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

REMPEC/WG.50/INF.9
Date: 23 April 2021

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Agenda Item 3

FINAL REPORT ON THE CARRYING OUT OF THE FURTHER STUDY RELATED TO THE ADDITIONAL ANALYSES OF FUEL SUPPLY AND ALTERNATIVE COMPLIANCE METHODS

Note by the Secretariat

SUMMARY

Executive Summary:	This document presents the final report on the carrying out of the further study related to the additional analyses of fuel supply and alternative compliance methods, 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 carrying out of the further study related to the additional analyses of fuel supply and alternative compliance methods, which was prepared pursuant to the road map according to the Terms of Reference set out in Appendix III to document REMPEC/WG.50/INF.6, is presented in the **Appendix** to the present document.

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

Action requested by the Meeting

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

APPENDIX

Final report on the carrying out of the further study related to the additional analyses of fuel supply and alternative compliance methods

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

FURTHER STUDY RELATED TO THE ADDITIONAL ANALYSES OF FUEL SUPPLY AND ALTERNATIVE COMPLIANCE METHODS PURSUANT TO THE ROAD MAP FOR A PROPOSAL FOR THE POSSIBLE DESIGNATION OF THE MED SO_X ECA

(LOT 3)

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

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Abbreviations and Definitions

Term	Explanation
bbl	Barrel
CAGR	Compound annual growth rate
CO_2	Carbon dioxide
DM	Distillate marine fuels
DWT	Deadweight tonne
ECA	Emission Control Area
EERA	Energy and Environmental Research Associates, LLC
EGCS	Exhaust gas cleaning system
EMEA	Europe, Middle East, and Africa
EU	European Union
FMI	Finnish Meteorological Institute
FRED	Federal Reserve Economic Data
GHG	Greenhouse gas
HFO	Heavy fuel oil
HSHFO	High sulphur heavy fuel oil
IEA	International Energy Agency
IFO	Intermediate fuel oil
IHO	International Hydrographic Organization
IMO	International Maritime Organization
ISO	International Organization of Standardization
JODI	Joint Organisations Data Initiative
ktonnes	Kilo-tonnes
LNG	Liquefied Natural Gas
LSFO	Low sulphur fuel oil
m/m	Mass by mass
MARPOL	International Convention for the Prevention of Pollution from Ships
MARPOL VI	MARPOL Annex VI
MDO	Marine distillate oil
Med SO_X ECA	Mediterranean Sea SO_X ECA
MEPC	Marine Environment Protection Committee
MGO	Marine gas oil
MMT	Million metric tonnes
RATES	Regional Assessment of Taxes, Tolls and Emissions from Ships
REMPEC	Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea
RM	Residual marine fuels
RoPax	Roll-on Passenger
S	Sulphur
SECA	SO_X Emission Control Area
SO_X	Oxides of sulphur
STEAM	Ship Traffic Emission Assessment Model
tonne-km or t-km	Tonne-kilometre
ULSFO	Ultra-low sulphur fuel oil
UNFCCC	United Nations Framework Convention on Climate Change
USD	United States Dollars
VLSFO	Very low sulphur fuel oil
WTI	West Texas Intermediate
Δ	Change (Greek letter delta), difference

1 Executive summary

This final report presents the result of the further study carried out under LOT 3 (Additional analyses of fuel supply and alternative compliance methods) 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.

LOT 3 comprises a further study, specifically to make additional analyses of fuel supply and alternative compliance methods (regional fuel production, fuel availability, and alternative compliance technologies), and provides the necessary input for the finalisation of the draft submission to the International Maritime Organization (IMO) under LOT 1 in accordance with the road map and Appendix III to Annex VI to the International Convention for the Prevention of Pollution from Ships (MARPOL).

1.1 Overview of project

The Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC) tasked Energy and Environmental Research Associates, LLC (EERA), to carry out the further study related to the additional analyses of fuel supply and alternative compliance methods, 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. EERA conducted additional and extended evaluation of fuel availability for the possible designation of the Med SO_X ECA. This study provides decision-support information to determine that adequate marine fuel availability will be sufficient for designation of the Med SO_X ECA in service of regional environmental and human health and maritime stewardship in the Mediterranean Sea.

We evaluate whether refining capacity exists to provide petroleum fuel at or below 0.10% S m/m to meet demand by ships operating in the Mediterranean Sea Area under the Med SO_X ECA. We quantitatively determine available regional supply of fuel products within and adjacent to the Mediterranean Sea Area. We also quantitatively evaluate expected demand for marine fuels compliant with the Med SO_X ECA. In addition to the focus on the Mediterranean Sea Area, we perform supply analyses at a global scale, with consideration of major refining countries and major bunkering countries. We evaluate a variety of information, including previous IMO studies of fuel supply availability, shipping fleet fuel demand estimated by two recent IMO Greenhouse Gas (GHG) Studies, and world oil outlook reports. We also consider reduced demand for 0.10% S m/m petroleum products through adoption of alternative compliance technologies and transition to alternative fuels.

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.

[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)

1.3 Findings confirm sufficient fuel availability to meet fleet demand for 0.10% S m/m fuels

The primary finding is that sufficient refinery capacity and production exists to meet fleet demand for 0.10% S m/m fuel under the Med SO_X ECA. Available supply is sufficient to meet demand, even considering a range of estimates and growth rates for fleet fuel use. This finding is prior to consideration of the additional compliance pathway using exhaust gas cleaning systems (EGCS), which may further reduce demand for 0.10% S m/m fuels. Therefore, adoption of EGCS technologies or alternative fuels among vessels where this is economically feasible reinforces the robustness of the primary finding by diversifying demand to include non-compliant petroleum fuels and other fuels with intrinsically lower sulphur content. Projections of excess (or spare) capacity further indicate that supply will continue to be available, perhaps with greater spare capacity for production than previously evaluated in earlier studies.

This study frames the fuel availability question at the regional scale, then considers major bunkering countries with ports adjacent to the Mediterranean Sea Area, then considers all major bunkering countries, then considers all countries that are major producers of product relevant to supply, then considers world production and production capacity. We evaluate potential fuel availability at each scale, recognising that international shipping depends on world markets for fuel availability in the Mediterranean Sea Area.

Figure 2 shows that refinery capacity to produce gas/diesel fuel is greater than consumption demand (including marine bunkers) at all scales, including among the Mediterranean coastal States. As shown, at the regional scales of the Mediterranean coastal States and inclusive of adjacent neighbouring countries, **Figure 2** shows that current production of gas/diesel is not sufficient to meet current consumption demand; Mediterranean coastal States that are Contracting Parties to the Barcelona Convention, in fact, import gas/diesel from other countries to satisfy market demand for gas/diesel. In other words, while refineries in these countries have capacity to produce more middle distillates, the economically optimal configuration produces more of other refining products for export, allowing the market to purchase gas/diesel on the global market. This is typical profit-maximising behaviour by refineries in a global petroleum market. **Figure 3** shows that refinery capacity to produce fuel oil and production of fuel oil exceeds demand, consistent with the by-product status of residual oils. Refinery production of fuel oil fails to meet consumption only under the conditions where bunker estimates are maximised. Combining fuel oil and gas/diesel, both refinery capacity estimates and production statistics demonstrate that supply exceeds consumption demand at all scales except that Mediterranean coastal States that are Contracting Parties to the Barcelona Convention must trade products, as shown in **Figure 4**. Therefore, sufficient fuel availability of both gas/diesel and fuel oil is available for provision of 0.10% S m/m fuels for the Med SO_X ECA through the combination of distillate fuels, and blended products to product low-sulphur residual fuels.

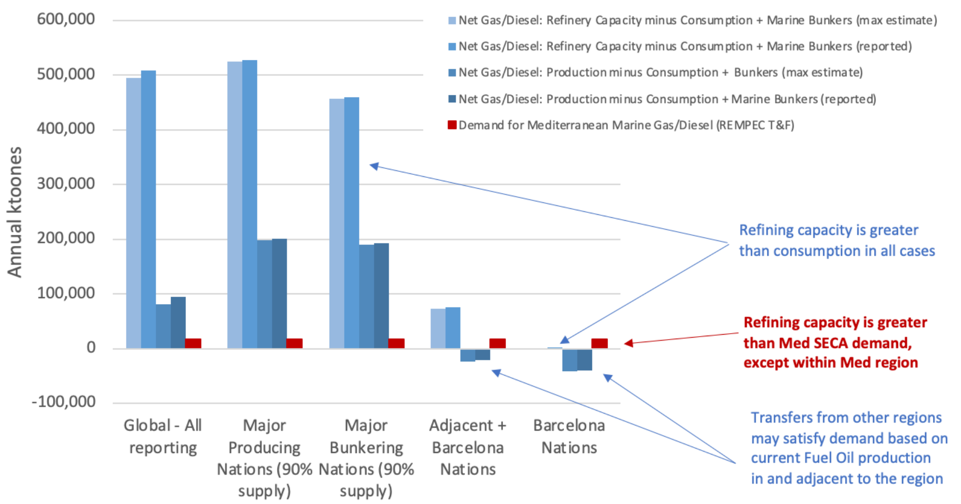

Figure 2: Net refining capacity to produce gas/diesel is greater than consumption demand, sufficient for Med SO_X ECA supply

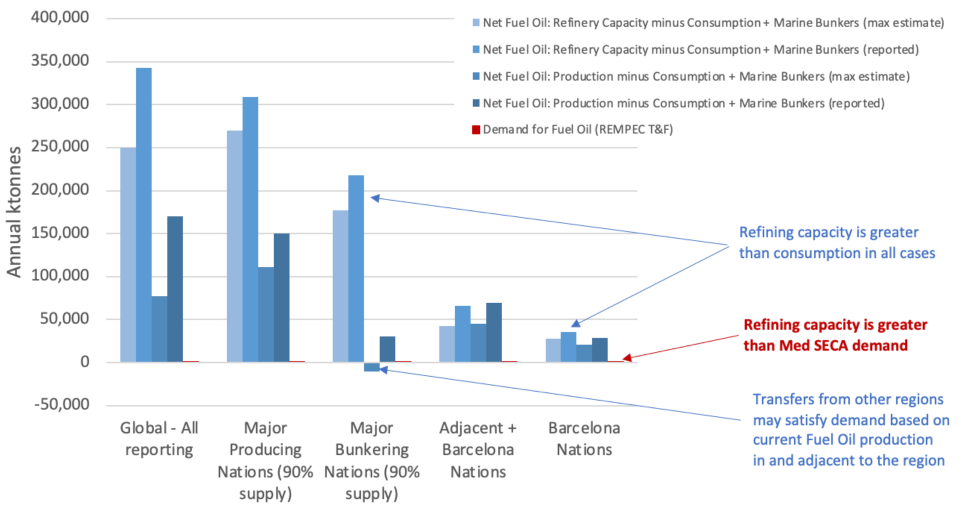

Figure 3: Net refining capacity for and production of fuel oil exceeds consumption demand, including marine bunkers

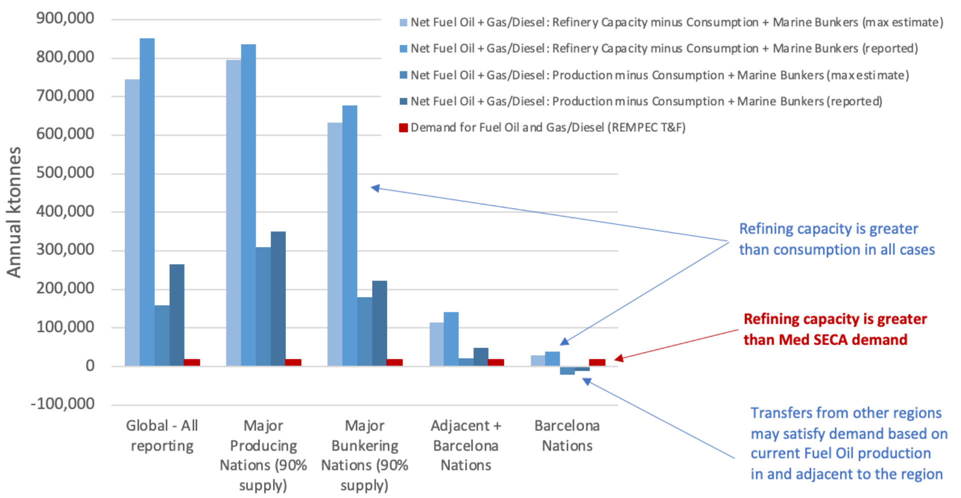

Figure 4: Net refining capacity for and production of fuel oil and gas/diesel exceeds consumption demand

1.4 Organisation of report

The report is organised in six sections.

Section 1 provides an executive summary.

Section 2 presents a summary of methodology and data.

Section 3 presents the demand projections for 0.10% sulphur compliant fuel oil in the Mediterranean Sea during the period 2024-2029 on the basis of the outcome of 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) (Corbett & Carr, 2019), hereinafter referred to as the Technical and Feasibility Study, and other relevant studies, including on effects due to the enhancement of energy efficiency of ships.

Section 4 summarises overall availability across regions ranging from the Mediterranean Sea Area to global based on the availability of fuel oil that could be supplied by countries outside the Mediterranean Sea Area to meet the Med SO_X ECA demand; we evaluate this in three contexts:

- supply capacity adjacent to the Mediterranean Sea Area;
- supply capacity among major bunkering/refining countries; and
- global supply capacity.

Section 5 provides a review of other information related to availability of compliant fuels including refining forecasts, changes in global demand for middle distillates used in production of gas/diesel, and marine sector uptake of alternative compliance technologies, alternative fuels, or other advanced energy carriers and technologies.

Section 6 presents references.

2 Methodology and data

This section provides background that informs our methodologies, defines our approach to evaluating fuel supply and demand balances, summarises how we estimate demand for marine fuel (bunkers) and non-marine fuel products including adjustments to demand due to adoption of alternative compliance technologies and fuels, and produce refining capacity and production estimates.

2.1 Background and overview of fuel availability to supply shipping demand

International ship power systems currently consume mainly petroleum-based fuel products and by-products, with limited use of liquefied natural gas (LNG). Most of the fleet consumes residual fuel, also known as heavy fuel oil (HFO), which includes several grades of blended petroleum by-products of refining (International Standardisation Organization (ISO), 2017). Under MARPOL Annex VI (MARPOL VI), marine vessels adopted fuels meeting a global limit of 0.50% S m/m beginning in 2020. This action, which has been implemented successfully, was informed by the final report of the Assessment of fuel oil availability (MEPC 70/INF.6) (IMO Secretariat, 2016), hereinafter referred to as the IMO Fuel Availability Study. That study confirmed that sufficient quantities of refinery products could be provided for global compliance with MARPOL VI 0.50% S m/m limits. The IMO Fuel Availability Study findings are general enough to suggest that they may apply to finding of availability for other marine fuel demand, including quantities of SECA fuel meeting limits of 0.10% S m/m to satisfy Mediterranean Sea Area shipping demand under the Med SO_X ECA.

Consistent with findings of the IMO Fuel Availability Study, energy providers produced sufficient marine fuel to meet world and fleet demand compliant with 2020 implementation of MARPOL VI global fuel sulphur limits (0.50% S m/m fuel). This included provision of marine fuel supply for current emission control areas (ECAs) requiring lower regional fuel sulphur limits (0.10% S m/m fuel). Moreover, fuel pricing trends in 2020 have not demonstrated substantial price shocks or regional price distortions, further indicating sufficient supply.

The term demand is contextually synonymous with the term consumption used by IEA to describe the use of (or demand for) fuels produced. This report refers to demand for consistency reasons, except where using consumption in the IEA context is clearer. Similarly, refinery capacity refers to the potential volume of crude that can be processed. Yield refers to the percentage of crude capacity of particular products (e.g., gas/diesel, fuel oil) that a refinery produces. Lastly, production refers to the reported product quantities in the context of supply.

In this context, this work provides further study of fuel availability to identify corroborating or contradictory information that may modify the findings of the IMO Fuel Availability Study with regard to the Mediterranean Sea and/or update supply and demand conditions with subsequent data and analyses.

2.2 Marine fuels overview

Terminology has varied between IMO regulations, ISO standards, and the fuel prices described in the market, further complicating the comparison of fuels and prices over time. Per resolution MEPC.320(74) on the *2019 Guidelines for consistent implementation of the 0.50% sulphur limit under MARPOL Annex VI* (IMO, 2020)[2], marine fuels are defined as shown in **Table 1**.

This report uses terminology from IEA statistics that include refinery fuel labels, e.g., gas/diesel. The term gas/diesel is used in this report primarily because the fuel availability scope deals necessarily if not centrally with refining supply and demand including non-marine demand for gas/diesel. Gas/diesel includes of all distillate marine fuels (DM) and distillate non-marine fuels in **Table 1**. For the purposes of clarity, IEA reported statistics for Gas/Diesel do not include natural gas or natural gas products, which are reported in separate data series.

[2] Available at https://www.imo.org/en/MediaCentre/PressBriefings/Pages/10-MEPC-74-sulphur-2020.aspx.

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

Fuel Category	ISO Standard	Fuel Sulphur Limit[3]	Terminology used in the Technical and Feasibility Study
Distillate marine fuels (DM)	ISO 8217:2017	1.0% S m/m maximum	Marine gas oil (MGO) if ≤ 0.10% S m/m Marine distillate oil (MDO) if ≤ 0.50% S m/m
Residual marine fuels (RM)	ISO 8217:2017	As per statutory requirements	Intermediate fuel oil (IFO) HFO
High sulphur heavy fuel oil (HSHFO)		> 0.50% S m/m	HFO
Very low sulphur fuel oil (VLSFO)	ISO 8217:2017	≤ 0.50% S m/m	MDO Compliant Blend
Ultra-low sulphur fuel oil (ULSFO)	ISO 8217:2017	≤ 0.10% S m/m	MGO MDO Compliant Blend

2.3 Fundamental market relationships among production capacity, production supply, general consumption of gas/diesel, and marine fuel demand

Fuel supply and demand define market relationships within which new demand for 0.10% S m/m marine fuel will need to be satisfied through available, upgraded, or new refining capacity. Refining capacity represents a potential to produce needed products. Where refining capacity fails to match market demand, interim shortages appear in the market and investment in additional capacity may occur in response to economic signals. Where refining capacity exceeds profitable operation and perceived new demand, refinery closures may occur; this essentially re-matches capacity to produce with expected production to meet demand. Employment of that capacity to supply a range of petroleum products includes economic optimisation decisions. Refineries determine their best mix of production to meet demand among all petroleum consuming sectors with a diverse set of petroleum products. Allocation of refining capacity to production of finished or intermediate inputs for marine fuel compliant with 0.10% S m/m limits depends in part on demand across other sectors and depends in part on competitive pricing that may reveal the value of demand among shipping and other sectors. These market relationships are dynamic, changing with seasons, changing over time with trends in changing consumption, changing with fuel quality standards including those meeting environmental requirements, etc.

Figure 5 summarises these fuel availability relationships with a simple illustration and a general equation. If capacity exceeds production, then additional capacity may be utilised for new demand if needed. If production can meet demand, then market competition will reveal prices that allocate supply efficiently. Three conditions may exist with regard to fuel availability:

1. **Under adequate production allocation, fuel availability supply is confident**. Market competition may reveal new options for alternative compliance technologies or alternative fuels to enter the market if they provide a means to use less costly fuels at lower net cost. Where production is not allocated to meet demand, consideration of increased use of alternative compliance technologies or alternative fuels becomes important.
2. **Under inadequate production allocation, fuel availability is contingent.** Blending of distilled products with residual fuel oil to achieve a compliant fuel increases estimates of available compliant fuel for the Med SO_X ECA. Alternative compliance strategies essentially adjust the demand for unallocated products by enabling use of traditional high-sulphur fuels or other alternatives. Examples include: i) energy conserving measures like efficient technologies and vessel designs; ii) alternative compliant technologies (EGCS or scrubbers); alternative fuels (LNG/Methanol); and/or advanced energy carriers and low-GHG technologies and vessel designs (ammonia, hydrogen, and hybrid electric or renewable power systems).
3. **Under production deficits through inadequate allocation or under-capacity, fuel becomes unavailable in the short or long term.**

[3] Fuel sulphur limits are, functionally and as per statutory limits, fuels with ≤ 0.50% S m/m globally and ≤ 0.10% S m/m in ECA regions, unless the vessel is operating HSHFO with an EGCS.

Current fuel availability: $Production\ Capacity \geq Production \geq Consumption$

Confident fuel availability: $Production\ Capacity \geq Production \geq Consumption + SECA\ Fuel\ Demand$

Contingent fuel availability: $Production\ Capacity \geq Production \geq Consumption + SECA\ Fuel\ Demand - Demand\ with\ alternatives$

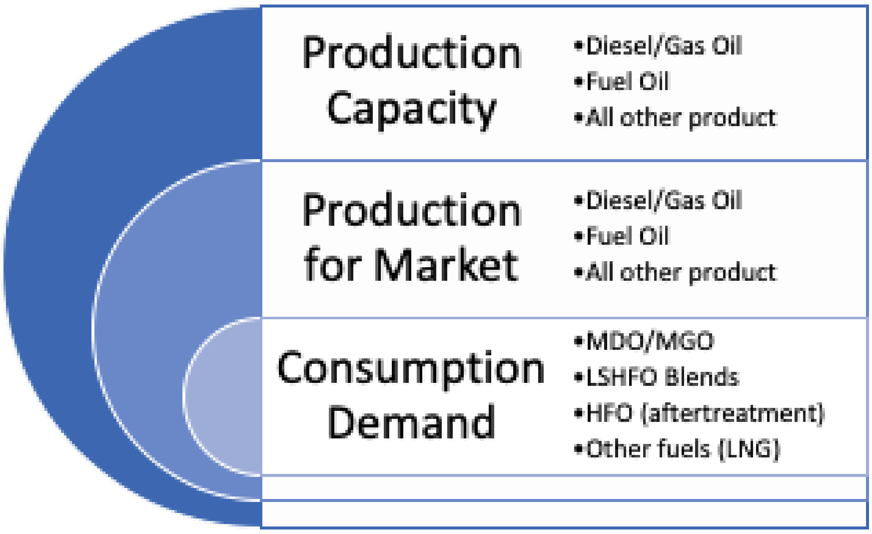

Figure 5: General relationships among Production Capacity, Production for Market, and Marine Fuel Consumption Demand

2.4 Demand methodology

Analysing demand for compliant marine fuels under the Med SO_X ECA required analysing three elements: i) demand estimation for marine fuel in a base year; ii) application of growth rate modelling to estimate change in demand in future years; and iii) analysis of potential economically feasible adoption of alternative compliance technologies and/or transition to alternative fuels, which may offset demand for compliant petroleum fuels with 0.10% S m/m or less.

Marine fuel demand reported in the Technical and Feasibility Study, provides the basis for the Med SO_X ECA fuel demand (**Table 2** and **Table 3**). In the Technical and Feasibility Study, the EERA team estimated that vessels operating in the Mediterranean Sea region used around 19 million metric tons (MMT) in 2016. The Technical and Feasibility Study also estimated that efficiency improvements in the vessel fleet would lead to overall declines in fuel demand in future years. In this work, we compare demand projections with the other studies related to the Med SO_X ECA. We also access IEA marine bunker statistics, including data on export-import discrepancies and net transfers statistics to calculate a fully adjusted top-down fuel inventory. We consider additional adjustments based on new literature and information on energy efficiency developments in the fleet. The results of this task update, where applicable, demand projections for fuel use from 2020 to 2050. We update the prior work by estimating annual fuel demand for the years 2024-2029, per scope.

Table 2: Baseline year (2016) fuel usage and projected 2020 fuel usage under MARPOL VI and Med SO_X ECA scenarios

ktonnes	MED 2016 Baseline	MARPOL VI 2020	Med SO_X ECA 2020
Total Fuel	19,160	17,100	17,100
MGO	542	522	16,700
MDO	3,290	16,340	164
HFO	15,090	100	95
LNG	243	141	138

Table 3: Fuel mix percentages for the Mediterranean Sea Area in 2016 and under MARPOL VI and Med SO_X ECA scenarios

Fuel Allocation	Pre-MARPOL VI Baseline Fuel Mix	MARPOL VI Fuel Mix	Med SO_X ECA Fuel Mix
MGO	2.8%	3.1%	97.7%
MDO	17.2%	95.5%	1.0%
HFO	78.8%	0.6%	0.6%
LNG	1.3%	0.8%	0.8%

2.4.1 Marine fuel demand growth rate comparisons of the Technical and Feasibility Study and other sources

The Finnish Meteorological Institute's STEAM model includes vessel-specific and dynamic step changes on an annual basis, assigned stochastically. This differs from the vessel-type category growth rates used in other work, and provides greater detail than some other vessel-specific models, which used simple categorical growth rates (IMO Secretariat, 2016; Sofiev et al., 2018). The growth rates are combined with energy efficiency improvements, described in the Energy Efficiency Design Index, to estimate future fuel use and emissions.

2.4.2 Demand for non-marine fuels

An assessment of net demand of petroleum is required to determine whether sufficient fuel availability exists to meet both non-marine and marine fuel demand. Similar to the analysis approach in the IMO Fuel Availability Study, global non-maritime fuel demand needed to be evaluated to compare with refinery production and capacity so that net availability for marine sector fuels could be evaluated. We obtained IEA data on petroleum demand by product and by sector for years 1990-2017.

We also accessed IEA petroleum demand statistics by sector and by product, including reported marine bunkers demand (known as top-down fuel use estimates in IMO GHG Studies). IEA Energy Balances[4] also provide statistics on exports, imports, and internal transfers of petroleum products. Net differences among export-import and transfer statistics provide additional information for reconciling bottom-up activity-based fuel estimates. EERA obtained a time series of IEA energy statistics, by country, by product, and by consumption sector, from which to evaluate production of fuel oil and gas/diesel. These statistics also were used to confirm demand estimates.

2.4.3 Cost methodology for evaluating alternative technology and advanced fuels adoption

The methods used in the Technical and Feasibility Study are reapplied to estimate EGCS fleet adoption rates and costs. These include assessing vessel-specific output from the STEAM model for the 2020 scenarios, including installed power on each of the >30,000 vessels, and fuel demand estimates under the Med SO_X ECA scenario condition. The STEAM model also reports annual operating hours in the region.

Capital and operating cost elements for alternative compliance technology (e.g., EGCS or scrubbers) were reviewed and updated to consider open loop, hybrid, and closed loop cost differences. These differentiated costs enable scenario assessments, including sensitivity analysis, to evaluate how EGCS technology adoption feasibility may be affected by technology prohibitions or discharge restrictions on the use of alternative compliance technologies.

Following the methods of the Technical and Feasibility Study, adapted from the published methodology for the RATES model (Carr & Corbett, 2015), we applied the annualised cost of capital, annualised cost of maintenance, and annual cost of operations provided in \$/kWh. Using the EGCS capital and OM cost inputs, we were able to estimate the annualised additional cost to operate an EGCS. By substituting the lower price for HFO fuels, we were able to estimate the annual savings in fuel costs if a vessel with a EGCS used the least cost non-ECA, non-MARPOL VI HFO. The net sum of the additional EGCS cost, and the net savings of EGCS operations using a less costly fuel was compared with the cost of compliance with Med SO_X ECA fuel standards.

[4] IEA World Energy Statistics energy balance statistics, Data Tables: Data and Statistics – Oil, accessed 2020, https://www.iea.org/data-and-statistics/data-tables.

Methodology for adoption of alternative compliance technology employs the assumption that a vessel that would install a EGCS would also use the least costly marine fuel, namely HFO. If the cost of operating a EGCS allowed the vessel to comply with ECA conditions at a lower cost than fuel switching, it was identified as an economically feasible investment. Moreover, updated fuel price inputs may also modify the financing incentives, compared with the analysis of the Technical and Feasibility Study.

For alternative fuels, we employ a similar methodology to that used for EGCS to estimate the costs and penetration of LNG in the Mediterranean Sea fleet. The cost of fuel-based compliance with the Med SO_X ECA defines the default from which fuel cost savings may be achieved through use of lower cost LNG fuel. As described in the Technical and Feasibility Study, an investment window for capital conversion to alternative fuels can be defined between bounds of the higher cost of Med SO_X ECA fuel and lower cost of using LNG fuel. We evaluate the fraction of the fleet that is replacement eligible in 2020, i.e., greater than 20 years since build. We evaluate the fraction of those vessels for which LNG would be economically feasible.

We identify and select a set of candidate replacement vessels [i.e., older vessels nearing typical scrapping age for that vessel type] and replacing them with a new LNG powered vessel. We apply a cost premium per installed kW to represent the cost of installation of necessary LNG power systems (Sames, Clausen, & Mads Lyder, 2011). Similar to the Technical and Feasibility Study, we apply a price premium of $450/kW to estimate the additional capital costs associated with containership LNG operation. Obtained from an industry report for LNG costs and benefits in the context of containerships, we apply this per-kW cost factor to all vessels eligible for age-related replacement.

We also apply fuel price premiums to determine the price difference between Med SO_X ECA fuel and LNG and other alternative fuels, where data availability permits. EERA performed a sensitivity analysis on the price of fuels based on observed trends and available data. Using this estimator of fuel cost savings, we compute the percent change in annual fuel costs. Using a ship financing investment rate of 6% and a financing period of 20 years, we compute the net present value of fuel cost savings.

With respect to EGCS knowledge gathering, we note that efforts continue to investigate potential negative effects of EGCS discharges, particularly untreated effluents, on the marine environment and biota. These negative impacts may result in near-term and long-term economic effects by modifying ecosystem balances. Publicly available studies are providing emerging evidence that is confirming concerns about untreated effluents from EGCSs. Studies indicate that EGCS may improve the air quality in harbour cities and at sea but will shift atmospheric pollution to the marine water body (Schmolke et al., 2020). “While a single ship with an installed scrubber may pose limited, local risk to marine ecosystem health, a global shipping community employing scrubbers to meet air emission limits is of serious concern” (Hassellöv et al., 2020). EGCS washwater is found to be acidic with elevated concentrations of metals and other contaminants (Teuchies, Cox, Van Itterbeeck, Meysman, & Blust, 2020). Increased acidification, i.e., pH decreases, are recognized, with larger pH changes occurring in areas of high traffic density on the scale of climate-related pH changes (Dulière, Baetens, & Lacroix, 2020). From a cost-methodology perspective, costs are not well differentiated between closed- and open-loop EGCS systems. We use cost estimates that may optimistic adoption rates for EGCS if future EGCS require more costly design for closed- or hybrid-operations. Therefore, we have no indication that our quantitative approach to evaluating socio-economic impacts would produce findings of greater adoption rates.

2.5 Supply methodology including analysis of refining capacity, production

Refinery capacity estimates are publicly available with crude processing capacity reported. Mediterranean coastal States that are Contracting Parties to the Barcelona Convention collectively operate more than seventy refineries, according to annual report of global refining by the Oil and Gas Journal (OGJ, 2020). Total crude processing capacity for these Mediterranean coastal States is presented in **Table 4**. **Figure 6** presents a map of these refinery locations (with some refineries located close together, overlapping markers). For example, in Turkey the STAR and TURPAS refineries are closely located.

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. The annual percent of finished product from input of crude oil defines the product yield statistic. This analysis reviewed literature reporting product yield statistics for refining, including publicly aggregated statistics such as IEA Oil Market Reports (International Energy Agency, 2016, 2017, 2020, 2018, 2019c, 2019f, 2019g, 2019b, 2019d, 2019e, 2019a), data from the Joint Organisations Data Initiative (JODI)[5], and industry publications such as Fuels Europe Statistical Reports (FuelsEurope, 2015, 2016, 2018, 2019). Data were reviewed across multiple years' reporting (2015-2020), among regional summaries, and for specific countries across month/year reporting. These were also reviewed in comparison with petroleum consumption statistics reported in the Statistical Review of World Energy (BP, 2020), recognising that production yield should closely align with consumption percentages by product. A descriptive summary of the set of data reviewed in presented in **Table 5**, showing good consistency. For this work, the mean yield percentages were applied to estimate production capacity for fuel oil and gas/diesel.

Table 4: Crude processing capacity for Mediterranean coastal States that are Contracting Parties to the Barcelona Convention

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[6]
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**

[5] JODI-Oil World Database, Country by Country Review of Oil Data, https://www.jodidata.org/oil/database/country-by-country-review.aspx.
[6] 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.

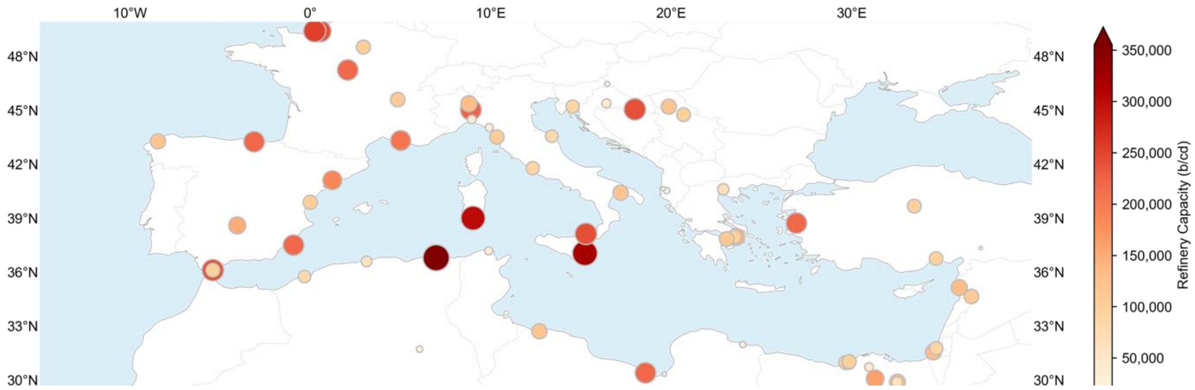

Figure 6: Refinery locations in Mediterranean Sea Area countries. Darker, larger circles show larger refining capacity (Note: some refineries are co-located, with overlapping markers)

Table 5: Summary of product yield statistics from various sources, with mean yield used in this work

Product yield data summary	Fuel oil	Gas/diesel
25th percentile	7.1%	32.4%
Mean	**12.3%**	**35.8%**
Median	10.2%	39.4%
75th percentile	12.9%	40.7%

Petroleum production statistics are provided by fuel product at the national level in statistical reporting by IEA, along with petroleum consumption statistics by sector and by product, including reported marine bunkers consumption (known as top-down fuel use estimates in IMO GHG Studies). Additionally, IEA Energy Balances also provide statistics on exports, imports, and internal transfers of petroleum products. Net differences among export-import and transfer statistics provide additional information for reconciling bottom-up activity-based fuel estimates. EERA obtained a time series of IEA energy statistics, by country, by product, and by consumption sector, from which to evaluate production of fuel oil and gas/diesel. These statistics also were used to confirm demand estimates.

2.6 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 3.5%, 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 gas oil (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.

2.6.1 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[7]. **Figure 7** 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.

[7] https://bunkerindex.com.

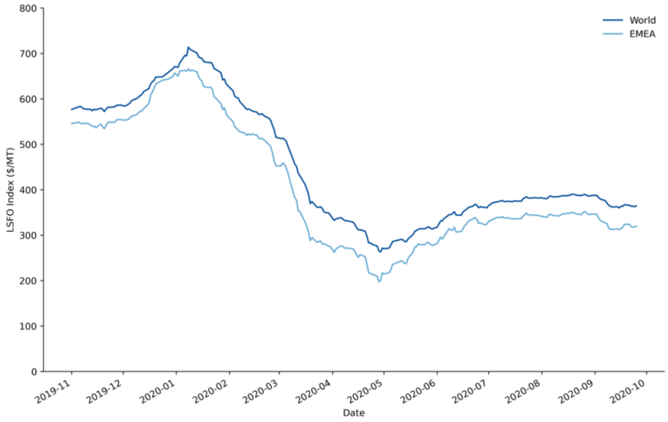

Figure 7: World and EMEA LSFO price indexes

2.6.2 Marine Gas Oil (0.10% S m/m)

Figure 8 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 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.

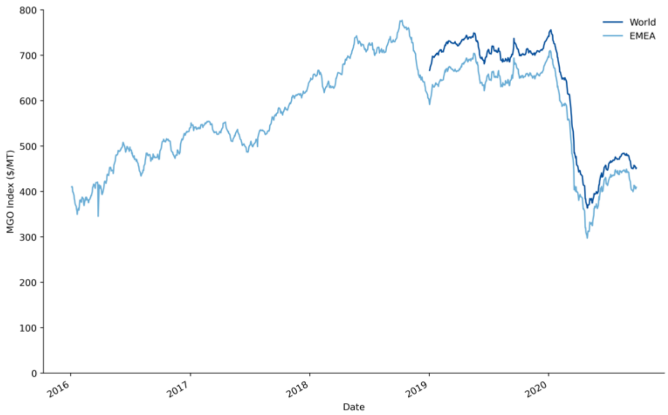

Figure 8: World and EMEA MGO price indexes

Prior to the IMO 2020 0.50% S m/m fuel rules going into effect, HFO 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.

2.6.3 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 9**, pricing data on LSFO is available from November 2019. EMEA and World price differentials have been closely aligned since January 2020.

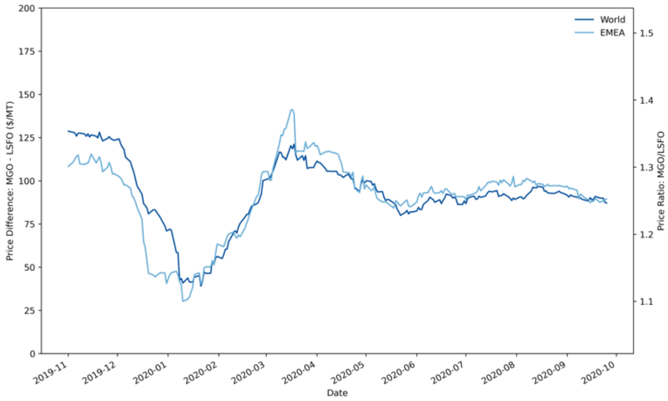

Figure 9: Price difference between MGO and LSFO for EMEA and World prices

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 price 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%.

2.6.4 Crude Prices

We also analysed crude barrel prices, based on available time series data from EIA[8]. We present results for two product areas, West Texas Intermediate (WTI) and Brent, which together describe the range of global crude oil prices. These are shown in **Figure 10**, with WTI and Brent oil prices per barrel shown on the right axis. Note that the axes are scaled[9] 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.

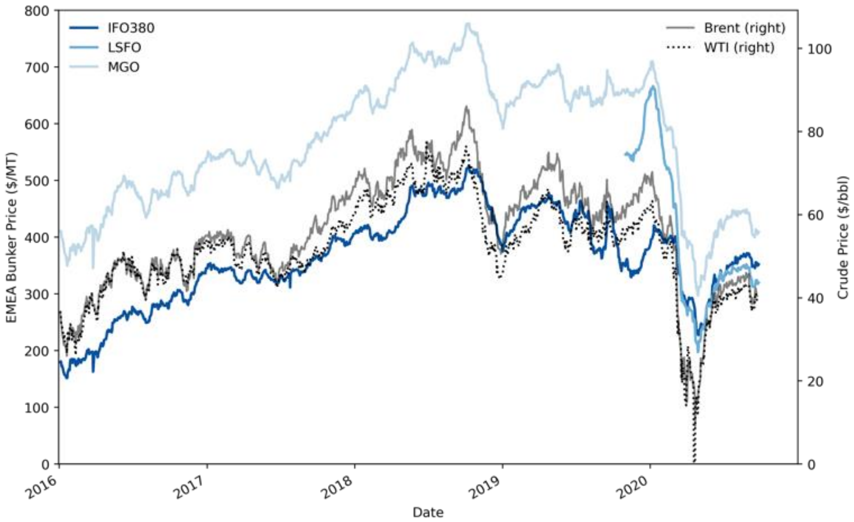

Figure 10: World prices for global oil price (Brent, WTI) and marine fuels (IFO 380, LSFO, MGO) in $/MT (left axis) and $/bbl (right axis)

The data in **Figure 10** 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 6**. The correlation coefficients show a high degree of correlation between all of the species in the table, and a strong correlation between Brent and WTI fuel prices and marine bunker prices.

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[8] https://www.eia.gov/dnav/pet/pet_pri_spt_s1_d.htm.
[9] Assuming 1 bbl = 0.1364 MT.

Table 6: Pearson correlation coefficients between marine bunker prices and crude oil prices

	IFO 380	**LSFO (0.50% S m/m)**	**MGO (0.50% S m/m)**	**Brent**	**WTI**
IFO 380	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 10**, a price inversion occurred when higher-sulphur IFO 380 was more expensive than lower sulphur LSFO.

3 Demand Estimates for marine and non-marine petroleum products

This report re-evaluates prior demand projections from the Technical and Feasibility Study, including comparison with updated information based on current output and trends based on energy efficiency improvements produced by the Finnish Meteorological STEAM model.

Figure 11 presents IEA data on international marine bunkers provided to ships by Mediterranean coastal States that are Contracting Parties to the Barcelona Convention. These data represent fuel provided to ships that stopped to bunker in these countries and should not be interpreted as demand for fuel by ships operating within the Mediterranean Sea Area. For example, ships obtaining bunkers from Mediterranean coastal States may have then consumed those fuels on voyages outside the Mediterranean Sea Area; moreover, some Mediterranean coastal States have coastlines and ports outside the Mediterranean Sea Area where ships may purchase marine fuels.

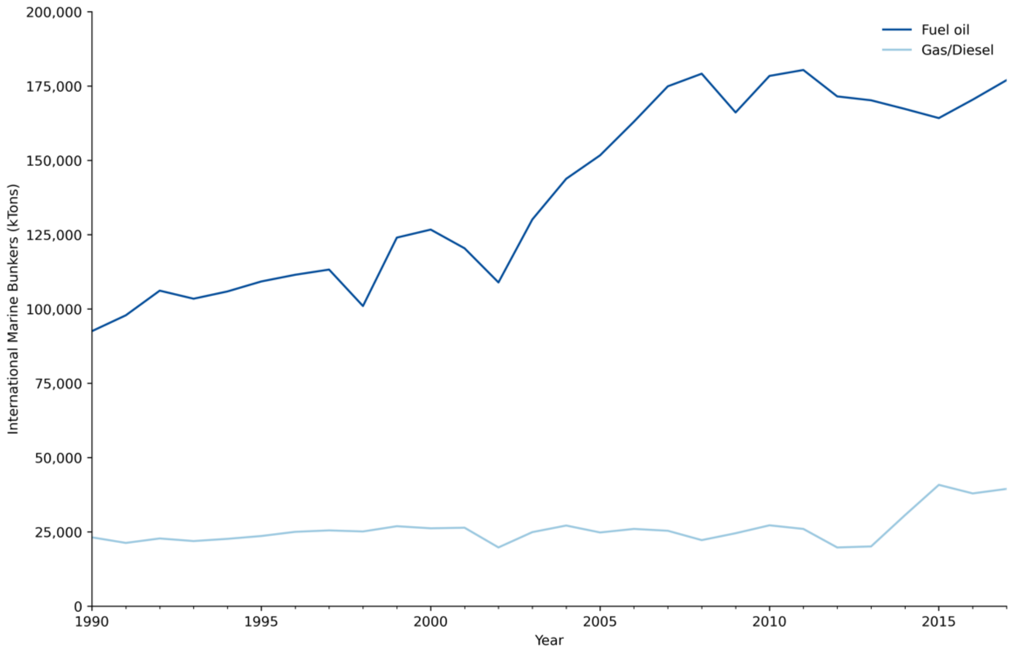


Figure 11: Fuel oil and gas/diesel International Marine Bunker trends (1990-2017) for Contracting Parties to the Barcelona Convention

3.1 Fuel demand by ships operating in the Mediterranean Sea Area (2020-2050)

These estimates of fuel demand derive from the Technical and Feasibility Study completed in 2018. These were updated for this study using more recent AIS data as modelled by FMI using STEAM. Data from the final report of the Fourth IMO GHG Study 2020 (MEPC 75/7/15), hereinafter referred to as the Fourth IMO GHG Study 2020, are reviewed in **Section 5.2**, demonstrating methodological consistency with the estimates and growth projections in this report; however, the Fourth IMO GHG Study 2020 does not report results by region for the Mediterranean, preventing direct comparison with the tables and figures in **Section 3**.

3.1.1 Updated fuel demand

The Technical and Feasibility Study estimated inventories for 2020 and for future years. This work updates those inventories to provide annual inventory estimates for 2024 through 2029 (see **Table 7**, **Table 8**, and **Figure 12**). These estimates are consistent with the baseline estimates in the study titled "*The potential for cost-effective air emission reductions from international shipping through designation of further Emission Control Areas in EU waters with focus on the Mediterranean Sea*" (Cofala et al., 2018) funded by the European Commission, hereinafter referred to as the European Commission Study, as well as those in the study titled "*ECAMED: a Technical Feasibility Study for the Implementation of an Emission Control Area (ECA) in the Mediterranean Sea*" commissioned by France (Rouïl, Ratsivalaka, André, & Allemand, 2019), hereinafter referred to as the French Study, and with IEA estimates summarised in **Section 3.2**, **Figure 15**. **Table 9** provides the effective rates of change in demand by marine fuel type, based on the methods described in this report and in the Technical and Feasibility Study.

The European Commission Study reports 2015 fuel demand and projects 2050 fuel demand associated with a higher growth rate of 2.67% per year (Cofala et al., 2018) (the European Commission Study included a scenario "with climate measures" that results in a growth rate to 2030 of 1.14%; see its Annex 3, Table 3.1). The growth rate used in the European Commission Study does not consider energy efficiency measures or other energy conserving behaviour by fleets; this explains why future year fuel demand falls in the higher range of growth rates used in the final report of the Third IMO GHG Study 2014 (MEPC 67/INF.3), hereinafter referred to as the Third IMO GHG Study 2014, and outside the upper range of all other studies reviewed in this work. The French Study reports only 2020 fuel estimates (Rouïl et al., 2019), which are in close agreement with 2020 fuel estimates in the Technical and Feasibility Study and does not make any future-year projections; however, the change in fuel consumption estimated between their reference year (2015) and 2020 corresponds to an annual change of -0.8%.

Table 7: Estimated annual fuel consumption in the Mediterranean Sea Area, 2024-2029

	2024	2025	2026	2027	2028	2029
ktonnes	**Med SO_X ECA**	**Med SO_X ECA**	**Med SO_X ECA**	**Med SO_X ECA**	**Med SO_X ECA**	**Med SO_X ECA**
Total Fuel	16,400	16,225	16,050	15,875	15,700	15,525
MGO	16,020	15,850	15,680	15,510	15,340	15,170
MDO	158	156	154	153	151	150
HFO	91	90	89	88	87	86
LNG	132	131	130	128	127	125

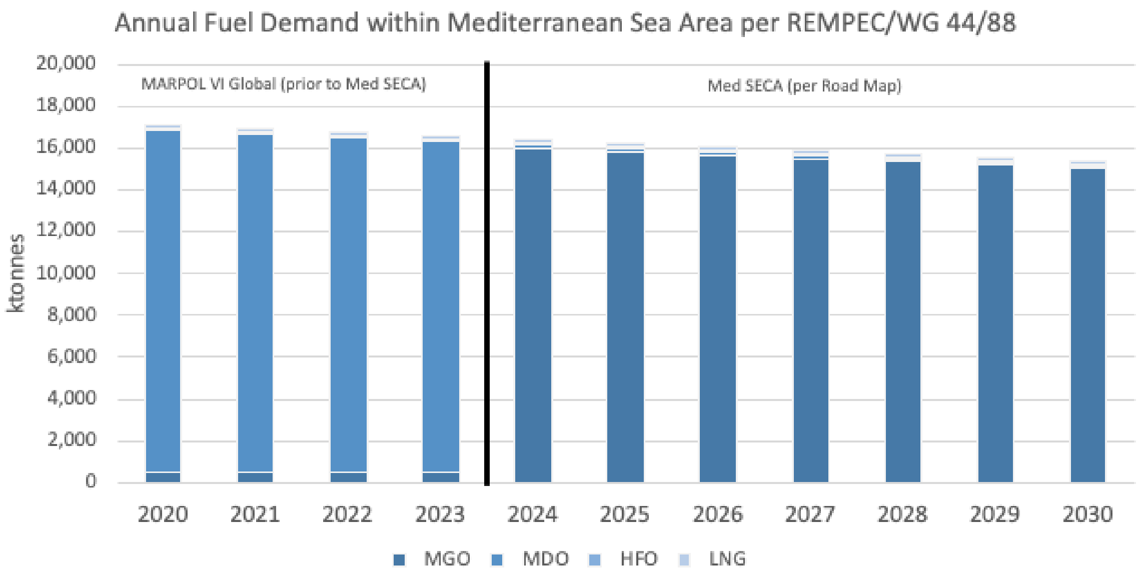


Figure 12: Multi-year estimates of annual fuel consumption in the Mediterranean Sea Area (2020-2030)

Table 8: Estimated Mediterranean Sea Area marine fuel demand, years 2020, 2025, 2030, 2040, 2050

	2020	2025	2030	2040	2050
ktonnes	**MARPOL VI**	**Med SO_X ECA**	**Med SO_X ECA**	**Med SO_X ECA**	**Med SO_X ECA**
Total Fuel	17,100	16,225	15,350	13,810	12,450
MGO	522	15,850	15,000	13,490	12,160
MDO	16,340	156	148	133	120
HFO	100	90	85	77	69
LNG	141	131	124	112	101

Table 9: Net change in demand for marine fuels, and annual rates of change, in the Mediterranean Sea Area 2020-2030

Fuel (ktonnes)	Change in demand 2020-2030	Percent change in annual demand
Total Fuel	-1,750	-1.1%
MGO	14,478	39.9%
MDO	-16,192	-37.5%
HFO	-15	-1.6%
LNG	-17	-1.3%

3.1.2 Demand by vessel type and by fuel type

Cargo ships represent the majority (51%) by number. Container ships represent 35% of main engine fuel consumption. Tankers and container vessels each have similar mean DWT per vessel. Cargo ships and tankers, because of the combination of their numbers and sizes, represent ~40% and ~41% of summed DWT active in the Mediterranean Sea Area, respectively. Importantly, the last column of **Table 10** shows the percent of transport work (percent of tonne-km) by vessel type. Container ships account for about 41% and tankers account for about 34% of transport work, respectively, (Cruise vessels do not perform cargo transport work in tonne-km, so are not shown on **Figure 13b**). **Table 11** presents a summary of the information illustrated graphically in **Figure 13**. **Figure 14** presents the same data, according to vessel type, allocating vessel voyages to international and national activity.

Table 10: Vessel type comparisons by count, fuel use, vessel size, and transport work

Vessel type	Vessel Count	ME Fuel Use (000 MT)	Mean DWT	Sum DWT (000)	Transport work	
					(Billion t-km)	(% t-km)
Cargo ships	7,333	2,111	37,488	274,896	1,435	25%
Container ships	2,061	3,876	65,189	134,354	2,361	41%
Cruise vessels	180	666	5,122	922	0	0%
RoPax vessels	538	1,754	2,401	1,292	50	1%
Tankers	4,309	2,669	65,807	283,563	1,959	34%

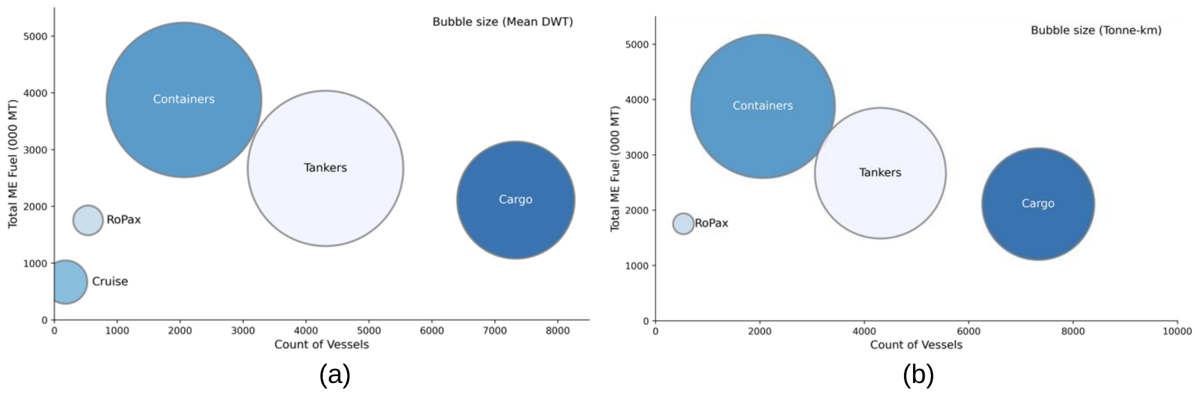


Figure 13: Vessel count (x-axis) and main engine fuel use (y-axis) according to (a) mean DWT (bubble size) and (b) transport work (bubble size) for vessels operating in the Mediterranean Sea Area

Table 11: Fuel use (ktonne/y) by vessel type and national versus international grouping

	National		International		Total	
Vessel type	**Count**	**Percent**	**Count**	**Percent**	**Count**	**Percent**
RoPax	4,196	55%	3,456	45%	7,653	11.6%
Vehicle Carriers	731	16%	3,898	84%	4,630	7.0%
Cargo Ships	1,951	17%	9,646	83%	11,597	17.6%
Container Ships	3,349	16%	17,665	84%	21,014	31.8%
Tankers	3,019	22%	10,738	78%	13,757	20.8%
Passenger Ships	607	84%	113	16%	720	1.1%
Cruise Vessels	541	26%	1,530	74%	2,071	3.1%
Fishing Vessels	740	89%	87	11%	827	1.3%
Service Ships	431	77%	126	23%	557	0.8%
Unknown	1,011	66%	529	34%	1,540	2.3%
Miscellaneous	1,013	63%	604	37%	1,617	2.5%
All fleet	**17,590**	**27%**	**48,393**	**73%**	**65,983**	**100%**

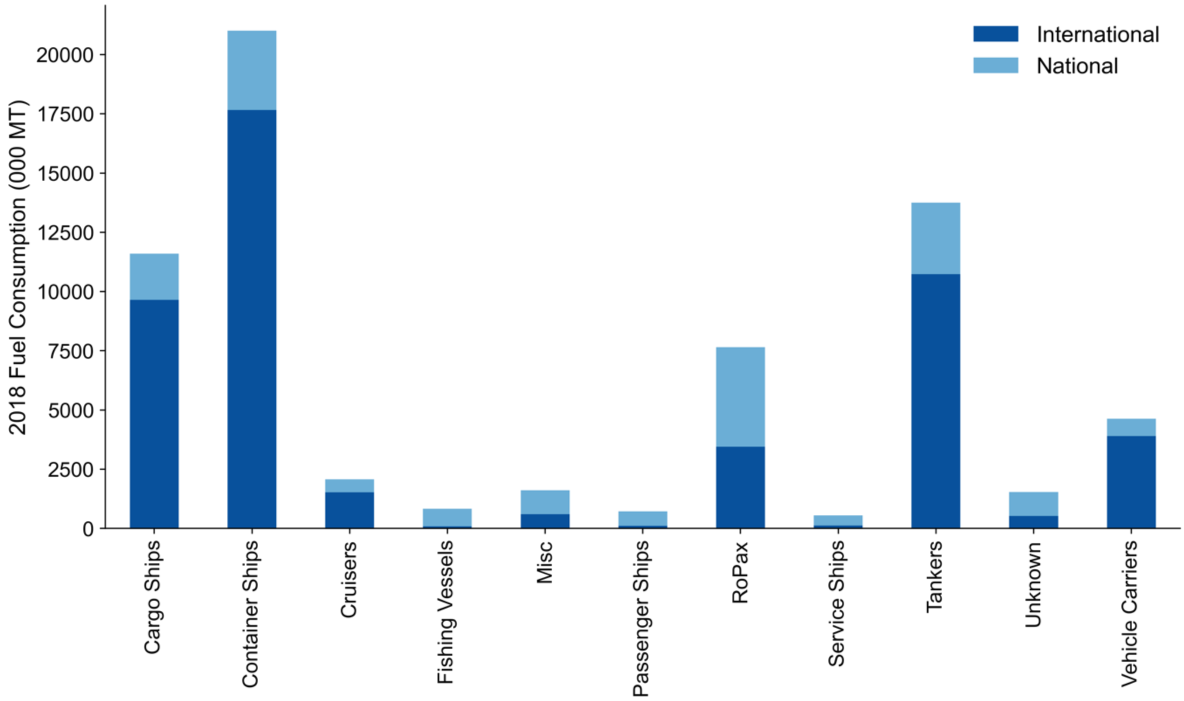


Figure 14: Main engine fuel use by vessel type, partitioned by international and national activity in the Mediterranean Sea Area (2018 data)

3.2 Marine fuel demand globally and among Mediterranean coastal States that are Contracting Parties to the Barcelona Convention based on IEA statistics

Table 12 presents gas/diesel consumption for non-marine and marine sectors, including marine bunker estimates adjusted according to methods in **Section 2.4.2** as reported by IEA. **Table 13** presents fuel oil consumption for non-marine and marine sectors, including marine bunker estimates adjusted according to methods in **Section 2.4.2** as reported by IEA. **Table 14** presents the sum of fuel oil and gas/diesel consumption for non-marine and marine sectors, including marine bunker estimates adjusted according to methods in **Section 2.4.2** as reported by IEA. These are all reported at the global scale, for the set of major producing countries, for the set of major bunkering countries, for the joint set of Mediterranean and adjacent countries, and for Mediterranean coastal States that are Contracting Parties to the Barcelona Convention. **Figure 15** and **Figure 16** present estimates for marine bunkers based on IEA data with export-import and net transfers data used to reconcile top-down and bottom-up fuel estimates.

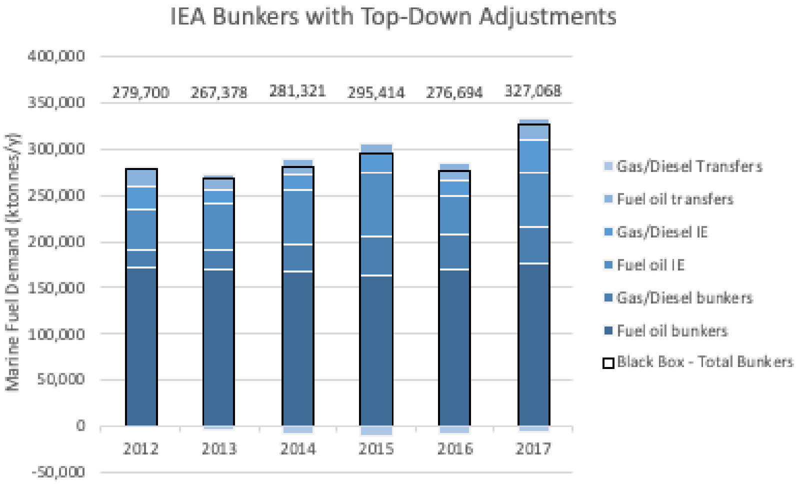


Figure 15: Global demand for marine bunkers reported by IEA, with top-down adjustments (2012-2017)

Table 12: Consumption of gas/diesel including bunkers across global, major country, regional, and Mediterranean scales (2017 IEA data)

			Per the Technical and Feasibility Study, Med SO_X ECA 2020 demand for gas/diesel is 16,862	
Scale of Summary (ktonnes/yr)	**Count of countries**	**Gas/diesel non-marine consumption**	**Gas/diesel bunkers (IEA reported)**	**Gas/diesel bunkers (Max estimate)**
Global - All reporting	141	1,214,690	39,478	52,925
Major Producing countries (90% supply)	38	997,004	31,943	34,601
Major Bunkering countries (90% supply)	24	783,764	34,272	37,124
Adjacent countries + Mediterranean coastal States	47	348,658	7,204	9,658
Mediterranean coastal States	21	166,583	2,828	3,791

Table 13: Consumption of fuel oil including bunkers across global, major country, regional, and Mediterranean scales (2017 IEA data)

			Per the Technical and Feasibility Study, Med SO_X ECA 2020 demand for fuel oil is 95	
Scale of Summary (ktonnes/yr)	**Count of countries**	**Fuel oil non-marine consumption**	**Fuel oil bunkers (IEA reported)**	**Fuel oil bunkers (Max estimate)**
Global - All reporting	141	87,297	177,007	269,786
Major Producing countries (90% supply)	38	74,498	152,806	191,755
Major Bunkering countries (90% supply)	24	60,772	160,865	201,868
Adjacent countries + Mediterranean coastal States	47	36,535	45,707	69,664
Mediterranean coastal States	21	8,510	14,924	22,746

Table 14: Consumption of fuel oil and gas/diesel summed across global, major country, regional, and Mediterranean scales (2017 IEA data)

			Per the Technical and Feasibility Study, Med SO_X ECA 2020 fuel oil + gas/diesel is 16,959	
Scale of Summary (ktonnes/yr)	**Count of countries**	**Fuel oil and Gas/diesel non-marine consumption**	**Total bunkers (IEA reported)**	**Total bunkers (Max estimate)**
Global - All reporting	141	1,301,987	216,485	322,710
Major Producing countries (90% supply)	38	1,071,502	184,749	226,356
Major Bunkering countries (90% supply)	24	844,536	195,137	238,992
Adjacent countries + Mediterranean coastal States	47	385,193	52,911	79,322
Mediterranean coastal States	21	175,093	17,752	26,538

3.2.1 Marine bunker demand trends, including top-down adjustments

Top-down inventory methods developed for the Third IMO GHG Study 2014 and applied again for the Fourth IMO GHG Study 2020 are applied here. This includes listing the IEA reported marine bunkers, with adjustment for export-import discrepancy and for fuels transfer balance reconciliation. The methods in the IMO GHG Studies are discussed further in **Section 5.2**. **Figure 16** presents a time-series of the elements of a top-down record of marine fuels demand using IEA statistics.

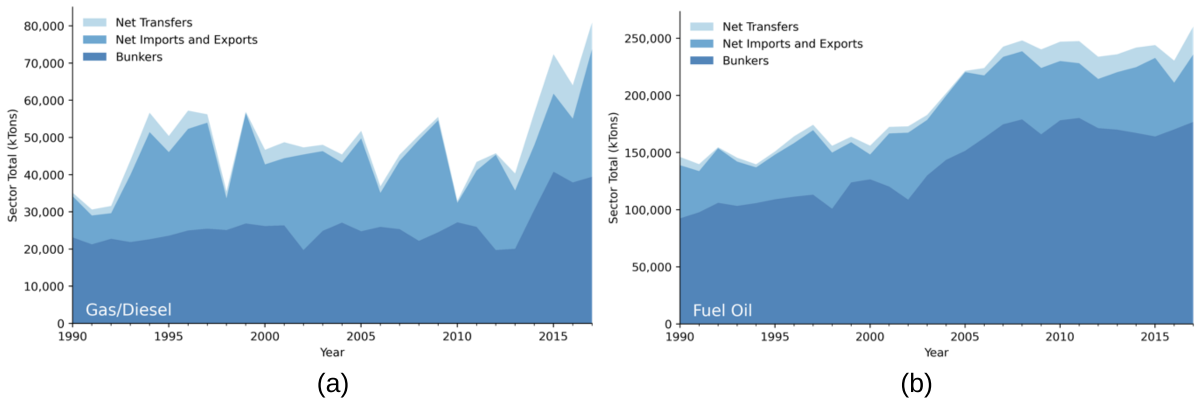


Figure 16: Marine bunker consumption trends since 1990, with top-down adjustments, for a) gas/diesel, and b) fuel oil

3.3 Demand sensitivity analysis with alternative compliance technologies and/or fuels

This section provides assessment, using the most recent forecasts of the Technical and Feasibility Study and other relevant information, of the availability, current use, and future uptake to comply with the 0.10% sulphur requirement of alternative compliance technologies (EGCS) or alternative fuels (such as LNG, biofuels, synthetic fuels, etc.) in the Mediterranean Sea, taking into account their economic viability as considered in the Technical and Feasibility Study.

Reanalysis produces similar results as the Technical and Feasibility Study, except that update fuel prices are lower so economically feasible adoption rates are estimated to be lower too (**Table 15**). This is expected because fuel price differentials are nearly identical even to those projected for 2020 in the prior study. We find continued feasibility for these alternative compliance technologies and alternative fuels. The reason fewer ships adopt these technologies can be explained by the combination of three factors: (a) the fuel price difference is about the same, indicating similar potential fuel savings for ships that can use higher sulphur fuel or use alternative fuel; (b) the absolute prices are lower, which increases the relative impact of capital costs in terms of the annualised costs for alternative compliance technologies and fuels; (c) the combined fuel and capital costs result fewer vessels with economically feasible conditions for EGCS and LNG adoption.

Table 15: Comparison of fuel prices from the Technical and Feasibility Study and this study

Study reference	> 0.50% S m/m	< 0.50% S m/m	< 0.10% S m/m	LNG Price
Technical and Feasibility Study	$424	$760	$858	$327
This study	$329	$344	$443	$137

Table 16 indicates that about 1,900 vessels, some 6% of the fleet operating in the Mediterranean Sea Area, could adopt EGCS technology, under conservative 100-year investment horizon and 15% investment rate. This conservative investment horizon may be considered to describe the least cost investment option, and therefore defines the most favourable conditions for investment in exhaust gas cleaning technology. Adoption rates for EGCS with current prices are much lower than the ~18% fleet adoption rate in the Technical and Feasibility Study with higher prospective fuel cost estimates.

Table 16: Fleet counts considered for EGCS technology

	Fleet Count	Percent of Total Fleet
EGCS	1,920	5.8%
No EGCS	31,243	94.2%

As with the Technical and Feasibility Study, we performed some sensitivity analyses to further explore economically feasible conditions. **Table 17** shows the expected EGCS investment rates over a range of investment horizons. Investment decisions are typically confidential business information, and thus we parameterise the decision over a range of investment lifetimes.

Table 17: Updated cost analysis relating EGCS capital costs and investment years to the percent of the fleet using EGCS technologies in the proposed Med SO_X ECA

	Feasible EGCS Use, Capital included		
Investment years	**Med SO_X ECA Compliance Savings ($Billions)**	**Number of EGCS installations**	**Percent of Fleet Using EGCS**
None	$0.38		5.8%
1	$0.00	0	0.0%
5	$0.02	54	0.2%
10	$0.10	473	1.4%
11	$0.13	648	2.0%
12	$0.16	782	2.4%
14	$0.19	1,025	3.1%
15	$0.26	1,243	3.7%
20	$0.38	1,920	5.8%
25	$0.48	2,733	8.2%
30	$0.54	4,199	12.7%
50	$0.61	5,780	17.4%
100	$0.62	5,972	18.0%

Table 18 presents a summary of overall fleet counts combining all ships using the updated observed fuel prices. Under our base input conditions, about 6.5% of the fleet operating in the Mediterranean Sea Area could feasibly consider alternative fuels for cost-saving compliance with the proposed Med SO_X ECA. The Technical and Feasibility Study assumed higher fuel prospective prices, which led to alternative fuel adoption rates nearly double those currently feasible.

The economic feasibility of alternative fuels will be sensitive to several inputs, primarily to the fuel-price differential between SECA compliant fuel and the alternative fuel (LNG in this analysis). **Table 19** illustrates this through sensitivity analysis that exercises the LNG fuel price from no-cost ($0) through a price equal to SECA fuel. As illustrated, fleet adoption rates from nearly 10% to 0% are dependent upon the net savings of installing power systems for and operating alternative fuels. The shaded row represents the results of this analysis using observed lower fuel prices from **Table 15**.

Table 18: Updated fleet counts considered for alternative fuel replacement, and the number that could reduce SECA compliance costs

Feasibility Category	Fleet Count	Percent of Total Fleet
Scrapping age (>20 yrs.)	19,659	59.3%
Alternative Fuel-cost Feasible	2,148	6.5%
Other Criteria Necessary	17,511	52.8%

Table 19: Updated cost analysis relating LNG price and LNG-MGO price differential to the percent of the fleet (all vessel types) adopting alternative fuel

LNG Price[1]	LNG-MGO Price Δ	Proposed Med SO_X ECA Cost with LNG Alternative ($ Billion per year)	Proposed Med SO_X ECA Savings with LNG ($ Billion per year)	Fleet Percent Adoption[2]
$0	$443	$6.917	$1.140	10.0%
$50	$393	$7.045	$1.012	8.8%
$100	$343	$7.173	$0.884	7.5%
$137	$306	$7.268	$0.789	6.5%
$150	$293	$7.302	$0.756	6.1%
$200	$243	$7.430	$0.627	4.7%
$300	$143	$7.686	$0.371	2.1%
$350	$93	$7.814	$0.243	0.8%
$400	$43	$7.943	$0.114	0.1%
$443	$0	$8.053	$0.004	0.0%

4 Supply estimates for marine and non-marine petroleum products

This report evaluates fuel oil and gas/diesel capacity and production to supply both marine and non-marine demand. **Figure 17** presents IEA fuel oil and gas/diesel production data for Mediterranean coastal States that are Contracting Parties to the Barcelona Convention. The data represent production that may contribute to exports and imports among these countries, or net export to world markets outside this group of countries. Other products may be imported to meet consumption demand in non-marine and marine sectors. In other words, these production statistics do not accurately describe production to meet regional demand.

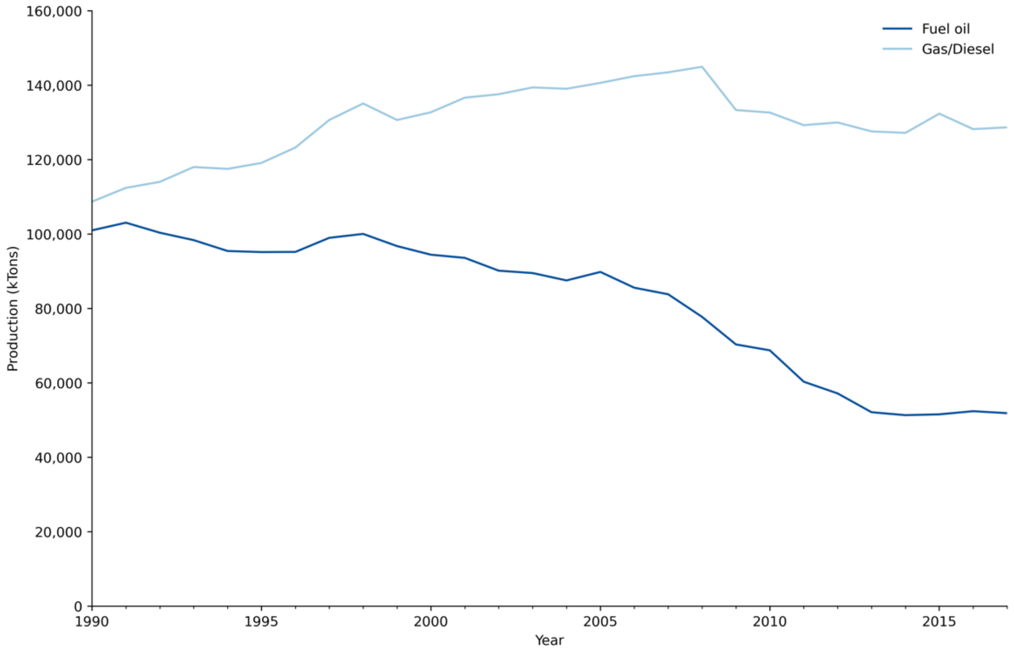


Figure 17: Fuel oil and gas/diesel production trends (1990-2017) for Contracting Parties to the Barcelona Convention

4.1 Refinery capacity and production

Table 20 presents crude capacity as reported by the Oil and Gas Journal, gas/diesel refining capacity estimated per **Section 2.5**, and gas/diesel production as reported by IEA. **Table 21** presents crude capacity as reported by the Oil and Gas Journal, fuel oil refining capacity estimated per **Section 2.5**, and fuel oil production as reported by IEA. **Table 22** presents crude capacity as reported by the Oil and Gas Journal, the sum of fuel oil and gas/diesel refining capacity estimated per **Section 2.5**, and fuel oil production as reported by IEA. These are all reported at the global scale, for the set of major producing countries, for the set of major bunkering countries, for the joint set of Mediterranean and adjacent countries, and for Mediterranean coastal States that are Contracting Parties to the Barcelona Convention.

Table 20: Production of gas/diesel across global, major country, regional, and Mediterranean scales (ktonnes per year)

Scale of Summary (units ktonnes/yr)	Count of countries	Crude capacity	Gas/diesel capacity	Gas/diesel production
Global - All reporting	141	4,929,022	1,763,017	1,348,905
Major Producing countries (90% supply)	38	4,352,402	1,556,771	1,229,145
Major Bunkering countries (90% supply)	24	3,571,015	1,277,284	1,011,159
Adjacent countries + Mediterranean coastal States	47	1,204,782	430,928	334,151
Mediterranean coastal States	21	480,178	171,751	128,683

Table 21: Production of fuel oil across global, major country, regional, and Mediterranean scales

Scale of Summary (units ktonnes/yr)	Count of countries	Crude capacity	Fuel oil capacity	Fuel oil production
Global - All reporting	141	4,929,022	607,091	434,040
Major Producing countries (90% supply)	38	4,352,402	536,071	377,756
Major Bunkering countries (90% supply)	24	3,571,015	439,830	251,995
Adjacent countries + Mediterranean coastal States	47	1,204,782	148,389	151,588
Mediterranean coastal States	21	480,178	59,142	51,866

Table 22: Production of fuel oil and gas/diesel summed across global, major country, regional, and Mediterranean scales

Scale of Summary (units ktonnes/yr)	Count of countries	Fuel oil and gas/diesel capacity	Fuel oil and gas/diesel production
Global - All reporting	141	2,370,108	1,782,945
Major Producing countries (90% supply)	38	2,092,842	1,606,901
Major Bunkering countries (90% supply)	24	1,717,114	1,263,154
Adjacent countries + Mediterranean coastal States	47	579,317	485,739
Mediterranean coastal States	21	230,892	180,549

4.2 Summary of refinery information obtained for Mediterranean coastal States that are Contracting Parties to the Barcelona Convention

Table 23 summarises capacity estimates by Mediterranean coastal State that are Contracting Parties to the Barcelona Convention, reported in million tonnes for crude processing, and for fuel oil and gas/diesel products. Data include more than seventy refineries within these countries as reported by the Oil and Gas Journal in 2019. We may provide a map of their locations based on publicly available data.

Table 23: Refining capacity estimates for Mediterranean coastal States that are Contracting Parties to the Barcelona Convention

MMT / Country	Crude capacity	Fuel oil capacity	Gas/diesel capacity
Albania	1,644	203	588
Algeria	28,926	3,563	10,346
Bosnia and Herzegovina	13,153	1,620	4,705
Croatia	11,757	1,448	4,205
Cyprus			
Egypt	41,800	5,148	14,951
France	69,169	8,519	24,740
Greece	23,182	2,855	8,292
Israel	12,057	1,485	4,313
Italy	116,340	14,329	41,613
Lebanon			
Libya	20,826	2,565	7,449
Malta			
Monaco			
Montenegro			
Morocco			
Slovenia	740	91	265
Spain	78,234	9,636	27,983
Syrian Arab Republic	13,146	1,619	4,702
Tunisia	1,863	230	666
Turkey	47,340	5,831	16,933

5 Analysis of other relevant information regarding fuel availability

This section evaluates other relevant information including: i) the IMO Fuel Availability Study; ii) the Third IMO GHG Study 2014; iii) the Fourth IMO GHG Study 2020; and iv) the World Oil Outlook 2040 (2019 edition).

The IMO Fuel Availability Study (Faber et al., 2020) estimates for refinery capacity and production in 2020 compare well with refinery capacity and production statistics assessed in this work; in fact, the agreement provides mutual validation for the quality of the conclusions of the IMO Fuel Availability Study and the findings of this report. The IMO Fuel Availability Study estimates for marine fuel demand, indeed for consumption demand across all petroleum product sectors, is also confirmed and consistent with the demand assessment in this report. In addition, the IMO Fuel Availability Study employed a demand growth assumption consistent with those used in the Technical and Feasibility Study, which used the STEAM model included dynamic step changes on an annual basis, assigned stochastically to employ fleet-specific adjustments for power, tonnage, and vessel counts, and combined energy efficiency improvements that the IMO Fuel Availability Study did not.

The Third IMO GHG Study 2014 and the Fourth IMO GHG Study 2020 provide a record of demand for marine bunkers that demonstrates consistent fuel inventory trends, validating the methods and precision of methods in both studies. The Third IMO GHG Study 2014 was the first IMO GHG Study to rigorously reconcile top-down statistics on marine bunker consumption with bottom-up estimates, by making adjustments for unreported marine bunker consumption embedded in export-import discrepancies and non-zero net transfers statistics. The Fourth IMO GHG Study 2020 confirmed these top-down adjustments help reconcile activity-based fuel demand and reported consumption of marine bunkers. This report also employs these rigorous top-down inventory adjustments at the global scale, thereby ensuring that our demand estimates are consistent with IMO GHG studies bottom-up inventories. In addition, the IMO GHG Studies produced future scenarios with explicit assumptions about fuel demand growth. Central growth rates in the Fourth IMO GHG Study 2020 are consistent with the demand growth evaluated in this report, while the Third IMO GHG Study 2014 presented a set of higher growth rate scenarios that overstated observations since.

The World Oil Outlook 2040 (OPEC Organization of the Petroleum Exporting Countries, 2019) provides insight into three issues relevant to this work. First, according to the World Oil Outlook Chapter 5, production capacity since 1980 has exceeded production, although “levels of total liquid demand and nameplate refinery capacity almost converged” in 2004-5, and 2013-2015. Nonetheless, with “assumed medium-term closures, spare capacity is expected to increase to around 4 mb/d in 2024”. Beyond 2025, the outlook for long-term regional refinery utilisation forecasts increasing excess capacity, suggesting that declining demand may result in additional refinery closures. While phrased in the context of refining economics, this result confirms that excess capacity exists to meet increasing demand for distillate fuels resulting from the Med SO_X ECA. Second, projected demand for international marine bunkers (2018-2040) is closely aligned with this work, providing a third point of validation along with the IMO Fuel Availability Study and the Fourth IMO GHG Study 2020. Third, international marine fuel demand growth rates associated with the World Oil Outlook are nearly identical to the central growth rates in this analysis, and in the other relevant studies.

As shown in **Section 3**, projected fuel demand of international shipping through at least 2040 is less than the supply potential estimated by the IMO Fuel Availability Study. This result is robust in comparison with the World Oil Outlook projections which have the same growth rate as the central estimate of the Fourth IMO GHG Study 2020 projections, and robust in comparison with the high-growth scenario in the Fourth IMO GHG Study 2020 (**Figure 18**).

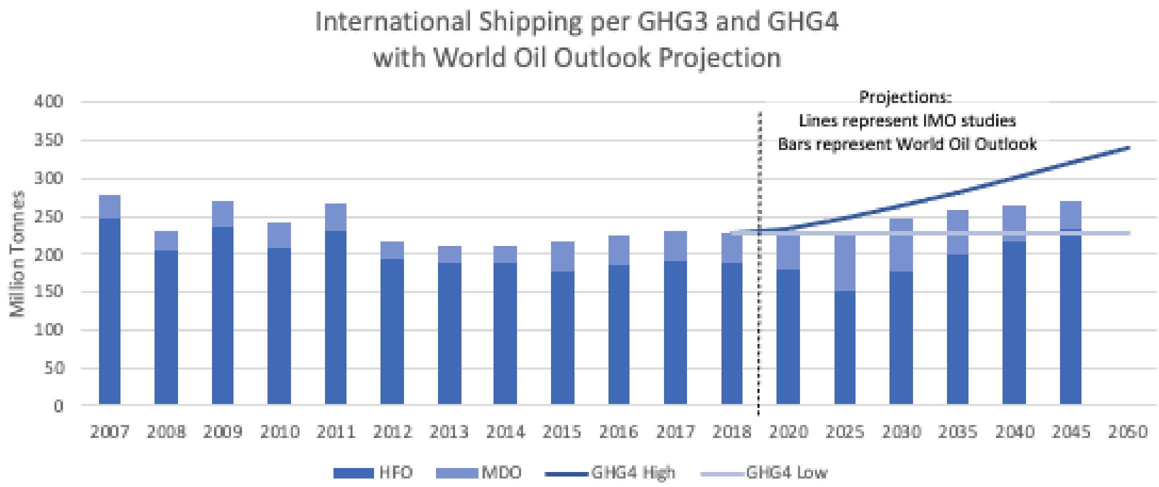


Figure 18: Combined time series of international shipping fuel estimates from the Third IMO GHG Study 2014 and the Fourth IMO GHG Study 2020 coupled with World Oil Outlook projections (bars) and the Fourth IMO GHG Study 2020 high and low scenarios (lines)

5.1 IMO Fuel Availability Study

The IMO Fuel Availability Study developed and calibrated a refinery supply model (really a set of regionally calibrated refinery supply models) for 2012, that was updated with all refinery expansions and closures expected through 2020. The IMO Fuel Availability Study work used the model to assess whether global refining could produce marine fuels in sufficient quantities, while economically meeting demand for other sectors. "*The main result of the assessment is that in all scenarios the refinery sector has the capability to supply sufficient quantities of marine fuels with a sulphur content of 0.50% m/m or less and with a sulphur content of 0.10% m/m or less to meet demand for these products, while also meeting demand for non-marine fuels*" (IMO Fuel Availability Study, Chapter 1). The IMO Fuel Availability Study also found that in 2020 "*regional imbalances can be addressed by transporting fuels or by changing vessels' bunkering patterns*".

5.1.1 IMO Fuel Availability Study marine fuel demand estimates

Figure 19 presents a summary of production (+ values) and consumption (- values), excluding marine bunkers, reported by the IMO Fuel Availability Study. **Table 24** and **Table 25**, respectively, present supply capacity and production, and consumption of non-marine and marine sectors for both fuel oil and gas/diesel. **Figure 20** presents the refining capacity for crude oil, fuel oil and gas/diesel as reported by the IMO Fuel Availability Study.

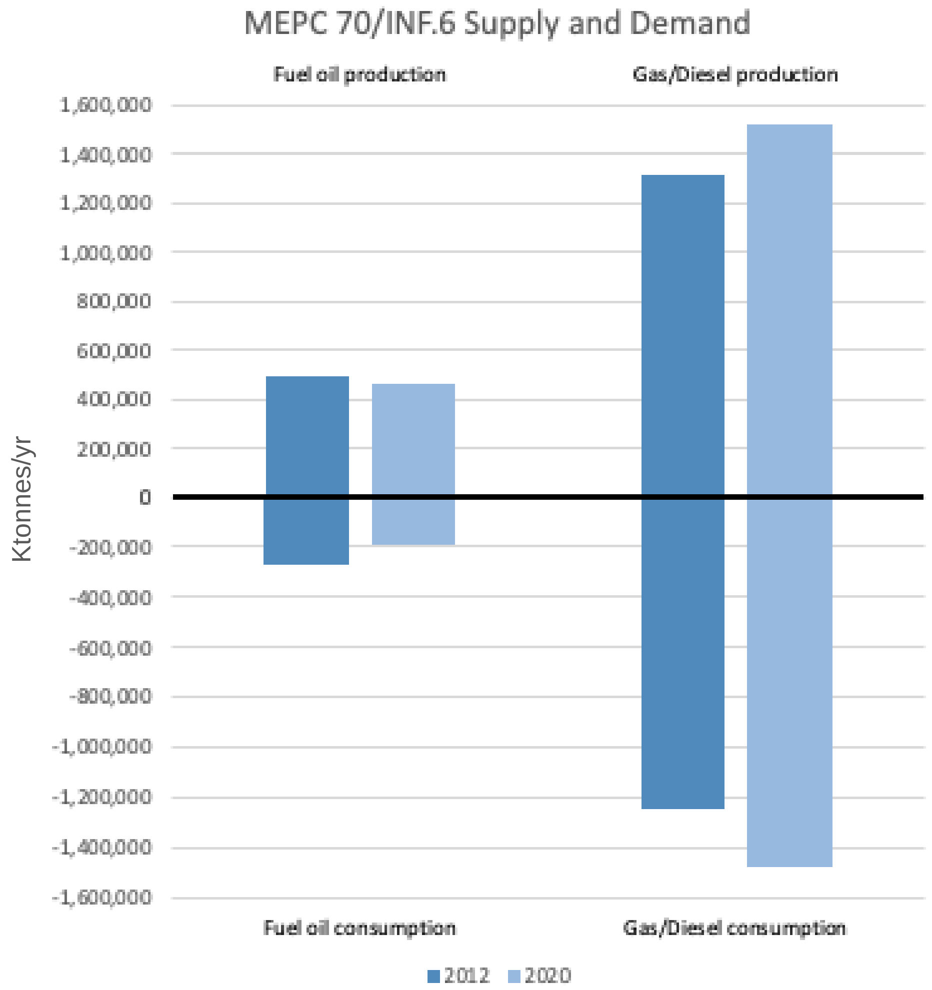


Figure 19: Summary of production-consumption balance (excluding marine bunkers) from the IMO Fuel Availability Study

Table 24: Fuel production results from the IMO Fuel Availability Study

Year	Crude capacity	Fuel oil capacity	Gas/diesel capacity	Fuel oil production	Gas/diesel production
2012	4,630,000	570,262	1,656,063	500,000	1,316,000
2020	5,020,000	618,297	1,795,558	463,000	1,521,000

Table 25: Fuel consumption results, including marine bunkers, from the IMO Fuel Availability Study

Year	Fuel oil consumption	Gas/diesel consumption	Fuel oil bunkers	Gas/diesel bunkers
2012	272,000	1,252,000	228,000	64,000
2020	194,000	1,482,000	269,000	39,000

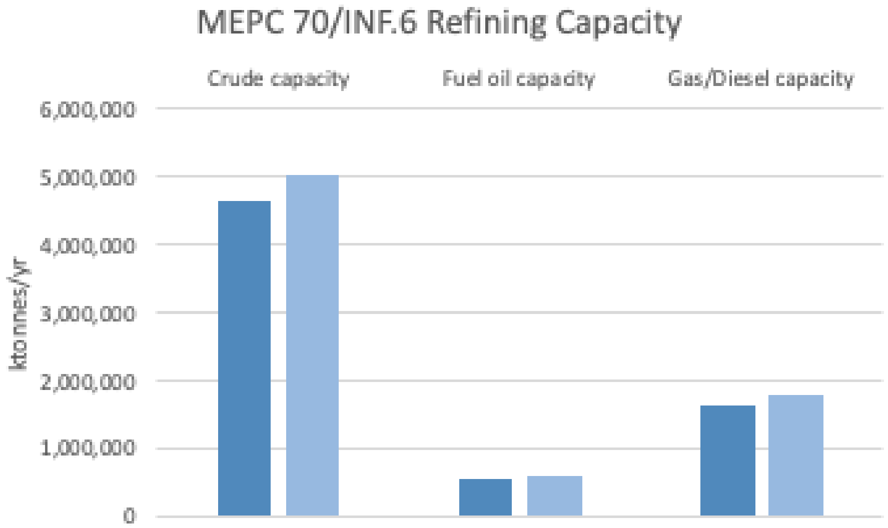


Figure 20: Refining capacity results from the IMO Fuel Availability Study for crude, fuel oil, and gas/diesel

Figure 21 presents a comparison of net capacity estimate for 2012 and 2020, respectively, from data reported in the IMO Fuel Availability Study, with net capacity estimates for this work using reported and adjusted top-down estimates of international marine fuel demand. Net capacity is greater because the investment in production exceeded assumption in the IMO Fuel Availability Study, and because change in demand for marine bunkers has been similar to (or less than) assumed in the IMO Fuel Availability Study.

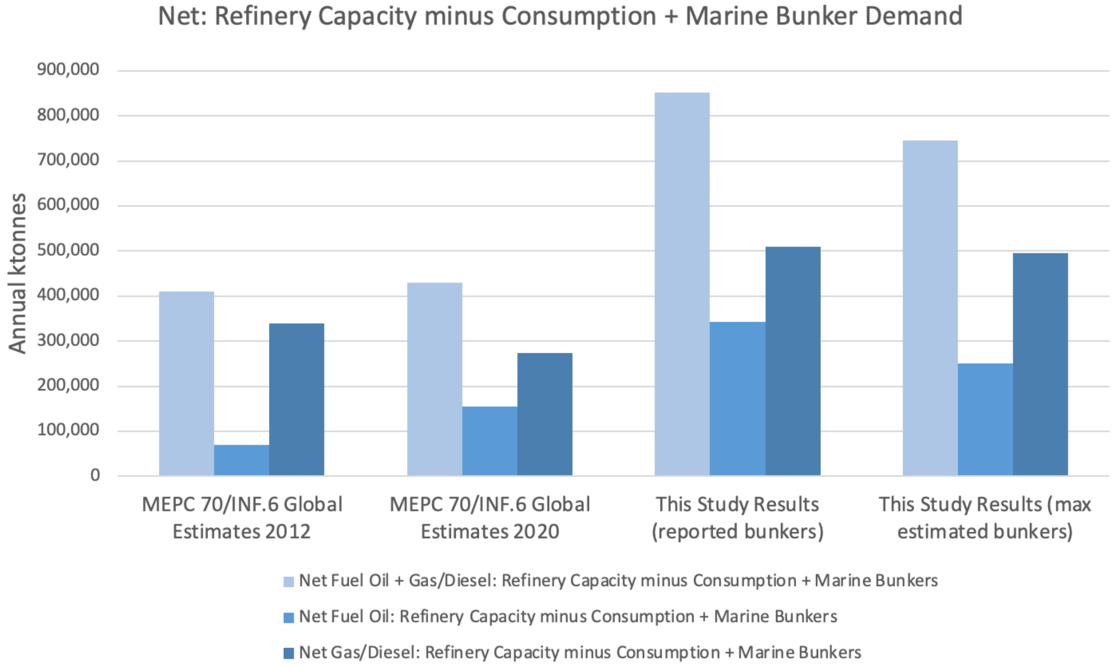


Figure 21: Net refining capacity estimated by IMO Fuel Availability Study underestimated current net capacity

5.1.2 IMO Fuel Availability Study fuel demand growth rates

The IMO Fuel Availability Study "*projected a compound annual growth rate (CAGR) of 1.5% for world petroleum demand. The IMO Fuel Availability Study compared their growth rates to projections in OPEC's World Oil Outlook 2015 (CAGR of 1.1%); IEA's Medium Term Oil Market Report 2016 (CAGR of 1.3%) and EIA's International Energy Outlook 2016 (EIA, 2016) (CAGR of 1.3%).*" That work explained the "*main reasons for the differences between the studies are different assumptions about economic growth and the fuel economy of road transport*". For non-marine fuels demand, the IMO Fuel Availability Study assumed in the base case that demand between 2012 and 2020 would grow by ~5.5% with a low rate of demand change at -8% and a high rate of demand change at 21% (IMO Fuel Availability Study, Section 4.7).

For marine petroleum demand, the IMO Fuel Availability Study (Table 27 of that report), projected a compound annual growth rate of 0.7% for marine petroleum demand (**Table 26**), with a range of annual growth rates between -1% and 2.4%.

Table 26: Change in fuel demand, annual growth rates, and growth ratios reported in the IMO Fuel Availability Study

	Marine Petroleum Demand			
Year	**Low**	**Base Case**	**High**	**Non-marine**
2012	292	292	292	3692
2020	269	308	352	4190
CAGR	**-1.0%**	**0.67%**	**2.4%**	**1.6%**
Ratio	0.92	1.05	1.21	1.13

5.1.3 IMO Fuel Availability Study production capacity, production, and consumption for gas/diesel and fuel oil

Table 27, **Table 28**, and **Table 29** present global refinery capacity and production data for gas/diesel, fuel oil, and the sum of fuel oil and gas/diesel, respectively. **Table 30**, **Table 31**, and **Table 32** present global consumption for non-marine and marine demand of gas/diesel, fuel oil, and the sum of fuel oil and gas/diesel, respectively.

Table 27: Production of gas/diesel reported for 2012 and 2020 by the IMO Fuel Availability Study

Year of estimate (units ktonnes/yr)	Crude capacity	Gas/diesel capacity	Gas/diesel production
2012 Global - IMO Fuel Availability Study	4,630,000	1,656,063	1,316,000
2020 Global - IMO Fuel Availability Study	5,020,000	1,795,558	1,521,000

Table 28: Production of fuel oil reported for 2012 and 2020 by the IMO Fuel Availability Study

Year of estimate (units ktonnes/yr)	Crude capacity	Fuel oil capacity	Fuel oil production
2012 Global - IMO Fuel Availability Study	4,630,000	570,262	500,000
2020 Global - IMO Fuel Availability Study	5,020,000	618,297	463,000

Table 29: Production of gas/diesel reported for 2012 and 2020 by the IMO Fuel Availability Study

Year of estimate (units ktonnes/yr)	Crude capacity	Fuel oil and gas/diesel capacity	Fuel oil and gas/diesel production
2012 Global - IMO Fuel Availability Study	4,630,000	2,226,324	1,816,000
2020 Global - IMO Fuel Availability Study	5,020,000	2,413,855	1,984,000

Table 30: Consumption of fuel oil and gas/diesel summed across global, major country, regional, and Mediterranean scales

Year of estimate (units ktonnes/yr)	Gas/diesel consumption	Gas/diesel bunkers Per IMO Fuel Availability Study
2012 Global - IMO Fuel Availability Study	1,252,000	64,000
2020 Global - IMO Fuel Availability Study	1,482,000	39,000

Table 31: Consumption of fuel oil and gas/diesel summed across global, major country, regional, and Mediterranean scales

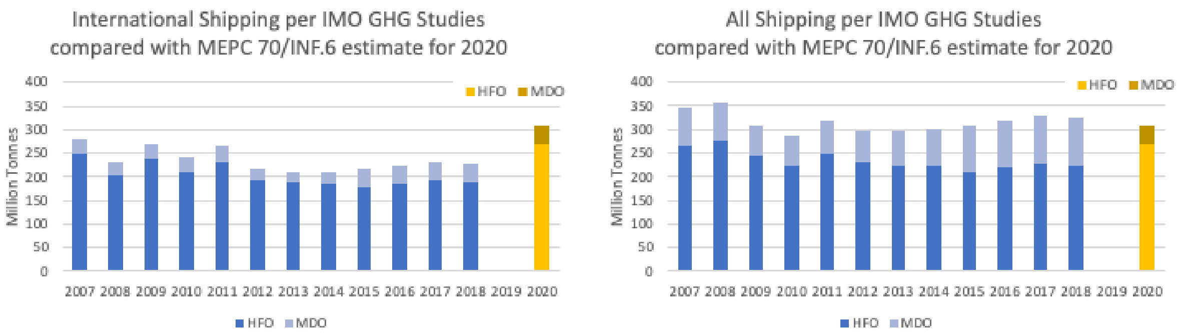
Year of estimate (units ktonnes/yr)	Fuel oil consumption	Fuel oil bunkers Per IMO Fuel Availability Study
2012 Global - IMO Fuel Availability Study	272,000	228,000
2020 Global - IMO Fuel Availability Study	194,000	269,000

Table 32: Consumption of fuel oil and gas/diesel summed across global, major country, regional, and Mediterranean scales

Year of estimate (units ktonnes/yr)	Fuel oil and gas/diesel consumption	Total bunkers Per IMO Fuel Availability Study
2012 Global - IMO Fuel Availability Study	1,524,000	292,000
2020 Global - IMO Fuel Availability Study	1,676,000	308,000

5.2 IMO GHG studies: Third IMO GHG Study 2014 and Fourth IMO GHG Study 2020

Figure 22 and **Table 33** present the set of bottom-up estimates for marine fuels use for (a) international shipping, and (b) all shipping as reported by the Third IMO GHG Study 2014 and the Fourth IMO GHG Study 2020. Also represented in **Figure 22** is the marine fuel demand estimate provided in the IMO Fuel Availability Study, demonstrating consistency with all-shipping marine fuel estimates among IMO studies.



(a) (b)

Figure 22: Demand for a) international marine bunkers, and b) all shipping, per the Third IMO GHG Study 2014 and the Fourth IMO GHG Study 2020

Table 33: Demand for global marine bunkers across years 2007-2018 per the Third IMO GHG Study 2014 and the Fourth IMO GHG Study 2020

Year / Fuel	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
HFO	265	276	246	223	250	231	225	223	208	219	227	223
MDO	82	83	62	64	70	68	72	77	100	100	103	103
Petroleum	348	358	308	287	320	299	297	299	308	319	330	326

5.2.1 Demand growth per the Third IMO GHG Study 2014

Growth rates for demand in the Third IMO GHG Study 2014 were associated with some 16 scenarios. Using projections reported by the Third IMO GHG Study 2014 (derived from Table 78 of that report), the range of growth rates can be observed for future marine fuel demand (**Table 34**).

Table 34: Third IMO GHG Study 2014 Annual Growth Rates summary across 16 Scenarios (2015-2050)

Scenario category	Annual Growth Rate	Range Descriptor
	0.04%	Min
Low	**1.09%**	25th Percentile
Middle	**1.69%**	Median
High	**2.51%**	75th Percentile
	3.61%	Max

5.2.2 Demand growth per Fourth IMO GHG Study 2020

Growth rates for total shipping demand in the Fourth IMO GHG Study 2020 were associated with Figure 26 of that report. "*In these BAU scenarios, the emissions of shipping are projected to increase from 1,000 Mt CO_2 in 2018 to 1,000 to 1,500 Mt CO_2 in 2050. This represents an increase of 0 to 50% over 2018 levels*". These projections translate to compound growth annual rate bounds between 0% and 1.28%; we evaluate the average of these bounds to be a middle estimate for annual growth rate of marine fuel demand as presented in **Table 35**.

Table 35: Fourth IMO GHG Study 2020 Annual Growth Rates for Scenarios (2018-2050)

Scenario	Annual Growth Rate
Low	0.00%
Middle	0.64%
High	1.28%

5.3 World Oil Outlook 2040 projections informing fuel availability

A review of the World Oil Outlook 2040 published by the Organization of the Petroleum Exporting Countries provides additional information on both petroleum supply and demand that relevant to the capacity to produce needed product. The World Oil Outlook also includes projections of international marine fuel demand through 2040; growth rates derived from these projections also offer another independent estimate for demand.

5.3.1 History and forecast of spare capacity for production by World Oil Outlook 2019

Figure 23 presents excess production capacity statistics since 1980 and projected through 2024.

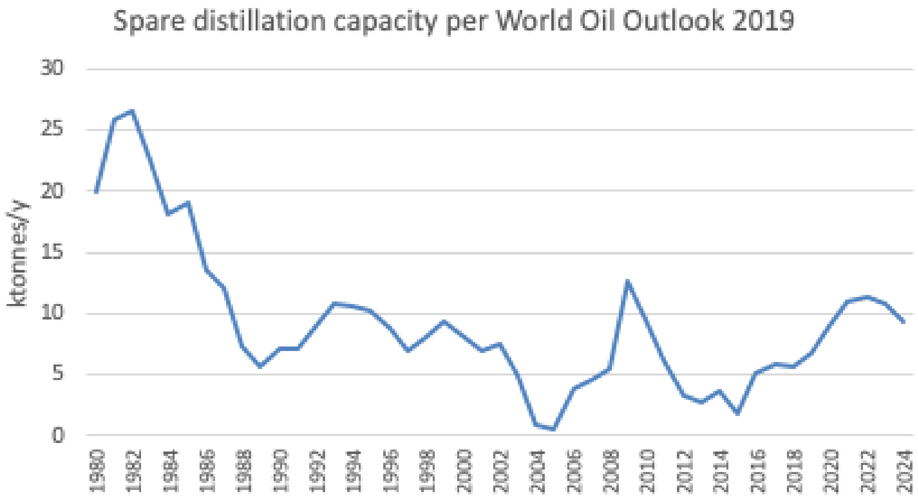


Figure 23: History and forecast of spare production capacity 1980-2024, based on 84% utilisation rates and closed capacity

5.3.2 Shipping fuel estimates from World Oil Outlook reports, compared with the IMO Fuel Availability Study

Figure 24 and **Table 36** present estimates for international marine fuels from 2018 through 2040. Also represented in **Figure 24** is the marine fuel demand estimate provided in the IMO Fuel Availability Study, demonstrating consistency with all-shipping marine fuel estimates among relevant global studies.

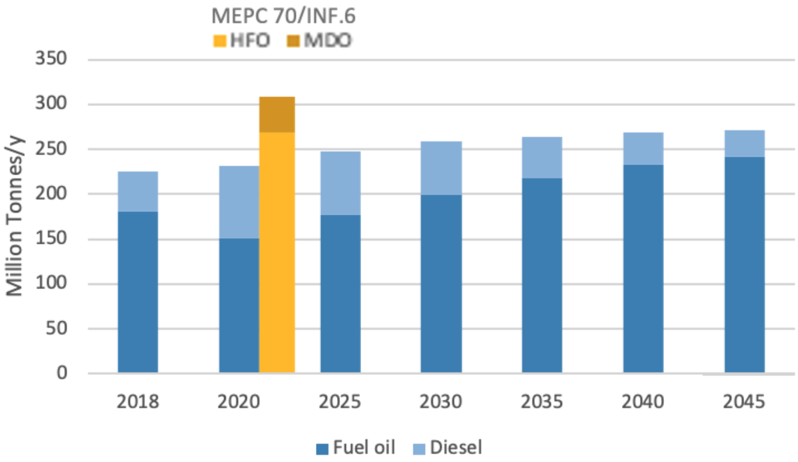


Figure 24: World Oil Outlook 2019 projected demand for International Marine Bunkers, compared with the IMO Fuel Availability Study

Table 36: World Oil Outlook 2019 Product demand for International Marine Bunkers, 2018-2040 (Million Tonnes)

Year / Fuel	2018	2020	2025	2030	2035	2040	2045
Diesel	44.6	80.7	71.2	59.1	46.1	36.3	30.9
Fuel oil	180.2	150.4	176.3	199.5	217.3	232.6	240.9
Total Marine Petroleum	224.9	231.1	247.5	258.6	263.4	268.9	271.7

5.3.3 Demand growth per World Oil Outlook to 2045

Table 37 presents annual growth rates associated with projected international marine bunkers.

Table 37: World Oil Outlook Annual Growth Rates for International Marine Bunkers 2018-2045

International Marine Bunkers	Annual Growth Rate
Diesel	-1.4%
Fuel oil	1.1%
Net Marine Petroleum	0.7%

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