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COUNCIL
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ENVIRONMENTAL AND CLIMATE CHANGE ISSUES IN THE SHIPBUILDING INDUSTRY

This report is submitted for consideration by the Council Working Party on Shipbuilding at its meeting on 2-3 November 2010.

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Summary

This report examines a number of environmental, climate change and sustainable development (green growth) issues that are affecting the shipbuilding industry.

The report notes that like other heavy fabricating sectors shipbuilding involves the use of materials and manufacturing practices that can impact on the environment, can contribute to climate change. The report also points out that as well as the construction phase ships can have such impact throughout their lives (which can extend to 30 or more years), and during their disposal.

Taking a holistic approach to ship construction could give the shipbuilding industry the opportunity of not only setting its own environmental agenda (rather than be forced by government or public pressure) but to also deal with such impacts more effectively, and perhaps even benefit commercially from associated innovations.

Action

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ENVIRONMENTAL AND CLIMATE CHANGE ISSUES IN THE SHIPBUILDING INDUSTRY

POLICY OVERVIEW

Background

1. This report was prepared for the Council Working Party on Shipbuilding by Mr. Karsten Olsen, a consultant who has worked at the OECD dealing with sustainable manufacturing issues. Mr. Olsen has also prepared a similar report on behalf of the Steel Committee.

Government and industry involvement

2. In recognition of the growing importance of environmental and climate change issues in both government policy and commercial decision making, the Secretariat tried to involve WP6 members, non-OECD economies, international organisations and industry in the project by seeking submissions on the study, so that it could reflect the situation facing the shipbuilding industry in the most accurate way possible.

3. Regrettably the response from governments and industry was very muted, and only a small number of inputs were received (and crucially none from the shipbuilding industry itself), even though a number of reminders were sent to potential participants. Those submissions that were received are listed at the end of the report, and the Secretariat would like to express its appreciation to those respondents.

Report Objectives

4. The broad objective of this project was to identify issues related to the environment, climate change (and where appropriate green growth and sustainable development) that are relevant to the shipbuilding sector, and to discuss the implications of these for the industry.

5. The study addresses both the positive and negative aspects of the role of the shipbuilding industry on the environment, global climatic change and sustainable development, and the consultant was asked to address the following aspects:

- A broad description of the types of activities, materials emissions products and practices that could impact (positively or negatively) on the environment, climate change and sustainable manufacture.
- An analysis of the impacts of shipyard activities on their immediate surroundings.
- An analysis of the impact of materials, components and practices used in the shipbuilding process (for example the carbon footprint associated with the production, transportation and final disposal of materials used in ship construction).

- Positive aspects of the shipbuilding industry that reduce or minimise the impact of their activities and products on the environment and climate change, and/or which support sustainable manufacturing.

Key Findings

6. The Secretariat suggests that the following are key findings of the report which may be greatest interest to the Working Party.

- While government and public attention is increasingly focused on the environmental, climate change and green growth impacts of industrial activities, there seems to be little apparent awareness of this in the shipbuilding sector, and there appears to be considerable reluctance by both governments and industry to discuss these issues.

- There is very little publicly available information that relates specifically to the shipbuilding sector, that that while the problems and hazards associated with materials and practices used at shipyards are well known, the actual impacts of the shipbuilding activities are not.

- The potential impact of emissions from shipbuilding operations on their immediate environment can be very significant, especially given that shipyards are inevitably near and on water, which increases the likelihood of propagation of some of those emissions.

- Ships are built to last for a very long time (up to 30 or more years) and their environmental and other impacts do neither start nor end when the ship leaves the shipyards in which it was built. After its construction ships will continue to have impacts throughout their operational lives, and right through until their final dismantling.

- However, there is resistance from the various maritime sectors (shipbuilding, ship operators and vessel recyclers) to deal with ships through "life-cycle" thinking, which would permit a more effective way of minimising the impacts from ships throughout their life.

- As well as providing a way of more effectively dealing with environmental and other issues, such an integrated approach may also offer commercial opportunities for shipyards to offer innovative solutions to their customers.

- As a mode of transport shipping is a relatively energy efficient way of moving goods, which should ship builders and ship operators an advantage in both offering efficient transport and meeting their respective environmental and associated responsibilities. However, shipping has a very low profile in both government and public consciousness, and the only negative news seems to be ever associated with the sector (such as major oil spills).

- While this lack of external focus may have helped the shipbuilding sector maintain a low profile, as public and government awareness inevitably focuses on the industry, there is a danger that the shipbuilding industry will not be able to set its own agenda on dealing with these issues, and may find itself subject to measures that may be draconian and perhaps inimical to the industry.

Issues for Consideration

7. The Working Party may wish to address the following issues during its consideration of the consultant's report:

- The report highlights a large number of materials and practices used by shipyards that can have significant environmental, climate change and other impacts. Do the shipyards take adequate precautions to minimise or eliminate those risks?

- Are governments sufficiently aware of those impacts, and do they have adequate reporting requirements and other regulations in place to be sure that everything that can be done is being done?

- What is the view of Delegates regarding the suggestion made by the consultant that a "life cycle" approach to ships would provide a more effective (and perhaps a more commercially viable) way of dealing with the impacts of ships throughout their life?

- Would such a life-long approach be an effective way of dealing with the significant problems that are becoming evident in ship recycling activities, and would this offer a way of complementing the IMO's ship recycling convention if and when that comes into force?

- Would the Working Party be interested in circulating the report to the shipbuilding industry, the shipping industry and (if contact can be made) with the ship recycling industry in order to hear of their reaction to the report?

- The WP6 has given the follow up study to this report (Environmental/Green Growth best practices) a relatively high priority for 2011-12. Can WP6 members give some assurance that they will participate more actively in that study in order to strengthen its analysis, especially as it will deal with "best practices"?

ENVIRONMENTAL AND CLIMATE CHANGE ISSUES IN THE SHIPBUILDING INDUSTRY

EXECUTIVE SUMMARY

The direct environmental impact of shipbuilding, which concerns the construction, maintenance and repair of ships, constitutes a major challenge to the industry. Also, while not being directly responsible for the impact on the environment from the operation and final recycling of commercial ships, shipbuilding is an integral part of these activities and therefore a key player for improving the environmental performance of the industry as a whole. The need for stepping up such efforts is growing as the environmental impact of the industry is becoming increasingly visible in the public domain.

From the perspective of climate change, ships offer many advantages due to their high energy-efficiency in transporting goods. However, the emission of greenhouse gases from this source is projected to increase by large amounts over the coming years. In addition, the shipbuilding industry suffers from significant environmental concerns in many other areas. Discharge of hazardous contaminants to waterways, marine ecosystems and food chains can be attributed to many activities in the industry, with risks of environmental damage generally being elevated by the industry's open air working environments and water front locations, as these provide direct pathways for pollutants to reach air, soil and water.

In general, there is inadequate information available for drawing a comprehensive picture of the shipbuilding industry's environmental impact; thus demonstrating a clear and timely need for greater environmental focus and transparency in the industry. In many cases, this need is exacerbated by the fact that many shipbuilding and ship recycling activities are conducted in countries where health, safety, and environmental regulations and enforcement are lax.

While there is no suggestion that shipbuilding is directly responsible for environmental, climate change and green growth concerns that may involve the use and final recycling of ships, which of course occur outside of the boundaries of the shipyards, it is suggested that there may be advantages to the shipbuilding industry to take a greater role as an integral part of the overall industry through a "life-cycle" approach to ships. This would demonstrate to governments and the public that the shipbuilding industry is ready to accept its environmental and related responsibilities.

Failing this, as public and government awareness focuses on the industry, there is a danger that it will not be able to set its own agenda on these issues, and may find itself subject to measures that may be draconian and perhaps inimical to the industry.

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1. INTRODUCTION

1. Shipbuilding, and its associated activities, is of tremendous importance to the functioning of the world economy, with ships accounting for the transportation of 90% (by volume) of internationally traded cargo (ICS, 2009) and thus constituting the backbone of world trade. Despite this importance, the industry's environmental credentials are relatively unknown in the public domain, and apart from some catastrophic oil spills there has been little focus on its environmental impact; especially when compared to other industries such as the air and ground transportation sectors.

2. Nevertheless, recent developments point to the growing importance of the shipbuilding industry's environmental agenda. This is mostly apparent with the rising urgency and concern over issues related to climate change[1] in the shipping sector (IMO, 2008a, 2009c), but it is also evident in the ship recycling sector where work by both environmental and human rights organisations have demonstrated a number of serious health, safety, and environmental problems. So far, the environmental impact of ship construction itself has been relatively unnoticed by the public; but given rising concerns over such impacts from shipping and ship recycling, not to mention from industrial production in general, it is likely that pressure for better environmental performance in the shipbuilding industry as a whole will grow.

3. Notionally, the environmental impact of shipbuilding is by no means small. The building of ships depends on a large number of processes which by themselves constitute significant risks of damage to the shipyards' surrounding environment and which lead to significant emissions of greenhouse gases. In addition, shipbuilding uses some materials which not only may carry serious implications for environmental harm during their production and usage in the ship construction process, but also subsequently during ship repairing, operation, and recycling activities.

4. One of the primary areas of focus in terms of the shipbuilding industry's environmental impact is climate change. Climate change has long been on the political agenda, but little is known about how much the industry contributes. In fact, lack of information on matters such as the industry's emissions of greenhouse gases extends to virtually all other potential environmental impacts of the industry, including discharge of wastes, emissions of pollutants to air soil of water, and the consumption of energy and raw materials.

5. At the same time, it must also be acknowledged that the shipbuilding industry provides for one of the most energy-efficient modes of transportation. For example, compared to other forms of transportation its CO_2 emissions are much lower per weight of goods carried. This is of considerable importance concerning issues of climate change; especially when bearing in mind the enormous role that ships play in international trade.

6. Nevertheless, the CO_2 emissions of shipping are projected to rise considerably in the future, and the shipbuilding industry cannot neglect taking urgent action to mitigate its contribution to climate change. A similar comment can be made about other environmental and "green growth" challenges faced by the industry.

7. The concept of "green growth" is particularly important for any industry, as it implies the ability to increase economic activity or output while lowering, or eliminating, environmental impacts. This will be an imperative for any future industrial activity and will naturally demand intricate environmental knowledge pertaining to all associated processes.

[1] Today it is widely acknowledged that particular greenhouse gases are responsible for potentially detrimental changes to the planet's climate.

8. However, little is currently known about the shipbuilding industry's actual environmental impact, and it remains extremely difficult to paint a comprehensive picture of this impact, let alone establishing its magnitude. By itself, this difficulty highlights a timely need for the industry to increase the openness and transparency of its environmental profile and performance, before it is forced to do so by public and government pressure. This also indicates the difficulty of establishing more precise and encompassing environmental analyses of ships, i.e. including issues arising from raw materials, construction, shipping, and dismantling, which essentially prevent shipyards from taking cost-effective actions that could help to improve the environmental performance of the industry as a whole.

9. To get a clearer picture of the situation, and to provide a basis for more detailed and specific analysis, this paper aims to identify and outline the major environmental and climate change issues in shipbuilding. In this context, this study takes a relatively "holistic" view of the shipbuilding industry, and looks beyond the simple act of constructing ships. The reason for this is that while shipbuilding is not directly responsible for the environmental impact of raw material production, shipping, or ship dismantling and recycling, the construction of ships can, from an environmental perspective, be intricately linked to these associated activities.

10. Taking this form of interdependence as a starting point, the paper will set out by outlining a conceptual framework for viewing the environmental impact of industrial activity and how it applies to shipbuilding. From this context, the paper will turn to the various environmental challenges faced by that shipbuilding, including issues related to raw materials, shipping, and ship dismantling and recycling activities.

11. It is hoped that this approach will minimize the inclination for the industry in its broadest sense to adopt a "silo" approach, where each simply looks at its own activities, without any thought as to how their decisions could subsequently affect downstream activities, and their impacts on the environment, climate change and green growth.

2. CONCEPTUAL FRAMEWORK

12. The growing attention given to the environmental impacts of industrial activity has been an ongoing trend for some decades, particularly since the early 1980s when the idea of sustainable development gained ground (IUCN, 1980). Over the years, the development of strategies for ensuring better environmental performance has likewise evolved; firstly as merely being concerned with diluting pollution, later with a stronger focus on pollution control and prevention measures.

13. More recently greater attention has been given to minimising the sources of pollution, and to integrate environmental thinking more thoroughly into the structure of industrial production (OECD, 2009). Among other things, this development has led to new and innovative ways to both analyse and organise production processes to reduce or eliminate environmental pollution; some of which also could play a significant role in improving the environmental performance of the shipbuilding industry.

14. One of the most widely used tools for applying a more integral environmental approach with regards to industrial activity, has been the introduction of life-cycle thinking (OECD, 2009). This approach to industrial production has led to the development of so-called life-cycle assessment or analysis methods (LCA) which can be of considerable importance for reducing the environmental footprint of products, companies and industries alike.

15. As the name suggests the aim of LCA is to evaluate the environmental impact of a product or a process throughout its entire lifespan. This constitutes a method by which the significance and magnitude

of environmental harm can be assessed across a large number of areas, i.e. starting from the materials used to produce the product, the construction processes, the product usage, as well as the product retirement.

16. From a business perspective, the life-cycle approach is of significance because it provides a measure by which companies can identify cost-effective or even profit generating ways to improve their environmental performance. Furthermore, the life-cycle approach is very important from an environmental perspective because it acknowledges that environmental pollution knows no boundaries. For example, thinking of the environmental impact of a product in terms of its life-cycle highlights the interdependent nature of environmental responsibilities, by drawing clear links between the design, development and construction of products, the use of raw materials, the product's final usage and eventual retirement.

17. The life-cycle philosophy and resulting approaches to environmental management have also laid the foundation for a range of relatively new production and business models, some of which take a highly proactive approach for the conservation of the environment. These methods signal a movement toward sustainable manufacturing, which can be defined as:

the "creation of goods and services using processes and systems that are: non-polluting, conserving of energy and natural resources, economically viable, safe and healthful for workers, communities, and consumers, and socially and creatively rewarding for all working people" (Nasr and Thurston, 2006).

18. In its application, sustainable manufacturing goes beyond the "cradle-to-grave" perspective of the life-cycle approach, adhering to a more holistic "cradle-to-cradle" concept.

19. An indication of the trend toward more integral ways of approaching the environmental impact of industrial production is given by the emergence of the concept and voluntary practice of corporate social responsibility (CSR) across industries; including shipbuilding. Through CSR, companies declare their commitment to take social and environmental responsibilities that go beyond legal requirements, and beyond impacts directly associated with internal operations. Even if such practices in many cases appear uncoordinated and unclear, they are still seen as important drivers for change (OECD, 2009).

Life-cycle thinking in shipbuilding

20. Nevertheless, the encompassing nature of life-cycle thinking also constitutes one of the main obstacles for implementing the concept in industry, particularly because it demands that companies look beyond conventional organisational boundaries when considering the environmental impacts of their activities. This is of high relevance to shipbuilding as it appears to be a classic example of an industrial activity with environmental, climate change and green growth boundaries tightly drawn around the act of construction, and with little consequent acknowledgement of impacts outside of those boundaries.

21. Despite this resistance, it is suggested that adopting a life-cycle approach could be a crucial step towards the implementation by the shipbuilding industry of a more integrated environmental focus. In the first instance this would necessitate that ship constructors not only pay respect to the environmental impacts that arise from the construction processes undertaken at shipyards, but also the environmental effects of the raw materials used for ship construction, the shipping operations themselves, as well as the dismantling and recycling activities at the end of a ship's life.

22. It is suggested that these aspects should be taken into account - at least in as far as such effects are possible to address through the shipyards' design and construction processes.

23. By the same token, ship buyers would also accept greater responsibility by requesting the use of environmentally sound practices when placing their orders for ships, for example in areas such as material usage, construction methods, and ship designs. In turn, ship dismantling enterprises could take greater

environmental responsibility by sharing information about their dismantling and recycling practices, and otherwise work with constructors on how to reduce the environmental and related impacts of the dismantling/recycling process.

24. It is clear that the implementation of a full-fledged life-cycle approach in the shipbuilding industry would not be an easy task. The process goes well beyond environmental management systems (EMSs), which to some extent have been implemented by the industry[2], and demands greater information sharing and collaboration between input manufacturers, construction yards, shipping companies, ship owners and dismantling and recycling yards.

25. Perhaps more importantly, there is a need for a shift in the prevailing industry culture from one where environmental factors are mostly seen from a perspective of inevitable burdens that disturb the industrial process and which incur higher operating costs, to one that is associated with innovation, competitiveness, and profit (i.e. see Wolska and Namiesnik, 2007). This perspective is of particular importance when considering that new ships and construction processes are likely to be perceived as more complex and costly to develop when compared to existing practices, designs and classes of ships.

26. Despite these difficulties, it is suggested that the shipbuilding industry should start looking beyond its own borders when assessing the environmental impacts of its operations. A demonstration of this can be found in the growing disquiet about factors that could contribute to climate change. Although most of the focus on climate change in the broad maritime sector so far has been attributed to the operation of ships, the focus is likely to broadening and shipbuilding itself will inevitably be brought into that equation—especially, as this study suggest, because many of its practices are themselves significant sources of greenhouse gas emissions.

27. Following this logic, taking action on climate change issues provides the shipbuilding industry with the possibility of moving toward a life-cycle environmental approach with respect to its operations. An entry-point for the industry to do this would be to embrace the carbon footprint concept, which is essentially an assessment of the greenhouse gases that can be attributed to a particular unit such as a ship, a shipyard, or the shipbuilding industry as a whole.

28. Carbon footprints vary in terms of scope, ranging from a narrow focus that only includes GHG (Green-House Gas) emissions that can be attributed to a shipyard's own construction processes, to more encompassing perspectives, which could also include GHG emissions from the use of raw materials, as well as those that can be attributed to the operation of ships, and their final dismantling and recycling. Such an approach would be more in line with the life-cycle philosophy.

29. While a broader measure of the carbon footprint attributed to shipbuilding would not necessarily provide a total understanding of the industry's broader environmental impact, it would nevertheless be a good way to initiate collaborative efforts between various partners associated with the shipbuilding sector. Not only would this be a significant contribution to a much better understanding of the industry's impact with respect to climate change, it would also be helpful in identifying areas for better environmental performance beyond the shipyards' own operations; for example by shedding light on how shipbuilding can help to enable greater efficiency and lower CO_2 emissions in shipping.

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2 The implementation of EMSs in shipbuilding is supported, for example, by a number of industry guidelines such as the "EMS implementation Guide for the Shipbuilding and Ship Repair Industry" which is developed by the EPA in the United States in collaboration with the American Shipbuilding Association and the Shipbuilders Council of America.

3. CONSTRUCTION, MAINTENANCE AND REPAIR

30. The most direct environmental impact from shipbuilding is naturally incurred by the shipyards' own activities, which apart from the construction of ships typically also include ship maintenance and repair services. Each of these processes is a major undertaking in its own right and includes a large number of intermediate steps. For shipbuilding these would include the:

- handling of raw materials; fabrication and surface treatment of basic steel parts;
- joining and assembly of fabricated parts into blocks;
- erection of ship structures through the fitting and welding of blocks;
- outfitting of ships with electronic equipment; and
- preparation and installation of various fabricated parts that are not of a structural nature.

31. Maintenance and repair activities typically include:

- surface cleaning and treatment operations;
- oil transfer operations; and
- servicing of machinery and other equipment.

32. The industry is also highly energy-intensive, with most of the energy consumption covered by electricity, the production of which has its own environmental and climate change impacts. While there is sometimes little choice for shipyards in their sources of electricity, where renewable energy sources are available these should be considered by the shipbuilders.

33. Construction, maintenance, and repair activities involve the generation and daily handling of a large number of toxic materials, fumes and fluids. Metal work and surface treatment operations, for example, generate particulate matter (PM) emissions and may lead to the discharge of toxic compounds to soil and water. Routine maintenance activities generate waste engine fluids, such as oil, hydraulic fluids, lubricants, and anti-freeze. Fuelling activities generate waste liquids and vapour releases to the air. The extensive use of underground storage tanks likewise carries the risk of the release of pollutants that can harm aquatic life. Bilge and ballast waters are additional waste streams are that contain oil, solvents and other hazardous substances.

34. Moreover, due to the size of ships only a few shipyards have the capability of constructing, maintaining and repairing vessels under cover. Like other outdoor construction zones this leads to elevated risks of exposing the surrounding environment to potential pollutants. However, for shipyards this risk is further exacerbated by the fact that shipyard activities happen over, in, under or around water, which creates additional pathways for exposing waterways to toxic and hazardous materials; either directly or through runoffs, also known as stormwater.

35. The activities in shipbuilding that are of highest direct environmental concern include:

i) metal working activities, including thermal metal cutting, welding and grinding;

ii) surface treatment operations, including abrasive blasting, coating and painting;

iii) ship maintenance and repair activities, such as bilge and tank cleaning; and

iv) noise.

36. In terms of raw materials, the use of steel is naturally of major importance in the shipyards' metal working activities, whereas the use of abrasive agents and coating material are of high importance during surface treatment operations.

Metal working operations

37. Shipbuilding is a basic metal industry and depends heavily on the use and forming of steel, at least with respect to the construction of larger ships, while smaller ships and boats can be constructed of aluminium, wood or composite materials such as fibreglass. Base materials include iron-containing steel (i.e. carbon steel) and non-iron-containing metals. Various grades of mild and high strength steel are used for the structural framework of most ships, while aluminium and other non-iron-containing materials are used for some superstructures and other areas with specific requirements for corrosion resistance.

38. Metal working operations include the cutting, pressing, boring, milling, grinding and assembly of metals and include the use of cutting oils and lubricants to cool high-speed tools and high-temperature operation techniques. Solvents, which are frequently used to clean/degrease parts and tools prior to and after machining, can lead to fugitive air emissions. Metal working operations generally lead to major residual wastes including cutting oils, lube oils, and degreasing solvents, as well as metal shavings and chips. Wastewater containing cleaning solvents and other pollutants is also generated.

39. The cutting and welding of metals are among the most important activities in shipbuilding as they form the basis for erecting the structure of the ships. Together with abrasive blasting and the application of marine coatings (see section: *Surface treatment*), they are also among the most energy-intensive processes of shipbuilding. Depending on the circumstances, cutting and welding operations use oxyfuel, plasma, laser and/or water jet technologies. A significant amount of the time spent on body construction is also spent on removing distortions in the hull.

Thermal metal cutting

40. Thermal metal cutting is a process used to slice metal by using very high temperature techniques. The process typically includes oxyfuel gas cutting and plasma arc cutting. More recently, new techniques for metal cutting have been employed using laser and water jet technologies to better avoid distortions in the metal generated by the thermal cutting processes.

41. Oxyfuel gas cutting, also often known as flame cutting, is used to slice through metal using high-temperature exothermic reactions of oxygen with the base metal. The oxygen stream performs the actual cutting. Environmental concerns from this process include emissions of PM and hazardous air pollutants associated with the fumes. Also, if the purity of the oxygen used for cutting is not high enough (99.5% or higher) the cutting efficiency can be significantly reduced, leading to longer cutting times and therefore increased emissions (EPA, 2005a).

42. Plasma arc cutting uses a constricted electric arc to melt a localized area of the metal, removing the molten material with a high-velocity jet of ionized gas issuing from the constricting orifice. Like the oxyfuel gas cutting process, this occurs at very high temperatures ranging from around 10 000 to almost 14 000 degrees centigrade (EPA, 2005a). During operations, plasma arc cutting generates significant amounts of metal oxide fumes and other pollutants.

43. The composition of the pollutants from thermal metal cutting operations varies significantly with the metal being cut, as well as with its coating. Cutting of carbon steel, for example, results in the emission of iron oxides; galvanized steel forms zinc oxides; stainless steel forms chromium and nickel, and some metal alloys emit cadmium.

44. The fumes generated by thermal cutting are also affected by the coating on the metal alloy that is being cut. These coatings can contain a number of different heavy metals and organic compounds (see section: *Coating and painting*) that can add substantially to both the load and significance of the pollutants that are being emitted from the cutting process. In many cases, this source of pollutants is the largest environmental concern of the cutting process, and can lead to emissions of manganese, nickel, chromium, cobalt, and lead. These particulates can be deposited on surfaces around the work area, where they are prone to contribute to the shipyard's stormwater pollutant loading.

45. The effects of fumes and emissions from the use of various fuel gases with respect to both oxyfuel gas cutting and the plasma cutting process are not well-known. However, in the case of oxyfuel gas cutting there is evidence that the use of gases contributes to heightened risks of health and safety hazards. The gases may also lead to significant emissions of carbon monoxide (CO) (EPA, 2005a).

Welding operations

46. Once the steel plates have been cut into the desired shapes and sizes, they are welded together to build the structure of the vessel. Welding takes place at almost every area of the shipyard. Advanced techniques of laser welding are being developed to increase the accuracy, depth and range of welding, but this method is not yet in common use.

47. The welding process involves bonding metal components together by heating adjacent surfaces to exceedingly high temperatures and fusing them together with molten filler. The adjoining areas are heated by an electric arc or gas flame and fused together with molten weld fill metal in the form of an electrode, wire or rod. Among the many welding techniques in shipbuilding, electric arc welding is by far the most popular (ILO, 1996) and emits the most substantial quantities of harmful gases (EPA, 1995).

48. Emissions from welding include GHG, toxic chemicals, and "criteria air pollutants"[3] (CAPs) which include ozone (O_3), particulate matter (PM), carbon monoxide (CO), nitrogen oxides (NO_x), sulphur dioxide (SO_2) and lead (Pb) (EPA, 2008a).

49. At high temperatures molten metal fill reacts with oxygen and nitrogen to lose its intensity. In order to ensure strength in the weld it is vital to buffer the molten metal from the atmosphere with an arc shield. The addition of a flux, or gas, or combination of the two, facilitates the weld by removing the oxidization from the metals to be joined. During this process differing pollutant compounds are released depending on the electrode type, the base metal material, voltage, current, arc length, shielding gas, travel speed and welding electrode angle (EPA, 1995).

50. Welding is a key source of hazardous air pollutants and a major environmental concern. Toxic fumes attributed primarily to welding activities include manganese and chromium. Other hazardous metals identified in welding fumes include nickel, cobalt, lead, carbon dioxide, carbon monoxide, nitrogen oxides and ozone (EPA, 1995).

51. One way to minimise welding fumes is to employ capture and collection systems. Capture systems work to contain fumes as they are released. Such systems include welding booths, hoods, torch fume extractors, flexible ducts, and portable ducts. Following containment of the fumes, collection systems gather the chemicals through filters, electrostatic precipitators, particulate scrubbers, and activated carbon filters. With respect to greenhouse gases, electric arc welding consumes large quantities of electricity, hence shipyards can minimise their GHG footprint by obtaining their electricity whenever possible from renewable energy sources, or sources that do not burn fossil fuel.

3 The term "criteria air pollutants" is particularly used by the United States Environmental Protection Agency.

Metal grinding

52. Metal grinding is a type of machining process which uses an abrasive tool to grind a metal surface. This process discharges polluting PM into the atmosphere, both from the grinding tool and the substrate being ground. Pollutants are in the form of fugitive air emissions of metal dust and fumes, as solid waste and as metal dust and chips from waste grinding tools. Metal grinding requires electricity which generally is sourced from fossil fuel and therefore associated with GHG emissions.

53. Metal grinding is carried out either in the shop or in outdoor work areas using portable handheld grinders. These particulates are released during the abrasion process and like other outside shipyard activities these grinding operations have the greatest potential for emitting pollutants to the environment, directly to the air and soil as well as to waterways through stormwater runoffs.

54. Harmful pollutants are present in the abrasive tools and substrates in differing concentrations. Substrates may be significant pollutants, particularly if these are coated. Metal grinding materials such as grinding discs and grinding rocks are characteristically fabricated by attaching an abrasive element to a backing with chemical binders. Common materials for the abrasives in these tools are aluminium oxide, silicon carbide, and zirconium oxide. Less common components are manganese compounds, crystalline silica and zinc compounds (EPA, 2005b).

55. Various capture and collection systems help minimise environmental exposure by reducing pollutant loading during metal grinding processes. These include vacuum dust extractors, area containment (notably ground tarps and curtain partitions), and area ventilation dust collectors.

Use of steel

56. By quantity, the most important material used in the construction of larger vessels is steel. From an environmental life-cycle perspective, shipyards share an indirect responsibility for minimizing the impact attributable to the steel used in the construction of ships. This could be done through the establishment of “green supply” management strategies that would pay close attention to raw material extraction methods and the energy used to produce the steel. By collaborating with steel producers, environmental performance could also be improved by optimizing various properties of the steel itself.

57. Steel production is among the world’s most energy intensive industrial processes, and is generally associated with a number of environmental concerns, including the generation of large volumes of wastewater from cleaning and quenching operations, solid and hazardous wastes, emissions of various air pollutants and the generation of very large volumes of waste from mining activities (OECD, 2007).

58. The significance of the environmental impact of steel production nonetheless largely depends how the steel is produced, which can follow two main routes. The most common of these is the blast furnace/basic oxygen furnace (BF/BOF) route, which accounts for nearly two thirds of the world steel production. This process depends on virgin iron ore as well as coke, which is a material that is high in carbon and produced from hard coal.

59. Steel produced in this manner is therefore not only linked to GHG emissions and other pollutants from the iron and steel-making process, but also with a large number of environmental concerns associated with mining of both coal and iron ore (OECD, 2007). The second route, which is known as the electric arc furnace (EAF), depends mostly on scrap steel. This does not require the use of coke, and is generally more cost-effective and less environmentally damaging than the BF/BOF route. However, this route is also heavily dependent on the availability and price of scrap steel, and of course cannot replace the production of virgin steel from raw materials.

60. Several advancements to reduce the environmental impact of iron and steelmaking have been made over the past years. Alternative methods and new production techniques have eliminated many of the energy-intensive steps, reduced the need for coke in the BF/BOF process and led to lower emissions of air pollutants. However, many of these technologies are still being piloted, while other, more mature technologies are only being used by a small number of steelmaking plants. There are consequently large differences in the environmental impact of steel across steelmakers.

61. Another noteworthy advancement in steelmaking concerns the development of ultra-light and high-strength steel. Research into these types of steel was originally undertaken in collaborative efforts between steel and automakers, with the goal of reducing the weight of automobiles, and thereby lowering both fuel consumption and emissions. Similarly, the application of ultra-light and high-strength steel in shipbuilding offers considerable weight saving potential for ships and could also increase the resistance of vessel hulls to corrosion (Worldsteel, 2008). In terms of the shipbuilding industry's response to climate change, this could be of particular interest, especially as life-cycle analysis of ships suggests that fuel consumption during the life of the ship is the biggest contributor to the overall energy-related environmental impact of the industry (Hayman et al., 2000).

Surface treatment

62. Surface treatment operations take place during ship construction, as well as during various ship maintenance and repair activities. These include operations such as the cleaning and coating of steel, cleaning of hulls, tanks and cargo areas and painting and paint removal.

63. Surface treatment is among the most environmentally hazardous processes in the shipbuilding industry (OSHA, 2006). Cleaning and coating activities use chemicals that include heavy metals, solvents, copper, and hazardous or flammable materials, and are associated with emissions of lead, PM, volatile organic compounds (VOCs), zinc and other air pollutants.

64. Given the many VOCs and other air toxics that are discharged through surface treatments, many shipyards have installed Regenerative Thermal Oxidisers (RTO). Through high temperature thermal oxidation, RTOs can convert VOCs and hazardous air pollutants to carbon dioxide and water vapour while reusing the thermal energy generated to reduce operating costs. RTOs have proven to be a very efficient measure in dealing with VOCs as well as other hazardous air pollutants.

65. Specific concerns can also be linked to the use of anti-fouling paints. These paints, which are used on the hulls of ships to prevent build-up of marine organisms, contain highly toxic compounds. Also, because anti-fouling paints can reduce, but not prevent, the build-up of marine organisms, ships are periodically docked for treatment, involving hull cleaning, paint removal and the application of new layers of paints, which in turn leads to further risk of environmental damage. In addition, the metal-based paints that are used to protect ship surfaces from corrosion can contain up to 30% heavy metals (OSHA, 2006).

Abrasive blasting

66. Abrasive blasting is a treatment technique that is used to prepare surfaces for coating and painting. The technique is used both in the construction of vessels and during ship maintenance and repair activities. For construction, blasting operations concern the ship's piping, steel plates and other steel elements used in the structural assembly of the ship. During maintenance and repair activities, abrasive blasting is applied to the ship's hull, and interior tanks and spaces, to clean the surfaces from contaminants such as old paint and coatings, rust, mill scale, dirt, and salts.

67. The most common blasting technique is dry-abrasive blasting, which relies on compressed air to propel the abrasive material onto the surface at very high velocity. This "bombardment" results in a

breakdown of the abrasive materials, as well as of certain surface elements including rust and paint chips. This generates PM emissions, which constitute a major source of hazardous air pollutants. As abrasive blasting is most often done manually, the activity also poses significant health risks, both to those who conduct the blasting as well as to employees who work in the vicinity of the blasting areas. Blasting is also associated with elevated noise levels from sources such as air discharge, air compressors, impact of the abrasives, exhaust ventilation systems, and blasting cabinets (OSHA, 2006).

68. Moreover, blasting creates large quantities of wastes that consist of spent abrasives mixed with surface elements such as paint chips, oil and toxic metals. There is a risk of these entering waterways when shipyard areas are flooded or through runoffs, and can therefore pose a threat to the balance of surrounding ecosystems. Costs of cleanup and disposal of these wastes can be considerable, especially if the wastes are contaminated with hazardous paints.

69. The number and significance of toxic air contaminants produced by the blasting depends on the materials that are used as abrasive agents as well as on the surface that is being blasted (see Table 1). These abrasives, which can be categorized as *i)* metallic, *ii)* slag, *iii)* synthetic and *iv)* natural oxides, tend to vary with the blasting operation at hand. However, the most common materials generally include coal slag, copper slag, steel grit and shot, aluminium oxide, garnet, walnut shells, and silica sand.

Table 1: Potential air contaminants from dry-abrasive blasting

Source	Potential air contaminants
Base Material: (e.g. steel, stainless steel, galvanized steel, aluminium, copper-nickel and other copper alloys)	Aluminium, cadmium, chromium, copper, iron, lead, manganese, nickel, and zinc
Surface Coatings: (e.g. pre-construction primers, anticorrosive and antifouling paints)	Copper, barium, cadmium, chromium, lead, tributyl tin compounds, zinc
Abrasive blasting materials: metallic (e.g. steel grit, steel shot, etc.); slag (e.g. coal slag, copper slag, nickel slag); synthetic (e.g. aluminium oxide, silicon carbide); and natural oxides (e.g. silica sand)	Arsenic, beryllium, amorphous silica, cadmium, chromium, cobalt, crystalline, silica, lead, manganese, nickel, silver, titanium, and vanadium

Source: (Kura et al., 2006; OSHA, 2006).

70. However, some shipyards still include traditional materials such as quartz rock, river sand, and beach sand (also known as crystalline silica) in the abrasives. When blasted, these materials produce a highly toxic "silica" dust which, when inhaled, can lead to the development of silicosis which is characterised as a stiffening and scarring of the lungs, and which can result in death. For this reason, the majority of shipyards have moved to the use of non-silica abrasives such as coal slag and metallic grit and shot.

71. The environmental impacts of blasting can generally be reduced by the use of non-silica blasting agents as well as different blasting techniques (Kotrikla, 2009). In terms of blasting agents, several guides are available for selecting materials for shipbuilding activities. However, the choice is made difficult by the fact that different materials lead to different contaminants, and while certain materials may eliminate or drastically reduce silica dust, they may lead to higher levels of other hazardous air contaminants. For example, a study by the United States National Institute for Occupational Safety and Health (NIOSH), found that while the use of coal slag generated substantially lower levels of airborne crystalline silica compared to silica sand, the levels of arsenic, beryllium, cadmium, chromium, lead, manganese, nickel, titanium, and vanadium were two to four times higher (OSHA, 2006).

72. The level of heavy metals in non-silica abrasives can also vary considerably with the source of the abrasives. For example, abrasives made from copper slag contain high levels of barium, cobalt, copper, chromium, and nickel if sourced from primary smelters, while the levels of arsenic and lead may be significant if sourced from secondary smelters.

73. Other measures to reduce pollutants from blasting include the use of controlled blasting environments and alternative blasting techniques. Much can be done, for instance, by using properly designed, sealed and ventilated blasting cabinets, or rooms for bigger objects. Also, in cases where the objects being blasted are too big to fit into blasting rooms, the emission of pollutants can be better managed by the use of sealing "screens".

74. Alternative blasting techniques such as wet-abrasive blasting, hydro-blasting, blasting with dry ice pellets, vacuum blasting or ultra-high-pressure water blasting, can likewise reduce the amount of dust and potential pollutants. Smaller cleaning operations could also be done with thermal, chemical, and mechanical stripping to avoid the use of abrasive blasting altogether. It has also been found that blast pressure and abrasive feed rates affect the PM emissions of blasting operations, and that shipyards can therefore minimise the cost of pollution control, and the impact on the surrounding environment and ecosystems, by carefully optimizing these aspects of the blasting (Kura et al., 2006).

Coating and painting

75. Both the interior and exterior surfaces of ships are applied with protective coatings to preserve the steel, prevent corrosion, and to protect the hull from the build-up of marine organisms. Coating activities use a number of chemicals that include heavy metals, solvents, copper and hazardous or flammable materials, and the activity emits a number of air pollutants including lead, PM, VOCs, and zinc. Solvents are also used to clean painting equipment such as spray guns, brushes, containers, and rags. Lead compounds, such as lead chromate and red lead tetraoxide, have been used extensively in marine paint to protect ship surfaces from corrosion, with some paints containing up to 30% heavy metals (OSHA, 2006). These are examined in more detail below.

Anti-fouling paints

76. For most of its life a ship is partly submerged in water, and as all other objects subjected to water in a marine environment, over long periods of time, ship hulls are prone to colonisation by marine organisms and micro-organisms, such as algae, barnacles and mussels. This colonisation, known as fouling, can cause increased drag on the hull and lead to increased fuel consumption. If not attended to, fouling can even lower the ship's manoeuvrability or cause damage to the hull. To prevent this from happening ship hulls are treated with anti-fouling materials which work to impede the build-up of marine organisms.

77. Some estimates suggest that the shipping industry saves substantial amounts of fuel by the use of antifouling coatings, thus leading to lower CO_2, SO_2 and NOx emissions (WBCSD, 2008). However, to be effective the anti-fouling paints usually contain a biocide, or toxin, which is designed to leach slowly into the marine environment to poison and stop marine organisms from settling. This process makes anti-fouling paints a source of significant environmental hazard.

78. One of the most popular anti-fouling paints was developed in the 1960s with the use of organotin compounds called tributyltin (TBT) and triphenyltin (TPT). These anti-fouling materials are highly toxic to marine life, and numerous studies have showed that organotin compounds can persist in water environments and sediments, leading to death and deformities across a variety of sea life including larvae, mussels, oysters and fish (WWF, 2006a).

79. Apart from such direct harm, the compounds can also lead to significant damages in marine ecosystems as they enter into the wider food chain through bioaccumulation, which eventually can reach humans. Studies have also shown that organotin compounds are toxic in marine environments even at extremely low concentrations, and that they interfere with biological processes in a diverse range of species. Organotin also accumulates in whales and other sea mammals and disrupts the endocrine system of a range of invertebrates leading to sterility and death (WWF, 2006a).

80. The environmental hazards associated with TBT and other organotin compounds have been known for many years, but countries have been slow to move towards a ban. The ban of organotin anti-foulants was first introduced in the EU, the US, and Japan in the 1980s for small vessels (below 25 meters) and several alternative anti-fouling paints have since become available. These initial bans were followed by the entry into force in September 2008 of the International Maritime Organisation's (IMO) Convention on the Control of Harmful Antifouling Systems for Ships. Parties to this Convention agree to completely prohibit the use of organotin compounds, and to refuse entry into port to any ship painted with TBT. As of 30 June 2010 the Convention had been ratified by 45 of IMO's 168 member states (representing over 74% of the world shipping tonnage - see Box 1).

Box 1: **Tributyltin is still in use**

Tributyltin (TBT), as well as its breakdown products DBT and MBT, is now an omnipresent global contaminant in global marine and freshwater environments due to its extensive use in antifouling paints on ships (WWF, 2006b). Areas with particularly high levels of TBT in water, sediment and wildlife species, or so-called "TBT hot spots", are normally associated with commercial ports, shipyards, shipping lanes, marinas and the like. TBT has nevertheless also been found in marine sediments in Antarctica (Negri et al., 2004). Following bans on the use of TBT, the situation has improved slightly. However, while a majority of the industry has been supportive of the bans, there are indications that some shipyards still releases fresh TBT into surrounding waters (Kim, 2008) and that the use of TBT in antifouling paints can be expected to continue in certain countries (Kotrikla, 2009).

Alternative coatings

81. Today, a number of effective anti-fouling systems are available which do not contain TBT. These include organotin-free anti-fouling paints, and biocide-free non-stick coatings that have an extremely slippery surface to prevent fouling from occurring, and which make surfaces easier to clean when fouling does occur. There also exist innovative examples of biomimicry - a concept that uses nature as a model, measure and mentor for industrial development, for example anti-fouling coatings based on sharks' skin. The inspiration may at first sight seem unusual, but sharks have no algae or barnacle problems despite being underwater all their lives. The reason is that their skin is of a highly irregular character, with a very large number of tiny raised, diamond-shaped patterns (see Box 2).

Box 2 Mimicking shark skin

The research behind the shark skin replica, also known as Gator Sharkote, is being led by a team at the University of Florida, in collaboration with the U.S. Navy (Leahy, 2005). The replica is made by a combination of plastic and rubber coating, and lab tests have found that the coating lead to a 85% reduction in settlement of spores from a common algae called 'Ulva' which is often found on the sides of ships. Marine plant spores, however, are highly adaptive to various forms of surfaces, and ships obviously lack the ability of sharks to move and flex their coating. To prevent settling from adaptability, the research team have therefore experimented with making the diamond-shaped pattern coating 'changeable' using the influence of a low-power electric current. The microscopic size of the diamond-shaped patterns of the coating also alludes to the fact that nano-technology may have an important future role to play in designing anti-fouling agents.

82. However, although some alternatives are less harmful than TBT based anti-foulants, environmental concerns persist. In China, for instance, DDT is widely used as an additive to anti-foulant paints, which leads to a number of environmental detriments that are not unlike those caused by TBT. It is estimated that approximately 200 tonnes of DDT is used every year in the production of anti-foulant paints in China (UNEP, 2008), and annually China consumes a total of 65 000 tonnes of anti-foulants. According to surveys, the country's fishing fleet, which numbers about 300 000 vessels, consumes around 10 000 tonnes of these anti-foulants, and 50% of these are DDT based (UNDP, 2006). Estimates furthermore suggest that this source is responsible for the annual emission of DDT in the range between 150 and 300 tonnes; either directly into the sea through antifouling paints, or in localised areas through paint manufacturing processes (Guo et al., 2008).

83. Increasing awareness and stricter environmental regulations are nonetheless leading to the development of new and more environmentally friendly coatings. AkzoNobel, the world's largest paints and coatings company, is one of the companies leading the way through its International Paint business (WBCSD, 2008). Together with the maritime classification society Lloyd's Register, International Paint is working to introduce China's largest shipyards to the Performance Standard for Protective Coatings (PSPC, see Box 3).

Box 3: Performance Standard for Protective Coatings (PSPC)

In December 2006, the IMO adopted a new Performance Standard for Protective Coatings (PSPC) which is also included in the International Convention on Safety of Life at Sea (the SOLAS Convention). The PSPC entered into force in July, 2008 for all new shipbuilding contracts and will apply to all vessels delivered from January 2012 onwards. The standard is targeted towards reducing failures of ballast tanks from corrosion by introducing new requirements on the technical specifications of coatings as well as on inspection and verification terms.

84. Today, some suppliers of coatings also offer free step-by-step consultancy advice to shipyards on how they can meet the requirements of the new standard, and help them understand that the PSPC regulations need to be taken into consideration, not only by the shipyard paint shops but by all departments involved in vessel production. By providing information on new and more environmentally friendly products, suppliers can combine their work to improve environmental performance with expanding their presence in emerging markets (see Box 4).

Box 4: Biocide-free antifouling

AkzoNobel has developed a new environmentally sensitive, fluoropolymerbased biocide-free antifouling paint that is not harmful to marine life; thus, demonstrating a viable alternative to otherwise harmful antifouling coatings. AkzoNoble estimates that its new product, which is called Intersleek 900, can reduce marine fuel consumption levels and environmental emissions by up to 6%. The company expects that sales will rise from 50,000 liters in 2007 to one million liters by 2010, and hopes to create a new benchmark for antifouling paints (WBCSD, 2008).

Treatment and reuse of surface-related wastes

85. The wastewater produced by abrasive blasting and other surface treatment operations is often discharged directly into rivers and coastal sea areas without due consideration of the toxic elements that the wastewater contains, including organotin compounds (Champ, 2003). Yet, methods exist for treating this wastewater that can effectively detoxify the wastewater stream.

86. For example, experiments have shown that organotin compounds can be reduced with a removal efficiency of 99% by exposing the waste to heat at 1,000 degrees centigrade for one hour (Song et al., 2005), even though the heat treatment itself results in the exhaust of gas leading to emissions of CO_2. It has also been found that ship diesel provides a good solvent for extracting TBT from the wastewater produced from ship hull washing (Song et al., 2005).

87. Additional options available to reduce environmental pollution also include the recycling of abrasive materials (sand and metal slag), the use of cleaner abrasive materials and the reuse of spent abrasive materials in public works (Kotrikla, 2009). For example, heat treated dried abrasive wastes could also be safely reused as building material (Song et al., 2005).

Ship maintenance and repair

88. Ship maintenance and repair services include ship conversions, overhauls, servicing programs, and damage repairs of ships and their equipment. These can both be unplanned, such as in the case of unexpected system failure, or planned, such as periodical or condition based servicing. To minimise the time that ships are out of service, maintenance and repair jobs are often carried out under severe time constraints, thus requiring the work to be completed as quickly as possible.

89. Although maintenance and repair processes vary from job to job, many of the operations are identical to those used in new ship construction; albeit on a smaller scale. The potential impact on the yards' surrounding environment and ecosystems following from maintenance and repair services are therefore similar. This is especially the case at larger shipyards which frequently are engaged in larger repair activities, including operations such as the manufacturing and assembly of piping systems, pumps, and propeller drive shafts.

90. In addition to the various surface treatment methods mentioned in the sections above, maintenance and repair activities also include the cleaning and servicing of mechanical, electrical, radiation and thermal equipment, as well as hydraulic and other pressure systems operating on air, gas and water. These may lead to the generation of hazardous waste in the form of oil, hydraulic fluids, lubricants, thinners, acids, and anti-freeze (EPA, 1991). Fuelling activities can generate waste liquids and vapour releases to the air.

91. While many maintenance and repair services are direct sources of potential environmental damage, shipyards are sometimes also held responsible for the discharge of pollutants that are not produced by the yards themselves. For example, this could be the case in vessel cleaning which could involve the handling and treatment of a number of different forms of ship-borne pollutants, such as bilge water, ballast water, cargo residue and sanitary wastes. The potential environmental impact of these pollutants is described later (see section: *Spills*).

92. The provision of facilities for the handling of such pollutants is part of the MARPOL protocol,[4] yet, many ports still lack adequate reception facilities (IMO, 2006), implying that ships sometimes may have no option but to discharge their waste directly into the ocean in violation of the protocol. The IMO has consequently developed an action plan designed to improve reception facilities.

93. On the other hand, the maintenance and repair services that are conducted at shipyards are also of major importance in preventing environmental pollution associated with system failures and accidents onboard ships. For example, even if much can be done to reduce the risk of hull corrosion in the ship's design phase, the avoidance of corrosion also relies on proper inspection and maintenance services. If these procedures are not properly conducted, corrosion and weakening of the hulls can lead to accidents and polluting spills. In general, improving maintenance and repair service protocols - for example through the use of computerised maintenance and planning systems - can also help to reduce waste streams, and offer better waste management and economic savings (Hayman et al., 2000).

Noise

94. Many construction, maintenance, and repair activities are major sources of noise, particularly operations that involve metal working, the use of heavy equipment and vehicles, abrasive blasting, and chemical and mechanical paint removal. Such noise naturally affects the people who are engaged in the noise generating activity, as well as those located in the vicinity. Depending on the task at hand, workers in shipbuilding may be exposed to continuous sound levels of between 85 and 105 dBA. The highest levels of dBA exposure are experienced during welding, fitting and blasting activities (OSHA, 2009). Without protection, exposure to such sound levels may lead to loss of hearing. There is hardly any information available as to what effect noise from shipyards has on the surrounding environment, and most evidence on sound effects is related to the noise made by ships during operations at sea (see section: *Vessel noise*).

Industry-wide environmental impacts

95. The direct environmental effects of world shipbuilding activities, such as those arising from the processes described in the sections above, are clearly significant. However, there is generally a dearth of information on the issue, and it is consequently difficult to give even an indicative assessment of the magnitude of the industry's environmental impact. This is especially noteworthy in relation to the strong international focus on climate change, and it is suggested that a strong case can be made for increased openness and transparency of shipyards regarding their environmental performance.

96. Indications of the industry's emissions of certain air pollutants can be given using country-specific studies, but as only a few have been undertaken this only provides a vague appreciation of the magnitude of the problem.

4 The MARPOL Convention is the main international convention covering prevention of pollution of the marine environment by ships from operational or accidental causes. It is a combination of two treaties adopted in 1973 and 1978 respectively and updated by amendments through the years.

97. For example, according to the United States Environmental Protection Agency (EPA) the emissions of CAPs by the shipbuilding industry in United States amounted to 6 000 tonnes in 2002, of which 44% could be attributed to energy-related emissions (EPA, 2007). Assuming that emissions have remained steady in proportion to output, and that similar proportionate amounts of CAPs are emitted by the world's shipyards on average, a very rough "back-of-the-envelope" calculation would put shipbuilding's total CAP emissions in the area of 984 000 tonnes in 2009[5].

98. However, this figure should be regarded as a generalised guesstimate and is likely to greatly underestimate world emissions due to the technologically advanced level of both the shipyards and energy infrastructure in the United States. Moreover, this figure does not say anything about the distribution of emissions of the various pollutants included in the CAP, nor does it include any reference to what extent the shipbuilding industry contributes to climate change.

99. It is also difficult to arrive at a reliable indication of marine pollution attributable to shipyards. However, there are indications that shipbuilding activities often lead to severe seabed contamination and impact on marine sediments in local waters. For example, studies from Norway have shown that some of the most common contaminants near shipyards include lead, mercury, copper, TBT, PCB, PAH and other chlorinated organic components (KLIF, 2004). In cases where shipyards are located in the vicinity of ports, the pollution is often more comprehensive and with a broader spectre of contaminants. This is typically due to larger sources of pollution from anti-fouling paints from the ships that operate in the area (NIVA, 2006). Given the thousands of active shipyards throughout the world, the magnitude of seabed pollution that could be attributed to the shipbuilding industry is likely to be very significant, particularly in the developing world where measures to prevent environmental harm are potentially lower.

100. Likewise, it is difficult to assess the industry's environmental impact stemming from raw material usage. However, one indication that can be derived is through the industry's extensive use of steel. While there are no official statistics on worldwide steel consumption by the shipbuilding sector, indicators suggest that the industry accounts for about 3% of global steel consumption[6], which, as mentioned earlier, can be associated with the discharge of a number of pollutants, including GHG. Applying another back-of-the-envelope calculation, it could be postulated that the shipbuilding industry in 2008 could be associated with CO_2 emissions in the region of 36 million tonnes[7]. This figure, however, is only based on on-site emissions from steel plants and does not include emissions from significant sources associated with the steelmaking process, such as coke ovens, blast furnaces, and power generation.

4. SHIPBUILDING AND RELATED ENVIRONMENTAL IMPACTS OF SHIPPING

101. Apart from the environmental impacts of internal shipyard activities, and the effects that can be attributed to raw materials used in the construction processes, the shipbuilding industry could be expected to play a potentially major role in securing better environmental performance from the operation of ships.

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5 This calculation assumes that the emissions of 6,000 tonnes of CAP by the United States's shipbuilding industry in 2002 (EPA, 2007) can be extrapolated such that, given the United States' industry share of 1.27% in 2002 of the global 21.4 million tonnnes CGT output, CAP emissions in 2002 on average would amount to 6000 tonnes per 271 253 CGT (IHS, 2009), or 1 tonne of CAP per 45 CGT output. With total shipbuilding output amounting to roughly 44.5 million CGT in 2009 (IHS, 2009) this would imply a global emission of around 984,000 tonnes.

6 OECD calculations based on data from China Iron and Steel Association (CISA), Japan Iron and Steel Federation (JISF), European Confederation of Iron and Steel industries (EUROFER), World Steel Association (worldsteel), and selected public media sources.

7 This figure is based on data that put the world average CO2 emission per tonne of steel produced at approximately 1 tonne (IEA, 2006). Given the shipbuilding industry's share of world steel consumption of 3%, this amounts to about 36 million tonnes.

102. There has been a tendency in the shipbuilding sector to view itself as a self contained and fully independent activity, which has no significant role outside its immediate responsibilities. Following this line of reasoning, while the shipbuilding industry is responsible for what happens at its yards, it is not responsible for what happens once the ship has been delivered. Therefore, if a shipowner places an order for a vessel and specifyies (for example) a propulsion system that uses heavy bunker fuel, then that is something over which the shipyard has no control, and therefore should not be held accountable.

103. There is logic to this argument, but commensurately it is a very narrow view of the interlinkages that exist (as outlined in the earlier section that raised the life-cycle approach) in the production, operation and eventual disposal of commercial and other vessels.

104. This is not to suggest that shipyards should carry the burden for the environmental and other impacts of ships from conception to grave, but that if there was a more integrated approach then there would be greater awareness of the challenges, better decisions taken and innovation more easily introduced. In turn this would lead to a greater responsiveness to the environment, climate change and green growth, and would place the marine sector (in its broadest context) at the forefront of environmental responsibility.

105. It is suggested that if the industry can take such an initiative, then it will be able to take decisions in an orderly and measured way, to minimise potential downside costs of becoming more environmentally friendly. Otherwise, if other industry sectors are any guide, when public and political attention is focussed on the industry, there may be some draconian, and perhaps unpalatable, action foisted on the industry.

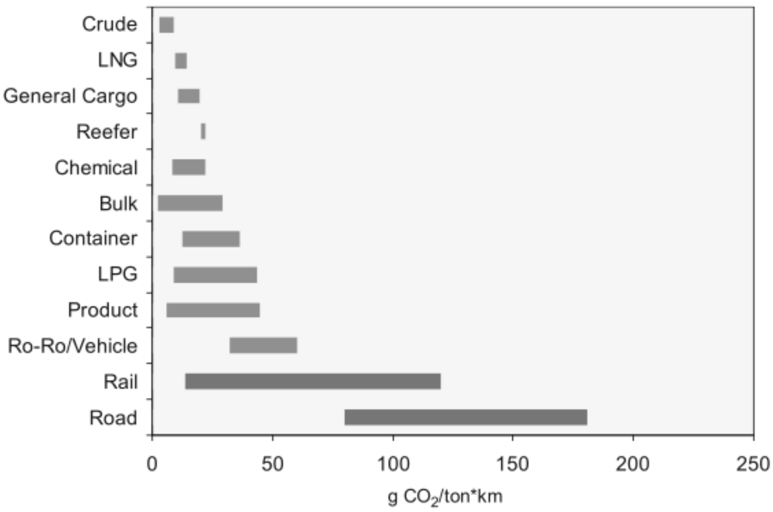
106. The significant potential for the shipbuilding industry to affect the environmental performance of the broader shipping sector—for example, by adopting and promoting better and more efficient ship designs and propulsion technologies—is perhaps best indicated by the size of the world's merchant fleet which, according to IHS Fairplay (IHS, 2009), numbered more than 102 000 registered ships in 2009. These vessels will eventually need to be replaced, and action now to recognise the environmental and other impacts of commercial and related shipping would enable these replacement vessels to me more environmentally and ecologically responsible.

107. The greatest environmental concerns associated with shipping are those relating to oil spillsfrom accidents, equipment malfunctions or operational decision (such as the dumping of bilges). However, there are other core operational activities, including loading and unloading and associated service and support tasks that can have environmental and other impacts, and these are examined here with the view of initially testing how the shipbuilding industry could play a positive role through a life-cycle approach.

108. Compared to air and ground transport, the environmental impact of shipping has received relatively little attention (apart from obvious oil spills). The primary reason for this is that shipping is generally considered (with good reason) to be more energy-efficient than other transport sectors, and this has partially shielded it from greater attention being paid to its core activities. For example, shipping produces considerably less CO_2 emissions per ton/km than other transport modes (see Figure 1).

109. However, its low profile can also be attributed to the fact that politicians and the public are less aware of shipping, and the role that shipping plays in their daily life. After all, most people are more familiar with air and ground transportation, and many airline companies are well-known brand names in most households; not unlike those of traditional consumer goods.

Figure 1: Typical ranges of CO2 efficiencies of ships compared with ground transportation



Source: IMO (2009c).

Note: The figure illustrates the average range of CO_2 efficiency from various vessel types compared with other modes of transportation. Efficiency is expressed as mass of CO_2 emissions per "tonne-kilometre".

110. However, growing environmental concerns, particularly over climate change are likely to intensify attention on maritime transport over the coming years; including as a spill-over as these issues continue to have increased traction in the airline and ground transportation sectors.

111. For example, recent studies have already put more emphasis on shipping, with results suggesting that CO_2 emissions, which is shipping's most important GHG emission, are higher than was previously thought. Shipping is also a major source of PM and black carbon, and the sector contributes heavily to the world's SO_2 and NOx emissions. The sector's actual contributions nevertheless appear to differ depending on sources. For example, shipping's world share of global CO_2 emissions ranges from 3% to 5%, according to Vidal (2008) and IMO (2009a, 2009c), while the sector is estimated to account for 4% to 8% of SO_2 emissions and about 15% of NOx emissions (Tzannatos, 2010).

112. While the IMO recently adopted amendments to the MARPOL regulations to reduce emissions, particularly of SO_2 (IMO, 2008b), NOx and CO_2 emissions from shipping are on the rise. In the European Union, for instance, shipping is expected to surpass all land-based sources in terms of NOx emissions by 2020 (ICCT, 2007). In the absence of policy measures and appropriate actions, CO_2 emissions could also rise by 200-300% by 2050, when compared to emission levels in 2007, due to growth in international shipping (IMO, 2009c).

113. Hence, shippers and shipbuilders are likely to meet increasing pressures and requirements for higher environmental standards. Also, shipping's share of emissions of other air pollutants, such as black carbon, is increasing significantly compared to land-based vehicles and activities, thus further increasing the likelihood for growing media attention and scrutiny.

114. With regards to the above, one of the primary environmental challenges in shipping undoubtedly pertain to the use of heavy bunker oils, which are considered to produce significant pollution. While the major environmental focus of the shipping industry remains the reduction of the impacts of spills of various substances—such as oil, cargo residues, and ballast water—concerns with the extensive use of bunker oil for the operation of heavy diesel engines is growing, as are more peripheral concerns such as the

growing evidence that noise generated by ships can disturb natural wildlife. Nevertheless, recent innovative and technological developments offer promising ways for shipowners and shipbuilders to address these challenges.

Energy and propulsion

115. While fuel is an essential component of shipping, it is also one of the largest sources of air pollution in the industry. Depending on estimates and vessel types, fuel can amount up to 40% of a ship's total operating costs (Stopford, 2009), and in an already fiercely competitive industry, low fuel prices are a highly important factor to achieve an edge over competitors. This naturally constitutes a large impediment to a transition to less polluting fuels, which typically also are more expensive. Such a transition is made even more difficult by the industry's current overcapacity and strained economic circumstances. On the other hand, from a shipbuilding perspective, pressure to move to less polluting fuels could provide an opportunity to adopt innovative ship designs and technologies for increasing propulsion efficiency.

116. In the face of climate change, it has also been argued that a carbon emissions program, where ships are penalised for fuel inefficiency and rewarded for conserving fuel, could spur much needed investments by both the shipping and shipbuilding industries; but such a program would be politically charged and highly complex. The IMO, for instance, has long held that because environmental pollution from shipping is global, a solution must also be global, but agreement to such a solution has been difficult to reach.

117. This is particularly due to the international character of greenhouse gases emitted by shipping, which has led to the exclusion of international shipping from the Kyoto protocol. Instead, the reduction of emissions by international shipping is instead undertaken by the IMO. This means that emissions by shipping are excluded from national totals and reduction targets, and by some accounts this has effectively weakened the incentive to set binding targets for emission reductions in the shipping sector (T&E, 2009). The search for global solutions to environmental problems in shipping is further complicated by the existence of open registers. While some open registers have rigorous standards, others have dubious reputations with respect to the implementation of internationally agreed regulations and standards.

Bunker-fuel

118. Contrary to public belief, large ships do not run on diesel in its conventional form. Instead, they run on a very particular form of diesel also known as bunker fuel, or fuel oil. Technically, bunker fuel is the name used to describe the fuel that is used to propel ships, but it can more accurately be described as a very dense and highly polluting residual substance from the oil refining process.

119. Because bunker fuel is a residual product, it carries everything that does not distil during the oil refining process, including a large number of pollutants. Methods exist to reduce the number of pollutants in bunker fuel, but these are typically not economically attractive. Moreover, the residual character of bunker fuel keeps its price low, thus providing little incentive for shipowners to switch to cleaner fuels.

120. Bunker fuel has a high concentration of nitrogen oxide, sulphur and particulate matter, all of which are all emitted into the air through the ship's exhaust. Among other things these pollutants have been linked to respiratory illnesses, cardiopulmonary disorders and lung cancers. Action toward the reduction of emissions of air pollutants of shipping should clearly be a priority, especially as 70-80% of the emissions occur within 400 kilometres of land (ICCT, 2007; WBCSD, 2010). Some studies even suggest that PM emissions from worldwide shipping each year lead to 60 000 cardiopulmonary and lung cancer deaths; mostly near the coastlines of Europe, East Asia, and South Asia (Corbett et al., 2007).

121. The problem of bunker fuel is recognized by the International Maritime Organization (IMO), which recently completed plans to introduce by 2012 a so-called "emissions control area" along a 370 kilometre wide buffer zone along the coastlines of the United States and Canada. This follows the example of active zones in the Baltic Sea, the North Sea, and the English Channel, in which ships must switch to cleaner forms of fuel. However, such policies are unlikely to take effect in the busy shipping lanes of Asia, such as the Pearl River Delta which includes the busy port of Hong Kong.

122. Not surprisingly, securing the use of cleaner fuel on a wider scale is even more difficult. Establishing low emission coastal areas, for example, require applicant countries to show that shore-based industries also are taking actions to reduce their emissions. This is not an easy task and will typically require more industrial regulation, as well as increased monitoring of industries.

123. On the other hand, policy trends like those mentioned above will continue to put increasing pressure on shipowners. Recently, for example, a British cruise line said that it was likely to drop its Canada-New England itinerary as a result of the "emissions control area" mentioned above, which would lead to significantly higher fuel costs (Stueck, 2010). Such circumstances could make more room for shipbuilders to design and construct more efficient ships by promoting and adopting advanced propulsion technologies.

Black carbon

124. Black carbon, which is a key component of soot, is a material generated by the incomplete combustion of heavy petroleum products, such as bunker fuel. When emitted into the air, the dark particles absorb sunlight and create a haze which can affect how clouds form and make rain, and may also have an effect on the heat balance in the geographical region. Black carbon is estimated to be the second largest contributor to global warming after $CO_{2,}$ and may lead to the darkening of snow and ice surfaces, thus contributing to the melting of ice in the arctic regions (Ramanathan & Carmichael, 2008). As well, it is believed to be a significant contributor to Arctic ice-melt (IGSD/INECE, 2008). Likewise, black carbon emissions are thought to cause around 3 million premature deaths per year (IGSD/INECE, 2008), and they are known to have damaging effects on plants, thus effecting crop productivity (Bergin, 2002).

125. In addition to recent studies pointing at higher CO2 emissions from shipping, a study by the NOAA and the University of Colorado have also found that large commercial vessels emit twice as much back carbon than previously thought (Lack et al., 2008). Compared to previous studies, which only covered emissions from a handful of different vessel types, the study from NOAA and the University of Colorado included emissions from 96 different vessel types, including tankers, cargo ships, container ships, large fishing boats, tug boats and ferries. The study found that commercial shipping releases about 130 000 metric tonnes of black carbon every year; amounting to 1.7% of the global total.

126. Much of the black carbon is emitted near highly populated coastal areas, especially due to the emissions of tugboats. The study found that tugboats emit far more soot for the amount of fuel burned compared to other commercial vessels - a result which in itself makes it likely that black carbon emissions could be largely under-reported in the emission inventories that are compiled by the world's ports.

127. Reducing emissions of black carbon in shipping is a feasible action for shipowners, given that technologies for doing so already exist. Moreover, given that black carbon has a significant contribution to global warming but only stays in the atmosphere for a few weeks - compared for instance to CO_2 which may last more than 100 years (Ramanathan & Carmichael, 2008) - addressing black carbon emissions should be considered an essential element in shipping's immediate strategy for mitigating its short-term effects on climate change.

Cleaner technologies

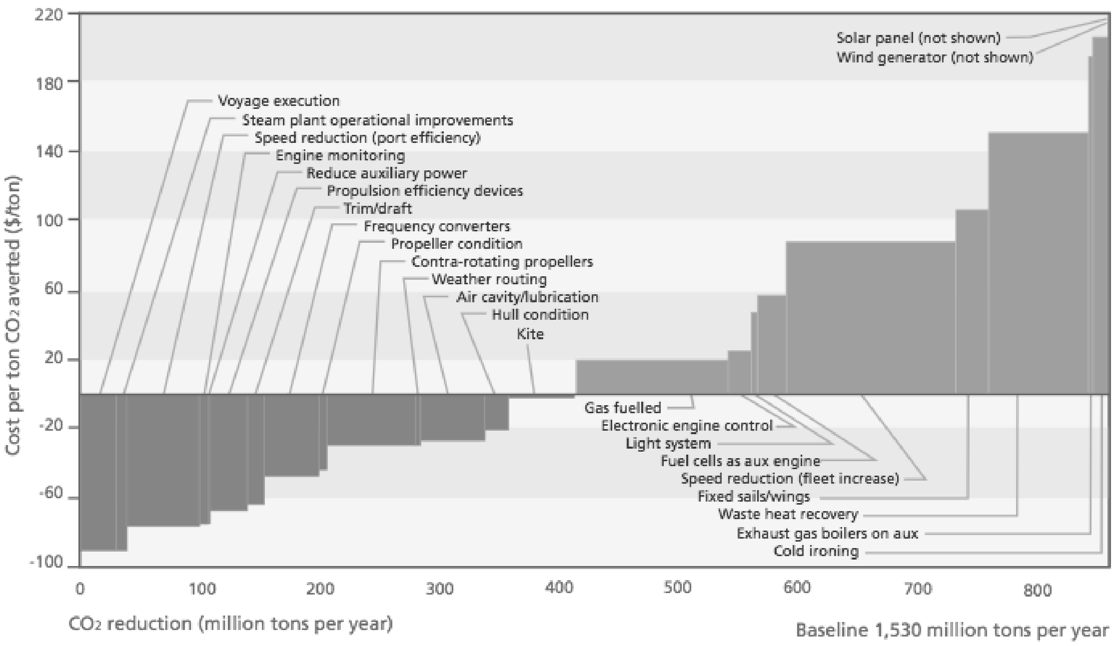
128. So far, the development and application of new technologies in shipbuilding have been relatively slow, but new ideas and innovative solutions for reducing the environmental impacts of ships during operations are beginning to surface, while some technologies already exist. Many of these are particularly targeted towards the reduction of shipping emissions by further improving the energy-efficiency of ships.

129. Initiatives span a broad spectrum; ranging from incremental changes such as lowering speeds, applying filters on exhausts, using currents for speed, or blending conventional bunker fuel with biodiesel; to more extensive implementations such as using photovoltaic panels and sails for propulsion, lowering friction through air-lubrication of ship hulls, or redesigning ship hulls altogether.

130. While some of these technologies are still in the experimental phase, many have made it to the commercial stage. It should also be mentioned that while some initiatives may entail only incremental modifications, their effect on improving environmental performance can be both significant and highly cost-effective. For example, if reductions from emissions in shipping through the use of particulate matter filters would be comparable to the reductions obtained from such filters on land vehicles, black carbon emissions in shipping could be reduced by up to 90% (IGSD/INECE, 2008).

131. Two recent studies by Det Norske Veritas have examined a number of technologies and their potential and cost-effectiveness for reducing CO_2 emissions in shipping, with one report looking at the period up to 2015, and the other looking ahead to 2030 (Alvik et al., 2010). The full list of technologies, as well as their cost-effectiveness and CO_2 reduction potential, can be seen in Figure 2. The list excludes a number of technologies, such as biofuels and hydrogen, as these were not deemed available on a commercial basis until after 2030.[8]

Figure 2: Average marginal CO2 reduction cost per option - world shipping fleet in 2030



Source: (Alvik et al., 2010).

8 For a full list of potential technologies, please refer to Alvik et al. (2010).

Biodiesel

132. Biodiesel is a particular form of biofuel used in diesel engines, and is typically produced from vegetable oil or animal fat. The use of biodiesel has been tested extensively by automakers in automobiles with both economic and environmental benefits, including lower emissions of greenhouse gases, sulphur dioxides, and particulate matter. However, in some cases emissions of NOx were higher than when burning conventional diesel.

133. Using biodiesel in ships has similar potential; but compared to biodiesel in land-based engines, there may be little economic incentive when used as blends in heavy bunker fuel. However, given the volatile oil prices, and increasing world production of crops for biofuels, the economics can change quickly.

Box 5: Bio-diesel

Maersk (Denmark) is one of the companies involved in projects of using bio-diesel as a mix in conventional fuels. Together with Lloyd's Register and a consortium of Dutch subcontractors, they are currently running a 2-year project, partially funded by the Dutch government, that initially will test the viability of using blends of 5 to 7% of bio-diesel, sourced from sustainably grown crops and recycled vegetable oils (Gallagher, 2010; CarbonPositive, 2010).

Testing is carried out on one of Maersk's container ships called 'Maersk Kalmar' and aims, among other things, to evaluate the extent to which the blend's adverse effects in marine engines will mimic that found by the automotive industry in land-based engines. The project aspires to find solutions for some of the drawbacks associated with using bio-diesel blends; particularly those associated with susceptibility to microbial growth, adverse effects on instrumentation of the bilge water system, and the impact on the level of NOx emissions. Although other test projects have used 100% biofuels, this is the first to be conducted on a large container ship.

Wind and solar power

134. Sail powered ships have been around for centuries, but new technologies in harnessing wind power may be giving sails a revival. The idea of using giant sails, or 'kites' not unlike a paraglider, to propel large commercial ships has been around for some time, but has usually been thought of as just that-- an idea. However, projects that test the viability of the technology have demonstrated significant potential for reducing fuel consumption; even on larger ships (see Box 6).

Box 6: Wind power is back

In 2008, the first commercial cargo ship MS Beluga SkySails sailed from Germany to Venezuela, partly powered by 160 m2 large, computer controlled kite (BBC, 2008). The result of the MS Beluga SkySails first voyage led to savings in fuel consumption of 10%. However, Depending on wind conditions, the shipping company, Beluga Shipping, and the kite's manufacturer, SkySails, have estimated that the kite propulsion system can lead to annual average fuel savings of up to 35%. These findings have been replicated by a study from Germany's University of Applied Sciences (Schlaak, 2009). Sails of greater sizes offer the potential to give additional benefits.

135. Solar power, on the other hand, is a relatively new and potentially promising form of propulsion for ships, but is not yet in a state for commercial application. The technology is new, and even if partially solar powered commercial ships already exist, they are both small and relatively few in number. Extensive

tests of photovoltaic panels are nonetheless also being conducted on larger cargo vessels, but it will take time before this technology can have a significant impact on reducing fuel consumption, let operate as the single source of power for propulsion (see Box 7).

Box 7: Extensive pilot project with solar energy

The first example of solar panels on a larger cargo vessel is the fitting of 328 solar panels on the 60,000 ton Toyota car carrier, MV Auriga Leader, which is operated by Japan's largest shipping company Nippon Yuse Kaisha (NYK Line), and co-developed with Nippon Oil. The fitting of solar panels is part of a 2-year project which started in the beginning of 2009.

The solar panels on the MV Auriga Leader are capable of generating 10% of the energy while the ship is docked. When at sea, the solar power generated can provide 0.05% of the ship's propulsion power and 1% of the electricity used onboard the vessel. These effects are not capable of reducing fuel consumption and CO2 emissions by any significant level, but the aim has also been to test the endurance of solar panels under the harsh conditions at sea (NYK Line, 2009).

Liquefied natural gas

136. Liquefied natural gas (LNG) promises an efficient way to cut emissions for short sea and inland water ways shipping. In effect, the burning of LNG can eliminate all SOx emissions, and cut emissions of CO_2 and NOx by as much as 20% and 80%, respectively (Hannula et al., 2006). According to Det Norske Veritas, LNG is currently one of the most cost-effective ways to cut CO_2, SOx and NOx emissions. Moreover, given the high volatility and uncertainty in oil prices, LNG has the potential to be an economically attractive solution to control those emissions.

137. However, one of the main obstacles in using natural gas onboard ships is storage. Even in its liquefied state, which is obtained by cooling the gas, the volume of the tank that is needed to store LNG is more than double the volume of the tank needed for storing conventional oil fuel with the same energy effect (Hannula et al., 2006). Therefore, in most cases retro-fitting an LNG energy system onto ships is a significant task; and may reduce a ship's cargo space. Another big challenge is the building of an LNG fuelling infrastructure in ports.

138. While this is not impossible, the use of LNG is perhaps best suited for the construction of new vessels where space requirements can be adequately designed for, and this may be a commercially viable opportunity available for exploitation by innovative shipyards.

Ship design

139. In addition to alternative fuels and propulsion systems, shipbuilders can also apply different ship designs to improve energy efficiency. One way that this effect can be obtained is by reducing a ship's friction or resistance in water, either through ship modifications such as the application of more efficient propeller designs, or air-lubrication systems, or by entirely re-designing the hull.

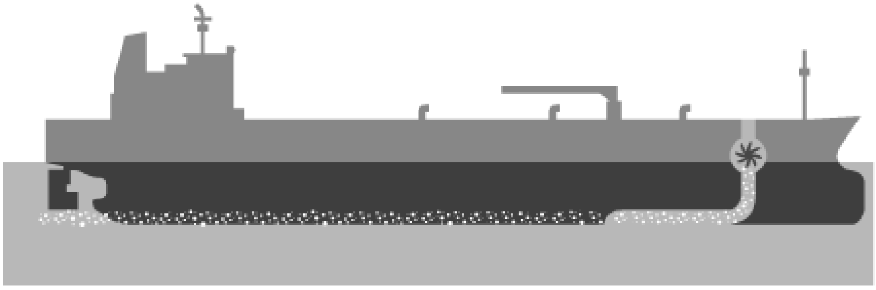
Air Lubrication

140. Air lubrication is a method which uses air to cause less friction when a ship's hull glides through the water. The effect is obtained by blowing air between the ship's hull and the water, and thus literally reducing the contact surface between the ship and the water. Commercial applications of this technology already exist (see Box 8).

Box 8 The Air Cavity System

The Air Cavity System is an air lubrication system invented by the DK Group (Netherlands). The system can reduce fuel consumption of up to 15% while requiring between 0.5 to 1% of the propulsion power to keep the air compression going.

The system works by reducing the frictional resistance of the ship's hull in the water, by blowing air under the ship's hull whose midship and bow sections have been replaced with a flat-bottom surface.



Source: DK Group.

Based on figures from DK Group, the implementation of the Air Cavity System on the global fleet of vessels being targeted by the technology (ocean-going commercial ships longer than 275 meters), could reduce world shipping emissions of CO_2 by some 3.5%.

Hull design

141. Hull designs can be optimized for maximum energy efficiency by minimizing friction and wave resistance. This process typically relies on advanced research tools such as computational fluid dynamics (CFD) which can be used to alter the hull's design in a computer simulated environment. Besides lowering the friction of the ship's hull, this technique also allows for optimizing hull designs across a number of other parameters, including stability, safety, noise and vibration.

142. One example of hull design for greater fuel economy, as well as increased stability, is the Ulstein yard's recent introduction of a new bow design. The bow, which is known as the X-bow, bears some resemblance to the bow of a medieval Viking ship, is almost an inversion of today's conventional bow designs (see Box 10).

Box 10: Inverted bow design

When compared with a traditional bow, the X-bow by the Ulstein Group of Norway provides a 'softer' entry into oncoming waves. This has the effect of reducing the loss of speed from wave resistance, especially in heavy weather, and provides a more stable speed which, apart from saving fuel, also provides a higher comfort for the crew because of less violent motions. There are currently more than 30 X-bow vessels on the sea (Ulstein, 2010).

Source: Ulstein Group.

Results from a comparison study of short sea container vessels conducted by the Ulstein Group have shown that the X-bow can reduce fuel consumption by 7 to 16% (Ulstein, 2010).

Spills

143. While ships may be energy-efficiency compared to other modes of transportation, they are also sources of a number of polluting substances that, when discharged into the ocean, can have significant damaging effects on the aquatic environment. These substances include oil and fuel, ballast water, bilge water, black and greywater, as well as solid and hazardous wastes. While some of these are permitted to be released during normal ship operations, there are strict requirements as to the type of waste and distance from land where such disposal may take place. For shipbuilders, sources of environmental pollution arising from spills may be harder to influence, compared with improving energy-efficiency, but could be addressed through changes in ship design and structures.

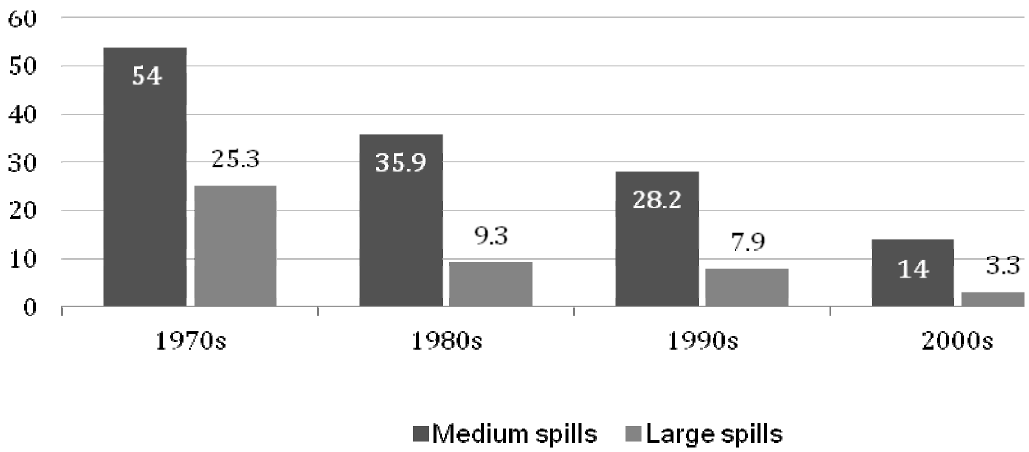
144. Oil and fuel

145. Shipping is the single largest source of oil and fuel spills into the oceans, representing more than 68% of the world's total (Renilson, 2005). Oil and fuel spills can occur either by accident or by intent. Accidental spillage can occur through accidents involving ships, during fuelling operations, or during the loading and unloading of cargo. Intentional spillage typically occurs through some form of "operational dumping". Contrary to public belief, roughly two thirds of all oil and fuel spills in shipping are caused not by accident but by operational dumping (Renilson, 2005); mainly through the discharge of bilge water (see section: *Bilge water*).

146. The most commonly known form of oil spill, and for which there are available statistics, are those that happen by accident. Spills of this kind are typically caused by ship collisions, onboard fires and explosions, or ship wreckage. The largest such oil spill ever to take place was in 1979 when the 288 000 DWT oil tanker "Atlantic Empress" collided with another large ship in the Caribbean Sea. The Atlantic Empress eventually sank after burning for 14 days and led to the spill of 287 000 metric tonnes of oil (ITOPF, 2009).

147. The International Tanker Owners Pollution Federation (ITOPF) maintains data on accidental oil spills from tanker carriers and barges since 1970. Detailed statistical analysis of such spills is rarely possible, and the data therefore puts emphasis on incidents and trends instead of amounts. From Figure 3 there is a clear trend that major oil spills (more than 700 tonnes) have decreased significantly during the last 40 years, with the average number of incidents involving major spills between 2000 and 2009 falling to 3 per annum (ITOPF, 2009). The average number of medium spills (between 7 and 700 tonnes) has also fallen.

Figure 3: Accidental medium and large oil spills: average annual spills by decade (1970-2009)



Source: Oil Tanker Spill Statistics (ITOPF, 2009).

Note: Because most oil spills are small (less than 7 tonnes), data on numbers and amount of oil tend to be incomplete due to inconsistent, or lack of reporting. Reporting on medium and large oil spills tend to be more reliable.

148. The environmental impact of oil spills can be nothing short of devastating. The magnitude of the impact nonetheless depends crucially on the amount and type of oil that is spilled, the location of the spill, the time of the year, as well as on local sea and weather conditions (Patin, 1999). The same variables also typically play a large role in how effective clean-up efforts will be, and thus the chances of minimizing the risk of lasting environmental impact. For this reason, major spills can sometimes be less damaging than smaller spills.

149. Regardless, oil spills always cause extensive short-term damage to the environment. These effects typically include large-scale deaths of sea creatures as well as the poisoning and death of birds, mammals, reptiles and amphibians, if the oil reaches the shore. In the long run, oil spills may also contaminate or destroy the sensitive marine and coastal substrate. This can alter the food chain, interrupt the breeding process of animals, and lead to lasting changes, or disappearance, in population species. Oil spills can therefore also have severe long-term impacts on deep-ocean and coastal fishing, as well as on sea tourism.

150. While oil spills from operational dumping obviously do not have the same immediate environmentally damaging effects as accidental oil spills, the long run effects can be very similar. For example, one study has estimated that as many as 300 000 seabirds are killed annually along Canada's Atlantic coast, due to routine discharge of oily wastewater (WWF, 2002). Moreover, even if some of the oil that spills into the water evaporates, petroleum hydrocarbons can remain suspended in the water column, concentrate on the surface, or settle to the bottom. This persistence can lead to environmental damage - even if the amount of the spill is small. Hydrocarbons in oil can harm juvenile fish, upset fish

reproduction, and interfere with the growth and reproduction of bottom-dwelling organisms (WWF, 1997). Oil sheens can also block necessary oxygen and light from moving through the surface of the water.

Bilge water

151. The bottom of a ship's hull, where the two sides of the ship connect, is called the bilge, and the water that accumulates here is known as bilge water. Because bilge water is virtually impossible to avoid, these bilge are usually designed as "tanks" which are able to contain the liquids that collect there.

152. Bilge water comes from a number of different sources, including rainwater, seawater, and wastewater from the ships sewage system. Oil, fuel, antifreeze and other potential pollutants originating from the ships' engines, piping and fittings, and other operational machinery also often find their way to the bilge through leaks, condensation, evaporation and washdowns. The end result of this collection of fluids is therefore a mixture containing water, oily fluids, lubricants, cleaning fluids, and other similar liquid waste forms. Due to their larger number of waste streams, bilge water accumulated on larger vessels can also contain, among other things, waste oil, fuel oil sludge, and cylinder oil (EPA, 2008b).

153. To prevent spills and potential hazardous conditions onboard the ship, bilge water must be periodically flushed out of the bilge. This operation can be done in three ways:

i) Retained onboard the ship in special holding tanks and then later discharged to special port reception facilities when docked.

ii) Treated onboard by various methods and then discharged, or

iii) Discharged untreated into the ocean.

154. There are different ways to treat bilge water. Some methods use mechanical devices to separate oil and other pollutants from the water. Other methods make use of bioremediation, where biological processes are used to clean up the bilge water. Regardless, treatment of bilge water often involves costly equipment, and the oily substances that are separated from the bilge water must eventually be disposed of. This process can be very expensive, and as mentioned earlier some ports may lack adequate reception facilities.

155. For these reasons the deliberate discharge of untreated oily bilge water still occurs on a very large scale - despite the fact that it is in violation of the MARPOL protocol. Untreated bilge water can also be discharged unintentionally if the method used to separate pollutants from the water does not work properly.

156. Because of the many polluting and toxic substances contained in bilge water, the discharge of untreated bilge water can cause significant harm to both fish and wildlife. If ingested, it may also pose health risk to people. Given the large scale of dumping of untreated bilge water, there are indications that the environmental damage from this source could even be worse than the damage caused by accidental oil spills (ENS, 2009).

Ballast water

157. One of the main concerns regarding intentional spills in shipping is the discharge of ballast water. Ballast water is used by larger vessels, such as tankers an bulk cargo ships, to maintain operational stability when these are operating empty or when carrying small loads. For example, after an oil tanker unloads its cargo, it will then fill its tanks with ballast water to ensure stability on the return trip. Before arriving at the next loading port, the tanker dumps the ballast to make room for its new cargo. Because the ballast water uses the same tanks as those used for transporting oil, it is typically referred to as "dirty" or

"unsegregated" ballast water. Newer oil tankers, however, operate with dedicated or segregated tanks for ballast water, thus preventing the discharge of oily water.

158. However, there are other environmental problems with the discharge of ballast water than those associated with oil and water mixtures from unsegregated ballast tanks. Dedicated tanks or not, ballast water also typically contains a variety of biological material, including plants, animals, viruses and bacteria. Every year, up to 10-12 billion tonnes of salt water is 'moved' this way (EMEC, 2009), and the discharge of ballast water is thus a large-scale means of transporting non-native species to new environments, with potentially damaging effects to local aquatic ecosystems, economies and people (OC, 2002).

159. For example, the arrival of the American comb jellyfish into the Black Sea through ballast water is thought to have led to the destruction of 26 commercially valuable fish stocks (Reid, 2005). Several other such examples exist (EMEC, 2009).

160. In February 2004, the IMO adopted an international convention[9] to prevent, minimize and ultimately eliminate the transfer of harmful aquatic organisms and pathogens, through better control and management of ship's ballast water (IMO, 2004). The convention, however, has not yet entered into force, as this requires ratification by 30 member states representing 35% of world merchant shipping. As of June 2010, 26 states (representing 24%) had ratified the convention.

161. On the other hand, new ship designs are currently being explored and tested with the aim of eliminating the conventional form of ballast-tanks, with consequent potential benefits to the environment (Parsons and Kotinis, 2008). This could provide some opportunities for innovative ship designs that would efficiently and economically deal with ballast water in compliance with the BWM Convention.

Black and greywater

162. Blackwater is used to describe spills from sewage that originates from wastewater sources such as toilets and medical facilities. Greywater is non-sewage wastewater (and thus from lower risk sources) such as sinks, showers and laundry and cleaning activities (Copeland, 2008). Because these wastewater streams are proportional to the number of people on ships, black and greywater management is a particular challenge for cruise and other passenger ships. The risk of damage inflicted by waste streams from cruise ships may be further elevated because the operations of these ships are typically concentrated in specific coastal areas and ports.

163. Blackwater sewage can, if untreated or inadequately treated, contain harmful bacteria, pathogens, viruses, and intestinal parasites. If discharged, this can cause bacterial and viral contamination of fisheries and shellfish beds, and elevate public health risk from those food sources (Copeland, 2008). Estimates put the amount of blackwater generated on cruise ships with a capacity of 2-3 000 passengers and crew members to between 100 000 and 115 000 litres per day (OCEANA, 2003).

164. Greywater constitutes by far the largest source of liquid waste generated by cruise and passenger ships, and like blackwater, can contain a number of polluting substances, including bacteria, detergents, oil and grease, metals, organics, petroleum hydrocarbons, nutrients, food waste, and medical and dental waste (Copeland, 2008). Levels of pollutants in greywater may sometimes even exceed those found in untreated domestic wastewater (EPA, 2008b). Cruise ships with similar capacity as above are estimated to generate between 550 000 and 800 000 litres of greywater per day.

9 2004 International Convention for the Control and management of Ships' Ballast Water and Sediments (the BWM Convention).

165. Black and greywater can be cleansed by the use of membrane bioreactors. In this process, the black and greywater is first fed into a bioreactor where biomass breaks down the organic matter. Then the solution is processed through a cleaning filter, or membrane, into a second bioreactor, after which it can be discharged directly into the sea (EMEC, 2009). The amount of blackwater can furthermore be reduced by some 30% by the implementation of vacuum toilets, which when combined with a sludge reactor with membrane filtration for treating and collecting greywater for flushing, can reduce wastewater volumes from this source by 75% (EMEC, 2009).

Solid and hazardous wastes

166. Solid waste from shipping can, among other things, include glass, paper, cardboard, aluminium and steel cans, and plastics (Copeland, 2008). Estimates suggest that 70% of the waste and garbage from ships sinks directly to the bottom of the ocean, 15% is washed up on shore, while the remaining 15% floats on or just under the surface, which due to sea currents often end up forming large “garbage islands” (EMEC, 2009).

167. Given the nature of these wastes, the solid waste problem pertains mostly to cruise and passenger ships which generate large quantities of such wastes. For example, an average cruise ship passenger generates between 1 to 3.5 kg of solid waste every day, and cruise ships are generally thought to account for about a quarter of the total amount of solid waste generated by seaborne vessels worldwide (Copeland, 2008; OCEANA, 2003).

168. If solid wastes are discharged at sea they may end up as marine debris, which in turn can threaten the life of marine mammals, fish, sea turtles, and birds. Although some solid waste generated by cruise ship is landed ashore for disposal or recycling, much of it (estimated at between 75% and 85% - see OC, 2002) is incinerated at sea; with the resulting ash typically disposed into the ocean. Incinerated waste may or may not be toxic and efforts are consequently being made to make sure that the ashes do not meet the definition of hazardous waste. Efforts are also being made to more generally improve waste management in terms of source reduction, waste minimization, waste compression and recycling (Copeland, 2008).

169. Even if the quantities of solid and hazardous wastes from shipping are typically small, their toxicity to sensitive marine organisms can be significant. Hazardous materials in shipping include photo processing chemicals, print shop wastes, dry cleaning fluids, photo copying and laser printer cartridges, fluorescent and mercury vapour light bulbs, lead-acid, nickel-cadmium, lithium, and alkaline batteries, as well as unused or outdated pharmaceuticals. These waste streams contain a number of highly toxic pollutants and can, without careful management, find their ways into graywater, bilgewater, or the solid waste stream. However this area has received little regulatory attention, mostly because the problem is specific to wastes from cruise ships (OC, 2002).

Vessel noise

170. There is a growing focus on the potential implications from hydro-acoustic noise pollution generated by ships. However, this particular form of pollution and its adverse effects on the marine environment is not well understood, and the impacts can be very hard to detect. It is consequently an issue that shipbuilders and shipowners are probably largely unaware of. It is also considered to be an area in which legislation would be hard to introduce, let alone establish voluntary codes of conduct (Renilson, 2005).

171. Nevertheless, this is an environmental issue that seems to be gathering some attention, and it is worthwhile examining in some detail as a foreshadowing of the next likely area of public and government attention.

172. While noise from ships can emanate from a large number of sources, they can be grouped into three principal categories (IFAW, 2009):

i) the propeller,

ii) the ship's machinery and equipment, and

iii) the movement of the ship's hull through the water.

173. One of the most apparent and well-documented effects on marine life from noise pollution in shipping is the mass stranding of whales due to military sonars (ASOC, 2005). However, while military sonars arguably provide the most conclusive evidence of noise impact on marine animals, it remains to be determined which characteristics of noise, and their impact on sea life, are the most significant. For this reason, the potential of all intense noise sources to cause adverse effects to marine life is being looked at more closely.

174. For example, while the nature of the effects on sea animals from ship noise is still largely unknown, there is emerging evidence that sound levels may inflict damages to whale tissue, and that damage can be caused at lower sound levels than previously thought (ASOC, 2005). Noise is also thought to affect sea animals by triggering a behavioural response such as ascending too rapidly from a deep dive, or spending too much time at the surface than is natural to avoid higher sound levels below the surface (ASOC, 2005). Experiments furthermore suggest that even modest acoustic intensities under supersaturated conditions can trigger bubble formations in blood, liver and kidneys.

175. Previous suggestions for avoiding damaging effects from noise have included 'detect and shut down' procedures, where ships scan for sea animals and shut down intense noise emitting sources when at close range, but there are difficulties with this approach, and its application to commercial shipping is as yet unclear.

176. Generally, however, there appears to be some movement towards the development and implementation of "ship-quieting" technologies. These technologies have long been an important aspect for the construction of military ships, but little attention has focused on how to reduce the noise from cavitation (that is, the noise from the propeller's formation of vapour bubbles when it turns), which would be critical for quieting large commercial vessels (IMO, 2009b).

177. There are currently little data available on the underwater noise levels from commercial ships, and more research in this area is needed (IMO, 2009b). The re-design of propellers with noise reduction in mind nevertheless has the potential to reduce vessel noise considerably while at the same time increasing the ship's propulsion efficiency. As an indication of the greater attention that is being directed to this relatively esoteric aspect of ship design and operation, the International Fund for Animal Welfare (IFAW) has recently published a report which investigates current technologies for reducing noise pollution in shipping (IFAW, 2009).

Building greener ships

178. It is suggested that in a life-cycle scenario the shipbuilding industry sits at the heart of improvements to both the economic and environmental performance of the shipping sector, and there are signs that efforts are already being made in this direction. A specific example is the Japanese NYK Super Eco Ship project which seeks to construct a zero-emission ship by combining a long list of energy-efficient technologies. This is a project that is partly a response to strong emission targets set by Japan.

179. The NYK Super Eco Ship is a 2030 concept design for a container ship that is intended to identify which technologies should be developed, and how to apply them, in order to achieve greater economic and environmental performance in shipping. The design promises by 2030 a reduction of CO_2 emissions of 70%, compared to similar sized ships, increasing to 100% by 2050. Emissions of NOx and SO_2 would also reduced.

180. The reduction in emissions results from a number of factors. For example, weight is reduced by using high-strength ultra-light steels, but also from changes in ship structure and from using LNG fuel cells as a main power source instead of diesel engines. Propulsion is furthermore assisted by solar and air power, as solar cells cover the entire top container area. They are also located on the side on the ship and on the ship's 8 airfoil sails. These cover a total area of 31 000 m^2 , with a peak energy output of up to 9MW. The sails, which are located on retractable telescopic masts, are of a triangular shape to improve their effectiveness under different wind conditions. The vessel's frictional resistance is furthermore reduced by an air cavity system.

1.1 In addition, pods and fore propellers allows the ship to manoeuvre flexibly, and the ship does therefore not depend on tugs for docking, leading to emission reductions from this source. The ship is furthermore constructed following a modular design, which allows the ship to 'break' into different parts for docking. This means that the ship's middle section can be separated from the hull and left for unloading and loading, while the fore and aft are reconnected to other middle sections that are pre-loaded and ready for re-integration with the vessel. Combined with a new loading concept for the ship as a whole, it is estimated that this will lead to a decrease in loading time of 50%.

1.2 Such design innovations are practical only when there are sufficient incentives for the investment to be made into research, development and production, and for the designs to be taken up as commercially viable vessels. There are indications that there is growing government, public, environmental and economic pressure to produce ships that meet environmental, climate change and green growth expectations, and there is a challenge for shipyards to build greener ships that are also commercially viable.

5. SHIP DISMANTLING AND RECYCLING

181. At the end of their life ships are dismantled for disposal or recycling. Because virtually every part of a ship's hull, machinery, equipment, fittings, and even furniture can be recycled (Mikelis, 2006) these recycling activities constitute to an important source of valuable materials. By some estimates, 95% of ships can be scrapped and recycled (Hossain & Islam, 2006), with arguably the large quantity of high quality steel being the most important resource. By these measures, ship recycling constitutes a valuable economic activity, but there are also strong environmental interests in ensuring the existence of a well functioning ship recycling industry. The primary locations for ship recycling include Bangladesh, India, China, Pakistan, and Myanmar; with Bangladesh holding the largest share.

182. For some years, the annual world scrap rate of ships has been between 200 and 600 ships (above 2 000 DWT). However, in recent years ship recycling has been increasing and the demand for greater ship recycling capacity has grown. This development was originally triggered by stricter regulations on certain types of ships, in particular the gradual phasing out of single hull tankers (EC, 2007). The trend has also been accelerated by the recent global financial crisis, which has resulted in shipping over-capacity, which has led many shipowners to opt for earlier retirement of some of their ships.

183. Ship recycling is complicated by the size and complex ship infrastructures. Recycling activities range from the removal of onboard gear and equipment to the actual dismantling and cutting down of the ship's hull. Most of these activities are heavy and highly labour intensive tasks, and if best practices are

followed they require a number of safety standards and environmental precautions to be followed. Ship recycling can therefore be relatively costly if all safety and environmental measures are adhered to.

1.3 However, in practice ship recycling is undertaken in conditions that fall a long way short from best practices, and there is a considerable body of evidence with respect to the health, safety and environmental consequences of today's ship recycling industry.

1.4 The ILO generally considers ship recycling as one of the most hazardous occupations in the world, due to its heavy and destructive nature. It also poses significant environmental concerns, as ships are the source of many polluting materials. These concerns are magnified by the fact that ship recycling and dismantling activities in Bangladesh, India, Pakistan on occasions in China, typically take place on sandy beaches and under very primitive conditions. Apart from the Occupational Health and Safety aspects (OH&S), this also implies that there are few facilities for receiving and handling hazardous wastes and polluting substances. For example, typically there are few or no containment or barriers to prevent water and soil pollution from spills and runoffs, and that materials which cannot be recycled, such as PVC coatings of cables, are either dumped on the spot, or burned in open fires (EC, 2007). Since the industry already suffers from an insufficient capacity for dealing with ship recycling in a safe and environmentally sound way, the situation is further aggravated by rising demand for ship recycling services.

184. However, even if the potential impact to the environment and workers—who often are in direct contact with polluting and toxic substance without any form of protection—is of grave concern, little is known about the actual effects that are inflicted on the people and the environment in and around the world's primary ship recycling locations (EC, 2007).

185. From the perspective of the shipbuilding industry, ship dismantling and recycling activities are the most remote and loosely connected of all the maritime related activities that could be of interest to the shipbuilder, especially as this recycling takes place 20, 30 or more years after the ship is built.

186. However, it is suggested that there is still room for shipbuilders to take a greater interest in the eventual impacts associated with the recycling of their ships. For example, ships could be constructed in ways that are both easier and safer to dismantle. In the longer term shipbuilders could move further towards adopting accepted sustainable manufacturing practices by sourcing raw materials from ship dismantling and recycling activities themselves and, to the extent possible, implement a closed-loop production structure. From this perspective, the social and environmental impact of ship dismantling and recycling activities could be considered to also be of potential significance to the shipbuilding industry.

Environmental impact

187. When a ship is scrapped, steel is recovered by cutting the ship hulls and other structural parts into steel plates. This process can lead to the discharge of pollutants such as lead, cadmium, organotins, arsenic, zinc and chromium stemming from the steel's paint. For example, depending on size, the steel for a single ship can be coated by between 10 and 100 tonnes of paint (Hossain & Islam, 2006).

188. Ship recycling inevitably also involves the removal of a large number of toxic and hazardous materials, such as asbestos, preservatives, cargo residues, and thousands of litres of oil, including engine oil, bilge oil, hydraulic and lubricant oils and grease. Cargo residues from oil tankers can be of the order of 1 000 cubic meters of residual oil (Hossain & Islam, 2006). Very few of the sites used for ship recycling in South Asia have containment to prevent pollution of soil and water, few have waste reception facilities, and the treatment of many hazardous and toxic wastes rarely conforms to even minimum environmental standards (EC, 2007). It should therefore come as no surprise that ship recycling activities pose an enormous threat not only to the immediate workforce, but also to the marine environment that surrounds

the dismantling yards; a situation that is aggravated by lax and poorly enforced safety and environmental requirements.

189. Even if there are no records on the actual magnitude of discharged polluting materials it is likely to be significant. For example, the amount of oil sludge from scrapped ships alone has been estimated to be between 400 000 and 1.3 million tonnes annually. Similarly, environmentally harmful paints are estimated to be between 6 000 to 12 000 tonnes, and the highly toxic TBT anti-fouling coating between 170 and 540 tonnes (EC, 2007). Ship recycling also includes the removal of insulating materials which can contain asbestos - especially on ships built before the 1980s. Asbestos from scrapped ships is estimated to be between 1 000 and 3 000 tonnes (EC, 2007). It has been estimated that ships scrapped between 2006 and 2015 will yield an estimated 5.5 million tonnes of materials of potential environmental concern that will end up in dismantling yards (in particular oil sludge, oils, paints, PVC and asbestos) (EC, 2007).

190. As with shipbuilding, there is little research available on the environmental impact of ship recycling on the surrounding environment and aquatic life. Yet, ship recycling activities undoubtedly hamper the aquatic environment's primary productivity which is the base of the marine food chain, supporting a diverse marine life. Oil that floats over large areas, for example, inhibits the penetration of light in the water and reduces the growth of phytoplankton which is important for securing rich biological productivity in the aquatic habitat.

191. Studies on the impact of ship recycling on the biodiversity in the coastal zone of Chittagong, for example, have found that the occurrence and distribution of phytoplankton were very poor in ship recycling areas compared to non-ship recycling control sites (Hossain & Islam, 2006). Ship recycling areas also demonstrated low numbers of zooplankton, which are important for securing a healthy aquatic life, as well as low numbers of bottom living organisms which play an important role as food for fish. Moving further along the food chain, there are indications of increasing fishing efforts to secure adequate catches, reductions in the number of available fish species, and an increasing number of "trash" fish from normally productive fishing areas (Hossain & Islam, 2006).

192. Ship recycling also leads to the discharge of persistent toxic metals which, when settling in the sediment, not only pose a threat to the biodiversity of the area but to all organisms by entering the food chain through bioaccumulation. Some research in areas near ship recycling sites, for example, has found the presence of certain metals in fish that occasionally exceed international limits for human exposure. Other research has found negative impacts on coastal birds, mangroves and marine grass due to oil spills (Hossain & Islam, 2006).

Health and safety

193. Ship recycling can be linked to two main categories of health and safety hazards, (i) hazards caused by accidents that happen at the ship recycling yards, and (ii) hazards that follow from sustained contact with dangerous substances.

194. Most accidents at ship recycling yards are caused by toxic gas explosions, but the falling of heavy metal plates from upper decks also cause a large number of accidents. It is not uncommon for such accidents to lead to the death of ship recycling workers (see Box 11). Similarly, the carrying of metal plates, as well as other heavy parts, by workers on their bare shoulders and on slippery surfaces is also cause for many deaths and injuries (Hossain & Islam, 2006).

Box 11: Deaths in ship recycling

During onsite research for the report by Greenpeace and the International Federation for Human Rights in one of the Bangladeshi ship recycling yards, the researchers witnessed a serious accident only two days after having arrived to the site. In this accident, three workers died, and one was seriously injured. Only nine days later, they witnessed another accident killing one worker. The researchers also learned that another two workers had died in an accident three weeks prior to their arrival (Greenpeace-FIDH, 2005).

In Bangladesh alone, it is estimated that, on average, one worker dies at the yards every week, and that one worker gets injured every day (Greenpeace-FIDH, 2005). A recent report from the EC also states that one in six of the workers at the world's largest single location for ship recycling activities (Alang, India) is suffering from asbestosis; and that the fatality rate of Alang's ship recycling workplaces is six times higher than in the Indian mining industry (EC, 2007).

195. A very important cause of injury and death among ship recycling workers is caused by diseases that workers acquire from exposure to hazardous and toxic substances (Greenpeace-FIDH, 2005; Hossain & Islam, 2006). Moreover, some toxins, such as asbestos, are not only found at the shipyards, but also in nearby living quarters; thus affecting people other than shipyard workers. It is virtually impossible, however, to obtain a factual picture of the casualties from these diseases.

196. The health and safety conditions at many ship recycling locations, particularly in Bangladesh, India and Pakistan, are of grave concern and have been heavily criticized in the media and by a number of environmental and human rights organizations across the world. The concern is aggravated by the fact that workers engaged in ship recycling are often uneducated (or illiterate), unqualified and from very poor backgrounds.

197. These workers are subject to high risks of serious accidents due to the lack of heavy machinery and safety equipment for the dismantling tasks. In most cases, workers are not even provided with basic personal protective equipment (PPE) such as helmets or gumboots (Greenpeace-FIDH, 2005), and there is generally a lack of PPE that otherwise would be considered appropriate for ship recycling activities. In addition, workers do not receive any formal training about ship recycling, and are they are typically unaware of the dangers associated with the handling of hazardous and toxic substances that they come in direct contact with.

198. By some estimates, the death toll of ship recycling activities over the last 20 years could very well be in the thousands (EC, 2007; Greenpeace-FIDH, 2005)—a number that is increasing with the hiring of more inexperienced workers to deal with the growing demand for ship recycling activities (EC, 2007).

Nearby communities

199. The ship recycling industry offers a variety of employment opportunities to surrounding coastal communities. However, these communities, which are generally quite poor, may also be exposed to health hazards from the pollutants discharged during ship recycling operations as well as substantial noise pollution.

200. For instance, toxic oil and metallic substance through the intake of affected fish may cause health hazards to humans, and the disruption of biodiversity in the aquatic environment that surround ship recycling yards may deplete fish stock. (Hossain & Islam,2006). Also, the expansion of ship recycling yards may lead to a shrinking of areas suitable for fishing villages and may push many coastal fishermen out of their profession (Hossain & Islam, 2006).

Regulatory frameworks

201. Ship recycling has rightfully received a lot of attention in the past years, mostly due to the sector's dangerous working conditions, and the regulatory framework dealing with this activity has evolved considerably. Organisations working on the issue include the UN, the International Maritime organization (IMO) and the International Labour Organization (ILO). For example, as of June 2010 the UN's Basel Convention[10] that aims to protect human health and the environment had been ratified by 173 states, including India and Bangladesh.

202. Technical guidelines for ship recycling were adopted as part of the Convention in 2002, and in 2004 it was declared that "End of Life Ships" are subject to the provisions and principles of the Basel Convention. In compliance with these provisions, shipowners are required to inform the authorities about their ship dismantling plans, and to request the necessary permissions. Another provision controls whether the ship recycling facility is capable of dismantling the ship and deal with the waste in an environmentally sound way. A Joint ILO/IMO/Basel Convention Working Group on Ship Scrapping produced these broad objectives:

- Avoid duplication of work and overlapping of responsibilities and competencies and identify further needs.
- Ensure a coordinated approach to all relevant aspects of ship scrapping.
- Examine with a view to identifying any possible gaps, overlaps, or ambiguities; and
- Consider mechanisms to promote jointly the implementation of the relevant guidelines on ship scrapping.

203. More recent developments in the area of ship recycling concerns the Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships, which was adopted for signature by the IMO in May 2009. This Convention, which builds upon the Basel Convention has been under negotiation for several years and is intended to address all issues related to the recycling of ships, including poor working conditions and the existence of environmentally hazardous substances found on ships sold for scrapping. For example, the new Convention will, among other things, require that ships sent for recycling should carry an inventory of hazardous materials found onboard, and that ships are surveyed prior to recycling to verify the inventory.

204. Ship recycling yards will also be required to provide a "Ship Recycling Plan" that specifies how each particular ship will be recycled. A series of guidelines are now being developed to assist in the implementation of the Convention. So far, no IMO member states have ratified the Convention, and it has consequently not entered into force.

6. CONCLUSIONS

205. Shipbuilding, shipping, and ship recycling are three very distinct industrial operations, and are typically treated as such. However, they are highly interlinked activities when considering the impact that ships have on the environment over their life-cycle. Attempting to assess the environmental impact of shipbuilding and its associated activities on this basis is nonetheless a daunting task, not the least because there is so little environmental information available on so many of the industry's activities. This also means that while it is possible to establish the importance and seriousness of many of the industry's

[10] Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal.

environmental challenges, it remains difficult to make judgements as to their significance in terms of magnitude and impact.

206. Therefore, it is suggested that there is a clear and timely need for strengthening the focus on environmental information and transparency in the shipbuilding industry, including as how the industry is linked to impacts of environmental concern following from its use of raw materials, and through shipping and ship recycling operations. This need is growing as the industry's environmental agenda is becoming increasingly visible in the public domain.

207. So far, the direct environmental impact of shipbuilding, which concerns the construction, maintenance and repair of ships, has received relatively public little attention. However, the activity constitutes a significant source of potential environmental harm, including through the daily handling of large quantities of toxic materials, fumes and fluids. Risks of exposing various hazardous and toxic contaminants to the environment are furthermore exacerbated in the industry; firstly by the open air environment, in which most shipbuilding activities take place; and secondly by the waterfront location of shipyards which provide pathways for potential pollutants to enter directly into the aquatic environment. However, there are virtually no industry-wide estimates available regarding any of these impacts, nor of the industry's direct contribution to climate change.

208. Indirectly, the shipbuilding industry is contributing to make shipping the world's most energy-efficient transportation sector. Considering that shipping is responsible for carrying the vast majority of internationally traded goods this has obvious advantages with respect climate change. Nonetheless, shipping is still a major contributor to emissions of GHG and air pollutants, and emission reductions therefore remain a highly critical challenge for the industry, especially as shipping activities are projected to grow substantially in coming years.

209. Shipping is also responsible for the discharge of hazardous contaminants into waterways, marine ecosystems and food chains. This occurs through spills of large volumes of polluting substances such as oil, bilge water, ballast water, and solid and hazardous wastes, and through the leaching of toxins from the ships' surface coatings and paints.

210. Ship recycling concerns the dismantling and recycling of ships, and while these activities may appear remote when considering the environmental impact of the construction of ships, they represent the culmination of concern regarding the sustainability of the shipbuilding industry as a whole. Ship recycling is generally associated with the handling and discharge of large quantities of toxic and hazardous polluting substances, derived from the ships' insulation materials, bilge and ballast tanks, fuel tanks, cargo tanks, and so on. Very few ship recycling sites, which typically are located on sandy beaches in developing countries, have the reception and containment facilities to handle these wastes, and many of the ship recycling workers come in direct contact with them without any form of protection. For these reasons ship recycling has received much attention from both human rights and environmental advocates.

211. As a whole, the shipbuilding industry faces major challenges in reducing the environmental impact of its own and associated activities. The industry has nevertheless been slow to embrace new technologies for improving environmental performance, even if such technologies exist. As such there is a growing need for increasing the awareness and focus on the availability of cost-effective and environmentally friendly alternatives to conventional designs, materials and processes used within the industry.

212. Also, the prevailing culture in the industry has long been that a ship must be profitable from the first day in operation, and apart from a few exceptions very little attention and money is generally put into research and full-scale experiments with new technologies. This conservative culture of an otherwise

hugely critical and important industry must be highlighted as a serious impediment to fostering green growth. Generally, the shipbuilding industry needs to take a more integrated and open view of its environmental agenda, by recognising the environmental responsibilities that it shares, even if indirectly, with shipping and ship dismantling and recycling activities.

213. Finding regional solutions to reduce the industry's environmental impact, such as by introducing stricter technological and environmental requirements to yards and ports, could perhaps be a step in the right direction. However, such solutions are frequently considered to skew competition, by giving an advantage to shipbuilders in countries where the stricter regulations are not imposed. On the other hand, stronger regional requirements, especially in already technologically advanced economies, such as OECD member states, could spur a separate competitive advantage in shipbuilding by pushing the industry onto a path of green growth.

214. The current economic recession may even be an appropriate time to embrace stricter regional environmental regulations. In general there is already a large potential in the shipbuilding industry for eliminating much of the environmental stress by adopting new technologies and materials which are optimized for better product and environmental performance, as well as by implementing new design processes that pay respect to life-cycle thinking. As a start, with freight rates being historically low, combined with the current over-capacity of ships, retrofitting of already existing and cost-effective technologies could be an opportunity for otherwise financially challenged, but technologically advanced, shipyards and shipping companies to reduce their fuel consumption and gain an economic advantage in the industry.

7. SUBMISSIONS/COMMENTS RECEIVED

Governments

Argentina, Ministerio de Economia y Produccción

Australia, Department of Innovation, Industry, Science and Research

Chinese Taipei, United Ship Design and Development Center

Denmark, Danish Maritime

Norway, Royal Norwegian Ministry of Trade and Industry

International organisations

International Metalworkers' Federation (IMF) on behalf of the OECD's Trade Union Advisory Committee (TUAC)

Industry

European Marine Equipment Council

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