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

Regional Expert Meeting on the possible designation of the Mediterranean Sea, as a whole, as an Emission Control Area for Sulphur Oxides (Med SO_X ECA) pursuant to MARPOL Annex VI

REMPEC/WG.50/INF.7
Date: 23 April 2021

Online, 27-28 April 2021

Original: English only

Agenda Item 2

FINAL REPORT ON THE COMPLETION OF THE KNOWLEDGE GATHERING AND THE FINALISATION OF THE DRAFT SUBMISSION TO THE IMO

Note by the Secretariat

SUMMARY

Executive Summary:	This document presents the final report on the completion of the knowledge gathering and the finalisation of the draft submission to the IMO, pursuant to the Road Map for a Proposal for the Possible Designation of the Mediterranean Sea, as a whole, as an Emission Control Area for Sulphur Oxides Pursuant to MARPOL Annex VI, within the Framework of the Barcelona Convention.
Action to be taken:	Paragraph 4
Related documents:	REMPEC/WG.50/INF.3, REMPEC/WG.50/INF.5, REMPEC/WG.50/INF.6

Background

1 As presented in document REMPEC/WG.50/INF.5, COP 21[1] adopted Decision IG.24/8 on the Road Map for a Proposal for the Possible Designation of the Mediterranean Sea, as a whole, as an Emission Control Area for Sulphur Oxides Pursuant to MARPOL Annex VI, within the Framework of the Barcelona Convention, hereinafter referred to as the road map, as set out in the Appendix to document REMPEC/WG.50/INF.3.

2 COP 21 agreed to extend the mandate of the Mediterranean Action Plan (MAP) sulphur oxides (SO_X) Emission Control Area (ECA)(s) Technical Committee of Experts, until 30 April 2021, to oversee the completion of the knowledge gathering and the preparations of further studies, notably socio-economic impacts on individual Contracting Parties to the Barcelona Convention *inter alia* as indicated in the road map, including the development of their respective terms of reference, through correspondence coordinated by the Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC), when examining the possibility of designating the proposed Mediterranean Emission Control Area (Med SO_X ECA).

3 The final report on the completion of the knowledge gathering and the finalisation of the draft submission to the IMO, which was prepared pursuant to the road map according to the Terms of Reference set out in Appendix I to document REMPEC/WG.50/INF.6, is presented in the **Appendix** to the present document.

[1] Twenty-first Ordinary Meeting of the Contracting Parties to the Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean ("the Barcelona Convention") and its Protocols (Naples, Italy, 2-5 December 2019).

Action requested by the Meeting

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

APPENDIX

Final report on the completion of the knowledge gathering and the finalisation of the draft submission to the IMO

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

COMPLETION OF THE KNOWLEDGE GATHERING AND FINALISATION OF THE DRAFT SUBMISSION TO THE IMO PURSUANT TO THE ROAD MAP FOR A PROPOSAL FOR THE POSSIBLE DESIGNATION OF THE MED SO_X ECA

(LOT 1)

Final Report

Prepared and submitted by

Dr Edward Carr, REMPEC Consultant

April 2021

This activity was financed by the Mediterranean Trust Fund (MTF) and implemented by the Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC), in cooperation with the Mediterranean Pollution Assessment and Control Programme (MED POL) as well as the Plan Bleu Regional Activity Centre (PB/RAC) of the Mediterranean Action Plan (MAP) of the United Nations Environment Programme (UNEP).

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Abbreviations and Definitions

Term	Explanation
AOD	Aerosol optical depth
ARP	Alpha-Riskpoll health benefits model
BTU	British Thermal Unit
CO_2	Carbon dioxide
DM	Distillate marine fuels
ECA	Emission Control Area
EERA	Energy and Environmental Research Associates, LLC
EGCS	Exhaust gas cleaning system
EJ	Exajoules
EMRC	Ecometrics Research and Consulting
EU	European Union
FMI	Finnish Meteorological Institute
g	Grams
GAINS	Greenhouse Gas - Air Pollution Interactions and Synergies, a model
GHG	Greenhouse gas
HFO	Heavy fuel oil
HSHFO	High sulphur heavy fuel oil
IFO	Intermediate fuel oil
IHO	International Hydrographic Organization
IIASA	International Institute for Applied Systems Analysis
IMO	International Maritime Organization
J	Joules
kJ	Kilojoules
LNG	Liquefied Natural Gas
LSFO	Low sulphur fuel oil
m/m	Mass by mass
MARPOL	International Convention for the Prevention of Pollution from Ships
MARPOL VI	MARPOL Annex VI
MDO	Marine distillate oil
MEPC	Marine Environment Protection Committee
MGO	Marine gas oil
MMT	Million Metric Tonne
MT	Metric Tonne (1,000 kg)
NECA	NO_X Emission Control Area
NO_X	Oxides of Nitrogen
pH	A measure of the acidity of a solution
PM_{10}	Particulate matter 10 microns or smaller
$PM_{2.5}$	Particulate matter 2.5 microns or smaller
REMPEC	Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea
RM	Residual marine fuels
S	Sulphur
SECA	SO_X Emission Control Area
SO_X	Oxides of Sulphur
STEAM	Ship Traffic Emission Assessment Model
ULSFO	Ultra-low sulphur fuel oil

UNFCCC	United Nations Framework Convention on Climate Change
VLSFO	Very low sulphur fuel oil
WOO	World Oil Outlook

1 Introduction

This report presents the result of the knowledge gathering completed under LOT 1 (Draft submission to the IMO) pursuant to the Road Map for a Proposal for the Possible Designation of the Mediterranean Sea, as a whole, as an Emission Control Area for Sulphur Oxides (Med SO_X ECA) Pursuant to MARPOL Annex VI, within the Framework of the Barcelona Convention (Decision IG.24/8), hereinafter referred to as the road map.

The Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC), in cooperation with the Mediterranean Pollution Assessment and Control Programme (MED POL) as well as the Plan Bleu Regional Activity Centre (PB/RAC) of the Mediterranean Action Plan (MAP) of the United Nations Environment Programme (UNEP), tasked Dr Edward Carr, REMPEC Consultant, to complete the knowledge gathering under LOT 1 pursuant to the road map with a view to more fully addressing the criteria and procedures for designation of emission control areas laid down in Appendix III to Annex VI to the International Convention for the Prevention of Pollution from Ships (MARPOL).

LOT 1 comprises knowledge gathering only, specifically to address the square brackets and the placeholders set out in the initial draft submission to the International Maritime Organization (IMO) (REMPEC/WG.45/INF.10)[1], including, but not limited to, the synopsis of the assessment and the quantification of the impacts associated with deposition of $PM_{2.5}$ and air toxics, and is subject to the completion of LOT 2 (Land-based emissions control measures of SO_X and PM in the Mediterranean coastal States), LOT 3 (Additional analyses of fuel supply and alternative compliance methods) and LOT 4 – Regional (Additional economic impact evaluation) that provide the necessary input for the verification of completeness of the information gathered and, accordingly, the finalisation of the draft submission to the IMO in accordance with the road map and Appendix III to MARPOL Annex VI.

Section 2 of this report presents an examination and synthesis of three independent studies on the possibility of designating the Med SO_X ECA. These studies are:

- the study titled "Technical and feasibility study to examine the possibility of designating the Mediterranean Sea, or parts thereof, as sulphur oxides (SO_X) emission control area(s) (ECA(s)) under MARPOL Annex VI (REMPEC/WG.45/INF.9)[2] (REMPEC 2019), hereinafter referred to as the Technical and Feasibility Study;
- the study titled "*The potential for cost-effective air emission reductions from international shipping through designation of further Emission Control Areas in EU waters with focus on the Mediterranean Sea*"[3] (Cofala et al. 2018) funded by the European Commission, hereinafter referred to as the European Commission Study; and
- the study titled "*ECAMED: a Technical Feasibility Study for the Implementation of an Emission Control Area (ECA) in the Mediterranean Sea*"[4] (Rouïl et al. 2019) commissioned by France, hereinafter referred to as the French Study.

Section 3 of this report lays out a series of tables:
- a summary table detailing the main assumptions and outcomes of the three studies;
- the placeholders identified in the initial draft to the IMO as areas for further study under the road map;
- the list of relevant criteria collected through the completion of LOT 1, LOT 2, LOT 3, and LOT 4 – Regional; and
- the list of criteria for the designation of an emission control area, as set out in Appendix III to Annex VI to the International Convention for the Prevention of Pollution from Ships (MARPOL).

Section 4 includes the list of references used in this report.

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[1] Available at: https://www.rempec.org/en/our-work/pollution-prevention/hop-topics/med-eca.
[2] Available at: https://www.rempec.org/en/our-work/pollution-prevention/hop-topics/med-eca/study.
3 Available at: https://iiasa.ac.at/web/home/research/researchPrograms/air/news/190131_SR13_shipping.html
[4] MEPC 74/INF.5.

2 Examination of the Technical and Feasibility Study, the French Study, and the European Commission Study

This section discusses and compares the Technical and Feasibility Study, the French Study, and the European Commission Study. The three studies were completed in 2018, and the terminology and language related to different marine fuels and their compliance has evolved somewhat in the interim. Earlier work referred to marine distillate oil, or MDO, as the main fuel pathway to compliance with the IMO 2020 0.50% S m/m global sulphur cap. Subsequently, the market has met demand for 0.50% S m/m fuels using fuel blends containing several streams of residuals and lighter products, termed Low Sulphur Fuel Oils, or LSFO. Very low sulphur fuel oil, or VLSFO, has a maximum sulphur content of 0.50% S m/m and ultra-low sulphur fuel oil, or ULSFO, has a maximum sulphur content of 0.10% S m/m. Distillate marine fuels (DM) include MDO and marine gas oils, or MGO. While this report retains the original intent of the Technical and Feasibility Study, French Study, and European Commission Study by referring to MDO as the compliant pathway for IMO 2020 0.50% S m/m fuels, the market has moved towards LSFOs as the compliant pathways, and the reader may benefit from considering references to MDO as being in parallel to 0.50% S m/m LSFO.

Generally, references to HFO or Intermediate fuel oil (IFO) in prior work are referring to fuels with a sulphur content ≥ 0.50% S m/m. MDO generally refers to fuels ≤ 0.50% S m/m but ≥ 0.10% S m/m, and MGO refers to fuels ≤ 0.10% S m/m.

Terminology has varied between IMO regulations, ISO standards, and the fuel prices described in the market, further complicating the comparison of fuels and prices over time. Per resolution MEPC.320(74) on the *2019 Guidelines for consistent implementation of the 0.50% sulphur limit under MARPOL Annex VI*[5], marine fuels are defined as shown in **Table 1**.

Table 1: Definitions of marine fuel oils from resolution MEPC.320(74)

Fuel Category	ISO Standard	Fuel Sulphur Limit[6]	Terminology used in the Technical and Feasibility Study
Distillate marine fuels (DM)	ISO 8217:2017	1.0% S m/m max.	MGO if ≤ 0.10% S m/m MDO if ≤ 0.50% S m/m
Residual marine fuels (RM)	ISO 8217:2017	As per statutory requirements	IFO HFO
High sulphur heavy fuel oil (HSHFO)		> 0.50% S m/m	HFO
Very low sulphur fuel oil (VLSFO)	ISO 8217:2017	≤ 0.50% S m/m	MDO Compliant Blend
Ultra-low sulphur fuel oil (ULSFO)	ISO 8217:2017	≤ 0.10% S m/m	MGO MDO Compliant Blend

2.1 Technical and Feasibility Study

The Technical and Feasibility Study was conducted for the Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC) by a team comprised of researchers from Energy and Environmental Research Associates, LLC (EERA) and the Finnish Meteorological Institute (FMI). The Technical and Feasibility Study found that compliance with 0.10% S m/m fuel limits would produce additional reductions of emissions over global 0.50% S m/m fuel standards in 2020, resulting in environmental and human health benefits.

[5] Available at: https://www.imo.org/en/MediaCentre/PressBriefings/Pages/10-MEPC-74-sulphur-2020.aspx.
[6] Fuel sulphur limits are, functionally and as per statutory limits, fuels with ≤ 0.50% S m/m globally and ≤ 0.10% S m/m in ECA regions, unless the vessel is operating HSHFO with an Exhaust gas cleaning system (EGCS).

2.1.1 Description of the Mediterranean Sea Area Domain and Shipping Activity

The Mediterranean Sea area is an important region for international shipping and commercial navigation. The Mediterranean Sea represents approximately 0.7% of navigable seas and oceans, and Mediterranean ship traffic accounts for about 7% of global shipping activity, energy use, and emissions. Based on AIS observations, more than 30,000 vessels are observed to operate annually in the Mediterranean Sea area. Based on this work, shipping CO_2 emissions represent about 10% of Mediterranean coastal States' CO_2 inventories, as reported to the United Nations Framework Convention on Climate Change (UNFCCC).

The proposed area of application for the designation of the Med SO_X ECA, as modelled in the Technical and Feasibility Study, is illustrated in **Figure 1**. The proposed area of application follows the International Hydrographic Organization (IHO) definition of the Mediterranean Sea[7] as being bounded on the southeast by the entrance to the Suez Canal, on the northeast by the entrance to the Dardanelles, delineated as a line joining Mehmetcik and Kumkale lighthouses, and to the west by the meridian passing through Cap Spartel lighthouse, also defining the western boundary of the Straits of Gibraltar. The waters of the proposed Med SO_X ECA involve the twenty-two (22) Contracting Parties to the Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean (the Barcelona Convention), namely Albania, Algeria, Bosnia and Herzegovina, Croatia, Cyprus, Egypt, France, Greece, Israel, Italy, Lebanon, Libya, Malta, Monaco, Montenegro, Morocco, Slovenia, Spain, the Syrian Arab Republic, Tunisia, Turkey, and the European Union.

Figure 1: Contracting Parties to the Barcelona Convention (in grey) and proposed area of the Med SO_X ECA (in dark blue)

2.1.2 Shipping Activity and Fuel Use

The Technical and Feasibility Study found that vessel operating in the Mediterranean Sea used around 19 million metric tonnes (MMT) of fuel annually in 2016 at a cost of around $9.9 billion (2016$). STEAM[8] model outputs indicate that projected improvements in power system fuel economy and vessel economies of scale will lead to a 10.8% reduction in fuel consumption from 2016 to 2020, with total fuel use in 2020 estimated at 17.1 MMT, as shown in **Table 2**. Under the IMO 2020 fuel rules, compliance costs were estimated to rise to $13.85 billion, an increase of $3.97 billion, as vessels switch from 3.50% S m/m to 0.50% S m/m fuels. The proposed Med SO_X ECA is estimated to increase compliance costs by $1.77 billion over IMO 2020 costs.

[7] https://iho.int/uploads/user/pubs/standards/s-23/S-23_Ed3_1953_EN.pdf.
[8] https://en.ilmatieteenlaitos.fi/resources-available-for-the-atmospheric-dispersion-modeling-activities.

Table 2: Baseline year (2016) fuel usage and projected 2020 fuel usage under MARPOL VI and the proposed Med SO_X ECA scenarios (Technical and Feasibility Study, Table 4)

	2016 Baseline	MARPOL VI 2020	Med SO_X ECA 2020
Total Fuel (MT)	19,160,000	17,100,000	17,100,000
MGO	542,000	522,000	16,700,000
MDO	3,290,000	16,340,000	164,000
HFO	15,090,000	99,900	94,700
LNG	243,000	141,000	138,000

The Technical and Feasibility Study projected fuel use for the years 2020, 2030, 2040, and 2050. Fuel consumption is projected to decrease over time due to efficiency improvements in the vessel fleet resulting in lower energy consumption per ton-mile (BTU/ton-mile) and associated reductions in total fuel consumption of around 10% per decade. Over the future decades, the Technical and Feasibility Study projections hold the relative mix of fuels consumed constant, with 97.7% of fuels in the Med SO_X ECA as MGO, 0.96% as MDO, 0.55% as HFO in use by vessels with scrubbers, and 0.81% as Liquefied Natural Gas (LNG), as shown in **Table 3**.

Table 3: Projected fuel use from 2030 to 2050 from the Technical and Feasibility Study

MT	2030	2040	2050
Total Fuel	15,350,000	13,810,000	12,450,000
MGO	15,000,000	13,490,000	12,160,000
MDO	148,000	133,000	120,000
HFO	85,000	76,500	68,900
LNG	124,000	112,000	101,000

2.1.3 Baseline and Projected Emissions

The Technical and Feasibility Study estimated emissions reductions in two stages. First baseline 3.50% S m/m fuel emissions were estimated, before estimating the reduction in 2020 from IMO 2020 compliant 0.50% S m/m fuels. Then the emissions reductions from IMO 2020 to the 0.10% S m/m (Med SO_X ECA 2020) were estimated. SO_X reductions are directly proportional to the sulphur content of the fuels, whereas PM reductions depend primarily on the fraction of ship-emitted PM that results from fuel sulphur content. The Technical and Feasibility Study estimates that the Med SO_X ECA will reduce emissions by 78.7% compared with the IMO 2020 emissions, from 168,000 MT of SO_X annually to 35,800 MT, a reduction of 132,200 MT.

Particulate matter 2.5 microns or smaller ($PM_{2.5}$) are estimated to decrease by 23.7% with the Med SO_X ECA compared to IMO 2020 compliant fuels, an overall reduction of 11,400 MT $PM_{2.5}$, as shown in **Table 4**.

Table 4: Estimated SO_X and $PM_{2.5}$ emissions under different Mediterranean regulatory and compliance scenarios (Technical and Feasibility Study, Table 2)

	SO_X Emissions (MT)	$PM_{2.5}$ Emissions (MT)
MARPOL VI (0.50% S m/m)	168,000	48,100
Proposed Med SO_X ECA (0.10% S m/m)	35,800	36,700

As with fuel consumption, the Technical and Feasibility Study projects declining emissions in 2030, 2040, and 2050. All pollutant species are estimated to declines around 10% each decade from 2020 to 2050, as shown in **Table 5**.

Table 5: Projected total fuel use and emissions for the IMO 2020 and Med SO_X ECA scenarios in the Technical and Feasibility Study

	2030		2040		2050	
	MARPOL VI	**Med SO_X ECA**	**MARPOL VI**	**Med SO_X ECA**	**MARPOL VI**	**Med SO_X ECA**
Total Fuel	15,350,000	15,350,000	13,810,000	13,810,000	12,450,000	12,450,000
Total SO_X	151,000	33,600	136,000	30,100	122,000	25,900
Total $PM_{2.5}$	43,400	34,500	39,100	30,900	35,200	26,800
Total NO_X	986,000	1,030,000	875,000	908,000	785,000	785,000
Total CO_2	46,600,000	48,520,000	41,910,000	43,530,000	37,790,000	37,650,000

2.1.4 Geographic distribution of emissions

The geographic distribution of shipping emissions for a 2016 non-MARPOL VI baseline case, the MARPOL VI 2020 case, and the proposed Med SO_X ECA 2020 case from the Technical and Feasibility Study is shown in **Figure 2**.

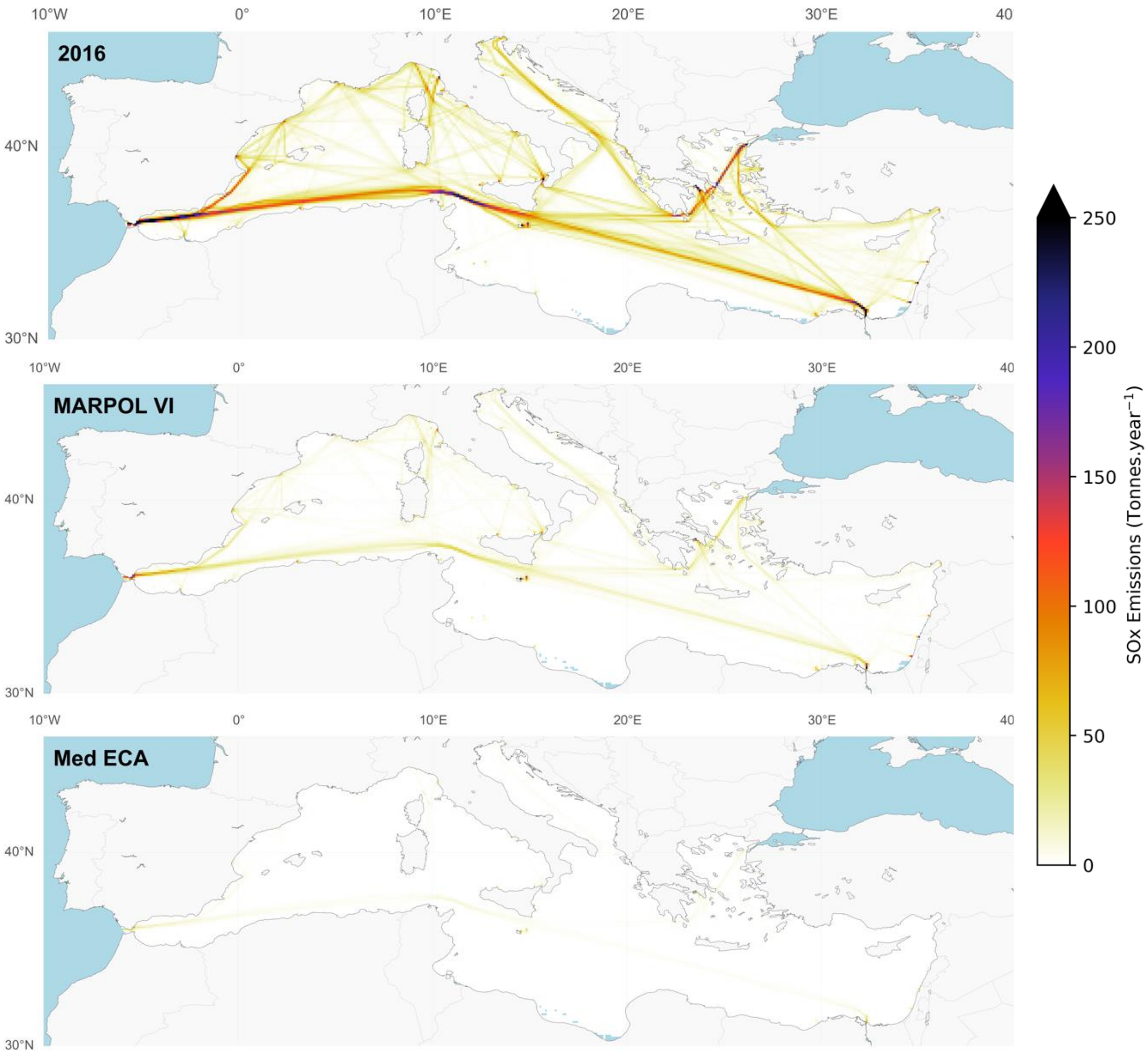

Figure 2: SO_X emissions under 2016 baseline, MARPOL VI 2020, and the proposed Med SO_X ECA 2020 scenarios

2.1.5 Health Benefits

The Technical and Feasibility Study uses FMI's SILAM[9] model to estimate high-resolution (0.1° x 0.1°, or ~ 10 km x 10 km) fate and transport of pollutants. Health benefits are estimated using EERA's health model, state-of-the-art health model, recently published in *Nature Communications* (Sofiev et al. 2018), and referenced in document MEPC 70/INF.34.

Health benefits (mortality and morbidity) were estimated for expected avoided lung cancer and cardiovascular disease mortality, and childhood asthma morbidity, associated with the proposed Med SO_X ECA at a high resolution (10 km x 10 km).

Annual health benefits estimated by the Technical and Feasibility Study are summarised in **Table 6**. Health benefits were estimated to occur far inland, away from major shipping routes, though the largest benefits were seen in large population centres near major shipping lanes. Modelling results estimate avoided cardiovascular mortality of around 970 deaths per year, and lung cancer mortality of around 149 deaths per year. Due to the interaction between air quality improvements, population centres, and country-specific incidence rates, hotspots occur where avoided mortality from reduced ship emissions is greater. Clusters of these hotspots can be seen in north Africa as well as areas of the Eastern Mediterranean. Avoided childhood asthma morbidity was around 2,310 incidents per year.

Table 6: Summary of health benefits evaluated for the proposed Med SO_X ECA (model year 2020)

Scenario Results (Linear C-R Model)	**Reduced Mortality (annual premature adult deaths)**		**Avoided Childhood Asthma (annual avoided incidents)**	
Health benefits of the proposed Med SO_X ECA	**Reduced Mortality**		**Reduced Asthma Morbidity**	
	CV Mortality Avoided	969 (CI 95% 551; 1,412)	**Avoided Childhood Asthma**	**2,314 (CI 95% 1,211; 3,406)**
	LC Mortality Avoided	149 (CI 95% 32; 270)		
	Combined Avoided Mortality	**1,118 (CI 95% 583; 1,682)**		

2.1.6 Environmental Benefits

The environmental benefits estimated by the Technical and Feasibility Study are summarised in **Table 7.** As noted in the Technical and Feasibility Study, sulphate deposition reductions are a proxy indicator for potential change in pH acidification to aquatic and terrestrial ecosystems. PM_{Total} deposition reductions are a proxy indicator for potential change in other particle and nutrient effects. Note that Dry PM_{Total} deposition indicated some regions with small increases in deposition, due to non-linear PM formation responses with the reduction of sulphates, consistent with findings reported in science literature. Aerosol optical depth (AOD) is a proxy for increased suspended particles affecting regional haze and visibility impairment, an increase in aerosol optical depth indicates an improvement in visibility.

Table 7: Summary of proxies for other benefits associated with the proposed Med SO_X ECA

Environmental Benefit Proxy	**Relative Range of Change (%)**
Wet sulphate deposition	1 to 15% reduction
Dry sulphate deposition	1 to 50% reduction
Wet PM_{Total} deposition	0.5 to 5% reduction
Dry PM_{Total} deposition	0 to 10% reduction
Aerosol optical depth (PM-related)	1% to 6% increase

[9] http://silam.fmi.fi.

As shown in **Table 7**, the Technical and Feasibility Study found that the Med SO_X ECA would lead to widespread reductions in pollution deposition and improvements in AOD, likely leading to improvements in environmental quality Mediterranean-wide.

2.1.7 Economic Costs

The Technical and Feasibility Study estimates that compliance with the Med SO_X ECA would carry an additional cost of $1.766 billion on top of compliance with IMO 2020 global 0.50% S m/m fuel standards. This cost is based on fuel switching and is therefore a function of the estimated mix of fuels used and the price differential between 0.50% S m/m IMO 2020 fuels and 0.10% S m/m ECA compliant fuels. The Technical and Feasibility Study also modelled the additional compliance costs based on economic uptake and use of scrubbers in the Mediterranean. With scrubbers, the additional total cost of compliance is lower than fuel switching alone, at $1.157 billion, or a difference of $0.609 billion per year.

2.2 The French Study

In parallel with the Technical and Feasibility Study, the French Study was commissioned by France and independently performed by Ineris, with contributions from Cerema, Citepa and Plan Bleu.

2.2.1 Description of Study Area

The French Study area is shown in **Figure 3**.

Figure 3: French Study domain

2.2.2 Shipping Activity and Fuel Use

The French Study uses AIS derived estimates of activity and load, coupled with classification society power data to estimate fuel use and emissions. The French Study looks at. Arrange of scenarios, include the 2015/16 baseline, IMO 2020 compliant fuels (0.50% S m/m), and a set of SECA scenarios including the whole Mediterranean as a sulphur ECA (0.10% S m/m), and a Med SO_X ECA + 50% compliance NO_X ECA and a Med SO_X ECA + 100% NO_X ECA scenarios.

The whole Mediterranean scenario is directly comparable with the Technical and Feasibility Study estimate assumptions. The French Study estimates Med SO_X ECA fuel use 17.7 MMT of MGO in 2020. The French Study does not provide emissions or fuel use projections beyond 2020.

2.2.3 Baseline and Projected Emissions

The French Study estimates that the implementation of the Med SO_X ECA would reduce SO_X emissions by 95% and PM by 80% compared to the 2015/16 baseline. These estimates correspond to **Table 8**.

Table 8: SO_X and $PM_{2.5}$ emissions under the baseline, MARPOL VI, and Med SO_X ECA scenarios from the French Study

	SO_X Emissions (MT)	$PM_{2.5}$ Emissions (MT)
Baseline (2015-16)	759,000	79,000
MARPOL VI (0.50% S m/m)	153,000	22,400
Proposed Med SO_X ECA (0.10% S m/m)	35,200	15,800

2.2.4 Geographic Distribution of Emissions

As with the Technical and Feasibility Study, the French Study also assumes no changes to land-based emissions, with only shipping emissions being changed by the Med SO_X ECA. The geographic distribution of emissions, including land-side emissions produced by the Chemair model, is shown in **Figure 4**.

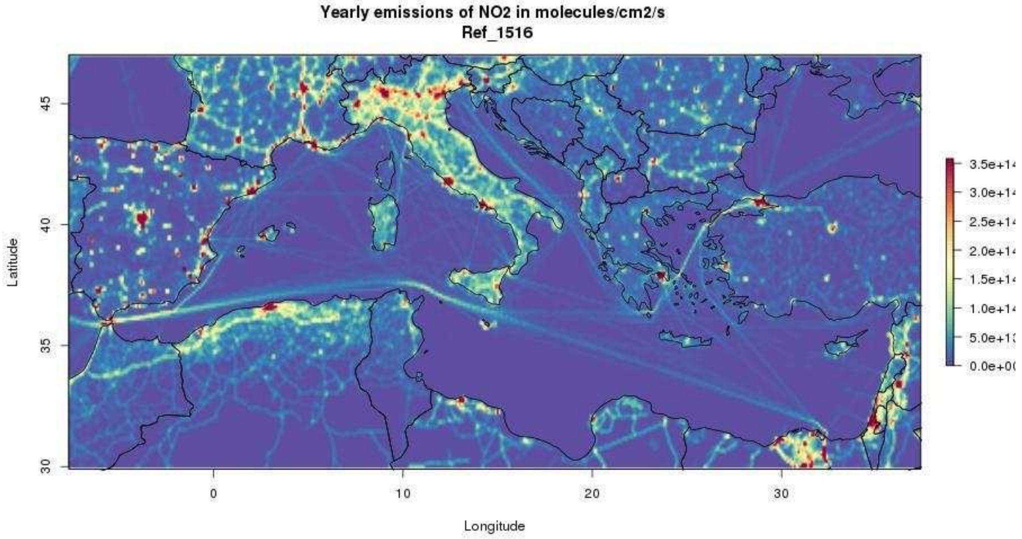

Figure 4: Gridded NO_X emissions showing distribution of landside and waterborne emissions in the French Study (ECAMED, figure 15)

2.2.5 Health Benefits

The French Study used the Alpha-Riskpoll (ARP) model[10] to estimate health benefits. The ARP model estimates benefits across a series of mortality endpoints, which include all cause chronic mortality and all cause infant mortality, and a set of respiratory and cardiac morbidity endpoints.

The French Study estimates the health benefits of compliance with IMO 2020 at 4,519 avoided premature deaths, with an additional 1,728 avoided premature deaths with the proposed Med SO_X ECA.

2.2.6 Environmental Benefits

$PM_{2.5}$ concentrations are reduced over the whole domain, with a maximum reduction of around 11%. Reductions in $PM_{2.5}$ concentrations are greatest in northern Italy, around Cairo in Egypt, in Greece, and along the coast of Spain (**Figure 5**).

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[10] Developed by EMRC and others: http://www.ec4macs.eu/content/report/EC4MACS_Publications/MR_Final%20in%20pdf/Alpha_Methodologies_Final.pdf.

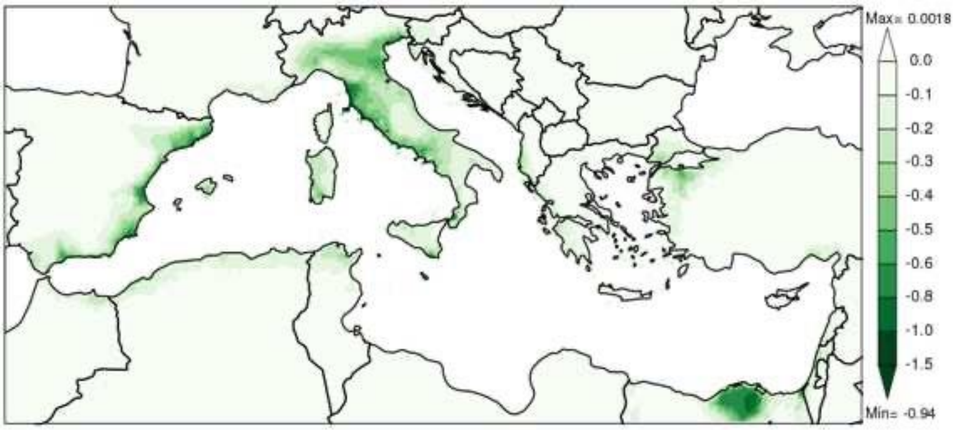

Figure 5: Absolute change in $PM_{2.5}$ concentration difference (Figure 16 ECAMED)

The French Study estimates that the Med SO_X ECA would lead to eutrophication benefits, with nitrogen deposition on coastal ecosystems reduced by up to 40% compared to 2020 legislation.

2.2.7 Economic Costs

The French Study uses the costs outlined in **Table 9** to estimate costs of implementation. The French Study, contrary to the Technical and Feasibility Study, assumes that ship fuel prices will increase into the future, with MDO reaching up to €1,800 by 2040. Though the French Study also estimates costs associated with a NO_X ECA, this synopsis focuses on SECA compliance costs.

Table 9: Average fuel prices used in the cost calculations for each scenario (ECAMED, Table 3)

	€ 2015 / ton of fuel						
	LNG	**MGO 0.10% S**	**MGO 0.50% S**	**HFO 0.50% S**	**HFO 1.50% S High Price**	**HFO 1.50% S Average Price**	**HFO 2.7% S**
World	414	472	453	410	524	358	296
Mediterranean	414	473	465	385	482	334	273
Average	414	472	459	398	503	346	284

Based on these cost-differentials, the French Study estimates that the additional cost of the Med SO_X ECA, on top of the additional costs associated with IMO 2020, would be between €0.1 - €0.27 billion per year. If using cost differentials more closely aligned with those used in the Technical and Feasibility Study, the additional cost of the Med SO_X ECA would be €1.25 billion per year.

2.3 The European Commission Study

In parallel with the Technical and Feasibility Study and the French Study, the European Commission Study was led by the International Institute for Applied Systems Analysis (IIASA) with contributions from Ecometrics Research and Consulting (EMRC) and the Norwegian Meteorological Institute, and funded by the European Commission.

2.3.1 Description of Study Area Shipping Activity and Fuel Use

The European Commission Study used emission estimates from FMI’s STEAM3 model to produce geospatially resolved estimates of emissions from marine sources based on AIS data observations (**Figure 6**).

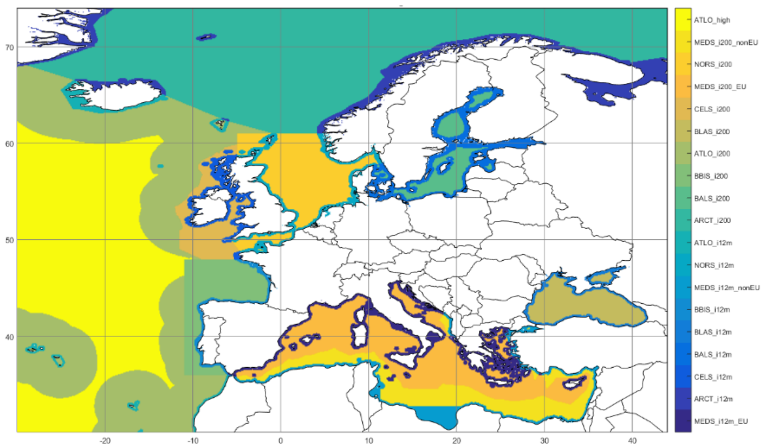

Figure 6: Emission source regions distinguished in the European Commission Study (Cofala et al. 2018, Figure 1)

The European Commission Study estimates fuel use in the Mediterranean Sea area amounted to around 0.713 EJ (Annex 3). As HFO contains around 41kJ/g [11] (MGO contains around 45 kJ/g), this corresponds to around 17.4 million metric tonnes of HFO consumed in European Seas in 2015.

2.3.2 Baseline and Projected Emissions

The European Commission Study identifies two projections for fuel demand, first the baseline projection extrapolates current trends in economic growth, trade relations, and fuel efficiency. The “with climate measures” scenario includes potential GHG reduction scenarios and the potential effects on air pollutant emissions.

Annex 3 to the European Commission Study shows projected baseline growth in fuel consumption in the Mediterranean Sea to grow from 0.713 EJ (17.39 MMT HFO) in 2015 to 1.794 EJ (~39.9 MMT MGO) in 2050, corresponding to a compound annual growth rate of around 2.67%, or linear growth of around 0.03 EJ (~0.667 MMT MGO) per year. The climate measures scenario estimates stabilising fuel consumption around 0.85 EJ in 2035 before ultimately declining to levels slightly above 2015 estimates in 2050 (0.734 EJ).

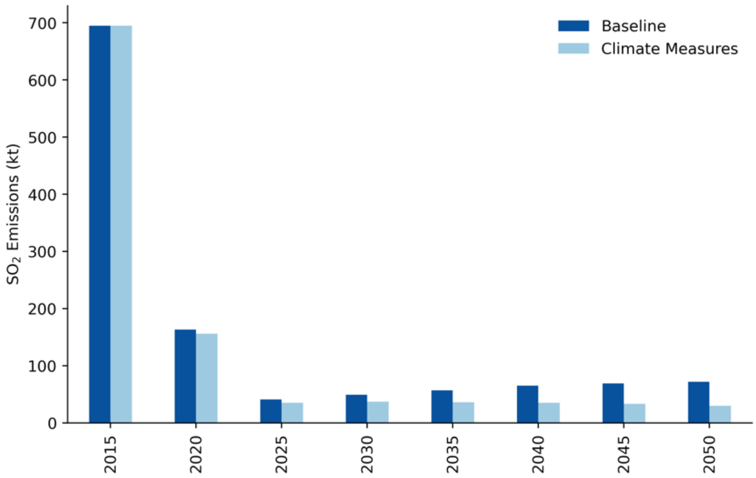

Figure 7: SO_2 emissions in the Mediterranean Sea area (IIASA, Annex 5, Table 5.1)

[11] https://www.ntnu.edu/documents/20587845/1266707380/01_Fuels.pdf/1073c862-2354-4ccf-9732-0906380f601e.

The European Commission Study estimates baseline SO_2 emissions of 695 kt in 2015, falling 76.5% to 163 kt in 2020 with IMO 2020, and then again to 41,000 MT in 2025 with the proposed Med SO_X ECA. Subsequently, baseline SO_2 emissions are projected to grow from 41,000 MT in 2025 to 72,000 MT in 2050. Under the climate measures scenario, SO_2 emissions are slightly declining, from 35 kt in 2025 to 30 kt in 2050 (**Figure 7**).

2.3.3 Geographic Distribution of Emissions

As shown in **Figure 8**, the geographic distribution of emissions of SO_2 estimated by the European Commission Study follows primary shipping lanes in the Mediterranean and is extended to lanes outside the Straits of Gibraltar, as well as through the Dardanelles, the Marmara Sea, the Bosporus, and into the Black Sea.

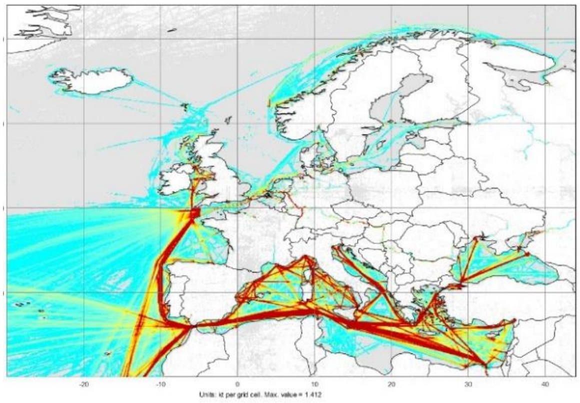

Figure 8: Gridded emissions of SO_2 (Cofala et al. 2018, Figure 6)

2.3.4 Health Benefits

As discussed previously, the European Commission Study includes analysis of additional regions outside the Mediterranean Sea, as well as additional control measures beyond the Med SO_X ECA. Based on $PM_{2.5}$ exposure, the entire suite of emission control measures (SECA + NECA + PM filters) would avoid up to 8000 cases of premature deaths annually, with about 40% of those avoided deaths in North Africa and the Middle East.

Taking only the Med SO_X ECA control measures, in all Mediterranean Sea areas, the European Commission Study estimates annual health benefits between ~2,700 and ~3,500 avoided deaths in 2030 (with climate measures and baseline, respectively), with over half the benefits accruing in the Middle East and Africa (**Figure 9**).

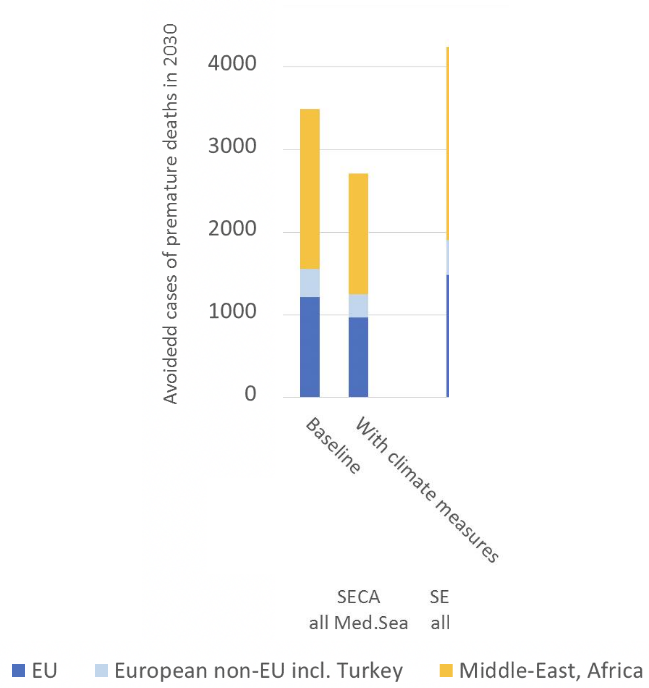

Figure 9: Avoided cases of premature deaths from the control of shipping emissions in the Mediterranean Sea in 2030 (Cofala et al. 2018, Figure 26)

Analysis of health benefits using the ALPHA-Riskpoll model shows that the most important monetary benefits from controlling emissions of air pollutants in the reduction in premature mortality associated with improved air quality. Baseline estimates show benefits of around €8 billion per year in 2030 under the baseline scenario.

2.3.5 Environmental Benefits

The European Commission Study used the GAINS[12] model, coupled with data from the EMEP[13] atmospheric chemistry and transport model. The European Commission Study focuses on exposure to $PM_{2.5}$ pollution as the most relevant health impact indicator.

Generally, emission reductions from the European Commission Study show the largest effect along the coasts of the Mediterranean Countries, most notably along the coastlines of north Africa, where $PM_{2.5}$ emissions reductions are estimated to lead to $PM_{2.5}$ concentration reductions of up to 1.2 µg/m^3 in 2030. Though largest along the coastlines, air quality benefits from controlling international ship emissions extend far inland, potentially benefitting more than half the EU population.

Deposition and AOD were not evaluated by the European Commission Study.

2.3.6 Economic Costs

The economic costs estimated by the European Commission Study are laid out in detail in Annex 6. Focusing on scenarios H5M (Med SO_X ECA: Baseline) and L5M (Med SO_X ECA: Climate Measures), which correspond to the Med SO_X ECA scenarios, the European Commission Study estimates additional costs of the Med SO_X ECA based on fuel price differentials, supplemented by analysis of the costs with scrubbers. The European Commission Study assumes a base MDO 0.50% S m/m fuel price of €363/t, and an MGO 0.10% S m/m fuel price of €401/t, a price differential of €38/t. The European Commission Study estimates an incremental cost of between €0.764 billion (climate measures) and €1.001 billion (baseline) for the Med SO_X ECA using 0.10% S m/m fuels compared to the 0.50% S m/m baseline in 2030.

[12] https://iiasa.ac.at/web/home/research/researchPrograms/air/GAINS.html.
[13] https://emep.int/mscw/.

3 Status of the Knowledge Gathering and Draft Submission to the IMO

This section provides a compilation of data in tabular format to allow for comparison and evaluation. First, **Table 10** provides a summary of the outcomes of the Technical and Feasibility Study, the French Study, and the European Commission Study, allowing for direct comparison of the outcomes of the independent studies. **Table 11** sets out the list of placeholders in the initial draft submission to the IMO, identified in the road map as areas for further study. **Table 12** supplies the list of criteria for designation of an emission control area as set out in Appendix III to MARPOL Annex VI. Lastly, **Table 13** provides an overview of the relevant information and data that will be gathered through completion of LOT 1, LOT 2, LOT 3, and LOT 4 – Regional in support of completing sections left as placeholders in the initial draft submission to the IMO.

3.1 Comparison of the Technical and Feasibility Study and other Relevant Studies

Table 10 identifies the primary outcomes of the Technical and Feasibility Study and other relevant studies, including the French Study and the European Commission Study. Though in some instances the source data are similar, each of these studies was carried out concurrently, independently, and using independent methodologies and health effects endpoints. As such, any comparisons between the studies are unbiased, as none of the studies was unduly influenced by any other study.

The three studies are generally in very good agreement regarding their central findings. First, the three studies are in very good agreement regarding the baseline levels of total fuel use in the Mediterranean Sea area in 2020, with estimates ranging from 17.1 MMT to 17.7 MMT, a difference of just 3.5% from the lower estimate to the upper estimate. Additionally, the independent studies are in strong agreement regarding the SO_X emissions associated with the Med SO_X ECA, estimating a range between 0.153 MMT and 0.168 MMT for SO_X emissions under IMO 2020, and between 0.035 MMT and 0.037 MMT under the Med SO_X ECA scenario. It should be noted that the best agreement is between the French and Technical and Feasibility studies and the European Commission Study "Climate measures" scenario estimates. These SO_X emission estimates are in very strong agreement, supporting a high level of confidence in the quality of the estimates.

The three studies differ slightly in their treatment of health benefits in terms of the endpoints used, though the methodologies are consistent and, considering the differing endpoints, the results are in good agreement. The Technical and Feasibility Study employs EERA's health model to estimate health benefits at three endpoints, cardiovascular and lung cancer mortality, and childhood asthma morbidity. The French Study and the European Commission Study employ the Alpha-Riskpoll model to estimate all-cause mortality, as well as differing morbidity endpoints. For the purposes of comparison, we focus on mortality endpoints for discussion. Furthermore, the modelling domain for health benefits differs across the three studies, the Technical and Feasibility Study and French studies focus on the Contracting Parties to the Barcelona Convention, while the European Commission Study expands the analysis to other Member States of the European Union that are not Contracting Parties to the Barcelona Convention and that also experience benefits.

Table 10: Main assumptions and outcomes of the Technical and Feasibility Study, and other relevant studies

Criteria	Technical and Feasibility Study	French Study	European Commission Study
2020 Fuel Consumption	17.10 MMT	17.7 MMT	17.4 MMT
SO_X Emissions **2015-16 Baseline** **2020** **2030** **2040** **2050**	0.681 MMT 0.168 MMT / 0.036 MMT[14] 0.034 MMT 0.030 MMT 0.026 MMT	0.759 MMT[15] 0.153 MMT / 0.035 MMT	Baseline / Climate Measures 0.695 MMT / 0.695 MMT 0.163 MMT / 0.156 MMT[16] 0.049 MMT / 0.037 MMT 0.065 MMT / 0.035 MMT 0.072 MMT / 0.030 MMT
Avoided Mortality	1,118[17]	1,728[18]	3,500 / 2,700[19]
Economic Costs	$1.766 billion	€1.25 billion	€1.001 billion / €0.764 billion
Cost Effectiveness	$13,400 /MT SO_X $155,000 /MT $PM_{2.5}$		
Net Benefits		€8.1 billion benefits €2.7 billion costs	€4.8 billion benefits €1.001 billion costs
Benefit-Cost Ratios	$1.58 million/ ΔMortality $0.763 million/ ΔMorbidity	3	4.8[20]

3.2 Synopsis of the Fourth IMO GHG Study 2020

The Final report of the Fourth IMO GHG Study 2020 (MEPC 75/7/15) (Faber et al. 2020), hereinafter referred to as the Fourth IMO GHG Study 2020, found that the CO_2eq emissions from all shipping activity (international, domestic, and fishing) grew by 9.3% since 2012 to 1,076 million tonnes, with shipping emissions making up 2.89% of global total anthropogenic greenhouse gas emissions in 2018. The Fourth IMO GHG Study 2020 estimated that emissions are projected to increase from around 90% of 2008 emissions to 90-130% of 2008 emissions by 2050.

The Fourth IMO GHG Study 2020 projections (Faber et al. 2020, figure 26) "*increase from 1,000 MT CO_2 in 2018 to 1,000 to 1,500 MT CO_2 in 2050. This represents an increase of 0 to 50% over 2018 levels*". These estimates are based on projections of transport work under a set of socioeconomic pathways, coupled with estimated reductions in vessel carbon intensity. Taking the range of projections, the pathways translate to compound annual growth rates in CO_2 emissions of between 0% and 1.28%.

Taking prior estimates of CO_2 emissions from the Fourth IMO GHG Study 2020, coupled with projected emissions from the same report and the World Oil Outlook yields the time series shown in **Figure 10**.

[14] Technical and Feasibility Study results presented here for the Med SO_X ECA implemented in 2020.
[15] The French Study uses 2015-2016 as the baseline year, and MARPOL VI implementation in 2020.
[16] The European Commission Study assumes implementation of the Med SO_X ECA in 2025, whereas the Technical and Feasibility Study results are presented in this summary table as if implemented in 2020.
[17] Lung cancer and cardiovascular disease mortality endpoints.
[18] All-cause mortality.
[19] All-cause mortality in 2030 under the baseline and climate measures scenarios, respectively, including Member States of the European Union that are not Contracting Parties to the Barcelona Convention.
[20] Based on Scenario H5M in 2030, no scrubbers.

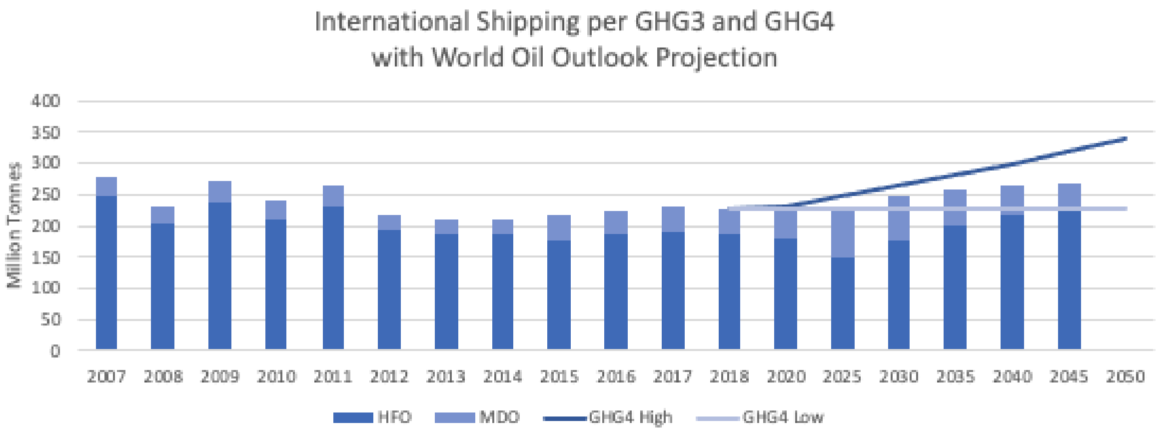

Figure 10: Combined time series of international shipping fuel estimates coupled with the World Oil Outlook projections (bars, post-2018) and the Fourth IMO GHG Study 2020 high and low scenarios (lines)

This time series shows flat or increasing fuel consumption post 2020, which corresponds to CO_2 emissions. The Technical and Feasibility Study projections show decreasing fuel demand over time due to vessel efficiency improvements over time, aligned with the Energy Efficiency Design Index parameters laid out by IMO, and discussed in **Section 2.1.2** and **Section 2.1.3** of this report, and section 7.5.1 of the Technical and Feasibility Study. The Technical and Feasibility Study projections are well aligned with the French Study and the European Commission Study estimates, and while valid in their own right, when considered against the Fourth IMO GHG Study 2020 projections they stand as conservative lower bounds of fuel consumption and associated emissions.

3.3 Checklist of Placeholders Identified in the Initial Draft Submission to the IMO

The initial draft submission to the IMO identified and suggested a set of areas for further research under the road map. These placeholders are laid out in **Table 11**, along with the working response for how the placeholder text will be addressed by the efforts under LOT 1, LOT 2, LOT 3, and LOT 4 – Regional.

Table 11: List of placeholders set out in the initial draft submission to the IMO

Location	Comment	Working Response
Paragraph 16	The submission can present additional data if made available from relevant Mediterranean coastal States	Additional data on the land-based measures undertaken by Mediterranean coastal States is addressed by **LOT 2**.
Paragraph 17	Aside from the European Union and some Unites Nations reporting, national level detail was not identified; the submission can present additional data if made available from relevant Mediterranean coastal States	Additional data on the levels of pollution abatement by land-based measures undertaken by Mediterranean coastal States is addressed by **LOT 2**.
Section 1.1	**Countries Submitting this Proposal** PLACEHOLDER FOR DESCRIPTION OF FURTHER ACTIONS TOWARDS RATIFICATION	The status of ratification of MARPOL Annex VI by Mediterranean coastal States will be addressed under **LOT 1** when finalising the draft submission to the IMO.
Table 1.1-1	**Status of ratification of MARPOL Annex VI by [Mediterranean coastal States] (as of [date])**	This table will be updated under **LOT 1**, as appropriate, when finalising the draft submission to the IMO.

Section 3.1	**Synopsis of the Assessment** PLACEHOLDER FOR SYNOPSIS TO BE PROVIDED THROUGH ROAD MAP	The synopsis of the Technical and Feasibility Study is addressed by **LOT 1**.
Section 5.3	**Impacts Associated with Deposition of $PM_{2.5}$ and Air Toxics** PLACEHOLDER FOR QUANTIFICATION TO BE PROVIDED THROUGH ROAD MAP	Qualitative discussion of the impacts associated with deposition of $PM_{2.5}$ is addressed by **LOT 1**.
Section 8.1	**Land-Based Emissions Controls of SO_X and PM in the [Mediterranean coastal States]** PLACEHOLDER FOR ADDITIONAL DETAILS TO BE PROVIDED THROUGH ROAD MAP	Additional data on the land-based measures undertaken by Mediterranean coastal States is addressed by **LOT 2**.
Section 8.2	**Summary of Control of Land-Based Sources** PLACEHOLDER FOR ADDITIONAL DETAILS TO BE PROVIDED THROUGH ROAD MAP	Additional data on the levels of pollution abatement by land-based measures undertaken by Mediterranean coastal States is addressed by **LOT 2**.
Section 9.6	**Economic Impacts on Shipping Engaged in International Trade** PLACEHOLDER FOR ADDITIONAL ELEMENTS TO BE PROVIDED THROUGH ROAD MAP	The economic impacts on shipping engaged in international and national trade are addressed by **LOT 4 – Regional**.

3.4 Checklist of Criteria for Designation of an Emission Control Area

Appendix III to MARPOL Annex VI sets out a list of eight criteria necessary for the designation of an emission control area. This section addresses the status of each of the criteria based on efforts in the Technical and Feasibility Study and under the road map for LOT 1, LOT 2, LOT 3, and LOT 4 – Regional. **Table 12** provides the list of criteria, a description of the status of whether the criteria has been addressed and where, and if the criteria has not been fully addressed how it will be addressed.

Table 12: List of criteria for designation of an emission control area as set out in Appendix III to MARPOL Annex VI

Criteria	Criteria Description	Status
Criterion 3.1.1	a clear delineation of the proposed area of application, along with a reference chart on which the area is marked	This criterion is addressed in Annex 1, Section 2.1, and Annex 2 of the initial draft submission to the IMO.
Criterion 3.1.2	the type or types of emission(s) that is or are being proposed for control (i.e. NO_X or SO_X and particulate matter or all three types of emissions)	This criterion is addressed in Annex 1, Section 2.2 of the initial draft submission to the IMO.
Criterion 3.1.3	a description of the human populations and environmental areas at risk from the impacts of ship emissions	This criterion is addressed in Annex 1, Section 2.3 of the initial draft submission to the IMO.
Criterion 3.1.4	an assessment that emissions from ships operating in the proposed area of application are contributing to ambient concentrations of air pollution or to adverse environmental impacts. Such assessment	This criterion is addressed in Annex 1, Section 3, Section 4, and Section 5 of the initial draft submission to the IMO.

	shall include a description of the impacts of the relevant emissions on human health and the environment, such as adverse impacts to terrestrial and aquatic ecosystems, areas of natural productivity, critical habitats, water quality, human health, and areas of cultural and scientific significance, if applicable. The sources of relevant data including methodologies used shall be identified	
Criterion 3.1.5	relevant information pertaining to the meteorological conditions in the proposed area of application to the human populations and environmental areas at risk, in particular prevailing wind patterns, or to topographical, geological, oceanographic, morphological, or other conditions that contribute to ambient concentrations of air pollution or adverse environmental impacts	This criterion is addressed in Annex 1, Section 6 of the initial draft submission to the IMO.
Criterion 3.1.6	the nature of the ship traffic in the proposed emission control area, including the patterns and density of such traffic	This criterion is addressed in Annex 1, Section 7 of the initial draft submission to the IMO.
Criterion 3.1.7	a description of the control measures taken by the proposing Party or Parties addressing land-based sources of NO_X, SO_X and particulate matter emissions affecting the human populations and environmental areas at risk that are in place and operating concurrent with the consideration of measures to be adopted in relation to provisions of regulations 13 and 14 of MARPOL Annex VI	This criterion is addressed in Annex 1, Section 8 of the initial draft submission to the IMO with additional data on the land-based measures undertaken by Mediterranean coastal States and on the levels of pollution abatement resulting from such measures are addressed by **LOT 2**.
Criterion 3.1.8	the relative costs of reducing emissions from ships when compared with land-based controls, and the economic impacts on shipping engaged in international trade	This criterion is addressed in Annex 1, Section 9 of the initial draft submission to the IMO, with additional elements on fuel availability addressed by **LOT 3** and additional elements on economic impacts addressed by **LOT 4 – Regional**.

3.5 Checklist of Information and Data for Completion under the Road Map

This section details the additional actions identified under the road map, including additional knowledge gathering and further studies to address placeholders in the initial draft submission to the IMO, as shown in **Table 13**.

Table 13: List of relevant information and data that will be gathered through completion of LOT 1, LOT 2, LOT 3, and LOT 4 – Regional

Study Type	Action Identified	Action Taken
Knowledge Gathering	Synopsis of the assessment	The synopsis of the Technical and Feasibility Study is addressed by **LOT 1**.
	Quantification of the impacts associated with deposition of $PM_{2.5}$ and air toxics	Qualitative discussion of the impacts associated with deposition of $PM_{2.5}$ is addressed by **LOT 1**.
	Additional detail of land-based emissions controls of SO_X and PM in the Mediterranean coastal States	Additional data on the land-based measures undertaken by Mediterranean coastal States and on the levels of pollution abatement resulting from such measures are addressed by **LOT 2**.
	Additional elements on the economic impacts on shipping engaged in international trade	Economic impacts on shipping engaged in international trade are addressed in Annex I, Section 9.6 of the initial draft submission to the IMO. Additional elements are addressed by **LOT 4 – Regional**.
Further Studies	Analyses of the impacts on shipping engaged in international trade as well as on trade modal shift outside the Mediterranean	Economic impacts on shipping engaged in international trade are addressed in Annex I, Section 9.6 of the initial draft submission to the IMO. Additional elements are addressed by **LOT 4 – Regional**. Analysis of the potential for trade modal shift is addressed by **LOT 4 – Regional**.
	Analyses of the impacts on short-sea shipping activity as well as on the social and economic impact on Contracting Parties including on development for islands, insular, and remote areas	Analysis of the impacts on short sea shipping and on insular, remote, and island area is addressed by **LOT 4 – Regional**.
	Additional fuel supply and technology analyses (regional fuel production, fuel availability, and alternative compliance technologies	Analysis of additional fuel supply, technology, and alternative compliance technologies is addressed by **LOT 4 – Regional**.

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