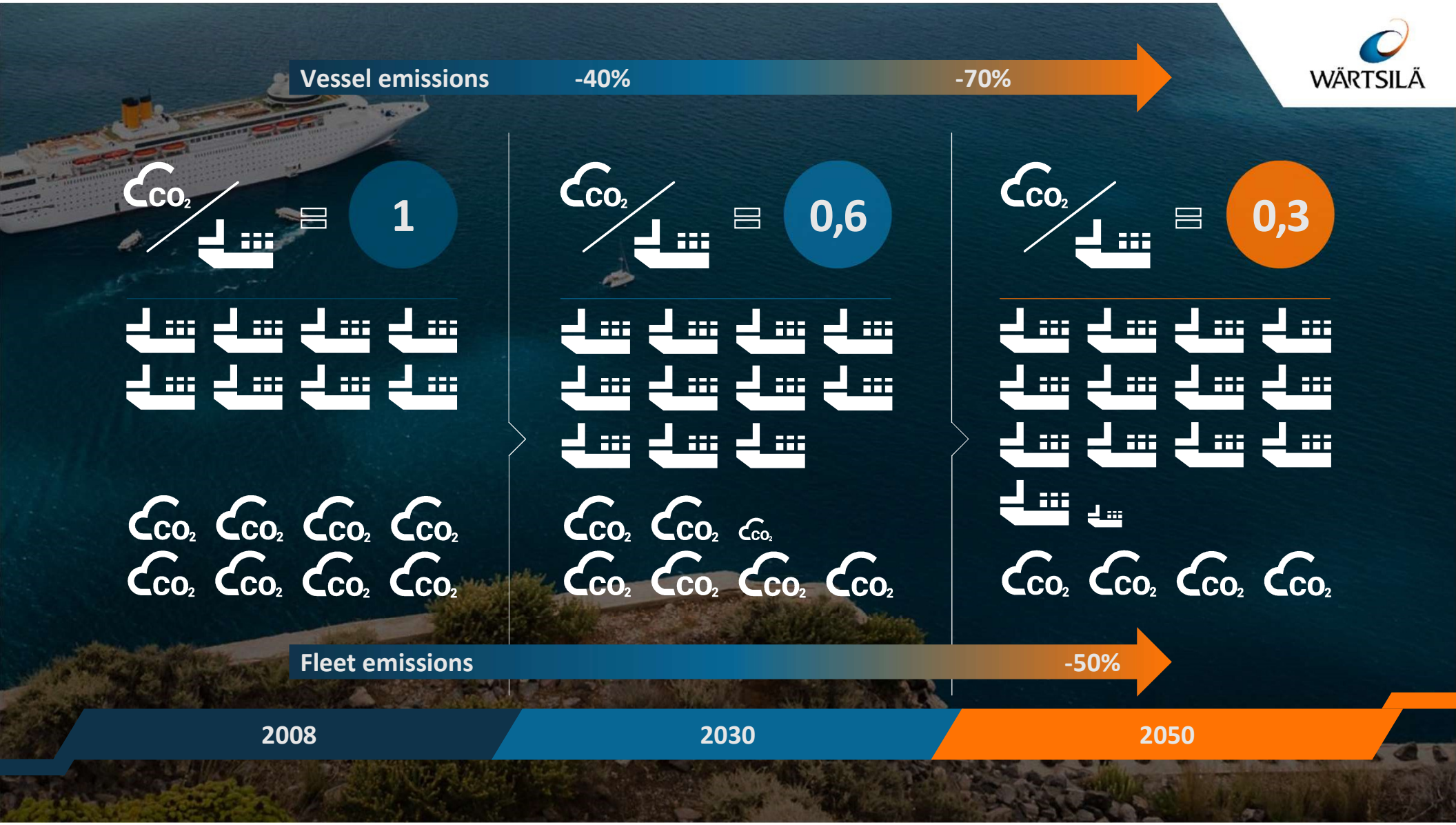
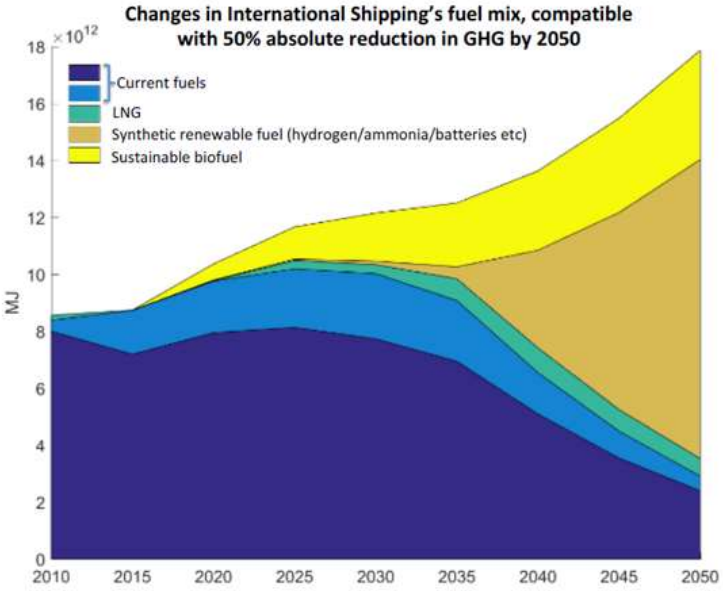
FUTURE FUELS

KAJ PORTIN, FEBRUARY 2020


Vessel emissions
-40%
-70%
1
0,6
0,3
Fleet emissions
-50%
2008
2030
2050

Where to go?

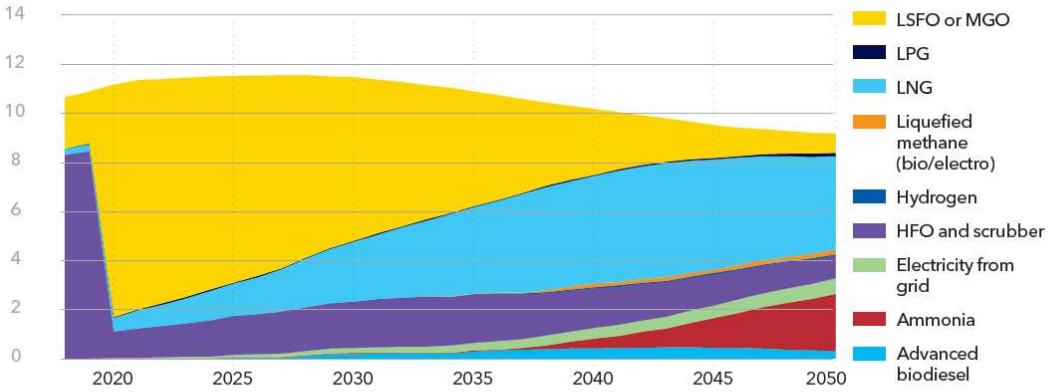
Future fuel scenarios for shipping



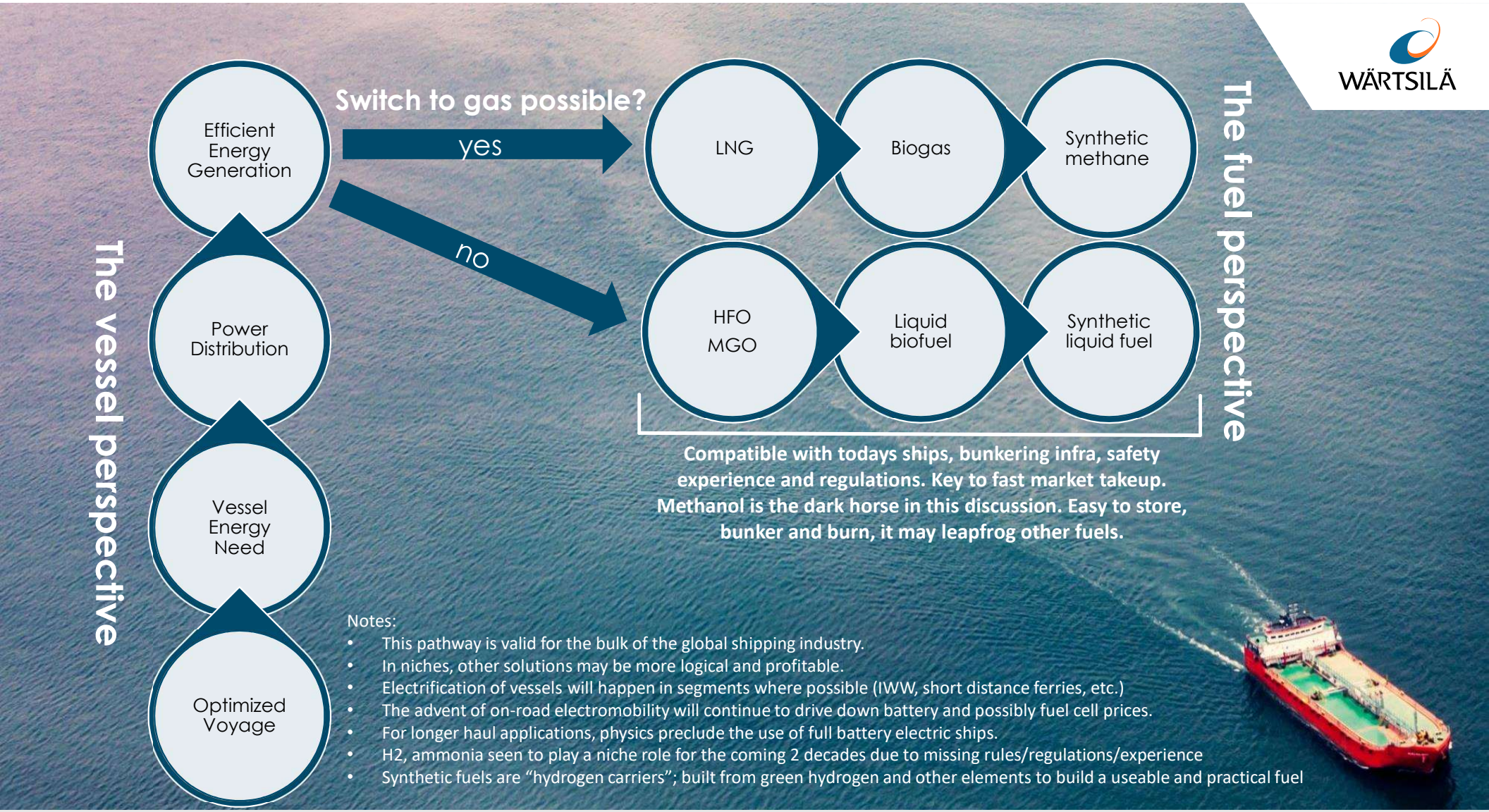
Smith, T., Raucci, C., Haji Hosseinloo S., Rojon I., Calleya J., De La Fuente. S., Wu P., Palmer K. CO2 emissions from international shipping. Possible reduction targets and their associated pathways. Prepared by UMAS, October 2016, London.

FIGURE 4

Energy use and projected fuel mix 2018-2050 for the simulated IMO ambitions pathway with main focus on design requirements



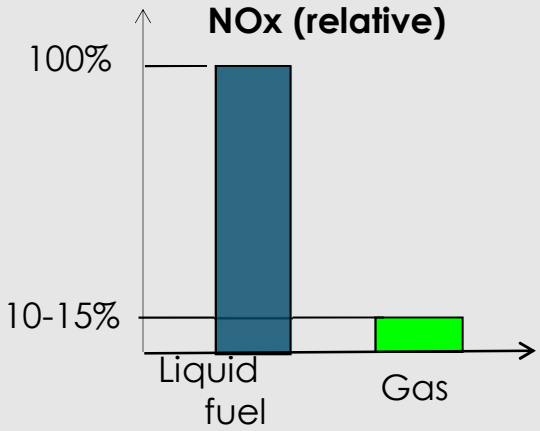
LSFO, low-sulphur fuel oil; MGO, marine gas oil; LPG, liquefied petroleum gas;
LNG, liquefied natural gas; HFO, heavy fuel oil;
Advanced biodiesel, produced by advanced processes from non-food feedstocks

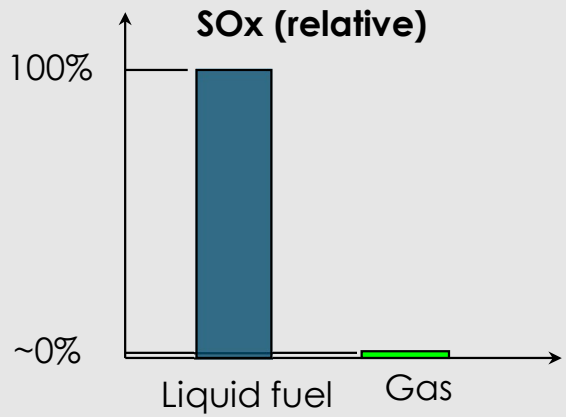


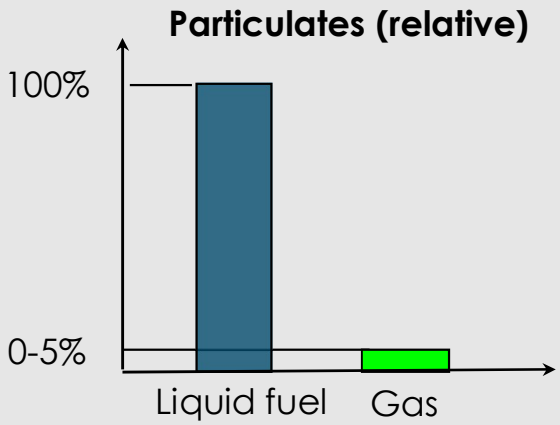
Notes:

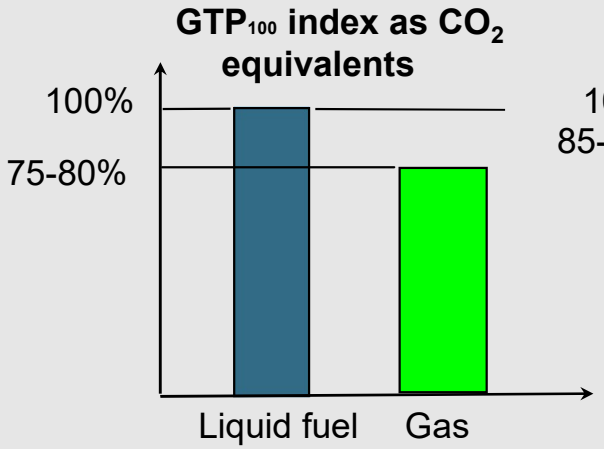
- This pathway is valid for the bulk of the global shipping industry.
- In niches, other solutions may be more logical and profitable.
- Electrification of vessels will happen in segments where possible (IWW, short distance ferries, etc.)
- The advent of on-road electromobility will continue to drive down battery and possibly fuel cell prices.
- For longer haul applications, physics preclude the use of full battery electric ships.
- H2, ammonia seen to play a niche 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

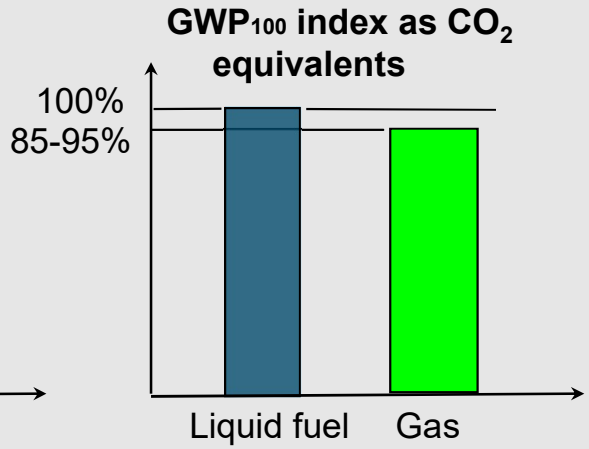
Why lean burn gas engines ⇨ Low emissions





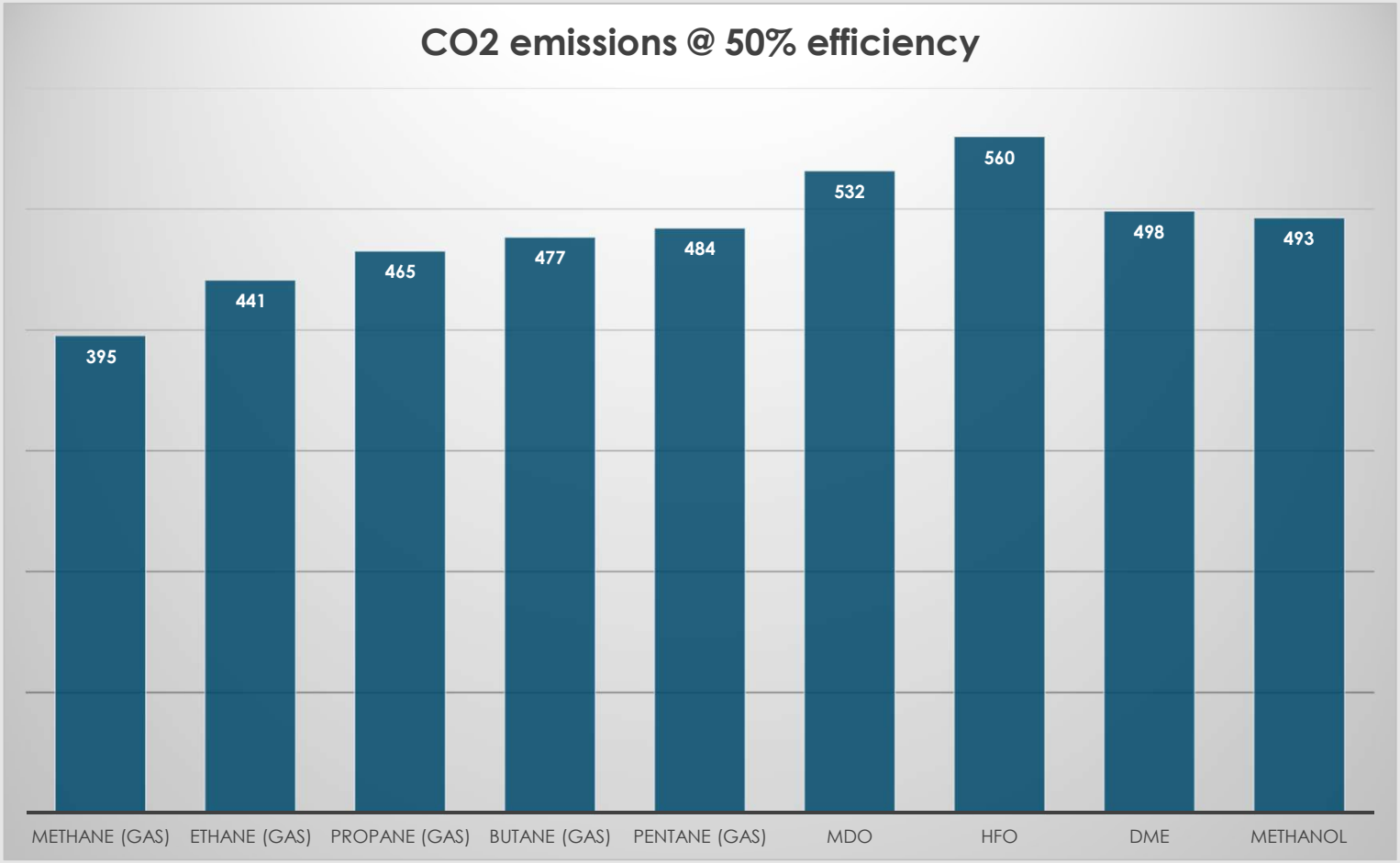




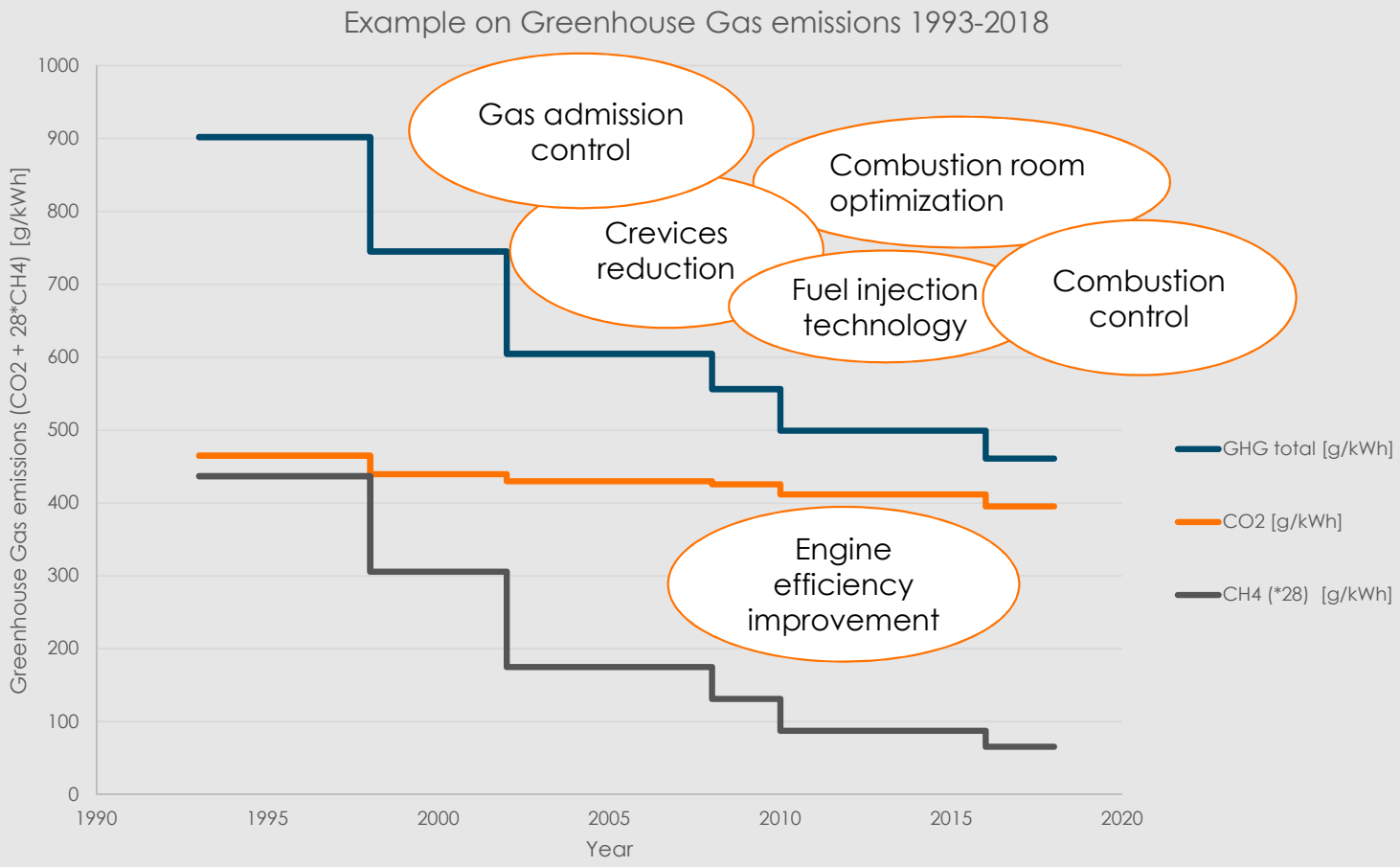


GTP = Global Temperature Change Potential GWP = Global Warming Potential

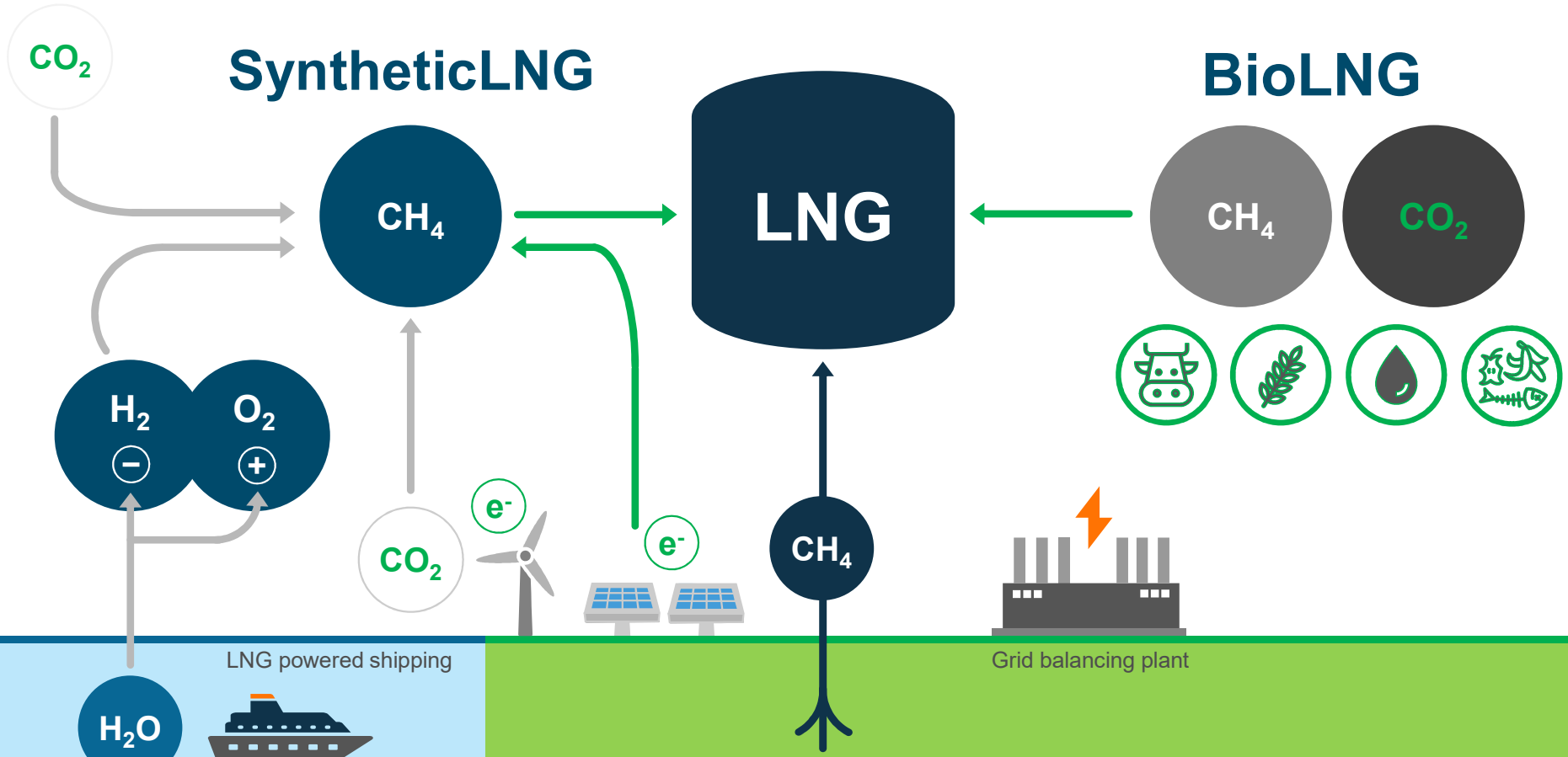
Comparison of CO_2 emissions for different fuels



GHG emissions development 1993-2018



WE CAN START RIGHT NOW!



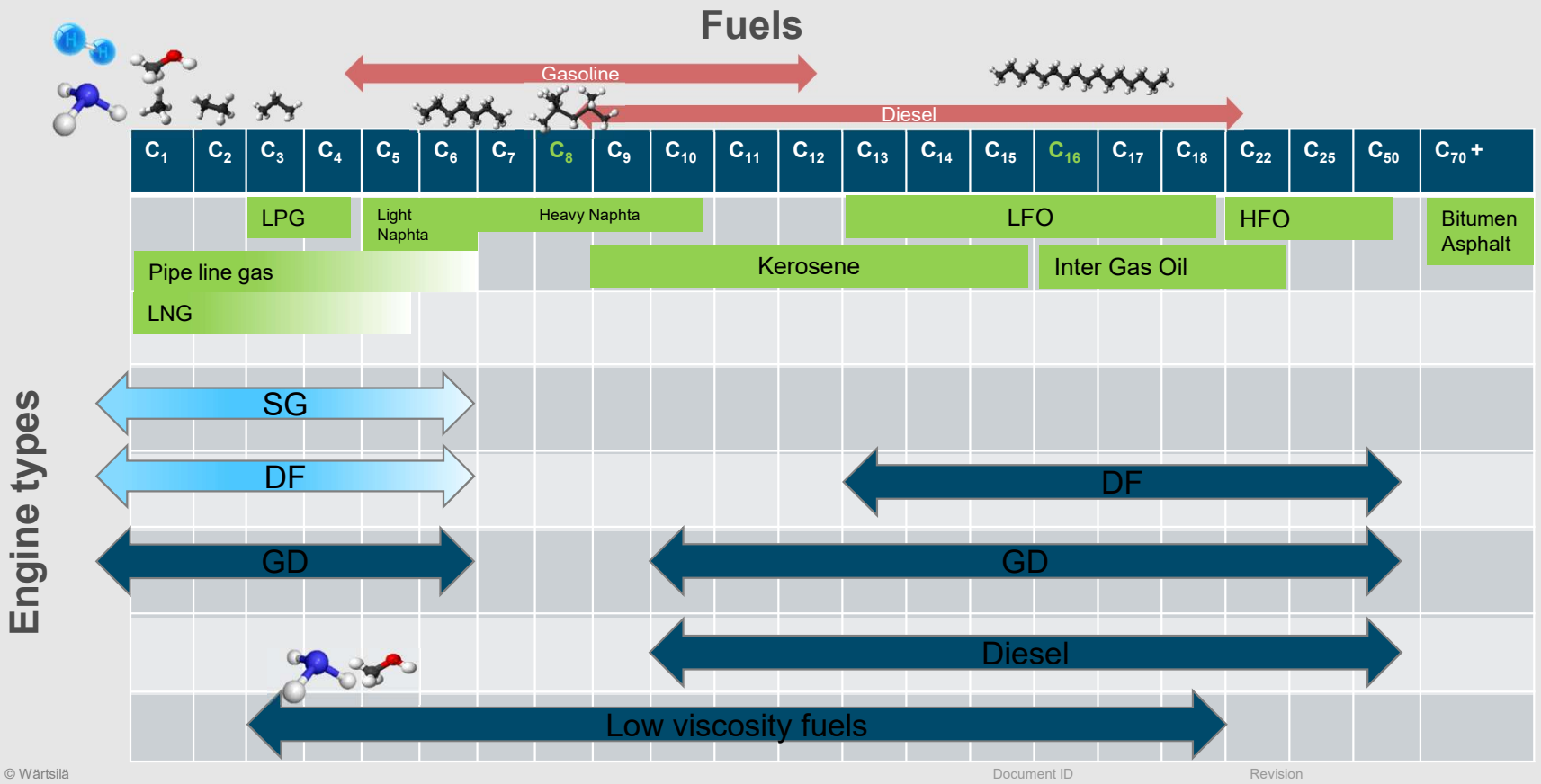
FUEL ROADMAP

	Pros	Cons
Fossil LNG / Bio LNG / Synthetic LNG	• Cleanest fossil fuel, -5 to -20% GHG depending on engine type (well-to-wake) LNG infrastructure, rules and regulations exist, fuel is available • Bio/syn GHG -70 to -100% depending on source (well to wake) • Clear transition pathway as same infra can be used for all	• Methane slip, must be reduced with on/off engine techs as novel combustion (e.g. HCCI, RCCI), Oxicat or Sandbed
*) green Hydrogen	• No emissions • Can be blended with LNG	• Massive investments in infra and challenges in handling the fuel (minus 253°C)
*) green Ammonia	• Only NOx emissions (=SCR)	• Toxic, not available, no rules & regulations
*) green Methanol	• Carbon neutral, only NOx emissions	• Toxic, not available yet

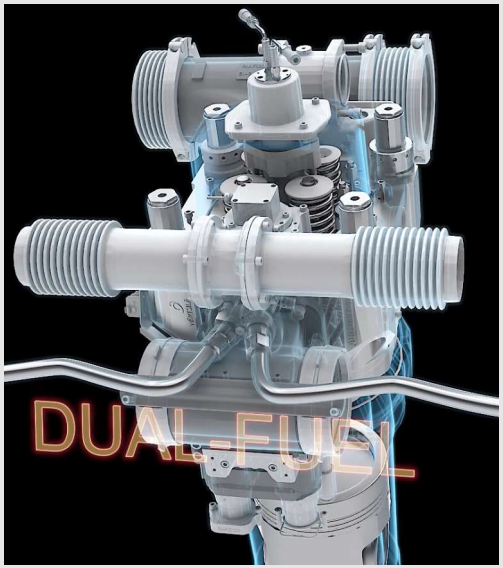
*) Introduction year only indicative

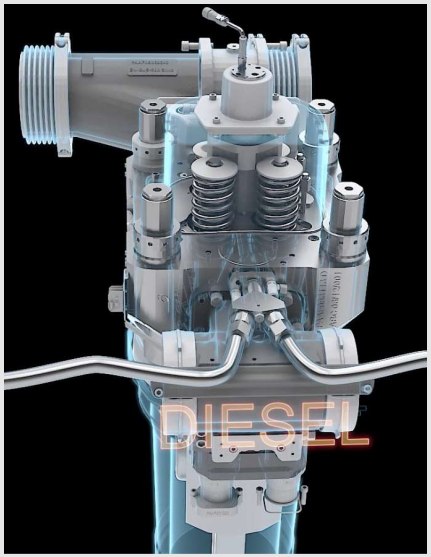
Hydrocarbons in Wärtsilä ICE – fuel flexibility is key

SG = Spark Ignited	DF = Dual Fuel	GD = Gas Diesel	Diesel
-Otto process	-Otto process + pilot	-Diesel process + pilot	-Diesel process
-Fuel: gas	-Diesel process	-Fuel: gas + liquid fuels	-Fuel: MDO, HFO and Crude oil
-low pressure gas	-Fuel: gas + liquid fuels	-high pressure gas	
	-low pressure gas	-large fuel mixture ratio	



FUEL FLEXIBILITY BY MODULAR ARCHITECTURE





A modular design of the engine is providing a flexible platform for a wide variety of applications and fuels.

Summary

- GHG is an important topic, but local emissions should not be forgotten
- Natural gas operation result significantly lower emissions already today, and provides gaseous fuel infrastructure for future fuels
- GHG reduction enablers
  - Fuel flexible engine technologies
  - Renewables - both on liquid and gaseous fuels
  - Hybrid solutions