MAN Energy Solutions
Future in the making

Decarbonizing Large Bore Engines

CIMAC Cascades 2021

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MAN Energy Solutions

Strategic Business Fields

Marine

Emission reduction in maritime applications

Energy & Storage

Sustainable generation of energy

Industries

Increased efficiency across segments

Aftersales MAN PrimeServ

50% of power for all world trade covered by our engines

3%

of worldwide CO_2 emissions are caused by shipping (~ 1.2 bn tons of CO2)

90%

of the goods traded around the world are transported via maritime shipping

50%

IMO: Reduction of annual shipping emissions by 2050 (compared to 2008)

Only with alternative green fuels

the CO_2 reduction targets can be reached

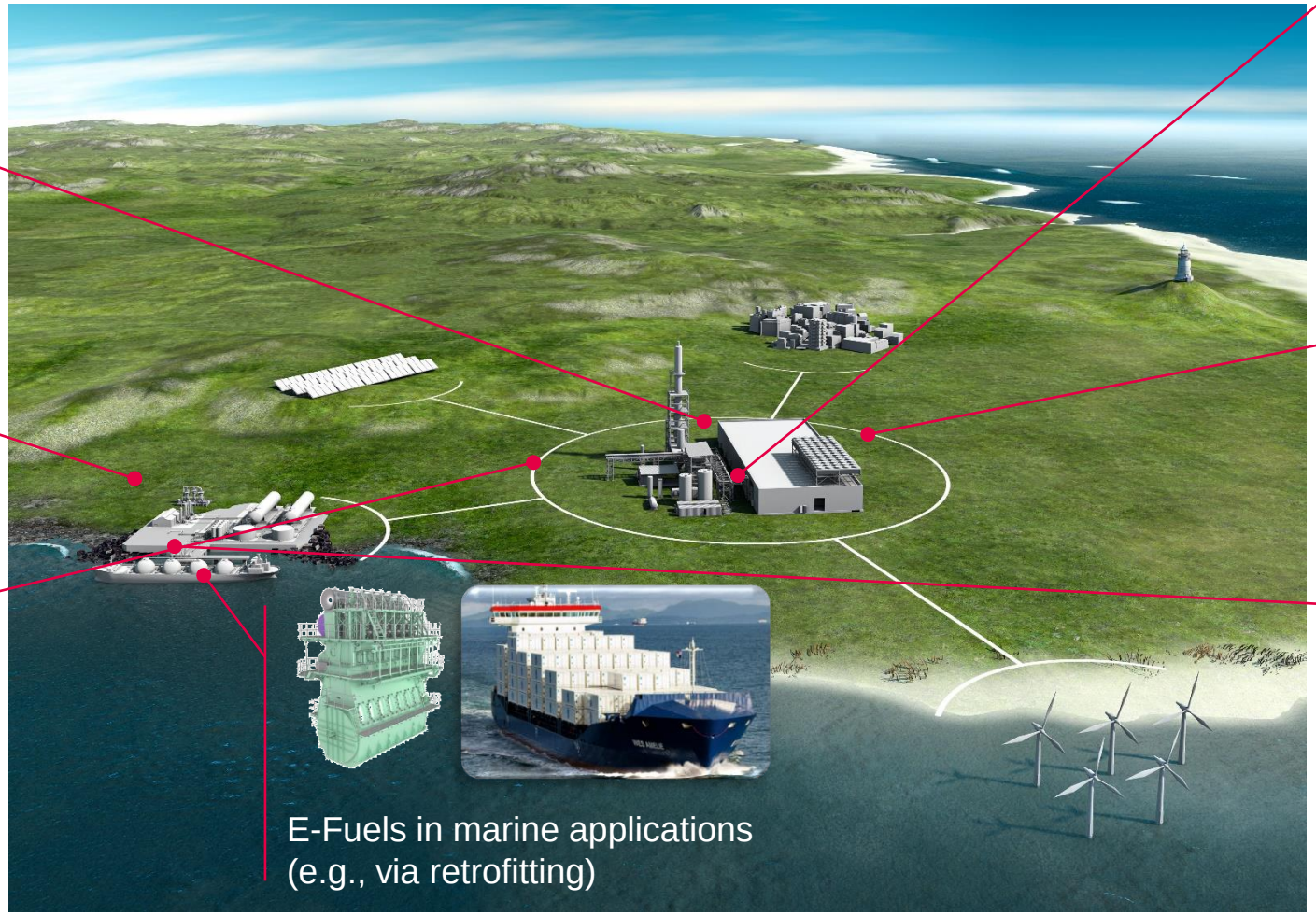
Hydrogen: Important pillar for decarbonisation

Our products and solutions cover the entire e-fuels value chain

Electrolysis

H_2-Storage

Compression and Transport



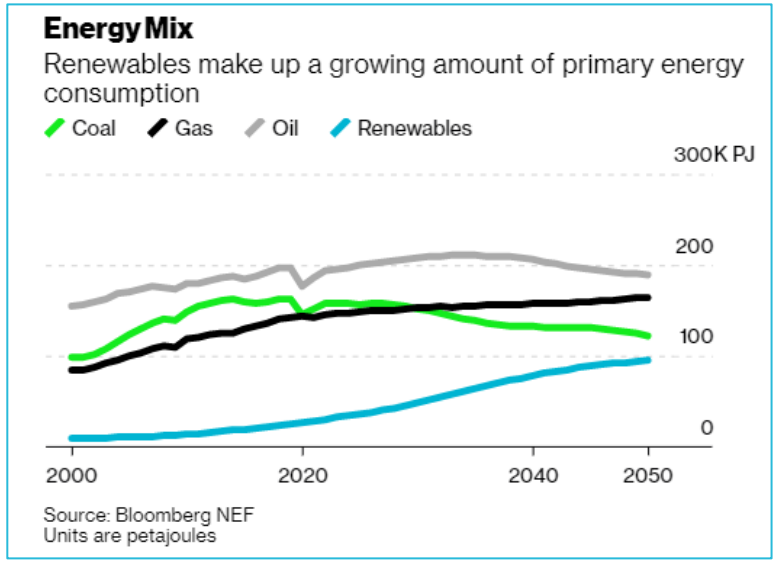
PtX Technology and Reactor Competence

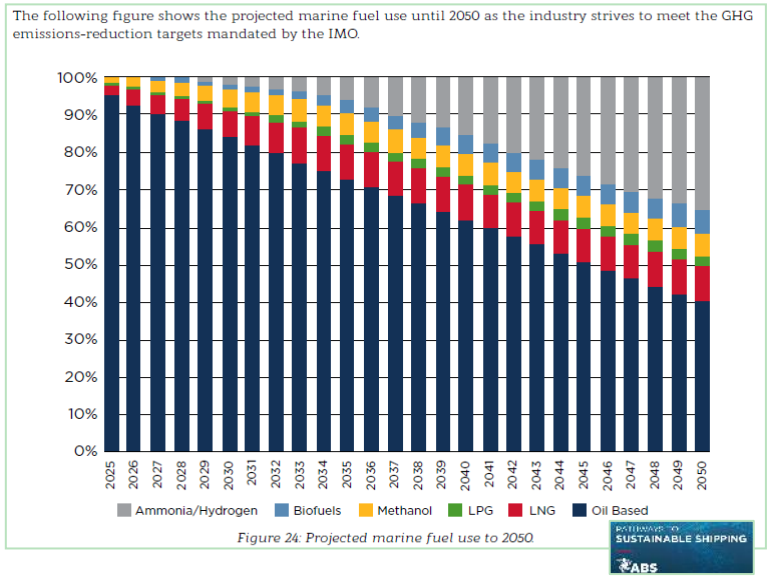
EPC Solutions

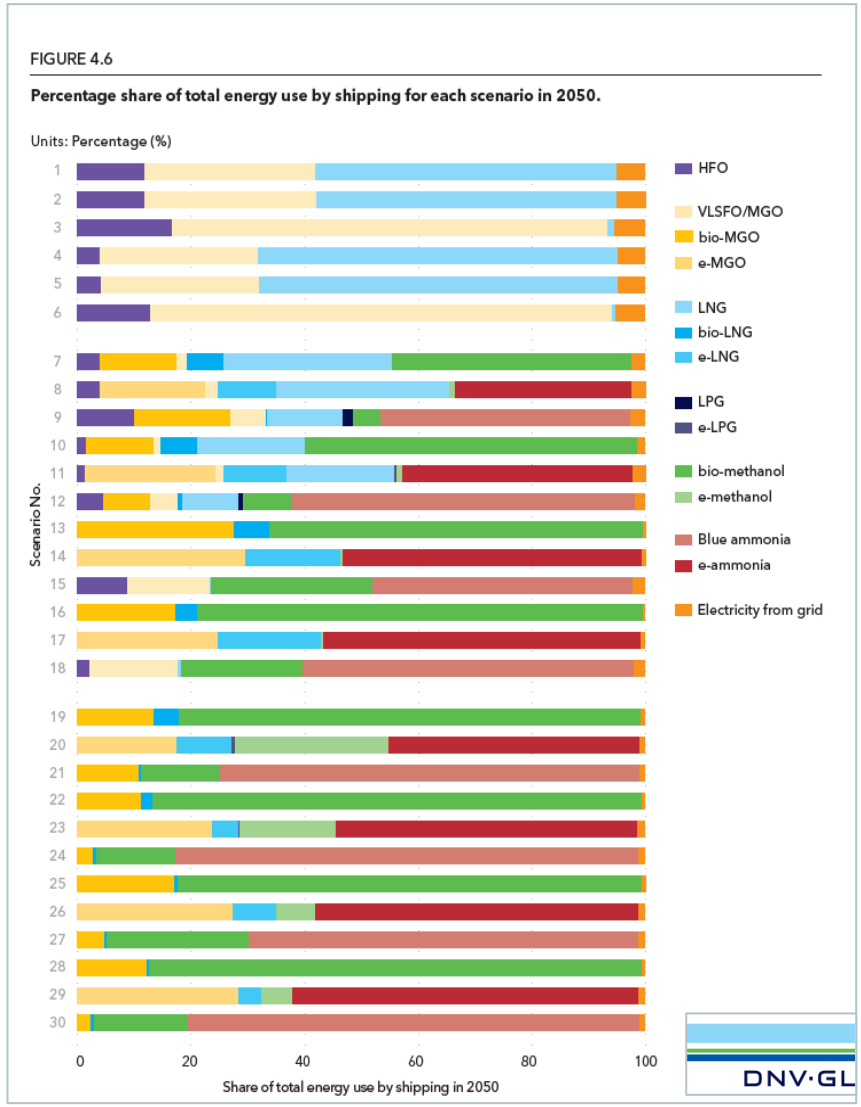
(L)SNG Infrastructure

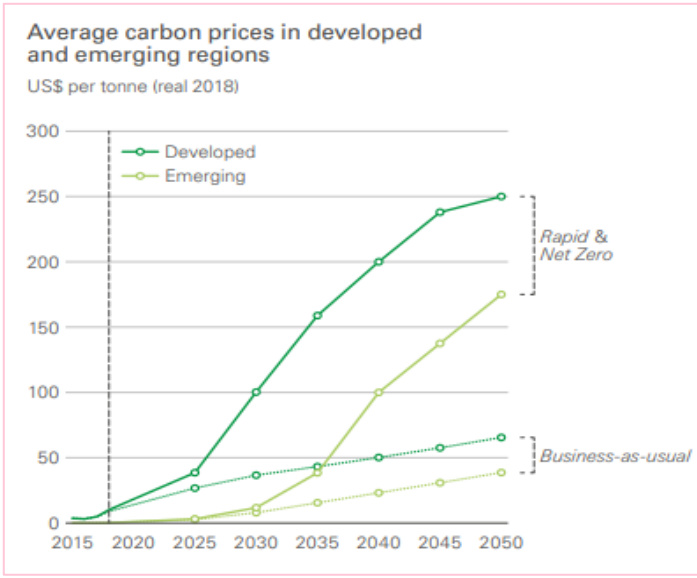
Picture Source: Logos © H-TEC SYSTEMS GmbH

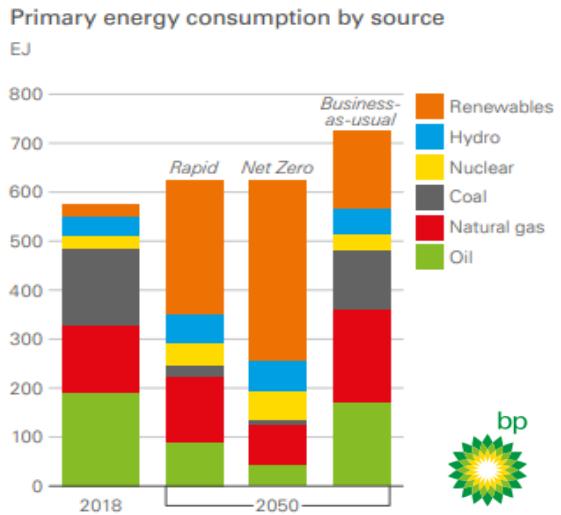
There are multiple future-fuel mix scenarios



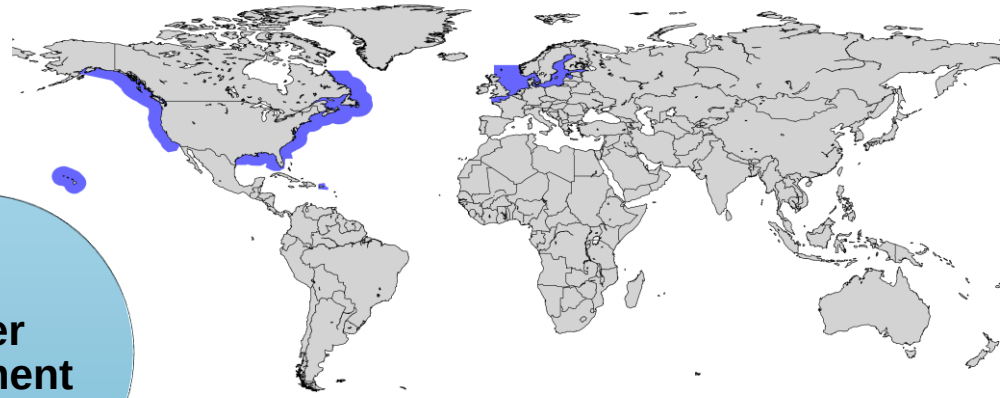


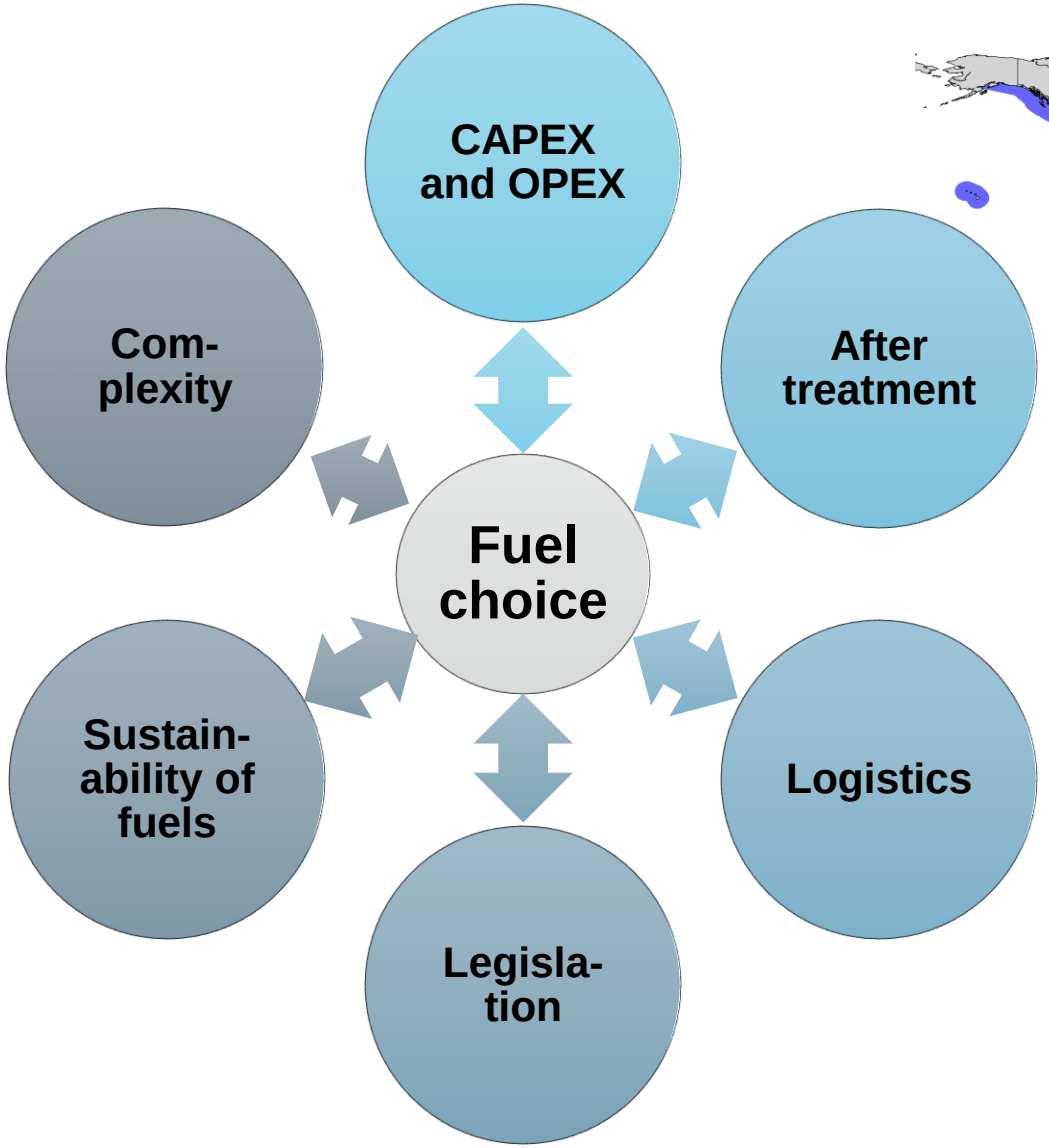


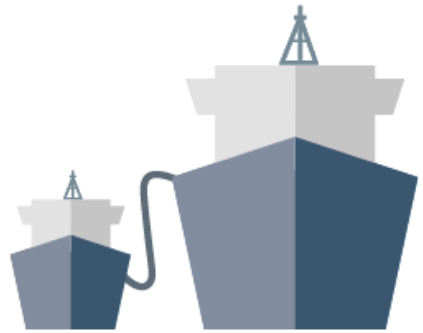




Influencing factors on fuel choice

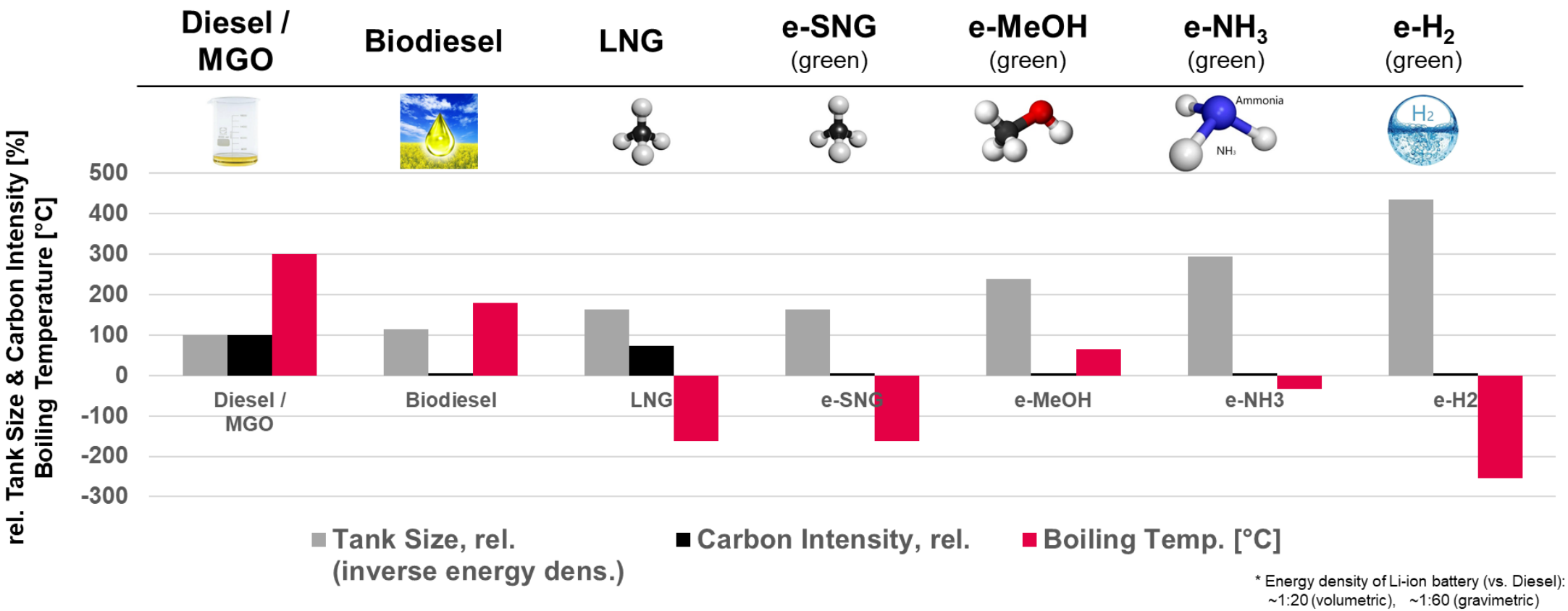






Fuels Towards Carbon Neutrality

Alternative Future Fuel Options

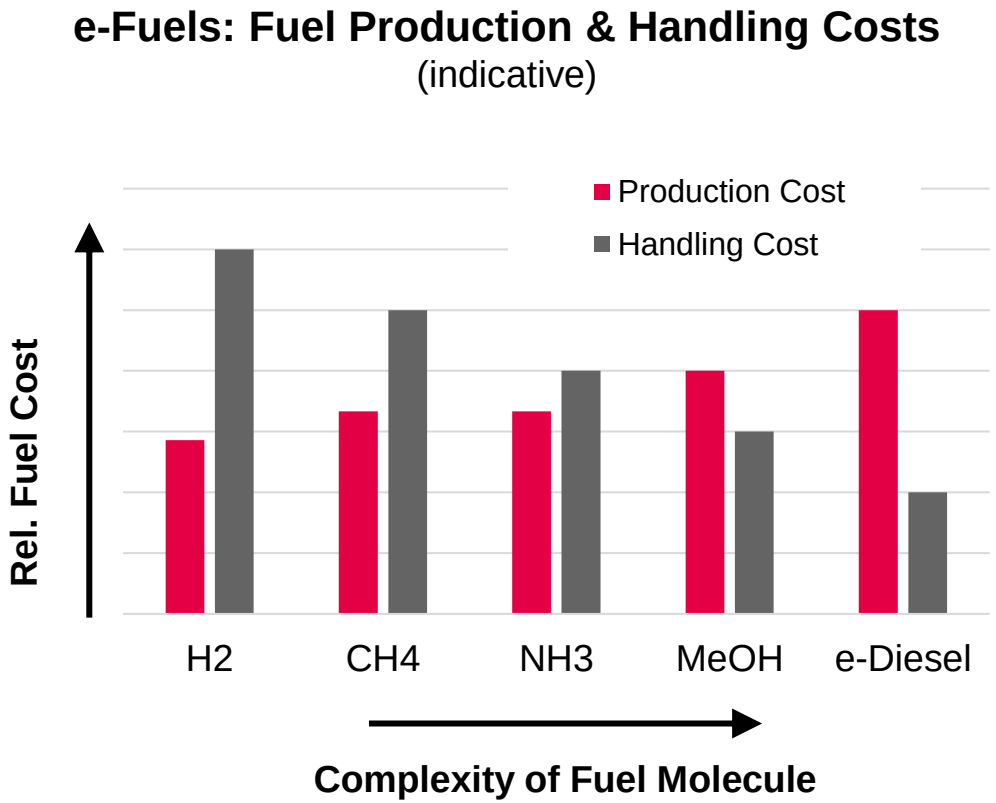


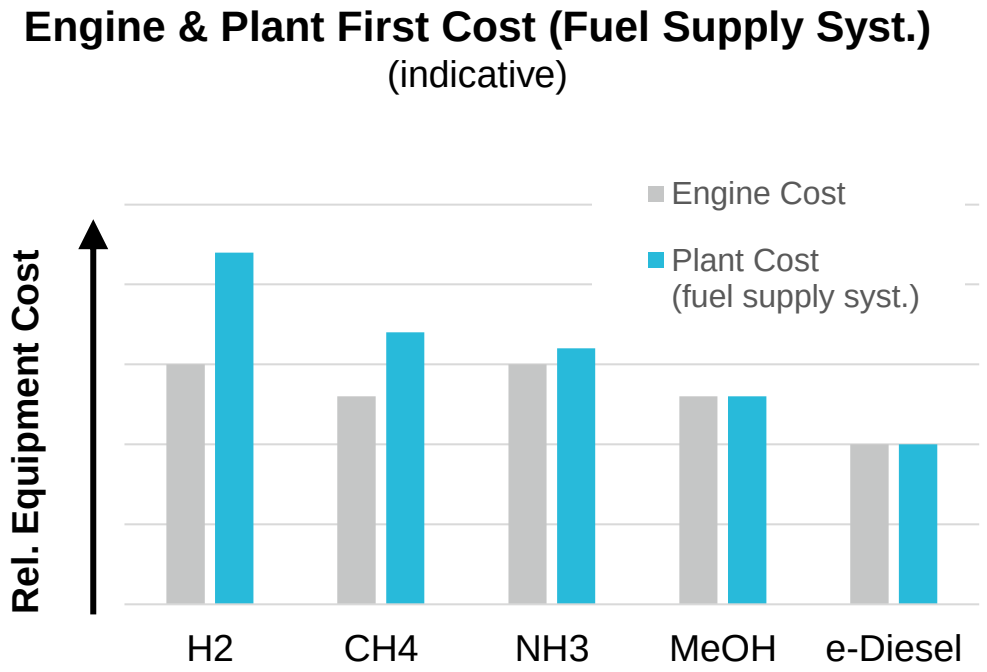
* Energy density of Li-ion battery (vs. Diesel):
~1:20 (volumetric), ~1:60 (gravimetric)

The engine can burn it => cost, infrastructure & handling are decisive => there will be multiple fuels in parallel !

Cost of Alternative Fuels (indicative figures)

E-Fuels: Production & Handling – Engine & Plant Cost

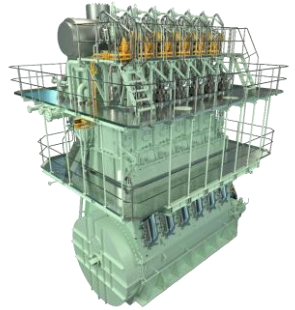




The optimum e-Fuel will likely depend on vessel type, trade scheme and region – We have to expect a variety of fuels !

Dual Fuel Engine Technology

2-Stroke Modular & Future Proof Design



Built-in Fuel Flexibility - A Necessity

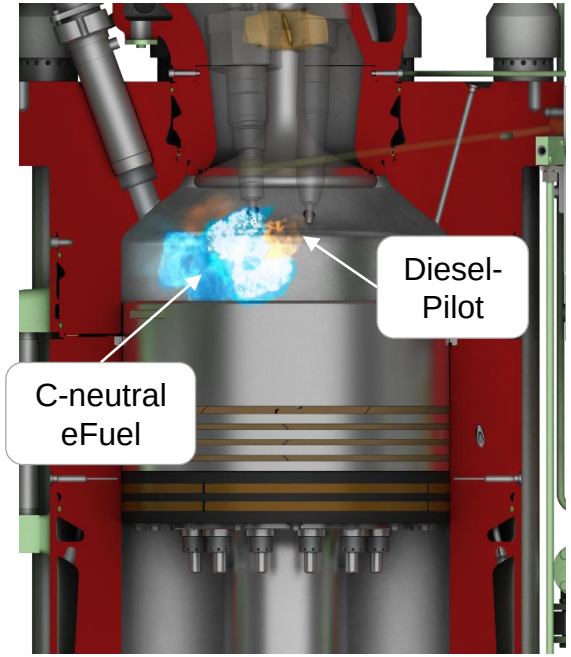
Fuel types	MC	ME-B	ME-C	ME-GI	ME-GA	ME-GIE	ME-LGIM	ME-LGIP
0-0.50% S VLSFO	Design	Design	Design	Design	Design	Design	Design	Design
High-S HSHFO	Design	Design	Design	Design	Design	Design	Design	Design
LNG	-	-	Retrofit***	Design	Design	Retrofit***	Retrofit***	Retrofit***
LEG (Ethane)	-	-	Retrofit***	Retrofit***	-	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**)

Fuel by original design of type

** One second fuel per retrofit

*** Both LNG and LEG

**** available in 2024



World's 1st **LNG** driven container vessel

World's 1st **MeOH** driven vessel

World's 1st **Ethane** driven vessel

World's 1st **LPG** driven vessel

4-Stroke Solutions towards Decarbonization

Fuel Flexibility & Robustness as Key Advantage of Combustion Engines

- ✓ **VLSFO / MGO**
- ✓ **Biofuels**
- ✓ **LNG / eSNG** (PtX)
- ✓ **≤ 25% H_2 in NG**
- ✓ **Battery Hybrid Systems**
- **MeOH, NH_3, H_2** as future alternatives

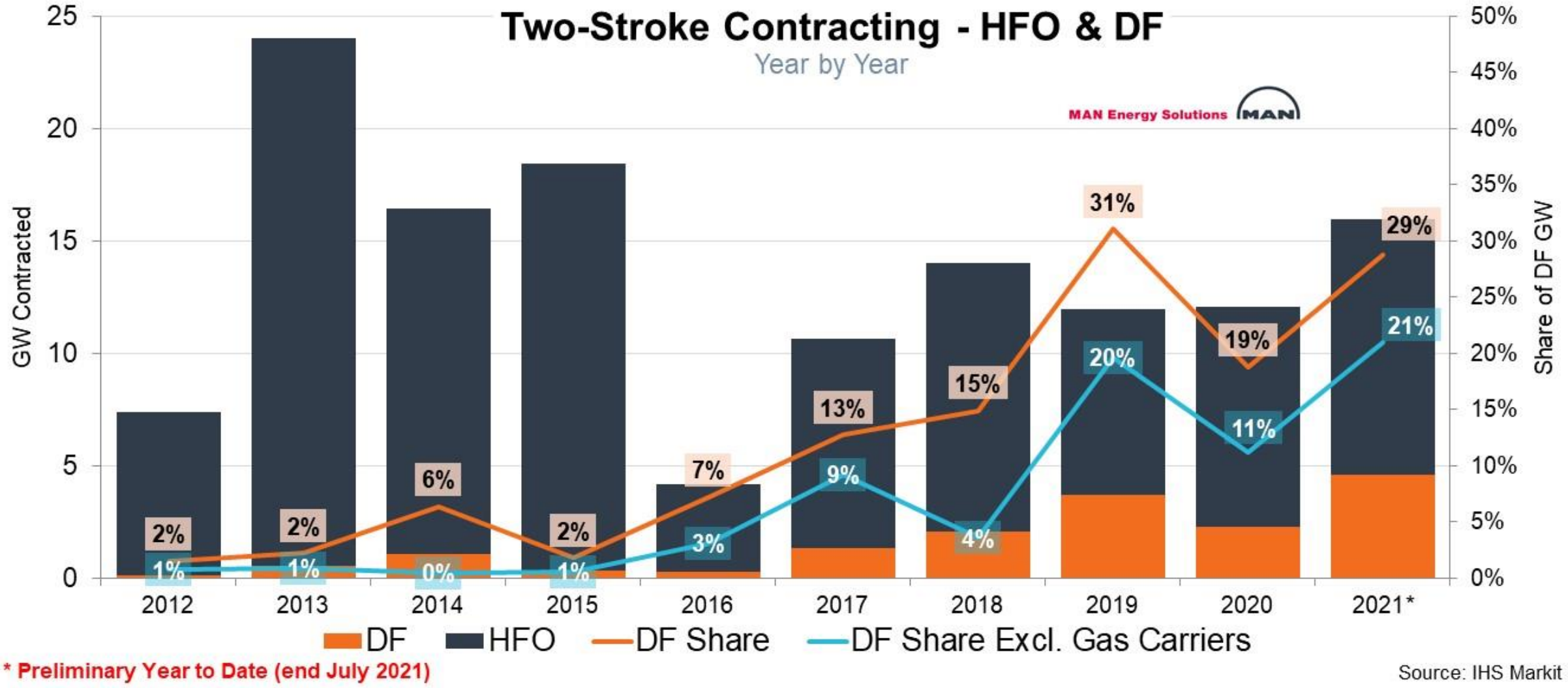
indicative timeline*: MeOH ~2024, NH_3 ~2025, $H2_{100\%}$ ~2026/27

Retrofits necessary and available! ✓

*) Technology development in progress, product availability subject to market demand

Uptake of dual-fuel contracting is increasing

Historical and current dual-fuel uptake.



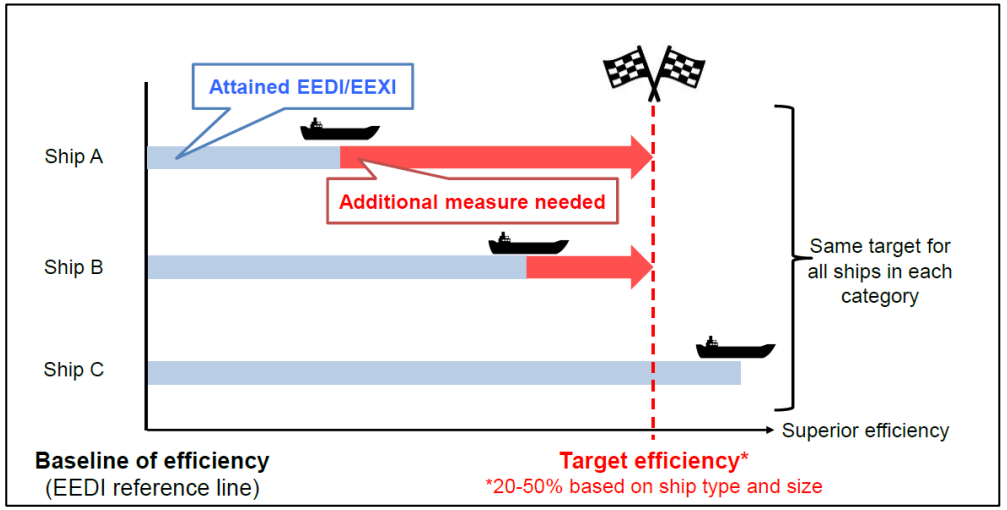
EEXI & CII

New IMO Regulation

All ships above 400GT to be effected

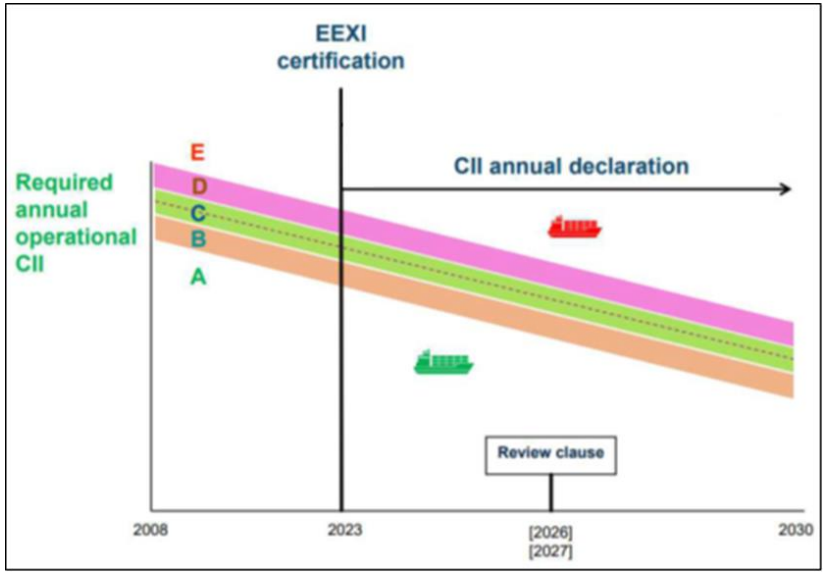
EEXI: Energy Efficiency Existing Ship Index (Technical efficiency)

- **Similar to EEDI, but for all +20.000 existing ships**
- EEXI-compliance to be certified by 1 January 2024
- If non-compliance, no operation of the ship



CII: Carbon Intensity Indicator (Operational efficiency of all ships)

- CO2 pr. transport work, based on fuel used and distance sailed*
- Ships to be rated (A: Best, E: Worst), rating to improve over time
- Low performing ships to develop a plan of corrective actions



*) Typically CO2/(DWT*Nautical mile).

Dual Fuel Retrofit Conversions

Accelerating the Maritime Energy Transition

⇒ **Retrofits necessary** to accelerate marine energy transition; **available today**

⇒ **Future-proofing investments** by conversion-options

CV Feeder ELBBLUE*

48/60 => 51/60DF

Balearia RoPax Ferries

48/60 => 51/60DF

15.000 TEU CV

9S90ME-C => ME-GI

BW LPG

6G60ME-C => ME-LGIP

*) Utilizing 20 tons of 100% renewable SNG per round-trip

Fuels available today: Diesel, Biodiesel, LNG / eSNG, LPG, Ethane, MeOH,
Under development: Ammonia (NH_3) and Hydrogen (H_2)

Summary

Decarbonizing Large Bore Engines

- The **low carbon vessels** of tomorrow must be **commercially viable**
- Alternative **fuel selection not obvious –** optimum depends on application
- **Fuel flexibility** and **retrofit options** are decisive!
- **Natural gas (LNG) is available now** – both engine technology and infrastructure
- Smooth, gradual transition by **drop-in of eSNG** possible
- **MeOH, NH_3, H_2** as additional future fuels with zero carbon potential
- **CO_2 -pricing** & **legislation** to drive decarbonization
  – must be **Globally Harmonized**
- **Ramp-up of eFuel production** is critical factor

Thank you very much!

The maritime energy transition has started - we are here to shape it

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