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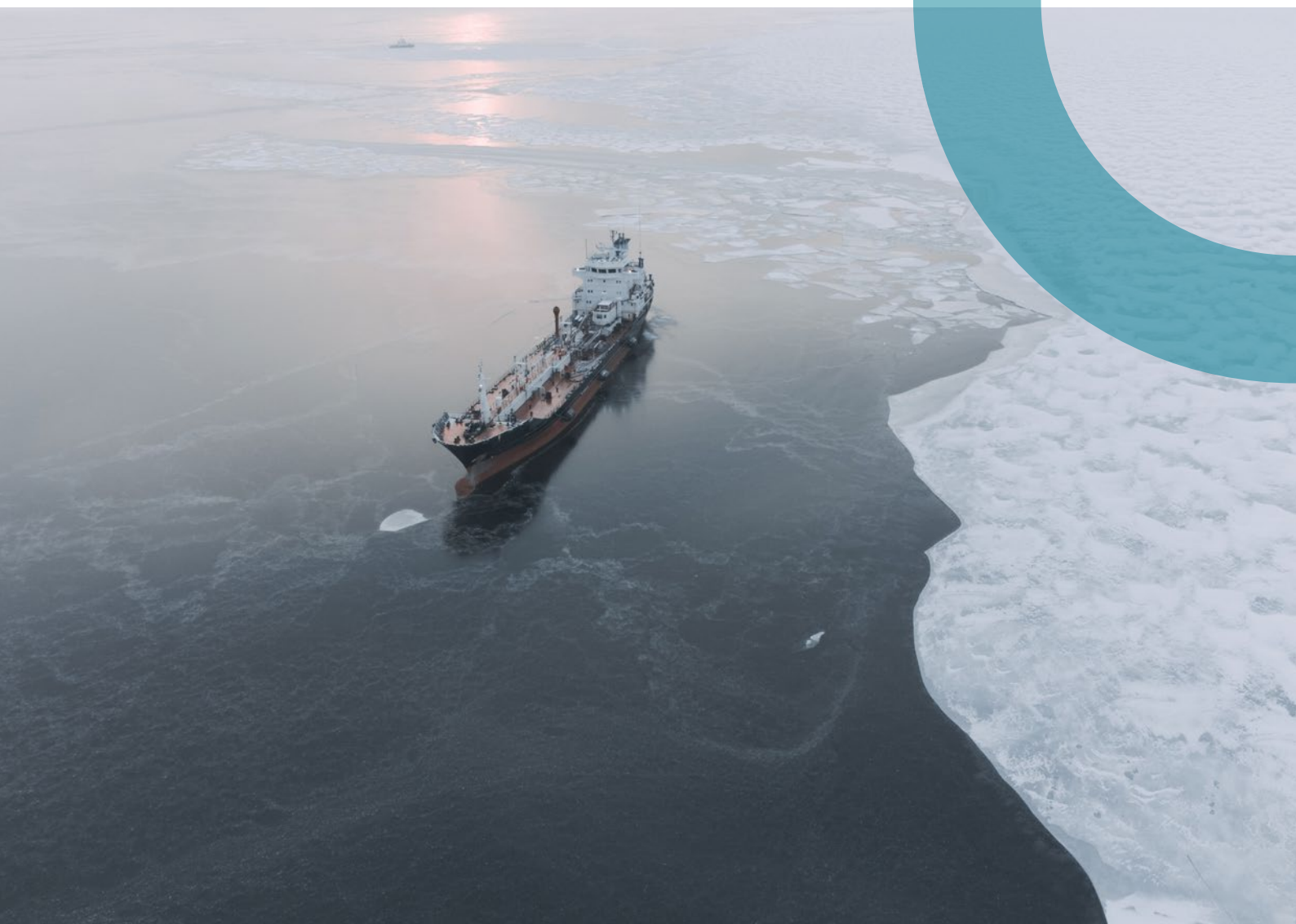
MAY 2025

Black carbon and CO_2 emissions from EU-regulated shipping in the Arctic

LIUDMILA OSIPOVA AND KETAN GORE



ACKNOWLEDGMENTS

We thank reviewers Xiaoli Mao and Yoann Bernand for their insightful feedback, and Bill Hemmings for his valuable contributions. Our appreciation also goes to the editorial and design team for preparing this paper for publication.

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EXECUTIVE SUMMARY

The Arctic region is experiencing significant environmental stress due to rapid warming, with temperatures rising 3–4 times faster than the global average. As Arctic shipping activity increases, so do associated black carbon (BC) emissions. Black carbon has a 100-year global warming potential 900 times greater than that of carbon dioxide (CO_2), and its effects are amplified in the Arctic region due to the albedo effect. These emissions contribute to further warming and environmental degradation, compounding the challenges faced by this already vulnerable region.

The European Union (EU) has committed to addressing shipping emissions as part of its broader Arctic climate strategy. To date, the contribution of EU shipping to Arctic emissions has been primarily assessed based on data from EU-flagged ships. However, the number of ships navigating the Arctic to and from EU ports may be substantially higher, suggesting that previous assessments may underestimate the total impact.

This study compares the composition, fuel use, and BC and CO_2 emissions of the EU-flagged fleet in the Arctic and the EU-regulated fleet in the Arctic, the latter are defined as ships reporting to the EU Monitoring, Reporting, and Verification (MRV) system, meaning they are voyaging to or from EU ports. To capture the full scope of emissions, we assess impacts across both a broadly defined Geographic Arctic region (north of 59°N) and the more limited Arctic region as defined by the International Maritime Organization (IMO)'s Polar Code.

The main findings of our assessment are as follows:

In 2021, nearly three-quarters of the ships operating in the Geographic Arctic and half of those in the IMO Arctic were navigating to or from EU ports. Of the 3,171 ships of 5,000 gross tonnage (GT) or more identified in the Geographic Arctic, 2,315 reported to the EU MRV (73%), while only 816 were flagged to an EU state (26%). In the IMO Arctic, 278 of the 564 ships of 5,000 GT or more reported to the EU MRV (49%), while only 112 flew an EU flag (20%).

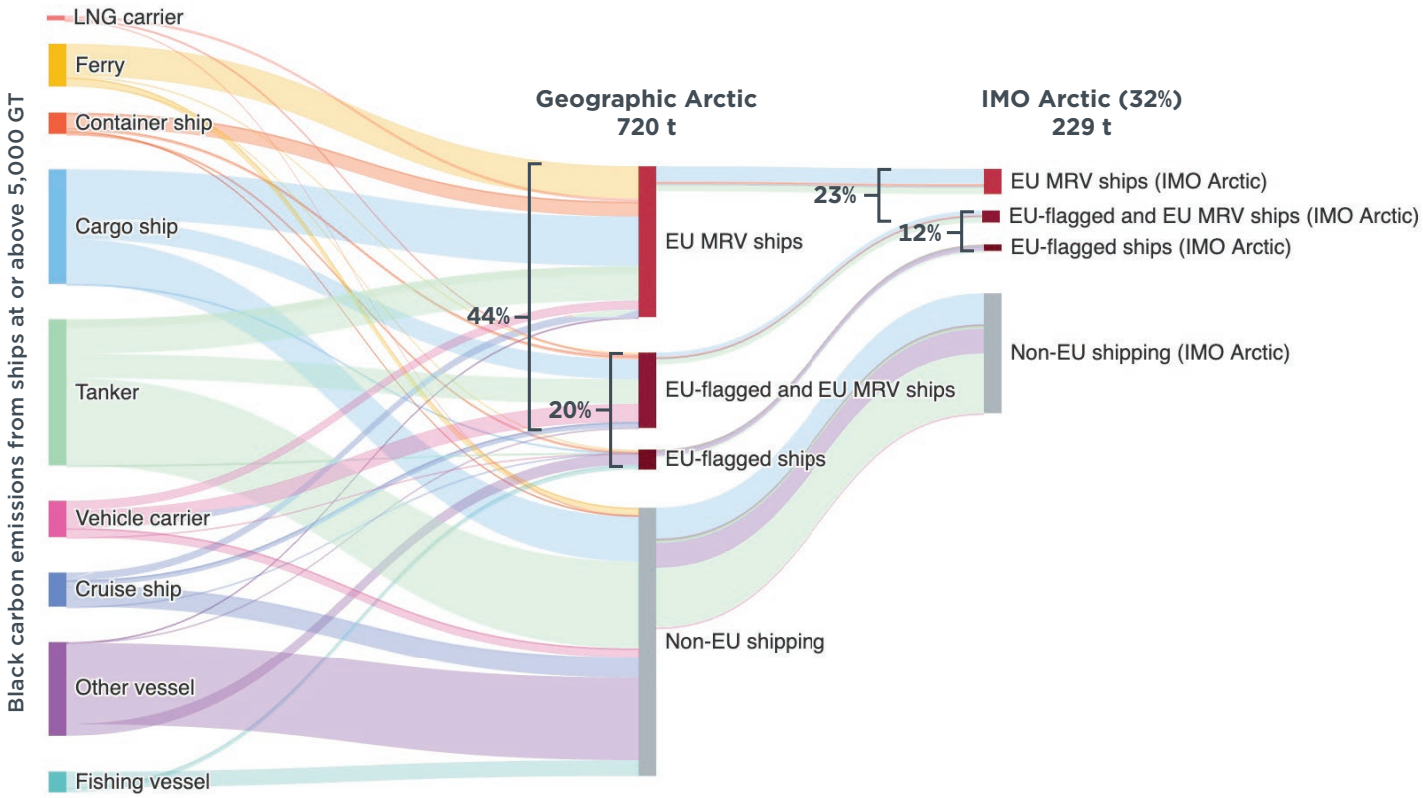
In 2021, ships flagged to Norway burned the most fuel by mass in the Geographic Arctic, while Russian-flagged ships burned the most in the IMO Arctic. Norwegian-flagged vessels consumed an estimated 33% of the 3,789 kilotons (kt) of fuel used in the Geographic Arctic in 2021, while Russian-flagged vessels burned closed to half of the 877 kt of fuel consumed in the IMO Arctic the same year.

Black carbon emissions in the IMO Arctic nearly doubled between 2015 and 2021. In 2021, Arctic shipping emitted 1.5 kt of BC and 12 kt of CO_2 north of 59°N, with about a quarter of these emissions occurring within the boundaries of the IMO Arctic. This indicates a strong growth trend in BC emissions in the IMO Arctic, from 193 tonnes in 2015 to 413 tonnes in 2021.

Black carbon and CO_2 emissions from EU-regulated ships of at least 5,000 GT were nearly double those from EU-flagged ships. In the Geographic Arctic, EU-regulated ships contributed 44% of BC emissions and 60% of CO_2 emissions from ships at or above 5,000 GT, while EU-flagged vessels accounted for 20% and 23%, respectively. Notably, 72% of BC emissions from EU-regulated ships came from residual fuels. Liquefied natural gas (LNG)-fueled vessels accounted for 31% of the total CO_2 emissions from EU-regulated ships, despite contributing only 2% of BC emissions from all EU-regulated ships operating in the Geographic Arctic. In the IMO Arctic, EU-regulated ships accounted for 23% of BC emissions and 49% of CO_2 emissions from ships at or above 5,000 GT, while EU-flagged ships at or above 5,000 GT contributed only 12% and 20%, respectively.

Figure ES1

Black carbon emitted per ship class in the Geographic Arctic and in the IMO Arctic by EU-flagged and EU-regulated vessels



Note: Ships under 5,000 GT emitted 53% of BC, 48% from fishing vessels.

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To reduce BC emissions in the Arctic from ships operating to and from EU ports, the following measures could be considered:

Accounting for BC emissions in the EU MRV database would provide a more comprehensive assessment of the European Union's role in shipping-related BC emissions, both globally and in the Arctic. Currently, the EU MRV system only mandates the reporting of CO_2, methane, and nitrous oxide emissions from maritime transport.

Recognizing BC as a significant climate pollutant would support the European Union's efforts to mitigate its climate footprint in the Arctic and help inform policy measures, such as future revisions of the EU Emissions Trading System and FuelEU Maritime.

Replacing residual fuel with distillate could reduce BC emissions by 50%–80%, depending on engine type and operating conditions. For EU-regulated ships over 5,000 GT in the Geographic Arctic, this would cut BC emissions by 115–183 tonnes—a 16%–25% reduction of the total BC emissions in this size category. Installing diesel particulate filters could increase the emission reductions to 206 tonnes, achieving up to a 29% total BC emissions reduction from ships over 5,000 GT sailing in the Geographic Arctic.

Our findings highlight the significant contribution of EU-regulated ships to emissions in the Arctic, and underscore the need for more stringent regulations that address BC emissions from ships operating to and from EU ports. Such measures would further demonstrate the European Union's commitment to mitigating climate change in the Arctic and globally.

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INTRODUCTION

Dwindling sea ice has unlocked the Arctic Ocean, leaving it open to human activities, particularly oil and gas extraction and shipping. Several new shipping routes in the Arctic Ocean, including the Northern Sea Route, Northwest Passage, and the Transpolar Sea Route, reduce the sailing distance from Asia to Europe compared with the traditional route via the Suez Canal (Becker et al., 2018; Joseph et al., 2021; Zhang et al., 2019). Although expanded Arctic shipping may provide commercial benefits, the associated environmental burden in the form of accidents, oil spills, and emissions is of significant concern both for human health and climate impact (Comer et al., 2017a; Corbett et al., 2010).

Black carbon (BC) emissions in the Arctic are considered one of the primary causes of the rapid decline in Arctic sea ice (Comer et al., 2017a, 2017b; Zhang et al., 2019). It is usually formed due to incomplete combustion in the internal combustion engines commonly used in shipping (Brewer, 2019); it is the most potent light-absorbing component of particulate matter (PM) and has a relatively short atmospheric lifetime, typically depositing on the Earth's surface within a few days of emission (Azzara et al., 2015). When BC particles settle on snow or ice, they reduce the albedo of these surfaces, or the amount of light the surface reflects, leading to accelerated melting and contributing significantly to global warming (Comer et al., 2017a).

This is particularly concerning for the Arctic, as the growing prominence of maritime activities within the region and the rise in BC emissions further amplify the warming effect. Sand et al. (2013) estimated that BC emitted in the Arctic (between latitudes 60°–90°N) warms the Arctic surface nearly 5 times more than BC emitted in mid-latitudes (28°–60°N). In addition to its climate impacts, exposure to PM and BC emissions can lead to negative health outcomes like cardiopulmonary disease, respiratory illness, and lung cancer (Brewer, 2019; Comer et al., 2017b). Particulate matter was previously identified as the most harmful air pollutant for human health, with ship-based PM emissions having been linked to approximately 60,000 premature deaths worldwide in 2015 (European Environment Agency, 2019; Rutherford & Miller, 2019).

In this study, we assess the contribution of European Union (EU) shipping activities to Arctic BC and CO_2 emissions. We consider both the EU-flagged fleet as well as the EU-regulated fleet, or ships reporting to the EU Monitoring, Reporting, and Verification (MRV) system, meaning they are voyaging to or from EU ports. We examine emissions from ships of all sizes in a broadly defined Geographic Arctic (north of 59°N) and a more limited Arctic region as defined by the International Maritime Organization (IMO).

We first survey the different geographic and administrative definitions of the Arctic region and the regulatory landscape for BC emissions from Arctic shipping. We then discuss our methodology before turning to the results of our analysis of fleet composition, fuel use, and emissions. We conclude with a discussion of our results and policy considerations.

GEOGRAPHIC AND REGULATORY LANDSCAPE

GEOGRAPHIC AND ADMINISTRATIVE DEFINITIONS OF THE ARCTIC REGION

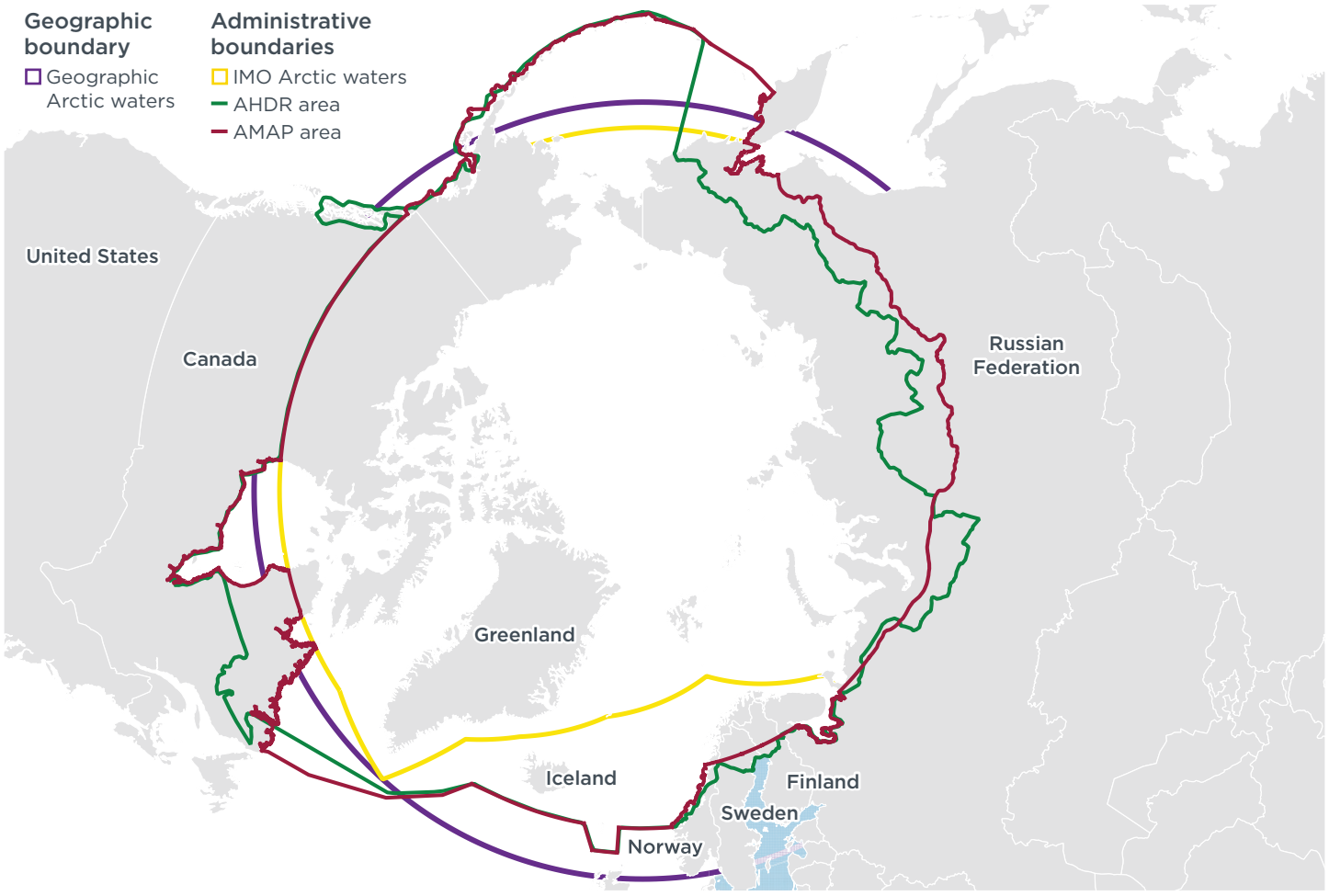
Many studies have quantified BC emissions in the Arctic region, but cross-comparison is challenging because these studies use different geographic definitions of Arctic waters. The Geographic Arctic region covers the Arctic Sea north of 59°N (Figure 1). While the Baltic Sea mainly falls within the latitudes of the Geographic Arctic region,

it is excluded from the Geographic Arctic definition due to climatic, geographic, and socio-political factors.[1]

The IMO uses a narrower delineation of the Arctic, as set out in its International Code for Ships Operating in Polar Waters, also known as the Polar Code (IMO, 2015). The Polar Code was developed to regulate shipping in polar regions by enhancing safety measures and environmental protection. In this paper, we refer to the IMO-defined region as the IMO Arctic.

Meanwhile, the Arctic Council—which convenes the eight states with territory in the Arctic region—has delineated its own Arctic boundary under the Arctic Monitoring and Assessment Program (AMAP), which assesses the impacts of pollution in the Arctic (AMAP, 1998).[2] The AMAP area includes the terrestrial and marine regions north of the Arctic Circle (66°32'N; AMAP, 1998; Grid Arendal, 2013). These boundaries differ, however, from those set out in the Arctic Council-mandated Arctic Human Development Report (AHDR), which defines the Arctic to encompass regions inhabited by Arctic Indigenous peoples and other communities experiencing similar Arctic conditions (Arctic Council, 2004). This socio-cultural approach to defining the Arctic highlights the human dimension and the unique challenges faced by populations living in this region.

Figure 1
Geographical and administrative boundaries of the Arctic region



1 The Helsinki Commission coordinates and implements measures for the protection and restoration of the marine environment in the Baltic Sea region.

2 The eight Arctic Council Member States are Canada, Denmark, Finland, Iceland, Norway, Russia, Sweden, and the United States.

SHIPPING EMISSIONS INVENTORIES IN THE ARCTIC

BC emissions inventories in the Arctic vary based on how the Arctic is defined and the methods authors use to quantify emissions. The latter include assumptions about BC emission factors, engine operational conditions, and the shipping data used for estimation. Because emission factors for BC are not standardized and shipping data vary widely by source, there is no general consensus on the current state of BC emissions in the Arctic.

Winther et al. (2014) estimated that there were 1,585 tonnes of BC emitted from ships in the Geographic Arctic in 2012 and projected this would increase to 1,615 tonnes in 2020, 1,656 tonnes in 2030, and 1,845 tonnes in 2050, assuming a BC emission factor of 0.35 g/kg fuel. Assuming the same emissions factor, Mjelde et al. (2014) estimated a similar level of BC emissions in the Geographic Arctic in 2012: 1,330 tons, or 1,206 tonnes.

Comer et al. (2017a) estimated that Arctic shipping emitted 1,453 tonnes of BC in the Geographic Arctic in 2015, assuming that emission factors range from 0.3 to 0.56 g/kg fuel, depending on the engine and fuel type. The emission factors from Comer et al. (2017a) were later adopted in the IMO's *Fourth Greenhouse Gas Study* (Faber et al., 2020). Geels et al. (2021) estimated that 800 tonnes of BC were emitted by ships operating in the Geographic Arctic in 2015 and projected this to increase to 810 tonnes in 2030 and 970 tonnes in 2050, assuming a business-as-usual scenario. These lower values are due to the use of lower emission factors: 0.0015–0.155 g/kg fuel, depending on the engine and fuel type.

For the IMO Arctic, DNV (2013) reported 52.3 tons (~47.4 tonnes) of BC emissions from shipping in 2012, assuming a BC emission factor of 0.18 g/kg fuel. Mjelde et al. (2014) estimated total shipping BC emissions of 105 tons (~95 tonnes) in the IMO Arctic in 2012, assuming an emission factor of 0.35 g/kg fuel. Comer et al. (2017a) estimated that 193 tonnes of BC were emitted by shipping in the IMO Arctic in 2015. Chen et al. (2021), using the emission factors from Comer et al. (2017a) but assessing only passenger ships, estimated annual average BC emissions in the IMO Arctic to be 39.17 tons (~35.53 tonnes) between 2012 and 2017, and predicted an increase to 39.34 (~35.68 tonnes) in 2020 and 39.41 (~35.75 tonnes) in 2025. EPRD (2021) estimated that 355 tonnes of BC were emitted in 2019 in IMO Arctic waters by the fleet at or above 300 gross tonnage (GT).

Considering the AMAP regional definition, Peters et al. (2011) estimated a total of 1,151 tonnes of BC emissions in 2004 and predicted that emissions would grow to 2,160 tonnes in 2030 and 2,960 in 2050, assuming an emission factor of 0.35 g/kg fuel. Mjelde et al. (2014) estimated total shipping BC emissions of 1,165 tons (1,057 tonnes) in 2012 within the AMAP Arctic.

REGULATORY LANDSCAPE FOR BLACK CARBON EMISSIONS FROM ARCTIC SHIPPING

Despite its potent climate and health impacts, BC remains arguably one of the most unregulated short-lived climate and air pollutants. Currently, there are no regulations that impose limits on BC from shipping, though some regulations have an indirect effect on reducing such emissions. For instance, in 2021, the IMO agreed to ban the carriage and use of heavy fuel oil (HFO) in the IMO Arctic, effective from July 1, 2024 (IMO, 2021a). This ban was expected to significantly reduce BC emissions in the IMO Arctic: Comer (2019) estimated that 68% of BC emissions in 2015 came from HFO-fueled ships, and that switching from HFO to distillate fuels could lead to a 50%–80% reduction in BC emissions, depending on the engine type (Comer, 2019). However, the ban includes exemptions and waivers that allow ships with protected fuel tanks and

those flagged to and navigating in the correspondent Arctic-flagged ships' states to continue carrying and using HFO in Arctic waters until 2029. As a result, Comer et al. (2020) expected the ban to reduce the use of HFO in the Arctic by just 16% and the carriage of HFO as fuel by 30%, to produce a 5% reduction in BC emissions.

In addition to the HFO ban, the IMO's Marine Environment Protection Committee adopted a resolution in 2021 calling on the shipping industry and Member States to take voluntary measures to address BC emissions from shipping in the Arctic. Ship operators were encouraged to "voluntarily use distillate or other cleaner alternative fuels that could contribute to the reduction of BC emissions when operating in or near the Arctic" (IMO, 2021b). Additionally, the Arctic Council's AMAP initiative approved a voluntary framework for addressing BC emissions in the Arctic, including biennial national reporting and national reduction goals for addressing black carbon emissions (Arctic Council, n.d.).

THE EUROPEAN UNION'S ROLE IN MITIGATING BLACK CARBON EMISSIONS IN THE ARCTIC

In 2021, the European Union announced its intention to increase engagement in and near the Arctic region in response to a range of environmental and social challenges (European Commission, 2021). Black carbon emissions in general, and those from Arctic shipping specifically, were identified as major issues to be addressed. The European Union commissioned a technical study to measure its environmental footprint in the Arctic and established a partnership instrument through AMAP to support stronger commitments and targets for reducing BC emissions in the region (AMAP, n.d.; EPRD, 2021). However, two major EU policies adopted in 2023 aimed at regulating shipping emissions as part of the "Fit for 55" initiative—FuelEU Maritime and the EU Emissions Trading System (ETS) extension to maritime—did not include BC in their scope, postponing this decision to future revisions (Directive 2003/87/EC; Regulation (EU) 2023/1805).

The study commissioned by the European Commission quantifies the EU-related BC and CO_2 footprint in the IMO Arctic using a "flag-based" and "state-ownership" approach, considering BC emissions from ships flying EU Member State flags and from ships flying non-EU flags but owned and operated by companies based in EU Member States (EPRD, 2021). The study estimated that out of 1,718 unique vessels of 300 GT or more sailing in the Arctic, 259 were flying EU Member flags and 10 were flying non-EU Member flags but were owned by companies in the European Union. Consequently, the combined direct contribution of EU Member States to CO_2 emissions in the IMO Arctic was estimated at 26%, and to BC emissions at 16% (EPRD, 2021; European Commission, 2021). The study concluded that the European Union's footprint can be classified as "high" for CO_2 emissions and "medium" for BC emissions. Moreover, the study found that the impact of cruise shipping and liquefied natural gas (LNG) carriers was "very high" for both pollutants, while there was insufficient data to classify the impact of crude oil, general cargo, and bulk transportation.

One limitation of the flag-based footprint assessment is that it does not align with the European Union's approach to regulating GHG emissions through the EU MRV system (Regulation (EU) 2015/757). Under this system, ships must report emissions if their voyages include arrivals to or departures from any EU ports. This applies to both EU-flagged and non-EU-flagged vessels. This means ships do not need to be exclusively operating between EU ports; they only need to arrive at or depart from an EU port at some point during the reporting period. This approach enables a more accurate assessment of EU fleet activities in the Arctic and associated BC emissions compared with the flag-based assessment.

METHODOLOGY

We conducted an inventory of maritime BC and CO_2 emissions in the Geographic Arctic, defined as the region covering the Arctic Sea north of 59°N, and in IMO Arctic waters, defined by the Polar Code (IMO, 2015). We excluded the Baltic Sea from the Geographic Arctic inventory but performed an independent emissions inventory for the Baltic Sea using boundaries defined by the International Hydrographic Organization (1953); see Appendix C. In this report, ships flying EU flags while operating in the Arctic are referred to as the EU-flagged fleet, while ships reporting to the EU MRV system and carrying out voyages to or from EU ports within the Arctic are referred to as the EU-regulated fleet.

We used the ICCT's Systematic Assessment of Vessel Emissions (SAVE) model to analyze shipping activities, fuel consumption, and CO_2 and BC emissions in 2021 in the Geographic Arctic and IMO Arctic (Mao et al., 2025). SAVE is a global shipping inventory model built by the ICCT that uses automatic identification system data (Spire, n.d.). Ship characteristics, including ship type, fuel type, and flag state, were obtained from an IHS Markit dataset (S&P Global, n.d.).[3]

The SAVE model estimates hourly ship-specific power demand and fuel consumption based on the engines and fuel type used by each ship. The detailed methodology used for this inventory is published in Mao et al. (2025). To identify the vessels that reported to the EU MRV, we cross-referenced the IMO numbers of ships that reported to the EU MRV in 2021 (European Maritime Safety Agency, 2023) with those operating in the Geographic Arctic and IMO Arctic during the same year, using the SAVE model. We only selected vessels that spent two or more hours within the Arctic area. Ship classes were aggregated by general category to simplify reporting, as shown in Appendix A. Until January 2025, the EU MRV system required only ships of 5,000 GT and above to report their emissions, but starting this year, the scope was expanded to include general cargo vessels and offshore ships of 400 GT and above. Since our analysis is based on 2021 data, we considered only ships 5,000 GT and above when comparing different emission reporting scopes within the European Union.

Black carbon emission factors were estimated as a function of fuel type and engine type and varied by engine load. Black carbon emissions for vessels using residual fuels and distillates in slow-speed diesel (SSD), medium-speed diesel (MSD), and high-speed diesel (HSD) engines were derived from Faber et al. (2020). As noted above, these emissions were initially estimated by the ICCT (Comer et al, 2017a). Emission factors for BC from distillates are typically 40%–50% lower than those from residual fuels in 4-stroke engines and can be up to 80% lower in 2-stroke engines. For other types of engines and fuels, we used energy-based emission factors and accounted for the instantaneous power output of engines, consistent with the methodologies outlined in Faber et al. (2020) and Comer et al. (2017a). Ships with scrubbers installed were identified using the IHS Markit dataset, and BC emission factors for the scrubbers-equipped ships were adjusted as estimated by Comer et al. (2020).

FLEET CHARACTERISTICS AND FUEL USE IN THE ARCTIC AND EU-REGULATED SHIPPING

This section provides an inventory of vessel types and fuel use across both the Geographic and IMO Arctic regions. It also estimates the share of EU-flagged and EU-regulated vessels within these areas.

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GEOGRAPHIC ARCTIC

Fleet composition

We estimated that 8,577 ships sailed the Geographic Arctic in 2021, of which 3,171 (37%) were at or above 5,000 GT. Fishing vessels were the most common ship type in the Geographic Arctic, representing 25% of the total ship count. However, the majority of fishing vessels fall below 5,000 GT, while ships at or above 5,000 GT consist mainly of bulk carriers, general cargo, and oil tankers. Combined, these three ship types represented 57% of all ships at or above 5,000 in the Geographic Arctic in our estimates, with bulk carriers being the most common.

We found that of the 12,211 ships that reported to the EU MRV globally in 2021, 2,315 were engaged in shipping activities in the Geographic Arctic. With an estimated 3,171 vessels at or above 5,000 GT in the Geographic Arctic, this means that 73% of all ships at or above 5,000 GT navigating in the Geographic Arctic reported to the EU MRV in 2021. In contrast, only 26% of ships at or above 5,000 GT in the Geographic Arctic were flying EU flags (Table 1).

Table 1

Estimated ships per ship class navigating in the Geographic Arctic and IMO Arctic in 2021

General ship type	Ship class	Geographic Arctic				IMO Arctic			
		All ships	Ships ≥ 5,000 GT	EU-flagged ships ≥ 5,000 GT	Ships ≥ 5,000 GT reporting to the EU MRV	All ships	Ships ≥ 5,000 GT	EU-flagged ships ≥ 5,000 GT	Ships ≥ 5,000 GT reporting to the EU MRV
Fishing vessel	Miscellaneous-fishing	2,151	59	12	0	793	24	3	0
Cargo ship	Refrigerated bulk	180	87	4	45	85	35	0	4
	General cargo	1,651	505	218	414	254	164	48	103
	Bulk carrier	848	817	147	735	137	131	24	103
Tanker	Oil tanker	585	496	128	436	71	43	5	22
	Chemical tanker	576	406	117	350	50	27	4	11
	Other liquids tanker	2	0	0	0	0	0	0	0
Other vessel	Service – tug	499	41	7	0	170	9	0	0
	Service – other	436	98	28	0	163	57	16	0
	Miscellaneous – other	71	24	6	0	14	8	0	0
	Yacht	55	2	0	0	10	0	0	0
	Offshore	511	187	14	4	42	17	0	1
Ferry	Ferry – Ro-Pax	342	49	6	24	4	1	0	0
	Ferry – Pax only	171	0	0	0	10	0	0	0
LNG carrier	Liquefied gas tanker	183	139	39	136	27	27	8	27
Cruise	Cruise	116	84	18	27	16	10	1	1
Container	Container	104	101	46	81	11	10	3	6
Vehicle carrier	Ro-Ro	58	38	20	26	9	1	0	0
	Vehicle	38	38	6	37	0	0	0	0
			All ships	All ships ≥ 5,000 GT			All ships	All ships ≥ 5,000 GT	
Total		**8,577**	**3,171**	**816**	**2,315**	**1,866**	**564**	**112**	**278**
Total (%)			**37%**	**26%**	**73%**		**30%**	**20%**	**49%**

Fuel use

In 2021, ships sailing in the Geographic Arctic burned an estimated 3,789 kt of fuel, of which 2,021 kt (53%) was distillate fuel largely burned by smaller fishing vessels (see Figure 2a and Table B1 in Appendix B). Residual fuels came second, comprising 33% of the total fuel mix, with 5% burned by ships equipped with scrubbers.

The top 10 flag states by fuel consumption in the Geographic Arctic fleet accounted for 80% of total fuel consumed in 2021. Norway and Russia were by far the largest consumers of fuel in the region (Figure 3; Table B6 in Appendix B). Among EU-flagged ships, only two EU Member States, Cyprus and Denmark, ranked in the top 10; together, these two states were responsible for 8% of the fuel consumed by the top 10 flag states.

For ships at or above 5,000 GT, residual fuel accounted for the largest share of total fuel consumption (52%), while distillate fuels made up 24% (Figure 2a). These larger ships also had greater shares of LNG use (24%) and fuel consumption by vessels with scrubbers (10%) compared with the Geographic Arctic fleet average.

For vessels at or above 5,000 GT, in 2021, EU-flagged ships were responsible for 24% of total fuel burned, while EU-regulated vessels were responsible for 60%. We also found that large numbers of ships coming in and out of EU ports used LNG as a primary fuel, with LNG accounting for 34% of the total fuel burned (Table B1).

Figure 2
Ship classes and fuels burned in the Geographic Arctic in 2021

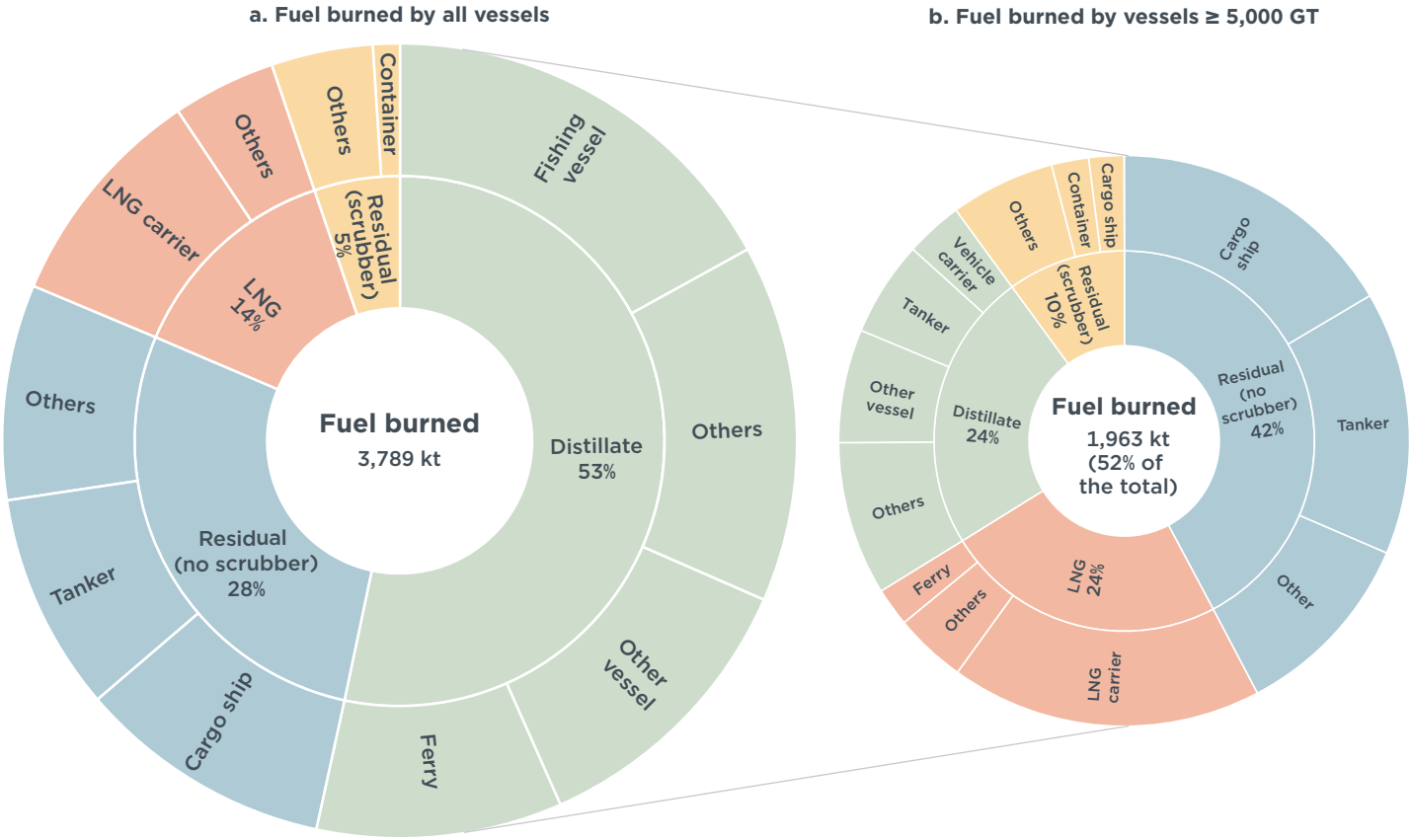
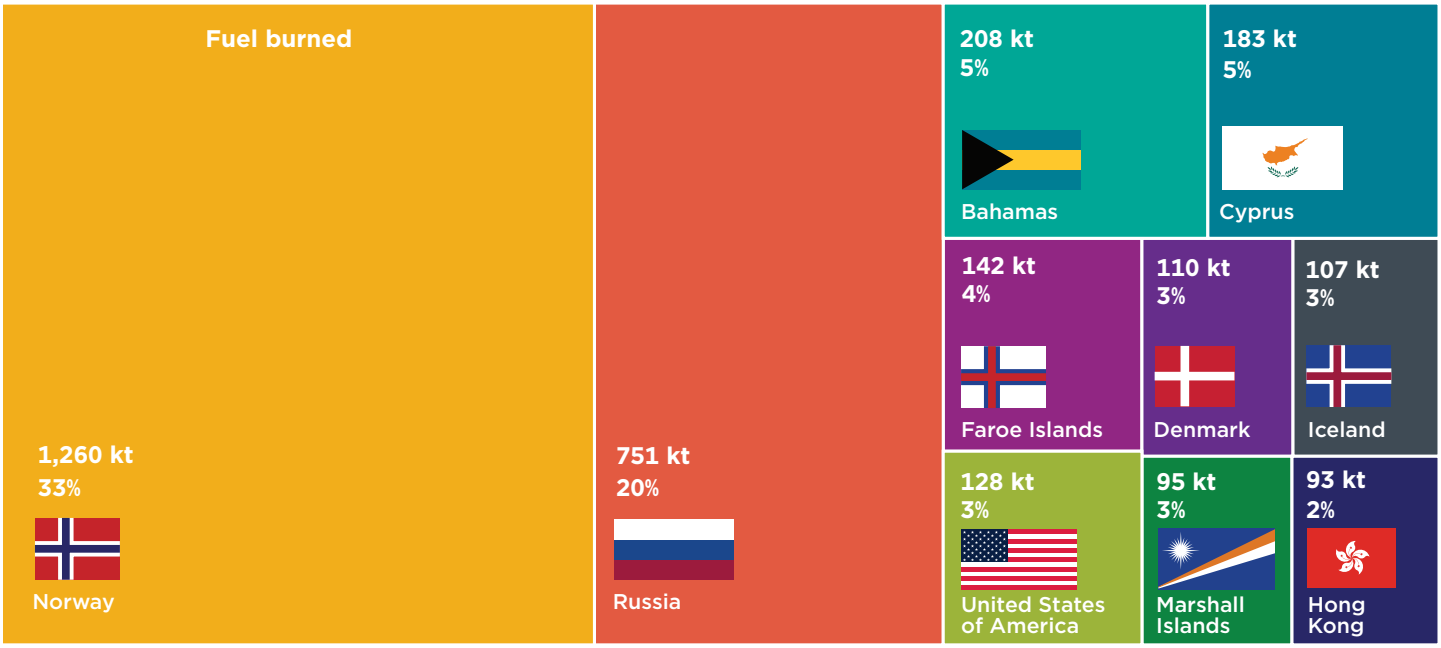


Figure 3

Top 10 flag states in the Geographic Arctic by fuel consumption



IMO ARCTIC

Fleet composition

An estimated 1,866 ships sailed in the IMO Arctic in 2021, which is 22% of the total estimated number of ships that sailed in the Geographic Arctic. Of these, 564 (30%) were at or above 5,000 GT (Table 1). The fleet composition in the IMO Arctic was similar to that of the Geographic Arctic: Fishing vessels were the most common ship type, while bulk carriers, general cargo ships, and tankers made up approximately 60% of the fleet at or above 5,000 GT (Table 1). Of an estimated 564 ships at or above 5,000 GT sailing in the IMO Arctic, 112 (20%) were EU-flagged while 278 (49%) were EU-regulated.

Fuel use

An estimated 877 kt of fuel was burned in the IMO Arctic in 2021, representing about 23% of the total estimated fuel burned in the Geographic Arctic (3,789 kt; see Table A1 in Appendix A). Residual oil accounted for just over half of the total fuel mix (51%), followed by distillates (26%), and LNG (23%).

Vessels at or above 5,000 GT consumed 70% (613 kt) of fuel burned by the IMO Arctic fleet; of this fuel, 63% was residual and only 3% distillate. The share of LNG in the fuel mix for ships at or above 5,000 GT was 34%, compared with 24% in the Geographic Arctic (Table B1).

Russian-flagged ships were predominant in the IMO Arctic, both in terms of ship count and fuel consumption (Figure 5; Table B6). These ships represented 49% of the total number of ships and 48% of the total fuel burned in the IMO Arctic in 2021.

We estimated that EU-regulated ships burned 51% of the fuel consumed by ships at or above 5,000 GT sailing in the IMO Arctic in 2021, while EU-flagged ships burned 21%. We found that most LNG-fueled vessels sailing in the IMO Arctic came from EU ports: The EU-regulated fleet accounted for all 27 LNG tankers sailing in the IMO Arctic and nearly all LNG consumed in the IMO Arctic in 2021, and LNG represented 65% of the IMO Arctic fuel mix of these vessels.

Figure 4

Ship classes and fuel burned in the IMO Arctic in 2021

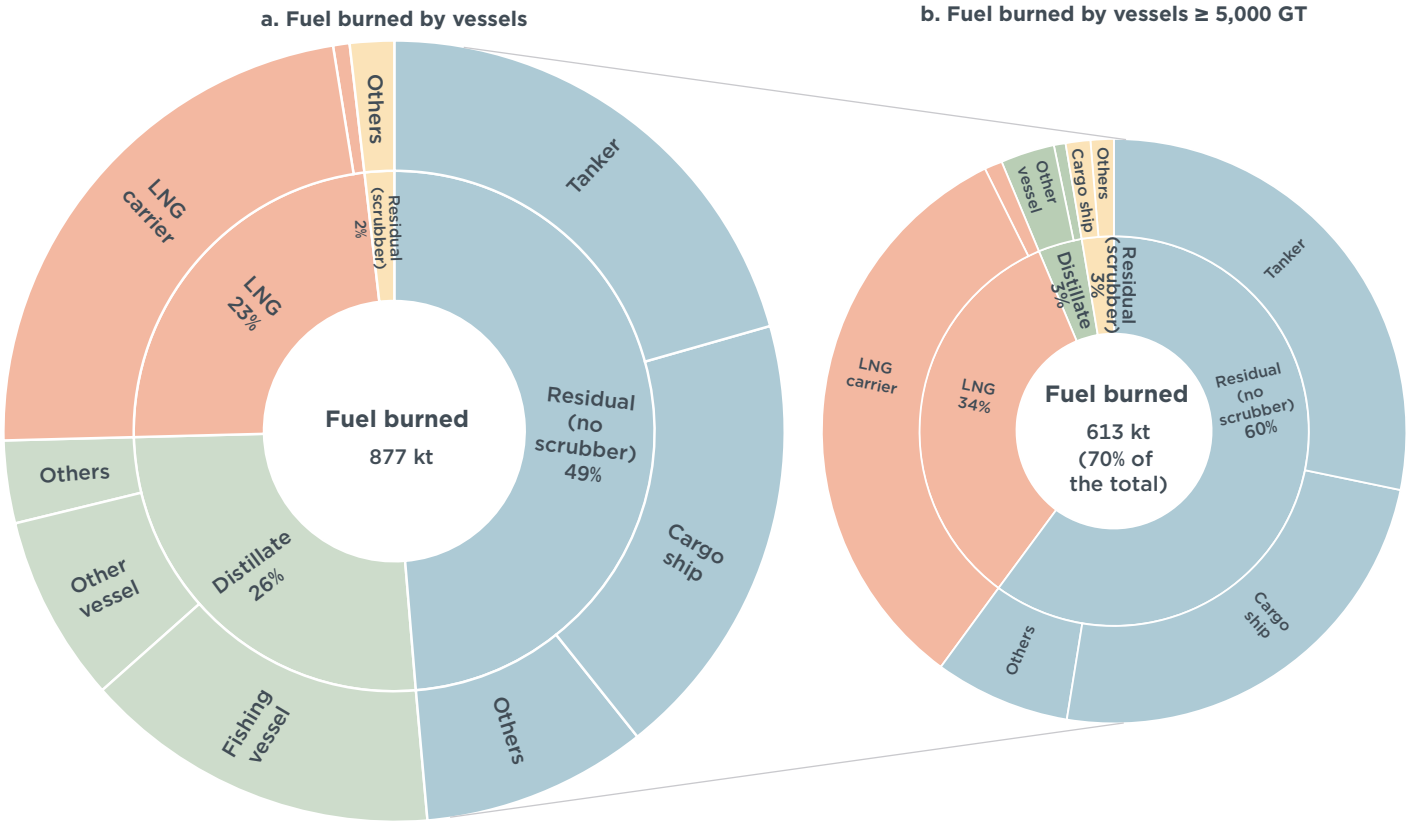


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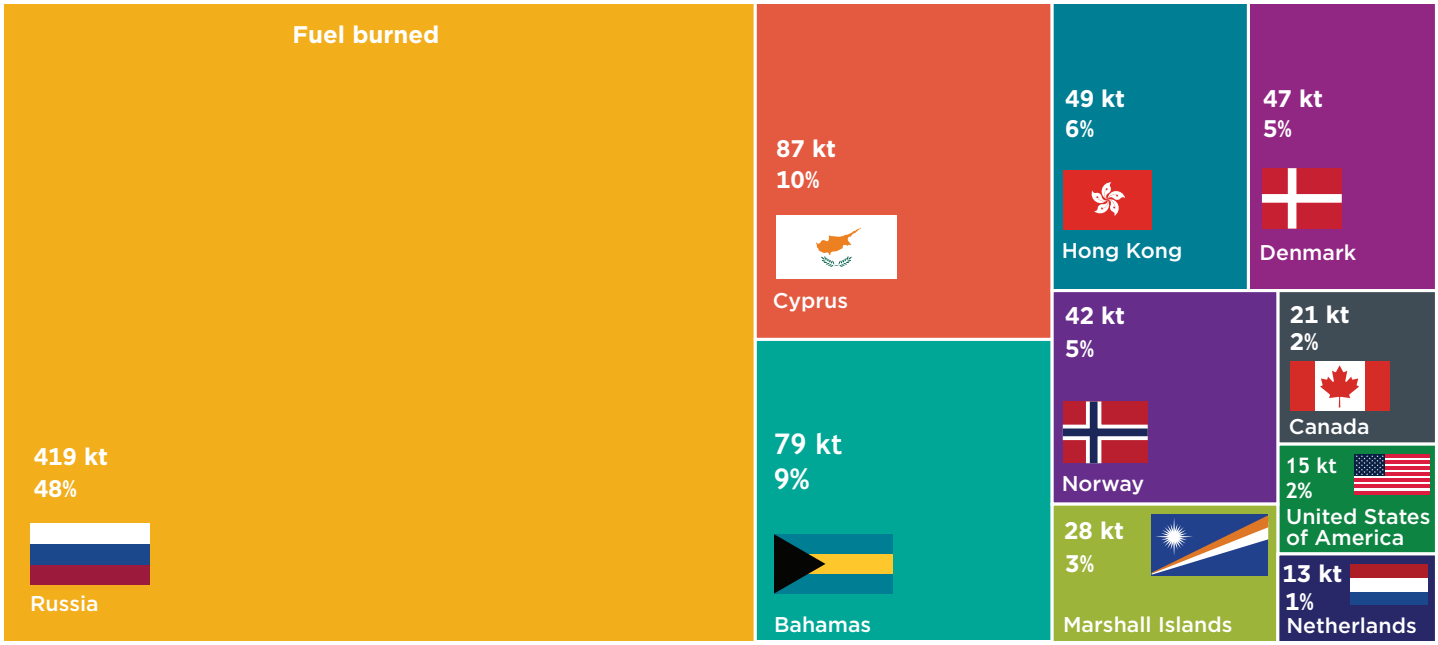
Figure 5

Top 10 flag states in the IMO Arctic by fuel consumption



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BC AND CO_2 EMISSIONS OF EU-FLAGGED AND EU-REGULATED SHIPPING IN THE ARCTIC

This section analyzes the BC and CO_2 emissions from vessel operations in the Geographic and IMO Arctic regions. It estimates emissions from the EU-flagged and EU-regulated fleet, emphasizing their overall contribution to Arctic emissions.

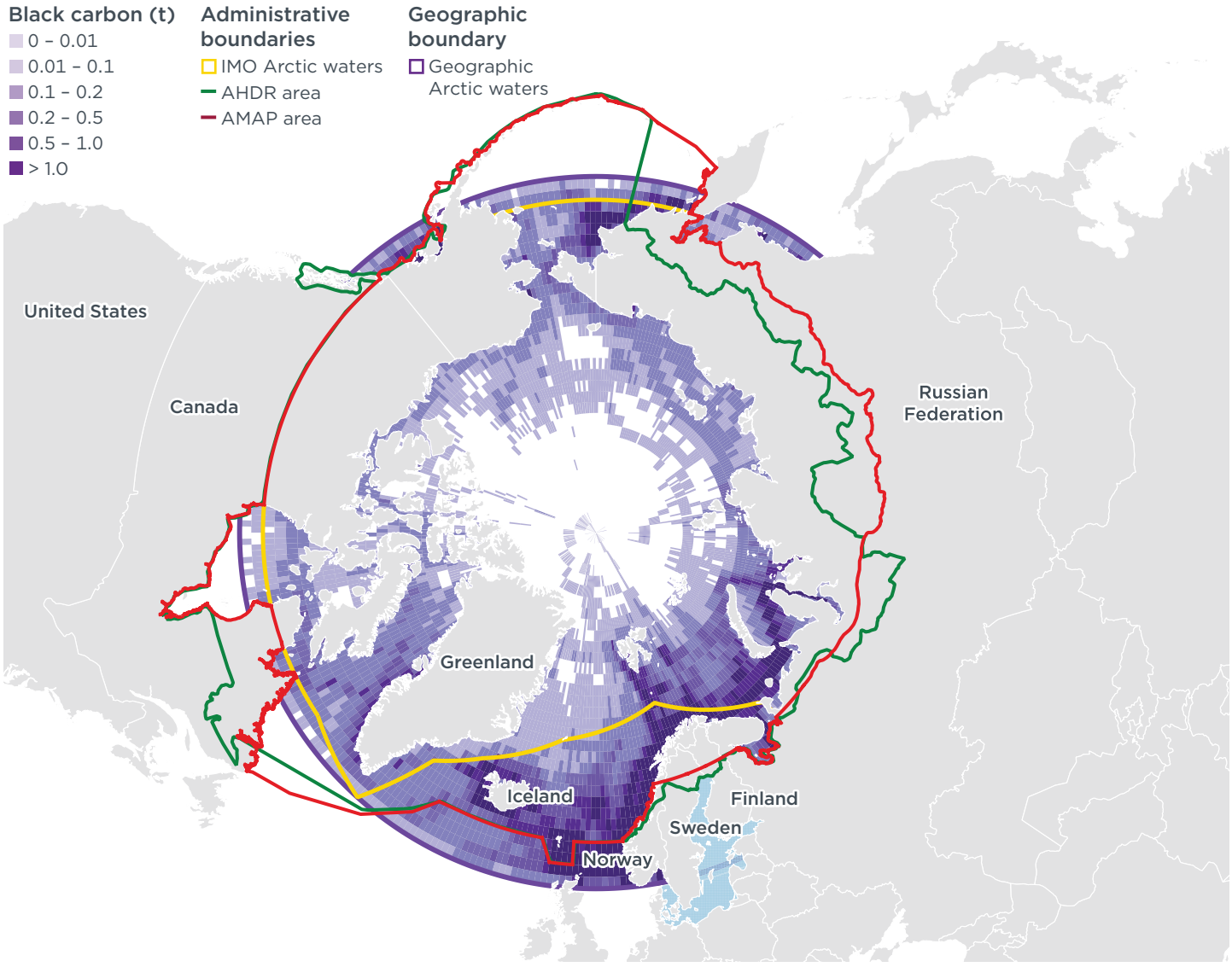
GEOGRAPHIC ARCTIC

Black carbon emissions

In 2021, ships operating in the Geographic Arctic emitted an estimated 1,529 tonnes of BC. The distribution of these emissions is shown in Figure 6. Fishing vessels accounted for the largest share by ship type, at 414 tonnes (27%). Since fishing vessels are the most common vessel type in the Geographic Arctic and they mostly use distillate fuels, the distillate fuel accounted for over half (55%) of the total BC emissions, at 840 tonnes (Table B3 in Appendix B). Ships at or above 5,000 GT emitted an estimated 720 tonnes of BC in the Geographic Arctic in 2021. Approximately 72% of these emissions were attributed to residual fuels.

Figure 6

Black carbon emissions in the Geographic Arctic in 2021

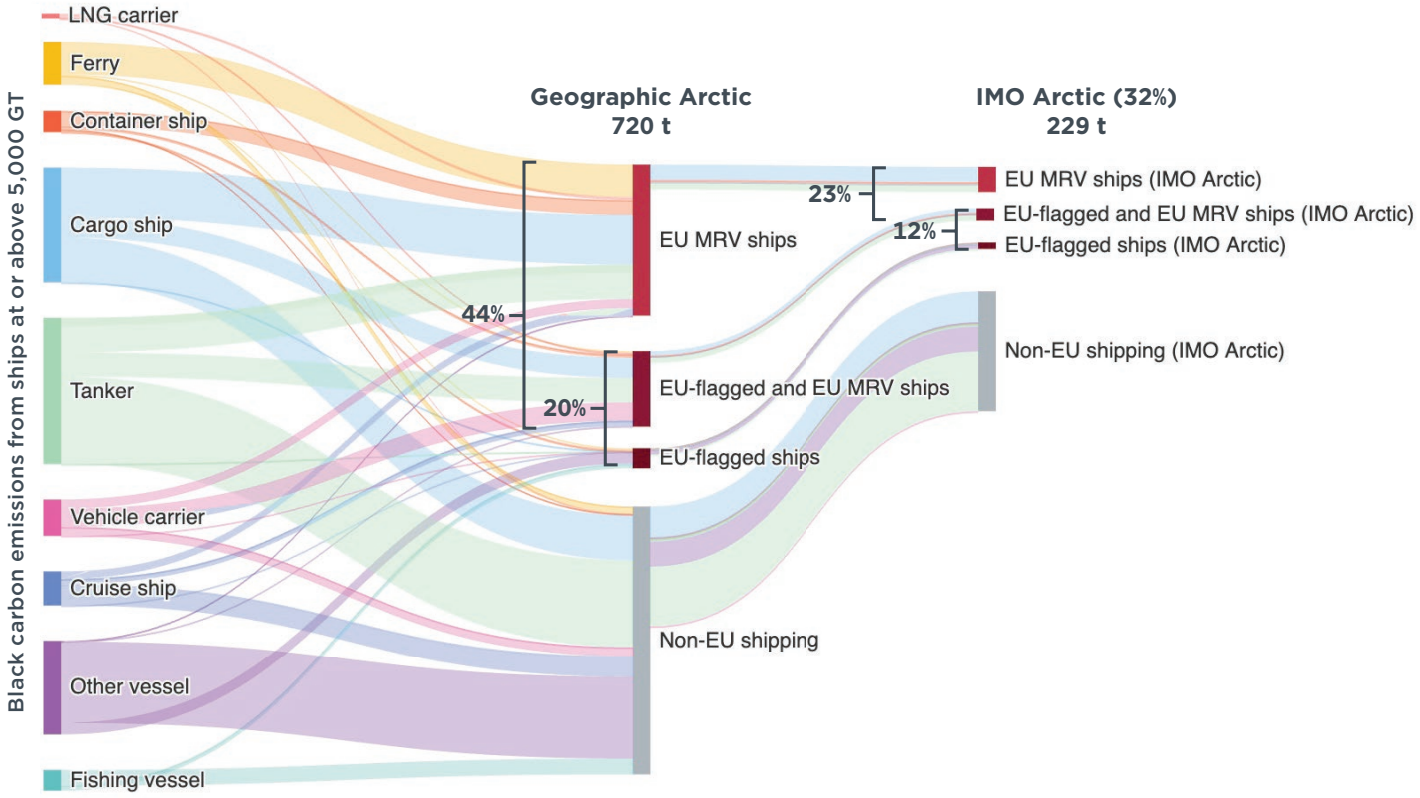


Of the 720 tonnes of BC emitted by ships at or above 5,000 GT, 317 tonnes (44%) were emitted by the EU-regulated fleet; of this total, 229 tonnes (72%) were attributable to residual fuels, with a significant contribution from ships equipped with scrubbers (22%). Liquefied natural gas, despite being the most common fuel burned by EU-regulated ships in the Geographic Arctic in 2021 (34% of the total), accounted for only 2% of BC emissions emitted in this region by the EU-regulated fleet. However, LNG has a strong negative climate impact due to the release of unburned methane from ships equipped with the most commonly used engines (Comer et al., 2024; Pavlenko et al., 2020). Similar to BC, methane is a potent short-lived climate pollutant; its global warming potential is 21 times stronger than that of CO_2 on a 100-year time horizon.

EU-flagged ships emitted less than half the total estimated amount of BC emitted by EU-regulated vessels in the Geographic Arctic in 2021. Specifically, EU-flagged ships emitted 145 tonnes, while EU-regulated ships emitted 317 tonnes, representing 20% and 44% of the total, respectively (Figure 7 and Table B2 in Appendix B). Among EU-flagged ships, the top 5 flag states in terms of BC emissions were Cyprus, the Netherlands, Finland, Malta, and Denmark (Figure 8).

Figure 7

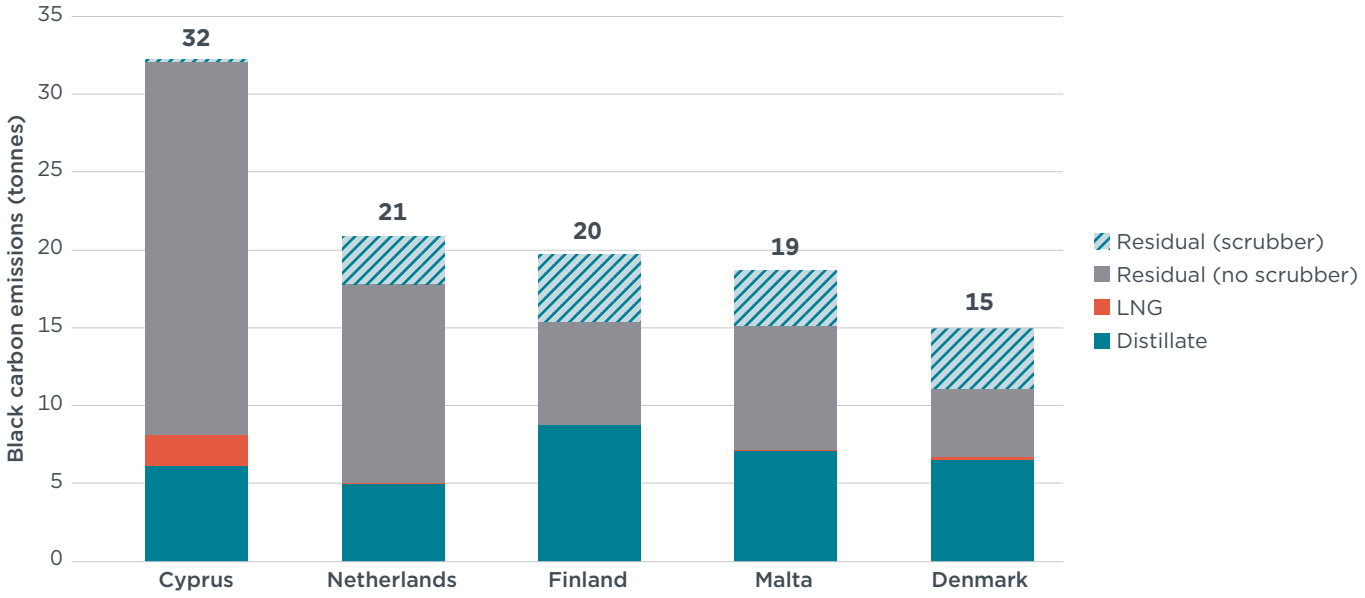
Black carbon emitted in the Geographic Arctic and in the IMO Arctic by EU-flagged and EU-regulated vessels, by ship class



Note: Ships under 5,000 GT emit 53% of BC, 48% from fishing vessles.

Figure 8

Top 5 EU flag states in terms of black carbon emissions from ships at or above 5,000 GT sailing in the Geographic Arctic



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CO_2 emissions

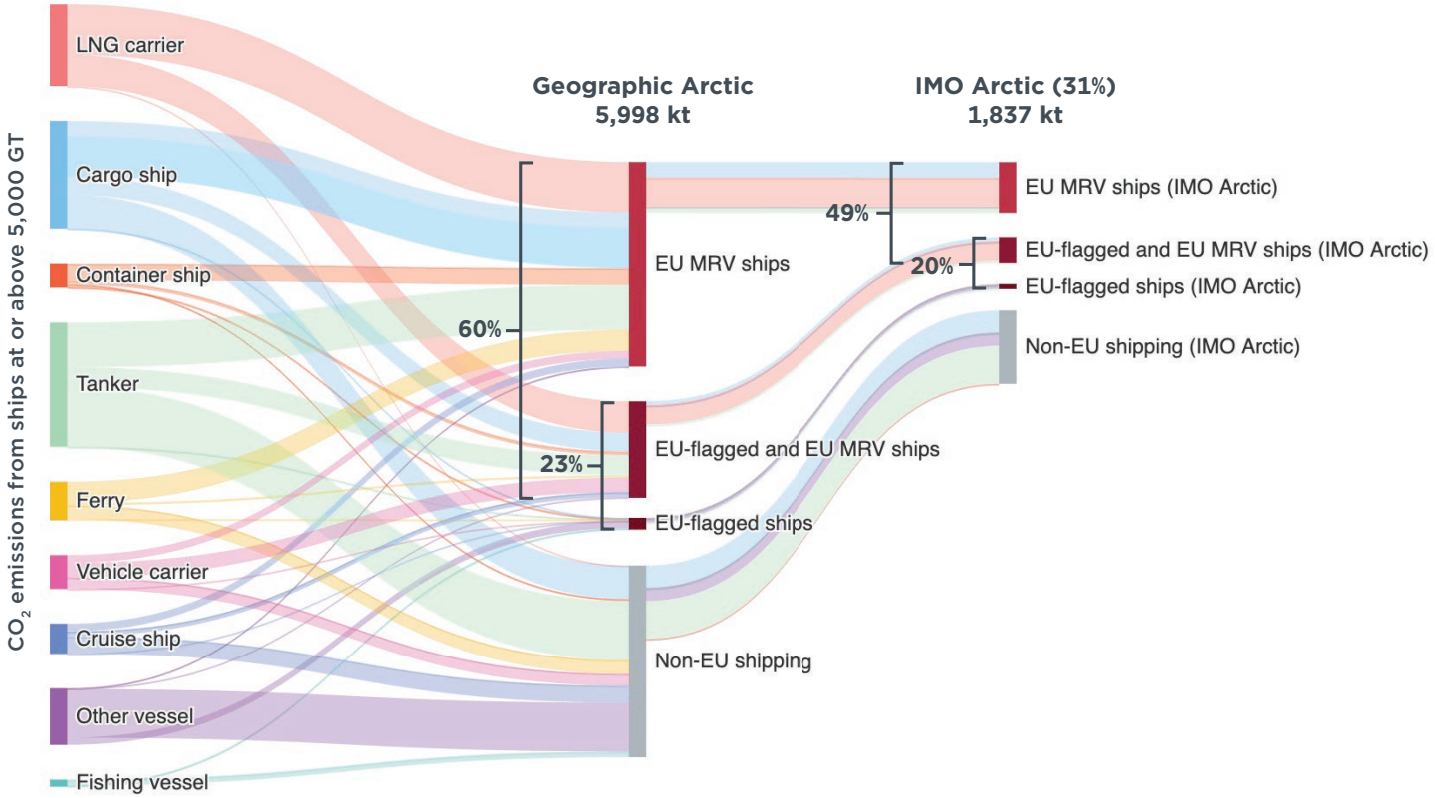
Ships operating in the Geographic Arctic in 2021 produced an estimated 11,813 kt of CO_2 emissions, with 5,998 kt (51%) coming from ships at or above 5,000 GT (Figure 9 and Table B4 in Appendix B). As with BC emissions, fishing vessels were the largest contributor to CO_2 emissions in the Geographic Arctic (2,352 kt), with distillate fuels being the main source of CO_2 emissions (6,479 kt, 55% of the total).

Residual fuels accounted for over half of all CO_2 emissions from ships at or above 5,000 GT in the Geographic Arctic (3,209 kt, 53% of the total). Among these ships, oil tankers accounted for the largest share of CO_2 emissions (Tables B4 and B5 in Appendix B). We estimated that the EU-regulated fleet was responsible for 60% of total CO_2 emissions (3,573 kt) from ships at or above 5,000 GT sailing the Geographic Arctic in 2021, in contrast to 23% (1,397 kt) from EU-flagged ships.

In 2021, liquefied gas tankers were the largest CO_2 emitters among EU-regulated ships in the Geographic Arctic, releasing 973 kt in total, including 375 kt from EU-flagged ships. While LNG-fueled ships were responsible for just 2% of the BC emissions from EU-regulated vessels, they accounted for 31% of this fleet's total CO_2 emissions. Among EU-regulated ships in the Geographic Arctic, those equipped with scrubbers emitted nearly 90% (561 kt) of CO_2 emissions; by contrast, scrubber-equipped vessels accounted for roughly 28% (177 kt) of CO_2 emissions from the EU-flagged fleet.

Figure 9

Carbon dioxide emitted in the Geographic Arctic and in the IMO Arctic by EU-regulated vessels, by ship class



Note: Ships under 5,000 GT emit 49% of CO_2, 40% from fishing vessles.

IMO ARCTIC

Black carbon emissions

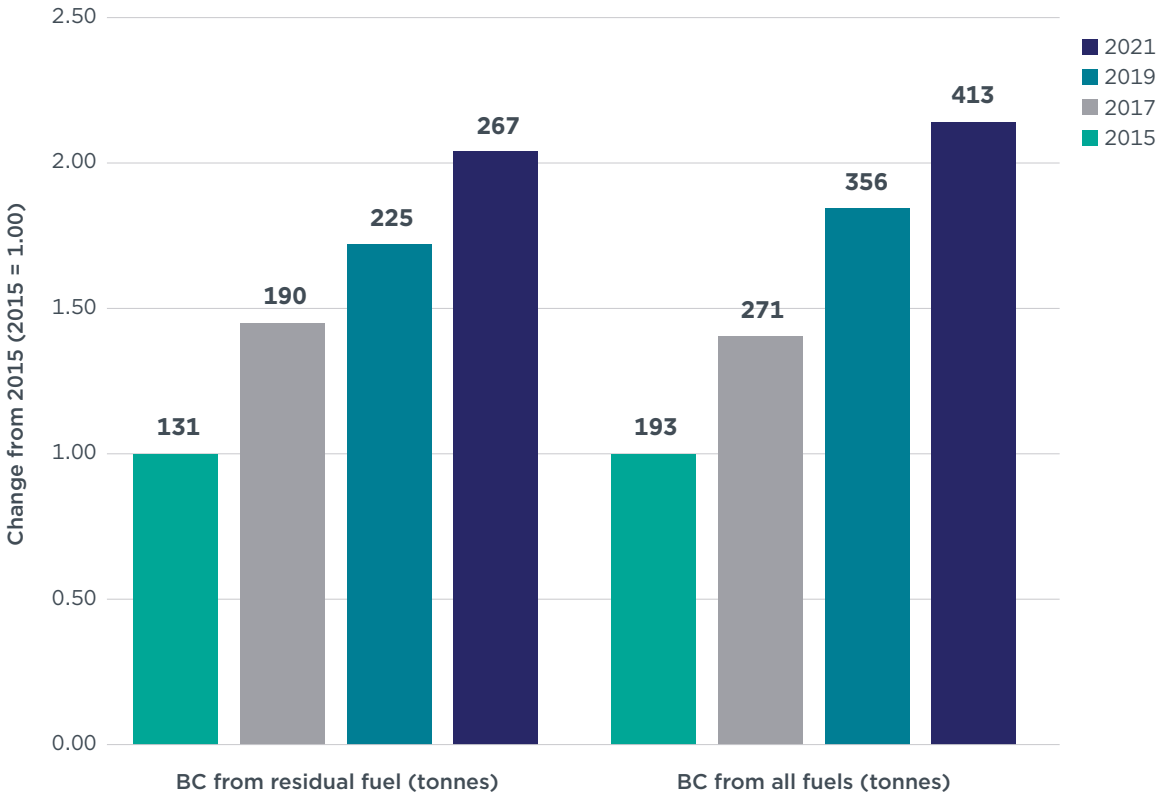
In 2021, ships operating in the IMO Arctic emitted 413 tonnes of BC, 27% of the total BC emissions from shipping in the Geographic Arctic. This was more than twice the estimated BC emissions in the IMO Arctic in 2015, when it stood at 193 tonnes (Comer et al., 2017a; see Figure 10).

Similar to the Geographic Arctic, fishing vessels were the primary contributors to BC emissions in the IMO Arctic, where they emitted an estimated 133 tonnes of BC, 32% of total BC emissions. Among ships of 5,000 GT or above, oil tankers were the primary BC emitters, responsible for 42% of total emissions from all ships in this size category.

In contrast to the Geographic Arctic, most BC emissions in the IMO Arctic were from residual fuel oil rather than distillate fuel. Specifically, 267 tonnes (64%) of all BC emissions in the IMO Arctic were from residual fuel. Ships at or above 5,000 GT emitted 229 tonnes of BC, 92% of which were from residual fuel (Table B3 in Appendix B). Estimated BC emissions from residual fuel oil in the IMO Arctic doubled between 2015 and 2021, despite a slight increase (of 3%) in distillate fuel consumption since 2015 (Comer et al., 2017a; Figure 10).

Figure 10

Black carbon emissions growth in the IMO Arctic, 2015–2021



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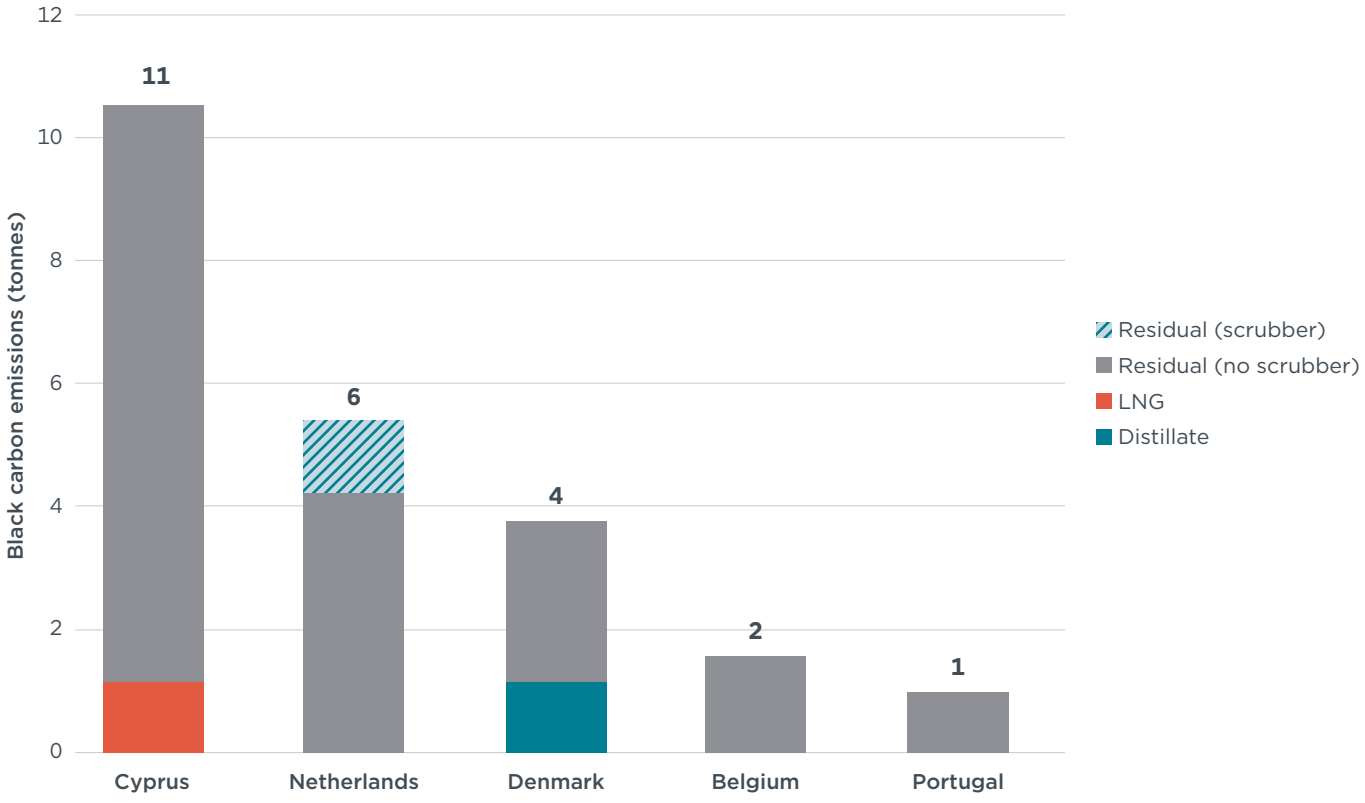
We estimated that out of the 229 tonnes of BC emitted by ships at or above 5,000 GT, 27 tonnes (12%) were emitted by EU-flagged ships. Almost 90% of these emissions (24 tonnes) came from the top 5 EU flag states: Cyprus, the Netherlands, Denmark, Belgium, and Portugal (Figure 11). This ratio is slightly lower than EPRD's (2021) findings, which reported that 15% of BC emissions in the IMO Arctic were from EU-flagged vessels, although EPRD considered all vessels at or above 300 GT in their study. For comparison, we also estimated BC emissions from ships at or above 300 GT and found that these ships emitted 47 tonnes of BC in the IMO Arctic, while EPRD reported a similar estimate of 53.5 tonnes.

The EU-regulated fleet emitted 52 tonnes of BC, equivalent to 23% of BC emissions in the IMO Arctic—nearly twice what EU-flagged ships emitted (Figure 7).

Figure 11

Top 5 EU flag states sorted by BC emissions from the ships at or above 5,000 GT sailing in the IMO Arctic waters



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CO_2 emissions

Ships operating in the IMO Arctic emitted an estimated 2,676 kt of CO_2, of which 1,837 kt (69%) came from ships at or above 5,000 GT (Table A4). In contrast to the Geographic Arctic, where fishing vessels had the largest CO_2 share, the main CO_2 contributors in the IMO Arctic waters were liquefied gas tankers (551 tonnes, 21% of total CO_2 emissions). Fishing vessels below 5,000 GT also produced a significant CO_2 footprint in the IMO Arctic (512 tonnes, 19%), emitting slightly more CO_2 than oil tankers (511 tonnes, 19%).

Among all vessels, half of CO_2 shipping emissions in the IMO Arctic came from residual fuels, followed by distillates (27%; Table B5 in Appendix B). Residual fuels comprised 62% of fuel consumed by ships at or above 5,000 GT, followed by LNG (31%) with a minimal contribution from distillate fuel (4%).

We estimated that out of 1,837 kt of CO_2 emitted in the IMO Arctic in 2021 by ships at or above 5,000 GT, 906 kt (49%) were emitted by EU-regulated ships, while EU-flagged ships emitted 374 kt (20%; Figure 9). EPRD (2021) reported a similar ratio (24.6%) of CO_2 emissions from EU-flagged vessels, although they used a different size category for their estimates (ships at or above 300 GT). Based on these estimates, quantifying the EU footprint in Arctic waters using a flag-state approach captures less than half of the CO_2 emissions from ships sailing in and out of EU ports.

CONCLUSIONS AND POLICY CONSIDERATIONS

In this report, we estimated the size, fuel use, and BC and CO_2 emissions from fleets operating in the Geographic Arctic (north of 59°N) and the IMO Arctic (as defined by the IMO Polar Code). We assessed that a substantial portion of these emissions came from the EU-regulated fleet: ships traveling to and from EU ports, regardless of flag state. By considering only ships flying EU flags in Arctic waters, prior assessments have likely significantly underestimated the contribution of EU shipping to emissions in the region.

In 2021, shipping in the Geographic Arctic emitted approximately 1.5 kt of BC and 12 kt of CO_2, with about a quarter of these emissions occurring within the IMO Arctic. Notably, estimated BC emissions in the IMO Arctic have nearly doubled since 2015. Fishing vessels were the most common ship type in both the Geographic and IMO Arctic in 2021, contributing 27% and 32% of the total BC emissions in these regions, respectively. For vessels over 5,000 GT, bulk carriers, general cargo ships, and oil tankers made up the largest share, collectively responsible for 43% and 69% of BC emissions in the Geographic and IMO Arctic, respectively.

Our study indicates that a significant portion of the fleet operating in Arctic waters is connected to EU ports. Specifically, 73% of ships over 5,000 GT in the Geographic Arctic and 49% in the IMO Arctic reported to the EU MRV system. The BC and CO_2 emissions from EU-regulated ships were nearly double those from EU-flagged ships. In the Geographic Arctic, EU-regulated ships accounted for 44% of BC emissions and 60% of CO_2 emissions, compared with only 20% of BC emissions and 23% of CO_2 emissions from EU-flagged ships alone. In the IMO Arctic, EU-regulated ships were responsible for 23% of BC emissions and 49% of CO_2 emissions, against 12% and 20%, respectively, for EU-flagged vessels. These results highlight the significant role of EU-regulated shipping in contributing to both BC and CO_2 emissions in the Arctic, and the need for more comprehensive policies that extend beyond EU-flagged vessels.

While shipping is recognized as a significant source of BC pollution, the European Union's approach to quantifying its emissions in the Arctic has focused on EU-flagged ships. Moreover, BC emissions have not been included in the scope of EU maritime policies under the "Fit for 55" package, such as FuelEU Maritime and the extension of the EU Emissions Trading System to the maritime sector.

To address this gap, EU policymakers could consider including BC among the pollutants measured and reported within the EU MRV system. BC is a short-lived climate forcer with an atmospheric lifetime of days to weeks—unlike CO_2, which persists for centuries. Due to BC's high radiative forcing and albedo-reducing effects on snow and ice, immediate BC emission reductions can provide rapid and measurable climate mitigation benefits in the Arctic. Policymakers could therefore consider requiring separate reporting of fuel consumption and BC emissions for vessels that spend a portion of their operational time in the Arctic. Moreover, defining "Arctic waters" as the area north of 59°N, rather than as the IMO Arctic as defined in the Polar Code, would enable a more comprehensive assessment of emissions.

Beyond improved emissions tracking, policymakers could consider various measures to reduce BC emissions from ships operating to and from EU ports. One option would be to incentivize the use of distillate fuel instead of residual fuel, as distillate fuels are widely available in EU ports and do not require engine modifications. Switching to distillate fuels could reduce BC emissions by 50%–80%, resulting in an immediate reduction of 115–183 tonnes (16%–25%) of BC emissions from EU-regulated ships of 5,000 GT or more in the Geographic Arctic. Additionally, as highlighted in previous ICCT work (Comer, 2019), encouraging the installation of diesel particulate filters on these ships could reduce BC emissions up to 90%. By applying the assumptions from

the aforementioned research, we estimated that BC reductions from EU-regulated vessels can reach 206 tonnes, achieving a 29% total BC reduction from the Geographic Arctic fleet over 5,000 GT.

Once BC emissions are incorporated into the EU MRV, future revisions of the EU Emissions Trading System and FuelEU Maritime policies could include BC alongside other greenhouse gases like nitrous oxide and methane. This would acknowledge BC as a significant climate pollutant and encourage efforts to address its impact in both EU waters and the Arctic, aligning with the EU's commitment to reducing its climate footprint in the region. By taking measures such as these, the European Union can play a pivotal role in mitigating the environmental impact of Arctic shipping and support its broader climate and sustainability goals.

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APPENDIX A. GENERAL SHIP TYPES FROM THE SAVE MODEL

Table A1

General ship types including aggregated ship classes from the SAVE model

Ship type	Subclasses
Cargo ship	Bulk carrier
	General cargo
	Refrigerated bulk
Container	Container
Cruise	Cruise
Ferry	Ferry – Pax only
	Ferry – Ro-Pax
Fishing vessel	Miscellaneous – fishing
Liquefied natural gas carrier	Liquefied gas tanker
Other vessel	Miscellaneous – other
	Offshore
	Service – other
	Service – tug
	Yacht
Tanker	Chemical tanker
	Oil tanker
	Other liquids tanker
Vehicle carrier	Ro-ro
	Vehicle

APPENDIX B. TOTAL AND EU-REGULATED FUEL CONSUMPTION, BC, AND CO_2 EMISSIONS IN THE GEOGRAPHIC ARCTIC AND THE IMO ARCTIC

Table B1

Shipping fuel consumption in the Geographic Arctic and IMO Arctic and corresponding fuel used by EU-flagged ships and ships reported to EU MRV in 2021

	Geographic Arctic								IMO Arctic							
	All ships		Ships ≥ 5,000 GT		EU-flagged ships ≥ 5,000 GT		Ships ≥ 5,000 GT reporting to the EU MRV		All ships		Ships ≥ 5,000 GT		EU-flagged ships ≥ 5,000 GT		Ships ≥ 5,000 GT reporting to the EU MRV	
Fuel	Fuel use (kt)	% in mix	Fuel use (kt)	% in mix	Fuel use (kt)	% in mix	Fuel use (kt)	% in mix	Fuel use (kt)	% in mix	Fuel use (kt)	% in mix	Fuel use (kt)	% in mix	Fuel use (kt)	% in mix
Distillate	2,021	53%	467	24%	101	22%	237	20%	228	26%	22	3%	3	2%	0.3	0.1%
LNG	508	14%	469.8	24%	159	34%	402	34%	206.4	23%	206	34%	83	64%	202.5	65%
Residual (no scrubbers)	1,062	28%	829.7	42%	147.6	32%	368	31%	426.2	49%	369	60%	39	30%	97.8	31%
Residual (with scrubbers)	198	5%	196.7	10%	55.6	12%	177	15%	16	2%	16	3%	5	4%	13.8	4%
			All ships		All ships ≥ 5,000 GT						All ships		All ships ≥ 5,000 GT			
Total	3,789		1,963		463		1,184		877		613		130		314	
Total (%)			52%		24%		60%				70%		21%		51%	

Table B2

Total and EU-regulated BC emissions (tonnes) by ship class in the Geographic Arctic and IMO Arctic, 2021

General ship type	Ship class	Geographic Arctic				IMO Arctic			
		All ships	Ships ≥ 5,000 GT	EU-flagged ships ≥ 5,000 GT	Ships ≥ 5,000 GT reporting to the EU MRV	All ships	Ships ≥ 5,000 GT	EU-flagged ships ≥ 5,000 GT	Ships ≥ 5,000 GT reporting to the EU MRV
Fishing vessel	Miscellaneous – fishing	413.8	28.8	6.9	0	133.4	5.2	1.1	0
Other vessel	Offshore	103.5	44.5	2.5	1	8.1	4.6	0	0.01
	Service – other	100.8	52.3	10.7	0	47.6	34	6	0
	Service – tug	65.9	21.7	0.8	0	16.1	1.2	0	0
	Miscellaneous-other	25.7	13.1	3.1	0	3.9	1	0	0
	Yacht	1.6	0.1	0	0	0.2	0	0	0
Cargo ship	Refrigerated bulk	45.6	19	0.6	9.1	15.6	9.9	0	2.7
	Bulk carrier	51.8	48.2	10.4	42.6	11.9	11.7	1.2	8.6
	General cargo	157.2	93.3	20.6	45.8	53.4	48.8	6	15.7
Tanker	Oil tanker	186.3	170	22.7	57.7	98.6	96.5	8.3	17.6
	Chemical tanker	51.7	34.3	12.6	24.4	10.4	6.7	0.2	2
	Other liquids tanker	0.5	0	0	0	0	0	0	0
Ferry	Ferry – Pax only	24.8	0	0	0	1.7	0	0	0
	Ferry – Ro-Pax	147.7	59.9	4.5	47.4	0.1	0.02	0	0
Vehicle carrier	Vehicle	3.4	3.4	0.4	3.3	0	0	0	0
	Ro-Ro	57	47.6	25.6	34.8	2.5	0.002	0	0
Cruise	Cruise	55.1	47.6	8.4	18.1	2.8	2	0.02	0.02
Container	Container	30.2	29.8	13.1	25.8	4	3.9	2.8	2
LNG carrier	Liquefied gas tanker	6.9	6.6	2.4	6.6	3.1	3.1	1.2	3.1
			All ships	All ships ≥ 5,000 GT			All ships	All ships ≥ 5,000 GT	
Total		**1,529**	**720**	**145**	**317**	**413**	**229**	**27**	**52**
Total (%)			**47%**	**20%**	**44%**		**55%**	**12%**	**23%**

Table B3

Total and EU-regulated BC emissions by fuel type in the Geographic Arctic and IMO Arctic, 2021

Fuel	Geographic Arctic								IMO Arctic							
	All ships		Ships ≥ 5,000 GT		EU-flagged ships ≥ 5.000 GT		Ships ≥ 5,000 GT reporting to the EU MRV		All ships		Ships ≥ 5,000 GT		EU-flagged ships ≥ 5,000 GT		Ships ≥ 5,000 GT reporting to the EU MRV	
	BC, tonnes	% mix	BC, tonnes	% mix	BC, tonnes	% mix	BC, tonnes	% mix	BC, tonnes	% mix	BC, tonnes	% mix	BC, tonnes	% mix	BC, tonnes	% mix
Distillate	840.4	55%	195	27%	45	31%	81.4	26%	143.6	35%	14	6%	2	6%	0.1	0%
LNG	7.7	1%	7	1%	2	2%	6	2%	3	1%	3.2	1%	1	5%	3	6%
Residual (no scrubber)	601.6	39%	439	61%	75	51%	159	50%	261	63%	206	90%	22	82%	44	85%
Residual (with scrubber)	79.8	5%	79	11%	23	16%	70.3	22%	5.4	1%	5.4	2%	2	8%	5	10%
	All ships				All ships ≥ 5000 GT				All ships				All ships ≥ 5000 GT			
Total	1,529		720		145		317		413		229		27		52	
Total (%)			47%		20%		44%				55%		12%		23%	

Table B4

Total and EU-regulated CO_2 emissions (kt) by ship class in the Geographic Arctic and IMO Arctic, 2021

General ship type	Ship class	Geographic Arctic				IMO Arctic			
		All ships	Ships ≥ 5,000 GT	EU-flagged ships ≥ 5,000 GT	Ships ≥ 5,000 GT reporting to the EU MRV	All ships	Ships ≥ 5,000 GT	EU-flagged ships ≥ 5,000 GT	Ships ≥ 5,000 GT reporting to the EU MRV
Fishing vessel	Miscellaneous – fishing	2,351.6	85.3	17.3	0	512.2	16.8	5	0
Cargo ship	General cargo	1,129.5	603.9	143.5	325.5	324.2	294.2	43.7	105.6
	Bulk carrier	586.7	554.2	107.8	492.5	137.8	136.2	13	104.2
	Refrigerated bulk	348.7	122.2	3.5	60.5	108.3	62.4	0	17.8
Tanker	Oil tanker	1,302.8	1,166.2	134.5	541.2	510.8	493.6	28.4	77.4
	Chemical tanker	484.4	315.5	114.6	228.4	80	55.3	1.6	18.9
	Other liquids tanker	6.4	0	0	0	0	0	0	0
Other vessel	Offshore	732.8	327.7	19.5	9.2	42.1	22.4	0	2.2
	Service – other	532.3	213.1	61.1	0	215.7	143.8	39.6	0
	Service – tug	354.8	74.5	2.4	0	73	3.2	0	0
	Miscellaneous-other	143.1	56.8	8.3	0	23.4	7.1	0	0
	Yacht	12.6	0.4	0	0	1.2	0	0	0
Ferry	Ferry – Ro-Pax	1,372.7	459.5	43.3	279.3	1.7	0.2	0	0
	Ferry – Pax only	228.6	0	0	0	11.8	0	0	0
LNG carrier	Liquefied gas tanker	979.2	972.8	375.3	972.8	550.7	550.7	215.4	550.7
Vehicle carrier	Ro-Ro	481.7	376.6	173.5	239.9	23.9	0.3	0	0
	Vehicle	25.2	25.2	3.2	25.1	0	0	0	0
Cruise	Cruise	452.5	361.5	68	151.9	21.8	12.7	3.3	3.3
Container	Container	287.1	282.5	121.1	246.4	37.9	37.6	24.0	25.9
		All ships		**All ships ≥ 5,000 GT**		**All ships**		**All ships ≥ 5,000 GT**	
Total		**11,813**	**5,998**	**1,397**	**3,573**	**2,676**	**1,837**	**374**	**906**
Total (%)			**51%**	**23%**	**60%**		**69%**	**20%**	**49%**

Table B5

Total and EU-regulated CO_2 emissions by fuel type in the Geographic Arctic and IMO Arctic, 2021

Fuel	Geographic Arctic								IMO Arctic							
	All ships		Ships ≥ 5,000 GT		EU-flagged ships ≥ 5,000 GT		Ships ≥ 5,000 GT reporting to the EU MRV		All ships		Ships ≥ 5,000 GT		EU-flagged ships ≥ 5,000 GT		Ships ≥ 5,000 GT reporting to the EU MRV	
	CO_2, kt	% mix	CO_2, kt	% mix	CO_2, kt	% mix	CO_2, kt	% mix	CO_2, kt	% mix	CO_2, kt	% mix	CO_2, kt	% mix	CO_2, kt	% mix
Distillate	6,479	55%	1,497	25%	324	23%	761	21%	731	27%	71	4%	9	2%	1	0%
LNG	1,396	12%	1,292	22%	436.7	31%	1,104	31%	568	21%	567.4	31%	227	61%	557	61%
Residual (no scrubber)	3,309	28%	2,584	43%	459.8	33%	1,147	32%	1,327	50%	1,148	62%	121	32%	304	34%
Residual (with scrubber)	629	5%	625	10%	176.7	13%	561	16%	50	2%	50.3	3%	17	4%	44	5%
	All ships				All ships ≥ 5,000 GT				All ships				All ships ≥ 5,000 GT			
Total	11,813		5,998		1,397		3,573		2,676		1,837		374		906	
Total (%)			51%		23%		60%				69%		20%		49%	

Table B6

Ship count and fuel consumption in the Geographic Arctic and IMO Arctic by flag state, 2021

Flag State	Geographic Arctic		IMO Arctic	
	Fuel use (kt)	Number of ships	Fuel use (kt)	Number of ships
Norway	1,259.7	1,778	41.7	195
Russia	751.3	1,483	419.2	910
Bahamas	207.8	207	78.6	17
Cyprus	182.6	195	86.7	16
Faeroe Islands	141.7	146	7.3	21
United States of America	128.4	484	15.0	142
Denmark	110.2	270	47.0	84
Iceland	107.2	186	0.7	18
Marshall Islands	94.7	458	27.6	57
Hong Kong	92.8	96	49.0	20
United Kingdom	83.8	412	0.8	7
Netherlands	75.7	456	12.5	50
Liberia	74.6	312	10.2	41
Malta	68.9	248	6.4	17
Finland	46.9	34	2.0	4
Panama	43.8	272	6.3	32
Portugal	37.6	173	4.5	22
Antigua and Barbuda	29.1	207	1.3	8
Barbados	25.8	96	4.5	12
Canada	23.4	66	21.1	59
Singapore	20.7	131	2.2	5
Sweden	19.2	64	0.5	4
France	16.9	48	1.9	5
Isle Of Man	16.6	45	0.0	0
Germany	13.6	81	2.9	10
Gibraltar	13.1	52	0.3	2
Others[a]	102.9	577	26.4	108
Total	**3,789**	**8,577**	**877**	**1,866**

[a] Others include flag states which when combined represented ≤ 3% of total fuel use. These flag states are: Italy, Greece, Belgium, Luxembourg, Bermuda, Estonia, China, Saint Kitts and Nevis, South Korea, Ireland, Lithuania, Cayman Islands, Spain, Japan, Palau, Latvia, Vanuatu, Sierra Leone, Curaçao, Poland, Indonesia, Saint Vincent and The Grenadines, Croatia, Philippines, Türkiye, Malaysia, Gabon, Cook Islands, Belize, Cameroon, Nigeria, Thailand, Brazil, Moldova, Kuwait, India, Saudi Arabia, Mongolia, Libya, São Tomé and Príncipe, Togo, Azerbaijan, Jamaica, Qatar, Uruguay, Switzerland, Guernsey, Dominica, Chile, Comoros, Vietnam, Iran, Mexico, United Arab Emirates, Virgin Islands, Ukraine, Falkland Islands, Israel, and flag not required or unknown (N/A).

APPENDIX C. FLEET COMPOSITION, FUEL USE, AND EU-REGULATED BC AND CO_2 EMISSIONS IN THE BALTIC SEA

Table C1

Number of ships per ship class in the Baltic Sea, 2021

General ship type	Ship Class	All ships		All ships ≥ 5,000 GT		EU-flagged ships ≥ 5,000 GT		Ships ≥ 5,000 GT reporting to the EU MRV	
		Count	% Share	Count	% Share	Count	% Share	Count	% Share
Cargo ship	Bulk carrier	734	28%	723	41%	125	22%	669	41%
	General cargo	506	19%	244	14%	93	16%	230	14%
	Refrigerated bulk	39	1%	39	2%	0	0%	39	2%
Tanker	Chemical tanker	342	13%	302	17%	130	22%	293	18%
	Oil tanker	199	7%	170	10%	50	9%	160	10%
	Other liquids tanker	1	0.04%	0	0	0	0%	0	0%
Other vessel	Service – tug	185	7%	1	0.1%	0	0%	0	0%
	Service – other	110	4%	23	1%	13	2%	0	0%
	Offshore	37	1%	5	0.3%	0	0%	0	0%
	Miscellaneous – other	35	1%	2	0.1%	1	0.2%	0	0%
	Yacht	26	1%	0	0%	0	0%	0	0%
Ferry	Ferry – Ro-Pax	95	4%	35	2%	35	6%	35	2%
	Ferry – Pax only	74	3%	0	0%	0	0%	0	0%
Container	Container	124	5%	124	7%	77	13%	119	7%
Vehicle carrier	Ro-Ro	59	2%	53	3%	39	7%	42	3%
	Vehicle	7	0.3%	7	0.4%	3	1%	7	0.4%
Fishing vessel	Miscellaneous – fishing	60	2%	1	0.1%	0	0%	0	0%
Liquefied natural gas carrier	Liquefied gas tanker	22	1%	16	1%	4	1%	15	1%
Cruise	Cruise	13	0.5%	13	1%	11	2%	8	0.5%

	All ships		All ships ≥ 5,000 GT	
Total	**2,668**	**1,758**	**581**	**1,617**
Total (%)		**66%**	**33%**	**92%**

Table C2

Total fuel consumed in the Baltic Sea, 2021

Fuel, kt	All ships		All ships ≥ 5,000 GT		EU-flagged ships ≥ 5,000 GT		Ships ≥ 5,000 GT reporting to the EU MRV	
	Fuel use	% Share	Fuel use	% Share	Fuel use	% Share	Fuel use	% Share
Distillate	1,283	73%	891	66%	536	59%	794	65%
Liquefied natural gas	77	5%	77	6%	68	8%	69	6%
Residual (no scrubbers)	4	0.2%	2	0.2%	0.5	0.1%	1	0.1%
Residual (with scrubbers)	385	22%	382	28%	301	33%	361	29%
	All ships				All ships ≥ 5,000 GT			
Total	1,749		1,352		906		1,225	
Total (%)			77%		67%		91%	

Table C3

Total and EU-regulated BC emissions by ship class in the Baltic Sea

General ship type	Ship class	All ships		All ships ≥ 5,000 GT		EU-flagged ships ≥ 5,000 GT		Ships ≥ 5,000 GT reporting to the EU MRV	
		BC (t)	% Share	BC (t)	% Share	BC (t)	% Share	BC (t)	% Share
Ferry	Ferry – Ro-Pax	177.7	28%	164.7	32%	164.7	44%	164.7	35%
	Ferry – Pax only	8.9	1%	0	0%	0	0%	0	0%
Vehicle carrier	Ro-Ro	128.7	20%	123.7	24%	99.3	26%	108.8	23%
	Vehicle	1.6	0.2%	1.6	0.3%	0.6	0.2%	1.6	0.3%
Cargo ship	General cargo	73.4	11%	35.6	7%	25.6	7%	33.7	7%
	Bulk carrier	23.9	4%	21.9	4%	4.9	1%	20.3	4%
	Refrigerated bulk	14.8	2%	13.3	3%	0.4	0.1%	13.3	3%
Tanker	Chemical tanker	52.2	8%	42.3	8%	19.7	5%	40.7	9%
	Oil tanker	47.5	7%	36.4	7%	13.4	4%	33.8	7%
	Other liquids tanker	0.4	0.1%	0	0%	0	0%	0	0%
Other vessel	Service – other	22.8	4%	13.3	3%	8.1	2%	0	0%
	Service – tug	16.5	3%	0.1	0.02%	0	0%	0	0%
	Offshore	4.4	1%	0.7	0.1%	0	0%	0.2	0.04%
	Miscellaneous – other	3.8	1%	0.7	0.1%	0.03	0.01%	0	0%
	Yacht	0.6	0.1%	0	0%	0	0%	0	0%
Container	Container	35.2	5%	35.2	7%	23.7	6%	34.4	7%
Cruise	Cruise	25.6	4%	25.5	5%	15.9	4%	12.8	3%
Fishing vessel	Miscellaneous – fishing	5.6	1%	0.2	0.03%	0	0%	0	0%
Liquefied natural gas carrier	Liquefied gas tanker	1.9	0.3%	1.8	0.3%	0.6	0.2%	1.7	0.4%
		All ships				All ships ≥ 5,000 GT			
Total		645		517		377		466	
Total (%)				80%		73%		90%	

Table C4

Total and EU-regulated CO_2 emissions by ship class in the Baltic Sea

General ship type	Ship class	All ships		All ships ≥ 5,000 GT		EU flagged ships ≥ 5,000 GT		Ships ≥ 5,000 GT reporting to the EU MRV	
		CO_2 (kt)	% Share	CO_2 (kt)	% Share	CO_2 (kt)	% Share	CO_2 (kt)	% Share
Ferry	Ferry – Ro-Pax	1,275.6	23%	1,121.9	26%	1,121.9	39%	1,121.9	29%
	Ferry – Pax only	78.5	1%	0	0%	0	0%	0	0%
Tanker	Oil tanker	594.5	11%	449.3	10%	148.6	5%	414.6	11%
	Chemical tanker	583.6	10%	467.2	11%	201.4	7%	452.2	12%
	Other liquids tanker	4.5	0.1%	0	0%	0	0%	0	0%
Cargo ship	Bulk carrier	306.3	6%	288.2	7%	64.6	2%	268.3	7%
	General cargo	626.1	11%	302.8	7%	212.3	7%	282	7%
	Refrigerated bulk	144.4	3%	127.1	3%	3.9	0.1%	126.6	3%
Vehicle carrier	Ro-Ro	932.5	17%	869.2	20%	693.8	24%	754	19%
	Vehicle	26.5	0.5%	26.5	1%	9.7	0.3%	26.5	1%
Other vessel	Service – other	145.4	3%	64.4	2%	42.9	1%	0	0%
	Service – tug	135.7	2%	0.5	0.01%	0	0%	0	0%
	Miscellaneous – other	42.3	1%	6.2	0.1%	0.2	0.01%	0	0%
	Offshore	42	1%	4.1	0.1%	0	0%	1.7	0.04%
	Yacht	6.6	0.1%	0	0%	0	0%	0	0%
Container	Container	339.7	6%	339.4	8%	223	8%	330.7	9%
Cruise	Cruise	190.4	3%	189.1	4%	128.1	4%	80.1	2%
Fishing vessel	Miscellaneous – fishing	54.1	1%	1.5	0.04%	0	0%	0	0%
LNG carrier	Liquefied gas tanker	31.9	1%	30.1	1%	14.7	1%	27.7	1%

	All ships		All ships ≥ 5,000 GT	
Total	**5,561**	**4,288**	**2,865**	**3,886**
Total (%)		**77%**	**67%**	**91%**

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