



## CO2 Emissions from International Shipping

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**WORKING PAPER SERIES 2017: 4**

**CO<sub>2</sub> Emissions**

**from International**

**Maritime Shipping**

**Niels Freese**

# CO<sub>2</sub> Emissions from International Maritime Shipping

## - regulations, challenges and possibilities

### Foreword

International maritime shipping accounts for approximately 800 million tonnes of CO<sub>2</sub> emissions a year, but it is not regulated by the Paris Agreement. The UN's International Maritime Organisation (IMO) has the task of launching initiatives to reduce the sector's CO<sub>2</sub> emissions, but it is proving difficult to agree on solid rules and restrictions. The strong growth in the global population is causing a growing demand for maritime shipping, resulting in a tendency to increase CO<sub>2</sub> emissions in the sector.

This working paper describes the current situation regarding international maritime shipping, its regulation of CO<sub>2</sub> emissions, and ways of reducing them on the part of the shipowners. Changes have to begin.

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## Introduction

Actual CO<sub>2</sub> emissions from maritime shipping have been falling for a long period, mainly because of slow steaming by the vessels and other means of reducing fuel costs. CO<sub>2</sub> emissions per item of cargo transported are declining. However, after 2040 new concepts of propulsion will have to be implemented in order for the sea transportation area to be able to maintain a stable “fair share”, 2.2%, of global CO<sub>2</sub> emissions. The development of alternative fuels and propulsion systems will have to be accelerated if the global fleet is to reduce its CO<sub>2</sub> emissions significantly, and the first steps in doing so have been taken. Nonetheless the introduction of alternative new fuels in the sector is complex and time-consuming, and the trend is for enormous container vessels with a length of up to 400 metres and a daily fuel consumption of 80,000 litres to be used for the ocean-going transport of goods.

## Executive Summary

Ships are responsible for 90% of international transport, their CO<sub>2</sub> emissions accounting for approximately 2.2% of the global total of such emissions.<sup>1</sup> This share, calculated for 2012, was equivalent to 796 million tonnes a year, which is on the same level as Germany’s CO<sub>2</sub> emissions.

International maritime shipping is not included in the Paris Agreement, but regulations to limit the sector’s CO<sub>2</sub> emissions have been established, and it is implementing them at the present time. The regulations have been introduced late and can be adopted relatively easily by most types of ship by 2025.



[www.wikipedia.org](http://www.wikipedia.org)



www.maritime-connector.com

*Plates 1 and 2. Container ships. Ship transportation covers approximately 90% of international freight transport.*

The UN's International Maritime Organisation (IMO) has the task of regulating global maritime activities and has launched a complex set of rules and restrictions to lower their CO<sub>2</sub> emissions. The decisive instrument within this complex is the Energy Efficiency Design Index (EEDI), an initiative to limit the CO<sub>2</sub> emissions for newly built ships. The last phase of EEDI is being launched in 2025, after which more drastic steps will have to be taken if CO<sub>2</sub> emissions from maritime shipping are to fall or at least remain at the 2.2% level.

In general, ocean-going vessels have used harmful heavy fuel oil and the same propulsion concept since 1912. This concept has to change, with engines suitable for alternative fuels being developed and made available to shipowners before 2050 in order for sources of CO<sub>2</sub> from maritime shipping to fall. Stricter international rules are needed to drive such climate friendly development.

## **1. Facts about CO<sub>2</sub> emissions and shipping**

### **Amounts and shares of global CO<sub>2</sub> emissions**

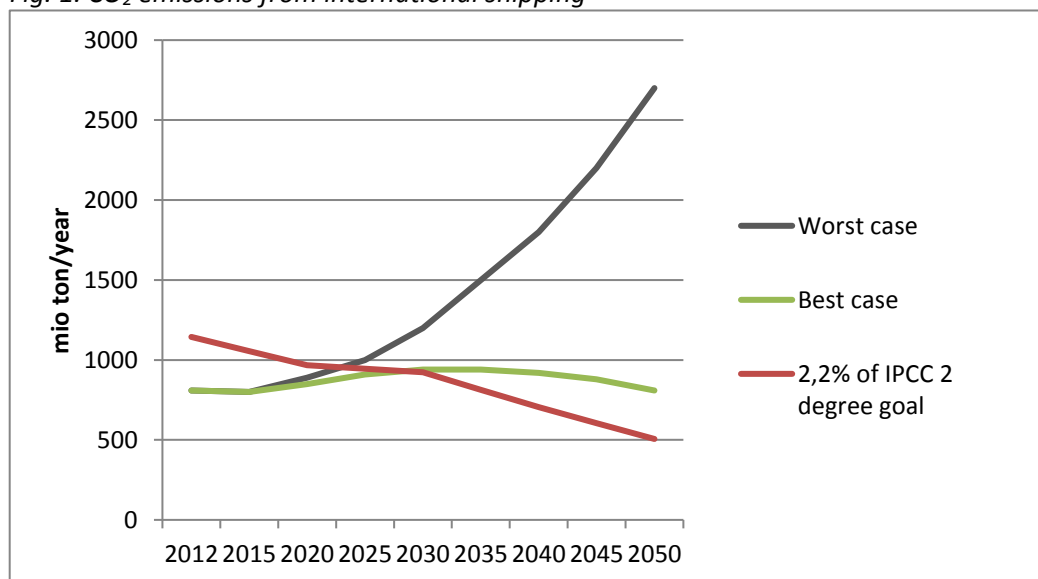
It is estimated that CO<sub>2</sub> emissions from maritime shipping account for 2.2 % of global CO<sub>2</sub> emissions. This share has been falling since 2007, but largely due to declining traffic and various measures taken by the shipping owners themselves. However, this share could easily rise to more than 10% after 2040 if world transport demand grows. It is difficult to predict the future amount of CO<sub>2</sub> emissions from maritime shipping because this is highly dependent on international shipping demand. Other factors influence the size of CO<sub>2</sub> reductions in shipping, such as the availability of technical solutions and as the development of alternative fuels and their profitability. A high increase in maritime shipping levels would result in a similar increase in CO<sub>2</sub> emissions and a much higher share of the global emissions. In a major IMO study<sup>ii</sup>, it has been predicted that CO<sub>2</sub> emissions from shipping will be 50-250% higher in 2050 than in 2012, based on the assumption of very steep rises in transport demand. Given such a steep increase and a lack of action, the share of global CO<sub>2</sub> emissions from maritime shipping will grow drastically.

In its study of CO<sub>2</sub> emissions projections, the IMO uses sixteen different scenarios based on various combinations of fuel types and traffic demand. The scenario with the lowest CO<sub>2</sub> emissions is based on a mixture of low use of carbon fuels, high liquid natural gas (LNG) usage and low global economic growth and traffic demand. The scenario with the highest CO<sub>2</sub> emissions reflects high rates of fossil-fuel consumption and maritime shipping. The number of scenarios reflects the difficulty in predicting the industry's future CO<sub>2</sub> emissions.

Since the IMO's study and its predictions were published in 2014 traffic has fallen, and today most observers expect much lower traffic growth because of the trends towards in-sourcing by the industry and decreasing oil transport on a global basis. New technologies, robotics and 3D printing are enabling cheaper and more flexible production in Europe and the USA. The present nationalistic trends and retreat from free trade are further decreasing international trade and causing fewer CO<sub>2</sub> emissions. On the other hand, population growth and global economic growth are causing a greater level of maritime shipping activities.

The diagrams below, drawn from the IMO, show that CO<sub>2</sub> emissions from shipping are expected to grow despite the introduction of the EEDI and other initiatives. The worst-case scenario is based on the assumption that traffic amounts will grow intensively and that the fuel mix is not reducing CO<sub>2</sub> emissions. In the best-case scenario, the amount of traffic will grow less strongly, and the fuel mix will include more LNG and other alternative fuels producing fewer CO<sub>2</sub> emissions. However, under both scenarios the expected CO<sub>2</sub> emissions will be above the amount permitted if the 2°C limit agreed by the Intergovernmental Panel on Climate Change (IPCC) is to be met, as shown in the lowest graph. The IPCC's values are CO<sub>2</sub> equivalents, and maritime CO<sub>2</sub> emissions exclude other greenhouse gasses (GHG) such as methane and PM.

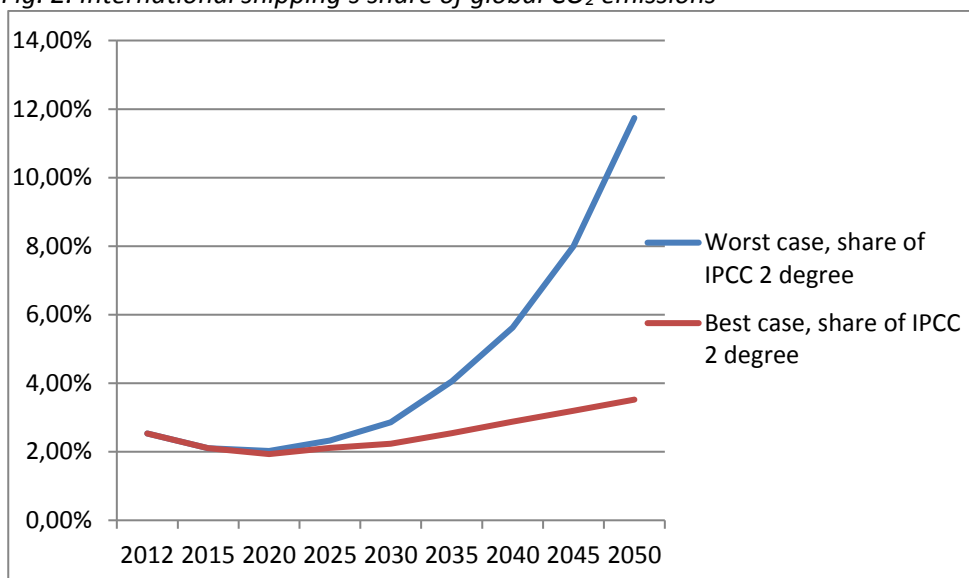
Fig. 1. CO<sub>2</sub> emissions from international shipping



Sources: IMO GHG study 2013 and IPCC

The CO<sub>2</sub> emissions above amount to more than shipping's "2.2% fair share" of global CO<sub>2</sub> emissions as illustrated below. The share is growing and could amount to about 10% in 2045, as shown below.

Fig. 2. International shipping's share of global CO<sub>2</sub> emissions



Sources: IMO GHG study 2013 and IPCC

Certainly ships have large emissions. The container ships are the largest, such as the Maersk Line's new Triple E-class vessels with a length of approximately 400 metres and powered by two 32 MW engines weighing approximately 3,000 tonnes. The energy consumption of such ships is enormous, about 80,000 litre of oil a day, but they can also carry, for example, 10,000 trucks or 400,000 tonnes of iron.

It is possible to decrease the CO<sub>2</sub> emissions per ton of goods moved, as is shown by, for example, the Danish shipping company Maersk Line (see section 6 below).

Given the amount of CO<sub>2</sub> emissions from maritime shipping, which covers approximately 90% of all goods transport between countries<sup>iii</sup>, sea transport is actually relatively CO<sub>2</sub> friendly compared to air and truck transport. The following table shows the amount of CO<sub>2</sub> in grams emitted per metric ton of freight and per km of transportation. The figure for "Modern ship" shows a minimum rate of CO<sub>2</sub> emissions for maritime shipping:

Table 1. CO<sub>2</sub> emissions/transport<sup>v</sup>

CO <sub>2</sub> emissions by mode of transportation	CO <sub>2</sub> g/ km
Airplane (air cargo)	560 g
Modern lorry or truck	45 g
Modern train	18 g
Modern ship (Maersk Line, Triple E)	3 g

Older and smaller ships will not show such low CO<sub>2</sub> emissions as the "Modern ship" of Maersk Line.

The costs of maritime shipping are low, much lower than transport by other means. The transportation cost of a bottle of wine shipped from New Zealand to Europe is approximately 0.07 Euros. Freight rates could be raised to finance CO<sub>2</sub> reductions.

It is the aim of the maritime shipping industry to maintain a “fair share” of global CO<sub>2</sub> emissions at 2.2%, which is the current rate. However, the goal for the world and the recommendation of the Intergovernmental Panel on Climate Change (IPCC) are to keep the global temperature increase below 2°C, which means steadily reducing global CO<sub>2</sub> emissions. CO<sub>2</sub> emissions from maritime shipping must be reduced at the same rate as in the world in general in order that the “fair share” of the total emissions does not change. Drastic measures will be needed in the shipping sector to secure permanent low emissions, just as in any other field with high energy consumption. Larger CO<sub>2</sub> reductions earlier than 2025 could be enforced by a stricter IMO regulation than that introduced in 2012. In any case the CO<sub>2</sub> emissions from maritime shipping must be reduced in order to keep to the “fair share” figure of 2.2% of total global CO<sub>2</sub> emissions, and appropriate actions have already started to meet the IMO’s global regulations.

## **2. EEDI Regulation**

### **No Paris Agreement**

Like air transport, sea transport is not included in the Paris Agreement. However, the industry in general accepts that it must restrict itself to a “fair share” of global CO<sub>2</sub> emissions at 2.2% of total global emissions as registered by IMO in 2012.

The IMO brings together the world’s nations to agree upon global initiatives in GHG reductions, environmental protection and safety. However, it has proved difficult to find agreement on CO<sub>2</sub> reductions, as it has proved difficult to settle the balance of costs between the rich and poor regions of the world, which is emphasised by countries like India, Brazil, Russia and Saudi Arabia. Some countries fear that CO<sub>2</sub> regulations will result in more expensive transport, which can harm their exports. It has been a matter of relief in this situation to observe that China has become more open to adopting initiatives and taking action. The maritime shipping industry participates in these discussions and recommends equitable and globally applicable regulations. However, it is generally not very flexible, nor very open to changing conditions, because its assets and investments are cost enormous, such as Maersk Line’s new Triple E vessels, which cost USD 185m apiece. This encourages a philosophy of caution.

In any case, the IMO is focused on the CO<sub>2</sub> emissions and has agreed the new EEDI regulation. This initiative will take some time and has not been very sharp, but at least the process of its implementation has started.

The aviation sector has taken less time than the IMO to conclude a relatively ambitious plan for CO<sub>2</sub> reductions, to enter into force from 2021. This is the Carbon Offsetting and Reduction Scheme (CORSIA) of the UN’s aviation agency, the International Civil Aviation Organisation (ICAO).

### **The IMO’s Energy Efficiency Design Index (EEDI)**

The IMO has also agreed an Energy Efficiency Design Index (EEDI), which covers ships over 400 gross tonnes (GT) for international traffic, or approximately 95% of all ships. Domestic shipping is excluded from the EEDI and falls under the CO<sub>2</sub> emissions accounts for each country instead. Not all cruise ships have as yet been included in the EEDI regime. The EEDI has the following requirements and phases:

Phase 0 of the EEDI entered into force in 2013 and gave all new diesel and dual-fuel types of ship built after 1 January 2013 a formula for efficiency. This phase was fulfilled relatively easily by the industry. From 2015, Phase 1 demanded a CO<sub>2</sub> reduction of 10% compared with 2013 levels, which was also easily implemented by the industry. Phase 2 will enter into force after 1.1.2020, but this is encountering resistance in the shipping industry. The stricter Phase 3, demanding a 30% reduction in



CO<sub>2</sub> emissions, will enter into force 2025. It is being strongly opposed by the industry because it requires more radical changes to both ships and investments to reach the required level of energy efficiency.

*Table 2. Implementation of EEDI*

Energy Efficiency Design Index (EEDI), CO <sub>2</sub> reductions compared with base year 2013			
2013, Phase 0	2015, Phase 1	2020, Phase 2	2025, Phase 3
Base year	- 10%	- 20%	- 30%

The EEDI might be changed, but it will not become any less strict; rather, Phase 2 might be shortened or an additional phase introduced.

EEDI is a measure of the CO<sub>2</sub> efficiency per ship in grams of CO<sub>2</sub> per ton per mile. EEDI is calculated for each newly built ship using a complex formula consisting of a number of factors and coefficients to express the climate benefits to society, the ship’s deadweight, emissions and speed, and more technical parameters. High levels of efficiency and climate benefits result in a low figure.

After a new ship is built, it is tested in a sea trial in which a class company verifies all specifications and approves the ship, and the EEDI is also tested and verified at the same time. If it is found that the ship has not been constructed according to the requirements, it cannot be approved by the authorities or released from the shipyard.

The shipowner can meet the EEDI’s demands for a higher level of energy efficiency by the various means presented in section 5 below. However, the preferred way of fulfilling the requirements is slow steaming. A speed reduction of 3% produces fuel savings of 10%, so slow steaming is a simple means to gain CO<sub>2</sub> reductions. Slow steaming may become the primary means whereby ship owners comply with the EEDI requirements, but this may cause difficulties in manoeuvring and threaten the safety in bad weather conditions. In rough weather the IMO safety rule, “Minimum Propulsion Power” can easily be violated by slow steaming. The EEDI has been agreed and launched by the IMO’s Marine Environmental Protection Committee (MEPC), while the Minimum Propulsion Power requirement falls under the Maritime Safety Committee. It seems most probable that Minimum Propulsion Power rule will be regulated in order to avoid conflicts with the EEDI. One possibility is to allow a greater use of power in bad weather.

Most ships can meet the 2015 requirement without making large investments. The largest ship type, container ships, are responsible for most CO<sub>2</sub> emissions, but they can nonetheless meet the 2025 requirement relatively easily. It will be more difficult for bulk carriers and tankers to do so, as they already have to be designed carefully by 2020 and especially by 2025, with greater attention being paid to their efficiency.

It is already difficult for Roll-on Roll-off (Ro-Ro) vessels to adopt the EEDI requirements. Ro-Ro vessels can be very large, and their freight is rolled on board and not lifted by crane. The EEDI formula is not really designed for this specialized type of ship, which has some unusual dimensions and other characteristics. This can nonetheless be regulated by the IMO using some special correction factors for Ro-Ro ships, but there are still question marks over these factors, which have not been very well documented. The table below shows the main types of ship and their CO<sub>2</sub> emissions.

Table 3. Adoption of EEDI by types of ship

Ship type	In general complying with EEDI before 2025	CO <sub>2</sub> emissions, m tonnes in 2012 (IMO <sup>v</sup> )
Container	<i>Easy</i>	205
Bulk carrier	<i>Easy, but some obstacles</i>	166
Oil tanker	<i>Easy, but some obstacles</i>	124
General cargo	<i>Easy</i>	68
Chemical tanker	<i>Easy, but some obstacles</i>	55
LGP tanker	<i>Easy, but some obstacles</i>	46
Ro-Ro	<i>Serious obstacles</i>	29
Refrigerated bulk	<i>Easy</i>	18
Cruise	<i>Easy</i>	35
Others		54

University Maritime Advisory Services (UMAS), a partnership between the University College London (UCL) Energy Institute and MATRANS Ltd, has concluded that the effects of EEDI are indeed small and not likely to stimulate CO<sub>2</sub> reduction initiatives on a large scale because they are being developed anyway.<sup>vi</sup> It has proved difficult for the IMO to agree on a CO<sub>2</sub> regulation, but voices have been raised to strengthen the CO<sub>2</sub> reduction initiatives. During the summer of 2017 the IMO held meetings and decided to agree a new strategy by April 2018, but also that it cannot enter into force before 2021. A large session took place in October 2017, to be followed by intersessional meetings to speed up the decision-making process. This is a positive sign that the formal procedures for agreeing a strategy have been intensified.

### 3. Other initiatives to reduce CO<sub>2</sub> emissions

IMO and other institutions have launched other initiatives than EEDI to regulate CO<sub>2</sub> emissions from maritime shipping as presented below.

#### IMO Energy Efficiency Operational Indicator (EEOI)

The Energy Efficiency Operational Indicator (EEOI) was introduced by the IMO in 2010 as a set of voluntary guidelines for monitoring and managing ships' efficiency performance over time in day-to-day operations. According to the guidelines, the ship's fuel consumption and operational conditions should be recorded. The objective of the EEOI is to observe the ship's energy efficiency, record the effect of any changes in operation, and increase the industry's awareness of the importance of energy efficiency.

### **IMO Ship Energy Efficiency Management Plan (SEEMP)**

In 2011 IMO introduced SEEMP, which has been in force since 2013. SEEMP is a management tool used by ship owners to control the environmental performance of each vessel and improve its energy efficiency. All large vessels above 400 GT have to use the SEEMP in order to register and report trends in fuel consumption and energy efficiency.

### **EU Monitoring, Reporting and Verification (MRV)**

MRV, agreed in 2015, is the EU's CO<sub>2</sub> data collection system for all ships entering harbours in the EU area. MRV was introduced in August 2017 and will have several phases. It requires a system on each ship over 5000 GT to measure its CO<sub>2</sub> emissions on a daily basis. A verified annual report has to be provided for each ship, including data on its route, cargo and fuel. The reports have to be submitted from 2019 by the sea transportation authority in each EU member state.

It is expected that in 2018 MRV will be replaced by the international reporting system, SEEMP, designed by the IMO. The SEEMP system is less demanding for shipping owners and is not applicable at the level of the individual vessel.

### **EU Emission Trading System (ETS)**

At the end of 2016 the Environment Committee of the European Parliament decided that the EU's emissions from maritime shipping should be included in the EU Emission Trading System from 2023 if the IMO does not deliver a global deal by 2021. However, this system is strongly opposed by the industry within the EU, which fears that the competitiveness of European shipowners will fall if faced with such extra costs. The industry favours equal global rules.

### **National and regional initiatives**

At the present time there are no national or regional restrictions on CO<sub>2</sub> emissions in the sector. Restrictions on emissions of NO<sub>x</sub> and SO<sub>2</sub> are implemented in various regions, such as the North Sea and North America. It is in the interests of the shipowners to avoid having to deal with a whole range of different national rules by supporting equitable global rules.

### **Carbon tax? The IMF and OECD proposal**

At the beginning of 2016, the International Monetary Fund (IMF) and the Organisation for Economic Co-operation and Development (OECD) suggested a carbon tax for both sea transport and aviation in order to fulfil the Paris agreement. A tax rate of USD 25 per tonne of CO<sub>2</sub> was suggested. Such a tax would stimulate investments in energy efficiency, but this suggestion has not yet made it on to the IMO's agenda.

## **4. Perceptions of the regulations in the market**

Ship owners are becoming used to restrictions enforced by the IMO, the EU or regionally in order to limit emissions of undesirable substances. In many sea areas there have been restrictions on SO<sub>2</sub> and NO<sub>x</sub> since 2011. Shipowners, who already follow an environmentally friendly strategy, will be at the forefront of trends when the new regulations are put into force and will enjoy competitive advantage as a result. For other shipowners the regulations mean large-scale investments. However, EEDI Phase 3, which will enter into force from 2020, is not regarded well anywhere in the industry because compliance is expected to be difficult and to involve investments in energy efficiency measures.

In general shipowners are attracted by energy efficiency because fuel covers approximately 25% of the basic costs of maritime shipping<sup>vii</sup>. However, the low oil prices since mid-2014 have reduced the interest in investing in energy efficiency as profitability has fallen. Retrofit solutions are available in the market, but sales are low.

## **5. Alternative technologies and means to comply with the EEDI regulation**

Shipowners have many options available to them to comply with EEDI, and for larger vessels it is easy, for example, to design a longer ship or introduce slow steaming. Technology and systems to improve energy efficiency have been available in the market for a long time, but are only slowly being adopted by shipowners.

### *Delaying ship-building*

At the present time, given shipping overcapacity, ship owners can bypass the EEDI requirements by simply not building any new ships and continuing to use their existing fleets. The lifetime of a large vessel is normally twenty to thirty years, so the CO<sub>2</sub> effects of the requirements related to new construction are coming slowly, but will be maintained for a long period. Shipowners may delay new constructions and use their existing fleet. In the present period of overcapacity there is also a tendency to scrap vessels earlier than normal, thus increasing total energy efficiency.

### *Slow steaming*

Slow steaming is a very efficient way to save fuel, as a speed reduction of 3% causes a reduction in fuel use of 10%. However, slow steaming also carries safety risks, as it provides less propulsive power and therefore less manoeuvrability. Bulk carriers and tankers especially have limited propulsion power. One effect of slow steaming may be that the global fleet must be expanded with more ships.

### *Operational efficiency, network, voyage optimization*

The shipowner or charterer can obtain greater efficiency by planning routes and networks in order to use the fleet's full capacity. Voyage optimization is helped by weather forecasts.

### *Ship design*

The length and width of a ship influence its energy efficiency, and dimensions can be optimized. A longer ship will have less friction and a lower power demand, but it will be more expensive to build, and very often ports have length restrictions. The longest and newest vessels are 400 m long. Much longer ships would have difficulties in finding port facilities to take them. The design of hull forms and propellers can also be optimized.

### *New combinations of engine components and auxiliary systems*

It is indeed difficult to increase engine efficiency, which is around 50%. However, engine components could be combined in new ways, and facilities such as waste heat recovery systems can reduce fuel consumption. Energy savings in auxiliary systems can be found in combination with the engine.

### *Kites, batteries, solar cells*

Renewable sources of energy can be applied to ship propulsion, but replacing engines in large vessels with a capacity of up to 72 MW is indeed difficult. Alternative sources can be used as supplements for the electrical systems on board and thus assist in propulsion.

Demonstrations have been made of kites, batteries and solar cells installed in vessels, but the costs and the space such systems occupy are preventing commercialization at present. Various research institutions, such as MARIN in Holland, are investigating the possibilities of wind power for ships and conducting tests in model tanks. The main problem in using wind-powered propulsion is that it is an unstable and unpredictable resource. Practical experience is being obtained of hybrid ferries in

Denmark, for example. Battery-powered propulsion alone will soon be started in ferries between Denmark and Sweden and within Denmark to and from the island of Ærø.



www.pinterest.com

Plate 3. Experiments with windpower are taking place

## 6. Heavy fuel oil and alternative fuels

### Heavy fuel oil (HFO)

Today heavy fuel oil (HFO) accounts for approximately 90% of energy consumption by international shipping. The propulsion design for ships' engines originates from 1912, when the diesel engine was used for the first time in a ship. Since then maritime shipping has mainly been fuelled by HFO.

HFO is a residual product after crude oil has been refined to jet oil and gas oils. In a way, the HFO combustion at sea can be seen as representing the waste incineration of this residual product.

HFO is very competitive in price, but harmful to the environment, as it has a high sulphur content and causes large CO<sub>2</sub> emissions, as well as pollution by NO<sub>x</sub>, SO<sub>2</sub>, particulate matters (PM) and methane. Before propulsion it is preheated to remove its high viscosity.

After 2040 alternative fuels will have to replace a large amount of HFO in order to obtain a constant and low share of global CO<sub>2</sub> emissions. Lloyd's Register <sup>viii</sup> is not optimistic about substantial reductions in HFO, predicting that in 2030 HFO will still be responsible for 47-66% of marine energy consumption.



www.wikipedea.com

*Plate 4. Heavy fuel oil. Before combustion it is heated in order to achieve a suitable viscosity*

In the long run HFO will have to be replaced by CO<sub>2</sub> neutral fuels similar to those in other industries, or else alternative modes of transport will have to be developed. Alternative fuels for maritime transport are now on the market, but on a very small scale. After 2030 they will indeed be needed, as shown by the IMO<sup>x</sup>.

### **Alternative fuels**

It is possible to construct ship engines that can use different types of fuel. Alternative fuels can be used in two-stroke and four-stroke diesel engines after major engine modifications. Engines fuelled by LNG and methanol are being offered in the market, but their numbers are small and are expected to rise only moderately.<sup>x</sup> A breakthrough in alternative fuels depends on the costs of the fuel and the engine, as well as availability and harbour facilities. Alternative maritime fuels are similar to the same fuels that can be used by other modes of transport.

- **LNG.** LNG's future maximum share of fuel consumption in shipping has been estimated at 11% by 2030 in a Lloyd's Register study<sup>xi</sup>. Dual-fuel ship engines have been available since 2012 and are used by, for example, LNG carriers and container vessels plying the US west coast. Given that LNG is a huge resource available in many places around the world, its expected future share of maritime fuels must be considered small. Its small share is due to a lack of bunkering facilities in ports, the large investment costs needed in LNG-fuelled ships and the fact that LNG tanks take up vessel space. By the end of 2016 there were 97 smaller LNG-fuelled vessels in operation, a number that had risen drastically since 2015, when the first large LNG-propelled vessel started service in the US Emission Control Area (ECA)<sup>xii</sup>.
- **Biofuels.** Fuels derived from biomass can be used for maritime transport, but enormous land areas to grow the necessary quantities of crops would be needed. Methanol made from forest residuals is already being used in ships. Methanol can be produced from biowaste and is being used in a few methanol tankers and by a ferry between Sweden and Germany, the *Stena Germanica*. Dimethyl ether (DME) made from biomass could also be used. Another possible biofuel source is the jatropha plant, which grows in Africa and has a high oil content. Global bio-fuel resources are very large, but they probably cannot cover the energy needs of heating and land transport as well as sea transport. Ethical problems could also arise in producing biomass for energy purposes on farmland.

- **Fuel cells.** Use of hydrogen in fuel cells is an available technology on a small scale. Hydrogen is often mentioned as a future energy source, and it can be produced by wind energy. However, safe storage would be a challenge, and much space is needed. Some small passenger excursion boats have been built using fuel cells for their propulsion. They are not yet at a very mature level, but the potential is large because of the future surplus production from renewable energy sources that can be converted into hydrogen.

The carbon content of alternative fuels is shown in the table below<sup>xiii</sup>.

*Table 4. Carbon contents of various fuels*

Fuel	CO <sub>2</sub> emissions t-CO <sub>2</sub> /t-Fuel)
Diesel/gas oil	3.2
Light fuel oil	3.1
HFO	3.1
Liquefied petroleum gas (LPG)	3.0
LNG	0.75
Methanol	1.4
Ethanol	1.9

## 7. CO<sub>2</sub> reductions: the Maersk Line example

The experience of Maersk Line shows that reductions in CO<sub>2</sub> emissions are perfectly possible. Between 2007 and 2016 CO<sub>2</sub> emissions per Maersk container decreased by 42%, the goal being that the reduction should be larger and reach 60% by 2020 (maerskline.com). Maersk Line's CO<sub>2</sub> reduction initiatives also include the commercial aspects, as many customers plan to reduce their CO<sub>2</sub> footprints, and firms like BMW, AkzoNobel and Huawei have concluded carbon pacts with Maersk Line. Maersk Line has reached these CO<sub>2</sub> reductions by, among other things, slow steaming, route planning, investments in new vessels and components, traffic optimization, and retrofitting existing vessels. However, the effects of these measures are gradually coming smaller.

Maersk Line's fleet mostly consists of container vessels, a type of ship for which investments in CO<sub>2</sub> reductions have higher yields than for many other types. Container vessels can comply with the EEDI's requirements more easily than many other types.

Maersk Line supports international rules regarding CO<sub>2</sub> reductions in shipping, as does the Danish branch association, Danish Shipping. Danish shipowners together have reduced their CO<sub>2</sub> emissions by an average of 27% a year since 2008, a figure adjusted for fleet size<sup>xiv</sup>.

## 8. The basis of CO<sub>2</sub> reductions – the maritime shipping market

The demand for sea transport grew steadily for many years, but it seems that its growth is stabilizing at a level that will remain low for a very long period. For the last two or three years there has been overcapacity in the shipping market and sharp competition: too many ships are squeezing profit margins and causing huge losses to many shipowners. Very few new ships are being built, and the major yards in Asia have been restructured and some closed down.

Due to overcapacity in the market, shipowners have started to scrap vessels earlier than normal. The lifetime of a vessel was considered to be 25-30 years, but at the present time ten-year-old vessels

are being scrapped and in some cases replaced by newer models. A newer fleet results in emissions reductions due to their greater efficiency.

Three parties are playing a part in the operation of ship transport:

- **Shipowners.** Owners and investors in ships. There are approximately ten very large ship owners, many of them based in Europe. The market is complex, and there are also a number of SME's with small fleets.
- **Charterers.** Shipping companies that rent and operate a vessel to deliver a cargo.
- **Technical managers.** The shipping company may use an external company for the technical management of the ship.

This division of roles provides fewer incentives for shipowners to invest in CO<sub>2</sub> reducing equipment in vessels used by charterers, who will benefit from lower fuel costs.

## 9. Acknowledgements

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## 10. References

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- <sup>iv</sup> Maersk Line information about its Triple E series.
- <sup>v</sup> "Third IMO Greenhouse Gas study 2014", IMO.
- <sup>vi</sup> "CO<sub>2</sub> Emissions from International Shipping", UMAS 2016.
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- <sup>viii</sup> "Global Marine Fuel Trends 2030", Lloyd's Register 2017.
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- <sup>xii</sup> [www.sea-Ing.org](http://www.sea-Ing.org)
- <sup>xiii</sup> Resolution MEPC 245(66), IMO.
- <sup>xiv</sup> [www.danishshipping.dk](http://www.danishshipping.dk)