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An Analysis Of The Carbon Footprint In Maritime Transport: Challenges And Opportunities For Reducing Greenhouse Gas Emissions

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ABSTRACT: The process of decarbonization and the pursuit of zero-emissions growth are a challenge for maritime transport, while strict environmental regulations regarding greenhouse gas emissions call for changes in both organizational and technological processes. The aim of the article is to present the problem of carbon footprint in relation to the maritime transport industry . The article discusses the negative impact of sea transport on the environment. The main research objective was to shed light on carbon footprint in the context of maritime transport as well as to identify the possibilities of its reduction, including through regulatory measures. Various research methods were used in the study, including a literature review, a review of the documentation of IMO regulations, reports and an analysis of technologies implemented to reduce pollutant emissions in maritime transport.

1 INTRODUCTION

The transport industry contributes to climate change by emitting significant amounts of greenhouse gasses into the atmosphere and at the same time plays an important role in the economy, conditioning its development. The economic advancement achieved over the last few decades, together with the rapid demographic explosion, has spawned huge environmental costs around the world [1]. Despite the positive aspects of transport, it affects not only the environment, but also people. The transport industry emits significant amounts of pollutants and is responsible for around a quarter of the EU's total greenhouse gas (GHG) emissions. It is transport that is the only major economic sector in Europe where the amount of greenhouse gasses has increased markedly since 1990. It is also the largest contributor to nitrogen oxide emissions, which are harmful to health and the environment. Similarly, road transport is recognized as the main source of environmental noise pollution in Europe. The volume of transport activity has affected greenhouse gas emissions and it is expected that the requirements as well as restrictions for all modes of transport will become more stringent. According to the European Commission's report Stepping up Europe's 2030 climate ambition. Investing in a climate-neutral future for the benefit of our people, the EU has adopted the target of climate neutrality by 2050, consisting in. reducing greenhouse gas emissions to net zero. Its current 2030 climate target of at least a 40% reduction in greenhouse gas emissions, as well as relevant climate, energy and transport legislation, have been adopted with a view to reducing greenhouse gas emissions by at least 80% by 2050. Europe, aiming to achieve climate neutrality by 2050, must consider a sustainable mobility system based on cleaner and more active modes of transport, cleaner fuels and, where possible, reducing the demand for mobility [2,3].

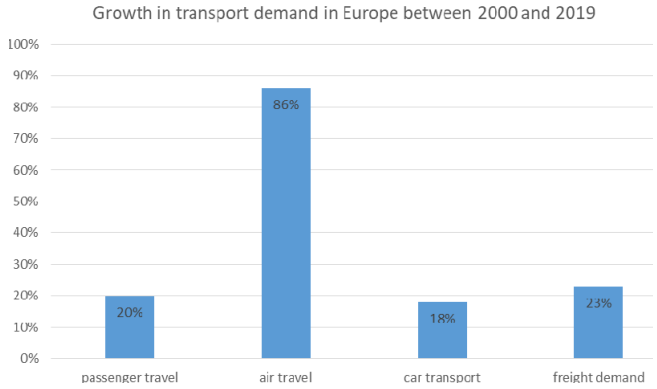

Figure 1. Growth in transport demand in Europe between 2000 and 2019
Source: own study basen on: „Transport and environment report 2021, Decarbonising road transport — the role of vehicles, fuels and transport demand" EEA Report, No 02/2022.

2 CARBON FOOTPRINT IN MARITIME TRANSPORT

Maritime transport plays a key role in the global economy, enabling goods to be transported over vast distances between continents. According to World Trade Organization (WTO) data [4], maritime transport accounts for nearly 80% of global international trade. Meanwhile, the annual UNCTAD - Review of Maritime Transport reports show that the maritime transport market is still evolving and will become a more energy-intensive sector than it is now [5]. At the same time, maritime transport is also one of the most emissive sectors of the economy. According to the International Maritime Organization (IMO), greenhouse gas emissions related to maritime transport account for approximately 2.5% of global emissions, and their annual emissions exceed 1,000 million tonnes of CO2 [6].

Carbon footprint is a blanket term that refers to the emissions of greenhouse gasses generated by human activities, and in particular to carbon dioxide emissions, including the life cycle of a product [7,8]. Nowadays, when climate change is becoming more and more tangible, the carbon footprint is one of the most important issues to address in an attempt to curb the negative implications of global warming. On the upside, however, the awareness concerning carbon footprint is on the rise, accompanied by increasing awareness of climate change and the need to reduce greenhouse gas emissions.

The carbon footprint of maritime transport is a measure of the total amount of greenhouse gasses emitted during the transportation process, from the production of fuels to the delivery of cargo to its destination. The carbon footprint is an important tool in assessing the impact of maritime transport on the environment and climate change, as well as in identifying areas where innovations, technologies, changes in operating practices can be introduced, or a policy of greening seaports and implementing good environmental practices can be implemented. It allows for the precise determination of the impact of activities on the environment, which in turn makes it possible to take appropriate action to protect the environment, while verification of the reliability and safety of technologies aimed at reducing pollution from ship operations is of significant importance in the development of new technologies developed in response to environmental regulations [9].

The carbon footprint in maritime transport can be calculated for individual ships, shipping lines, ports, but also for entire supply chains. As with other sectors, the calculation of the carbon footprint of maritime transport covers all stages of the life cycle, including fuel production and transport, ship operation, loading and unloading, as well as emissions related to the delivery of cargo to the port and its transport from the final port to final destination. Calculation of the carbon footprint in maritime transport is a complex process and requires detailed data on the fuel consumption of ships, transport routes, the amount of goods transported and their characteristics, as well as the technologies used. However, there are tools and standards, such as ISO 14067 and the GHG Protocol, that define the methodology for calculating the carbon footprint of maritime transport and help in reporting greenhouse gas emissions [10].

Standards, programs, tools, schemes and methodologies for calculating CO2 are commonly used [11]. The most important of them are standards, tools, spreadsheets. Legal regulations are based on three basic documents:
- EN 16258
- ISO 14067
- Greenhouse Gas Protocol [12].

An important measurement parameter is the European standard EN 16258 establishing a preliminary methodology for calculating and declaring energy consumption and greenhouse gas emissions related to transport activities. The standard defines general principles, definitions, system limits, calculation methods, division and evaluation rules [12].

The ISO 14067 standard was issued in 2013 to comply with the rules for calculating the carbon footprint that is created during the life cycle of the product. The standard also presents conclusions and is obtained for organizations as well as other applications for entities for which it is required and important to verify the carbon footprint. The purpose of the standard is the source of origin for the method and the extraction of GHG emissions [13].

One of the tools is also the GHG Protocol, which establishes global standards, a standardized framework for measuring and managing greenhouse gas emissions. It is a tool for calculating greenhouse gas emissions - GHG Emissions Calculation Tool, as a free Excel tool from Greenhouse Gas Protocol and WRI [14].

3 REDUCING THE CARBON FOOTPRINT IN MARITIME TRANSPORT

The carbon footprint, or greenhouse gas (GHG) emissions, associated with transport activities, is one of the major challenges facing the maritime industry

today. One of the key challenges in reducing the carbon footprint of maritime transport is the introduction of more efficient energy solutions, and the industry is adopting various initiatives to reduce its carbon footprint. There is, however, no foolproof solution, and advanced carbon footprint reduction requires a multifaceted approach [15]. The scale of this challenge is still under investigation and not easy to assess.

Further efforts to reduce greenhouse gas emissions from maritime transportation can be expected in the coming years.

1. Developing alternative energy sources. As technology advances, there will be new sources of energy that can be used for marine transportation. Examples include biofuels, hydrogen fuel cells, ammonia, and solar and wind power. Modern engines and propulsion systems, such as hybrid electric, can significantly reduce greenhouse gas emissions compared to traditional engines. However, the introduction of these technologies requires significant investment. In addition, the use of marine energy carries great potential, as offshore renewable energy generation is driven by tides, wind and waves [16].
2. Optimization of operational activities. Another way to reduce the carbon footprint of shipping is to optimize operational practices. Reducing ship speeds, minimizing berthing time in ports, cleaning and maintaining the hull to reduce drag, or using the latest monitoring and cargo management technologies are just some examples of practices that can significantly reduce greenhouse gas emissions. Ship speed optimization systems make it possible to accurately determine a ship's optimal speed and route, taking into account wind and currents. Energy management systems allow for the optimal use of energy on board a ship, thus significantly reducing fuel consumption and greenhouse gas emissions at the same time [17].
3. Implementing more efficient technologies. Examples include improving exhaust gas cleaning systems, installing energy recovery systems and installing waste heat recovery systems, and using lightweight materials.
4. Adopting more stringent regulations. Another possible approach to reducing greenhouse gas emissions in maritime transport is the adoption of more stringent regulations. Examples include: limiting the speed of ships, introducing CO2 emissions charges, and stricter requirements for SOx and NOx emissions.
5. Launching Emissions Trading System. Emissions trading schemes such as the European Emissions Trading System (EU ETS) provide for the inclusion of emissions from shipping in the EU Emissions Trading Scheme. The system will allow emissions trading, which encourages companies to reduce greenhouse gas emissions. There are currently no specific regulations for the scheme, but the European Commission is proposing to expand the scope of the EU ETS to include CO 2 emissions from large ships (above 5,000 gross tons), regardless of flag [18].
6. Cold ironing. The provision of adequate infrastructure on the part of ports is also important, and energy facilities at seaports are seen as an integral part that significantly supports the decarbonization of global shipping. The installation of shore power facilities in ports contributes to minimizing emissions from ships docking at a seaport. Land-based power supply for ships while at berth, or cold ironing, as an environmentally friendly technical solution, helps eliminate emissions from engines while at berth [19].
7. Artificial intelligence (AI). The use of artificial intelligence based on digital platforms is designed to provide real-time data on the route, speed and position of ships heading to seaports. This data is then analyzed to provide an accurate estimate of a ship's arrival time and adjust its route according to the availability of berths. The data analysis is expected to allow optimization of shipping and operations, which in turn is expected to translate into reduced greenhouse gas emissions. Ultimately, the green digital corridor concept is expected to enable accurate, real-time communication between ports, terminal operators and carriers [20].
8. Supporting research and development. In order to accelerate technological progress and increase energy efficiency in maritime transportation, it is necessary to support research and development. To this end, research grants and scholarships may be awarded, and competitions and industry events may be held to raise public awareness of GHG emissions problems in maritime transportation.

4 IMO REGULATIONS

One of the most important regulatory instruments dealing with pollution in maritime transport is the International Convention for the Prevention of Pollution from Ships (MARPOL), which was adopted in 1973. MARPOL regulates emissions of greenhouse gasses and other air pollutants related to maritime transport [21]. As part of the MARPOL Convention, in 2013, in accordance with Annex VI to the Convention, it was established that ships with a gross tonnage of 400 and more, engaged in international voyages, should carry onboard a Ship Energy Efficiency Management Plan (SEEMP). The IMO has adopted requirements for the energy efficiency of ships to ultimately reduce greenhouse gas (GHG) emissions from global shipping, recognizing that there are several ways to improve energy efficiency and reduce CO2 intensity, citing as examples optimization of speed, confirmation of berth accessibility and time of arrival at port of destination, meteorological navigation and hull maintenance, modernization of equipment to optimize energy efficiency and the use of alternative fuels. However, in the case of measures implemented for enterprises, the IMO stipulates that the improvement of the energy efficiency of ship operations and the reduction of carbon dioxide emissions depend on many other participants beyond the ship's manager, including ship repair yards, shipowners, operators, charterers, cargo owners, port service providers and ship traffic management entities [22].

The next measure adopted by the IMO in 2018 was a strategy to reduce greenhouse gas emissions related

to maritime transport. These actions set out that, by 2050, emissions should be reduced by 50% compared to their 2008 levels. To this end, a number of regulations have been introduced regarding fuel consumption, the use of low emission technologies and the introduction of new energy efficiency standards for ships [23]. As part of the IMO plan, from 1 January 2020, the permissible sulfur content in fuel used by ships around the world was lowered from 3.5% to 0.5%, which means that shipping companies must invest in new technologies or change their approach to fuel to meet new requirements and restrictions. Shipping will undoubtedly need new technologies, new fuels and innovations in the years to come in order to meet its greenhouse gas emissions targets and move towards zero emissions growth. In addition to modern technologies, investments in research and development and infrastructure are equally necessary, and so is striving to ensure the safety and profitability of projects.

The latest IMO 2023 regulations are to be a continuation of the previous strategy to reduce greenhouse gas emissions caused by global maritime transport. The new rules aim to reduce carbon emissions from both new and existing ships, as measured by two main energy performance indicators - the Energy Efficiency eXisting Ship Index (EEXI) and the Carbon Intensity Indicator (CII). Amendments to Annex VI to the MARPOL Convention became effective on November 1st, 2022, while the EEXI and CII certification requirements apply from January 1st, 2023, which means that the first annual reporting will end in 2023 and the first CII authorizations will be issued in 2024.

The IMO's global environmental regulator is also considering policies that encourage polluters to reduce greenhouse gas emissions through price signals, such as putting a price on carbon emissions from ships. Emissions revenues could significantly support these two principles - provided that appropriate carbon revenues are strategically planned and implemented. For example, carbon revenues could be prioritized for countries that may have a more difficult transition to offshore energy, have been less affected by climate change in the past, or may have less capacity to cope. According Baresic et al., studies and projections show that the evolution of the carbon price could be significant [24]. Carbon pricing, introduced in a scenario in which the minimum targets set in the original IMO greenhouse gas strategy are met, could generate a total of $1.3 trillion to $2.6 trillion; In a full decarbonization scenario, revenues could range from $1 trillion to $2 trillion by 2050 [25]. Another study – Maersk found that a fixed carbon tax of $250 per ton of greenhouse gases would raise $3.7 trillion by 2050 [26].

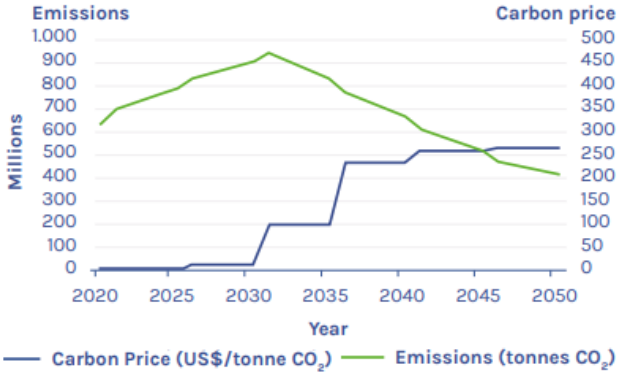

Figure 2. Carbon prices in the -50% scenario
Source: Baresic D. et al., 2022.

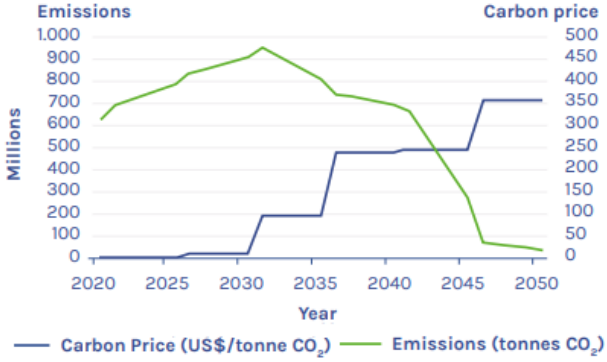

Figure 3. Carbon prices in the -100% scenario
Source: Baresic D. et al., 2022.

For the shipping industry, the implementation of the new regulations means an assessment of the measures already adopted so far, as well as taking further steps towards modernizing the fleet and implementing modern solutions. In the longer term, the IMO 2023 restrictions are intended to help promote more sustainable maritime transport and contribute to the IMO's broader and overarching objective of reducing global warming [27]. At present, one of the biggest challenges is to maintain a balance between ambitious decarbonization policies and the regulatory sphere, which is preparing strategic action plans, and the real maritime sector, in order to agree on a decarbonization path for the maritime sector by 2050 acceptable to all parties [28].

Solutions proposed by the IMO [18]:
- 5-15% power systems, alternative propulsion systems
- 5-50% fleet management
- 1-10% voyage optimization
- 2-50% concept, speed, capability
- up to 75% speed optimization
- 50-90% full electric systems
- 35% Bio-LNG/LPG fuel
- 90% of third generation biofuel
- 80-100% hydrogen, synthetic fuels
- 1-10% energy management
- 2-20% change in the construction of hulls, superstructures
- 5-25% combating ship biofouling.

5 CONCLUSIONS

In conclusion, reducing the carbon footprint of maritime transport is key to protecting the environment. The introduction of new technologies, changes in operating practices, the use of alternative energy sources and the establishment of regulations are the main ways to achieve this objective. For years, the International Maritime Organization (IMO) has been adopting a number of rules and regulations that set limits for sulfur, nitrogen or carbon dioxide emissions, while calling for more ambitious and decisive solutions that will reduce greenhouse gas emissions resulting from maritime transport. The IMO strategy clearly underscores the ambition to continue efforts to completely eliminate greenhouse gas emissions from international shipping, and although the maritime industry has been facing the need to implement such solutions for years, the current ones are merely temporary fixes on the path towards more optimal models of action. Regulations and implemented solutions should not be a quest for makeshift ideals, and the maritime industry needs mature large-scale solutions.

Currently, global shipping is participating in decarbonization in a selective way at best, and entities that meet environmental requirements are few. And while shipping companies are already testing solutions to change that, the challenges related to the production methods of alternative solutions must be recognized, as it is envisaged to replace energy sources with fuels that are neutral in terms of both production and extraction. At the same time, let us keep in mind that the implementation of these measures will require significant outlays and time, which constitutes an important challenge for the maritime industry.

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