Emissions from Baltic Sea Shipping in 2024

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Key findings

IMO registered vessels

1. **Total emissions from IMO registered vessels in the Baltic Sea in 2024 were 215 thousand tonnes of NO_x, 6.7 thousand tonnes of SO_x, 3.4 thousand tonnes of PM, 22.2 thousand tonnes of CO, 2.2 thousand tonnes of Non-Methane Volatile Organic hydroCarbons (NMVOC), 12.9 million tonnes of CO_2 , 9 thousand tonnes of CH_4 and 0.7 thousand tonnes of N_2O. The emissions of greenhouse gases (CO_2, CH_4 and N_2O) correspond to 13.3 million tonnes of CO_{2eq}.** The CO_2 amount corresponds to 4.1 million tonnes of fuel (Energy shares of different fuels were for LNG: 7.2%; distillates: 74.9%; residual fuels: 17.9%). From total fuel consumption 22% was used in auxiliary engines and boilers. These emissions contain only the IMO-registered traffic and do not include any contribution from inland waterway traffic or non-IMO registered vessels.

   When the current emission trend of 2006-2024 is linearly extrapolated to future years, CO_{2eq} emissions of the international shipping in the Baltic Sea area in 2050 are estimated to be -21% lower than in 2008 considering only those ships which have an IMO number. The trendline based on 19 years of ship emissions was used in this projection, considering emissions of CO_2, CH_4 and N_2O, and continuing the observed linear trend between 2006-2024 to year 2050.

All vessels

2. **For all vessels sailing the Baltic Sea (international shipping and domestic shipping, but excluding the inland waterway traffic), emission totals are NOx: 222 thousand tonnes, SOx: 7.0 thousand tonnes, PM: 3.6 thousand tonnes, CO: 23.2 thousand tonnes, NMVOC: 2.3 thousand tonnes, CH4: 9 thousand tonnes, N2O: 0.7 thousand tonnes and CO_2: 13.3 million tonnes. These correspond to 13.8 million tonnes of CO_{2eq}.**

Emission of domestic shipping

3. **Projected CO_2eq emissions of domestic shipping were four million tonnes and** are projected to be -28% less in 2050 than in 2008. The trendline based on 18 years of ship emissions was

used in this projection, considering emissions of CO_2, CH_4 and N_2O, and continuing the observed linear trend between 2006-2023 to year 2050.

Transport work

4. **Overall transport work has decreased by -2.1% and the total travelling distance of IMO-registered vessels has decreased by -1.1%**. The transport work of containerships, general cargo ships and Ropaxes increased by +9.1%, +2.8% and +2.1%, whereas the transport work of vehicle carriers, bulk carriers and roro segments decreased by -16.7%, -6.8% and -5.3%.

Emissions from Baltic Sea shipping in 2024 compared to year 2023

5. **Most air emissions from all waterborne traffic have decreased (NO_x: -11.6%; SO_x: -10.0%; PM2.5: -11.0%; CO: -12.4; CO_2: -8.1%; N_2O: -6.6%; CH_4: +6.2%) when compared to year 2023. These correspond to -7.8 decrease in CO_{2eq} emissions. However, this decrease is mostly driven by small vessels, because much smaller decreases were predicted for IMO -registered ship traffic (NO_x: -2.8%; SO_x: -0.6%; PM2.5: -0.3%; CO: +1.7; CO_2: +0.3%; N_2O: +0.2%; CH_4: +6.4%, CO_{2eq}: +0.4%).** The emissions of CO_2 from non-IMO registered vessels were 3.4% of total CO_2 emitted from ships. During the 2024 study period, the number of IMO-registered vessels operating in the area has decreased by -2.5%.

6. **The CO_2 emissions from ships in 2024 are lower than the pre-pandemic emission levels**. Emissions of CO_2 from ships were -9.7% lower than the 2019 CO_2 total.

7. **Methane emissions were estimated as 9046 tonnes (+6.2% from previous year).** Most of the methane was released from RoPax (45%), RoRo (20%) and tankers (14%) ships.

8. **For 2024, emissions of NH_3 and N_2O were 29 tonnes and 721 tonnes, respectively.** Ammonia slip arises from Tier III vessels which use SCR for NOx abatement. Currently, no ammonia-fueled ships are known to sail in the Baltic Sea area.

The effect of weather and sea conditions on carbon intensity and fuel oil consumption

9. **During 2024, 2126 ships with 5,000 gross tonnage and above were sailing in ice conditions in the Baltic Sea area**. These ships have been estimated to travel approximately 1.5 million nautical miles in ice conditions which corresponds to 4.1% of the total travel distance of these vessels.

10. **For all ship types, including the operation in ice conditions in the calculation increases the annual median of Carbon intensity indicator (CII) by an average of 1.8% for ships with 5,000 gross tonnage and above.** The largest average increase takes place for bulk carriers with a difference of 3.5% between the CII values with and without sailing in ice conditions

included in the calculation of the indicator.

11. **On average, sea ice increases the total annual fuel consumption of ships with 5,000 gross tonnage and above sailing in ice conditions by 0.8% in the Baltic Sea in 2024.** The largest annual effect can be seen for general cargo ships of which fuel consumption has increased on average by 1.7% due to sailing in ice conditions. The lowest annual increase is observed for vehicle carriers and cruise passenger ships.

    Total effect of weather and sea condition on the total fuel consumption of shipping in the Baltic Sea in 2024 is +5.9%. Wind, waves and sea currents affect ship passages globally, but sea ice cover is relevant only for some sea areas. From the total weather impact, an average contribution of +1.1% was predicted to arise from sailing in ice conditions in the Baltic Sea region.

Validation of the results of STEAM with MRV data

12. The updated Ship Traffic Emission Assessment Model (STEAM v5.1) was used in this work. The new version of the model enables 1:1 comparison with the EU Monitoring, Reporting and Verification fuel reporting. **provides fleet total fuel consumption which is within +2.9% of the MRV reports**. In case of MRV CO_2 emissions and those predicted by STEAM, overprediction is +4.6%. Both positive and negative uncertainties exist.

Abbreviations

AIS	Automatic Identification System
CH_4	Methane
CII	Carbon Intensity Index
CMEMS	Copernicus Marine Environment Monitoring Services
CO	Carbon monoxide
CO_{2eq}	Carbon dioxide equivalent, a measure to compare the effect of other greenhouse gases to carbon dioxide on the basis of their global warming potential
CO_2	Carbon dioxide
DCS	Data Collection System
EC	Elementary Carbon
EGCS	Exhaust Gas Cleaning System
ERA5	5th atmospheric reanalysis of the global climate
GHG	GreenHouse Gas
GT	Gross Tonnage
HELCOM	Baltic Marine Environment Protection Commission
HFO	Heavy fuel oil
IMO	International Maritime Organization
IPCC	Intergovernmental Panel for Climate Change
LFO	Light Fuel Oil
LNG	Liquefied Natural Gas
MEPC	Marine Environment Protection Committee
MMSI	Maritime Mobile Service Identity
MRV	Monitoring, Reporting and Verification
N_2O	Nitrous oxide
NH_3	Ammonia
NMVOC	Non-methane volatile organic hydrocarbon
NO_x	Nitrogen oxides

OC	Organic carbon
PM2.5	Particulate Matter, smaller than 2.5 micrometer diameter
SCR	Selective Catalytic Reaction
SECA	Sulphur emission control area
SO_x	Sulfur oxides
STEAM	Ship Traffic Emission Assessment Model

1. Emissions of atmospheric pollutants

This work reports the Baltic Sea ship emissions, including contributions from wind, waves, sea currents and ice cover. The STEAM model used in this work was version 5.1 (Jalkanen et al., 2009, 2012, 2018; Johansson et al., 2013, 2017; Majamäki et al., 2025). The whole timeseries from 2006 to 2024 was updated for this report using Copernicus atmosphere and ocean datasets (Copernicus Marine Service Information (CMEMS), 2024) to describe the ambient conditions.

The emissions from Baltic Sea shipping have remained relatively stable when compared to year 2023 and were generally less than the 2019 pre-pandemic levels, with some exceptions. Annual totals reported by sea area and vessel type are given in Table 1. The transport work of IMO registered ships decreased from last year's value (-2.1%) and CO_2 emissions were increased by +0.3%. The total CO_2 emitted (vessels with an IMO number) in 2024 was 12.9 million tonnes, which corresponds to roughly 1.5% of the global shipping CO_2 emissions in 2023 (FMI modelling using global 2023 AIS data). Considering only the international shipping, the share of the Baltic Sea shipping is about 1.3% of the global international shipping.

In addition to CO_2 emissions, also 721 tonnes of N_2O and 9046 tonnes of CH_4 were released. Assuming 100-year values for global warming potentials, then the total CO_{2eq} emissions were 13.3 million tonnes for all Baltic Sea shipping (IMO registered ships only). Considering only the international traffic, 8.9 million tonnes of CO_2, 486 tonnes of N_2O and 5272 tonnes of CH_4 were emitted, which correspond to 9.2 million tonnes CO_{2eq}.

Table 1 Emissions from Baltic Sea shipping in 2024.

Baltic – 2024	MAIN FUEL	AUX + B_FUEL	NOx	SOx	PM25	CO	CO_2	CH_4	NH_3	N_2O	CO_{2eq}	TRAVEL	TRANSP WORK	VOC	SHIPS
	[10^3 tonnes]	[10^3 tonnes]	[tonnes]	[tonnes]	[tonnes]	[tonnes]	[10^3 tonnes]	[tonnes]	[tonnes]	[tonnes]	[10^3 tonnes]	[10^6 nm]	[10^6 tonne nm]	[tonnes]	
All	3288	955	222024	7004	3566	23173	13323	9046	29	721	13768	65	615474	2325	12726
IMO	3193	907	214994	6732	3431	22156	12870	9038	28	699	13308	57	612057	2247	9129
Baltic Proper	1976	435	128237	3954	2026	12599	7581	4479	16	412	7815	38	359918	1317	4171
Kattegat	614	206	44214	1390	714	4279	2581	1035	8	139	2647	14	141968	455	6918
Gulf of Finland	391	240	33169	1054	533	3889	1976	1826	4	106	2056	6	87380	346	910
Gulf of Bothnia	264	61	13912	503	244	2096	1009	1690	1	55	1071	6	21942	176	593
Gulf of Riga	42	14	2492	103	49	310	175	16	0	9	178	1	4265	31	134
RoPax_ships	982	148	58	2	834	5847	3537	4029	0	194	3701	8	17213	579	220
Ro-ro cargo ships	316	35	13117	472	263	2238	1089	1766	0	60	1154	3	24961	187	101
Vehicle_carriers	12	5	1173	27	14	82	54	3	0	3	55	0	1416	10	118
General_cargo ships	402	100	24889	927	445	2784	1584	275	3	82	1614	18	66145	272	2448
Bulk_carriers	284	112	24123	733	390	1826	1253	2	4	68	1272	5	142987	234	1909
Container_ships	287	92	22662	626	360	2197	1195	139	5	65	1216	4	87797	235	443
Reefers	31	9	3218	69	37	191	126	0	0	7	128	1	3396	23	104
Tankers	585	288	50287	1497	748	3604	2743	1216	15	151	2817	10	259874	482	2361
LNG_tankers	43	23	1868	73	36	575	197	979	1	12	228	0	9340	39	120
Gas_tankers	18	11	1705	55	26	135	91	0	0	5	92	1	2324	15	97
Passenger_ships	21	19	1880	77	34	288	126	0	0	6	127	3	0	20	521
Cruisers	92	8	4275	144	78	547	314	450	0	17	331	0	0	53	93
Fishing_vessels	18	16	1712	66	33	239	108	0	0	5	109	3	0	19	827
Service_ships	24	18	1722	81	40	315	134	5	0	7	136	2	0	23	459

Emission totals reported in Table 1 include emissions of both the IMO registered traffic and all vessels. Similar tables for the previous years are given in Appendix 1. The difference of these two is the vessel fleet which is smaller in size than the required IMO registration threshold and the part of the fleet which operates only on national waters without an IMO number, using only MMSI code. Regardless, all vessel traffic using Automatic Identification System (AIS) transceivers is included in the modelling, but those traveling on inland waterways have been removed from the dataset. The five largest emission sources (CO_{2eq}) in the Baltic Sea fleet are the ro-ro passenger ships, tankers, general cargo ships, bulk carriers and containerships.

The lines in Figure 1 depict the emissions over the study period and includes all vessels. The open symbols in Figure 1 indicate the total emissions of NO_x and CO for large vessels which have an IMO registry number. Data describing the ambient conditions (wind, waves, sea current and sea ice) have been included in the modeling and their impact on ship resistance is considered. However, complete ambient datasets describing all four contributions were available for years 2018-2024. For 2014-2017, only three of the four contributions were available and the sea current data was missing and has been neglected. The sea current contribution to emission totals is small in the Baltic Sea area, +0.2-0.3%, based on our earlier work. The years 2006-2013 were modeled adding average ambient contribution of eight percent to propulsion power requirements, which was identified as the average contribution of all four ambient effects based on the 2018-2023 results. More details of the ambient conditions and their effect can be found in a recent study (Majamäki et al., 2025).

It should be kept in mind, that these numbers include only partial contribution from recreational boating which can be a significant source of Non-Methane Volatile Organic hydroCarbons (NMVOC) and CO emissions, especially during summer months. The AIS equipment is not mandatory for these vessels and thus their contribution to overall emissions are underestimated in the current analysis, but further details can be found in a recent work of Johansson et al. (2020). The symbols and lines of Figure 1 diverge from 2014 onwards which is because of increasing number of small vessels in the AIS data. This underlines the need to present separate emission totals for large ships and smaller vessels.

Figure 2 depicts the emissions of greenhouse gases of Baltic Sea shipping for the 2006-2024 period. Despite the rapid growth of CH_4 emissions, the contributions of non-CO_2 emissions to CO_2 equivalents are small.

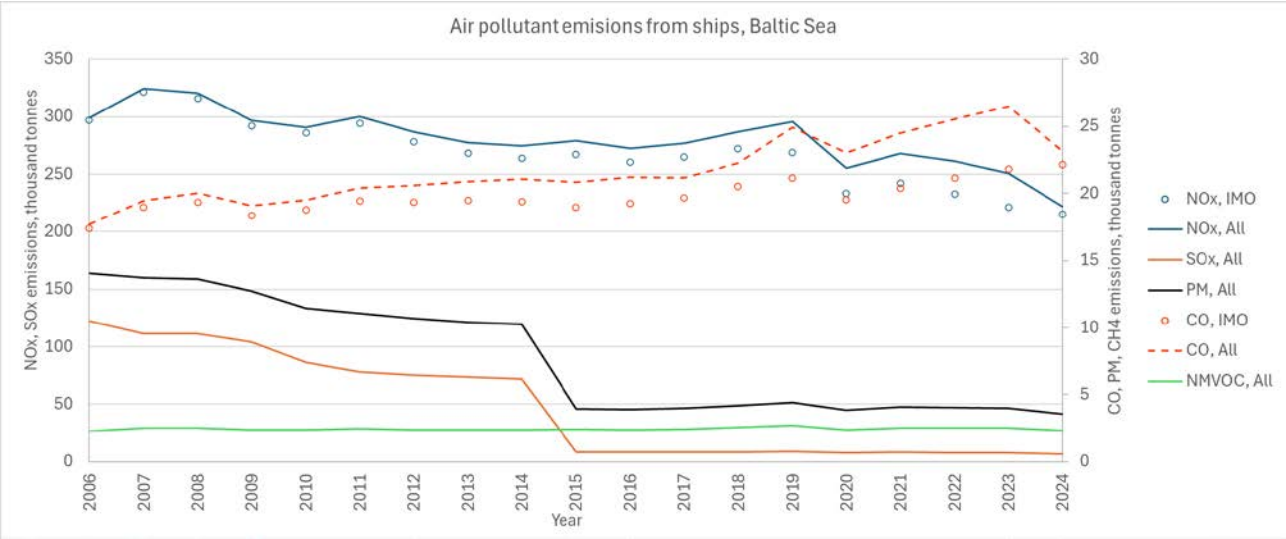

Figure 1 Emissions of NO_x, SO_x, $PM_{2.5}$, CO and NMVOC from ships in the Balti Sea during 2006-2024. Significant decreases in SO_x and $PM_{2.5}$ are results of regulatory changes concerning the maximum Sulphur content of fuel. Coloured lines depict total emissions from all vessels with an active AIS transceiver; empty symbols indicate the contribution from IMO-registered ships

only. Note that the left vertical axis is for NOx and SOx, whereas the emission totals of other pollutants are reported using the right-side axis.

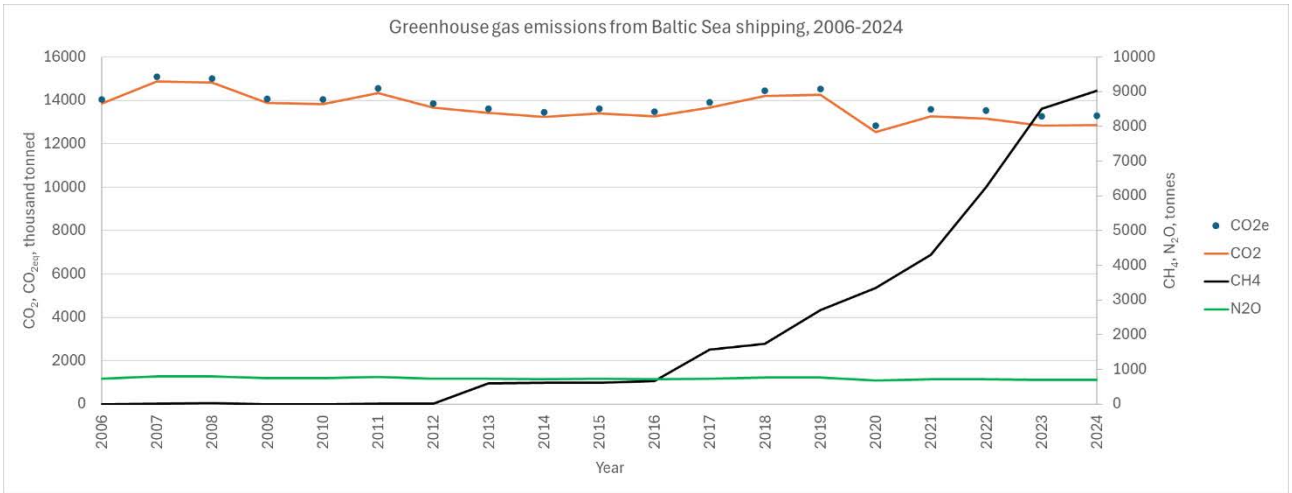

Figure 2 Emissions of greenhouse gases (CO_2, CH_4, N_2O) and their CO_2 equivalent of the Baltic Sea shipping in 2006-2024.

Figure 3 contains a summary of estimated fuel types used by the Baltic Sea fleet during 2006-2024, including only those vessels which have an IMO number. The coloured bars illustrate different fuel types. Increase in energy consumption from 2023 to 2024 is less than +0.3% The total energy consumed by Baltic Sea shipping in 2024 was about -8.8% lower than in 2019.

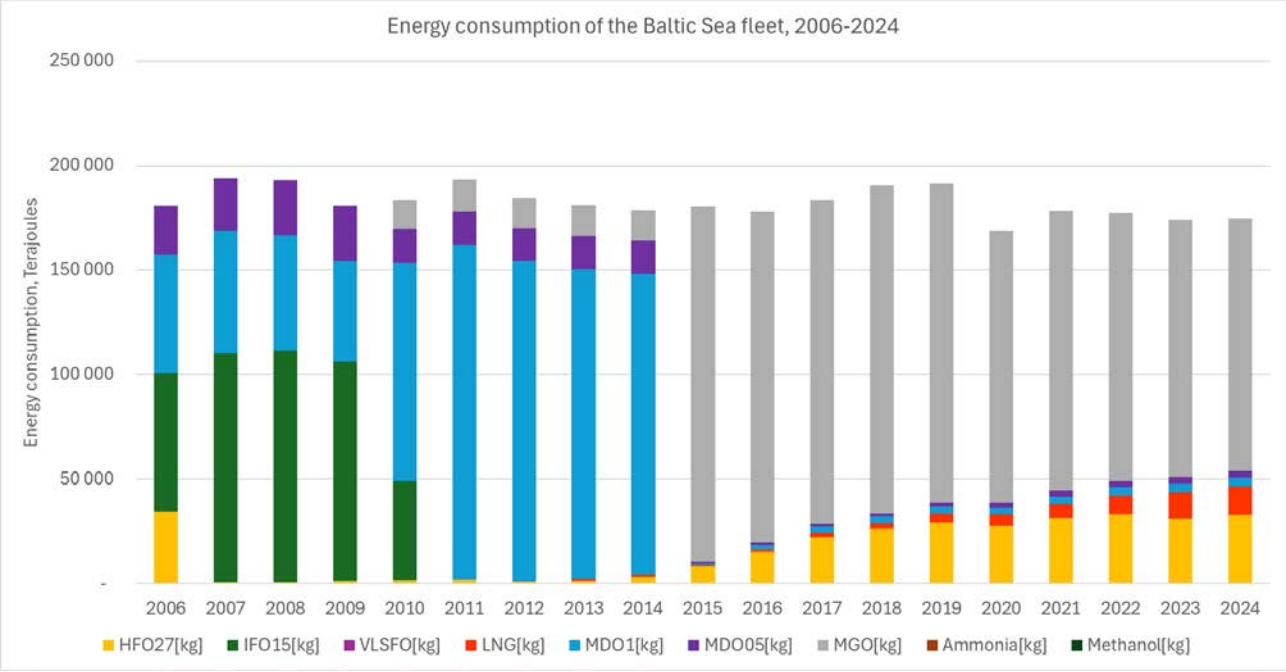

Figure 3 Energy consumption of the Baltic Sea fleet between 2006-2024.

Heavy fuel use is concentrated on ro-ro passenger ships, roro cargo and containerships, some of which are equipped with exhaust gas cleaning systems (scrubbers) and enable the use of HFO with high sulphur content regardless of the tight sulphur rules of a SECA (Figure 4). Ultra low sulphur residual oils may be an option for a part of the fleet, but the share of its use is not known. Fuel type prediction

is made considering the engine specifications of vessels, which engines can use various fuels. HFO with high sulphur content operation is considered in ships which have installed an EGCS, considering the cleaning efficiency of an EGCS.

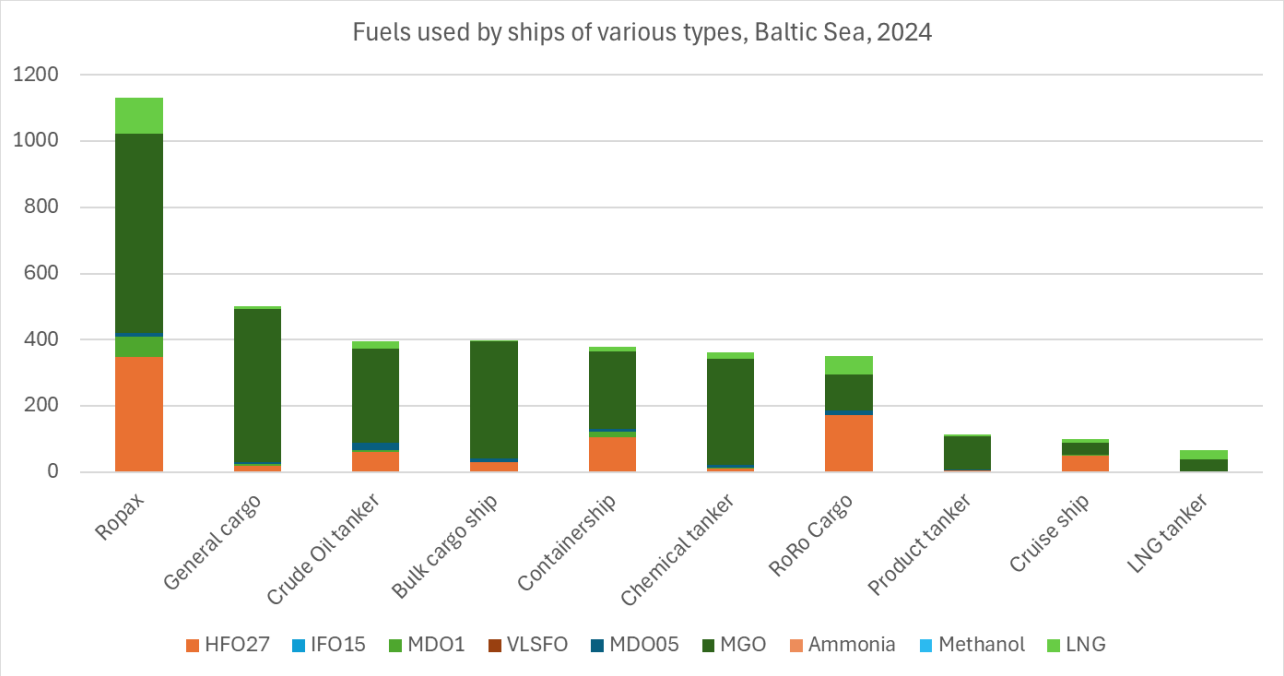

Figure 4 Estimated fuel used by various ship types in the Baltic Sea area during 2024.

In Figure 5, the share of CO_2 equivalent (CO_{2eq}) emissions in national and international shipping is reported for the period 2006-2024. These are calculated using the GWP100 values (IPCC, 2013) for CO_2, CH_4 and N_2O using the allocation based on voyage-based definition consistent with the IPCC definitions and the Fourth IMO GHG study (Faber et al, 2020). According to the Fourth IMO GHG study report, one third of the global fuel was reported to be consumed in national shipping. Regardless, if a vessel departs and arrives in a port within the same country, its activities are considered as national shipping. In contrast, if departure and arrival ports are in different countries, this voyage is international shipping.

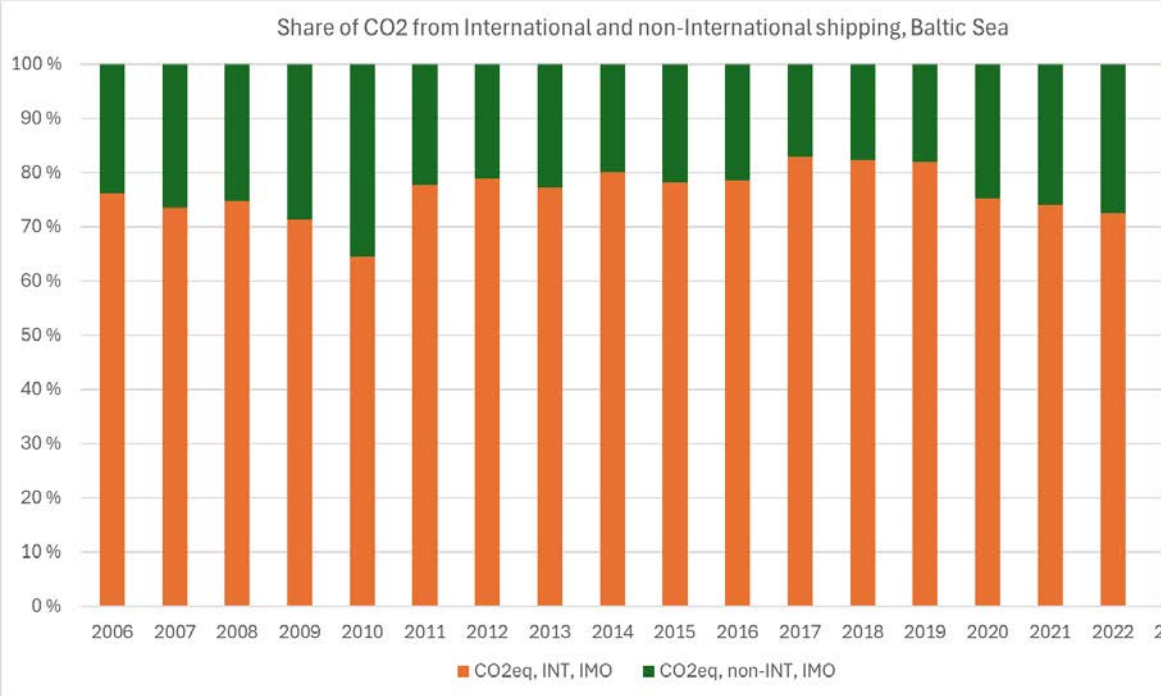

Figure 5 CO_{2eq} emissions of the Baltic Sea fleet during 2006-2024, divided into domestic and international shipping contributions. The share of fuel used in national navigation is about 31%, whereas most of the fuel is consumed in international traffic (69%).

Emissions of CO_{2eq} from the Baltic Sea fleet have decreased over the study period of eighteen years (Figure 6). Compared to year 2008, CO_{2eq} emissions from international shipping in 2024 have been reduced by -18%. If this trend continues until year 2050, reduction of only -21% will be achieved. Considering only the IMO registered ships, the continuation of the CO_2 emission trend for domestic shipping leads to a decrease of CO_{2eq} emissions by -28% percent in 2050. If the current trends continue, the total CO_2 emissions (international + domestic + undefined) will be 77% of those emitted in 2008.

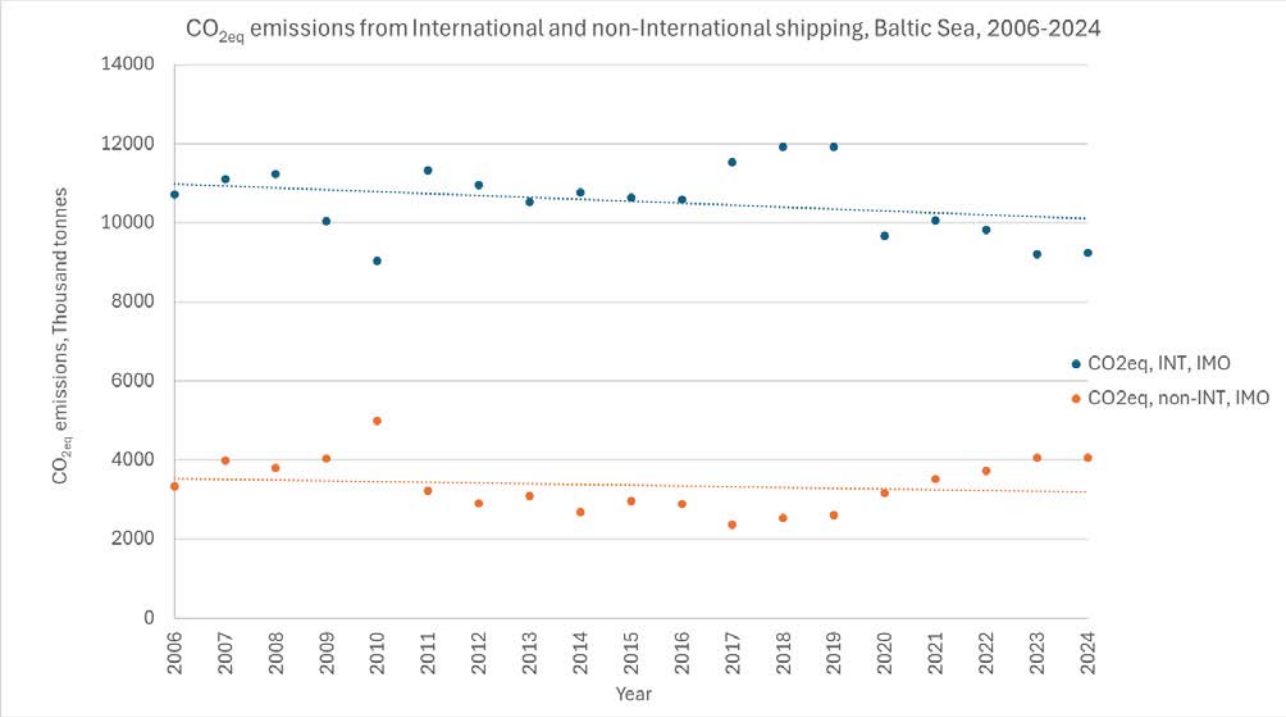

Figure 6 Emissions of CO_2 from Baltic Sea shipping during 2006-2024. The trendlines indicate the development over the past 19 years.

The largest fuel consumers in the Baltic Sea are the ro-ro passenger ships, tankers, and bulk carriers and general cargo ships, which mostly operate on international voyages. Most of the smaller vessel classes consume their fuel in national routes (Figure 7).

The Covid19 pandemic had a major impact on cruise passenger ship operation in the Baltic Sea area and in 2020 most of the fuel used by the cruise passenger ships were used in domestic routes. In 2024 the fuel used in international voyages was about 90% of the total cruise ship fuel consumption, which is similar to the pre-pandemic years.

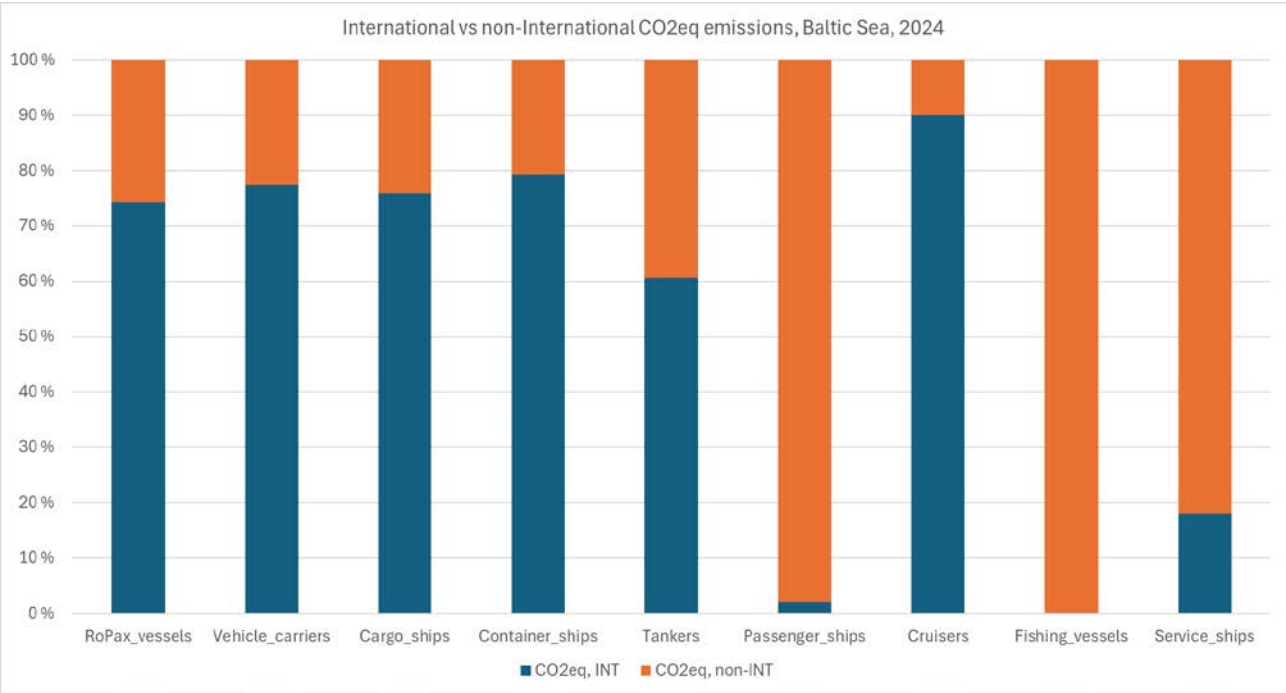

Figure 7 CO_2 emitted from various ship types in domestic and international voyages. Most of the fuel used by passenger, fishing and service vessels falls under national navigation. For other ship types, most of their fuel is used in international traffic.

The share of fuel used during voyages and harbour visits are depicted in Figure 8. It should be noted that the list of ports with shore power and ships with shore power connections were updated using the European Alternative Fuels Observatory information and S&P Global data. List of terminals with shore power was collected using the TEN-T harbor list and updating the information in each case from various online sources. Current model setup allows definition of port terminals with shore power connections, ship type definitions and start date of shore power connections. For shore power consideration, three conditions need to be met; a) both the ship and the terminal need to have shore power capability, b) the ship needs to be inside the port terminal polygon, and c) the date of berthing must be after the launch of shore power infrastructure. The model currently has information of 30 existing port terminals with shore power capability in the Baltic Sea area, and seven more with future shore power installation dates. Similar definitions have been made for 148 European port terminals, considering the EU alternative fuels directive (2023/1805) requirements for offering shore power to

container and passenger vessels by 2030. However, there is no check is currently made against shore power offered (in MW) to shore power required by ships of each type at berth.

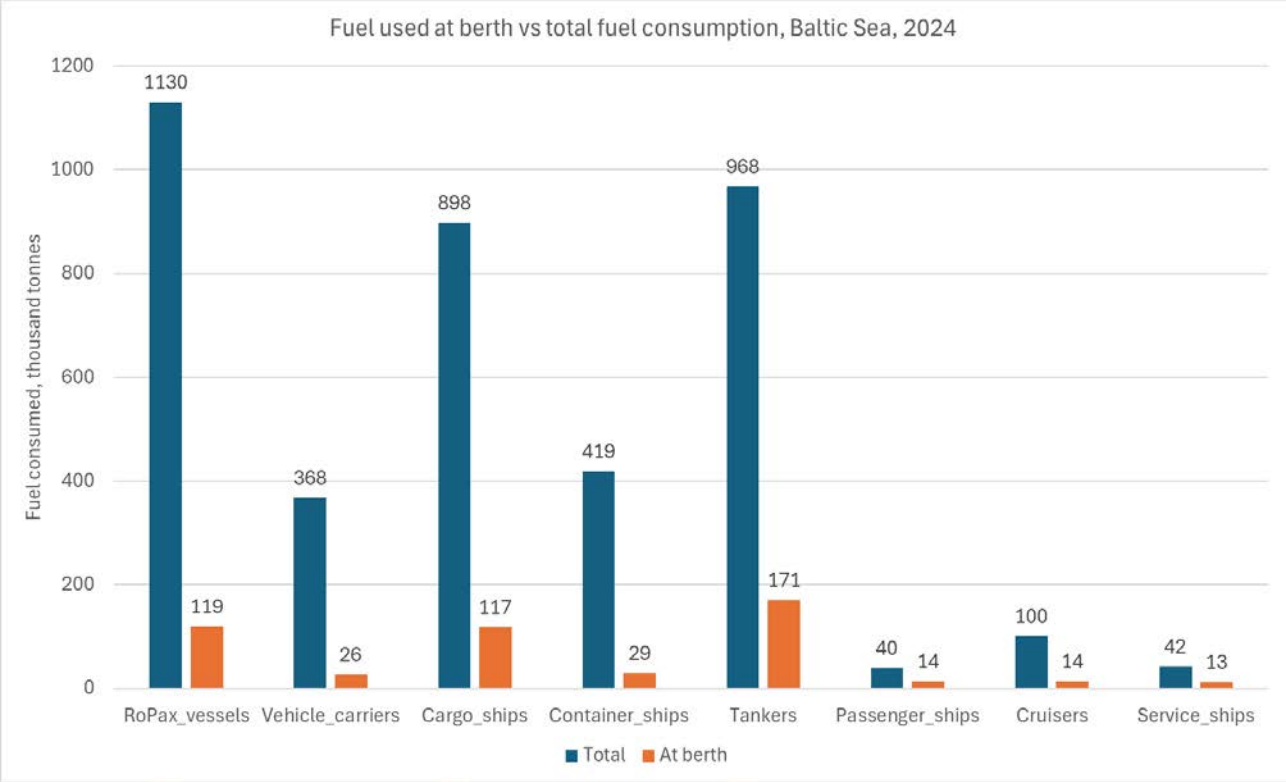

Figure 8 The share of fuel used in harbour areas by vessel type, Baltic Sea fleet, year 2023

2. Country specific CO_2 budgets of international shipping and the role of domestic traffic

The updates made to STEAM enable voyage specific tracking of ships. This facilitates comparisons of STEAM model predictions to EU MRV fuel reports in 1:1 manner, which was not previously possible. Now it is feasible to analyse how different ports connect to each other, but also to identify the role of different ships play in the global shipping network. For example, the port of Helsinki (FIHEL) connects to 43 different ports in the Baltic Sea countries, except Russia, with 96 different ships. Similar analysis of traffic networks can be made for any port or ship globally, identifying the fuel used and emissions released to the atmosphere.

The country specific inbound/outbound emissions of CO_2 from ships were calculated based on global 2024 STEAM runs. For each pair of countries, the emissions from ship traffic could be estimated based on the vessel traffic which happens between ports. Two examples of this data are given in Figures 9 and 10, country specific totals are listed in Table 2. Maps for all Baltic Sea countries and their share of ship emitted CO_2 from inbound and outbound traffic are provided as internet links in Table 2. The outbound CO_2 emission calculation was made considering any ship leaving from one country and traveling to any other country.

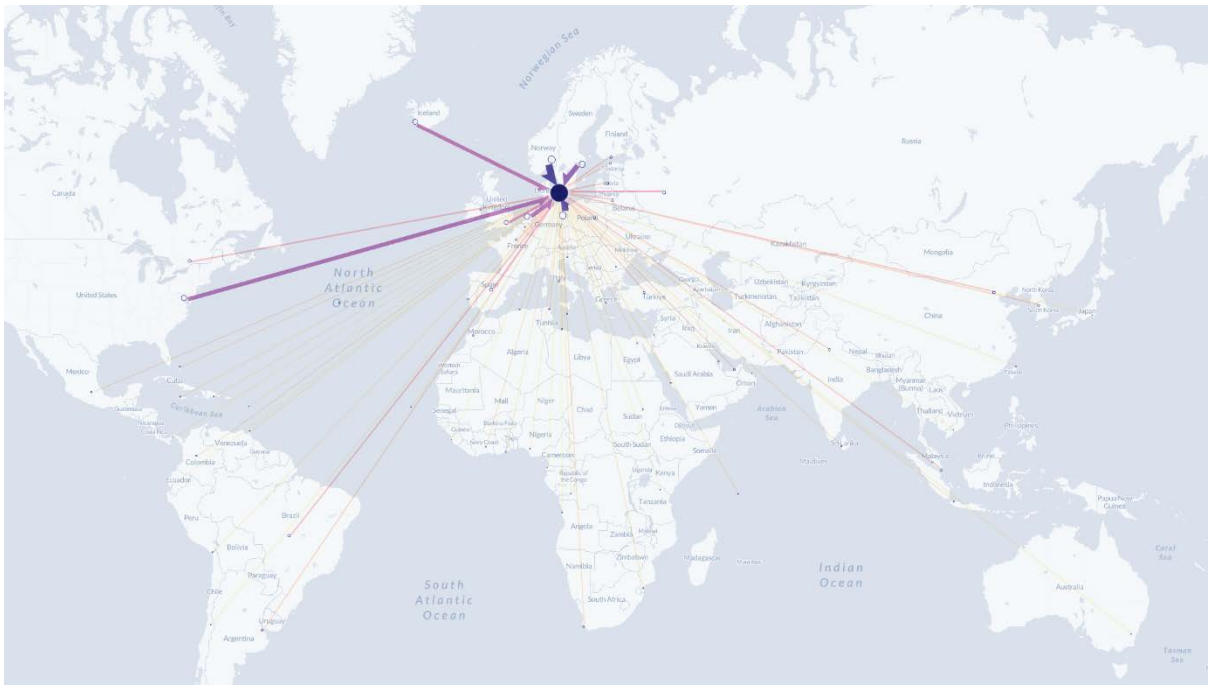

Figure 9 Example of CO_{2eq} emissions of inbound traffic network of Denmark. The width of the arrows and the size of the circles are relative to CO_{2eq} emissions from ships travelling between different countries. For Denmark, the largest emissions from inbound traffic were associated with ships coming from Norway, Sweden and Germany.

Figure 10 CO_2 emissions of outbound shipping for Denmark. The arrow weight indicates the CO_{2eq} emissions. Shipping from Denmark to Norway, Germany and Sweden produced the largest emissions of CO_{2eq} from outbound traffic.

Table 2 Country specific inbound/outbound emissions of CO_{2eq} (thousand tonnes) from global ship traffic in 2024. The table contains internet links for maps for each country. These emission totals were computed for global inbound/outbound shipping in 2024 between any two countries. The "Total" column consists of the sum of 50% "Inbound", 50% "Outbound" and all "Domestic" CO_{2eq} emissions. The last column indicates the share of Domestic CO_{2eq} emissions from national total ship emitted CO_{2eq}. Links in this table lead to visualization of import/export traffic and their emissions. The numbers in parenthesis indicate the change from previous year.

Country	Inbound, 10^3 tonnes	Outbound, 10^3 tonnes	Domestic, 10^3 tonnes	Total, 10^3 tonnes	Domestic, share (%)
Finland	1735 (-4.8%)	1783 (-10.1%)	643 (-12.3%)	2402 (-8.9%)	26.8 %
Russia	11761 (+1.6%)	14329 (-1.3%)	6215 (-4.2%)	19260 (-1.4%)	32.3 %
Estonia	709 (+1.0%)	558 (-9.0%)	92 (-22.5%)	726 (-6.5%)	12.7 %
Latvia	475 (-17.2%)	625 (-3.9%)	29 (-16.0%)	579 (-10.4%)	5.1 %
Lithuania	689 (+3.7%)	711 (-10.2%)	31 (-19.0%)	730 (-4.6%)	4.2 %
Poland	2333 (+11.8%)	2167 (-4.2%)	200 (-24.6%)	2450 (+0.4%)	8.2 %
Germany	7395 (-4.3%)	9235 (-3.5%)	2014 (+2.4%)	10328 (-2.7%)	19.5 %
Denmark	1881 (+1.1%)	1845 (-2.6%)	916 (-22.3%)	2779 (-9.1%)	33.0 %
Sweden	2839 (-4.8%)	2794 (-10.1%)	934 (-12.3%)	3750 (-8.9%)	24.9 %

Calculating the emissions of ships sailing between two different countries includes only the international part of ship traffic. Reporting and summing all the CO_2 from both inbound and outbound traffic leads to double counting of emissions since routes between countries are considered both for import and export traffic. For example, considering the traffic between Finland and Germany; shipping from GE to FI is considered as outbound from GE and inbound to FI. In the opposite case, inbound for Germany is outbound from Finland. For this reason, the total emissions consist of 50% inbound, 50%

outbound and 100% of Domestic CO_2 emissions in Table 2. This avoids double counting and maintains consistency of emission totals.

This analysis can be repeated for all the countries of the world but reported here only for the Baltic Sea countries. These numbers include explicitly the impact of wind, sea currents, the effect of waves and sea ice. It should also be noted that the updated voyage calculation method is now better suited for tracking long voyages with intermediate stops which do not occur in harbor areas. Such example is the traffic from China to Europe, where intermediate stops may occur in areas like the Suez Canal, but cannot be considered as port visits.

3. Effect of weather and sea conditions on fuel consumption and carbon intensity

Model runs have been done separately for each variable (ice, wind, currents, and waves) in order to allocate the impact on the total fuel consumption to the factor causing it. Seasonal effect of sea ice on fuel consumption of the ship fleet is characteristic of the Baltic Sea and thus, the analysis highlights the contribution of sea ice.

3.1. Materials and methods

The additional power need caused by sea ice is calculated using the method described in Juva and Riska (Juva and Riska, 2002). The model assumes that ice breakers are the only vessel type sailing independently in level ice. All other ship types are assumed to sail in broken ice on an ice channel. This may underestimate the ice resistance of some 1A Super vessels which can also break ice independently of ice breakers. The global sea ice thickness data was obtained from the CMEMS product the Global Ocean 1/12°Physics Analysis and Forecast(Galloudec et al., 2024) with a resolution of 0.083°×0.083°. Ice fields are updated in 24h intervals. In this study, the edge of the sea ice is defined based on the sea ice thickness; the ship is assumed to travel in ice conditions if the sea ice thickness in the area is more than zero meters.

The impact of sea waves is calculated using two different methods depending on the characteristics of the vessel and the wave conditions. The primary method is a semi-empirical SNNM method presented by Liu et al. (Liu and Papanikolaou, 2019, 2020). For ships that do not meet the requirements of using the SNNM method, added resistance in short head waves can be estimated following STAWAVE-1 method(Van den Boom et al., 2013). The mean wave height data, the wave mean direction data, and mean wave period data are obtained from the CDS ERA5 reanalysis dataset(Hersbach et al., 2023) (Hersbach et al., 2023) with a spatial resolution of 0.5°x0.5°. The additional resistance or assistance due to wind is computed following a method proposed by Blendermann (1993, 1996). Wind vector component data is obtained from the CDS ERA5 reanalysis dataset(Hersbach et al., 2023) with spatial resolution of 0.25°x0.25°. The effect of sea currents has been estimated with vector operations calculating the vessel's speed relative to the water. The sea current velocity data used are from EU CMEMS product the Global Ocean Physics Analysis and Forecast(Galloudec et al., 2024) with a resolution of 0.083°×0.083°. All variables are updated in the simulations with a six-hour interval. More details of the method can be found in Majamäki et al. (2025).

3.2. Total fuel consumption

Total annual fuel consumption and the impact of different external factors were calculated for the entire fleet, including also ships with gross tonnage less than 5000, that have operated in the Baltic Sea in 2024. The increase in total fuel consumption caused by including the sea ice, wind, sea waves, or sea currents was +5.9%. Wind resistance increased annual fuel consumption by 2.5%, sea waves by 2.3%, sea ice by 1.1%. The total effect of sea currents was lower than 0.1%. It should be noted that

the contribution of sea ice is relevant only for some sea areas, whereas wind, waves and sea currents are relevant for every sea region.

3.3. Effect of sea ice

An analysis of the effect of sea ice on the efficiency and fuel consumption of shipping in the Baltic Sea in 2024 was performed. Only ships in size class of 5000 gross tonnage and above have been included in this analysis. During 2024, 2126 ships with 5000 gross tonnage and above were sailing in ice conditions in the Baltic Sea area. These ships have been estimated to travel 1.5 million nautical miles in ice conditions which corresponds to 4.1% of the total travel distance of ships with 5000 gross tonnage and above.

3.3.1. Effect of sea ice on carbon intensity

The impact of sea ice on the annual carbon intensity of ships, which had sailed in ice conditions in 2024, was analyzed by modelling the CO_2 emissions from shipping with the STEAM model and comparing the carbon intensity of shipping in open water with the carbon intensity including the operation in ice conditions. This comparison was performed only for ships with 5000 gross tonnage or more that had sailed at least 10 kilometers both in ice conditions and open water. The minimum sailing distance of 10 km is set to reduce the impact of ships that have mainly been at berth or anchoring. Number of ships included in the analysis of carbon intensity is given in Table 3. Additionally, the share of the annual travel distance travelled in ice conditions by the ships included in the analysis are shown.

Table 3 Number of ships included in the analysis of Carbon intensity indicator (CII) and the share (%) of the total distance travelled in ice conditions by the ships included in the analysis.

	Number of ships	Distance share travelled in ice (%)
Ro-Ro passenger ships	81	3.07
Vehicle carriers	12	1.12
Ro-Ro cargo ships	71	4.45
Bulk carriers	545	3.20
General cargo ships	346	6.24
Container ships	171	2.39
Refrigerated cargo carriers	60	3.98
Tankers	731	3.91
LNG carriers	21	2.28
Gas tankers	20	3.14
Passenger ships*	5	7.80
Cruise passenger ships	11	1.00

** Low number (<10) of ships in this type category will affect the reliability of the results*

Carbon intensity indicator is calculated as defined in International Maritime Organization (IMO) resolution MEPC.336(.76) i.e., the correction coefficients and voyage exclusions given in resolution MEPC.355(78), 2022 Interim guidelines on correction factors and voyage adjustments for CII calculations (CII guidelines, G5), were not included in the calculation of carbon intensity indicators in this study.

$$CII_{ship} = \frac{M_{CO2}}{W} \quad (1)$$

where:

M_{CO2} = total mass of CO_2 (g),

W = transport work (ton nm).

The transport work is calculated as a product of ship's capacity (in tons) and the distance sailed (in nautical miles). For bulk carriers, LNG carriers, gas tankers, tankers, container ships, general cargo ships, ro-ro cargo ships and refrigerated cargo carriers, the deadweight tonnage is used to represent the capacity, and for passenger vessels, cruise passenger ships, vehicle carriers and ro-ro passenger ships, gross tonnage is used to represent the capacity.

The CII values have been calculated for each ship by with Eq. (1) including all the ship's activity in the calculation, leaving out the sailed distance and the fuel consumed when the ship has been operating in ice conditions. Results are shown in Table 4. For all ship types, including the operation in ice conditions in the calculation increases the annual median of Carbon intensity indicator (CII) by an average of 1.8% for ships with 5000 gross tonnage and above. The largest average increase takes place for bulk carriers with a difference of 3.5% between the CII values with and without sailing in ice conditions included in the calculation of the indicator. For some ship types, the CII value decreases when operation in ice conditions is included in the calculation. Removing the operation in ice conditions from the CII calculation will also reduce the transport work and thus, it is possible that the CII value increases. This is likely to happen for ships that have high hoteling emissions as removing a part of the operation at sea will emphasize the emissions at berth.

Table 4 The median value of annual Carbon intensity indicator CII (g-CO2 ton^{-1} nm^{-1}) for each ship type calculated by including both the operation in ice conditions and in open water, including only operation in ice and including only operation in open water. The final column shows the change in the median of CII when the operation in ice is included in the calculation.

	All operation	Operation only in ice	Operation only in open water	Change (%) due to operation in ice
Ro-Ro passenger ships	19.13	18.60	19.07	+0.29
Vehicle carriers	10.78	11.65	10.76	+0.19
Ro-Ro cargo ships	30.80	31.07	30.86	-0.19
Bulk carriers	5.33	6.11	5.15	+3.45
General cargo ships	13.79	14.62	13.65	+1.01
Container ships	12.95	14.80	12.59	+2.91
Refrigerated cargo carriers	25.65	21.73	25.43	+0.87
Tankers	6.43	7.15	6.36	+1.20
LNG carriers	17.24	16.49	16.78	+2.71
Gas tankers	11.66	13.09	11.65	+0.12
Passenger ships*	58.03	45.18	62.76	-7.54
Cruise passenger ships	16.45	15.97	16.46	-0.04
MEAN	10.16	10.76	10.03	+1.78

** Low number (<10) of ships in this type category will affect the reliability of the results*

Figure 11 shows increase in CII values of individual ships as a function of the percentage of the annual distance the ship has travelled in ice conditions. For a few ships, the CII value decreases when

operation in ice conditions is included in the calculation. This is caused by high hoteling emissions that increase the CII value calculated for only open water operation and thus, including the operation in ice conditions decreases the overall CII value of the ship. Sea ice only affects the required propulsion power and therefore, has no impact on the fuel consumption and emissions of the ship while berthing or anchoring.

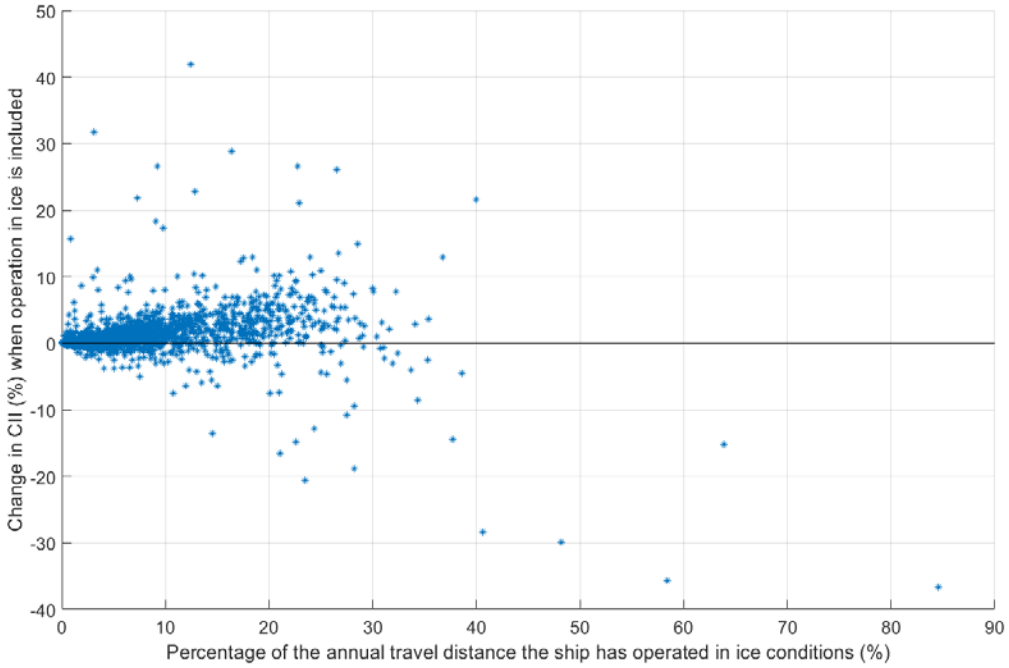

Figure 11 Increase in CII due to sea ice as a function of the percentage of the annual travel distance the ship has operated in ice conditions in the Baltic Sea in 2024. Only commercial ships with 5000 gross tonnage or above that have operated in ice conditions are included.

3.3.2. Effect of sea ice on fuel consumption

The impact of sea ice on the total annual fuel consumption of all ships that have sailed in the Baltic Sea area was also analyzed. Model runs were done separately with and without the effect of sea ice to estimate the increase in annual fuel consumption caused by ice conditions in the Baltic Sea in 2024. All ships with 5,000 gross tonnage and above were included in the analysis, regardless of if they had operated only in open water.

The total annual fuel consumption in the Baltic Sea without and with the effect of sea ice, and the increase in the total fuel consumption in percentages of the total fuel consumed annually due to ice conditions, are shown in Table 5. On average, sea ice increases the total fuel consumption of ships sailing in the Baltic Sea area by +0.8% in 2024. Regarding the different ship types, the largest average annual effect can be seen for general cargo ships of which fuel consumption has increased on average by +1.7% due to sailing in ice conditions. The lowest annual increase is observed for vehicle carriers and cruise passenger ships.

Table 5 Total fuel consumption of ships with 5000 gross tonnage or above without and including the impact of sea ice, as well as the increase in the total fuel consumption cause by sea ice in the Baltic Sea in 2024.

	Without sea ice (tons of fuel)	Including sea ice (tons of fuel)	Increase caused by sea ice (%)
Ro-Ro passenger ships	1390876	1396122	+0.38
Vehicle carriers	26452	26500	+0.18
Ro-Ro cargo ships	424656	427379	+0.64
Bulk carriers	431122	436578	+1.27
General cargo ships	227152	231057	+1.72
Container ships	473466	476072	+0.55
Refrigerated cargo carriers	46543	46943	+0.86
Tankers	959713	970374	+1.11
LNG carriers	25848	25958	+0.43
Gas tankers	80071	80343	+0.34
Passenger ships	7458	7514	+0.76
Cruise passenger ships	123543	123678	+0.11
TOTAL	4216899	4248519	+0.75

Figure 12 shows the increase in annual fuel consumption of individual ships due to operation in ice as a function of the percentage of the annual travel distance the ship has operated in ice conditions in 2024 in the Baltic Sea. Commercial ships with 5,000 gross tonnage or above that have travelled in ice are included in the analysis. This graph illustrates that although the average increase in fuel consumption is relatively low, for individual vessels that operate often in ice conditions, the annual increase in fuel consumption might be significant.

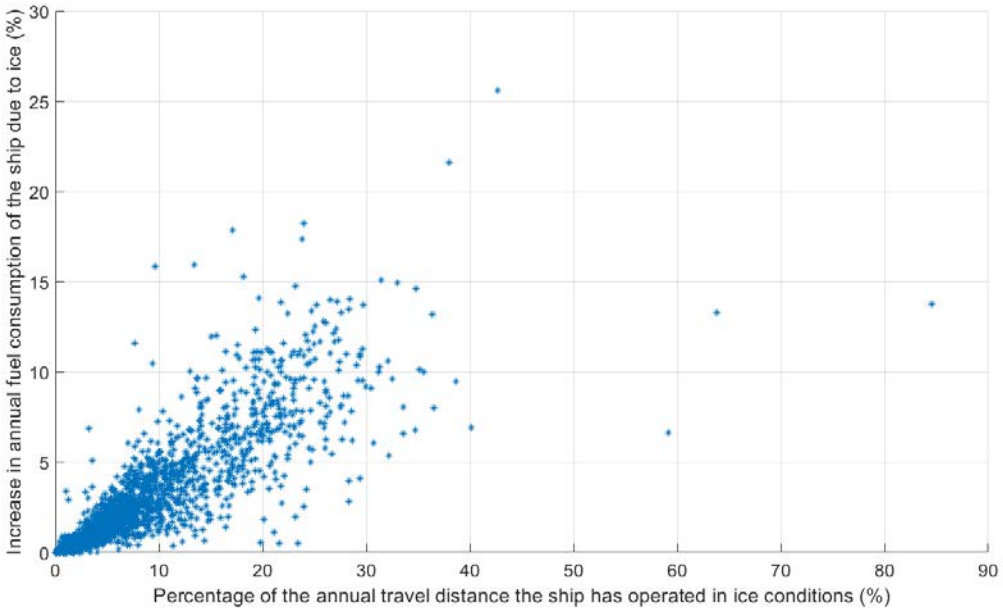

Figure 12 Increase in annual fuel consumption of ships due to sea ice as a function of the percentage of the annual travel distance the ship has operated in ice conditions in the Baltic Sea in 2024. Only commercial ships with 5,000 gross tonnage or above that have operated in ice conditions are included.

Figure 13 below shows the total fuel consumption in ice conditions during the year 2024 in the Baltic Sea. This figure includes all ship types and size classes that have sailed in the Baltic Sea. This figure depicts the maximum ice extent during the target year 2024.

Figure 13 Total annual fuel consumption (kg) in ice conditions in the Baltic Sea in 2024

4. Accuracy of emission modelling and the comparison of predicted (STEAM) to reported fuel consumption (MRV)

The new version (v5.1) of the Ship Traffic Emission Assessment Model (STEAM) was used in this work. The updates from the previous model version include a significant change how the vessel voyages are constructed based on AIS data. Previously only those voyages which included similar sailing distance both in STEAM and MRV data were included, which enabled comparisons of roughly 10% of the ships included in the MRV reporting. Reason for this was that the earlier model version included by default all ship activity withing a defined geographical area, but it did not consider voyage endpoints like MRV reporting requirements do. In the new STEAM v5.1 this has been changed, and the modeled values are fully compliant to MRV reporting requirements, which enable 1:1 comparison of modeled and reported fuel consumption and GHG emissions. The new comparison includes the added uncertainty resulting from incomplete AIS coverage of vessel activity, which was previously largely ignored to facilitate comparison to MRV. Since previous STEAM version only compared ships with matching distances in STEAM and MRV data, the influence of this source of uncertainty was not fully included in the comparisons. In STEAM v5.1 this uncertainty source is now included in all the following comparisons unless specifically mentioned otherwise.

An accuracy comparison was made between the STEAM predictions for 2024 considering all weather parameters and the EU MRV database for the corresponding year. Version 23 (dated 24th July 2025) of the MRV data was obtained from EMSA. The dataset contains information for 12,471 unique vessels with specific IMO numbers. The STEAM dataset for 2024 contains data of 273,494 AIS broadcasting vessels of which 81,860 had unique IMO numbers. Vessels with multiple MMSI numbers were left out from the comparison.

Annual distance sailed was calculated for the MRV dataset by dividing the total annual fuel consumed (reported in metric tonnes but converted into kilograms for the calculation) with the annual mean fuel consumption reported in kilograms per nautical mile.

4.1. Total annual fuel and CO_2

The total annual fuel consumed of the 12,471 vessels was 46.1 million tonnes in MRV and 47.4 million tonnes in STEAM – a difference of +2.9%. The total annual CO_2 emitted by the same 12,471vessels was 142.6 million tonnes in MRV and 149.3 million tonnes in STEAM – a difference of +4.6%. Total annual fuel consumed, and CO_2 emitted by vessel type are in Table 6.

STEAM seems to overpredict fuel consumption for some cargo-carrying vessel types. For most of the shiptypes, the error is within ten percent of the fleet total for each type, but gas carriers, containerships and bulk cargo ships the fleet total is overestimated by more than ten percent. Bulk cargo ships have the largest uncertainty, overestimation of +18.8% for CO_2 emissions.

Table 6 Vessels by type, their number, total annual fuel consumed, and CO_2 emitted according to MRV and STEAM. The difference between reported and modelled totals is given in percent. A negative difference indicates that STEAM is underpredicting and a positive that STEAM is overpredicting.

Vessels	MRV	STEAM	Differences (%)

Type	Number	Fuel (10^3 tonnes)	CO_2 (10^3 tonnes)	Fuel (10^3 tonnes)	CO_2 (10^3 tonnes)	Fuel	CO_2
Bulk carrier	3 645	4 371	13 703	5 121	16 275	17.2 %	18.8 %
Chemical tanker	1 335	2 552	7 993	2 614	8 266	2.4 %	3.4 %
Container ship	2 060	16 597	51 582	18 178	57 495	9.5 %	11.5 %
Container/ro-ro cargo ship	65	386	1 206	385	1 224	-0.2 %	1.5 %
Gas carrier	329	782	2 400	848	2 664	8.5 %	11.0 %
General cargo ship	1 170	1 583	4 978	1 607	5 093	1.5 %	2.3 %
LNG carrier	323	2 713	7 496	2 497	7 199	-8.0 %	-4.0 %
Oil tanker	1 789	5 424	16 953	5 857	18 486	8.0 %	9.0 %
Other ship types	345	708	2 222	690	2 190	-2.4 %	-1.4 %
Passenger ship	195	2 179	6 759	2 053	6 413	-5.8 %	-5.1 %
Refrigerated cargo carrier	110	216	677	233	740	7.7 %	9.2 %
Ro-pax ship	408	4 227	13 158	4 385	13 794	3.7 %	4.8 %
Ro-ro ship	214	1 569	4 879	1 513	4 791	-3.5 %	-1.8 %
Vehicle carrier	458	1 389	4 285	1 317	4 134	-5.2 %	-3.5 %
All vessels	**12 470**	**46 076**	**142 605**	**47 415**	**149 138**	**2.9 %**	**4.6 %**

A similar comparison for CH_4 and N_2O emissions is given in Table 7. The methane emissions are overpredicted by one third, but N_2O emissions are well in line with those reported to the MRV system. STEAM identified 536 LNG-fuelled vessels, whereas MRV included 583, but it is challenging to determine whether dual-fuel vessels run on LNG or diesel fuel. Regardless, STEAM misses about eight percent of the LNG fleet, but overpredicts the methane slip. This is probably because the modeled slip percentage is slightly higher than what is used in MRV as default slip percentage.

Table 7 Vessels by type, their number, CH_4 and N_2O emitted according to MRV and STEAM.

Type		CH_4, MRV (tonnes)	CH_4, STEAM (tonnes)	N_2O, MRV (tonnes)	N_2O, STEAM (tonnes)
Bulk carrier	3 645	230	1	821	855
Chemical tanker	1 335	3 459	1 616	471	442
Container ship	2 060	2 228	7 050	3 032	3 044
Container/ro-ro cargo ship	65	20	-	72	65
Gas carrier	329	1 735	1 866	134	146
General cargo ship	1 170	387	412	292	265
LNG carrier	323	35 779	45 012	332	472
Oil tanker	1 789	1 789	3 737	999	998
Other ship types	345	164	87	131	114
Passenger ship	195	6 640	9 887	382	348
Refrigerated cargo carrier	110	11	-	40	39
Ro-pax ship	408	7 319	10 916	764	739
Ro-ro ship	214	456	402	300	254
All vessels	**12 470**	**61 358**	**81 850 (+33%)**	**8 035**	**8 029 (-0.1%)**

Using the distance matching requirement as it was defined in the previous STEAM version (v4.3), comparing only ships within ±15% travel distance in STEAM and MRV, the error of total modeled fuel consumption and CO_2 emissions is less than one percent for fuel and about 2.9% for CO_2. This indicates that the largest sources of uncertainty come from the gaps in the global ship activity data, the path interpolation applied and a bias associated to larger ship types.

4.2. Correlation between STEAM and MRV

In Figure 14, the 12,470 ships are plotted for total annual fuel consumed in metric tonnes and in Figure 15 for total annual CO_2 emitted. Different vessel types as characterised in the MRV database are

plotted with corresponding colours. The correlation between STEAM and MRV fuel data is 0.924 and 0.926 for CO_2.

If the sailing distances (Figure 16) of the 12,470 vessels are compared, the correlation is 0.941. It should be noted that previous STEAM version (v4.3) only allowed comparison of those vessels which had similar (±15%) reported voyage distance, whereas the new version (v5.1) uses all MRV data.

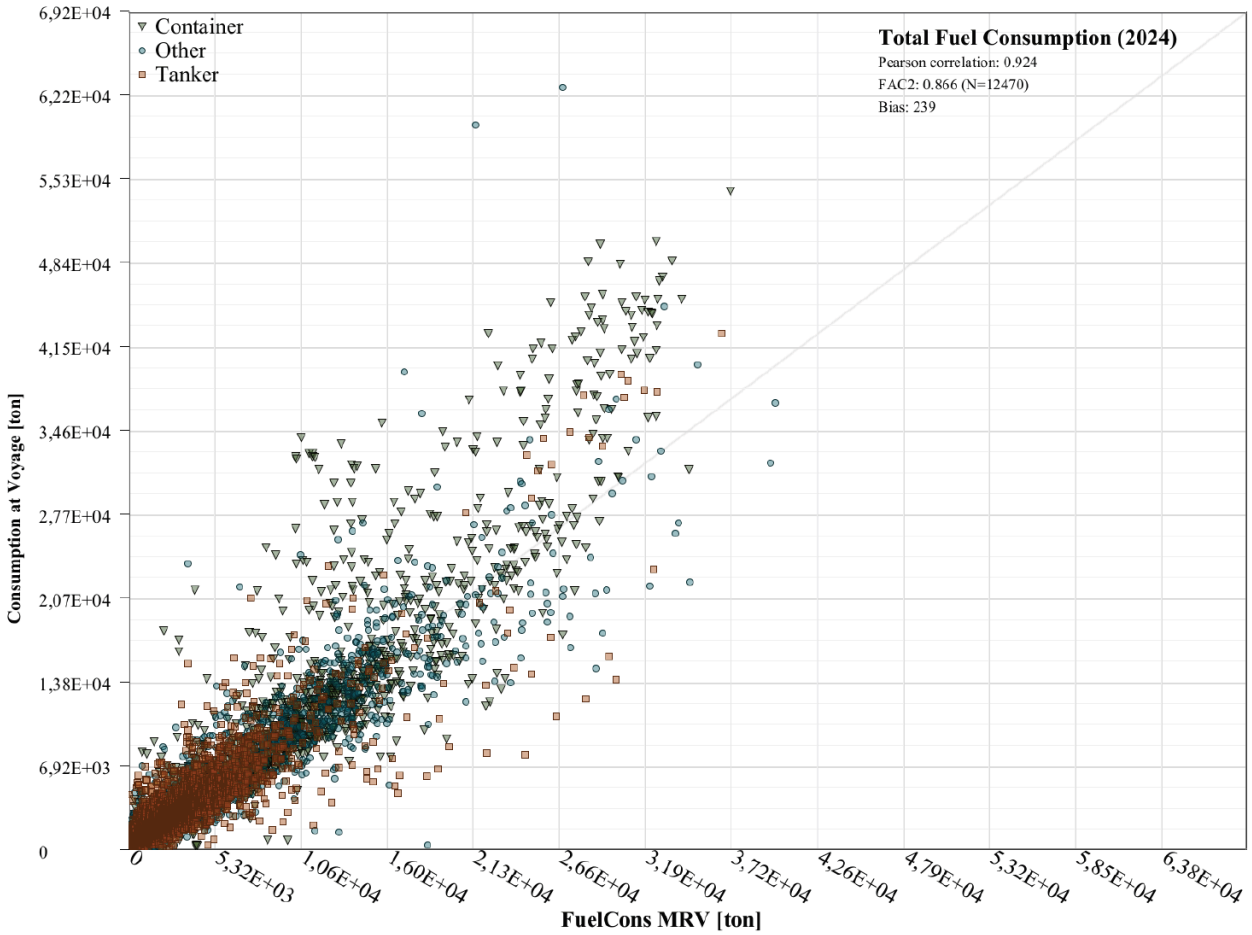

Figure 14 Scatterplot of total annual fuel consumed between STEAM (y-axis) and MRV (x-axis) with different vessel types coloured. The plot includes data for all the 12,470 vessels of the MRV dataset.

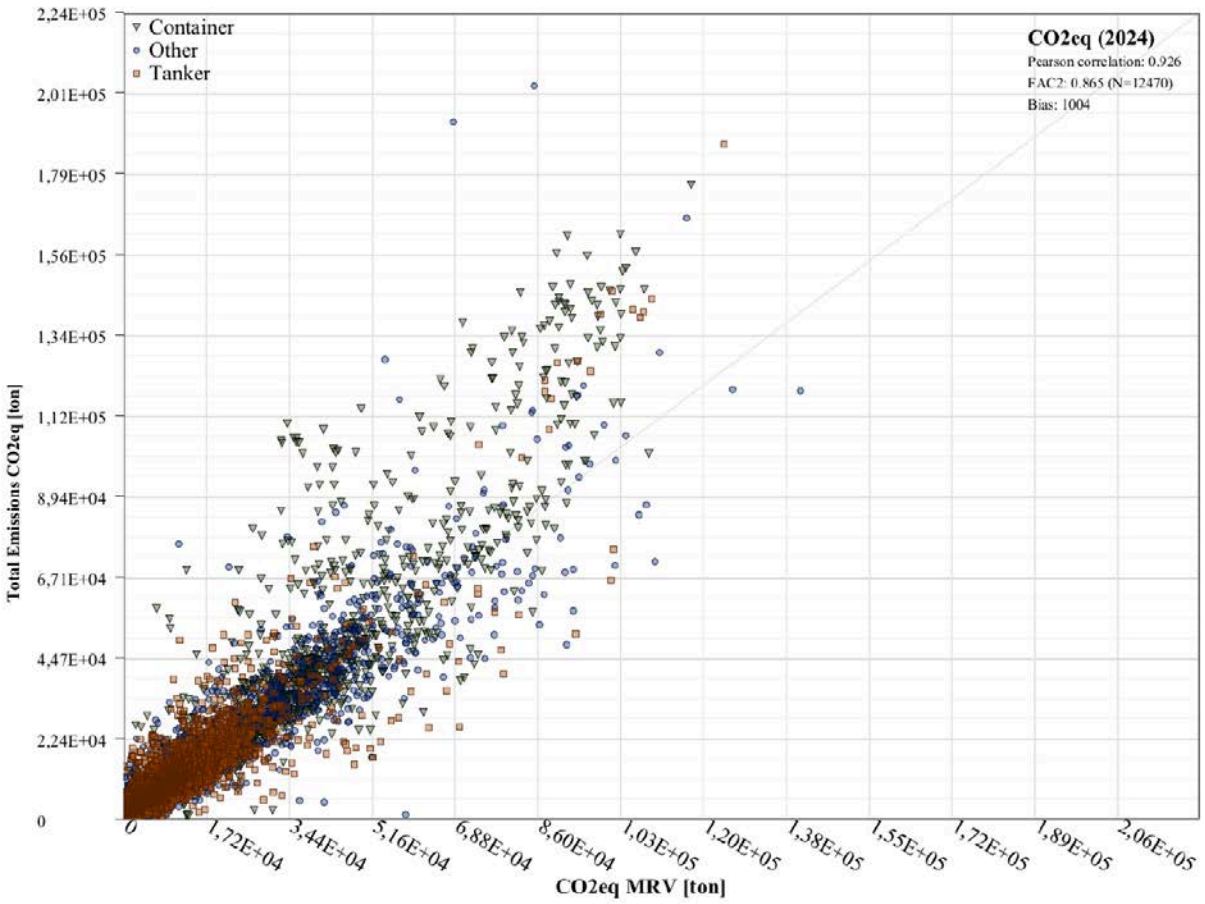

Figure 15 Scatterplot of total annual CO_{2eq} emitted between STEAM (y-axis) and MRV (x-axis) with different vessel types coloured. The plot consists of the 12,470 vessels included in the MRV dataset.

Some differences in the travel distances can be observed, which can be attributed to imperfect activity description of AIS data or deficiencies in MRV reporting. STEAM interpolates vessel location between two known positions, considering the land masses, but assumes the shortest realistic path to be followed.

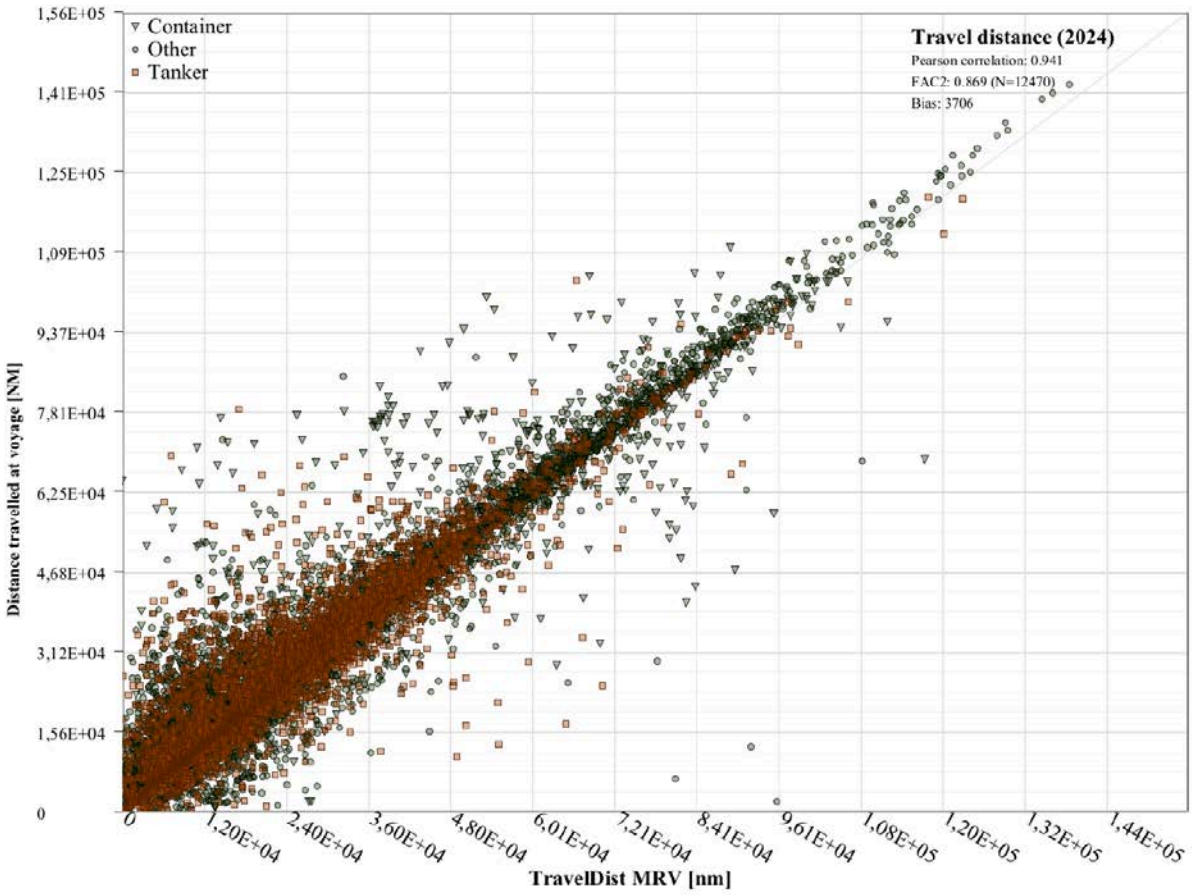

Figure 16 Scatter plot of total voyage distance computed with STEAM, based on AIS position reports, and those reported to MRV by ships.

About half of the vessels reporting to MRV system report sailing distances which are within ±15% of those computed from AIS position reports (Figure 17).

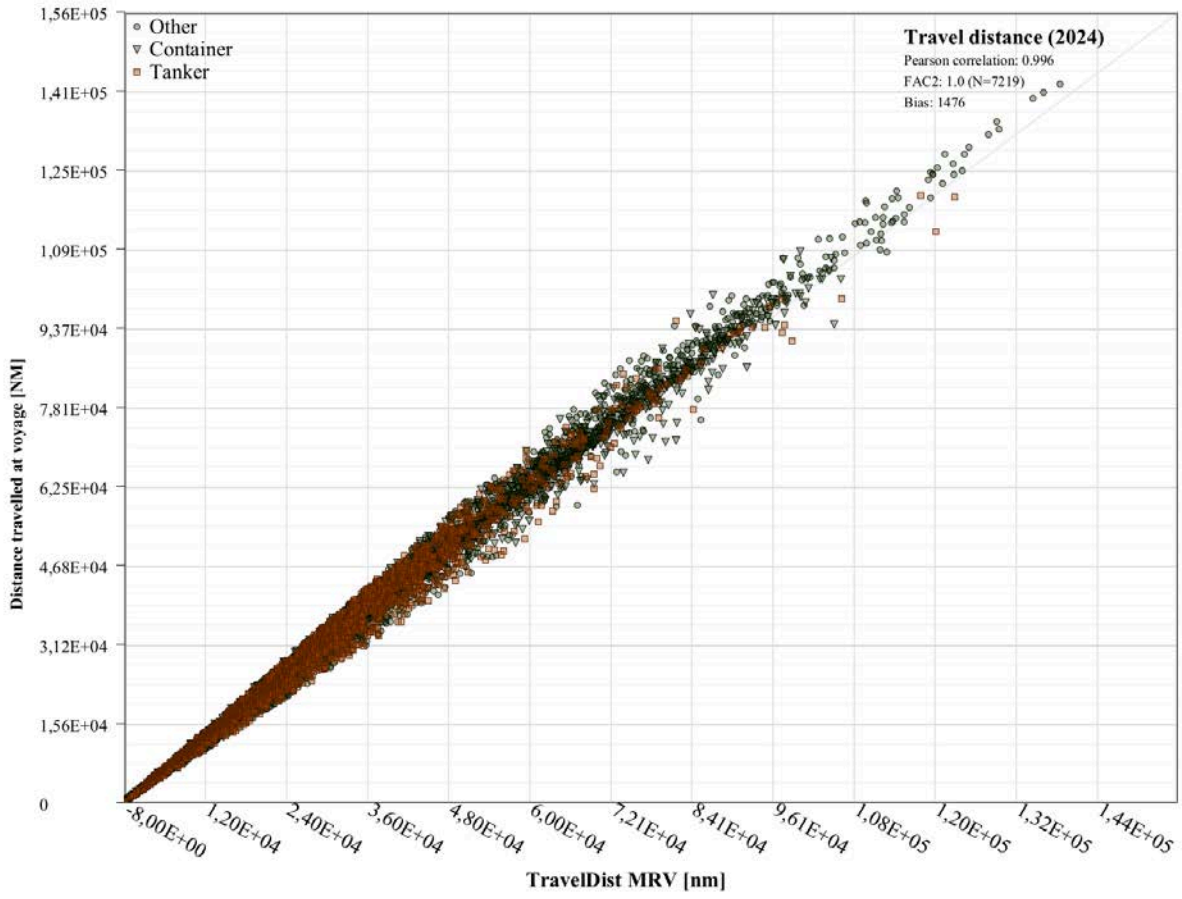

Figure 17 Scatter plot of voyage distances reported to MRV and those computed from AIS position reports by STEAM. There are 12,470 ships reporting to MRV, whereas for 7,219 of those the computed travel distance is within ±15% computed by STEAM. In cases of good AIS coverage, the positive correlation between the two is near perfect.

Comparing vessels depicted in Figure 17 yields information on other sources of uncertainty than those associated with path interpolation. These include potential problems with propulsion power prediction, needs of auxiliary power, ambient contributions and emission factors.

4.3. Differences between ship types, voyages and flag states

Some differences can be observed between different vessel types. Scatterplots for each vessel type are presented in Figure 18 (distance traveled) and Figure 19 (CO_{2eq} emissions). The goodness of fit of linear regression varies and is heavily driven by outliers. Some outliers could be reporting errors in the MRV data even though it is verified by a third party. Others are missing specific data from the vessel database that STEAM uses for modelling.

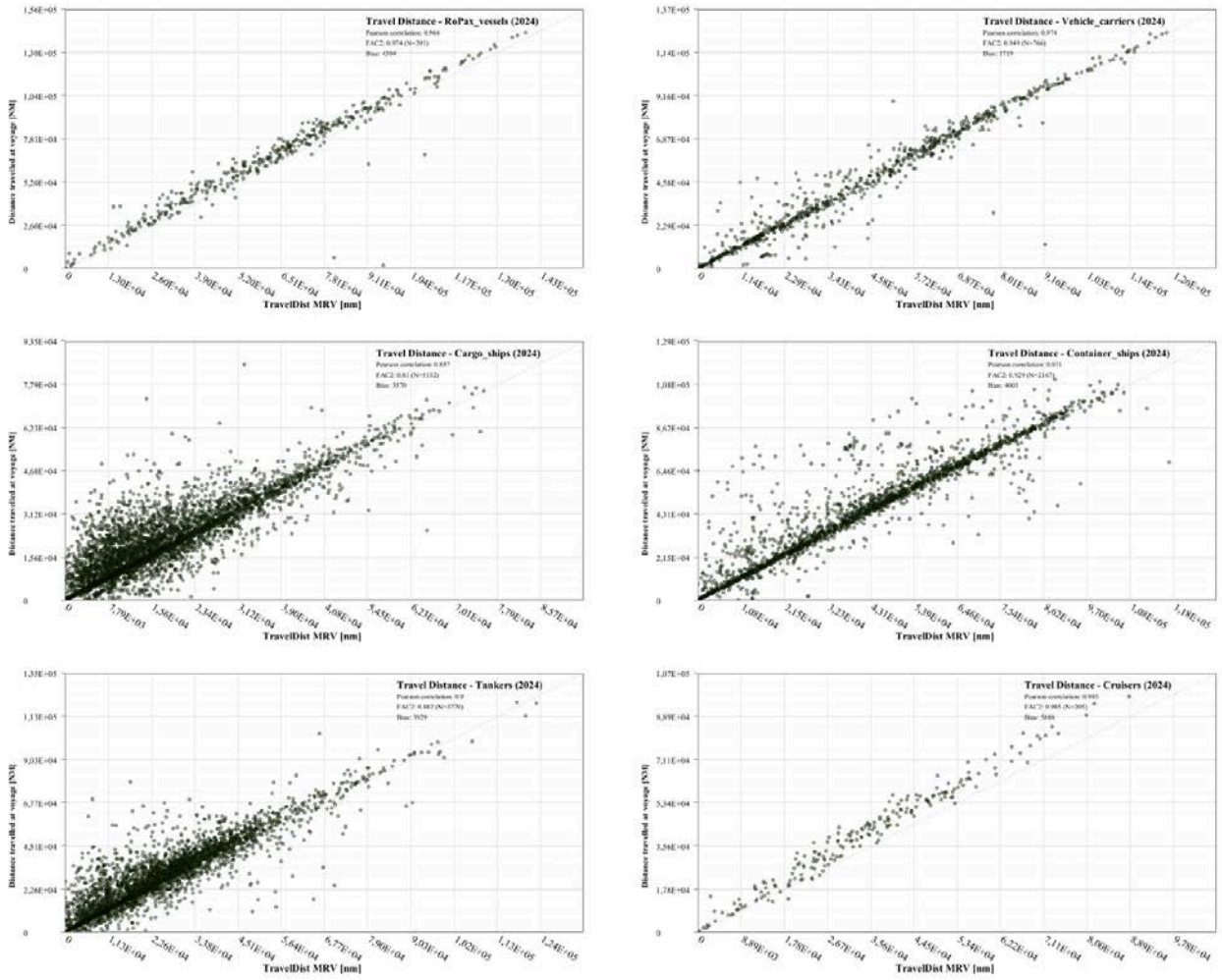

Figure 18 Comparison of 2024 travel distances reported to MRV and those computed from position reports send by ships during STEAM model run. Top left = Ropax, Tor right = Vehicle carriers, Middle row left = Cargo ships, Middle row right = Containerships, Bottom left = Tankers, Bottom right = Passenger Cruise ships.

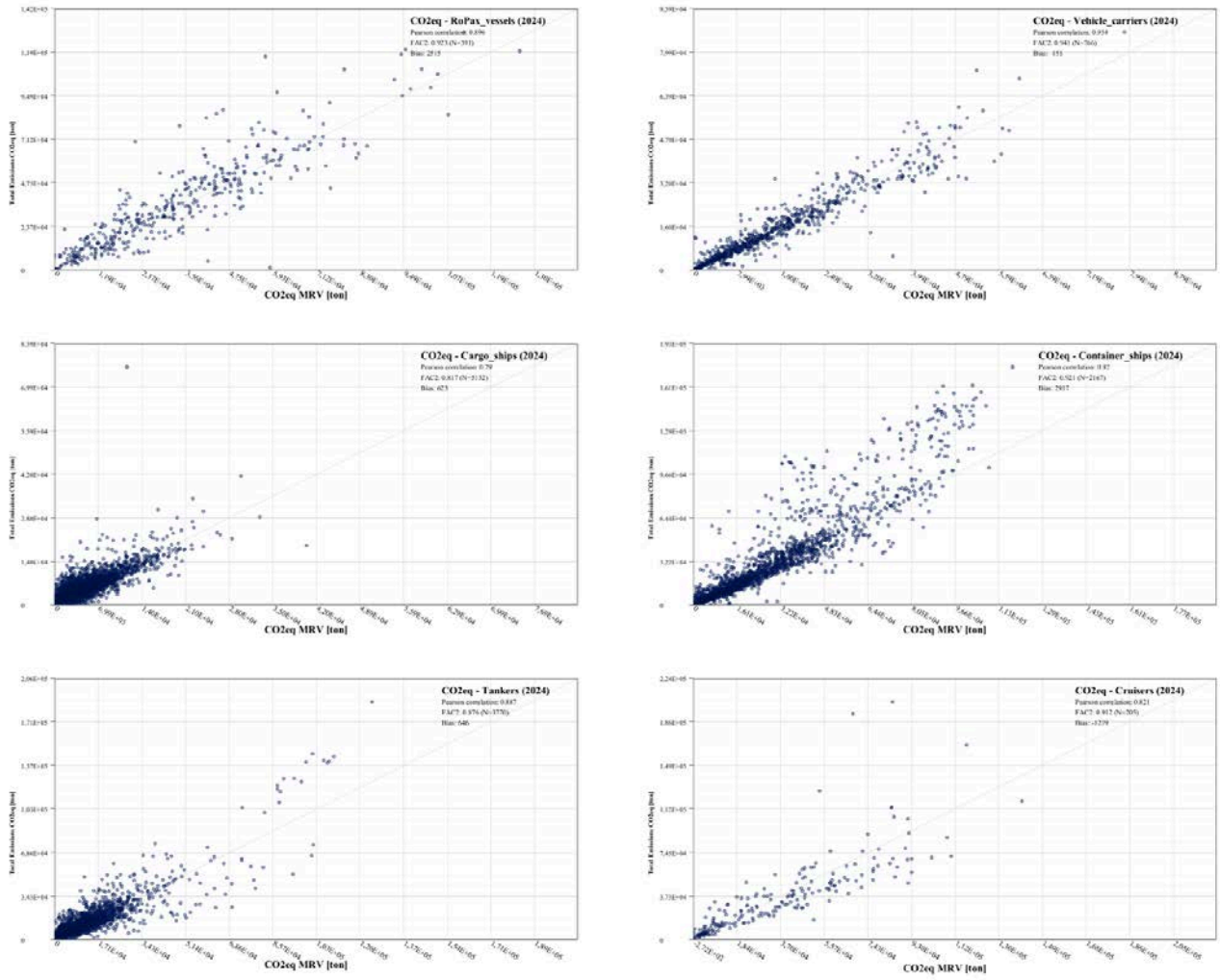

Figure 19 Scatter plots for 2024 CO2eq emissions of various types of ships as reported to EU MRV system and those modeled with STEAM. Top left = Ropax, Tor right = Vehicle carriers, Middle row left = Cargo ships, Middle row right = Containerships, Bottom left = Tankers, Bottom right = Passenger Cruise ships.

Comparisons of fuel consumption and emission totals between STEAM and EU MRV reporting reveal a good match of these quantities. Outliers exist for all ship types, but systematic bases are mainly seen with very large ships (Figure 20) for which STEAM slightly overpredicts both the fuel consumption and CO_{2eq} emissions. It is also noteworthy that these ships are mainly cargo carrying types (Figure 21), and STEAM does not include variable vessel draught in the modeling. This should be investigated in the future whether it could be used to reduce the uncertainty, especially seen with the largest size category.

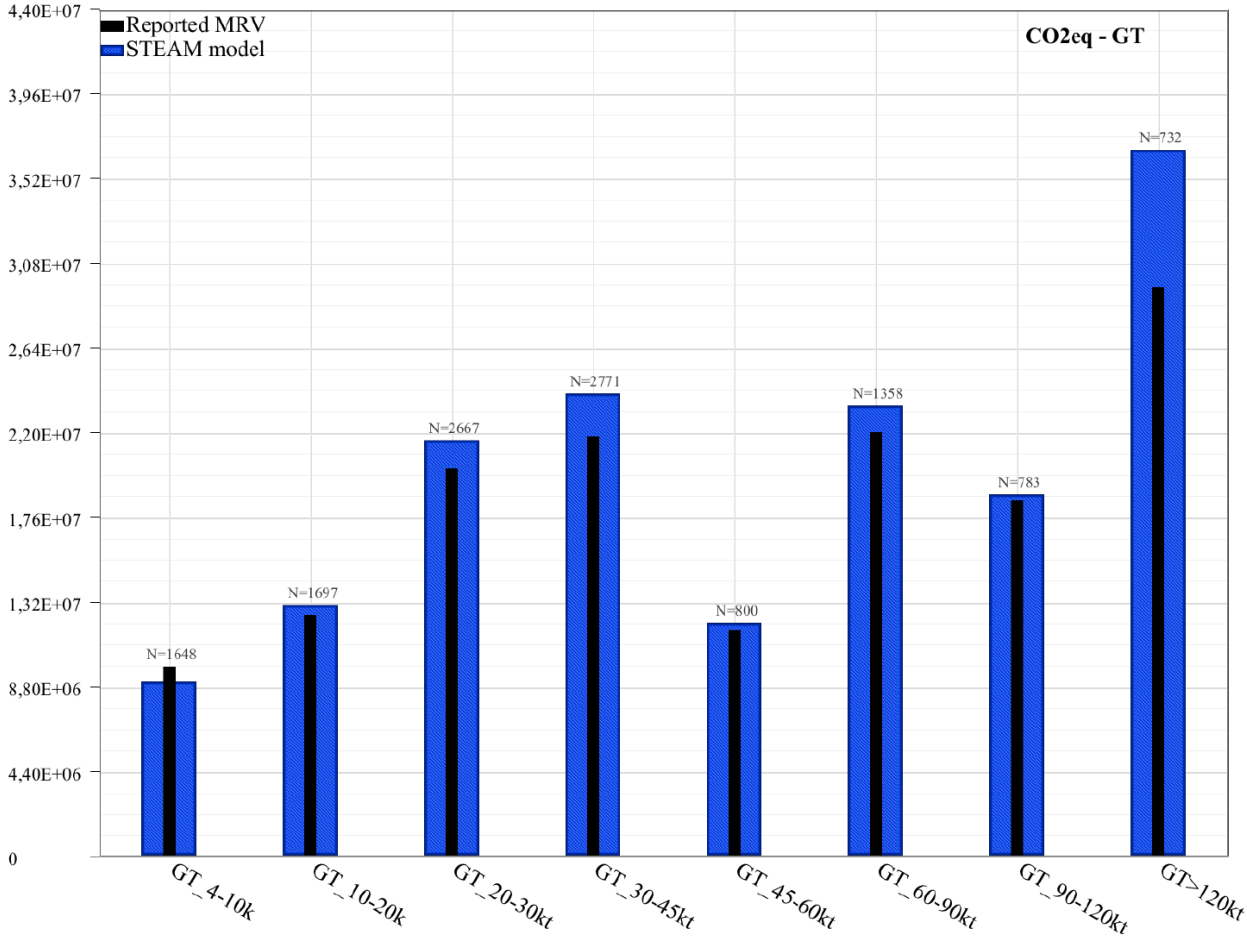

Figure 20 CO_{2eq} emission comparison between STEAM and EU MRV reporting for 2024. Wide blue bars = STEAM, thin black bars = MRV reporting.

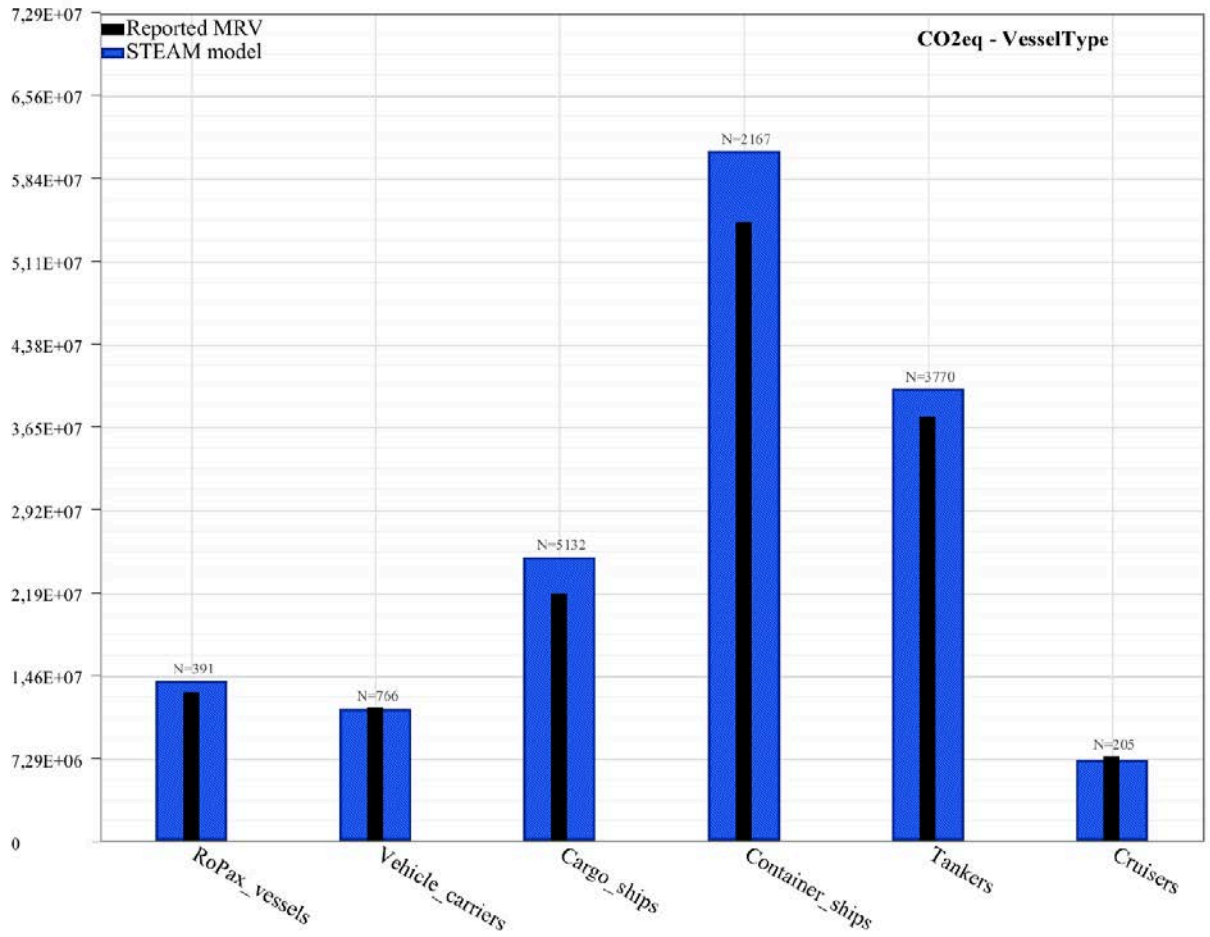

Figure 21 Reported and modeled CO_{2eq} emissions of various types of ships in 2024. Wide blue bar = STEAM modeled total CO_{2eq} emissions, thin black bar = CO_{2eq} emissions reported to EU MRV system.

The uncertainty involved in the largest ship size group is also reflected in the accuracy of predicted CO_{2eq} emissions for various flag states. Those flag states which have lot of ships in the largest size class also have the largest uncertainties in predicted vs reported emissions.

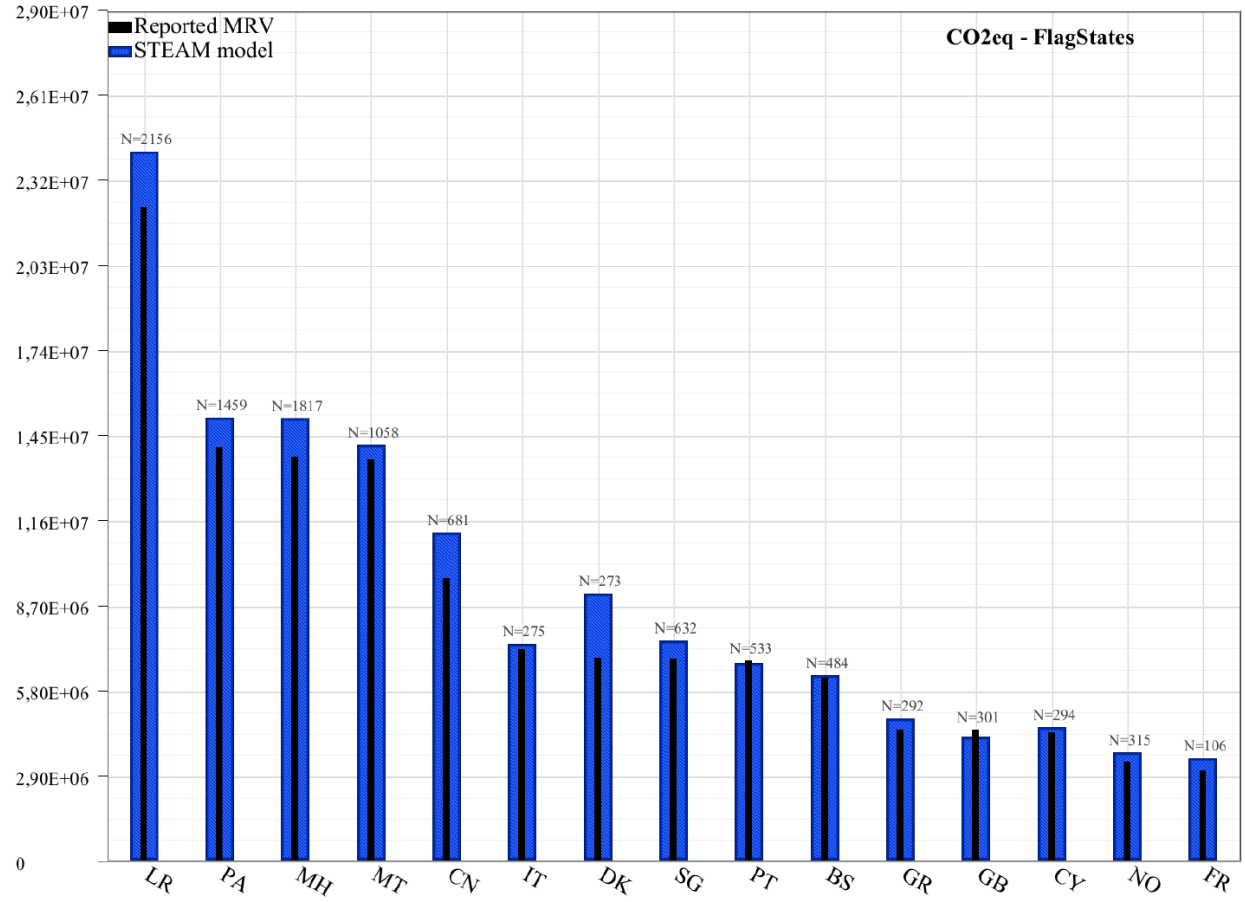

Figure 22 Accuracy of modeled and reported CO_{2eq} emissions by flag state. Largest uncertainties are with flag states with very large ships (Liberia, Panama, Marshall Islands, China, Denmark).

5. Summary

The comparisons reveal that a good match can be obtained when fleet fuel consumption and CO_2 emissions are compared between STEAM and MRV. The Ship Traffic Emission Assessment Model (STEAM) used in this work provides fleet total fuel consumption which is within +2.9% of the MRV reports.

Both positive and negative uncertainties exist. Large part of the uncertainty is driven by outliers, which reflect missing data concerning e.g. battery hybrid vessels and various retrofitted equipment. Discrepancies are usually connected to incomplete technical description of vessels, mistakes in auxiliary engine power prediction, but the data gaps concerning the position updates from Automatic Identification System (AIS) remains a significant source of uncertainty. This could be seen by looking at the predicted fuel consumption and CO_{2eq} emissions of those ships which had distance matching both in modeled and reported data.

In several cases, outliers exist both on the STEAM predictions and MRV fuel reports.

Data

The emission estimates for the Baltic Sea area during the year 2024 are based on over 502 million AIS-messages sent by almost 27,000 different ships, of which 9,675 had an IMO registry number indicating commercial marine traffic. The AIS position reports were received by terrestrial base stations in the Baltic Sea countries and collected to regional HELCOM AIS data server. Emissions are generated using the Ship Traffic Emission Assessment Model, STEAM version 5.1 (Jalkanen et al., 2009, 2012, 2018, 2021; Johansson et al., 2013, 2017; Majamäki et al., 2025).

The Baltic Sea AIS data for year 2024 had no temporal gaps, AIS data was available throughout the year, and the temporal coverage was 100%. This is the third time for HELCOM AIS service with a perfect service record. Most of the messages originate from South-Western region of the Baltic Sea near the Danish and southern Swedish sea areas (Figure 23). On average, data flow was lower in 2024 (57,000) than in 2023 (90,000) messages per hour. STEAM applies distance, speed and identity checks during the AIS processing steps which allow consistent voyage construction, but vessels sailing without an active AIS transponder are not covered in this analysis.

The uncertainty evaluation and comparison to EU MRV fuel reporting was made using global AIS data for 2024 from Orbcomm Ltd. This global dataset includes both terrestrial and satellite AIS position reports and includes over 3.11 billion (10^9) position reports. STEAM also uses the technical details of the global fleet based on S&P Global database.

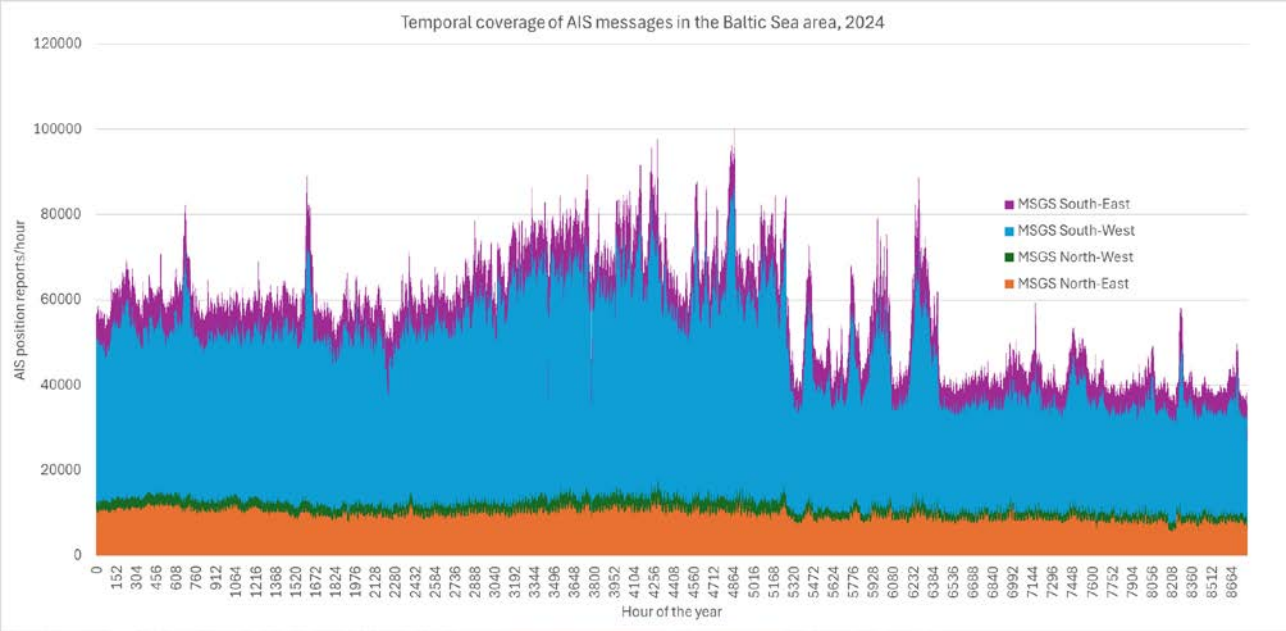

Figure 23 AIS-data hourly coverage in different parts of the Baltic Sea region for 2024.

Metadata

It should be noted that current estimates do not include contributions from vessels without active AIS equipment, which may lead to underestimation of ship activity. Work is in progress to investigate the

significance of this issue using complementary datasets. All calculations were made including the effects of sea currents, winds, waves and ice cover thickness.

The STEAM model used in this work was upgraded from v4.3 to v5.1. The new model version was used to recalculate the whole Baltic Sea ship emissions time series, to provide a consistent view over the last 19 years. Significant technical changes were made to improve the modeling accuracy and compatibility with the EU's Monitoring, Reporting, and Verification (MRV) data.

• The modeling of shipping in the Baltic Sea continued to rely primarily on AIS data from the HELCOM AIS data archive. For a broader global perspective, a combination of satellite-AIS and terrestrial-AIS data from Orbcomm Ltd was also utilized. Integrating global AIS data enables comparisons with the MRV reporting scheme. STEAM v5.1 adopted the same voyage-based emission allocation methodology used by both the IPCC and the Fourth IMO GHG Study for international and domestic shipping. Voyages were constructed from confirmed port calls and AIS position reports, ensuring 1:1 compliance with MRV reporting and enabling the detection of anomalies and deviations. AIS decoding and filtering rules have been strengthened. Handling of spurious or faulty identification numbers has been improved.

• The resistance calculation method in STEAM v5.1 is a hybrid approach, combining the Hollenbach method with the methodology consistent with the Fourth IMO GHG Study. The Hollenbach method is applied by default; however, if a vessel falls outside the applicable range or if data is insufficient, a simpler formula is used. It is important to note that static draught is assumed in the calculations, and changes in draught or trim are not accounted for.

• Weather effects—such as wind and current speed and direction, wave height and direction, and ice coverage and thickness—are included in STEAM v5.1 in the same way as in STEAM v4.3. Details of the methods used are described in Majamäki et al (2025).

• By default, STEAM v5.1 uses a simplified auxiliary engine model, like the one in STEAM 2, which improves the comparison scores of STEAM against the MRV data. Users still have the option to choose how auxiliary engines and boilers are modeled. However, due to limitations of the global fleet description, modeling auxiliary systems remains a significant source of uncertainty. This was evident during extensive comparisons with MRV fuel reports. Some biases found in large containership modeling have been addressed, resulting in improved consistency with MRV data, but some biases remain.

• Geographical rules for regional air and water environmental regulations have been updated. These now include vessel-type-specific discharge rules, such as the sewage discharge ban for passenger ships in the Baltic Sea region.

• The modeling of shore-side electricity in STEAM has been revised. The updated setup uses terminal data from the EU Alternative Fuel Observatory (https://alternative-fuels-observatory.ec.europa.eu/transport-mode/maritime-sea/ports-and-infrastructure) to identify ports and terminals equipped with shore power connections. Installation dates and applicable ship types for each terminal are also defined. The model now incorporates the EU requirement for shore power readiness within the TEN-T network by 2030 for container and passenger ships. However, the model does not account for potential incompatibilities between shipboard and land-based electrical

frequencies. It also assumes that if both the ship and terminal are shore power-ready, connection is possible during berthing and power needed is always available from the land-based power grid.

• Ships operating in NOx Emission Control Areas (NECAs) now use SCR (Selective Catalytic Reduction) or EGR (Exhaust Gas Recirculation) systems only when required by regulation. This is different from the earlier versions of STEAM, which assumed that vessels with SCR systems would use them regardless of build year. For instance, in the previous model, a ship built in 2005 and retrofitted with SCR would have been treated as compliant with Tier III requirements. In STEAM v5.1, such a ship is modeled using Tier II emission factors, reflecting its exemption from Tier III and its likely focus on minimizing operational costs. Currently, 2,068 entries in the global fleet technical database indicate the presence of SCR systems. Modern EGR units, often paired with scrubbers, are modeled in line with IMO Tier III emission factors. Active SCR systems are modeled to reduce NOx based on engine load, with ammonia slip also considered.

• Global zones with EGCS (Exhaust Gas Cleaning System) discharge bans have been updated, particularly in the Baltic Sea. Recent updates to Danish, Swedish, and Finnish environmental legislation now include restrictions on both Open Loop and Closed Loop discharges. In STEAM, the guiding principle is that EGCS shutdowns must be required by maritime authorities, with clear geographical boundaries and start dates for the restrictions. Recommendations to avoid EGCS use are not included in the model as these are not compulsory bans.

• The model now includes a broader range of fuel types, including High Sulfur Heavy Fuel Oil (HSHFO), Intermediate Fuel Oil (IFO), Very Low Sulfur Fuel Oil (VLSFO), Marine Diesel Oil (MDO), Marine Gas Oil (MGO), Methanol, Ammonia, and LNG. The fuel allocation logic in STEAM v5.1 is based on a combination of technical feasibility, legal compliance, and cost. The model can also examine fuel mixtures, including the use of pilot and alternative fuels. Ships with engines capable of using gas as fuel are identified by manufacturer and engine type codes, with Brake Specific Energy Consumption (BSEC) curves provided by the engine manufacturer. Gas engines are categorized into compression-ignited dual-fuel low-pressure, compression-ignited dual-fuel high-pressure, spark-ignited, and turbines.

• The modeling of sewage discharges and the nutrients contained within assumes a removal rate of 70% for nitrogen (N) and 80% for phosphorus (P). However, these values may be somewhat optimistic, considering the variability in system type, maintenance, and operating conditions within the Baltic Sea fleet. There is also a lack of sufficient data regarding the specific types of sewage treatment systems installed on ships.

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Appendix 1. Annual summaries of ship emissions to air in the Baltic Sea area

Baltic – 2006	MAIN FUEL	AUX + B_FUEL	NOx	SOx	PM25	CO	CO_2	CH_4	NH_3	N_2O	CO_{2eq}	TRAVEL	TRANSP WORK	VOC	SHIPS
	[10^3 tonnes]	[10^3 tonnes]	[tonnes]	[tonnes]	[tonnes]	[tonnes]	[10^3 tonnes]	[tonnes]	[tonnes]	[tonnes]	[10^3 tonnes]	[10^6 nm]	[10^6 tonne nm]	[tonnes]	
All	3797	622	298971	122327	14037	17723	14001	0	0	735	14195	70	414162	2280	8271
IMO	3767	609	296866	121529	13933	17420	13864	0	0	728	14057	68	413425	2257	7353
Baltic Proper	2361	281	179731	75480	8636	10120	8370	0	0	441	8487	42	247841	1362	2795
Kattegat	657	136	55340	21660	2484	3343	2512	0	0	132	2547	14	92509	415	4601
Gulf of Finland	416	135	36212	14009	1619	2413	1747	0	0	90	1771	7	47491	284	532
Gulf of Bothnia	331	55	24777	10209	1183	1638	1225	0	0	64	1242	6	22499	197	271
Gulf of Riga	32	14	2912	969	116	209	146	0	0	7	148	1	3823	23	72
RoPax_ships	1173	184	86339	38174	4322	5446	4301	0	0	226	4361	10	18205	680	241
Ro-ro cargo ships	488	31	33999	17306	1922	1948	1645	0	0	86	1668	5	33625	265	167
Vehicle_carriers	54	7	4608	1786	203	226	195	0	0	10	198	1	4151	33	185
General_cargo ships	542	84	39699	13004	1634	2829	1982	0	0	100	2008	25	67458	318	2395
Bulk_carriers	213	50	22572	7761	837	1038	834	0	0	43	845	4	68123	138	1163
Container_ships	334	25	24672	11977	1326	1417	1140	0	0	62	1156	5	42516	196	447
Reefers	60	11	6221	2018	220	342	226	0	0	12	229	2	5420	39	330
Tankers	643	151	58582	22411	2588	2279	2514	0	0	136	2550	10	172751	420	1378
LNG_tankers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gas_tankers	19	7	1968	581	71	95	79	0	0	4	81	0	1914	13	123
Passenger_ships	12	11	1113	339	45	133	72	0	0	3	73	1	0	11	164
Cruisers	123	24	8970	3472	417	580	464	0	0	25	470	1	0	75	83
Fishing_vessels	13	9	1541	477	54	112	69	0	0	3	70	1	0	11	245
Service_ships	8	3	478	175	24	82	33	0	0	2	33	1	0	5	176

Baltic – 2007	MAIN FUEL	AUX + B_FUEL	NOx	SOx	PM25	CO	CO_2	CH_4	NH_3	N_2O	CO_{2eq}	TRAVEL	TRANSP WORK	VOC	SHIPS
	[10^3 tonnes]	[10^3 tonnes]	[tonnes]	[tonnes]	[tonnes]	[tonnes]	[10^3 tonnes]	[tonnes]	[tonnes]	[tonnes]	[10^3 tonnes]	[10^6 nm]	[10^6 tonne nm]	[tonnes]	
All	4094	674	324701	111520	13714	19441	15091	12	0	810	15306	77	454663	2505	9341
IMO	4047	655	321365	110292	13553	18962	14880	12	0	800	15092	73	453929	2470	7706
Baltic Proper	2556	310	196282	68535	8409	11203	9069	12	0	489	9199	45	272761	1505	3288
Kattegat	693	151	58975	19310	2384	3639	2670	1	0	144	2708	15	98970	449	5044
Gulf of Finland	469	142	40620	13734	1687	2667	1935	0	0	103	1962	8	55319	321	586
Gulf of Bothnia	339	55	25445	8885	1102	1691	1246	0	0	66	1263	7	23577	204	339
Gulf of Riga	38	15	3378	1057	131	241	171	0	0	8	173	1	4036	27	84
RoPax_ships	1305	198	96541	35940	4359	6108	4758	0	0	256	4826	11	20319	770	258
Ro-ro cargo ships	485	31	33589	13578	1632	2024	1631	0	0	89	1655	5	35971	271	163
Vehicle_carriers	65	10	5794	1787	220	278	239	0	0	13	242	1	5698	41	220
General_cargo ships	561	89	41204	12602	1632	2966	2058	0	0	104	2085	26	70509	330	2513
Bulk_carriers	196	46	21055	5818	688	980	767	0	0	41	778	4	62977	130	1011
Container_ships	414	38	31938	12158	1459	1799	1430	0	0	80	1451	7	57050	251	493
Reefers	73	13	7559	2059	246	401	272	0	0	14	275	2	6578	48	348
Tankers	681	158	62937	19307	2414	2368	2656	12	0	147	2695	11	193157	452	1473
LNG_tankers	0	0	8	7	1	2	1	0	0	0	1	0	15	0	3
Gas_tankers	20	7	2099	539	69	97	84	0	0	5	85	0	2019	14	137
Passenger_ships	16	13	1420	431	57	171	92	0	0	4	93	2	0	14	212
Cruisers	125	21	8813	3511	429	579	461	0	0	25	467	1	0	76	82
Fishing_vessels	15	11	1726	460	59	141	83	0	0	4	84	1	0	14	377
Service_ships	9	4	612	225	31	99	42	0	0	2	43	1	0	7	210

Baltic – 2008	MAIN FUEL	AUX + B_FUEL	NOx	SOx	PM25	CO	CO_2	CH_4	NH_3	N_2O	CO_{2eq}	TRAVEL	TRANSP WORK	VOC	SHIPS
	[10^3 tonnes]	[10^3 tonnes]	[tonnes]	[tonnes]	[tonnes]	[tonnes]	[10^3 tonnes]	[tonnes]	[tonnes]	[tonnes]	[10^3 tonnes]	[10^6 nm]	[10^6 tonne nm]	[tonnes]	
All	4062	709	320419	111603	13649	20014	15100	33	0	812	15316	76	447159	2515	10558
IMO	3999	682	315776	109951	13430	19362	14813	31	0	798	15025	71	445698	2466	7796
Baltic Proper	2533	326	193655	68308	8332	11571	9046	24	0	488	9176	45	266894	1505	3829
Kattegat	685	160	57976	19257	2370	3751	2674	4	0	144	2712	16	96085	452	5445
Gulf of Finland	476	150	40648	14228	1736	2766	1982	2	0	106	2010	8	55915	330	754
Gulf of Bothnia	326	56	24421	8618	1066	1662	1210	0	0	64	1227	7	23568	198	434
Gulf of Riga	42	17	3719	1192	146	265	188	3	0	9	191	1	4697	30	96
RoPax_ships	1292	203	95161	35889	4324	6126	4733	0	0	255	4801	11	20254	766	232
Ro-ro cargo ships	480	34	32824	13529	1609	2105	1626	0	0	88	1649	5	36740	269	167
Vehicle_carriers	83	14	7494	2310	283	356	307	0	0	17	312	1	7619	53	217
General_cargo ships	515	87	37758	11664	1512	2838	1908	0	0	97	1933	24	64963	309	2393
Bulk_carriers	183	44	19480	5432	645	911	717	0	0	38	727	3	59243	122	1028
Container_ships	451	42	34799	13237	1578	2056	1559	0	0	87	1582	7	63173	277	544
Reefers	67	13	6984	1910	227	373	252	0	0	13	256	2	6037	44	336
Tankers	651	166	59835	18703	2324	2443	2588	2	0	143	2626	11	185898	440	1617
LNG_tankers	0	0	7	4	0	1	1	0	0	0	1	0	6	0	3
Gas_tankers	21	8	2346	604	77	115	94	0	0	5	95	1	2889	16	132
Passenger_ships	17	12	1394	447	59	175	92	0	0	4	93	2	0	14	250
Cruisers	141	25	9830	3861	469	706	524	31	0	29	533	1	0	87	94
Fishing_vessels	20	14	2116	576	76	197	108	0	0	5	109	1	0	18	444
Service_ships	8	4	533	200	27	101	38	0	0	2	39	1	0	6	245

Baltic – 2009	MAIN FUEL	AUX + B_FUEL	NOx	SOx	PM25	CO	CO_2	CH_4	NH_3	N_2O	CO_{2eq}	TRAVEL	TRANSP WORK	VOC	SHIPS
	[10^3 tonnes]	[10^3 tonnes]	[tonnes]	[tonnes]	[tonnes]	[tonnes]	[10^3 tonnes]	[tonnes]	[tonnes]	[tonnes]	[10^3 tonnes]	[10^6 nm]	[10^6 tonne nm]	[tonnes]	
All	3758	721	297032	104289	12720	19061	14173	1	0	764	14376	68	434567	2363	11203
IMO	3698	688	292327	102720	12505	18334	13881	1	0	750	14080	63	433759	2312	7816
Baltic Proper	2285	325	175064	62153	7555	10734	8260	0	0	447	8379	39	253712	1375	3704
Kattegat	685	175	57784	19390	2384	3857	2721	1	0	146	2760	15	100282	460	6201
Gulf of Finland	437	147	37468	13282	1614	2586	1849	0	0	99	1875	7	54276	309	748
Gulf of Bothnia	306	56	22784	8162	1009	1601	1144	0	0	61	1160	6	21183	187	441
Gulf of Riga	45	18	3932	1302	159	282	199	0	0	10	201	1	5114	32	109
RoPax_ships	1237	202	90585	34761	4173	5934	4553	0	0	247	4618	10	19008	739	236
Ro-ro cargo ships	399	36	27767	11457	1350	1849	1377	0	0	75	1397	4	32307	227	151
Vehicle_carriers	32	11	3128	938	116	182	136	0	0	7	138	1	3019	23	177
General_cargo ships	451	80	33029	10322	1338	2524	1681	0	0	86	1704	20	57857	274	2410
Bulk_carriers	189	43	19725	5609	669	909	735	0	0	40	746	3	62356	125	1006
Container_ships	350	40	27371	10384	1231	1703	1234	0	0	69	1252	6	52782	221	451
Reefers	60	12	6218	1695	202	335	228	0	0	12	231	2	5506	40	299
Tankers	679	187	61915	19852	2447	2663	2740	1	0	152	2780	11	199661	464	1762
LNG_tankers	1	1	46	25	4	7	4	0	0	0	4	0	30	1	6
Gas_tankers	15	7	1620	421	54	88	69	0	0	4	70	0	1827	11	128
Passenger_ships	16	14	1475	453	60	187	97	0	0	5	98	2	0	15	278
Cruisers	163	23	11200	4210	511	768	588	0	0	32	597	1	0	97	89
Fishing_vessels	21	12	1987	560	75	195	106	0	0	5	107	2	0	18	487
Service_ships	10	5	665	255	34	115	47	0	0	2	48	1	0	8	255

Baltic – 2010	MAIN FUEL	AUX + B_FUEL	NOx	SOx	PM25	CO	CO_2	CH_4	NH_3	N_2O	CO_{2eq}	TRAVEL	TRANSP WORK	VOC	SHIPS
	[10^3 tonnes]	[10^3 tonnes]	[tonnes]	[tonnes]	[tonnes]	[tonnes]	[10^3 tonnes]	[tonnes]	[tonnes]	[tonnes]	[10^3 tonnes]	[10^6 nm]	[10^6 tonne nm]	[tonnes]	
All	3689	772	290876	86511	11460	19527	14119	5	0	759	14321	68	442610	2372	12430
IMO	3637	735	286238	85246	11268	18784	13836	5	0	746	14034	63	442193	2322	7903
Baltic Proper	2241	352	170757	52217	6849	10976	8205	3	0	444	8323	39	258755	1377	4382
Kattegat	652	173	54721	15562	2080	3773	2610	2	0	140	2647	15	98671	445	6459
Gulf of Finland	434	165	37689	10401	1417	2738	1894	0	0	101	1920	7	56351	318	935
Gulf of Bothnia	321	65	24032	7324	975	1752	1219	0	0	64	1236	6	23538	201	552
Gulf of Riga	42	18	3677	1007	138	288	191	0	0	10	194	1	5295	31	102
RoPax_ships	1132	195	83316	26600	3438	5506	4200	0	0	228	4260	9	17264	683	249
Ro-ro cargo ships	365	33	25179	8682	1114	1697	1257	0	0	69	1275	4	29114	209	140
Vehicle_carriers	39	9	3692	924	125	185	153	0	0	8	155	1	3738	26	173
General_cargo ships	492	95	35794	10525	1434	2870	1859	0	0	95	1884	22	63997	307	2437
Bulk_carriers	194	45	19266	4709	623	916	754	0	0	41	765	3	64714	130	1045
Container_ships	375	55	29665	9363	1221	2004	1362	0	0	75	1382	6	61070	248	367
Reefers	48	11	5003	1150	152	276	185	0	0	10	188	1	4523	33	296
Tankers	663	196	59527	16293	2183	2814	2717	5	0	150	2757	11	196050	461	1727
LNG_tankers	1	1	67	22	4	9	6	0	0	0	6	0	39	1	7
Gas_tankers	13	6	1427	329	46	80	63	0	0	3	63	0	1566	10	118
Passenger_ships	15	15	1411	357	52	178	92	0	0	4	93	2	0	14	298
Cruisers	157	21	10446	3032	414	735	564	0	0	31	572	1	0	94	89
Fishing_vessels	17	14	1731	436	63	188	97	0	0	5	99	2	0	16	575
Service_ships	24	11	1748	536	76	212	113	0	0	6	114	1	0	18	321

Baltic – 2011	MAIN FUEL	AUX + B_FUEL	NOx	SOx	PM25	CO	CO_2	CH_4	NH_3	N_2O	CO_{2eq}	TRAVEL	TRANSP WORK	VOC	SHIPS
	[10^3 tonnes]	[10^3 tonnes]	[tonnes]	[tonnes]	[tonnes]	[tonnes]	[10^3 tonnes]	[tonnes]	[tonnes]	[tonnes]	[10^3 tonnes]	[10^6 nm]	[10^6 tonne nm]	[tonnes]	
All	3833	818	300423	78094	11048	20414	14719	9	0	794	14929	74	477527	2466	14373
IMO	3763	770	294290	76407	10792	19418	14346	8	0	776	14552	65	476771	2401	8392
Baltic Proper	2345	368	177570	47373	6625	11478	8587	3	0	466	8710	43	283513	1439	5684
Kattegat	638	172	53061	13165	1890	3679	2564	2	0	138	2601	15	102988	435	6968
Gulf of Finland	479	189	41467	10002	1466	3139	2114	0	0	113	2144	8	61072	354	962
Gulf of Bothnia	327	68	24489	6611	930	1810	1250	3	0	66	1268	7	24169	205	629
Gulf of Riga	44	20	3836	943	138	309	204	0	0	11	206	1	5785	33	130
RoPax_ships	1242	205	90988	25229	3480	6007	4579	0	0	249	4645	10	20032	747	265
Ro-ro cargo ships	371	33	25384	7288	1016	1772	1281	0	0	70	1300	4	30585	212	137
Vehicle_carriers	48	12	4542	1020	146	233	190	0	0	11	193	1	4682	33	187
General_cargo ships	452	95	32392	9213	1280	2666	1729	0	0	88	1752	21	62719	283	2597
Bulk_carriers	209	51	20225	4235	614	988	823	0	0	45	835	3	75176	142	1183
Container_ships	425	61	33955	8645	1243	2125	1538	0	0	86	1561	7	75843	277	575
Reefers	40	10	4296	827	119	236	157	0	0	8	159	1	4001	28	242
Tankers	635	201	56997	13302	1926	2755	2646	8	0	146	2685	11	202308	446	1788
LNG_tankers	2	0	90	36	5	10	7	1	0	0	7	0	53	1	6
Gas_tankers	14	6	1381	300	44	77	62	0	0	3	63	0	1479	10	127
Passenger_ships	18	16	1626	430	61	222	107	0	0	5	108	2	0	16	379
Cruisers	158	22	10422	2629	384	735	569	0	0	31	577	1	0	94	98
Fishing_vessels	17	15	1741	436	63	198	101	0	0	5	102	2	0	17	675
Service_ships	31	15	2248	690	98	273	144	0	0	7	146	1	0	23	318

Baltic – 2012	MAIN FUEL	AUX + B_FUEL	NOx	SOx	PM25	CO	CO_2	CH_4	NH_3	N_2O	CO_{2eq}	TRAVEL	TRANSP WORK	VOC	SHIPS
	[10^3 tonnes]	[10^3 tonnes]	[tonnes]	[tonnes]	[tonnes]	[tonnes]	[10^3 tonnes]	[tonnes]	[tonnes]	[tonnes]	[10^3 tonnes]	[10^6 nm]	[10^6 tonne nm]	[tonnes]	
All	3672	807	286605	75473	10673	20613	14172	16	0	764	14375	74	497024	2391	15581
IMO	3574	746	278394	73161	10325	19322	13673	16	0	741	13870	64	496049	2304	8232
Baltic Proper	2250	378	170233	45911	6419	11771	8316	11	0	451	8436	44	296161	1402	6700
Kattegat	606	179	50761	12717	1831	3733	2485	1	0	134	2520	14	104435	425	6975
Gulf of Finland	478	170	40137	9924	1447	3136	2051	1	0	110	2080	8	66437	346	1059
Gulf of Bothnia	293	62	21768	5959	838	1670	1123	3	0	59	1139	7	23794	185	696
Gulf of Riga	45	17	3705	962	139	304	197	0	0	10	200	1	6196	33	151
RoPax_ships	1189	187	86583	24116	3317	5871	4354	8	0	237	4417	10	19354	709	243
Ro-ro cargo ships	320	30	21354	6292	875	1636	1107	3	0	61	1124	4	27264	185	130
Vehicle_carriers	54	12	4948	1136	161	276	210	0	0	12	213	1	5069	36	161
General_cargo ships	420	83	29287	8556	1185	2536	1591	0	0	82	1613	20	60389	262	2505
Bulk_carriers	211	51	19431	4304	625	1035	828	0	0	46	841	3	84078	145	1239
Container_ships	424	70	34371	8723	1260	2285	1563	0	0	87	1586	7	80770	285	562
Reefers	57	15	5706	1187	173	413	229	0	0	12	232	2	5404	40	252
Tankers	609	200	54599	12875	1863	2887	2562	0	0	141	2599	10	212378	435	1748
LNG_tankers	3	1	144	54	8	18	11	4	0	1	11	0	144	2	8
Gas_tankers	14	7	1384	312	45	86	66	0	0	4	67	0	1551	11	134
Passenger_ships	21	17	1868	502	71	247	120	0	0	6	121	2	0	18	409
Cruisers	151	24	10219	2865	408	736	553	0	0	31	561	1	0	92	98
Fishing_vessels	18	16	1857	474	69	234	109	0	0	5	110	3	0	19	755
Service_ships	19	11	1379	433	63	208	95	0	0	5	97	1	0	15	328

Baltic – 2013	MAIN FUEL	AUX + B_FUEL	NOx	SOx	PM25	CO	CO_2	CH_4	NH_3	N_2O	CO_{2eq}	TRAVEL	TRANSP WORK	VOC	SHIPS
	[10^3 tonnes]	[10^3 tonnes]	[tonnes]	[tonnes]	[tonnes]	[tonnes]	[10^3 tonnes]	[tonnes]	[tonnes]	[tonnes]	[10^3 tonnes]	[10^6 nm]	[10^6 tonne nm]	[tonnes]	
All	3597	814	277338	73516	10425	20900	13953	609	0	753	14169	74	499481	2365	17201
IMO	3496	746	268486	71087	10056	19498	13417	608	0	728	13627	63	498424	2272	7967
Baltic Proper	2162	373	162290	44090	6174	11701	8021	181	0	435	8141	43	296086	1358	7306
Kattegat	603	181	49381	12652	1824	3793	2479	1	0	133	2515	15	102952	425	7567
Gulf of Finland	482	177	40635	9822	1446	3246	2086	0	0	112	2115	8	69703	355	1410
Gulf of Bothnia	306	64	21376	6001	844	1846	1168	427	0	62	1197	7	24609	194	752
Gulf of Riga	44	18	3656	952	138	314	199	0	0	10	201	1	6131	33	166
RoPax_ships	1150	191	82435	22873	3155	5943	4238	608	0	232	4317	10	18952	692	250
Ro-ro cargo ships	319	29	20861	6257	871	1666	1101	0	0	61	1117	4	27615	184	117
Vehicle_carriers	58	12	5069	1203	170	301	220	0	0	12	224	1	5044	38	147
General_cargo ships	408	82	27953	8331	1156	2550	1550	0	0	80	1571	20	60334	257	2434
Bulk_carriers	207	54	18676	4309	626	1080	825	0	0	46	837	4	88731	146	1218
Container_ships	403	70	32820	8343	1211	2266	1499	0	0	83	1521	7	77612	278	406
Reefers	38	7	3977	773	110	200	142	0	0	8	144	1	3851	25	177
Tankers	596	205	53334	12657	1839	2924	2534	0	0	139	2570	10	214573	433	1718
LNG_tankers	3	1	201	55	9	18	12	1	0	1	12	0	122	2	10
Gas_tankers	17	7	1625	377	55	97	78	0	0	4	79	0	1972	13	139
Passenger_ships	20	17	1784	480	69	265	117	0	0	5	119	2	0	18	460
Cruisers	165	23	10881	3022	433	812	597	0	0	33	605	1	0	100	95
Fishing_vessels	21	18	2050	526	77	258	121	0	0	6	123	4	0	21	888
Service_ships	16	10	1125	374	54	193	81	0	0	4	82	1	0	13	354

Baltic – 2014	MAIN FUEL	AUX + B_FUEL	NOx	SOx	PM25	CO	CO_2	CH_4	NH_3	N_2O	CO_{2eq}	TRAVEL	TRANSP WORK	VOC	SHIPS
	[10^3 tonnes]	[10^3 tonnes]	[tonnes]	[tonnes]	[tonnes]	[tonnes]	[10^3 tonnes]	[tonnes]	[tonnes]	[tonnes]	[10^3 tonnes]	[10^6 nm]	[10^6 tonne nm]	[tonnes]	
All	3554	835	274587	72018	10272	21091	13883	612	0	748	14098	76	521944	2366	20084
IMO	3441	747	263969	69220	9841	19378	13247	612	0	719	13455	62	520640	2254	8068
Baltic Proper	2145	392	161188	43351	6105	11934	8028	186	0	435	8149	44	309050	1365	8484
Kattegat	599	179	48921	12485	1805	3802	2460	4	0	132	2495	15	107271	424	9122
Gulf of Finland	474	178	40302	9535	1417	3212	2064	0	0	111	2094	8	73451	353	1420
Gulf of Bothnia	293	67	20604	5732	811	1829	1134	421	0	60	1161	7	25270	190	881
Gulf of Riga	43	19	3572	916	134	314	196	0	0	10	199	1	6902	33	177
RoPax_ships	1102	182	78528	21867	3014	5710	4057	604	0	222	4132	9	18026	663	229
Ro-ro cargo ships	319	28	20794	5821	819	1666	1099	0	0	60	1115	4	28207	182	108
Vehicle_carriers	52	11	4692	1094	155	275	201	0	0	11	204	1	4795	35	149
General_cargo ships	401	84	27267	8185	1141	2591	1534	0	0	79	1555	19	61764	257	2397
Bulk_carriers	233	62	20814	4864	708	1214	934	0	0	52	948	4	104564	166	1550
Container_ships	408	74	33530	8405	1232	2371	1525	0	0	84	1548	7	83793	286	451
Reefers	34	6	3609	698	100	174	127	0	0	7	129	1	3508	23	146
Tankers	596	209	53144	12679	1844	2980	2546	0	0	139	2583	11	213146	436	1703
LNG_tankers	4	2	275	84	13	27	19	8	0	1	19	0	290	3	15
Gas_tankers	28	9	2402	587	86	131	116	0	0	6	118	1	3479	20	131
Passenger_ships	23	21	2101	558	80	314	138	0	0	7	139	3	0	21	540
Cruisers	159	23	10324	2671	390	784	577	0	0	32	585	1	0	95	101
Fishing_vessels	22	19	2162	567	84	288	131	0	0	6	132	4	0	22	988
Service_ships	15	9	1051	358	52	193	77	0	0	4	78	2	0	13	367

Baltic – 2015	MAIN FUEL	AUX + B_FUEL	NOx	SOx	PM25	CO	CO_2	CH_4	NH_3	N_2O	CO_{2eq}	TRAVEL	TRANSP WORK	VOC	SHIPS
	[10^3 tonnes]	[10^3 tonnes]	[tonnes]	[tonnes]	[tonnes]	[tonnes]	[10^3 tonnes]	[tonnes]	[tonnes]	[tonnes]	[10^3 tonnes]	[10^6 nm]	[10^6 tonne nm]	[tonnes]	
All	3605	853	278876	8414	3931	20862	14105	612	0	762	14325	75	527459	2408	20573
IMO	3489	748	266985	7984	3704	18959	13404	611	0	730	13615	61	525110	2283	8033
Baltic Proper	2090	401	157947	4704	2209	11601	7884	188	0	428	8003	43	311053	1343	9297
Kattegat	595	189	49008	1495	712	3904	2481	5	0	133	2516	15	112589	429	8823
Gulf of Finland	589	176	47879	1440	659	3260	2423	1	0	131	2457	8	73220	414	1344
Gulf of Bothnia	288	65	20344	649	293	1780	1115	419	0	60	1142	6	23760	188	924
Gulf of Riga	44	21	3698	127	58	317	203	0	0	11	206	1	6836	34	185
RoPax_ships	1052	180	75467	2297	983	5452	3895	601	0	213	3968	9	17457	636	229
Ro-ro cargo ships	342	28	21514	645	315	1681	1171	0	0	63	1187	4	28072	190	119
Vehicle_carriers	38	8	3394	89	41	190	147	0	0	8	149	1	3203	26	147
General_cargo ships	421	85	28230	962	444	2576	1600	0	0	83	1622	19	61195	267	2328
Bulk_carriers	253	67	22334	615	303	1298	1010	0	0	56	1025	4	109585	182	1580
Container_ships	406	71	33542	917	466	2192	1510	0	0	84	1532	6	80357	284	432
Reefers	35	7	3845	81	39	170	132	0	0	7	134	1	3225	24	145
Tankers	658	213	58213	1670	782	3049	2757	1	0	153	2797	11	220181	474	1721
LNG_tankers	5	2	342	14	6	34	24	10	0	1	24	0	481	4	15
Gas_tankers	30	10	2607	77	33	144	126	0	0	7	128	1	3703	21	125
Passenger_ships	24	22	2194	89	38	325	146	0	0	7	148	3	0	23	532
Cruisers	143	21	9113	304	144	731	520	0	0	29	528	1	0	87	89
Fishing_vessels	22	21	2288	84	43	311	138	0	0	6	140	4	0	24	1000
Service_ships	13	9	997	43	21	209	71	0	0	3	72	2	0	12	384

Baltic – 2016	MAIN FUEL	AUX + B_FUEL	NOx	SOx	PM25	CO	CO_2	CH_4	NH_3	N_2O	CO_{2eq}	TRAVEL	TRANSP WORK	VOC	SHIPS
	[10^3 tonnes]	[10^3 tonnes]	[tonnes]	[tonnes]	[tonnes]	[tonnes]	[10^3 tonnes]	[tonnes]	[tonnes]	[tonnes]	[10^3 tonnes]	[10^6 nm]	[10^6 tonne nm]	[tonnes]	
All	3525	881	272440	8158	3921	21198	13945	667	0	749	14162	77	545209	2381	23078
IMO	3409	782	260840	7741	3697	19233	13263	666	0	718	13472	62	544691	2258	8419
Baltic Proper	2112	408	158161	4626	2235	11753	7977	214	0	430	8097	45	319849	1359	9974
Kattegat	633	204	52065	1586	761	4155	2650	18	0	142	2688	17	120336	460	10393
Gulf of Finland	450	179	38074	1173	568	3116	1989	20	0	106	2018	8	74513	339	1461
Gulf of Bothnia	290	71	20723	657	303	1868	1140	414	0	61	1168	7	23965	192	1061
Gulf of Riga	40	20	3416	116	54	306	188	0	0	10	191	1	6545	32	189
RoPax_ships	904	119	62	2	804	4520	3233	479	0	177	3294	8	14945	526	228
Ro-ro cargo ships	290	21	17797	508	272	1347	987	5	0	52	1001	3	23489	157	130
Vehicle_carriers	30	6	2712	64	32	142	114	0	0	6	116	1	2798	20	158
General_cargo ships	344	63	22568	771	358	2037	1287	0	0	67	1304	16	51356	215	2463
Bulk_carriers	212	56	18437	515	258	1078	847	7	0	47	860	4	96781	153	1676
Container_ships	356	62	29786	802	416	1941	1323	0	0	74	1343	5	82515	252	567
Reefers	30	6	3386	71	35	160	117	0	0	6	119	1	3015	21	151
Tankers	519	154	44628	1293	612	2396	2131	4	0	118	2163	9	184992	367	1759
LNG_tankers	7	2	440	17	8	43	29	18	0	2	30	0	1162	5	19
Gas_tankers	28	9	2362	70	31	130	115	0	0	6	117	1	3546	20	142
Passenger_ships	17	17	1671	66	28	218	109	0	0	5	110	2	0	17	580
Cruisers	111	12	6959	228	102	537	391	0	0	22	397	1	0	66	95
Fishing_vessels	20	21	2170	80	41	301	130	0	0	6	132	4	0	23	1031
Service_ships	16	14	1460	58	28	221	96	4	0	5	97	1	0	16	412

Baltic – 2017	MAIN FUEL	AUX + B_FUEL	NOx	SOx	PM25	CO	CO_2	CH_4	NH_3	N_2O	CO_{2eq}	TRAVEL	TRANSP WORK	VOC	SHIPS
	[10^3 tonnes]	[10^3 tonnes]	[tonnes]	[tonnes]	[tonnes]	[tonnes]	[10^3 tonnes]	[tonnes]	[tonnes]	[tonnes]	[10^3 tonnes]	[10^6 nm]	[10^6 tonne nm]	[tonnes]	
All	3659	885	277169	8263	4012	21192	14371	1579	0	774	14620	68	552412	2450	13358
IMO	3533	791	265045	7840	3800	19697	13672	1579	0	740	13913	61	548776	2328	8507
Baltic Proper	2227	428	164342	4809	2351	11950	8404	266	0	453	8532	40	327223	1426	4988
Kattegat	610	197	49893	1508	725	3779	2551	62	0	137	2589	14	118973	440	6769
Gulf of Finland	471	177	38531	1156	569	3295	2042	779	0	110	2093	7	76110	353	950
Gulf of Bothnia	303	67	20940	664	308	1836	1167	471	0	62	1196	6	24338	196	499
Gulf of Riga	49	16	3464	126	58	331	206	0	0	11	209	1	5768	35	152
RoPax_ships	1087	173	74	2	986	5711	3975	1382	0	217	4071	9	17669	646	230
Ro-ro cargo ships	352	27	21412	602	337	1557	1204	0	0	63	1220	3	27477	192	125
Vehicle_carriers	46	10	3798	88	45	248	176	4	0	10	179	1	4239	31	156
General_cargo ships	437	92	29350	1005	472	2711	1676	5	0	87	1699	19	64368	282	2605
Bulk_carriers	267	76	23012	660	331	1402	1084	6	0	61	1101	4	124449	196	1726
Container_ships	413	86	35333	956	503	2401	1579	0	0	88	1602	6	90929	301	443
Reefers	36	8	3909	84	42	188	138	0	0	8	140	1	3581	25	145
Tankers	598	213	52318	1549	737	2988	2565	54	0	141	2604	10	214787	441	1821
LNG_tankers	10	4	597	22	10	77	41	83	0	2	44	0	1597	7	30
Gas_tankers	29	10	2489	75	33	146	124	0	0	7	126	1	3303	21	124
Passenger_ships	23	33	2966	109	47	322	178	0	0	9	180	2	0	28	541
Cruisers	151	24	9578	304	145	791	554	0	0	30	563	1	0	93	95
Fishing_vessels	23	22	2330	86	43	311	141	0	0	7	142	3	0	25	881
Service_ships	18	18	1656	69	33	226	113	0	0	6	115	1	0	19	409

Baltic – 2018	MAIN FUEL	AUX + B_FUEL	NOx	SOx	PM25	CO	CO_2	CH_4	NH_3	N_2O	CO_{2eq}	TRAVEL	TRANSP WORK	VOC	SHIPS
	[10^3 tonnes]	[10^3 tonnes]	[tonnes]	[tonnes]	[tonnes]	[tonnes]	[10^3 tonnes]	[tonnes]	[tonnes]	[tonnes]	[10^3 tonnes]	[10^6 nm]	[10^6 tonne nm]	[tonnes]	
All	3798	956	286721	8588	4198	22257	15034	1733	0	808	15297	71	566212	2563	14654
IMO	3638	854	272032	8088	3948	20521	14207	1732	0	768	14459	63	560870	2418	8832
Baltic Proper	2296	479	170100	5007	2460	12587	8784	308	0	473	8918	42	334132	1492	5692
Kattegat	625	201	50275	1523	748	3903	2613	124	0	140	2654	14	120673	450	7183
Gulf of Finland	493	190	40086	1209	596	3458	2152	802	0	116	2205	8	79583	370	1024
Gulf of Bothnia	330	71	22573	715	331	1958	1264	498	0	67	1296	6	25543	212	624
Gulf of Riga	54	16	3687	135	63	352	221	0	0	12	224	1	6280	38	131
RoPax_ships	1107	177	75	2	1010	5798	4053	1380	0	220	4150	9	18073	656	230
Ro-ro cargo ships	351	29	21397	614	336	1544	1207	0	0	64	1224	3	27683	194	118
Vehicle_carriers	45	11	3731	87	46	260	174	4	0	10	177	1	4154	30	160
General_cargo ships	470	106	31813	1094	511	2936	1825	5	0	94	1850	20	70532	306	2624
Bulk_carriers	270	79	23308	672	338	1443	1105	7	0	62	1122	5	127828	200	1798
Container_ships	450	109	39198	1066	561	2640	1770	0	0	99	1796	6	99923	337	468
Reefers	29	7	3051	69	34	155	113	0	0	6	114	1	2840	20	137
Tankers	579	227	50934	1534	734	3041	2548	83	0	140	2587	10	210408	440	1923
LNG_tankers	11	4	587	22	10	94	47	149	0	3	51	0	1704	9	43
Gas_tankers	26	10	2259	68	30	135	113	0	0	6	115	1	3050	19	102
Passenger_ships	26	29	3032	107	48	329	176	0	0	9	178	2	0	28	552
Cruisers	180	28	11018	336	173	913	657	0	0	35	667	1	0	108	103
Fishing_vessels	24	19	2298	84	42	300	137	0	0	6	139	3	0	24	933
Service_ships	22	22	2052	84	40	275	138	2	0	7	139	2	0	23	488

Baltic – 2019	MAIN FUEL	AUX + B_FUEL	NOx	SOx	PM25	CO	CO_2	CH_4	NH_3	N_2O	CO_{2eq}	TRAVEL	TRANSP WORK	VOC	SHIPS
	[10^3 tonnes]	[10^3 tonnes]	[tonnes]	[tonnes]	[tonnes]	[tonnes]	[10^3 tonnes]	[tonnes]	[tonnes]	[tonnes]	[10^3 tonnes]	[10^6 nm]	[10^6 tonne nm]	[tonnes]	
All	3877	1105	295585	8923	4444	24931	15743	2713	0	838	16041	79	571107	2705	31275
IMO	3649	864	269003	8015	3955	21135	14259	2713	0	771	14540	63	568313	2436	8922
Baltic Proper	2316	543	172042	5099	2556	13873	9042	1067	0	483	9200	46	335551	1548	14367
Kattegat	663	261	55622	1697	858	4875	2922	164	0	154	2968	17	123830	509	13212
Gulf of Finland	516	206	41763	1274	630	3733	2275	887	0	122	2332	9	81353	393	2082
Gulf of Bothnia	329	79	22557	721	337	2090	1287	594	0	68	1321	6	24594	217	1377
Gulf of Riga	53	16	3601	132	62	360	218	2	0	11	221	1	5779	38	237
RoPax_ships	1147	171	76	2	1030	6051	4155	1906	0	226	4268	9	18500	673	236
Ro-ro cargo ships	339	29	20526	594	325	1491	1168	0	0	62	1184	3	26239	187	123
Vehicle_carriers	42	10	3513	81	43	242	164	4	0	9	167	1	4052	29	166
General_cargo ships	451	100	29736	1040	488	2871	1743	5	0	90	1767	20	66260	294	2505
Bulk_carriers	262	79	22442	655	331	1419	1078	9	0	60	1095	4	126303	196	1817
Container_ships	424	110	37290	1001	546	2692	1689	55	0	94	1715	6	103563	326	426
Reefers	31	7	3232	74	38	176	121	0	0	7	123	1	3047	22	119
Tankers	587	233	50986	1532	736	3227	2588	325	0	143	2635	10	215108	447	1974
LNG_tankers	18	7	928	34	17	170	74	228	0	4	82	0	2959	14	62
Gas_tankers	26	12	2311	72	32	145	119	0	0	7	120	1	3235	20	126
Passenger_ships	24	29	2830	103	46	324	169	0	0	8	171	3	0	27	700
Cruisers	178	25	10608	323	169	908	644	57	0	35	655	1	0	106	107
Fishing_vessels	24	22	2433	89	45	326	145	0	0	7	147	3	0	26	1044
Service_ships	36	29	2995	125	59	394	205	3	0	11	208	2	0	35	478

Baltic – 2020	MAIN FUEL	AUX + B_FUEL	NOx	SOx	PM25	CO	CO_2	CH_4	NH_3	N_2O	CO_{2eq}	TRAVEL	TRANSP WORK	VOC	SHIPS
	[10^3 tonnes]	[10^3 tonnes]	[tonnes]	[tonnes]	[tonnes]	[tonnes]	[10^3 tonnes]	[tonnes]	[tonnes]	[tonnes]	[10^3 tonnes]	[10^6 nm]	[10^6 tonne nm]	[tonnes]	
All	3335	1032	255485	7707	3877	23004	13787	3348	0	732	14075	78	554226	2371	30681
IMO	3149	830	233624	6954	3462	19543	12557	3348	0	678	12830	60	551977	2146	8408
Baltic Proper	2027	480	149139	4388	2217	12681	7916	1695	0	423	8076	45	322419	1356	14102
Kattegat	599	257	50713	1552	787	4772	2705	311	0	142	2751	17	118665	472	12743
Gulf of Finland	385	194	32646	1005	510	3237	1823	850	0	97	1872	8	82387	316	2073
Gulf of Bothnia	278	86	19873	644	307	1974	1148	487	0	60	1177	7	25621	193	1510
Gulf of Riga	46	16	3114	118	56	340	195	3	0	10	198	1	5134	34	253
RoPax_ships	992	173	66	2	900	5553	3667	2168	0	200	3781	9	17055	592	220
Ro-ro cargo ships	320	30	19686	568	308	1544	1111	0	0	59	1126	3	26114	178	110
Vehicle_carriers	26	12	2449	55	31	196	119	3	0	7	121	1	3043	21	156
General_cargo ships	431	97	28235	995	472	2846	1672	4	0	86	1695	20	68225	284	2685
Bulk_carriers	273	85	23028	666	342	1496	1132	14	0	63	1149	5	132916	204	1812
Container_ships	366	90	31750	825	459	2398	1443	132	0	80	1467	5	97672	278	358
Reefers	31	8	3207	70	37	177	123	0	0	7	124	1	3113	22	117
Tankers	540	230	45849	1384	670	3187	2427	576	0	133	2479	10	199980	416	1919
LNG_tankers	21	9	1077	38	19	222	90	366	0	5	102	0	3489	17	69
Gas_tankers	21	11	1897	61	27	131	100	0	0	5	101	1	2589	17	104
Passenger_ships	21	19	1963	78	34	297	127	0	0	6	129	3	0	20	628
Cruisers	26	17	2291	75	39	305	138	64	0	7	141	0	0	24	40
Fishing_vessels	21	20	2133	79	40	296	128	0	0	6	130	4	0	23	1024
Service_ships	17	15	1390	62	31	260	102	5	0	5	104	2	0	17	411

Baltic – 2021	MAIN FUEL	AUX + B_FUEL	NOx	SOx	PM25	CO	CO_2	CH_4	NH_3	N_2O	CO_{2eq}	TRAVEL	TRANSP WORK	VOC	SHIPS
	[10^3 tonnes]	[10^3 tonnes]	[tonnes]	[tonnes]	[tonnes]	[tonnes]	[10^3 tonnes]	[tonnes]	[tonnes]	[tonnes]	[10^3 tonnes]	[10^6 nm]	[10^6 tonne nm]	[tonnes]	
All	3603	1065	268291	8156	4091	24482	14731	4301	2	783	15059	85	571689	2525	34002
IMO	3379	830	242321	7269	3601	20405	13276	4301	2	718	13587	63	568963	2260	8533
Baltic Proper	2177	504	156429	4652	2349	13616	8465	2204	1	452	8647	50	339797	1444	16040
Kattegat	614	256	50646	1563	797	4897	2749	381	0	144	2798	18	116579	480	13750
Gulf of Finland	453	206	37012	1137	568	3515	2077	934	0	111	2132	9	85223	358	2282
Gulf of Bothnia	314	85	21336	692	325	2126	1252	776	0	66	1291	7	24817	211	1631
Gulf of Riga	44	15	2868	112	53	327	188	6	0	10	191	2	5274	32	299
RoPax_ships	1051	164	68	2	927	5800	3818	2702	0	208	3949	9	17512	620	211
Ro-ro cargo ships	347	31	20878	610	330	1662	1199	115	0	64	1219	3	27669	194	111
Vehicle_carriers	31	9	2603	60	32	186	125	3	0	7	127	0	3327	22	148
General_cargo ships	479	103	30712	1091	509	2983	1841	3	0	96	1866	21	74704	309	2758
Bulk_carriers	295	89	24317	698	353	1511	1216	33	0	68	1235	5	141175	215	1831
Container_ships	358	82	29857	782	428	2247	1391	166	0	77	1416	5	91137	262	328
Reefers	28	7	2813	62	32	159	108	0	0	6	110	1	2826	20	116
Tankers	547	227	45457	1364	666	3180	2436	738	0	134	2492	10	208501	421	1874
LNG_tankers	24	13	1282	49	23	256	111	385	0	7	123	0	3537	20	77
Gas_tankers	20	9	1751	56	25	116	92	0	0	5	93	1	2795	15	108
Passenger_ships	25	20	2141	87	38	332	142	0	0	7	144	3	0	22	645
Cruisers	56	19	3739	126	69	440	236	13	0	12	240	0	0	40	59
Fishing_vessels	20	18	1984	75	39	286	122	0	0	6	124	3	0	22	1005
Service_ships	32	25	2541	108	51	384	179	16	0	9	182	2	0	30	454

Baltic – 2022	MAIN FUEL	AUX + B_FUEL	NOx	SOx	PM25	CO	CO_2	CH_4	NH_3	N_2O	CO_{2eq}	TRAVEL	TRANSP WORK	VOC	SHIPS
	[10^3 tonnes]	[10^3 tonnes]	[tonnes]	[tonnes]	[tonnes]	[tonnes]	[10^3 tonnes]	[tonnes]	[tonnes]	[tonnes]	[10^3 tonnes]	[10^6 nm]	[10^6 tonne nm]	[tonnes]	
All	3588	1089	261303	8035	4063	25548	14738	6256	8	784	15121	81	579796	2544	37219
IMO	3343	839	232897	7079	3534	21147	13169	6256	7	714	13533	59	575917	2257	8879
Baltic Proper	2145	521	151333	4548	2311	14098	8405	3101	4	449	8611	47	343793	1443	17332
Kattegat	659	265	52325	1632	848	5294	2917	639	2	153	2976	18	126714	511	15471
Gulf of Finland	422	204	34685	1081	538	3406	1970	1022	1	105	2027	8	80746	341	2294
Gulf of Bothnia	316	80	19786	649	308	2375	1235	1484	0	66	1294	7	23636	213	1808
Gulf of Riga	47	19	3173	124	59	375	210	10	0	11	213	2	4907	36	314
RoPax_ships	1059	155	68	2	925	5881	3817	2843	0	209	3952	9	17452	621	225
Ro-ro cargo ships	376	37	19067	597	326	2361	1296	1440	0	70	1355	4	29722	218	126
Vehicle_carriers	19	7	1743	40	21	118	82	3	0	4	83	0	2067	14	126
General_cargo ships	415	102	26899	965	455	2717	1636	54	0	85	1660	18	65326	275	2542
Bulk_carriers	279	101	23811	699	360	1615	1203	13	1	66	1221	5	140713	217	2003
Container_ships	256	73	21628	581	323	1814	1039	117	0	57	1057	4	70310	201	339
Reefers	27	7	2939	63	33	159	108	0	0	6	109	1	2801	20	105
Tankers	584	245	48160	1455	717	3318	2611	874	5	144	2674	10	241782	455	2110
LNG_tankers	36	18	1759	67	31	425	162	534	1	10	180	0	6815	31	106
Gas_tankers	21	13	1867	65	29	141	108	0	0	6	110	1	2772	18	122
Passenger_ships	34	21	2814	107	47	394	175	0	0	8	177	4	0	28	665
Cruisers	126	14	6772	219	120	691	442	214	0	24	454	1	0	72	96
Fishing_vessels	17	18	1838	69	35	259	113	0	0	5	114	3	0	20	977
Service_ships	23	15	1635	72	35	295	120	24	0	6	122	2	0	20	459

Baltic – 2023	MAIN FUEL	AUX + B_FUEL	NOx	SOx	PM25	CO	CO_2	CH_4	NH_3	N_2O	CO_{2eq}	TRAVEL	TRANSP WORK	VOC	SHIPS
	[10^3 tonnes]	[10^3 tonnes]	[tonnes]	[tonnes]	[tonnes]	[tonnes]	[10^3 tonnes]	[tonnes]	[tonnes]	[tonnes]	[10^3 tonnes]	[10^6 nm]	[10^6 tonne nm]	[tonnes]	
All	3433	1178	251029	7783	4005	26463	14497	8516	18	772	14940	81	628385	2543	40774
IMO	3181	906	221194	6771	3442	21790	12837	8514	17	698	13261	58	624897	2239	9362
Baltic Proper	2056	584	145313	4432	2287	14578	8308	4247	10	444	8545	46	369448	1450	19158
Kattegat	668	285	53760	1668	876	5616	3006	946	5	157	3074	19	144168	536	16667
Gulf of Finland	401	214	32986	1027	520	3632	1928	1770	3	103	2005	8	89002	338	2653
Gulf of Bothnia	264	78	16137	542	267	2280	1065	1539	0	57	1123	7	21208	186	1950
Gulf of Riga	43	17	2833	113	55	358	190	13	0	10	193	2	4559	33	346
RoPax_ships	971	147	59	2	824	5764	3500	3859	0	192	3659	9	16862	572	223
Ro-ro cargo ships	323	38	13947	479	268	2321	1120	1881	0	62	1189	3	26357	192	107
Vehicle_carriers	15	5	1410	30	17	93	63	4	0	3	64	0	1699	11	130
General_cargo ships	393	99	25241	914	436	2685	1555	162	0	81	1581	18	64349	265	2493
Bulk_carriers	297	116	25903	763	400	1853	1308	13	2	72	1327	5	153371	240	2078
Container_ships	262	92	22828	605	354	2137	1116	188	3	60	1137	4	80481	224	415
Reefers	33	9	3383	75	39	194	132	0	0	7	134	1	3443	24	121
Tankers	610	271	51940	1527	764	3559	2771	1054	10	153	2841	10	269970	488	2500
LNG_tankers	43	33	2247	95	45	572	230	847	2	14	257	0	9389	44	114
Gas_tankers	18	12	1716	59	27	133	97	0	0	5	98	1	2442	16	112
Passenger_ships	27	22	2405	94	42	352	155	0	0	7	157	4	0	24	683
Cruisers	90	10	4307	143	80	577	314	434	0	17	331	0	0	53	88
Fishing_vessels	19	18	1854	72	37	272	118	0	0	6	119	3	0	21	1008
Service_ships	24	16	1676	77	37	302	125	0	0	6	127	2	0	21	474