MAN Energy Solutions
Future in the making

A marine fuel standard for Ammonia

- an engine designers perspective

17 November 2020

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Engine Process Development, R&D, Two-stroke
17 November 2020

Agenda

1 **Our business in a global context**

2 **Future fuels**

- MAN B&W Two-stroke – Multi fuel engines

3 **Drivers for change**

4 **Ammonia:**

- Why Ammonia?
- Challenges?
- Fuel spec.

5 **Summary**

1 Our business in a global context

Our Business in a Global Context

United Nations Climate Change

13 CLIMATE ACTION

Paris Agreement

UN Sustainable Development Goals

IMO INTERNATIONAL MARITIME ORGANIZATION

IMO Initial GHG Strategy (13 April 2018):

Goals for International Shipping:

- Reduction of CO_2 **per transport work**: min. **40% by 2030** towards min. **70% in 2050***
- GHG emissions to **peak as soon as possible**
- Reduction the **total annual GHG** emissions by **min. 50% by 2050***

*) Compared to 2008

MAN Energy Solutions

Our marine engines for large ships

≈ 1.5 % of world's CO_2

We take responsiblity to reduce climate impact!

2 MAN B&W two-stroke – multi fuel engines

MAN B&W Two-Stroke – Multi fuel Engines

Historical timeline

2011 — Engine delivery for TOTE Maritime

2012 — Engine delivery for TEEKAY LNG

2013 — ME-GI retrofit for Nakilat

2015 — 1st sea trial on methanol

2016 — 1st sea trial on ethane

2017 — First order of MAN B&W 6G60ME-LGIP engines by Exmar

2018 — 4 x MAN B&W ME-LGIP Retrofit orders for BW LPG. Dry dock 2020

2019 — Hapaq Lloyd 9S90ME-C ME-GI retrofit. Dry dock 2020

2011 — ME-GI test at RCC

2012 — ME-GI demonstration test at HHI

2013 — ME-GI demonstration test at MES

2015 — Development of ME-LGI

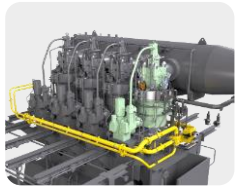
2016 — Ethane development

2017 — ME-GI/E PVU at RRC

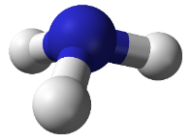
2018 — LPG tightness- & function test at RCC

2019 — LGIP cylinder installed on research engine at RCC

2020 — ME-GA test at RCC



2023/24 — Ammonia burning engine



New Fuels

Modular design enables extensive retrofit options and MAN Energy Solutions future proof your investment

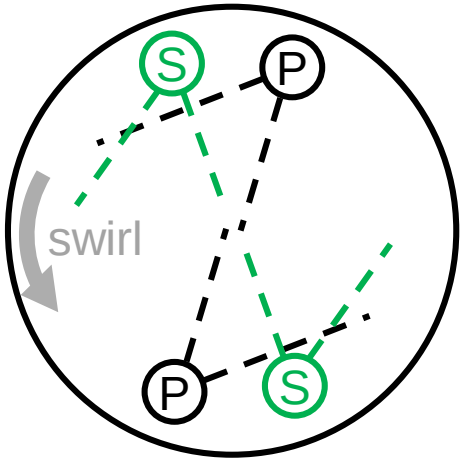
Fuel types	MC	ME-B	ME-C	ME-GI	ME-GA*	ME-GIE	ME-LGIM	ME-LGIP
0-0.50% S VLSFO	Design	Design	Design	Design	Design	Design	Design	Design
High-S HSHFO	Design	Design	Design	Design	Design	Design	Design	Design
LNG	-	-	Retrofit**	Design	Design	Design	Retrofit**	Retrofit**
LEG (Ethan)	-	-	Retrofit**	Retrofit**	-	Design	Retrofit**	Retrofit**
Methanol / Ethanol	-	-	Retrofit**	Retrofit**	-	Retrofit**	Design	Retrofit**
LPG	-	-	Retrofit**	Retrofit**	-	Retrofit**	Retrofit**	Design
Biofuels	Design	Design	Design	Design	Design	Design	Design	Design
Ammonia***	-	-	(Retrofit**)	(Retrofit**)	-	(Retrofit**)	(Retrofit**)	(Retrofit**)

*Otto-cycle gas engine.
**Only one second fuel per retrofit.
*** Ammonia burning engine development started.

For description of MAN ES 2-stroke engine types:
https://marine.man-es.com/two-stroke/2-stroke-engines/overview

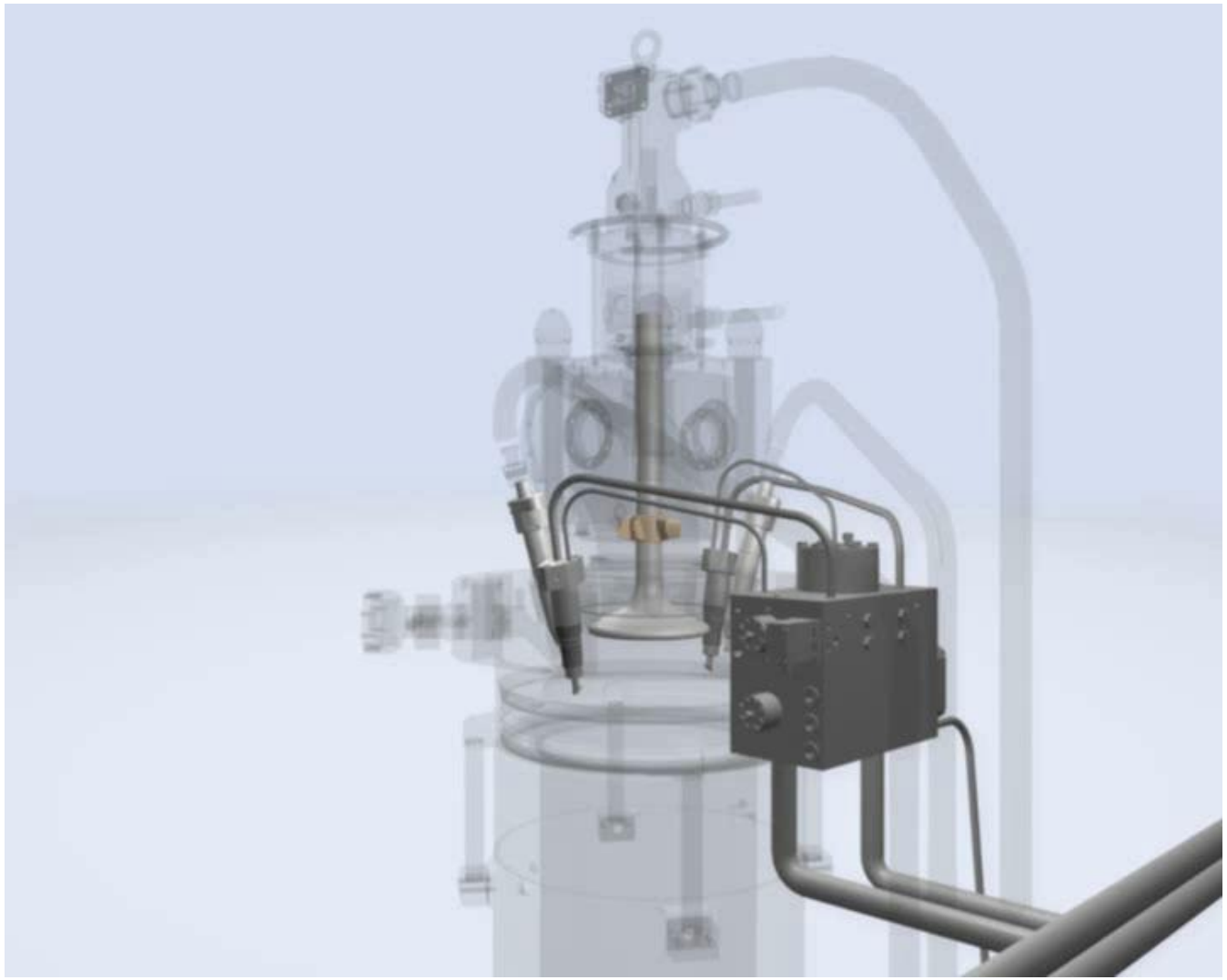
Dual fuel engines

Engines capable of operating on conventional HFO / Diesel and an additional fuel through a separate fuel injection system.



P Diesel injector for pilot injection

S Second fuel injector

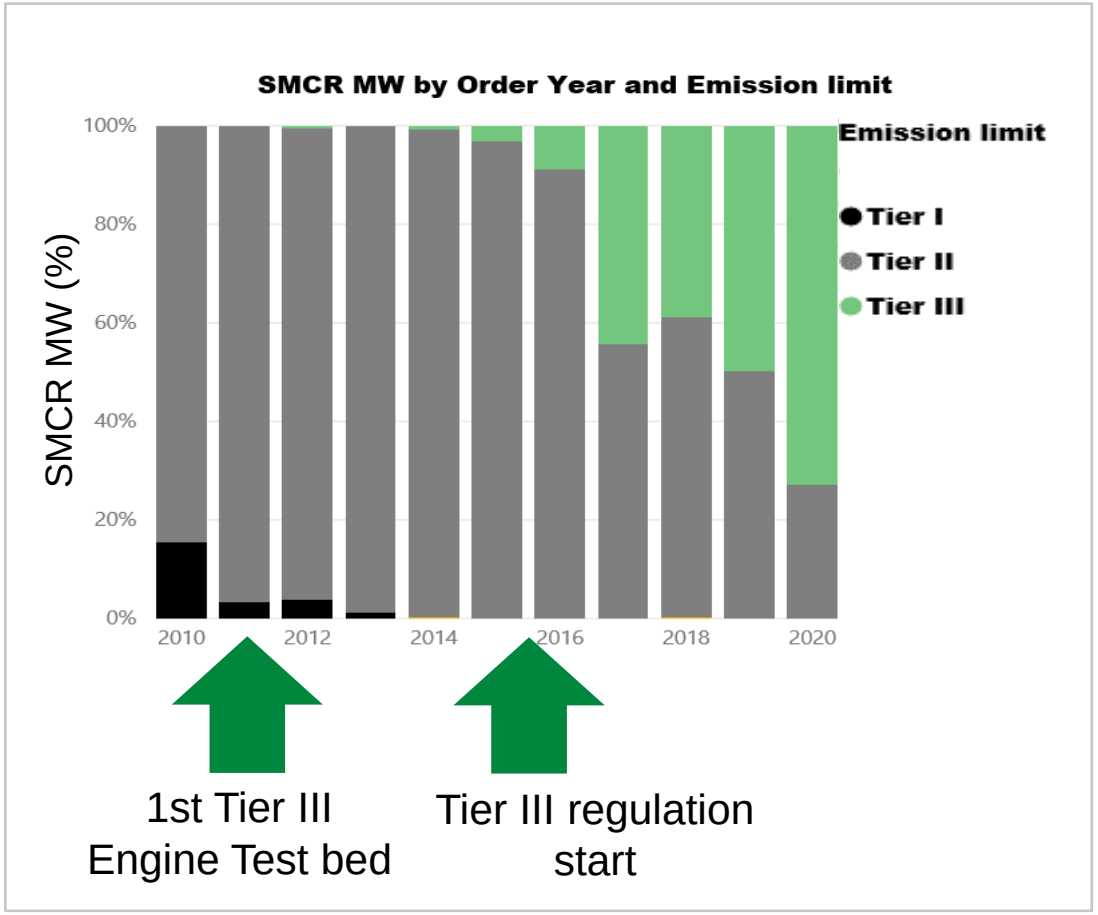


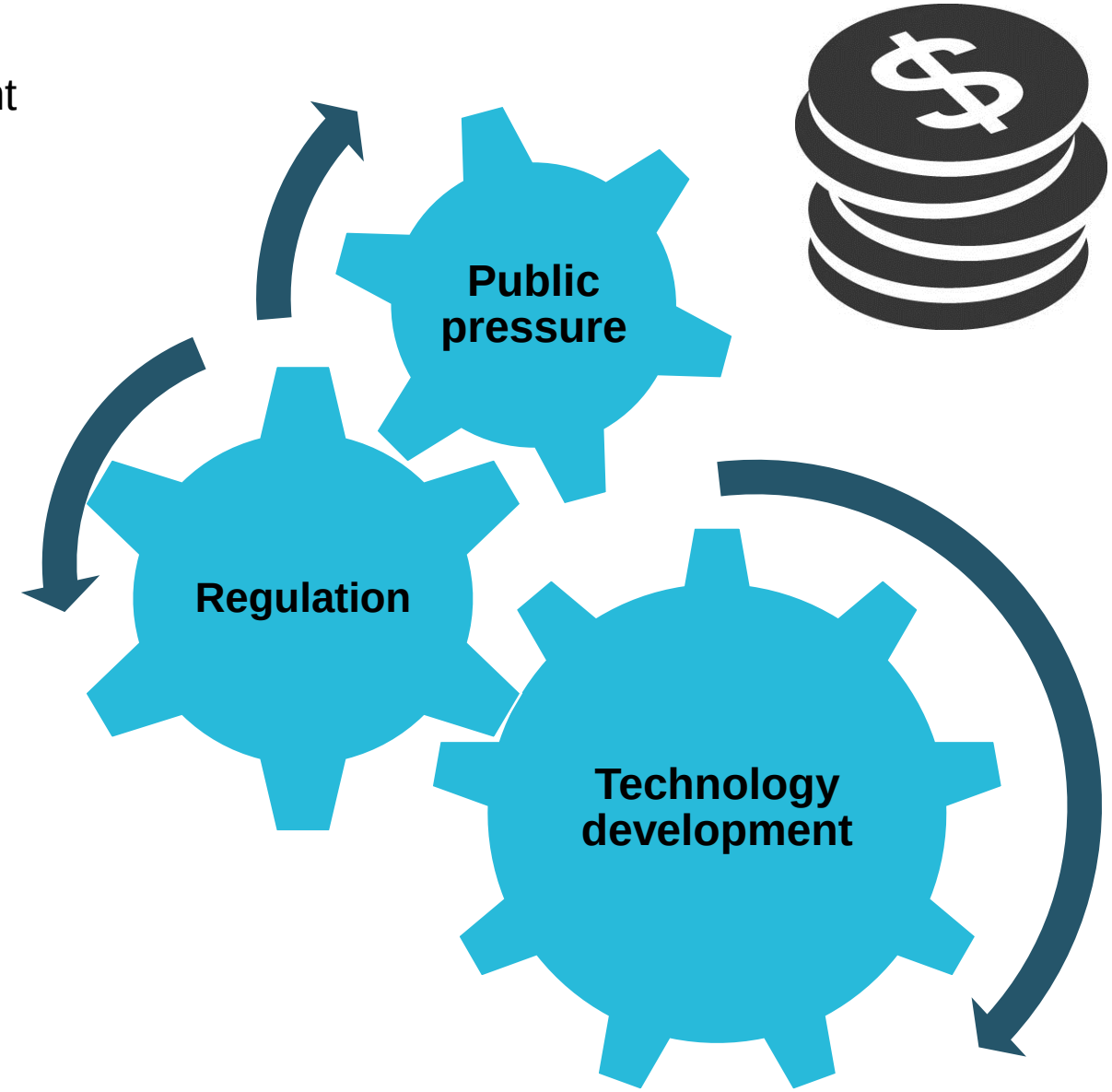
3 Drivers for change

Drivers for change

Public pressure + Regulation + Technology development

Market introduction: NOx reduction technology





4 Ammonia:

- Why Ammonia?
- Challenges?
- Fuel spec.

Marine fuels: 2020 -> 2030 -> 2050

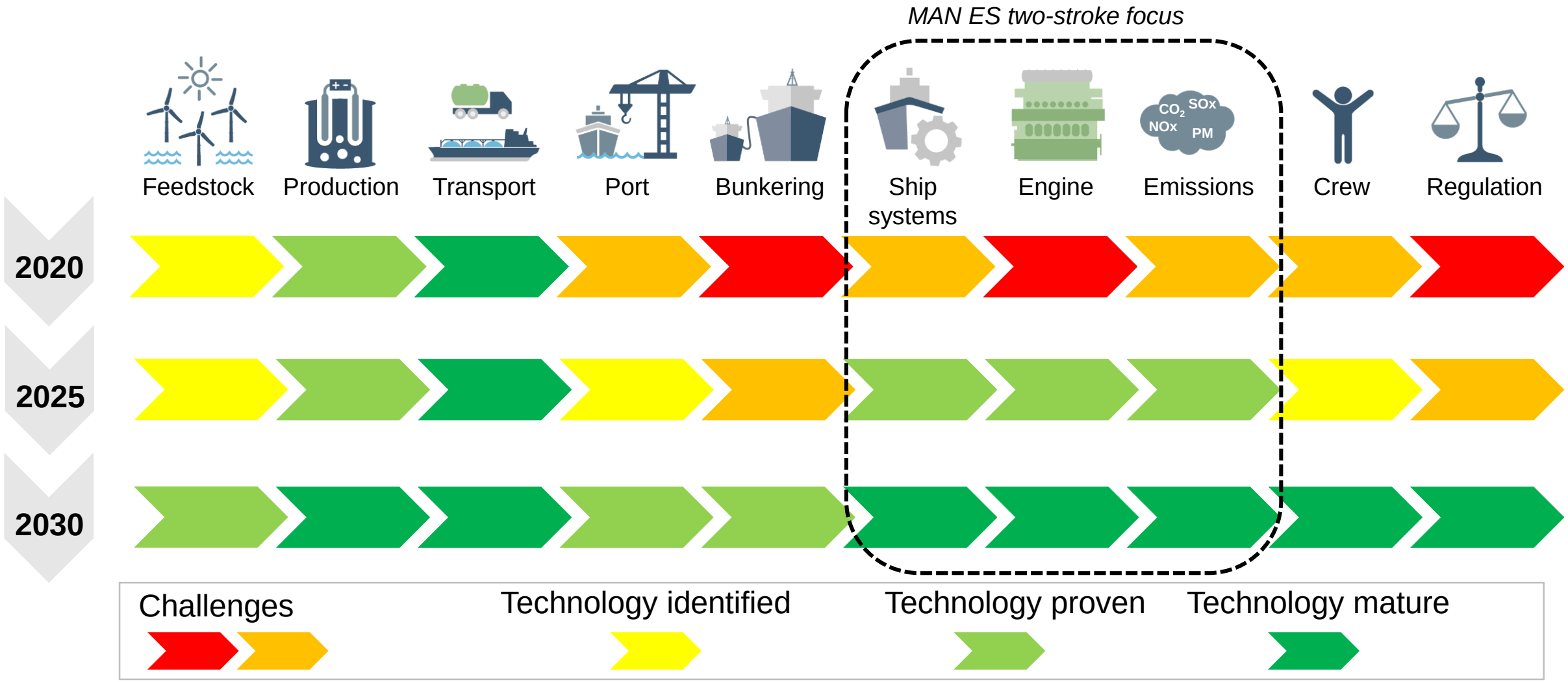
Green: Good
Red: Major challenge

Current status for different fuel types

Fuel Type	Fuel production	Price	Availability	Competences in the marine industry	Regulation	Safety		Environment		
						Toxicity	Flamability	GHG		NOx, PM, SOx, BC
								Fuel production	On the ship	
0.10%S ULSFO	Fossil									
	Bio									
	PtX									
0.50 %S VLSFO	Fossil									
	Bio									
	PtX									
High-S Heavy fuel	Fossil									
LNG	Fossil									
	Bio									
	PtX									
Methanol	Fossil									
	Bio									
	PtX									
LEG (Ethane)	Fossil									
LPG	Fossil									
Ammonia (NH_3)	Fossil									
	Bio									
	PtX									
Hydrogen	Fossil									
	Bio									
	PtX									

Possible implementation pathway for a new marine fuel

Example: PtX Ammonia

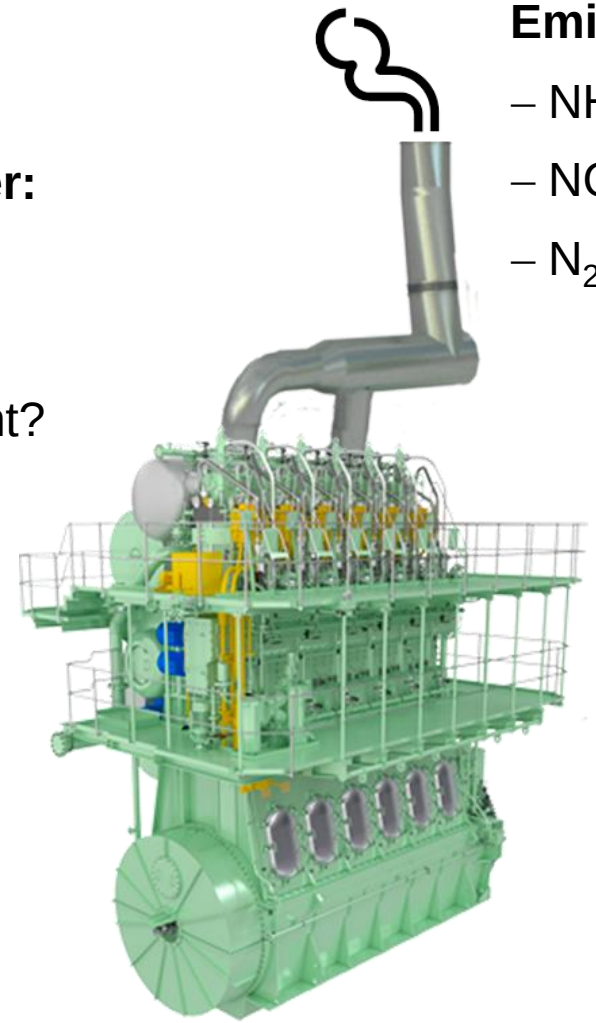


Challenges for operation on NH_3

Engine designer perspective

Combustion chamber:

- Combustion:
  - Dual fuel
  - Pilot fuel amount?
- Cylinder condition
- Lube oil



Emissions:

- NH_3 slip
- NOx
- N_2O?

Fuel system:

- No leak
- Seal
- Lubricate
- Suitable materials
- Bigger

NH_3 characterisics

- Safety: Toxic
- Smelly
- Volatile
- Degreaser
- Very low viscosity
- Low energy density
- Difficult to ignite
- Aggresive to materials:
  - Elastomers
  - Metals:
    - SCC
    - General corrosion

Guiding fuel spec. for NH_3 – at engine inlet

MAN Energy Solutions: ME-LGIA engine type

PRELIMINARY

Designation	Unit	Limit	Value	Test Method Reference[1]	
Ammonia	% (w/w)	min.	99.5	TBD	– Energy content
Water	% (w/w)	min.	0.1	ISO 7105	– Inhibit SCC
		max.	0.5		
Oil	% (w/w)	Max.	0.4	ISO 7106	– Control amount
Oxygen	% (w/w)	max.	TBD	TBD	– Inhibit SCC
Nitrogen	% (w/w)	max.	0.3	TBD	– Control air amount
Sulfur	% (w/w)	max.	TBD[2]	TBD	– Regulation
Particles	-	max	Note[3]	-	– Reduce wear

1. Latest edition to be applied. ISO standards methods are the highest level of international methods and are therefore recommended. Equivalent methods from ASTM, GPA and IP can also be used.
2. Compliant with statutory requirements
3. Most particles are expected to end up in the NH3 due to transport of the NH3, not during NH3 production. Particle sizes and amounts are therefore dependent on the actual NH3 logistics involved between NH3 production and vessel fuel tank. Filtering to 10 µm between vessel fuel tanks and engine is therefore considered the best way to avoid engine problems due to particles. Particles breaking free from the NH3 production catalyst may be an issue with respect to wear of the engine and this topic is subject to further evaluation.

NH_3 transported as liquid

– Atmospheric pres., -33 C

– High pressure, atmospheric temp.

SCC – Stress Corrosion Cracking

NH_3 fuel spec.

General recommendation to avoid NH_3 induced SCC:

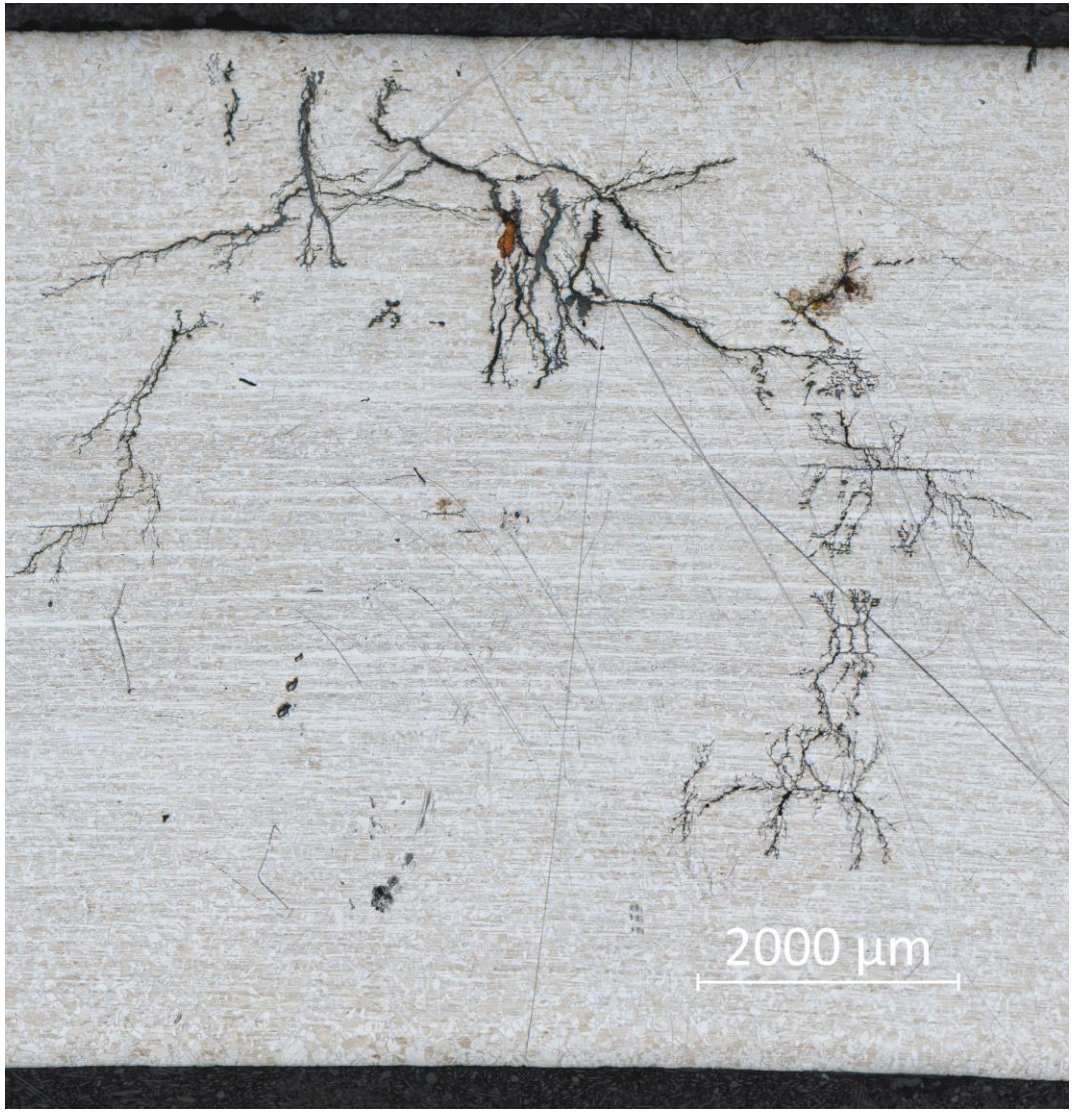
– Water: > 0.1 %

– Reduce O_2 level

– Reduce stress

– Use resistant materials

Illustration: Cl^- induced SCC in 316



Particles

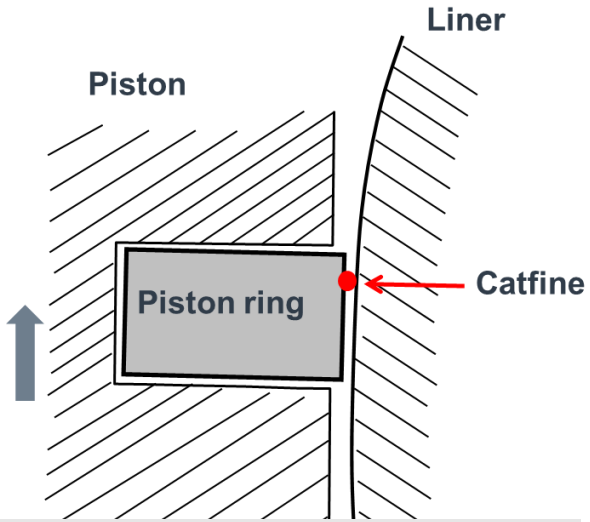
NH_3 fuel spec.

General recommendation to avoid wear from particles:

– Reduce amount of particles

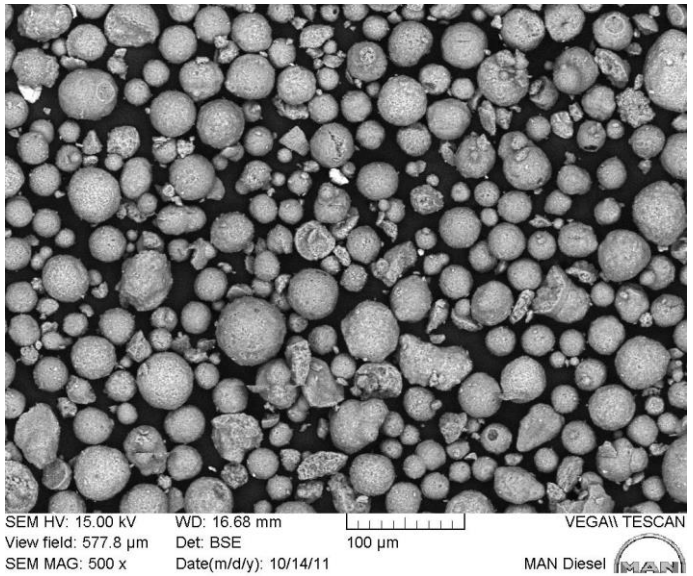
– In traditional fuels:
  – Max. amount as bunkered
  – Fuel cleaning system:
    – Settling tanks
    – Separators
    – Day tank
    – Filters
  – Max. amount at engine inlet

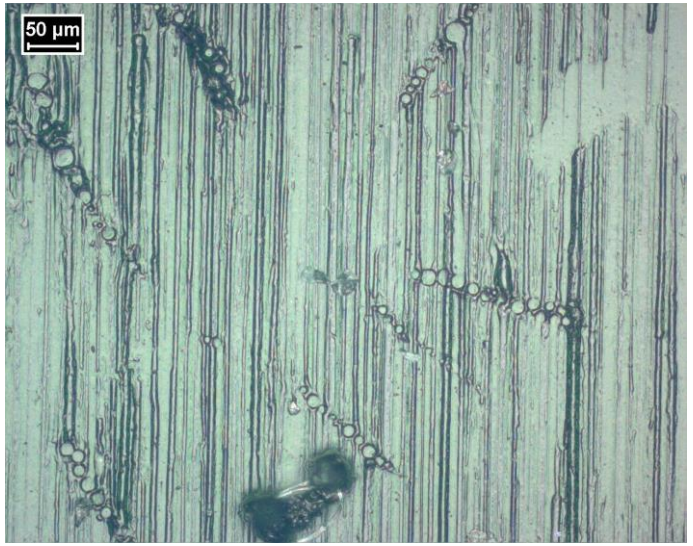
– In LNG, LEG, MeOH, LPG:
  – Fuel cleaning system:
    – Filters



Particle size > 1 µm may wear combustion chamber parts

Cat fines from petroleum refining





Marine Fuel regulation and standards

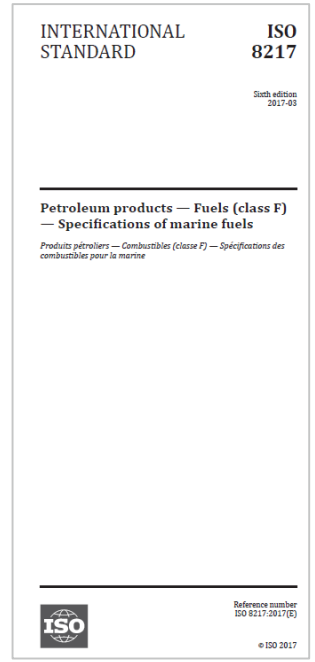
Status

Fuel Type	MAN ES 2-Stroke	IMO Regulation	ISO Standard*
Diesel/Heavy fuel	X	OK	OK
Low-flash point traditional fuel	X	Almost done (IGF code, 01.01.2024)	Not started
LNG	X	OK	OK
LEG (Ethane)	X	Ethane carriers OK (IGC code)	Not started
Methanol	X	Interim guidelines	WG approved
LPG	X	In progress	Not started
Biofuels	X	NOx compliance?	ISO 8217:2017 6th ed. allows 7% FAME*** in DM. New sub group started
Ammonia (NH_3)	(X)**	Not started	Not started

*) Compliance with ISO standards are not mandatory

**) Under development

***) *FAME: EN 14214*


INTERNATIONAL STANDARD ISO 8217

Sixth edition 2017-03

Petroleum products — Fuels (class F) — Specifications of marine fuels

Produits pétroliers — Combustibles (classe F) — Spécifications des combustibles pour la marine

Reference number ISO 8217:2017(E)

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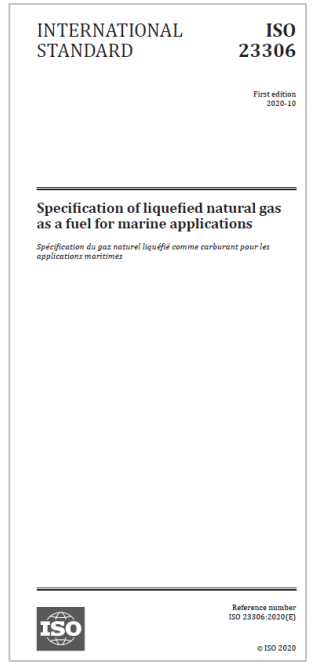

INTERNATIONAL STANDARD ISO 23306

First edition 2020-10

Specification of liquefied natural gas as a fuel for marine applications

Spécification du gaz naturel liquéfié comme carburant pour les applications maritimes

Reference number ISO 23306:2020(E)

© ISO 2020

5 Summary

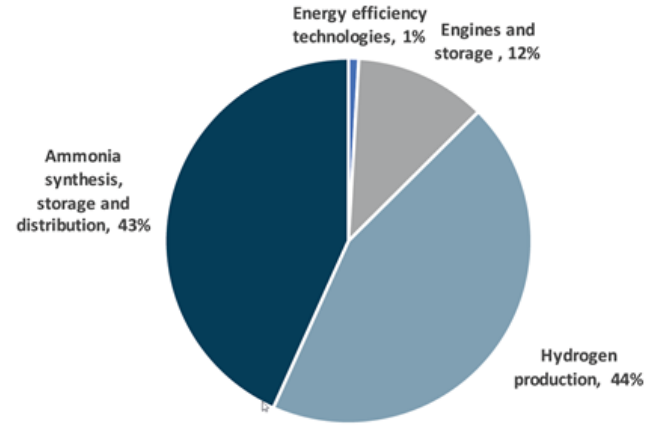
The way to zero carbon shipping

At least 50% GHG reduction in 2050 requires:

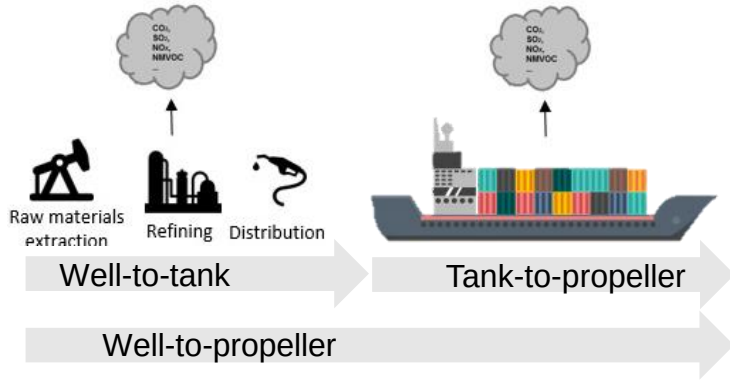
- Drivers (regulatory and/or economical)
- Major investments in energy/fuel production (upstream)
- Funding: Research, development and demonstration
- Cross-sectoral cooperation projects
- LCA approach to ensure net-GHG reduction
- **Implementation of new fuels to start by 2030 - preferably sooner**

Work should start now - and we all have our roles

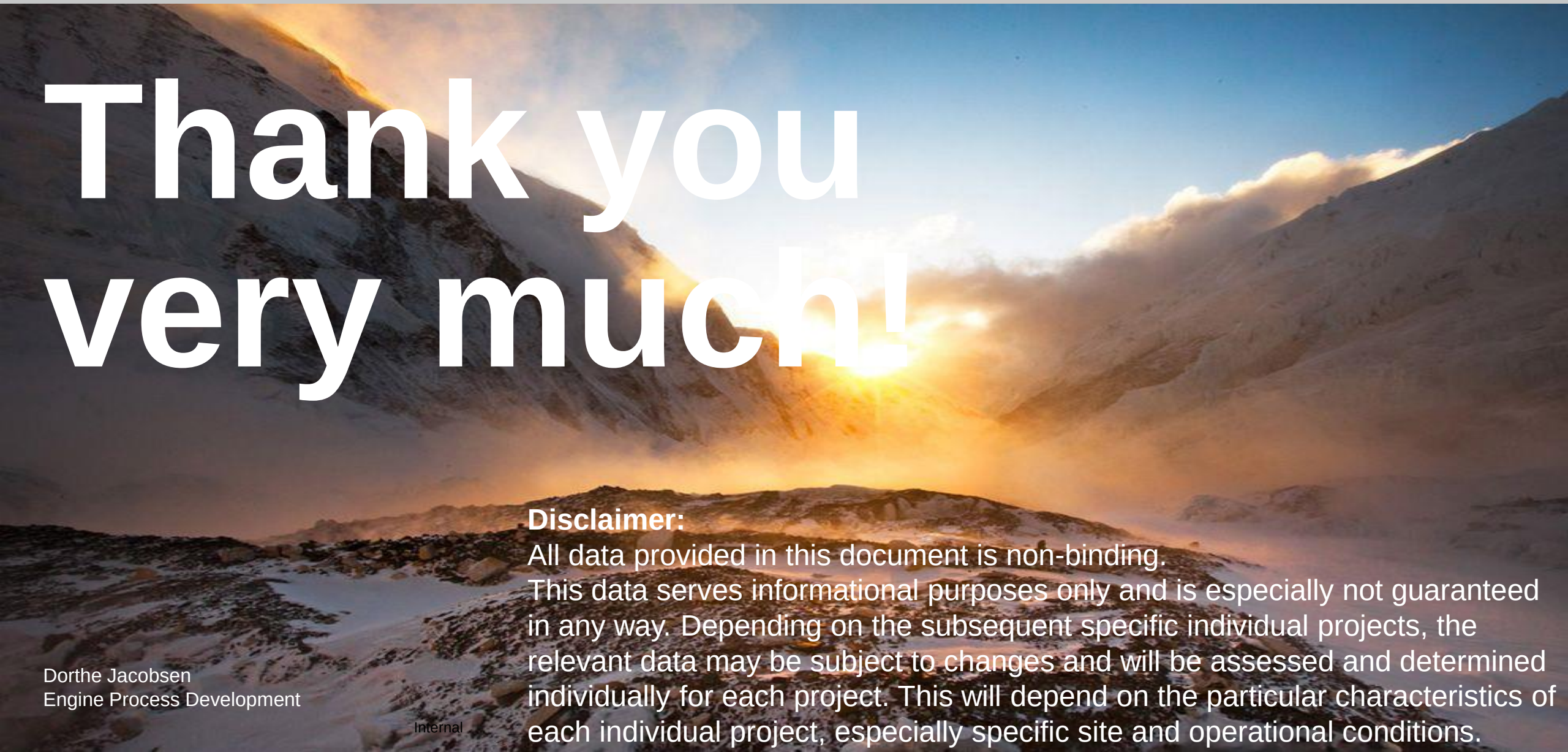
Investment breakdown across vessels and land-based infrastructure*



Life Cycle Analysis



*) Getting to Zero Coalition: https://www.globalmaritimeforum.org/news/the-scale-of-investment-needed-to-decarbonize-international-shipping/



Thank you very much!

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Engine Process Development

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