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Analyzing Vessel Emissions from Vessels Calling in the Port of HaminaKotka: Identifying Opportunities to Support Green Investments

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Abstract. To curtail emissions from maritime transport, both the European Union and the International Maritime Organization have instituted increasingly stringent environmental legislation. The EU's Monitoring, Reporting, and Verification regulation necessitates the transparent reporting of verified emissions and fuel consumption for ships. FuelEU Maritime advocates a systematic transition away from fossil fuels, while the EU Emissions Trading System imposes a financial penalty for greenhouse gas emissions. The IMO's Carbon Intensity Indicator is a classification system that categorizes vessels by their levels of energy efficiency. It is anticipated that ports would offer economic advantages to vessels falling within the highest CII categories. The Port of HaminaKotka, Finland's largest general cargo port, is part of the core network of the Trans-European Transport Network. Vessels with a gross tonnage of more than 5,000 gross tonnage calling at the port are required to comply with the MRV reporting obligation. All port calls are recorded in the national database maintained by Fintraffic. This paper analyzes MRV-reported emissions from vessels visiting the Port of HaminaKotka based on the Fintraffic database. The objective of this analysis is to determine the quantity of the reported emissions for each port call, thereby fostering a deeper understanding of the distribution of emissions by vessel type. This will create opportunities to develop effective support actions for shipowners committed to green technologies.

1 Introduction

Efforts to reduce emissions from maritime transport are being pursued through a variety of approaches. Reducing carbon dioxide emissions is particularly challenging as they closely follow the amount of fuel burned [1]. By improving the energy efficiency of vessels, emissions can be reduced relative to transport work. This is encouraged, for example, by the ship energy efficiency design indexes (the Energy Efficiency Design Index and the Energy Efficiency Existing Ship Index) defined by the International Maritime Organization (IMO), as well as the Ship Energy Efficiency Management Plan [2]. In addition, the IMO's Carbon Intensity Indicator (CII) and the EU Emissions Trading System [3], which both apply to ships

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over 5,000 gross tonnage (GT), steer shipowners toward more energy-efficient operations. In this respect, FuelEU Maritime [4] represents a different type of regulation as it obliges shipping companies to gradually transition to the use of non-fossil fuels. However, it should be noted that, ultimately, global warming is driven by the absolute amount of greenhouse gases released into the atmosphere.

Emissions from fossil fuels are largely associated with the end use of the fuel [1,5]. For many renewable solutions, greenhouse gas emissions over the entire fuel life cycle are often decisive when assessing the environmental sustainability of the proposed option [6-8]. In the production of biofuels, factors such as land-use changes can significantly influence the overall environmental footprint of the fuel product [9]. In addition to greenhouse gas emissions, many other types of emissions are also generated, such as nitrogen oxides and sulfur compounds, both of which are highly harmful to human health and the environment [10]. Sulfur emissions can be reduced by lowering the sulfur content of the fuel, but nitrogen oxides present a more complex challenge, and many proposed fuel options, such as methanol or ammonia, do not offer a straightforward solution to this problem [11].

Ships with a gross tonnage exceeding 5,000 GT are required to report their annual fuel consumption and the produced greenhouse gas emissions to the EU Monitoring, Reporting, and Verification (MRV) database [12]. A corresponding reporting obligation also exists towards the IMO Data Collection System (DCS) database [13], although this database is only partially public. Using the MRV database, it is possible to link vessels' reported emissions, based on their IMO numbers, to the port call database maintained by Fintraffic [14]. In these databases, vessels are also classified by ship type and size category, which makes it possible to draw conclusions about which types of vessels calling at a particular port generate the highest levels of emissions.

The objective of this paper is to examine the emissions reported to the EU MRV database by ships over 5,000 GT that called at the Port of HaminaKotka in 2024 [12,15]. The vessels are categorized by ship type, port calls, and individual vessels. The objective is to obtain an overall understanding of which types of vessels or which individual ships visiting the port generate the highest emissions, thereby helping to identify those vessels where targeted measures could, in principle, maximize environmental benefits. The paper also examines the vessels' specific emission factors, which can be used to identify the types of fuels currently being used in their engines. This paper is structured as follows: Section 2 describes the data sources and methods used in the analysis. Section 3 presents the results, and Section 4 discusses the findings and their implications for port-level emission reduction measures.

2 Methods

2.1 The Port of HaminaKotka

The Port of HaminaKotka, located on Finland's southeastern coastline close to the Russian border, is the country's largest general cargo port and a central node in its logistics system [15]. The port comprises several terminals across both Kotka and Hamina cities and forms part of the Trans-European Transport Network core network within the North Sea–Baltic Corridor [16]. In 2024, the port reported 2,181 vessel calls and processed roughly 15 million tons of cargo [14,15]. Its activities span a wide selection of cargo categories, including containers, ro-ro and ro-pax services, dry and liquid bulk, gas logistics, project shipments, and general cargo flows. The Port of HaminaKotka plays a key role in Finland's export supply chains—particularly for forest industry products, machinery, and chemicals—while facilitating significant import volumes of consumer goods and energy. As the EU's easternmost deep water commercial port, the Port of HaminaKotka holds strategic relevance for Baltic Sea transport. It offers efficient maritime links to Central Europe and serves as a major gateway for eastern Finland, while its strong integration with rail and road networks supports hinterland connections [17]. The port also handles short sea services, such as traffic between Finland and the Baltic States.

This analysis focuses on port calls at the Port of HaminaKotka during the year 2024. Only vessels with a gross tonnage exceeding 5,000 GT are included in the analysis as these are subject to mandatory reporting under the EU MRV regulation. Emissions related to port calls are examined to assess the contribution of different vessel types and size classes to the total CO_2 emissions generated by ships calling at the port. These efforts align with Finland's national climate objectives and the port's own long term sustainability strategy, which emphasizes emission reductions, circular economy approaches, and the digitalization of port operations [15].

2.2 The Fintraffic port calls database

Information on vessel calls at the Port of HaminaKotka was obtained from the national marine traffic database maintained by Fintraffic [14], which records all port calls at Finnish ports. The dataset includes vessel identification by IMO number, vessel type, gross tonnage, and the timestamps of departures and arrivals. The dataset used in this study consists of port call data from 2024 for ships over 5,000 GT as this is the reporting threshold under the EU MRV regulation. According to the port's annual reporting [15], a total of 2,181 port calls were made to the Port of HaminaKotka in 2024. In the dataset, 60 vessel calls had incomplete information and were excluded from the analysis. In some cases, this may be explained by vessel departure or arrival times falling around the turn of the year. In any case, the number of such cases is limited. In total, 1,050 port calls by ships over 5,000 GT are included in this analysis.

2.3 The MRV database

Verified greenhouse gas emissions and fuel consumption data were retrieved from the EU MRV database [18] maintained by the European Maritime Safety Agency. Each vessel over 5,000 GT operating within the EU is subject to an annual reporting obligation. The data used in this study are from 2024 as this was the most recent year available in the database at the time the research was conducted. The reporting in the MRV database is carried out on a per-vessel basis, with the IMO number used as the vessel identifier. This identifier was used to link the MRV data with the port call dataset maintained by Fintraffic [14]. Emission factors were derived from the reported fuel consumption and the associated CO_2 emissions, enabling vessels to be grouped according to their fuel types and emission characteristics.

3 Results

Table 1 presents the number of port calls at the Port of HaminaKotka, sorted by vessel type [14] for ships over 5,000 GT. The total number of port calls listed in this table is 1,050. In addition, a significant number of vessels calling at the port are smaller than 5,000 GT. However, emission data for these vessels are not available in the MRV database as the latest dataset from 2024 does not cover them since they were not yet subject to reporting obligations. Nevertheless, among vessels below 5,000 GT, ship types are strongly dominated by general cargo vessels (975 out of 1,071 calls). The other common ship types are oil/chemical tankers (41 out of 1,071) and cement carriers (24 out of 1,071). All other ship types only occur as single vessels. As shown in Table 1, among the vessels over 5,000 GT, the distribution of ship types is considerably more balanced, although certain vessel types, such as container ships and general cargo vessels, are still clearly dominant. Ro-ro vessels, including ConRo types, also represent a significant portion of ships calling at the port, as do chemical tankers.

Table 1. Total port calls and port emissions by ship type (for ships over 5,000 GT)

Type	Port calls (quantity)	Port calls (percent)	CO_2 emissions (tons)	Mean (tons/hour)
Bulk carrier	52	5.0	295.4	5.7
Chemical tanker	119	11.3	625.2	5.3
Container ship	391	37.2	4,401.4	11.3
ConRo cargo	73	7.0	1,861.8	25.5
Gas carrier	5	0.5	15.7	3.1
General cargo	238	22.7	1,253.6	5.3
LNG carrier	15	1.4	223.6	14.9
Oil tanker	13	1.2	51.6	4.0
Other ship types	32	3.0	118.7	3.7
Passenger ship	5	0.5	30.4	6.1
Ro-ro ship	107	10.2	2,904.0	27.1
Total	1050	100	11,781.4	-

Data source: Fintraffic [14]; European Maritime Safety Agency [18]

Table 2 lists port calls by different ship types in the Port of HaminaKotka, also showing the distribution according to vessel size (in GT). In the smaller size range (5,000–9,999 GT), general cargo vessels are strongly dominant, with chemical tankers ranking second. A significant number of container ship port calls fall within the 10,000–19,999 GT range, but container ships also make a considerable number of calls in the over 30,000 GT category. ConRo vessels are found exclusively in the 25,000–29,999 GT size range, whereas ro-ro vessels are concentrated in classes above 25,000 GT. The number of calls by all other ship types is relatively marginal when considering the overall total.

Table 2. The number of port calls by ship type and size class (for ships over 5,000 GT)

Gross tonnage (GT)	5,000–9,999	10,000–14,999	15,000–19,999	20,000–24,999	25,000–29,999	over 30,000
Bulk carrier	1	1	10	15	10	15
Chemical tanker	71	39	5	0	1	3
Container ship	16	134	174	0	1	66

ConRo cargo	0	0	0	0	73	0
Gas carrier	5	0	0	0	0	0
General cargo	201	9	13	3	4	8
LNG carrier	13	0	2	0	0	0
Oil tanker	6	6	0	1	0	0
Other ship types	29	0	2	0	1	0
Passenger ship	0	0	0	1	1	3
Ro-ro ship	0	0	0	0	50	57
Total	342	189	206	20	141	152

Data source: Fintraffic (14)

The number of port calls is an important indicator of traffic intensity at a seaport. However, by examining the absolute number of vessels, a more accurate understanding can be obtained of whether port calls by different vessel types are isolated cases or whether there is repetition. The differences between vessel types are significant. As shown in Table 3, for example, bulk carrier port calls are by individual vessels, which is typical of tramp shipping. In contrast, for container and ConRo vessels, it is typical that the same ship calls regularly at the same port, operating on a fixed route or otherwise on a service that is quite regular compared with bulk carriers. Regarding chemical tanker port calls, there is less regularity, with an emphasis on smaller vessels. The same also applies to general cargo vessels.

Table 3. The number of distinct ships by ship type and size class (for ships over 5,000 GT)

Gross tonnage (GT)	**5,000–9,999**	**10,000–14,999**	**15,000–19,999**	**20,000–24,999**	**25,000–29,999**	**over 30,000**
Bulk carrier	1	1	10	15	10	15
Chemical tanker	25	15	4	0	1	1
Container ship	8	20	18	0	1	7
ConRo cargo	0	0	0	0	6	0
Gas carrier	1	0	0	0	0	0
General cargo	51	6	11	3	4	5
LNG carrier	3	0	1	0	0	0
Oil tanker	4	6	0	1	0	0
Other ship types	20	0	2	0	1	0
Passenger ship	0	0	0	1	1	2
Ro-ro ship	0	0	0	0	6	3

Total	113	48	46	20	30	33

Data source: Fintraffic [14]

The CO_2 emission factors for fuels are as follows [19]: marine gas oil (MGO) 3.206, heavy fuel oil (HFO) 3.114, liquefied natural gas (LNG) 2.74, and methanol 1.375 $kgCO_2/kgfuel$. The Baltic Sea is a sulfur emission control area, and many vessels have shifted to using low-sulfur fuels, thereby avoiding the need to invest in exhaust gas sulfur scrubbers. Low-sulfur fuel product families include numerous different fuel types, some of which are conventional gas oils, while an increasing number of intermediate residual-containing distillate fuels are also available on the market. This is reflected in part by the fact that, based on the consumption and emissions data reported to the MRV database, many vessels fall into the emission factor category of 3.15–3.20 (see Table 4). This may also result from the use of multiple fuels: at sea, vessels may use high-sulfur heavy fuel oil in the main engines while operating scrubbers, but during port operations they switch to low-sulfur MGO when only auxiliary engines are running as scrubbers may only be installed on the main engine exhaust stack or their operation in port may not be practical. LNG-fueled vessels use multiple fuels in any case as they require MGO as pilot fuel. In addition, some LNG vessels switch to MGO during port calls, depending on engine type. A few shipping companies have reported using biofuels, which is reflected in Table 4 by emission factors falling in the 2.9–3.10 category. Vessels with emission factors below 2.7 are methanol fueled.

Table 4. The number of port calls by ship type and emission factor category (for ships over 5,000 GT)

CO_2 factor	**under 2.7**	**2.7–2.9**	**2.9–3.10**	**3.10–3.15**	**3.15–3.20**	**over 3.20**
Bulk carrier	0	0	0	29	23	0
Chemical tanker	0	5	24	5	18	67
Container ship	18	12	58	164	85	54
ConRo cargo	0	0	0	73	0	0
Gas carrier	0	5	0	0	0	0
General cargo	0	31	0	40	59	108
LNG carrier	0	15	0	0	0	0
Oil tanker	0	1	6	0	3	3
Other ship types	0	0	0	11	17	4
Passenger ship	0	0	0	0	4	1
Ro-ro ship	0	0	0	107	0	0
Total	18	69	88	429	209	237

Data source: Fintraffic [14]; European Maritime Safety Agency [18]

Table 5 categorizes the emission factors of separate vessels into the same emission factor categories as used in Table 4. Two methanol-fueled vessels have called at the port. In terms of vessel numbers, LNG- and bio-fuel-powered vessels are also few, although many of them operate in regular shipping routes, which is reflected in Table 4 as significantly higher numbers of port calls. However, most vessels, when measured by vessel count, operate on residual, intermediate, or full distillate fuel oils.

Table 5. The number of distinct ships by ship type and emission factor category (for ships over 5,000 GT)

CO_2 factor	under 2.7	2.7–2.9	2.9–3.10	3.10–3.15	3.15–3.20	over 3.20
Bulk carrier	0	0	0	29	23	0
Chemical tanker	0	1	6	4	13	22
Container ship	2	1	8	26	15	2
ConRo cargo	0	0	0	6	0	0
Gas carrier	0	1	0	0	0	0
General cargo	0	4	0	30	29	17
LNG carrier	0	4	0	0	0	0
Oil tanker	0	1	4	0	3	3
Other ship types	0	0	0	8	12	3
Passenger ship	0	0	0	0	3	1
Ro-ro ship	0	0	0	9	0	0
Total	2	12	18	112	98	48

Data source: Fintraffic [14]; European Maritime Safety Agency [18]

Table 6 presents the calculated amount of CO_2 emissions produced by different vessel types representing various size classes during a port call. Significant differences are easy to observe, and the results particularly highlight vessels that visit the port frequently and are large. This is especially evident for ro-ro vessels: although there are only nine such vessels in our data, their large size and regular port calls mean they account for nearly 25% of the total calculated carbon dioxide emissions produced during port calls at the Port of HaminaKotka. Container vessels and ConRo vessels are also significant sources of emissions. Only 54 container vessels call at the port, yet they are responsible for more than 37% of total emissions. Similarly, there are only six ConRo vessels, but their share of emissions is nearly 16%.

Table 6. The total amount of CO_2 emissions produced at the Port of HaminaKotka by ship size and type (for ships over 5,000 GT)

Gross tonnage (GT)	5,000–9,999	10,000–14,999	15,000–19,999	20,000–24,999	25,000–29,999	over 30,000	Total
Bulk carrier	0.0	0.0	46.4	93.2	105.4	50.4	295.4
Chemical tanker	321.9	249.7	15.2	0.0	0.0	38.3	625.2

Container ship	56.2	1,156.5	2,132.1	0.0	12.4	1,044.2	4,401.4
ConRo cargo	0.0	0.0	0.0	0.0	1,861.8	0.0	1,861.8
Gas carrier	15.7	0.0	0.0	0.0	0.0	0.0	15.7
General cargo	905.1	126.4	48.9	10.4	30.5	132.3	1,253.6
LNG carrier	218.9	0.0	4.7	0.0	0.0	0.0	223.6
Oil tanker	16.9	23.1	0.0	11.7	0.0	0.0	51.6
Other ship types	108.4	0.0	5.5	0.0	4.7	0.0	118.7
Passenger ship	0.0	0.0	0.0	3.2	7.3	19.9	30.4
Ro-ro ship	0.0	0.0	0.0	0.0	779.6	2,124.5	2,904.0
Total	1,643.1	1,555.8	2,252.8	118.5	2,801.8	3,409.6	11,781.6

Data source: Fintraffic [14]; European Maritime Safety Agency [18]

4 Discussion

Emission levels can be studied from many different perspectives [1,5-8], and adopting a particular viewpoint can enhance understanding, which in turn makes it easier to select appropriate measures for reducing emissions. In this paper, the focus is on the CO_2 emissions reported to the MRV database [18] by ships over 5,000 GT calling at the Port of HaminaKotka [15]. The advantage of this perspective is that it provides insights into the emissions of vessels visiting a specific port. This information can be used, for example, when designing port fee systems or other economic incentives that support a transition to non-fossil fuels or, at least, to lower emissions. Such mechanisms could, for instance, guide the allocation of collected emission fees to maritime actors who have invested in cleaner technologies or operational practices [19]. To design such solutions, it is necessary to have information on where actions should be targeted to ensure effectiveness. It should also be noted that ports often operate as commercial enterprises with the objective of generating profit. Even if a port is environmentally conscious, one may question whether it is in the port's interest to provide direct support to shipping companies without some form of compensation from society, for example, support through tax instruments or directly earmarked subsidies.

The criteria used to target support measures are crucial as different approaches can lead to very different outcomes. Support may be based on absolute emissions during port calls, on vessels' energy efficiency indicators, or on a combination of both. One potential tool is the IMO's CII, particularly if incentives are directed toward vessels in the higher-performing A or B categories [2]. However, any chosen indicator must be applied in a way that aligns with port-specific objectives and operational realities. This underscores the importance of complementary public policy instruments. Targeted subsidies, tax mechanisms, or earmarked funding could help compensate ports for offering incentives to low-emission vessels, while still allowing the flexibility to tailor measures to local conditions. Because ports vary significantly in size, function, and strategic priorities, a uniform incentive model is unlikely to be effective. From the perspective of port authorities, designing such schemes also raises economic considerations: ports are often commercial entities that must remain profitable. Even though environmental performance is increasingly important, unilateral financial support for shipping companies may not be feasible unless clear benefits are generated in return, such as improved competitiveness, compliance with regulatory requirements, or greater appeal to environmentally conscious cargo owners.

The results indicate that a relatively small number of vessel types and individual ships account for a disproportionately large share of port call–related CO_2 emissions at the Port of HaminaKotka. Vessels operating on regular services—particularly ro-ro, container, and ConRo vessels—dominate total emissions due to their large size and frequent calls. Consequently, emission reduction measures implemented at the port level are likely to be most effective when targeted at vessels that visit the port regularly rather than those only calling occasionally. Overall, the analysis shows that combining MRV emissions data with detailed port call statistics provides a solid empirical foundation for developing targeted and economically justified measures that support the transition toward greener maritime transport at the port level. As the adoption of alternative fuels is expected to increase, this approach also provides an open data-based framework that enables the systematic monitoring of the evolution of emissions.

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