Emissions from Baltic Sea shipping in 2023

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Key findings

IMO registered vessels

1. **Total emissions from IMO registered vessels in the Baltic Sea in 2023 were 218 thousand tonnes of NO_x, 7.3 thousand tonnes of SO_x, 3.3 thousand tonnes of PM, 20.9 thousand tonnes of CO, 2.5 thousand tonnes of Non-Methane Volatile Organic hydroCarbons (NMVOC) and 13.1 million tonnes of CO_2.** The CO_2 amount corresponds to 4.2 million tonnes of fuel (Energy shares of different fuels were for LNG: 7%; distillates: 72%; residual fuels: 21%). From total fuel consumption 14% was used in auxiliary engines and 4% in auxiliary boilers. These emissions contain only the IMO-registered traffic and do not include any contribution from inland waterway traffic or non-IMO registered vessels.

   Projected CO_{2eq} emissions of the international shipping in the Baltic Sea area in 2050 are estimated to be -48.1% lower than in 2008 considering only those ships which have an IMO number. 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.

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: 252 thousand tonnes, SOx: 8.6 thousand tonnes, PM: 4.0 thousand tonnes, CO: 27 thousand tonnes, NMVOC: 2.8 thousand tonnes and CO_2: 15.2 million tonnes.**

Emission of domestic shipping

3. **Projected CO_2eq emissions of domestic shipping** in the Baltic Sea area in 2050 are estimated to be 8.9% larger in 2050 than those in 2008. The trend **between 2008 and 2022 is positive and does not indicate a reduction in the CO_{2eq} emissions of domestic shipping.** 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.

Vessels over 5000 GT

4. **Considering only vessels over 5000 GT,** the emissions were 195 thousand tonnes of NO_x (78% from NO_x total), 6.3 thousand tonnes of SO_x (74% from SO_x total), 2.9 thousand tonnes of PM2.5 (72% from PM2.5 total), 17.9 thousand tonnes of CO (66% from CO total), 11.4 million tonnes of CO_2 (75% from CO_2 total), 8.2 thousand tonnes of CH_4 (98% from CH_4 total) and 0.6 thousand tonnes of N_2O (79% from N_2O total). These totals consider both International and Domestic shipping contributions together.

5. **The most significant contribution to emissions can be associated with ro-ro passenger ships, oil and chemical tankers and general cargo ships.** In terms of million tonnes of CO_2 emitted, the respective shares for these vessel types in the presented order are 3.6 million tonnes (corresponds to 28% from total CO_2 emitted; -8.1% decrease from 2022), 2.8 (corresponds to 21.5% from total CO_2 emissions; +10.3% increase from 2022), 1.4 (corresponds to 11% from total CO_2 emissions; -4.9% decrease from 2022).

Transport work

6. **Overall transport work has increased by +7.6% while the total travelling distance of IMO-registered vessels have decreased by -2.4%**. The transport work of LNG tankers, reefers, oil and chemical tankers increased by +35.4%, +22.2% and +11.8%, whereas the transport work of vehicle carriers, gas tankers and roro segments decreased by -17.8%, -11.8% and -11.0%.

Emissions from Baltic Sea shipping in 2023 compared to year 2022

7. **Most air emissions from all waterborne traffic have decreased (NO_x: -2.1%; SO_x: -1.8%; PM2.5: -0.2%; CO: +4.7%; CO_2: -0.4%) when compared to year 2022.** The emissions of CO_2 from non-IMO registered vessels were 14% of total CO_2 emitted from ships. During the 2023 study period, the number of IMO-registered vessels operating in the area has increased by +3.6%.

8. **The CO_2 emissions from ships in 2023 are lower than the pre-pandemic emission levels**. Emissions of CO_2 from ships were -10.1% lower than the 2019 CO_2 total.

9. **Methane emissions were estimated as 8449 tonnes (+36% from previous year).** Most of the methane was released from RoPax (51%), RoRo (22%) and LNG tankers (11%) ships.

10. **For 2023, emissions of NH_3 and N_2O were 38 tonnes and 778 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

11. **During 2023, 2,135 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 4.6% of the total travel distance of these vessels.

12. **For all ship types, including the operation in ice conditions in the calculation increases the annual average Carbon intensity indicator (CII) by an average of 1.6% for ships with 5,000 gross tonnage and above.** The largest average increase takes place for general cargo ships with a difference of 2.9% between the CII values with and without sailing in ice conditions included in the calculation of the indicator. Vehicle carriers, ro-ro passenger ships, and passenger/cruise ships have the lowest change with less than 1% increase from including operation in ice in the average CII value.

13. **On average, sea ice increases the total annual fuel consumption of ships with 5,000 gross tonnage and above sailing in ice conditions by 1.2% in the Baltic Sea in 2023.** The largest annual effect can be seen for bulk carrier ships of which fuel consumption has increased on average by 2.4% due to sailing in ice conditions. The lowest annual increase is for cruise passenger ships with no significant increase in the fuel consumption caused by sea ice.

14. **Total effect of weather and sea condition on the total fuel consumption of shipping the in Baltic Sea in 2023 was 8.9%.** Winds, 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 +1.9% was predicted to arise from sailing in ice conditions in the Baltic Sea region.

Validation of the results of STEAM with MRV data

15. The Ship Traffic Emission Assessment Model (STEAM) used in this work **provides fleet total fuel consumption which is within +11.4% of the MRV reports**. In case of MRV CO_2 emissions and those predicted by STEAM, overprediction is +5.3%. The average absolute deviation of a single vessel of the studied fleet is less than 13%. Both positive and negative uncertainties exist. Largest difference in predicted fuel consumption was

found for vehicle carriers and container-RoRo ships, whereas the predictions were most accurate for containerships and gas tankers.

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	5^{th} 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 4.3.1 (Jalkanen et al., 2012, 2009, 2018; Johansson et al., 2013, 2017). The whole timeseries from 2006 to 2023 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, except for CO and CH_4, have decreased when compared to year 2022 and were less than the 2019 pre-pandemic levels. Annual totals reported by sea area and vessel type are given in Table 1. The transport work of IMO registered ships increased from last year's value (+7.6%) and CO_2 emissions were decreased by -1.7%. The total CO_2 emitted (all vessels) in 2023 was 15.2 million tonnes, which corresponds to roughly 2.0% 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 1.4% of the global international shipping.

In addition to CO_2 emissions, also 778 tonnes of N_2O and 8449 tonnes of CH_4 were released. Assuming 100-year values for global warming potentials, then the total CO_{2eq} emissions were 15.6 million tonnes for all Baltic Sea shipping. Considering only the international traffic, 8.4 million tonnes of CO_2, 447 tonnes of N_2O and 4607 tonnes of CH_4 were emitted, which correspond to 8.6 million tonnes CO_{2eq}. Limiting this analysis to vessels over 5000 GT only, engaged in international shipping, CO2 emissions were 7.5 million tonnes, N2O emissions 408 tonnes and CH4 emissions 4514 tonnes. These correspond to 7.8 million tonnes of CO_{2eq}.

Table 1 Emissions from Baltic Sea shipping in 2023.

Baltic – 2023	MAIN_FUEL [10^3 tonnes]	AUX_FUEL [10^3 tonnes]	AUX Boiler [10^3 tonnes]	NOx [tonnes]	SOx [tonnes]	PM25 [tonnes]	CO [tonnes]	CO_2 [10^3 tonnes]	CH_4 [tonnes]	NH_3 [tonnes]	N_2O [tonnes]	CO2e [10^3 tonnes]	TRAVEL [10^6 nm]	TRANSPORT WORK [10^6 tonne nm]	VOC [tonnes]	SHIPS
All	3647	1018	154	251644	8576	3974	27166	15157	8449	38	778	15600	80	629048	2845	39238
IMO	3413	602	147	217610	7304	3294	20904	13077	8449	38	692	13497	59	625316	2489	9587
Baltic Proper	2219	510	69	147843	4996	2294	14930	8808	4350	22	455	9050	46	370186	1638	18093
Kattegat	743	272	33	56571	1933	913	6191	3307	702	3	166	3370	18	144126	612	16425
Gulf of Finland	409	155	41	30681	1038	486	3588	1897	1909	8	99	1977	8	88912	372	2512
Gulf of Bothnia	242	67	8	14177	513	235	2133	984	1470	5	51	1039	7	21251	189	1880
Gulf of Riga	34	14	3	2373	96	46	324	161	17	0	8	164	2	4574	33	328
RoPax_ships	1040	116	10	56558	1938	800	5498	3647	4271	25	196	3819	9	16733	671	237
Ro-ro cargo ships	351	28	3	14581	594	254	2186	1191	1878	11	65	1261	3	26478	216	113
Vehicle_carriers	19	9	0	1843	49	22	113	91	7	0	5	93	0	1705	17	131
General_cargo ships	361	63	30	22171	857	396	2566	1434	143	1	70	1456	18	64541	261	2426
Bulk_carriers	331	71	21	25642	799	378	1686	1336	41	0	71	1356	5	153120	255	2067
Container_ships	296	84	7	23765	703	358	2184	1224	214	0	64	1247	4	80136	264	411
Reefers	38	5	2	3578	85	40	199	142	0	0	7	144	1	3438	26	120
Tankers	692	132	70	53422	1616	755	4125	2815	817	0	151	2878	10	271193	533	2469
LNG_tankers	43	8	3	1432	46	25	561	158	891	0	10	186	0	9222	37	112
Gas_tankers	20	5	1	1503	51	23	119	84	3	0	4	85	1	2482	16	112
Passenger_ships	45	28	6	4147	150	60	444	248	0	0	12	251	3	0	41	547
Cruisers	82	4	1	3879	159	65	410	274	113	1	14	281	0	0	55	88
Fishing_vessels	22	14	0	1707	69	30	202	114	0	0	5	115	3	0	21	807
Service_ships	22	14	0	1564	69	29	220	113	0	0	6	115	2	0	24	412

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 in the Baltic Sea fleet are the ro-ro passenger ships, tankers, general cargo ships, bulk carriers and ro-ro cargo ships.

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 2018-2023. 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.

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.

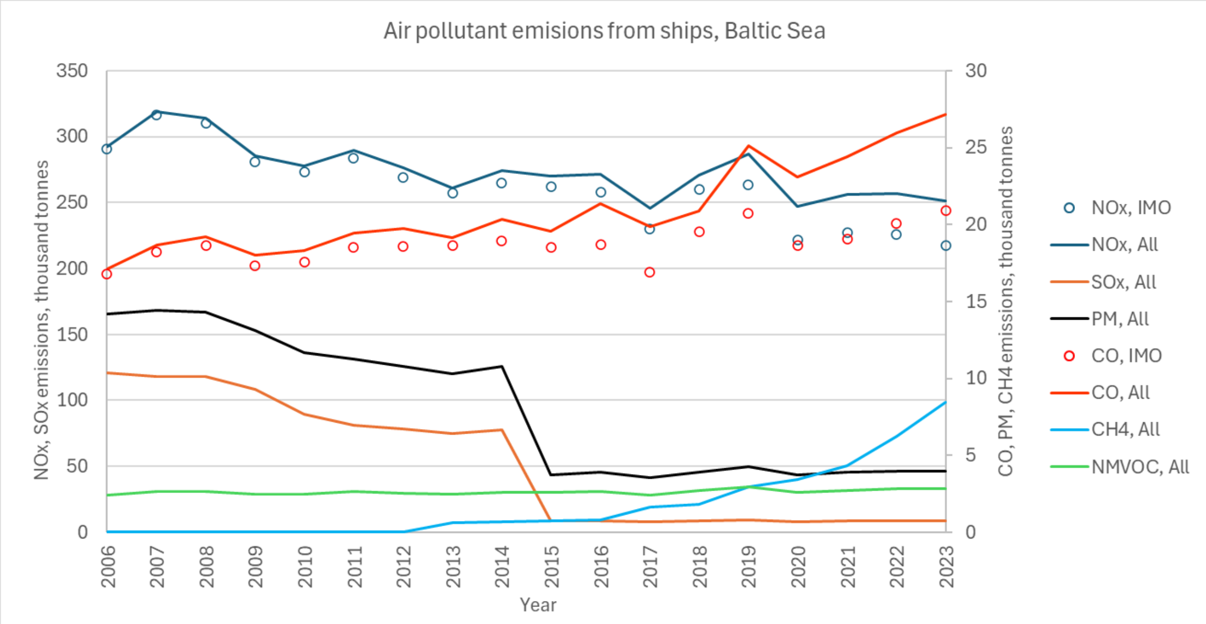


Figure 1 Emissions of NO_x, SO_x, $PM_{2.5}$, CO, CH_4 and NMVOC from ships in the Balti Sea during 2006-2023. Significant decreases in SO_x and $PM_{2.5}$ are results of regulatory changes concerning the maximum Sulphur content of fuel. Coloured lines depict total emissions from all vessels with an 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 righ side axis.

Figure 2 contains a summary of estimated fuel types used by the Baltic Sea fleet during 2006-2023. The coloured bars illustrate different fuel types. Increase in energy consumption as fuel from 2022 to 2023 is less than +0.1%. Energy consumed as fuel in 2023 is about -4.7% lower than in 2019.

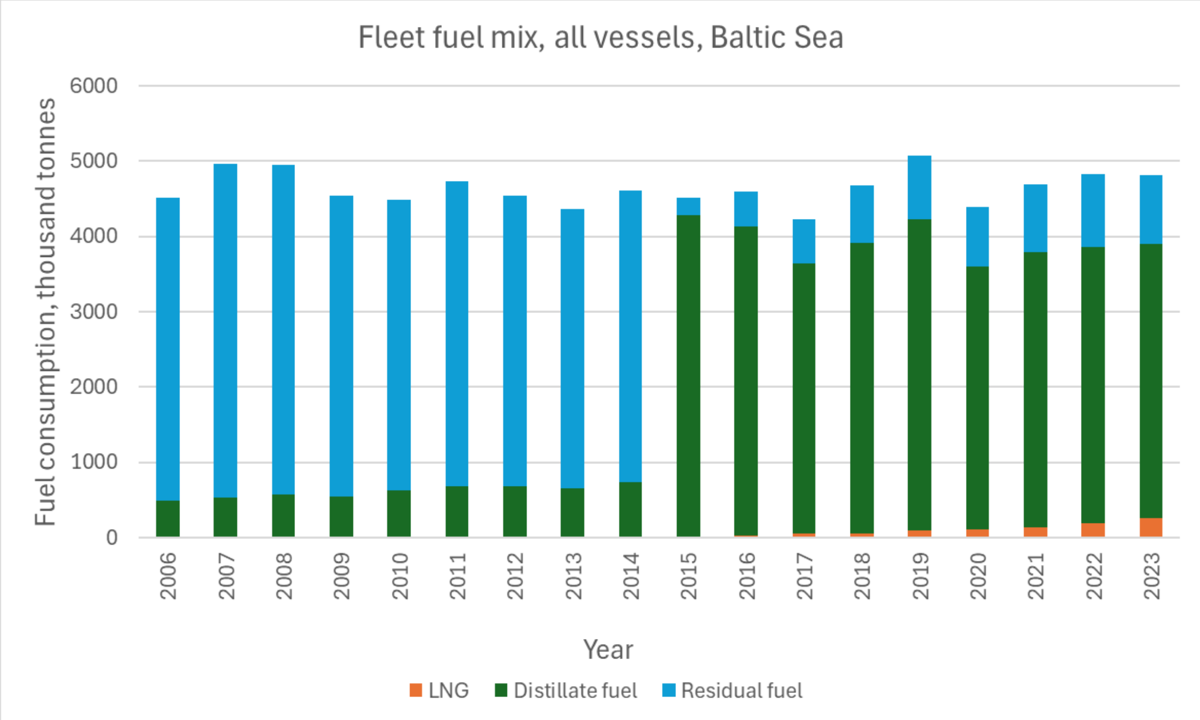


Figure 2 Estimated fuel used in ships operating in the Baltic Sea area in 2006-2023.

Heavy fuel use is concentrated on ro-ro passenger ships, roro cargo and cruise ships, 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 3). Rest of the fleet is assumed to operate on distillate fuels. 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.

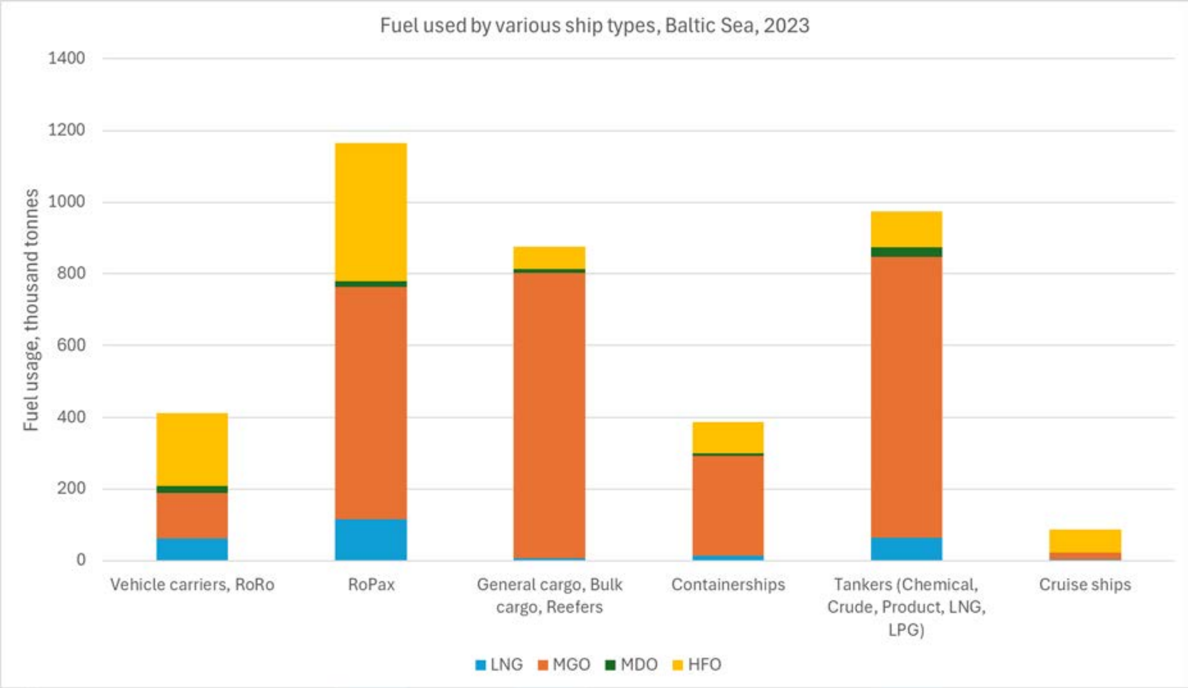
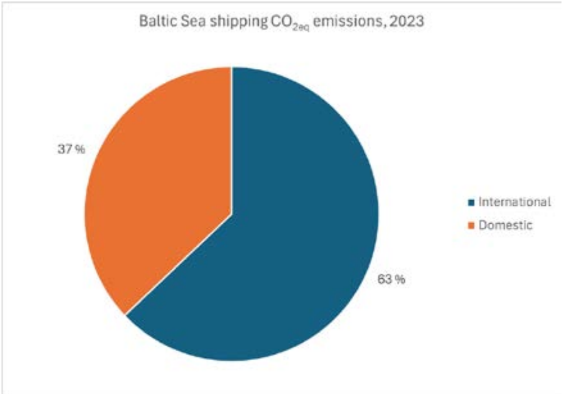


Figure 3 Estimated fuel used by various ship types in the Baltic Sea area during 2022.

In Figure 4, the share of CO_2 equivalent (CO_{2eq}) emissions in national and international shipping is reported for both 2023 and 2022. 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.



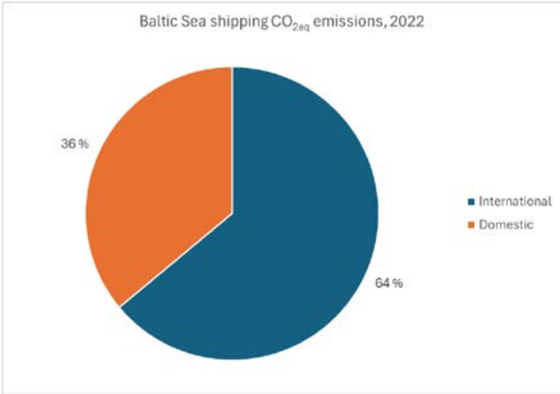


Figure 4 CO_{2eq} emissions of the Baltic Sea fleet in 2023(left) and 2022(right), divided to domestic and international shipping contributions. The share of fuel used in national navigation is about 37%, whereas most of the fuel is consumed in international traffic (63%).

Emissions of CO_2 from the Baltic Sea fleet have decreased over the study period of eighteen years (**Figure** 5). Compared to year 2008, CO_2 emissions from international shipping in 2023 have been reduced by -22%. If this trend continues until year 2050, reduction of -50% will be achieved. However, continuation of the CO_2 emission trend for domestic shipping leads to an increase in CO_2 emissions by four percent in 2050. If the current trends continue, the total CO_2 emissions (international + domestic + undefined) will be 63% of those emitted in 2008.

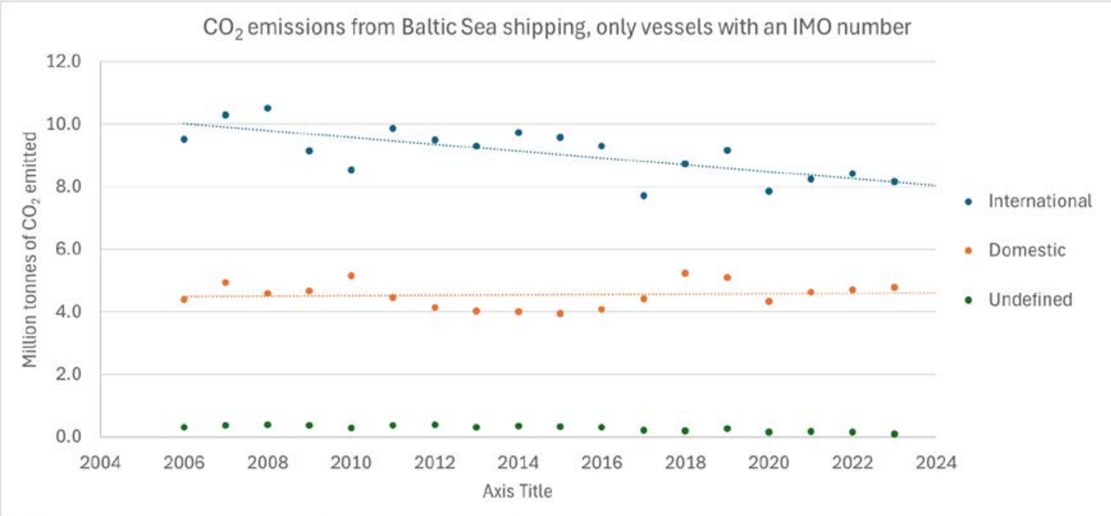


Figure 5 Emissions of CO_2 from Baltic Sea shipping during 2006-2023. The trendlines indicate the development over the past 18 years.

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 6).

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 2023 the fuel used in international voyages was about two thirds of the total cruise ship fuel consumption. However, before the pandemic, international shipping dominated (86%) the fuel consumption of cruise passenger ships, which indicates that cruise shipping has not returned to pre-pandemic operations. Also, the total time spent cruising, berthing and hoteling by the cruise ships was very different in 2023 than before the Covid19 pandemic. Pre-pandemic data for 2018 and 2019 show that cruise passenger ships spent as much time when sailing as in port, but in 2023 the time spent when sailing is only about one third of the total time (Figure 7). It is probable that these differences also reflect the geopolitical situation and decreased passenger traffic to Russian ports.

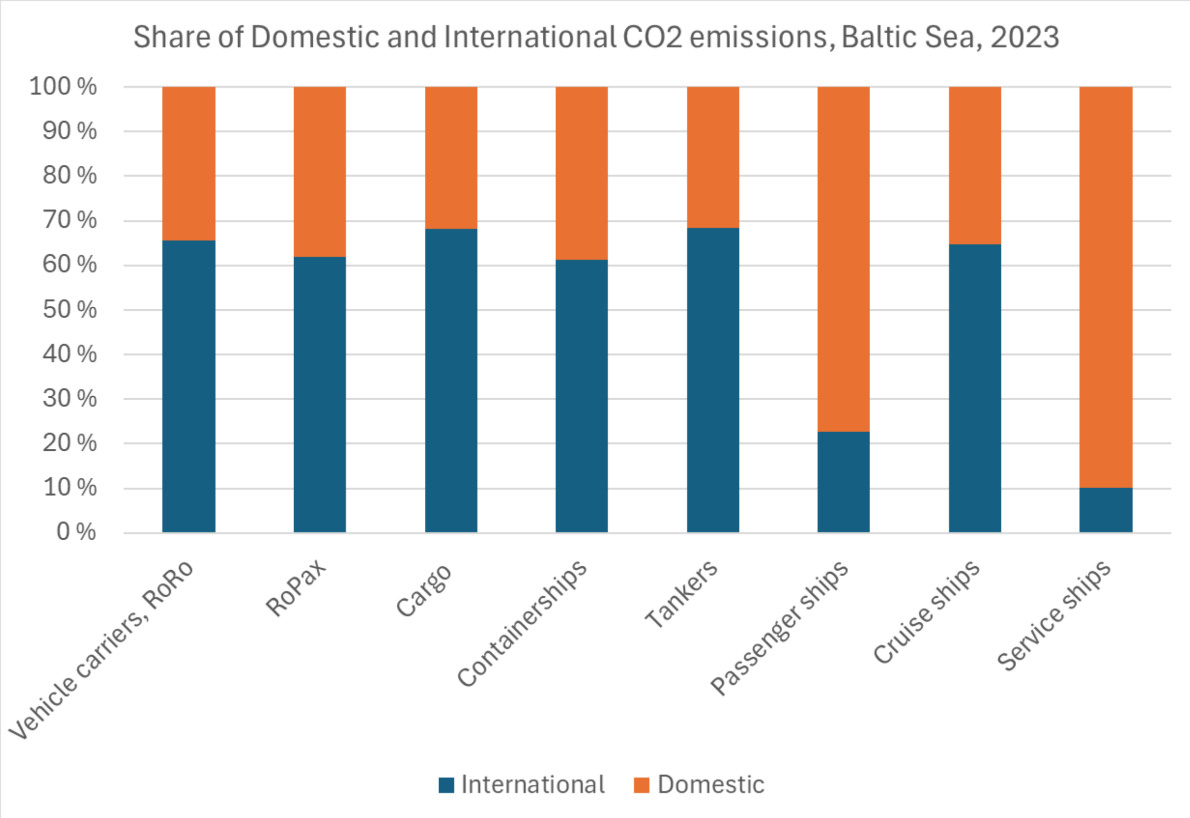


Figure 6 CO_2 emitted from various ship types in domestic and international voyages. Most of the fuel used by passenger, fishing and service vessels falls under national navigation. For other ship types, most of their fuel is used in international traffic.

The share of fuel used during voyages and harbour visits are depicted in Figure 7. The top locations for fuel used at ports are Świnoujście (Poland), Trelleborg (Sweden), Gothenburg (Sweden) and Rostock (Germany). It should be noted that no comprehensive up-to-date list of ports with shore power and ships with shore power connections were available. For this reason, fuel used in ports may be overestimated, because shore power usage cannot be described accurately.

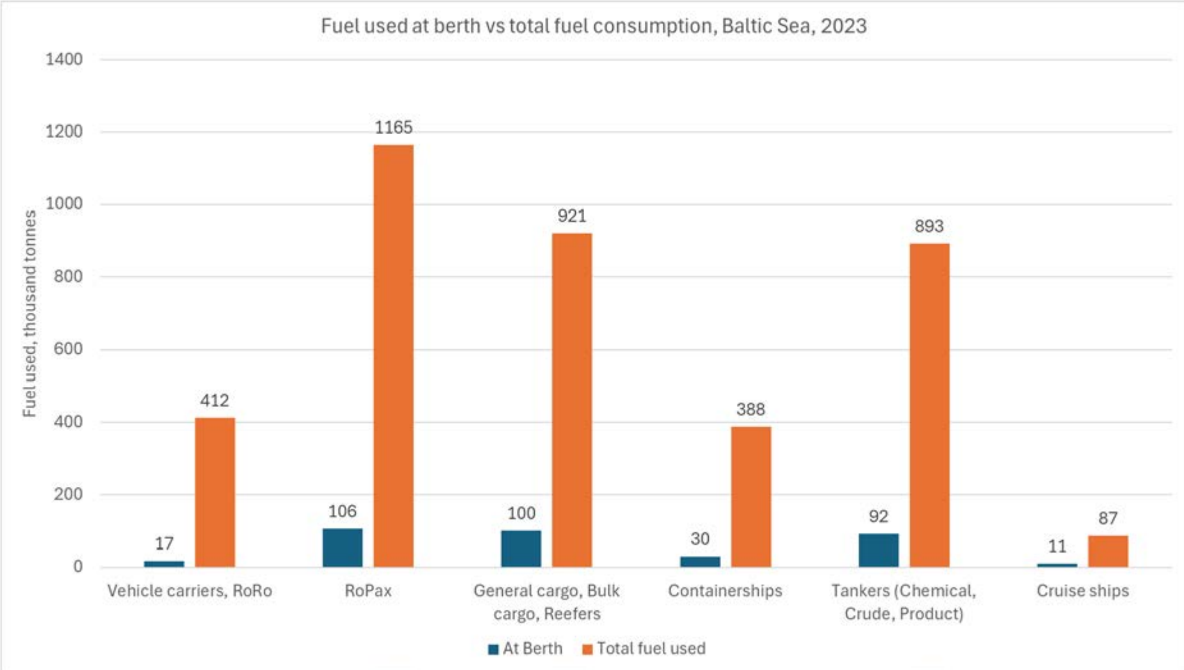


Figure 7 The share of fuel used in harbour areas by vessel type, Baltic Sea fleet, year 2023

2. Country specific CO_2 budgets of international shipping

The country specific inbound/outbound emissions of CO_2 from ships were calculated based on global 2023 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 Figure 8 and Figure 9, 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 8 Example of CO_2 emissions of inbound traffic network of Poland. The width of the arrows and the size of the circles are relative to CO_2 emissions from ships travelling between different countries. For Poland, the largest emissions from inbound traffic were associated with ships coming from Sweden, Germany, the Netherlands and the USA.

Figure 9 CO_2 emissions of outbound shipping for Poland. The arrow weight indicates the CO_2 emissions. From this it can be seen that shipping from Poland to Sweden, Germany, the USA and the Netherlands produced the largest emissions of CO_2 from outbound traffic.

Table 2 Country specific inbound/outbound emissions of CO_2 (thousand tonnes) from global ship traffic in 2023. The table contains internet links for maps for each country. These emission totals were computed for global inbound/outbound shipping in 2023 between any two countries. The "Total" column consists of the sum of 50% "Inbound", 50% "Outbound" and all "Domestic" CO_2 emissions. The last column indicates the share of Domestic CO_2 emissions from national total ship emitted CO_2.

Country	Inbound, 10^3 tonnes	Outbound, 10^3 tonnes	Domestic, 10^3 tonnes	Total, 10^3 tonnes	Domestic, share (%)
Estonia	1972	713	227	1569	14.5 %
Latvia	471	445	86	544	15.8 %
Lithuania	636	549	71	664	10.7 %
Poland	1490	1416	294	1747	16.8 %
Germany	5609	5943	1219	6995	17.4 %
Denmark	4130	4366	1329	5577	23.8 %
Sweden	4340	4731	1584	6120	25.9 %
Finland	2013	1989	639	2640	24.2 %
Russia	1972	713	227	1569	14.5 %

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.

2. 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) to allocate the impact on the total fuel consumption to the factor causing it. This might affect the estimate of the total annual fuel consumption as any possible combined effect of these variables on the fuel consumption of the vessel is not included in this study.

2.1. 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 being assisted by an icebreaker and are therefore assumed to sail in broken ice in an ice channel. This assumption might result in underprediction of the resistance in ice conditions as icebreaker assistance is only provided in case the merchant ship is not able to sail in ice conditions in a safe manner. Coverage and thickness of the ice are obtained from Copernicus Marine (Copernicus Marine Service Information (CMEMS), 2024). 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 larger than zero.

Sea current data used in this study is from Global Ocean Physics Analysis and Forecast - product in CMEMS. Sea current velocity is used to calculate the relative speed of the ship which is used to calculate the water resistance. Additional resistance due to waves is calculated as described in our earlier work (Jalkanen et al., 2009) and the wave height and direction are obtained from ERA5 data from Copernicus Climate Data Store. The method used in the earlier work of Jalkanen et al (Jalkanen et al., 2009), is originally based on the work of Townsin (Townsin et al., 1993). Wind resistance is computed following the method in Blendermann (1993, 1996) and using ERA5 data from Copernicus Climate Data Store. All meteorological data is updated every six hours in STEAM.

2.2. Total fuel consumption

In this chapter, the results of the model runs including the effect of sea ice, wind, sea waves, and sea currents are shown. 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 2023. The increase in the total fuel consumption including the effect of sea ice, wind, sea waves, or sea currents was +8.9%. On average the contribution of sea ice cover to the Baltic Sea fleet fuel consumption was two percent. It should be noted that this contribution is relevant only for some sea areas of the world, whereas wind, waves and sea currents are relevant for every sea region globally.

2.3. 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 2023 was performed. Only ships in size class of 5000 gross tonnage and above have been included in this analysis.

During 2023, 2135 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 4.6% of the total travel distance of these vessels. Miscellaneous ship type has the largest fraction of the travel distance operated in ice and this is mainly due to ice breakers that are included in this ship type. Cruise passenger ships, small passenger ships and service ships have operated less than 1% of their annual travel distance in ice conditions, which seems consistent of the fact that the peak season for these ships occurs during open water conditions.

2.3.1. 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 2023, 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. None of the cruise passenger ships and small passenger ships operated in ice conditions more than 10 km during the year and therefore, it was not possible to perform the analysis for these ship types.

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

	Number of ships	Distance share travelled in ice (%)
Ro-Ro passenger ships	39	3.2
Vehicle carriers	6	0.9
Ro-Ro cargo ships	56	5.5
Bulk carriers	326	6.8
General cargo ships	650	4.3
Container ships	143	2.4
Refrigerated cargo carriers	55	5.2
Tankers	791	5.0
LNG carriers	15	3.8
Gas tankers	13	4.3
Passenger ships	7	3.4
Cruise passenger ships	2	0.2

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.:

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

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 with Eq. (1) including all ship's activity in the calculation, leaving out the sailed distance and the fuel consumed when the ship has been operating in ice conditions. The average CII values for each ship category are shown in Table 4. For all ship types, including the operation in ice conditions in the calculation increases the annual average Carbon intensity indicator (CII) by an average of 1.6% for ships with 5000 gross tonnage and above. The largest average increase takes place for general cargo ships with a difference of 2.9% between the CII values with and without sailing in ice conditions included in the calculation of the indicator. Vehicle carriers, ro-ro passenger ships, passenger ships and cruise ships have the lowest change with less than 1% increase from including operation in ice in the average CII value.

Table 4 The average annual Carbon intensity indicator CII (g-CO_2 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 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	15.63	15.10	15.67	-0.28
Vehicle carriers	13.32	12.26	13.32	-0.02
Ro-Ro cargo ships	27.62	31.32	27.17	+1.66
Bulk carriers	11.47	13.17	11.32	+1.33
General cargo ships	5.12	6.49	4.98	+2.92
Container ships	12.33	14.39	12.22	+0.89
Refrigerated cargo carriers	19.90	21.58	19.73	+0.85
Tankers	5.95	7.24	5.83	+2.00
LNG carriers	17.44	18.04	17.34	+0.53
Gas tankers	13.36	15.82	13.22	+1.07
Passenger ships	49.82	37.24	50.98	-2.28
Cruise passenger ships	22.49	20.31	22.89	-1.76

MEAN	8.41	9.83	8.28	+1.60

Figure 10 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.

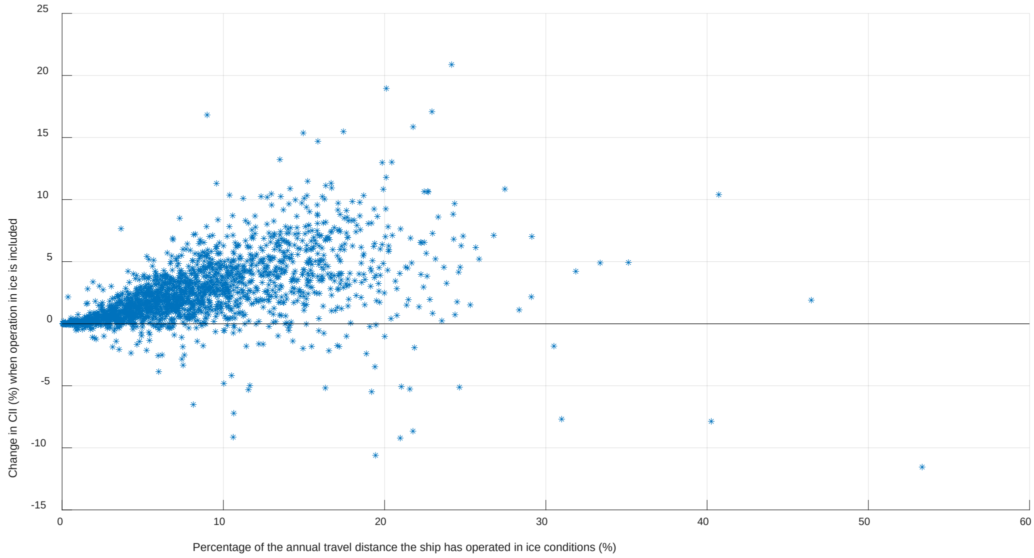


Figure 10 Increase in CII due to sea ice as a function of the percentage of the annual travel distance the ship has operated in ice conditions in the Baltic Sea in 2023. Only commercial ships with 5000 gross tonnage or above that have operated in ice conditions are included.

2.3.2. 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 2023. 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 +1.2% in 2023. Regarding the different ship types, the largest average annual effect can be seen for bulk carrier ships of which fuel consumption has increased on average by +2.4% due to sailing in ice conditions. The lowest annual increase is for cruise passenger ships with no significant increase in the fuel consumption caused by sea ice.

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 2023.

	Without sea ice (tons of fuel)	Including sea ice (tons of fuel)	Increase caused by sea ice (%)
Ro-Ro passenger ships	992,098	997,238	+0.52
Vehicle carriers	24,533	24,551	+0.07
Ro-Ro cargo ships	334,042	337,685	+1.09
Bulk carriers	154,046	157,724	+2.39
General cargo ships	367,212	374,370	+1.95
Container ships	327,252	329,374	+0.65
Refrigerated cargo carriers	35,287	35,835	+1.55
Tankers	690,555	705,152	+2.11
LNG carriers	16,881	17,024	+0.85
Gas tankers	51,275	51,636	+0.70
Passenger ships	22,599	22,613	+0.06
Cruise passenger ships	79,015	79,025	+0.01
TOTAL	3,094,793	3,132,227	+1.21

Figure 11 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 2023 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 is significant.

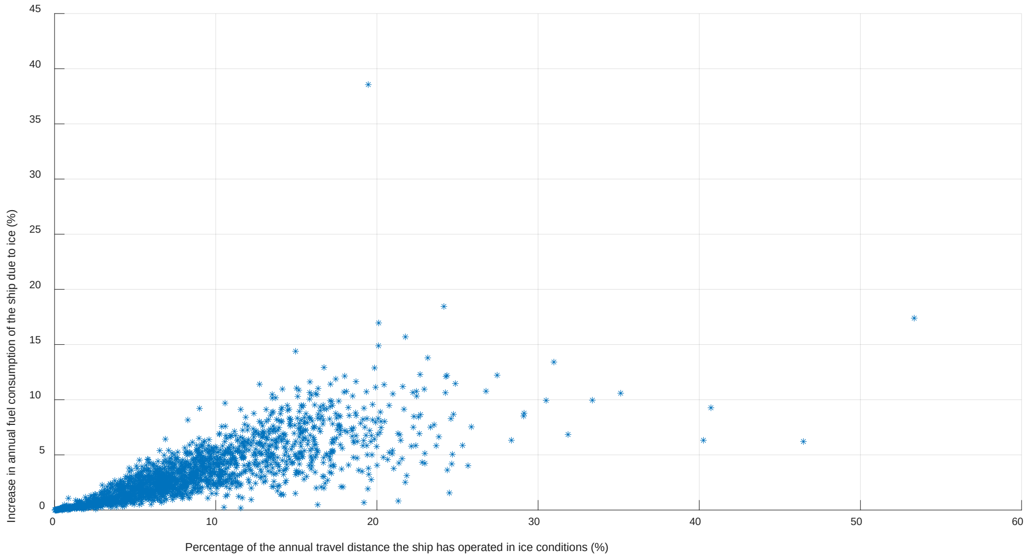


Figure 11 Increase in annual fuel consumption of ships due to sea ice as a function of the percentage of the annual travel distance the ship has operated in ice conditions in the Baltic Sea in 2023. Only commercial ships with 5,000 gross tonnage or above that have operated in ice conditions are included.

Figure 12 below shows the total fuel consumption in ice conditions during the year 2023 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 2023.

Figure 12 Total annual fuel consumption (kg) in ice conditions in the Baltic Sea in 2023

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

An accuracy comparison was made between the STEAM predictions for 2023 considering all weather parameters and the EU MRV database for the corresponding year. Version 10 (dated 21st August 2024) of the MRV data was downloaded from mrv.emsa.europa.eu. The dataset contains information for 12256 unique vessels with specific IMO numbers. 186 vessels in MRV had a fuel consumption marked Division by zero and were removed from the comparison. The STEAM dataset for 2023 contains data of 299,534 AIS broadcasting vessels of which 47,775 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 tons but converted into kilograms for the calculation) with the annual mean fuel consumption reported in kilograms per nautical mile.

Distances travelled calculated in the MRV and STEAM were compared to each other. First, the distances sailed in STEAM were converted to nautical miles by diving the modelled kilometres by 1.852. Out of 12,070 vessels in the combined dataset, 765 vessels had a distance difference between STEAM and MRV less than 10%, 986 vessels less than 20% and 1495 less than 50%.

3.1 Total annual fuel and CO_2

The total annual fuel consumed of the 765 vessels within 10% of distance difference was 4,707,006 tonnes in MRV and 5,243,877 tonnes in STEAM – a difference of 11.4%. The total annual CO_2 emitted by the same 765 vessels was 14,620,907 tonnes in MRV and 15,402,624 tonnes in STEAM – a difference of 5.3%. Total annual fuel consumed, and CO_2 emitted by vessel type are in Table 6.

STEAM seems to overpredict fuel consumption for most vessel types (8 vessel types) apart from the chemical tankers, general cargo vessels, LNG carriers, other ship types and passenger vessels. With all ship types except vehicle carriers, STEAM models less CO_2 emitted divided by fuel consumed than what was reported to MRV.

Table 6 Vessels by type, their number with annual total distance within less than 10% of STEAM and MRV, 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 (tonnes)	CO_2 (tonnes)	Fuel (tonnes)	CO_2 (tonnes)	Fuel	CO_2
Bulk	28	80,112	251,471	90,706	272,958	13.2	8.5
Chemical tanker	102	288,772	907,667	256,571	722,428	-12.6	-25.6
Container-ship	151	783,041	2,457,680	825,266	2,444,320	5.1	-0.5%
Container/ roro	2	19,579	60,374	26,356	77,563	25.7%	22.2%
Gas carrier	29	110,776	345,877	116,528	345,167	4.9%	-0.2%
General cargo	76	140,981	446,591	126,242	365,165	-11.7%	-22.3%
LNG carrier	10	119,479	336,239	108,390	301,024	-10.2%	-11.7%
Oil tanker	80	346,863	1,093,085	353,372	1,010,626	1.8%	-8.2%
Other	22	93,497	290,542	90,847	276,254	-2.9%	-5.2%
Passenger	3	65,064	189,386	54,032	141,665	-20.4%	-33.7%
Reefer	0	0	0	0	0	0	0
Ropax	153	1,705,837	5,319,487	2,011,683	5,867,311	17.9%	10.3%
Roro	93	875,089	2,726,939	1,068,131	3,252,970	18.1%	16.2%
Vehicle carrier	16	77,917	195,569	115,753	325,171	32.7%	39.9%
All vessels	765	4,707,006	14,620,907	5,243,877	15,402,624	11.4%	5.3%

3.2 Correlation between STEAM and MRV

In Figure 13, the 765 ships with an annual distance sailed within 10% of STEAM and MRV are plotted for total annual fuel consumed in metric tonnes and in Figure 14 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 0.962 (95% confidence interval 0.957-0.967, $p<0.001$). The goodness of fit (adjusted r^2) of a linear regression between the annual fuel consumptions is 0.926 ($p<0.001$).

If the 986 vessels with an annual distance sailed difference of less than 20% are compared, the correlation between total annual fuel consumed is 0.960 (95% confidence interval 0.954-0.964, $p<0.001$) and the goodness of fit (adj. r^2) of a linear regression is 0.921 ($p<0.001$). The correlation between the 1495 vessels with an annual distance sailed difference of less than 50% is 0.930 (95% confidence interval 0.923-0.936, $p<0.001$) and the goodness of fit of a linear regression is 0.865 ($p<0.001$).

The correlation between STEAM modelled total annual CO_2 emitted and MRV reported total annual CO_2 emitted is 0.958 (95% confidence interval 0.952-0.964, $p<0.001$) and the goodness of fit (adjusted r^2) of a linear regression between annual CO_2 emitted is 0.918 ($p<0.001$).

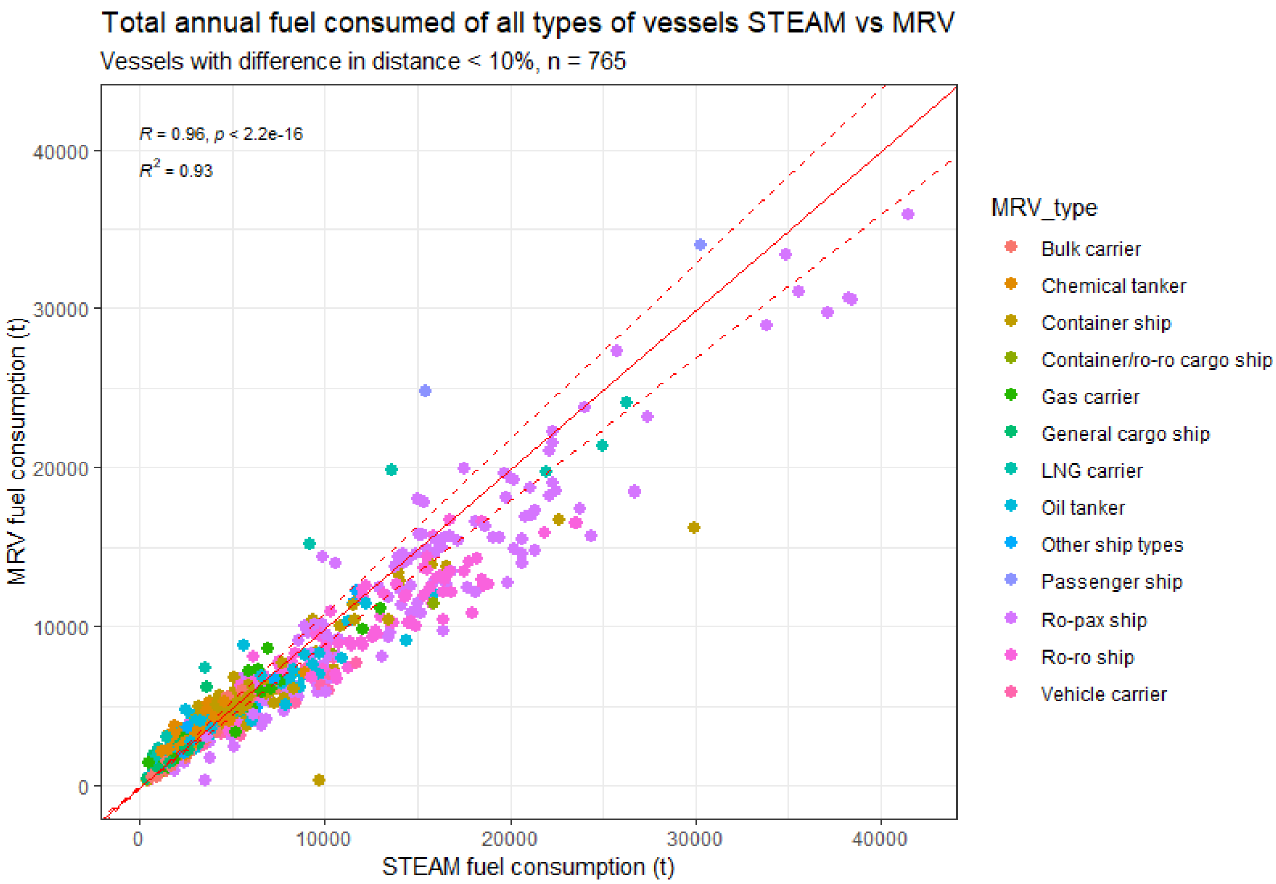


Figure 13 Scatterplot of total annual fuel consumed between STEAM (x-axis) and MRV (y-axis) with different vessel types coloured. The plot consists of the 765 vessels that have a difference <10% between the total annual distance sailed in STEAM and MRV. The solid red line indicates 100% correlation between STEAM and MRV and the dashed lines a 10% deviation from perfect correlation.

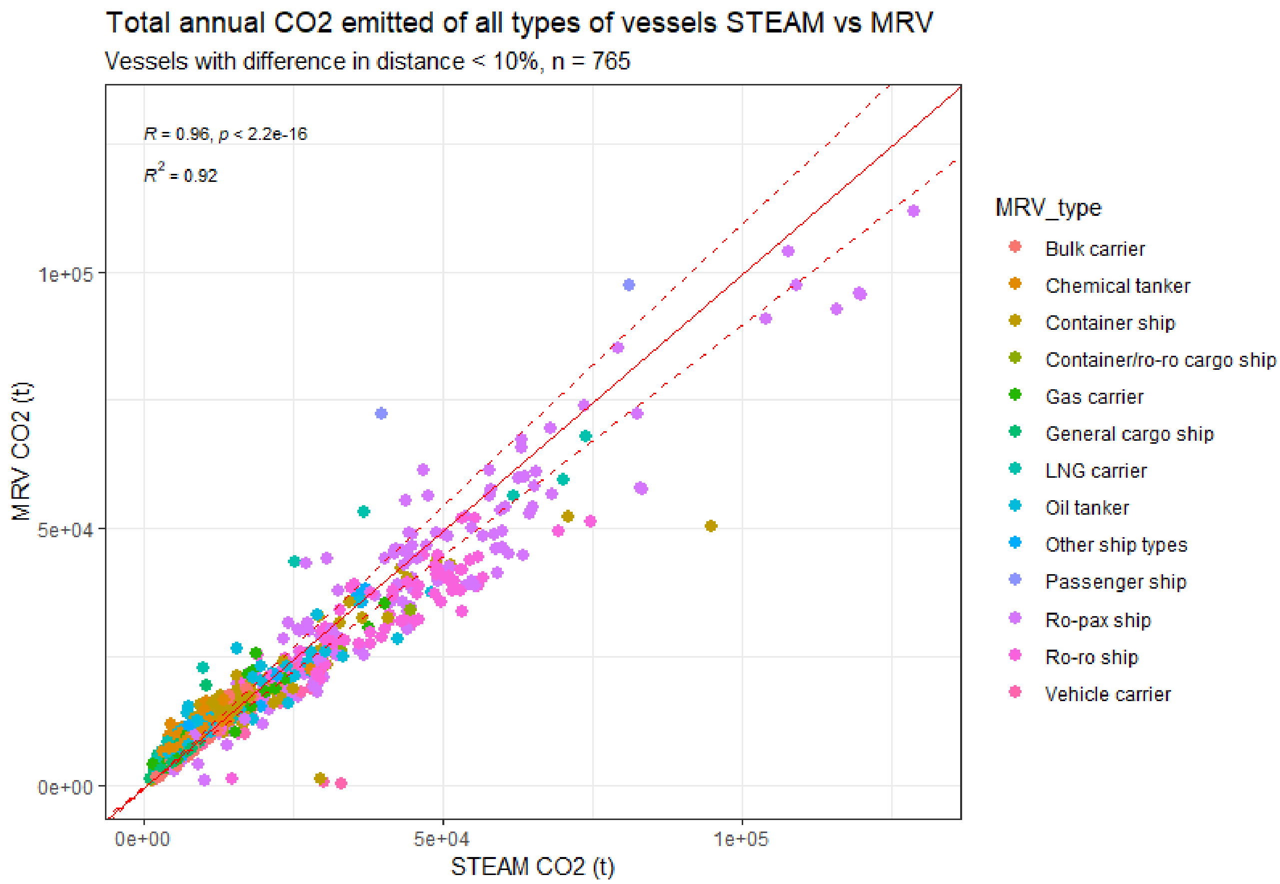


Figure 14 Scatterplot of total annual CO_2 emitted between STEAM (x-axis) and MRV (y-axis) with different vessel types coloured. The plot consists of the 765 vessels that have a difference <10% between the total annual distance sailed in STEAM and MRV. The solid red line indicates 100% correlation between STEAM and MRV and the dashed lines a 10% deviation from perfect correlation.

3.3 Differences between ship types and outliers

Some differences can be observed between different vessel types. Scatterplots for each vessel type are presented in Figure 15-Figure 27. 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.

For example, four ropax vessels were retrofitted to be battery powered and therefore STEAM overpredicts them by 213%-1088%. Also, STEAM underpredicts gas turbine powered LNG tankers significantly.

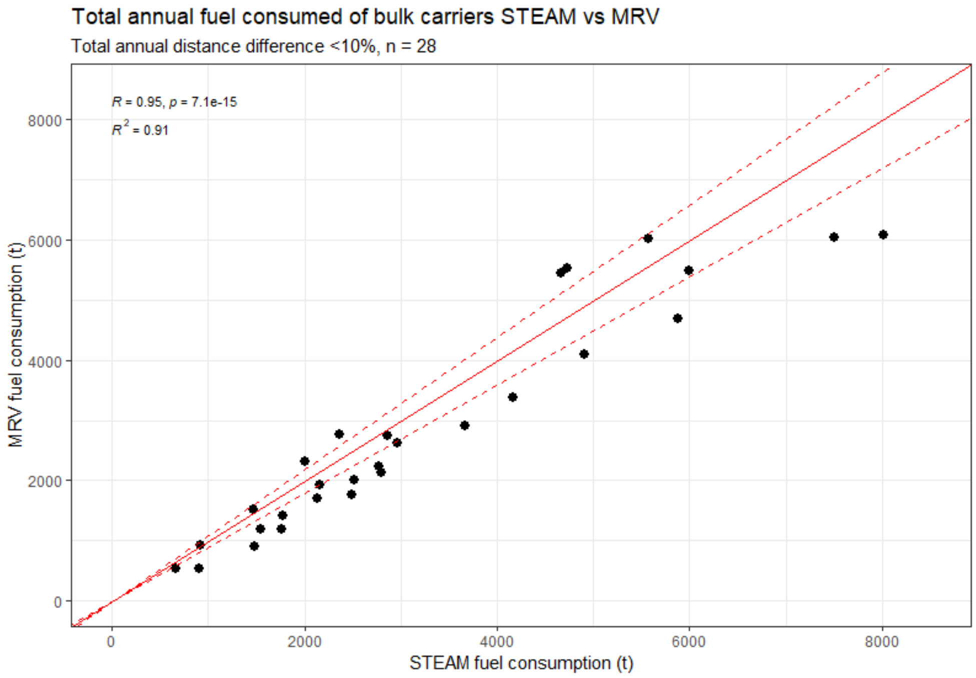


Figure 15 Scatterplot of total annual fuel consumed between STEAM (x-axis) and MRV (y-axis) of bulk carriers. The solid red line indicates 100% correlation between STEAM and MRV and the dashed lines a 10% deviation from perfect correlation. Correlation (R) and goodness of fit (R^2) of linear regression in the top left corner.

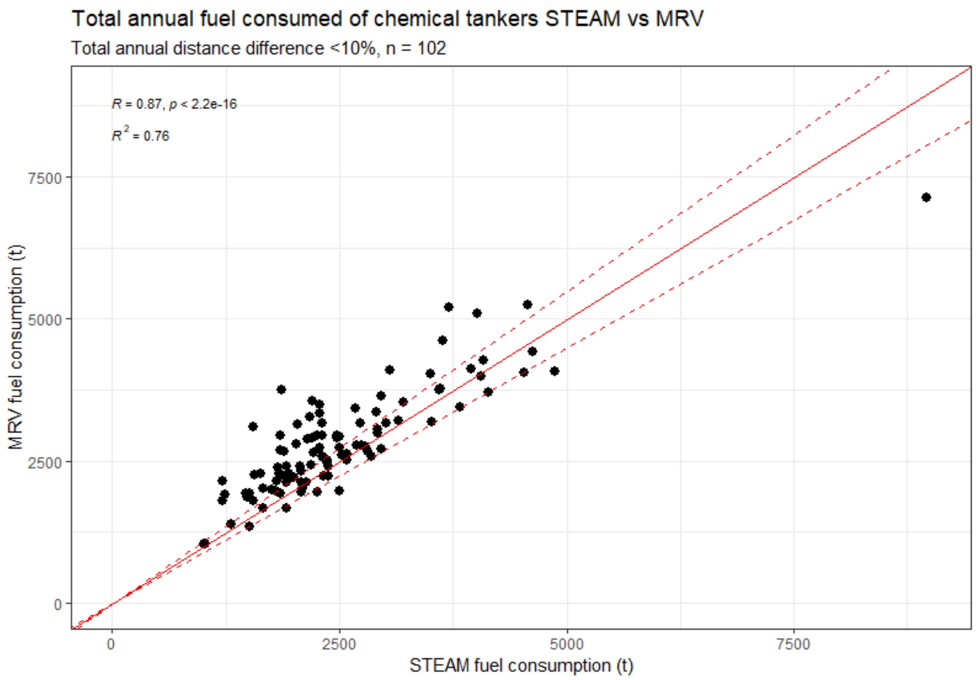


Figure 16 Scatterplot of total annual fuel consumed between STEAM (x-axis) and MRV (y-axis) of chemical tankers. The solid red line indicates 100% correlation between STEAM and MRV and the

dashed lines a 10% deviation from perfect correlation. Correlation (R) and goodness of fit of linear regression (R^2) in the top left corner.

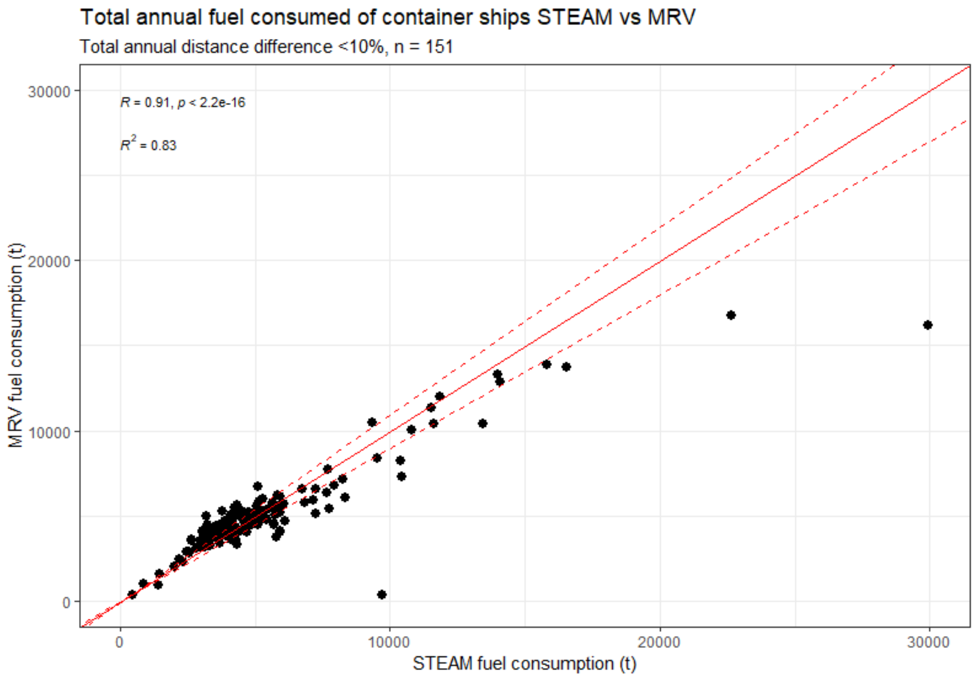


Figure 17 Scatterplot of total annual fuel consumed between STEAM (x-axis) and MRV (y-axis) of container vessels. The solid red line indicates 100% correlation between STEAM and MRV and the dashed lines a 10% deviation from perfect correlation. Correlation (R) and goodness of fit of linear regression (R^2) in the top left corner.

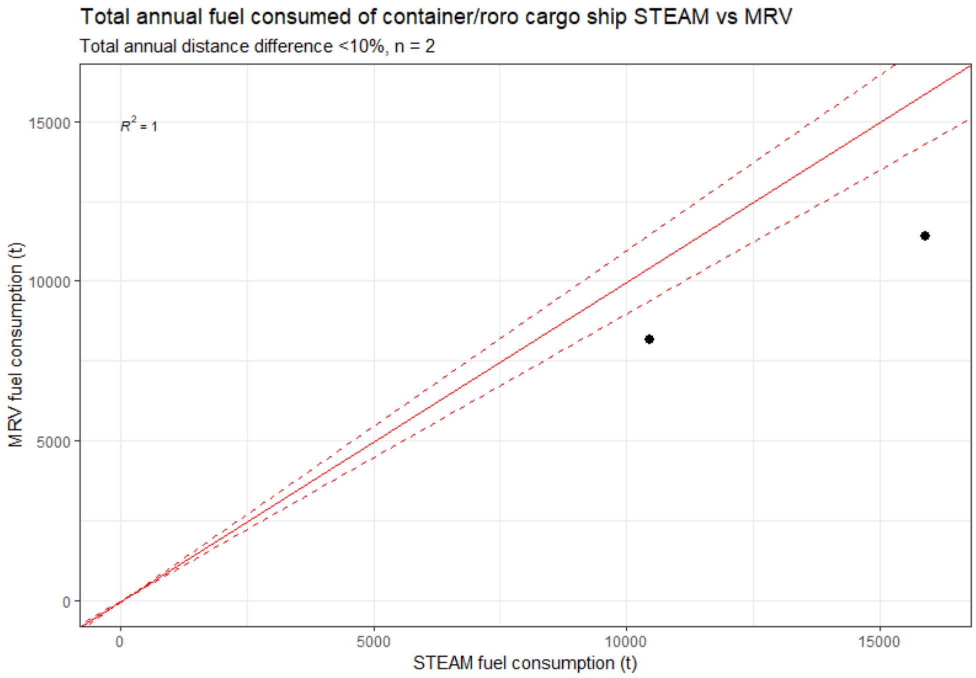


Figure 18 Scatterplot of total annual fuel consumed between STEAM (x-axis) and MRV (y-axis) of container/roro cargo ships. The solid red line indicates 100% correlation between STEAM and MRV and the dashed lines a 10% deviation from perfect correlation. Goodness of fit of linear regression (R^2) in the top left corner.

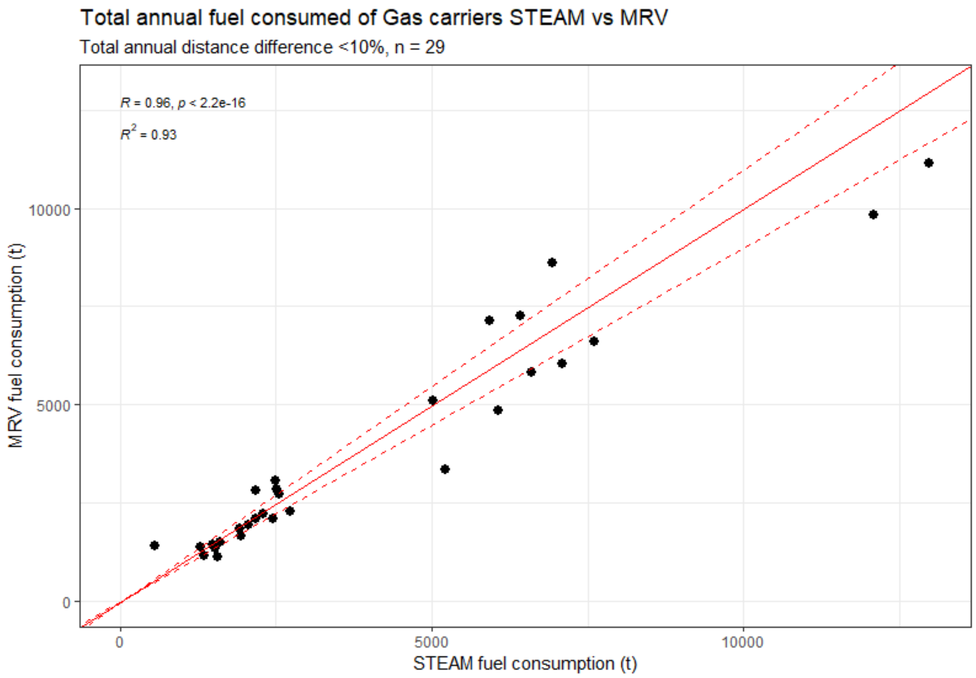


Figure 19 Scatterplot of total annual fuel consumed between STEAM (x-axis) and MRV (y-axis) of gas carriers. The solid red line indicates 100% correlation between STEAM and MRV and the dashed lines a 10% deviation from perfect correlation. Correlation (R) and goodness of fit of linear regression (R^2) in the top left corner.

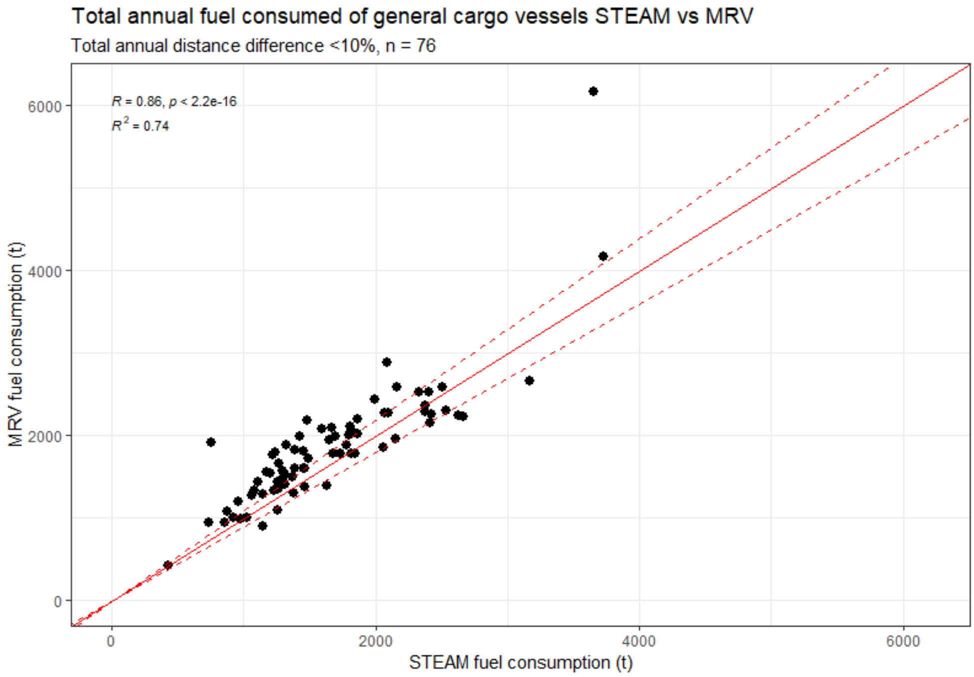


Figure 20 Scatterplot of total annual fuel consumed between STEAM (x-axis) and MRV (y-axis) of general cargo vessels. The solid red line indicates 100% correlation between STEAM and MRV and the dashed lines a 10% deviation from perfect correlation. Correlation (R) and goodness of fit of linear regression (R^2) in the top left corner.

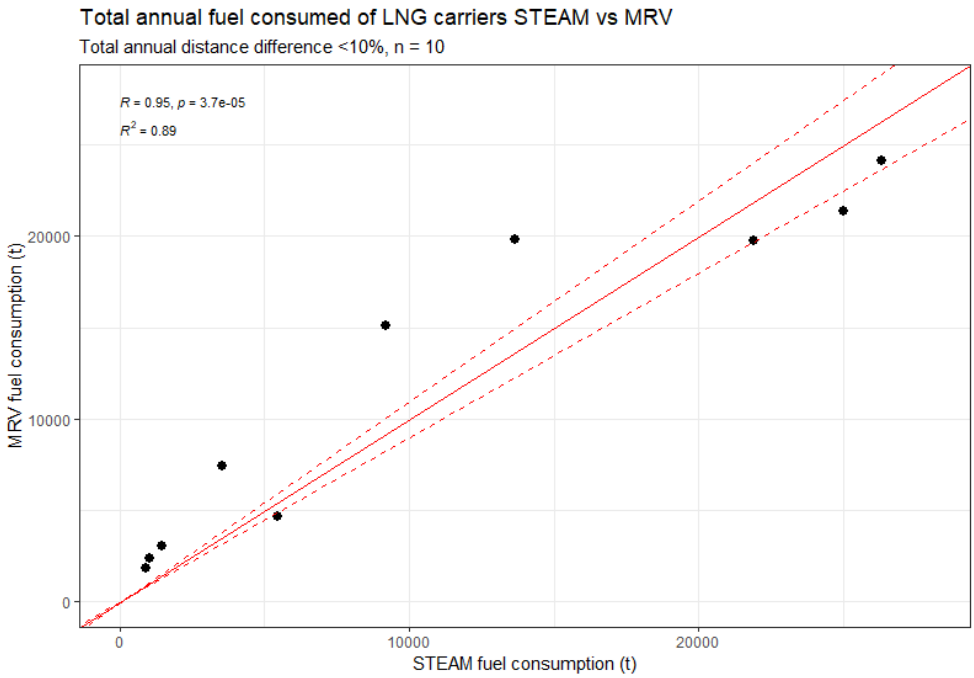


Figure 21 Scatterplot of total annual fuel consumed between STEAM (x-axis) and MRV (y-axis) of LNG carriers. The solid red line indicates 100% correlation between STEAM and MRV and the dashed lines a 10% deviation from perfect correlation. Correlation (R) and goodness of fit of linear regression (R^2) in the top left corner.

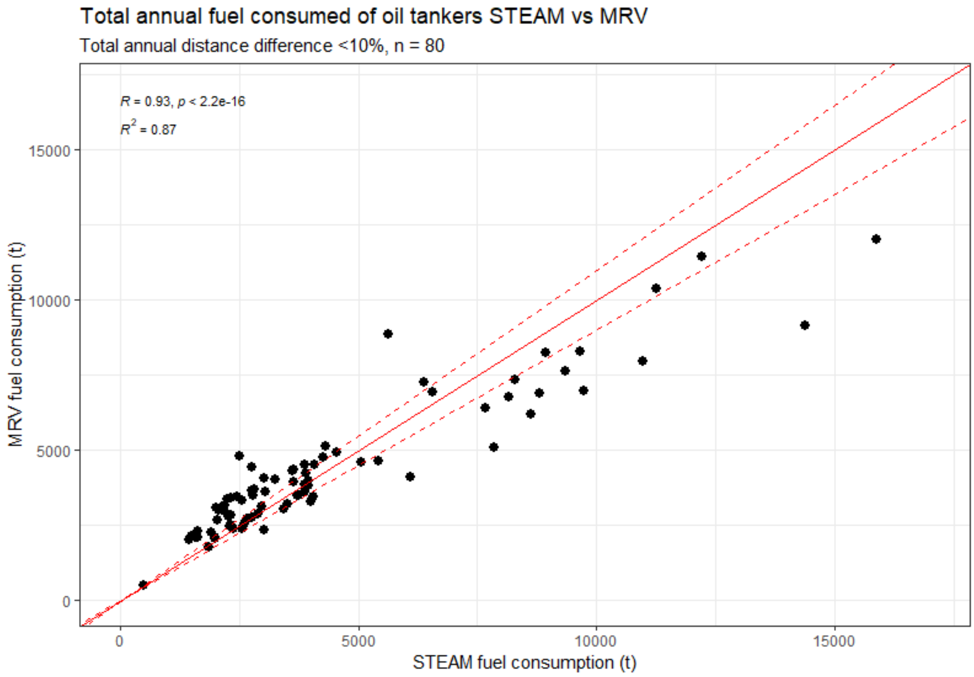


Figure 22 Scatterplot of total annual fuel consumed between STEAM (x-axis) and MRV (y-axis) of oil tankers. The solid red line indicates 100% correlation between STEAM and MRV and the dashed lines a 10% deviation from perfect correlation. Correlation (R) and goodness of fit of linear regression (R^2) in the top left corner.

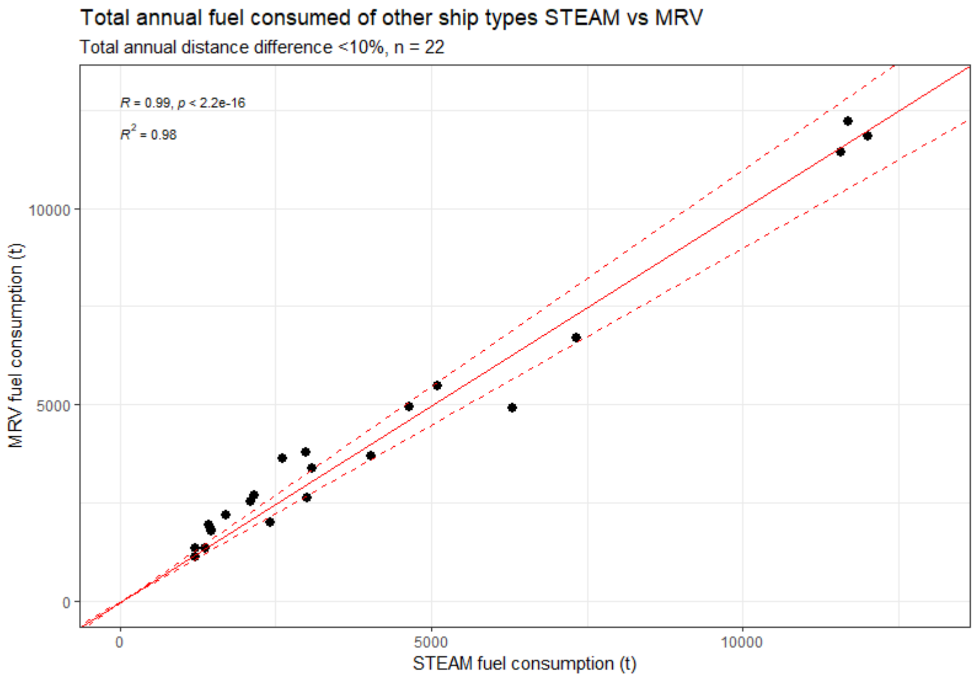


Figure 23 Scatterplot of total annual fuel consumed between STEAM (x-axis) and MRV (y-axis) of other vessel types. The solid red line indicates 100% correlation between STEAM and MRV and the dashed lines a 10% deviation from perfect correlation. Correlation (R) and goodness of fit of linear regression (R^2) in the top left corner.

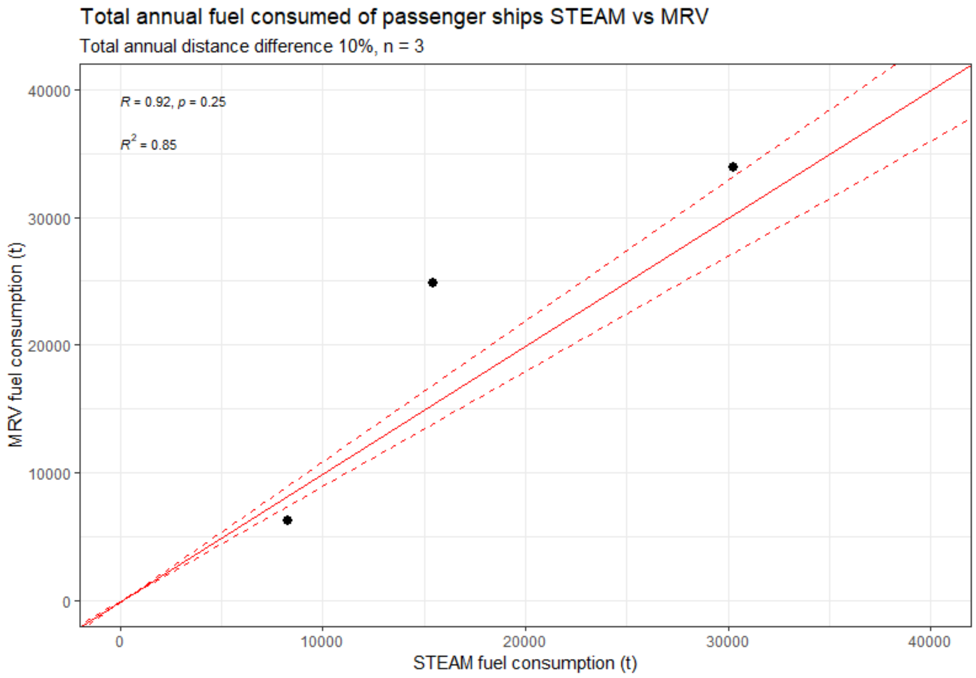


Figure 24 Scatterplot of total annual fuel consumed between STEAM (x-axis) and MRV (y-axis) of passenger ships. The solid red line indicates 100% correlation between STEAM and MRV and the dashed lines a 10% deviation from perfect correlation. Correlation (R) and goodness of fit of linear regression (R^2) in the top left corner.

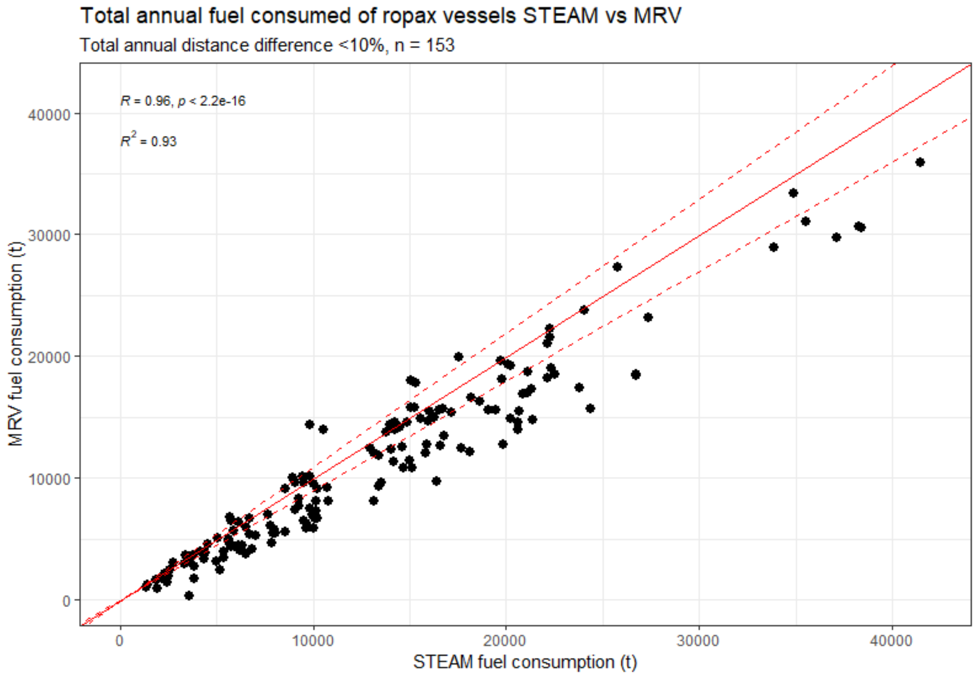


Figure 25 Scatterplot of total annual fuel consumed between STEAM (x-axis) and MRV (y-axis) of ropax vessels. The solid red line indicates 100% correlation between STEAM and MRV and the dashed lines a 10% deviation from perfect correlation. Correlation (R) and goodness of fit of linear regression (R^2) in the top left corner.

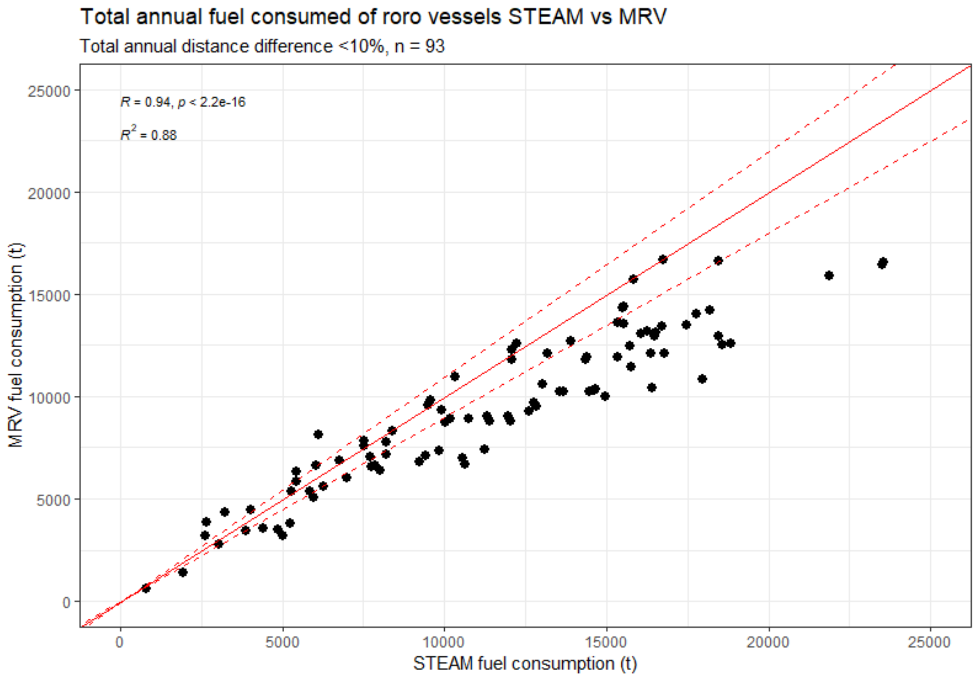


Figure 26 Scatterplot of total annual fuel consumed between STEAM (x-axis) and MRV (y-axis) of roro vessels. The solid red line indicates 100% correlation between STEAM and MRV and the dashed lines a 10% deviation from perfect correlation. Correlation (R) and goodness of fit of linear regression (R^2) in the top left corner.

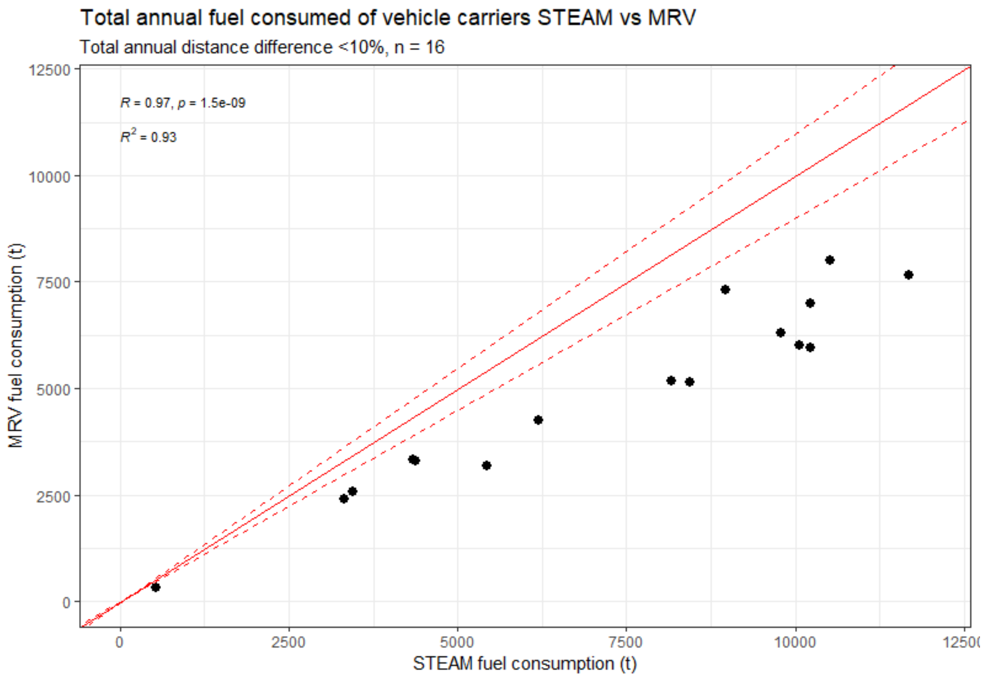


Figure 27 Scatterplot of total annual fuel consumed between STEAM (x-axis) and MRV (y-axis) of vehicle carriers. The solid red line indicates 100% correlation between STEAM and MRV and the dashed lines a 10% deviation from perfect correlation. Correlation (R) and goodness of fit of linear regression (R^2) in the top left corner.

4. Summary

The comparisons reveal that a reasonable 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 +11.4% of the MRV reports.

During the berthing period, ships normally require auxiliary power for onboard systems. If there are inaccuracies in auxiliary power prediction, the impact of these inaccuracies will be emphasized with increasing berthing time. However, there are also other contributions to inaccuracies, like the simplistic description of resistance caused by biofouling and exclusion of squat in the modelling.

The average absolute deviation of a single vessel of the studied fleet is about 13%. 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, data gaps concerning the position updates from Automatic Identification System (AIS) and weather contributions.

In several cases, outliers exist both on the STEAM predictions and MRV fuel reports. Resolving potential errors in MRV data should be communicated further to the European Maritime Safety Agency, but that is beyond the scope of this work.

Data

The emission estimates for the year 2023 are based on over 789 million AIS-messages sent by 39,238 different ships, of which 9,587 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, version 4.3.1 (STEAM; (Jalkanen et al., 2009, 2012, 2018, 2021; Johansson et al., 2013, 2017).

The AIS data for year 2023 had no temporal gaps, AIS data was available throughout the year and the temporal coverage was 100%. This is the second 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 28). On average, data flow was around 90,000 messages per hour.

The uncertainty evaluation and comparison to EU MRV fuel reporting was made using global AIS data for 2023 from Orbcomm Ltd. This global dataset includes both terrestrial and satellite AIS position reports and includes over 8.9 billion (10^9) position reports. STEAM also uses the technical details of the global fleet based on S&P Global database.

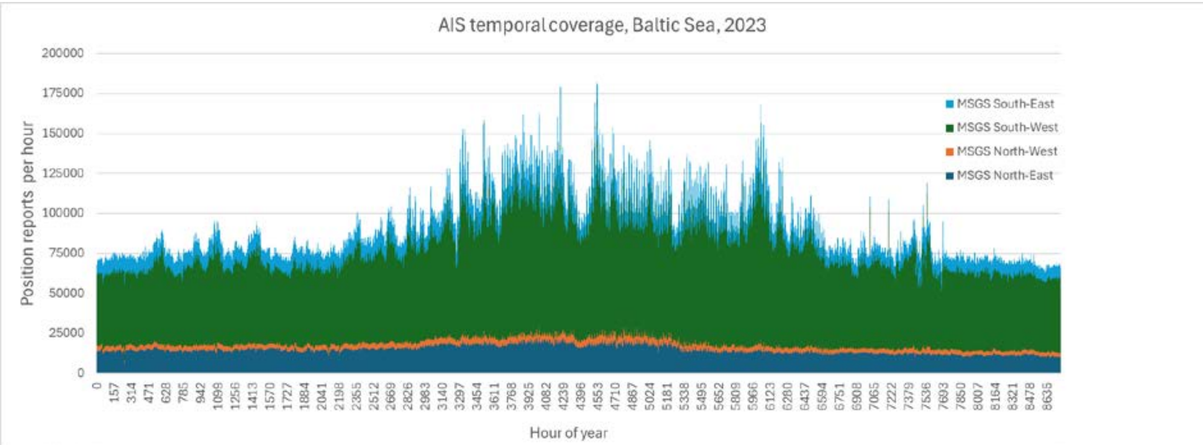


Figure 28 AIS-data hourly coverage in different parts of the Baltic Sea region for 2023.

Metadata

It should be noted that current estimates do not include contributions from vessels without active AIS equipment.

All calculations were made including the effects of sea currents, winds, waves and ice cover thickness. Impact of biofouling to vessel resistance was modeled with a simplified scaling approach, and impact of squat was neglected entirely.

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

Baltic – 2006	MAIN_FUEL [10^3 tonnes]	AUX_FUEL [10^3 tonnes]	AUX Boiler [10^3 tonnes]	NOx [tonnes]	SOx [tonnes]	PM25 [tonnes]	CO [tonnes]	CO_2 [10^3 tonnes]	CH_4 [tonnes]	NH_3 [tonnes]	N_2O [tonnes]	CO2e [10^3 tonnes]	TRAVEL [10^6 nm]	TRANSPORT WORK [10^6 tonne nm]	VOC [tonnes]	SHIPS
All	3987	436	90	292425	121247	14171	17110	14356	0	0	718	14546	70	412964	2409	8223
IMO	3966	422	89	290408	120686	14091	16816	14240	0	0	713	14429	68	412664	2390	7415
Baltic Proper	2477	201	45	177121	75322	8778	9801	8663	0	0	434	8778	42	248136	1438	2786
Kattegat	715	97	18	55528	21926	2572	3279	2637	0	0	132	2672	14	91070	449	4562
Gulf of Finland	446	93	17	35089	13824	1635	2324	1766	0	0	87	1789	7	47363	306	531
Gulf of Bothnia	318	35	8	22068	9246	1075	1513	1151	0	0	57	1166	6	22655	192	271
Gulf of Riga	32	10	2	2620	930	112	193	139	0	0	7	141	1	3739	24	73
RoPax_ships	1213	143	10	82088	36773	4258	5195	4346	0	0	219	4404	10	18280	728	243
Ro-ro cargo ships	517	16	5	33664	17020	1920	1910	1710	0	0	85	1733	5	33734	272	169
Vehicle_carriers	65	12	1	5440	2068	248	241	250	0	0	13	253	1	4138	41	183
General_cargo ships	546	65	33	37821	13031	1619	2811	2048	0	0	97	2073	25	67487	327	2395
Bulk_carriers	232	31	10	22542	7852	863	977	865	0	0	43	876	4	67657	149	1167
Container_ships	380	26	6	26461	12646	1464	1443	1312	0	0	67	1330	5	41605	222	420
Reefers	75	8	2	7211	2402	270	364	274	0	0	13	277	2	5482	46	334
Tankers	692	65	21	57270	22292	2639	2513	2473	0	0	128	2507	10	172604	429	1372
LNG_tankers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gas_tankers	21	3	1	1891	591	73	89	76	0	0	4	77	0	1978	13	125
Passenger_ships	14	7	2	1066	348	47	128	72	0	0	3	73	1	0	12	151
Cruisers	114	17	1	7653	3199	378	502	418	0	0	21	424	1	0	74	84
Fishing_vessels	15	9	0	1581	509	58	112	76	0	0	4	77	1	0	14	254
Service_ships	8	2	0	593	181	25	61	33	0	0	2	34	1	0	6	152

Baltic – 2007	MAIN_FUEL [10^3 tonnes]	AUX_FUEL [10^3 tonnes]	AUX Boiler [10^3 tonnes]	NOx [tonnes]	SOx [tonnes]	PM25 [tonnes]	CO [tonnes]	CO_2 [10^3 tonnes]	CH_4 [tonnes]	NH_3 [tonnes]	N_2O [tonnes]	CO2e [10^3 tonnes]	TRAVEL [10^6 nm]	TRANSPORT WORK [10^6 tonne nm]	VOC [tonnes]	SHIPS
All	4391	475	96	319275	118282	14443	18698	15784	11	0	794	15995	76	452382	2656	9306
IMO	4362	451	95	316302	117473	14327	18251	15612	11	0	787	15821	73	451788	2626	7855
Baltic Proper	2750	220	48	194802	73466	8945	10811	9600	11	0	485	9728	45	272010	1598	3294
Kattegat	764	108	19	59123	20755	2551	3541	2835	0	0	143	2873	15	97479	486	5003
Gulf of Finland	511	101	18	39778	14501	1785	2575	2005	0	0	100	2032	8	55299	348	585
Gulf of Bothnia	329	35	9	22563	8539	1037	1555	1184	0	0	59	1199	7	23710	197	339
Gulf of Riga	37	11	2	3008	1021	125	217	161	0	0	8	163	1	3883	27	85
RoPax_ships	1379	151	11	92102	37198	4494	5821	4904	0	0	248	4970	11	20446	825	266
Ro-ro cargo ships	531	12	5	33414	14634	1737	1969	1743	0	0	88	1766	5	36061	279	168
Vehicle_carriers	81	16	1	6912	2266	286	294	313	0	0	16	317	1	5690	52	218
General_cargo ships	562	69	35	38931	12815	1620	2927	2118	0	0	100	2144	26	70418	338	2526
Bulk_carriers	219	28	9	21082	6361	742	919	812	0	0	41	823	4	62423	140	1025
Container_ships	486	36	7	34453	13982	1695	1804	1684	0	0	87	1707	6	54576	285	479
Reefers	92	10	3	8768	2590	309	425	334	0	0	17	339	2	6670	56	353
Tankers	758	71	22	62513	20946	2609	2678	2704	11	0	142	2742	11	194013	470	1482
LNG_tankers	0	0	0	6	2	0	1	0	0	0	0	0	0	15	0	3
Gas_tankers	22	3	1	1974	563	72	90	81	0	0	4	82	0	2070	14	140
Passenger_ships	18	10	2	1404	458	62	166	94	0	0	4	95	1	0	15	209
Cruisers	118	15	1	7623	3326	395	502	425	0	0	22	431	1	0	74	84
Fishing_vessels	17	12	0	1755	506	63	138	90	0	0	4	91	1	0	17	383
Service_ships	10	4	0	783	243	33	84	46	0	0	2	46	1	0	9	189

Baltic – 2008	MAIN_FUEL [10^3 tonnes]	AUX_FUEL [10^3 tonnes]	AUX Boiler [10^3 tonnes]	NOx [tonnes]	SOx [tonnes]	PM25 [tonnes]	CO [tonnes]	CO_2 [10^3 tonnes]	CH_4 [tonnes]	NH_3 [tonnes]	N_2O [tonnes]	CO2e [10^3 tonnes]	TRAVEL [10^6 nm]	TRANSPORT WORK [10^6 tonne nm]	VOC [tonnes]	SHIPS
All	4341	507	98	314284	118125	14328	19216	15731	0	0	793	15941	76	447972	2674	10514
IMO	4301	475	96	310198	116984	14166	18613	15496	0	0	783	15703	71	447222	2634	8095
Baltic Proper	2699	236	48	190785	72677	8781	11085	9491	0	0	480	9618	45	267853	1597	3814
Kattegat	758	112	19	58137	20741	2539	3669	2829	0	0	143	2866	15	95833	492	5421
Gulf of Finland	521	109	19	39887	15099	1845	2663	2060	0	0	104	2087	8	56066	359	751
Gulf of Bothnia	322	37	9	22091	8437	1022	1554	1171	0	0	58	1186	7	23575	195	431
Gulf of Riga	42	12	3	3382	1172	142	244	181	0	0	9	184	1	4646	31	97
RoPax_ships	1355	155	12	89800	36856	4417	5824	4840	0	0	246	4905	11	20421	822	245
Ro-ro cargo ships	519	13	5	32213	14419	1690	2031	1710	0	0	86	1733	5	36775	276	170
Vehicle_carriers	104	21	1	8960	2954	372	375	402	0	0	21	408	1	7618	68	220
General_cargo ships	510	67	34	35238	11716	1480	2776	1940	0	0	92	1964	24	65115	313	2452
Bulk_carriers	205	27	8	19654	5992	701	861	764	0	0	39	774	3	59515	132	1051
Container_ships	529	44	8	37634	15288	1837	2083	1845	0	0	95	1871	7	61872	317	519
Reefers	86	10	3	8202	2433	287	404	313	0	0	16	317	2	6257	53	348
Tankers	726	75	23	59542	20290	2506	2725	2621	0	0	137	2658	11	187638	458	1671
LNG_tankers	0	0	0	5	2	0	1	0	0	0	0	0	0	6	0	3
Gas_tankers	25	3	1	2288	651	83	103	90	0	0	5	91	1	2755	16	135
Passenger_ships	19	10	2	1477	488	66	177	100	0	0	4	102	2	0	17	252
Cruisers	134	16	1	8508	3706	437	593	481	0	0	25	488	1	0	87	94
Fishing_vessels	20	14	0	1986	582	74	178	107	0	0	5	109	1	0	20	436
Service_ships	10	4	0	774	239	33	85	46	0	0	2	47	1	0	9	229

Baltic – 2009	MAIN_FUEL [10^3 tonnes]	AUX_FUEL [10^3 tonnes]	AUX Boiler [10^3 tonnes]	NOx [tonnes]	SOx [tonnes]	PM25 [tonnes]	CO [tonnes]	CO_2 [10^3 tonnes]	CH_4 [tonnes]	NH_3 [tonnes]	N_2O [tonnes]	CO2e [10^3 tonnes]	TRAVEL [10^6 nm]	TRANSPORT WORK [10^6 tonne nm]	VOC [tonnes]	SHIPS
All	3947	495	96	285150	108565	13108	18006	14435	2	0	730	14628	68	431378	2475	11179
IMO	3905	457	94	280677	107346	12933	17310	14175	2	0	719	14365	63	430908	2430	7955
Baltic Proper	2403	225	44	169273	65259	7847	10121	8500	1	0	431	8614	39	252846	1441	3761
Kattegat	738	122	24	56712	20425	2494	3726	2812	1	0	142	2850	15	98043	492	6125
Gulf of Finland	465	99	17	35447	13753	1665	2430	1849	0	0	93	1873	7	54225	327	742
Gulf of Bothnia	296	36	8	20172	7839	947	1463	1082	0	0	54	1096	6	21168	183	442
Gulf of Riga	45	13	3	3545	1288	155	267	192	0	0	9	194	1	5097	33	109
RoPax_ships	1276	147	11	83709	35152	4198	5514	4563	2	0	232	4625	10	19013	779	242
Ro-ro cargo ships	424	16	5	26604	11981	1385	1761	1415	0	0	72	1434	4	32250	231	153
Vehicle_carriers	40	16	1	3727	1200	151	195	180	0	0	9	183	1	3001	31	176
General_cargo ships	440	57	29	30183	10180	1283	2410	1671	0	0	79	1692	20	57408	272	2415
Bulk_carriers	210	26	8	19633	6109	721	854	774	0	0	40	785	3	61904	134	1007
Container_ships	410	40	7	29455	12033	1430	1706	1451	0	0	75	1471	5	51361	253	444
Reefers	75	9	3	7171	2120	251	355	277	0	0	14	280	2	5599	46	304
Tankers	755	83	29	61071	21401	2624	2908	2757	0	0	145	2795	11	199151	482	1764
LNG_tankers	0	0	0	32	12	2	7	2	0	0	0	2	0	29	0	6
Gas_tankers	16	3	1	1434	414	52	74	60	0	0	3	60	0	1662	11	126
Passenger_ships	19	12	3	1555	503	68	193	106	0	0	5	107	2	0	18	284
Cruisers	146	15	1	9208	3920	462	636	516	0	0	26	523	1	0	93	90
Fishing_vessels	20	12	0	1816	544	70	172	102	0	0	5	103	1	0	19	468
Service_ships	10	5	0	813	256	35	90	50	0	0	2	50	1	0	10	244

Baltic – 2010	MAIN_FUEL	AUX_FUEL	AUX Boiler	NOx	SOx	PM25	CO	CO_2	CH_4	NH_3	N_2O	CO2e	TRAVEL	TRANSPORT WORK	VOC	SHIPS
	[10^3 tonnes]	[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	3855	528	103	277630	89706	11669	18319	14266	5	0	722	14458	68	447517	2482	1237 5
IMO	3816	485	101	273027	88718	11507	17567	14000	5	0	710	14189	64	447292	2435	8048
Baltic Proper	2340	240	47	163992	54145	6988	10180	8358	4	0	425	8471	39	263347	1435	4362
Kattegat	702	121	24	53662	16518	2172	3682	2694	1	0	136	2730	15	98443	478	6449
Gulf of Finland	459	110	20	35248	10901	1452	2571	1874	0	0	94	1899	7	56371	339	928
Gulf of Bothnia	311	43	9	21374	7103	920	1609	1152	0	0	57	1168	6	24051	198	534
Gulf of Riga	43	13	3	3355	1039	137	276	188	0	0	9	191	1	5305	33	102
RoPax_ships	1152	135	10	75680	26558	3399	5006	4128	5	0	211	4184	9	17231	708	256
Ro-ro cargo ships	387	14	4	24138	9186	1147	1613	1292	0	0	66	1309	4	29338	214	142
Vehicle_carriers	51	13	1	4513	1193	163	195	206	0	0	11	208	1	3767	35	174
General_cargo ships	483	63	31	32680	10384	1373	2743	1837	0	0	87	1860	22	64757	303	2426
Bulk_carriers	215	27	8	19270	5150	666	863	796	0	0	41	807	3	65412	140	1047
Container_ships	446	55	8	32345	10989	1419	2046	1618	0	0	84	1640	6	61143	291	366
Reefers	59	8	2	5651	1410	182	292	220	0	0	11	222	1	4570	37	295
Tankers	736	86	33	58567	17607	2314	3049	2718	0	0	142	2756	11	199682	481	1729
LNG_tankers	1	0	0	39	12	2	8	3	0	0	0	3	0	39	1	7
Gas_tankers	15	2	1	1298	335	46	70	56	0	0	3	57	0	1579	10	119
Passenger_ships	17	12	3	1499	418	60	190	100	0	0	4	101	1	0	17	321
Cruisers	135	13	1	8276	2765	362	587	475	0	0	24	482	1	0	87	92
Fishing_vessels	16	12	0	1477	383	55	153	89	0	0	4	90	2	0	17	544
Service_ships	21	11	0	1621	453	64	162	103	0	0	5	104	1	0	21	309

Baltic – 2011	MAIN_FUEL [10^3 tonnes]	AUX_FUEL [10^3 tonnes]	AUX Boiler [10^3 tonnes]	NOx [tonnes]	SOx [tonnes]	PM25 [tonnes]	CO [tonnes]	CO_2 [10^3 tonnes]	CH_4 [tonnes]	NH_3 [tonnes]	N_2O [tonnes]	CO2e [10^3 tonnes]	TRAVEL [10^6 nm]	TRANSPORT WORK [10^6 tonne nm]	VOC [tonnes]	SHIPS
All	4034	587	112	289785	81354	11255	19458	15052	0	0	765	15254	73	476985	2628	14325
IMO	3983	532	109	283899	80074	11045	18498	14708	0	0	750	14906	66	476376	2568	8525
Baltic Proper	2475	270	50	173478	49465	6777	10926	8888	0	0	454	9009	43	284561	1533	5711
Kattegat	697	126	24	52388	14165	1990	3582	2693	0	0	137	2729	14	101418	474	6895
Gulf of Finland	505	130	26	38917	10439	1488	2980	2101	0	0	106	2129	8	60997	383	962
Gulf of Bothnia	313	46	9	21530	6328	865	1674	1172	0	0	58	1187	7	24243	203	627
Gulf of Riga	44	15	3	3472	956	135	295	198	0	0	10	201	1	5766	36	130
RoPax_ships	1286	152	11	84636	25768	3493	5618	4608	0	0	236	4670	10	20026	794	270
Ro-ro cargo ships	396	16	4	24453	7722	1044	1698	1321	0	0	67	1339	4	30650	219	138
Vehicle_carriers	63	16	1	5557	1315	189	243	255	0	0	13	259	1	4660	44	185
General_cargo ships	443	66	32	29706	9116	1230	2616	1722	0	0	82	1743	21	62595	287	2562
Bulk_carriers	231	31	10	20194	4605	648	927	865	0	0	45	877	4	75359	152	1187
Container_ships	505	64	8	37177	10168	1431	2195	1835	0	0	96	1860	7	75065	328	561
Reefers	50	7	2	4900	1016	142	252	187	0	0	9	190	1	4030	32	245
Tankers	707	91	38	56222	14299	2017	3055	2658	0	0	140	2695	11	203071	470	1787
LNG_tankers	1	0	0	45	17	3	7	3	0	0	0	3	0	54	1	6
Gas_tankers	15	2	1	1233	297	42	69	55	0	0	3	56	0	1475	10	127
Passenger_ships	22	14	3	1833	529	75	234	123	0	0	5	124	2	0	20	426
Cruisers	135	14	1	8265	2395	334	606	480	0	0	25	486	1	0	89	100
Fishing_vessels	16	13	0	1517	391	56	160	93	0	0	4	94	2	0	17	634
Service_ships	27	13	0	2026	589	83	204	127	0	0	6	129	1	0	25	311

Baltic – 2012	MAIN_FUEL [10^3 tonnes]	AUX_FUEL [10^3 tonnes]	AUX Boiler [10^3 tonnes]	NOx [tonnes]	SOx [tonnes]	PM25 [tonnes]	CO [tonnes]	CO_2 [10^3 tonnes]	CH_4 [tonnes]	NH_3 [tonnes]	N_2O [tonnes]	CO2e [10^3 tonnes]	TRAVEL [10^6 nm]	TRANSPORT WORK [10^6 tonne nm]	VOC [tonnes]	SHIPS
All	3858	579	110	276471	78107	10781	19733	14457	13	0	735	14652	73	494556	2544	15542
IMO	3790	518	106	269233	76567	10530	18557	14037	13	0	717	14227	65	493805	2472	8363
Baltic Proper	2368	275	50	165814	47586	6502	11248	8567	10	0	437	8683	43	295301	1494	6688
Kattegat	658	128	24	49799	13476	1891	3649	2575	1	0	131	2610	14	102956	458	6946
Gulf of Finland	500	118	24	37861	10258	1457	2962	2041	0	0	103	2068	8	66331	372	1057
Gulf of Bothnia	286	43	9	19562	5815	795	1577	1077	2	0	53	1091	7	23810	185	696
Gulf of Riga	46	14	3	3435	972	136	296	197	0	0	10	200	1	6159	35	155
RoPax_ships	1229	147	11	81243	24658	3330	5561	4413	9	0	226	4473	10	19540	762	251
Ro-ro cargo ships	336	13	4	20230	6576	885	1562	1125	0	0	58	1140	4	27255	190	132
Vehicle_carriers	70	16	1	6034	1453	207	285	278	0	0	15	282	1	5095	48	159
General_cargo ships	411	58	29	26916	8452	1138	2508	1583	0	0	75	1603	20	60202	267	2481
Bulk_carriers	236	31	10	19579	4723	664	966	879	0	0	46	891	4	84208	156	1237
Container_ships	497	71	8	37023	10128	1424	2347	1833	0	0	95	1858	7	79587	335	542
Reefers	67	11	3	6209	1376	194	428	259	0	0	13	262	2	5423	46	255
Tankers	671	87	38	53155	13628	1908	3142	2532	0	0	133	2567	10	211603	451	1752
LNG_tankers	1	0	0	65	24	4	12	5	4	0	0	5	0	92	1	8
Gas_tankers	15	2	1	1206	305	43	78	57	0	0	3	58	0	1551	10	136
Passenger_ships	24	15	3	2006	577	82	250	133	0	0	6	134	2	0	22	462
Cruisers	139	16	1	8570	2654	362	633	496	0	0	26	503	1	0	93	100
Fishing_vessels	17	13	0	1557	413	59	175	97	0	0	4	98	3	0	18	714
Service_ships	17	12	0	1414	388	56	157	90	0	0	4	92	1	0	18	344

Baltic – 2013	MAIN_FUEL [10^3 tonnes]	AUX_FUEL [10^3 tonnes]	AUX Boiler [10^3 tonnes]	NOx [tonnes]	SOx [tonnes]	PM25 [tonnes]	CO [tonnes]	CO_2 [10^3 tonnes]	CH_4 [tonnes]	NH_3 [tonnes]	N_2O [tonnes]	CO2e [10^3 tonnes]	TRAVEL [10^6 nm]	TRANSPORT WORK [10^6 tonne nm]	VOC [tonnes]	SHIPS
All	3708	543	108	261113	74666	10295	19148	13854	634	0	707	14059	67	499122	2474	9724
IMO	3672	520	106	257583	73830	10168	18667	13661	634	0	699	13864	63	498460	2441	8013
Baltic Proper	2239	246	48	154597	44919	6126	10746	8056	184	0	413	8170	39	296292	1426	3152
Kattegat	639	118	25	47228	13124	1831	3444	2486	1	0	127	2519	13	102528	443	5204
Gulf of Finland	502	122	23	37925	10128	1449	3017	2058	0	0	105	2086	8	69539	381	856
Gulf of Bothnia	285	42	9	18047	5552	757	1645	1061	450	0	54	1087	6	24610	189	387
Gulf of Riga	44	15	3	3317	942	132	296	194	0	0	10	196	1	6153	35	125
RoPax_ships	1172	152	11	76306	23082	3125	5575	4239	634	0	218	4315	10	18948	747	249
Ro-ro cargo ships	338	16	4	20002	6611	892	1608	1137	0	0	58	1153	4	27616	193	119
Vehicle_carriers	72	16	1	5975	1481	210	306	282	0	0	15	286	1	5045	49	146
General_cargo ships	395	56	29	25452	8135	1099	2509	1526	0	0	73	1545	19	60179	261	2286
Bulk_carriers	230	33	10	18726	4696	657	1003	870	0	0	46	882	4	89127	157	1223
Container_ships	474	74	8	35488	9731	1372	2351	1769	0	0	92	1793	7	77531	329	409
Reefers	48	5	2	4665	968	134	217	173	0	0	9	176	1	3868	30	184
Tankers	651	88	40	51339	13312	1864	3245	2478	0	0	129	2512	10	214732	446	1676
LNG_tankers	2	0	0	111	40	6	14	8	0	0	0	8	0	118	2	10
Gas_tankers	19	3	1	1458	376	54	88	70	0	0	4	71	0	1959	12	139
Passenger_ships	19	11	2	1520	449	63	216	101	0	0	5	102	2	0	17	225
Cruisers	155	16	1	9320	2851	391	711	545	0	0	28	553	1	0	104	95
Fishing_vessels	16	13	0	1443	390	56	161	92	0	0	4	93	2	0	17	588
Service_ships	12	8	0	940	275	40	112	62	0	0	3	62	1	0	13	254

Baltic – 2014	MAIN_FUEL [10^3 tonnes]	AUX_FUEL [10^3 tonnes]	AUX Boiler [10^3 tonnes]	NOx [tonnes]	SOx [tonnes]	PM25 [tonnes]	CO [tonnes]	CO_2 [10^3 tonnes]	CH_4 [tonnes]	NH_3 [tonnes]	N_2O [tonnes]	CO2e [10^3 tonnes]	TRAVEL [10^6 nm]	TRANSPORT WORK [10^6 tonne nm]	VOC [tonnes]	SHIPS
All	3896	600	111	274247	77574	10804	20363	14642	686	0	744	14858	75	521085	2601	19992
IMO	3807	522	107	264844	75556	10478	18923	14097	686	0	721	14308	64	520287	2508	8355
Baltic Proper	2366	283	51	163230	46948	6470	11488	8585	203	0	438	8706	44	308952	1510	8443
Kattegat	651	131	24	48374	13312	1873	3702	2562	8	0	130	2597	15	106661	459	9066
Gulf of Finland	534	123	24	40056	10540	1523	3099	2166	5	0	110	2195	8	73317	398	1427
Gulf of Bothnia	300	48	9	19151	5814	802	1764	1128	470	0	57	1156	7	25243	198	875
Gulf of Riga	45	15	3	3436	961	136	311	201	0	0	10	204	1	6912	37	181
RoPax_ships	1208	148	11	77978	23639	3222	5525	4340	661	0	224	4417	9	18019	757	246
Ro-ro cargo ships	371	16	4	21896	6776	936	1650	1243	0	0	64	1259	4	28220	207	112
Vehicle_carriers	71	15	1	5903	1453	206	283	275	0	0	14	279	1	4795	47	148
General_cargo ships	405	56	29	25675	8295	1128	2550	1558	0	0	74	1578	19	61624	268	2375
Bulk_carriers	264	38	12	21124	5367	752	1122	996	0	0	53	1010	4	104628	181	1552
Container_ships	476	77	8	35975	9745	1383	2460	1783	0	0	93	1808	6	83462	336	446
Reefers	43	4	1	4255	877	121	183	156	0	0	8	158	1	3518	27	146
Tankers	664	90	39	51895	13551	1898	3301	2523	0	0	132	2558	11	213056	453	1691
LNG_tankers	3	0	0	143	51	8	23	11	16	0	1	12	0	286	2	15
Gas_tankers	31	4	1	2295	619	89	120	113	0	0	6	115	1	3478	20	136
Passenger_ships	24	15	4	2150	587	83	292	138	0	0	6	139	3	0	23	682
Cruisers	150	17	1	8995	2660	371	692	534	0	0	28	541	1	0	102	102
Fishing_vessels	27	15	0	2134	587	85	224	134	0	0	6	136	4	0	23	985
Service_ships	14	9	0	1173	333	48	142	72	0	0	3	73	1	0	14	378

Baltic – 2015	**MAIN_FUEL**	**AUX_FUEL**	**AUX Boiler**	**NOx**	**SOx**	**PM25**	**CO**	**CO_2**	**CH_4**	**NH_3**	**N_2O**	**CO2e**	**TRAVEL**	**TRANSPORT WORK**	**VOC**	**SHIPS**
	[10^3 tonnes]	**[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	3829	573	109	270025	8596	3734	19557	14274	718	0	736	14489	74	526097	2568	20528
IMO	3743	526	106	262281	8334	3613	18510	13842	718	0	718	14052	62	524949	2496	8319
Baltic Proper	2245	263	51	155673	4889	2128	10933	8097	203	0	419	8214	43	311393	1450	9259
Kattegat	646	127	23	47738	1524	672	3627	2518	46	0	129	2554	15	111281	457	8817
Gulf of Finland	616	125	24	45347	1455	619	3067	2422	16	0	126	2456	8	72843	438	1344
Gulf of Bothnia	278	43	8	17854	608	262	1634	1039	452	0	53	1066	6	23724	186	918
Gulf of Riga	44	15	3	3414	121	53	296	197	0	0	10	200	1	6856	36	190
RoPax_ships	1153	146	11	75285	2459	984	5338	4138	672	0	216	4214	9	17475	731	254
Ro-ro cargo ships	375	17	4	21993	748	313	1661	1256	0	0	65	1273	4	28108	210	127
Vehicle_carriers	48	11	1	4031	115	47	195	190	0	0	10	193	1	3198	33	145
General_cargo ships	395	56	28	25118	919	411	2499	1516	0	0	73	1536	19	60808	266	2302
Bulk_carriers	276	41	13	22111	635	292	1197	1044	0	0	56	1059	4	109514	194	1584
Container_ships	453	74	8	34804	1030	485	2274	1694	0	0	89	1717	6	80231	325	434
Reefers	41	5	1	4135	90	41	181	149	0	0	8	151	1	3255	26	157
Tankers	708	94	39	55458	1615	734	3331	2661	0	0	141	2698	11	219323	482	1704
LNG_tankers	5	0	0	223	9	4	30	16	20	0	1	17	0	482	3	15
Gas_tankers	33	4	1	2448	72	30	130	119	1	0	6	121	1	3705	21	129
Passenger_ships	21	6	2	1428	56	21	176	93	0	0	4	95	2	0	15	774
Cruisers	141	15	1	8280	301	126	668	496	0	0	26	503	1	0	94	91
Fishing_vessels	29	18	0	2349	89	38	262	146	0	0	7	148	3	0	26	896
Service_ships	15	11	0	1389	50	21	170	83	2	0	4	84	1	0	17	566

Baltic – 2016	MAIN_FUEL [10^3 tonnes]	AUX_FUEL [10^3 tonnes]	AUX Boiler [10^3 tonnes]	NOx [tonnes]	SOx [tonnes]	PM25 [tonnes]	CO [tonnes]	CO_2 [10^3 tonnes]	CH_4 [tonnes]	NH_3 [tonnes]	N_2O [tonnes]	CO2e [10^3 tonnes]	TRAVEL [10^6 nm]	TRANSPORT WORK [10^6 tonne nm]	VOC [tonnes]	SHIPS
All	3782	703	115	271760	8724	3886	21352	14559	771	0	745	14778	77	544180	2641	23066
IMO	3679	539	111	257676	8200	3608	18682	13702	771	0	709	13912	63	543711	2493	8564
Baltic Proper	2272	334	52	159657	5042	2236	11793	8414	224	0	432	8535	44	319687	1514	9974
Kattegat	680	173	26	51969	1679	763	4377	2781	71	0	141	2821	16	119737	509	10378
Gulf of Finland	496	127	25	37631	1230	551	3051	2051	27	0	105	2080	8	74237	381	1464
Gulf of Bothnia	294	55	9	19262	658	286	1831	1125	450	0	57	1153	7	23953	202	1056
Gulf of Riga	41	15	3	3241	115	51	300	187	0	0	9	190	1	6567	35	194
RoPax_ships	1151	143	11	74421	2415	979	5272	4124	681	0	215	4200	9	17568	731	237
Ro-ro cargo ships	372	19	4	21864	737	313	1644	1253	6	0	64	1270	4	28585	211	127
Vehicle_carriers	44	12	1	3903	105	44	182	179	0	0	9	182	1	3222	31	151
General_cargo ships	386	56	29	24511	904	408	2487	1491	0	0	72	1510	19	61304	262	2290
Bulk_carriers	271	43	13	21483	629	293	1205	1035	19	0	55	1050	4	113247	194	1641
Container_ships	449	79	8	35187	1033	498	2378	1696	0	0	89	1720	6	89581	331	419
Reefers	42	5	2	4325	95	44	207	156	0	0	8	158	1	3568	28	146
Tankers	658	93	42	51348	1526	705	3292	2511	4	0	133	2546	11	221606	459	1690
LNG_tankers	8	1	0	431	17	8	48	29	24	0	2	30	0	1303	6	18
Gas_tankers	36	5	1	2649	80	34	146	132	1	0	7	134	1	4197	24	141
Passenger_ships	25	17	4	2286	88	35	314	145	0	0	7	147	3	0	25	412
Cruisers	133	12	1	7712	277	118	643	462	0	0	24	468	1	0	90	97
Fishing_vessels	26	16	0	2139	81	34	226	134	0	0	6	135	4	0	24	859
Service_ships	16	14	0	1534	59	24	206	97	3	0	5	99	1	0	21	400

Baltic – 2017	MAIN_FUEL [10^3 tonnes]	AUX_FUEL [10^3 tonnes]	AUX Boiler [10^3 tonnes]	NOx [tonnes]	SOx [tonnes]	PM25 [tonnes]	CO [tonnes]	CO_2 [10^3 tonnes]	CH_4 [tonnes]	NH_3 [tonnes]	N_2O [tonnes]	CO2e [10^3 tonnes]	TRAVEL [10^6 nm]	TRANSPORT WORK [10^6 tonne nm]	VOC [tonnes]	SHIPS
All	3468	653	102	245929	7935	3547	19891	13353	1627	0	684	13580	78	564921	2431	25176
IMO	3337	480	97	229787	7339	3242	16922	12376	1627	0	643	12592	64	564210	2265	8902
Baltic Proper	2046	311	46	142318	4535	2017	10829	7607	255	0	390	7717	46	342368	1368	11344
Kattegat	641	171	24	49109	1591	722	4096	2644	81	0	134	2682	15	113831	487	10778
Gulf of Finland	473	108	22	34251	1102	499	2981	1898	810	0	99	1947	8	73783	357	1703
Gulf of Bothnia	262	47	7	16817	578	251	1633	995	481	0	50	1022	6	21555	179	1117
Gulf of Riga	47	15	4	3435	129	59	352	209	0	0	10	212	3	13384	41	234
RoPax_ships	1147	132	10	72335	2334	956	5367	4068	1487	0	214	4166	9	17579	730	243
Ro-ro cargo ships	371	19	3	21549	731	312	1521	1247	0	0	64	1264	3	27415	208	127
Vehicle_carriers	56	15	1	4626	115	49	303	224	10	0	12	227	1	4237	40	156
General_cargo ships	390	55	28	24518	908	413	2501	1498	0	0	72	1517	19	62556	265	2433
Bulk_carriers	293	46	14	22701	678	316	1285	1117	34	0	60	1133	4	124277	208	1728
Container_ships	456	84	9	36386	1058	516	2474	1739	0	0	91	1763	6	90640	342	451
Reefers	41	5	2	4144	92	43	196	152	0	0	8	154	1	3573	27	145
Tankers	631	96	43	49081	1475	686	3264	2437	51	0	129	2472	10	213764	449	1782
LNG_tankers	9	1	1	496	19	9	64	34	54	0	2	36	0	1597	7	31
Gas_tankers	31	4	1	2309	69	29	130	115	1	0	6	116	1	3453	21	127
Passenger_ships	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cruisers	147	16	1	8497	313	132	717	522	0	0	27	529	1	0	100	96
Fishing_vessels	26	16	0	2104	80	34	221	131	0	0	6	133	3	0	24	886
Service_ships	17	18	0	1689	67	28	181	111	0	0	5	113	1	0	24	421

Baltic – 2018	MAIN_FUEL	AUX_FUEL	AUX Boiler	NOx	SOx	PM25	CO	CO_2	CH_4	NH_3	N_2O	CO2e	TRAVEL	TRANSPORT WORK	VOC	SHIPS
	[10^3 tonnes]	[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	3878	670	124	271140	8757	3895	20895	14776	1793	0	762	15028	69	558239	2709	14396
IMO	3771	592	119	260349	8389	3722	19557	14171	1793	0	736	14416	63	556064	2607	8960
Baltic Proper	2368	338	57	162991	5207	2310	11833	8749	328	0	452	8878	41	330128	1585	5584
Kattegat	666	144	26	49076	1588	711	3772	2647	110	0	136	2686	14	119051	490	7030
Gulf of Finland	498	128	29	36795	1193	540	3252	2061	851	0	107	2114	8	77827	392	1028
Gulf of Bothnia	300	49	9	19094	653	281	1739	1129	503	0	57	1158	6	24962	204	620
Gulf of Riga	46	11	3	3183	116	52	299	190	0	0	10	193	1	6271	37	134
RoPax_ships	1153	135	10	72749	2345	965	5413	4097	1448	0	215	4195	9	17832	735	238
Ro-ro cargo ships	368	19	3	21246	728	308	1502	1239	0	0	64	1256	3	27349	206	119
Vehicle_carriers	54	15	1	4453	111	48	307	218	10	0	12	221	1	4093	40	157
General_cargo ships	419	64	31	26590	986	446	2725	1629	2	0	79	1650	20	67974	288	2439
Bulk_carriers	298	50	15	23195	697	326	1332	1148	41	0	62	1166	5	127299	215	1799
Container_ships	494	105	9	39779	1169	564	2679	1927	0	0	102	1954	6	99005	381	464
Reefers	33	4	1	3161	74	35	161	121	0	0	6	123	1	2810	22	138
Tankers	603	99	46	46760	1429	671	3287	2365	81	0	125	2401	10	207170	441	1849
LNG_tankers	11	1	0	510	19	9	75	38	98	0	2	42	0	1707	8	45
Gas_tankers	27	4	1	1973	60	26	114	100	0	0	5	101	1	2983	18	102
Passenger_ships	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cruisers	167	20	1	9535	357	148	802	595	0	0	31	603	1	0	113	104
Fishing_vessels	26	13	0	1994	75	32	210	123	0	0	6	125	3	0	22	878
Service_ships	20	19	0	1868	76	32	205	125	2	0	6	127	1	0	27	468

Baltic – 2019	MAIN_FUEL [10^3 tonnes]	AUX_FUEL [10^3 tonnes]	AUX Boiler [10^3 tonnes]	NOx [tonnes]	SOx [tonnes]	PM25 [tonnes]	CO [tonnes]	CO_2 [10^3 tonnes]	CH_4 [tonnes]	NH_3 [tonnes]	N_2O [tonnes]	CO2e [10^3 tonnes]	TRAVEL [10^6 nm]	TRANSPORT WORK [10^6 tonne nm]	VOC [tonnes]	SHIPS
All	4037	904	131	287001	9445	4275	25130	16025	2931	0	818	16324	81	581577	2937	29248
IMO	3872	606	127	263236	8541	3796	20759	14548	2931	0	758	14831	65	580784	2686	9156
Baltic Proper	2411	441	57	167351	5429	2443	13708	9198	1187	0	471	9356	47	338871	1667	13130
Kattegat	746	240	32	57904	1931	895	5422	3221	197	0	162	3270	18	130434	595	12502
Gulf of Finland	525	149	30	38887	1281	584	3659	2219	935	0	115	2276	9	81655	421	1980
Gulf of Bothnia	307	61	9	19578	682	297	1998	1186	610	0	60	1219	7	24722	214	1392
Gulf of Riga	47	13	3	3281	123	56	342	201	2	0	10	203	1	5894	39	244
RoPax_ships	1219	137	11	75156	2438	1002	5921	4310	2119	0	227	4430	10	18682	770	246
Ro-ro cargo ships	361	18	3	20628	715	303	1484	1212	0	0	63	1229	3	26443	201	130
Vehicle_carriers	54	16	1	4489	114	50	312	221	10	0	12	224	1	4137	40	169
General_cargo ships	404	61	31	25134	946	429	2692	1567	4	0	76	1588	20	65950	279	2357
Bulk_carriers	299	50	15	22949	700	327	1354	1153	42	0	62	1171	5	128488	216	1783
Container_ships	490	106	9	39355	1149	562	2778	1912	67	0	101	1941	6	112478	384	604
Reefers	36	5	1	3405	81	38	180	133	0	0	7	135	1	3080	24	119
Tankers	619	105	52	47372	1460	684	3501	2450	291	0	130	2492	10	216059	460	1897
LNG_tankers	19	2	1	812	28	14	161	65	233	0	4	73	0	3003	14	57
Gas_tankers	29	5	1	2125	65	28	132	109	2	0	6	110	1	3257	20	119
Passenger_ships	22	18	4	2154	84	33	279	139	0	0	6	141	3	0	23	460
Cruisers	170	18	1	9544	358	148	816	600	35	0	31	609	1	0	114	110
Fishing_vessels	28	13	0	2075	78	33	216	129	0	0	6	131	4	0	23	894
Service_ships	37	23	0	2744	114	48	323	188	1	0	9	191	2	0	39	443

Baltic – 2020	MAIN_FUEL [10^3 tonnes]	AUX_FUEL [10^3 tonnes]	AUX Boiler [10^3 tonnes]	NOx [tonnes]	SOx [tonnes]	PM25 [tonnes]	CO [tonnes]	CO_2 [10^3 tonnes]	CH_4 [tonnes]	NH_3 [tonnes]	N_2O [tonnes]	CO2e [10^3 tonnes]	TRAVEL [10^6 nm]	TRANSPORT WORK [10^6 tonne nm]	VOC [tonnes]	SHIPS
All	3444	821	130	246915	8107	3717	23072	13877	3433	0	707	14161	77	554730	2578	30006
IMO	3268	527	123	221959	7184	3231	18641	12368	3433	0	644	12634	61	551435	2320	8688
Baltic Proper	2119	394	56	146782	4744	2155	12735	8116	1780	0	416	8276	45	322361	1488	13781
Kattegat	634	227	33	50224	1680	787	5099	2827	290	0	141	2872	17	119568	527	12536
Gulf of Finland	404	131	29	30910	1011	472	3132	1774	863	0	92	1822	8	81906	344	1976
Gulf of Bothnia	251	57	9	16442	576	258	1807	1001	493	0	50	1028	7	25743	187	1464
Gulf of Riga	36	12	3	2558	97	45	298	160	7	0	8	163	1	5152	32	249
RoPax_ships	1017	101	10	60941	1982	821	5167	3553	2377	0	188	3669	9	17087	654	231
Ro-ro cargo ships	338	18	4	19636	675	284	1501	1141	0	0	59	1157	3	26177	191	117
Vehicle_carriers	33	18	1	3160	83	37	220	162	6	0	9	164	0	3048	29	155
General_cargo ships	391	63	32	24693	928	430	2774	1538	3	0	74	1558	20	68490	280	2595
Bulk_carriers	302	51	15	22928	699	326	1377	1165	41	0	63	1182	5	132869	219	1822
Container_ships	415	91	8	33388	957	471	2479	1625	161	0	86	1652	6	98214	330	370
Reefers	35	5	1	3344	79	37	175	132	0	0	7	134	1	3121	24	120
Tankers	551	106	51	41756	1307	616	3438	2234	458	0	118	2278	10	199625	423	1875
LNG_tankers	21	3	1	859	29	15	201	74	338	0	4	84	0	3494	16	70
Gas_tankers	23	4	1	1721	54	24	123	89	1	0	5	90	1	2606	17	107
Passenger_ships	23	18	5	2268	87	35	301	144	0	0	6	145	3	0	24	589
Cruisers	25	4	1	1400	55	23	163	92	10	0	5	94	0	0	22	42
Fishing_vessels	32	14	0	2711	89	37	234	146	0	0	7	148	3	0	26	869
Service_ships	18	15	0	1487	63	26	202	104	4	0	5	106	2	0	23	446

Baltic – 2021	MAIN_FUEL [10^3 tonnes]	AUX_FUEL [10^3 tonnes]	AUX Boiler [10^3 tonnes]	NOx [tonnes]	SOx [tonnes]	PM25 [tonnes]	CO [tonnes]	CO_2 [10^3 tonnes]	CH_4 [tonnes]	NH_3 [tonnes]	N_2O [tonnes]	CO2e [10^3 tonnes]	TRAVEL [10^6 nm]	TRANSPORT WORK [10^6 tonne nm]	VOC [tonnes]	SHIPS
All	3671	891	132	255966	8598	3918	24440	14812	4327	49	754	15133	83	573797	2729	33975
IMO	3480	531	125	227455	7517	3338	19061	13045	4327	49	681	13347	64	570342	2427	8885
Baltic Proper	2250	441	58	152418	5045	2281	13575	8678	2321	28	444	8861	49	340567	1586	16003
Kattegat	647	236	30	50279	1708	800	5298	2888	332	3	144	2936	18	117967	533	13762
Gulf of Finland	452	139	32	32789	1109	510	3305	1957	916	8	101	2010	8	85159	372	2290
Gulf of Bothnia	289	64	9	18140	644	285	1971	1135	747	9	57	1171	7	24825	207	1618
Gulf of Riga	34	12	3	2340	92	43	290	153	11	0	7	155	2	5279	30	302
RoPax_ships	1075	100	10	61860	2060	852	5190	3724	2863	31	198	3857	9	17515	681	226
Ro-ro cargo ships	364	24	3	20187	725	305	1501	1239	93	16	64	1258	3	27627	208	119
Vehicle_carriers	38	13	1	3228	80	35	226	161	8	0	9	163	1	3327	30	149
General_cargo ships	434	67	33	26783	1015	462	2891	1688	3	1	82	1710	21	74822	300	2684
Bulk_carriers	327	55	16	24347	746	338	1388	1257	59	0	68	1277	5	141244	232	1837
Container_ships	401	84	8	31324	911	437	2326	1559	200	0	83	1586	5	91492	311	343
Reefers	32	4	1	3004	71	33	165	119	0	0	6	121	1	2880	22	125
Tankers	555	102	51	41200	1289	607	3444	2232	586	0	118	2279	10	208448	425	1835
LNG_tankers	23	3	1	965	34	17	230	83	347	0	5	94	0	3643	18	79
Gas_tankers	23	3	1	1623	51	23	105	85	0	0	5	86	1	2799	15	112
Passenger_ships	26	18	5	2447	94	38	319	156	0	0	7	157	3	0	26	564
Cruisers	49	2	1	2390	97	41	273	164	29	0	8	167	0	0	35	65
Fishing_vessels	23	13	0	1781	70	30	200	115	0	0	5	117	3	0	21	851
Service_ships	29	21	0	2238	96	40	280	159	8	0	8	161	2	0	35	442

Baltic – 2022	MAIN_FUEL [10^3 tonnes]	AUX_FUEL [10^3 tonnes]	AUX Boiler [10^3 tonnes]	NOx [tonnes]	SOx [tonnes]	PM25 [tonnes]	CO [tonnes]	CO_2 [10^3 tonnes]	CH_4 [tonnes]	NH_3 [tonnes]	N_2O [tonnes]	CO2e [10^3 tonnes]	TRAVEL [10^6 nm]	TRANSPORT WORK [10^6 tonne nm]	VOC [tonnes]	SHIPS
All	3739	950	139	256952	8730	3980	25957	15213	6218	50	778	15593	81	583877	2807	37219
IMO	3533	559	132	225981	7561	3352	20088	13303	6218	50	699	13662	60	581009	2479	9255
Baltic Proper	2271	470	61	151533	5080	2298	14355	8837	3236	31	454	9048	47	346548	1616	17327
Kattegat	711	261	32	53917	1863	871	5827	3171	520	3	158	3228	18	127879	582	15479
Gulf of Finland	430	141	34	31660	1076	493	3244	1903	1044	9	99	1958	7	80787	362	2312
Gulf of Bothnia	290	64	9	17253	608	270	2200	1130	1406	7	58	1185	7	23730	212	1791
Gulf of Riga	37	15	3	2590	103	48	332	172	12	0	8	175	2	4933	35	310
RoPax_ships	1129	124	10	65310	2187	899	5493	3971	3095	34	211	4113	9	17603	714	245
Ro-ro cargo ships	397	26	4	18996	715	301	2169	1337	1383	14	72	1395	4	29758	235	131
Vehicle_carriers	24	9	0	2134	55	24	136	106	5	0	6	107	0	2075	19	129
General_cargo ships	380	65	32	23659	904	414	2646	1507	49	1	73	1528	18	66038	271	2495
Bulk_carriers	311	61	18	23774	736	342	1482	1236	45	0	66	1255	5	141666	233	2025
Container_ships	286	73	7	22476	671	329	1876	1156	140	0	61	1176	4	71784	239	348
Reefers	32	4	1	3147	71	33	160	119	0	0	6	120	1	2813	22	109
Tankers	642	111	57	47316	1472	687	3763	2553	692	0	137	2608	10	242512	481	2114
LNG_tankers	34	4	2	1281	39	19	391	120	532	0	8	137	0	6813	27	106
Gas_tankers	23	5	1	1643	57	25	127	94	3	0	5	95	1	2814	17	125
Passenger_ships	34	24	6	3227	122	49	394	201	0	0	9	203	3	0	34	576
Cruisers	120	6	1	5991	236	96	579	403	123	1	21	412	1	0	80	99
Fishing_vessels	19	15	0	1628	65	28	188	107	0	0	5	108	3	0	20	788
Service_ships	21	14	0	1602	67	28	223	112	12	0	6	114	2	0	24	406

Baltic – 2023	MAIN_FUEL [10^3 tonnes]	AUX_FUEL [10^3 tonnes]	AUX Boiler [10^3 tonnes]	NOx [tonnes]	SOx [tonnes]	PM25 [tonnes]	CO [tonnes]	CO_2 [10^3 tonnes]	CH_4 [tonnes]	NH_3 [tonnes]	N_2O [tonnes]	CO2e [10^3 tonnes]	TRAVEL [10^6 nm]	TRANSPORT WORK [10^6 tonne nm]	VOC [tonnes]	SHIPS
All	3647	1018	154	251644	8576	3974	27166	15157	8449	38	778	15600	80	629048	2845	39238
IMO	3413	602	147	217610	7304	3294	20904	13077	8449	38	692	13497	59	625316	2489	9587
Baltic Proper	2219	510	69	147843	4996	2294	14930	8808	4350	22	455	9050	46	370186	1638	18093
Kattegat	743	272	33	56571	1933	913	6191	3307	702	3	166	3370	18	144126	612	16425
Gulf of Finland	409	155	41	30681	1038	486	3588	1897	1909	8	99	1977	8	88912	372	2512
Gulf of Bothnia	242	67	8	14177	513	235	2133	984	1470	5	51	1039	7	21251	189	1880
Gulf of Riga	34	14	3	2373	96	46	324	161	17	0	8	164	2	4574	33	328
RoPax_ships	1040	116	10	56558	1938	800	5498	3647	4271	25	196	3819	9	16733	671	237
Ro-ro cargo ships	351	28	3	14581	594	254	2186	1191	1878	11	65	1261	3	26478	216	113
Vehicle_carriers	19	9	0	1843	49	22	113	91	7	0	5	93	0	1705	17	131
General_cargo ships	361	63	30	22171	857	396	2566	1434	143	1	70	1456	18	64541	261	2426
Bulk_carriers	331	71	21	25642	799	378	1686	1336	41	0	71	1356	5	153120	255	2067
Container_ships	296	84	7	23765	703	358	2184	1224	214	0	64	1247	4	80136	264	411
Reefers	38	5	2	3578	85	40	199	142	0	0	7	144	1	3438	26	120
Tankers	692	132	70	53422	1616	755	4125	2815	817	0	151	2878	10	271193	533	2469
LNG_tankers	43	8	3	1432	46	25	561	158	891	0	10	186	0	9222	37	112
Gas_tankers	20	5	1	1503	51	23	119	84	3	0	4	85	1	2482	16	112
Passenger_ships	45	28	6	4147	150	60	444	248	0	0	12	251	3	0	41	547
Cruisers	82	4	1	3879	159	65	410	274	113	1	14	281	0	0	55	88
Fishing_vessels	22	14	0	1707	69	30	202	114	0	0	5	115	3	0	21	807
Service_ships	22	14	0	1564	69	29	220	113	0	0	6	115	2	0	24	412