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## SUSTAINABILITY AND ENVIRONMENTAL CHALLENGES OF MODERN SHIPPING INDUSTRY

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# SUSTAINABILITY AND ENVIRONMENTAL CHALLENGES OF MODERN SHIPPING INDUSTRY

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*Nowadays, maritime transport faces more challenges than at its beginning. Like any other industry, the maritime sector must adapt to the needs of the modern world and carry out its activities with respect for the environment. Continuous technological development and increased environmental awareness are the determining factors of changes in modern shipping. Therefore, one of the main challenges of maritime transport is to implement innovative solutions to protect the marine environment. However, it is quite challenging to achieve both ecological and economic benefits at the same time. That is why it is very important to apply the win-win principle, which refers to the sustainable development of maritime transport. The paper provides an overview of applicable and promising technological solutions, logistical activities, and regulatory provisions applied in reduction of shipping gas emissions, as well as importance of points to be considered in development of sustainable shipping. Innovative methods of adapting to the increasingly restrictive environmental regulations are presented as well.*

*Key words: maritime transport, ship, environment, noxious emissions, green logistics, sustainability*

## INTRODUCTION

The share of maritime trade over the last century in the total value of world trade has been steadily increasing. Maritime transport remains the backbone of international trade and globalization, serving around 90% of world trade in goods [1] [2]. With shipbuilding growing to record highs in recent years, continuous improvements in technology and fleet efficiency and with maritime transport being a relatively cost-effective transport, it remains highly competitive compared to other modes of transport.

About 200 years ago, sailing ships sailed the oceans with speeds of 16 knots or more and enabled worldwide trade. One of the best qualities of maritime trade at that time was that the ships did not release any noxious gases into the atmosphere, and were able to sail the world without using a single drop of fuel oil. Since then, world shipping has deviated from the "green road" and the benefits of wind energy have been forgotten.

Nowadays, shipping is one of the biggest air pollution sources, which, according to some studies, causes about seven million premature deaths annually [3]. It has to be noted that there are other environmentally negative aspects of shipping besides emissions of harmful gases. These include pollution by garbage, oils, ballast, hazardous substances, dry bulk cargo, environmental effect of noise, ship-strikes on marine fauna, usage of harmful marine paints for hull coating, etc. [1] [2] [4]. However, authors' focus in this paper is the previously mentioned emissions of noxious gases.

Climate change is recognized as the most serious environmental challenge and the focus is on noxious gas emissions from freight transport [5]. According to the Third International Maritime Organization (IMO) Green-

house gas (GHG) Study from 2014, international shipping accounts for 2.4% of global GHG emissions [6]. Therefore, shipping industry has been in progress of adopting technical and operational measures in order to be more eco-friendly.

Consequently, IMO responded by introducing various regulations. Over the last few decades, IMO has adopted several conventions and protocols (London Convention and Protocol, MARPOL Annex VI and NTC and Hong Kong Convention) whose aim is to preserve marine environment for future generations. IMO has also developed several important regulations and launched several projects related to Sustainable Development Goals (SDG), owing to the seventieth session of the United Nations (UN) General Assembly where "Resolution Transforming our world: the 2030 Agenda for Sustainable Development" was adopted [7]. Currently, one of the IMO's goals is to introduce changes on ships and in seaports in order to make maritime transport and logistics environmentally sustainable.

This paper presents an overview of the main legislation and measures aimed at reduction of noxious gases emissions adopted in maritime transport. Chapter two deals with sustainability challenges in shipping, chapter three gives an overview of international legislation related to emissions, while in chapters four and five authors summed up measures used to reduce emissions from ships and ports. In chapter six a short discussion about difficulties and side effects that might be encountered during implementation of emissions reduction measures is given. Concluding thoughts are given in chapter seven.

## CHALLENGES TO SUSTAINABILITY IN SHIPPING

Sustainable maritime transport and logistics includes a

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complex system that combines economic, environmental and social elements [7] [8]. The systems interact and overlap with each other, thus creating sustainability (Figure 1). The transport system on the one hand influences the functioning of the other systems. On the other hand, the tasks that are set for it are determined and dependent on the needs of the other systems.



Figure 1: Interaction of sustainable maritime transport elements

There is no doubt that non-sustainable maritime transport and logistics has many negative side effects. A great deal of scientific work that confirms this fact has already been done in this area [9] to [11]. One of the side effects are the noxious gases emitted while manoeuvring, performing cargo operations and while waiting at berth or anchorage [7]. However, creation of smog and absence of clean air in ports are not the worst consequences from shipping emissions. Studies indicate that ships are responsible for 24 000 premature deaths in East Asia alone [3].

Since the world's first "Earth Summit" held in Rio de Janeiro (1992), there has been a growing interest of all stakeholders in the phenomenon of sustainability for the planning and operation of maritime transport systems [12]. Accordingly, the sustainable maritime transport system should take into account the requirements of social and environmental safety, as well as economic benefits.

However, it might be quite difficult to make positive impact on environment and at the same time reap economic benefits. All shipping stakeholders are striving to achieve globally sustainable maritime transport and logistics in order to provide an economically beneficial shipping service while respecting the environment and social aspects of modern society. This might be possible with a thorough understanding and implementation of the factors that may affect balance between social, economic and environmental objectives. All three key elements

must reach a level that is acceptable to all stakeholders at the same time. If they are kept in balance, there is an opportunity to create a sustainable maritime transport and logistics that is financially viable and does not have a destructive impact on the environment and human lives.

### LEGISLATIONS REGULATING THE EMISSION OF NOXIOUS GASES IN MARITIME TRANSPORT

As maritime transport is international in nature, it means involvement of many countries and their legislations. Therefore, their rights and obligations must be harmonized internationally. There are a few regulatory measures to limit or reduce emissions. Thus, actions to regulate harmful gases emissions from ships are taken at the international level by IMO. The work of the IMO on noxious gas emissions is carried out in the framework of the Marine Environment Protection Committee (MEPC).

The most important international regulatory instrument regarding emission of noxious gases in international maritime transport is the adoption of International Maritime Organization's (IMO) MARPOL Annex VI, Regulations for the Prevention of Air Pollution from Ships, adopted at the Conference of the Parties to the IMO on 26 September 1997 which entered into force on 19 May 2005. It urges shipowners to apply solutions to reduce emissions of air pollutants contained in ships' exhaust gases, namely Sulphur oxides ( $SO_x$ ) and Particulate matter (PM), Nitrous oxides ( $NO_x$ ), Ozone Depleting Substances (ODS) and Volatile Organic Compounds (VOC). Emission Control Areas (ECA), for  $SO_x$ , PM and  $NO_x$  were introduced over time [13].  $NO_x$  Technical Code, constituent part of the Annex VI Regulations covering testing, survey and certification of marine diesel engines has been significantly revised and adopted at MEPC 58 in October 2008 and since then is known as  $NO_x$  technical code 2008.

MEPC 70 considered an assessment of fuel oil availability to inform the decision to be taken by the Parties to MARPOL Annex VI. Consequently, under the currently revised MARPOL Annex VI sulphur regulations, the global sulphur limit is reduced from 3.50% to 0.50%, effective from 1 January 2020. Based on the results of the conducted assessment related to availability of fuel oil with 0.50% sulphur content, on MEPC 70 session sulphur limit requirements were revised and implementation date set. The sulphur limit applicable in ECAs was previously reduced to 0.10% and became effective from 1 January 2015 [14].

However,  $SO_x$  and  $NO_x$  are not the only harmful compounds emitted to atmosphere from ships. Greenhouse gases (GHG) emissions must be reduced as well. One of the most represented GHG gases is  $CO_2$ . In 2011, driven by the need to reduce emissions of GHG gases, IMO adopted mandatory technical and operational energy efficiency measures, Energy Efficiency Design Index (EEDI) and Ship Energy Efficiency Management Plan (SEEMP), were expected to significantly reduce the

amount of CO<sub>2</sub> emissions in international shipping. EEDI and SEEMP, contained in new Chapter 4 of Annex VI, entered into force on 1 January 2013.

The goal of the EEDI is to promote more environmentally friendly and energy efficient equipment and engines on ships. It is expected to promote continued technical development and innovations of all technical components influencing the fuel efficiency of a ship [14]. SEEMP is an operational measure that provides a tool to enhance the energy efficiency of a ship in a cost-effective manner. It encourages the shipowners to take into account modern technologies and practices when seeking to optimise the performance of a ship [14].

Subsequently, in October 2016, the MEPC 70 adopted the mandatory requirements of MARPOL Annex VI for the collection and reporting of Data Collection System (DCS) for fuel oil consumption of ships. The establishment of a system to collect data on ships' fuel consumption is the first instrument to allow the IMO to take future emission reduction decisions based on reliable, verified information. It entered into force on 1 March 2018 [15].

For their ships to comply with enforced regulations, shipowners have to adopt and apply recommended measures.

### **MEASURES TO REDUCE EMISSIONS OF NOXIOUS GASES FROM SHIPS**

Maritime transport is the least harmful mode of transport to the environment, due to the possibility of transporting a huge mass of cargo by one ship. Compared to other modes of transport, it has the lowest carbon footprint per tonne-kilometre. However, its emissions are projected to increase over the next 40 years [6]. Nowadays, climate change is recognized as the most serious environmental challenge and the focus is on noxious gas emissions from freight transport [5]. As a response to those issues, shipping industry has started to make changes and has adopted measures to be more eco-friendly.

According to [16], measures to reduce emissions in maritime transport could be divided into three groups: technological, operational and market based.

Technological measures include changes in the construction of ships and the application of new technologies in shipping, such as [1] [2] [16] to [18]:

- Changes and innovations in hull design
- Changes and innovations in power and propulsion systems
- Usage of alternative fuels
- Usage of alternative energy sources
- Usage of exhaust gas abatement technologies: Exhaust Gas Cleaning systems – scrubbers; Selective Catalytic Reduction (SCR) systems

Changes and innovations in hull design to reduce CO<sub>2</sub> emission include measures related to ship size, shape of hull, lightweight materials used for hull construction,

hull air lubrication, fitting of resistance reduction devices, reduction of ballast water capacity and usage of distinct types of hull coating. Ship size, or economy of scale, is one of the more promising measures of reducing CO<sub>2</sub> emissions. Larger ships can carry more cargo and they are more energy-efficient per freight unit. For example, if cargo capacity is doubled, fuel consumption will not be doubled, but will be increased by about two-thirds, thus reducing the ship's consumption of fuel per freight unit. Design and form optimization of hull affects fuel consumption, since it improves hydrodynamic performance and minimizes resistance. Building ship's hulls from high strength steel or composite materials reduces emissions of CO<sub>2</sub> as well. Installation of air cavity lubrication systems on some types of ships (bulk carriers, tankers, container ships) can reduce total fuel consumption of main engine, since it improves ship's hydrodynamics performance. Fitting or retrofitting of other devices that minimize resistance of ship's hull, innovative design of ships that allows reduction in total ballast capacity and usage of distinct types of hull coatings can also reduce emissions of CO<sub>2</sub> [5] [17] [18].

Changes and innovations in power and propulsion system include hybrid electric auxiliary power and propulsion, variable speed electric power generation, various propulsion efficiency devices such as sails or kites, recovery of waste heat and reduction of auxiliary power demand [2] [5] [17] [18].

Usage of alternative fuels can cut not only the emissions of CO<sub>2</sub>, but SO<sub>x</sub> and NO<sub>x</sub> as well. Examples used in maritime industry are biofuels and Liquefied Natural Gas (LNG) [2] [5] [17] [18].

Usage of alternative energy sources includes kites or sails (usage of wind power), fuel cells, "cold ironing" during port stay (electricity from shore) and solar panels on deck (usage of solar power) [2] [5] [17] [18].

Scrubbers are generally accepted as an alternative measure to reduce SO<sub>x</sub> emissions. There are four types of scrubbers available on the market: seawater, freshwater, hybrid and dry scrubbers. Seawater scrubbers are often referred to as open loop scrubbers, since they use untreated seawater in an open system to neutralize sulphur from exhaust gases. Freshwater or closed loop scrubbers neutralize exhaust gases with caustic soda added to freshwater in a closed system. Hybrid scrubbers have the possibility to use either open or closed loop technology. Dry scrubbers need no liquids during the process of neutralization of exhaust gases, hydrated lime-treated granulates are used [19].

SCR is an advanced active emissions control technology system that injects a liquid-reductant agent through a special catalyst into the exhaust stream of a diesel engine. Liquid-reductant agent is commonly in the form of a urea solution. Urea sets off chemical reaction called "reduction" that converts NO<sub>x</sub> into nitrogen and water. In that way it reduces NO<sub>x</sub> emissions [2].

Operational measures include optimization of processes

where usage of fuel can be reduced, like [1] [2] [16] [17]:

- Speed optimization
- Capacity utilization
- Voyage optimization
- Other operational measures

Speed optimization implies operational reduction of ship's speed or so called "slow steaming". There can be several reasons for utilisation of slow steaming, but most common one is economic benefit, since shipowners want to save fuel while ship is in ballast voyage. Positive side effect of this is its lower environmental impact, as slow steaming reduces emissions of noxious gases into the atmosphere [16] [17] [20].

Capacity utilization mainly includes software for optimising loading condition of ships, but can also reduce emissions since more cargo is transported during the same voyage of ship [17] [21].

Voyage optimization includes measures like weather routing, route planning and voyage execution, through which operators try to reduce fuel burnt during voyage. The most common solutions are software for optimising routing condition of ships [17] [21].

Market-based measures include introduction of the Emissions Trading Schemes (ETS) [22], and emission tax included in price of fuel [23]. Market-based measures can affect technological and operational measures, and there is a close link and interdependence between them. However, they are separated as specific measures for the purpose of the paper.

### **GREEN LOGISTICS IN SEAPORTS**

The use of logistics to solve environmental problems and implement sustainable development principles began in the 1980s. Many scientists pointed out that logistics has a significant impact and potential in terms of transport system control, control and minimization of environmental pollution and control of energy and resource saving processes [24]. It is worth noting that the logistics sector is responsible for about 5% of global exhaust gas emissions. The main challenge is to reduce the carbon footprint of the entire supply chain. The pro-ecological approach has become a part of the "green" marketing of shipping lines. Therefore, for the logistics operator one of the most important aspects of its activity is their impact on the natural environment. In order not to exceed the acceptable standards, it is necessary to use logistic solutions and tools as well. Nowadays, many logistics companies, such as DHL, Schenker AG, Green Cargo Kuehne Nagel, UPS, COSCO Group and others, apply green technology in their operations. They define green logistics as "an effective approach to managing technological processes, resource and energy flows to reduce environmental and economic damage" [24].

The environmental element of sustainability is an important aspect for seaports which are a key element in the supply chain. Green logistics is of particular in-

terest today and seaports are accelerating the introduction of new technologies that contribute to the reduction of GHG. Such innovative ports are often referred to as "Green Ports" [4]. The environmental concept in seaports aims at achieving zero-emission, which could be based on smart grid technology connected mainly with renewable energy sources, in order to reduce emissions. Renewable energy sources include wind energy, solar energy, geothermal energy, wave energy, as well as biomass and earthquake energy [5].

Environmentally differentiated port dues based on ship emissions, i.e. ship's participation in "green" rating systems, for example Environmental Ship Index (ESI), are also one of the measures that increases sustainability of the seaport. Ships "greener" than others get fixed or proportional deduction on regular port fees.

Measuring ship emissions is an important aspect of seaport sustainability. In order to reduce the negative effect of emissions they need to be monitored. One of the innovative solutions in seaports is usage of drones to ensure the safety of port operations and monitoring the state of the natural environment. A new comprehensive yetiSense system for monitoring air pollution emissions, created by SeaData, has been implemented in the port area of Gdynia. Such actions are to serve not only the expectations of customers, but also to increase the social responsibility of the port, and thus take care of the environment [25].

Ships are one of the most difficult regulated sources of air pollution in the world, but they are also an important part of international trade. It has been pointed out that seagoing ships are becoming larger and will need more and more electrical energy. Therefore, most ports around the world are exploring the possibility of using shore-side energy [4]. Onshore Power Supply (OPS) is an electrical system for ships that allows the ship to be charged with electricity while docked. This means that all systems on the ship will be able to operate without the use of auxiliary engines. Such a system has been implemented mostly in Sweden, Germany, Western Europe and it has slowly started to appear on the Baltic Sea ports.

One can conclude that maritime transport is trying to increase the environmental element of sustainability and implements different measures and solutions for reducing emissions. However, the efficacy of certain measures and solutions could be doubtful in given conditions.

### **DISCUSSION**

The so-called win-win solution is becoming a very popular term, which means creating social, economic and environmental benefits at the same time. Nevertheless, it is quite difficult to achieve it, since "green fashion" does not always have a positive impact on the development of maritime transport and logistics according to some studies [16].

Unfortunately, solutions for optimal environmental and social efficiency are not necessarily the same as solutions for optimal economic efficiency. Therefore, instead

of "win-win" principle, "push down, pop up" principle emerges. If one pushes a given button down, some other button will pop up somewhere else. In other words, measures to reduce emissions can have consequences for the logistics supply chain, such as choice of another mode of transport, trade restrictions, relocation and even closure of production. This may make shipping unprofitable [16]. These cases may discourage shipowners, companies, customers and other stakeholders from taking necessary abatement measures.

One of the fine examples are measures imposed on ship's speed. As mentioned earlier, reduction in speed results in reduced emissions of GHG. However, this may have a negative impact on safety as it may conflict with the minimum safe power required by a ship in adverse weather conditions. This issue is already under intensive discussion at the IMO. It should be mentioned that reducing the speed of vessels leads to additional costs, such as the costs of stock-taking in transit. This is due to delays in arrival of cargo. The inventory costs are proportional to the value of the cargo, so if the shipper has a very high value of the cargo, cost of the cargo transport increases due to delivery time. Another consequence may be an increase in freight rates. When the total transport supply is reduced due to lower speed, shipowners will increase freight rates. The introduction of a fleet of identical vessels of the same power could become a probable solution. This will reduce speed, but also maintain high throughput [16].

Pollution shifting is also one of the emerging issues. It is defined as a "transfer" of pollution from one medium (air, water, soil) to another. Example of maritime pollution "transfer" could be the usage of open loop scrubbers to cut down on emissions. Wash water used to neutralize sulphur from exhaust gases could contain large share of pollutants that could be released into the sea instead air. Open loop scrubbers might have a negative impact on marine environment because of acidification, eutrophication and build-up of hazardous hydrocarbons and heavy metals in cases of limited dilution. Some countries, like Germany, Belgium and California in the USA, have already restricted discharge of wash water in their national waters [19].

The issue of price and time of transport, rather than ecology, remains the most important concern for the maritime transport stakeholders. Ecology is still an area addressed by business-advanced stakeholders with a well-recognized market position and high awareness of the effects of their business activities. The main problem remains finding a mutually beneficial solution.

## CONCLUSION

Currently, human awareness of the negative impact of emitted gases on the environment is growing steadily. Nowadays transport should be as fast as possible, relatively cheap, but also socially responsible and environmentally friendly. For this reason, maritime transport is

increasingly characterised by innovative solutions aimed at reducing noxious gas emissions. In order to keep its regular customers and attract new ones, maritime transport needs to grow steadily and listen to their needs. This is sometimes very difficult, particularly when it comes to the environmental aspect.

Green technologies take up a lot of money from the shipping budget, but they are necessary. This could have negative consequences for customers, such as, who will have to pay more for maritime transport and for shipping itself, which could result in losing customers. That is why it is very important to maintain a balance between the environmental and economic aspects.

The sustainable development is now a very popular slogan for maritime companies and organizations that regulate the emission of noxious gases. Work on improving the environment continues and shipping is increasingly involved in projects that will make possible the use of maritime transport in an environmentally and, at the same time, socially and economically viable manner.

Future research will be focused on cost-effectiveness of emission reduction measures and their actual implementation on ships and in ports. Another aspect of research will be human element, which was not mentioned in this paper. Implementation of modern technologies for emission reduction bears additional burden for seafarers, since they are the ones to operate them. Question that raises is whether that equipment is user friendly, maintenance-free and whether seafarers have adequate training and knowledge to use it?

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