Navigating the future-fuel outlook for large merchant marine vessels

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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](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+

LNG/methane

<table>
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<tr>
<th>Type</th>
<th>2021</th>
<th>2022</th>
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<tr>
<td>ME-GI</td>
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<td>ME-GA</td>
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<td>ME-GIE</td>
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Ethane

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Methanol

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LPG

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Ammonia

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<th>Type</th>
<th>2021</th>
<th>2022</th>
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<tr>
<td></td>
<td>31%</td>
<td>57%</td>
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Two-stroke dual fuel uptake forecast

2022: 57% of contracted two-stroke vessels were dual-fuel. We expect 85% towards end of the decade.
Dual-fuel two-stroke vessel contracting per yard area

Two-Stroke DF contracting by Yard Area

Year by Year

Source: IHS Markit

* Preliminary Year to Date (end Feb 2023)
Fuel type distribution in newbuilding project pipeline

Fuel distribution (GW)
- Methanol: 33%
- Methane: 37%
- Fuel oil: 27.5%
- LPG: 2.3%
- Ethane: 0.2%

Dual fuel vessel type distribution (number of ships)
- Tankers: 49%
- Container vessels: 37%
- Bulk carriers: 10%
- Gen. Cargo: 10%
Fuel type distribution in newbuilding project pipeline

Dual fuel vessel type distribution (Engine power)

- Container vessels: 52%
- Tankers: 35%
- Gen. Cargo: 4%
- Bulk carriers: 9%

SEIZING OPPORTUNITIES FOR GREEN SHIPPING IN ASIA AND THE PACIFIC
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

Share of Fuel based on kW installed

- LNG
- LPG
- Ethane
- Methanol
- Ammonia

Source: FRD/MAN ES

January 2023

SEIZING OPPORTUNITIES FOR GREEN SHIPPING IN ASIA AND THE PACIFIC

2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033
Ammonia engine development
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?

$\text{N}_2\text{O}$ is a very potent GHG with GWP of 298. It will also be accounted for in FUELEU regulation.

- Nitrous oxide ($\text{N}_2\text{O}$) will be removed by engine tuning.

**Ammonia slip and NOx emissions**

- Unburned $\text{NH}_3$ and $\text{NO}_x$ 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

- Container: 68%
- Bulk: 15%
- Tank: 9%
- General cargo: 8%

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.
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, Memorandums of Understanding, Letters of Intent and Final Investment Decisions for production plants are clearly increasing in parallel with the ME-LGIM engine order book.

- Significant speed up of Final Investment Decisions 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.
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.

<table>
<thead>
<tr>
<th>Fuel type</th>
<th>Engine technology maturity</th>
<th>Engine availability</th>
<th>Auxiliary system complexity</th>
<th>Toxicity and safety hazard?</th>
<th>Greenhouse gas emission reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methanol</td>
<td>High</td>
<td>High</td>
<td>Low</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>Operational experience since 2016.</td>
<td>S50, G50, G80, G95 (committed to G45, G60, S60, G70).</td>
<td>Simple tanks. Only 13 bar for LFSS.</td>
<td>Toxic and can poison onboard personal. Approved as marine fuel.</td>
<td>Green methanol is carbon neutral, but rely on bio-genic CO₂.</td>
</tr>
<tr>
<td>Ammonia</td>
<td>Low - R&amp;D phase</td>
<td>Low</td>
<td>High</td>
<td>High</td>
<td>High</td>
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<tr>
<td></td>
<td>First combustion test first half of 2023.</td>
<td>First bore size will be 60-bore. 2nd bore size TBA in 2024.</td>
<td>Additional requirements to double wall ventilation and ammonia catch system.</td>
<td>More toxic &amp; can poison onboard personnel. Currently not approved as marine fuel.</td>
<td>Green ammonia is carbon free. However, N₂O emissions must be avoided.</td>
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</tbody>
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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.
Thank you very much!