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PAPER PRESENTATION ON

GREEN TECHNOLOGIES

PREPARED

FOR

TRANSTECH-12

INNOVATION IN TRANSPORTATION

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Abstract

This document presents a study carried out by Lloyd's Register and DNV on estimated CO₂ emission reductions associated with the mandatory technical and operational measures adopted at MEPC 62 as resolution MEPC.203(62) by adding a new chapter 4 on energy efficiency to MARPOL Annex VI.

Mandatory measures to increase energy efficiency and reduce greenhouse gas emissions from international shipping, in particular CO₂ emissions, were adopted by Parties to MARPOL Annex VI at MEPC 62, representing the first ever mandatory global CO₂ reduction regime for an international industry sector.

Key Words;

Hydroxyl radical -is the neutral form of the hydroxide ion (OH⁻). *Hydroxyl radicals* are highly reactive and consequently short-lived.

Turbochargers – This increase engine performance without adding much weight.

Introduction

Why Green Technology?

Shipping is the primary means of transport worldwide. We, in Europe, rely on it for goods and travelling from one corner of our continent to the other. Today's globalised world trade would not be able to function without ships, after all approximately 70% of the earth's surface is covered by water.

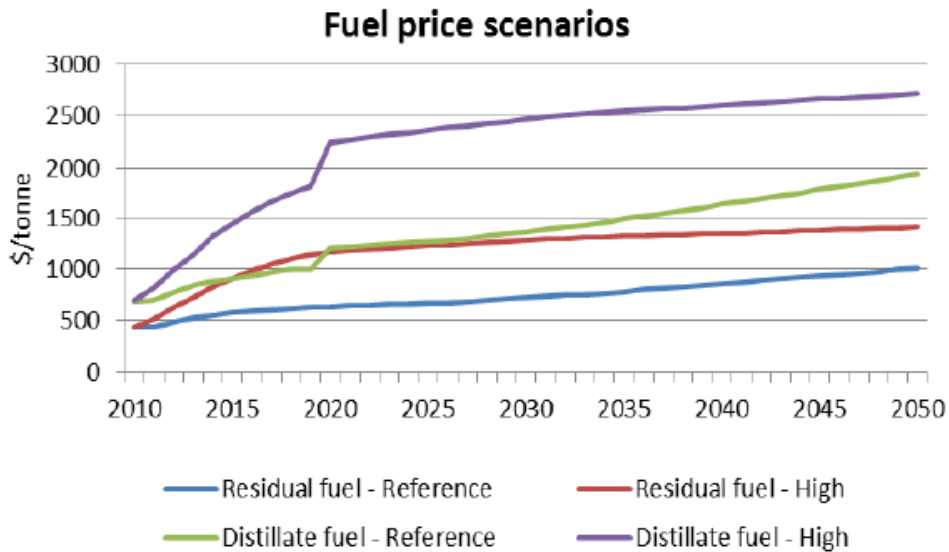
The main reasons for moving towards green technologies are global warming caused due to emissions and increasing fuel prices.

Ship type	CO ₂ emission 2010
Bulk carrier	169.3
Gas tanker	40.8
Tanker	181.3
Containership	231.6
General cargo ship	91.1
Refrigerated cargo carrier	18.6
Other	132.9
Total	865.6

Baseline data for international shipping (numbers in million tonnes CO₂ in 2010)

Ship type	2005	2010
Bulk carrier	9	9
Gas tanker	13	12
Tanker	13	12
Containership	30	28
General cargo ship	40	37
Refrigerated cargo carrier	40	37

Baseline data (numbers in grams CO₂ per tonne-nm; MEPC 59/INF.10



\$/tonne in 2050.

Fuel price scenarios. The sharp increase in distillate fuel in 2020 is due to the 0.5% global sulphur requirement

Let us explain a bit about, ' The Emission Reduction Methods'...

Listed below are some of the emission reduction measures, which have been developed in recent years. The main methods are:

- ENERGY EFFICIENCY DESIGN INDEX (EEDI)
- ENERGY EFFICIENCY OPERATION INDEX (EEOI)
- SHIP ENERGY EFFICIENCY MANAGEMENT PLAN (SEEMP)

The claimed potential for each measure is listed as well. The idea of this concept study is to determine, for a specific ship design, the combined effect of some of these measures.

Let us discuss the above mentioned methods.....

The EEDI requires a minimum energy efficiency level (CO2 emissions) per capacity mile (e.g. tonne mile) for different ship type and size segments. The measures used in EEDI are listed in the table below.

No.	EEDI reduction measure	Remark
1	Optimized hull dimensions and form	Ship design for efficiency via choice of main dimensions (port and canal restrictions) and hull forms.
2	Lightweight construction	New lightweight ship construction material.
3	Hull coating	Use of advanced hull coatings/paints.
4	Hull air lubrication system	Air cavity via injection of air under/around the hull to reduce wet surface and thereby ship resistance.
5	Optimization of propeller-hull interface and flow devices	Propeller-hull-rudder design optimisation plus relevant changes to ship's aft body.
6	Contra-rotating propeller	Two propellers in series; rotating at different direction.
7	Engine efficiency improvement	De-rating, long-stroke, electronic injection, variable geometry turbocharging, etc.
8	Waste heat recovery	Main and auxiliary engines' exhaust gas waste heat recovery and conversion to electric power.
9	Gas fuelled (LNG)	Natural gas fuel and dual fuel engines.
10	Hybrid electric power and propulsion concepts	For some ships, the use of electric or hybrid would be more efficient.
11	Reducing onboard power demand (auxiliary system and hotel loads).	Maximum heat recovery and minimising required electrical loads flexible power solutions and power management.
12	Variable speed drive for pumps, fans, etc.	Use of variable speed electric motors for control of rotating flow machinery leads to significant reduction in their energy use.
13	Wind power (sail, wind engine, etc.)	Sails, fletnner rotor, kites, etc. These are considered as emerging technologies.
14	Solar power	Solar photovoltaic cells.
15	Design speed reduction (new builds)	Reducing design speed via choice of lower power or de-rated engines.

With the level being tightened over time, the EEDI will stimulate continued technical development of all the components influencing the energy efficiency of a ship. Reduction factors are set until 2025 when a 30% reduction is mandated over the average efficiency for ships built between 1999 and 2009. The EEDI has been developed for the largest and most energy intensive segments of the world merchant fleet and will embrace about 70% of emissions from new oil and gas tankers, bulk carriers, general cargo, refrigerated cargo and container ships as well as combination carriers (wet/dry bulk). For ship types not covered by the current EEDI formula, suitable formulas will be developed in the future according to a work plan agreed at MEPC 62.

The **SEEMP** establishes a mechanism for a shipping company and/or a ship to improve the energy efficiency of ship operations. The SEEMP provides an approach for monitoring ship and fleet efficiency performance over time using, for example, the **Energy Efficiency Operational Indicator (EEOI)** as a monitoring and/or benchmark tool. The SEEMP urges the ship owner and operator at each stage of the operation of the ship to review and consider operational practices and technology upgrades to optimize the energy efficiency performance of a ship.

The measures used in **SEEMP** are listed in the table below.

No.	Energy Efficiency Measure	Remark
1	Engine tuning and monitoring	Engine operational performance and condition optimization.
2	Hull condition	Hull operational fouling and damage avoidance.
3	Propeller condition	Propeller operational fouling and damage avoidance.
4	Reduced auxiliary power	Reducing the electrical load via machinery operation and power management.
5	Speed reduction (operation)	Operational slow steaming.
6	Trim/draft	Trim and draft monitoring and optimisation.
7	Voyage execution	Reducing port times, waiting times, etc. and increasing the passage time, just in time arrival.
8	Weather routing	Use of weather routing services to avoid rough seas and head currents, to optimize voyage efficiency.
9	Advanced hull coating	Re-paint using advanced paints.
10	Propeller upgrade and aft body flow devices	Propeller and after-body retrofit for optimisation. Also, addition of flow improving devices (e.g. duct and fins).

SEEMP related measures

Let us discuss some of the methods in detail the first one being 'Water in Fuel (WIF)'.....

Operating on WIF gives the following possibilities:

- o Based on already obtained experience the effect of adding 50 % water to the fuel is expected to give a 30-35% NOx reduction of the exhaust gas, at the expense of an increase in CO2 emissions of 1-2%.
- o To be used as an alternative measure to reduce the NOx level instead of mechanical adjustments / modification of the engine and thereby being able to fulfill the IMO Tier II limit.
- o To be used to reduce CO2 emission together with turbochargers with variable nozzle area, as the maximum fuel oil reduction potential cannot be obtained operating on fuel only (without WIF) as the NOx emissions would exceed an unacceptable level.

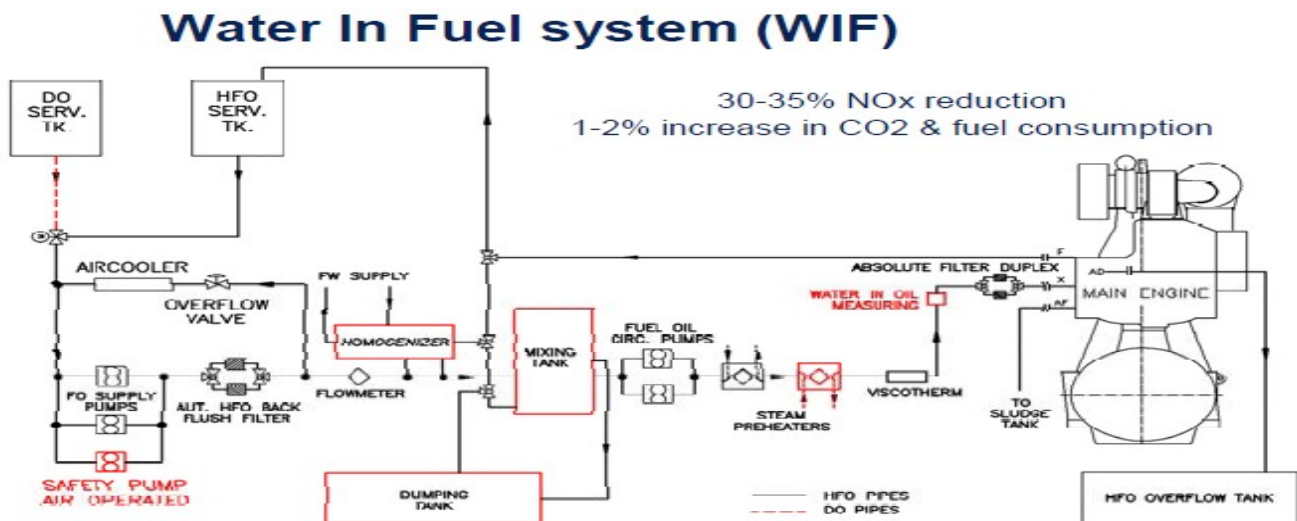
The mechanism of water in fuel...

WIF is believed to decrease the NOx formation because the peak temperature is lowered due to the higher heat capacity of water vapour (compared to ambient air) and the heat absorption by water vaporization. It has also been observed, that the formation of PM is lowered when WIF is employed, which can be explained by the phenomenon micro-

explosions or secondary atomization of emulsified fuel. This occurs, because the boiling point of water is lower than that of the surrounding fuel oil. The overall effect of the improved mixing of fuel with the combustion air is a decrease of the final CO, THC and PM concentrations. The improved mixing is also due to an increased momentum of the vaporized fuel jet (the mass is increased due to addition of water), which also improves the mixing. The presence of water in the fuel leads to a potential ignition delay, which means that more time for premixing of fuel and air is available. The last effect of WIF is an increased amount of hydroxyl radicals due to the higher water concentration. Hydroxyl radicals are essential in the oxidation of CO and THC.

Water in fuel on MAN two-stroke engines...

MAN diesel delivers the main components of the system, assembled in a so-called WIF unit, plus the necessary modifications to the main engine.



Modifications to main engine:

In general the needed changes to ME/ME-C and ME-B engines are very limited, whereas the mechanical camshaft engine types MC and MC-C requires more changes.

Modifications to auxiliary systems:

When adding water to the fuel, the emulsion needs to be heated to a higher temperature than without water and the pressure in the system has to be increased in order to avoid evaporation of the water. Furthermore, the auxiliary engines will be required to be supplied

from a separate fuel oil system, as they will not be capable to operate on the same amount of water. The amount of water added is 50 % of the fuel, corresponding to app. 13.5 tonne of fresh water per 24 hours. This means that a larger fresh water generator is needed; but enough heat is available from the main engine jacket cooling water system. For new buildings the extra investment is limited, as many of the components just differ a little from its specification and placement in the systems. For existing vessels the piping system and many of the components needs to be replaced, which will be relatively costly.

The WIF fuel system for the main engine is shown in the diagram on next page. The new components are water in fuel measuring device, homogenizer, dumping tank, and an air driven back-up fuel oil supply pump for securing pressure in the fuel system, in case of black-out. The supply pump pressure must be increased from the normal 6 bar to 13 bar, meaning that all components in the re-circulation circuit, including the homogenizer, mixing tank, circulating pumps, preheaters, viscotherm, filter and main engine, must be designed for this pressure.

The preheating temperature must be increased to 180 deg. C, which cannot be obtained by heating with 6 bar service steam. A 14 bar steam system has been introduced, in order to boost the temperature of the fuel emulsion. Water In Fuel system (WIF) helps in 30-35% NOx reduction.

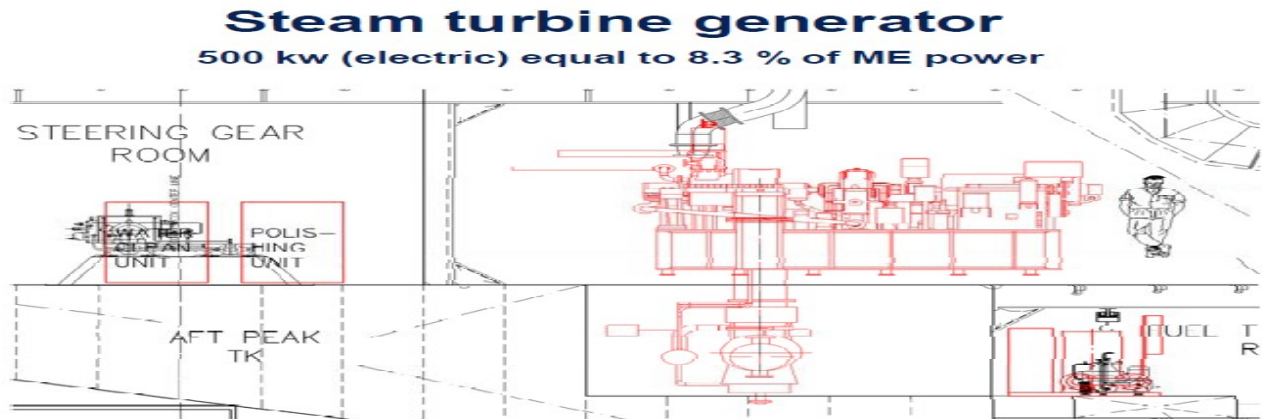
After discussing the WATER IN FUEL (WIF), we shall discuss on the 'The Waste Heat Recovery System (WHR)'.



Project facts
Category: Machinery
Emission reductions:
CO ₂ 20 %
NO _x 20 %
SO _x 20 %
Partners:
APV
DESMI
LR Marine

Steam turbine generator: 500 kw (electric) equal to 8.3 % of ME power

Waste heat recovery systems, with different degrees of sophistication, have been used on ships for decades, and with respect to CO₂, it gives by far the largest emission reduction, of the systems in this case study. Experience from existing installations, e.g. large container vessels owned by A.P.Møller-Mærsk, shows a potential for recovery of 10-15 % of the main engine power.



The system in this case study has been designed in a co-operation between MAN Diesel, Aalborg Industries and MAN Turbo. The steam turbine generator, which replaces one of the existing diesel generators, has been designed by MAN Turbo, and has an electric output of 500 kW, when sailing at service speed, corresponding to 8.3 % of the main engine output. The reason for this relatively modest output is, partly that the so called power turbine *) has been omitted for simplicity on this relatively small system, partly that a substantial portion of the generated steam must be used for fuel heating, not least due to the WIF system, and finally that the main engine exhaust gas temperature is relatively low, due to the de-rating. There is simply less wasted heat to utilize. The power turbine (omitted) is similar to the turbine part of a turbocharger, and some of the exhaust gas is led through this, thereby bypassing the turbochargers. The power turbine is part of the steam turbine generator unit. It typically provides 15 - 25 % of the WHR output.

The vessels boiler plant has been designed by Aalborg Industries, and consists in total of six individual boilers, out of which four (intermediate and low pressure boilers) produces steam for the steam turbine: **High pressure (HP), intermediate pressure (IP) and low**



Project facts

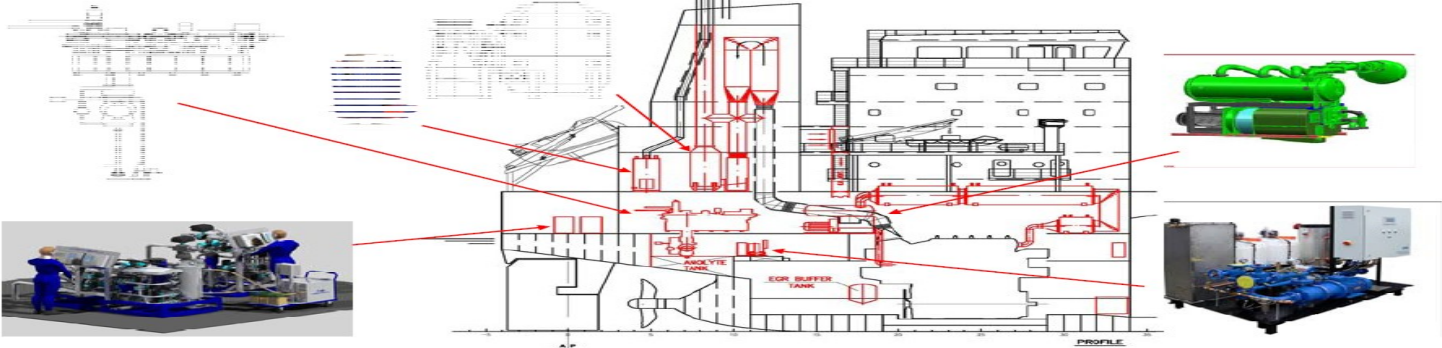
Category: Machinery

Emission reductions:
 CO₂ 7 - 14 % depending on installation
 NO_x 7 - 14 % depending on installation
 SO_x 7 - 14 % depending on installation

Partners:
Aalborg Industries A/S
AP Møller Maersk
MAN Diesel
Odense Steel Ship Yard

After having said about The Waste Heat Recovery System (WHR, I must emphasize on the 'Consequences of Modification'....

Where do we put it ?



Let us throw some light on 'certain Observations'.....

Regulation 21 of MEPC provides the EEDI implementation phases as shown below. In this Study, it is assumed that Phase 3 ends in 2040 and that a new Phase 4 will be introduced in 2040 with an EEDI reduction factor of 40%, applicable from 2040 and onwards.

Reduction factors (in percentage) for the EEDI relative to the reference line for each ship type.

	Size	Phase 0 1 Jan 2013 – 31 Dec 2014	Phase 1 1 Jan 2015 – 31 Dec 2019	Phase 2 1 Jan 2020 – 31 Dec 2024	Phase 3 1 Jan 2025 onwards
Bulk Carriers	>20,000 Dwt	0%	10%	20%	30%
	10-20,000 Dwt	n/a	0-10%*	0-20%*	0-30%*
Gas tankers	>10,000 Dwt	0%	10%	20%	30%
	2-10,000 Dwt	n/a	0-10%*	0-20%*	0-30%*
Tanker and combination carriers	>20,000 Dwt	0%	10%	20%	30%
	4-20,000 Dwt	n/a	0-10%*	0-20%*	0-30%*
Container ships	>15,000 Dwt	0%	10%	20%	30%
	10-15,000 Dwt	n/a	0-10%*	0-20%*	0-30%*
General Cargo ships	>15,000 Dwt	0%	10%	15%	30%
	3-15,000 Dwt	n/a	0-10%*	0-15%*	0-30%*
Refrigerated cargo carriers	>5,000 Dwt	0%	10%	15%	30%
	3-5,000 Dwt	n/a	0-10%*	0-15%*	0-30%*

* The reduction factor is to be linearly interpolated between the two values depending on the vessel size. The lower value of the reduction factor is to be applied to the smaller ship size.

The estimated average emission reduction for new ships resulting from the EEDI reduction factor requirements. These are shown in the table below:

	Reduction factor (from Table 1)							
	2013	2015	2017	2020	2025	2030	2040	2050
Bulk carrier	0 %	10 %	10 %	20 %	30 %	30 %	40 %	40 %
Gas tanker	0 %	10 %	10 %	20 %	30 %	30 %	40 %	40 %
Tanker	0 %	10 %	10 %	20 %	30 %	30 %	40 %	40 %
Containership	0 %	10 %	10 %	20 %	30 %	30 %	40 %	40 %
General cargo ship	0 %	10 %	10 %	15 %	30 %	30 %	40 %	40 %
Refrigerated cargo carrier	0 %	10 %	10 %	15 %	30 %	30 %	40 %	40 %

EEDI reduction factors

	Average EEDI reduction rate							
	2013	2015	2017	2020	2025	2030	2040	2050
Bulk carrier	9 %	15 %	15 %	22 %	31 %	31 %	40 %	40 %
Gas tanker	14 %	18 %	18 %	25 %	33 %	33 %	41 %	41 %
Tanker	14 %	18 %	18 %	25 %	33 %	33 %	41 %	41 %
Containership	14 %	18 %	18 %	25 %	33 %	33 %	41 %	41 %
General cargo ship	20 %	25 %	25 %	25 %	39 %	39 %	45 %	45 %
Refrigerated cargo carrier	14 %	18 %	18 %	18 %	33 %	33 %	41 %	41 %
Other	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %

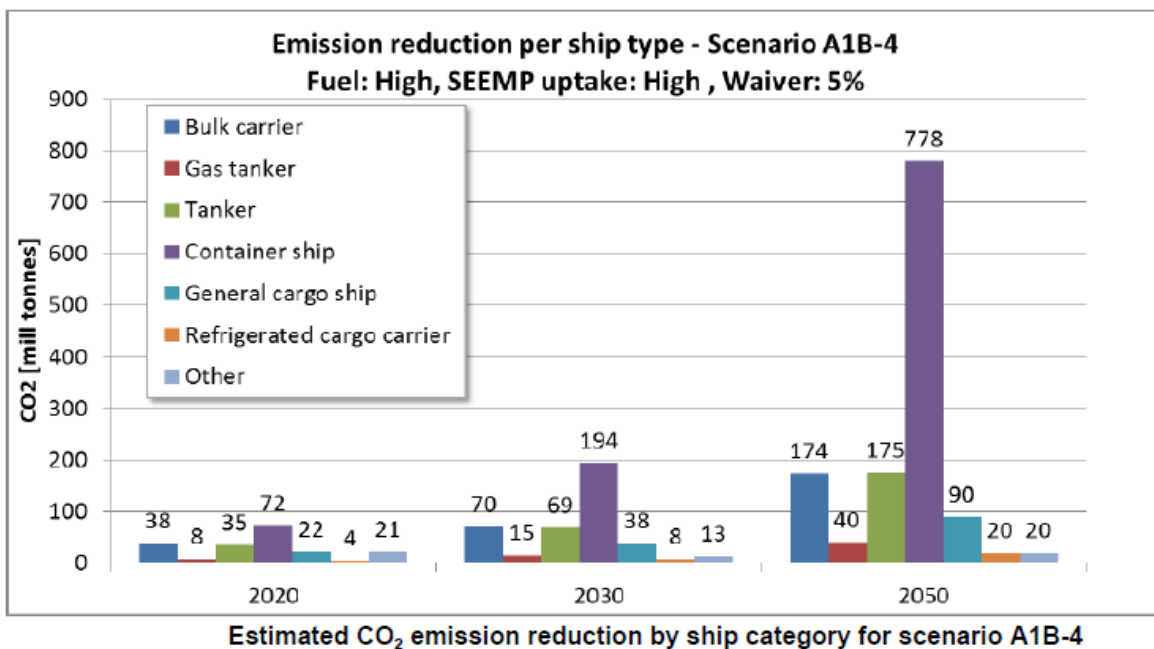
Average emission reduction of new builds

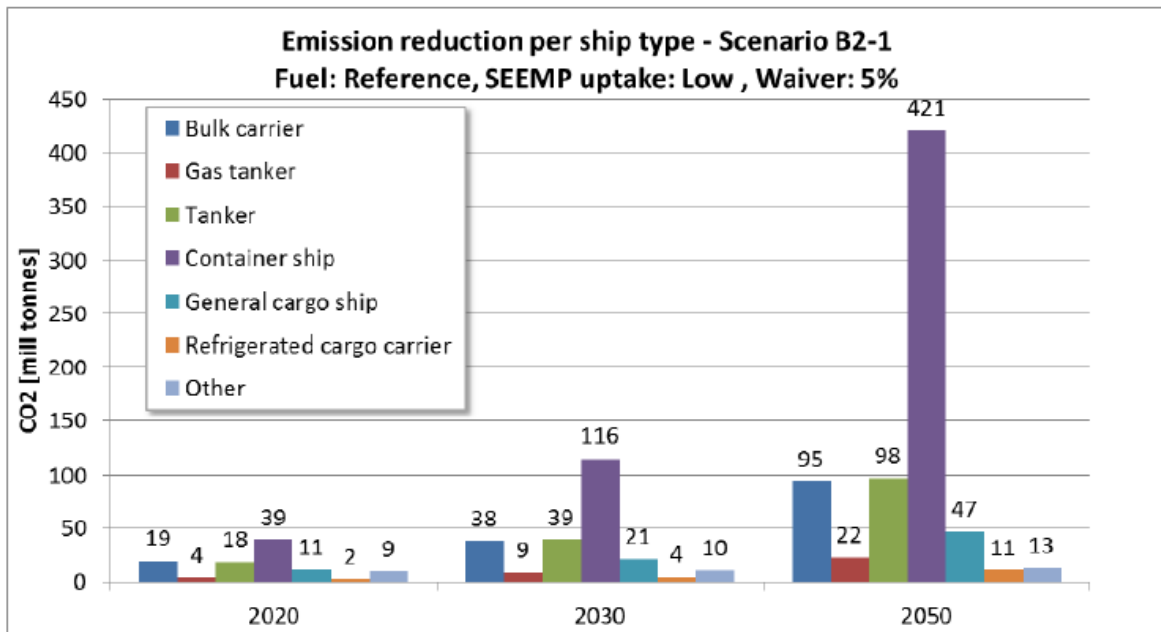
Now the ‘Conclusions and Final Remarks’...

Significant reduction of CO2 emissions from ships due to EEDI and SEEMP regulations is foreseen to 2050 with emission reduction due to SEEMP (primarily operational measures) likely to be realized more rapidly in the short to medium term than that for EEDI

(primarily technical measures), as the effect of EEDI will occur as and when older and less efficient tonnage is replaced by new more efficient tonnage.

Forecasts with different scenarios indicate total annual CO2 emissions in 2050 of 3215 million tonnes for BAU and new emissions level of 1895 million tonnes (1320 million tonnes reduced) for scenario A1B-4 (high growth combined with high SEEMP uptake and high fuel price) and a total annual CO2 emissions in 2050 of around 2014 million tonnes for BAU and new emissions level of 1344 million tonnes (706 million tonnes reduced) for scenario B2-1 (low growth combined with low SEEMP uptake and reference fuel price).



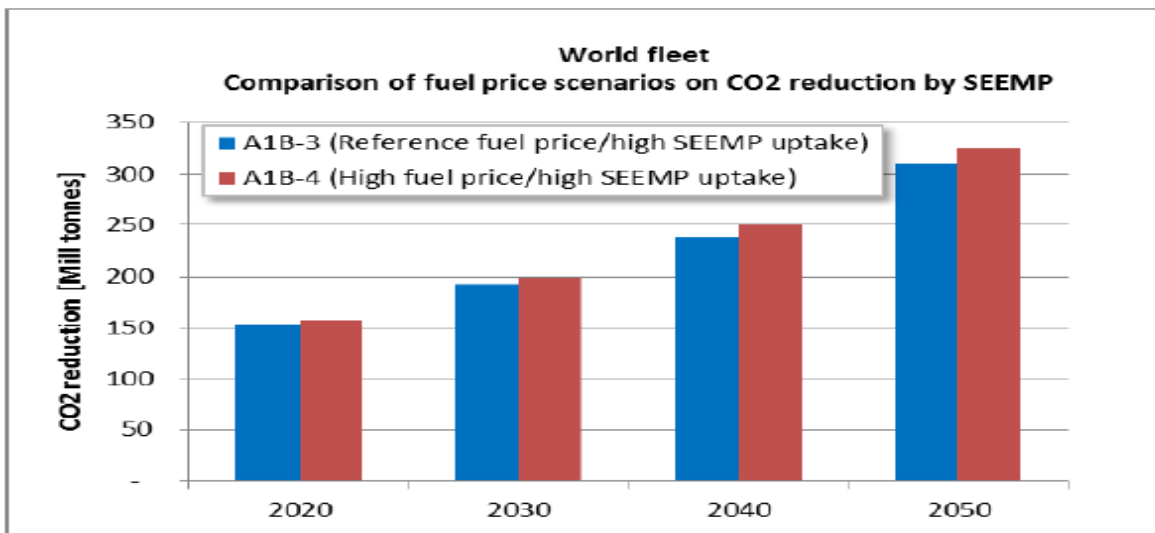


Estimated CO₂ emission reduction by ship category for scenario B2-1

A1B - Rapid and successful economic development, economic and cultural convergence globally, pursuit of personal wealth and use of a balanced mix of energy sources.

B2 - Emphasis is on local solutions to economic, social, and environmental sustainability, with continuously increasing population and intermediate economic development.

The estimated reductions in CO₂ emissions, for combined EEDI and SEEMP, from the world fleet translate into a significant average annual fuel cost saving of about US\$50 billion in 2020 and about US\$200 billion by 2030; using fuel price increase scenarios that take into account the switch to low sulphur fuel in 2020.



The impact of fuel price (fixed SEEMP uptake) on CO₂ reduction

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