is a mature fuel, with ~2,000 ships in services and on order

✓ Pros

- Safe to use, proven technology
- ~20% reduction on tank-to-wake GHG emissions vs Heavy Fuel Oil (HFO)
- No need for aftertreatment to reach Nitrogen Oxides (NOx) Tier III compliancy
- Very low Sulphur Oxides (SOx) and Particulate Matter (PM) emissions

✓ Cons

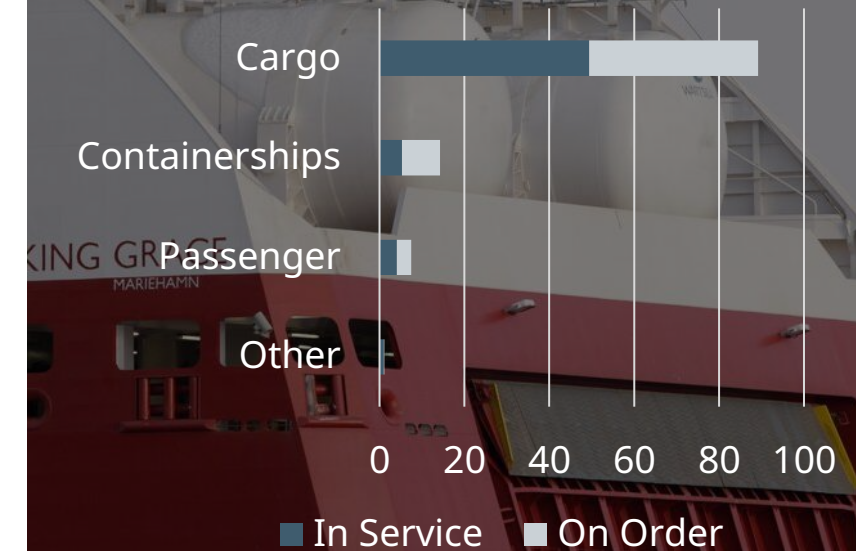
- Methane slip

✓ Wärtsilä positioning

- 15+ years of experience in Marine
- Complete offering from fuel supply system to engine

1) Source: Clarksons, May 2024, vessels >2000 GT; mCGT = Compensated Gross Tonnage, millions; 'Cargo' includes gas carriers; 'Other' includes offshore, fishing vessels, dredgers, yachts, tugs, etc.; 2) Fuel production cost estimate for 2035; source: Maersk Mc-Kinney Møller Center for Zero Carbon Shipping – NavigaTE 2023; 3) Assuming 100% consumption subject to EU Fit-for-55, EU allowances at EUR 159/ton (source: Transport & Environment NGO); 4) Price range spans between fossil and electro- methane; 5) Estimations based on Wärtsilä data; 6) 1.7x membrane tanks, 2.4x type C tanks

LNG uptake by segment, mCGT¹⁾



LNG vs. Low Sulphur Fuel Oil

Fuel price factor in EU in 2035²⁾³⁾

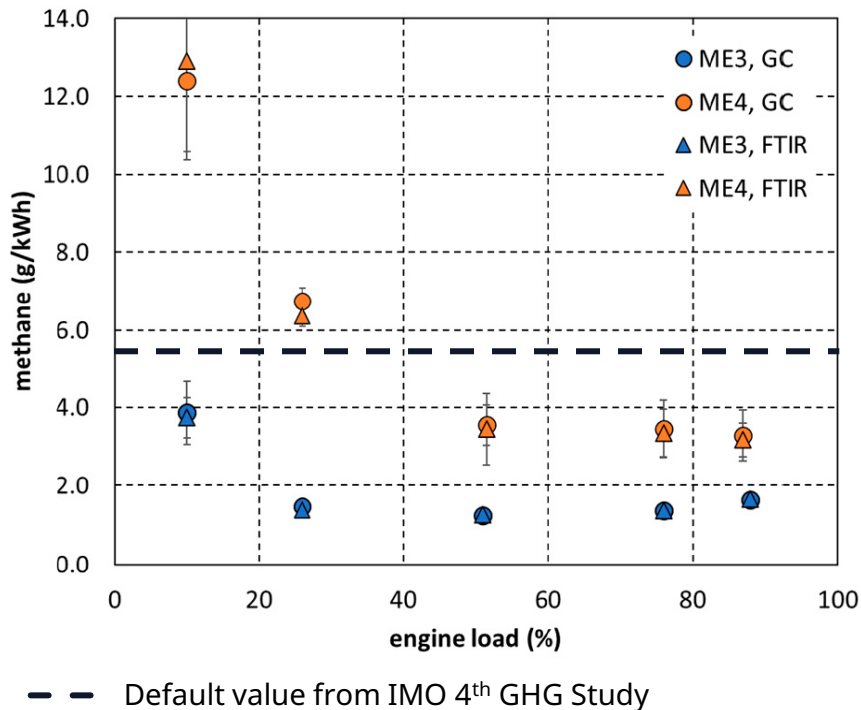
0.8x – 1.4⁴⁾

Gross tank size factor⁵⁾

1.7x – 2.4x⁶⁾

Independent third-party measurements show that we are well below default methane slip values defined in regulations

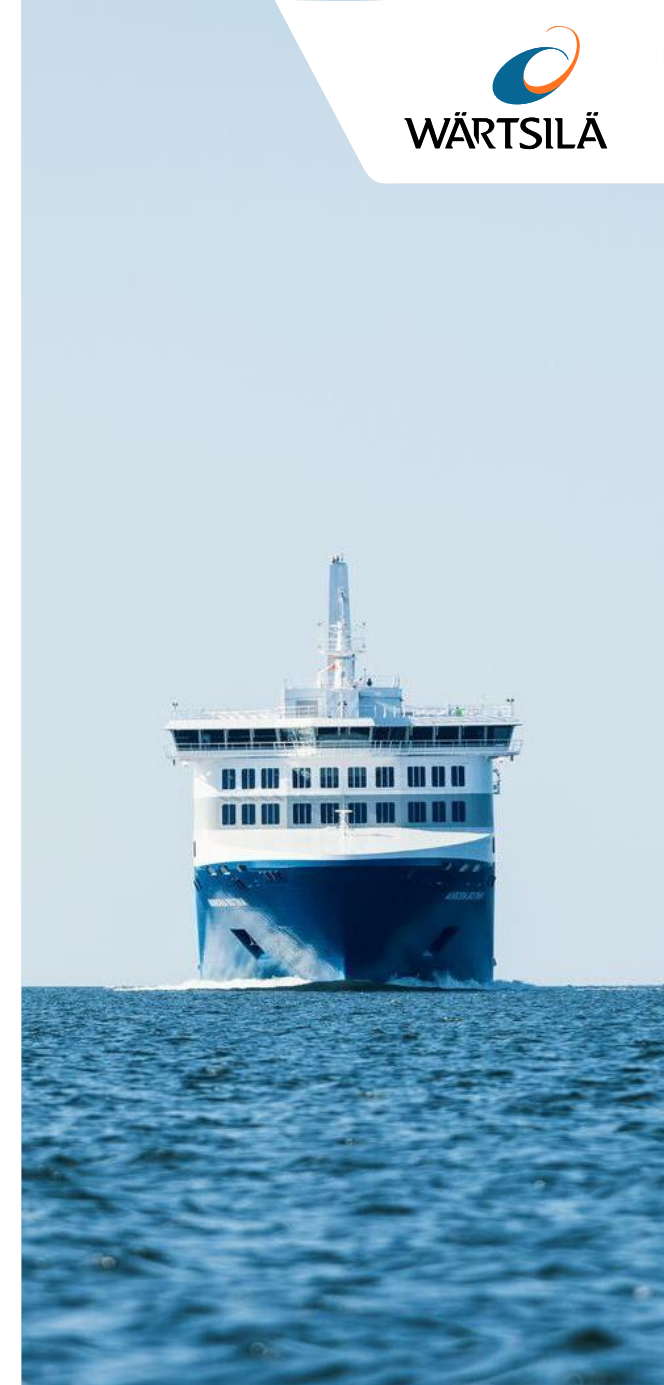
Measurement results¹⁾



State of the art technology

- Standard Wärtsilä 31DF has methane emission clearly below the default factors of recent EU regulations and IMO LCA²⁾ guidelines, which is based on the 4th IMO GHG study
- Wärtsilä has introduced a new ultra-low emissions version of its already efficient Wärtsilä 31DF engine, the EnviroPac
- Whilst operating on LNG, this new version can further reduce methane emissions on a 50% load point by up to 56% and nitrogen oxide (NOx) by up to 86%
- On a weighted average, this new technology can reduce methane emissions by 41% more than the standard Wärtsilä 31DF engine, which has already the lowest emission levels on the market

DF = Dual Fuel; ME = Main Engine; 1) Methane emissions measured as a function of engine load with Gas Chromatography (GC) and Fourier Transform InfraRed spectroscopy (FTIR); ME3 – standard 31DF engine, ME4 – 31DF with EnviroPac; error bars show the standard deviations; source: third-party peer-reviewed scientific article, [Atmosphere 2023, 14\(5\), 825](#); 2) IMO Guidelines on Life Cycle GHG Intensity of Marine Fuels

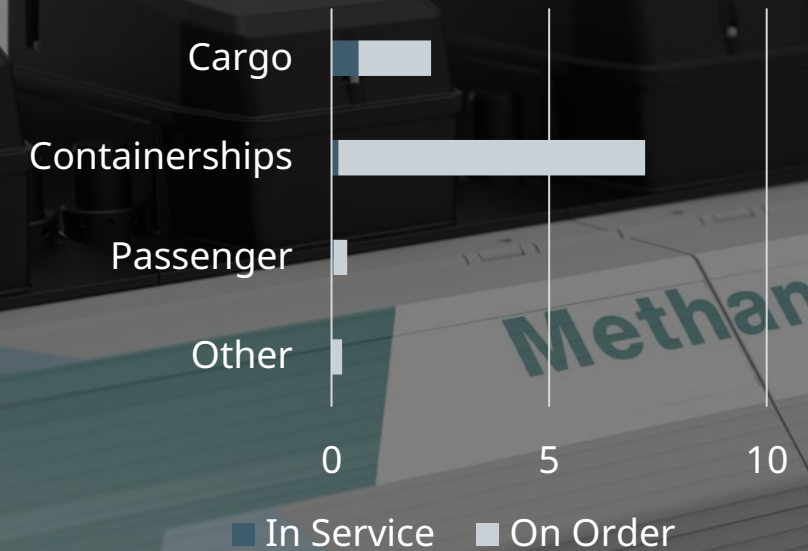


Methanol has rapidly become the preferred choice for containerships and is expanding to other sectors

- ✓ **Pros**
 - Fuel handling simpler than LNG
 - Very low Sulphur Oxides (SOx) and Particulate Matter (PM) emissions
 - Retrofit potential: easier engine and less costly conversion than LNG
- ✓ **Cons**
 - Toxic and flammable
 - Aftertreatment needed to reach Nitrogen Oxides (NOx) Tier III compliancy
- ✓ **Wärtsilä positioning**
 - Pioneer in methanol engines market
 - >160 engines sold to date

1) Source: Clarksons, May 2024, vessels >2000 GT; mCGT = Compensated Gross Tonnage, millions; 'Cargo' includes gas carriers; segment 'Other' includes offshore, fishing vessels, dredgers, yachts, tugs, etc.; 2) Fuel production cost estimate for 2035; source: Maersk Mc-Kinney Møller Center for Zero Carbon Shipping – NavigaTE 2023; 3) Assuming 100% consumption subject to EU Fit-for-55, EU allowances at EUR 159/ton (source: Transport & Environment NGO); 4) Price range spans between bio- and electro- methanol; 5) Gross tank estimations based on Wärtsilä data

Methanol uptake by segment, mCGT¹⁾



Methanol vs. Low Sulphur Fuel Oil

Fuel price factor in 2035²⁾³⁾

0.8x – 1.6x⁴⁾

Gross tank size factor⁵⁾

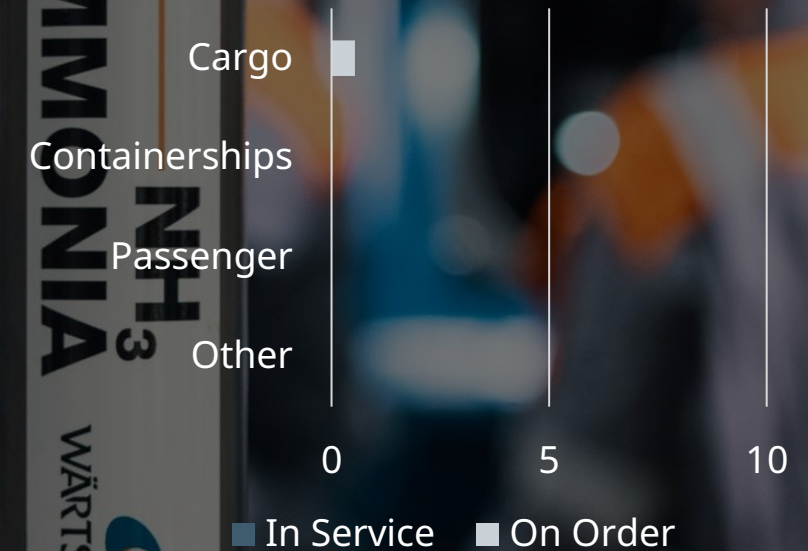
1.7x

Ammonia as fuel is gaining interest

- ✓ **Pros**
 - Zero carbon fuel
 - Very low Sulphur Oxides (SOx) and Particulate Matter (PM) emissions
- ✓ **Cons**
 - Toxic and corrosive
 - Lower energy density compared to LNG, i.e., it requires bigger volumes to store the same amount of energy
 - Aftertreatment needed to reach Nitrogen Oxides (NOx) Tier III compliancy
- ✓ **Wärtsilä positioning**
 - World's first 4-stroke ammonia solution for marine launched in Dec 2023
 - Target to sign first contract in 2024

1) Source: Clarksons, May 2024, vessels above 2000 GT; mCGT = Compensated Gross Tonnage, millions; 'Cargo' includes gas carriers; segment 'Other' includes offshore, fishing vessels, dredgers, yachts, tugs, etc.; 2) Fuel production cost estimate for 2035; source: Maersk Mc-Kinney Møller Center for Zero Carbon Shipping – NavigaTE 2023; 3) Assuming 100% consumption subject to EU Fit-for-55, EU allowances at EUR 159/ton (source: Transport & Environment NGO); 4) Price range spans between blue- and electro- ammonia; 5) Gross tank estimations based on Wärtsilä data

Ammonia uptake by segment, mCGT¹⁾



Ammonia vs. Low Sulphur Fuel Oil

Fuel price factor in 2035²⁾³⁾

0.7x – 1.2x⁴⁾

Gross tank size factor⁵⁾

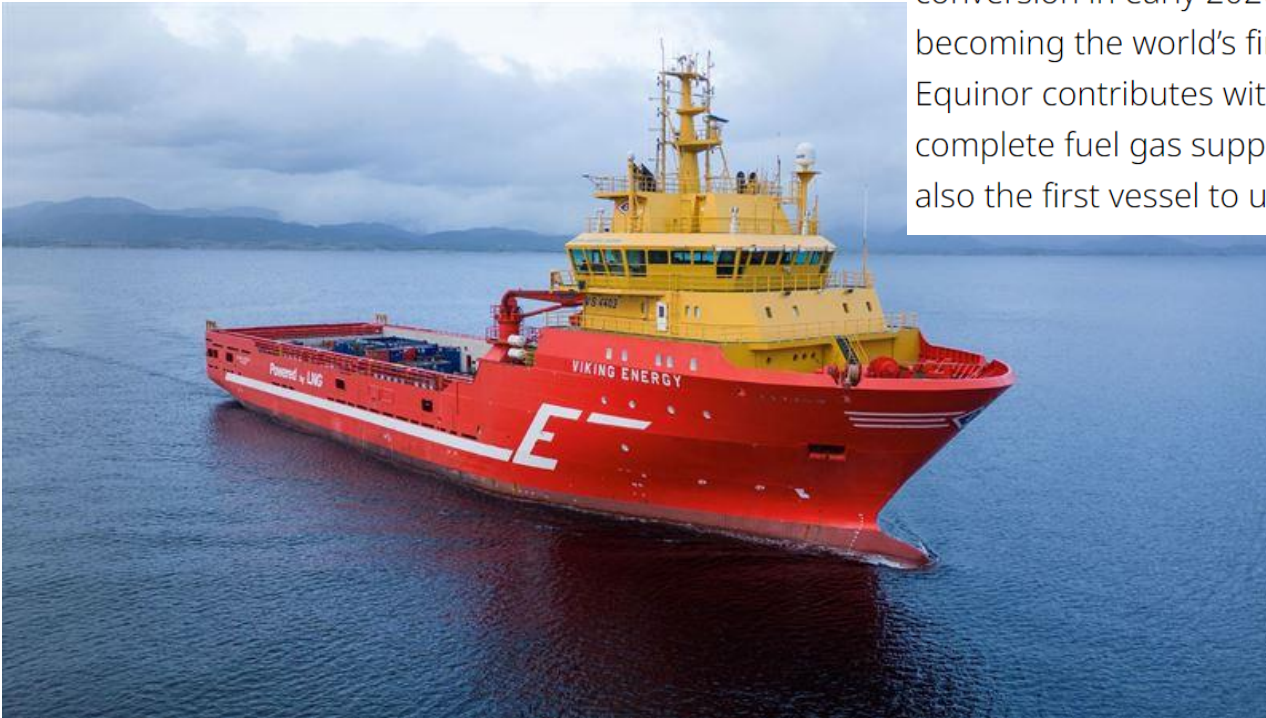
3.9x

Landmark deal between Wärtsilä and Eidesvik Offshore pioneers growing demand for ammonia in shipping

Wärtsilä Corporation, Press release 26 August 2024 at 13:00 UTC+2

Wärtsilä partners with Norwegian ship owner, Eidesvik, on world's first ammonia-fuelled platform supply vessel conversion

Technology group Wärtsilä has signed a contract with Norwegian shipowner Eidesvik to supply the equipment for the conversion of an offshore platform supply vessel (PSV) to operate with ammonia fuel. The vessel, 'Viking Energy', which is on contract to energy major Equinor, is scheduled for conversion in early 2026 and is expected to start operating on ammonia in the first half of 2026, becoming the world's first ammonia-fuelled in-service ship. In addition to chartering the vessel Equinor contributes with financing for the conversion. Wärtsilä will then supply the engine and complete fuel gas supply system and exhaust after-treatment needed for the conversion, making it also the first vessel to use [Wärtsilä's recently released ammonia solution](#).



Hydrogen's transportation and storage challenges will limit the uptake in marine

✓ Pros

- Zero carbon fuel
- No need for aftertreatment to reach Nitrogen Oxides (NOx) Tier III compliancy
- Very low Sulphur Oxides (SOx) and Particulate Matter (PM) emissions

✓ Cons

- Very low energy density limits the application in shipping
- Expensive and challenging to store as a liquid at -253°C

✓ Wärtsilä positioning

- 15%¹⁾ hydrogen blends possible on LNG dual fuel engines
- 100% hydrogen technical concept ready by 2025 for Energy market

1) Based on fuel volume; 2) Fuel production cost estimate for 2035; source: Maersk Mc-Kinney Møller Center for Zero Carbon Shipping – NavigaTE 2023; 3) Assuming 100% consumption subject to EU Fit-for-55, EU allowances at EUR 159/ton (source: Transport & Environment NGO); 4) Price range spans between blue- and electro- hydrogen; 5) Gross tank estimations based on Wärtsilä data

Liquid Hydrogen vs. Low Sulphur Fuel Oil

Fuel price factor in 2035²⁾³⁾

1.2x – 1.5x⁴⁾

Gross tank size factor⁵⁾

7.3x

Compressed Hydrogen vs. Low Sulphur Fuel Oil

Fuel price factor in 2035²⁾³⁾

1.2x – 1.5x⁴⁾

Gross tank size factor⁵⁾

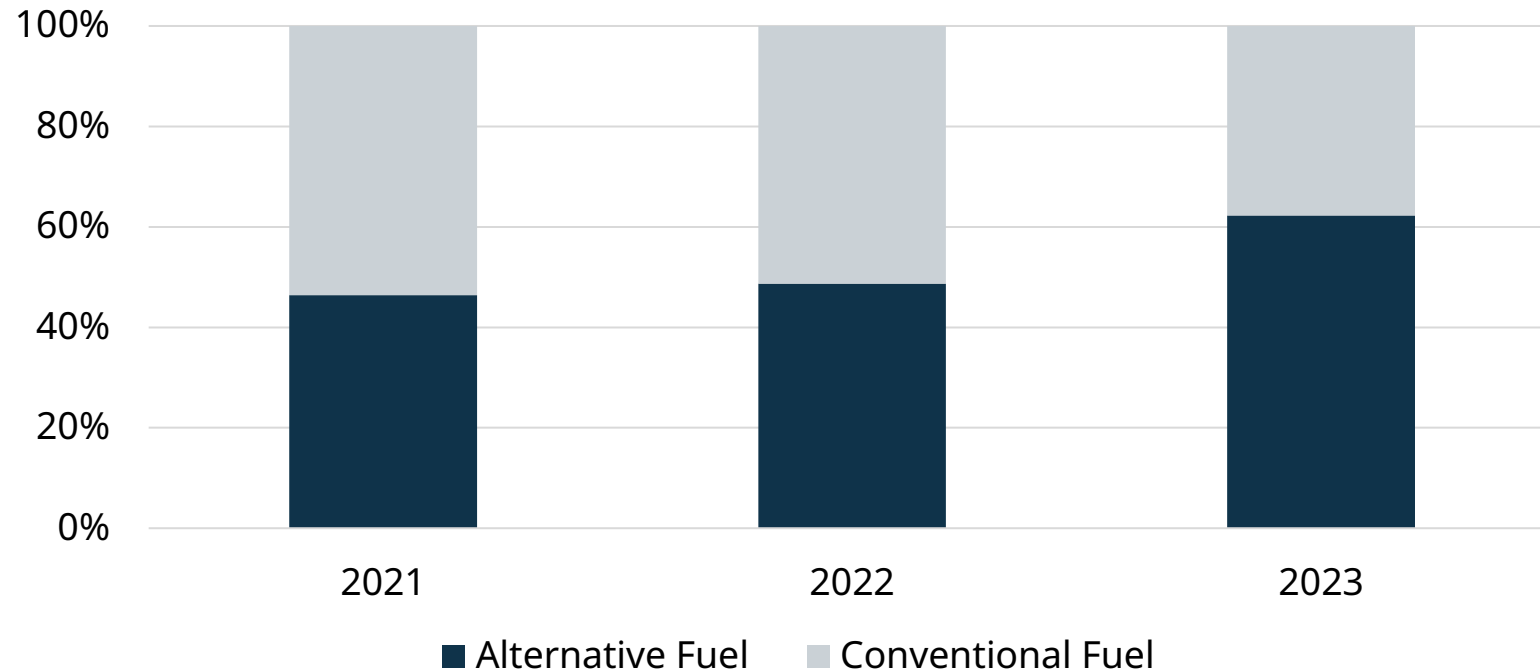
19.5x



The share of our alternative fuel-capable engine orders is steadily growing, standing at >60% MW in 2023

Alternative fuel-capable engine order intake

% 4-stroke engine orders, alternative vs conventional fuel-capable, MW



'Alternative fuel' includes LNG and methanol

>3,000

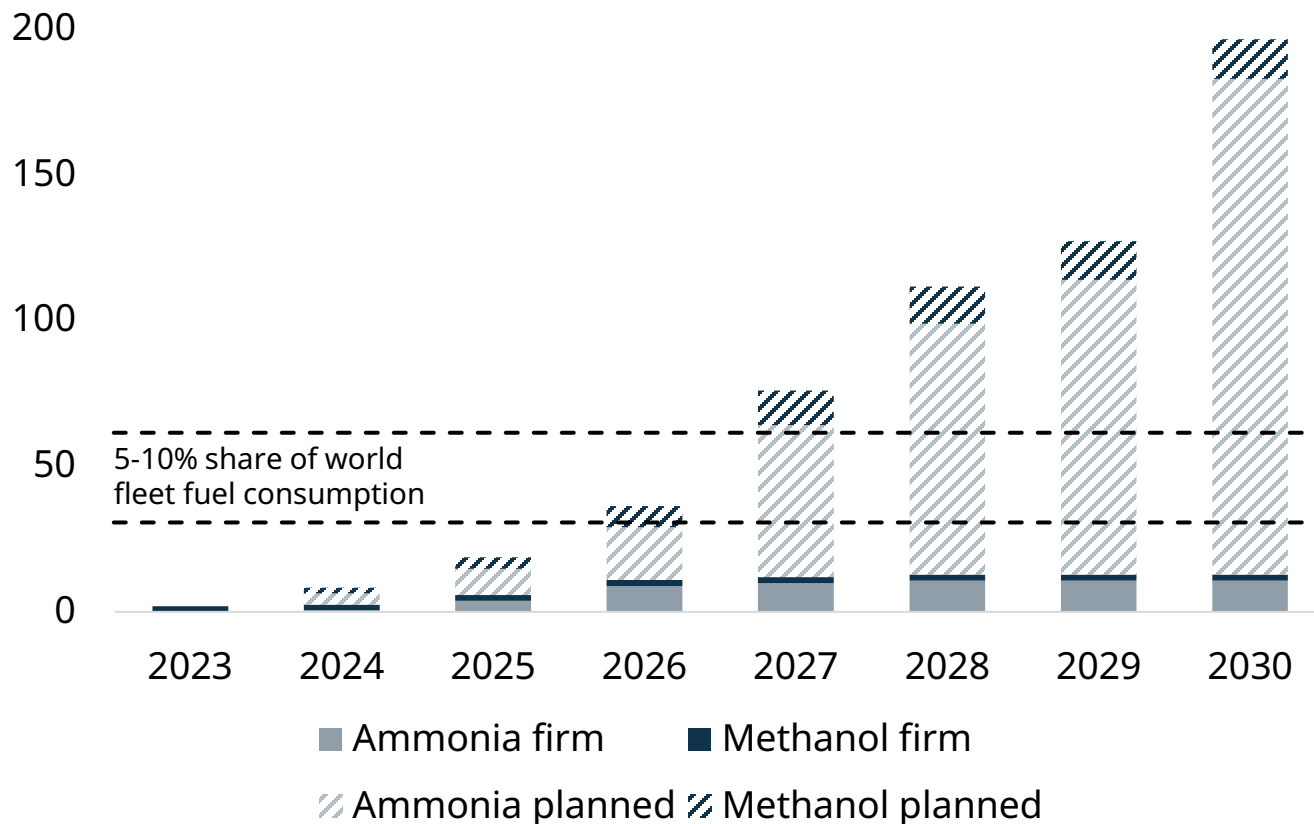
LNG engines
sold to date

>160

methanol engines
sold to date

By 2030, the confirmed global production capacity for sustainable ammonia and methanol is ~2% of the planned fuel need

Projected production of sust. methanol and ammonia¹⁾, million tonnes



Key considerations

- The estimated world fleet bunker fuel consumption 2023 was ~280 million tonnes²⁾; if the world fleet would rely solely on ammonia and methanol as bunker fuel, it would require ~600 million tonnes of fuel due to their lower energy content
- The announced production capacity plan for sustainable methanol and ammonia is adding up to ~190 million tonnes by 2030; green and blue ammonia account for >90%, while the share of green and bio methanol is <10%
- Competition with other verticals may amplify under-supply; current global ammonia production is ~180 million tonnes per year³⁾, while global methanol production is ~100 million tonnes per year⁴⁾; a significant share of sustainable ammonia and methanol production will not be available as bunker fuel, as it will be used to reduce CO₂ emissions from today's applications

1) Source: DNV AFI; 2) Clarksons; 3) Yara; 4) Methanol Institute

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



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