Inclusion of the Maritime Sector in the European ETS: Analysing Future Impacts Using MRV Data

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Abstract. Anthropogenic climate change is recognized by the scientific community as a key challenge for human society, with greenhouse gas emissions (GHG) as one of the main drivers. In fact, over the last 10 years, combustion of fossil fuels has been responsible for approximately 86% of the total anthropogenic CO_2 emissions. However, the existing policies and the political responses to mitigation are so far insufficient to achieve the goals of the Paris Agreement.

International shipping was one of the sectors excluded from the 2015 Paris Agreement and although it contributes less than 3% to global CO_2 emissions, they are expected to increase by 90–130% of 2008 levels by 2050.

In this paper, a descriptive analysis of the EU-MRV database was conducted. The EU-MRV database collects major information related to CO2 emissions of ships in the European Economic Area (EEA) from 2018. This study analyses the first six years of the EU-MRV data and traces the future possible impacts of the inclusion of the maritime sector in the EU-ETS.

The results highlight the differences between the shipping segments, suggesting the importance of analyzing them singularly. Indeed, the shipping sector includes cargo ships, Ro-Pax and cruise passenger ships. Furthermore, in each segment, the technical and operational differences among vessel categories should be considered. The impacts of the inclusion of the shipping sector in the EU-ETS are not still evident.

Keywords: MRV data · EU-ETS · decarbonization of the shipping sector

1 Introduction

Anthropogenic climate change is recognized by the scientific community as a key challenge for human society, with the greenhouse gas emissions (GHG) as one of the main drivers [1]. In fact, over the last 10 years, combustion of fossil fuels has been responsible for approximately 86% of the total anthropogenic CO_2 emissions [2]. However, the existing policies and the political responses to mitigation are so far insufficient to achieve the goals of the Paris Agreement [3].

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International shipping was one of the sectors excluded from the 2015 Paris Agreement [4] and although it contributes less than 3% to global CO_2 emissions [5], emissions are expected to increase by 90–130% of 2008 levels by 2050 [6].

At a global level, the International Maritime Organisation (IMO) adopted the "Initial Strategy on the Reduction of GHG Emissions from Ships" in 2018 [7]. At a regional level, the inclusion of the maritime sector in the EU Emissions Trading System (EU-ETS) [8] is the first attempt of the European Union to impose an emission reduction path to shipping companies. It followed the adoption of the EU Monitoring, Reporting and Verification (EU-MRV) Regulation, that provided the basis for the inclusion of the sector [9].

The EU-MRV database collects major information related to CO_2 emissions of ships in the European Economic Area (EEA) from 2018. This study analyses the first six years of the EU-MRV data and traces the future possible impacts of the inclusion of the maritime sector in the EU-ETS.

The following sections describe the study in more detail. Sect. 2 provides an overview of measures to reduce GHG emissions from shipping. Chapter 3 presents the regulatory framework at global and regional level. Sect. 4 explains the functioning of the EU Emissions Trading Scheme for maritime transport. Section 5 presents the results of the analysis of the MRV database. Finally, the last chapter concludes the work and suggests some future research topics.

2 Reducing GHG Emissions from Shipping

The shipping industry is called to reduce its carbon footprint. This can be achieved through various measures to reduce GHG emissions. GHG emission reduction measures can be grouped into three categories: operation measures, technical measures, and market-based measures [10–12].

2.1 Operational Measures

Operational measures are those that improve the system without the need for a change in technology. One of the main measures is the voyage optimization (weather routing, reduced port time, speed optimization) or the supply chain and logistics optimization. Other measures include cold ironing, slow steaming, maintenance, ship-port interface, human factors [13, 14].

2.2 Technical Measures

The technical measures are often (but not always) technological measures that can be used to reduce GHG emissions [15]. They can focus on different aspects. The most traditional one looks at the ship's efficiency, i.e. hydrodynamic resistance, the design of the hull, friction reduction. Technical measures can be taken also to enhance the efficiency of the propulsion system, such as waste heat recovery or wind-assisted ship propulsion (e.g. Flettner rotors, rigid sails) [16]. Carbon capture technologies are also

included. Shifts to more efficient technologies are central to any successful emissions reduction effort [17].

Although some authors collocate alternative fuels and alternative power sources as separate categories, they can theoretically still be considered technical measures [18]. The most common alternative fuels are liquefied natural gas (LNG), biofuels (alcohols, hydrocarbons) synthetic fuels (hydrogen, ammonia), biogas and methanol. Among the alternative power sources, wind energy, solar energy, nuclear energy, and fuel cells can be named.

2.3 Market-Based Measures

On top of the operational and technical measures, GHG reduction policies can be adopted to reduce GHG emissions from the shipping industry. GHG reduction policies need to be consistent with cost-effective approaches [19]. The two most common ones are the "command-and-control" regulations and the market-based measures [13, 20]. Command-and-control measures are a form of environmental regulation that enables decision-makers to regulate the extent to which a company can impact the environment, such as a policies that employ fuel efficiency standards, transport and electric generation emission intensity standards, [17].

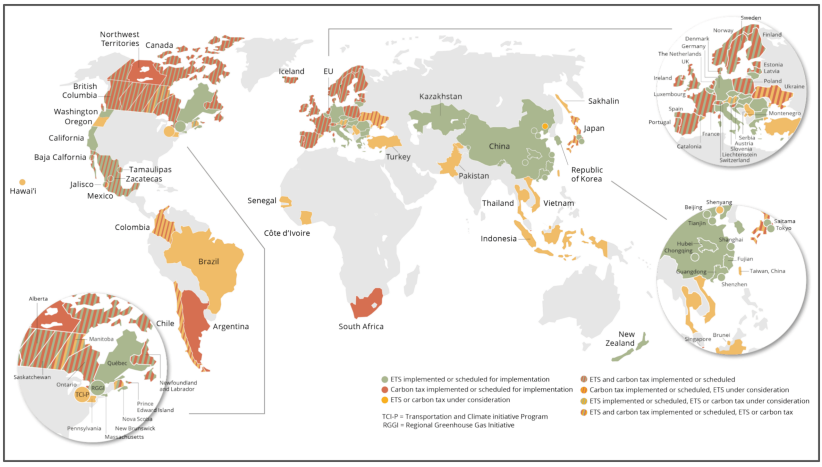

Fig. 1. Map of global status of ETS and carbon tax systems implemented (or in the process of implementation)[1]. Source: [21]

MBMs are environmental policy instruments that use markets, prices, and other economic variables to provide incentives for polluters to reduce or eliminate negative environmental externalities. They can be classified as price or quantity measures [22].

[1] Note: Carbon pricing initiatives are considered "scheduled for implementation" once they have been formally adopted through legislation and have an official start date and "under consideration" if the government has announced its intention to work toward implementation.

For example, "cap-and-trade" programmes are purely market-based quantity measures while carbon taxation is a price measure [18]. Hybrid schemes that incorporate both measures are also common [23].

Emissions Trading Systems (ETSs) are based on a "cap-and-trade" principle. They can be categorized as either global or regional, depending on their geographical scope. A global ETS has been shown to have certain advantages over a regional ETS, in that it can avoid the risk of carbon leakage and pollution transfer [24]. Figure 1 depicts the global status of ETS and carbon tax systems implemented (or in the process of implementation).

3 Regulatory Framework

3.1 Global Level (IMO)

The International Maritime Organization (IMO) plays a critical role in setting global standards for international shipping, with a growing attention towards energy efficiency and reduction of GHG emissions. In 2003, IMO started to consider several measures to induce shipping companies to limit or reduce their emissions, such as technical, operational and market-based solutions [25].

From 2011, the IMO adopted new technical measures, including the Energy Efficiency Design Index (EEDI) who sets minimum energy efficiency standards for new ships, the Energy Efficiency Operational Indicator (EEOI) which enables ship operators to monitor energy efficiency of a ship in operation, the Ship Energy Efficiency Management Plan (SEEMP) for managing fuel-efficient ship operations, and a Monitoring, Reporting, and Verification (MRV) system for tracking emissions from ships [6, 13, 24, 25]. The SEEMPT is composed of three parts:

- Part I: a ship management plan to encourage shipping companies to adopt the best practices for improving energy efficiency.
- Part II: a ship fuel oil consumption data collection plan that requires ship operators to include a methodology for Data Collection System (DCS), with the scope of improving data reporting and transparency.
- Part III: ship operational carbon intensity plan, based on the use of a Carbon Intensity Indicator (CII) rating, which links a ship's GHG emissions to the amount of cargo carried over the travelled distance.

Discussions on MBMs to incentivise emission reductions started in the IMO's Marine Environment Protection Committee (MEPC) in 2006. These discussions were then suspended in 2013 [26, 27]. In 2017, the European Parliament's intention to include shipping into the EU-ETS from 2023 onwards resulted in an increase in international pressure on the IMO, culminating in the adoption of the "Initial Strategy on the Reduction of GHG Emissions from Ships" in 2018 [7]. This strategy sets targets to reduce the carbon intensity of shipping by 40% by 2030 (compared to 2008 levels) and to reduce total GHG emissions by 50% by 2050 (IMO 2018). It also explicitly recognizes the importance of the technological innovation and the global introduction of alternative fuels and/or energy sources in achieving the environmental goals.

3.2 Regional Level (European Union)

At a regional level, the European Union has introduced one of the first market-based solutions, implementing the world's first emissions trading scheme (EU-ETS) in 2005. It requires polluters to pay for their GHG emissions in the attempt to reduce overall emissions in the EU while generating revenues to finance the green transition [28]. It covers emissions from installations and operations in the electricity and heat generation sector, the industrial manufacturing sector, and, since 2012, the aviation sector. Following its inclusion in the "Fit-for-55" and the European Green Deal, the maritime sector has been covered by the EU ETS since 2024 [29].

It is based on the "cap-and-trade" principle. The cap represents the maximum level of emissions that can be generated by the sectors involved in the system. The cap is reduced over time to ensure that all ETS sectors cumulatively contribute to the EU's climate objectives. To take account of the introduction of the shipping sector into the EU-ETS, the Union-wide cap was brought to 1,386,051,745 emission allowances (EUA) in 2024 [30]. Each year, companies need to surrender the necessary EUA to cover their emissions. One EUA gives the right to emit one tonne of CO_2eq (carbon dioxide equivalent). The individual cap for the maritime sector is set at 78 million for the first year, with a linear reduction factor of −4.3% from 2024 to 2027 and −4.4% from 2023. The aviation sector has a separate cap.

4 Maritime EU-ETS: How Does It Work?

4.1 The EU Monitoring, Reporting and Verification Regulation

In 2011, considering that no international agreement on the reduction of GHG emissions from international shipping had been approved by Member States through the International Maritime Organisation (IMO), the European Commission proposed to include international maritime emissions in the Community reduction commitment. The document was adopted as the Monitoring, Reporting, and Verification (EU-MRV) Regulation (EU) 2015/757, which entered into force in 2015 [9].

In its first version, the EU-MRV Regulation defined a framework for the monitoring, reporting and verification of CO_2 emissions from maritime transport that involved at least one port under the jurisdiction of a Member State. It applied only to ships above 5,000 gross tonnage operating commercial routes, both during navigation and berthing. Data collection started on 1 January 2018 on a per-voyage basis and is managed by the European Maritime Safety Agency (EMSA).

This Regulation requires shipping companies to submit a verified annual emissions report (ER) via THETIS-MRV for each ship calling EU/EEA (European Economic Area) ports during the previous year. The ER includes GHG emissions, fuel consumption, time at sea, distance travelled, and cargo carried for each of their ships on a voyage-by-voyage basis (Table 1).

Table 1. Summary of the main requirement from EU-MRV Regulations

	Regulation (EU) 2015/757	Regulation (EU) 2023/957
Monitoring, reporting and verification	Carbon dioxide (CO_2)	From January 2024: Carbon dioxide (CO_2), Methane (CH_4), Nitrous oxide (N_2O)
Vessel/company level	Per vessel	Per vessel and company
Application	Ships* above 5,000 GT calling EU/EEA ports for commercial reasons	From January 2025 also includes offshore ships above 400 GT and general cargo ships between 400 and 5,000 GT

* Excluding warships, naval auxiliaries, fish catching or processing ships, wooden ships of a primitive build, ships not propelled by mechanical means, government ships used for non-commercial purposes.

In 2023, Regulation (EU) 2023/957 amended Regulation (EU) 2015/757 by adding, from January 2024, other GHG emissions to the CO_2 emissions (namely, methane CH_4 and Nitrous oxide N_2O). CH_4 emissions will be covered due to the increasing use of liquefied natural gas (LNG) as a marine fuel, which can lead to CH_4 leakage from ship engines. Similarly, N_2O will be included to take account of possible future emissions from the introduction of new fuels such as ammonia [33].

Table 2. Key differences between EU-MRV and IMO-DCS.

	EU-MRV	IMO-DCS
Type of transport	Only transport of goods and persons	Any activity carried out by ships in the marine environment
Type of voyages	Only voyages to and from EU/EEA ports, including domestic voyages	Only international voyages (no domestic ones)
Emissions in port	Emissions in EU/EEA ports are reported separately	Emissions in port are not reported separately
Type of data aggregation	Requires data per voyage	Requires annual aggregated data
Type of data	Data related to transport work (weight of actual cargo carried or number of passengers)	Data on the deadweight tonnage (the carrying capacity of the ship)
Type of data publication	Publishes data on the performance of individual ships	Publication of aggregated data

Source: authors elaboration on [8, 31, 32]

It also requires shipping companies to provide data on a company basis and to submit an aggregated report of emissions from all their ships. From January 2025, the EU-MRV Regulation applies also to general cargo ships between 400 and 5,000 gross tonnage, and offshore ships of 5,000 gross tonnage [8].

In 2016, one year after the introduction of the EU-MRV Regulation, the IMO adopted its own Data Collection System (DCS). From 2019, the DCS requires shipping companies to record and report fuel consumption data (for each type of fuel oil they use) along with traveled distance, for ships exceeding 5,000 gross tonnage [32]. The IMO-DCS has been introduced within SEEMP Part II, and since 2023 the recorded data is used to calculate ship's operational carbon intensity (CII).

Overall, the two monitor systems are not yet aligned and have some key differences as shown in Table 2.

4.2 The EU Emission Trading System

The EU-MRV formed the basis for the inclusion of shipping in the EU-ETS from 2024 [9]. In the first three years (2024–2026), the EU-ETS will only apply to ships above 5,000 gross tonnage (GT), regardless of flag. The system covers 100% of emissions from voyages between EU/EEA ports and occurred in EU/EEA port areas, 50% of emissions trat occur from incoming voyages from non-EU to EU/EEA ports and outgoing voyages from EU/EEA to non-EU ports. This cluster of ships represents 55% of all cargo and passenger ships calling at ports in the European Economic Area and covers more than 90% of the CO_2 emissions from shipping in the EU [34].

The EU ETS is a market-based measure that relies on the purchase and use of EU Emission Allowances (EUAs) by shipping companies for each reported tonne of CO_2 (or CO_2 equivalent for the activities after 1 January 2026) emitted under the scope of the EU ETS. To ensure a smooth transition, shipping companies only have to surrender allowances for a portion of their emissions during an initial phase-in period:

- 2025: for 40% of their emissions reported in 2024;
- 2026: for 70% of their emissions reported in 2025;
- 2027 onwards: for 100% of their reported emissions.

The allocation of EU allowances (EUA) is primarily conducted through the auction process, while the remaining part is allocated for free to the industry sectors that may be vulnerable to carbon leakage risk. In the case of the maritime sector, no free allocation has been decided. The price of the EUA is determined by the spot market logic and is thus defined by the rules of supply and demand.

Figure 2 shows the auction price trend (€/tCO_2) of EUA from 2018 to 2024 [35, 36]. From the beginning of 2021, the EUA price rises sharply, reaching a first peak of nearly 95 €/tCO_2 in February 2022, a 70% increase on the 2019 values of about 20–30 €/tCO_2. This volatility complicates the estimation of the economic impacts of the EU-ETS on the maritime sector. In addition, fuel prices have to be considered. Ref. [37] analysed how fuel costs and EUAs prices can affect the reduction of CO_2 emissions from the maritime sector. Their findings underline that in scenarios characterized by low EUA price signals, the model indicates small reductions (or even increases) in CO_2 emissions. Conversely, in scenarios with higher EUA prices, the most common lowest

cost investment options are biofuels and battery electric propulsion. In the latter scenario, investments in renewable fuels are indicated to occur earlier compared to scenarios with lower EUA prices. They also found that renewable fuels are economically competitive if EUAs prices are higher enough to compensates for the lower cost of conventional fuels.

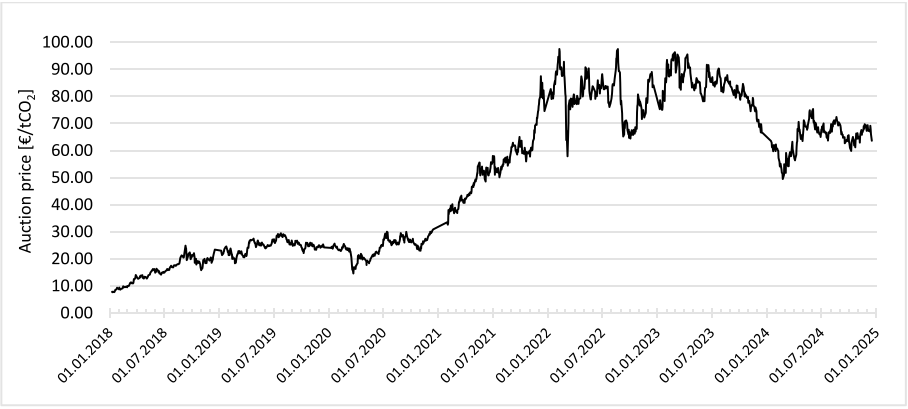

Fig. 2. EU Allowance Price on the Emission Spot Primary Market Auction, 2018–2024. Source: authors elaboration on data from [35, 36]

5 Descriptive Analysis of the MRV Database

As described in the previous chapter, the EU-MRV Regulation requires shipping companies to provide data both at a company and at a ship level. The latter are then published on an annual basis by the European Maritime Safety Agency (EMSA) in accordance with Article 21 of Regulation (EU) 2015/757. The typology of the data, referred to singular ships, can be summarized as:

- Ship and verifier details
- Monitoring methods
- Annual monitoring results

The EU-MRV database [38] covers all maritime voyages, that include a port call at an EU/EEA port, either at the start or at the end of the voyage. It also includes domestic voyages, i.e. voyages between two EU/EEA ports. Only ships above 5,000 GT used for the transport of goods and persons are included. Warships, naval auxiliaries, fish catching or processing ships, wooden ships of a primitive build, ships not propelled by mechanical means, government ships used for non-commercial purposes are excluded.

The MRV data cover all segments of the maritime sector, identifying 15 vessel categories. For the scope of this study, and for a better comprehension of the figures, only the first 10 categories will be considered in the analysis. This cluster represents more than 90% of the total CO_2 emissions. The segments considered are container ships, oil tankers, bulk carriers, Ro-pax ships, chemical tankers, passenger ships, general cargo ships, Ro-ro ships, LNG carriers and vehicle carriers.

CO_2 emissions are reported by separating emissions released during navigation and during port calls (both emissions at berth and emissions released in ports when the ship is not at berth but is moving within a port of call between two voyages). Emissions during navigation are then split in emissions occurred during voyages between EU ports, during voyages departing from a EU/EEA port to a non EU/EEA port, and during voyages arriving in a EU/EEA port from a non EU/EEA port.

The data analysed in this paper was the most recent one (at the time of writing) and it is referred to the period 2018–2023. Data was downloaded during February 2025.

5.1 Descriptive Analysis

In order to perform a descriptive statistical analysis of the MRV database, an initial screening was conducted to remove outliers and errors. As reported by (EC, 2025b), 0.44% of the total reports contained one or more outliers in 2023, compared to 4% in 2018.

The shipping industry includes distinct and diverse maritime segments. Each segment is defined by different characteristics, such as the technical characteristics of the ships, the type of fuel used, the geographical area of interest and the type of service provided, such as long-distance routes (typically container ships) or short sea routes (SSS with Ro-Ro and Ro-Pax ships). Furthermore, certain segments are dedicated to the transport of goods (solid/liquid bulk, containers, vehicles, etc.), others to the transport of passengers (i.e. passenger ships, both leisure and public transport), while others provide a mixed transport of cargo and passengers (Ro-Pax ships).

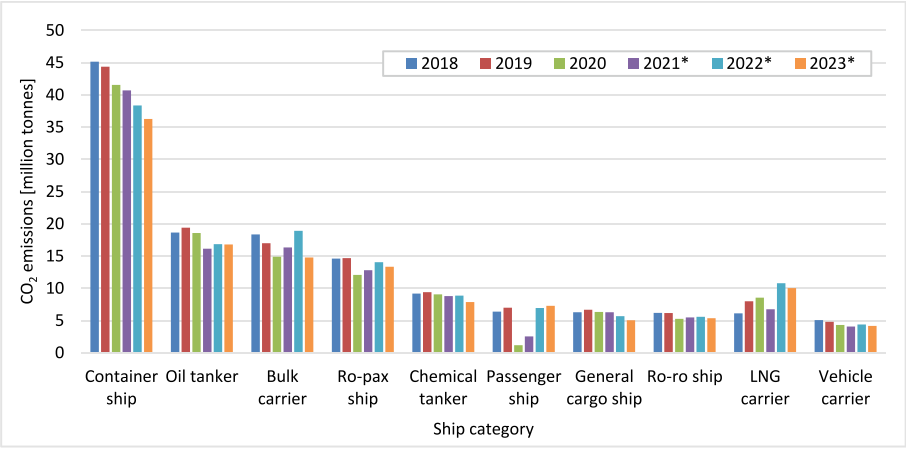

Fig. 3. Total CO_2 emissions (Mtonnes), top 10 ship categories, 2018–2023, descending 2018 order. Source: authors' elaboration on EU-MRV data. Note: * without UK

In order to describe the heterogeneity of the sectors, the MRV data are presented disaggregated for each maritime segment. Figure 3 shows the total CO2 emissions recorded by the MRV system between 2018 and 2023, split for the 10 ship categories analysed.

With the exception of LNG carries, all the other segments reduced their emissions over the years, with the container ships, bulk carriers, and general cargo ships reducing their emissions by 20% between 2018 and 2023. In 2023, the share of the container sector in total emissions is 28%, followed by oil tankers (13%) and bulk carriers (12%). Looking at the passenger shipping sector, emissions in 2020 and 2021 were affected by the Covid-19 pandemic.

Table 3. Number of recorded ships, 2018–2023. Source: authors' elaboration on EU-MRV data.

2018	2019	2020	2021	2022	2023
11,428	11,923	11,653	11,962	13,018	12,571

The average CO_2 emissions per ship (Fig. 4) suggest that, although the first three segments on the left are responsible for almost 50% of the total emissions, passenger ships (Ro-Pax and cruise ships) are the most polluting ones in the system. This is due to two main factors: the geographical area of interest and the propulsion characteristics of the engines. The average emissions from each ship are also related to the time spent on operations. Table 3 shows the total number of ships recorded by the MRV system.

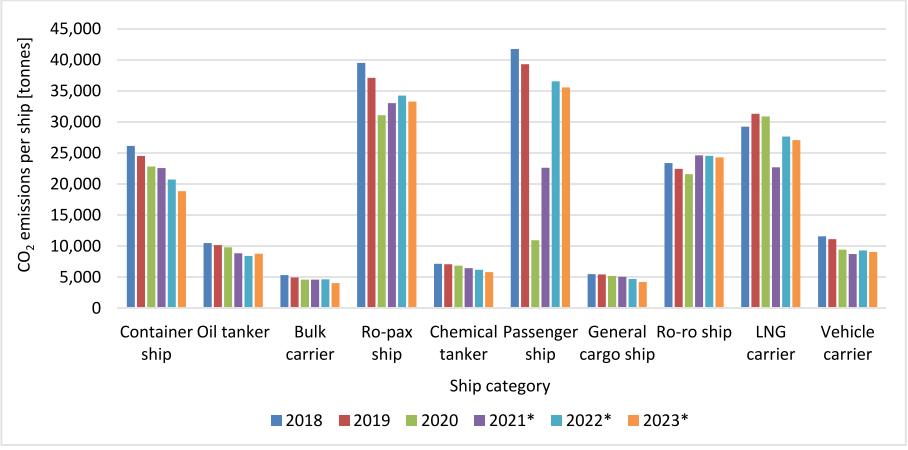

Fig. 4. Average CO_2 emissions per ship (tonnes), top 10 ship categories, 2018–2023. Source: authors' elaboration on EU-MRV data. Note: * without UK

For each segment, the total CO_2 emissions are split into emissions from navigation at sea and emissions in the port area (Fig. 5). In absolute value, oil tankers and container ships were the first emitters in EU ports in 2023. However, in relative values, passenger ships are the segment with the highest emissions in ports (15% of the total), due to the high consumption during berthing time and the longer stays at the quay. Furthermore, oil tankers and chemical tankers also show higher percentages, possibly related to operations in the port areas.

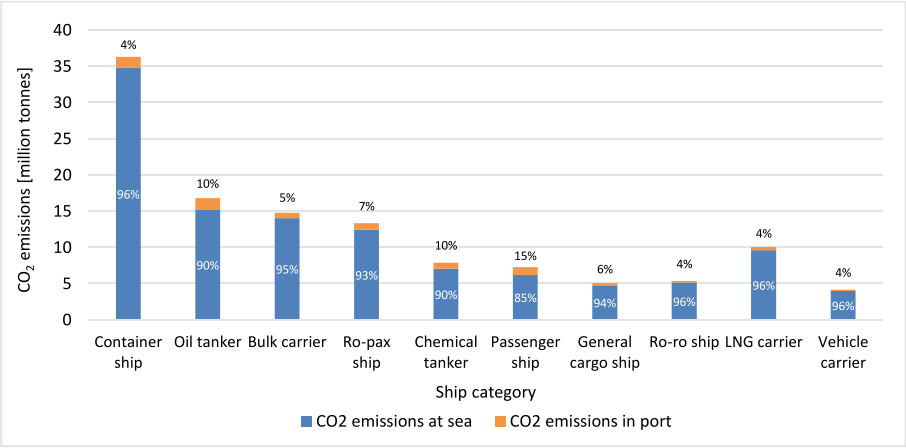

Fig. 5. CO_2 emissions at sea and in the port area (Mtonnes), top 10 ship categories, 2023. Source: authors' elaboration on EU-MRV data.

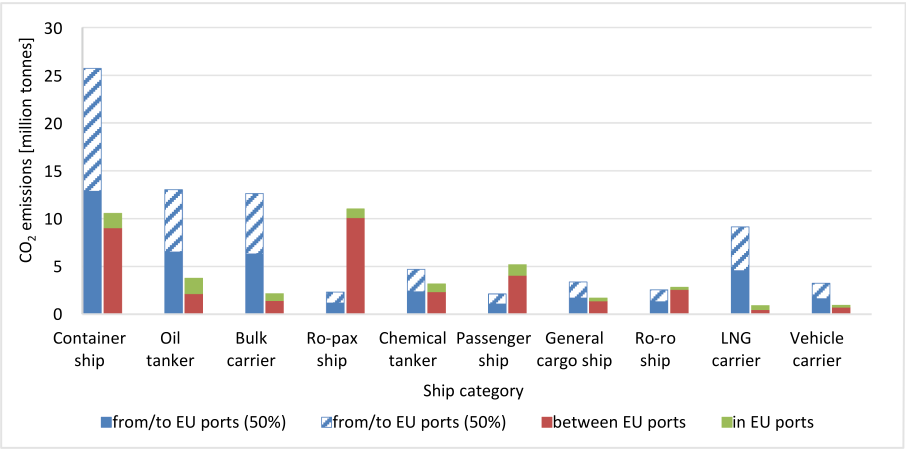

Fig. 6. CO_2 emissions during voyages from/to EU ports, between EU ports, and in EU port areas (Mtonnes), top 10 ship categories, 2023. Source: authors' elaboration on EU-MRV data.

In the EU-MRV system, CO_2 emissions from navigation at sea are divided into emissions from voyages starting or ending in an EU/EEA port and emissions from voyages between EU/EEA ports (Fig. 6). From 2024 onwards, this distinction will be essential for the proper functioning of the EU-ETS, as shipping companies will pay the EU allowances for 100% of the emissions from voyages between EU/EEA ports and 50% from voyages to/from EU/EEA ports. Therefore, from an economic perspective, it is important to consider the distinction between the different geographical scopes of the EU-ETS. Furthermore, from an environmental perspective, emissions between EU/EEA ports and in EU/EEA port areas can be geographically allocated to the European area, whereas it's more difficult to allocate the other emissions geographically.

Figure 6 shows the CO_2 emissions for the different geographical scopes. The Ro-Pax is the segment that emits the most during voyages between EU/EEA ports, followed by container ships. On the other hand, the segment responsible for the highest levels of total emissions from voyages to and from EU/EEA ports is the container ships. This is followed by oil tankers, bulk carriers and LNG carriers.

Table 4. EU-ETS CO_2 emissions, 2023. Source: authors' elaboration on EU-MRV data.

Maritime segment	ETS emissions [tonnes]	ETS/MRV [%]
Container ship	23,417,630	65%
Oil tanker	10,287,768	61%
Bulk carrier	8,466,942	57%
Ro-pax ship	12,183,342	91%
Chemical tanker	5,527,094	70%
Passenger ship	6,228,944	85%
General cargo ship	3,362,842	67%
Ro-ro ship	4,088,915	76%
LNG carrier	5,475,003	54%
Vehicle carrier	2,542,473	61%
Gas carrier	1,536,214	60%
Ref. Cargo carrier	607,467	57%
Container/ro-ro ship	742,466	69%
Other ship types	1,499,036	65%
Combination carrier	22,066	57%

According to the scope of the EU-ETS, only 50% of the emissions from voyages from/to EU/EEA ports are covered by EU allowances. Therefore, in this paper, the *ETS emissions* are defined as the sum of the emissions covered by the EU-ETS, i.e. 50% of emissions from voyages from/to EU/EEA ports, 100% of emissions from voyages between EU/EEA ports and emissions while in EU/EEA ports. Shipping companies must purchase one EUA for each tonne of *ETS emissions.* Table 4 shows the amount of *ETS emissions* for all the maritime segments. It is interesting to note that for the Ro-Pax sector, the *ETS emissions* account for 91% of the overall emissions recorded in the EU-MRV system, while for the containerized sector, the same figure drops to 65%.

6 Conclusions

This paper presents a descriptive analysis of the EU-MRV database. The findings underscore the necessity to analyse the various shipping segments independently, given the evident differences between them. Indeed, the shipping sector includes cargo ships, ro-pax and cruise passenger ships. Furthermore, within each segment, the technical and

operational differences between the ship categories should be taken into account. The impact of the inclusion of the shipping sector in the EU ETS is not yet evident.

The EU-MRV data analysed refer to the period 2018–2023, which is not yet covered by the EU-ETS. For this reason, further analysis needs to be carried out on data relating to 2024, the first payment year for shipping companies.

Although the sectors with the highest emissions are container ships, oil tankers and bulk carriers, when ETS emissions are taken into account (i.e. 50% of emissions from voyages to/from EU/EEA ports, 100% of emissions from voyages between EU/EEA ports and emissions while in EU/EEA ports), the Ro-Pax sector is the segment that pays the largest percentage of total emissions (91%).

Some sectors, such as the Ro-Pax sector, are characterised by lower emission intensity factors compared to other sectors (e.g. container sector). Furthermore, the Ro-Pax and the Ro-Ro segments could suffer from higher EUA prices. This could lead to a modal shift towards more economic alternatives (e.g. road transport).

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