GasKraft Engineering

Sustainable Shipping

Alternative Fuels and Other Technologies

Prof. Dr.-Ing. Hinrich Mohr, Dr.-Ing. René Wolf

29th January 2026
Hamburg Aerospace Lecture Series, HAW Hamburg

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RAeS Hamburg in cooperation with the DGLR, VDI, ZAL & HAW invites you to a lecture

Sustainable Shipping – Alternative Fuels and Other Technologies

Prof. Dr.-Ing. Hinrich Mohr

GasKraft Engineering

Date: **Thursday 29 January 2026, 18:00**

Location: **HAW Hamburg, Berliner Tor 5, Hörsaal 01.10** (in-person only!)

International trading relies largely on goods transport by ships. The overall CO2 emissions are approximately 3 %. Similar to industries and emission sources, these emissions need to be reduced. The IMO (International Maritime Organization) has committed to achieve full climate neutrality for sea-going vessels by 2050. Inland waterway shipping must follow local regulations accordingly.
As sea-going ships are typically used for 25 years and inland vessels even longer, the greenhouse gas reduction can't only be achieved by building new ships.


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It is necessary to find solutions for existing vessels as well. Several technologies can be used, such as slow steaming, usage of renewable fuels like biofuels, methanol, ammonia or hydrogen, carbon capture, wind-assisted propulsion, hybridization and air lubrication.

This presentation gives an overview of the actual and future challenges of the shipping branch. It provides insights into typical maritime propulsion systems, alternative fuels and further applicable technologies and potential impacts on ship design, operation and safety.

Hinrich Mohr studied mechanical engineering at TU Braunschweig, specializing in combustion engines, and earned his doctorate in 1993. He worked as a research associate at the University before moving to Blohm+Voss, where he progressed to Head of Engine Systems Development. From 2004 to 2020, he served as Key Account and Product Manager for system integration in the large-engine sector at AVL List GmbH. Since 2020, he has run his own engineering consultancy, GasKraft Engineering, focusing on alternative fuels, new propulsion technologies for ships and power plants, and digitalization. He has been a lecturer at TU Braunschweig since 2003 and was appointed honorary professor in 2017.

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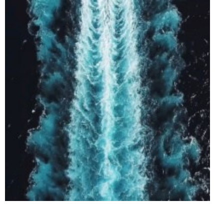

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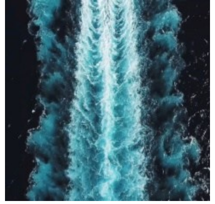
Sustainable Shipping
Content

- Introduction to Maritime Challenges
- Maritime Propulsion Systems
- Alternative Fuels & Further Technologies
  - Biofuels, Methanol, Ammonia, Hydrogen
  - OCCS
  - Electric/hybrid propulsion
  - Wind Assisted Ship Propulsion
  - Hydrodynamic measures
- Impact on Ship Design, Operation & Safety
- Conclusion & Outlook



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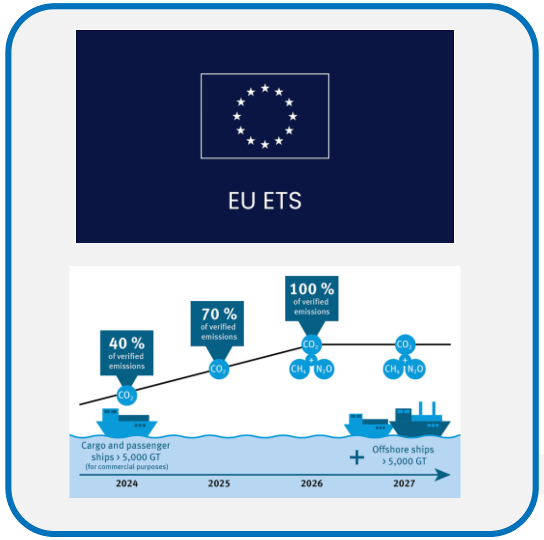
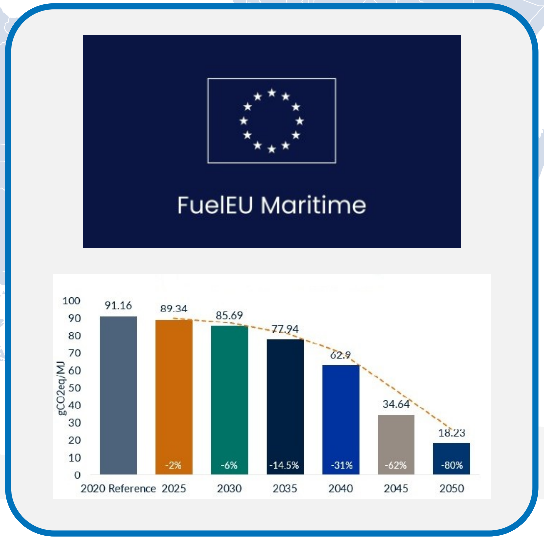
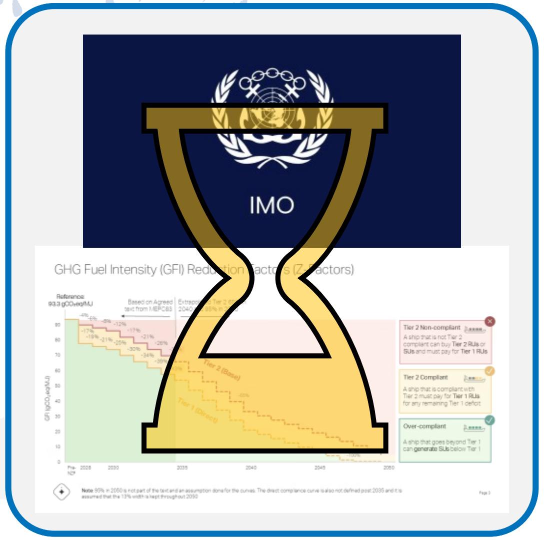
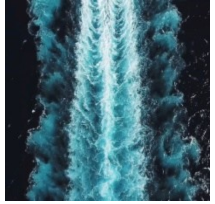
Sustainable Shipping
Introduction

- Shipping is extremely cost-sensitive.
- Shipping is responsible for approximately 2 … 3 % of annual global CO_2 emissions.
  - Aviation is responsible for approx. 2,5 … 3 %
  - Germany emits approx. 1,5 … 1,8 %
- Globally, restrictions on greenhouse gas emissions have been introduced and are becoming increasingly stringent.









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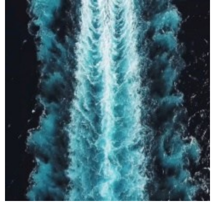
Sustainable Shipping
Introduction

Ship	11 … 12 billion tons	> 80 %	31.7 million cruise passengers + ferries in 2023	Primarily leisure (cruises) and regional connections; considerably less than air travel. (informare.it)
Airplane	60 … 62 million tons	< 1 % But 30 … 35 % of global trade value	4.4 - 5 billion in 2023	Global long-distance transport; mass transit for the civilian population. (atag.org)

Sustainable Shipping

Introduction - Greenhouse Gas Regulations for Aircraft



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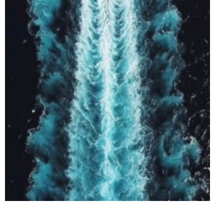
	Type of Regulation	Start / Status	Targets / Amount
CORSIA	CO_2-reduction compared to base 2019 (100%)	2027	Emissions growth over 85 % → Mandatory offset certificates (>3000 t CO2/3a)
ICAO CAEP/13 (2025)	CO_2-certificates for aircrafts	2032/2035	-10 % for new-types (CAEP/10, 2020), -6 % for in-production (CAEP/10, 2023)
EU ETS	Cap-and-Trade	2012; exacerbated in 2024	Annually -4,3 % (2024-27), -4,4 % (ab 2028); Certificate price up to 135 €/t
ReFuelEU	SAF-Blending-Quota	2025	Percentage mix renewable fuels (Bio, RCF, RFNBO)
US EPA	CO_2-certification according to ICAO standards	Since 2020	Equivalent ICAO Annex 16

SAF: Sustainable Aircraft Fuel
RCF: Recycling Fuel



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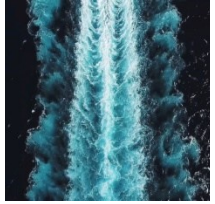
Introduction - Greenhouse Gas Regulations for Ships

Regime	Type of Regulation	Start / Status	Targets / Amount
MARPOL Annex VI - Air Emissions	Limits for NO_x, SO_x, PM, ODS; ECAs	In force since 2005, continuously tightened	Reduction of airborne pollutants worldwide
CII - Carbon Intensity Indicator	Annual CO_2-intensity rating (A … E)	Mandatory since 2023	Increasingly stringent required CII values each year; continuous CO_2-intensity decline until 2030
IMO Net-Zero Framework (NEW - 2025 / 2027)	Global GHG fuel standard + global GHG pricing	Approved April 2025; enters into force 2027 ???	Net-zero shipping "by or around 2050"; GFI reductions from 4% to 30% by 2035
Emission Control Areas (ECA/SECA)	Regional stricter emission limits	Ongoing; Mediterranean Sea became SECA in May 2025	Significant improvements in regional air quality
EU ETS	Cap-and-Trade	Introduced in 2005, currently in its fourth trading phase (2021-2030)	Reduce GHG emissions by 62% by 2030 compared with 2005 levels
Fuel EU Maritime	EU regulation	Into force since 1 January 2025	GHG intensity reduction, WTW basis, objective is to progressively achieve 80 % GHG reduction by 2050 compared to 2020



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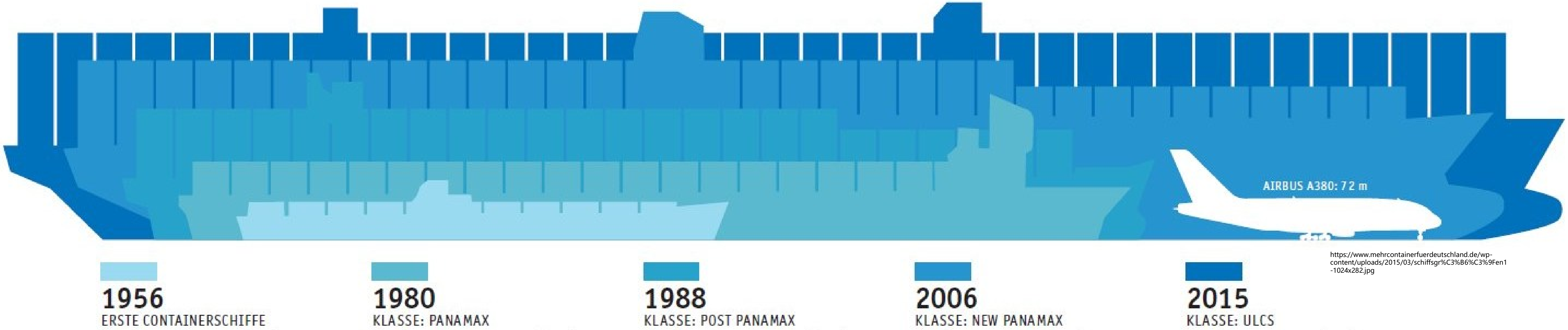
Sustainable Shipping

Introduction



https://www.mehrcontainerfuerdeutschland.de/wp-content/uploads/2015/03/schiffsgr%C3%B6%C3%9Fen1-1024x282.jpg

Airbus A380

- Length approx. 72 m
- MTOW approx. 560 .. 575 t
- Up to 853 passengers
- Price approx. 430 Mio USD
- 4 high-bypass turbofan engines
- Thrust approx. 356 kN

Container Vessel Megamax-Class

- Length approx. 399,9 m
- Gross Weight approx. 280.000 t
- Approx. 24.000 TEU x 8 t = 192.000 t (max. freight weight)
- Price approx. 190 Mio USD
- 1 Main Engine with 11 cylinders
- Output approx. 60.000 kW at 60 rpm, Propeller-Ø up tp 11 m

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Marine Propulsion Systems - Slow-Speed Engine

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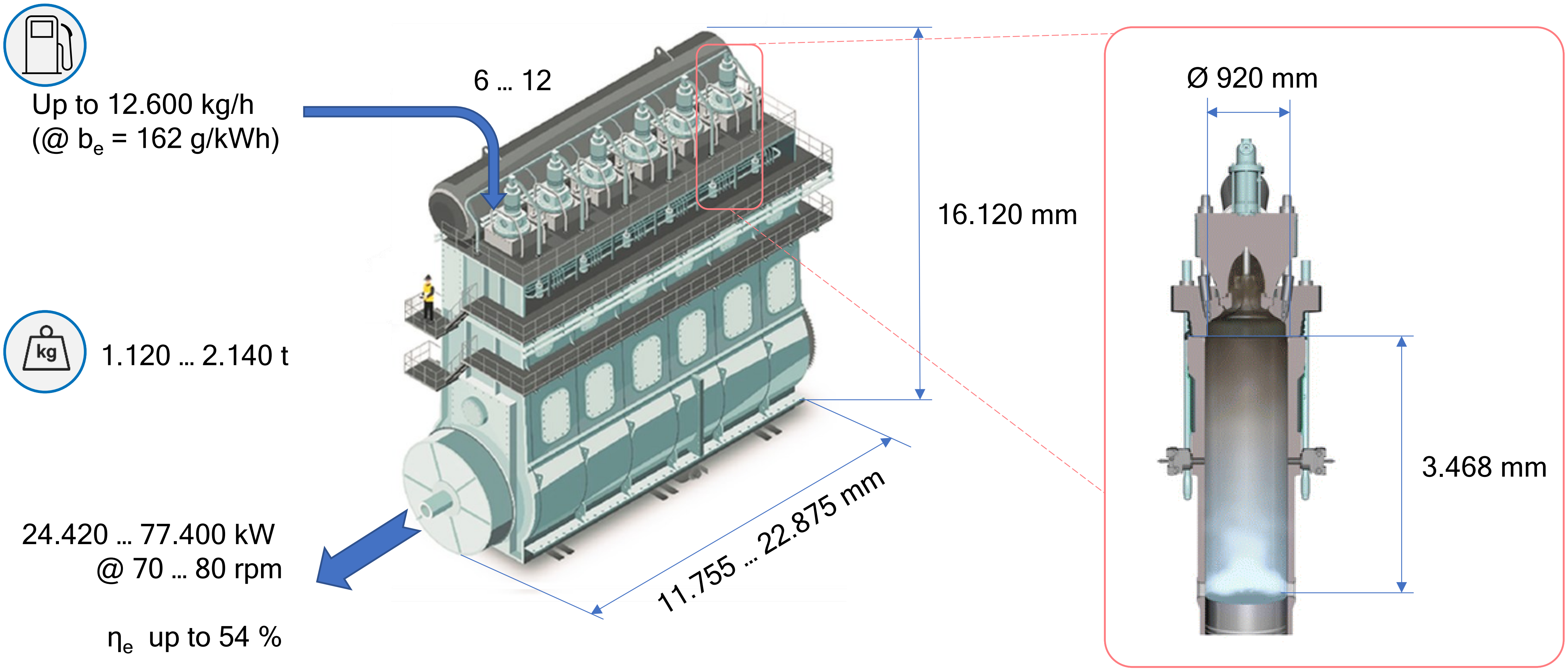

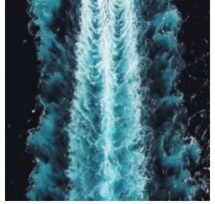

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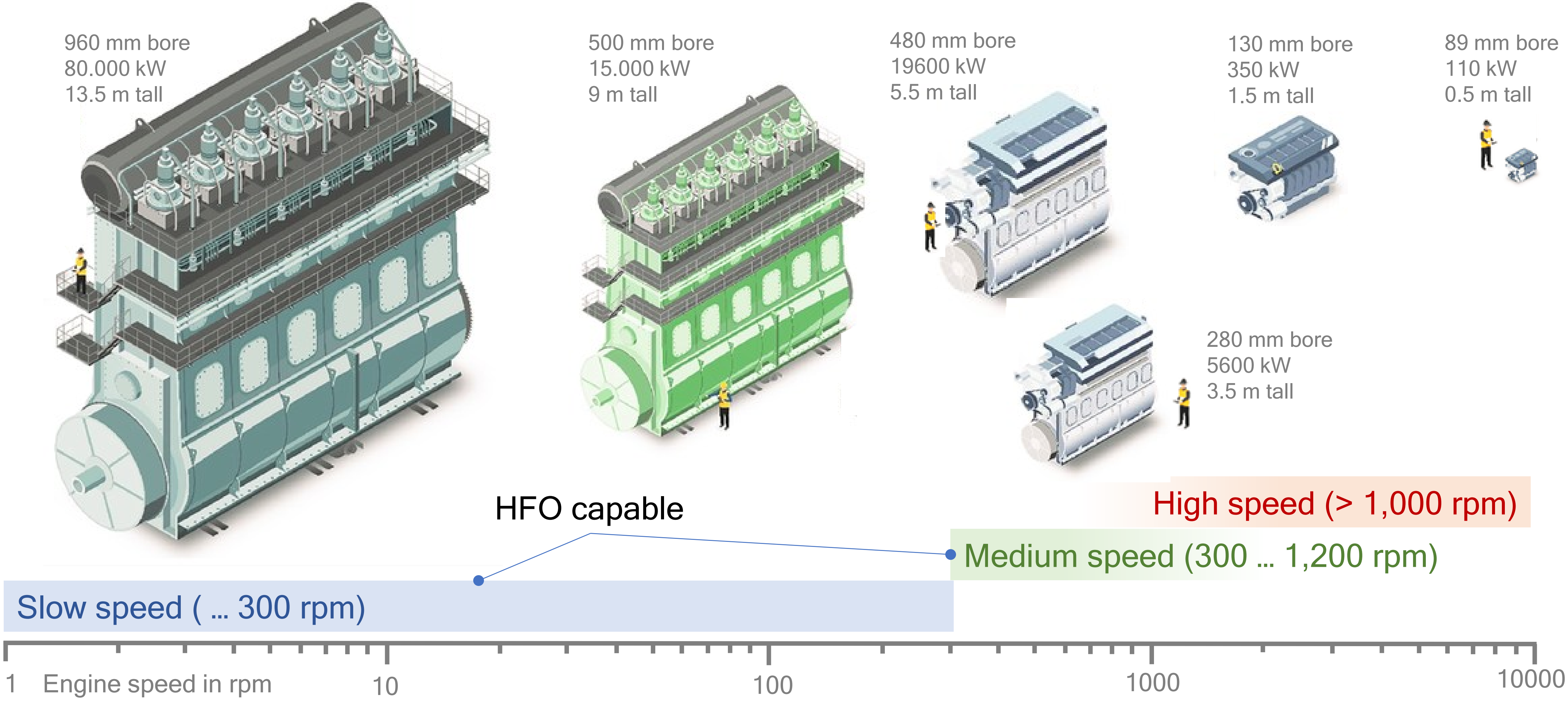
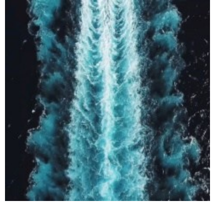
Marine Propulsion Systems – Engine Comparison





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Marine Propulsion Systems - Electrification

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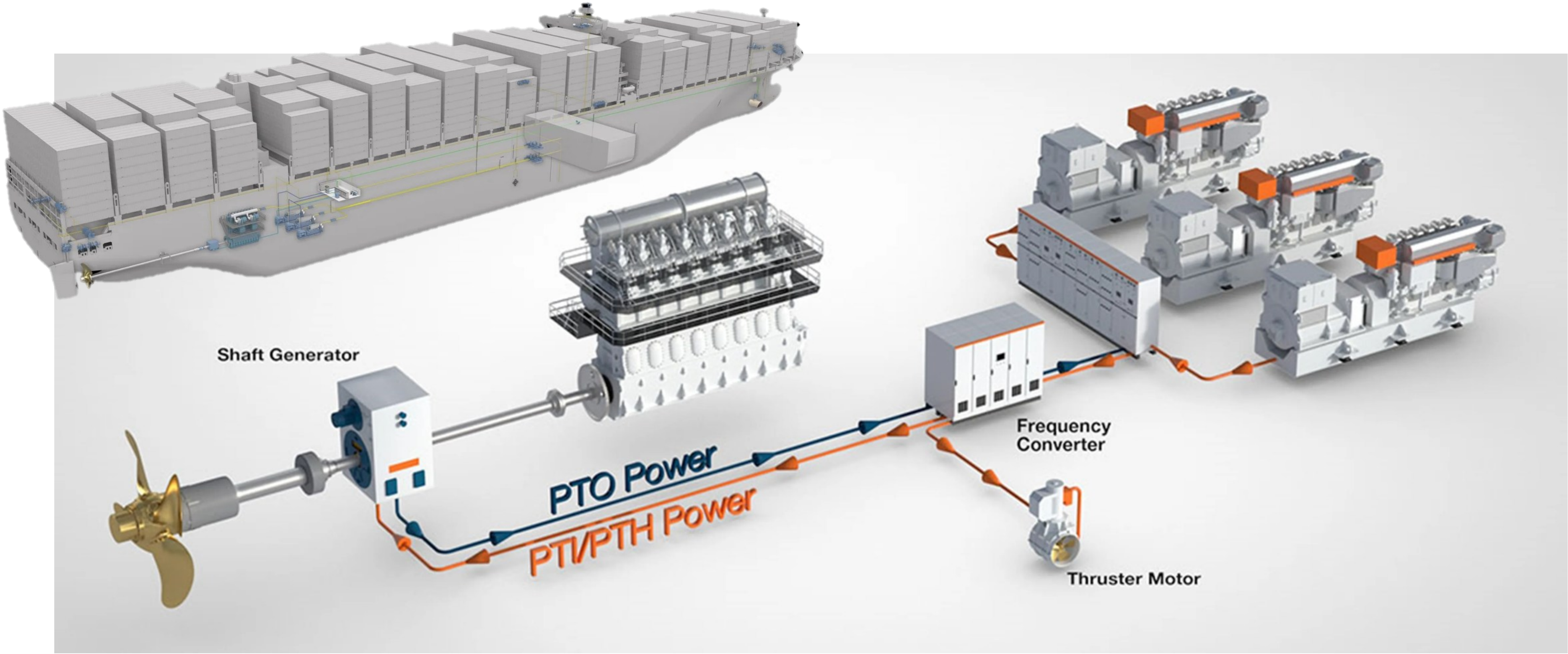

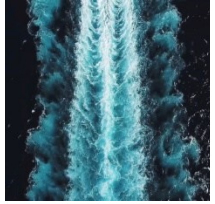

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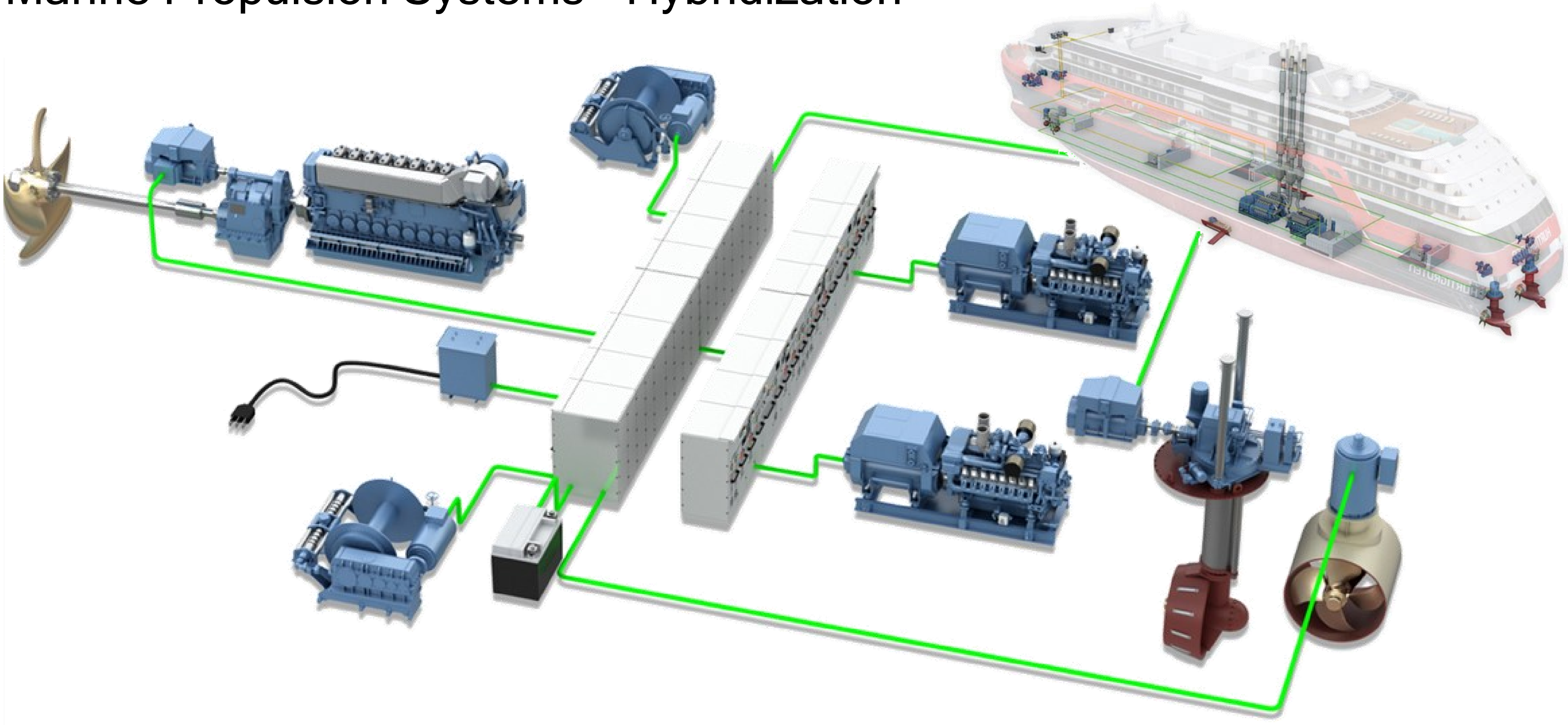
Marine Propulsion Systems - Hybridization



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What's that?

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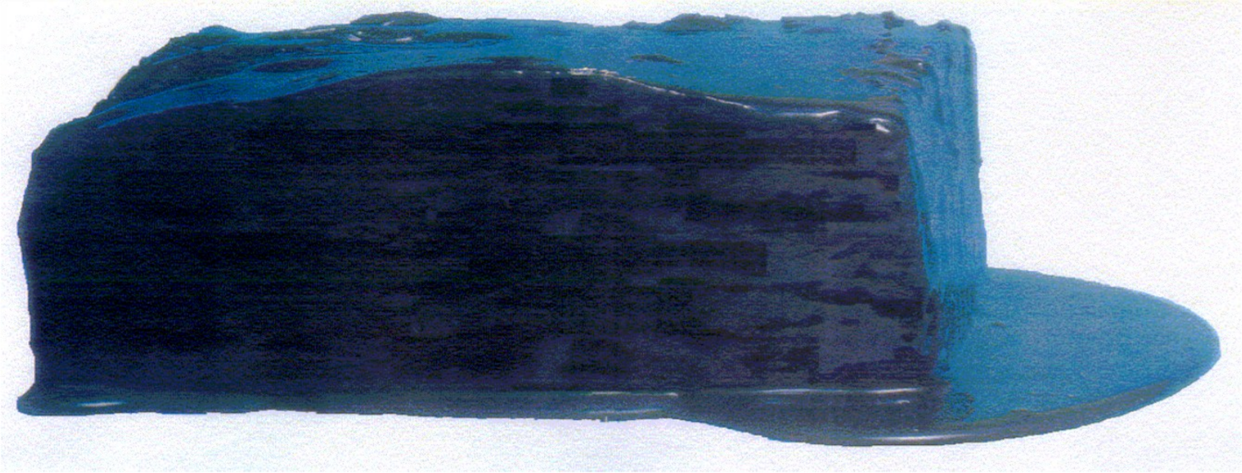
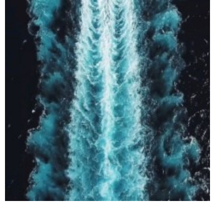


☐ a piece of chocolate cake ☐ a portion of sticky toffee pudding ☑ 1 l of Heavy Fuel Oil (HFO)



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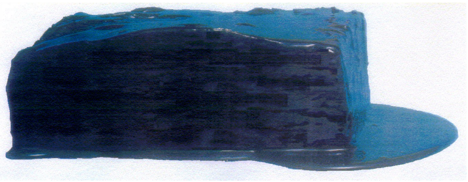
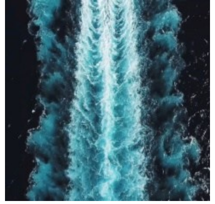
Sustainable Shipping
Marine Fuel vs. Jet Fuel

Characteristic	IFO 380 ISO 8217 (RMG 380)	EN 590 Diesel EN 590:2022	Kerosin Jet A-1 DEF STAN 91-091
Viscosity in mm²/s	max. 380 (@ 50 °C)	2,0 - 4,5 (@ 40 °C)	max. 8,0 (@ -20 °C)
Sulfur content in % m/m	max. 3,50 (0,50 % IMO 2020 variant)	max. 0,001	max. 0,30
Density in kg/m³ (@ 15°C)	max. 991	820 - 845	775 - 840
Pourpoint in °C	summer: max. +30 winter: max. 0	depending on climate zone: Up to -20	max. -47
Al + Si (CAT fines) in mg/kg	max. 60	max. 24 (total contamination)	unspecified
Micro Carbon Residue (MCR) in % m/m	max. 18	max. 0,30	max. 0,15

Complex onboard pre-processing:
Filters, separators,
preheating to about 135°C





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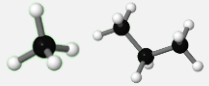
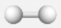
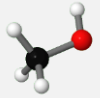
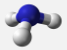
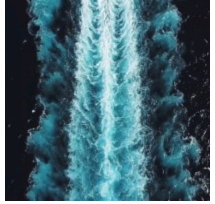
Alternative Fuels – Overview (1)

Characteristic	HFO	MDO	LNG	FAME	Hydrogen	Methanol	Ammonia
Molecular formula	C_nH_{2n} (n = 8 … 20)	C_nH_{2n} (n = 8 … 20)	CH_4, C_3H_8 	R-$COOCH_3$ (R depending on the fatty acid used, C_n mostly 16 … 18)	H_2 	CH_3OH 	NH_3 
State of aggregate @0°C + 1,013 bar	liquid	liquid	gaseous	liquid	gaseous	liquid	gaseous
Storage conditions	ambient	ambient	-164 … -161 °C @ athm. pressure	ambient	-250 … -245 °C @ 13 bar 350 or 700 bar @ amb. temp.	ambient	-34°C @ athm. press. 10 … 30 bar @ amb. temp.
Lower heating value in MJ/kg	40 … 41	42	50	36 … 37	120	20	19
GHG WTW in kgCO2eq/MJ	91,74	90,8	76,1	11,3	132,4 ~0	103,2 ~16	165,5 ~17

Fossil origin

Renewable source



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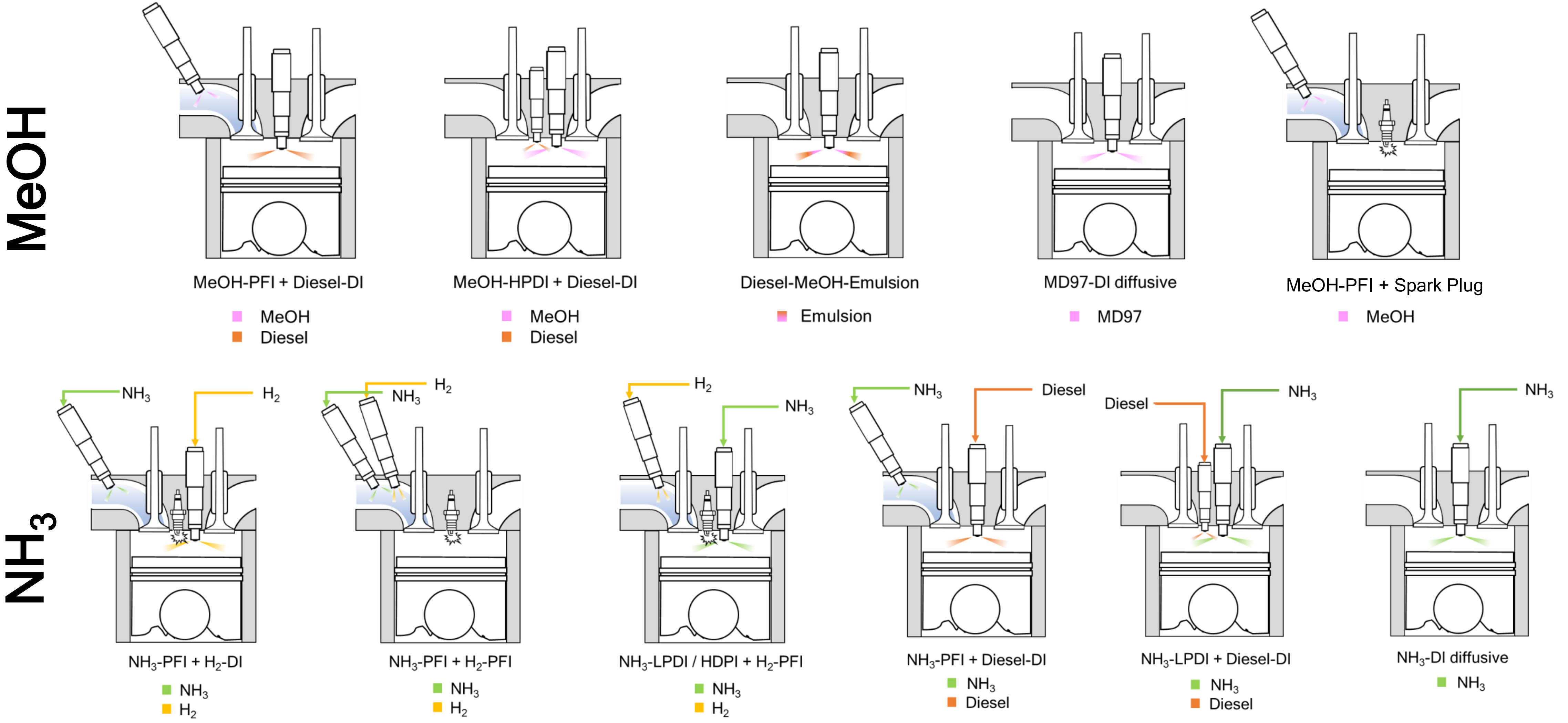
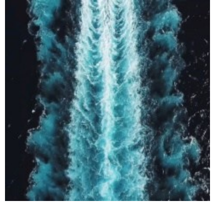
Alternative Fuels – Combustion Concepts





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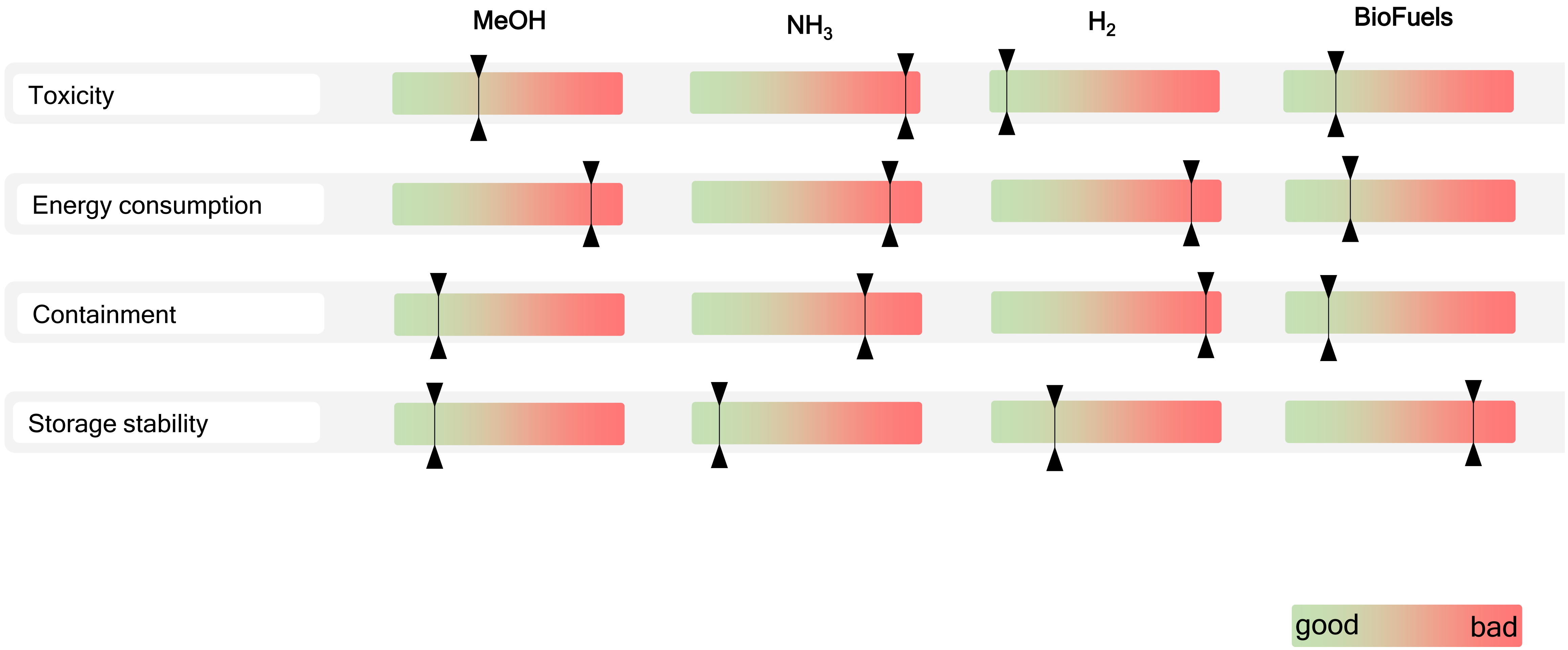
Alternative Fuels - Characteristics



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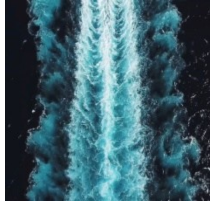
Alternative Fuels - Storage Characteristics



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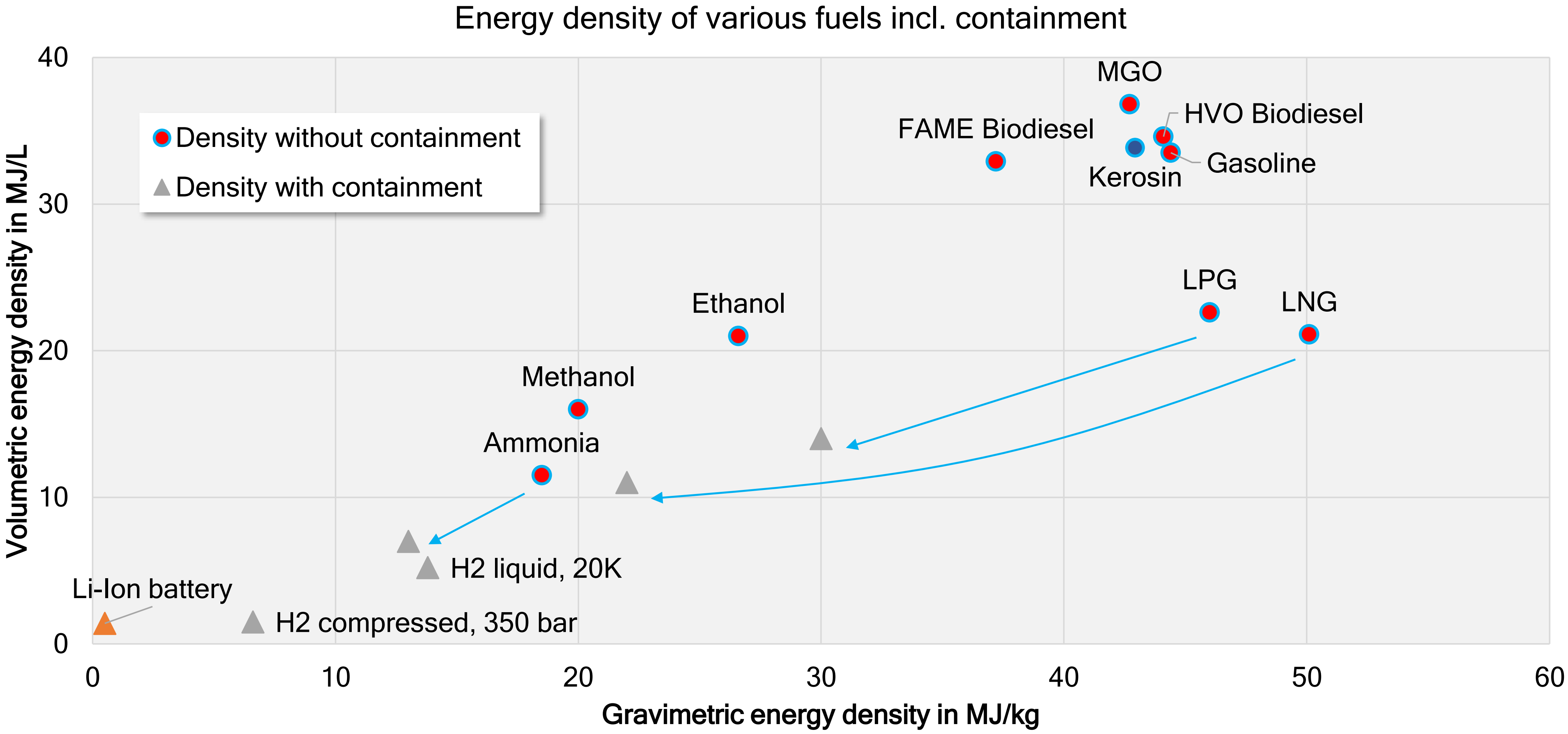

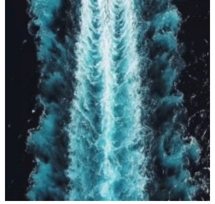

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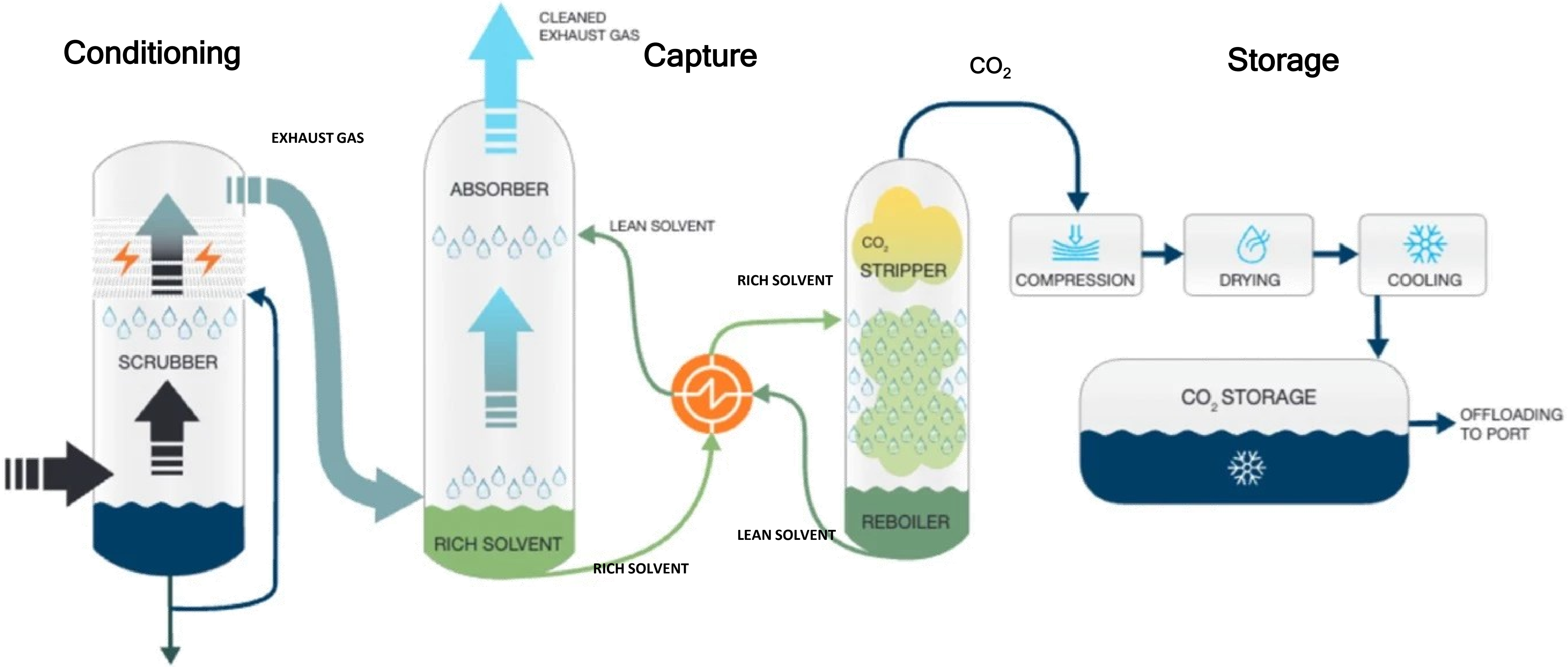
Onboard Carbon Capture and Storage - Process



- Exhaust gas is cleaned and cooled to about 40 … 60 °C

- Amin-solvent absorbing up to 90 % of the CO_2
- Heating of the volevent releases the CO_2 from the solution

- Cooling and compression of the extracted CO_2
- Storage in large tanks

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Onboard Carbon Capture and Storage - Handling

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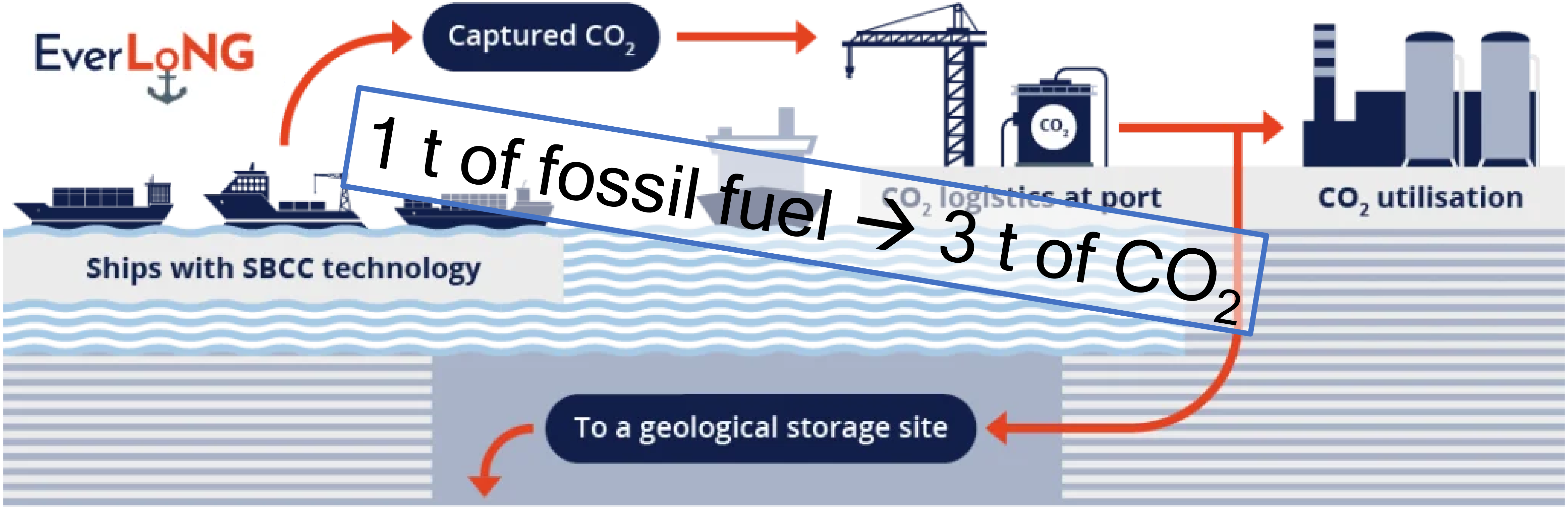
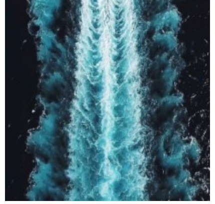


- Captured CO_2 is stored onboard and unloaded ashore for utilization or underground storage
- Another scenario can be a reutilisation onboard to produce e. g. Methanol directly



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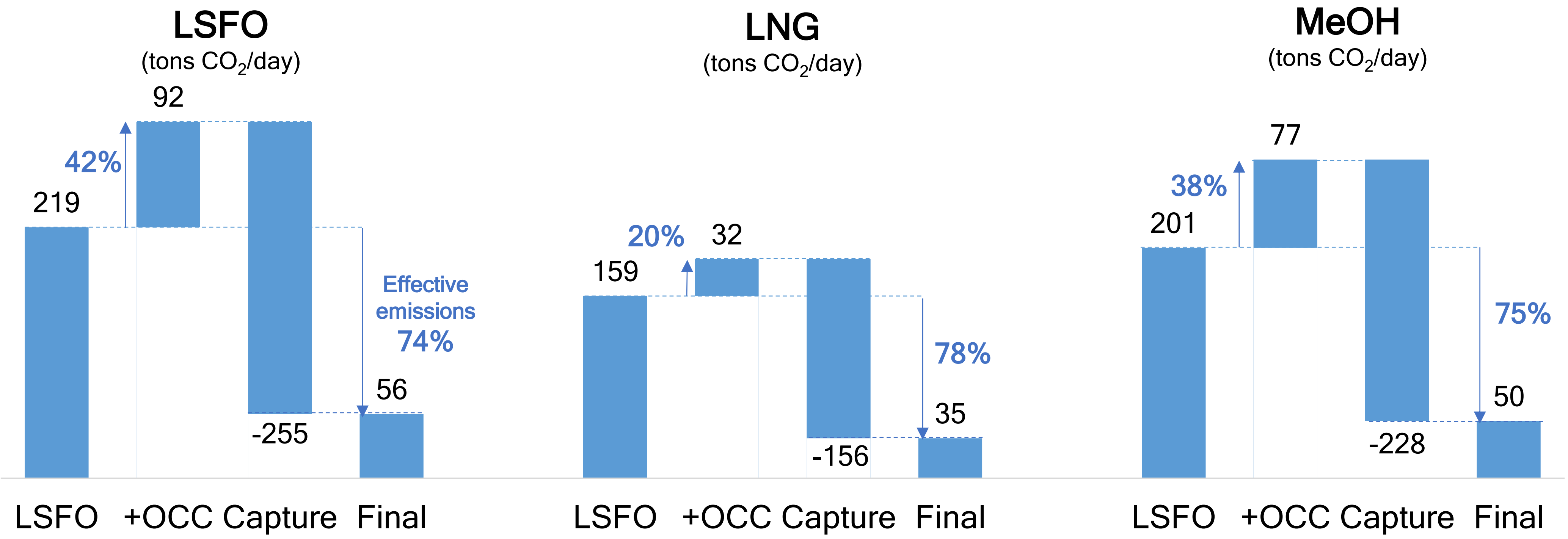
Onboard Carbon Capture – Effective Reduction



- OCCS requires a vast amount of additional energy depending on the capturing system and the amount of captured CO_2
- It can help to reach the required GHG targets without changing the propulsion system or fuel

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Sustainable Shipping
Electric and Hybrid Propulsion Systems

Hybrid propulsion ships

- Combination of internal combustion engines and battery powered electric motors
- Not to be mixed up with diesel-electric drive / gensets!

Conventional hybrid propulsion ships

- Without the possibility of using shore power
- Recharging during low-power situations to improve engine operation efficiency

Plug-in hybrid propulsion ships

Batteries can be recharged using the power derived from the main engine or the auxiliary engines (generators, alternators) and when berthing using shore power

➢ Even on 2-stroke engine powered vessels the hybrid implemenatation is under consideration

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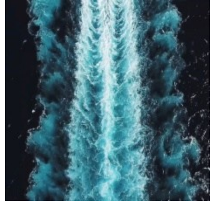
Electric and Hybrid Propulsion Systems - Example



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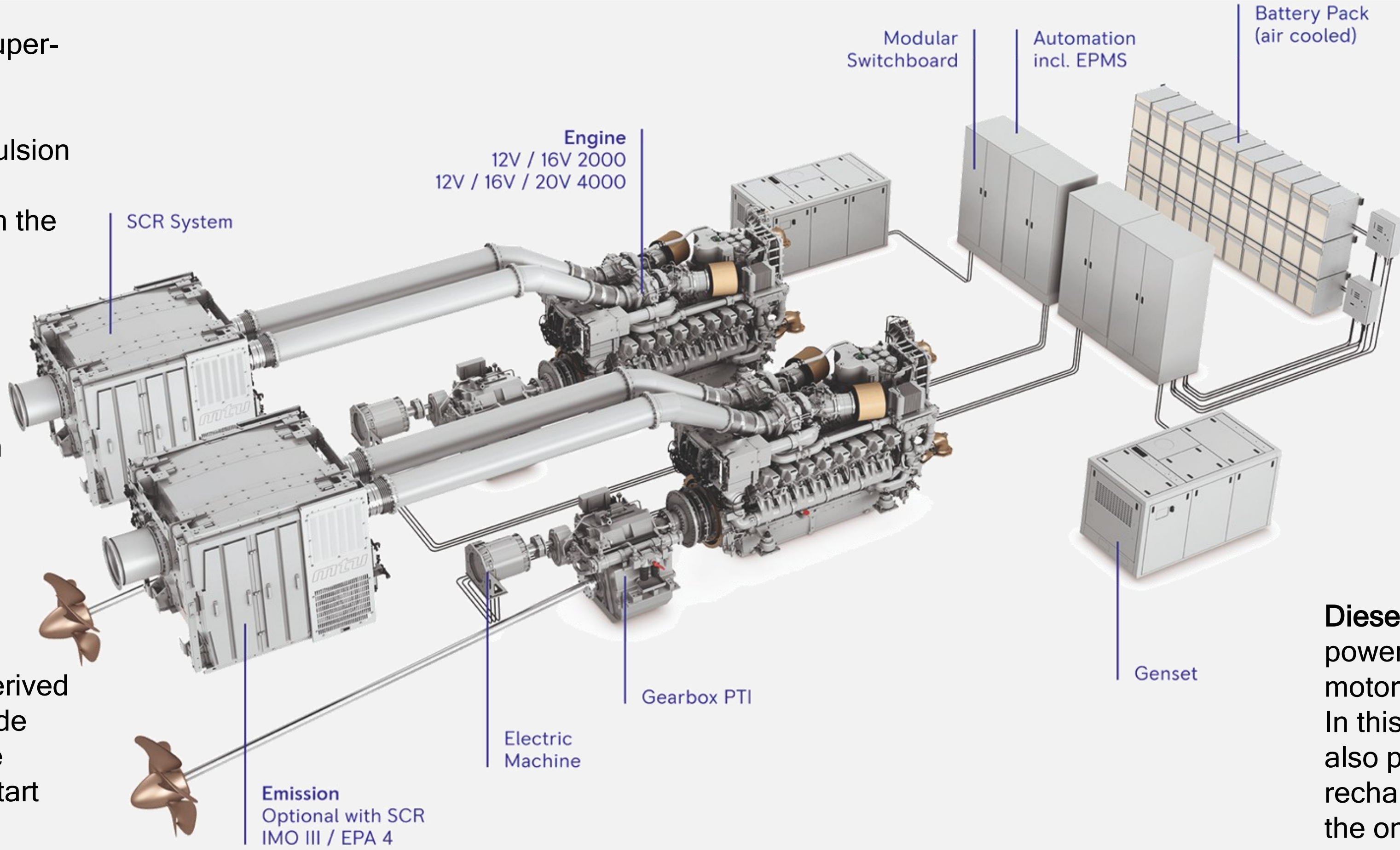
Zero-Emissions, with no exhaust emissions and super-quiet operation.

Diesel-Electric, with propulsion and on-board electrcity delivered by gen-sets with the support of the batteries upon demand.

Cross-Over, when the vessel has a twin- or more engine propulsion arrangement, the cross-over option allows to pperate each propulsion train in a different mode.

Hotel, when all power is derived from the batteries; this mode allows for a long use of the batteries with no need to start the diesel engines.



Boost, when diesel engines and the electric motors act together and complement each other to reach the higher power output. For example, a 12-cylinder engine operating together with the electric motor, can reach a power output comparable to that of a 16-cylinder engine.

Diesel operation that can provide power for propulsion while the electric motor runs eithout producing energy. In this mode, diesel operation can also provide the electricity needed to recharge the batteries without using the onboard gen-sets.

Sustainable Shipping
Wind Assisted Ship Propulsion - Solutions

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Wing-Sail Systems

Kite Systems

Rotor-Sail Systems

Suction-Wing Systems

Sustainable Shipping
Wind Assisted Ship Propulsion

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Retrofit — New built

Wind assisted
In operation

Eship 1 - 2013


Pyxis Ocean, JP - 2023


Wind ships
Research & First Mover

Canopée, FR – 2023


Neoliner, FR – 2025


Grain du Sail III, FR – exp. 2027

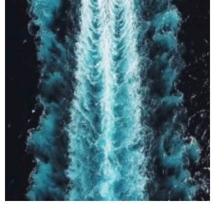

Energy harvester
Concepts, Research

OCEANERGY, DE


Windhunter, JP

0

degree of self-sufficiency



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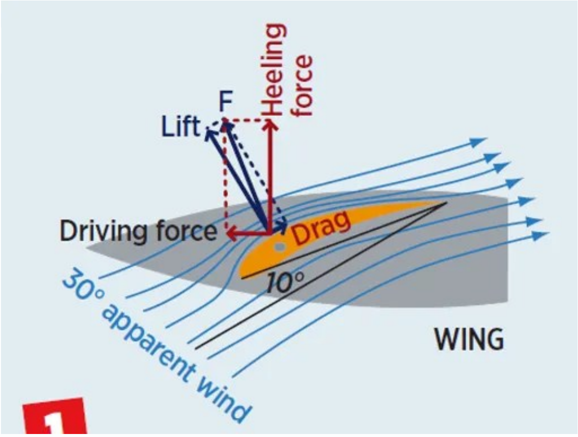
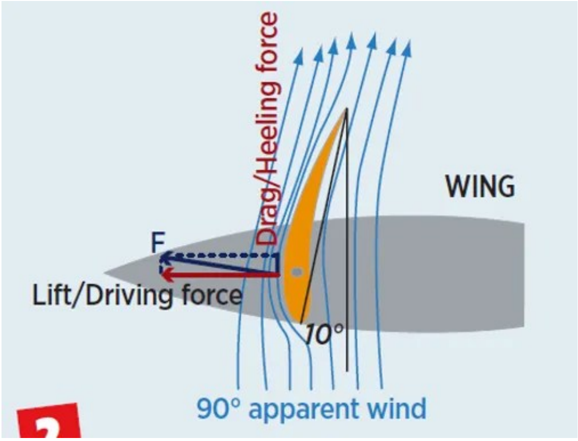
Wind Assisted Ship Propulsion – Example 1

New Aden

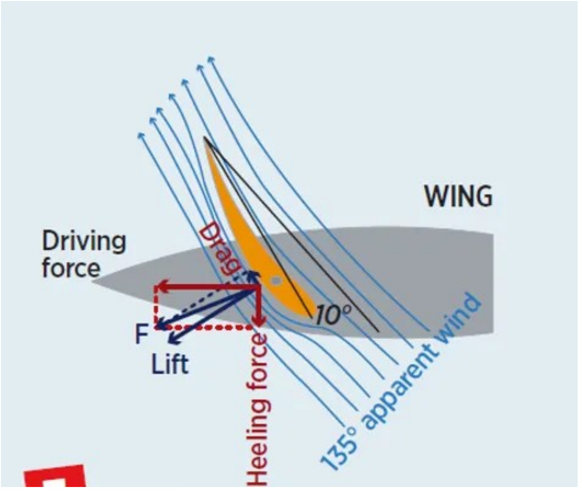
- Crude oil supertanker
- Length: 333 m
- Main engine: 7G80ME-C9.5-EGRTC-TIII*1
- Max. speed: 14,8 knots
- DW: 306.474 tons
- GT: 162.925



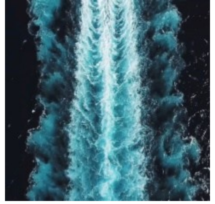


Sailing system

- Wing-Sail system
- Fixed aerofoils with 1.200 m²
- Fuel comsumption savings up to 10 %



Sustainable Shipping
Wind Assisted Ship Propulsion – Example 2



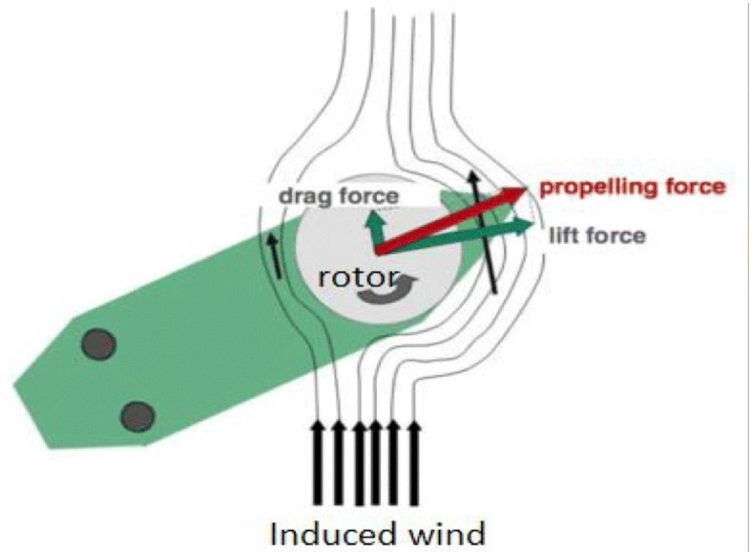
GasKraft
Engineering

Scandlines Copenhagen

- Flettner rotor supported hybrid ROPAX ferry
- Length: 169,5 m
- Output: 2 x 4.500 kW (main),
  1 x 4.500 kW (hybrid),
  1 x 4.500 kW (main gen.),
  1 x 1.540 kW (harbour gen.)
- Battery Capacity: 1 x 1500 kWh
- Max. speed: 14,8 knots
- DW: 4.814 tons
- GT: 22.319

Sailing system

- Flettner rotor system
- Support performance: 4 … 5 % CO_2-savings



Flettner rotors working principle is based on the Magnus Effect:

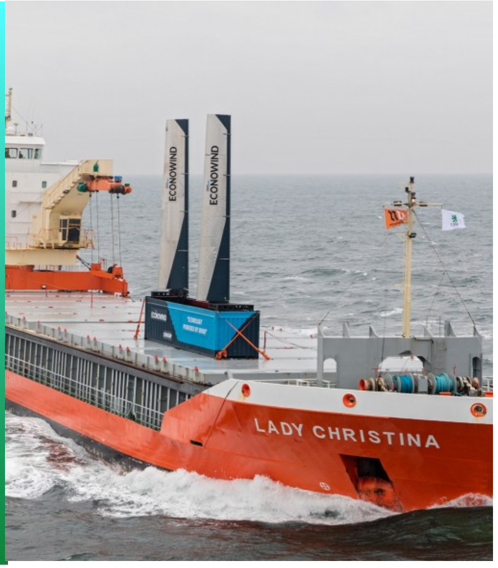
A rotating object (rotor) undergoes a lift force under windy conditions

Sustainable Shipping
Wind Assisted Ship Propulsion – Example 3

GasKraft Engineering

MV Ankie

- General cargo ship
- Length: 90 m
- Main engine: Wärtsilä 9L20
- Max. speed: 12,5 knots
- DW: 3.638 tons
- GT: 2.528



Sailing system

- Suction Wing system
- Fuel consumption savings up to 30 %
- Foldable and even a …
- … containerised soultion available

An underpressure is created inside the sail and sucks in air flowing aorund it at a certain position.

This increases the effciency of the sail significantly under not ideal wind condtions

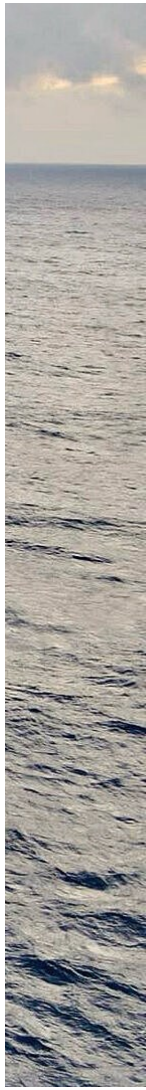
Sustainable Shipping
Wind (Assisted) Ship Propulsion – Example 4

Juren Ae

- Cargo ship
- Length: 48 m
- Aux. engine: 250 kW
- Max. speed: 12 knots
- DW: 300 tons
- GT: 455

Sailing system

- Sail system
- Fuel consumption savings up to 80 %

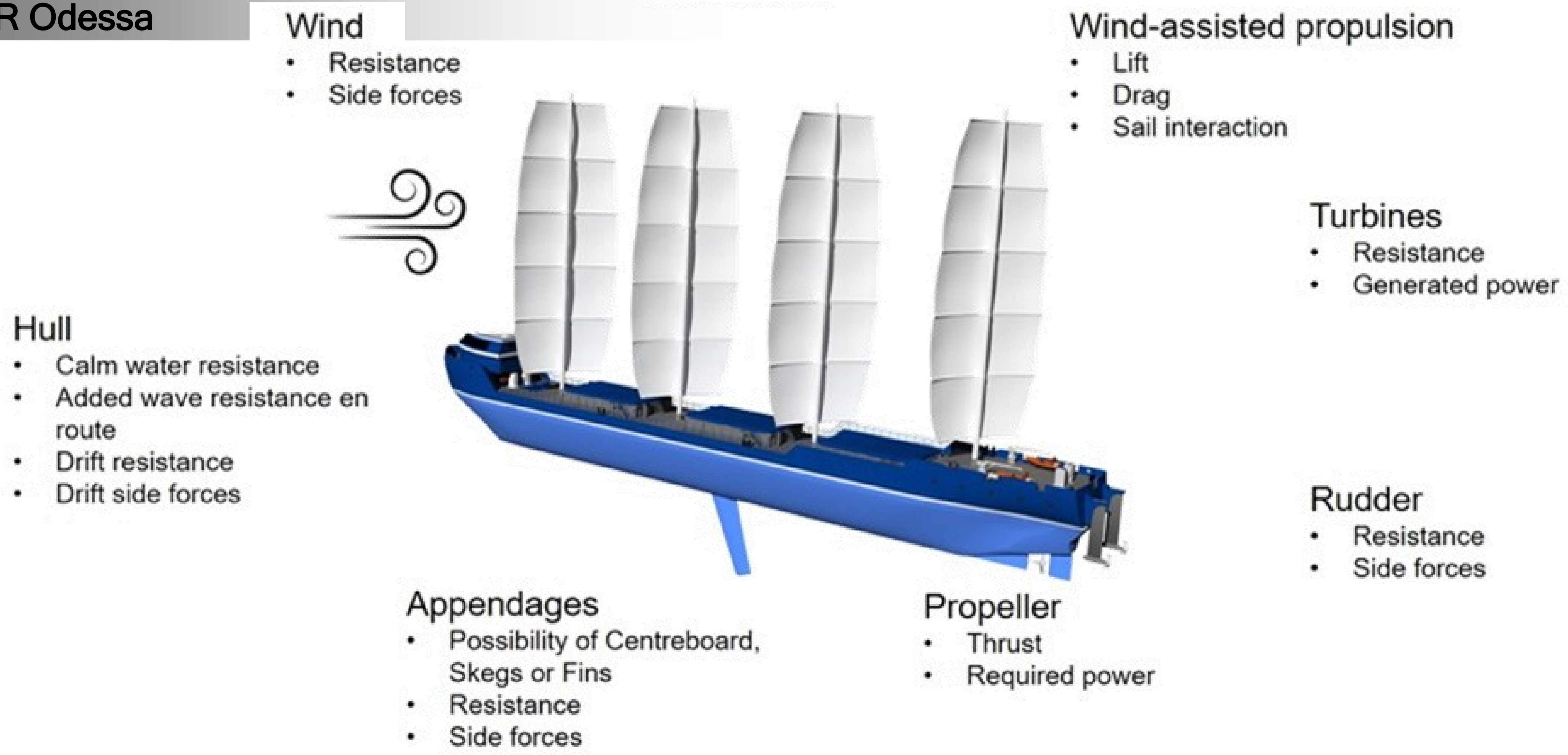


Sustainable Shipping

Wind Assisted Ship Propulsion – Example 5

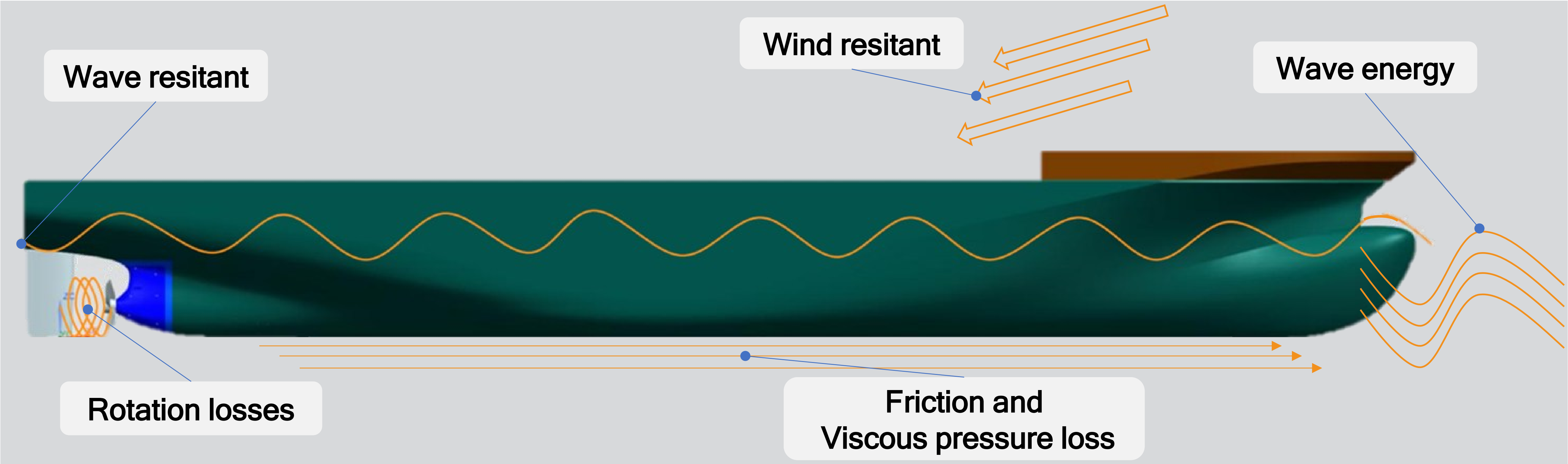
GasKraft Engineering

DLR Odessa



Sustainable Shipping
Hydrodynamic Optimisation

GasKraft Engineering



Sustainable Shipping
Hydrodynamic Optimisation – Propeller Retrofit

GasKraft Engineering

The main driver

Slow Steaming

↓

New operating profile

↓

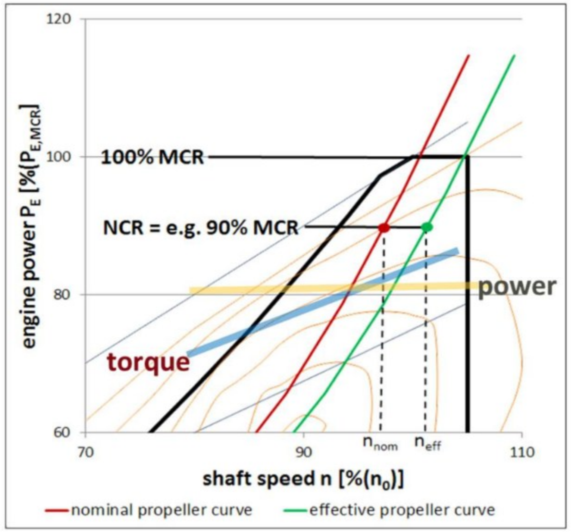
Re-design Propeller & limitation of engine

↓

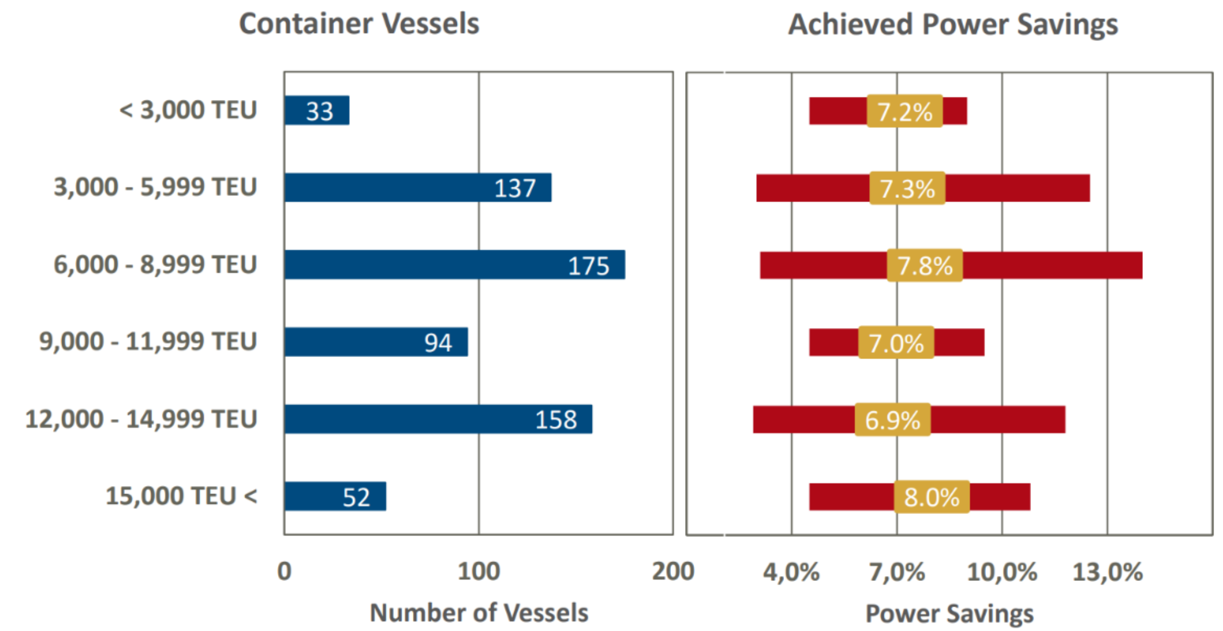
New strength layout criteria

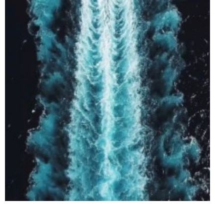
↓

New optimal main dimensions = new propeller



MMG Re-Design Programme





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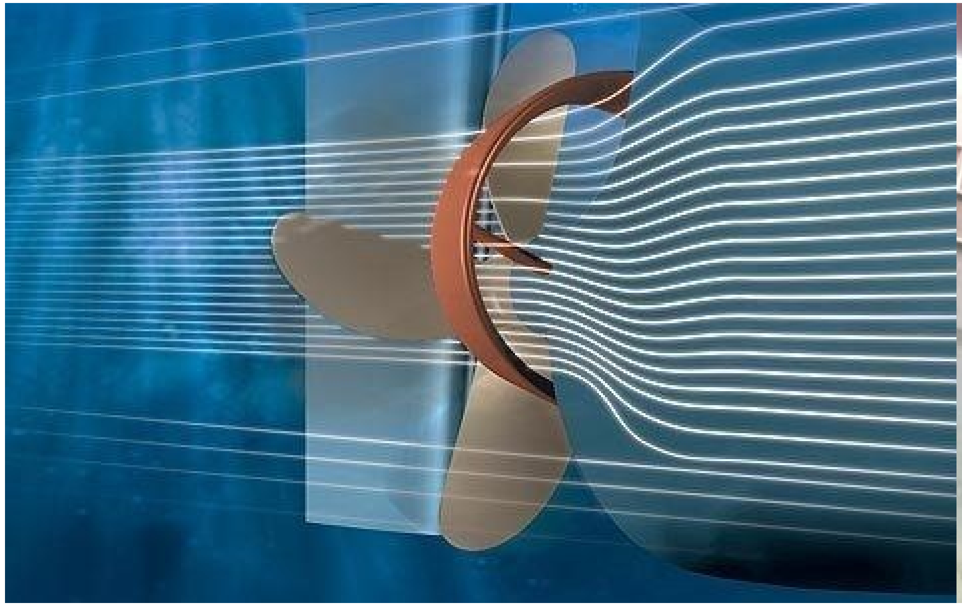
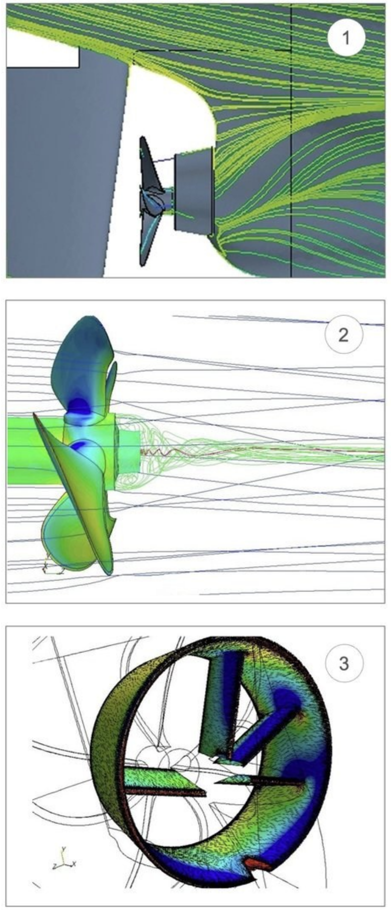
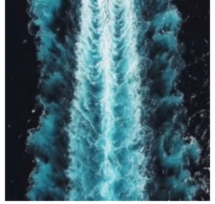
Sustainable Shipping
Hydrodynamic Optimisation – Inflow Harmonization

Example: Mewis Duct







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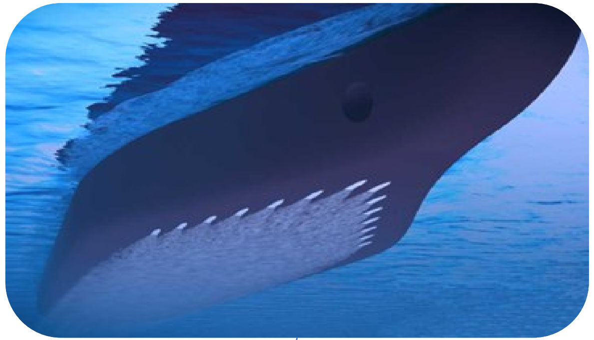
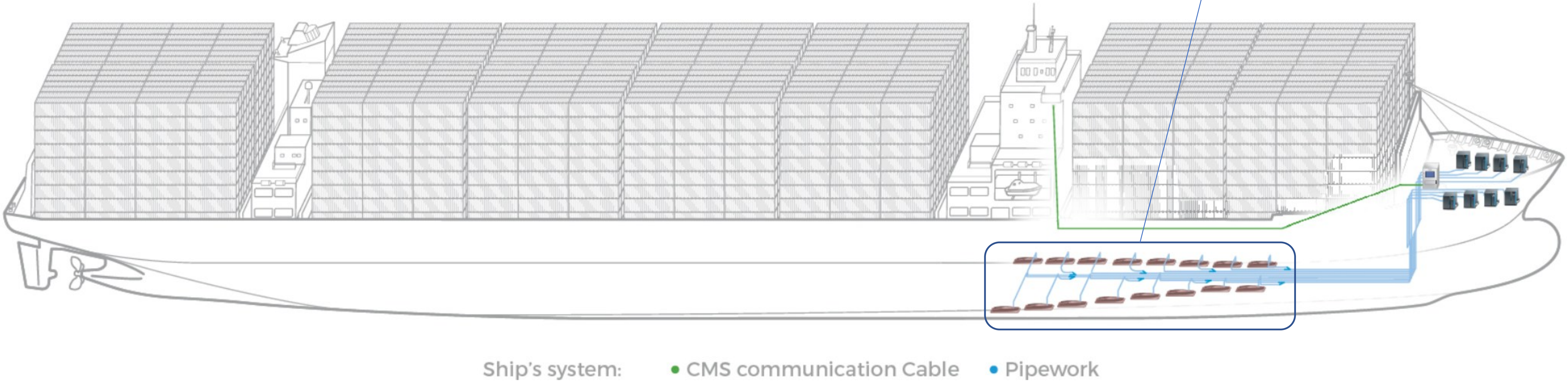
Hydrodynamic Optimisation – Air Lubrication

- Aim is to reduce the hull friction losses by blowing air under the vessel
- 5 - 10 % fuel and emission savings

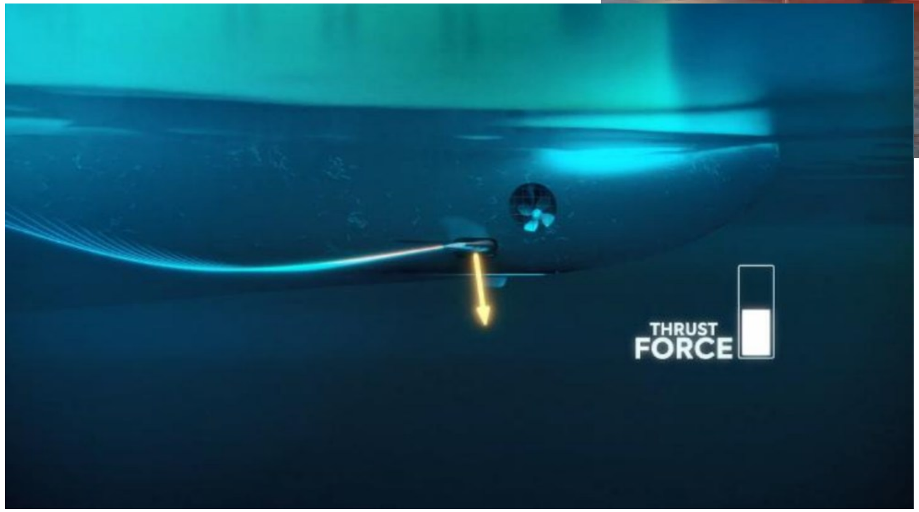


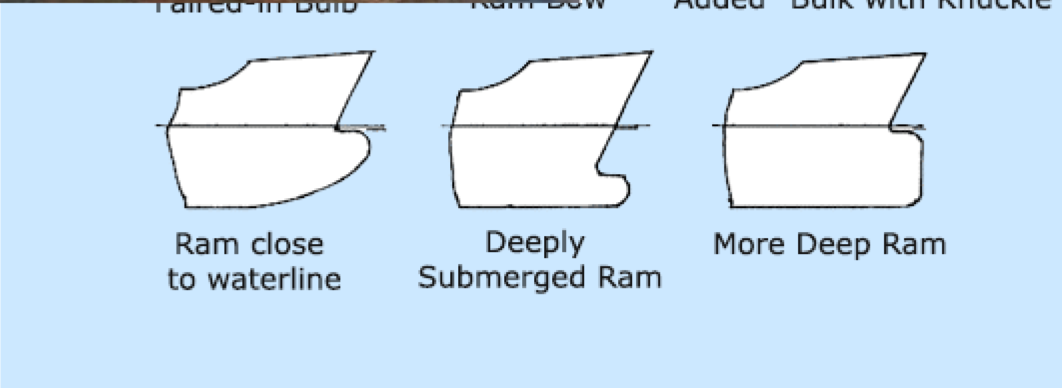


Sustainable Shipping

Hydrodynamic Optimisation – Bow Improvements

- Optimised bow shape
- Usage of wave energy via bow fin systems as option





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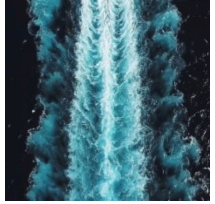

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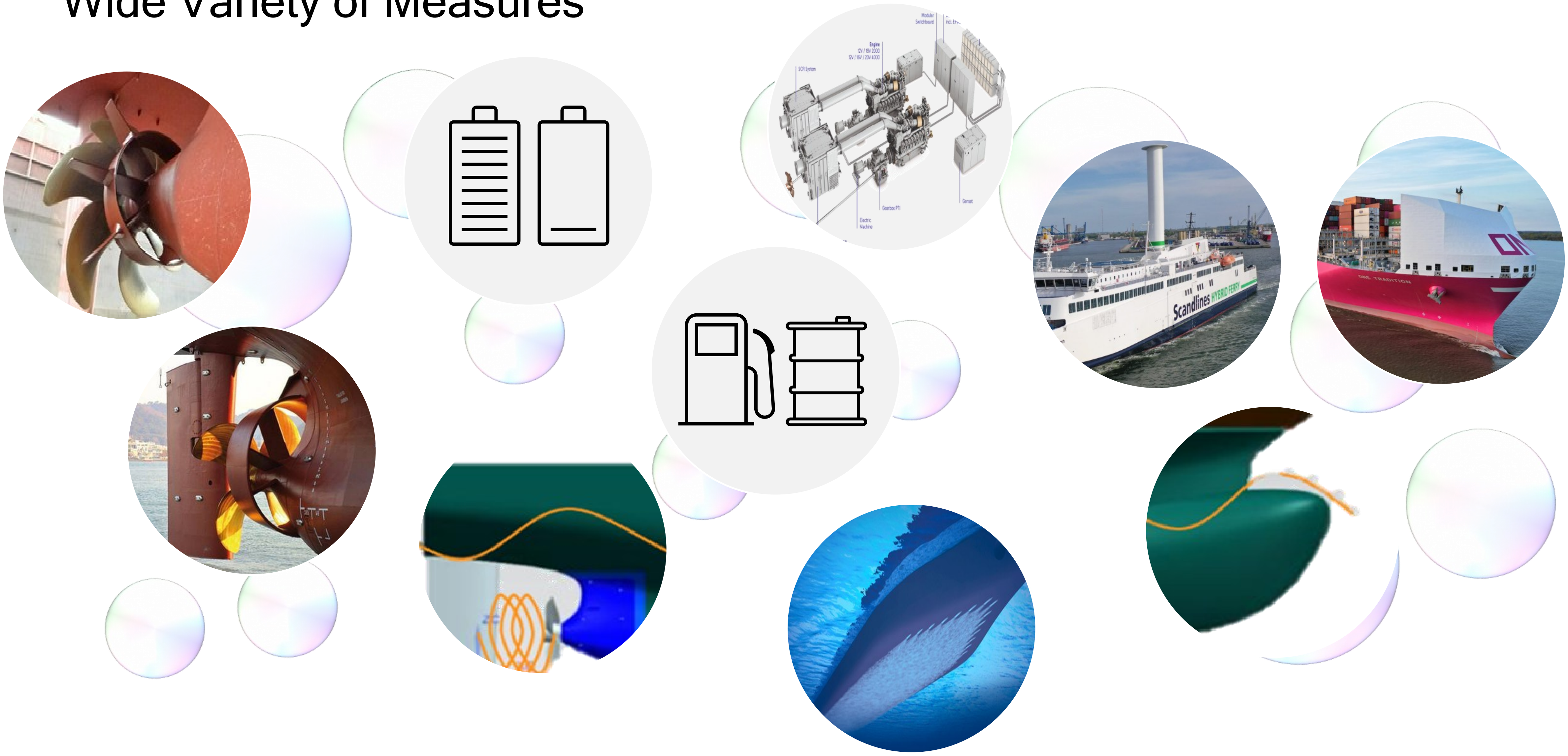
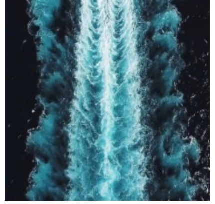
Sustainable Shipping

Wide Variety of Measures





GasKraft
Engineering

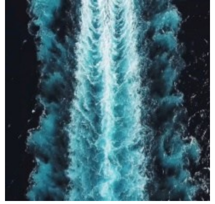
Sustainable Shipping
Impact on Ship Design, Operation & Safety

Approx. 70,000 large sea-going vessels in operation today

→1,500 … 2,000 newbuilts per year – approx. 2.5 % replacement

→ New technologies to be retrofitted to the majority of the existing fleet !

- In general: increased system complexity → yard & crew skills to be improved for engineering, operation & maintenance
- Toxicity of Methanol & Ammonia to be considered in handling & storage
- Extended safety measures to be implemented, including large scale battery management
- Ship design must be brought to another stage of engineering



Sustainable Shipping

Actual state and outlook

- Effective engine effciency already up to 54 %
- Alternative fuels for lower GHG emissions → production ramp-up required
- On-board carbon capture systems might support the further use of fossil fuels → what to do with the CO_2?
- Electrification: supportive for lower GHG emissions, but pure electric propulsion not feasible for large sea-going vessels
- WASP systems can be of interest for specific route applications
- Increasing hull performance (e. g. propeller flow improvements, air lubrication, hydrodynamic & aerodynamic optimization) can deliver an essential share in GHG reduction
- Not to forget: whole-ship system efficiency improvement & optimised routing

Sustainable Shipping
Actual state and outlook

BUT …

- current worldwide situation do not support the ramp-up of sustainable measures (IMO decision for GHG taxation delayed)
- the consumers are not willing to pay higher prices for products transported by sustainable operated ships
- only few shipowners go for founded pilot projects yet
- shipowners wait for clear technology decisions before investing into these

Contact

Gaskraft Engineering will be proud to support you on your way to sustainability!

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Sustainable Shipping
Sources

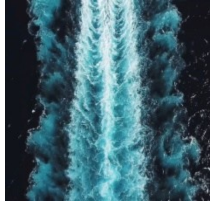

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Chart	Source
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