MARINE FUEL FACTS

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BACKGROUND INFORMATION

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1 Background on Shipping

Summary

- Around 80% of global trade by volume is carried by sea
- Marine Fuel demand: 6.1% of global world oil demand (2012)
- Residual Marine Fuel demand: 49.5% of total global residual demand

«Shipping: indispensable to the world»
- Around 80% of global trade by volume and over 70% by value is carried by sea and is handled by ports worldwide
- More than 50,000 merchant ships are trading internationally
- The world fleet is registered in over 150 nations

Main Flags of Registration
- share of world total (% dwt)

<table>
<thead>
<tr>
<th>Country</th>
<th>Share (%)</th>
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<tr>
<td>Panama</td>
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<tr>
<td>Liberia</td>
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<tr>
<td>China</td>
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<tr>
<td>Cyprus</td>
<td>1.92%</td>
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</tbody>
</table>

Source: UNCTAD, Review of Maritime Transport 2015, October 2015

World Fleet by Type (% dwt)

- Bulk carries: 44%
- Oil tankers: 27%
- Container ships: 14%
- Ferries & passenger: 0.6%
- Chemical tanker: 6%
- General cargo: 1%
- Other: 8%

Source: IMO 3rd GHG study, MEPC 67/INF.3, July 2014

Note: Due to the rounding, figures may not add up to 100%
**Fuel Consumption by Ship Type (2012)**

- **Container**: 22%
- **Bulk carrier**: 18%
- **Oil tanker**: 13%
- **General cargo**: 7%
- **All other ship types**: 8%
- **Vehicle**: 3%
- **Offshore**: 3%
- **Cruise**: 4%
- **Liquefied gas tanker**: 5%
- **Fishing**: 5%
- **Chemical tanker**: 6%
- **Ro-Ro and RoPax**: 6%
- **General cargo**: 7%
- **Oil tanker**: 13%

**Total Marine Fuel Consumption (2012):** 300 Mt
(international + domestic)

Sources: IMO 3rd GHG study and BP Statistical Review of World Energy, June 2015
**Marine Fuel Consumption 2012 (Mt/y)**

Marine Fuel demand: 6.1% of global world oil demand (2012)

Residual Marine Fuel demand: 49.5% of total global residual demand

Sources: IMO 3rd GHG study and BP Statistical Review of World Energy, June 2015
2 Sources of Atmospheric Sulphur Emissions

Summary

- Shipping contributes to around 10% of current global man-made SO$_2$ emissions
- Projected growth in shipping SO$_2$ emissions is now significantly lower than what was expected in 2008 when the current regulation was adopted
- There are also significant natural sources of Sulphur emissions (volcanoes, plankton): three to six times more sulphate is generated above the oceans from dimethyl sulphide released by plankton than from SO$_2$ emissions from shipping*

- Sulphur is a naturally occurring element, essential for life
- Largest man-made sources of global SO$_2$ emissions are land-based:
  - In 2005, SO$_2$ emissions from international shipping amounted to 10% of global anthropogenic emissions
  - Land-based emissions projected to decrease substantially in coming decades (see Global SO$_2$ Emissions graph)

- Natural sources of Sulphur emissions are also significant:
  - Volcanic emissions
  - Biogenic emissions, primarily dimethyl sulfide (DMS) generated by plankton in the oceans
  - Both SO$_2$ and DMS are oxidized to form sulphate aerosols through atmospheric chemistry processes (see maps in additional information)

- Projected shipping emissions are now significantly lower than when the revision of MARPOL Annex VI was adopted in 2008:
  - Improved emission inventory lowered expected growth

* based on data from the 3rd IPCC Assessment Report
Background Information

**Anthropogenic SO₂ Emissions (Mt/y)**


**Global SO₂ Emissions**

(100 Gg = 1 Mt)

Source: S. J. Smith and T. C. Bond, Two hundred fifty years of aerosols and climate: the end of the age of aerosols, Atmos. Chem. Phys., 14, 537–549, 2014
Global Sulphur Emissions to Atmosphere

Million tonnes Sulphur/year

- Antropogenic (excl. shipping)
- Shipping Biomass burning
- Volcanoes
- Oceans
- Land biota and soils

Emission level range

Note: One tonne of Sulphur to atmosphere is equivalent to two tonnes of SO2

Data sources:
- Smith, et al. (2011)
- IPCC 3rd Assessment Report (2001)
- IMO, 3rd GHG report (2014)

Projected Global Shipping SO₂ Emissions (Mt/y)

2007 IMO projection (Business As Usual)
2007 IMO projection 0.50% Sulphur global cap 2020
IMO 3rd GHG report actuals
Current projection Business As Usual
Current projection 0.50% Sulphur global cap 2020

Data sources:
- IMO Scientific Group of Experts Report, BLG 12/6/1, 2007
- Concawe inter- and extrapolations
3 Marine Fuel Regulations

Summary

- Bunker Fuel Sulphur is regulated under Annex VI of the MARPOL Convention.
- The Convention is administered by the Marine Environment Protection Committee (MEPC) of the International Maritime Organization (IMO).
- The Convention foresees reducing the global fuel Sulphur cap from 3.5% to 0.5% as of 2020, however subject to a review on fuel availability.
- IMO has initiated the Fuel Availability Review in 2015 and is expected to review the results at the October 2016 MEPC meeting.
- Europe has decided unilaterally to implement 0.5% in its Exclusive Economic Zones (up to 200 nm from the coast) regardless of the forthcoming IMO decision.

MARPOL Annex VI Marine Fuel Sulphur Regulation

- Global cap 4.5% Sulphur
- Global cap 3.5% Sulphur
- All ECA 1.5% Sulphur
- All ECA 1% Sulphur
- All ECA 0.1% Sulphur

- 2008
- 2009
- 2010
- 2011
- 2012
- 2013
- 2014
- 2015
- 2016
International shipping is governed by Conventions administered by the International Maritime Organization (IMO), a UN body based in London.

Annex VI of the International Convention for the Prevention of Pollution from Ships MARPOL 73/78 covers fuel Sulphur levels.

As of March 8, 2016, 86 states have ratified Annex VI, representing 95.34% of the world’s tonnage.

IMO’s MEPC maintains MARPOL Annex VI.

Global Sulphur Cap
• Mandatory review by 2018 to determine 0.5% Sulphur fuel availability
• IMO’s MEPC to decide whether it will be possible to comply in 2020

IMO has initiated the Fuel Availability Review in 2015
• Steering Committee appointed
• Contractor appointed to perform study (CE Delft)
• Results to be available for discussion at October 2016 MEPC meeting

Supplemental study co-sponsored by several industry bodies.

*Pending October 2016 MFPC meeting review
**Emission Control Areas (ECAs)**

**Regional regulations**
- EU Sulphur in Liquid Fuels Directive
  - 0.1% Sulphur at berth since 2010
  - 0.5% Sulphur in EU waters effective 2020 (regardless of IMO decision)
- California rules – being aligned with IMO
- Hong Kong/China: local initiatives

CURRENT SITUATION, ALTERNATIVES AND POSSIBLE OUTCOMES

1. Refining Impact - Fuel Availability Concerns
2. Scrubbers and Other Alternatives
3. Timetable and Possible Outcomes
1 Refining Impact - Fuel Availability Concerns

Summary

- Estimated fuel switch volumes in the range of 2 Mb/d to more than 3 Mb/d (depending on total demand projection and scrubber/LNG penetration)
- Represents an unprecedented step change compared to:
  - Annual trend line growth rate for distillate demand: 500 kbd
  - Annual trend line decline in residual demand: 150 kbd
  - Experience with introduction of 0.1% Sulphur fuel in 2015: ~ 400 kbd
- Sound, realistic assessment of fuel availability is key:
  - Distillate production, capacity to process residual fuel oil no longer needed
  - Impacts on other products

- Unprecedented impact of global cap on the refining industry

- IEA’s Mid-Term Oil Market Report 2015 expects that 2 Mb/d of fuel oil would need to be switched to distillate type of fuels, while other sources show even higher switch volume estimates

- Very high switch volume compared long-term distillate growth and fuel oil decline trends:
  - Distillate: + 500 kbd/yr
  - Fuel oil: - 150 kbd/yr

- Critical elements of IMO Fuel Availability Study:
  - Realistic forecast of 2020 fuel demand with appropriate high and low cases
  - Realistic assessment of scrubber and LNG penetration ahead of 2020
  - Solid assessment of general refining and conversion capacities that will be online by the end of 2019
  - Solid global modelling:
    ▶ Crude outlook and low Sulphur crude opportunities
    ▶ Proven fuels
    ▶ No discontinuity in supply to other petroleum product markets
    ▶ Surplus fuel oil used as feedstock for conversion units
    ▶ Interregional trade
    ▶ Avoidance of over-optimisation in aggregated LP model
Product Demand Trendline (Mb/d)


Petroleum Product Demand Changes (Mb/d)

2 Scrubbers and Other Alternatives

Summary

- Production of compliant fuels will involve switching a significant volume of residual fuel to lower Sulphur distillate type fuels; contribution of LNG expected to be small by 2020.
- The Convention allows use of exhaust gas scrubbers as an alternative compliance method:
  - Proven technology, economically viable (new and retrofit, though retrofit not possible on all ships).
  - Several types available: open loop, closed loop, hybrid.
  - Some local restrictions apply to scrubber effluent and some on-going discussion in EU on the acceptability of scrubber wash water discharges.
  - Scrubbers offer overall GHG benefit – net CO₂ reduction of 9 Mt/y compared to removing Sulphur in European refineries.

- MARPOL Annex VI requires ships to use fuels with a maximum Sulphur content.
  - Equivalent compliance methods can be used when approved by Administrations.

- Exhaust Gas Cleaning Systems (EGCS, also called “scrubbers”) are being used as equivalent method:
  - Initial interest in scrubbers from ship owners was limited.
    - See results December 2014 survey European Chamber of Shipping Association (ECSA).
    - EnSys/Navigistics estimated that as of the first half of 2016 some 350 ships had installed or ordered scrubbers.

- Several commercially proven scrubber designs:
  - Sea Water Scrubber (open loop).
  - Fresh Water Scrubber with alkaline reactant (closed loop):
    - Can operate with zero discharge for a limited time.
  - Hybrids: scrubbers can alternate between open and closed loop modes.

- Overall energy benefits:
  - Considerable CO₂ emission savings can be achieved by scrubbing:
    - The scrubber case would avoid a 17 Mt/y increase in refinery CO₂ emissions.
    - Partially offset by 8 Mt/y increase CO₂ emissions from scrubber energy need.
    - Net saving of 9 Mt/y (source Concawe Report 1/13R).

- Acceptability and technology choice considerations:
  - For retrofitting a ship: available space, loss of cargo space, age, stability.
  - Effluent impact on environment.
- On-going discussion in EU on the acceptability of scrubber wash water discharges (in particular when operating in coastal waters and harbours) and on the status of effluents under the Water Framework Directive
- Several measurement campaigns are underway on ships operated with scrubbers in EU and North America waters

### Compliance Method(s) for ECA 0.1% Sulphur Requirements

![Bar chart showing compliance methods for ECA 0.1% Sulphur Requirements](chart)

- Compliant Fuel of 0.1% Sulphur content: 97.4%
- Scrubbing Technology: 15.4%
- LNG: 15.4%
- Methanol: 2.6%

*Data source: ECSA*

### Effect of On-Board Scrubbers on EU Refinery CO₂ Emissions

![Chart showing refinery CO₂ emissions with and without scrubbers](chart)

- **Without scrubbers**: Orange dots
- **With scrubbers**: Green dots

*Data source: CONCAWE report 1/13R*
3 Timelines and Possible Outcomes

Summary

- Earliest possible decision point will be at October 2016 MEPC meeting
- MEPC will review the results of the IMO Fuel Availability Study and any comments submitted by IMO Member States and/or Observer Organisations
- Regulation 14.10 of Annex VI only foresees two possible outcomes:
  - Implementation of the 0.5% Sulphur requirement in 2020 (base case)
  - Postponement of the implementation date until 2025

| May 2016 | Draft Report CE Delft available |
| June 2016 | Steering Committee comments |
| July 2016 | Final Report CE Delft available |
| August 2016 | Steering Committee Report to MEPC |
| October 2016 | MEPC Review of Fuel Availability Study Possible decision on implementation date |
| Mid-2017 | Next meeting: Further discussion and decision making in case no decision was made in October 2016 meeting |
April 2016 MEPC meeting agreed “in principle” to take the decision at the October 2016 MEPC meeting.

MEPC will review the results of the IMO Fuel Availability Study and any comments submitted by IMO Member States and/or Observer Organisations.

Regulation 14.10 of Annex VI only foresees two possible outcomes:
• Implementation of the 0.5% Sulphur requirement in 2020 (base case)
• Postponement of the implementation date until 2025

Decision will be made by the IMO Member States that have ratified MARPOL Annex VI.
ENVIRONMENTAL AND CLIMATIC IMPACT

1. Environmental Impact of SO$_2$ Emissions
2. Climate Impact
3. Additional Information: Anthropogenic and Natural Sulphate Sources
1 Environmental Impact of SO$_2$ Emissions

Summary

- Contribution to air quality on shore decreases rapidly as ships move away from shore.
- Concentration of sulphate aerosol that reaches land from a ship 25 nm away from shore is only about 1/10\(^{th}\) of concentration from a ship in the harbor.
- Cost-effectiveness analysis on basis of benefits' analysis as used for EU air policy shows that only emission reductions close to shore (<12 nm or <25 nm depending on the sea area) would be potentially cost-effective compared to land-based measures.

- Rapid decrease in impact on air quality as ships move away from shore:
  - Example: calculations for a ship sailing west out of Lisbon.
  - At 25 nm from shore, concentrations that reach land are about 1/10\(^{th}\) of concentrations when the ship leaves port.

- Population weighted environmental impact analysis of three European sea areas:
  - Emissions >25 nm away from shore have <20\% of impact of emissions within the territorial seas (<12 nm).

- Cost-effectiveness analysis on basis of benefits analysis as used for EU air policy shows that only emission reductions close to shore (<12 nm or <25 nm depending on the sea area) would be potentially cost-effective compared to land based measures under consideration.
  - Shipping SO$_2$ emissions should be reduced where they contribute measurably to air quality concerns.
**Sulphate PM$_{2.5}$ Concentration ($\mu$g/m$^3$ per kt SO$_2$) at Lisbon Centre (F) Versus Distance from Shore & Designation of Zones Within 200 nm**

Source: Aeris re-analysis of Lisbon Ship trajectory study undertaken for Concawe by the Swedish Meteorological and Hydrological Institute, soon to be published.

**Relative Impact of Shipping Emissions as a Function of Distance from Shore**

Source: Aeris Europe, SMARTER population weighted modelling analysis, February 2016
2 Climate Impact

Summary

- Removal of Sulphur in refineries around the globe will amount to at least 30 million tonnes CO₂/ years – equivalent to 3% increase in global shipping emissions
- Sulphate has a significant climate cooling effect – this will be lost when the global cap is introduced

- Global shipping CO₂ emissions represented 2.6% of total CO₂ emissions (IMO 3rd GHG study, MEPC 67/INF.3, July 2014)

- Climate impact is also affected by other pollutants emitted
  - Short Lived Climate Forcers (SLCFs)
    - E.g. Black Carbon and methane have a warming effect
    - Sulphate aerosols have a cooling effect on the climate
    - Longer term warming effect of CO₂ will dominate

- Shipping is assessed to have an overall cooling effect when integrated over a 20 years period
  - Warming effect only when integrating over a 100 years period

- Reducing the global Sulphur cap to 0.5% will affect climate impact in two ways:
  - Increased GHG from the global refining industry to desulphurise refinery streams and convert heavy residue to lighter fractions
    - Concawe analysis for Europe estimates increase at 7.5 Mt CO₂
    - Globally increase of ~ 30 Mt/y can be expected
    - This would be equivalent to a 3% increase in global shipping CO₂ emissions (2012 basis)
  - Short-term cooling effect will essentially be eliminated
**Shipping Climate Impact - 20 and 100-year time horizon**


**Step-Wise Evolution of Total CO₂ Emissions from EU27+2 Refineries**

Source: CONCAWE report 1/13R – Oil refining in the EU in 2020, with perspectives to 2030, available at www.concawe.org
Additional Information: Anthropogenic and Natural Sulphate Sources

**Anthropogenic Sulphate Production Rate**

![Anthropogenic sulphate production rate map](image)

Source: Penner, J.E. et al., IPCC 3rd Assessment report, Aerosols, their Direct and Indirect Effects, 2001

**Annual average source strength in kg km⁻² hr⁻¹**

(a) the column average H₂SO₄ production rate from anthropogenic sources
(b) the column average H₂SO₄ production rate from natural sources

(DMS and SO₂ from volcanoes)
Natural Sulphate Production Rate

Data source: Penner, J.E. et al., IPCC 3rd Assessment report, Aerosols, their Direct and Indirect Effects, 2001