THE PATH TO DECARBONIZATION

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TRENDS AND DRIVERS

- Digitalization and new technologies create **new business opportunities**
- **Complexity** of engines, propulsion, auxiliary and automation systems is **continuously increasing**
- Crews are reducing in number and is **difficult** to **find professional skills** to be utilized for maintenance and troubleshooting
- Big and specialized **technical offices** are getting more and more difficult to afford
- Needs to meet upcoming **emissions regulations**

REGULATORY FRAMEWORKS

EU ETS FOR SHIPPING

Sept. 17th 2020
GHG emissions from ships over 5,000 GT will now be included in the EU ETS by 1 January 2022

IMO GHG REGULATIONS

The initial GHG strategy envisages, in particular, a reduction in carbon intensity of international shipping (to reduce CO2 emissions per transport work, as an average across international shipping, by at least 40% by 2030, pursuing efforts towards 70% by 2050, compared to 2008); and that total annual GHG emissions from international shipping should be reduced by at least 50% by 2050 compared to 2008

EEDI / SEEMP EEOI

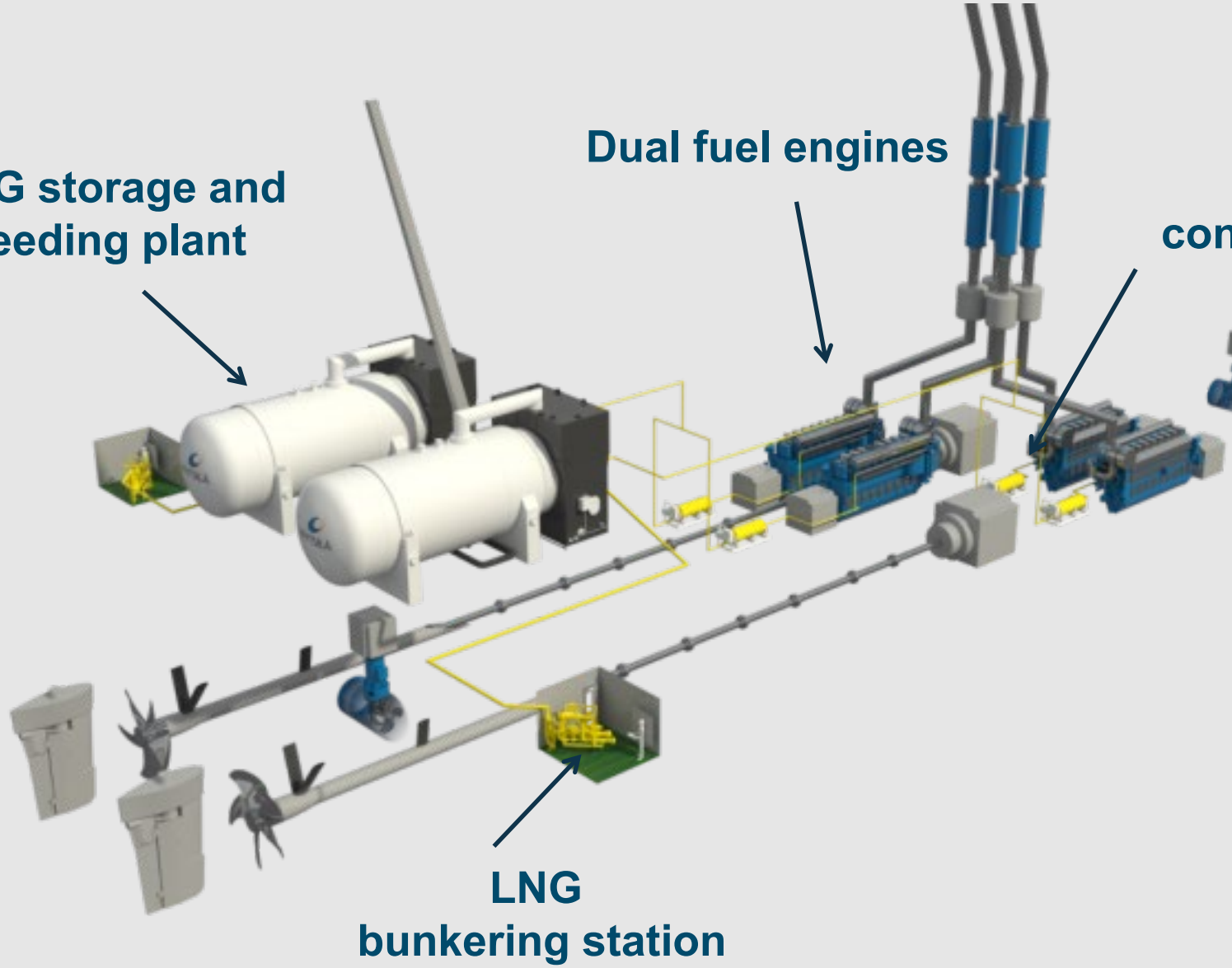
The Energy Efficiency Design Index (EEDI) “provides a robust mechanism that may be used to increase the energy efficiency of ships”

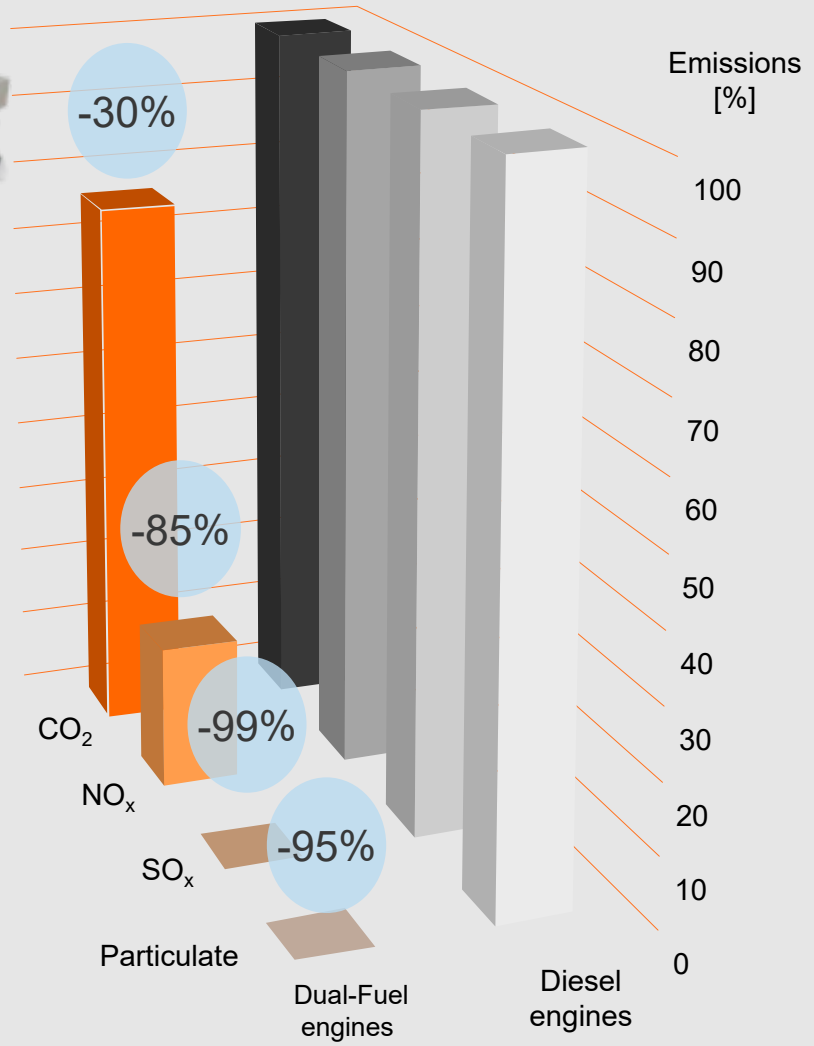
Optimisation of vessel operation plus LNG as a fuel

Carbon-neutral fuels

LIQUIFIED NATURAL GAS

- **Green synthetic fuels** are not expected to become widely / globally available before the end of this decade
- **Fossil methane** alone can already reduce the greenhouse gases
- Blending bio/synthetic fuels into fossil fuels are good steps towards **decarbonisation**, even without changes to the installation


LNG storage and feeding plant
Dual fuel engines
Gas control valve
LNG bunkering station


Emissions [%]
100
90
80
70
60
50
40
30
20
10
0
-30%
-85%
-99%
-95%
CO_2
NO_x
SO_x
Particulate
Dual-Fuel engines
Diesel engines

FUEL ALTERNATIVES

Fossil fuels

HFO, MGO, LNG, LPG, Methanol

To fulfil the emission legislation additional technologies might have to be deployed:

- Scrubbers (SOx)
- SCR (NOx)
- Carbon capture (not yet available)

Biofuels

Liquid biofuels

- HVO (hydrated vegetable oils)
- FAME (fatty and methyl esters)
- Crude biofuels (soya, rapeseed, palm oils, fish fat)

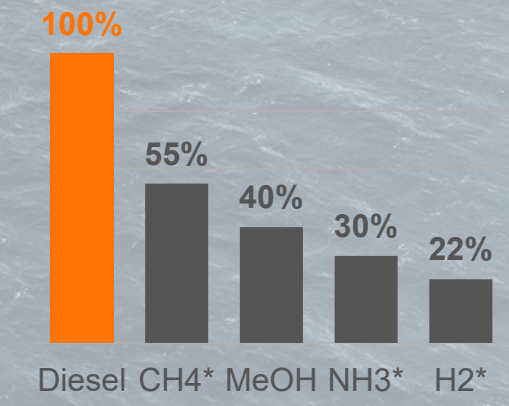
Biogas

- Compressed biogas (CBG)
- Liquid biomethane (LBM)

Green fuels (Power-to-X)

- Hydrogen
- Ammonia
- Methanol
- Synthetic methane

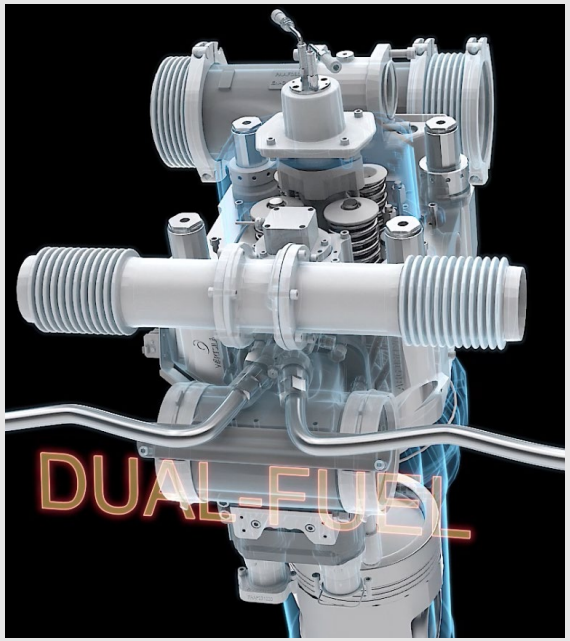
Vessel-operation range with the same fuel volume and efficiencies

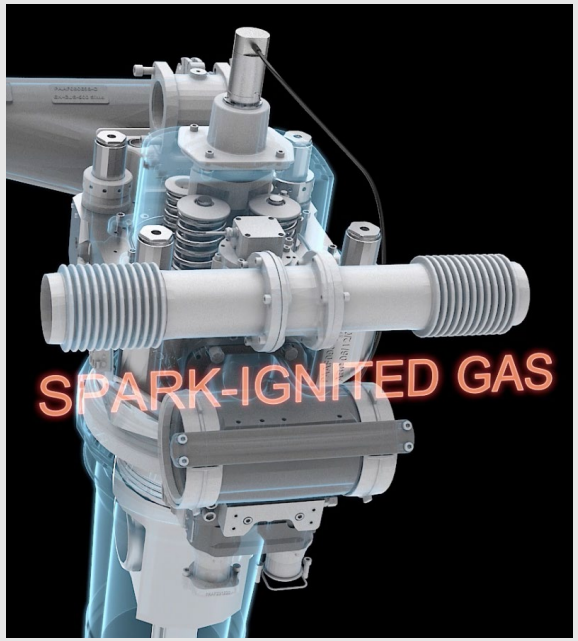


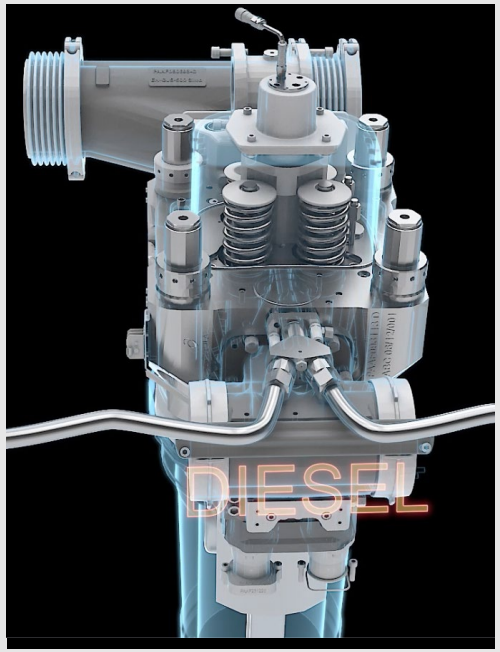
*in liquid form

THE COMBUSTION ENGINE
A TRUE OMNIVORE

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







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

DEVELOPMENT OF ENGINE TECHNOLOGY

2003

CH_4

Bio- or Synthetic methane

Contains about 99% methane and can readily be used in liquid form with equipment made for LNG.

2015

MeOH

Methanol

A methanol conversion package is available for the ZA40 engine and we have the technology to burn methanol.

The next step is to industrialise this technology on the relevant portfolio engines according to market needs.

2022

NH_3

Ammonia

We have already technologies that are capable of using Ammonia.

The needed combustion concepts to maximise engine performance and related safety technologies are currently being investigated

2025

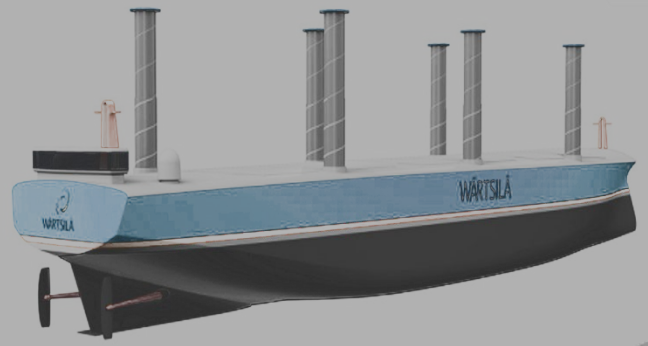
H_2

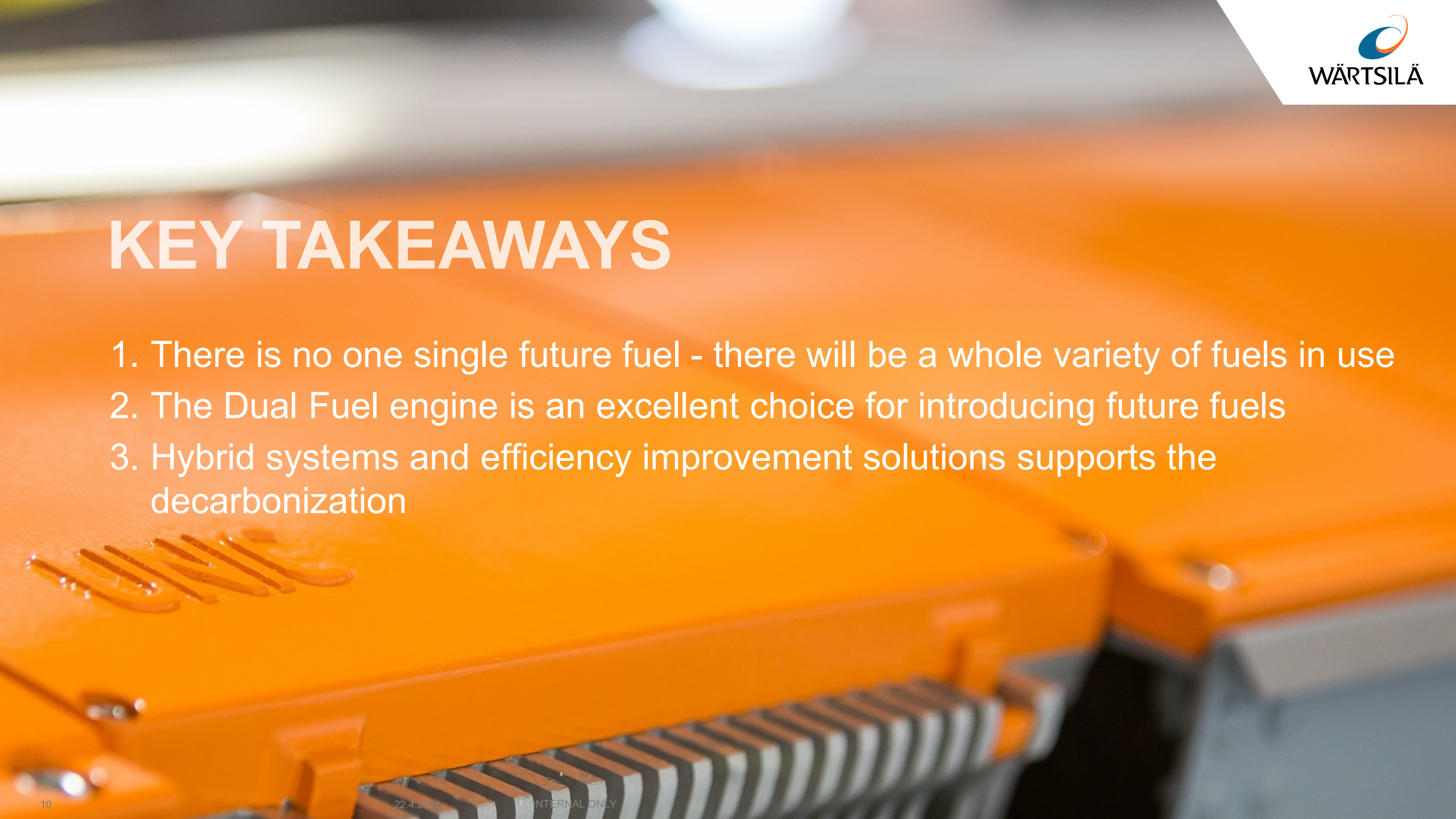
Hydrogen

Our gas engines are already able to blend LNG with up to 20% hydrogen, and combustion concepts have made for 100% hydrogen.

Our future efforts will be directed towards maximising engine performance.

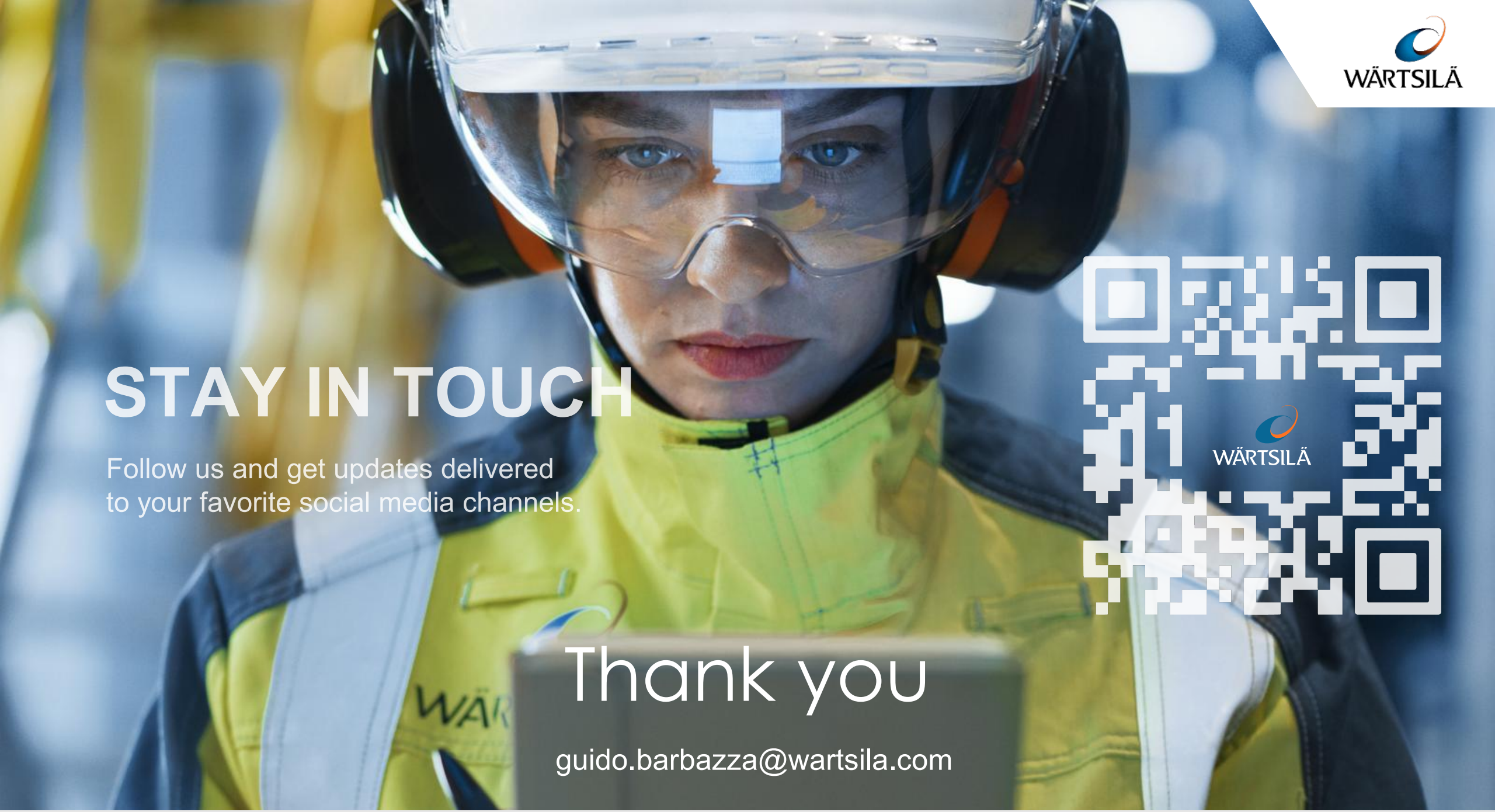
HYBRID SYSTEMS





KEY TAKEAWAYS

1. There is no one single future fuel - there will be a whole variety of fuels in use
2. The Dual Fuel engine is an excellent choice for introducing future fuels
3. Hybrid systems and efficiency improvement solutions supports the decarbonization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