TNO innovation for life

REDUCTION OF EMISSIONS AND UNDERWATER RADIATED NOISE FROM SHIPS

CHRIST DE JONG & JAN HULSKOTTTE

EMISSION REDUCTION MEASURES

$$gCO_2 = \overbrace{\underbrace{\frac{gCO_2}{MJ}}_{\text{carbon intensity of energy carrier}} \times \underbrace{\frac{MJ}{v.nm}}_{\text{ship efficiency}} \times \underbrace{\frac{v.nm}{ton.nm}}_{\text{load factor}}}^{CO_2 \text{ intensity of shipping}} \times \overbrace{\underbrace{\frac{ton.nm}{ton}}_{\text{transport distance}} \times \underbrace{\frac{ton}{product}}_{\text{product characteristics and packaging}} \times \underbrace{\#products}_{\text{volume of production}}}^{\text{transport demand}}$$

- C-containing fuels: HFO, MGO, methanol - Less C: LNG - **New** Non-C containing fuels: H2, NH3, (syn-fuels)	- Engine efficiency - Hull resistance - Propeller efficiency - Speed - Routing - Weather - Trim - Maintenance	- Optimal ship size (load-distance) - Harbor and ship lanes depth - Logistics optimization	- Price differences of materials and end-products vs. transport price - Historical regional production capacity	Bulk transport versus unitized (boxes in boxes)	- Regional population and income - Regional demand of products and semi-products

EMISSION REDUCTION MEASURES

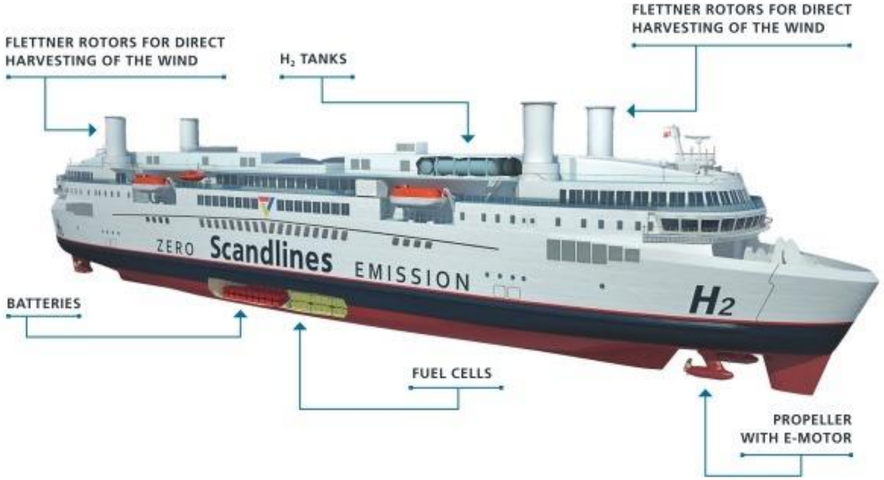
CONCLUSION

- Total emissions depend on properties of shipping as well as on transport demand

- For a given transport demand, emission reduction can be achieved by:
  - Alternative energy carriers and power generation,
  - Energy efficiency and aftertreatment,
  - Operations and logistics.

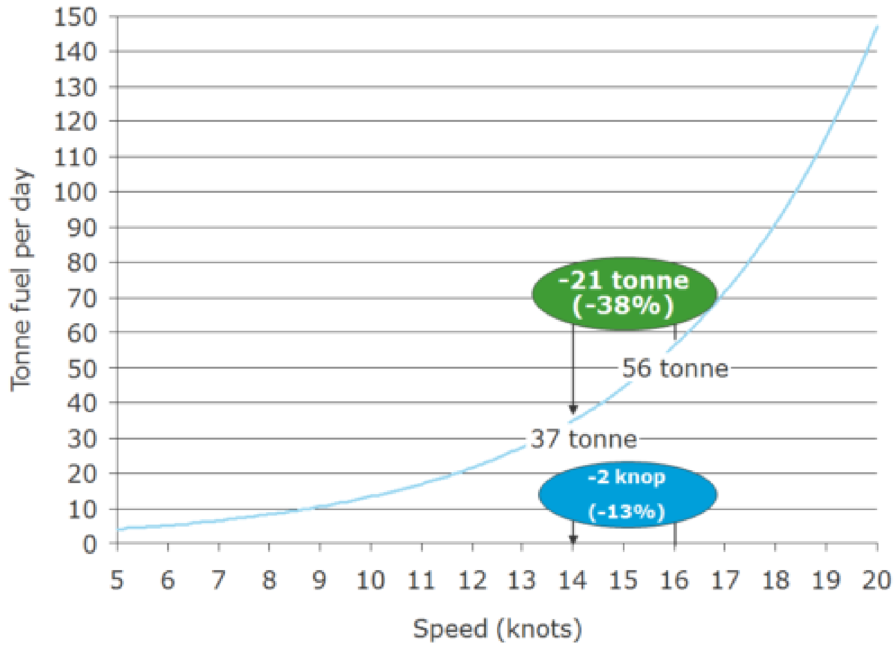
ENERGY EFFICIENCY AND AFTERTREATMENT

- Improvement of frictional resistance of the vessel
  - Antifouling and low friction hull coating
  - Hull air lubrication
  - Hull design
- Improvements of the ship propulsion system
  - Propulsion improving devices (PIDs)
  - Wind assistance (kites, sails, Flettner rotors)
- Emission control systems
  - in-engine control
  - aftertreatment (catalysts, scrubbers, filters etc.)



https://www.marineinsight.com/green-shipping/top-5-zero-emission-ship-concepts/

OPERATIONS AND LOGISTICS



- Slow steaming
  - Reduces fuel consumption and hence emissions and costs
  - *A speed reduction of 10% results in a fuel (for propulsion) saving of approximately 19%*
  - Can be facilitated by data exchange enabling ‘Just-in-time sailing’

- Application of monitoring tools
  - sensors and engine room related monitoring systems can record how the ship's propulsion and energy system are functioning and give advice on the optimized speed an engine load given the nautical conditions

REDUCTION OF EMISSIONS BY SLOW STEAMING

- North Sea Slow Steaming Scenario (speed limit at 75% of design speed)
- Reduction of emission of greenhouse gasses and pollutants

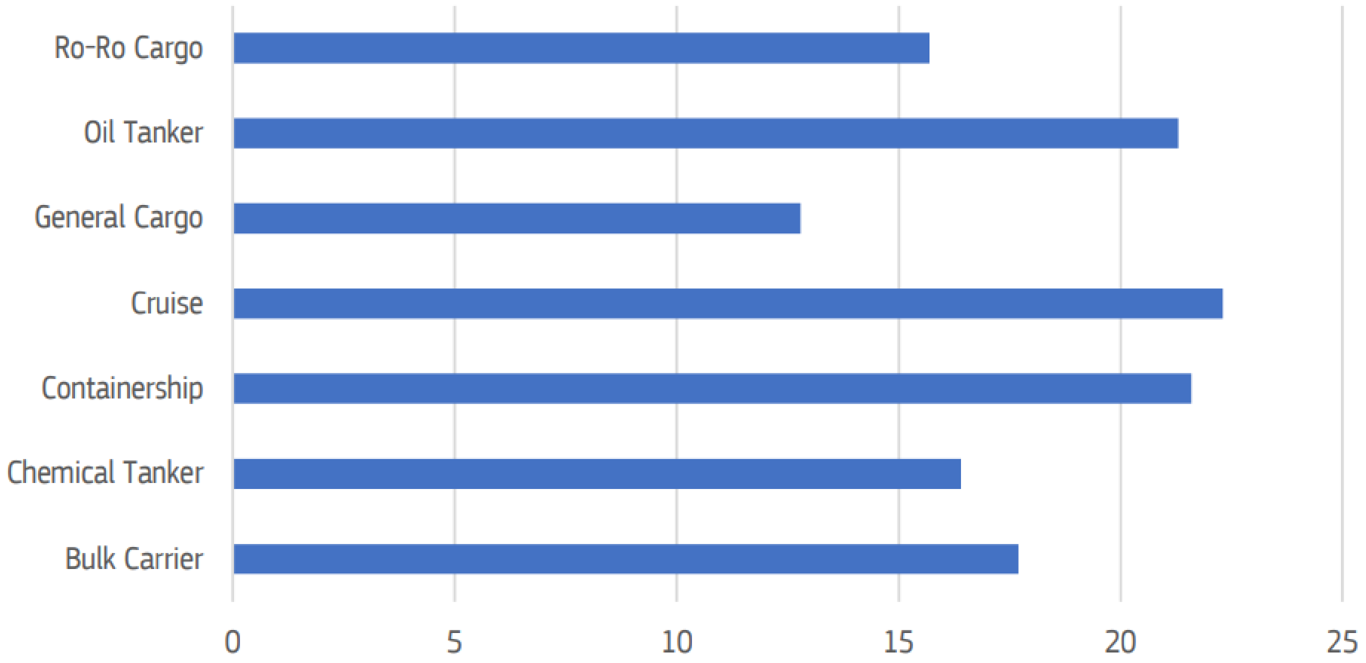
Table 1 Calculated yearly reductions of emissions for the proposed slow steaming scenario at the North Sea (based on data of May 2019

Substance	CO2	NOx	SOx	CO	PM10	VOC
Reference scenario	17768	357	16,1	21,7	7,4	17,1
Slow Steaming	15960	318	14,5	22,4	6,7	16,3
Reduction (kilotons/year)	**1808**	**38**	**1,6**	**-0,8**	**0,7**	**0,8**
Reduction %	**10%**	**11%**	**10%**	**-3,5%**	**10%**	**5%**

- Remark: PBL NECA-study 2009: 472 kton emission of Nox on North Sea in2009)

VESSEL SPEEDS WERE REDUCED ALREADY BEFORE 2019

Figure 25: Weighted average speed reduction in the monitored fleet 2008-2018 (%)

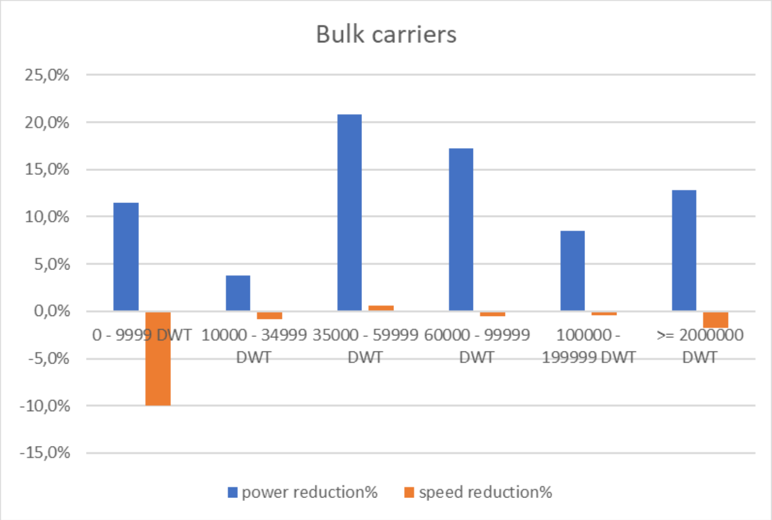


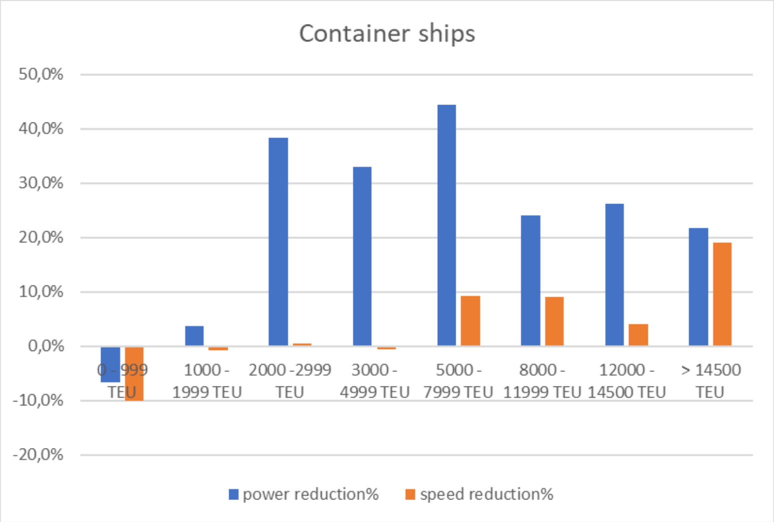
Source: Elaborations based on THETIS-MRV (Data extracted on 23 September 2019) and the 3rd IMO GHG Study.
Notes: Averages are based on the speed reduction for each ship type, weighted for different size segments. Ship categories selected on basis of data availability.

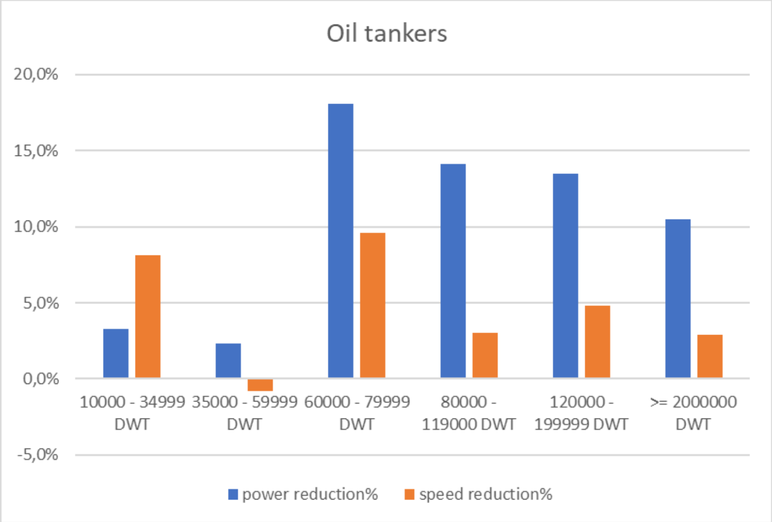
Source : 2019 Annual Report on CO2 Emissions from Maritime Transport; European Commission SWD(2020) 82 final

VESSEL SPEEDS WILL DECREASE EVEN MORE

Graphs show comparison of speed and power of vessels with age between 5-10 year, compared to 0-5 year







Source : 2019 Annual Report on CO2 Emissions from Maritime Transport; European Commission SWD(2020) 82 final

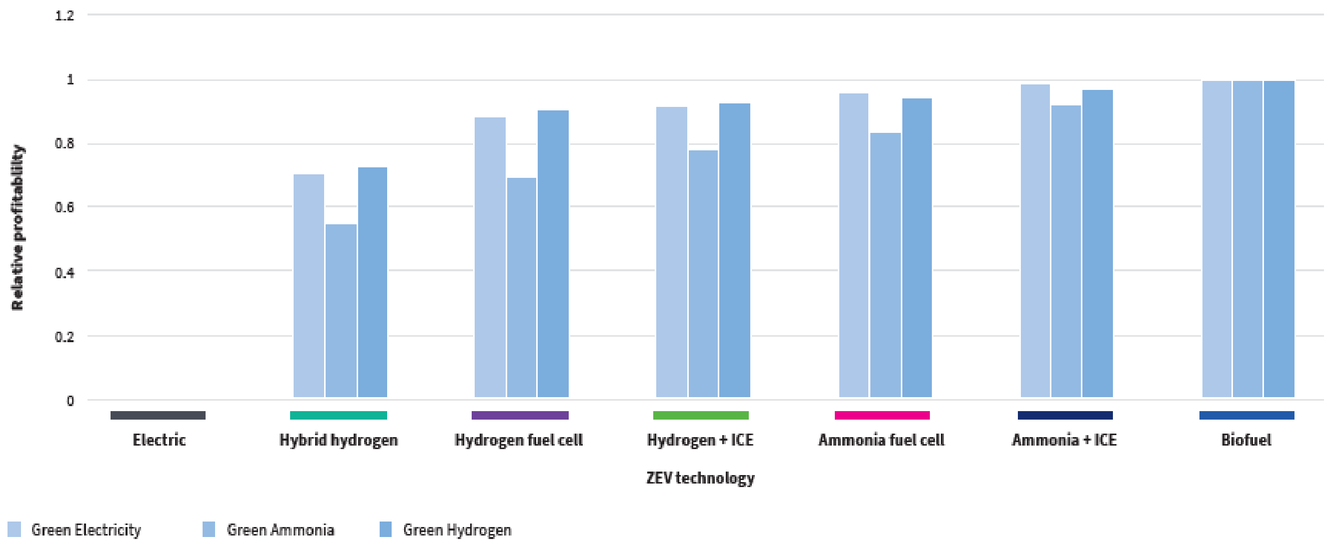
- Graphs show that propulsion power of all vessel categories has been reduced rather strongly
- Design speeds of container ships and oil tankers are still being reduced but not as strongly as propulsion power
- EEDI phase III by 2030 probably will cause even stronger reduction of propulsion power

ALTERNATIVE ENERGY CARRIERS AND POWER GENERATION

‘ZERO EMISSION VESSEL‘ TECHNOLOGY

- Internal combustion engines with sustainable biofuels and synthetic fuels (e.g. ammonia, hydrogen, methanol)
- Electrical engines powered by fuel cells (ammonia, hydrogen), or batteries → *quieter*

Profitability of ZEV technologies relative to heavy fuel oil, from [Lloyds, UMAS, 2017]



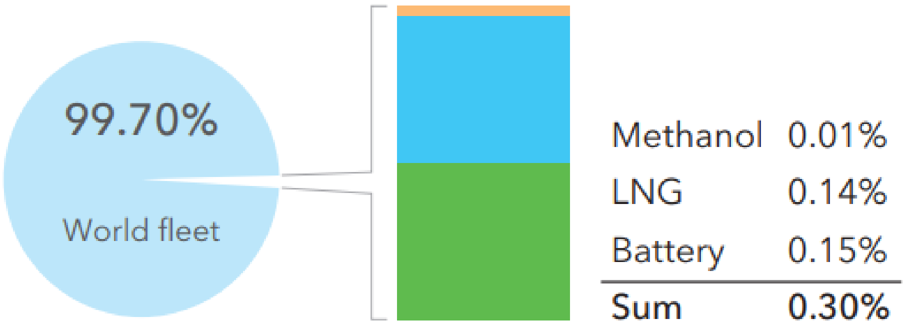
To be balanced against emissions for production of synthetic fuels or electrical power generation

CHANGE OF ALTERNATIVE FUELS HAS STARTED ALREADY

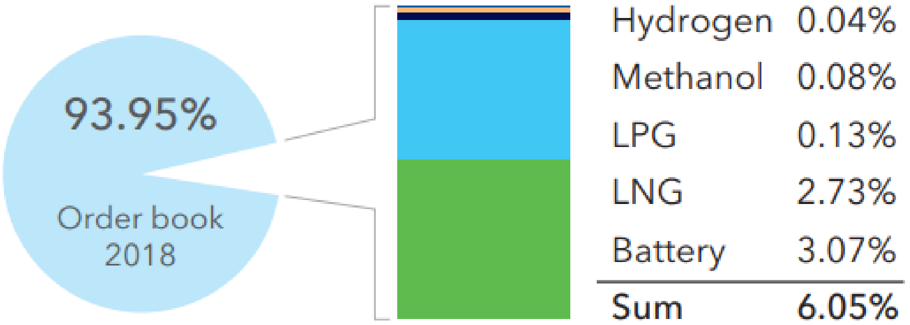
Alternative fuel uptake (percentage of ships)[a]

Ships in operation

Ships on order



Methanol	0.01%
LNG	0.14%
Battery	0.15%
Sum	0.30%



Hydrogen	0.04%
Methanol	0.08%
LPG	0.13%
LNG	2.73%
Battery	3.07%
Sum	6.05%

[a] Source: DNV GL's Alternative Fuels Insight (AFI) portal, https://www.dnvgl.com/services/alternative-fuels-insight-128171

Source : Energy Transition Outlook 2019: Maritime Forecast to 2050; DNV-GL

POTENTIAL CO-BENEFITS OF REDUCING URN FOR ENERGY EFFICIENCY AND EMISSION REDUCTION

- In general, all measures taken to reduce propulsion power and propeller thrust loading are beneficial for energy efficiency, emission reduction and underwater radiated noise reduction.
- Design measures to reduce propeller cavitation will reduce underwater radiated noise and will to some extent also increase energy efficiency, and reduce emissions.
  - but propeller designs optimized for cavitation reduction are generally not the most energy efficient.
- Speed limits (‘slow steaming’) have a potential to be effective to control shipping underwater noise as well as energy efficiency and emission reduction
  - but different ship types have different optimum speeds and not all ship types can slow down to the same extent.

THANK YOU FOR YOUR ATTENTION

TNO innovation for life

Commissioned by

federal public service
HEALTH, FOOD CHAIN SAFETY AND ENVIRONMENT

.be BELGIË

In cooperation with

Royal Belgian Shipowners' Association

FOD MOBILITEIT EN VERVOER
SPF MOBILITÉ ET TRANSPORTS

ocean care

ifaw
International Fund for Animal Welfare

Special thanks to

otary

PARKWIND

C-Power

museum
Operational Directorate Natural Environment
OD Nature | OD Natuur | DO Nature