



MAN Energy Solutions

Future in the making

Decarbonization – The maritime energy transition

Future fuels for large merchant marine vessels



Agenda

- 1 Alternative fuels - market update and outlook
- 2 MAN B&W LNG engine
- 3 MAN B&W Methanol engine
- 4 Ammonia engine market introduction
- 5 Retrofit
- 6 Summary
- 7 Joint Development Projects with Korean Shipyards

1 Alternative fuels - market update and outlook



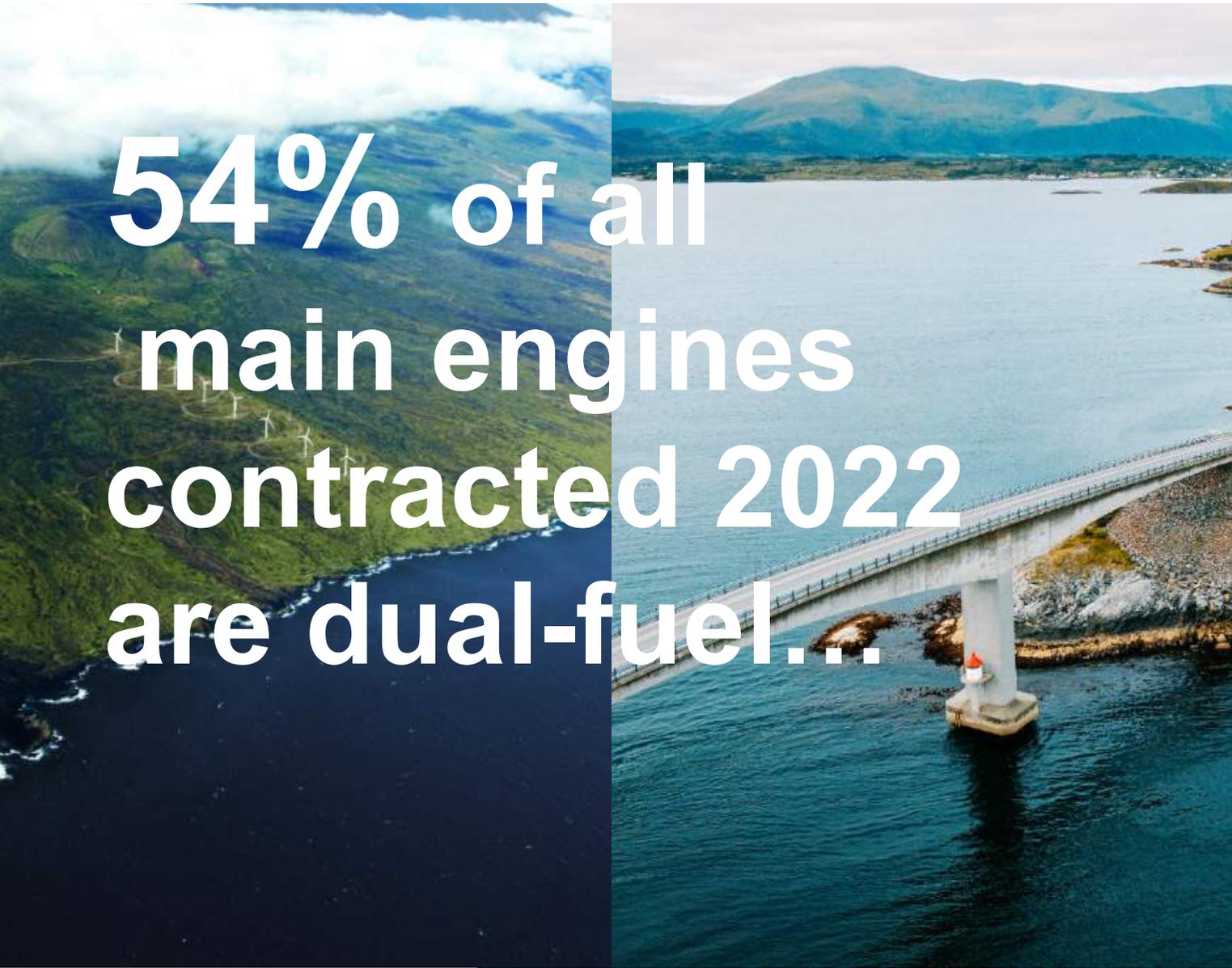
The maritime industry is the backbone of global trade

A photograph showing the silhouettes of several large ships, including a tanker and a smaller vessel, against a bright orange sunset sky. The water in the foreground is dark with shimmering highlights from the low sun.

~ **80-90%** of global freight is transported by sea.

Shipping is responsible for ~ **3%** of the global CO2 emissions.

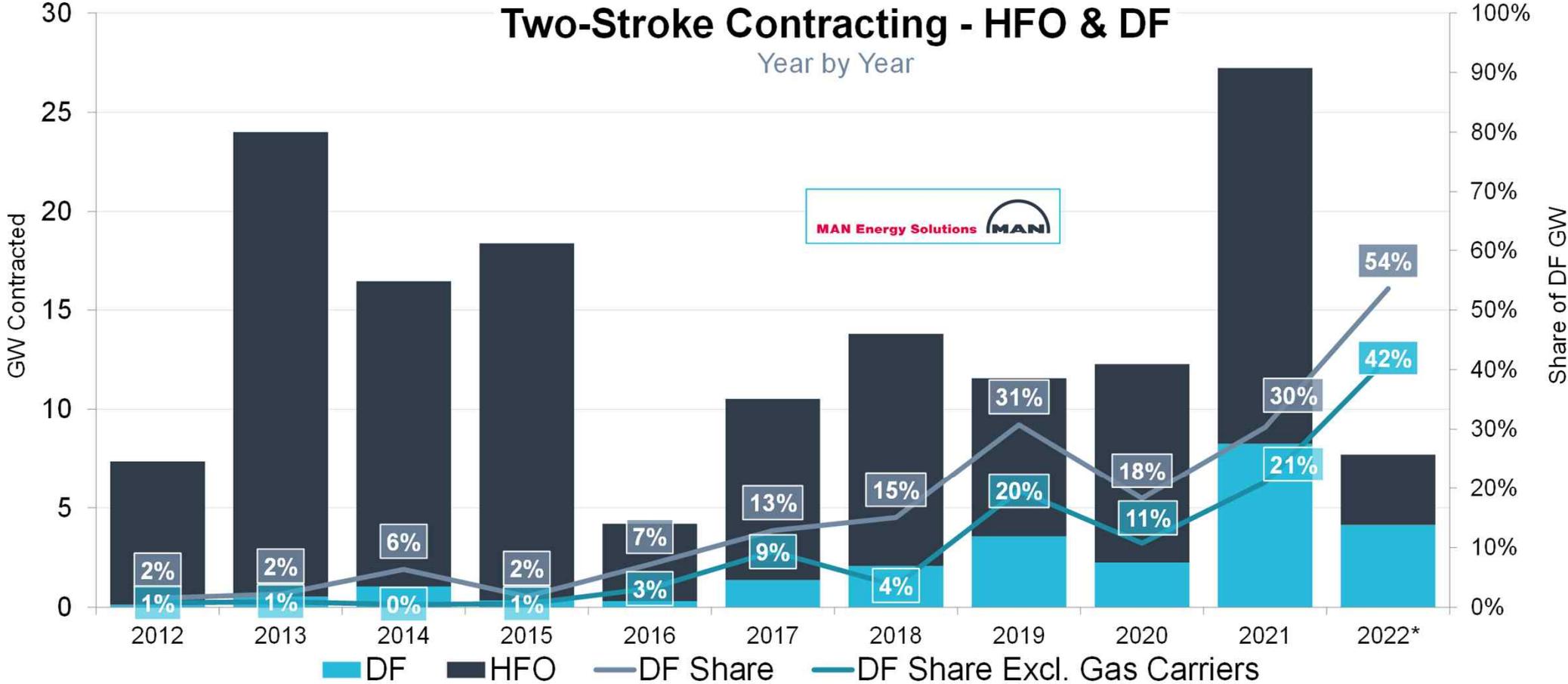
~ **50 %** of global freight are transported by a MAN ES engine.



54% of all
main engines
contracted 2022
are dual-fuel...



Conventional and dual-fuel two-stroke contracting



* Preliminary Year to Date (end May 2022)

Source: IHS Markit

Powering sustainable **shipping** by opening clear routes

MAN Energy Solutions supports all

EE

AP

LNG

Ethane

Methanol

LPG

Ammonia

ME-GI

ME-GA

ME-GIE

ME-LGIM

ME-LGIP

→ 2024

MAN B&W two-stroke engines for alternative fuels



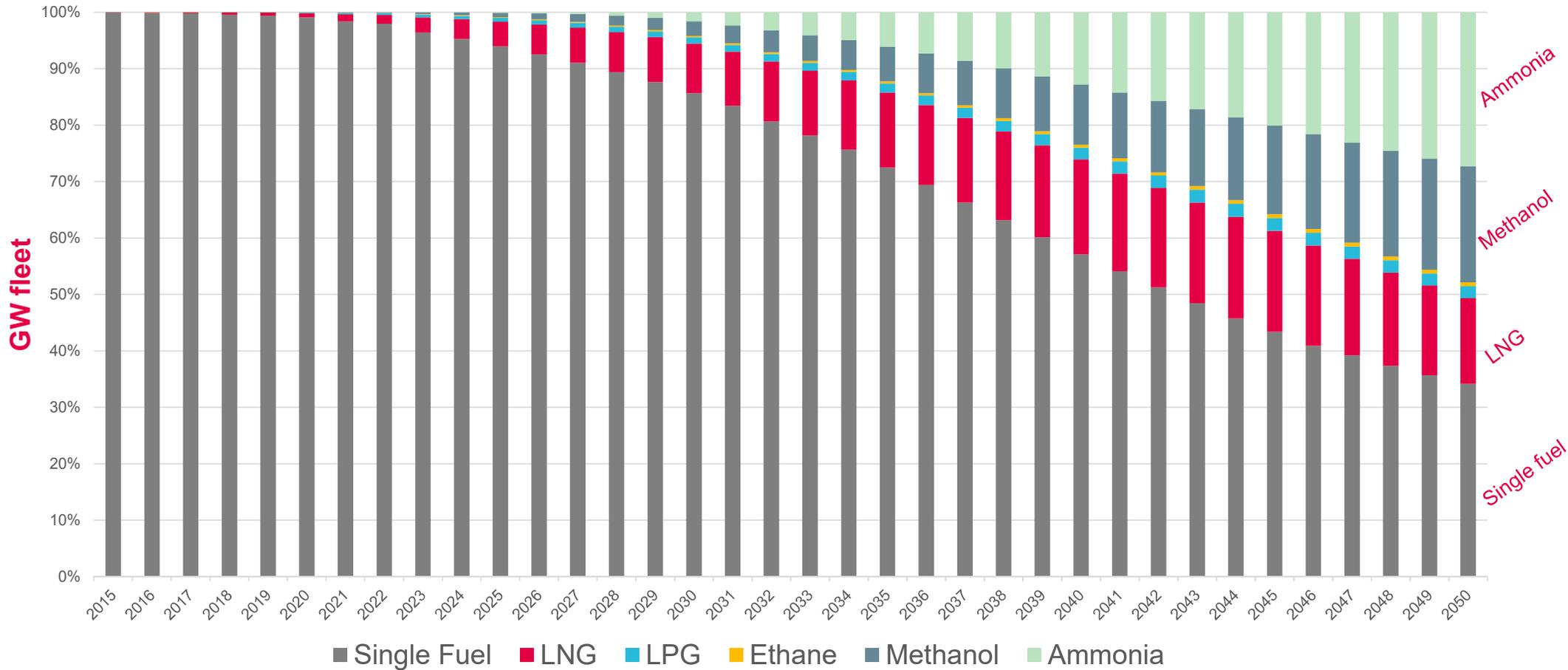
Extensive experience in the development of dual-fuel engines



What will the future fuel mix look like?

Two-stroke fuel mix **forecast** towards 2050

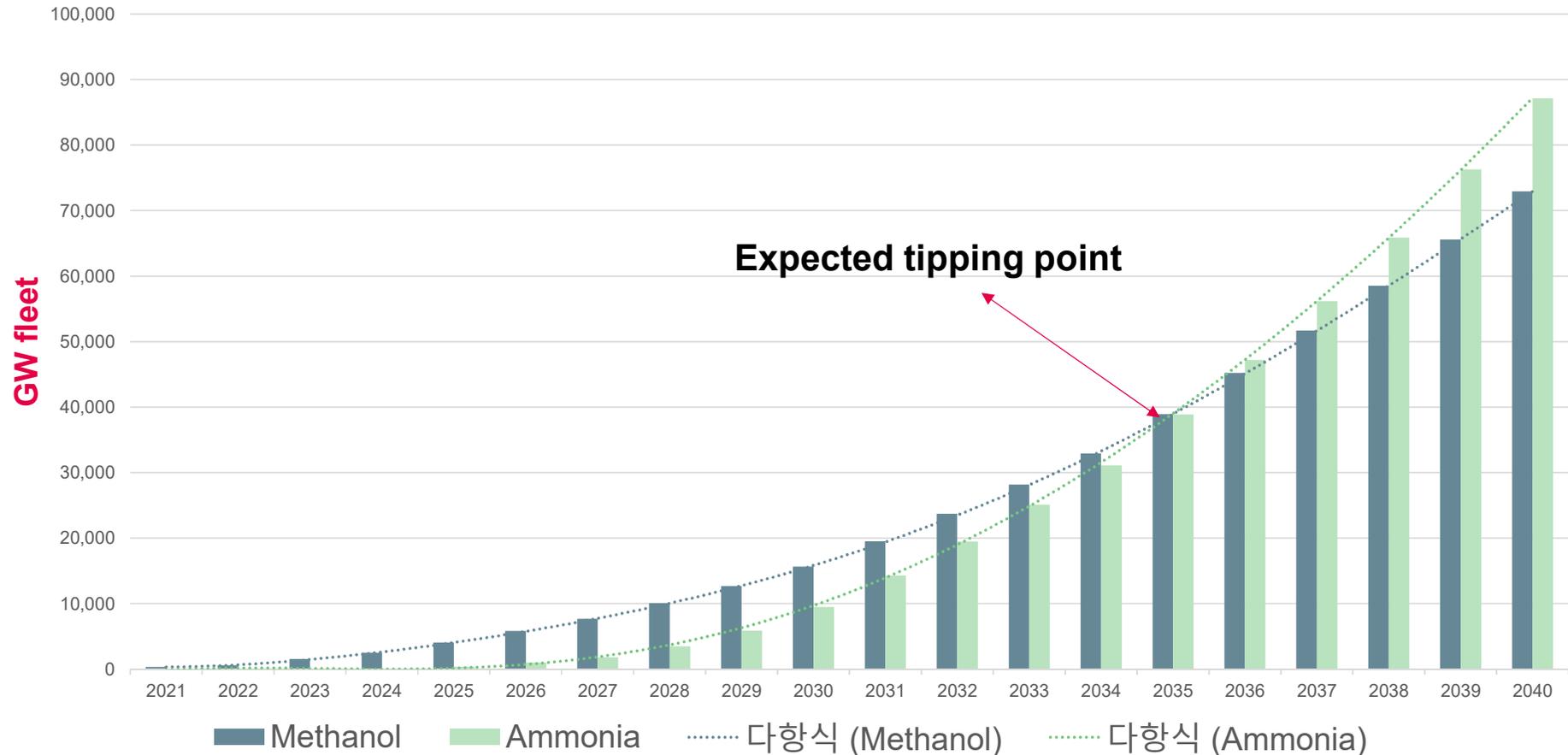
Distribution of 34% single fuel, 27% Ammonia, 21% Methanol, and 15% LNG expected in 2050



Assumptions: Scenario is based on known factors such as world trade growth, EEDI, EEXI, expected CO2 regulation (currently unspecified), etc.

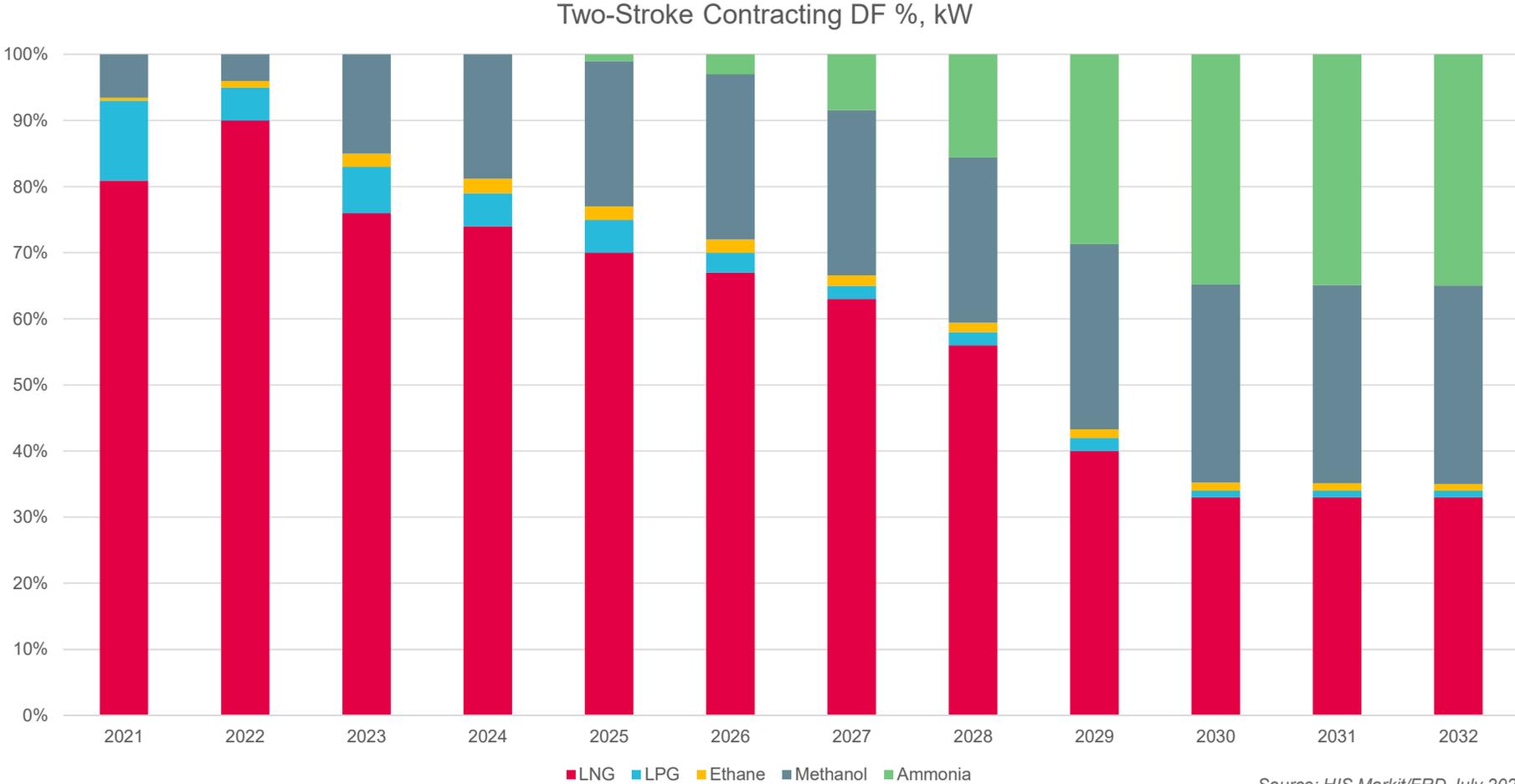
Two-stroke fleet fuel mix: focus methanol and ammonia

Methanol is expected to have a fast uptake based on technology experience and market demands, ammonia as a new fuel will have a responsible introduction emphasizing safety (S-shaped curve).

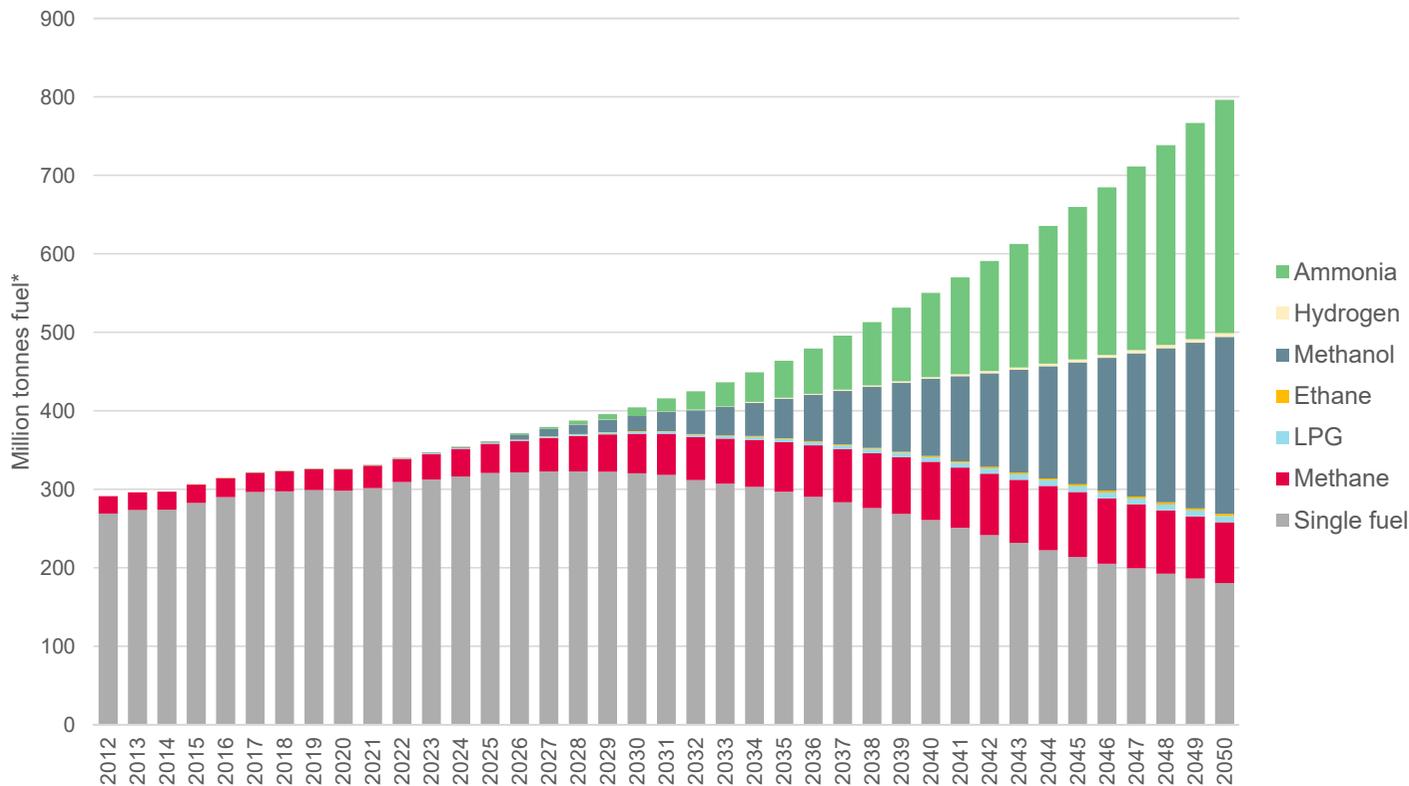


Dual-fuel fuel-mix in newbuilding contracting

Contracting in kW



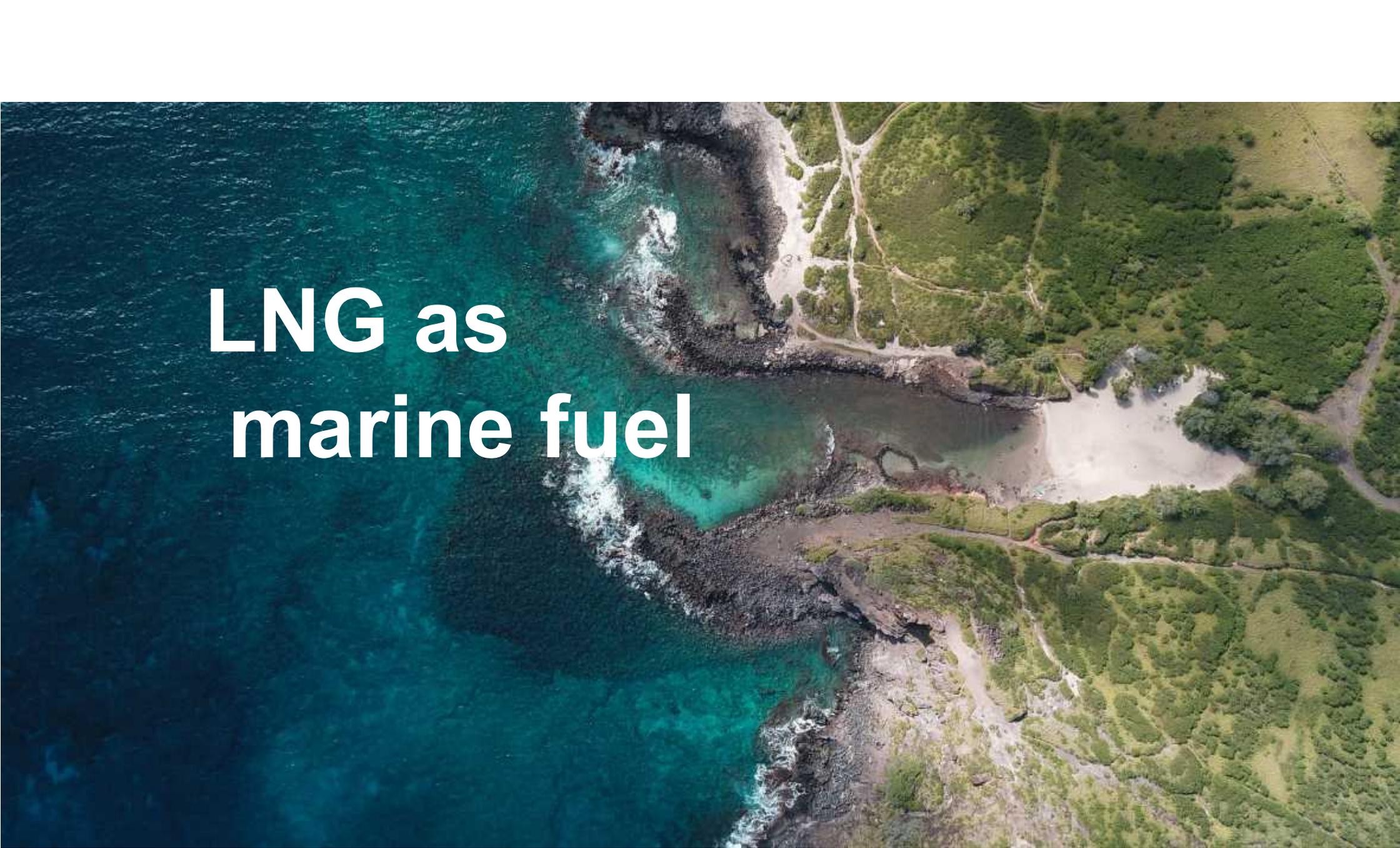
Contracting of conventional engine technology will continue until regulated



Only newbuilding included in graph; a more or less gradual transition to green fuels is built into each fuel which then contains both a fossil and green share
 *Mass of the fuel types: Energy content of fuels varies due to differences in gravimetric heating value

- Drivers of methanol and ammonia uptake are availability of technology, consumer demand, expectation of future CO2e regulation and/or carbon pricing
- Other factors such as efficiency, batteries, ship design, operational improvements contribute to decarbonization

2 MAN B&W LNG engines ME-GI & ME-GA

An aerial photograph of a coastline. The left side shows deep blue and turquoise ocean water with white foam from waves crashing against a rocky shore. The right side shows a lush green landscape with a sandy beach and a small inlet. The text 'LNG as marine fuel' is overlaid in white on the left side of the image.

LNG as marine fuel



Methane slip mitigation is shaping **LNG** fueled two-stroke engine contracting



The world's
most efficient LNG
fueled engine

MAN B&W ME-GI

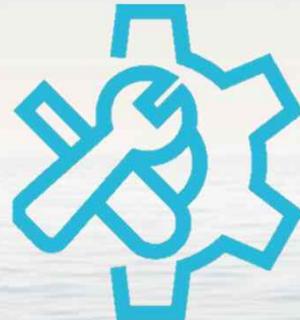
OPEX

MAN B&W ME-GI



Lowest GHG emissions

- ✓ Negligible methane slip.
- ✓ Lowest fuel consumption.



Proven reliability

- ✓ Based on more than 2 million running hours.
- ✓ Exceptionally good cylinder condition.



Lowest OPEX

- ✓ Efficiency is the currency of the future where the more costly green fuels will be needed to meet decarbonization targets.



CAPEX

LNG Carrier

Lower the pressure
on your
capital cost

MAN B&W ME-GA

The leading 2nd generation two-stroke Otto cycle engine

214 engines on order for modern LNG carriers

Performance and emission benefits are reliably delivered via MAN-ES' integrated and proven EGR.

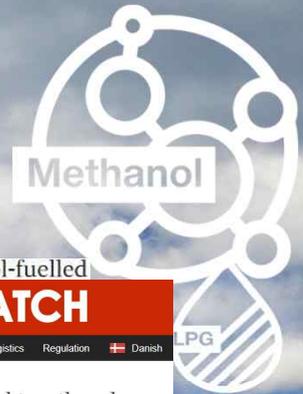
Decision making aspects:

- ✓ MAN-ES' long track record of taking new engine designs from concept to reliable world wide engine operation.
- ✓ Tailored for easy application and cost efficient integration in contemporary LNG carrier designs.



3 MAN B&W Methanol engine ME-LGIM

Methanol as a marine fuel is gaining momentum



CNN BUSINESS Markets Tech Media Success Perspectives Videos Edition ▾

Maersk just ordered 8 carbon neutral ships. Now it needs green fuel

COAL | ELECTRIC POWER | OIL | PETROCHEMICALS | SHIPPING — 16 February 2022 6:33 GMT

DFDS advances methanol use plans for shipping fleet as part of climate goals

16-04-2021 | SHIPPINGWATCH.COM

Shipping majors bet on different paths in decarbonizing shipping

"The only tangible solution you have today, apart from **methanol**, is LPG or LNG. ... "For **methanol**, the technical feasibility is already there, since (there are, ed.) vessels operating on **methanol** as a fuel out there.

Cosco and DSIC reveal design for a green methanol-fuelled VLCC

Published 19 February 2022 6:33 GMT

SHIPPINGWATCH

Carriers Suppliers Offshore Ports Logistics Regulation Danish

X-Press Feeders orders eight methanol-powered container vessels

Methanol advances as alternative bunker fuel with barge-to-ship operation

14 May 2021 - Methanex Corporation subsidiary Waterfront Shipping carried out barge-to-ship bunkering of methanol in collaboration with

European Energy will establish a new e-methanol facility in Denmark and provide renewable energy to fuel it.

icct THE INTERNATIONAL COUNCIL ON Clean Transportation

A step forward for “green” methanol and its potential to deliver deep GHG reductions in maritime shipping

Waterfront Shipping orders 8 methanol dual-fuel ships from Hyundai Mipo Dockyard

VESSELS

December 1, 2020 by [Lorenz G. Dierker](#)

Canada-based Waterfront Shipping Company (WFS), a wholly-owned subsidiary of Methanex Corporation, has placed an order for eight new methanol dual-fuel vessels with South Korean shipbuilder Hyundai Mipo Dockyard.

WFS has ordered eight dual-fuel vessels from Hyundai Mipo Dockyard.

Design for Methanol-Fueled Tanker Receives Class AiP

Concept design for Methanol-fueled tanker - courtesy Methanol Institute

Bloomberg Green

Green

Maersk Makes \$1.4 Billion Green Bet on Methanol-Fueled Ships

Swedish Climate Leap, “Klimatklivet”, invests SEK 151 million (€15 million) in Liquid Wind’s facility, FlagshipONE, producing carbon neutral fuel

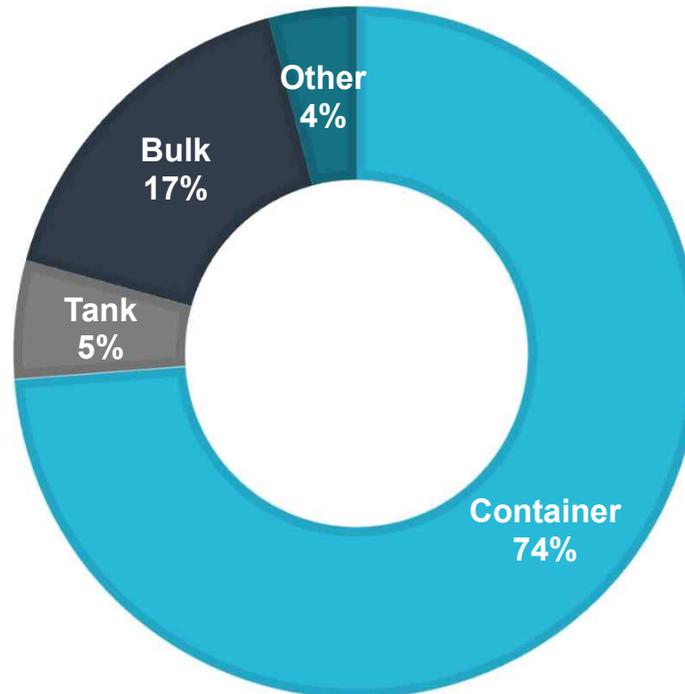
Will deliver 50,000 tons renewable and fossil free fuel for the shipping industry

FlagshipONE will be connected to Övik Energi's combined heat and power (CHP) plant Hörneborgsverket in Örnköldsvik, in the north of Sweden. The construction process is scheduled to start in the spring of 2022. Once operational, the facility is expected to produce 50,000 tons of eMethanol starting in 2024. The new facility will upcycle carbon dioxide emissions and combine this with green hydrogen, made from renewable electricity and water to produce eMethanol.

The main driver: Container vessels

Requests for MAN B&W ME-LGIM engines are increasing significantly

Main drivers: Large and ultra large container vessels – Midsize container vessels – Container feeders
Increasing interest from bulk carrier segments, tankers, RoRo and PCTCs.



Methanol as a marine fuel

The main advantages of methanol as a marine fuel for large merchant marine vessels



Proven MAN B&W engine design

More than 140.000 running hours on ME-LGIM



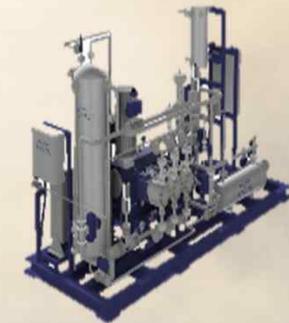
Carbon-neutral

Green methanol can be carbon-neutral



Easy storage

No cryogenic equipment needed



Simple FGSS

Only 13 bar required

Production of green methanol is picking up!

Significant uptake in green-methanol production plants on-going. Demand from shipping will be very high.

Yearly total production capacity from **E-methanol** and **bio-methanol** plants (known Q4 2021) from 2024-2025 onwards, where production capacity is already published:
≈2.6 million tons of green methanol

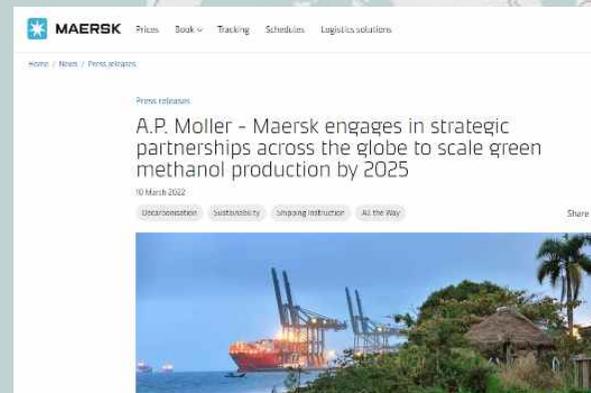
Enough to fuel **≈ 150 Aframax Tankers** for one year

Or **≈ 250 small feeder vessels**

Or **≈ 60 very large container vessels**

Product
■ Biomethanol
■ E-methanol

Source: <https://www.methanol.org/renewable>



Q1 2022: Maersk have themselves secured 6-700.000 tons of green methanol, starting from 2025

MAN B&W LGIM engine development milestones

Historical timeline

Test at MES
7S50ME-B9.3-LGIM



1st sea trials on
methanol



NOx certification 6G50ME-
C9.5-LGIM-W at HHI June 2019



Introduction of G95-LGIM for large
and ultra large container vessels



Design plans for
S60 / G60 / G70
ME-LGIM published

2015

2016

2017

2018

2019

2020

2021

2022

LGI demonstration event at RCC
4T50ME-X



Test at HHI
7G50ME-B9.3-LGIM



Development of Tier III compliance by
Water in methanol



First order for LGIM on
non-methanol tanker

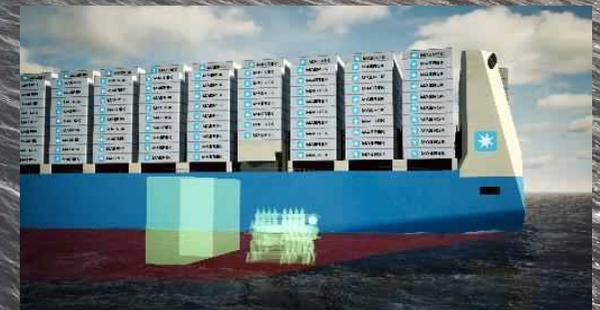


Introduction of
G80ME-C10.5-LGIM



The world's first methanol engine for large and ultra large container vessels

MAN B&W 8G95ME-C10.5-LGIM EGRTC
12 X 16200 TEU Container vessels

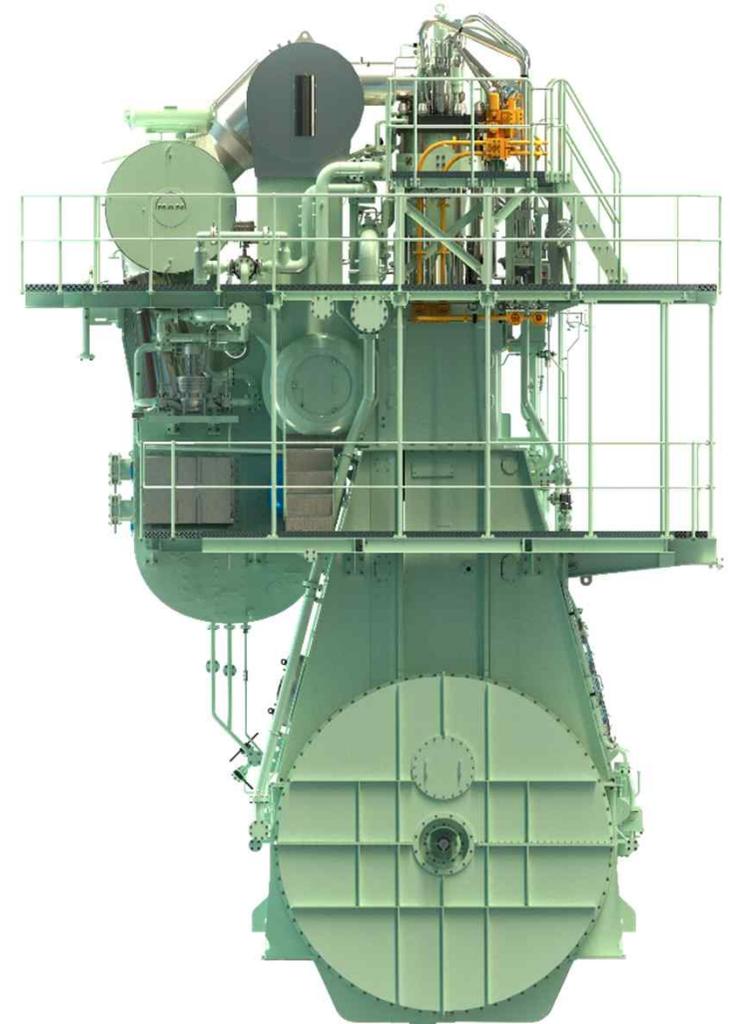


MAN B&W ME-LGIM Engine

Design philosophy

Based on the proven and high efficiency Diesel cycle as we know it from the ME-C, ME-GI and LGIP engines.

- 13 bar supply pressure – 600 bar injection pressure.
- 5% pilot energy fraction – can be any compliant fuel.
- Operation on MeOH from 10-100% load.



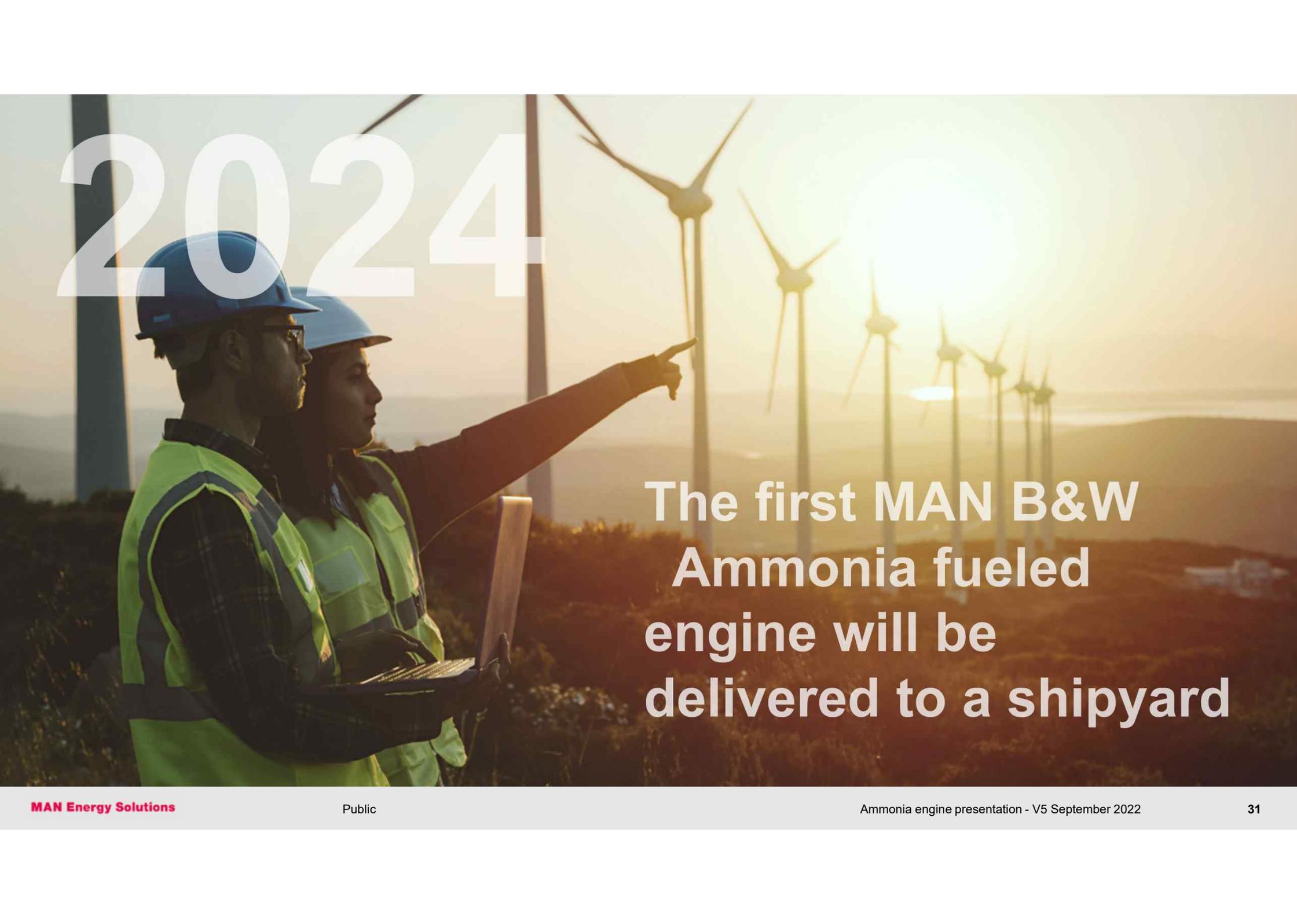
Summary

We expect the uptake of methanol as a marine fuel to increase significantly

1. The proven MAN B&W ME-LGIM engines are available today for a wide range of vessels
2. ME-LGIM engines can be fueled with VLSFO until green methanol is available at scale and- or at attractive prices.
3. Relatively simple auxiliary systems means that conversion to ME-LGIM is attractive
4. Huge demand for green methanol provide positive outlook for the supply of green methanol in the future

4 MAN B&W Ammonia engine market introduction

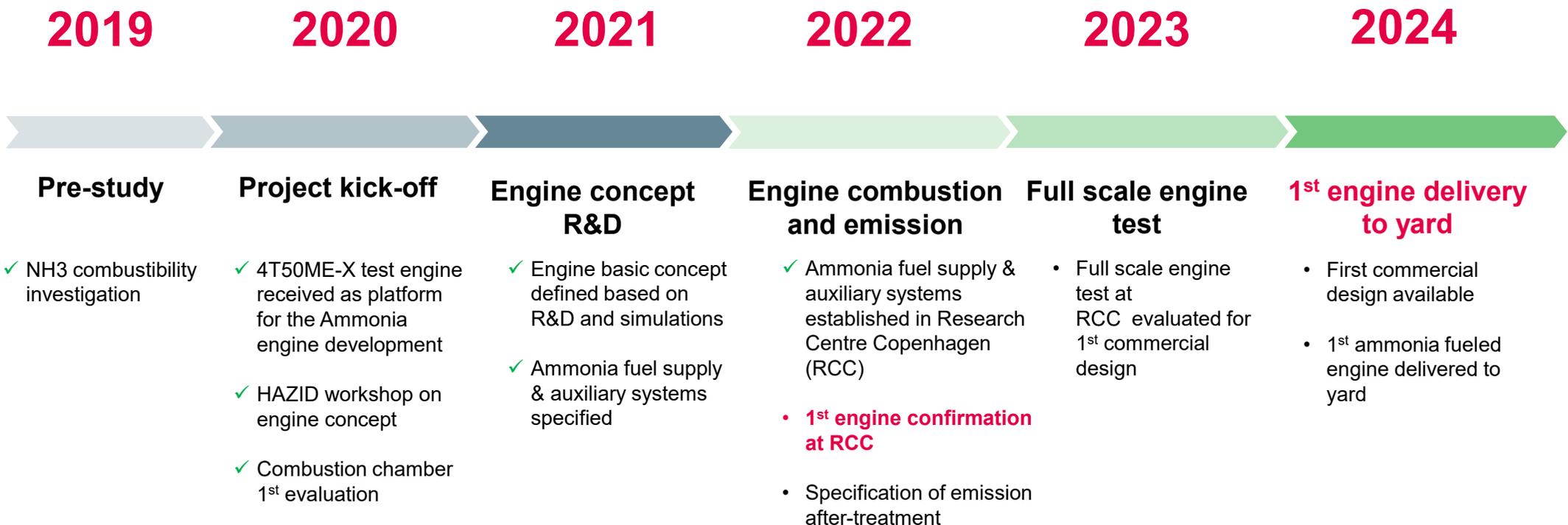


A photograph of two workers in safety gear (hard hats and high-visibility vests) standing in a field of wind turbines at sunset. The sun is low on the horizon, creating a warm, golden glow. One worker is pointing towards the turbines. The overall scene is industrial and focused on renewable energy.

2024

**The first MAN B&W
Ammonia fueled
engine will be
delivered to a shipyard**

Two-stroke ammonia engine development schedule



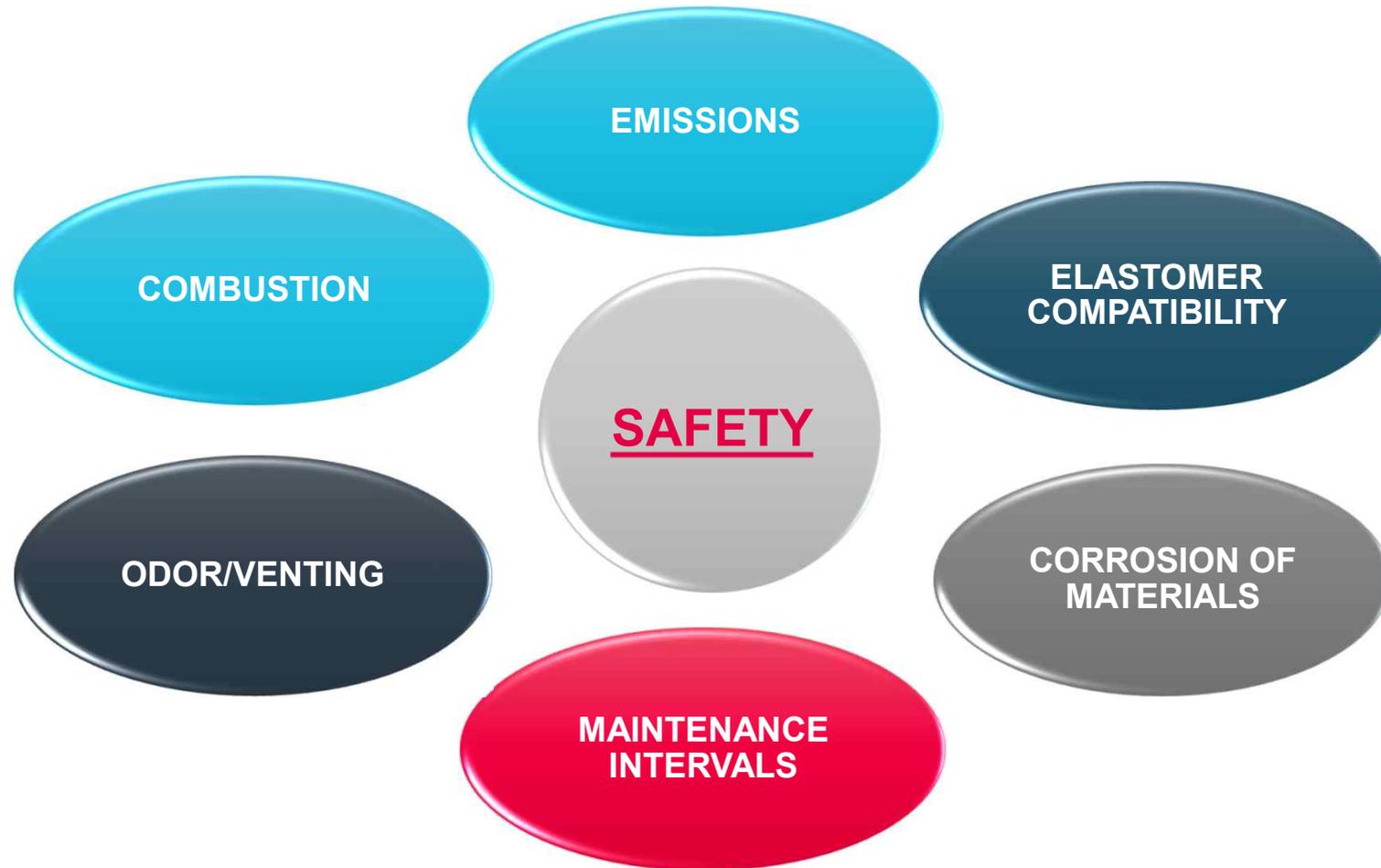


Components at RCC for ammonia engine development



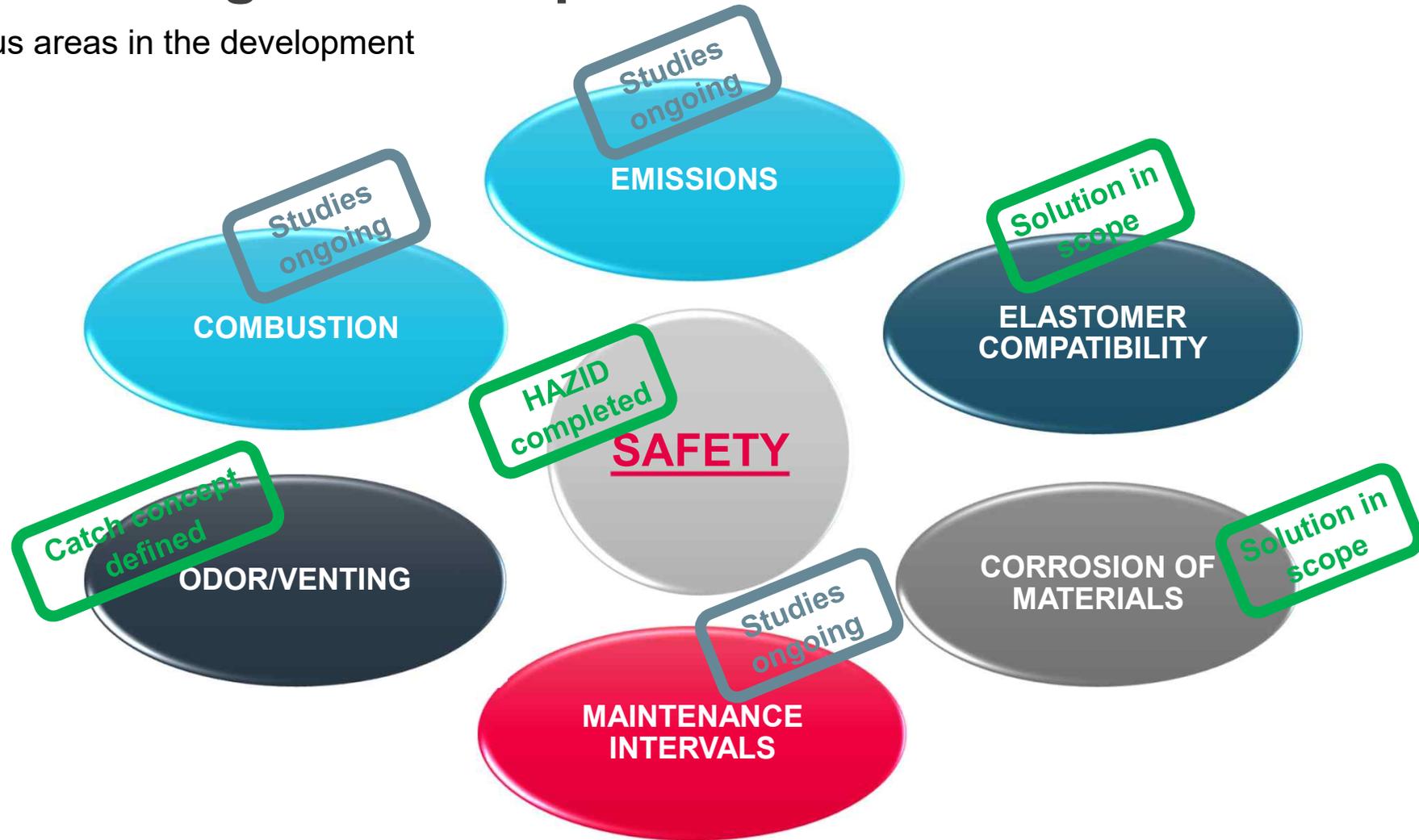
Ammonia engine development

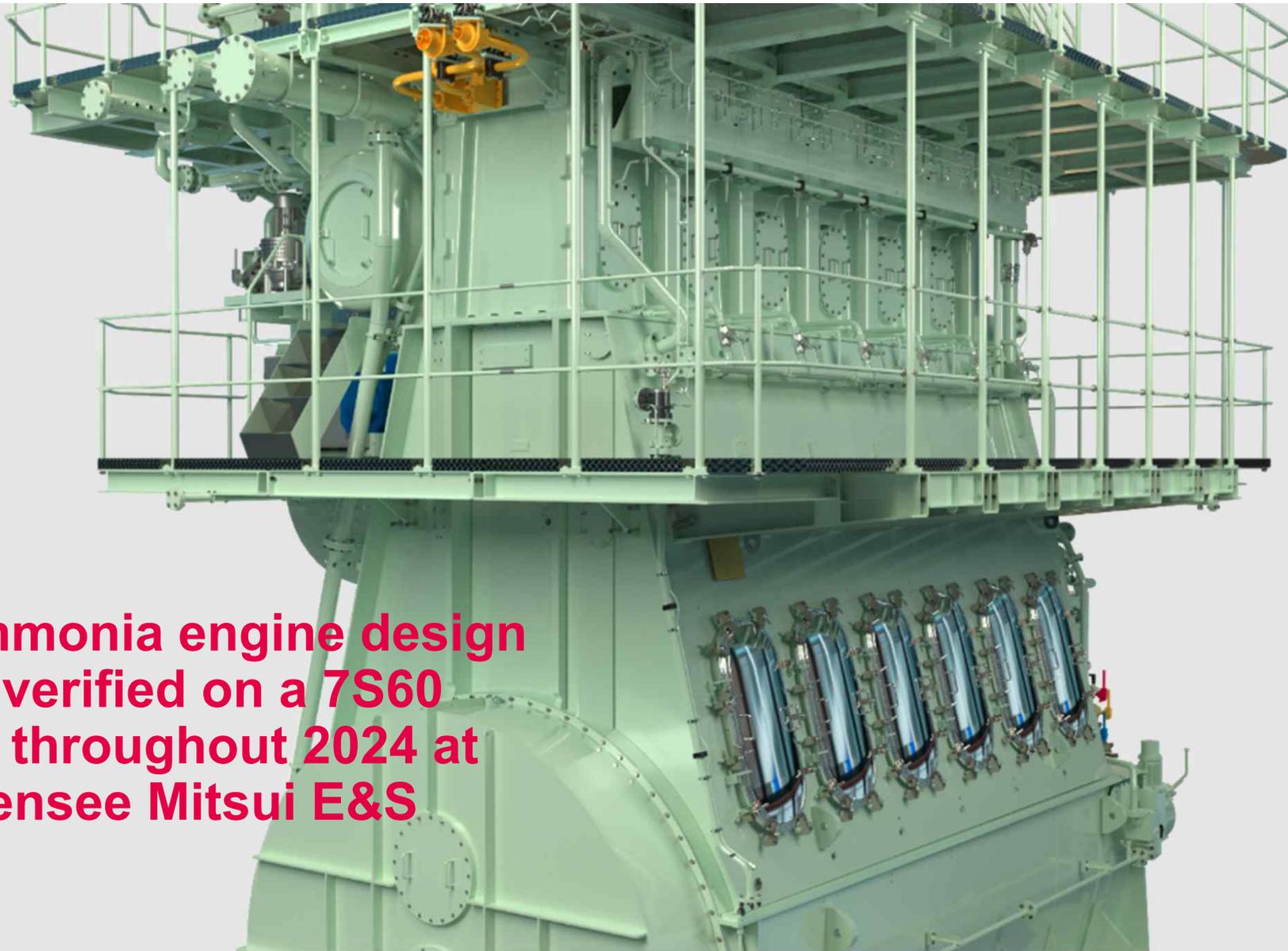
Main focus areas in the development



Ammonia engine development

Main focus areas in the development





The ammonia engine design will be verified on a 7S60 engine throughout 2024 at our licensee Mitsui E&S

Market introduction plan for two-stroke ammonia engine

The 7S60ME-C engine will be available for development and prototype testing

- It will supplement the tests carried out at Research Centre Copenhagen.
- The ammonia engine will be available for initial sales by the end of 2024, when the final design has been thoroughly tested and verified.
- The second bore-size will be announced in 2023

The 60-bore engine

Typical applications



VLGC



Container feeders



Panamax & newcastlemax bulk carriers



PCTC



LR1 & LR2 tankers

Summary



Ammonia versus methanol?

- Currently very strong interest for methanol because MAN B&W engines are ready and proven.
- Ammonia is expected gain marked share towards end of the decade, driven by lower production cost and zero carbon properties.
- The technologies are ready, but the uptake of alternative fuels in shipping depends on legislation regulating and incentivizing decarbonization of shipping.

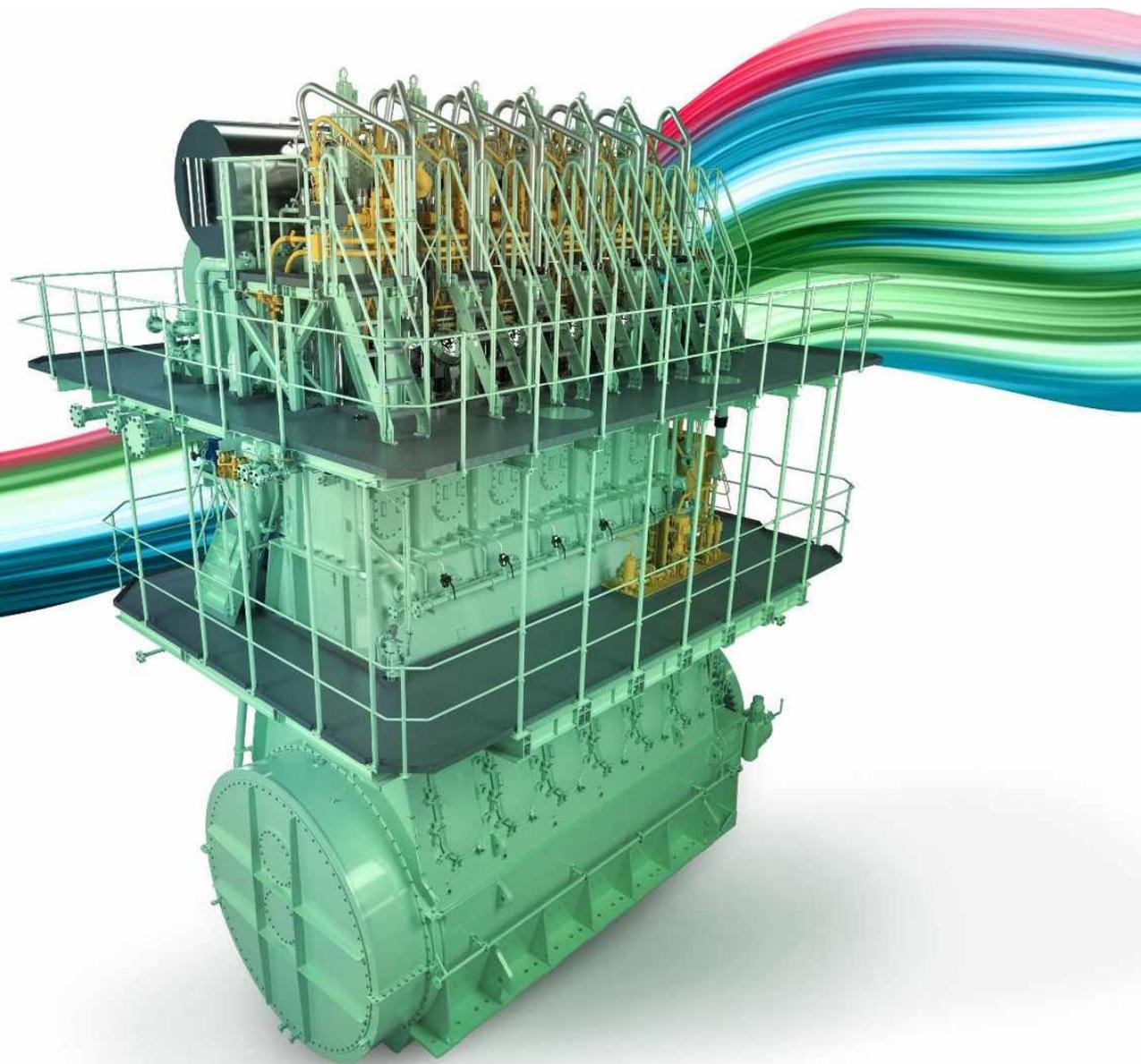
MAN B&W G70ME-C10.5-GA EGRBP update

- The commercial MAN B&W G70ME-C10.5-GA EGRBP R&D tests in South Korea are well underway.

MAN Energy Solutions
Future in the making

4 Retrofit market

5 Retrofit market



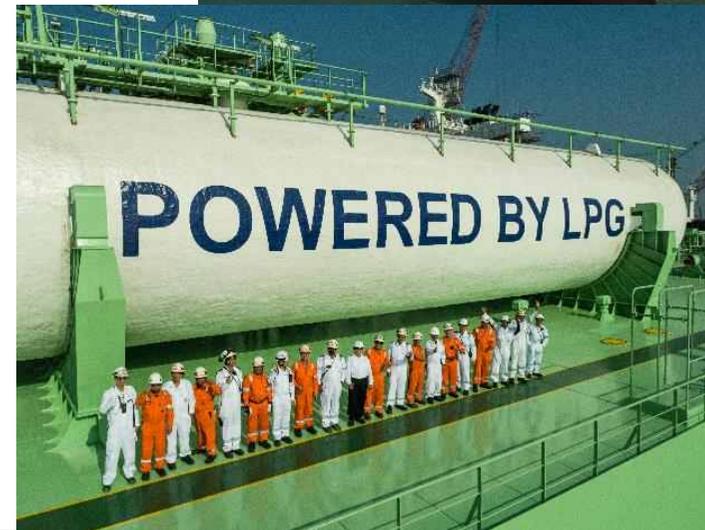
Proven solutions for upgrade to alternative fuels

MAN B&W ME-C engines are future proof and can be upgraded to use LNG, LPG, Ethane, Methanol and Ammonia as fuel.

In Service

- ME-GIE: 1
- ME-GI: 3
- ME-LGIP: 15

*Pictures courtesy of BW Gas. 15 VLGCs will be retrofitted to LPG propulsion with MAN B&W engines.



Modular design enables extensive retrofit options

By ensuring full fuel flexibility and extensive retrofit capabilities with a proven record, MAN Energy Solutions future proof your investment

Fuel types	ME-C	ME-GI	ME-GA	ME-GIE	ME-LGIM	ME-LGIP
Fuel oil	✓	✓	✓	✓	✓	✓
LNG	Retrofit	✓	✓	Retrofit	Retrofit	Retrofit
LEG (Ethane)	Retrofit	Retrofit	-	✓	Retrofit	Retrofit
Methanol	Retrofit	Retrofit	-	Retrofit	✓	Retrofit
LPG	Retrofit	Retrofit	-	Retrofit	Retrofit	✓
Ammonia	Retrofit	Retrofit	-	Retrofit	Retrofit	Retrofit

Solutions for retrofitting to alternative fuels

- Now adding Ammonia (NH₃)

Retrofit to use of Ammonia as fuel

- MAN Energy Solutions is working diligently towards being able to offer retrofit conversion of ME-C engines (including –GI, -GIE, -LGIP and -LGIM variants^{*}) to use Ammonia (NH₃) as fuel, preferable meeting vessels 5 year docking schedules after Q1 2025.

^{*} The ammonia ready engine is a MAN B&W ME type (except ME-GA), no engine is more prepared than others.

How to prepare vessels for future-fuels?

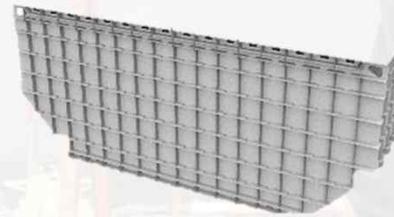
Focus areas for large merchant marine vessels



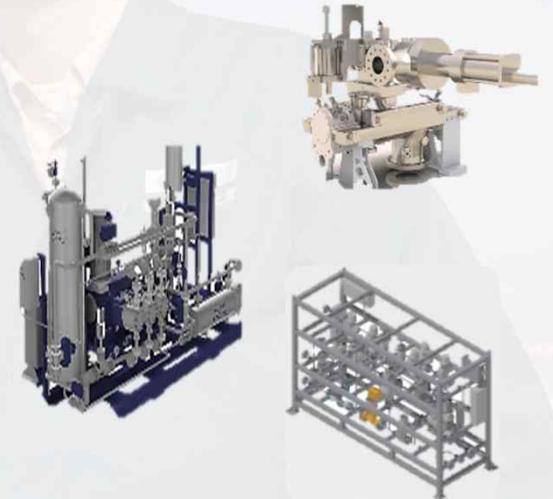
Main engine
Upgrade-ability
future-fuel possibilities



Tank systems
Fuel flexibility
endurance



Design
Hull structural
reinforcement for tank
systems



Machinery space
Bunker stations, fuel supply
systems, FVT, Hazardous areas
classification and vent mast
arrangement preparations

Dual-Fuel Retrofits of Low-Speed Engines

*MAN Energy Solutions' engine designs currently drive some 22,000 vessels globally, of which 3,500 are fully electronically controlled and with the potential for conversion to operate on alternative, green fuels. It has further evaluated that approximately 2,300 or so of these vessels are appropriate candidates for retrofitting, resulting in savings as much as **86 million tons CO2 emissions annually** when fueled by carbon-neutral fuels.*

MAN Energy Solutions 

Press release
Copenhagen, 29.01.2022

**Dual-Fuel Retrofits of Low-Speed Engines
Key in Push towards Decarbonisation**

Dual-fuel retrofits already proven on MAN B&W low-speed engines; potential emission savings of more than 80 million tons CO₂ annually when fueled by carbon-neutral fuels.

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In light of the emerging trend for decarbonisation within the marine sector, MAN Energy Solutions notes that the modular design of the conventionally fuelled, low-speed ME-C engine portfolio lends itself to extensive retrofit options in regard to alternative green fuels, and that such retrofits already have a proven track record.

Thomas S. Hansen, Head of Promotion and Customer Support, MAN Energy Solutions, said: "At MAN Energy Solutions, we design and service many of the global fleet's low-speed engines, in effect contributing to worldwide CO₂ emissions. As a result, we feel a great responsibility in pursuing decarbonisation and thus we are pleased that many sources predict that more than half of all newbuildings will specify dual-fuel engines after 2025. Since ships have an average lifetime of around 25 years, the retrofit of vessels will be necessary in order for the industry to decarbonise."

Indeed, as the demand for engines and ships designated 'future-fuel ready' increases, MAN Energy Solutions – through its after-sales division, MAN PrimeServ – has a proven, unique track-record with such conversions and has already completed 16 such projects with the first dating back to 2015.

Customers can benefit from the fact that all of MAN Energy Solutions' conventionally-fueled ME-C low-speed engines ordered today can be converted to alternative fuels at a later time when the future-fuel landscape is more clear.

MAN Energy Solutions presently offers multiple options for the retrofit conversion of ME-C engines – including their -GI (LNG), -GIE (ethane), -LGIP (LPG) and -LGIM (methanol) variants – and is steadily working towards being able to offer a retrofit option using ammonia as fuel, preferably meeting vessels' five-year docking schedules after Q1 2025.

Conversion potential

Klaus Rasmussen, Head of Projects and PVU Sales, MAN PrimeServ, said: "A massive number of vessels in the current, ocean-going fleet have the potential for conversion, and our broad and continuously expanding portfolio of dual-fuel engines offers extensive options when it comes to retrofitting. The huge market potential within, for example, S/G50-, G95- and G80-bores for conversion to methanol running as ME-LGIM units is especially notable."

MAN Energy Solutions' engine designs currently drive some 22,000 vessels globally, of which 3,500 are fully electronically controlled and with the potential for

Page 1 of 3

<https://www.man-es.com/company/press-releases/press-details/2022/01/28/dual-fuel-retrofits-of-low-speed-engines-key-in-push-towards-decarbonisation>

Summary

The ammonia engine is a viable solution for decarbonizing of shipping, however it must be ensured that no other emissions compromises the environmental benefits of ammonia as fuel.

- N_2O will be handled through engine tuning.
- MAN ES is also looking into N_2O handling by after-treatment, in the unlikely event that engine tuning is not sufficient to handle all N_2O .
- NO_x will be in compliance with existing TII and TIII limits.
- NH_3 emission (slip) from the combustion will be handled via an SCR.
- Ammonia is expected gain significant market share towards end of the decade, driven by lower production cost and zero carbon properties.

Joint Development Projects with Korean Shipyards

Dual Fuel	Date	Parties		Ship type	Title
		Charterer or Shipowner	Shipyard or Engineering		
Ammonia	21 Jan. 2022	-	DSME	VLCC	Memorandum of Understanding for Joint Development Project of DSME NH3 Dual Fuel VLCC
Methanol	5 Apr. 2022	-	DSME	Container	Memorandum of Understanding for Joint Development Project of DSME Methanol Fueled Containership
Ammonia	2021	-	DHSC	115K Tanker	Development of NH3 fueled 115K Tanker with DHSC
Ammonia	2020	-	HMD	50K P/C	Development of NH3 fueled 50K P/C with HMD
Ammonia	2020 ~	-	DSME	23K CV	Development of NH3 fueled 23K CV with DSME
Ammonia	2020 ~	-	HHI	VLCC	Development of NH3 fueled VLCC with HHI
Ammonia	2020 ~	Navig8	KMS-EMEC	Bunkering Vessel	Development of NH3 fueled NH3 bunkering vessel with KMS-EMEC
Ammonia	2020 ~	MISC	SHI	115K Tanker	Development of NH3 fueled 115K Tanker with SHI
LNG	2020 ~	Shell	DSME	LNGC	Future LNGC with Shell & DSME
-	30 Sep. 2019	-	HHI & Global Service	-	Cooperation agreement with digital platform & Service



MAN Energy Solutions

Future in the making

Thank you
very much



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confidential

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