
Emissions from ships in Faxaflóahafnir 2024



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Summary

In this study we calculate and present the ship to air emissions for Faxaflóahafnir harbours in 2024. Emissions are presented for four operational modes; *in port basin*, *at anchor*, *manoeuvring* and *at berth*. Further, emissions are allocated to different engine types, ship types, and also to the four harbour areas of Faxaflóahafnir: Akranes harbour, Grundartangi harbour, Old harbour, and Sunda harbour. The results are compared to the emissions calculated for the years 2016 to 2024.

For each port call, emissions of greenhouse gases (*well-to-wheel*, WTW, and *tank-to-wheel*, TTW), nitrogen oxides (NO_x), non-methane volatile organic compounds (NMVOC), particulate matter (PM), and sulphur dioxide (SO₂) are calculated using an emission inventory model specifically developed for port areas. Total emissions in 2024 are presented in Table 1.

Table 1: Summary of emissions for 2024

	Greenhouse gas emissions			NO _x (tonne)	NMVOC (tonne)	PM (tonne)	SO ₂ (tonne)
	WTW CO _{2e} (tonne)	TTW CO _{2e} (tonne)	TTW CO ₂ (tonne)				
Total emissions 2024	72 800	58 700	57 800	677	28	18	20

Like the previous year, the largest emitting ship categories are cruise ships, container ships and fishing vessels in that order, accounting for 42%, 29% and 15% of the WTW CO_{2e} emissions respectively. This distribution is similar to last year. Port calls from whale watching boats have been rising steadily since the pandemic and increased from 4387 to 4589 calls between 2023 and 2024. Since these vessels in general have relatively small engines, their contribution to the total WTW CO_{2e} is calculated to be only 1.4%. For other ship types, the total emissions and number of calls were similar to last year. Use of shore-side electricity went down for ships overall but increased at Sunda harbour where Dettifoss and Brúarfoss are heavy consumers, standing for 19% of the total consumption in 2024.

Sunda harbour and Old harbour receive significantly more ship calls than Akranes and Grundartangi. Sunda harbour received most container (332) and cruise (168) ships in 2024, which are the ship categories with the most emissions in total. Ships calling at Sunda harbour were responsible for around 70% of CO_{2e} emissions to air in Faxaflóahafnir.

The methodology for calculating avoided emissions from shore power use was altered this year. Energy use at shore had previously been slightly overestimated, and the change increases at berth

emissions slightly for all pollutants. Further, the calculation was updated to account for the 0.1% sulphur limit in the territorial sea of Iceland, applicable from 2020 onward.

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1 Introduction

IVL Swedish Environmental Research Institute, on assignment from Faxaflóahafnir, has calculated the emissions from ships visiting its harbours in 2024. Faxaflóahafnir comprises the four ports of Akranes harbour, Grundartangi harbour, and Sunda harbour and Old harbour in Reykjavik. The locations of the different ports are shown in Figure 1, which also indicates with red lines the traffic areas covered in the emission inventory.

The inventory includes emissions of greenhouse gases (*well-to-wheel*, WTW and *tank-to-wheel*, TTW) carbon dioxide (CO₂) and carbon dioxide equivalent (CO₂e) (including the global warming potentials of nitrous oxide (N₂O) and methane (CH₄)), nitrogen oxides (NO_x), non-methane volatile organic compounds (NMVOC), particle matter (PM), and sulphur dioxide (SO₂). The emission calculations are based on call statistics provided by the port.

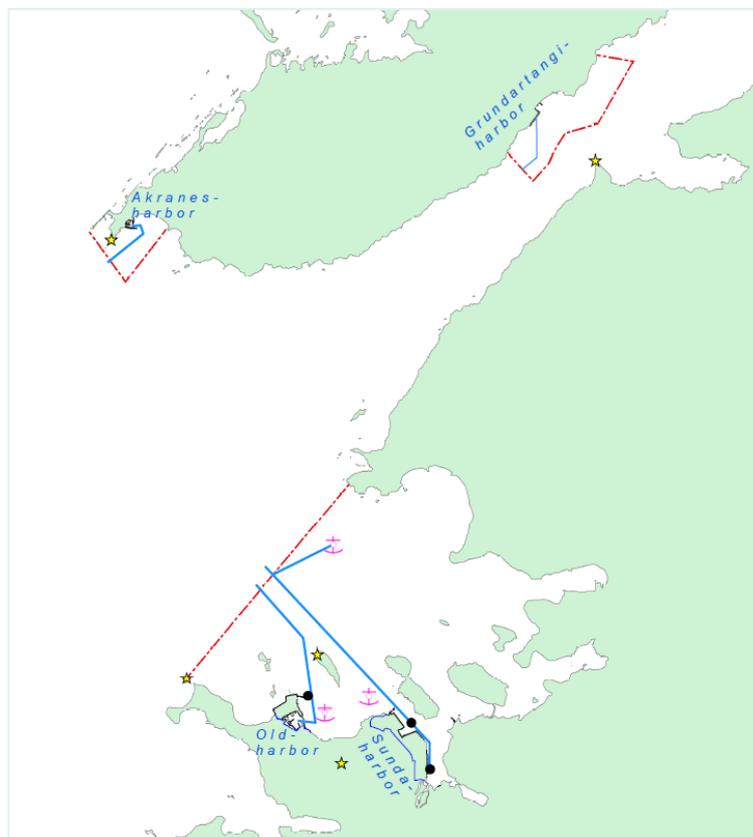


Figure 1: The four ports of Faxaflóahafnir and the areas outside the ports included in the emission inventory.

This report describes the emission calculation model, the data used, and the results. Results for 2024 are analyzed and discussed in relation to emission calculations made from ships calling the port in the years 2017 - 2023.

2 Ship traffic

In total, this inventory covers 5 999 port calls comprising in total 1 410 larger vessels. In addition to these calls, the port received 4 589 calls from whale watching boats in 2024, which is still lower compared to the 5 542 calls in 2019. These are all included in the inventory.

The ship traffic to the different harbours in Faxaflóahafnir comprises several different ship types and ship sizes: from large container vessels to small whale watching boats. These ships have been categorized into nine ship types, depending on the type of cargo they carry or the service they provide. The ship types are “Dry bulk carriers”, “Container ships”, “Cruise ships”, “Oil- and chemical tankers”, “RoRo-vessels/Ferries”, “General cargo ships”, “Fishing vessels”, “Whale watching boats” and “Other ships”.

For each of the four harbours, a surrounding area has been identified within which emissions from the ships are calculated. These areas are indicated by red lines in Figure 1. The emissions from ships in these areas are calculated for four different operational modes: *in port basin*, *maneuvering*, *at berth*, and *at anchor*. Emissions from *in port basin* operations are calculated from the time each ship spends in transit between the outer boundary of the port area and their assigned berth. *Maneuvering* operations are assumed to be twenty minutes per call, during which the ships are maneuvered with high precision before and after standing stationary at the quayside – a period which often requires rapid engine load changes that strongly influences emissions. During periods *at berth*, the ships are assumed to use auxiliary engines for electricity requirements on board. An exception are cruise ships with diesel electric power trains that provides auxiliary power from the main engines. Several of the ships in Faxaflóahafnir also use shore side electricity when at berth. Statistics on time at berth and shore side power use for individual ship calls have been provided by Faxaflóahafnir. There are four anchoring sites in the traffic areas covered by the inventory. During periods *at anchor*, operation of ship engines is similar to operation *at berth*, although power needs are lower for certain ship types.

The time in the *port basin* is estimated from the distance between a quay and the limits of the traffic area, and ship speed, which is assumed to be relative to the size of the vessel. Therefore, ship size has been used as a proxy to estimate time in the area. All time estimates have been provided by Faxaflóahafnir and can be found in Appendix 1. Whale watching boats are assumed to be berthing if they stay longer than one hour in the port area.

Table 2: Number of port calls and ship movements registered in 2024 in the different harbours in Faxaflóahafnir. The number of ship movements in the used data are lower than in the data from port call statistics since some ships are omitted, for example due to being military vessels or lacking information.

Harbor	Port calls (cargo, cruise, fishing and "other")	Port calls (whale watching boats)	Ship movements (cargo, cruise, fishing and "other")	
			Used data	Port call statistic in data
Akranes harbour	26	0	28	28
Grundartangi harbour	150	0	279	284
Old harbour	557	4 589	703	732
Sunda harbour*	677	0	927	954
TOTAL	1 410	4 589	1 937	1 998

*Includes anchorage outside the harbour at berth 951 "Kollafjörður".

3 Emission calculation

For each ship call, engine emissions are calculated as a product of emission factors, the utilised engine power, and time. For each engine and during each of the four operational modes equation (1) is applied.

$$E = EF \cdot t \cdot P \quad (1)$$

Where E is the emission in grams of a certain substance from an engine in a certain operating mode, EF is the emission factor for a pollutant in g / kWh in a certain operating mode, t is the time in hours when the engine operates in this mode, and P is the power output in kW from the engine during this operating mode.

3.1 Emission factors

The emission factors for marine engines used in this report are presented in Appendix 2. The main parameters determining emission factors are the fuel used and the engine speed. To give two examples: heavy fuel oil with high sulphur content results in significantly higher emission factors for sulphur dioxide and particles than lighter fuel qualities, while NO_x emissions depend on engine speed to a large extent with less emissions per unit energy from high-speed engines than from slow speed engines.

Emission factors for CO₂, CH₄, N₂O, and NMVOC for main engines and auxiliary engines are taken from Cooper and Gustavsson (2004). Emission factors for NO_x are assumed to follow the regulatory standards that were introduced in 2005, which apply to all ship keels laid from 2000 (Tier I) onwards, and further strengthened in 2011 (IMO, 2011). Ships constructed prior to 1990 are not covered by any regulations unless they have undergone significant engine changes. Ships constructed between 1990 and 2000 are only covered if specific criteria on engine size and technical possibilities for emission reductions are met. Due to lack of data availability, it is not possible to identify which ships from before 2000 fulfil Tier 1 requirements. For these vessels, no NO_x reduction measures are assumed used (Cooper and Gustafsson, 2004). NO_x-emission factors for post-2000 ships follow regulatory standards: Tier I levels for ships constructed between 2000 and 2011, and Tier II levels for ships built after 2011 (IMO, 2011).

Fishing vessels are assumed to use different qualities of fuel, depending mainly on vessel size, with fuel sulphur content varying from 0.001% to 0.5%. Whale watching boats are assumed to use only marine gasoil with an estimated sulphur content of 0.1%. For the ships using scrubbers, we assume the same SO₂ emission factor as for Very Low Sulphur Fuel Oil (VLSFO).

The emission factors for particulate matter (PM) are to certain extent dependent on the sulphur content of the fuel. A literature review of emission measurement results shows no clear relationship between fuel sulphur content and PM emissions at low sulphur content (<0.1 %), and, further, that a dependence on engine load is uncertain. Here, a distinction between PM emission factors is made for fuels that have an assumed sulphur content of <0.1 %, such as Ultra-Low Sulphur Fuel Oil (ULSFO)/MGO and fuels that have an assumed sulphur content of <0.5 % (such as VLSFO). The emission factors for PM emissions are presented in Appendix 2.

It is common to use diesel-fired boilers onboard ships to produce steam and heat. When the main engine is running on high loads, the boiler is often replaced by an exhaust gas economizer that uses excess heat from the exhausts for heat and steam production. However, when at berth or operating on low main engine loads, the diesel-fired boilers are needed since the exhaust gas heat is too low to meet heating demands. Only few studies report emission factors from boilers. In this study, emission factors from USEPA (1999) reported for boilers in relevant sizes for ship installations are used (Appendix 2). Emissions of CO₂ and SO₂ from boilers are calculated from the carbon and sulphur fuel contents, assuming complete combustion. The uncertainties in the calculated emissions from boilers are relatively high due to the lack of reliable emission factors, average fuel consumption, and due to limited available information on the utilization of boilers.

Some ships are assigned individual emission factors. These include ships that connect to shore side electricity at berth, which are assumed to have no emissions at berth except for the time used to connect and disconnect to the power grid. The fishing vessels in the HB Grandi fleet are also treated as special cases as these are known to use fuel with very low sulphur content.

Another category of ships that are assigned individual emission factors for NO_x are those registered for the Environmental Ship Index (ESI). The ESI is an index that indicates a ship's emission performance, specifically regarding NO_x and CO₂. The ESI system combines NO_x emission factors for all engines on board via a weighing process to a single value. Details on these calculations are presented in Appendix 3.

3.2 Engines and fuels

Emissions are calculated for main engines, auxiliary engines and auxiliary boilers separately. The database *Sea-Web Ship* contains information on all ships with IMO-numbers (IHS, 2022). *Sea-Web Ship* has been used for retrieving information on installed main engine power for an absolute majority of the ships visiting Faxaflóahafnir. For a limited number of ships, the installed main engine power has been estimated from ship size and ship type according to statistics developed by the IMO (IMO, 2014). *Sea-web Ship* also contains information on engine

speed for most main engines. If this information is not given in the database, an estimated engine speed based on known engine speeds for similar ship types and ship sizes is calculated.

The installed power in auxiliary engines is not given in the database. Instead, empirical relations from a large number of ships of similar types that relate installed auxiliary engine power to ship size are used (Sjöbris et al., 2005). All auxiliary engines are assumed to be high speed diesel engines, except for container ships at berth and anchor and product tankers at anchor, for which auxiliary engine powers are determined from specific power demand instead (Appendix 2). The installed main engine power for fishing vessels is taken from *Sea-Web*. Auxiliary engine powers are estimated as central values in a span of likely installed auxiliary power for ships of different sizes and installed main engine power. A categorization of fishing vessels has, in a previous study, been provided by HB Grandi (HB Grandi, 2017). HB Grandi is a large sea food company based in Reykjavík and owner of ten large fishing vessels. Each category was assigned a typical range of installed main engine and auxiliary engine powers. The categories and the installed main engine power of shipping vessels in Faxaflóahafnir stated in the *Sea-web Ship* data base have been matched. As a result, fishing vessels are divided into five categories primarily based on installed main engine power. The categories and the central values for installed auxiliary engine power used in the calculations are presented in Table 3.

Table 3: Categories of installed power on fishing vessels, main engines and aux engines

Category No.	Fishing vessel - Main engine power category (min – max, kW)	Fishing vessel - Aux engine power category (min – max, kW)	Aux Engine central value (kW)
1	37 – 559	0	0
2	600 – 1 035	220 – 600	410
3	1 036 – 1 762	220 – 600	410
4	1 763 – 3 699	700 – 900	800
5	3 700 – 9 000	1 500 – 2 000	1 750

The utilization of power from the engines during the different operational modes is required for the emission calculations. This information is often relatively uncertain and differs greatly between different ships. For this study, general values first reported by Entec UK (2002) are used. These values are presented in Table 4. However, for container ships at berth and at anchor and product tankers at anchor, the used auxiliary power demand is used (Appendix 2).

Table 4: Estimated power utilization (as share of installed engine power) at different operational modes (Entec UK Ltd, 2002).

	In port basin	In port basin	Manoeuvring	At anchor/at berth ¹
Main Engine		20%	20%	0%
Auxiliary Engine		40%	50%	40%

¹Cruise ships with diesel electric drives use main engine power at berth. 12% power utilization is assumed corresponding power needs of cruise ships with diesel mechanic drive and aux engines installed.

The main engine load of fishing vessels is assumed to be the same as for the other ship categories. However, the installed auxiliary engine power on certain categories of fishing vessels is, to a large extent, designed to manage the electricity needs for freezing fish or for trawling. From information and values provided by HB Grandi, we have made assumptions on utilization of auxiliary engine power as presented in Table 5 (HB Grandi, 2017).

Table 5: Estimated power utilization or power requirements of auxiliary engines in different categories of fishing vessels.

Category Nr.	In port basin	Manoeuvring	At berth	Comment
1	0	0	0	No auxiliary engines are installed on these vessels
2	0	50%	21%	Auxiliary engine system dimensioned for trawling. Therefore, lower aux engine load at berth assumed than for other ship types. 21 % is an estimated value.
3	0	50%	40%	These ships often use shaft generators, and the engine dimensions and utilization can be assumed to be similar to most ship types.
4	40%	50%	26%	These ships can process and freeze fish on board. Between 17% and 43% of installed aux engine power is needed for freezing. At berth, shore side electricity is not always enough. It is assumed that for 50% of the time these vessels need power for freezing and un-loading (up to 300 kW). For 50% of the time, during lay-up, 150 kW is assumed to be needed. 26% auxiliary engine utilization is an approximate average for time at berth.
5	40%	50%	23%	These ships can process and freeze fish on board. Between 15% and 40% of installed auxiliary engine power is used at berth. At berth, shore side electricity is not always enough. It is assumed that for 50% of the time these vessels need power for freezing and un-loading (500-600 kW). For 50% of the time, during lay-up, 300 kW is assumed to be needed. 23% aux engine utilization is an approximated average for time at berth.

For ships using shore-side power, the kWh values listed in the port call statistics for various calls are used to calculate how much of the fuel consumed at berth is offset by electricity use. It is assumed that the ships only use electricity produced as “green” electricity¹ which do not add any emissions to the calculations. See *Chapter 5.3.1 Shore-power update* for more information.

Tankers often use electricity from the auxiliary engines to run cargo pumps. This is accounted for by adding fuel consumption that relates to the carrying capacity of the individual tanker. According to information from a tanker operator, the typical fuel consumption for cargo pumps is 3 tonnes/day at off-loading. An off-loading operation for 14 000 tonnes oil requires about 15 hours. Based on this information, a general value of 0.13 kg fuel/tonne cargo has been calculated and is used for all tanker ships at off-loading operations. Further, the amount of cargo on the tankers is estimated as 42% of the ships’ dead weight tonnage. The value is based on a study made for Port of Gothenburg in 2017. Thus, for each tanker call, additional fuel consumption (in kg) according to equation (2) is assumed.

$$\text{Fuel consumption} = 0.42 * DWT * 0.13 \quad (2)$$

Large tankers sometimes use steam from boilers to run their cargo pumps. However here it is assumed that all cargo pumps use electricity from auxiliary engines. This seems to be the most common arrangement for tankers of the size classes that are common in Faxaflóahafnir; tankers of smaller sizes tend to use electricity driven pumps while larger ships use steam driven pumps.

The main engines fuel during operations *in port basin*, and *manoeuvring* is assumed to be VLSFO or heavy fuel oil for ships that have a scrubber installed, while the fuel used in the auxiliary engines is assumed to be marine gasoil with 0.1% sulphur content (S). More detailed information on the use of different fuel qualities by fishing vessels has been possible to include in the model after communication with HB Grandi (HB Grandi, 2017). Large fishing vessels are assumed to use fuel with a sulphur content of 0.5% in the main engines, and marine gasoil with 0.1% sulphur content in the auxiliary engines, while small fishing vessels are reported to use marine gasoil with 0.1% sulphur content, exclusively. All small fishing boats in the HB Grandi fleet use diesel oil with a sulphur content of 0.001%. The fuel types reported by Grandi are assumed for all fishing vessels of the respective size in the inventory. Further, whale watching boats are assumed to use only marine gasoil.

¹ As a comparison, the emissions from the Icelandic electricity was 8.6 g CO_{2e}/kWh_{el} in 2020 while the emission at berth from auxiliary engine was calculated to be about 870 g CO_{2e}/kWh_{el} on average.

A size dependent generic value on fuel consumption in ship boilers has been calculated for all visiting ships from values from a report from the Port of Los Angeles (2010). Exceptions are made for the category RoRo/ferry and container ships, for which values from a study in Gothenburg is used (Winnes and Parsmo, 2016). The values are presented in

Table 6. It is assumed that the boilers exclusively use MGO as fuel.

Table 6: Fuel consumption in oil fired boilers for operational modes at anchor, in port basin, manoeuvring, and at berth. Fuel consumption is given per thousand gross tonnes and hour.

Ship type	Fuel consumption/ (1000 GT *hour)
Bulk carriers	1.4
Oil- and chemical tankers	4
Container ships (0–5 000 TEU)	4.2
Container ships (< 17 000 TEU)	0.8
Cruise ships	4
General cargo ships	0.9
Other ships	4
Reefers	5.4
RoRo/Ferries	2

3.3 Upstream emissions

The emissions of greenhouse gases that occur during the production, refining, and transportation of fuel are commonly referred to as well-to-tank (WTT) emissions. These emissions can be contrasted with those that occur during combustion, typically known as tank-to-wheel (TTW) emissions. It is particularly important to include these upstream emissions, when using biofuels and electricity. This is because greenhouse gas emissions from these sources are not usually accounted for at the exhaust pipe/propeller. Instead, emissions are reported during the production of these fuels, thus WTT emissions are also included in this study. We refer to the total emissions as well-to-wheel/propeller (WTW), which encompasses both WTT and TTW emissions.

For upstream emissions related to MGO, we have as utilized emission factors from JEC, which have until recently been the standard emission factors used within Europe (Prussi et al. 2020). However, new standard values have recently been produced by IMO, which have been used as the basis for determining new recommended values presented in Appendix 4. These were not deployed this year as we did not want to hastily change the methodology. But if the new values still appear as the best alternative in time for the next emission inventory, then the calculation will be updated.

To calculate the upstream emissions, first the amount of primary energy found in the unburned fuel is calculated. Then the upstream emissions can be calculated using the upstream emission factors.

The energy consumption for main motors and auxiliary machines is calculated using Equation 3:

$$\text{Fuel}_{\text{MJj}} = t \cdot P \cdot \text{LCV} \cdot \text{SFOC} \quad (3)$$

Where:

t: is the time in hours when the engine is operating in this mode

P: is the power output in kW from the motor during this operating mode

LCV: Lower calorific value of the fuel in MJ / kg fuel (heating value), see Table 7 for details.

SFOC: Specific fuel oil consumption is the engines' assumed fuel consumption in kilograms per kWh, i.e. including the assumed engine efficiency, see Appendix 2 for more detailed information.

Fuel consumption for the boilers has been calculated by Equation 4.

$$\text{Fuel}_{\text{MJ}} = \text{FC}_{\text{GT}} \cdot \text{LCV} \cdot \text{GT} \cdot t \quad (4)$$

Where:

FC_{GT}: are standard values for the boilers' fuel consumption

GT: is the ship's gross tonnage

t: is the time the boilers have been used

Table 7: Lower heating value for different fuels.

Fuel type	Lower heating value	Source
MD	43.0	Bengtsson et. al. (2011)
RO	40.4	Bengtsson et. al. (2011)
VLSFO	40.4	Assumed same as RO

3.4 Global warming potential (GWP100)

To assess the emissions of the climate gasses methane (CH₄) and nitrous oxide (N₂O), their total emissions are multiplied by their global warming potential over a 100-year time horizon (GWP100) to produce CO₂ equivalents (CO_{2e}). The GWP100 is 25 for CH₄ and 298 for N₂O (IPCC, 2013).

3.5 Model updates

This year saw an update in how emission saving from shore power use is calculated, as well as new SO₂ limits from 2020 and onward.

3.5.1 Shore power update

It has previously been thought that the reported electricity in kWh in the port call statistics did not always represent electricity used. Due to low values for large ships such as cruisers, some values were thought to rather represent power (kW). It has now been clarified that the values reported are always for electric energy (kWh) and nothing else. For cruise ships, the low values are likely electricity used to power conveyors and reefers etc., rather than an actual OPS connection.

A previous issue has been interpreting the multiples of 400 kWh appearing in the statistics. The following explanation has been given:

400 kWh is the least electric energy the customer can pay for, meaning that if an entry says 400 kWh the charged amount could be anywhere in the range 0-400 kWh. If there are multiples of 400 kWh (such as 800, 1200 etc.) this means that several cables have been connected. So, 800 kWh would be 2 cables each charging 0-400 kWh.

For cruisers, Faxaflóahafnir has informed us that entries of 400 kWh are not actual OPS connections, but smaller cables powering for example reefers and conveyor belts. This power is

not replacing any fuel consumption. Therefore, entries with multiples of 400 kWh can be removed for all cruisers.

Earlier it was assumed that the power values were accurate for fishing vessels but no other ships. Non-fishing vessels using electricity during a call were therefore treated as if they charged for the entire duration of the stay (minus 2 hours for connection). Now all vessels are treated the same, and the power values entered in the port call statistics are taken at face value. The emission reduction of using OPS is simply determined by calculating how much fuel consumption at berth is replaced by the reported shore-side power use.

Previous years data have been changed so that electricity use in multiples of 400 kWh have been removed for all cruise ships, and the results from earlier years have recalculated according to the new method. This has led to the earlier years' results becoming slightly higher than before.

3.5.2 Sulphur limit update

During this year's work it was made known to us that there is a sulphur limit of 0.1% within Iceland's territorial sea and internal waters starting from 2020². This is further clarified by the Environment Agency of Iceland as:

“Where sulphur content of marine fuels is restricted to 0,10 % (m/m), the maximum emission ratio of SO₂ (ppm)/CO₂ (%v/v) is 4.3”

What this means is that ships using fuels with sulphur content above 0.1% need to use scrubbers in order to reduce SO₂ in the exhaust gas to reach an equivalent amount. The sulphur content of RO/VLSFO has therefore been set to the same value as for MD from 2020, assuming that the exhaust is cleaned below the limit with some margin (emission factors for sulphur are provided in Appendix 2). SO₂ emissions for 2020-2024 have been recalculated with this new limit in mind, leading to lower results than before.

² Government of Iceland: <https://www.government.is/news/article/?newsid=05452daa-183d-11ea-944f-005056bc530c>

4 Results

Table 8 presents the emissions of the different substances per engine type and operational mode. The period at berth accounts for the largest share of emissions of all substances. Auxiliary engines are the dominant source for all the emissions.

Emissions of SO₂ are directly related to the sulphur content in the fuel except for the ships with scrubbers. Even though most of the fuel is consumed in the auxiliary engines, SO₂ emissions from main engines are higher relative to auxiliary engines, since it is assumed that main engines run on high sulphur fuel to a large extent. Further, main engines are almost exclusively used for propulsion which is the reason for the relative importance of emissions during the in-port basin operational mode. The diesel electric driven cruise ships are an exception as they use their main engines at berth as well, although they use exclusively low sulphur fuel or after-treatment. CO₂ (TTW) emissions are almost directly related to the fuel consumption and are therefore a good proxy to use for fuel consumption in the analysis. In a comparison between the different operational modes, for 2024, the operations at berth can be attributed approximately 78% of the total CO₂ emissions. The CO₂ emissions from the auxiliary engines is calculated to be 44% of the total fuel consumed by all three engine types. Emissions of the greenhouse gases, dominated by CO₂ emissions, reached a value of 72 800 tonnes of CO_{2e}.

Table 8: Overview of emissions from ships in Faxaflóahafnir 2024

		Greenhouse gas emissions			NO _x (tonne)	HNMVOC (tonne)	PM (tonne)	SO ₂ (tonne)
		CO _{2e} (tonne)	CO _{2e} (tonne)	CO ₂ (tonne)				
		Well-To-Propeller (WTW)	Tank-to-Propeller (TTW)					
Main Engines	In port basin	8 100	6 700	6 500	100	3	6	2
	At anchor**	200	200	200	2	0	0	0
	Manoeuvring	1 200	1 000	1 000	20	1	1	0
	At berth*	16 900	14 000	13 700	180	6	4	5
Auxiliary Engines	In port basin	2 200	1 700	1 700	20	1	1	1
	At anchor*	800	600	600	10	0	0	0
	Manoeuvring	500	400	400	5	0	0	0
	At berth*	28 800	22 800	22 500	330	17	6	7
	Tankers at berth using cargo pumps	200	100	100	1	0	0	0
Boilers	In port basin	1 000	800	800	1	0	0	0
	At anchor**	200	200	200	0	0	0	0
	Manoeuvring	100	100	100	0	0	0	0
	At berth*	12 600	10 100	9 900	9	0	1	4
TOTAL (Engines and boilers)	Main engines	26 400	21 800	21 300	300	9	10	8
	Auxiliary engines	32 400	25 700	25 400	370	19	7	8
	Boilers	14 000	11 200	11 100	10	0	1	4
TOTAL (Operational modes)	In port basin	11 300	9 200	9 100	130	4	6	3
	At anchor**	1 100	900	900	10	1	0	0
	Manoeuvring	1 800	1 500	1 500	20	1	1	1
	At berth*	58 500	47 000	46 400	520	23	10	16
TOTAL	All engines and boilers, all operational modes	72 800	58 700	57 800	680	28	18	20

*Only cruise ships with diesel electric power trains

**Include emissions from ships in shipyard

In Table 9 the emissions from 2016-2024 are presented together. All years have been recalculated according to the electricity update (see Chapter 3.5.1 Shore-power update) which changes the overall emissions slightly. Most noticeably however, the SO₂ emissions have been recalculated from 2020 and onward (see Chapter 3.5.2 Sulphur limit update).

Table 9: Emissions and number of calls from 2016 to 2024 for ships visiting Faxaflóahafnir.

Year	Växthusgasutsläpp			N ₂ O (tonne)	NO _x (tonne)	HC (tonne)	PM (tonne)	SO ₂ (tonne)	Ship calls
	CO ₂ -e (tonne) WTW	CO ₂ -e (tonne) TTW	CO ₂ (tonne) TTW						
2016	45 900	36 700	36 300	1.41	500	20	11	72	7 136
2017	52 600	42 200	41 700	1.60	560	23	13	89	7 059
2018	57 200	45 900	45 300	1.76	610	25	14	93	6 006
2019	68 100	54 600	54 000	2.10	730	30	16	104	6 955
2020	50 600	40 300	39 800	1.51	500	23	11	13	2 818
2021	44 600	35 700	35 300	1.34	430	19	11	14	3 670
2022	63 200	50 800	50 100	1.89	600	26	15	18	5 394
2023	72 800	58 700	57 900	2.17	680	28	17	21	5 892
2024	72 800	58 700	57 800	2.16	680	28	18	20	5 999

In Figure 2, CO₂ emissions are presented for the different ship types in 2016 to 2024, demonstrating trends over time.

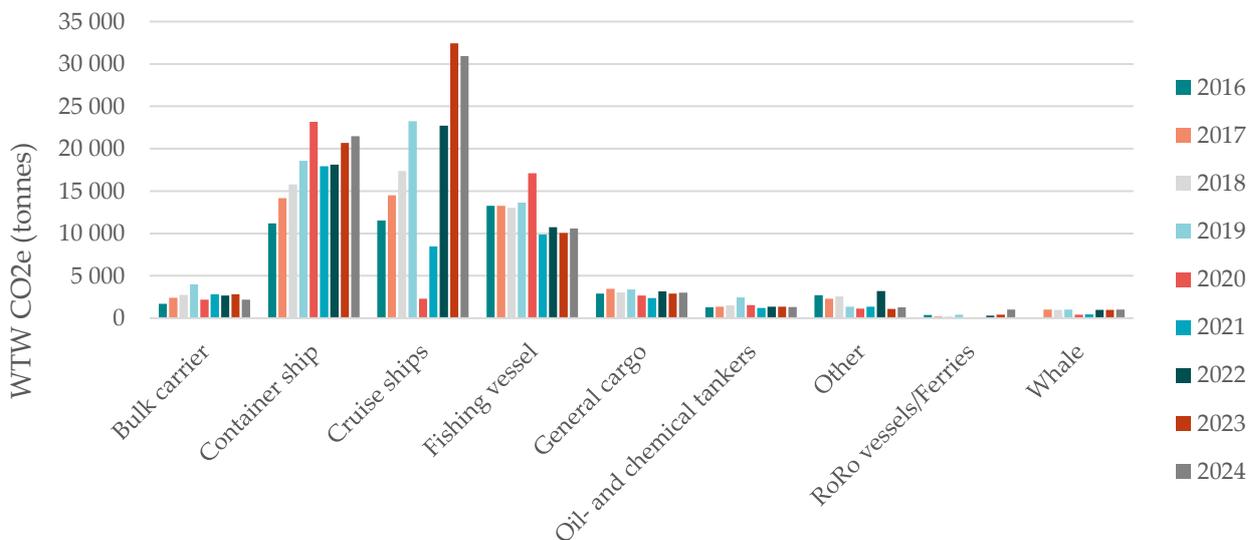


Figure 2: WTW CO₂e emissions for different ship types from 2016 to 2024

Figure 3 illustrates the number of port calls by each ship type for the above-mentioned years, excluding whale-watching boats. The most noticeable change this year is the drop in the number of calls from fishing vessels compared to previous years. Container and cruise ships show an increasing trend over time.

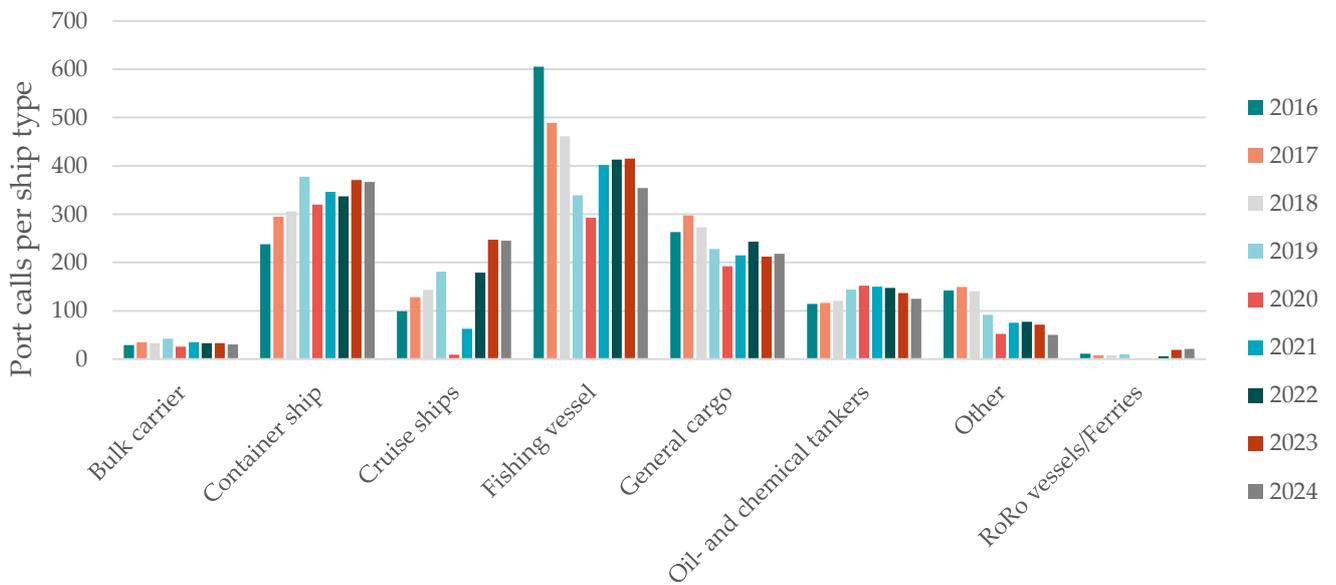


Figure 3: Port calls for different ship types from 2016 to 2024

In Figure 4, a calculation of the average CO₂ emission per port call for different ship categories provides an insight into the impact that a single port call can have. Cruise ships cause the most emission per port call by far due to their high emissions at berth, while for example RoRo-vessels and whale watching boats have very low impact per individual call.

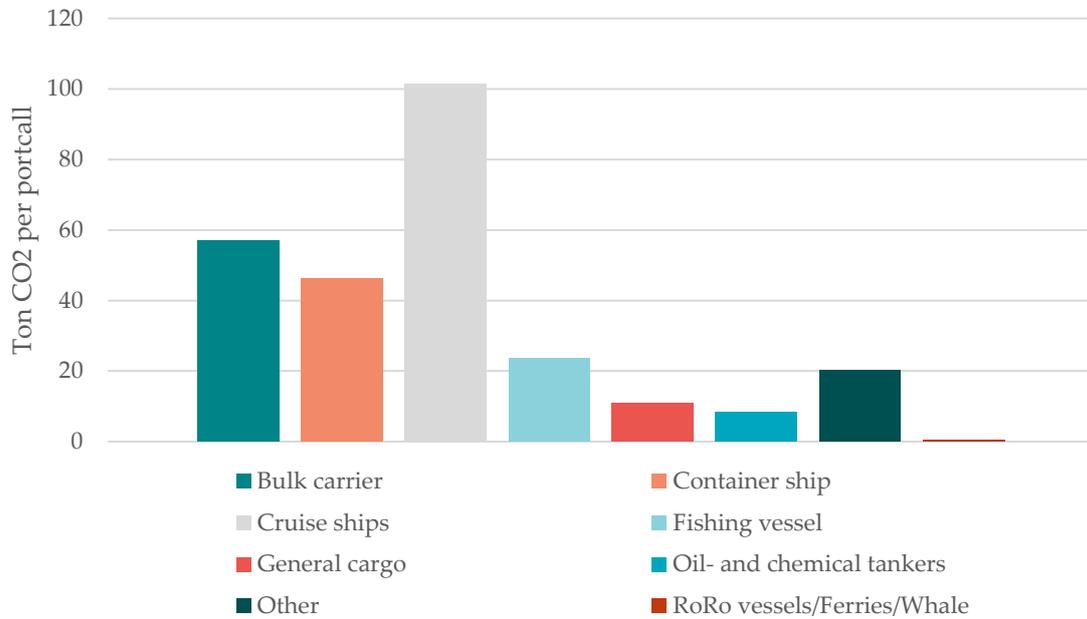


Figure 4: Emission intensity of different ship types.

Faxaflóahafnir provides connections to shore side electricity in Old harbour, Sunda harbour, and Akranes harbour, and many ships use shore side power at berth. By assuming these ships used electricity from onboard diesel generators if the shore side connections were not available, a measure of “avoided emissions” is estimated. This is the difference between emissions at berth if no ships were to use shore side power and the calculated actual emissions at berth. The avoided emissions are presented in Table 10 for the four harbour areas, and Table 11 shows the emissions divided by ship type.

Table 10: Avoided emissions from on-shore power use.

Harbour	Växthusgasutsläpp			NO _x (tonne)	NMVOC (tonne)	PM (tonne)	SO ₂ (tonne)
	CO ₂ -e (tonne) WTW	CO ₂ -e (tonne) TTW	CO ₂ (tonne) TTW				
Akranes harbour	6	5	5	0	0.00	0.00	0.00
Grundartangi harbour	0	0	0	0	0	0	0
Old harbour	1 204	954	941	14	0.7	0.3	0.3
Sunda harbour	479	380	374	5	0.3	0.1	0.0
TOTAL	1 689	1 339	1 321	19	1.0	0.4	0.3

Table 11: Emissions for 2024 divided into ship type

Ship type	Greenhouse gas emissions			N ₂ O (tonne)	NO _x (tonne)	HC (tonne)	PM (tonne)	SO ₂ (tonne)	Ship calls
	CO ₂ -e (tonne) WTW	CO ₂ -e (tonne) TTW	CO ₂ (tonne) TTW						
Dry bulk carriers	2 180	1 730	1 710	0.1	18	1.0	0.5	0.6	30
Container ships	21 460	17 140	16 960	0.6	198	8.6	5.9	6	367
Cruise ships	30 920	25 290	24 830	0.9	282	9.7	7.6	9	245
Oil- and chemical tankers	1 320	1 060	1 030	0.04	8	0.6	0.2	0.4	125
RoRo vessels/Ferries	1 030	820	810	0.03	12	0.5	0.2	0.3	21
General cargo ships	3 020	2 400	2 370	0.1	34	1.6	0.7	0.9	218
CRUISE AND CARGO SHIPS*	59 930	48 440	47 710	2	551	22	15	18	1006
OTHER SHIPS	1 280	1 020	1 010	0.0	8	0.5	0.2	0.4	50
FISHING VESSELS	10 570	8 400	8 300	0.3	108	5.2	2.1	2	354
WHALE WATCHING BOATS	1000	810	800	0.03	11	0.5	0.2	0.3	4589
TOTAL 2024	72 800	58 700	57 800	2.2	677	28	18	20	5 999

* "CRUISE AND CARGO SHIPS" contains the sum of emissions from "Dry bulk carriers", "Container ships", "Cruise ships", "Oil- and chemical tankers", "RoRo vessels/Ferries", and "General cargo ships".

Figure 5 gives a graphical representation of how much different ship types contribute to the total of different emissions.

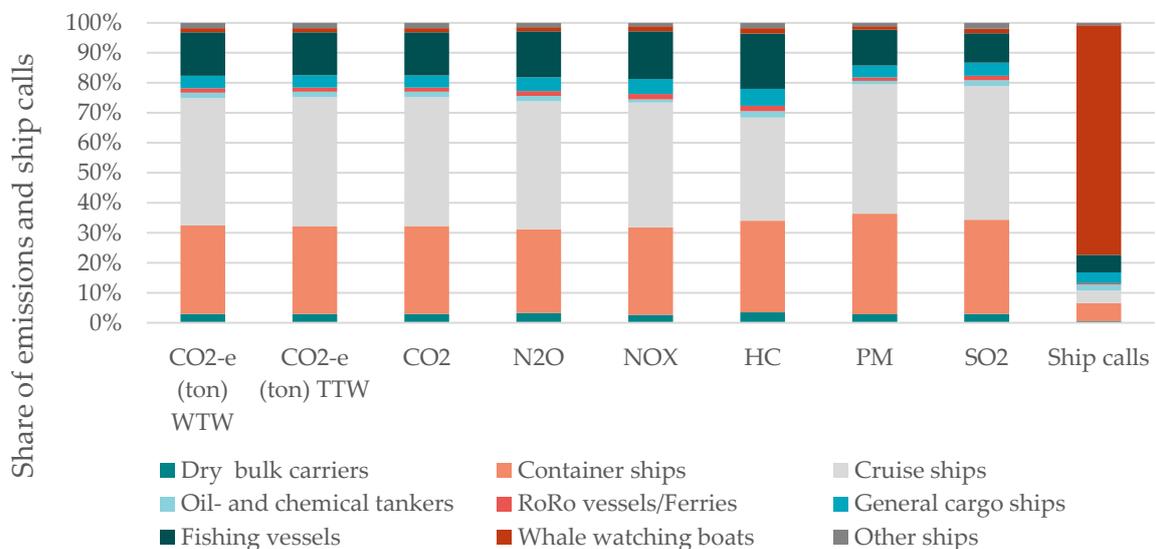


Figure 5: Emissions by ship type for 2024.

Whale-watching boats can be seen to have the most port calls by far while contributing very little to the overall emissions. The inverse can be said for especially cruise and container ships. Fishing vessels also contribute with a solid amount in comparison to their total shares of port calls.

4.1 Emissions from ships in the different harbour areas

The different harbour areas in the port serve different ship and have large differences in the total emissions. Sunda harbour is the busiest cargo and cruise port with roughly 51 250 tonnes of emissions of CO₂e. Akranes harbour is the least emitting harbour with approximately 410 tonnes of CO₂e emitted in 2024. Table 12 shows an overview of the emissions in the different harbour areas of Faxaflóahafnir.

Table 12: Emissions from ships in the different harbour areas of Faxaflóahafnir in 2024.

Harbour	Væxthusgasutsläpp			NO _x (tonne)	NMVOC (tonne)	PM (tonne)	SO ₂ (tonne)	Port calls (cargo, cruise, fishing and "other")	Port calls (whale watching boats)
	CO ₂ -e (tonne) WTW	CO ₂ -e (tonne) TTW	CO ₂ (tonne) TTW						
Akranes harbour	410	320	320	4.0	0.2	0.1	0.1	26	0
Grundartangi harbour	6 650	5 300	5 240	66.8	3.1	1.4	2.0	150	0
Old harbour	14 480	11 550	11 390	138.2	7.0	2.8	3.6	557	4589
Sunda harbour*	51 250	41 500	40 880	468.1	18.0	13.2	14.7	677	0
TOTAL	72 790	58 700	57 800	680	28	18	20	1 410	4 589

*Includes anchorage outside the harbour at berth 951 "Kollafjörður".

Further details on emissions per ship type in the different harbour areas are presented in Table 13 (Akranes harbour), Table 15 (Grundartangi harbour), Table 17 (Old harbour), and Table 19 (Sunda harbour). The total emissions from each harbour area for the last seven years are accounted for in separate tables, Table 14 (Akranes harbour), Table 16 (Grundartangi harbour), Table 18 (Old harbour), and Table 20 (Sunda harbour).

We recommend using only two digits of significance in communication of the results.

Akranes harbour

Table 13. Akranes harbour - emissions from different ship types 2024 and the number of calls.

Ship type	Væxthusgasutsläpp			NO _x (tonne)	NMVO C (tonne)	PM (tonne)	SO ₂ (tonne)	Ship calls
	CO ₂ -e (tonnene) WTW	CO ₂ -e (tonnene) TTW	CO ₂ (tonne)					
Dry bulk carriers	183	146	143	1.50	0.10	<0.05	0.05	11
Container ships	12	9	9	0.1	<0.05	<0.05	<0.05	1
Cruise ships	0	0	0	0	0	0	0	0
Oil- and chemical tankers	0	0	0	0	0	0	0	0
RoRo vessels/Ferries	13	10	10	<0.05	<0.05	<0.05	<0.05	1
General cargo ships	106	85	83	1.3	0.06	<0.05	<0.05	7
CRUISE AND CARGO SHIPS*	310	250	250	3	0	0	0	20
OTHER SHIPS	3	2	2	0.03	<0.05	<0.05	<0.05	1
FISHING VESSELS	87	70	69	0.90	<0.05	<0.05	<0.05	5
WHALE WATCHING BOATS	0	0	0	0	0	0	0	0
TOTAL 2024	410	320	320	4.0	0.2	0.1	0.1	26

Table 14. Emissions from ships calling Akranes harbour 2016 to 2024, and the number of calls.

Year	Væxthusgasutsläpp			NO _x (tonne)	NMVOC (tonne)	PM (tonne)	SO ₂ (tonne)	Ship calls
	CO ₂ -e (tonne) WTW	CO ₂ -e (tonne) TTW	CO ₂ (tonne)					
2016	2 640	2 100	2 070	28.9	1.4	0.5	1.1	34
2017	3 350	2 660	2 630	28.7	1.6	0.6	0.8	44
2018	1 300	1 040	1 020	12.2	0.7	0.3	0.5	34
2019	1 250	1 000	980	14.3	0.6	0.3	0.6	26
2020	210	170	170	2.4	0.1	0.05	0.1	15
2021	500	400	390	5.5	0.3	0.1	0.2	31
2022	910	730	720	9.7	0.5	0.2	0.2	57
2023	880	700	690	8.5	0.4	0.2	0.2	38
2024	410	320	320	4.0	0.2	0.1	0.1	26

Grundartangi harbour

Table 15: Grundartangi harbour – emissions from different ship types in 2024.

Ship type	Væxthusgasutsläpp			NO _x (tonne)	NMVOC (tonne)	PM (tonne)	SO ₂ (tonne)	Ship calls
	CO ₂ -e (tonne) WTW	CO ₂ -e (tonne) TTW	CO ₂ (tonne)					
Dry bulk carriers	1 905	1514	1496	15.8	0.9	0.4	0.6	15
Container ships	3 385	2705	2675	35.9	1.5	0.8	1.0	30
Cruise ships	0	0	0	0	0	0	0	0
Oil- and chemical tankers	0	0	0	0	0	0	0	0
RoRo vessels/Ferries	0	0	0	0	0	0	0	0
General cargo ships	1 360	1081	1067	15.1	0.7	0.3	0.4	105
CRUISE AND CARGO SHIPS*	6 650	5 300	5 240	66.8	3.1	1.4	2.0	150
OTHER SHIPS	0	0	0	0	0	0	0	0
FISHING VESSELS	0	0	0	0	0	0	0	0
WHALE WATCHING BOATS	0	0	0	0	0	0	0	0
TOTAL 2024	6 650	5 300	5 240	66.8	3.1	1.4	2.0	150

Table 16: Emissions from ships calling Grundartangi harbour 2016 to 2024, and the number of calls.

Year	Væxthusgasutsläpp			NO _x (tonne)	NMVOC (tonne)	PM (tonne)	SO ₂ (tonne)	Ship calls
	CO ₂ -e (tonne) WTW	CO ₂ -e (tonne) TTW	CO ₂ (tonne)					
2016	4 860	3 870	3 830	52.2	2.3	1.1	10.7	203
2017	6 050	4 820	4 770	62.1	2.8	1.3	11.5	166
2018	6 310	5 030	4 970	62.9	2.9	1.4	11.2	179
2019	5 630	4 490	4 440	58.3	2.6	1.3	10.5	153
2020	6 180	4 920	4 870	62.0	2.9	1.3	1.8	144
2021	6 730	5 370	5 300	69.7	3.2	1.5	2.3	160
2022	7 270	5 800	5 730	72.8	3.4	1.6	2.2	166
2023	7 350	5 860	5 790	71.2	3.5	1.6	2.2	155
2024	6 650	5 300	5 240	66.8	3.1	1.4	2.0	150

Old harbour

Table 17: Old harbour – emissions from different ship types in 2024.

Ship type	Växthusgasutsläpp			NO _x (tonne)	NMVOC (tonne)	PM (tonne)	SO ₂ (tonne)	Ship calls
	CO ₂ -e (tonne) WTW	CO ₂ -e (tonne) TTW	CO ₂ (tonne)					
Dry bulk carriers	15	12	11	0.2	<0.05	<0.05	<0.05	1
Container ships	66	53	52	0.7	<0.05	<0.05	<0.05	4
Cruise ships	3 308	2649	2604	31	1.7	0.7	1.0	77
Oil- and chemical tankers	1 227	977	957	6.6	0.6	0.2	0.3	120
RoRo vessels/Ferries	534	425	420	6.0	0.3	0.1	0.2	15
General cargo ships	21	17	16	0.2	<0.05	<0.05	<0.05	2
CRUISE AND CARGO SHIPS*	5 170	4 130	4 060	45	2.6	1.1	1.5	219
OTHER SHIPS	1 172	934	926	7.1	0.3	0.2	0.3	44
FISHING VESSELS	7 140	5672	5603	75	3.6	1.4	1.4	294
WHALE WATCHING BOATS	1000	810	799	11	0.5	0.2	0.3	4 589
TOTAL 2024	14 480	11 550	11 390	138.2	7.0	2.8	3.6	5 146

Table 18: Emissions from ships calling Old harbour 2016 to 2024, and the number of calls.

Year	Växthusgasutsläpp			NO _x (tonne)	NMVOC (tonne)	PM (tonne)	SO ₂ (tonne)	Ship calls
	CO ₂ -e (tonne) WTW	CO ₂ -e (tonne) TTW	CO ₂ (tonne)					
2016	13 450	10 710	10 580	146.6	6.4	2.6	8.6	6412
2017	12 850	10 250	10 120	138.8	6.1	2.5	9.5	6209
2018	15 950	12 700	12 550	168.4	7.7	3.1	9.1	5182
2019	17 850	14 210	14 040	191.9	8.8	3.5	9.6	6138
2020	14 640	11 650	11 510	148.8	7.1	2.8	3.1	2217
2021	10 860	8 680	8 570	102.6	5.1	2.1	3.2	2960
2022	15 910	12 670	12 510	153.2	7.6	3.1	4.2	4554
2023	13 490	10 780	10 640	126.0	6.3	2.6	3.6	5002
2024	14 480	11 550	11 390	138.2	7.0	2.8	3.6	5146

Sunda harbour

Table 19: Sunda harbour – emissions from different ship types in 2024.

Ship type	Växthusgasutsläpp			NO _x (tonne)	NMVOC (tonne)	PM (tonne)	SO ₂ (tonne)	Ship calls
	CO ₂ -e (tonne) WTW	CO ₂ -e (tonne) TTW	CO ₂ (tonne)					
Dry bulk carriers	74	59	58	0.6	<0.05	<0.05	<0.05	3
Container ships	17 995	14 375	14 221	161	7.1	5.1	5	332
Cruise ships	27 616	22 640	22 225	251	8.1	7.0	8	168
Oil- and chemical tankers	98	78	76	0.9	<0.05	<0.05	<0.05	5
RoRo vessels/Ferries	484	385	380	5.7	0.2	0.1	0.1	5
General cargo ships	1 534	1 221	1 205	18	0.8	0.34	0.5	104
CRUISE AND CARGO SHIPS*	47 800	38 760	38 170	436	16.3	12.5	14.2	617
OTHER SHIPS	107	86	85	0.8	<0.05	<0.05	<0.05	5
FISHING VESSELS	3 345	2 657	2 625	31	1.64	0.66	0.52	55
WHALE WATCHING BOATS	0	0	0	0	0	0	0	0
TOTAL 2024	51 250	41 500	40 880	468.1	18.0	13.2	14.7	677

Table 20: Emissions from ships calling Sunda harbour 2016 to 2024, and the number of calls.

Year	Växthusgasutsläpp			NO _x (tonne)	NMVOC (tonne)	PM (tonne)	SO ₂ (tonne)	Ship calls
	CO ₂ -e (tonne) WTW	CO ₂ -e (tonne) TTW	CO ₂ (tonne)					
2016	24 920	20 030	19 800	276.0	10.2	5.9	52.0	487
2017	30 390	24 460	24 180	327.8	12.0	7.3	67.5	640
2018	33 680	27 110	26 790	364.4	13.3	8.1	72.6	611
2019	41 420	33 370	32 980	447.7	16.4	9.8	82.2	619
2020	29 520	23 550	23 290	282.4	12.8	6.5	7.7	442
2021	26 470	21 240	21 000	248.6	10.5	7.3	8.8	519
2022	39 120	31 630	31 190	364.1	14.2	10.3	11.5	617
2023	51 060	41 340	40 770	473.7	18.0	13.1	14.8	697
2024	51 250	41 500	40 880	468.1	18.0	13.2	14.7	677

5 Discussion

5.1 Differences in emissions

The results are largely consistent with last year, with minor differences across the various ship segments that more or less offset each other overall.

The number of calls from the different ship categories were similar to last year, except for fishing vessels which decreased by 15%. Calls from whale watching ships have been increasing each year since the pandemic, now reaching 4 589 calls compared to last year's 4 387.

As for the emissions, the most important factor affecting the total sum is the time at berth for cruise and container ships, which are the largest emitting categories by far. Cruise ships decreased their total emissions by 5% from last year. The time at berth decreased, and the time at anchor was greatly reduced. However, emissions from anchorage are small compared to the total. Container ships instead observed an increase in total emissions of around 4%, with a slight increase of time at berth. The time at anchor was almost halved since last year.

Regarding the model updates, the change in the electricity calculation increased the WTW CO₂ emissions around 4% for previous years at most (for 2022-2023). From 2016-2021 the difference was below 1%, probably due to the fact that the kWh was entered on a different format these years in the files delivered to us. The difference was also less than 1% for 2023, likely due to a fluke in which our previous calculation method happened to produce results similar to the updated method. For the update in the SO₂ calculation, the effect has been greater. From 2020-2023, the new SO₂ results are around 40% lower than in previous emission inventories.

5.2 Model considerations

The model used includes generalized values in many instances. These are often based on averages from many observations or reports, which include variations around the average value. Examples of such general values are the emission factors and engine loads at different operational modes. This causes uncertainty in the results. However, in an emission inventory like this with many ships and ship calls, the total results will present a fair view of the actual emissions. If the scope is narrowed to few ships or single ship types, the uncertainty in the result increases. The model is therefore unsuitable for analysis of emissions from individual ships or small groups of ships.

5.3 Comparison between ports

It is difficult to compare one port to another since the characteristics of ports vary considerably. Differences in ship sizes, logistic requirements, and ship types can all influence emissions; large ships need longer time at berth, small tankers in general cause more emissions at berth than small RoRo vessels, and the fairway channel varies in length in different ports, to give some examples.

Given this information, here is a comparison of average values in tonne CO₂ emissions (Tank-to-propeller) per call in the four port areas from 2016 to 2024:

- In Akranes harbour, the average values for tonne CO₂ emissions per port call have been:

2016: 61	2019: 38	2022: 13
2017: 60	2020: 11	2023: 18
2018: 30	2021: 13	2024: 12

Due to the total amount of port calls being low for Akranes, the average can fluctuate heavily dependent on the individual ships that call the port.

- In Grundartangi harbour, the average values for tonne CO₂ emissions per port call have been:

2016: 19	2019: 29	2022: 35
2017: 29	2020: 34	2023: 37
2018: 28	2021: 33	2024: 35

General cargo ships were more efficient this year, spending less time at berth in total despite having fewer calls.

- In Old harbour, the average values for tonne CO₂ emissions (excluding whale-watching boats) per port call have been:

2016: 13	2019: 22	2022: 20
2017: 14	2020: 25	2023: 16
2018: 18	2021: 14	2024: 19

Average emissions in Old harbour saw an increase which can be attributed mainly to fishing vessels spending about twice as much time in shipyards compared to last year.

- In Sunda harbour, the average values for tonne CO₂ emissions per port call have been:

2016: 41	2019: 53	2022: 51
2017: 38	2020: 53	2023: 58

2018: 44 2021: 40 2024: 60

No particular difference from last year. Cruise ships calling Sunda have very high CO₂ emissions per port call, and there were two more calls from this ship category than last year.

These comparisons are most relevant to make for Sunda harbour and Old harbour which each year receives a high number of calls. The “emission per call” ratios in these harbour areas are less sensitive to single calls that may cause very high emissions and that may influence the results significantly.

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