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

Online, 27-28 April 2021

Agenda Item 3

REMPEC/WG.50/INF.10
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FINAL REPORT ON THE COMPLETION OF THE KNOWLEDGE GATHERING AND THE CARRYING OUT OF THE FURTHER STUDY RELATED TO THE ADDITIONAL ECONOMIC IMPACT EVALUATION

Note by the Secretariat

SUMMARY

Executive Summary:	This document presents the final report on the completion of the knowledge gathering and the carrying out of the further study related to the additional economic impact evaluation, 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 carrying out of the further study related to the additional economic impact evaluation, which was prepared pursuant to the road map according to the Terms of Reference set out in Appendix IV to document REMPEC/WG.50/INF.6, is presented in the **Appendix** to the present document.

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[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 carrying out of the further study related to the additional economic impact evaluation

MEDITERRANEAN ACTION PLAN (MAP)
PLAN BLEU POUR L'ENVIRONNEMENT ET LE DÉVELOPPEMENT EN MÉDITERRANÉE (PLAN BLEU)
REGIONAL MARINE POLLUTION EMERGENCY RESPONSE CENTRE FOR THE MEDITERRANEAN SEA (REMPEC)

COMPLETION OF THE KNOWLEDGE GATHERING AND CARRYING OUT OF THE FURTHER STUDY RELATED TO THE ADDITIONAL ECONOMIC IMPACT EVALUATION PURSUANT TO THE ROAD MAP FOR A PROPOSAL FOR THE POSSIBLE DESIGNATION OF THE MED SO_X ECA

(LOT 4 – Regional)

Final Report

Prepared and submitted by

Energy and Environmental Research Associates, LLC (EERA)

April 2021

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

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Abbreviations and Definitions

Term	Explanation
AIS	Automated Identification System
bbl	Barrel
cm	Centimetre
CO_2	Carbon dioxide
COMPETE	Analysis of the contribution of transport policies to the competitiveness of the EU economy and comparison with the United States of America
EERA	Energy and Environmental Research Associates, LLC
EEZ	Exclusive economic zone
EIA	Energy Information Administration, United States Department of Energy
EMEA	Europe, Middle East, and Africa
FMI	Finnish Meteorological Institute
GHG	Greenhouse gas
HDV	Heavy duty vehicle (on-road)
HFO	Heavy fuel oil
IFO	Intermediate fuel oil
IHO	International Hydrographic Organization
IMO	International Maritime Organization
ITF	International Transport Forum
kg	Kilograms
km	Kilometres
ktonnes	Kilotonnes
lb	Pound
LDV	Light duty vehicle (on-road)
LNG	Liquified natural gas
LSFO	Low-sulphur fuel oil
MAP	Mediterranean Action Plan
MARPOL Annex VI	Annex VI to the International Convention for the Prevention of Pollution from Ships
MDO	Marine distillate oil
MED POL	Programme for the Assessment and Control of Marine Pollution in the Mediterranean
Med SO_X ECA	Mediterranean Sea Area SO_X Emission Control Area
MGO	Marine gas oil
mm	Millimetre
MT	Metric tonnes
MTCs	Maritime Transport Costs
MTF	Mediterranean Trust Fund
O-D	Origin-destination
OECD	Organisation for Economic Cooperation and Development
passenger-km or p-km	Passenger-kilometres
PB/RAC	Plan Bleu Regional Activity Centre
PED	Price elasticity of demand
REMPEC	Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea
Ro-Ro	Roll on/Roll off vessel
RoPax	Roll-on/Roll-off Passenger vessel
S (and S m/m)	Sulphur (and Sulphur on a mass percent solution in fuel)
SO_X	Oxides of sulphur
STEAM	Ship Traffic Emission Assessment Model
TEU	Twenty-foot equivalent container
tonne-km or ton-km or t-km	Tonne-kilometres
UNCTAD	United Nations Conference on Trade and Development
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
USD	United States Dollars

Term	Explanation
USDA	United States Department of Agriculture
VLSFO	Very low-sulphur fuel oil
WTI	West Texas Intermediate

1 Executive Summary

This final report presents the results of the knowledge gathering and the further study completed and carried out under LOT 4 – Regional (Additional economic impact evaluation) 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.

Characterization of socio-economic impacts presented in this report describe how costs of a Med SO_X ECA may affect fuel prices, freight rates, product prices and market behaviour across diverse routes and commodities serving coastal states, remote areas, and island states. In the context of the Technical and Feasibility Study net benefits to the environment, to human health, and to the goals of countries that are Parties to the Barcelona Convention, the common finding of importance to the Road Map is that the benefits to countries and the Mediterranean Sea Area exceed the costs of a Med SO_X ECA.

1.1 Overview of project

The Plan Bleu Regional Activity Centre (PB/RAC), in cooperation with the Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC), tasked Energy and Environmental Research Associates, LLC (EERA), to complete the knowledge gathering and carry out the further study related to the additional economic impact evaluation 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). EERA conducted additional and extended evaluation of economic impacts related to the possible designation of the Med SO_X ECA. This work provides additional decision-support information related to specific issues identified in the road map.

1.2 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 this study, is illustrated in **Figure 1**. The proposed area of application follows the International Hydrographic Organization (IHO) definition of the Mediterranean Sea[1] 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.

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[1] https://iho.int/uploads/user/pubs/standards/s-23/S-23_Ed3_1953_EN.pdf.

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

Ship traffic in the Mediterranean Sea Area is substantial as it is navigated by more than thirty thousand vessels annually, with the majority of vessels calling on Mediterranean ports and engaging in regional commerce among the Mediterranean coastal States. In addition, many vessels transit the Mediterranean Sea Area in close proximity to heavily populated areas collectively containing hundreds of millions of inhabitants. Shipping traffic occurs throughout the Mediterranean Sea Area along shipping lanes presented in **Figure 2**.

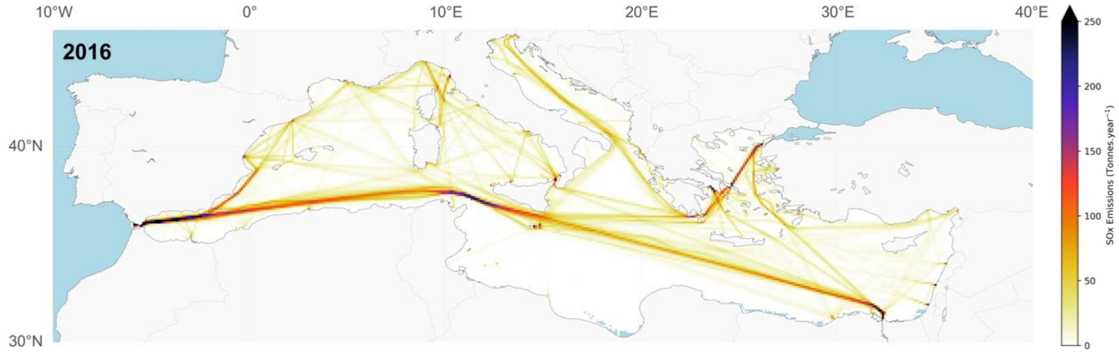

Figure 2: Shipping traffic (shown as SO_X emissions) in the Mediterranean Sea Area in 2016

1.3 Hypotheses summary and finding from further study

Table 1 presents the set of hypotheses for evaluation from further study, along with a brief summary of the findings based on economic analyses.

Table 1: Five hypotheses testing the economic impacts of the Med SO_X ECA

Hypothesis	**Null Hypothesis (H_0)**
Hypothesis 1	H_0: Shipping costs using 0.10% S m/m fuel do not produce systematic economic pressure for mode shift to alternative route
	Further study does not find evidence to reject the null Hypothesis 1, or the sub hypotheses 1a, 1b, and 1c.
Hypothesis 1a	H_0: Cargo shipping costs using 0.10% S m/m fuel do not produce systematic economic pressure for mode shift all-land alternative route
	This work does not find evidence of systemic economic pressure for shift to land-based transport modes. The changes in shipping costs associated with the proposed Med SO_X ECA will be modest, on the order of \$0.16 to \$1.31 per tonne of cargo, depending on the length of the vessel transit in the Mediterranean Sea.
Hypothesis 1b	H_0: Cargo shipping costs using 0.10% S m/m fuel do not produce systematic route diversion (i.e., re-routing of shipping to alternative ports)
	This work does not find evidence of systemic route diversion associated with the proposed Med SO_X ECA. Comparing the increased vessel transit costs with truck and train modes on a per tonne-km basis, this work does not find evidence of lower costs using land-based transport modes.
Hypothesis 1c	H_0: Passenger vessel costs using 0.10% S m/m fuel cannot produce systematic shifts of passenger transport to all-land alternative route or alternative sea route
	This work does not find evidence of systemic passenger transport shifts associated with the proposed Med SO_X ECA. Further study of waterborne passenger transit costs range between \$0.073 and \$0.302 per passenger-km, depending on the length of the route, origin and destination pairs, and the vessel configuration. The percent change in price associated with the Med SO_X ECA ranges from 0.8% to 5.0%.
Hypothesis 2	H_0: Demand for goods and services, including passenger transport, will be unchanged due to vessels using 0.10% S m/m fuels
	Further study finds evidence of changes in pricing and demand resulting from the proposed Med SO_X ECA and presents evidence that these changes will be small. Inelastic demand for goods and services is confirmed, meaning that demand changes disproportionally with, and less than, price; in other words, the percent change in demand for the good is smaller than the percent change in price. Using the maximum price increase of \$1.31 per tonne cargo associated with a full transit of the Mediterranean Sea (see hypothesis 1a), identified price changes across commodities range from 0.009% to 1.489%, with 8 of 10 commodities studied showing price changes less than 0.1%. This study does find evidence for modest changes in passenger transportation costs, on the order of EUR € 0.8 and EUR € 2.1 (\$0.94 to \$2.48) per one-way ticket, with price increases ranging from 0.8% to 5%. Resulting changes in passenger transport demand may be between 0.24% and 1.5%. However, the quantifiable estimate of change in demand may be essentially unobservable where: i) waterborne transit is the only, most viable, or most convenient option; or ii) passenger transits via waterborne routes significantly reduce the travel distance.

Hypothesis	Null Hypothesis (H_0)
Hypothesis 3	H_0: Purchasing power of citizens in remote island locations will not be changed due to vessels using 0.10% S m/m fuels
	Further study finds evidence of price changes associated with the Med SO_X ECA and presents evidence that these changes will be small. Using the maximum per tonne cargo increase of $1.31 would be on the order of 0.009% to 1.489%, with 8 of the 10 commodities studied seeing price changes of less than 0.1%. Higher value goods see lower percent changes in their prices. Food commodities studied indicate that the prices of one kilogram of common goods (salmon, bananas, coffee, tea) would all increase by less than $0.01. Similarly, the costs of building materials show price changes of less than 0.08%. Among other changes over the long run, the quantifiable estimate of change in consumer purchasing power may be essentially unobservable.
Hypothesis 4	H_0: Port competition will not be distorted by demand for 0.10% S m/m marine fuels
	Further study does not find evidence to reject the null Hypothesis 4. Cargo connectivity and port competitiveness rely on many factors more influential than fuel price, including cargo throughput efficiency, transhipment, intermodal connectivity, and tariffs, among others.
Hypothesis 5	H_0: Refinery competition will not be distorted by demand for 0.10% S m/m marine fuels
	Further study does not find evidence to reject the null Hypothesis 5. Refineries optimise to meet market demand for these products, particularly where a price signal to provide more product is clear. Production and capacity data since implementation of MARPOL Annex VI 0.50% S m/m global limits provides evidence that the refining sector has sufficient capacity to produce fuels for the Med SO_X ECA. Given the observed price differentials between 0.50% S m/m and 0.10% S m/m fuels or fuel blends, refineries are shifting supply from low-value residual by-product to a value-added product – either distillate or residual/distillate blend.

1.4 Primary findings

This study confirmed the estimated $1.7 Billion costs to implement a 0.10% S m/m fuel limit in the Mediterranean Sea Area. Updated fuel prices have not changed substantially the costs to implement a Mediterranean Sea Area SO_X Emissions Control Area (see **Section 6.1**). Benefits are estimated to be greater than $2.4 Billion only considering avoided premature deaths exceed the costs of implementing the Med SO_X ECA. Costs estimated based on observed fuel prices in 2020 are within 0.3% of the costs estimated in the 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] (Corbett & Carr, 2019), hereinafter referred to as the Technical and Feasibility Study.

Increased marine fuel costs to adopt 0.10% S m/m limits result in quantifiable cost increases; however, the percent change in this effect diminishes as the fuel cost impact is embedded in voyage costs, freight rates, and product costs:

- Fuel costs represent 30% to 60% of at-sea voyage costs for container ships (see **Section 5.1**);
- Higher fuel prices for 0.10% S m/m fuel estimated at 1.29 times prices for 0.50% S m/m fuel increase container ship daily at-sea voyage costs by 10% to 16% (see **Section 5.1**);
- Fuel costs represent on average about 0.9% to 2.1% of container freight rates on a per tonne-km basis (see **Section 5.2**);

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[2] Available at: https://www.rempec.org/en/our-work/pollution-prevention/hop-topics/med-eca.

- Freight route costs are affected less by fuel costs, in the range of 0.30% to 1.44% depending on route length and how much of the route is subject to the 0.10% S m/m fuel limit (see **Section 5.3**);
- Commodity prices are even less affected by 0.10% S m/m fuel costs, depending on the product value by weight (see **Section 5.4**); and
- Passenger route cost increases due to 0.10% S m/m fuel may range between 0.8% and 5% per passenger fare depending upon what non-fuel costs are included in the fare (see **Section 5.4**).

Analysis of seventeen diverse freight routes found no economic conditions where land-side rail or road alternative routes are favourable, including route origin-destination pairs defining intra-Mediterranean, inter-Mediterranean, and through-Mediterranean routes (see **Section 5.3**). In fact, waterborne route costs would need to reach “break-even” ratios between 1.6 and 30 times more costly to equal the land-side route cost. This finding is consistent with knowledge gathering insights that as much as 75% of regional trade is waterborne (see **Section 2.2**), and the function of the land rail and road networks as connectors with the waterborne freight network. That is, road and rail networks are complements to water transport rather than competing modes.

Freight and passenger service to remote areas and islands typically do not compete with rail and road modes, so therefore do not face mode shift potential. Transportation cost increases with 0.10% S m/m fuels are in a range where the commodity or product price changes very little, often by a fraction of a percent. At these price signals, considering the effect of price elasticity of demand these results indicate that change in consumption is less than the estimated change in price and perhaps unobservable.

Connectivity elements such as efficiency of cargo clearance, infrastructure quality, multi-shipment logistics, tracking, tariffs, or free-trade conditions, etc., affect the competitive position for ports to much greater degree than the embedded price effect on cargo costs from Med SO_X ECA fuels. Ports in the Mediterranean are heterogeneous, serving to various degrees the hierarchy of transport functions that include global ports, transhipment ports, and hinterland gateway ports. Annually, Mediterranean ports handle more than 9% of global containerised cargo throughput (cite UNCTAD), between 12% - 13% of container vessel traffic, more than 12% of liquid bulk vessel traffic, more than 12% of dry bulk vessel traffic, more than 20% of roll-on/roll-off (Ro-Ro) vessel traffic, and more than 30% of global passenger vessel traffic (by arrivals). Excluding passenger vessel traffic to describe cargo transport, dry and liquid bulk vessels jointly account of nearly two-thirds of Mediterranean port calls, about 15% of port calls are Ro-Ro vessels, and container vessels account for 23% of port calls.

Refineries invest to make more value-added products and fewer residual by-products if the expected value of the market for products justifies additional refining investment. With excess capacity, refineries can also adjust utilisation and product yield to match supply to market demands. Mediterranean coastal States that are Contracting Parties to the Barcelona Convention collectively operate more than seventy refineries, accounting for nearly 10% of global refining capacity. Refineries optimise to meet market demand for these products, particularly where a price signal to provide more product is clear. Refinery investment and upgrades, generally, have aligned to produce more middle distillate fuels in anticipation of demand for freight and marine transportation energies. Given the observed price differentials between 0.50% S m/m and 0.10% S m/m fuels or fuel blends, refineries are shifting supply from low-value residual by-product to a value-added product – either distillate or residual/distillate blend.

1.5 Organisation of report

Section 2 presents the [draft] report of knowledge gathering. **Section 3** introduces the [draft] report of further study. **Section 4** describes the preparation of data inputs for modelling socio-economic effects, including further study to obtain, evaluate, and derive necessary data. **Section 5** presents the methodological approaches that evaluate socio-economic effects on voyage cost, freight rates, potential for mode shift, and commodity/product price effects. **Section 6** presents results and findings of further study. **Section 7** provides report references. An appendix is provided in **Section 8** with ancillary information.

2 Knowledge gathering related to socio-economic effects

This section provides a summary of knowledge gathering based on a review of studies and data related to economic impacts on shipping engaged in international trade. This knowledge gathering provides decision support input for the possible designation of the Med SO_X ECA.

2.1 Summary of knowledge gathering findings

2.1.1 MARPOL Annex VI ratification status for the Mediterranean coastal States that are Contracting Parties to the Barcelona Convention

The International Maritime Organization (IMO) maintains information on the status of ratification of IMO conventions. **Table 2** describes the MARPOL Annex VI ratification status and the status of membership of the European Union for the Mediterranean coastal States that are Contracting Parties to the Barcelona Convention. **Table 2** also identifies which Mediterranean coastal States that are Contracting Parties to the Barcelona Convention have substantial remote/island areas.

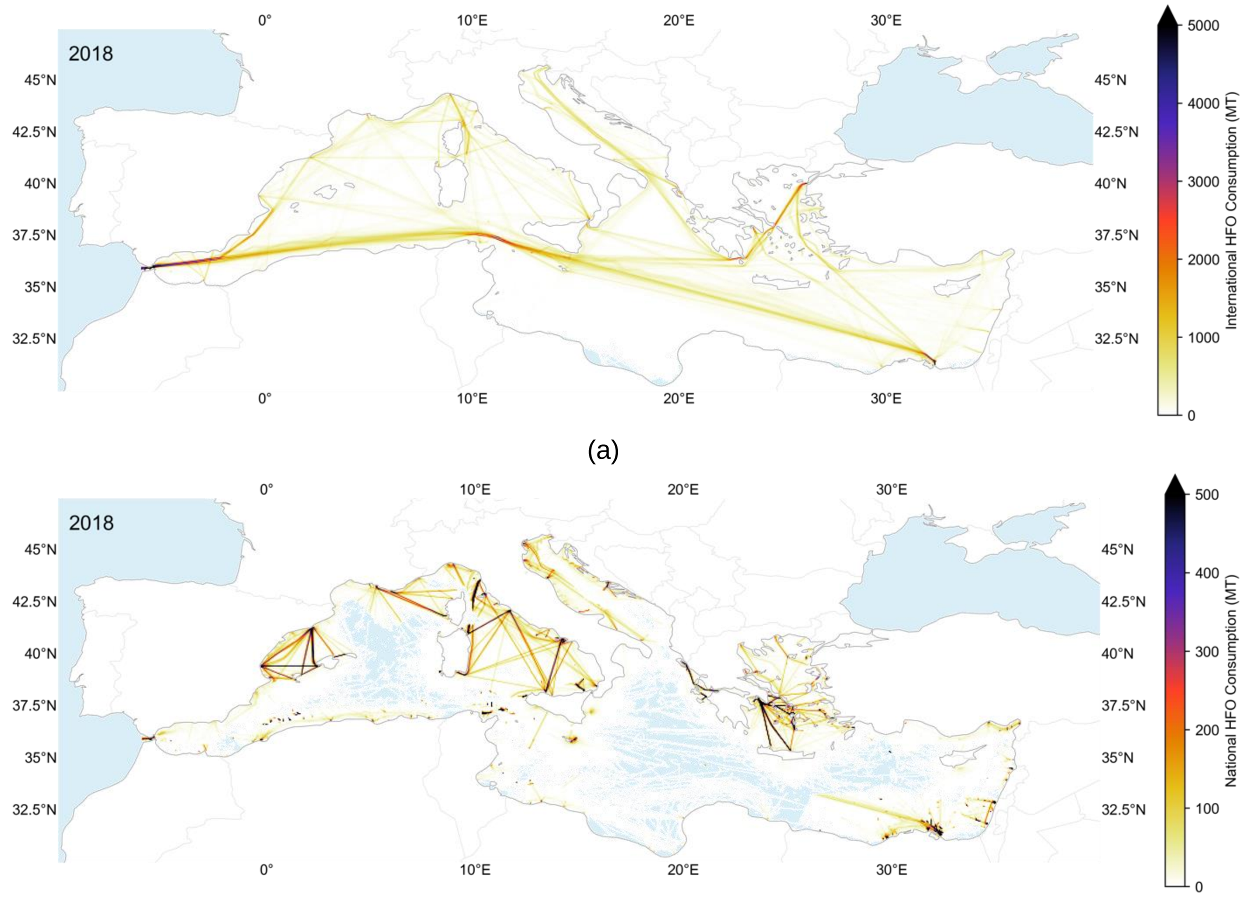
Table 2: MARPOL Annex VI ratification status, status of membership of the European Union, and identification of remote/island areas for the Mediterranean coastal States that are Contracting Parties to the Barcelona Convention

Country Name	MARPOL Annex VI ratification Status	Status of membership of the European Union	Remote/island Areas
Albania	X	Candidate country	
Algeria			
Bosnia and Herzegovina			
Croatia	X	X	X
Cyprus	X	X	X
Egypt			
France	X	X	X
Greece	X	X	X
Israel			
Italy	X	X	X
Lebanon			
Libya			
Malta	X	X	X
Monaco	X		
Montenegro	X	Candidate country	
Morocco	X		
Slovenia	X	X	
Spain	X	X	X
Syrian Arab Republic	X		
Tunisia	X		X
Turkey	X	Candidate country	X

Sources: i) IMO Status of Conventions; ii) Member States of the European Union

2.1.2 International shipping, short-sea shipping, national shipping, and island shipping descriptions

Figure 3 shows fuel consumption by international (a) and national (b) shipping. International shipping is defined, based on analysis of the AIS data signal, as when a voyage originates in one EEZ and the next stop is in a different EEZ. National shipping is classified as when a voyage originates and terminates in the same EEZ. Island shipping is not explicitly specified in the data outputs but occurs when a voyage is between the mainland and an island. As shown in **Figure 3**, most major island shipping in the Mediterranean Sea is between the mainland and islands of the same country. Short sea shipping occurs when trade moves coastwise, without crossing open ocean. Examples of short sea shipping lanes are visible in **Figure 3** along the southern and eastern coasts of Spain and the south coast of France.



(b)

Figure 3: Mediterranean Sea Area shipping fuel consumption for (a) international and (b) national shipping. Note that scale for (a) is one order of magnitude greater than scale for (b)

2.2 List of key reports reviewed during knowledge gathering phase

Following suggestions from the Technical Committee of Experts, the following reports were reviewed. They provide background context, confirming knowledge, or extend beyond the Terms of Reference focus and requirements. These are cited in the report of further study where appropriate and necessary.

2.2.1 Studies on maritime transport of goods in the Mediterranean

According to the 2010 Plan Bleu report (Vallouis, 2010), Mediterranean regional trade “is conducted mainly in maritime mode (75%), as well as via fixed connections (20%) consisting of gas pipelines. The remaining 5% are conducted via land and air routes. The Plan Bleu “*outlook relates to non-bulk transport of goods which has reported the highest growth over the past ten years. This prospective study takes into account economic growth, price of energy and* CO_2 *and the various transport policies integrating infrastructures, use of equipments, commercialisation and regulation*”.

One relevant finding is that maritime traffic will continue to be dominant in inter-regional and intra-regional transport unless substantial infrastructure changes occur. The report finds that “*Non-bulk transport offers the largest capacity and reports the highest growth*”. Major route patterns of non-bulk shipping are also described that help inform the modal analyses in this report.

Quoting in part from the report:

“*Ro-Ro routes are intra-Mediterranean and follow a North-South direction (Algeria-France, Morocco-Spain), but also a East-West direction between Greece, Italy and Turkey. Large container ships present mainly a East-West direction: they start off in Asia, head towards the ports of the north European range and undertake transhipment with smaller units in the Mediterranean.*”…

"*Container ships follow a transhipment logic in hubs that are often without a hinterland. Thus, the larger container ships are supplied and downloaded by smaller feeders which ensure links with Mediterranean ports. These hubs are located along the direct maritime route between the Suez Canal and Gibraltar, at exit of the Suez Canal, at the centre of the Mediterranean (Malta, southern Italy) and in the western zone (Tangiers, Algesiras).*"

"*Land exchanges among the Southern and Eastern Mediterranean Countries (SEMCs) remain low, due to administrative or political border crossing difficulties. … International road transport of goods is, in fact, generated by ports for distribution in major national cities"* … and *"rail transport of goods is mainly connected with ports.*"

This is consistent with our analyses which show very limited road and rail connectivity among these countries. Rail connections in those countries are concentrated are regional and interconnections are limited.

The Plan Bleu outlook presents information on transport costs by mode. This information was useful in comparing with more detailed studies reviewed, including those described below. "*Energy cost is a component of transport operational cost that varies according to the modes:*

- *Road: 25%*
- *Rail: 7.5% electricity powered (15% diesel powered)*
- *Sea: between 30 and 60%, but sensitive to speed: if speed drops from 22.5 to 18 knots, the energy cost item falls by 30% (and it increases by 50%, if the speed rises to 25 knots).*"

During the second round of review by the REMPEC Technical Committee of Experts, another report, an independent study prepared in December 2020 by the Environment and Resources Authority and E-Cubed Islands (referred to as the Malta Study) was provided and reviewed as a key report (Cordina, Vella, & Vella, 2020). This is a non-public report; nonetheless, we provide a summary of the report elements in the context of LOT 4 work, including forward-referencing to sections of the LOT 4 analyses, results, and conclusions.

The 2020 Malta Study recognizes that the "Med SO_X ECA will create strong environmental and health benefits" with net economic benefits estimated in prior REMPEC decision support documents. The Malta Study affirms that "the shipping industry was effective in adapting operations to comply with [previous] SO_X ECA requirements as well as with the new global 0.5% sulphur limit." Elements of LOT 4 and the REMPEC Technical and Feasibility Study served as inputs to the Malta Study, e.g., summed costs related to a Med SO_X ECA used to demonstrate net benefits share among Mediterranean countries, fuel costs as a share of voyage costs, etc.

The literature review in comparing ex-ante and ex-post studies in Section 7 of the Malta Study is significant with regard to LOT 4, because the Malta Study documents that ex-ante studies tend to over-estimate socio-economic impacts such as mode shift, and that no ex-post studies identified observable modal shifts from prior SO_X ECA designations or from implementation of the global 0.50% S m/m limits under IMO Annex VI. The Malta Study finds that "shipping operations of intercontinental routes is not expected to be impacted by the designation of the proposed Med SO_X ECA" (Section 7.3 of the Malta Study, consistent with LOT 4 analysis). The ex-post studies summarized by the Malta Study indicate no evidence for modal shifts in short-sea shipping, by "gain[ing] market share from longer sea routes" and that "land-based transport modes have not become more attractive." Moreover, an ex-post study for Northern Europe documented "positive economic performance after establishment of SO_X ECA", consistent with LOT 4 Sections 5.5.1 and 6.4 summarizing adaptive behaviours that improve port and shipping competitiveness. This is well-presented in Table 11, Section 7.3 of the Malta Study, and generally confirms the LOT 4 findings with respect to Hypothesis 1 and related sub-hypotheses (Section 6.2).

Consistent with the rejection of Hypothesis 2 in the LOT 4 report (Section 6.3), the Malta Study finds that “implementation of the Med SO_X ECA is expected to impact the economy in terms of an increase in shipping costs which would in turn affect the price […] of goods and services” (Section 12 of Malta Study). Identified price changes in LOT 4 range from 0.009% to 1.489% across a range of commodities; results in the Malta Study suggest household price effects of ~0.38%, which are within LOT 4 ranges despite employing differing price assumptions and alternative survey and input-output methods. For example, the Malta Study did not account for product price elasticity, which LOT 4 explicitly employed to find evidence that the purchasing power of citizens in the Mediterranean, including those in remote and island locations, will be changed and the [Hypothesis 3] null hypothesis is not supported.

2.2.2 Studies that report fundamental elements determining costs in maritime (and freight transport)

One example report by the OECD Trade and Agriculture Directorate, Trade Committee, Report TAD/TC/WP(2008)10/FINAL (Korinek, 2008), makes clear that factors unrelated to the voyage itself (and the voyage costs, including fuel) can be significant; these include the costs of loading, unloading, services including Canal services, revenue back-haul utilisation, insurance, etc.

This report also presents an example calculation evaluating the freight transport cost per unit (e.g., per container, per product unit). That example uses a freight rate of $5,000 per container filled with 10,000 product units valued at $100,000 ($10/product unit) to estimate transport costs of approximately 5% of loaded container value, adding $0.50 to the price unit product unit.

2.2.3 A set of studies related to European Commission transportation and infrastructure planning

These studies provide analyses and trends being developed in the context of the EU Sustainable and smart mobility strategy. Among these reports, the COMPETE project provided freight mobility operating costs for road, rail, and short sea modes (Maibach, Peter, & Sutter, 2006). Other work describes the multimodal (primarily rail) freight corridors that i) connect waterborne transport with hinterland markets, and/or ii) offer alternative land-side routes for mode-shift analyses (Ceuster, Herbruggen, & Logghe, 2006; European Commission, 2017; Zeebroeck, Ceuster, & Herbruggen, 2006).

2.2.4 A set of studies primarily related to long-term decarbonisation, independent of the objective to protect human health and environment with lower-sulphur marine fuels through designation of the Med SO_X ECA

Several reports offer primary insight relevant to the present knowledge gathering: Confirmed market-ready pathways including available fuels and alternative compliance technologies can achieve health and environmental benefits through adoption of 0.10% S m/m marine fuels in the Mediterranean Sea Area with lower cost impact within the time frame outlined in the road map. Very little related to the adoption of the Med SO_X ECA impedes efforts toward more sustainable environmental performance related to decarbonisation of transport, including shipping.

1. The Techno-economic assessment of zero carbon fuels (UMAS, 2020) provides a forward looking narrative of potential economic viability for advanced energy carrier fuels compared with current marine petroleum fuels. The work may be important for decarbonisation studies over the coming decades but provides no information relevant to the decision to possibly designate the Med SO_X ECA.

2. European Commission communication COM(2018) 773, subtitled “*A European long-term strategic vision for a prosperous, modern, competitive and climate neutral economy*” (European Commission, 2018), presents a high-level summary of decarbonisation goals and emerging road maps for decarbonisation across sectors. Some discussion of waterborne transportation is included. We note that this document references much higher projected growth in the maritime sector than more recent studies are reporting, e.g., 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.

3. European Commission communication COM(2020) 562, subtitled "*Investing in a climate-neutral future for the benefit of our people*" (European Commission, 2020), presents a high-level summary of elements related to decarbonisation targets. This report suggests that decarbonisation of the transport fuel mix by 2050 will also be supported by greater use of rail and other sustainable transport modes such as inland waterways and short sea shipping, in particular for freight transport. Otherwise, the report does not address shipping related to the Mediterranean Sea Area.

4. The reporting Decarbonising Maritime Transport (International Transport Forum, Kirstein, Halim, & Merk, 2018) includes a general discussion related to the shift to lower-sulphur fuels. Without direct analysis, the International Transport Forum (ITF) report suggests that global 0.50% S m/m fuels limits "*might be substantial enough to lead to changes in trade flows. Depending on price elasticities – most of which are not exactly well-known – one could assume that these cost increases lead to shortening of certain supply chains, considering that the increase in maritime costs makes nearby sourcing more attractive. We suppose this will be particularly the case for goods where transport costs make up a high share of the import value and where alternatives from nearby countries or the local market are available*.".

   As evidence, an ITF 2016 report (International Transport Forum, Merk, & Petrosyan, 2016) claimed that under 0.50% S m/m fuel limits (MARPOL Annex VI global cap), container shipping costs "*could increase between 20-85%*". In particular, the ITF 2016 claimed that "*increase costs for container ship operators on the Asia-North Europe route … could be substantial in 2020, with increases possibly up by 85%*". These were upper bound estimates assuming that a switch to 0.50% S m/m fuels would more than double fuel prices, part of a worst-case price effect modelled to bound the sensitivity ranges for implementation of MARPOL Annex VI 2020 limits. As demonstrated in the Technical and Feasibility Study and this report, no such price effect was observed following the shift to 0.50% S m/m fuel limits, and current price differentials for 0.10% S m/m fuels do not support these "*a priori*" analytical ranges.

3 Further study of socio-economic effects

This section presents a summary of further study related to the additional economic impact evaluation 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 MARPOL Annex VI. This further study provides decision support input for the possible designation of the Med SO_X ECA.

3.1 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 this study, is illustrated in **Figure 4**. The proposed area of application follows the International Hydrographic Organization (IHO) definition of the Mediterranean Sea[3] 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 4: Contracting Parties to the Barcelona Convention (in grey) and proposed area of the Med SO_X ECA (in dark blue)

3.2 Main questions to be informed by further economic analysis

This study examines the economic impacts of the proposed Med SO_X ECA by testing five different hypotheses (**Table 3**). Each numbered hypothesis may be considered as "null hypothesis", that is, the claim to be proven. Where findings support the claim, a conclusion in this report would support the null; where findings do not support the claim, we will not make finding in support of the impact or benefit described by the null and may reject the null hypothesis.

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[3] https://iho.int/uploads/user/pubs/standards/s-23/S-23_Ed3_1953_EN.pdf.

Table 3: Five hypotheses testing the economic impacts of the Med SO_X ECA

Hypothesis	**Null Hypothesis (H_0)**
Hypothesis 1	H_0: Shipping costs using 0.10% S m/m fuel do not produce systematic economic pressure for mode shift to alternative route
Hypothesis 1a	H_0: Cargo shipping costs using 0.10% S m/m fuel do not produce systematic economic pressure for mode shift all-land alternative route
Hypothesis 1b	H_0: Cargo shipping costs using 0.10% S m/m fuel do not produce systematic route diversion (i.e., re-routing of shipping to alternative ports)
Hypothesis 1c	H_0: Passenger vessel costs using 0.10% S m/m fuel cannot produce systematic shifts of passenger transport to all-land alternative route or alternative sea route
Hypothesis 2	H_0: Demand for goods and services, including passenger transport, will be unchanged due to vessels using 0.10% S m/m fuels
Hypothesis 3	H_0: Purchasing power of citizens in remote island locations will not be changed due to vessels using 0.10% S m/m fuels
Hypothesis 4	H_0: Port competition will not be distorted by demand for 0.10% S m/m marine fuels
Hypothesis 5	H_0: Refinery competition will not be distorted by demand for 0.10% S m/m marine fuels

Hypothesis 1 evaluates whether the change in shipping costs associated with using 0.10% S m/m fuels produces systematic economic pressure for mode shift. Hypothesis 1 includes three sub-hypotheses Hypotheses 1a, 1b, 1c. Hypothesis 1a tests the potential for a shift to an all-land alternative route, Hypothesis 1b tests for the potential for re-routing of shipping to alternative ports, and Hypothesis 1c tests the potential for a shift in passenger transport to an all-land alternative. This hypothesis is tested using route scenarios which compare selected origin-destination (O-D) routes, termed *Default Scenario Routes*, with routes representing mode shift, termed *All-Land Alternative Routes*. The Default Scenario Route is comprised of: (1) the *Base Case* which models the use of LSFO with 0.50% S m/m; and (2) the *Med SO_X ECA Case* which models the use of MGO at 0.10% S m/m. In each scenario, the cost of transporting the commodity via the *Med SO_X ECA Case* of the Default Scenario Route is compared with the cost of transporting the same commodity via the *All-Land Alternative Route*.

Hypothesis 2 evaluates whether demand for goods and services, including passenger transport will be unchanged due to vessels using 0.10% S m/m fuels. Using a similar approach to that used in Hypothesis 1, changes in commodity prices along identified origin and destination routes are estimated and evaluated in the context of available data on price elasticity of demand for various commodities, including passenger transport.

Hypothesis 3 evaluates whether the purchasing power of citizens in remote island locations will be unchanged due to vessels using 0.10% S m/m fuels. This hypothesis is tested by evaluating a range of commodity prices to assess the embedded costs of freight transport (in general), with links to the methods in Hypotheses 1 and 2 that evaluate how fuel price effects voyage costs that may or may not adjust demand for goods and services. In other words, impact on purchasing power is assessed to be related to potential for increased product process combined with potential change in demand.

Hypothesis 4 evaluates the role of voyage fuel costs in a larger and more complex set of factors relating to port competitiveness. This further study identified in major economic studies, by public bodies and peer-reviewed economic scholars, the key drivers for port choice and market share among peer-competitor ports. This further study included literature specific to the Mediterranean Sea Area and to port competition economics more generally. Using the work quantifying potential cost impacts on voyages, freight rates, and goods/services, this further study places the role of vessel costs during voyages in that context to assess the relative potential for increased fuel prices to motivate changes – including positive effects such as improved efficiency and transportation infrastructure investment.

Hypothesis 5 evaluates how the refining sector may respond to demand shift by ships operating in the Mediterranean Sea Area from 0.50% S m/m marine fuel to 0.10% S m/m ship fuel. Refineries may respond to this regional demand shift with less distortion than may be observed from the much larger shift in refineries supply requirements associated with implementation of MARPOL Annex VI global requirements (0.50% S m/m) from relatively unconstrained production requirements for marine fuels (3.50% S m/m). The recent successful shift to global 0.50% S m/m fuels offers direct insight into how refining remained competitive overall. Refining experience and outlook studies by refining experts provide insight into how petroleum supply will adapt to more substantial changes in demand. This further study reviews how refining is adapting to increased demand for middle distillate fuels in non-marine transport, changing demand in the non-transport sectors, and longer-term shifts to renewable and low-carbon energy carriers.

4 Socio-economic effects data inputs

This section describes the processes by which data inputs were obtained, evaluated from available data and reports, or derived for analysis of potential for 0.10% S m/m fuels to impact socio-economic conditions. This section meets further analysis scope elements, at least in part, through the evaluation of fuel price statistics, and **Section 4.1.5** presents fuel price inputs fundamental to socio-economic analyses of costs, rates, price signals relevant for mode choice, and product price effects described in **Section 5**.

4.1 Fuel Prices

This section discusses the available history of fuel prices in the Mediterranean Sea Area, and also in a global context. This section focuses on prices of heavy fuel oil (HFO) with a sulphur content of up to 3.50%, low sulphur fuel oil (LSFO) with a sulphur content of 0.50% that is compliant with IMO 2020 MARPOL VI regulations, and fuels with a sulphur content of 0.10% that is compliant with MARPOL VI ECA regulations, referred to as very low sulphur fuel oil (VLSFO) or marine gasoil (MGO). Costs of production and transport are embedded in sale prices that are used in these analyses. Fuel prices here reflect reported MGO prices, and thus we use MGO as the terminology to describe Med SO_X ECA compliant fuel prices. We also include data on price differentials and comparison with global oil barrel prices.

4.1.1 Low Sulphur Fuel Oil (0.50% S m/m)

The price histories described below are for both the Europe, Middle East, and Africa (EMEA) area average as well as the World average. Prices are based on indexes provided by Bunker Index[4]. **Figure 5** shows the time series of LSFO prices for the EMEA region and Worldwide average. The two data series track one another closely, with global LSFO prices $46/MT greater than EMEA prices on average. Though the time series are abbreviated, due to the relatively recent availability of LSFO in global markets, EMEA LSFO fuel prices varied greatly, ranging from a minimum of $197/MT to a maximum of $666/MT. The median LSFO price for the EMEA region since November 2011 is $344/MT.

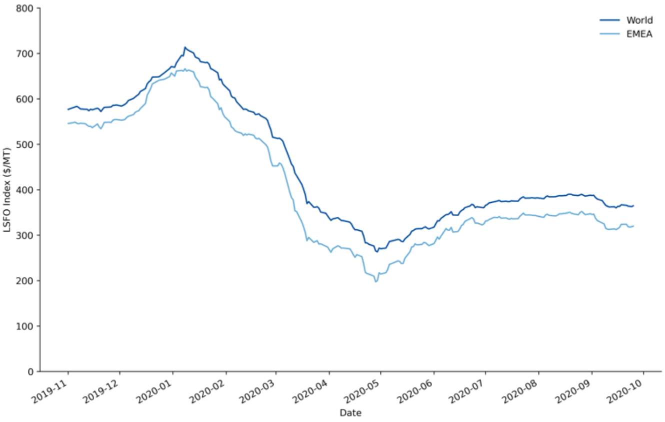

Figure 5: World and EMEA LSFO price indexes

4.1.2 Marine Gasoil (0.10% S m/m)

Figure 6 shows the time series of MGO prices for the EMEA region and Worldwide average. As with LSFO prices, world average MGO prices are typically greater than EMEA MGO prices. The average price differential between world and EMEA MGO prices is $50/MT, which is closely aligned with the world and EMEA differential for LSFO prices. MGO fuel prices have been volatile since 2016, ranging from $297/MT to $777/MT, with a median price of $443/MT, and a range of 2.6x from the low to the high values.

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[4] https://bunkerindex.com.

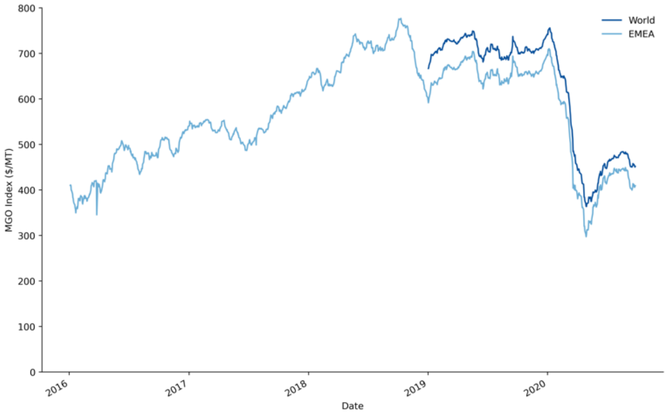

Figure 6: World and EMEA MGO price indexes

Prior to the IMO 2020 0.50% S m/m fuel rules going into effect, HFO fuel prices were similarly volatile. From 2008 to December 2019, HFO prices ranged from $152/MT to $742/MT, a range of 4.9x from the lowest price to the highest price.

4.1.3 Price differentials

While total costs are useful to understand total price impacts, fuel price differentials are important for evaluating the additional costs of the Med SO_X ECA compared to 0.50% S m/m fuels, i.e. the delta in price between 0.50% S m/m and 0.10% S m/m fuels. As shown in **Figure 7**, pricing data on LSFO is available from November 2019. EMEA and World price differentials have been closely aligned since January 2020.

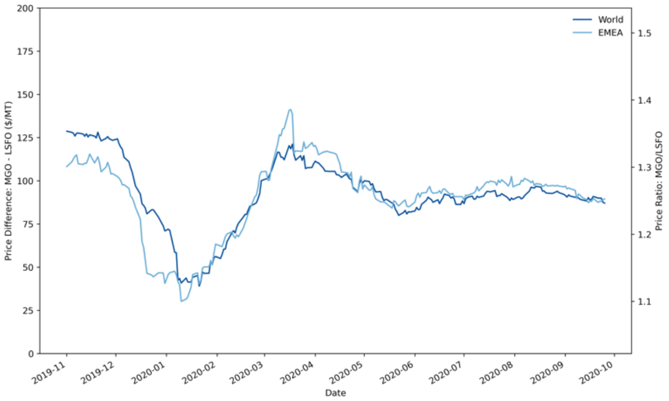

Figure 7: Price difference between MGO and LSFO for EMEA and World prices

The price differential between MGO and LSFO has stabilised since June 2020 at around $95/MT in the EMEA region. Over the period of available data (November 2019 to October 2020), the median difference is also $95/MT, corresponding with the period of price stabilisation post June 2020.

The ratio of MGO price to LSFO in the EMEA region has ranged from 1.05 to 1.51, with a median value of 1.29, i.e., the price increase from LSFO to MGO is between 5% and 51%, with a central value of 29%.

4.1.4 Crude Prices

We also analysed crude barrel prices, based on available time series data from EIA[5]. We present results for two product areas, West Texas (WTI) and Brent, which together describe the range of global crude oil prices. These are shown in **Figure 8**, with WTI and Brent oil prices per barrel shown on the right axis. Note that the axes are scaled[6] such that either axis may be used for all data series depending on whether the reader is interested in fuel prices as $/MT or $/bbl.

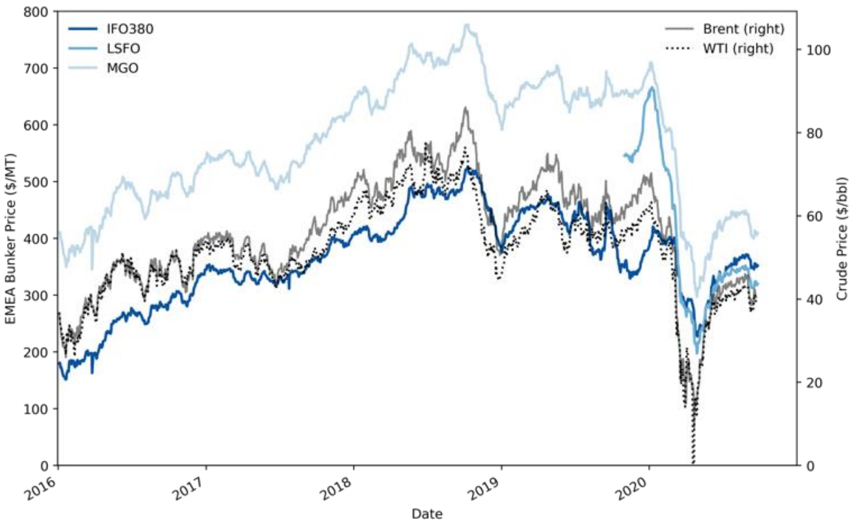

Figure 8: World prices for global oil price (Brent, WTI) and marine fuels (IFO 380, LSFO, MGO) in $/MT (left axis) and $/bbl (right axis)

The data in **Figure 8** clearly demonstrate the relationship of global oil prices to marine bunker fuels. The Pearson correlation coefficients for marine bunkers and crude oil prices are shown in **Table 4**. The correlation coefficients show a high degree of correlation between all of the species in **Table 4**, and a strong correlation between Brent and WTI fuel prices and marine bunker prices.

Table 4: Pearson correlation coefficients between marine bunker prices and crude oil prices

	IFO380	**LSFO (0.50% S m/m)**	**MGO (0.50% S m/m)**	**Brent**	**WTI**
IFO380	1.000	0.752	0.895	0.866	0.801
LSFO (0.50% S m/m)	0.752	1.000	0.990	0.932	0.875
MGO (0.10% S m/m)	0.895	0.990	1.000	0.961	0.913
Brent	0.866	0.932	0.961	1.000	0.972
WTI	0.801	0.875	0.913	0.972	1.000

While the price differential associated with the transition from 0.50% S m/m fuel to 0.10% S m/m fuels is equivalent to around $95/MT of fuel, the shipping industry has regularly seen volatility in fuel prices greater than that fuel price differential, regularly adjusting freight rates to accommodate fuel price volatility. In the first part of 2020, as may be observed in **Figure 8**, a price inversion occurred when higher-sulphur IFO380 was more expensive than lower sulphur LSFO.

4.1.5 Statistical summary of fuel prices

The central fuel prices for 0.50% S m/m fuels and 0.10% S m/m fuels used in this analysis are $344/MT and $443/MT, corresponding to the median values of the common data series available for the two fuel species (**Table 5**). These prices will be used as the central estimates for modelling voyage costing, freight rate pricing, and commodity price effects.

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[5] https://www.eia.gov/dnav/pet/pet_pri_spt_s1_d.htm.

[6] Assuming 1 bbl = 0.1364 MT.

Table 5: Statistical summary of marine fuel prices evaluated (inclusive dates)

EMEA USD per tonne	**>0.50% S m/m**		**0.50% S m/m**	**0.10% S m/m**	
	IFO 380		**LSFO**	**MGO/ULSFO**	
Date period	2008-04 to 2020-09	**2019-11 to 2020-09**	**2019-11 to 2020-09**	2016-01 to 2020-09	**2019-11 to 2020-09**
Minimum	$ 152	**$ 227**	**$ 197**	$ 297	**$ 297**
10th percentile	$ 269	**$ 277**	**$ 263**	$ 409	**$ 363**
25th percentile	$ 342	**$ 317**	**$ 308**	$ 482	**$ 403**
Median	$ 450	**$ 349**	**$ 344**	$ 579	**$ 443**
75th percentile	$ 594	**$ 370**	**$ 541**	$ 660	**$ 642**
90th percentile	$ 645	**$ 398**	**$ 608**	$ 709	**$ 666**
Maximum	$ 743	**$ 421**	**$ 666**	$ 777	**$ 710**

4.2 Fuel consumption and vessel activity data

The primary source of fuel consumption data for this project is provided by FMI's STEAM model outputs. The STEAM model is widely cited[7, 8], and was used in both final report of the Third IMO GHG Study 2014 (MEPC 67/INF.3) and the Technical and Feasibility Study. Data for this project use similar baseline data to those used for the Technical and Feasibility Study, updated to use 2018 inventory data for the baseline (compared to the 2016 baseline for the Technical and Feasibility Study).

4.2.1 Vessel Activity Data

This section provides high-level graphical representations of vessel activity, based on the count of messages received by each vessel type. We provide a breakdown of vessel activity by national and international activity. The share of fuel consumption by vessel type is illustrated in **Table 6**. **Figure 9** through **Figure 13** provide geographic representations of activity for RoPax, Passenger, Container, Cargo, and Fishing vessels. Note that scales are consistent across vessel types and international and national shipping.

Table 6: Fuel consumption percentages by vessel type

Vessel type	Share of fuel consumption
Cargo ships	15.4%
Miscellaneous	2.8%
Passenger ships	0.5%
Tankers	21.2%
Unknown	1.2%
Service ships	0.7%
Fishing vessels	0.3%
Vehicle carriers	7.6%
Cruise vessels	4.3%
RoPax vessels	11.3%
Container ships	34.8%

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[7] https://en.ilmatieteenlaitos.fi/surveying-maritime-emissions.

[8] https://en.ilmatieteenlaitos.fi/documents/30106/42382/STEAM_reference_list_22012018.pdf/a340344c-8b05-4d10-be6f-287b54c53b3e.

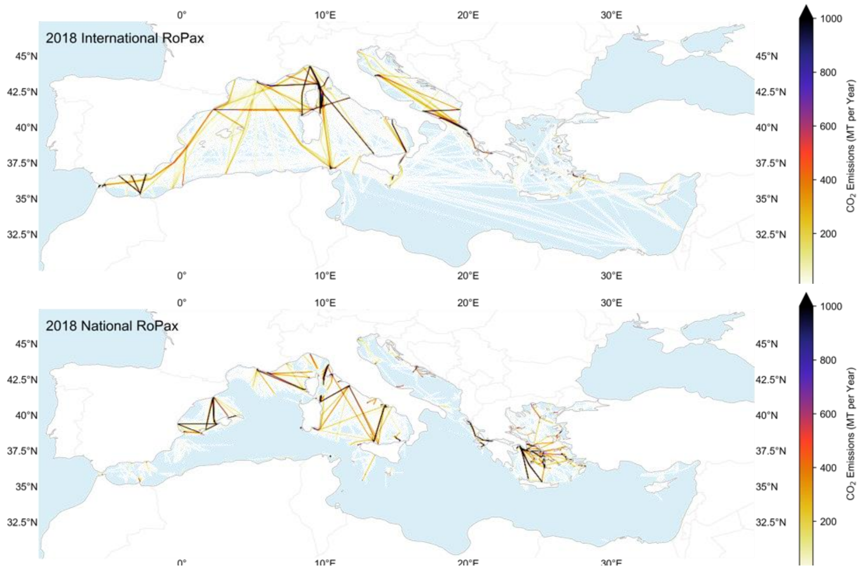


Figure 9: International and national RoPax activity

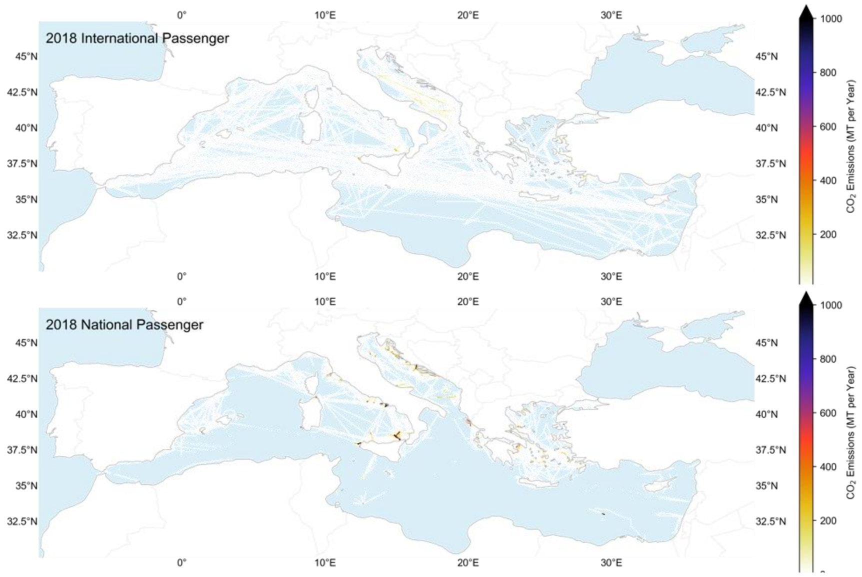


Figure 10: International and national passenger vessel activity

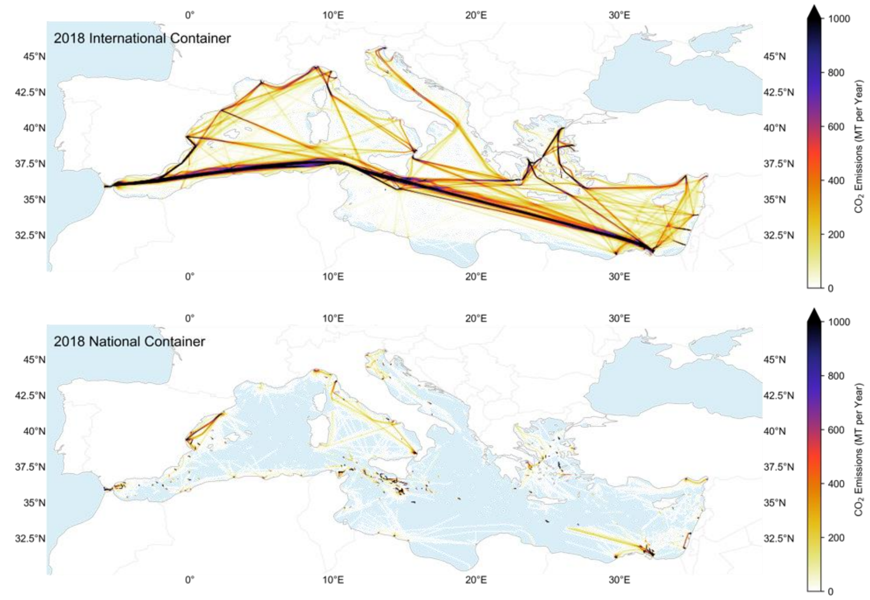


Figure 11: International and national container vessel activity

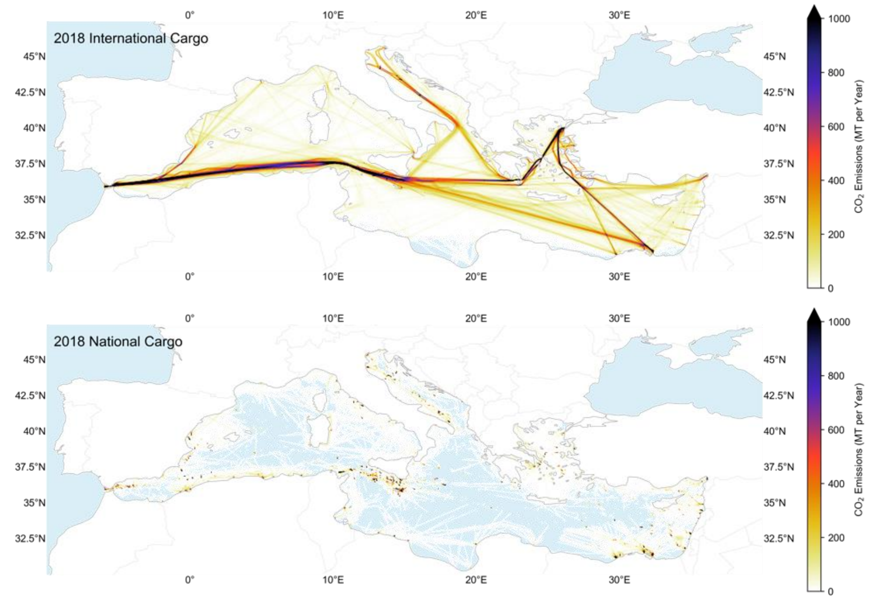


Figure 12: International and national cargo vessel activity

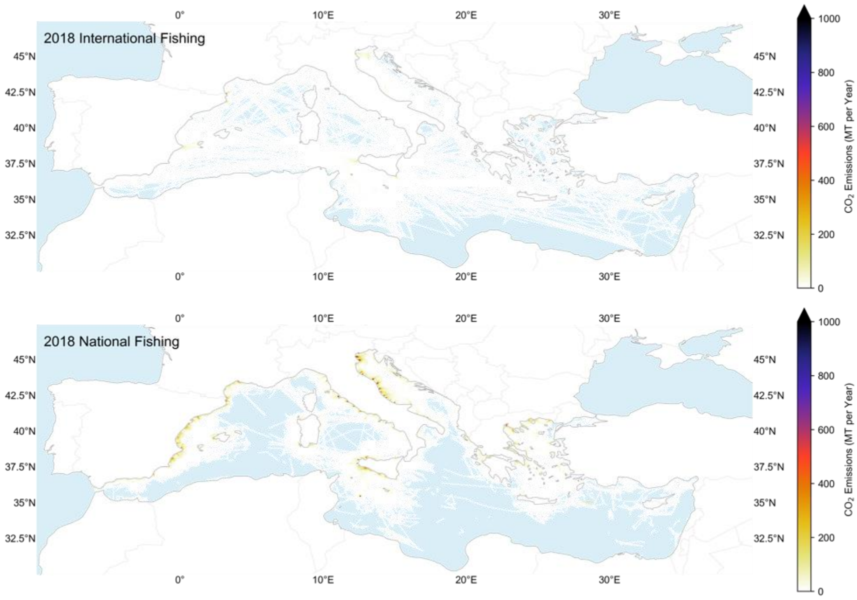


Figure 13: International and national fishing vessel activity

4.2.2 Baseline and Projected Fuel Consumption

Figure 14 shows the fuel consumption modelled by FMI's STEAM model for 2020 under the Med SO_X ECA and No Med SO_X ECA scenarios. We present 2030 estimates of fuel consumption for illustrative purposes. Data are available for the 2018 baseline, as well as projections for 2020, 2030, and 2040 (**Table 7**). As shown, consumption of HFO and LNG is largely anticipated to be unchanged between the two scenarios, with the largest change resulting in the changeover from 0.50% S m/m compliant MDO to 0.10% S m/m ECA compliant fuel.

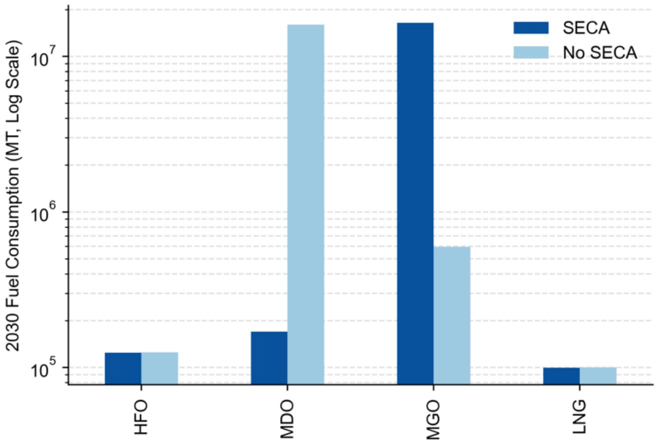


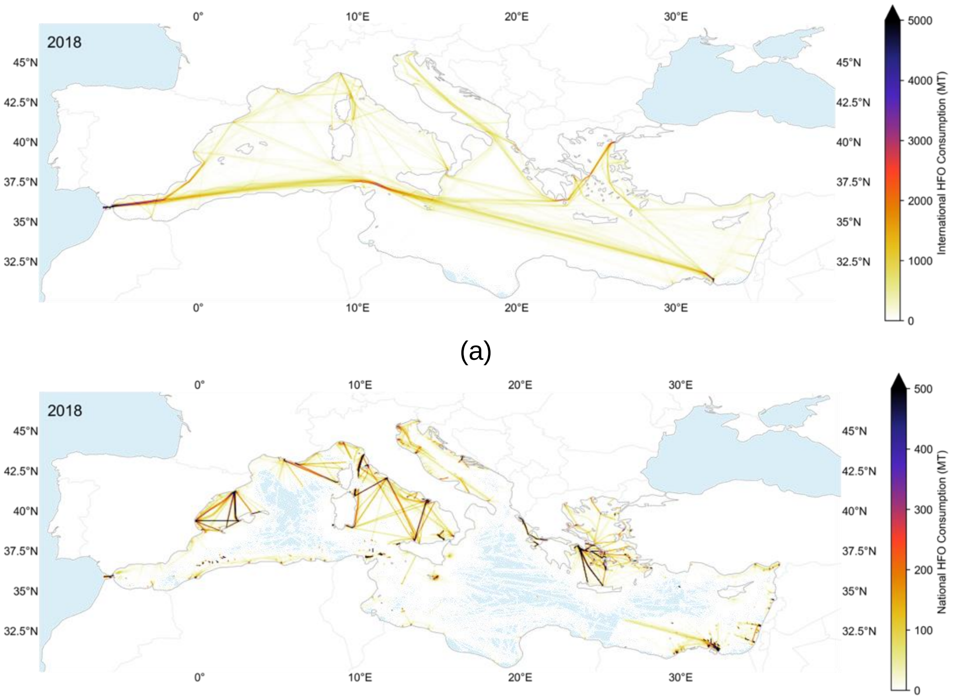
Figure 14: Fuel consumption, by fuel type, under the Med SO_X ECA and No Med SO_X ECA scenarios

Table 7: Baseline and projected fuel consumption under Med SO_X ECA and No Med SO_X ECA scenarios (MT)

	2018 Baseline	**2020 No Med SO_X ECA**	**2020 Med SO_X ECA**	**2030 No Med SO_X ECA**	**2030 Med SO_X ECA**	**2040 No Med SO_X ECA**	**2040 Med SO_X ECA**
HFO	15,559,900	138,600	138,100	124,800	124,600	113,300	113,100
MDO	3,043,100	18,039,600	193,100	16,036,300	169,700	14,266,400	154,700
MGO	1,894,700	661,900	18,457,100	595,400	16,422,600	550,000	14,618,600
LNG	236,200	147,100	147,300	99,800	99,700	90,500	90,500
Total	**20,733,900**	**18,987,200**	**18,935,600**	**16,856,300**	**16,816,600**	**15,020,200**	**14,976,900**

4.2.3 Geographic Distribution of Fuel Consumption

FMI's STEAM model generates geospatially (0.1° x 0.1°) resolved distributions of emissions, and also delineates between international voyages and national voyages. Activity is classified as national when consecutive ports of call are within the same country. Activity is classified as international when consecutive ports of call are in differing countries. **Figure 15** illustrates the traffic distribution of (a) international and (b) national shipping for the Mediterranean Sea Area, scaled according to 2018 bottom-up STEAM model estimates for HFO fuel consumption. National shipping in the Mediterranean Sea Area accounts for 25% of total fuel consumption (all fuel types, **Table 8**).



(a)

(b)

Figure 15: Mediterranean Sea Area shipping fuel consumption for (a) international and (b) national shipping

Note: scale for (a) is one order of magnitude greater than scale for (b)

Table 8: Summary of fuel consumption for international and national shipping by fuel type (ktonnes/year)

	2018 Fleet modelling results				**2020 Fleet modelling results**			
	International Shipping	**%**	**National Shipping**	**%**	**International Shipping**	**%**	**National Shipping**	**%**
HFO	13,171	85	2,389	15	117	85	21	15
MDO	1,948	64	1,095	36	11,545	64	6,494	36
MGO	194	10	1,701	90	68	10	594	90
LNG	219	93	17	7	137	93	10	7
Total	15,532	75	5,202	25	11,867	75	7,120	25

Note: 2018 estimates predate the 0.50% S m/m limits; 2020 is estimated from 2018 by FMI

4.3 Marine freight and passenger rates

This section describes the data gathering and synthesis to provide freight and passenger rates for marine transportation. Freight rates data gathering included a broad review of rates for major commodity groups (agriculture, manufacturing, raw materials) and for commodities within those groups. Data include rates for containerised, clean bulk, and dirty bulk shipping, reflecting a range of high-value and lower-value cargoes. Passenger freight rates focus on ferry transportation, typically larger RoPax vessels which account for the majority of waterborne passenger transportation.

4.3.1 Freight rate assessment

Cargo-based freight rates include voyage-based fuel costs and much more. Cargo freight rates represent the cost from origin to destination including cargo handling, storage during transit, intermediate mode transfers, and mode. Voyage fuel costs are divided by the cargo load (in net tons or in net TEUs, as appropriate). The cost model multiplies by two (2) this value to account for fuel costs associated with an empty return trip. Sensitivity analysis can adjust this empty-return adjustment between a minimum value of zero (fully loaded revenue back-haul voyage) and two (no revenue back-haul). The use of the empty return adjustment, therefore, ensures more robust analysis (e.g., estimate cost impacts that may better test the null hypotheses).

Where a scenario depicts a port-to-port cargo movement, these approaches describe the net costs based on voyage costs and transfer costs. Where a scenario depicts origin-to-destination cargo movements that require land transport modes, the model would sum costs across the water leg and the land mode leg(s) of the route. The model provides generalised rates in costs per cargo distance (cargo tonne-kilometre or t-km). These generalised rates allow for efficient application to route scenarios and facilitate sensitivity analysis.

Cargo rates are derived from the Maritime Transport Costs (MTCs) statistics database maintained by the Statistics and Data Directorate of the Organisation for Economic Cooperation and Development (OECD).

“The Maritime Transport Costs (MTC) database contains data from 1991 to the most recent available year of bilateral maritime transport costs. Transport costs are available for 43 importing countries (including EU15 countries as a custom union) from 218 countries of origin at the detailed commodity (6 digit) level of the Harmonized System 1988.”

The database is built on data for “*a combination of shipping rates actually charged data with the UN Comtrade statistics have been used to estimate actual transport costs at the product level. The shipping rates have been collected from selected sources, such as: the United Nations Conference on Trade and Development (UNCTAD), Containerisation International, Drewry Shipping Consultants, International Grains Council (IGC), and the Baltic Exchange.*”

For this work, MTCs data were extracted from the MTC database for agriculture, manufacturing, and raw material commodities for the countries and country groups listed in **Table 9**. We attempted to include all available data for countries that are Contracting Parties to the Barcelona Convention, or their representative country group.

Table 9: List of countries (and EU 15 country group) for which MTC data was queried

Countries or country group	
Albania	Malta
Algeria	Montenegro
Egypt	Slovenia
European Union (EU15)	Syrian Arab Republic
Israel	Tunisia
Lebanon	Turkey
Libya	

Using the MTCs reported by OECD.Stat, we updated reported freight rates to 2020 dollars and converted the units to costs per tonne-km so that these could be applied to route distances to yield waterborne freight transport costs. **Figure 16** presents the median freight rates (dash markers), in box-and-whisker plots representing 25th and 75th percentiles (boxes) and 10th and 90th percentiles (whiskers). **Table 10** presents the average freight rate across by selected commodities in the extracted data; **Table 11** presents a statistical summary of freight rates including upper and lower ranges. **Figure 16** illustrates that containership freight rates are typically higher than bulk ship freight rates (although there is overlap), and that clean bulk rates are higher than dirty bulk rates. This sets an expectation that commodities with higher freight rates may be less influenced than commodities associated with lower freight rates by voyage costs (or the influence of voyage fuel cost differentials).

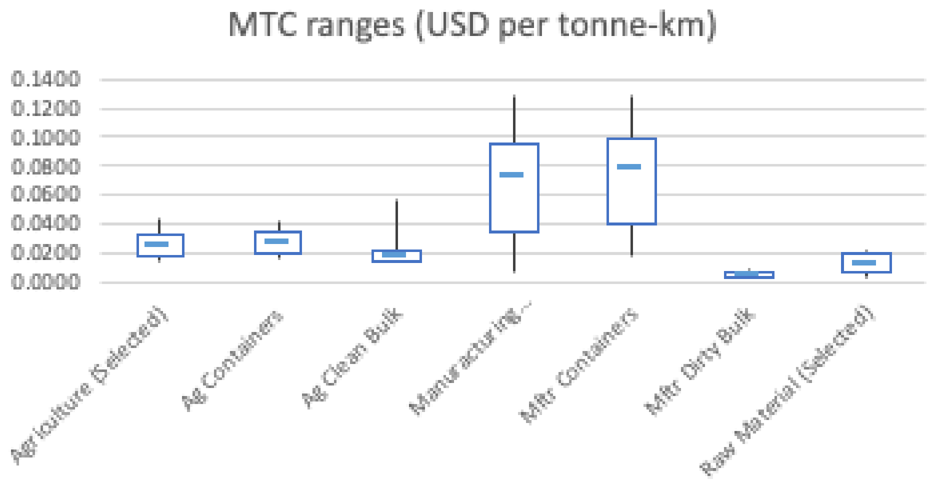


Figure 16: Plot of MTCs for commodity groups and vessel types

Table 10: Summary of MTCs by type of vessel for a selected range of commodities

	MTC by type of vessel (average USD per tonne-km)		
Commodity	**Clean bulk**	**Containers**	**Dirty bulk**
General Agriculture	**0.0397**	**0.0299**	
07: Edible vegetables and certain roots and tubers		0.0257	
08: Edible fruit, nuts, peel of citrus fruit, melons		0.0354	
09: Coffee, tea, mate, and spices		0.0278	
10: Cereals	0.0246		
12: Oil seed, oleagic fruits, grain, seed, fruit, etc, ne	0.0549		
19: Cereal, flour, starch, milk preparations and products		0.0286	
22: Beverages, spirits, and vinegar		0.0211	
General Manufacturing		**0.0794**	**0.0060**
31: Fertilisers			0.0060
47: Pulp of wood, fibrous cellulosic material, waste etc		0.0164	
48: Paper & paperboard, articles of pulp, paper, and board		0.0308	
52: Cotton		0.0486	
61: Articles of apparel, accessories, knit or crochet		0.1252	
62: Articles of apparel, accessories, not knit or crochet		0.1501	
64: Footwear, gaiters and the like, parts thereof		0.1483	
73: Articles of iron or steel		0.0354	
84: Nuclear reactors, boilers, machinery, etc		0.0522	
85: Electrical, electronic equipment		0.0616	
87: Vehicles other than railway, tramway		0.0702	
95: Toys, games, sports requisites		0.0873	
General Raw material			**0.0128**
25: Salt, sulphur, earth, stone, plaster, lime, and cement			0.0116
72: Iron and steel			0.0142

Table 11: MTCs statistics by commodity group and vessel type

USD per tonne-km	**Agriculture**			**Manufacturing**			**Raw Material**
	Combined	Containers	Clean Bulk	Combined	Containers	Dirty Bulk	
Minimum	0.0100	0.0100	0.0132	0.0000	0.0000	0.0042	0.0023
10th percentile	0.0145	0.0172	0.0139	0.0075	0.0188	0.0042	0.0040
25th percentile	0.0180	0.0199	0.0152	0.0343	0.0393	0.0043	0.0073
Median	0.0253	0.0266	0.0173	0.0740	0.0784	0.0060	0.0128
75th percentile	0.0334	0.0339	0.0213	0.0957	0.0982	0.0074	0.0199
90th percentile	0.0434	0.0421	0.0570	0.1287	0.1289	0.0086	0.0214
Maximum	0.2461	0.1044	0.2461	0.4348	0.4348	0.0096	0.0233

4.3.2 Passenger rate assessment

Passenger rates for marine transportation in this work refers to ferry service. We do not evaluate cruise vessel passenger service because those excursions compare more with hospitality and vacation travel. We recognise these typical factors in a mode choice context:

- Waterborne transport of passengers is typically a “premium mode”, priced higher than road travel by personal vehicle or transit. (Perhaps priced similarly or higher than rail.)
- Waterborne passenger transport is often a complement to rail and road travel, offering connectivity via RoPax. (Waterborne passenger transport rarely is competing with land-side modes.)
- Costs for passenger travel per unit (per passenger) is typically greater than cost per unit cargo. Therefore, the expected price effect from higher priced 0.10% S m/m fuel would necessarily be smaller than the price effects evaluated per unit cargo.

We therefore focus our analysis on remote areas and island communities where modal shift is not an option for remote or island areas, as intermodal connections do not exist, or are limited. As such, all goods and passenger movements must occur either by sea or by air.

Passenger ferries, including RoPax vessels, operate along numerous routes in the Mediterranean Sea, as shown in **Figure 17** and **Figure 18**. As shown by the intensity of emissions in the two figures, RoPax vessels are far higher emitters of CO_2, and therefore consume greater quantities of fuel.

This work analyses a set of ten ferry routes in the Mediterranean Sea, including five national and five international routes. All ferry routes analysed are between the mainland and islands. One-way prices for a single adult booking deck passage were retrieved from published fare schedules for each of the routes shown in **Table 12**. The RoPax vessels serving each route were identified and representative vessel categories in the Fourth IMO GHG Study 2020 (Faber et al., 2020) for fuel consumption were matched with ferry vessel characteristics (e.g., gross tons).

Table 12: Ferry routes, distances, prices, number of passengers

Ferry Route	Distance (NM)	One-way cost (EUR)	Cost (EUR/p-km)	Cost (USD/p-km)	Passengers
Naples - Cagliari	282	42.41 [9]	€ 0.0812	$0.0967	1845
Barcelona - Porto Torres	307	35 [10]	€ 0.0616	$0.0733	2794
Marseille - Algiers	421	198 [11]	€ 0.2539	$0.3023	2400
Piraeus - Paros	107	33 [12]	€ 0.1665	$0.1982	1715
Piraeus - Kos	203	52.5 [11]	€ 0.1396	$0.1662	2000
Piraeus - Rhodes	256	61.5 [11]	€ 0.1297	$0.1544	2000
Valetta - Pozzallo	53	68[13]	€ 0.6928	$0.8247	1120
Mykonos - Naxos	26	14.5[14]	€ 0.3011	$0.3585	2400
Famagusa - Mersin	112	42.93[15]	€ 0.2070	$0.2464	343
Barcelona - Genoa	352	49[16]	€ 0.0752	$0.0895	2230

Compared to the average cost (per p-km) for road passenger transport, reported by COMPETE to be ~0.25 Euro, the ferry routes reported in **Table 12** could be competitive at water distances equal to the road distances or up to 4 times longer than road distances. In other words, there is no evidence in the selected routes for a price-induced signal for mode shift.

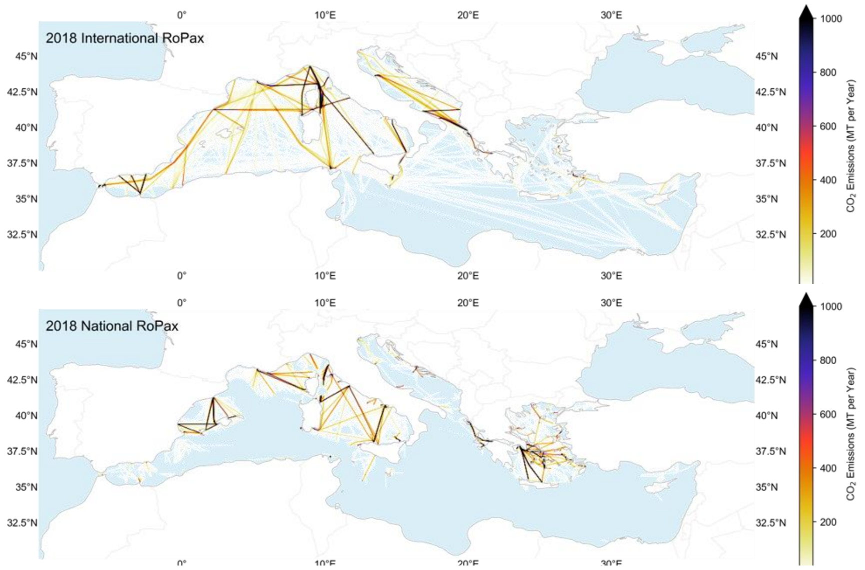


Figure 17: International and national RoPax activity

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[9] https://en.tirrenia.it/ferry-sardinia/naples-cagliari/index.html.
[10] https://www.grimaldi-lines.com/.
[11] https://www.corsicalinea.com/.
[12] https://www.ferryhopper.com/.
[13] http://www.virtuferries.com.
[14] http://www.bluestarferries.com.
[15] https://www.akgunlerbilet.com/.
[16] https://www.gnv.it.

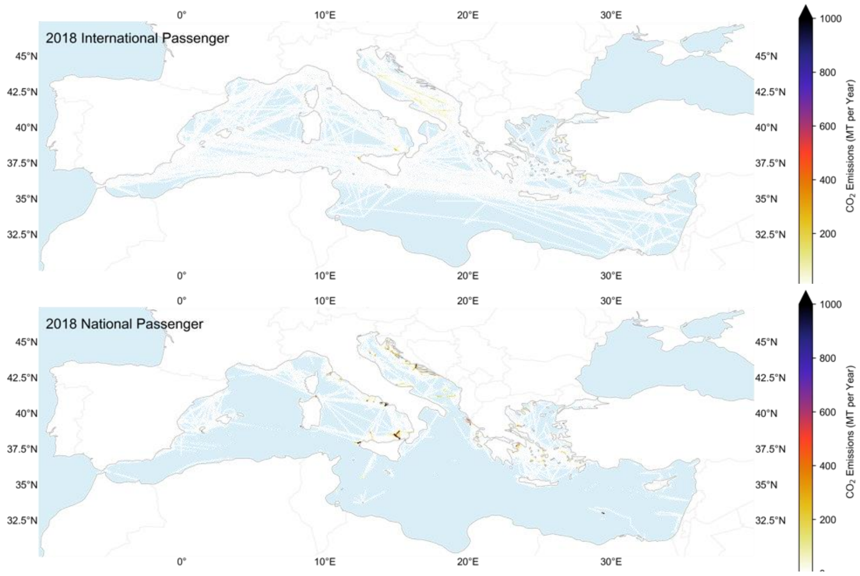

Figure 18: International and national passenger vessel activity

4.4 Land-side freight and passenger rates

Operating costs for land-side modes vary by mode, by country and by route. Using an analysis of transportation operating costs in the European Union and the United States produced by research collaboration funded by the European Commission (Maibach, Peter, et al., 2006), this analysis updated costs to 2020 equivalents in US dollars and selected costs representative of Mediterranean coastal States for which the study provided data. **Table 13** summarises average costs per passenger-km or freight ton-km for Mediterranean coastal States included in the European Commission report (Maibach, Peter, et al., 2006). **Table 14** provides a statistical summary of the range of costs that will be used in later analyses.

Table 13: Average costs per passenger-km (rail), freight ton-km (rail, LDV and HDV road)

	Rail		**Road**			
Country	**Passenger (in 2020 USD/p-km)**	**Freight (in 2020 USD/t-km)**	**Buses (in 2020 USD per p-km)**	**Coaches (in 2020 USD per p-km)**	**LDV freight (in 2020 USD/t-km)**	**HDV freight (in 2020 USD/t-km)**
Greece	$0.3410	$0.3875	$0.0930	$0.0930	$4.2160	$0.1395
Spain	$0.1860	$0.1085	$0.1395	$0.1085	$6.7115	$0.1860
France	$0.3100	$0.0930	$0.2325	$0.2325	$9.2535	$0.2635
Italy	$0.3100	$0.1550	$0.1705	$0.1395	$8.5250	$0.1860
Slovenia	$0.1240	$0.1085	$0.0465	$0.0310	$4.6190	$0.2015
EU 25 *	$0.2635	$0.1705	$0.1705	$0.1395	$7.8275	$0.2170

Table 14: Cost statistics per passenger-km (rail), freight ton-km (rail, LDV and HDV road)

	Rail		**Road**			
Statistic	**Passenger (in 2020 USD/p-km)**	**Freight (in 2020 USD/t-km)**	**Buses (in 2020 USD per p-km)**	**Coaches (in 2020 USD per p-km)**	**LDV freight (in 2020 USD/t-km)**	**HDV freight (in 2020 USD/t-km)**
Max	$0.3875	$0.4495	$0.2000	$0.1900	$12.9270	$0.2945
Median	$0.3100	$0.1550	$0.1100	$0.1000	$6.8045	$0.2015
Mean	$0.2550	$0.2015	$0.1064	$0.0968	$6.9680	$0.2071
Min	$0.0620	$0.0620	$0.0200	$0.0100	$2.4335	$0.1085

4.5 O-D Pair Distances

This section discusses the set of route distances between identified Origin and Destination (O-D) pairs. O-D pairs were selected based on a set of criteria, first evaluating the level of observed marine traffic between origin and destination based on AIS observations, and second evaluating the economic viability of a route based on published commercial schedules between origin and destination, either independently or as part of a voyage string, calling at a number of other ports along the way.

Route distances for water, rail, and road routes are shown in **Table 15**. All O-D pairs were selected as having a viable water route between the two ports, however not all instances had viable rail or road connections between the ports. in cases where a viable road or rail route was unavailable the distance is shown as not available (NA). O-D routes include short-sea routes, island country routes, intra-Med routes, and routes transiting the Med. Note that routes inside, to, through, and around the Mediterranean Sea are many and varied. Selected O-D port pairs are intended to be representative as a sample to test the hypotheses for this further study.

Table 15: Water, road, and rail distances between origin and destination pairs (km)

		Water Distance (km)				
Origin	**Destination**	**In-Med**	**Ex-Med**	**Total**	**Rail Distance (km)**	**Road Distance (km)**
Port Said	Gibraltar	3,591	0	3,591	NA	7,431
Algeciras	Fos-sur-Mer	1,367	0	1,367	1,997	1,781
Algeciras	Koper	3,126	0	3,126	3,283	3,007
Genoa	Gioia Tauro	909	0	909	1,277	1,348
Koper	Malta Freeport	1,422	0	1,422	NA	1,955
Koper	Singapore	2,471	9,325	11,795	NA	12,987
Port Said	Koper	2,471	0	2,471	NA	3,498
Lisbon	Jeddah	3,591	1,917	5,508	NA	8,602
Piraeus	Limassol	983	0	983	NA	2,633
Port Said	Beirut	432	0	432	NA	710
Shanghai	Rotterdam	3,591	15,964	19,555	15,267	10,881
Shanghai	Fos-sur-Mer	2,895	13,386	16,281	15,983	11,671
Port Said	Fos-sur-Mer	2,895	0	2,895	NA	4,413
Singapore	New York	3,591	15,177	18,768	NA	NA
Tangier	Oran	485	0	485	1,022	745
Tangier	Tunis	1,515	0	1,515	2,531	2,221
Thessaloniki	Piraeus	500	0	500	597	580
Xiamen	Beirut	432	12,323	12,755	13,966	NA

4.6 Commodity Prices

Food and commodity prices are available from UNCTAD[17] for 2019, as shown in **Table 16**. These selected commodity prices represent a range of common commodities at different economic endpoints, from raw materials, to manufacturing, building, and textile inputs, to food prices. Commodities are shown in their unit prices in USD and converted to price per metric tonne for the purposes of unit-based comparisons between commodities. Unit mass conversions are straightforward, and the mass of a 91 cm x 182 cm x 4 mm sheet of lauan plywood was assumed to be 3kg.

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[17] http://unctadstat.unctad.org/wds/TableViewer/tableView.aspx?ReportId=140865.

Table 16: Selected food, beverage, and commodity prices ($2019) from UNCTAD

Commodity	Unit	Unit Price	Price ($/MT)
Salmon, fresh, fish-farm bred, export price, Norway	($/kg)	6.94	$6,940.0
Bananas, Central and South America, FOT, US import price	($/kg)	1.14	$1,140.0
Coffee, other mild Arabicas, ex-dock EU	(¢/lb.)	125.52	$2,767.2
Tea, Kenya Mombasa/Nairobi, auction price	($/kg)	2.2	$2,200.0
Tobacco, unmanufactured, US import unit value	($/MT)	4,578.65	$4,578.7
Phosphate rock, Khouribga, 70% BPL, contract, FAS Casablanca	($/MT)	87.95	$88.0
Zinc, Prime Western, delivered, North America	(¢/lb.)	124.13	$2,736.6
Rubber, TSR 20, New York CIF	($/MT)	1,662.17	$1,662.2
Plywood, Africa & SE Asia, Lauan, 3-ply, 91cmx182cmx4mm, wholesale Tokyo*	(¢/sheet)	500.93	$1,669.8
Fine wool, 19 Micron, AWEX auction price, Australia	($/MT)	14,183.23	$14,183.2

** Assumes one 4- mm plywood sheet = 3 kg*

4.7 Price Elasticity of Demand

The price elasticity of demand (PED) measures the change in the quantity of a good demanded when the price of that good changes, i.e., it may be thought of as the ratio of the percent change in quantity demand to the percent change in the price of the good. PED is estimated based on the formula in Equation 1, where $e_{(p)}$ is the price elasticity of demand, Q is the quantity of the good demanded, and P is the price of the good.

Equation 1: Price elasticity of demand

$$e_{(p)} = \frac{dQ/Q}{dP/P}$$

Where Q is the quantity demanded and P is the price. Price elasticity of demand is typically negative, i.e. when the price of a good goes up the quantity demanded goes down, following the law of demand. Conventionally, though PED estimates are typically negative, PED coefficients are typically discussed as positive, omitting the negative sign on the coefficient. For goods that show elastic demand, the change in quantity demanded is proportional, or more than proportional, to the change in price, and the elasticity is greater than or equal to 1. For goods that show inelastic demand, the change in quantity demanded changes less than proportionally to the change in price, and the elasticity is less than 1.

The United States Department of Agriculture (USDA) provides access to a set of commodity elasticities through their “Commodity and Food Elasticities” database. These data include elasticities for 115 countries, including for 8 commodity groups in 13 countries that are Contracting Parties to the Barcelona Convention. These commodities and their elasticities are shown in **Table 17** and **Figure 19**. The elasticity data from USDA are supplemented with estimates compiled by Fally and Sayre, 2018 for additional commodities (**Table 18**). For the purposes of this analysis, the upper bound elasticity is assumed as a conservative estimate for the maximum possible effect on demand for goods and commodities based on increased costs associated with the proposed Med SO_X ECA.

Table 17: Price elasticity of demand for 8 food and beverage commodity groups in available Mediterranean coastal States that are Contracting Parties to the Barcelona Convention from USDA

	Beverage and tobacco	Bread and cereal	Dairy	Fish	Food other	Fruit and vegetable	Meat	Oil and fat
count	13.000	13.000	13.000	13.000	13.000	13.000	13.000	13.000
mean	0.594	0.259	0.493	0.512	0.456	0.366	0.457	0.281
std	0.171	0.091	0.126	0.133	0.113	0.094	0.114	0.090
min	0.337	0.129	0.294	0.303	0.274	0.217	0.275	0.150
25%	0.469	0.187	0.407	0.420	0.379	0.300	0.380	0.213
50%	0.660	0.294	0.529	0.552	0.485	0.393	0.487	0.320
75%	0.726	0.332	0.599	0.623	0.552	0.445	0.554	0.354
max	0.831	0.385	0.641	0.671	0.591	0.476	0.593	0.401

Table 18: Price elasticity of demand for selected consumable and durable commodities (Fally and Sayre, 2018)

Commodity	Price Elasticity of Demand
Bananas	0.566 to 0.738
Cobalt	0.029 to 0.5
Coffee	0.07 to 0.54
Cotton	0.684
Manganese	0.1
Nickel	0.038

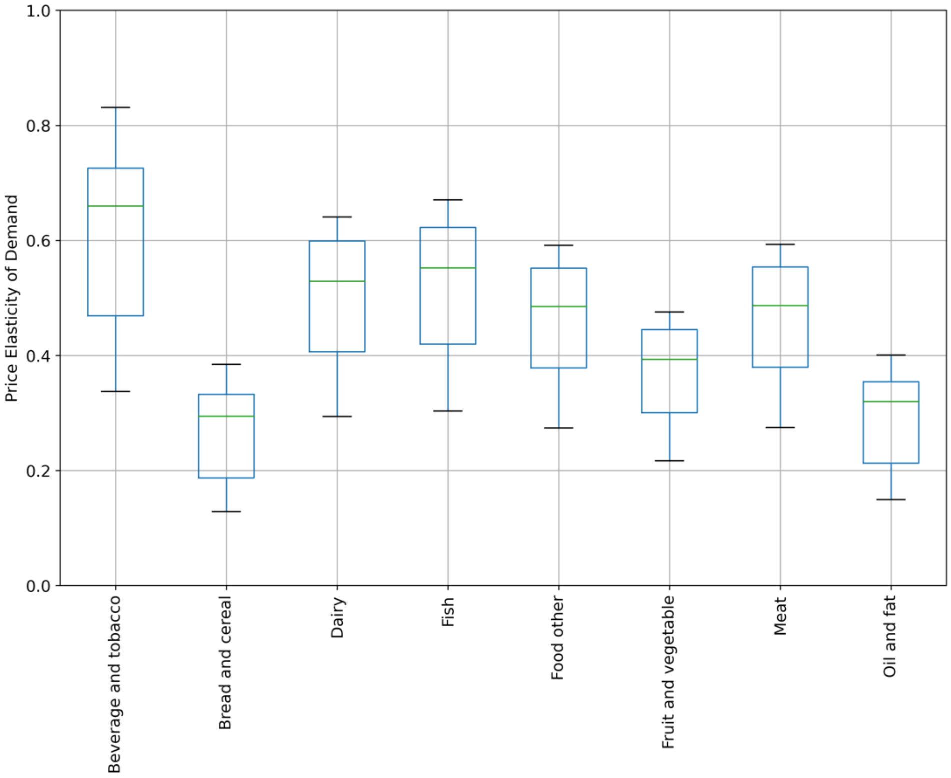

Figure 19: Price elasticity of demand for 8 commodity groups in available Mediterranean coastal States that are Contracting Parties to the Barcelona Convention

5 Socio-economic effects modelling

This section describes the methodological approach for describing fuel consumption and changes in fuel costs, identifying major shipping lanes and corridors, and evaluating mode shift potential and economic costs. affect marine freight rates, provide economic signal related to potential mode shift. This section provides necessary further analysis of scope elements, using data inputs from **Section 4**.

Methods in this analysis are grounded in the following economic principles:

i) cost changes may be reflected in the rates that suppliers present to demanders, i.e., supplier costs are passed on to the buyers embedded within market prices; and
ii) demand may be affected where the price signal changes along with demand elasticity for transport service and/or for the delivered product.

There are three stages of analysis available to evaluate socio-economic impact of price changes resulting from adoption of Med SO_X ECA fuels complying with 0.10% S m/m limits. This section describes each of these three stages. First, the relative effect of fuel price is evaluated in terms of voyage costs, which engages the EERA cost model (**Section 5.1**). The second stage considers how freight rates, which generally are inclusive of services and transport in addition to waterborne voyage costs, may be impacted by changes in voyage costs. To do this, we assemble published data on freight rates and evaluate how voyage costs are reflected in freight rates (**Section 5.2**). Third, freight rates embedded in the purchase prices of a commodity or product need to be evaluated for potential direct change in product prices and potential for indirect effects on consumption demand (**Section 5.4**).

5.1 Voyage cost evaluation

EERA applied its cost model for vessel and alternative mode costs under changing fuel cost scenarios (Winebrake et al., 2010).[18] Evaluating changing fuel costs for marine transport enables comparison with cost statistics for land-based transportation modes including truck and rail transportation.

Fuel consumption and fuel price data are used in the cost model to inform cost-based freight rates. Marine fuels can account for 30-50% of voyage costs depending on vessel capital financing costs. Marine fuels have also shown a large amount of volatility in recent years, largely tied to volatility in crude oil prices. For road freight, fuel accounts for around 20-25% of truck trip costs,[19] and for about 40-45% of rail costs.[20] In addition, freight rates based on transportation costs would include per-cargo based allocation of transfer costs related to loading/unloading (cargo handling) and storage; demand-premium freight rates would be higher than cost-based freight rates. Also, freight rates vary by commodity based on cargo densities, utilisation of payload space, perishability, etc. Importantly, including more cost elements reduces the fuel-price effects. Fuel prices reported in **Section 4.1.5** are applied in a *Base Case* (using 0.50% S m/m fuel prices) and the *Med* SO_X *ECA Case* (using 0.10% S m/m fuel prices). This incremental fuel cost is then added to the estimated voyage costs to estimate new voyage cost under Med SO_X ECA conditions.

We can illustrate the fuel price effect on typical voyage daily rates with an example. Using a fuel price ratio of 1.29 (representing a 29% increase in observed price ratio between 0.10% S m/m and 0.50% S m/m fuels during the latter months of 2020), typical fuel costs represent about 25% to 56% of daily voyage costs for containerships and less for bulk ships (**Table 19**). Sensitivity analysis of how this varies with reference fuel price and price ratio is presented in **Table 20**.

We observe that the voyage costs per tonne-km estimated by the EERA cost model are in good agreement with other work, such as the COMPETE Report (Maibach, Martin, & Sutter, 2006), Table 6, which reports short-sea costs per tonne-km. Sensitivity analysis on the cost impact is presented in **Table 20**, where the base fuel price is varied from $150 to$700 per tonne fuel (left column), and the Med SO_X ECA fuel price ratio between 0.10%S m/m-to-0.50% S m/m is varied from equal to double the price of base fuel.

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[18] https://www.epa.gov/regulations-emissions-vehicles-and-engines/study-impacts-compliance-eca-fuel-sulfur-limits-us. https://www.epa.gov/regulations-emissions-vehicles-and-engines/designation-north-american-emission-control-area-marine#Great-lakes.

[19] https://ec.europa.eu/jrc/sites/jrcsh/files/jrc114409.pdf.

[20] https://ec.europa.eu/ten/transport/studies/doc/compete/compete_report_en.pdf and related documents https://ec.europa.eu/transport/themes/infrastructure/studies/ten_t_en.

Table 19: Estimated daily voyage fuel cost and increase cost using 1.29 ECA fuel price ratio

Vessel	Fuel Price	Container (2800 TEU)	Container (4800 TEU)	Container (10,000 TEU)	Bulk (30,000 DWT)
Base Voyage Cost USD per tonne-km		$ 0.0022	$ 0.0021	$ 0.0012	$ 0.00079
Fuel Cost as percent of Daily Voyage Cost	Base case (Median 2020 price)	37%	56%	53%	25%
	Med SO_x ECA case **1.29x** Base	43%	62%	59%	30%
Increased Voyage Cost USD per tonne-km		$ 0.0025	$ 0.0026	$ 0.0014	$ 0.00084
Percent Change in Daily Voyage Cost with Med SO_x ECA fuel		**10.6%**	**16.2%**	**15.2%**	**7.1%**

Table 20: Relationship between voyage cost increase (table values in percent), fuel base price (column), and ECA fuel price ratio (row) using the 10,000 TEU containership example from Table 19

Price Ratio **Base Price**	1	1.2	**1.29**	1.4	1.6	1.8	2
$150	0.0%	6.5%	9.4%	13.1%	19.6%	26.1%	32.7%
$200	0.0%	7.9%	11.3%	15.7%	23.6%	31.4%	39.3%
$250	0.0%	8.9%	12.9%	17.9%	26.8%	35.8%	44.7%
$300	0.0%	9.8%	14.2%	19.7%	29.5%	39.4%	49.2%
$344	0.0%	10.5%	**15.2%**	21.1%	31.6%	42.1%	52.7%
$350	0.0%	10.6%	15.3%	21.2%	31.8%	42.5%	53.1%
$400	0.0%	11.3%	16.2%	22.6%	33.8%	45.1%	56.4%
$450	0.0%	11.9%	17.1%	23.7%	35.6%	47.4%	59.3%
$500	0.0%	12.4%	17.8%	24.7%	37.1%	49.4%	61.8%
$550	0.0%	12.8%	18.4%	25.6%	38.4%	51.2%	64.0%
$600	0.0%	13.2%	19.0%	26.4%	39.6%	52.8%	66.0%
$650	0.0%	13.6%	19.5%	27.1%	40.7%	54.2%	67.8%
$700	0.0%	13.9%	20.0%	27.7%	41.6%	55.5%	69.4%

5.2 Marine freight rate evaluation

Here we estimate the impact on the freight rate from higher fuel pricing. **Table 21** presents the percent increase in MTC corresponding with the increased voyage cost added to the freight rate delineated by vessel type and commodity group.
Table *22* presents the percent increase in MTC corresponding with the increased voyage cost added to commodity-specific freight rates.

Note in **Table 21** that the median of price increase effects ranges between 0.3% and 1.45% across all commodities, and that relative price impact is greater for lower freight rates (e.g., 10th and 25th percentiles). Moreover, the effect for specific commodities can vary more widely within the range of prices observed in the commodity group, as illustrated in
Table *22*.

Table 21: Percent increase in MTCs from higher fuel costs by commodity group and vessel type

USD per tonne-km	**Agriculture**			**Manufacturing**			**Raw Material**
	Combined	Containers	Clean Bulk	Combined	Containers	Dirty Bulk	
10th percentile	2.5%	2.1%	0.4%	4.9%	1.9%	1.3%	1.4%
25th percentile	2.0%	1.8%	0.4%	1.1%	0.9%	1.3%	0.8%
Median	1.4%	1.4%	0.3%	0.5%	0.5%	0.9%	0.4%
75th percentile	1.1%	1.1%	0.3%	0.4%	0.4%	0.8%	0.3%
90th percentile	0.8%	0.9%	0.1%	0.3%	0.3%	0.6%	0.3%

Table 22: Fuel cost impact on MTCs by type of vessel for a selected range of commodities

	MTC by type of vessel (average USD per tonne-km)		
Commodity	**Clean bulk**	**Containers**	**Dirty bulk**
General Agriculture	0.1%	0.9%	
07: Edible vegetables and certain roots and tubers		1.0%	
08: Edible fruit, nuts, peel of citrus fruit, melons		0.7%	
09: Coffee, tea, mate, and spices		0.9%	
10: Cereals	0.2%		
12: Oil seed, oleagic fruits, grain, seed, fruit, etc, ne	0.1%		
19: Cereal, flour, starch, milk preparations and products		0.9%	
22: Beverages, spirits, and vinegar		1.2%	
General Manufacturing		0.3%	0.9%
31: Fertilisers			0.9%
47: Pulp of wood, fibrous cellulosic material, waste etc		1.6%	
48: Paper & paperboard, articles of pulp, paper, and board		0.8%	
52: Cotton		0.5%	
61: Articles of apparel, accessories, knit or crochet		0.2%	
62: Articles of apparel, accessories, not knit or crochet		0.2%	
64: Footwear, gaiters and the like, parts thereof		0.2%	
73: Articles of iron or steel		0.7%	
84: Nuclear reactors, boilers, machinery, etc		0.5%	
85: Electrical, electronic equipment		0.4%	
87: Vehicles other than railway, tramway		0.4%	
95: Toys, games, sports requisites		0.3%	
General Raw material			0.4%
25: Salt, sulphur, earth, stone, plaster, lime, and cement			0.5%
72: Iron and steel			0.4%

5.3 Route cost evaluation for mode shift, diversion, or remote/island service

Marine route costs were evaluated with potential land-side alternative modes and routes to evaluate the potential for a price signal to divert goods and passengers to other modes, diverted routes or interrupted service to remote locations and islands due to adoption of 0.10% S m/m fuel. This is evaluated separately for a set of cargo routes and a set of passenger ferry routes to inform Hypothesis 1 and as input to subsequent hypotheses.

5.3.1 Potential for freight mode shift

This analysis does not find significant evidence of pressure to mode shift with estimated voyage costs associated with the proposed Med SO_X ECA. As shown in **Table 10** and **Table 11**, MTCs are an order of magnitude lower than land-based costs, by rail or by truck. Ships benefit from significant economies of scale, efficiently moving tens of thousands of containers and tonnes of cargo along waterborne trade routes. With the proposed Med SO_X ECA, estimated changes in MTCs range from 0.3% to 1.4% per tonne-km cargo.

The cost changes described in (**Table 23**) show central estimates for the estimated cost change across a set of routes using 0.10%S m/m fuel. These routes cover a range of distances, chosen to be representative of the set of routes in the Mediterranean, including coastwise movements, mainland – island movements, and transits. The estimated cost changes are primarily a function of changes in fuel price and voyage distance.

The maximum total cost change estimated, for the full transit of the Mediterranean, from entrance to the Suez Canal at Port Said to the Straits of Gibraltar, is $1.31 per tonne cargo (**Table 23**). For shorter route segments within the Mediterranean, the estimated change in costs is correspondingly lower, as changes in cost scale with changes in vessel transit distance in the proposed Med SO_X ECA. Considering the vessel costs associated with the proposed Med SO_X ECA, which are embedded in the freight rate, compared to the least cost feasible land-side mode, all routes studied show that the water route remains the least-cost option compared to the lowest cost all-land alternative route (**Table 24**).

Table 23: Maritime transport baseline freight costs between origin and destination pairs (USD/tonne cargo) and incremental cost linked to a change from 0.50% S m/m fuel to 0.10% S m/m fuel

Origin	Destination	Agriculture	Manufacturing	Raw material	Cost change with 0.10%S m/m fuel
Port Said	Gibraltar	$90.86	$265.66	$46.11	$1.31
Algeciras	Fos-sur-Mer	$34.58	$101.11	$17.55	$0.50
Algeciras	Koper	$79.10	$231.27	$40.14	$1.14
Genoa	Gioia Tauro	$23.01	$67.27	$11.68	$0.33
Koper	Malta Freeport	$35.99	$105.22	$18.26	$0.52
Koper	Singapore	$298.46	$872.61	$151.46	$0.90
Port Said	Koper	$62.51	$182.77	$31.72	$0.90
Lisbon	Jeddah	$139.37	$407.46	$70.72	$1.31
Piraeus	Limassol	$24.88	$72.75	$12.63	$0.36
Port Said	Beirut	$10.92	$31.92	$5.54	$0.16
Shanghai	Rotterdam	$494.81	$1,446.68	$251.10	$1.31
Shanghai	Fos-sur-Mer	$411.96	$1,204.44	$209.06	$1.05
Port Said	Fos-sur-Mer	$73.24	$214.14	$37.17	$1.05
Singapore	New York	$474.90	$1,388.45	$241.00	$1.31
Tangier	Oran	$12.28	$35.90	$6.23	$0.18
Tangier	Tunis	$38.33	$112.07	$19.45	$0.55
Thessaloniki	Piraeus	$12.65	$36.99	$6.42	$0.18
Xiamen	Beirut	$322.74	$943.58	$163.78	$0.16

Table 24: Proposed Med SO_X ECA freight costs between O-D pairs compared with land-side mode (USD/tonne cargo)

		Waterborne Commodities				
Origin	**Destination**	**Agriculture**	**Manufacturing**	**Raw material**	**Land-side cost**	**Alternate mode**
Port Said	Gibraltar	$92.17	$266.97	$47.42	1,151.81	Road
Algeciras	Fos-sur-Mer	$35.08	$101.61	$18.05	276.06	Road
Algeciras	Koper	$80.24	$232.41	$41.28	466.09	Road
Genoa	Gioia Tauro	$23.34	$67.60	$12.01	197.94	Rail
Koper	Singapore	$299.36	$873.51	$152.36	2,012.99	Road
Port Said	Koper	$63.41	$183.67	$32.62	542.19	Road
Lisbon	Jeddah	$140.68	$408.77	$72.03	1,333.31	Road
Port Said	Beirut	$11.08	$32.08	$5.70	110.05	Road
Shanghai	Rotterdam	$496.12	$1,447.98	$252.41	2,366.39	Rail
Shanghai	Fos-sur-Mer	$413.02	$1,205.50	$210.11	2,477.37	Rail
Port Said	Fos-sur-Mer	$74.30	$215.20	$38.22	684.02	Road
Tangier	Oran	$12.45	$36.07	$6.41	115.48	Road
Tangier	Tunis	$38.88	$112.63	$20.00	344.26	Road
Thessaloniki	Piraeus	$12.83	$37.17	$6.60	89.90	Road
Xiamen	Beirut	$322.89	$943.74	$163.94	2,164.73	Rail

Analysis of the marine freight rate increase necessary to break even with the lowest cost all-land alternative, i.e., the point at which mode shift becomes economically feasible, is presented in **Table 25**. These estimates show that waterborne freight rates would need to increase by 1.6 – 32.3x in order for the all-land alternative to become economically feasible. The ratios are generally lower for manufactured goods, typically transported using containerised modes, ranging from 1.6 to 4.3. As such, containerised transport costs would need to increase by 1.6x to 4.3x before all-land transport modes became feasible. Raw material and agriculture break even ratios are considerably higher, making the potential for mode switch from bulk vessels to all-land alternatives less feasible than for containerised goods.

Table 25: Break-even freight rate between origin and destination pairs

			Route-specific break-even freight rate ratios necessary to equal land-side mode costs		
Origin	**Destination**	**Break-even MTC rate (USD/t-km)**	**Agriculture**	**Manufacturing**	**Raw material**
Port Said	Gibraltar	0.3207	12.7	4.3	25.0
Algeciras	Fos-sur-Mer	0.2020	8.0	2.7	15.7
Algeciras	Koper	0.1491	5.9	2.0	11.6
Genoa	Gioia Tauro	0.2177	8.6	2.9	17.0
Koper	Singapore	0.1707	6.7	2.3	13.3
Port Said	Koper	0.2195	8.7	3.0	17.1
Lisbon	Jeddah	0.2421	9.6	3.3	18.9
Port Said	Beirut	0.2550	10.1	3.4	19.9
Shanghai	Rotterdam	0.1210	4.8	1.6	9.4
Shanghai	Fos-sur-Mer	0.1522	6.0	2.1	11.9
Port Said	Fos-sur-Mer	0.2363	9.3	3.2	18.4
Tangier	Oran	0.2380	9.4	3.2	18.5
Tangier	Tunis	0.2272	9.0	3.1	17.7
Thessaloniki	Piraeus	0.1798	7.1	2.4	14.0
Xiamen	Beirut	0.1697	6.7	2.3	13.2

5.3.2 Potential for passenger mode shift

As illustrated in **Table 26**, ferry water route distances could range between 1 and 4 times longer than rail passenger routes before rail would be economically preferred on a cost per passenger-kilometre basis. For road transport, the median cost (per p-km) for buses and coach passenger transport (from **Table 13**), ferry routes reported in **Table 26** could be competitive at water distances ranging from ~1/3rd to 1.5 times an alternative road distance. In other words, there is no evidence in the selected routes for a price-induced signal for mode shift.

Table 26: Relative mode-cost equivalent distance per passenger for selected ferry routes

Ferry Route Case Study	**Ferry Cost (USD/p-km)**	**Price Difference per p-km**	**Percent change in price per passenger**	**Ratio of water-to-road distance for mode shift indifference**		
				Passenger Rail	**Buses**	**Coaches**
A	$0.10	$0.0089	5.0%	3.21	1.14	1.03
B	$0.07	$0.0054	4.0%	4.23	1.50	1.36
C	$0.30	$0.0046	0.8%	1.03	0.36	0.33
D	$0.20	$0.0092	2.5%	1.56	0.55	0.50
E	$0.17	$0.0066	2.1%	1.87	0.66	0.60
F	$0.15	$0.0052	1.8%	2.01	0.71	0.65
G	$0.19	$0.0080	2.2%	1.60	0.57	0.52

5.4 Commodity and product price effects

Here we estimate the impact of the fuel price increase on the commodity cost as a chained function of the price effect of fuel on voyage cost, price effect of voyage cost on freight rate, price effect of freight rate on product price. This analysis is applied to consider the case of goods and passenger service to remote areas and island communities where no feasible land-route substitute may exist. These price effects are then evaluated in terms of potential effects on consumer demand for products, considering price elasticity of demand.

Island and remote area economies in the Mediterranean are highly dependent on maritime transport for goods and passenger movement. Land-side intermodal connections to hinterland networks are unavailable for islands and remote areas, leaving air and water modes. As such, it is a characteristic of islands and remote areas that the share of goods movements via water is larger than for connected regions as they do not have access to truck or rail connections. Goods and services in island and remote areas currently internalise costs related to the maritime economy. Where the transport contribution to the economies of other areas is shared across three surface modes (water, road, and rail), maritime transport is the only surface mode in service of the economies of islands and remote areas.

As such, many goods sold in islands and remote areas will be affected by changes in MTCs from the Med SO_X ECA. This analysis shows that Med SO_X ECA fuel price differentials, and associated changes in costs for maritime transport are expected to be small, less than 0.1% of current prices. Moreover, this study shows that economies with land transport alternatives will absorb these price effects without socioeconomic behaviour change, because price effects do not present an economic motivation for mode shift. Therefore, this work does not find evidence that socioeconomic impacts from the Med SO_X ECA will result in economy-wide distortions across mainland, island, or remote economies.

5.4.1 Fuel price impact on freight service to remote areas and island communities

Analysis of the impacts of remote areas and island communities revolves around analysis of changes in marine freight costs. Modal shift is not an option for remote or island areas, as intermodal connections do not exist, or are limited. As such, all goods movements must occur either by sea or by air. Additional costs of marine freight transportation are discussed in **Section 5.3.1**, and we do not find evidence supporting the potential for mode shift. The work in **Section 5.4** provides evidence that cargo transport serving islands and remote areas will not be disproportionally affected by the change in costs associated with the Med SO_X ECA.

An example using the commodity coffee transported by containership can demonstrate the cascade effect of embedded fuel price changes. In **Table 27** and in **Figure 20**, we follow the change of USD $99 per tonne fuel price (USD $344 for 0.50% S m/m fuel increasing to USD $443 for 0.10% S m/m fuel). The fuel price increases by about 29%, which represents a ~16% increase in the daily at-sea voyage cost (refer to **Table 19** in **Section 5.1**). Adding the increase in the voyage cost to the median freight rate (refer to **Table 21** in **Section 5.2**) increases the freight rate for transporting agriculture cargos like coffee by ~1.4%. Given that coffee by the tonne costs more than $2,700 per tonne (refer to **Table 16** in **Section 4.6**), the fuel-related price change per tonne of coffee is less than one-tenth of a percent (0.05%).

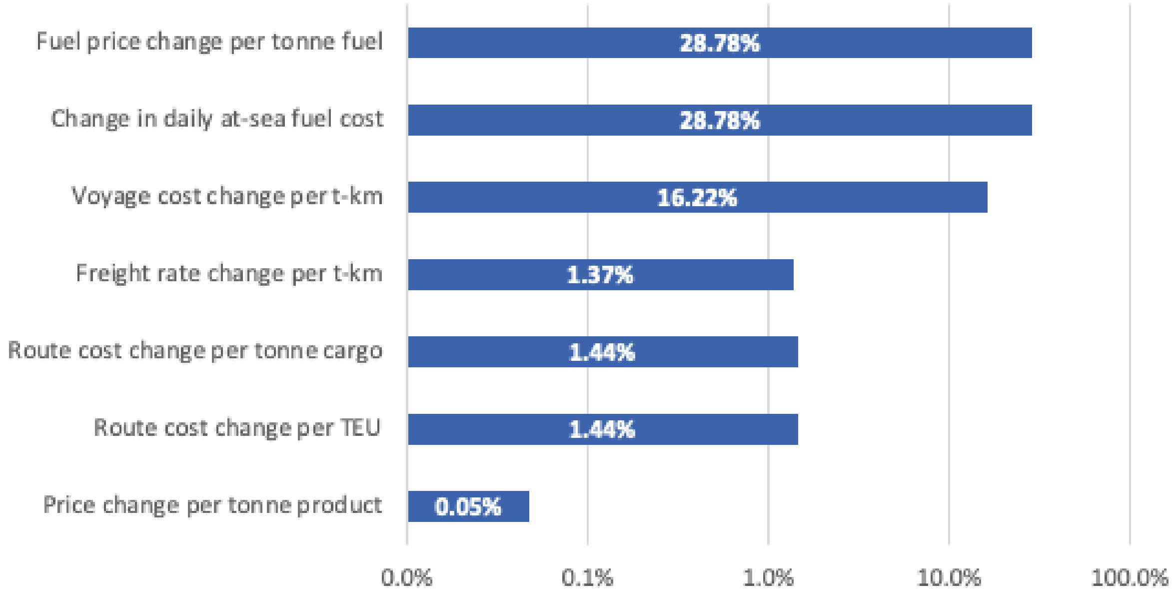

Figure 20: Example for coffee of fuel price embedded in voyage cost, freight rates, route costs, and product prices

Table 27: Example for coffee how fuel price changes voyage cost, rates, route cost, and product price

Different contexts for price effect	Price/cost change	Units	Percent of cost
Fuel price change per tonne fuel	$99	USD/tonne	28.78%
Change in daily at-sea fuel cost	$20,356	USD/day	28.78%
Voyage cost change per t-km	$0.00036	USD/t-km	16.22%
Freight rate change per t-km	$0.00036	USD/t-km	1.37%
Route cost change per tonne cargo	$1.31	USD/tonne cargo	1.44%
Route cost change per TEU	$13.08	USD/TEU	1.44%
Price change per tonne product	$1.31	USD/tonne product	0.05%

5.4.2 Fuel price impact on passenger service to remote areas and island communities

Analysis of the impacts of remote areas and island communities revolves around analysis of changes in marine passenger costs. Modal shift is not an option for remote or island areas, as intermodal connections do not exist, or are limited. As such, all passenger movements must occur either by sea or by air. Based on the data developed in **Section 4.3.2**, we evaluate whether passenger transport serving islands and remote areas may be disproportionally affected by the change in costs associated with the Med SO_X ECA.

Passenger ferries, including RoPax vessels, operate along numerous routes in the Mediterranean Sea, as shown in **Figure 17** and **Figure 18**. As shown by the intensity of emissions in the two figures, RoPax vessels are far higher emitters of CO_2, and therefore consume greater quantities of fuel. This work analyses a set of ten ferry routes in the Mediterranean Sea, including five national and five international routes. Ferry routes analysed were selected for routes between the mainland and islands, as well as inter-island routes. One-way prices for a single adult booking deck passage were retrieved from published fare schedules for each of the routes shown in **Table 28**.

These estimates show that ferry prices may rise by between €0.8 and €2.1 per passenger ticket, a ticket increase of 0.8% to 5.0% per passenger. The literature indicates that the price elasticity of demand (PED) for ferry travel is significant and inelastic, with a coefficient of 0.3 (Adler, Dehghani, & Gihring, 2010). As such, using *Equation 1*, we can estimate that demand for ferry transport may be reduced by between 0.25% on the Marseille -Algiers route, 1.49% on the Naples – Cagliari route, and 1.45% on the Famagusa – Mersin route, all else equal. Interpretation of these coefficients demonstrates the inelastic relationship of ferry transport and ticket prices, with demand changing disproportionally with price.

Table 28: Ferry routes, distances, prices, and ticket price change with shift to 0.10% S m/m fuel

Ferry Route	Distance (NM)	One-way cost (EUR)	Passengers	Ticket price change (EUR)	% Change
Naples - Cagliari	282	42.41	1845	2.1	5.0%
Barcelona - Porto Torres	307	35	2794	1.4	4.0%
Marseille - Algiers	421	198	2400	1.6	0.8%
Piraeus - Paros	107	33	1715	0.8	2.5%
Piraeus - Kos	203	52.5	2000	1.1	2.1%
Piraeus - Rhodes	256	61.5	2000	1.1	1.8%
Valetta - Pozzallo	53	68	1120	0.2	0.3%
Mykonos - Naxos	26	14.5	2400	0.02	0.1%
Famagusa - Mersin	112	42.93	343	0.6	1.5%
Barcelona - Genoa	352	49	2230	1.7	3.5%

Of the routes studied, the inter-island route between Mykonos and Naxos represents the smallest price change of the routes studied, in absolute terms, and the smallest percent change in price.

While the above table includes estimated changes in price across a set of routes between specific port pairs, the routes were selected to be representative of the possible set of routes transited by ferries in the Mediterranean. The routes in Table 28 include both mainland – island routes and inter-island routes, representative of the whole Mediterranean, and may be used for comparison of expected changes in costs across routes with similar parameters.

Coastwise ferry transits, such as the Barcelona – Genoa route, are shown in Figure 17. The economics of land-based transportation costs mean that water transit by ferry typically offers lowest cost route, for equivalent transit distances. The data in Table 13 and Table 14 show that transit by coach typically costs around $0.10 per p-km. From Table 28 the data show that ferry transit on the Barcelona – Genoa route costs $0.0895 per p-km (assuming $1 = €0.84) with estimated price changes expected to increase the route costs to $0.0926 per p-km. As shown this price differential from the Mediterranean ECA is small in terms of absolute price, and in terms of price per p-km, and is unlikely to induce mode shift to the land-based alternative route.

For islands and remote areas, air travel offers the only mode option other than water for transit of passengers to and from those regions. Air prices are typically more variable than ferry mode prices, responding dynamically to changes in demand by reallocating resources to high demand and priority routes. On the other hand, ferries typically operate transit operations, with fixed schedules and resources allowing for more stable prices.

A review of airfares[21] among the Greek Islands show flight prices from Athens to Paros, Kos and Rhodes were \$97, \$66, and \$57 respectively (€80.6, €54.9, and €47.4). Flights from Athens to Paros and Kos are higher priced than the respective ferry routes, while the Rhodes ferry is higher priced than the corresponding air fare. This example of coexistence of a relatively higher priced ferry mode and a relatively lower priced air connection shows that mode price is not the only determinant of consumer choices. It is important to consider that mode selection for passengers depends on a set of factors in addition to price, including travel time, route availability, convenience, and capacity (i.e. vehicle transport). Considering transit price, estimated changes in ferry prices as a result of the proposed Med SO_X ECA do not induce modal switchover in any of the routes studied.

5.4.3 Fuel price impact on price and demand for commodities

As discussed in **Table 29** the maximum price increase, along the route from Port Said to Gibraltar, a full transit of the Mediterranean, per ton cargo is \$1.31. Assuming this \$1.31/ton price increase is fully transferred to the end user price of the group of commodities studied, the estimated change in demand is shown in **Table 29** Applying the maximum elasticity by commodity group we show that the largest change in demand is for phosphate rock, where demand is estimated to decrease by 0.759%. Phosphate rock, a primary ingredient of fertilisers, is the lowest cost per metric tonne commodity on the list, therefore projected changes in price of transit per ton cargo have the largest effect on the price of the commodity in terms of percent change. Detailed tables of commodity price changes are presented in the Appendix, **Section 8**.

All estimated changes in demand are less than 0.8%, and less than 0.1% in all cases studied other than phosphate rock. As discussed above, all elasticities show inelastic demand for the goods and commodities studied. Given inelastic demand, and the relatively small changes in commodity prices estimated with the proposed Med SO_X ECA, the anticipated change in demand for goods and commodities is generally very small.

Table 29: Estimated change in demand for commodities based on estimated change in price and price elasticity of demand

Commodity	Price ($/MT)	New Price	% Change Price	Max Elasticity	% Change Demand
Salmon, fresh	6940.0	6941.31	0.019%	0.671	0.013%
Bananas	1140.0	1141.31	0.115%	0.738	0.085%
Coffee	2767.2	2768.55	0.047%	0.831	0.039%
Tea	2200.0	2201.31	0.060%	0.831	0.049%
Tobacco	4578.7	4579.96	0.029%	0.831	0.024%
Phosphate rock	88.0	89.26	1.489%	0.509	0.759%
Zinc	2736.6	2737.90	0.048%	0.5	0.024%
Rubber	1662.2	1663.48	0.079%	0.91	0.072%
Plywood	1669.8	1671.08	0.078%	0.91	0.071%
Fine wool	14183.2	14184.54	0.009%	0.684	0.006%

5.5 Ports and Refinery Data

This section discusses proposed data sources for ports and refineries. Port locations in the Mediterranean Sea Area are shown in **Figure 21** along with major sea routes. Port locations are derived from World Ports Index data[22]. Refinery locations and crude oil capacity are derived from Oil and Gas Journal annual worldwide refining survey data (**Figure 22**)[23]. Note that refineries may be co-located and thus may not appear as distinct entities at the scales shown in the refinery maps. Per tonne-km price changes are small and are unlikely to pose a competitive disadvantage to ports and refineries in the Mediterranean Sea Area.

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[21] One-way economy, single passenger, 21-day advance ticket, cheapest flight of day in March 2021.
[22] https://msi.nga.mil/Publications/WPI.
[23] https://www.ogj.com/ogj-survey-downloads/worldwide-refining.

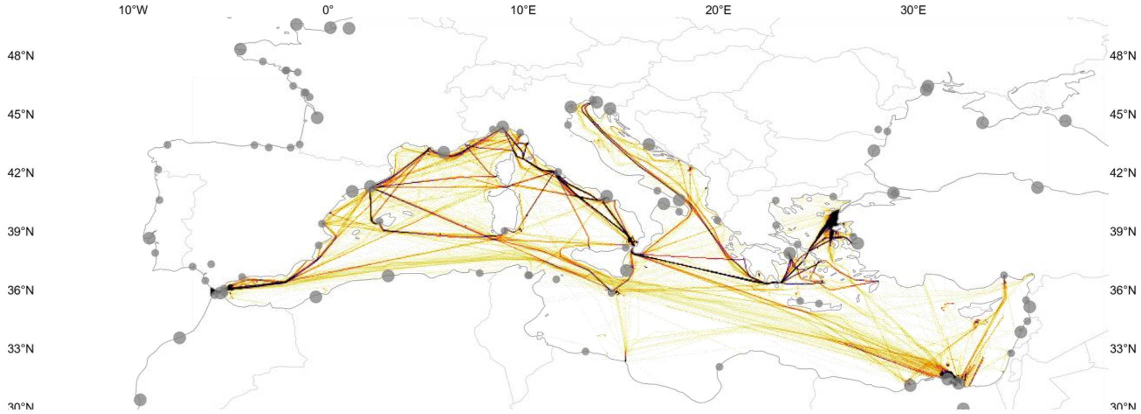


Figure 21: Port locations (for medium and large ports) and marine traffic in the Mediterranean Sea region

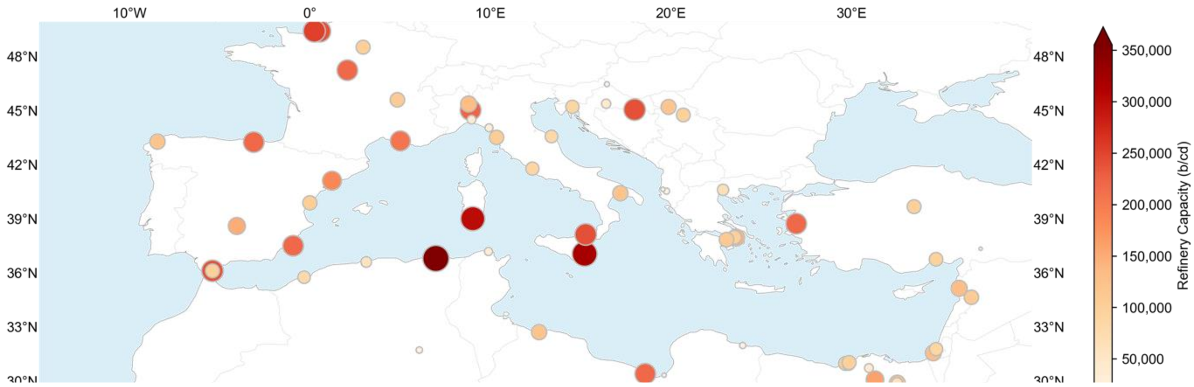


Figure 22: Refinery locations in Mediterranean Sea Area countries. Darker, larger circles show larger refining capacity (Note: some refineries are co-located, with overlapping markers)

5.5.1 Ports

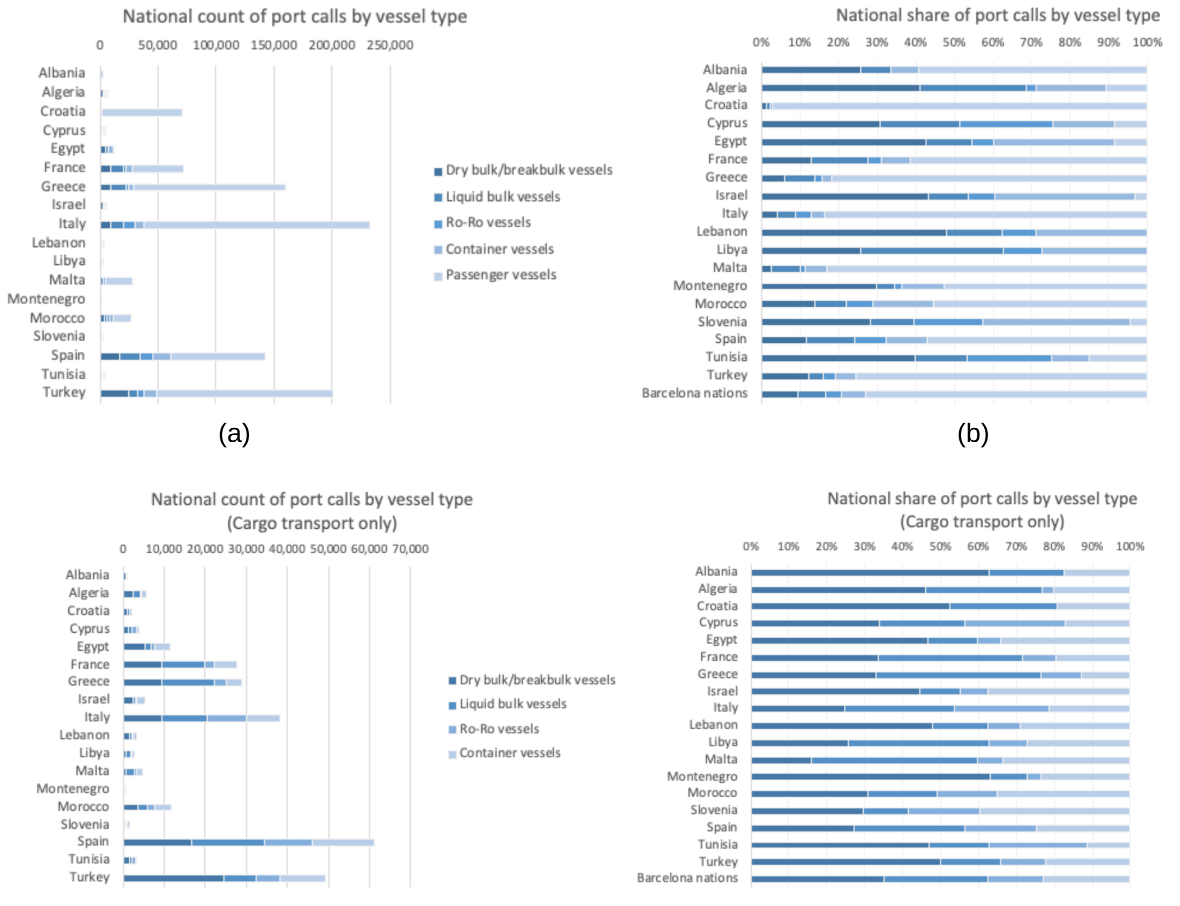
As described in **Section 5**, fuel price increases from the Med SO_X ECA affect mainly the voyage cost portion within "maritime connectivity", which results in a modest signal for port productivity and competitiveness. The Mediterranean maritime network consists of more than its sea routes. Relevant to this work on socio-economic effects, this section discusses the Mediterranean Sea Area as an extended network of maritime and hinterland routes, trading centres, and ports. Ports in the Mediterranean are heterogeneous, serving to various degrees the hierarchy of transport functions that include global ports, transhipment ports, and hinterland gateway ports. Many Mediterranean Sea routes serve a "hub-and-spoke system where local shipping links transhipment hubs to regional ports" (Arvis, Vesin, Carruthers, Ducruet, & de Langen, 2019).

Mediterranean ports offer connectivity with regional and global trade that is significant and robust. Annually, Mediterranean ports handle more than 9% of global containerised cargo throughput (cite UNCTAD), between 12% - 13% of container vessel traffic, more than 12% of liquid bulk vessel traffic, more than 12% of dry bulk vessel traffic, more than 20% of roll-on/roll-off (Ro-Ro) vessel traffic, and more than 30% of passenger vessel traffic (by arrivals). Statistics for port calls by vessel type in 2019 are summarised in **Table 30**.

Data from **Table 30** is illustrated graphically in **Figure 23**. As illustrated in **Figure 23b**, many countries and the region overall are well served by passenger vessels – in terms of number of port calls; this is expected because passenger transit and cruise services depend upon frequent and multiple daily port calls. Focusing only on cargo transport port calls, in **Figure 23c**, dry and liquid bulk vessels jointly account of nearly two-thirds of Mediterranean port calls, about 15% of port calls are Ro-Ro vessels, and container vessels account for 23% of port calls.

Cargo connectivity and port competitiveness rely on many factors more influential than voyage fuel price. **Figure 24** presents Figure ES.1 from (Arvis et al., 2019) illustrating the many points of connectivity across three dimensions where costs of transport and cargo handling contribute to the freight rate (see **Section 4.3.1**).

"*An expanded hinterland or captive cargo base turns a port into a must-call destination. A port with a favorable location in maritime networks and decent capacity and terminal productivity can attract additional transhipment. Better overseas and hinterland connectivity increases the attractiveness of a port for logistics and manufacturing activities, which also require the location to have solid fiscal performance, a strong labor market, and high scores for ease of doing business. A strong captive cargo base provides a basis for expanding the hinterland. Flows directly to the hinterland can be combined with flows generated by local logistics and manufacturing activities.*" (Arvis et al., 2019)



(a) (b)

(c) (d)

Figure 23: National count (a) and share (b) of port calls by vessel type including cargo-and-passenger vessel calls and count (c) and share (d) including cargo transport vessel calls only

Table 30: Port calls in 2019 by vessel type

Country	**Dry bulk vessels**		**Liquid bulk vessels**		**Ro-Ro vessels**		**Container vessels**		**Passenger vessels**	
	Count	**Percent**	**Count**	**Percent**	**Count**	**Percent**	**Count**	**Percent**	**Count**	**Percent**
Albania	566	0.6%	177	0.2%	0	0.0%	157	0.3%	1,306	0.2%
Algeria	2,540	2.8%	1,696	2.4%	167	0.4%	1,119	1.9%	666	0.1%
Croatia	1,067	1.2%	572	0.8%	0	0.0%	395	0.7%	68,989	9.7%
Cyprus	1,344	1.5%	901	1.3%	1,056	2.7%	684	1.1%	380	0.1%
Egypt*	5,339	5.8%	1,503	2.1%	709	1.8%	3,913	6.5%	1,070	0.1%
France*	9,350	10.2%	10,542	14.7%	2,395	6.2%	5,447	9.0%	44,280	6.2%
Greece	9,532	10.4%	12,649	17.6%	3,000	7.8%	3,781	6.3%	130,621	18.3%
Israel	2,333	2.5%	557	0.8%	380	1.0%	1,961	3.3%	172	0.0%
Italy	9,474	10.3%	10,979	15.3%	9,465	24.6%	8,171	13.5%	194,992	27.3%
Lebanon	1,598	1.7%	486	0.7%	288	0.7%	965	1.6%	0	0.0%
Libya	713	0.8%	1,024	1.4%	279	0.7%	756	1.3%	0	0.0%
Malta	758	0.8%	2,086	2.9%	333	0.9%	1,597	2.6%	23,216	3.3%
Montenegro	263	0.3%	40	0.1%	16	0.0%	98	0.2%	463	0.1%
Morocco*	3,628	4.0%	2,170	3.0%	1,870	4.9%	4,130	6.8%	14,619	2.0%
Slovenia	443	0.5%	179	0.2%	282	0.7%	598	1.0%	73	0.0%
Spain*	16,653	18.1%	17,890	24.9%	11,529	29.9%	15,137	25.1%	81,564	11.4%
Tunisia	1,618	1.8%	548	0.8%	895	2.3%	392	0.6%	615	0.1%
Turkey*	24,606	26.8%	7,840	10.9%	5,838	15.2%	11,011	18.3%	151,199	21.2%
Total	**91,825**	**100.0%**	**71,839**	**100.0%**	**38,502**	**100.0%**	**60,312**	**100.0%**	**714,225**	**100.0%**
Contracting Parties to the Barcelona Convention, as percent of world traffic	12.7%		12.1%		20.2%		12.7%		30.0%	

* These countries have ports outside the Mediterranean, and UNCTAD data reporting totals by country are not port specific; therefore, these totals include port call traffic outside the Mediterranean Sea Area.

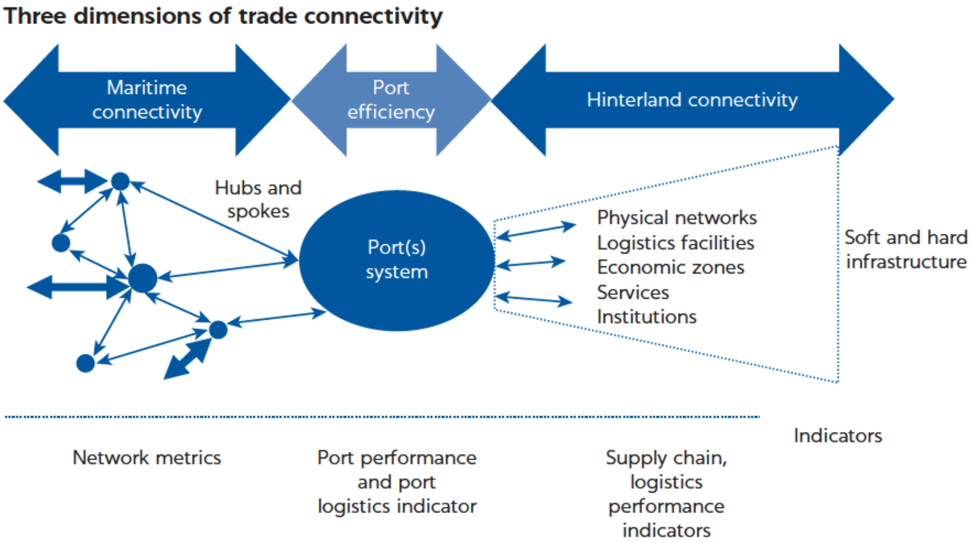


Figure 24: Dimensions of trade connectivity [reproduced from (Arvis et al., 2019), figure ES.1]: i) maritime networks; ii) port efficiency; iii) hinterland connectivity

In these three dimensions of trade connectivity (**Figure 24**), the direct effect of fuel prices on voyage costs related to the maritime networks – that is, the structure and performance of shipping before port and hinterland dimensions. Connectivity elements such as efficiency of cargo clearance, infrastructure quality, multi-shipment logistics, tracking, tariffs, or free-trade conditions, etc., affect the competitive position for ports to much greater degree than the embedded price effect on cargo costs from Med SO_X ECA fuels. Key influencing determinants of MTCs that affect competition are summarised below (UNCTAD, 2015; Wilmsmeier, 2014).

1. Ship operating costs
    a. Crewing
    b. Bunker (fuel)
    c. Registration
2. Trade facilitation
    a. Free trade zones
    b. Bureaucracy
    c. Customs, etc.
3. Shipped product
    a. Volume shipped
    b. Value
    c. Perishable/time-sensitivity
4. Ports
    a. Infrastructure
    b. Port productivity
    c. Port operations
    d. Port tariffs
5. Trade flows
    a. Imbalances
    b. Volumes of trade
    c. Complexity of trade
6. Structure of maritime industry
    a. Competition/cooperation
    b. Liner services supply
    c. Regulation
7. Position within the global shipping network
    a. Connectivity
    b. Centrality
    c. Distance

Vessel fuel costs (bunker) are one part of ship operating costs, which represent one of many determinants of MTCs (#1 in the list). Taking an alternative perspective, the Med SO_X ECA may be viewed as a regulatory signal, modifying the structure of the maritime industry (#6 in the list). From either perspective, the analysis here provides evidence that vessel compliance with the Med SO_X ECA fuel standard will not distort port competition.

Three main factors of this logic include:

1. The price signal is modest, as depicted by the price differential between 0.50% S m/m and 0.10% S m/m fuels or fuel blends (**Section 5.3** and **Section 5.4**)
2. Port competitiveness depends on many factors which are more influential than vessel voyage fuel costs (Arvis et al., 2019; UNCTAD, 2020; Wilmsmeier, 2014).
3. Ports innovate in response to regulatory or cost signals, generally improving their competitiveness in the long run (Coleman et al., 2019; Di Vaio, Varriale, & Alvino, 2018; Ke & Wang, 2017). Therefore, voyage-based price changes resulting from cleaner fuels, include collateral sustainability measures through port innovation, with the co-benefit of improving port energy efficiency, reducing port costs, and increasing port productivity. [In this regard, vessel-based energy cost changes are more likely to provide such a signal as fleet energy systems decarbonise (DNV GL, 2019; Faber et al., 2020; OPEC Organization of the Petroleum Exporting Countries, 2019; UMAS, 2020)].

5.5.2 Refineries

Energy production from petroleum requires value-added processing, i.e., refining. Economic elements that determine net profitability and competitiveness include i) feedstock; ii) capital costs/investments in refinery configuration; iii) operational costs including energy costs for the refinery itself; iv) refinery utilisation; v) market prices for the products produced; and vi) the slate or mix of products provided to the market. All of these can be adjusted for profitability and to maintain supply that meets demand.

Before 2020, the majority of marine fuels were residual and residual blends that typically cost less than the crude oil inputs. In other words, typical marine fuels were by-products; these refinery outputs have energy content of value to shipping and other large power generating systems. By-product sales do reduce residual stock and avoid storage or disposal costs, thereby indirectly contributing to net positive revenues at the refinery. This is illustrated in **Figure 25**, where the IFO380 fuel price (dark blue line) is typically lower than the WTI and Brent crude oil prices (grey and dashed lines). WTI and Brent oil prices per barrel shown on the right axis. Note that the axes are scaled[24] such that either axis may be used for all data series depending on whether the reader is interested in fuel prices as \$/MT or \$/bbl.

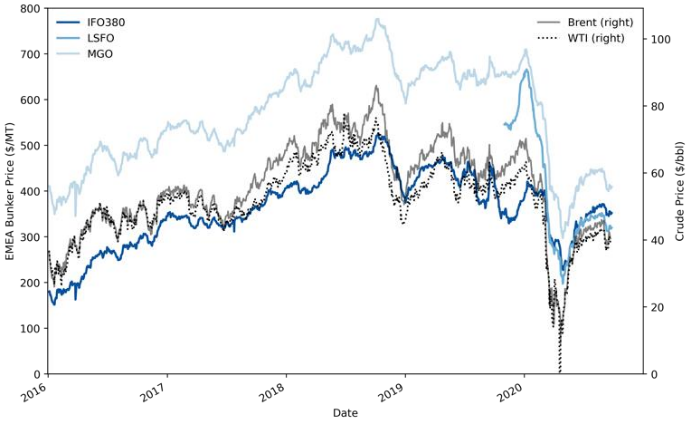


Figure 25: World prices for global oil price (Brent, WTI) and marine fuels (IFO 380, LSFO, MGO) in \$/MT (left axis) and \$/bbl (right axis)

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[24] Assuming 1 bbl = 0.1364 MT.

As can be seen in **Figure 25**, distillate fuels meeting 0.10% S m/m limits (MGO, light blue line) and value-added blends to make marine fuels meeting 0.50% S m/m limits (LSFO, medium-light blue line) typically sell at prices higher than crude oil. Refineries invest to make more value-added products and fewer residual by-products if the expected value of the market for products justifies additional refining investment. With excess capacity, refineries can also adjust utilisation and product yield to match supply to market demands.

Balancing of supply production to market demand benefits from more certainty, such as when a market signal is clear. MARPOL Annex VI announced regulatory plans for global limits of 0.50% S m/m, and SO_X ECA limits of 0.10% S m/m with sufficient clarity and advanced notice of implementation to enable planned responses by the refinery sector. As discussed in the further study related to the additional analyses of fuel supply and alternative compliance methods pursuant to the road map carried out under LOT 3, the refining sector has capacity to produce sufficient quantities of 0.10% S m/m fuel for the Med SO_X ECA, and the future outlook for refinery investment and operations reinforces confidence that the refinery sector can produce adequate supply to meet demand for marine and non-marine fuels in the Med SO_X ECA.

Mediterranean coastal States that are Contracting Parties to the Barcelona Convention collectively operate more than seventy refineries, accounting for nearly 10% of global refining capacity, according to annual report of global refining by the Oil and Gas Journal (OGJ, 2020). Total crude processing capacity for these countries is presented in **Table 31**. Refinery production of a mix of petroleum products can be adjusted within the technological limits of each refinery, and according to short-term demand that varies among products. As discussed in the further study related to the additional analyses of fuel supply and alternative compliance methods pursuant to the road map carried out under LOT 3, gas/diesel production accounts for about 36% of crude refining output, and fuel oil production account for about 12% of crude refining output.

Table 31: Crude Processing Capacity for Mediterranean coastal States that are Contracting Parties to the Barcelona Convention, reported by the Oil and Gas Journal (OGJ) as of 1 January 2020

Country	**Number of Refineries**	**Crude Processing Capacity (b/cd)**
Albania	2	30,000
Algeria	5	527,800
Bosnia and Herzegovina	1	240,000
Croatia	2	134,551 – 193,000[25]
Cyprus	0	None reported by OGJ
Egypt	8	762,713
France	7	1,262,100
Greece	4	423,000
Israel	2	220,000
Italy	13	2,122,809
Lebanon	0	None reported by OGJ
Libya	5	380,000
Malta	0	None reported by OGJ
Monaco	0	None reported by OGJ
Montenegro, grouped with Serbia per OGJ	2	214,826
Morocco	0	None reported by OGJ
Slovenia	1	13,500
Spain	9	1,427,500
Syrian Arab Republic	2	239,865
Tunisia	1	34,000
Turkey	7	863,800
Total	**72**	**91,634,128**

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[25] Range reflects estimates from the Oil and Gas Journal (lower bound) and comments from the representatives from Croatia (upper bound). The lower bound estimate is used for analysis.

This analysis provides evidence that vessel compliance with the Med SO_X ECA fuel standard will not distort refinery competition. Three main factors of this logic include:

1. Marine fuel represents one of many products across the refinery output slate. Refineries optimise to meet market demand for these products, particularly where a price signal to provide more product is clear. Given the observed price differentials between 0.50% S m/m and 0.10% S m/m fuels or fuel blends, refineries are shifting supply from low-value residual by-product to a value-added product – either distillate or residual/distillate blend.
2. Refinery investment and upgrades, generally, have aligned to produce more middle distillate fuels in anticipation of demand for freight and marine transportation energies. Refinery spare capacity is projected to exceed demand in world outlooks, suggesting product slate flexibility and utilisation adjustments will supply sufficient fuel for market demand.
3. When refineries must meet market demand for a regulated fuel quality, refiners may respond with new production of existing product or specify processes to produce compliant blends. In other words, refiners respond to the combined effect of market demand and fuel quality requirements with their most economically feasible actions. These refinery responses to fuel standards result in better efficiencies. More importantly, refiners consider multiple criteria and plan for multiple objectives to supply product for anticipated changes in demand. In this regard, refinery innovation appears to be adapting to increased demand for middle distillate fuels in non-marine transport, changing demand in the non-transport sectors, and longer-term shifts to renewable and low-carbon energy carriers (DNV GL, 2019; Faber et al., 2020; OPEC Organization of the Petroleum Exporting Countries, 2019; UMAS, 2020)].

6 Results and findings

Characterization of socio-economic impacts presented in this report describe how costs of a Med SO_X ECA may affect fuel prices, freight rates, product prices and market behaviour across diverse routes and commodities serving coastal states, remote areas, and island states. In the context of the Technical and Feasibility Study net benefits to the environment, to human health, and to the goals of countries that are Parties to the Barcelona convention, the common finding of importance to the Road Map is that the benefits to countries and the Mediterranean Sea Area exceed the costs of a Med SO_X ECA.

This section summarises results and insights from further study. Expected costs of compliance with the Med SO_X ECA confirm earlier analysis carried out in the Technical and Feasibility Study. Following a global shift to 0.50% S m/m fuel, this analysis finds no economic motivation for significant mode shift, diversion, or loss of service to remote areas/islands resulting from higher priced 0.10% S m/m fuel. Price effects passed through freight rates and embedded in the prices for goods and services are quantified and found to be minor in terms of product value and consumer purchasing power. Where increased fuel prices may be quantifiable, this work finds that ports handling cargoes and passengers can respond competitively by improving service efficiency, reducing costs, or providing value-added services. Similarly, suppliers operating refineries demonstrate the ability to meet demand and regulatory requirements for both marine and non-marine fuels.

6.1 Total costs discussion

The Technical and Feasibility Study estimated the additional costs of the Med SO_X ECA, relative to the IMO 2020 baseline, at an additional $1.766 billion per year, based on anticipated shifts in fuel usage in the Mediterranean. Using the most recently available fuel prices to update the estimate, this study finds that the estimated additional costs of the Med SO_X ECA would be $1.761 billion per year, a difference of 0.28% (**Table 32**). In other words, robust estimates were provided to REMPEC regarding compliance costs of the proposed Med SO_X ECA.

Table 32: Estimated Med SO_X ECA compliance costs comparing the Technical and Feasibility Study and this study

Technical and Feasibility Study	$ 1.766 billion
This study	$ 1.761 billion

Among Mediterranean coastal States, the Container throughput in 2019 was 73.892 Million TEUs. As a first-order example, if all of the additional costs of the Med SO_X ECA were borne by container vessels, which make up 35% of the total fuel usage in the Mediterranean, then the additional cost per TEU would be $8.30/TEU or $0.83/MT, assuming 10 MT per TEU. This example demonstrates upper bounds in costs per containerised tonne of freight, and is very consistent with the results in **Table 23**, as described in **Section 5.3.1**, which report route specific cost increases averaging $7.30/TEU or $0.73/MT.

The estimated changes in transport costs will have both short-term transitional, and long-term effects. In the short term, the price change associated with 0.10% S m/m fuels will affect the market in much the same way that the large changes in observed fuel prices have done previously, by adjusting freight rates to accommodate changing fuel prices. Those freight rates are embedded in market prices for products, as described in **Section 5.4**. The analysis shows that these costs are not large, but they are computable, and economic theory suggests a range of market responses other than decreasing demand or substitution. Long-run cost changes can be expected to signal an adjustment in the market, that might include cost cutting elsewhere in supply chain, cargo handling efficiency improvements, and innovation in transport, intermodal, and cargo handling procedures and technology.

6.2 Analysis of potential permanent and transitional changes in competitiveness of the shipping industry due to compliance with the Med SO_X ECA

Hypothesis 1	H_0: Shipping costs using 0.10% S m/m fuel do not produce systematic economic pressure for mode shift to alternative route
Hypothesis 1a	H_0: Cargo shipping costs using 0.10% S m/m fuel do not produce systematic economic pressure for mode shift all-land alternative route
Hypothesis 1b	H_0: Cargo shipping costs using 0.10% S m/m fuel do not produce systematic route diversion (i.e., re-routing of shipping to alternative ports)
Hypothesis 1c	H_0: Passenger vessel costs using 0.10% S m/m fuel cannot produce systematic shifts of passenger transport to all-land alternative route or alternative sea route

This work does not find evidence to reject the null hypothesis for Hypothesis 1, or the sub hypotheses 1a, 1b, and 1c. The changes in shipping costs associated with the proposed Med SO_X ECA will be modest, on the order of \$0.16 to \$1.31 per tonne of cargo, depending on the length of the vessel transit in the Mediterranean Sea. Comparing the increased vessel transit costs with truck and train modes on a per tonne-km basis, this work does not find evidence of lower costs using land-based transport modes. For land-based modes to be cost competitive, the freight rate of marine transport, in tonne-km, would need to increase by 1.6x to 25x. There is no evidence found in this analysis that the change in marine freight rate associated with the proposed Med SO_X ECA would come close to the break-even ratio, meaning that no evidence was found for the Med SO_X ECA fuel price to signal mode shift or route diversion.

Waterborne passenger transit costs range between \$0.073 and \$0.302 per passenger-km, depending on the length of the route, origin and destination pairs, and the vessel configuration. Estimated one-way ticket price changes are between EUR € 0.8 and EUR € 2.1, and the percent change in price ranges from 0.8% to 5.0%.

6.3 Analysis of the permanent and transitional additional costs and benefits and their distribution for economies and citizens from 2024 onwards

Hypothesis 2	H_0: Demand for goods and services, including passenger transport, will be unchanged due to vessels using 0.10% S m/m fuels

Using published estimates for the price elasticity of demand for the set of commodities studied, this study finds that changes in demand resulting from the proposed Med SO_X ECA will be small. All of the goods and commodities studied are inelastic, that is, the percent change in demand for the good is smaller than the percent change in price. As such, demand changes disproportionally with, and less than, price. Identified price changes are small, 0.009% to 1.489%, with 8 of 10 commodities studied showing price changes less than 0.1%, even when using the maximum price increase of \$1.31 per tonne cargo associated with a full transit of the Mediterranean Sea. Using the maximum elasticities from the ranges described in the literature, this study shows that changes in demand associated with the proposed Med SO_X ECA is less than 0.8% for all goods and commodities studied. For 9 of 10 commodities the change in demand is less than 0.1%. Accordingly, while we must reject the null hypothesis, as we do find evidence for changes in demand for goods and commodities associated with the proposed Med SO_X ECA, those price changes are small, and this study demonstrates that changes in demand will also be very small.

Changes in passenger transport demand may be between 0.24% and 1.5%. Importantly, many of the passenger services in the Mediterranean are to remote areas and island, where waterborne transit is the only, or most viable, option. In other instances, passenger transits via waterborne routes significantly reduce the travel distance, and time compared to land-based modes of transit. In such cases, the literature estimate of 0.3 for the price elasticity of demand for ferry transportation may in fact be too high, as the set of substitute options is limited. Regardless, this study does find evidence for modest changes in passenger transportation costs, on the order of EUR € 0.8 and EUR € 2.1 ($0.94 to $2.48) per one-way ticket, with price increases ranging from 0.8% to 5%. Therefore, the null hypothesis for Hypothesis 2 is rejected, though the price changes are modest, both in terms of absolute dollars and percent change, and the expected change in passenger demand is small.

Hypothesis 3	H_0: Purchasing power of citizens in remote island locations will not be changed due to vessels using 0.10% S m/m fuels

This analysis finds that the price changes associated with the Med SO_X ECA, using the maximum per tonne cargo increase of $1.31 would be on the order of 0.009% to 1.489%, with 8 of the 10 commodities studied seeing price changes of less than 0.1%. Intuitively, higher value goods see lower percent changes in their prices. Food commodities studied indicate that the prices of one kilogram of common goods (salmon, bananas, coffee, tea) would all increase by less than $0.01. Similarly, the costs of building materials show price changes of less than 0.08%. As such, this analysis does find evidence that the purchasing power of citizens in the Mediterranean, including those in remote and island locations, will be changed and the null hypothesis is not supported. However, though prices will likely be changed, importantly any impacts to the purchasing power of citizens in the Mediterranean will be minor.

6.3.1 Scenarios for mitigating impacts

Whether or not to attempt to mitigate price signals from the Med SO_X ECA becomes a policy question. This work finds that an offsetting subsidy from the price effects evaluated here would be small. Countries may subsidise costs for fuel or other operating costs or discount in the price or a fixed quantity of discount in price, e.g., France, Greece, Italy, and Spain subsidise at least some of their ferry services (Baird & Wilmsmeier, 2011; Jiménez, Valido, & Morán, 2018). If a government wanted to fully offset the price effect of the Med SO_X ECA, the relative subsidy increase per passenger would range from 0.8% to 5% on ferry routes (see **Table 26**), and the relative subsidy increase per tonne cargo would range between less than 0.001% and 0.11% for most products evaluated (see **Table 29**). However, as described in **Section 5.5.1**, price signals can motivate efficiency improvements and competitiveness. In this regard, some research on subsidised ferry routes suggests that “prices on subsidised routes are 53.6 or 59.3% higher than on control group routes” (Jiménez et al., 2018).

6.4 An analysis of the economic impacts on ports and refineries

Hypothesis 4	H_0: Port competition will not be distorted by demand for 0.10% S m/m marine fuels

Per tonne-km price changes associated with the proposed Med SO_X ECA are small and are unlikely to pose a competitive disadvantage to ports in the Mediterranean Sea Area. Ports are part of existing complex and highly inter-connected systems, connecting maritime and hinterland routes with trading centres. Cargo connectivity and port competitiveness rely on many factors more influential than fuel price. These factors include cargo throughput efficiency, transhipment, intermodal connectivity, and tariffs, among others, which can all exert pressure on port competitiveness in additional to vessel transit costs. Given the small, estimated changes in per tonne-km vessel transit costs associated with the Med SO_X ECA, taken in the context of additional factors affecting port competition, the null hypothesis for Hypothesis 4 cannot be rejected.

Hypothesis 5	H_0: Refinery competition will not be distorted by demand for 0.10% S m/m marine fuels

Refineries are components of highly connected systems, receiving upstream feedstocks, and producing products for downstream consumption as part of a complex supply chain. Marine transport of refinery products is but one component of the complex system. Per tonne-km price changes associated the proposed Med SO_X ECA for transport of refinery products are unlikely to pose a competitive disadvantage in the context of additional factors affecting refinery supply chains and competition. Refineries optimise to meet market demand for these products, particularly where a price signal to provide more product is clear. Given the observed price differentials between 0.50% S m/m and 0.10% S m/m fuels or fuel blends, refineries are shifting supply from low-value residual by-product to a value-added product – either distillate or residual/distillate blend. The null hypothesis for Hypothesis 5 cannot be rejected.

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8 Appendix

8.1 Commodity Price Changes

Route	Commodity	Base Price ($/MT)	Med SO_X ECA Price ($MT)	Percent Change
Port Said-Gibraltar	Salmon, fresh, fish-farm bred, export price, Norway	6940.00	6941.31	0.019
Port Said-Gibraltar	Bananas, Central and South America, FOT, US import price	1140.00	1141.31	0.115
Port Said-Gibraltar	Coffee, other mild Arabicas, ex-dock EU	2767.24	2768.55	0.047
Port Said-Gibraltar	Tea, Kenya Mombasa/Nairobi, auction price	2200.00	2201.31	0.059
Port Said-Gibraltar	Tobacco, unmanufactured, US import unit value	4578.65	4579.96	0.029
Port Said-Gibraltar	Phosphate rock, Khouribga, 70% BPL, contract, FAS Casablanca	87.95	89.26	1.488
Port Said-Gibraltar	Zinc, Prime Western, delivered, North America	2736.59	2737.90	0.048
Port Said-Gibraltar	Rubber, TSR 20, New York CIF	1662.17	1663.48	0.079
Port Said-Gibraltar	Plywood, Africa & SE Asia, Lauan, 3-ply, 91cmx182cmx4mm, wholesale Tokyo	1669.77	1671.08	0.078
Port Said-Gibraltar	Fine wool, 19 Micron, AWEX auction price, Australia	14183.23	14184.54	0.009
Algeciras-Fos-sur-Mer	Salmon, fresh, fish-farm bred, export price, Norway	6940.00	6940.50	0.007
Algeciras-Fos-sur-Mer	Bananas, Central and South America, FOT, US import price	1140.00	1140.50	0.044
Algeciras-Fos-sur-Mer	Coffee, other mild Arabicas, ex-dock EU	2767.24	2767.74	0.018
Algeciras-Fos-sur-Mer	Tea, Kenya Mombasa/Nairobi, auction price	2200.00	2200.50	0.023
Algeciras-Fos-sur-Mer	Tobacco, unmanufactured, US import unit value	4578.65	4579.15	0.011
Algeciras-Fos-sur-Mer	Phosphate rock, Khouribga, 70% BPL, contract, FAS Casablanca	87.95	88.45	0.566
Algeciras-Fos-sur-Mer	Zinc, Prime Western, delivered, North America	2736.59	2737.09	0.018
Algeciras-Fos-sur-Mer	Rubber, TSR 20, New York CIF	1662.17	1662.67	0.030
Algeciras-Fos-sur-Mer	Plywood, Africa & SE Asia, Lauan, 3-ply, 91cmx182cmx4mm, wholesale Tokyo	1669.77	1670.26	0.030
Algeciras-Fos-sur-Mer	Fine wool, 19 Micron, AWEX auction price, Australia	14183.23	14183.73	0.004
Algeciras-Koper	Salmon, fresh, fish-farm bred, export price, Norway	6940.00	6941.14	0.016
Algeciras-Koper	Bananas, Central and South America, FOT, US import price	1140.00	1141.14	0.100

Route	Commodity	Base Price ($/MT)	Med SO_X ECA Price ($MT)	Percent Change
Algeciras-Koper	Coffee, other mild Arabicas, ex-dock EU	2767.24	2768.38	0.041
Algeciras-Koper	Tea, Kenya Mombasa/Nairobi, auction price	2200.00	2201.14	0.052
Algeciras-Koper	Tobacco, unmanufactured, US import unit value	4578.65	4579.79	0.025
Algeciras-Koper	Phosphate rock, Khouribga, 70% BPL, contract, FAS Casablanca	87.95	89.09	1.295
Algeciras-Koper	Zinc, Prime Western, delivered, North America	2736.59	2737.73	0.042
Algeciras-Koper	Rubber, TSR 20, New York CIF	1662.17	1663.31	0.069
Algeciras-Koper	Plywood, Africa & SE Asia, Lauan, 3-ply, 91cmx182cmx4mm, wholesale Tokyo	1669.77	1670.91	0.068
Algeciras-Koper	Fine wool, 19 Micron, AWEX auction price, Australia	14183.23	14184.37	0.008
Genoa-Gioia Tauro	Salmon, fresh, fish-farm bred, export price, Norway	6940.00	6940.33	0.005
Genoa-Gioia Tauro	Bananas, Central and South America, FOT, US import price	1140.00	1140.33	0.029
Genoa-Gioia Tauro	Coffee, other mild Arabicas, ex-dock EU	2767.24	2767.57	0.012
Genoa-Gioia Tauro	Tea, Kenya Mombasa/Nairobi, auction price	2200.00	2200.33	0.015
Genoa-Gioia Tauro	Tobacco, unmanufactured, US import unit value	4578.65	4578.98	0.007
Genoa-Gioia Tauro	Phosphate rock, Khouribga, 70% BPL, contract, FAS Casablanca	87.95	88.28	0.377
Genoa-Gioia Tauro	Zinc, Prime Western, delivered, North America	2736.59	2736.93	0.012
Genoa-Gioia Tauro	Rubber, TSR 20, New York CIF	1662.17	1662.50	0.020
Genoa-Gioia Tauro	Plywood, Africa & SE Asia, Lauan, 3-ply, 91cmx182cmx4mm, wholesale Tokyo	1669.77	1670.10	0.020
Genoa-Gioia Tauro	Fine wool, 19 Micron, AWEX auction price, Australia	14183.23	14183.56	0.002
Koper - Malta Freeport	Salmon, fresh, fish-farm bred, export price, Norway	6940.00	6940.52	0.007
Koper - Malta Freeport	Bananas, Central and South America, FOT, US import price	1140.00	1140.52	0.045
Koper - Malta Freeport	Coffee, other mild Arabicas, ex-dock EU	2767.24	2767.76	0.019
Koper - Malta Freeport	Tea, Kenya Mombasa/Nairobi, auction price	2200.00	2200.52	0.024
Koper - Malta Freeport	Tobacco, unmanufactured, US import unit value	4578.65	4579.17	0.011
Koper - Malta Freeport	Phosphate rock, Khouribga, 70% BPL, contract, FAS Casablanca	87.95	88.47	0.589
Koper - Malta Freeport	Zinc, Prime Western, delivered, North America	2736.59	2737.11	0.019

Route	Commodity	Base Price ($/MT)	Med SO_X ECA Price ($MT)	Percent Change
Koper - Malta Freeport	Rubber, TSR 20, New York CIF	1662.17	1662.69	0.031
Koper - Malta Freeport	Plywood, Africa & SE Asia, Lauan, 3-ply, 91cmx182cmx4mm, wholesale Tokyo	1669.77	1670.28	0.031
Koper - Malta Freeport	Fine wool, 19 Micron, AWEX auction price, Australia	14183.23	14183.75	0.004
Koper - Singapore	Salmon, fresh, fish-farm bred, export price, Norway	6940.00	6940.90	0.013
Koper - Singapore	Bananas, Central and South America, FOT, US import price	1140.00	1140.90	0.079
Koper - Singapore	Coffee, other mild Arabicas, ex-dock EU	2767.24	2768.14	0.033
Koper - Singapore	Tea, Kenya Mombasa/Nairobi, auction price	2200.00	2200.90	0.041
Koper - Singapore	Tobacco, unmanufactured, US import unit value	4578.65	4579.55	0.020
Koper - Singapore	Phosphate rock, Khouribga, 70% BPL, contract, FAS Casablanca	87.95	88.85	1.024
Koper - Singapore	Zinc, Prime Western, delivered, North America	2736.59	2737.49	0.033
Koper - Singapore	Rubber, TSR 20, New York CIF	1662.17	1663.07	0.054
Koper - Singapore	Plywood, Africa & SE Asia, Lauan, 3-ply, 91cmx182cmx4mm, wholesale Tokyo	1669.77	1670.67	0.054
Koper - Singapore	Fine wool, 19 Micron, AWEX auction price, Australia	14183.23	14184.13	0.006
Port Said-Koper	Salmon, fresh, fish-farm bred, export price, Norway	6940.00	6940.90	0.013
Port Said-Koper	Bananas, Central and South America, FOT, US import price	1140.00	1140.90	0.079
Port Said-Koper	Coffee, other mild Arabicas, ex-dock EU	2767.24	2768.14	0.033
Port Said-Koper	Tea, Kenya Mombasa/Nairobi, auction price	2200.00	2200.90	0.041
Port Said-Koper	Tobacco, unmanufactured, US import unit value	4578.65	4579.55	0.020
Port Said-Koper	Phosphate rock, Khouribga, 70% BPL, contract, FAS Casablanca	87.95	88.85	1.024
Port Said-Koper	Zinc, Prime Western, delivered, North America	2736.59	2737.49	0.033
Port Said-Koper	Rubber, TSR 20, New York CIF	1662.17	1663.07	0.054
Port Said-Koper	Plywood, Africa & SE Asia, Lauan, 3-ply, 91cmx182cmx4mm, wholesale Tokyo	1669.77	1670.67	0.054
Port Said-Koper	Fine wool, 19 Micron, AWEX auction price, Australia	14183.23	14184.13	0.006
Lisbon-Jeddah	Salmon, fresh, fish-farm bred, export price, Norway	6940.00	6941.31	0.019
Lisbon-Jeddah	Bananas, Central and South America, FOT, US import price	1140.00	1141.31	0.115
Lisbon-Jeddah	Coffee, other mild Arabicas, ex-dock EU	2767.24	2768.55	0.047
Lisbon-Jeddah	Tea, Kenya Mombasa/Nairobi, auction price	2200.00	2201.31	0.059

Route	Commodity	Base Price ($/MT)	Med SO_X ECA Price ($MT)	Percent Change
Lisbon-Jeddah	Tobacco, unmanufactured, US import unit value	4578.65	4579.96	0.029
Lisbon-Jeddah	Phosphate rock, Khouribga, 70% BPL, contract, FAS Casablanca	87.95	89.26	1.488
Lisbon-Jeddah	Zinc, Prime Western, delivered, North America	2736.59	2737.90	0.048
Lisbon-Jeddah	Rubber, TSR 20, New York CIF	1662.17	1663.48	0.079
Lisbon-Jeddah	Plywood, Africa & SE Asia, Lauan, 3-ply, 91cmx182cmx4mm, wholesale Tokyo	1669.77	1671.08	0.078
Lisbon-Jeddah	Fine wool, 19 Micron, AWEX auction price, Australia	14183.23	14184.54	0.009
Piraeus-Limassol	Salmon, fresh, fish-farm bred, export price, Norway	6940.00	6940.36	0.005
Piraeus-Limassol	Bananas, Central and South America, FOT, US import price	1140.00	1140.36	0.031
Piraeus-Limassol	Coffee, other mild Arabicas, ex-dock EU	2767.24	2767.60	0.013
Piraeus-Limassol	Tea, Kenya Mombasa/Nairobi, auction price	2200.00	2200.36	0.016
Piraeus-Limassol	Tobacco, unmanufactured, US import unit value	4578.65	4579.01	0.008
Piraeus-Limassol	Phosphate rock, Khouribga, 70% BPL, contract, FAS Casablanca	87.95	88.31	0.407
Piraeus-Limassol	Zinc, Prime Western, delivered, North America	2736.59	2736.95	0.013
Piraeus-Limassol	Rubber, TSR 20, New York CIF	1662.17	1662.53	0.022
Piraeus-Limassol	Plywood, Africa & SE Asia, Lauan, 3-ply, 91cmx182cmx4mm, wholesale Tokyo	1669.77	1670.12	0.021
Piraeus-Limassol	Fine wool, 19 Micron, AWEX auction price, Australia	14183.23	14183.59	0.003
Port Said-Beirut	Salmon, fresh, fish-farm bred, export price, Norway	6940.00	6940.16	0.002
Port Said-Beirut	Bananas, Central and South America, FOT, US import price	1140.00	1140.16	0.014
Port Said-Beirut	Coffee, other mild Arabicas, ex-dock EU	2767.24	2767.40	0.006
Port Said-Beirut	Tea, Kenya Mombasa/Nairobi, auction price	2200.00	2200.16	0.007
Port Said-Beirut	Tobacco, unmanufactured, US import unit value	4578.65	4578.81	0.003
Port Said-Beirut	Phosphate rock, Khouribga, 70% BPL, contract, FAS Casablanca	87.95	88.11	0.179
Port Said-Beirut	Zinc, Prime Western, delivered, North America	2736.59	2736.75	0.006
Port Said-Beirut	Rubber, TSR 20, New York CIF	1662.17	1662.33	0.009
Port Said-Beirut	Plywood, Africa & SE Asia, Lauan, 3-ply, 91cmx182cmx4mm, wholesale Tokyo	1669.77	1669.92	0.009
Port Said-Beirut	Fine wool, 19 Micron, AWEX auction price, Australia	14183.23	14183.39	0.001
Shanghai-Rotterdam	Salmon, fresh, fish-farm bred, export price, Norway	6940.00	6941.31	0.019
Shanghai-Rotterdam	Bananas, Central and South America, FOT, US import price	1140.00	1141.31	0.115
Shanghai-Rotterdam	Coffee, other mild Arabicas, ex-dock EU	2767.24	2768.55	0.047

Route	Commodity	Base Price ($/MT)	Med SO_X ECA Price ($MT)	Percent Change
Shanghai-Rotterdam	Tea, Kenya Mombasa/Nairobi, auction price	2200.00	2201.31	0.059
Shanghai-Rotterdam	Tobacco, unmanufactured, US import unit value	4578.65	4579.96	0.029
Shanghai-Rotterdam	Phosphate rock, Khouribga, 70% BPL, contract, FAS Casablanca	87.95	89.26	1.488
Shanghai-Rotterdam	Zinc, Prime Western, delivered, North America	2736.59	2737.90	0.048
Shanghai-Rotterdam	Rubber, TSR 20, New York CIF	1662.17	1663.48	0.079
Shanghai-Rotterdam	Plywood, Africa & SE Asia, Lauan, 3-ply, 91cmx182cmx4mm, wholesale Tokyo	1669.77	1671.08	0.078
Shanghai-Rotterdam	Fine wool, 19 Micron, AWEX auction price, Australia	14183.23	14184.54	0.009
Shanghai-Fos-sur-Mer	Salmon, fresh, fish-farm bred, export price, Norway	6940.00	6941.05	0.015
Shanghai-Fos-sur-Mer	Bananas, Central and South America, FOT, US import price	1140.00	1141.05	0.093
Shanghai-Fos-sur-Mer	Coffee, other mild Arabicas, ex-dock EU	2767.24	2768.29	0.038
Shanghai-Fos-sur-Mer	Tea, Kenya Mombasa/Nairobi, auction price	2200.00	2201.05	0.048
Shanghai-Fos-sur-Mer	Tobacco, unmanufactured, US import unit value	4578.65	4579.70	0.023
Shanghai-Fos-sur-Mer	Phosphate rock, Khouribga, 70% BPL, contract, FAS Casablanca	87.95	89.00	1.199
Shanghai-Fos-sur-Mer	Zinc, Prime Western, delivered, North America	2736.59	2737.65	0.039
Shanghai-Fos-sur-Mer	Rubber, TSR 20, New York CIF	1662.17	1663.22	0.063
Shanghai-Fos-sur-Mer	Plywood, Africa & SE Asia, Lauan, 3-ply, 91cmx182cmx4mm, wholesale Tokyo	1669.77	1670.82	0.063
Shanghai-Fos-sur-Mer	Fine wool, 19 Micron, AWEX auction price, Australia	14183.23	14184.28	0.007
Port Said-Fos-sur-Mer	Salmon, fresh, fish-farm bred, export price, Norway	6940.00	6941.05	0.015
Port Said-Fos-sur-Mer	Bananas, Central and South America, FOT, US import price	1140.00	1141.05	0.093
Port Said-Fos-sur-Mer	Coffee, other mild Arabicas, ex-dock EU	2767.24	2768.29	0.038
Port Said-Fos-sur-Mer	Tea, Kenya Mombasa/Nairobi, auction price	2200.00	2201.05	0.048

Route	Commodity	Base Price ($/MT)	Med SO_X ECA Price ($MT)	Percent Change
Port Said-Fos-sur-Mer	Tobacco, unmanufactured, US import unit value	4578.65	4579.70	0.023
Port Said-Fos-sur-Mer	Phosphate rock, Khouribga, 70% BPL, contract, FAS Casablanca	87.95	89.00	1.199
Port Said-Fos-sur-Mer	Zinc, Prime Western, delivered, North America	2736.59	2737.65	0.039
Port Said-Fos-sur-Mer	Rubber, TSR 20, New York CIF	1662.17	1663.22	0.063
Port Said-Fos-sur-Mer	Plywood, Africa & SE Asia, Lauan, 3-ply, 91cmx182cmx4mm, wholesale Tokyo	1669.77	1670.82	0.063
Port Said-Fos-sur-Mer	Fine wool, 19 Micron, AWEX auction price, Australia	14183.23	14184.28	0.007
Singapore-New York	Salmon, fresh, fish-farm bred, export price, Norway	6940.00	6941.31	0.019
Singapore-New York	Bananas, Central and South America, FOT, US import price	1140.00	1141.31	0.115
Singapore-New York	Coffee, other mild Arabicas, ex-dock EU	2767.24	2768.55	0.047
Singapore-New York	Tea, Kenya Mombasa/Nairobi, auction price	2200.00	2201.31	0.059
Singapore-New York	Tobacco, unmanufactured, US import unit value	4578.65	4579.96	0.029
Singapore-New York	Phosphate rock, Khouribga, 70% BPL, contract, FAS Casablanca	87.95	89.26	1.488
Singapore-New York	Zinc, Prime Western, delivered, North America	2736.59	2737.90	0.048
Singapore-New York	Rubber, TSR 20, New York CIF	1662.17	1663.48	0.079
Singapore-New York	Plywood, Africa & SE Asia, Lauan, 3-ply, 91cmx182cmx4mm, wholesale Tokyo	1669.77	1671.08	0.078
Singapore-New York	Fine wool, 19 Micron, AWEX auction price, Australia	14183.23	14184.54	0.009
Tangier-Oran	Salmon, fresh, fish-farm bred, export price, Norway	6940.00	6940.18	0.003
Tangier-Oran	Bananas, Central and South America, FOT, US import price	1140.00	1140.18	0.016
Tangier-Oran	Coffee, other mild Arabicas, ex-dock EU	2767.24	2767.42	0.006
Tangier-Oran	Tea, Kenya Mombasa/Nairobi, auction price	2200.00	2200.18	0.008
Tangier-Oran	Tobacco, unmanufactured, US import unit value	4578.65	4578.83	0.004
Tangier-Oran	Phosphate rock, Khouribga, 70% BPL, contract, FAS Casablanca	87.95	88.13	0.201
Tangier-Oran	Zinc, Prime Western, delivered, North America	2736.59	2736.77	0.006
Tangier-Oran	Rubber, TSR 20, New York CIF	1662.17	1662.35	0.011
Tangier-Oran	Plywood, Africa & SE Asia, Lauan, 3-ply, 91cmx182cmx4mm, wholesale Tokyo	1669.77	1669.94	0.011
Tangier-Oran	Fine wool, 19 Micron, AWEX auction price, Australia	14183.23	14183.41	0.001

Route	Commodity	Base Price ($/MT)	Med SO_X ECA Price ($MT)	Percent Change
Tangier-Tunis	Salmon, fresh, fish-farm bred, export price, Norway	6940.00	6940.55	0.008
Tangier-Tunis	Bananas, Central and South America, FOT, US import price	1140.00	1140.55	0.048
Tangier-Tunis	Coffee, other mild Arabicas, ex-dock EU	2767.24	2767.79	0.020
Tangier-Tunis	Tea, Kenya Mombasa/Nairobi, auction price	2200.00	2200.55	0.025
Tangier-Tunis	Tobacco, unmanufactured, US import unit value	4578.65	4579.20	0.012
Tangier-Tunis	Phosphate rock, Khouribga, 70% BPL, contract, FAS Casablanca	87.95	88.50	0.628
Tangier-Tunis	Zinc, Prime Western, delivered, North America	2736.59	2737.15	0.020
Tangier-Tunis	Rubber, TSR 20, New York CIF	1662.17	1662.72	0.033
Tangier-Tunis	Plywood, Africa & SE Asia, Lauan, 3-ply, 91cmx182cmx4mm, wholesale Tokyo	1669.77	1670.32	0.033
Tangier-Tunis	Fine wool, 19 Micron, AWEX auction price, Australia	14183.23	14183.78	0.004
Thessaloniki-Piraeus	Salmon, fresh, fish-farm bred, export price, Norway	6940.00	6940.18	0.003
Thessaloniki-Piraeus	Bananas, Central and South America, FOT, US import price	1140.00	1140.18	0.016
Thessaloniki-Piraeus	Coffee, other mild Arabicas, ex-dock EU	2767.24	2767.42	0.007
Thessaloniki-Piraeus	Tea, Kenya Mombasa/Nairobi, auction price	2200.00	2200.18	0.008
Thessaloniki-Piraeus	Tobacco, unmanufactured, US import unit value	4578.65	4578.83	0.004
Thessaloniki-Piraeus	Phosphate rock, Khouribga, 70% BPL, contract, FAS Casablanca	87.95	88.13	0.207
Thessaloniki-Piraeus	Zinc, Prime Western, delivered, North America	2736.59	2736.78	0.007
Thessaloniki-Piraeus	Rubber, TSR 20, New York CIF	1662.17	1662.35	0.011
Thessaloniki-Piraeus	Plywood, Africa & SE Asia, Lauan, 3-ply, 91cmx182cmx4mm, wholesale Tokyo	1669.77	1669.95	0.011
Thessaloniki-Piraeus	Fine wool, 19 Micron, AWEX auction price, Australia	14183.23	14183.41	0.001
Xiamen-Beirut	Salmon, fresh, fish-farm bred, export price, Norway	6940.00	6940.16	0.002
Xiamen-Beirut	Bananas, Central and South America, FOT, US import price	1140.00	1140.16	0.014
Xiamen-Beirut	Coffee, other mild Arabicas, ex-dock EU	2767.24	2767.40	0.006
Xiamen-Beirut	Tea, Kenya Mombasa/Nairobi, auction price	2200.00	2200.16	0.007
Xiamen-Beirut	Tobacco, unmanufactured, US import unit value	4578.65	4578.81	0.003
Xiamen-Beirut	Phosphate rock, Khouribga, 70% BPL, contract, FAS Casablanca	87.95	88.11	0.179
Xiamen-Beirut	Zinc, Prime Western, delivered, North America	2736.59	2736.75	0.006
Xiamen-Beirut	Rubber, TSR 20, New York CIF	1662.17	1662.33	0.009
Xiamen-Beirut	Plywood, Africa & SE Asia, Lauan, 3-ply, 91cmx182cmx4mm, wholesale Tokyo	1669.77	1669.92	0.009

Route	**Commodity**	**Base Price ($/MT)**	**Med SO_X ECA Price ($MT)**	**Percent Change**
Xiamen-Beirut	Fine wool, 19 Micron, AWEX auction price, Australia	14183.23	14183.39	0.001