MAN Energy Solutions
Future in the making

# MAN B&W Ammonia fueled engine development status

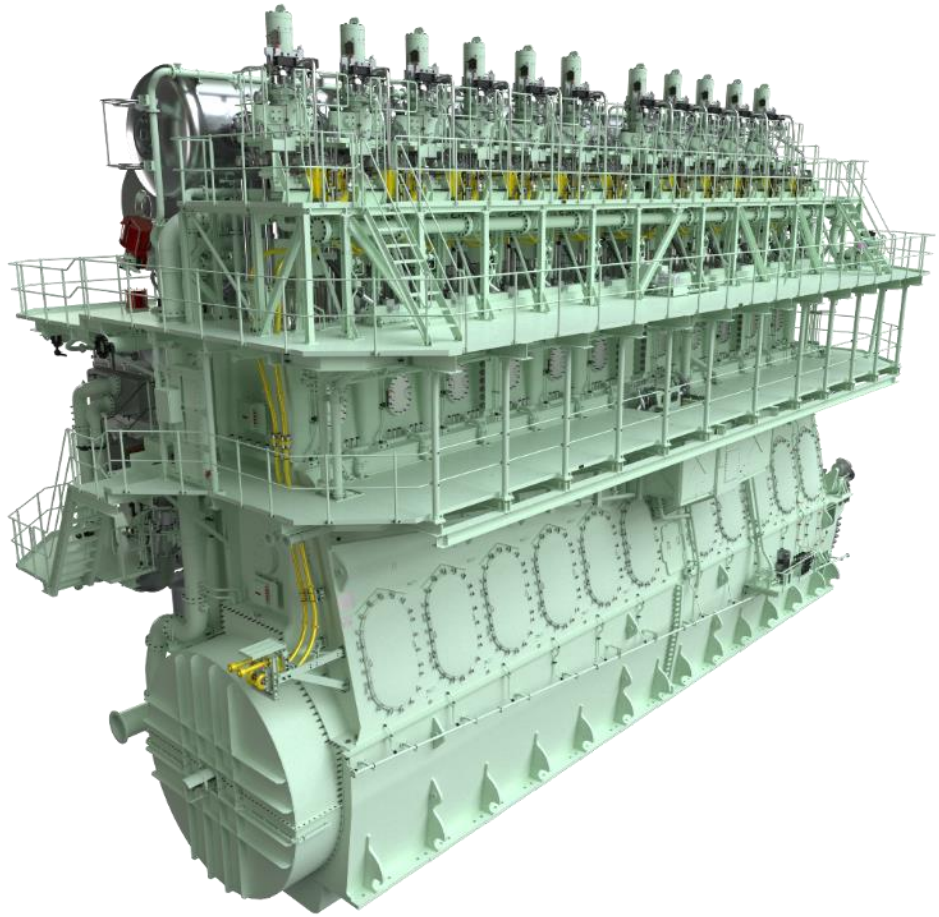
# Agenda

1 MAN B&W engines for alternative fuels

2 Ammonia engine development

3 Future-proof propulsion

# 1 MAN B&W engines for alternative fuels



# Powering sustainable shipping by opening clear pathways

MAN Energy Solutions supports all

LNG | Ethane | Methanol | LPG | Ammonia

ME-GI | ME-GA | ME-GIE | ME-LGIM | ME-LGIP | → 2024

# 2 Ammonia Engine Development


# New test engine underway

# Two-stroke ammonia engine development schedule

## 2019

### Pre-study

- ✓ NH3 combustibility investigation.

## 2020

### Project kick-off

- ✓ 4T50ME-X test engine received as platform for the Ammonia engine development.
- ✓ HAZID workshop on engine concept.
- ✓ Combustion chamber 1st evaluation.

## 2021

### Engine concept R&D

- Engine basic concept defined based on R&D and simulations.
- Ammonia fuel supply & Auxiliary systems specified and established in RCC.

## 2022

### Engine combustion and emission

- 1st engine confirmation at Research Centre Copenhagen (RCC).
- Specification of emission after-treatment done.

## 2023

### Full scale engine test

- Full scale engine test at RCC evaluated for 1st commercial design.

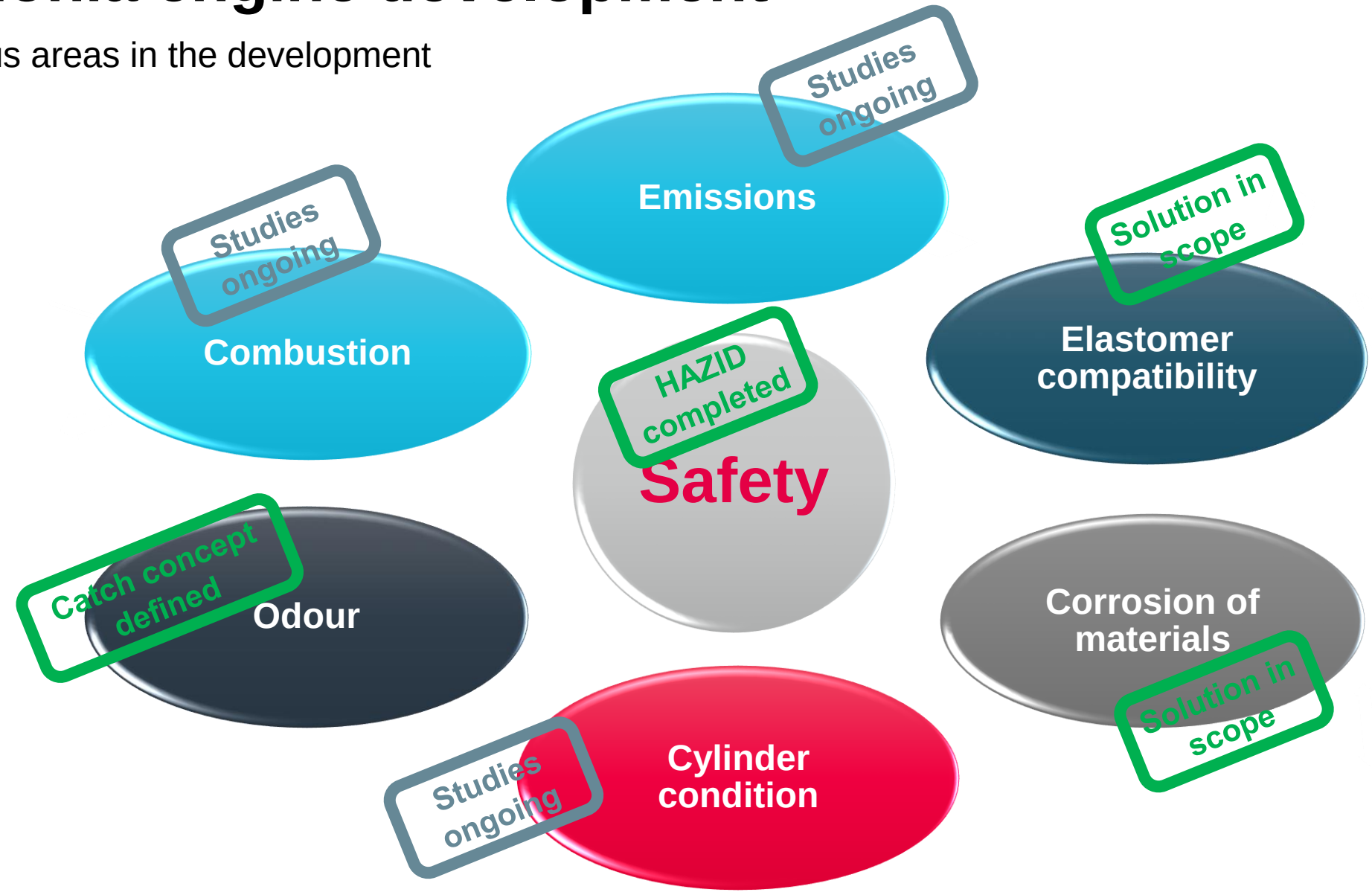
## 2024

### 1st engine delivery to yard

- Ammonia engine in engine programme.
- 1st ammonia fueled engine delivered to yard.

# Ammonia engine development

Main focus areas in the development



# Ammonia engine Development

Materials

**Fuel Supply System**

– 316L steel is recommended.
– To be welded with backing gas / pickling.

**LGI injection system**

– Current materials expected to perform satisfactorily.

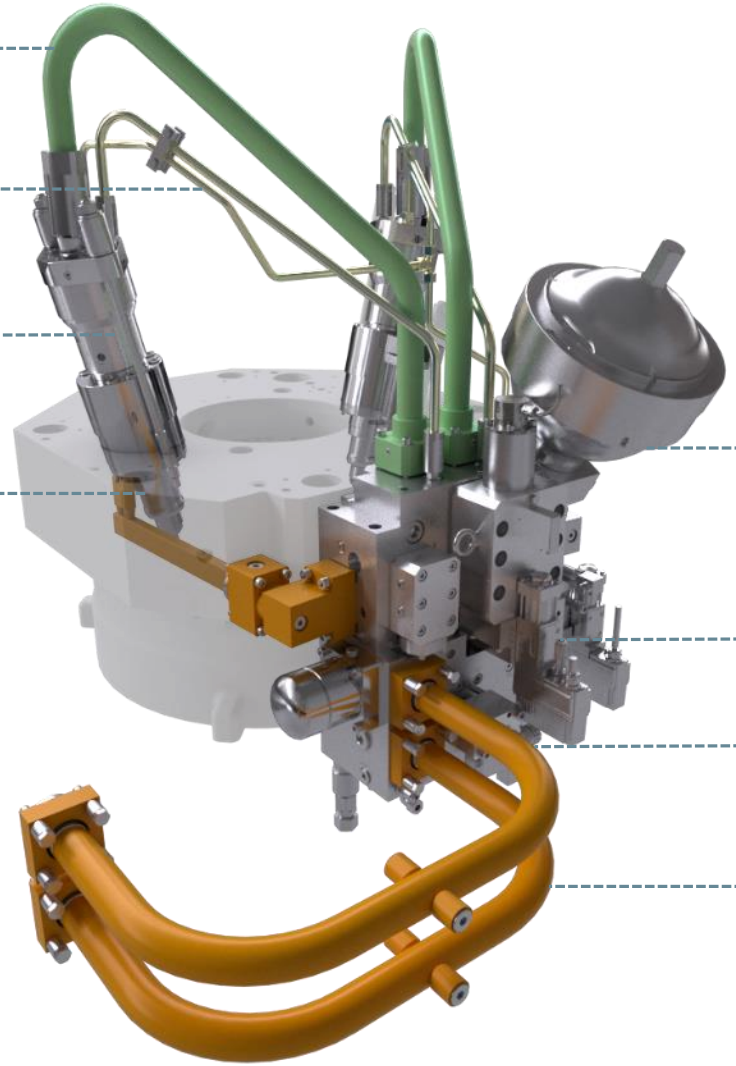
**Elastomers**

– Suitable material found for both O-rings and accumulators.

**Stress corrosion cracking is solved** by the industry already, by requiring small amount of water in the ammonia and requirements to the steel grades, welding procedures etc.

# Ammonia engine development

The LGI injection system



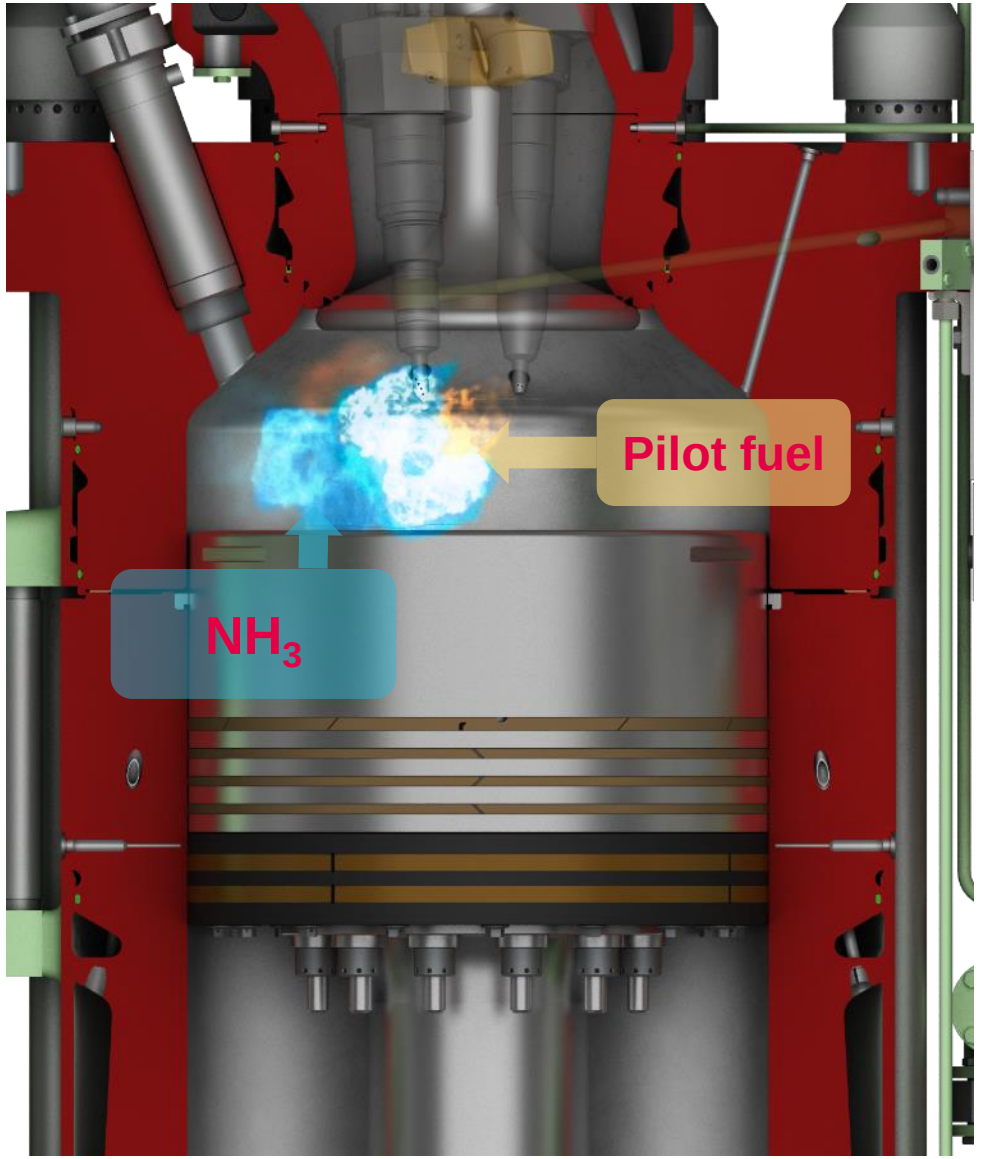
# Ammonia engine development

The LGI combustion principle

## Two running modes

1. “Ammonia mode”:
   - Small pilot flame (hydrocarbon fuel)*.
   - Ammonia ignited by the pilot flame.
2. “Liquid fuel mode”:
   - Identical performance as conventional fueled Diesel engine.

*Subject to future development and evaluation

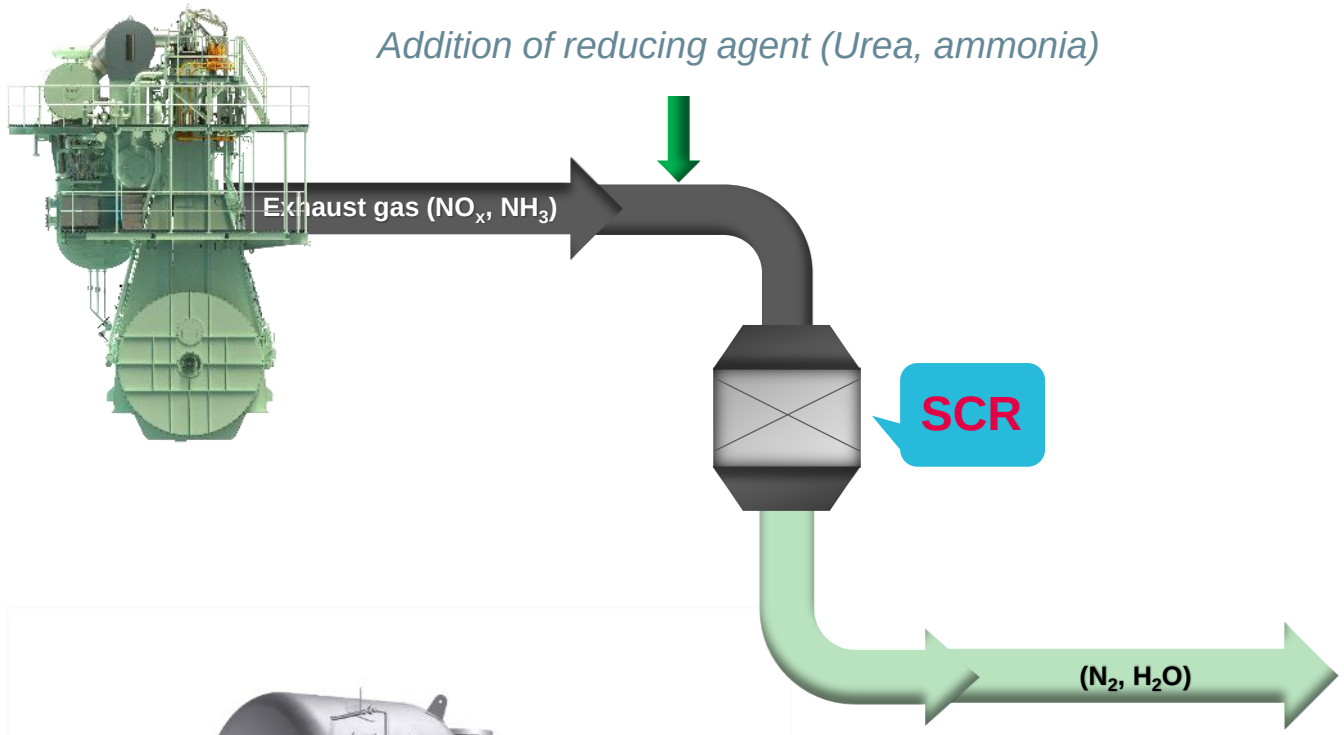


# Ammonia engine development

**Preferred solution:** Emission abatement by **engine tuning** and SCR

**Nitrous oxide** ($N_2O$) **removed by engine tuning.**

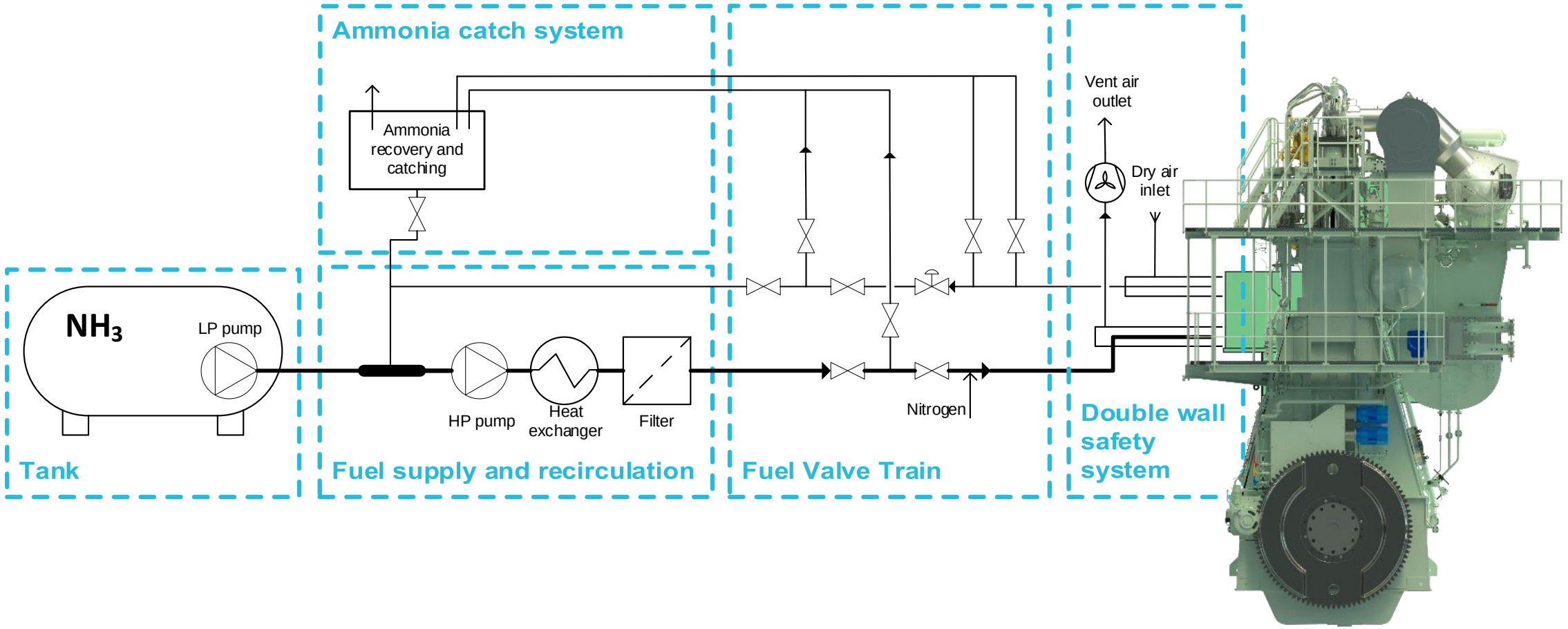
- Unburned $NH_3$ and $NO_x$ is removed in the SCR reactor.
- Dosing of additional ammonia to SCR reaction if needed.
- Known SCR technology is suitable. MAN SCR reactor can be applied.




*MAN SCR*

# Ammonia engine development

Auxiliary systems




Preliminary FGSS specification available on request.

# Ammonia engine development

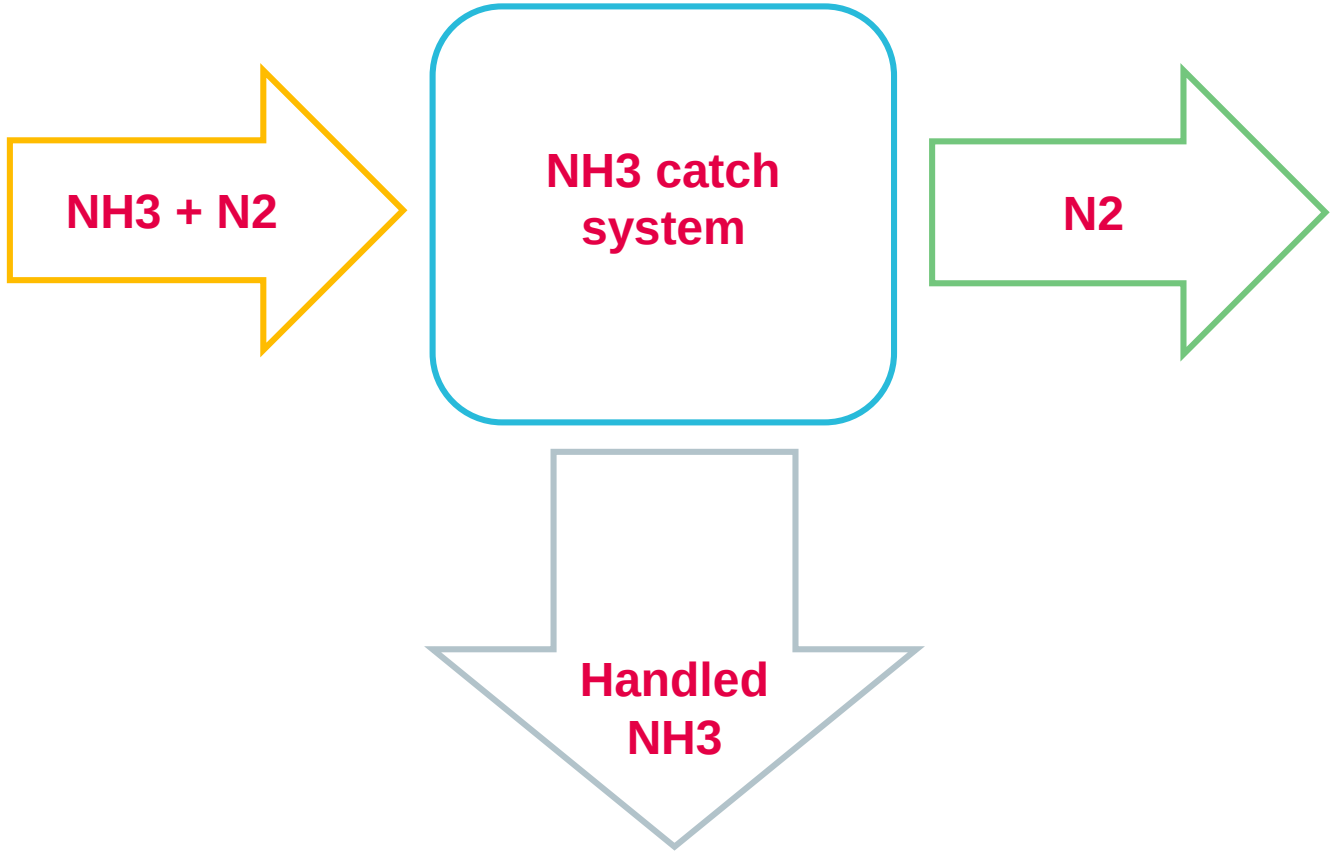
Ammonia catch system

## Requirements

- Catch blow off ammonia safely.
- Avoid ammonia odor and toxicity.
- To work even in the event of system failure.

## Status

- Small scale test at our research centre completed with good results.
- Full scale solution being designed.
- Patent pending.



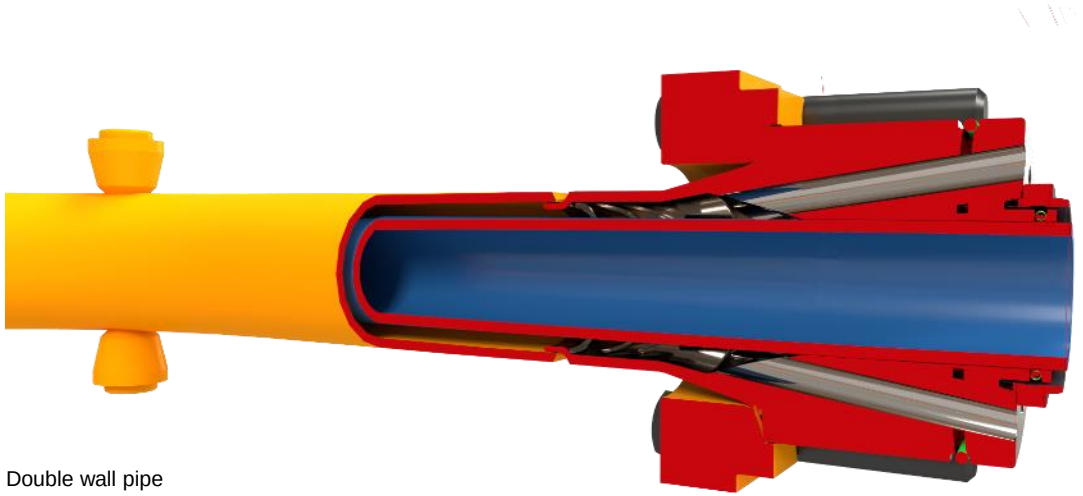
# Ammonia engine development

Safety

## Safety principle based on well known dual fuel technology

**Safe operation ensured by:**

- Double walled fuel pipes with supervision of pipe integrity.
- Leakage detection principles from well known dual fuel technology.
- Purging media is $N_2$.
- Ammonia catch system for purging.
- Thorough risk assessment and identification of hazardous zones on the vessel.



Double wall pipe

# Ammonia engine development

Emissions and pilot fuel concept

**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**

- $NO_x$ will be in compliance with existing TII and TIII limits.
- NH3 emission (slip) from the combustion will be handled via an SCR.
- $N_2O$ will be handled either through combustion control or after-treatment.
- $SO_x$ and particulate matters reduced significantly.

**We are targeting a pilot fuel concept with a specific consumption of approximately 5%**

# 3 Future-proof propulsion

# 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

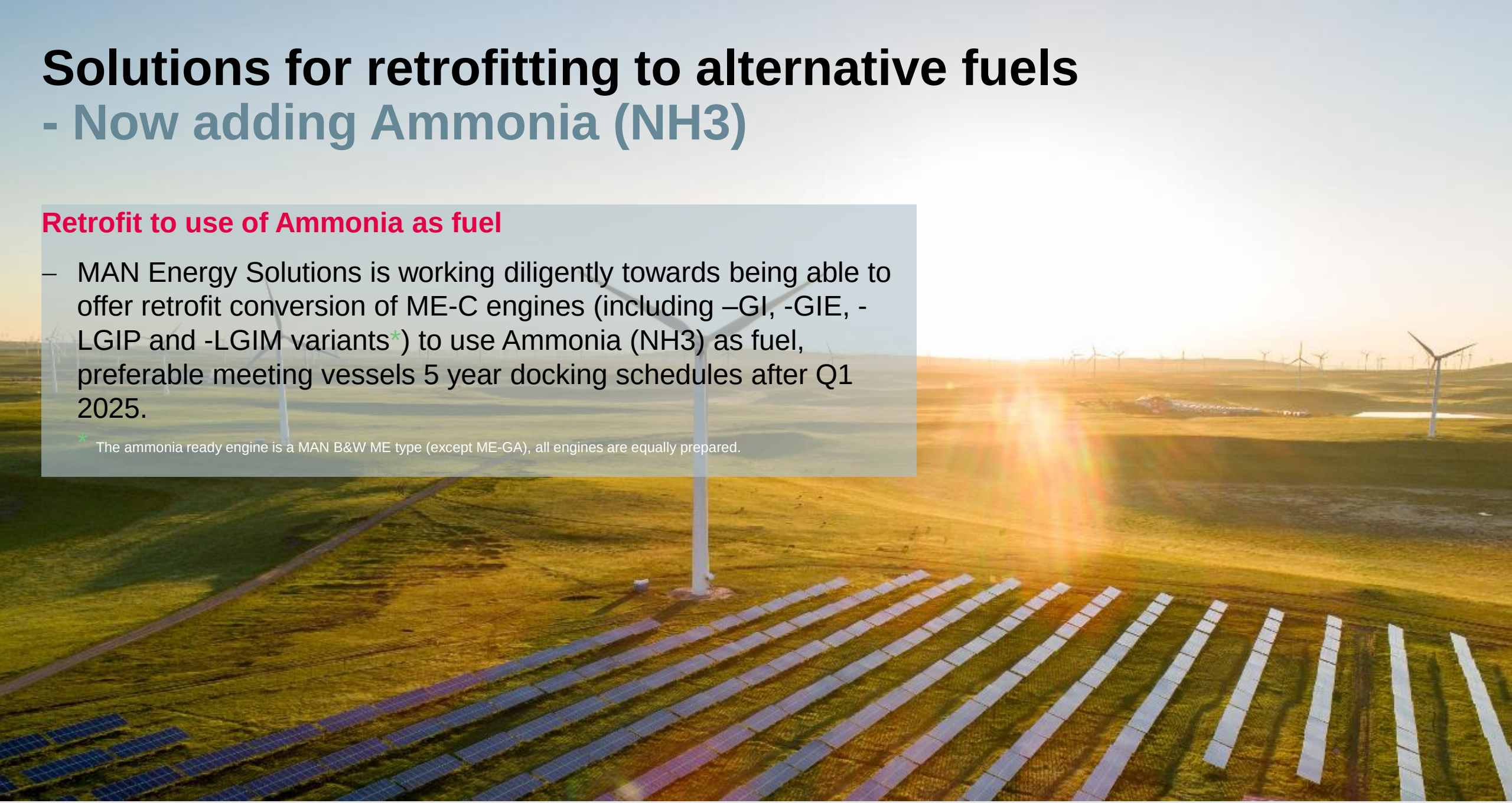
| Fuel types | MC | ME-B | ME-C | ME-GI | ME-GA | ME-GIE | ME-LGIM | ME-LGIP |
|---|---|---|---|---|---|---|---|---|
| 0-0.50% S VLSFO | Design | Design | Design | Design | Design | Design | Design | Design |
| HFO | Design | Design | Design | Design | Design | Design | Design | Design |
| Biofuels | Design | Design | Design | Design | Design | Design | Design | Design |
| LNG | - | - | Retrofit | Design | Design | Retrofit | Retrofit | Retrofit |
| LEG (Ethane) | - | - | Retrofit | Retrofit | - | Design | Retrofit | Retrofit |
| Methanol / Ethanol | - | - | Retrofit | Retrofit | - | Retrofit | Design | Retrofit |
| LPG | - | - | Retrofit | Retrofit | - | Retrofit | Retrofit | Design |

# 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), all engines are equally prepared.



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| LPG | - | - | Retrofit | Retrofit | - | Retrofit | Retrofit | Design |
| Ammonia | - | - | Retrofit | Retrofit | - | Retrofit | Retrofit | Retrofit |

# Solutions for retrofitting to alternative fuels
## - Now adding Ammonia (NH3)

**Future-proof engine Technology.**

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

**Proven track record of engine conversions.**

**In Service**

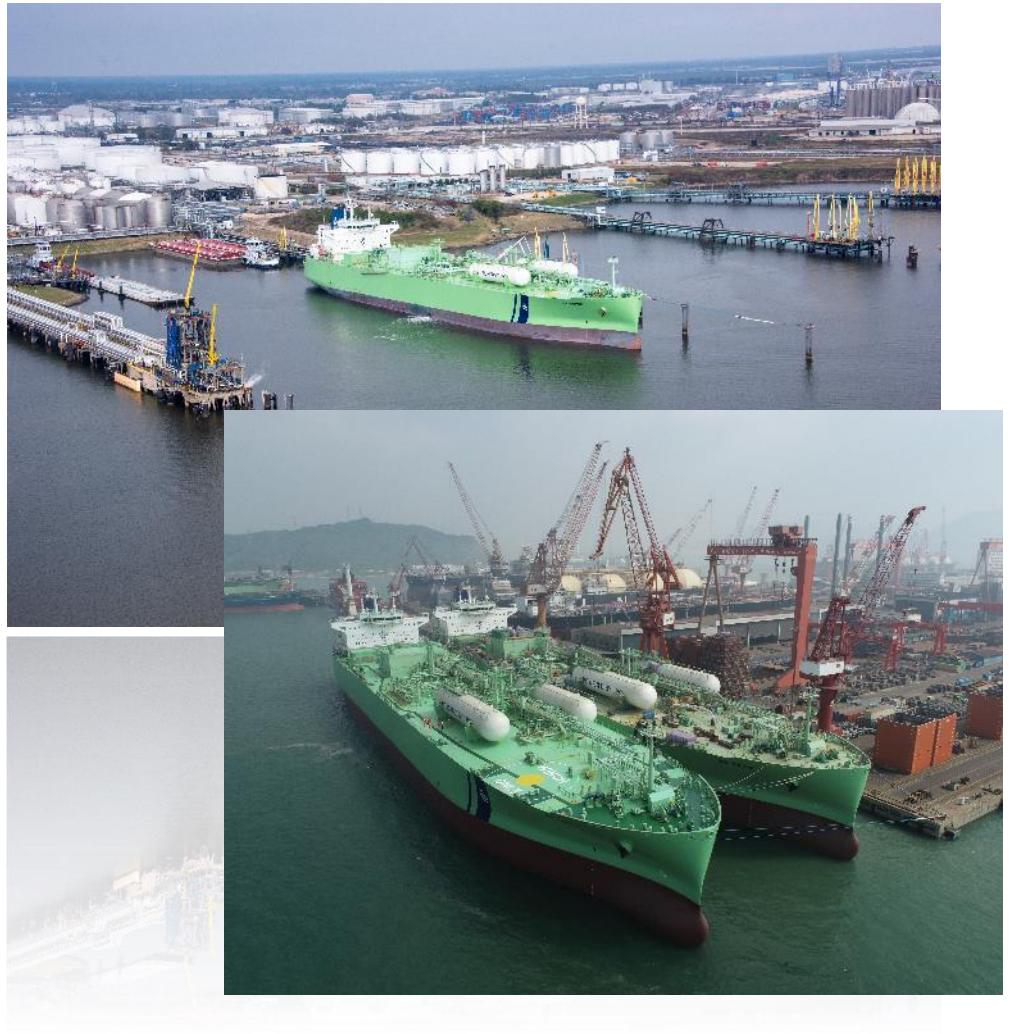
– ME-GIE: 1

– ME-GI: 3

– ME-LGIP: 5

**In process and on order**

– ME-LGIP: 10



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

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Future in the making

# Thank you very much!

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