SUSTAINABLE FUELS

A BRIEF INTRODUCTION

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LEADING THE WAY TOWARDS A SMART MARINE ECOSYSTEM

A Smart Marine Ecosystem is about the maritime industry working together to address critical challenges and to generate solutions towards a sustainable future.

TOWARDS ZERO EMISSIONS | **EFFICIENCY** | **SAFETY** | **RELIABILITY**

Where to go?


Hydrogen, Ammonia, Methanol, Bio fuels
LNG, gas
HFO/MDO + aftertreatment

PATHWAY TO DECARBONISATION

The vessel perspective

Efficient Energy Generation

Power Distribution

Vessel Energy Need

Optimized Voyage

Switch to gas possible?

yes

no

LNG

Biogas

Synthetic methane

HFO MGO

Liquid biofuel

Synthetic liquid fuel

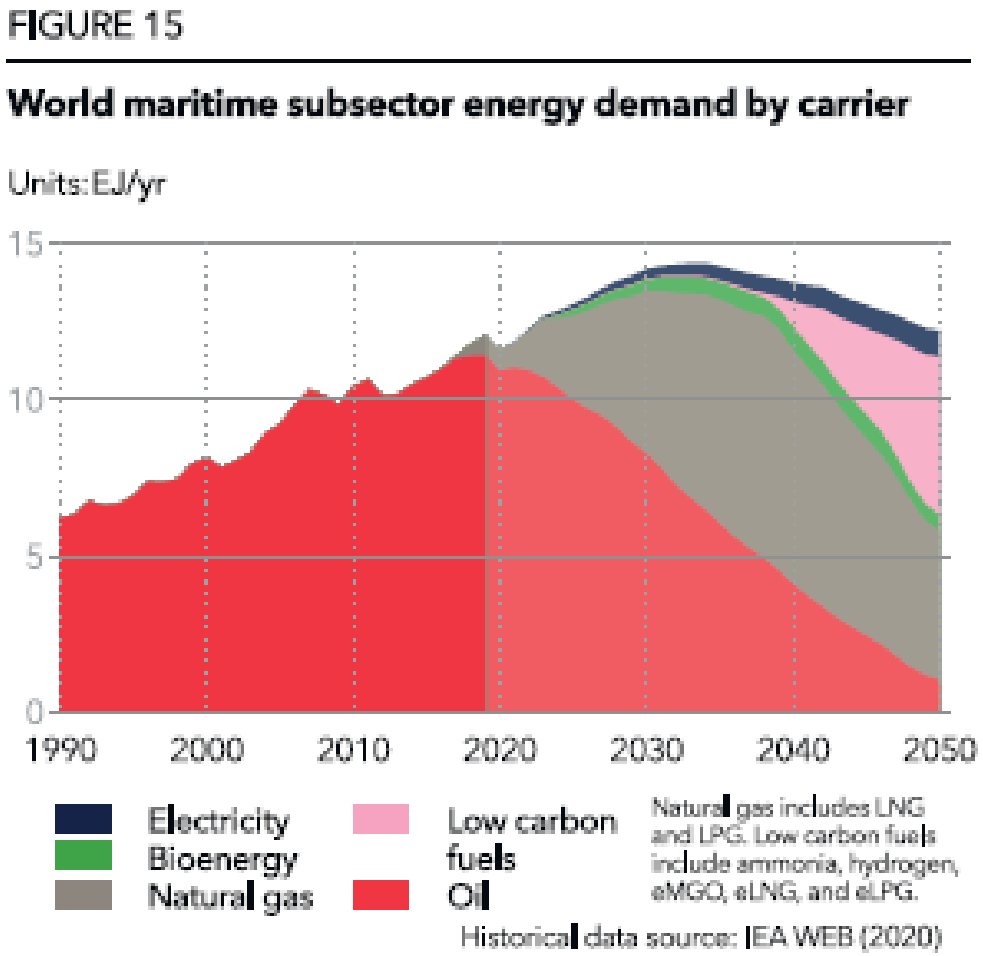
The fuel perspective

Compatible with todays ships, bunkering infra, safety experience and regulations. Key to fast market take-up. Methanol is the dark horse in this discussion. Easy to store, bunker and burn, it may leapfrog other fuels.

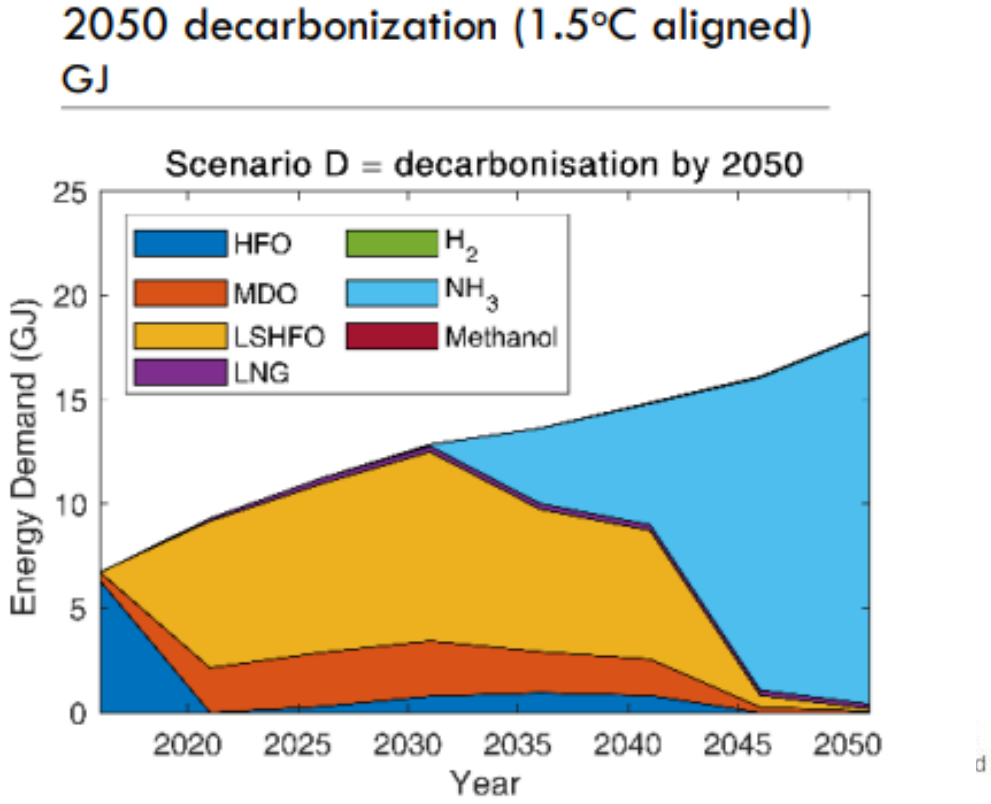
Notes:

- This pathway is valid for the bulk of the global shipping industry.
- In certain areas, other solutions may be more logical and profitable.
- Electrification of vessels will happen in segments where possible (IWW, short distance ferries, etc.)
- The advent of on-road electromobility will continue to drive down battery and possibly fuel cell prices.
- For longer haul applications, physics preclude the use of full battery electric ships.
- Hydrogen and Ammonia seen to play a smaller role for the coming 2 decades due to missing rules/regulations/experience
- Synthetic fuels are “hydrogen carriers”; built from green hydrogen and other elements to build a useable and practical fuel

MARINE FUEL SCENARIOS AND ROAD MAPS

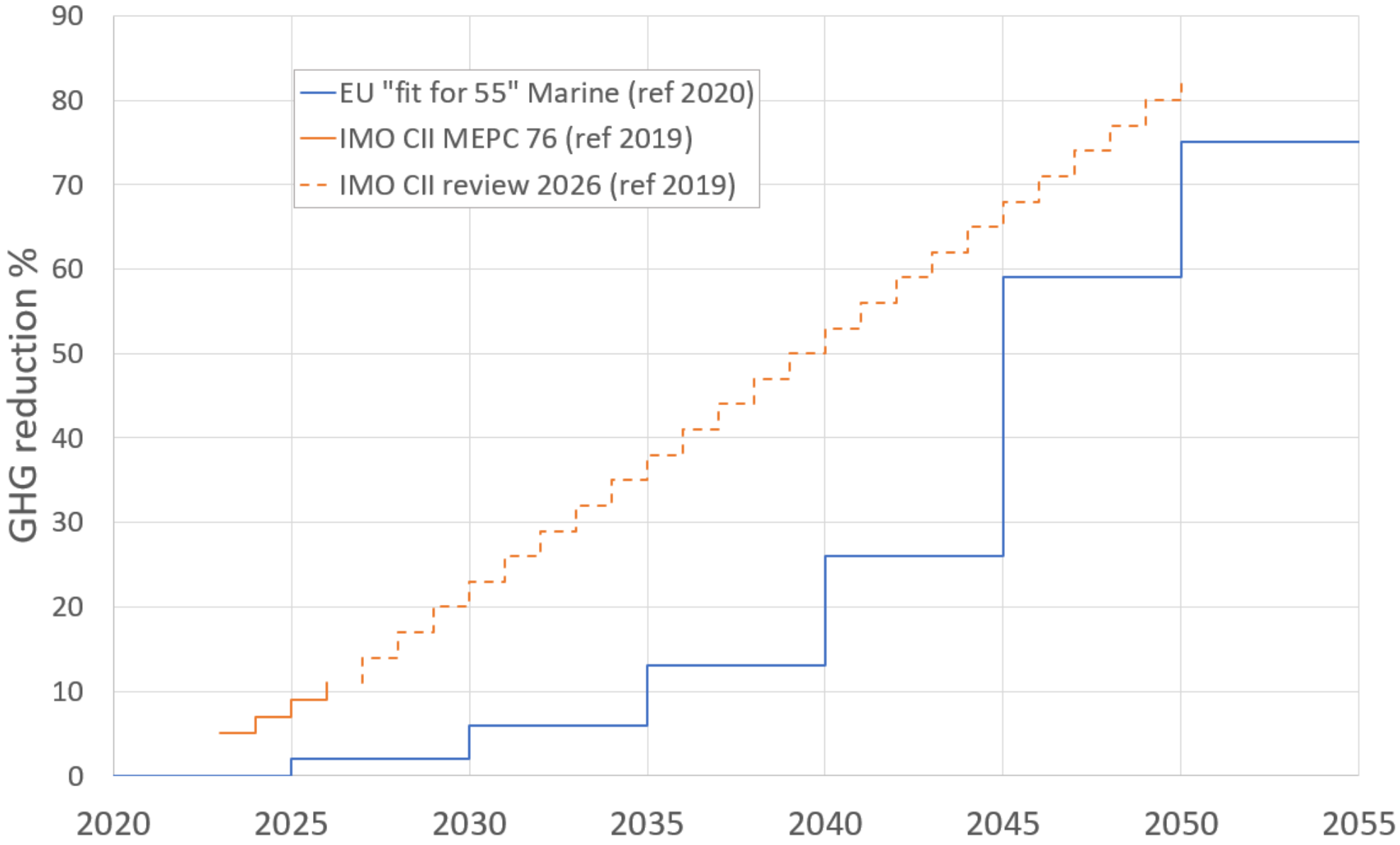


DNV: ENERGY TRANSITION OUTLOOK 2021



UMAS: Aggregate investment for the decarbonisation of the shipping industry 2020

The Regulation - Proposed



The stick is defined

Can we identify any carrots?

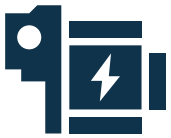
Transition will not happen overnight

Where to identify segments where accelerating the transition becomes good business?

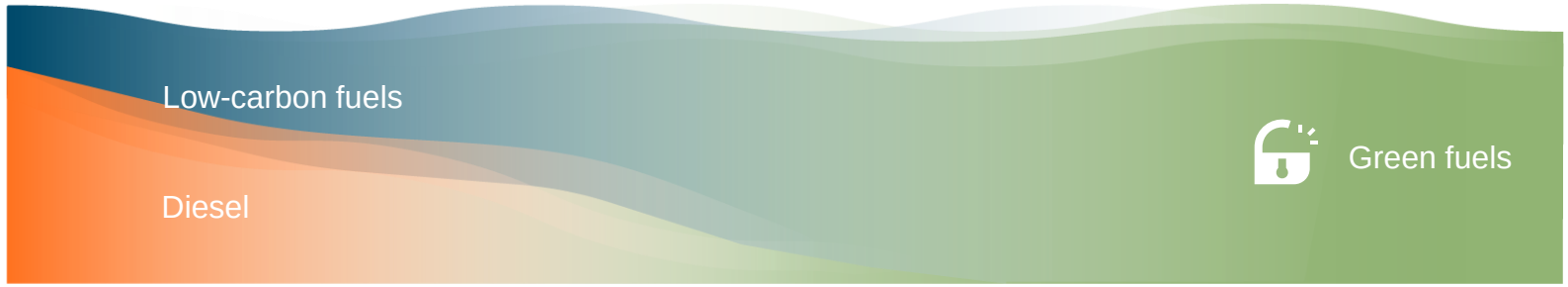
CERTAINTY IN TRANSITION

Infrastructure and availability of green fuels need time to mature –
current Wärtsilä multi-fuel technology offer a viable upgrade path

TRANSITION FUELS ▶ DROP IN ▶ FUEL BLENDS ▶ NET-ZERO-CARBON FUELS



Multi-fuel
Engine



2021
Today

2023
EEXI

2030
- 40% carbon intensity

2050
-70% CI & -50% in total GHG

WÄRTSILÄ

Fossil fuels
HFO, MGO, LNG, LPG

To fulfil the emission legislation within shipping, additional technologies have to be deployed

- Scrubbers (SOx)
- SCR (NOx)
- Carbon Capture – not yet available

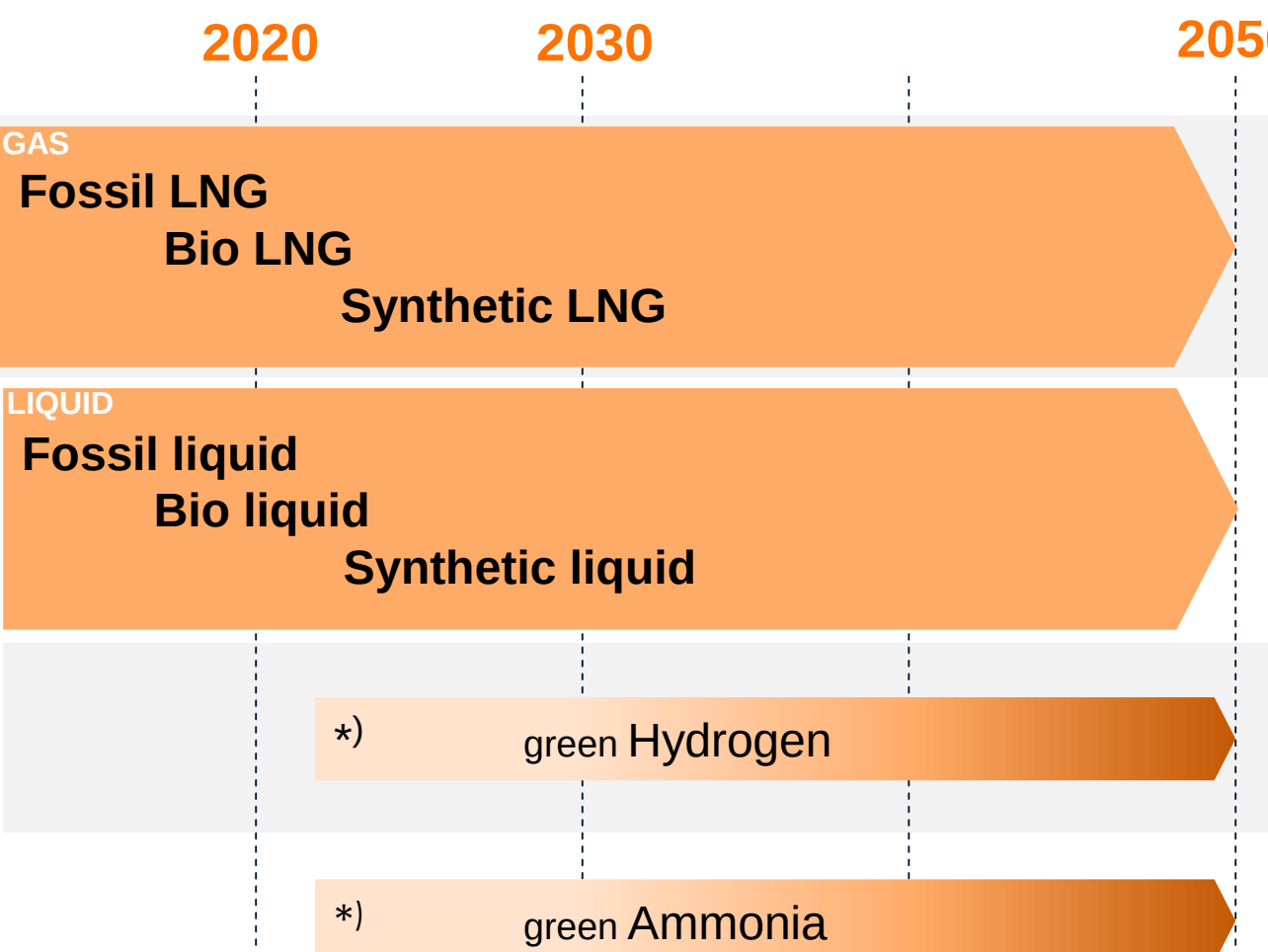
Biofuels

- Liquid biofuels
  (HVO, FAME, Crude biofuels (soya, rapeseed, palm oils, fish fat)
- Biomethane (CBG/ LBM)
- Bioethanol

Power-to-X (electric fuels)

- Hydrogen (H_2)
- Ammonia (NH_3)
- Methanol (CH_3OH)
- Methane (CH_4) (LSM)

FUEL ROADMAP – SUSTAINABLE SOLUTIONS EXIST ALREADY NOW



Note

- LNG is the cleanest fossil fuel, -5 to -20% GHG (well to wake/power)
- Bio & synthetic possible already today, infra, rules and regulations exist
- Methane slip to be considered, great reduction ongoing

- Bio/synthetic reduce -70 to -100% GHG (well to wake/power)
- Bio & synthetic possible already today, infra adjustment considerations

- Zero carbon, no CO_2 emissions
- Can be blended with LNG, 15-25% vol possible already today
- Liquid storages possible, at -253 °C

- Zero carbon, no CO_2 emissions
- Can be blended with liquids or gases
- Toxic, safety concepts & regulation being developed

- Carbon neutral, can be blended with liquids
- Technology developed, one engine product released
- Toxic, safety regulations exist

**) timing depends on the market demand*

DEVELOPMENT FOR FUTURE FUELS CONTINUES

BioLNG

or Synthetic methane

Can readily be used with equipment made for fossil LNG and blended in all ratios

Verified: 2003

Cryogenic LNG operations are well-known (IGF code of safety for ships since 2016)

MeOH

Green Methanol

A methanol conversion package for the engine is required.
Stena Germanica started operation on Methanol in March 2015

Verified: 2015
Volume ramp-up: 2023

Non-pressurised tanks.
Toxic, local emissions (NOx)

NH_3

Green Ammonia

Combustion concepts to maximise engine performance and related safety technologies are currently being investigated
70% Ammonia blend on typical marine engine load achieved already

Indicative: 2021, Tech ready: 2023
Volume ramp-up: 2025

Non-cryogenic but toxic.
No rules & regulations
Local (NOx) and GHG emissions (N2O)

H_2

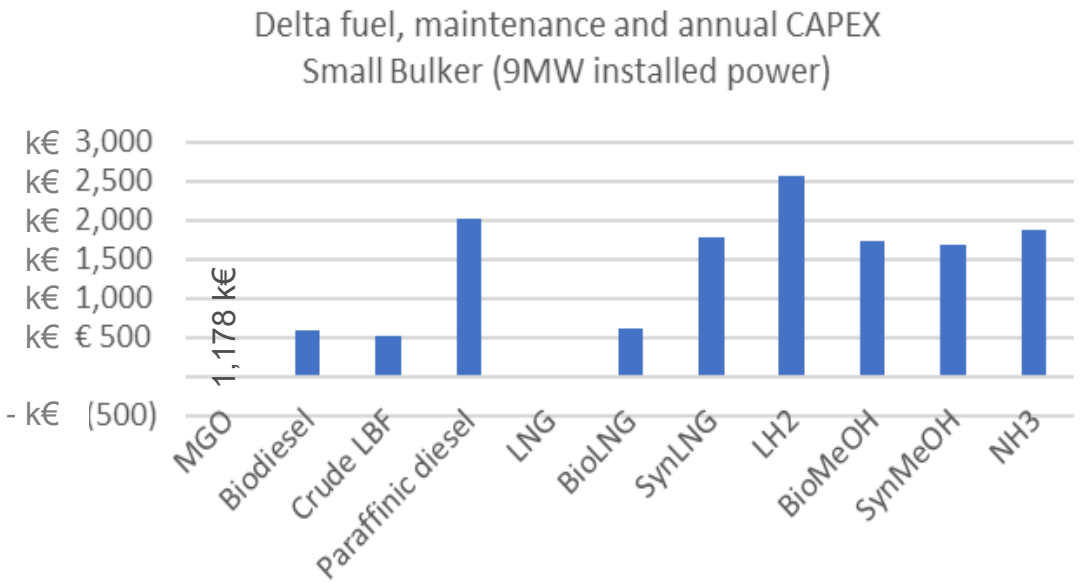
Green Hydrogen

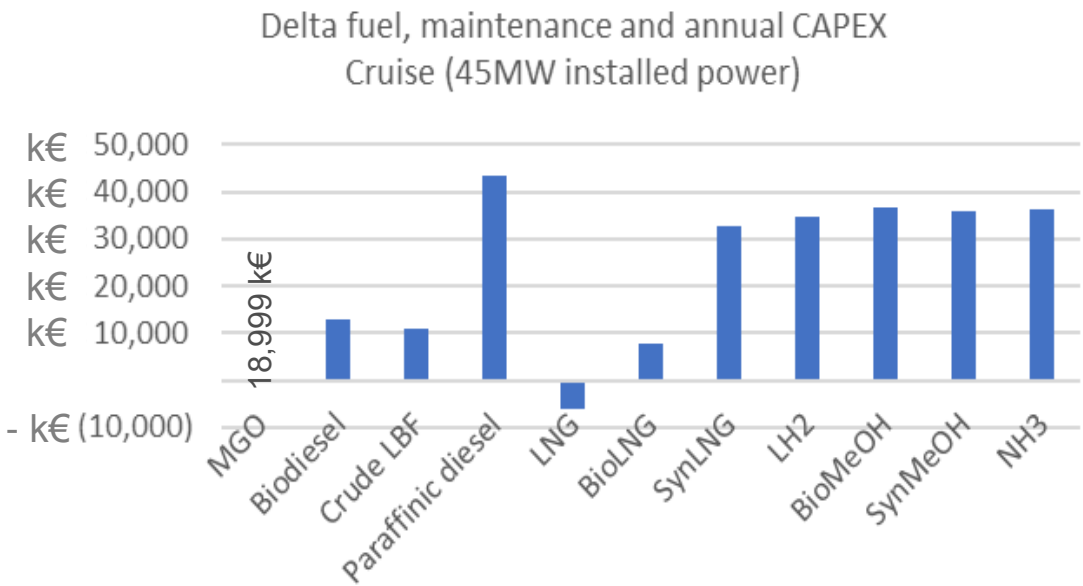
Our gas engines are already able to blend up to 25% hydrogen in LNG, and combustion concepts under work for 100% hydrogen.
Pure Hydrogen on 70% of typical marine engine load achieved already

Indicative: 2021
Pilots with blends: 2021
Tech for pure H2 ready 2025
Volume ramp-up: 2027

Storage of LH2 at -253 C
Local emissions (NOx)

LEVELISED COST OF ELECTRICITY (LCOE) CONCLUSIONS – MARINE FORECAST YEAR 2030





Annual delta cost for fuel, maintenance and annual engine + tank capex (10yr, 5% basis) in k€. MGO column has the calculated baseline cost for comparison purposes.

- Paraffinic diesel (HVO) has no place in shipping as it is way too expensive. IT is best used in other industries. For the same benefit, biodiesel / crude liquid biofuel are better
- All fossil fuels fall in the same €/MWh ballpark except methanol (logical, as it needs additional processing from CH4)
- Most biofuels are ~2x fossil fuels. Except Bio MeOH and HVO, those are more expensive
- Most synthetic fuels are ~3x fossil fuels
- All synthetic options work out at almost the same annual cost – probably within the error margin
- LH2 CAPEX (tank!) negates the lower fuel cost, even in the highest consumption case of the cruise liner

Fuel cost used in this study, estimate for year 2030:

- Fossil natural gas **21,5 USD/MWh** (6 USD/GJ)
- Fossil light fuel oil **52,0 USD/MWh** (620 USD/ton)
- Synthetic natural gas **114 USD/MWh**
- Sustainable hydrogen **80,5 USD/MWh** (~2,7 USD/kg)
- Sustainable methanol **127 USD/MWh**
- Sustainable ammonia **117 USD/MWh**

GREEN FUELS WILL BE INTRODUCED SLOWLY

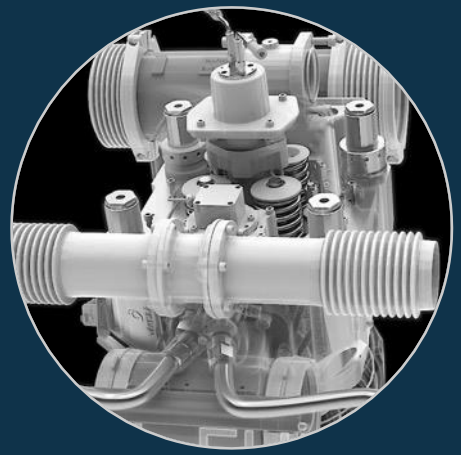
- **Green synthetic fuels are not expected to become widely / globally available to power generation before 2030 and to shipping industry before 2040**
- **Blending bio/synthetic fuels into fossil fuels are good steps towards decarbonisation, even without changes to the installation**

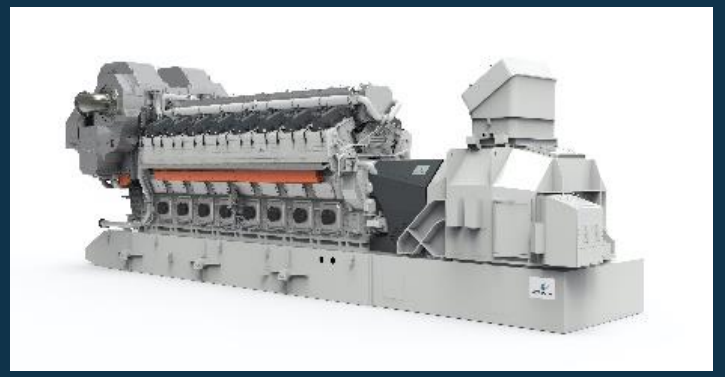
GREEN FUEL

A synthetic fuel produced only with renewable energy or a fuel produced from sustainable biomass

Long asset lifetimes in ships and power plants mean that owners will require a clear upgrading / retrofit path towards use of green fuels

STEPWISE APPROACH IN DEVELOPMENT OF TECHNOLOGIES FOR FUTURE FUELS





Idea

WE ARE CURRENTLY HERE

Proof of Concept

Laboratory engines operating on hydrogen, ammonia and methanol

PoC duration 2021 – 2022….2025

- **Methanol industrialised on one product 2023**
- **Ammonia concept ready 2023**
- **Hydrogen concept ready 2025**

Industrialised solution

Can be done when PoC ready

Needed when

- **green fuels available**
- **infra for them exist**
- **etc**

BIO- & HYDROGEN-BASED FUELS ESSENTIAL IN DECARBONISING THE SHIPPING INDUSTRY

- while additional factors must also be taken into consideration

FUEL AVAILABILITY

INCREASED CAPEX AND OPEX

IMPACT ON VESSEL STRUCTURE

INCREASED COMPLEXITY

SHIPYARD CAPACITY

SYSTEMS TO BE CHANGED WHEN INTRODUCING A NEW FUEL

FUEL-GAS SUPPLY SYSTEM

Materials
Pressurisation
Insulation
Toxicity

ENGINE TOP PART

Fuel-injection
Cylinder heads
Piston tops

EXHAUST-GAS ABATEMENT

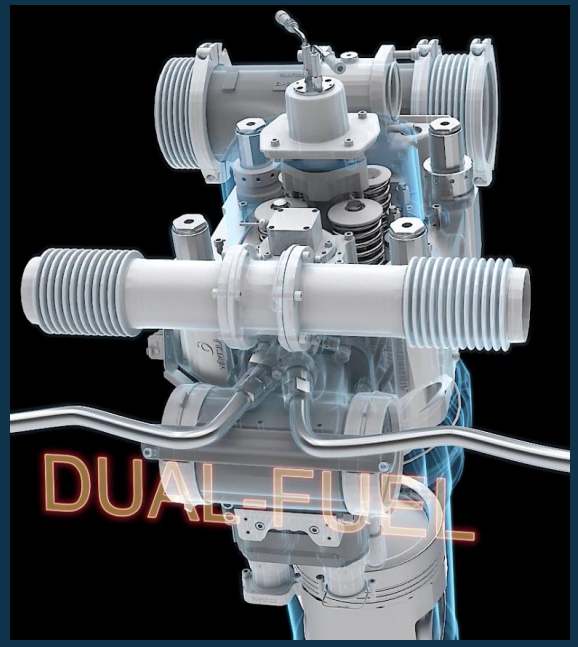
SCR
Scrubbers
Carbon capture

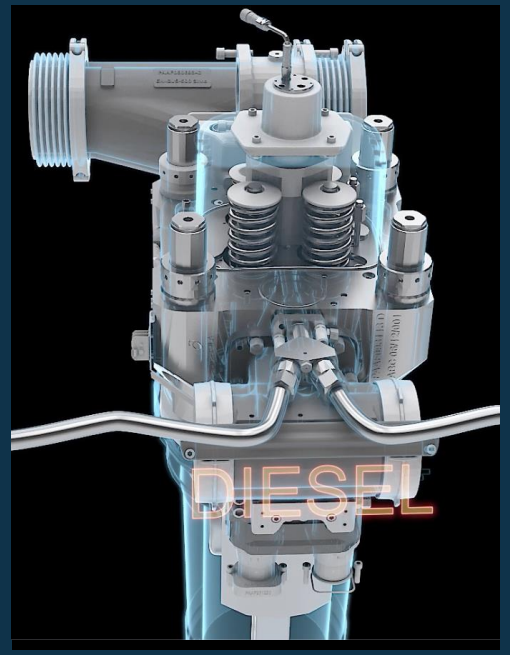
SAFETY SYSTEMS

Impact on safety systems
and regulatory bodies

THE COMBUSTION ENGINE: A TRUE OMNIVORE

HFO, MGO, HVO, LNG, LPG, HYDROGEN, METHANOL, AMMONIA, ...





WITH 95% PARTS COMMONALITY, THE ENGINE IS NOT THE LIMITING FACTOR

Fuel availability, storage, safety and regulations determine the environmentally and economically sustainable solutions.

WÄRTSILÄ, EQUINOR, REPSOL, AND KNUTSEN TO TEST AMMONIA FOUR-STROKE ENGINE

World's first full scale ammonia engine test - an important step towards carbon free shipping

Wärtsilä Corporation, Trade press release, 30 June 2020 at 10:01 AM E. Europe Standard Time

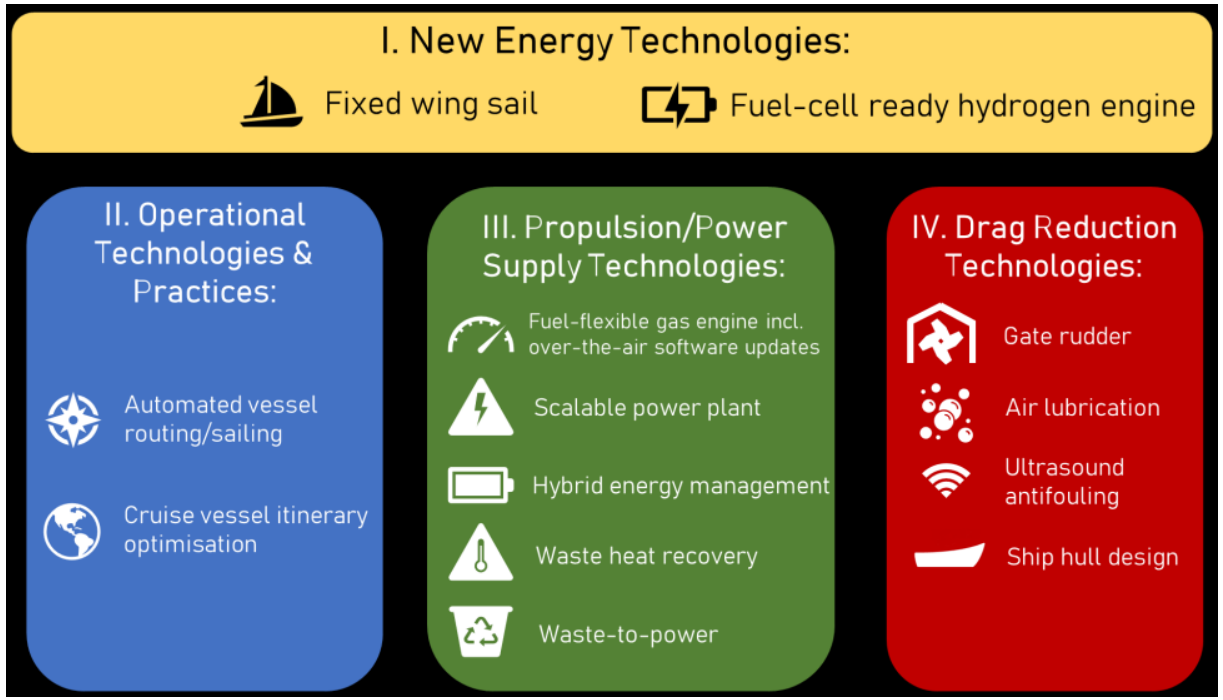
The technology group Wärtsilä, in close customer cooperation with Knutsen OAS Shipping AS and Repsol, as well as with the Sustainable Energy Catapult Centre, will commence the world's first long term, full-scale, testing of ammonia as a fuel in a marine four-stroke combustion engine. The testing is made possible by a 20 MNOK grant from the Norwegian Research Council through the DEMO 2000 programme.

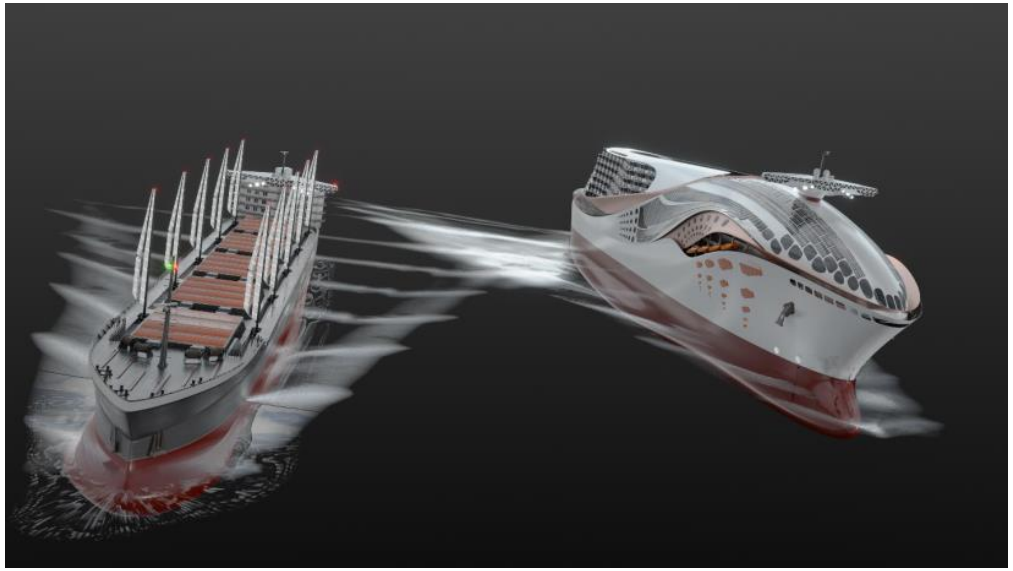
PROJECT ’CHEK’

deCarbonising sHipping by Enabling Key technology symbiosis on real vessel concept designs

Lowest cost path to decarbonisation

The overall objective of project CHEK is to develop and demonstrate at full scale **two first-of-a-kind vessel concept designs** (*Kamsarmax* bulk carrier and *Meraviglia* class cruise ship, see above) based on **real operational profiles** and equipped with an interdisciplinary **combination of innovative technologies working in symbiosis to reduce greenhouse gas emissions by 99%, achieve at least 50% energy savings and reduce black carbon emissions by over 95%.**





10M€ EU funding 100%

Partners:

- Vaasan Yliopisto (Coordinator)
- Wärtsilä
- Cargill
- MSC
- Lloyd’s Register
- World Maritime University
- Silverstream Technologies
- HASYTEC Electronics
- Deltamarin
- Climeon
- BAR Technologies

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