



BULLETIN

FAL

FACILITATION OF TRANSPORT AND TRADE IN LATIN AMERICA AND THE CARIBBEAN

Measures to improve energy efficiency in shipping

Background

The transport sector is under considerable pressure to increase fuel efficiency. While CO₂ emissions are falling in many other sectors, transport emissions are expected to rise in the future. Shipping currently accounts for about 3% of global anthropogenic CO₂ emissions, but its share is expected to grow as a result of increased transportation, in combination with difficulties in implementing effective fuel efficiency measures and replacing fossil fuels.

In Latin America and the Caribbean, maritime transport is responsible for over 90% of all international freight movements in volume terms and is thus the most important facilitator of the region's participation in the global market (Wilmsmeier and Hesse, 2011). The sector, and more specifically its energy efficiency, has received little attention from governments in Latin America and the Caribbean. However, the region is striving to become more competitive in international trade and this, together with the increasing cost of marine fuels, has put pressure on the industry to become more fuel efficient. As fuel efficiency is inextricably linked to air emissions, measures and policies that successfully improve energy efficiency will have positive implications for the region's emission levels.

Research has already been carried out in the field of alternative power sources and into technical, operational and structural energy saving measures for shipping. However, gaps remain between current knowledge and the implementation of energy efficiency measures by shipping companies (Styhre and Winnes, 2013). As in many industries, a number of measures that would improve fuel efficiency in shipping have yet to be implemented despite known cost efficiency. This situation is known as an energy efficiency gap. There is also an extensive list of barriers that explain the non-adoption of measures. Sorrell and others (2004) summarized these barriers as risk, imperfect information, hidden costs, access to capital, split incentives and bounded rationality.

This paper provides an overview of several parameters that would improve the fuel efficiency of shipping. Calculations are carried out from a Latin American perspective, and illustrate the emissions to air and the fuel consumed by different transport modes.

One of the conclusions is that initiatives and incentives to improve energy efficiency in the shipping sector are few and far between in the region and that Latin America and the Caribbean lags behind other regions.

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Thanks to initiatives within the International Maritime Organization (IMO), a new chapter was added to MARPOL Annex VI¹ on the prevention of CO₂ emissions, which entered into force on 1 January 2013. An energy efficiency design index (EEDI) value, which relates the mass of CO₂ emissions per transport work to ship size, must be produced for all new ships. The EEDI of a specific ship is compared to a reference line that dictates the maximum allowable limit. The reference line varies by ship type. A “ship energy efficiency management plan” (SEEMP) is also required. A SEEMP should function as an operational tool to improve energy efficiency. Goods volumes transported at sea are, however, predicted to rise, and absolute reductions in fuel consumption and CO₂ emissions from the industry are not expected despite the new regulations (Bazari and Longva, 2011; Anderson and Bows, 2012).

In addition to efforts to reduce fuel consumption and CO₂ emissions from shipping, regulations covering other pollutants are being implemented, which also have cost implications. Emissions of sulphur dioxide (SO₂) and particulate matter (PM) are regulated according to the sulphur content of the fuel. There is a direct correlation between SO₂ emissions and sulphur content, and a connection between PM emissions and sulphur content has also been established. These regulations are intended to address problems with acidification (SO₂) and health risks (PM). However, explicit PM regulations, as apply to other diesel engines, may be needed in the future to further mitigate the health risks associated with ship exhausts. The sulphur regulations mean that the maximum permissible sulphur content of fuel will be 0.5% from 2020, down from 3.5% today, and further, in special areas (Sulphur Emission Control Areas – SECAs) the limit will be 0.1% from 2015. Today, these areas comprise the North and Baltic Seas, the English Channel and coastal waters around the United States and Canada. The other pollutant that is regulated is nitrogen oxides, NO_x, and emissions limits have been somewhat tightened for engines installed after 2011. A further restriction will be implemented at some point during the period 2016-2021, but only for special NO_x emission control areas, currently only coastal waters around the United States and Canada.

This paper contains an overview of important parameters to consider in order to improve the fuel efficiency of shipping. In addition, emissions are discussed and are compared with other transport modes.

I. Ship design for energy efficiency

Technical measures that reduce fuel consumption in a cost-efficient way have resulted in highly efficient marine engines and power trains, optimized flow profiles around

hull, rudder and propeller, and innovations such as the bulbous bow. Still, it is not unusual for individual ships to consume up to 30% more fuel than necessary due to imperfect design, badly used propulsive arrangements, or a poorly maintained hull and propeller. High expectations of improved energy performance from technical improvements are also found in a report for the Marine Environment Protection Committee of IMO, which estimates that design measures could potentially reduce CO₂ emissions by 10% to 50% per transport work.

Knowledge of the fuel-saving potential of technical measures related to hull and propeller geometry, hull construction, propulsion machinery, auxiliary machinery and equipment, heat recovery, cargo handling, and alternative energy sources is, in general, good within the industry. There is a long tradition of development and research in these areas and the improvement potential is estimated to be, on average, a few per cent of fuel savings in each category. A remaining challenge is to increase knowledge of how the different technical systems on a ship affect one other. Such knowledge is needed in order to enhance waste heat recovery or efficiently reduce the use of electricity on board, which are highly effective measures for overall energy economy.

Ships have long lifetimes and modifications and retrofits to existing ships are more expensive than new designs, from a life-cycle perspective. The ship design process begins with a mission analysis that outlines factors such as the types of goods to be transported, how they will be loaded and unloaded, the routes and the service time. Based on these requirements, the conceptual design phase starts, the dimensions and layout of the ship are determined and powering needs are decided. The conceptual design phase consists mainly of technical feasibility studies in order to decide whether the mission requirements can be translated into reasonable technical parameters and still produce a seaworthy ship. This is followed by an increasingly detailed design and refined ship characteristics.

Energy efficiency decisions are to a large extent already included in the conceptual phases of the ship design process. Among the most important parameters for ship energy efficiency are the main dimensions of the ship: length, breadth, depth and displacement. Small changes in these parameters can result in big changes in energy need. The operational phase is by far the most demanding period of a ship's life cycle in energy terms. A well defined operational profile from the early design stages is a promising way to develop an energy efficient ship of high quality. Designing for operations should therefore also be prioritized over a less costly construction at the yard from an energy efficiency perspective. Optimization efforts can be counteracted by the yard's requirements for

a cost-efficient construction. Yards do not necessarily take a life-cycle approach and are not always able to change an existing design, or the changes may be very costly for the owner. The ship owner is unlikely to have the skill or the power to plan for life-cycle costs under such conditions.

Fuel prices have long maintained an upward trend and fuel's share of the total cost has increased. Furthermore, environmental regulations that demand the use of low-sulphur fuels will result in even higher fuel costs for ship operators, and markedly so for operators active in the Emission Control Areas where requirements are strictest. As fuel prices rise, interest in energy saving measures within the industry grows. The ships constructed today are likely to sail the oceans into the 2040s and during the lifetime of these ships energy-efficient solutions will most likely be more valuable than ever before.

II. Alternative fuels

There are a few liquid fuels that could replace oil for ship propulsion and these are in various stages of development –from pilot project to commercial implementation. Liquefied natural gas (LNG) could potentially replace oil in a large share of the fleet. LNG has previously been used as a fuel for LNG carriers but it is being introduced in other segments of the fleet. Natural gas is a fossil fuel and will, like traditional fuel oil, contribute to increasing CO₂ levels in the atmosphere. However, lower emissions of sulphur dioxide and nitrogen oxides also make LNG an option for ships in the emission control areas where marine gasoil is the only other fuel alternative available today unless abatement technology is installed. Furthermore, natural gas reserves are expected to last longer than oil reserves (EIA, 2009). Two issues that are likely to hold back LNG use are the costly engine retrofits for existing ships, which make LNG an option primarily for new builds, and the additional space requirements for LNG storage. LNG is stored in specially designed pressurized tanks on board and requires approximately 2.5 to 4 times more storage space than conventional fuel oils. The lack of infrastructure for LNG in many ports is also an obstacle.

Once a ship has been constructed for operations on LNG, the use of liquefied biogas becomes an option. Biogas and natural gas are made up of the same hydrocarbon molecules (mainly methane) and are only different in the sense that they are of different origin; natural gas is a non-renewable resource from the earth's crust while biogas is from renewable sources, typically produced by the fermentation of biomaterial such as food and sewage. LNG can be combusted in dual-fuel diesel engines, where a small amount of diesel oil is injected simultaneously with the gas. LNG can also be used as the only fuel in

Otto engines, similar to methanol engines –another fuel discussed for marine use.

Methanol is an alcohol that potentially could be a bridge to a fossil-fuel-free future, although today it is mainly produced with natural gas as feedstock. Methanol is a liquid at room temperature and does not require pressurized tanks. The use of methanol as marine fuel is at a trial stage. Another option is synthetic diesel, which can be produced by the Fischer-Tropsch method or similar processes from basically any hydrocarbon raw material: natural gas, biogas, coal or biomass. Synthetic diesel is, however, not yet beneficial to use from either an energy efficiency or cost point of view (Bengtsson and others, 2011). Another fuel that can be used directly in diesel engines is dimethyl ether (DME).

The Marine Environment Protection Committee of IMO forecasts that heavy fuel oil (HFO) will be completely replaced by distillate oils and LNG by 2020. In a scenario analysis, it is assumed that 5% of tank ships and 5%-10% of coastal shipping will be fuelled by LNG by 2020 and that these figures will rise to 10%-20% for tankers and 25%-50% for coastal shipping by 2050. In 2050, only minor shares of synthetic diesel are expected to have been introduced to the marine fuel market (Buhaug and others, 2009).

III. Operational measures

A wide variety of measures are needed to achieve successful and sustainable reductions in the amount of fuel used per tonne of goods transported between ports of origin and destination. Logistic measures, including slow-speed operations, higher capacity utilization, and route planning are important, as are communication measures for improved port call efficiencies and changed behaviour, for example renewed incentive structures within and between organizations. Communication and behavioural aspects are important for successful implementation of all measures, particularly during operations.

The operational energy efficiency measure with the most potential is slow steaming (Buhaug and others, 2009). As the relationship between ship speed and fuel consumption per unit time is approximately cubical, a minor speed reduction can have a considerable impact on fuel consumption. Slow steaming is an attractive option in times of economic recession with an overcapacity of ships, but the effects of slow steaming cannot be expected to be equally significant as the economy recovers and shipping services are more in demand (Lindstad and others, 2011). Suggestions for maintaining slow-speed operations in the international fleet in order to reduce CO₂ emissions from ships include fuel taxes (Cariou, 2011; Corbett and others, 2009) and regulated speed restrictions for ships (Faber and others, 2012; Lindstad and others, 2011).

Another measure that would increase ships' energy efficiency is to improve port efficiency, as this would reduce vessels' turnaround time in port. With a shorter time in port, the speed at sea can be reduced while preserving the transport service. Johnson and Styhre (2013) investigated the possibilities of reducing speed at sea for short sea bulk shipping by decreasing unproductive waiting time in port. The results show that the two largest sources of unproductive time in port are waiting time at berth when the port is closed, and waiting time at berth due to early arrival. With one to four hours of decreased time per port call, the potential for increased energy efficiency was 2%-8%.

When discussing ship energy efficiency measures it is important to stress the different premises for liner shipping and tramp shipping. Liner shipping provides regular services between specified ports according to timetables and usually carries cargo for a number of cargo owners, while tramp shipping is irregular in time and space. Ships in liner traffic have in many cases been subject to careful logistic arrangements, including long-term cooperation with a limited number of ports and fixed timetables and designated berths. Ships in tramp traffic will seldom have dedicated berths and port slots and will most often visit several different ports, all of which have specific procedures and administration relating to a port call.

Different ship types have different energy needs. A relevant example for the Latin American market is the transport of reefer cargo. Reefer cargo, transported in specialized reefer vessels or in refrigerated containers, demands extra energy for cooling. About 20% of the energy needed to transport food in refrigerated containers is used for refrigeration. Low freight rates have hit reefer companies hard as container ship operators have filled idle capacity in their ships by loading containerized reefer cargo. The ongoing cargo shift from specialized reefer vessels to container ships is likely to continue; there are no specialized reefer vessels on order and new-build container ships are increasing their capacity for refrigerated cargo.

IV. Effects and barriers

A number of energy efficiency measures in shipping are also cost efficient. Eide and others (2011) estimate that approximately 400 million tonnes of CO₂ emissions could feasibly be prevented by only using cost-efficient measures until 2030. Over the past several years, marginal abatement cost curves (MACCs) have been used to determine the cost efficiency of measures. However, published MACCs project different abatement potential, which is largely explained by the fact that they use different emission baselines, different sets of measures and different assumptions

about future fuel prices (Faber and others, 2011a). The fuel prices used by Eide and others (2011) were US\$ 350/tonne for heavy fuel oil and US\$ 500/tonne for marine distillate. With higher prices (the price today for marine distillates is over US\$ 600/tonne), it is obviously possible to reduce CO₂ emissions even further while simultaneously reducing costs. MACCs are very sensitive to assumptions such as discount rates, investment costs, vessel service life and annual transport work (Kesicki and Ekins, 2012). The analysis of measures includes highly aggregated data on efficiency and costs, and does not include important aspects such as revenues that can be expected from speed increases. Also, the MACC analysis does not take into account all the perceived costs that a ship owner and a ship operator associate with a certain technology. Perceived risks associated with new technologies, which can be referred to as technological risks, are highly important reasons for low implementation rates. Other barriers to implementation are found to be of an institutional or financial nature (Faber and others, 2009).

Institutional barriers inherent in organizations made up of shipping industry stakeholders influence the implementation of fuel-saving measures. Measures that overcome institutional barriers are believed to have significant potential to reduce emissions, but are generally hard to develop and implement (Eide and others, 2011). Typically, two or more shipping counterparts have to work together to implement these measures and increase efficiency. As already pointed out, tramp shipping is in a more extreme situation than liner shipping with regard to these issues because these ships are subject to agreements between ship operators and charterers which may limit the implementation of technical and logistic measures (Faber and others, 2009). For example, the contract between a ship charterer and a ship operator in tramp shipping will stipulate who pays for the fuel at different times during the ship's journey. Special contracts, or charter parties, are used, which state the conditions for use of a vessel during the chartering period. These agreements contain a number of clauses that in different ways include the voyage, the cargo to be transported and the time frame. There are also clauses on performance and guarantees for speed and bunker consumption and regulations regarding delays. Such clauses can affect energy efficiency since they provide incentives to save fuel to varying degrees. In a voyage charter party agreement, there may even be an incentive for the crew or ship owner to sail at high speed since the charterer pays rent for the ship in port, or demurrage.¹ During an economic recession, the cost of demurrage may be even higher than freight earnings for

¹ Demurrage refers to the period when the charterer remains in possession of the vessel after the period normally allowed to load and unload cargo (laytime).

ship operators. Thus, a voyage with demurrage may be a more attractive option for the individual operator than sailing at a reduced speed and saving bunker.

In general, ships also have a second-hand value that does not reflect investments in energy efficient equipment. Faber and others (2011b) refer to low second-hand values, and prices to charter a ship that do not reflect the ship's energy efficiency, as highly important institutional barriers to the implementation of energy efficiency measures in the shipping industry.

Furthermore, an important factor that affects the ability to implement energy efficiency measures concerns transaction costs and the difficulties of allocating costs and profits among different companies for an investment that benefits multiple stakeholders (Kesicki and Strachan, 2011). Consequently, there is an additional, non-negligible cost associated with the measures, which can mean that capital is not allocated to the business where it is most needed. Smith (2012) points out that low charter prices and high fuel prices are effective drivers of energy efficiency efforts among shipping companies. This partly explains ship operators' increased interest in energy efficiency in shipping recently.

V. Shoreside electricity

The time a ship spends in port is usually considered as insignificant when it comes to its total fuel consumption. However, emissions of pollutants, as well as noise, can be significant problems for the city where the port is located, and these emissions potentially affect a larger number of people compared with emissions at sea. There are some specific measures that can be applied in ports and it is also possible to influence a ship's performance by differentiating the port fees.

The fuel consumed by ships at berth is mostly used to produce electricity in order to run facilities on board for passengers and crew such as air conditioning, cooking and lighting, and also for pumps to load and unload cargo on tanker ships. This means that ferries, cruise ships and tankers use relatively more fuel at berth compared with other ship types.

One alternative is for ships to use shoreside electricity at berth. So far, this technology is not widely used but a number of ports have the facilities and ships in the liner trade connect to shoreside electricity. A number of practical issues have hampered development, such as variations in the voltage and frequency of the electrical current, investment costs, and crew availability to make the actual connection. Furthermore, until a few years

ago low bunker fuel prices made it possible to produce electricity on board at a low cost.

Whether shoreside electricity is a good option for reducing CO₂ emissions or not depends entirely on how the electricity is produced: coal-powered electricity may increase CO₂ emissions, while they will be significantly reduced with hydro- or wind-power. The main advantage of shoreside electricity is, however, that it reduces the emission of pollutants such as particles and NO_x in populated areas.

VI. Modal comparison

Shipping has, in general, been able to maintain its image of an environmentally friendly mode of transportation. In some respects this is accurate: shipping is in most cases relatively fuel efficient; it can ease problems with road congestion; it uses relatively little land; and there are relatively few accidents. However, there are also significant problems: high emissions to air of noxious substances such as NO_x, SO₂ and PM in addition to polycyclic aromatic compounds and other toxic organic substances; emissions to water of oil and toxic hull paints; and the introduction of alien species into sensitive environments in ballast water discharge.

In order to illustrate the different emissions to air of CO₂, NO_x, SO₂ and PM of different transport modes, as well as the fuel consumed, some sample calculations have been carried out. It should be noted that other important issues will of course vary between the transport modes, such as impact on water, congestion, accidents and infrastructure. However, problems with emissions of climate gases and air pollutants are major issues for the transport sector.

The calculations are carried out from a South American perspective for transporting 1000 tonnes of cargo between Manaus, Brazil and either Buenos Aires, Argentina or Santos, Brazil. For shipping this means that the international rules apply, that is, a maximum fuel sulphur content of 3.5% and, for ships constructed after 2000, tier 1 NO_x levels. It is assumed that the fuel sulphur content is 2.7%. Two ships are studied: a container ship of 10,000 dwt and a bulk ship of 60,000 dwt. Train² emissions are for the most part unregulated in South America. It is assumed that the train is pulled by a diesel engine with emissions typical for unregulated large diesel engines. Truck regulations in South America vary from country to country, but generally newer trucks follow, approximately, the Euro III emission standard. The sulphur limits for diesel fuel used by train engines and trucks also vary across the continent. A diesel fuel with 500 ppm S, which may be regarded as a common quality, was chosen for the calculations.

² There does not seem to be good train coverage for these hauls but the train is included in order to illustrate its potential.

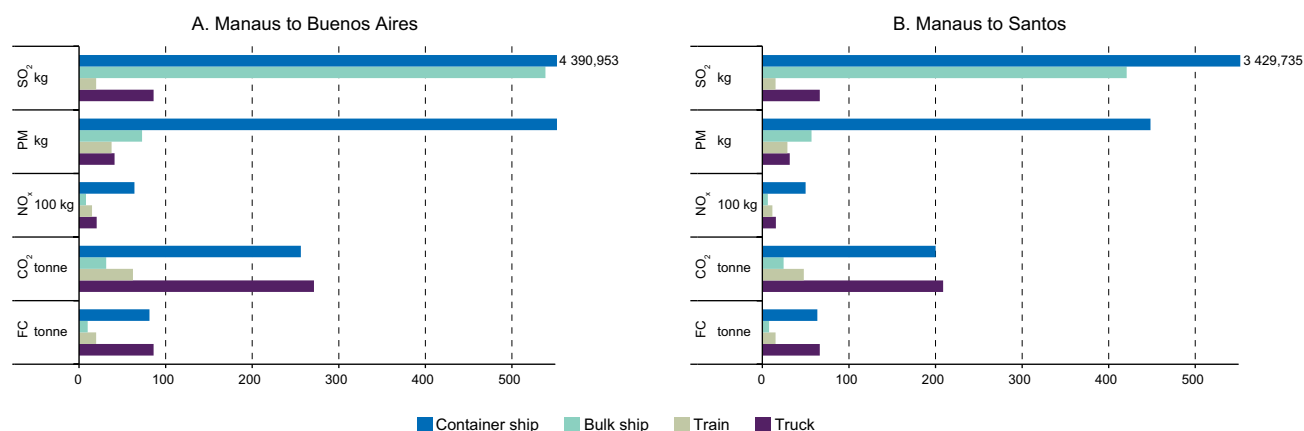


Of great importance for the results is the capacity utilization, or the load factor. It is assumed that the truck, the train and the container ship carry containers that are filled to 75% of the maximum weight capacity. In addition, the ships and the train are assumed to have load factors of 75% when it comes to the number of containers that are loaded.

The results may be seen in Figure 1. One can immediately see the difference between the two ships, as the emissions are much lower for the bulk ship. This

is due to its larger size, but also to bulk ships being more efficient thanks to lower speed and the fact that a higher fraction of the deadweight is cargo compared with a container ship. Fuel efficiency is highest for bulk ship transportation and lowest for the truck. The train has relatively high fuel efficiency and is clearly more efficient than the container ship. CO₂ emissions are directly proportional to fuel efficiency in these examples, the reason being that the assumed fuels have similar CO₂ emissions related to the energy content in the fuels. NO_x emissions are highest for the container ship. This is related to the low degree of abatement normally found for ships. The train is also responsible for relatively high NO_x emissions, since train diesel engines are normally unabated. For PM, emissions are similar among the various alternatives in this example except for the container ship, which has much higher emissions. The ships have high SO₂ emissions because of the high sulphur content of marine fuel.

Figure 1
RESULTS FROM EMISSION CALCULATIONS FOR TRANSPORTING 1000 TONNES OF GOODS
USING DIFFERENT VESSELS AND VEHICLES



Source: Prepared by the authors.

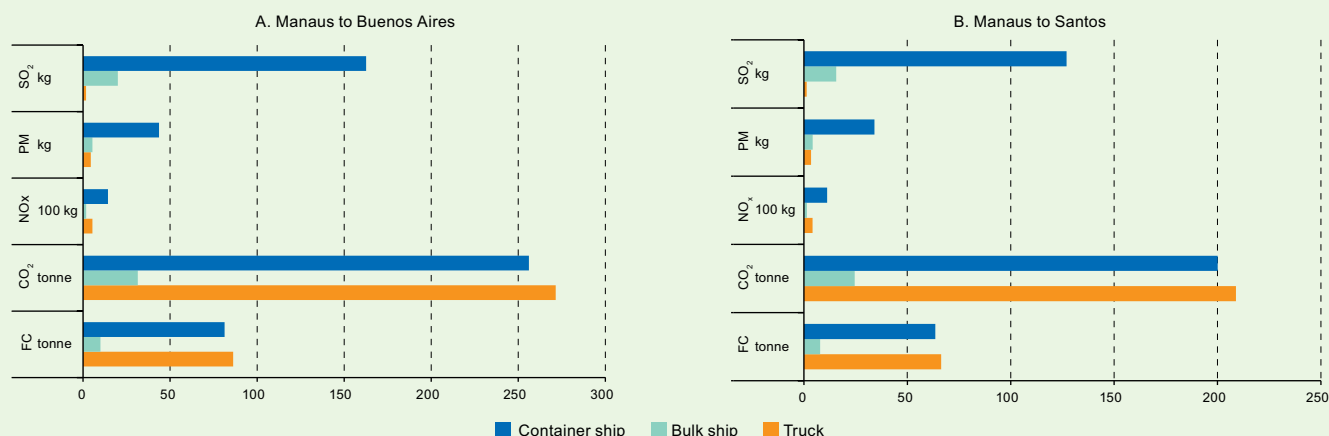
Note: The SO₂ value for the container ship is off the scale.

It should be noted that these results are merely examples. The picture changes on choosing other types of vessels, as these would be of a different size and have different exhaust abatement equipment.

Figure 2 illustrates how emissions would be lower if the ships were to use marine gasoil with 0.1% sulphur rather than heavy fuel oil and comply with the tier

3 NO_x regulations, and if the truck were to meet the Euro V emission standard and use diesel with 10 ppm sulphur. Note that fuel efficiency and thus CO₂ emissions are unaffected by these measures. NO_x emissions are significantly lower for both vessels and for the truck, as are PM emissions. SO₂ emissions are drastically reduced due to lower fuel sulphur content.

Figure 2
RESULTS FROM EMISSION CALCULATIONS FOR TRANSPORTING 1000 TONNES OF GOODS USING DIFFERENT VESSELS
AND VEHICLES WITH ENHANCED EMISSION CLEANING AND LOW-SULPHUR FUELS



Source: Prepared by the authors.

VII. Policies and incentives

Efforts to improve conditions for nature and man have appeared on the political agenda for decades. Environmental sustainability is discussed at the local, regional and global level with a view to improving living conditions for present and future generations. Since the industrial revolution, fossil fuel combustion has caused a net increase in atmospheric CO₂ content that impacts our climate. Air pollution by ozone, NO_x, SO₂ and particles has a more direct impact on human health and is mainly of local and regional concern. International agreements and conventions such as the Kyoto Protocol to the United Nations Framework Convention on Climate Change and the Convention on Long-range Transboundary Air Pollution (CLRTAP) have been established following cooperation between several nations. These forums however, do not include shipping and environmental regulations on air pollution from international shipping originating from IMO conventions.

accompanied by measures for reducing emissions to air from ships. This can be accomplished through technical measures such as low-sulphur fuel and exhaust abatement technologies. However, since these measures come with a cost, a prerequisite for their introduction is that suitable policy measures be introduced.

There are a number of policy options for increasing fuel efficiency and/or lowering noxious gas emissions. As increased fuel efficiency and reduced CO₂ emissions go hand in hand, these are largely motivated by the need to limit impact on the climate. At present only a few such policy measures are in place. The regulations mentioned earlier that were decided on by IMO regarding EEDI and SEEMP are the only notable examples. The EEDI regulations will put pressure on ship design to become more fuel efficient in the future and the SEEMP will hopefully highlight operational measures for better fuel

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