MEDITERRANEAN ACTION PLAN (MAP)
REGIONAL MARINE POLLUTION EMERGENCY RESPONSE CENTRE FOR THE MEDITERRANEAN SEA (REMPEC)

Sixteenth Meeting of the Focal Points of the Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC)

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Agenda Item 7: Air Pollution from ships

Study on the Environmental and Legal Impacts of the Use of Exhaust Gas Cleaning Systems (EGCS) in the Mediterranean Sea

Note by the Secretariat

This document presents the Study on the Environmental and Legal Impacts of the Use of Exhaust Gas Cleaning Systems (EGCS) in the Mediterranean Sea.

Background

1 The entry into effective implementation of the Mediterranean Sea Emission Control Area for Sulphur Oxides and Particulate Matter (Med SOx ECA), on 1 May 2025, will bring along new environmental and legal challenges to Mediterranean coastal States. Inter alia, the use of Exhaust Gas Cleaning Systems (EGCS) may give raise to both environmental and legal challenges.

2 In this context, the Secretariat commissioned Drewry Maritime Services, to prepare a Study on the Environmental and Legal Impacts of the Use of Exhaust Gas Cleaning Systems (EGCS) in the Mediterranean Sea, hereinafter referred to as the Study, in order to support any possible future regulatory or policy action by the Contracting Parties to the Barcelona Convention, in their efforts towards the consistent implementation of the Med SOx ECA.

3 The Study was carried out, pursuant to the Programme of Work and Budget for 2024-2025 of the Mediterranean Action Plan (MAP) of the United Nations Environment Programme (UNEP), adopted by the Twenty-third Ordinary Meeting of the Contracting Parties to the Barcelona Convention and its Protocols (Portorož, Slovenia, 5-8 December 2023).

4 This activity was financed by the Integrated Technical Cooperation Programme (ITCP) of the International Maritime Organization (IMO) and the voluntary contribution from the Italian Ministry for Environment and Energy Security.

5 The Study is presented in the **Appendix** to the present document.

Action requested by the Meeting

6 **The Meeting is invited to take note** of the information provided in the present document.

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Appendix

Study on the Environmental and Legal Impacts of the Use of Exhaust Gas Cleaning Systems (EGCS) in the Mediterranean Sea

MEDITERRANEAN ACTION PLAN (MAP)
REGIONAL MARINE POLLUTION EMERGENCY RESPONSE CENTRE FOR THE MEDITERRANEAN SEA (REMPEC)

Final Report

Study on the Environmental and Legal Impacts of the Use of Exhaust Gas Cleaning Systems (EGCS) in the Mediterranean Sea

Prepared by Drewry Maritime Services, January 2025

This activity is financed by the Integrated Technical Cooperation Programme (ITCP) of the International Maritime Organization (IMO) and the voluntary contribution from the Italian Ministry for Environment and Energy Security and is implemented by the Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC), in cooperation with the International Maritime Organization (IMO).

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Abbreviations

Short form	Full name
AIS	Automatic Identification System
APMs	Associated Protective Measures
BBNJ agreement	Agreement on the Marine Biological Diversity of Areas beyond National Jurisdiction
BC	Black Carbon
BDN	Bunker Delivery Note
BPA	British Port Association
BSH	Federal Maritime and Hydrographic Agency
CBD	Convention on Biological Diversity
CEFAS	Centre for Environment Fisheries and Aquaculture Science
CO_2	Carbon Dioxide
CPs	Contracting Parties to the Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean (the “Barcelona Convention”)
CPA	Cyprus Port Authority
CSB	Coastal Soft Bottoms
DEHP	Di(2-ethylhexyl) phthalate
DHI	Danish Hydraulics Institute
DMA	Distillate Marine Fuel Grade
DMZ	Distillate Marine Fuel Grade
DOI	Digital Object Identifier
EC	European Commission
ECA	Emission Control Area
EEZ	Exclusive Economic Zone
EF	Emission Factor
EGCS	Exhaust Gas Cleaning System
EGCSA	Exhaust Gas Cleaning System Association
EM Generator	Emergency Generator
EPA	U.S. Environmental Protection Agency
ETM	EGCS Technical Manual
EU	European Union
EWQS	European Water Quality Standard
FAO	Food and Agriculture Organisation
FNU	Formazin Nephelometric Units
FOEI	Friends of the Earth International
GEnS	Good Environmental Status
GESAMP	Group of Experts on the Scientific Aspects of Marine Environmental Protection
GFOP	Green Fuels Optionality Project
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
Gt	Gigatonnes
HAA	Haloacetic acid

HFO	Heavy Fuel Oil
Hz	Hertz
IAEA	International Atomic Energy Agency
IAPP	International Air Pollution Prevention
ICCT	International Council on Clean Transportation
ICES	The International Council for the Exploration of the Sea
IMO	International Maritime Organization
ISA	International Seabed Authority
LSMGO	Low Sulphur Marine Gas Oil
MAP	Mediterranean Action Plan
MARPOL	International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978
MCR	Maximum Continuous Rating
MDO	Marine Diesel Oil
MEA	Multilateral Environmental Agreement
Med SO_x ECA	Mediterranean SO_x Emission Control Area
MEPC	Marine Environment Protection Committee
MGO	Marine Gas Oil
MMMCZCS	Maersk Mc-Kinney Moller Center for Zero Carbon Shipping
MoU	Memorandum of Understanding
MSFD	Marine Strategy Framework Directive
NaOH	Sodium Hydroxide
NECA	Nitrogen Emission Control Area
NO_x	Nitrogen Oxide
NTU	Nephelometric Turbidity Units
OCCS	Onboard Carbon Capture and Storage
OMM	Onboard Monitoring Plan
OpEx	Operational Expenses
OSPAR	Oslo and Paris Convention for the Protection of the Marine Environment of the North-East Atlantic
PAH	Polycyclic Aromatic Hydrocarbons
PAHphe	Phenanthrene equivalence
PECs	Predicted Environmental Concentrations
PFAS	Perfluoroalkyl and polyfluoroalkyl substances
pH	Potential of Hydrogen
PM	Particulate Matter
PNEC	Predicted No-effect Concentration
POS	Posidonia Oceanica Beds
PPM	Parts Per Million
PPR	Pollution Prevention and Response
PRF	Port Reception Facility
PSC	Port State Control
PSSA	Particularly Sensitive Sea Area
RBINS	Royal Belgian Institute of Natural Sciences

REMPEC	Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea
RIF	Rocky Intertidal Fringe
SECA	Sulphur Emission Control Area
SECC	SO_x Emission Compliance Certificate
SECP	SO_x Emission Compliance Plan
SI	International System of Units
SO_2	Sulphur Dioxide
SO_x	Sulphur Oxide
SSR	Shallow Subtidal Reefs
STEAM	Ship Traffic Emission Assessment Model
TSS	Traffic Separation Scheme
UK	United Kingdom of Great Britain and Northern Ireland
UKMPG	UK Major Ports Group
ULSFO	Ultra Low Sulphur Fuel Oil
UN	United Nation
UNCLOS	United Nations Convention on the Law of the Sea
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO-IOC	Intergovernmental Oceanographic Commission of United Nations Educational, Scientific and Cultural Organisation
UNIDO	United Nations Industrial Development Organisation
USA	United States of America
UTC	Universal Coordinated Time
VLSFO	Very Low Sulphur Fuel Oil
WDR	Waste Delivery Receipts
WET	Whole Effluent Testing
WFD	Water Framework Directive
WMO	World Meteorological Organisation
EIHA	Environmental Impacts of Human Activities

1 Executive summary

Growing concerns about the pollution generated by ships in the air as well as in the sea have forced the International Maritime Organization (IMO) to work on frameworks that can mitigate the global environmental impact of the shipping industry. Sulphur oxides (SO_x) and Particulate Matter (PM) are harmful to humans and the environment, and therefore, the designation of Emission Control Areas (ECAs) was introduced as an amendment to the International Convention for the Prevention of Pollution from Ships (MARPOL) to curtail SO_X and PM emissions and protect marine diversity and ecosystems.

There are presently four ECAs for sulphur emissions under MARPOL Annex VI and three new regions have been approved as ECA. The Mediterranean Sulphur Emission Control Area (Med SO_x ECA) will enter into effective implementation as of 1 May 2025, followed by the Norwegian Sea and Canadian Arctic Sulphur ECA from 1 March 2027. With the implementation of the Norwegian Sea ECA and Med SO_x ECA, ship operators will be dealing with a new scenario where these new ECAs, along with the existing North Sea and Baltic Sea ECA, form a European super emission control area.

The Mediterranean Sea is an important waterway for trade and tourism accounting for 20% of the global seaborne trade, and is, therefore, exposed to higher levels of SO_x and PM emissions. The implementation of stringent measures with the Med SO_x ECA will help the Mediterranean region to reduce damage to the environment because of dense traffic shipping. MARPOL Annex VI Regulation 4 allows equivalent means to comply with other regulations of Annex VI. One such equivalent is the Exhaust Gas Cleaning System (EGCS) which allows ships to continue using fuel oils with sulphur content exceeding regulated values by reducing their SO_x emissions through the treatment of exhaust gas. EGCS, coequally called scrubber, is designed to reduce SO_X emissions with an operating principle where sulphur compounds in the flue gases react with the water and form various compounds that get dissolved in water and do not escape along with flue gases into the atmosphere. To comply with Med SO_x ECA requirements, ships will have to switch from Very Low Sulphur Fuel Oil (VLSFO) with 0.50% sulphur content to low sulphur marine gas oil (LSMGO) with 0.10% sulphur content. EGCS, which was initially intended to reduce SO_x emissions from Heavy Fuel Oil (HFO) with sulphur content of 3.50% to 0.50%, can now reduce sulphur emission to below 0.10%. This means vessels may run on HFO while emitting similar amounts of SO_x as they would be emitting while operating on LSMGO. However, other measures such as the use of multi-fuel and alternative fuel can also be opted for when necessary.

EGCS has gained momentum for use on ships to mitigate SO_x emissions. However, many coastal States are restricting the use of EGCS because of the resulting water pollution. The IMO Resolution Marine Environment Protection Committee (MEPC), 259(68) on 2015 Guidelines for Exhaust Gas Cleaning Systems (Annex I), under MARPOL Annex VI applies when ships install EGCS to comply with MARPOL Annex VI.

Emission reductions by ships operating in the Mediterranean Sea area are expected to reduce SO_x by 79% and $PM_{2.5}$ by 24% after the implementation of Med SO_x ECA. In order to implement Med SO_x ECA effectively, all Mediterranean coastal States need to be ratified to MARPOL Annex VI. However, five Contracting Parties to the Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean (the “Barcelona Convention”) (CPs) have not as yet, ratified MARPOL Annex VI.

Wet ECGS is commonly used for marine purposes and is categorised as open-loop, close-loop and hybrid EGCS. In open-loop, washwater is discharged at sea, in close-loop small bleedoff water is discharged while hybrid EGCS can be used in either open- or close-loop. Regulations to reduce SO_x and fuel price spread between HFO, VLSFO and LSMGO are the key drivers for the popularity of EGCS.

After the installation of the EGCS on vessels, its compliance requires a proper emission monitoring system termed exhaust gas monitoring system. In accordance with Regulation 14 of MARPOL Annex VI there should be an SO_x Emission Compliance Plan (SECP) for the ship. The monitoring is also carried out for pH, PAHs, Turbidity and Nitrates of the washwater discharge. It is to be noted that the efficiency of open-loop EGCS drops considerably when seawater pH is lower or in freshwater while the efficiency of close-loop/hybrid EGCS is not affected as the washing medium remains freshwater.

There are global resolutions, regulations and guidelines that support measures such as implementation of ECAs. Certain global laws, such as the United Nations Convention on the Law of the Sea (UNCLOS), mention how the State may establish large maritime zones outside the territorial sea.

The IMO also classifies certain sensitive areas as Particularly Sensitive Sea Area (PSSA) for their ecological, socio-economic and scientific importance which may be very sensitive to damage caused by international shipping. Certain areas of the Mediterranean have already been declared as PSSA, but a more detailed study should be carried out to consider including the larger areas such as Natura 2000[1] because of the detrimental effects of washwater discharge in the entire region of the Mediterranean Sea. When an area is approved by the IMO as PSSA, specific measures can be adopted to control the maritime activities in that area.

The Water Framework Directive (WFD) and the Marine Strategy Framework Directive (MSFD) are two directives of the European Union (EU) that can be reviewed for a consensus among Contracting Parties to the Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean (the “Barcelona Convention”). The WFD prohibits the deterioration of water quality and the activities that deteriorate the ecological or chemical status of seawater. The objective of the MSFD is to achieve and maintain Good Environmental Status (GEnS) in the EU's marine areas. Marine strategies need to be developed and implemented to prevent and reduce discharges into the marine environment with the long-term aim of phasing out certain pollutants. The geographic scope of the MSFD covers the area from the coastline up to and including the Exclusive Economic Zone (EEZ). With various reforms introduced globally in the field of EGCS, certain MEPC circulars are also approved such as MEPC.1/Circ.899, containing guidelines that provide information on the recommended methodology for risk and impact assessments of the EGCS discharge water that Member States ratified to MARPOL Annex VI should follow when considering local or regional regulations to protect the sensitive waters/environment.

Ongoing discussions at IMO, recalled the duty of Parties to MARPOL Annex VI to not impair or damage the environment, human health, property or resources when approving alternative compliance methods and reflects the importance of not interpreting Regulation 4 of MARPOL Annex VI in isolation of other regulations and obligations. It also refers to the precautionary principle, which States that the absence of adequate scientific information should not be used as a reason to postpone measures for preventing environmental degradation and, therefore, support the ban or restrictions of EGCS. In addition, an agenda on legal analysis of the use of EGCS outlined that EGCS should not be regarded as an alternative compliance method under Regulation 4 of MARPOL Annex VI, which is also discussed.

It should be noted that MARPOL Annex VI does not specifically limit PM, but this is reduced by lowering the sulphur content of the fuel oil. In addition, there are no regulations under MARPOL in

[1] Natura 2000 is the largest network of protected areas in the world protecting more than 27,000 nature sites under the EU legislation established in 1992.

relation to EGCS washwater discharge, and although there are guidelines for it, a few Mediterranean Coastal States have individually taken initiatives to restrict the discharge in their seas. More than 50% of the Contracting Parties to the Barcelona Convention have developed local regulations or policies to restrict the discharge of washwater in areas within the control of the States or port authority. Of these, authorities in 24% of States have imposed restrictions beyond their port areas. However, at present there is no comprehensive policy regarding the ban/restriction for the discharge of EGCS washwater in the Mediterranean region as a whole.

MEPC adopted guidelines for Port Reception Facilities (PRF) under MARPOL Annex VI which require all Parties to MARPOL Annex VI to ensure that ports and terminals have the capacity to collect and store EGCS residues.

There were various environmental studies carried out on EGCS washwater discharge, which have produced conflicting results, and some studies also identified gaps in the scientific data of many contaminants. Estuaries and coastal waters contain pollutants, such as naphthalene that are part of the 'priority hazardous substance' list, which cause reduced egg production, higher deformations and abnormal development of the larvae of the species, in addition to most cancer-causing PAHs found in marine environments from open-loop EGCS and death of copepods from exposure to close-loop EGCS samples. However, some studies also found that the risks to marine life are within acceptable limits.

During the EMERGE project, it was found that many important shipping lanes run close to shore and archipelago areas in the Mediterranean region, threatening the coastal ecosystem. The study concluded that it is merely moving the problem from the atmosphere to the hydrosphere, which in turn increases the exposure of toxicants such as vanadium, PAHs and alkylated PAHs to marine biota. It was also found that the ecotoxicological effects were mostly related to alkylated PAHs. The exclusion of alkylated PAHs from EGCS washwater discharge criteria is unfortunate as it causes major toxicological effects. Therefore, it is possible that EGCS criteria can comply with the current guidelines but still harm the marine environment.

While the implementation of the Med SO_x ECA will improve air quality in the Mediterranean region, the EGCS washwater from ships plying in the region could create other environmental challenges, as the exchange rates[2] reduction during winter can lead to heavy concentrations of PAHs that are hazardous for marine species and human health.

The survival of the coastal and inland saline wetlands and coastal benthic[3] ecosystems in the Mediterranean Sea will be a challenge as they are subjected to EGCS washwater discharges. A major concern was evident for Shallow Subtidal Reefs[4] (SSR) for which two-thirds of the sites showed moderate-to-bad ecological status.

[2] The Mediterranean has been metaphorically described as breathing—i.e., inhaling surface water from the Atlantic and exhaling deep water in a counter-current below. Current is most strong in the summers when evaporation in the Mediterranean is at its peak resulting in sufficient exchange of water. In winter, evaporation reduces which lowers the rate of exchange between the Atlantic water and Mediterranean water.

[3] The term benthic refers to anything associated with or occurring on the bottom of a body of water.

[4] Shallow/nearshore reefs (2-15 metre deep) are dominated by kelp and other seaweeds, and are among the most productive habitats in the world.

Some States/regions, such as Sweden and OSPAR, are setting examples by coming up with stricter proposals for banning EGCS. As per the Swedish Government, any washwater discharge from EGCS in the State's maritime territory is prohibited and has thus proposed the ban in two steps. First, from 1 July 2025, emissions from EGCS operating in open-loop mode will be prohibited, and thereafter from 1 January 2029, emissions from all types of EGCS, including those used in close-loop mode, will be prohibited. The CPs of the Oslo and Paris Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR) Convention[5] carried out a modelling study and found that most of the effluent discharges are within the 200 nautical mile zones of the OSPAR region and related to open-loop EGCS.

The implementation of the Med SO_x ECA in the Mediterranean Sea will be a major step in reducing SO_x emissions. However, a higher spread between HFO and LSMGO may encourage the use of EGCS in this region, which will create challenges. The current environmental policies with a primary focus on air pollution, a lack of proper data for evaluation and the exclusion of alkylated PAHs create challenges in assessing the effectiveness of the measures to reduce SO_x and PM and the lack of comprehensive water quality guidelines and the absence of metal concentration from EGCS revised guidelines from (MEPC 2015, 2018 and 2021) also present risks to marine life and coastal populations.

CPs to the Barcelona Convention need to align their national legislation and establish sufficient port reception facilities for implementing regulation and proper handling of EGCS residue. Promotion of Dry EGCS technology and Onboard Carbon Capture and Storage (OCCS), along with funding various research and studies for overcoming the ill effects of discharge water from EGCS, also need to be prioritised.

Reduction in the exchange rate of seawater in the Mediterranean Sea during winter and dependency of open-loop EGCS on seawater alkalinity needs to be taken into consideration to study the effects of discharge water from open-loop EGCS and national, sub-national and port level restrictions to be considered. A holistic approach to emphasise the use of Hybrid EGCS, approval for sensitive areas under PSSA, and training the related workforce to be considered for framing short-, mid- and long-term strategy.

It can be concluded that the present environmental policies in shipping focus on air pollution assessment and its impact on climate change and human health, and could be biased against the impact on the marine environment.

Overall, with reference to various studies and environmental assessments, it can be seen that the open-loop EGCS is hazardous to marine ecosystems. The Mediterranean coastal States need to carry out an environmental impact assessment of the whole Mediterranean region and align their national law and policies to achieve good GEnS. Training and funding concerning upcoming technologies and newer regulations will also help the implementation of the Med SO_x ECA and further actions concerning washwater discharge from the EGCS.

[5] The CPs for this Convention are Belgium, Denmark, the EU, Finland, France, Germany, Iceland, Ireland, Luxembourg, the Netherlands (Kingdom of the), Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

2 Introduction to regulations and legislation related to Sulphur Oxide (SO_x) emission

This section introduces regulations and legislation requirements related to sulphur oxide (SO_x) emissions in the maritime sector. The Mediterranean Sea is an important waterway for trade and tourism and is exposed to air pollution through various sources including SO_x and Particulate Matter[6] (PM) from the shipping industry.

There is a growing concern globally on pollution generated by ships and the International Maritime Organization (IMO) as well as the European Union (EU) has been continuously working on legal frameworks that can mitigate the global environmental impact of the shipping industry. The designation of Emission Control Areas (ECAs)[7] was introduced as an amendment to the International Convention for the Prevention of Pollution from Ships (MARPOL) through the Marine Environment Protection Committee (MEPC) circular MEPC.1/Circ.778/Rev.4 to curtail emissions and protect marine diversity and ecosystems.

The mitigation of SO_x emissions using Exhaust Gas Cleaning Systems (EGCS), colloquially termed “scrubbers” is gaining momentum for being used on ships. However, many coastal States are restricting their use because of the resulting water pollution.

Global and regional regulations for sulphur emissions have been implemented in different parts of the world to preserve biodiversity and human health. As a result, shipowners, operators, ports and the maritime industry will be able to address environmental challenges, which will support emission reduction technologies and green fuels to achieve sustainability.

2.1 SO_x regulations

The International Convention for the Prevention of Pollution from Ships (MARPOL) is the main international convention covering the prevention of pollution of the marine environment by ships from operational or accidental causes. This Convention currently includes six technical Annexes.

.1 **Annex I** Regulations for the Prevention of Pollution by Oil.

.2 **Annex II** Regulations for the Control of Pollution by Noxious Liquid Substances in Bulk.

.3 **Annex III** Prevention of Pollution by Harmful Substances Carried by Sea in Packaged Form.

.4 **Annex IV** Prevention of Pollution by Sewage from Ships.

.5 **Annex V** Prevention of Pollution by Garbage from Ships.

.6 **Annex VI** Prevention of Air Pollution from Ships.

In MARPOL, general requirements to reduce air pollution due to sulphur emissions are provided in Regulation 14 of Annex VI and are mentioned below:

[6] PM is a complex mixture of particles and liquid droplets, generally from unburned fuel, oil and incombustible, and which consists of a number of components, including acids (such as nitrates and sulphates), organic chemicals, metals, and soil or dust particles. $PM_{2.5}$ and PM_{10} are the two types of air pollution, the “10” and the “2.5” refer to microns.

[7] Emission Control Areas (ECAs) are defined under MARPOL Annex VI as areas where the adoption of special mandatory measures to regulate emissions from ships is required to prevent, reduce and control air pollution from NO_x and/or SO_x and/or PM.

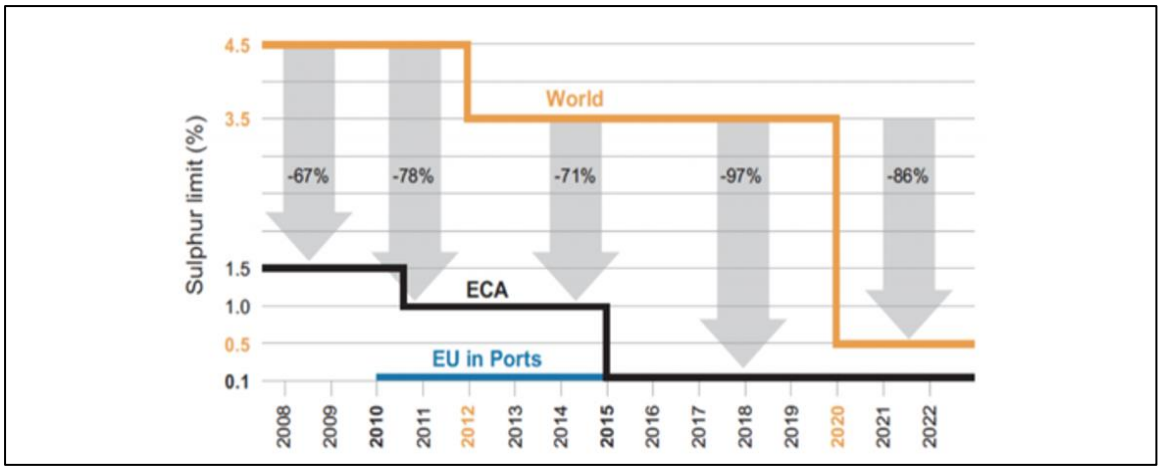
.1 The sulphur content of any fuel oil used on board ships shall not exceed the following limits:

- 4.50% m/m[8] prior to 1 January 2012;
- 3.50% m/m on and after 1 January 2012; and
- 0.50% m/m on and after 1 January 2020.

.2 While ships are operating within an ECA, the sulphur content of fuel oil used on board ships shall not exceed the following limits:

- 1.50% m/m prior to 1 July 2010;
- 1.00% m/m on and after 1 July 2010; and
- 0.10% m/m on and after 1 January 2015.

Figure 1 MARPOL sulphur limits timeline



Source: Sustainable ships, IMO

The revision of MARPOL 73/78 Annex VI Regulation 14 on SO_x and PM, came into effect on 1 January 2020, whereby the sulphur content of fuel oil used on ships was limited to a maximum of 0.10% in ECAs and 0.50% limit was implemented when ships are in the open sea. The burning of these fuels includes the main engine, the auxiliary engine and the boilers.

The MARPOL 73/78 Annex VI Regulation 4 allows equivalent means to comply with other regulations of Annex VI. One such equivalent is the Exhaust Gas Cleaning System (EGCS) which allows ships to continue using fuel oils with sulphur content exceeding regulated values by reducing their SO_x emissions through the treatment of exhaust gas.

It should be noted that MARPOL Annex VI does not specifically limit PM but this is reduced by reducing the sulphur content of the fuel oil.

[8] % *m/m* (percentage, mass in mass) expresses the number of grams of substance in 100 g of final product in percentage terms

In order to comply with the regulation, the following actions are recommended by IMO and MEPC.259(68) for port States, flag States, shipowners, shipbuilders and fuel oil suppliers.

.1 Multi-fuel: This is to carry two or more separate fuels (one with sulphur not exceeding 0.1%m/m and another with sulphur not exceeding 0.5%m/m) and use them accordingly.

.2 Changing to alternate fuels: Vessels can change to alternate fuels such as LNG, methanol, etc. whose sulphur content is not exceeding 0.1% m/m

.3 EGCS: Alternatively, EGCS can be used.

2.2 Sulphur Emission Control Area (SECA)

IMO under MARPOL Annexes I, IV, V and VI has categorised the areas that need the utmost attention to protect marine biodiversity and ecological systems as Special areas and ECAs. Special areas are defined as sea areas where, for recognized technical reasons in relation to their oceanographical and ecological conditions and to the particular character of their sea traffic, the adoption of special mandatory methods for the prevention of pollution of the sea from ships by oil, sewage or garbage, as applicable, is required. ECAs are related to a major concern of air pollution.

ECAs are provided with a higher level of protection than other seas. When Parties to the MARPOL Convention enforce controls to minimise airborne emissions from ships where controlled emissions are SO_x and PM, it is defined as Sulphur emission control area (SECA), whereas when these measures are related to emissions from NO_x, such areas are defined as Nitrogen emission control area (NECA). IMO has defined various SECA under MARPOL Annex VI.

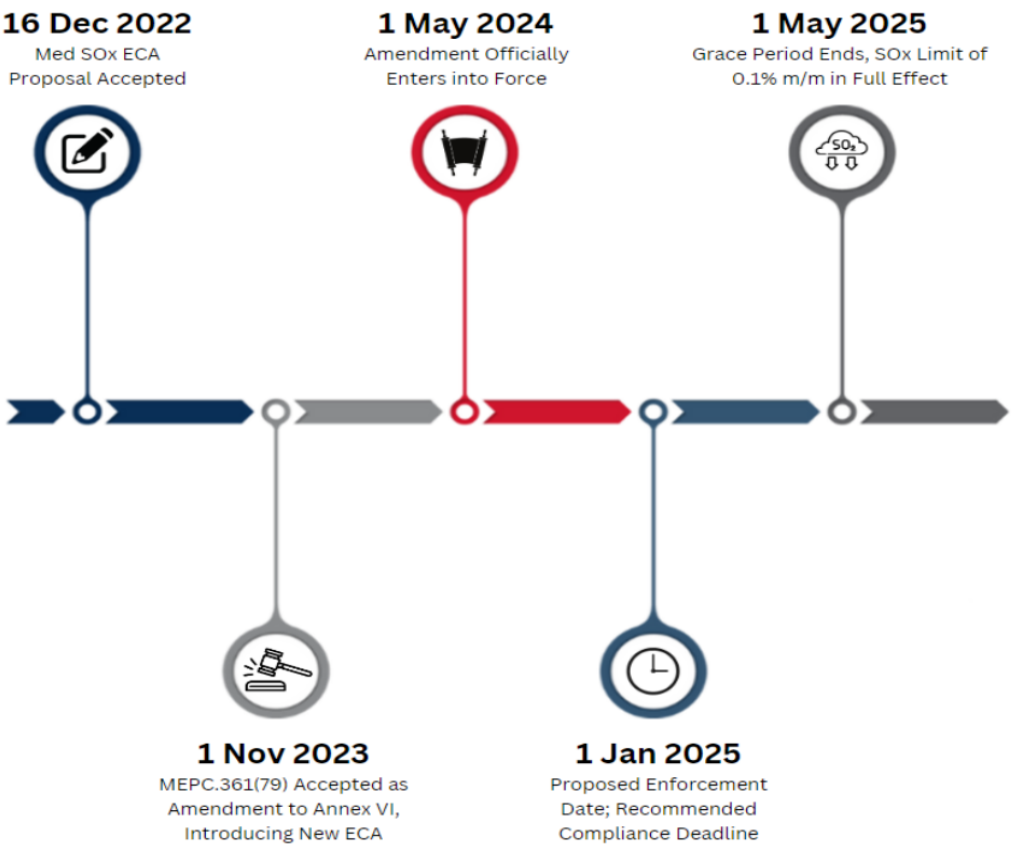
Table 1 List of SECA areas

Emission Control Areas	Amendments adopted to the MARPOL Annex	Entry into force of the amendments	More stringent measures in effect from
Baltic Sea[9] (SO_x)	-	-	19 May 2006
North Sea (SO_x)	22 July 2005 (MEPC.132(53))	22 Nov 2006	22 Nov 2007
North America (SO_x and PM)	26 Mar 2010 (MEPC.190 (60)	1 Aug 2011	1 Aug 2012
United States Caribbean Sea (SO_x and PM)	15 July 2011(MEPC.202 (62))	1 Jan 2013	1 Jan 2014
Mediterranean Sea (SO_x and PM)	16 December 2022 (MEPC.361(79))	1 May 2024	1 May 2025
Norwegian Sea (SO_x and PM)	Resolution MEPC.392(82)	1 March 2026	1 March 2027
Canadian Arctic (SO_x and PM)	Resolution MEPC.392(82)	1 March 2026	1 March 2027

Source: IMO

[9] The Baltic Sea was designated as ECA for SO_x when the MARPOL Annex VI entered into force (May 2005).

Figure 2 Timeline for the progress of Med SOx ECA proposal



Source: American Bureau of Shipping, Regulatory news, No. 07/2024

The 22nd session of the Conference of the Parties (COP 26) to the United Nations Framework Convention on Climate Change (UNFCCC) adopted Decision IG.25/14 on the Designation of the Mediterranean Sea, as a whole, as an Emission Control Area for Sulphur Oxides and Particulate Matter (Med SO_X ECA). Subsequently, the Contracting Parties to the Barcelona Convention as well as the Member States of the European Union and the European Commission submitted the joint and coordinated proposal on the designation of the Med SO_X ECA on 4 February 2022 to the 78th session of the International Maritime Organization (IMO)'s Marine Environment Protection Committee (MEPC 78) (London, United Kingdom of Great Britain and Northern Ireland (UK), 6-10 June 2022), which endorsed the proposal and approved the related draft amendments to MARPOL Annex VI. In December 2022, the Med SO_x ECA proposal for the Mediterranean region to reduce sulphur emissions and eventually improve the air quality standards in the Mediterranean region was accepted. Accordingly, Med SO_x ECA is to be implemented from 1 May 2025 with restrictions on SO_x and PM.

To comply with Med SO_x ECA, as of 1 May 2025, ships will have to switch from very VLSFO with 0.50% sulphur content to low sulphur marine gas oil (LSMGO[10]) with 0.10% sulphur content. However, EGCS, which was initially intended to reduce SO_x emission from 3.50% to 0.50%, can now reduce sulphur emission to below 0.10%. This means vessels can run on high sulphur fuel while emitting similar amounts of SO_x as they would be emitting while operating on LSMGO.

[10] LSMGO is max 0.10% sulphur distillate (DMA, DMZ) for compliance with 2015 ECA Regulations.

The Mediterranean Sea is one of the major maritime shipping routes with 20% of worldwide seaborne trade passing through it. This resulted in the utmost need to include the whole of the Mediterranean Sea under MARPOL Annex VI. Emission reductions by ships operating in the Mediterranean Sea area are expected to reduce SO_x by 79% and $PM_{2.5}$ by 24 % due to the implementation of Med SO_x ECA and reduce exposure to $PM_{2.5}$ for communities of people living in Mediterranean coastal States as per the "The technical and feasibility study for the designation of Med SO_x ECA commissioned by REMPEC" (REMPEC, 2019). These improved exposure conditions are associated with additional health benefits, namely reduced risk of premature cardiovascular and lung cancer mortality and reduced risk of childhood asthma.

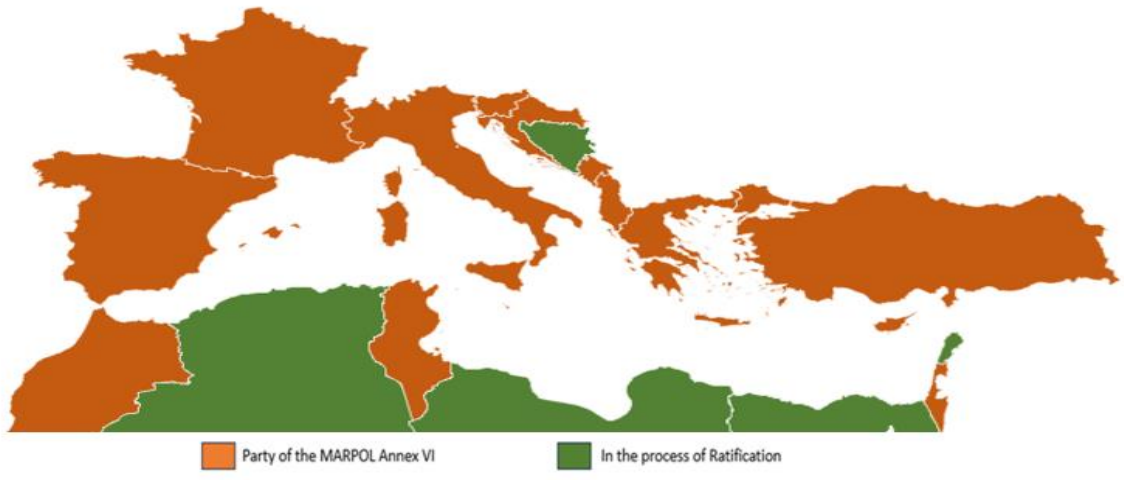
With the implementation of the Norwegian ECA and Med SO_x ECA, ship operators will be dealing with a new scenario where these new ECAs, along with the existing North Sea and Baltic Sea ECA, form a European super emission control area.

The primary responsibility for enforcement is carried out by Flag States which must issue an International Air Pollution Prevention (IAPP)[11] Certificate to the ship on which the fuel oil is recorded as per Bunker delivery note (BDN). Changing to a different grade of fuel to comply with Regulation 14 of MARPOL Annex VI is to be recorded in the "Fuel Changeover Plan" while entering/leaving SECA. The control is envisaged as the samples can be taken by Flag/Port States and non-compliance by the shipowners can lead to moderate to severe penalties. It could lead to loss of license to operate; retraction of the IAPP certificate and heavy fines can be imposed from flag states and port authorities.

The 22nd Conference of the Parties Meeting of the Contracting Parties to the Barcelona Convention and its Protocols Decision IG.25/14 unified to ratify and implement MARPOL Annex VI at least by the date of entering into force of the Med SO_x ECA.

Five out of the 21 Contracting Parties to the Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean (the "Barcelona Convention") (CPs) have not ratified to the MARPOL Annex VI as of date.

Figure 3 Map depicting ratification status of Contracting Parties to the Barcelona Convention



Source: IMO, Drewry (2024)

[11] An IAPP Certificate shall be issued, after an initial or renewal survey in accordance with the provisions of Regulation 5 of this Annex VI.

2.3 Section Summary

The Mediterranean Sea is one of the major maritime shipping routes with 20% of worldwide seaborne trade passing through it. The high volume of ships passing through the Mediterranean Sea creates a lot of emissions in the form of SO_x and PM from the shipping industry. This is becoming a concern for the Mediterranean coastal States.

The designation of ECA was introduced as an amendment to MARPOL through the MEPC circular (MEPC.1/Circ.778/Rev.4) to curtail emissions and protect marine diversity and ecosystems. The MARPOL 73/78 Annex VI Regulation 14 on SO_x and PM (*Prevention of Air Pollution from Ships*), where the sulphur content of fuel oil used on ships was limited to a maximum of 0.10% in ECAs and 0.50% limit was implemented when ships are in the open sea from 1 January 2020. The MARPOL Annex VI does not specifically limit PM but it is reduced by reducing the sulphur content of the fuel oil.

The Resolution MEPC.361(79) was brought to IMO in December 2021. In December 2022, the Barcelona Convention SECA proposal for the Mediterranean region to reduce sulphur emissions and eventually improve the air quality standards in the Mediterranean region was accepted. Accordingly, the Mediterranean SO_x emission control area (Med SO_x ECA) is to be implemented from 1 May 2025 with restrictions on SO_x and PM.

Emissions reductions by ships operating in the Mediterranean Sea area are expected to reduce SO_x by 79% and $PM_{2.5}$ by 24 % due to the implementation of Med SO_x ECA and reduce exposure to $PM_{2.5}$ for communities of people living in Mediterranean coastal States.

The mitigation of SO_x and PM can be achieved by carrying two or more separate fuels (one with sulphur not exceeding 0.1% m/m and another with sulphur not exceeding 0.5%m/m) and using them accordingly, adapting to alternate fuel and by equivalent means. One such equivalent is EGCS. EGCS (colloquially termed “Scrubbers”) allows ships to continue using fuel oils with sulphur content exceeding regulated values by reducing their SO_x emissions through the treatment of exhaust gas. It has gained momentum in recent years; however, many coastal States are restricting their use because of the resulting water pollution.

With the implementation of the Norwegian ECA and Med SOx ECA, ship operators will be dealing with a new scenario where these new ECAs, along with the existing North Sea and Baltic Sea ECA, form a European super emission control area.

Five out of the 21 CPs to the Barcelona convention have not ratified MARPOL Annex VI as of date.

3 Exhaust Gas Cleaning Systems

The maritime sector is growing with the increase in the global demand and supply requirements of goods in various sectors. With this, shipping emissions are likely to increase, and environmental measures to reduce them are becoming critical.

If the vessel uses Heavy Fuel Oil (HFO), which is cheaper than Very Low Sulphur Fuel Oil (VLSFO)[12], SO_x emission can be reduced from 3.5% to 0.5% by using Exhaust Gas Cleaning Systems (EGCS). This section covers various types of EGCS and the bans imposed on their usage in various coastal States.

Several measures can be introduced to comply with Regulation 14 of MARPOL Annex VI. Such compliance options include low sulphur content fuels such as VLSFO, Ultra Low Sulphur Fuel Oil (ULSFO), Marine Gas Oil (MGO), Liquified Natural Gas (LNG), methanol and ammonia or the usage of HFO (high sulphur content fuel) along with alternate means of compliance.

3.1 Introduction of EGCS

EGCS is one of the alternate means to meet the air emission requirements. The new designs of EGCS are capable of reducing more SO_x and are also effective in the SECA, where the emission has to be reduced to 0.1% SO_x.

The specific guidelines (2015 Guidelines for exhaust gas cleaning, Resolution MEPC.259(68)) apply when ships are installing EGCS to comply with MARPOL Annex VI. As per these guidelines, the compliance and monitoring of SO_x emission is based on the SO_2(Sulphur dioxide) (ppm)/CO_2 (Carbon dioxide) (%) ratio method.

Table 2 Fuel oil sulphur emissions in MARPOL Annex VI Regulation 14

Fuel oil sulphur content (% m/m)	Ratio emission[13] SO_2(ppm[14])/CO_2(%)
4.5	195
3.5	151.7
1.5	65
1	43.3
0.5	21.7
0.1	4.3

Source: IMO

[12] VLSFO is typically a blend of lower-cost oil components. It is a Max 0.50% sulphur fuel (Also known as IMO2020 grade bunkers).

[13] The use of the ratio emissions limits is only applicable when using petroleum-based distillate or residual fuel oils.

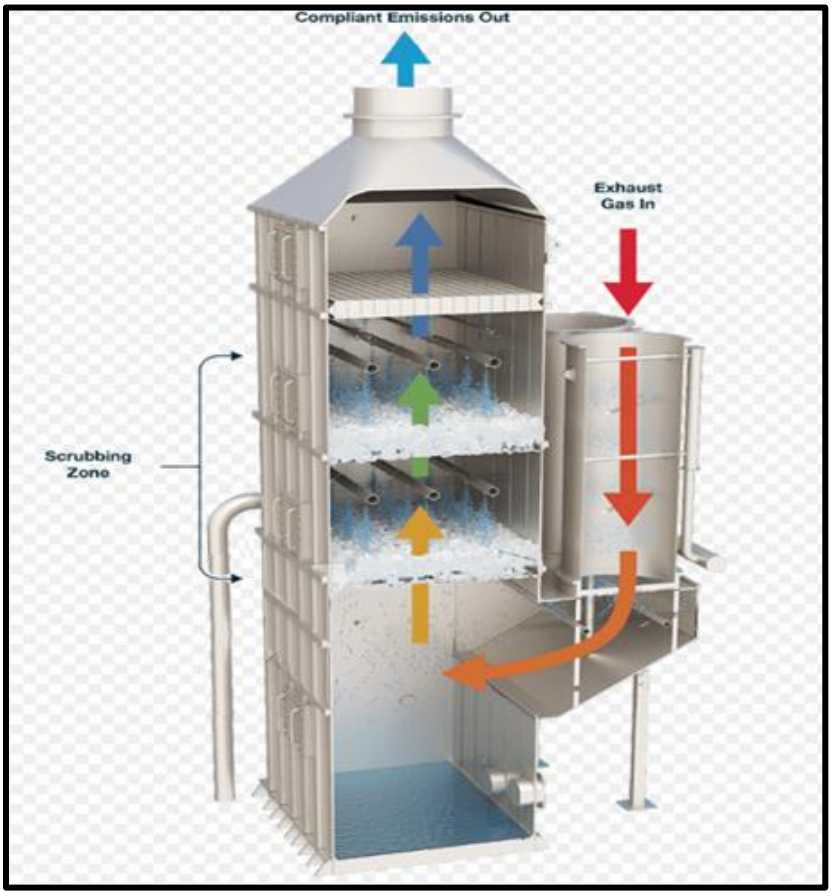
[14] "ppm" means "parts per million". It is assumed that ppm is measured by gas analysers on a molar basis, assuming ideal gas behaviour. The technically correct units are actually micro-moles of substance per mole of the total amount (μmol/mol).

The SO_2/CO_2 ratio enables direct monitoring of exhaust gas emissions to verify compliance with the emission limits mentioned in Table 3.1. An EGCS unit should be certified as capable of meeting the Certified Value[15] specified by the manufacturer, within the range of operating parameters for various fuel oil combustion units[16], using fuel oils of the manufacturer's specified maximum % m/m sulphur content.

3.1.1 EGCS system description

EGCS systems are scrubbers that are designed to reduce sulphur emissions with an operating principle where sulphur compounds in the flue gases react with the water; the sulphur reacts with the scrubbing medium[17] and forms various compounds, which get dissolved in water and do not escape along with flue gases into the atmosphere.

Figure 4 EGCS system general operation cross-section



Source: Pacific Green Marine Technologies

[15] The SO_2/CO_2 ratio specified by the manufacturer that the EGC unit is certified as meeting when operating on a continuous basis on the manufacturer's specified maximum fuel sulphur content.

[16] Fuel oil combustion unit is any engine, boiler, gas turbine, or other fuel oil-fired equipment, excluding shipboard incinerators.

[17] Water used in inside EGCS for getting sprayer to remove SO_x and PM, such as sea water for open-loop and freshwater with caustic soda for close-loop

Seawater is alkaline and thus the water is used in the scrubbing zone to absorb Sulphur dioxide (SO_2)[18] emissions produced during the combustion. During the process, water is continuously sprayed down into the EGCS, reacting with the flue gases moving upwards where it utilises the maximum surface area using baffles and mesh, which are designed to encourage the interaction between the water and flue gases. The maximum surface area and change in direction of gases using baffles also help in reducing the PM from the exhaust.

The chemical reaction involved in the process involves SO_2 reacting with water to form a sulphate ion compound.

$$SO_2 \text{ (gas)} + H_2O + 1/2\ O_2 \rightarrow SO_4^{2-} + H_2$$

This reaction produces sulphate ions and hydrogen. Sulphate ions become a part of the alkaline water used for scrubbing and are removed from the exhaust gas.

The marine EGCS system comprises three basic components:

.1 An exhaust stream that is mixed with scrubbing water.

.2 A treatment plant to remove pollutants from the scrubbing water after the process.

.3 Sludge handling facilities: Sludge removed from the scrubbing water after the process must be retained on ships for proper disposal ashore and is not allowed to be burned in the ship's incinerator.

3.1.2 Different kinds of EGCS

Ships mostly use wet EGCS which are categorised into three types. According to Clarkson, globally, there are about 5,484 vessels using the below-listed types of EGCS.

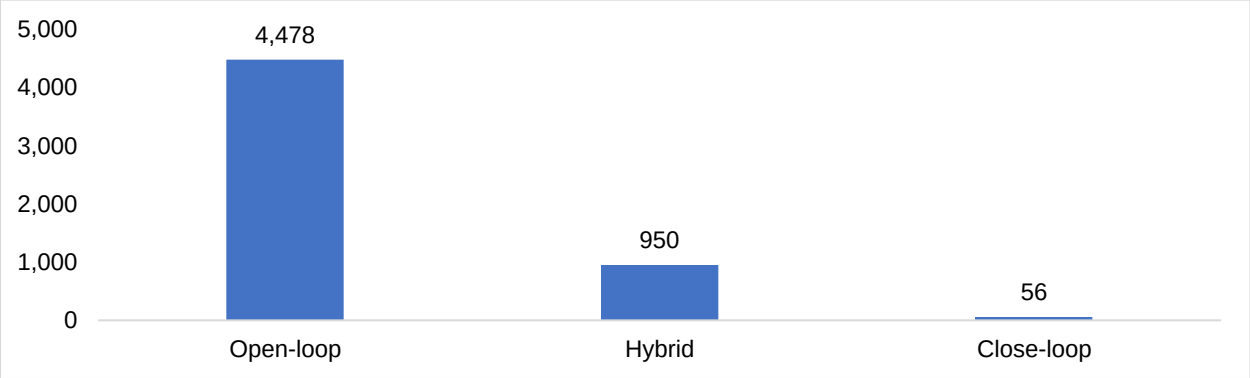
.1 Open-loop EGCS are around 82% (4,478 out of 5,484) of EGCS

.2 Hybrid (open-loop when at sea, close-loop when in port or as required) are around 17% (950 out of 5,484) of EGCS

.3 Close-loop EGCS are around 1.0% (56 out of 5,484) of EGCS

[18] SO_x gases are compounds of sulphur and oxygen molecules that are formed when fuel containing sulphur is burned. SO_2 is the component of greatest concern and is used as the indicator for the larger group of gaseous sulphur oxides (SO_x). Other gaseous SO_x (such as SO_3) are found in the atmosphere at concentrations much lower than SO_2. SO_2 dissolves in water vapor to form acid, and interacts with other gases and particles in the air to form sulphates and other products that can be harmful to people and their environment.

Figure 5 Different types of wet EGCS

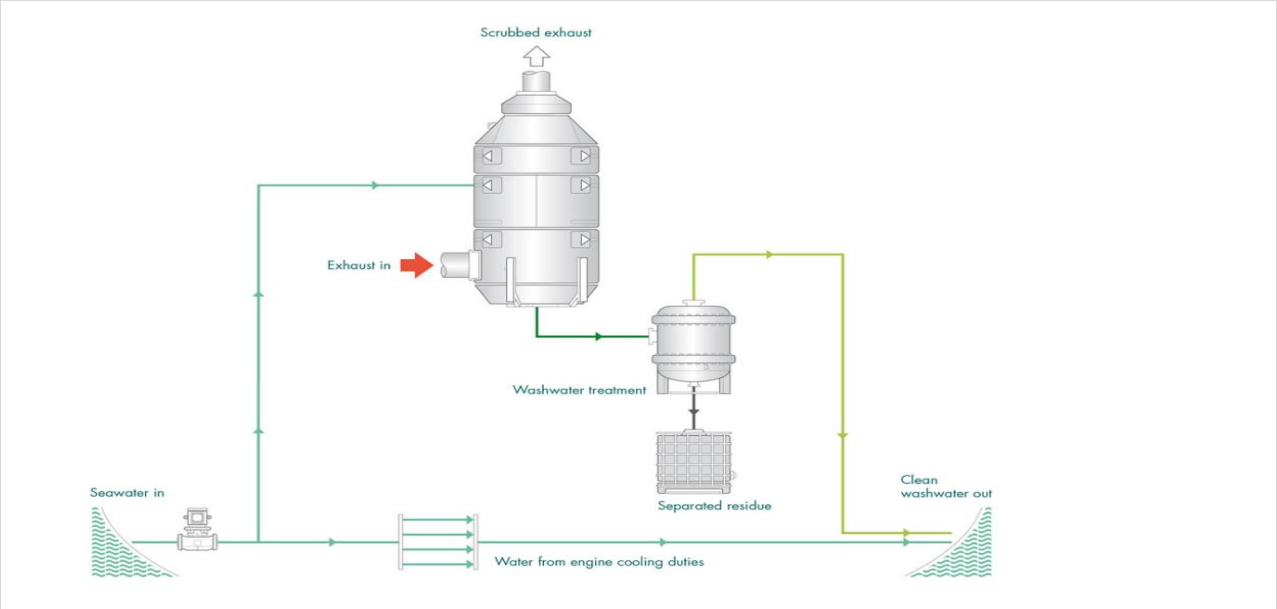


Source: Clarkson's, Drewry (2024)

Open-loop EGCS

These EGCS use untreated seawater (i.e. the natural alkalinity of the seawater) to neutralise the sulphur from exhaust gases.

Figure 6 Open-loop EGCS



Source: Exhaust Gas Cleaning System Association (EGCSA)

In this type of EGCS, seawater is taken from the sea and used as a scrubbing medium. Thereafter, it is treated and discharged back to sea. This system uses about 45m^3/MWh[19] for scrubbing. MARPOL regulations require the water used to be monitored before being discharged overboard to ensure that its pH[20] value is not too low.

[19] A megawatt hour is a unit of measurement for electricity generation, where one megawatt is produced over a period of one hour.

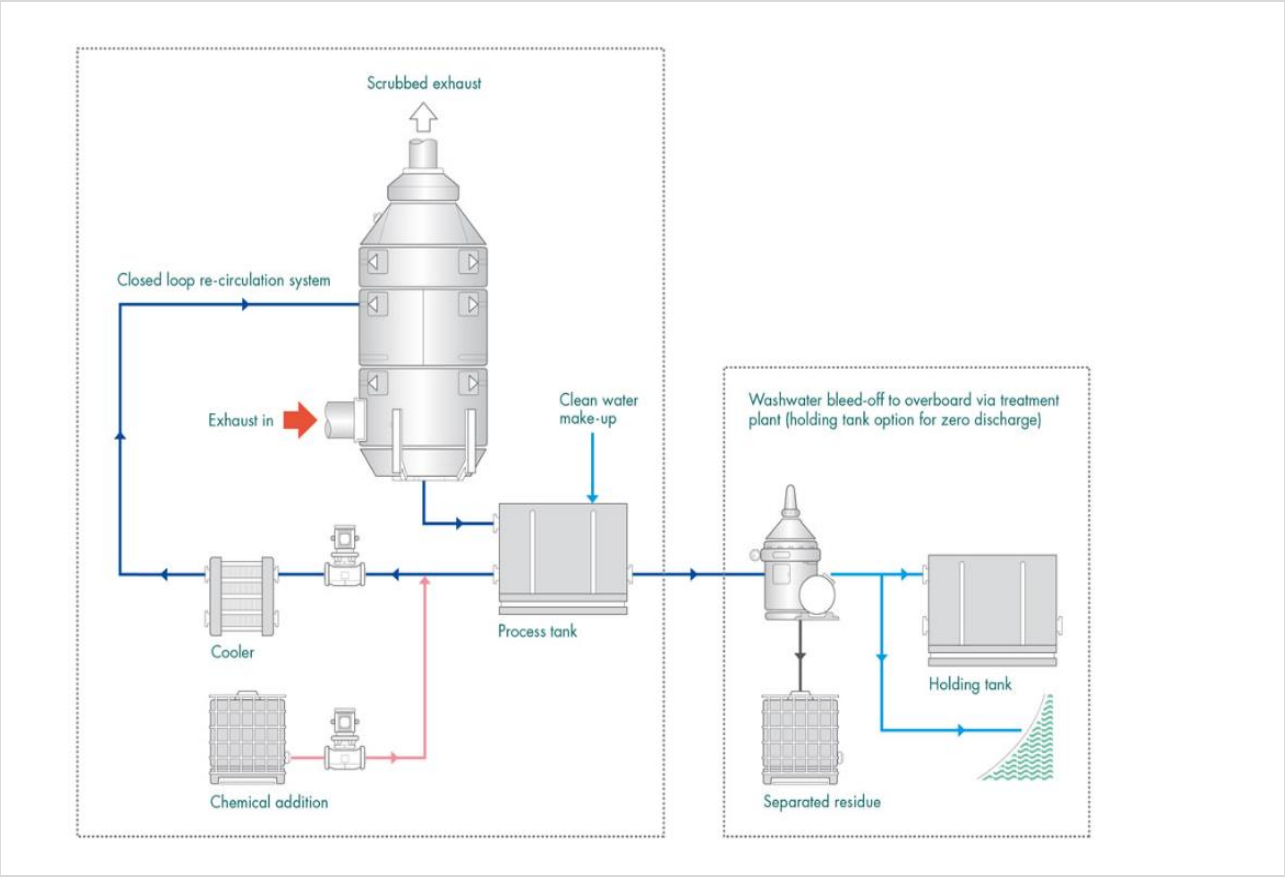
[20] Potential of Hydrogen (pH) is a measure of how basic or acidic a substance is. pH has a range of 0 to 14. A pH greater than 7 means the substance is alkaline/basic whereas a pH less than 7 means the substance is acidic. When the pH is exactly 7, it indicates that the substance is neutral.

Close-loop EGCS

Close-loop EGCS use freshwater treated with alkaline chemicals such as caustic soda[21] as scrubbing medium. It is circulated in a loop into the EGCS and losses in the quantity of water are made up with additional freshwater (make-up water). A small quantity of the water is bleedoff[22] to a treatment plant before discharging it overboard. Close-loop freshwater EGCS have a discharge rate of about 0.1-0.3m^3/MWh, with a limited operational time and zero discharge.

This system includes a process tank/buffer tank, a holding tank (through which discharge to sea is prohibited) and also a storage tank for sodium hydroxide with temperature regulation between 20ºC and 50ºC. The SO_x from the exhaust gas is turned into sodium sulphate which is harmless and is recirculated and cleaned.

Figure 7 Close-loop EGCS



Source: EGCSA

[21] Caustic soda is one of the common names for sodium hydroxide (NaOH)

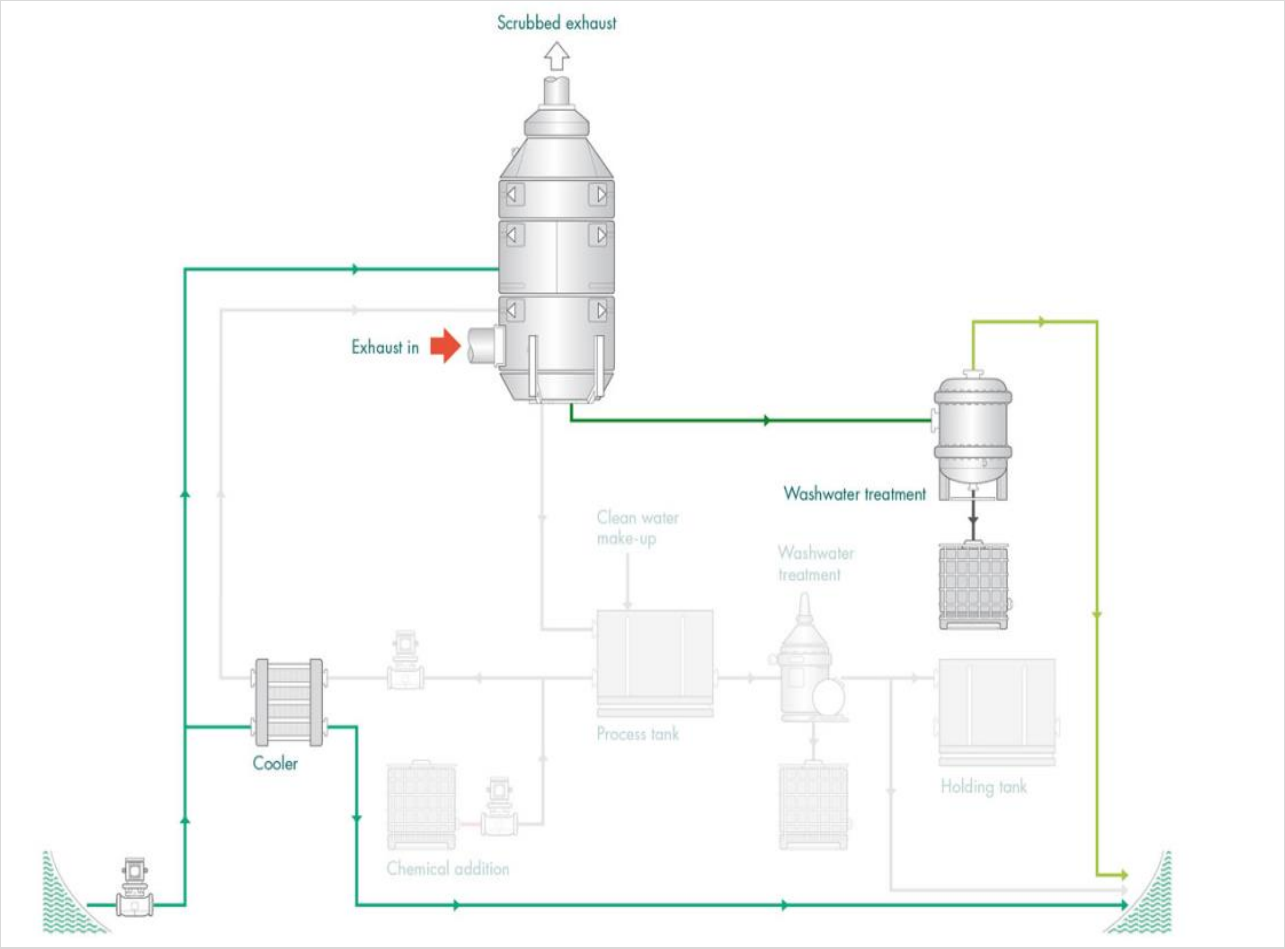
[22] Aqueous solution is removed from the washwater of an EGCS operating in a close-loop mode to keep its required operating properties and efficiency. This is carried out to avoid the build-up of sodium sulphate in the system.

Hybrid EGCS

Hybrid systems can operate in either open-loop or close-loop depending on the requirement and can use either freshwater or seawater as per the selected operational mode.

They can run in open-loop mode during open sea voyages and in close-loop mode while the vessel is plying in territorial waters or ports. As hybrid systems run on low-cost fuel for longer intervals, they can overcome the higher initial installation cost, making them economical in comparison to close-loop EGCS for shipowners, and comply with international regulations.

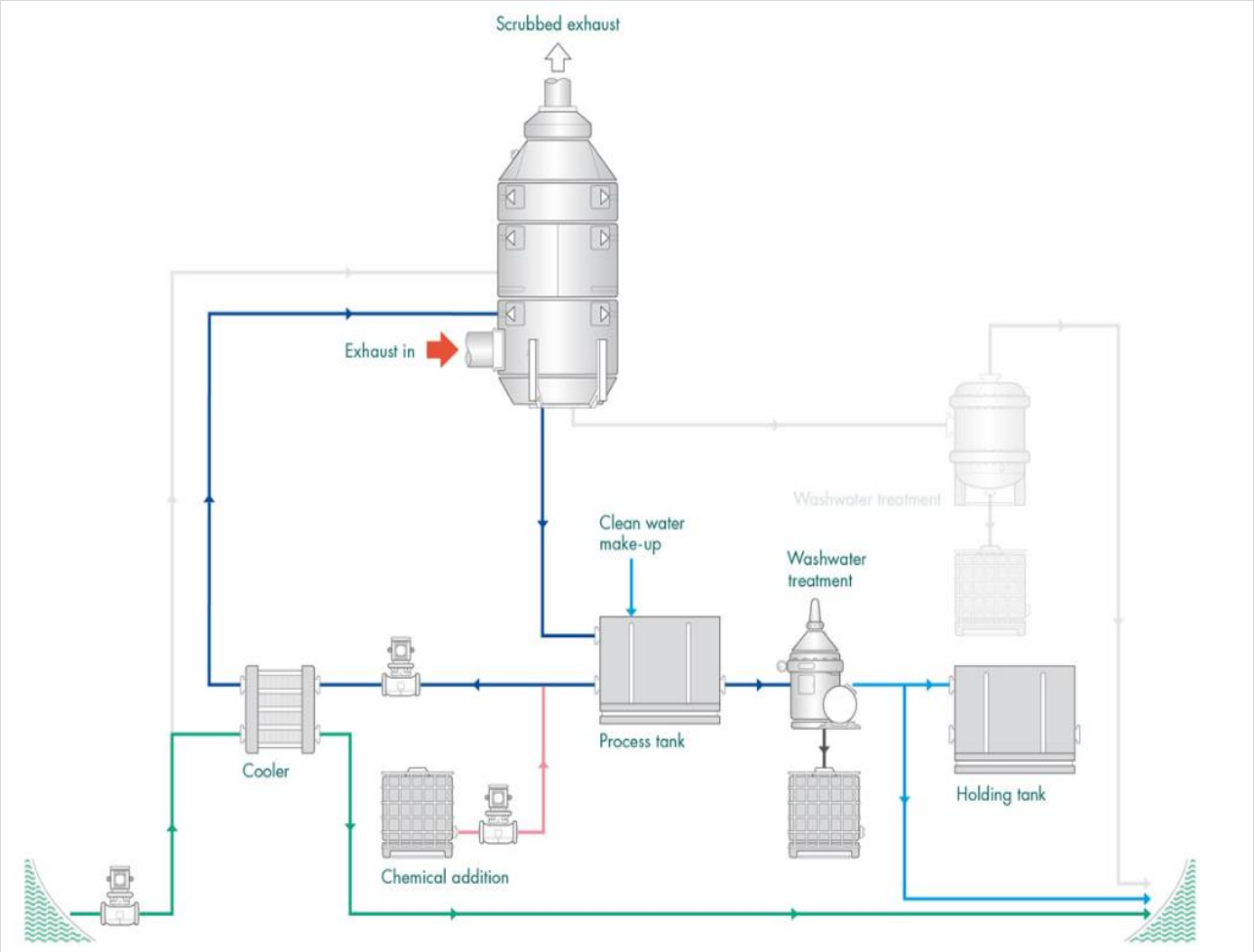
Figure 8 Hybrid EGCS open-loop operation



Source: EGCSA

The above-illustrated system demonstrates the hybrid EGCS in open-loop mode, where seawater is used as a scrubbing medium and is discharged overboard after treatment.

Figure 9 Hybrid EGCS close-loop operation



Source: EGCSA

In close-loop operations, freshwater is used as a scrubbing medium with the addition of chemicals, whereas bleedoff is discharged overboard.

3.1.3 Pros and cons of different EGCS

Table 3 Pros and Cons of different EGCS

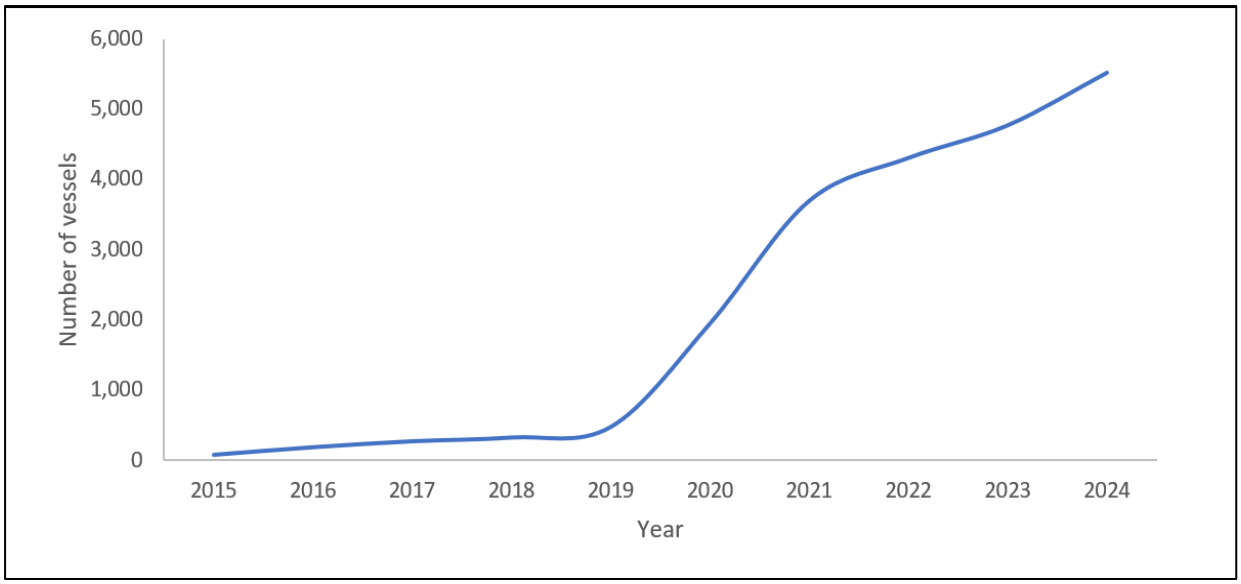
EGCS	Pros	Cons
Open-loop	• Uses seawater for scrubbing • Does not require storage or handling of hazardous chemicals (caustic soda) Is comparatively simple (less equipment/ system compared to close-loop) Involves relatively low capex and opex	• Unsuitable for low alkalinity water • Restriction on washwater discharge in certain coastal/port areas • High demand for washwater
Close-loop	• Independent of operation location – in low alkalinity water in a discharge-restricted coastal/port area. • Effluent is stored onboard as per the dedicated tank volume	• Complex washwater system. • More space required. • Special care for handling and storage of NaOH solution, a hazardous substance. • Operation duration limited by effluent tank size • Relatively higher capex. • Relatively higher opex due to use of NaOH and residue handling
Hybrid	• Significant flexibility for operating in all regions regardless of seawater alkalinity or temperature. • Effluent is stored onboard as per the dedicated tank volume.	• Complicated system with more components. • More space required. • Handling and storage of NaOH, and residue disposal for closed mode operation. • Highest capex. • Higher opex due to use of NaOH and residue handling.

Source: American Bureau of Shipping advisory on EGCS systems, July 2018

3.1.4 Key drivers for EGCS popularity

The popularity of EGCS increased from 2018 as it increased from 326 at the beginning of 2018 to 5484 globally by the end of 2023.

Figure 10 Increase in the global popularity of EGCS



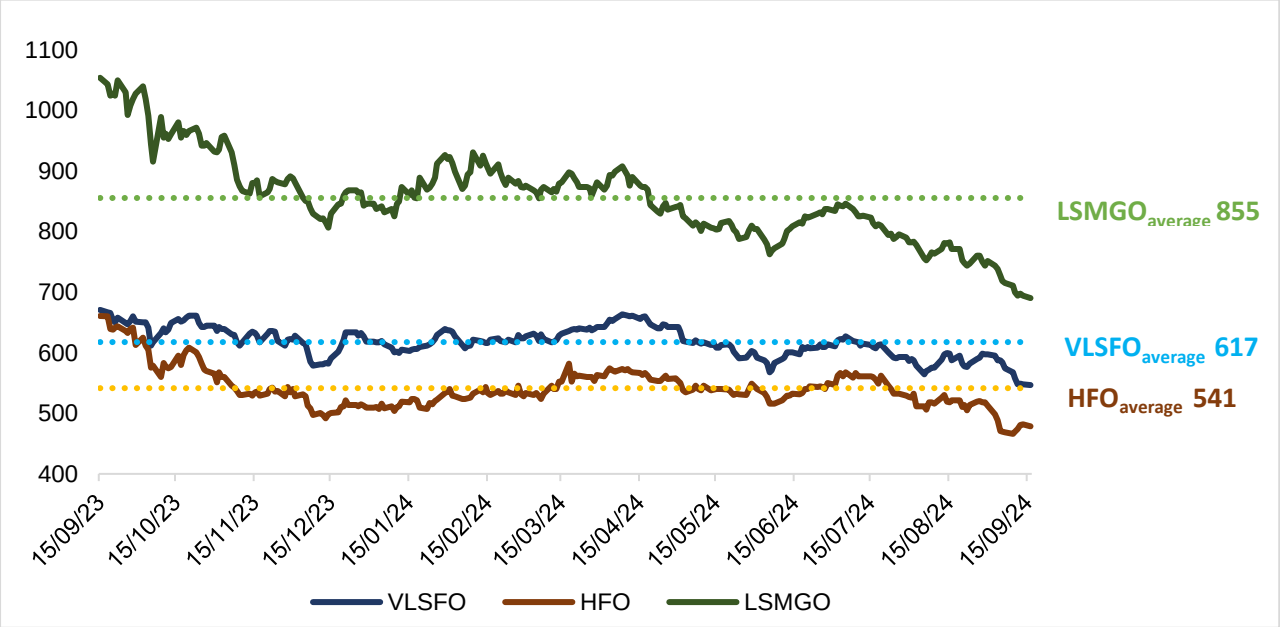
Source: Clarkson's, Drewry (2024)

The main drivers for EGCS's popularity are explained below:

.1 Regulations: The first and primary driver for the EGCS system is the regulation to reduce SO_x emissions. One of the possible options is to use EGCS. The EGCS systems remove SO_2 from exhaust gases, allowing ships to continue to use cheaper high sulphur fuel such as HFO, which results in acceptable SO_x emissions.

.2 Fuel price spread: The second driver for the popularity of the EGCS is the cost difference among HFO, VLSFO and LSMGO as shown in the chart below. Based on the estimated price of an EGCS of USD 2-5 million for a VLCC, the payback period is about four years, making EGCS a commercially attractive option.

Figure 11 Gibraltar price spread of HFO, VLSFO and LSMGO

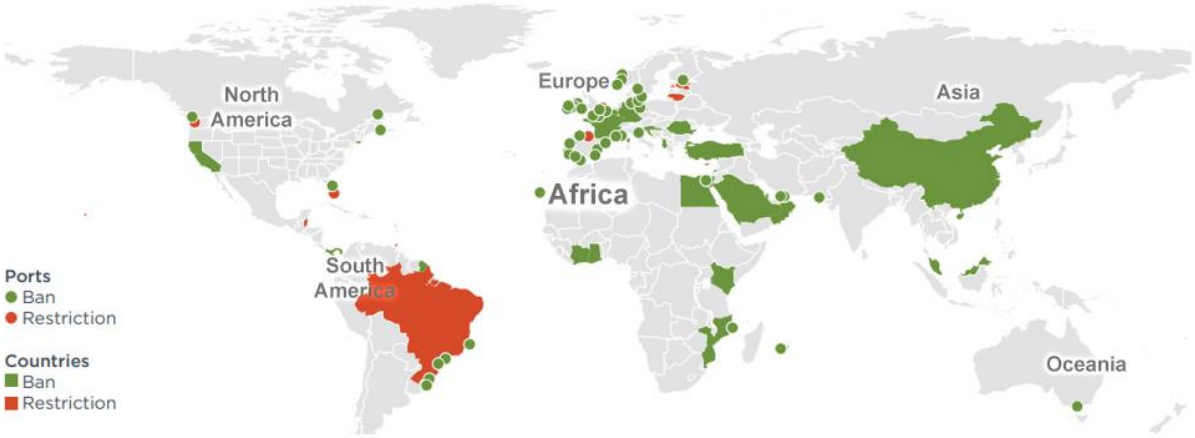


Source: Ship and Bunker, Drewry (2024)

3.2 Restrictions on EGCS discharge water

Certain coastal States have imposed restrictions or bans on EGCS due to their local environmental conditions, marine ecosystem, population residing in coastal areas and/or local regulations.

Figure 12 Bans and restrictions on EGCS by coastal States and ports on a global map[23]

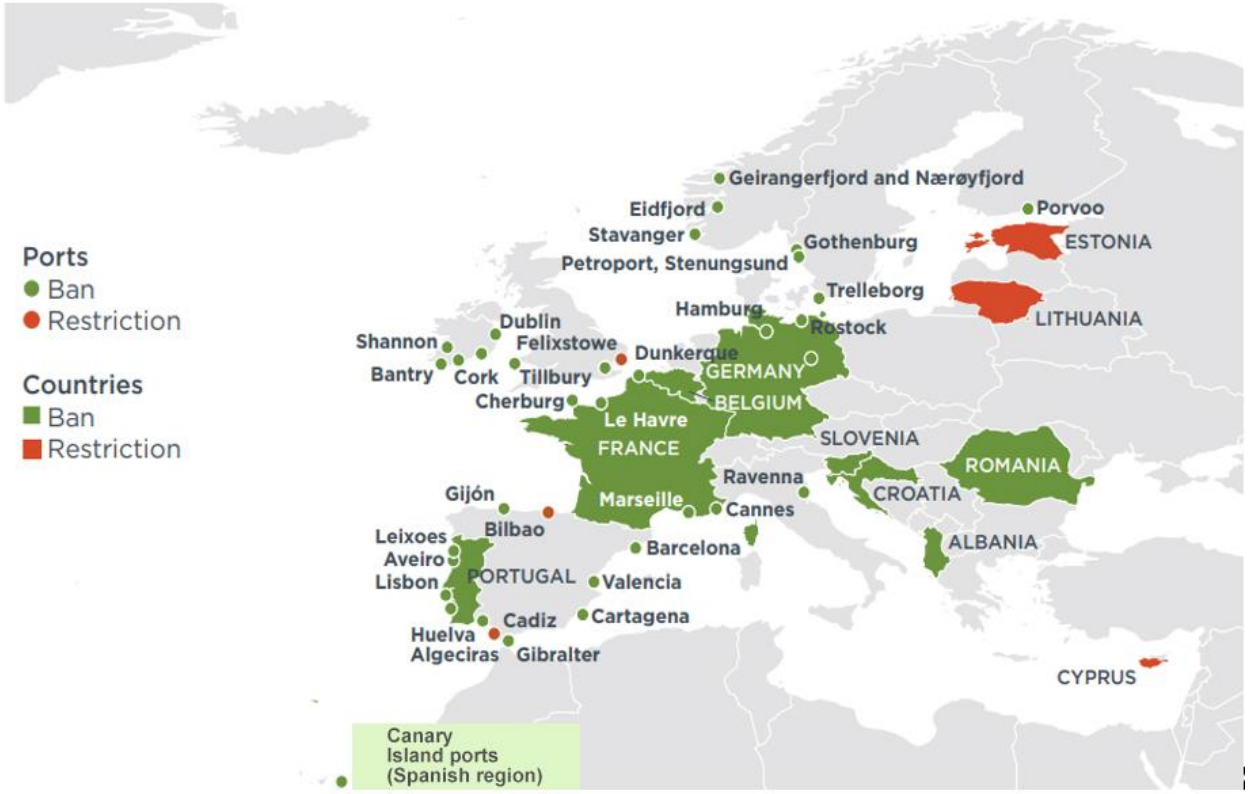


Source: International Council on Clean Transportation (ICCT), Global update on scrubber bans and restrictions-Policy update, June 2023

The above illustration shows the bans and restrictions on EGCS implied at the global scale.

[23] This map is presented without prejudice as to the status of or sovereignty over any territory, the delimitation of international frontiers and boundaries, and the name of any territory, city or area.

Figure 13 Bans and restrictions on EGCS in Europe



Source: International Council on Clean Transportation (ICCT), Global update on scrubber bans and restrictions-Policy update, June 2023

The above figure shows the bans and restrictions in the European region.

Table 4 Bans and restrictions on EGCS in different global regions

Global region	Coastal State	Ports[24]	Ban/ Restriction[25]	Ban on	Area[26]	Year[27]
Africa & Middle East	Bahrain		Restriction		Territorial waters	2019
	Egypt		Ban	All scrubbers	Territorial waters and ports	N/A
		Suez Canal	Ban	All scrubbers	Port area	2019
	Ghana		Ban	Open-loop	Territorial waters	N/A
	Israel		Ban	Open-loop	Port area and at anchor	2023
	Ivory Coast		Ban	Open-loop	Territorial waters and ports	N/A
	Kenya		Ban	Open-loop	All ports area	2019
	Mauritius		Ban	Open-loop	Territorial waters	2019
	Mozambique		Ban	Open-loop	All ports area	2021
		Nacala	Ban	All scrubbers	Port area	2006
	Oman		Ban	All scrubbers	Territorial waters	2020
	Pakistan	Karachi and Bin Qasim	Ban	Open-loop	Port area	2020
	Qatar		Ban	Open-loop	Territorial waters	2020
	Saudi Arabia		Ban	Open-loop	All ports area	2020
	Türkiye		Ban	All scrubbers	Territorial waters	2021
	United Arab Emirates	Fujairah	Ban	Open-loop	Port area	2019
		Dubai	Ban	All scrubbers	Territorial waters and ports	N/A
America	Argentina[28]		Prohibition currently suspended		Territorial waters and ports	2020

[24]Ports that have implemented the ban/restriction. This can be a decision of the port/port authority (e.g., Gothenburg in Sweden), or of the State (e.g., Kenya). A blank row indicates that the measure is applied at a national level.

[25] Whether the measure is a ban that completely prohibits the use of EGCS or the dump of their discharges; and or a restriction that allows their use or the dump of discharges prior to the satisfaction of certain clauses or requites that are port or State-dependent.

[26] Geographical area where the ban/restriction is applied.

[27] Years when the ban/restriction was announced in official documents.

[28] The information is not classified either as ban or restriction.

	Belize		Ban	All scrubbers	Territorial waters and ports	2018
	Bermuda		Ban	All scrubbers	Territorial waters	N/A
	Brazil	Vale S.A. ports	Ban	All scrubbers	Port area	2019
			Restriction		Territorial waters	2019
		Pelotas	Ban	All scrubbers	Port area and inland waterway	2021
		Porto Alegre	Ban	All scrubbers	Port area and inland waterway	2021
		Porto de Rio Grande	Ban	All scrubbers	Port area and inland waterway	2022
		Paranaguá e Antonina	Ban	Open-loop	Port area	2022
		Santos	Ban	Open-loop	Port area	2022
	Canada	Vancouver	Ban	All scrubbers	Port area and at anchor	2022
		Port of St. John	Ban	Contaminated or wastewaters[29]	Port area	2022
		Port of Cartier	Ban	Open-loop	Port area	N/A
	Panama		Ban	All scrubbers	Port area	2020
	Trinidad & Tobago		Restriction		Territorial waters	2019
	United States of America (USA) - California		Ban	All scrubbers	Territorial waters	2008
	USA - Connecticut		Ban	All scrubbers	Territorial waters	2013
	USA - Washington State	Seattle	Restriction		Port area	2023
	USA - Hawaii		Restriction		Territorial waters	2013
	USA - Florida	Canaveral	Ban	All scrubbers	Port area	2020
		Everglades	Restriction		Port area	2020
Asia	China[24]		Ban	Open-loop	Inland rivers in ECAs, ports in ECA and Bohai Sea	2018
	Hong Kong		Restriction		Territorial waters	2018
	Malaysia		Ban	Open-loop	Territorial waters	2019

[29] Dirty waste and contaminated water from vessel

	Singapore		Ban	Open-loop	Port area	2019
EU, United Kingdom of Great Britain and Northern Ireland (UK), Norway	Albania		Ban	Open-loop	All ports area	N/A
	Belgium		Ban	Open-loop	All ports and inland waters	2016
	Croatia		Ban	Open-loop	All ports area	2017
	Cyprus		Restriction		Port area and at anchor	2016
	Estonia		Restriction		Territorial waters and ports	2019
	Finland	Porvoo	Ban	Open-loop	Port area	2020
	France		Ban	Open-loop	Territorial waters	2021
		Cannes	Ban	All scrubbers	Port area	N/A
		Marseille	Ban	Open-loop	Port area	2014
		Le Havre	Ban	Open-loop	Port area	N/A
		Cherbourg	Ban	Open-loop	Port area	N/A
		Dunkerque	Ban	Open-loop	Port area	N/A
		Reunion	Ban	Open-loop	Port area	N/A
	Germany		Ban	Contaminated or wastewaters	Inland waterways (including ports and Rhine)	2018
		Hamburg	Ban	Open-loop	Port area	N/A
		Rostock	Ban	Open-loop	Port area	N/A
		River Elbe	Ban	Open-loop	Port area	N/A
	Gibraltar		Ban	Open-loop	Territorial waters	N/A
	Ireland	Dublin	Ban	All scrubbers	Port area	2018
		Waterford	Ban	All scrubbers	Port area	2019
		Cork	Ban	All scrubbers	Port area	2018
		Bantry	Ban	Open-loop	Port area	N/A
		Shannon	Ban	Open-loop	Port area	2021
	Italy	Ravenna	Ban	Contaminated or wastewaters	Port area	2011
	Lithuania		Restriction		Territorial waters and ports	2010
	Norway	Fjords area (Geirangerfjord and Nærøyfjord)	Ban	Open-loop	Port area	2019
		Eidfjord	Ban	Open-loop	Port area	N/A
		Stavanger	Ban	Open-loop	Port area	N/A
	Portugal	Lisbon	Ban	Contaminated or wastewaters	Port area	N/A

		Aveiro	Ban	Open-loop	Port area	N/A
		Sines	Ban	Open-loop	Port area	N/A
		Leixoes	Ban	Open-loop	Port area	N/A
			Ban	Open-loop	All ports area	2007
	Romania		Ban	Open-loop	All ports area	N/A
	Slovenia		Ban	Open-loop	Territorial waters	2022
	Spain	Algeciras	Ban	Open-loop	Port area	N/A
		Valencia	Ban	Open-loop	Port area	N/A
		Cartagena	Ban	Open-loop	Port area	N/A
		Huelva	Ban	Open-loop	Port area	N/A
		Gijón	Ban	Open-loop	Port area	N/A
		Barcellona	Ban	Open-loop	Port area	N/A
		Bilbao	Restriction		Port area	N/A
		Cadiz	Restriction		Port area	N/A
		Canary Islands ports	Ban	Open-loop	Port area	N/A
	Sweden	Petroport, Stenungsund	Ban	Open-loop	Port area	2020
		Trelleborg	Ban	Contaminated or wastewaters	Port area	2020
		Gothenburg	Ban	All scrubbers	Port area	2021
	UK	Tillbury	Ban	Open-loop	Port area	2020
		Felixstowe	Restriction		Port area	2020
		Forth and Tay	Ban	Open-loop	Port area	2019
		Milford Haven	Ban	All scrubbers	Port area	2019
Oceania	Australia	Hastings	Ban	Contaminated or wastewaters	Port area	2020
	New Zealand[28]		Discouraged use of scrubbers		Territorial waters	2021

Source: International Council on Clean Transportation (ICCT), Global update on scrubber bans and restrictions-Policy update, June 2023.

The number of vessels with EGCS are increasing and so are the bans and restrictions associated with the discharge of washwater. The measures are implemented at the national, sub-national and port levels with most bans on the use of open-loop EGCS. In certain cases, bans have been imposed on the EGCS discharge into the sea because of levels of contaminants in the EGCS washwater from open-loop EGCS and bleedoff water from close-loop EGCS.

3.3 Onboard verification procedures for compliance

Water is used by EGCS to remove sulphur oxides and PM from exhaust streams, but different manufacturers use different engineering technologies which vary considerably. The IMO Resolution MEPC.259(68) on 2015 Guidelines for Exhaust Gas Cleaning Systems (Annex I), under MARPOL Annex VI for EGCS have therefore been performance-based rather than design-based from the outset and contain two methods of complying with MARPOL 73/78 Annex VI Regulation 14 on SO_x and PM. The methods can be summarised as “Scheme A” and “Scheme B”.

The two EGCS schemes apply the following concepts:

.1 "Scheme A" is based on initial emission performance unit certification together with a continuous check of operating parameters and exhaust emission monitoring.

.2 "Scheme B" is based on continuous exhaust emission monitoring together with a daily check of operating parameters.

The EGCS is accompanied by the EGC System Technical Manual "Scheme A" (ETM[30]-A) or the EGC System Technical Manual "Scheme B" (ETM-B) which should contain information regarding the verification procedure which will be used during surveys. The adjustment and service to the EGCS need to be recorded in the EGC Record Book[31]. The individual system meeting the certified value criteria after following the EGCS guidelines will be issued with SO_x Emissions Compliance Certificate (SECC). It is important that the EGCS needs to be installed on the fuel oil combustion unit for which it is rated which is to be part of the SO_x Emissions Compliance Plan (SECP) for each vessel. The EGCS unit should include means to automatically record when the system is in use at the frequency specified in the guidelines with inputs such as washwater pressure and flow rate at the EGC unit's inlet connection, exhaust gas pressure before and pressure drop across the EGC unit, fuel oil combustion equipment load, and exhaust gas temperature before and after the EGC unit. In case the unit is using chemicals, a record of its consumption is to be mentioned in the EGC Record Book. In case the EGCS manufacturer is unable to provide assurance that the unit will meet Certified Value criteria, or it requires special equipment, then it is recommended to use a continuous exhaust gas monitoring system, which is part of "Scheme B".

Shipowners are responsible for recording, maintaining and servicing the EGCS unit along with like-for-like replacement. The EGC Record Book should be available during surveys, with engine-room log book entries and other data necessary to ascertain the appropriate usage of the EGCS. The SO_2/CO_2 ratio measurement is required daily for ascertaining emission checks as a vital parameter to monitor system compliance with the Onboard Monitoring Manual (OMM)[32] included as the means for recording ongoing compliance temporarily and in case of failure of a single monitoring device.

[30] ETM is a technical manual provided by the manufacturer containing identification details of the unit, operating limits, restrictions applicable to the unit, maintenance schedule, required adjustments, corrective actions and design requirements.

[31] A record of the EGC unit in-service operating parameters, component adjustments, maintenance and service records as appropriate

[32] A manual should be prepared to cover each EGC unit installed in conjunction with fuel oil combustion equipment, which should be identified, for which compliance is to be demonstrated. It should include the sensors to be used in evaluating EGC system performance and washwater monitoring, their service, maintenance and calibration requirements, the position of sensors, type of analysers used, zero and span calibration of analyser and other information regarding correct functioning of the monitoring system.

Table 5 EGCS documentation for onboard verification and compliance

Document	Scheme A – Parameter Check	Scheme B – Continuous Monitoring
SOx Emissions Compliance Plan (SECP)	X	X
SOx Emissions Compliance Certificate (SECC)	X	
EGCS Technical Manual, Scheme A (ETM-A)	X	
EGCS Technical Manual, Scheme B (ETM-B)		X
Onboard Monitoring Manual (OMM)	X	X
EGC Record Book or Electronic Logging System	X	X

Source: American Bureau of Shipping advisory on EGCS, July 2018

3.3.1 Exhaust gas monitoring system

After the installation of the EGCS on vessels, its compliance requires a proper emission monitoring system termed an exhaust gas monitoring system. For EGCS operating on the distillate and residual fuel oils, the compliance with emissions where equivalent sulphur oil content is verified using the SO_2/CO_2 ratio, monitoring of both gases can be undertaken after the cleaning process. For those EGCS which get affected by CO_2 concentration in the exhaust gas, the CO_2 concentration is measured before the scrubber unit and the SO_2 concentration is measured after the scrubber unit in order to calculate the correct ratio. The emission monitoring comprises a data-monitoring system or data recording devices which is provided as a part of EGCS installation. The details are monitored and recorded automatically against Universal Coordinated Time[33] (UTC) and vessel position by the Global Navigational Satellite System[34] (GNSS).

[33] Coordinated Universal Time—is the 24-hour time standard used as a basis for civil time today. All time zones are defined by their offset from UTC. The offset is expressed as either UTC- or UTC+ and the number of hours and minutes.

[34] GNSS stands for Global Navigation Satellite System. A GNSS consists of a constellation of satellites orbiting the Earth in very specific trajectories. For global coverage, it is estimated that a constellation requires 18 to 30 satellites. Navigation satellites provide orbit information and accurate timing (and other services) to radio receivers specifically designed to receive those satellite signals and decode the signal message contents. GNSS is often generically referred to as GPS (Global Positioning System).

The monitoring parameters required are enlisted below:

.1 Washwater pressure and flow rate at the EGC unit's inlet connection.

.2 Exhaust gas pressure before and the pressure drop[35] across the EGC unit.

.3 Engine and/or boiler load[36].

.4 Exhaust temperature before and after the EGC unit

.5 Exhaust gas SO_2 (ppm) and CO_2 (%)

.6 Washwater pH, Polycyclic Aromatic Hydrocarbons (PAHs)[37] and turbidity[38]

.7 Temperature

Other requirements for data recording and processing devices for monitoring systems are:

.1 They should be capable of preparing reports over specified time intervals.

.2 It should be able to retain the data for a period of not less than 18 months from the date of recording.

- In case the unit is changed then the shipowner should ensure that the required data is retained onboard and available as required for surveys and inspections.

.3 The system should be capable of downloading a copy of the recorded data and reports in a readily unseeable format, which can be presented to the port state authorities as requested.

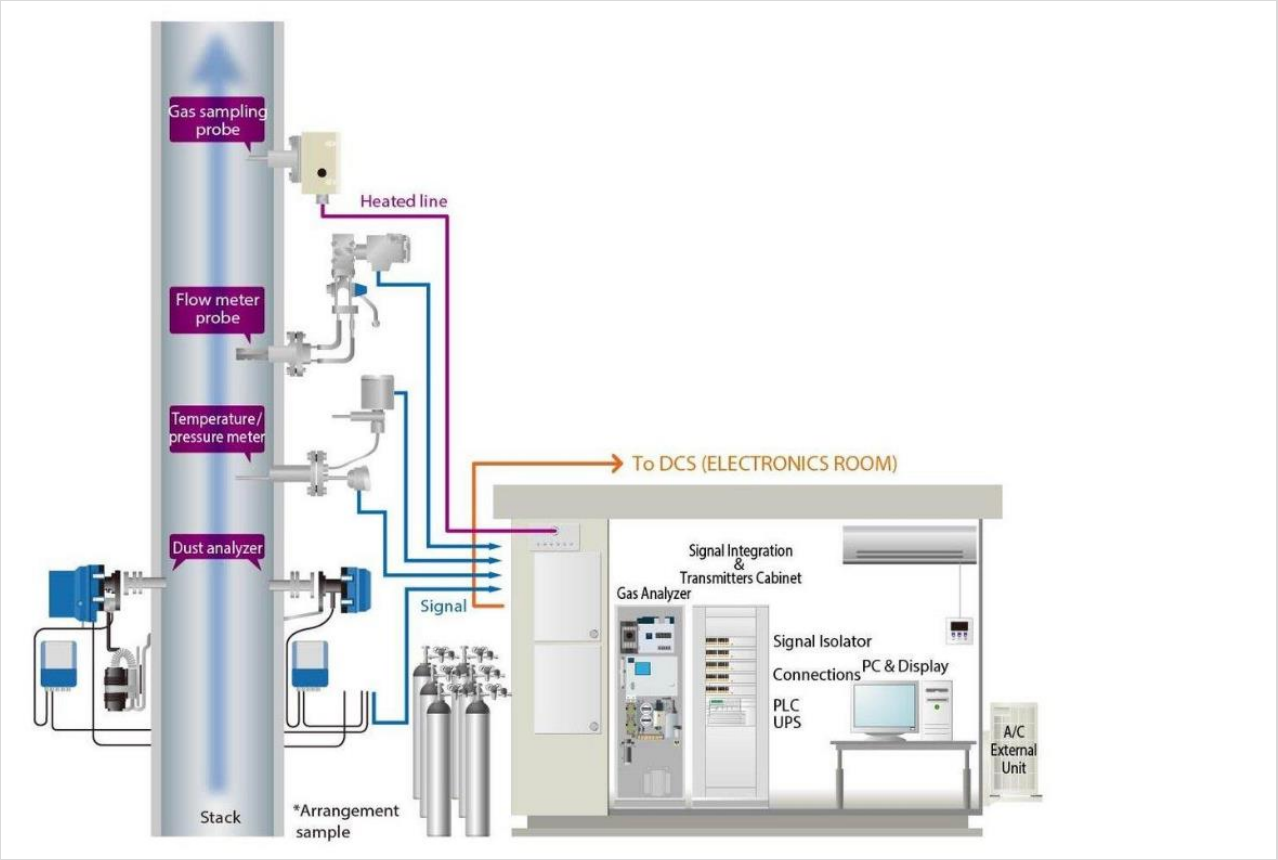
[35] The pressure inside the pipe can be different from the ambient pressure outside of the process. A pressure drop in the system can be caused by friction or a physical obstruction in the pipe that results in a loss of line pressure.

[36] Engine load refers to the percentage of maximum rating of the engine and boiler load refers to the percentage of the maximum capacity of the boiler.

[37] PAHs are a class of organic compounds produced by incomplete combustion or high-pressure processes. PAHs form when complex organic substances are exposed to high temperatures or pressures.

[38] Turbidity refers to the light-scattering properties of a sample. Turbidity can be described as "haziness" or "milkiness," and is caused by fine particles scattering light at more or less 90 degrees to the direction from which the light enters the sample. Turbidity is not to be confused with colour, nor colour with turbidity.

Figure 14 A general outline of the continuous exhaust monitoring system



Source: Continuous emission monitoring system, HORIBA process and environmental.

The monitoring of the exhaust gas for the calculation of the emission rate in terms of SO_2(ppm)/CO_2(%) should be measured at a specified and appropriate position in accordance with the EGCS guidelines. The monitoring of this ratio and its recording onto a data recording and processing device should be done at a rate that is not less than 0.0035Hz[39] (approximately every 5 minutes); and in case more than one analyser is used for measuring the ratio, these should be tuned to have similar sampling and measurement times with data outputs aligned so that the ratio is fully representative of the exhaust gas composition.

3.3.2 SO_x Emission Compliance Plan

In accordance with Regulation 14 of MARPOL Annex VI, there should be an SO_x Emission Compliance Plan (SECP) for the ship, which is approved by the flag Administration. It should comprise the items of fuel oil combustion equipment which is required to meet the operating requirements as per Regulation 14 of MARPOL Annex VI.

Under Scheme A, it should present how the continuous measurement of data will be maintained within the manufacturer's recommended specifications. The same data under Scheme B will be demonstrated using daily recordings of key parameters.

[39] The hertz is the unit of frequency in the International System of Units (SI) and its symbol is Hz. It is defined as one event or cycle per second and represented as s^{-1} in SI base units. One hertz equals one occurrence per second.

Under Scheme B, continuous measurement data of ship total SO_2(ppm)/CO_2(%) ratio demonstration and comparison with Regulation 14 of MARPOL Annex VI is done. Under Scheme A this will be carried out by using daily exhaust gas emission recordings.

Table 6 Example of combustion machinery installed onboard and means of compliance in SECP

Engine/ Boiler	Main Engine	AE 1	AE 2	AE 3	Boiler	EM generator
Engine manufacturer	Hyundai Heavy Industries Co. Ltd.	Hyundai Heavy Industries Co. Ltd.	Hyundai Heavy Industries Co. Ltd.	Hyundai Heavy Industries Co. Ltd.	Kang Rim	DOOSAN INFRACORE
Engine model	7S50MC-C7	6H17-28	6H17-28	6H17-28	MC0904P15	AD136TI
MCR	11,060 kW @127rpm	640 kW @900rpm	640 kW @900rpm	640 kW @900rpm	N/A	138KW @1800rpm
Cycle	2	4	4	4	N/A	4
Serial Number	AA3643	BA2744-1	BA2744-2	BA2744-3	MCW08SD1054	EDPEG-907034
Fuel	HFO/ MDO	HFO/ MDO	HFO/ MDO	HFO/ MDO	MGO	MGO/ Compliant
Scrubber	Yes	Yes	Yes	Yes	No	No
By-Pass	No	No	Yes	No	N/A	N/A
Location	Main machinery space	Main machinery space	Main machinery space	Main machinery space	Main machinery space	EM Generator room

Source : VDL AEC Maritime, Vessel Star Despoina

In the above table, it can be seen that the SECP contains EGCS for the main and auxiliary engine, while the boiler and emergency generator (EM generator)[40] don't have an EGCS.

The involved stakeholders such as port State control (PSC), ship crew and port authority need to be trained for maintaining, validating and serving the EGCS along with the handling of EGCS residue.

3.3.3 Discharge water monitoring system and various monitored criteria

Discharge water monitoring also termed a washwater monitoring system is a pollution prevention mechanism to ensure the EGCS is working along the IMO Resolution MEPC.259(68) on 2015 Guidelines for Exhaust Gas Cleaning Systems (Annex I), under MARPOL Annex VI. A major issue with EGCS is that on one hand, it helps to reduce SO_x and other harmful gases but on the other hand washwater releases harmful materials to the marine environment.

It is estimated that EGCS discharge more than 10 gigatonnes (Gt) of washwater worldwide yearly and there are three spatial hot spots:

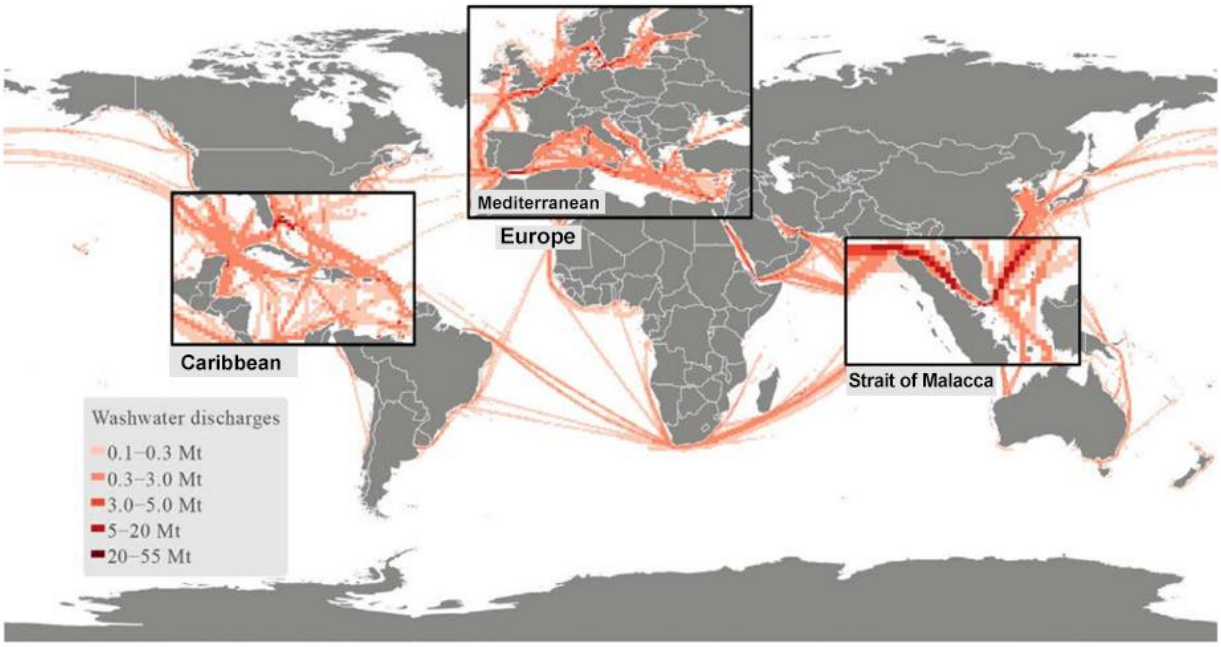
.1 Caribbean Sea

.2 European region (Baltic Sea, Mediterranean Sea and English Channel in Europe)

.3 Strait of Malacca along the South and East China Sea

[40]It is a small separate generator that supplies electric power for emergency load in the event of main power supply failure.

Figure 15 Global map with washwater discharges and sites resembling hotspot



Source: Liudmila, O., Elise, G., Bryan, C. (2021) Global scrubber washwater discharges under IMO's 2020 fuel sulphur limit, ICCT (April 2021).

There is a need for utmost compliance within the Mediterranean region considering the amount of washwater discharged in the region as it is a common trade route.

A list of such harmful factors is given below:

.1 pH (Potential of Hydrogen)
.2 PAHs (Polycyclic Aromatic Hydrocarbons)
.3 Turbidity/PM
.4 Nitrates
.5 Washwater additives
.6 Washwater residue

Various limits have been mentioned in the IMO Resolution MEPC.259(68) on 2015 Guidelines for Exhaust Gas Cleaning Systems (Annex I), under MARPOL Annex VI and the discharge water should comply with them. Washwater discharge criteria[41] are mentioned below.

pH criteria

Low pH water can adversely impact marine organisms, such as shellfish, that survive only when environmental conditions are stable; a decrease in pH may put the survival of these organisms at risk.

[41] The washwater discharge criteria should be revised in the future as more data becomes available on the contents of the discharge and its effects, taking into account any advice given by GESAMP (Group of Experts on the Scientific Aspects of Marine Environmental Protection).

The washwater pH should comply with one of the following requirements and should be recorded in ETM-A or ETM-B as applicable:

.1 The discharge water should have a pH of no less than 6.5 measured at the ship's overboard discharge with the exception during manoeuvring and transit when the maximum of 2 pH unit difference is allowed between the inlet and overboard discharge.

.2 The overboard pH discharge limit at the overboard monitoring position can be determined either by using a calculation-based methodology or using direct pH measurement at 4 metres from the overboard discharge point when the ship is stationary. The pH value at this point should not reach below 6.5.

PAHs

PAHs are the largest known group of carcinogenic substances and include many individual chemical substances containing two or more condensed aromatic rings. They occur naturally in petroleum and are also byproducts of fuel combustion. PAHs are an important class of environmental contaminants that are known to accumulate in ecosystems.

The washwater PAH should comply with the below-mentioned criteria and the appropriate limit to be specified in ETM-A or ETM-B as applicable:

.1 The maximum continuous PAH concentration in the washwater should not be greater than 50 µg/L PAHphe (phenanthrene equivalence) above the inlet water PAH concentration. For the purposes of this criteria, the PAH concentration in the washwater should be measured downstream of the water treatment equipment, but upstream of any washwater dilution or other reactants dosing unit, if used, prior to discharge.

.2 The 50 µg/L limit described above is normalised for a washwater flow rate through the EGC unit of 45 t/MWh where the MW refers to the MCR[42] or 80% of the power rating of the fuel oil combustion unit. This limit would have to be adjusted upwards for lower washwater flow rates per MWh, and vice-versa, according to the table below.

Table 7 PAHs criteria table

Flow rate (t/MWh)	Discharge concentration limit (µg/L PAHphe equivalents)	Measurement technology
0-1	2250	Ultraviolet light
2.5	900	Ultraviolet light
5	450	Fluorescence[43]
11.25	200	Fluorescence
22.5	100	Fluorescence
45	50	Fluorescence
90	25	Fluorescence

Source: IMO

[42] Maximum continuous rating (MCR) is the maximum output power for the engine running continuously under safe conditions. Contractual maximum continuous rating is the rating according to the contract agreed upon.

[43] For any Flow Rate > 2.5 t/MWh Fluorescence technology should be used.

.3 For a 15-minute period in any 12-hour period, the continuous PAHphe concentration limit may exceed the limit described above by up to 100%. This would allow for a delay in ramp-up of the EGC unit.

Turbidity

Turbidity is a measure of the amount of suspended solids in the water-based upon the loss of optical transparency (i.e., cloudiness) of the water. When combined with PAH, the measurement of turbidity is intended to demonstrate that the EGCS and washwater treatment system is operating correctly.

The washwater turbidity should comply with requirements and its treatment system should be designed to minimise suspended particulate matter, including heavy metals and ash.

.1 The maximum continuous turbidity in washwater should not be greater than 25 FNU (formazin nephlometric units) or 25 NTU (nephlometric turbidity units) or equivalent units, above the inlet water turbidity. However, during periods of high inlet turbidity, the precision of the measurement device and the time lapse between inlet measurement and outlet measurement are such that the use of a difference limit is unreliable. Therefore, all turbidity difference readings should be a rolling average over a 15-minute period to a maximum of 25 FNU. For these criteria, the turbidity in the washwater should be measured downstream of the water treatment equipment but upstream of washwater dilution (or another reactant dosing) prior to discharge.

.2 For a 15-minute period in any 12-hour period, the continuous turbidity discharge limit may exceed 20%.

Nitrates

Nitrate is the most oxidized form of nitrogen, and excess nitrate concentrations in aquatic systems can result in a rapid increase or accumulation in the population of algae, possibly leading to algae blooms and eutrophication. This can disrupt functioning of an aquatic system, causing a variety of problems such as a lack of oxygen in the water needed for fish and shellfish to survive (Behrends and Liebezeit, 2003).

.1 The washwater treatment system should prevent the discharge of nitrates beyond that associated with a 12% removal of NOx from the exhaust, or beyond 60 mg/l normalised for a washwater discharge rate of 45 tonnes/MWh whichever is greater.

.2 At each renewal survey nitrate discharge data is to be available in respect of sample overboard discharge drawn from each EGCS within the previous three months prior to the survey. However, the Administration may require an additional sample to be drawn and analysed at their discretion. The nitrate discharge data and analysis certificate are to be retained onboard the ship as part of the EGC Record Book and be available for inspection as required by PSC or other parties.

.3 All systems should be tested for nitrates in the discharge water. If typical nitrate amounts are above 80% of the upper limit, it should be recorded in the ETM-A or ETM-B.

Washwater additives

.1 An assessment of the washwater is required for those EGCS technologies that make use of chemicals, additives, preparations or create relevant chemicals in situ[44].

Washwater residue

The residues generated from the EGCS should be delivered ashore to adequate reception facilities[45]. Such residue should not be discharged to the sea or incinerated onboard. The record of such storage and disposal is to be maintained including date, time and location in an EGCS log book.

3.4 Brief review of technical data on SO_x and PM from EGCS water discharge

The EGCS's primary goal is the removal of SO_x and PM from the exhaust stream to achieve SO_x compliance as per MARPOL Annex VI. Hence, the effectiveness of the exhaust cleaning system and technical data concerning SO_x and PM after operation are important.

A key element in open-loop EGCS is the alkalinity of the seawater where the system operates and the effectiveness of an open-loop system is reduced in freshwater or lower pH seawater. The alkalinity of seawater can vary as per the distance from land, volcanic activity, marine life present in it, etc. In the case of lower alkalinity of seawater, lower SO_x levels can only be achieved by using more volume of scrubbing water. Almost seven times more water for dilution is needed when scrubbing takes place in freshwater, compared to seawater of standard salinity. The higher flow rate requires more energy and hence results in more emissions.

Table 8 Amount of water (t/hr) for EGCS of 12 MW engine

	Quantity of Water		
	Open Ocean	**Baltic Sea**	**Freshwater River**
Water for scrubbing	700	900	2,500
Water for dilution to pH = 6.5	1,400	1,700	15,000
Factor for dilution to ΔpH of 0.2	3	3.5	2.5
Total amount of water	6,300	9,100	44,000

Source: Hassellöv and Turner (2007), United States Environmental Protection Agency Office of Wastewater Management (2007)

[44] Sampling directly within an exhaust gas stream

[45] Port Reception Facility is a kind of provision that any international shipping port must provide to collect residues, oily mixtures and garbage generated from a seagoing vessel. The oil residue mixture and garbage generated by the vessel cannot be discharged directly to the sea as per the law to avoid Marine pollution and hence they are disposed to the Port reception facilities all around the world.

Table 9 EGCS effectiveness[46] for SO_x and PM

EGCS performance factor	Rate %	Remark
SO_x removal required	97.10	Makes 3.5% sulphur fuel equivalent to 0.1% sulphur fuel
Expected SO_x removal rate	>96	Depends on alkalinity of the water
Typical particulate removal rate	30-60	When using heavy fuel, particulate emissions are higher than for 0.1% sulphur distillate diesel fuel

Source: American Bureau of Shipping Advisory on EGCS, July 2018

In Close-loop EGCS alkalinity is directly controlled by the dosing process that injects an alkaline material into the scrubbing medium, and so the performance of EGCS can generally be controlled.

3.5 Incorporation of advance technologies in EGCS

Onboard Carbon Capture and Storage (OCCS) is an emerging new technology where, in most versions, the exhaust gas is cooled and SO_x removed before passing the exhaust into the CO_2 removal unit. The required cooling of the exhaust gas and SO_x removal is done by EGCS; therefore, for many OCCS systems, EGCS is a pre-requisite.

There are new EGCS technologies being developed as well, which require no water for SO_x removal.

3.5.1 OCCS

The IMO has adopted requirements for international shipping to reduce 20-30% of GHG emissions by 2030 and reach net zero GHG emissions around 2050 as part of 2023 IMO Strategy on Reduction of GHG Emissions from Ships (2023 IMO GHG Strategy). Due to the high cost of low-/zero-carbon fuels and uncertainties about their availability, OCCS is an emerging technology which could play a crucial role in achieving the decarbonisation goals. Accordingly, IMO intends to incorporate the application of OCCS in the IMO Lifecycle Assessment (LCA) Guidelines.

The CO_2 can be separated or captured both pre- and post-combustion. Pre-combustion capture uses reforming to separate gases into mainly hydrogen and CO_2 and this process is used when reforming carbon-containing fuels to hydrogen for onboard use in fuel cells. On the other hand, post-combustion captures the CO_2 from the exhaust gas and there are several different capture technologies and CO_2 storage types[47] which could be considered for onboard usage. The most accepted technology for ships is the absorption-based OCCS using an amine-based solution. The solution in the unit absorbs CO_2, which is then extracted from the solution and stored.

[46] Notes: If burning fuel with 3.5% sulphur, the EGCS must remove 97.1% of the SO_x in the exhaust to achieve emissions similar to 0.1% sulphur fuel. EGCS are expected to have removal rates in excess of 96%, and so some of the EGCS may be able to achieve equivalence with 0.1% sulphur fuel, but not all EGCS will. Manufacturers should specify the maximum sulphur content in the fuel that the EGCS can reduce. EGCS are expected to have removal rates in excess of 96%, and so some of the EGCS may be able to achieve equivalence with 0.1% sulphur fuel, but not all EGCS will.

[47] Potential technologies for OCCS include membrane separation, adsorption separation, liquid absorption separation and solid absorption separation. CO_2 storage types include single components (dry ice, liquid CO_2, or supercritical CO_2).

The popularity of OCCS depends on its technological developments, commercial viability, low-/zero-carbon fuel prices and future emission-related regulations. Case study, "The role of onboard carbon capture on marine decarbonisation" carried out by Maersk Mc-Kinney Moller Center for Zero Carbon Shipping (MMMCZCS) under the Green Fuels Optionality Project (GFOP) in 2022 concluded that:

.1 OCCS with chemical absorption is technically feasible and will reach commercial availability by 2030;

.2 the total fuel consumption increases by up to 45%; and

.3 it is most promising for newbuilds as retrofitting requires higher capex and major modifications[48].

Although the overall technology is still under development for ships, progress is being made on increasing capture rates and lowering energy requirements. OCCS is only one part of a multi-step process for atmospheric carbon reduction involving land-based and offshore carbon capture technology, temporary storage, offloading and discharging infrastructure, transportation by pipeline or vessel, and utilisation or geological sequestration.

3.5.2 Dry EGCS

Dry EGCS is popular on land-based systems and is being tested for ships as well. When the sorbent is injected into the exhaust system, it interacts with the SO_x, forming byproducts, thereby removing the sulphur from the exhaust gas. These byproducts, along with any unreacted sorbent material are captured by particulate control devices and thereafter disposed of or recycled appropriately.

3.5.3 Ongoing development and recent technology in the field of OCCS and dry EGCS

The development of OCCS- and EGCS-related technologies is actively being pursued, with emerging efforts focusing on the feasibility of OCCS for a wider range of operations.

.1 One company is using amine-based OCCS, whereby CO_2 is extracted from the amine solution ashore so there is no need to liquify the captured CO_2, reducing the demand for extra fuel. However, this system presently uses EGCS.

.2 One of the OCCS designs does not have an EGCS and does not use water. The process also requires no cooling of the exhaust like amine-based OCCS; instead, it uses quicklime, which gets converted to limestone in the process. It might require heating the exhaust to raise the temperature to ~400ºC to enable the absorption of SO_x and CO_2. The additional fuel consumption is much less than in other traditional systems and is mainly for heating if the exhaust gas temperature is lower than required.

[48] When retrofitting OCCS, one of the important items to consider is the increase in onboard power generation (gensets) capacity. As the increase in electric demand is large, gensets need to be increased by both number and unit capacity. This also requires dedicated storage space and possibly a reliquefication plant.

Advantages:

- No major modification required; only some pipework required for directing exhaust to the seabound containers
- Minor maintenance is required from engineers onboard
- Low power demand, that too only for a heater and/or a blower
- Ports have more acceptance of the byproduct (limestone) than liquid CO_2 during the abatement process

The system has a higher OPEX related to Quicklime use.

.3 Another company's dry EGCS works on fabric filter technology. The system does not require any water as a scrubbing medium which causes zero washwater and hence no damage to the marine environment. The system is installed at low capex and has very high efficiency for PM removal.

3.6 Section Summary

The maritime sector has made significant strides to meet the global demand for goods which resulted in higher trade and thereby shipping emissions. With the increase in emissions, regulators have come up with stricter environmental regulations to achieve climate goals where the use of EGCS is one of the alternatives that allow vessels to run on HFO. The new designs of EGCS are effective in the SECA, where emissions have to be reduced to 0.1% SO_x.

As per specific guidelines under Resolution MEPC.259(68), the compliance and monitoring of SO_x emission is based on the SO_2(ppm)/CO_2(%) ratio method. An EGCS unit should meet the standards of Certified Value specified by the manufacturer, within the range of operating parameters for various fuel oil combustion units, using fuel oils of the manufacturer's specified maximum % m/m sulphur content.

An EGCS is designed to reduce sulphur emissions. When flue gases react with water, sulphur is converted into its various compounds which get dissolved in the water and do not escape along with the flue gases into the atmosphere.

An EGCS comprises three basic components: exhaust steam mixed with scrubbing water, treatment plant to remove pollutants from scrubbing water and sludge handling facilities for proper disposal of residues from washwater.

EGCS has gained popularity over the past decade with several factors propelling its growth:

.1 The first and primary driver for the EGCS system is the regulation to reduce SO_x emissions.

.2 The secondary driver is the cost difference among HFO, VLSFO and LSMGO.

Ships mostly use wet types of EGCS which are of three types; open-loop, close-loop and hybrid. All three of them have separate pros and cons related to them. With ongoing strict measures for sulphur emissions and upcoming regional and local regulations along with global measures; open-loop EGCS is banned in many places. Therefore, a hybrid system will be the most preferred option as it can be operated in close-loop mode in areas of restrictions.

Shipowners are responsible for recording, maintaining and servicing the EGCS unit along with like-for-like replacement with EGCS needing to follow onboard verification procedures and compliance to remain operational. The EGC Record Book should be available during surveys, with engine-room log book entries and other data necessary to ascertain its appropriate use.

Once EGCS is installed, it needs a proper emission monitoring system or exhaust gas monitoring system, SECP and discharge water monitoring system. The limits for pH, PAHs, turbidity, PM, nitrates, additives and other substances have been mentioned in the IMO Resolution MEPC.259(68) on 2015 Guidelines for Exhaust Gas Cleaning Systems (Annex I), under MARPOL Annex VI.

It is worth mentioning that the effectiveness of EGCS depends upon seawater alkalinity in open-loop EGCS while in close-loop EGCS it can be controlled through a dosing process of alkaline material. Hence the effectiveness of open-loop is very low in freshwater areas where seven times more water is required for dilution, which in turn requires more fuel and results in higher emissions.

With many countries raising concerns over washwater discharge from the EGCS, upcoming advancements such as dry EGCS and OCCS could play a major role in marine decarbonisation. Several companies are coming up with different technological measures to eliminate hurdles, such as issues related to washwater discharge and tackling SO_x and CO_2 emissions together. With these technologies, they could meet the requirements related to SO_x and PM, and at the same time tackle CO_2 emissions, aiming to meet carbon neutrality targets.

4 Review of Legal Frameworks and Policies related to EGCS

This section relates to IMO standards and guidelines related to EGCS along with policies adopted and required facilities provided by the Parties to MARPOL Annex VI regarding washwater discharge from EGCS.

4.1 Overview of the impact of IMO standards and guidelines on EGCS

The IMO standards are mentioned in Sections 2 and 3 of this report. While the IMO regulates the SO_x emissions through MARPOL Annex VI. Certain IMO guidelines for EGCS and various circulars governing these guidelines will also be discussed briefly in this section in addition to other international conventions, regulations and EU directives that are important and need to be taken into consideration to mitigate the concerns of marine ecosystem depletion.

4.1.1 United Nations Convention on The Law of The Sea (UNCLOS)

The United Nations Convention on the Law of the Sea (UNCLOS) was adopted in 1982 which lays down a comprehensive regime of law and order in the world's oceans and seas establishing rules governing all uses of the oceans and their resources.

The Convention also provides the framework for further development of specific areas of the law of the sea. UNCLOS contains detailed provisions on, among others, the geographical extent of a coastal state's territorial sea. It also mentions how the state may establish large maritime zones outside the territorial sea and which regime of international law applies in each sea area. Article 194 of UNCLOS sets out the obligation to prevent, reduce and control pollution of the marine environment with Article 195 explicitly referring to the obligation not to transfer damage or hazards or transform one type of pollution into another. In the Exclusive Economic Zone (EEZ), the coastal State has certain jurisdiction, including that over the protection and preservation of the marine environment (Article 56(2) of UNCLOS).

As per the Study by the Secretariat of IMO " Implication of the UNCLOS for the IMO", "*Within the framework of articles 212(3) and 222 of UNCLOS, IMO is the appropriate forum for States to establish global and regional rules, standards and recommended practices and procedures applicable to vessels to prevent, reduce and control pollution of the marine environment from or through the atmosphere. States are required to adopt laws and regulations to prevent, reduce and control such pollution, taking account of internationally agreed rules, standards and recommended practices and procedures (UNCLOS (article 212(1)), including relevant IMO regulations. In accordance with article 222 of UNCLOS, States are also under an obligation to enforce their laws and regulations and implement applicable rules and standards established through competent international organizations or diplomatic conference to prevent, reduce and control such pollution*".

This framework entitles States that are Parties to establish global and regional rules to safeguard their marine environment and air pollution interest in their coastal state jurisdiction[49].

[49] IMO treaties do not regulate the nature and extent of coastal State jurisdiction. In this regard, the degree to which coastal States may enforce IMO regulations in respect of foreign ships in innocent passage in their territorial waters or navigating the EEZ is provided by UNCLOS. The same principle applies to transit passage in straits used for international navigation or to archipelagic sea lane passage in archipelagic waters (it should be noted that MARPOL includes provisions on monitoring and investigating illegal discharges of harmful substances into the marine environment). The enforcement of routing measures adopted at IMO also relies primarily on the exercise of coastal State jurisdiction.

4.1.2 Agreement on the Marine Biological Diversity of Areas beyond National Jurisdiction (BBNJ Agreement)

The agreement under the UNCLOS on the conservation and sustainable use of marine biological diversity of areas beyond national jurisdiction (BBNJ Agreement), also known as the "Treaty of the High Seas", is key to protect the ocean, promote equity and fairness, tackle environmental degradation, fight climate change and prevent biodiversity loss in the high seas.

The BBNJ Agreement was adopted on 19 June 2023 and on 20 September 2023 it was signed by the President of the European Commission on behalf of the EU. The Agreement sets up a procedure to establish large-scale marine protected areas in the high seas. This facilitates the achievement of the target to effectively conserve and manage 30% of land and sea by 2030, which was agreed in December 2022 and falls within the Kunming-Montreal Global Biodiversity Framework.

4.1.3 MARPOL Convention and other measures for conserving the Mediterranean Sea

Air pollution and marine ecosystem is a major concern and perhaps the primary reason for climate change in the world which for shipping is regulated by the IMO.

In addition, IMO, through MEPC, is responsible for assessing proposals and designating Particularly Sensitive Sea Areas (PSSAs)[50] and adopting associated protective measures (APMs)[51] applicable to international shipping.

Table 10 List[52] of PSSAs

No.	PSSA	Proposing state(s)	APM[53]
1	Great Barrier Reef Region	Australia	IMO-recommended Australian system of pilotage; mandatory ship reporting system
	Torres Strait extension	Australia, Papua New Guinea	IMO-recommended Australian system of pilotage; two-way route
	South-West Coral Sea extension	Australia	Area to be avoided; traffic separation systems
2	Archipelago of Sabana-Camaguey	Cuba	Area to be avoided
3	Sea area around Malpelo Island	Colombia	Area to be avoided
4	Sea area around the Florida Keys	United States	Areas to be avoided; mandatory no anchoring areas

[50] PSSAs is an area that needs special protection through action by IMO because of their significance for recognised ecological or socio-economic or scientific reasons and which may be vulnerable to damage by international maritime activities.

[51] Associated protective measures (APMs) are measures where IMO defines the means by which a PSSA is protected against environmental threats posed by international shipping.

[52] As per MEPC.1/Circ.778/Rev.4

[53] This table lists only those APMs that have been specifically identified as APMs per se. It is believed that there are other IMO-adopted measures such as national measures in the designated PSSA which may also be relevant.

5	Wadden Sea	Netherlands (Kingdom of the), Denmark, Germany	Mandatory deep-water route
6	Paracas National Reserve	Peru	Area to be avoided
7	Western European Waters	Belgium, France, Ireland, Portugal, Spain, UK	Mandatory ship reporting system
8	Canary Islands	Spain	Area to be avoided; traffic separation systems; recommended routes; mandatory ship reporting system
9	Galapagos Archipelago	Ecuador	Area to be avoided; mandatory ship reporting system; recommended tracks
10	Baltic Sea Area	Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Poland, Sweden	Traffic separation schemes (TSS); deepwater route; areas to be avoided; mandatory ship reporting system; MARPOL Special Area; MARPOL SECA
11	Papahānaumo-kuākea Marine National Monument	United States of America	Areas to be avoided; recommended/mandatory ship reporting system
12	Strait of Bonifacio	France, Italy	Recommendation on navigation
13	Saba Bank (Caribbean Island of Saba)	Netherlands (Kingdom of the)	Area to be avoided; mandatory no anchoring area
14	Jomard Entrance	Papua New Guinea	Routing system (four two-way routes and a precautionary area)
15	Tubbataha Reefs Natural Park	Philippines	Area to be avoided
16	North-Western Mediterranean Sea	France, Italy, Monaco, Spain	Speed reductions; appropriate safety distances; broadcasting the position of medium and large cetaceans observed; reporting of all collisions
17	Nusa Penida Islands and Gili Matra Islands in Lombok Strait[54]	Indonesia	TSS of Lombok Strait

Source: IMO, Drewry (2024)

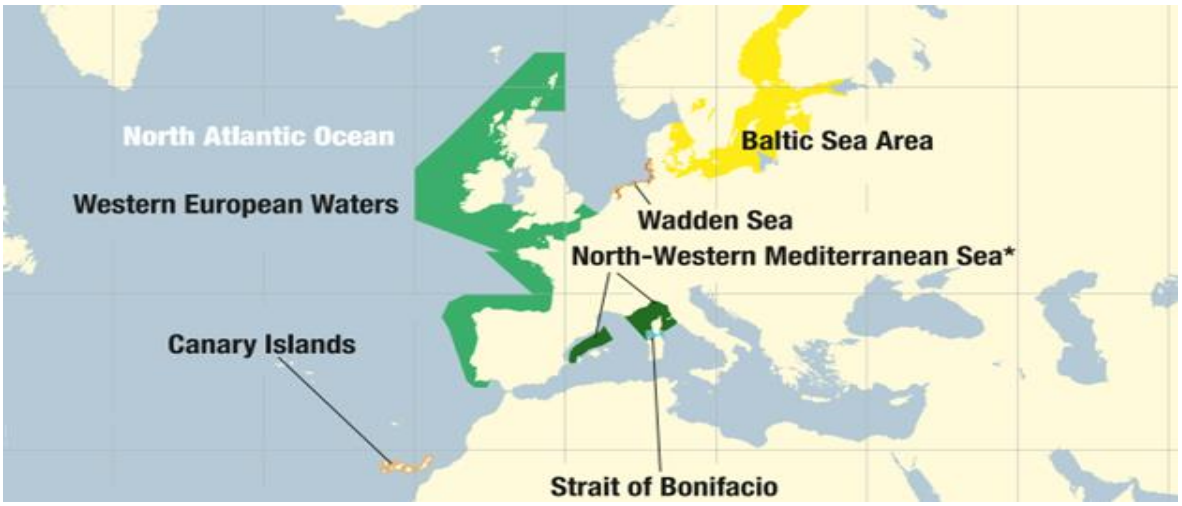
In the Lloyd's Register's report[55], it was noted that the Government of Peru is currently in the process of completing the information required to finalise the proposal for the following sea areas to be classified as a PSSA:

[54] As per MEPC 82
[55] MEPC 82 Summary report from Lloyd's Register.

.1 Reserva Nacional Mar Tropical de Grau (Grau Tropical Sea National Reserve)

.2 Reserva Nacional Dorsal de Nasca (Nasca Ridge National Reserve)

Figure 16 Current PSSAs in the Mediterranean Sea and Baltic Sea area



Source: IMO, (2024)

The Mediterranean coastal States should follow “Revised guidelines for the identification and designation of Particularly Sensitive Sea Areas” Resolution A.982(24) of the IMO. When an area is approved as PSSA, specific measures, such as can be adopted to control the maritime activities in that area.

Certain areas of the Mediterranean already fall under PSSA but a more detailed study should be carried out to include the larger area such as Natura 2000 because of the detrimental effects in the entire region of the Mediterranean Sea.

4.1.4 Water Framework Directive (WFD) and Marine Strategy Framework Directive (MSFD)

.1 The Water Framework Directive (WFD), i.e. Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishes a framework for Community action in the field of water policy, as well as the marine and aquatic environment, and protects species and habitats.

.2 Marine Strategy Framework Directive (MSFD), i.e. Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 has been establishing a framework for community action in the field of marine environmental policy. This Directive contributes to coherence between, and aims to ensure the integration of environmental concerns into, the different policies, agreements and legislative measures which impact the marine environment.

MSFD imposes obligations on EU Member States to protect the marine environment by enabling Good environmental status (GEnS) and aims to create compatible conditions for shipping to achieve that status. It provides a basis for how the environmental impacts of different activities may be regulated in EU Member States.

The WFD prohibits the deterioration of water quality and the activities that deteriorate ecological or chemical status or jeopardise its objectives mentioned in Article 4(1).

The objective of the MSFD is to achieve and maintain GEnS in the EU's marine areas. The marine strategies need to be developed and implemented to prevent and reduce discharges into the marine environment with the long-term aim of phasing out certain pollutants. The geographic scope of the MSFD covers the area from the coastline up to and including the economic zone.

4.1.5 Brief review of recent IMO Resolutions, guidelines and discussions

Many guidelines regarding the concern of EGCS washwater have been adopted by the IMO which are to be considered while operating EGCS. Meanwhile, several ongoing discussions during various IMO Committees and Sub Committees are to be considered as agenda items for discussion in the next planned meeting of the committee. All such ongoing discussions have been reviewed and summarised below.

MEPC.1/Circ.883

This circular provides guidance on the failure of a single monitoring instrument and recommends actions to be taken if EGCS fails to meet the provisions of the 2015 EGCS guidelines (resolution MEPC.259(68)).

Any malfunction that lasts for more than one hour or repetitive malfunctions should be reported to the flag state as well as the port State's Administration along with an explanation of the steps the ship operator is taking to resolve the issue.

MEPC.1/Circ.899

This MEPC Circular contains the "*2022 Guidelines for risk and impact assessments of the discharge water from exhaust gas cleaning systems*". These guidelines provide information on the recommended methodology for risk and impact assessments of the EGCS discharge water that Parties to MARPOL Annex VI should follow when considering local or regional regulations to protect the sensitive waters/environment. The guidelines include assessments of the risks from a long-term perspective, with respect to aquatic quality, aquatic organisms, and/or human health, and the impact assessment approach for the specific receiving environment.

The guidelines serve the purpose of a common unified approach containing procedures that would support Parties to MARPOL Annex VI in judging whether the introduction of restrictions/conditions of discharge water from EGCS would be needed and whether it would be justified. In all aspects of risk and impact assessments, the need for evidence-based decision-making should be balanced with the precautionary approach set out in the resolution MEPC.67(37)[56].

[56] Guidelines on Incorporation of the precautionary approach in the context of specific IMO activities.

Various ongoing discussions at IMO

.1 One of the documents[57] recalls the duty of parties to MARPOL Annex VI to not impair or damage the environment, human health, property or resources when approving alternative compliance methods and reflects the importance of not interpreting Regulation 4 of MARPOL Annex VI in isolation of other regulations and obligations. The document also states "EGCS (Scrubbers) convert air pollution into water pollution". The use of EGCS as an alternative compliance method has been questioned at previous MEPC and Pollution Prevention and Response (PPR) meetings over environmental and social concerns. These concerns relate chiefly to the deposition of deleterious substances, acidification and ecotoxicological effects associated with EGCS washwater discharges.

The International Council for the Exploration of the Sea (ICES), an impartial intergovernmental marine science organisation, the purpose of which is to provide evidence on the state and sustainable use of the ocean, outlines many of these risks and provides facts to support this conclusion as follows:

- EGCS washwater is toxic to marine biota and has been shown to have lethal and sub-lethal effects on the marine zooplankton community.
- EGCS washwater discharge contains large quantities of metals and PAHs in dissolved, readily bioavailable form. These contaminants may concentrate at ultra-trace levels in the water column and bioaccumulate in plankton, fish and marine mammals, to levels that may impair vital functions and population productivity.
- In areas of intense maritime traffic where EGCS washwater is permitted, annual EGCS-related ocean acidification could be similar to that induced by carbon dioxide over several years to decades.

This signifies that marine traffic areas are already on the agenda at the global level while intense marine traffic areas such as the Mediterranean Sea are at greater risk where strict reforms are required.

Some concerns mentioned in the document questioning the equivalency, are mentioned below:

- Concerns have been raised as to whether EGCS are fit for reducing pollution in the water bodies. It has been reported that ships using HFO along with EGCS does not produce emissions that are equivalent to compliant low-sulphur fuels and result in greater emissions of PM, including Black Carbon (BC) and CO_2.

The document also refers to the precautionary principle in support of calls to ban or restrict EGCS. The precautionary principle states that the absence of adequate scientific information should not be used as a reason to postpone measures for preventing environmental degradation.

[57] MEPC 81/5/4

One of the recommendations in the document is "*Until a global ban is introduced, encourage national maritime administrations to ban the discharge of scrubber waste within their jurisdictional waters and to stop approving scrubbers as an alternative compliance method for ships registered under their flags*".

.2 A document[58] submitted to IMO summarises a study by the International Council on Clean Transportation (ICCT), which has found that the CO_2, PM and BC emissions from ships using EGCS are higher than those using marine gas oil. Additionally, the washwater discharged by open-loop and hybrid EGCS and the bleedoff water generated by close-loop EGCS is contaminated with PAH, PM, nitrates, nitrites and heavy metals, and it is often more acidic than the water into which it is discharged[59].

.3 One of the documents[60] contains information regarding a summary of the ongoing process mentioned in the Commission for Environmental Cooperation on EGCS in Pacific Canada. After studying the washwater discharge into the world's oceans, including IMO-designated PSSAs and Special Areas, and other ecologically vulnerable areas, it was found that EGCS discharges (open-loop, close-loop and hybrid) are more acidic and turbid than the surrounding water.

This document also states that PM, including BC, and CO_2 emissions from ships using HFO with EGCS are higher than those using MGO. Additional inputs of contaminants from EGCS washwater will push ecosystems beyond ecological thresholds, adversely impacting predators at or near the top of the food chain, such as salmon and orcas.

.4 A proposed document[61] sets out an agenda for discussion on legal analysis of the use of EGCS with a focus on its impact on air quality under MARPOL Annex VI. It outlines that EGCS should not be regarded as an alternative compliance method under Regulation 4 of MARPOL Annex VI and states certain facts such as:

- SO_x and PM vary with sulphur content in fuel; therefore, they are reduced when a ship is operating on lower sulphur fuels[62].
- The use of EGCS reduces SO_x emissions from the exhaust gas and intends to enable ships to use HFO instead of the more expensive low-sulphur fuels such as MGO. EGCS may also be used in conjunction with VLSFO to comply with ECAs.
- In MEPC 81 it was noted that MEPC also received legal advice provided by the IMO Secretariat to establish the threshold for EGCS use that would cause deleterious effects and/or harm to the marine environment. If the IMO determines that continued acceptance of EGCS would be in conflict with UNCLOS, further regulatory control on the use of EGCS would be required. The legal advice concluded that while coastal States have sovereignty over their territorial seas, they may not impose restrictions in their EEZ that are more stringent than international rules and standards without consulting the IMO.

[58] As per MEPC 81/INF.36

[59] Document MEPC 79/5/3 (FOEI et al.) shows how the discharge of wastes from EGCS into the marine environment can raise issues of inconsistency with the law of the sea obligations of States to protect the marine environment.

[60] As per MEPC 82/5/4

[61] As per MEPC 82/5.

[62] Faber et al., Fourth IMO Greenhouse Gas Study 2020, pages 74 to 75 and 278.

.5 The MEPC 82 committee considered draft terms of reference for the re-establishment of the GESAMP Task Team on EGCS. During the discussion, several views supported amending the proposed terms of reference: 1) to include the determination of EF in addition to the methodology, 2) to consider any other relevant chemical substances in EGCS discharge water in addition to the proposed list of priority hazardous substances, 3) to remove the reference to the use of 50% of laboratory detection limits as assigned values for non-detects, 4) to align key terminology and evaluation criteria with the 2022 Guidelines for risk and impact assessments of the discharge water from EGCS, and 5) to guarantee the reliable and thorough implementation of the applicable environmental risk assessment process. Due to time limitations, proposed terms of reference for the re-establishment of the GESAMP Task Team were referred in January 2025[63] for further consideration.

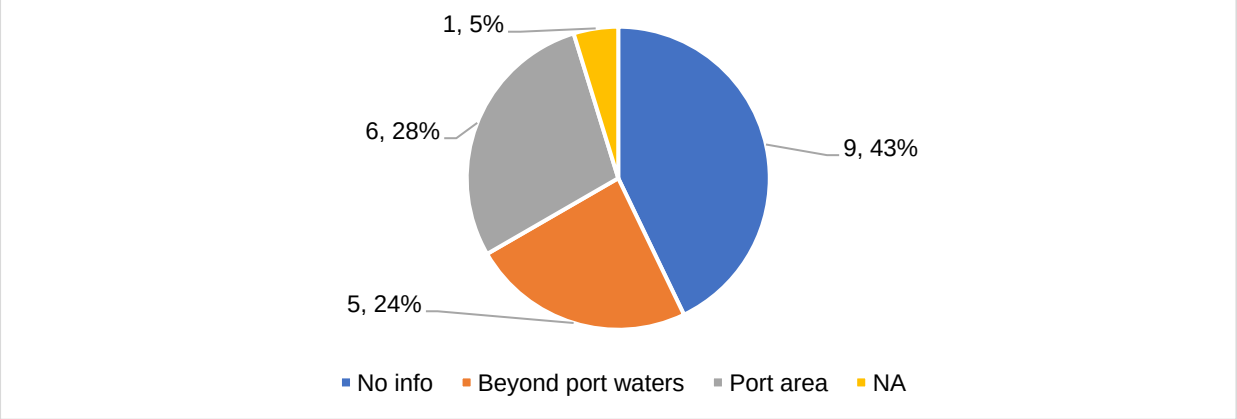
4.2 Existing policies adopted by the CPs to the Barcelona Convention regarding discharge washwater from EGCS

Apart from IMO directing the regulations to control different kinds of discharge in the sea, States can come up with their own policies and regulations to help systemise the implementation of IMO regulations or implement even stricter/additional regulations if the States believe their coastal waters need them.

Given that there are no regulations under MARPOL in relation to EGCS washwater discharge, although there are related guidelines, a few Mediterranean coastal States have individually taken initiatives to restrict the discharge in their seas.

The current policies regarding EGCS washwater discharge in the Mediterranean region needed to be reviewed and Drewry approached CPs through REMPEC to get the latest updates and first-hand information directly from them.

Figure 17 Region of bans/restrictions by authorities in the Mediterranean coastal States



Source: Drewry (2024)

The above information gives a clear idea about the aversion of the CPs to the Barcelona Convention to EGCS washwater discharge. More than 50% of the Mediterranean coastal States[64] have developed local regulations or policies to restrict the discharge of washwater in areas within

[63] In reference to PPR 12.

[64] Since the State of Bosnia and Herzegovina does not have major ports, it does not need such policies.

the control of the States or port authority. Of these, authorities in 24% of CPs to the Barcelona Convention have imposed restrictions beyond their port areas. However, at present there is no comprehensive policy regarding the ban/restriction for the discharge of EGCS washwater in the Mediterranean region as a whole.

4.3 Port Reception Facilities (PRF)

There is a need for a port reception facility (PRF) for washwater or residues from different sources under various Annexes of MARPOL. MARPOL Annex VI, Regulation 17 specifies two types of wastes for which reception facilities must be provided, to ships calling at their ports:

.1 Ozone Depleting Substances are those defined in MARPOL Annex VI, Regulation 2.16.

.2 Exhaust gas cleaning residues are ship-generated residues that may be liquid or solid.

MEPC adopted IMO Resolution MEPC.199(62) Annex 7, which contains Guidelines for reception facilities under MARPOL Annex VI for PRF under MARPOL Annex VI on 15 July 2011. These guidelines list the general requirements for PRF under Annex VI which states that treatment and disposal of EGCS residues should be safe and environmentally benign in addition to being based on industry best practices and best available technologies. All Parties to MARPOL Annex VI should ensure that ports and terminals have the capacity to collect and store, if necessary, EGCS residues from any and all ships that use their port terminals. These reception facilities are required to provide Waste Delivery Receipts (WDRs) to ships discharging EGCS residues. PRF already exist in some of the ports of the Mediterranean region.

When a port or terminal cannot provide EGCS residue reception facilities, Parties must notify the IMO and in addition, notify the Organisation about the alternative facilities provided. Masters of ships should ensure that there is adequate onboard capacity for storing all EGCS residues that may be generated during the course of voyages including visits to ports or terminals where reception facilities are not available.

As explained earlier, the close-loop EGCS system involves storage of residues collected after purifying washwater. These residues cannot be discharged at sea and have to be offloaded to a PRF.

The 2022 guidance regarding the delivery of EGCS residues to PRFs under MEPC.1/Circ.900 states that as EGCS residues are prohibited from being discharged in the sea, ships that produce these types of waste should have the following on board:

.1 where applicable, evidence of a contract to prove that arrangements are in place to deliver the waste in the region where the ship is operating;

.2 waste receipts from the use of that contract to prove previous deliveries of such waste; such receipts should be kept on board for a period of 12 months after the delivery has been made; and

.3 an estimation of the amount of EGCS residues produced on a daily basis, with records of the volume of solids and sludge produced.

The EU has also adopted Directive (EU) 2019/883 of the European Parliament and of the Council of 17 April 2019 on PRF for the delivery of waste from ships, amending Directive 2010/65/EU and repealing Directive 2000/59/EC for all its Member States to arrange PRFs in their ports. It states that the procedures for reception, collection, storage, treatment and disposal should be in compliance with Regulation (EC) No 1221/2009 of the European Parliament and the Council, which ensures the correct environmental management scheme suitable for the progressive reduction of the environmental impact of these activities. The Commission shall evaluate this Directive and submit the results to the European Parliament and the Council by 28 June 2026. The evaluation shall also include a report detailing best waste prevention and management practices on board ships under Article 23 of Directive (EU) 2019/883 of the European Parliament and of the Council of 17 April 2019 on PRF for the delivery of waste from ship.

4.4 Section summary

Air pollution and marine ecosystems has become a major concern and is the primary reason for climate change. Since the shipping industry has also been contributing to air pollution, protection against such pollution from ships is regulated by Annex VI of the MARPOL Convention.

The IMO has classified many areas under PSSA. Certain areas of the Mediterranean Sea have also come under PSSA but a more detailed study should be carried out to include larger areas such as Natura 2000 as these regions are especially vulnerable to pollution because of its geographical location. The Mediterranean coastal States should follow “Revised guidelines for the identification and designation of Particularly Sensitive Sea Areas” Resolution A.982(24) of the IMO. When an area is approved as PSSA, specific protective measures can be adopted to control maritime activities in that area.

UNCLOS lays down a comprehensive regime of law and order in the world's oceans and seas establishing rules governing all uses of the oceans and their resources. It provides a framework for further development of specific areas of the law of the sea and suggests the possible establishment of large maritime zones outside the territorial sea whereby the regime of international law applies in each sea area. Article 194 of UNCLOS sets out the obligation to prevent, reduce and control pollution of the marine environment with Article 195 explicitly referring to the obligation not to transfer damage or hazards, or transform one type of pollution into another.

In the EEZ, the coastal state has certain jurisdictions, including that over the protection and preservation of the marine environment (Article 56(2) of UNCLOS). This framework entitles States that are parties to establish global and regional rules to safeguard their marine environment and air pollution interest in their coastal state jurisdiction.

A facilitator needs to be involved to help and negotiate with the CPs to the Barcelona Convention that have not ratified the UNCLOS to come to a mutual understanding so that regional measures can be taken for EGCS washwater discharge in the entire Mediterranean region.

MSFD and **WFD** are two major directives to establish a framework for the EU water policy, marine environment policy, and protection of marine species and their habitats. The WFD prohibits the deterioration of water quality and activities that deteriorate ecological or chemical status, or jeopardise its objectives mentioned in Article 4(1). The MSFD imposes obligations on Member States to protect the marine environment by enabling GEnS and aims to create compatible conditions for shipping to achieve that status. The geographic scope of the MSFD covers the area from the coastline up to and including the economic zone.

BBNJ Agreement, which was adopted on 19 June 2023, states the setting up of a procedure to establish large-scale marine protected areas in the high seas and thereby facilitates the achievement of the goal to effectively conserve and manage 30% of land and sea by 2030. This was agreed in December 2022 and falls within the Kunming-Montreal Global Biodiversity Framework.

The recent developments related to EGCS in terms of MEPC resolutions, guidelines and agendas are mentioned below:

.1 MEPC.1/Circ.883: It provides guidance on the failure of a single monitoring instrument and recommends actions to be taken if EGCS fails to meet the provisions of the 2015 EGCS guidelines (resolution MEPC.259(68)).

.2 MEPC.1/Circ.899: It provide information on the recommended methodology for risk and impact assessments of the EGCS discharge water that Member States should follow when considering local or regional regulations to protect the sensitive waters/environment. It also provides guidelines for long-term risk assessments for aquatic life and impact assessments for the marine environment.

.3 Various important findings from ongoing discussions and proposals:

- The precautionary principle states that the absence of adequate scientific information should not be used as a reason to postpone measures for preventing environmental degradation.
- The washwater discharged by open-loop and hybrid EGCS and the bleedoff water generated by close-loop EGCS are contaminated with PAH, PM, nitrates, nitrites and heavy metals, and it is often more acidic than the water into which it is discharged.
- The following steps have been suggested in the document “The IMO should prohibit the use of EGCS as an alternative compliance method for new ships and establish a timeline for phasing out EGCS already installed on existing ships”.
- SO_x and PM vary with sulphur content and are lower in low-sulphur fuels.
- The legal advice concluded that while coastal States have sovereignty over their territorial seas, they may not impose restrictions in their EEZ that are more stringent than international rules and standards without consulting the IMO.

- The impact assessments of the discharge water from EGCSs are being reviewed and the results will be sent in January 2025 for further consideration.

Apart from IMO directing the regulations to control different kinds of discharge in the sea, States can come up with their own policies and regulations to help systemise the implementation of IMO regulations or implement even stricter/additional regulations if the States believe their coastal waters need them. It is to be noted that there is no regulation under MARPOL in relation to EGCS washwater discharge, although there are guidelines for it.

More than 50% of the Mediterranean coastal States have developed local regulations or policies to restrict the discharge of washwater in areas within the control of the States or port authority. Of these, authorities in 24% of States have imposed restrictions beyond their port areas. While a lot is happening locally, there is no comprehensive policy regarding the ban/restriction for the discharge of EGCS washwater in the Mediterranean region as a whole.

MEPC adopted guidelines for PRF under MARPOL Annex VI which states that treatment and disposal of EGCS residues should be safe and environmentally benign in addition to being based on industry best practices and best available technologies. All parties of MARPOL Annex VI should ensure that ports and terminals have the capacity to collect and store, if necessary, EGCS residues from any and all ships that use their port terminals. These reception facilities are required to provide WDRs to ships discharging EGCS residues.

The 2022 guidance under MEPC.1/Circ.900 of 10 June 2022 regarding the delivery of EGCS residues to PRFs states that as EGCS residues are prohibited from being discharged in the sea, ships that produce these types of waste should have the following on board:

.1 where applicable, evidence of a contract to prove that arrangements are in place to deliver the waste in the region where the ship is operating;

.2 waste receipts from the use of that contract to prove previous deliveries of such waste; such receipts should be kept on board for a period of 12 months after the delivery has been made; and

.3 an estimation of the amount of EGCS residues produced on a daily basis, with records of the volume of solids and sludge produced.

The EU has also released Directive 2019/883 PRF for the delivery of waste from ships, which states that the procedures for reception, collection, storage, treatment and disposal should be in compliance with Regulation (EC) No 1221/2009 of the European Parliament and the Council, which ensures the correct environmental management scheme suitable for the progressive reduction of the environmental impact of these activities. The Commission shall evaluate this Directive and submit the results to the European Parliament and the Council by 28 June 2026. The evaluation shall also include a report detailing best waste prevention and management practices on board ships.

5 Potential environmental impact of EGCS on the marine environment in the Mediterranean Sea

The popularity of EGCS has led to an increasing number of ships installing different types of EGCS as can be seen in Figure 10. As washwater discharge contains pollutants (e.g. PAHs, lead, mercury, benzene, naphthalene, anthracene) that 'pose' a risk to the aquatic environment, various ports and environmental regulators have expressed their concern over ships using open-loop EGCS in ports and coastal waters.

5.1 European water quality standard and 'priority hazardous substances'

The EU Directive 2020/2184 of the European Parliament and of the Council of 16 December 2020 on the quality of water intended for human consumption suggests guidelines and limits on the quality of water intended for human consumption as per the European Water Quality Standard (EWQS). The parameters along with their value are given in the below table.

Table 11 Chemical parameters as per EWQS

Parameter	Parametric value	Unit
Acrylamide	10	µg/l
Antimony	10	µg/l
Arsenic	10	µg/l
Benzene	10	µg/l
Benzo(a)pyrene	10	µg/l
Bisphenol A	25	µg/l
Boron	15	mg/l
Bromate	10	µg/l
Cadmium	50	µg/l
Chlorate	25	mg/l
Chlorite	25	mg/l
Chromium	25	µg/l
Copper	20	mg/l
Cyanide	50	µg/l
1,2-dichloroethane	30	µg/l
Epichlorohydrin	10	µg/l
Fluoride	15	mg/l
Haloacetic acids (HAAs)	60	µg/l
Lead	5	µg/l
Mercury	10	µg/l
Microcystin-LR	10	µg/l
Nickel	20	µg/l
Nitrate	50	mg/l
Nitrite	50	mg/l
Pesticides	10	µg/l
Pesticides (total)	50	µg/l
Perfluoroalkyl and polyfluoroalkyl substances (PFAS) (total)	50	µg/l
Sum of PFAS	10	µg/l
Polycyclic aromatic hydrocarbons	10	µg/l
Selenium	20	µg/l
Tetrachloroethene and Trichloroethene	10	µg/l
Trihalomethanes (total)	100	µg/l
Uranium	30	µg/l
Vinyl chloride	50	µg/l

Source: EU

On a similar note, Decision No 2455/2001/EC of the European Parliament and of the Council of 20 November 2001 establishing the list of priority substances[65] in the field of water policy.

Table 12 List of priority substances

Number	Name of priority substance	Identified as priority hazardous substance
1	Alachlor	
2	Anthracene[66]	X
3	Atrazine[66]	X
4	Benzene	
5	Brominated diphenyl ethers	X
6	Cadmium and its compounds	X
7	C_{10-13}-chloroalkanes	X
8	Chlorfenvinphos	
9	Chlorpyrifos[66]	X
10	1,2-Dichloroethane	
11	Dichloromethane	
12	Di(2-ethylhexyl) phthalate (DEHP)[66]	X
13	Diuron[66]	X
14(a)	Endosulfan[66]	X
(b)	(alpha-endosulfan)	
15	Fluoranthene[67]	
16	Hexachlorobenzene	X
17	Hexachlorobutadiene	X
18(a)	Hexachlorocyclohexane	X
(b)	(gamma-isomer, Lindane)	
19	Isoproturon[66]	X
20	Lead and its compounds[66]	X
21	Mercury and its compounds	X
22	Naphthalene[66]	X
23	Nickel and its compounds	
24(a)	Nonylphenols	X
(b)	(4-(para)-nonylphenol)	
25(a)	Octyl phenols[66]	X
(b)	(para-tert-octyl phenol)	
26	Pentachloro benzene	X
27	Pentachlorophenol[66]	X
28(a)	Polyaromatic hydrocarbons	

[65] EU Water Framework Directive (WFD), classifies the substances that pose risks to man and the environment to an extent that priority action must be taken to reduce their occurrence as priority substances.

[66] Priority substance is subject to a review for identification as possible “priority hazardous substance”.

[67] Fluoranthene is on the list as an indicator of other, more dangerous, Polyaromatic Hydrocarbons.

(b)	(Benzo(a)pyrene),	
(c)	(Benzo(b)fluoranthene),	
(d)	(Benzo(g,h,i)perylene),	
(e)	(Benzo(k)fluoranthene),	
(f)	(Indeno(1,2,3-cd) pyrene)	
29	Simazine[66]	X
30(a)	Tributyltin compounds	X
(b)	(Tributyltin-cation)	
31(a)	Trichlorobenzenes[66]	X
(b)	(1,2,4-Trichlorobenzene)	
32	Trichloromethane (chloroform)	
33	Trifluralin[66]	X

Source: Official Journal of the European Communities, EU,

5.2 Various environmental impact studies and findings

A few studies have been conducted on the environmental impact of EGCS washwater but their scope is limited. There have also been conflicting results in these studies.

.1 A modelling study "The impact of scrubber discharge on the water quality in estuaries and ports, (Teuchies, J., Tom, C., et al., 2020)" carried out in the Flemish region[68] found that EGCS washwater increases surface water concentrations of naphthalene[69,66] by 189% and vanadium[70] by 46%. However, the higher concentration of these substances was not considered high-risk under EU Water Quality Standards. Although, Naphthalene is a part of the "priority substance list" and is under review for identification as a possible "priority hazardous substance".

.2 While conducting the study, the IMO Task Team on EGCS identified gaps in scientific data of many contaminants and suggested the collection of additional data (GESAMP[71], 2020). Accordingly, the agreement was signed under the UNCLOS on the conservation and sustainable use of marine biological diversity of areas beyond national jurisdiction (BBNJ Agreement)[72].

[68] The Flemish region is also referred to as Flanders and is found on the northern side of Belgium.

[69] The structure of naphthalene consists of two fused benzene rings, rendering it a PAH. In terms of environmental impact, naphthalene can pose risks to both soil and aquatic life. It has the potential to contaminate water sources and can prove toxic to several organisms at sufficiently high concentrations.

[70] It is a chemical element, which is considered as an emerging environmental hazard. A review of ecotoxicology data commissioned by The Netherlands' Government has subsequently proposed water quality standards for dissolved "Vanadium" of 1.2 and 3.0 µg/L for long- and short-term exposure (Smit, C. E. Environmental Risk Limits for Vanadium in *Water: A Proposal for Water Quality Standards* following the Water Framework Directive, RIVM Letter Report 601714021/2012; National Institute for Public Health and the Environment, Bilthoven, 2012)

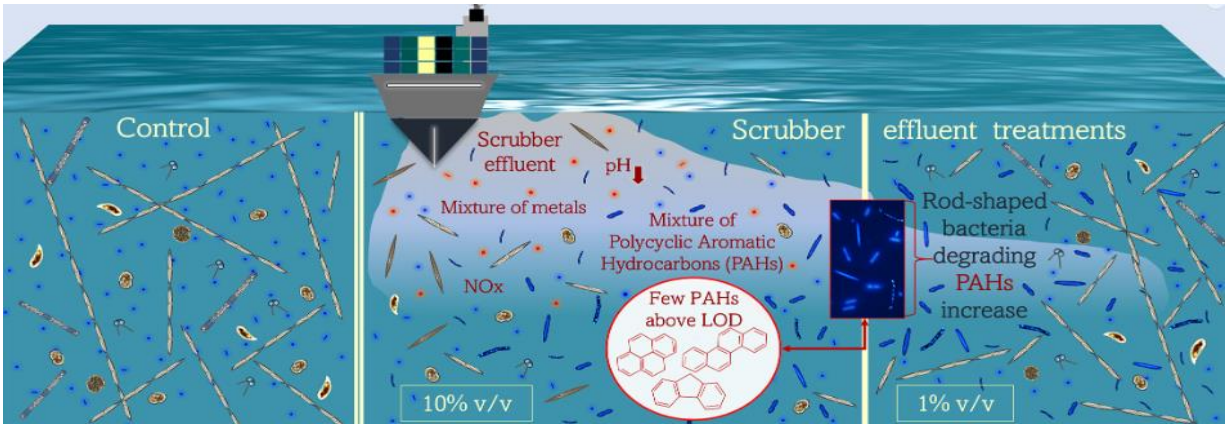
[71] This is a Joint Group of Experts on the Scientific Aspects of Marine Environmental Pollution. GESAMP is an advisory body consisting of specialised experts nominated by the Sponsoring Organisations (IMO, FAO, UNESCO-IOC, UNIDO, WMO, IAEA, UN, UNEP, UNDP and ISA). Its principal task is to provide scientific advice concerning the prevention, reduction and control of the degradation of the marine environment to the Sponsoring Organisations.

[72] Details of BBNJ agreement is given in Section 4.1.2.

.3 Based on dilution series of the Whole Effluent Testing (WET), a report by Evaluation, control and Mitigation of the Environmental impacts of Shipping Emissions (EMERGE) (Jukka-Pekka, J., Erik, F., et al., 2024) on the impact of the EGCS washwater on marine invertebrate species and on phytoplankton found variations in taxonomic groups and between different stages of the invertebrate life cycle. Invertebrates were more affected than phytoplankton. The fertilisation of sea urchin eggs was affected at a low concentration of 1: 1,000,000. In addition, dilutions of 1:100,000 were harmful to the early development of several of the tested species, including mussels, polychaetes and crustaceans. The observed effects at these low concentrations of EGCS washwater discharge were reduced egg production, and deformations and abnormal development of the larvae of the species.

.4 A few studies show that the impact of vessel EGCS washwater on marine ecosystems create adverse effects on phytoplankton and bacterioplankton. The sample was obtained in November 2021 from the open-loop EGCS on board the DANAOS Leo C container ship during an onboard campaign of the EMERGE project at the Mediterranean Sea site south of the Peloponnese (36°16´25´´N, 22°02´51´´E).

Figure 18 Effect of EGCS effluents on marine



Source: EMERGE project (European Union's Horizon 2020 research and innovation programme), ELSEVIER

.5 A marine environmental risk assessment was performed for the Öresund region for the baseline year 2018, where predicted environmental concentrations (PECs)[73] of open-loop washwater discharge were compared with the predicted no-effect concentration (PNEC)[74] value. The results showed concentrations of open-loop washwater in large areas to be 2-3 times higher than the derived PNEC value, yielding a risk characterisation ratio of 500-5000, which indicates significant environmental risk. Further, it should be noted that the number of EGCS vessels has since increased significantly.

[73] Predicted environmental concentrations is a calculated value of a chemical in the environment based on exposure models such as the EU System for the Evaluation of Substances.

[74] PNEC is the concentration of a substance in any environment below which adverse effects will most likely not occur during long-term or short-term exposure.

.6 The research “Metal and PAH loads from ships and boats, relative other sources, in the Baltic Sea, (Ytreberg E., Katarina H., et al., 2022)” on the Baltic Sea ports found that EGCS accounts for 9% of certain ***cancer-causing PAHs*** found in marine environments (>98% comes from open-loop EGCS). However, it was also found that the environmental impact of discharged washwater was far lower than that of air emissions (when measuring the total pollutant impact per vessel per trip).

.7 The British Port Association (BPA) and UK Major Ports Group (UKMPG) commissioned the Centre for Environment Fisheries and Aquaculture Science (CEFAS) to review CE Delft study on Comparison air pollutant emissions MARPOL Annex VI compliance options in 2020, Anne, K. (2021), which pointed out that areas with limited water exchange can lead to higher sediment concentrations creating potential contamination hotspots. BPA also pointed to a study “Ship emissions and the use of current air cleaning technology: contributions to air pollution and acidification in the Baltic Sea, (Claremar, B., Haglund, K., et al., 2017)” which focused on the Baltic Sea and found that open-loop EGCS could increase shipping lane acidification to the 1970s-90s level.

.8 The Danish Environment Ministry found that the use of open-loop EGCS has resulted in excessive levels of heavy metals and tar substances in the marine environment and by calling for actions in Danish waters they could reduce the quantity of nickel (EWQS chemical list) in the seawater by 20% and anthracene (priority hazardous substance) by 7% as per “Jamey, B. (2024). Denmark bans scrubber discharge in coastal waters from mid-2025. Riviera, 2024”.

.9 Separate ecotoxicological studies on marine species by Exhaust Gas Cleaning System Associations (EGCSA) and Danish Hydraulics Institute (DHI) as well as the Japanese Government found that risks to marine life are in acceptable range and were only slightly above detection limits (EGCSA, 2021; Ministry of Land, Infrastructure, Transport and Tourism, 2019).

.10 The German Environment Agency and its Federal Maritime and Hydrographic Agency (BSH) studied the washwater from EGCS between 2020 and 2023, tracking the water-soluble as well as particle-bound contaminants including vanadium, nickel, copper, iron and zinc, as well as PAHs. The tests on total toxicity of marine organisms were found from “practically non-toxic” to “highly toxic” and in some cases “extremely toxic” with close-loop EGCS samples, suggesting that the current regulatory measures are insufficient and there is a need for stricter regional measures.

.11 In a project[75] carried out on the samples collected from three vessels in service in the North Sea, it was found that the ubiquitous planktonic copepod[76] suffered severe toxic effects from the exposure to washwater discharge from two close-loop EGCS systems and one open-loop system. The study “Severe Toxic Effects on Pelagic Copepods from Maritime Exhaust Gas Scrubber Effluents, (Peter, T., Maria, G., et al. (2021)” also found that all copepods died within one day of being exposed to a 5% concentration of the sample from the EGCS and within 8 days when exposed to a 40% concentration of the EGCS effluents.

.12 A 2020 study carried out by the Royal Belgian Institute of Natural Sciences (RBINS) found that SO_x pollution in the English Channel may cause a yearly pH

[75] This project was financed through the EU via Connecting Europe Facility Agreement number INEA/CEF/TRAN/M2014/1025417 and the IVL foundation and in part by the EU H2020 GRANT AGREEMENT 874990 EMERGE.

[76] Copepods are tiny crustaceans known as the “insects of the sea and are the critical base of the food chain in the Arctic”.

drop equivalent to 2-4 times the annual rate of climate change caused by the acidification process in water bodies because of EGCS washwater than the natural annual rate of climate change acidification. However, because of the flushing effect[77] in this channel, researchers did not anticipate the accumulation of SO_x pollution from shipping.

The EMERGE project also suggests that EGCS washwater affects components of the marine food web due to the restriction of planktivorous invertebrates, fishes and their larval stages. The study shows further evidence that EGCS operating in an open-loop mode is not environmentally sustainable for reducing sulphur emissions.

In the Mediterranean region, many important shipping lanes run close to shore and archipelago[78] areas, and this also puts the sensitive shallow-water coastal ecosystems at risk. It should be noted that there are no studies or data available on sub-lethal effects on early life stages of fish that were included in the EMERGE project; the direct toxic effects on fish at the expected concentrations of EGCS washwater are therefore largely unknown. These have high biodiversity and represent significant spawning areas for many marine species. Considering the existence of densely trafficked shipping lanes in regional seas, most of the European coastline and marine life in those areas will be impacted by EGCS effluents.

EGCS is engineered to reduce the impact of sulphur emissions from HFO in the atmosphere. However, the EMERGE project concludes that it is merely moving the problem from the atmosphere to the hydrosphere, which in turn increases the exposure of toxicants such as vanadium, PAHs and alkylated PAHs to marine biota[79]. It also suggests that the use of HFO in vessels equipped with open-loop EGCS be discouraged and a shift towards less impacting technological alternatives be sought.

5.3 Estimating emissions and discharge from shipping in the Mediterranean Sea

The emissions and discharge from shipping have been estimated using the Ship Traffic Emission Assessment Model (STEAM[80]) in the EMERGE project[81] for environmental impacts of EGCS in the Baltic Sea, North Sea and the Mediterranean Sea. Below are the key findings from the EMERGE project.

5.3.1 Spatial distribution of $PM_{2.5}$ and SO_x

The spatial distribution of $PM_{2.5}$ and SO_x air emissions from shipping in the Mediterranean Sea area is given below.

[77] Flushing in a channel is an environmental flow that removes residual sediments and reduces the likelihood of large particles entering the channel.

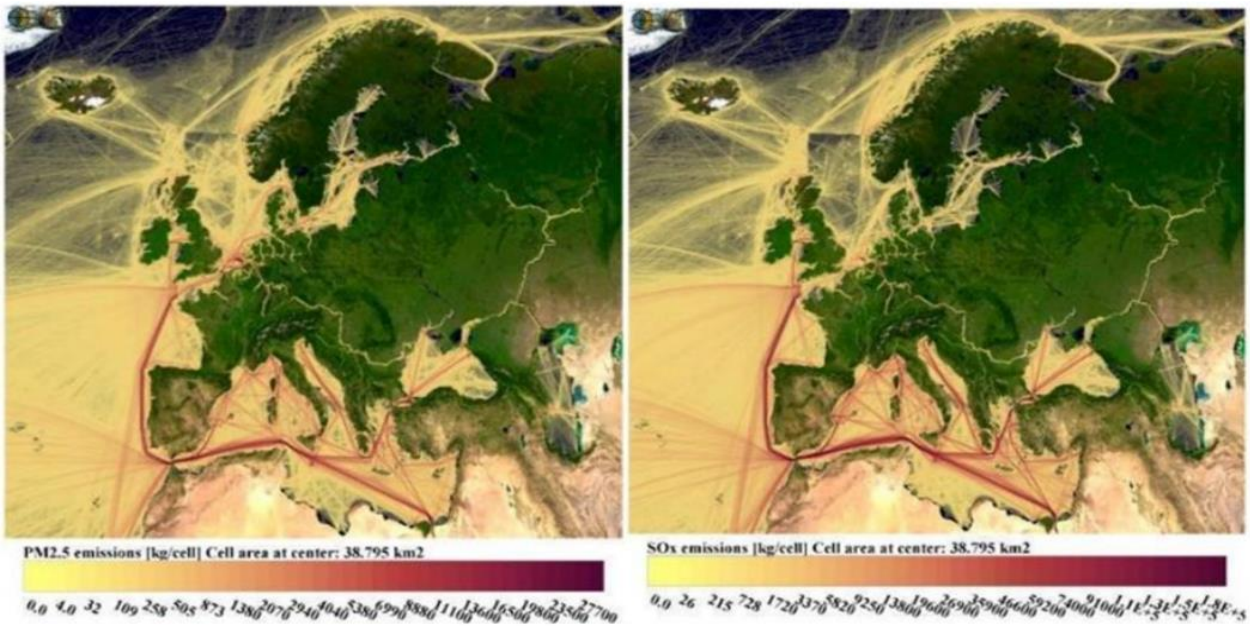
[78] a group of small islands or an area of sea in which there are many small islands.

[79] Marine biota and especially microbes can affect the composition of the atmosphere by producing and consuming a number of trace gases that influence climate and atmospheric chemistry

[80] STEAM (Jalkanen et al., 2012, 2018, 2021, 2009; Johansson et al., 2013, 2017) was used to describe the environmental pressures from shipping. This model uses vessel speed and location information from Automatic Identification System (AIS) data and technical information of individual ships from the S&P Global database to model the power load, fuel consumption and air emissions.

[81] The Baseline year for the study is 2018.

Figure 19 Spatial distribution of $PM_{2.5}$ (figure on the left) and SO_x (figure on the right) in the Mediterranean Sea



Source: EMERGE project (Jukka-Pekka, J., Erik, F., et al. (2024))

The above figure shows that the Mediterranean Sea has a high concentration of SO_x and $PM_{2.5}$ in the air because of heavy traffic movement.

Table 13 Air emission and discharge of contaminants from ships in the Mediterranean Sea in 2018

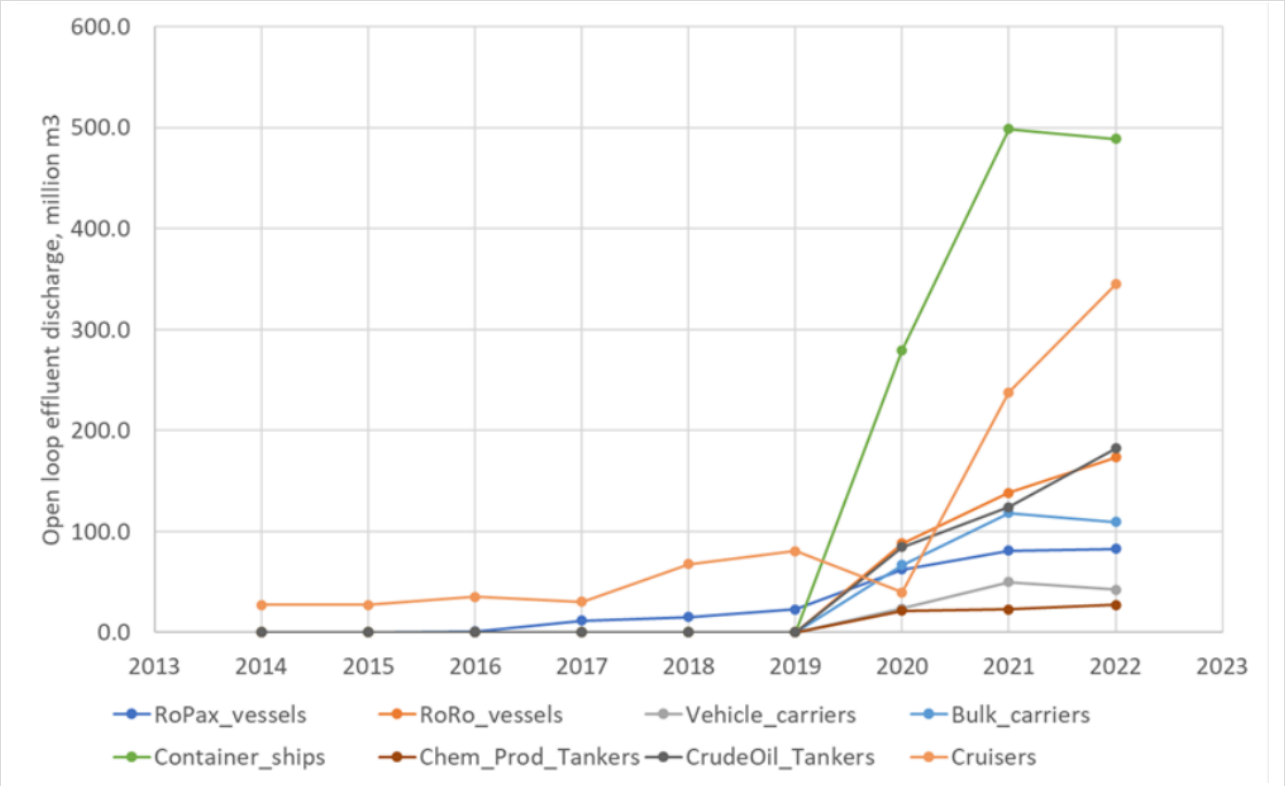
Contaminant	Mass in tonnes from air emission	Mass in tonnes from discharge water
Arsenic	3.6	0.58
Cadmium	0.8	0.07
Chromium	6.9	1.2
Copper	8	3.2
Iron	178.1	20
Mercury	0	0.07
Nickel	236.2	3.9
Lead	4.4	0.76
Vanadium	476.3	15
Zinc	71	9.2
Naphthalene	96.3	0.23
Acenaphthene	1.9	0.016
Acenaphthylene	0.6	0.011
Fluorene	1.4	0.038
Phenanthrene	6.8	0.13
Anthracene	0.2	0.007
Fluoranthene	0.8	0.013
Pyrene	0.8	0.027
Benzo[a]anthracene	0.7	0.011
Chrysene	5.2	0.016
Benzo[b]fluoranthene	0.5	0.003
Benzo[k]fluoranthene	0.4	0.001
Benzo[a]pyrene	0.5	0.004
Dibenzo[a,h]anthracene	0.4	0.002
Benzo[g,h,i]perylene	0.6	0.002
Indeno[1,2,3-cd]pyrene	0.4	0.006

Source: EMERGE project (Jukka-Pekka, J., Erik, F., et al. (2024))

The comparison made in the above table between contaminants in air emission and discharge water shows that most of the contaminants were emitted into the atmosphere in 2018. For

example, in 2018, the amount of nickel emitted in the air because of combustion in engines using HFO was 236.2 tonnes whereas the corresponding amount in EGCS washwater discharges was less than four tonnes (3.9 tonnes). In 2018, only passenger vessels used EGCS regularly but in 2022 other types of vessels also started using EGCS because of the sulphur cap; nickel emissions to the atmosphere were about 27 tonnes from low sulphur fuels, whereas nickel in EGCS washwater was 70 tonnes. This shows that emissions in the air have reduced while the concentration of nickel contaminant in the water has surged.

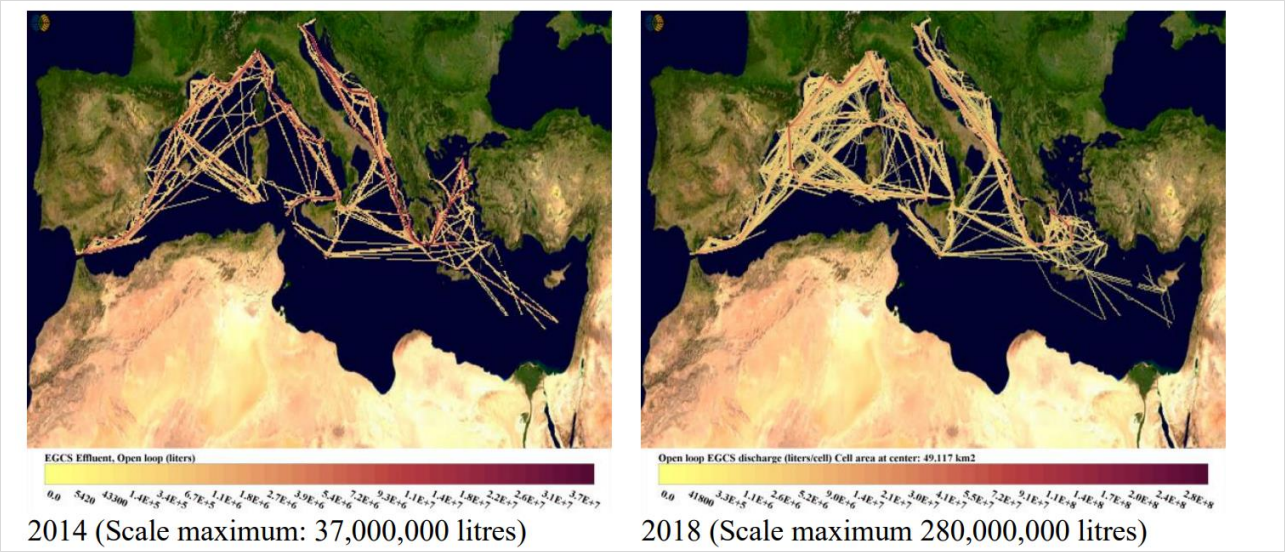
Figure 20 Effluent discharge from ships of various types sailing the Mediterranean Sea during 2014-22



Source: EMERGE project (Jukka-Pekka, J., Erik, F., et al. (2024))

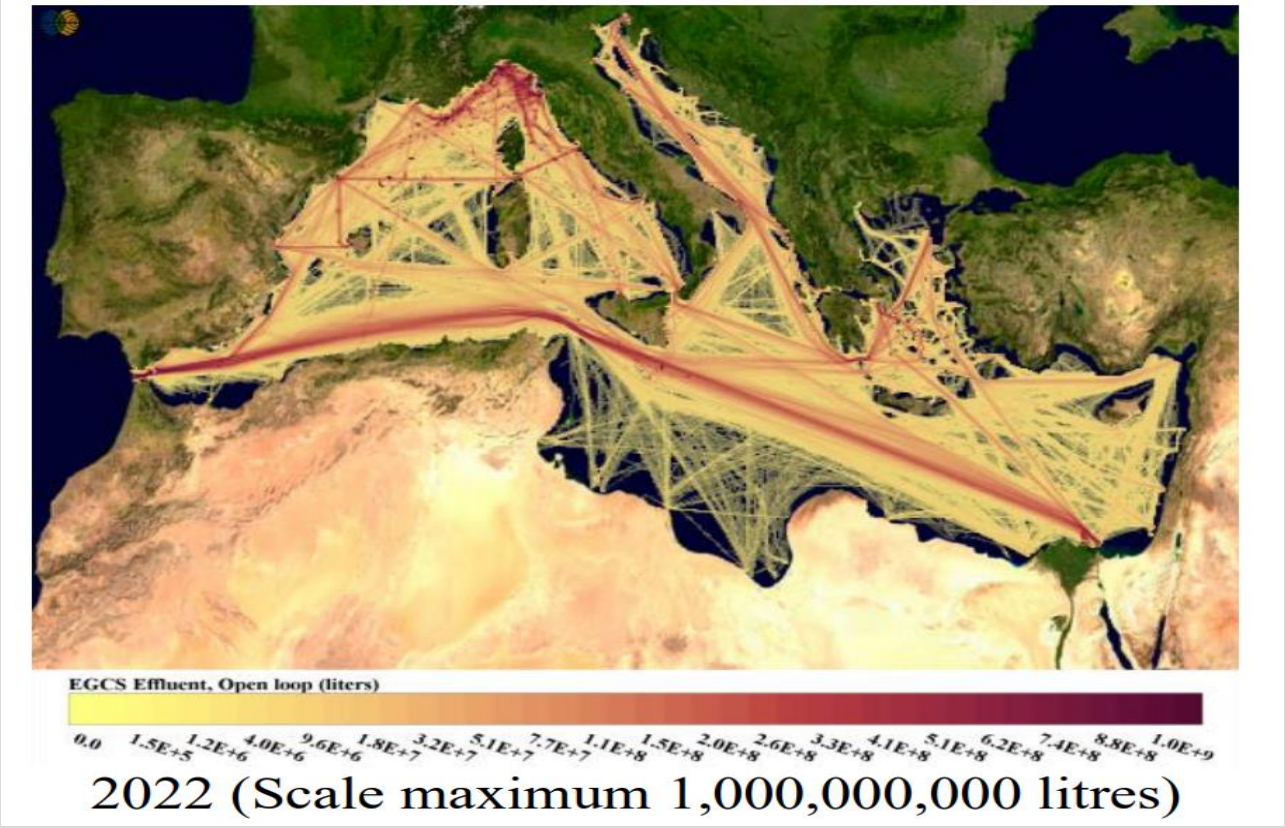
The above figure shows that in 2018, most of the EGCS washwater was released by passenger vessels (Cruise, RoPax), but after the implementation of the sulphur cap in 2020, container vessels constituted most of the effluent gas released as they made up most of the vessel movement in the Mediterranean coastal States. Since the Mediterranean Sea is one of the major maritime shipping routes with 20% of worldwide seaborne trade passing through it, the spatial geographical distribution of open-loop EGCS water discharge has increased in the Mediterranean Sea creating a major concern for the future as shown below. It is distributed along the economic exclusive zones of Spain, France, Italy and Greece.

Figure 21 Geographical distribution of open-loop EGCS washwater discharges in 2014 and 2018 before implementation of sulphur cap



Source: EMERGE project (Jukka-Pekka, J., Erik, F., et al. (2024))

Figure 22 Geographical distribution of open-loop EGCS water discharges in 2022 after implementation of sulphur cap in 2020

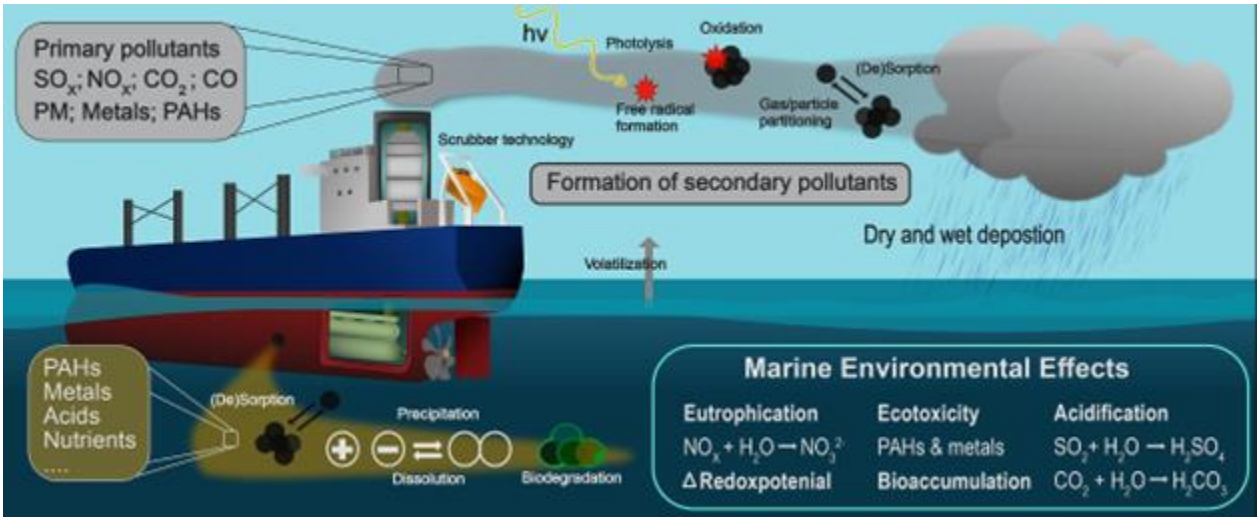


Source: EMERGE project (Jukka-Pekka, J., Erik, F., et al. (2024))

5.4 SO_x, $PM_{2.5/10}$, metal and PAH emission

New global regulation IMO 2020 Sulphur Cap was implemented to limit the sulphur content in marine fuels in January 2020. EGCS was developed to reduce sulphur emissions by spraying water and dissolving SO_x which resulted in more acidic water. Other contaminants (e.g. PAHs and metals) are also washed out during the scrubbing process turning the washwater into a toxic cocktail (Tao et al., 2013, Turner et al., 2017) (Anna, H., Ida, H., et al., 2021).

Figure 23 Marine pollutants and environmental effects



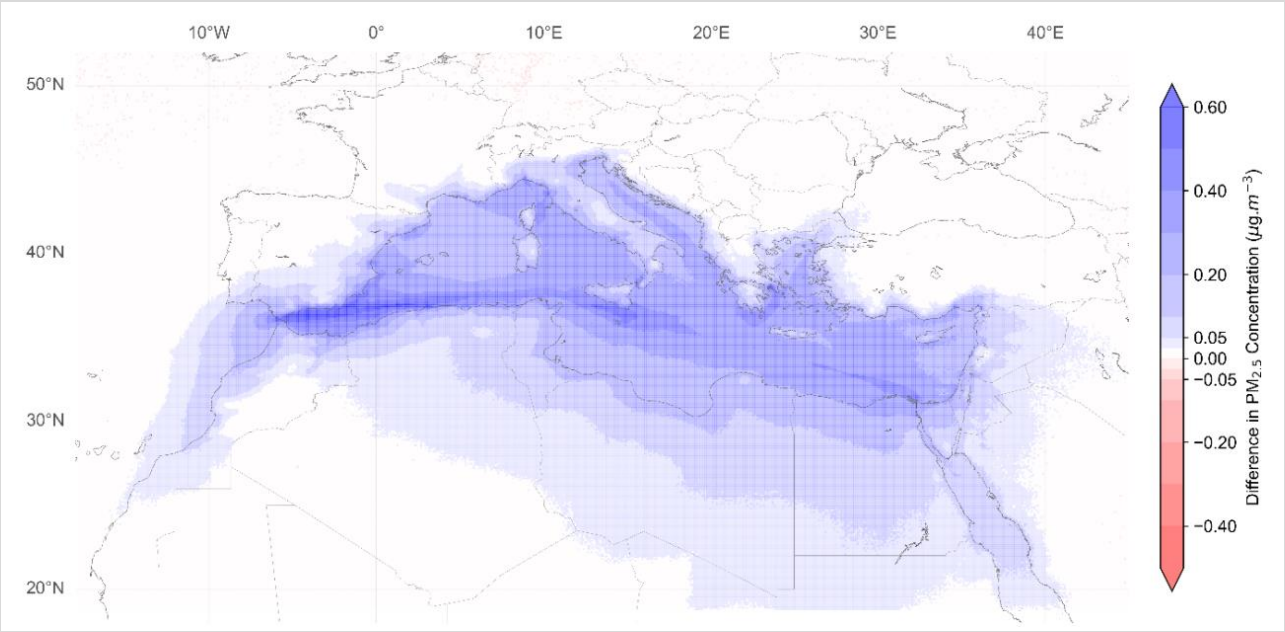
Source: Sciencedirect, Study on Comparing emissions of polyaromatic hydrocarbons and metals from marine fuels and scrubbers (Anna Lunde, H., Ida-Maja, H., et al. (2021))

It is paramount that the fuel used should not only prevent air pollution but should also not harm the marine environment. However, present environmental policies in shipping focus on air pollution assessment and its impact on climate change and human health, which could have introduced a bias against its impact on the marine environment. Hence, the impact on the marine environment is not clear.

5.4.1 Change in $PM_{2.5}$ concentration as per geospatial model

Geospatial modelling for the annual average in $PM_{2.5}$ concentration due to the implementation of the Med SO_x ECA was used to compare with MARPOL Annex VI requirements for the use of low sulphur fuel from 2020.

Figure 24 Difference in $PM_{2.5}$ concentration between MARPOL Annex VI implementation scenario and Med SO_x ECA implementation scenario[82]



Source: Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC)

It can be seen from the above-illustrated figure that the $PM_{2.5}$ reduction can be seen throughout the Mediterranean Sea, with coastal land benefits along the North African coastline, Spain, France, Italy, Malta and Greece. The greatest reduction in concentration is observed in the western Mediterranean Sea, along the coastlines of Spain and Morocco, in the central Mediterranean Sea to the south of Sicily and over Malta, to the south and east of Greece, and along the north coast of Egypt approaching the entrance to the Suez Canal. Hence, it can be concluded that the concentration of $PM_{2.5}$ will reduce once Med SO_x ECA is implemented.

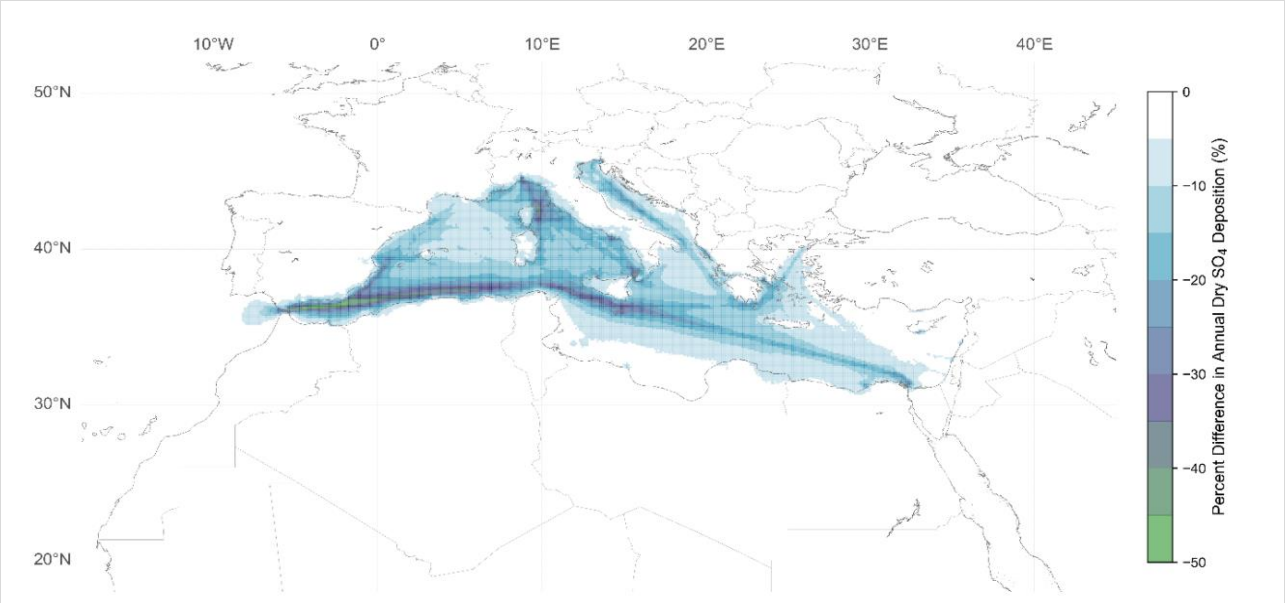
5.4.2 Change in sulphur (dry and wet)[83] deposition as per the geospatial model

A percentage decrease in annual dry and wet sulphate deposition has been shown below in between the Med SO_x ECA implementation scenario and MARPOL Annex VI requirement for usage of low sulphur fuel from 2020.

[82] Areas in blue show places where $PM_{2.5}$ with implementation of MARPOL Annex VI is greater than for the proposed Med SO_x ECA scenario, i.e. where the proposed Med SO_x ECA leads to a reduction in $PM_{2.5}$.

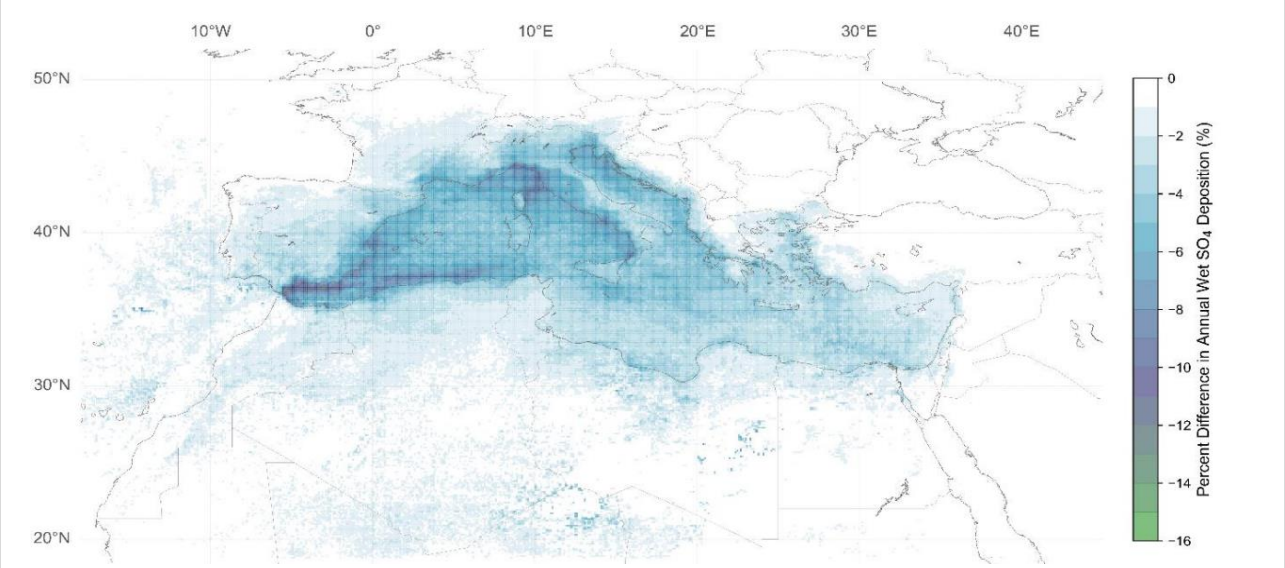
[83] Dry and wet deposition are the primary mechanisms of sulphur and nitrogen deposition in ecosystems. The dry deposition primarily occurs through gaseous compounds (sulphur dioxide, nitric acid, ammonia and nitrogen dioxide) in conjunction with aerosols while the wet deposition occurs by incorporating aerosol particles.

Figure 25 Percentage decrease in annual dry sulphate deposition between MARPOL Annex VI implementation scenario and Med SO_x ECA implementation scenario[84]



Source: REMPEC

Figure 26 Percentage decrease in annual wet sulphate deposition between MARPOL Annex VI implementation scenario and Med SO_x ECA implementation scenario[84]



Source: REMPEC

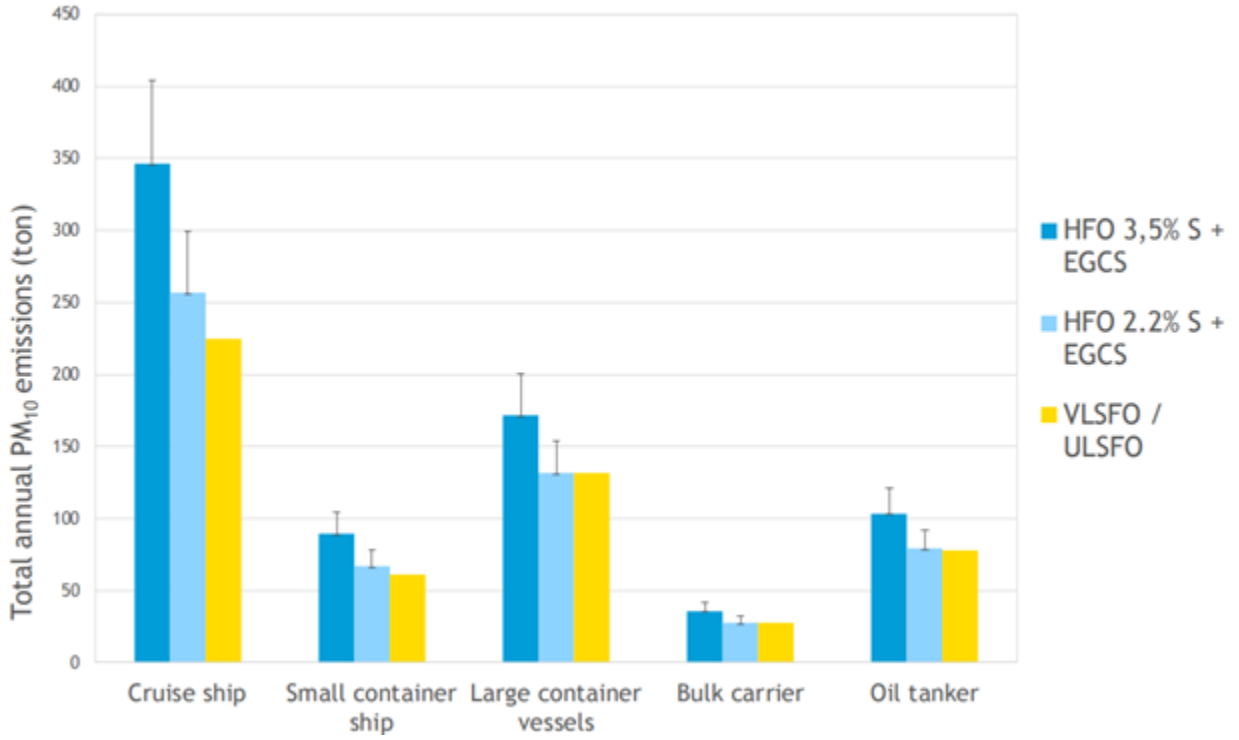
The maximum percentage decrease in dry sulphate deposition is over the Straits of Gibraltar and extending eastwards towards Algiers whereas the decrease in wet sulphate deposition is largest in the western and northern Mediterranean. The reductions in dry sulphate deposition are more closely correlated to the high traffic shipping lanes.

[84] Area in green shows maximum percentage decrease in dry/wet sulphate deposition

5.4.3 Annual emission of PM_{10} – a comparison between 'high-sulphur fuel with EGCS' and low-sulphur fuel

High-sulphur fuels result in higher PM emissions. When they are used along with EGCS, the latter removes part of PM from the exhaust. However, PM emissions after using EGCS are still higher when compared with ships using low-sulphur fuel, as can be seen from the graph below.

Figure 27 Annual PM_{10} emission[85] to the air as per different types of vessels



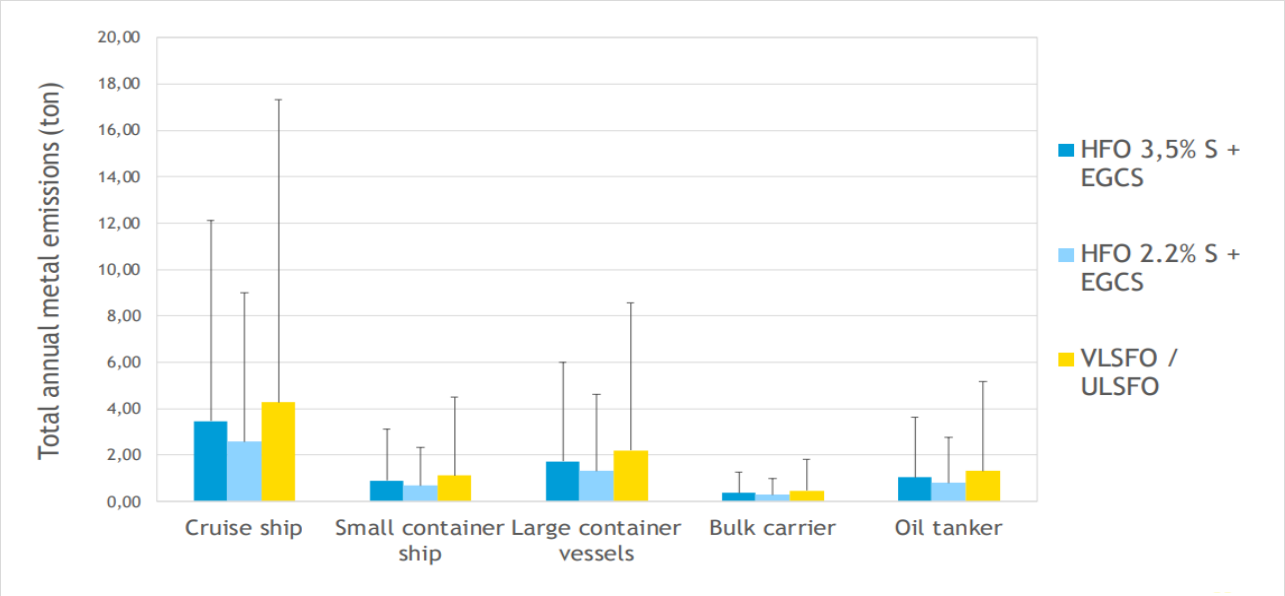
Source: Comparison air pollutant emissions MARPOL Annex VI compliance options, CE Delft, (Anne K. (2021))

5.4.4 Annual metal emission[85] in the air - 'high-sulphur fuel with EGCS' vs low-sulphur fuel

Low-sulphur fuels such as VLSFO and ULSFO probably contain similar amounts of metals as high-sulphur fuels. EGCS removes part of the metal from the exhaust, and therefore, metal emissions from ships using compliant fuels are higher than those using high-sulphur fuel with EGCS. This implies that metal concentration in water increases as it has been removed from air emissions. IMO EGCS Guidelines (MEPC.259(68)) stipulate only four threshold limits on the washwater discharge of EGCS, namely, pH, PAH, turbidity and nitrates. The guidelines currently do not specify a threshold limit for heavy metals.

[85] PM reduction efficiency of 40% is considered for bar graph and error bar is added on bars in case EGCS has a reduction efficiency of 30%.

Figure 28 Annual metal emission to the air as per different type of vessels



Source: Comparison air pollutant emissions MARPOL Annex VI compliance options, CE Delft, (Anne K. (2021))

5.4.5 PAH - 'high-sulphur fuel with EGCS' vs low-sulphur fuel

Emissions of SO_X and PM are not the only combustion-related hazards, and regulations should aim at targeting all pollutants to the entire environment. The study on comparing emissions of PAHs and metals from marine fuels and EGCS (Anna Lunde Hermansson, Ida-Maja Hassellöv, Jana Moldanová, Erik Ytreberg, 2021) found that the emission factors (EFs) for PAHs are higher for HFO combustion, varying from 2 to 20 times compared to EFs for MGO combustion. The study also concluded that HFO should be replaced by less polluting alternatives.

This study is supported by "On-board measurements of particle emissions from marine engines using fuels with different sulphur content" study (Winnes et al., 2016) and "Primary particulate matter emitted from heavy fuel and diesel oil combustion in a typical container ship: characteristics and toxicity" study (Wu et al., 2018).

Many PAHs are carcinogenic[86], mutagenic[87] and toxic. Due to their biological and chemical stability and potential for accumulation, they are persistent in the environment and can accumulate in organisms (Turner, et al., 2017; German Federal Environment Agency, 2012).

It should be noted that the traditional assessments of PAHs in environmental and marine samples focus only on the U.S. Environmental Protection Agency (EPA), which includes a list of 16 priority PAHs. The list should be reviewed and extended considering the complex PAHs assemblages as it does not include alkyl-PAHs. Therefore, it is not appropriate to assess the impact of EGCS washwater discharges in the marine environment. Based on the experimental characterisation of EGCS washwater discharge under the EMERGE project, it is evident that the complexity of the washwater composition should be considered in more detail. As per the study it was found that the ecotoxicological effects were mostly related to alkylated PAHs. It is unfortunate that alkylated PAHs are excluded from EGCS washwater discharge criteria despite their toxicological effects.

[86] It refers to things that are likely or able to cause cancer.

[87] A mutagen is a physical or chemical agent that can cause mutations in DNA.

So, it is possible that shipping can comply with the current EGCS guidelines despite harming the marine environment.

5.5 Section summary

The popularity of EGCS has grown globally and various authorities have expressed their concern regarding the use of open-loop EGCS in port and coastal waters. EU Directive 2020/2184 suggests guidelines and limits as per EWQS and Decision No 2455/2001/EC establishes the list of priority substances that are important measures to understand the impact of the EGCS in respective waters.

Various studies carried out show the impact of the EGCS on marine biodiversity but have been limited in scope. Some important findings are mentioned below:

.1 Estuaries and coastal waters contain pollutants such as naphthalene that are part of the 'priority hazardous substance' list.

.2 The dilution series of the EMERGE project observed the effects at low concentrations of EGCS washwater discharge and found reduced egg production, higher deformations and abnormal development of the larvae of the species.

.3 The research into the Baltic Sea ports found that EGCS accounts for 9% of certain cancer-causing PAHs found in marine environments (>98% comes from open-loop EGCS).

.4 The BPA pointed out that areas with limited water exchange can lead to higher sediment concentrations creating potential contamination hotspots.

.5 Open-loop EGCS has resulted in excessive levels of heavy metals and tar substances in the marine environment and could increase shipping lane acidification to the 1970s-90s level.

.6 Close-loop EGCS samples were found "extremely toxic" in some cases with other samples ranging from "practically non-toxic" to "highly toxic. During a project[7575] it was found that copepods died within one day of being exposed to a 5% concentration of the sample from the EGCS and within 8 days when exposed to a 40% concentration of the EGCS effluents.

.7 It was found that SO_x pollution in the English Channel may cause a yearly pH drop equivalent to 2 to 4 times the annual rate of climate change caused by the acidification process in water bodies. However, acidification is reduced because the flushing effect in the channel is high.

.8 While conducting the study, the IMO Task Team on EGCS identified gaps in scientific data of many contaminants and suggested the collection of additional data.

.9 Another study found that risks to marine life are in acceptable range and were only slightly above detection limits.

During the EMERGE project, it was found that in the Mediterranean region, many important shipping lanes run close to shore and archipelago areas, putting the coastal ecosystem at risk. Considering the existence of dense shipping traffic in regional seas, most of the European coastline, and marine life in those areas, will be impacted by EGCS effluents. It affects marine food web due to the restriction of planktivorous invertebrates, fishes and their larval stages. It concludes that it is merely moving the problem from the atmosphere to the hydrosphere, which in turn increases the exposure of toxicants such as vanadium, PAHs and alkylated PAHs to marine biota.

The spatial distribution of open-loop EGCS has increased in the Mediterranean Sea from various kind of vessels, especially from container ships. During various studies it was concluded that less polluting alternatives should replace HFO. Ships using higher-sulphur fuels in combination with EGCS have higher PM emissions than ships using low-sulphur fuel which suggests that the use of high-sulphur fuel should be prohibited to reduce PM emissions.

The list of PAHs and hazardous substances should be reviewed and extended considering the complex PAHs assemblages as it does not include alkyl-PAHs and paints an incomplete picture on the impact of EGCS washwater discharges in the marine environment. The EMERGE project found that the ecotoxicological effects were mostly related to alkylated PAHs. The exclusion of alkylated PAHs from EGCS washwater discharge criteria is unfortunate as it causes major toxicological effects. So, it is possible that EGCS criteria can comply with the current guidelines while at the same time, we may be harming the marine environment.

It is paramount that the fuel used should not only prevent air pollution but should also not harm the marine environment. However, it can be concluded that the present environmental policies in shipping focus on air pollution assessment and its impact on climate change and human health. This may be biased against the impact on the marine environment.

6 Best Practices in Other Regions

Air pollution has become one of the biggest environmental health threats in Europe with shipping contributing majorly in port areas and coastal regions. While the implementation of the Med SO_x ECA will improve air quality in the Mediterranean region, the EGCS washwater from ships plying in the region could create other environmental challenges as the exchange rates[88] reduction during winter can lead to heavy concentrations of PAHs which is hazardous for marine species and human health.

There is a need to take measures so that reform can be made to recover the lost biodiversity. EU has taken a step forward in the form of regional measures for the prevention of "climate change and environment degradation" include:

.1 The European Green Deal[89] that contains the EU's biodiversity strategy for 2030 which is a comprehensive, ambitious and long-term plan to protect nature and reverse the degradation of ecosystems.

.2 Nature Restoration law which entered into force in August 2024 and comprises "Natura 2000" and other habitats. The law covers a range of coastal and freshwater bodies including wetlands, rivers and lakes, as well as marine ecosystems.

A brief mention of the strict proposals to ban EGCS in Sweden and Oslo and Paris Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR) is done to show the State's particular agendas to move forward for saving their coastal water and habitat.

6.1 Biodiversity Strategy for 2030

The main objective of the "Biodiversity Strategy 2030" is to bring Europe's biodiversity on the path to recovery by 2030 for human benefit and climate recovery. The major actions and commitments to be delivered by 2030 are:

.1 Establishing a larger EU-wide network of protected areas on land and the sea which includes enlargement of existing Natura 2000 areas.

.2 Launching an EU nature restoration plan with the European Commission's first-ever Nature Restoration Law which includes an overarching restoration objective for the long-term recovery of nature in the EU's land and sea areas with binding restoration targets for specific habitats and species.

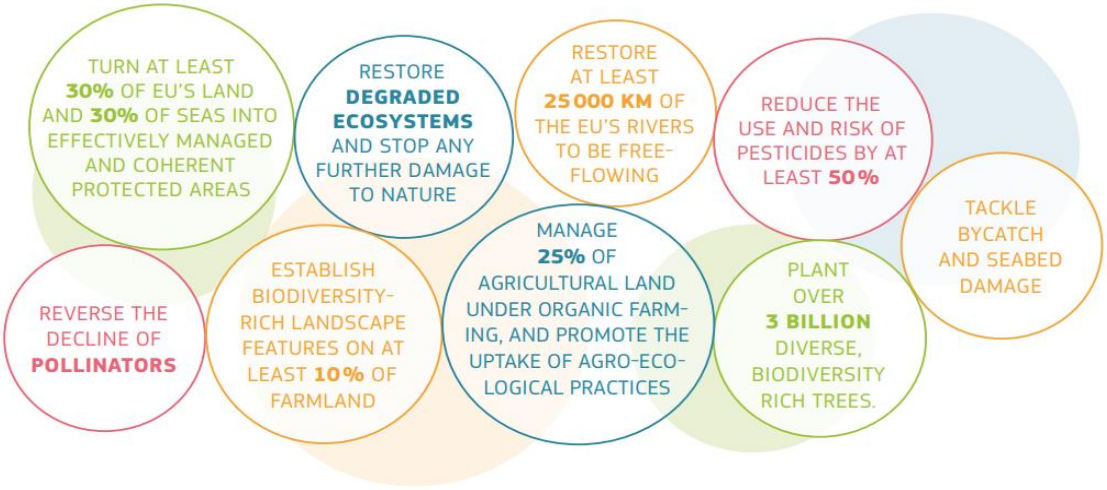
.3 Taking measures such as better implementation, as well as improving financing and investments, and prioritising nature in public and business decision-making process.

[88] The Mediterranean has been metaphorically described as breathing—i.e., inhaling surface water from the Atlantic and exhaling deep water in a counter current below. Current is most strong in the summers when evaporation in the Mediterranean is at its peak resulting is sufficient exchange of water. In winter, evaporation reduces which lowers the rate of exchange between the Atlantic water and Mediterranean water.

[89] The European Green Deal will lead to a progressive and profound transformation of the economy of the EU and its Member States, which in turn will have a strong bearing on the EU's external action. It is important that the EU uses its trade policy and extensive network of trade agreements to engage with partners on the protection of the environment and biodiversity, while promoting a level playing field.

.4 Introducing measures such as the adoption of a global biodiversity framework under the 15th session of the Conference of the Parties to the United Nations Convention on Biological Diversity (CBD) global biodiversity conference. These measures, when adopted, will restore 30% of degraded ecosystems on land and sea by 2030 and will conserve 30% of the world's marine and terrestrial areas, reducing risks from pollution, targeting subsidies harmful to biodiversity, mobilising funds and bringing businesses on board. Before the Conference Of Parties in November 2024, all Parties have to prepare the updated National Biodiversity Strategies and action plans as well as the National Biodiversity Finance Strategies.

Figure 29 Biodiversity strategy 2030



Source: European Commission (DOI:10.2779/9896)

Financial prospect

The strategy will require a significant investment of about €20 billion a year in nature to restore ecosystems. This investment is to be directed towards Natura 2000 network and in green and blue infrastructure across EU Member States. Under InvestEU[90], a dedicated natural-capital and circular-economy initiative will be established to mobilise at least €10 billion over the next 10 years, based on public/private blended finance. Nature and biodiversity are also a priority for the European Green Deal Investment Plan.

6.2 Nature Restoration Law

The EU has taken a unique step to restore at least 20% of the EU's land and sea by 2030 and eventually complete the restoration by 2050 for all needed ecosystems by legally binding targets and obligations for listed ecosystems – from terrestrial to marine, freshwater and urban ecosystems. This Law has already been in force since August 2024 and will be reviewed in 2033 for its impact on sectors such as agriculture, fisheries and forestry, as well as its wider socio-economic effects. This is the first time that a law has been passed which incorporates measures to not only preserve, but also restore the ecosystem.

[90] The InvestEU Programme supports sustainable investment, innovation and job creation in Europe. With the EU budget guarantee provided to International and National promotional banks, the InvestEU programme aims to trigger more than €372 billion in private investments to high EU policy priority areas.

.1 Until 2030, Member States will prioritise Natura 2000 sites when implementing the restoration measures.

.2 For habitats listed as deemed in poor condition, in the law, Member States will take measures to restore:

- At least 30% by 2030
- At least 60% by 2040
- At least 90% by 2050

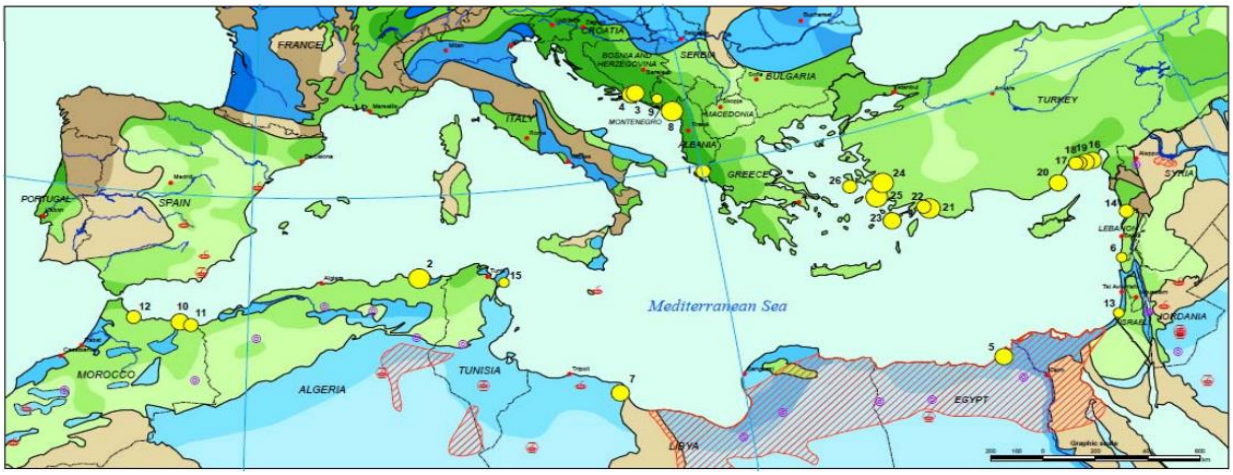
The Law will help the EU reach its international commitments, in particular the Kunming-Montréal Global Biodiversity Framework agreed at the 2022 United Nations (UN) Biodiversity Conference (15th session of the Conference of Parties).

EU Member States are expected to submit national restoration plans to the Commission within two years of the law coming into force (i.e. by mid-2026), showing how they will deliver on the targets. They will also be required to monitor and report on their progress. This means that the Mediterranean coastal States that are EU Member States will be subjected to this law and have to start building the framework to preserve the sensitive ecosystem.

6.2.1 Coastal and inland saline wetland[91] ecosystems of the Mediterranean

The survival of the coastal and inland saline wetland ecosystems/marine ecosystems will be a challenge as they are subjected to EGCS washwater discharges. The wetlands depicted by yellow circles in the figure below are on the Mediterranean shipping routes and are most susceptible to EGCS washwater discharges. These wetlands will come under protection with a regulatory framework formed by mid-2026.

Figure 30 Map[92] of selected wetlands in the Mediterranean area



Source: Hydrogeological and ecosystem services classification of representative Mediterranean groundwater-related wetlands. Map Explanation. UNESCO-IHP & MedPartnership, 2015; ResearchGate

Formulation of the framework to achieve the biodiversity strategy by 2030 can be a tough task and other Mediterranean coastal States should follow the same path in order to save their own

[91] Ecosystems on the land-water interface under the influence of tides and with salinity higher than 0.5%" which, beside coastal wetlands, also include 'lagoons, estuaries and other transitional waters, fjords and sea lochs as well as embayment.

[92] The size of the yellow circles is proportional to the wetland size.

ecosystem. To achieve this, better monitoring with stricter reforms in washwater discharge will be required.

6.2.2 The Mediterranean's marine ecosystems and future relevance with Nature Restoration Law

The coastal benthic[93] ecosystem in the Mediterranean Sea is at risk because of several factors including EGCS washwater discharge. From the research report *The Status of Coastal Benthic Ecosystems in the Mediterranean Sea: Evidence from Ecological Indicators, 2020 (Stanislao, B., Stelios, K., Fiorenza, M., et al., 2020)*, ecological status of the four types of ecosystems were carried out in areas of the Mediterranean region mentioned below.

.1 Southwest Mediterranean Sea (including the Alboran Sea)
.2 Northwest Mediterranean Sea
.3 Tyrrhenian/Ligurian Sea
.4 Ionian Sea
.5 Adriatic Sea
.6 Aegean/Levant Sea

The four types of ecosystems are:

.1 Coastal soft bottoms (CSB)[94]
.2 Rocky intertidal fringe (RIF)[95]
.3 Posidonia oceanica beds (POS)[96]
.4 Shallow subtidal reefs (SSR)[97]

[93] The term benthic refers to anything associated with or occurring on the bottom of a body of water.

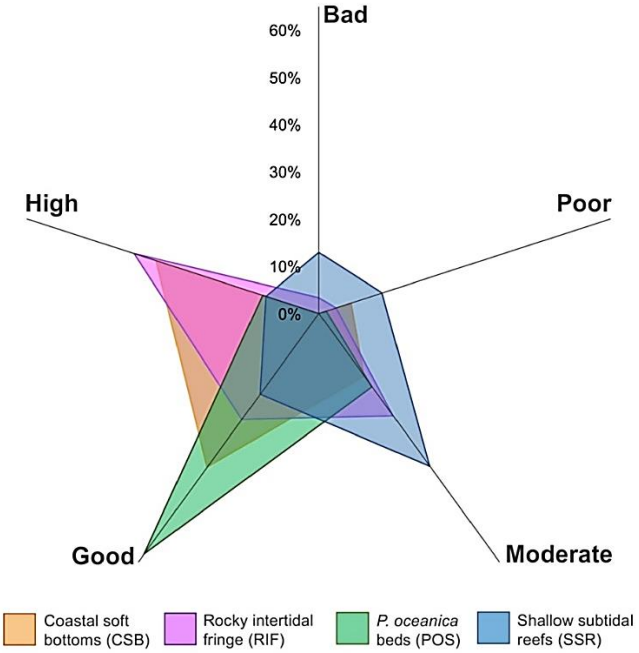
[94] A habitat used by many coastal fish, including planktivores like anchovy and menhaden. Soft-bottom sediments are common in some areas, such as the Florida Keys National Marine Sanctuary.

[95] A zone that can extend from low tide to high tide and is indicated by the presence of barnacles and red algae. It is vulnerable to climate change and pollution, such as oil spills.

[96] A seagrass bed

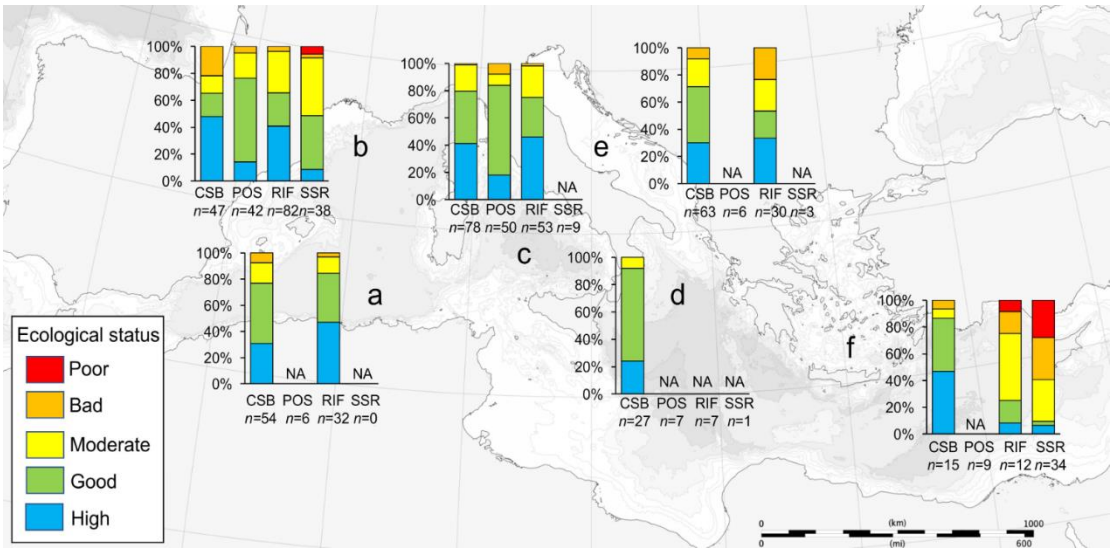
[97] Shallow/nearshore reefs (2-15 metre deep) are dominated by kelp and other seaweeds, and are among the most productive habitats in the world.

Figure 31 Ecological status of investigated ecosystem in the Mediterranean Sea (as per data collection and literature review)



Source: Frontiers in Marine Science, (DOI=10.3389/fmars.2020.00475)

Figure 32 Ecological status of investigated ecosystem in the Mediterranean Sea (as per evidence from ecological indicators)[98]



Source: Frontiers in Marine Science, (DOI=10.3389/fmars.2020.00475)

[98]CSB; POS; RIF; SSR. NA ≤ 10 sites available. Ecological status, from the top to the bottom of bars: poor (red), bad (orange), moderate (yellow), good (green) and high (blue). With the exception of Tunisia (where the available data is focused almost exclusively on coastal soft bottoms), published data on the selected ecological indicators are virtually lacking for the southern Mediterranean coast – from Egypt, Libya, Algeria, and Morocco, and are really scant in the Levant region, recommending a precautionary interpretation of these results.

From the above graphs, it can be seen that the overall ecological status of coastal environments of the Mediterranean Sea, indicated by ecological indicators, appeared moderate to high with a relatively minor proportion of sites in bad-to-poor conditions in the above-mentioned four ecosystems. The major concern is evident for subtidal reefs in regions (b) and (f), for which two-thirds of the sites showed moderate-to-bad ecological status. Among the major causes of this degradation are climate change as well as disappearance of structurally complex macroalgal stands (e.g., *Cystoseira* spp.), increased barren grounds or turf assemblages, increased herbivory by sea urchins or invasive fish and decline of predator fish populations.

Insufficient information and data on the status of marine ecosystems in the Mediterranean Sea are major drawbacks to proper impact analysis.

6.3 Natura 2000

Natura 2000 is the largest network of protected areas in the world which protects more than 27,000 nature sites under the EU legislation established in 1992. The extent of this protection has expanded over the years and now covers almost one-fifth of the land and one-tenth of surrounding seas – which is about the size of Spain and Italy combined.

Directive 92/43/EEC and Directive 2009/147/EC of the European Parliament and the Council aim to ensure the long-term protection, conservation and survival of Europe's most valuable and threatened species and habitats as well as their ecosystems. Some of these States form the coastlines of the Mediterranean Sea where marine species are under threat.

Figure 33 Natura 2000 sites[99] in the Mediterranean Sea

Source: Natura 2000 viewer (biodiversity information system for Europe)

The coastal areas are the most productive and diverse marine environments, providing habitat, nursery and feeding grounds for marine species (Seitz et al., 2014). These sites (coloured green in the above graph) are under threat because of inaccurate and undetailed assessments. It is crucial to implement a consistent record of the ecological conditions of marine ecosystems, allowing stringent comparisons of their status through time to achieve environmental targets.

[99] The Natura 2000 interactive tools (map and summary lists viewers) display the Natura 2000 network (the sites' borders and the sites' Standard Data Forms) for the year 2022, as provided by the EU Member States. For Denmark, the viewer shows the data from the year 2017, for Germany the data is from the year 2019.

6.4 Best practices in other regions

With the EGCS washwater becoming a source of detrimental effects on the coastal marine life and depleting marine biodiversity, certain regional and national proposals have been considered by the government to take the step to restrict the discharge of EGCS washwater in their jurisdiction.

6.4.1 Sweden's proposal to ban EGCS water discharge

The Swedish Government has decided that any washwater discharge from EGCS in the State's maritime territory is prohibited and has thus proposed the ban in the following two steps:

.1 Step 1- From 1 July 2025, emissions from EGCS operating in open-loop mode will be prohibited.

.2 Step 2- From 1 January 2029, all types of EGCS, including those used in close-loop mode, will be prohibited.

Similarly, an amendment to the Sulphur Ordinance (2014: 509) on measures against the pollution from ships has been proposed for Section 27. Previously, the section stated, "*the scrubbing water may be discharged into the sea only if it can be demonstrated that it has no significant effect on and poses no risk to human health or the environment. This also applies to discharges into the sea made in sheltered harbours or estuaries".*

The following is the proposed change to the above section:

"*EGCS discharge can only take place if*

.1 the discharge is not prohibited under Section 33 of the Ordinance (1980:789)[100] *on measures against pollution from ships.*

.2 it can be shown that the release does not have a significant effect on and does not pose a risk to human health or the environment."

The Swedish Government commissioned the Swedish Transport Agency along with the Swedish Agency for Marine and Water Management to produce the documentation on washwater discharge from EGCS. This supplemented the Government's report on ecotoxicological analyses of the EGCS washwater, comparisons of similar discharge from other relevant sources in shipping and land-based sources, and their effects on the marine environment.

The agencies presented a legislative proposal for a total ban on the discharge of EGCS from ships in the Swedish maritime territory.

The proposal also mentioned that the close-loop EGCS discharge rate is about 4 cubic meters per day, and many other new designs operate in zero-discharge mode or can collect washwater in tanks on board depending on water characteristics, design, size and condition of the ship.

[100] Section 33 of the Ordinance (1980:789) is proposed to be changed to "Discharges to water are prohibited within Sweden's maritime territory from a waste gas treatment system used on board a ship to reduce sulphur emissions to air." This will come into force on 1 January 2029

This assessment also raises concerns about eutrophying[101] nitrogen oxides, toxic metals and organic compounds such as PAHs. Metals, especially copper, nickel, lead, mercury and cadmium, are found in elevated concentrations in EGCS washwater. Some of these metals are controlled through monitoring programmes and are measured under WFD, while others, such as vanadium, are not. As mentioned in Section 5.2 of this Study, modelling research carried out in the Flemish Region found that vanadium has increased by 46%, and yet there are no WFD directives stringent enough to curtail such metal discharge along with the EGCS washwater. The sample collected during the compliance inspection can be sent to a laboratory to ascertain whether the washwater discharge is under the WFD to prevent the coastal population and marine species from being subjected to the hazardous effects of the washwater.

The study also refers to the EU's EMERGE framework programme, which shows that "*as little as five millilitres washwater discharge from EGCS can affect the organisms in entire one cubic meter of water"* because it contains harmful substances, indirectly affecting fish species and thereby disrupting the food chain. This clearly shows that the effects of high concentration of washwater discharged from the close-loop will be quite severe and its discharge needs to be restricted in the jurisdictional waters of the State. Vessels should also consider PSSAs to prevent any damage to marine biodiversity and restrict EGCS washwater discharge in these areas.

The Swedish proposal also indicates the reason for HFO not being a good option over the long term by citing points such as:

.1 The use of EGCS increases the overall fuel consumption by 2-3%, and since EGCS does not reduce carbon dioxide emissions, this higher fuel consumption will only lead to higher emissions.

.2 The reduction of HFO in shipping will reduce the negative effects on the environment in the event of an oil spill as the effects of an MGO oil spill are usually not as long-lasting as the effects of an HFO oil spill. Moreover, the clean-up of an HFO oil spill is also technically more difficult and more costly.

At present, Sweden does not have GEnS[102]. The different legislative mandates to assess the status come from the MSFD (covering all marine waters up to the limit of the EEZ and extended continental shelf), WFD (for transitional and coastal waters up to 1 nm from the continental baseline) (2000/60/EC) and Habitats Directive (92/43/EEC), and other international initiatives. As a result, different methodologies can be used for different ecosystem components, such as various taxonomic or functional groups, habitats, traits, physical features, or the whole ecosystem (Birk et al., 2012; Halpern et al., 2012). In addition, there is a proposed Directive for Maritime Spatial Planning and Integrated Coastal Management (European Commission, 2013) which will integrate management and planning. While the legal framework for 'maritime spatial planning and coastal development' is relatively new (Ehler and Douvere, 2009; European Commission, 2013), most of the legislation to protect, conserve, or enhance marine ecosystems is based on UNCLOS.

To achieve these objectives, the emission of hazardous substances should be reduced, both from shipping and other sources, which completely justifies the ban on discharging washwater and discharge water into Swedish territorial waters.

[101] eutrophying effect is associated with increased leaching of nitrogen to ground water, streams and lakes and changes in the forest ecosystems leading to vegetation changes favouring nitrogen-tolerant species.

[102] "The environmental status of marine waters where these provide ecologically diverse and dynamic oceans and seas which are intrinsically clean, healthy and productive, and the use of the marine environment is at a level that is sustainable, thus safeguarding the potential for uses and activities by current and future generations" (European Commission, 2008).

Similarly, as per the Directorate-General for Environment, EC, Issue 584 “The EU aims to achieve GEnS in marine areas across all Member States. This study assessed protected and non-protected sites in the Mediterranean Sea according to key ecological indicators”. The study assessed 26 marine protected areas alongside corresponding non-protected control areas (more than 20 kilometres away). According to the Study, the assessment for the entire Mediterranean Sea returned a ‘moderate’ environmental status. However, there were notable differences between ecoregions, with the Western Mediterranean achieving ‘good’ status, the Adriatic and Aegean seas ‘moderate’ status and the Ionian ‘poor’. Protected areas in the Western Mediterranean mostly achieved ‘good’ or ‘high’ status, they report. The no-trawl area was very effective, with ‘high’ environmental status, while the trawled control areas were ‘poor’ or ‘bad’. The researchers also suggest that an increase in systematic, long-term monitoring is needed to provide adequate data for thorough assessments of the ecosystem’s health. They note that many of the source studies are based on samples from very small areas and highlight the need for larger-scale surveys to more accurately represent the areas being considered. They also recommend further development of complementary protection measures and proposed that future work should support the development of flexible environmental indicators that can be adapted to site-specific conditions and situations.

Marine diversity protection is ascertained by the UN’s Sustainable Development Goal 14 and in the EU primarily via the MSFD. The main goal is to achieve GEnS. Since the Mediterranean Sea achieved moderate status as per Directorate-General for Environment, EC, Issue 584, immediate strict reforms should be undertaken in the region, not only to control the situation but also to attain good status.

Sweden has also emphasised that it will continue to work for regulations of such discharges within the framework of the OSPAR Convention (for the protection of the marine environment of the North-East Atlantic) and the Helsinki Convention (for the protection of the marine environment of the Baltic Sea), within the EU and within the IMO. Regional bans or regulations are also currently being discussed under the OSPAR and Helsinki Conventions, as well as national bans in Denmark and Finland, among others.

Shipowners with ships installed with EGCS can:

.1 use close-loop EGCS with sufficient storage capacity to hold the washwater until it can be discharged in the harbour or outside the prohibited area,

.2 switch to low-sulphur fuel, and/or

.3 shift vessels between the prohibition area and the no-prohibition area.

However, it was acknowledged that a phase-in period should be provided to ban the EGCS so that shipowners can recover their costs. The document also mentions a Swedish-Finnish study, which found that within five years of installation, more than 95% of open-loop EGCS reached breakeven, after which economic savings from fuel act as a surplus, but hybrid and closed systems take a little longer to reach breakeven as suggested by the Study “Ship pollution promotion - the strong economic incentives of scrubbers”, Anna Lunde, H., Ida-Maja, H., et al. (2023).

6.4.2 OSPAR Commission modelling of discharges from open-loop EGCS on ships in the OSPAR Maritime area

The Oslo and Paris Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR) Commission[103] report on Modelling of discharges to the marine environment from open circuit flue gas scrubbers on ships in the OSPAR Maritime Area (Jukka, J., Tiia, G., et al. 2023) was prepared for the OSPAR Environmental Impacts of Human Activities (EIHA) group by the Finnish Meteorological Institute in cooperation with the Chalmers University of Technology.

The modelling results indicate certain key points that are mentioned below:

.1 The total effluent release volume from EGCS in all OSPAR regions was about 622 million tonnes in 2020, of which 99.9% was from open-loop EGCS.

.2 About 84% of the EGCS effluent in OSPAR Maritime Area was released inside the 200 nautical mile zones and about 21% was in the 12 nautical mile zone.

.3 Previous reports (Linders et al. 2019, and Hassellöv et al. 2020) raised concerns regarding the lack of monitoring of metals in the discharge water guidelines. In the revised IMO guidelines for EGCS (MEPC 2015, 2018 and 2021) metal concentrations are still not directly targeted but only indirectly assessed using turbidity as a proxy.

.4 A recent study by Du et al. (2022) mentioned in the OSPAR Commission report on “Modelling of discharges to the marine environment from open circuit flue gas scrubbers on ships in the OSPAR Maritime Area” concluded that the reported data on EPA 16 PAHs, not including alkylated PAHs, may lead to significant underestimations (between 5-15 times lower) of PAH concentrations in EGCS washwater discharge. In addition, the estimated total load of PAHs is close to 2.5 times higher than the mass of EPA 16 PAH, suggesting that alkylated PAHs should also be considered. In the same report, other studies conclusions were mentioned such as Ytreberg et al. (2022, preprint pending revision) concluded that switching to operations in the close-loop mode could reduce the load of most PAHs and metals by 90%. Although there is limited data on vanadium toxicity, an increasing number of studies (e.g. Shiffer and Liber 2017a and b; Watt et al. 2018) suggested that water quality guidelines for vanadium should be developed and they should be included in marine monitoring programmes. Some other conclusions mentioned are:

- The discharge from open-loop EGCS was identified as a major source of vanadium and anthracene in the Baltic Sea.
- The study concluded that EGCS is a substantial source of contaminants in the Baltic Sea.

[103] The Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR) entered into force in March 1988. The CPs for this Convention are Belgium, Denmark, the EU, Finland, France, Germany, Iceland, Ireland, Luxembourg, the Netherlands (Kingdom of the), Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom. Of these, the EU, France and Spain are also signatories to the Barcelona Convention.

6.5 Section summary

In addition to other sectors, shipping also contributes to environmental health concerns in Europe especially in port areas and coastal regions. With the implementation of Med SO_x ECA, the air quality in the Mediterranean region will improve at the cost of hazardous effects on marine species and human health which are part of the coastal ecosystem. This is because of the possible increase in EGCS washwater discharge which is leading to heavy concentrations of PAHs that are harmful for marine life. This effect increases in winter because of the lower exchange rate of water between the Atlantic Ocean and the Mediterranean Sea.

There is a need to take measures so that a reform can be made to recover the lost biodiversity. EU has taken a step forward in form of regional measures such as “Biodiversity Strategy for 2030 and Natura 2000” play a pivotal role in improving the degrading marine biodiversity. The main objective of the Biodiversity Strategy for 2030 is to bring the Europe’s biodiversity on a recovery path by 2030 by actions and commitments like:

.1 An EU-wide network of protected areas on land and the sea which includes enlargement of existing Natura 2000 areas.

.2 Launching of an EU nature restoration plan with the EC’s first-ever Nature Restoration Law.

.3 Measures such as better implementation, improving financing and investments, prioritising nature in public, and business decision-making process.

.4 The global biodiversity framework was adopted in 2022 at the 15th session of the Conference of Parties to the United Nations Convention on Biological Diversity (CBD) global biodiversity conference. Before the Conference of Parties in November 2024, all Parties had to prepare updated National Biodiversity Strategies and Action Plans and National Biodiversity Finance Strategies.

The survival of the coastal and inland saline wetlands and coastal benthic ecosystems in the Mediterranean Sea will be a challenge as they are subjected to EGCS washwater discharges. From the research report *The Status of Coastal Benthic Ecosystems in the Mediterranean Sea: Evidence from Ecological Indicators (Stanislao, B., Stelios, K., Fiorenza, M., et al., 2020)*, the ecological status of the four types of ecosystems (CSB, RIF, POS and SSR) in the Mediterranean region concluded that overall ecological status of Mediterranean coastal environments emerging from ecological indicators appeared moderate to high with a relatively minor proportion of sites in bad-to-poor conditions in the four ecosystems. A major concern was evident for SSR for which two-thirds of sites showed moderate-to-bad ecological status. The insufficient knowledge and data on the status of marine ecosystems in the Mediterranean Sea are major drawbacks to proper impact analysis.

Natura 2000 is the largest network of protected areas in the world which protects more than 27,000 nature sites under the EU legislation established in 1992. Directive 92/43/EEC and Directive 2009/147/EC of the European Parliament and the Council aim to ensure the long-term protection, conservation and survival of Europe’s most valuable and threatened species and habitats as well as their ecosystems. It is crucial to implement a consistent record of the ecological conditions of marine ecosystems, allowing stringent comparisons of their status through time to achieve environmental targets.

Member States must prioritise Natura 2000 sites until 2030 when implementing the restoration measures under the Nature Restoration law of the EU. For habitats listed as deemed in poor condition in the law, Member States will take progressive measures to restore at least 90% ecosystem by 2050.

Some States/commissions such as Sweden and OSPAR are setting examples by coming up with stricter proposals for banning EGCS.

.1 The Swedish Government has decided that any washwater discharge from EGCS in the State's maritime territory is prohibited and has thus proposed the ban in two steps. Firstly, from 1 July 2025, emissions from EGCS operating in open-loop mode will be prohibited and thereafter from 1 January 2029, all types of EGCS, including those used in close-loop mode, will be prohibited. Major key points from their proposal are:

- There is no WFD designated for the Mediterranean Sea.
- Vessels to consider PSSAs to prevent damage to marine biodiversity by restricting EGCS washwater discharge.
- According to the study, the assessment for the entire Mediterranean Sea returned a 'moderate' environmental status.
- A phase-in period should be provided to ban the EGCS so that shipowners can recover their costs of installing EGCS.

CPs of the OSPAR Convention carried out a study modelling of discharges from open-loop EGCS on ships in the OSPAR region. The key results from the study concerning EGCS are mentioned below:

.1 The total effluent release volume from EGCS in all OSPAR regions was about 622 million tonnes in 2020. Of this, 99.9% can be attributed to open-loop EGCS with about 84% released inside the 200 nautical mile zones and about 21% in the 12 nautical mile zone.

.2 The estimated total load of PAHs is close to 2.5 times higher than the mass of 16 PAH, suggesting that alkylated PAHs should also be included.

.3 In the revised IMO guidelines for EGCS (MEPC 2015, 2018 and 2021), metal concentrations are still not directly targeted but only indirectly assessed using turbidity as a proxy.

7 Challenges, opportunities and recommendations

The implementation of Med SO_x ECA in the Mediterranean Sea is a major step towards reducing SO_x and PM emissions. This will may lead to an increase in the use of EGCS, among others, creating challenges, opportunities as well as recommendations.

7.1 Challenges related to the EGCS system

Implementing the Med SO_x ECA is fraught with challenges related to EGCS, some of which are mentioned below:

.1 Higher spread between HFO and LSMGO will continue to encourage shipowners to install EGCS, which in turn contributes to overall higher emissions which can hinder the decarbonisation efforts.

.2 The present environmental policies related to SO_x in shipping focus primarily on pollution in the air, with little consideration given to the marine environment and human health. The fuel used should not only prevent air pollution but should also not harm the marine environment. This results in higher uptake of EGCS as it meets the regulations for air pollution, but damages the marine environment.

.3 Emissions of SOX and PM are not the only pollutants, and regulations should aim at targeting all pollutants in the entire environment. While many PAHs are carcinogenic, mutagenic and toxic, the harmful impact of alkylated PAHs discharged with EGCS washwater as well as the compounds formed in the discharge water is not known. This prevents the appropriate impact assessment of the marine environment, which enables the shipping to comply with the current EGCS guidelines despite harming the marine environment.

.4 Lack of proper data in many parts of the Mediterranean Sea makes it difficult to effectively conclude the harmful effects of EGCS. In addition, there are no studies or data available on the sub-lethal effects of early life stages in fish as mentioned in the EMERGE project; therefore, direct toxic effects on fish are largely unknown. This creates ambiguity around the interpretation of harmful effect of EGCS, leading to resistance from stakeholder to ban EGCS and protests from proponents of EGCS against any ban. In the Mediterranean region, many important shipping lanes run close to the shore and archipelago, which puts the sensitive shallow-water coastal ecosystems at risk.

.5 MARPOL Annex VI does not specifically limit the PM, although it reduces when the sulphur content of the fuel oil is decreased. The lack of quantitative measures will create challenges when assessing the effectiveness of the measures to reduce PM.

.6 Revised guidelines for EGCS (MEPC 2015, 2018 and 2021) have still not targeted metal concentrations and have only indirectly assessed it by using turbidity as a proxy.

.7 Vanadium and Anthracene have been identified as major discharge compounds from open-loop EGCS in the Baltic Sea, yet no clear water quality guidelines exist for measures against their toxicity.

.8 There are few CPs to the Barcelona Convention that have not ratified MARPOL Annex VI, which may prevent smooth implementation of Med SO_x ECA.

.9 A number of CPs to the Barcelona Convention have not ratified the UNCLOS which can create problems in the implementation of regional measures for EGCS washwater discharge in the entire Mediterranean region.

.10 National legislations of various Mediterranean coastal States are not fully aligned with MARPOL Annex VI.

.11 Since PRFs have yet to be established for handling EGCS residue, effectively implementing the regulations for its disposal will be challenging.

.12 Funding and research are required for different methods to improve water quality.

.13 Dry EGCS technology needs to be promoted as it can eliminate the washwater discharge and simultaneously address air pollution. It also lays the foundation for new technological developments in the field of OCCS.

.14 The efficiency of open-loop EGCS reduces as alkalinity in seawater and freshwater decreases, resulting in the need for a higher flow rate of seawater, which requires more energy. This results in more fuel consumption and therefore higher emissions.

.15 Reduction in the exchange rate of seawater in the Mediterranean Sea during winter can result in a heavy concentration of PAHs coming from EGCS washwater discharge posing hazards to marine species and human health alike.

.16 Higher capex and opex for the hybrid-loop EGCS can lead to a slower transition towards the acceptance of this system.

.17 Use of EGCS with HFO also creates a challenge as hazardous effects of HFO oil spill are usually long-lasting when compared with the effects of an MGO oil spill.

.18 The workforce involved in the process of implementing Med SO_x ECA needs to be trained by the Contracting Parties to the Barcelona Convention.

7.2 Opportunities related to the EGCS system

Implementing Med SO_x ECA will bring a number of opportunities for various stakeholders related to EGCS as mentioned below.

.1 There is an opportunity to create a unified and common environmental policy for all Contracting Parties to the Barcelona Convention, taking into consideration Natura 2000 sites, PSSA and all other regional protected sites.

.2 Achieving good GEnS status for the Mediterranean Sea will help improve the state of marine biodiversity in all the regions, not limited to those concentrated around protected sites. This will create an opportunity for formulating WFD for the Mediterranean region as well as for research and development in the Mediterranean Sea.

.3 Tourism will get a boost in the long run because of better air and water quality, along with improving marine life.

.4 The creation of the European super emission control area should encourage various stakeholders to take advanced initiatives such as forming green fuel bunkering hubs, green corridors, advanced EGCS technologies, and OCCS and CCS supply chain systems.

.5 Requirement for research and development in dry EGCS and OCCS technologies, which do not have washwater discharge, creates opportunities for institutions involved in such research.

.6 Developing PRFs will create opportunities and thereby jobs for waste disposal companies.

.7 Increased interest towards hybrid EGCS will favour suppliers and manufacturers of desired commodities such as NaOH.

.8 Design advancements in EGCS and OCCS could facilitate the continuing use of HFO without impacting marine life and coastal ecosystems.

.9 Higher demand for LSMGO offers growth opportunities for bunker trades and bunkering companies in the Mediterranean region.

.10 Awareness about the harmful effects of EGCS washwater discharge creates the opportunity for a global regulation to ban EGCS washwater discharge to sea. With increasing awareness, new ECAs, such as the Norwegian Sea and the Canadian Arctic, are being announced.

7.3 Recommended initiatives and measures

The implementation of the new Med SO_x ECA creates several opportunities despite throwing up certain challenges. The following recommendations have been arrived at after studying various reports and literature reviews.

7.3.1 Recommendations related to EGCS

.1 Restriction on washwater discharge at national, sub-national and port levels from the open-loop and close-loop EGCS in various countries, dependency on alkalinity of seawater, high flow rate requirement for washwater and less efficient operation in freshwater suggests that open-loop EGCS should not be used.

.2 CPs should consider emphasising the use of Hybrid EGCS as the system does not depend on seawater alkalinity and can efficiently work in freshwater basins as well as sources of water with less alkalinity. This eliminates the use of seawater, and reduces fuel and overall emissions, as well as the discharge of marine pollutants into the sea.

.3 Shipowners are recommended to fit appropriate-sized tanks on ships for storing the bleedoff water in areas where close-loop scrubber discharge is banned, taking any future bans into consideration.

.4 Many PAHs can be carcinogenic, mutagenic and toxic. The list of 16 priority PAHs from the EPA does not include alkyl-PAHs, which leads to an inappropriate impact assessment of EGCS washwater discharge in the marine environment. From the experimental characterisation of EGCS washwater discharge under the EMERGE project, it was found that ecotoxicological effects were mostly related to alkylated PAHs. So, it is possible that shipping can comply with current EGCS guidelines despite harming the marine environment. A detailed analysis of alkyl PAHs should be carried out and the conclusion should be incorporated in WFDs of CPs for appropriate action, which should be taken.

7.3.2 Recommendations related to the legal framework and policies related to EGCS

.1 MARPOL Annex VI does not specify any limits on PM emissions. It is recommended that such measures need to be quantified so that the decline in PM emissions in the SECA region can be measured which in turn will help to analyse and reduce the effect of air pollution and air hazards on the coastal population.

.2 A third-party facilitator can work with all CPs to the Barcelona Convention to formulate long-term plans considering UNCLOS and developing certain

measures till EEZ within the *framework of articles 212(3) and 222 of UNCLOS.* It entitles all CPs to propose global and regional rules, after taking approval from the IMO, to safeguard their marine environment and reduce air pollution in their coastal state jurisdiction.

.3 The BBNJ Agreement should be considered by CPs to the Barcelona Convention with emphasise on the need for conserving sensitive areas beyond national jurisdiction. This will help decide whether or not to extend the ban on EGCS washwater discharge beyond territorial waters.

.4 CPs to the Barcelona Convention to make use of the Circular *MEPC.1/Circ.899* for understanding risk and impact assessments of EGCS washwater. CPs to the Barcelona Convention should review various ongoing discussions in IMO for coming up with a framework and strategy to take steps towards consideration of banning open-loop EGCS and relevant restriction in their coastal States.

.5 The CPs to the Barcelona Convention should follow “Revised guidelines for the identification and designation of Particularly Sensitive Sea Areas” Resolution A.982(24) of the IMO, and try to get appropriate areas approved as PSSA.

.6 CPs to the Barcelona Convention should align with the MEPC adopted guidelines “Annex 7 resolution MEPC.199(62); Guidelines for reception facilities under MARPOL Annex VI” for PRF. CPs to the Barcelona Convention to verify that PRF facilities in their national jurisdiction are adequate. and are capable of receiving the increased residual waste from vessels calling their ports after the implementation of Med SO_x ECA.

.7 Certain metals, such as vanadium, naphthalene, nickel, copper, zinc and anthracene, which pose a risk to the environment, should be included in the EGCS guidelines and with appropriate limits assigned. The list is to be prepared after the conclusion of a global study to evaluate the hazardous effects related to open-loop EGCS washwater discharge and bleedoff water from closed-loop EGCS on marine life and coastal ecosystem.

7.3.3 Recommendations related to coastal marine life and environmental perspective

.1 Since heavy release of discharge washwater can raise the acidification level, as was seen in the Baltic Sea (Claremar, Haglund and Rutgerson, 2017), the CPs to the Barcelona Convention should take preventive measures to reduce the harmful effects of open-loop EGCS in the Mediterranean Sea and carry out a study on the amount of washwater discharge per year in the Mediterranean Sea and acidic levels at major hotspots in the region. The study should also include close-loop bleedoff water evaluation.

.2 CPs to the Barcelona Convention should formulate a long-term goal to acquire the good status of coastal environments of the Mediterranean Sea. In addition, all ecological indicators in the Mediterranean marine ecosystem should be periodically checked. Shallow Subtidal Reefs (SSRs) are areas of most concern and immediate action for their preservation should be proposed. The data collected after the periodical checks, literature review and ecological evidence should be maintained to identify the impact of the applied regulatory framework and further directives should be proposed as per the result of the analysis. It is crucial to maintain a consistent record of the ecological conditions of marine ecosystems, allowing stringent comparisons of their status over time to achieve environmental targets.

.3 CPs to the Barcelona Convention should model their own report for the whole of the Mediterranean region, similar to the OSPAR commission report on the ban of open-loop EGCS.

.4 A holistic joint study of environmental impact analysis of EGCS discharge from open-loop and closed-loop EGCS should be carried out after considering the super emission control area comprising Med SO_x ECA, Baltic SECA and the newly approved Norwegian ECA.

.5 CPs to the Barcelona Convention should align with the Biodiversity Strategy for 2030 and Natura 2000 which ensure long-term protection, conservation and survival of Europe's most valuable and threatened species and habitats as well as their ecosystems. Similarly, the survival of the coastal and inland saline wetland ecosystems/marine ecosystems is a challenge because these are being subjected to EGCS washwater discharge and are expected to come under protection within the regulatory framework by mid-2026. Similar strategies should also be developed for CPs to the Barcelona Convention that are not part of the EU to implement the measures unanimously in the whole of the Mediterranean Sea.

.6 REMPEC should consider organising a meeting of all CPs highlighting/pinpointing the need to restore the lost biodiversity and suggesting steps to implement measures for improving marine biodiversity such as the EU Nature Restoration Law.

7.3.4 Recommendations related to other issues

.1 CPs to the Barcelona Convention should work together to develop Project Proposal which is to be considered under InvestEU programme such as "Investments in zero and low carbon vessels and related land-based infrastructure in Norway during 2024-2030" of EUR 50 million.

.2 The low flushing effect and exchange rate in the Mediterranean Sea during winter can lead to potential contamination hotspots because of higher sediment concentration. Local water authorities should increase their checks for water quality during winter specifically in regions with dense shipping traffic.

.3 CPs to the Barcelona Convention can submit proposal to IMO for considering phasing out EGCS for preserving coastal marine life from long-term effects of EGCS washwater.

.4 A proper familiarisation for the MARPOL Annex VI should be carried out for various stakeholders of the CPs to the Barcelona Convention with REMPEC providing adequate training for staff, including the PSC inspectors who board the vessels to check for compliance. REMPEC can also organise training workshops to explain the implications and suggestions concerning the implementation of Med SO_x ECA.

.5 CPs to the Barcelona Convention need to encourage and promote advance technologies such as OCCS and Dry EGCS. Research and development for better technologies should be collaborated with academic institutions and research organisations.

.6 With the development of a European super emission control area, CPs to the Barcelona Convention may explore ways to collaborate with other countries of different regions to establish green hubs/corridors.

.7 A facilitator needs to encourage the CPs to the Barcelona Convention that have not ratified UNCLOS and MARPOL Annex VI to come to a mutual understanding

so that regional measures can be taken for EGCS discharge in the entire Mediterranean region.

.8 CPs to the Barcelona Convention to encourage shipowners to promote considering the harmful effects of EGCS discharge before deciding to build ships running on HFO.

.9 LSMGO trade and bunkering prospects should be promoted in the Mediterranean region.

.10 Chemical suppliers' preparedness near ports will be required over time with an increased preference towards Hybrid EGCS.

.11 Waste disposal companies of the region can improve preparedness to receive EGCS residue from vessels.

8 Action plan for further development of the study

The implementation of Med SO_x ECA will create challenges for various stakeholders as reforms will be needed in various parameters, industries and policies for the smooth transition towards implementing new rules for the Mediterranean Sea. Certain policy changes will be required which will need to be explained to various stakeholders so that they can take the desired actions for this plan to succeed. Drewry suggests short-, mid- and long-term action plans for improving the marine environment.

The action plans are presented in the table below.

Table 14 Recommended action plans with the implementation of the Med SO_x ECA

Timeline	Area / Type	Recommended action	Responsibility
Short-term	Legal framework and policy	A detailed study should be carried out in the whole of the Mediterranean Sea to analyse the harmful effects of EGCS on the marine environment. The study should include an in-depth analysis of various metals, alkyl PAHs and other harmful compounds present in the washwater that is discharged from the EGCS in order to prevent any damage to the marine species and coastal ecosystem.	CPs
	Legal framework and policy	Certain metals, such as vanadium, naphthalene, nickel, copper, zinc and anthracene, threaten the environment and should therefore be included in the EGCS guidelines with limits assigned to each. CPs should lobby with the IMO for its implementation.	CPs
	Legal framework and policy	The risk and impact assessment to analyse the effects of EGCS washwater discharge should be carried out. If the assessment shows the EGCS washwater will harm the marine environment, CPs to Barcelona Convention should make proposal to IMO for considering phasing out EGCS for preserving coastal marine life from long-term effects of EGCS washwater.	CPs
	Legal framework and policy	PRF facilities in respective CPs to the Barcelona Convention need to be aligned with the IMO guidelines. These facilities should be able to receive higher residual waste from vessels calling their ports after the implementation of Med SO_x ECA.	CPs

Timeline	Area / Type	Recommended action	Responsibility
Mid-term (till 2030)	EGCS	Due to the ban on open-loop EGCS washwater in various States, it is prudent to educate stakeholders and popularise hybrid EGCS to reduce concerns about seawater alkalinity and the environmental impact on coastal marine life.	CPs, shipowners and port authorities
	EGCS	Newbuild ships to be future-ready with possible changes in the fleet due to bans/restrictions around the world because of EGCS washwater. Tanks of sufficient capacity should be arranged to store bleed-off water from closed-loop or hybrid EGCS.	Shipowners
	Legal framework and policy	Specific limits need to be ascertained for PM emissions to better resolve the issue related to coastal pollution health and coastal marine biota. CPs should lobby with the IMO for this.	CPs
	Legal framework and policy	A joint study should be carried out to save the sensitive areas in the whole of the Mediterranean region. These regions should be proposed to the IMO for consideration under PSSA. Such areas should also consider Natura 2000 sites as part of sensitive areas. APMs should be formulated and recommended in the same study as part of the proposal.	CPs
	Others	Adequate training for the staff to enable them to monitor and comply with the newly implemented Med SO_x ECA.	CPs
	Others	Members of CPs to the Barcelona Convention that have not ratified UNCLOS need to be brought to a common accord for framing a common regional policy.	CPs
	Others	LSMGO trade and related bunkering prospects need to be promoted in the Mediterranean region.	Various stakeholders
	Others	The waste disposal company should be prepared to accept increased EGCS waste residue.	Port authority and various stakeholders
	Others	Chemical suppliers of the region should increase their preparedness to supply Hybrid/close-loop related chemicals to vessels.	Various stakeholders

Timeline	Area / Type	Recommended action	Responsibility
Long term (beyond 2030)	Legal framework and policy	During the study of the environmental status of the Mediterranean Sea as a whole, if a certain area is outside the territorial waters of the Mediterranean coastal States, regional laws can be established to safeguard the environmental interest of these states in their respective coastal state jurisdictions after approval from the IMO.	CPs
	Environmental	Measures similar to MSFD should be undertaken for the whole of the Mediterranean Sea to meet the long-term goal of achieving GEnS.	CPs
	Environmental	With the implementation of Med SO_x ECA, a joint environmental study could be carried out to create a super emission control area, considering EGCS washwater, green fuel availability and green corridor creation. Additionally, future policies and strategies should be formulated that align with the Biodiversity Strategy for 2030, Natura 2000 and coastal/saline wetlands. Such studies should also be taken forward to restore the lost biodiversity. REMPEC should carry out workshops to encourage CPs and suggest measures to restore the lost marine biodiversity.	CPs, shipowners and other relevant stakeholders
	Others	Stakeholders should collaborate with academic institutions and research organisations to encourage and promote advanced technologies.	CPs, shipowners and other relevant stakeholders

Timeline	Area / Type	Recommended action	Responsibility
Ongoing	Environmental	Studies should be carried out regularly at major hotspots in the region to keep a check on the acidification level of the Mediterranean Sea. The correlation of these studies should be maintained along with yearly washwater discharge in the respective region to ascertain the harmful effects of washwater discharge from EGCS.	CPs
	Environmental	A periodical check of all the ecological indicators in the Mediterranean marine ecosystem should be carried out and documented to enable the recovery of the ecological status of SSR, in particular.	CPs
	Others	In order to educate stakeholders about the harmful effects of HFO, a global initiative should be undertaken.	Various stakeholders
	Environmental	Authorities should increase their checks for water quality during winter, specifically in regions with dense shipping traffic, to cater for the low-flushing effect and exchange rate of water during winters.	CPs

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