International Transport Forum | CPB Corporate Partnership Board

Reducing Sulphur Emissions from Ships

The Impact of International Regulation

Corporate Partnership Board Report

OECD

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The International Transport Forum at the OECD is an intergovernmental organisation with 57 member countries. It acts as a think tank for transport policy and organises the Annual Summit of transport ministers. ITF is the only global body that covers all transport modes. It is administratively integrated with the OECD, yet politically autonomous.

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Foreword

The work for this report was carried out in the context of a project initiated and funded by the International Transport Forum's Corporate Partnership Board (CPB). CPB projects are designed to enrich policy discussion with a business perspective. They are launched in areas where CPB member companies identify an emerging issue in transport policy or an innovation challenge to the transport system. Led by the ITF, work is carried out in a collaborative fashion in working groups consisting of CPB member companies, external experts and ITF staff.

Many thanks to the members of the Corporate Partnership Board involved; COSCO, ExxonMobil and Total. The principle author of this report was Olaf Merk (OECD/ITF), with a contribution by Kristine Petrosyan (International Energy Agency). Reviewers from the Corporate Partnership Board included: Eddy van Bouwel (Exxon) and Thierry Chanteraud (Total). External reviewers of the report included Anna Larsson (Wallenius Wilhelmsen) and Dea Forchhammer (Maersk).

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The report also draws from contributions and discussions during an expert's workshop, organised 1 February 2016 in Paris. Participants in this workshop included:

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What we did

This study assesses the impact of international sulphur emission reduction regulations on global shipping. Ships emit a large amount of sulphur oxides that have significant health impacts. To mitigate these, international regulations cap the sulphur content of ship fuel. In certain parts of the world, emission control areas (ECAs) with even stricter standards have been established. In the emission control areas, new requirements introduced in 2015 limit the sulphur content of ship fuel to 0.10%. A new, lower global sulphur cap of 0.50% is planned for 2020. This report examines the 2015 cap effects on shipping and the potential effects of the new requirements foreseen for 2020. It assesses the cost increase for maritime transport associated with the sulphur caps, impacts on shipping operations as well as on other transport modes, and on the environment. The report also highlights policy gaps and challenges for the enforcement of sulphur emissions regulation for shipping.

What we found

The impact of the sulphur emission requirements introduced in 2015 on global trade flows has been negligible. The resulting total cost increase for a container ship on the Asia-North Europe trade lane ranges between 1.2% and 3.6%. Even for industrial sectors that are very sensitive to maritime transport costs, the cost increases would not exceed 0.5%. Nevertheless, the total increase in container shipping costs due to the 2015 requirements amounts to USD 500 million. For an industry operating on very slight margins this represents significant cost increases, but it remains fairly small compared to the fuel price decrease of 38% over the fourth quarter of 2014.

The sulphur cap of 0.50% planned for 2020 will have a more significant effect on shipping costs. Our calculations show that they could increase between 20% and 85%, depending on the assumptions regarding speed, fuel price and ship size. The relatively large margin is due largely to the uncertainty surrounding the availability of low-sulphur ship fuel. The 2020 requirements could add annual total costs in the order of USD 5 billion to USD 30 billion for the container shipping industry. A postponement of the 0.50% global sulphur cap to 2025 maritime transport costs in 2020 would still increase in the order of 4% to 13%. This is due to the fact that a 0.50% sulphur cap will come into effect in European Union waters from 2020, irrespective of the introduction of the global cap.

Such cost increases may have an impact on sectors that are sensitive to changes in shipping costs. In high-cost scenarios the cost increases of the goods value due to the 2020 requirements are 4% for manufactured goods, 9.5% for agricultural goods and 20% for industrial raw materials.

Considering the significant costs to the shipping industry, effective enforcement is of utmost importance to guarantee a level playing field. This would allow compliant companies to avoid incurring considerable additional costs whilst non-compliant operators enjoy an unfair competitive advantage. Effective enforcement would also be needed to achieve the emissions reductions and health benefits that the regulation aims to realise. Numerous enforcement challenges remain unresolved, however. Enforcement of a global sulphur cap at high seas would need to be carried out by flag states. Yet many of these might not be inclined to act accordingly, since their competitive advantage as flag state is based on lenience with regard to enforcing international regulations. Port states would only be able to enforce the leg of the trip in its territorial waters.

In addition, the detection of non-compliance is technically challenging. Current detection measures such as airborne "sniffers" carried by planes or drones are too costly for use at high seas and lack reach. Other detection mechanisms, such as on-board monitoring equipment or probing using big data, have not yet reached the required level of reliability. Moreover, the current sanctions are hardly dissuasive. Non-compliance has only rarely been penalised and penalties hardly ever exceed the savings that ship operators make by not complying with sulphur emission regulations. These challenges would need to be resolved before the 0.50% requirements enter into force.

What we recommend

Harmonise requirements on maritime sulphur emissions with regard to compliance options

Clarify and harmonise norms with respect to compliance options such as Liquified Natural Gas (LNG), LNG bunkering, shore power and scrubbers, in particular wash water from open-loop scrubbers. In the longer term, provide clarity on the conditions for use of alternative energy sources, including nuclear energy.

Apply sanctions for non-compliance with sulphur emissions regulations for ships that are sufficiently dissuasive

Sanctions imposed on non-compliant ship operators in the past have been very limited. Despite some differences between countries, a common trait seems to be that fines imposed rarely ever surpass the cost advantage ship operators reap by ignoring existing sulphur emissions restrictions.

Inverse the burden of proof for compliance by prohibiting ships to carry heavy fuel oil except as cargo

It is currently the responsibility of the maritime administration to prove that a ship has not complied with sulphur emissions regulations. This is costly, complicated, error-prone and possible only in the territorial waters of the port state. Enforcement could be much easier if ship operators were required to provide proof of compliance. This could be achieved by prohibiting ships to carry heavy fuel oil for propulsion purposes from 2020. Ships with scrubbers, or similar approved systems, could be exempted.

1. Regulating sulphur emissions from shipping

Ships generate approximately 5-10% of all SO_2 anthropogenic emissions at a global level. These shipping emissions can represent a large share of total emissions in port-cities and have important health impacts. The reduction of sulphur emissions of ships is regulated at the international level, in the sixth Annex of the Marpol Convention of the International Maritime Organisation (IMO). Key provisions of this regulation include a global sulphur cap and emission control areas (ECAs). The global sulphur cap identifies the maximum sulphur content in ship fuels to be used throughout the world. Another key mechanism embedded within the Marpol legislation is the creation of ECAs – zones in the sea in which stricter requirements are applied to the contents of bunker fuels being used.

Since 2015 the sulphur content allowed in ECAs is 0.10%; the global sulphur cap is foreseen to be reduced to 0.50% by 2020, subject to a review on the availability of low sulphur fuel, to be completed by 2018 at the latest, but already scheduled for the IMO Marine Environment Protection Committee (MEPC) of October 2016. Within this context, the aim of our study is to:

- Estimate the cost impacts of the ECA requirements in force since 2015 and the global sulphur cap in 2020/25. The cost impacts refer to maritime transport costs in global trade flows. The cost impacts will be modelled with cost model of a typical containership, with different sizes and will take into account different scenarios in terms of speed and fuel price.
- Give an overview of the available indications of the other impacts of the new requirements in ECAs since 2015.
- Discuss possible policy and implementation gaps that appear from this assessment of impacts.

This chapter will introduce the subject by highlighting the relevance of reducing SO_x emissions from ships, by indicating the relevant international regulation, compliance options, enforcement mechanisms and the interplay with national and local regulations.

Shipping emissions

Shipping generates important quantities of emissions. The main compounds of concern emitted by shipping and port operations are sulphur dioxide (SO_2), carbon dioxide (CO_2), black carbon (BC), carbon monoxide (CO), nitrogen oxides (NO_x), and various kinds of particulate organic matter (OECD 2011). Generally, a distinction is made between greenhouse gas emissions (GHG) and other emissions (non-GHG). GHG emissions are at the origin of climate change and affect the stratospheric ozone layer, so have global impacts, whereas non-GHG emissions generally have more local impacts.

Maritime transport is at the origin of a large share of global non-GHG emissions, among which SO_2 emissions. Ships generate approximately 5-10% of all anthropogenic SO_2 emissions at a global level, according to various estimations (Corbett & Köhler 2003; Eyring et al., 2005). This represents around 7-15 million tonnes on average per year over the last couple of years.

In comparison with other transport modes, SO_x emissions from shipping are substantial. Shipping SO_x emissions are substantially higher than those of road transport by a factor of 1.6 to 2.7 (ICCT, 2007) and international shipping produced approximately 80 times more SO_x emissions than aviation in 2000 (Eyring et al., 2005). Until 2008, shipping made a very limited contribution to the efforts to improve air quality in Europe (EMSA 2010). The current ECA limit is of the same order of magnitude as emission limits for land based combustion facilities in Europe. The strictest regulation for heavy-duty diesel engines (Euro VI, January 2013) will limit NO_x emissions to 0.40-0.46 g/kWh which is significantly lower than the Tier III limits. Additionally, the ECA regulations do not include any quantitative emission standards for particulate matter PM, while this has been incorporated in the Euro standards for trucks, non-road machinery and inland waterway vessels. The PM emissions for international shipping are only regulated indirectly through the sulphur levels in the fuels (Brynolf et al., 2014).

These shipping emissions can represent a large share of total emissions in the port-city. For example, shipping represented 54% of Hong Kong's total SO_2 emissions in 2008 (Civic Exchange, 2009), while the share for Los Angeles/Long Beach was 45% (Starcrest, 2011). Obviously, shipping does not represent the majority of SO_x emissions in all port-cities, as much depends on the size of the port and the city, and the character of the city, such as the industrialisation rate. However, even if shipping activity is much lower, it can still represent a substantial share of local SO_x emissions. For example, the share amounted to 7% for Taranto and 10% for Izmir (Gariazzo et al., 2007; Saraçoglu et al., 2013).

SO_x emissions have serious health impacts. Sulphur is at the origin of many particulate matters that epidemiological studies have consistently linked with a range of illnesses, including pulmonary diseases and premature death (Eyring et al., 2005). Corbett et al. (2007) have estimated that, because the vast majority (70%) of these emissions occur within 400 km of coastal communities, around 60 000 early mortalities each year are attributed to shipping emissions, mainly in the seaside areas of East Asia, South Asia and Europe. Uncertainties in the data and methods used to calculate mortalities bound this estimate within the range of 20 000-104 000 (Eyring et al. 2010), but the impacts remain within a concerning order of magnitude. Therefore, where shipping emissions contribute measurably to poor air quality, reductions of SO_x emissions should contribute to significant improvements of quality of life for many people and reductions of healthcare costs.

International regulation to reduce sulphur emissions

The reduction of sulphur emissions of ships is regulated at the international level, in the sixth Annex of the Marpol Convention of the IMO. This annex provides "Regulations for the Prevention of Air Pollution from Ships". First adopted in 1997 and entered into force in 2005, it plays the most direct role in regulating the emissions of the shipping sector globally. With 86 contracting parties (as of 20 January 2016), Annex VI covers 95.34% of the merchant fleet.

Key provisions of this regulation include a global sulphur cap and ECAs. The global sulphur caps identify the maximum sulphur content in ship fuels to be used throughout the world. These emissions caps that entered into force on 2005 were tightened through the adoption of revisions to the Annex VI in 2008, which entered into force in 2010. The 2008 amendment reduced the global sulphur cap from 4.50% to 3.50%, effective from 2012, and will reduce the cap further to 0.50% by 2020. This last reduction is subject to a review to be completed in 2018 by IMO which will cover the availability of low sulphur fuel, and which may conclude to prolong introduction of the stricter requirement to 2025. Another key mechanism embedded within the Marpol legislation is the creation of ECAs – zones in the sea in which stricter requirements are applied to the contents of bunker fuels being used. Thus, while sulphur is limited by the 2008 amendments to 3.50% of fuel globally from 2012, and to 0.50% from 2020, in ECAs the limits are 1.00% and 0.10% respectively.

There are currently four ECAs. These are located in areas that contain high concentrations of both shipping activity and coastal populations. The first two ECAs that came into force were located in the Baltic and North Seas and set limits on sulphur emissions only (Sulphur ECAs or SECAs), whereas the subsequent North American and US Caribbean Sea ECAs cover sulphur and nitrogen emissions.

Annex VI of the Marpol Convention also regulates NO_x emissions. It also introduced a new "three-tiered" approach to reducing NO_x emissions, in which ships built after 2000, 2011 and 2016 have respectively stricter limits on their NO_x emissions. Since 1 January 2016 more stringent NO_x regulations are in force in the North American and US Caribbean ECAs: all new-built vessels from that date operating in these ECAs should now have Tier III engines, which lead to much lower maximum NO_x emissions (3.4 g/kWh at lowest speed).

In addition, supra-national regulation can be even stricter; e.g. the EU Sulphur directive. The latest version of this directive, Directive 2012/33/EU, is more stringent as it stipulates a cap of 0.50% sulphur content to be unilaterally implemented in the EU in 2020, irrespective of the outcome of the IMO review in 2018. Furthermore, it imposes that all passenger ships in EU non-ECA waters will have a maximum 1.5% sulphur content until 2020. An earlier version of the sulphur directive (Directive 2005/33/EC) already introduced a 0.10% maximum sulphur requirement for fuels used by ships at berth in EU ports since 1 January 2010. China has recently introduced its own requirements, which will be covered later in this chapter.

Table 1. **Emission control areas in force**

Emission control area	Limited compounds	Adopted	In effect from
Baltic Sea	SO_x	26/09/1997	19/05/2006
North Sea	SO_x	22/07/2005	22/11/2007
North American	SO_x, NO_x, PM	26/03/2010	01/08/2012
US Caribbean Sea	SO_x, NO_x, PM	26/07/2011	01/01/2014

Source: www.imo.org

Table 2. **Allowed sulphur emissions inside and outside ECAs**

Outside ECAs	Inside ECAs
4.50% prior to 1 January 2012	1.50% prior to 1 July 2010
3.50% between 1 January 2012 and 2020	1.00% between 1 July 2010 and 1 January 2015
0.50% from 1 January 2020	0.10% from 1 January 2015

Source: www.imo.org

Compliance options for shipowners

There are three main compliance options for shipowners with the sulphur emission regulations: using low-sulphur fuels, scrubbers and liquefied natural gas (LNG). The section below describes these three compliance options and the conditions under which these options make sense. It also adds other compliance options that might become viable in the future.

Low sulphur fuels

About 80% of the total bunker fuel is heavy fuel oil (HFO), which contains a share of sulphur that is higher than what is allowed in ECAs. The first compliance option when sailing in an ECA is to use fuels that have lower sulphur content. This could be marine diesel oil (MDO), which mainly consists of distillate oil, and marine gas oil (MGO), which is a pure distillate oil that could be treated to reach a maximum sulphur content of 0.10%. For short sea shipping companies that operate only in ECAs this would mean using low-sulphur fuel all of the time. As most ships do not sail exclusively in ECAs, this compliance option implies switching to low sulphur fuels when entering an ECA and using high sulphur fuels outside an ECA. This switching would take place because low sulphur costs are considerably more expensive than the regular heavy bunker fuel. For shipowners there are also cost savings from using low sulphur fuels. Distillate fuels have higher thermal value which reduces engine wear – so it requires less frequent maintenance – and it lowers fuel consumption as it has higher energy content. Distillate fuel also results in less sludge on board. On the other hand, low sulphur fuels have a lower lubricity than high sulphur fuels and this requires use of different lubricants.

Fuel switching requires some adjustments to the ship. Ships would need to have two sets of segregated fuel tanks, one for HFO and one for LSFO. The fuel oil system for switching to low sulphur oil ideally allows LSFO to be completely segregated from HSFO from the storage to the service tank. Blending will only take place in the piping between the service tanks and the inlet to the engine. Modifications would have to be made in the fuel pump system, which would involve installing a fuel switch and a cooler, as HFO is pre-heated whereas MGO should be injected cold. In practice most vessels nowadays have multiple fuel tanks, as they are already supposed to comply with the Marpol Annex VI pre-2015 requirements and the EU Sulphur Directive to use 0.10% sulphur at berth in EU ports.

Scrubbers

Scrubbers are a cleaning system to remove sulphur from the exhaust, permitting ships to use heavy fuel oil in ECAs. So scrubbers are also known under the name of ship exhaust gas cleaning systems. There are in essence two different types of scrubbers: wet scrubbers with sulphur oxides being absorbed in water, or dry scrubbers where sulphur is reduced through reactions and chemically bound to a solid substance. Most of the scrubbers used on ships are wet scrubbers. Three types of wet scrubbers can be distinguished: open loop scrubbers, closed loop scrubbers and hybrid scrubbers, which have both functions. The difference between these scrubbers is the type of water they use to absorb sulphur oxides.

Seawater scrubbing (open loop) is based on the natural alkaline characteristic of sea water, which is used to neutralise the acidic exhaust gases. After the absorption of the SO_x molecules by the sea water, the water is then discharged back into the sea after extracting and storing the relevant sludge from scrubbing. The resulting sludge must be stored on board prior to delivery to a shore reception facility.

Freshwater scrubbing (closed loop) requires the addition of caustic soda to react with and absorb the sulphurous emission gases. It makes it possible to use scrubbing in sea areas where the natural alkalinity of the sea water is not sufficient to react on its own with sulphuric products. Like with the sea water scrubber, the resulting sludge must be stored on board prior to delivery to a shore reception facility.

Hybrid scrubbers combine the two technologies to be more flexible and be able to switch between sea water and fresh water depending on the alkalinity of the water. Hybrid scrubbers are used as an open loop system when the vessel is operating in the open sea and as a closed loop system when operating in SECA. Hybrid scrubbers are most commonly used, because of their flexibility, even if their installation is more complicated and expensive.

The investment costs of scrubbers range from EUR 2-8 million per ship, depending on the ship type, scrubber type and new build/retrofit. In addition to investment costs, the operation of scrubbers increases fuel consumption, estimated to be around 1-3% (EMSA, 2010). Moreover, scrubbers need space on a ship, which is often scarce. Along with scrubbers, peripheral equipment, such as equipment for wash-water, pumps, pipe systems and monitoring systems need space. This makes it easier to install scrubbers on large vessels.

Liquified natural gas

Liquefied natural gas (LNG) is widely considered to be a promising energy source for shipping in the short to medium term. Although the price of LNG is currently lower than for marine gas oil and heavy fuel oil, the costs of distributing LNG to ports and ships is very high. These distribution costs depend on the distance from LNG import terminals, the method of distribution and LNG volumes, which currently make LNG a more expensive fuel than MGO or HFO. This might change if the LNG bunkering network would be expanded and more ports would be able to offer LNG bunkering possibilities.

Investment costs for new build vessels are estimated to be EUR 4-6 million according to some sources (EMSA, 2010). Other sources however show much higher estimations: according to Carr and Corbett (2015) the LNG conversion of a 19 000 tonnes Great Lakes bulk carrier would cost USD 24 million, and they speculate that conversion costs of Panamax and Post-Panamax container vessels would be larger considering that they have larger engines. Considering these costs, LNG retrofitting does not seem to be cost-competitive compared to open-loop scrubbing or fuel switching due to high initial capital costs (Carr and Corbett, 2015). An additional cost – opportunity cost – is the large space that LNG fuel tanks take up in ships. LNG has various environmental side-effects, predominantly positive. Using LNG as ship fuel eliminates virtually all sulphur emissions and particulate matter, as well as NO_x by approximately 90% and CO_2 by 20-25%. A negative side effect of LNG is methane slip, the emissions of non-combusted methane.

Other compliance options

Methanol is another alternative compliance option. It has almost the same molecular structure and properties as natural gas, and is used as fuel for racing cars and model planes, mainly because of its high octane rating. Methanol can also be used for ships through modification of existing engines and fuel systems. Stena Line has recently put into operation a ship fueled with methanol. One main advantage of methanol is that distribution costs are much cheaper than for LNG. While it has similar emission reduction properties, it does not have the disadvantage of methane slips like LNG: SO_x emissions are reduced by approximately 99 %, NO_x by 60%, PM by 95% and CO_2 by 25% compared with heavy fuel oil. Methanol can be produced from natural gas, coal, biomass or CO_2. Its production is relatively large with an annual world supply of 55 million tonnes (ESN, 2015). Stena Line started to operate the first methanol-fueled ship in March 2015, the Stena Germanica, a ferry ship operating between Kiel (Germany) and Gothenburg (Sweden). Conversion of the Stena Germanica took three months; it received support through the EU Motorways of the Seas initiative; the total costs were approximately EUR 22 million. If these costs are indicative of the investment costs needed, this compliance option might be considered a "low viable option".

Nuclear marine propulsion is the propulsion of a ship or submarine with heat provided by a nuclear power plant. The power plant heats water to produce steam which in turn powers the steam turbines and turbo generators. The power is then transferred to a gearbox that reduces the ratio by around 50 to 1 and this powers the propulsion. Nuclear energy so far has mostly been used for naval warships, submarines and ice-breakers. Nuclear-fueled ships operate for years without refueling, and the vessels have powerful engines, well-suited to the task of icebreaking. Nuclear-powered, civil merchant ships have not developed beyond a few experimental ships. Pilot studies show that this concept would be feasible, but that further maturity of nuclear technology and the development and harmonisation of the regulatory framework would be necessary before the concept would be viable (Hirdaris et al., 2014a, 2014b).

Other compliance options include renewable energy sources such as wind energy and solar energy. Various designs have been presented for wind-powered vessels, but so far this has not really been successful. Solar panels have been used on some vessels to provide additional energy, but have not been used as the exclusive energy source for vessels.

Which compliance options under which conditions?

Deciding on the most effective compliance option for the 2015 requirements in ECAs, depends on how often the ship operates in an ECA, its fuel consumption and the price level of low sulphur fuels.

Ship time in ECAs: Fuel switching is the lowest cost retrofit option for vessels operating fewer than 4 500 hours annually in SECAs (Carr and Corbett, 2015). As measures to comply with the ECA requirements in 2015, scrubbers are less cost effective for deep-sea vessels as the portion of time they spend in ECAs is relatively low; retrofitting open-loop scrubbers currently only makes sense for vessels such as ferries or short-sea vessels that operate within ECAs for more than 50% of the year (Carr and Corbett, 2015). The calculations are very different for newbuilds and crucially depend on assumptions about fuel price developments.

Fuel consumption: Fast vessels or vessels navigating through ice have a huge fuel consumption which makes this type of vessel more suitable for scrubber installations.

Price of low sulphur fuels: There is also a clear relation between bunker fuel prices and scrubber uptake. If bunker prices decline the relative cost of scrubbers increases, making it a less attractive option than fuel switching. It is the price spread between marine gas oil and heavy fuel oil that is the determining factor in choosing a compliance option (Jiang et al., 2014). In their calculations, marine gas oil tends to have higher net present values than scrubbers when the price spread of fuel is less than EUR 231 per tonne. They also find that an old ship is not suitable for a scrubber installation if its remaining lifespan is less than four years.

Table 3. **Attractiveness of other ECA compliance options compared to low sulphur fuel**

	Scrubbers	LNG
Investment costs (newbuild)	-	-/-
Investment costs (retrofit)	-	--
Operational costs	+	-/+
Environmental side effects	-	++
Most attractive for which ships?	Ships with a large operations outside ECA Larger ships because of space needed	Regular routes Larger ships because of space needed

Source: ITF/OECD elaborations

These assessments are complicated by the fact that a considerable number of ships is chartered – so not owned by the party that operates the ship. This means that there might be split incentives. In the case of scrubbers and LNG, a shipowner would need to invest, but if the ship is chartered out, the benefits of this will accrue to the ship operator in the form of cheaper fuels (HFO instead of MGO; LNG instead of MGO).

Enforcement of sulphur regulations

Enforcement of the sulphur regulations is done in the ports to which ships are calling, via port state control inspections by maritime administrations. Guidelines for such inspections have been written up by authorities such as the European Maritime Safety Agency and the US Environmental Protection Agency (EPA). On ships that use low sulphur fuels sulphur, inspections strive to determine whether the ship was using the correct fuel in the territorial seas on its last voyage and whether the ship is using the correct fuel at the time of the inspection at port. This inspection is based on two sources: checking documentation and sampling fuels.

Three sorts of documents might be examined: bunker delivery notes, ships' log books and the written procedure for fuel oil change over. Bunker delivery notes record the details of fuel oil delivered for combustion purposes, accompanied by a representative sample of the fuel oil delivered. Other important documents that form part of the ships' log book are the Oil Record Book and the records of navigational activities. The Oil Record Book documents all the relevant operations related to the handling of oil, including ballasting, discharge, collection and bunkering. Records of navigational activities are daily reports that contain the ship's position, the ship's course and speed, and details of conditions that affect the ship's voyage and normal operation of the ship.

Compliance with the sulphur regulations can be determined by checking and comparing these different sources of information: the bunker delivery notes, the Oil Record Book, fuels logs, benchmarks from the tanks at the starting point of the verification period, the fuel change-over plan, record of navigational activities, fuel line diagrams or information on which fuel is in which tank.

Scrubbers are permitted under Marpol Annex VI, as long as these or other alternative compliance options are at least as effective as low sulphur fuels. For the development of scrubbing equipment, the regulatory framework is provided by the Guidelines for on board exhaust gas cleaning systems (EGCS). These guidelines specify the requirements for testing, survey certification and verification of the EGCS. In these guidelines two different regimes are outlined: a model based on type approval and certification (scheme A) and a model based on continuous monitoring of SO_x emissions (scheme B). In the case of scheme A, a SECA Compliance Certificate (SCC) must be obtained. In the case of scheme B, there should be a monitoring system, approved by the administration, which is able to produce results (SO_2 and CO_2) that can be used to demonstrate compliance. At the EU level, Directive 2005/33/EC which is in place is narrower in scope, only recognising scheme B.

Compliance data per ship are collected in the Thetis database, developed by the European Maritime Safety Agency (EMSA), and shared with European and other countries, including the US and Russia. The EMSA also provides constant overview regarding the enforcement of the sulphur directive based on annual reports on fuel sampling coming from the member states, as well as studies related to the quality of fuel bunkered by ships.

Interplay with national and local instruments

SO_x emissions from shipping are not only subject to international regulations, but also in some cases to national and local regulations or schemes. China has introduced its own requirements regarding sulphur content of fuels used in its waters. At the end of 2015, the Chinese Ministry of Transport published new regulations designating parts of its coastal waters as an ECA: the Yangtze River Delta, the Pearl River Delta and the Bohai Sea. Vessels which operate in these areas will be obliged to use low sulphur fuels (less than 0.50 %) as of 1 January 2019. Eleven ports within these three areas are allowed to apply the same requirement to ships at berth from 2016 onwards, a requirement that will become mandatory from 2017 in all the ports in the three designated areas, including the eleven key ports. By the end of 2019, China will consider the necessity to reduce the sulphur limit to 0.1% based on an assessment at that point. Other countries have also developed national regulations, independent from the ECAs designated by IMO, e.g. the national regulation for Turkish ports is in line with EU regulation since 1 January 2012.

In many cases, local initiatives are carried out by ports that want to improve their local impacts, often pressured by local population, city or regional administration. An example of a comprehensive policy effort to reduce emissions from shipping and port activities is the San Diego Bay Ports Clean Air Action Plan (CAAP). As part of such programmes, several instruments have been applied to reduce shipping emissions in ports, including voluntary fuel switch programmes and shore power facilities.

Voluntary fuel switch programmes are applied in various ports and provide incentives to shipping lines to use low sulphur fuel. These incentives are either in the form of compensations to shipping lines for the additional fuel costs due to their fuel switches, or lower port dues and tariffs. Programmes in Seattle and Houston, for example, give reimbursements to shipping lines based on the volume of low-sulphur fuel burned during each port call. In contrast, the Green Port Programme in Singapore gives a 15% reduction of port dues for vessels that switch to clean fuel (or use approved scrubbers or other abatement measures). These programmes usually take the form of collaboration between the port administration and one or more shipping lines (e.g. the programme in Houston is exclusively with the shipping line CMA CGM, whereas the Fair Winds Charter in Hong Kong was with the 17 main shipping lines calling the port). There can be a large difference in programme coverage, ranging from 0.4% (in Singapore) to 73% in Seattle (Merk, 2014). As a follow up to its voluntary fuel switch programme, Hong Kong has introduced a mandatory requirement since mid-2015 for ships at berth to use low sulphur fuel (not exceeding 0.50% sulphur content).

Shore power facilities in ports allow ships to shut off their auxiliary engine and use the power of the grid in the port. Ships that use shore power minimise their emissions and can be considered negligible during their stay in the port. Whereas shore power facilities are often relatively available in container and Ro/Ro terminals, this is not the case for tankers and bulk carriers. The Port of Long Beach is the only port that provides shore power facilities for tankers. Not all ships are equipped to be connected to shore power facilities and not all of these facilities are actually used.

2. Focus and methodology

This chapter describes the focus and methodology of the study. It will set up the framework and assumptions that are used for the modelling of the impacts of the international sulphur emissions regulation. The main impact identified in this study will be maritime transport costs, which will be used to assess the effects on global trade flows. The focus of the study is on global containerised trade, not on intra-continental trade. Impacts on maritime transport costs are estimated via a cost model for containerships. We will assume that compliance is near-perfect and that using low sulphur fuels is the predominant compliant option.

Our study will shed light on the increase of maritime transport costs. Costs are by far the most important indicator determining competitiveness of shipping lines, and indeed shipping as a transport mode. It has been widely acknowledged that shipping has developed into a commodity, with very little differentiation between shipping lines. Although shippers value reliability and avoidance of delays, they are in practice not willing to pay more for better service.

This calculation of increases of maritime transport costs provides the core of an assessment of other impacts, in particular what the increase in maritime transport costs means for global trade flows? The increased maritime transport costs will have different consequences for different economic sectors, and depends on the elasticity between maritime transport costs and seaborne trade. Will the increase in maritime transport costs lead to less seaborne trade, would it lead to a modal shift on certain global trade routes, and might it lead to industrial relocation? These are the central questions that this chapter will try to answer. Various other impacts will also be discussed, including impacts on transport (ship operation; routing, modal shifts) and emission reductions.

Assessing impacts of global container trades

This study will focus on the impacts on intercontinental trade. An abundance of studies on the (predicted) impacts of emission control areas on intra-continental trade exists – in particular short sea shipping in Europe – but assessments of impacts on global trade are fairly rare. Our study aims to fill that gap. This is all the more relevant in anticipation of the 0.50% global sulphur cap, foreseen to be introduced in 2020.

The focus on container ships was chosen because of the substantial share of marine fuel consumption that it represents (22% in 2012). Moreover, container shipping and ships are relatively standardised, which makes a calculation of a relatively small set of ships meaningful for the whole sector. This would not be the case to the same extent in bulk or break-bulk shipping, where ships and shipping patterns are more custom-made. In addition to that, container shipping is fuel intensive when compared to other shipping sectors: a relatively large share (around half) of its operating costs is bunker costs (see Table 4). As such, container vessels might be particularly affected by an increased fuel price.

Table 4. **Share of fuel costs in total operational ship costs per ship type**

Ship type	Share fuel costs, in %	Source
Container vessels	54	MTC Finland 2009
	47	COMPASS 2010
General cargo	38	MTC Finland 2009
Dry bulk vessels	40	MTC Finland 2009
Tankers	33	MTC Finland 2009
Ro/Ro	36	MTC Finland 2009
	32	COMPASS 2010
Ferries	30	MTC Finland 2009

Sources: MTC Finland (2009), COMPASS (2010)

The evaluation of costs will be conducted for container shipping in one of the busiest maritime trade lanes, namely between the Far East and North Europe, for different ship size types and different speeds. The focus on the Far East-North Europe trade lane is based on the wish to consider large ship sizes, including the largest ships currently in operation only on this trade lane, but possibly deployed on other trade lanes within a few years.

In our cost model three main cost categories are taken into account: capital, operational and voyage costs. The following approaches were used to include the relevant costs in our model. The capital cost of ships is determined by the newbuilding price as well as the cost of finance. Newbuilding prices are based on data from Clarksons Research Services Limited (CSRL); the newbuilding prices were made comparably using the CRSL Newbuilding Price Index. For finance costs we assume 5% depreciation and 4% interest per year.

The operational cost, the second cost category, for different container ships is based on research carried out by Drewry Maritime Research that takes into account the following cost items: manning, insurance, stores, spares, lubricating oils, R&M, dry docking and management and administration. The third cost category, the voyage cost, indicates the propulsion consumption of the ships, calculated using an ISL database about merchant vessels, their engine particulars and estimated consumption patterns, described in more detail in ITF/OECD (2015).

The scenarios will be differentiated according to assumptions on bunker fuel prices and voyage speeds. These are the main variable indicators impacting on total costs. Fuel costs are the most important cost item for most shipping lines. Reducing speed limits fuel consumption exponentially. We take three different average fuel prices into account: USD 300 per tonne, USD 450 per tonne and USD 600 per tonne; and three different voyage speeds: 16 knots, 20 knots and 24 knots.

In our calculations we will take three different ship sizes into account, namely containerships with capacity of 8 500, 15 000 and 19 000 TEUs. These have different cost structures, therefore Marpol VI has different impacts on them. These ship types represent the three most recent generations of container ships. As such, we can assume that container ships with larger TEU capacity have more or less similar cost structures, because their characteristics are more or less similar. In our calculations, we assume a roundtrip of 21 000 nautical miles, with three weeks presumed tied up for loading and discharging, as well as idle time. We assume an 85% utilisation rate of each ship.

Voyage costs will be calculated for three situations: one prior to 2015, one in 2015 and a projection for the situation in 2020. This allows for an assessment of impacts between 2014 and 2015 (when the 0.10% rule became operational in ECAs) and between 2019 and 2020 (when the 0.50% global cap is expected to enter in force).

Assumptions about compliance

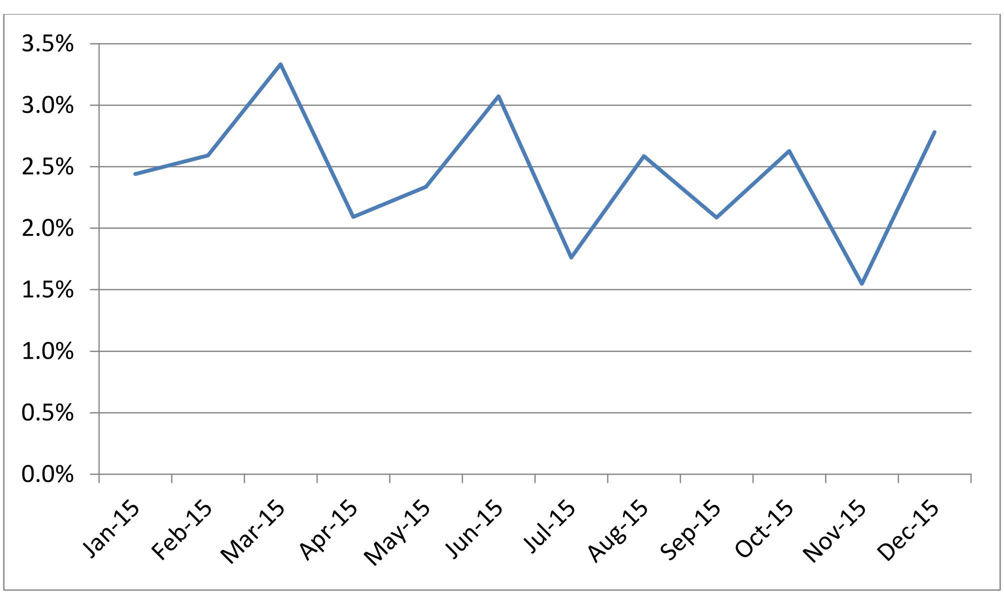
The default compliance option is assumed to be the use of cleaner fuels, namely marine distillates instead of fuel oil. For 2015 calculations, this is aligned to reality as the uptake of scrubbers and LNG ships is still limited: there were around 60 ships (or ship orders) with scrubber installations in November 2013 (ESN, 2013) and world-wide there were only 42 LNG-powered ships with additional 39 ships on order (October 2013). Most of the LNG-powered ships are Norwegian, as Norwegian shipowners benefit from investment support from the Norwegian NO_x Fund.

Our calculations will therefore take into account the price differential of cleaner fuels for the relevant leg of the voyage, namely the emission control area. This will give an assessment of the increase in maritime transport costs on this trade lane. This will be used to reflect on the relation between these cost increases and maritime trade flows. We will also take into account other compliance options including scrubbers and alternative fuels, such as LNG.

In our calculations we will assume that there is near-perfect compliance. This assumption is based on the inspection records of the EU port state controls. In 2015, around 2.8% of the ships inspected had deficiencies related to sulphur dioxides (Marpol Annex VI): based on the Thetis database of EMSA, 15 247 ships were inspected over the period 1/1/2015-31/12/2015. Of these ships, 427 were shown to have Marpol Annex VI deficiencies. The non-compliance in the second half of 2015 was slightly lower than in the first half of 2015 (see Figure 1). The jigsaw shape of the figure indicates a fairly large variation on a month-by-month basis.

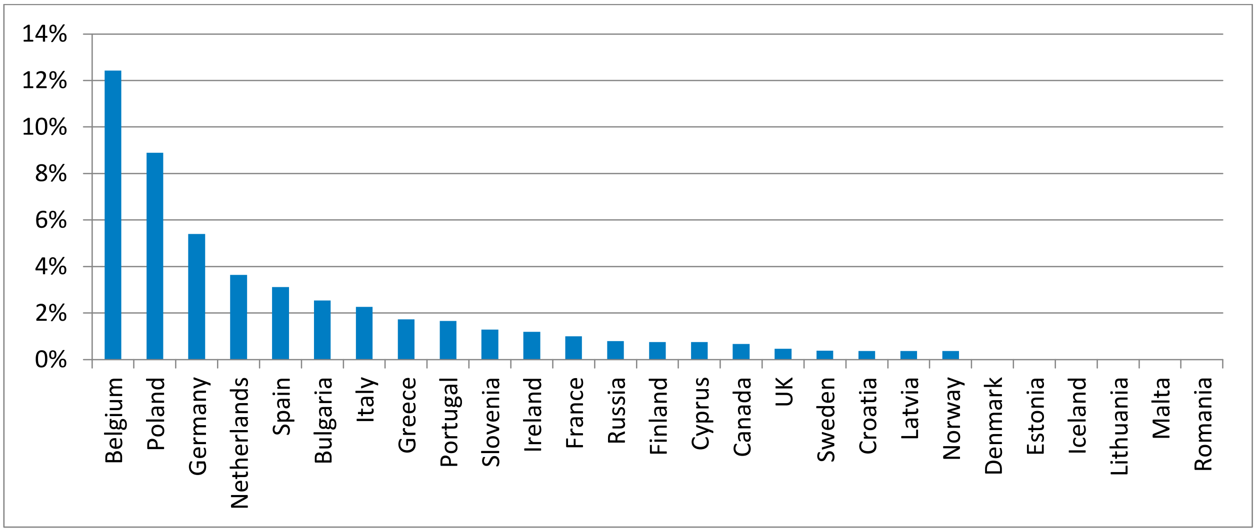
Non-compliance is relatively high in ECA countries like Belgium, Poland and Germany (see Figure 2). However, one could wonder if there is a direct link between the non-compliance rate based on port inspections and the real level of non-compliance, considering the low odds to be caught in certain port states. It would also be interesting to distinguish between deliberate and non-deliberate non-compliance. Marginal non-compliance might happen due to fuel issues, e.g. fuel providers that did not check sulphur levels with sufficient diligence, or a contamination on board of the ship, e.g. in the ship's fuel tank.

Figure 1. **Non-compliance rates with SOx regulations**



Source: own elaboration based on Thetis database of EMSA

Figure 2. **Non-compliance rates with SO_x regulations per country in 2015**



Source: own elaboration based on Thetis database of EMSA

Approximately 7% of a typical Far East-North Europe voyage takes place within emission control areas, considering the demarcations of the ECAs in North Sea and Baltic Sea (see Figure 3). This share is based on the assumption that Hamburg is the last port of call of the large majority of Far East-North Europe loops. In practice, there are a few loops that call ports in the Baltic Sea, such as Aarhus, Gothenburg and Gdansk, which would mean that the share of the voyage within ECAs would be slightly longer. However, the total share of these ports in the total Far-East-North Europe traffic is very small (approximately 2%) and compensated by the fact that in some cases ships spend less time in ECAs, e.g. when Bremerhaven is the last port of call, or for loops in which no German ports are called.

Figure 3. **Emission control areas**

Source: The Shipowners' Club

We assume that in 2014, 2015 and 2019 IFO380 fuels are used outside ECAs, which are max. 3.5% sulphur fuels. Inside ECAs, we assume that in 2014 LS380 fuels were used, which are max. 1.00% sulphur bunkers; for 2015 we assume that LSMGOs are used, which are max. 0.10% sulphur distillates compliant with 2015 ECA regulations. In order to establish the price differential between the different fuels, we use the average price differential over 2014-2015 Rotterdam bunker prices. As such we have established a markup of approximately 70% between LS380 and LSMGOs. However, it has been noted that the difference between HFO and MGO is not constant and varies over time, which is also illustrated by the different values and ratios found in other studies.

Figure 4. **Price differentials of bunker fuels and ECA 2015 compliant fuels**

Source: own elaboration of data from Ship and Bunker

3. Impacts on maritime transport costs

This chapter contains our calculations on increases in maritime transport costs related to the different international sulphur regulations for shipping: the new ECA requirements in 2015, a 0.50% global sulphur cap in 2020, and we also include a possible scenario in which the 0.50% global sulphur cap would only be introduced in 2025, but in which the EU introduces its own 0.50% cap in 2020. Our calculations show that the increase costs for container ship operators on the Asia-North Europe route was fairly marginal in 2015, but could be substantial in 2020, with increases possibly up by 85%.

Cost increases in 2015

Our cost calculations for 2015 show price increases for container ship operators between 1.2% and 3.6% related to the new 0.10% sulphur requirements. The impacts differ depending on ship size, speed and fuel price. The largest difference is with the smallest vessel, the highest speed and the highest fuel price. In this most extreme case, the cost per TEU would be USD 16 higher. These calculated and modelised cost increases have been counterbalanced by the decline of the fuel price over the same period: the price of low sulphur fuel between September 2014 and September 2015 almost halved, resulting in a price level that was lower than for high sulphur fuel a year before.

Table 5. **Cost increases on Far East-North Europe voyage due to ECA 2015 regulations**

	With fuel price of USD 300/tonne, in %			**With fuel price of USD 450/tonne, in %**			**With fuel price of USD 600/tonne, in %**		
	16 knots	**20 knots**	**24 knots**	**16 knots**	**20 knots**	**24 knots**	**16 knots**	**20 knots**	**24 knots**
~8 500 TEU	1.5	2.2	2.8	2.0	2.7	3.3	2.3	3.1	3.6
~15 000 TEU	1.4	2.0	2.6	1.8	2.5	3.1	2.2	2.9	3.4
~19 000 TEU	1.2	1.8	2.3	1.5	2.2	2.8	1.9	2.6	3.2

Source: Own elaborations based on ITF/OECD (2015)

The effect on other intercontinental routes is dependent on the share of the route within one or more ECAs. Various trade lanes do not cross any ECA, e.g. Asia-Med, Asia-Mid East, Asia-Latin America and Asia-Africa. Some routes have larger shares in ECAs than Asia-North Europe as is the case for the Trans-Atlantic trade route. We assume that a typical voyage on this trade lane has 20% of its routes within an ECA. Other intercontinental trade routes involving either Europe or North America have shares within ECA that are more or less comparable with the Asia-North Europe route.

Considering these effects, one could calculate the total costs for the container shipping industry related to the 2015 requirements to be in the order of USD 0.5 billion. This takes the ECAs shares of all containerised trade routes into account, as well as the extent of these flows, based on a dataset of Drewry Maritime Advisors. The impacts for individual shipping companies can be substantial. The Maersk Group, for example, estimated the additional costs for its total fleet as a result of the 2015 ECA requirements in the order of USD 200 million.

Prior to the introduction of the 2015 ECA limit, there was a discussion on how the increased demand for MGO would affect its price. Some studies (Notteboom et al., 2010) stressed the added need for desulphurisation which would result in additional costs. Other studies (COMPASS, 2010) underlined that the increase in demand for this type of fuel could result in a decrease of the relative price due to economies of scale. It has been generally accepted that there was enough refinery capacity in 2015 to provide sufficient amounts of low sulphur fuel.

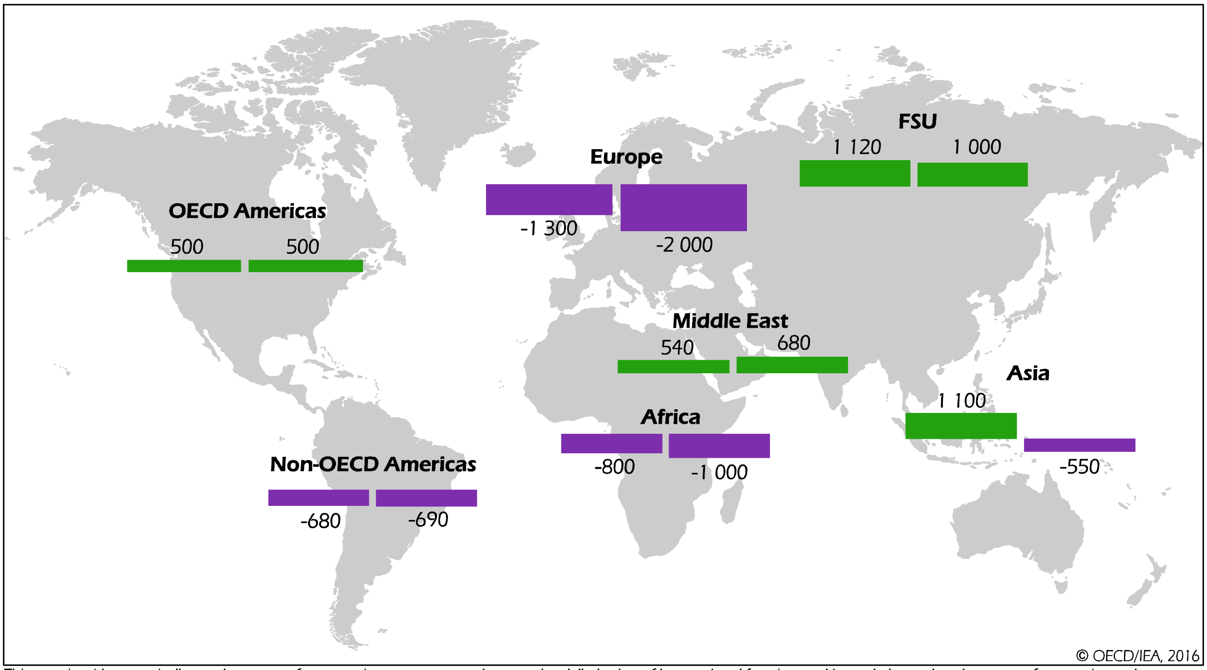
Cost increases due to global sulphur cap in 2020

There are two crucial assumptions to make when estimating cost impacts in 2020: what will be the refinery capacity for low-sulphur fuel and – related to that – what will be the price differential between high and low sulphur fuel? Regarding the availability of low sulphur fuel, the IMO has commissioned separate research in order to facilitate the discussion, on whether the introduction date of the global sulphur cap should remain 2020 as foreseen, or should be postponed to 2025. That research is currently ongoing and will be an essential element in the discussion on the introduction date, which would need to be finalised by 2018 at the latest. Our study does not aim to provide an in-depth analysis on the availability of low sulphur fuel in 2020. However, it will use existing data and insights to make a few assumptions needed to conduct estimations on the potential increase of maritime transport costs by that date. The fuel availability study, commissioned by the IMO, does not cover expected price differentials between high and low sulphur fuels. As our aim is to estimate cost impacts, we will have to make assumptions about this price differential – these will be made on the basis of historical data and in relation to the foreseen refinery capacity.

We assume that there is an undersupply of refinery capacity for low sulphur fuels of 2 million barrels per day in 2021, a contrasting situation from 2015 when there was a net global refinery supply of 0.5 million barrels per day (see Figure 5). These numbers are based on the "Medium-Term Oil Market Report 2016" of the International Energy Agency at the OECD (OECD/IEA) and represent a balance of expected supply and demand. The refinery supply is based on an inventory of current capacity, taking into account planned expansions of refinery capacity. The demand for low sulphur fuel is based on a few crucial assumptions. On the uptake of LNG as a ship fuel, it is assumed that LNG will replace 0.3 mb/d of oil-based bunker fuel by 2021. The oil-based marine fuel consumption in international shipping is estimated to be around 3.9 million barrels a day in 2020 and 2021; 30% of this would be residual fuel oil and 70% gasoil. This represents a demand shift of 2.0 mb/d from residual fuel oil to gasoil (OECD/IEA, 2016). We assume that the EU will be the biggest net importer and Asia the biggest net exporter of low sulphur fuel.

There are margins of uncertainty with respect to these assumptions. On the refinery supply side, the uncertainty is relatively small considering that it takes on average five years to add or adapt refinery capacity and get it operational. Considering the large investments needed for these expansions and adaptations, the refinery industry has an incentive to wait for more certainty on the introduction date of the 0.50% global sulphur cap before taking on the investment. On the demand side, the uptake of LNG and scrubbers could be higher or lower than expected. Freight rates are currently very low and many shipping companies have difficulties being profitable; considering these circumstances one could wonder if shipping companies will invest in scrubbers or LNG propulsion if they can also comply without having to invest, by using low sulphur fuels. So, it is not unimaginable that the uptake figures assumed by IEA will not be reached, which would increase the projected undersupply of refinery capacity for low sulphur fuels. For the purpose of our calculations we will assume that the undersupply of refinery capacity will in practice not be a barrier for introduction in 2020 (even if it might be), but that the scarcity of refinery capacity will translate in higher price differences between high and low sulphur fuels.

Figure 5. **Refinery capacity for low sulphur fuels in 2021**

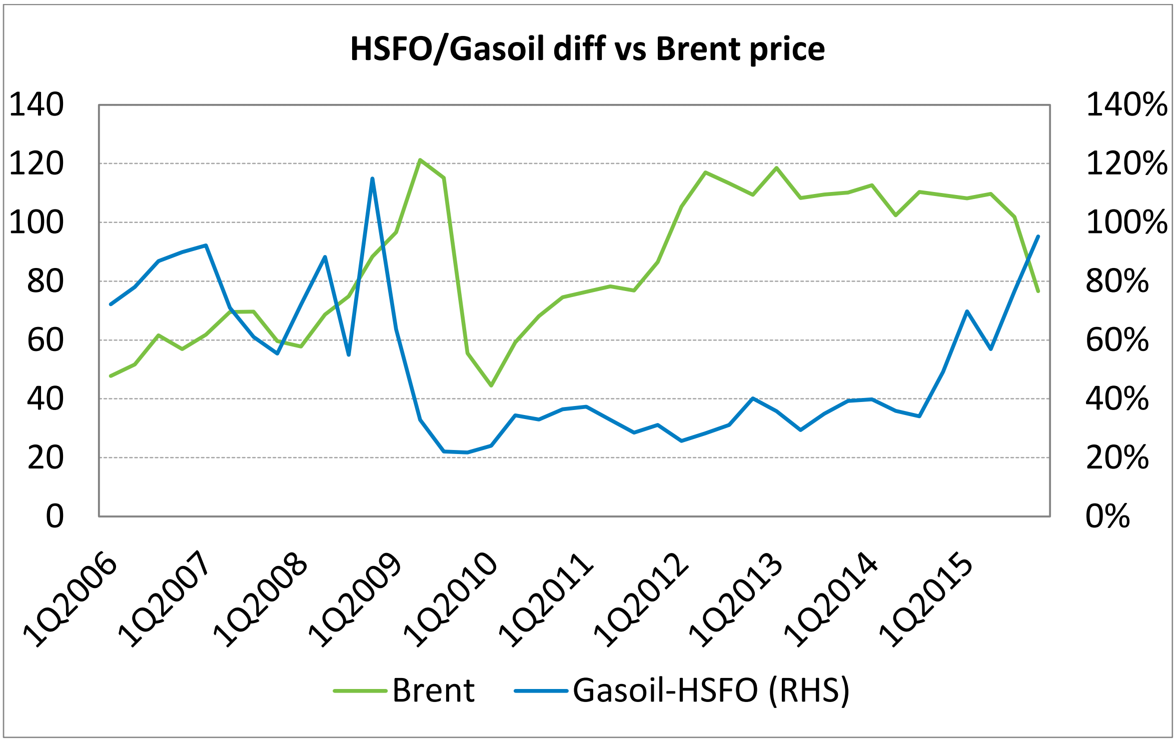


This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

Source: © OECD/IEA (2016) Medium-Term Oil Market Report, IEA Publishing. Licence: www.iea.org/t&c
Note: green indicates positive supply, purple indicates net undersupply; the left bar indicates the situation in 2015, the right bar in 2021.

We assume that in 2020 the price difference between high and low sulphur fuel will be in the range of 100-120%. As Figure 6 illustrates, the price differential between high and low sulphur fuel over the last decade has most of the time been between 20% and 80%; over 2006-2015 only once did the differential surpass 100%; this was in 2009 when the middle distillates market was very tight. Considering the projected shortage of refinery supply of low sulphur fuels, one would expect the price differential to be high in 2020 and surpass the 100% threshold. We assume for our calculations that the price differential could range from 100% to 120%.

Figure 6. **Price differentials between high and low sulphur fuels (2006-2015)**



Source: Own elaborations based on data provided by OECD/IEA. Note: Brent curve to be read with the left axis; the premium for gasoil over HFSO should be read with the right axis.

Our cost calculations for 2020 show price increases for container ship operators between 20% and 85% related to a global 0.50% sulphur cap. The impacts differ depending on ship size, speed and fuel price. The largest difference is with the smallest vessel, the highest speed and the highest fuel price. In this most extreme case, the cost per TEU would be approximately USD 400 higher. The price effect on other intercontinental routes is arguably in the same order. Considering these effects, one could calculate the total costs for the container shipping industry related to the 2020 requirements to be in the order of USD 5-30 billion per year. Maersk Group estimates its increased costs due to the global sulphur cap in 2020 in the order of USD 0.5-3.5 billion for its entire fleet.

Table 6. **Cost increases on Far East-North Europe voyage due to 2020 global sulphur cap**

With fuel price of USD 300/tonne	With fuel price of USD 450/tonne	With fuel price of USD 600/tonne
20-65%	30-75%	35-85%

Source: Own elaborations based on ITF/OECD (2015)

Cost increases due to EU sulphur cap in 2020

Should the global sulphur cap only be introduced in 2025, costs for container ship operators could increase between 4% and 13%. An important share of these increases would be caused by the sulphur cap of 0.50% that would be introduced in EU waters irrespective of the IMO Review on low sulphur fuel availability. In such a case, the demand for low sulphur fuels would be much smaller and the transition period for building up more low sulphur fuel refinery capacity longer, so the price differential is likely to be much smaller than in 2020; we assume a price differential of 75%. The impacts differ depending on ship size, speed and fuel price, the largest difference being with the smallest vessel, the highest speed and the highest fuel price. These effects are particularly large on the Asia-North Europe route, because the share of time spent in EU waters is large in this trip.

Table 7. **Cost increases on Far East-North Europe voyage due to a 2020 EU sulphur cap**

With fuel price of USD 300/tonne	With fuel price of USD 450/ tonne	With fuel price of USD 600/ tonne
4-10%	6-12%	7-13%

Source: Own elaborations based on ITF/OECD (2015)

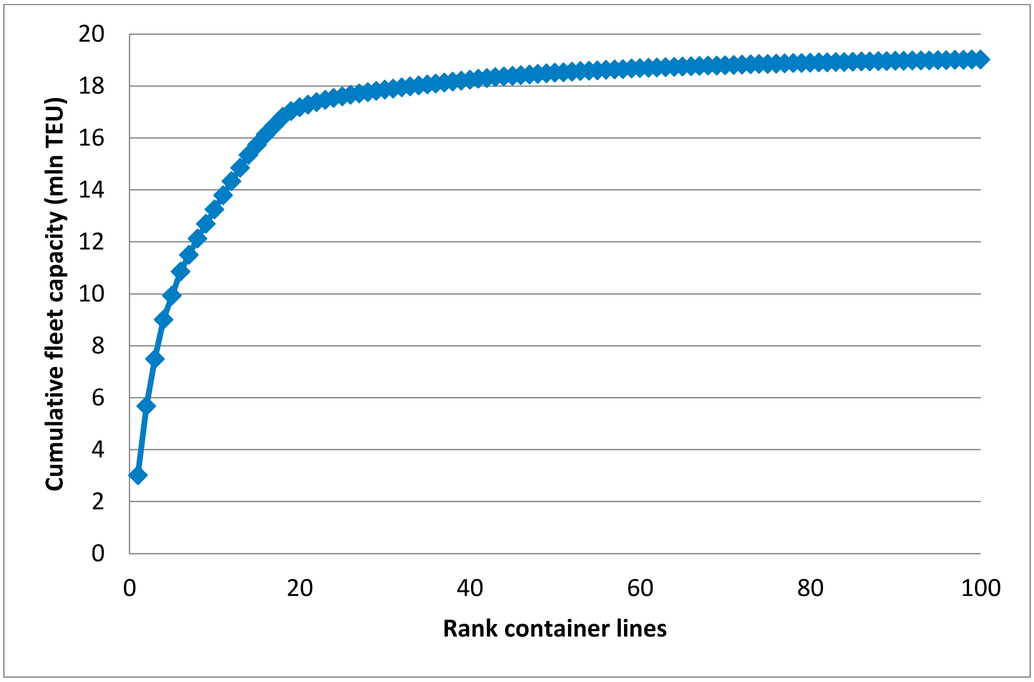
4. Impacts on global trade flows

This chapter aims to link the increase in maritime transport costs – calculated in Chapter 3 – to global trade flows. The central question is: will increases in maritime transport costs lead to lower global trade flows? In order to answer this question, a few other questions need to be answered. If the shipping sector were to absorb the cost increases – by making less profit – there would be no impact for shippers (customers of the shipping industry) and cargo owners. However, we will indicate that it is likely that cost increases will be transferred to shippers and cargo owners; the impact of this is uneven and will be different per sector. We will show which sectors will be most sensitive to increases in maritime transport costs. In reaction or anticipation of these cost increases, we could expect mitigations of these cost increases which could reduce the cost increases for shippers and cargo owners. All these factors contribute to determining how increased maritime transport costs could affect global trade, both with regards to the direction and the extent of global trade flows.

Will shipping absorb the cost increases?

Whether shipping will absorb cost increases depends on the competitive pressure in the sector and the profitability. The container shipping industry has become more concentrated over the last decades, resulting in a situation in which the main four container lines had 47% of the market share by March 2016 (see Figure 7). These market shares are higher on certain trade routes. Intensified cooperation between liners in four large alliances means that shippers have less choice than before and fewer tools for risk management. At the same time, the individual shipping lines compete with each other on price, as expressed in containerised freight rates. These freight rates have over the last years seen a spectacular decrease. At the same time, many shipping lines have had significant difficulties in achieving profits on a more than occasional nature. Based on these elements, we will assume that container shipping lines have limited possibility to absorb cost increases, so they will likely transfer these to their customers: shippers and cargo owners.

Figure 7. **Market shares of container shipping lines (March 2016)**



Source: ITF/OECD elaborations based on data from Alphaliner

What will be the cost increases for shippers and cargo owners?

Maritime transport costs make up a substantial share of the value of traded goods, so an increase in maritime transport costs could translate into higher prices of traded goods. On average around 5% of the imported value of manufactured goods can be attributed to shipping, this is 11% for agricultural goods and 24% for industrial raw materials. These shares can be higher for specific categories of goods. Manufactured goods for which shipping costs represent more than 20% include knitted or crocheted fabric, nickel and ceramic products. Agricultural goods for which shipping costs represent more than 25% include milling products and vegetable plaiting materials.

The cost impact of sulphur regulations could be substantial for shippers: up to 7.5% in agricultural goods, 3.5% in manufactured goods and 16.4% for industrial raw materials, in the case of a global sulphur cap. These cost increases refer to the introduction of a global sulphur cap of 0.50% in 2020 – in the high cost scenarios, so with the highest fuel prices, highest speeds and smallest ships. The cost increases of the 2015 ECA requirements are fairly marginal, not exceeding 0.5% in most of the cases. In case a global cap would be postponed until 2025, but an EU cap of 0.50% introduced in 2020, the effects on industry would also be relatively limited, with effects up to a 3% price increase.

Table 8. **Cost increases for different goods due to the international sulphur regulations**

	Agricultural goods, in %	Manufactured goods, in %	Industrial raw materials, in %
2015 ECA requirements	¼	0.1	½
2020 Global sulphur cap	2½ - 9½	1 - 4	5 - 20
2020 Only EU sulphur cap	½ - 1½	¼ - ½	1 - 3

Source: own ITF/OECD elaborations

Certain industries have raised concerns that ECAs would distort the level playing field of globally operating industries. The Confederation of European Paper Industries and the Swedish Forest Industry Federation feared in 2012-13 that the more stringent SO_x regulations to come in effect in 2015 would disadvantage industry competitiveness in global markets and international trade (Korhonen et al., 2015). These claims were underpinned by referring to the estimated rise in maritime transport costs, as indicated by some studies. Nietola (2013; referred to in Korhonen et al., 2015) calculated that the 2015 regulation would add EUR 200 million to the shipping costs of the paper industry exports from Finland, which represents a 20-45% increase. It was also calculated that the Nordic bulk industry might face an increase of the average transport costs per tonne from site to customer of more than 20% if the costs of MDO were to be 100% more than HFO's (Hämäläinen, 2015).

Declining fuel prices have mitigated this issue, but until 2020 the level playing field concern could be justified to some extent for certain industries. The most affected commodity types will be metal and agricultural products (COMPASS, 2010), and the forestry industry, with an anticipated increase of 25% to 35% per tonne freight, implying a final price increase for the paper product ranging from 0.4% to 2.6% (Notteboom et al., 2010). It has been speculated that the increase in costs could possibly lead to relocation effects of industries. Hämäläinen (2015) states that paper machine and mill closures could be expected in Finland due to the SECA directive, with global paper companies answering to cost challenges by relocating bulk paper production from the paper production from the periphery closer to markets.

Could these cost increases be mitigated?

The cost increases for shippers could be lower than calculated in Table 8, because there might be some room for mitigation of cost increases. We will distinguish here three different cost mitigation possibilities: speed adaptation, route adaptation and shift to other transport modes.

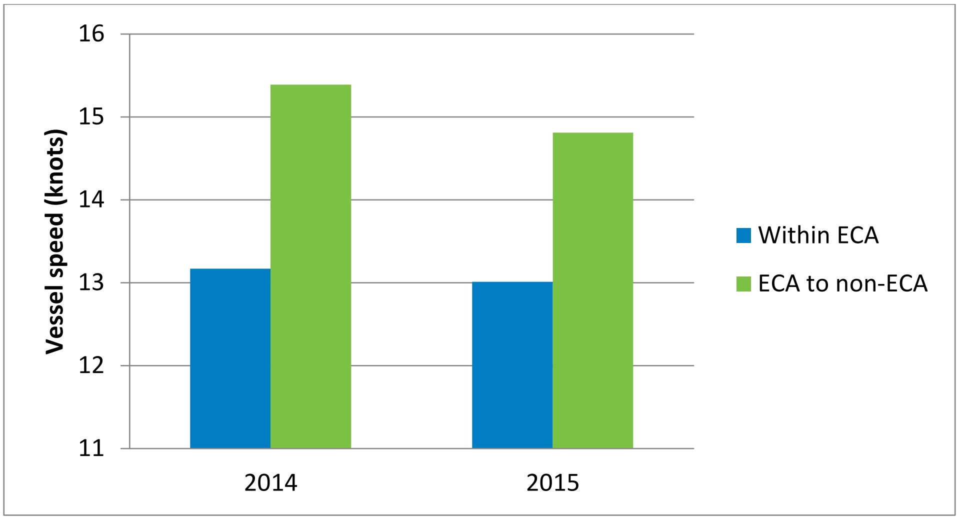
Speed adaptation

Fuel consumption and fuel costs increase exponentially with an increase of vessel speed. At the same time, shipowners are paid for each container (or other cargo unit) that they deliver, so slowing down brings in fewer revenues. For container shipping, organised as a liner service with regular (e.g. weekly) frequencies, slow steaming implies that more vessels are needed to sustain the same service. In a situation of vessel oversupply, as is currently the case, this is not problematic, so shipowners have an incentive to slow down when or where fuel costs are higher.

Considering the price differences between high and low sulphur fuels, it is optimal to sail with different speeds within and outside and ECA. Fagerholt and Psaraftis (2015) show that - in a situation where MGO is twice as expensive as HFO - the optimal vessel speed is 15.8 knots within an ECA and 19.9 outside an ECA. When the ratio between the prices of the two fuels decreases, so does the difference of the two speeds. When the fuel price ratio is 2.4 or higher, the optimal speed within the ECA reaches the ship's minimum speed of 15 knots.

Our data confirm that speed adjustment is in practice used as a way to mitigate compliance costs. Not only was vessel speed within ECAs in 2014 lower than outside (13.2 knots vs. 15.4 knots), the new requirements in force since 2015 have led to a further decrease of vessel speed: from 15.4 knots in 2014 to 14.8 knots in 2015 (for the voyages going from ECA to non-ECA and vice versa); and from 13.2 knots to 13.0 knots for the voyages within ECAs. This can be concluded from an analysis that we conducted of the sailing time of vessels that called ports in Scandinavia, Baltic Sea and North European Atlantic Coast in May 2014 and 2015. The reduction of speed over 2014-2015 is actually larger for voyages from ECA to non-ECA (and vice versa), possibly because these ships have more possibilities to make up for their lost time on sea legs completely outside ECAs, an option that ships operating exclusively in ECAs do not have, which might explain the relatively small reduction of speed on these voyages. The overall speeds found are somewhat lower than the ones cited above in the study by Fagerholt and Psaraftis (2015), due to different context and model specifications.

Figure 8. **Speed adjustments within and coming to/from ECA 2014-2015**



Source: ITF/OECD elaboration of vessel movements' database of Lloyds Intelligence Unit.
Note: Data over May 2014 and May 2015, covering container ships that called ports in Scandinavia, Baltic Sea and North European Atlantic Coast.

These adjustments in speed could have impacts for ports. If ships were to slow down in ECAs – and the speed in non-ECAs would remain the same as before – ship operators will lose time at sea that they might want to compensate by shorter port times. There are some indications that there is potential for energy reduction here. In a study on a short sea shipping company in the North Sea and the Baltic Sea indicated that ships spent more than 40% of their time in ports and that half of the time was not productive. This could be explained by the fact that ports were closed at night and during weekends, and that ships arrived before stevedores were ready to handle the cargo (Johnson and Styhre, 2015).

Considering the likelihood of a container fleet oversupply beyond 2019, it is possible that shipping lines will absorb part of the increased costs of switch to 0.50% compliant fuel via slower vessel speeds. Deploying an average vessel speed of 16 knots instead of 20 knots reduces the cost impacts due to the global sulphur cap by 30-35%.

Different routes

It is possible to save costs by re-routing; the new route will replace part or the entire maritime leg in the ECA by a non-ECA alternative. Several shipowners have indicated that they have adjusted passage plans to ensure they spend as little time as possible in an ECA. This could mean that if a vessel is leaving a port on the East Coast of North America and destined for a Central or South American port, it will likely sail a more easterly direction to get outside the ECA sooner and then spend more of the voyage able to burn fuel oil (Eason, 2015).

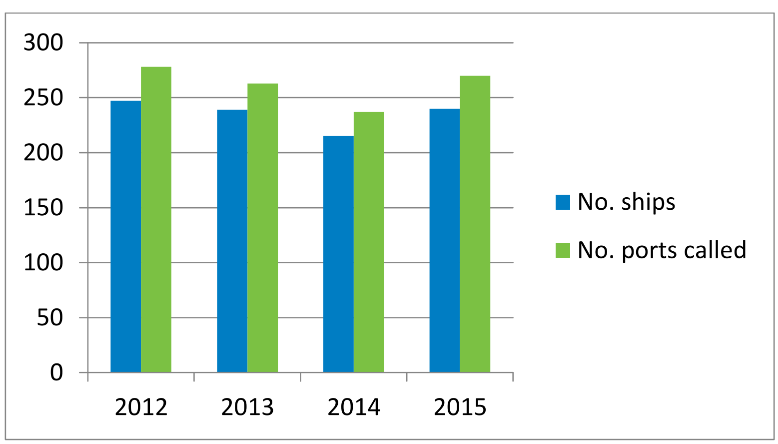
Some ports may have benefited from their position outside an ECA. Some argue that this could have been the case for ports like Liverpool. It is however difficult to isolate an "ECA-effect" as there could be various other reasons for this better growth performance, including the new container terminal and a competitive proposition, also illustrated in its growth numbers before 2015. It is also possible that the ECAs facilitated shifts to certain hub ports, such as Tanger-Med. Again, this effect is difficult to isolate.

Different transport modes

The shift to other transport modes – and the risk of a modal backshift - was a subject extensively debated prior to the 2015 requirements for emission control areas, in particular in relation to short sea shipping and Roll-on roll-off (Ro/Ro)shipping in Europe. The possibility of a modal shift and the possibility of closure of certain ferry routes has been widely discussed (Kehoe et al., 2010; Notteboom et al., 2010). At the same time it was clear that much depends on the local circumstances. A study conducted by Holmgren et al. (2014) concluded that a modal backshift to road transport is unlikely to occur for the types of transport that they studied, namely the shipments of relatively high value added containerised goods from Lithuania to the British Midlands.

There are no indications that a modal backshift has taken place following the 2015 ECA requirements. Our analysis shows that in 2015 the number of Ro/Ro-ships within SECAs and the number of ports called within the SECA increased, rather than decreased. In 2015, 240 Ro/Ro-ships were active in a SECA, as opposed to215 in 2014. They made calls in 270 ports within the SECA, opposed to 237 in 2014. This can be concluded from an analysis of vessel movements covering Ro/Ro ships that called ports in Scandinavia, Baltic Sea and North European Atlantic Coast. What can also be deducted from this analysis is that this reversal in 2015 follows what seems to be a longer period of decline for Ro/Ro-shipping (in terms of ships and ports called), at least since 2012 (see Figure 9).

Figure 9. **Number of Ro/Ro-ships within ECA and number of ports called within ECA**



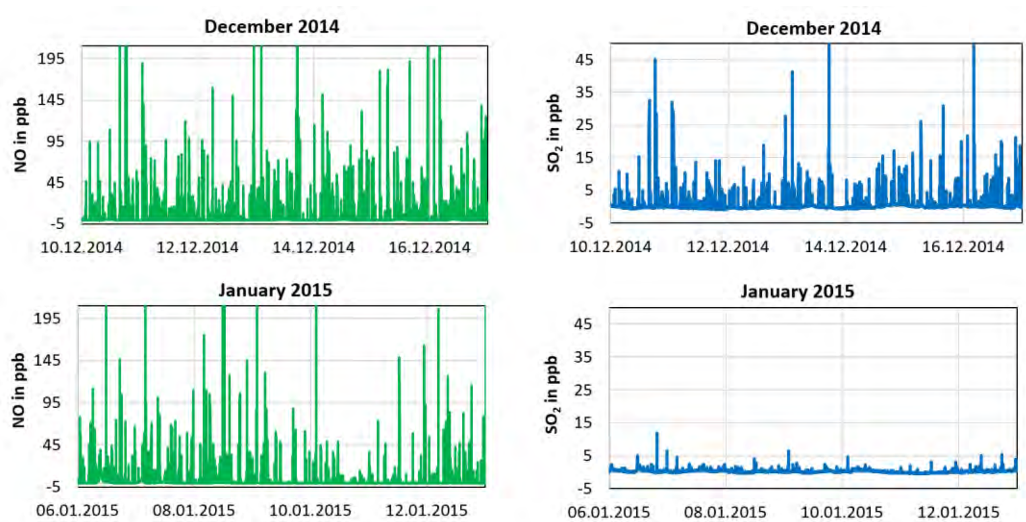
Source: ITF/OECD elaboration of vessel movements' database of Lloyds Intelligence Unit.
Note: Data over May 2012-2015, covering Ro/Ro ships that called ports in Scandinavia, Baltic Sea and North European Atlantic Coast.

The issue is different for deep sea shipping, as it has few real substitutes. Maritime transport is so much cheaper than potential other long-range transport modes, such as long-range rail freight or air freight transport, that even a doubling of the maritime transport costs would not change much to modal patterns. Rail freight transport between China and Europe has developed over the last years, but these volumes are still fairly marginal and have arguably gone at the cost of air freight market shares. Over 2000-2013 air freight has lost market share to ocean freight: its share in containerised trade weight was 3.1% in 2000, but declined to 1.7% in 2013. Around one-third of the decline can be attributed to mode shift. Although this presents an important decline for air cargo, it only presents a small fraction of the overall containerised ocean trade growth (Seabury, 2014). Maritime transport is expected to gain more market shares in certain industries, such as the automotive industry and electronics. The increase in maritime transport costs related to a global sulphur cap could possibly moderate such a modal shift, as the most important driver of a modal shift from air to ocean trade for shippers are the transportation costs (Seabury, 2014).

5. Emission impacts

First results seem to indicate that the 2015 sulphur regulations have brought about substantial emission reductions. Measurements in three different air pollution monitoring areas in Denmark show that the SO_2 concentration in the air during January-May 2015 is 47% to 60% lower than the average concentration during the same months in 2011-2014 (Ellermann, 2015). Measurements at the Port of Gothenburg show that sulphur emissions have fallen by 80% since the introduction of the 0.10% requirement in 2015 (Mellqvist et al. 2016). Measurement studies in Hamburg also indicate significant reductions in the SO_2 concentrations in the port-city of Hamburg (Kattner et al., 2015). The greatest benefits of these emission reductions are felt in the areas in and bordering ECAs, particularly in densely populated and trafficked areas, notably the North Sea region.

Figure 10. **Reduction of sulphur dioxides around the port of Hamburg**



Source: Kattner et al., 2015

One side-effect could be CO_2 emissions reductions. However, this depends on the compliance option chosen. An all vessels fuel switch by 2020 would lead to a significant CO_2 reduction: almost 1.5 million tonnes of CO_2, whereas a compliance option that would consist of "all vessels use wet scrubbers" would lead to an increase of 0.6 million tonnes of CO_2 (ENTEC, 2009). Avis and Birch (2009) have estimated that the total CO_2 emissions from European refineries will increase by approximately 3% in 2020 compared with a baseline scenario without any regulation of the sulphur content in marine fuels. This increase in CO_2 emissions has been estimated at 17 million tonnes (Concawe, 2013).

Other positive environmental effects were also identified. These include the reduction of emissions of particles, estimated to be around 65-77% (ENTEC 2009) and 80-85% (Swedish Maritime Administration, 2009) depending on the study. Other environmental effects would be the reduction in acidification (-25% in SECAs) and reduction of eutrophication by 3% in 2015 (AEA, 2009). In addition, the environmental consequences of oil spills would be less damaging in the case of distillates as compared to HFOs. Moreover the use of distillates reduces the onboard production of oil waste. And according to another study, less local emissions would lead to less damage to buildings and materials adding up to GBP 6.32 million in the UK (ENTEC, 2009).

These emission reductions represent positive health effects and savings on health costs. According to the US Environmental Protection Agency, the North American ECA should save more than 14 000 lives annually by 2020, and improve the respiratory health of some 5 million people in the United States and Canada. It further estimates that the ECA will cost USD 3.2 billion by 2020, but that it will have generated between USD 47 billion and USD 110 billion in estimated health related benefits. According to AEA the net health benefits to society in 2015 of the new rules – ranging from EUR 8-16 billion – will be far greater than the costs, which were estimated at EUR 3.7 billion in the highest estimate. In the same study the health benefits in 2020 were estimated to be EUR 10-23 billion. Yet another study estimated the health benefits in the UK to be GBP 309-622 million, related to avoided life years lost, reduction in respiratory and cardiovascular hospital admission etc.

It is unlikely that similar emission reductions could have been reached in other transport sectors. Until 2008, shipping made very limited contribution to the efforts to improve air quality in Europe (EMSA 2010). Even the current shipping emission regulations are considerably less strict than for the road sector. The maximum sulphur content in road based fuels is 10 ppm: 100 times lower than the ECA Sulphur regulation in 2015. In view of this, it is commonly accepted that regulatory attention to shipping emissions is cost-effective in terms of potential air emission reductions. Various studies (AEA, ENTEC 2009) showed that the benefit-cost ratio for the 2015 shipping regulations would be higher than for stricter regulations for the road sector.

6. Implications for policy

The assessment in earlier chapters has implications for policy and implementation. Considering the impacts in 2015, what would be needed to make sure that the 2020 global sulphur cap achieves its objectives without leading to unforeseen adverse effects? This chapter will take a look at this, and more specifically will treat required adjustments in ports, gaps in policies and enforcement issues.

Required adjustments in ports

Effective compliance with the sulphur regulations requires sufficient availability of low sulphur fuel bunker facilities. There are no indications that this has been a problem in 2015. In the monitoring report of the European Community Shipowners'Association (ECSA) on the impact of the impact of the low sulphur requirements in 2015 only one case was mentioned of a port (in Russia) that did not have low sulphur fuel bunker facilities (ECSA, 2015).

In order for LNG to become a feasible compliance option, there needs to be a sufficient number of ports with LNG bunker facilities. This is essential because LNG tanks take up considerable space on a ship. The business case for shipowners becomes more attractive if LNG-powered ships can bunker regularly, so as not to maximise ship space for cargo. This is currently a large bottleneck as only a limited number of ports have invested in such facilities – also due to uncertainty on the uptake of LNG as ship fuel. This can be illustrated by recent mapping of the available LNG bunkering facilities in European ports (see Figure 11), the continent with arguably the largest share of LNG bunkering facilities in place. For deep sea shipping, a network of LNG bunkering facilities in ports along the main trade lanes would be needed.

Figure 11. **Overview of LNG bunkering facilities in European ports**

Source: DNV GL

A possible compliance option for ships in ports is onshore power, so using the power of the land-based grid when berthed in port. When at berth, ships typically use the auxiliary engines of the ship to generate electrical power for communications, lighting, ventilation and other on-board equipment. Using shore side electricity, also indicated as "shore power" or "cold ironing", means that the ship is plugged into the electricity network instead of using auxiliary engines, which reduces the emissions from ships while in the port. Various ports have over the last years installed such facilities (see Table 9), and various shipowners have adapted their ships so that these ships can use shore power. The business case for shore-side energy was found to be most attractive for ships with high electricity demand per berthing, such as cruise ships, container ships and Ro/Ro-ships. In addition, shore power facilities make most sense for ships that call regularly at the same ports, such as ferries, barges and short sea ships; but less so for ships that only have occasional calls in most ports, such as oil tankers. For some very energy-intensive ships, such as cruise ships, there are concerns about the grid stability in case of massive uptake (Ecofys, 2015). Shore power can be considered complementary to some of the other Marpol Annex VI compliance options, such as scrubbers, as most scrubbers are installed on the main engines, not on the auxiliary engines used at berth. An EU directive on the deployment of alternative fuels infrastructure states that shore-side electricity supply needs to be installed in TEN-T Core network ports and other ports by 31 December 2025, "unless there is no demand and the costs are disproportionate to the benefits, including environmental benefits" (Directive 2014/94/EU).

Table 9. **Ports with shore power facilities for cargo ships**

Port	Country	Ship type	Traffic share of terminal(s) with shore power	Frequency of use shore power facilities
Antwerp	Belgium	Containers	n.a.	0%
Prince Rupert	Canada	Containers	-	(25%)
Shanghai	China	Containers	-	(25%)
Shekou	China	Containers	-	(25%)
Long Beach	USA	Containers	100%	50%
Los Angeles	USA	Containers	-	(25%)
Oakland	USA	Containers	100%	38%
Zeebrugge	Belgium	Ro/Ro	28%	45%
Luebeck	Germany	Ro/Ro	n.a.	11%
Kemi	Finland	Ro/Ro	100%	55%
Osaka	Japan	Ro/Ro	-	(25%)
Gothenburg	Sweden	Ro/Ro	100%	40%
Trelleborg	Sweden	Ro/Ro	34%	0%
Tacoma	USA	Ro/Ro	8%	100%
Long Beach	Ro/Ro	Tankers	-	0%

Source: Merk 2014

Note: The Port of Long Beach does not track data on shore power visits, but under the shore power regulation, fleets must plug in 50% of their visits. The estimation of usage of container terminals at the port of Oakland are based on statistics from January-July 2014. The percentages between brackets are assumptions, as the ports in question never responded to our inquiry.

Implementation of shore power for ships would contribute to decreasing CO_2 emissions in case the carbon content of electricity from the grid is lower than of electricity produced on board of ships, which is the case in most EU countries. Lower oil prices have deteriorated the business case for ship operators to use shore power; various ports (e.g. in Spain) support uptake of shore power by giving reductions on port tariffs. Another support measure by states is the exclusion of shore power from the tax base, applied in Sweden and Germany. Roll out of shore power as compliance option would benefit from harmonisation and standardisation of installations so as to facilitate uptake.

Scrubber use requires sufficient waste reception facilities in ports. Shipowner associations frequently receive complaints from their members on the lack of such facilities in some ports. This means that ships in these ports cannot discharge the sludge resulting from the scrubbing process which contains heavy metals. If there are too few such facilities, the risk is that ship operators discharge the sludge in open sea. In order to create disincentives to do so, Swedish ports charge a uniform waste reception fee to all ships, including ships that do not use the waste facilities. Such a structure could be considered to provide an incentive to discharge waste in the port facilities rather than at sea. In a way, such a fee structure cross-subsidises ships with scrubbers.

Policy gaps

Considering that fuel costs make up around half of the total ship costs, one would expect that shipping companies have an incentive to reduce fuel costs. That the existing mitigation potential is not exploited more often is due to split incentives: a substantial share of ships is chartered (around half of the container ships in 2015), so shipowners in many instances would not see the benefits of their investments, which would flow to the ship charterers. Moreover, the information on the effectiveness of technologies and designs is not easily quantifiable for shipowners, so that they have difficulties gauging the benefits of certain measures they could take (Gençsü and Hino, 2015). In terms of compliance, there might be yet another split incentive: controls apply to vessels – and thus the vessel owner or manager – whereas the charterer is responsible for fuels. The charterer could take the decision not to be compliant by not using low sulphur fuel, but it would be the vessel owner that would be fined and his ship might be detained (ECSA, 2015).

With regards to LNG marine fuel, there exists a significant regulatory gap for bunkering and associated infrastructure operation, according to DNV-GL (2014). In the US, regulatory gaps were identified for LNG metrology, local versus federal jurisdiction over bunkering operations, and a lack of framework for the review of potential risks related to LNG bunkering from non-self-propelled barges. In addition, not enough clarity was observed in regulations addressing simultaneous operations (DNV*GL, 2014). A 2012 study commissioned by the European Maritime Safety Agency (EMSA) identified three different gaps:

- Legal gaps severely limit or even block the use of LNG as fuel for ships and development of infrastructure.
- Harmonisation gaps exist in the EU with respect to methods, rules, guidelines, provisions and safety aspects for LNG as fuel and (small scale) LNG infrastructure.
- Knowledge gaps can be specific points where more research is needed towards the implementation and development of a small scale LNG infrastructure and the use of LNG as fuel.

Also with respect to scrubbers, regulatory gaps and unclarity are regularly cited as concerns blocking further uptake of this compliance option. At the core of this are the differences between states to what extent and under which conditions they accept open-loop scrubbers and the discharge of wash water, which provides uncertainty to shipowners on where they can use these types of scrubbers.

7. Challenges for enforcement

Effective enforcement is of crucial importance. The intended SO_x emission reductions cannot be achieved if regulation is not enforced. Moreover, lack of effective enforcement risks to distort shipping markets. If shipowners see that regulation is not being enforced, they could decide that there is little risk for them to avoid investing in reduction of their SO_x emissions, therefore giving them a clear competitive advantage over those who do decide to comply with the regulations.. Considering the high costs for shipowners of the international sulphur regulation, the need for assuring a level playing field is all the more relevant. We identify below three enforcement gaps: a legal gap, a detection gap and a sanction gap.

Legal gap

The international sulphur emission regulations form part of a body of international regulation for shipping that is generally dependent on implementation by flag states and port states. The IMO has countries that are members in their capacity as flag states; their membership contributions are determined by the size of fleet that uses their national flag. Shipowners can register their ships wherever they want; in many cases they chose ship registries (and use their flag) that propose favourable conditions, such as limited costs and flexibility with regards to regulations and their implementation. In the case of the international sulphur regulation, shipowners could tend to favour shipping registries that practice limited enforcement of the regulation. For this reason, for the enforcement on its regulation the IMO depends on a second mechanism: port state control. When a ship enters the territorial waters of the state, this state can control that the relevant international regulations are respected, irrespective of the flag of the ship. These port states have regional memorandums of understanding (MOUs) to harmonise and coordinate enforcement efforts, e.g. for European states this is the Paris MOU.

Due to its specific nature, the enforcement of international sulphur emissions regulation for shipping is constrained by the limits of port state control. Most other international regulations for shipping specify requirements for ships and ship design, which can be fairly easy to certify. Classification societies certify ships and enforcement focuses on checking the availability and validity of these documents. A more or less similar procedure is in place if a ship uses scrubbers. However this is different in the case of compliance via low sulphur fuels: the question here is not to know if the required equipment is in place, but rather if the ship has used the right fuel in the areas where it should. And it is this specific character that exposes the limits of port state control: port states can only apply sanctions for irregularities in their coastal waters, not in those of other port states. For example, during a control, should Finland find a vessel that was non-compliant to the ECA requirements throughout its entire voyage before coming to Finland, it can only start a procedure for the non-compliance in Finnish waters. As most of the ECAs are composed of a collection of territorial waters, this requires strong co-operation between authorities, so that ships which are non-compliant in the territorial waters in one state will also be controlled in the other port states in the same ECA.

The enforcement of the 2020 global cap will pose a real challenge of legal nature. The reason is that the regulation will cover all seas and oceans, a large share of which belongs to no state. Whereas non-compliance in territorial waters can be prosecuted by port states, this is not the case for non-compliance at high seas outside territorial waters. This reduces the likelihood that shipowners and operators will comply with the global cap outside the territorial waters, and as such reduces the environmental and health impacts that the regulation is aiming to realise.

Detection gap

The reported non-compliance rate in the European ECAs since 2015 has been below 5%. This can be concluded from data from port state controls, additional monitoring of smokestacks of ships and air quality monitoring in or outside port-cities, as referred to in Chapter 5. This relatively low non-compliance rate could illustrate high compliance, or indicate the difficulty to detect non-compliance. Port state control inspections take place in ports, well after ships entered an ECA. As was explained in Chapter 1, main control mechanisms include oil samples and bunker delivery notes. Bunker fuel delivery notes are notoriously subject to irregularities and fraud, whereas it is difficult to determine on the basis of fuel tanks and oil samples if the fuel switch was operated enough in advance to comply with the ECA requirements or simply enough to suggest compliance when arriving in the port. That said, measures could be taken to improve this form of monitoring by delivery notes, sampled fuels analysis, procedures and on-board log books, e.g. by introduction of mandatory use of mass flowmeters to know more accurately the exact tonnages bunkered by each ship and for each fuel – a measure taken by MPA Singapore that will enter in force in 2017.

In addition to port state control, various states have intensified other forms of monitoring. The EU implementing act for the Sulphur in liquid fuels directive mandates a minimum number of inspections to EU member states. Air pollution monitoring at strategic locations has been intensified, including via planes and drones. For example, the Danish maritime administration has placed sniffers under the Great Belt Bridge, under which all the maritime traffic to and from the Baltic Sea passes. Various countries (Sweden, Netherlands, Belgium) have used small aircraft to measure smoke stacks from ships. Some of these programmes have been financed by the European Union. Pilot programmes have been developed to use drones to monitor air pollution. Some of these measures could be considered of a temporary nature, considering their costs. E.g. the Danish Environmental Protection Agency has earmarked an additional EUR 0.9 million in 2015-2016 for developing technologies for better sulphur enforcement.

For monitoring compliance with the global sulphur cap these measures would only be appropriate to a limited extent. Sniffers situated at strategic locations at some of the maritime chokepoints, such as the main canals and straits, might be feasible in a technical sense. However, some of the concerned states are also large flag states and might not be tempted to possibly undermine their position as one of the leading flags with such surveillance. Sniffers on unmanned drones are beginning to be used and their application could be expanded, but it would be too costly to fly over all shipping routes and probably out of reach for port states in less developed countries. This means that alternative measures might be needed, possibly along three different lines: big-data solutions, on-board monitoring equipment and satelites.

Big data solutions rely on a marine benchmark system that brings together all kinds of data, such as automatic identification system (AIS)-data, speed, ship and engine characteristics. The data become inputs to a modelling exercise that could show which amounts of which fuel would need to be present in fuel thanks at the moment of inspection. Together with the more traditional elements of inspection, such as bunker delivery notes, this could give an indication of the level of compliance on each ship. A step further would be to use the data delivered to bunker companies to tax authorities, if it would be possible to disaggregate these at the ship level.

On board monitoring equipment, when installed on a ship, could monitor which type of fuel is used at any given moment on a ship and the information could be transmitted to the relevant authorities. Some shipping companies are currently testing such installations to assess their merits. First indications seem to show that installation of such equipment during port stays is complicated. Such equipment needs to be well covered, to avoid damage, and it needs to be close to the fuel tanks, which is complicated due to the heat. Considering these elements, installing equipment might need to take place in dry docks, which would mean additional costs to shipowners, because the ship cannot be used during this period. In addition, the risk of tampering with the equipment (or hacking) cannot be excluded.

Satellites are the third possibility to monitor smoke stacks from ships. It appears that this possibility could not immediately be realised and could take another 15-20 years before reaching maturity.

Sanction gap

Of the detected cases only a very limited number leads to a sanction. One of the few known cases in which an offender was prosecuted was in Norway. In some other countries (e.g. Denmark) the first court cases are now going to take place.

When sanctions were imposed, the amount of the sanction was very limited. Despite some variety between countries, a common trait seems to be that sanctions hardly ever surpass the cost savings of ship operators due to non-compliance. The average savings of using heavy fuel oil instead of low sulphur fuel in an emissions control area amount to approximately EUR 100 000 per trip per ship. The cost savings for ocean-going vessels in global trade lanes in case of non-compliance to a global sulphur cap could be several times higher. The maximum financial sanctions so far communicated for non-compliance to ECA SO_x regulations show a large variation, ranging from EUR 2 900 to around EUR 6 million (see Table 10). Some countries, such as Denmark, have taken the approach that the penalty should be equal to the cost advantage that carrier had on that voyage.

Table 10. **Penalties for non-compliance to SO_x regulations in selected countries within SECAs**

Country	Maximum financial penalty for non-compliance
Belgium	EUR 6 million
Canada	CAD 25 000
Denmark	No maximum
Finland	EUR 800 000
France	EUR 200 000
Germany	EUR 22 000
Latvia	EUR 2 900
Lithuania	EUR 14 481
Netherlands	EUR 81 000 + gains
Norway	No maximum
Sweden	SEK 10 million
UK	GBP 3 million
USA	USD 25 000 per day

Source: data provided by Trident Alliance

Towards greater enforceability

Greater enforceability could be achieved by reversing who carries the burden of proof. Currently it is the maritime administration's responsibility to prove that a ship was not compliant with the regulations. This is costly and complicated, as was mentioned above, with margins of error. At best, it only applies to the territorial waters of the port state. Enforceability could be much less challenging if the burden of proof would be for the ship to show how he has complied.

This could be achieved by introducing the prohibition for ships to carry heavy fuel oil for propulsion purposes. Ships with scrubbers could be exempted from this requirement. The provision would only apply to carrying HFO for propulsion, so ships could still carry around HFO as cargo from port to port. Such a requirement would need to be put into the existing body of international regulation.

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International Transport Forum

Reducing Sulphur Emissions from Ships

The Impact of International Regulation

Ships emit a large amount of sulphur oxides, with significant health impacts. To mitigate these, international regulations cap the sulphur content of ship fuel. They have also established emission control areas with stricter standards in certain parts of the world.
New requirements introduced in 2015 limit the sulphur content of ship fuel to 0.1% in these emission control areas, and a lower global sulphur cap of 0.5% is planned for 2020.
This report examines the impacts of the 2015 cap and potential effects of the new requirements foreseen for 2020. It assesses the cost increase for maritime transport associated with the sulphur caps, impacts on shipping operations as well as on other transport modes, and on the environment. The report also highlights policy gaps and challenges for the enforcement of sulphur emissions regulations for shipping.

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