Targeting the Environmental Sustainability of European Shipping

The Need for Innovation in Policy and Technology

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EPSD – European Panel of Sustainable Development

Foreword

At their Summit meeting in Gothenburg in June 2001, Europe's heads of state and government reached agreement on a European strategy for sustainable development. The social and economic dimensions of the Lisbon strategy were complemented by an environmental dimension. Thus, the Gothenburg Summit represents a breakthrough for sustainable development in the European Union (EU). The University of Gothenburg and Chalmers University of Technology made a commitment to serve, through the joint Centre for Environment and Sustainability (GMV), as a hub for research and scientific follow up of the EU sustainable development strategy. In order to fulfill this commitment, the two universities have established a European Panel for Sustainable Development (EPSD), together with Lund University. In addition, individual members from other universities and research institutes contribute to the work of the Panel. The Centre for Environment and Sustainability (GMV) in Gothenburg is the lead organization in the EPSD.

The first report produced by the Panel in 2004 was "From Here to Sustainability – Is the Lisbon/Gothenburg Agenda Delivering?" This was put forward as an independent contribution from academics to the mid-term review of the Lisbon strategy for growth, competitiveness and jobs. The second report "Make the Kok-report sustainable" was produced by the EPSD as a reflection on, and a response to, the mid-term review on the Lisbon strategy chaired by the former Prime Minister of the Netherlands, Wim Kok. The third report "Towards a Smart Growth Strategy for Sustainable Development" aimed to contribute to the re-launch of the EU sustainable development strategy. It contained a critical assessment of "A Platform for Action", the proposal for an updated strategy put forward by the European Commission. The fourth report "TAKING CHILDREN SERIOUSLY – How the EU can Invest in Early Childhood Education for a Sustainable Future" presented research on children's interest and ability to understand questions on the social, economic and environmental dimensions of sustainable development.

The present report "Targeting the Environmental Sustainability of European Shipping: The Need for Innovation in Policy and Technology" has emerged from a background survey with the aim of mapping what is being done on sustainable shipping within the European Union. A wide scope of strategic EU policy sectors and documents, including existing directives, legislation and regulations on shipping were scrutinized to describe the actual knowledge framework. The background study defines areas where new research could contribute in closing knowledge gaps, and gives a compilation of directives and policy documents concerning sustainable shipping in a European perspective. Based on a definition of sustainable shipping that include all three pillars of sustainable development, the present report presents a holistic view and strategies for achieving a sustainable shipping industry. The report provides scientifically based knowledge of various aspects that affect sustainability at sea, such as particles, greenhouse gases, ship wrecks, ship recycling, and intermodality, as well as a comprehensive overview and updates on regulations. These various areas are presented as separate chapters and solid recommendations are presented on future actions (on EU and international level) to make the shipping industry in Europe a sustainable business.

The main author of the report was Prof. Kevin Cullinane, Edinburgh Napier University, UK. The separate chapters in the report were written by Lars Barregård, University of Gothenburg, Erik Fridell, Hulda Winnes, IVL Swedish Environmental Research Institute (Particle emission from ships); Hannes Johnson [1] , Chalmers University of Technology (GHG Emissions and the Energy Efficiency Gap in Shipping); Peter Domini, Stena Metall (Ship Recycling: A Global Issue); Lars Barregård, University of Gothenburg (The Health Risks Associated with the Ship Breaking Industry); Ida-Maja Hassellöv, Chalmers University of Technology (Potentially Polluting Shipwrecks); Abhinayan Basu Bal, University of Gothenburg (Sustainable Intermodal Transport with Short Sea Shipping in the EU);

A number of researchers and knowledgeable persons have constituted a reference group and further contributed to the report: Katarina Gårdfeldt, Maria Svane, Dan Strömberg, and Jonas Norrman, GMV, Gothenburg; Karin Andersson, Björn Södahl, Josefin Borg, and Oliver Lindqvist, Chalmers University of Technology; Lars Göran Malmberg, Johan Boman, Johan Woxenius, and Mattias Hallquist, University of Gothenburg, Christer Forsgren, Stena Metall; Anders Carlberg, Vgregion; Carl Carlsson, Swedish Shipowners Association, and Axel Wenblad, Former GD National Board of Fisheries.

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The report has been endorsed by the EPSD.

Bo Samuelsson
Chairman of EPSD

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1 Introduction and Overview

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1.1 Introduction

As consumers in Europe, we all take for granted the vast array of items for sale in our shops. Much of what is on offer are imports, sourced from a wide range of exporting nations across the world. Further back along the supply chain, countries exporting to Europe may need to import raw materials and other inputs to the production process (e.g. iron ore and coking coal for steel production, fertilizer for crops, oil for heating and fuel etc). Of course, international trade among all the nations and regions of the world is nothing new. What is perhaps less well understood is that over 90% of the volume of world trade is carried in ships. Without ships, therefore, the transport of raw materials and the import/export of affordable food and manufactured goods simply would not happen. As Erling Naess, the Norwegian shipping magnate is famously quoted as saying "God must have been a shipowner. He placed the raw materials far from where they were needed and covered two-thirds of the earth with water."

As can be inferred from the correlation between the curves shown in Figure 1, the shipping industry not only facilitates international trade and the effective and efficient operation of the global supply chain network, it also plays a fundamental and pivotal role in the world economy.

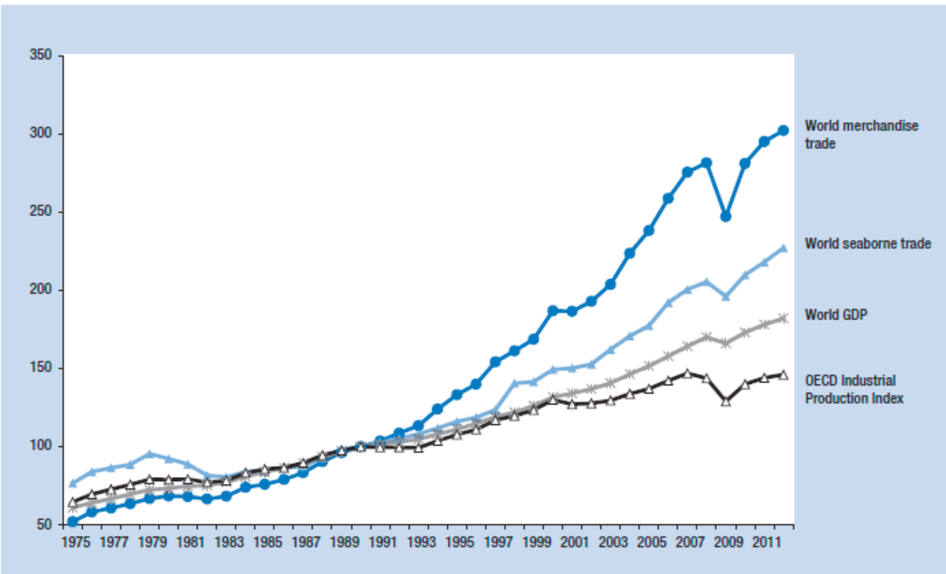
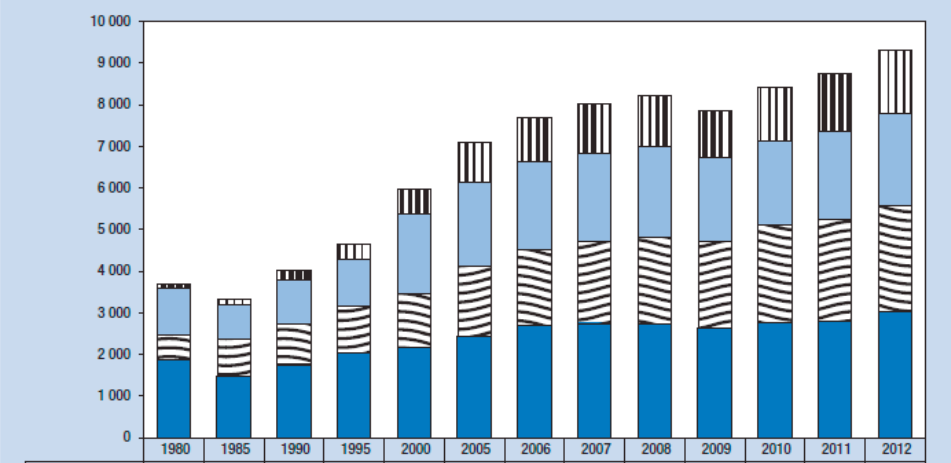


Figure 1: The relationship between the OECD Industrial Production Index and indices for world GDP, world merchandise trade and world seaborne trade (1990 = 100).
Source: UNCTAD (2012)

Over time, the shipping industry has continuously developed to become more sophisticated, efficient and effective and has been instrumental in the globalization of production and consumption. The advent of ever-larger container ships, together with the development of intermodal supply chains have led to a continuous and general decline in the price payable for shipping services. This has supported the trend towards the globalization of production and consumption, with all of these factors combining to contribute to a significant increase in demand for shipping services since the mid-1990s. Indeed, as shown in Figure 2, the growth in seaborne trade has averaged 4% per annum since the 1970s and cargoes now regularly move between about 3,000 commercial ports around the globe, mainly on the major trade lanes portrayed in Figure 3.



	1980	1985	1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012
Container	102	152	234	371	598	969	1 076	1 193	1 249	1 127	1 275	1 385	1 498
Other dry cargo	1 123	819	1 031	1 125	1 928	2 009	2 112	2 141	2 173	2 004	2 027	2 090	2 219
Five major bulks	608	900	988	1 105	1 295	1 709	1 814	1 953	2 065	2 085	2 335	2 477	2 547
Oil and gas	1 871	1 459	1 755	2 050	2 163	2 422	2 698	2 747	2 742	2 642	2 772	2 796	3 033

Figure 2: International seaborne trade by cargo type (millions of tons loaded).
Source: UNCTAD (2012)

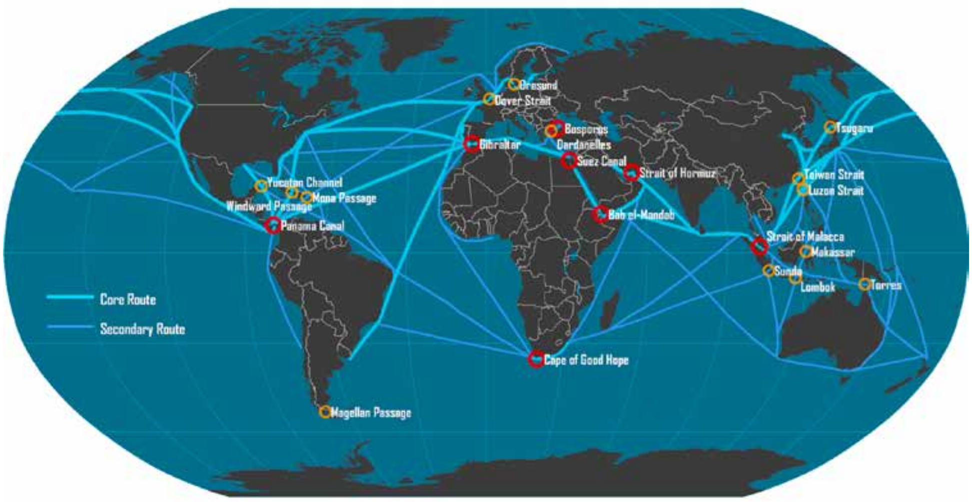


Figure 3: The world's major shipping lanes.
Source: Rodrigue et al (2013)

1.2 The maritime sector in Europe

Europe is an important origin and destination for shipping movements, connected as it is to two of the three most important global shipping routes – Europe-Asia and Transatlantic. As shown in Figure 4, although Asia leads the world in its shares of both goods loaded and unloaded, Europe is an important contributor to global shipping movements; accounting for 18% of all goods loaded and 23% of all goods unloaded.

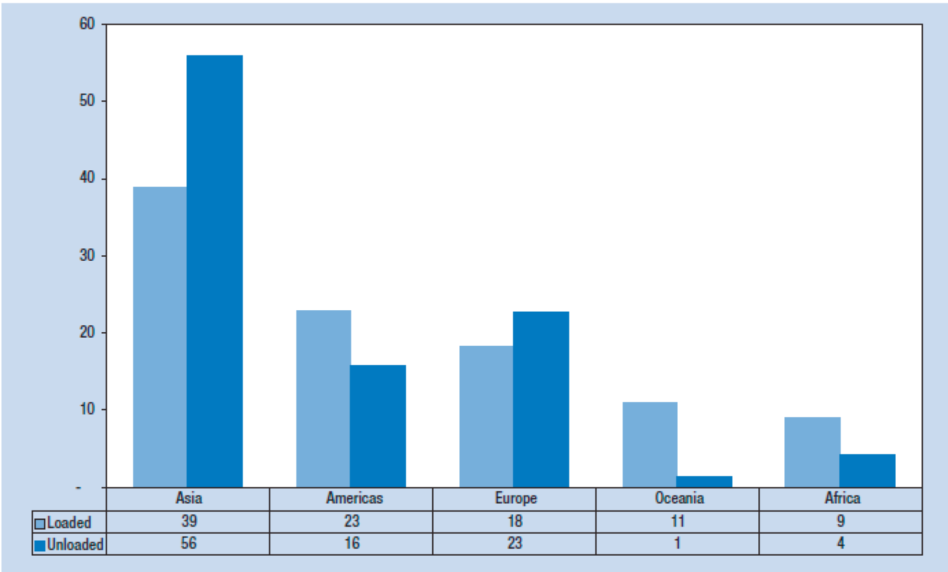


Figure 4: World seaborne trade by region in 2011 (percentage share in world tonnage).
Source: UNCTAD (2012)

Within Europe itself, it is estimated that approximately 4.78 million people (i.e. 2.25% of total European employment) are directly employed in maritime-related activities. Figure 5 shows how these jobs are distributed geographically across Europe, and the percentage of the workforce this number represents in each of the main maritime countries. The total number of maritime-related jobs includes a quite significant share of shipboard personnel, with Europe providing 143,967 officers and 110,152 ratings, sourced from each of the EU member states and Norway as shown in Figure 6. However, the shipping and associated maritime industries are not confined simply to what happens on ships at sea. Indeed, they encompass a wide range of other activities and jobs. In order of numbers employed, the main maritime sectors within Europe are coastal tourism, national navies, marine equipment, shipping, seaports and shipbuilding.

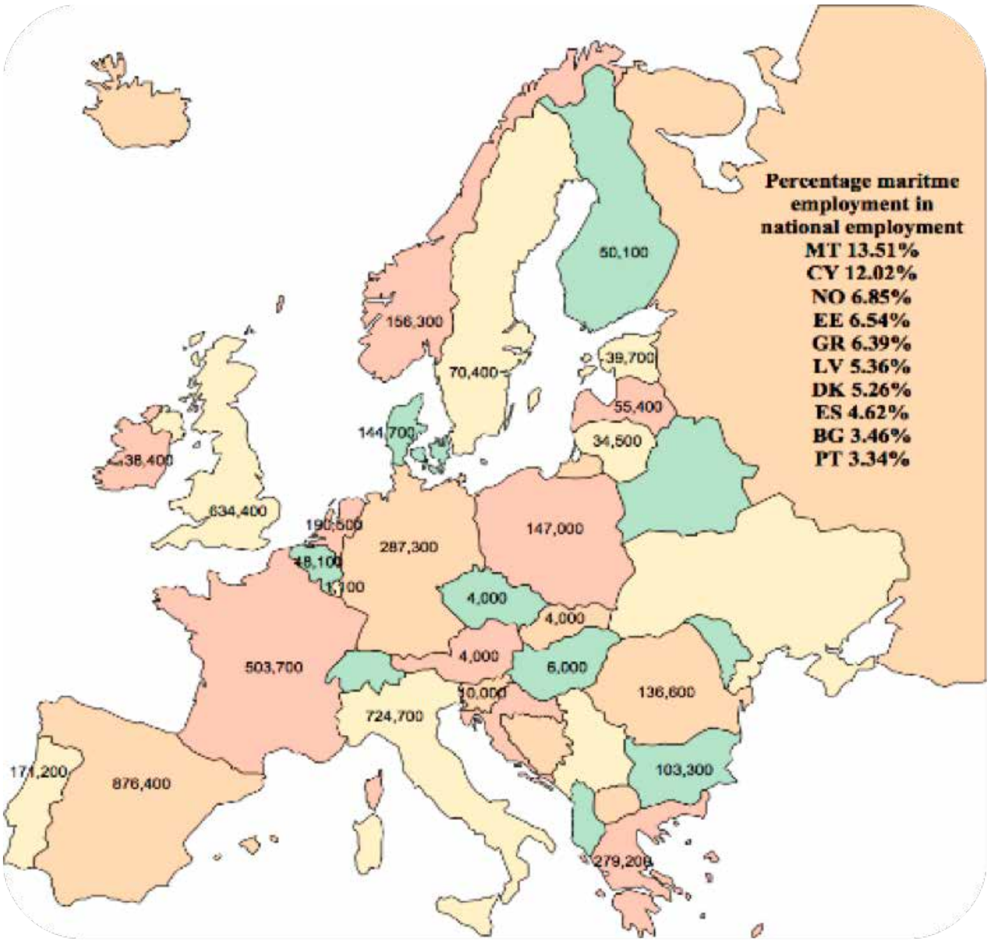


Figure 5: Employment in all maritime sectors in the EU and Norway and percentage of the total workforce in 2009.
Source: European Commission (2009)

From a business perspective, Europe's shipping and associated maritime industries enjoy one of the strongest positions in the world. For example, European shipowners control almost 40% of the world fleet in terms of tonnage, a highly specialised shipbuilding sector is a world leader in terms of turnover and innovation, dredging companies have an 80% market share of the global market and European companies dominate the emerging market for offshore renewable energy. The European maritime cluster, as conceptually illustrated in Figure 7, comprises a number of significant companies and organizations: Maersk Line, MSC and CMA/CGM are the world's largest container shipping companies; Rotterdam, Antwerp and Hamburg are three of the world's busiest ports; HSH Nordbank, RBS, Nordea and DNB are some of the world's biggest shipping banks; Lloyds Register is the world's oldest classification society and DNV GL is the world's largest; Clarksons, RS Platou, SSY and BRS are among the world's leading shipbrokers and; London is home to both the International Maritime Organisation (IMO) and the Baltic Exchange.

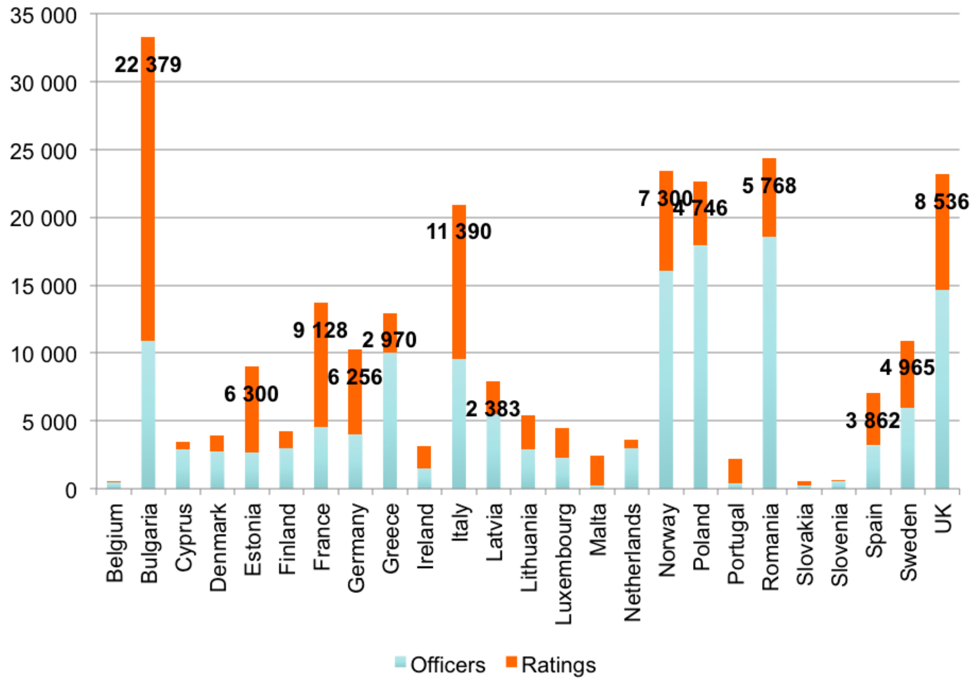


Figure 6: Active seafarers in EU member states and Norway in 2010. *Source: Theotakas et al (2013) as derived from BIMCO/ISF (2010)*

Figure 7: Conceptual representation of the European maritime cluster. *Source: derived from Theotakas et al (2013)*

The direct production value of the overall maritime cluster in the EU and Norway in 2009 amounted to €450 billion, consisting of 58% intermediate purchases and 42% added value. Thus, the direct added value of the European maritime cluster amounts to approximately €186.8 billion, equating to a 1.65% share of the total European GDP and implying an average added value per person employed of € 39,000. Figure 8 shows the geographical distribution of this added value across the EU and Norway. Taking into account indirect and induced effects through the workings of an economic multiplier yields a further added value of €110 million associated with the activities of the maritime cluster. In order of added value and production value the largest sectors in Europe's maritime cluster are coastal tourism, followed by shipping, seaports, marine equipment, national navies and shipbuilding. Figure 9 shows the distribution of the total added value accruing from the European maritime cluster across its various constituent sectors.

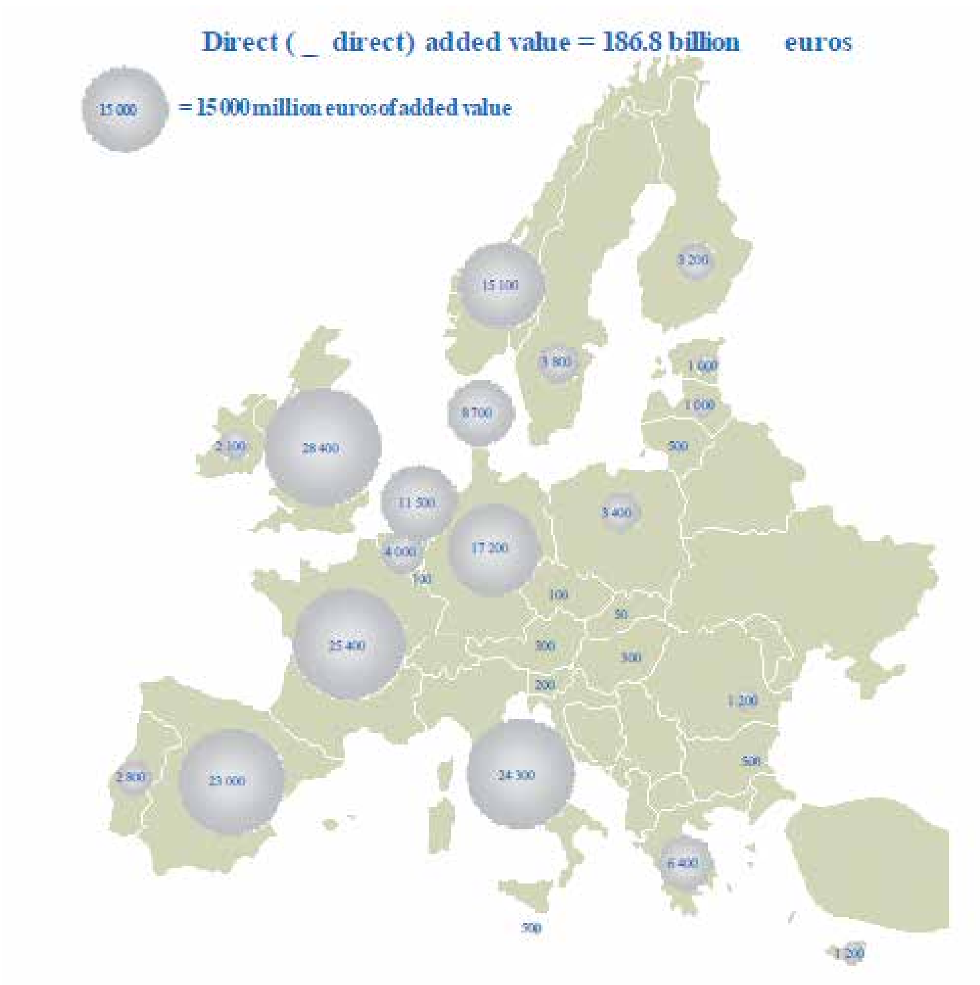


Figure 8: Added value in all maritime sectors in the EU and Norway in 2009. *Source: European Commission (2009)*

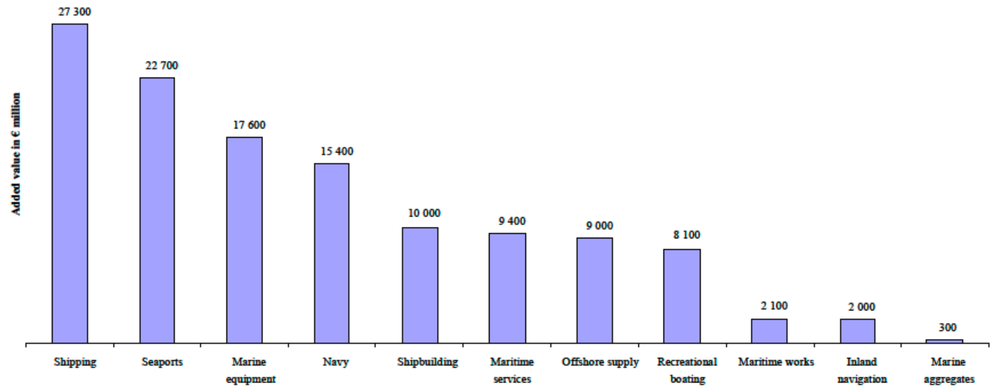


Figure 9: Added value in the European maritime sector by industry (all areas) in 2009.
Source: European Commission (2009)

1.3 Shipping and the Environment

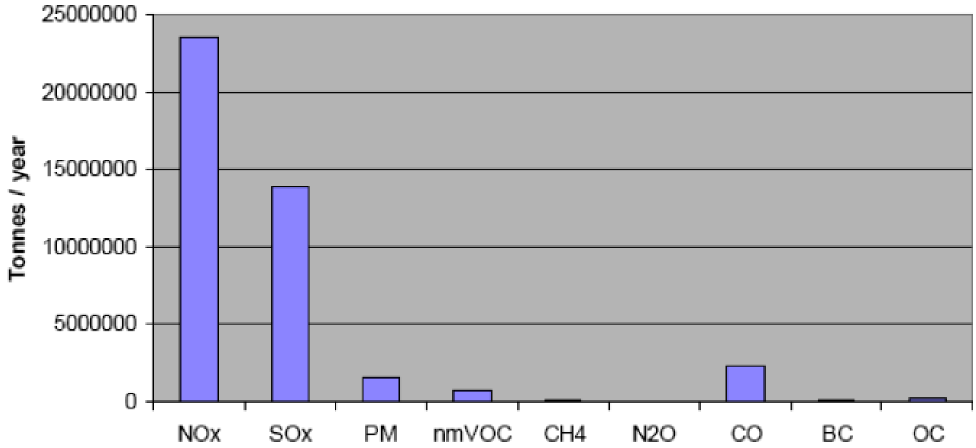
1.3.1 Some Basics

The significant growth in shipping that has taken place over the past two decades has occurred without too much scrutiny of its environmental impact. This is partly due to the international nature of the industry – meaning that regulations are difficult to agree and to enforce – and partly because most of the work of ships takes place well away from centres of population (i.e. at sea) and, therefore, is not so immediately obvious or open to public scrutiny.

The vast majority (95%) of the world's shipping fleet runs on diesel (Deniz *et al*, 2010). Diesel used in ships (usually referred to as bunker oil) is, however, different from that used in road vehicles in that it is of lower quality[1]. Bunker fuel (nicknamed Dirty Fuel) is a waste product of the standard oil refining process and is a cross between a solid and a liquid that is too thick for road vehicles – it is literally 'the bottom of the barrel'. Because it is regarded as virtually a by-product in the oil refining business, it is very cheap compared to normal diesel.

1.3.2 Air Pollution

Even the most modern marine engines produce higher emissions per power output than regulated on-road diesel engines (Corbett and Farrell, 2002). Because of the low quality of the bunker fuel used in ships, there are a range of pollutants which are of more concern in relation to the shipping industry than they are in other modes of transport and of greater immediate concern than the CO_2 produced by the industry. These include Oxides of Sulphur (SOx), Oxides of Nitrogen (NO_X), Volatile Organic Compounds (VOCs) and Particulate Matter (PM).



Figur 10: Estimates of Polluting Emissions from Shipping.
Source: derived from data contained in Buhaug et al. (2009)

Ships produce emissions whilst at sea, whilst they are manoeuvring into and out of ports and whilst they are berthed. At sea, the main concern is with emissions of gases that can harm the environment (and those which may harm the health of personnel working on board ship). At closer proximity to ports, however, the situation changes and concern focuses on the quality of the water and the impact of the emissions on people's health and wellbeing in and around the port. Whilst in a port, ships contribute a substantial amount of emissions to the local environment. Around 55–77% of total emissions in port regions can be attributed to ships (Lowles, 1998; Hulskotte and Gon, 2010). Even when they are in 'hotelling' mode (i.e. when they are stationary), ships typically leave their engines running in order to be able to carry out other functions necessary on the ship (such as maintenance and heating). Ship emissions at berth can be three to five times higher than when they are cruising at sea and are the fundamental determinant of the concentration of exhaust emissions in ports (Deniz et al., 2010; Tzannatos, 2010).

1.3.3 CO2 Emissions

The Kyoto Protocol, adopted in 1997 and brought into force in 2005, set out legally binding commitments for the reduction of greenhouse gases in industrialised countries. However, because of the difficulties in attributing emissions from shipping and aviation to specific countries, these two industries were omitted from the Protocol. Instead, Article 2.2 of the Kyoto Protocol calls on Annex I countries[2] to "pursue limitation or reduction of emissions of greenhouse gases not controlled by the Montreal Protocol from aviation and marine bunker fuels, working through the International Civil Aviation Organization and the International Maritime Organization, respectively."

Since the mid-2000s, the worldwide focus on global CO2 emissions has highlighted the importance of analysing shipping emissions. With ships often quoted as carrying over 90% of world trade by volume (e.g. Mitropoulos, 2010 p.5; ECSA/ICS, 2008 p.2), the industry's greenhouse gas emissions have increasingly become the subject of public attention (UNCTAD, 2009). The issue of greenhouse gas emissions from shipping was, for example, a specific item on the agenda for consideration and debate at the United Nations Climate Change Conference in Copenhagen (COP 15) in December 2009 (UNFCCC, 2010).

The Intergovernmental Panel on Climate Change (IPCC) lists 27 substances as greenhouse gases (IPCC, 2000). The six main ones are: Carbon dioxide (CO_2 – by far the most abundant greenhouse gas), Methane (CH_4), Nitrous Oxide (N_2O), Hydro fluorocarbons (HFCs), Per fluorocarbons (PFCs) and Sulphur Hexafluoride (SF_6). The emission of these gases by the shipping industry (as with other modes of freight transport) is highly correlated to the amount of fuel consumed. However, in the shipping industry, due to international inconsistencies in auditing methods, even the seemingly simple task of calculating fuel consumed is not easy.

According to bottom-up estimates of fuel consumption, international shipping accounts for between 1.6% and 4.1% of CO2 from total worldwide fuel consumption, or 943.5m tonnes of CO2 (Psaraftis and Kontovas, 2009). Marintek (2008) similarly estimated 954m tonnes, divided between 111m tonnes for domestic shipping and 843m tonnes for international shipping. This equates to approximately the same level of national CO2 emissions produced by Germany (Davidson and Faber, 2009).

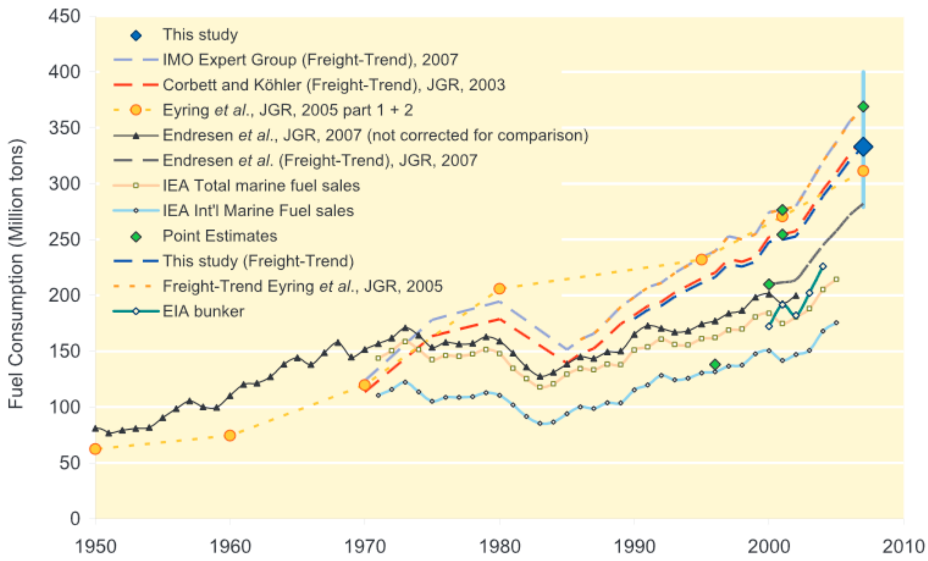


Figure 11: Estimates of World Fleet Fuel Consumption. Note: The blue diamond shows the IMO consensus estimate (333 Mton) and the whiskers the high (400 Mton) and low (279 Mton) bound estimates
Source: Buhaug et al (2009)

The IMO uses the figure of 2.7% as being international shipping's share of global CO2 emissions (in both percentage and absolute terms, considerably higher than the 1.9% share attributed to international aviation), with a further 0.6% contributed by the world's domestic shipping and fishing industries (Buhaug et al, 2009). Interestingly, shipping has attracted only a fraction of the attention of aviation in terms of negative press coverage and public outcry (Olsthoorn, 2001; Upham, 2003; Mayor and Tol, 2007; Bows and Anderson, 2007).

As implied in the introduction, the volume of trade carried by sea must be borne in mind when discussing emissions. According to the IMO (2011), more than 90% of global trade in volume is carried by sea. Although there have been minor variations around this figure, with globalisation continuing unabated, the proportion is likely to increase. Stopford (2010) has suggested that by 2060 the volume of goods that will be carried by sea could increase to 23 billion tons and that if this did prove to be the case, the carbon footprint of shipping would increase by 300% if no corrective measures are taken. However, the fact remains that in terms of volume of CO_2 emissions per unit of activity, as shown in Figure 12, shipping remains much less damaging than other standard modes of freight transport.

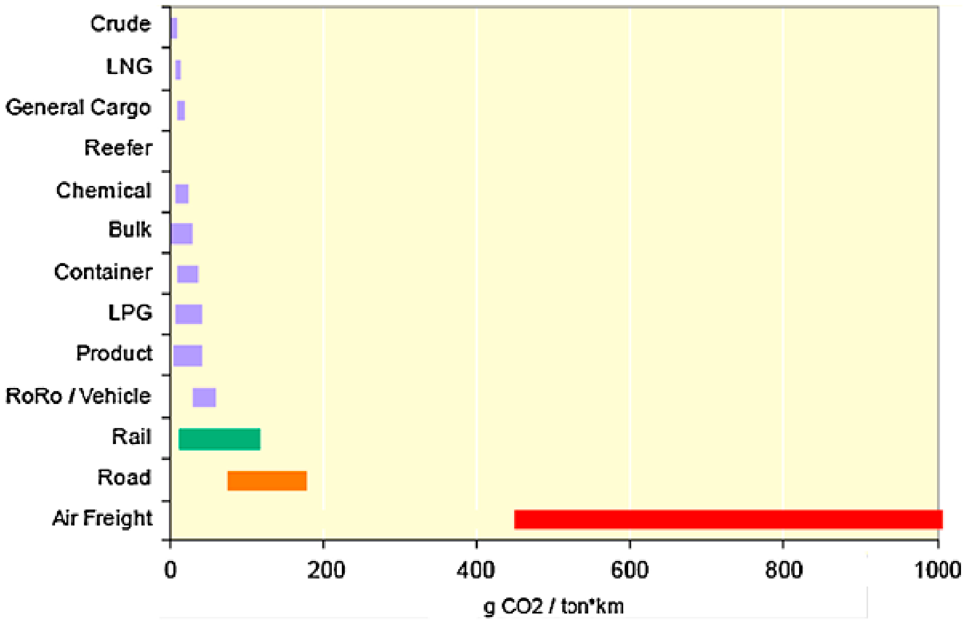


Figure 12: Typical range of ship CO_2 efficiencies compared to rail, road and airfreight
Source: Buhaug et al (2009)

1.3.4 Other Issues

There are numerous other aspects pertaining to ship operations and the wider workings of the shipping industry which give rise to environmental concerns. Many of these aspects have been, and continue to be, addressed by policy makers at global, regional and national level. The IMO has been pivotal in establishing an international regulatory regime for shipping. For matters relating to the environment, this has largely, but not exclusively, been achieved through the provisions of its International Convention for the Prevention of Pollution from Ships, more commonly simply referred to as 'The MARPOL Convention'. Originally adopted in 1973, it was substantially revised in 1978 following a spate of serious tanker accidents and ultimately entered into force in 1983. In 1997, a Protocol was adopted to amend the Convention and to add a new Annex VI which specifically addressed the issue of air emissions. This entered into force on 19 May 2005.

In broad terms, the various annexes of the MARPOL Convention seek to regulate aspects of shipping operations and accidents relating to oil pollution, noxious liquid cargoes, harmful or dangerous goods, sewage, garbage and, most recently, air emissions. Clearly, with changing aspirations over time and as operational practices within the shipping industry change, new environmental challenges emerge for the industry and there is always scope to revise, improve and supplement the existing regulatory framework. As such, at different times and in different parts of the world, criticisms concerning the shortcomings of the existing regulatory regime may abound.

At the present time, there are a number of environmental issues which are, in parallel, concentrating the minds of global, regional and national policy makers in seeking to enhance the regulatory framework within which the international shipping industry operates. Clearly, it would be impossible for a report such as this to comprehensively address such a voluminous and diverse subject matter. Instead, based on the recommendations of a previous report of the European Panel on Sustainable Development by Svensson (2012), the focus for this report rests with a few select, topical and, primarily, EU-relevant areas of concern for the environmental sustainability of the shipping industry. To this end, the two significantly important, and currently highly topical (even controversial), environmental issues of air pollution and CO_2 emissions have already been introduced within this overview section and are covered in much greater detail within Chapters 3 and 4 of this report. In addition, the report also includes detailed analyses of two further challenges to the wider environmental sustainability of the shipping industry, namely the issues of ship recycling (see Chapter 5) and potentially polluting shipwrecks (see Chapter 6), where the existing regulatory policy will not be found within the MARPOL Convention. In selecting these two areas of environmental concern for further detailed analysis and scrutiny, it should be pointed out that there is no intention to belittle the importance of addressing other areas of concern such as: ballast water and invasive species and organisms, noise and the impact both on marine life and in human communities, waste water, sediment transport etc.

In addition to the analysis of environmental problems or challenges that are faced by the shipping industry, it is also important to overcome any barriers to the successful implementation of potential solutions or beneficial practices. In this respect, the final scientific input to this report relates to the issue of intermodality (see Chapter 7) and its potential to have a positive impact upon the environmental situation within the EU specifically, by diverting freight from land-based modes to waterborne modes for significant parts of their journeys. Of course, the environmental benefits of any intermodal freight movement which encompasses a waterborne leg will only materialise if measures which aim to minimise the environmental footprint of water-based modes have proven effective. As is shown all too clearly in Chapter 7, there are also a number of technological, operational and policy barriers which need to be overcome in order to ensure the maximum attractiveness of intermodal options that encompass the least environmentally damaging transport mode.

Emerging from the scientific inputs contained in Chapters 3–7, a set of recommendations for EU policy makers has been formulated and outlined in Chapter 2. Whilst recognising that the environmental sustainability of the shipping industry lies at the core of these recommendations, it is vitally important that in formulating relevant and appropriate policy the potential impact on the European maritime cluster and wider interests is evaluated and taken into account. Only then can the true socio-economic costs and benefits of proposed policy changes be comprehensively accounted for and a full understanding and acceptance gained of the trade-offs between intended improvements in environmental sustainability and potential adverse impacts on the regional economy.

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2 Policy recommendations

Given the proven importance of the European maritime cluster, it is important that policies for the improved environmental sustainability of the shipping industry are assessed and evaluated within the context of both social and economic sustainability.

2.1 Emissions of Sulphur dioxide, Nitrogen oxides and Particles from Ships

1. **The EU should consider the possibility of accelerating the process of an expansion of the already decided Emission Control Areas (ECAs), both in terms of area and the inclusion of NO_X.** The forthcoming more stringent regulation of sulphur emissions could be addressed in three major ways; low sulphur oils, fuels like LNG or CNG or by scrubber installations. The EU must be prepared for a situation, where scrubbers are a necessary compliment to low sulphur fuels. More independent research should be conducted on the potential environmental damage associated with the waste products (and their disposal) of the different scrubber and other abatement technologies. **The verification systems for scrubbers, proposed by IMO, need to be further promoted.**
2. **The EU should address further incentives for NO_X-reductions, including also the existing fleet.** One possibility could be to further investigate the possibility to implement a cap and trade system, or a refunded NO_X-fee system. Technology solutions are already available on the market for most types of ships, manifested by more than 500 installations world-wide. European companies are among the world leaders in this technology area.
3. Inhaled particles have been shown to be a major health problem for the European citizens, and probably there is a future need for specific particle abatement technologies, in spite of the benefits coming from SO_2 and NO_X abatement measures. **The EU should take initiatives to enhance knowledge about the complexity of the particle emission, covering number, mass and composition.** Black carbon (soot), trace metals and organics (PAHs) as well as secondary particle formation should specifically be considered. Relevant emission standards should be developed and implemented.
   Test installations of filter technologies have been made on a handful of ships, although support are still needed for technology development, mainly due to the challenges caused by the higher sulphur content in marine fuels, compared to road diesel engines. **The EU should support further technology development of marine particle filters, also considering the combination with "dry" SO_2-abatement methods, available for land-based combustion facilities.**
4. Accurate and efficient monitoring methods and strategies are vital for a successful surveillance of mandatory measures for emission reductions. **The EU ought to support further technological development of remote monitoring of exhaust gases and particles (from shore), as well as cost efficient continuous end of pipe measurements of SO_2 and NO_X, e.g. within programs like Horizon 2020, Life+, CIP and perhaps also Interregional funds.** The developed methodology should facilitate the evaluation of the compliance with various legislation initiatives.

5. **Detailed evaluation studies should be carried out, further investigating the linkage between the maritime emissions and major air pollution related health problems as well as difficulties in managing air quality limit values.** The results will be of great help in the process of evaluating decided measures, as well as for designing and implementing future incentives for e.g. NO_X and particle reductions.

2.2 GHG Emissions and the Energy Efficiency Gap in Shipping

6. There exists significant scope for greater energy efficiency within shipping. Although this energy gap could be filled relatively simply, there is transaction costs associated with implementing the range of possible measures for enhancing energy efficiency. **The EU should continue the efforts to identifying these transaction costs and implementing policies or actions for their reduction or elimination.** Example of possible measures could be implementation of instruments for monitoring, verification and certification of energy performance, and together with support to R&D, and measures to overcome the fragmentation of responsibilities and actions relating to energy use.
7. **In the absence of any truly effective IMO regulation of greenhouse gas emissions from ships, unilateral regulatory action within the EU should be considered.** Such action might take the form of implementing a cap-and-trade system for maritime transport emissions (including PM, SO_2 and NO_X as well as CO_2), an emissions tax with hypothecated revenues, a mandatory efficiency limit for ships in EU ports and a baseline and credit system based on an efficiency index. The potential for interactive effects of different policy options should be taken into account.
8. When compared to where the potential in energy efficiency really lies, the SEEMP is limited solely to ship-specific measures. In this respect, an introduction of **ISO 50001 for shipping companies, on a broader scale,** could provide a feasible way forward.

2.3 Ship Recycling: A Global Issue

9. In order to address the problem of European out-ranged ships being recycled on e.g. an Indian beach under uncontrolled forms, we propose the following idea: **The EU should investigate the feasibility of requiring a recycling insurance for ships entering EU waters. The insurance should cover the cost of recycling using a sustainable approach and the ship-owner can only make a claim against this insurance by scrapping the vessel at a facility which is approved by the insurance company.** If vessels entering EU waters do not fulfil this requirement, the cost of entering the port should be set at an exorbitantly high level in order to force ship-owners to comply with the regulations. Today's EU-regulations and other international conventions can easily be avoided by changing the registration of a ship prior to it being sent to the breaker's yard or beach.
10. **The EU and other international actors should consider their possibilities to help to create incentives for a more sustainable ship recycling in countries like India, Bangladesh and Pakistan.**

2.4 Potentially Polluting Shipwrecks

11. **The EU should support the establishment a European shipwreck database which is harmonized across member states so as to facilitate the input of data to risk assessment models.** Such a database could be the basis for developing a proactive approach and plan for the management of potentially polluting shipwrecks.
12. **A robust and objective risk assessment model needs to be developed and applied in order to prioritize which shipwrecks should be investigated further in situ and/or monitored and/or remediated.** Data from any in situ investigation, monitoring or remediation then needs to be fed back into the shipwreck database.
13. **Further research should be conducted about the effects of low concentrations of oil in the marine environment and the interactive effect of multiple stressors.** This knowledge should then be linked to the valuation of ecosystem services.

2.5 Sustainable Intermodal Transport with Short Sea Shipping in the EU

14. **The EU should support the knowledge-building as well as the development and implementation of practical solutions within the area of short sea shipping,** in order to e.g. shorten turnaround time in ports, increase efficiency of customs operations and administrative procedures, improve data and information systems and investigate harmonized rules for land and sea carriage of hazardous goods. Several of the EU programs could be utilised, such as Horizon 2020, Life+, CIP, Interreg, and so forth.
15. **The EU should continue and intensify efforts like the 'Blue Belt' and 'Blue Lane' concepts, as well as within more established initiatives such as the 'TEN-T' and 'Green Corridors' programmes.** There is a need to enhance the level of interoperability between sea and land-based modes and to increase the seamlessness of intermodal transport within the EU by promoting the deployment of appropriate technology and integrated information systems which minimise the cost, time and administrative difficulty associated with this mode of transport. Also efforts to strengthen the link with railway and inland waterway transport are vital.
16. **As part of the Europe 2020 Strategy, the implementation of strategic projects to address critical bottlenecks at border crossings and intermodal nodes (i.e., cities, ports and logistic platforms) should be pursued with greater vigour**
17. **Different economic aspects of/for increased short shipping ought to be examined thoroughly. The EU could take initiatives to launch studies in this important area, including the need for investments in new infrastructure, and aspects of port pricing.**
18. **Work should be made to explore the possibilities to develop a legally binding instrument on intermodal liability in the EU, either through the implementation of the UN's 'Rotterdam Rules' or through the development of the EU's own instrument, either supplemental to or independent of global regulations.**

3 Particle Emissions from Ships

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3.1 Particles from marine engines

The marine fuels and the large diesel engines normally installed on ships cause high concentrations of number and mass of particles in ship exhaust. The particle emissions from ships depend on both engine characteristics and fuel composition. The analysis of the contents of the particle samples from ship exhausts show that they consist mainly of elemental carbon, organic carbon, sulphates and ashes (e.g. Moldanová et al., 2012b). During sampling of particles, the exhaust is diluted prior to particle collection. This is done to mimic atmospheric conditions and contributes to a generation of secondary particles such as sulphates and nitrates. Depending on the sampling method, the content of the condensable fractions (mainly sulphates and organic compounds) therefore vary (Moldanová et al., 2009, Ristimäki et al., 2011). Black carbon emissions are less dependent on mesaurement technique as it is part of the solid fraction of particles.

Sulphates, ashes and parts of the organic carbon are related to the quality of the fuel which is burned; the heavy fuel oils that are commonly used in ships are highly viscous and contain a concentration of the sulphur and mineral contents that are found in the original crude oil. Heavy fuel oils often also have several tens of percent content of polycyclic aromatic hydrocarbons (PAH). Some PAH species survive the combustion process and initiate, and attach to, particles in the exhaust gases. Asphaltenes, large and complex hydrocarbon molecules, are also found in particle samples from exhausts after the combustion of unrefined fuel oils.

There is a strong connection between the sulphur content of fuel and the level of particles in ship exhausts. The presence of PAH species and certain minerals also influences particle formation during combustion. Engine and combustion properties that affect particle formation are related to the shape of the combustion chamber; in large cylinders there are local differences that may cause more or less complete combustion of the injected fuel (Heywood, 1988). Particle formation is also an effect of fuel injection pressure and timing; factors that typically influence the content of elemental carbon and organic carbon in exhaust particles.

A highly important and related parameter is engine load. More complete combustion occurs at high engine loads and the emission of black carbon per volume of consumed fuel decreases as the load increases. Fuel consumption increases cubically with ship speed. Still, the absolute emissions of BC (i.e. the emission factor for BC/Nautical Mile) increase from idling to around 50% load (Lack and Corbett, 2012). Sulphate is positively correlated to engine load, i.e. it contributes most to particle mass at high loads (Petzold et al., 2010).

The particle mass size distribution in exhausts from marine engines is often of bi-modal character with one mode at 0.06-0.5 µm and another at 7–10 µm (Lyyränen et al., 1999, Lyyränen et al., 2002, Fridell et al., 2008, Moldanová et al., 2009). This mass size distribution is different from the number size distribution. Typically, a mode where particle diameters are less than 100 nm dominate in number, and the particles in the coarse mode (diameters >2.5 µm) dominate in mass. The number concentration is an interesting quantity from a health perspective, as high concentrations of fine particulate matter have been found to be associated with elevated mortality rates and other health effects.

A few measurement studies have been conducted to establish emission factors for numbers of emitted particles. There is a convergence towards emission factors in the order of magnitude of $1*10^{16}$/kg fuel. Measurements, presented by Petzold et al. (2010), for a 4-stroke medium speed diesel engine burning heavy fuel oil show emission factors for total particle number between 1 and 4.5×10^{16}/kg fuel, with a positive correlation between emission factor and engine load. Measurements of concentrations in ship plumes have shown emission factors of the same order of magnitude but factors of 2–3 lower (Lack et al., 2009; Petzold et al., 2008; Murphy et al, 2009, Jonsson et al., 2011). Measurements reported by Agrawal et al. (2008, 2010) and Moldanová et al (2012a) show that the previously mentioned PAH emissions tend to be substantially higher at low engine load than at optimum load.

In addition to sulphur dioxide and particulate matter, nitrogen oxides (NO_X) are a major pollutant emitted by ships. Most of the emitted NO_X is formed in the high temperature environment in the cylinders of a marine engine from nitrogen and oxygen gas in the air. NO_X contributes to problems with eutrophication and acidification, as well as to health risks. The latter is brought about through both its contribution to high urban NO_2 concentrations and also through the formation of secondary particles.

Normally, NO_X emission levels are measured as mass of NO_X emitted per work produced by the engine, i.e. in g/kWh. The emission factor depends on the engine type, most significantly on the engine speed (with the highest emissions for slow speed engines) and on the type of fuel used, where emissions are normally higher for heavy fuel oil than for gasoil.

Today, shipping is a major sector when it comes to NO_X emissions and their corresponding deposition. In many countries in Europe, shipping is the most important source of deposited NO_X. Further, while other sectors such as road traffic, general industry, heating and electricity production are predicted to lower their emissions in the future due to more stringent emission regulations, the emissions from shipping are expected to increase as ship traffic increases (EEA, 2013).

3.2 Health risks

Significant health risks can be linked to the emission of particles from ships. Particulate matter (PM) air pollution is heterogeneous with respect to particle size, area, and number, and chemical composition. Ambient concentrations of PM are causally related to increased total mortality, and mortality in cardiovascular disease, respiratory disease, and cancer (Pope and Dockery, 2006; Brook et al, 2010; Pope et al, 2011). There are short term effects (increased mortality on days with high air pollution levels), as well as long term effects (effects of cumulative exposure over many years). Also morbidity: myocardial infarction, chronic obstructive pulmonary disease (COPD) and asthma are associated with particulate air pollution; in adults as well as in children, and children's lung growth is impaired (World Health Organisation, 2006; Brook et al, 2010; Eisner et al, 2010; Gauderman et al, 2005; Gowers 2012). In addition to these proven effects, there are strong suspicions that particulate air pollution also increases the risk of atherosclerosis, and when pregnant women are exposed, the risk of premature birth and low birth weight. Most scientific data are available for combustion-derived PM (e.g. road traffic exhaust and biomass smoke), but effects have been reported also for several other sources such as coarse PM from road traffic, Sahara sand dusts, and various occupational PM species.

Which PM properties are most important for health risks is not fully understood. Most epidemiological evidence is available for the mass concentration of fine particles ($PM_{2.5}$), but it is likely that particle surface area, particle size and chemical (elemental, organic) composition is important. There are fewer studies on effects in humans of coarse ($PM_{2.5-10}$) and ultrafine (<100 nm) particles, and the available data are too limited to permit a definitive conclusion on their health risks compared to those shown for $PM_{2.5}$ mass. The same is true for other PM metrics such as soot, EC (Elemental carbon), OC (Organic carbon), BC (Black carbon) or BS (Black smoke). Some data indicate that primary PM emissions imply a larger risk than secondary aerosols. The most commonly used exposure-response functions are based on long term mortality from ambient $PM_{2.5}$ levels in the US. Sometimes ER functions are used for other metrics as well.

There are no long term studies on health effects performed specifically on PM emissions from ships. Instead, such estimates have to be based on estimated population-weighted contributions of PM emissions to PM levels at residences; people living close to harbours or ship routes being more affected. These estimates are combined with exposure-response functions based on epidemiologic studies usually performed in areas not very affected by PM emissions from shipping.

Corbett et al. (2007) estimated the global contributions of ship emissions in 2002 to $PM_{2.5}$ concentrations to be below 0.1 µg/m3 in most populated areas, but 1–2 µg/m3 in some coastal areas. This was transformed into an estimated 64,000 premature deaths per year, predicted to increase to 91,000 by 2012. A Danish study indicates that, in Europe alone, the numbers of premature deaths due to ship emissions were about 50,000 in 2000 (Brandt et al, 2011) and Andersson et al. (2009) estimated ship emissions to contribute 5–10% of total PM emissions in Europe, and the number of premature deaths in Europe to be about 40,000 per year. These three estimates are for premature deaths only. As mentioned above, several other adverse health outcomes are caused by particulate air pollution. For some of these outcomes, crude exposure-response functions are available (Brandt 2011). PAHs in ship emissions contain several established lung carcinogens and must be assumed to contribute to lung cancer mortality. In summary PM emissions from shipping contributes substantially to mortality and morbidity in Europe.

3.3 Environmental risks

The environmental risks of particles can be linked to the particle transport of specific acidifying and eutrophying substances and the aesthetical pollution of cultural environments. Much debated is the contribution of particles to climate effects. Aerosol particles might have either a cooling or a warming effect; sulphate particles typically cools the troposphere as it reflects part of the incoming solar radiation and soot particles will instead absorb radiation and thereby trap heat in the atmosphere. A secondary effect of particles in the air is their role in cloud formation. Clouds form as water is condensed on particle surfaces. This effect has been estimated to contribute to significant cooling of the troposphere (Lee et al., 2006, Eyring et al. 2007, Lauer et al., 2007).

Adopting a short term perspective, therefore, the emissions from ships are considered to have a cooling effect on the climate, due to high emissions of sulphur dioxide which forms sulphate particles, as well as due to the cloud formation which follows. However, the substances that contribute to cooling have considerably shorter residence times in the atmosphere and the warming effects of CO_2 will be dominant over a longer perspective (Buhaug et al, 2009, Eyring et al., 2009).

Black carbon emissions in ship exhausts are currently much debated. Black carbon is a measure of the light absorption capacities of carbon in aerosol particles. Emissions of black carbon from diesel engines measured using BC (hereinafter referred to as "BC emissions") are high in certain operational modes, due to the combustion characteristics. The total contribution of ship emissions to atmospheric BC has been estimated to be 0.4 to 1.4% (Lauer et al., 2007). The regional differences in the importance of BC emissions and in specific emissions of BC in Arctic regions are debated, due to the effects of BC interaction with snow.

3.4 Regulations and abatement

In MARPOL Annex VI, Regulation 14 regulates the emission of sulphur oxides by limiting the allowed concentration of sulphur in fuel. The global limit is set to 3.5% wt sulphur in fuel, while stricter limits are in effect in emission control areas. Both the North Sea and the Baltic Sea are emission control areas (ECAs), with a current limit set to 1.0% wt sulphur in fuel. A tightening of this rule will take place in 2015, when the maximum allowed sulphur concentration in marine fuels is limited to 0.1% wt in ECAs (see Table 1). In the rest of the world there will be a limit of 0.5% by 2020 or possibly 2025.

Table 1: Maximum sulphur content of marine fuels regulated by MARPOL Annex VI

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Global	4.5	4.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	0.5
SECA	1.0	1.0	1.0	1.0	1.0	0.1	0.1	0.1	0.1	0.1	0.1

The fuel available with 0.1% S is typically *marine gas oil* and it is believed that the fuel used in SECA areas after 2015 will be mainly gas oil. Fuel with a sulphur content of 0.5% can be residual fuel that has been de-sulphurised or *marine diesel oil* which is a mixture between residual oil and distillates. However, there is a question over the availability of low sulphur fuel in 2020 when the regulation of 0.5% S is valid in the whole world. The solution may be the use of high sulphur heavy fuel oil in combination with SO_2 abatement.

The same IMO regulation also covers particle emissions but without stating any limits for the emissions. A low sulphur content of the fuel will reduce sulphate particle concentrations which can be a dominant part of the total particle mass.

The European Union regulates the sulphur content of marine fuels in the Directive 2012/33/EU, amending Council Directive 1999/32/EC. In addition to reinforcing the international regulations, the Directive places a 0.1% wt limit on sulphur content on marine fuel for ships at berth. This rule does not apply for ships in regular traffic with stops of less than two hours. It also limits the sulphur content of marine gas oils and marine diesel oils placed on the market to 0.1% wt and 1.5% wt respectively. Further, the directive limits the sulphur content for the fuel used in ferries in the EU to 1.5%.

The NO_X emission regulations for shipping must be considered as weak. For engines delivered before the year 2000 there are no NO_X regulations. These engines (sometimes denoted as Tier 0 engines) typically emit between 12 and 18 g NO_X/kWh at sea. For newer engines, there are emissions regulations decided by the IMO. For engines delivered between the years 2000 and 2012 (Tier I), the allowed emissions are 9.8-17 g/kWh, and for engines after 2012 (Tier II) 7.7-14.4 g/kWh. There is also a Tier III level of 2-3.4 g/kWh that will only be applied in special NO_X emission control areas. At the moment, the only such areas that have been decided upon are the coastlines of the USA and Canada. Tier III was meant to be applied for new engines from 2016 but has been postponed until 2021 as the result of a decision at the IMO's MEPC 65 meeting in 2013. These regulations can be compared directly to what is applied for other Diesel engines: for trucks in the EU, the Euro VI regulations, that are applicable from 2013, allow a maximum of 0.4 g NO_X/kWh; for non-road vehicles the limit is 0.4 g/kWh from 2014. In addition to the emission regulations, the air quality standards in Europe will have an impact on shipping. In many cities around Europe, the limits for NO_2 concentration are exceeded and in many cases emissions from shipping are a strong contributory factor. This may impose restrictions on shipping in the future.

3.5 Technical solutions

3.5.1 Fuel Change

The choice of fuel significantly influences the mass emissions of particles; high sulphur heavy fuel oils cause more emissions than distillate fuels, where sulphur and other fuel impurities have been removed. Sulphate is one of the components that contribute to the particle mass, but also organic components and ash residues are more abundant in particle samples from heavy fuel oil combustion (Lewtas, 2007). The same dependences on fuel type and sulphur content and particle number emissions are less obvious (Lack et al., 2011, Winnes and Fridell, 2009, Winnes et al., 2012).

3.5.2 After-treatment

Even though there are possibilities to reduce SO_X-emissions by using low sulphur fuel, because of the higher costs involved, these fuels are almost exclusively used in areas where this is made mandatory or on ships with special performance requirements.

Both the international and the European regulations accept emission abatement technologies on board ships that reduce the emission of SO_2 from the funnel to levels comparable to those achieved by the use of the stipulated fuel. The currently available techniques rely upon scrubber technology, either dry or wet (see below). Also, should one choose to install a scrubber in order to fulfil the regulatory requirements on SO_2 emissions, the scrubber will simultaneously reduce the particle emissions as well.

For smaller diesel engines in cars, trucks and off-road machinery, particle abatement is usually done with ***particulate filters***. In these filters the exhaust is led into a honeycomb structure and through narrow pores in the material in which the particulate matter is trapped. The cleaning efficiency of these devices is very high. However, as more and more particulate matter is trapped, the pores eventually become blocked. This leads to a lower exhaust flow and to a build-up of pressure over the filter. This will in turn lead to problems for the engine. In a car or a truck, the particulate matter is dominated by soot. When the filter becomes saturated it has to be regenerated and this is done by burning the trapped soot. This combustion can be achieved by temporarily increasing the exhaust temperature. The regeneration therefore means a certain fuel penalty. For marine engines, particle filters have not been used to a large extent. The use of filters in combination with heavy fuel oil will be very difficult due to the large particle emissions and the high ash content (ash cannot be combusted and must be physically removed from the filter). Different designs of particle filters result in varying efficiencies between filter types and different sensitivities to sulphur content. Further, filters of the size to fit marine engines would be a challenge to manufacture and are likely to turn out very expensive. Another option is to use ***Diesel Oxidation Catalysts*** (DOC) which are sometimes implemented in combination with particle filters. DOCs oxidize the soluble organic fraction of particles and also remove hydrocarbons and carbon monoxide. DOCs are sensitive to the sulphur content of the fuel.

A further possible solution could be the use of ***electro static precipitators*** (ESP) which charge the particles and then attracts them to metal plates with opposite charges. The way they function can be divided into the following steps: (1) charging of particles in the exhaust gases, (2) migration and collection of particles on the metal plates, (3) removing of particles into container and (4) removing of the collected particles. ESPs are well established as exhaust cleaning for thermal power plants (Shanthakumar. et al., 2008).

Cyclones use centrifugal force to remove large particles from exhausts. The cyclone efficiency for different sizes of particle depends on parameters such as design and inlet velocity, with the technology used mainly used as a first step for industrial applications in order to remove large particles (Shanthakumar S. et al., 2008).

After-treatment options for the reduction of SO_2 are mainly ***scrubbers*** of different design. Some scrubber designs have also proven very efficient in particle removal. There are a few technologies being discussed, but the only one for which there is sufficient data is wet scrubbing. Wet scrubbing to reduce SO_2 emissions is a well-established technique in land-based combustion plants. The basis is that the exhaust gas is brought into contact with water of a certain alkalinity and SO_2 is trapped and forms sulphate ions. The acidity of the water is reduced through the buffering capacity of the scrubber water.

Scrubbers for marine applications can be divided into open or seawater scrubbers and closed or freshwater scrubbers. The former utilises the natural alkalinity of sea water for the scrubbing and neutralisation process. The sea water is also treated before being returned to the sea. The emissions of SO_2 out from the scrubbers depend on the sulphur content of the fuel, the alkalinity of the seawater and the flows of exhaust and scrubber water. These systems have been demonstrated to reach a high reduction in SO_2 and particle emissions. There are certain criteria for the wash water that should be fulfilled before it is returned into the sea. The closed scrubber system uses freshwater with an added neutralising agent (normally caustic soda). These systems have been demonstrated to meet the emission criteria and the wash water criteria. In the future it is anticipated that combined systems will be used where seawater is used in open waters with high buffering capacity while closed loop operation can be used in ports and estuaries and in seas with brackish water.

As a consequence of the environmental concerns and doubts which exist surrounding the deployment of wet scrubbers, particularly in an open loop configuration, much recent interest has been seen in dry scrubber technology and commercial systems have been developed and are now marketed for ships. Dry scrubbers have been used in land-based industry since the 1970s and work on the basis that the sulphur oxides are dissolved with the help of calcium hydroxide granules inside a heated absorber (Lloyd's Register, 2012). Dry scrubbers operate at temperatures of between 240 and 450 degrees Celsius.

The ***Selective Catalytic Reduction*** (SCR) system is a commercial product that reduces NO_X. It is a catalytic exhaust treatment with an additional oxidation option to lower volatile organic compounds (VOCs) and carbon monoxide (CO) (Nikopoulou et al, 2013). Urea is injected into the hot exhaust gas and reacts with the NO_X content to produce harmless nitrogen (N_2) and water. The system requires space for deployment within the engine room, but the reduction rate of NO_X achieved is somewhere around 90–95%.

3.5.3 Combustion modifications

Other technologies that have been proven effective in reducing particle emissions are engine modifications such as ***slide valves*** for fuel injection ***and water in fuel emulsification***. Slide valves reduce emissions of particulate matter by approximately 25% and the emulsion of water in fuel results in approximately 30–50% reduction (Corbett et al., 2010). Another way makes use of the so-called ***common rail technique***. Common rail replaces camshafts with electronically controlled inlet valves and elevates fuel injection pressures. By this arrangement, it is possible to optimise the fuel injection with respect to time, compression and rate shaping during operation and facilitates keeping low emission levels during extreme loads of the engine (Goldsworthy, 2002).

Combustion modifications are also applied in order to reduce NO_X emission. A set of technologies where water is used together with fuel oil in the combustion can substantially reduce NO_X emissions. However, there is often a fuel penalty associated with these technologies. Further, exhaust gas recirculation (EGR) for marine systems are in a development state. EGR is however not compatible with the use of heavy fuel oils, and add-on technologies cleaning the exhausts before the EGR equipment are needed.

3.5.4 Particle abatement potential

The function of ***diesel oxidation catalysts, particle filters, cyclones, electrostatic precipitators*** and ***wet scrubbers***, and the required maximum sulphur concentration in the fuel when using these particle abatement technologies, are summarised in Table 2.

Table 2: Abatement technologies for particle: Fuel requirements, principle function and potential applicability in marine systems.

Abatement technology	Fuel requirements	Function	Obstacles for applicability for marine fuel
Diesel Oxidation Catalysts (DOC)	UNEP: <500ppm NREL: <350 ppm	Oxidation of soluble organic PM (SO_2 can be oxidized to SO_4 particles in DOC)	Too high S in marine fuel
Diesel Particulate Filters (DPF)	<50ppm S	Particles trapped in pores	Too high S and Ash in marine fuel
Flow Through Filter (FTF, less efficient and more permeable than DPF)	<500ppm S	Particles trapped in pores	Too high S and Ash in marine fuel
Cyclones	No	Centrifugal force removes large particles	*The technology is likely applicable for marine fuels*
Electro Static Precipitators (ESP)	No	Charging and collection of particles on plates	*The technology is likely applicable for marine fuels*
Wet scrubbers	No	Particles adhere to droplets and precipitates, form sludge	*The technology is proven applicable for marine fuels*

Source: United Nations Environmental Programme (UNEP), 2007; National Renewable Energy Laboratory (NREL), 2002; Shanthakumar S et al., 2008; Corbett et al., 2010.

The methods that have so far proven effective for marine applications are the wet scrubber technology, slide valves and the replacement of fuel for a water in fuel emulsion. Of those, wet scrubbers with an estimated cleaning potential of 75% of particle mass (Corbett et al., 2010), have proven the most efficient in removing particulate matter. DPF, DOC and FTF have the common characteristic of being sensitive to sulphur and ash content in the exhaust gas. However, the mass could be significantly reduced since the large particles, although few, represent a large share of the mass of particles. The use of ESPs is not limited by the high sulphur and ash content in the fuel, but will not remove the abundant number of fine particles. Here too, the mass could be significantly reduced since because large particles represent a large share of the mass of particles. However, the particle emissions from marine diesel engines are by number completely dominated by smaller particles which, in general terms, narrows the selection of efficient particle reduction technologies.

3.5.5 Cold Ironing

At berth, there is also the option to connect to shore-side electricity instead of running auxiliary machinery. This is referred to as 'cold ironing'. Since the health risks from particle emissions are most significant in populated areas, where more people are affected, the use of shore-side electricity, rather than auxiliary engines while at berth can have a significant impact on local air quality in port cities. Additionally, where the shore-side electricity is derived from renewable energy sources, there are also likely to be net environmental benefits.

3.6 Concluding remarks

Reducing the emissions of particles from ships will contribute to positive health effects and reduce climate warming black carbon emissions. Existing regulations will result in a fuel shift from HFO to MGO in ECAs, which will result in lower particle emission levels in these areas.

A sulphur content of 0.1% (wt) will still be higher than acceptable for diesel oxidation catalysts and particle filters. Wet scrubbers have so far proven to be the most efficient abatement technology for particle emissions from ships.

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4 GHG Emissions and the Energy Efficiency Gap in Shipping

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4.1 Introduction

The importance of shipping in today's increasingly globalized world can probably not be understated. The sector is a major facilitator of both intra-continental and international trade, with more than 80% of goods by volume transported by ship (UNCTAD, 2012). Due to economies of scale, better ports, more efficient cargo handling etc., the cost of freight is no longer a major issue when deciding where to produce or market goods (Stopford, 2009). The volume of merchandise trade has grown on average by 5% per annum for decades, which is 2% faster than the growth of the world economy (UNCTAD, 2013).

By lowering the costs associated with international trade, shipping is of particular importance to developing economies. Their share in world trade increased from 36% in 2007 to 42% in 2012, and now make up approximately half of global import growth (UNCTAD, 2013). Developing countries are also expanding their role in the shipping business itself. For example, more than 70% of all ships built in 2010 were built in China and the Republic of Korea (UNCTAD, 2011) and more than 70% of all ships are now flagged in a developing country (Kageson, 2011).

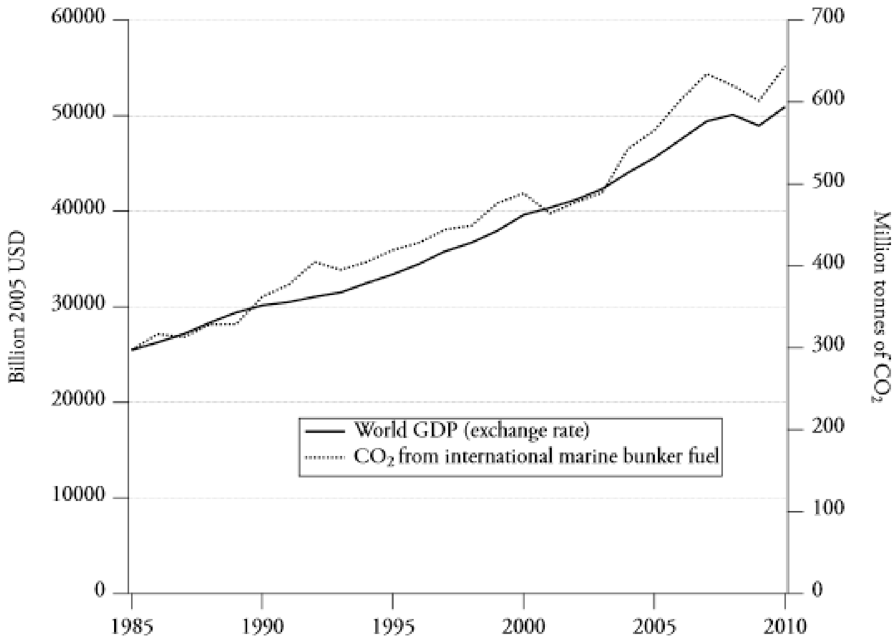

Figure 13: World GDP and CO2 Emissions from International Marine Bunker Fuel. *Source: IEA (2012)*

Exponential growth in the world economy has gone hand-in-hand with a similar rate of growth in the shipping sector. As shipping runs on fossil fuels, this has meant a corresponding exponential increase in CO_2 emissions, as illustrated in Figure 13. The effect of shipping's greenhouse gas (GHG) emissions in terms of total radiative forcing is rather complex. For example, it is positive through its emissions of CO_2, negative through its emissions of sulphur, and both positive and negative through its emissions of NO_X (Lund et al, 2012). Through the combination of the effects of these particular GHGs, on a net basis shipping has been assessed to make a negative contribution overall to radiative forcing (Eyring et al, 2010; Lund et al, 2012).

4.2 The Scale of the Problem

There are two main ways of determining the scale of GHG emissions from shipping: the `bottom-up' approach uses data on the technical composition and actual movements of the world fleet, or a `top-down' approach uses statistics on the amount of bunker fuel sold (see Miola et al (2011) for a literature review). Buhaug et al (2009) concluded that the latter approach produces results that are always lower than the former, and that the former method provides more accurate measures.

In the Second GHG study undertaken on behalf of the International Maritime Organisation (IMO), Buhaug et al (2009) apply the bottom-up approach by estimating the GHG emissions from shipping that are derived from: the exhaust gas of main engines, auxiliary engines and boilers; refrigerants from the storage of cargo and provisions; air-conditioning; ship scrapping and; cargo emissions due to leakage. Total CO_2 emissions from international and domestic shipping are estimated to lie within a range of roughly 870 to 1250 million tonnes per annum, representing something in the range of 2.7% to 3.6% of all CO2 emissions across all sources (Buhaug et al, 2009: p. 27).

The International Energy Agency estimated that the amount of CO_2 from international marine bunker sales attributed to developing (Non-Annex I) countries had risen in 2009 by 3.1% from 2007, but fell by 14.5% in developed (Annex I) countries, leading to a net reduction of 5.2% (IEA, 2012). In 2010, however, total emissions have rebounded past the levels pertaining prior to the global economic crisis (increasing 7% from 2009 to 2010). An overview of recent estimations is presented in Figure 14, which also reveals that the sales of bunkers have increased constantly in non-Annex I countries over the last decade, and have for years surpassed sales in Annex I countries.

As the world moves towards the middle of the twenty-first century, the small share of global CO_2 emissions which is attributable to shipping today is expected to grow substantially under a business-as-usual scenario. Buhaug et al (2009) estimate a 150% to 250% growth in shipping's CO_2 emissions by 2050, as it follows global growth in GDP. In total, this equates to approximately 1.5-2.5 GT CO_2 a year. Future scenarios for total global emissions vary widely, depending on the required certainty of projections with respect to temperature increases, and also with the assumed point in time at which the world reaches a peak in emissions. However, Meinshausen et al (2009) have shown how the probability of not exceeding a 2 degrees C warming lies in the range of 85% to 36% when emissions lie in the range from the equivalent[6] of 10 GT CO_2 per year to 36 GT CO_2 equivalent per year by the year 2050. Under the scenario with a high probability of not exceeding 2 degrees C, shipping could thus constitute 15–25% of the available global budget in 2050. It has also been suggested that CO_2 emissions for shipping could be even larger than total global emissions by 2050 in

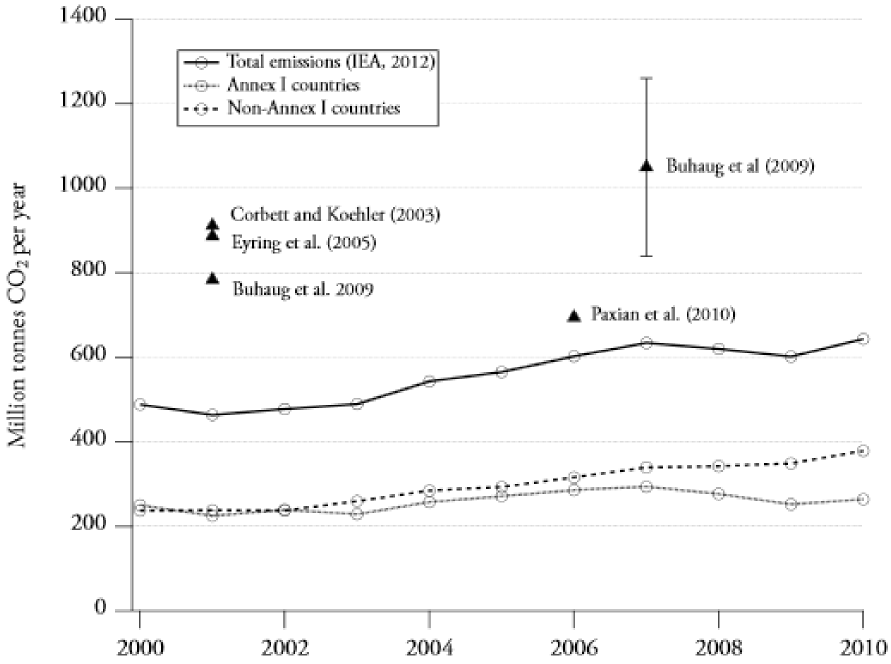

Figure 14: Different Estimates of CO2 Emissions from International Shipping. Note: Buhaug at al (2009) provided an upper and lower bound to their final estimate, which is depicted in this graph as an error bar.
Source: Developed by the author

scenarios "that have realistic peaking dates and the highest probability of not exceeding 2 degrees C" (Gilbert and Bows, 2012: p.614).

Efforts have been made to produce scenarios for future emissions from shipping, using a set of scenarios developed by the IPCC (e.g. Eyring et al, 2005; OPRF, 2008; Buhaug et al, 2009). Recognizing that economic growth (as represented by GDP) and the growth of international trade have historically been closely correlated, both Eyring et al (2005) and Buhaug et al (2009) used the development of economic growth from the different IPCC scenarios as the only input to their scenarios for shipping. OPRF (2008) took a different approach by utilising available projections of world energy consumption, population, etc., and treating the growth of various cargoes differently. For example, the growth in crop transportation is assessed in tandem with data from the United Nations Food and Agriculture Organization (UN FAO). For the growth of the container sector, they used the same historical relationship between GDP growth and demand for transportation. All in all, this different approach produces a demand for transport in terms of tonnes-miles per year that is *half* of what is estimated using simply the correlation between GDP and transport demand. To acknowledge the difference, in their analysis, Buhaug et al (2009) used both the mean values of the OPRF study and a GDP correlation approach. Low and high bounds were chosen that encapsulated the results of both studies.

4.3 Future Scenarios and Abatement Potential

The available projections thus produce Business-As-Usual scenarios; they do not include assumptions on switches in energy carriers or increases in energy efficiency. In order to understand the technical and economic potential of abating the projected level of CO_2 emissions, *marginal abatement cost* (MAC) curves have been developed. An example can be seen in Figure 15. On the horizontal axis, the abatement potential in tonnes of CO_2 for a number of measures are given, while on the vertical axis, the cost of each measure can be found. Figure 15 reveals the existence of a large potential for abatement at below zero cost. However, this could signal the presence of additional and unaccounted for transaction costs[8] associated with the measures that should add to MAC estimates. For this reason, the use of these curves to support policy decisions has been criticized (Kesicki and Strachan, 2011; Kesicki and Ekins, 2012).

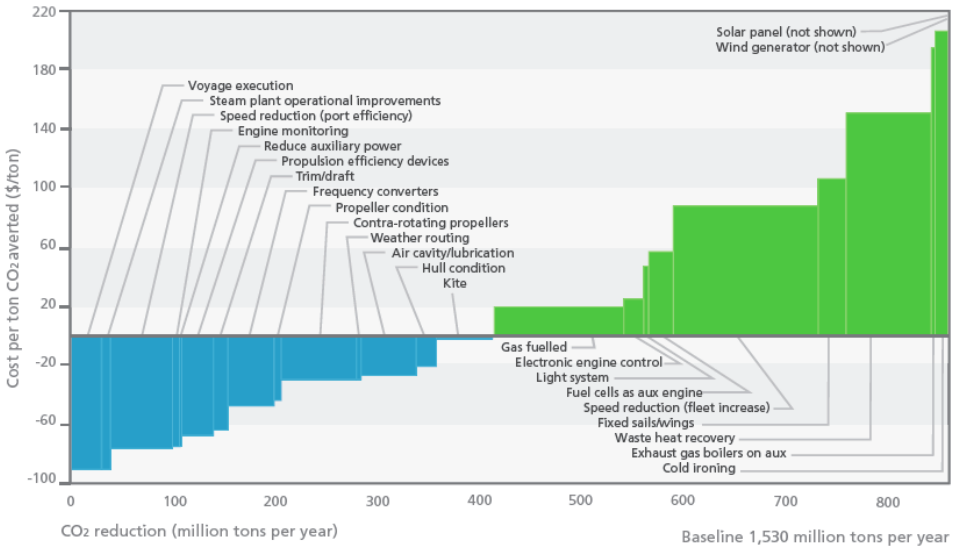

Figure 15: Marginal Abatement Cost Curves
Source: DNV (2010)

The potential for improvements in energy efficiency appears to be substantial. Indeed, Buhaug et al (2009) estimated that CO_2 efficiency in shipping could be increased by some 25–75%, of which the majority is due to measures that increase *energy* efficiency. However, the projections that have been made which have included abatement measures have shown that, even assuming a high cost of CO_2 (assuming such a cost is also imposed on ship emissions), the magnitude of measures thus made 'cost-efficient' would not lead to any reduction in the *total* emissions of the shipping industry (Buhaug et al, 2009; CE Delft, 2009; Eide et al, 2011). The anticipated future increased use of shipping will thus need to be accompanied by an even greater increase in efficiency if *total emissions* are to be reduced. This will be very difficult to achieve.

If the shipping sector is expected to institute reductions in *total* emissions, radical changes are necessary (Buhaug et al, 2009). These include '"an abrupt decoupling between seaborne trade and economic growth; very low global economic growth; extreme shortage of fossil energy; and, introduction of unexpected technologies"

(Buhaug et al, 2009: p. 149). The currently conceivable measures are simply insufficient to counter the expected growth of the sector (Buhaug et al, 2009; CE Delft, 2009; Eide et al, 2011). Bazari and Longva (2011) showed that, despite regulation recently adopted by the IMO, emissions will continue to rise. Eide et al (2011) constructed a model to project future CO_2 emissions from shipping, taking into account world fleet development and a range of measures. The analysis concludes that emissions could be reduced by 33% from a baseline scenario when implementing all measures that have a marginal cost below 0 USD. It was also found that stabilization at the present level of emissions is technically possible, but any significant total reductions are difficult to reach. In addition, the timing of global action on CO_2 emissions will also have significant consequences for the shipping sector. Gilbert and Bows (2012: p.614) have identified "a need for complete decarbonisation of the shipping sector by or soon after 2050", if action is delayed beyond this decade. It is interesting to contrast these scenarios for the shipping industry with the European Union's target of a 40–50% reduction in *total* emissions across all sectors by 2050 compared to 2005 (EC, 2011).

4.4 Measures for Improving Energy Efficiency in Shipping

The shipping industry is an energy intense industry in the sense that energy costs constitute a large portion of total operating costs. For a typical tanker, 50% of total operating costs are energy related[9]. Compared to other sectors, this is a very large ratio. Thollander and Ottosson (2010), for example, in their paper on energy management practices in Sweden, define energy intense production industries as those industries with energy costs above 5% and mostly between 5 and 20%.

Compared to other transportation modes, shipping is in general considered to be characterized by relatively high energy efficiency levels (Buhaug et al, 2009). In some sectors, however, such as short sea shipping, the efficiency of shipping as opposed to land-based transportation has been questioned, in particular with respect to SO_X and NO_X emissions per transportation work, but also when it comes to energy efficiency (Hjelle, 2010). Thus, although it is often said that shipping is the most energy efficient means of transportation, not only is this questionable under certain circumstances, contexts, but also rendered rather meaningless within the context of climate change; as noted above, what is important is a reduction in the *total* emissions of the sector, rather than solely in the emissions per unit of transportation work.

General energy conservation and efficiency have been of interest to policy-makers and researchers from a range of scientific backgrounds since the oil crises of the 1970s. Freight rates remained low throughout the 1970s and the immense surplus of tanker and bulk vessel capacities was particularly problematic (Chrzanowski, 1980, Bohme, 1983). The price of fuel rose considerably following the first crisis in 1973, and had risen from 10–20% of ship operating costs to over 50%, excluding capital and cargo handling costs (Buxton, 1985). It was the deepest recession for the maritime sector since the Great Depression (Bohme, 1984).

The short-term response was to reduce operating speeds, so slow-steaming became common, especially in the tanker sector (Artz, 1975). Significant research effort was invested in determining the optimal speed of ships and the associated energy savings that could be derived from minimizing idle time in port, i.e. by reducing speed, where possible, to arrive just in time before port operations start (Zubaly, 1975; Ronen, 1982). Researchers also studied the technical implications of slow-steaming. For example, Rein (1980) reviewed various means of increasing the efficiency of steam turbine engines at part load. The potential was high, ranging from 0.5 to 10%, because existing engines had not been designed for part loads.

Other improvements in operational practices, such as hull cleaning and other planned maintenance regimes, were enabled by advanced ship performance monitoring and analysis systems (Drinkwater, 1967; Reid, 1985). The potential for further improvements in energy efficiency was derived from all kinds of technical innovations; sails, Flettner rotors, waste heat recovery systems, frequency regulation of pumps and fans, contra-rotating propellers etc. were all being discussed and/or tested (Bertram, Saricks and Gregory II, 1983; Morisseau, 1985). In addition, better ships could be designed with new computer models of onboard energy systems (DeTolla and Fleming, 1984). However, the lack of equipment and processes onboard ships for measuring and analyzing performance hindered increased energy efficiency; a problem which apparently remains unresolved (Drinkwater, 1967; Reid, 1985; Leifsson et al, 2008; Petersen et al, 2011).

Soft factors were also heavily influential in undermining operational and technical measures. In consequence, the development of crew understanding, motivation, cooperation and participation were deemed to have the highest potential for saving fuel. While new types of organizational structures and roles were created in shipping companies to facilitate this, such as the role of the energy manager (Sweeney, 1980), it remained a challenge to convince shipping companies to increase energy efficiency as a way of cutting costs, rather than simply laying off crew (Bertram and Saricks, 1981).

Interest in energy efficiency waned when shipping markets improved and, more importantly, as oil prices fell and stayed low for decades. Today, fuel prices are again high and freight rates low. Moreover, there is another driver; energy efficiency forms a key element in the discussion to abate rising GHG emissions. Many recent reviews and reports on the potential for energy efficiency in shipping have been prompted, therefore, not by the commercial desire to save on energy costs, but by the policy discussions in the IMO and the EU within the context of GHG abatement. The actual measures discussed, however, are similar to those discussed in the 1970s and 80s.

The first IMO study of GHG emissions from shipping discussed operational, as well as technical, measures to reduce these emissions (Skjolsvik et al, 2000). In total, 1–40% improvement in CO_2 efficiency was possible due to operational energy efficiency measures. New ships could become 5–30% more energy efficient through technical measures, while existing ships could implement measures which would yield a 4–20% improvement in energy efficiency (Skjolsvik et al, 2000: p.14). The IMO's 2nd GHG report detailed more measures and assessed the total potential for increased CO_2 efficiency to range from 25–75%, of which the major share is due to increased energy efficiency (Buhaug et al, 2009). Table 3 shows the breakdown of estimates made by Buhaug et al (2009). The measures are not only technical changes to existing ships and new builds, but also operational measures are of great importance.

In a report commissioned by the European Commission, the list of measures was expanded to also include solar energy, waste heat recovery, a speed reduction of 20% and Flettner rotors (CE Delft, 2009: p.77). Faber et al (2011) studied the cost-effectiveness of eight groups of operational measures and 20 groups of technical measures. Since this represents the most complete assessment thus far undertaken, they are summarized together with abatement potential and cost in Tables 4 and 5.

Table 3: Measures for CO_2 Reduction

	Saving of CO_2/tonne-mile (%)	Combined (%)	Combined (%)
Design (New ships)			
Concept, speed and capability	2–50	10–50	
Hull and superstructure	2–20		
Power and propulsion systems	5–15		
Low-carbon fuels	5–15[a]		
Renewable energy	1–10		
Exhaust gas CO_2 reduction	0		25–75
Operation (all ships)			
Fleet management, logistics and incentives	5–50[b]	10–50	
Voyage optimization	1–10		
Energy management	1–10		

[a] Based on the use of Liquid Natural Gas (LNG).
[b] Including reduced operational speed.

Source: adapted from Buhaug et al (2009)

Table 4: Operational Measures: Potential Efficiency Gains and Costs.

Operational measures	Gross potential	Cost
Speed reduction	10% or 20%	See Faber et al. (2011, pp. 97-199)
Voyage optimization, reduced port time	0-10%	Not known
Bulbous bow	>10%	Not known
Optimization of ballast and trim	<5%	Not known
Using existing larger ships	<4%	Not known
Increasing cargo load factor	Not known	Not known
Weather routing	0.1-4%	800-1600 USD/year
Autopilot adjustement	0.5-3%	Not known
Increasing energy awareness	Not known	Not known
Polishing on a regular basis	2-5%	3000-5000 USD
Polishing when required	2.5-8%	See Faber et al. (2011, pp. 105-106)
Hull cleaning	1-10%	35-45 USD per foot of the ship

Source: adapted from Faber et al (2011)

4.5 The Energy Efficiency Gap in Shipping

The fact that, at the present time, the major route for pursuing CO_2 abatement in shipping is through energy efficiency poses some complicated problems for policy-making. As exhibited by the available evidence, a significant and cost-effective potential for improving the energy efficiency of shipping is already available. This seems paradoxical in that if the evidence exists to show that a range of measures is cost-effective, why have they not already been implemented? This phenomenon has been shown to exist in many sectors and is commonly referred to as an "energy efficiency gap'" (Jaffe and Stavins, 1994). Depending on the scientific perspective adopted, the

Table 5: Technical Measures: Potential Efficiency Gains and Costs.

Technological measures	Gross potential	Cost
Lightweight construction	0.1-2%	Not known
Optimising hull dimension	<9%	Not known
Aft waterline extension	0.1-2%	Not known
Economies of scale	Not known	Not known
Hull coating	0.5-5%	43000 USD - 265200 USD[a]
Low profile hull openings	Not known	Not known
Optimising water flow of hull openings	1-5%	See appendix
Covering bow thruster hull openings	Not known	Not known
Design speed reduction	Varying[b]	Not known
Optimising propeller hull interface	<4%	Not known
Optimization of skeg shape	<2%	Not known
Interceptor trim plates	<4%	Not known
Air lubrication	10-15%[c] 5-9%[d]	Varying[g]
Propeller-rudder upgrade	2-6%	Varying[g]
Propeller upgrades (nozzle, winglets etc.)	0.5-3%	Varying[g]
Propeller boss cap with fins	1-3%	146000 USD [e]
Contra rotating propellers	3-6%	Not known
Common rail technology	0.1-0.5%	Varying[g]
Diesel-electric propulsion	<20% [f]	Not known
Main engine tuning	0.1-0.8%	Varying[g]
Waste heat recovery	8-10%	Varying[g]
Towing kite	Varying[g]	Varying[g]
Flettner rotors	Varying[g]	Varying[g]
Hybrid fuel cell auxiliary power generation	<2%	Not known
Solar power	0.2-3.75%	Varying[g]
Low energy lighting	0.1-0.8%	Varying[g]
Energy efficient HVAC	Not known	Not known
Speed control of pumps and fans	0.2-1%	Varying[g]
Fuel-efficient boilers	Not known	Not known

[a] For a Panamax bulker
[b] Higher than operational speed reduction
[c] For a tanker
[d] For a container ship
[e] For a 22,050 kW engine
[f] Depending on operational profile
[g] See Appendix II, Faber et al. (2011)

Source: adapted from Faber et al (2011)

existence of such a gap has been explained by the presence of transaction costs associated with the implementation of measures, as well as to failures and barriers in markets, institutions and organizations. Some of these barriers might possibly be removed cost-effectively, but others might not. The various assessments of possible energy efficiency improvements thus show a potential that will never fully be reached.

Within the context of the shipping sector, information asymmetry occurs in that it is very difficult for a charterer to understand the performance and quality of a ship, while the seller in the market will know more about the performance and quality of their ships than does the buyer. In such markets, ships with better than average quality or performance will not necessarily receive a premium price and, as such, are unlikely to be built. It is easy to extend this reasoning to the energy efficiency of vessels. Similarly, the concept of split-incentives in shipping has been discussed in reports to the European Commission (CE Delft, 2009: pp.94–98). The dominant split-incentive situation is probably that bunker costs are often paid by the charterer and not the operator. CE Delft (2009: p.95) suggested that bunker costs are passed on to the cargo owner in 70 to 90% of all contracts. Even where bunker costs are internalized, split incentives may also arise in cases where some functions are outsourced. A technical management company may, for example, economize on maintenance costs to increase their profits. This may affect bunker costs, but since these are passed on to the commercial operator, the incentive disappears (Buhaug et al, 2009: p.64).

All this suggests that, if it can be argued to be cost-efficient for society, policy should be driven by the ambition to change the structure and/or behaviour of companies operating within the shipping sector, To this end, the regulation of the shipping industry's GHG emissions, as undertaken by the IMO, can be construed in this way; on a similar basis to the mandatory implementation of energy management systems that has been a successful part of national energy efficiency programmes for general industry (Stenqvist and Nilsson, 2011).

4.6 The Policy and Regulatory Context

The work undertaken by the IMO in relation to shipping and climate change is very much shaped by the Kyoto Protocol of the UNFCCC [10]. Assigning the IMO the responsibility for reducing the GHG emissions from shipping was very much a compromise solution, as countries could not agree on how to apportion emissions from either aviation or shipping to individual countries (Oberthur and Ott, 1999). This assignment of responsibility was effectively implemented via the following text:

> "The Parties included in Annex I shall pursue limitation or reduction of emissions of greenhouse gases not controlled by the Montreal Protocol from aviation and marine bunker fuels, working through the International Civil Aviation Organization and the International Maritime Organization, respectively." (Article 2.2, Kyoto Protocol).

The implications of the terms 'pursue' and 'working through' have been the subject of extensive discussions at IMO meetings ever since. Diplomatic discussions between countries have effectively been stymied due to a fundamental disagreement over the interpretation of two basic concepts underpinning the work of the IMO and the Kyoto protocol (Kageson, 2011). The first, the concept of *Common But Differentiated Responsibilities* (CBDR) is a fundamental part of UNFCCC:

> "The Parties should protect the climate system for the benefit of present and future generations of humankind, on the basis of equity and *in accordance with their common but differentiated responsibilities* and respective capabilities. Accordingly, the developed country Parties *should take the lead in* combatting climate change and the adverse effects thereof." (Article 2, FCCC – author's emphasis).

In the development of IMO regulations, on the other hand, the concept of *No More Favourable Treatment (NMFT)* is universally used such that a port state can apply IMO legislation to any ship entering its waters or ports. The IMO secretariat itself has made it clear that they have "…not identified any potential treaty law conflict between the Kyoto Protocol and the provisions that may be developed by the Committee on GHG emissions from the combustion of marine bunker fuels" (IMO, 2011). Among other reasons, they state that "[...] 'pursue limitation' [...] is not the same as limiting the outcome of IMO's decision-making process to application to Annex I countries exclusively". Finally, it is concluded that shipping regulation must, both as a principle and for practical purposes, be global in scope.

A compromise is undoubtedly required, as applying solely the NMFT principle may weaken the negotiating position of developing countries in global climate change discussions (Hackmann, 2012). Several ways have been proposed to reconcile these principles. Kageson (2011) argued for two: either to apply an instrument globally, with economic compensation given to non-Annex I countries, or that the application is limited to Annex I countries, with or without compensation to other parties.

The IMO has adopted a dual approach to reducing the greenhouse gases of the shipping industry. First, it is devising a range of 'Technical and Management Strategies' which will either improve the fuel efficiency of the sector or reduce greenhouse gas emissions in some other way. In a study conducted on behalf of the IMO, however, Buhaug et al (2009) concluded that even if the whole range of available 'Technical and Management Strategies' were to be implemented, they would lead to fewer reductions in greenhouse gases than is required by the UNFCCC.

The IMO's Energy Efficiency Design Index (EEDI) is a formula that is intended to enable ship designers and builders to design and construct ships of the future for maximum fuel efficiency and, thus, minimum greenhouse gas emissions. Conceptually, the index is a ratio of environmental costs to the benefit to society. The IMO's Marine Environment Protection Committee (MEPC) adopted the EEDI at its meeting in July 2011 as a mandatory element within a newly amended MARPOL Annex VI, with the intention that the EEDI will apply to all new ships as from 2019. It is envisaged that a baseline maximum limit for greenhouse gas emissions according to ship type, size, age etc will gradually be reduced over time to ensure a declining trend in such emissions. This regulation does not apply retrospectively, however, so will do nothing to deal with the existing least fuel-efficient ships.

The IMO's Energy Efficiency Operational Index (EEOI) has been designed to measure the operational efficiency of all new and existing ships, by allowing efficiency comparisons between similar ships on similar routes and, therefore, prompting the operator to introduce further efficiency measures. In practice, the EEOI amounts to a purely voluntary voyage-by-voyage comparator and, despite original intentions, is not really suitable for comparing ships; even sister ships can have quite different operational characteristics.

The IMO recommends that the EEOI should be used in conjunction with a Ship Energy Efficient Management Plan (SEEMP). In July 2011, the mandatory possession of such a plan was adopted for inclusion in MARPOL Annex VI and will come into force as from 2019. The SEEMP was developed in close collaboration with the shipping industry and is intended to make ship crews and owners think about how energy is used on board ship. It encompasses a guidance document from the IMO setting out best practice on shipboard environmental measures and providing ship operators with practical advice on how to make their ships more efficient. Measures include improving voyage planning (weather routeing/routeing for just-in-time), speed and power optimization, optimized ship handling (ballast/trim/use of rudder and autopilot), improved fleet management, improved cargo handling and better energy management. However, it is only mandatory to have a SEEMP on board a ship, rather than to actually use it.

A critical review of these regulatory instruments is difficult to provide as peer-reviewed papers on them are very scarce. While the EEDI has spawned hundreds of submissions to IMO meetings, only one paper (Devanney, 2011) has been published in a peer-reviewed journal (and that paper is very critical of the EEDI concept). Commissioned by the IMO to assess the EEDI and SEEMP, Bazari and Longva (2011) estimated that a 30% improvement in energy efficiency would be possible through the application of the measures embodied within the SEEMP alone. The dominant source of efficiency gain in this assessment is speed reduction due to increased port efficiency, corresponding to roughly half of the total potential. Johnson et al (2013) identify gaps in the SEEMP guidelines compared to those of the international standard for energy management systems (EMS), ISO 50001 and the International Safety Management (ISM) code and conclude that these shortcomings will be detrimental to the success of the SEEMP.

The IMO and a number of other industry stakeholders argue fervently in favour of further measures, mainly market-based in the form of e.g. a tax on bunker or an emissions trading scheme, in order to complement the regulatory measures already implemented. However, these remain very much in their infancy, largely as the result of the considerable opposition to them which exists among many industry players (suggesting them to be excessive) or as the result of the CBDR conflict (Kageson, 2011). Commentary and analysis of the potential for market based measures is provided to a slightly larger extent in the academic literature. Corbett et al (2009) found that a fuel tax of 150 USD/ton fuel would lead to reductions in CO_2 emissions of about 20–30%. Miola et al (2011) discussed different market based measures for shipping, including a global emissions trading scheme, and concluded that a global market-based system would overcome challenges present in regional regimes, such as carbon leakage and how to apportion emissions.

The number of proposals for market based measures being considered by the IMO is increasing. Psaraftis (2012) reviewed several submissions to the MEPC on the topic. He emphasises a problem of insufficient transparency in the IMO process to review market based measures; they are based on MAC curves, containing assumptions on costs and effectiveness which are not fully disclosed. However, despite the number of subtly different options which have been proposed (including a 'do-nothing' option), there are, essentially, just three types of market-based mechanisms under consideration by the IMO:

1. An international fund for greenhouse gas emissions from ships, proposed and supported primarily by Denmark and Japan. In effect, this is a 'carbon offset' scheme, where flag states would make a contribution to the fund on the basis of the total emissions from their flag fleet.
2. A global emissions trading scheme for shipping, proposed and supported primarily by France, Germany and Norway. The UK government has also explicitly stated that it favours a global emissions trading scheme for shipping (Gilbert et al, 2010). This is also the case for the shipping chambers of Australia, Belgium and Sweden. This would be an open cap and trade scheme involving full auctioning, as successfully utilised in numerous contexts and across multiple industries (Hepburn, 2007; Skjaerseth and Wettestad, 2008; US EPA, 2009)
3. A trading scheme using energy efficiency credits that is based on the EEDI, proposed and supported primarily by the United States. This represents a hybrid form of the first two main alternatives.

Overall, whichever market based measure is applied, it has been agreed that any profits generated must be used to deal with climate change effects in developing countries. At present there is no agreement on what types of market-based measures should be implemented, let alone how they would be incorporated into an IMO instrument. In the meantime, the EU is currently unilaterally exploring potential mitigation options for shipping, given its declaration to include shipping emissions in its greenhouse gas reduction commitment if the IMO had not agreed the implementation of a market-based mechanism by 31st December 2011; a deadline which has long since passed.

In the absence of any effective IMO regulation of greenhouse gas emissions from ships, unilateral regulatory action has indeed been threatened by a number of nations and regions (such as Australia, the EU and Japan). This, of course, would undermine the IMO's efforts to achieve a global and generally applicable solution that encompasses both regulatory and market-based measures. A report by CE Delft (2009) highlights four potential policy instruments that could be used by the EU and which would appear to be quite similar to those already under consideration at the IMO:

- A cap-and-trade system for maritime transport emissions.
- An emissions tax with hypothecated revenues.
- A mandatory efficiency limit for ships in EU ports.
- A baseline and credit system based on an efficiency index.

4.7 Rebound Effects

No overview of the role of energy efficiency as a strategy to abate GHG emissions is complete without at least mentioning the issue of *rebound effects*. The term relates to a broad concept covering the potential mechanisms which may be presumed to exist following the advent of greater energy efficiency and which lead to additional energy use. Thus, the net effect of any energy saving measure becomes uncertain at best. This problem was first formulated by Jevons (1865), who argued that increased energy efficiency could ultimately even lead to a net increase in energy use, a process which is often referred to as Jevons' paradox (Alcott, 2005; Sorrell, 2009). This subject has received little treatment in either scientific or policy discussions on shipping and climate change. However, if energy demand is reduced, this could lead to reduced energy prices, which could again lead to a rebounding demand. In a shipping context, the question arises as to what will happen to total emissions as measures prompting greater energy efficiency are introduced? Buhaug et al (2009) dismissed the possibility of rebound effects as follows:

"In general, policies aiming at improving efficiency, whether it is operational or design efficiency, may suffer from a rebound effect (Sorrell, 2007). The ``rebound effect'' is the effect that an improvement in the efficiency often translates into a much smaller reduction in emissions. The reason is that, as the efficiency improves, the marginal costs often decrease (shipping becomes cheaper), which in turn increases demand. The rebound effect is larger if the demand is price-sensitive, i.e. if the price elasticity of demand is high. In shipping, the scarce evidence that is available suggests that the price elasticity is low. Reported price elasticity is in the range from -0.06 to -0.25 (OECD, 2003). The only exception seems to be transport of general cargo in short sea shipping. For all other types of maritime transport, the rebound effect is likely to be small." (Buhaug et al, 2009: p.106).

However, over a longer time-scale, the price elasticity of demand for shipping services is likely to change, as evidenced by the fact that cheap transportation was surely the medium which supported globalization and the shift from *fordian* (local and integrated) to post-fordian (distributed) production (Ruzzenenti and Basosi, 2008).

4.8 Conclusions

The proliferation and growth of maritime transport is a fundamental prerequisite for, and facilitator of, increased international trade and, therefore, of the economic growth and development which is pursuant upon it. Motivated by the desire to achieve greater profits, it is reasonable to assume that the suppliers of shipping services will continuously seek to cut fuel costs by improving energy efficiency. At first glance, therefore, this would appear to be a win-win situation, or what has been referred to within the logistics discipline as a 'green-gold solution', where environmental benefits are simultaneously derived from implementing cost-saving measures (Cullinane, 2009; Mackinnon, 2010; Cullinane and Cullinane, 2013). However, while it is apparent that, on a marginal basis (i.e. fuel used per ton-km travelled), energy efficiency within the shipping industry is indeed improving continuously, these marginal benefits are being overwhelmed by the sheer pace and volume of the increase in transport work undertaken by the sector. As such, the global economy faces the seemingly intractable problem that as the demand for shipping services expands then, ceteris paribus, so too will both the volume of fossil fuels consumed by the sector and, by close association, the volume of greenhouse gas which it emits into the atmosphere.

Against a background of diminishing GHG emissions from other sectors and making the baseline assumption of 'business as usual', many studies estimate that the total GHG emissions from shipping will continue to rise and that the future contribution of this sector to total GHG emissions will become much more significant than it is now (Eyring et al, 2005; OPRF, 2008; Buhaug et al, 2009). In other words, based on the type of energy efficiency innovations that are currently implemented, the growth of the sector is projected to be faster than what these measures can achieve. These forecasts are largely rooted in an assumed continuous and positive rate of growth in global GDP, albeit with some inherent variability.

At the same time, a number of studies also reveal not only the existence of an extremely large potential for further improvements in energy efficiency, but also that a substantial part of the potential could be implemented cost-effectively, even where the price of carbon is zero (Eide et al, 2011). Moreover, the measures and innovations that would be required for greater energy efficiency are not that radical, with many already proposed, discussed or implemented during, or shortly following, the oil crises of the 70s.

Ostensibly, this represents somewhat of a paradox. If there exists significant scope for greater energy efficiency within the sector and this could be achieved relatively simply, then why are shipping companies not moving more quickly to implement these measures in order to reduce their costs and increase profitability? As was explained earlier, this type of energy gap is ubiquitous across all sectors and has its roots in the possibility that there is a transaction cost associated with implementing each of the possible measures for enhancing energy efficiency.

Pressure on the shipping industry to reduce its environmental impacts will inevitably increase and the most cost-efficient route to CO_2 emission reduction is undoubtedly through enhanced energy efficiency. Given that the process to replace today's ships with new, more energy efficient ships will be slow, recent assessments have shown that the only way to attain the desired level of emission reductions in the short term is through improved managerial practices with respect to energy efficiency. Unfortunately, however, given that shipping markets do not currently respond well to energy price signals with innovation in terms of energy efficiency (Eide et al, 2011: p.32), the imperative exists to develop and implement policies that overcome existing barriers to improvements in energy efficiency and to incentivise the required behavioural change (Sandén and Azar, 2005).

Specific policies could be implemented, therefore, which address the following potential barriers to the adoption and deployment of measures for improving energy efficiency within shipping companies.

- The increasing uncertainty related to the prediction of the future fuel savings that might be derived from a particular measure, as well as around future energy prices and the expected lifetime of the measure.
- Insufficient information to verify or trust the claims made with respect to the estimated fuel savings to be derived from investing in a measure.
- The difficulty of assessing the energy performance of ships, due to the varying impact of weather conditions, the quality of measuring equipment, efficiency of reporting systems etc. In fact, there could be so much noise surrounding information that it becomes very difficult to prove the effectiveness of measures.
- There is a tendency for nobody within a shipping organization to be specifically accountable for energy efficiency. Thus, few incentives exist for its improvement.
- Fragmentation of responsibilities and action concerning energy use is common, not only within firms but also in contracts between different firms. This is expected to be particularly aggravating in the absence of monitoring.
- Given the emphasis that transaction cost economics puts on the role of monitoring performance vis-à-vis contracts, there needs to be a better understanding of the role and use of monitoring of energy use in various forms of contracts; new buildings, third party management, charter parties etc., as well as internally.
- Current forms of contracts exacerbate information asymmetries. An example from shipping is the case where a ship operator may have financial (dis)incentives to not slow down in respect of an agreed contractual speed, as demurrage is received for the time spent waiting in port before the contracted 'arrival time', while the cargo owner pays costs of fuel. The "virtual arrival" process, where vessels may receive information of a delay at their upcoming port and then reduce speed in order to arrive in time for unloading, is an example of resolving contractual issues that affect energy efficiency. An external verification service could calculate what the fuel consumption and arrival time would have been should the ship have continued on its initial contract speed. This kind of process could then be used to share savings between cargo owner and ship operator, with the operator still receiving demurrage.

In developing policies which seek to overcome these barriers and inculcate behavioural change, it is critical that an understanding is gained of how knowledge and competence on energy issues can be enhanced internally within shipping organizations, for example through applying various available "best practices". With the laudable exception of the IMO's recent introduction of the SEEMP, many "best practices" or standards for managing energy efficiency that are currently in use within shipping organizations were developed during the last decade. When compared to where the potential in energy efficiency really lies, the SEEMP is itself limited; in the sense that it applies solely to ship-specific measures. In this respect, the increased detail in ISO

50001 could provide a feasible and satisfactory way forward. Released in 2011, the aim of the ISO 50001 standard is "to enable organizations to establish the systems and processes necessary to improve energy performance, including energy efficiency, use and consumption", through setting a framework "...upon which an organization can develop and implement an energy policy, and establish objectives, targets and action plans which take into account legal requirements and information related to significant energy use" (ISO, 2011). It also requires that an organization incorporates energy efficiency in procurement and design processes. Other similar developments which have already been inaugurated within the shipping sector include a new Tanker Management Self-Assessment which has been revised to also include energy efficiency (OCIMF, 2008) and Intertanko's Guide for a Tanker Energy Efficiency Management Plan (Intertanko, 2009).

Based on studies in the field of the effectiveness of what has thus far been implemented, it will be possible to further refine existing, and develop new, policy instruments that overcome the barriers that have fostered the energy gap in shipping. By so doing, both a viable cost-cutting strategy for shipping companies and also a much-needed policy-route towards mitigating the climate impacts of the shipping sector will be achieved.

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5 Ship Recycling: A Global Issue

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Stena Metall

5.1 Background

Today's shipbreaking industry exemplifies both the potential and the dangers of an increasingly globalized economy. In general terms, most corporations in the developed world are motivated to devolve activities to developing countries so as to take advantage of a cheaper labour force. Clearly, this possibility holds potential benefits for all parties. However, where the activity concerned is shipbreaking, in the developing world there is a dearth of regulations and also of knowledge on how to safely dispose of or treat hazardous materials. Despite this, the environmental repercussions or, indeed, even the health and safety of the workforce (see Appendix A at the end of this Chapter) are factors which are seldom, if ever, considered when arriving at such decisions on where ships should be scrapped (Jager, 2012).

The issue of where to have ships recycled has been addressed by many shipping organizations over the years. Economics, rather than environmental and social concerns, has invariably played the most significant role in that decision, especially when it comes to deep sea tonnage owed by private companies. Ships registered in countries that have ratified the Basel convention have, however, to be taken care of in the developed world at a much higher cost. Indeed, for some naval vessels it has even been the case that following a depollution process, they have simply been sunk in deep waters.

Currently, the biggest shipbreaking nations are India, Bangladesh, Pakistan and China. The evolution of their respective market shares can be seen in Figure 16. All except China use the beaching method for the recycling of ships. In contrast, China uses quayside demolition as the most common method. The fact that this latter method is more costly can be seen in the yield for vessels sold to Chinese demolition yards. In those countries where beaching is the commonly used method, the industry creates hundreds of thousand jobs and makes a significant contribution to the local economy (FIDH, 2002). Thus, both the social and environmental costs of ship recycling need to be carefully considered by a responsible and sustainable maritime community. However, in order to implement policy or regulations with the intention of bringing about any changes, it is important to gain an understanding of the current context of the shipping industry and who are the key players and stakeholders when it comes to the end of life and the recycling of deep sea vessels.

5.2 The Market Dynamics of Ship Recycling

Figure 17 shows that the average age of vessels at the time they were recycled increased steadily from the early 1990s until the time of the global financial crisis in 2008. This trend can be seen across all ship types and can be attributed largely to the continuous development of shipbuilding technology over time. An important symptom of the worldwide financial crisis in 2008 was the restrictions and more onerous conditions which financial institutions imposed on the availability and supply of credit. This has clearly resulted in a reversal of this long-established trend such that in more recent years ships have been sold for recycling at a younger age than before the financial crisis (Holman Fenwick Willan, 2012). This relationship between the availability of credit and the volume of ship recycling is graphically portrayed in Figure 18.

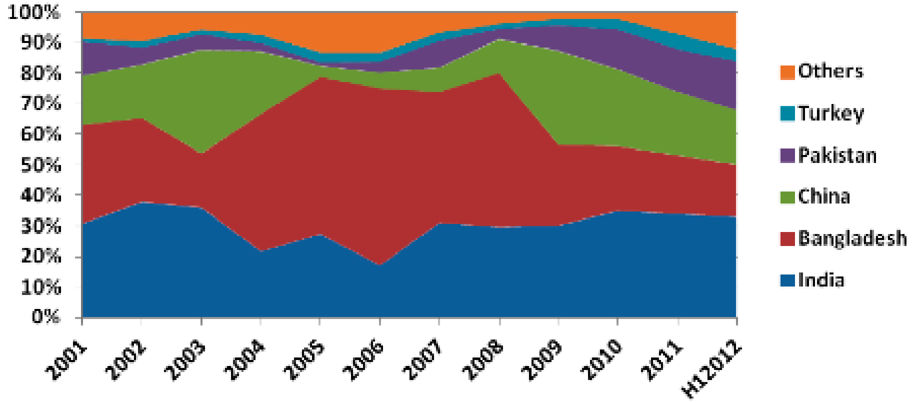

Figure 16: Ship Recycling Market Shares in LDT
Note: Ship size coverage = 100 Gross Tons and above.
Source: ICRA (2012)

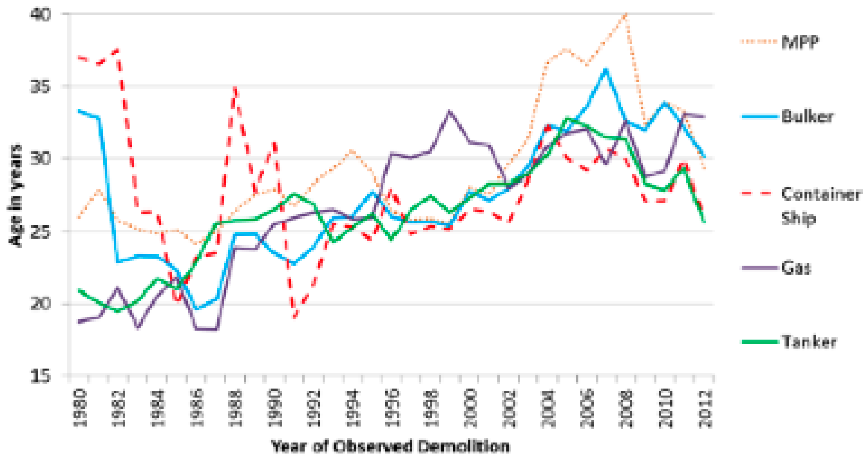

Figure 17: The Average Age of Ships at the Time of Recycling. *Source: Williams (2012)*

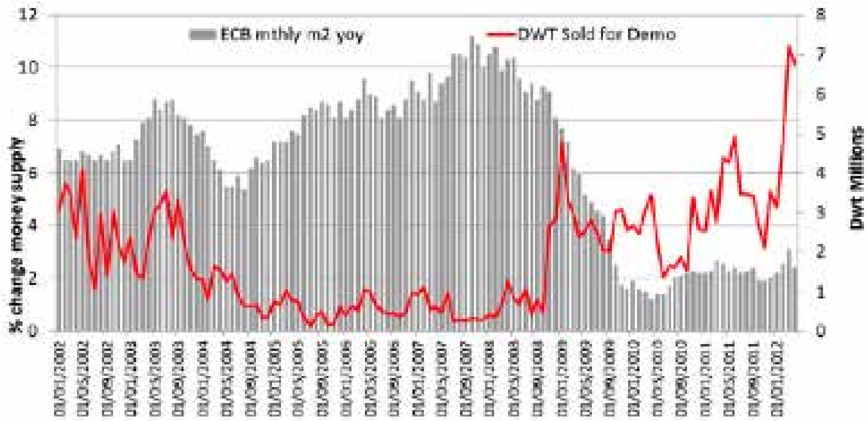

Figure 18: Credit Supply and scrapping rates
Source: Williams (2012)

One conclusion that can be drawn from the present credit supply situation is that poorly financed shipowners, that are operating in a weak market with low freight rates, will sell ships for recycling in order to avoid going into bankruptcy and that, under such circumstances, environmental and social costs are not considered. Figure 19 shows that the amount of ships going for recycling in times when freight rates are high is limited, even though the demand for, and price of, steel was at a peak. This suggests that neither freight rates nor steel prices exert an overwhelming influence on demolition activity. As is implied in Figure 20, it is instead the reduced supply of credit and the consequent pressure on cash-flow which is the key determinant in prompting shipowners to demolish their ships.

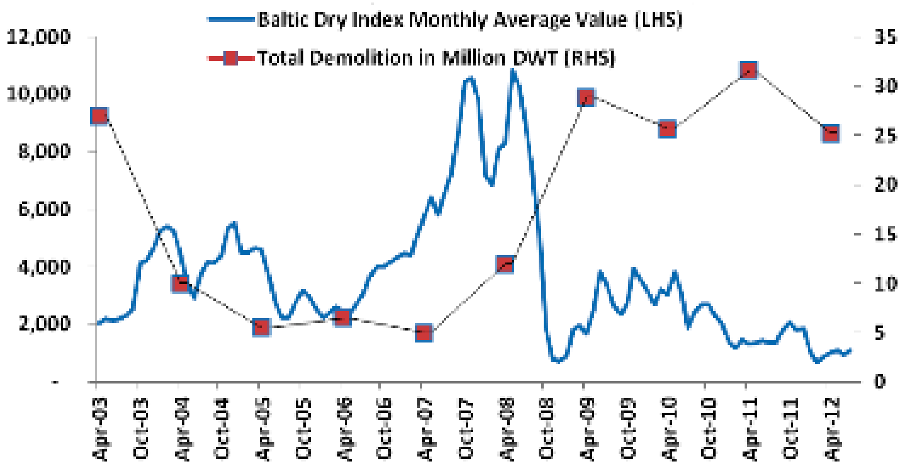

Figure 19: Freight Rates vs. Demolition Activity
Source: ICRA (2012)

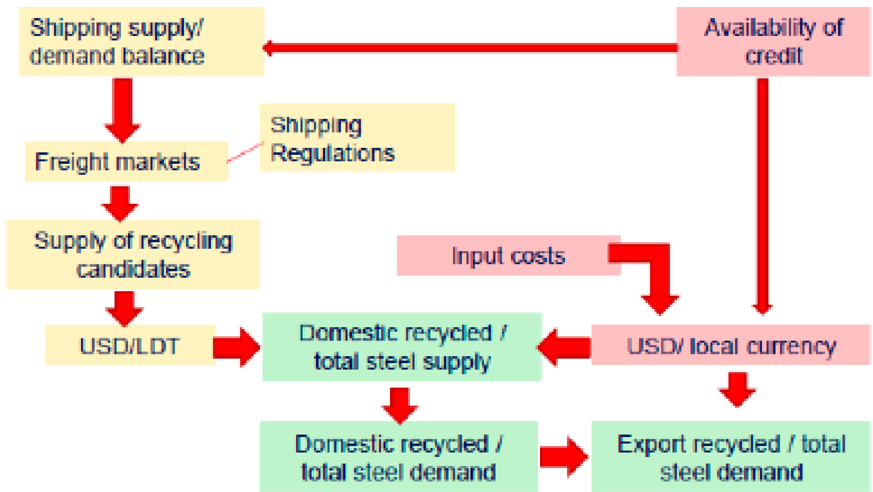

Figure 20: The Market Dynamics of Ship Recycling
Source: Williams (2012)

5.3 The Role of the Cash Buyer

It is very rare for a ship breaker/recycling yard to purchase a vessel directly from a shipowner. Due to the nature of their business, the scrap yard will usually wish to pay for a vessel on deferred payment terms under a letter of credit issued by their bankers. The shipowner, on the other hand, required payment on a cash basis. This impasse is resolved by trading companies (referred to as "Cash Buyers") which act as 'middlemen' and stand between the shipowners and the recycling yards as principles in the transaction. The Cash Buyers pay the shipowners in cash for the vessel, but are prepared to accept payment under a letter of credit from the recycling yard. Since Cash Buyers take ownership of the asset (and, sometimes, even the physical delivery of the vessel), they cannot be classified as brokers (McCarthy, 2012a). In essence, therefore, the Cash Buyers are true *market makers* and, in their dealings with the shipowner, can engage in either of two forms of transaction:

- DELIVERED – where the Cash Buyer agrees to purchase the vessel from a shipowner subject to the shipowner delivering the vessel to the recycling yards within a certain time and subject to certain conditions; mainly relating to the condition and specification of the vessel and the release of all mortgages and debts. The risk, responsibility and the cost of delivering the vessel to the recycling yard is borne by the shipowner. The agreement between the Cash Buyer and the shipowner is evidenced by a sale and purchase agreement called a Memorandum of Agreement ("MOA"), which contains details of the vessels specifications, the date by which the vessel must be delivered to the recycling yard etc. and will require a deposit to be lodged to secure the sale. The amount of deposit varies between 10–30 per cent. The release of the deposit is conditional upon the shipowner complying with all conditions under the MOA.
- AS-IS – where the Cash Buyer pays the shipowner for a vessel at a price based on the condition of the vessel ("AS-IS") at the time of sale and for taking immediate delivery at its current location or last port of discharge. This means that the Cash Buyer will, at its own risk and expense, deliver the vessel to the recycling yard against payment under a letter of credit.

The advantages to a shipowner of using the services of a Cash Buyer are that they possess good industry knowledge, provide the best return to the shipowner for the sale of a ship for scrap and they provide an efficient mechanism for completing a sale, especially in the sense that the contract for the delivery of the vessel takes a highly structured form; either on a 'delivered' or 'as-is' basis. For the ship breakers, the main advantages of using Cash Buyers is that they have significant skills and experience in sourcing vessels, sufficient resources for financing the purchase of the vessel, knowledge of how to deal with local delivery procedures and also have a global presence for taking delivery. Finally, a major advantage for the recycling yard is that it is able to pass the risk associated with purchasing a ship for scrap onto the Cash Buyer, who is extremely adept at managing those risks.

5.4 The Regulatory Context

With the exception of nuclear waste, the *Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal* is an international treaty that was designed to reduce the movements of any other form of hazardous waste between nations, and specifically to prevent the transfer of hazardous waste from developed to developing countries. The Convention was opened for signature on 22 March 1989, and entered into force on 5 May 1992. As of October 2013, 179 states and the European Union are parties to the Convention.

After its initial adoption, some countries argued that it did not go far enough. For example, it did not actually *prohibit* the movement of hazardous waste to any location except Antartica, but instead established a notification and consent system for other *transboundary movements*. As the result of increasing concerns over waste movements badged as '*for recycling*', many regional bans had already been put in place. Further pressure for change led to the adoption of an amendment to the Basel convention in 1995 termed the *Basel Ban Amendment*. It has since been accepted by 73 countries and the European Union, but has not yet received sufficient support to enter into force. The European Union, however, has fully implemented the Basel Ban in its *European Waste Shipment Regulation (EWSR)*, making it legally binding in all EU member states. The Amendment prohibits the export of hazardous waste from a list of developed (mostly OECD) countries to developing countries and applies to export for any reason, including recycling. An area of special concern in the lobbying for the Ban Amendment was, in fact, ship recycling specifically and, in consequence, the term *waste* includes ships for recycling within the context of both the Basel Convention and the Basel Ban Amendment.

It soon became obvious that there were practical and legal difficulties in enforcing the provisions of the Basel Convention and, for the EU in particular, its EWSR on ship recycling. In 2009, for example, it was estimated that 91% of European end-of-life ships had avoided or evaded the provisions of the EWSR. In recognition of this failing, the parties to the Basel Convention tasked the IMO with developing a set of globally applicable mandatory requirements that would ensure an equivalent level of control as under the Basel Convention. In 2009, the Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships was adopted.

The Hong Kong Convention has not yet received sufficient support to enter into force. In advance of it doing so and in order to introduce workable regulations now, on 27 June 2013 the Council of Europe and the European Parliament agreed the contents of a new Ship Recycling Regulation which should enter into force by the end of 2013. This is closely based on the Hong Kong Convention, although containing certain additional requirements. Under this regulation, ships registered in the EU must use 'green' listed ship recycling facilities, wherever in the world they might be (Nyhlén and Jonsson, 2012). This is effectively a ban on the use of beaching facilities. There is also a requirement that all ships calling at EU ports should be in possession of an inventory of hazardous materials (IHM). This is perceived as a prerequisite for clean and safe ship recycling. Unfortunately, some large shipping nations within the EU, such as Greece, Malta and Cyprus blocked the imposition of more stringent regulations that would have ensured the traceability of hazardous wastes that are dumped in developing countries and clearly linked any liability for these wastes to the shipowner (EC, 2008; EC, 2012). Most controversially, the new EU Ship Recycling Regulation exempts ships from the EWSR and this has raised a number of questions over its legality (McCarthy, 2012b).

5.5 Conclusions and Recommendations

In most cases, when the Cash Buyer takes over responsibility for the vessel, it will be renamed, reinsured and, finally, re-flagged before it is delivered to a recycling yard. The average profit or commission earned by a Cash Buyer lies somewhere between $1 and $6 per LDT (Light Deadweight Ton). It is, therefore, in a Cash Buyer's interests to deliver the vessel to the recycling yard while incurring the lowest possible costs and without, therefore, taking into account the environmental or social cost. As long as the yard fulfills local regulations and laws, that is the only concern. This makes regulations such as the Basel and Hong Kong conventions ineffective. Indeed, the new EU regulation will have only a very limited effect in that it will apply only to ships registered under an EU flag at the time they are recycled. Usually with (but also even without) the services of a Cash Buyer, the regulation offers nothing to prevent shipowners switching the registration of a ship to a non-EU flag prior to sending it to the breaker's yard, in order that they can avoid the requirements of this new EU law. The new EU law may even have the unintended effect of driving ships away from registering under an EU flag and thereby undermine other EU initiatives aimed at reinforcing the strength of the EU shipping fleet and associated maritime industries. As such, there needs to be other incentives in order to change the present situation.

The need for steel is one of the drivers in the ship dismantling business. As the economies of China, India and Brazil continue to grow into the future, the consumption of steel will also grow over the next decade (as can be imputed from Figure 21), keeping steel prices at a relatively constant level. The consequence of this growing demand for steel in the emerging economies will probably mean that prices for end of life ships per LDT will also remain fairly constant. This suggests that the current market situation is unlikely to change and that there will be a need for other incentives to make ship recycling in countries like India, Bangladesh and Pakistan more sustainable.

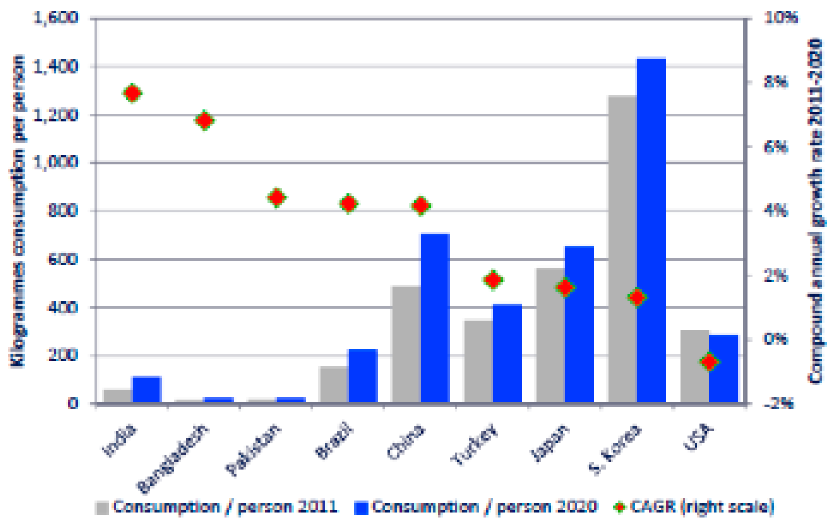

Figure 21: Steel consumption potential
Source: Williams (2012)

Over the years, a number of proposals have been made, without success, to try and make ship recycling in Europe possible and attractive for vessels registered in non- EU states. The main reason for their failure is the cost of labour, infrastructure etc. The proposals made have usually revolved around the creation of some sort of fund to cover the gap between sustainable and non-sustainable ship dismantling. So far, none of these proposals have been implemented in practice. Ultimately, the main reason for this is that it is still much more profitable for a shipowner to scrap their vessels on a beach in Asia.

A solution to this would be to require a recycling insurance for ships entering EU waters. This insurance should be a part of the normal ship insurance and be based on a "green passport"; a declaration made when the ship is built. The insurance should cover the cost of recycling using a sustainable approach, but exclude the scrap value. The shipowner can only make a claim against this insurance by scrapping the vessel at a facility which is approved by the insurance company. If vessels entering EU waters do not fulfill this requirement, the cost of entering port should be set at an exorbitantly high level in order to force shipowners to comply with regulations.

There may be legal issues in relation to such an approach if it is deemed not to respect the non –discrimination principle as laid down in the WTO/GATT agreements. However, the placing of European Court financial obligations on non-European companies is not contrary to the principles of international law, since each member state has sovereignty over its own territory. In addition, the Directive 2009/14 gives the port authorities in EU-member states the necessary legal instrument to enforce international obligations to control ships entering ports.

The use of some form of financial incentive for all ships calling at EU ports has, in fact, received a lot of support and recent studies have proposed a variety of alternative mechanisms to that outlined above (e.g. Ecorys, 2005; Milieu Ltd./Cowi, 2009; van Gelder et al, 2013). All of them, however, are based on the 'polluter pays' principle, whereby the focus is very much on the shipowner. These studies clearly show that the imposition of a financial incentive for sustainable ship recycling is legally feasible, enforceable and effective in achieving the objectives set for it.

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Appendix A The Health Risks Associated with the Ship Breaking Industry

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Ship recycling is a hard and dangerous job. In most major ship recycling sites in Asia, the control of workplace conditions is limited as is the use of protective equipment for workers (Graham-Rowe, 2004: Rousmaniere and Nikhil, 2007).

The occupational risk factors depend on the tasks performed. Common problems for many workers are accidents (falling from one level to another, falling objects, crushings, wounds from sharp edges, gas explosions) and musculoskeletal disorders due to strain and/or repetitive movements (Graham-Rowe, 2004; Rousmaniere and Nikhil, 2007). Those using grinding machines may develop hand-arm vibration disease and noise-induced hearing loss. Flame cutting of metal results in a high risk of asthma and other airway disease due to exposure to dust, smoke and irritant gases. Lead poisoning is a risk when flame cutting or grinding in lead paint (Ho 1989, Huang 1997, Deshpande et al, 2012). Many ships contain parts insulated with asbestos (Mangold et al, 2006; Rousmaniere and Nikhil, 2007; ILO 2009), and exposure to asbestos fibres results in increased risk of cancer, as does exposure to polycyclic aromatic hydrocarbons emitted during the burning of organic material or hexavalent chromium (Blade et al, 2007; Neser et al, 2012a).

Apart from occupational risks of workers directly engaged in ship recycling, the nearby marine environment is affected by pollutants emitted in ship recycling areas (Srinivasa et al, 2003; Srinivasa et al, 2005; Neser et al, 2012b; Abdullah et al, 2013; Hasan et al, 2013). Possible health risks for the general population from such emissions have not been studied.

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6 Potentially Polluting Shipwrecks

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6.1 Definition

To be defined as potentially polluting, a shipwreck should either contain oil as a bunker fuel or oil and/or other hazardous substances as cargo. The first condition implies that ships that did not use oil, diesel or a similar fuel for their propulsion are excluded. Indirectly, this means that only ships built later than 1914 are to be considered. However, by virtue of the second condition, there are some exceptions where older ships were carrying hazardous substances as cargo at the time of the wrecking. Commonly, there is also a limit defined regarding the potential volume of oil or hazardous substances. As it might be difficult to find the true value of, for example, the bunker volume present in a ship at the time of the wrecking, the bunker volume can be indirectly assessed through the size of a vessel. A similar logic is applied for the size of cargo tanks for tankers.

Michel et al (2005) define potentially polluting shipwrecks as sunken non-tank vessels larger than 400GRT and tankers larger than 150GRT. Using this definition, 8,569 potentially polluting shipwrecks are identified worldwide. It should be noted, however, that many smaller vessels may also pose a severe threat to the coastal environment, even though they have been excluded in the report by Michel et al (2005). In recognition of this, the definition used by Bergen Maritime Museum (Lindström, 2006) includes smaller vessels, larger than 100GRT.

6.2 A global problem

Potentially polluting shipwrecks containing oil or other hazardous substances pose a threat to the marine environment (Michel et al, 2005; Landquist et al., 2013; Sprovieri et al., 2013). The majority of these wrecks originate from World War II and they have now been corroding on the sea floor for more than 65 years. Another common characteristic of such wrecks is the absence of a liable owner that could be held responsible for remediation or salvage of the wreck. Hence, it will be the nation whose coastal marine environment is impacted by a leaking shipwreck that will have to bear the costs associated with the remediation of both the shipwreck and the environmental damage. Specialized technology for proactive actions, including for example the removal of oil from shipwrecks, is available but very costly. To ensure the efficient use of resources, it is therefore of great importance to conduct a theoretical risk assessment of all known shipwrecks in order to identify which of them should be prioritized for remediation (Landquist et al., 2013). The scale and difficulty of such a task can be inferred from the map of known shipwrecks worldwide shown in Figure 22.

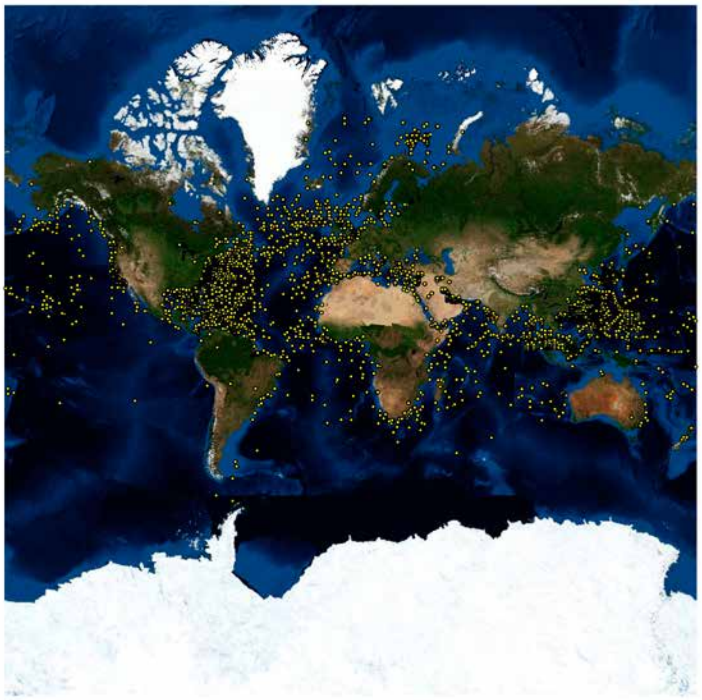

Figure 22: The Spatial Distribution of Shipwrecks
Source: Dr. Dagmar Schmidt Etkin of Environmental Research Consulting.

6.3 Effects on the marine environment

The general image of the impact of oil pollution on the marine environment is derived from reports in the media of maritime disasters such as Exxon Valdez, Erika and Prestige or the blowout of the oil rig Deepwater Horizon, where pictures of oil-spilled beaches and dead birds are cabled around the world. It is important to recognize that there are many different types of oil and tankers may transport either crude oil or refined products. The engines of early oil-fuelled ships used relatively light diesel oils, while ships of today normally use the heaviest fraction remaining from the refinery process, heavy fuel oil. From a risk assessment point of view, all wrecks of oil-fuelled ships may leak refined oil products from their bunker tanks, while tankers may also leak the crude oil which they may be carrying as cargo. Despite the fact that refined products are often more toxic than crude oil (Environment Canada, 2013), the vast majority of all ecotoxicological studies on the effects of oil focus on different types of crude oil.

Beyond the immediate physical and acute toxicological effects of oil, it has also been shown that even only very low concentrations of oil in the marine environment adversely affects, among other things, the embryonic and larval development of fish (e.g. Page et al, 2012); the growth and species composition of plankton communities (Hjort et al, 2007); the ability of sediment-living organisms to recycle nutrients in coastal environments (Lindgren et al, 2012) and; community resilience towards other stressors, such as other contaminants or rising temperature levels due to global warming (Vieira and Guilhermino, 2012). These results are not in conflict with the fact that oil is degraded by natural processes (e.g. Venosa and Zhu, 2003), but they do emphasize the cost to nature associated with the impact of even only low concentrations of oil. To conclude, in addition to major oil spill disasters, slow leaking shipwrecks may also have a significant impact on the marine environment. Further, such slow leakage may be of special concern when considering potential synergistic or 'cocktail' effects, where the net overall impact of all stressors on a species or an environmental compartment may be much more severe than the simple additive effects of the individual stressors (e.g. Hjort et al 2007, Vieira and Guilhermino, 2012).

6.4 Socio-economic consequences and the link to loss of ecosystem services

There is no question as to whether or not the oil in a shipwreck will enter the environment; it is a question of when it will. Even though the remediation of shipwrecks is very costly, the alternative of taking no action whatsoever may be associated with even higher costs in the longer term. The easiest basis for comparison is to the cost situation associated with the cleanup of larger spills reaching the coastline (Hassellöv, 2007). A non-linear relationship exists between the volume of oil spilled and its clean-up cost (Franzén et al, 2006) in that the cost per unit volume of oil spilled is often lower in the case of a larger spill. However, no universal definition exists as to what constitutes a large versus a small or medium-sized oil spill. Depending on factors such as the location of the spill, a certain volume of oil may cause more or less severe damage to the environment and, therefore, the approximate cost of a no-action approach, against which the cost of taking action might be assessed, is highly event-specific.

The cost of slow leakage is even harder to assess, though attempts to link the effects in terms of loss of ecosystem services to socioeconomic values are presently ongoing (Swedish EPA, 2009). This coupling is likely to be included in the aim of the Marine Strategy Framework Directive, 2008/56/EC, Descriptor 8: Contaminants. Within a context where the results of recent studies on the effects of low concentrations of oil are taken into consideration, shipwrecks leaking oil into the marine environment presents a challenge for achieving the aim of keeping "contaminants at a level not giving rise to pollution effects".

Finally, it should be recognized that the need for the socio-economic valuation of the effects of oil in the marine environment is not limited merely to oil originating from shipwrecks, but also to other sources of oil such as the bilge water from ships. This emphasizes the need for more research on the effect of low concentrations of oil in the marine environment and the link to the loss of ecosystem services.

6.5 Shipwreck inventories

A first step towards risk assessment is to gather inventories of known shipwrecks. In addition to the historical interest of older shipwrecks, Svensson (2010) concludes that the main reason for the existence of shipwreck inventories in the countries around the Baltic Sea is to ensure the safety of navigation, rather than registration or the prevention of pollution from shipwrecks. For this reason, the shipwreck databases of many nations are very sparse and contain no more information than position and water depth. Further, it may be difficult to find information on ships, bunkers, cargo and wreckage from the time of World War II. Apart from the shipwreck inventories of national authorities, fishermen and wreck divers also have good knowledge of wreck positions. However, fishermen and divers, as well as national authorities where there are archaeological, national security or peace of grave implications, may be reluctant to share their knowledge of wreck positions to inform official databases. This may limit the possibility of creating one comprehensive and complete European database. However, there are both national and international databases available on the internet (e.g. www.wrecksite.eu). To facilitate the use of a shipwreck risk assessment model, it is preferable that the very same format for shipwreck inventories is utilized throughout all the European countries. This would also facilitate feedback to the risk assessment model through the possible evaluation of remediation operations.

6.6 Shipwreck risk assessment

Several studies worldwide have stated the need for objective and robust risk assessments of potentially polluting shipwrecks in order to enable a prioritization of the large number of wrecks that pose a threat to the marine and coastal environment (Landquist et al, 2013 and the references contained therein). However, the available risk models lack a standardized risk assessment methodology. Landquist et al (2013) have reviewed the six most mature risk assessment models for shipwrecks and their ongoing research has the aim of developing a risk assessment model for potentially polluting shipwrecks following international standards of risk management.

Within the European Union Strategy for the Baltic Sea Region (EUSBSR), the issue of potentially polluting shipwrecks is highlighted within 'Priority Area 3: To reduce the use and impact of hazardous substances'. The flagship project led by Poland is solely focused, however, on dumped chemical munitions and does not take oil into account.

6.7 Legal and financial aspects of shipwreck risk assessment and remediation

Despite decades of discussion about the threat of potentially polluting shipwrecks (Girin 2004), there currently exists no international legislation or regulations that cover the management or financial issues relating to abandoned shipwrecks. The financial liability issue is also further complicated by the fact that oil pollution from shipwrecks pays no heed to national borders or sovereign or international waters. The Nairobi convention (IMO, 2007) is still only signed by four nations and will need ratification by another six nations in order to enter into force. Even then, although the Nairobi convention may be a good platform to start from, it has to be further developed if it is to play a central role in the management of shipwrecks in the future.

Today the handling of potentially polluting shipwrecks is only addressed in a reactive manner. If oil is spilled into the environment, the present oil response and preparedness plans such as the Copenhagen agreement enable countries to take immediate cooperative action, regardless of the source of the oil or the state whose coast line is threatened. In the case of potentially polluting shipwrecks, however, the potential exists for a common saving of resources if proactive approaches are undertaken. This may provide a reasonable driving force for the development of a European plan specific to the handling of such wrecks, starting with a theoretical risk assessment.

6.8 Recommendations

The overall recommendation is to strive for a European plan allowing for a proactive approach to the management of potentially polluting shipwrecks. Three initial needs can be identified:

1. Establish a European shipwreck database which is harmonized so as to facilitate the input of data to risk assessment models.
2. Apply a robust and objective risk assessment model to prioritize which shipwrecks should be investigated further *in situ* and/or monitored and/or remediated and then feed the data from the *in situ investigation* back into the shipwreck database.
3. Further research should be conducted into the effects of low concentrations of oil and the interactive effect of multiple stressors and this should then be linked to the valuation of ecosystem services.

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7 Sustainable Intermodal Transport with Short Sea Shipping in the EU

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7.1 Introduction and Background

Short sea shipping as part of the intermodal transport chain has evoked interest from governments worldwide, as they seek to reduce traffic congestion on land and greenhouse gases. The European Union (EU) has been developing its own shipping policy as a part of its Common Transport Policy (CTP) for more than the past two decades. A number of EU projects, such as Short Sea Shipping and Motorways of the Sea in the context of the Trans-European Transport Network policy (TEN-T), play an important role in the development of intermodal transport in Europe because the use of ships to carry goods is regarded as a relatively less environmentally damaging mode of transport.

The European short sea shipping sector is comparatively well established compared to its counterparts in the United States or Canada (Brooks and Frost, 2004).[11] This sector in Europe has benefitted from the liberalisation of cabotage policies within the EU since 1990, which made it possible for short sea shipping to start competing effectively with land-based transport. Advances in modern ship building technology greatly increased the speed of vessels and their cargo-handling efficiency. Ro-ro ships and ro-pax combination vessels provide faster services with higher cargo carrying capacity. This not only supplements deep sea shipping but also provides the possibility for door-to-door multimodal carriage solutions between points within Europe.

TEN-T was adopted by the EU in 1996, with the aim of removing obstacles to the implementation of the Single European Market through the creation of modern and efficient strategic transport infrastructure across the continent. European policymakers have recognised that the basic requirements for improved short sea shipping services are technical and infrastructural aspects, commercial aspects and political aspects.[12] The Motorways of the Sea initiative[13] was adopted as part of the TEN-T programme in 2004, with the following four principal aims:

(a) to encourage more efficient, cost-effective freight transport that is less polluting,
(b) to alleviate road congestion in Europe's strategic road network,
(c) to improve the connectivity of peripheral regions, thereby enhancing cohesion across Europe, and
(d) to assist in promoting economic growth in a more sustainable manner (UNECE, 2010).

The short sea shipping initiative is now part of the *Europe 2020 Strategy* which promotes a strategy for smart, sustainable and inclusive growth. It includes the implementation of strategic projects with a strategic European focus to address critical bottlenecks, in particular, cross border sections and intermodal nodes, i.e., cities, ports and logistic platforms.[14] For instance, the Netherlands has special short sea tariffs and terminals frequently offer 24/7 services. Spain has developed a major network of short sea ports. In March 2011, there were 72 regular services from 12 Spanish ports with direct connections to 53 foreign destinations (Burgess et al, 2012).

The EU has embraced the so-called "Blue Belt" concept, which aims at using technology, integrated maritime transport monitoring capabilities (notably SafeSeaNet) and best practices to facilitate intra-EU waterborne transport and to integrate it within seamless EU logistics chains. Under this initiative the "Blue Belt" ships, irrespective of their flag, can operate freely within the internal market with a minimum of administrative formalities.[15] The "Blue Lane" concept relates to the administrative, technological, and/or physical facilitations granted by ports and customs authorities with a view to ensuring a swift port transit of goods originating from the EU. This is still being refined for further advancement in close cooperation with the European Maritime Safety Agency (EMSA).[16]

The Commission is also closely monitoring the development of short sea shipping costs and, in particular, the possible distortions in the logistics chain and modal backshift from sea to land that may result from the expected initial higher costs for sea carriage generated by the use of low sulphur bunker fuels. However, the EU is supportive of the initiatives at the IMO to reduce sulphur content in bunker fuels and also in the development of an effective global policy framework for the reduction of CO_2 emissions from international shipping.

The EU has emphasised the need for a comprehensive approach to address intra-EU waterborne transport environmental issues and the Commission is tasked with proposing a "sustainable waterborne transport toolbox", i.e. a multi-dimensional action approach which could assist the sector to improve its environmental performance while maintaining its competitive position. The toolbox comprises the following components: alternative fuels such as Liquefied Natural Gas; green technology; adequate infrastructure; where appropriate,
possible economic and funding instruments such as the Ecobonus scheme and; research and innovation, all working at the international level wherever possible.

The aim of this report is to examine, from a commercial and legal standpoint, the evolution of EU shipping policy in the field of intermodal transportation especially focussing on short sea shipping. The report discusses the critical limitations and impediments to further growth of sustainable short sea services in the EU, and identifies a number of issues EU policymakers need to ponder upon. It also analyses some of the key issues which may further the development of short sea shipping in Europe.

7.2 Commercial Sustainability of Short Sea Shipping in the EU

Any discussion on sustainable short sea shipping from an economic perspective mainly focuses on its commercial sustainability. Existing research on the economic aspects shows that short sea shipping is viable in Europe because of the following advantages over other transportation modes:
(i) Two-thirds of industrial production capacity lies near the seacoast or inland water way network.
(ii) Transport by waterways does not suffer from restrictive hours of work as compared to other modes of transportation. This leads to higher utilization of the available assets.
(iii) Severe road and rail congestion in Europe has led to the imposition of road pricing schemes or limitations placed on access to the network.

(iv) Short sea shipping is highly energy efficient and has lower accident rates than road (Paixao and Marlow, 2002).

However, research also points out that short sea shipping is a disadvantageous mode from the shippers' perspective. The three main problems which hinder the growth of intermodal transport using short sea shipping are quality, price and coverage. More specifically, the disadvantages of using short sea shipping over other modes are as follows:

The movement of goods using intermodal transport is often slower, less reliable and complex. The shorter the distance, the less likely short sea shipping is competitive against the road mode on cost. The longer the distance, the less likely short sea shipping will be road competitive on transit time (Weisbrod, 2002).

(i) The transport chain, which forms part of the larger supply chain, is broken due to the lack of integration with the land modes at either end of the short sea service. This interoperability problem extends to information technology systems and documentary requirements as well which are largely due to the lack of modern laws.
(ii) Port charges are a significant factor in the competitiveness of short sea shipping. Strandenes and Marlow (2000) have suggested that ports seeking to improve short sea business might develop a differentiated port pricing policy that reflects the time-sensitive nature of the vessel; less time-sensitive short sea vessels might call at a discount relative to time-sensitive deep-sea or short-sea vessels, encouraging some modal switching and a better allocation of port resources (Strandenes and Marlow, 2000).
(iii) The higher transit time faced by shippers leads to increased inventory costs.
(iv) Short sea shipping is available in selected freight corridors only.
(v) Short sea shipping suffers from an image problem in Europe in that a difficulty is perceived in meeting the service and price requirements of shippers.

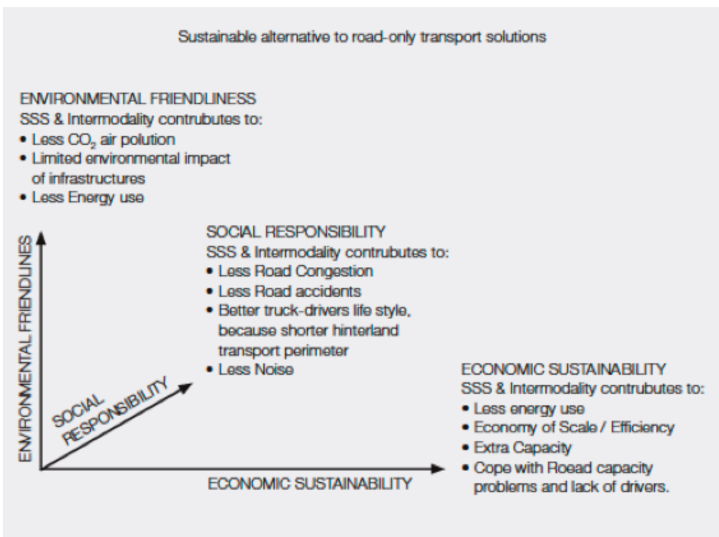

Figure 23: Short sea shipping as a sustainable alternative to road only transport solutions
Source: Adapted from MOSES (2008)

A study by the Port of Hamburg (2002) found that to make short sea shipping viable as part of intermodal transport in Europe, increased reliability, high frequencies, and short transit times have to be achieved in order to gain the benefits of reduced road congestion and reduced fuel consumption and pollution effects. This leads to the inference that short sea shipping will be economically viable only when road congestion reaches sufficiently severe levels that there is increased unreliability in land transport delivery times and/or that environmental savings are sufficient enough that customers are willing to pay for them.

In a Swedish survey in 1999 it was demonstrated that the increased costs of less environmentally damaging transport would be compensated for by good will and consumers' perceptions of the environmentally positive profile of the company (Laitila and Westin, 1999). However, a survey conducted as part of the EU-funded MOSES project points out that customers are not yet willing to engage gratuitously in environmentally beneficial solutions, even if they acknowledge the advantage of sea and intermodality in environmental protection.

Due to the importance of costs in freight transport selection, the MOSES project suggests expanding the environmental aspect to sustainability in general, including not only environmental, but also social and, not least, economic sustainability. Customers have more chance to be convinced by long-term sustainability and economic viability rather than by environmental friendliness alone. Therefore, when integrated in an intermodal transport chain, short sea shipping conveys a clear sustainability-benefit, and outperforms road only in all three different ways described in Figure 23.

The other critical question that largely remains unanswered is: where do the monetary benefits lie? Attracting finance for building new infrastructure to meet the requirements of short sea shipping will only be possible when this question is answered. Studies suggest that short sea shipping may yield savings up to 20% against land transport (Jonkman, 2002); however, the distributional consequences of these savings are not clear. Do the savings accrue to the European consumer as a net economic benefit, the carrier as higher profits or the cargo owner in terms of lower transport prices. Identifying the financial winners and losers is critical to understanding what can be done to influence the adoption of short sea shipping by shippers. Another associated problem from a financial perspective is that the cargo carrying capacity of short sea vessels is significantly greater than that of trucks, so much so that the capital cost of the transport equipment means that the short sea option is riskier to offer.

7.3 An Overview of the Legal Framework for Short Sea Shipping in the EU

The legal aspects of short sea shipping mainly comprises two components; one relating to the environmental regulations that govern shipping and the other concerning the facilitation of intermodal transport, which is related mainly to administrative and commercial law. It is notable that the environmental aspects of shipping are mainly regulated through convention law, primarily drawn up by the International Maritime Organization (IMO).[17] This report will not discuss this area of law in detail as most EU Member States are parties to the relevant IMO conventions and the EU has promulgated Regulations and Directives to effectuate those conventions within its jurisdiction. The report will instead focus on the evolution of the laws related to intermodal transport and short sea shipping, especially focussing on the liability aspects related to intermodal transport that involves a shipping leg and the associated interoperability problems which extend to information technology systems and documentary requirements.

The first legal instrument to address combined transport in the EU was Directive 75/130 adopted in 1975[18] which mainly concerned the transportation of goods by road/rail among Member States. This instrument has been subsequently amended a number of times. In 1977, one of the first measures in EC shipping law came through the Council Decision 77/587/EEC concerning the consultation procedure on relations between Member States and third countries in shipping matters and on actions relating to such matters in international organizations (Power, 1998). Furthermore, in the Opinion addressed by the Economic and Social Committee of the European Communities 1983, the Committee called for the Council and Commission to be guided by the consideration that intermodal cooperation in long-distance transport within the Community should be encouraged so that the technical and economic advantages of each mode can complement each other and the cost to the economy as a whole can be reduced (Economic and Social Committee of the European Communities, 1983). In September 1990, the Commission created a high level Working Group for the promotion of combined transport (Chlomoudis and Pallis, 2002). In 1992, Council Directive 92/106/EEC was adopted, concerning the establishment of common rules for certain types of combined transport of goods between Member States. This referred to problems regarding road congestion, the environment and road safety and, in the public interest, called for the further development of combined transport as an alternative to road transport.[19] It was stated that such measures must cover combined forms of transport, bringing together road and other modes of transport, such as rail, inland waterway and sea transport. In a Council Decision 93/628 on combined transport[20], maritime transport was included in the chain of combined transport that the Common Transport Policy was promoting. After having included maritime transport in that chain, an intention to integrate all networks, *i.e.* conventional rail, high-speed rail, ports, airports, other combined transport terminals etc., into a multimodal system was delivered in the Communication from the Commission.[21]

In 1997, through a Communication, the action plan for a sustainable, intermodal European transport chain was launched with the goal of developing a framework for an optimal integration of different modes so as to enable an efficient and cost-effective use of the transport system through seamless, customer-oriented door-to-door services whilst favouring competition between transport operators.[22] It is notable that in section 11 of the Communication, intermodal liability is mentioned as a key action. A definition for "intermodality" is provided as "a characteristic of a transport system that allows at least two different modes to be used in an integrated manner in a door-to-door transport chain". It is further stated in the Communication that "more intermodality means more integration and complementation between modes, which provides scope for a more efficient use of the transport system".[23] Thus, it is apparent that intermodality is not bound to certain modes. The subject of liability is addressed in section 4.10, paragraph 81 which stipulates that "the intermodal operators should be able to offer their customers a clear set of transparent liability conditions and procedures for any cargo that is damaged or lost in its journey", and that "the liability rules should not be mode-specific and should not distinguish between national and international transport". In paragraph 82 it is mentioned that the Commission has called for a working group of experts to examine the possibility of creating an intermodal liability concept. Although it is only a recommendation, this Communication sets the agenda for further action in terms of the development of intermodal transport and moves even further to look at legal issues such as liability.

Other documents that are worthy of mention in this connection include the Report entitled "The economic impact of carrier liability on intermodal freight transport"(European Commission, 2001b), an amended proposal for a Directive of the European Parliament and the Council on Intermodal Loading Units[24] and the Strategic Intermodal Research Agenda 2010-2030 (EIRAC, 2010).

At present there is no legally binding instrument on intermodal liability in the EU. However, the numerous documents, conferences at the EU, and consultations with stakeholders and academics indicate a clear intention to create such an instrument. In this connection, it is necessary to draw attention to the recently adopted *United Nations Convention on Contracts for the International Carriage of Goods Wholly or Partly by Sea* (otherwise referred to as the Rotterdam Rules) as an intended global solution to multimodal transportation within the framework of the maritime plus approach.

The European Council in a 2010 report agreed that the aim of the co-modality principle is to attain an optimal and sustainable utilisation of resources.[25] The Council acknowledged that the Rotterdam Rules addresses aspects of specific co-modal arrangements and invited the Member States to explore such aspects of the Rotterdam Rules. It is noteworthy that a number of maritime states, namely, Denmark, France, Greece, Netherlands, Spain, Sweden, Poland and Norway (as a member of the EEA), acting in their own national interests, have signed the Rotterdam Rules. In certain quarters within the EU, opinions were expressed that the Rotterdam Rules do not deserve to be supported because the Convention does not promote intermodal transport which includes all combinations of modes and that the EU should create a specifically designed regime to suit its needs (Greaves, 2009). Even before the UN General Assembly adopted the Rotterdam Rules in 2008, the European Commission had already started to consider the idea of creating liability rules for intermodal transport at a pan-European level[26]. Many stakeholders, academics and government officials were involved in that process to determine whether the global regime emanating from the CMI/UNCITRAL initiative would be suitable for intermodal transport in the EU.

A recent study commissioned by the EU reveals that there are two major strands of thought in the EU with respect to the Rotterdam Rules.[27] One strand, dominated by the maritime carriers, shipowners, liner shipping companies and leading maritime nations such as Denmark and the Netherlands, which urges for signature and the ratification of the Rotterdam Rules at a global level. Another strand, mainly dominated by shippers and short sea shipping operators, opposes the Rotterdam Rules on the grounds that they are considered to be biased in favour of carriers and, instead, supports the creation, in the short term, of a contractual regime based on the CMR (the United Nations Convention on the Contract for the International Carriage of Goods by Road), but implemented initially at a European level with the intention of fostering global uniformity in the long term. Amongst those stakeholders, many hold that the Rotterdam Rules do not promote the Motorways of the Sea initiative because it essentially addresses transoceanic trade on the basis of negotiable documents. It is submitted that, by its very nature, maritime transport is prone to be subject to global regulation, whereas inland transport is more suitable for regional agreements. Proof is the essentially "European" COTIF/CIM Rules and the CMR. Moreover, EU shipping law constitutes only a part of international shipping law and potential conflict between EU law and international shipping law will lead to fragmentation that is patently undesirable and not conducive to progress in shipping and international trade in the EU within a global framework.

7.4 Concluding Remarks

Sustainable economic growth depends on sustainable transport, which is a key driving force of the economy as is any other vital means of production. The development of an efficient and, in all aspects, sustainable transport and logistics network is of paramount importance for the future of the EU. The EU acknowledges that expansion of the transport and logistics network is severely hampered by the saturation of the inland transport network, which necessitates bringing to the fore a general policy that aims at the optimal use of the different available modes of transportation. This optimal use of different transport modes has not yet been achieved and, in particular, it is recognized that short sea shipping and inland waterway transportation has great potential in the optimization process. However, promoting the maritime mode would not be possible without strengthening the link with rail and inland waterway transport and also developing those modes to be better geared for co-modality with intra-EU maritime transport. The EU recognizes the necessity to optimize ports as key modal interfaces and work towards better co-modal logistic chains. Therefore, the development of ports with the involvement of the private sector is now considered to be a key element in revising the TEN-T policy. As part of the "European maritime transport space without barriers" initiative, a new Customs Regulation[28] and port formalities Directive[29] have been promulgated to facilitate intermodal transport and especially short sea shipping.

Looking at the liability aspects, multimodal transport within the EU is currently performed on the basis of either issuing a set of multiple transport documents per mode, or on the basis of a single transport document issued by a multimodal transport operator. Liner shipping carriers often make use of comprehensive insurance, whereas insurance is less common for rail or inland waterway carriers. The governing liability rules is an important determining factor for insurance pricing. As discussed in the earlier section of this report, whether or not the newly adopted carriage liability regime called the Rotterdam Rules, with its maritime plus scope, will be successful in Europe is a matter of calculated optimism at best and speculative pessimism at worst. If the Rules are rejected globally, then the EU will not hesitate to put into place its own regional instrument. What might be the scope of such an instrument is not yet known. In a contemporary context, EU shipping law is admittedly still in a state of relative infancy given that international shipping law through the instrumentality of conventions spearheaded by the CMI, and latterly the IMO, began to take shape over a century ago. The role of international conventions is a formidable one in terms of unification of maritime law and the influence exerted in the evolution and development of national legal regimes in the maritime field. The role played in recent times by the EU in the development and propagation of shipping law, albeit primarily in terms of European interests, is not to be disregarded. Recent EU projects that include the environmental consideration of transport activities are admirable and deserve due attention. However, regional law making and implementation should always take cognisance of international legal norms and the obligations of state parties to international conventions.

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Footnotes

[1] The three main types of marine fuel (bunkers) are most usually referred to as Heavy Fuel Oil (HFO), Intermediate Fuel Oil (IFO) and Marine Diesel Oil (MDO). HFO is the highly viscous residual fuel oil that remains after the more valuable cuts (or fractions) of crude oil have been boiled off during the refining process. MDO is the highest quality common marine fuel, being a gasoil distillate which, as distinct from ordinary diesel, contains some HFO. IFO is the medium quality of the three standard marine fuels and contains blended volumes of HFO, MDO and other lighter, higher quality fuel oils.

[2] These comprise 41 nations classified as 'industrialised countries and economies in transition', in addition to the European Union. A full list of the countries included under this definition provided by the United Nations Framework Convention on Climate Change can be found at: http://unfccc.int/parties_and_observers/parties/annex_i/items/2774.php

[3] The author is grateful for the valuable contributions of Karin Andersson, Mikael Johansson and Björn Södahl.

[4] The dominant GHG emitted by ships

[5] The impact of the economic crisis was a major justification for the recent decision taken at the IMO to conduct a new GHG study (MEPC 64/WP.1, p. 40): "the current estimate does not take account of the economic downturn experienced globally since 2009" (MEPC 64/5/5, Annex, p. 1). While the financial crisis had little impact on global CO_2 emissions, it might be different for the shipping industry. Trade collapsed in 2009 – trade volumes fell 17.5% between September 2008 and January 2009 (Gregory et al, 2010) – but have now recovered to pre-crisis levels. Recovery is uneven, however; with developing countries having exceeded these levels (particularly China and East Asia), while developed countries which saw the greatest drop in trade have still to catch up in terms of trade volume (UNCTAD, 2012). From the perspective of many investors, ship owners, ship operators and other stakeholders, this is much less than expected. A record delivery of new ships in 2010 (ordered in good times, well before the crisis), resulting in 8.6% growth in the world fleet that year, ensured that there is still an oversupply of shipping capacity compared to transport demand (UNCTAD, 2012). In total, the world fleet had by January 2012 grown by 37% in four years (UNCTAD, 2012). What this means for total CO_2 emissions does not seem entirely trivial.

[6] As indicated previously, different GHGs contribute to radiative forcing differently. The CO_2 equivalent is a normalized unit that is utilised to facilitate discussions on the combined impact of all GHGs, i.e. the total contribution if all gasses had been CO_2.

[7] In order to provide a basis for assessing impacts of future climate change, the IPCC (2007) developed various scenarios in an attempt to capture different possible world pathways. The main factors driving GHG emission growth were shown to be attributed to demographic and socio-economic development, as well as the rate and direction of technological change. The resulting scenarios are regarded by the IPCC as "alternative images of how the future might unfold and are an appropriate tool with which to analyse how driving forces may influence future emission outcomes and to assess the associated uncertainties" (Nakicenovic et al, 2000: p. 4). No single scenario should be regarded as being the most likely. Rather, policymakers and researchers are recommended to use a range of scenarios in their analysis.

[8] A simple way of explaining transaction costs is that these are the costs of "running the economic system" (Arrow, 1969), i.e. costs for searching for information, for establishing and monitoring contracts, for setting up and running internal organizations etc. In orthodox (neo-classical) economic theory, transaction costs are assumed to be zero. Furubotn and Richter (2005) provide a good introduction to the concept.

[9] In this context, costs are taken to be fuel, time charter and cargo costs.

[10] However, GHG emissions first appeared on the IMO's agenda as early as 1991. It was then argued by the UK delegation that "consideration should be given to accurate monitoring and forecasting of carbon dioxide emissions from shipping and the difficulty of allocating responsibilities to individual states" (report from the BCH-subcommittee, MEPC 32/12, quoted in Strong (2011)).

[11] The European Commission in its aim to promote short sea shipping has committed vast sums of money to research and subsidy programmes since the 1990s which resulted in hundreds of studies being completed under the direction of the Concerted Action on Short Sea Shipping initiative. The Pilot Action for Combined Transport (PACT) programme, introduced in 1992, financed several projects during the period 1992–2000 (European Commission, 2001a). The Marco Polo programmes, which superseded PACT in 2001, provided further financial assistance to develop short sea shipping services.

[12] Shorter turnaround time in ports, more efficient customs operations and administrative procedures and more favourable port pricing are some of the technical and infrastructural aspects; better integration of short sea shipping in supply chain practices, which includes data and information systems, frequency, reliability, etc. relates to the commercial aspects and; policies to internalize the external costs of transport modes, the ending of discriminative treatment by customs procedures of inner-EU shipping in favour of overland traffic, the harmonization of rules for land and sea carriage of hazardous goods are all considered as some constituents of the political aspects.

[13] Motorways of the sea are key sea routes between EU Member States, offering regular, high-quality services, which, combined with other transport modes, provide an efficient alternative to road-only transport. The EU is currently supporting the development of motorways of the sea in four key corridors: the Baltic Sea, Western

Europe, South-Western Europe and South-Eastern Europe (European Commission, 2013).

[14] For further details, see the Commission Communication and the Council conclusions on the strategic goals and recommendations for the EU's maritime transport policy until 2018, Doc. COM(2009) 8 final and Council conclusions of 30 March 2009 (doc. 7866/09); the Commission Communication and action plan and the Council conclusions on establishing a European maritime transport space without barriers, Doc COM(2009) 10 final and Council conclusions of 30 March 2009 (doc. 8079/09); the Commission Communication on a European Ports Policy, Doc. COM(2007) 616 final; the Commission Communication on Freight Transport Logistics Action Plan 5, Doc. COM(2007) 607 final; the Commission Communication on the first progress report on the implementation of the NAIADES Action programme for the promotion of inland waterway transport, Doc. COM(2007) 770 final.

[15] The European Commission is analyzing possible legal amendments to resolve the issue related to national customs authorities. See, Report from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, Progress of the EU's Integrated Maritime Policy, COM (2012) 491, final at pp. 7-8.

[16] See ibid.

[17] There are twelve IMO and two non-IMO conventions which deal with marine pollution from ships. They are - Intervention Convention 1969, Dumping Convention 1972 and its Protocol of 1996, MARPOL 73/78, Salvage Convention 1989, HNS Convention 1996 and its Protocol of 2010, OPRC Convention 1990 and OPRC-HNS Protocol of 2000, CLC 1992, FUND 1992 and Supplementary Fund Protocol of 2003, AFS Convention 2001, Bunkers Convention 2001, BWM Convention 2004, SRC 2009, UNCLOS 1982, Basel Convention 1989. Status of IMO Conventions is available online at http://www.imo.org/About/Conventions/StatusOfConventions/Pages/Default.aspx.

[18] Council Directive of 17 February 1975 on the establishment of common rules for certain types of combined road/rail carriage of goods between Member States (75/130/EEC) with further amendments.

[19] Council Directive 92/106/EEC of 7 December 1992 on the establishment of common rules for certain types of combined transport of goods between Member States, OJL 368, 17/12/1992, at p. 38-42.

[20] Council Decision 93/628/EEC of 29 October 1993 on the creation of a trans-European combined transport network.

[21] "The development of guidelines for the trans-european transport network", Communication from the Commission COM (93) 701 final.

[22] The Communication entitled "Intermodality and intermodal freight transport in the European Union - A systems' approach to freight transport - Strategies and actions to enhance efficiency, services and sustainability" consists of 5 chapters, chapter 1 of which concerns the concept of intermodality, chapter 2 is about logistics, chapter 3 relates to the obstacles to the use of intermodal freight transport, chapter 4 in on Europe's intermodal freight transport system and finally, chapter 5 addresses issues of intermodality and other policy areas. It is the first comprehensive document which addresses intermodal matters within the EU and calls for an integrated approach to the development of intermodal freight transport. See "Intermodality and intermodal freight transport in the European Union - A systems' approach to freight transport - Strategies and actions to enhance efficiency, services and sustainability", Communication from the commission to the Council, the European Parliament, the Economic and Social Committee and the Committee of the Regions, COM (97) 243 final.

[23] Council Decision 93/628/EEC of 29 October 1993 on the creation of a trans-European combined transport network, section 16.

[24] COM (2004) 361 FINAL.

[25] See "Draft Council conclusions on full integration of waterborne transport into the EU transport and logistics chains", Doc. 16266/10 TRANS 329 MAR 121, 19 November 2010 available online at http://register.consilium.europa.eu/pdf/en/10/st16/st16266.en10.pdf

[26] See TREN/CC/01-2005/LOT1/Legal assistance activities. Study on the details and added value of establishing a (optional) single transport (electronic) document for all carriage of goods irrespective of mode, as well as a standard liability clause (voluntary liability regime), with regard to their ability to facilitate multimodal freight transport and enhance the framework offered by multimodal waybills and or multimodal manifests. Final report. available online at:
http://ec.europa.eu/transport/strategies/studies/doc/2009_05_19_multimodal_transport_report.pdf.

[27] See "Study On The Details And Added Value Of Establishing A (Optional) Single Transport (Electronic) Document For All Carriage Of Goods, Irrespective Of Mode, As Well As A Standard Liability Clause (Voluntary Liability Regime), With Regard To Their Ability To Facilitate Multimodal Freight Transport And Enhance The Framework Offered By Multimodal Waybills And Or Multimodal Manifests", Final Report, TREN/CC/01-2005/LOT1/Legal Assistance Activities, pp. 9-10, 182-184.

[28] 11 OJ L 145, 4.6.2008, p. 1.

[29] Directive 2010/65/EU of the European Parliament and of the Council of 20 October 2010 on reporting formalities for ships arriving in and/or departing from ports of the Member States and repealing Directive 2002/6/EC, OJ L 283 of 29.10.2010, p. 1.

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