Managing emissions from ammonia-fueled vessels

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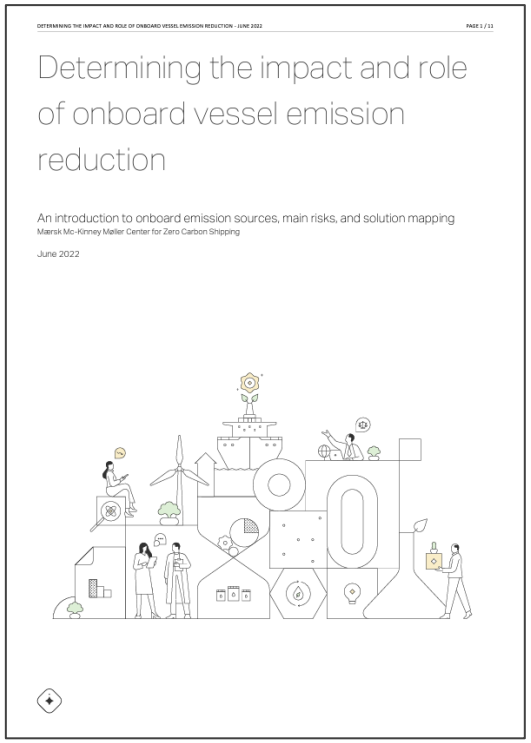
for Zero Carbon Shipping

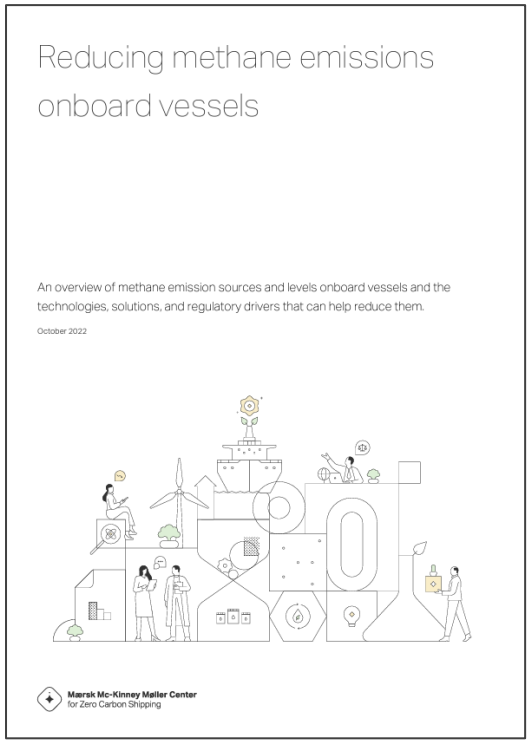
The Onboard Vessel Solutions Paper Series:

Vessel Emission Reduction Technologies & Solutions

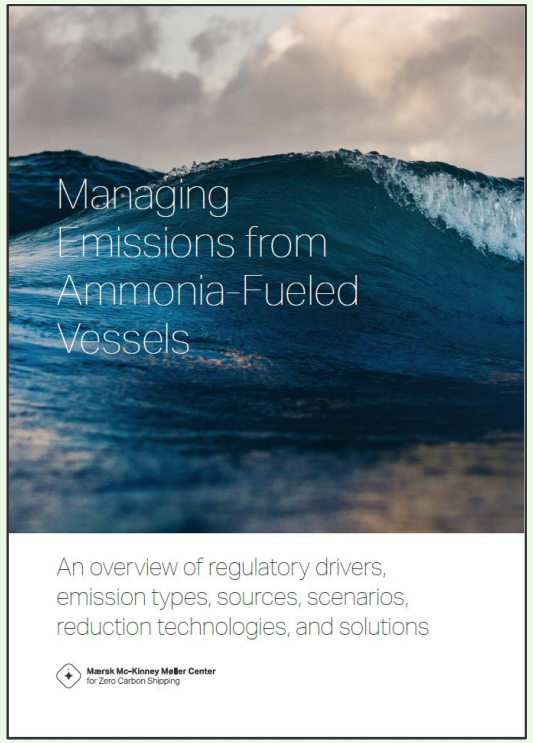
Introduction (June 2022)



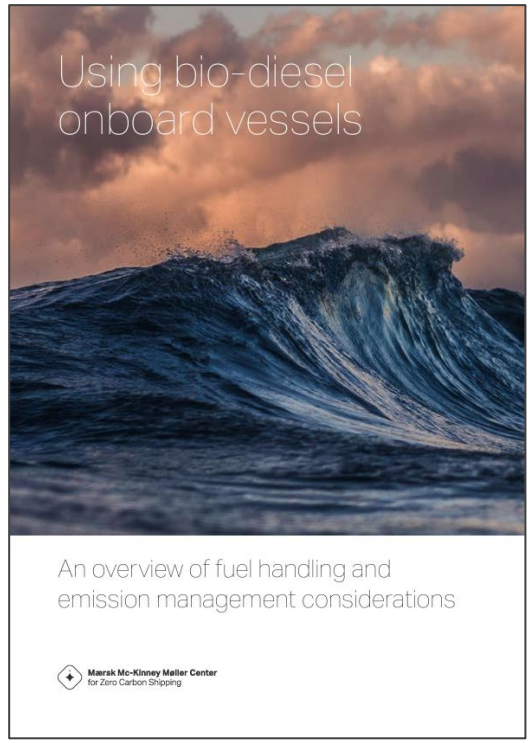
Methane (October 2022)



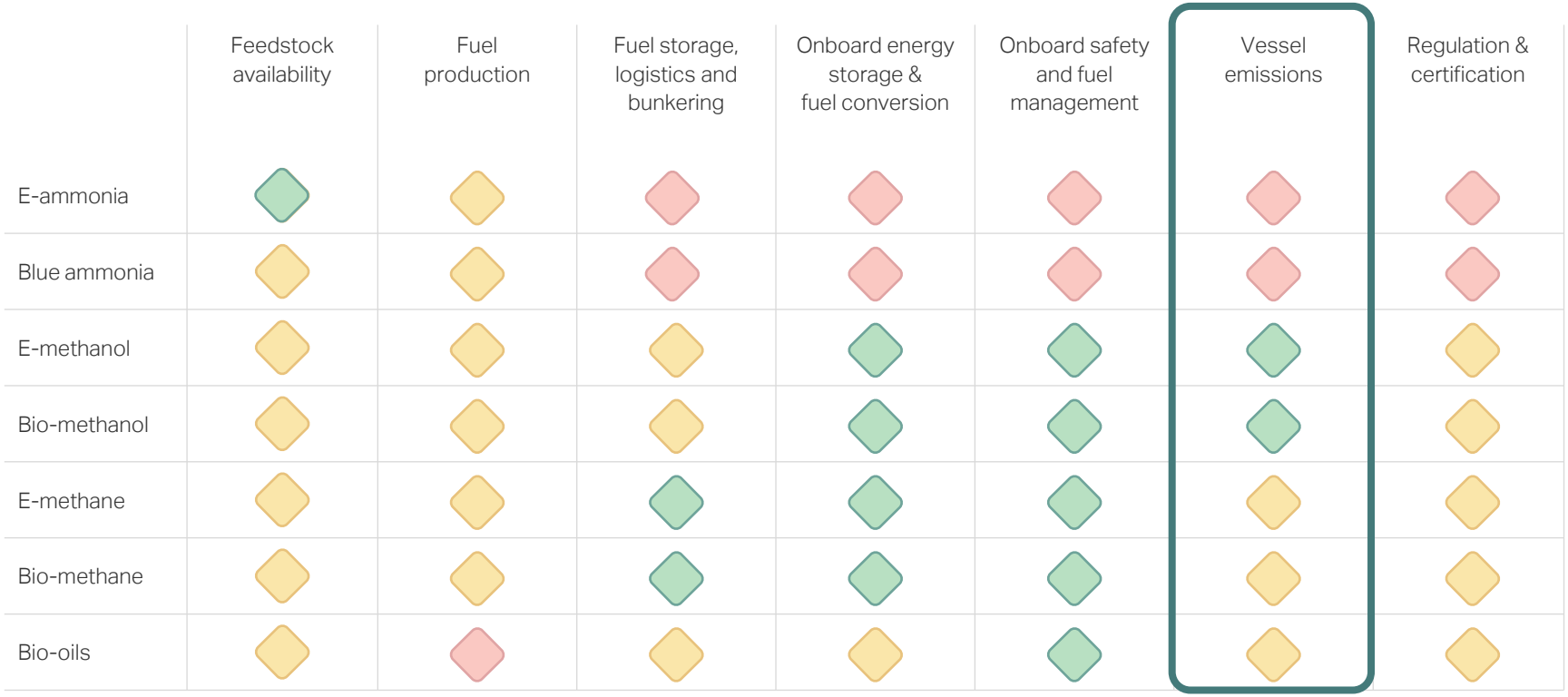
Ammonia (March 2023)



Bio-diesel (June 2023)



Fuel Pathway Maturity Map



MATURE

Solutions are available, none or marginal barriers identified.

SOLUTIONS IDENTIFIED

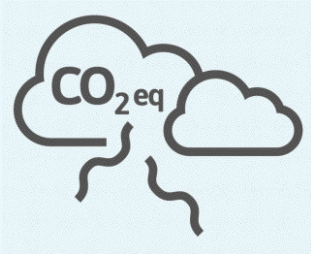
Solutions exist, but some challenges on e.g., maturity and availability.

MAJOR CHALLENGES

Solutions are not developed or lack specification.

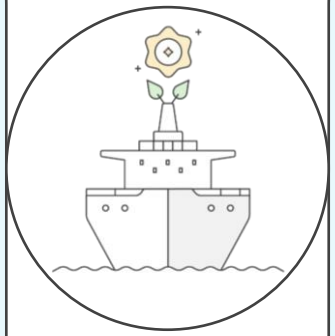
Vessel emissions can play an important role in alternative fuel pathway viability and selection…something that should be addressed upfront!

Emissions



Greenhouse Gases (GHGs)

Air Pollutants



Vessel Technologies & Solutions

Regulations

	GLOBAL	REGIONAL			LOCAL		
Air Emission	IMO	United States	European Union	China	California	Norway	Hong Kong
Black Carbon (BC)	👥						
Nitrous Oxide (N2O)			⚙				
Methane (CH4)	👥		⚙				
NOx	✓	✓		✓	✓	✓	
SOx	✓	✓	✓	✓	✓	✓	✓
PM		✓	✓		✓	✓	
VOCs	✓				✓	✓	

✓ Currently applied ⚙ To be implemented 👥 Under consideration

Emissions Web

Emission Type

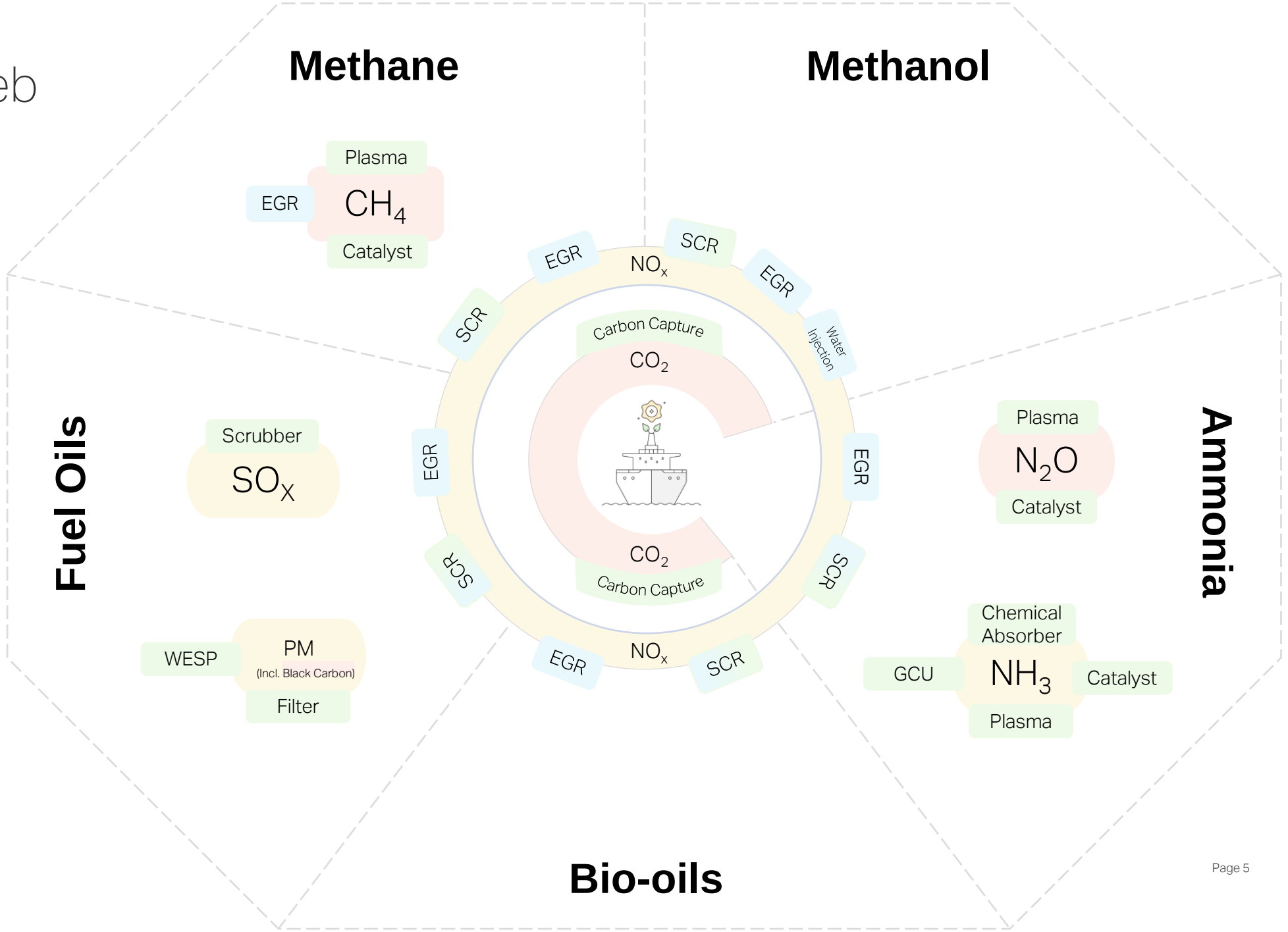
Greenhouse Gas
→ Global impact on the climate

Air pollutant
→ Local impact on human health and the environment

Reduction Technology

Engine technology
→ Fully integrated with engine

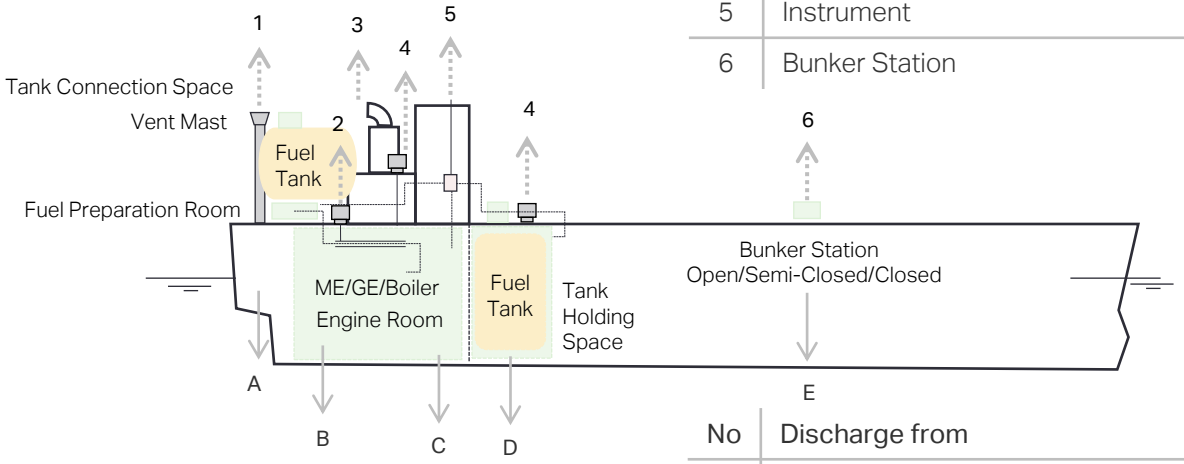
After treatment
→ Separate from engine, but integrated



Onboard vessel ammonia emissions sources

(for illustrative purposes; not based on a specific design)

NH_3 gas

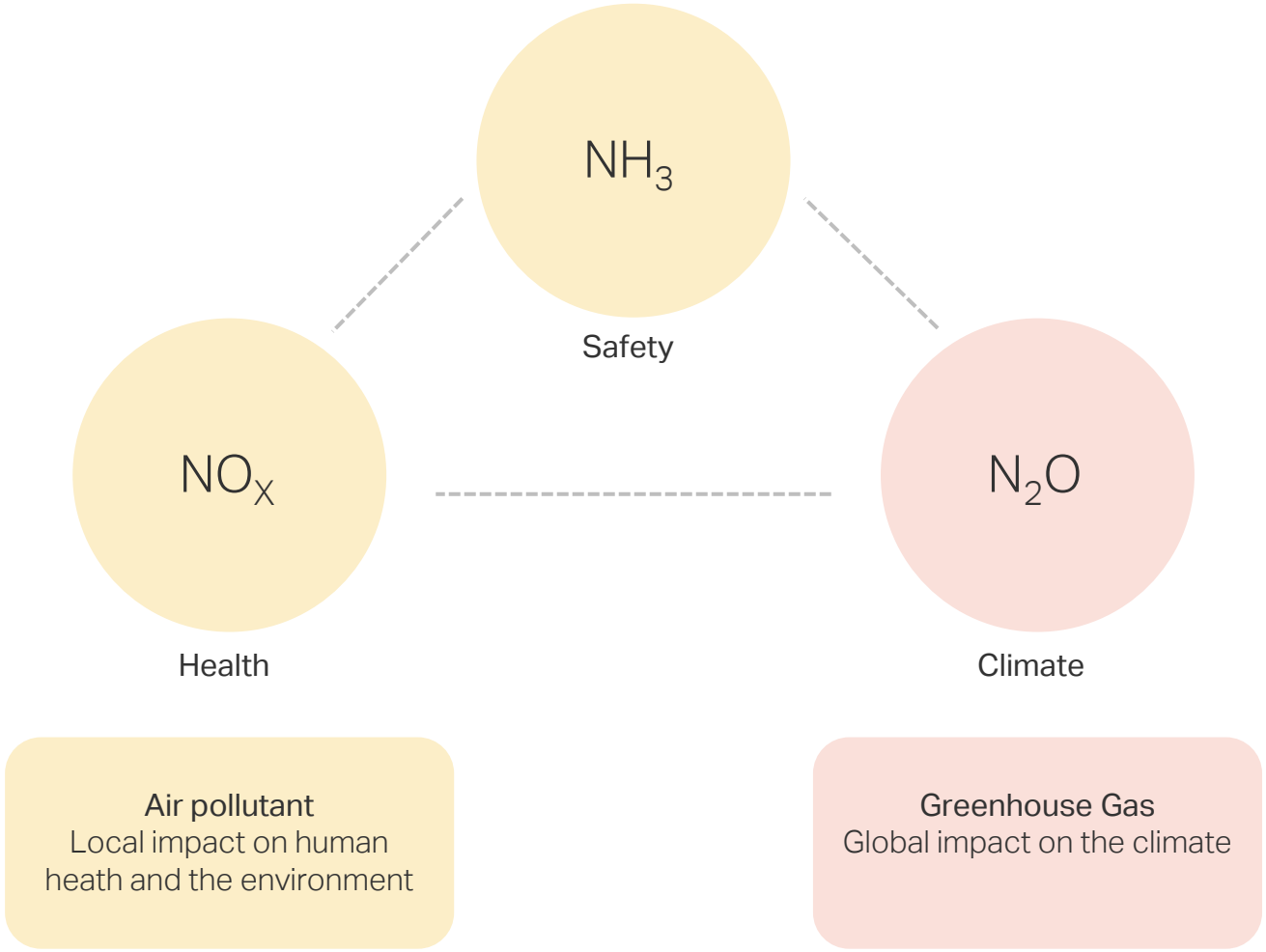


No	Emission from	Originated
1	Gas Vent Mast	Tank & Line Safety Valve, Catch & detox System
2	Ventilation of double wall pipe system	NH_3 Fuel Liquid and Gas Piping in Engine Room , Piping from bunker station to engine room.
3	NH_3 Slip of various consumers	Main Engine, Generator Engine, Aux Boiler, GCU, Reliq. plant, Compressor
4	Ventilation of enclosed space	Machinery/Fuel handling system in that space or from surrounding space
5	Instrument	Gas detector, Calorific Meter, Calibration gas
6	Bunker Station	Hose connection/disconnection, quick coupler, emergency release system

NH_3 solution

No	Discharge from	Source
A	Deck Water Spray System	Leakages from Piping system and storage tank on exposed deck
B	NH_3 Catcher and Detox system	Main Engine, Generator Engine, Aux Boiler, GCU, if equipped, Compressor
C	Heat Exchange Fluid	Heat Exchanger (Tube/Plate)
D	Enclosed space Bilge System	Leakages from Independent tank, piping, stub piece, valve, plug etc If equipped, local water sprinkler for NH_3
E	Water Curtain / Spill Tank System	Leakages from Bunker Hose, quick coupler, emergency release system

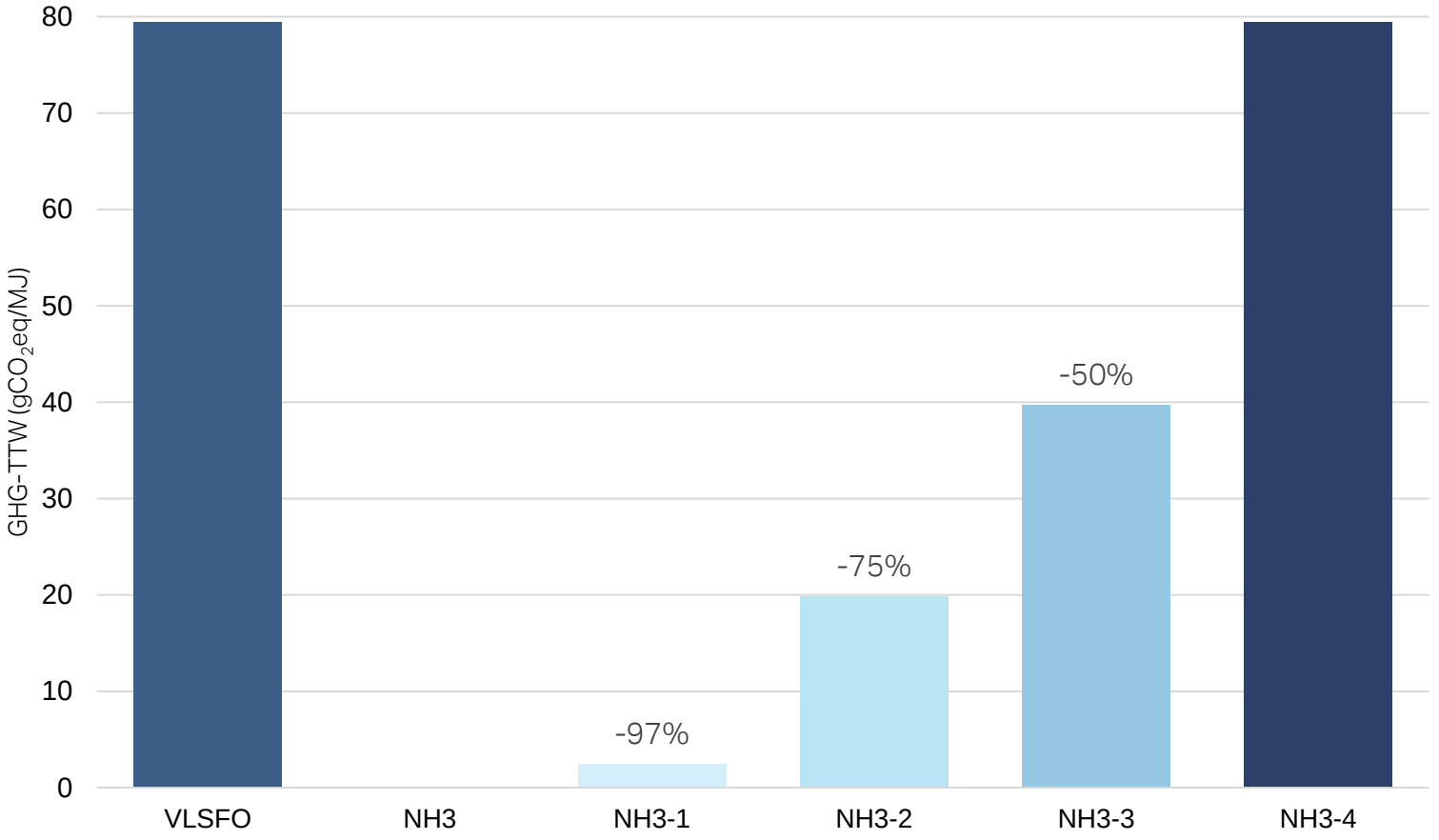
Ammonia combustion emission risk triangle



Ammonia limits (in ppm) from Class guidelines

Classification Society	ppm limits for release, alarm, and safety systems activation	Source
ABS	10 ppm as release/exhaust limit, gas alarms at 25 ppm and safety systems activated at 150 ppm	ABS, “Guide for Ammonia Fueled Vessels”, September 2021
BV	30 ppm exposure limit, triggering shut down and other safety measures	Bureau Veritas, “AMMONIA-FUELED SHIPS TENATIVE RULES - NR671 - JULY 2022”, 2022
Class NK	25 ppm as release/exhaust limit, same safety and alarm provisions as Korean Registry	ClassNK, “Guidelines for Ships Using Alternative Fuels (Edition 2.0) - Methy/Ethyl Alcohol/LPG/Ammonia, June 2022
DNV	30 ppm as release/exhaust limit, gas alarms at 150 ppm and safety systems activated at 350 ppm	DNV, RULES FOR CLASSIFICATION, Ships, “Part 6 Additional class notations, Chapter 2 Propulsion, power generation and auxiliary systems”, July 2022
Korean Register	Safety systems activated at 300 ppm. Alarm sounds at 25 ppm	Korean Register, “Guidelines for ships using Ammonia as fuels (2021.26)”, 2021
Lloyd’s Register	Prevent venting in normal and abnormal conditions. Safety systems activated at 220 ppm and alarm sounds at 25 ppm.	Lloyd’s Register, Notice No. 1, Rules and Regulations for the Classification of ships using Gases or other Low-flashpoint Fuels, December 2022

Potential impact of N_2O on total GHG emissions

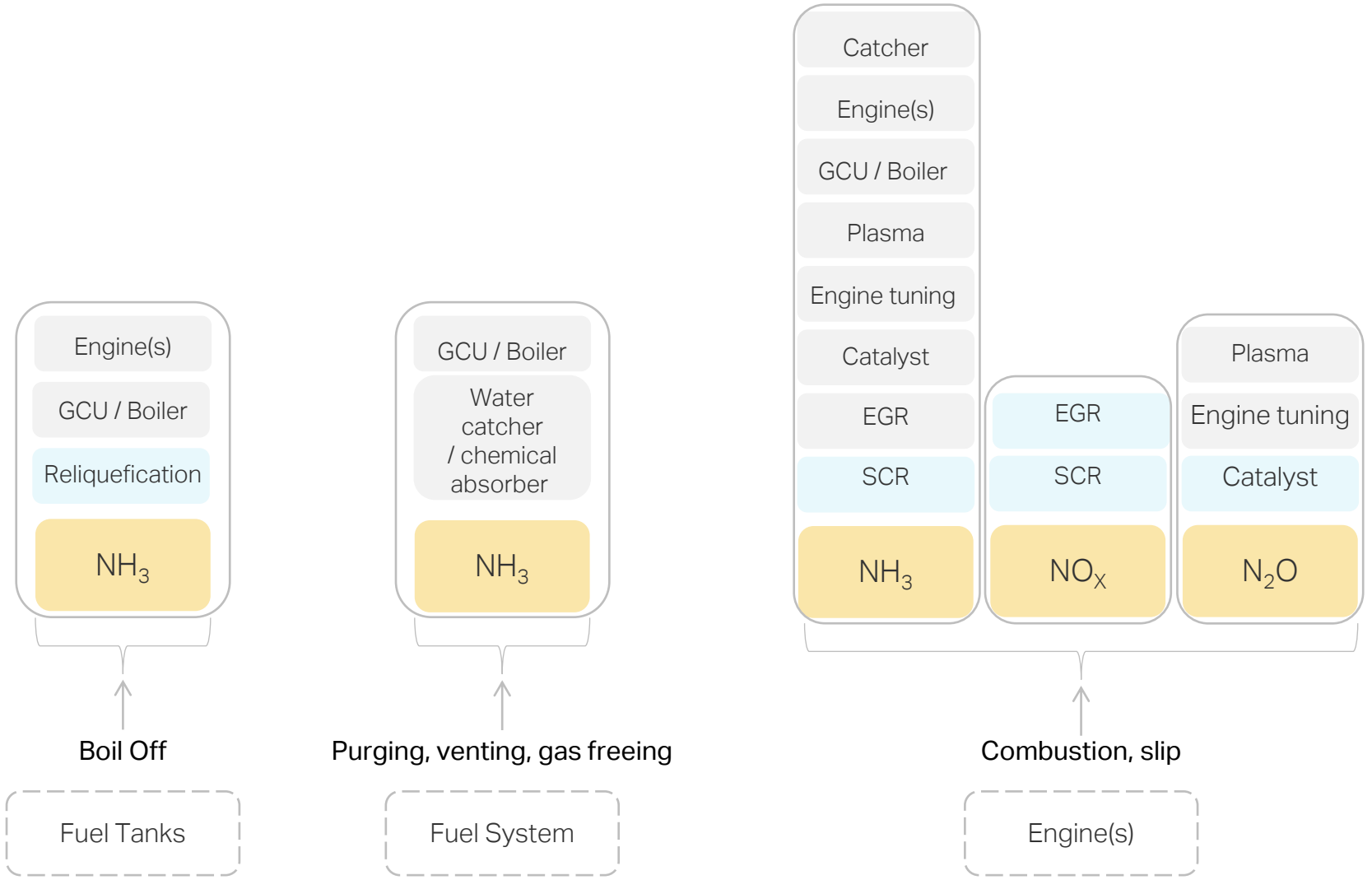


	% N_2O / NH_3 fuel	g N_2O / kWh
NH_3-1	0.01757%	0.06 g/kWh
NH_3-2	0.1336%	0.47 g/kWh
NH_3-3	0.2435%	0.95 g/kWh
NH_3-4	0.5572%	1.90 k/kWh

Working group's emission target levels

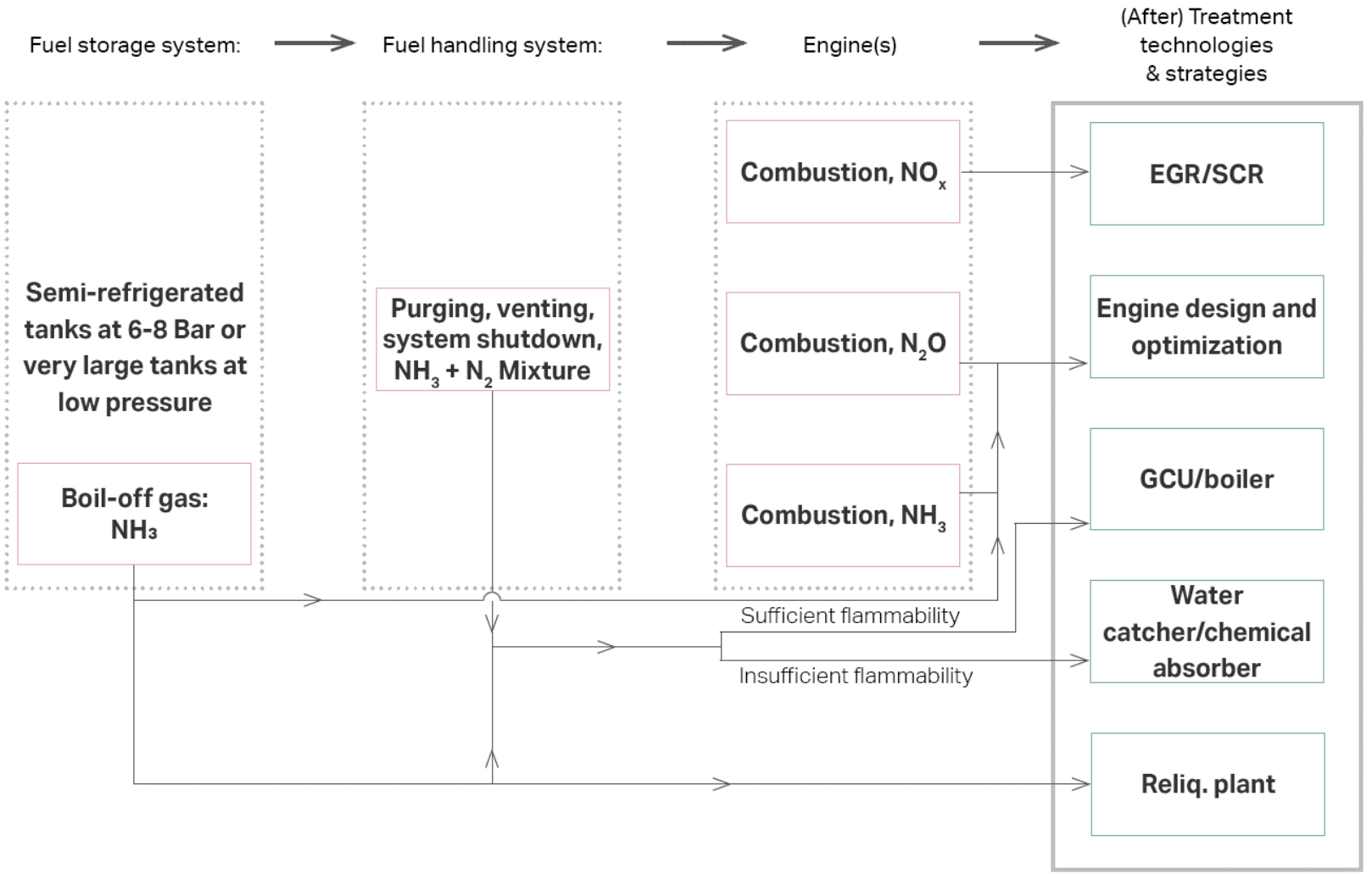
Emission	Target Level
NH_3	10-30 ppm
N_2O	0.06 g/kWh
NO_X	Tier III (≈2 g/kWh)
SO_X	N/A
PM	N/A

Ammonia-fueled vessel emission management technologies



Technology Maturity: Available | Under Development

Ammonia emission scenario 1 (target scenario with boil-off)



Working group conclusions

The **combination of different technologies** will play a key role. Some are still at the development stage and direction and the pace of future development strongly depends on **full-scale tests on 2-stroke engines**.

Engines and after-treatment technologies should be developed jointly, to ensure that material requirements, energy demand and costs are optimized.

Regulators should closely follow the upcoming tests and technology development, to make sure that **practical, effective and realistic targets and goals** are set from the very beginning.

Industry-wide collaboration needed to promote **information sharing and joint development**.

Questions

What are the greater challenges for social license?

Risk of operational or emergency ammonia releases impacting crew/operators, local communities and the environment

How can we best address it?

– Inherently safe ship designs including digitalization and automation

– Human factors: safety culture, perception and training, upskilling

– Bunkering standards and practices established and well communicated

– Emergency response and contingency plans: utilize shore-based knowledge and experience

Thank you!

Let's stay in touch

Visit our website www.zerocarbonshipping.com and make sure to follow us on LinkedIn to stay up to date with the latest news and events.

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