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

Regional Expert Meeting on the possible designation of the Mediterranean Sea, as a whole, as an Emission Control Area for Sulphur Oxides (Med SO_X ECA) pursuant to MARPOL Annex VI	REMPEC/WG.50/INF.8* Date: 23 April 2021
Online, 27-28 April 2021	Original: English only
Agenda Item 2	

FINAL REPORT ON THE COMPLETION OF THE KNOWLEDGE GATHERING RELATED TO LAND-BASED EMISSIONS CONTROL MEASURES OF SO_X AND PM IN THE MEDITERRANEAN COASTAL STATES

Note by the Secretariat

SUMMARY

Executive Summary: This document presents the final report on the completion of the knowledge gathering related to land-based emissions control measures of SO_X and PM in the Mediterranean coastal States, 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).

* Reissued for technical reasons.
[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).

3 The final report on the completion of the knowledge gathering related to land-based emissions control measures of SO_X and Particulate matter (PM) in the Mediterranean coastal States, which was prepared pursuant to the road map according to the Terms of Reference set out in Appendix II to document REMPEC/WG.50/INF.6, is presented in the **Appendix** to the present document.

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 related to land-based emissions control measures of SO_X and PM in the Mediterranean coastal States

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

COMPLETION OF THE KNOWLEDGE GATHERING RELATED TO LAND-BASED EMISSIONS CONTROL MEASURES OF SO_X AND PM IN THE MEDITERRANEAN COASTAL STATES PURSUANT TO THE ROAD MAP FOR A PROPOSAL FOR THE POSSIBLE DESIGNATION OF THE MED SO_X ECA

(LOT 2)

Final Report

Prepared and submitted by

Dr Edward Carr, REMPEC Consultant

April 2021

This activity is financed by the Mediterranean Trust Fund (MTF) and implemented by the Mediterranean Pollution Assessment and Control Programme (MED POL) 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) and the Plan Bleu Regional Activity Centre (PB/RAC).

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Abbreviations and Definitions

Term	Explanation
CNY	Chinese Yuan
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
ECA	Emission Control Area
EERA	Energy and Environmental Research Associates, LLC
EJ	Exajoules
EU	European Union
g	Grams
GAINS	Greenhouse Gas - Air Pollution Interactions and Synergies, a model
Gg	1,000 metric tonnes
GHG	Greenhouse gas
HFO	Heavy fuel oil
IHO	International Hydrographic Organization
IIASA	International Institute for Applied Systems Analysis
IMO	International Maritime Organization
J	Joules
kJ	Kilojoules
LNG	Liquefied Natural Gas
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
MGO	Marine gas oil
MMT	Million Metric Tonne
MT	Metric Tonne (1,000 kg)
NECA	NO_X Emission Control Area
NO_X	Oxides of Nitrogen
pH	A measure of the acidity of a solution
PM	Particulate Matter
PM_{10}	PM with a mass median diameter less than 10 µm
$PM_{2.5}$	PM with a mass median diameter less than 2.5 µm
REMPEC	Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea
S	Sulphur
SECA	SO_X Emission Control Area
SO_2	Sulphur dioxide
SO_X	Oxides of Sulphur
UNFCCC	United Nations Framework Convention on Climate Change
WHO	World Health Organization
µm	micrometre or micron

1 Introduction

This report presents the result of the knowledge gathering completed under LOT 2 (Land-based emissions control measures of SO_X and PM in the Mediterranean coastal States) pursuant to the Road Map for a Proposal for the Possible Designation of the Mediterranean Sea, as a whole, as an Emission Control Area for Sulphur Oxides (Med SO_X ECA) Pursuant to MARPOL Annex VI, within the Framework of the Barcelona Convention (Decision IG.24/8), hereinafter referred to as the Road Map.

The Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC), in cooperation with the Mediterranean Pollution Assessment and Control Programme (MED POL) of the Mediterranean Action Plan (MAP) of the United Nations Environment Programme (UNEP), tasked Dr Edward Carr, REMPEC Consultant, to complete the knowledge gathering under LOT 2 pursuant to the road map with a view to more fully addressing the criteria and procedures for designation of emission control areas laid down in Appendix III to Annex VI to the International Convention for the Prevention of Pollution from Ships (MARPOL).

LOT 2 comprises knowledge gathering only, specifically to provide additional details on land-based emissions control measures of SO_X and PM in the Mediterranean coastal States 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 MARPOL Annex VI.

Ocean-going vessel engines emit a range of pollutants that have significant impacts on human health. Fine particulate matter ($PM_{2.5}$), which is less than 2.5 microns in diameter, and sulphur oxides (SO_X) emitted from vessels contribute to degraded air quality and when inhaled can lead to premature mortality and morbidity (Corbett et al. 2007; Winebrake et al. 2009; Sofiev et al. 2018; Viana et al. 2015). SO_X emissions react to form atmospheric sulphate (SO_4) aerosols, and which have been shown to have adverse effects on human health, and contributes to acid deposition and acidification of terrestrial and aquatic environments (Hassellöv et al. 2013). Globally, cleaner fuels for ships associated with the implementation of the global fuel sulphur cap of 0.50% S m/m in 2020 (IMO 2020) under MARPOL Annex VI are estimated to lead to 137,000 avoided premature deaths each year (Sofiev et al. 2018).

This report focuses on the efforts of the twenty-two (22) Mediterranean coastal States that are 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, Syrian Arab Republic, Tunisia, Turkey, and the European Union. Considering the Parties to the Barcelona Convention, **Table 1** shows the status of signatories to MARPOL Annex VI, and status of membership of the European Union.

Table 1: MARPOL Annex VI ratification status and status of membership of the European Union 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
Albania	X	Candidate country
Algeria		
Bosnia and Herzegovina		
Croatia	X	X
Cyprus	X	X
Egypt		
France	X	X
Greece	X	X
Israel		
Italy	X	X
Lebanon		
Libya		
Malta	X	X
Monaco	X	
Montenegro	X	Candidate country
Morocco	X	
Slovenia	X	X
Spain	X	X
Syrian Arab Republic	X	
Tunisia	X	
Turkey	X	Candidate country

As of 20 April 2021

Section 2 of this report presents a country-by-country summary of existing land-based measures and policies for control of SO_X and PM emissions in the Mediterranean coastal States. Where available, this section also describes changes in ambient air quality related to SO_X and PM emissions measures. **Section 3** of this report lays out country-by-country discussion of SO_X and PM emission reductions, and **Section 4** of this report details available information on the relative costs of land-based control measures. **Section 5** provides references.

The results of this knowledge gathering effort show that all Mediterranean coastal States have adopted measures in some form for the control of emissions from land-based sources. The extent and implementation of these measures varies across the region, with European Union standards representing the strictest standards for ambient air quality and emission reductions. In total, emissions from transport and non-transport sources in the Mediterranean coastal States have declined significantly since 1975.

1.1 Methodology

This work evaluates land-based measures to control SO_X and PM emissions. Land-based measures include those that regulate stationary and mobile sources of pollution on land. Analysis of land-based measures occurs in three phases. First, a systematic review of available public policies, laws and regulations identifies the set of policies, by country, aimed at reducing SO_X and PM pollution from land-based sources. Land-based sources of pollution include stationary sources, such as power generation facilities and industrial plants, and mobile sources, such as trucks, cars, and buses. Land-based emissions also include non-point source emissions, though those are typically not relevant for sulphur dioxide (SO_2) and $PM_{2.5}$ emissions. Second, analysis of emission inventory data identifies sectoral reductions in SO_X and PM emissions, and third, analysis of regional data from air quality monitoring stations identifies compliance with $PM_{2.5}$ standards.

To begin, a systematic review of air quality and pollution abatement policies was undertaken country-by-country for the Mediterranean coastal States that are Contracting Parties to the Barcelona Convention. This review included review of National Action Plans[1] and a search of publicly available air quality policies undertaken using common search terms (i.e. "Nation" + "Pollution" + "SO_X" + "PM" + "Policy") including national-level laws and policies, and white papers describing the set of policies. This effort also undertook to review available information in Mediterranean coastal States' National Action Plans (NAPs) for the marine environment. While systematic, this literature review process benefitted from additional insights from Mediterranean coastal States. As part of the review process, Contracting Parties to the Barcelona Convention reviewed the information gathered, adding feedback, clarifications, and suggested additions for their national-level land-based sources abatement descriptions.

Evaluation of emissions abatements, based on national level inventories, was undertaken using two primary data sources, the Emissions Database for Global Atmospheric Research (EDGAR)[2] (Crippa et al. 2020), and data from the European Environment Agency (EEA)[3]. EEA consolidated national total and sectoral emissions of air pollutants consistent with the European Union's air pollutant emission inventory methodology for submission to the Convention on Long-range Transboundary Air Pollution (LRTAP). Pollutants relevant to this study include both SO_X and $PM_{2.5}$. The EEA LRTAP inventories represent the most up-to-date and best available estimates for emissions activity by the Member States of the European Union.

EDGAR data are useful for comparing emissions in the Mediterranean Sea area for a few reasons. First, the data source is consistent, meaning that similar methodologies are applied for all regions, reducing the potential for bias or inaccuracies when comparing emission estimates generated using different methodologies. Second, the time series available from EDGAR is long, with data available from 1975 to 2015. While this data series does not cover the most recent years, it does allow for analysis and discussion of long-run trends in emissions. Third, the data set is highly pedigreed, developed by the European Commission Joint Research Centre (JRC), and peer reviewed (Crippa et al. 2020) over many years, leading to a high level of confidence in the quality of the data. EDGAR emission estimates are calculated using a technology-based emission factor approach, where sector-specific country-level emissions are estimated by species based on geospatially gridded inventories of human activity. EDGAR data are used to describe time trends in emissions when country-level inventories are unavailable. Where EEA LRTAP inventory data are available those emission estimates are presented. For the Mediterranean coastal States where EEA LRTAP data are not available, EDGAR emission estimates are used.

Land based emission reduction policies, and their associated emission reductions, are then put in the context of air quality changes, using station-level geospatial data available from the 2018 World Health Organisation (WHO) Air Quality Database[4]. Data were processed and aggregated to the year and country-level for plotting time series changes in air quality. Additionally, station-level data from 2016, the most recent complete year of data available as of November 2020, are plotted geospatially county-by-country to illustrate areas of compliance with WHO $PM_{2.5}$ guidelines ($\leq 10\ \mu g/m^3$) and EU standards ($\leq 25\ \mu g/m^3$).

Finally, this work analyses land-side emission abatement costs, or cost-effectiveness, in the context of the proposed Med SO_X ECA. Data from land-side abatement cost data are not widely available for all Mediterranean coastal States that are Contracting Parties to the Barcelona Convention, and therefore we employ a technology/benefits transfer approach, using published literature estimates of abatement costs, cost effectiveness, and shadow prices. Pollution abatement technology is available on global markets, and therefore while regional differences in abatement costs may exist, the available estimates may reasonably be transferred from one region to another.

[1] National Action Plans prepared under the Strategic Action Programme (SAP-MED) adopted at the 10th Meeting of the Contracting Parties. UNEP(OCA)/MED IG.11/09
[2] https://data.europa.eu/doi/10.2904/JRC_DATASET_EDGAR.
[3] https://www.eea.europa.eu/data-and-maps/dashboards/air-pollutant-emissions-data-viewer-3.
[4] https://www.who.int/airpollution/data/en/.

2 Existing Land-Based Measures for the Control of SO_X and PM Emissions in the Mediterranean Coastal States

The acidifying characteristics of SO_2 pollution are well known. Leading to acid rain and associated acidification of soils, ground- and freshwaters along with harmful impacts on human health through increased rates of cardiovascular and pulmonary diseases and asthma (Pope et al. 2002).

Criteria 3.1.7 for designation of an emission control area, described in the box below, requires a description of the control measures taken by the proposing parties to address land-based sources of SO_X and PM.

Criteria 3.1.7, Appendix III to MARPOL Annex VI

A description of the control measures taken by the proposing Party or Parties addressing land-based sources of NO_X, SO_X and particulate matter emissions affecting the human populations and environmental areas at risk that are in place and operating concurrent with the consideration of measures to be adopted in relation to provisions of regulations 13 and 14 of Annex VI

This section presents results from knowledge gathering of national- and international-level policies, in order to describe land-based efforts for SO_X and PM abatement in accordance with fulfilment of Criteria 3.1.7. This section provides an overview of existing land-based measures for the control of SO_X and PM emissions in the Mediterranean coastal States that are Contracting Parties to the Barcelona Convention, including those relevant to transportation and stationary sources. Existing measures are reported on a country-by-country basis, where available.

The Contracting Parties to the Barcelona Convention are Albania, Algeria, Bosnia and Herzegovina, Croatia, Cyprus, Egypt, France, Greece, Israel, Italy, Lebanon, Libya, Malta, Monaco, Montenegro, Morocco, Slovenia, Spain, Syrian Arab Republic, Tunisia, Turkey, and the European Union. There are eight countries that are both Contracting Parties to the Barcelona Convention and Member States of the European Union. These countries are Croatia, Cyprus, France, Greece, Italy, Malta, Slovenia, and Spain.

Country-level descriptions are included in the sections below and summarised in **Table 2**. Note that **Table 2** refers to transportation and stationary source pollution measures that were identified by systematic review of publicly available literature, and simply denotes the presence of laws and regulations without identifying the level of control.

Table 2: Land-based measures identified at the country-level for SO_2 and $PM_{2.5}$ pollution control

Country Name	Member State of the European Union	Transportation	Stationary Sources
Albania	Candidate country	X	X
Algeria		X	
Bosnia and Herzegovina		X	X
Croatia	X	X	X
Cyprus	X	X	X
Egypt		X	X
France	X	X	X
Greece	X	X	X
Israel		X	X
Italy	X	X	X
Lebanon		X	X
Libya		X	
Malta	X	X	X
Monaco		X	X
Montenegro	Candidate country	X	X
Morocco		X	X
Slovenia	X	X	X
Spain	X	X	X
Syrian Arab Republic		X	
Tunisia		X	X
Turkey	Candidate country	X	X

2.1 Albania

Albania is in the process of applying to become a Member State of the European Union. Albania has been prioritising measures to align national air quality legislation with EU policies and has fully transposed the EU Directive 2008/50/EC into national law by the adoption of law no.162/2014 "On protection the ambient air quality" and DCM No. 352 dated 29.04.2015 "On air quality assessments and requirements concerning certain pollutants" that prescribes reference methods for air quality assessment. On 21 March 2007 Decision 147, governing the sulphur content in fuels, was adopted. Decision 147 limited the sulphur content of fuels to 10 ppm, aligned with the EU standards.

2.2 Algeria

The average fuel sulphur content for transportation gasoline fuels is 100 - 150 ppm and diesel is restricted to 2,500 ppm in Algeria[5]. This is equivalent to Euro 3/III emission standards for gasoline, and Euro 1/I standards for diesel. Only new vehicles leaving the factory are admitted for sale in Algerian territory. No air quality data are available from the WHO for Algeria in 2016.

2.3 Bosnia and Herzegovina

Ambient air quality standards in Bosnia and Herzegovina are aligned with EU standards, though implementation and enforcement of the legal framework for air quality are in development (UN 2017). The Law on Air Protection (OG FBiH No. 33/03, 4/10) provides for monitoring of emissions from stationary sources, development of monitoring plans, and the development of monitoring networks. Furthermore, Continuous emissions measurement at large combustion plants is provided for in Article 18.

5 https://wedocs.unep.org/bitstream/handle/20.500.11822/25233/FuelQualityEmissionStandardDevelopments.pdf?sequence=3&isAllowed=y.

2.4 Croatia

Since 1 July 2013, Croatia has been a Member State of the European Union. Air quality policy and emissions management and reporting in Croatia is harmonised and aligned with current EU air quality legislation **(Table 4)**.

2.5 Cyprus

Ambient air quality management in Cyprus is performed under the provisions of the Ambient Air Quality Laws 2010 to 2020[6]. The legislation is implemented by the Department of Labour Inspection of the Ministry of Labour, Welfare, and Social Insurance. Based on the Department of Labour Inspection website, the Ambient Air Quality Laws 2010 to 2020 harmonise with EU Directives 2004/107/EC, 2008/50/EC, and 2015/1480/EU regarding air quality matters. The target limits of ambient air quality are aligned with those laid out in **Table 4**.

2.6 Egypt

The primary law governing air pollution in Egypt is Law 4/1994[7]. Under Law 4, Article 35, the law provides that emissions of air pollutants should not exceed those permitted by the regulations. Law 4 does not specify those standards, directly, and they are instead prescribed by executive regulations. The Draft Executive Regulation for Law 9/2009 sets out the ambient air quality standards for Egypt as shown in **Table 3**.

Table 3: PM_{10}, $PM_{2.5}$ and SO_2 ambient air quality standards in Egypt

Pollutant	Period	Standard
PM_{10}	24h	150 µg/m^3
	1yr	100 µg/m^3
$PM_{2.5}$	24h	100 µg/m^3
	1yr	70 µg/m^3
SO_2	1h, Industrial	300 µg/m^3
	1h, Urban	350 µg/m^3
	24h, Industrial	125 µg/m^3
	24h, Urban	125 µg/m^3
	1yr, Industrial	50 µg/m^3
	1yr, Urban	60 µg/m^3

In 2004 the national air quality strategy framework was formulated by Egypt in collaboration with USAID in order to improve urban air quality (World Bank 2013). Furthermore, Egypt has implemented legislation requiring catalytic converters in imported vehicles and has endorsed the use of compressed natural gas (CNG) as a transportation fuel due to its lower pollutant emissions profile (Abbass, Kumar, and El-Gendy 2018). Furthermore, Egypt has implemented a strategy to address the issue of open waste burning and as of 1994 the cement industry has been subject to emissions regulations set by Law 4/1994 (Abbass, Kumar, and El-Gendy 2018).

[6] https://www.airquality.dli.mlsi.gov.cy/legislation.
[7] http://www.eeaa.gov.eg/en-us/laws/envlaw.aspx.

2.7 European Union

The European Union has a long history of policymaking to improve air quality, by controlling the emission of pollutants to the atmosphere, improving quality of transport fuels, and cross-sectoral environmental protection measures. Clean air policy is based on three central tenets:

1. Ambient air quality standards;
2. National emission reduction commitments; and
3. Emission and energy efficiency standards for key sources of air pollution.

The Clean Air Programme for Europe[8] is aimed at tackling poor air quality in the short term through a range of measures, including light-duty diesel engines, tightening existing legislation, enhancing technical capabilities, and the ambient air quality directive. In the long term, the Clean Air Programme for Europe is expected to reduce premature mortality by 37% and reduce ecosystem damage through eutrophication by 21% in 2025.

There are eight countries that are both Contracting Parties to the Barcelona Convention and Member States of the European Union. These countries are Croatia, Cyprus, France, Greece, Italy, Malta, Slovenia, and Spain. The national legislations of these Mediterranean coastal States fully transpose the EU legal provisions.

Recently, the EU has undertaken the 2019 European Green Deal (COM/2019/640 final), Europe's 2030 climate ambition (COM(2020) 562) and the Sustainable and Smart Mobility Strategy (COM(2020) 789 final, SWD(2020) 331 final), and undertakes to act on a set of environmental policies, including climate change, biodiversity loss, circular economy, oceans health, including to reduce pollution from ships. Under the Green deal, the ongoing revision of the Ambient Air Quality Directive (AAQD) will set increasingly stringent standards for air quality and provide guidance for facilitating meeting those standards. A recent report from the European Environment Energy Agency shows significant proportion of the burden of disease in Europe continues to be attributed to environmental pollution resulting from human activity[9]. To address this, in June 2021, the EU will adopt the Zero Pollution Action plan.

On the sea-going vessel side, the EU Sulphur Directive (Directive 2016/802) requires that vessels calling any European ports have an obligation to switch to 0.10% S m/m at berth for calls longer than 2 hours. This obligation to use less polluting fuel oil in the ports is in force since 2005. Additional to the at-berth requirement, prior to IMO 2020 going into effect, passenger vessels on regular service were required to use 1.50% S m/m fuels. On the port side, the Fuel EU Maritime initiative (https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12312-FuelEU-Maritime-) and the revision of the Alternative Fuel Infrastructure Directive the Alternative Fuel Directive will contain mandatory provisions for shore power and alternative fuels to significantly reduce ship emissions in ports as well as coastal areas.

2.7.1 EU Ambient Air Quality Standards

The Ambient Air Quality Directive (2008/50/EC) sets limits for atmospheric concentrations of pollutant species in the EU, including SO_2 and airborne PM_{10} and $PM_{2.5}$. These standards are implicitly linked with transport and stationary source emission standards (EEA 2020d).

Ambient Air Quality Directives require Member States of the European Union to assess air quality in their territories and implement plans to maintain compliant air quality or reduce emissions and improve air quality in regions where standards are not met.

Atmospheric concentrations of PM_{10}, $PM_{2.5}$, and SO_2 are each governed by the EU Ambient Air Quality Directives and are subject to the temporal standards laid out in **Table 4**.

[8] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52013DC0918&from=EN.
[9] https://www.eea.europa.eu/publications/healthy-environment-healthy-lives.

Table 4: Selected EU Ambient Air Quality Directive pollution concentration standards

Pollutant	Period	Concentration	Comments
PM_{10}	1 Day	50 µg/m³ limit	For no more than 35 days per year
	Calendar Year	40 µg/m³ limit	
$PM_{2.5}$	Calendar Year	25 µg/m³ limit	
		20 µg/m³	Concentration exposure obligation
SO_2	1 Hour	350 µg/m³ limit	For no more than 24 hours per year
		500 µg/m³	Alert threshold for 3 hours in 100 km² zone
	1 Day	125 µg/m³ limit	For no more than 3 days per year

2.7.2 EU National Emission Reduction Commitments

National emission reduction commitments were established in the 2016 National Emission Ceilings (NEC) Directive (EU 2016), which require Member States of the European Union to develop air pollution control measures to meet their commitments[10]. Under the NEC Directive the EU-28 committed to dropping SO_2 emissions from 24,747 Gg[11] in 1990 to 2,031.4 Gg in 2018, and $PM_{2.5}$ emissions from 1,981.7 Gg in 1990 to 1,253.5 Gg in 2018 (**Figure 1**). These commitments represent emission reductions of 91.8% for SO_2 and 36.7% for $PM_{2.5}$ (UNECE 2019).

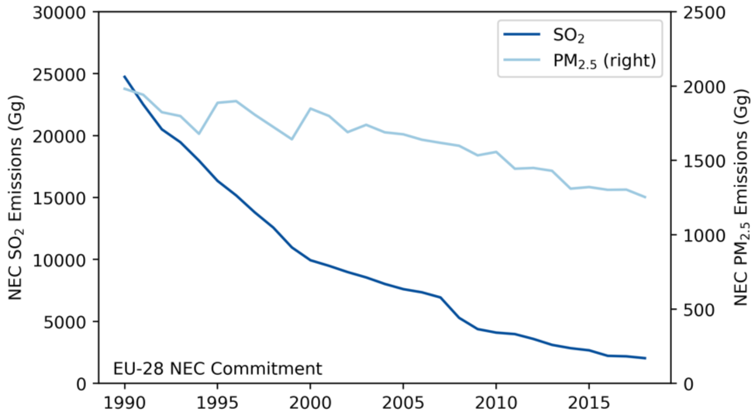

Figure 1: EU-28 National Emission Ceiling Commitments 1990-2018

Since 2016, all Member States of the European Union have been in compliance with their NEC commitments for SO_2. Cyprus is the only Member State of the European Union and Contracting Party to the Barcelona Convention that is not on track to meet their 2020 commitment for SO_2. Additionally, Cyprus and Slovenia are not on track to meet their $PM_{2.5}$ commitments in 2020 (European Commission 2020b). Spain is projected to comply with their NEC commitments for $PM_{2.5}$ for 2020 under their existing policies and measures, and with their 2030 commitments under the additional measures scenario (European Commission 2020a). The 2nd Clean Air Outlook[12] has shown prospects for the air pollution situation in the EU up to 2030 and beyond.

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[10] https://www.eea.europa.eu/data-and-maps/dashboards/necd-directive-data-viewer-3.
[11] 1 Gg = 1,000 metric tons.
[12] https://ec.europa.eu/environment/air/clean_air/outlook.htm.

2.7.3 Emission and Energy Efficiency Standards

The European Union currently lists four pieces of existing legislation related to air quality.

Directive 98/70/EC lays out initial emission standards for petrol and diesel fuels intended for the use of vehicle propulsion. Under articles 3 and 4, the directive requires a maximum sulphur content of 10 mg/kg (10 ppm) for petrol and diesel fuels in Member States of the European Union.

Since 1 January 2016, large combustion plants have been regulated in the EU through the Industrial Emissions Directive (IED) (2010/75/EU), which imposes minimum requirements for emissions of nitrogen oxides (NO_X), SO_2 and dust. Under IED 2010/75/EU combustion plants are required to use the best available techniques (BATs), or equivalent techniques for emission control. As emission limits are tied to BATs, which are updated over time, there is not any overarching prescriptive standard beyond those referenced in BAT reference documents (BREFs).

Energy efficiency is governed by the Energy Efficiency Directive (2012/27/EU) in the EU, which sets out an energy efficiency goal of 20% by 2020, relative to the 2005 baseline. The Energy Efficiency Directive was revised upwards in 2018 (EU Directive 2018/2002), setting a new energy efficiency target of 32.5% by 2030, including an annual reduction of 1.5% in national energy sales. In 2017, 16 states were aligned with their energy consumption trajectories, which if maintained, would allow those states to meet their 2020 final energy targets. Overall, final energy consumption in the EU-28 was 5.7% lower in 2017 than in 2005 (EEA 2020c).

Policies related to large combustion plants (LCPs) decreased total fuel use in the EU by one fifth, while thermal capacity increased by one tenth between 2004 and 2015. Facilities with more LCPs powered by solid and liquid fuels were generally less efficient than LCPs with a greater share of biomass and natural gas. These policies led to a 77% decrease in SO_2 emissions from 2004 to 2015 (EEA 2020b).

2.8 France

Air quality policy and emissions management and reporting in France is fully harmonised and aligned with current EU air quality legislation (**Table 4**).

2.9 Greece

Air quality policy and emissions management and reporting in Greece is fully harmonised and aligned with current EU air quality legislation (**Table 4**).

2.10 Israel

The Clean Air Law[13] came into effect in January 2011 in Israel (Ministry of Environmental Protection 2019). The law provides a comprehensive framework for the reduction and prevention of air pollution by establishing emission limits, creating a system for permitting emissions, publishing air quality data and forecasts, and monitoring air pollutants. The Clean Air Law set an average ambient air concentration of SO_2 at an average of 350 µg/m^3 over an hour, 50 µg/m^3 over a 24-hour period and 20 µg/m^3 annually. PM_{10} average limits were set at 50 µg/m^3 over a year and 130 µg/m^3 over 24 hours (Negev 2020).

On the transport side, vehicle emission standards are aligned with EU standards, with diesel and petrol sulphur content limited to 10 ppm.

2.11 Italy

Air quality policy and emissions management and reporting in Italy is fully harmonised and aligned with current EU air quality legislation (**Table 4**).

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13 https://main.knesset.gov.il/Activity/Legislation/Laws/Pages/LawPrimary.aspx?t=lawlaws&st=lawlaws&lawitemid=2000055.

2.12 Lebanon

In the transportation sector, Decree 8442/2002 defines the sulphur standards for gasoline at 0.05% (500 ppm) by weight, and diesel oil at 0.035% (350 ppm), as amended by decree No. 3795 dated 30/6/2016 stating the modification of the table No. 3 in the law No. 8442, by requiring an additional test the ratio/percentage of FAME biodiesel up to a maximum limit not exceeding 7% volumetric on the applicable laboratory tests for Diesel Oil according to the test method ASTM D7371 or ASTM D7963; along with additional laws designed to reduce air pollution from the transport sector by discouraging imports of older vehicles (Law 341, Law 380, and Law 453) and incentivise the use of public transport (Decree 8941/2012)) (MoE 2017).

In the energy and industrial sectors, the Ministry of Environment (MoE) Decision 8/1-2001 defines emission limits for stack emissions and effluents from new and existing combustion plants and industrial establishments generating emissions.

Ambient air quality standards for Lebanon are shown in **Table 5**.

Table 5: PM_{10} and SO_2 ambient air quality standards in Lebanon

Pollutant	Period	Standard
PM_{10}	24h	80 µg/m^3
SO_2	1h	350 µg/m^3
	24h	120 µg/m^3
	1yr	80 µg/m^3

2.13 Libya

Libya has been heavily affected by regime change in recent years. Air pollution in Libya has previously been regulated under Article 10-17 of law no. 15 of 2003 (UNEP 2015a). Environmental law 15 stipulates that vehicles pass internal combustion and fuel quality tests, though exhaust gas tests are not performed. UNEP identify a 10,000-ppm sulphur limit in Libya, though they also note that the dominant fuel in the market has a sulphur content of 1,500 ppm.

2.14 Malta

Air quality policy and emissions management and reporting in Malta is fully harmonised and aligned with current EU air quality legislation (**Table 4**).

2.15 Monaco

Sustainable development in Monaco is reflected in Act No. 1.456 of 12/12/2017 concerning the Environment Code, which covered all aspects of pollution, energy, and environmental management (Principaute de Monaco 2019). Under the Kyoto Protocol, Monaco set a target of improving energy efficiency by 20% by 2020 and transitioning 20% of final energy consumption to renewable sources. Furthermore, Monaco has set a goal to be carbon neutral by 2050, with an interim goal of 50% by 2030, compared to 1990 levels.

In Part II of the Code of the Sea, Chapter V specifies that all ships equipped with diesel engines must use fuels compliant with 0.10% S m/m standards, or alternatively be equipped with closed loop exhaust gas cleaning systems (Journal de Monaco 2018).

2.16 Montenegro

Montenegro is a candidate country for entry into the EU and is in the process of integrating EU legislation into the system of national laws. Once it is a Member State of the European Union, air quality policies in Montenegro will be harmonised with the EU system of laws.

In 2010 Montenegro enacted the Law on Air Protection (OG 25/10, 40/11) to define a framework for air protection. The law lays out a range of measures for improving air quality, including setting emission limits for stationary and mobile sources and setting national emission ceilings for specific pollutants (UNECE 2015). Where air quality targets are not met, regional authorities should adopt air quality plans to mitigate emissions.

Montenegro has also enacted a 2005 law on Integrated Prevention and Control of Environmental Pollution (OG 80/5, 54/09, 40/11), which lays out the policies for permitting potential sources of environmental pollution.

2.17 Morocco

As of 2018, the maximum sulphur content in gasoline fuels in Morocco was 50 ppm, and 15 ppm for diesel.[14] Morocco has also implemented a set of urban transportation initiatives aimed at reducing GHG emissions by up to 50 MMT CO_2e (carbon dioxide equivalent). These strategies include tramway extensions, modal shifts to low carbon transport systems, and expansion of alternative fuels and renewable energy.

Though details on the air quality benefits of these programs are not available, they will likely have beneficial effects on air quality in Morocco, in addition to quantified GHG benefits.

2.18 Slovenia

Air quality legislation in Slovenia is aligned with EU regulations (**Table 4**). Slovenia has aligned their SO_2 emissions ceiling with their commitments to the NEC Directive under national law OP TGP-1 2009, which are projected to reduce national SO_X emissions from 16,300 MT in 2010 to 8,600 MT in 2020. Similar tightening of legislation is projected to reduce PM_{10} emissions from 10,150 MT in 2010 to 9,320 MT in 2020 as a result of policy intervention.

Relevant Operational Programmes adopted by Slovenia include:

- OP NEC, which aligns national emissions with EU NEC directive commitments; and
- OP PM_{10}, 2009, which aims to protect ambient air from PM_{10} pollution, including restrictions on the use of vehicles that do not meet emission standards among other policies to reduce emissions from transportation including traffic easing measures and establishing environmental zones.

2.19 Spain

Air quality policy and emissions management and reporting in Spain is fully aligned with current EU air quality legislation (**Table 4**).

2.20 Syrian Arab Republic

The energy sector in the Syrian Arab Republic has been heavily affected by conflict, which caused damage and destruction to energy infrastructure, including production plants, treatment facilities, and pipelines. Furthermore, the energy sector has been affected by economic sanctions imposed on the country. In parallel with these events the Syrian Arab Republic has seen CO_2 emissions from the energy sector drop from around 75 MMT CO_2e in 2011 to around 30.5 MMT CO_2e in 2016. Similarly, energy demand has fallen by over 50% from 25 MMT in 2011 to 10 MMT in 2016.

The Syrian Arab Republic adopted national ambient air quality standards in 2011 and in 2012 under Environment Law No. 12. Though fuel sulphur limits are high in the Syrian Arab Republic (6,500 ppm) (UNEP 2015b), the Syrian Arab Republic is engaging a transportation strategy to mitigate emissions in the transport sector emission standards, improved fuel quality, and encouraging the use of gas powered buses and alternatively fuelled vehicles (Syrian Arab Republic 2018).

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[14] See footnote 5.

2.21 Tunisia

Article 8 of Tunisia's Air Pollution and Noise Emissions Law No. 88-91 dictates that any industrial, agricultural, or commercial establishment as well as any individual or corporate entity carrying out activity that may cause pollution to the environment is obliged to eliminate or reduce discharges. The Institut National de la Normalisation et de la Propriété Industrielle (INNORPI) in Tunisia is a member of ISO and adopted ISO 14,000 series standards[15].

As of 2018, the maximum sulphur content in gasoline fuels in Tunisia was < 10 ppm[16], and diesel sulphur content is limited to 50 ppm. Tunisia has an import restriction on vehicles over 5 years old.

2.22 Turkey

Regarding the national strategy for air quality management, the Ministry of Environment and Urbanisation (MoEU) started to prepare strategical air quality maps to facilitate the decision-making process. Clean Air Action Plans of the provinces are being monitored electronically for the measures taken for air quality.

In order to comply with the EU regulations, Turkey is integrating the policies under the topic of air quality step-by-step into national legislation. The "Technical Assistance for Transposition of the Large Combustion Plants Directive for Better Air Quality" Project was resulted on addressing the compliance status and needs of large combustion plants under the scope of the industrial emissions directive (IED). In this project, an inventory of large combustion plants in Turkey, a web-based database for reporting and RIA report were prepared.

The "Support to the Implementation of Integrated Pollution Prevention and Control Directive in Turkey" (IPPC) project, has been conducted by MoEU during 2011-2014. In order to determine the compliance status of installations in Turkey with the IED, sectoral projects (large combustion plants, automotive, cement, iron and steel, glass, and paper) were conducted. Review of the waste management sector is underway.

The "Project for Determination of Industrial Emissions Strategy of Turkey in Accordance with Integrated Pollution Prevention and Control (DIES Project)" started in 2020. The DIES Project aims to increase the technical and institutional capacity of the competent authorities for the effective implementation of the IPPC approach in Turkey in line with the EU Industrial Emissions Directive.

In the transport sector, Euro 6 vehicle 6 emission standards became applicable in Turkey in 2017, and fuel sulphur is aligned with EU directives and regulated at 10 ppm (UNEP 2015c).

[15] http://www.infoprod.co.il/country/tunis2i.htm.
[16] See footnote 5.

3 Assessment of SO_X and PM Emission Reductions from Land-Based Measures

Criteria 3.1.7 for designation of an emission control area, laid out in Appendix III to MARPOL Annex VI (MEPC.176(58)) requires a description of the control measures taken by the proposing parties to address land-based sources of SO_X and PM emissions affecting human populations. This section presents results from analysis of trends in national-level emissions, in order to describe land-based efforts for SO_X and PM abatement. The trends discussed in this section focus on land-based transportation specific emissions[17], and emissions from all land-based sources, not including waterborne navigation[18] or aviation[19].

EDGAR data show that overall SO_2 emissions from all sources, not including waterborne transportation, are falling among the Mediterranean coastal States that are Contracting Parties to the Barcelona Convention. From a peak of 9,567 Gg in 1980, SO_2 emissions fell to 5,068 Gg in 2015, an overall reduction of 47% compared to the peak emissions. Emission reductions are non-uniform in the region, however, with the downward trend being driven by larger reductions in Member States of the European Union. Meanwhile, overall emissions of SO_2 from other Mediterranean coastal States are flat or slightly increasing since around the year 2000 (**Figure 2**). Greater detail in the trends in emissions by country may be found in **Section 3.2** through **Section 3.22**.

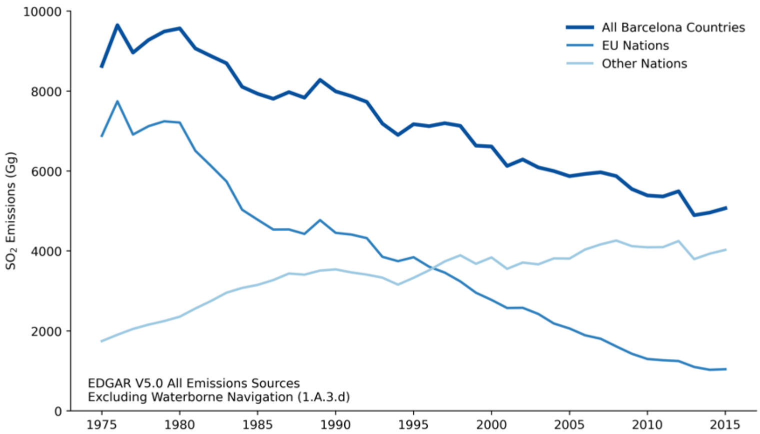

Figure 2: All sources of SO_2 emissions among Mediterranean coastal States that are Contracting Parties to the Barcelona Convention

Looking in more detail at the transportation sector, excluding waterborne transit as well as aviation, EDGAR data show that overall transport related SO_2 emissions have fallen in recent years in the Mediterranean coastal States that are Contracting Parties to the Barcelona Convention. Overall emissions of SO_2 have fallen from 222 Gg in 1978 to 70 Gg in 2015, an overall reduction of over 68%.

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[17] IPCC sectors 1.A.3.b, 1.A.3.c, and 1.A.3.e.
[18] IPCC emission sector code 1.A.3.d.
[19] IPCC emission sector code 1.A.3.a.

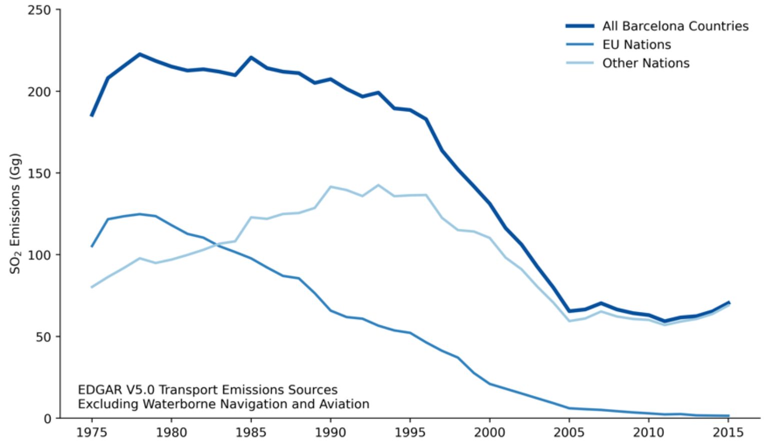


Figure 3: Transport emissions of SO_2 in the Mediterranean coastal States that are Contracting Parties to the Barcelona Convention (excluding waterborne navigation and aviation)

As shown in **Figure 3**, SO_2 emissions from the transportation sector have fallen across the region, in both the Member States of the European Union and other Mediterranean coastal States. SO_2 emissions from the Member States of the European Union have fallen to very low levels in recent years, and emissions from other Mediterranean coastal States have been flat since around 2005.

Figure 2 and **Figure 3** show large overall reductions in SO_2 emissions among the Mediterranean coastal States that are Contracting Parties to the Barcelona Convention, both in stationary sources and the transportation sector. These results show that, regionally, the Mediterranean coastal States that are Contracting Parties to the Barcelona Convention are undertaking land-based measures to control land-based sources of SO_2 and $PM_{2.5}$ emissions. The following sections provide a brief overview of the country-specific trends in emissions.

3.1 Regional Ambient Air Quality Observations

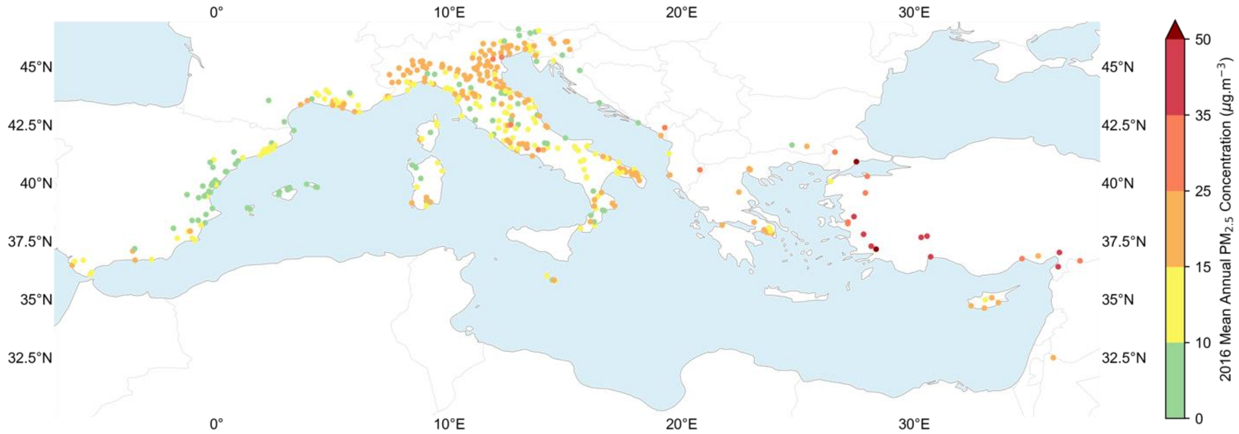


Figure 4: Mean annual air quality ($PM_{2.5}$ µg/m^3) observed at coastal observation stations (within 100 km of the coastline)

Figure 4 shows mean annual ambient air quality ($PM_{2.5}$ µg/m^3) observed at stations within 100 km of the coastline of the Mediterranean Sea from the World Health Organization's Ambient Air Pollution, Concentrations of fine particulate matter (PM2.5) database[20]. Subsequent sections present country-level observations from the WHO data, where available, and do not limit observations solely to those stations withing 100 km of the coastline. The WHO data are the most complete set of observations for the Mediterranean coastal States, with 2016 as the most recent year of data available. All maps shown in this section are based on the WHO Ambient Air Quality database. As shown, air quality in the region varies greatly, with many coastal stations $PM_{2.5}$ concentrations exceeding WHO guidelines of 10 µg/m^3.

20 https://www.who.int/data/gho/data/indicators/indicator-details/GHO/concentrations-of-fine-particulate-matter-(pm2-5).

Country-level time series data shown in this section are derived from station-level data provided by the European Environment Agency.[21]

Figure 5 shows a histogram of station counts by their annual $PM_{2.5}$ concentrations. Most stations do not meet WHO guidelines of 10 µg/m^3, with only 19.9% of stations meeting that threshold. The EU standard is set at 25 µg/m^3, which 94.4% of stations do comply with. Notably, the geographic distribution of stations is non-uniform, with a high concentration of monitoring stations in northern and western Mediterranean coastal States, and comparatively lower numbers in southern and eastern Mediterranean coastal States. As such, these air quality observations are best taken in context, with consideration for the differences in sampling between the Mediterranean coastal States.

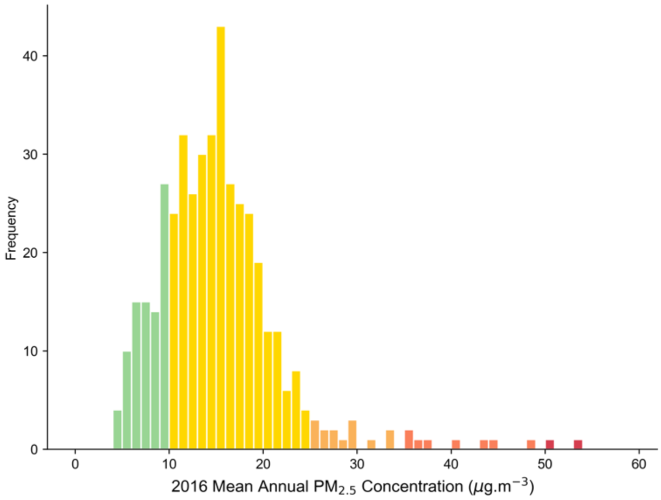


Figure 5: Histogram of WHO mean annual air quality ($PM_{2.5}$ µg/m^3) observed at coastal observation stations (within 100 km of the coastline)

3.2 Albania

Transportation related emissions of SO_2 in Albania peaked in 1980 at 0.94 Gg and have subsequently declined to very low levels (0.008 Gg in 2015). The trend in SO_2 emission reductions has been consistent since 1999 and demonstrates a high level of control of SO_2 emissions from transportation sources. In total emissions in 2015 had declined by over 99% relative to their peak in 1980.

[21] https://www.eea.europa.eu/data-and-maps/data/aqereporting-8.

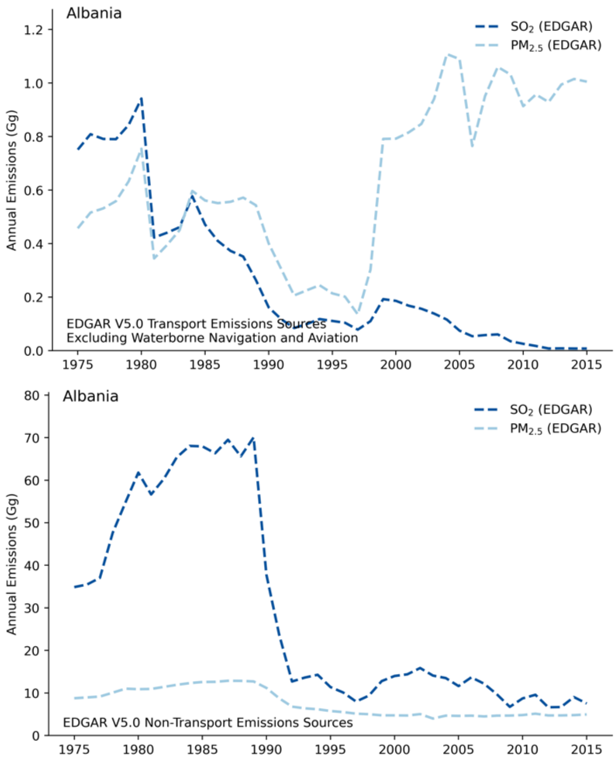


Figure 6: Transport (left) and non-transport (right) emissions of SO_2 and $PM_{2.5}$ in Albania

Transportation related $PM_{2.5}$ emissions have not followed a similar trajectory to SO_2 emissions in Albania. After 1997 $PM_{2.5}$ emissions grew sharply, though they have remained flat since the mid-2000s.

All sources of SO_2 emissions fell sharply in Albania after 1990 and have remained flat since then. This reduction in SO_2 was accompanied by a similar decline in non-transport $PM_{2.5}$, which has also remained flat in Albania since around the year 2000 (**Figure 6**).

Mean annual $PM_{2.5}$ concentrations from 2016 (**Figure 7**) show that all stations meet EU $PM_{2.5}$ concentrations (<25 µg/m^3), though all three stations do exceed WHO $PM_{2.5}$ guidelines (<10 µg/m^3).

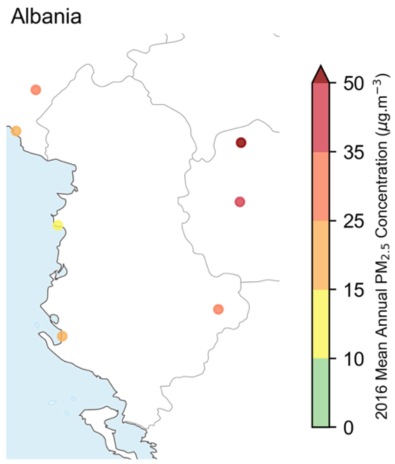


Figure 7: WHO mean annual $PM_{2.5}$ concentration observations in Albania (2016)

3.3 Algeria

Transportation related emissions of SO_2 in Algeria peaked in 1991 at 27.70 Gg followed by a decline to 8.26 Gg in 2005, a 70% reduction over that time period. The trend in SO_2 emissions has been rising since 2005, to 12.93 Gg in 2015, equivalent to a 53.3% reduction compared to 1991 peaks. Transportation related $PM_{2.5}$ has also grown in Algeria since 1975.

All source emissions of SO_2 declined in later years, from 2012 to 2015, though the general trend in both SO_2 and $PM_{2.5}$ emissions in Algeria is upward (**Figure 8**).

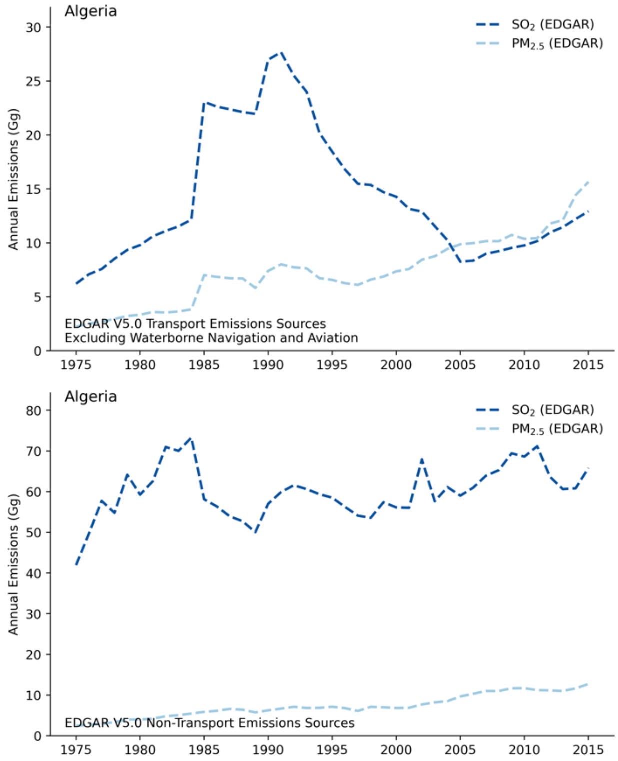


Figure 8: Transport (left) and non-transport (right) emissions of SO_2 and $PM_{2.5}$ in Algeria

3.4 Bosnia and Herzegovina

Transportation related emissions of SO_2 in Bosnia and Herzegovina peaked in 1979 at 1.74 Gg and have subsequently declined to very low levels (0.01 Gg in 2015). The trend in SO_2 emission reductions has been consistent since 1999 and demonstrates a high level of control of SO_2 emissions from transportation sources. In total emissions in 2015 had declined by over 99% relative to their peak in 1979. Transportation-related emissions of $PM_{2.5}$ have declined since 2010, though they have increased slightly since 1975.

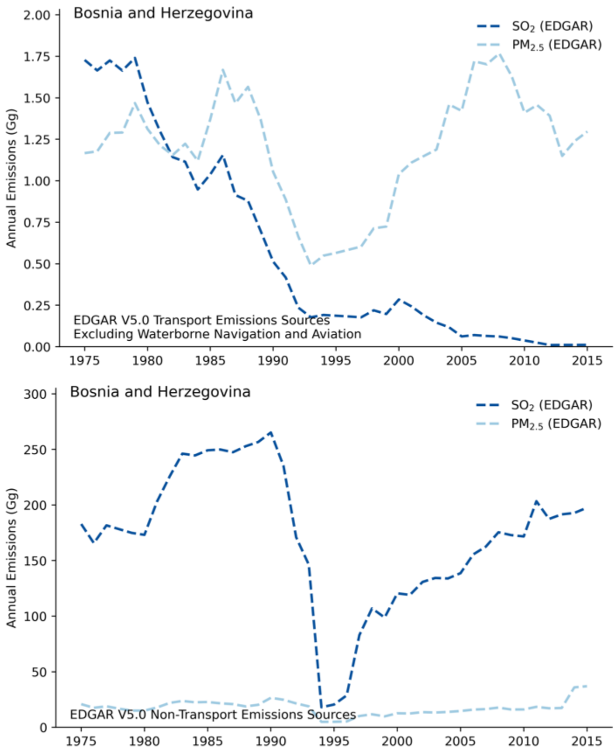


Figure 9: Transport (left) and non-transport (right) emissions of SO_2 and $PM_{2.5}$ in Bosnia and Herzegovina

Overall emissions of $PM_{2.5}$ have been low in Bosnia and Herzegovina, since 1975, however overall SO_2 emissions have been rising steadily since 1994 (**Figure 9**).

Mean annual $PM_{2.5}$ concentrations from 2016 (**Figure 10**) show that 1 of 5 stations in Bosnia and Herzegovina meets EU $PM_{2.5}$ concentrations (<25 µg/m^3), and all stations exceed WHO $PM_{2.5}$ guidelines (<10 µg/m^3).

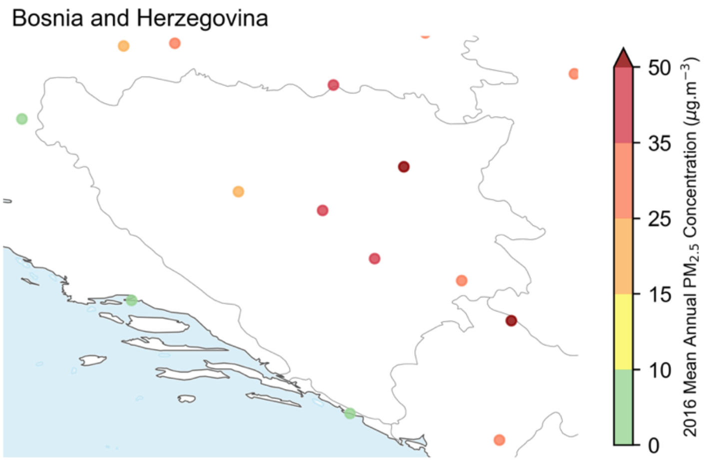


Figure 10: WHO mean annual $PM_{2.5}$ concentration observations in Bosnia and Herzegovina (2016)

3.5 Croatia

Transportation related emissions of SO_X in Croatia peaked (over this time series) in 2003 at 5.95 Gg and have subsequently declined to very low levels (0.03 Gg in 2018). The trend in SO_X emission reductions has been consistent since 2003 and demonstrates a high level of control of SO_X emissions from transportation sources.

Non-transport emissions of $PM_{2.5}$ have been flat in Croatia since 1990 and non-transport SO_X declined around >90% from 1990 levels. Non-transport emissions of SO_X declined from 162.83 Gg in 1990 to 10.25 Gg in 2018 (**Figure 11**).

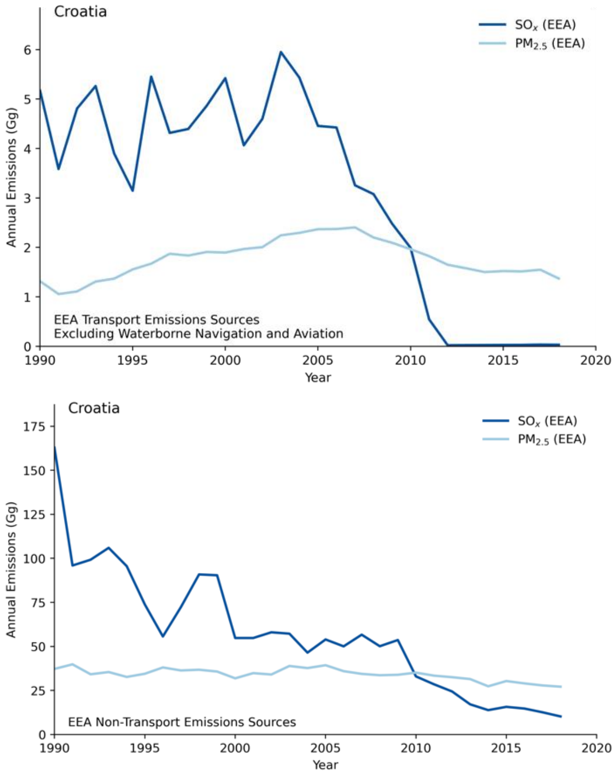


Figure 11: Transport (left) and non-transport (right) emissions of SO_X and $PM_{2.5}$ in Croatia

Mean ambient $PM_{2.5}$ concentrations in Croatia (**Figure 12**) have been compliant with EU ambient air quality standards since 2013, though the 95% confidence interval has had an upper bound above 25 µg/m³ since 2014, and country-wide average concentrations have been greater than the WHO guidelines since the data series began (EEA 2020a).

Looking at station measurements, shown in **Figure 13**, the data show that 4 of 12 stations in Croatia are compliant with WHO guidelines for $PM_{2.5}$, and 8 of 12 stations are compliant with EU $PM_{2.5}$ regulations.

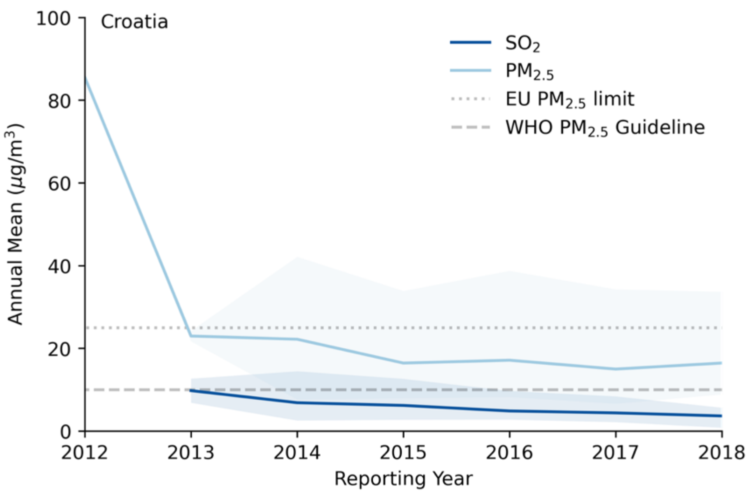


Figure 12: Annual mean concentrations of SO_2 and $PM_{2.5}$ in Croatia (shaded areas show 95% CI)

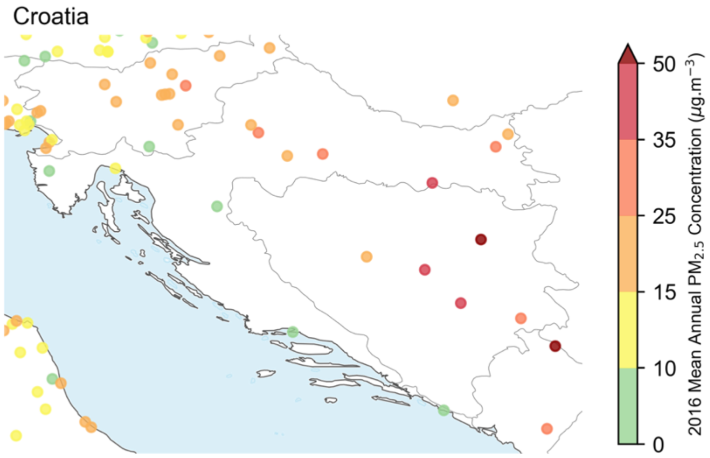


Figure 13: WHO mean annual $PM_{2.5}$ concentration observations in Croatia (2016)

3.6 Cyprus

Transportation related emissions of SO_X in Cyprus peaked in 1999 at 7.32 Gg and have subsequently declined to low levels (0.0.01 Gg in 2018). The trend in SO_X emission reductions saw a sharp drop beginning around the year 2001. These results demonstrate control of SO_X emissions from transportation sources.

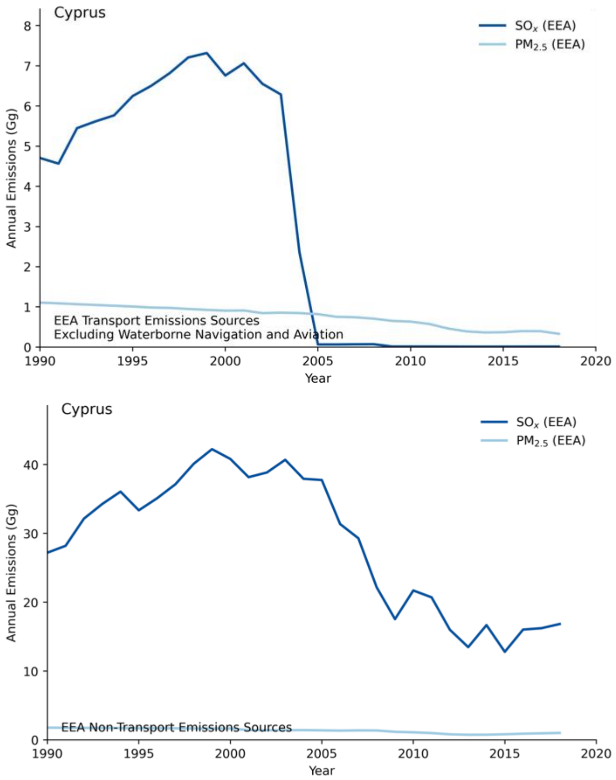


Figure 14: Transport (left) and non-transport (right) emissions of SO_X and $PM_{2.5}$ in Cyprus

Non-transport emissions of SO_X also peaked in 1999 at 42.23 Gg, and subsequently declined to 16.83 Gg in 2018 (**Figure 14**).

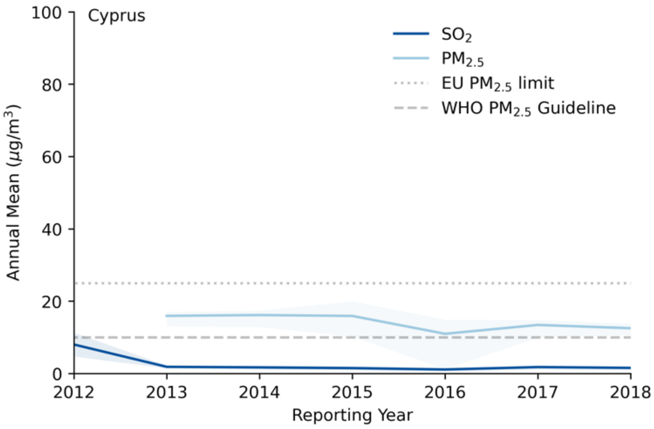


Figure 15: Annual mean concentrations of SO_2 and $PM_{2.5}$ in Cyprus (shaded areas show 95% CI)

As shown in **Figure 15**, country-level mean concentrations of SO_2 and $PM_{2.5}$ in Cyprus are in compliance with EU ambient air quality standards, however they do not meet WHO guidelines. Station-level measurements (**Figure 16**), support the annual data, demonstrating that no stations in Cyprus had annual mean $PM_{2.5}$ concentrations less than 10 µg/m³ in 2016.

[Placeholder for map]

Figure 16: WHO mean annual $PM_{2.5}$ concentration observations in Cyprus (2016)

3.7 Egypt

Transportation related emissions of SO_2 in Algeria peaked in 1991 at 29.73 Gg followed by a decline to 10.28 Gg in 2005, a 65.4% reduction over that time period. The trend in SO_2 emissions has been rising since 2005, to 13.59 Gg in 2015, equivalent to a 54% reduction compared to 1991 peaks. The trend in non-transport emissions of SO_2 and $PM_{2.5}$ has been growing since 2004 in Egypt (**Figure 17**).

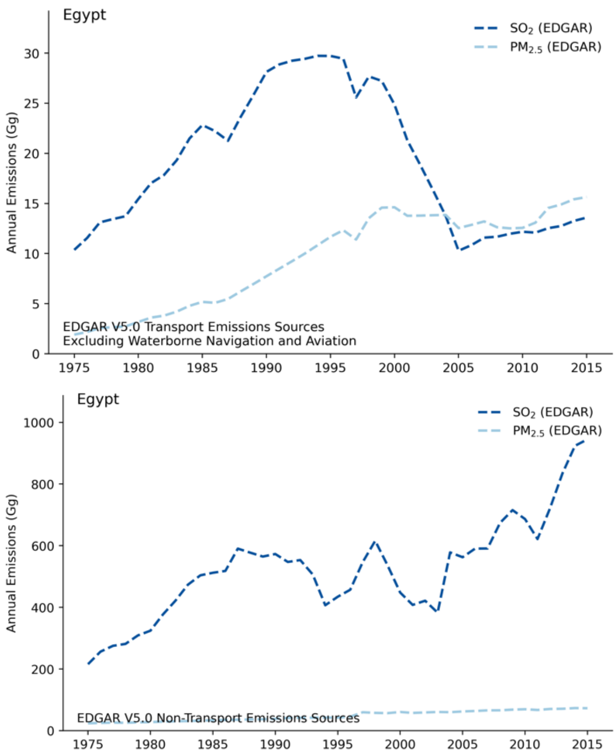


Figure 17: Transport (left) and non-transport (right) emissions of SO_2 and $PM_{2.5}$ in Egypt

3.8 France

Transportation related emissions of SO_X in France peaked at 158.94 Gg in 1993 and have subsequently declined to 0.84 Gg in 2018. The trend in SO_X emission reductions has been consistently downward since 1993. These results demonstrate control of SO_X emissions from transportation sources. In total emissions in 2015 had declined by over 80% relative to 1991. Emissions for SO_X from non-transport sources have declined from 1,225.28 Gg in 1991 to 133.36 Gg in 2018 (**Figure 18**).

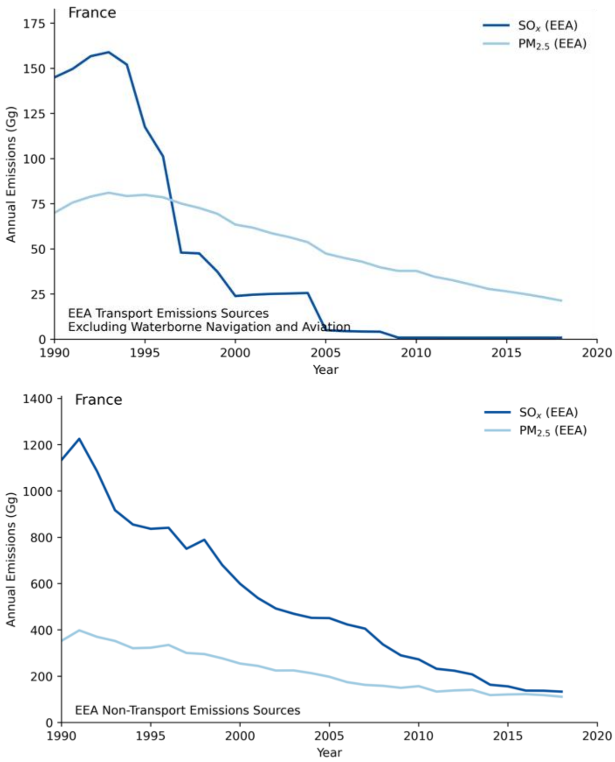


Figure 18: Transport (left) and non-transport (right) emissions of SO_X and $PM_{2.5}$ in France

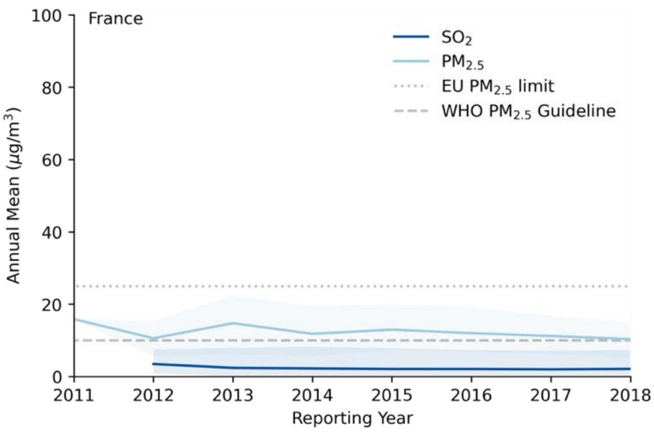


Figure 19: Annual mean concentrations of SO_2 and $PM_{2.5}$ in France (shaded areas show 95% CI)

As shown in **Figure 19**, mean concentrations of SO_2 and $PM_{2.5}$ meet EU ambient air quality standards (EEA 2020a), but do not meet WHO $PM_{2.5}$ guidelines. Station-level data show that all stations in France met EU $PM_{2.5}$ standards in 2016, but just 65 of 282 (23%) stations in France met WHO $PM_{2.5}$ guidelines of 10 μg/m^3. Notably, stations along the southern cost of France saw some of the highest $PM_{2.5}$ concentrations in the country (**Figure 20**).

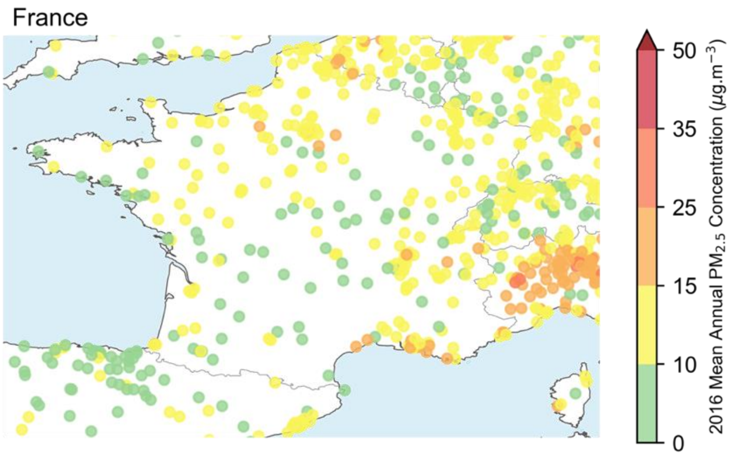
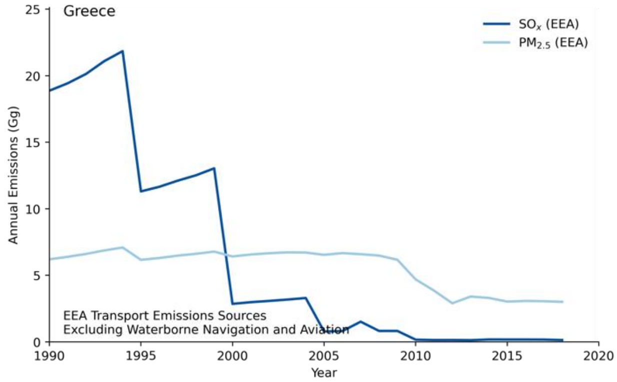


Figure 20: WHO mean annual $PM_{2.5}$ concentration observations in France (2016)

3.9 Greece

Transportation related emissions of SO_X in Greece peaked in 1994 at 21.85 Gg and have subsequently declined to low levels (0.14 Gg in 2018). These results demonstrate a high level of control of SO_X emissions from transportation sources. Non transport source gradually increased until their peak at 548.41 Gg in 2005, after which emissions fell rapidly to 64.12 Gg in 2018 (**Figure 21**).



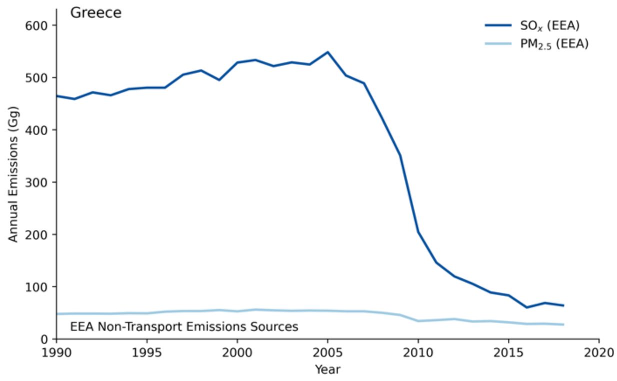


Figure 21: Transport (left) and non-transport (right) emissions of SO_X and $PM_{2.5}$ in Greece

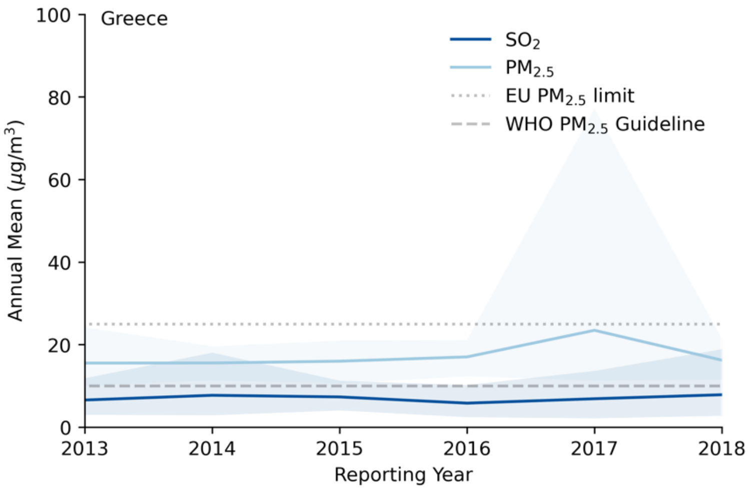


Figure 22: Annual mean concentrations of SO_2 and $PM_{2.5}$ in Greece (shaded areas show 95% CI)

As shown in **Figure 22**, mean concentrations of SO_2 and $PM_{2.5}$ in Greece meet EU ambient air quality standards, though the 95% CI for 2017 does not meet the EU standard of 25 µg/m^3 for $PM_{2.5}$, and $PM_{2.5}$ concentrations do not meet WHO guidelines(EEA 2020a). Station-level data (**Figure 23**) show that all stations in Greece met EU $PM_{2.5}$ standards in 2016, but no stations met WHO $PM_{2.5}$ guidelines of 10 µg/m^3.

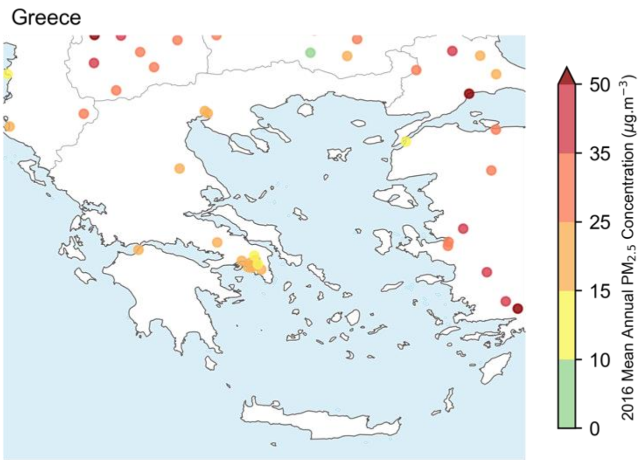


Figure 23: WHO mean annual $PM_{2.5}$ concentration observations in Greece (2016)

3.10 Israel

Prior to 1990, SO_2 emissions in Israel were flat. From 1989 to 1997 SO_2 emissions increased 90% to 11.84 Gg. Since 1997 Israel has seen a strong and consistent annual decline in SO_2 emissions falling to 4.17 Gg in 2015, a 64.8% drop since the 1997 peak. Emissions of $PM_{2.5}$ and SO_2 from transport sources have both declined in 2000 in Israel, and non-transport SO_2 emissions have declined overall by over 80% since 2000 (**Figure 24**).

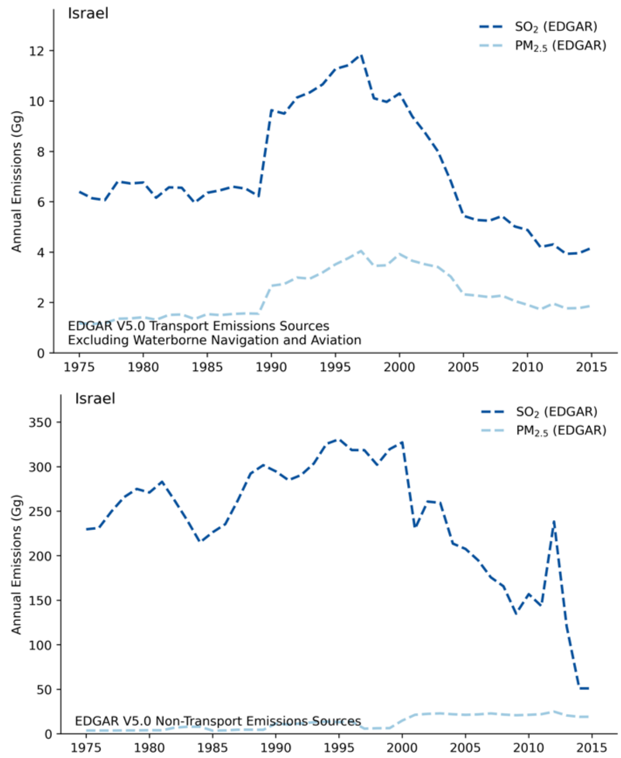


Figure 24: Transport (left) and non-transport (right) emissions of SO_2 and $PM_{2.5}$ in Israel

3.11 Italy

Transportation related emissions of SO_X in Italy peaked in 1992 at 135.71 Gg and have subsequently declined to very low levels (0.41 Gg in 2018). The annual trend in SO_X emission reductions has been consistently downward since 1992. These results demonstrate a high level of control of SO_2 emissions from transportation sources. In total emissions in 2015 had declined by over 99% relative to 1979. Emissions for SO_X from non-transport sources have declined significantly, from 1,574.99 Gg in 1990 to 87.60 Gg in 2018 in Italy (**Figure 25**).

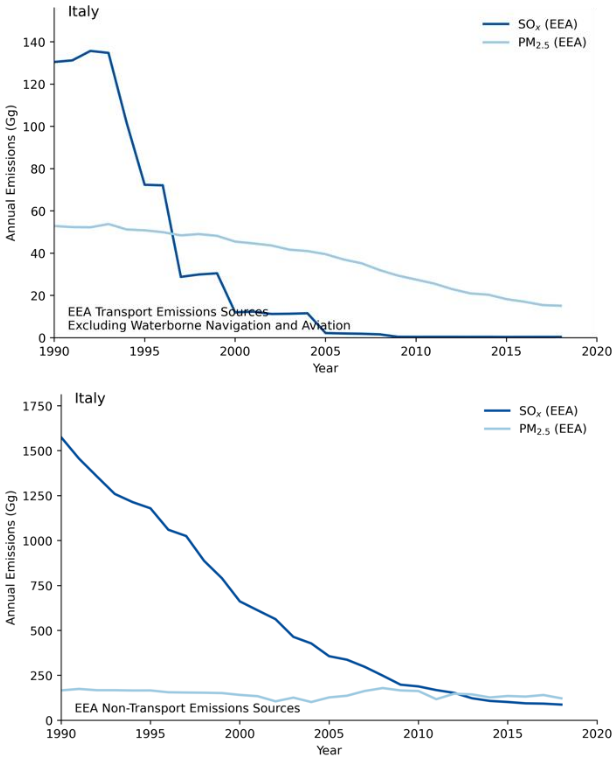


Figure 25: Transport (left) and non-transport (right) emissions of SO_X and $PM_{2.5}$ in Italy

As shown in **Figure 26**, mean concentrations of SO_2 and $PM_{2.5}$ in Italy meet EU ambient air quality standards (EEA 2020a), though the country-level annual means do not meet WHO $PM_{2.5}$ guidelines. Station-level data (**Figure 27**) show that 320 of 334 (95.8%) stations in Italy met EU $PM_{2.5}$ standards in 2016, but just 36 of 334 (10.85) of stations met WHO $PM_{2.5}$ guidelines of 10 µg/m³.

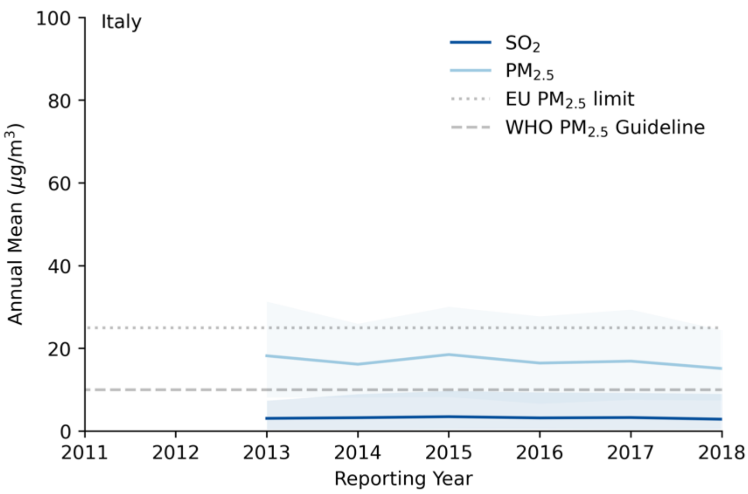


Figure 26: Annual mean concentrations of SO_2 and $PM_{2.5}$ in Italy (shaded areas show 95% CI)

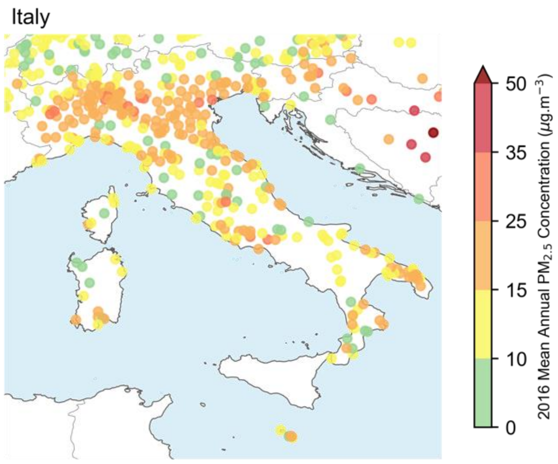


Figure 27: WHO mean annual $PM_{2.5}$ concentration observations in Italy (2016)

3.12 Lebanon

From 1988 to 1998 SO_2 emissions from transportation sources increased 184% from 0.90 Gg to 2.56 Gg. Since 1998, annual SO_2 emissions in Lebanon have mostly declined, to 0.97 Gg in 2015, roughly the same as levels prior to the increase seen in the 1990s. While transport SO_2 emissions have declined, non-transport emissions have grown in Lebanon since 1975 (**Figure 28**).

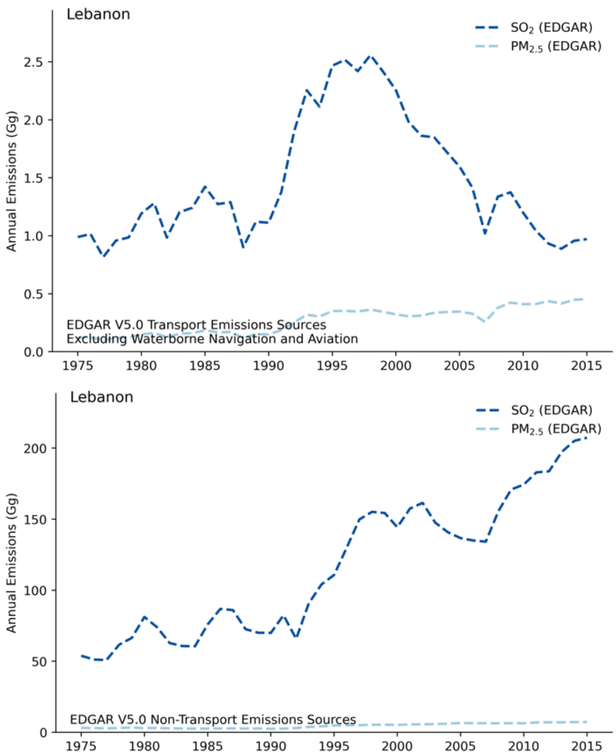


Figure 28: Transport (left) and non-transport (right) emissions of SO_2 and $PM_{2.5}$ in Lebanon

3.13 Libya

Transportation related SO_2 emissions in Libya have seen a strong decline since their peak at 12.76 Gg in 1996. By 2015, transportation SO_2 emissions in Libya had fallen to 4.03 Gg, a decrease of 68%. Transportation-related $PM_{2.5}$ emissions have declined since 2010, and non-transport SO_2 and $PM_{2.5}$ have both shown declines since the mid-2000s in Libya (**Figure 29**).

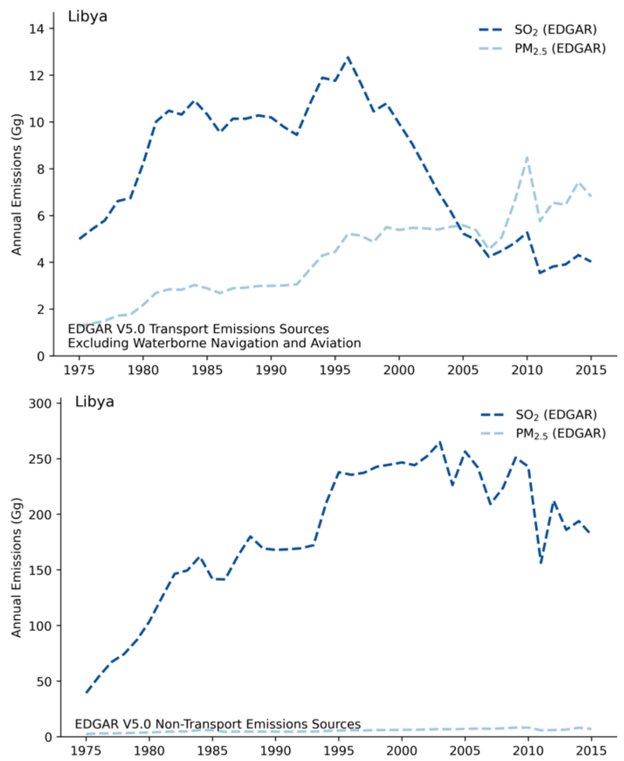


Figure 29: Transport (left) and non-transport (right) emissions of SO_2 and $PM_{2.5}$ in Libya

3.14 Malta

SO_X transportation emissions in Malta have been 0.005 Gg per year since 2005. Non-transport emissions of SO_X have fallen from 12.61 Gg in 2007 to 0.15 Gg in 2018 (**Figure 30**).

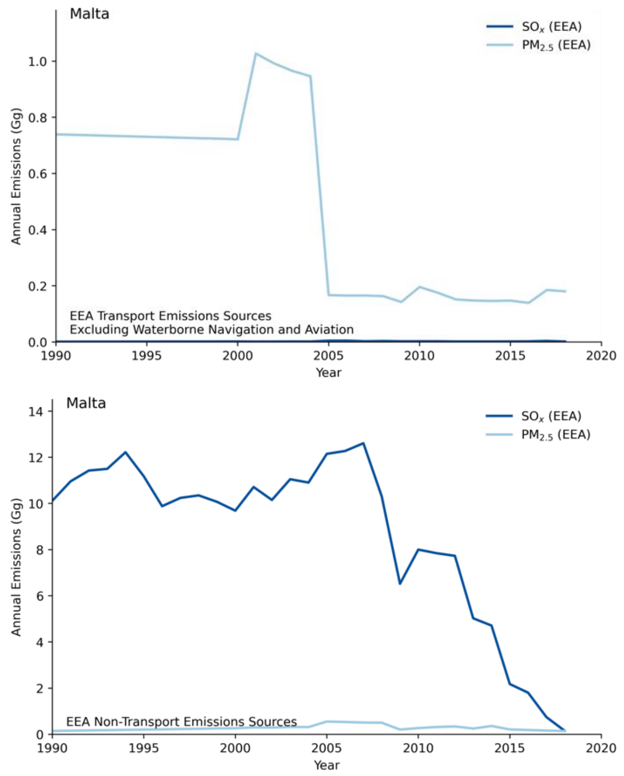


Figure 30: Transport (left) and non-transport (right) emissions of SO_X and $PM_{2.5}$ in Malta

As shown in **Figure 31**, mean concentrations of SO_2 and $PM_{2.5}$ in Malta meet EU ambient air quality standards (EEA 2020a), but with the exception of 2017, exceed WHO guidelines. Station-level data (**Figure 32**) show that all 5 stations in Malta met EU $PM_{2.5}$ standards in 2016, but just 1 of 5 stations met WHO $PM_{2.5}$ guidelines of 10 µg/m³.

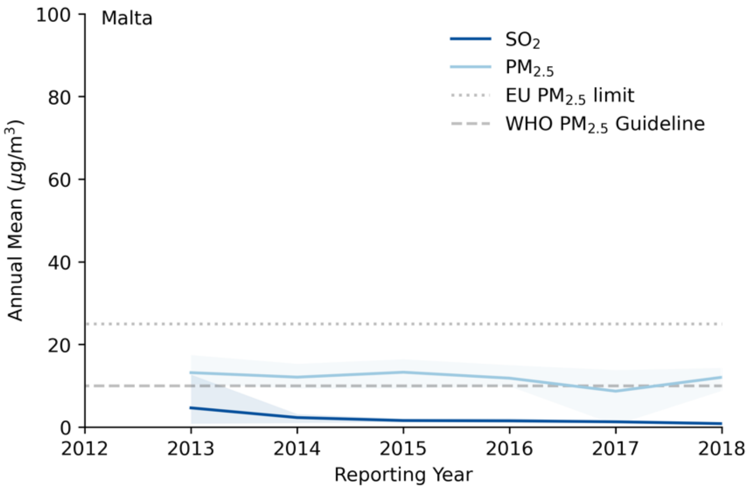


Figure 31: Annual mean concentrations of SO_2 and $PM_{2.5}$ in Malta (shaded areas show 95% CI)

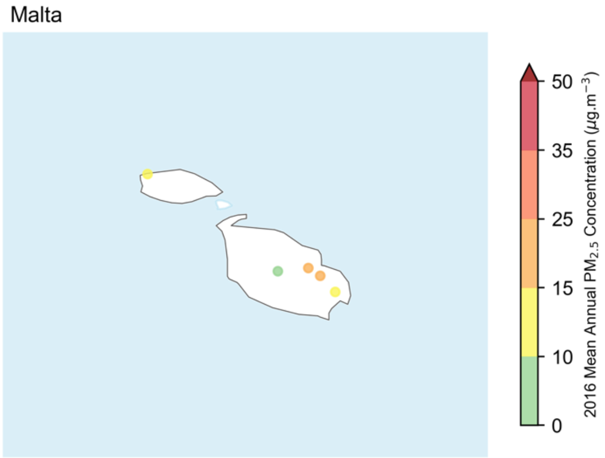


Figure 32: WHO mean annual $PM_{2.5}$ concentration observations in Malta (2016)

3.15 Monaco

No data were available from EDGAR or EEA regarding emissions estimates for Monaco.

Station level data (**Figure 33**) show that the single monitoring station reported by the WHO in Monaco meets EU standards but does not meet the WHO guideline of 10 µg/m³ for annual average $PM_{2.5}$ concentrations.

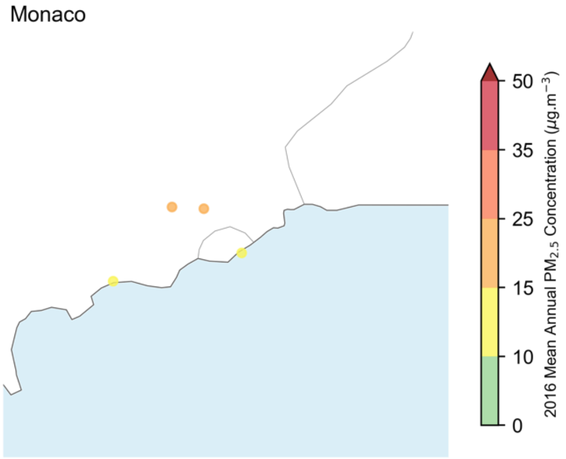


Figure 33: WHO mean annual $PM_{2.5}$ concentration observations in Monaco (2016)

3.16 Montenegro

Transportation related emissions of SO_2 in Montenegro peaked in 1979 at 3.77 Gg and have subsequently declined to very low levels (0.039 Gg in 2015). The overall annual trend in transportation SO_2 emission reductions has been downward since 1978, with a few exceptions in the early 1990s and 2007 These results demonstrate a high level of control of SO_2 emissions from transportation sources. In total transportation SO_2 emissions in 2015 had declined by 99% relative to 1979. Non-transport emissions of SO_2 have declined in Montenegro since 1991 (**Figure 34**).

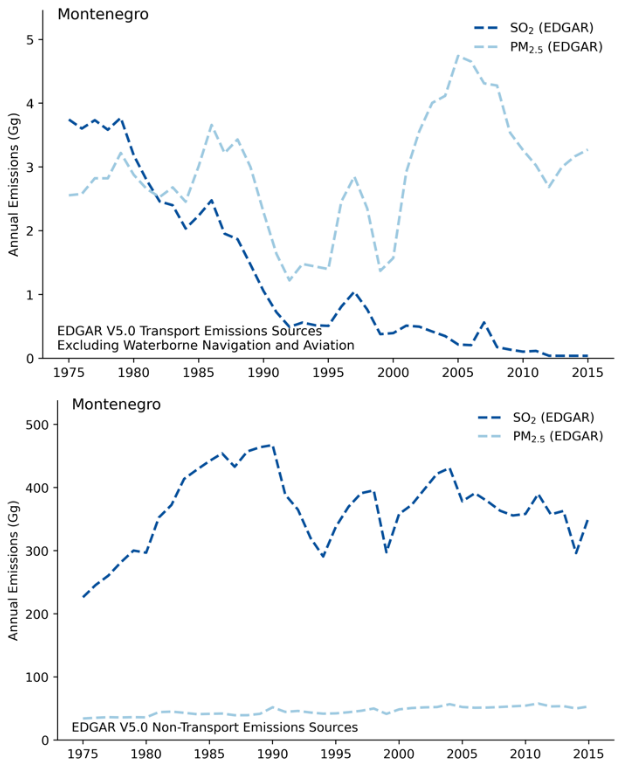


Figure 34: Transport (left) and non-transport (right) emissions of SO_2 and $PM_{2.5}$ in Montenegro

Station level data (**Figure 35**) show that mean annual $PM_{2.5}$ concentrations at 1 of 3 reporting stations in Montenegro met EU standards of 25 µg/m³ in 2016.

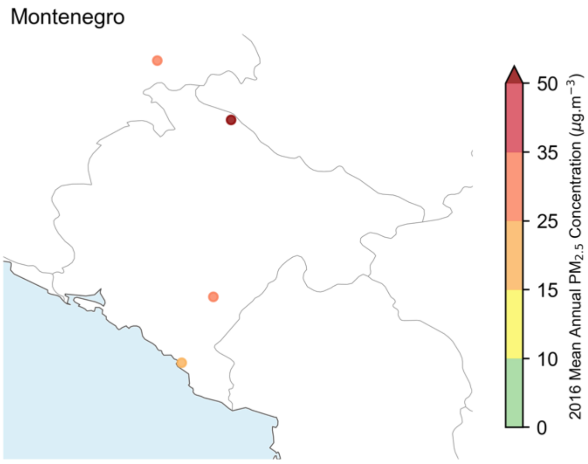


Figure 35: WHO mean annual $PM_{2.5}$ concentration observations in Montenegro (2016)

3.17 Morocco

Prior to 1988, SO_2 emissions from the transport sector in Morocco were flat. From 1989 to 1995 SO_2 emissions increased 105% to 9.84 Gg. Since 1995 Morocco has seen a strong decline in SO_2 emissions falling to 3.53 Gg in 2005, before rising to 4.9 Gg in 2015. Non-transport $PM_{2.5}$ has declined in Morocco since 2004, though non-transport SO_2 emissions have been rising steadily in Morocco since 1975 (**Figure 36**).

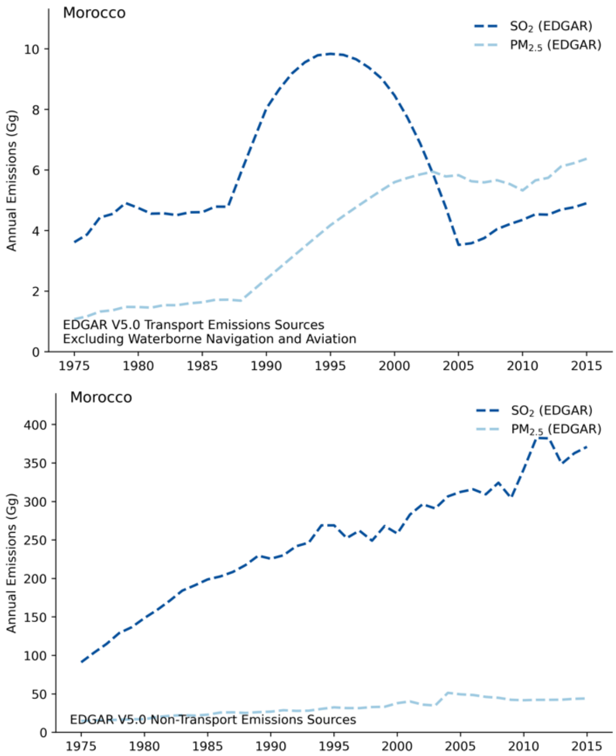


Figure 36: Transport (left) and non-transport (right) emissions of SO_2 and $PM_{2.5}$ in Morocco

Station level data (**Figure 37**) show that no stations in Morocco were compliant with WHO $PM_{2.5}$ guidelines in 2016, with 3 of 6 stations meeting the 25 µg/m^3 standard.

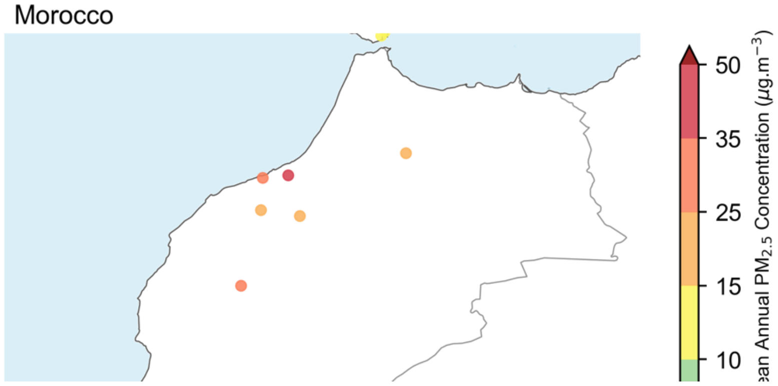


Figure 37: WHO mean annual $PM_{2.5}$ concentration observations in Morocco (2016)

3.18 Slovenia

SO_X emission in the transportation sector have declined from 7.29 Gg in 1994 to 0.04 Gg in 2018. Both transport and non-transport $PM_{2.5}$ have fallen in Slovenia since 2009, along with large overall reductions in SO_X. Non-transport SO_X fell from 194.04 Gg in 1990 to 4.74 Gg in 2018 (**Figure 38**).

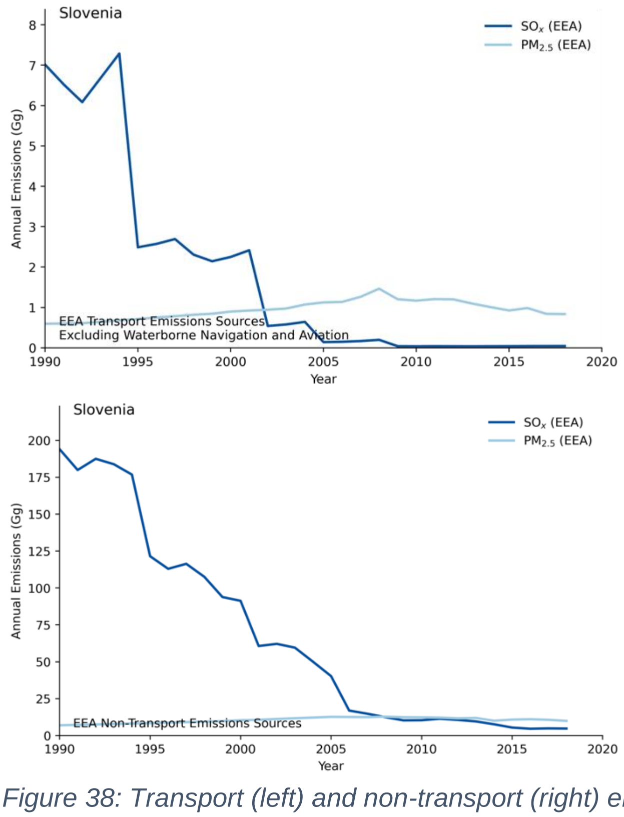


Figure 38: Transport (left) and non-transport (right) emissions of SO_X and $PM_{2.5}$ in Slovenia

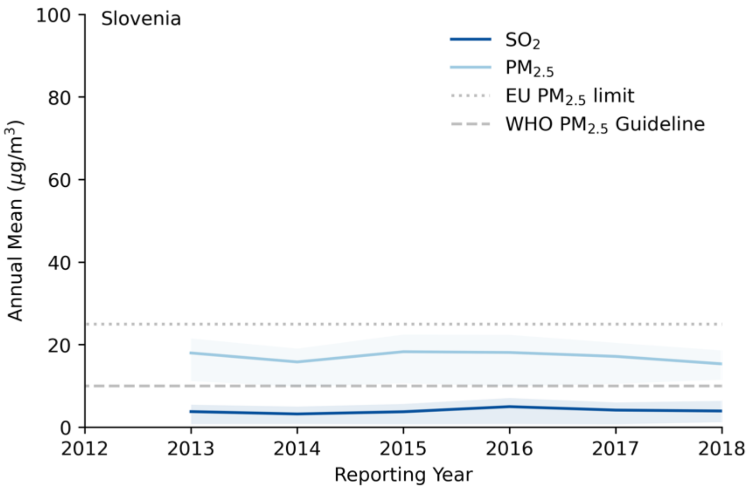


Figure 39: Annual mean concentrations of SO_2 and $PM_{2.5}$ in Slovenia (shaded areas show 95% CI)

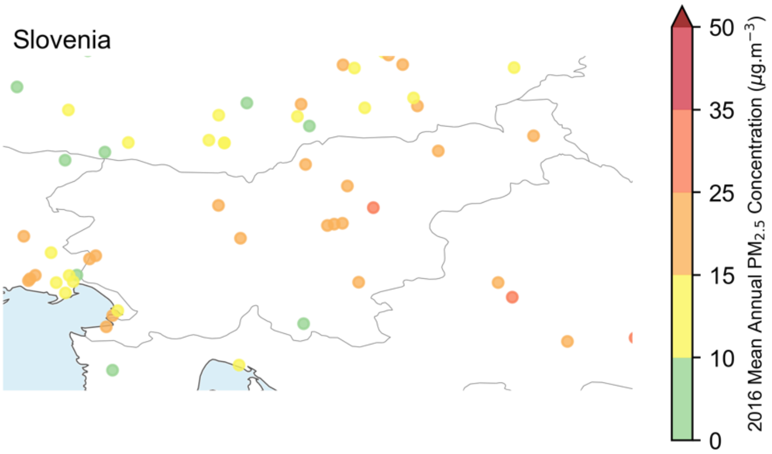


Figure 40: WHO mean annual $PM_{2.5}$ concentration observations in Slovenia (2016)

As shown in **Figure 39**, mean concentrations of SO_2 and $PM_{2.5}$ in Slovenia meet EU ambient air quality standards (EEA 2020a), but exceed WHO guidelines for $PM_{2.5}$ (10 µg/m^3). Station level data (**Figure 40**) show that 1 of 14 stations in Slovenia met WHO $PM_{2.5}$ guidelines in 2016, while 13 of 14 stations met EU standards (25 µg/m^3).

3.19 Spain

SO_X emission in the transportation sector have declined in Spain since their peak in at 63.36 Gg in 1994 to 0.43 Gg in 2018. Non-transport emissions of SO_X have fallen significantly since the early 1990s (**Figure 41**).

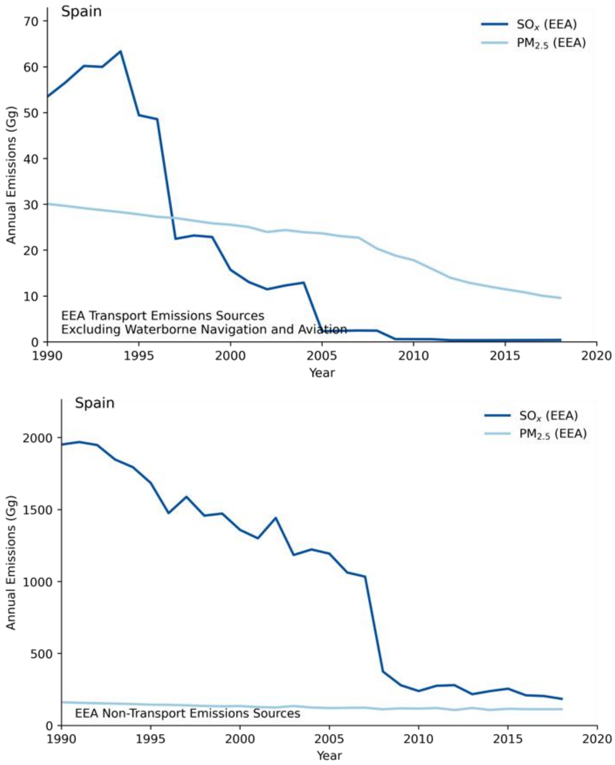


Figure 41: Transport (left) and non-transport (right) emissions of SO_X and $PM_{2.5}$ in Spain

As shown in **Figure 42**, mean concentrations of SO_2 and $PM_{2.5}$ in Spain meet EU ambient air quality standards (EEA 2020a), and are slightly above WHO guidelines (10 µg/m^3), with a mean annual concentration of 10.3 µg/m^3 in 2018. Station-level data (**Figure 43**) show that 163 of 252 (64.7%) stations in Spain met WHO guidelines in 2016, and all stations met EU $PM_{2.5}$ standards.

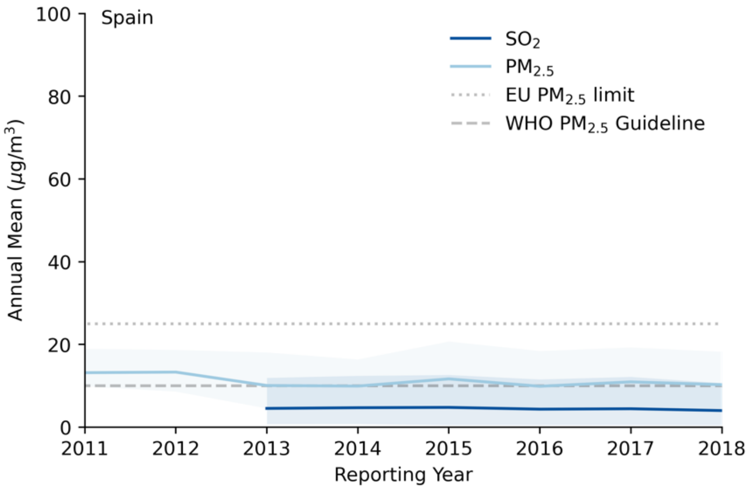


Figure 42: Annual mean concentrations of SO_2 and $PM_{2.5}$ in Spain (shaded areas show 95% CI)

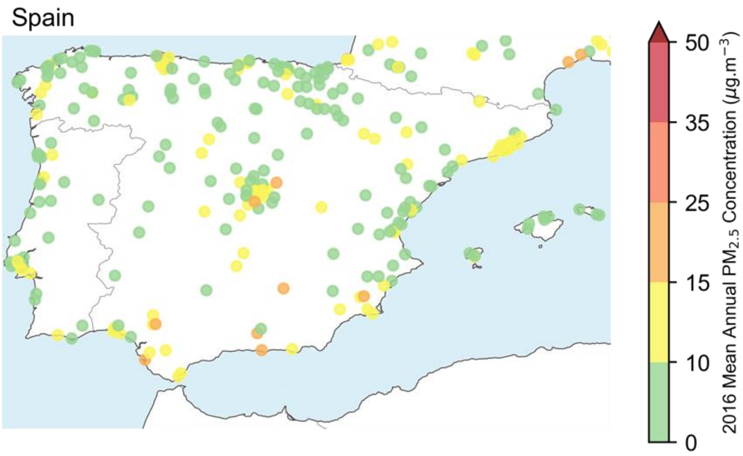


Figure 43: WHO mean annual $PM_{2.5}$ concentration observations in Spain (2016)

3.20 Syrian Arab Republic

SO_2 emission in the transportation sector have declined by 84% in the Syrian Arab Republic since their peak in 1991 (10.12 Gg). Emissions of SO_2 from the transport sector were 1.61 Gg in 2015. Both transport and non-transport related emissions of SO_2 and $PM_{2.5}$ have fallen significantly in the Syrian Arab Republic since around 2008 (**Figure 44**).

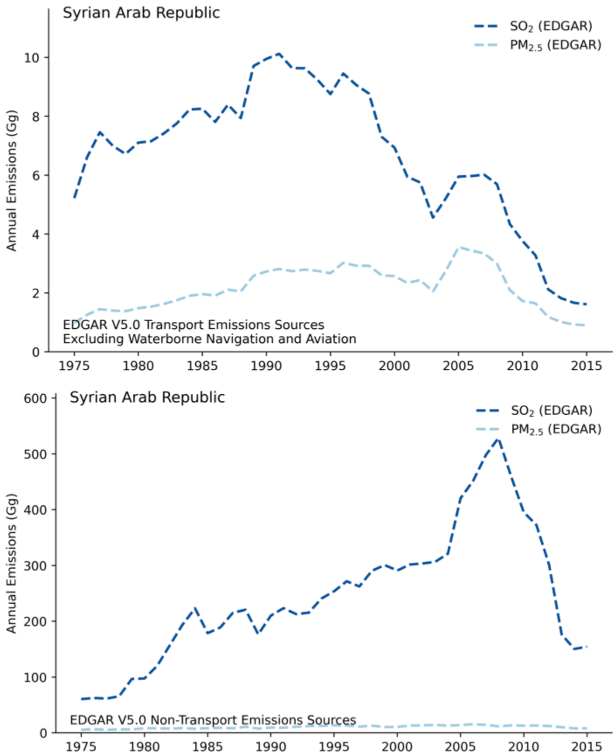


Figure 44: Transport (left) and non-transport (right) emissions of SO_2 and $PM_{2.5}$ in the Syrian Arab Republic

3.21 Tunisia

SO_2 emission in the transportation sector peaked at 5.47 Gg in 1995 in Tunisia and have since declined by 65.6% to 1.88 Gg in 2015. Emissions of SO_2 in the transport and non-transport sectors have declined significantly in Tunisia since their respective peaks, though $PM_{2.5}$ emissions in have continued to grow in both areas (**Figure 45**).

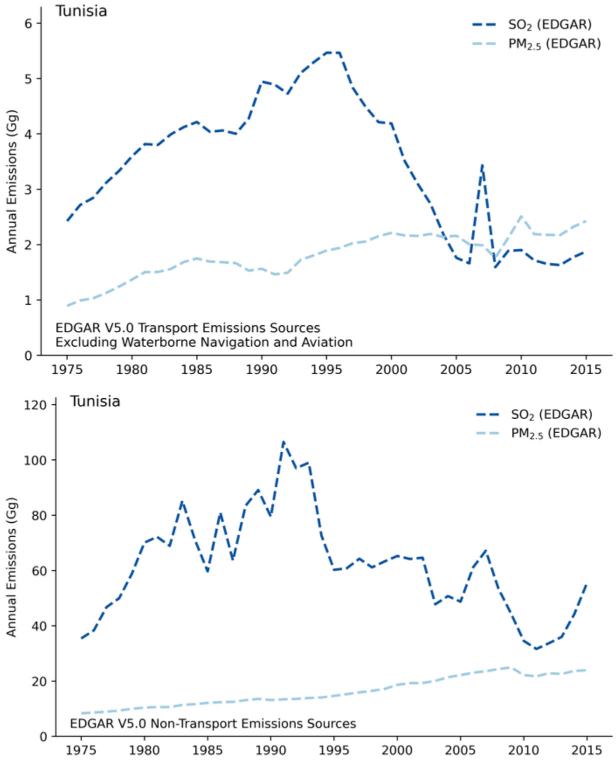


Figure 45: Transport (left) and non-transport (right) emissions of SO_2 and $PM_{2.5}$ in Tunisia

3.22 Turkey

SO_2 emissions have declined overall in Turkey since 1986, though they did increase slightly from 2011 to 2015. SO_2 emissions from the non-transport sectors have been flat or slightly declining since the late 2000s. Similarly, emissions of $PM_{2.5}$ in both the transport and non-transport sectors have been flat since the late 1990s (**Figure 46**).

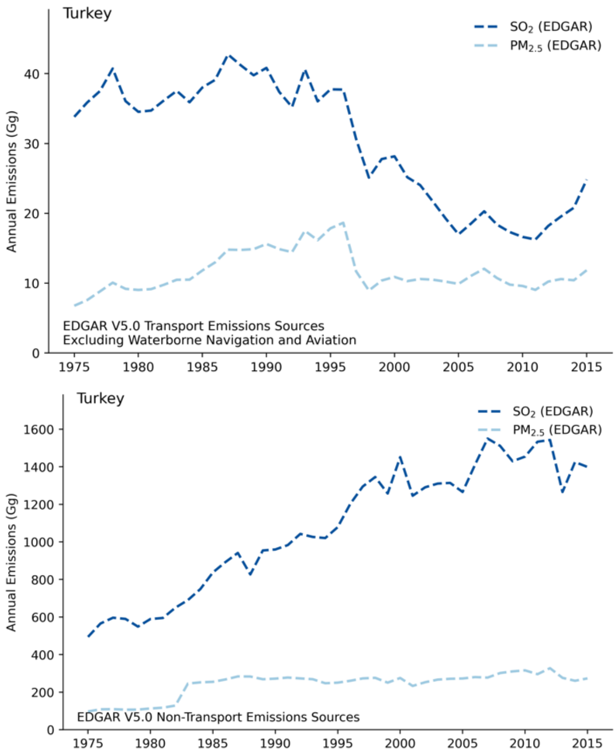


Figure 46: Transport (left) and non-transport (right) emissions of SO_2 and $PM_{2.5}$ in Turkey

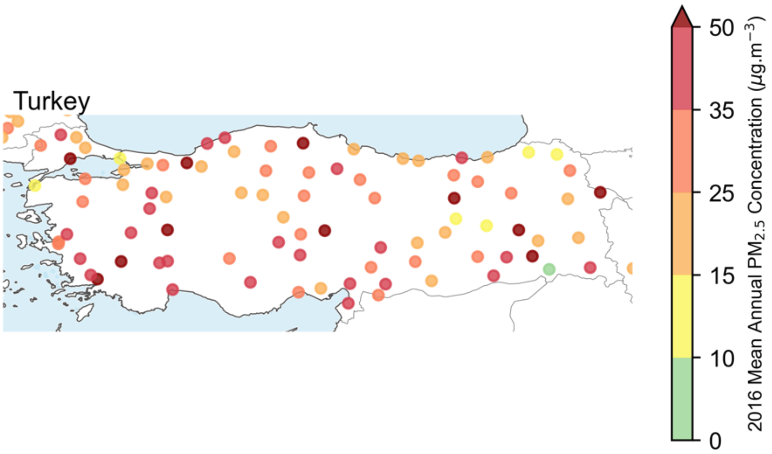


Figure 47: WHO mean annual $PM_{2.5}$ concentration observations in Turkey (2016)

Station-level data (**Figure 47**) show that just 1 of 87 stations reported by the WHO in Turkey meets WHO $PM_{2.5}$ guidelines, and 29 of 87 (33%) meet EU annual mean $PM_{2.5}$ standards (25 µg/m^3).

4 An Assessment of the Relative Costs of introducing the Med SO_X ECA in Comparison with the cost of Land-Based Control Measures

Criteria 3.1.8 for designation of an emission control area, laid out in Appendix III to MARPOL Annex VI requires a description of the relative costs of reducing emissions from ships when compared with land-based controls.

Criteria 3.1.8, Appendix III to MARPOL Annex VI

The proposal shall include:
The relative costs of reducing emissions from ships when compared with land-based controls, and the economic impacts on shipping engaged in international trade

This section presents results from international experience with pollution abatement control costs. Detailed information on control costs is not available on a country-by-country basis, and analysis of results from international studies show that the range of expected control costs, on a per-unit pollution abated basis, are generally in good agreement, indicating that international experiences with control costs are similar.

4.1 Estimates of Cost Effectiveness

There is a large variety of technology and operational choices available for pollution abatement. For sulphur abatement, these options fall under four broad categories: the use of low sulphur fuel, fuel desulphurisation, combustion processes, and desulphurisation of the exhaust gasses. The costs of these technologies, and the associated emission reductions, may be estimated in a range of ways. First, engineering estimates look specifically at technology and operating costs, and associated changes in emissions levels. Engineering approaches are useful when applied to specific plants but can raise issues when applied broadly to an industry, due to the many and varied compositions of individual plants. Another method of estimating environmental regulatory compliance costs is to survey industry, asking facilities' their direct capital and operational costs to reduce pollution. Again, this methodology is challenged, as issues with sample size, response rate, and difficulty in accurately separating costs associated with different pollution species challenge the results.

A 1999 report by IIASA for the European Commission (European Commission 1999), estimates that the costs of abating SO_2 range from \$586 to \$860/MT SO_2. Recent work in China (Zhang et al. 2020) estimates potential emissions abatement of 19.2 million tonnes of SO_2 from switching to renewable energy technologies at a cost of 92.5 billion CNY (Chinese Yuan), or 4,818 CNY/MT SO_2 abated, equivalent to around \$730/MT SO_2 abated.

The United States Environmental Protection Agency (EPA) is in the process of updating their Air Pollution Control Cost Manual. Section 5 of the report identifies the most recently available technologies and costs for removing acidifying gases, such as SO_X, from emissions. The EPA manual provides an engineering example of the cost effectiveness, akin to the MAC, of a wet FGD (flue gas desulphurisation) unit on a 500 MW coal facility at \$681/MT SO_2 abated, and \$945/MT SO_2 for a dry FGD unit on a similar sized plant. For a wet-packed tower absorber the EPA report estimates \$636/MT SO_2. Notably, these engineering examples are just that, calculations for specific example facilities, but they align well with other literature estimates to provide an additional reference for the abatement costs.

4.2 Shadow Prices of Pollution

Another approach to estimating costs of pollution controls is to measure indirect and revealed costs. Using econometric techniques to identify revealed rather than stated pollution abatement costs, abatement costs which are more indicative of the total cost of regulatory compliance may be estimated. One such approach that is widely applied is to use shadow prices.

The shadow price is the opportunity cost of incremental reductions in pollutant species in terms of reductions in production output. Shadow prices in the USA for SO_2 abatement from coal power plants range from \$1,806 - \$18,018 / MT SO_2 (Swinton 1998; Färe et al. 2005) and from \$2,044 - \$21,749 / MT SO_2 for industrial processes in the USA, Korea and China (Coggins and Swinton 1996; Turner 1995; Boyd, Molburg, and Prince 1996; Lee, Park, and Kim 2002; Tu 2009; He and Ou 2017).

CE Delft publishes a Shadow Price Handbook (CE Delft 2010) which finds SO_2 shadow prices of $6,461 - $12,943 / MT SO_2 and PM_{10} shadow prices of €2,300 – 50,000 / MT PM_{10}. The CE Delft Environmental Prices Handbook estimates that the environmental cost, not the abatement cost, of SO_2 pollution is €24,900 / MT SO_2, while the environmental cost of $PM_{2.5}$ is €79,500 / MT SO_2 (CE Delft 2018), values which well-exceed the land-side abatement costs.

A 2014 study of OECD economies found that the shadow prices for PM_{10} abatement were highly variable, ranging from $5,079/ MT PM_{10} to $295,832 / MT PM_{10} (in 2005$), with a mean and median of $99,500 / MT PM_{10} and $82,161 / MT PM_{10}, respectively (Dang and Mourougane 2014).

4.3 Estimates of Cost-Effectiveness from Prior ECA Applications

The North American ECA application (EPA 2009) lists a set of land-based source controls. The dates of the control costs span a wide range, and so may be best thought of as descriptive rather than prescriptive of current abatement costs, which are likely different due to policy changes in recent years and technology improvements. The report list costs of between $11,000 – $16,000 / MT PM_{10} (2006$) for non- and on-road diesel and gasoline engine applications and a range of $4,000 to $46,000 / MT PM_{10} (2006$) for stationary diesel engines. Locomotive and harbour craft costs range from $9,300 / MT PM_{10} (2006$) for new builds up to $50,000 / MT PM_{10} (2006$) for retrofits. SO_X emission abatement costs estimated by EPA are generally lower than PM_{10} abatement costs. Stationary source SO_X abatement costs range from $300 to $6,000 / MT SO_X, whereas on-road SO_X abatement costs are estimated at $6,400 / MT SO_X for heavy-duty diesel engines, and $6,600 / MT SO_X for light duty gasoline/diesel engines.

4.4 Cost Effectiveness of the Med SO_X ECA

Findings from independent peer reviewed and grey literature find that ranges for PM_{10} and SO_X abatement costs are broad and overlapping. The costs assigned to removal of any single species (of either SO_X or PM) cannot be treated as fully independent, as PM and SO_X pollutant species are entwined. Therefore, though the costs are attributed to a single pollutant, in reality there will likely be co-reductions for both SO_X and PM with any abatement measure.

Table 6: Marginal SO_2 abatement costs ($/MT) adapted from Mekaroonreung and Johnson (2012)

Study	Average Price of SO_2 abatement ($/ton)
(Färe et al. 2005)	76 - 142
(Mekaroonreung and Johnson 2012)	201 - 343
(Coggins and Swinton 1996)	292
(EPA 2009) - Stationary	300 – 6,000
(Mekaroonreung and Johnson 2012)	509 – 2,020
(European Commission 1999)	586 - 860
(Zhang et al. 2020)	730
(Turner 1995)	826
(Färe et al. 2005)	1,117 – 1,974
(Boyd, Molburg, and Prince 1996)	1,703
(Lee, Park, and Kim 2002)	3,107
(EPA 2009) – On-Road	6,400 – 6,600
(CE Delft 2010)	6,461 - 12,943

Table 6 shows the range of identified SO_2 abatement costs from the literature, discussed above. The range in abatement costs is wide, ranging from $76/MT SO_2 abated to $6,600/MT SO_2 abated. Ranges this wide are consistent with the literature, as they represent a suite of technology and operational measures possible to reduce SO_2 emissions, as well as a suite of sectors, including stationary and mobile sources, for which abatement technologies can vary greatly. As shown in **Table 7**, the marginal abatement costs of the proposed Med SO_X ECA are aligned with the SO_X and PM marginal abatement costs for both the base case, and the proposed Med SO_X ECA with scrubbers.

Table 7: Cost effectiveness of the Med SO_X ECA from the Technical and Feasibility Study

Benefit Type	**MARPOL VI**	**Proposed Med SO_X ECA**	**Proposed Med SO_X ECA with scrubbers**
Control Target			
Abated SO_X emissions	$7,730 / MT SO_X	$13,400 / MT SO_X	$8,750 / MT SO_X
Abated $PM_{2.5}$ emissions	$80,300 / MT $PM_{2.5}$	$155,000 / MT $PM_{2.5}$	$101,000 / MT $PM_{2.5}$

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)[22] (REMPEC 2019), hereinafter referred to as the Technical and Feasibility Study, found that the proposed Med SO_X ECA has a cost effectiveness of around $8,750 - 13,400/MT SO_X abated (**Table 7**). For comparison, the North American ECA cost effectiveness was estimated at $1,200/MT SO_X. However, it must be remembered that the North American ECA was implemented at a time when the global fuel sulphur cap was 3.50% S m/m, and thus step down to 0.10% S m/m represented a larger step than the proposed Med SO_X ECA.

The benefit-cost ratio of the proposed Med SO_X ECA estimated in the Technical and Feasibility Study is $1.58 million per avoided mortality. Parallel studies from France (Rouïl et al. 2019) and the European Commission (Cofala et al. 2018) find benefit-cost ratios of 3 and 4.8 respectively. The cost effectiveness of the proposed Med SO_X ECA is at the upper end of many of the stationary source abatement costs identified. However, as noted by the benefit cost-ratios, the health and environmental benefits of the proposed Med SO_X ECA are far larger than the costs.

[22] https://www.rempec.org/en/knowledge-centre/online-catalogue/2019/rempec-wg-45-inf-9-technical-and-feasibility-study-to-examine-the-possibility-of-designating-the-mediterranean-sea-or-parts-thereof-as-sox-eca-s-under-marpol-annex-vi-english-only.

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