SINTEF

HOW CAN SHIPPING BEST CONTRIBUTE TO MITIGATE CLIMATE CHANGE

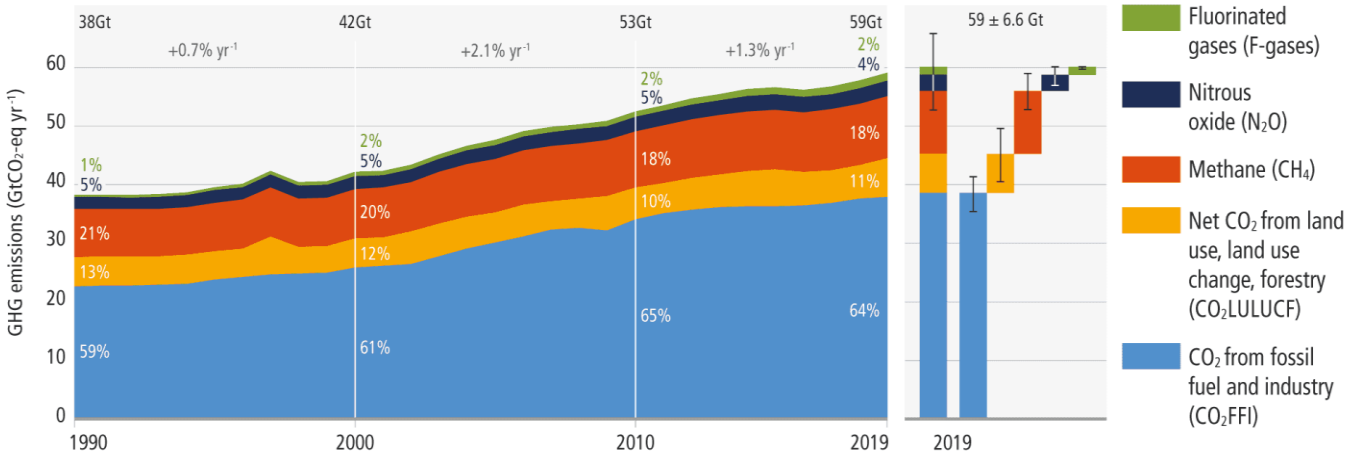
IMSF 2022 -HAMBURG
25. OKTOBER 2022

Chief Scientist Dr. Elizabeth Lindstad, SINTEF Ocean

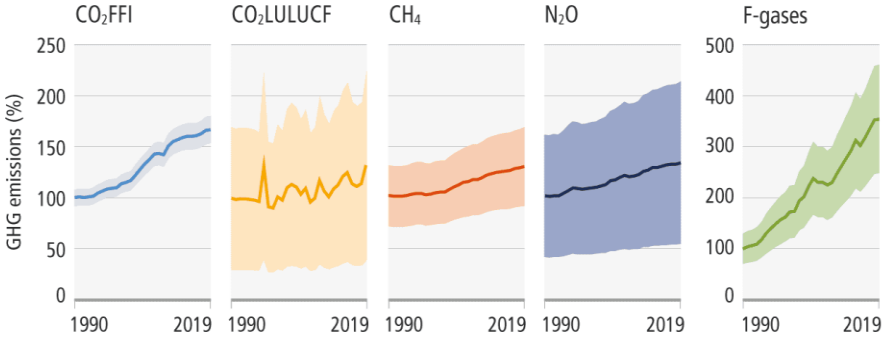
IPCC urges for rapid Global decarbonization. The big question is: How to make it happen?

Global net anthropogenic emissions have continued to rise across all major groups of greenhouse gases.

a. Global net anthropogenic GHG emissions 1990–2019 [5]



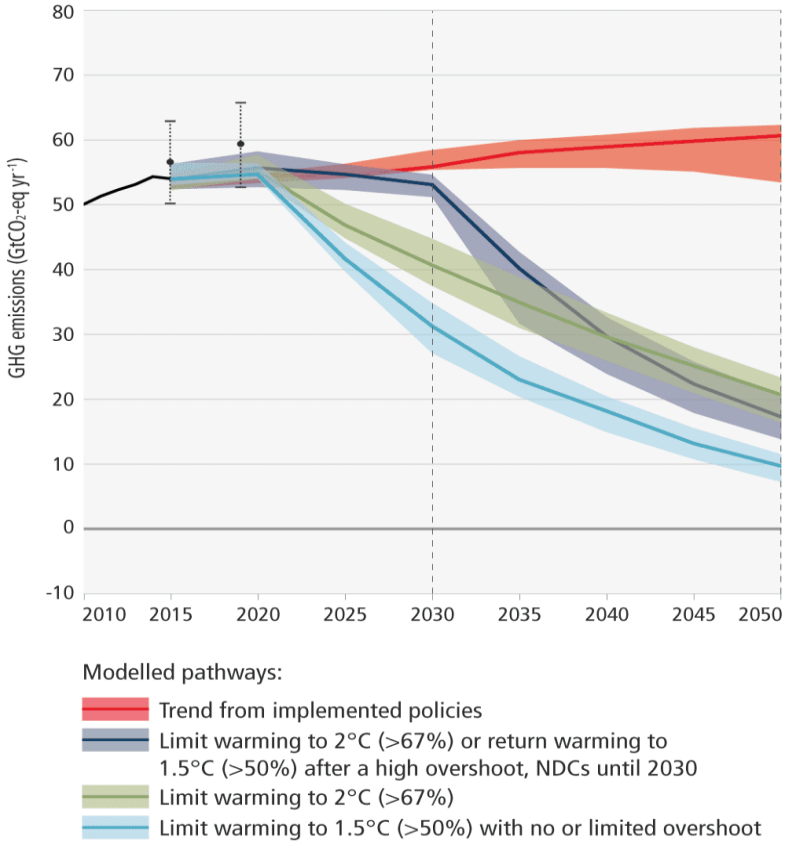
b. Global anthropogenic GHG emissions and uncertainties by gas – relative to 1990



	2019 emissions ($GtCO_2$-eq)	1990–2019 increase ($GtCO_2$-eq)	Emissions in 2019, relative to 1990 (%)
CO_2 FFI	38±3	15	167
CO_2 LULUCF	6.6±4.6	1.6	133
CH_4	11±3.2	2.4	129
N_2O	2.7±1.6	0.65	133
F-gases	1.4±0.41	0.97	354
Total	59±6.6	21	154

The solid line indicates central estimate of emissions trends. The shaded area indicates the uncertainty range.

a. Global GHG emissions



Source: Climate Change 2022: Mitigation of Climate Change (IPCC, 2022), Fig. SPM.1 and SPM.4

Two major de-carbonizing scenarios published in 2021- keeping temperature rise below 1.5–2 ºC

- The **IEA Net Zero by 2050** scenario: Equal efforts. All sectors including transport shall do their outmost to be nearly fully de-carbonized by 2050.
- The **Shell Sky s**cenario: Picks the lowest hanging fruits first. With other sectors being easier and more cost efficient to de-carbonize, transport will remain 80% fossil-fuelled in 2050.

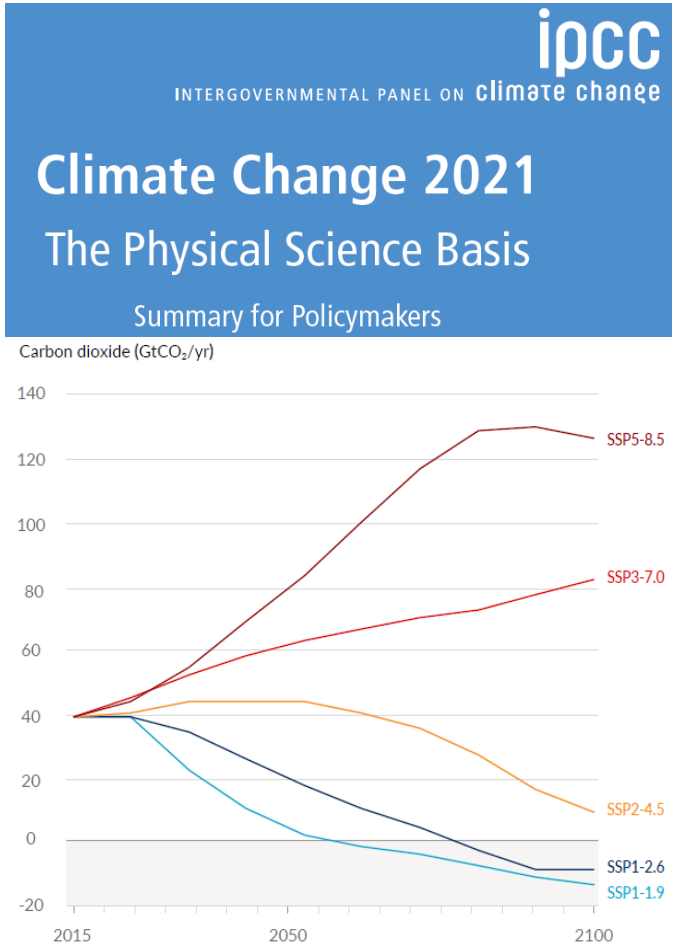
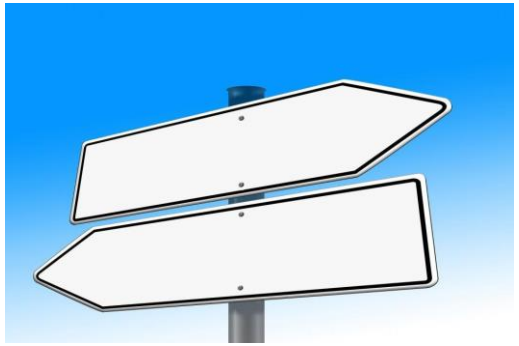


Figure source: Summary for Policymakers – The Physical Science Basis. IPCC AR6 WG1 2021.

References: The energy transformation scenarios (Shell, 2021); Net Zero by 2050 (IEA, 2021)

Why using scenarios?



- From early philosophers and visioners, to military strategists, to business planning, to socio-political development, scenarios have been a valuable tool for planning for an uncertain future.
- Scenarios are:
  - Plausible and simplified descriptions of how the future may develop.
  - A support tool for dealing with uncertainties and what-if analysis
  - A test ground for robust strategy planning.
- Main premisses for scenarios:
  - Plausible, logical and consistent
  - Structurally different, explore future uncertainties
  - Few (2-5): sufficiently distinct and manageable
- Main industrial references of foresight studies and scenario planning: RAND Corporation, Shell, GE.

3 types of scenarios

- **Predictive and Probabilistic – what will happen**

trend extrapolations, business-as-usual scenarios, prediction, forecast.

- **Explorative – what can happen**

Structurally different stories about how the future might develop.

- **Normative – what should happen**

desirable future, a vision to be achieved.

Source: Kroneberg (2000); Bradfield (2005); Vergragt and Qvist (2011)

Scenarios applied to global energy transition and decarbonization

- Consider distinct future scenarios for global energy production and consumption.
- Test out distinct strategies for maritime decarbonization.

Global transition to renewable and low carbon energy

Fighting for Full Decarbonization

Exploit global opportunities

Equal individual efforts. Chasing zero

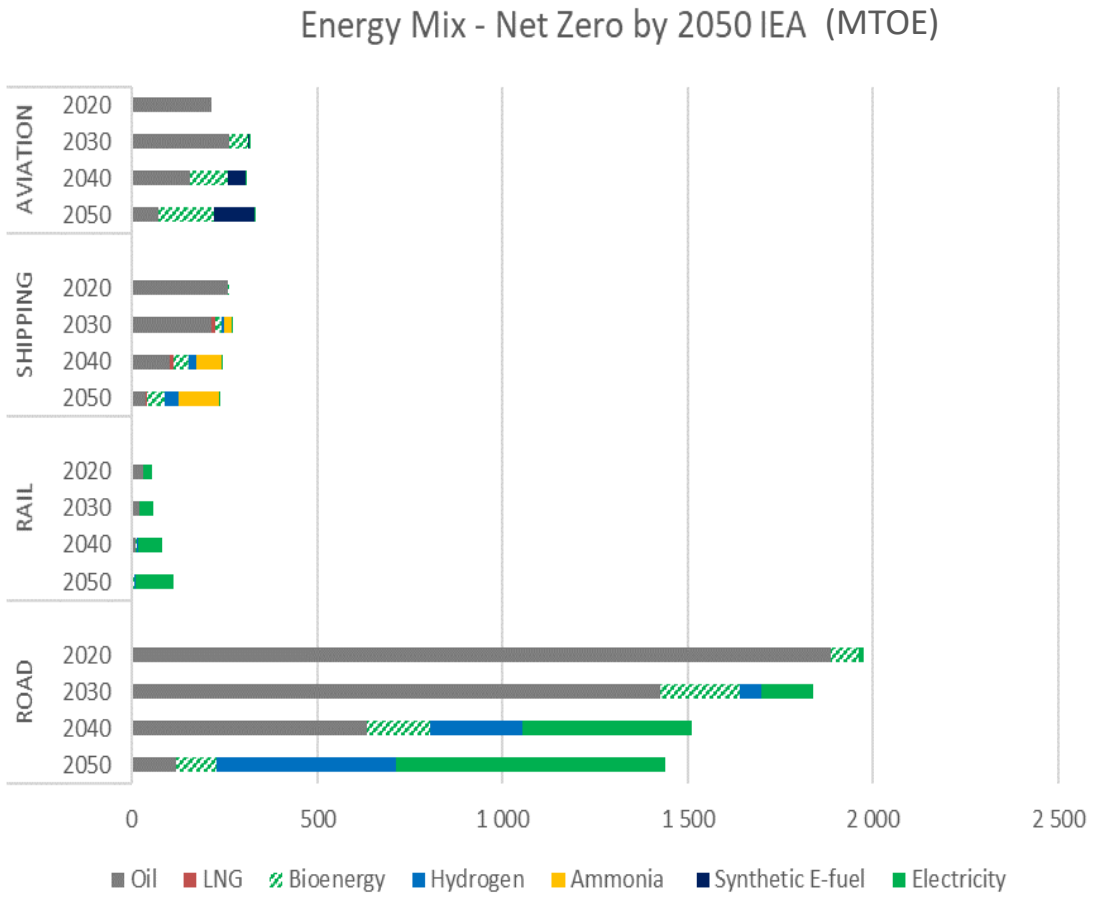
Global distributed efforts. Biggest impact

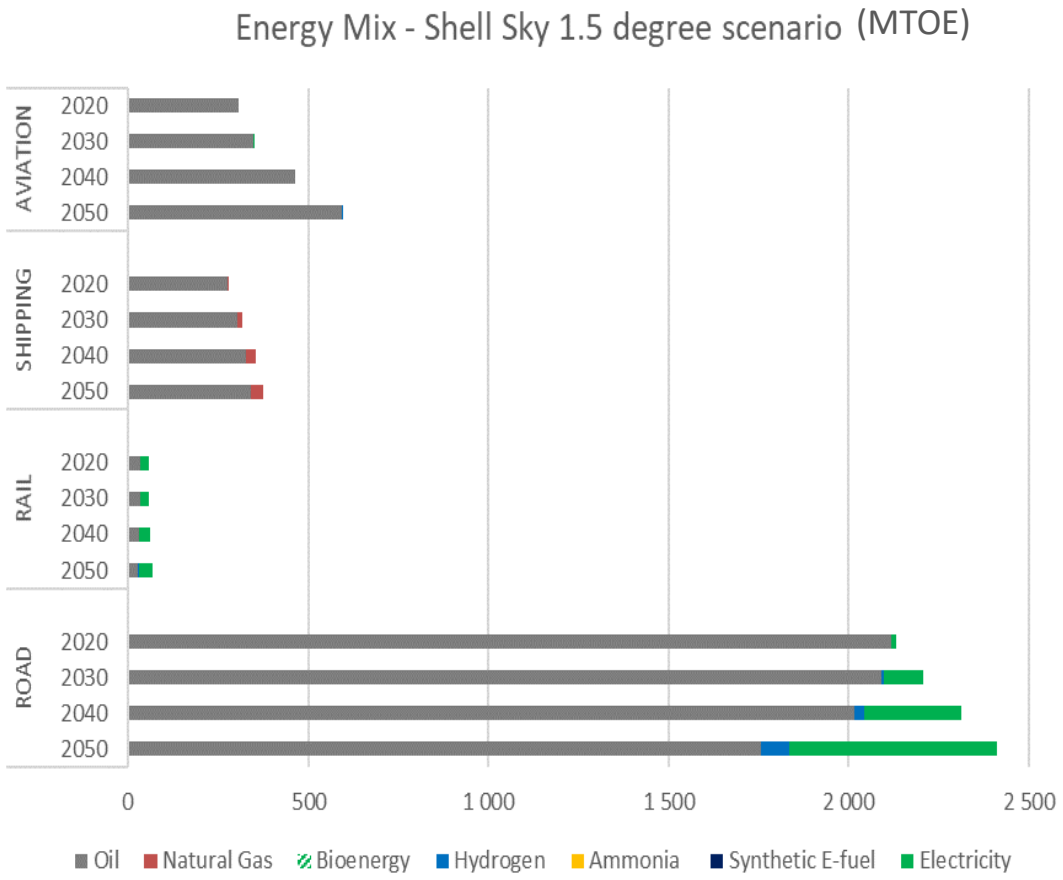
Ineffective and painful decarbonization

Lowest hanging fruits

Mixed fossil/alternative global energy supply

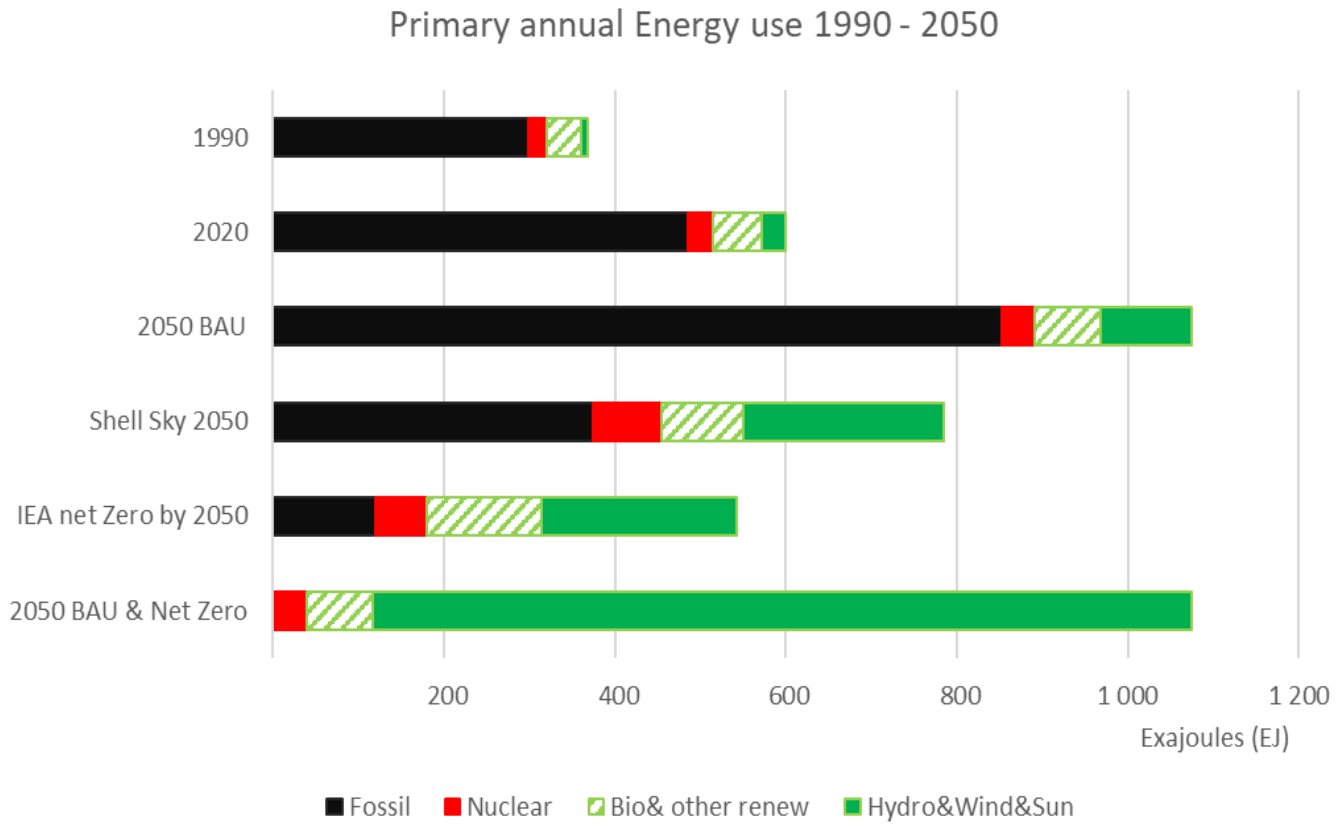
Energy mix in Transport 2020 – 2050: IEA Net Zero versus Shell Sky scenario

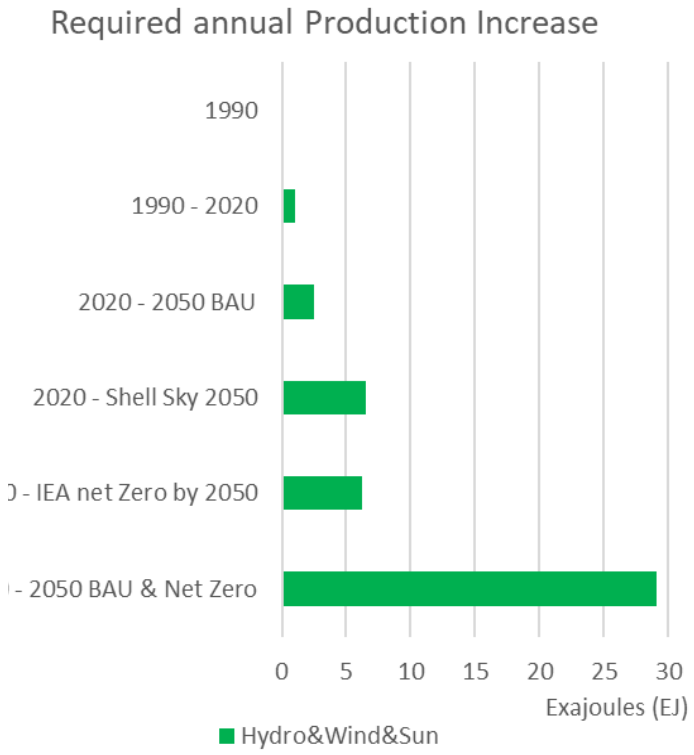




Source: Lindstad et al. (2021) compiled from The energy transformation scenarios (Shell, 2021), Net Zero by 2050 (IEA, 2021)

To reduce Global GHG scenarios: We need a major ramp-up of renewable energy production

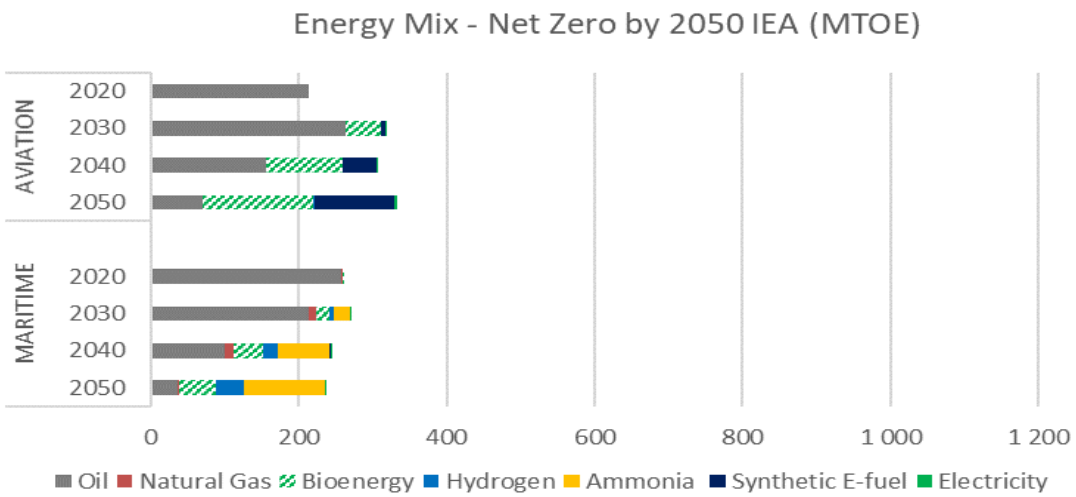


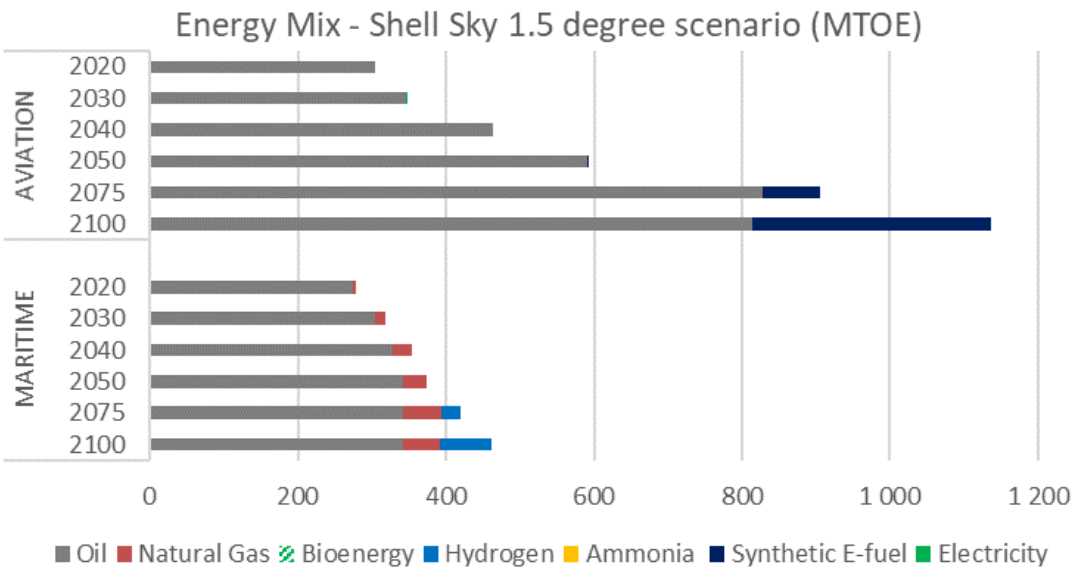


Source: Lindstad et al. (2021) compiled from The energy transformation scenarios (Shell, 2021), Net Zero by 2050 (IEA, 2021)

Large gap in energy mix, yet both scenarios gives de-carbonization: ALL ROADS LEADS TO ROME

- IEA assumes nearly a full decarbonization of Maritime and Aviation by 2050
- Shell assumes that Maritime and Aviation consumption will be mainly fossil-even in 2100
- Shell assumes a large increase in energy use, especially in aviation.

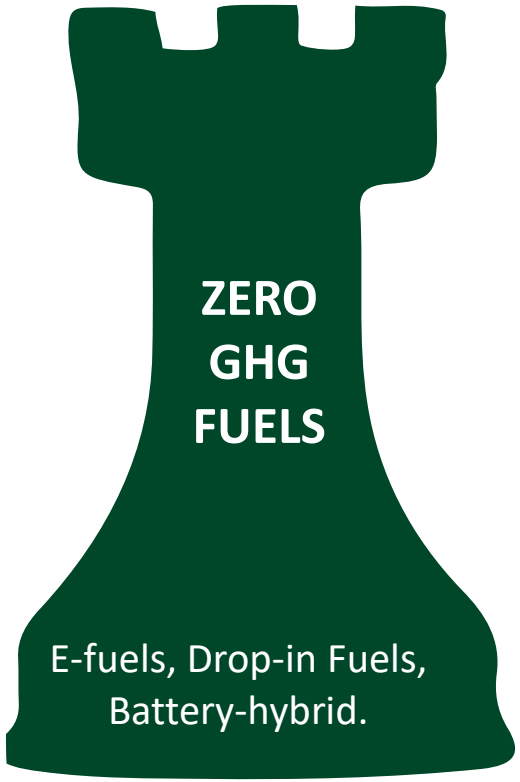




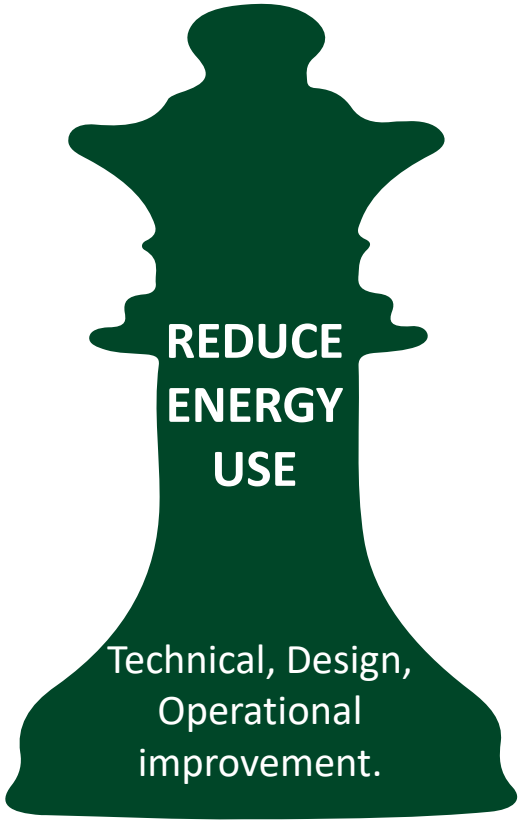
Source: Lindstad et al. (2021)

How can shipping best contribute to mitigating climate change and avoid boosting global warming

ZERO CARBON scenario



ENERGY EFFICIENCY scenario

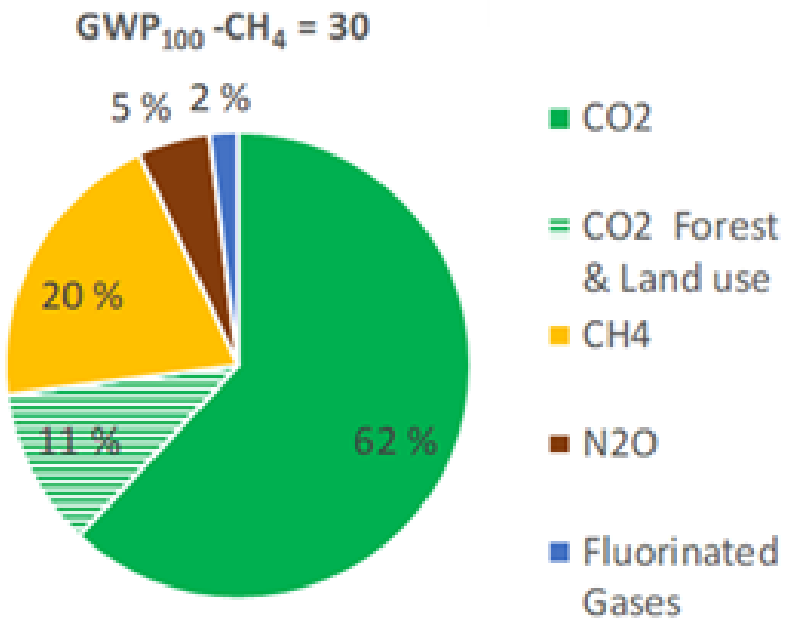


PRAGMATIC scenario

Current IMO Emission Regulations

- Current regulations:
  - NO_X and SO_X regulated due to human health and local pollution.
  - CO_2 regulated due to global warming.
  - IMO regulations are on a Tank-to-Wake (TTW) basis

- IMO is now under increased pressure to:
  - Regulate un-combusted methane (CH_4) and N_2O
  - Regulate aerosols like Black Carbon
  - Switch scope from Tank-to-Wake to Well-to-Wake (WTW) to avoid shifting GHG emissions from fuel combustion to fuel production phase.



55 Billion tons of Global annual anthropogenic GHG emissions, divided by source.

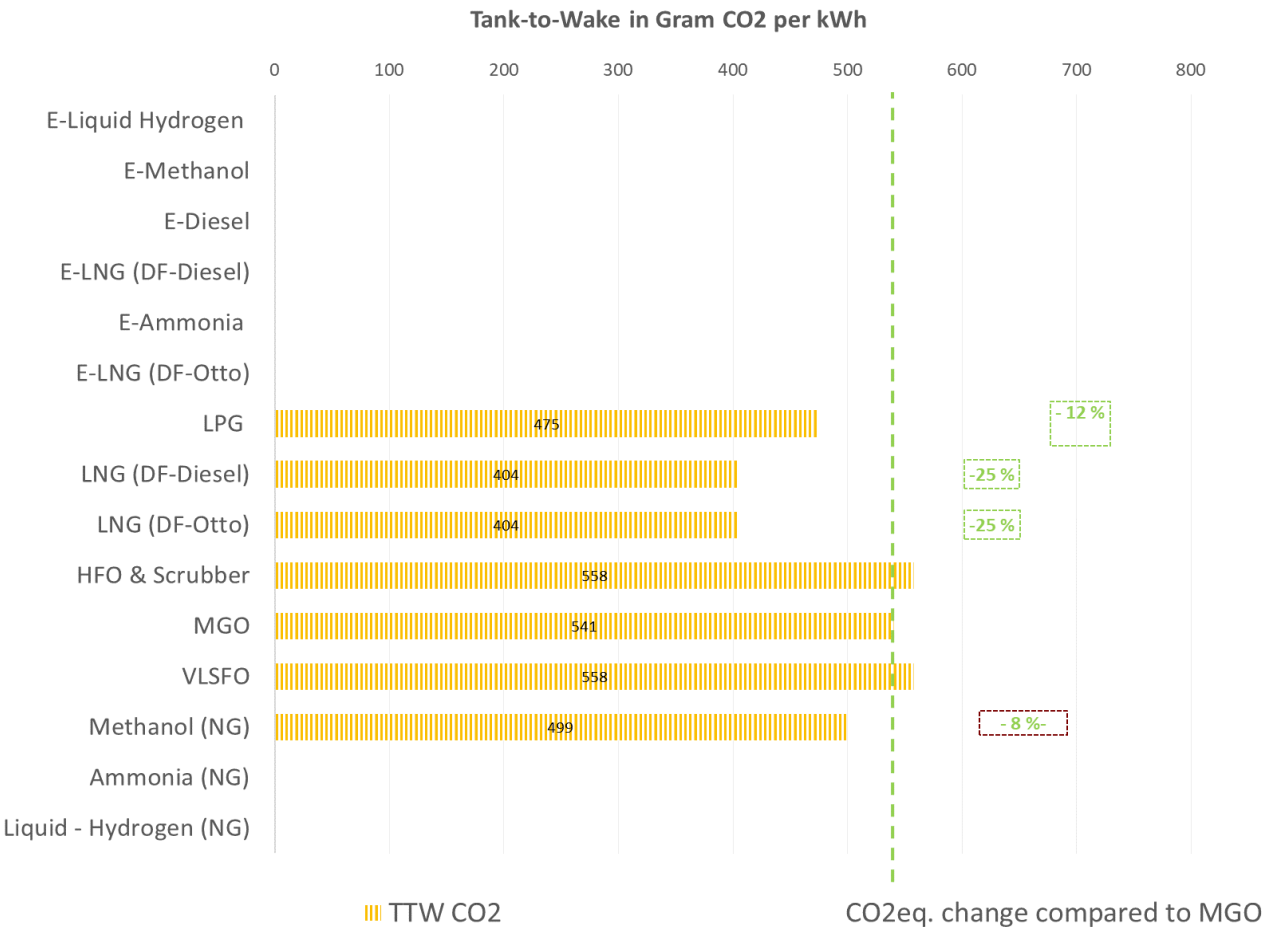
Correspondence Group on Marine Fuel Lifecycle GHG Analysis to draft LCA guidelines for IMO

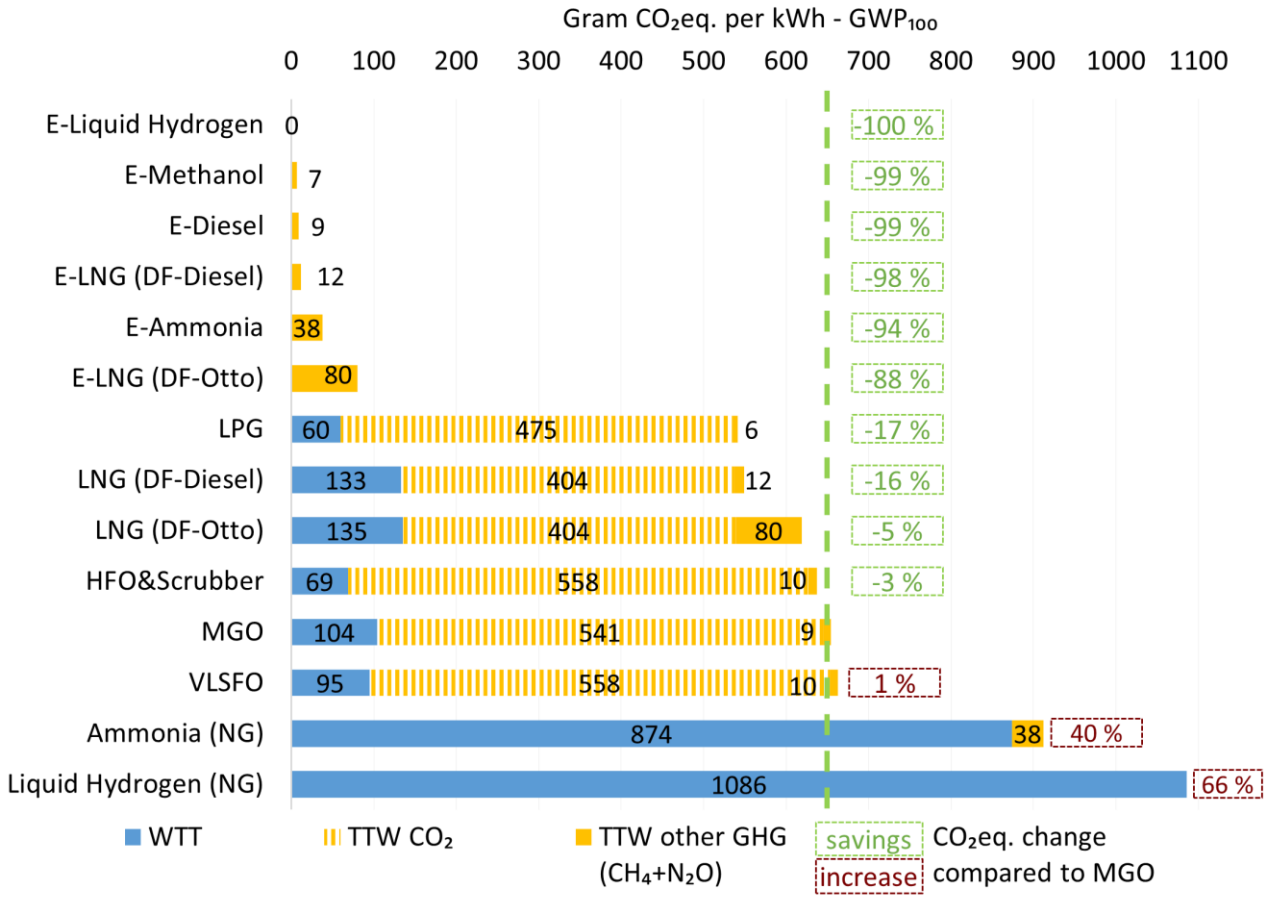
To be reported to **MEPC 80 July 2023**. Work lead by **EU, China, Japan**:

- TOR 1.1 Identify main initial **fuel production pathways** and feedstocks for inclusion in the draft LCA guidelines, and how they could be sub-categorized and further specified.
- TOR 1.2 Further consider sustainability criteria issues and develop **Fuel Lifecycle Label** (FLL).
- TOR 1.3 Develop methodologies for calculation of Well-to-Tank, Tank-to-Wake and entire **Well-to-Wake GHG** emissions default values for the fuels.

Fuel type	Feedstock nature	Production pathway
MDO/MGO	Fossil	Default
LFO	Fossil	Default
HFO	Fossil	Default
LPG	Fossil	Default
LNG/methane	Fossil	Default
	Biogenic	Main products / wastes / feedstock mix
	Captured carbon	Captured carbon / biomass gasification / electricity mix
		Captured carbon
Butane	Fossil	Default
Diesel	Biogenic	Main products / wastes / feedstock mix / rapeseed incl LUC
		Main products / wastes / feedstock mix / palm incl LUC

Ongoing IMO Work: Switching from Tank-to-Wake to Well-to-Wake: Much larger impact for new alternative fuels than for conventional fossil fuels





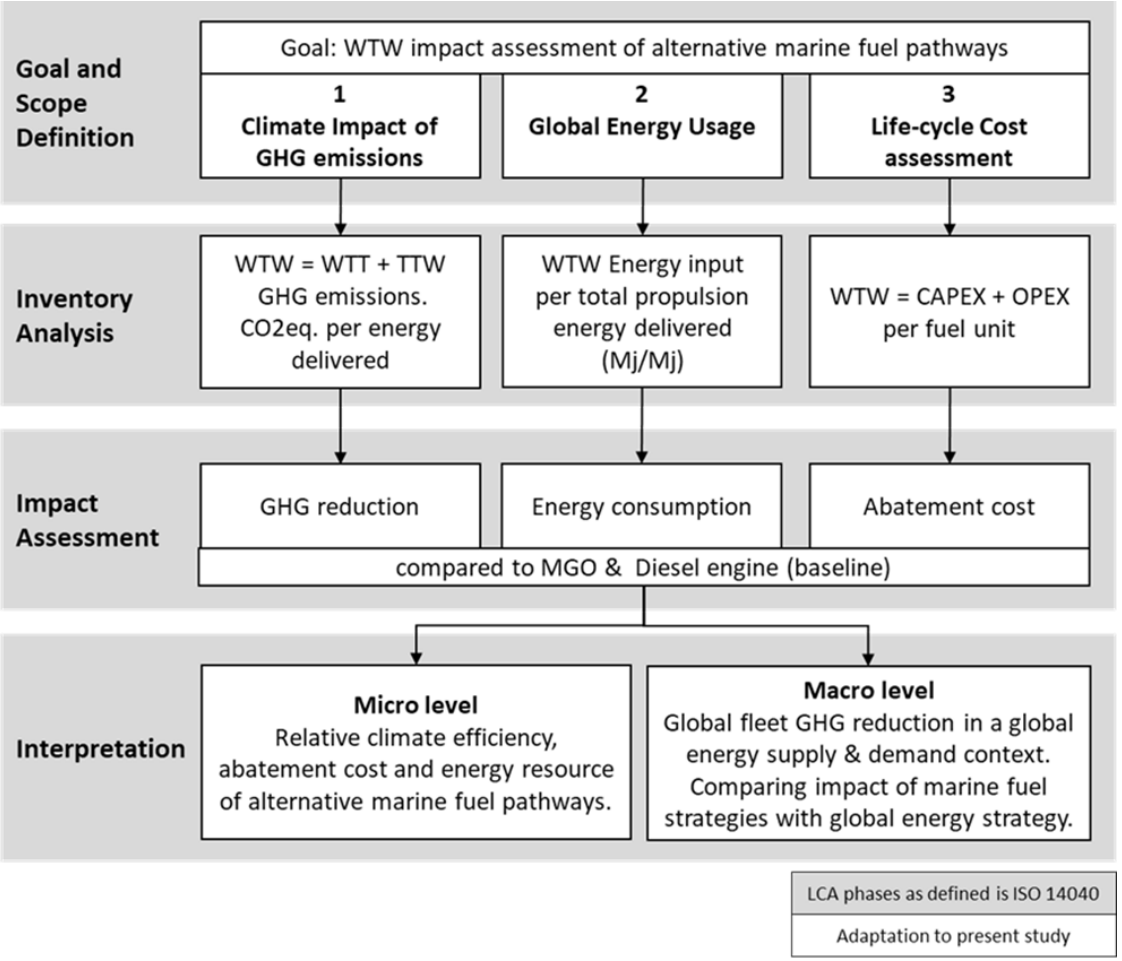
Source: Lindstad, E., Lagemann, B., Rialland, A., Gamlem, G., M., Valland, A. 2021. Reduction of Maritime GHG emissions and the potential role of E-fuels, TRD

Our methodology for assessing Alternative Fuels & Technologies

To evaluate alternative fuel & technologies options, we compare their:

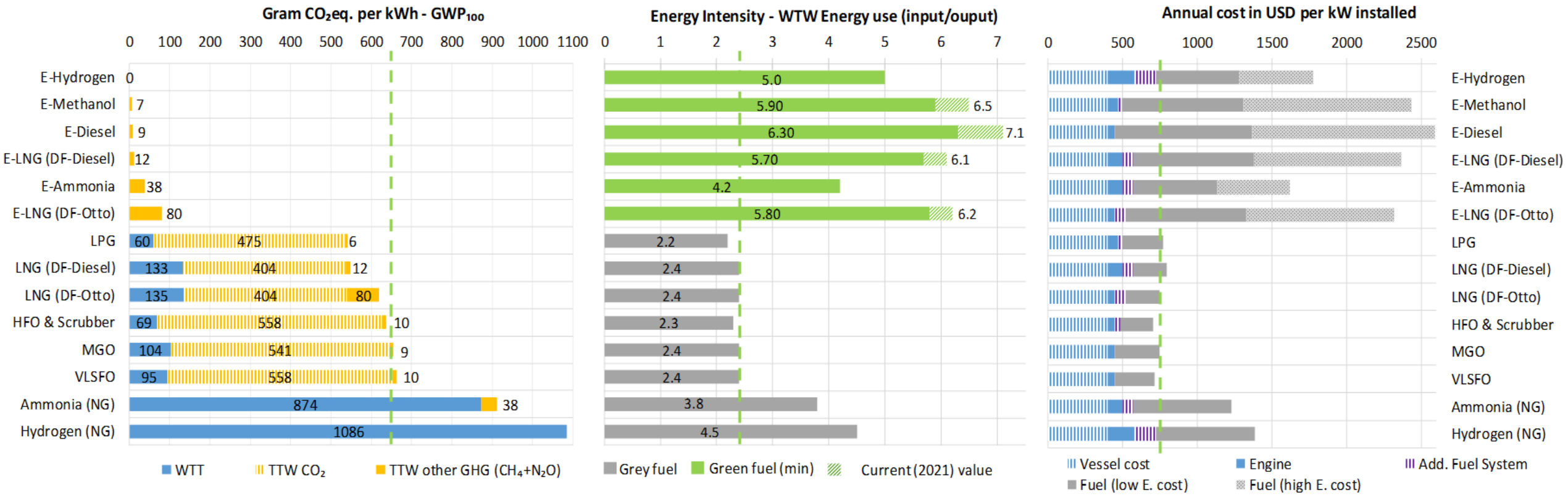
1-GHG emissions
2-Energy consumption WTW
3-Cost per energy unit delivered for propulsion

which enables a holistic assessment



Source : Lindstad, E., Gamlem, G., Rialland, A., Valland, A, - Assessment of Alternative Fuels and Engine technologies to reduce GHG, SMC-099-2021

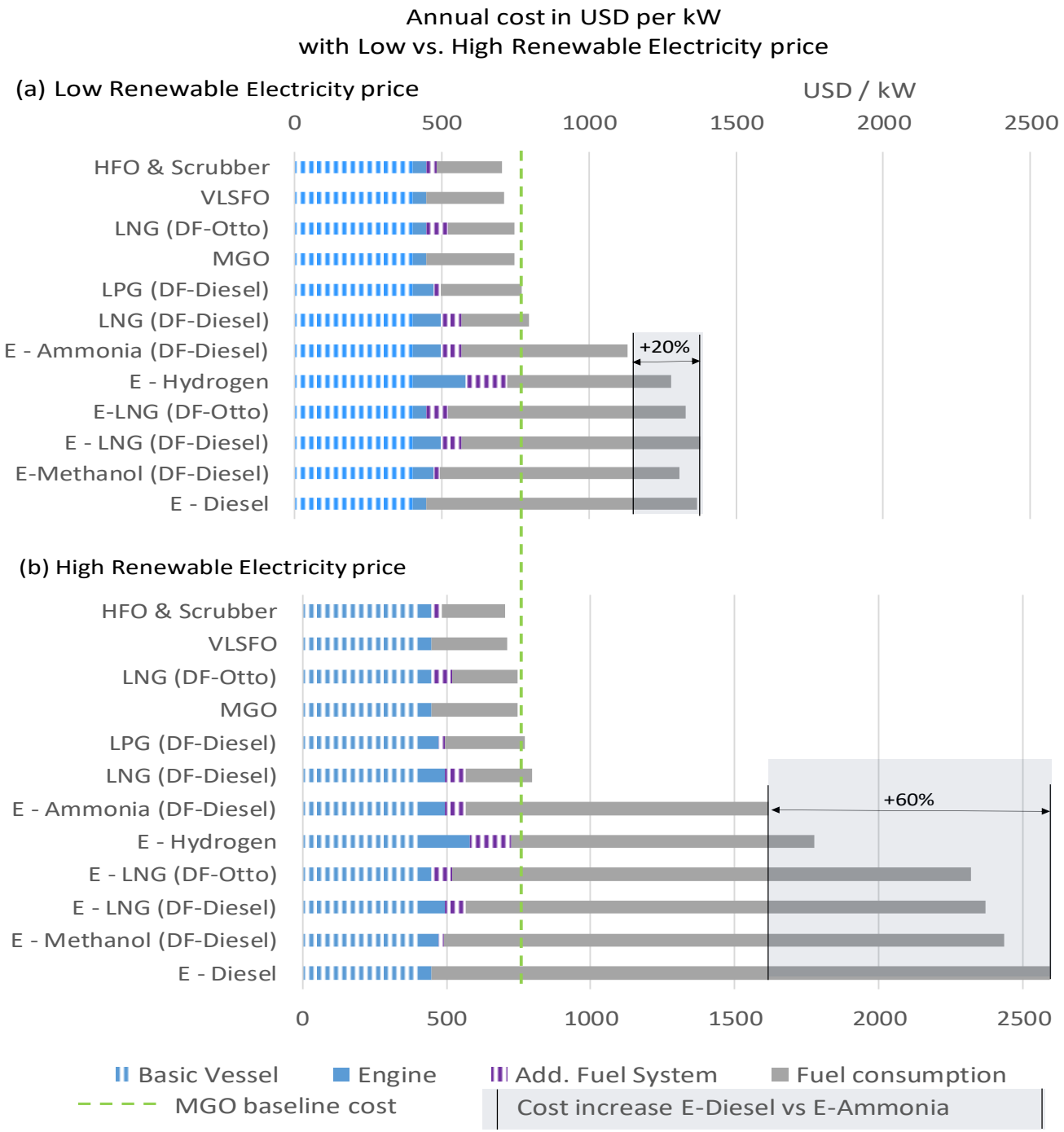
Assessment of fuels based on: GHG emissions, Energy use, Annual vessel cost



Source: Lindstad, E., Lagemann, B., Rialland, A., Gamlem, G., M., Valland, A. 2021. Reduction of Maritime GHG emissions and the potential role of E-fuels, TRD

Annual cost per kW installed

- Cost of fossil fuels kept constant
- Dashed green vertical line is MGO-benchmark
- Electricity prices Low/High are 20 and 60 USD/MWH
- Annual total costs (capex + opex+ fuel) for a Dry bulk Supramax with 8000 kW installed power:
  - MGO 6 MUSD
  - E-Ammonia 9 – 13 MUSD
  - E-Methanol 10 – 20 MUSD
  - E-LNG 11 – 19 MUSD
  - E-Diesel 11 – 21 MUSD



Source: Lindstad et al. (2021), TRD

Examples of some of our papers within LCA and Well-to-Wake of fuels

sustainability

MDPI

Article

Decarbonizing Maritime Transport: The Importance of Engine Technology and Regulations for LNG to Serve as a Transition Fuel

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Received: 11 September 2020; Accepted: 20 October 2020; Published: 22 October 2020

check for updates

Abstract: Current Greenhous gas emissions (GHG) from maritime transport represent around 3% of global anthropogenic GHG emissions and will have to be cut in half by 2050 to meet Paris agreement goals. Liquefied natural gas (LNG) is by many seen as a potential transition fuel for decarbonizing shipping. Its favorable hydrogen to carbon ratio compared to diesel (marine gas oil, MGO) or bunker fuel (heavy fuel oil, HFO) translates directly into lower carbon emissions per kilowatt produced. However, these gains may be nullified once one includes the higher Well-to-tank emissions (WTT) of the LNG supply chain and the vessel's un-combusted methane slip (CH_4) from its combustion engine. Previous studies have tended to focus either on greenhouse gas emissions from LNG in a Well-to-wake (WTW) perspective, or on alternative engine technologies and their impact on the vessel's Tank-to-wake emissions (TTW). This study investigates under what conditions LNG can serve as a transition fuel in the decarbonization of maritime transport, while ensuring the lowest possible additional global warming impact. Transition refers to the process of moving away from

SNAME Maritime Convention 2021
27-29 October, Providence RI

www.sname.org

Assessment of Alternative Fuels and Engine Technologies to Reduce GHG

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Current greenhouse gas emissions (GHG) from maritime transport represent around 3% of global anthropogenic GHG emissions. These emissions will have to be cut at least in half by 2050 compared to 2008 as adopted by IMO´s initial GHG-strategy to be consistent with the Paris Agreement goals. Basically, the required GHG emissions reduction can be achieved through: Design and other technical improvement of ships; Operational Improvement; Fuels with zero or lower GHG footprint; or a combination of these. Fuels with zero or lower GHG footprints are often perceived to be the most promising measure. The motivation for this study has therefore been to investigate these alternative fuels with focus on their feasibility, energy utilization and cost in addition to their GHG reduction potential. The results indicate: First, that fuels with zero or very low GHG emissions will be costly; Second, that these fuels might double or triple the maritime sector's energy consumption in a Well-to-Wake context; Third, if large amounts of renewable electricity becomes available at very low prices, synthetic E-fuels such as E-diesel and E-LNG which can be blended with conventional fuels and used on conventional vessels, will be more commercially attractive than hydrogen and ammonia.

Transportation Research Part D 102 (2022) 103145

Contents lists available at ScienceDirect

Transportation Research Part D

journal homepage: www.elsevier.com/locate/trd

ELSEVIER

Optimal ship lifetime fuel and power system selection

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ARTICLE INFO

Keywords:
Shipping
GHG
Alternative fuels
Multi-objective
Optimization
Flexibility
Retrofit

ABSTRACT

Alternative fuels and fuel-flexible ships are often seen as promising solutions for achieving significant greenhouse gas reductions in shipping. We formulate the selection of alternative fuels and corresponding ship power systems as a bi-objective integer optimization problem. We apply our model to a Supramax Dry-bulker and solve it for a lower bound price scenario including a carbon tax. Within this setting, the question whether bio-fuels will be available to shipping has significant effect on the lifetime costs. For the given scenario and case study ship, our model identifies LNG as a robust power system choice today for a broad range of GHG reduction ambitions. For high GHG reduction ambitions, a retrofit to ammonia, produced from renewable electricity, appears to be the most cost-effective option. While these findings are case-specific, the model may be applied to a broad range of cargo ships.

How can shipping best contribute to mitigate climate change

- Presently NO_X and SO_X are regulated due to human health and local pollution and CO_2 is regulated due to global warming while the remaining exhaust gases are un-regulated.
- This represents a conflict, since NOx and SOx emissions tend to mitigate global warming while the unregulated emissions, BC and CH_4, contribute to global warming
- Complicating matters, emissions in one region may lead to a direct climate forcing that differs in magnitude from the same quantity emitted in another region. This is due to regional differences in sea ice extent, solar radiation, and atmospheric optical conditions
- For example, the deposition of black carbon over highly reflective surfaces such as snow and sea ice, reduces the albedo of these surfaces, thereby increased melting and reductions in snow/sea ice extent.
- Moreover, Sot and Black carbon previously washed out by the high Sulphur content in the exhaust gas now rise into the atmosphere and heat it

Alternative IPCC approaches to explain Global warming

There are two main schools of thought to explain Global warming:

- GHG emissions only and land use (b)
- Radiative forcing studies including all emissions and exhaust gases and land use (c)

(a) Observed warming

(b) GHG emissions only and land use

(c) Radiative forcing studies including all exhaust gases and land use

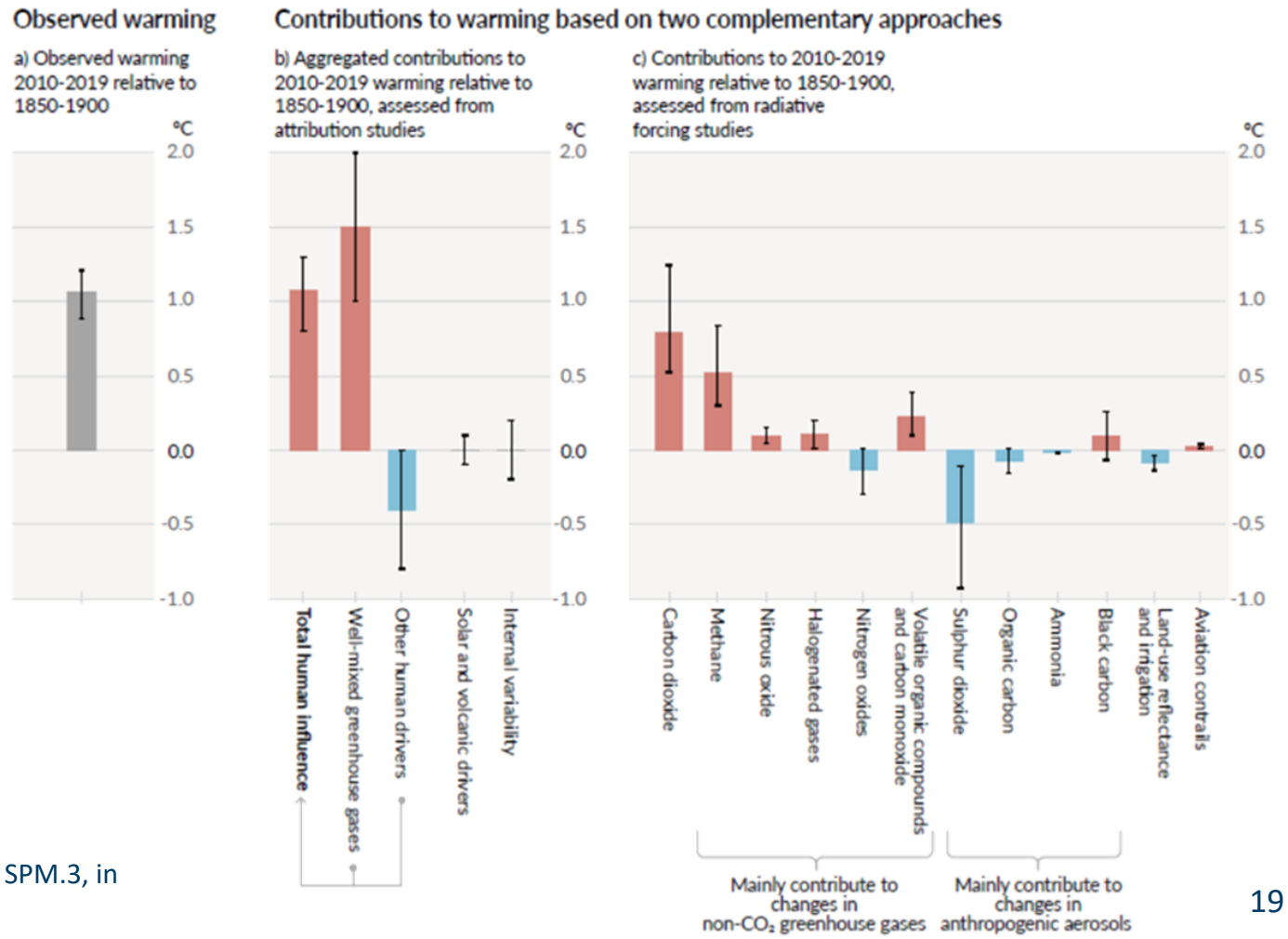
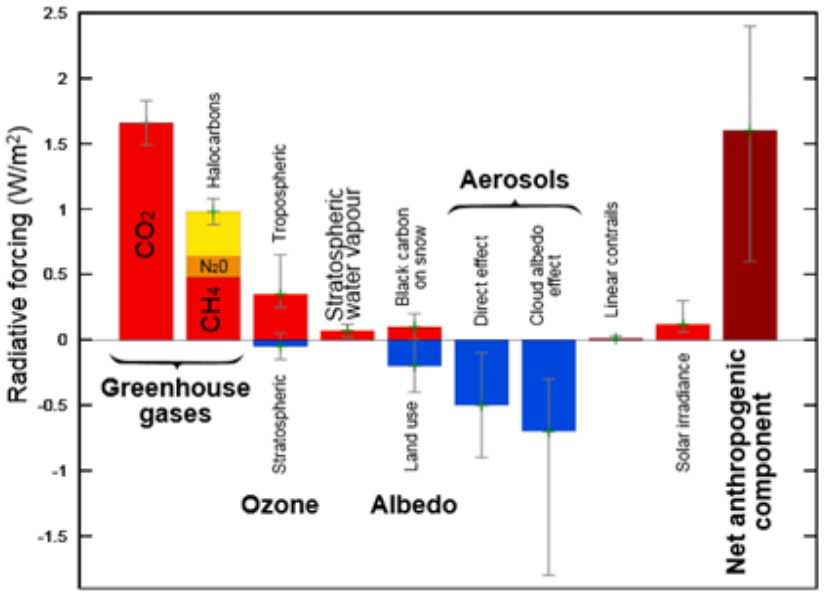
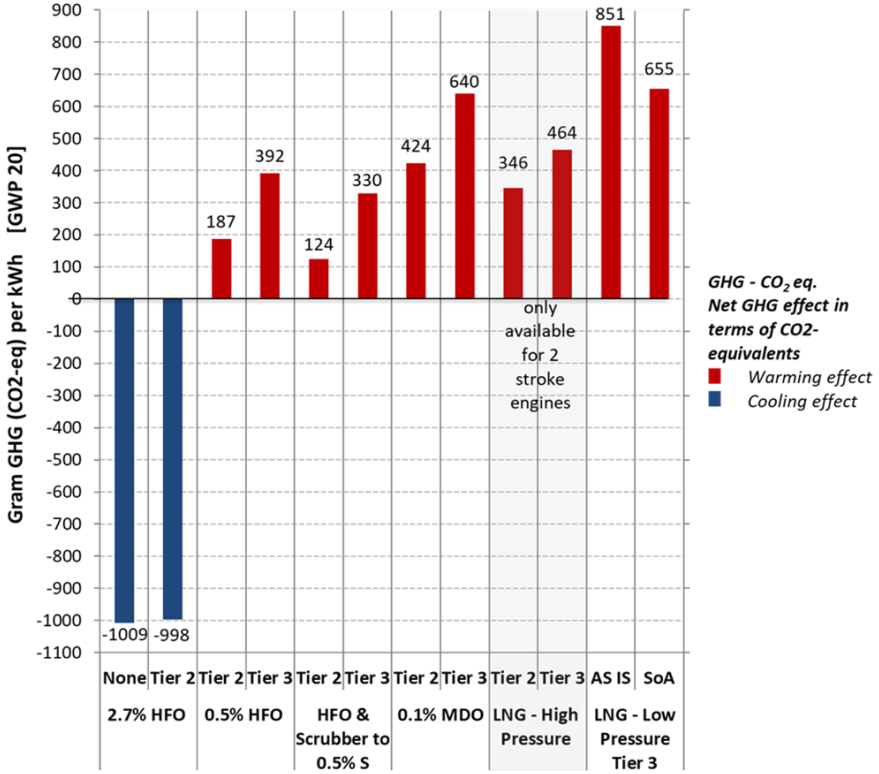


Figure source: Summary for Policymakers – The Physical Science Basis. Figure SPM.3, in Working group 1 contribution assessment report 6 IPCC AR6 WG1 2021.

Shipping's contribution to global warming is the net effect of all exhaust gases emitted and has increased due to stricter pollution regulations especially with the introduction of ECA's and Global sulphur cap



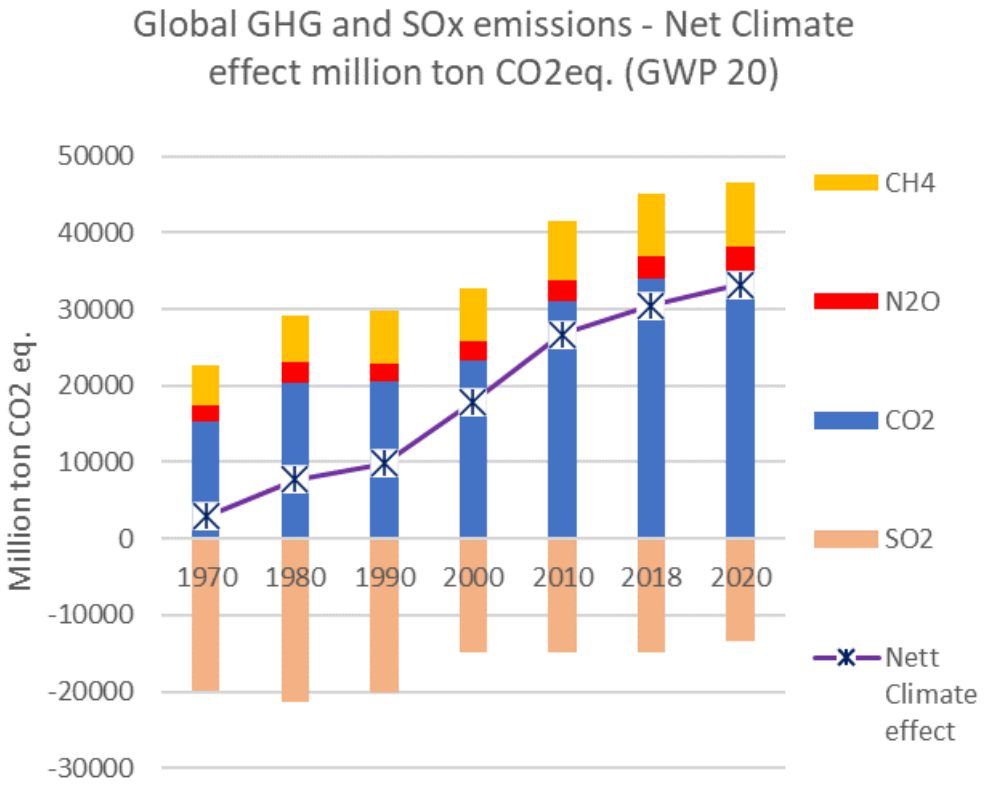
Source: Leland McInnes based on IPCC Natural Drivers of Climate Change, Figure SPM.2, in IPCC AR4 WG1 2007.



Source: Lindstad 2019

Global GHG and SOx emissions 1970 – 2020 and their joint impact

- Core GHG emissions (CO_2, CH_4, N_2O) has increases with 100% from 1970 - 2020
- The effect of the increased GHG emissions have been partly masked by aerosol cooling from Sulphur, NOx and OC.
- Sulphur emissions peaked in 1980, the Sulphur cap of 0,5% decreased them further in 2020
- In total, this partly explain peak temperatures seen after 2000 and from 2020 in particular
- Moreover, with the Sulphur removal we have not only lost its cooling effect, but also increased the amount of Sot and Black Carbon in the atmosphere, boosting Global warming



AGU Advances

RESEARCH ARTICLE
10.1029/2019AV000111

Substantial Cloud Brightening From Shipping in Subtropical Low Clouds

Michael S. Diamond[1,2], Hannah M. Director[3,2], Ryan Eastman[1], Anna Possner[4], and Robert Wood[1]

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Key Points:

- For the first time, observations show that ship emissions induce a cloud brightening effect on climate-relevant spatial and temporal scales
- Brightening is dominated by an increase in the number of cloud droplets, with small or countervailing adjustments in liquid water path
- Observationally informed global effective radiative forcing in low clouds is calculated as -1.0 W/m^2 (-1.6 to -0.4 W/m^2)

- Abstract The influence of aerosol particles on cloud reflectivity remains one of the largest sources of uncertainty in our understanding of anthropogenic climate change. Commercial shipping constitutes a large and concentrated aerosol perturbation in a meteorological regime where clouds have a disproportionally large effect on climate. Yet, to date, studies have been unable to detect climatologically relevant cloud radiative effects from shipping, despite models indicating that the cloud response should produce a sizable negative radiative forcing (perturbation to Earth's energy balance). We attribute a significant increase in cloud reflectivity to enhanced cloud droplet number concentrations within a major shipping corridor in the southeast Atlantic. P

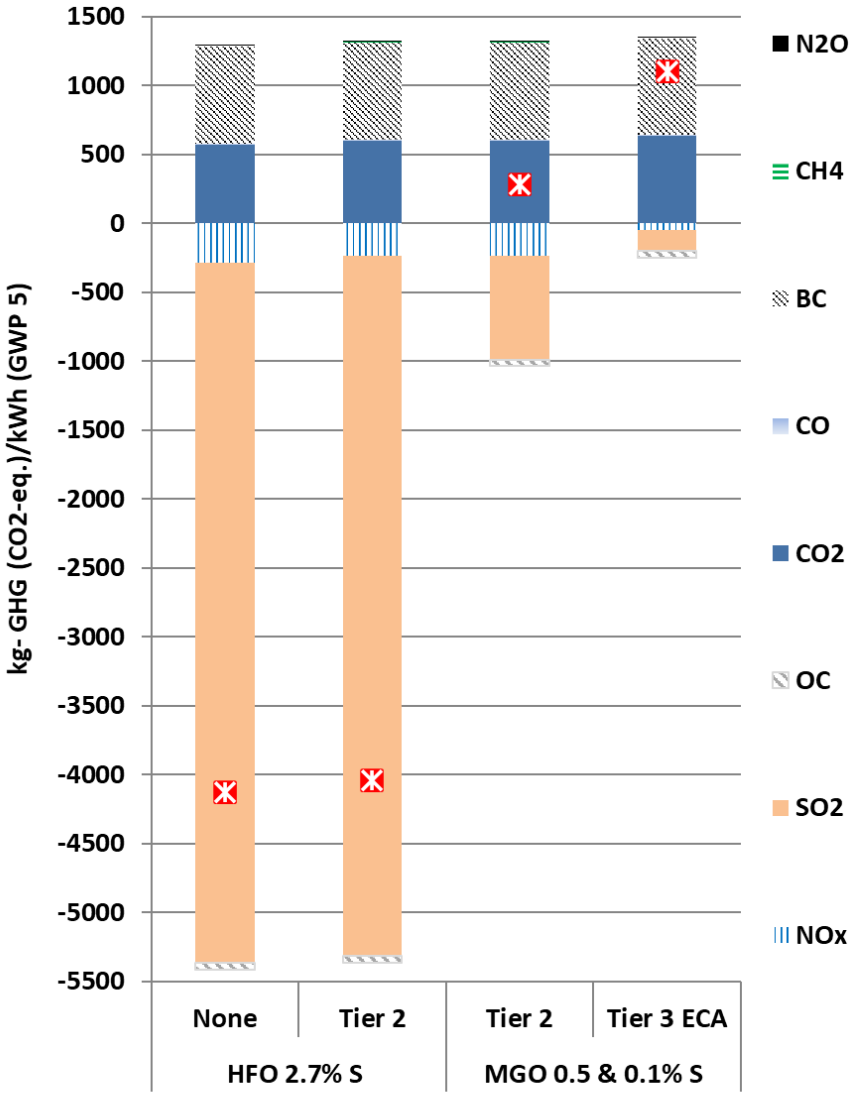
NASA shows that with the Sulphur 0.5% sulphur cap we have lost the cloud building (cooling from shipping)

- Ship tracks, the polluted marine clouds that trail ocean-crossing vessels, are a signature of modern trade, described by NASA as "ghostly fingerprints" tracing shipping lanes around the globe. Ship tracks are formed by water vapour coalescing around small particles of pollution - aerosols - in ship exhaust
- NASA has hailed the beneficial effects of the global sulphur cap to the atmosphere. A newly published study from the American space agency has found that so-called ship track clouds dropped dramatically in 2020, the first year of the implementation of the International Maritime Organization's new fuel regulations

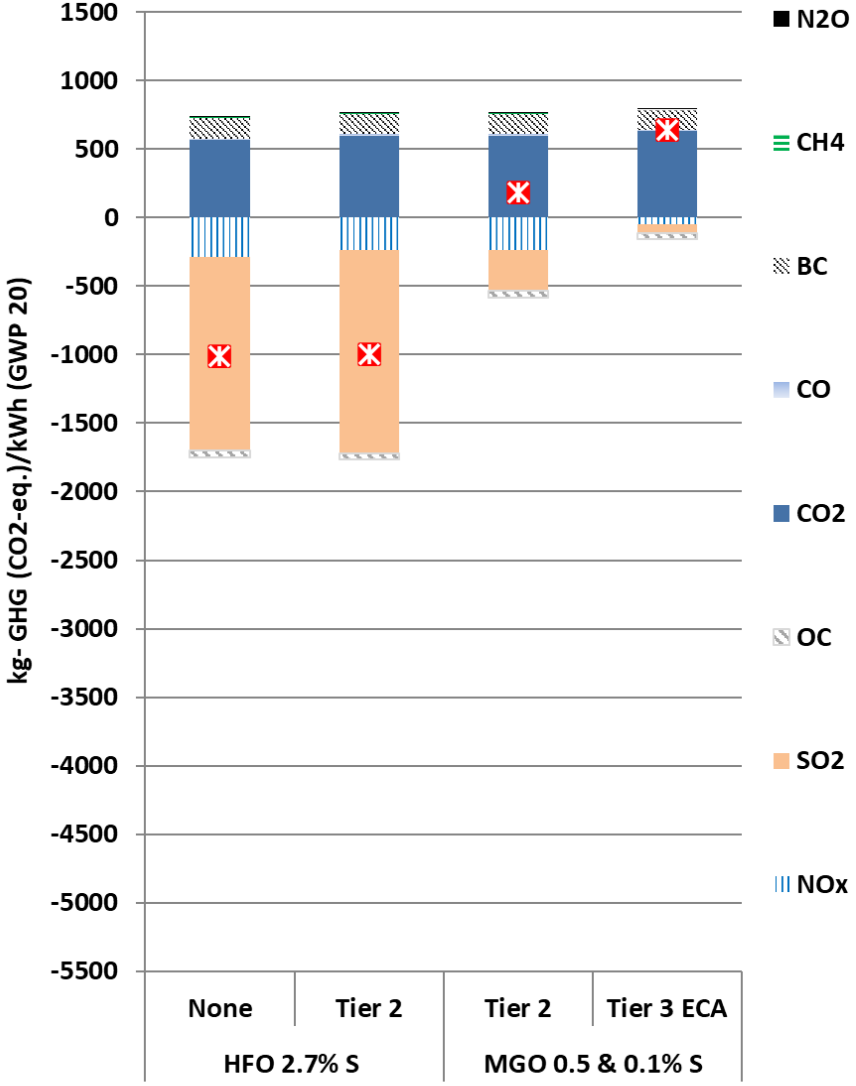
GHG Impact of shipping before& after 1st of January 2020

- It is easy to see that cooling emissions makes a large impact when comparing fuels with high (up to 2020) and low sulphur content.

Net Climate impact with a 5 year time horizon (GWP 5)



Net Climate impact with a 20 year time horizon (GWP 20)



Minimizing Climate impact of Ship's exhaust gas emissions requires holistic regulations

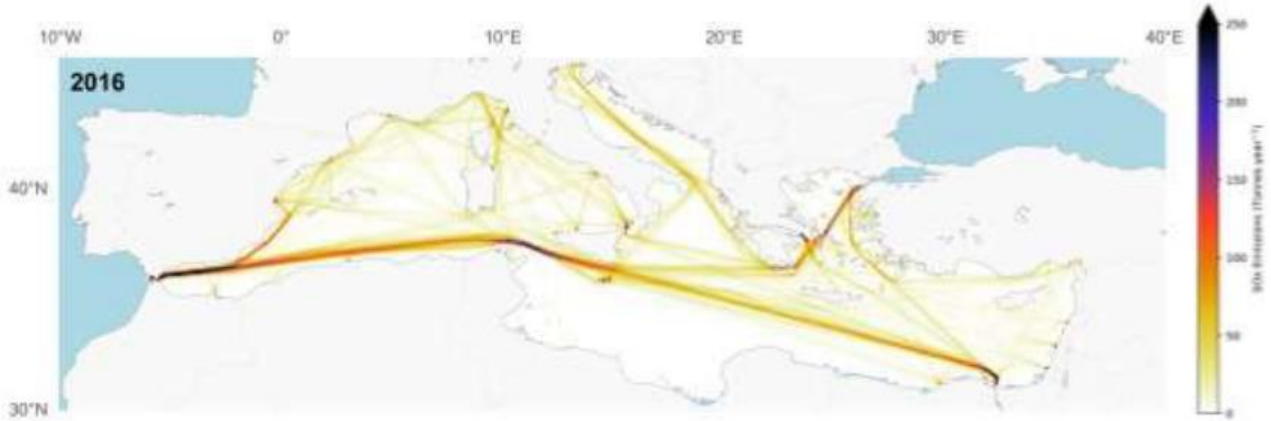
Dr. Elizabeth Lindstad, Chief Scientist in Sintef Ocean, Trondheim, Norway

- After two very hot summers, i.e., two out of there years since the sulphur cap came into effect in 2020 and serve drought in areas with major shipping traffic as the Western Mediterranean and the South-West coast of Europe, it's a need for investigate how much of this temperature rise is potentially caused by the sulphur cap.
- With the high sulphur content, we had up to 2020 we got huge amounts of see-through aerosols (small airborne droplets) which worked in three ways: First they contributed to cloud building; Second, they brightened the clouds; Third they connected to the soot particles (Black Carbon) and when they connect most of them fell into water quite fast. Contrary with less sulphur we have since 2020 lost the brightening effect of the clouds, and the soot particles goes higher and stays longer up in the atmosphere. Resulting in darker clouds containing more red light which absorbs more of the heat from the sun.

The arguments for the proposed MED ECA illustrates that there is an urgent need for taking more holistic approaches and not like here try to drive the car forward by looking in the mirror

- *The Mediterranean Sea Area is an important region for international shipping and commercial navigation. The Mediterranean Sea represents approximately 0.7% of navigable seas and oceans, and Mediterranean ship traffic accounts for about 7% of global shipping activity, energy use, and emissions*
- *The present report financed by the Mediterranean Trust Fund (MTF) and implemented by the Plan Bleu Regional Activity Centre (PB/RAC) concludes that a Med ERCA from 2025 only will raise sea transport cost marginally and that the benefit of the human health advantages are fare larger than any competitive disadvantages*
- *The report does not take into account or discuss cooling effects from shipping's sulphur and NOx shipping emissions and that temperature might raise much faster than expect as a consequence of the around 85% global reduction from a maximum of 3.5% to 0.5% sulphur in the fuel globally from 1st of January 2020*

Figure 2. Shipping traffic (shown as SO_x emissions) in the Mediterranean Sea Area in 2016



#OCEAN MARITIME TRANSPORT

Zero Carbon E-Fuels: Are they sustainable for maritime transport?

BY ELIZABETH LINDSTAD
SEPTEMBER 12, 2022

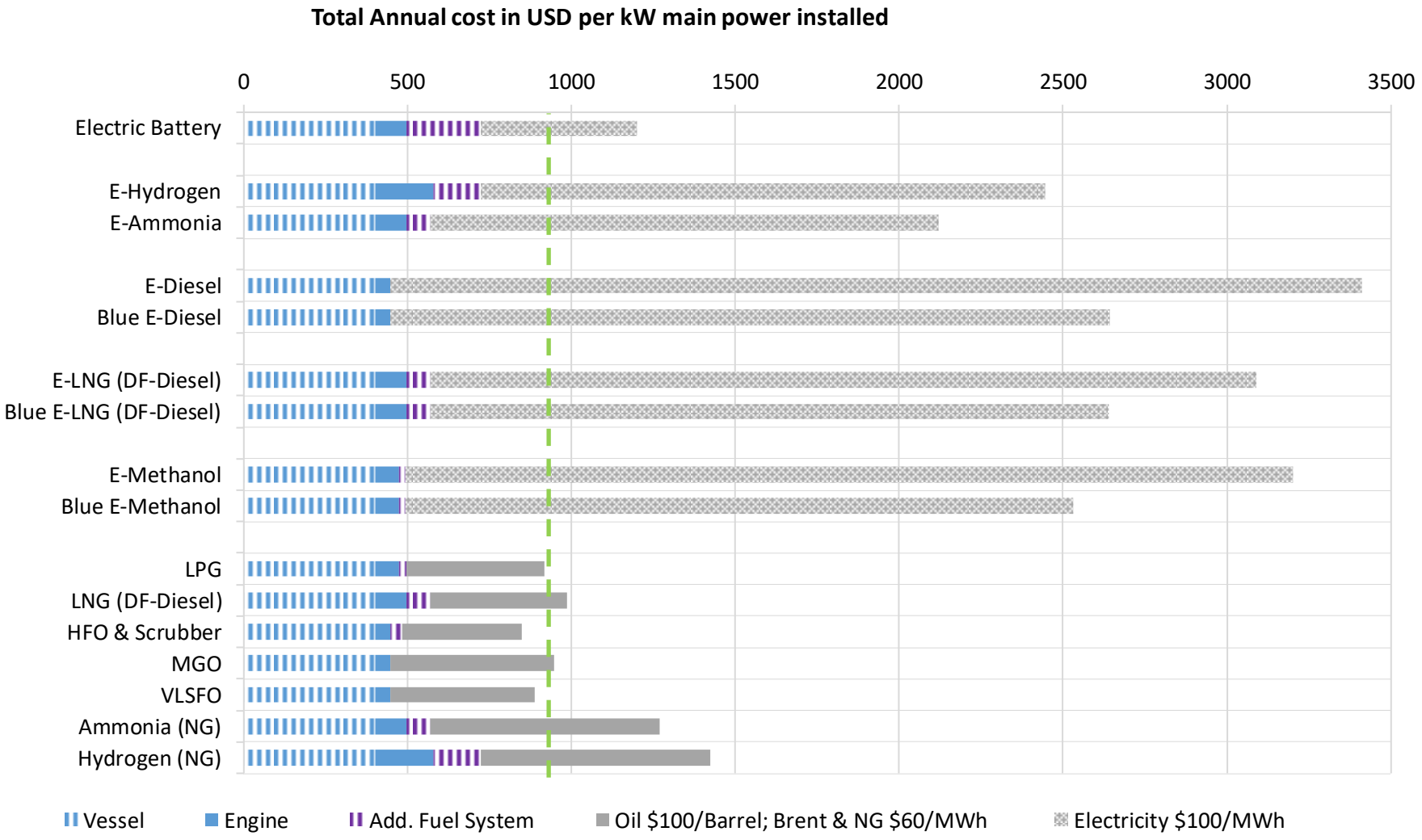
COMMENTS
2

From the first days of our civilization maritime transport has dominated trades between nations, regions, and continents. Today, maritime transport accounts for 80% of the Global trade measured in ton miles and 3% of global Greenhouse gas (GHG) emissions. The Intergovernmental Panel on Climate Change stress the urgent need for rapidly reducing Global GHG to mitigate global warming and to reach Net Zero GHG within a few decades. The term net zero imply that all remaining anthropogenic GHG emissions will have to be offset with carbon removal from the atmosphere.

In that perspective, a rapid de-carbonization of the whole transport sector is often seen as necessity to mitigate global warming. That view is strongly advocated by the International Energy Agency (IEA) in its “Net Zero by 2050” scenario, published in May 2021. Conversely, in their 2021 “Sky” scenario, Shell brings us to Net Zero by 2070 picking the lowest hanging fruits first and implying a continuous use of fossil fuel both for maritime and aviation. To reach Net Zero, both IEA and Shell need technical removal of carbon from the atmosphere in the form of Carbon Capture and Storage (CCS) to offset the remaining fossil use in 2050, as shown in Figure 1.

The term net zero imply that all remaining anthropogenic GHG emissions will have to be off-set with carbon removal from the atmosphere.

E-fuels are costly and gives abatement cost of 651 – 1369 USD per ton of CO_2*

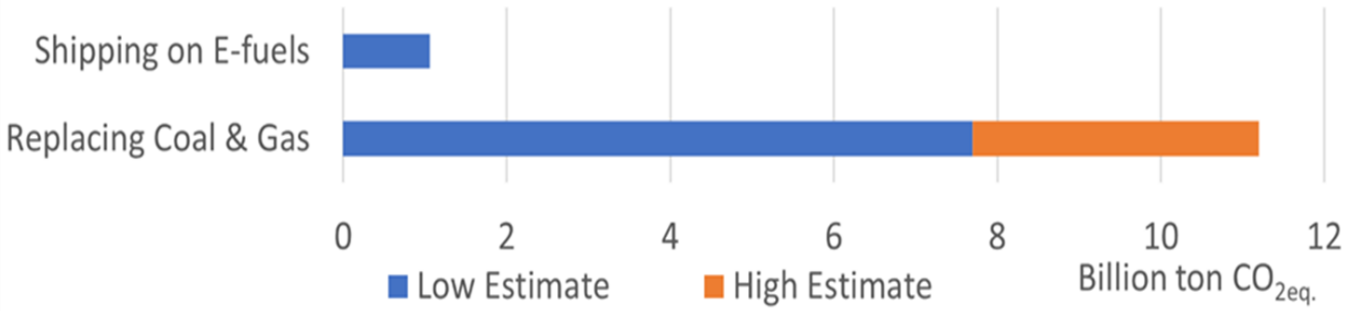


Abatement cost per ton CO_2
140
832
651
1 369
941
1 190
939
1 251
880

* with an electricity price of 100 USD per MWh. Most published studies have used something in the range of 20 – 60 USD per MWh

Are Zero-carbon fuels for shipping sustainable compared to the alternative use of renewable energy?

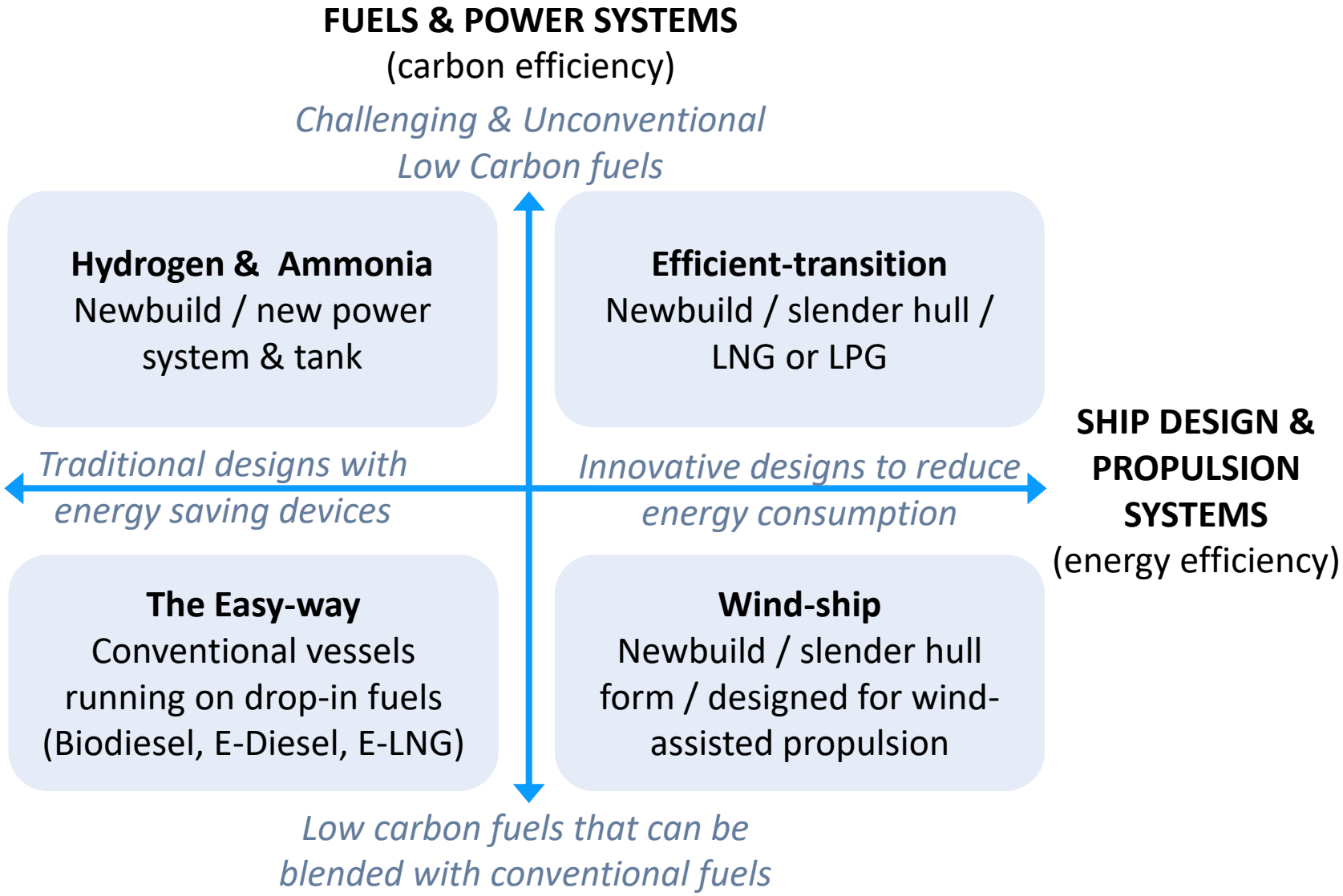
1. Global production of electricity is 84 EJ, of which around 25 EJ comes from renewables
2. Fuelling ships on E-fuel requires: E-ammonia: 14EJ * 4.2/2 = 29EJ; E-diesel: 14EJ * 7.1/2 = 50EJ
3. If that renewable energy instead is used to replace electricity from Coal (around 30EJ) and Natural gas (around 20 EJ) we will get 7 – 10 larger CO_2 reductions, i.e. 20-30% Global CO_2 reductions instead of 3% from shipping.



Source: Elizabeth Lindstad, Sustainability of Zero carbon E-fuels for maritime transport; MT- Marine Technology, in press July 2022.

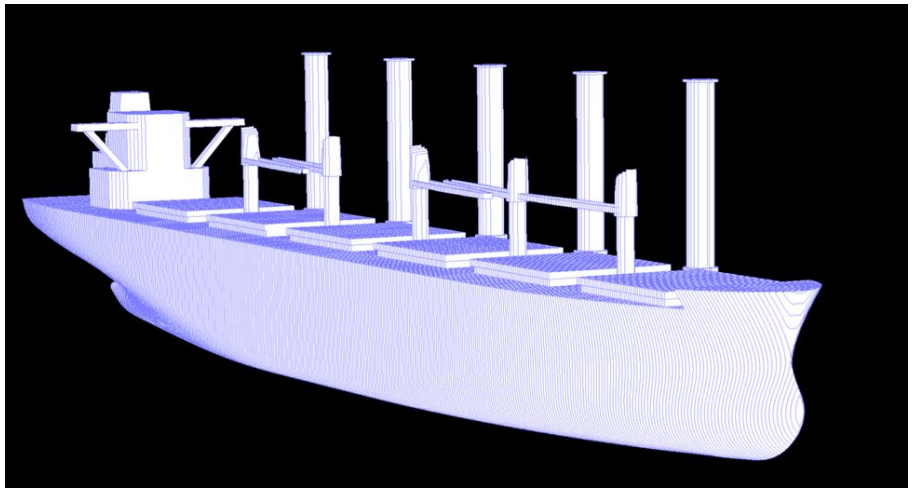
All roads leads to Rome: IMO's 50% GHG reduction how we have presented in the past

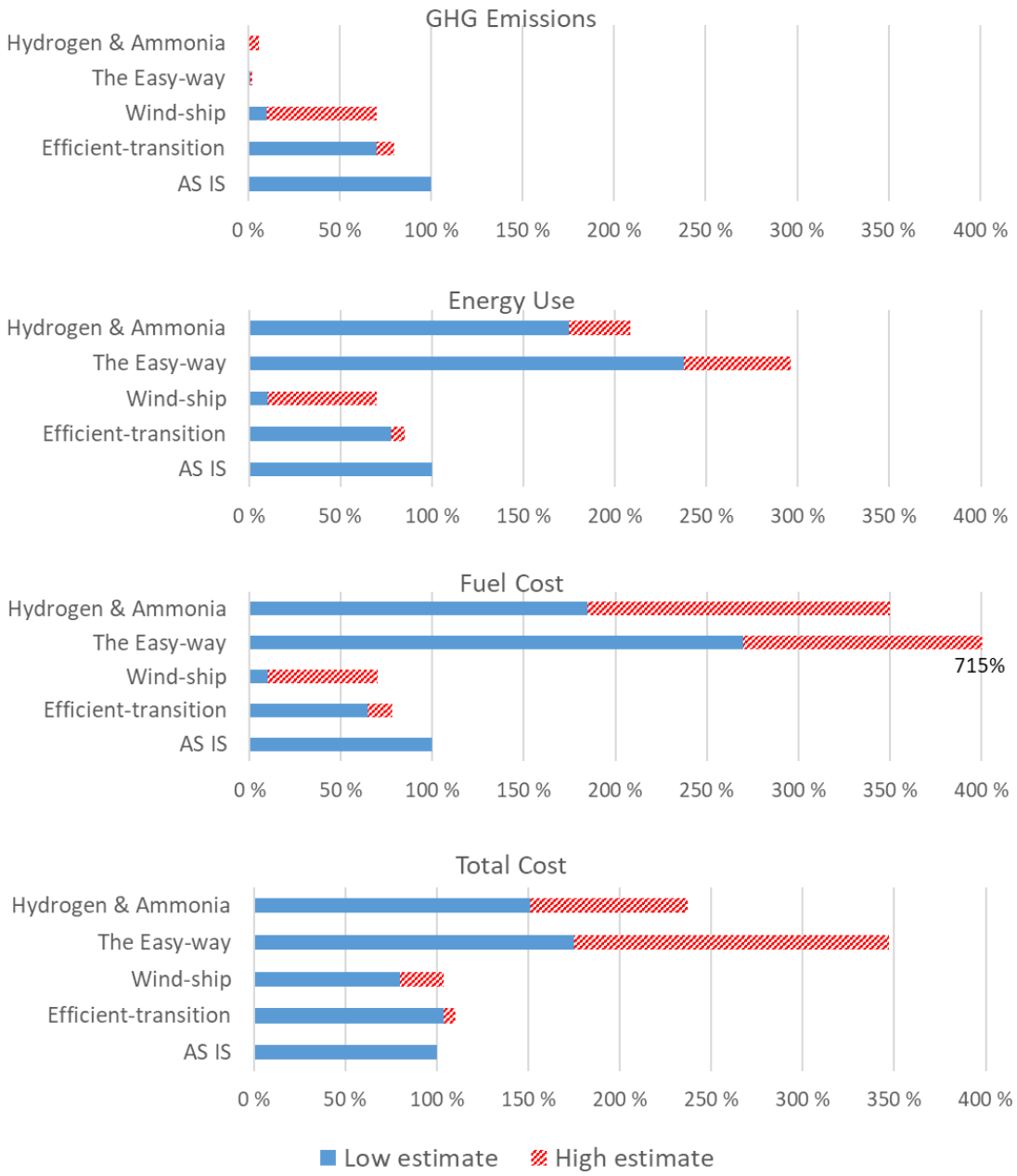
4 fundamentally distinct shipping de-carbonization scenarios



Source: Rialland and Lindstad (2021) Shipping decarbonization scenarios, IAME 2021

Comparing the four shipping Scenarios to reach the 50% GHG reduction by 2050

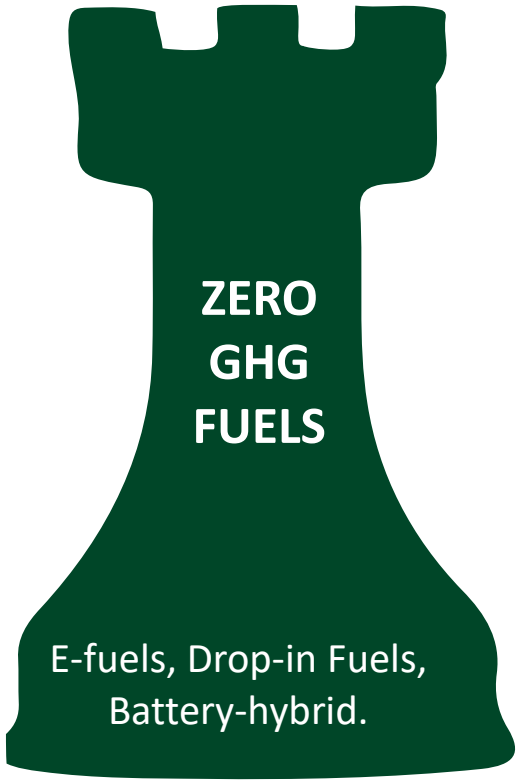




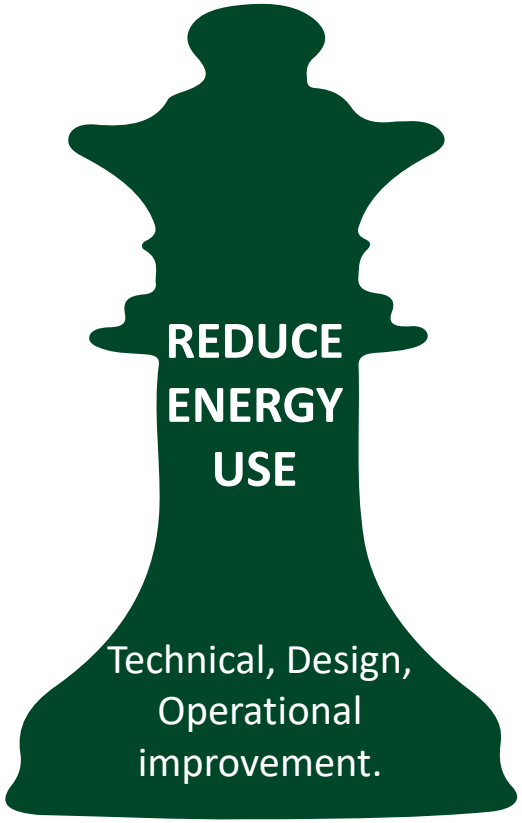
Source: Rialland & Lindstad, 2021

How can shipping best contribute to mitigating climate change and avoid boosting global warming

ZERO CARBON scenario



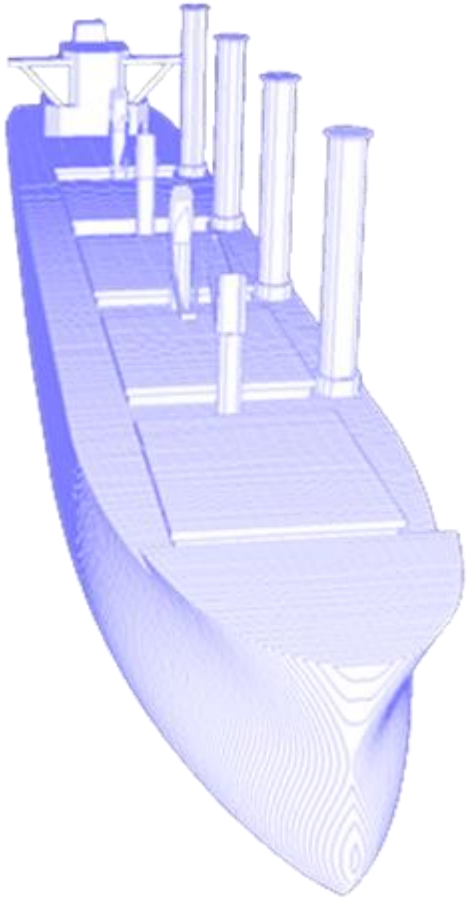
ENERGY EFFICIENCY scenario



PRAGMATIC scenario

The investigated designs

Vessel		Supramax 200m		200m Slender Supramax	
			WASP		WASP
LOA (m)		200	200	200	200
Beam (m)		32.3	32.3	32.3	32.3
Displace-ment (Ton)	11.7 (m)	64 300	64 300	57 900	57 900
	13.4 (m)	73 700	73 700	66 700	66 700
	14.4 (m)			73 700	73 700
Volume capacity (m^3)		79 000	79 000	77 000	77 000
Block – Cb		0.88	0.88	0.79	0.79
Bow length -L_{BWL} (m)		15.5	15.5	38.8	38.8
Boundary speed (knots)		11.7	11.7	15.1	15.1
LDT (Ton)		10 700	10 900	10 700	10 900
Dwt (Ton)	11.7 (m)	53 600	53 400	47 200	47 000
	13.4 (m)	63 000	62 800	56 000	55 800
	14.4 (m)			63 000	62 800
Main Power (KW)		8 500	8 500	8 500	8 500
Newbuild Cost (MUSD)		30	33.5	30	33.5



Our three 2022 papers on Wind assistance propulsion - WASP

Ocean Engineering 266 (2022) 112798

Contents lists available at ScienceDirect

Ocean Engineering

journal homepage: www.elsevier.com/locate/oceaneng

Decarbonizing bulk shipping combining ship design and alternative power

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ARTICLE INFO

Keywords:
Maritime transport
Bulk shipping
GHG
Ship design
Wind assisted propulsion
Alternative fuels

ABSTRACT

The Sixth Assessment Report by the Intergovernmental Panel on Climate Change (IPCC) stresses the urgency to rapidly reduce global Greenhouse Gas (GHG) emissions to contain global warming. The main focus in the design of bulk vessels for several decades has been maximizing cargo-carrying capacity at the lowest build cost. Reduction in energy consumption and emissions, if achieved at all, was heavily limited by the main design focus. This paper decarbonizes bulk shipping by combining ship design and alternative power. The results indicate: First, building more slender bulk vessels that are powered with wind-assisted propulsion reduces fuel consumption and GHG emissions by around 25% at an abatement cost of less than Zero, i.e., free of charge; Second, when combining slender hull and wind-assisted propulsion with Zero-carbon fuels, a 100% GHG reduction comes at an abatement cost of 328 USD per ton of CO_2, which is still significantly less than the 459 USD per ton of CO_2 with Zero-carbon fuels only.

Contents lists available at ScienceDirect

Maritime Transport Research

journal homepage: www.sciencedirect.com/journal/maritime-transport-research

Ship of the future – A slender dry-bulker with wind assisted propulsion

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ARTICLE INFO

Keywords:
Ship design
Maritime transport
Energy efficiency
Wind assisted propulsion
Performance in the seaway
IMO

ABSTRACT

From the first days of our civilization sea transport has enabled trades. Today sea transport accounts for 80% of the Global trade measured in ton miles and 3% of Greenhouse gas (GHG) emissions. More than 40% of this sea trade is performed by the Dry bulkers, making them the real workhorses of the sea. Compared to other transport modes, Sea transport and Dry bulkers in particular, are energy efficient. Despite this, with the urgent need to reduce Global GHG emissions according to the Paris agreement (UNFCCC 2015), all sectors including shipping, needs to deliver major GHG reduction within the next decades. This paper focus on potential energy reductions through building more slender bulk vessels in combination with wind assisted propulsion (WASP). The results indicates that fuel consumption and hence GHG emissions can be reduced by up to 40% on an operational basis (EEOI) and 30% when shipbuilding is included (LCA).

SNAME Maritime Convention 2022
26-29 September, Houston, TX

www.sname.org

Reaching IMO 2050 GHG Targets Exclusively through Energy efficiency measures

Elizabeth Lindstad[1] (FL), **Dražen Polić**[2] (V), **Agathe Rialland**[1] (V), **Inge Sandaas**[1] (V), **Tor Stokke**[3] (V)
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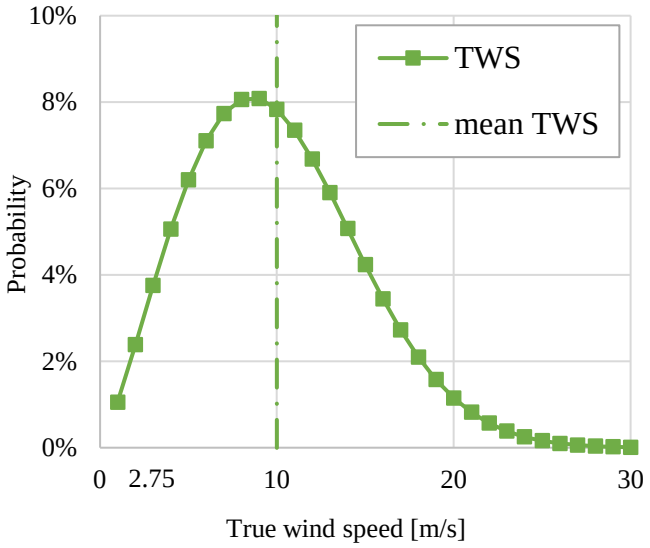
[3] Stokke Marine, Tveit, Norway

Maritime transport accounts for around 3% of global anthropogenic greenhouse gases (GHG) emissions (Well-to-Wake). GHG emissions must be reduced by at least 50% in absolute values by 2050 to contribute to the ambitions of the Paris agreement signed in 2015. Switching to Zero-carbon fuels made from renewable sources (hydro, wind, or solar) is seen by many as the most promising option to deliver the desired GHG reductions. However, renewable energy is a scarce resource that gives a much larger GHG reduction spent within other sectors. This study explores how to reach the IMO 2050 GHG targets exclusively through energy efficiency measures. The results indicate that by combining wind-assisted propulsion (WASP) with a slender hull form, fuel consumption and GHG emissions can be reduced by 30 – 35%, and transport cost by 5 – 10%. In comparison, GHG reductions through Zero-carbon fuels will increase transport costs by 50-200%.

Wind and wave probability correlation

Wind probability

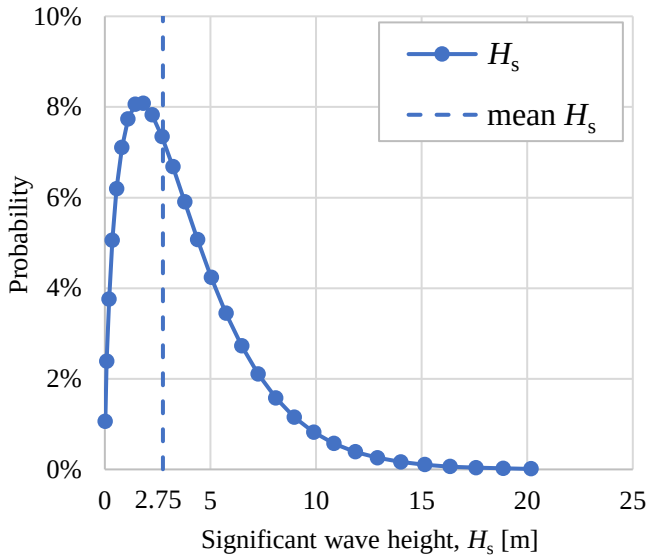
c_w = 11.3 and k_w = 2.2



Average true wind speed is 10m/s

Pierson-Moskowitz spectrum

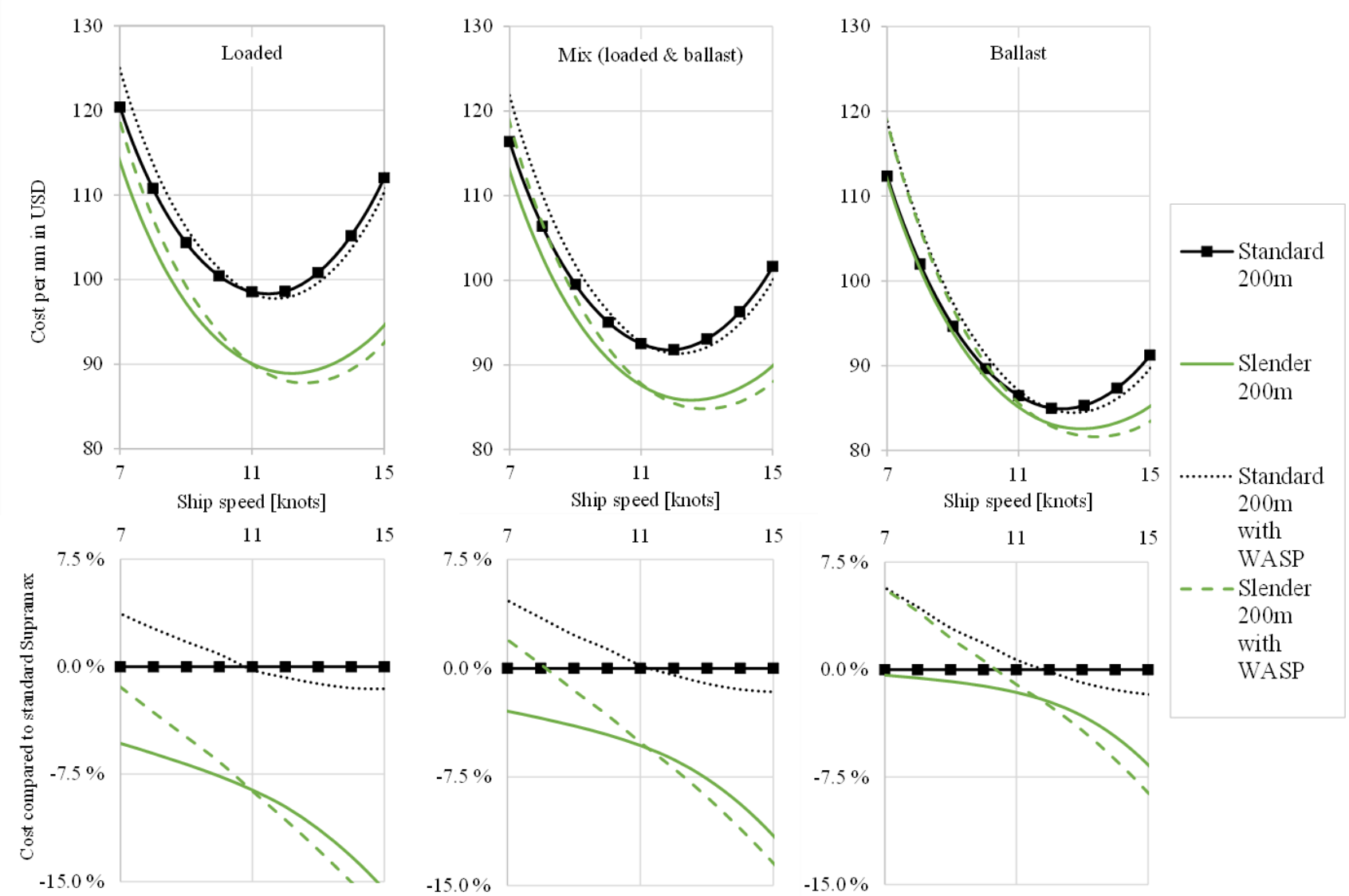
Wave probability



Average significant wave height is 2.75m

Average significant wave height of 2.75 is also in line with average annual global resistance pattern presented in earlier studies, e.g., Lindstad et al. (2011, 2019)

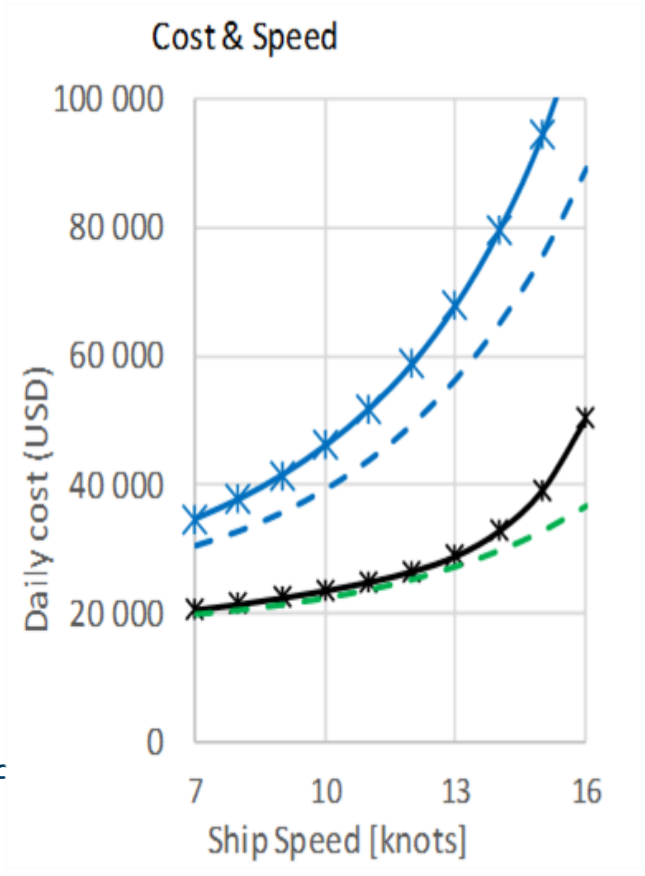
Comparing cost

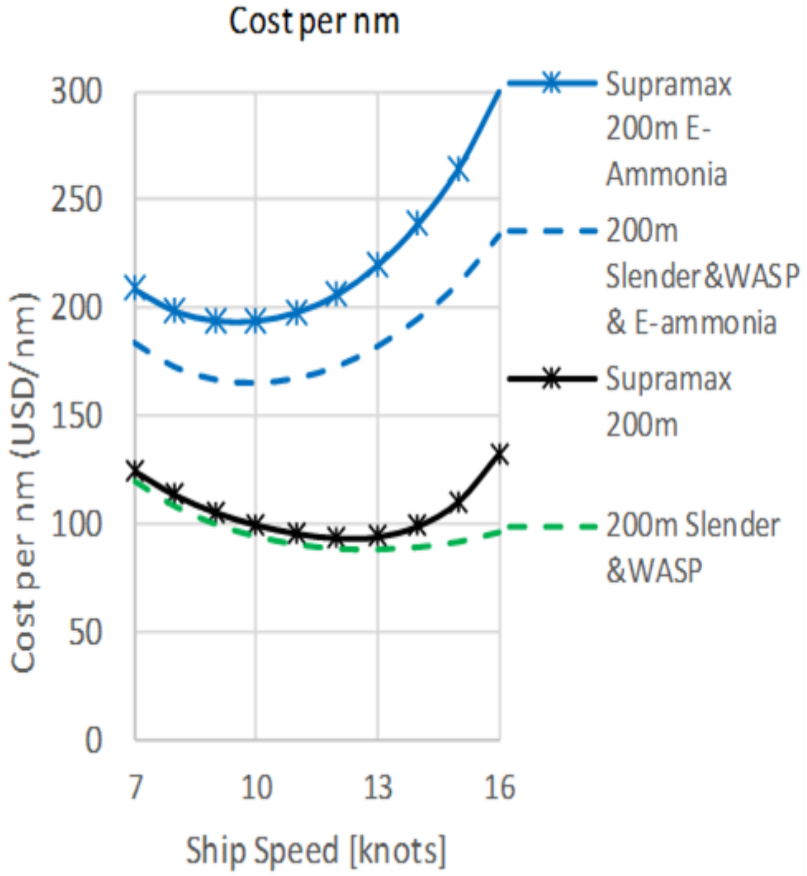


Decarbonizing Bulk Shipping through combining Ship Design and Alternative Power

Lindstad, E., Polić, D., Rialland, A., Sandaas, I., Stokke, T., 2022, Accepted for publication in Ocean Engineering Journal

1. Slender bulk vessels in combination with wind-assisted propulsion reduce fuel & GHG by 25%, with negative abatement costs.
2. Combining Slender & Wind with Zero-carbon fuels, a 100% GHG reduction comes at a cost of 325 USD / ton CO_2
3. De-carbonizing through Zero-carbon fuels only: abatement cost 459 USD / ton CO_2
   (* renewable electricity price of 60 USD per MWh)
4. Fuel & technology neutral study. E-ammonia selected because least expensive E-fuel. My view is that Ammonia and Hydrogen safety risk for the WTW supply chain and the cost of new infrastructure exceeds their cost-benefit versus E-Methanol, E-LNG and E-diesel.





Source: Lindstad et al. (2022) Decarbonizing Bulk Shipping through combining Ship Design and Alternative Power, Ocean Engineering.

Takeaways – How can shipping best contribute to Global De-carbonization

- New **renewable** electricity is a scare resource which gives the largest GHG reduction when it **replaces coal** fired power plants.
- **Shipping** largest contribution to reaching net zero will be on improving energy efficiency through **technical**, **design** and **operational** measures.
- Of all Zero-carbon fuels and propulsion solutions, **Wind** is the **most promising** and comes **at the lowest cost.**
- **We need to Stop creating legislation which makes marginal or no impact and in Worst case boost global warming. Contrary there is an urgent need to minimize BC and Sot emissions**
- **Utilizing the Geo-engineering effect of shipping, through more differentiated Sulphur and NOx rules (abolish the General Sulphur cap) might be shipping's best contribution to keeping global temperature rise bellow 2 degrees.**

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