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THE PRESENT LANDSCAPE OF GREENHOUSE GAS EMISSIONS IN MARITIME TRANSPORTATION

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Abstract
This article presents the evolution of greenhouse gas emissions from different types of ships. Since the total decarbonization of the maritime sector is being pursued worldwide, it is important to analyse which are the ships with the highest greenhouse gas emissions and to present methods by which these values can be reduced. Thus, starting from the current level of greenhouse gas emission levels, an analysis was started that follows their evolution depending on the type of ship and the fuel used. The results presented in the study have the role of identifying the major problems in this sector and support the formulation of solutions that can reduce values
Keywords Greenhouse gas emissions, maritime industry, vessels, decarbonization

Introduction

World seaborne transport accounts for more than 80% of world trade volume and almost 3% of global greenhouse gas emissions, with emissions increasing by 20% in the last decade (Table 1, Figure 1 and 2). Maritime transport must decarbonise as soon as possible while ensuring economic growth. A prosperous, fair and sustainable future for international shipping requires a balance between environmental sustainability, regulatory compliance and economic requirements. UNCTAD called for a 'just and equitable transition' to a decarbonised shipping industry. Cleaner fuels, digital solutions and a just transition are urgently needed to combat continued carbon emissions and regulatory uncertainty in the shipping industry (UNCTAD, 2023).

Table 1. Carbon dioxide emissions by main vessel types, thousand tons, 2012–2023 (UNCTAD 2023)

Year	Tankers	Dry bulk and general cargo	Containerships	Other	
2012	174.9	192.2	194.6	122.8	684.5
2013	174.2	194.2	190.0	129.1	687.5
2014	176.9	202.3	188.4	136.3	703.9
2015	177.2	195.0	188.0	135.4	695.6
2016	183.2	206.3	196.8	141.8	728.1
2017	194.6	211.8	201.4	146.3	754.1
2018	201.1	209.6	214.2	150.0	774.9
2019	209.2	212.9	209.1	159.0	790.2

2020	225.3	211.4	205.3	165.5	807.5
2021	226.4	221.3	218.0	150.8	816.5
2022	231.1	232.1	215.1	164.2	842.5
2023	236.3	226.5	199.8	167.9	830,5
Total	2,410.4	2,515.6	2,420.7	1,769.1	9,115.8
Average	200.86	209.63	201.72	147,42	

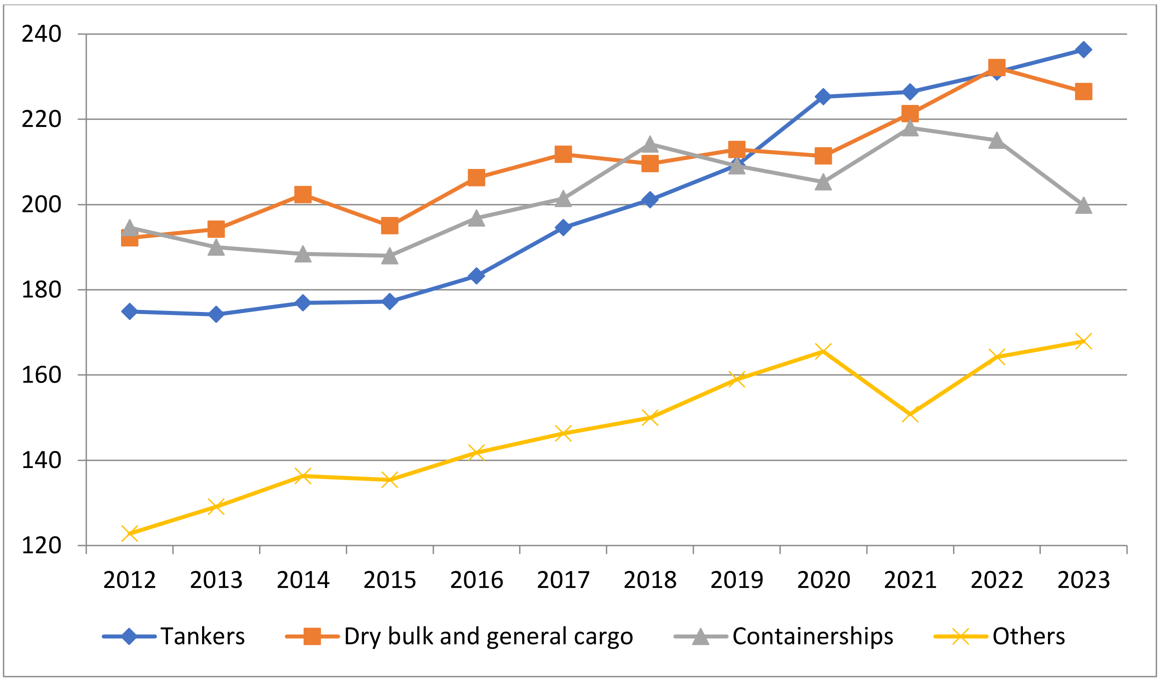

Figure 1. Carbon dioxide emissions by main vessel types, thousand tons, 2012–2023

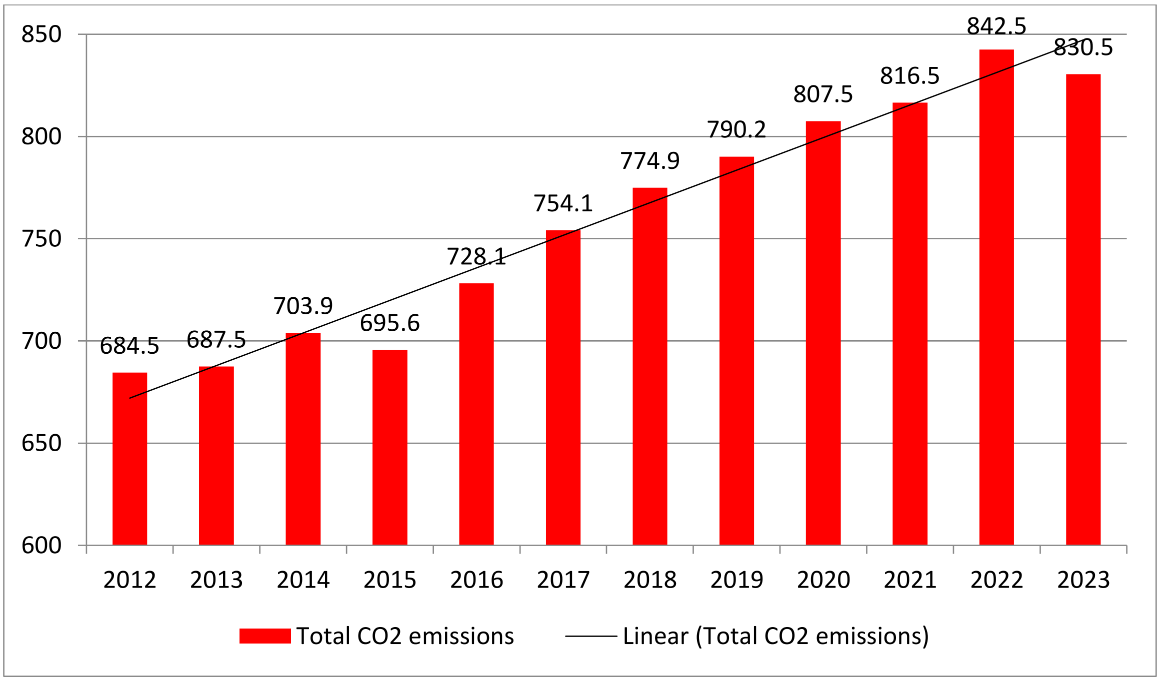

Figure 2. Total Carbon dioxide emissions by vessels, thousand tons, 2012–2023

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In this paper is present the evolution of greenhouse gas emissions (GHG) from ships. This study is based on the 4th IMO study, others IMO reports and recent specialised studies, and starting with the known values in the last 13 years it is made an analysis in which is forecast the evolution of the emissions until 2050.

The factors that have a strong influence in this evolution of the values, the most important ones are the fuel used and the destination of the ship according to its type. From this point of view, will be analysed the chemical compounds such as carbon dioxide (CO_2), methane (CH_4) and nitrogen peroxide (NO_x). As a sum, these compounds are expressed as CO_2 and the value of this indicator, from ships, reached 1,076 million tons in 2018, with an increase of 9.6% compared to 2012, where its value was 977 million tons. From the total value of the indicator, in 2012, CO_2 reached 962 million tons, while in 2018, this indicator reached the value of 1,056 million tons of CO_2 emissions.

Current status

In Table 2 can be seen the evolution of CO_2 emissions from ships, compared to the total value at global level. The values presented are expressed in millions of tons. According to the table, of the total of globally values of GHG, maritime vessels increased by 0.13% from 2012 to 2018, representing 2.89%.

Table 2. Total CO_2 emissions between 2012-2018

Year	Global anthropogenic CO_2 emissions	Total vessels CO_2	Total vessel as a percentage of global	Voyage-based international vessels CO_2	Voyage-based international vessels as a percentage of global	Vessel-based international vessels CO_2	Vessel-based international vessels as a percentage of global
2012	34,793	962	2.76%	701	2.01%	848	2.44%
2013	34,959	957	2.74%	684	1.96%	837	2.39%
2014	35,225	964	2.74%	681	1.93%	846	2.37%
2015	35,239	991	2.81%	700	1.99%	859	2.44%
2016	35,380	1,026	2.90%	727	2.05%	894	2.53%
2017	35,810	1,064	2.97%	746	2.08%	929	2.59%
2018	36,573	1,056	2.89%	740	2.02%	919	2.51%

Source: *Fourth IMO GHG Study 2020*

During this study, the emissions energy efficiency indicator is note as EEOI, the emissions per hour underway as TIME, the emissions per distance travelled as DIST and emissions annual efficiency ratio as AER (Figure 3).

Carbon intensity shows an improvement starting with 2012 until the end of 2018 on both ways. As an average, international ships had an improvement of the annual efficiency of 29% in 2008 and 21% of emissions energy efficiency in the same year. Based on the vessel type, it is shown an improvement of 22% of AER and 32% of EEOI.

As it is presented, even if the evolution of the carbon intensity, half of these values were reduced before 2012. Because the evolution of the carbon intensity is not in a linear path, before

2012, more than half of these values were reduced. The improvement of the CO_2 emissions slowed down in 2015, where starts the fluctuations of 1-2%.

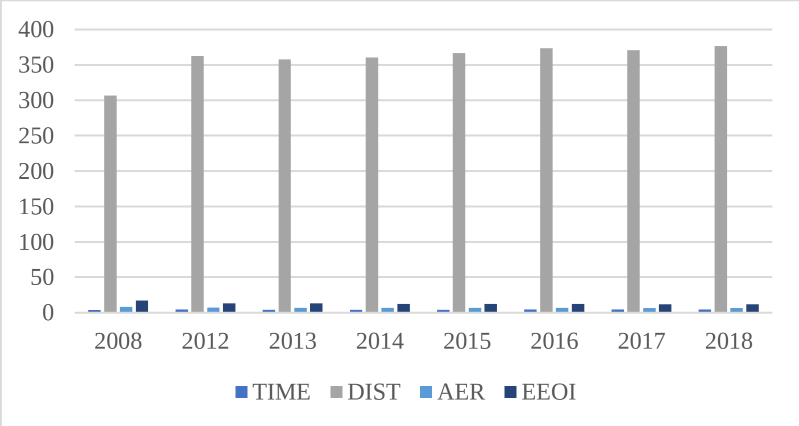

Figure 3. Evolution of CO_2 emissions, Source: *Fourth IMO GHG Study 2020*

Between 2012 and 2022, there has been a steady reduction in the carbon intensity of ships, with the carbon intensity of container ships decreasing by 21 per cent and that of bulk and general cargo ships by 18 per cent. In contrast, for tanker ships, the decrease was only 1%; the carbon intensity of tanker ships reached a minimum in August 2018 and then peaked in October 2020 (Review of Maritime Transport 2022).

During the period of the COVID pandemic (2020 - 2021), total CO_2 emissions increased by 4.7%, with most of the increase coming from container ships, bulk carriers and cargo ships. CO2 emissions also increased from Ro/Ro vehicles and ships and passenger ships. The increases were primarily due to the 3.1% growth in world seaborne trade, but also emissions in grams of CO_2 per ton-mile (Review of Maritime Transport 2022).

Greenhouse gas emissions from ships vary according to levels of shipping activity, trade flows, ship type, size, age and operational practices. Total CO_2 emissions have evolved over the last ten years and have continued to increase, even though emissions per ton-mile have decreased. The intensity of carbon dioxide emissions varies according to the type of ship, with emissions from container shipping being higher per ton-mile than from dry and liquid bulk shipping. However, total emissions per ton of shipping have reduced over the last decade (Review of Maritime Transport 2023).

The evolution of GHG emissions according to the vessel type

Depending on each type of vessel, the consummation of the fuel is different, as the emissions. Starting from industrial vessels to cruises, it is important to keep a record of emissions in order to find the most optimal solutions to improve values and reduce fossil fuel consumption.

In the second figure, the evolution of the GHG emissions is showed for the bulk carriers according to its deadweight tonnage (dwt). Through this, the first category of bulk carriers had a continuity in the values, which underline the stability in the emissions values. For the second category, it is showed an improvement along the years, even if are some fluctuations. This kind of fluctuations underlines the improvement in energy efficiency from the year 2012 to 2018.

Taking into consideration the vessel 60.000 dwt, a high increase is showed. This variation it is explained by the intensification of the activities for this type of vessels for a certain period of years. For the higher tonnage bulk carriers, the increase in greenhouse gas emission values for them underlines the preference over time for the use of large vessels that have a higher loading capacity, being lower transport costs for the charterer (Figure 4).

The evolution of greenhouse gas emission values for port-container vessels shows a slow decrease in emission values is for 1.000-1.999 TEU containers,that can be understanding as a slowdown in the improvement of the energy efficiency or decrease in demand. An improvement it is showed for the 3.000-4.999 TEU vessels (Figure 5). Along the years, the value of the emissions decreases which means the improvement on the energy efficiency.
The linear increase in the emission’s value of 8.000-11.999 TEU containers suggests the increase in demand for the use of this type of vessel, while in the case of 14.500-19.999 TEU containers there is a constant large fluctuation of values between the years 2012-2014. Thus, the traffic in this category suddenly increased in 2013, after which there was an equally sudden decrease. Correlating with the previously mentioned values, it is established that the sudden decrease in emissions in 2014 is due to the increase in values for 8.000-11.999 TEU container. The charterer turned to vessels with lower loading capacity.

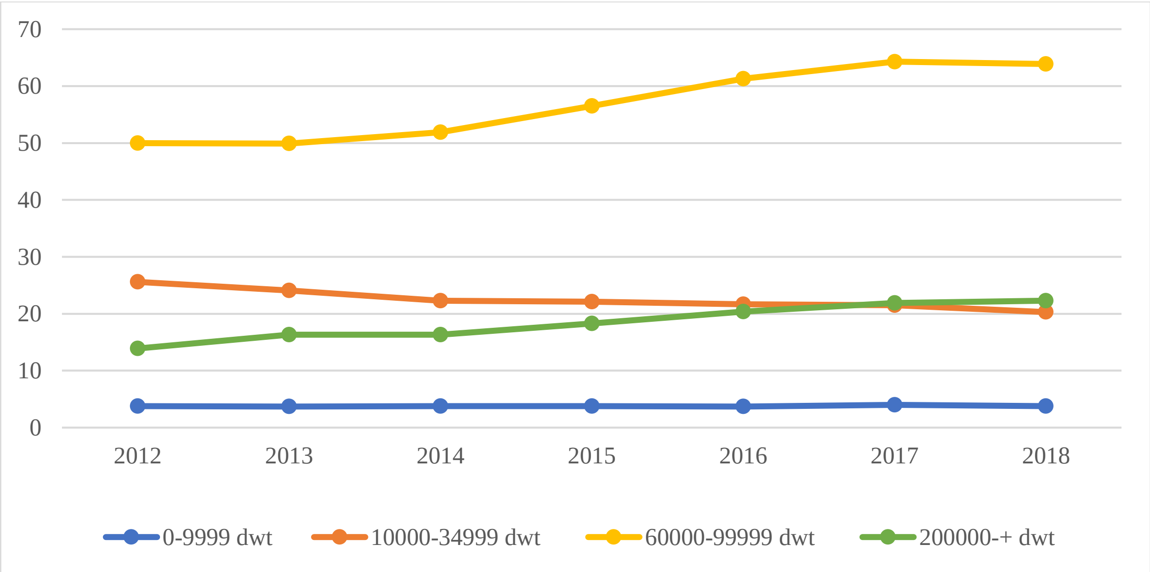

Figure 4. Greenhouse gas emissions evolution for bulk carriers, Source: *Fourth IMO GHG Study 2020*

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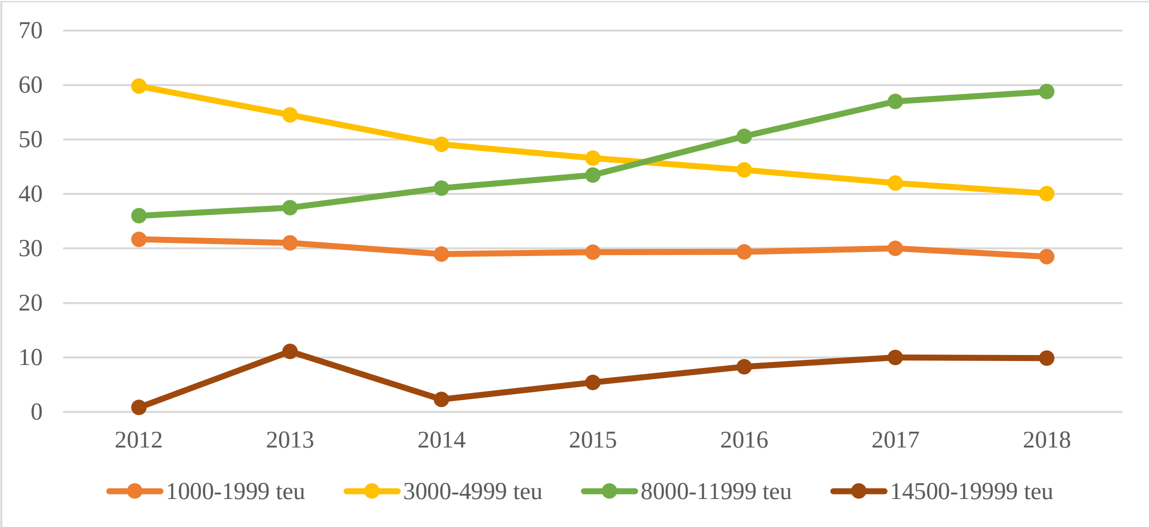

Figure 5. Greenhouse gas emissions evolution for container vessels, Source: *Fourth IMO GHG Study 2020*

It can be seen that that the vessels between 10.000-19.999 CBM are preferred, due to the high increase in the last 3 analyzed years (Figure 6). Thus, starting from constant values that underline a stagnation in the development of vessel technology until 2014, starting from 2016 there is a sudden increase, the peak being reached in 2018. This fact highlights either the increase in demand for this type of vessels, or increasing the number of vessels that carry out this type of transport.

For vessels with a carrying capacity of more than 20.000 CBM, the use of alternative fuels led to a slight decrease in the level of GHG. At the same time, analyzing the lines for vessels 0-4.999 and 5.000-9.999 it is found that the minimum fluctuations between the years 2016-2018 are given by the accelerated growth of ships 10.000-19.000.

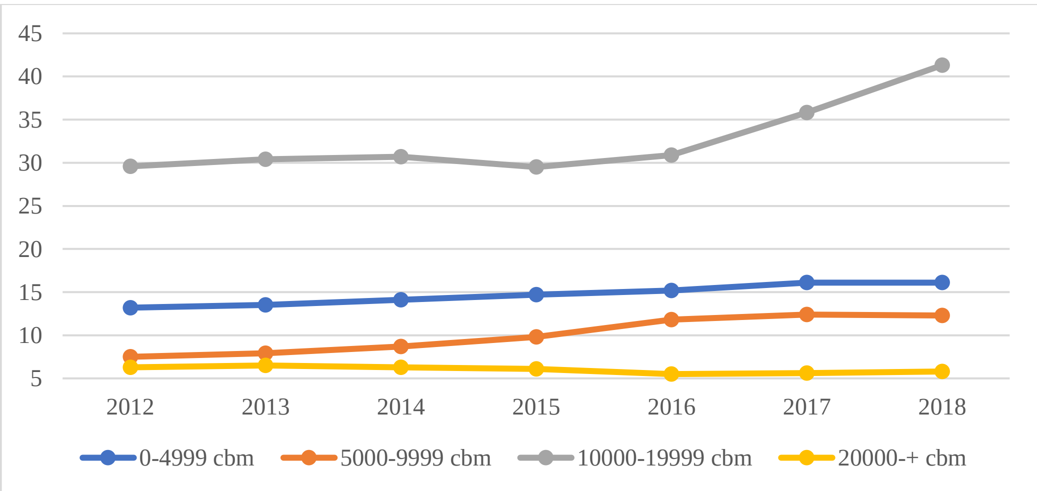

Figure 6. Greenhouse gas emissions evolution for liquefied gas tanker, Source: *Fourth IMO GHG Study 2020*

As the graphic shows, for cruise vessels, the greenhouse gas emissions are smaller comparing to the other vessels types (Fig. 5). The fluctuations over the years are minimal, the needles denote a modern technology for the propulsion system and at the same time not very frequent use. The highest emissions are for medium-sized vessels, which are the most used in international voyages.

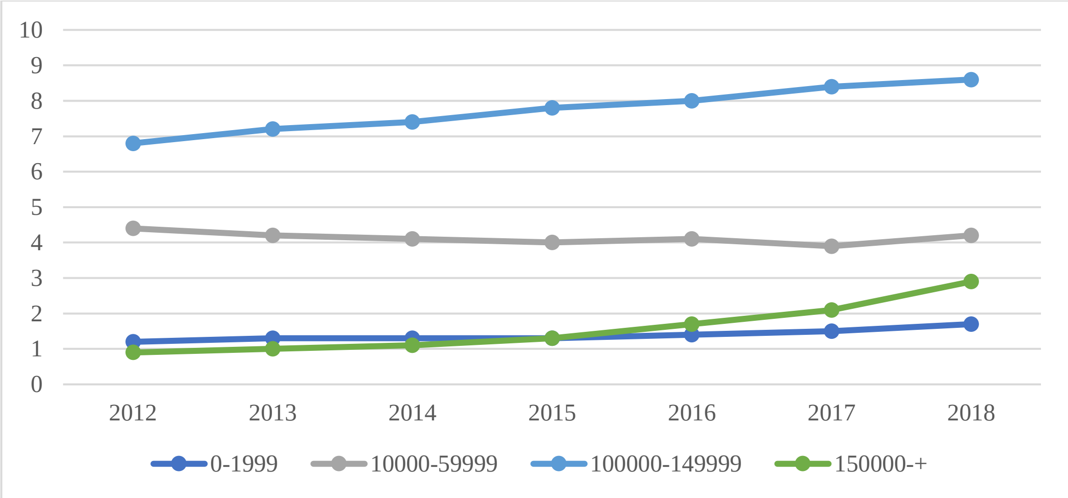

Figure 7. Greenhouse gas emissions evolution for cruise vessels, Source: *Fourth IMO GHG Study 2020*

In conclusion, the highest values of GHG emissions are found from bulk carriers and containers, while the lowest are from cruise vessels. As it is known, sea transportation represents one of the most preferred way to transport bulk goods and large quantities, being cheaper and faster than the air or ground ways.

A way to reduce the emissions from liquefied natural gas carriers came out once with the evolution of the technology. The emissions could be stocked and used as a fuel, without the need to burn fossil fuel in its entirety.

Evolution of greenhouse gas emissions according to the fuel used

The emissions from naval transportation could be measured by dividing the energy products in three types – HFO (fuel oil), MDO (gas diesel oil) and NG (natural gas). The next three figures present the evolution of the greenhouse emissions composed depending on the fuel used (Fig. 6, 7, 8).

Fuel oil along with diesel oil are the conventional fossil fuels. As was expected, fuel oil has the highest emission, being the most used for large ships. Due to the high carbon composition, slightly refined, HFO has the highest CO_2 and NO_x emissions. Compared to HFO, MDO represents the more refined version of fossil fuels. This variant has lower CO_2 and NO_x emissions compared to HFO. At the same time, it is not as economical and used fuel as HFO.

From the graphs, natural gas seems to be a less polluting option, which supports the hypothesis of reducing carbon emissions based on international norms. Although the advantage is presented by the minimal emissions of CO_2 and NO_x, a significant disadvantage is represented by the high emissions of CH_4. From this perspective, CH_4 is a natural gas with a

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greenhouse effect, with a high risk, as CO_2. Thus, the recorded values raise questions about the sustainability of using natural gas as fuel, without reducing CH_4 emissions.

At the same time, there is a slight fluctuation over the years in the emission values. This fact underlines the attempt to keep at an acceptable level over the years. However, NG has significantly higher CH_4 emissions since 2015, which affects its environmental benefits. the most polluting fuel, and MDO is a cleaner but still polluting alternative compared to NG.

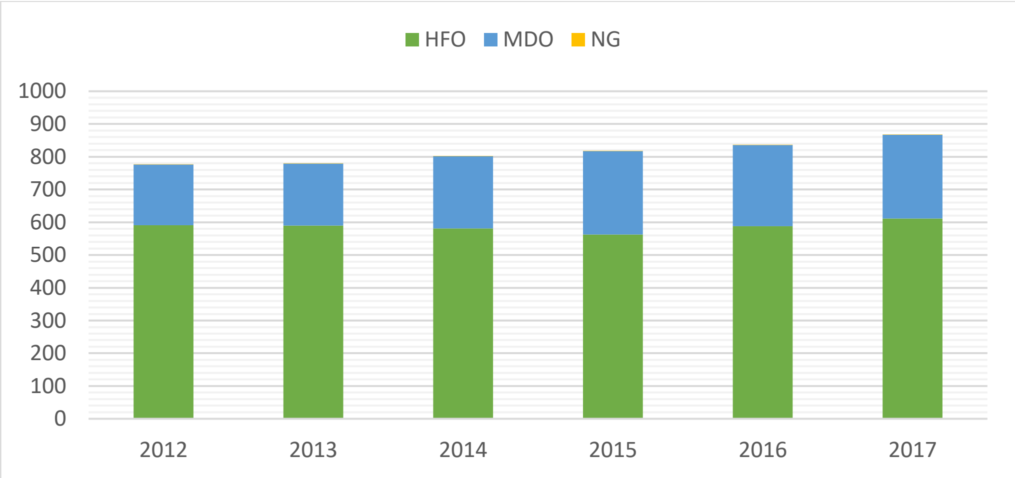

Figure 8. CO_2 emissions due to the fuel used, Source: *Fourth IMO GHG Study 2020*

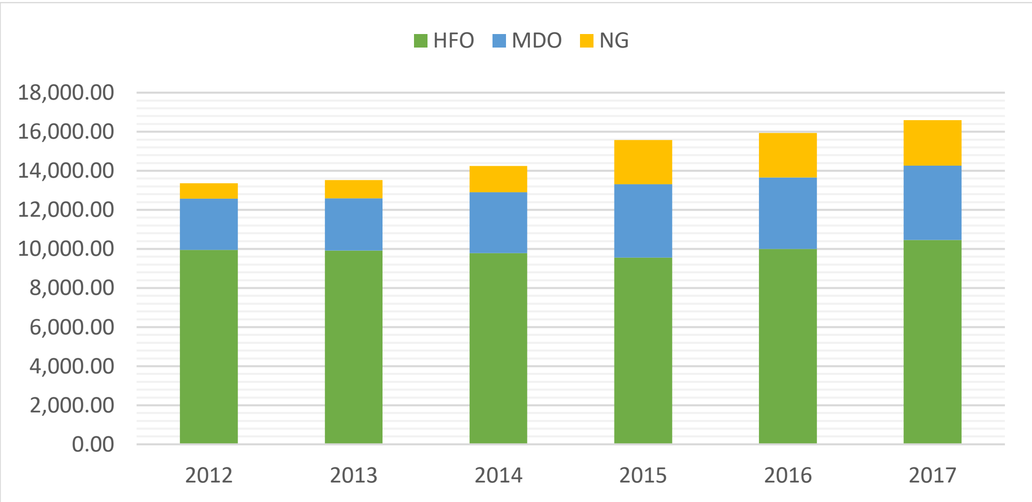

Figure 9. CH_4 emissions due to the fuel used, Source: *Fourth IMO GHG Study 2020*

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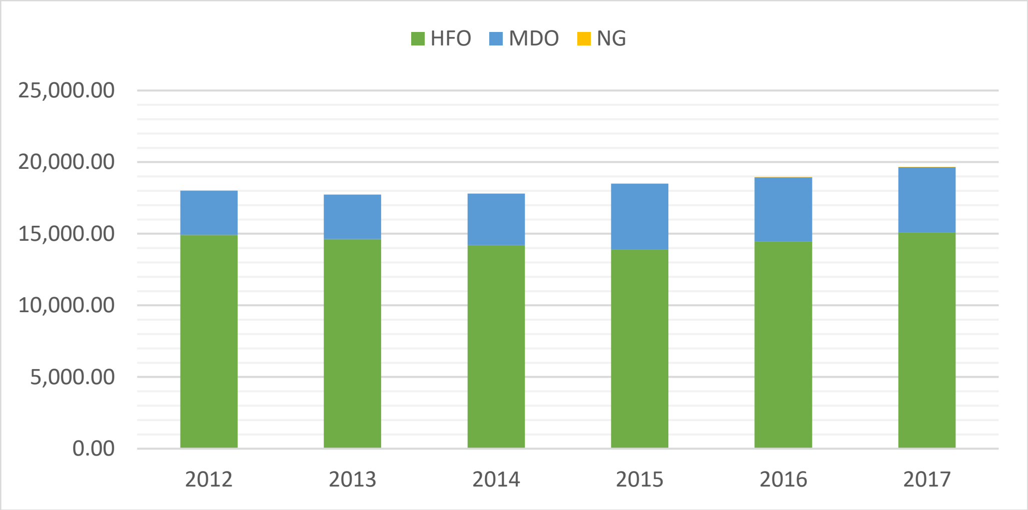

Figure 10. NO_x emissions due to the fuel used, Source: *Fourth IMO GHG Study 2020*

In conclusion, natural gas produces the lowest CO_2 and NO_x emissions, making it a cleaner option than fossil fuels. Natural gas can be a transitional solution for the shipbuilding industry, but managing methane emissions is essential to increase its sustainability.

Forecasts on greenhouse gas emissions for 2030-2050

The evolution of the GHG in the future from ships is present in the figure 9. Compare with the previous results, its evolution shows that will be an increase from 90% in 2008 to 90%-130% in 2050 (Fig. 11).

Figure 9 shows the evolution of the indicator until the year 2050, for a series of economic scenarios and energetic, where SSP2 defines the middle of the road of the long-term socio-economic scenario, SSP4 is a road divided and OECD is the long-term baseline projections.

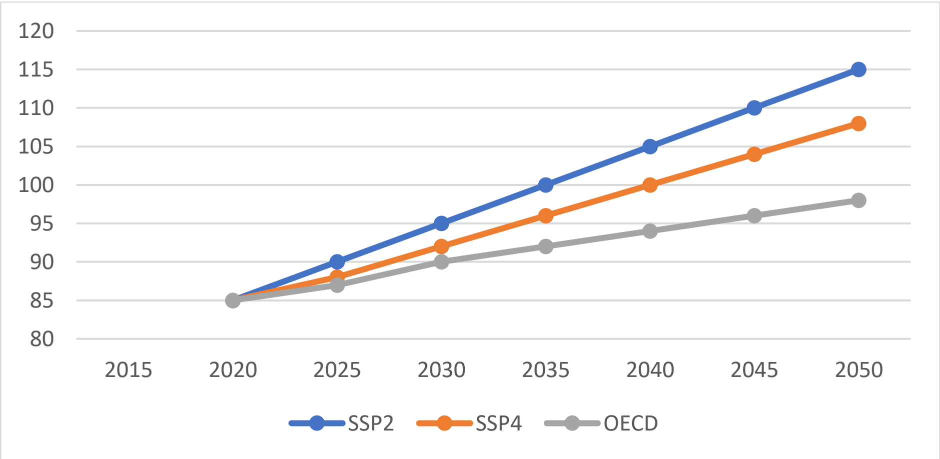

Figure 11. Forecasts of greenhouse gas emissions, Source: *Fourth IMO GHG Study 2020*

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All projections presented are called business as usual projections (BAU). In the context of this study, BAU refers to the shipping sector and is defined as the new adoption of regulations that have an impact on energy efficiency and carbon intensity. As previously mentioned, the projections are based on long-term socio-economic paths.

Some of these pathways involve non-shipping sectors undergoing transitions that require policies such as carbon pricing or energy efficiency regulations. These still represent BAU scenarios in the context of the study. Thus, as seen in the previous figure, three long-term scenarios were presented in which the energy mix of the terrestrial sectors would not be able to increase well below 2^0 in the global temperature.

In these BAU scenarios, emissions from shipping are projected to increase from 1,000 Mt carbon dioxide in 2018 to 1,500 Mt carbon dioxide in 2050. This increase represents a 0 to 50% increase over levels from 2018 and is down 90-130% from the 2008 level.

Conclusions

Although maritime transport is the most sustainable form of transport compared to others, the emissions from the vessels cannot be overlooked. The international maritime organization have brought a set of rules that limit the use of polluting technologies, that help them to keep under control the evolution of greenhouse gas emissions. Based on them, the sectors activities are reduced or use new technology, less polluting.

The final goal is that by 2030, to achieve a 40% reduction in emission's intensity compared to 2008 levels. In the same time, to reduce with 70% the carbon emission by 2050. Also, by 2050, the total annual emissions must decrease by at least 50%, in that way being almost touch the IMO's target of the total carbonisation of the maritime sector. Some alternatives to reach the goal are given by using low or zero emission fuel as hydrogen, biofuels or ammonia. At the same time, a carbon tax or the sale of emission certificates could be a step forward.

Newly introduced IMO and EU environmental regulations have an impact on shipping operating costs and freight rates and are expected to continue to influence the dynamics of the shipping industry.

Compliance with short-term IMO measures such as the carbon intensity indicator means lower vessel speeds, particularly for less energy-efficient ships, and longer modernization periods for energy-saving technologies.

Extending these measures could lead to new supply constraints, with effects on the value of ships.

In early 2024, the EU included shipping was included in the ETS (the EU Emissions Trading System is a way for all companies in all countries within the EU to contribute to research and development to eliminate greenhouse gas emissions by 2050), which, for the first time, imposed a cost for carbon emissions from shipping. This inclusion prompted operators to introduce surcharges to cover the additional CO2 costs charged to shippers. These costs vary significantly depending on the length of shipping lanes, affected by the conflicts in Europe and

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Asia running into hundreds of thousands of dollars. Under the ETS, ships will have to pay for 40% of their emissions in 2024, rising to 70% in 2025 and 100% in 2026. This increase in ETS costs will have an impact on the shipping industry, including ports, likely leading to higher freight rates and charges, which operators will continue to pass on to shippers and ultimately consumers (Review of Maritime Transport 2024).

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