Cleaner Fuels in shipping or are Climate and Cost better off with HFO & Scrubbers

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THIS STUDY HAS BEEN FINANCED BY SFI SMART MARITIME

NORWEGIAN CENTRE FOR IMPROVED ENERGY EFFICIENCY AND REDUCED HARMFUL EMISSIONS FROM THE MARITIME SECTOR.

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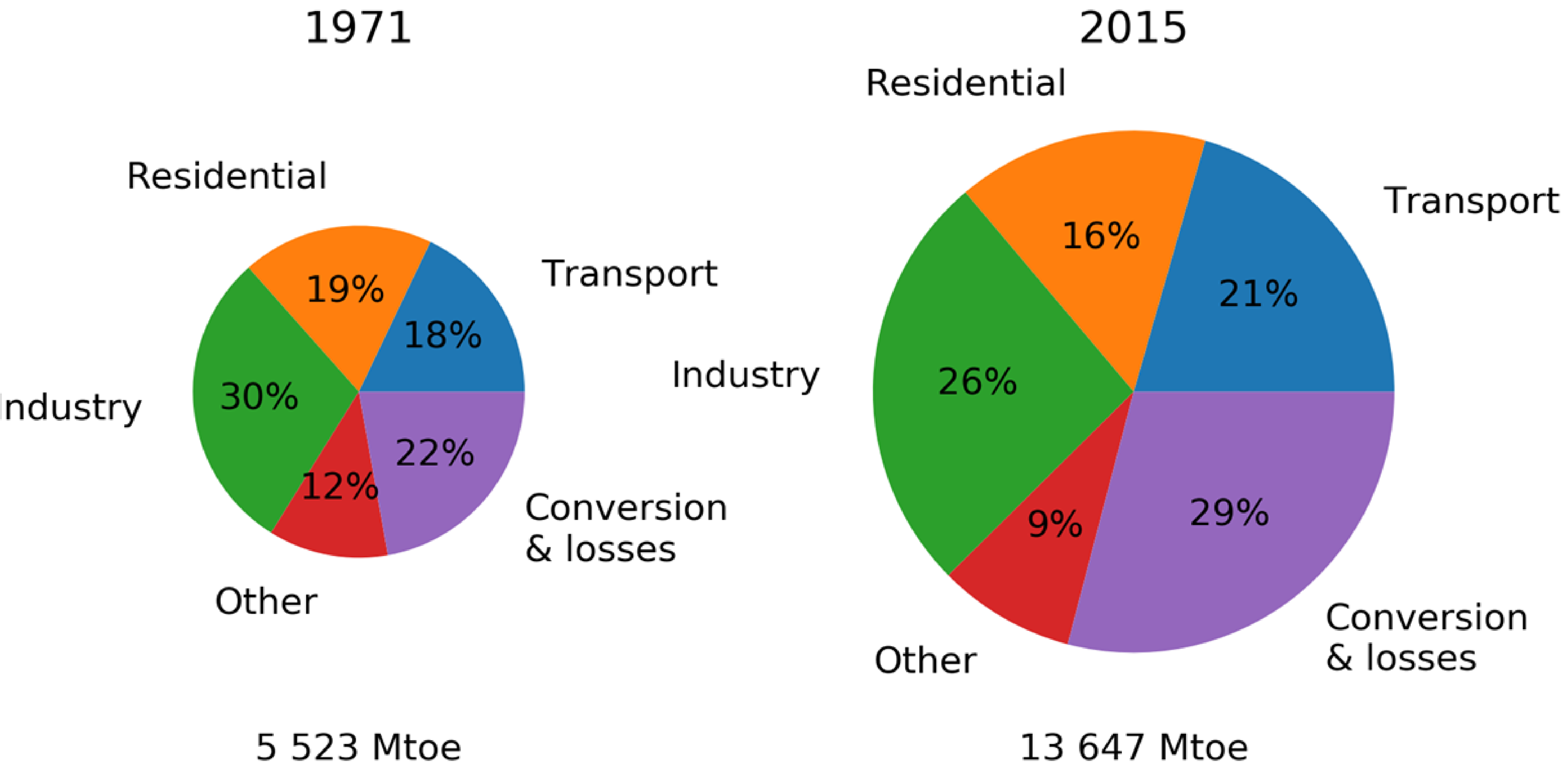
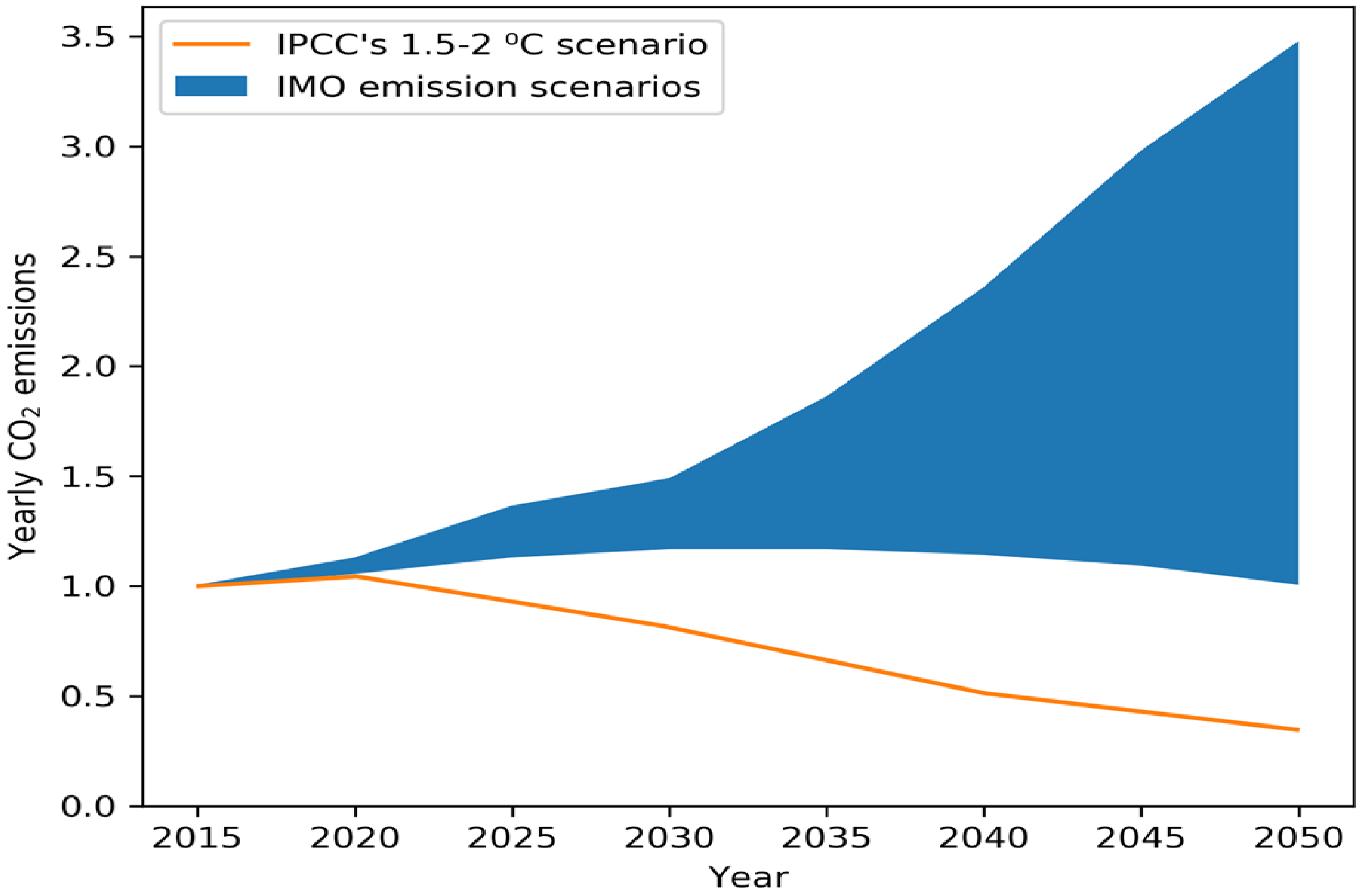
Background

- The environmental consequences of increased maritime transport due to globalization have become important due to its impact on local pollution and climate change.
- This environmental impact is (mainly) caused by the exhaust gas from the ship's combustion engines.
- The first regulation of exhaust gas in the late 1990-ties , was not strict.
- The global 2020 cap on maximum 0.5 % sulphur in the exhaust gas, combined with the required NOx and CO2 reductions for new-built vessels, is an economical and technical challenge for the shipping industry.
- Alternative fuels such as LNG, LPG, Methanol or Hydrogen is one tempting option for meeting these new requirements.

World Energy Consumption 1971 – 2015 Source: www.iea.org



Development of shipping emissions up to 2050 for 16 different scenarios developed by the Third IMO GHG study



Source: Smith et al. (2014) and IPCC (2013)

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Sulphur abatement globally in maritime shipping

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Environmental regulations in shipping: Policies leaning towards globalization of scrubbers deserve scrutiny

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Maritime shipping and emissions: A three-layered, damage-based approach

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State-of-the-art technologies, measures, and potential for reducing GHG emissions from shipping – A review

Evert A. Bouman[a,*], Elizabeth Lindstad[b], Agathe I. Rialland[b], Anders H. Strømman

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Economic savings linked to future Arctic shipping trade are at odds with climate change mitigation

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Energy Policy
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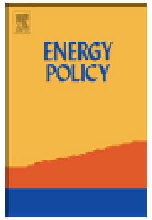


Reductions in greenhouse gas emissions and cost by shipping at lower speeds

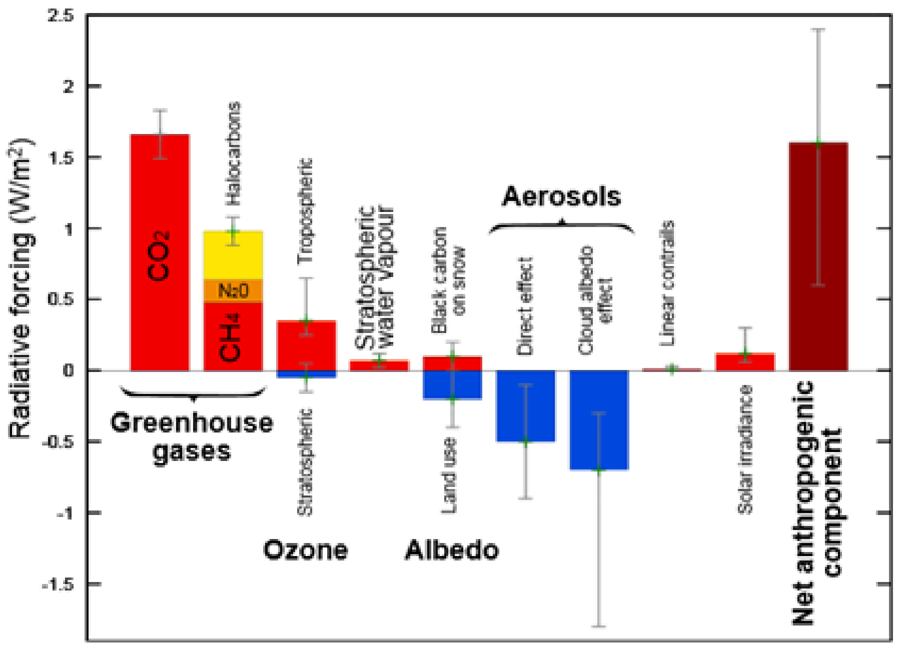
Life-Cycle Assessment (LCA)

- Studies of alternative marine fuels have used both simplified and more advanced life-cycle assessment (LCA) methodology
- LCA enables the evaluation of a product environmental performance throughout its whole life cycle, i.e. raw materials extraction, production, usage and final disposal.
- LCA presents a holistic overview and it enables us to identify the most relevant environmental impacts.
- LCA helps to avoid potential shifting of environmental impacts between the different phases of a product’s life cycle, or from one environmental impact to another

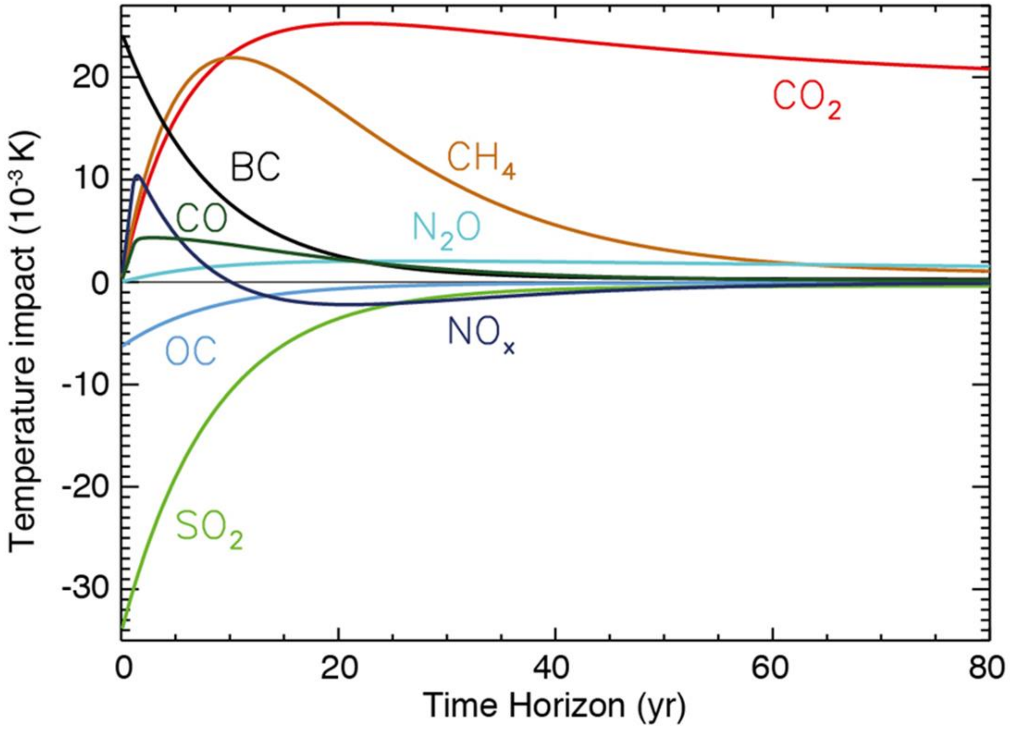
The fuel and abatement options considered in this study are

- Heavy fuel oil (HFO) with a maximum sulphur content up to 3.5%.
- Desulphurised HFO, i.e. LSHFO<0.5%S and 0.1 %S
- HFO in combination with an exhaust gas scrubber to comply with sulphur caps
- Marine gas oil (MGO), which is a diesel with a maximum sulphur content of 0.1%.
- Biodiesel or Biogas produced from crops or waste materials.
- Liquid Natural Gas (LNG) in combination with diesel dual-fuel engines.
- Synthetic diesel (GTL), Methanol and Hydrogen all produced from natural gas. Hydrogen produced from renewable sources such as wind or hydropower.
- Batteries charged from the land based grid.

The human contribution to climate change & mitigation is net effect of Greenhouses gases, Ozone, Water vapour, Albedo and Aerosols which means that focus has to be on more than CO_2 only reductions



Source: Leland McInnes based on IPCC Natural Drivers of Climate Change, Figure SPM.2, in IPCC AR4 WG1 2007.



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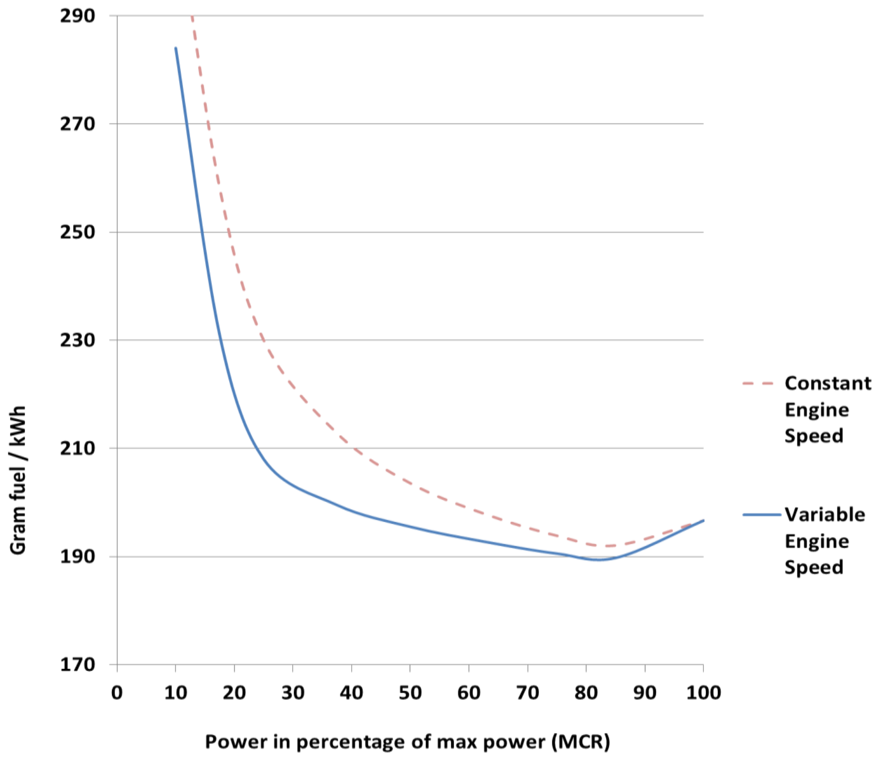
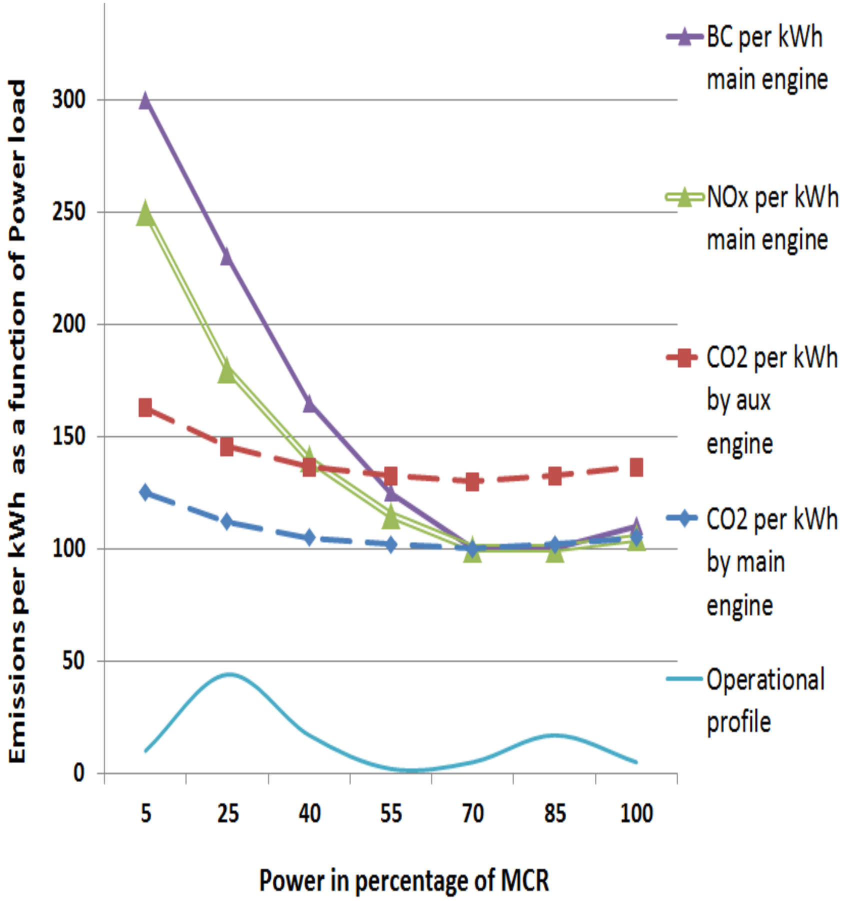
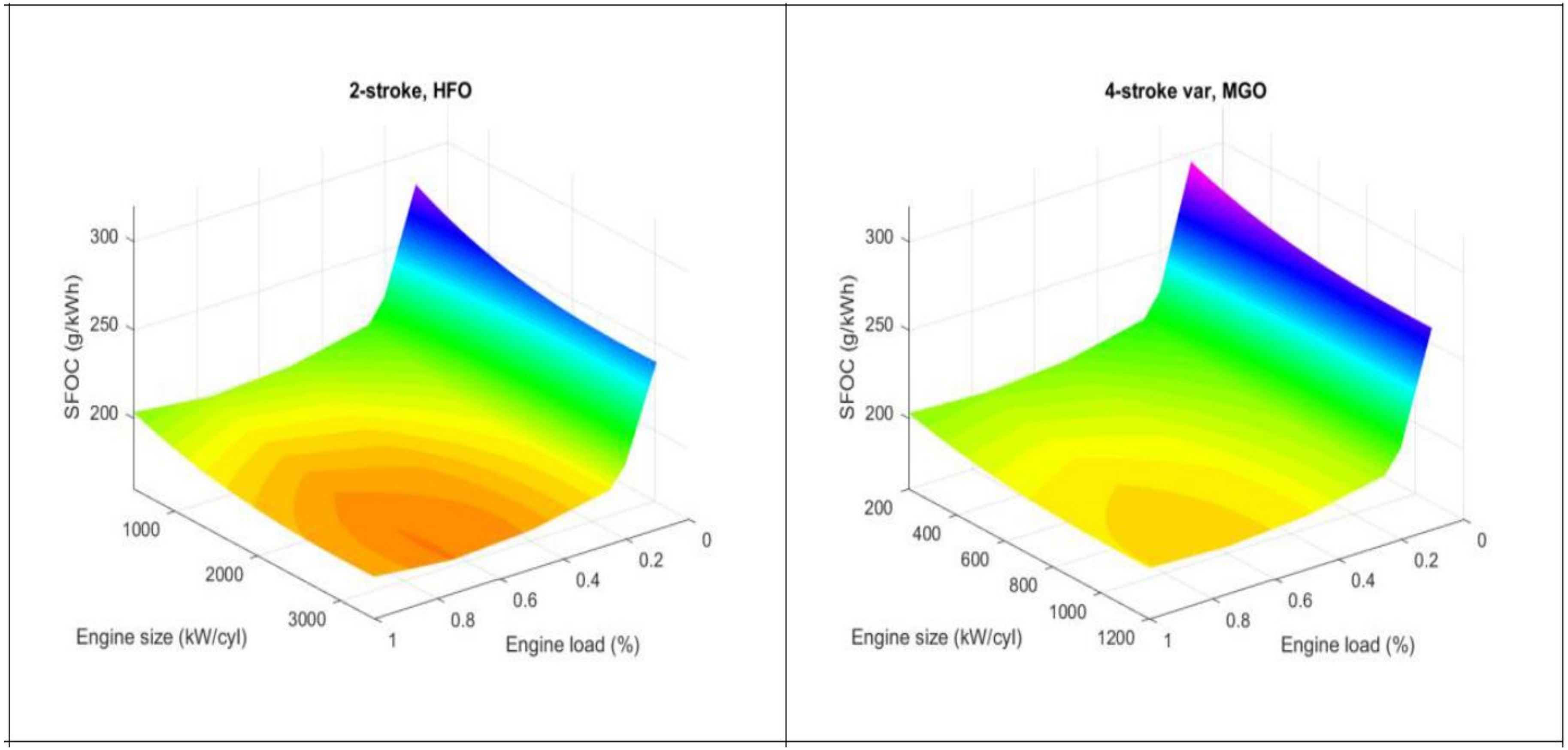
Modelling challenges Tank to wake emissions (TTW)

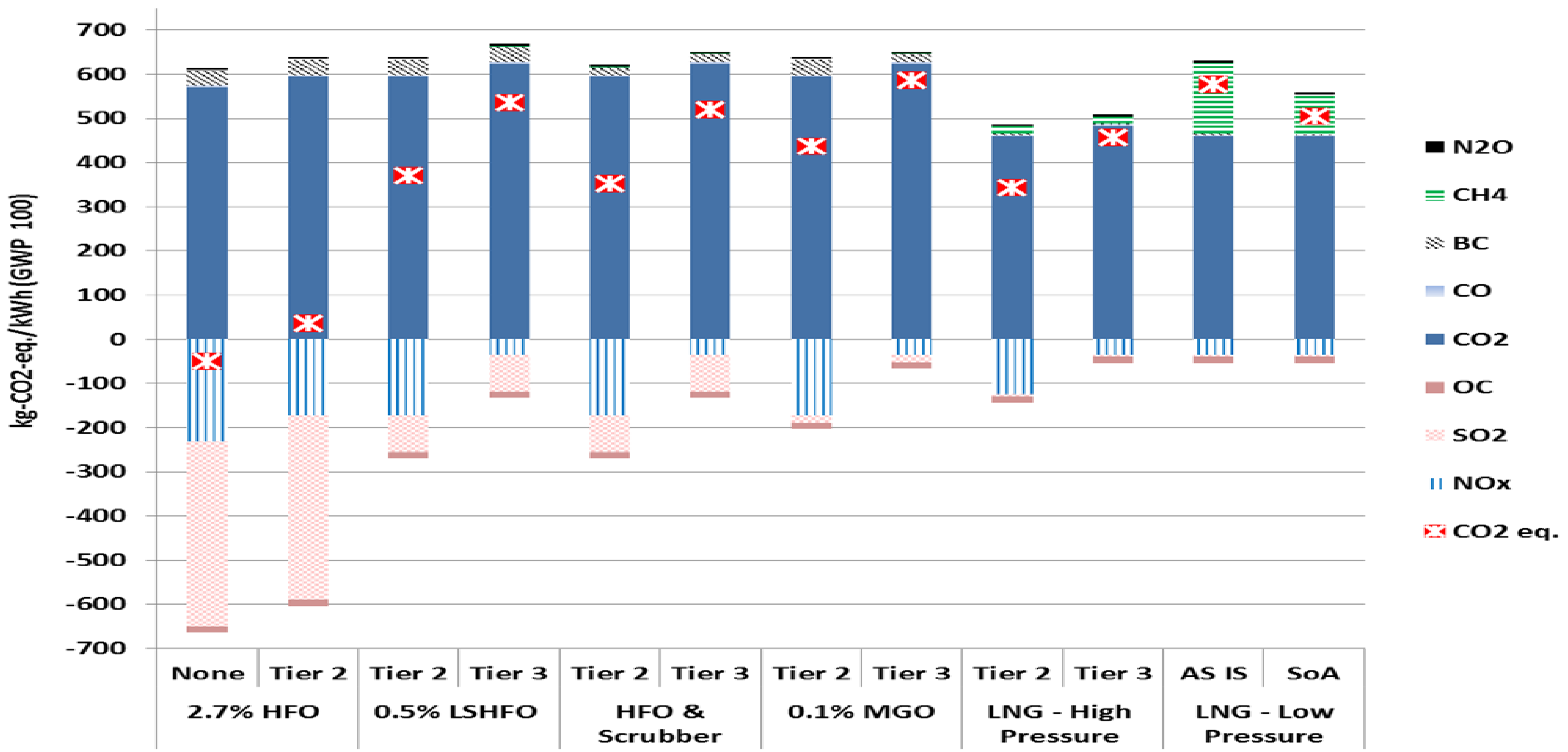




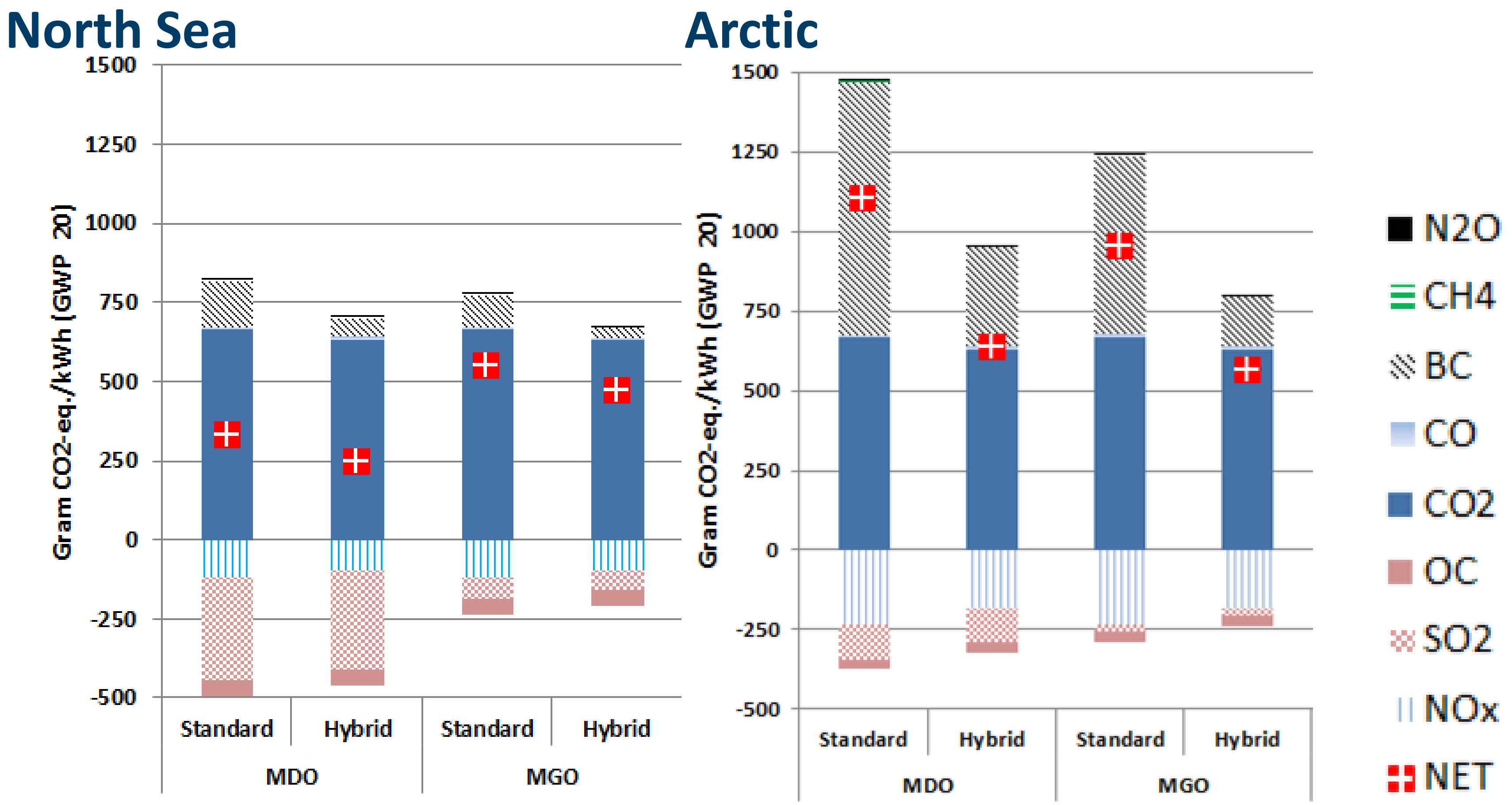
Global fleet - Modelling Fuel consumption and emissions as a function of engine specifics and engine (source: Ringvold et al., 2018)



Tank to Wake (TTW) emissions for fossil fuel used in shipping



The impact of the emissions depends on where a vessel operates

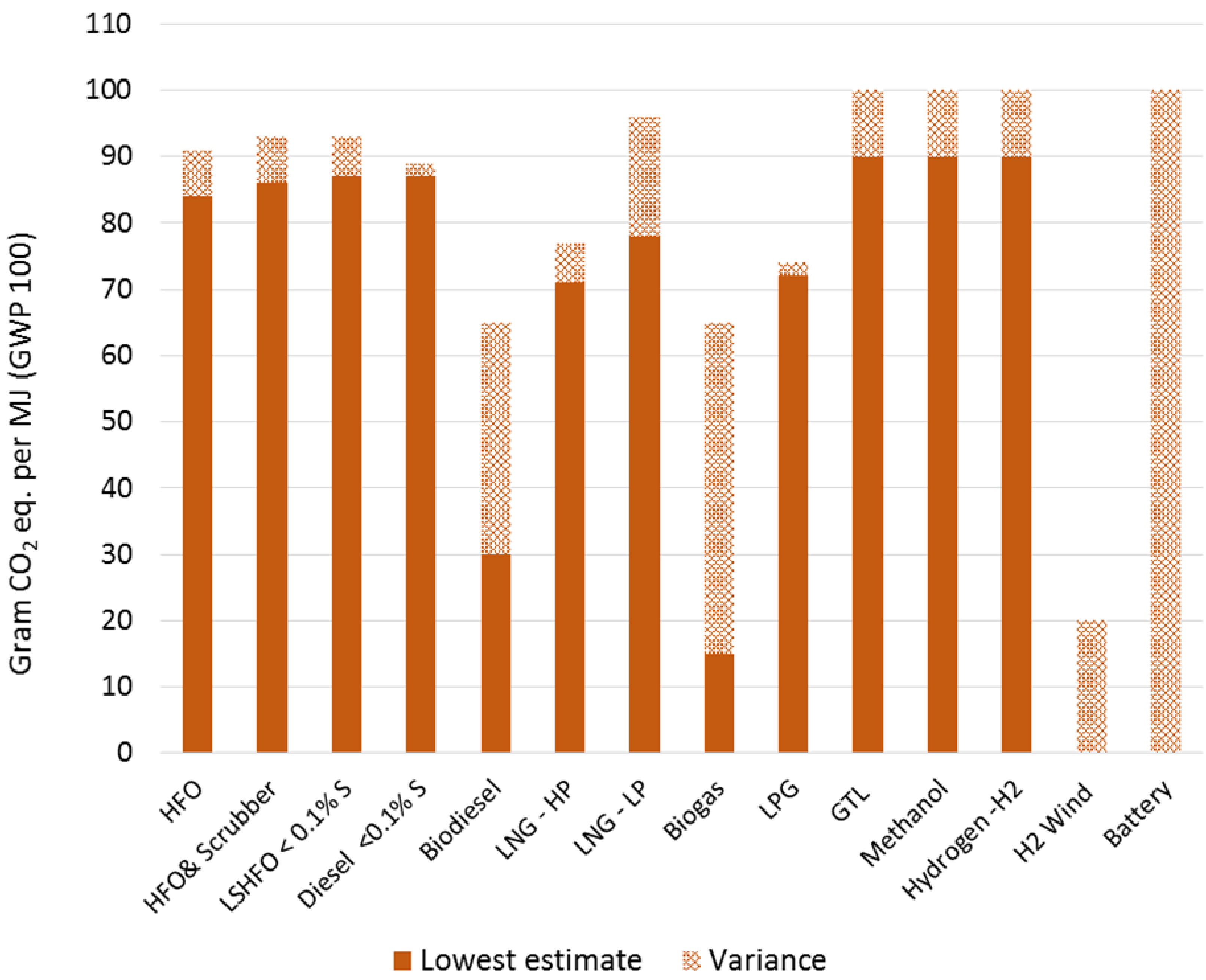


Source: Lindstad, H., E., Sandaas, I., 2016 *Emission and Fuel Reduction for Offshore Support Vessels through Hybrid Technology*. Journal of Ship Production and Design, Vol. 32, No. 4, Nov 2016, pp. 195–205

WELL TO WAKE EMISSIONS

- The well to wake (WTW) emissions of a vessel includes in addition to combustion (TTW) emissions the extraction or production, processing and the distribution of the fuel.
- While biofuels, hydrogen or electricity has no TTW emissions, the full amount of carbon oxide emitted during their production is included in their well to tank emissions.
- In addition to CO_2 emissions, two other greenhouse gases are generally included in the WTT emissions, i.e. methane CH_4 and nitrous oxide N_2O, which are converted into CO_2 equivalents.

Well to Wake (WTW) emissions for alternative versus traditional fuels in shipping



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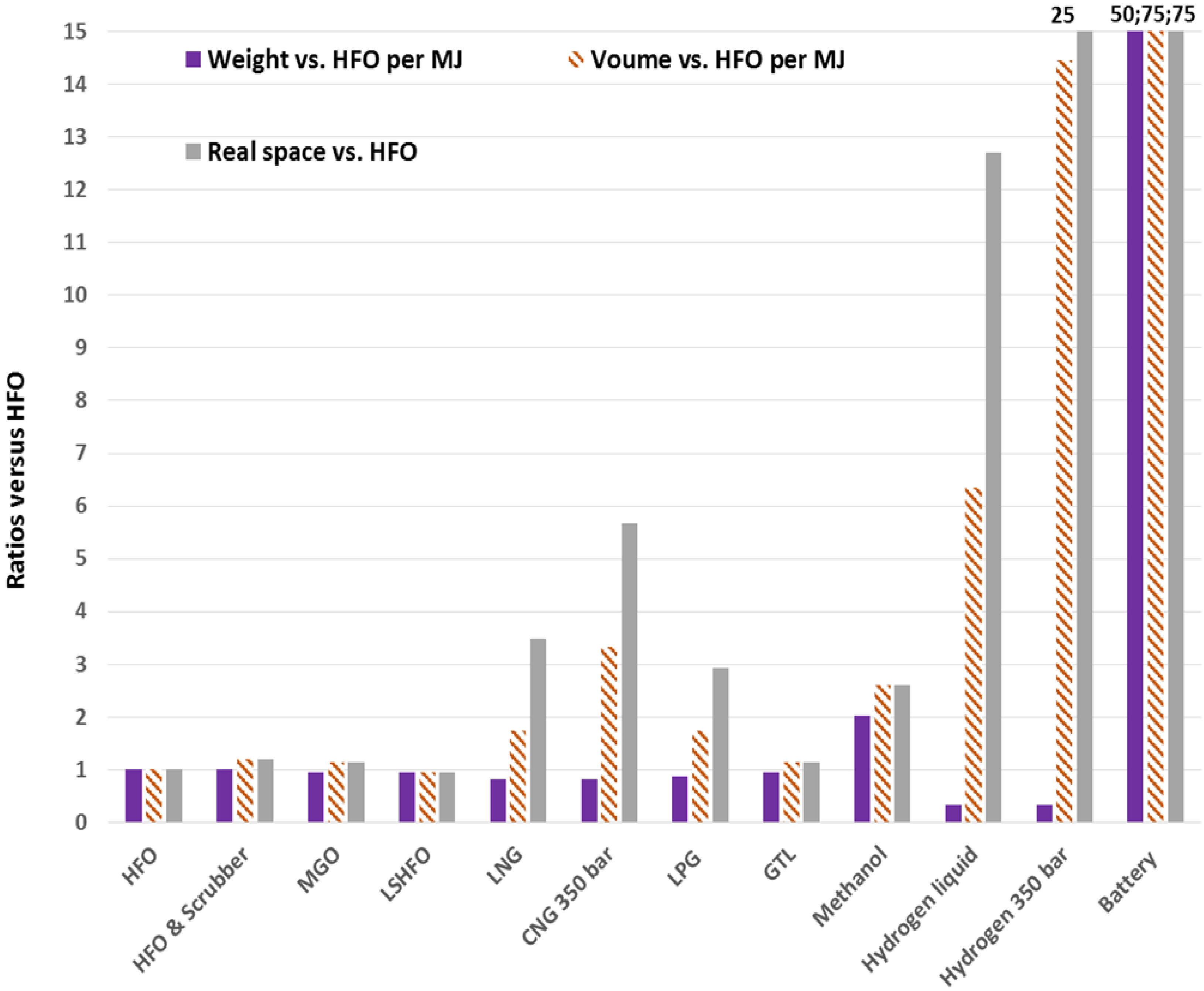
Space and weight requirements

for alternative fuels versus traditional fuels



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Macro Figures

- Total Oil 4 000 million tons
  - Total Residual 500 – 750 million tons
- Shipping consummes 300 million tons
  - 75 % of consumption is residual HFO
  - 23 % of consumption is distilate (diesel)
  - 2 % is LNG and other

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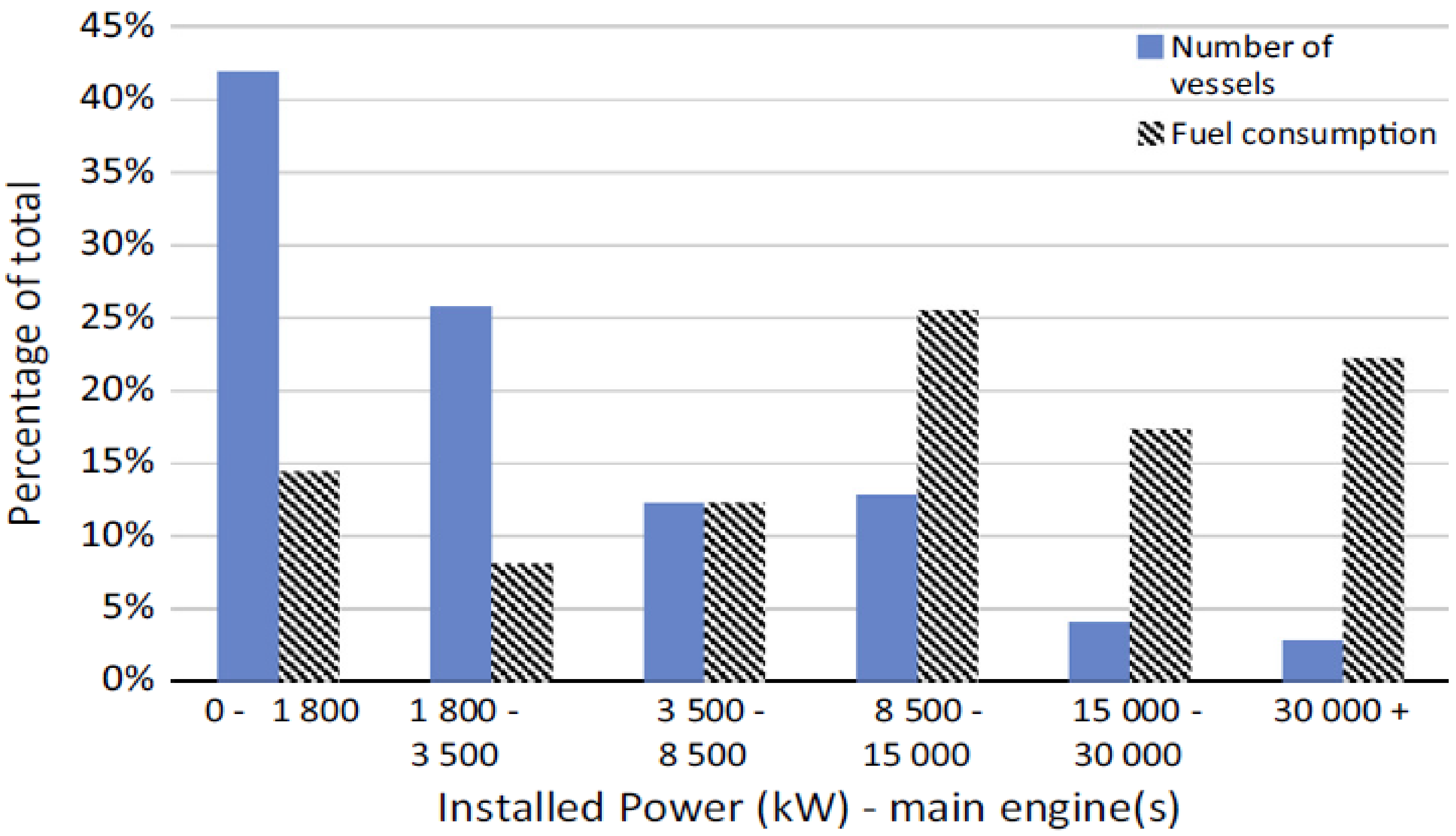
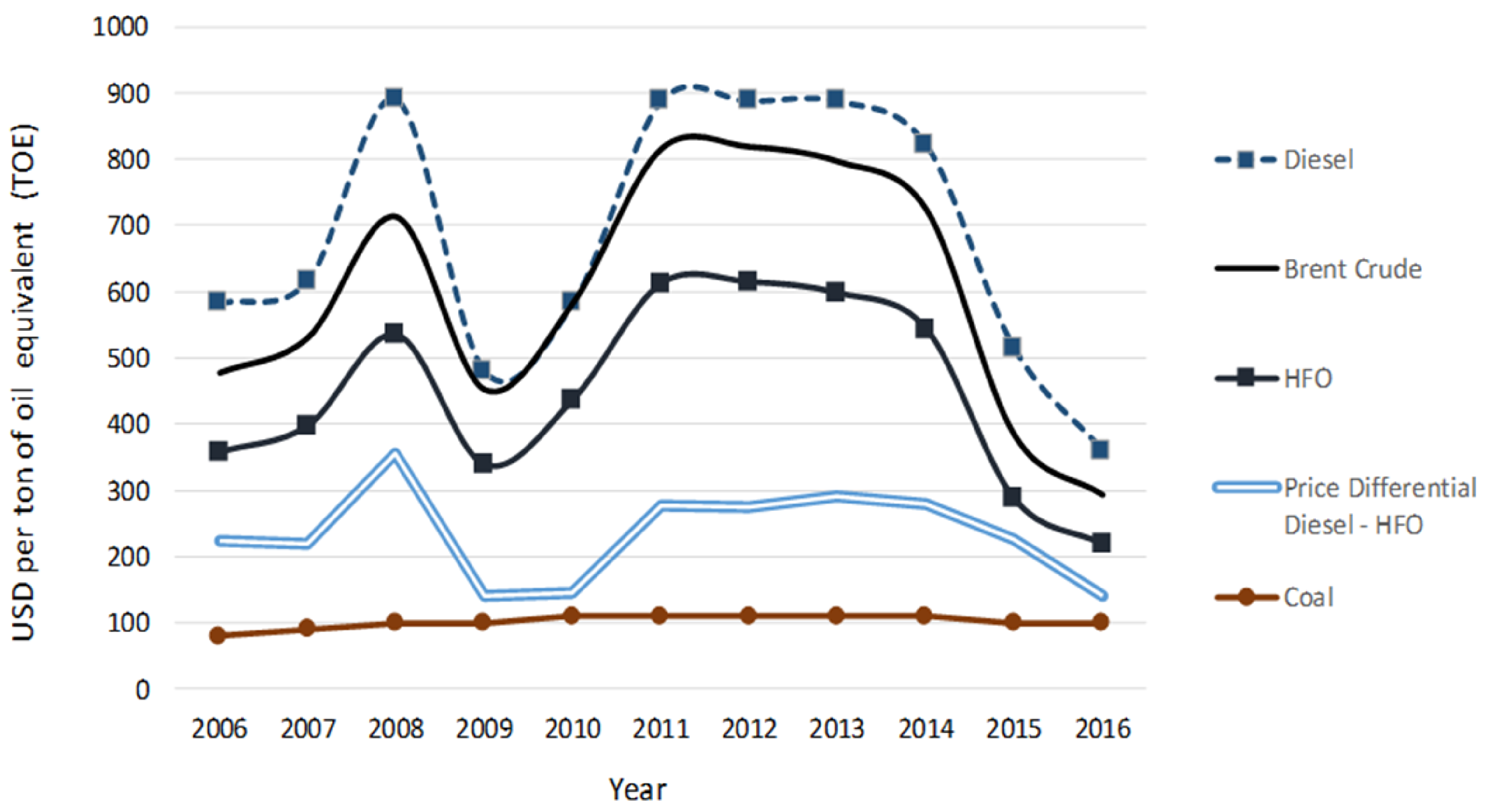
Number of vessels and bunker consumption as a function of installed power source: Lindstad and Eskeland 2016



Fuel prices per ton of oil equivalents (TOE) from 2006 to 2016 Source: Bunker World; US EIA; BP 2017; Lindstad and Eskeland 2016



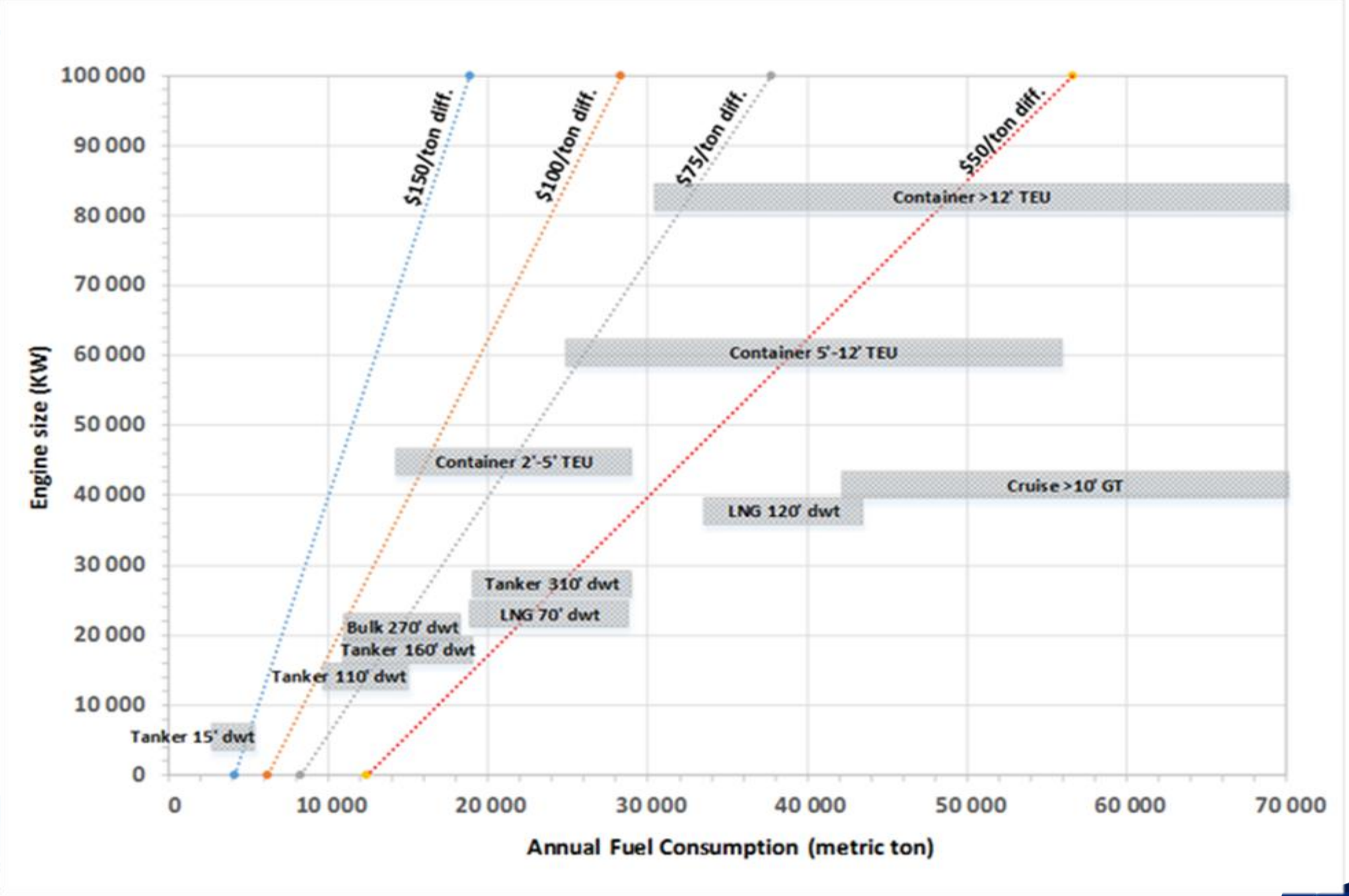
Cost for Fuel and Abatement all tons are Ton of oil equivalents

Fuel and Abatement Option	50 USD per barrel of crude oil	Price Increase compared to HFO	Basic Capex cost	Cost per 1000 kW installed power	Equipment and installation 2.5MW vessel	Equipment and installation 5MW vessel	Equipment and installation 10MW vessel	Equipment and installation 20MW vessel
	USD/ton	USD/ton	MUSD	MUSD	MUSD	MUSD	MUSD	MUSD
HFO	300	-	-	-				
LSHFO < 0.5% S	375	50 - 200	-	-				
Diesel	500	100 - 300	-	-				
HFO - Hybrid Scrubber	300	-	2.25	0.07	2.4	2.6	3.0	3.7
Gas on newbuilt LNG/LPG vessels		-	2.00	0.10	2.3	2.5	3.0	4.0
Methanol on newbuilt vessel			2.00	0.20	2.5	3.0	4.0	6.0
LPG - newbuilt vessel			2.00	0.30	2.8	3.5	5.0	8.0
LNG - newbuilt vessel		-	2.00	0.40	3.0	4.0	6.0	10.0
Hydrogen - newbuilt vessel		-	4.00	0.80	6.0	8.0	12.0	20.0

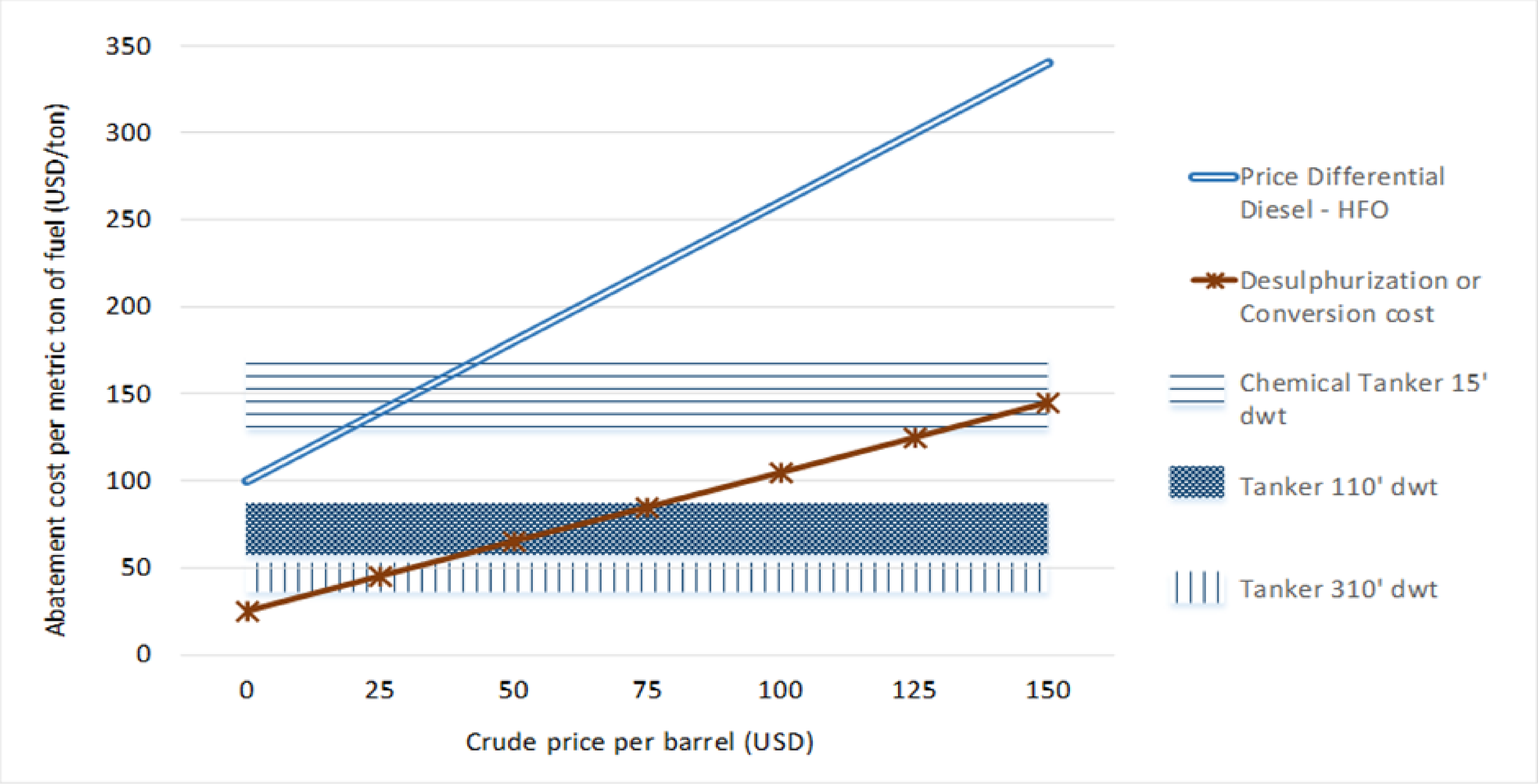
Abatement cost per ton of fuels with retrofitted scrubbers

Ship type	No. of vessels	DWT (ton)	Installed Power (kW)	Design speed (knots)	Speed at Sea 2012	Days at sea sailing 2012	Fuel per vessel 2012 (ton)	Fuel per vessel upper limit (ton)	Abatetment cost per ton high end	Abatetment cost per ton low end	Total 2012 fuel (million ton)
General Cargo 7' dwt	2 900	7 300	3 300	13.6	10.1	166	1 800	2 900	331	205	5.2
Tank 15' dwt	1 050	15 300	5 100	14.1	11.7	181	3 700	4 800	169	130	3.9
Dry Bulk Panamax	2 300	82 000	10 900	15.3	11.9	191	6 200	9 200	117	79	14.3
Tank 110' dwt	900	109 300	13 800	15.3	11.6	186	9 000	14 100	86	55	8.1
Tank 160' dwt	500	162 300	18 800	16.0	11.7	206	10 900	18 400	79	47	5.5
Dry Bulk 270' dwt	300	271 400	22 200	15.7	12.2	202	11 400	17 000	80	54	3.4
Container 2'-5' TEU	1 700	46 800	30 500	23.3	15.5	224	14 600	29 800	72	35	24.8
Tank 310' dwt	600	313 400	27 700	16.0	12.5	233	19 100	28 200	53	36	11.5
Container 5'-12' TEU	900	87 300	59 500	25.3	16.3	250	25 600	55 700	60	28	23.0
Container > 12' TEU	100	177 000	83 000	25.0	14.8	242	30 200	77 800	64	25	3.0
LNG 120' dwt	50	121 300	37 400	19.3	16.9	277	34 100	40 100	34	29	1.7
Cruise > 10' GT	250	7 300	42 600	21.3	15.5	261	42 000	71 600	30	18	10.5

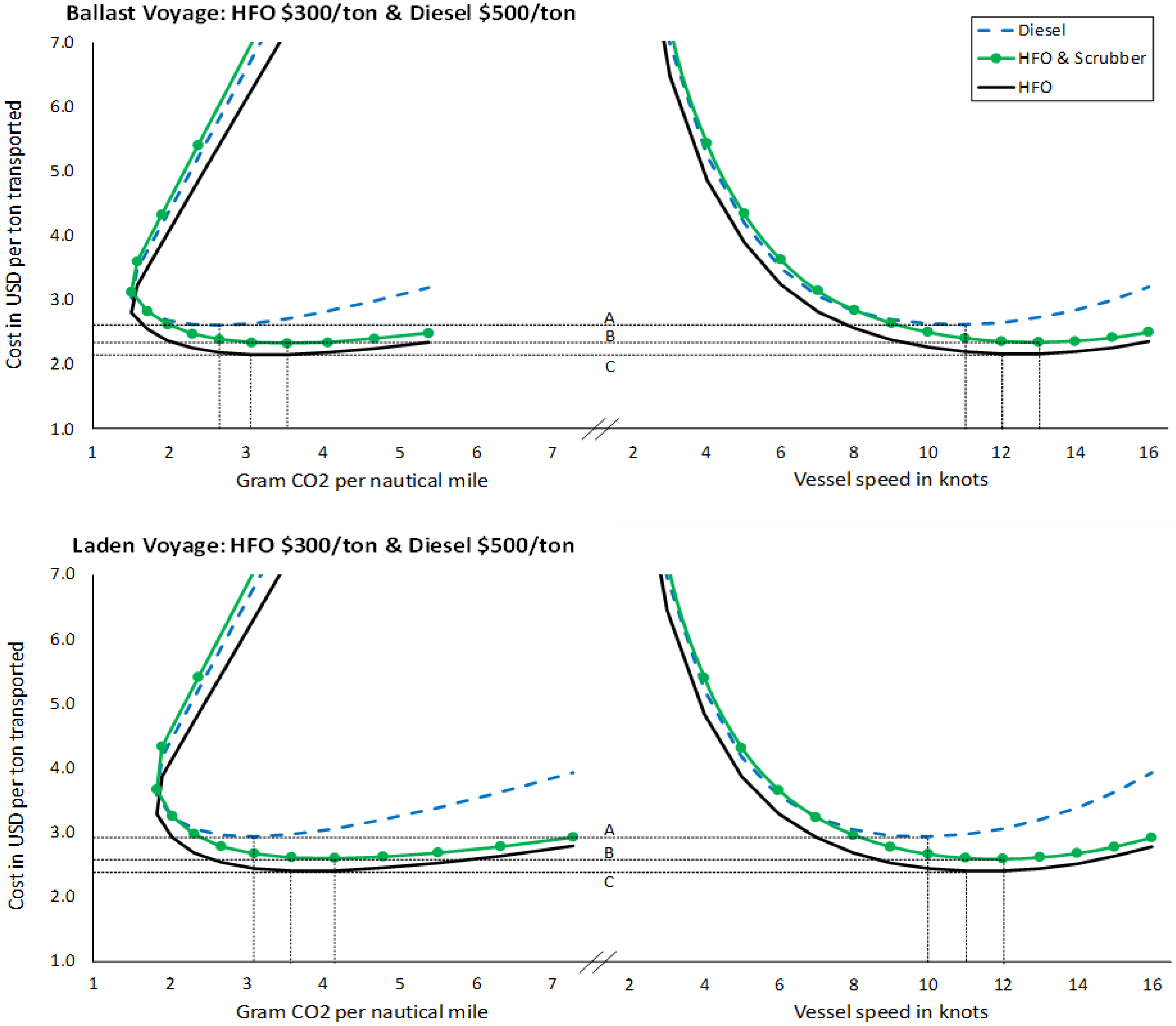
Scrubber abatement cost per vessel as a function of engine size and annual fuel consumption



Abatement cost per ton for tankers with scrubbers retrofitted versus the fuel options -> increased consumption reduces the cost per ton for the scrubber option



Cost Minimizing speeds 110' dwt Aframax tanker



Main Conclusions

- HFO & Scrubber encourage higher speeds, diesel reduces the speed
- Increased Energy usage 5 – 10 % (at refinery or higher speeds with scrubbers)
- Scrubber is most cost efficient for large consumers and most competitive at high fuel prices for nearly all vessels
- Versus retrofitting, HFO<0.5% S might be cost competitive for vessels with fuel consumption up to 10 000 tons
- Diesel is only an alternative for the smallest consumers of HFO today
- To be an competitive option, the LNG price has to be lower than the HFO price
- If the Global temperature continues to peak (Increase) the regulation might be reversed, i.e. continued use of HFO at the high seas

State-of-the-art technologies, measures, and potential for reducing GHG emissions from shipping – A review

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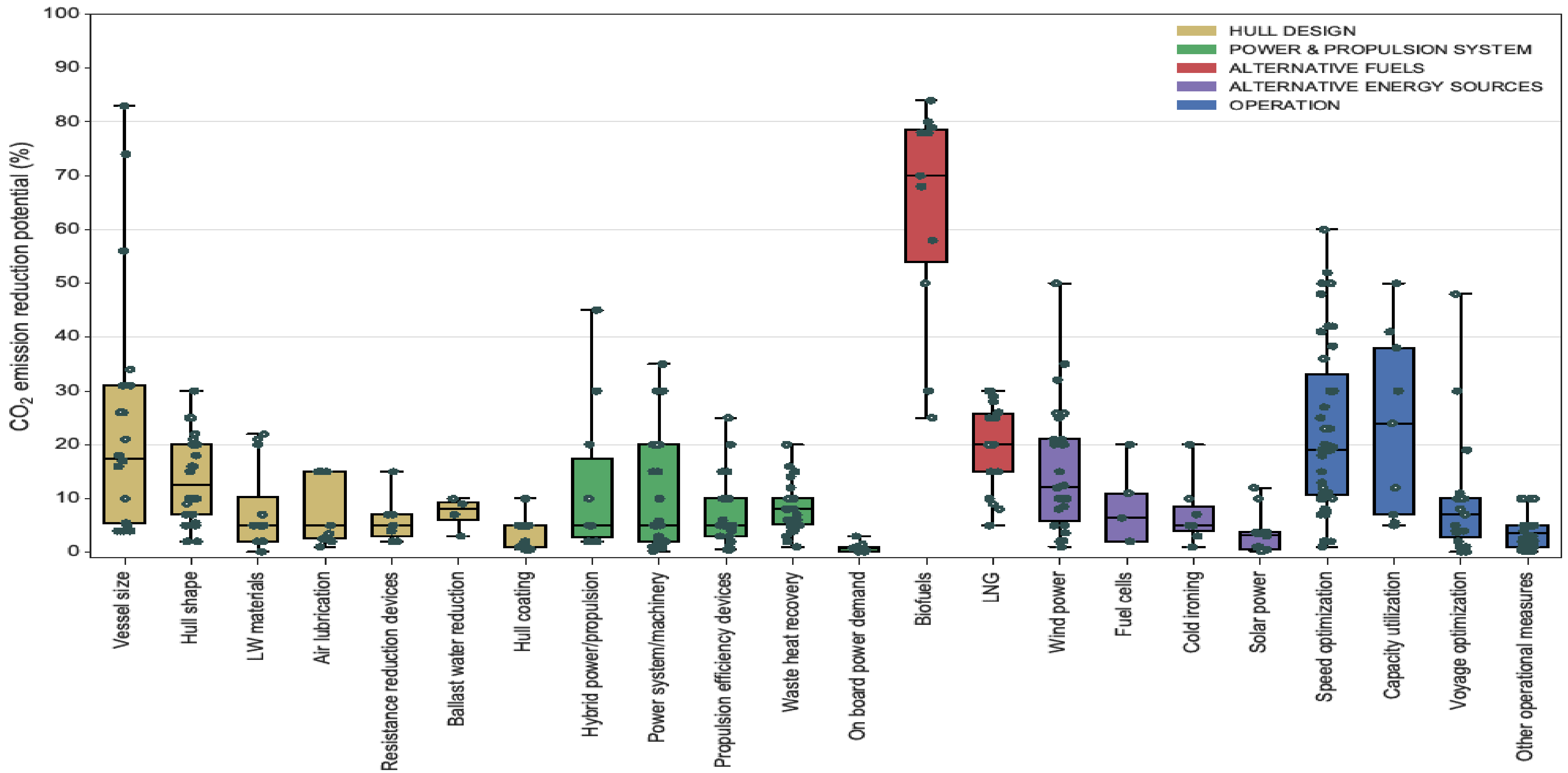

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THANK YOU !

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