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IDENTIFICATION AND PROTECTION OF SPECIAL AREAS, ECAs AND PSSAs

Proposal to designate the North-East Atlantic Ocean as an Emission Control Area for sulphur oxides, particulate matter and nitrogen oxides

Submitted by Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands (Kingdom of the), Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, United Kingdom and EC*

SUMMARY

Executive summary:	This document proposes to designate the North-East Atlantic Ocean as an Emission Control Area for sulphur oxides, particulate matter and nitrogen oxides, pursuant to MARPOL Annex VI.
Strategic direction, if applicable:	4
Output:	4.1
Action to be taken:	Paragraph 37
Related document:	MEPC 80/INF.35

Introduction

1 In 2023, document MEPC 80/INF.35 (Austria et al.) highlighted that a prospective Emission Control Area (ECA) in the North-East Atlantic Ocean (herein referred to as the NE Atlantic ECA), for sulphur oxides (SO_x) and particulate matter (PM), and nitrogen oxides (NO_x), linking existing ECAs in the Baltic Sea, North Sea and the English Channel with the recently adopted Mediterranean SO_x ECA, the Norwegian ECA and the Canadian Arctic ECA, would constitute a fundamental step towards tackling air pollution from international shipping in a consistent manner in all coastal areas of IMO Member States and Associate Members in the region.

* By MEPC 83, the list of co-sponsors may be further expanded. Whilst Iceland, the Faroe Islands and Denmark (Greenland) are familiar with the content of this document, due to time considerations they were not able to co-sponsor this document in time for submission under the 13-week document deadline. The IMO Member State and/or Associate Member in question may still do so ahead of MEPC 83.

2 With this document, France, Ireland, Portugal, Spain and the United Kingdom, which are IMO Member States bordering the North-East Atlantic, propose to designate an ECA in the territorial seas and Exclusive Economic Zones (EEZ) under their jurisdiction[1] in view of its entry intro force at the earliest possible date in 2027. The NE Atlantic ECA will contribute to preventing, reducing and controlling NO_x, SO_x and PM emissions from ships, pursuant to regulations 13 and 14 and appendix III to MARPOL Annex VI.

3 Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, Germany, Greece, Hungary, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands (Kingdom of the), Poland, Romania, Slovakia, Slovenia and Sweden, as members of the European Union, associate themselves with this proposal as the extension of ECAs to additional waters of the IMO Member States and Associate Members in the region will not only preserve the level playing field for economic operators but will also contribute to better public health and environmental protection within the European Union and beyond.

4 Annex 1 to this document includes the complete analysis of how the proposal satisfies the criteria for designation of ECAs set out in appendix III of MARPOL Annex VI, annexes 2 and 3 describe and illustrate, respectively, the proposed NE Atlantic ECA, while annex 4 outlines the necessary amendments to MARPOL Annex VI.

Summary of the proposal

5 The designation of the proposed NE Atlantic ECA will significantly reduce ship emissions, improve air quality, and contribute to improved public health and environmental protection in the North-East Atlantic region. The reductions in PM emissions will also have the co-benefit of reducing Black Carbon (BC) emissions, provided distillate fuel is used. The reduction of air pollutant's deposition through the NE Atlantic ECA will help protect over 1,500 marine protected areas, 17 key marine mammal habitats, and 148 UNESCO sites by mitigating environmental damage from pollution deposition and ocean acidification.

6 The proposed NE Atlantic ECA could also prevent 118 to 176 premature deaths in 2030, with a cumulative reduction of 2,900 to 4,300 premature deaths from 2030 to 2050. The economic value of these health benefits is estimated at €0.82 to €1.23 billion in 2030 and €19 to €29 billion between 2030 and 2050. On the other hand, the operational costs from fuel switching (MGO mix scenario) and Tier III engine standard compliance are estimated at €472 million in 2030, sitting significantly below the total economic health benefits for the same period. Moreover, almost 90% of ships sailing across the proposed NE Atlantic ECA also navigate across other ECA areas.

7 This proposal includes an analysis of cost and benefits in the NE Atlantic region which provides ample scientific and technical basis for the highest possible number of involved littoral States. They represent a clear-cut upper limit fully demonstrating the cost-effectiveness of the initiative in the region.

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1 Excluding EEZ surrounding Azores, Madeira and Canary archipelagos.

Description of the proposed area of application

8 The proposed ECA area of the NE Atlantic for SO_x, PM and NO_x ship emissions, includes the exclusive economic zones (EEZ)[2] and territorial seas of Portugal, Spain, France, the United Kingdom, Ireland, Iceland, Faroe Islands and Denmark (Greenland), excluding:

.1 where the proposed area intersects North Sea area in the east; bound by latitude 62°N, longitude 4°W of the North Sea; and by latitude 48°30'N, longitude 5°W of the English Channel as described in MARPOL Annex V 1.14.6;

.2 where the proposed area intersects Mediterranean ECA in the south by a line joining the extremities of Cape Trafalgar-Spain and Cape Spartel-Morocco as described in appendix VII of MARPOL Annex VI; and

.3 the EEZ maritime areas adjacent to Madeira, Azores and Canary archipelagos.

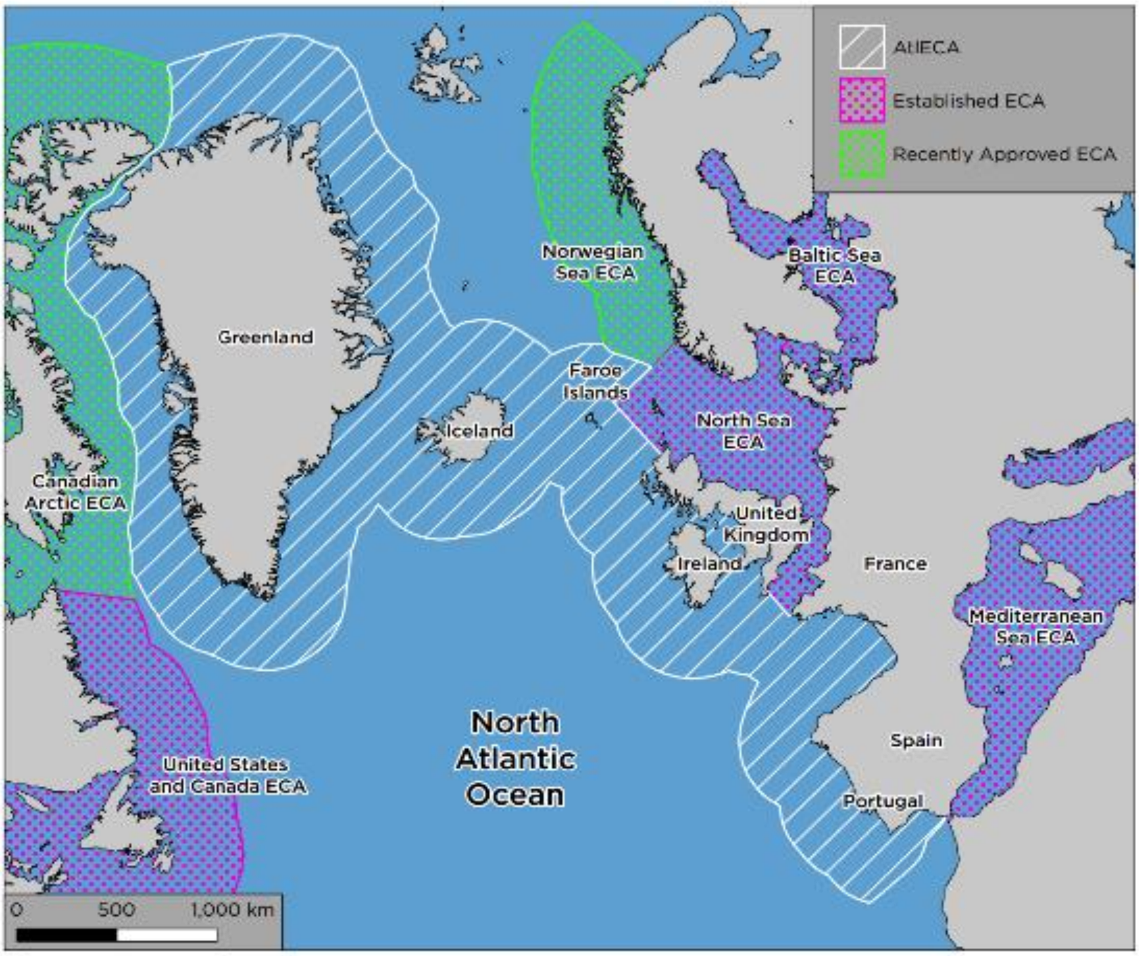

Figure 1: Proposed North-East Atlantic Emission Control Area alongside the other established and proposed ECAs

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[2] The EEZ definition is based on the United Nations Convention on the Law of the Sea (UNCLOS), Part V, article 57, as amended by relevant delimitation and delineation legislations and treaties established by the countries.

Human populations and environmental areas at risk

9 Approximately 193 million people live in coastal States whose marine waters are included in the proposed NE Atlantic ECA, with over 90% residing in the United Kingdom, France, and Spain. Overall, the region is expected to see population growth from 2021 to 2030. The most populated major port cities in the proposed NE Atlantic ECA are Lisbon, Porto, Bilbao, Liverpool and Dublin. In Greenland, the Indigenous Greenlandic Inuit comprise 89% of the population, and nearly all of the population lives in coastal settlements and cities in the southern and western parts of the country, being directly affected by air pollution in general and by pollution from shipping specifically, with the added consequences and hardship to already climate-vulnerable communities in the north posed by exposure to particulate matter and BC emissions.

Table 1. Total population of Atlantic ECA IMO Member States and Associate Members for 2021 and 2030[3].

Regions	2021	2030
United Kingdom	68,207,104	70,485,467
France	65,505,213	67,204,319
Spain (excluding the Canary Islands)	44,566,273	47,837,014
Portugal (excluding Açores & Madeira)	9,676,424	9,408,766
Ireland	4,982,900	5,248,025
Iceland	358,298	424,407
Denmark (Greenland)	56,421	56,544
Faroe Islands	53,370	56,341
Total:	**193,406,003**	**200,720,883**

10 The proposed area also includes over 1,500 marine protected areas, which account for 10% of the total area of the proposed NE Atlantic ECA, and 17 important marine mammal habitats, which make up 16% of the area. Additionally, 17% of the NE Atlantic ECA falls within the IMO-designated Western European Waters Particularly Sensitive Sea Area. The region also contains 148 UNESCO World Heritage sites, representing about 12% of the global total. Shipping emissions of SO_x and NO_x contribute to pollutant deposition and ocean acidification, harming marine biodiversity and UNESCO sites. Therefore, by significantly reducing levels of SO_x and NO_x emissions, the proposed NE Atlantic ECA would contribute to diminishing their detrimental impacts on natural and cultural heritage, as well as vulnerable ecosystems and habitats critical for species conservation. This positive effect would be particularly strong in areas with exceptional protection status.

Ship traffic and meteorological conditions

11 The ships operating in the proposed NE Atlantic ECA consumed 265 petajoules (PJ) of fuel in 2021, with fuel consumption predicted to increase to 311 PJ by 2030. Ships sailing in the waters of Portugal, Spain, and the United Kingdom consumed 187 PJ of fuel, which

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3 Population data for 2021 and projections for 2030 for Ireland, Portugal, and the United Kingdom: https://www.un.org/development/desa/pd/sites/www.un.org.development.desa.pd/files/wpp2022_summary_of_results.pdf. Data for France: Institut national de la statistique et des études économiques (2024). Data for Iceland: Statistics Iceland (2024). Data for Spain: Instituto Nacional de Estadística (2024). Data for the Faroe Islands: Statistics Faroe Islands (2022). Data for Greenland (2021): Statistics Greenland (2023); 2030 projection: ICCT estimate based on historical trend.

represents 70% of the total fuel consumption in the proposed NE Atlantic ECA region. In Portugal and Spain, fuel consumption is mainly by container ships and tankers while in the United Kingdom, it is mainly tankers and RoPax vessels. On the other hand, 48% of all fuel burned in Iceland's waters is by fishing vessels, followed by the Danish autonomous territories of Faroe Islands and Greenland - 40% and 31%, respectively (figure 2).

12 It is especially noteworthy that out of 17,640 ships sailing in the proposed NE Atlantic ECA in 2021, 88% are already navigating in other established or proposed ECAs: out of 17,640 ships detected in the proposed NE Atlantic ECA area in 2021, 76% also navigated in the North Sea ECA and 74% in the Mediterranean Sea SO_x ECA, where fuel sulphur requirements begin in 2025. Ships operating in active ECAs will already bunker low-sulphur fuels that comply with fuel sulphur requirements or otherwise use HFO with exhaust gas cleaning systems (EGCS).

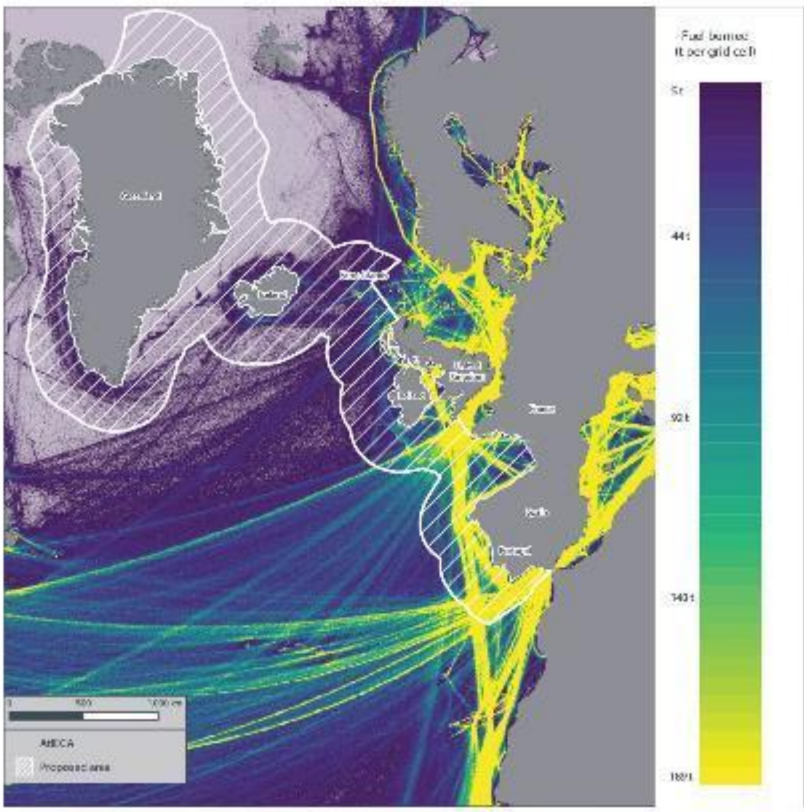

Figure 2: shipping traffic and fuel consumption in the NE Atlantic in 2021

13 The proposed NE Atlantic ECA covers a large area in the North Atlantic region with diverse meteorological conditions. The variability of the weather in this region is largely driven by the North Atlantic Oscillation and the Gulf Stream. Thus, shipping emissions' impact on air quality varies across mid and high latitudes. The prevailing westerly winds in mid-latitudes are a dominant force in the North Atlantic, steering weather systems across the ocean towards Europe, and polar easterlies in higher latitudes contributing to the region's dynamic weather patterns, influence the dispersion of pollutants, with cyclonic activity in the North Atlantic further contributing to pollutant distribution and air quality challenges in coastal regions. Consequently, meteorological conditions of the North Atlantic significantly influence how shipping emissions impact air quality in the region. Prevailing westerly winds in mid-latitudes often disperse pollutants over long distances, spreading them from shipping lanes toward coastal areas in Europe and North America. The meteorological conditions in the proposed NE Atlantic ECA region were incorporated into the air quality modelling.

Projected reduction in SO_x, PM and NO_x emissions

14 The emission reduction potentials from introducing a SO_x, PM and NO_x ECA in the North-East Atlantic are estimated based on ship activity (AIS data) and emission modelling assuming two 2030 potential ECA compliance scenarios, using different fuel mixes and compliance technology. The considered scenarios are:

.1 2030 Business-As-Usual (BAU): this scenario assumes that the proposed NE Atlantic ECA is not implemented in the study area;

.2 MGO Mix: this scenario assumes that vessels currently using very-low sulphur fuel oil (VLSFO) will transition to distillate fuel or marine gas oil (MGO). Ships already operating on distillates, liquified natural gas, and methanol are assumed to maintain their behaviour. Ships equipped with EGCS are expected to adjust their performance to match a fuel sulphur content of 0.10%, compared to the 0.50% sulphur content in the BAU scenario; and

.3 ULSFO Mix: this scenario assumes that vessels using VLSFO switch to ultra-low sulphur fuel oil (ULSFO). It is assumed that ULSFO's sulphur content remains at 0.10%, with other properties and emissions staying consistent with VLSFO.

15 The proposed NE Atlantic ECA's designation will significantly lower emissions of SO_x, PM, and also Black Carbon, a component of PM emissions. If distillate fuel is used for compliance, the ECA would result in an 82% reduction in SO_x emissions, a 64% reduction in $PM_{2.5}$, and a 36% reduction in BC emissions. However, the analysis shows that using ULSFO is not as effective as distillates at reducing SO_x, PM, or BC, as the use of ULSFO produces 9% more SO_x, 55% more $PM_{2.5}$, and 36% more BC emissions. While the use of EGCS is equally effective as burning distillates in reducing SO_x emissions, it generates 17% more $PM_{2.5}$ and 32% more BC emissions. A more detailed analysis of the different compliance scenarios was conducted by the International Council on Clean Transportation (ICCT) [4].

16 Given that NO_x Tier III standards apply only to newly built ships, the impact on NO_x emissions is not expected to be significant immediately after the proposed NE Atlantic ECA designation. In fact, by 2030, Tier III standards will reduce expected NO_x emissions by about 3% below the Business-As-Usual scenario if they apply only to ships built in 2027 or later.

Table 2. The emission reduction potentials from introducing a NO_x, SO_x and PM emission control area in the NE Atlantic.

Scenarios	**SO_x, kt**	**$PM_{2.5}$, kt**	**BC, kt**	**NO_x, kt**	
MGO Mix	8.13	6.73	1.59	**Tier III new ships only**	486.7
ULSFO Mix	12.39	17.17	2.47		
2030 BAU	45.48	18.94	2.47	**2030 BAU**	500.3
2021 Baseline	40.63	16.84	2.10	**2021 Baseline**	433.3

4 ICCT (2024). *From concept to impact: Evaluating the potential for emissions reduction in the proposed Northeast Atlantic Emission Control Area under different compliance scenarios*.

Contribution of ships to adverse impacts on the environment and human health

17 Designation of the proposed NE Atlantic ECA has the potential to reduce shipping-attributable ambient air concentrations of SO_2 by 86%, $PM_{2.5}$ by 59%, and NO_2 by 3% in the proposed NE Atlantic ECA region alone, as well as approximately halve shipping-attributable population-weighted exposure to $PM_{2.5}$ in 2030 in the median member State. Moreover, the proposed NE Atlantic ECA is also expected to reduce shipping-attributable population-weighted $PM_{2.5}$ exposure in the most populous regions by 35% to 55%, depending on whether ULSFO or MGO, respectively, is used as the main compliance strategy.

18 Reducing shipping emissions will positively impact the environment, particularly in coastal areas of Portugal, Spain, the United Kingdom and Ireland where pollutant deposition is most significant. Reductions of 60% to 68% in dry sulphur deposition and 12% to 14% in wet deposition were observed within the area, with nitrogen deposition also reduced up to 5.5% in dry deposition and 1.7% in wet deposition. Visibility is expected to improve by up to 1.8%. These benefits will enhance air quality, contributing to improved human health outcomes and reduced environmental degradation in these regions.

19 Pollutant emissions from ships can adversely impact Indigenous Peoples' food security, health, culture, and traditional ways of life. Greenland's population, predominantly Indigenous Greenlandic Inuit residing in coastal areas, faces higher levels of air pollution and more limited access to healthcare infrastructure. With nearly all residents living in coastal settlements affected by shipping-related pollution, this contributes to lower life expectancy and higher infant mortality when compared to non-Indigenous populations.

20 The proposed NE Atlantic ECA would also help mitigate acidification and eutrophication of water and soil, as sulphur and nitrogen compounds from ship emissions can significantly impact marine ecosystems, particularly in biologically rich areas. Therefore, reducing these pollutants will protect marine biodiversity, and help control eutrophication, a key threat to marine ecosystems.

21 The designation of the proposed NE Atlantic ECA could additionally result in 118 to 176 premature deaths being avoided in 2030 only, with potential approximate cumulative benefits of between 2,900 and 4,300 avoidable premature deaths from 2030 to 2050, depending on the compliance scenario (Table 3). Higher benefits are expected when MGO is used for ECA compliance, while lower benefits are expected when using ULSFO. In absolute terms, the United Kingdom accounts for nearly half of the total avoidable premature deaths in 2030 across all scenarios, followed by Spain and Portugal. Economically, the value of these health benefits based on the value of a statistical life is estimated to be between €0.82 and €1.23 billion in 2030 and approximately €19 to €29 billion cumulatively from 2030 to 2050.

Table 3. Health benefits summarized per scenario evaluated for the proposed NE Atlantic ECA.

Scenarios	Avoided premature deaths and related economic benefits			
	2030		2030 to 2050 cumulative	
	Avoided premature deaths	Economic benefits (€ Billion)	Avoided premature deaths	Economic benefits (€ Billion)
MGO Mix	176 (95% CI= 9; 290)	1.23 (95% CI= 0.6; 2.02)	4,300 (95% CI= 2,100; 7,500)	29.11 (95% CI= 14.08; 50.99)
ULSFO Mix	118 (95% CI= 61; 195)	0.82 (95% CI= 0.4; 1.35)	2,900 (95% CI= 1,400; 5,000)	19.37 (95% CI= 9.35; 33.96)

22 All the proposed NE Atlantic ECA IMO Member States and Associate Members in the region have implemented land-based air quality control measures that have significantly improved their air quality. Temporal trends reveal a reduction in SO_x, NO_x, and PM emissions from both transport and other land sectors in all NE Atlantic Member States, except for Iceland, where non-transport related SO_2 emissions are still increasing. However, the recommended World Health Organisation (WHO) Global Air Quality Guidelines for NO_2 and $PM_{2.5}$ are still not met across the region by Ireland, France, Spain, Portugal, and the United Kingdom. Additionally, current emissions projections indicate that these member states will not meet their post-2030 national emission reduction commitments. In light of this, there is an urgent need for stricter regulatory measures in the area.

Estimated costs, cost-effectiveness and cost-benefit

23 The fuel prices analysis reveals a strong correlation between global crude oil prices and marine fuel prices in the proposed NE Atlantic ECA, with Pearson correlations exceeding 0.9. World prices for IFO380, VLSFO, and MGO are consistently higher than prices in the proposed NE Atlantic ECA, with differentials of 56 € to 72 €/tonne. LNG prices in the proposed NE Atlantic ECA region are notably higher than other fuels, peaking in 2022 due to supply shortages and geopolitical tensions. Methanol prices have steadily increased throughout 2022.

24 Regarding fuel availability, the current refining capacities of the IMO Member States and Associate Members in the proposed NE Atlantic ECA region are sufficient to meet future demand. The region can meet the 6 million tonnes of MGO required under the MGO Mix scenario by adjusting the production to increase the share of MGO from 1.5% to 2.5%. This adjustment ensures compliance with marine fuel sulphur regulations.

25 Cost analysis for 2030 scenarios shows that MGO Mix scenario incurs an additional 437 million € annually, while ULSFO Mix adds 121 million €. NO_x reduction via selective catalytic reduction (SCR) systems for new ships costs 35 million €.

26 The cost-effectiveness analysis of the proposed NE Atlantic ECA implementation shows that implementing the MGO Mix and ULSFO Mix scenarios to reduce SO_x, PM, and NO_x emissions from ships offers favourable outcomes[2]. The MGO Mix provides significant emissions reductions at a competitive cost, with economic health benefits surpassing costs (figure 4).

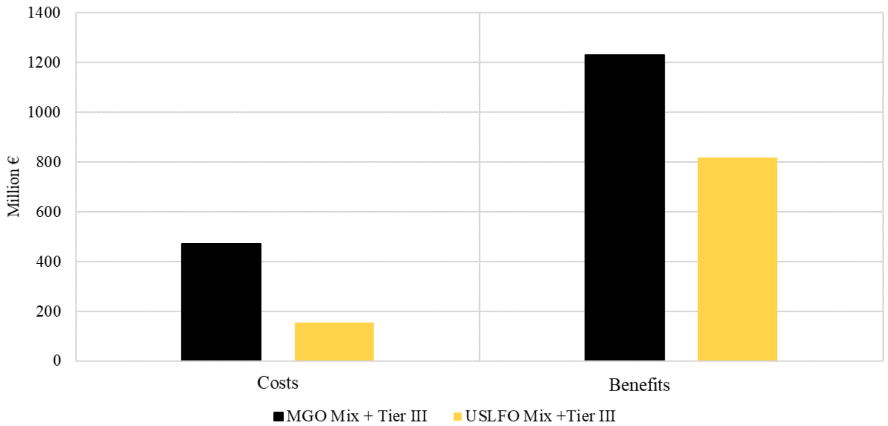

Figure 4: costs of proposed Atlantic ECA implementation and the health economic benefits for each scenario

27 Compared to land-based emission control measures and previous ECA proposals, the costs of MGO Mix, ULSFO Mix, and Tier III NOx standards for the proposed NE Atlantic ECA fall within the ranges reported. The analysis highlights that implementing a SO_x, PM and NO_x ECA with MGO fuel would be the most cost-effective strategy, with economic health benefits estimated at 1.23 billion € for IMO Member States and Associate Members in the proposed NE Atlantic ECA region, far exceeding the costs of 472 million €.

28 Economic impacts on maritime sectors will be moderate. The implementation of the MGO Mix and the Tier III NO_x scenarios will lead to a 0.48% to 1.24% increase in freight rates and a 2% to 4% rise in cruise ship voyage prices. However, the impact on commodity prices is not expected to be significant, with changes below 0.01%.

Conclusion

29 The designation of the proposed NE Atlantic ECA by the relevant IMO Member States and Associated Members in the region will significantly reduce ship emissions, improve air quality, and thereby contribute to public health and environmental protection in the North-East Atlantic region. This is paramount to ensure an even and fair application of environmental and human health protection not only across European Member States' waters but also in sensitive regions in and near the Arctic.

30 The costs for the proposed NE Atlantic ECA, regardless of the compliance scenario (MGO Mix, ULSFO Mix), fall well within the ranges reported on previous ECA proposals. Moreover, given that almost 90% of ships sailing across the proposed NE Atlantic ECA also navigate across other ECA areas the burden on the affected sectors is reduced. Overall, the health economic benefits far outweigh the costs on impacted sectors.

Proposed amendments to MARPOL Annex VI

31 The NO_x Tier III requirements apply to ships constructed on or after a certain date while operating in an ECA. The definition of "ship constructed" is given in regulation 2.1.28 of MARPOL Annex VI: "Ships constructed means ships the keels of which are laid or that are at a similar stage of construction."

32 A study by Ward Van Roy et al[5] highlighted that many keels are being laid prior to the entry-into-force date of a NO_x ECA and sold at a later stage. When the keel is laid, the ship can be built, delivered and put into operation several years later. This practice delays the positive health and environmental effects represented by new NO_x ECAs and hampers a level playing field among the "new ships" operating in the area.

33 MSC.1/Circ.1500/Rev.2 provides guidance on drafting of amendments to the SOLAS Convention and related mandatory instruments and chapter 4.2.1 gives guidance on the format of application dates including the "three dates criteria" (building contract, keel laid and delivery dates).

34 The three dates criteria are also used in MARPOL Annex VI, for example, in regulation 2.2.1 where "A ship delivered on or after 1 September 2019" is defined using the "three dates criteria".

[5] Ward Van Roy, Kobe Scheldeman, Benjamin Van Roozendael, Annelore Van Nieuwenhove, Ronny Schallier, Laurence Vigin, Frank Maes. 2022. *Airborne monitoring of compliance to NOx emission regulations from ocean-going vessels in the Belgian North Sea.*

35 The co-sponsors are of the view that using the keel laying date, and the current definition of "ship constructed", delays the desired effect of new regulations and propose to use the "three dates criteria" for the designation of the proposed new NO_x ECA in the North-East Atlantic.

36 Annex 4 to this document contains proposed amendments to MARPOL Annex VI in order to designate the North-East Atlantic as an emission control area for nitrogen oxides and sulphur oxides.

Action requested of the Committee

37 The Committee is invited to consider the information contained in this document and, in particular to approve at this session the proposed amendments (as set out in the annexes) to regulation 13.5, 13.6, 14.3 and appendix VII to MARPOL Annex VI on the designation of the North-East Atlantic Ocean as an Emission Control Area, as appropriate, with a view to adoption at a subsequent MEPC session in view of their entry intro force at the earliest possible date in 2027, and take action as appropriate.

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ANNEX 1

INFORMATION RESPONDING TO THE CRITERIA IN APPENDIX III TO MARPOL ANNEX VI

Disclaimer: Whilst Iceland, the Faroe Islands and Denmark (Greenland) are familiar with the content of this document, due to time considerations they were not able to co-sponsor this document in time for submission under the 13-week document deadline. The IMO Member State and/or Associate Member in question may still do so ahead of MEPC 83.

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1. Introduction

The information in this annex supports the proposal for the designation of the North East Atlantic Ocean as an Emission Control Area to prevent, reduce and control emissions of sulphur oxides (SO_x), particulate matter (PM) and nitrogen oxides (NO_x) from ships pursuant to Regulations 13 and 14 and Appendix III to Annex VI to the International Convention for the Prevention of Pollution from Ships (MARPOL), hereinafter referred to as the proposed NE Atlantic ECA.

2. Description of the proposed area of application

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*This section presents information addressing **criterion 3.1.1 of Appendix III to MARPOL Annex VI**, as cited: "The proposal shall include a clear delineation of the proposed area of application, along with a reference chart on which the area is marked" and **criterion 3.1.2 of Appendix III to MARPOL Annex VI**, as cited: "The proposal shall include the type or types of emission(s) that is or are being proposed for control (i.e. NO_x or SO_x and particulate matter or all three types of emissions)."*

2.1. Delineation of the proposed area

The proposed area of application of the North East Atlantic Ocean Emission Control Area (NE Atlantic ECA), shown in Figure 1, consists of:

- The mainland exclusive economic zones and territorial seas of Portugal, Spain, France, United Kingdom; and all of the exclusive economic zones and territorial seas of Ireland and Iceland;

- The exclusive economic zones and territorial seas of the Associate Member of Faroe Islands and Denmark (Greenland);

- Excluding where the combined area intersects with the North Sea area in the east; bound by latitude 62°N, longitude 4°W of the North Sea; and by latitude 48°30'N, longitude 5°W of the English Channel as described in MARPOL Annex V 1.14.6 (IMO, 2016a);

- Excluding where the combined area intersects with the Mediterranean ECA in the south by a line joining the extremities of Cape Trafalgar–Spain and Cape Spartel–Morocco (IMO, 2022).

The exclusive economic zone definition is based on the United Nations Convention on the Law of the Sea (UNCLOS) Part V Article 57, as amended by relevant delimitation and delineation legislations and treaties established by the countries (United Nations, 1994).[1]

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[1] *A list of national claims to maritime jurisdiction can be found at: https://www.un.org/depts/los/LEGISLATIONANDTREATIES/toc.htm*

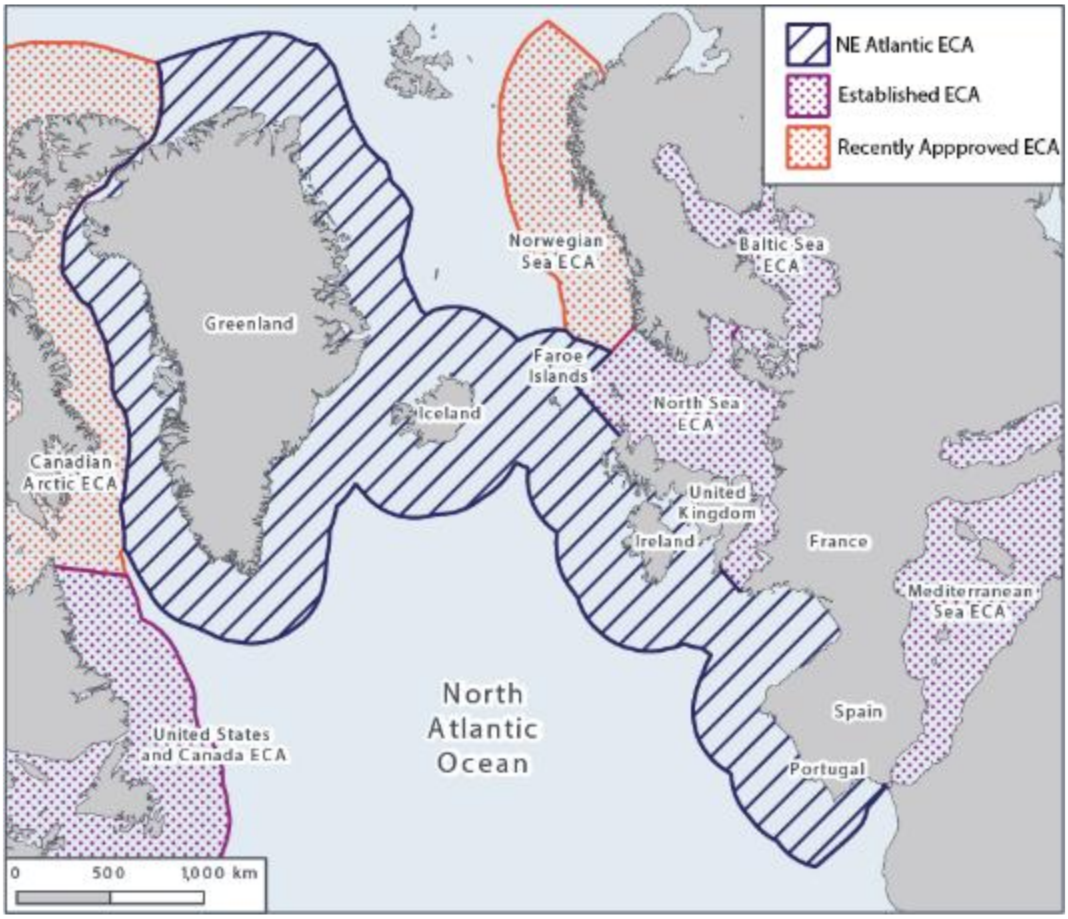

Figure 1: The North East Atlantic Ocean Emission Control Area (NE Atlantic ECA) and other established and recently approved emission control areas

2.2. Types of emissions proposed for control

The NE Atlantic ECA would impose stricter regulations aimed at reducing emissions of sulphur oxides (SO_x), particulate matter (PM), and nitrogen oxides (NO_x), according to MARPOL Annex VI regulations with requirements and rules for control of emissions from ships: Regulation 13, applicable to NO_x emissions, and Regulation 14, applicable to SO_x and PM emissions (MEPC 58/23/Add.1 Annex 13).

SO_x and PM emissions

Sulphur oxides (SO_x) and primary particulate matter (PM) are both byproducts of marine engine combustion, originating from the sulphur content in marine fuels. When this fuel burns, sulphur within it oxidizes, primarily forming sulphur dioxide (SO_2), which is released as a gaseous emission. Simultaneously, combustion produces primary PM, consisting of particles such as unburned carbon, metals, and ash derived from the fuel and engine materials. Chronic exposure to PM is linked to increased mortality rates and significant morbidity, particularly related to respiratory system diseases.

NO_x emissions

Nitrogen oxides (NO_x) are a group of gases that form during the combustion of fuels, primarily from the reaction of nitrogen in the air with oxygen at high temperatures. In marine engines, NO_x forms mostly from nitrogen in the air during fuel combustion, with a small contribution from nitrogen in the fuel itself. The levels of NO_x produced depend on factors like engine load, speed, and temperature. Once released into the atmosphere, NO_x can participate in atmospheric chemical processes that lead to the formation of secondary PM. NO_x emissions, along with volatile organic compounds, are key precursors for ozone production, which occurs when sunlight and high temperatures drive chemical reactions in the atmosphere. Ground-level ozone can travel long distances from the source of emission, leading to elevated ozone levels in regions far from ship traffic, which can harm air quality and pose significant health risks, including respiratory problems, worsen asthma and reduce lung function even at low exposure levels (Soares & Silva, 2022).

3. Populations and areas at risk from the impact of ship emissions

*This section presents information addressing **criterion 3.1.3 of appendix III to MARPOL Annex VI**, as cited: "The proposal shall include a description of the human populations and environmental areas at risk from the impacts of ship emissions".*

The proposed NE Atlantic ECA encompasses approximately 5.05 million km² of the North East Atlantic Ocean, including the territorial seas and exclusive economic zones (up to 200 nm) of four EU member states (Spain, Portugal, France, and Ireland), one country in the European Economic Area (Iceland), Denmark (Greenland), the United Kingdom, and the Associate Member of Faroe Islands.

Table 1 includes the total populations for 2021, as well as 2030 population projections in selected jurisdictions, while population densities for 2021 are shown in Figure 2 and Figure 3. There are approximately 193 million people within the borders of the proposed NE Atlantic ECA member states, with more than 90% in France, Spain, and the United Kingdom. The NE Atlantic ECA region is expected to see approximately 4% population growth between 2021 and 2030 (Table 1). The most populated major port cities in the NE Atlantic ECA member states are Lisbon, Porto, Dublin, Liverpool, and Bilbao.

The outermost regions of Portugal (the Azorean Islands and Madeira) and Spain (the Canary Islands) are outside of the scope of this study. However, potential emission reductions associated with expanding the proposed areas to include these regions have been estimated and are detailed in (Osipova et al., 2024b).

Table 1. Total population of NE Atlantic ECA IMO member states and associate members for 2021 and projections for 2030

Regions	2021	2030
United Kingdom	68,207,104	70,485,467
France	65,505,213	67,204,319
Spain (excluding the Canary Islands)	44,566,273	47,837,014
Portugal (excluding Azores & Madeira)	9,676,424	9,408,766
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Iceland	358,298	424,407
Denmark (Greenland)	56,421	56,544
Faroe Islands	53,370	56,341
Total	**193,406,003**	**200,720,883**

Sources: Population data for 2021 and projections for 2030 for Ireland, Portugal, and the United Kingdom: UN World Population Prospects (2022). Data for France: Institut national de la statistique et des études économiques (2024). Data for Iceland:

Statistics Iceland (2024). Data for Spain: Instituto Nacional de Estadística (2024). Data for the Faroe Islands: Statistics Faroe Islands (2022). Data for Greenland (2021): Statistics Greenland (2023); 2030 projection: ICCT estimate based on historical trend.

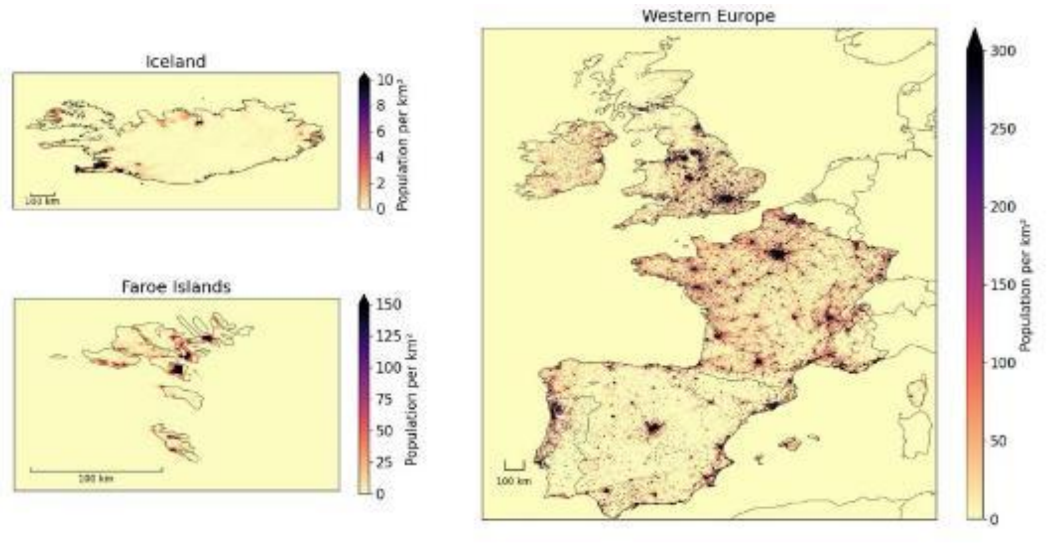


Figure 2: Population densities in 2021 for Iceland, the Faroe Islands, the United Kingdom, Ireland, France, Spain, and Portugal. Source: GPWv4

Figure 3: Population density in 2021 for Greenland. Source: Statistics Greenland (2023).

Children aged 0–4 years and adults aged 65 years and older are the age groups most vulnerable to the impacts of air pollution, as they face an elevated mortality risk from asthma, respiratory diseases, and cardiovascular diseases (Boing et al., 2022; Yap et al., 2019). In 2021, the combined share of young children and older adults in the proposed NE Atlantic ECA member states made up 25% of their total population, and their share is projected to increase by 3% by 2030. This rising vulnerability to adverse environmental factors is expected in every member state of the proposed NE Atlantic ECA, with Portugal (4.2%) and Spain (4.5%) showing the greatest increases in their ratio of vulnerable population to total population between 2021 and 2030 (Figure 4).

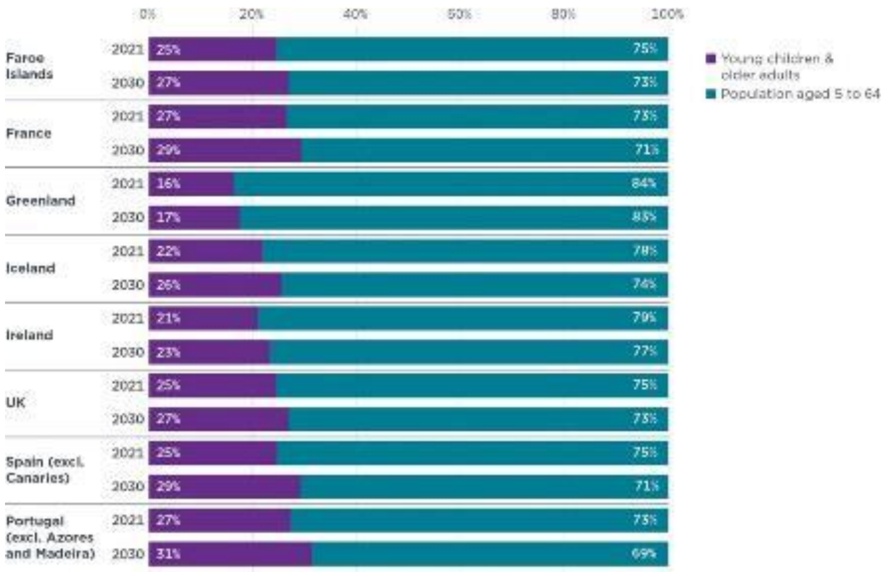


Figure 4: Projected share of children aged 0–4 and adults aged 65+ in NE Atlantic ECA regions in 2021 and 2030

In Greenland, the indigenous Greenlandic Inuit comprised 89% of the total population in 2016 (OECD, 2018). Despite being covered by the United Nations Declaration on the Rights of Indigenous Peoples, when compared to non-indigenous people, these communities have lower life expectancy, higher infant mortality, and worse economic conditions (Anderson et al., 2016). Almost all of Greenland's population resides near coastal settlements and cities in southern and western Greenland and are affected directly by air pollution generally and shipping-related pollution specifically (Figure 3). Although healthcare is a publicly financed government responsibility in Greenland, long travel distances, lack of specialized medical personnel in sparsely populated areas, and cultural factors complicate access to healthcare infrastructure and may delay treatment (Niclasen and Mulvad, 2010).

4. Shipping traffic analysis in the proposed area

*This section presents information addressing **criterion 3.1.6 of Appendix III to MARPOL Annex VI**, as cited: "The proposal shall include the nature of the ship traffic in the proposed emission control area, including the patterns and density of such traffic".*

Section Summary

This section reports shipping traffic and fuel consumption in the proposed NE Atlantic ECA region for 2021 and expected projected changes by 2030 (business-as-usual scenario). It describes the distribution of vessel types, the age of the fleet, and the breakdown of fuel usage across different operational activities. The 2030 projections reflect expected growth in shipping activity and fuel consumption, considering changes in fleet composition and energy demand by vessel type.

4.1. Method for analysing shipping traffic in 2021 and 2030 projection

To analyse shipping activities, fuel consumption, and related emissions in the proposed NE Atlantic ECA for the baseline year 2021, the ICCT's Systematic Assessment of Vessels Emissions (SAVE) model (Olmer et al., 2017a, 2017b) was used. SAVE is a global shipping inventory model built by the ICCT that uses automatic identification system (AIS) data (Spire, 2021) and the ship characteristics dataset, including identification of ships equipped with exhaust gas cleaning system (EGCS or scrubbers), from IHS Markit Global (2022).[2] The detailed methodology used for this inventory is available in Olmer et al. (2017b) and has been updated to align with the *Fourth IMO Greenhouse Gas Study* (Faber et al., 2020).

The SAVE model estimates hourly ship-specific power demand and fuel consumption based on the engines and fuel type used by each ship. The model accounts for the impact on energy use and emissions of ship age, speed, draught, hull-fouling factors, and weather conditions. It also accounts for regional regulations and allows switching between fuels to comply with local requirements. Thus, it is presumed that ships use distillate fuels when local regulations restricted sulphur in fuels to a maximum of 0.10% m/m, such as in Iceland's national waters (12 nm from the baseline of the territorial sea) and while berthing at EU ports to comply with the EU Sulphur Directive (European Legislation, 2016bis). Fuel consumption was summarized for eight ship types, which were aggregated from the 19 ship classes used by the SAVE model. These ship types include cargo ships, containers, tankers, passenger ships, vehicle carriers, roll-on/roll-off passenger ferries (RoPax), fishing vessels, and others (service and offshore vessels, yachts, and miscellaneous).

2 IHS Markit merged with S&P Global in 2022.

To forecast the future 2030 fuel demand, the ICCT's global maritime fuel demand and emissions projection model Polaris (ICCT, 2022) was used. Polaris predicts fleet turnover and energy demand by ship type and fuel type. The model estimates the retirement of older vessels and introduces new ships to the global fleet to meet demand targets. The demand assumptions are based on historical shipping demand reported by the United Nations Conference on Trade and Development (UNCTAD, 2021). It is expected that the increase in shipping activity in the proposed NE Atlantic ECA will align with the global growth trend. Therefore, the growth coefficients estimated in Polaris to the hourly power demand in the study area to estimate future power and fuel demand for ships in 2030 were used. It was also assumed that traffic patterns will remain unchanged.

The demand projections in Polaris account for technical efficiency improvements under the IMO's greenhouse gas policies and integrates the Energy Efficiency Existing Ship Index (EEXI) for the existing fleet and the Energy Efficiency Design Index (EEDI) for the newly built ships. Polaris also calculates the operational carbon intensity indicator (CII), but because ships are not required to achieve a particular grade, the CII is assumed to not influence ship behaviour. EEXI is also expected to have a very limited effect on a ship's energy efficiency improvement: applying EEXI will result in just 0.7%–1.3% CO_2 reduction by 2030 because it does not limit engine power below current operational levels (Rutherford et al., 2020). Therefore, the existing vessels will most likely comply with the EEXI requirement without significant energy efficiency adjustments.

4.2. Analysis of shipping traffic for 2021

The number of vessels identified sailing in the proposed NE Atlantic ECA in 2021 was 17,640, from which 21% of the vessels were built before 2000 (Tier 0), 45% of the vessels were built after 2000 and before 2011 (Tier I), and 34% were built in 2011 or later (Tier II). The vessels sailing in the proposed NE Atlantic ECA in 2021 consumed fuels equivalent to 265 petajoules (PJ). It was also estimated that 64% of all fuel burned in the NE Atlantic ECA in 2021 was VLSFO, and only 13% of the energy consumed was by ships using HFO with installed scrubbers (

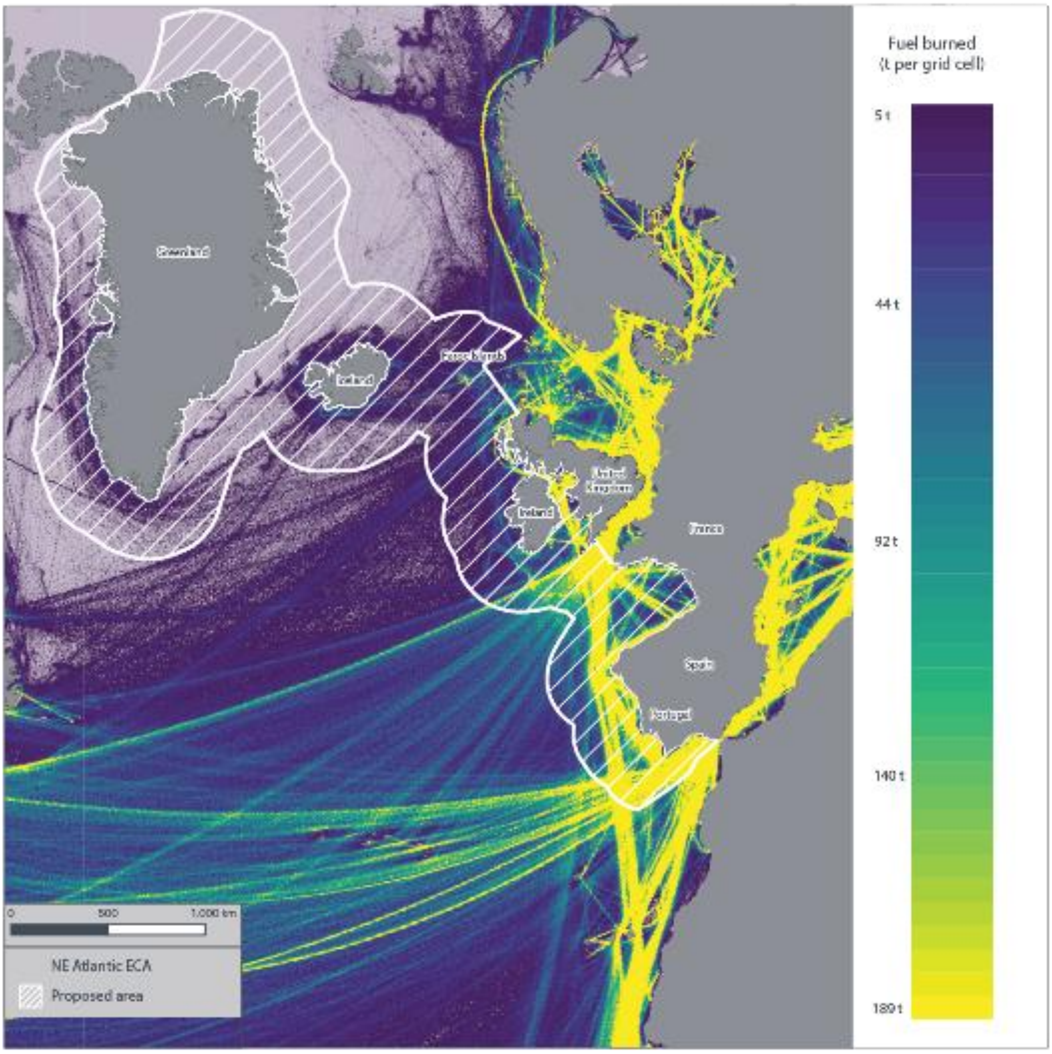


Figure **5** and Figure 6). The remaining 23% of the 2021 fuel mix was distillate fuels (18%) and LNG (nearly 5%). Six ships in the NE Atlantic ECA used methanol as a primary fuel (less than 0.10% of the total).

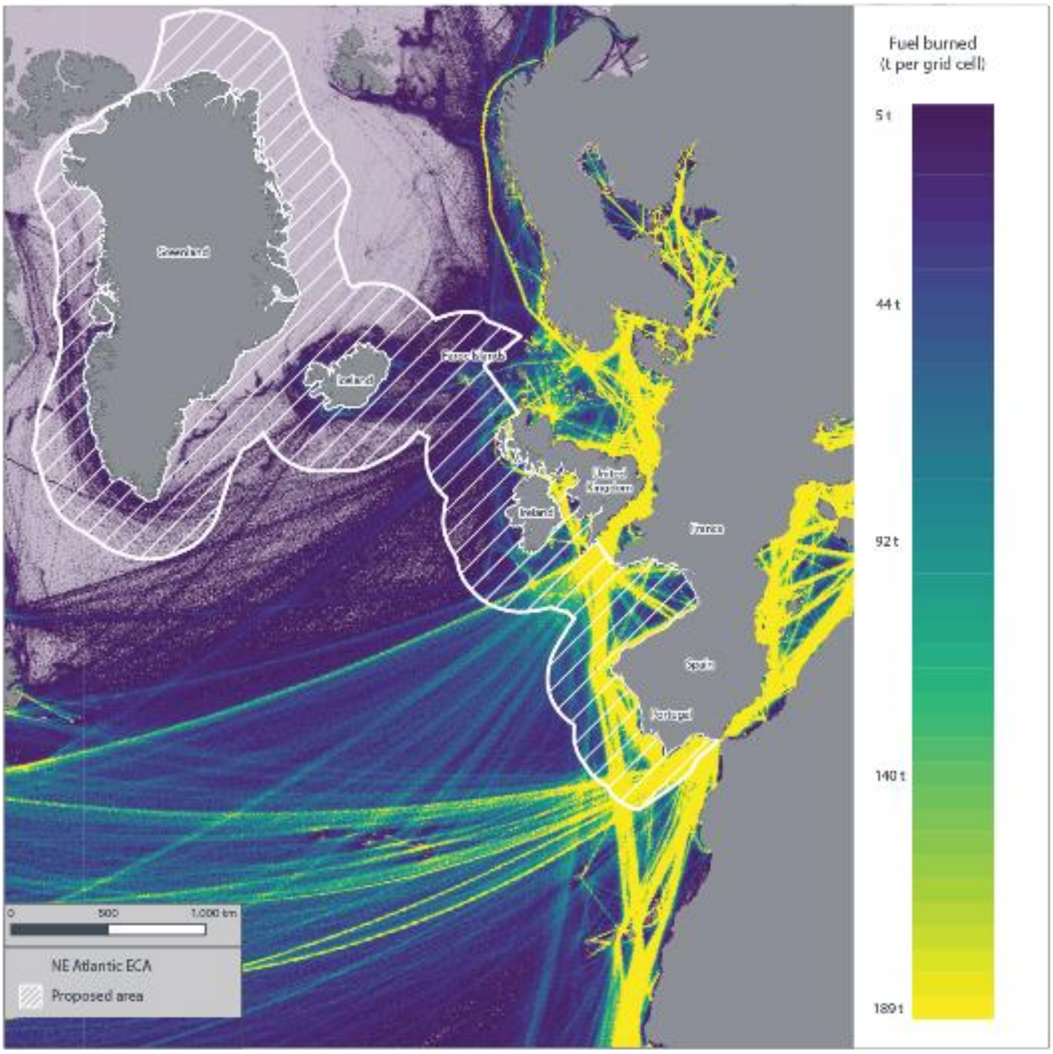


Figure 5: Shipping traffic and fuel consumption in the area of the proposed NE Atlantic ECA in 2021

The data also shows that ships berthing and anchoring used 20% of the 265 PJ consumed in 2021 (Figure 6). About 53% of the fuels burned in ports are distillates (MGO), but only 9% of fuels burned are distillates while ships cruising and manoeuvring. Residual fuels (VLSFO and HFO with scrubber) accounted for 85% of fuels burned during cruising and manoeuvring. This difference is explained by the EU Sulphur Directive requiring ships at berths in EU ports to use marine fuel with a sulphur content lower or equal to 0.10% or to use an emission-abatement method (i.e. scrubbers) providing emission reductions at least equivalent to those achievable by using low sulphur fuel (European Union, 2016 bis). Ships using HFO with scrubbers accounted for 8% of in-port fuel consumption. Ships at ports within the NE Atlantic ECA area not covered by the EU Sulfur Directive, and therefore used VLSFO, accounted for 37% of in-port fuel consumption.

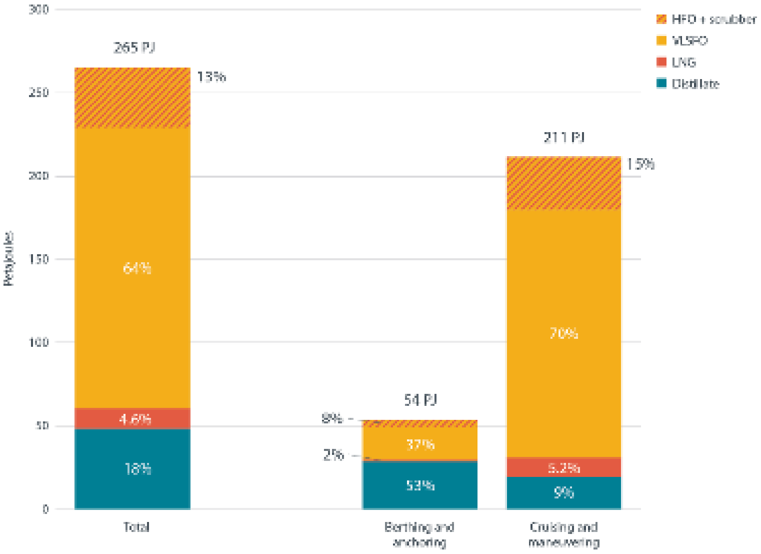


Figure 6: Fuel consumption of ships operating in the proposed NE Atlantic ECA in 2021
Note: Methanol represents less than 0.10% of the 2021 fuel mix and is not shown in the figure

Ships sailing in the exclusive economic zones of Portugal, Spain, and the United Kingdom consumed 187 PJ of fuel, as shown in Table 2 and Figure 7; which represents 70% of the total fuel consumption in the NE Atlantic ECA region. In Portugal and Spain, fuel consumption is mainly by container ships and tankers and in the United Kingdom, it is mainly tankers and RoPax vessels. Fishing activities largely impact Iceland, Greenland, and the Faroe Islands with 48% of all fuel burned in Iceland's waters being by fishing vessels, followed by the Faroe Islands and Greenland (40% and 31%, respectively).

Table 2. Fuel used (PJ) by ship type and IMO member state and associate members in the proposed NE Atlantic ECA in 2021.

Ship Type	**Portugal**	**Spain**	**UK**	**France**	**Ireland**	**Iceland**	**Faroe**	Denmark (**Greenland**)
Container	26.97	16.64	5.15	12.24	3.23	0.98	0.35	0.54
Tanker	20.91	15.95	12.04	10.68	3.21	0.32	0.34	0.15
Cargo ship	15.77	13.33	6.18	9.75	2.85	0.87	1.09	0.87
Vehicle carrier	3.55	4.15	6.03	3.78	1.75	0.26	0.28	0.00
Passenger	3.33	4.32	2.76	1.95	0.36	0.69	0.04	0.14
RoPax	0.56	0.89	10.46	1.29	2.92	0.27	0.54	0.00
Fishing vessel	1.44	4.98	4.17	3.14	3.79	3.45	1.95	0.99
Other	1.84	2.03	3.27	1.83	0.71	0.36	0.22	0.47
Total energy demand (PJ)	**74.4**	**62.3**	**50.1**	**44.7**	**18.8**	**7.2**	**4.8**	**3.2**

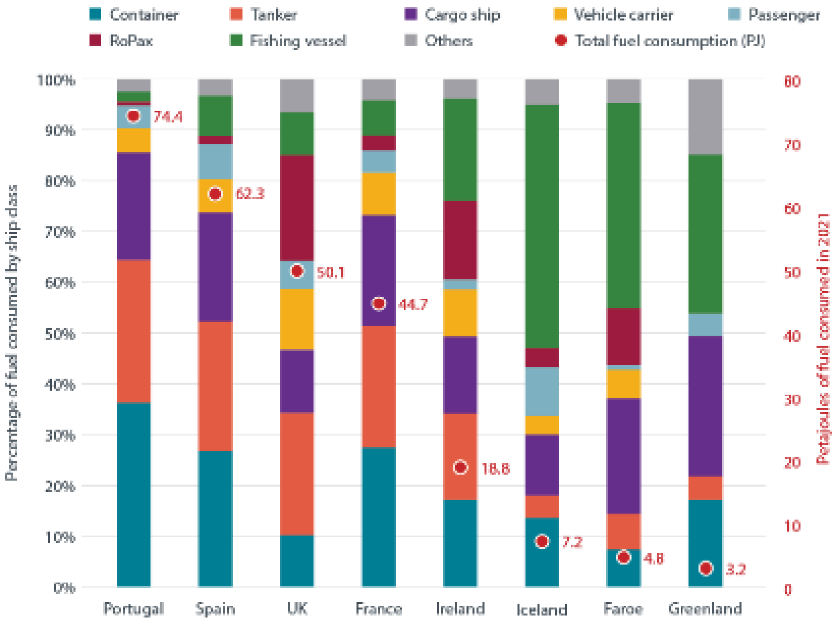


Figure 7: Estimate of fuel consumption in 2021 per member state.

It was also estimated that 88% of the vessels sailing in the proposed NE Atlantic ECA are already navigating in other established or proposed ECAs. Out of 17,640 ships detected in the NE Atlantic ECA area in 2021, 76% also navigated in the North Sea ECA and 74% in the Mediterranean Sea SO_x ECA, where fuel sulphur requirements begin in 2025 (

Figure **8**). Ships operating in active ECAs will already bunker low-sulphur fuels that comply with fuel sulphur requirements or otherwise use HFO with scrubbers. Newer ships will also have installed NO_x reduction technologies if they are subject to Tier III requirements in the North American, Baltic Sea, or North Sea ECAs.

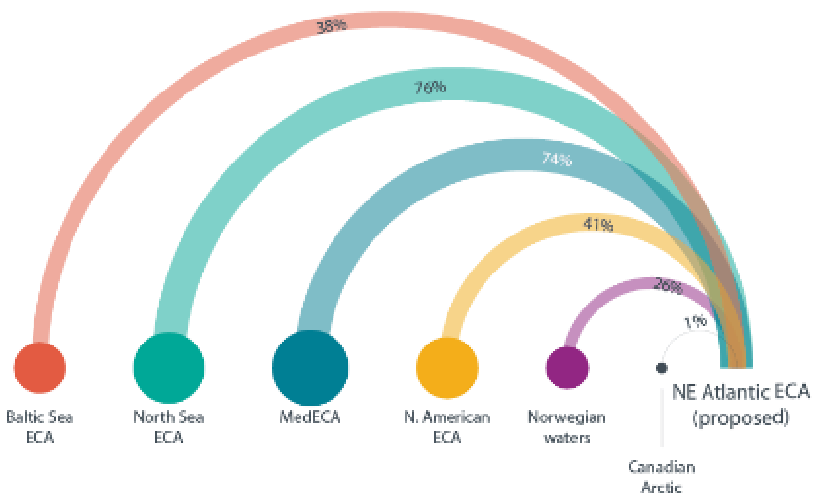


Figure 8: Percentage of vessels navigating in established and proposed ECAs that operate in the proposed NE Atlantic ECA. The diameter of each circle representing an ECA is proportional to the percentage of ships operating in both that ECA and in the proposed NE Atlantic ECA

4.3. Projected growth in fuel demand between 2021 and 2030

Total fuel demand in the proposed NE Atlantic ECA region will grow by 17% between 2021 and 2030, from 265 PJ to 311 PJ (Figure 9). However, fuel consumption is expected to grow unevenly among different ship types. Residual fuels (VLSFO and HFO) will have the largest share of the 2030 fuel mix (227 PJ out of the total 311 PJ) but that represents an increase of only 11% from 2021. In contrast, the demand for distillate and LNG fuels will grow by 41% and 29%, respectively, by 2030. Their joint share in the fuel mix will increase from 23% in 2021 to 27% in 2030. Methanol uptake will grow by 76% compared to 2021, but its share will remain very low. Because of the small number of ships operating on methanol in this area, methanol's total share of the fuel mix will remain less than 0.10% in the 2030 fuel mix.

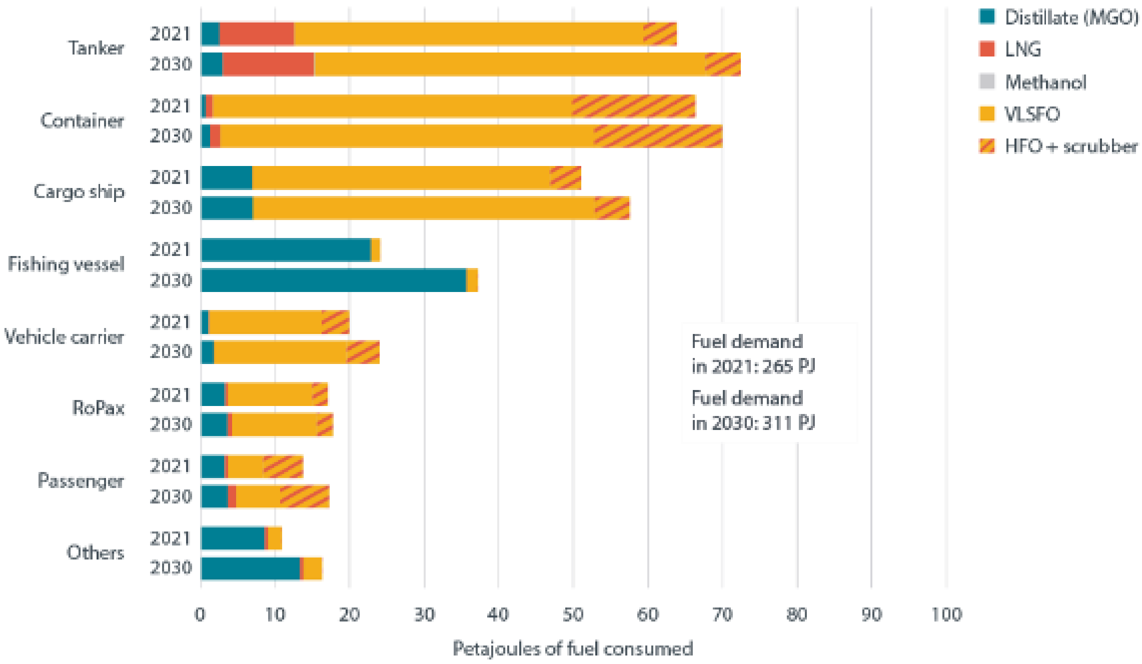


Figure 9: Predicted fuel consumption by ship class and fuel type for the proposed NE Atlantic ECA region in 2021 and 2030

5. Contribution of Ships to Air Pollution and Other Environmental Problems

*This section presents information addressing **criterion 3.1.4 of Appendix III to MARPOL Annex VI**, as cited: "The proposal shall include an assessment that emissions from ships operating in the proposed area of application are contributing to ambient concentrations of air pollution or to adverse environmental impacts. Such assessment shall include a description of the impacts of the relevant emissions on human health and the environment, such as adverse impacts on terrestrial and aquatic ecosystems, areas of natural productivity, critical habitats, water quality, human health, and areas of cultural and scientific significance, if applicable. The sources of relevant data including methodologies used shall be identified" and **criterion 3.1.5 of Appendix III to MARPOL Annex VI**, as cited: "The proposal shall include relevant information pertaining to the meteorological conditions in the proposed area of application to the human populations and environmental areas at risk, in particular prevailing wind patterns, or to topographical, geological, oceanographic, morphological or other conditions that contribute to ambient concentrations of air pollution or adverse environmental impacts".*

Section Summary

This section reports an overview of current and projected shipping emissions (sub-section 5.1), their contribution to ambient air pollution (sub-section 5.4), including an explanation of the meteorological conditions affecting their dispersion (sub-sections 5.2 and 5.3), and the associated environmental (sub-sections 5.5 to 5.7) and health (sub-section 5.8) impacts. The analysis quantifies expected increases in SO_x, NO_x, and PM pollutant concentrations by 2030 if NE Atlantic ECA is not implemented and demonstrates the effectiveness of the NE Atlantic ECA in mitigating these emissions under different compliance scenarios. Moreover, it reports the deposition of sulphur, nitrogen, and PM compounds, as well as changes in visibility. Furthermore, it compares health benefits by quantifying avoided premature deaths and related economic benefits due to the NE Atlantic ECA designation.

5.1 Shipping emissions from ships operating in the proposed area

5.1.1. Scenarios used for shipping emissions estimations

The compliance scenarios developed to be used in the estimations can be seen in Figure 10, and their description is as follows:

Business-As-Usual 2030 (2030 BAU): This assumes no NE Atlantic ECA implementation in the study area. Consequently, vessels are expected to use fuel as predicted by the Polaris model described in Section 4.3: vessels using HFO with scrubbers represent 13% of the total fuel consumption (17% of all residual fuels), while VLSFO composes 60% of the projected fuel within the proposed NE Atlantic ECA (Figure 10) . Distillates account for 22% of ships' fuel consumption, LNG makes up 5%, and methanol contributes less than 0.1%.

MGO Mix scenario: This scenario assumes that the fleet operating on VLSFO will switch to MGO (60% of the fuel mix). The sulphur content of distillates such as MGO falls well below the mandatory 0.10% m/m limit; the global average sulphur content of distillates was 0.06%

in 2022 (MEPC 80/INF.4). Ships already using distillates (22%), LNG (5%), and methanol (< 0.1%) are not expected to change behaviour. Ships predicted to have installed scrubbers will need to adjust performance to be equivalent to 0.10% fuel sulphur content, in contrast to the 0.50% sulphur content in the BAU scenario.

ULSFO Mix scenario: This scenario is similar to the MGO Mix scenario, with the distinction that ships operating on VLSFO will switch to ULSFO (60% of the fuel mix). It is assumed that the sulphur content of ULSFO does not exceed 0.10% m/m while other properties and emissions remain similar to VLSFO. Unlike MGO, ULSFO is a residual fuel that does not go through the distillation process but is desulfurized so that it has a significantly lower sulphur content than heavy fuel oil. ULSFO has a viscosity and density comparable with heavy fuel oil and we assume it has similar BC emissions as HFO. Ships already using distillates (22%), LNG (5%), and methanol (<0.1%) are not expected to change behaviour. Ships predicted to have installed scrubbers will need to adjust performance to be equivalent to 0.10% fuel sulphur content, in contrast to the 0.50% sulphur content in the BAU scenario.

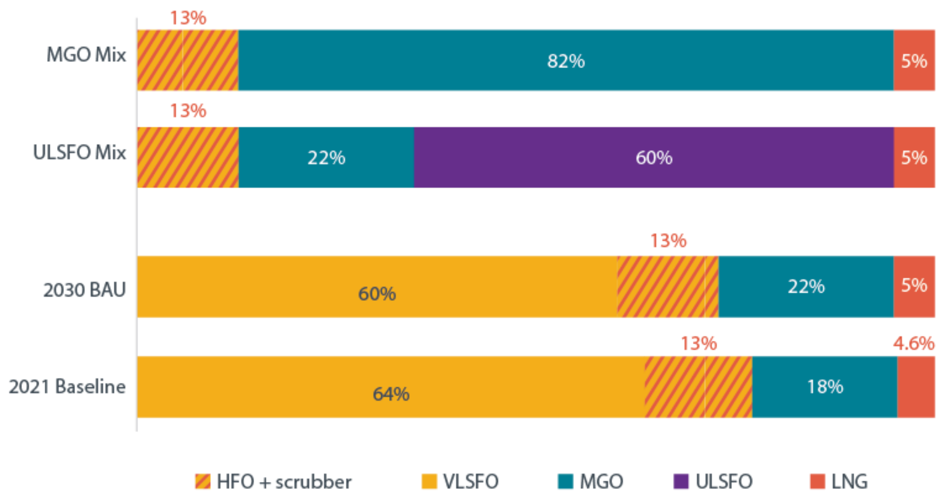


Figure 10: Fuels consumed in 2021 and 2030 under the BAU and ECA compliance scenarios. ***Note: Methanol constitutes less than 0.1% of the total fuel mix in each scenario and is not shown in the figure***

In our projections, a significant increase in scrubber installations is not anticipated, which peaked in 2019 prior to the implementation of the global sulphur cap in 2020 and has since then stabilized (DNV, 2022). Although establishing a new ECA might boost scrubber uptake, results show that 88% of all ships operating in the NE Atlantic ECA are concurrently active in other ECAs, 67% operating in the North Sea ECA, where the emission control area has been in effect since 2006. This suggests that ship owners have already installed scrubbers for compliance with the 2020 sulphur cap or operations in other ECAs, whereas other vessels may opt for low-sulphur fuels to ensure regulatory compliance. Therefore, for the ECA compliance scenarios, we assume that the proportion of ships with scrubbers would not grow substantially following the designation of an ECA as compared with the BAU scenario (13% in the fuel mix). These vessels are expected to maintain using HFO with scrubbers but with the adjusted sulphur limits equivalent to 0.10% sulphur fuel content. However, two additional scenarios to compare the differences in emissions reduction and health impacts between the use of scrubbers and distillates for compliance are reported in Osipova et al. (2024a). These scenarios assessed emission reductions and health impacts by comparing the outcomes of all HFO-fuelled ships using scrubbers versus all ships – including those already equipped with scrubbers – switching to MGO for compliance.

5.1.2. Business-as-usual scenario: 2021 and 2030 emissions

Shipping emissions of SO_x, $PM_{2.5}$, and NO_x for 2021 and predicted emissions for 2030 (2030 BAU scenario) are calculated based on fuel consumption and shipping activities in the proposed area, explained in detail in Sections 4.2 and 4.3. The emission factors and engine operational load assumptions are fully aligned with the *Fourth IMO Greenhouse Gas Study* (Faber et al., 2020) and described in (Osipova et al., 2024b). In addition to the pollutants proposed for control, it was also projected a reduction in black carbon (BC) emissions to highlight the additional benefits of an NE Atlantic ECA designation. Although MARPOL Annex VI does not directly regulate BC, it is a component of particulate matter produced by the incomplete combustion of fuel, contributing to air pollution and posing significant health risks. BC emission factors depend on fuel type, engine type, and engine load, as outlined in (Osipova et al., 2024b).

It was estimated that the ships sailing in the proposed NE Atlantic ECA in 2021 emitted 433 kt of NO_x, 40.6 kt of SO_x, 16.8 kt of $PM_{2.5}$, and 2.1 kt of BC. Most of the NO_x (226 kt, or 52% of the total) were emitted by Tier I ships, followed by Tier II ships (129 kt), and Tier 0 ships (78 kt). Without any policy intervention by 2030, these emissions are expected to grow to 500 kt of NO_x (15% increase), 45.5 kt of SO_x (12% increase), 18.9 kt of $PM_{2.5}$ (12% increase), and 2.5 kt of BC (18% increase) (Figure 11 and Table 3).

The geographical distribution of pollutants aggregates over the shipping lanes, creating emissions intensity hotspots, as shown in Figure 11. The emission concentrations follow the pattern of the burned fuel intensity and cause an uneven burden for different member states. Portugal, Spain, the United Kingdom, and France experience the highest emissions due to heavy traffic of container ships, tankers, and cargo ships burning predominately heavy fuel oil. Ships sailing in the exclusive economic zones of these four countries combined emit 90% of the SO_x emissions in the proposed NE Atlantic ECA, along with 89% of $PM_{2.5}$ emissions, 82% of BC, and 87% of NO_x emissions (Table 3).

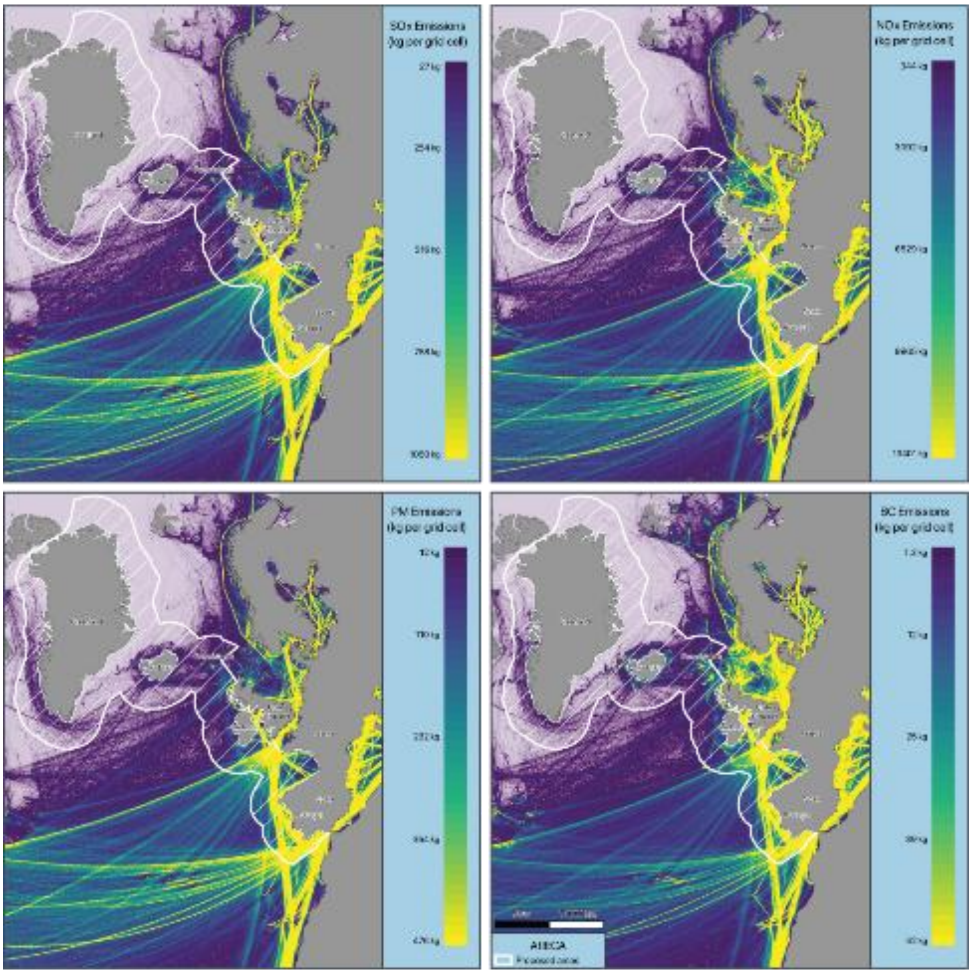


Figure 11: Maps of SO_x, $PM_{2.5}$, NO_x, and BC emissions in 2021

5.1.3. Expected emission reductions after ECA designation

Projected reduction in SO_x, $PM_{2.5}$, and BC emissions

Based on the fuel mix compliance scenarios described in the previous section, the projected reductions in SO_x, $PM_{2.5}$, and BC emissions are shown in Figure 12. Table 3 details the absolute emission reductions achievable by each member state. When compared to 2030 BAU scenario, the MGO Mix scenario results in an 82% reduction in SO_x emissions, 64% in $PM_{2.5}$ emissions, and 36% in BC emissions. Using ULSFO for ECA compliance results in a 9% reduction in $PM_{2.5}$ emissions compared to the 2030 BAU scenario and no reduction in BC emissions (Figure 12). Furthermore, the effectiveness of ULSFO in reducing SO_x emissions is inferior to that of MGO. The ULSFO Mix scenario reduces SO_x emissions by 73% from 2030 BAU scenario, compared with an 82% reduction for the MGO Mix scenario.

Table 3. SO_x, PM, and NO_x emissions from shipping by IMO member states and associate members in the proposed NE Atlantic ECA in baseline year 2021 and projected to 2030 under a BAU and ECA compliance scenarios.

SO_x emissions (kt)				
	Current 2021	**BAU 2030**	**ULSFO Mix**	**MGO Mix**
Portugal	12.48	13.88	3.38	2.12
Spain	9.60	10.84	3.01	2.02
United Kingdom	7.70	8.47	2.33	1.51
France	6.86	7.72	2.07	1.34
Ireland	2.71	3.01	0.88	0.59
Faroe Islands	0.54	0.64	0.23	0.16
Iceland	0.40	0.51	0.33	0.26
Denmark (Greenland)	0.34	0.41	0.16	0.11
Total:	40.63	45.48	12.39	8.13
$PM_{2.5}$ emissions (kt)				
	Current 2021	**BAU 2030**	**ULSFO Mix**	**MGO Mix**
Portugal	5.24	5.83	5.23	1.87
Spain	4.00	4.52	4.08	1.60
United Kingdom	2.90	3.23	2.90	1.18
France	2.97	3.35	3.06	1.16
Ireland	1.11	1.25	1.14	0.48
Faroe Islands	0.23	0.28	0.25	0.13
Iceland	0.23	0.30	0.31	0.21
Denmark (Greenland)	0.16	0.19	0.19	0.09
Total:	16.84	18.94	17.17	6.73
BC emissions (kt)				
	Current 2021	**BAU 2030**	**ULSFO mix**	**MGO mix**
Portugal	0.50	0.57	0.57	0.30
Spain	0.45	0.53	0.53	0.33
United Kingdom	0.47	0.55	0.55	0.38
France	0.34	0.40	0.40	0.24
Ireland	0.17	0.20	0.20	0.14
Faroe Islands	0.05	0.07	0.07	0.06
Iceland	0.08	0.11	0.11	0.10
Denmark (Greenland)	0.03	0.04	0.04	0.03
Total:	2.10	2.47	2.47	1.59

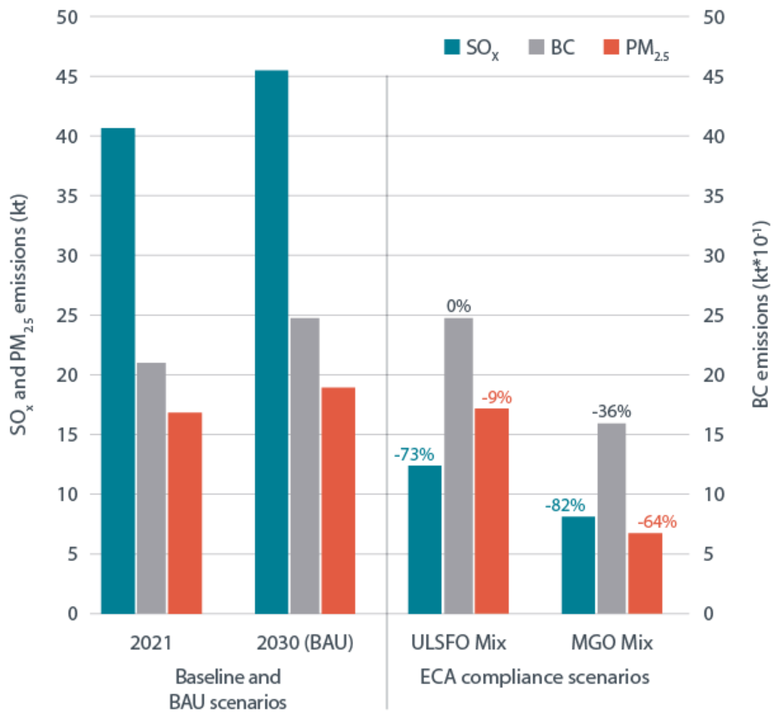


Figure 12: Emissions in the proposed NE Atlantic ECA by compliance scenario and reductions in emissions compared to the 2030 BAU scenario.
Note: The percentages indicate the decrease in emissions compared to the 2030 BAU scenario

Across all countries except Iceland, using MGO for ECA compliance is expected to reduce SO_x emissions by 73%–85%, while using ULSFO for compliance is projected to result in SO_x reductions of 61%–76% (Table 3). Iceland has already imposed a 0.10% m/m sulphur content limit within its territorial seas and internal waters, resulting in lower ECA-related advantages than other member states. However, because the ECA would cover the 200-nautical-mile exclusive economic zone of Iceland rather than the 12-nautical-mile territorial seas and internal waters, the introduction of the NE Atlantic ECA can still bring benefits for the country. In Iceland, if MGO were used for compliance, the ECA would result in a 48% reduction in SO_x emissions, a 29% reduction in $PM_{2.5}$, and a 7% reduction in BC emissions compared to the 2030 BAU scenario. Opting for ULSFO as a compliance fuel reduces these benefits as there would be a 35% reduction in SO_x emissions and no apparent change for $PM_{2.5}$ and BC emissions (Table 3).

All member states can expect substantial reductions of $PM_{2.5}$ and BC emissions when MGO is chosen as a primary compliance fuel. The reductions range from 53% to 68% for $PM_{2.5}$ and 17% to 46% for BC, depending on the country. In contrast, using ULSFO as the primary compliance fuel brings significantly more modest emission reductions, varying between 1% and 10% for $PM_{2.5,}$ and showing no effect on BC emissions across all member states. For the Arctic States and territories (Denmark (Greenland), Iceland, and the Faroe Islands), the expected reduction in $PM_{2.5}$ and BC emissions an ECA would bring is not as high as in other states. This is primarily because a large portion of the shipping traffic in these Arctic States and territories consists of smaller fishing vessels that already use low-sulphur distillate fuel.

NO_x Tier III compliance

For modelling NO_x Tier III compliance, a different approach is employed because NO_x emissions depend mainly on engine type, age, and revolutions per minute (rpm). Depending on the engine type, Tier III compliance can be achieved by installing SCR or EGR systems. The regulations apply only to ships built after an ECA designation and operating within that ECA's boundaries. Therefore, to model the NO_x emission reduction induced by the NE Atlantic ECA designation, we assumed a potential NE Atlantic ECA designation year of 2027 and estimated the number of newly built ships from 2027 to 2030. Consistent with MARPOL Annex VI Regulation 13, for engines larger than 130 rpm, we assume ships achieve 3.4 g NO_x/kWh. Engines equal to or larger than 2,000 rpm are assumed to emit 2.0 g NO_x/kWh. For engines between 130 rpm and 2,000 rpm, NO_x emissions in g/kWh are calculated as 9 x $rpm^{-0.2}$.

To understand the impact of an NE Atlantic ECA on NO_x emissions, the Polaris model was used to estimate the number of newly built ships in the NE Atlantic ECA area between 2027 and 2030. To predict where these newly built ships will operate, it was assumed that the shipping traffic patterns in 2030 would remain similar to those in 2021. A randomized selection within each ship class sailing in the NE Atlantic ECA in 2021 was made and assume that the new Tier III ships will follow similar routes. The number of newly built ships within each class was obtained from the Polaris model, and NO_x emissions from these ships are assumed to meet Tier III requirements.

It was also assumed that ships built between 2027 and 2030 always emit the test-cycle weighted Tier III amounts (e.g., 3.4 g NO_x/kWh for engines larger than 30 rpm) when operating inside the NE Atlantic ECA. However, real-world measurements indicate that ships with Tier III engines often exceed the weighted Tier III limits when operating at below 25% main engine load (Comer et al., 2023). The issue of potential Tier III noncompliance is outside this work's scope. Additionally, the potential NO_x reduction that could be achieved if all ships predicted to sail in the NE Atlantic ECA in 2030 are retrofitted to achieve Tier III compliance was calculated. No claims are made about the practical feasibility of retrofitting all engines to achieve Tier III.

Projected reduction in NO_x emissions

Given that NO_x Tier III standards apply only to ships newly built after an ECA's designation year, the impact on NO_x emissions is not expected immediately after the NE Atlantic ECA designation. Assuming that the tentative NE Atlantic ECA designation year is 2027—and that only vessels built that year and after will need to comply with the Tier III NOx regulations—a 3% reduction in NO_x emissions can be expected by 2030 compared to the 2030 BAU scenario (
Table **4** and Figure 13). Additionally, growth in shipping traffic will offset the effects of Tier III regulations in the initial years. NO_x emissions will still increase in the NE Atlantic ECA, but at a slower pace. NO_x emissions in 2030 will be 12% greater than 2021 levels with Tier III regulations compared to 15% greater without the Tier III regulations.

The potential of Tier III regulations to reduce NO_x emissions could be significantly enhanced by requiring older ships operating in the ECA to be retrofitted to meet Tier III standards. Figure 13 shows a scenario where all ships are retrofitted to comply with Tier III, leading to a potential reduction of up to 71% of NO_x emissions in the proposed NE Atlantic ECA in 2030 compared to the 2030 BAU scenario. Similar conclusions have been drawn by the International Institute for Applied Systems Analysis in their cost-benefit analysis of an ECA designation in EU waters (Cofala et al., 2018). They estimated that applying Tier III regulations solely to newly built ships in 2025 would result in an increase in NO_x emissions of up to 5% by 2030. In contrast, retrofitting old engines to Tier III could yield emission reductions ranging from 16% to 31% by 2030. The technical and practical feasibility of retrofitting older engines to achieve Tier III is beyond the scope of this project.

Table 4. NO_x emissions from shipping by IMO member States and associate Members in the proposed NE Atlantic ECA in the baseline year 2021 and projected to 2030 under 2030 BAU and ECA compliance scenarios.

NO_x emissions (kt)				
	Current 2021	**2030 BAU**	**Tier III new ships only**	**Tier III all ships retrofitted**
Portugal	129.7	145.0	141.9	34.5
Spain	103.4	119.5	116.8	34.6
United Kingdom	70.8	82.1	79.6	26.9
France	76.9	88.2	86.2	24.5
Ireland	29.7	35.1	33.6	12.5
Faroe Islands	7.1	9.2	8.7	3.0
Iceland	10.5	14.4	13.4	5.3
Denmark (Greenland)	5.1	6.6	6.4	2.0
Total:	**433.3**	**500.3**	**486.7**	**143.3**

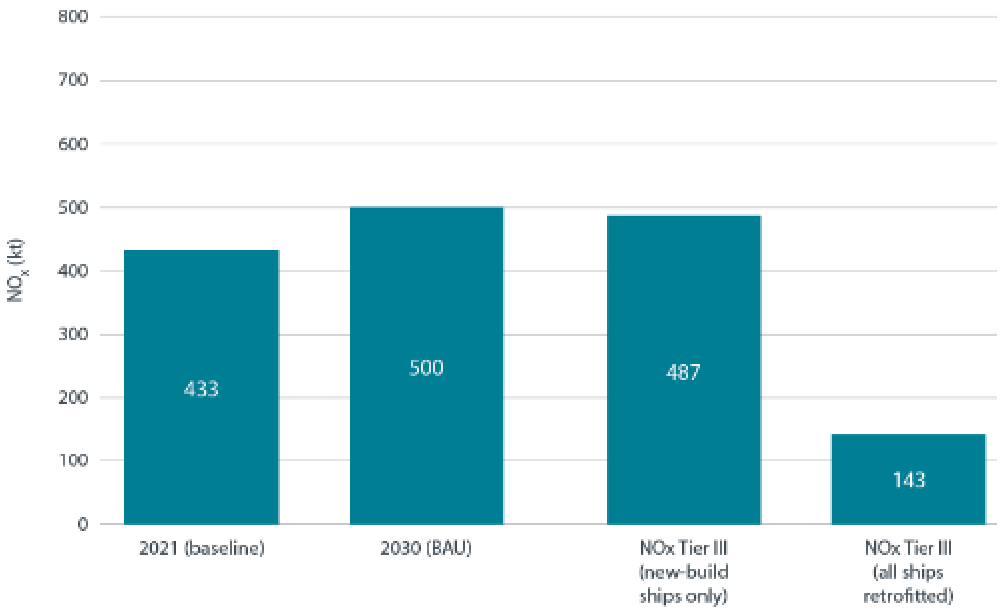


Figure 13: Total NO_x emissions and Tier III-affiliated reductions in the proposed NE Atlantic ECA

5.2. Meteorological conditions in the proposed area influencing air pollution

Due to the vast extent of the NE Atlantic ECA and the fact that it includes regions in both mid and high latitudes, the meteorological conditions of the region are heterogeneous. The prevailing westerly winds in the mid-latitudes are a dominant force in the North Atlantic, steering weather systems across the ocean towards Europe (Fleming et al., 2024; Semedo, 2005). In higher latitudes, near Greenland and Iceland, polar easterlies become more common during the winter months, contributing to the region's dynamic weather patterns influenced by the interaction of oceanic and atmospheric systems (Fleming et al., 2024). The variability of the weather in this region is largely driven by the North Atlantic Oscillation (NAO) and the Gulf Stream (Hauser et al., 2015; Sorooshian et al., 2020).

The NAO is a critical driver of weather variability in the North Atlantic region, characterised by changes in a north-south atmospheric pressure gradient over the North Atlantic. A positive NAO generally brings stronger westerly winds across the Atlantic, leading to mild and wet winters in Northern Europe and colder, drier conditions in Greenland. A negative NAO results in weaker westerlies, allowing cold air to penetrate further south, often leading to harsher winters in Europe and milder conditions in Greenland (Hauser et al., 2015; Semedo, 2005; Sorooshian et al., 2020). The Gulf Stream carries warm water from the Gulf of Mexico across the Atlantic, moderating the climate of Western Europe. The warmth of the Gulf Stream also contributes to the development of cyclones, particularly during winter, as it can intensify storm systems moving across the Atlantic. In fact, cyclogenesis, or the formation of low-pressure systems, is especially common in the North Atlantic, making it one of the most active regions for such phenomena. Cyclones often form near the eastern coast of the United States and travel across the Atlantic, affecting Europe and the Arctic (European Space Agency, 2024; Fleming et al., 2024; Sorooshian et al., 2020). The maritime climate of the North Atlantic, especially along coastal areas, contributes to mild temperatures and high humidity. This is particularly evident in Western Europe, where the ocean's moderating effect leads to relatively mild winters and cool summers. Additionally, the presence of polar ice, especially around Greenland, influences local meteorological conditions, as the melting and movement of ice can affect ocean currents and contribute to foggy conditions, particularly in the summer (Shahi et al., 2023).

The meteorological conditions of the North Atlantic significantly influence how shipping emissions impact air quality in the region. Prevailing westerly winds often disperse pollutants over long distances, spreading them from shipping lanes towards coastal areas in Europe and North America. The frequent storms in the region, especially in winter, enhance the vertical mixing of pollutants, which can lead to their broader dispersion and/or transformation into secondary pollutants. The Gulf Stream's warm waters can create stable atmospheric conditions that trap pollutants closer to the surface, particularly along the eastern United States and Western Europe. In coastal areas, the maritime climate and high humidity can lead to the formation of particulate matter (PM) from shipping emissions, degrading air quality. Meteorological conditions in the NE Atlantic ECA region were incorporated into the air quality modelling that is described in the following section.

5.3. Dispersion modelling

The open-source EMEP/MSC-W chemistry transport model, version rv5.0, was used to evaluate air pollution and the deposition of nitrogen, sulphur and PM in the NE Atlantic ECA region domain. The model was run with a horizontal resolution of ~0.5° x 0.5° (longitude x latitude) on a domain that extends from -76.85ºE to 11.75ºE and 31.95ºN to 88.05ºN. The initial and the lateral boundary conditions for most of the chemical compounds were defined by functions defining concentrations and depositions in terms of latitude and time, based on measurements and/or model calculations. More information about the EMEP/MSC-W configuration for initial and boundary conditions used in this study can be found in Simpson et al. (2012). Meteorological data for 2021 was generated using the Weather Research and Forecasting (WRF) Model version 4.5 with a resolution of ~0.5º x 0.5º. Emissions at 0.5º x 0.5º (longitude x latitude) for other anthropogenic sources, reported across multiple sectors such as energy production, industrial combustion and processes, gas venting and flaring, solvent production and use, transport, agriculture, open burning of agricultural waste, residential combustion and waste were obtained from the ECLIPSE (Evaluating the Climate and Air Quality Impacts of Short-Lived Pollutants) V6b emission inventory, developed by the International Institute for Applied Systems Analysis (IIASA). The ECLIPSE V6b considers anthropogenic emissions of SO_2, NO_x, $PM_{2.5}$ (BC, particulate organic matter, other primary $PM_{2.5}$), NMVOC, CO, NH_3 and CH_4 with annual and monthly temporal detail for 2000 to 2050 (IIASA, 2024). Moreover, it was also considered the dust emissions from the Sahara desert, NO_x from lightning and forest fires (Norwegian Meteorological Institute, 2017; Simpson et al., 2012; Wiedinmyer et al., 2011). The model was run for scenarios 2030 BAU, MGO Mix and ULSFO Mix.

5.4. Influence of shipping emissions on ambient air quality

EMEP/MSC-W dispersion modelling indicates that, without NE Atlantic ECA implementation, shipping-attributable air pollution concentrations will increase by 12% for SO_2, 16% for NO_2, and 12% for $PM_{2.5}$ on average over waters in the NE Atlantic ECA region in 2030. In absolute terms, the increase in ambient pollutant concentrations driven by increased shipping emissions is expected to be greatest along the coastal regions of the Faroe Islands, France, Ireland, Portugal, and the United Kingdom (

Figure 14). NO_x concentrations also show substantial percentage increases near the Faroe Islands, Iceland, and Western Greenland. Shipping-attributable population-weighted $PM_{2.5}$ exposure within the member states increases by 9% to 34% within the member states, with a median of 14%, between 2021 and 2030.

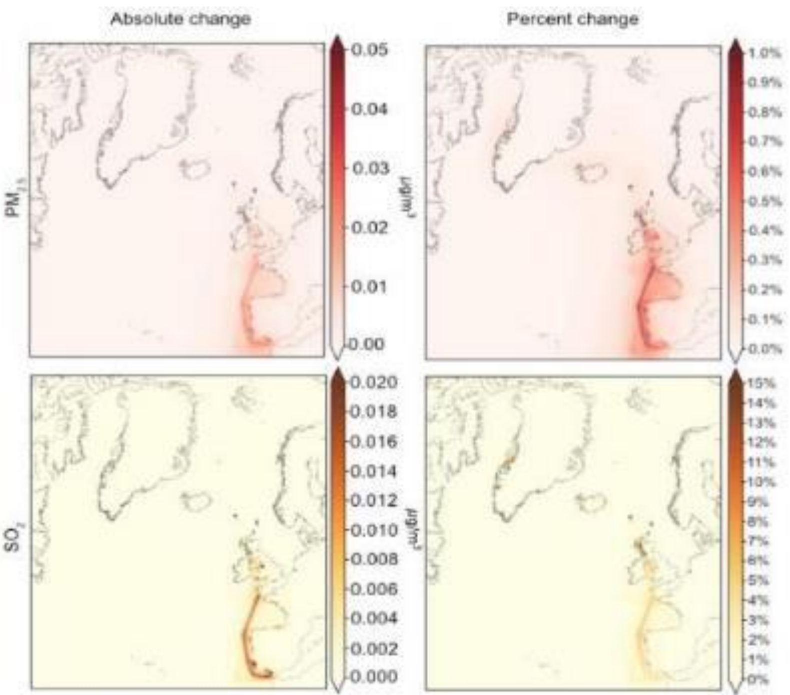


Figure 14: Projected increase in total $PM_{2.5}$, SO_2, and NO_2 concentrations (2021–2030) without proposed NE Atlantic ECA implementation

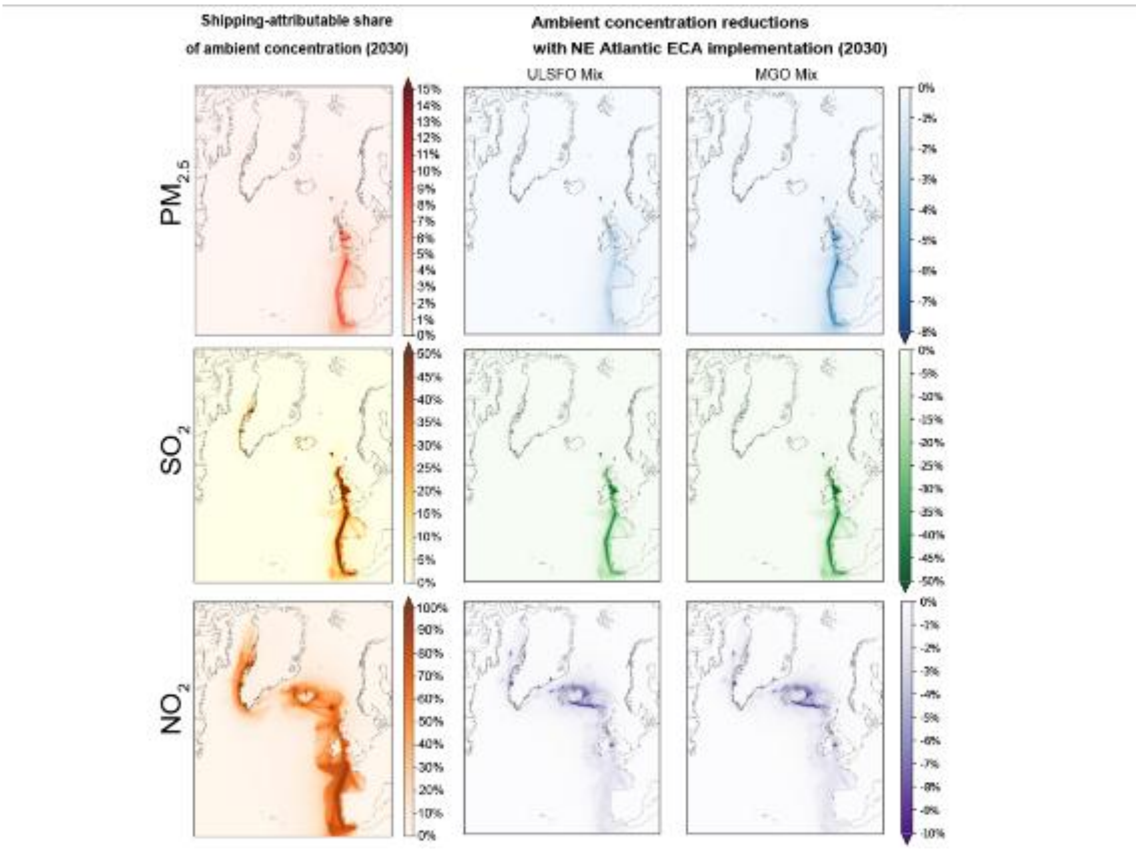


Figure 15: Shipping-attributable share of ambient $PM_{2.5}$, SO_2, and NO_2 concentrations in 2030 and predicted reductions in ambient concentrations following NE Atlantic ECA implementation compared to the 2030 BAU scenario

Implementing the NE Atlantic ECA would address a large portion of shipping's contribution to pollutant concentrations. Results show that NE Atlantic ECA compliance under the MGO Mix scenario would mitigate 86% of shipping-attributable (2.6% of ambient) SO_2, 59% of shipping-attributable (0.4% of ambient) $PM_{2.5}$, and 3% of shipping-attributable (1.2% of ambient) NO_2 averaged concentrations in the NE Atlantic ECA region. Following the ULSFO Mix scenario, the reductions are 77% for shipping-attributable (2.3% of ambient) SO_2, 31% for shipping-attributable (0.2% of ambient) $PM_{2.5}$, and 3% for shipping-attributable (1.2% of ambient) NO_2 (

Figure **15**). Establishing the NE Atlantic ECA would also be expected to reduce shipping-attributable population-weighted $PM_{2.5}$ exposure in the most populous regions in the study area by 35% – 55%, depending on whether ULSFO or MGO is used as the main compliance strategy (Figure 16).

Therefore, emission reductions vary across scenarios, with the greatest reductions achieved when MGO is used for compliance and the lowest reductions when ULSFO is used. While shipping-related SO_2 and $PM_{2.5}$ reductions are substantial under all scenarios, NO_2 reductions are modest. This is because NO_2 emissions depend primarily on engine type and technical specifications, with the type of fuel used for ECA compliance playing only a minor role.

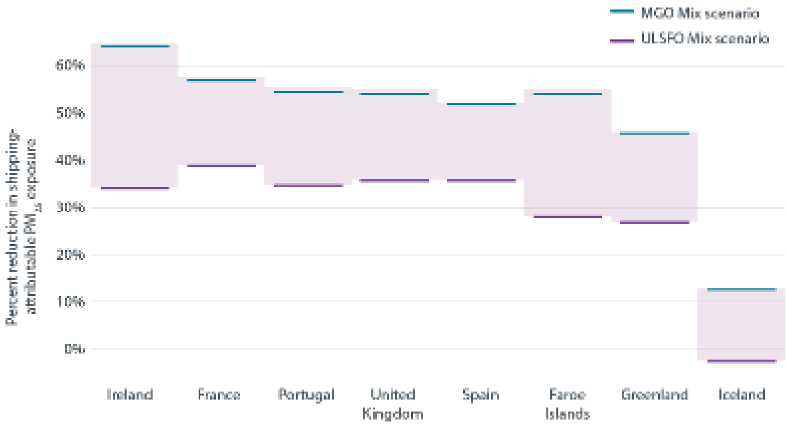


Figure 16: Percent reduction in national population-weighted shipping-attributable $PM_{2.5}$ exposure in each NE Atlantic ECA compliance scenario

5.5. Environmental and ecosystem impacts from deposition

5.5.1. Deposition of sulphur

Sulphur deposition is a significant environmental issue with long-term consequences, primarily driven by both natural processes and human activities (Chen et al., 2019; Gao et al., 2018). The major sources of sulphur emissions are anthropogenic, stemming from the combustion of fossil fuels, which is the case of shipping-related emissions, and various industrial processes that release substantial amounts of SO_2 into the atmosphere (Chen et al., 2019). Once in the atmosphere, sulphur undergoes deposition through dry and wet forms. Dry deposition occurs when sulphur compounds, particularly SO_2, settle directly onto surfaces such as soil, water, or vegetation without the involvement of precipitation. In contrast, wet deposition involves the incorporation of sulphur compounds into precipitation, leading to the formation of acid rain. This occurs when SO_2 dissolves in water droplets within clouds, forming sulfuric acid (H_2SO_4), which subsequently falls to the ground. Sulphur deposition leads to ecological impacts such as the acidification of soils, freshwater bodies, and marine ecosystems (Shammas et al., 2019). Forest ecosystems are affected as vegetation absorbs sulphur compounds through stomatal uptake, which can disrupt growth and vitality (Forsius et al., 2021). Moreover, sulphur in the atmosphere can influence climate patterns by acting as cloud seeds, potentially inducing a light scattering effect, which can lead to increased haze and reduced amount of sunlight that reaches the Earth's surface (change in visibility discussed in sub-section 5.6) (CAMS, 2023).

To understand the impact of the implementation of NE Atlantic ECA on the deposition of sulphur, the differences between the 2030 BAU scenario and the NE Atlantic ECA compliance scenarios - MGO Mix and ULSFO Mix were calculated. These differences were converted into percentages. Figure 17 shows the differences in annual dry deposition (left panel) and wet deposition (right panel) due to the implementation of NE Atlantic ECA scenarios, i.e. the difference between 2030 BAU and NE Atlantic ECA MGO Mix (Figure 17 a) and b)) and ULSFO Mix (Figure 17 c) and d)).

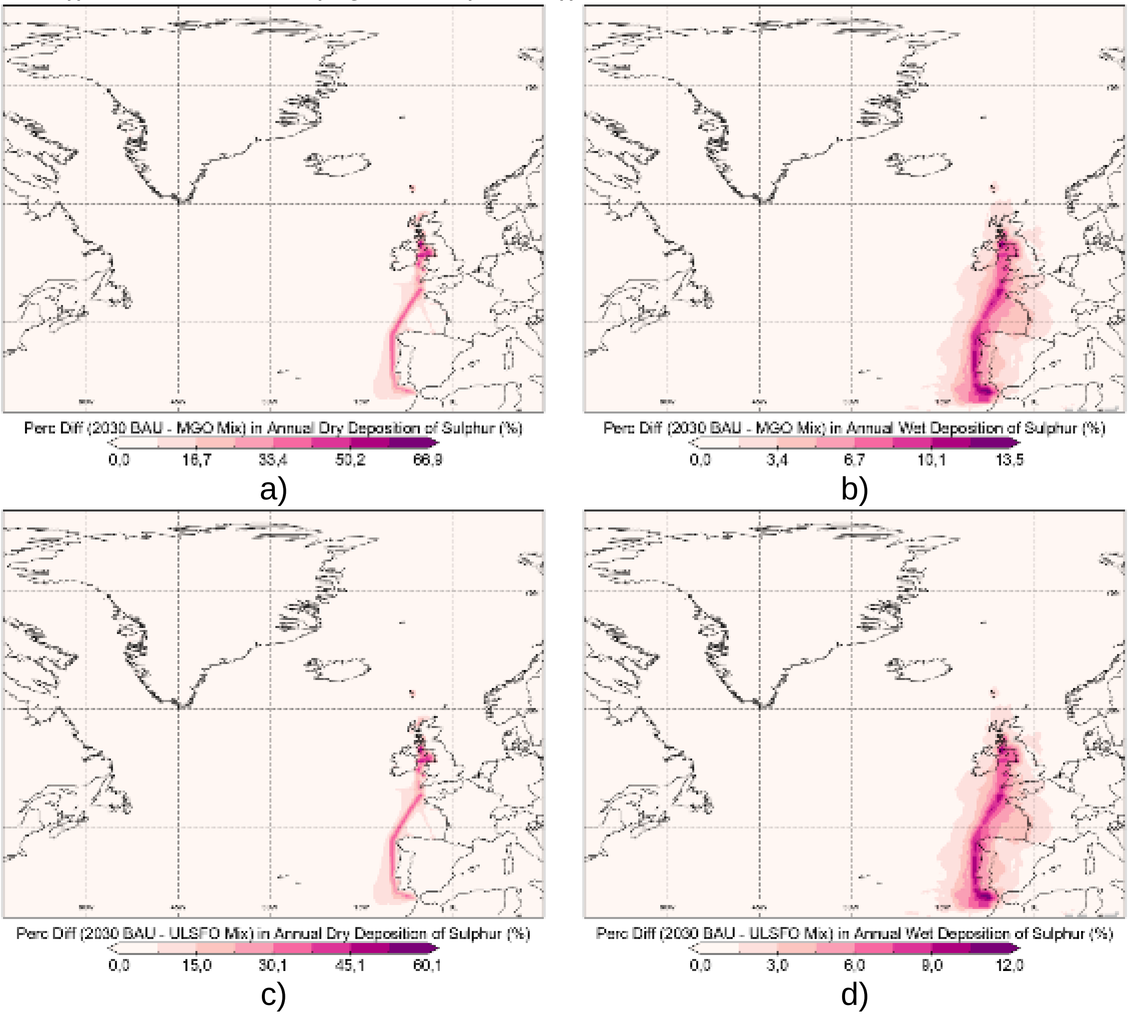
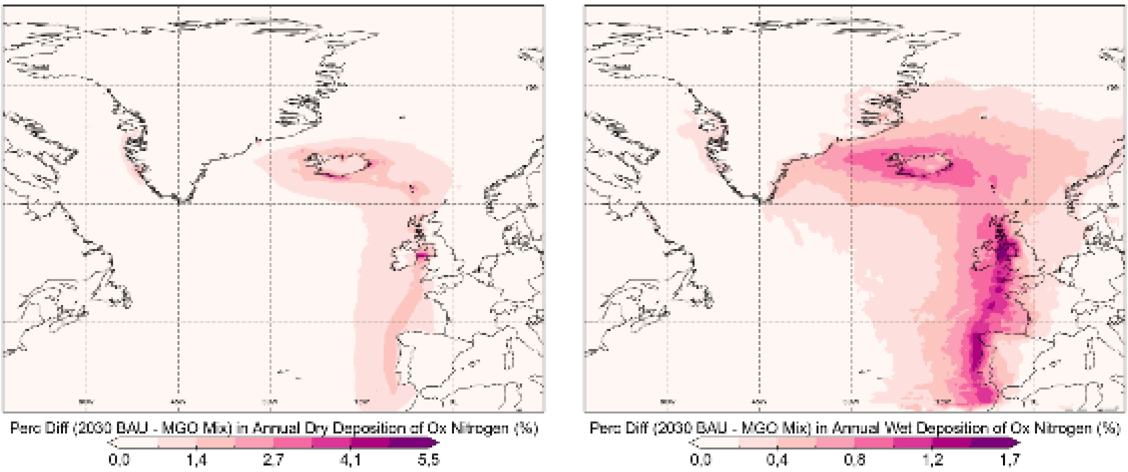


Figure 17: Differences in percentage of the annual sulphur dry deposition (left panel) and wet deposition (right panel) for: a) and b) 2030 BAU – MGO Mix; c) and d) 2030 BAU – ULSFO Mix

Differences in annual dry (Figure 17 a) and c)) and wet (Figure 17 b) and d)) sulphur deposition associated with the proposed NE Atlantic ECA implementation show reductions in similar orders of magnitude and patterns across the different scenarios. The largest reductions in dry and wet depositions were found along the Portuguese coast, the north coast of Spain, the west coast of the United Kingdom and the east coast of Ireland. Regarding dry deposition, the reductions seem to be correlated with the high traffic in shipping tracks. Dry deposition is influenced by the concentration of pollutants at the surface and the deposition velocity. Since sulphur emitted by ships is released close to the water's surface, the reductions in dry deposition were found mainly near the shipping tracks. However, the impact of shipping related sulphur emissions on dry deposition was minimal inland NE Atlantic ECA countries. Reductions in wet sulphur deposition were lower when compared to dry deposition, however, these were also found inland. As was mentioned before, wet deposition is dependent on the solubility of sulphur and precipitation amount and frequency. Maximum reductions in wet deposition occurred mostly along the north coastlines of Portugal and Spain and the west coast of the United Kingdom. This result appears to be related to the precipitation that occurs in these areas. These areas are characterized by having a high number of days of heavy rainfall per year with more than 20 mm of precipitation (ECMWF, 2024). According to Figure 17 (left panel), the maximum percent reduction in dry sulphur deposition was 66.89% for MGO Mix scenario, followed by 60.12% for the ULSFO Mix scenario. For all the NE Atlantic ECA domain, the estimated average percent decrease in dry sulphur deposition was around 1% for the two scenarios (1.04% and 1.01% for MGO Mix and ULSFO Mix, respectively). The maximum percent reduction in wet sulphur deposition (Figure 2 right panel) was 13.45% for MGO Mix scenario, followed by 11.97% for the ULSFO Mix scenario. For all the NE Atlantic ECA domain, the estimated average percent decrease in wet sulphur deposition was around 0.7% (0.71% and 0.65% for MGO Mix and ULSFO Mix, respectively).

5.5.2. Deposition of nitrogen

Like sulphur, nitrogen is also deposited in ecosystems through dry and wet deposition. In terms of ecological impacts, nitrogen deposition plays a different role compared to sulphur. While sulphur deposition primarily causes acidification, nitrogen deposition can also lead to nutrient over-enrichment in ecosystems. In many ecosystems, excessive nitrogen deposition can lead to nutrient imbalances, promoting the overgrowth of certain plant species while suppressing others, which disrupts biodiversity (Chen et al., 2019; Reich, 2009). In aquatic environments, this nutrient enrichment often results in eutrophication, leading to algal blooms, oxygen depletion, and the degradation of water quality (Liu et al., 2017). Furthermore, nitrogen deposition also contributes to the acidification of soils and water bodies (Shammas et al., 2019). To understand the impacts of the implementation of the NE Atlantic ECA regarding Tier III standards on the deposition of nitrogen, the differences between the 2030 BAU scenario and the NE Atlantic ECA compliance scenarios – MGO Mix and ULSFO Mix were calculated. Tier III compliance was uniformly accounted for across all scenarios. As the reductions were the same for the different scenarios, only the results for the difference between the 2030 BAU scenario and the MGO Mix scenario are shown as examples. Figure 18 shows the differences in the annual dry and wet deposition of oxidized nitrogen for NE Atlantic ECA.



a) b)

Figure 18: Differences in percentage of the annual oxidized nitrogen dry deposition (left panel) and wet deposition (right panel) for 2030 BAU – MGO Mix

According to Figure 18, the most significant reductions in dry oxidised nitrogen deposition were found between the west coast of the United Kingdom and the east coast of Ireland, as well as in some port regions of the Iceland coastline. Contrary to what was found for the dry deposition, reductions in the wet deposition of oxidized nitrogen were found inland. Since the Tier III standards will only apply to new ships from 2027 to 2030, their impact is reduced. For wet oxidized nitrogen deposition, the largest reductions were found along the northwest coastlines of Portugal and Spain, and between the west coast of the United Kingdom and the east coast of Ireland. Reductions were also found along the coastline of Iceland and in some regions of the southern coast of Greenland. According to Figure 18 (left panel), the maximum percent reduction in dry oxidised nitrogen deposition was 5.49%. For all the NE Atlantic ECA domain, the average percent decrease in dry oxidised nitrogen deposition estimated was 0.35%. The maximum percent reduction in wet oxidized nitrogen deposition (Figure 18 right panel) was 1.66%. For all the NE Atlantic ECA domain, the average percent decrease in wet oxidised nitrogen deposition was 0.29%.

5.5.3. Deposition of PM_{10}

PM deposition poses significant environmental challenges, like nitrogen and sulphur deposition. PM deposition contributes to the development of acidifying agents, promotes eutrophication and introduces heavy metals and polycyclic aromatic hydrocarbons (PAHs) into ecosystems (Chang et al., 2022). PM deposition also occurs in dry and wet forms. Wet deposition involves the settling of PM, acidifying compounds, and toxic substances through precipitation, where they act as cloud seeds. Dry deposition occurs when airborne particles and associated pollutants settle onto terrestrial or marine environments through atmospheric processes (Chang et al., 2022; Laaksonen and Malila, 2022).

To understand the impact of the implementation of NE Atlantic ECA on the deposition of PM_{10}, the differences between the 2030 BAU scenario and the NE Atlantic ECA compliance scenarios – MGO Mix and ULSFO Mix were calculated.

Figure 19 shows the differences in PM_{10} annual dry deposition (left panel) and wet deposition (right panel) due to the implementation of NE Atlantic ECA MGO Mix (Figure 19a) and b)) and ULSFO Mix (Figure 19 c) and d)) scenarios.

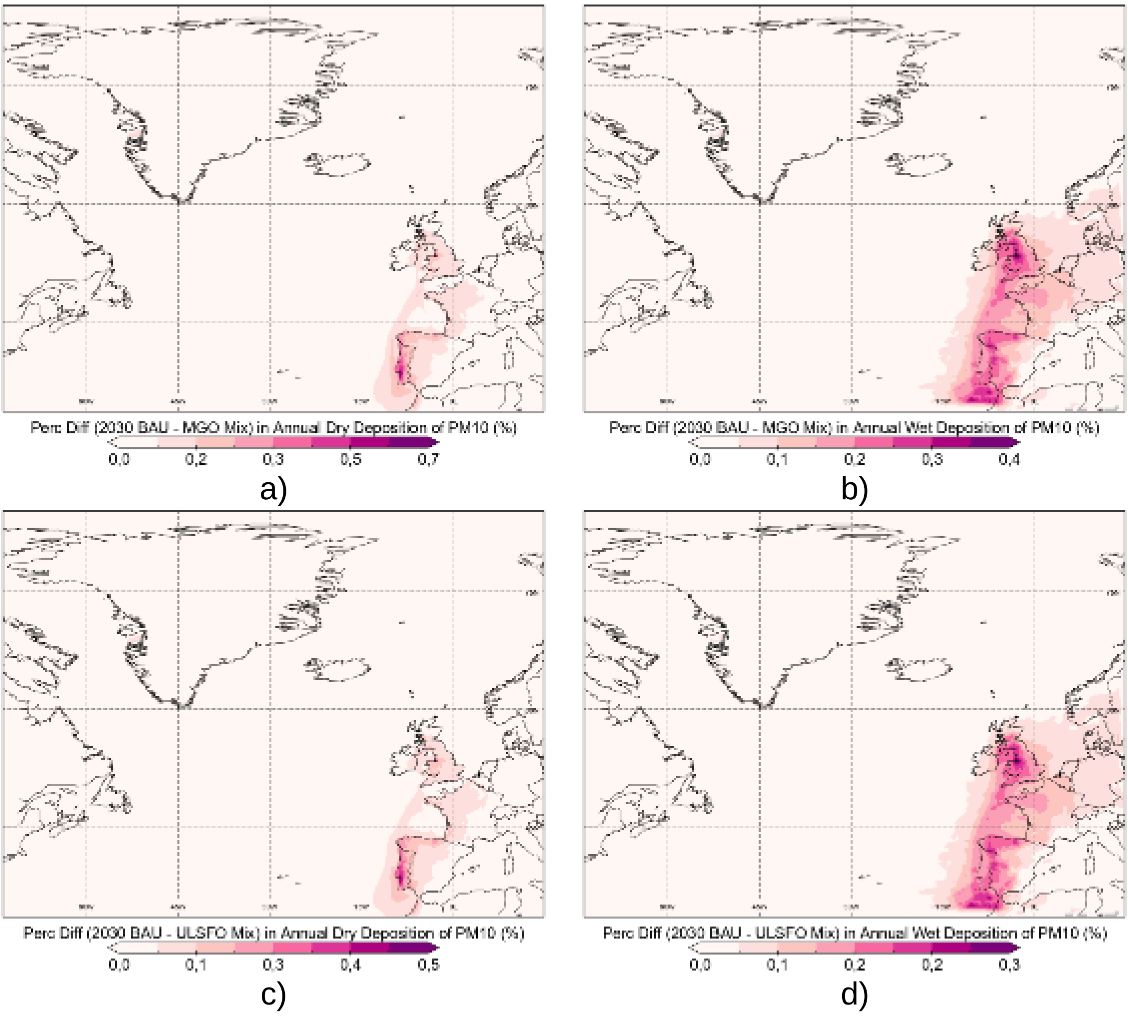
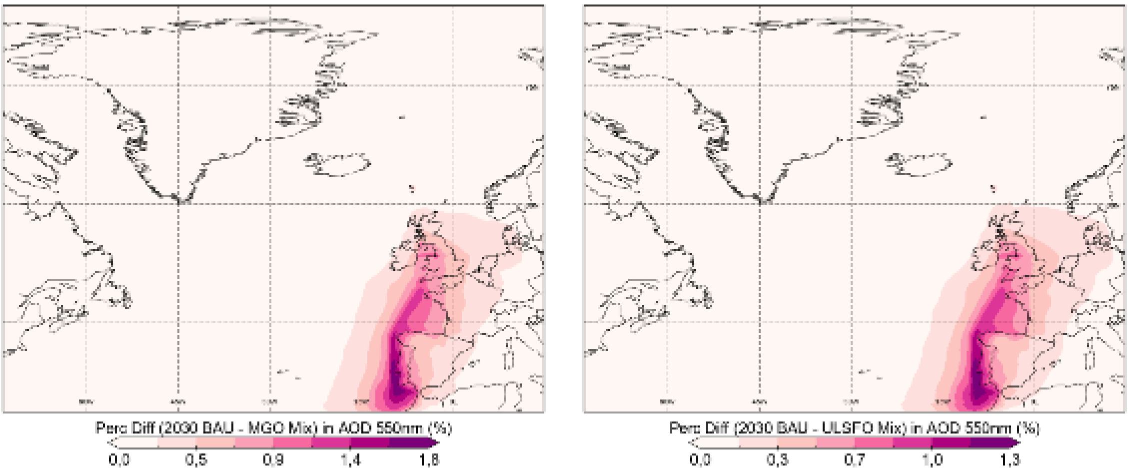


Figure 19: Differences in percentage of the annual PM_{10} dry deposition (left panel) and wet deposition (right panel) for: a) and b) 2030 BAU – MGO Mix; c) and d) 2030 BAU – ULSFO Mix

According to Figure 19 (left panel), the reduction patterns were similar between scenarios. Dry PM_{10} deposition differences showed the largest reductions inland in the south of Portugal. The largest reductions in PM_{10} wet depositions were found in the south coastline of Portugal, in the west coast of the United Kingdom and inland in the north of Spain and the United Kingdom. According to Figure 19 (left panel), the maximum percent reductions in dry PM_{10} deposition were 0.67% for the MGO mix scenario, followed by 0.53% for the ULSFO Mix scenario. The maximum percent reductions in wet PM_{10} deposition (Figure 19 right panel) were 0.38% for the MGO Mix scenario, followed by 0.32% for the ULSFO Mix scenario.

5.6. Change in visibility

To access the change in visibility due to the NE Atlantic ECA implementation, the Aerosol Optical Depth (AOD) was used. AOD is a measure of the extent to which aerosols prevent light from travelling through the atmosphere by absorbing or scattering it. AOD is dimensionless and represents the fraction of sunlight blocked by aerosols in a column of air from the Earth's surface to the top of the atmosphere. Typically, AOD can range from 0 to 5 where an AOD equal to 0 indicates a perfectly clear sky with no aerosols, an AOD equal to 1 means that about 60% of sunlight is blocked or scattered by aerosols in the atmosphere and an AOD higher than 1 indicate higher concentrations of aerosols, leading to a reduction in the sunlight reaching the surface. AOD 550 nm (wavelength of 550 nanometers) was chosen because it falls within the green portion of the visible light spectrum, where the human eye is most sensitive (NASA, 2024; Norwegian Meteorological Institute, 2015; Schulz and McConnell, 2022). This makes it a good representative wavelength for assessing how aerosols affect visibility and the clarity of the atmosphere. As for deposition, to understand the NE Atlantic ECA impact on visibility, the differences in AOD 550nm between the 2030 BAU and the NE Atlantic ECA scenarios were calculated. Figure 20 shows the differences in visibility (in percentage) due to the implementation of NE Atlantic ECA regulations, i.e. the difference between the 2030 BAU scenario and NE Atlantic ECA compliance scenarios – MGO Mix and ULSFO Mix.



a) b)

Figure 20: Percentage of AOD difference between 2030 BAU and NE Atlantic ECA a) MGO Mix and b) ULSFO Mix

According to Figure 20, decreases in AOD (increases in visibility) are expected with the implementation of NE Atlantic ECA for all the studied scenarios. The improvements in visibility associated with the proposed NE Atlantic ECA show similar orders of magnitude and patterns across the different scenarios. The largest improvements in visibility were found along the Portuguese coastline. Improvements were also found inland mainly in Portugal, Spain, France and the United Kingdom. The maximum percent increase in AOD 550 nm of 1.8% were found for the MGO Mix scenario.

5.7. Environmental areas at risk from ship emissions

5.7.1. Vulnerable ecosystems and critical habitats

Shipborne NO_x and SO_x emissions contribute to ocean acidification, which adversely affects the development of crustaceans such as decapods, isopods, and krill, leading to decreased survival rates, impaired calcification and growth, and reduced abundance of marine organisms (Hassellöv et al., 2013; Kroeker et al., 2013). Additionally, ocean acidification is shown to impact the sensory abilities of fish larvae, causing decreased response to external cues, and reducing their ability to locate habitats and avoid predators (Munday et al., 2009). NO_x emissions from shipping also contribute to the atmospheric deposition of oxidized nitrogen into the ocean, leading to increased eutrophication (Neumann et al., 2020). Overall, combined with other environmental stressors, climate and health related air pollutants cause reduced taxonomical diversity in marine ecosystems (Doney et al., 2020).

Mitigating the sources and impacts of air pollution is essential for preserving the structural and ecological integrity of vulnerable ecosystems. Results presented in previous sections demonstrated that the designation of an NE Atlantic ECA would significantly reduce levels of SO_x and NO_x emissions, thus diminishing their detrimental impacts on natural and cultural heritage, as well as vulnerable ecosystems and habitats critical for species conservation. This positive effect would be particularly strong in areas with exceptional protection status, as described below.

Particularly Sensitive Sea Areas

Particularly Sensitive Sea Areas (PSSAs) are regions that require special protection from international shipping activities due to their recognized ecological significance or for socioeconomic reasons. The IMO recognizes the rich marine biodiversity and ecological significance of specific marine regions and has adopted measures such as deep-sea routes, traffic separation schemes, vessel traffic services, areas to be avoided, and mandatory reporting schemes to protect these areas.

The proposed NE Atlantic ECA overlaps with one of the largest PSSAs, the Western European Waters Particularly Sensitive Sea Area (PSSA), designated under MEPC.121(52) in 2004. The Western European Waters PSSA includes European waters near Belgium, France, Ireland, Portugal, Spain, and the United Kingdom. Estimations show that 17% of the proposed NE Atlantic ECA area falls into the Western PSSA.

Since the adoption of the Western European Waters PSSA, international shipping traffic has increased substantially. While existing measures aim to prevent oil spills by reducing the risk of accidents and subsequent environmental disasters, they do not address air pollution from shipping, which also threatens this sensitive region. Establishing the NE Atlantic ECA could enhance protection by mitigating air pollution, thereby preserving this marine environment.

Marine Protected Areas

Marine Protected Areas (MPAs) are designated areas in marine environments where human activities are restricted to protect natural or cultural resources. The proposed NE Atlantic ECA includes 1,693 MPAs, with 44% designated at a regional level, 51% at a national level, and about 5% at an international level. Of the 1,693 MPAs, 743 are in the United Kingdom, 252 in Spain, 250 in Ireland, 203 in France, 183 in Portugal, 48 in Iceland, and 14 in Greenland (UNEP-WCMC and IUCN, 2024) (Figure 21). These MPAs cover approximately 500,000 km^2, representing about 10% of the area of the proposed NE Atlantic ECA. Additionally, the area is likely to expand, as the European Commission has pledged to increase MPA coverage in European waters from 12.1% in 2021 to 30% by 2030 (European Environment Agency, 2023). As part of the "Biodiversity Strategy for 2030", this initiative aims to reverse the degradation of ecosystems, and establishment of the NE Atlantic ECA could help to achieve this goal (European Commission, 2020).

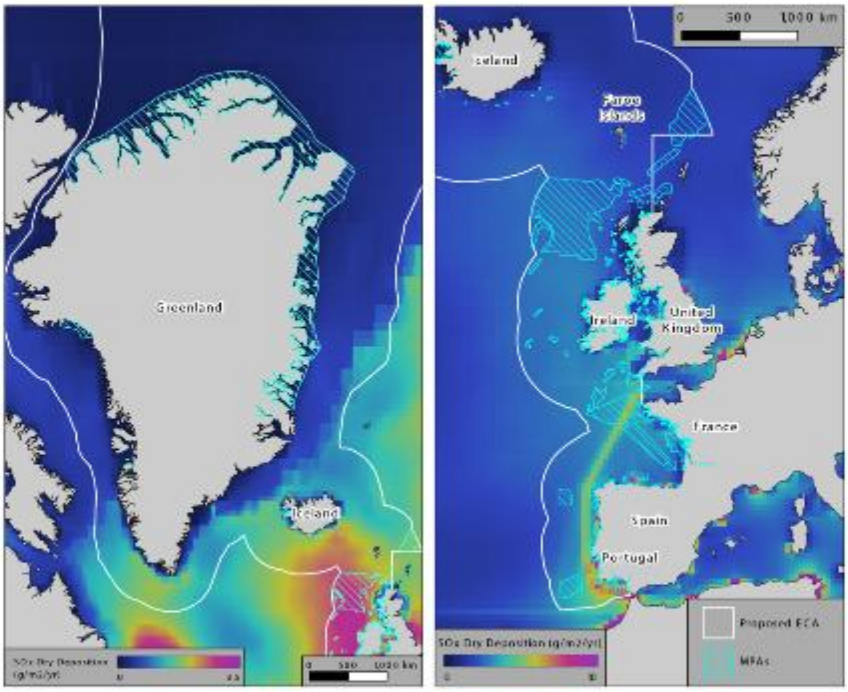


Figure 21: Marine Protected Areas identified in the proposed NE Atlantic ECA, mapped over the predicted 2030 SO_2 shipping-related deposition

Important Marine Mammal Areas

Important Marine Mammal Areas (IMMAs) are discrete habitats important to marine mammal species, identified using criteria such as population vulnerability, distribution, abundance, reproductive areas, feeding areas, migration areas, distinctiveness, and diversity (IUCN-MMPATF, 2024a).[3] IMMAs are established and agreed upon by the Marine Mammal Protected Areas Task Force, formed by the International Committee on Marine Mammal Protected Areas, the International Union for Conservation of Nature, and the Species Survival Commission.

The proposed NE Atlantic ECA includes 17 IMMAs covering 800,000 km^2 within the region, 16% of the total proposed NE Atlantic ECA area (Figure 22). Additionally, more candidate IMMAs were proposed during a regional workshop in 2024. Therefore the list of IMMAs in the North Atlantic Ocean might be partly expanded to the seas around Iceland and Greenland (IUCN-MMPATF, 2024b).

3 *Full criteria for the selection of IMMAs can be found on MMPATF's website: https://www.marinemammalhabitat.org/immas/imma-criteria/*

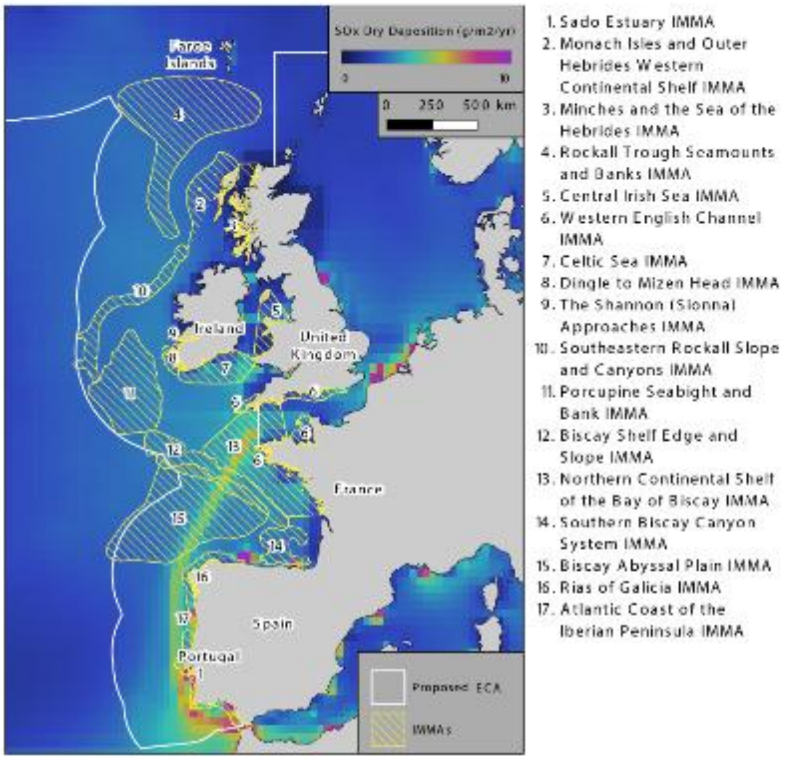


Figure 22: Important Marine Mammal Areas in the Northeast Atlantic Ocean overlaid on the proposed NE Atlantic ECA

Among these 17 IMMAs, there are two areas of great significance for marine mammal habitats (#2 and #14 in Figure 22). These areas include the highest diversity of marine mammals, including vulnerable and endangered species. For instance, an endangered blue whale, with a total population of fewer than 1,000 mature adults in the North Atlantic, was observed in at least two IMMAs (#4 and #11 in Figure 22).

While the designation of an NE Atlantic ECA in the North East Atlantic Ocean could be highly beneficial to marine mammals due to the reduction of air pollution and the potential for residual fuel spills for ships that switch to distillate fuels, the continued use of scrubbers in the ECA presents a risk to marine life. Some components found in scrubber washwater, like heavy metals and PAHs, are not biodegradable and accumulate over time in the marine food web. High PAHs concentrations have been shown to correlate with the highest rates of cancer in beluga whales and orcas, while heavy metals negatively affect marine mammals' reproductive and immune systems (Georgeff et al., 2019).

Other Sensitive and Threatened Ecosystems: Faroe Islands, Iceland, and Greenland

The Faroe Islands, Iceland, and Greenland, despite having the smallest number of MPAs among member states and no designated IMMAs, have ecologically sensitive ecosystems already impacted by human activities.

The marine ecosystem around the Faroe Islands is one of the cleanest globally (Faroese Ministry of Foreign Affairs, 2018), making it highly vulnerable to environmental changes and pollution. Fishing activities pose the primary threat to this ecosystem, with mortality rates for some fish species exceeding sustainable levels. Plankton production in this area is crucial for higher trophic levels, including marine species and seabirds (Gaard et al., 2002). The Faroe Islands are also vital breeding grounds for numerous seabirds, including vulnerable species such as the Horned Grebe (*Podiceps auratus*), and the Leach's Storm-petrel (*Hydrobates leucorhous*) (IUCN, 2024). According to the International Council for the Exploration of the Sea (ICES, 2024), the seabird population in the Faroe Islands has decreased by more than 60% since the 1950s.

Similarly, Iceland serves as a critical breeding site for a wide variety of bird species, with 121 important bird areas, the majority of which are home to seabird colonies. Overall, more than 2,500 species of marine animals have been identified within Iceland's exclusive economic zone (Government of Iceland, 2024). Iceland's trophic network of marine fishes and invertebrates is experiencing ecosystem pressures caused by ocean warming and acidification, causing planktonic and forage fish to benefit but benthic groups and predatory fish to decrease (Oostdijk et al., 2022). In Iceland, Greenland and the Faroe Islands, fishing is a nationally important activity, providing income, employment, and food security. As the steep decline of ocean pH is expected to continue, the consequences for commercially available fish remain unclear (Barange et al., 2018).

In Greenland, the ice sheet has been shown to exhibit increased melting due to anthropogenic air pollution (Vikrant et al., 2020). The rapid melting of glaciers has been a major contributor to global sea-level rise in recent decades (IMBIE, 2020). Freshwater from melting ice alters the marine ecosystem by affecting water salinity and reducing ocean water mixing, which affects nutrient distribution and phytoplankton growth. Additionally, sediment from the ice sheet decreases water transparency, limiting light for photosynthesizing organisms. These disturbances are transforming Greenland's marine ecosystems, altering the distribution of marine species, and disrupting ecological balance (World Wildlife Fund, 2023).

5.7.2. Areas of cultural and scientific significance

The North Atlantic region hosts numerous UNESCO World Cultural and Natural Heritage sites, recognized for their "outstanding universal value" and considered part of the common heritage of humankind (UNESCO World Heritage, 2024). Of the 1,199 registered UNESCO World Heritage Sites listed in 2023, 148 (12.3%) are located within the proposed NE Atlantic ECA member states: 46 in Spain, 45 in France, 31 in the United Kingdom, 16 in Portugal, 3 in Greenland, 3 in Iceland, 2 in Ireland, 1 shared between Spain and Portugal, and 1 between Spain and France (UNESCO/WHC, 2023). The region also encompasses several scientifically important natural world heritage sites: the St. Kilda volcanic archipelago in Scotland is one of 43 dual (cultural and natural) world heritage sites, serving as a unique wildlife sanctuary for more than a million birds during their breeding season; the fast-moving glacier Ilulissat Icefjord in Greenland has helped scientists understand climate change and glaciology for the past 250 years; and the Surtsey Volcanic Island in Iceland, which formed after a series of volcanic eruptions between 1963 and 1967, is studied to learn how newly formed land becomes colonized by flora and fauna. These sites function as natural laboratories, providing unique opportunities for scientific research.

These sites may be at risk of degradation due to air pollution, including emissions from ships. The effects of air pollution on stone and buildings have long been studied, with SO_2 particularly linked to increased crust formation on stone structures, accelerating their rate of degradation (Graue et al., 2013; Reyes et al., 2011). Acid rain, resulting from pollutants such as SO_2 and NO_2, has also been extensively documented (Grennfelt et al., 2020). Acidification affects the chemical reactions in stone formations, generating defects and weakening structures, thereby posing a risk to UNESCO World Heritage Sites (Hou et al., 2023). Air pollution has also been shown to negatively affect natural heritage sites, such as the Ilulissat Icefjord (Vikrant et al., 2020). Similarly, anthropogenic air pollution could disrupt the pristine conditions at Surtsey Volcanic Island, potentially influencing the colonization processes of flora and fauna on this newly formed landmass. Therefore, imposing stricter regulations on shipping emissions within the NE Atlantic ECA could help preserve UNESCO areas of cultural and scientific significance.

5.8. Health benefits of reducing shipping emissions in the NE Atlantic ECA

This section provides an analysis of the impact of shipping-related ambient air quality in the NE Atlantic ECA region on human health. Ambient air quality maps, with and without the implementation of ECA, were used to evaluate the health consequences of exposure to shipping emissions. The health burden associated with ship-borne $PM_{2.5}$ and ozone emissions were modelled, and outcomes were compared across various scenarios. Finally, the health benefits of reducing these emissions were quantified, including the number of preventable deaths and the corresponding monetized health benefits under different compliance scenarios.

5.8.1. Number of avoidable premature deaths

The health impact associated with exposure to shipping emissions in the NE Atlantic ECA region has been evaluated using the Fast Assessment of Transportation Emissions (FATE) model (ICCT, 2023). FATE model applies health impact assessment methods from the 2019 Global Burden of Disease (GBD 2019) (Murray et al., 2020). The population data have been combined with the gridded air quality outputs for each scenario to calculate the changes in national-average pollutant exposures for each compliance scenario compared to the 2030 BAU scenario. The health burden has been quantified by assessing population exposure to $PM_{2.5}$ from both primary sources and secondary formation and ozone.

For $PM_{2.5}$, the health burden was modelled for ischemic heart disease, stroke, chronic obstructive pulmonary disease (COPD), lower respiratory infections, type 2 diabetes, and lung cancer. The population-attributable fraction ($PAF_{a,h,I}$) for $PM_{2.5}$ has been estimated using relative risk look-up tables based on the GBD 2019 and gridded $PM_{2.5}$ concentrations to relative risk values ($RR_{a,h,I}$) for each age group (*a*), mortality cause (*h*), and grid cell (*I*) using the following equation:

$$PAF_{a,h,I} = \frac{\left(RR_{a,h,I} - 1\right)}{\left(RR_{a,h,I}\right)}$$

Then, $PAF_{a,h,I}$ values are used to estimate premature deaths (y_I):

$$y_I = m_{a,h,c} \times pop_{a,I} \times PAF_{a,h,I}$$

where y_I is the number of premature deaths, $m_{a,h,c}$ is the country-specific (c) baseline mortality rates for each age group (a), mortality cause (h) and $pop_{a,I}$ is the age-stratified population size.

Baseline mortality rates and gridded population data for 2020 at 0.01° x 0.01° resolution were used from the GBD 2019 and WorldPop databases (Tatem, 2017). Age stratification was applied from GPWv4 data at the 0.25° x 0.25° resolution for ages 25 and older (Center for International Earth Science Information Network, 2010).

The calculations of years of life lost from premature deaths were calculated using the following equation:

$$YLL = y_I \times \frac{(YLL_0)_{a,h,c}}{m_{a,h,c}}$$

where YLL is years of life lost, y_I is the incidence of the death within a population, $(YLL_0)_{a,h,c}$ is baseline YLL (GBD 2019) and $m_{a,h,c}$ is baseline disease rates.

For calculating the PAF associated with COPD from ozone exposure, a log-linear model was applied, independent of age, following Jerrett et al. (2009) methodology:

$$RR_I = e^{\left(\beta(x_I - x_{cf})\right)}$$

where β is the concentration-response factor derived from a 1.06 increase in relative risk per 10 ppb taken from the GBD 2019, x_I is the ozone concentration per a grid cell, x_{cf} is the counterfactual concentration (32.4 ppbv; GBD 2019).

The long-term health benefits of implementing the NE Atlantic ECA were estimated by extrapolating the number of avoidable deaths from 2030 to 2050 under compliance scenarios, using a conservative approach that assumed constant absolute reductions in pollutant exposure from 2030 through 2050. Population growth projections between 2021 and 2030, and between 2030 and 2050 considered expected age-specific changes in demographic trends and disease rates and are based on the data published by the United Nations (2022), the Statistics Faroe Islands (2022), and Statistics Greenland (2023). Although some populations are expected to decline in the designated member states, the calculation of avoidable deaths accounts for changes in population structure by age group. Since these diseases primarily affect older adults, and the population in this region is projected to age, the estimated number of avoidable deaths reflects both demographic shifts and changes in baseline disease rates (Murray et al., 2020).

The total estimated avoidable premature deaths per scenario for 2030 and approximate cumulative avoidable deaths for 2030–2050 are shown in Table 5, while avoidable premature deaths by cause and pollutant are shown in Table 6. The use of ULSFO (ULSFO Mix scenario) provides the lowest health benefits due to its higher sulphur content and higher primary $PM_{2.5}$ emissions compared to the use of MGO. It is projected to prevent 118 deaths in 2030 and approximately 2,900 deaths cumulatively between 2030 and 2050. In contrast, using MGO for compliance (MGO Mix scenario) provides greater benefits, with the potential to prevent 176 deaths in 2030 and 4,300 deaths cumulatively between 2030 and 2050. This shows that the benefits of the ECA are estimated to be approximately 50% greater if ships use MGO to comply instead of ULSFO.

Table 5. Health benefits summarised per scenario evaluated for the proposed NE Atlantic ECA.

Scenarios	Avoided premature deaths and related economic benefits			
	2030		2030–2050 cumulative	
	Avoided premature deaths	Economic benefits (€ Billion)	Avoided premature deaths	Economic benefits (€ Billion)
MGO Mix	176 (95% CI= 9; 290)	1.23 (95% CI= 0.6; 2.02)	4,300 (95% CI= 2,100; 7,500)	29.11 (95% CI= 14.08; 50.99)
ULSFO Mix	118 (95% CI= 61; 195)	0.82 (95% CI= 0.4; 1.35)	2,900 (95% CI= 1,400; 5,000)	19.37 (95% CI= 9.35; 33.96)

Table 6. Avoidable premature deaths in 2030 and cumulative (2030-2050) avoidable premature deaths by cause and pollutant.

		Number of avoidable premature deaths			
		2030		2030-2050 cumulative	
Cause	**Pollutant**	**MGO Mix**	**ULSFO Mix**	**MGO Mix**	**ULSFO Mix**
COPD	O_3	1	2	30	60
	$PM_{2.5}$	31	20	880	600
Diabetes 2	$PM_{2.5}$	11	8	300	200
IHD	$PM_{2.5}$	47	31	970	640
LRI	$PM_{2.5}$	23	15	740	490
Lung Cancer	$PM_{2.5}$	31	21	760	500
Stroke	$PM_{2.5}$	32	21	660	430
Total		**176**	**118**	**4,300**	**2,900**

Note: Numbers greater than one thousand are rounded to the nearest hundred; others are rounded to the nearest integer.

The estimated health benefits of the NE Atlantic ECA vary greatly among member states due to differences in the proximity of shipping emissions to populated areas and demographic factors such as population size and age distribution. In absolute terms, the United Kingdom accounts for nearly half of the total avoidable premature deaths in 2030 across all scenarios, followed by Spain and Portugal. However, the United Kingdom is projected to account for 36% of the total population in the study area by 2030. When the number of avoidable premature deaths is normalized per population size (i.e., number of avoided deaths per 100,000 inhabitants), other member states also show substantial health benefits. Thus, when adjusted for population size, the United Kingdom ranks third in avoided premature deaths, following the Faroe Islands and Portugal. Specifically, the Faroe Islands show 0.22-0.43 avoided premature deaths per 100,000 inhabitants, Portugal shows 0.25-0.39, and the United Kingdom shows 0.11–0.17 (Figure 23).

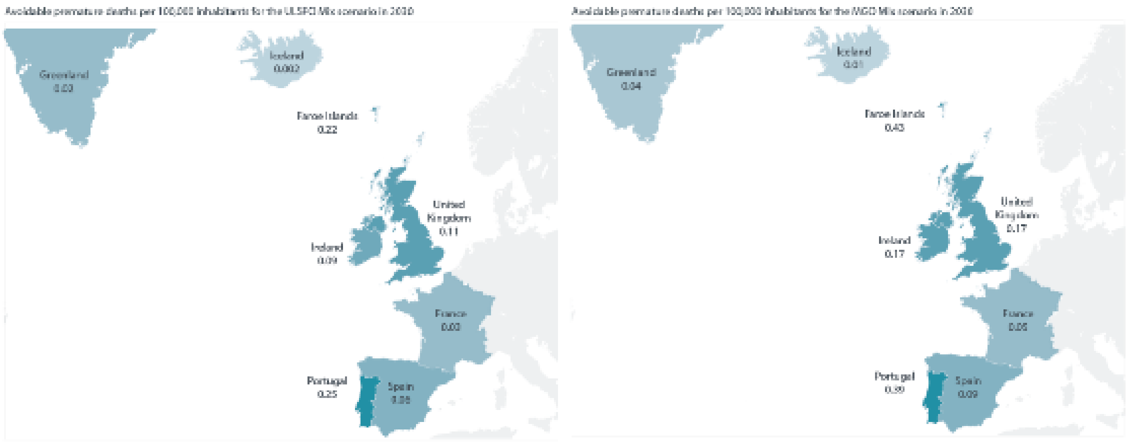


Figure 23: Estimated avoidable premature deaths per 100,000 inhabitants in 2030 under the ULSFO Mix (left) and MGO Mix (right) NE Atlantic ECA compliance scenarios

5.8.2. Health-related economic benefits

The monetized benefits associated with avoidable premature deaths have been estimated based on the value of statistical life (VSL), using the methodology for calculating VSL and related economic impacts aligned with Narain and Sall (2016). By applying the VSL in cost-benefit analyses, policymakers estimate the total economic value of interventions that reduce mortality risks from air pollution (OECD, 2016). The reduction in deaths due to improved air quality can be multiplied by the VSL to assess whether the benefits of pollution control measures outweigh the costs.

The FATE model, developed by the ICCT, takes into consideration the influence of a nation's wealth on its ability to allocate resources for reducing the risk of premature death and considers projected growth in per-capita income over time (ICCT, 2023). The methodology for calculating the VSL is described in Narain and Sall (2016), referred to as the "World Bank" method, and the Gross Domestic Product per capita for each country is updated according to the International Monetary Fund. The economic benefits were adjusted to 2021 Euro values using a consumer price index inflation calculator from the Bureau of Labor Statistics (2024). According to their estimate, $1 in June 2020 had the same purchasing power as $1.05 in June 2021. This amount was then converted to Euros using the 2021 exchange rate from the European Central Bank (2024) (€1 = $1.19). VSL values were multiplied by the number of premature deaths generated by FATE's health impacts module for each scenario to estimate the associated welfare loss from premature death for each country, age category, and cause.

To project cumulative economic benefits based on the VSL between 2030 and 2050, the number of avoidable deaths and the economic value of these health benefits from 2030-2050 under both compliance scenarios were extrapolated. For the 2050 health impact forecast, a conservative approach was used and held the absolute reductions in pollutant exposure in 2030 constant through 2050. No adjustments were made for potential future fluctuations in gross domestic product (GDP), given the substantial uncertainty associated with such projections. This approach maintains conservative estimates and reduces the likelihood of overestimating potential benefits.

The monetized health benefits from establishing the NE Atlantic ECA are estimated to be €0.82–€1.23 billion in 2030 (in 2021 Euro values), depending on the compliance scenario. Between 2030 and 2050, the approximate cumulative monetized health benefits could reach €19.4–€29.1 billion (in 2021 Euro values) (Table 5). The variation in monetized health benefits across scenarios follows the variation in estimated avoidable premature deaths, showing the highest benefits for the MGO Mix scenario, and the lowest for the USLFO Mix scenario. In absolute terms, the United Kingdom has the highest estimated value of health benefits in 2030 (€446–€667 million), followed by Spain (€126–€179 million) and Portugal (€107–€165 million) (Table 7) Between 2030 and 2050, the approximate cumulative benefits for these three countries are estimated to be between €9.3–€13.9 billion for the United Kingdom, €3.7–€5.2 billion for Spain, and €3.0–€4.6 billion for Portugal (in 2021 Euro values) (Table 7).

Table 7. Estimated value of health benefits (€ million) in 2030 and cumulative benefits from 2030 to 2050 due to avoidable premature deaths by IMO member state and associate member.

Health benefits value in 2030 (€ million)			Cumulative health benefits value 2030 - 2050 (€ million)	
	MGO Mix	**ULSFO Mix**	**ULSFO Mix**	**MGO Mix**
Faroe Islands	1.4	0.7	13	26
France	146	101	2,500	3,500
Denmark (Greenland)	0.1	0.1	1	2
Iceland	0.2	0	1	5
Ireland	72	37	943	1,900
Portugal	165	107	3,000	4,600
Spain	179	126	3,700	5,200
United Kingdom	667	446	9,300	13,900
Total:	**1,230**	**818**	**19,400**	**29,100**

Note: Numbers greater than one thousand are rounded to the nearest hundred; others are rounded to the nearest integer.

6. Control measures addressing land-based sources

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*This section presents information addressing **criterion 3.1.7 of Appendix III to MARPOL Annex VI**, as cited: "The proposal shall include a description of the control measures taken by the proposing Party or Parties addressing land-based sources of NO_x, SO_x and particulate matter emissions affecting the human populations and environmental areas at risk that are in place and operating concurrently with the consideration of measures to be adopted in relation to provisions of regulations 13 and 14 of Annex VI".*

Section Summary

This section provides systematic evaluation of the land-based regulatory measures implemented by NE Atlantic ECA member states to mitigate emissions of SO_x, NO_x, and $PM_{2.5}$. Sub-section 6.1 provides a comprehensive analysis of these measures, assessing the effectiveness of policy interventions through a data-driven evaluation of their impact on SO_x, NO_x, and $PM_{2.5}$ emissions. Sub-section 6.2 presents a land-based emissions inventory and analyses the temporal trends in emissions by member state. Sub-section 6.3 provides a summary of measures addressing land-based sources.

6.1. Existing land-based measures for the control of SO_x, NO_x, and $PM_{2.5}$ emissions

European Union and European Economic Area: Portugal, Spain, France, Ireland, and Iceland

The European Union (EU) regulates air quality and emission limits from land-based sources through the Ambient Air Quality Directive (AAQD) (European Legislation, 2008) and by establishing member-state level reduction commitments for air pollution via the National Emission Ceilings Directive (EU NECD) (European Legislation, 2016). Additionally, the EU has enacted several sector-specific emission standards, including the Industrial Emission Directive (European Legislation, 2010) and regulations for the transportation sector (European Legislation, 2022). National air pollution legislation in France, Ireland, Portugal, and Spain is harmonized with these EU legal provisions. Iceland, as a member of the European Economic Area, is also a signatory to the EU policymaking framework for main directives, ensuring alignment with its national regulations (European Free Trade Agreement, 2023; Iceland Environment Agency, 2020).

The Ambient Air Quality Directive (AAQD)

The AAQD sets the EU air quality standards for 12 air pollutants, including SO_2, NO_2, and $PM_{2.5}$ (European Legislation, 2008). The AAQD requires the EU and European Economic Area member states, to monitor, assess, and manage ambient air quality levels, ensuring that the pollutant concentration won't exceed the set threshold (Table 8). In 2023, the European Parliament adopted new amendments to the AAQD. The amendments set intermediatory 2030 targets and improved 2035 air quality standards to be more closely aligned with World Health Organization (WHO) guidelines (Table 8) (European Parliament, 2023; WHO, 2021).

Based on the mean ambient air quality levels recorded in 2021, France, Iceland, Ireland, Portugal, and Spain did not exceed the AAQD air quality annual limits for SO_2, NO_2, and $PM_{2.5}$. However, except for Iceland, Denmark (Greenland), and the Faroe Islands, none of the member states and associate members met the WHO air quality thresholds. Figure 24 shows the 2021 ambient air concentrations of sulphur dioxide (SO_2), nitrogen dioxide (NO_2), and $PM_{2.5}$ from land-based sources in NE Atlantic ECA member states, plotted against EU-AAQD limits, UK AQSR standards, and WHO global guidelines.

Table 8. EU Ambient Air Quality Directive and World Health Organization's air quality thresholds for SO_2, NO_2 and $PM_{2.5}$.

Pollutant	Period	Concentration thresholds	
		European Union	World Health Organization
SO_2	1 hour	By 2030 – 350 µg/m^3 By 2035 – 200 µg/m^3	500 µg/m^3 (10 min.)
	24 hours	By 2030 – 50 µg/m^3 By 2035 – 40 µg/m^3	40 µg/m^3
	Annual	By 2030 – 20 µg/m^3 By 2035 – 20 µg/m^3	–
NO_2	1 hour	By 2030 – 200 µg/m^3 By 2035 – 200 µg/m^3	200 µg/m^3
	24 hours	By 2030 – 50 µg/m^3 By 2035 – 25 µg/m^3	25 µg/m^3
	Annual	By 2030 – 20 µg/m^3 By 2035 – 10 µg/m^3	10 µg/m^3
$PM_{2.5}$	24 hours	By 2030 – 25 µg/m^3 By 2035 – 15 µg/m^3	15 µg/m^3
	Annual	By 2030 – 10 µg/m^3 By 2035 – 5 µg/m^3	5 µg/m^3

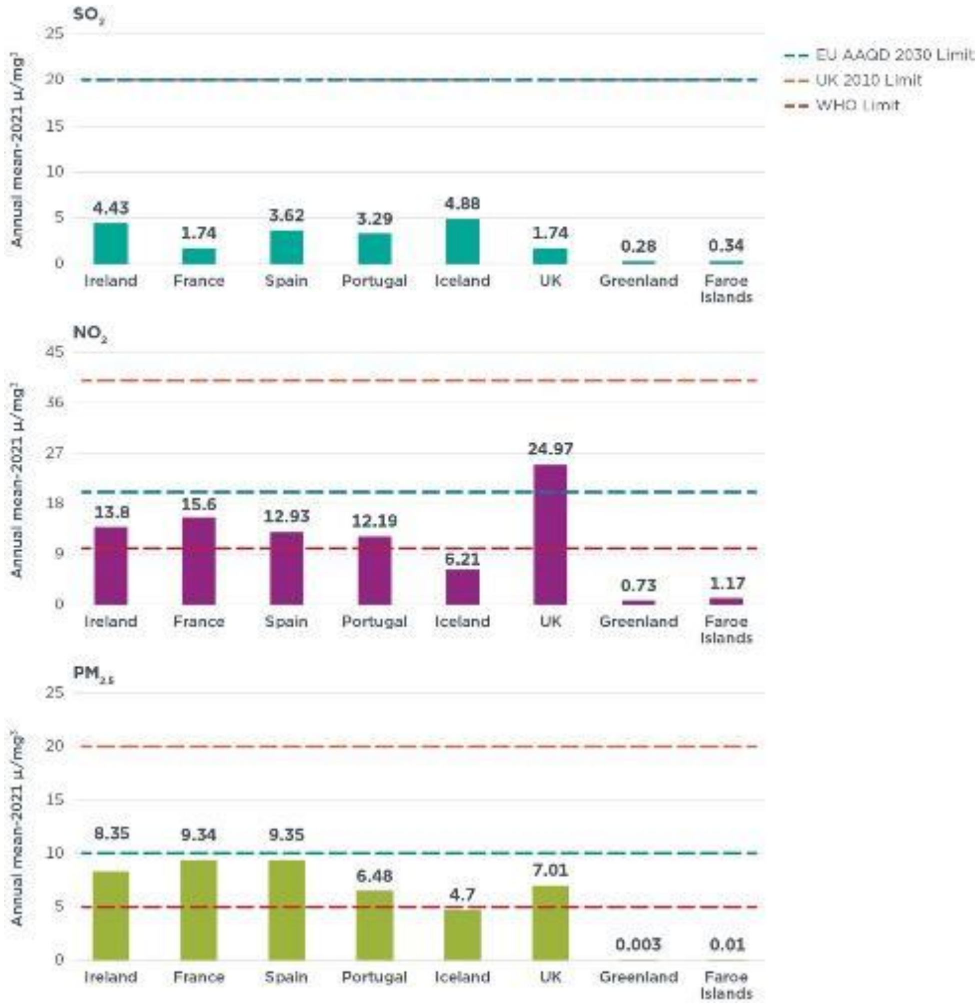

Figure 24: Mean ambient air concentrations of SO_2, NO_2, and $PM_{2.5}$ in NE Atlantic ECA member states in 2021 compared with EU Ambient Air Quality Directive 2030 limits, UK 2010 limits, and WHO guidelines. Note: Concentrations for Greenland and the Faroe Islands are shown for informational purposes

National Emission Ceilings Directive

The EU National Emission Ceilings Directive (EU NECD) sets 2020–2029 Member State emission levels and beyond-2030 reduction targets for five air pollutants, including SO_2, NO_x, and $PM_{2.5}$ (European Legislation, 2016). Under the EU NECD, each EU Member State must monitor and report their emissions levels compliance. The directive requires each Member State to adopt and implement the National Air Pollution Control Program, including policies and measures for meeting individual emission reduction commitments. France, Ireland, Portugal, and Spain currently comply with their set 2020–2029 reduction targets for SO_2, NO_x, and $PM_{2.5}$, while for targets beyond-2030, NO_x and $PM_{2.5}$ emissions are projected to exceed the post-2030 targets (Table 9).

Iceland, being an European Economic Area member, implemented the initial emission reduction directive (2001/81/EC) in 2009. However, the revised EU NECD (2016/2284) is yet to be implemented within the European Economic Area agreement, after new national targets revisions (Iceland Environment Agency, 2023).

Table 9. 2021 reduction levels compared to the 2005 baseline year for SO_2, NO_x, and $PM_{2.5}$ emissions for France, Ireland, Portugal, and Spain.

	Reduction Levels	France	Ireland	Portugal	Spain
SO_2 reduction compared with 2005	Target 2020–2029	55%	65%	63%	67%
	Target Beyond 2030	77%	85%	83%	88%
	Actual levels 2021	**81%**	**84%**	**84%**	**90%**
NO_x reduction compared with 2005	Target 2020–2029	50%	49%	36%	41%
	Target Beyond-2030	69%	69%	63%	62%
	Actual levels 2021	**62%**	**65%**	**56%**	**59%**
$PM_{2.5}$ reduction compared with 2005	Target 2020–2029	27%	18%	15%	15%
	Target Beyond 2030	57%	41%	53%	50%
	Actual levels 2021	**44%**	**34%**	**21%**	**19%**

Note: Green shading indicates that the targets were met in 2021, while orange shading indicates the limits were exceeded.

Key sector-specific EU emission standards

The Industrial Emissions Directive (IED – 2010/75/EU) recognizes large combustion plants as the single largest source of air pollution in the EU and imposes strict emission limits for SO_2, NO_X, and dust emissions (European Legislation, 2010). In 2015, the EU IED for large combustion plants was complemented by Directive (2015/2193/EU) covering emissions also from medium combustion plants (European Legislation, 2015).

In addition to the industrial sector, the road transport segment has also been recognized as a major contributor to air pollution in the EU (European Commission, 2022). The Euro 7 emission regulations (2022/3065/EU) adopted in 2024 set the specific emission limits for NO_x and PM emissions for road vehicles in the EU and the European Economic Area (European Legislation, 2024). The Euro 7 regulations will come into effect for new light-duty vehicles on July 1, 2025, and for new heavy-duty vehicles on July 1, 2027.

The United Kingdom

The United Kingdom has a national legislative framework generally aligned with EU air pollution regulations. The United Kingdom Air Quality Standards Regulations (UK AQSR) set the allowed emissions thresholds for SO_2, NO_2, and $PM_{2.5}$, and it is fully harmonized with the EU AAQD (2008/50/EC) (UK Government, 2010). However, the United Kingdom AQSR did not adopt the EU AAQD amendments passed by the EU Parliament (European Parliament, 2023). Therefore, the United Kingdom meets the SO_2, NO_2, and $PM_{2.5}$ UK AQSR emissions thresholds, but it does not meet the updated EU AAQD threshold for NO_2 emissions.

Similarly, the UK's National Emissions Ceilings Regulations (UK NECR) were adopted from the EU NECD in 2018, setting local goals for SO_2, NO_x, and $PM_{2.5}$ emissions reduction (Government, 2018). Additionally, the United Kingdom applies the EU laws of the Industrial Emissions Directive (2010/75/EU) and the Medium Combustion Plants Directive (2015/2193/EU) (UK Government, 2022). For the road transport sector, all vehicles registered in the United Kingdom must meet the EU standards (UK Government, 2021).

Table 10. UK Air Quality Standard Regulations and World Health Organization air quality thresholds for SO_2, NO_2, and $PM_{2.5}$.

Pollutant	**Period**	**Concentration threshold**	
		United Kingdom	**World Health Organization**
SO_2	1 hour	350 µg/m^3	500 µg/m^3 (10 min.)
	24 hours	125 µg/m^3	40 µg/m^3
	Annual	20 µg/m^3	–
NO_2	1 hour	200 µg/m^3	200 µg/m3
	Annual	40 µg/m^3	10 µg/m3
$PM_{2.5}$	Annual	20 µg/m^3	5 µg/m^3

The United Kingdom successfully met its 2020–2029 reduction targets for SO_2 and NO_x but not the $PM_{2.5}$ reduction commitment (

Table **11**). Moreover, between 1990–2021, SO_2 and NO_x emissions in the transport and non-transport sectors significantly declined in the United Kingdom (Figure 30). However, $PM_{2.5}$ emissions have plateaued since the mid-2000s. Further policy improvements would help the United Kingdom to meet the beyond-2030 thresholds for this pollutant (Ingledew et al., 2023).

Table 11. The 2021 reduction levels compared to the 2005 baseline year for SO_2, NO_X, and $PM_{2.5}$ emissions for the United Kingdom and NECD 2020–2029 and beyond-2030 targets.

Scenario	Reduction levels	United Kingdom
SO_2 reduction compared with 2005	Target 2020–2029	59%
	Target beyond 2030	88%
	Actual levels 2021	**84%**
NO_X reduction compared with 2005	Target 2020–2029	55%
	Target beyond 2030	73%
	Actual levels 2021	**62%**
$PM_{2.5}$ reduction compared with 2005	Target 2020–2029	30%
	Target beyond 2030	46%
	Actual levels 2021	**28%**

Note: Green shading indicates that the targets were met in 2021, while orange shading indicates that the limits were exceeded.

Greenland

Greenland does not have obligations to comply with EU directives. Instead, it implements an independent regional environmental legislation policy (Danish Parliament, 2021; The Prime Minister's Office, 2024). Currently, land-based air pollution control in Greenland is regulated by the Environmental Protection Act, which addresses pollution from main industrial activities (Greenland Government, 2011), and the Mineral Resource Act, which sets air emission limits for the exploration and exploitation of mineral resources (IEA, 2023).

The Environmental Protection Act does not set any nationwide emissions limits; instead, it authorizes local governments to limit sector-specific pollution through specific air quality guidelines. In contrast, the Mineral Resource Act grants mineral exploitation licenses that require Environmental Impact Assessments, which set emissions threshold values based on its own air quality criteria for mining in Greenland (Greenland Government, 2009; IEA, 2023) (Table 12).

The 2021 data show that Greenland's annual mean ambient air concentrations are significantly lower than those of the EU and European Economic Area member states. Additionally, SO_2 emissions in Greenland have been decreasing over time, but at a slower and less steep rate than the emissions in other NE Atlantic ECA member states, while NO_x emissions have increased (Figure 31).

Table 12. Greenland's SO_2, NO_2 and $PM_{2.5}$ criteria for the mining sector compared with EU AAQD 2030 and WHO air quality thresholds.

Pollutant	Period	Concentration Threshold		
		Greenland (Mining)	EU AAQD 2030	WHO
SO_2	**24 hours**	125 µg/m³	50 µg/m³	40 µg/m³
NO_2	**24 hours**	100 µg/m³	50 µg/m³	25 µg/m³
$PM_{2.5}$	**24 hours**	30 µg/m³	25 µg/m³	15 µg /m³

The Faroe Islands

Like Greenland, the Faroe Islands do not apply EU directives but instead enforce regional environmental legislation (Danish Parliament, 2021; Government of The Faroe Islands, 2024). The Faroe Islands Environmental Protection Act was legislated in 1988 and last amended in 2021. It requires an environmental impact assessment plan for heavily polluting industries, including an air pollution assessment (Government of The Faroe Islands, 2021). The sectors covered include mining, metal production (iron and steel) manufacturing, energy and power plants, chemical and fertilizer plants, waste incineration, agriculture, and transportation. Like Greenland's Environmental Protection Act, the Environmental Protection Act of the Faroe Islands does not establish specific nationwide limits but allows the Ministry of Environment to set sector-specific regulations for limiting and preventing air pollution. The Act emphasizes the importance of utilizing best practices for pollution prevention. Also, like Greenland, the Faroe Islands have annual mean air concentrations significantly below the EU and WHO-recommended emissions thresholds.

6.2. Assessment of time-based trends in SO_x, NO_x, and $PM_{2.5}$ emissions from land sources

This sub-section includes an inventory of land-based emissions based on air quality levels for the year 2021 across the NE Atlantic ECA member states and an analysis of temporal land-based emissions trends for transport and non-transport sectors. The data were analyzed for each member state using the European Environment Agency (EEA, 2023b), United Kingdom Government (UK Government, 2024), and European Environment Information and Observation Network (CDR, 2023) databases.[4]

France

France experienced a 92% drop in non-transport-related SO_2 emissions between 1990 and 2021, attributed to a reduction in the sulphur content of fossil fuels and a shift towards renewable sources in major industrial sectors. The improved performance of residential heating appliances also contributed to a 45% reduction in $PM_{2.5}$ emissions between 2000 and 2021. Between 1990 and 2021, transport-based NO_x emissions decreased by 73% due to Euro standards, which led to the gradual introduction of catalytic purification devices on road vehicles (EEA, 2023b, 2023c).

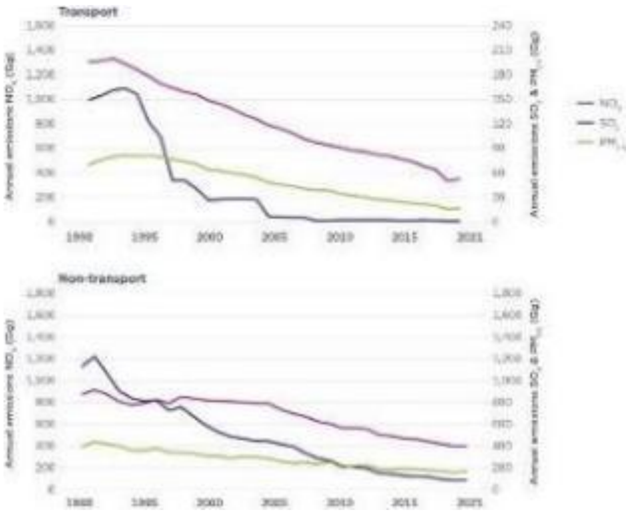

Figure 25: Transport and non-transport SO_2, NO_x, and $PM_{2.5}$ emissions in France. Source: (EEA, 2023b)

4 *The Faroe Islands are not included in the emissions inventory due to the unavailability of relevant data.*

Iceland

In Iceland, non-transport-related SO_2 emissions increased by 165% from 1990–2021, primarily due to expanded electricity generation from geothermal power plants and the growth of aluminium production facilities. $PM_{2.5}$ emissions fell by 40% from 2000–2021, largely due to decreased road construction activities, the elimination of open waste burning, and the reduction of emissions from heat plants. Transport-based NO_x emissions decreased by 32% between 1990 and 2021, mostly attributed to the implementation of Euro standards in the road transport sector (EEA, 2023b; Iceland Environment Agency, 2023).

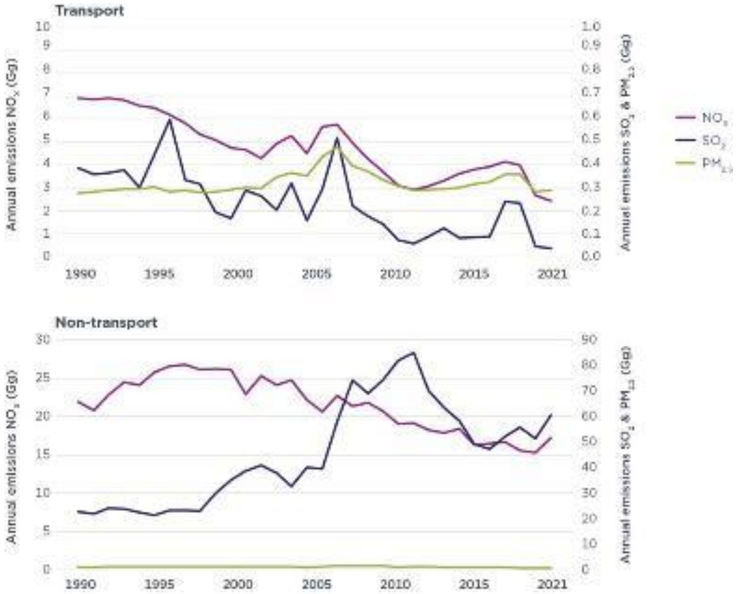

Figure 26: Transport and non-transport SO_2, NO_x, and $PM_{2.5}$ emissions in Iceland. Source: (EEA, 2023b)

Ireland

In Ireland, non-transport-related SO_2 emissions declined by 93% between 1990 and 2021 due to reduced consumption of coal, oil, and peat for electricity and heat production. Additionally, the switch from coal and peat to natural gas in the residential and commercial sectors played a major role in the reduction of $PM_{2.5}$ emissions, which decreased by 28% between 2000 and 2021. Transport-based NO_x emission trends show that the positive impact of implementing Euro standards became noticeable only in the mid-2000s. Overall, NO_x emissions dropped by 44% in 2021 compared to 1990 (EEA, 2023b; EPA, 2023).

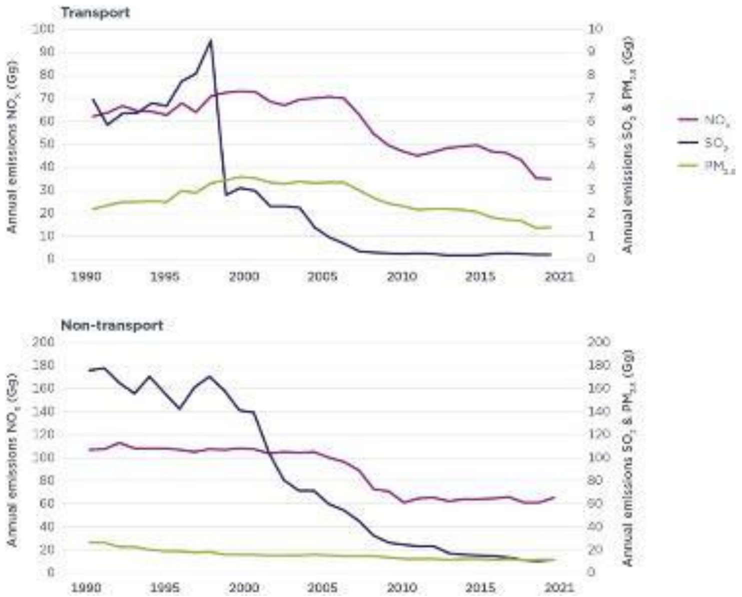

Figure 27: Transport and non-transport SO_2, NO_x, and $PM_{2.5}$ emissions in Ireland. Source: (EEA, 2023b).

Portugal

In Portugal, non-transport-related SO_x emissions decreased by 88% between 1990 and 2021, mainly due to the shift in grid energy mix from coal and oil towards gas and renewable sources. NO_x emissions also reduced, while $PM_{2.5}$ emission levels remained mostly steady. The reduction of NO_x and $PM_{2.5}$ emissions from road transportation in Portugal became apparent only after 2005 due to more stringent Euro standards, which had earlier been offset by vehicle fleet growth (Pereira et al., 2023). By 2021, transport-based NO_x emissions were reduced by 42% compared to 1990 levels, while $PM_{2.5}$ emissions in 2021 were reduced by 51% compared to the year 2000, which is the base year for PM measurements (EEA, 2023b).

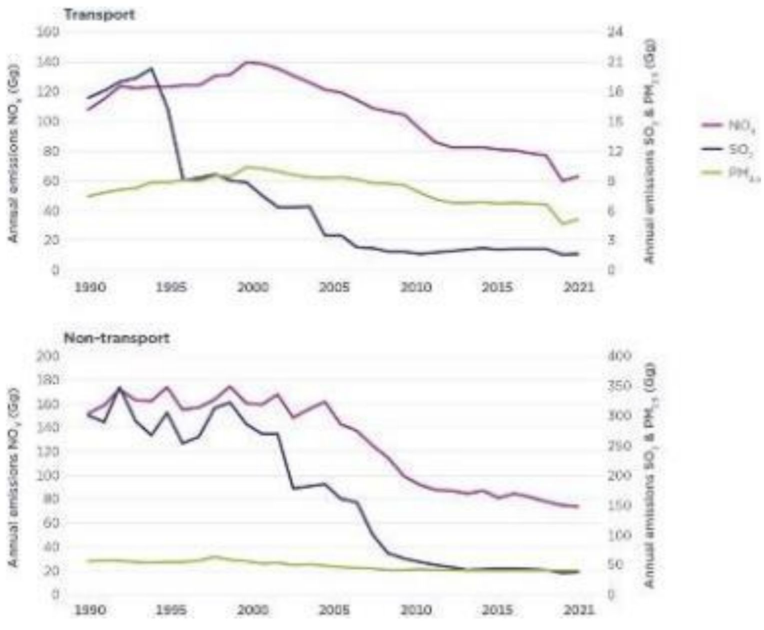

Figure 28: Transport and non-transport SO_2, NO_x, and $PM_{2.5}$ emissions in Portugal. Source: (EEA, 2023b)

Spain

In Spain, non-transport-related SO_2 emissions were reduced by 94% between 1990 and 2021, driven by the progressive introduction of desulfurization techniques in thermal plants and the shift from coal-powered stations towards gas-fired plants. Abandonment of coal as fuel in the residential (stationary) combustion sector also helped reduce $PM_{2.5}$ emissions by 24% between 2000–2021. The rollout of Euro standards for passenger cars, heavy-duty trucks, and buses reduced transport-based NO_x emissions by 60% between 1990–2021 (EEA, 2023b; MITECO, 2023).

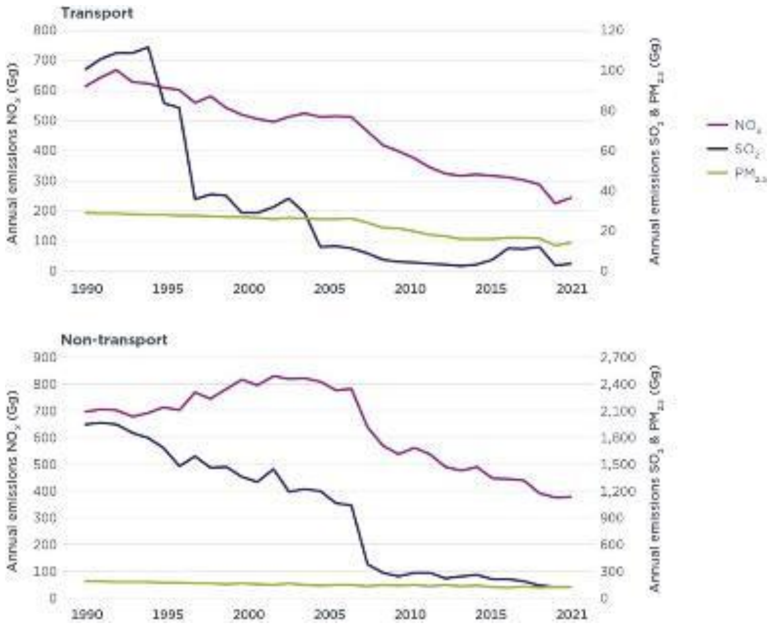

Figure 29: Transport and non-transport SO_2, NO_x, and $PM_{2.5}$ emissions in Spain. Source: (EEA, 2023b)

The United Kingdom

In the United Kingdom, non-transport-related SO_2 emissions declined by 96% between 1990 and 2021, as natural gas replaced coal in the country's grid and residential heating, with high-emitting sectors such as steelmaking and metal production relocating outside the country in the 1990s and early 2000s. Additionally, $PM_{2.5}$ emissions declined by 31% between 2000 and 2021, mainly driven by reduced use of coal for residential combustion. Transport-based NO_x emissions in the United Kingdom decreased by 79% between 1990 and 2021, largely due to the use of catalytic converters as part of the Euro standards (Ingledew et al., 2023; UK Government, 2024).

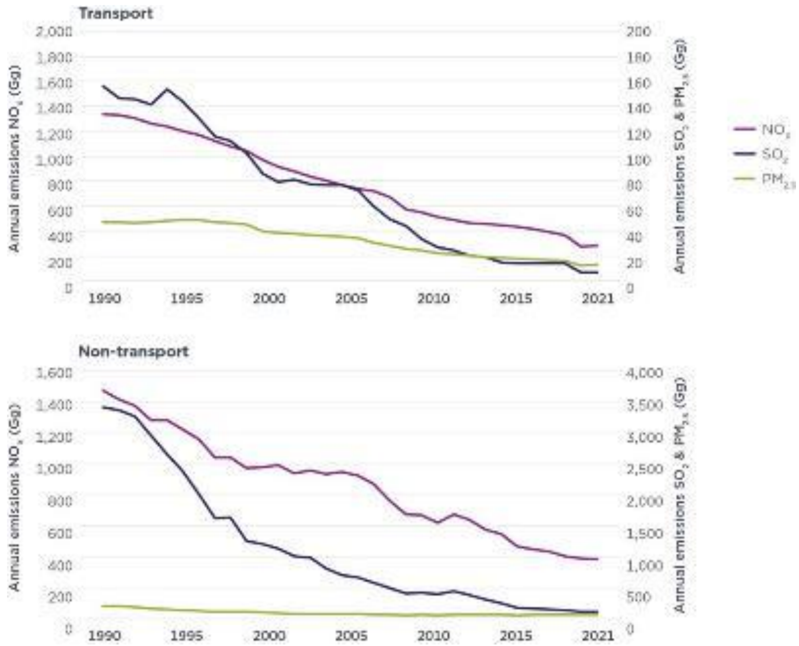

Figure 30: Transport and non-transport SO_2, NO_x, and $PM_{2.5}$ emissions in the United Kingdom. Source: (UK Government, 2024)

Greenland

In Greenland, non-transport-related SO_2 emissions increased by 16% between 1990 and 2011, reaching their peak in 2011. Since then, SO_2 emissions have been in steady decline, resulting in an overall reduction of 12% between 1990 and 2021. This improvement can largely be attributed to the increased use of hydropower for electricity production post-2010 and a decline in emissions from residential heating. Non-transport-related NO_x emission levels peaked in 2000 but have decreased by 14% by 2021. However, overall levels remain 20% higher in 2021 compared to 1990. Agriculture and forestry are the largest land-based sources of NO_x emissions in Greenland, with emissions increasing by 34% between 1990 and 2021, while transport-based NO_x emissions increased by 14% (CDR, 2023) (Statista Research Department, 2024).

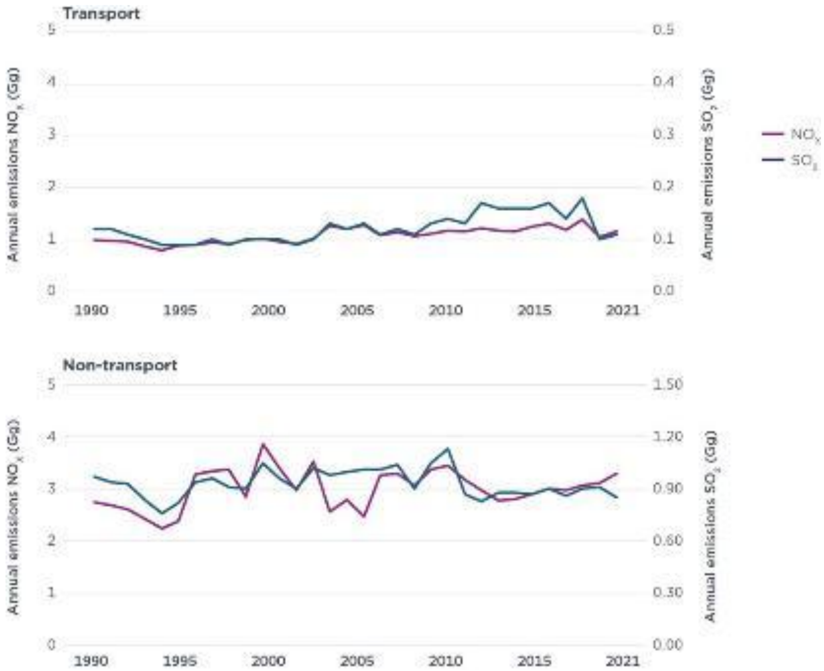

Figure 31: Transport and non-transport SO_2 and NO_x emissions in Greenland. $PM_{2.5}$ emissions data for Greenland is unavailable. Source: European Environment Information and Observation Network (2023)

6.3. Summary of measures addressing land-based sources

All EU and European Economic Area NE Atlantic ECA member states (France, Iceland, Ireland, Portugal, and Spain) meet the EU-AAQD 2030 thresholds, and the United Kingdom complies with its domestic UK AQSR limits. However, only the Associate Members of Faroe Islands, Denmark (Greenland), and Iceland meet the WHO-recommended air quality guidelines. The Faroe Islands and Greenland are not required to comply with EU regulations; they instead implement independent regional environmental policies.

France, Ireland, Portugal, and Spain meet their NECD 2020–2029 reduction targets for SO_2, NO_x, and $PM_{2.5}$. However, NO_x and $PM_{2.5}$ emission levels are projected to exceed post-2030 targets, indicating a need for additional policy intervention. Similarly, the United Kingdom has achieved its National Emission Ceilings Regulations 2020–2029 reduction targets for SO_2 and NO_x but has not achieved its $PM_{2.5}$ reduction commitments. Projected reduction levels for the United Kingdom also have not met post–2030 targets, suggesting further policy improvements may be needed. Iceland, as a member of the European Economic Area, has not yet implemented the revised EU NECD reduction targets; it is the only member state experiencing a noticeable increase in non-transport SO_2 emissions.

Overall, the implementation of land-based air quality control measures has considerably improved air quality in most NE Atlantic ECA member states, and temporal trends reveal a reduction in SO_x, NO_x, and $PM_{2.5}$ emissions from both transport and non-transport sectors. However, exceptions such as the increase in non-transport-related SO_2 emissions in Iceland, and the fact that only the Faroe Islands, Greenland, and Iceland meet WHO-recommended air quality thresholds, highlight the potential need for targeted interventions in specific areas.

7. Costs of Reducing Emissions from Ships

*This section presents information addressing **criterion 3.1.8 of Appendix III to MARPOL Annex VI**, as cited: "The proposal shall include the relative costs of reducing emissions from ships when compared with land-based controls, and the economic impacts on shipping engaged in international trade".*

Section Summary
This section presents the estimation and related discussion of the costs associated with the implementation of NE Atlantic ECA, considering the MGO Mix and ULSFO Mix scenarios, as well as the Tier III regulations. For that, fuel costs for the NE Atlantic ECA and the fuel availability were analysed (sub-section 7.1), followed by the assessment of the costs of SO_x and NO_x emissions reductions (sub-sections 7.2 and 7.3), the cost-effectiveness and cost-benefit analysis (sub-sections 7.5 and 7.6), the comparison of the NE Atlantic ECA costs with land-based measures and other previous ECA applications (sub-section 7.7) and the economic impacts on shipping engaged in international trade (sub-section 7.8).

7.1. Fuels costs analysis

In this sub-section, the available history of fuel prices in the NE Atlantic ECA implementation area and globally is discussed. The fuels analysed are IFO380 with a sulphur content of up to 3.50% m/m, VLSFO with a sulphur content of 0.50% m/m, which is compliant with IMO 2020 MARPOL VI regulations, MGO and ULSFO with a sulphur content of 0.10% m/m that are compliant with MARPOL VI ECA regulations, LNG and methanol (as alternative fuels). The sale prices analysed include the costs of production and transport. The analyses cover data on world crude prices, world and NE Atlantic ECA marine fuel prices (IFO380, VLSFO, MGO and ULSFO) and price differentials between MGO and VSLFO, as well as between ULSFO and VLSFO. All prices presented are based on indexes provided by the Bunker Index database (https://bunkerindex.com), with the exception of those for methanol provided by IndexBox (2024).

7.1.1. Crude oil prices

Crude barrel prices, which are feedstocks for marine fuels, were analysed based on available time series data from the Bunker Index database. Figure 32 shows the world crude prices per barrel of West Texas Intermediate (WTI) and Brent ($/bbl), as well as the prices of the NE Atlantic ECA marine bunker fuels ($/tonne).

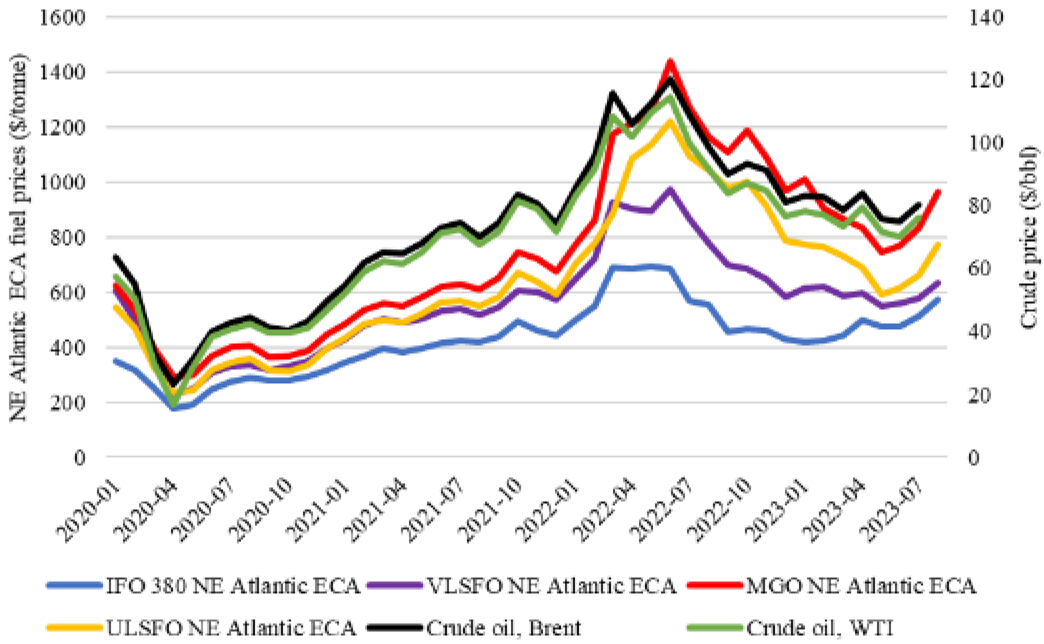

Figure 32: World crude oil (Brent, WTI) and NE Atlantic ECA marine fuels (IFO380, VLSFO, MGO) prices

From Figure 32 it is clear that there is an association between global oil prices and NE Atlantic ECA marine bunker fuels. Table 13 shows the Pearson correlation coefficients for NE Atlantic ECA marine bunkers and world crude oil prices. The correlation coefficients show that all species are strongly correlated (> 0.9).

Table 13. Pearson correlation coefficients between marine bunker prices and crude oil prices.

	VLSFO	MGO	ULSFO	Brent	WTI
VLSFO	1.000	0.947	0.954	0.979	0.971
MGO		1.000	0.991	0.950	0.934
ULSFO			1.000	0.952	0.940
Brent				1.000	0.997
WTI					1.000

7.1.2. Conventional Fuels

Figure 33 shows the time trend of the average marine bunker fuel prices for ports in countries within the NE Atlantic ECA implementation area and the global world average.

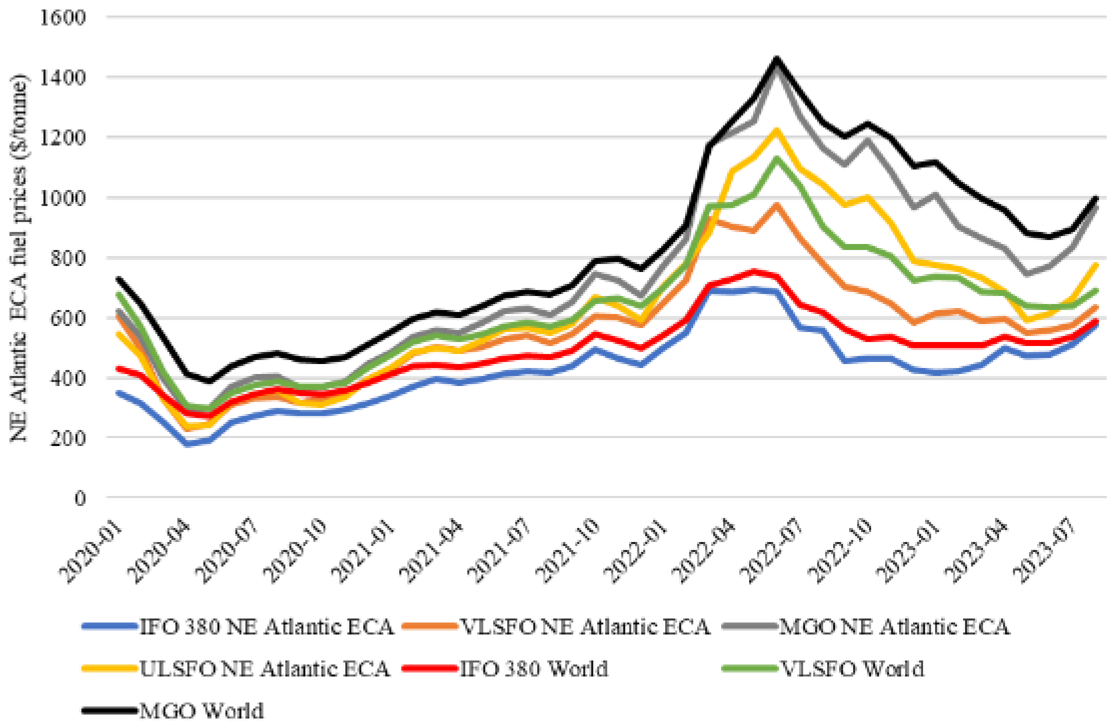

Figure 33: Historical marine bunker fuel prices for the world and NE Atlantic ECA region

According to Figure 33, NE Atlantic ECA and World data series both exhibit a significant correlation, closely tracking each other's trends, despite the NE Atlantic ECA ULSFO prices in Figure 33 (yellow line). On average, global IFO380 prices (Figure 33 red line) surpass NE Atlantic ECA prices (Figure 33 blue line) by approximately 61 $/tonne. Within the NE Atlantic ECA region, IFO380 fuel prices have displayed substantial variability, spanning from an average minimum of 126 $/tonne to a maximum of 769 $/tonne. Since January 2020, the median IFO380 price for the NE Atlantic ECA region has stood at 425 $/tonne. These findings highlight the dynamic nature of IFO380 fuel prices, reflecting the market's response to various factors such as supply and demand dynamics, regulatory changes, and geopolitical influences. Further analysis and a comprehensive examination of the underlying drivers are warranted to gain deeper insights into the observed trends and potential future developments in IFO380 pricing within the global and NE Atlantic ECA contexts.

On average, world VLSFO prices (Figure 33 green line) surpass NE Atlantic ECA prices (Figure 33 orange line) by approximately 76 $/tonne. Within the NE Atlantic ECA region, VLSFO fuel prices, like IFO380, have displayed substantial variability, spanning from an average minimum of 175 $/tonne to a maximum of 1064 $/tonne. Since January 2020, the median VLSFO price for the NE Atlantic ECA region has stood at 566 $/tonne.

World average MGO prices (Figure 33 black line) were typically greater than NE Atlantic ECA MGO prices (Figure 33 grey line), as seen with IFO380 and VLSFO prices. The average price differential between world and NE Atlantic ECA MGO prices was 78 $/tonne, which is closely aligned with the world and NE Atlantic ECA differential for VLSFO prices. MGO prices have displayed substantial variability, spanning from an average minimum of 231 $/tonne to a maximum of 1518 $/tonne. Since January 2020, the median MGO price for the NE Atlantic ECA region has stood at 699 $/tonne. All prices reached higher values between February and July 2022 due to the Russian invasion of Ukraine (S&P Global, 2023).

7.1.3. Alternative Fuels

Figure 34 represents the time series of LNG prices for the NE Atlantic ECA region. The LNG prices did not show an association with the other marine bunker fuel prices. LNG traded at higher prices than MGO and ULSFO in the NE Atlantic ECA region. LNG prices spiked towards the end of 2021 due to the scarcity of supply ahead of winter. Like conventional fuels, LNG prices reached the maximum value between February and July 2022 due to the Russian invasion of Ukraine. According to S&P Global Commodity Insights similar patterns were verified in the Rotterdam bunkering hub and Singapore (S&P Global, 2023). Since January 2020, the median LNG price for the NE Atlantic ECA region has stood at 1216 $/tonne.

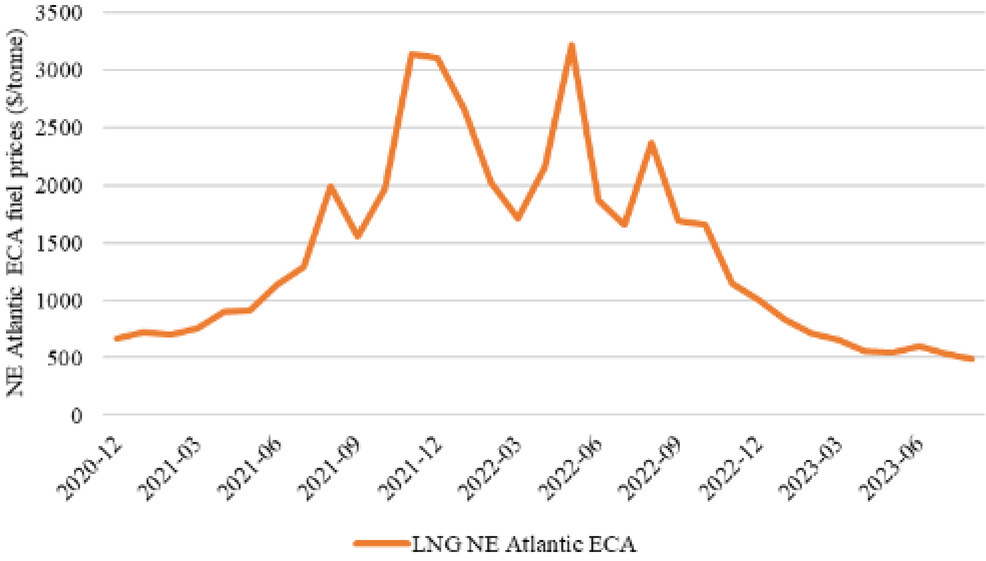

Figure 34: LNG NE Atlantic ECA price indexes

Methanol price per metric tonne for June 2022 was obtained from the Methanol (Methyl Alcohol) - Market Analysis, Forecast, Size, Trends and Insights report. According to the report, the methanol price per ton amounted to 372 $/tonne. From January to June, the price increased at an average monthly rate of 1.3% (IndexBox, 2024)**.**

7.1.4. Statistical summary of fuel prices and price differentials

Table 14 to Table 18 show a descriptive statistical analysis of fuel prices in the NE Atlantic ECA region from 2020 to 2022. According to the results, the central prices for IFO380 (3.50% S m/m), VLSFO (0.50% S m/m), MGO (0.10% S m/m), ULSFO (0.10% S m/m) and LNG are 425$/tonne, 566$/tonne, 699$/tonne, 592$/tonne and 1216$/tonne, respectively. These values correspond to the median values of the available data series for the fuel types. These prices will be used as central estimates for calculating the effects on travel costs and commodity prices of the implementation of NE Atlantic ECA.

Table 14. Statistical summary of IF380 prices in NE Atlantic ECA for the period of 2020-2023 and total ($/tonne).

NE Atlantic ECA	IF380 ($/tonne)				
Data Period	2020	2021	2022	2023	Total
Minimum	178	343	426	418	178
10th Percentile	196	370	457	421	276
25th Percentile	252	392	465	439	336
Median	279	416	552	475	**425**
75th Percentile	299	439	686	503	494
90th Percentile	317	461	689	530	571
Maximum	350	493	696	574	696

Table 15. Statistical summary of VLSFO prices in NE Atlantic ECA for the period of 2020-2023 and total ($/tonne).

NE Atlantic ECA	VLSFO ($/tonne)				
Data Period	2020	2021	2022	2023	Total
Minimum	232	429	582	549	232
10th Percentile	252	481	647	556	330
25th Percentile	314	498	676	572	467
Median	331	522	750	592	**566**
75th Percentile	360	551	895	616	637
90th Percentile	487	597	925	624	840
Maximum	605	604	974	634	974

Table 16. Statistical summary of MGO prices in NE Atlantic ECA for the period of 2020-2023 and total ($/tonne).

NE Atlantic ECA	MGO ($/tonne)				
Data Period	2020	2021	2022	2023	Total
Minimum	292	484	772	745	292
10th Percentile	303	536	873	763	375
25th Percentile	368	557	1058	817	522

Median	391	616	1168	850	**699**
75th Percentile	416	658	1224	918	966
90th Percentile	526	719	1269	978	1183
Maximum	623	746	1440	1009	1440

Table 17. Statistical summary of ULSFO prices in NE Atlantic ECA for the period of 2020-2023 and total ($/tonne).

NE Atlantic ECA	**ULSFO ($/tonne)**				
Data Period	2020	2021	2022	2023	Total
Minimum	240	434	701	592	240
10th Percentile	249	486	779	608	321
25th Percentile	315	496	860	651	463
Median	331	556	988	710	**592**
75th Percentile	369	583	1089	765	775
90th Percentile	465	633	1130	774	1030
Maximum	543	670	1222	774	1222

Table 18. Statistical summary of LNG prices in NE Atlantic ECA for the period of 2020-2023 and total ($/tonne).

NE Atlantic ECA	**LNG ($/tonne)**				
Data Period	2020	2021	2022	2023	Total
Minimum	-	536	1555	668	536
10th Percentile	-	545	1658	690	607
25th Percentile	-	591	1827	720	722
Median	-	771	2004	825	**1216**
75th Percentile	-	1269	2772	968	1977
90th Percentile	-	1689	3138	1178	2631
Maximum	-	2368	3215	1292	3215

The fuel price differentials between VLSFO (0.50% S m/m) and IFO380 (up to 3.50% S m/m), between MGO (0.10% S m/m) and VLSFO, and MGO and ULSFO (0.10% S m/m) are important for evaluating the additional costs of the fuel switching for the NE Atlantic ECA scenarios. The NE Atlantic ECA fuel price differentials were calculated, and a descriptive statistical analysis of fuel price differentials from 2020 to 2022 is shown in Table 19.

Table 19. Statistical summary of fuel price differentials for the NE Atlantic ECA from 2020 to 2022 ($/tonne).

Price differential	VLSFO – IFO380 ($/tonne)	MGO – VLSFO ($/tonne)	MGO – ULSFO ($/tonne)
Minimum	37	18	46
10th Percentile	55	50	51
25th Percentile	76	60	58
Median	**112**	**117**	**78**
75th Percentile	188	289	147
90th Percentile	234	402	185
Maximum	301	502	290

7.1.5. Fuels availability

International shipping power systems primarily rely on petroleum-based fuel products, with most of the fleet using fuels with a maximum sulphur content of 0.50% m/m since the Global Sulphur Cap was implemented in 2020 (IMO, 2016b). The successful implementation of this regulation was supported by the findings of the "Assessment of Fuel Oil Availability" (MEPC 70/INF.6), commonly known as the IMO Fuel Availability Study, conducted in 2016 (Faber et al., 2016). Furthermore, the findings also suggested that there were adequate supplies of marine fuels with even lower sulphur content, such as those meeting the 0.10% m/m sulphur limit required in SO_x ECAs. More recently, for the proposed implementation of the MedECA, it was reported that there was sufficient fuel available to meet the demand for fuels with a sulphur content of 0.10% m/m for the ECA in this region (Concawe, 2020).

To investigate whether there will be sufficient fuel to meet the demand with the NE Atlantic ECA implementation, the required fuel demand was analysed. The marine fuel demand is presented in Table 20.

Table 20. Marine fuel demand for the 2030 BAU and NE Atlantic ECA scenarios (million tonnes/year).

Scenario	VLSFO (Mt/y)	HFO (Mt/y)	MGO (Mt/y)	LNG (Mt/y)	Methanol (Mt/y)	ULSFO (Mt/y)	Total (Mt/y)
2030 BAU	4.652	0.982	1.600	0.329	0.005	-	7.567
MGO Mix	-	0.982	5.991	0.329	0.005	-	7.307
ULSFO Mix	-	0.982	1.600	0.329	0.005	4.652	7.567

The fuel availability was accessed for the MGO Mix scenario, as this is the scenario that requires the highest amount of 0.10% m/m sulphur fuel. According to Table 20, approximately 6 million tonnes of MGO will be required under the MGO Mix scenario to meet the demand. To this end, an assessment of the crude oil refining capacities of the NE Atlantic ECA countries was conducted using data from the Oil & Gas Journal (Oil & Gas Journal, 2020). It is important to note that the Faroe Islands, Greenland, and Iceland do not have refining capacity. The crude refining capacity by country for the NE Atlantic ECA is presented in Table 21.

Table 21. Crude refinery capacities for the NE Atlantic ECA countries (million tonnes/year).

Countries	Refining Capacity (Mt/y)
France	66.4
Ireland	3.5
Portugal	10.9
Spain	75.2
United Kingdom	85.2
Total	241.2

To determine the percentage of total refining that corresponds to marine fuels, regional refinery production data from the "Assessment of Fuel Oil Availability Final Report" by CE Delf was used (Faber et al., 2016). The percentage that each marine fuel represents in the total refining was calculated. Table 22 presents the percentages that each marine fuel represents in the total refining capacity in Europe.

Table 22. Percentages of each marine fuel in the total refining capacity in Europe.

Fuel	% of the total
Marine MGO <0.10%S	1.5
Marine HFO <0.50%S	9.1
Marine HFO >0.50%S	1.3

Using the previously mentioned data, the production capacity of marine fuels for the NE Atlantic ECA countries was calculated. Table 23 shows the refining capacities of marine fuels for the NE Atlantic ECA countries.

Table 23. Refining capacities of marine fuels for the NE Atlantic ECA countries (million tonnes/year).

Marine Fuels	France (Mt/y)	Ireland (Mt/y)	Portugal (Mt/y)	Spain (Mt/y)	United Kingdom (Mt/y)	Total (Mt/y)
Marine MGO <0.10%S	0.064	0.003	0.011	0.073	0.082	0.233
Marine HFO <0.50%S	0.587	0.031	0.097	0.665	0.753	2.133
Marine HFO >0.50%S	0.085	0.005	0.014	0.097	0.110	0.310
Total	6.424	0.341	1.057	7.280	8.246	23.348

According to Table 23, refineries will need to adjust their production of MGO from 1.5% to around 2.5%. NE Atlantic ECA countries will be capable of refining the 6 million tonnes of MGO that will be needed. It is anticipated that the market dynamics will change without the need to increase refining capacity.

7.2. Costs of SO_x emission reductions

Sulphur emission regulations outlined in Annex VI of the IMO MARPOL Convention could be achieved by ship operators with two primary compliance options: switching to low-sulphur fuel or installing an approved equivalent SO_x emission reduction method, such as exhaust gas cleaning systems, commonly known as scrubbers. Each option presents advantages and challenges and entails distinct costs related to capital expenditure (CAPEX) and/or operational expenditure (OPEX) that influence their feasibility and attractiveness.

The use of low-sulphur fuels involves switching from fuel with 0.50% S m/m to fuels with a sulphur content of no more than 0.10% m/m. The main advantage of using fuels with 0.10% S m/m is that ships can readily meet regulatory requirements with almost no additional CAPEX. In fact, ships that burn residual fuels and fuels with 0.50% S m/m can also burn ECA compliant fuels with small modifications. Moreover, the required modifications are often a necessity for the ships that also operate in other existing ECA areas, and in that way the CAPEX costs were considered negligible. The main challenge of the fuel switch is the increase in the OPEX associated with the cost difference between bunkering of VLSFO and MGO or ULSFO.

7.2.1. Cost of SO_x emission reduction from fuel switching

Given the mean values of the fuel prices analysed in sub-section 7.1.4 and the total emissions in each scenario per ship type, the differences in costs due to fuel switching were estimated for each scenario that considered this type of measure. Table 24 shows the differences in the costs between the 2030 BAU scenario and NE Atlantic ECA compliance scenarios - MGO Mix and ULSFO Mix.

Table 24. Differences in the overall costs between the 2030 BAU scenario and NE Atlantic ECA scenarios (MGO Mix and ULSFO Mix).

Difference to 2030 BAU (million €)	
MGO Mix	**ULSFO Mix**
437	121

7.3. Costs of NO_x emission reductions

In NO_x emissions control areas (NO_x ECAs), ships need to comply with Tier III requirements to control NO_x emissions (IMO, 2005). The reduction of NO_x emissions from ships in ECAs can be achieved through the use of technologies for their reduction and through the use of fuels whose combustion emits lower amounts of NO_x (e.g., LNG). In terms of technologies, there are two that enable compliance with Tier III: exhaust gas recirculation in combination with water-in-fuel injection (EGR+WI) and selective catalytic reduction (SCR). According to the literature, EGR+WI is more expensive than SCR per unit of NO_x reduction (EGCSA, 2014). Concerning fuel use, LNG provides an additional pathway for reducing NO_x emissions, as it emits significantly lower levels of NO_x compared to diesel fuels, aligning with Tier III requirements. However, future LNG penetration rates are uncertain and require significant changes in fuel storage and handling infrastructure, which is beyond the scope of this study. Therefore, the analysis included in this study was limited to the calculation of SCR implementation costs. According to the literature and previous ECA implementation studies, SCR systems are still considered the most likely and typically applied technology. SCR is an exhaust gas after-treatment technology that achieves a NO_x reduction of over 80% (EGCSA, 2014). It must be installed separately for each ship engine and requires urea as a reagent. The costs associated with SCR systems include CAPEX (SCR unit and installation) and OPEX, mainly driven by the consumption of urea and maintenance costs that involve regular inspections, cleaning, and catalyst replacement.

7.3.1. SCR cost assumptions and data used

The Tier III regulations apply only to ships built after an ECA designation and operating within that ECA's boundaries. Therefore, to model the NO_X emission reduction induced by the NE Atlantic ECA designation, it was assumed that 2027 would be the year of the designation of NE Atlantic ECA, and the number of newly built ships from 2027 to 2030 was estimated. According to the estimations, a total of 885 ships must comply with Tier III standards in the conditions referred to above.

Table **25** shows the total power installed in the ME and in the auxiliary engine (AE) by ship type that needs to comply with Tier III standards from 2027. Figure 35 shows the total fuel consumption of ME and AE and the number of ships per ship type.

Table 25. Total installed main (ME) and auxiliary engines (AE) by ship type that needs to comply with Tier III standards from 2027 (data provided by the ICCT).

Ship type	Total installed ME power (kW)	Total installed AE power (kW)
Bulk Carriers	1 809 147	396 943
Cruise ships	405 033	120 293
Ferries	112 291	20 214
Fishing vessels	285 580	200 561
General Cargo	226 123	62 031
Offshore Ships	362 748	52 986
Other	733 807	138 141
Ro-Ro Ships	968 680	274 788
Tankers	1 609 829	579 429
Tugs	268 781	34 675
Yachts	85 542	22 211
Total	6 867 561	1 902 271

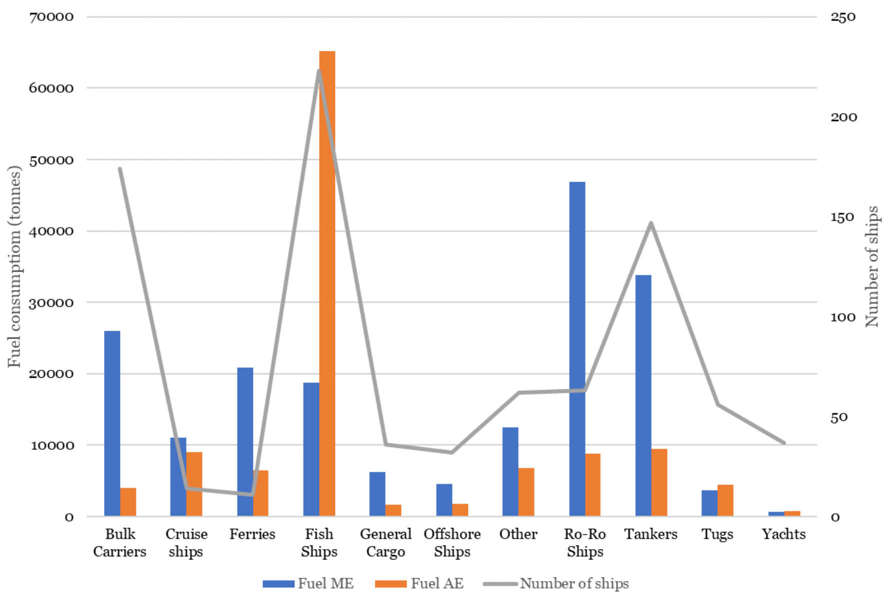

Figure 35: Total fuel consumption of ME and AE and the number of ships per ship type of ships that need to comply with Tier III (data provided by the ICCT)

The values used as a basis for the CAPEX and OPEX estimations of this study were based on the ECA application to designate the Baltic Sea as an Emission Control Area for nitrogen oxides (Baltic Marine Environment Protection Commission, 2016). CAPEX was estimated based on the installed engine power (kW) of the new ships constructed on or after 01/01/2027 until 2030 (including both ME and AE powers). The CAPEX of SCRs was annualized considering a period of 30 years (according to the engine manufacturers, the lifetime of a basic SCR is the same as the ship) and a discount rate of 4%. The CAPEX of the SCR equipment was considered to be 50 €/kW (Baltic Marine Environment Protection Commission, 2016). Table 26 shows the estimated annualized CAPEX for the SCR equipment per ship type.

Table 26. Capital costs for the SCR equipment per ship type.

Ship type	CAPEX (€)
Bulk Carriers	6 378 920
Cruise ships	1 518 983
Ferries	383 138
Fishing vessels	1 405 678
General Cargo	833 198
Offshore Ships	1 202 096
Other	2 521 241
Ro-Ro Ships	3 595 494
Tankers	6 330 251
Tugs	877 443
Yachts	311 569
Total	25 358 011

The estimation of SCR OPEX was based on the fuel consumption of the new ships built on or after 2027 until 2030. It was assumed that if a ship leaves the NO_x ECA it will shut down its SCR. Operating costs of SCR mainly arise from the urea consumption, which depends on the efficiency rate of NO_x emissions abatement. Urea consumption is estimated to be about 10% of fuel consumption to achieve the Tier III level. In this study, urea costs accounted for almost 80% of total operating costs. As was already mentioned it was estimated that the lifetime of a SCR can be as long as the ship, but regular maintenance and replacement of components and catalyst elements at certain intervals is required. The cost of catalyst elements replacement was considered to be 0.5 €/MWh (Baltic Marine Environment Protection Commission, 2016). The elements will be replaced only when their activity level drops below a set level. In addition, a visual inspection and, as needed, simultaneous manual cleaning should be performed once a year. However, the cost of these operations is residual compared to the cost of urea consumption, which accounts for almost the total OPEX. It was considered a urea price of 334 €/tonne, based on monthly data from 2010 to 2024 available from the World Bank Commodity Price Data (World Bank, 2023). No estimates for the future development of urea prices are available; however historical data from the last 20 years are shown in Figure 36. Since Urea accounts for almost the total operating costs, the price of urea is clearly a sensitive factor. Table 27 presents the OPEX for the SCR equipment per ship type.

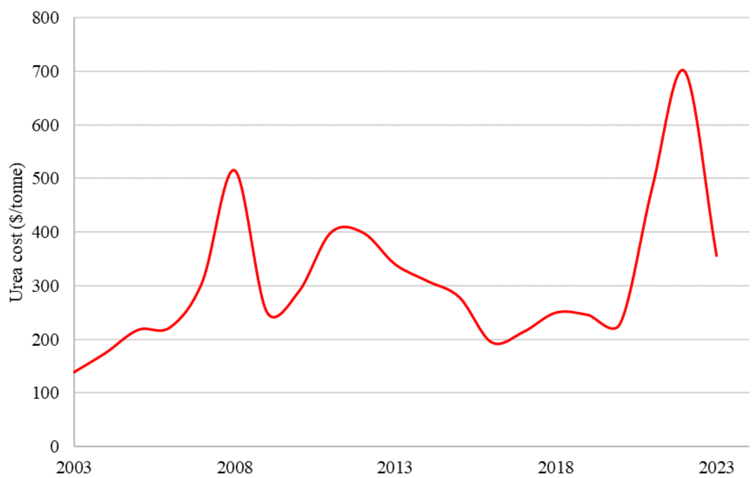

Figure 36: Urea cost ($/tonne) from 2003 to 2023 (World Bank, 2023).

Table 27. Operating costs for the SCR equipment per ship type.

Ship type	OPEX (€)
Bulk Carriers	933 133
Cruise ships	624 045
Ferries	850 283
Fishing vessels	2 608 899
General Cargo	245 592
Offshore Ships	196 823
Other	600 162
Ro-Ro Ships	1 730 882
Tankers	1 345 011
Tugs	252 459
Yachts	42 787
Total	9 430 076

7.4. Total estimated NE Atlantic ECA costs in 2030

The additional costs associated with the implementation of NE Atlantic ECA in 2030 considered the comparison of costs associated with the 2030 BAU scenario with the costs of switching to low sulphur content fuels (MGO Mix and ULSFO Mix scenarios), and of the use of SCR systems for ships built after 2027 until 2030 to comply with the NO_x Tier III requirement, as described in a previous sub-section. Regarding the fuel switch, adopting the

MGO Mix scenario was estimated to have an additional annual cost of 437 million € and adopting the ULSFO Mix scenario was estimated to have an additional cost of 121 million €, compared to the 2030 BAU scenario. The scenario related to NO_x emission reduction, which considered the installation of SCR on new ships built between 2027 and 2030, was estimated to cost a total of 35 million €. Table 28 summarizes the estimated costs with each scenario analysed, as well as the total costs associated with the implementation of a SO_x ECA and a NO_x ECA.

Table 28. Total estimated NE Atlantic ECA costs in 2030.

Scenario	Type of costs	Costs (Million €)
MGO Mix	Fuel switching	437
USLFO Mix	Fuel switching	121
Tier III compliance	CAPEX	25.4
	OPEX	9.4
NE Atlantic ECA total costs (SO_x ECA+NO_x ECA)	MGO Mix + Tier III	472
	ULSFO Mix + Tier III	156

7.5. Cost-Effectiveness

This sub-section analyses the cost-effectiveness of the NE Atlantic ECA implementation, considering the emissions averted. A comparison with previous ECA designation studies and with land-based control programs is also presented.

7.5.1. Emissions reduction cost-effectiveness

Table 29 summarises the projected shipping emission for the different scenarios and the reductions compared to the 2030 BAU scenario due to the proposed ECA.

Table 29. Total of SO_x, $PM_{2.5}$ and NO_x shipping emissions for the different scenarios and differences compared to the 2030 BAU scenario.

Total	SO_x (tonnes)	$PM_{2.5}$ (tonnes)	PM_{10} (tonnes)	NO_x (tonnes)
2030 BAU	45 475	18 942	20 589	500 304
MGO Mix	8 134	6 730	7 315	486 749
USLFO Mix	12 390	17 167	18 660	486 749
Reductions	**SO_x (tonnes)**	**$PM_{2.5}$ (tonnes)**	**PM_{10} (tonnes)**	**NO_x (tonnes)**
2030 BAU – MGO Mix	37 341	12 212	13 274	13 555
2030 BAU – ULSFO Mix	33 085	1 775	1 929	

The costs associated with SO_x, PM and NO_x emission reduction described in sub-sections 7.2 and 7.3, and the emission reductions shown in Table 29 were used to calculate the cost per tonne of abated emissions for the proposed NE Atlantic ECA. The cost per tonne of abated emissions depends on the allocation of these to each pollutant. Consequently, the costs were allocated as closely as possible to the pollutants for which they incurred and based on information from previous ECA applications. The costs of fuel switching (MGO Mix and ULSFO Mix scenarios) were allocated half to PM (PM_{10} and $PM_{2.5}$) and half to SO_x, as the control measures to reduce SO_x emissions have a direct impact also on the reduction of PM emissions (IMO, 2009). The costs to meet Tier III NOx standards (SCR implementation costs) were allocated to NO_x. The cost-effectiveness calculated per type of abated emissions is shown in Table 30.

Table 30. Cost-effectiveness of the NE Atlantic ECA (€/tonne).

Benefit Type	MGO Mix (€/tonne)	ULSFO Mix (€/tonne)	Tier III standards (€/tonne)
Abated SO_x emissions	5 845	1 828	-
Abated $PM_{2.5}$ emissions	17 872	34 066	-
Abated PM_{10} emissions	16 442	31 341	
Abated NO_x emissions	-	-	2 566

7.6. Cost-benefit analysis

The cost-benefit analysis was performed considering the health benefits estimated, i.e. the monetary values of the avoided deaths, and presented in sub-section 5.8. Figure 37 shows the costs and the health economic benefits for the different scenarios of the proposed NE Atlantic ECA.

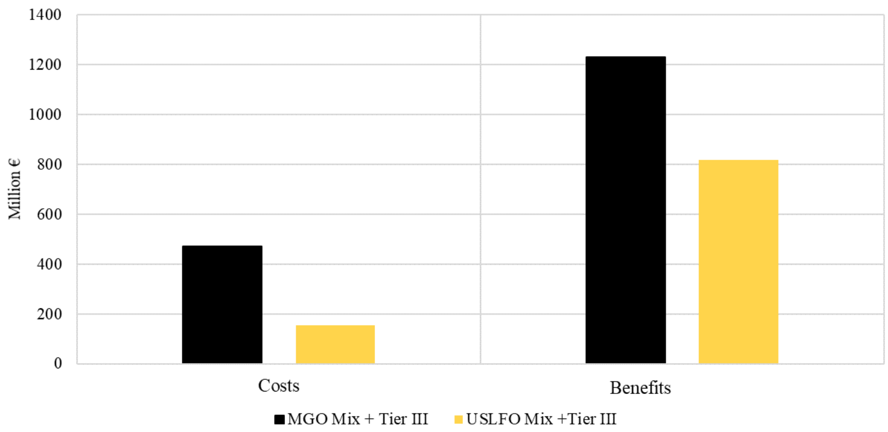

Figure 37: Costs of NE Atlantic ECA implementation and health economic benefits for each scenario

According to Figure 37, the health-related economic benefits surpass the costs of NE Atlantic ECA implementation independently of the scenario considered. Although the costs associated with the ULSFO Mix scenario were lower than the MGO Mix scenario, the benefits were also lower. Policies where the benefits outweigh the costs are generally considered acceptable from a societal perspective. Thus, the option that offers the best cost-benefit ratio is the implementation of an ECA including NO_x ECA and SO_x ECA, replacing VLSFO fuel with MGO. This option is estimated to have a cost of approximately 472 million €, with benefits of at least 1 230 million €. These results clearly demonstrate the importance and effectiveness of this strategy in reducing shipping emissions in the North Atlantic region, along with the consequent impacts on air quality, human health, and their associated economic benefits. Moreover, it is also expected that with the implementation of the NE Atlantic ECA, CO_2 emissions will be reduced, consequently having an impact on climate change. This reduction will also be important in terms of costs for the shipping industry because as part of the European Union Emissions Trading System (EU ETS), which is a key tool for reducing greenhouse gas emissions, maritime transport is being gradually incorporated to curb emissions from the shipping industry (from 2024). This means that shipping companies will need to buy carbon allowances for a portion of their CO_2 emissions, starting with 40% in 2024 and increasing to 100% by 2026. The scheme applies to large ships over 5,000 gross tons engaged in voyages within the EU, as well as 50% of emissions from international voyages starting or ending in the EU (European Commission, 2024a).

7.7. NE Atlantic ECA Costs in Comparison with Land-based Measures

As stated in Criterion 3.1.8 of Appendix III to MARPOL Annex VI, the inclusion of a comprehensive assessment detailing the relative costs involved in reducing emissions from ships compared to land-based controls is required. Since the availability of detailed country-specific information on land-based control costs for the countries of the NE Atlantic ECA is limited, comparisons with the ranges of costs per tonne of pollutant abated associated with land-based pollution measures reported in previous ECA proposals (for the USA and Norway) were performed. To extend the comparisons, the cost-effectiveness results for the NE Atlantic ECA above detailed were compared with the cost-effectiveness results reported in previous ECA proposals. All values were converted and standardised to euros for 2021. Table 31 provides a comprehensive overview of the cost-effectiveness of land-based measures for reducing emissions collected in the previous ECA applications.

Table 31. Cost-effectiveness values of land-based measures for reducing emissions collected in the previous ECA applications.

ECA application	Source Category (Land based)	PM_{10} (€/tonne)	SO_x (€/tonne)	NO_x (€/tonne)
United States and Canada (MEPC 59/6/5) and Puerto Rico and the U.S. Virgin Islands (MEPC 61/7/3)	Non- and on- road diesel and gasoline engine applications	12 586 – 18 249	-	1 259 – 2 517
	Stationary diesel engines	4 906 – 56 415		
	Locomotive and harbour craft costs	10 619 – 57 028		
	Stationary source SO_x abatement	-	315 – 6 843	-
	On-road SO_x abatement	-	7 315	
	Heavy duty diesel engines and light duty gasoline/diesel engines	-	7 551	2 517
Norwegian Sea (MEPC 81/11/1)	NO_x reductions	-	-	151 – 2 258

According to Table 31, the costs vary significantly depending on factors such as the type of pollutant, source, and the specific method employed for reduction. Although direct comparisons between the costs of land-based measures and those of the proposed NE Atlantic ECA should be performed with caution, it is possible to verify that the costs reported for NE Atlantic ECA in the MGO Mix and ULSFO Mix scenarios, as well as the Tier III NO_x standards, are within the ranges reported for land-based measures. NE Atlantic ECA demonstrates favourable cost-effectiveness when compared to land-based measures, making it a competitive option for reducing shipping emissions in the NE Atlantic ECA.

In Table 32, the cost-effectiveness values regarding emissions reduction reported in the previous ECA proposals and for the NE Atlantic ECA are presented.

Table 32. Cost-effectiveness values concerning emission reduction reported for the implementation of the previous ECA proposals and for NE Atlantic ECA MGO Mix and ULSFO Mix scenarios.

ECA application	SO_x (€/tonne)	PM_{10} (€/tonne)	$PM_{2.5}$ (€/tonne)	NO_x (€/tonne)
United States and Canada (MEPC 59/6/5)	1 360	11 334	12 467	2 947
Puerto Rico and the U.S. Virgin Islands (MEPC 61/7/3)	1 247	11 334	12 467	680
Baltic and NorthSea NOx ECA (MEPC 70/5/Rev.1	-	-	-	1 434 – 2 010
Mediterranean Sea (MEPC 78/11)	10 540	-	121 922	
Canadian Arctic waters (MEPC 81/11)	5 487	-	24 791	968
Norwegian Sea (MEPC 81/11/1)	8 102	18 170	-	1 314
NE Atlantic ECA MGO Mix	5 845	16 442	17 872	**2 566**
NE Atlantic ECA ULSFO Mix	1 828	31 341	34 066	

As for land-based measures, any comparison between these reported values should be made with caution. Nevertheless, it can be observed that the values reported for the MGO Mix and ULSFO Mix scenarios, as well as the Tier III NOx standards for the NE Atlantic ECA, align with the ranges observed in other ECA applications.

7.8. Economic Impacts on Shipping Engaged in International Trade

7.8.1. Impacts on Freight rate and commodities prices

This sub-section describes how the implementation of the NE Atlantic ECA might economically affect freight rates and the prices of key commodities for the states within the NE Atlantic ECA. Only the operational costs of the fuel change from the MGO Mix scenario (changing from VLSFO to MGO) were considered in the analysis, as it was identified as the solution with the best overall cost-effectiveness (SO_x plus PM cost reductions). The costs of the NO_x ECA implementation were not considered because it is a measure whose costs will not have an immediate effect from the date of implementation of the ECA. The methods of this analysis are based on the economic principle that the cost of the measure will affect the price of the voyage, which will be assumed by shipowners and subsequently reflected in the final prices of the transported commodities. The economic impact of implementing NE Atlantic ECA was assessed by calculating the increase in voyage costs due to the rise in fuel prices, and how this increase could be affecting the purchase prices of certain commodities. Initially, a survey of maritime transport costs was conducted. Maritime Transport Costs (MTCs) were obtained from the database maintained by the Directorate of Statistics and Data of the Organisation for Economic Co-operation and Development (OECD). The MTCs database contains data from 1991 up to the most recent year available on bilateral maritime transport costs. Transport costs are available for 44 importing countries (including the EU15 countries as a customs union) from 228 countries of origin, at the detailed commodity level (6-digit) of the 1988 Harmonised System (OECD, 2024). Unit transport costs (USD/tonne) were extracted from the MTCs database by commodity groups (agriculture, manufacturing, and raw materials including crude oil) and ship type (clean bulk, dirty bulk, containers, and tankers) for the countries or group of countries within the NE Atlantic ECA. An effort was made to include all available data for the NE Atlantic ECA IMO member states and associate members. Table 33 summarises the average MTCs data extracted for the set of countries or specific countries by commodity groups and ship type.

Table 33. Average of MTCs for commodity groups and ship type for the NE Atlantic ECA IMO members and associate members (USD/tonne).

		EU15 (USD/tonne)	Denmark (Greenland) (USD/tonne)	Faroe Islands (USD/tonne)	Iceland (USD/tonne)
Type of good	**Agriculture**	122	181	329	286
	Crude oil	30	-	-	297
	Manufacturing	337	480	1 034	2 181
	Raw material	34	78	3	49
	Total	131	246	455	703
Ship type	**Clean bulk**	64	-	-	-
	Containers	292	370	-	1 590
	Dirty bulk	35	78	60	162
	Tankers	61	-	-	-
	Total	113	224	461	876

Using these MTCs and considering information on typical voyages between the NE Atlantic ECA IMO member states and associate members and those with which they engage in imports and exports, freight rates were calculated in USD/tonne per km. Since MTCs represent the total MTCs, it was necessary to calculate the portion of the MTCs values that correspond to fuel costs. Marine fuels can account for 30-50% of the voyage costs, depending on the type of ship (Bergqvist et al., 2015). It was considered that fuel represented 54%, 40%, 40% and 33% of the total MTCs value for containers, dirty bulk, clean bulk and tankers, respectively (Bergqvist et al., 2015). Subsequently, new MTCs were calculated exclusively for the fraction of the voyage that will take place within the NE Atlantic ECA. These MTCs were updated by considering the percentage of the voyage that will be made within the NE Atlantic ECA, and the fuel price information reported in sub-section 7.1.4

to apply a fuel price ratio to the voyage cost, based on the observed price difference between 0.50% S m/m and 0.10% S m/m fuels (23% difference in cost). Finally, the differences between the initial MTCs and the MTCs after the implementation of the NE Atlantic ECA were calculated. Table 34 and Table 35 show the average percentage increases in MTCs after the application of the NE Atlantic ECA by type of commodity group and ship type, respectively. The effect for specific commodities for the 2-digit level was also accessed.

Table 34. Average increases in MTCs after the application of the NE Atlantic ECA by type of commodity group, in percentage.

Commodity group	EU15 (%)	Denmark (Greenland) (%)	Iceland (%)	Faroe Islands (%)
Agriculture	0.480	1.242	0.805	1.242
Crude oil	0.368	-	-	-
Manufacturing	0.486	1.242	0.702	1.178
Raw material	0.364	0.920	0.599	0.920
Total	**0.481**	**1.204**	**0.719**	**1.170**

Table 35. Average increases in MTCs after the application of the NE Atlantic ECA ship type, in percentage.

Ship type	EU15 (%)	Denmark (Greenland) (%)	Iceland (%)	Faroe Islands (%)
Clean bulk	0.417	-	-	-
Containers	0.489	1.242	0.732	1.242
Dirty bulk	0.372	0.920	0.568	0.920
Tankers	0.303	-	-	-
Total	**0.481**	**1.204**	**0.719**	**1.170**

To assess the impact of NE Atlantic ECA implementation on the prices of key commodities for the NE Atlantic ECA IMO member states and associate members, a survey of their prices was conducted. Commodity prices were obtained from the World Bank Commodity Price Data (World Bank, 2023). The key commodities were based on information provided by the NE Atlantic ECA IMO member states and associate members regarding their main imports and exports. Initially, the portion of the commodity cost that corresponded to the transportation price was calculated, using the corresponding MTCs for the commodities and the distance of a typical voyage between NE Atlantic ECA IMO member states and associate members and others outside NE Atlantic ECA. The increase in transportation costs due to the implementation of NE Atlantic ECA was calculated, considering the new MTCs determined earlier. Finally, the increase in the final commodity price was calculated. As an example, soybeans transported by a clean bulk carrier from Buenos Aires to Algeciras can demonstrate the impact on the final price of this commodity due to changes caused by ECA implementation (fuel change). As previously mentioned, the fuel price increases by about 23%, which results in an approximate 0.1% increase in the freight rate for agricultural cargo on this route. Given that soybeans cost over €493 per tonne, the price change related to NE Atlantic ECA implementation per tonne of soybeans is less than 0.01%. Table 36 shows some examples of commodity prices and price changes per tonne of product for NE Atlantic ECA IMO member states and associate members before and after its implementation.

Table 36. Commodity prices and price change per tonne of product for NE Atlantic ECA IMO member states and associate members before and after NE Atlantic ECA implementation.

Area	Commodity	Commodity price before NE Atlantic ECA (€/tonne)	Commodity price after NE Atlantic ECA (€/tonne)	Price change per tonne of product (%)
Faroe Islands	Crude oil	432	432	0.039
	Shrimps	11 645	11 648	0.022
	Salmon	5 830	5 833	0.043
Denmark (Greenland)	Shrimps	11645	11 648	0.026
	Salmon	5 830	5 833	0.051
	Aluminum	2 092	2 093	0.078
Iceland	Shrimps	11 645	11 647	0.018
	Salmon	5 830	5 833	0.048
	Aluminum	2 092	2 093	0.078
EU15	Crude oil	432	432	0.014
	Beef	4 519	4 519	0.005
	Copper	7 881	7 882	0.003
	Gold	48 891 234	48 891 234	3.529E-07
	Rubber	363	363	2.050E-06

7.8.2. Impacts on cruise ships voyage prices

This sub-section describes the potential economic impact of NE Atlantic ECA implementation on cruise ship voyage prices. To assess the increase in costs, a survey was conducted on typical cruises passing through the NE Atlantic ECA designated area. Six cruise ships have been identified with annual routes that pass through the NE Atlantic ECA area. From these, four typical voyages were selected. For each voyage (AIS data from 2021 was used), the distance and time spent in other ECAs and outside ECAs were identified. Using this information, prices for cruises with similar voyages in 2024 (because it was difficult to obtain data for same voyages for 2021) were identified (CruiseMapper, 2024; Fred. Olsen Cruise Lines, 2024; Fusion Cruises, 2024; Princess Cruise Lines, 2024). Table 37 presents the distance and time that cruise ships spent within the NE Atlantic ECA, outside the NE Atlantic ECA, in all ECAs, and outside of ECAs per voyage.

Figure 38 to Figure 40 show the annual route maps for the ships from which the voyages were selected.

Table 37. Distance and time that cruise ships spent in NE Atlantic ECA, outside the NE Atlantic ECA, in all ECAs and outside of ECAs per voyage.

Area	Distance and Time	Voyage 1	Voyage 2	Voyage 3	Voyage 4
NE Atlantic ECA	Distance (nm[a])	1162	1526	1099	2000
	% of distance	40	45	66	47
	Time (h)	165	233	155	113
	% of time	45	53	62	32
Total Non-NE Atlantic ECA	Distance (nm)	1770	1846	564	2214
	% of distance	60	55	34	53
	Time (h)	201	210	96	235
	% of time	55	47	38	68
Total ECA	Distance (nm)	2932	3372	1662	4200
	% of distance	100	100	100	100
	Time (h)	366	443	251	347
	% of time	100	100	100	100
Total Non-ECA	Distance (nm)	0	0	0	14
	% of distance	0	0	0	0
	Time (h)	0	0	0	1
	% of time	0	0	0	0.3

[a] nm - nautical miles

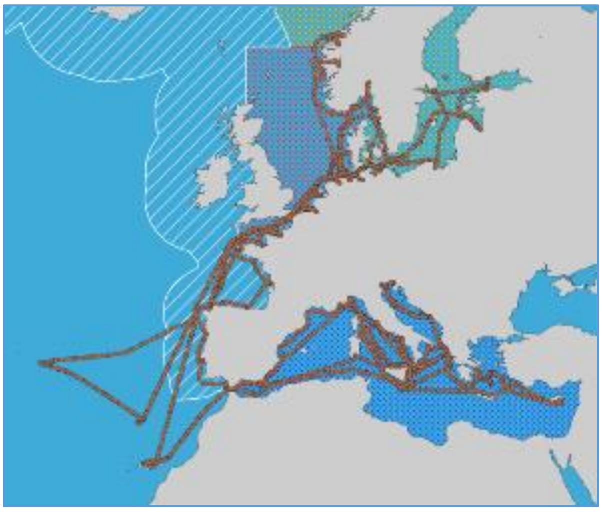

Figure 38: The annual route of the ship for which data from voyage 1 was analysed (ECAs delimited with lines and dots and NE Atlantic ECA delimited in white line with dashes)

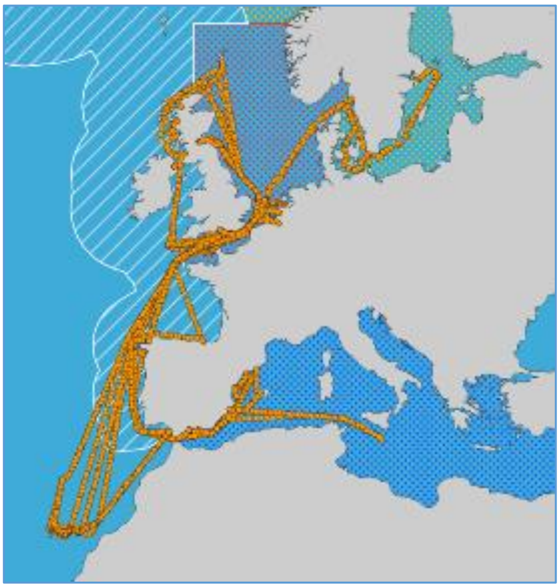

Figure 39: The annual route of the ship for which data from voyage 2 was analysed (ECAs delimited with lines and dots and NE Atlantic ECA delimited in white line with dashes)

Figure 40: The annual route of the ship for which data from voyages 3 and 4 was analysed (ECAs delimited with lines and dots and NE Atlantic ECA delimited in white line with dashes)

A similar methodology to that used in the previous sub-section has been applied to the collected prices. For cruise ships, fuel costs account for 30% of the total voyage cost (Bergqvist et al., 2015). The increase in voyage costs was then calculated by considering a 23% rise in fuel costs and the percentage of the voyage that the ship travels within the NE Atlantic ECA region. Table 38 presents the voyage prices before and after NE Atlantic ECA implementation and the expected percentage increase in prices. According to the results, cruise voyage prices are expected to increase by 2 to 4%, depending on the percentage of the distance that the ship sail within the NE Atlantic ECA designated area.

Table 38. Voyages prices before and after the NE Atlantic ECA implementation and percentage of prices increase.

Voyage	Cruise price before NE Atlantic ECA (€)	Cruise price after NE Atlantic ECA (€)	Price increase (%)
1	2 999	3 092	3.1
2	3 520	3 648	3.6
3	1 540	1 606	4.3
4	741	758	2.2

7.8.3. Impacts on the fishing sector and fish prices

This sub-section describes the impact of the NE Atlantic ECA implementation on the profitability of the fishing industry in the NE Atlantic ECA states and on fishing product prices. It is, however, very important to note that the analysis presented in this section only applies to vessels that do not yet use MGO, which represents, on average, only 5% of the fishing fleet in the area.

Fishing is an energy-intensive activity, where fuel costs are a major operational expense. It has been reported that fuel costs can represent between 20% and 50% of the operational costs for fishing vessels, depending on the size of the ship (Cheilari et al., 2013). To determine whether the fishing industry will remain profitable with the change of fuel due to the implementation of NE Atlantic ECA, research was conducted on the fuel prices used in 2021 by the fishing industry for the NE Atlantic ECA IMO member states and associate members. The cost values reported monthly by the European Market Observatory for Fisheries and Aquaculture Products (EUMOFA) were used. As it was not possible to obtain values for the Faroe Islands, Denmark (Greenland), and Iceland, an average value from nearby EU IMO member states and associate members was used. A 23% increase was applied to the 2021 prices to reflect the switch from 0.50% S m/m (VLSFO) to 0.10% S m/m fuel (MGO). Table 39 presents the monthly marine fuel prices for NE Atlantic ECA IMO member states and associate members before and after the implementation of the ECA.

Table 39. Marine fuel prices used by the fishing sector before and after the implementation of the NE Atlantic ECA.

IMO member states and associate members	Fuel price before NE Atlantic ECA (€/L)	Fuel price after NE Atlantic ECA (€/L)
France	0.46	0.56
Ireland	0.46	0.57
Portugal	0.46	0.57
Spain	0.49	0.60
UK	0.48	0.59
Faroe Islands, Denmark (Greenland) and Iceland	0.45	0.56

The prices after the implementation of the NE Atlantic ECA were compared with a break-even fuel price of 0.60 €/L, reported as the limit below which the EU fishing sector remains profitable (Guillen et al., 2023). For the United Kingdom the break-even fuel price reported is 1.35 €/L, which is more than double the EU value (Guillen et al., 2023; The Guardian, 2022). As shown in Table 39, the 0.60 €/L value was not exceeded. However, from February 2022, energy prices drastically increased drastically due to the Russian invasion of Ukraine. In 2022, the EU fishing sector paid an average of 0.93 €/L for marine diesel, with prices reaching 1.20 €/L in June 2022. In response, the EU has been subsidising the fishing sector to ensure its continued profitability. After fuel prices peaked at 1.20 €/L in 2022, prices have gradually fallen to 0.80-0.90 €/L in the first quarter of 2024 (European Commission (2024b)). In the future, with the implementation of the NE Atlantic ECA, it is expected that the fishing sector in the region will remain profitable, despite the challenges posed by the energy crisis.

To assess the impact of NE Atlantic ECA implementation on the price of fish caught and sold in NE Atlantic ECA IMO member states and associate members, data collected from the EUMOFA database were used. EUMOFA provides data on the retail prices of fish products collected from online stores through a price scraper. The data include products and online stores representative of the monitored national markets. Prices are collected daily and aggregated monthly. For the analysis, the average prices of wild-caught fish from 2021 to 2024 were considered. As the database did not include prices for the Faroe Islands, Greenland, and Iceland, the prices for Denmark were used as a reference. In the case of the United Kingdom, prices from the websites "*The Fresh Fish Shop*" and "*AO Seafoods Fish Distributors*" were used (AO Seafoods Ltd, 2024; The Fresh Fish Shop UK, 2024). To assess how the final consumer price of fish will increase with the implementation of NE Atlantic ECA, a sensitivity analysis was conducted by varying the percentage that fuel costs represent in fish prices. Table 40 presents the prices of wild-caught fish products (a few examples) by country before the implementation of NE Atlantic ECA and the projected costs after its implementation for different percentages (20%, 30%, 40% and 50%) of fuel costs on the product's final cost.

Table 40. Fish product prices before NE Atlantic ECA implementation and projected costs after its implementation for various percentages of fuel costs on the product's final cost.

Country	Product	Price before ECA (€/kg)	Fish product prices after ECA (€/kg)			
			20%	30%	40%	50%
Denmark	Cod fillets	31.00	32.42	33.14	33.85	34.56
	European plaice fillets	33.08	34.60	35.36	36.12	36.88
France	Gilthead seabream	10.14	10.60	10.84	11.07	11.30
	Seabass	11.09	11.60	11.86	12.11	12.37
Ireland	Cod fillets	20.75	21.71	22.18	22.66	23.14
Portugal	Gilthead seabream	9.03	9.44	9.65	9.86	10.06
	Seabass	8.15	8.53	8.71	8.90	9.09
Spain	Gilthead seabream	11.19	11.70	11.96	12.22	12.47
	Seabass	9.27	9.69	9.91	10.12	10.33
UK	Cod fillets	28.67	29.99	30.65	31.31	31.97
	Mackerel Fillets	28.79	30.11	30.78	31.44	32.10

8. Conclusions

This study evaluates the environmental and public health benefits of establishing the North East Atlantic Ocean Emission Control Area to reduce shipping emissions. Covering the territorial seas and exclusive economic zones of the autonomous territory of Faroe Islands, France, Denmark (Greenland), Iceland, Ireland, Portugal, Spain, and the United Kingdom, the NE Atlantic ECA would enforce stricter limits on sulphur oxides (SO_x), nitrogen oxides (NO_x), and particulate matter ($PM_{2.5}$).

Despite ongoing land-based air quality improvements, shipping remains a significant pollution source in the region. Implementing NE Atlantic ECA could reduce shipping-related pollution by 77–86% for SO_2, 31–59% for $PM_{2.5}$, and 3% for NO_2, depending on the fuel used for compliance. Population-weighted $PM_{2.5}$ exposure attributable to shipping could decrease by 35–54%, especially benefiting vulnerable populations, including indigenous Greenlandic Inuit communities, who face disproportionate health risks. Health benefits include preventing 118–176 premature deaths in 2030 and up to 4,300 deaths between 2030-2050, with cumulative economic benefits valued at €19–29 billion. The implementation of NE Atlantic ECA will improve visibility, and protect marine ecosystems by mitigating acidification and eutrophication, particularly in coastal areas of Portugal, Spain, the UK, Ireland, and Iceland. NE Atlantic ECA could protect over 1,500 marine protected areas, critical marine mammal habitats, and 148 UNESCO World Heritage sites by mitigating air pollutant deposition and ocean acidification, thus supporting regional biodiversity and cultural heritage preservation.

Favourable cost-benefit outcomes were obtained although fuel change to MGO seemed the most cost-effective strategy. Economic impacts on the maritime sector, including freight and cruise ship prices, will be moderate, with minimal effects on commodity prices. The profitability in the fishing sector will continue to be assured even with increased fuel costs.

9. References

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ANNEX 2

DESCRIPTION OF THE PROPOSED NORTH-EAST ATLANTIC ECA

The area of application of the proposed North-East Atlantic European ECA includes waters bounded in the North by the coasts of Norway, surrounding Iceland, Greenland and the Faroe Islands, the coasts of France and in the South of Europe by the coasts of mainland Portugal and Spain until the western entrance to the Straits of Gibraltar as follows:

.1 The area is adjacent to the North Sea area in the east; bound by latitude 62°N, longitude 4°W of the North Sea; and by latitude 48°30'N, longitude 5°W of the English Channel in line with the definition set out in MARPOL Annex V 1.14.6; and

.2 The area in the south is adjacent to the Mediterranean ECA in correspondence of the eastern entrance to the Straits of Gibraltar, defined as a line joining the extremities of Cape Trafalgar, Spain (36°11'N, 6°02'W) and Cape Spartel, Morocco (35°48'N, 5°55'W).

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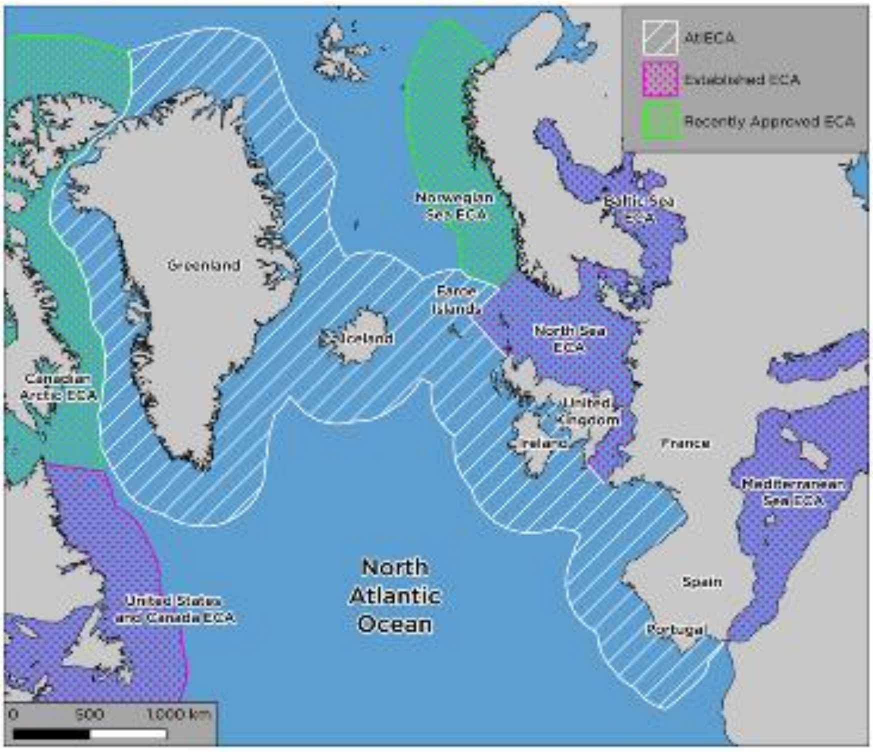
ANNEX 3

CHART OF THE PROPOSED NORTH-EAST ATLANTIC EMISSION CONTROL AREA

The area of application of the proposed NE Atlantic ECA includes waters shown in the chart below.



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ANNEX 4

PROPOSED AMENDMENTS TO REGULATIONS 13 AND 14 OF APPENDIX VII AND REGULATION 2 OF MARPOL ANNEX VI

(Designation of the North-East Atlantic as a new emission control area)

Note: The area proposed for ECA designation is the Atlantic area of North-East European coasts, including the gulfs and seas therein taking into account regulation 1.11.8 under Chapter 1 of MARPOL Annex I corresponding to the coordinates and the chart set out in annexes 2 and 3, respectively, to this document.

Regulation 13.5 and 13.6
Nitrogen Oxides (NO_X)

Tier III

At the end of regulation 13.5.1.3, a new sub-paragraph .2 is added as follows:

".2 that ship is constructed on or after 1 January 2027 and is operating in the North-East Atlantic Emission Control Area. For the North-East Atlantic Emission Control Area, "ship constructed on or after 1 January 2027" means a ship:

.1 for which the building contract is placed on or after [1 January 2027]; or

.2 in the absence of a building contract, the keels of which are laid or which are at the similar stage of construction on or after [1 January 2027]; or

.3 the delivery of which on or after [1 January 2027]."

Emission control area
A new sub-paragraph .7 is added to regulation 13.6 as follows:

".7 the North-East Atlantic Emission Control Area, which means the area described by the coordinates provided in appendix VII to this Annex."

Regulation 14.3
Sulphur oxides (SO_X) and particulate matter

A new paragraph .8 is added as follows:

".8 the North-East Atlantic Emission Control Area which means the area described by the coordinates provided in appendix VII to this Annex "

Appendix VII
Emission control areas (regulations 13.6 and 14.3)

New paragraphs 6 and 7 are inserted, as follows:

"6 The North-East Atlantic Emission Control Area (NE Atlantic ECA) encompasses the Exclusive Economic Zones (EEZ) and territorial seas, extending up to 200 nautical miles from the baselines, of Greenland, Iceland, the Faroe Islands, Ireland, the mainlands of the United Kingdom, France, Spain, and Portugal. This designation excludes the seas bounded by the North Sea area, as defined in regulation 1.14.6 of Annex V of the present Convention.

7 The geographic outer boundaries of the proposed NE Atlantic ECA are delineated by a series of geodetic lines connecting specified coordinates of latitude and longitude. These coordinates are referenced to the World Geodetic System 1984 (WGS 1984) datum and are presented in a clockwise order, as outlined below: *

.1 The northernmost outer boundary of the proposed NE Atlantic ECA begins at the point of intersection of the EEZ of Greenland and the Canadian Arctic area, as outlined in regulation 14.3 and appendix VII of MARPOL Annex VI, at the coordinate 86°19'.18 N, 60°10'.17 W. From this point, the boundary extends eastward, following the outer boundaries of the EEZs of Iceland, the Faroe Islands, and the eastern part of the mainland of the United Kingdom, until reaching the coordinate 62°00'.00 N, 01°22'.27 E, where it intersects with the northern boundary of the North Sea area. The boundary of this section is defined by connecting the following coordinates in sequential order:

* The exact coordinates are provisional and maybe subject to revision at a later stage. The coordinates relating to Ireland's EEZ will be provided at a later date by Ireland.

Point	Latitude	Longitude
1	86°19'.30 N	60°10'.28 W
2	86°57'.80 N	37°45'.68 W
3	86°39'.87 N	12°26'.95 W
4	85°37'.64 N	01°00'.60 E
5	83°42'.56 N	07°58'.17 E
6	82°20'.92 N	05°51'.60 E
7	79°52'.93 N	01°38'.37 W
8	78°19'.00 N	03°20'.63 W
9	76°59'.35 N	02°49'.70 W
10	76°03'.97 N	04°27'.87 W
11	75°18'.13 N	04°17'.90 W
12	74°30'.64 N	04°50'.57 W
13	72°49'.62 N	11°28'.77 W

Point	Latitude	Longitude
14	71°52'.99 N	12°46'.03 W
15	69°54'.98 N	13°37'.77 W
16	69°35'.00 N	13°16'.00 W
17	69°34'.77 N	12°24'.42 W
18	69°09'.46 N	09°42'.43 W
19	68°20'.93 N	07°34'.34 W
20	67°30'.09 N	06°32'.60 W
21	66°24'.66 N	05°45'.14 W
22	65°41'.60 N	05°34'.40 W
23	65°15'.62 N	02°38'.26 W
24	64°26'.05 N	00°29'.18 W
25	63°53'.25 N	00°29'.33 W
26	62°00'.00 N	01°22'.27 E

.2 Continuing from the coordinate 62°00'.00 N, 01°22'.27 E, the boundary proceeds along the northwestern outer limits of the North Sea area, as defined in regulation 1.14.6 of Annex V of the present Convention. The boundary excludes the area south of latitude 62°00'.00 N and east of longitude 04°00'.00 W, connecting the following coordinates:

Point	Latitude	Longitude
26	62°00'.00 N	01°22'.27 E
27	62°00'.00 N	04°00'.00 W
28	58°33'.94 N	04°00'.00 W

.3 Continuing southward, the boundary follows the southwestern outer limits of the North Sea area, as defined in regulation 1.14.6 of Annex V of the present Convention, excluding the English Channel and its approaches eastward of longitude 05°00'.00 W and northward of latitude 48°30'.00 N, until the boundary reaches its southernmost coordinate at 48°30'.00 N, 05°00'.00 W.

Point	Latitude	Longitude
29	48°30'.00 N	05°00'.00 W

.4 The following section of the NE Atlantic ECA extends southward from the coordinate 48°30'.00 N, 05°00'.00 W, until it reaches the intersection of two boundaries: the line joining Cape Trafalgar, Spain (36°11'.00 N, 06°02'.00 W), and Cape Spartel, Morocco (35°48'.00 N, 05°55'.00 W), as outlined in regulation 14.3 and this appendix; and the eastern outer limit of Spain's mainland EEZ at the coordinate 35°57'.59 N, 05°58'.27 W. This section of the NE Atlantic ECA encompasses the waters within the EEZ and territorial seas of the mainland territories of France, Portugal, and Spain. The area is bounded to the east by the coasts of these countries and to the west by the outer limits of their respective EEZ. The coordinates defining the outer limits, extending from the southernmost points northward, are as follows:

Point	Latitude	Longitude
30	35°57'.59 N	05°58'.27 W
31	35°57'.88 N	06°02'.14 W
32	35°57'.94 N	06°03'.00 W
33	35°57'.98 N	06°03'.48 W
34	35°58'.09 N	06°04'.90 W
35	35°55'.91 N	06°16'.72 W
36	35°54'.85 N	06°22'.58 W
37	35°54'.63 N	06°23'.83 W
38	35°53'.50 N	06°30'.25 W
39	35°53'.34 N	06°31'.23 W
40	35°52'.13 N	06°38'.74 W
41	35°51'.94 N	06°39'.54 W
42	35°49'.70 N	06°48'.66 W
43	35°49'.60 N	06°49'.22 W
44	35°49'.18 N	06°51'.55 W
45	35°48'.61 N	06°59'.14 W
46	35°48'.51 N	06°59'.81 W
47	35°47'.62 N	07°06'.03 W
48	35°46'.01 N	07°31'.75 W
49	35°46'.00 N	07°32'.00 W
50	35°26'.00 N	08°05'.00 W
51	35°19'.00 N	08°21'.00 W
52	35°11'.00 N	08°53'.00 W
53	35°07'.00 N	09°13'.00 W
54	35°01'.00 N	10°30'.00 W
55	34°55'.00 N	11°40'.00 W
56	34°57'.00 N	12°17'.00 W
57	37°00'.00 N	13°09'.00 W
58	38°10'.00 N	13°42'.00 W
59	38°43'.00 N	13°46'.00 W
60	41°09'.00 N	13°16'.00 W
61	41°23'.77 N	13°18'.00 W
62	41°24'.03 N	13°17'.61 W
63	41°24'.04 N	13°17'.61 W
64	41°28'.00 N	13°18'.00 W
65	41°29'.12 N	13°19'.54 W
66	41°30'.12 N	13°20'.50 W
67	41°30'.99 N	13°21'.34 W
68	41°35'.55 N	13°25'.32 W

69	41°44'.00 N	13°30'.10 W
70	41°54'.17 N	13°35'.21 W
71	42°04'.57 N	13°39'.38 W
72	42°15'.70 N	13°43'.28 W
73	42°24'.69 N	13°45'.77 W
74	42°31'.79 N	13°47'.34 W
75	42°39'.44 N	13°48'.60 W
76	42°52'.53 N	13°50'.12 W
77	43°00'.67 N	13°50'.66 W
78	43°09'.85 N	13°50'.86 W
79	43°18'.03 N	13°50'.54 W
80	43°27'.44 N	13°49'.62 W
81	43°41'.45 N	13°47'.12 W
82	43°57'.73 N	13°42'.42 W
83	44°10'.36 N	13°37'.36 W
84	44°20'.93 N	13°32'.09 W
85	44°25'.70 N	13°29'.41 W
86	44°33'.99 N	13°24'.15 W
87	44°43'.13 N	13°17'.74 W
88	44°55'.81 N	13°08'.03 W
89	45°01'.23 N	13°03'.33 W

90	45°01'.37 N	13°03'.21 W
91	45°07'.52 N	12°57'.42 W
92	45°14'.79 N	12°49'.94 W
93	45°22'.20 N	12°41'.48 W
94	45°29'.33 N	12°32'.60 W
95	45°35'.60 N	12°23'.73 W
96	45°43'.59 N	12°11'.30 W
97	45°50'.60 N	11°59'.37 W
98	46°02'.77 N	11°37'.11 W
99	46°08'.97 N	11°24'.71 W
100	46°15'.55 N	11°09'.69 W
101	46°21'.12 N	10°55'.44 W
102	46°25'.27 N	10°47'.40 W
103	46°29'.31 N	10°39'.08 W
104	46°32'.75 N	10°31'.66 W
105	46°37'.94 N	10°19'.19 W
106	46°42'.62 N	10°06'.98 W
107	46°45'.83 N	09°58'.26 W
108	46°48'.86 N	09°48'.96 W
109	46°52'.16 N	09°37'.92 W
110	46°52'.73 N	09°35'.99 W

.5 Continuing from the coordinate 46°52'.73 N, 09°35'.99 W, the boundary proceeds in a northern direction, following the western outer limits of the EEZ of the mainland of the United Kingdom, Ireland, Iceland, the Faroe Islands, and Greenland, until it reaches the southernmost intersection of the EEZ of Greenland and the Canadian Arctic ECA, at the coordinate 61°24'.74 N, 57°16'.16 W, as detailed in regulation 14.3 and this appendix. The coordinates for this section are as follows:

Point	Latitude	Longitude
111	48°10'.49 N	10°48'.56 W
112		
113		
114		
115		
116		
117		
118		
119		
120		
121		
122		
123		
124		
125		
126		
127		
128		
129	56°57'.19 N	14°36'.16 W
130	57°25'.36 N	14°48'.11 W
131	57°46'.48 N	14°52'.42 W
132	58°10'.58 N	14°52'.18 W
133	58°37'.54 N	14°47'.13 W
134	59°08'.50 N	14°29'.17 W
135	59°36'.59 N	14°03'.25 W
136	59°55'.59 N	13°37'.56 W
137	60°09'.13 N	13°16'.39 W
138	60°42'.23 N	14°00'.03 W
139	60°09'.28 N	17°03'.21 W
140	59°58'.44 N	20°22'.34 W
141	60°03'.00 N	22°08'.29 W
142	60°31'.10 N	25°30'.33 W
143	60°55'.19 N	27°17'.15 W
144	61°31'.52 N	28°48'.06 W
145	62°14'.11 N	29°52'.18 W
146	63°18'.12 N	30°52'.05 W
147	62°30'.13 N	33°39'.15 W
148	61°24'.86 N	35°02'.45 W
149	58°10'.71 N	37°39'.21 W
150	57°12'.46 N	39°29'.13 W
151	56°31'.75 N	42°11'.97 W
152	56°23'.72 N	44°27'.68 W
153	56°42'.83 N	47°08'.20 W
154	57°52'.48 N	51°48'.36 W
155	58°41'.66 N	53°40'.40 W
156	61°24'.74 N	57°16'.16 W

.6 Continuing along the common points between the EEZ of Greenland and the Canadian Arctic ECA until reaching the northernmost outer boundary of the NE Atlantic ECA at the intersection of the EEZ of Greenland and the Canadian Arctic ECA (Point 1), at the coordinates 86°19'.18 N, 60°10'.17 W. The coordinates for this section are as follows:

Point	Latitude	Longitude
157	63°35'.00 N	58°02'.00 W
158	66°37'.15 N	57°39'.10 W
159	67°27'.05 N	57°54'.15 W
160	68°25'.05 N	58°42'.07 W
161	69°29'.06 N	60°51'.10 W
162	70°33'.02 N	61°17'.06 W
163	72°06'.07 N	63°30'.15 W
164	73°25'.15 N	66°25'.05 W
165	74°44'.03 N	72°53'.00 W
166	76°41'.06 N	75°00'.00 W
167	77°30'.00 N	74°46'.00 W
168	78°48'.08 N	73°00'.00 W
169	79°39'.00 N	69°20'.00 W
170	80°25'.00 N	68°20'.00 W
171	80°45'.00 N	67°07'.12 W
172	82°24'.83 N	58°59'.72 W
173	83°35'.80 N	56°51'.48 W
174	84°21'.79 N	56°28'.88 W
175	85°50'.08 N	57°57'.22 W

"