

Navigating the future-fuel outlook for large merchant marine vessels

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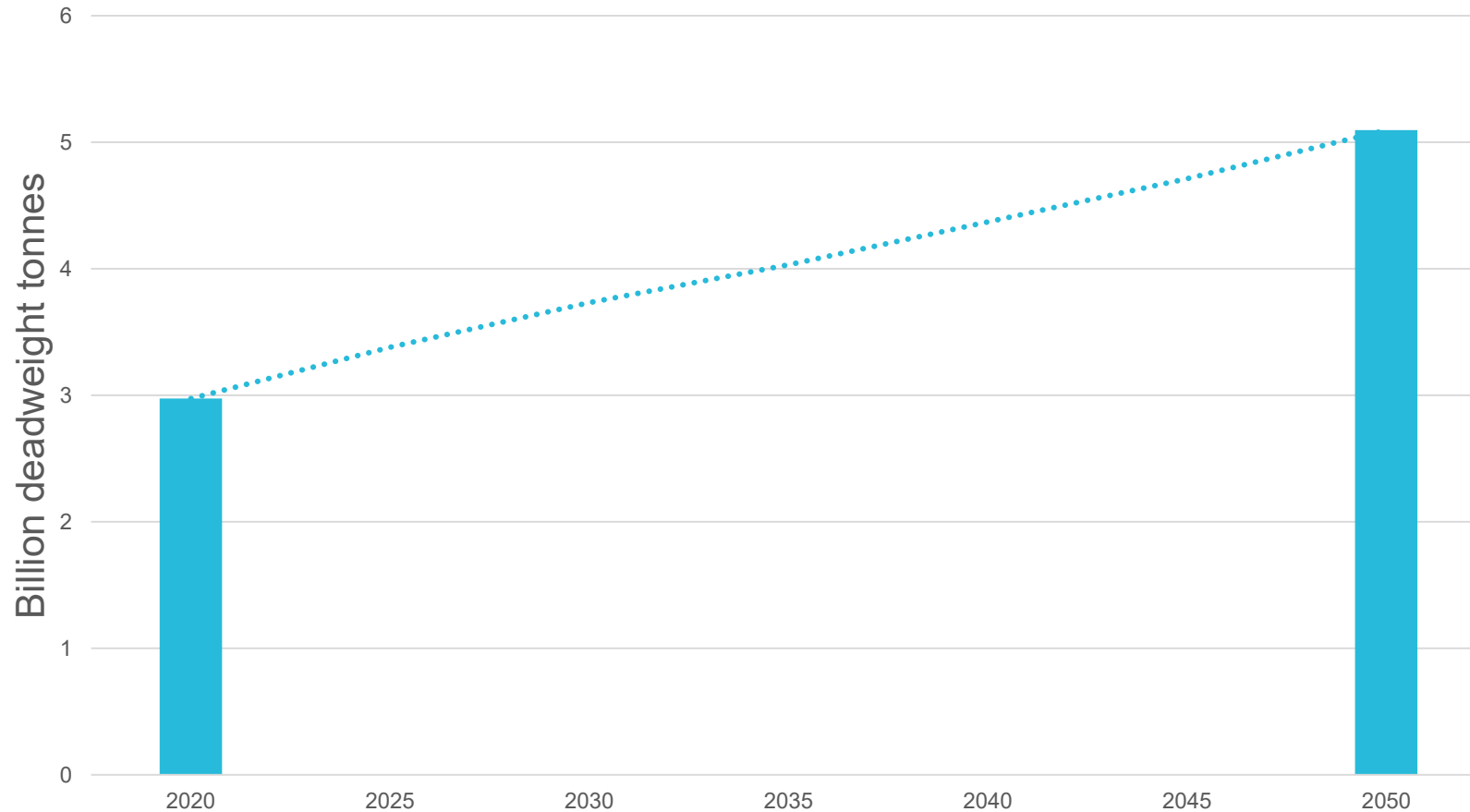
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Agenda

- 1 Alternative fuels: status & outlook
- 2 Ammonia engine development
- 3 MAN B&W ME-LGIM methanol engines
- 4 Summary

Alternative fuels: status & outlook

We expect the shipping sector to grow 60% over the next 30 years



- Primary drivers of growth are foreseen to be **increased globalization** and **elevating standards of living** in developing countries which will trigger increased **cross- and intracontinental transport**
- Limiting factors are **geopolitical uncertainties** and increasing **nationalism/regionalism**

Projections are based on MAN ES assessment and OECD, Real GDP long-term forecast, predating war in Ukraine: <https://data.oecd.org/gdp/real-gdp-long-term-forecast.htm#indicator-chart>



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

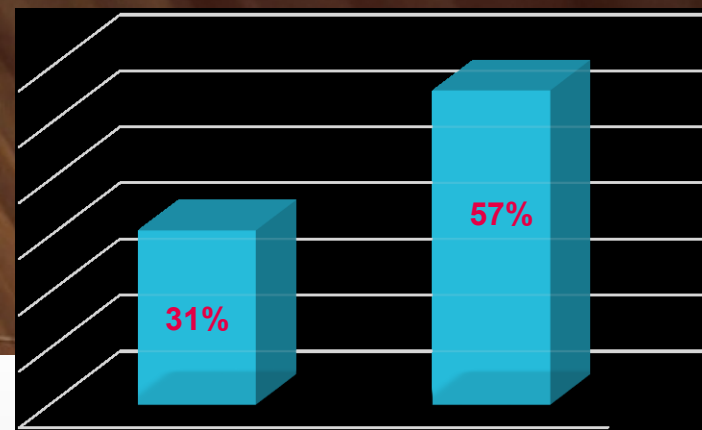
~ 23.000 MAN B&W two-stroke engines.

~ 12.000 MAN four-stroke propulsion engines.

Powering sustainable **shipping** by opening clear routes

MAN Energy Solutions supports all

1100+



2021

2022

LNG/methane

Ethane

Methanol

LPG

Ammonia

ME-GI

574

engines

(≈14.7 GW)

ME-GA

268

engines

(≈3.7 GW)

ME-GIE

39

engines

(≈0.5 GW)

ME-LGIM

110

engines

(≈3.9 GW)

ME-LGIP

149

engines

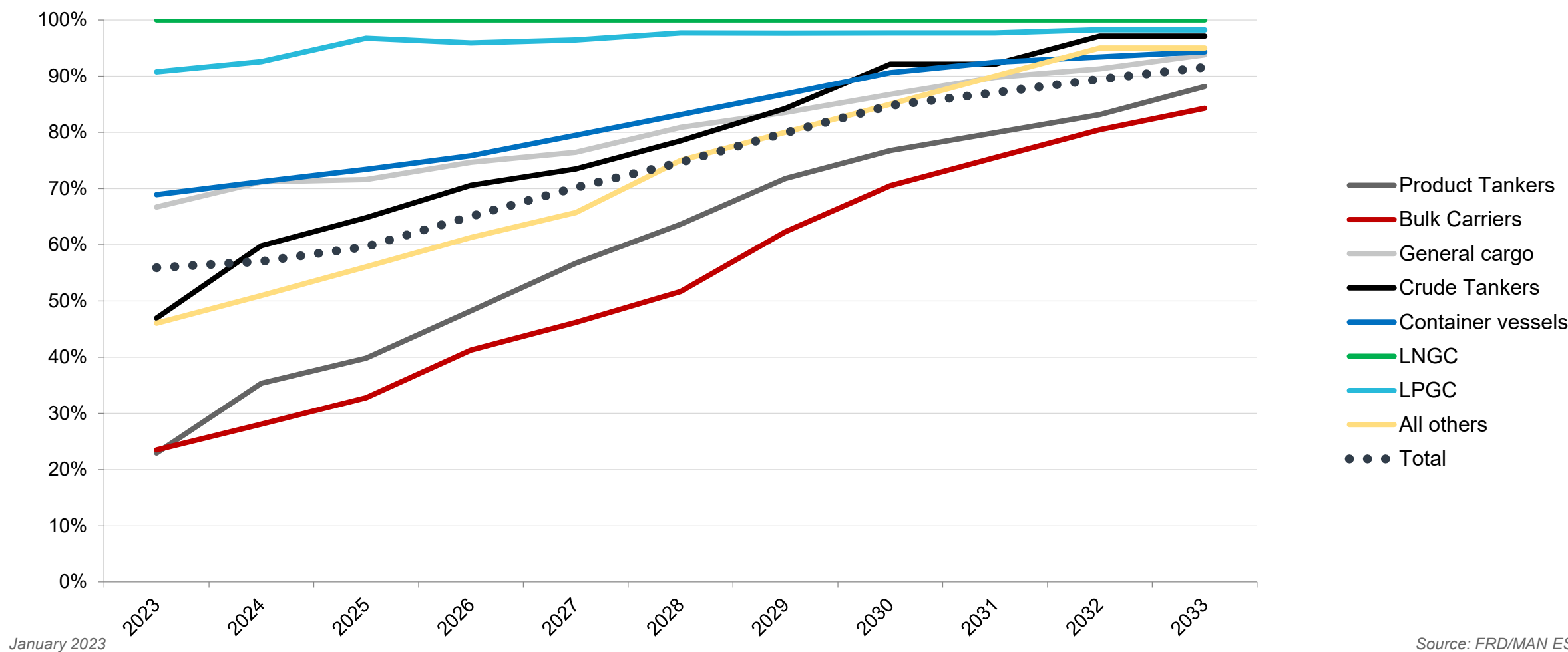
(≈2.2 GW)



Two-stroke dual fuel uptake forecast

2022: 57% of contracted two-stroke vessels were dual-fuel. We expect 85% towards end of the decade.

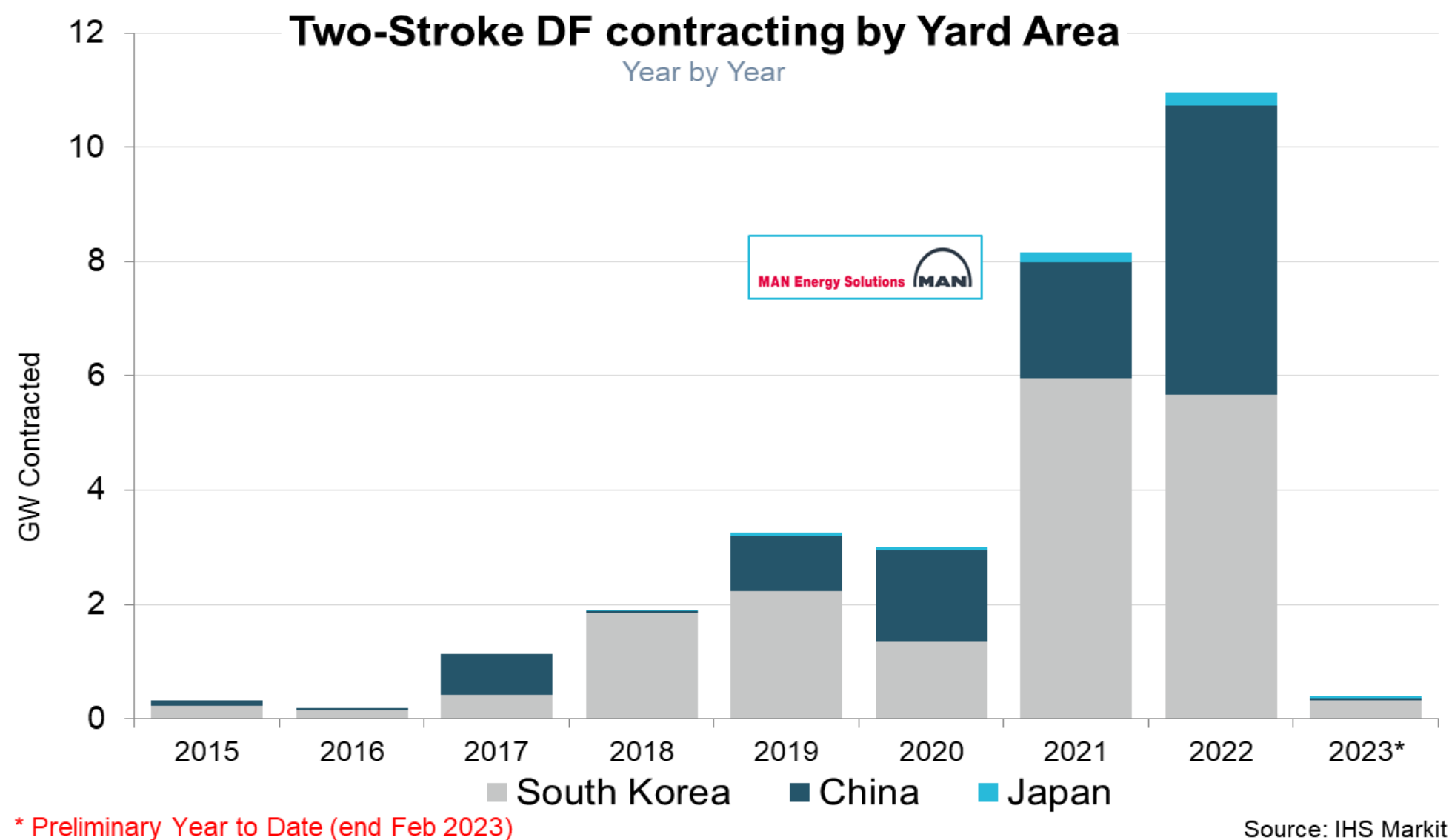
DF Two-Stroke Contracting - % of MW Contracted per Year



January 2023

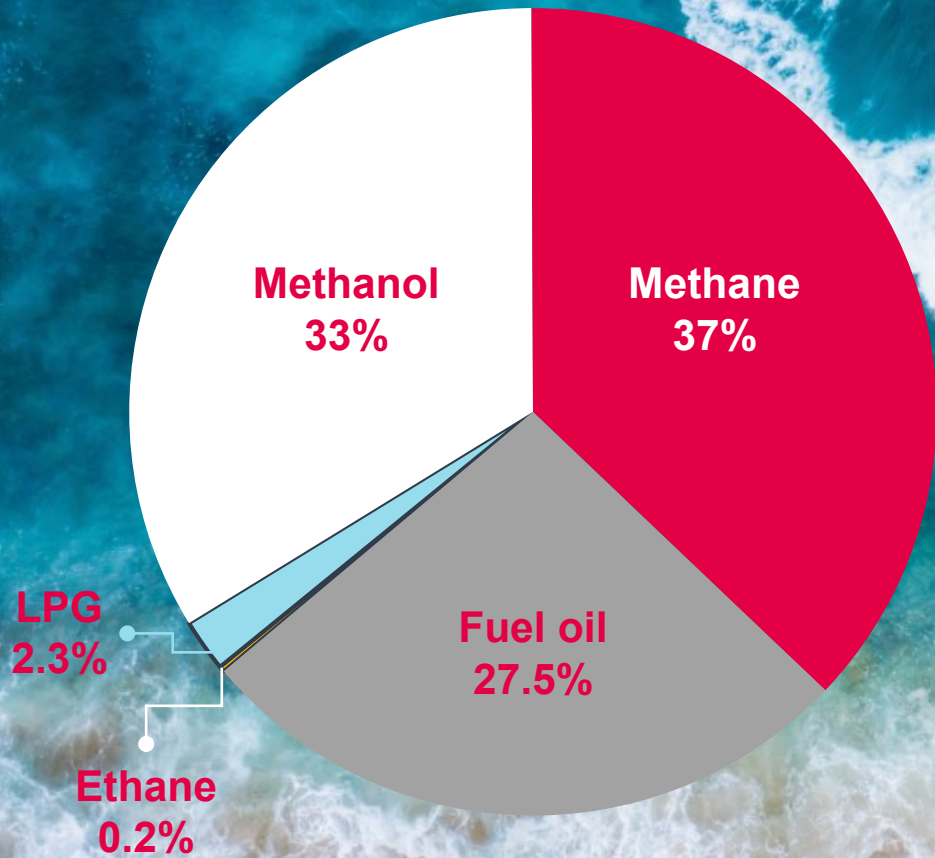
Source: FRD/MAN ES

Dual-fuel two-stroke vessel contracting per yard area

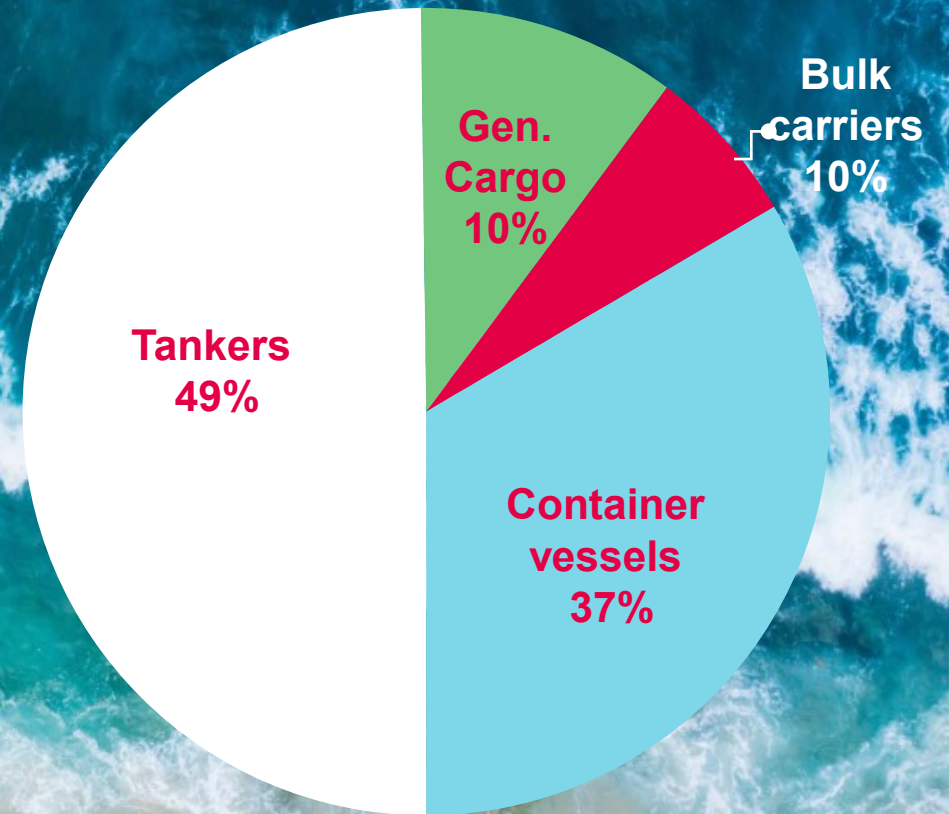


Fuel type distribution in newbuilding project pipeline

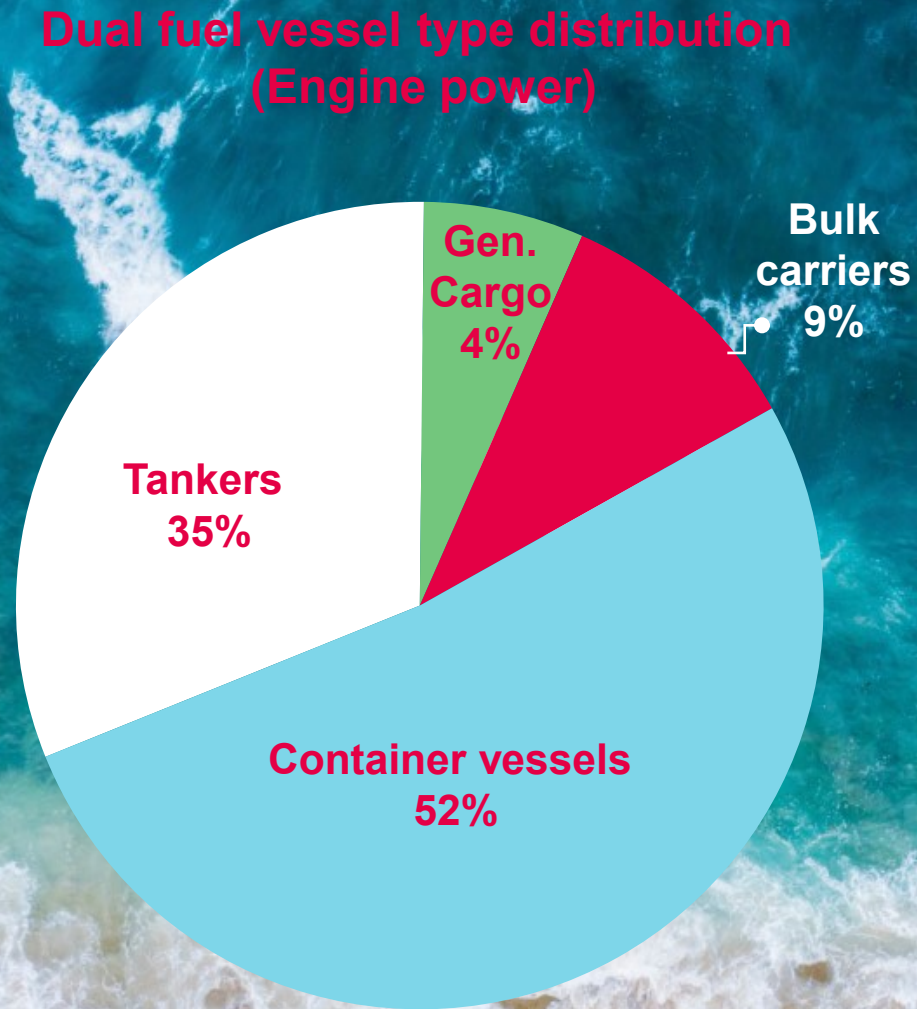
Fuel distribution (GW)



Dual fuel vessel type distribution (number of ships)



Fuel type distribution in newbuilding project pipeline

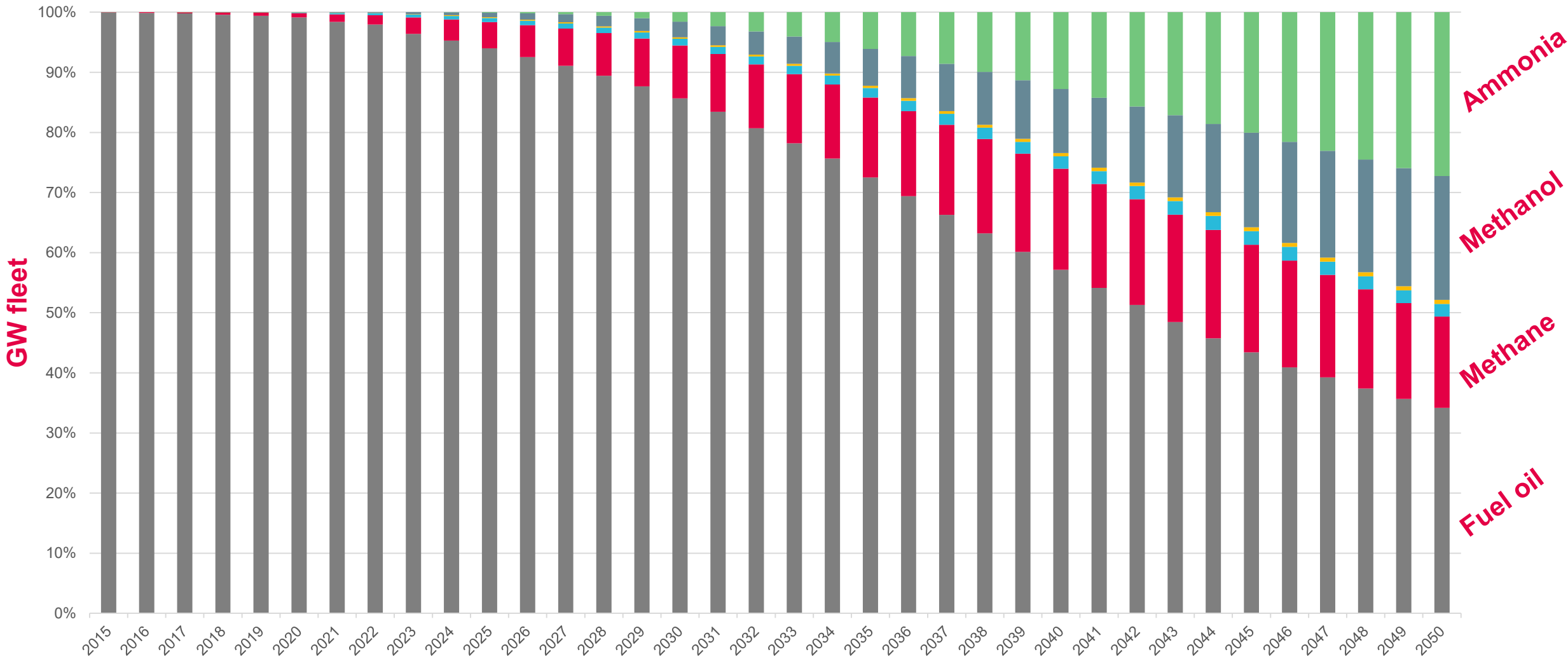


Future fuel mix



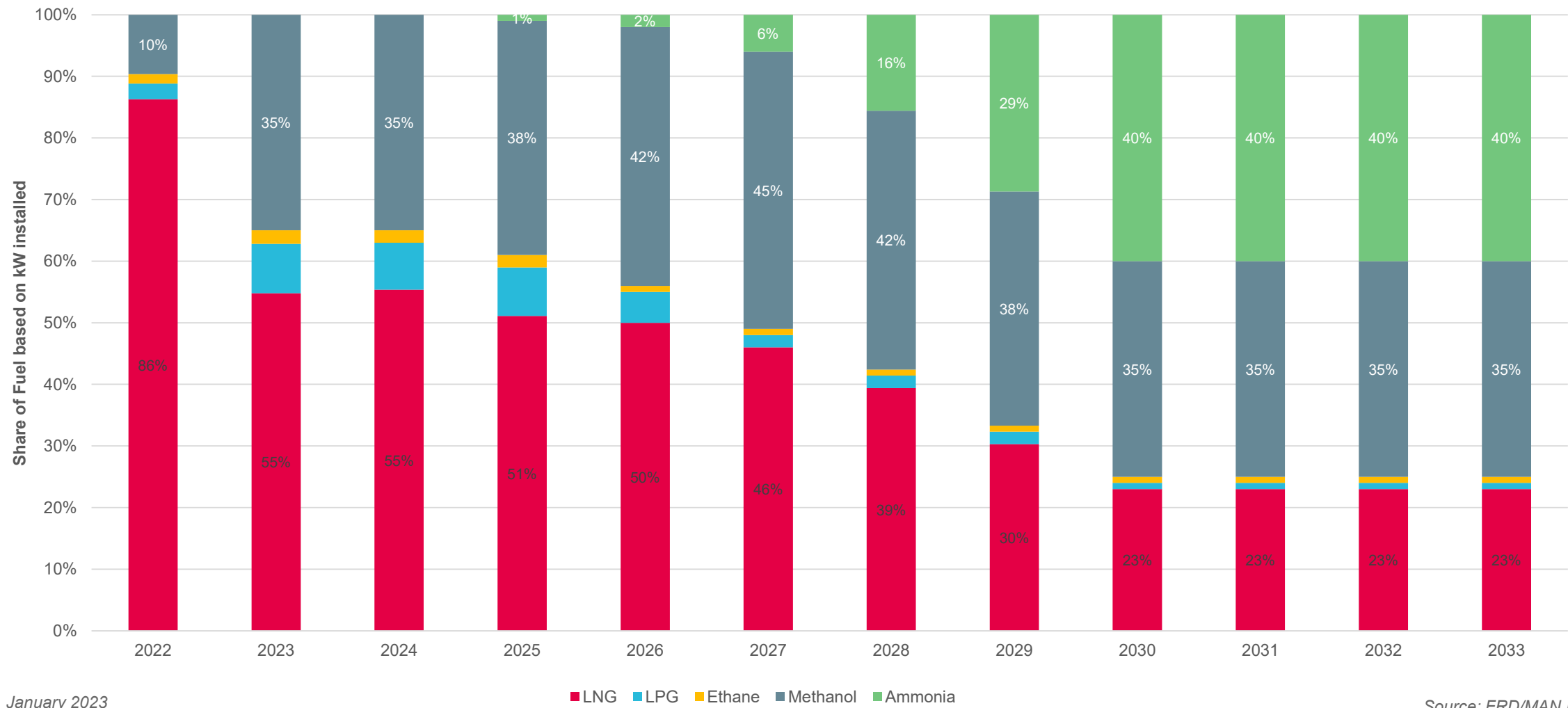
Two-stroke fuel mix forecast towards 2050

34% fuel oil, 27% ammonia, 21% methanol, and 15% methane expected in 2050. Remaining share is LPG and ethane.



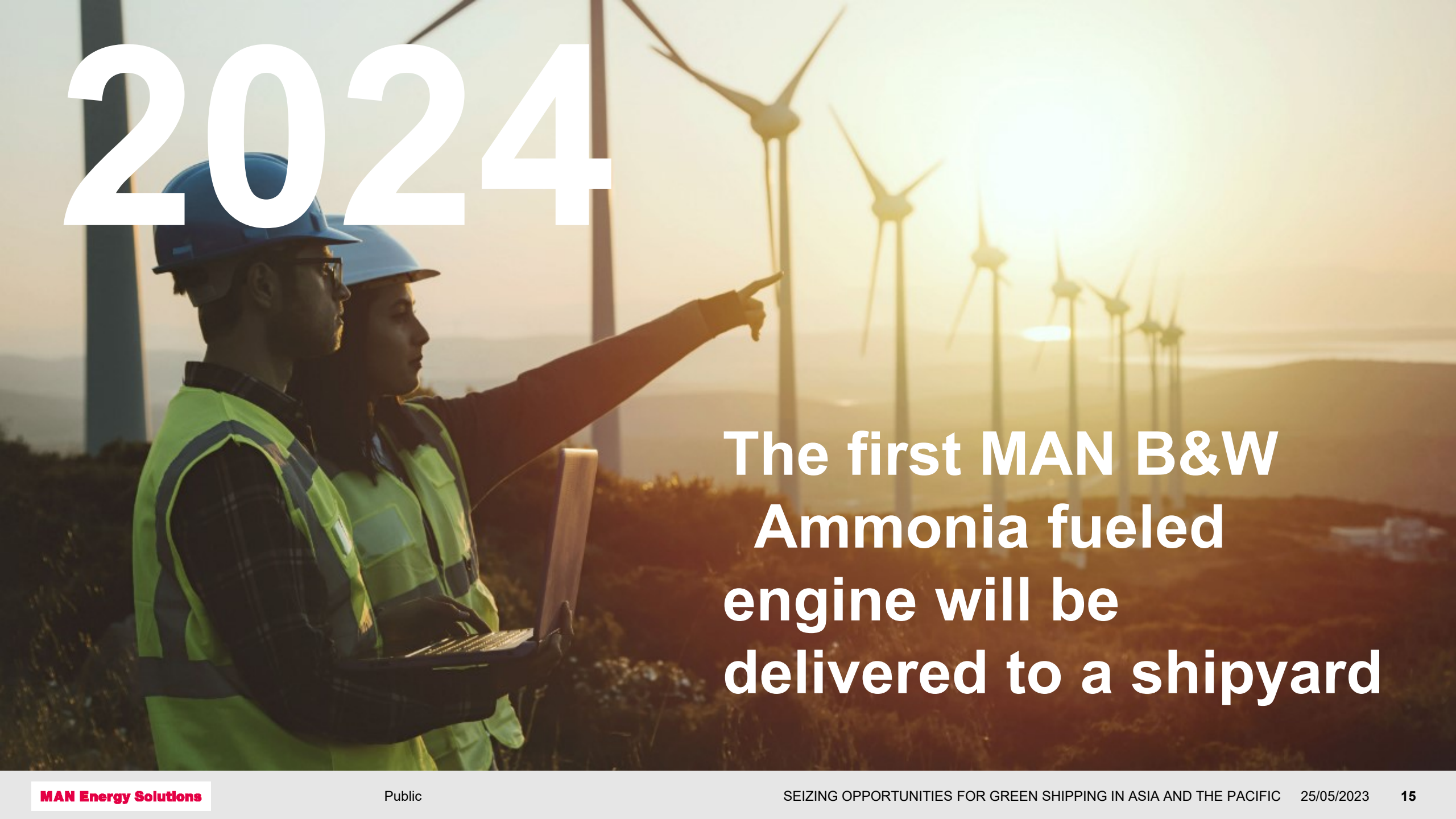
Assumptions: Scenario is based on known factors such as world trade growth, EEDI, EEXI, expected CO2 regulation (currently unspecified), etc.

Two-stroke dual-fuel mix forecast



Ammonia engine development

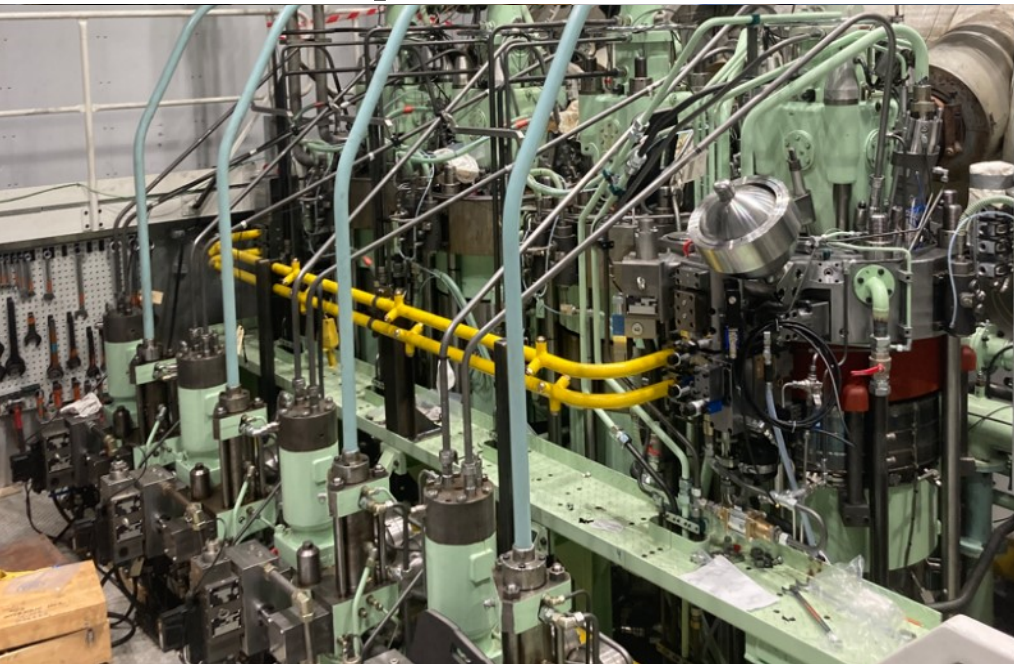
2024

A photograph of two people, a man and a woman, wearing blue hard hats and high-visibility yellow safety vests. They are standing in a field with several wind turbines in the background under a bright, hazy sky. The woman is pointing her right hand towards one of the turbines. The man is holding a tablet or a set of plans. The overall scene suggests a renewable energy project site.

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



Components at RCC for ammonia engine development



Ammonia engine development

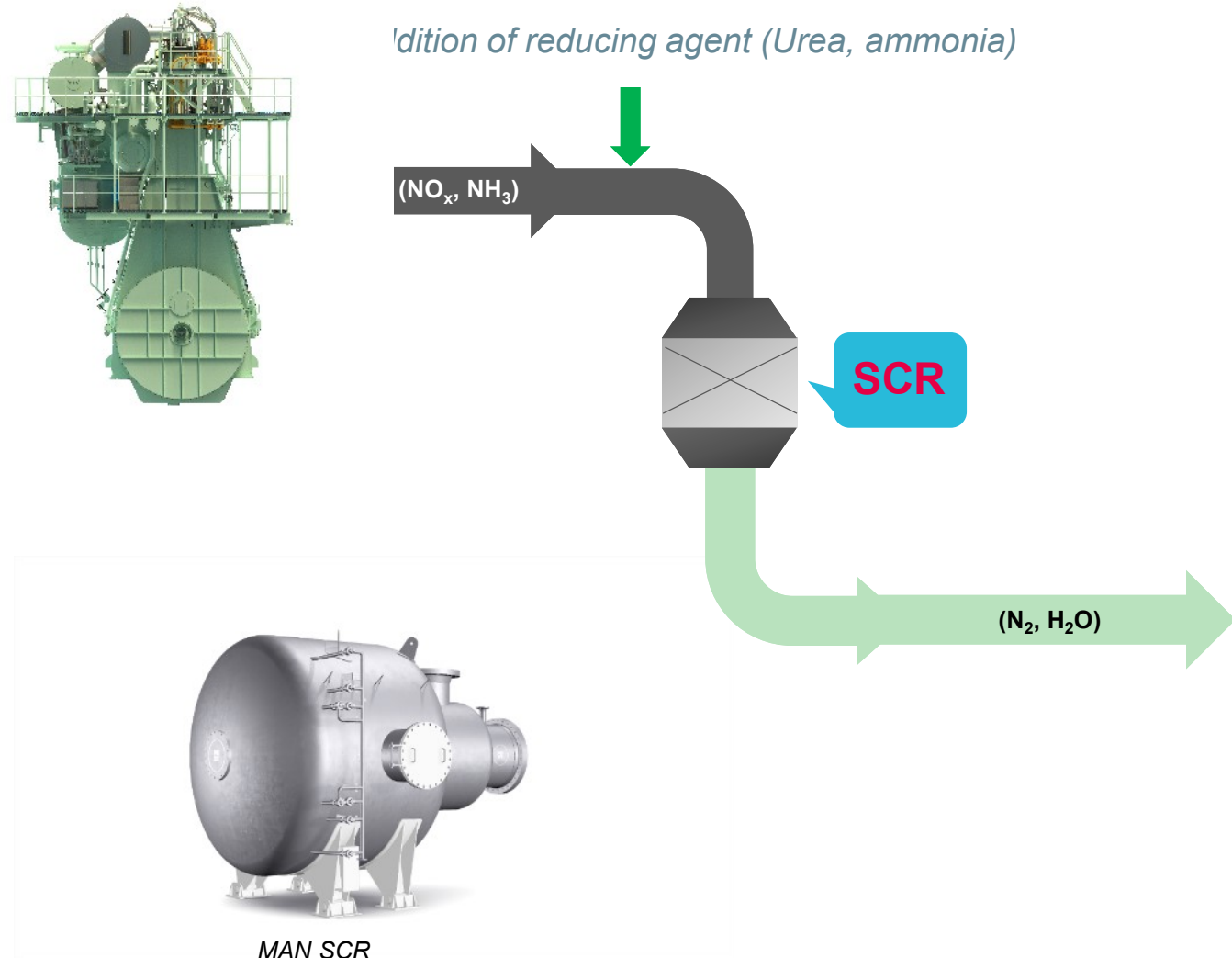
How do we handle potential Nitrous Oxide emissions?

N_2O is a very potent GHG with GWP of 298. It will also be accounted for in FUELEU regulation.

- Nitrous oxide (N_2O) will be removed by engine tuning.

Ammonia slip and NO_x emissions

- Unburned NH_3 and NO_x is removed in the SCR reactor.
- Dosing of additional ammonia to SCR reaction if needed.
- Known SCR technology is suitable. MAN SCR reactor can be applied.



Market introduction strategy

Ammonia engine - market introduction

Delivery of the first ammonia engine to a shipyard ultimo 2024.

Available for general ordering after obtaining positive seagoing service experience.

Event:

Commercial 60 bore engine design tested and verified (FAT).



Positive seagoing service experience obtained.

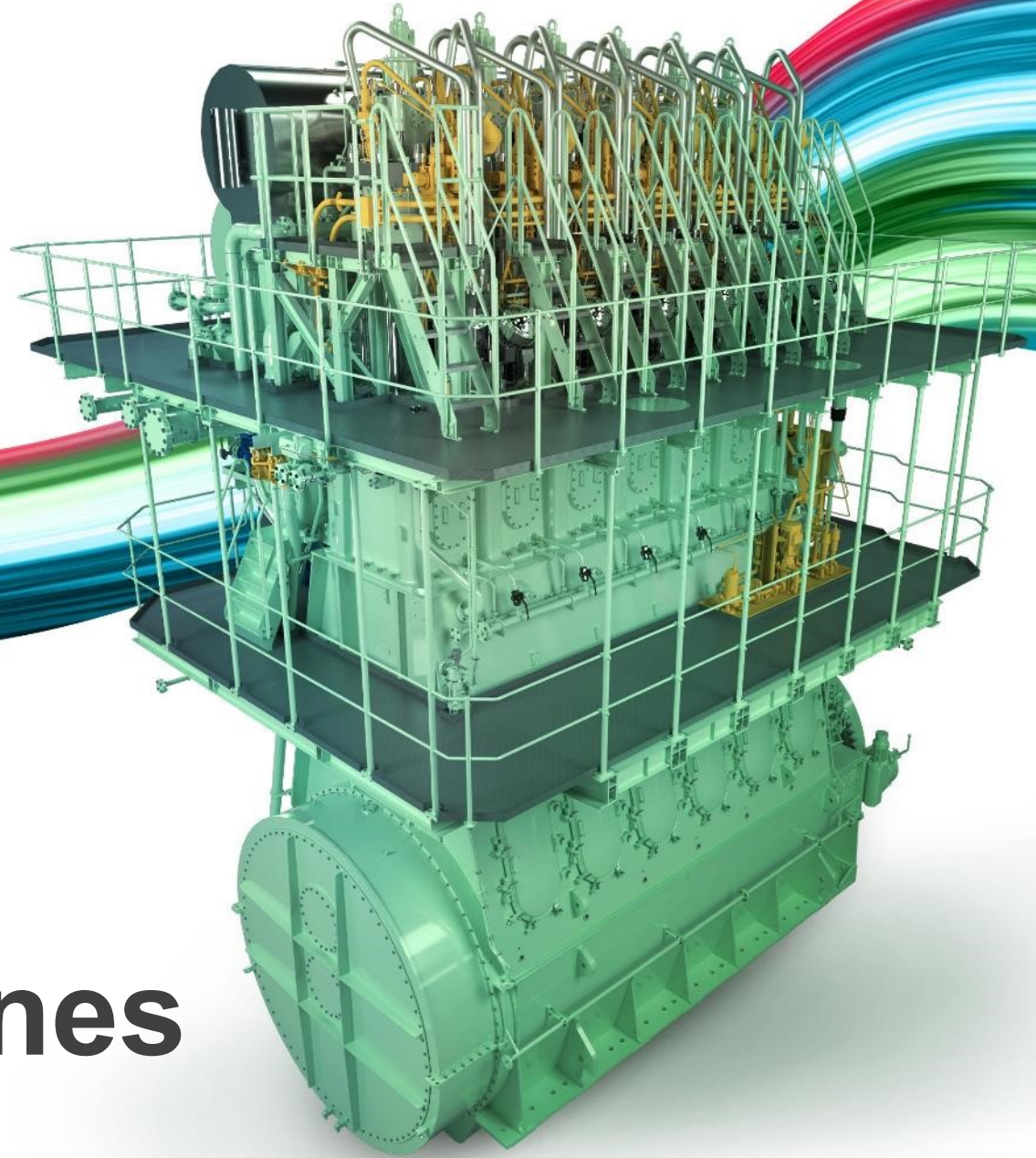


Action:

- **Delivery of the engine to a shipyard.**
 - **2nd bore size announced.**

- **Design available to licensees to order and produce from.**
 - **Start of unlimited sales.**

**MAN B&W
ME-LGIM
methanol engines**



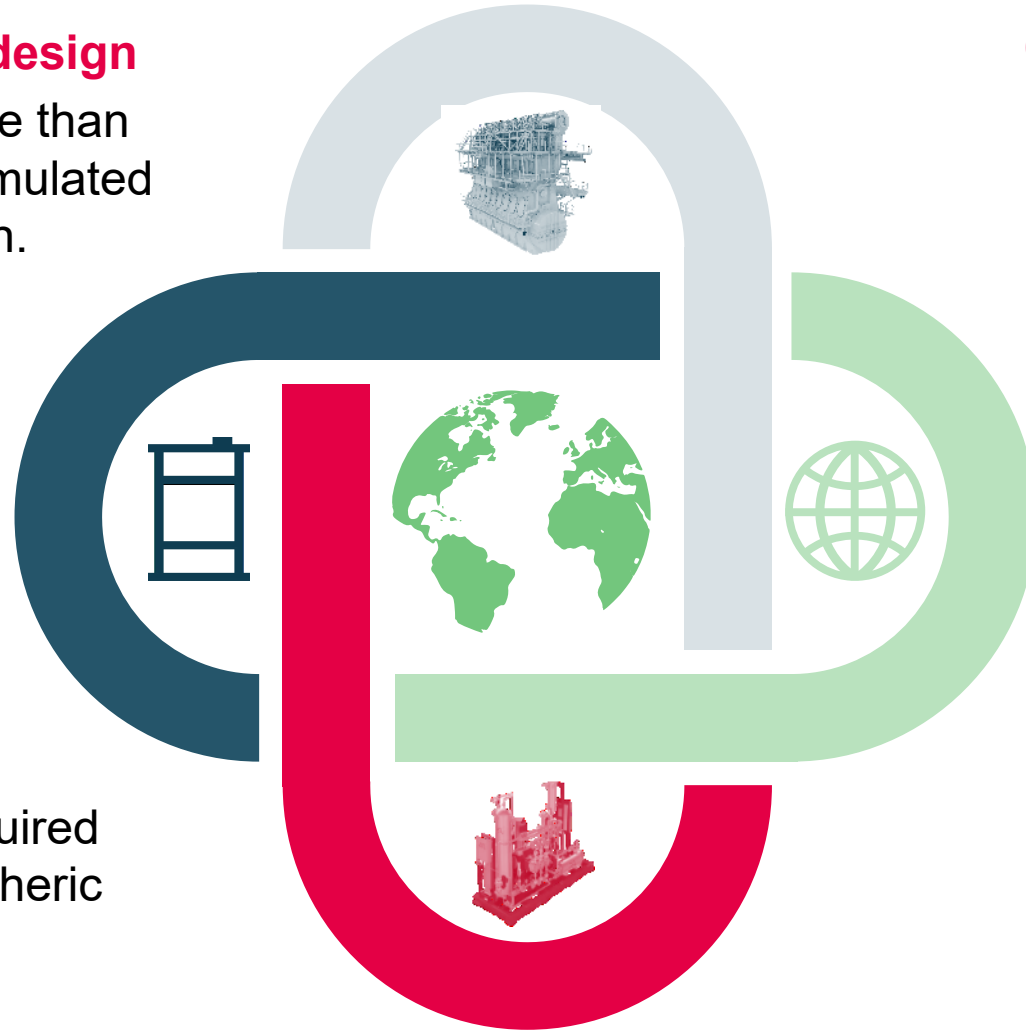
Why select methanol as marine fuel?

Proven MAN B&W engine design

In operation since 2016. More than 400.000 running hours accumulated on methanol alone since then.

Carbon neutral

Methanol can be carbon neutral.



Easy storage

No cryogenic equipment required and can be stored in atmospheric pressure tanks.

Simple fuel supply system

Only 13 bars required.

Methanol – 30% of total newbuilding project pipeline



Newbuilding pipeline fuel distribution based on engine power: 30% methanol, 36% methane, 32.3% fuel oil, 1.5% LPG, and 0.2% ethane.

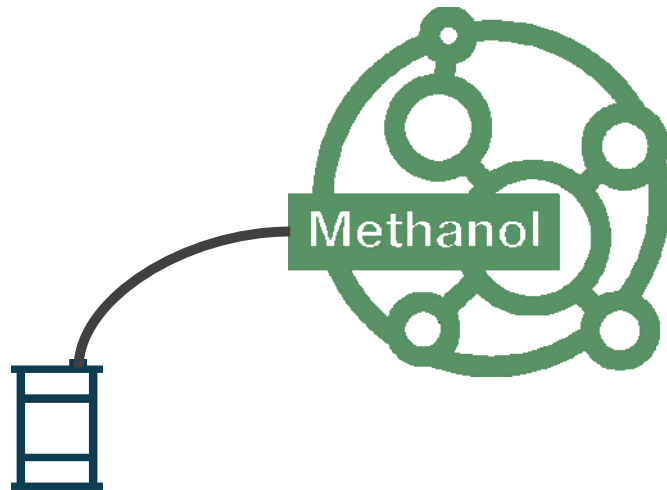


Where will the green methanol supply come from?

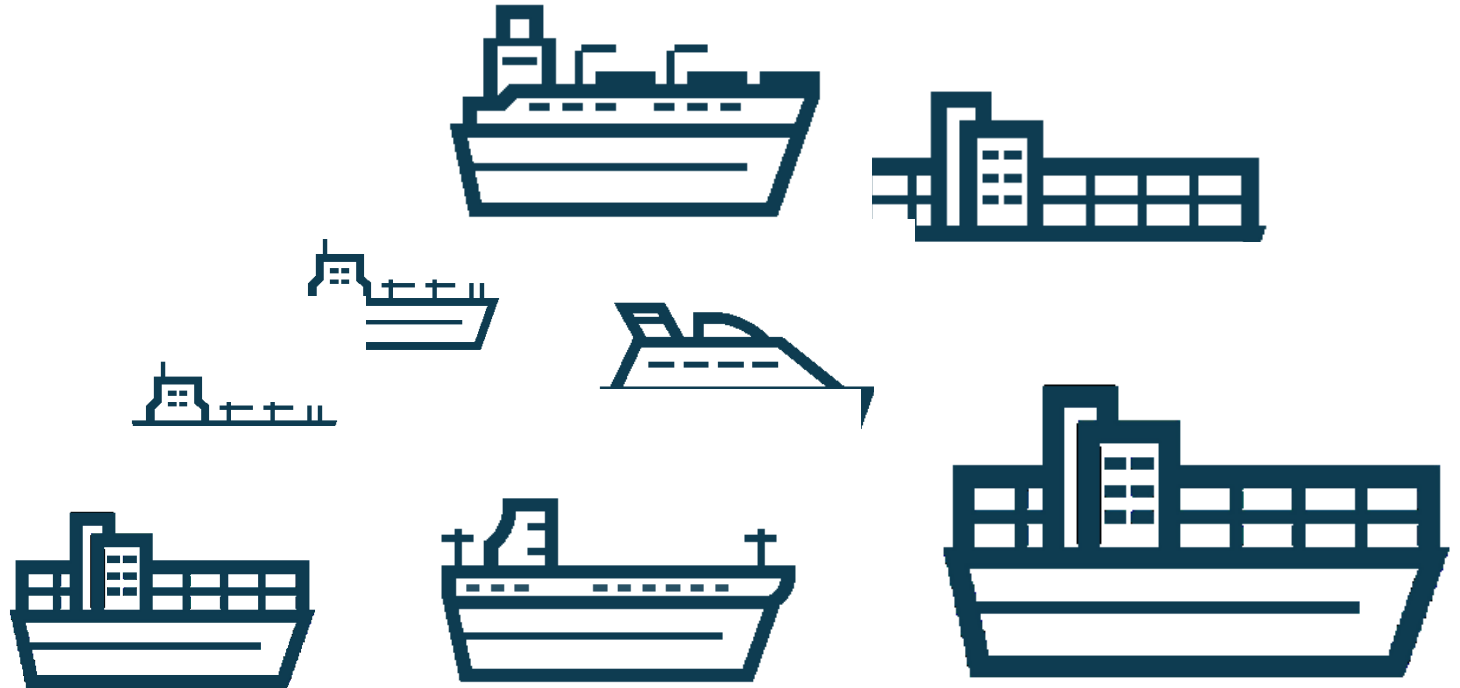
The demand is here – and the supply is picking up

The green methanol demand from upcoming methanol-fueled newbuildings is clearly bigger than the supply of green methanol – as it seems today.

Supply



Demand

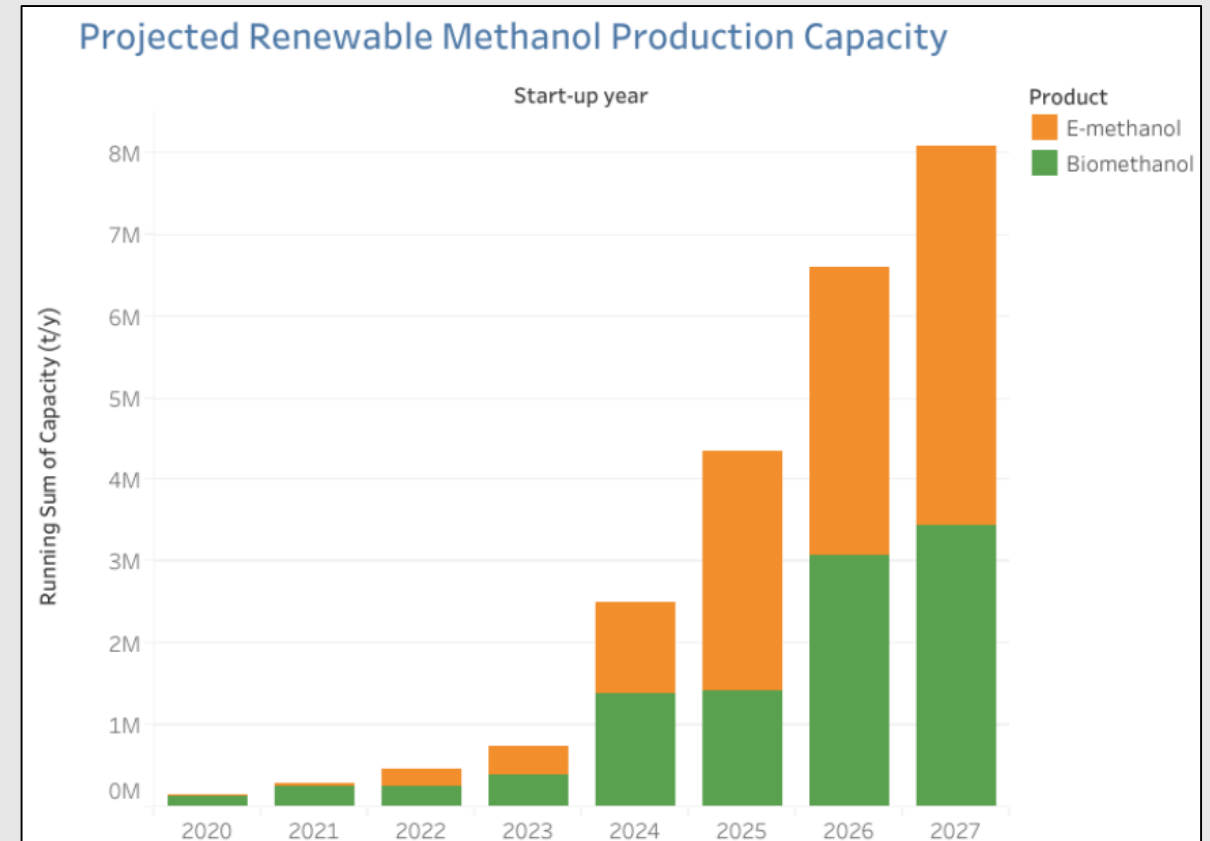
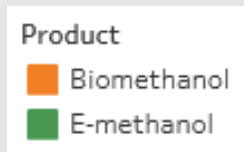


Green methanol projects as of Q1 2023

Today, 110 X ME-LGIM engines are in the order book.

Green methanol production projects as of Q1 2023:

- Projects are since Q1 2022 increased as:
 - from around 2.6 million tons a year
 - to upwards of 8 million tons a year in 2027
 - across more than 80 projects

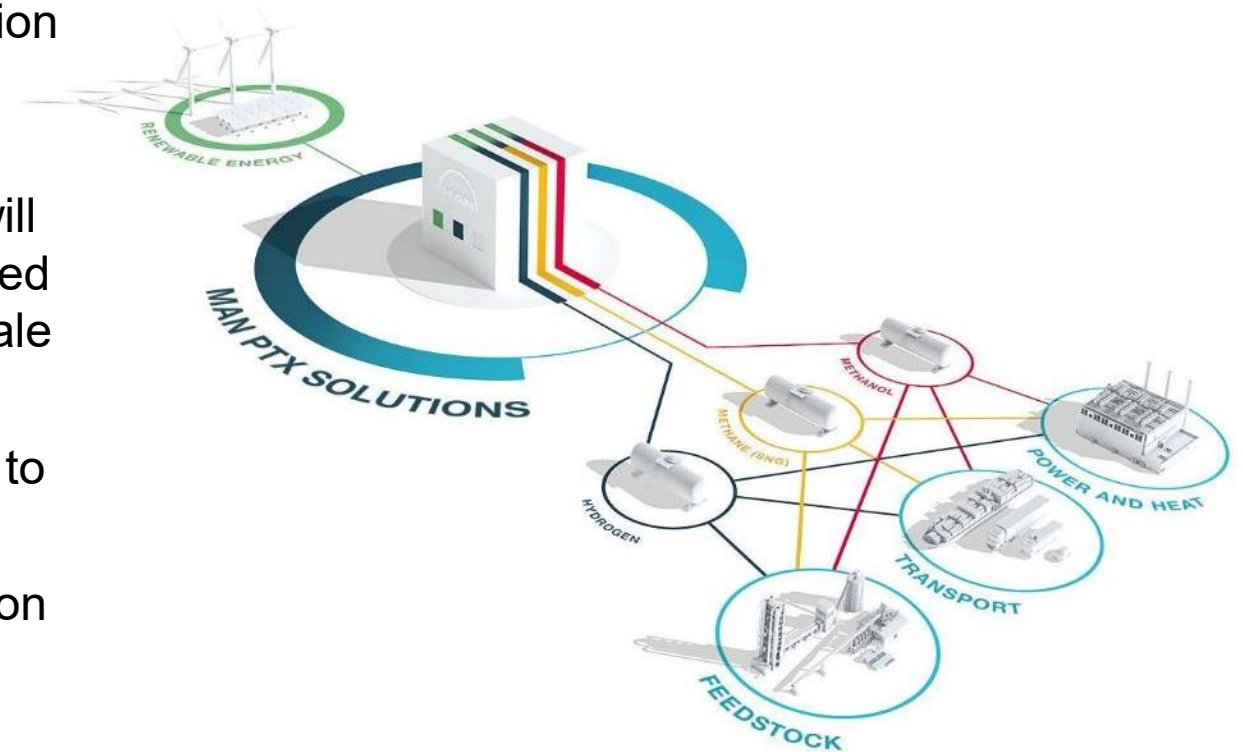


Source: Methanol Institute Renewable Methanol Database of Current/Announced projects, <https://www.methanol.org/renewable/>

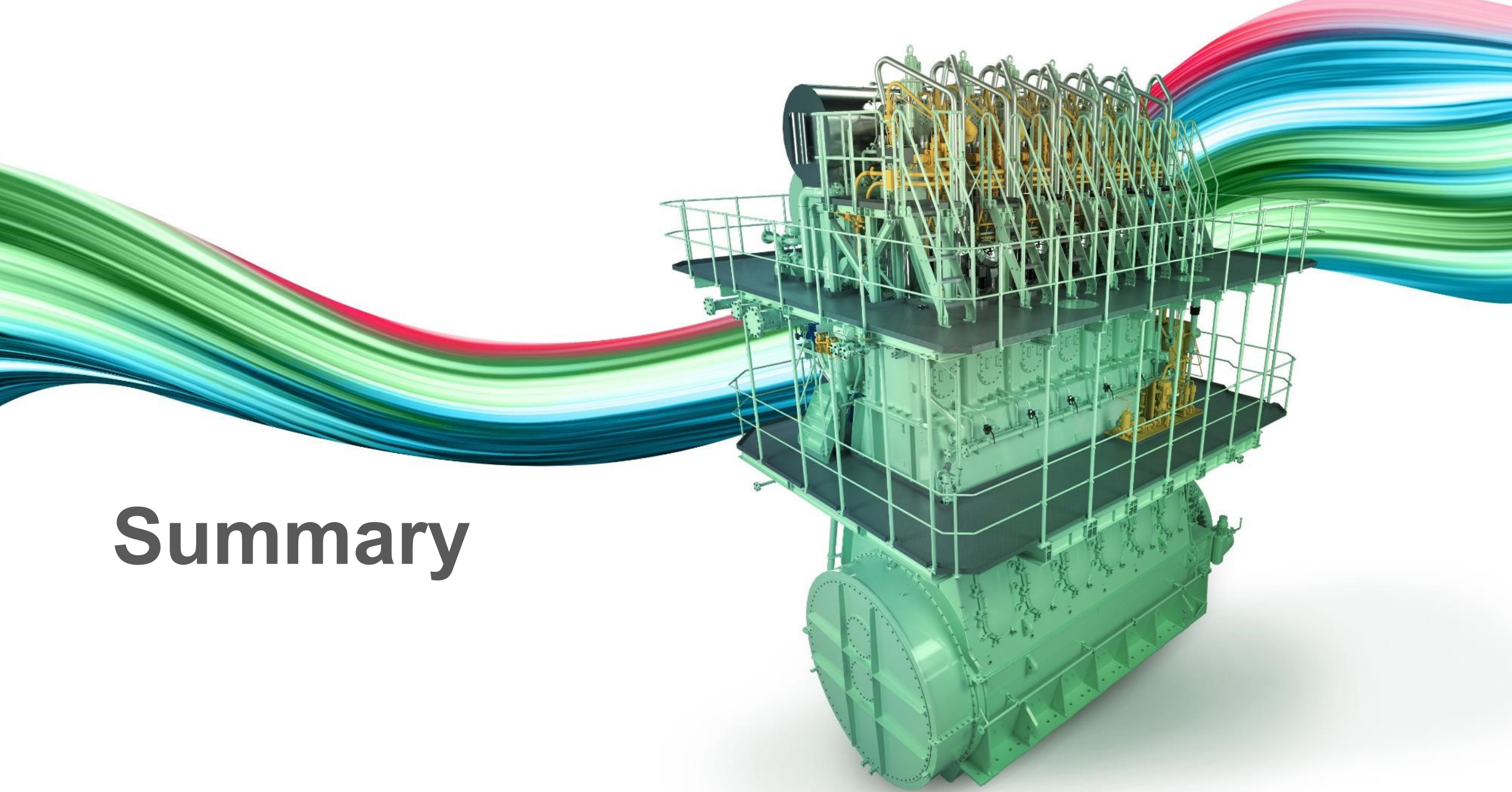
The trend is clear

Production and supply of green methanol

- Partnerships, **M**emorandums of **U**nderstanding, **L**etters of **I**ntend and **F**inal **I**nvestment **D**ecisions for production plants are clearly increasing in parallel with the ME-LGIM engine order book.
- Significant speed up of **F**inal **I**nvestment **D**ecisions will happen once the price becomes competitive compared to fossil alternatives: This comes with carbon tax, scale and volume.
- MAN B&W ME-LGIM can make a scalable transition to green methanol.
- MAN Energy Solutions foresees a need of ≈ 128 million tons by 2040 and ≈ 255 million tons by 2050.

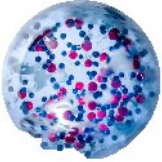


Summary



Both **green methanol** and **ammonia** are expected to become very prominent marine fuels

However, the current maturity levels of methanol and ammonia as marine fuels are very different.

 Fuel type	 Engine technology maturity	 Engine availability	 Auxiliary system complexity	 Toxicity and safety hazard?	 Greenhouse gas emission reduction
Methanol	<u>High</u> Operational experience since 2016.	<u>High</u> S50, G50, G80, G95 (committed to G45, G60, S60, G70) .	<u>Low</u> Simple tanks. Only 13 bar for LFSS.	<u>Medium</u> Toxic and can poison onboard personal. Approved as marine fuel.	<u>High</u> Green methanol is carbon neutral, but rely on bio-genic CO ₂ .
Ammonia	<u>Low - R&D phase</u> First combustion test first half of 2023.	<u>Low</u> First bore size will be 60-bore. 2 nd bore size TBA in 2024.	<u>High</u> Additional requirements to double wall ventilation and ammonia catch system.	<u>High</u> More toxic & can poison onboard personnel. Currently not approved as marine fuel.	<u>High</u> Green ammonia is carbon free. However, N ₂ O emissions must be avoided.

Disclaimer

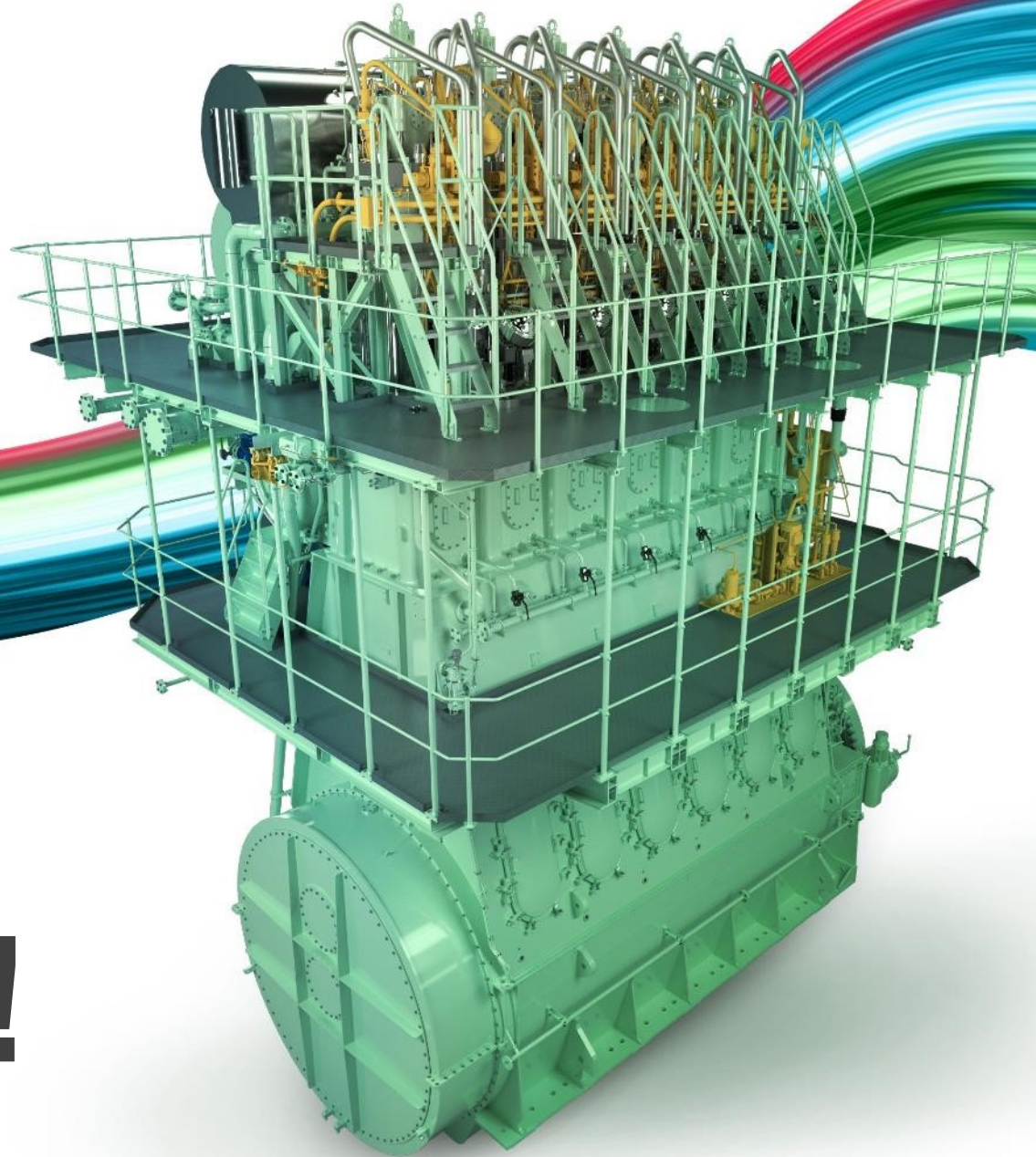
All data provided in this document is non-binding.

This data serves informational purposes only and is especially not guaranteed in any way.

Depending on the subsequent specific individual projects, the relevant data may be subject to changes and will be assessed and determined individually for each project. This will depend on the particular characteristics of each individual project, especially specific site and operational conditions.



MAN Energy Solutions
Future in the making



**Thank you
very much!**