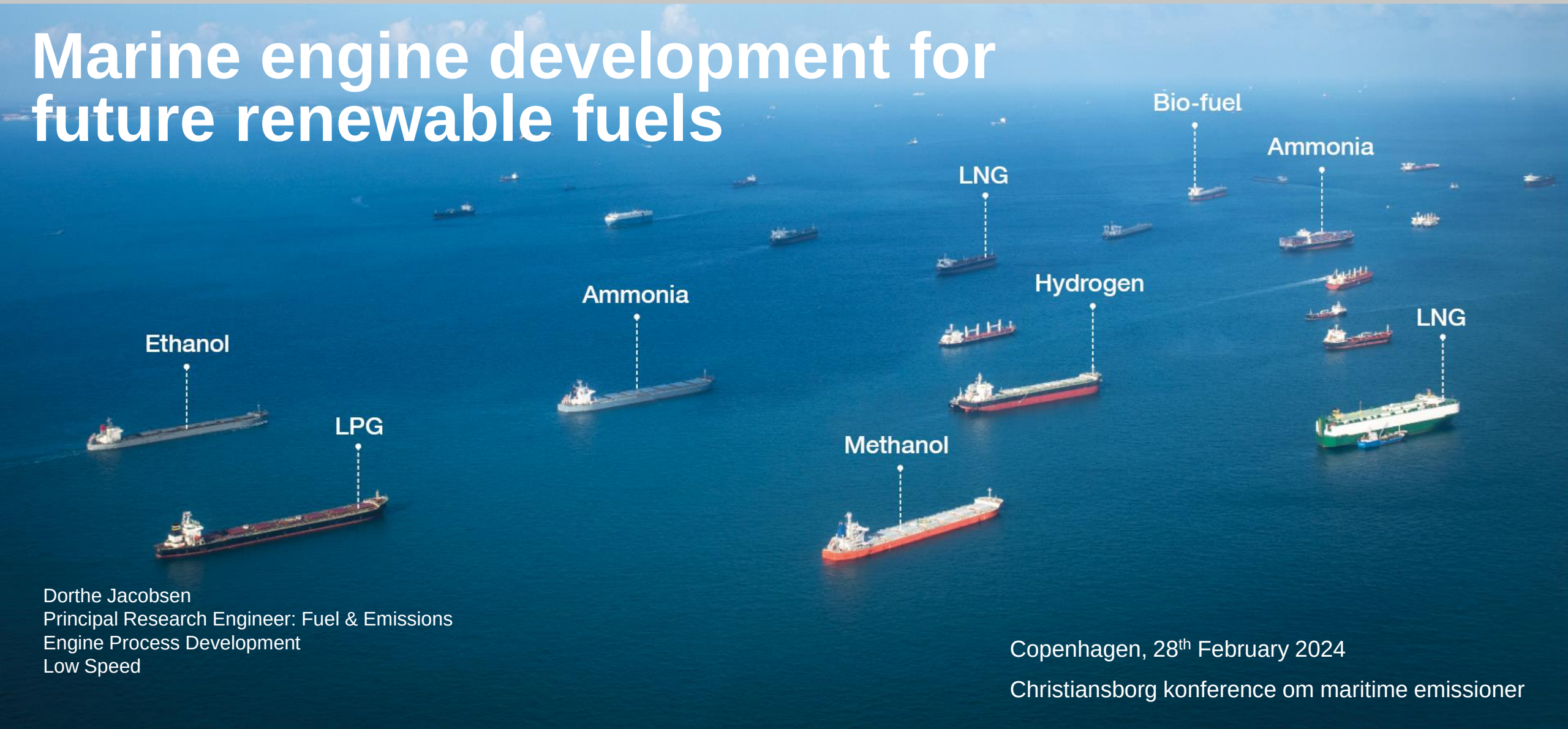
MAN Energy Solutions
Future in the making

Marine engine development for future renewable fuels



Dorthe Jacobsen
Principal Research Engineer: Fuel & Emissions
Engine Process Development
Low Speed

Copenhagen, 28th February 2024

Christiansborg konference om maritime emissioner

Agenda

1 Dual fuel engines

2 Drivers for change

3 Emissions

4 NH3 engine

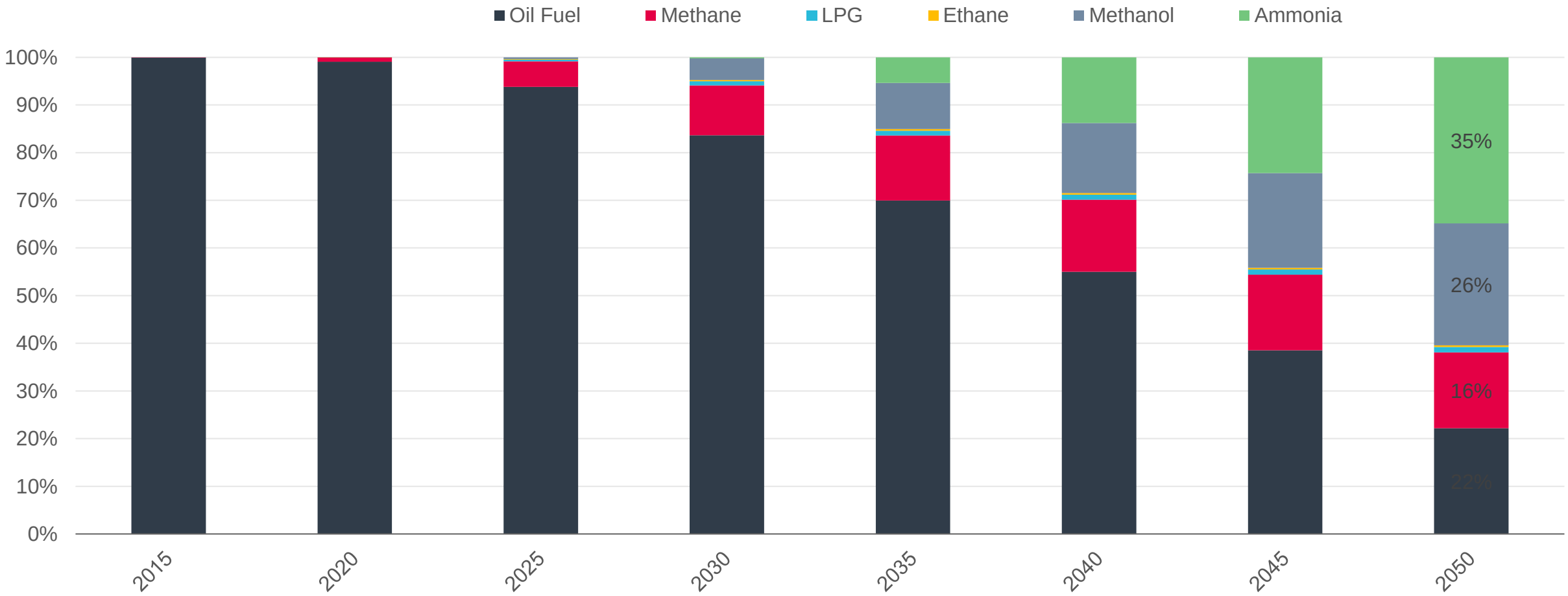
5 Conclusion

1 Dual fuel engines

Demand for e-Fuels from shipping will be high

MAN ES evaluation

*After MEPC 80 scenario is Work in Progress and subject to changes



Powering sustainable shipping

Methane
ME-GI & ME-GA
>687 - 278

LPG
ME-LGIP
183

Ammonia
→

Methanol
ME-LGIM
>177

Ethane
ME-GIE
54

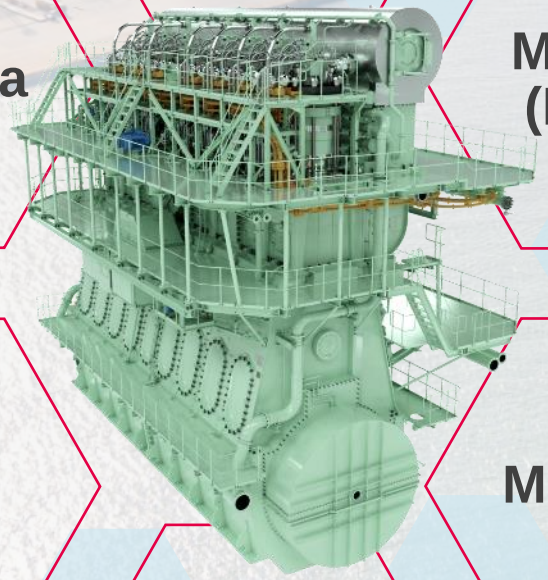
1380+
dual-fuel engine orders

Modular design enables extensive retrofit options

Retrofit options

Ammonia

Methane (ME-GI)



LPG

Methanol

Ethane

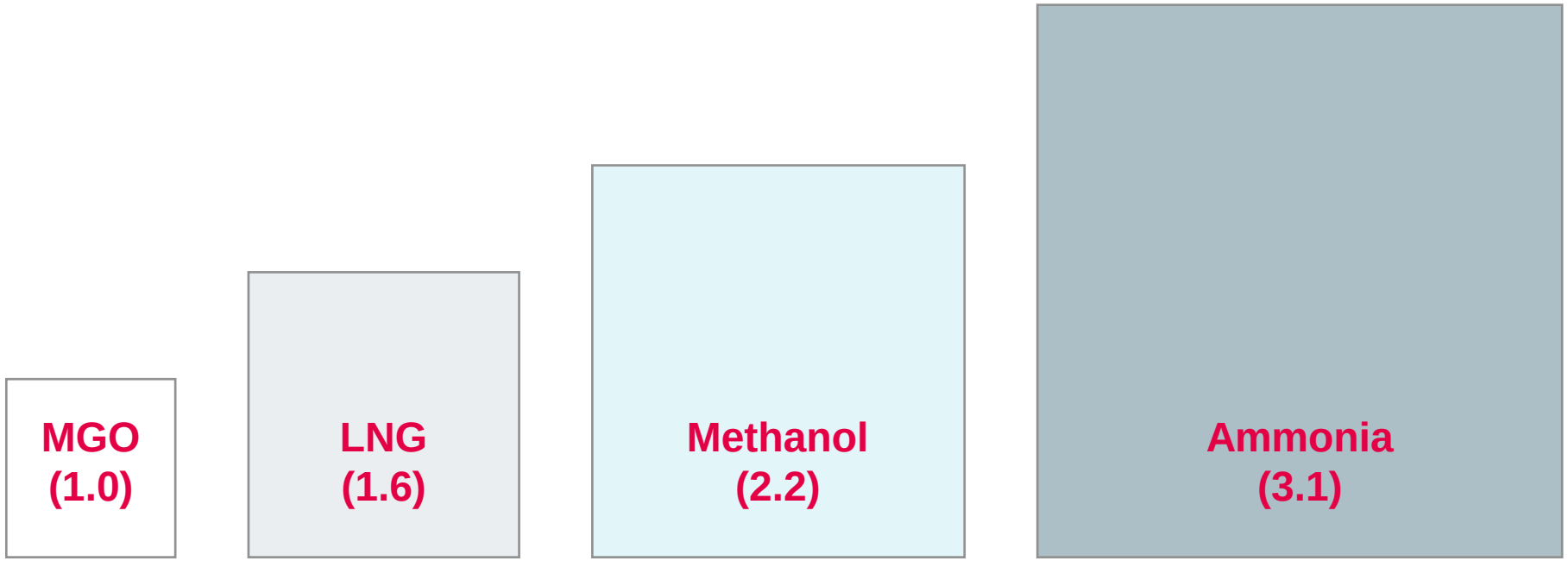
Retrofitting is a proven concept for MAN Energy Solutions engines

- ✓ 21 Two stroke engines retrofitted
- ✓ 4 Four stroke engines retrofitted

Tank considerations for alternative fuels

Storage tanks

– Based on the specific energy density alone, the below tank sizes apply.



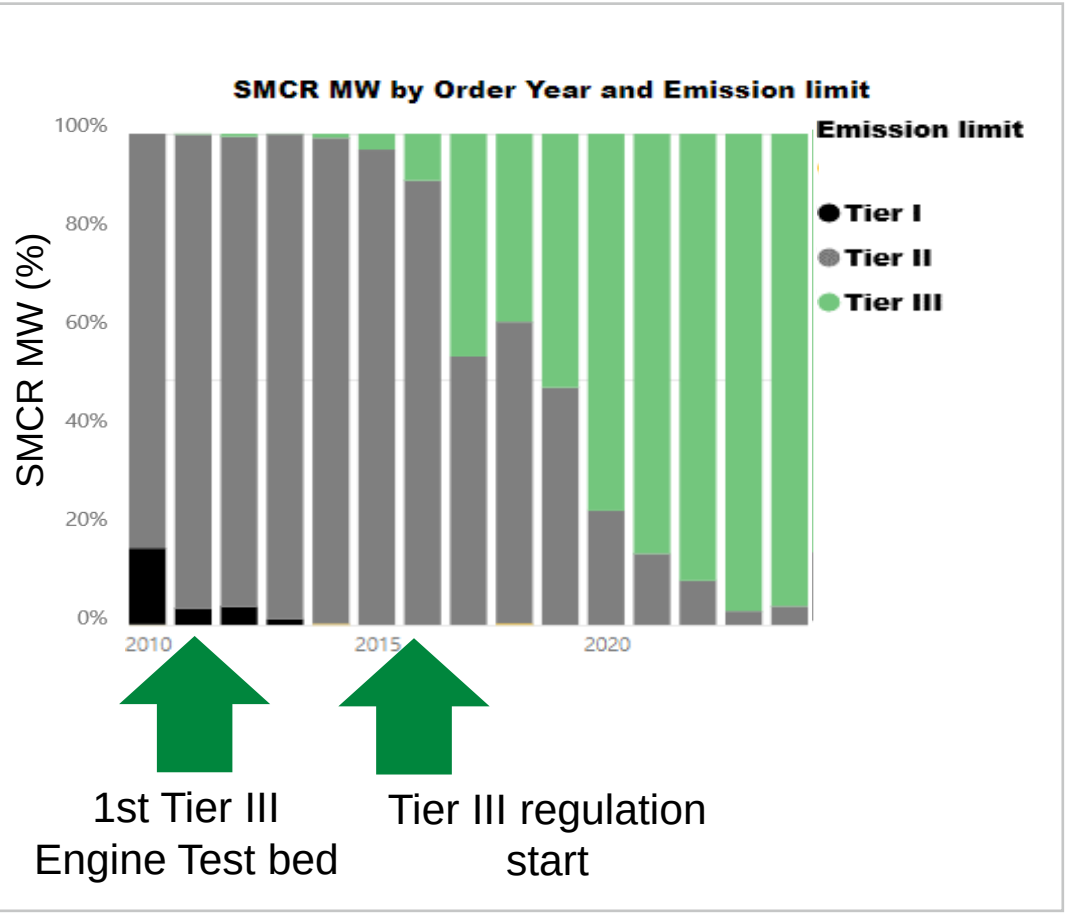
Above tank sizes are based on the specific energy density alone. Additional space for insulation etc. must be considered as well

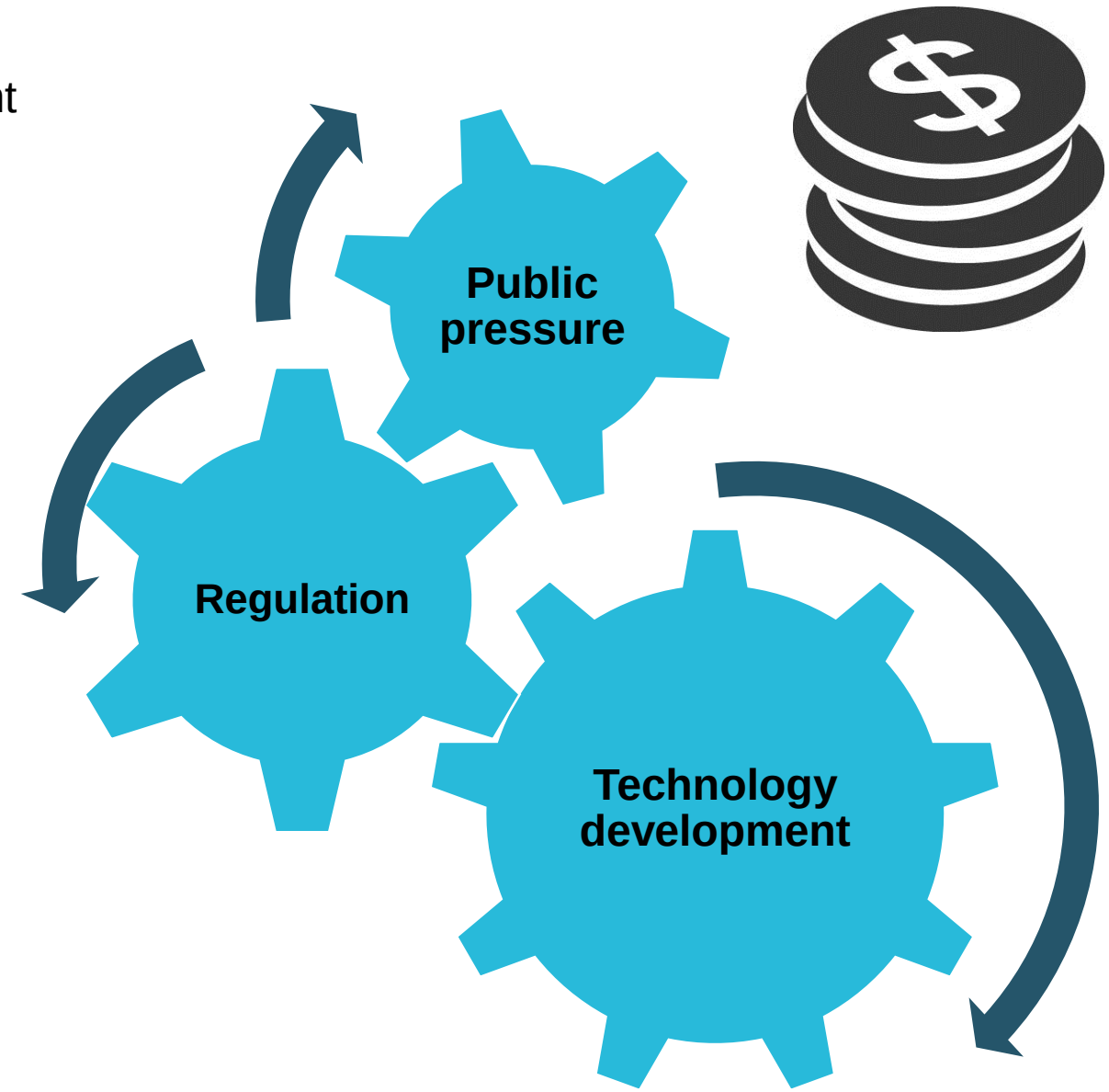
2 Drivers for change

Drivers for change

Public pressure + Regulation + Technology development

Market introduction: NOx reduction technology





International Maritime Organization

IMO

- International Maritime Organization (IMO)
- United Nations specialized agency for shipping
- Regulates environmental issues and safety for international shipping
- 174 member states and 63 intergovernmental organizations represented
- Regulation enforced by flag States and port States
- Classification Societies act on behalf of flag States

IMO Headquater in London

- MAN ES participate in:
  - MSC (1 person)
  - MEPC (5 persons)
  - ISWG (2 persons)
  - PPR (5 persons)

The way to zero carbon shipping

What are the challenges in using new fuels on international, short-sea and inland shipping?
How can these challenges be addressed?

1. Upscale production of green fuels
2. Reduce (eliminate) price differential on fossil and green fuels
    1. Increase price on traditional fuels (CO_2 pricing)
    2. Develop cheap green fuels
3. Make regulation to support/enable use of new, green fuels
    1. Requirement
    2. Ports
    3. Bunkering
    4. Ships
4. Develop ship technology to handle new, green fuels
    1. Systems
    2. Engines
    3. Emissions
5. Enablers for use of new fuels
    1. International fuel specifications
    2. Training

Actors

ISO

IMO

Company

3 Emissions

What is Air Pollution?

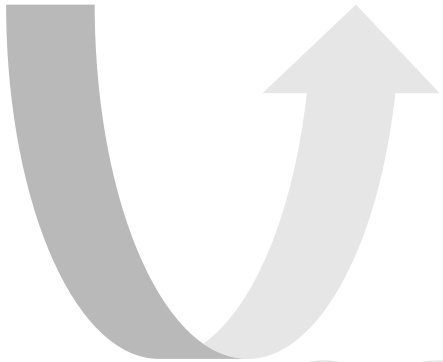
Impacts on human health and environment

Air Pollution
Affects human health and environment

Particulate Matter (PM)
Nitrogen Oxides (NOx)
Sulphur Oxides (SOx)

NH_3
HCHO
CO
HC
Other…

Atmospheric chemistry



Green House Gases
Contributes to global warming

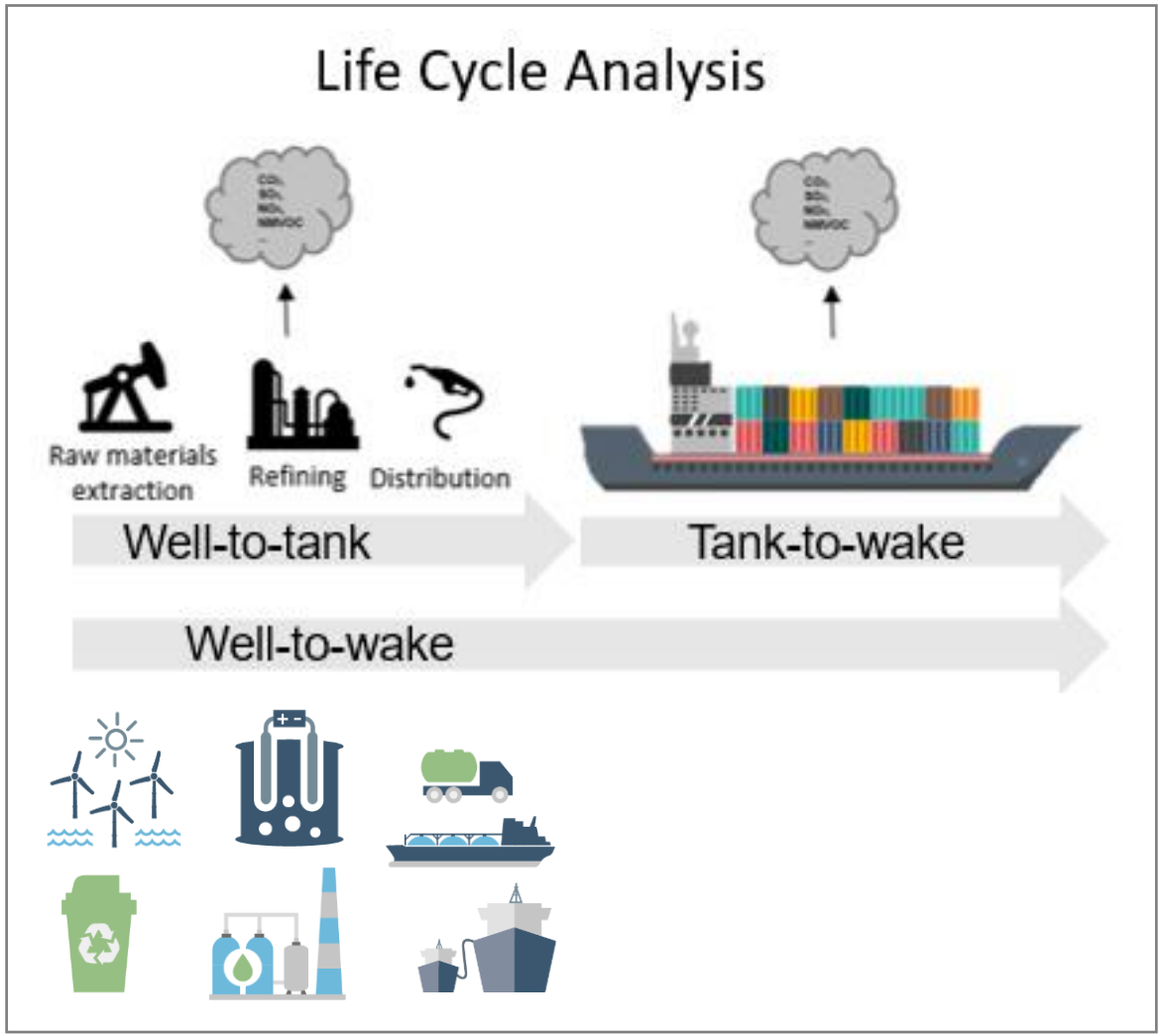
CO_2
N_2O
Methane (CH_4)
Fluorinated gases

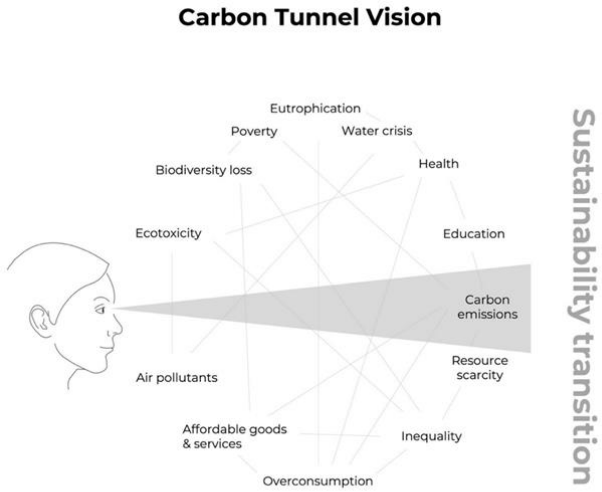
Short lived climate forcers

Black carbon (BC)
Ozone

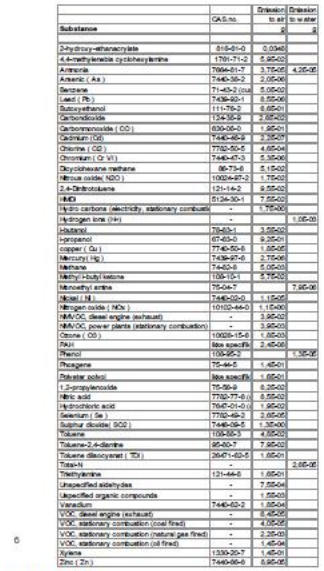
LCA – Life Cycle Assessment

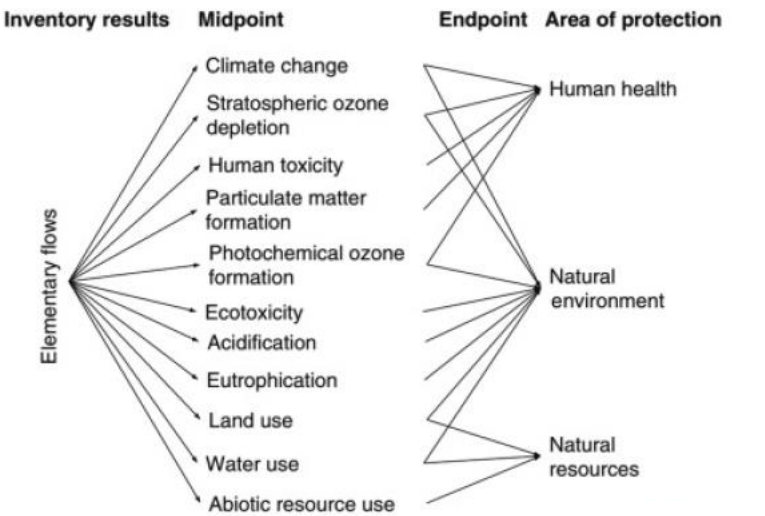
Introducing new fuels





Life Cycle Impact Assessment (LCIA)

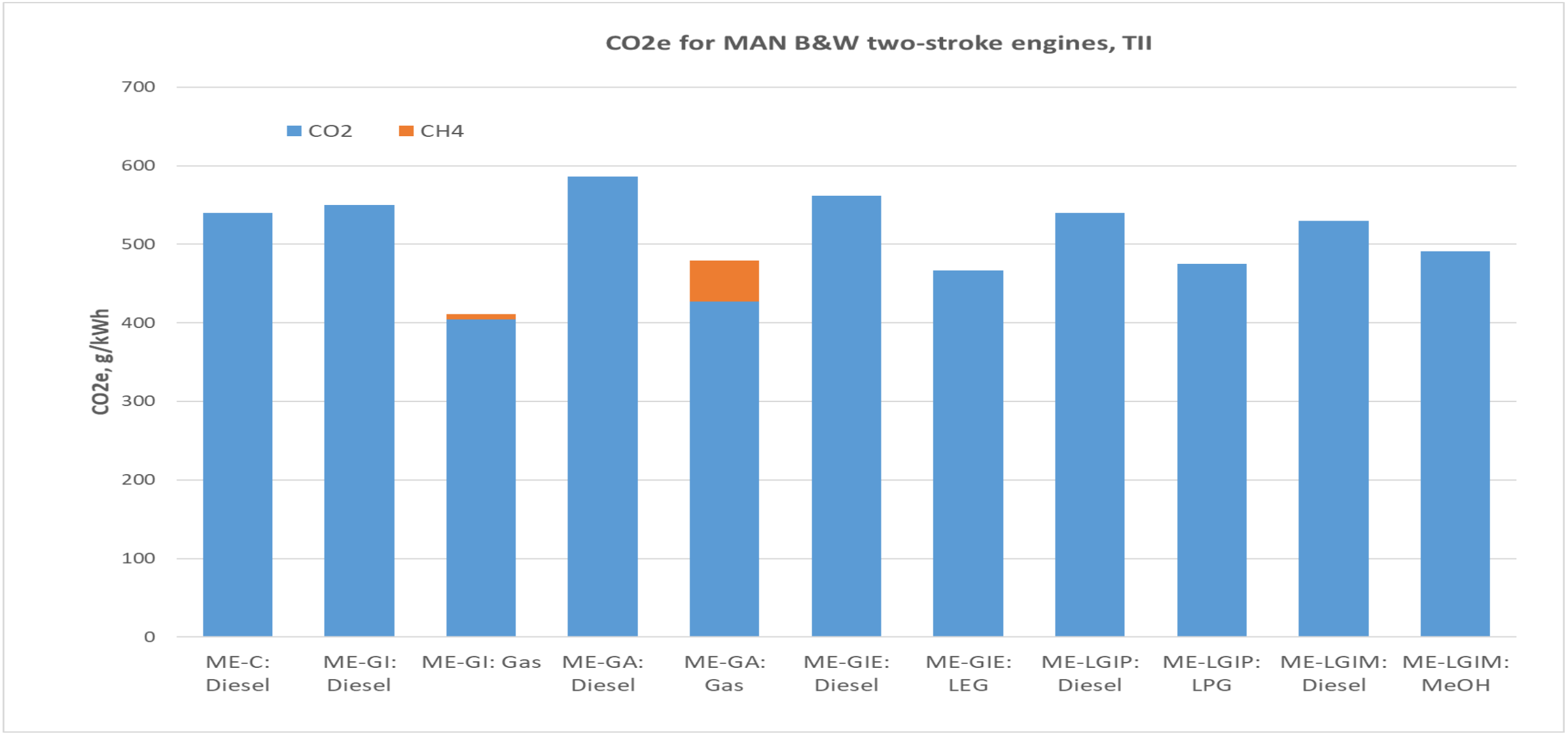




Source: ILCD Handbook (2010)

2S: CO2e emissions, Tier II

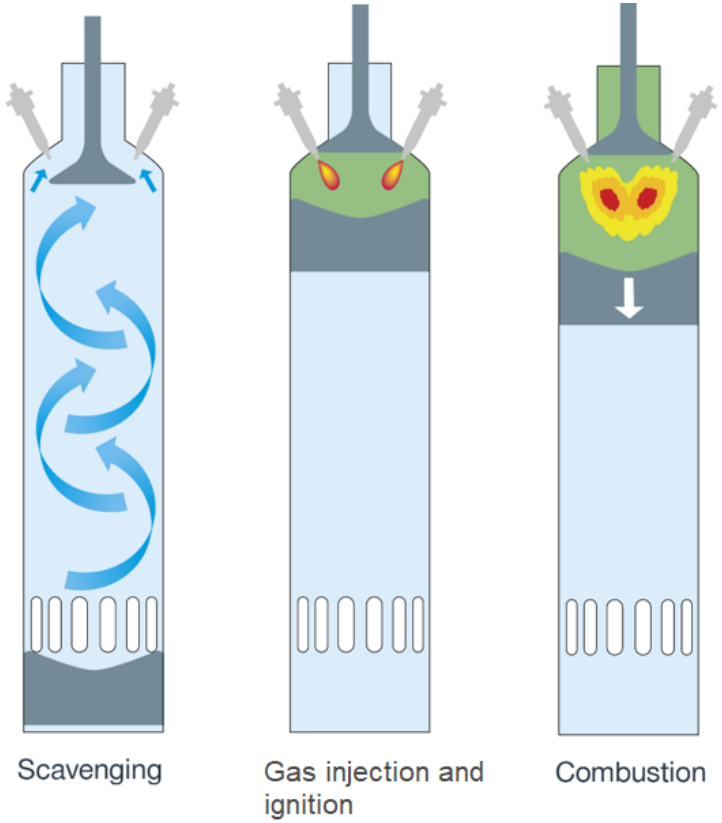
GWP100, Tank-to-propeller



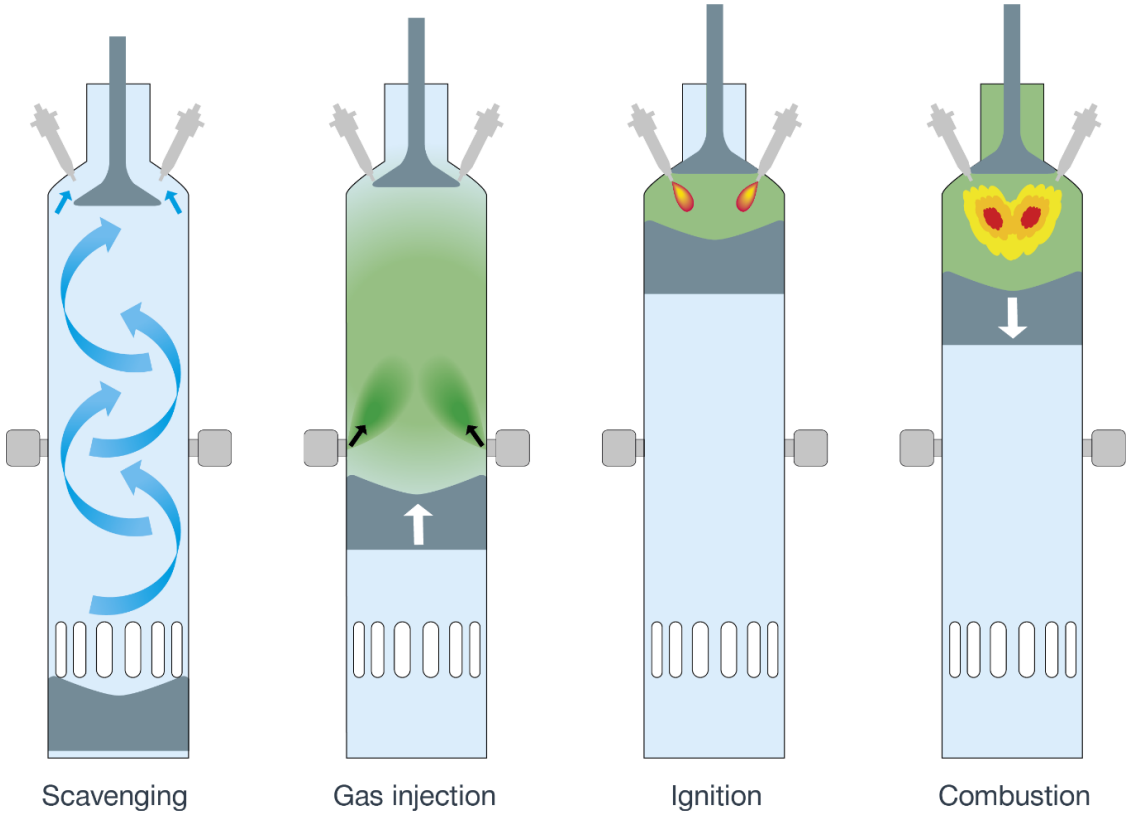
Otto vs. Diesel cycle

Gas engine combustion principles and why there is a difference in Methane slip

ME-GI: Diesel cycle



ME-GA: Otto cycle



4 NH3 engine

Foundation for design - Risk Assessment – HAZID & HAZOP

Risk assessment

- Failure Modes and Effects Analysis (FMEA) made in order to evaluate where and how components may fail and to assess the impact of different failures.
- Hazard identification (HAZID) and Hazard and Operability (HAZOP) assessments were made in order to live up to our own safety requirements.
- Experience from previous dual-fuel engine development projects.
- **More than 4,000 hours spent on FMEA, HAZID and HAZOP**

Engine emissions

How do we handle potential Nitrous Oxide (N_2O) emissions?

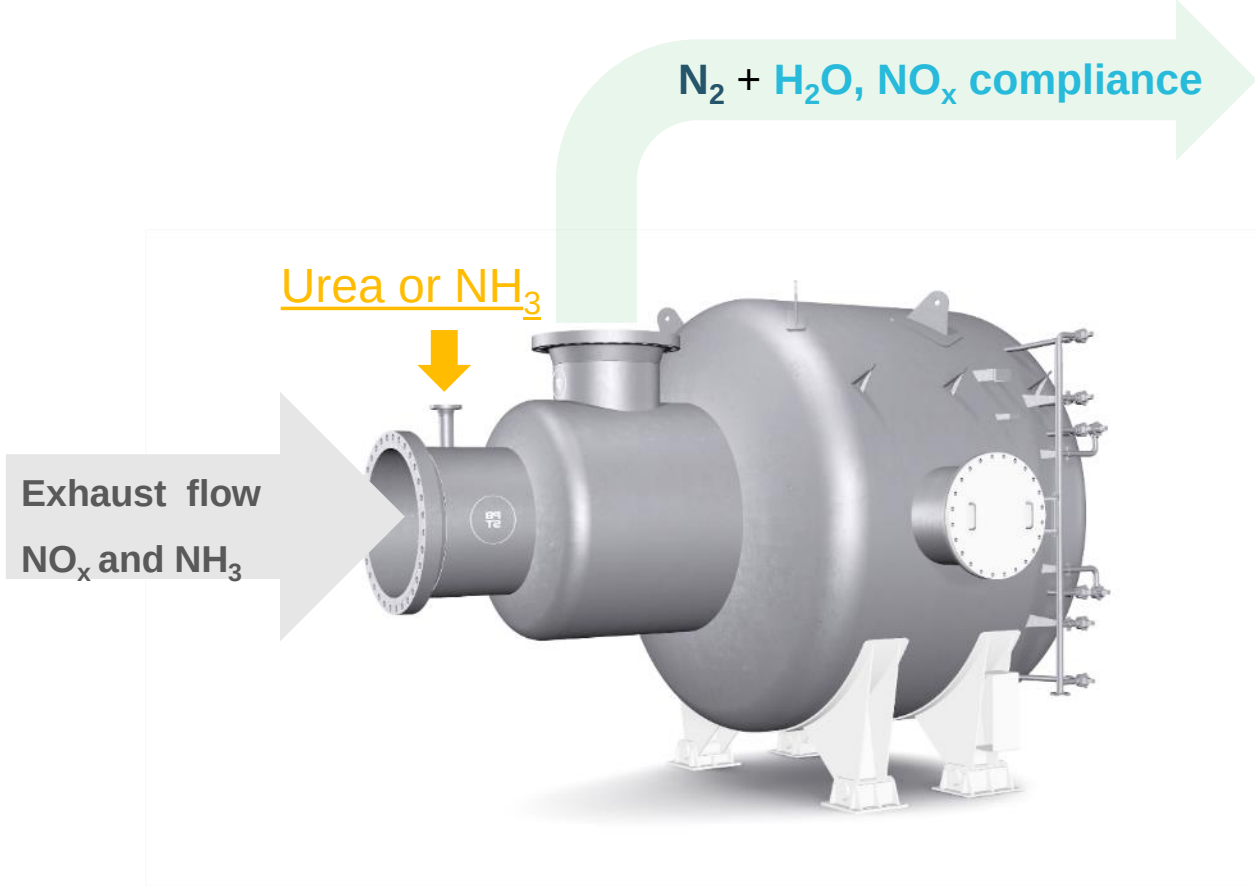
N_2O is a very potent GHG with GWP of 298.

It will also be accounted in on-going adopted regulations

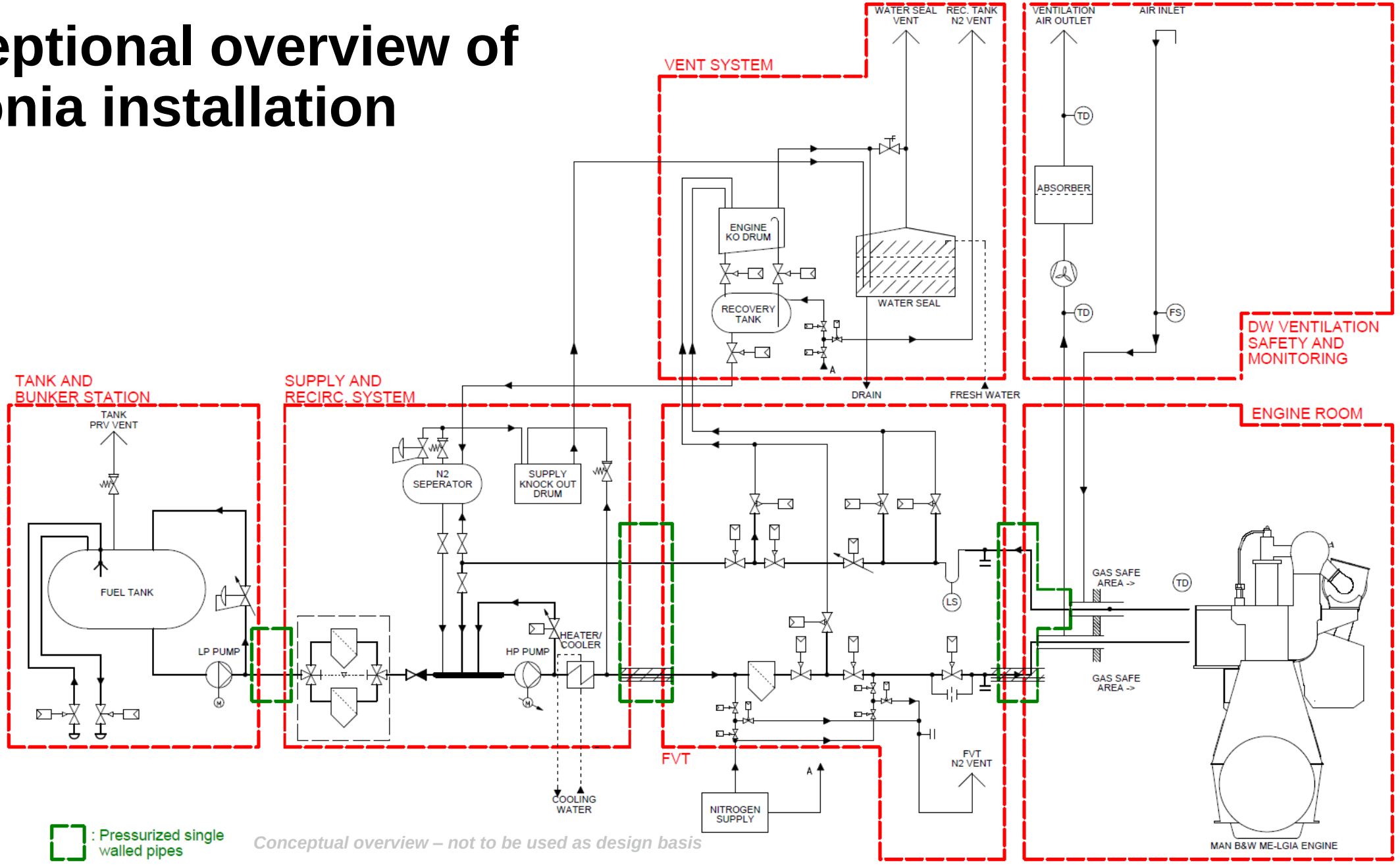
- Nitrous oxide (N_2O) will be removed by engine tuning.

Ammonia slip and NOx 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 and MAN HP-SCR reactor can be applied.

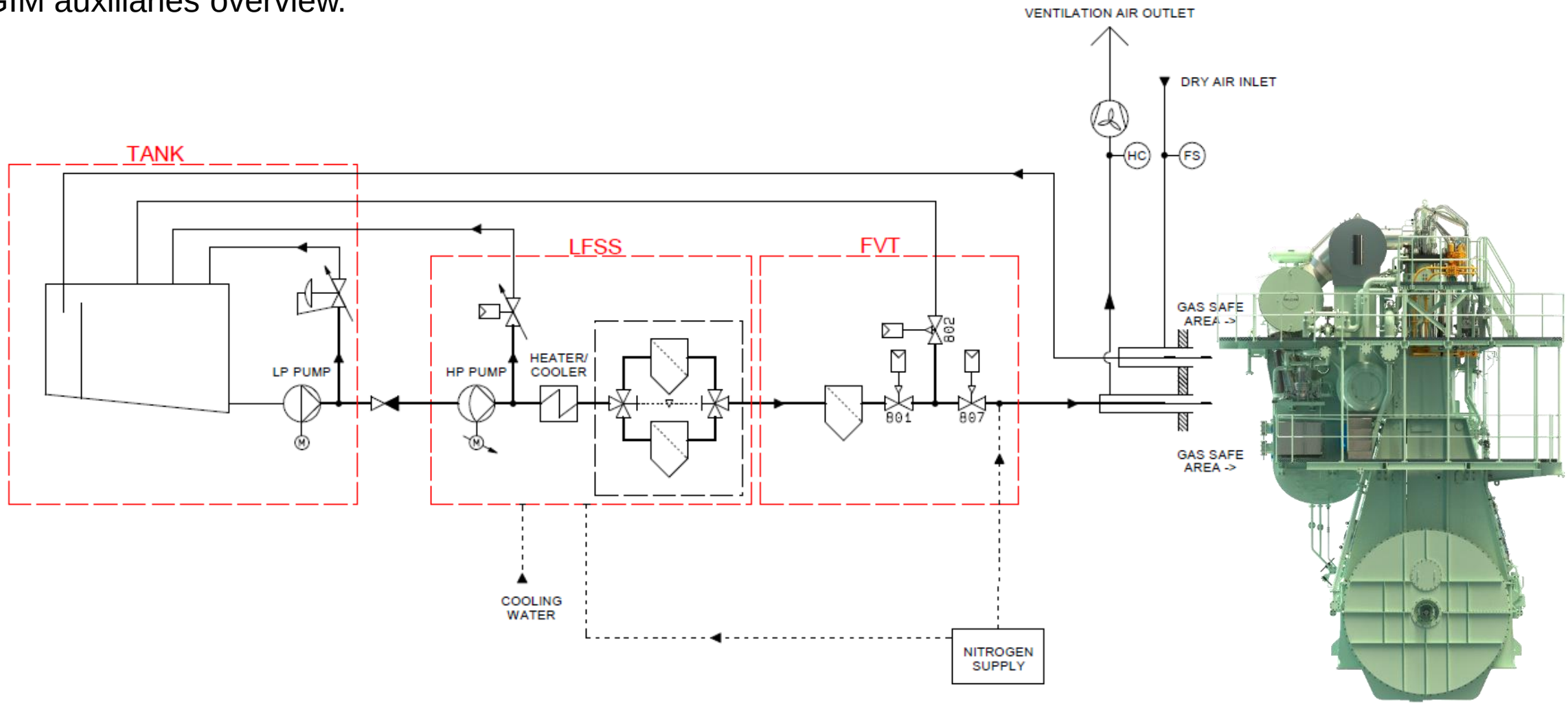


Conceptional overview of ammonia installation



Fuel supply system

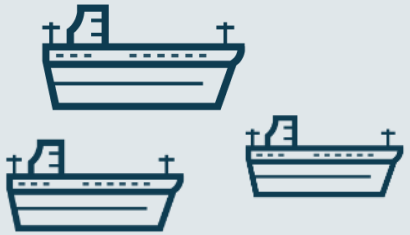
ME-LGIM auxiliaries overview.



Two-stroke ammonia engine main development timeline

R&D development
Copenhagen

First engine delivery
2024



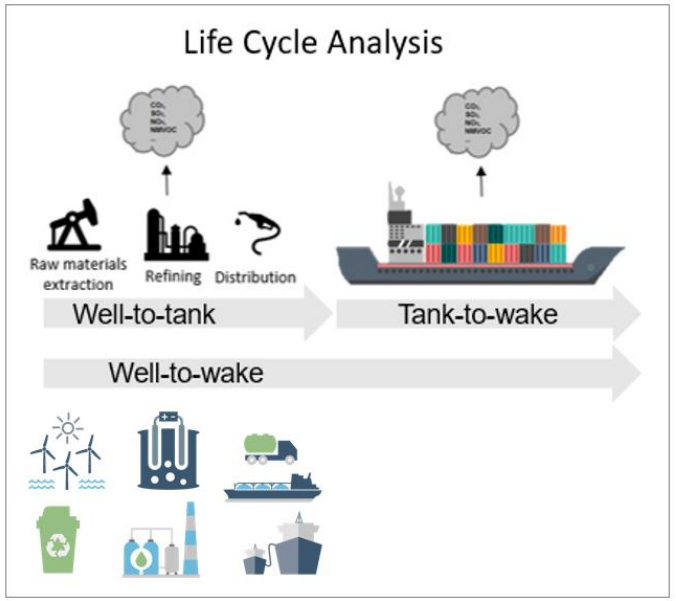
Positive seagoing experience
of pilot projects 2026-2027

Full sales release

5 Conclusion

A quick summary

- Focus emissions at present: **GHG,** NOx, SOx (PM)
- Decarbonization of shipping may well be based on:
  - Bio-oils
  - Renewable methanol
  - E-ammonia
  - Renewable gas
- Life cycle analysis (LCA) of well to wake (WTW) value chain is critical for GHG reduction assessment
- MAN Energy Solutions offers ship engine technology for methanol, gas and a wide range of bio-oils
- Development of an ammonia engine is underway – orders accepted from 2024
- **It is not the engine technology, that is the barrier for decarbonization of shipping – it is and will be the production capacity for renewable fuels! – and enabling regulation!**



Thank you very much!

Dorthe Jacobsen, Engine Process Development
Low Speed