MARINE OPERATIONS WITH LNG AND FUTURE FUELS

21.3.2019, Vaasa Gas Exchange

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Wärtsilä Gas Solutions

Shipping emits **972 Million ton CO2e/a** | **2.7%** of global CO2 emissions

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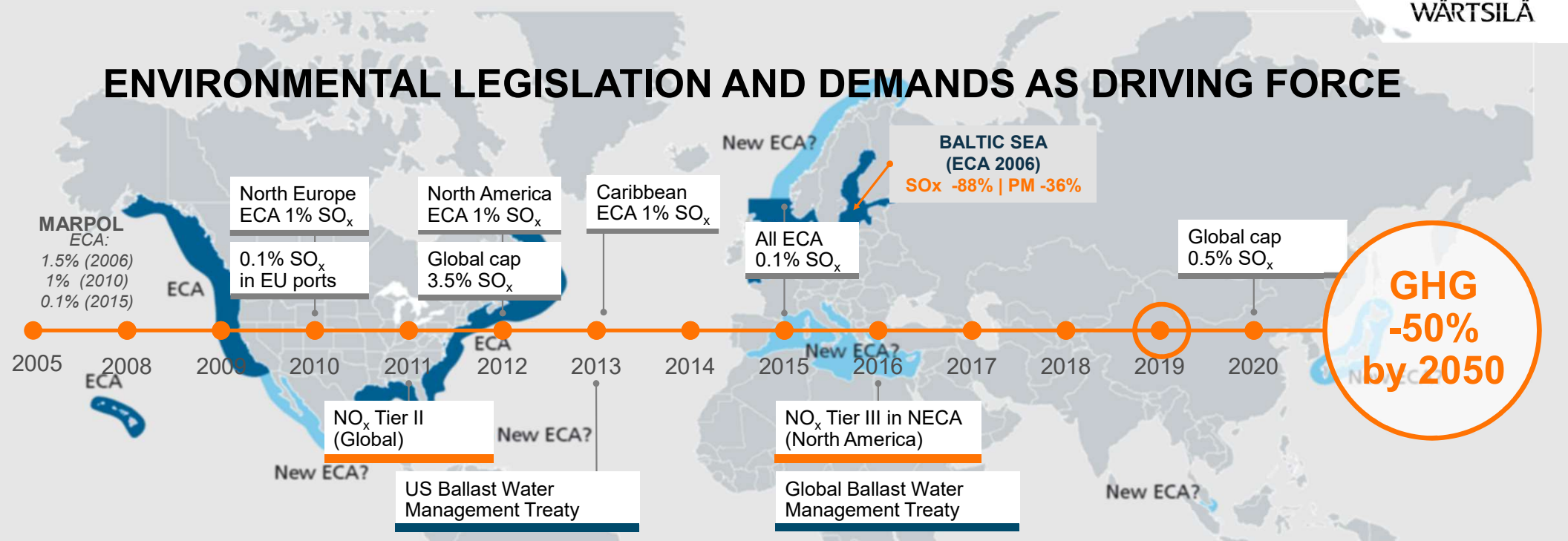
ENVIRONMENTAL LEGISLATION AND DEMANDS AS DRIVING FORCE



SO_x legislation:

- Sulphur free fuels
  - LNG
  - Methanol, LPG, bio-fuels
  - Distillates (MDO, MGO)
- Scrubbers in combination with HFO (~3 MEUR/15MW hybrid scrubber)

NO_x legislation:

Tier II
- Engine internal methods

Tier III
- Secondary methods (SCR,~2-300 kEUR)
- LNG/NG with lean burning process (dual-fuel engines)

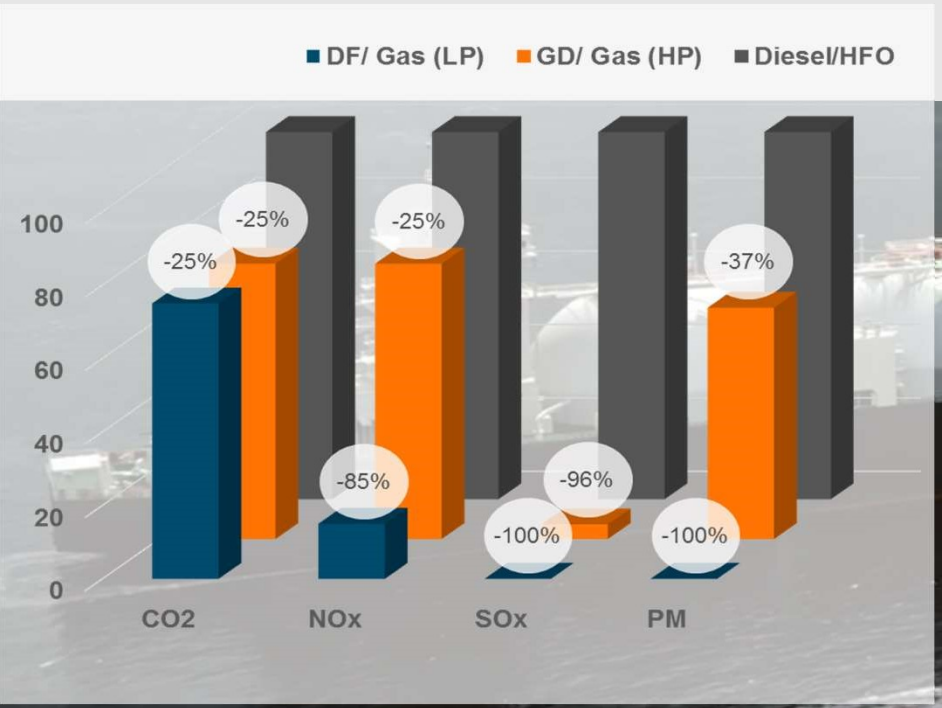
Ballast Water Treaty:

- UV ballast water treatment system
- EC ballast water treatment system
- Minimised amount of ballast water through Ship Design

https://www.lr.org/en/insights/articles/imo-ghg-strategy-what-does-it-mean/

IMO International Convention for the Prevention of Pollution from ships (MARPOL) into force in 05/2005

Reduced Emissions



LNG as marine fuel

Shifting from diesel to gas reduces

- **CO2 emissions by -18% (-25%)**

Without SCRs & scrubbers

- **TIER III compliant NOx emissions**
- **SOx & PM free emissions**

>2 100 Wärtsilä DF engines | >26 000 000 running hours

MARKET OVERVIEW

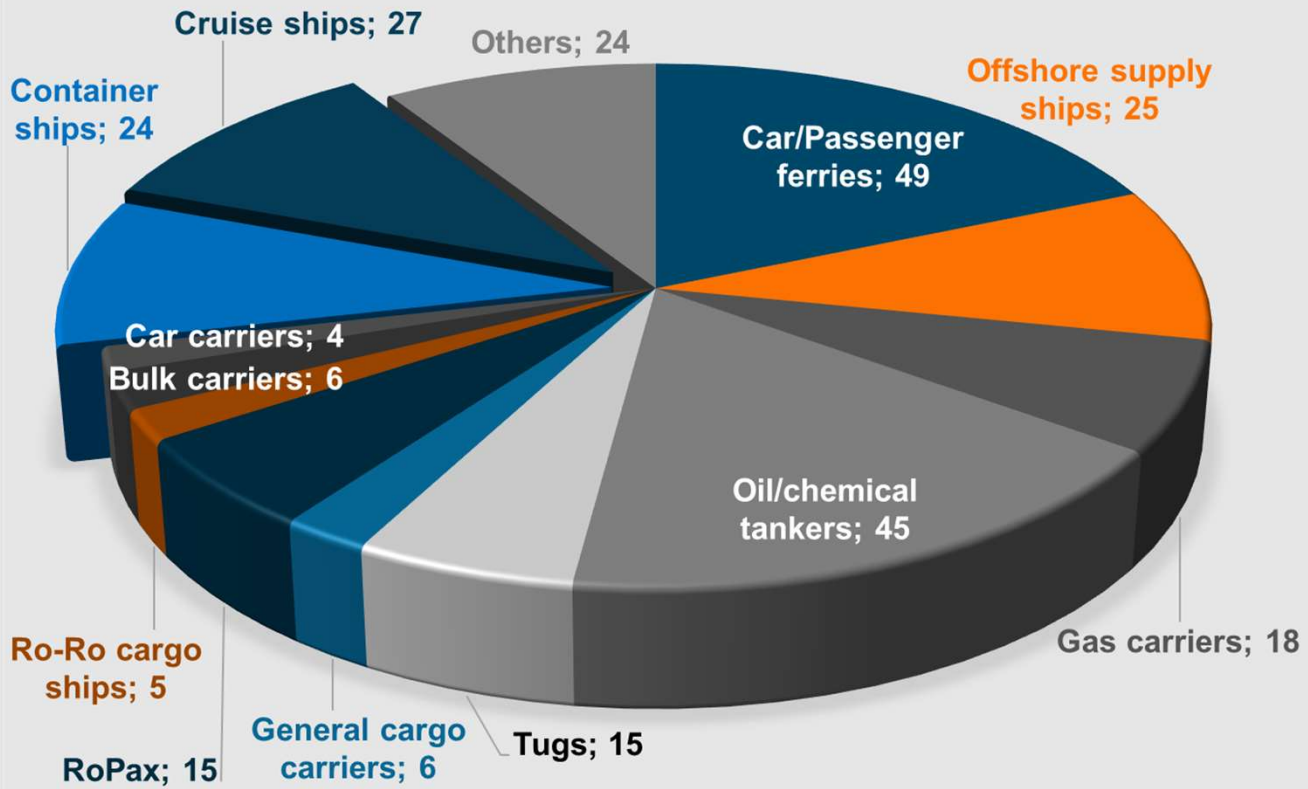
2019

LNG-fueled vessels

126
LNG-fueled vessels in operation

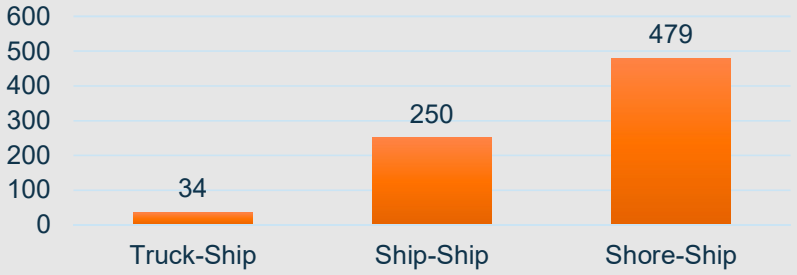
137
in orderbook

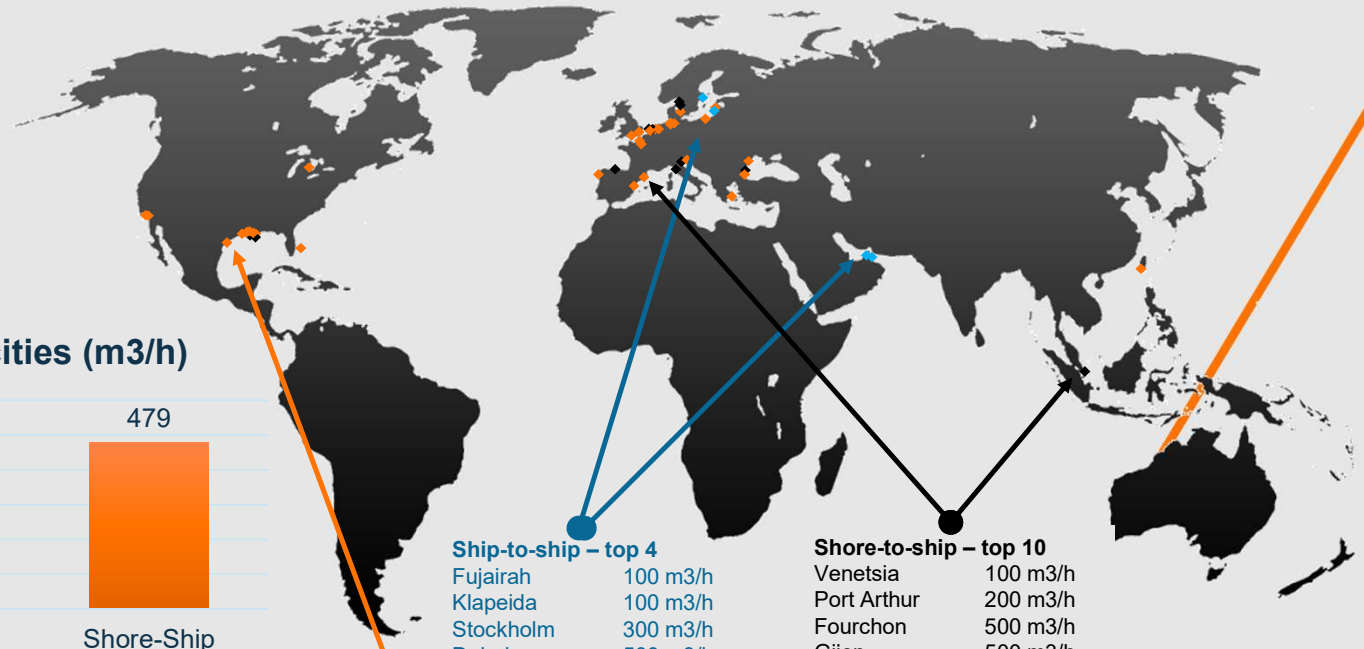
263 → 300 (update 2019)
contracted or keel-laid LNG-fueled vessels by 2024



| DNV | Excl. LNG carriers

Bunkering methods and capacities – world wide (01/2018)





Truck-to-ship – top 4

Port of Houston	100m3/h
Port of Galveston	100m3/h
Port of Beamount	100m3/h
Port of Geismar	150m3/h

Ship-to-ship – top 4

Fujairah	100 m3/h
Klapeida	100 m3/h
Stockholm	300 m3/h
Dubai	500 m3/h

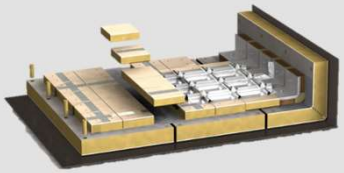
Shore-to-ship – top 10

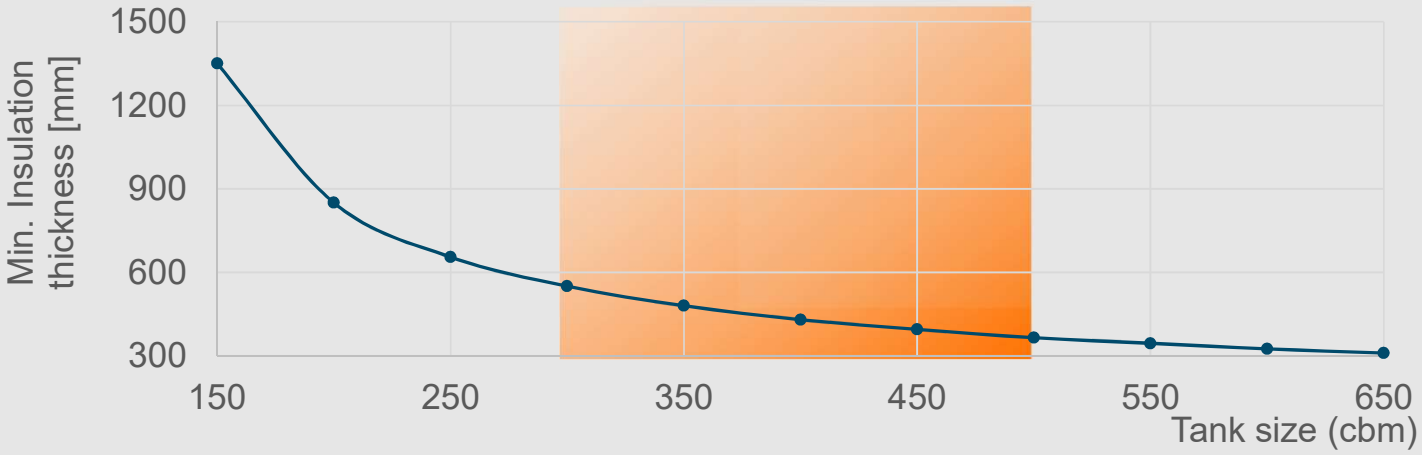
Venetsia	100 m3/h
Port Arthur	200 m3/h
Fourchon	500 m3/h
Gijon	500 m3/h
Zeebrugge	500 m3/h
Gothenburg	500 m3/h
Lysekil	800 m3/h
Singapore	1000 m3/h
Rotterdam	1500 m3/h

Truck-to-Ship 30 | Ship-to-Ship 4 | Shore-to-Ship 12 | SGMF

Standard systems with Mature technology

Vacuum insulated | PUR insulated | Membrane
< 500 cbm > 350 cbm > 1000 cbm





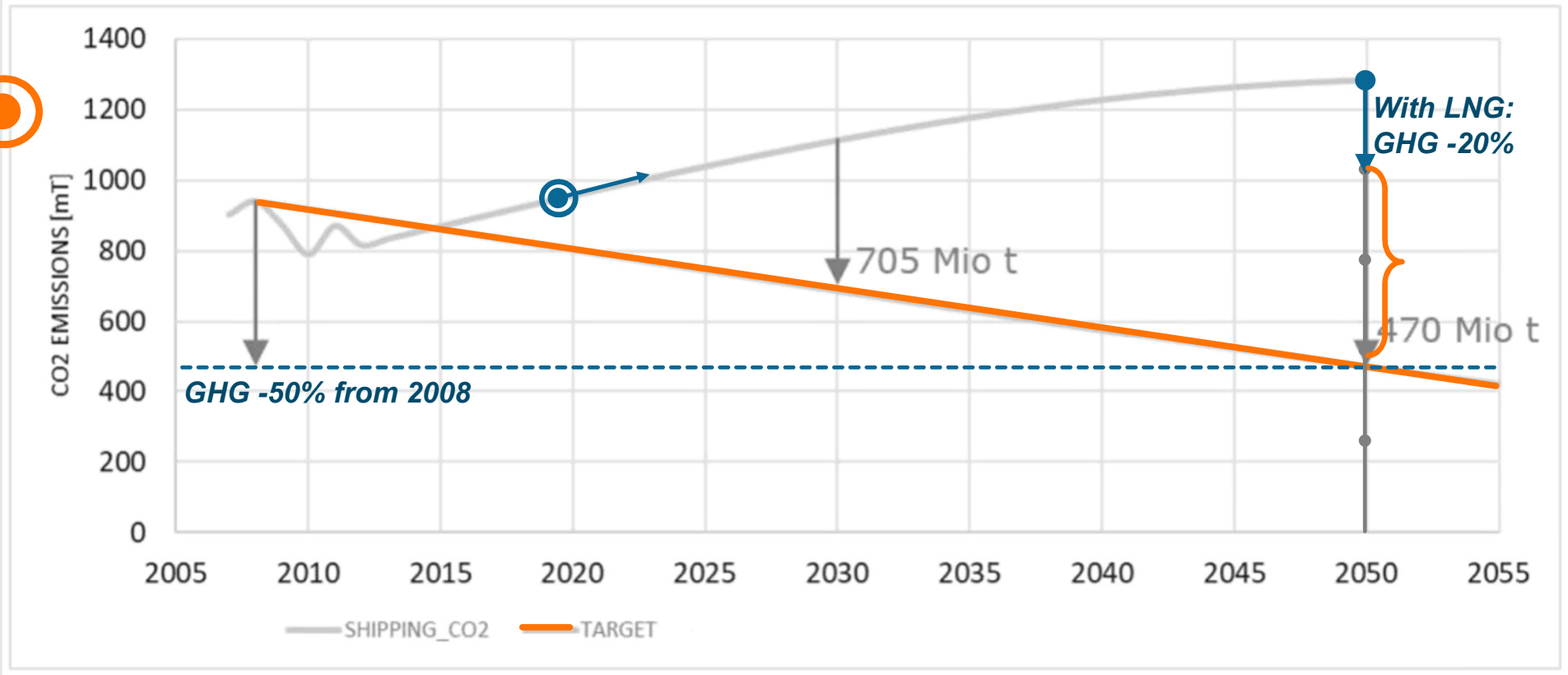
Storage tank
configuration & trend

IGF code* (2016)
for regulation of the Fuel Gas Supply System

Operational aspects
Gas supply
BOG management
Bunkering

*) The International Code of Safety for Ships using Gases or other Low-flashpoint Fuels (IGF Code)

International Maritime Organisation (IMO) strategy 2050



https://www.lr.org/en/insights/articles/imo-ghg-strategy-what-does-it-mean/, 16.4.2018

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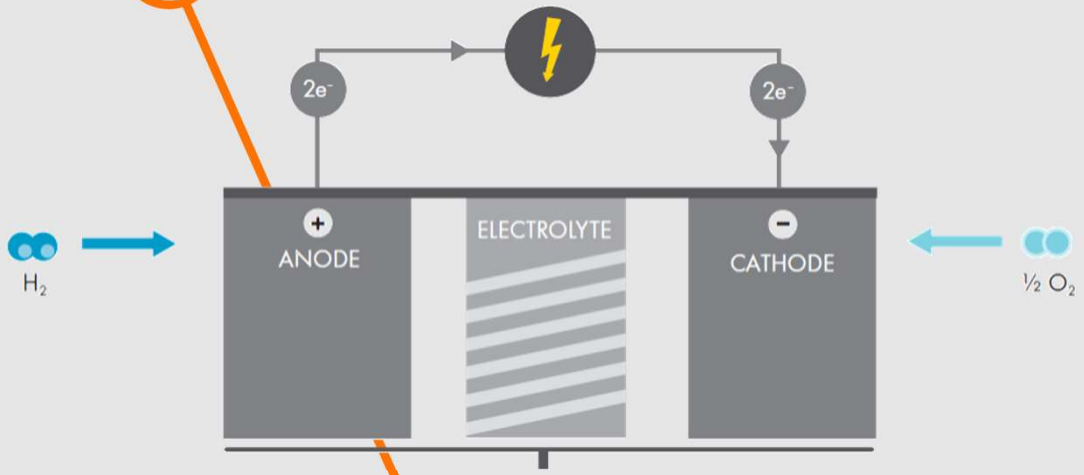
Reduced GHG emissions with improved shipping efficiency

Exhaust gas cleaning – local emissions
Improved efficiency: propulsion | power generation | hull design
Smart Marine Systems: navigation | smart operations | recovery of waste stream
Alternative fuels: LNG | carbon-free fuels | carbon-neutral fuels

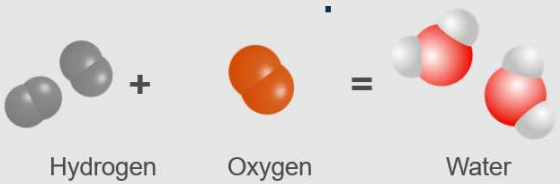
PROPULSORS | BALLAST WATER MANAGEMENT | COMPRESSORS | DYNAMIC POSITIONING | OIL SEPARATION | PROJECT MANAGEMENT | POWER ELECTRIC SYSTEMS | AUTOMATION
ENGINES & GENERATING SETS | ENTERTAINMENT | EXHAUST GAS CLEANING | GAS SYSTEMS | PUMPS & VALVES | SAFETY & SECURITY | SEALS, BEARINGS & STERNS TUBES | SERVICES
GEARS | INERT GAS | INTEGRATED SOLUTIONS | MARINE LIFECYCLE SOLUTIONS | NAVIGATION | SHIP DESIGN | SONAR & SENSORS | WASTE & FRESH WATER MANAGEMENT

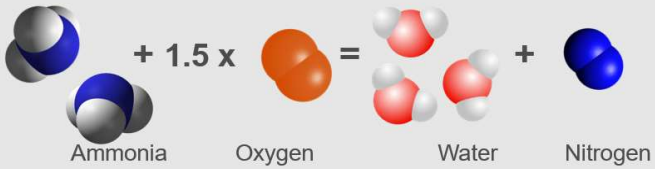
Carbon-free fuels | H2 & Ammonia

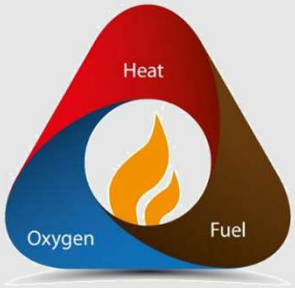


Only steam.
No local emissions.

No GHG emissions from tank-to-wake, but from well-to-tank?





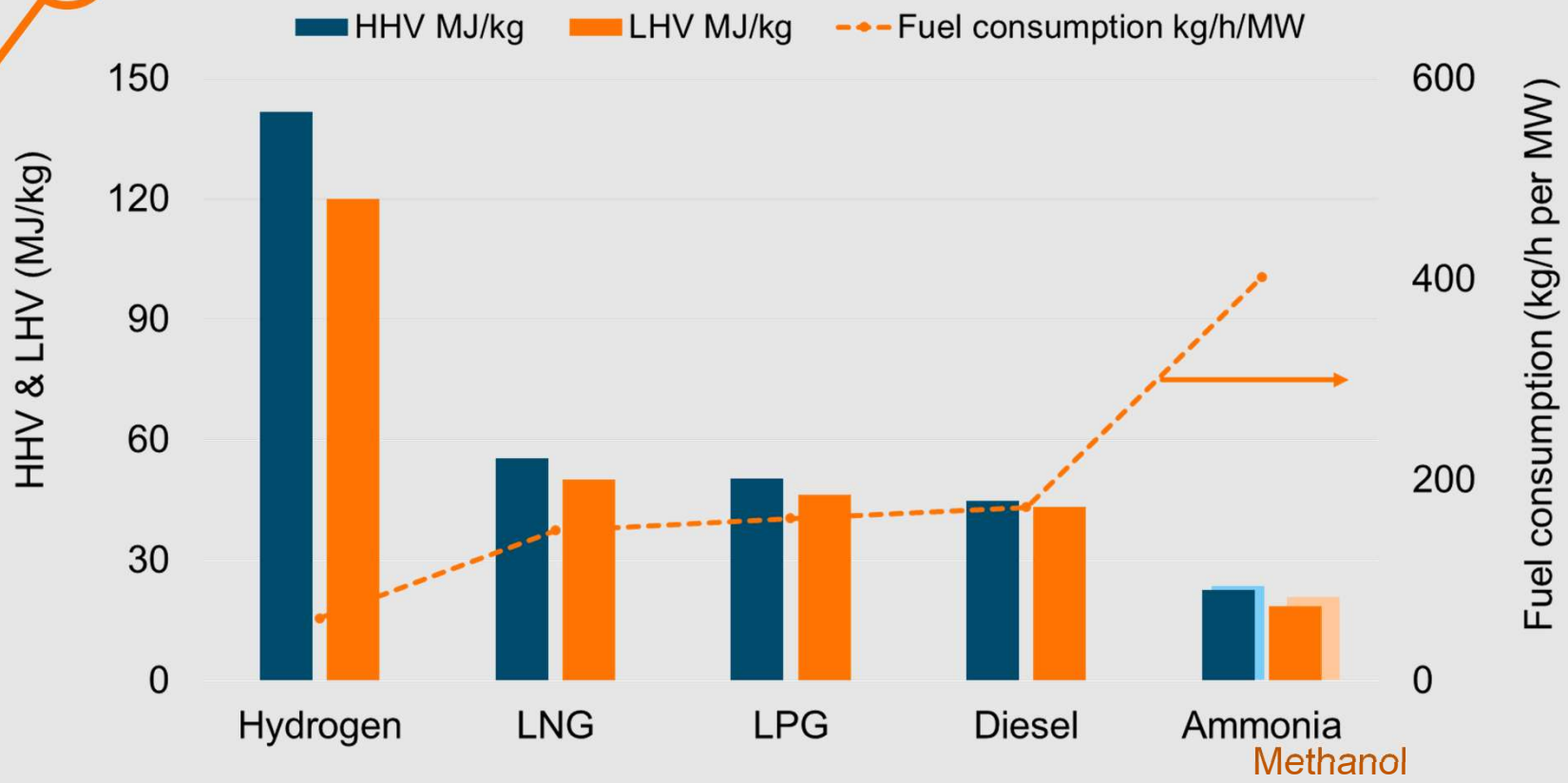


Operational hazards

Cryogenic fuels | LNG/LH2
Compressed fuels| CNG/C-H2

Storage & handling	LNG	LH2	CNG	C-H2	Ammonia (NH3, liq)
Temperature (°C)	-163	-253	25	25	25
Pressure (bar a)	1	1	200...250	300...700	10
Density (kg/m3)	420...480	70,8	180...215	20...40	683
Flammability LFL-UFL	5-15%	4-75%	5-15%	4-75%	15-25%
Safety hazards	• Cryogenic spillover, flashing • Heat ingress and pressure build-up		• Pressurised tank	• Pressurised tank • Top-deck	• Hazardous chemical, with strong odor
Other	• Heavier than air at below - 83 C • Bunkering well-known • IGF code in place	• Lighter than air - dissipates • Max 600 m3/tank =1400 MWh/tank	• Lighter than air – dissipates • Limited tank volumes	• Lighter than air - dissipates • Max 152 kg/tank = 5 MWh/tank	• Lighter than air – dissipates • Bulk chemical for fertiliser industry • Comparable to methanol
LNG: 2 x 600 m3 & 10 MW = 15d		**LH2:** 2 x 600 m3 & 10 MW = 7d		**C-H2:** 10 x 152 kg & 10 MW = 3h	

LHV and fuel consumption



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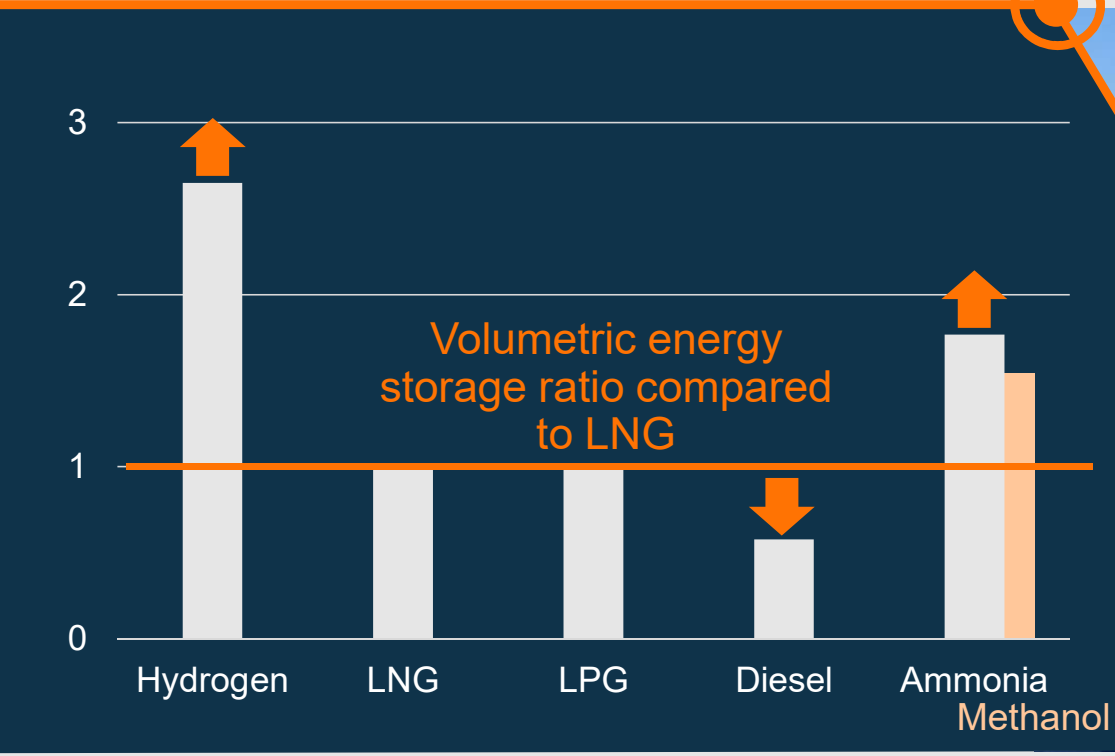
Storage space



Volumetric energy storage ratio of liquid fuels |

Conclusions

LNG operations
are well known today:
also in varying conditions,
abnormal situations

LH2
comes with high
operational challenges and CAPEX

Ammonia
is a non-cryogenic fuel
and can be bunkered without any
remarkable boil-off losses throughout its pathway

| type & efficiency of consumers | easy implementation | rules and regulations | drivers

Emissions in two categories

Category 1:
Local emissions

CARBON-FREE
H2, NH3

- Mainly NO_x, SO_x and particulates
- Health & environment related
- Short term impact
- Local effect

Category 2:
GHG emissions

CARBON-NEUTRAL
Biogas, Power-to-X

- Mainly CO_2 and CH_4 (methane)
- Contribute to global warming/ climate change
- Long term impact
- Global effect

LNG is a key enabler towards cleaner shipping

- Cutting Local and GHG Emissions
- Providing an infrastructure and the pathway for renewable fuels
- Blending with LBG and P2X fuels

H2 & NH3 – 95% from fossil source
LBG – liquefied biogas
P2X – Power-to-X, synthetised methane

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Towards Zero Emission Shipping by 2050

Renewables in every tank by 2025

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