Green growth opportunities in the EU shipbuilding sector

Final Report

Client: European Commission, DG Enterprise and Industry

Rotterdam, 5 April 2012

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ECORYS

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Preface

In recent decades, the EU shipbuilding landscape has changed significantly. Global competition has increased, especially from Asia, where low-wage countries have taken over building of more standard type ships and manufacturing of many components. However, the EU has managed to maintain a strong position in highly specialized and qualitatively outstanding vessels. The EU shipbuilding industry is globally renowned for its ability to develop and deliver new high-technology solutions and innovative production processes to existing and new markets.

The recent economic crisis and the increased regulatory and demand-driven push towards sustainable and environmentally friendly products and transportation services create new challenges as well as opportunities for the EU shipbuilding industry. The EU shipbuilding industry is asked to be even more creative and innovative in order to maintain its ground both in light of these developments, but also in view of its competitors. This is valid for the shipyards, but also for the marine equipment sector, which play an important role in responding to this call for green (technology) innovation. Also demands from emerging other sectors that are influenced by these greening trends (such as offshore sustainable energy initiatives) create new opportunities for the shipbuilding industry. If appropriate responses can be found, the European shipbuilding sector can contribute to economic growth and employment as well as to a technological innovation needed for a resource-efficient and sustainable future for Europe.

This final report provides the main findings on the challenges and market opportunities that face the shipbuilding and marine equipment industry in view of the above developments. Eight greening trends are addressed, covering both market, regulatory and other factors. For each trend, the resulting market potential is estimated, along with barriers identified that may affect the reaping of this potential. It also elaborates the current state of green technology developments within each market identified and the role of EU and competitor industries in providing these technologies. Policy measures taken by individual countries inside and outside the EU as well as at EU level to target the green market opportunities are identified and compared as to provide a solid basis for defining actions and directions in Europe that enable ceasing existing market opportunities.

This report is built on an extensive market consultation process through in-depth interviews with over 35 stakeholders, complemented with a review of the state of the art literature and a stakeholder workshop. As such it is not a statistical analysis, or an academic or political analysis, but it represents an in-depth insight based on key market actors and industry players.

During the assessment we have spoken to a large number of people from many different organisations and companies. We would like to express our gratitude to all people who have shared their valuable insight with us on the matter.

The study has been carried out by an independent team. It should be noted that this report represents the views of the consultant, which do not necessarily coincide with those of the Commission.

Rotterdam / Delft / Brussels, 5 April 2012

Executive Summary

Background and study objective

Driven by global competition and new market entrants, the European shipbuilding and marine equipment industry has developed into a highly innovative sector. Today Europe has a leading position in high value, high complexity segments, such as cruise ships, dredgers and other specialised ship types. At the same time, the European marine equipment industry has succeeded in creating and maintaining a strong competitive position.

This position is, however, being challenged by increased competition, which has been intensified by the current economic crisis. At the same time new market challenges and opportunities are arising from the expanding green economy, including the need to fulfil regulatory requirements, as well as a range of other drivers. If organised effectively, and if its innovation potential is realised, the European shipbuilding sector can contribute to both economic growth, job creation, and added value, as well as a resource-efficient and sustainable future.

Greening provides new opportunities for the European shipbuilding industry that respond to the current strengths of the sector. The main objective of this study is to identify market opportunities for the EU shipbuilding industry that follow from greening trends in shipping and other areas.

Eight greening trends have been identified that create market opportunities

Eight trends have been assessed, in three categories: market driven trends (trend 1 & 2), regulatory trends (trends 3, 4, 5 and 6) and other trends (trends 7 & 8). It should be noted that some trends overlap in terms of the market potential and impeding factors. For example the market trend of fuel efficiency and cost reduction has a certain degree of overlap with the regulatory trend of CO_2 reduction.

Market-driven trends lead to changes in company behaviour, even in the absence of direct regulatory pressures to do so. Changing behaviour can create cost advantages or lead to changes in market strategies. Examples of market drivers are increased levels of environmental awareness of customers and / or companies. Companies also change their behaviour, through necessity, because of financial pressures.

1. *The call for cost reductions through improved fuel efficiency of ships* is considered *the* main market driver for greening in the sector at present. The market potential is high, given that all new ships are expected to follow a trend towards higher fuel efficiency, partly driven by the increasing fuel prices but also by regulatory measures (EEDI is seen as a minimum level, see trend 5 below). Two main areas of market potential are fuel efficient systems and alternative fuel based solutions. For newbuilding, the market potential can be considered large, but not necessarily additional to existing demand, as all new ships are expected to follow the trend towards higher fuel efficiency. An accelerated replacement of vessels, driven by fuel efficiency, as is observed in some market segments (viz. containerships), may occur. However, this is difficult to quantify, given that at the same time this is hampered by the relatively young age of the existing world fleet. For retrofit, opportunities for ‘proven’ fuel-efficiency solutions will rise if fuel prices continue to increase rapidly, although market size is influenced by trade routes and the complexity of technology that needs to be installed.
2. *The market potential for increased environmental awareness and growing interest in Corporate Social Responsibility (CSR)* has a stronger impact in markets that are closer to the end

consumer, and where the green image of cargo owners positively affects their market position. The willingness to invest in green technologies to raise the environmental performance of ships; however, appears limited if no clear business case is present. In practice, investors' actions usually occur in combination with responding to other drivers.

Regulatory-driven trends lead to a direct or indirect change in company behaviour, given that they define a compliance requirement. Examples of regulatory drivers are the IMO MARPOL Convention and the Ballast Water Convention. The potential impacts of these trends are analysed:

3. *The market potential from the regulatory trend towards NO_x abatement* is seen to be important. The total market potential arising from the US NO_x ECA is estimated at € 7-9 bn for the period until 2030. If a European NO_x ECA were to be in place in the Baltic, North Sea and Mediterranean, an additional estimated global market potential of € 9-12 bn would be created. This potential only applies to new ships, not to retrofit.
4. *The global market potential for SO_x abatement technologies* is estimated at € 10 to 31 bn until 2030, based on the current European SECAs. If the Mediterranean were to be a SECA as well, an additional € 7-18 bn would be generated. In the short term (until 2020), this will largely relate to retrofit activities (installing on ships already built and operational in SECAs); however, after this period, demand will mainly relate to newbuilding.
5. *The regulatory drive towards CO_2 abatement initiatives*, has an estimated overall global market potential of approximately € 3 bn per year from 2015, rising to approximately € 10 bn per year in 2030. The increase is the consequence of expansion of the world fleet, as well as further tightening of the EEDI reduction levels over time. The estimated amount is seen as the minimum market potential, also for fuel-efficiency measures as targeted under the market trend of fuel efficiency.
6. With regard to *ballast water and sediment treatment,* the IMO has adopted the International Convention for the Control and Management of Ships' Ballast Water and Sediments in 2004. Once entered into force (now awaiting a few more countries to sign before it will be ratified), new and existing ships will need to comply with the convention. Given the world's fleet size, estimates suggest the total global market potential could be as high as about € 25 bn for the period 2013-2020.

The third category includes a series of drivers that are creating new markets or providing new business opportunities. Key drivers identified in this study are renewable energy policies that are driving the construction of offshore wind farms, and the climate change driven Arctic ice melt, creating opportunities for oil and gas extraction and shipping in the Arctic region (although the latter is not, in itself a green driver).

7. *Offshore renewable energy* is a major greening trend with an overall estimated global market potential as high as € 19 bn for the next 10 years, or around € 2 bn per year, based on European wind parks planned alone. This estimate is based on the number of ships required for constructing and operating the planned parks, including installation vessels, cable layers, support vessels (maintenance, crew accommodation and crew transfer), and repair vessels, as well as the manufacturing of foundations (jackets), platforms and other components. Given that such initiatives are also being undertaken in Asia and North America, the scale of market potential could increase further.
8. In order to exploit opportunities related to the *development of Arctic shipping routes*, ice breakers and ice strengthened ships will be required. The overall global market potential is estimated at some 15-20 ice breakers until 2020, resulting in an estimated potential of around € 0.4 bn per year. In addition, a demand for ice strengthened ships, both for freight shipping and

offshore oil and gas applications, will be created, and this is estimated at a further € 0.5 bn per year.

All trends and their estimated market potential are summarised in the table below. Taking the eight trends together, the estimated global market potential per year for the period until 2020 is estimated to be minimally € 12.5 – 15.5 bn per year, excluding the additional market potential from fuel efficiency trends above the minimum level required by EEDI and the (limited) market potential that is driven by environmental awareness and CSR. Within this market potential a possible overlap between trends, notably between NO_x an SO_x abatement, needs to be taken into consideration.

Table ES.0.1 Global greening market potential for shipbuilding

	Market trends		Regulatory trends				Other trends	
Trend	1	2	3	4	5	6	7	8
	Fuel efficiency	Environmental Awareness and CSR	NO_x	SO_x	CO2	Ballast Water	Offshore wind	Arctic dimension
Key driver	Fuel price	Image	Regulation	Regulation	Regulation	Regulation	Energy policy	Climate change
Market potential*	Large	Limited	2-3	2-4	3	2.5	2	0.9
Relevant markets:								
Newbuild	√	√	√	√	√	√	√	√
Retrofit	√	√		√		√	Limited	Limited

* Estimated market potential in bn EUR per year for the period until 2020

The position of the EU industry vis-à-vis Rest of World players

The key question is to what extent European shipbuilders will be able to take advantage of this global demand. At a general level, strengths of the European shipbuilding industry are founded on the competitive position the industry has gained in building high value high complexity ships in a number of niche segments (cruise, dredging, part of offshore) and high quality marine equipment. Furthermore, the industry benefits from the green focus that is in place across Europe in other sectors, which has helped to create spill-overs towards shipbuilding, and internal as well as cross-company knowledge transfer. The geographic clustering of companies in several regions, along with the historical ties that have built trust between them, has further enhanced the innovation process by ensuring various players from across the value chain participate.

Weaknesses of the European shipbuilding industry of a general nature include access to finance and skills – two factors that were identified in previous studies and are also witnessed in other technology industries across Europe. Also a large part of the market potential is expressed in shipbuilding outside Europe. Although the export position of marine equipment suppliers is strong, this puts them at a larger distance from the end-clients (ship-owners). The competition from yards near major trading routes is limiting possibilities for retrofit opportunities related to green market areas on a global scale. Whereas in some new market segments the position of Europe is favourable (e.g. icebreakers, or different vessel types plus installations for offshore wind parks) Europe doesn't yet have a track record in all sub-segments (e.g. installation vessels).

Taking together the global market opportunities and the above strengths and weaknesses, the EU position vis-à-vis each of the trends are described below:

The position of the EU shipbuilding industry in responding to *fuel efficiency demand* (Trend 1) and *CO_2 abatement initiatives* (Trend 5) is considered to be relatively strong. For most of the technology fields applicable, European equipment manufacturers have a competitive advantage, and in some cases virtually no non-EU suppliers have been identified as yet. Given that the majority of ship types are built outside Europe, European suppliers will have an export potential, but are less strongly connected within the value chain than if they were operating within Europe. For marine equipment manufacturers, the market potential is therefore partly dependent on the make-or-buy decisions of the main shipbuilding companies outside Europe.

However, other countries are also eagerly developing initiatives to enter this market as this is seen as one of the key trends in the coming decades. This trend is rather a necessity than an opportunity alone. Given that other shipbuilding nations are also expected to increase the delivery of fuel efficient ships, no major shifts in newbuilding construction are expected between global production regions in favour of Europe.

The position of the EU industry in responding to *environmental awareness and CSR* (Trend 2) is also considered advantageous. Environmental consciousness amongst the EU public is relatively high, which could stimulate local demand for ‘green ships’ or create new alliances (e.g. between ship owners and local suppliers). Furthermore, high value ships can more easily ‘afford’ additional environmental costs, whilst the European marine equipment sector is strong in many areas that are affected by this trend (fuel efficiency, air pollution, etc.).

European industry has developed a number of innovations in the area of *NO_x abatement* (Trend 3). European suppliers are therefore well-positioned with regard to both LNG systems (the main engine manufacturers MAN and Wärtsilä are Europe based, but also some Asian competitors are active), and the supply of SCR systems (a number of SMEs is active in this field).

Within the area of *SO_x abatement* (Trend 4), EU manufacturers have developed the required systems for both LNG and scrubber technologies. They are considered ‘best in class’ worldwide in these fields, although there are also a number of suppliers elsewhere.

EU players are relatively strong in the area of *Ballast water and sediment treatment* (Trend 6). As of November 2011, 54 systems had been granted basic or final approval, of which 16 by EU-based companies, and 5 by companies from EEA states. Several European SMEs are currently active in the field, and so are a number of larger companies. However, a few large Asian companies are also developing ballast water treatment systems.

The position of the EU shipbuilding industry is considered generally good in supplying the *offshore renewable energy* (Trend 7), with variations between segments. In most vessels types, relevant for offshore wind energy, Europe holds a strong position. The only exception is potentially the field of installation vessels, where the overall number built to date is rather low and only a few European players have been involved. However, in many cases where these ships are being built in Asian yards, European design offices are also involved. In contrast, the number of cable layers developed has been considerably higher, and the ship types already exist for numerous years – they are also being deployed in other sectors (energy grids, communication). According to existing studies, European shipbuilders should be able to capture a substantial share of this potential. A different segment is the manufacturing of foundations (jackets), platforms, and other components. Here, location is an important factor, particularly for the large sized platforms, where transport costs would become too high if manufacturing sites are not near the intended installation site. As a result, European yards located near offshore wind sites are expected to benefit.

Finland is very well placed to benefit from the development of new *Arctic shipping routes* (Trend 8), given that around 60% of all currently active ice breakers have been built in this Nordic country. The development of strategic alliances with Russia as its main client will contribute to maintaining this position.

Taken together, the EU industry appears well-positioned to capture a substantial part of the green growth potential. Based on its competitive position, its share in global markets is roughly being estimated between 15 and 50%. In several of the green market opportunities (CO_2/fuel, NO_x, SO_x, and Ballast Water), European equipment manufacturers have a competitive advantage, given that they are ahead in developing technologies and in some segments have implemented a number of systems. Competition from outside Europe is mainly seen in the CO_2/fuel efficiency segment. Europe's position with regard to the offshore wind market is more mixed, since in some parts a European track record is missing. On the other hand local demand for developing wind parks is likely to provide a competitive advantage for building certain offshore structures.

As markets will progress, it is expected that interest from non-EU manufacturers will further increase, especially as shipbuilders around the globe will make substantial additional efforts to fill their order books – particularly in such tough times. Again the challenge will most likely target the CO_2/fuel efficiency market, given that this is a truly global market, whereas some of the other market segments (viz. NO_x, SO_x, wind energy) have a stronger regional component. Support programmes in major competitor regions (in particular in Korea and Japan and to a lesser extent in China) focus on this market segment.

For European shipyards, market demand is likely to follow the overall trend for more fuel efficient ships that has been observed worldwide. The main new opportunities are related to retrofit activities (especially SO_x and to a much more limited extent, ballast water and retrofitted fuel efficiency technologies) and new market niches that develop. In this respect offshore wind energy will provide additional opportunities, although these will not be equally divided across all ship types that can be delivered.

For marine equipment suppliers, the world market is providing good to very good opportunities in many segments of the greening market. Indeed, the starting position of European suppliers is good (if not excellent). However the position in the value chain limits the amount of control that can be exerted, and the current overcapacity also drives foreign competitors to grasp part of this market. In the field of fuel efficiency, competition is expected to be particularly strong, given that the market potential is large and all ship types will be affected.

Policies supporting green market opportunities

The European Union has a number of policies in place that support the realisation of the greening market potential, as identified above. These include RTD support (FP7 notably but also the Waterborne Technology Platform related to this), as well as competition policy, and the specific shipbuilding State Aid framework. At Member State level, various support instruments can also be found in Germany (the Shipping and marine technology in the 21st Century programme), the Netherlands (the Maritime Innovation Programme – MIP), Italy (Maritime Technology Platform – PTNM), and Finland and Denmark (several projects).

In non-European countries, governments are also supporting the development of products to respond to the greening potential. These countries include Norway (the NO_x tax scheme is well known but other R&D programs are also in place), China (until date limited activity in the greening area but growing interest noticed), South Korea (which has a strong focus on fuel efficiency research, including cooperation with European companies, as well as the establishment of new financing organisation KOFC) and Japan (support to especially the development of LNG technology).

Gaps of existing European policies vis-à-vis green market opportunities

A real or perceived gap has been identified under the following domains:

- Perceived risks by ship-owners of new technologies that are not yet proven, which would call for specific measures (closer to prototyping, testing) that overcome these implementation barriers.
- Insufficient availability of bunkering facilities for LNG in Europe
- Building R&D alliances across borders
- Market based policy initiatives

General recommendations

- The need for the EU to enhance its cluster support provision (which is currently primarily provided by local and regional governments), through exploring links between clusters and enhancing cross-sectoral exchanges of experiences, both in markets served but also in use of resources (e.g. labour, skills, R&D and technologies).
- Continued promotion of the shipbuilding and marine equipment sectors as attractive work places. Building connections with eco-industries and using R&D results to update curricula are two potential actions that should be considered.
- Continue promoting the use of market based instruments at IMO level, and consider adopting schemes at EU level, while ensuring local initiatives are following a harmonised set-up
- Regarding the financing of green vessels, efforts to raise the knowledge levels and awareness of greening / improving fuel efficiency technologies among banks could help to increase their interest, for example, through disseminating business case analysis linked to R&D projects. Besides financing measures which promote green ships could be further pursued

Specific recommendations related to the business strategies identified

We see a number of key business strategies which to a large extent are already followed by companies. Under each strategy, specific recommendations have been formulated.

Support to strategy 1: Green innovation

The current strong position of the European shipbuilding industry to many of the green market opportunities is mainly driven by the existing high levels of innovation. Green and continuous innovation is critical to retaining this competitive position; however, this requires significant efforts. Recommendations are:

- RDI programs to provide stronger attention for prototyping, demonstrators and pilot projects, which could convince potential ship-owners of the effectiveness of new technologies and reduce the risk perception of ship owners. In addition to existing FP instruments, the establishment of specific testing facilities that resemble real life operations should be examined (e.g. testing facilities on board of operational ships).
- Continue environmental differentiation in innovation aid.

Support to Strategy 2: Green Links in Value Chain

Large parts of the green market opportunities are found in the export of green solutions to shipbuilders across the world. In particular, for marine equipment suppliers it is essential that they retain their competitive position and access to markets outside Europe, which requires them to develop a stronger position in the value chain. Recommendations are:

- Promote the development from components to systems.
- Support to maritime cluster initiatives.
- Promote value chain initiatives, such as can be found in Denmark, at a European level.

Support to Strategy 3: Green Specialisation

For decades already, European shipbuilding has been successful in specialising into new and high-value niches (examples of this strategy are cruise ships and dredgers). Green market opportunities offer new possibilities for specialisation and market niches. Recommendations are:

- Specific R&D in specialised production processes for retrofitting (cost-effective and fast).
- Assess the use of the existing State Aid framework to shipbuilding to use regional state aid for conversions of shipyards to new market segments. Before applying, it will be necessary to undertake specific assessments of the yards concerned, in order to assess the viability of the conversion.

1 Introduction

1.1 Background

The shipbuilding industry in Europe has a rich history. Over the course of years, global competition has increased, with various lower wage countries entering the shipbuilding scene. This has led to changes in the structure of the industry in Europe. By developing new products, innovating production processes and creating new markets, the European shipbuilding industry has been able to maintain a significant market position in the worldwide shipbuilding industry. The European shipbuilding industry is globally renowned for its innovative nature and its capability to deliver high quality, specialised vessels. Today Europe has a lead position in high value, high complexity segments such as cruise ships, dredgers and other specialised ship types. At the same time the European marine equipment industry has succeeded to create and maintain a strong competitive position.

The current global economic crisis has disrupted developments in the shipbuilding industry. Demand has dropped, and the number of cancellations and postponements of orders has increased. As a result, orderbooks – which were rather well filled at the start of the crisis – are rapidly depleting. For the short term, this puts pressure on the global (and European) shipbuilding industry, including both shipyards and marine equipment manufacturers.

Towards the future, new challenges and opportunities will arise for European shipbuilding. Increasingly European and national policy makers, as well as the wider public, call for sustainability and environmental friendly products and services. These drivers become visible both in the regulatory and the market domain. This does create new opportunities for the European shipbuilding industry. If organised effectively, the innovation potential of the European shipbuilding sector can contribute to both economic growth, jobs and added value, and to a resource-efficient and sustainable future.

This study looks into the possible market opportunities in shipbuilding that are affected by greening trends in society, both in term of new products and new markets.

This chapter describes the objective and scope of this study. It also provides the analytical framework used in order to analyse the green growth opportunities in the EU shipbuilding sector throughout the report.

1.2 Objective of the study

The main objective of the study, as stated in the Terms of Reference, is

> to identify market opportunities for the EU shipbuilding industry that follow from greening trends in shipping and other areas

This implies mapping out the innovation and environmental challenges likely to affect the industry within the next ten years, in particular in Europe, and analyse the market opportunities that they provide.

The main elements of the study objective are the following:

1. *Greening trends*: In this context, green is every regulatory or market development that aims at and/or results in a reduction of negative environmental impacts. These greening trends to a large extent do not take place in ship*building* as such, but rather in e.g. green *shipping* developments, which directly affect the shipbuilding (including marine equipment) sector.
2. *Green growth market opportunities*: This includes both policy- and technology-driven greening within the shipbuilding sector, as well as opportunities arising from greening trends that take place outside the shipbuilding sector but are directly relevant to it. The latter could for example be the increased demand for ships used for constructing offshore wind parks. The study focuses on the ability of the EU shipbuilding industry to grasp the economic opportunities arising from this greening trend in industry and decarbonisation-of-transport strategy and low carbon roadmap.[1]
3. *Innovation and environmental policies and challenges*: The study focuses on greening and innovation policies that have a direct influence on the shipbuilding sector. The trends towards greening, or grasping opportunities from it, can be directly policy-induced (e.g. as a result of regulatory emission standards), but also market-driven and autonomous. Both are taken into account as drivers of green (technology) innovation in the EU shipbuilding industry.

The study takes the on-going regulatory process in the field of green (technology) and innovation as a given and focuses on the dynamics and opportunities that arise from this process.

1.3 Scope of the study

The subject of this study is broad in nature. In order to ensure concrete outcomes and recommendations, the scope and focus of the study has been further elaborated. The main scoping issues are summarized below.

Definition of the European Union shipbuilding sector

The shipbuilding industry in Europe covers both shipyards (new-building, maintenance & repair) and the marine equipment industry (suppliers to shipyards). Both new-building and retrofit activities are considered. The study is directed at commercial shipbuilding activities (i.e. naval shipbuilding is excluded from the scope). It does not include recreational craft or inland waterway transport vessels.

The definition of the *European Union* shipbuilding sector is primarily based on geographic location criteria. This thus regards the employment and added value associated to economic activities located in the EU (regardless of ownership). In addition, added value for the EU shipbuilding industry that is created outside of the EU[2] may also be considered where relevant.

Coverage of greening trends and outcomes

The study analyses green growth opportunities for the EU shipbuilding sector. Several drivers for such market developments and resulting opportunities exist. Drivers can be, but are not

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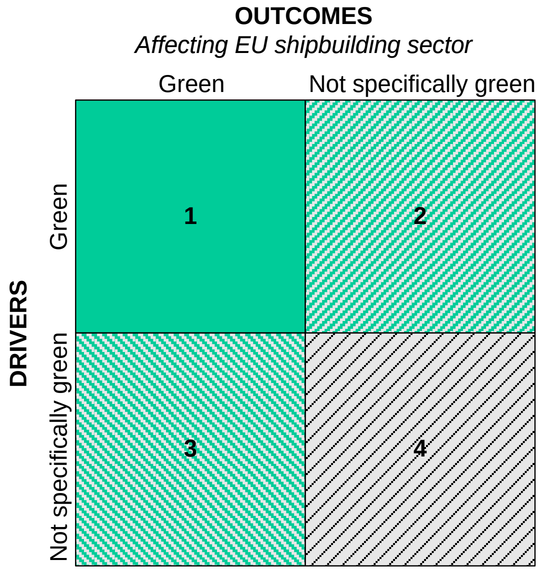
[1] See e.g. EC (2010) Communication 639 final. Energy 2020 - A strategy for competitive, sustainable and secure energy, White Paper "Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system", COM(2011) 144 final. And EC (2011), Communication (2011) 112 final, A roadmap for moving to a competitive low carbon economy in 2050.

[2] , For instance through direct license income for an EU shipbuilding company generated from having equipment manufactured under license outside the EU,

necessarily, "green" drivers. Similarly, market outcomes of specific drivers can also be, but not necessarily have to be "green". This distinction between green and non-green drivers and green and non-green outcomes is schematically depicted below.

Figure 1.1 Drivers and outcomes of green growth



Source: Ecorys

Given the purposes of this study, the following (possible) combinations are seen as inside the scope of the study:

1. ***Green drivers leading to green outcomes***; an example of this is EEDI (Energy Efficiency Design Index), which has a specific (green) goal of GHG emission reduction, which leads to a green outcome relevant for the shipbuilding sector. In this category, two types of drivers are specifically covered:
   - Market-based drivers (e.g. fuel cost or 'being green' as marketing policy or CSR policy of companies);
   - Regulatory-induced green drivers (e.g. EEDI, SO_x and NO_x ECAs);

2. ***Green drivers leading to not-necessarily-green outcomes***; this quadrant comprises drivers that have an environmental objective (e.g. the Renewable Energy Directive), leading to additional market opportunities for the EU shipbuilding sector. However these market opportunities in itself are not necessarily green (e.g. increase in demand for supply ships for construction of off-shore wind parks). In this category, only regulatory-induced drivers are considered, in line with the objectives of the study (opportunities from green growth trends for the shipbuilding sector). Furthermore under this quadrant, climate change is also addressed as a driver, although this is in itself not a green driver. It may lead to some additional market demand in specialised vessels in the coming decade. An example is the melting of the ice caps which enables Arctic oil- and gas extraction. Trading routes might shift when it becomes possible to use the Northern Sea route (north of Russia). In both cases the demand for icebreakers will increase.

3. ***Not-necessarily green drivers leading to green outcomes;*** for this category, only market-based drivers are considered. An example includes investments in fuel efficient vessels for

reasons of cost savings as a pure business consideration, which nonetheless has a green outcome.

Non-green drivers that lead to non-green outcomes (*matrix quadrant 4*) are considered to fall outside the scope of this study.

Within the regulatory drivers in the first category the study focuses on the main areas in which environmental legislation is likely to affect the shipbuilding industry in the coming ten years. These environmental areas are:
1. GHG emissions control (notably CO_2)[3];
2. NO_x emissions control;
3. SO_x emissions control;
4. Ballast water management.

Time horizon and geographical scope of the study

The study is related to the EU shipbuilding sector and relates its performance to its largest competitors worldwide: Japan, Korea and China. Also Norway is considered as a European player, given its status under the EEA and through its industry representation in e.g. CESA and EMEC. For some subjects, however, it is analysed separately or treated as a competitor of the EU.

The time horizon of the study is ten years. This horizon is especially relevant for the identification of policies and green technologies that are expected to have an impact on the EU shipbuilding sector. The chosen horizon is considered to be long enough to account for relevant developments to have an impact. This time horizon is also considered to be comprehensible enough to avoid abstract speculations on what the future might hold.

Selection of industry focus areas

The analysis to be conducted covers the entire EU shipbuilding industry. The main objective however is not to give a bird-eye's view snapshot of the sector as a whole, but to identify concrete industry opportunities. This requires insight into the business processes and value chain dynamics of the various parts of the EU shipbuilding industry.

The processes and dynamics can however differ considerably by type of ship or equipment component. Therefore, complementary to the more aggregate analysis that is done for the shipbuilding sector as a whole, a further in-depth analysis is performed for two specific market segments:
- Passenger vessels (both cruise and ferry ships will be addressed);
- dredgers.

These two segments are selected because of their importance for the EU and the competitive performance of the EU industry relative to the rest of the world.

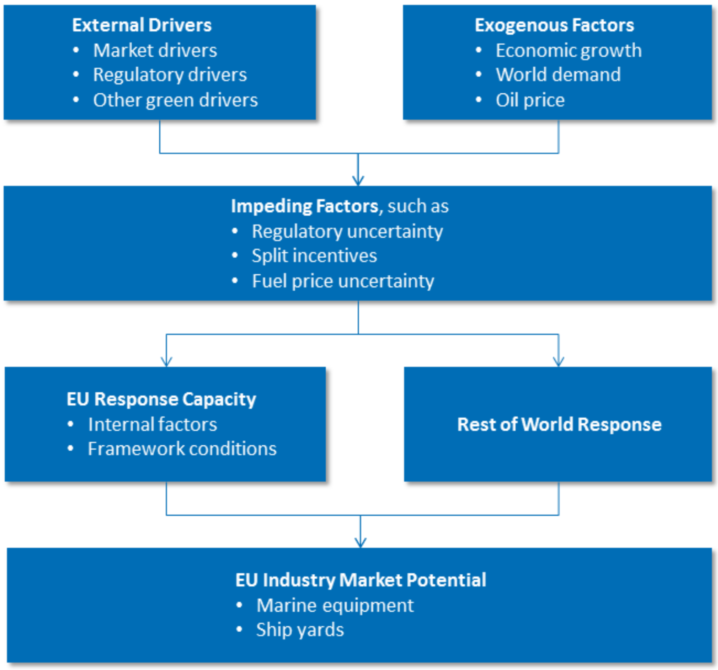
Besides these two segments, specific in-depth analysis is also done for the environmental focus areas of:
- Offshore wind developments, including the construction of offshore supply vessels and the assembly of turbine platforms and jackets;
- NO_x control technologies, a cross-cutting equipment field relevant to all ship types.

[3] Obviously this is closely related by the market driver that stimulates demand for more fuel efficient ships (quadrant 3).

1.4 Analytical framework

The following analytical framework is guiding the analysis.

Figure 1.2 Methodological framework



Source: Ecorys

Figure 1.2 shows how the European shipbuilding industry market potential can be determined and how it is influenced by several factors. At the basis of assessing the green market potential are external drivers and exogenous factors. The external drivers include those factors that can potentially create *green* growth market opportunities for the EU shipbuilding sector. Exogenous factors influence the volume of these market opportunities and the speed at which it will develop. They include factors such as the development of world demand for shipping and new vessels, oil price developments and economic growth.

Both external drivers and exogenous factors can create demand for new or refitted vessels and marine equipment. The demand will however be influenced by impeding factors. These factors may negatively influence the demand potential. For example, when it is not certain that new regulation will be actually implemented, companies are not willing to buy new equipment obligatory. Other impeding factors are split incentives in the value chain and fuel price uncertainty leading to uncertain payback times.

The impeding factors will influence both the industries in Europe and the rest of the world. It is important to know how industries will respond and how framework conditions, external to the shipbuilding industry, are influencing this response. Examples of internal industry response factors are the industry structure, the current knowledge base and the innovation strategies of the different companies. These aspects will determine how well the companies themselves can respond to changes in the external drivers / factors. Framework conditions can be the availability to finance, environmental policies and innovation policies.

Competitors in the rest of the world will also respond to market opportunities especially if these are of a global nature. As the European industry, they will also have an internal response and framework conditions in place in which their response takes place, but to the European industry these are both external and therefore they are placed in a separate box.

All factors mentioned above influence the resulting European industry market potential, and provide basic information for formulating conclusions and recommendations for policy to enhance the reaping of this market potential.

1.5 Typology of trends

By focusing on external drivers, we will pursue in this study a simple typology of trends: market-driven trends, regulatory driven-trends and other drivers.

Market-driven trends lead to a change in company behaviour without there being a direct regulatory pressure to do so. Changing behaviour can lead to cost advantages or changing market strategies. Examples of market drivers are an increased environmental awareness of customers and / or companies. Companies also change their behaviour because of financial pressures that they will have to respond to. The following trends are analysed in this report:

- Trend 1: Fuel efficiency and cost reductions;
- Trend 2: Environmental awareness and CSR.

Regulatory-driven trends lead to a direct or indirect change in company behaviour, since they define a compliance requirement. Examples of regulatory drivers are the IMO MARPOL Convention and the Ballast Water Convention. The following trends are analysed in this report:

- Trend 3: NO_x abatement;
- Trend 4:SO_x abatement ;
- Trend 5: CO_2: EEDI, SEEMP + market based measures under discussion at IMO;
- Trend 6: Ballast water and sediment treatment .

The third category contains *other drivers* that create new markets or provide new business opportunities. Two trends addressed in this study are renewable energy policies driving the construction of offshore wind farms, and the – in itself not green driver – climate change driven Arctic ice melt, creating opportunities for oil- and gas extraction and shipping in the Arctic region.

- Trend 7: Offshore renewable energy;
- Trend 8: The Arctic Dimension.

It should be noted that certain trends provide some overlap in terms of the market potential and impeding factors. For example trend 1 (fuel efficiency and cost reduction), has a certain degree of overlap with trend 5 (CO_2 reduction driven by regulatory measures). Due notice is taken of these possible overlaps in the report.

1.6 Methodology to assess the market potential

The findings of this study are based on in-depth interviews with industry stakeholders (see Annex 2), complemented with a review of available literature (see References). The interviews aimed to identify greening trends and the market potential they could create for both shipyards and marine equipment manufacturers, as well as to assess the importance of existing barriers, and the competitive position of European industry vis-à-vis players elsewhere. Two workshops were held with industry stakeholders to discuss and validate findings.

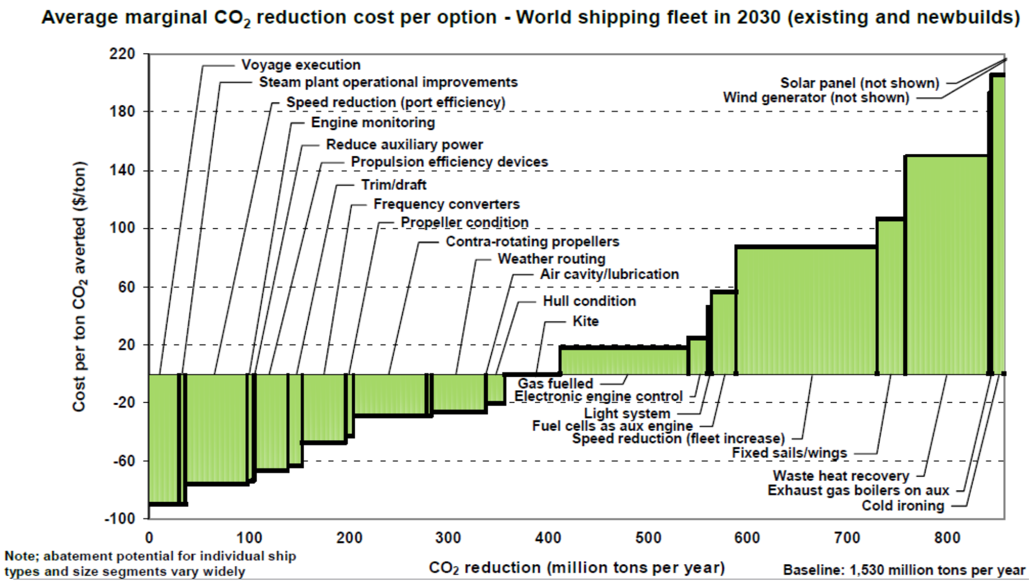
In addition, Germanischer Lloyd was involved in this study to identify key technologies available, their current level of implementation and main industry players in and outside Europe involved in these technologies. Their findings are integrated in this report.

The market potential resulting from environmental regulations (NO_x, SO_x, CO_2 and ballast water) directly follows legislation and therefore depends to a large extent on regulatory standards that are set (both existing and near future standards), as well as their effective enforcement. All these regulations create market potential, especially for equipment suppliers developing innovative technologies, but also for yards.

The logical response of ship owners will be to pursue the most cost effective measure for their ship, as to realise emission abatement measures at the lowest relative costs. The ranking of measures according to their cost-effectiveness leads to marginal abatement cost curves (MACC). An example is given in the box below.

Box 1.1 Cost effectiveness of a variety of measures to reduce CO_2 emissions

On behalf of IMO, DNV has assessed the abatement potential of a variety of technical solutions. Below picture indicates that while some measures are highly cost effective[4], others are still economically unattractive. It is remarked that these are however averages and the actual abatement potential for an individual ship can vary widely.



Source: DNV (2011), Shipping CO2 emissions –Technical solutions and abatement potential. Eirik Nyhus – Director, Environment, IMO, March 2011

To estimate the market potential of green drivers, these marginal abatement costs curves are applied to assess the most effective measure to be applied for specific ship types. For CO_2 drivers,

4 Those measures that show a negative cost per ton of CO_2 averted (as a result of related fuel consumption), would potentially create direct net benefits to ship owners.

use has been made of curves developed by IMO (see also Annex 3).[5] To assess the potential resulting from NO_x and SO_x, which are geographically defined by the assignment of Emission Control Areas (ECA's) and so far only found in Europe (SO_x ECAs of SECAs) and the US (NO_x ECAs or NECAs), use has been made of an earlier analysis done for DG Environment (Bosch (2009)). In this study a cost benefit analysis was carried out of the introduction of the legislation defined by IMO in 2008 (see box 1.2). Isolating the investments and operational costs from the overall cost assessment of strengthening the fuel sulphur limits and NO_x emission standards, provided information about the potential future size of the market. Future market growth estimates have been taken from IMO (2009).

Box 1.2 Method of estimating the market potential of SO_x and NO_x

As part of a cost-benefit analysis of the revision of Directive 1999/32/EC, which is an implementation of the legislation defined by IMO in 2008 (see section 4.1), Bosch (2009) calculated the costs for NO_x and SO_x abatement for different regions (e.g. Baltic and North Sea ECA zones already assigned for sulphur, and the considered Mediterranean sea) on the basis of cost units for several abatement options. The cost estimates are based on investment and operational costs and estimates on the hours of use for the different technologies. For each scenario calculated, total costs are specified for a high cost and a low cost estimate, taking into account different technologies and differences in new build and retrofit options.

The cost figures calculated are used in this study as an estimate of the potential market size. Especially the data on the costs of scrubber (reduced SO_x emission) scenarios and SCR (reduced NO_x emission) scenarios have been used.

Source: Bosch (2009), Cost-benefit analysis of revision Directive 1999/32/EC

The main hurdles in reaching the full market potential have been identified in a three-step process. First, an extensive literature survey was performed (AEA et al., 2008;[6] Buhaug et al., 2009; Crist, 2009;[7] CE Delft et al., 2009; Wang et al., 2010; CE Delft and Marena, 2011; Eide et al., 2011[8]). The barriers have been discussed with different stakeholders in 37 in-depth, semi-structured interviews. The results of the interviews were collated and discussed with other stakeholders in a workshop held in September 2011 in Hamburg.

Based on the literature research potential barriers are distinguished, which are structured in three main groups:

- Barriers for the development of technology;
- Barriers for scaling up technologies;
- Barriers for the expression of demand.

The results of this barrier analysis are described for each of the eight green markets identified (i.e. fuel efficiency, environmental awareness, NO_x, SO_x, CO_2, ballast water, offshore wind, Arctic). The barriers are classified according to the three stages of innovation:

- Development of technology and supply of innovation;
- scaling up and learning-by-doing; and
- the expression of demand for technology by ship owners and operators.

5 IMO, (2010), CE Delft et al. (2009), IMO (2009).
6 http://hmccc.s3.amazonaws.com/pdfs/AEA%20shipping%20report%20for%20the%20CCC.pdf.
7 http://www.internationaltransportforum.org/jtrc/DiscussionPapers/DP200911.pdf.
8 http://www.tandfonline.com/doi/pdf/10.1080/03088839.2010.533711.

Where relevant, a distinction is made between general barriers, affecting actors globally, and barriers that are specific to EU actors.

1.7 Structure of the report

Chapter 2 starts with providing an overview of the current position of the EU shipbuilding industry, presenting the various actors active in the value chain, the innovation potential and sketching the current competitive position of the EU industry. Within this chapter a more in-depth description of the market segments “passenger ships” and “dredgers” is given, two segments in which Europe holds a strong position, to further illustrate the position of the EU shipbuilding industry.

The following chapters then discuss the main greening trends, by assessing:

- the green drivers – providing the opportunities;
- the market potential;
- the impeding factors;
- EU industry response, including technological developments.

The greening trends are analysed in different chapters. Chapter 3 addresses the market-driven trends of fuel efficiency and cost reductions, and environmental awareness and CSR (Trends 1 and 2). Chapter 4 focuses on the regulatory-driven trends, notably NO_x and SO_x abatement, CO_2-related measures and ballast water management (Trends 3 to 6). Chapter 5 addresses other greening trends, including offshore renewable energy and the Arctic dimension (Trends 7 and 8).

Chapter 6 summarises the market potential and the business strategies pursued by industries. Policies supporting green market opportunities in Europe and in the rest of the world are then addressed, and based on this a gap analysis is given. The chapter concludes with recommendations.

2 The EU shipbuilding industry position today

The ability of the EU shipbuilding industry to take advantage of green growth opportunities depends strongly on the state-of-play of the industry today. Essential for the future response capacity of EU industry is its competitive position, including its current innovation potential and the composition of value chains – including the interaction between and access to different actors.

The EU shipbuilding industry is diverse and serves a wide range of market segments. In this chapter, first the various actors involved in the shipbuilding value chain will be assessed (section 2.1). In section 2.2 the current competitive position of the European shipbuilding is pointed out, followed by section 2.3 concerning R&D and innovation characteristics of the EU shipbuilding industry.

Within the scope of this study, two market segments are presented in further detail: passenger vessels and dredgers. In section 2.4 and 2.5 the current state of play with regard to these segments is elaborated.

2.1 Actors in the shipbuilding value chain

The main actors in the shipbuilding value chain are shown in figure 2.1. In the following text the main role of each actor is described including the specific role of the actor in the innovation process. Obviously this is a strong simplification of reality as actors differ very much in size and role and in some cases actors are not split but integrated in a single party (e.g. design activities directly undertaken by shipyards). Nevertheless, with keeping these limitations in mind, a number of key roles can be distinguished.

Figure 2.1 Value chain of the shipbuilding industry

Design offices

Design offices can play an important role as the conceptual design is crucial for a vessel's operational efficiency. They usually collaborate with shipyards (or are integrated in a shipyard) to develop a ship design which matches the operational criteria set by either the yard or the owner. In some cases, also large ship owners/operators undertake design activities.

Design offices (possibly in cooperation with research institutes, classification societies but also R&D and design divisions of other actors along the value chain) can play an initiating role in certain innovations (e.g. hull design). Designers also increasingly cooperate with marine equipment manufacturers to take part in joint development projects. Whether these innovations find their way on the market depends on their interaction mainly with the ship owner and/or shipyards. A general risk aversion of ship owners to new innovation that are not yet proven technology is an impediment.

On the other hand, shipyards may embrace new designs (or develop them internally) as it allows them to differentiate from competing yards.

Some design offices are connected to classification societies. In some cases classification societies also take part of the role of the design offices. While the cooperation between design offices and classification societies may provide benefits, as expertise of technical/survey staff can be used for pre-project consulting to assist in building a vessel, some interviewees suggested it could also limit the innovative capabilities of a designer due to the standards that are laid-out by the classification societies limiting more innovative designs. On the other hand this may represent a major advantage as being connected to classification societies entails the advantage of getting the innovation approved more rapidly.

Box 2.1 IMPROVE – Support for Designers

The main objective of the IMPROVE project, funded under the EU's FP6 program, was to develop three new ship designs in an integrated multiple criteria decision making environment by using the advanced design synthesis and analysis techniques at the earliest stage of the design process, which innovatively considers structure, production, operational aspects, performance, and safety criteria on a concurrent basis. The product types focused on in this project are new generations of LNG gas carriers and chemical tankers, and an innovative concept of a large Ro-Pax vessel.

Source: http://www.improve-project.eu/

Marine equipment suppliers

The marine equipment industry contributes to innovations through particular components that can make a difference for the total performance of the ship and/or operational costs. In general equipment suppliers are seen to be a major actor in innovations. The role of the supply industry is large in ship production as the value of today's ships consist for 50-70% (or more) of subcontracted supplies and activities. Although not fully conclusive, an analysis of R&D spending among major marine equipment producers, in comparison to shipyards, seems to indicate that R&D spending among marine equipment suppliers is higher than for shipyards[9].

Marine equipment actors interviewed tend to perform most innovations in-house and finance them with internal means. Especially product developments on the short term (1-2 years for development and placing on market) are being done in-house. The tendency to develop their innovations internally is also driven by the fact that innovations are of crucial importance to their existence and they fear knowledge leakage (risks of violation of property rights). Especially SMEs tend to prefer to develop innovation internally. In some cases, marine equipment suppliers (especially larger suppliers) set up partnerships with other companies or universities/research institutes, but mainly to develop specific techniques or technologies that target medium or long term developments.

The role of marine equipment suppliers towards ship owners and shipyards differs, also depending on the cooperation model that is followed. In complex ship types in general a more intense cooperation is sought between key actors across the value chain, while in more standard designs the role of marine equipment manufacturers may be less pronounced. In certain cases ship owners strongly influence the choice of equipment suppliers (also as the operational cost or performance perspective of a ship is more important to them than to a shipyard)[10]. For retrofit technologies the

9 See ECORYS (2009), Study on the Competitiveness of the European Shipbuilding Industry (table 5.4).

10 See also the issue of split incentives in this respect (chapter 3) where the ship operator may have a different interest than the ship owner.

role of marine equipment providers in innovation is essential as they can become a more direct contract party to the ship owner. Larger sized marine equipment manufacturers such as MAN and Wärtsilä are actively present in shipbuilding countries outside Europe and also engage in research cooperation with yards located there.

Box 2.2 Cooperation between Korean industries and European manufacturers

Focus on energy efficiency in South Korea has increased with R&D into dual fuel systems and cooperation with both MAN and Wärtsilä. The Korean based engine builder Doosan states to supply one of every four large ships built worldwide. Doosan's roots came from license agreements with both MAN and companies now part of Wärtsilä. A great variety of R&D projects between yards and engine manufacturers, also involving other suppliers and Korean Register, are expected to deliver energy improvements for wide power output ranges.

Source: Marine Propulsion, August/September 2011, p.141-148

Box 2.3 Siemens breaks into wind turbine market

Siemens is to supply diesel-electric propulsion gear to a jack-up sea installer that will be built in China at COSCO Nantong and is planned for delivery to Danish company A2SEA in July 2012. The vessel will be able to carry 8 to 10 complete wind turbines, and is optimised to build them in water depths up to 45m. Siemens acquired 49% of A2SEA's shares in 2010.

A similar project is developed by Aker Solutions from Norway, concerning a vessel able to operate in ECA zones and outfitted with Wärtsilä propulsion equipment

Source: Marine Propulsion, August/September 2011, p.155 & April/May 2011

As many marine equipment companies do not solely work for the shipbuilding industry (e.g. engine manufacturers like Rolls Royce, MAN, Wärtsilä all serve other markets such as land transport, power stations, etc.), they have the ability to make use of knowledge gathered in other industries and transfer this to the shipbuilding industry.

Moreover, several marine equipment actors are evolving towards a different business model in which maintenance or life cycle support becomes more important than pure direct product sales. This is often combined with a higher level of system integration in which systems (e.g. propulsion systems) rather than individual components are offered. Examples of this development can be found at companies like Rolls Royce, Wärtsilä, and Imtech. This development can partly be seen as a response to the economic crisis, but also as a business strategy to create a more permanent market position towards their clients. At the same time this corresponds with a trend in demand from ship owners and shipyards towards systems rather than components[11]. Finally this is also related to the overall trend of outsourcing in shipbuilding, and it also enables shipyards to transfer part of the liability of a specific system to a marine equipment supplier.

A large number of small and medium enterprises are found in the marine equipment industry. Their number has been estimated between 5,000 and 7,000 companies in Europe.[12] Typical problems faced by SMEs across industries, such as the difficulty of obtaining financing and moving from R&D to implementation, are also identified in this segment. An SME survey across a number of sectors indicated that “financing research and innovation activities” is their most important R&D and innovation need. [13]

Whereas the innovation potential of marine equipment manufacturers is seen as high, they are also faced with specific barriers in bringing their innovation to market. This is partly the result of barriers that affect the driving forces behind green innovation in shipbuilding (e.g. regulatory uncertainty), but also to conflicting interests and risk allocation/aversion of ship owners and operators. In this respect reference is made to chapter 4.

Some European ship equipment manufacturers interviewed stated they prefer to work with Asian rather than with European shipyards because financing arrangements were said to be easier to make. Asian shipyards are said to often be able to provide a letter of credit based on their government backing, which lowers the financial risk of the ship equipment manufacturer. From the point of view of the European equipment manufacturer this of course is not a barrier, from the point of view of the shipyard and also the buyer it might well be the case.

Shipyards

The current economic crisis has led to a reduced demand for new-built ships and has turned from a “sellers” market to a “buyers” market. This implies that innovation emphasis is put on efficiency, reliability, performance, standardization and cost-cutting as these are “safe bets”. This strategy is especially relevant for shipbuilding companies serving mass segments like container ships, tankers and bulkers, segments that are dominated by Asian yards. However also some European companies like Damen apply this strategy, e.g. by developing new ship types with the aim of building (smaller or larger) series of the same kind. Standardization and an aim for serial production of ships can reduce construction costs and allows for continuous improvement and the introduction of incremental innovations.

Other shipyards try to differentiate to other market segments where markets are less affected by the downturn in demand or specialise in niche markets. In fact this latter strategy has been the main strategy within Europe for many yards for the past decade or more. In this respect, the interest of shipyards in new upcoming market segments such as offshore wind energy is understandable.

In relation to innovation, shipyards take a position in the role of system integrator, combining innovations from third parties/marine equipment suppliers in an integrated ship design and construction, and are a driving force behind new ships designs and innovations in response to market demands and in view of enhanced (fuel) efficiency. The frequency and intensity of

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[11] See also Danish Maritime Authority (2011), Innovative green ship design.
[12] Balance Technology Consultants (2000); EMEC; CESA.
[13] European Commission (2010): Mid Term Report on SMEs' Participation in the 7th R&D Framework Programme. Brussels, 27.09.2010.

innovations is strongly influenced by the level of standardisation of the ship types that are being produced (mass production versus one-off ship types).

Box 2.4 Damen optimises ship design

Damen studies the behaviour of ships, together with MARIN, TU Delft and shipping companies, with the aim to develop new concepts on e.g. the ship's hull (like the axe bow), energy-saving air-Lubricated Ships (designs for IWT now being made, said to save 15% on fuel, equalling up to € 400,000 per year for an average IWT company) and propulsion & auxiliary systems.

Source: interview

In Europe, working in specialised (high value) niche markets in general involves an active innovation strategy (as many ships are one-off and build on demand of clients). The technological advance enables these specialised shipyards to retain their market position. IHC for example employs a roadmap to determine the innovations they will pursue, taking into account market foresights, different functionalities that can be realized with the innovation, and life-cycle opportunities. They mainly pursue process innovations as the integration of several techniques for a yard is key to obtain a competitive advantage. These yards for instance set up collaboration programs with marine equipment companies, universities and research institutes to study the behaviour and characteristics of ships. The presence of these actors in a certain geographical area is seen as an advantage to build up valuable knowledge and may limit knowledge leakage to other parts of the world. Also marine equipment suppliers indicate the importance of having high class shipyards in Europe in their role as integrators and proving new concepts developed by marine equipment manufacturers before exporting equipment.

Looking at R&D expenditures a mixed picture is sketched[14]. Europe has a relatively low R&D ratio (as a percentage of production value) in shipbuilding although the picture per country is rather diverse[15]. The Asian countries Korea and Japan have relatively high R&D ratios, whereas China is reported to spend limited funds on R&D in relation to the total volume of ships that is being produced[16]. Obviously this may also point to the fact the R&D is differently organised (in-house R&D versus outsourced R&D or direct purchase of innovations). On a company level the picture is reversed with high value ship yards like Fincantieri and IHC spending relatively large sums on R&D, whereas major Korean yards rank relatively low on R&D spending.

Box 2.5 Breakthrough in European Ship and Shipbuilding Technologies (BESST)

The strategic objective of BESST is to secure and improve the competitive position of European shipyards in a sustainable way, looking into the medium and long term future. Having in mind the comparatively high labour cost in Europe, the goal is to increase the competitiveness of European built ships through decreased life cycle cost, drastically reduced environmental impact and improved safety. Focus is put on the market segment of high value added, complex, one-of-a-kind ships, in particular cruise vessels, passenger ships, ferries and mega yachts. The project is funded under the EU's FP7 program. Coordinator is Fincantieri and project partners are Meyer Werft, Kockums, BALance Technology Consulting, Chalmers Tekniska Hoegskola, Diginext, DNV, Germanischer Lloyd, among others.

Source: http://www.besst.it/

14 See ECORYS (2009), Study on the Competitiveness of the European Shipbuilding Industry, section 5.3.1.

15 With Germany and Norway having relatively high R&D ratios and Italy and the Netherlands low R&D within the shipbuilding industry.

16 See also chapter 6.

Ship owners

Ship owners are the main decision takers in the shipbuilding industry value chain. They are the ones that take the purchasing decision and consequently the decision power to invest (or not) in innovations. Obviously ship owners also decide where to invest. In 2008, European ship owners accounted for over half (52%) of the entire demand for newbuild ships (whereas the share of Europan shipyards in the total global orderbook value at that time amounted to 13%)[17]. However with the rise of Asian shipping companies it can be expected that there will be a shift in origin of ship owners in favour of Asia.

Especially in view of the current shift from a sellers to a buyers market the position of ship owners has further increased. Potentially this allows ship owners to exert a major influence on the innovations that will enter a ship. They can determine the type, and often also the brand, of engines and other specific marine equipment and thus approve the application of innovations with regard to these items. The level to which they are interested to invest in green innovations is strongly dependent on their own business model and decisions (e.g. capex versus opex, CSR, self operating versus chartering, etc.). As such they are strongly influenced by the green drivers that have been identified earlier. At the same time they are strongly influenced by barriers like the uncertainty of fuel price developments, split incentive schemes, regulatory uncertainty, risk aversion toward technologies that are not proven, etc. (See chapters 3 and 4 for further elaboration of these barriers.). The risk aversion of ship owners towards new technologies seems to be also valid for banks financing their newbuild orders.

In certain segments, especially those where the owner is also the operator, ship owners increasingly engage in introducing innovations in close collaboration with shipyards and marine equipment manufacturers. The presence of a knowledge cluster is seen as advantageous in this respect.

Shipping companies

Shipping companies are the actual users of the ships; they operate the ship to transport goods, people or to provide other services. In the case of passenger vessels, dredgers and offshore ships, the ship operator often coincides with the ship owner. This implies that there is one decision power less in the value chain, which is considered beneficial to the introduction of new innovations: the ship owner is affected by the investment costs but also by e.g. the fuel costs, making it easier to convince them to install innovation for example to enhance energy efficiency and reduce operating costs.

In other segments, notably bulkers and container ships, ship operating companies are rarely also the ship owners, but the two different parties have different incentives, e.g. ship owners are mainly concerned with investment costs, whereas the ship operating companies have to bear the fuel costs. For a marine equipment manufacturer, this involves negotiations with two parties with very different incentives, making the introduction of innovations more difficult and/or resulting in the ship operating companies not being represented in the construction process.

Cargo owners

Cargo owners select a particular shipping company to ship their goods. A major factor in this decision is cost. However, recently a 'green' argument has gained importance and is now also

[17] 2008 figures. See ECORYS (2009), Study on the Competitiveness of the European Shipbuilding Industry, No more recent data could be obtained.

influencing the decision of some cargo owners. For example, some cargo owners demand that their goods are being transported on a 'green' ship (see the Environmental Shipping Index initiative in box 3.1 in Ch.3). This implies that the cargo owner can put pressure on the ship owners to do an effort in 'greening' the ships and thus allow innovation to happen.

Some marine equipment manufacturers have discovered the power of cargo owners. A new strategy for them is to approach the cargo owners in addition to the ship owners, to provide them with information regarding new innovative products or systems. If the cargo owner has an interest in the new product or system, it helps them to sell this to the ship owner. In this way, marine equipment manufacturers are creating a demand pull (from the cargo owners), creating a powerful argument to convince the ship owner to invest in their innovative offer.

Classification societies

Classification societies are important as they set standards and supervise rules in the shipbuilding industry. In principle, class societies check whether the products and systems on board of a ship comply or not. They set and apply technical standards relating to the design and construction of ships and carry out extensive surveys of ships and their main systems. The largest classification societies are Det Norske Veritas, Lloyd's Register, Germanischer Lloyd, Nippon Kaiji Kyokai, RINA and the American Bureau of Shipping. According to some interviewees, classification agencies have a tendency to be rather conservative and focused on their primary task (safety) above anything else. For example, for a ship to transfer between classes, it has to be re-examined and tested which implies a huge cost. Moreover, also the ship owner tends to be conservative in this regard and prefers to stick to his particular class.

Recently however, classification societies have started to take a more active role in the introduction of innovations in the area of greening ships. Det Norske Veritas for example jointly with Japanese shipyard Oshima Shipbuilding Co. started the Eco-Ship 2020 project aiming at a bulk vessel design with 50 percent less weight and powered by LNG.[18] Lloyds Register is doing a similar research with Shanghai based Bestway Marine Engineering Design. Furthermore they have started to partner in other R&D projects as they possess a lot of specific knowledge, potentially pushing innovations slightly. Lloyd's Register for instance presented some of the approaches that can be used to safely apply and integrate rapidly advancing (green) technology on board ships. Specific attention was devoted to their work that is concentrated on application of alternative fuels and future energy sources, such as LNG and fuel cells[19].

Where traditionally classification societies are called upon to decide if the end product complies with the class rules, they are now moving up the value chain. They increasingly engage with design offices, ship yards and marine equipment manufacturers to discuss innovations and developments that contribute to raising the ship's fuel efficiency or reduce its operating costs. While they may become drivers of innovation when following this track, they however should carefully address the balance between their commercial interests and their regulatory task.

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18 Marine Propulsion, August/September 2011, p.93.

19 http://www.lr.org/sectors/marine/Researchandtechnology/index.aspx.

2.2 Current competitive position of the European shipbuilding industry

Demand for shipbuilding and the economic crisis

Already for several decades European shipyards are facing strong global competition from especially Asian enterprises. First Japanese yards entered the global shipbuilding scene in the 1950s and 60s, followed by Korean yards from the 1970s and 80s onwards, and Chinese since the 1990s. In Europe this has led to an almost complete exit from the mass production segments of tankers, bulkers and containerships. Response of the EU industry has been to focus on the higher value, more complex ship types such as cruise, offshore vessels and installations and dredgers. The position of the European shipbuilding industry in the manufacturing of specialised innovative vessels is still strong. At the same time European equipment manufacturers have acquired a leading role in quality products especially in complex / high value equipment components. [20]

The current global crisis, which started in 2008, has intensified the pressure on the global shipbuilding industry, and resulted in a reduced global demand. In view of existing capacity at shipyards worldwide this has triggered various responses including the attempt of competitors across the world to enter other, higher value segments. The latter segments are also affected, but demand has fallen less steeply than for mass markets such as bulkers, tankers and container ships. Today more than ever Europe's shipbuilding industry prospects rely on its ability to maintain its competitive advantage and to further move into new high value – high complexity activities.

Analysis of demand and supply suggests that while the crisis may have been the trigger, the imbalance between fleet capacity and new orders on the one hand and gradual growth of transport demand on the other was already being built up in the years before. In fact shipbuilding is a highly cyclical industry and was about to enter its next down cycle because of this. The economic and financial crisis further aggravated this trend. Whereas shipbuilding is indeed a cyclical industry, the current global crisis may be more severe and last longer than previous economic downturn periods, which poses an even stronger challenge to the industry. Reference is regularly made to "The Great Depression" of the 1930s.[21]

This current crisis creates a number of specific challenges for the industry in order to survive the current downturn. Obviously the fight for the (limited amount of) new orders will become more intense. Recent figures show that in the first half of 2011 the orderbook of European shipyards slightly declined compared to 2010, further reducing the amount of work at hand (see figure 2.2).[22] As the limited amount of new orders placed in the first half of 2011 contained a number of larger orders received by a few yards[23], one may expect several players arriving at empty orderbooks very soon. This is most likely to lead to a (further) structural adjustment in capacity where the weaker yards will cease to exist. In comparison to the orderbook share in 2005, the position of EU27 yards has weakened dramatically. In terms of outputs Asian builders (China, Korea, Japan) do not show an output reduction yet.[24] However when analysing the orderbook a more diverse picture is shown. The share of Japan in the world orderbook reduced in comparison to 2005 and 2000, whereas Korea's position remained more or less stable. The share of China in the world orderbook and output on the other hand increased strongly, making it the largest shipbuilding nation in the world at this moment. Those shipyards that are able to stay in business will need sufficient

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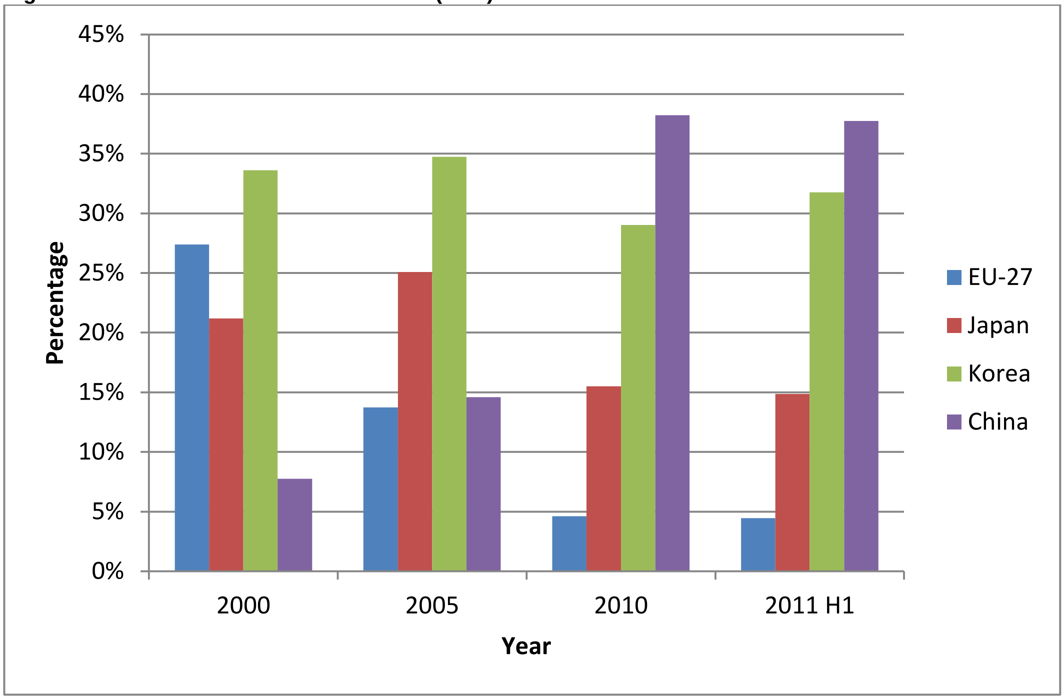
20 See Ecorys (2009), Study on Competitiveness of the European Shipbuilding Industry.
21 See for instance OECD (2011), Changing characteristics of the shipbuilding market.
22 CESA (2011), Shipbuilding Market Monitoring Report No. 24, September 2011.
23 CESA (2011), Shipbuilding Market Monitoring Report No. 24, September 2011.
24 OECD (2011) Changing characteristics of the shipbuilding market.

access to capital, since they, as a capital intensive industry, need to maintain high value assets until the market starts to show signs of recovery.

To maintain their market position also Asian yards focus more and more on greening opportunities. The Korean government for instance introduced a GHG emission reducing program in 2008.[25] The program is aiming at reducing GHG emissions throughout all economic sectors, including the shipping and shipbuilding industry. Also the Japanese Shipbuilding Association (SAJ)[26] is looking into the possibilities to reduce GHG emissions, so that the shipbuilding industry becomes greener and more competitive.

Figure 2.2 Shares in worldwide orderbook (CGT)



Source: CESA Shipbuilding Market Monitor September 2011, Calculations: Ecorys

In parallel, ship ownership is also shifting to other world regions. Where in the past more than 50% of the world fleet was European owned, managed and/or operated, nowadays the European share is gradually declining. This may eventually raise the dependency of European shipbuilders on Rest of World clients.

Segmentation of the European industry

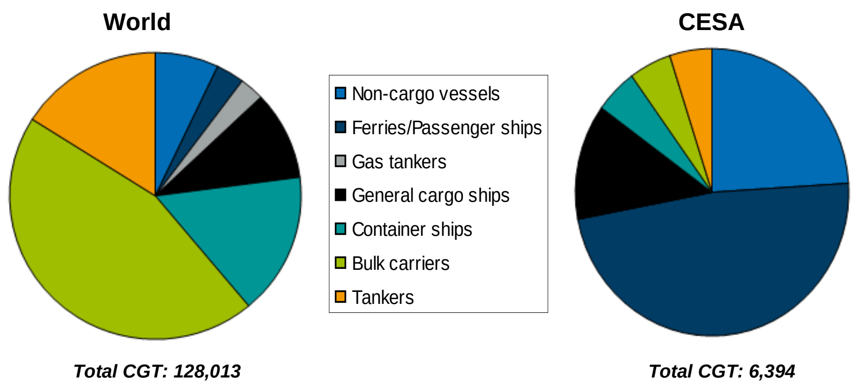
Europe has a strong position in more specialised higher value ships. These segments include ferries and passenger ships, non-cargo vessels and general cargo ships, which are characterised by a high degree of specialisation and complex production processes. In addition, only limited numbers of vessels of the same type are being built (in contrast with bulk vessels, which are mass produced). Europe has a 77 percent market share in building passenger vessels (including both cruise ships as well as ferries) and a 17 percent share in the construction of non-cargo vessels. These segments make up a relatively small share of the world orderbook (in CGT). However, in value they represent a much higher share due to their relatively sophisticated characteristics.

25 Republic of Korea (2011), Green growth in Korea, presentation for OECD Green growth workshop.

26 Hiroshi (Dave) Iwamoto (2011), The Shipbuilders' Association of Japan (SJA), presentation for OECD Green growth workshop.

Figure 2.3 shows the world orderbook and the CESA order book by ship type for 2010. First half year results for 2011 indicate that the development of orders and completions has been such that the EU share is declining rather than growing.

Figure 2.3 World orderbook and CESA orderbook by ship type (CGT x 1000) (2010)



Source: CESA Shipbuilding Market Monitoring, September 2011, Calculations Ecorys

Note: Other non-cargo vessels exclude naval vessels. The coverage of luxury yachts may be incomplete[27]

Whereas Europe has always been able to maintain its position in these high-value markets, also competition in these markets is increasing. Even market segments which previously remained unchallenged, such as the cruise market, show first (anecdotal) evidence of new competitors from outside Europe trying to climb the complexity ladder[28].

Marine equipment

There are close ties between (marine) equipment suppliers and shipyards. With technological advancement, the role of the marine equipment industry – as the supply industry to the shipyards – has increased considerably. While in the 1970s most of the shipbuilding work was carried out at the shipyards themselves, nowadays the share of marine equipment is assessed at 50-70 percent of the product value, and can be 70-80 percent in the more specialised segments.[29] The European equipment industry is renowned for propulsion, cargo handling, communication, automation, environmental and security systems.[30] This equipment is not only destined for complex, European-built ships; Asian yards, whether or not requested by their clients, also source heavily from European equipment suppliers, e.g. to ensure quality and consistency with their fleet inventory, maintenance support etc.

Compared to the ship construction sector, the marine equipment segment is highly heterogeneous and consists of companies that are often also active in other business areas (i.e. automotive or aircraft industry). Next to the strong export position of the marine equipment industry several of the

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27 Several sources suggest that luxury yachts may not be well covered in statistical sources, as the registration of newbuild yachts would be incomplete. Therefore the actual share of this segment may be higher than figures in this report indicate. The suggestion could however not be verified.

28 Although there have been some occurrences in the past where cruise ships were built by Asian shipyards (e.g. cruise ships built by Mitsubishi Heavy Industries in Japan; Diamond Princess (2004), Sapphire Princess (2008)), this never developed into a structural competition with European cruise shipyards. However, the recent announcement of the construction of a 105,000 tonnes cruise vessel, The Utopia,at Samsung Heavy Industries (operational in 2013), might be the start of a new chapter in this field.

29 Ecorys (2009).

30 Ecorys (2009).

larger companies have assigned licenses to Asian manufacturers to manufacture for them at sites near to Asian shipyard customers. Some European equipment manufacturers have moved their production facilities to Asia (instead of licensing) close to their clients' yards, not just for labour cost reasons but also for more effective implementation processes.[31] This may also be partially linked to the adoption of local content requirements in competing shipbuilding countries, which can create a threat for the export position of European marine equipment suppliers[32]. Within the marine equipment sector a tendency towards further consolidation is observed, where large manufacturers of main components acquire technologies and skills on adjacent equipment either through own development or acquisition, and gradually become system integrators and suppliers instead of delivering single components. In several cases this is combined by offering full life cycle solutions, where integrated services are delivered not only for supply but also for after sales maintenance and service delivery.

Just like shipyards also marine equipment suppliers are hit by the decreasing demand for newly built ships. However, it is expected that the impact for this group is slightly less[33] in view of the trend towards outsourcing in shipbuilding (increasing demand for marine equipment especially in high value ships) and the fact that marine equipment suppliers are delivering to shipyards across the world, thus being less hit by a decreasing market share of European shipbuilders. Moreover they also provide the maintenance market through replacement equipment and repair services, a segment which by its nature is affected less than new purchases. Finally, many marine equipment suppliers are also active in other sectors (which reduces their market exposure in one single sector).

Repair, maintenance and conversion yards[34]

Apart from ship building yards there are also yards specialized in repair, maintenance and conversion. In Europe in at least sixteen countries such activities take place. Many yards active in these segments are located in North West Europe, but also along the Mediterranean Sea repair, maintenance and conversion yards can be found.

Total European repair, maintenance and conversion turnover amounted to € 6.3 bn in 2010. The figure below shows the division between turnover generated in different European countries. No distinction is made between repair & maintenance yards and conversion yards.

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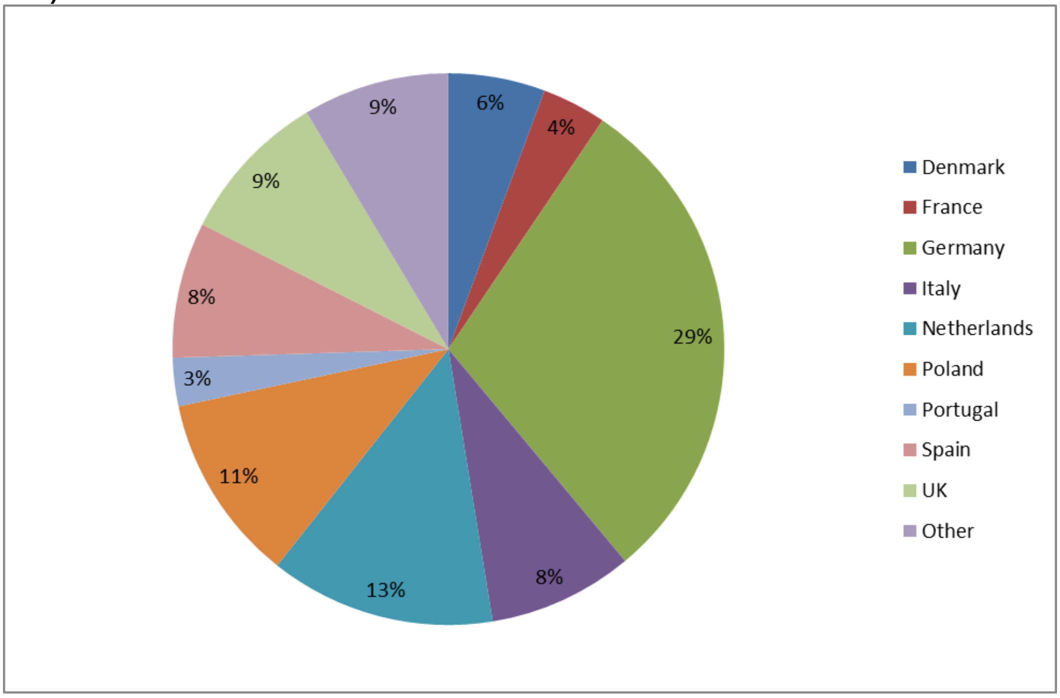
31 CESA (2010). Shipbuilding Market Monitoring. Report No 18 – March 2010.

32 CESA (2011), Annual Report 2010-2011.

33 This is also indicated by marine equipment suppliers that have been interviewed in this study. The fact that marine equipment suppliers are not discernable in statistics (as they do not compose a separate economic sector) makes it hard to prove this with hard figures.

34 Section based on: CESA (2011), Annual report 2010-2011; CESA (2010), Annual report 2009-2010.

Figure 2.4 EU countries active in repair, maintenance and conversion (share in European turnover in 2010)



Source: CESA annual report 2010-2011, Calculations: Ecorys

Repair and maintenance yards

Repair and maintenance is a short term activity. The dry dock period is generally 10 to 12 days. For some repair works, dry docking is not necessary. Yards providing this service can be qualified as a service industry rather than a manufacturing industry. Clients can make an appointment on short notice.

Different types of repair exist: there are scheduled repairs and unscheduled repairs. Scheduled repairs are done at specific points in time. Yards know in advance which vessels need to be repaired. Planning of the repair activities is relatively easy and yards can try to influence ship owners.[35] Unscheduled repairs on the other hand are the result of breakdowns and need to be done by the nearest yard at hand. The repairs cannot be planned and it is difficult for yards to influence the ship owner. A specific type of repair is the repair of a vessel that is taken back in service after it has been laid up. Yards close to the places were vessels are laid up will benefit from this trend.[36]

Repair and maintenance yards in Europe were doing quite well before the crisis. However as of early 2009 turnover and profit were declining, but initially most yards considered this logical, following the extremely good years before. As of 2010 the downturn was felt more strongly, caused by ship owners trying to save costs, cutting or postponing ship repair. In the second half of 2010 the market seemed to recover a little and waiting times were increasing again (from one week to three weeks). In 2011 the margins and budget were be more or less the same as in 2010.

[35] Repair and maintenance yards are located all over the world. Although yards in Asia are able to repair a vessels against lower costs, due to low labor costs, many ship owners choose a more expensive yard, because the more expensive yard is able to offer more sophisticated knowledge.

[36] OECD (2009), The interaction between the ship repair, ship conversion and shipbuilding industries.

North West European yards indicate facing strong competition from Black Sea repair yards. The latter have lower labour costs and are therefore able to offer their services against lower rates. In addition strong competition exists from repair yards in the Middle-East (United Arab Emirates and Bahrain[37]), Singapore and China, who can profit from lower wage costs[38] but also access to regional shipping markets.

Conversion activities

Conversions sector are in some aspects more similar to the newbuilding sector than to repair and maintenance. A ship conversion generally takes longer than normal maintenance and repair. The conversion activities can be qualified as manufacturing. The difference with the newbuilding sector is the level of flexibility needed: conversion yards have to be very flexible as to be able to constantly accommodate changes in the work plan according to the requirements of their clients and the particularities of the ship to be converted.

Also the conversion yards experienced a very good market before the crisis started. As of 2009 orders declined, facing the largest downturn early 2010. At that time most order books were empty. The market improved a little as of the second half of 2010 and yards received again a few orders for conversions. In 2011 the margins and budgets were be more or less the same as in 2010.

2.3 Research, development and innovation characteristics of the EU shipbuilding industry

Knowledge and technology transfer

Various mechanisms for knowledge transfer exist in shipbuilding. The extent to which these mechanisms apply differ strong between actors and market segment. This section describes the main mechanisms for knowledge and technology transfer that are present in the shipbuilding industry.

Several marine equipment suppliers are active in ship technologies and in land technologies such as the road and/or rail industry. This allows them to **transfer knowledge and technology to the shipbuilding domain from another economic sector**, or vice versa. For example, a company like Imtech develops air conditioning systems for offices and hotels that require the same comfort levels and capacities as used on board cruise ships. Also waste heat recovery systems are applied onshore in building environments. Operators may also be involved in various economic activities outside the marine domain. For instance dredging operators are often historically linked to construction firms (e.g. Boskalis). Another example is the design of offshore wind crane ships, which are derived from bridge laying pontoons.

Technology can also be transferred **between different ship types**. Damen for example has developed an axe bow for naval ships. This axe bow has helped to reduce the vertical movements of the ship (‘stamping the waves’) by increasing safety and comfort, and meanwhile contributed to 20% savings on fuel consumption. The launching customership of the Dutch navy was instrumental here to convince commercial clients of the benefits this design offered. The technology is now being applied for offshore ships and also for small support ships and mega yachts.

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37 Employing manpower from India, Pakistan and the Philippines.

38 According to OECD (OECD, 2009, The interaction between the ship repair, ship conversion and shipbuilding industries) if repair costs in the Middle East are set at an index of 100, costs in Europe are 150, Japan 250 and China 50.

Technology can also be **transferred through the collaboration of actors**. Typical collaboration models can be found in yards that tend to collaborate with equipment suppliers in order to realise innovations. In some cases this is stimulated by the establishment of research platforms , and it is also fostered through European research projects which support joint product development. Such programs are especially useful for complicated ship types/systems. Increasingly, there is also more collaboration between engine manufacturers and ship designers on a project basis through specific project consortia.

Collaboration can also be facilitated if a company is part of a cluster. For example, interviewees from the maritime cluster in the North of the Netherlands reported a relatively strong "integrated cooperation" between companies in the cluster there, also involving R&D institutes like the Faculty of Maritime Technology of the TU Delft, which resulted in more efficient production processes and lower costs.

Besides cooperation with geographically close partners, European players also increasingly cooperate in R&D and knowledge sharing with Asian enterprises. An example is classification society DNV who jointly with Japanese Oshima Shipbuilding Co. started the Eco-Ship 2020 project aiming to develop a bulk vessel design that has 50 percent less weight and is powered by LNG.[39] Lloyds Register is doing a similar research project with Shanghai based Bestway Marine Engineering Design. Another example is the intensive cooperation between propulsion suppliers MAN and Wärtsilä and Korean shipyards concerning energy efficiency improvements.

Licensing taking place in the shipbuilding industry is mainly driven by logistic reasons but also done for reasons of production costs. Especially large engines are often built under license as it is easier to build the engine at the same place where the ship is built. Several large equipment manufacturers have assigned licenses to Asian manufacturers to manufacture for them at sites near their Asian shipyard customers. According to a number of interviewees, however, Asian suppliers and ship yards tend to lack engineering, expertise and project management skills in shipbuilding. On the other hand, ship owners are expected to order more ships in China in the near future, as long as the main components are of European origin. For them, it is for instance important that spare parts are still available after a few years, and in that regard European equipment manufacturers have a better reputation. This implies that for marine equipment suppliers, offering service is becoming extremely important as buyers want to know that the system (and the company) will still be available in a couple of years. This implies a shift from pure product oriented towards complete life-cycle oriented solutions.

In conclusion, knowledge transfer is relevant to the green market opportunities for shipbuilding, is seen:

- Across industries, i.e. transferring from land based sectors where the greening trend is ahead in some aspects;
- Within the sector, across ship types, f.i. from launching customer naval ships to offshore and other vessel types;
- Within the value chain, between ship owners, yards and equipment manufacturers, as f.i. is seen in the dredging segment, where operators identify improvement opportunities from their day-to-day work which is transferred to manufacturers asked for developing solutions;

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[39] Marine Propulsion, August/September 2011, p.93.

- Between companies in the same sector, including between EU and elsewhere based enterprises, through research cooperation or through partnerships for specific manufacturing programs. In the latter case the risk of knowledge leakage and the relevance of IPR is particularly noted.

IPR issues

Knowledge leakage is highly important in a technology intensive industry as shipbuilding. Knowledge leakage and Intellectual Property Rights protection is an essential element of the LeaderSHIP2015 Strategy. Earlier studies have also stressed the importance of IPR[40].

Especially for marine equipment suppliers this appears to be a relevant issue, but also for shipyards that are involved in the construction of innovative ship types with a high technology content. In general, the current level of IPR protection is assessed to be limited. The current reaction of many marine equipment suppliers[41] is to mainly finance and develop innovations in-house and pursue a strategy of continuous R&D and innovation to stay ahead of competitors. Spending money on fighting alleged infringements of property rights is in general not seen as an effective strategy.

Nevertheless pressures on knowledge leakage will remain strong, partly due to an increasing integrating of European and Asian supply chains, but also due to overcapacity at Asian yards which are the result of the current down-cycle in demand. This is expected to result in an increased pressure on Asian yards (especially more advanced yards in Korea and Japan) to raise the local content of supply.

In view of these developments, IPR continues to be considered a key factor for European shipbuilding[42]. It is therefore considered essential to have a good working IPR framework in place.

For the shipbuilding industry, the most relevant category of IPRs is *industrial property* (the second main category relates to *copyrights*). [43] Industrial property includes patents (and licensing), trademarks, industrial design, inventions and geographical indications. Apart from this set of classic IPR protection instruments, the law of unfair competition and contractual clauses can be used to protect intellectual assets.

Most of the interviewees indicated that while for them it is important to protect their Intellectual Property, they are aware of the difficulties of enforcement especially if their rights are challenged in countries outside Europe where their access to legal support is limited. This results in choosing the abovementioned strategy of continuous innovation as this is seen as the most effective approach. Hence promotion of continuous innovation in Europe is equally important to the implementation of an effective IPR policy to address the issue of knowledge leakage.

Innovation in newbuilding versus retrofit activities

Some technological solutions are applicable to both newbuilding and retrofit activities, whereas others are only feasible for new ships (because of their size or cost). In part of the green markets,

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40 See Ecorys (2009).

41 But also a shipyard like IHC is perfectly reflecting this phenomenon. In an interview, they mentioned their decision not to build more advanced dredgers in China as a result of knowledge leakage and to keep most essential technology knowledge in-house (also not outsourcing it within Europe) to retain its competitive position.

42 Burke, A. & S. Fraser (2005) “The Impact of Intellectual Property Rights on Self-employed Entrepreneurship: An International Analysis.” Max Planck Institute Discussion Papers on Entrepreneurship, Growth and Public Policy.

43 WTO website, at http://www.wto.org/english/tratop_e/trips_e/intel1_e.htm.

specific applications have been developed for the retrofit market, because of the regulatory need (e.g. ballast water) or of acute operational cost factors (e.g. steep rise of fuel prices).

The innovation process to realise these innovations shows some differences. For retrofit innovations the role of marine equipment suppliers is larger (vis-à-vis shipyards) than for newbuilding as the focus is stronger on the installation of new (innovative) technology rather than on the construction of the ship as a whole. In addition for retrofit , besides costs also operational factors may hamper the process (e.g. ship may need to be brought to yard for installation, taken out of service for a short period of time, etc.). Since the commercial implication for the owner/operator is more direct here, it may require convincing efforts to obtain their interest. For newbuilding the step from design/model testing to commercial implementation is primarily influenced by cost considerations (next to the assessment of the operational benefits, which is especially relevant for non-proven technology).

Market potential of R&D activities

Most green innovation activities will be directly or indirectly related to market potential that is created by the green drivers identified in this study (chapters 3, 4 and 5). However, whereas R&D and innovation activities may aim to respond to this market potential resulting from external drivers (as is the case for the green growth opportunities identified in chapter 3), innovations may also create their own demand. In theory, innovations may be introduced that are superior to existing technologies and hence create their own driver and demand. For example if a new hull coating is developed which not only saves fuel but is also cheaper than existing coatings a new market will be created.

However, in view of green market opportunities this is only valid if they eventually correspond to external drivers (either regulatory or market based) that create the appropriate incentive for ship owners to invest in these technologies. It is not expected that these will differ significantly from the existing drivers that have been identified for the coming decade, i.e. responding to market drivers (especially fuel cost savings) or regulatory drivers. In addition, innovations may trigger also new regulation (e.g. if it makes a technical solution possible and financially feasible) if they succeed convincing regulatory authorities that the benefits outweigh the costs[44].

Finally innovations may be developed for other purposes, but which have ‘green’ side effects. An example is the axe bow (see box 3.1 in section 3.4.1) where the original aim was to increase stability and safety – especially desired in the offshore oil & gas industry –, but a side effect also was a saving on fuel consumption, resulting in the application also being relevant to other ship segments.

Conclusion on innovation processes

Innovation processes are essential to maintain the competitive position of Europe’s shipbuilding industry and marine equipment suppliers, given the fact that their position is primarily built on technology advances compared to competitors in the rest of the world. In this sense especially Korea and Japan should be seen as competitors, as China (at this moment in time) mainly tries to maintain its competitive position through its low labour cost base. The large shipyards in these countries, such as Mitsubishi, Samsung H.I, Hyundai H.I., and Daewoo, often are part of larger

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[44] For example if a technological breakthrough is realised that allows a complete removal of all NOx emissions at a low cost, this may trigger additional regulation that follows stricter emissions norms than currently applicable or planned. However, the process of regulatory adjustment (especially if taking place at an international level) is not expected to lead to short term additional market potential.

industrial conglomerates, which facilitates the transfer of know-how and technology between industrial sectors. On the other hand also large marine equipment producers are active in both land-based and sea-based activities which leads to similar transfer possibilities.

The existence of a large number of technologically advanced marine equipment suppliers in combination with European shipyards that produce complex, high value vessels creates a cluster of activities that fosters innovations in the shipbuilding industry. At the same time value chains have become global value chains, where large European marine equipment manufacturers also engage in innovation alliances across borders. IPR protection and avoidance of knowledge leakage is essential in these situations, as overcapacity on the market incentivises foreign shipbuilders to extend their activities and capture a wider part of the value chain and to increase the local content of supplies. At the same time this strengthens tendencies towards building stronger alliances across borders, but also the need for protecting technological innovations and knowledge by a process of continuous innovation by in-house RDI activities.

2.4 In-focus: the segment of passenger vessels

Within this study two specific sub-market segments have been selected to illustrate more in-depth industry dynamics. These are passenger vessels (this section) and dredgers (section 2.5).

The passenger vessel segment includes cruise vessels and ferries. Mega yachts are excluded from this segment. Overall the segment is small in the number of ships compared to the world's total shipbuilding demand, but the cruise segment offers ships of very high value and is almost completely dominated by European builders, while Europe also has a strong position with regard to ferries.

Main products and players

The distinction between ferry services and cruise services is not always clear. Many short distance ferry services are also promoted as cruise services. For instance the ferry service between IJmuiden, The Netherlands and Newcastle upon Tyne, UK, is a ferry service, but is also promoted for mini cruises. The same holds for the services provided by for instance Color Lines between Germany and Norway. As the quality standards desired for the upper end of passenger ferries are converging with those applied on cruise ships, shipyards to a certain extent are able to serve both segments. On the other side of the spectrum there are smaller sized ferry vessels operating on short distances serving as public transport facilities, in regions including the Greek Islands, the Norwegian Fjords and many other coastal zones with islands. Operators can be large companies operating several dozens of vessels versus small enterprises only serving one or two links. The building requirements for their ships are often dictated by the tender procedures applied by the government authorities for the ferry links concerned.

The market for cruise ships is strongly driven by tourism market trends. Raising welfare levels have contributed to substantial growth in number of cruise tourists over the past decade. The cruise market is dominated by a handful of operators such as Carnival, Royal Caribbean and MSC. At the production side there is also only a handful of yards in the world able to build these high value ships (an average price of € 300-700 million is common). Until recently, all these yards were located in Europe only, including Fincantieri (Italy), Meyer Werft (Germany) and STX Europe (Korean ownership, passenger shipyards in Finland and France). Recently however, the Japanese yard Mitsubishi has signed a contract with cruise operator Carnival Corporation (US) to build two new cruise vessels for AIDA (daughter company of Carnival). The vessels ordered will be the largest cruise ships ever built and will be finished in 2015 and 2016.[45] The recent announcement by Samsung Heavy Industries in Korea to construct a cruise ship in Korea is another step to introduce competition from outside Europe.

In the field of larger passenger ferries the same (cruise) yards are important players. For smaller sized ferries and RoRo ferries many more companies are important manufacturers. In Europe these yards are mainly located in the Netherlands, Norway, France, Italy, Germany and Finland.

Because of the market structure (a limited number of cruise operators), cruise liners have a strong position towards yards and equipment manufacturers. They set the requirements and for the high value components usually a 'makers-list' is agreed upon between the yard and the client. For the less valuable components, yards have more freedom to choose. In the field of smaller sized passenger ferries the market structure appears more dispersed with no clear domination of either manufacturers or owners in the value chain.

Performance

The passenger vessel segment is the most important part of the total European orderbook in terms of value. In terms of turnover value, almost half (47%) of all vessels built in Europe are passenger and cruise vessels. In 2010 the total turnover by European yards was € 19.4 bln, the share of passenger and cruise vessels was € 9.1 bln Euro.[46]

Cruise vessels

Although the crisis may cause a reduction of growth or short term decline, for the coming decade the cruise industry is expected to continue to grow because of the ageing of population in the US and EU and cruises becoming more affordable.[47]

Despite the growing demand for cruises and irrespective of the crisis, the orderbook for the upcoming years is expected to decline. For 2012, European yards indicate to have sufficient orders at hand, (see figure 2.5), but from 2013 onwards the orderbooks are not fully filled yet. Generally speaking, the main European cruise yards each have a capacity of typically 3 large cruise ships per year (with additional capacity for smaller ships in place). However, some of the cruise liners have indicated that in the coming years they will place only halve of their usual yearly orders, as fleets have been strongly modernised over the past decade and no additional growth is foreseen in demand for cruises.[48] If competition from Asia (Samsung, Korea and Mitsubishi, Japan) in this market proves to be successful this may form a further challenge to this market segment.

The developments in worldwide cruise ship production are shown in figure 2.5 where the cruise ships deliveries and orderbook for the main players are depicted.

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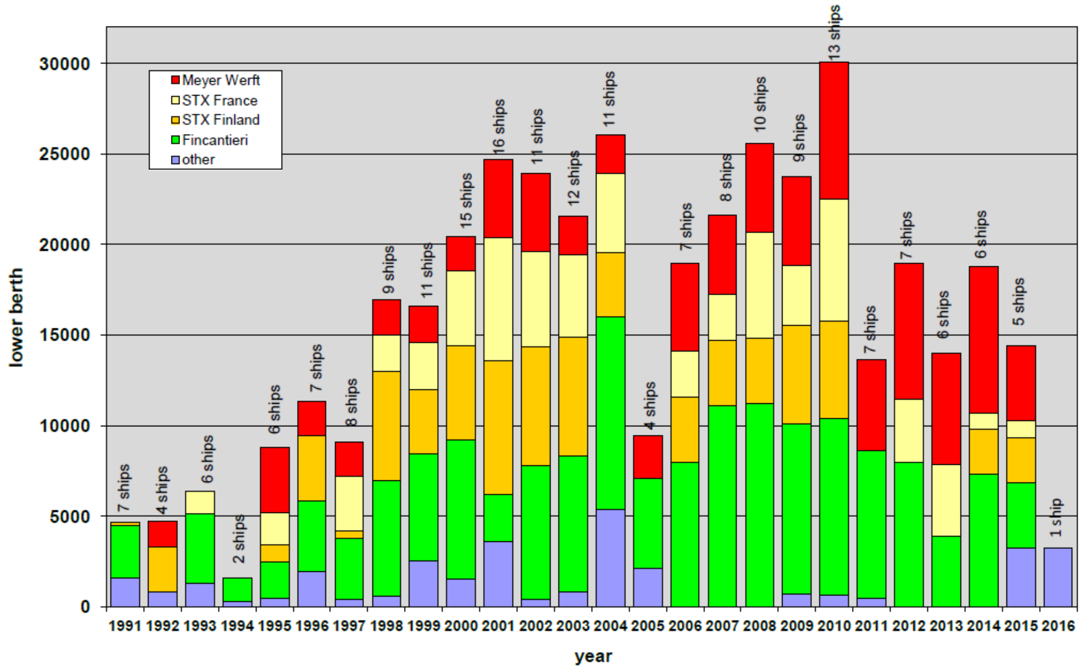
45 http://www.cruiseindustrynews.com/cruise-news/5946-mitsubishi-to-build-two-125000-ton-aida-ships.html.

46 CESA (2011), Annual report 2010-2011.

47 See also: http://www.cybercruises.com/cruisecolumn_sep2.htm; http://www.cruiseshippingasia.com/conference-program and http://www.dnv.com/industry/maritime/publicationsanddownloads/publications/updates/cruise/2010/01_2010/samsung_heavy_industries.asp.

48 Reference is made to Ecorys (2012) Blue Growth, Third Interim Report.

Figure 2.5 Worldwide cruise ship deliveries and orderbook by shipyard (total number of ships delivered)



Source: Meyer Werft GmbH

As regards the greening potential, most of the recently built cruise ships comply with the strictest regulatory regimes in existence as operators want their ships to be able to operate across the world, including attractive but vulnerable pristine tourist destinations (Baltic, Norway, Alaska). On the other hand however also a large number of older ships is still operational. As these may not comply with the strictest environmental rules, retrofit opportunities might arise from green regulatory drivers.

Ferries

Most ferries services operate within one country. The leading ferry operating countries (by numbers of passengers served within their borders) are Greece, Italy, Denmark and Norway. Most ferries can be found in the Mediterranean Sea, the North Sea and the Baltic Sea.

Although depending on the route that is operated, ferry services have long been pressured by the rise of low costs airline carriers in the last decade. This has reduced demand for ferries and has led to an increased price pressure. At present demand levels appear to have stabilised and no further market share appears to be lost. At the same time also the ferry market has been affected by the economic crisis. After yet a difficult year in 2009 for the European passenger ferry operators, the latest quarterly figures from 2010 show that for some countries a slight recovery set in from the second quarter of 2010, compared with the figures of the second quarter of 2008. In major ferry countries like Greece and Denmark, this recovery has not started yet. Nevertheless some companies still have been able to show increasing numbers of passengers. For instance DFDS Seaways saw a 10 percent increase in passenger number for UK and Northern European routes. Also Baltic Tallink was reporting record numbers of passengers e.g. in September 2010 (+5 percent compared to 2009).[49] Combined operations of these companies serving both freight and passengers seem to be beneficial in realising these growth figures.

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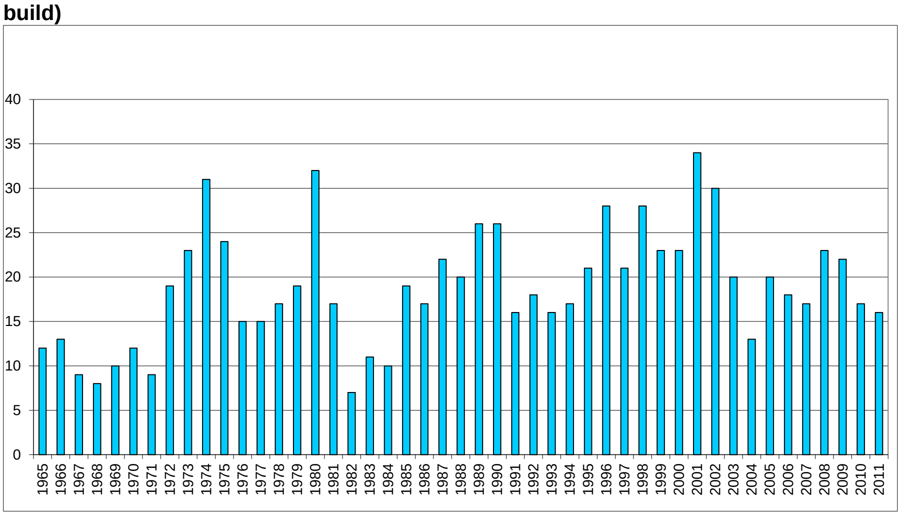
[49] www.tallink.com.

The average age of the current ferry fleet in Europe is quite high (32% older than 30 years, see figure 2.6 below), indicating a replacement need. Furthermore those ships operating in ECA areas (including all ferries operating the North Sea and the Baltic Sea) will have to meet certain emission standards which should create a demand for either retrofitting, or – for the older ships – earlier replacement.

A barrier to ship replacement however is the funding capability of owners/operators, especially in ferry segments where returns are low or where government owned companies have to meet public service level agreements on commercially non-attractive routes. With government budgets being cut because of the crisis, a quick change of this situation is not expected. In the past also certain categories were exempted from regulations (e.g. several Greek ferries were exempted from Directive 2005/33/EC on the Sulphur content in ports, but this exemption expired on December 31, 2011).

In other areas however, newbuilding replacements are seen on – apparently – commercially attractive routes[50]. With regard to operating greener ships, also a number of ferry operators (government supported or not) are choosing for 'green', e.g. ferries in Norwegian fjords, or the TESO ferry to Texel in the Netherlands.[51]

Figure 2.6 Age profile of the European ferry fleet (number of ships operational under EU flag, by year of build)



Source: Fairplay database. Calculations Ecorys. Data using EU flag ferries taken as proxy for ferries operating in EU countries

Innovation characteristics

The innovation characteristics of cruise vessels and ferries are described separately, although, as indicated above, the characteristics of the upper end of the ferry market converge with those of the cruise market.

Cruise vessel market

As described above the cruise liner market is dominated by a few companies, namely Carnival (US), Royal Caribbean (US), MSC (IT) and AIDA (GE, daughter of Carnival), which are both ship owners and operators. Their market share is over 80%. Market entry barriers are high because of

50 See for instance http://www.aferry.co.uk/news/stena_line_adds_new_ferries_on_scotland_to_northern_ireland_route-800446648.htm or http://www.stenaline.nl/ferry/schepen/superferries/fotos/.

51 See http://www.energietech.info/schonertransport/fjord1.htm and http://www.leaderkvnh.nl/news_details.asp?menu=1030000_000054.

the enormous capital costs involved. The increase in regulations has made the entry barriers higher, resulting in even more power for the dominant players. This dominance puts them in a strong position to exert power over shipyards, hence they have a strong voice in determining the requirements to the marine equipment suppliers and the yards. The ship owners have the decision power to introduce and install innovate products and systems. According to interviewees, some owners focus on becoming more environmental friendly, insisting on using the most green and efficient technologies. However, other ship owners are reportedly mainly driven by investment and fuel costs while abiding to minimum regulatory standards in the areas of operation. Stakeholder feedback indicates that for the last group the further green improvements are of secondary importance as only part of the passengers until now is willing to pay a premium for a ticket on a 'green' cruise ship[52].

At the same time also the number of cruise shipyards is limited, with Europe being world leader in the cruise vessel building market. As a result a kind of mutual dependence exist between cruise yards and cruise liners.

The cruise vessel market is quite small in number of ships as less than 10 cruise vessels are being built per year. Moreover there is a limit in series size of around 3 similar kinds of ships to be built for an owner. According to some interviewees, this number is too low to develop dedicated products for this segment only. Rather, modifications of designs developed for other shipbuilding markets are considered. On the other hand however while the number is low, the construction value is so high that for many suppliers the segment can still be important enough to develop specific product designs.

Innovations are especially interesting in this market segment if they can reduce the cost. There are some projects to enhance the energy performance criteria. E.g. the EU funded POSE²IDON project[53] looks at ways to encourage ships to switch to electric systems. Especially for cruise vessels this is an interesting option as these vessels regularly switch speeds.

Ferry vessel market

The ferry market is a highly differentiated market which encompasses large ferry operators that operate ferries that resemble small cruise vessels (e.g. Color Lines serving Norway/Sweden) and small ferry services that are active on specific routes in e.g. the Mediterranean. This makes it hard to draw general conclusions. Especially where ferries are operated by the larger sized ferry operator groups like Stena, DFDS or Grimaldi, innovation processes appear to take place in close cooperation between yards and owners/operators. Smaller regionally operating ferry companies, often based on public service agreements, have a much lower bargaining power and are more strongly inclined to use standard ship types. Still in this market also innovation initiatives are found, such as the STX France contract for a 110 passengers 'zero emissions' ferry to serve the Lorient harbour crossing[54] or hybrid ferries in Argyll County in Scotland. These innovations are often influenced by public bodies that support these investments as part of a wider greening strategy.

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52 At the same time this indicates that this may change rapidly if consumer preferences and pressure from passengers do require higher green standards. Hardly any other market segment is so close to consumer preferences as the cruise industry.

53 http://www.poseidon-ip.eu/.

54 Source: Passenger ship technology, Autumn 2011, p.12.

EU vis-à-vis the rest of the world

Cruise vessels

As indicated above, Europe has been world leader in the cruise building industry for nearly 40 years with close to 100 percent market share. The availability of specialist skills and sophisticated technology in areas such as navigation and outfitting are part of their strength[55]. Although other (international) yards may have the capacity and technology to build cruise ships, many believe they do not have the project management ability, aptitude or the desired balance of labour and skills required to deliver a cost effective result within a required budget in the contracted delivery time.[56] The current entry of Mitsubishi in this market as well as the attempt of Samsung is therefore seen as an important test case in this respect. For instance Fincantieri states that European shipyards will likely seek partnerships with Chinese yards to construct cruise vessels built for the Chinese cruise market.[57]

Passenger ferries

Europe has a leading position in building larger sized passenger ferries building on its leadership in the cruise segment. In the ferry market, operators of smaller ferries and RoPax vessels appear to choose local yards to build their ferries (e.g. the ferries of Tallink, Silja Line and Viking are built in Finland and Germany). Some ferry operators, like Stena Line, have their ferries built by yards in different countries across the world. Conventional ferries are built by many small yards scattered all over the world. The fast ferries market is dominated by Australian yards, like InCat International and Austal.[58]

2.5 In-focus: the segment of dredgers

Within the dredging market, there are three main ship types to be distinguished: backhoe/dipper and grab dredgers, cutter suction dredgers and trailing suction hopper dredgers.

Main products and players

Both in building and operating dredgers, Europe is leading. The top-4 dredging companies, DEME, Van Oord, Jan de Nul and Boskalis, are all located in Belgium and the Netherlands and together cover some 80 percent of the worldwide open tender market. IHC Merwede in the Netherlands is world market leader in the construction of sophisticated and highly specialised dredgers. Other yards in Europe as well as in Asia are able to build less complex dredgers.

In this segment, clients are very knowledgeable of their ships, which they usually operate during the entire economic life of 30-35 years. Working with high skilled crews and own design engineers, often these companies can design the ship they want to order, or at least the requirements, in detail. Furthermore, new orders are often related to specific projects for which unique performance or other specific environmental and technical requirements are to be met. The segment therefore delivers highly specialised and tailored products. On the other hand, modifications of vessels need to be possible based on standard functionalities, in order to allow fleet reallocation to different assignments. Some players also opt for a level of standardisation within their fleets to increase efficiency and flexibility of crews. An example of such a standardisation concerns the bridge design, making it more easy for crew to work on different ships. In general, life cycle cost approaches to

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55 Source: Contributions of cruise tourism to the Economics of Europe 2010.

56 European Cruise Council (2010). The cruise industry: a €34 Billion Partner in Europe's Economic Growth.

57 Shipyards likely to seek Chinese partners, Financial Times, March 14 2012.

58 Tally (2012) Maritime Economics.

vessel construction and operation together are common, implying that focus is laid not only on the purchase price, but also on the effective total costs per unit of performance (volume dredged) over a vessel's service life.

The strategies followed by the four main dredging operators indicate they are aiming to diversify and serve other markets including the offshore wind segment (for instance Van Oord ordered an installation vessel with Sietas), the oil & gas industry in the Arctic (informal talks between oil majors and dredging companies on the construction of Arctic supply infrastructure are being reported), marine minerals mining (for which DEME and IHC set up a joint venture), and activities in the servicing and maintenance sectors (for instance Boskalis took over Smit offering towage and pilotage services).

Performance

Until 2008, market demand for dredging services exceeded the capacity of global dredging operators resulting in a booming dredging industry over the last decade. Between 2000 and 2006, the global industry turnover doubled to € 8.3 billion[59]. In 2009, the Middle East, Europe and China were the largest dredging markets, representing 59 percent of global turnover. Especially the Middle East was a booming region with projects like 'Palm Island' and 'The World' in Dubai. This has led to high demand for new vessels, as well as for major investments in the renovation and upgrading of equipment[60]. It is estimated that the total European orderbook of dredging vessels has a value of around € 1 billion.[61]

Drivers for growth are population growth in coastal areas, climate change calling for increased coastal protection works, and contributing to new markets such as offshore wind and LNG use.[62]

The strong performance of the dredging industry positively affected the shipbuilding industry active in this segment. IHC as a leading company as well as the network of suppliers around it have benefited from orders for ever larger hoppers in the past few years. Also several other yards in Europe realised orders in this segment. On the other hand the demand for new ships also attracted other builders to enter this segment and several orders were placed in Asia, also by the big four European operators. Interviewees indicate that while only a handful of yards in China are considered capable of meeting their needs, the cost advantage as well as the available slots at the time were decisive factors. Furthermore the risk of knowledge leakage to competitors via yards is considered an issue.

Innovation characteristics

Ship owners are actively involved in the design of the ship and often perform the basic engineering internally to make sure the dredging vessel will be able to deliver the job. This includes for instance the choice to build a new dredging vessel or to convert an existing one. In the design of a dredging vessel it is important to allow for flexibility as in several occasions, conversion of dredging vessels takes place, depending on projects at hand, e.g. a cable layer can be converted to a heavy lift platform ship.

Innovations in the dredging industry are mainly driven by increase in scale, leading to higher overall fuel consumption but lower consumption per unit dredged. Innovation is also taking place in the

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59 IADC.
60 IHC Annual report 2007.
61 Ecorys estimate based on annual reports of main dredging operators.
62 IADC 2010 dredging in figures. At: www.iadc-dredging.com.

area of optimising systems through specific software. These innovations are incremental innovations that have the aim to increase the performance of the dredging vessel. As dredging vessels tend to be operated by the same company during its entire economic life, it makes it worthwhile to invest more in the early life stages of the ship, allowing innovations to enter.

Specific areas of innovation relate to the operating practices of dredging contractors. The concept of ' Building with nature' has been developed i.e. using natural processes and / or increasing the natural quality of the measure that is taken. In general this concept is applied when using soft nourishments and restoring the sediment balance. In addition, the interest in using the 'ecosystem service' is rising: Marine and coastal ecosystems are generally recognised as providing protection to flooding and erosion . Research activities focus on increasing the knowledge of the occurrence of such eco-systems, their contribution to coastal protection and the economic evaluation of their benefits results in optimization of the use of eco-system services.[63] Furthermore innovations include the development of devices that reduce turbidity and soil damages.

An important party in this industry are the clients. Clients heavily influence the introduction of innovations. As many clients are public or semi-public authorities, some clients demand green services and thereby trigger green innovations. Other clients focus on cost efficiency. However, it is the ship owners that determine the kinds of innovation they are willing to implement.

The potential for green innovation is very client dependent. Some clients value environmental friendly performance highly. In that case, ship owners include environmental friendly technologies and innovations in their offer. For example, for the Port Authority of Melbourne it was very important to limit the oil spillage. Boskalis offered an oil catching technology which convinced the client. This type of 'green' innovation referred to soil turbidity and the protection of coral reefs rather than to emissions, so the driver is not directly comparable to those mentioned in this study.

EU vis-à-vis the rest of the world

Europe is expected to stay dominant in this segment, although there is a cost pressure. More often dredgers are being built in Asia, although until date these concern the less complex types. Lower management costs, on time delivery, less fear of leakage of knowledge, creativity, having a specialised nearby cluster and culture similarities are reasons in favour of European shipbuilders.

Equipment of European origin has a very dominant position in this segment, due to their proven good quality and after sales services. The latter is of key importance to operators working under constant time pressure and high costs per day when facing demurrage.

The economic crisis will certainly affect this segment as well, partly because it drives on government budgets (coastal protection works and port expansion) which are under pressure, and private investor funds (tourism, real estate development) which are also facing weak times. Overall this shipbuilding segment is relatively small at a world scale.

2.6 Conclusions

The shipbuilding industry is embedded in a value chain consisting of designers, equipment manufacturers, yards, ship owners, operators and their clients, as well as supporting parties like

63 See for instance the EcoShape initiative, http://www.ecoshape.nl/.

classification societies and research institutes. Each party has its specific role to play when it comes to developing new (green) ships. In some ship segments, owners or operators are having a strong say, while in others yards and equipment manufacturers appear to dominate. Everywhere however, interdependencies are in place calling for effective cooperation.

European shipyards' competitive position vis-à-vis other world players can be characterised as a niche player active in high quality, high value segments. At the same time European marine equipment manufacturers have succeeded to retain a strong position supplying not only European but also Asian shipyards.

The current global crisis, which started in 2008, has intensified pressure on the worldwide shipbuilding industry, as it has resulted in reduced demand, now coming at points where individual yards across the world face depleted orderbooks soon. While the crisis may have triggered the drop in demand, analysis of demand and supply of shipping capacity suggests that overcapacity was being built up in the years before, and shipbuilding – as a cyclical industry – was about to enter a down-cycle at some point anyhow.

The impact of this on the European industry can be viewed from different angles. First of all, the reduction of demand appears strongest in mass segments like bulkers, tankers and container ships, segments in which European players are less active. On the other hand however drivers like fuel prices (addressed in the subsequent chapter) have also triggered new demand in these segments, mainly to replace smaller and/or less efficient ships for new, bigger ones. This demand is benefiting Asian yards dominating these segments more than European yards.

Secondly, the reduction in demand in the mass segments has triggered these yards – faced by depleting order books – to challenge other segments. While in the boom period several Asian shipyards already gained some experience in higher value segments (for instance dredgers) because of owners ordering where slots were available, nowadays yards are challenging higher value segments and in some areas seem to be successful (e.g. two cruise ships now ordered at Mitsubishi, several Korean yards active in the offshore wind segment).

In the area of R&D and innovation, knowledge transfer is seen between actors in the value chain, within sectors (between maritime and non-maritime applications or between ship segments), between different actors in the value chain (e.g. operational knowledge from operators used to improve designs), within specific production processes (level of intensity of cooperation between suppliers and yards) and also between companies through research projects (within Europe but also between European and Asian companies).

These opportunities resulting from knowledge transfer however also require good protection of Intellectual Property. Therefore the existing IPR framework is considered valuable to have in place. While some companies choose a strategy to minimise the leakage of knowledge, others focus on continuous R&D as to stay ahead of their competitors. Both strategies appear to be equally important to promote.

Two specific segments have been addressed in further detail: passenger vessels (cruise ships and ferries) and dredgers. Both segments are characterised by owners also being the operators of their ships, usually for their entire economic lifetime. Furthermore a concentration of owners is seen as well as a concentration of shipyards building these ships. The importance of greening is found in both segments, but it materialises in different ways. In the cruise segment, meeting regional environmental requirements is a prerequisite, but as fuel costs also make up a large share of operations some owners choose a strategy to optimise there. In the dredging segment, it is not about absolute costs but about per unit performance (amount dredged), and in many cases specific project requirements that define the innovation demand.

3 Market-driven trends

Different greening trends that drive market opportunities are analysed in this study. These have been distinguished in market driven trends, regulatory-driven trends and other green trends. This chapter discusses market-driven trends. It should be noted that there is a strong correlation between the trend of fuel-efficiency and the CO_2 regulatory trend in the next chapter.

Market-driven trends lead to a change in company behaviour without there being a direct regulatory pressure to do so. Market pressures, either in customer relations or market share or simply cost pressures, lead to decisions of ship owners that create an increased demand for “green” ships. The following trends are analysed:

- Trend 1: Fuel efficiency and resulting cost reductions;
- Trend 2: Environmental awareness and CSR.

3.1 Trend 1: Fuel efficiency and cost reductions[64]

3.1.1 *Drivers*

Prices and costs are important competition factors in shipping (and hence shipbuilding), especially in the more mature parts of the market. In an attempt to lower (increasing) transport costs, there has been a growing interest in fuel efficiency improvements. Although this is not a greening trend in itself, lower fuel consumption results in lower emissions of both CO_2 (greenhouse gas) and air pollutants such as SO_x en NO_x. Hence, an improvement in fuel efficiency results in an improvement of the environmental performance of ships. Stakeholders confirm that cost reduction through fuel efficiency is *the* main market driver for greening in the sector at present.

Two main underlying reasons for the strong focus on fuel-efficiency and associated cost savings in the European shipbuilding and maritime shipping sectors can be identified.

Firstly, competition in shipping has increased, especially in the tanker, bulker and container segments, resulting in a downward pressure on freight and charter rates. This has led to an increased pressure to reduce operating costs, of which fuel costs form a major share. When taking a cost-of-ownership approach, considering not only the initial purchasing price but also the costs of operation of a vessel over its lifetime, fuel cost savings can be considerable. While this is most directly relevant for the operator of the vessel, it also influences the demand for fuel-efficient vessels and technologies for the shipbuilding and marine equipment sector – unless there are market imperfections and other barriers.

Secondly, the focus on fuel cost savings has been strengthened by increasing oil prices (and volatility) over the past years. This is illustrated in Figure 3.1. Further increases in fuel prices in the coming decades are expected to spur the demand for fuel efficient ships[65].

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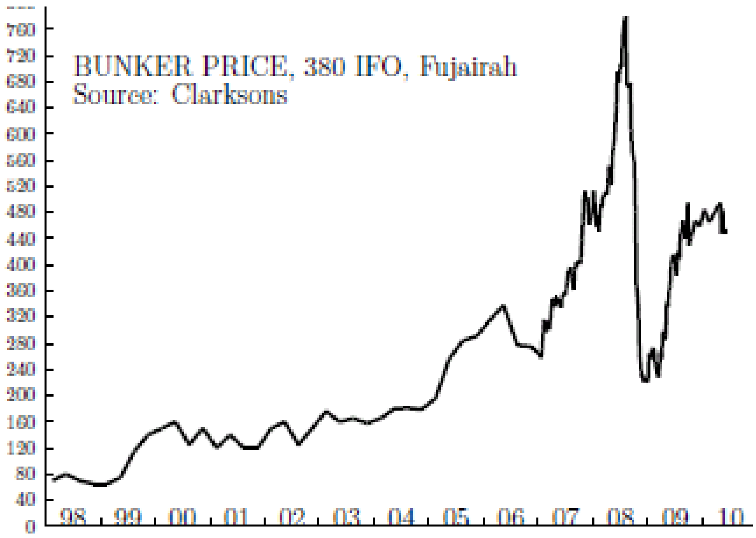
[64] In this report we focus on fuel efficiency, However, one may also consider this as part of the wider notion of energy efficiency which also includes issues like energy efficient appliances on-board ships.

[65] The latest IEA World Energy Outlook 2011 forecasts oil prices to increase from 114 USD/barrel to 212 USD/barrel (nominal prices) in 2035.

Figure 3.1 BFO prices, 380 IFO, Fujairah; 1998 – 2010 in US$



Source: Center for Tankship excellence, CO2 Emissions form Ships: the Case for Taking our Time, 26th of November 2010 (taken from Clarksons)

This increased focus on cost savings through fuel-efficiency has created stronger demand for energy-efficient vessels and equipment across the entire sector (although barriers exist that preclude the full exploitation of the efficiency improvement potential – see section 3.1.3). For example, in its last Annual Report, CESA indicates that this is expected to be a main driving force behind tonnage replacement as can be observed in the order intake for new containerships, driven by substantial fuel efficiency gains that can be reached[66]. Whether ships are replaced or retrofitted with fuel efficiency improvements obviously depends strongly on the characteristics of the ship itself (e.g. age) and the business case (and related parameters such as payback periods) for the ship's owner.

Although fuel efficiency is an important cost component for almost all ship types, sometimes a trade-off is made with other operational performance criteria. For example for highly-specialized dredgers, the first most important requirement is related to the level of dredging performance itself, after which of course also performance per unit of energy will be valued.

In Europe, the demand for fuel efficient solutions is a major factor in shaping demand in shipbuilding in general, but also for the marine equipment segment in particular. An example can be found in equipment manufacturers that are active in the field of propulsion systems. Within this market the demand for fuel efficiency leads both to a call for increased performance of existing propulsion technologies, as well as to the development of new technologies (propulsion with new fuel types, the use of wind power, or hybrid solutions like dual fuel engines), and finding new solutions with existing technologies (e.g. modular propulsion systems allowing for efficient slow steaming while retaining peak capacity).

3.1.2 *Assessment of the market potential*

The market potential resulting from the market driver fuel costs is highly dependent on the development of bunker prices in the future. With the expectation of continuous upward pressure on oil prices, market potential will arise in the following two areas:

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[66] See CESA Annual Report 2010-2011.

- *Fuel-efficient systems;* the main response in reaction to increasing fuel costs will be the adoption of technologies that help improve energy-efficiency (and reduce costs). These technologies are developed and implemented in many different fields. This includes propulsion systems, but also e.g. hull design, scale (larger ships are generally more efficient per unit of transport performed) or 'smart' positioning and navigation systems (voyage planning, resistance measuring). At present in the marine equipment sector, solutions aimed at enhancing the fuel efficiency of vessels are representing the main focus area for creating market potential (together with environmental regulation-driven technologies like scrubbers). This is expected to remain so in the coming years;
- *Alternative fuel type based solutions*; with rising oil prices, also the relative advantage of alternative ship fuels and propulsion systems increases (e.g. LNG, hybrid or wind). However, uncertainties regarding price developments (both oil and alternative fuels) create an obstacle to the introduction of alternative fuels, and so do required investments in bunkering infrastructure (e.g. for LNG and electric propulsion). Risks related to the implementation of new technologies or other obstacles related to the technology itself limit the adoption of alternative fuels. As a result, market drivers alone are not expected to create a massive shift in propulsion technologies and alternative fuel based solutions are expected to develop in parallel to the dominant more "conventional" systems.

Quantitative estimates of the market potential related to fuel efficiency enhancements are hard to make, since this is related to market developments in shipping, oil price developments (and volatility), and individual business considerations and criteria of ship owners. To some extent this is related to the market potential that results from regulatory CO_2 drivers (in particular EEDI), given the strong correlation between fuel consumption and CO_2 emissions. This is also valid in terms of the type of technology that is expected to profit from this development. This latter market potential is further detailed in section 4.3. EEDI driven fuel efficiency gains is seen as a minimum estimate as this is obligatory. Additional (fuel) cost saving measures may provide further fuel efficiency gains than measures only driven by regulation[67].

The driver is considered to create market potential both for newbuilding (any new ship to be more efficient as such, as well as accelerated fleet renewal to replace less efficient with more efficient ships) and for retrofit applications. The feasibility of accelerated fleet renewal will depend on ship type, design, and age. As the current world fleet is rather young (because of the massive newbuilding programs of the past decade), the replacement demand is expected to be limited as this would require an accelerated write-off of the existing fleet. This in combination with the current overcapacity of demand may also limit access to capital to finance an accelerated replacement. Only if a strong business case can be presented it is expected that an accelerated replacement of ships will occur. Finally it is expected that this will mainly occur in ship type market segments (e.g. containers) were the position of Europe is less strong.

3.1.3 *Main barriers*

With regard to the market potential for fuel-efficiency the following barriers are addressed:

- Barriers to the development of technologies to improve fuel-efficiency of ships;
- Barriers in scaling up technologies to improve fuel-efficiency of ships;

67 A study performed by the Holland Shipbuilding Association (CTMI study) has analysed the effect of EEDI on Dutch built and flagged ships. The CO_2 reduction potential from EEDI phase 1 has been assessed at 1.6%, whereas phase 3 would increase the CO_2 reduction to almost 15% Source: presentation of David Anink, Holland Shipbuilding Association, at the Maritiem Milieu Seminar 'CO_2-reductiemaatregelen': De nieuwe regels (maritime environment seminar: CO_2-reduction measures: the new rules), 15 December 2011.

- Barriers to the expression of demand for technologies to improve fuel-efficiency of ships.

Barriers in the development of technologies to improve fuel-efficiency of ships

The general finding is that the availability of alternative technologies to improve the fuel efficiency of ships[68] is not a real bottleneck. This is true globally as well as for the supply of technology from EU actors. Relatively few barriers relate to the development of new technologies. Both the European shipbuilding sector and the marine equipment industry have developed green innovations in this field and continue to do so. EU companies supply energy saving equipment including but not limited to low friction paints, kites and sails, air cavity systems, energy saving devices, et cetera. EU companies provide hull designs and are able to evaluate their energy efficiency, for example in towing tanks.

Some stakeholders indicate that there is a financial barrier because banks seem to be reluctant to provide funding for new ship designs and technology development because of the high perceived risk. This financial barrier is common to many newly developed technologies in other sectors.

Another barrier at this stage which has been mentioned by several interviewees is the additional costs and time delay imposed by class rules. Classification societies set technical standards for ships and offshore structures and ensure compliance with the class specific standards. Sometimes class rules are defined narrowly with the consequence that only specific technologies can be applied to fulfil them. This leads potentially to less diversification at the development and diffusion side. However, where this phenomenon may occur, the role of classification societies may also trigger development of new technologies as these organisations are increasingly involved in and aware of new technology development, which may positively influence that adaptation.

Availability of skilled labour is often mentioned as a barrier relevant to the EU specifically. In many countries it is observed that the ship building sector faces a lack of (naval) engineers. The demographic change, a lack of interest in the field and budget cuts at universities are held responsible for this labour market problem. However, this barrier is not equally felt in all companies and/or among other stakeholders. For example, Norwegian stakeholders indicated that this it not seen as a major problem as they are able to hire sufficient domestic or foreign engineers. However, in view of the ageing population this may become a real issue in the coming decades.

In sum, neither the literature review nor stakeholder feedback in this study have revealed major barriers in the development of fuel-efficiency improving technologies. The barriers mentioned above differ between countries and are in general a common barrier in technology industries (e.g. skilled labour force) or they are inherent at an innovation process (e.g. funding).

Barriers in scaling up technologies to improve fuel-efficiency of ships

Not all the innovations developed by the shipbuilding and marine equipment sectors appear to be considered effective and reliable by shipping companies and ship owners, as was indicated in several interviews. This may indicate a knowledge bottleneck among owners and operators. As a result, shipping companies are reluctant to invest in these technologies and hence to build up credibility in the technology. Also in the field of fuel efficiency improvements, shipping companies often have doubts about the claimed effectiveness of innovations. Both literature[69] and stakeholder feedback confirm that among other things doubts exists about low friction paints, air lubrication and

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[68] or more specifically to meet EEDI limit values.

[69] see e.g. CE Delft et.a al. 2011.

wind power, amongst others. Reports, even of supposedly independent parties, are not always trusted.

As far as efficiency improvements are market driven, this barrier is very important because doubts about the effectiveness of technologies undermine the business case for their implementation. As a result, instead of opting for technological improvements whose effectiveness is in doubt, shipping companies may opt for other ways to improve the fuel efficiency of their ships including slow steaming, of which they perceive the effects to be well known.[70]

This barrier is relevant both for global and EU shipyards and marine equipment industries.

Barriers to the expression of demand for technologies to improve fuel-efficiency of ships
Many stakeholders have expressed the opinion that availability of supply of technologies is larger than the current demand from ship owners and operators for these technologies. This is in line with other studies (e.g. Wang et al., 2010 and CE Delft et al., 2011).

A general barrier appears to lie in what many stakeholders in the shipbuilding and the marine equipment industry call the **conservatism of shipping companies**. Although there are notable exceptions, many shipping companies and ship owners appear to be risk averse when it comes to implementing new (green) technologies. This barrier is mainly relevant for market driven innovations, for which there is no obligation to use them. Apart from the risk aversion, specifically for fuel efficiency investments, many investment decisions are still made based on investment assumptions that apply relatively low fuel cost, whereas fuel costs over the life time of a vessel that is coming on the market at this moment are expected to increase significantly.

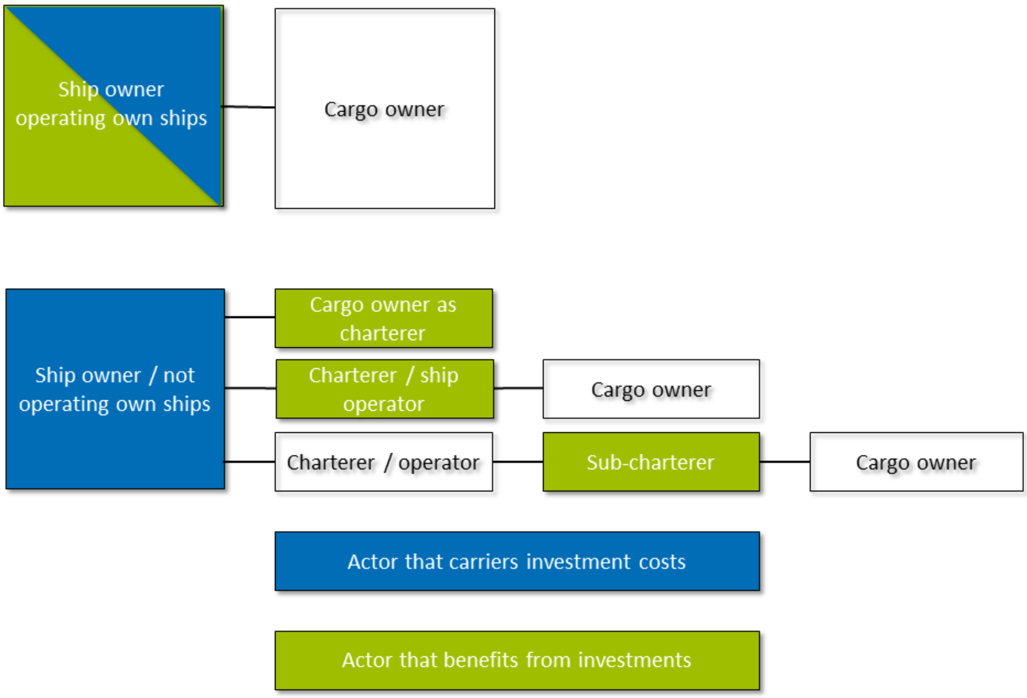
For technologies that can be applied only to **newbuildings**, the demand for new technologies is determined by the demand for new ships. Hence general market developments and demand for newbuilding will be the main factor behind market introduction. As stated earlier, high fuel prices in itself also trigger a newbuilding demand, as a means to accelerate replacement of the current tonnage by more fuel efficient tonnage. However, as mentioned above, the current world fleet is rather young (because of the massive newbuilding programs of the past decade). As a result, an accelerated replacement demand for more fuel efficient ships will only be justified if a very strong business case can be presented.

A specific barrier to the implementation of fuel saving technologies is the **split incentive**, related to the structure of the maritime transport sector. When ships are not operated by the ship owners themselves, as is the case for time chartered ships, the costs and benefits of an investment in fuel/CO_2-saving design and technology often accrue to different market players (see figure 3.2 for illustration). This is the case under a standard time and a bareboat charter party. This means that ship owners who invest in fuel efficiency improving measures cannot, in general, recoup their investment, unless they operate their own ships or have long term agreements with charterers.

Time charters and bareboat charters are common in dry bulk, liquid bulk and container markets. In these markets, a significant share of ships is operated by companies that do not own them. They are less common in specialised segments like cruise ships and dredgers. In these markets, most of the shipping companies own their vessels and hence there is no split incentive.

[70] While the direct impact of slow steaming may be rather certain (less fuel consumed), it may also have implications on the engines and systems concerned.

Figure 3.2 Distribution of costs and benefits of investments in fuel/CO2 saving technologies in maritime transport market



The split incentive has several aspects (CE Delft et al., 2009):

- In an estimated 70% - 80% of the shipping market, fuel costs can be passed through to the consumer either directly in charter parties or through bunker adjustment factors, fuel surcharges, et cetera;
- In most cases of chartering, charterers pay little attention to the fuel efficiency of a ship. The most important information in agreeing on a charter rate is the 'last done', i.e. the latest fixture that is similar to the fixture in question. In most cases, the similarity is expressed in terms of ship type, ship size, route (for voyage charters). Hence, the fuel efficiency of a specific ship is not usually taken into consideration;
- One of the reasons for the lack of attention to fuel efficiency in charter rates appears to be that historically, fuel has not been a major factor in the cost of operating a ship;
- Another reason is that fuel efficiency is dependent on the way in which a ship is operated, the route, cargo, and many other factors. Hence, a ship owner may be reluctant to guarantee a certain efficiency;
- Yet another reason is that until recently, there has not been a commonly agreed metric of a ship's efficiency. The EEDI (see section 4.3) may be such a metric, but only very few ships have an EEDI at the moment. An EEDI is obligatory only for ships built from 2013 onwards in countries that have not granted a waiver, and from 2018 onwards for all new ships. Whether the EEDI will be a good indicator of a ship's actual efficiency remains to be determined. While some shipping companies expect that the EEDI will result in a charter market that will take a ship's fuel efficiency into account, others do not (CE Delft et al., 2011).

Note that when ships are operated by the ship owners themselves, which is for example the case in the cruise and the dredgers market, there is no such split incentives problem (see section 2.4 and 2.5).

The fuel price and the expected future fuel price play a major role for the demand for fuel/CO_2 saving designs and technologies. A fluctuating oil price that shows no clear rising trend makes the sector reluctant to take investments that are associated with longer pay back times and explains a preference for operational measures such as slow steaming. In general **payback periods** that are used in making investment decisions (also for retrofits) are short (payback periods of 1.5 years have been mentioned by some stakeholders) which hampers the introduction of technologies where investments would be justified through a lifecycle cost approach.

3.1.4 *EU industry position and technological responses*

A variety of technical solutions has been developed to reduce fuel consumption and CO_2 emissions. Main areas for possible improvement are: design of the vessel, its propeller and propulsion devices, wind assistance, operation, engines and waste heat recovery[71] [72].

Design

Design is a broad category of solutions that enable a vessel to reduce fuel consumption and CO_2 emissions. Main design solutions are hull optimization and the reduction of frictional resistance. Usually designs are tested in a model basin and when successful sold to yards who will use the designs. Model basins are costly structures and are often found with national (semi-) public marine research institutes, who use them not only for testing ships but also for other purposes, such as coastal protection design. Lately also offshore wind structures have been tested in basins.

Design offices and research institutions are found all over the world and virtually every shipbuilding nation has them. Both Asia and Europe have many institutions that work on these subjects. According to industry interviews, European designers are leading, but competition is strong. Most companies that work on design solutions can be qualified as SMEs, whereas basin institutions operating basins are larger sized. Well known model basins in Europe are owned by MARIN of the Netherlands, the German HSVA and SVA, Force Technology in Denmark, SSPA in Sweden and the Italian based INSEAN. Marintek in Norway is also a European based basin operator. In Japan there is a model basin run by Miyata, part of the university of Tokyo and Kodoma (NMRI). Some of the large Japanese and Korean yards have their own in house model basins. Many larger sized shipyards also have their own design department in house, while also classification societies have diversified into research consulting and design activities. DNV and Germanischer Lloyds' subsidiary FutureShip are but a few examples of this. Designs can differ from a gradual development to new revolutionary hull designs (see box 3.1).

An example of what is considered a revolutionary design is the cachalot or sperm whale bow described in box 3.1. In most cases however design revisions are resulting from gradual development, For equipment solutions, for instance emission control systems, transfer from designs used in other sectors to shipbuilding are seen. In many cases these applications can be qualified as commercially off the shelf (COTS)[73].

Box 3.1 Optimizing ship and hull design: the cachalot or axe bow

A new type of vessel looking like a cachalot (a sperm whale) is seen more and more often in the offshore segment. The bow of the vessel has a different design which is developed by the Norwegian design bureau

[71] Within these areas different technical solution may be found. For an example of these reference is made to chapter 3.
[72] The use of LNG as an alternative fuel to lower CO2 emissions is addressed under NOx and SO2 emissions reductions,
[73] Definition is of COTS: *Item that is commercially available , leased, licensed, or sold to the general public and which requires no special modification or maintenance over its life cycle.* Definition taken from the Business Dictionary.

Ulstein Design. Also a number of other yards and design bureaus have developed something similar. The hull forms are also called axe bow. The bow of the vessel is much rounder shaped than traditional bows, with the main aim to raise safety when the vessel is at sea. The new bow has the advantage that it makes the vessel more seaworthy, able to stay longer at sea, and in bad weather the ship is able to sail with higher speed. The bow generates less noise and vibration and this makes the stay for the crew more comfortable. A side effect is that fuel consumption is reduced, so that operation becomes more environmental friendly. Already 20 vessels have this new bow and another 20 are on order. Until today only vessels in the offshore industry use this design, but there are designs being developed for tankers and bulk carriers as well.

Source: interviews conducted for this project and http://www.schuttevaer.nl/nieuws/offshore/nid14565-potviskoppen-veroveren-de-wereldzeen.html

Propellers

Another solution to reduce fuel consumption and CO_2 emissions is the usage of propellers that are designed to increase the energy efficiency of the vessel. Propeller design and technology is an area that has been investigated already for a long period. A propeller is usually designed by a design bureau or a research institution and then manufactured by a variety of propeller manufacturers. Examples of successful new propeller designs are the CLT propeller of Sistemar[74] of Spain (20 installations) and the Kappel[75] propeller designed by the Technical University of Denmark (10 installations).[76] So far the new, most energy efficient propellers have been designed and built in Europe. Asian companies are not really active in this area . As Asian yards however do build standard propellers, it is likely they will aim to enter this segment as well. The European companies that design the propellers can in majority be qualified as large companies.

Propulsion improving devices

A technical solution closely linked to energy efficient propeller design is the usage of PIDs (propulsion improving devices), that reduce or recuperate losses at the propeller. The first concept for PIDs already dates back to the 1970s. It is relatively easy to install PIDs on older vessels and so it is a suitable technology for retrofits. The effectiveness of PIDs is under discussion amongst hydrodynamic experts, because the effect of the different PIDs differs widely. Some PIDs have negative results on the reduction of CO_2-emissions while others are quite successful.

Both companies in Europe and Asia are developing PIDs, but Europe is in the lead in terms of number of installations. Main manufacturers of PIDs are Schneekluth of Germany (1,500 installations since 1984), Becker Marine Systems also of Germany (10 – 100 installations since

[74] http://www.sistemar.com/.
[75] http://www.skk.mek.dtu.dk/English/Research/KAPPEL_Propeller.aspx.
[76] Futureship (2011).

2000), Mitsui of Japan (some installations reported), Hyundai of Korea (1 installation) and the cooperation by SSPA of Sweden (for the design) and DSME of Korea (for building).[77] Besides these there are other companies and research institutions that are looking into the possibilities, but they have not constructed and installed any PID yet and it is not known if and when they will.

The companies that have manufactured and installed PIDs can all be qualified as large companies. In the market for PIDs hardly any SMEs are active except for Mewis (but integrated with Becker).

PIDs can be accompanied by fins. Fins guide the water towards the PID and increase the efficiency of the PID and the engine. For Europe no specific developers are found although fins are often integrated in the design process. In Asia there are some large companies that specifically design and produce fins. Main companies are Mitsui, Mitsubishi, Hyundai and DSME. All these companies are large. No SMEs are active on this market.

PIDs and fins can be applied for new vessels but are also suitable for installation on existing ships. As the payback time of the investment is considered relatively short, the retrofit market is attractive.

Wind assistance

Wind assistance is also seen as a solution to reduce fuel consumption and CO2 emissions. The results of using wind differ amongst ship types, ship sizes and trading routes. Wind assistance seems to be the most attractive for vessels operating with a speed up to 14-16 knots. Using wind has several disadvantages that reduce the speed of implementation: a large investment is needed, on deck space requirements are high, additional man-power is needed for operation and maintenance and problems with the stability and structure of the vessel can occur. An advantage is that the solution can be retrofitted on existing ships.

Companies offering wind assistance devices are mainly located in Europe. Most companies can be characterised as SMEs. Market leader is Skysails[78] of Germany (5 installations and 5 systems sold). The German company Enercon[79] has developed flettner rotors, but there are no established suppliers for these rotors yet.[80] Outside Europe the Australia based company Solar Sailor is a competitor. They develop solutions that use both wind and solar assistance. So far the company has installed three systems.[81] But also in Asia some design initiatives are being developed which endeavour wind energy (see box 3.3) although still in a conceptual phase.

Box 3.2 Fassmer builds environmental friendly vessel Rainbow Warrior III for Greenpeace

In 2011 Greenpeace took into service the Rainbow Warrior III. The vessel, built by Fassmer, is qualified as an environmental friendly vessel and has obtained a green passport from Lloyd' s Register. The vessel has several environmental friendly features: the vessels uses wind assistance, the paint used is free of poison, there is a separation system that splits clean water from polluted water, so that only clean water is led back into the sea, and the waste heat produced by the motors is used for heating on-board the vessel.

77 Futureship (2011).
78 http://www.skysails.info/english/.
79 http://www.enercon.de/de-de/.
80 Futureship (2011).
81 http://www.solarsailor.com/.

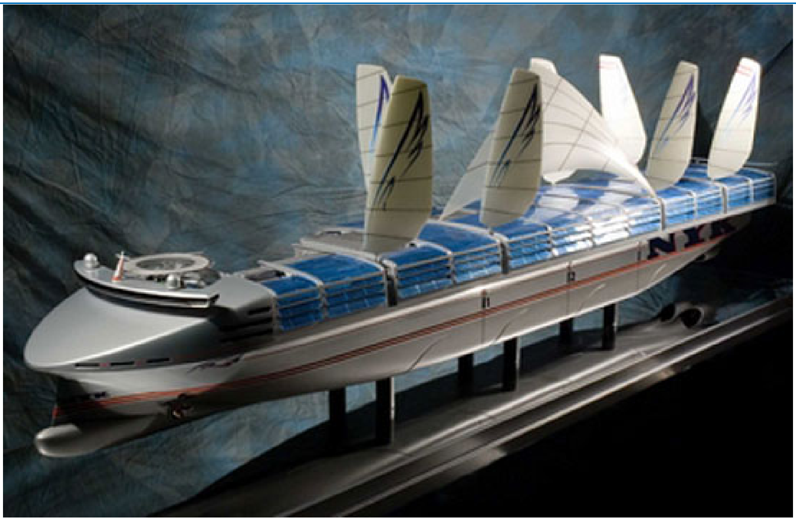
Source: www.greenpeace.nl/about/schepen; Fassmer (2011), Press release 'The New Rainbow Warrior'.

Box3.3 NYK Line Super Eco Ship 2030 – The container vessel of the future

Japanese container operator NYK Line has revealed plans for the NYK line Super Eco Ship 2030. This container vessel should produce up to 70% less CO_2 emissions than current container vessels of similar size. To reduce emissions the vessel weight is lower than that of current container vessels. The vessel uses solar cells and sails to reduce emissions. LNG cells are used as the main fuel system that optimises overall fuel efficiency.

The vessel has solar cells that cover the entire vessel. The total solar cells surface is 31,000 m^2. Also solar panels are placed at the sides of the vessel. These panels contribute to making an optimal use of sun energy. The peak performance of the solar cells and panels can be up to 9 MW. Besides using solar energy, the vessel also uses wind energy. Eight retractable sails are placed on top of the vessels. The entire surface of the foil sails is 4,000 m^2.

Furthermore the vessel will not require tugs to moor and has a loading concept that allows the port time to be halved.



Source: promotional movie on youtube: NYK Super Eco Ship 2030.m4v future ship of NYK-TDG Maritime Academy

Optimized operation

Optimising the operation of a vessel can also lead to a reduction in fuel consumption and CO_2 emissions. Within this category many solutions are possible, for instance route and speed can be optimised as well as the trim. Also solutions are developed for on-board monitoring and decision support on ship operation.

Leading companies offering operation support systems are located in Europe. It is unclear how many they have sold so far. The most important companies are FutureShip[82] of Germany, On-board Napa[83] of Finland, Eniram[84] also of Finland and Marorka[85] of Iceland. All these companies can be qualified as SMEs. Operation support systems can be applied both on new and existing ships. With regard to the latter it is observed that shipping companies aim to apply similar systems across their fleet, thus calling for integration into their own business applications. This potentially raises investment costs. On the other hand modular concepts offered by a number of suppliers allow step-by-step investment focused on the specific needs or interests of the operator.

Engines

Engine adjustments and engine management systems can be used to increase engine efficiency. The fuel injection can be modified so that the engine consumes less fuel, but also the air pressure can be reduced by the introduction of an intercooler between and a scavenge air cooler after the turbo chargers. Most of these applications are based on existing technologies.

New engines are designed and produced by long established engine manufacturers. The main producers are European companies; 90% of the marine engine market (large two-stroke engines) is in the hands of two European manufacturers, MAN of Germany and Wärtsilä of Finland.[86] These companies increasingly supply complete propulsion systems[87]. Besides these two companies also other European companies are active on this market, e.g. Rolls Royce of the UK, the German

82 http://www.futureship.net/.
83 http://www.napa.fi/.
84 http://www.eniram.fi/.
85 http://www.marorka.com/.
86 http://www.hercules-b.com.
87 including aftersales operation & maintenance contracts and services.

companies Caterpillar/MAK and DEUTZ, the Swedish company Volvo, ABB located in Switzerland and the UK based company Ruston that is part of the Siemens group. All these companies can be qualified as large players. Also in Asia some large companies are manufacturing engines. The main players in Asia are Mitsubishi of Japan, Niigata also based in Japan and the Korean company Hyundai. Also the USA has a large engine manufacturer, Cummins.

Waste heat recovery

A final technical solution category addressed here is the usage of waste heat recovery systems. The engines of a vessel produce, as a by-product, waste heat. Normally this heat is removed via cooling water and exhaust gas, but the heat can also be re-used, for instance to serve the heating demand on board or as input for power generation using turbines. Several companies have developed systems that are able to recover waste heat. The technique is relatively new for ships but has a substantial number of land-based applications. It is estimated that several hundreds of systems are installed on ships, both on new ships and as retrofit systems.[88]

Large European producers of waste heat recovery systems are the German companies Siemens, Imtech and the engine manufacturers MAN (Germany) and Wärtsilä (Finland). In addition Aalborg Industries located in Denmark, the UK based company Peter Brotherhood Ltd and the Italian company Turboden are identified as key players. Also in Asia some waste heat recovery systems are produced. The main manufacturers in Asia are the Japanese companies Mitsui and Mitsubishi. In the USA General Electric is a manufacturer of waste heat recovery systems. Both in and outside Europe companies active in the field of waste heat recovery can be classified as large companies.

Although there are some non-European producers, Europe is considered leading in the development and production of waste heat recovery systems. According to interviewees, Asia is not expected to take over their leading position in the near future.

3.1.5 *Conclusion*

The call for cost reductions through improved fuel efficiency of ships is considered *the* main market driver for greening in the sector at present. Two main underlying reasons are:

1. Competition in the shipping sector that has resulted in very low freight and charter rates at the moment. From a cost-of-ownership perspective, ship owners aim to reduce their cost base, and fuel costs make up a large part of their operational expenditures;
2. High fuel prices have spurred the demand for fuel efficiency as a means to reduce (or: to limit the rise) of fuel costs relative to other operating costs of a ship.

The market potential is taken to be high as all new ships are expected to follow a trend towards higher fuel efficiency, partly driven by the increasing fuel prices but also by regulatory measures. The demand for fuel-efficient ships that follows from regulatory drivers (notably related to EEDI (see section 4.3)) is seen as a minimum level. An accelerated replacement of vessels driven by fuel efficiency, as is observed in some market segments (viz. containerships), may occur, but is hard to quantify. At the same time it is hampered by the relatively young age of the existing world fleet. For retrofit, opportunities for 'proven' fuel-efficiency solutions will rise if fuel prices increase rapidly. Market size however depends on trade routes and complexity of technology that needs to be installed.

The two main areas of market potential are:

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[88] FutureShip (2011).

- Fuel-efficient systems, including hull design, propellers used, PIDs, optimised operations, engines, and waste heat recovery;
- Alternative fuel based solutions, including LNG, hybrid, or wind.

A number of barriers to the expression of demand for fuel efficient systems is identified, namely:
- Barriers in the development of technologies: here, only a few minor barriers were revealed, such as the concerns over lack of skills (varying per country) and funding (inherent to any innovation process);
- Barriers in scaling up technologies: the main barrier here is the reluctance of ship owners to invest in non-proven technologies, causing however the suppliers not being able to prove;
- Barriers to the expression of demand: generally, conservatism of shipping companies is seen as a barrier. More specific is the issue of split incentives related to the structure of the shipping sector: costs accruing to ship owners, but benefits to ship operators. Finally, uncertainties about (the level and rise of) the fuel price makes payback periods uncertain, resulting in hesitance to invest.

The position of the EU shipbuilding industry in responding to fuel efficiency demand is considered good. For most of the technology fields offering solutions to raise energy efficiency of ships, European manufacturers have a leading position, and in some cases virtually no non-EU suppliers have been identified as yet. Clearly differences between technology fields are seen, with some areas dominated by large enterprises (notably the engine manufacturing domain), and others by SMEs (for instance wind assistance).

All ship types are expected to follow the trend towards higher fuel efficiency. It is not expected that as a result of the competitive position of Europe, shipyards in Europe are able to regain the construction of building ship types, which have been lost to competing countries in Asia. However, all ship types that are built in Europe are expected to be confronted with an increasing demand for fuel efficiency. In addition, as the majority of ships is built outside Europe, European suppliers will have an export potential. This market potential is partly dependent on the make or buy decisions of main shipbuilding companies outside Europe.

3.2 Trend 2: Environmental awareness and CSR

3.2.1 *Drivers*

Increased environmental awareness of consumers can lead to a comparative advantage of those firms selling products with a relatively low environmental footprint. This can lead to cargo owners pushing shipping companies to operate green ships (frequently mentioned examples are Ikea and Cargill). As a result this incentivises a demand for ships that perform environmentally better and/or to an increased demand for equipment improving the environmental performance of ships. Increased corporate social responsibility (CSR) in (cargo owning as well as shipping) companies can have the same effect (e.g. Maersk is strongly promoting its green image). Some cargo owners and ports are pushing for improving the environmental performance of ships (examples are CSI, ESI, Green Award; see box 3.4). Also several regional initiatives are found (Baltic Shippers, NW European ports networks).

Examples of the expression of this driver include passengers of cruise ships who prefer to book a voyage on a ship that performs environmentally better than other cruise ships, even if such performance has a price. Besides consumers, also firms can act as an environmentally aware consumer, ports may offer discounts for cleaner ships or ship owners may themselves improve the environmental performance of their fleet for CSR reasons. Similarly, there are cargo owners for whom it is important to improve their environmental footprint, including transport, since their clients attach importance to the environmental footprint of the products they buy (e.g. Ikea or Cargill as large freight owners). Cargo owners then have the possibility to push for improvements of the environmental performance of the ships they have in long-term charter, or they charter a ship which performs environmentally better than others, providing the ship owner in turn with an incentive to improve performance of its vessels / fleet.

In this context, several environmental indices that are relevant for the shipbuilding sector have been developed to compare environmental performance and alleviate this choice (see Box 3.4).

Box 3.4 Clean Shipping Index and Environmental Ship Index

The Clean Shipping Index was set up in 2007 with the aim to create a tool for large Swedish cargo owners to evaluate the environmental performance of carriers when procuring. The index is based on the following major areas: CO_2, NO_x, SO_x, Particulate Matter (PM), water and waste control, chemicals. The scores from 20 questions for the different areas are weighted equally to arrive at an overall score. By now 30 large cargo owners have joined the clean shipping network. They have access to the clean shipping index database, enabling them to choose a ship on the basis of its environmental performance.

The Environmental Ship Index, an incentive scheme that was set up by ports, is another example that the EU shipbuilding industry could be affected by CSR considerations. Several European ports (13 ports in January 2012) have decided to grant a discount on harbour dues on the basis of the Environmental Ship Index, while by now 578 ships have been assigned a valid ESI score. The index takes the NO_x and SO_x emissions of the ships directly into account and awards documentation and management of the energy efficiency. PM10 is indirectly included because of its strong relationship to SO_x. The system is set up in a way that it rewards a performance that exceeds the current international legislation.

Sources: http://www.cleanshippingproject.se/ and http://www.environmentalshipindex.org/Public/Home

3.2.2 *Assessment of the market potential*

Although environmental awareness and focus on sustainable production and consumption has increased especially in Europe, the extent to which private actors in the shipbuilding sector are willing to invest without there being a business case is limited. (This is not different from most other private sectors). In addition, shipping is often “hidden” in the product value chain of consumer goods, implying that the shipping component is not so visible to consumers when purchasing a final consumer product (and obviously private consumers tend not to purchase vessels as final goods).

This implies that most CSR / environmental awareness driven activity is observed in cases where there is a clear synergy between sustainability and economic competitiveness. CSR considerations as driver in shipbuilding are, in short: 1) almost always linked to a direct business case; 2) often embedded in a business to business (B2B) context (e.g. between ship owner and operator) and 3) more likely to take place in segments that operate closer to the consumer (e.g. passenger ferries or cargo ships carrying consumer products).

Often, fuel-efficiency and CSR /green marketing are combined as underlying drivers for greener products. Especially where vessels operate close to the end-customer and are ‘visible’, CSR and increased environmental awareness go hand in hand with fuel costs savings. Box 3.5 provides an illustration of this combination.

Box 3.5 First bi-power ferry that uses wind energy

Stena Line is the first ferry operator that uses a ship with a wind farm on the front deck. The wind farm is applied to an already existing vessel; the re-building costs were € 110 thousand. Fuel economies of 2 percent are reached. Further research is done in Sweden and Germany to achieve even larger fuel savings. The vessel sails between Denmark and Sweden.

The initiative of Stena Line can be qualified as CSR on the one hand, and fuel-efficiency on the other. The company is one of many Scandinavian companies that tries to reduce its environmental footprint, including e.g. IKEA, Volvo, H&M and Scania.

Source: http://viaggi.repubblica.it/multimedia/svezia-il-primo-ferry-bipower-che-usa-energia-eolica/29966152/1/1

3.2.3 *Main barriers*

The main barrier to the expression of demand driven by environmental awareness is that a direct business case may be lacking, i.e. financial returns directly related to the investment. On a long term, image building is seen as an investment that can pay off if clients are becoming more aware and are willing to pay a supplement. In weak economic times however there appears to be reluctance among customers and therefore also among investors.

In terms of technologies available and the barriers associated to them, these do not differ from those relevant for improving energy efficiency or reducing emissions (see section 3.1 and chapter 4).

3.2.4 *EU Industry position and technological response*

Since the technologies available to respond to environmental awareness and CSR calls are similar to those for energy efficiency or emission improvements, the position of EU industry players can be considered similar as well. One positive factor to be mentioned is the general impression that environmental awareness and CSR developments are more progressed in Europe than in many other parts of the world, giving European industry the advantage of a ‘home market’.

3.2.5 *Conclusion*

Increased environmental awareness and growing interest in Corporate Social Responsibility (CSR) is seen worldwide, and more so in Europe, in a number of sectors. The general impression is that the relevance of this driver varies between commodities and in general has a stronger impact in markets that are closer to the end consumer, and where the green image of cargo owners positively affects their market position. This is because the environmental impacts of shipping are often hidden or relatively small in the total environmental impact of an end product.
The willingness to invest in green technologies to raise the environmental performance of ships however seems to be limited if no clear business case is present. In practice investors' actions are found usually in combination with responses to other drivers, notably those raising the fuel efficiency of a ship. The market potential therefore is difficult to estimate, and considered limited additional to the market resulting from other drivers addressed in this report.

Barriers to the expression of demand are caused by this financial return issue as well as by market factors like the current crisis reducing funds for 'green image' investments.

The position of the EU industry in responding to this driver is considered to be based on its strengths in technologies addressed under other drivers in this study. Specific strengths are:

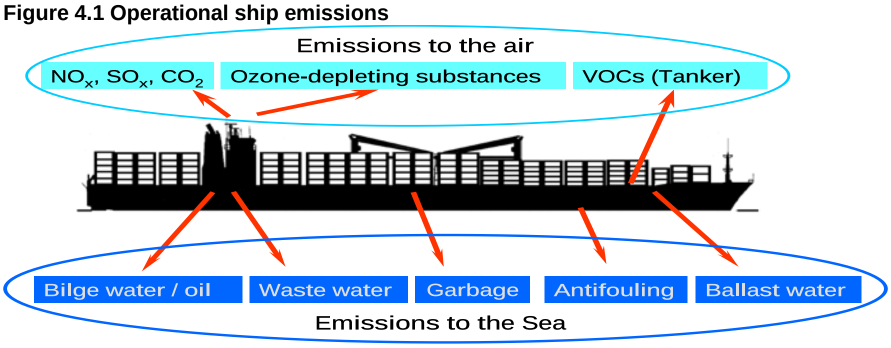
- The EU public being generally environmentally aware, which could stimulate local demand for 'green ships' (ships operated locally) or create new alliances (e.g. between ship owners and local suppliers);
- High value ships can more easily 'afford' additional environmental costs;
- The European marine equipment sector is strong in many areas that are affected by this trend (fuel efficiency, air pollution, etc.).

4 Regulatory-driven trends

Next to market-based drivers regulatory drivers exist that create green market opportunities. Regulatory drivers are factors that move businesses in an industry to exhibit certain behaviour that is a direct consequence of regulation. In theory these can be both “carrot” (e.g. subsidies, tax cuts rewarding certain green behaviour, but also port charges differentiation) as well as “stick” regulatory measures (e.g. an obligatory emission cap). In practice mainly the latter category appears to be relevant.

Regulatory-driven trends can originate at several layers of regulation: global regulation (IMO), EU, and national level regulation. Much of the environmental regulation regarding shipping is developed internationally within IMO. There are several categories of environmental IMO regulations that can affect the EU shipbuilding industry. Main environmental impacts of ship operations are related to their emissions, which can be divided into emissions to air and to water, as is depicted in figure 4.1. These ship emissions are primarily regulated by the IMO convention MARPOL (International Convention on the Prevention of Pollution from Ships). Another environmentally related convention is the Ballast Water Convention.

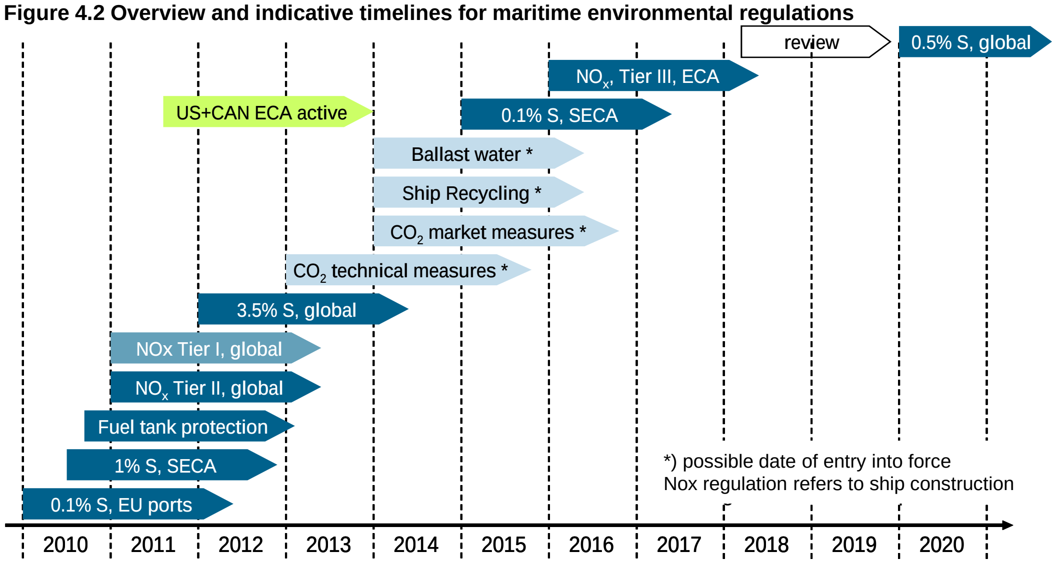
Figure 4.1 Operational ship emissions



Source: FutureShip GmbH (GL Group)

Shipping is facing progressively stricter environmental regulations in the future. A possible roadmap in this respect based on already adopted or currently debated regulations, is shown in figure 4.2. Obviously some of the dates of entry into force are not decided upon yet and thus these should be considered with care.

Figure 4.2 Overview and indicative timelines for maritime environmental regulations



Source: FutureShip GmbH (GL Group).Estimated dates of entry into force to be considered indicatively only

IMO MARPOL Annex VI sets limits on sulphur oxide (SO_x) and nitrogen oxide (NO_x) emissions from ship exhausts and prohibits deliberate emissions of ozone depleting substances. The IMO emissions standards apply to ships above 400 GT and engines above 130kW. NO_x emission standards are commonly referred to as Tier I / II / III standards. Tier I standards were defined in the 1997 version of Annex VI, whereas Tier II / III were introduced by Annex VI amendments that were adopted in 2008.

The introduction of stricter emissions standards in a defined geographic area is possible. The revised Annex VI allows for Emission Control Areas (ECAs) to be designated for SO_x and particulate matter (PM), or NO_x, or for all three types of emissions generated by ships.

Regulatory-driven trends lead to direct or indirect changes in company behaviour. The following trends will be analysed in this chapter:

- Trend 3: NO_x abatement;
- Trend 4: SO_x abatement;
- Trend 5: CO_2: EEDI, SEEMP and measures under discussion at IMO;
- Trend 6: Ballast water and sediment treatment.

4.1 Trend 3: NO_x abatement

4.1.1 *Drivers*

Global regulation

In March 2010, specific sections of the U.S., Canadian and French waters (outer boundary of 200 nautical miles from the territorial sea baseline) were designated internationally as an ECA with respect to both NO_x and SO_x emissions. This North American ECA will become enforceable in August 2012. In July 2011 the IMO designated a proposal for a U.S. – Caribbean ECA, including waters adjacent to coasts of the Commonwealth of Puerto Rico and the U.S. Virgin Islands. The first phase for SO_x will start in 2014, the second phase in 2015 and the NO_x standards will be in force in 2016.[89]

The countries around the Baltic Sea are working on a further application to the IMO for appointment of their sea area as a NO_x ECA (NECA). Also the North Sea Consultation Group is investigating the advantages and disadvantages of a North Sea NECA. No decisions have however been taken for either of them.

In Table 4.4.1, the maximum allowable NO_x emissions are depicted. Ships built before 1 January 2000 need to comply with Tier I. Tier II standards entered into force in January 2011. For areas designated as a NO_x emission control area (NECA) new ships will need to meet Tier III, a reduction of 80 percent compared to Tier I standards. Since NECAs are formally in place in the US only and not in Europe, the market potential that this will impede remains uncertain.

Table 4.4.1 Maximum allowable NO_x emissions

	Diesel engines installed on ships constructed	Speed (n) in rpm	Max. allowable NO_x emissions (g/kWh)
Tier I (Engine-based controls)	From 1 January 2000 to 1 January 2011	<130	17.0
		130 ≤ n < 2.000	$45.0*n^{-0.2}$
		n ≥ 2.000	9.8
Tier II (Engine-based controls)	After 1 January 2011	<130	14.4
		130 ≤ n < 2.000	$44.0*n^{-0.23}$
		n ≥ 2.000	7.7
Tier III (After treatment-forcing)	After 1 January 2016 when operating in NECA	<130	3.4
		130 ≤ n < 2.000	$9.0*n^{-0.2}$
		n ≥ 2.000	2.0

The development of **NO_x emissions** abatement technologies is driven by MARPOL Annex VI regulations which specify the emissions per unit of engine output of engines in ships built after 2016 (Tier-II). Most engine manufacturers offer these engines. For meeting more stringent norms (Tier-III) that apply in emission control areas, ships will often need to apply after treatment of exhaust gas, for example by using selective catalytic reduction (SCR), or install LNG or dual fuel engines.

EU regulation

IMO / MARPOL standards are providing the basis of NO_x emission standards to be met, and apply to EU Member States as well as others. The European Union itself is not a member to the MARPOL treaty[90], however to ensure that each Member State (participant to the IMO regulations or not) complies with the environmental standards, the Air Quality Directive[91] was adopted, reproducing the main standards of the MARPOL regulation.[92] The Directive contains a set of limit values for certain pollutants that may not be exceeded. On the basis of the EU air quality legislation, ports need to ensure that the air quality in port areas does not exceed the threshold values. Onshore power supply (OPS) is one example of the measures taken by ports to improve the air quality which can affect the EU shipbuilding industry.

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90 http://www.imo.org/About/Conventions/StatusOfConventions/Pages/Default.aspx, latest status update 29 February 2012.

91 Directive 2008/50/EC.

92 The Commission also states that it has the intention to push the IMO to implement sufficient emission reductions and when the IMO fails the Commission will bring forward measure of its own.

National and local regulation

Since 2007, a tax is levied in Norway on NO_x emissions from different sources. NO_x emissions from ships (engines exceeding 750 kW and boilers over 10 MW) sailing in Norwegian waters are subject to this tax as well. Entering a NO_x agreement entitles ships to be exempted from the tax. Exempted vessels have to make payments into a privately run NO_x fund instead. The revenue of the fund is used to support the acquisition of NO_x reducing measures (See also Box 6.1 in Chapter 6).

Several Swedish harbours, such as the Port of Gothenburg and the Port of Helsingborg, offer a discount on their harbour dues, depending on the sulphur content of the fuel used and/or depending on the engines' NO_x emissions per kWh. Also other ports in Europe have introduced similar initiatives. The Port of Hamburg offers a discount when the vessel reduces the overall emissions (e.g. NO_x, SO_x and CO_2). The port of Rotterdam offers a discount of 15% for clean inland vessels, while polluting vessels are charged 10% more.[93] It's expected that more ports will introduce similar initiatives.

4.1.2 *Assessment of the market potential*

To comply with the **NO_x emissions** levels under Tier-III, several techniques are considered and being developed, including:

- Selective Catalytic Reduction (SCR, a system to convert NO_x into nitrogen and water by leading it through a catalytic reaction process);
- Dual fuel engine (combining the use of HFO and LNG with the ability to switch between fuels, e.g. when in a NECA the engine can run on the more expensive low NO_x LNG, shifting back to the more polluting but cheaper HFO outside the NECA zone);
- Liquid Natural Gas engines (LNG);
- Exhaust Gas Recirculation (EGR, combined with multi stage turbo charging. EGR is a method to reuse the redundant gas and so energy can be saved). This system can also be applied as retrofit.

The Tier III limit value only applies to new ships. This implies that the investment costs will be spread over many years, as the renewal rate of ships lies at roughly once in 30 years[94]. Bosch (2009) estimates the additional investment cost for the year 2020 between € 452 and 645 million. The study by Bosch (2009) for DG Environment estimated the potential if NECA's would be in place in Europe (which is not the case today) including the assumption that a Mediterranean NECA will be established.

For the US, it is estimated that 15,200 unique ships will be affected by the IMO Tier III legislation from 2016 on (US EPA, 2009). Using investment costs cited by Bosch (2009), the US market size for Tier III can be estimated at a cumulative € 7-9 billion for the period until 2030.

[93] http://www.portofrotterdam.com/en/News/pressreleases-news/Pages/discount-port-dues-year-row.aspx.

[94] It is noted that this period may be shorter or longer depending on the economic situation. The current crisis for instance has resulted in reducing the average lifetime with 2 to 3 years during the period 2007/2010 (UNCTAD, 2011).

Table 4.2 Market potential for NOx reduction measures (bn EUR)

Period	Region	
	US NECA (already in place)	Estimate for possible EU NECAs (Baltic, North Sea and Mediterranean together)
2015-2019	2.0-2.6	2.6-3.5
2020-2024	2.4-3.0	3.0-4.0
2025-2030	2.7-3.5	3.4-4.6
Cumulative 2015-2030	7.1-9.1	9.0-12.1

None of the studies mentioned included LNG as a propulsion technique as a potential solution in the scenarios, and the potential would rise if a substantial share of LNG propulsion can be realised, since LNG is associated with higher additional investment costs.

4.1.3 *Main barriers*

Three categories of barriers have been identified:

- Barriers to the development of technologies to abate NO_x emissions;
- Barriers in scaling up technologies to abate NO_x emissions;
- Barriers to the expression of demand for technologies to abate NO_x emissions.

Barriers to the development of technologies to abate NO_x emissions

In general, a sufficient supply of NO_x emission control technologies is available to the shipbuilding and maritime equipment industry. Relatively few barriers relate to the development of new technologies. Both European shipyards and the marine equipment industry have developed green innovations and continue to do so.

EU based engine manufacturers such as MAN and Wärtsilä supply engines that meet Tier-II standards and equipment that meets Tier-III standards.

Barriers in scaling up technologies to abate NO_x emissions

Not all the innovations proposed by the shipbuilding and maritime equipment sectors appear to be considered effective and reliable by shipping companies. As a result, shipping companies are reluctant to invest in these technologies. This hampers innovation because companies do not have the possibility to learn by doing.

In the field or air emissions, the reliability of innovations is often questioned. Several technologies have been developed for stationary and/or land-based applications (SCR in trucks, for example), but many stakeholders have indicated that they doubt whether the same technologies can be used reliably in maritime conditions. This may create an important barrier for implementation of technology.

A positive incentive to scale up technology is the Norwegian NO_x fund. It provides shipping companies with a subsidy for investments in NO_x-reducing technologies. Under this fund, 32 ships have been equipped with LNG or dual fuel engines. Many more have installed SCR or other NO_x reducing technologies. Since the NO_x fund is open to companies of every nationality, and since there is no restriction on the source of the technology, EU marine equipment industries have also benefitted from the fund. In contrast to the MARPOL Annex VI requirements, the NO_x fund also incentivises existing ships to retrofit NOx abatement technologies. More details of the NO_x fund are presented in box 6.1 in chapter 6.

We have not found indications in the literature review, interviews or stakeholder workshop that EU marine equipment industries face specific barriers in scaling up technologies to abate NO_x emissions.

Barriers to the expression of demand for technologies to abate NO_x emissions

Many stakeholders express the opinion that the supply of technologies is larger than the demand from ship owners and operators for these technologies. There are, however, a number of barriers that prevent or postpone the expression of demand for new green products.

In general, the regulatory uncertainty for NO_x abatement technologies is limited. As a MARPOL regulation, ships built from 2016 onwards will need to comply if sailing in NECA zones. This means that they need to have engines which are certified to have emissions below the limit value of either Tier-II or Tier-III. Compliance can be monitored in every port, and every port state that has ratified MARPOL Annex VI may take action against non-compliant ships.

However, specific uncertainty, partly regulatory and partly market driven, affects the demand for LNG and dual fuel engines. A broader use of LNG as an alternative ship fuel is, among other things, hindered by the fact that there is no or no uniform safety regulation and that there is no uniform standard for the design of LNG fuelling facilities. The same holds for onshore electricity systems. Here also no uniform standard exists which makes the diffusion of the technology more difficult.

Moreover, the use of LNG as alternative fuel, or the use of cold ironing, requires infrastructure investments of third parties such as ports. As long as there is limited infrastructure capacity, application of these technologies is not feasible/profitable and demand for these technologies will be very limited.

Demand for LNG and dual fuel engines also depends on the current and forecasted relative prices of these fuels.

While the supply of LNG bunkering infrastructure is a global barrier, there is a clear regional aspect within the EU to it. For ferries, coasters, feeders, and other ships that sail predominantly within Europe, demand for LNG could increase if the European bunkering infrastructure is good, regardless of whether there is sufficient infrastructure in other parts of the world. Likewise, bunkering safety regulation is local or national and could be harmonised regionally.

4.1.4 *EU industry position and technological responses*

LNG

One of the solutions to reduce NO_x emissions is the use of LNG as ship fuel instead of oil based fuels. To be able to use LNG as ship fuel new engines are needed. These can be both specific LNG engines, as well as dual fuel engines which are able to run on both heavy fuel oil and LNG. The effects for a four-stroke engine is a reduction in NO_x emissions of 80% when LNG is used.[95]

The main actors in this segment are European companies. Logically these companies are all engine manufacturers. The main ones are MAN[96], Wärtsilä[97] and Caterpillar/MAK[98]. Although

95 Futureship (2011).
96 http://www.tge-marine.com/index.php?article_id=29.
97 http://www.wartsila.com/en/Home.
98 http://marine.cat.com/.

European companies are leading in the LNG market in terms of their market share, several large Asian companies are also developing engines suitable for LNG as ship fuel. Especially Korean companies are entering the LNG market. The main competitors of the European companies are Hyundai and Daewoo.

The engines needed for LNG as ship fuel are already used in many types of ships. Especially in the segments of passenger vessels and car ferries. already a number of ships are using LNG. Furthermore a number of other vessels are converted to LNG, examples are chemical tankers, cargo vessels and offshore vessels. As mentioned under barriers (section 4.1.3) however, the lack of infrastructure is a constraint for further rolling out LNG fuelled ships. This is attributed partly to the required investment in port infrastructure, and partly to the lack of clear regulatory standards.

SCR-catalytic converters

A second option to reduce NO_x emission is the installation of SCR systems on board of vessels. These systems convert NO_x into nitrogen and water. Advantage of an SCR system is that it can be easily retrofitted on existing vessels. The systems are already available on the market, but implementation and market penetration is still low.

All leading companies are found in Europe. All these companies can be qualified as SMEs. The most important players are H+H Umwelttechnik of Germany, Yarwill AS[99] located in Norway, D.E.C. Marine AB[100] of Sweden (cooperating with Wartsila), STT Emtec[101] (cooperating with Volvo Penta) also located in Sweden and Proventia[102] of Finland.

Retrofit engines to comply with Tier I

A third option to reduce NO_x emissions is to retrofit engines. This is needed for engines that were built between 1990 and 2000, which do not comply with IMO Tier I. The IMO has certified engine retrofits of only two companies, both European. No Asian competitors are active in this field.

MAN Diesel & Turbo and Wärtsilä are allowed to retrofit the vessels (certified by the IMO)[103]. MAN is using so-called slide valves, while Wärtsilä uses a variable injection system (VIT) to reduce the NO_x emissions.

4.1.5 *Conclusion*

IMO MARPOL Annex VI is the main regulatory driver with regard to NO_x emission. Emission requirements are set for new built ships from 1 January 2000 onwards (Tier I), with reduced levels for ships built from 1 January 2011 onwards (Tier II) and further reduced for ships sailing in NO_x ECAs from 1 January 2016 onwards (Tier III). In Europe, no NO_x ECAs are in place yet, only in the USA. Furthermore at national level, the NO_x tax and fund in Norway acts as a driver for reducing NO_x emissions.

Requirements for Tier I and Tier II can be met through engine-based controls (combustion process optimisation), while for Tier III either shifting to low NO_x fuels or after treatment is necessary. To comply with the NO_x emissions levels under Tier-III, the main techniques available are:

- Selective Catalytic Reduction (SCR);

99 http://www.yarwil.com/.
100 http://www.decmarine.com/.
101 http://www.sttemtec.com/1/1.0.1.0/104/2/.
102 http://www.proventia.com/sivu/en/.
103 FutureShip (2011).

- Dual fuel engine (combining the use of HFO and LNG);
- Liquid Natural Gas engines (LNG);
- Exhaust Gas Recirculation (EGR). This system can also be applied as retrofit.

Total market potential following from the US NO_x ECA is estimated at € 7-9 bn for the period until 2030. If a European NO_x ECA were to be in place in the Baltic, North Sea and Mediterranean, an estimated market potential of € 9-12 bn would be created. This potential only applies to new ships, not to retrofit.

Sufficient technologies are available to respond to the market potential. European industry has developed a number of innovations in this field. As market implementation so far has however been limited – because regulatory requirements for Tier III will only enter into force in 2016 – the effectiveness and reliability of systems is considered insufficient by shipping companies. This hampers market introduction. Incentive schemes like the Norwegian NO_x tax contribute positively to the introduction of NO_x abatement technologies on board ships.

Specific barriers are identified with regard to the application of LNG as a fuel. They involve both the availability of shore infrastructure and clear regulatory regimes with regard to safety.

European suppliers are well positioned with regard to both LNG systems (the main engine manufacturers MAN and Wärtsilä are Europe based, but also some Asian competitors active), and the supply of SCR systems (a number of SMEs is active in this field).

4.2 Trend 4: SO_x abatement

4.2.1 *Drivers*

IMO MARPOL Annex VI sets limits on SO_x emissions from ship exhausts. MARPOL requires ships to use fuels with a sulphur content of 1% from 2020 onwards (the current limit value is 3.5% and – see table 4.3 below). In SECAs, ships will be required to use fuels with a sulphur content of 0.5% or less from 2015 onwards.

Instead of using low sulphur fuels, which is costly compared to Heavy Fuel Oil, ships may use scrubbers to remove SO_x from their exhaust gas. LNG could also be used for compliance, as it contains hardly any sulphur, and as prices tend to be relatively lower than low sulphur diesel oil.

The fuel sulphur limits are presented in table 4.3 below. Alternative measures are also allowed to reduce sulphur emissions. For example instead of using a 1.5% gap on the sulphur content of fuel, ships can use technological methods to limit SO_x emissions (such as exhaust gas cleaning systems/scrubbers).

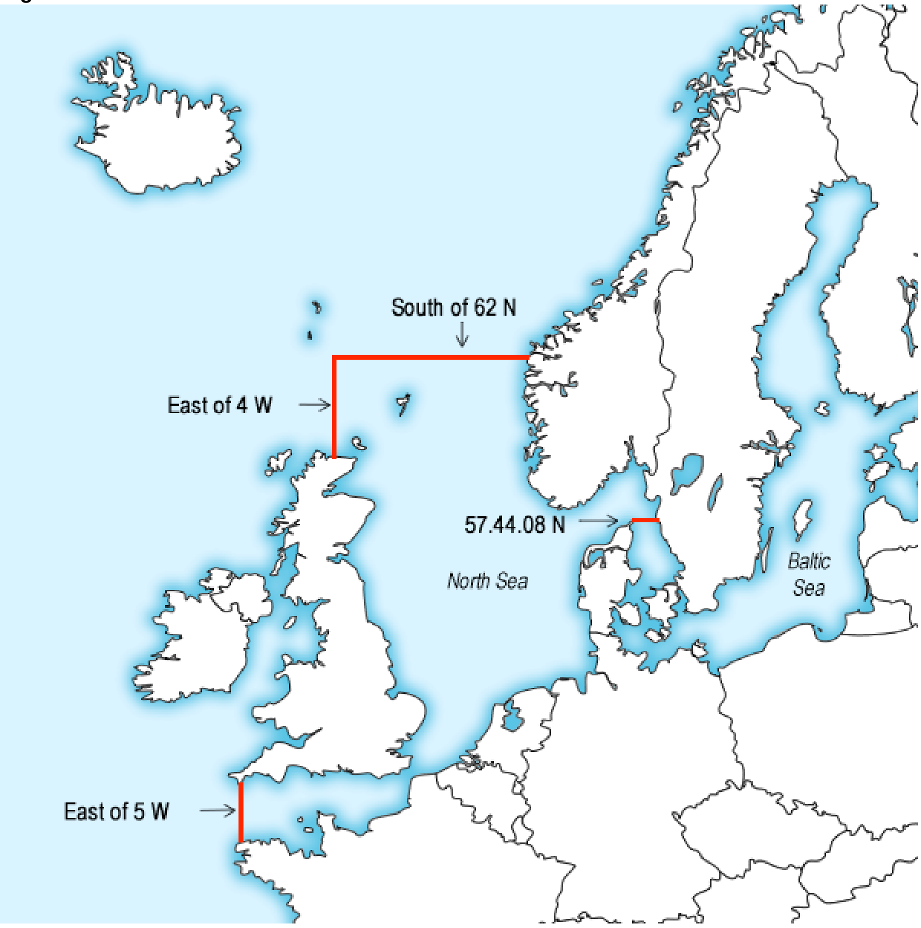
Table 4.3 Limits for Sulphur Content in Fuel Oil (revised MARPOL Annex VI)

	Maximum sulphur content (%)	Time period
Globally	4.5%	Until January 2012
	3.5%	From 1 January 2012

	Maximum sulphur content (%)	Time period
	0.5%	From 1 January 2020 (or 2025) [104]
In SECAs	1.5%	Until 1 March 2010
	1.0%	From 1 March 2010
	0.1%	From 1 January 2015

The Baltic Sea Area, the North Sea and the English Channel were adopted as SO_x Emission Control Area (SECA) in 2005.

Figure 4.3 The Emission Control Areas in the North Sea and Baltic Sea



Source: Sustainable shipping (2009), Emission control Areas (ECA's), what you need to know, www.sustainableshipping.com

EU regulation

In addition to the IMO sulphur regulation, Directive (2005/33/EC) sets limits for the fuel sulphur content of fuel used in European ports when berthed. From 1st of January 2010, the Directive prescribes a maximum of 0.1 percent sulphur. The exemptions that were in place for a number of Greek ferries expired 31st December 2011.

[104] The revised MARPOL Annex IV provides two dates for the entry into force. Initially the sulphur limit if 0,5% should enter in force in 2020, but the period can be extended to 2025. Extension of the date depends on the outcome of a review that must be concluded in 2018 at the latest.

4.2.2 *Assessment of market potential*

The main technologies to meet the sulphur requirements are:

- Use of low sulphur content fuel (MDO, or possibly LNG);
- Scrubbers, which remove the SO_x from exhaust gases by a (chemical) reaction. The SO_x reacts with a substance depending on the system used and is neutralized.

While most engines can run on low sulphur fuels, scrubbers or LNG engines offer a market potential for shipbuilding and marine equipment industries.

The shipping sector can observe the 0.1% fuel sulphur legislation in SECAs through the installation of a scrubber on board of a ship, or by using low sulphur fuel or LNG. Analysis has shown that the share of the fuel consumption inside a SECA (in relation to the fuel consumption outside the SECA) and the price differential between Marine Gas Oil (MGO) and Heavy Fuel Oil (HFO) influence the payback time of a scrubber. For example, a container ship travelling between China and Rotterdam – only sailing SECA waters for a small part of its sailing time – will have a much longer payback time than a RoRo vessel sailing in the North Sea SECA permanently.

Bosch (2009) has estimated the market size if scrubbers would be fitted on all ships sailing in the ECA. Depending on the type of scrubber, the annual costs are estimated between € 680 mln (open scrubber) and € 2 bln (closed scrubbers)[105]. These costs are based on a depreciation period of 12.5-15 years and 4% interest. 95% of the costs presented represent investment costs. Expressed as one-off investment costs, the investment costs for the current European SECAs amount to between € 16 and 46 billion for the next 30 years[106]. A significant part of the market will be retrofit. According to Bosch (2009), between 48 and 78% of the installation will be of a retrofit kind in the period up to 2020, depending on the ship type. Retrofitting explains the relatively high market potential for the 2015-2020 period, assuming that all ships in operation will be retrofitted in that period, leaving only the newbuilding market for the period afterwards.

Table 4.4 Market potential for SO_x reduction measures (bn EUR) in SECAs

	Current EU SECAs (Baltic and North Sea)	Estimate if Mediterranean were to be a SECA	
2015-2020	8-23	13-39	Mainly retrofit
2020-2025	1-4	2-5	Mainly for newbuilding
2025-2030	1-4	2-5	Mainly for newbuilding
Cumulative 2015-2030	10-31	17-49	

The investments need to be interpreted as an upper limit, since not all ships will be equipped with scrubbers, but will switch to the usage of LNG as fuel, or use low sulphur fuel. The market potential of scrubbers and LNG technology hence lies probably somewhere halfway between 0 and the limits mentioned.

The impact of the worldwide fuel sulphur reduction to 0.5% in 2020 (or 2025) may have a significantly bigger impact on the shipbuilding sector, as all ships sailing worldwide will need to significantly reduce their SO_x emission.

105 All costs in this section are expressed in Euros of 2005.

106 If the Mediterranean Sea would be added as well, the investment cost would increase to € 42-125 billion.

Since SO_x regulation affects all ships (above the size of 400 GT), this market potential applies both to new ships and to retrofits of existing ships.

4.2.3 *Main barriers*

Two categories of barriers have been identified:

- Barriers to the development of technology to abate SO_x emissions;
- Barriers to the expression of demand for technologies to abate SO_x emissions.

Barriers to the development of technologies to abate SO_x emissions

In general, we find that there is a sufficient supply of technologies in the shipbuilding and maritime equipment industry[107]. Relatively few barriers relate to the development of new technologies. Both the European shipbuilding sector and the marine equipment industry have developed green innovations and continue to do so.

In the field of sulphur emissions, scaling up is difficult because the reliability of innovations is often questioned. Many technologies have been developed for stationary and/or land-based applications (scrubbers in land based power plants, for example). Different stakeholders indicate that they doubt whether the same technologies can be used reliably in maritime conditions. This may create an important barrier for implementation of technology. For example, in order to meet ECA sulphur emission standards, shipping companies can choose between using low sulphur fuel or installing a scrubber. The impact of low sulphur fuel on emissions and on the ship are well known. If the reliability of the scrubber is questioned, however, shipping companies may run the risk that failure of the scrubber may result in penalties or in the need to use low sulphur fuel. They may consider this risk to be too high.

The requirement to reduce SO_x emissions comes into force in 2020 for all ships and in 2015 for all ships operated in ECAs. Since most ships are on a five-year dry dock cycle, it would have made sense if ship owners had started installing scrubbers from 2011 onwards. However, to date, very few ships have installed scrubbers. Many interviewees blame the shipping sector's conservatism. Yet, in this case, the reluctance to install scrubbers is understandable. From the point of view of the ship owner this is rational behaviour; until the regulation enters into force, the benefits associated with the investment are purely of external nature. This however means that when the whole sector invests just before the regulation enters into force, that the production of European market players will be under stress (similar problems are identified for Ballast Water Systems, see box 4.3 in section 4.4.3). Enforcement of the environmental regulation will play a major role here. When the penalty for non-compliance with the environmental regulation is known to be high and strict enforcement is a credible threat, then ship owners may tend to invest earlier to ensure compliance in time.

These barriers are important also for other regulatory segments addressed in this report and for EU and non-EU yards and equipment manufacturers alike.

Barriers to the expression of demand for technologies to abate SO_x emissions

In the field of air pollution, **regulatory uncertainty** is a factor that in the stakeholder interviews has often been stated as a barrier to diffusion. While the rules of MARPOL Annex VI are clear, there is an uncertainty about the date of introduction of the SECAs. The European Commission has tabled

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[107] Over the course of this project, We have interviewed 5 EU-based manufacturers who have developed maritime sulphur scrubbers in recent years. There are several more. See section 5.1 for an overview.

a proposal on the adoption of the stricter sulphur limits in July 2011 (COM(2011) 439 final). Subsequently, Finland and politicians from other Baltic states have called for a five-year delay.[108] Various stakeholders have supported these calls.[109] The European Parliament Environment Committee has backed the IMO legislation with a vote in February 2012[110]. On top of the IMO legislation, the Environment Committee also voted to set a 0.1 percent sulfur limit for fuel used by *all* passenger ships operating between European Union ports, beginning in 2020. Later in 2012, the Parliament and Council will have to come to a decision. Until a directive has been adopted, regulatory uncertainty remains.

Another barrier is the **uncertainty about the relative prices of low sulphur fuel and conventional fuel**. Since shipping companies can comply with the regulation either by using low sulphur fuel or by installing a scrubber, the projected additional costs for using low sulphur fuels have a major impact on the business case for a scrubber. Recently, a number of studies on the costs of low sulphur fuels have been published. An IMO expert group estimated in 2007 that low sulphur fuels have a historical price premium of 50% to 72% (BLG 12/6/1). For 2020, the expert group report suggests a price increase of 25%. Since then, additional studies have been published. In the Purvin *et al* (2009) study, it is estimated that bunker fuel with 0.5% maximum sulphur content will cost $120 to $170 more per tonne than the current high sulphur quality, leading to an increase of the costs of bunker fuel in the range of 30-50%, depending on the process option (Purvin *et al*, 2009). In a study of the Ministry of Transport and Communications Finland (2009), it is estimated that HFO with a maximum sulphur content of 0.5% will be about 13-29% more expensive than the HFO with a maximum sulphur content of 1.5%. For calculating the market potential (see figures in section 4.2.2 above), we assumed a cost increase range of 10-50%.

4.2.4 *EU industry position and technological responses*

For SO_x emissions two solutions are developed. Also in this case LNG is one of the solutions, the other is the installation of a scrubber on board of the vessel.

LNG

As for NO_x, LNG is also a solution to reduce SO_x emissions, because of its lower sulphur content.

Scrubbers

A second solution to reduce SO_x emissions is the use of a scrubber on board a vessel. Two types of scrubbers have been developed, dry and wet scrubbers. A scrubber removes the SO_x from the exhaust gas by a (chemical) reaction. The SO_x reacts with a substance depending on the system used and is neutralized. The technology has been proven for a variety of land based applications.

The main companies that are producing scrubbers are located in Europe. In the scrubber market both SMEs and large companies are operating. Important European SMEs are Hamann and

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[108] 'Wider push may be seen for ECA delay', http://www.sustainableshipping.com/news/i106618/Wider_push_may_be_seen_for_ECA_delay, accessed 06.12.2011

[109] Interferry: 2015 sulphur limit is 'mission impossible', http://www.sustainableshipping.com/news/i108533/Interferry_2015_sulphur_limit_is_mission_impossible, accessed 06.12.2011, Ferry firm predicts ECA-related job losses, http://www.sustainableshipping.com/news/i108644/Ferry_firm_predicts_ECA_related_job_losses, accessed 06.12.2011; BPO repeats call for delay of ECA sulphur limit, http://www.portworld.com/news/i108567/BPO_repeats_call_for_delay_of_ECA_sulphur_limit, accessed 06.12.2011.

[110] In addition the Committee voted to set a 0.1 percent sulfur limit for fuel used by passenger ships operating between European Union ports beginning in 2020. The current EU limit is 1.5 percent. Source: http://www.businessweek.com/news/2012-02-17/tougher-ship-fuel-sulfur-limits-endorsed-by-eu-parliament-panel.html

Couple Systems[111]. Besides these SMEs there are a few large players active in this market, like Hamworthy located in the UK, Wärtsilä of Finland, Aalborg Industries[112] of Denmark, and Clean Marine of Norway. Although European companies are leading in the scrubber market in terms of current market activity, a number of other companies can be found in the rest of the world. Main SME is Marine Exhaust Solutions (MES)[113] located in Canada. Large companies offering scrubbers are ACTI located in Taiwan and DuPont of the USA. DuPont has many branches in Europe and so it is likely that scrubbers are also being developed and/or manufactured in Europe.

Scrubbers can be installed on new as well as existing ships. The latter requires however sufficient (deck) space available. The number of installations so far is limited.

4.2.5 *Conclusion*

The market for SO_x abatement technologies is driven by IMO Marpol Annex VI and applies to both new and existing ships. As for NO_x, the emission limits become more stringent over time, with the most stringent regime applied in SO_x ECAs, starting from 2015 onwards. In the EU, the Baltic Sea and the North Sea/English Channel have been adopted as SECAs.

Solutions to meet requirements are either to apply low sulphur fuel, which is more costly than HFO, or through exhaust gas treatment using scrubbers. The commercially optimal choice will differ per ship and highly depends on the fuel price gap between the two fuel types. LNG as a fuel is a specific possibility because of its low sulphur content and its attractive price relative to other low sulphur fuels.

The market potential for SO_x abatement technologies is estimated at € 10 to 31 bn until 2030 based on the current European SECAs. If the Mediterranean were to be a SECA as well, another € 7-18 bn would be added. The total market potential including all three SECAs is estimated at 17-49 bn. For the short term (until 2020), this will largely relate to retrofit activities (installing on ships already built and operational in SECAs), while after this period demand will mainly relate to newbuilding. The impact of the worldwide fuel sulphur reduction to 0.5% in 2020 (or 2025) may have a significantly bigger impact on the shipbuilding sector, as all ships sailing worldwide will need to significantly reduce their SO_x emission.

Barriers for the scaling up of technologies are – as for NO_x – related to the perceived reliability of systems. Since the number of scrubbers installed is still very low, ship owners remain conservative. Also as the requirement will only start in 2015, there is no reward for early action. This may pose pressure on installation capacity once the entry date draws nearer. Furthermore several member states have expressed the wish to postpone the entry into force of the requirements, thereby raising the level of (perceived) regulatory uncertainty. Finally, uncertainties in the relative fuel prices affect the risk level of investment decisions to be made by ship owners.

For both LNG and scrubber technologies, EU manufacturers have developed the required systems and they are considered ‘best in class’ worldwide in these fields. There are however a number of suppliers elsewhere as well.

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[111] http://www.couple-systems.com/.
[112] http://www.aalborg-industries.com/scrubber/pro_exhaust_gas_scrubber.php.
[113] http://www.marineexhaustsolutions.com/products_commercial.asp.

4.3 Trend 5: CO_2: EEDI, SEEMP and measures under discussion at IMO

4.3.1 *Drivers*

Global regulation

In July 2011, the Marine Environmental Protection Committee of the International Maritime Organisation (IMO) has adopted the first mandatory global CO_2 regimes under MARPOL Annex VI: the Energy Efficiency Design Index (EEDI) and the Ship Energy Efficiency Management Plan (SEEMP). Next to these technical and operational measures the IMO is working on market based measures to curb greenhouse gas emissions from maritime shipping.

The EEDI sets a relative CO_2 design standard for new ships. Required reduction levels depend on the type and the size of a ship. These reduction levels have to be met through technological adaptation in the ship's design. In the first phase (from 2015 on) reduction levels are max. 10% of the reference efficiency and will be tightened every five years. Currently, the EEDI regulation does not apply to all ship types and types of propulsion systems. The regulation mainly applies to bulk carriers, gas carriers, tankers, container ships, general cargo ships, refrigerated cargo ships and combination carriers. Ship types exempted are vessels not carrying cargo, engine types exempted are diesel-electric, turbine or hybrid propulsion systems.[114] Whether the other ship types will eventually fall under the EEDI regulation is still a subject of discussion within IMO. Since only new ships have to comply with the EEDI, measures will, at least in the beginning, not be adopted on a large scale. Overcompliance with the standard is not rewarded.

The Ship Energy Efficiency Management Plan (SEEMP) is an operational measure/management tool to improve the energy efficiency of a ship's operation. In July 2011 the IMO decided to make the SEEMP obligatory for all newly built and existing vessels from 1 January 2013 onwards.[115] The intention of the SEEMP is to create an overview on the potential emission abatement options per ship, to monitor the ship's energy efficiency and to trigger self-evaluation by means of a benchmark and/or a voluntarily set of energy efficiency goals. In this respect the Energy Efficiency Operational Index (EEOI) that has been developed previously by the IMO, can be used as a benchmark. The SEEMP can stimulate operational as well as technical abatement measures. However, since the system works with voluntary target setting, it is not certain whether emission reduction measures will be adopted on a large scale. First results from operators like Maersk[116] are positive, which might trigger other shipping companies to follow.

In addition to these measures IMO is working on market based measures (MBM) to reduce CO_2 emissions. Within IMO there is a general agreement that MBM are needed as part of a comprehensive package of measures for regulation of GHG emissions.[117] However, these measures are still under discussion. Several governments and observer organizations have proposed different market based measures (MBM) to curb down CO_2 emissions (see Box 4.1). These proposals can be grouped as follows:

- a global emission trading scheme;
- a GHG fund financed from contributions levied on bunker fuel sales;
- a ship efficiency credit trading scheme (SECT);
- an efficiency incentive scheme/a differentiated bunker fuel charge;
- a uniform emission charge.

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[114] http://www.imo.org/MediaCentre/HotTopics/GHG/Pages/default.aspx.
[115] http://www.dnv.lt/binaries/Brief%20SEEMP%200811%20description_tcm173-477943.pdf.
[116] http://www.maerskline.com/link/?page=brochure&path=/about_us/environment/reducing_gas_emissions.
[117] IMO (2011), Steady progress on MBMs for international shipping during intersessional IMO meeting, 5 April 2011.

Box 4.1 Main features of some market based measures under discussion in IMO

Under **a global emission trading scheme**, a certain amount of CO_2 emission allowances would be issued and every ton of CO_2 emitted by the sector would have to be covered by such an emission allowance. Under the proposed scheme CO_2 emission allowances would be auctioned off to the sector and there would be the possibility to buy and sell allowances on the allowance market of other sectors. The use of CDM allowances would be allowed as well. Further, the system would allow for an exemption clause which can be used to exempt voyages to some developing countries such as SIDS/LDCs. The revenue from selling the allowances could be used for climate change mitigation and adaptation purposes in developing countries and for technical cooperation activities under the IMO.

Another proposal brings forward the idea of a **GHG fund** that is financed from contributions levied on bunker fuel sales. This proposal aims at meeting a sectoral emission target by raising, by means of contributions levied on bunker fuel sales, resources for a GHG fund to be able to buy enough CDM allowances to meet this emission target. Furthermore, revenues can be used to facilitate R&D activities and Technical Cooperation within the IMO framework. Either the bunker fuel supplier or the ship owner would be responsible for the payment of the charge.

Under the proposed **ship efficiency credit trading scheme**, credits are traded within the sector only. This system would be related to an efficiency standard like the EEDI in the sense that overcompliance with this standard would be rewarded with credits which have to be purchased by those that undercomply with the EEDI. In contrast to the EEDI (as a purely technical measure), all ships, new and existing ships, would fall under this scheme.

The proposed **energy efficiency incentive scheme** consists of a charge that is levied on the bunker fuel consumption/purchase, whereas the level of the charge is differentiated according to the efficiency of the ship measured by an index (EEDI for new ships). From a certain efficiency level onwards (stricter than required level of standard), no fee would be due. Both new and existing ships would have to pay the fuel charge. The revenue of this charge is supposed to be used to facilitate in-sector emission reductions rather than CO_2 reductions outside the sector.

Finally, there is one proposal that envisages a **uniform emission charge** (or a bunker fuel charge differentiated by the carbon content of the fuel) on vessels calling at a port, charging the vessels for the fuel used on the voyage to that port. The funds raised could be used for mitigation and adaptation measures to help countries such as SIDS (Small Island Developing States) but also to reward vessels that exceed a certain efficiency level.

Next to these MBMs, **rebate mechanisms** are discussed as well within the IMO.

The above measures can lead to different combinations of technological and operational solutions on board ships to respond to these measures. To a certain extent these will be dependent on the measure that is adopted. Table 4.6 gives an overview of the expected directions of these solutions per measure that are relevant for the shipbuilding and marine equipment industry.

Table 4.5 Characteristics of alternative CO_2 measures relevant for shipbuilding and equipment sector

	Incentivises technical measures	Incentivises operational measures	Incentivises the use of alternative fuels	New ships have to comply	Existing ships have to comply	Revenue presumably used for stimulating the sector
EEDI	x		x	x		
SEEMP*	x	x	x		x	
Emission trading scheme	x	x	x	x	x	x
Ship efficiency credit trading scheme	x		x (if EEDI is used)	x	x	
Differentiated bunker fuel charge	x	x (as long as level of charge is positive)	x	x	x	x
Uniform emission charge	x	x	x	x	x	
Uniform bunker fuel charge/GHG fund	x	x		x	x	x (partly)

* Note: SEEMP is associated with a voluntary target setting.

EU regulation

With regard to CO_2 emissions, the European Commission is in favour of a global measure to reduce GHG emissions from international maritime transport. However, in case IMO and UNFCCC[118] processes do not include emissions from shipping into their reduction commitments in 2011, the European Commission has stated that it will take steps to include CO_2 emissions into the EU reduction commitment and will consider regulation on European level in 2012, possibly through introducing a market based measure. Whether or not the measures undertaken by IMO until date are considered sufficient remains formally open, but reports available (see IMO MEPC 63) indicate that reductions will not be sufficient to achieve the reductions targeted in the Transport White Paper.

4.3.2 *Assessment of the market potential*

In estimating the future global market potential for CO_2 reducing measures for ships, two difficulties are encountered:

- Uncertainties about the future CO_2 regulation (especially the Market based measures);
- The solutions that will be adopted by ship owners.

Whereas the Marine Environmental Protection Committee of the International Maritime Organisation has indeed adopted the Energy Efficiency Design Index (EEDI) and the Ship Energy Efficiency Management Plan (SEEMP), as the first mandatory global CO_2 regimes, significant uncertainty remains regarding the introduction of market based instruments. Also the type of CO_2

[118] UNFCCC is the United Nationals Framework Convention on Climate Change, a treaty setting non-binding GHG emission limits, and is better known through its update the Kyoto Protocol. Discussions to bring maritime transport under the treaty are ongoing.

reducing solutions that are implemented are difficult to assess (including the retrofitting of existing ships when new MBM are introduced) partially due to a number of existing barriers (see section 4.3.3).

Given these uncertainties only the global market potential of cost-effective CO_2 reduction technologies that are induced by the EEDI[119] are estimated in quantitative terms.

Global market potential for CO_2 reduction measures due to EEDI

Ships can comply with the EEDI regulation by reducing main engine power with the help of innovative mechanical energy efficient technologies and/or by reducing auxiliary engine power with the help of innovative electrical energy efficient technologies.
The market potential of these technical measures can be estimated as follows:

1. For each CO_2 abatement measure the cost efficiency is determined for the different ship type/size categories of the global fleet. The cost effectiveness of an abatement measure relates the net costs that have to be incurred when applying the measure to the amount of CO_2 that can be reduced with this measure;
2. The CO_2 abatement measures are assumed to be applied to a ship in the order of their cost effectiveness until the required EEDI reduction level is reached;
3. Total capital expenditure of the according CO_2 measures is used as a proxy for the market potential that is induced by the EEDI.

For those technical measures that probably can be used to meet the EEDI reduction targets and for which cost data is available this estimation has been carried out on a global scale (see annex 3 for further details on the calculation method). For an overview of technologies that are considered reference is made to box 4.2. The market potential has been calculated, assuming that the below mentioned reduction measures are applied in the order of their cost effectiveness.

It is important to notice that the market potential as derived here is an indication in the sense that first of all some of the measures may not get approved by the IMO to be used for the EEDI, and in that case other measures would need to be selected with different costs. Currently there is still some regulatory uncertainty in this respect. In addition, the shipping sector may be reluctant to apply innovative technologies that currently are not widely used, being sceptical about the reduction potential that these measures might actually yield. Shipping companies might therefore choose to widely make use of speed reduction by installing engines with less power. This would reduce the market potential for reduction equipment significantly (while raising the need for ship capacity to compensate for the loss in transport performance levels[120]).

Box 4.2 CO_2 reduction technologies that are taken into account

- Propeller upgrade (only)
- Propeller boss cap fins
- Optimisation of water flow (e.g. with respect to transverse thruster openings)
- Main engine tuning
- Common rail technology upgrade
- Low energy/low heat lighting

[119] The market potential induced by the SEEMP is not taken into account, since the measure is not associated with mandatory emission reductions. The estimates in this section are based on earlier work done by CE for IMO (2009).

[120] If speed reduction is applied, sailing times will be lengthened and hence a larger amount of ships is needed to transport cargoes between ports in the same period of time, thus raising the demand for ship capacity. This is then attributed to the market potential related to this measure (see also annex 3).

- Speed control of pumps and fans
- Power management system
- Towing kites
- Wind engines (Flettner rotors)
- Solar cells
- Waste heat recovery
- Air lubrication system
- Speed reduction of 10% or 20%

EEDI measures only apply to new ships. The annual potential global market increases over time, from around 3 billion Euro in the period 2015-2019 to around 10 billion per annum in the period 2025-2030[121] (See annex 3 for the assumptions and calculations method underlying this estimate). The increase is the consequence of expansion of the world fleet and a further tightening of the EEDI reduction levels over time.

The total market potential of cost-effective measures in the period 2015-2030 is estimated to lie in a range of 112 – 124 billion Euro, which is dependent on the uncertainties in choice of technologies and the assumed growth scenarios.

Table 4.6 Global market potential for CO_2 reduction measures induced by EEDI (billion Euro)

Period	Total potential per period	Average annual potential per period
2015-2019	14-16	3
2020-2024	42-46	9
2025-2030	56-62	10
Cumulative 2015-2030	112-124	

4.3.3 *Main barriers*

The market potential has been assessed by ranking cost-effective technological measures (in a marginal abatement cost curve or MACC). Not all the technologies that were identified are considered to yield fuel savings by the ship owners and operators interviewed, which may be caused by a lack of knowledge or of trust since not all technologies are proven technologies yet. Moreover, some technologies are perceived to be associated with a high risk of failure.

The main barrier relevant to this trend is related to the expression of demand. As far as mandatory efficiency improvements are concerned, **stakeholders state an uncertainty about the IMO GHG emission legislation**. This uncertainty has reduced during the course of this project, at least to some extent. The IMO has adopted mandatory measures to reduce GHG emissions (EEDI, SEEMP). This requires all new ships from 2013 onwards to have an EEDI and a SEEMP. The EEDI limit value will be tightened over time. However, the regulation also allows states to grant a waiver for up to five years, thereby introducing some uncertainty in the market as to whether ships will actually be built to attain a certain EEDI. Whether market based measures will be introduced in addition is still under discussion.

[121] This implies that the potential of CO2 reduction measures represents a share in comparison to the global shipbuilding production value of about 1% on the short term, up to about 3% for the period after 2025.

Other barriers, relevant to the development and scaling up of technologies, are largely similar to those mentioned under trend 1 (see section 3.1.3).

4.3.4 *EU industry position and technological responses*

Different technological options are available to comply with CO_2 reduction triggered by e.g. EEDI regulation. The three main options are:

- the specific fuel oil consumption (SFOC) of the engines could be reduced (e.g. by improving the energy efficiency of the engine);
- fuel with lower carbon content could be used; or
- the engine power could be reduced (e.g. by making additional use of wind or solar power, improving hull efficiency, installing energy saving devices etc.).

These options largely overlap with the possible technologies to respond to the fuel efficiency driver (see section 3.1). Also the industry players developing and manufacturing these technologies are similar. As mentioned in section 3.1.4, Europe's position from the shipbuilding perspective is good in this respect. For example, for many of the technologies contributing to meeting EEDI requirements, European manufacturers have a leading market position, and in some cases virtually no non-EU suppliers have been identified as yet.

4.3.5 *Conclusion*

In July 2011, IMO has adopted the EEDI, setting standards for new ships built from 2013 onwards, with an increased energy efficiency level required over time. Furthermore the SEEMP has been introduced, and discussions are ongoing within IMO whether or not to introduce MBM, and in what form. At EU level, a CO_2 MBM is favoured.

For estimating the market potential of CO_2 reducing measures uncertainties about these MBM hamper a clear estimate. With regard to EEDI, an estimate is made assuming that:

1. The cost effectiveness of each CO_2 abatement measure is known for a given ship type;
2. Measures will be applied for a ship in their order of cost effectiveness, until the required EEDI level is reached;
3. The total capital expenditure for the entire world fleet is then taken as a proxy for the market potential.

Applying this approach and using assumptions as presented in annex 3, an overall market potential of about € 112-124 bn for the period 2015-2030 is estimated, or about € 3 bn per year from 2015 rising to about € 10 bn per year in 2030. The increase is the consequence of expansion of the world fleet and further tightening of the EEDI reduction levels over time.

This potential also contributes to increased fuel efficiency as targeted under trend 1, and technologies applied are largely similar.

The main barrier relevant to this trend is related to the expression of demand caused by the perceived **uncertainty about the IMO GHG emission legislation**. This uncertainty has reduced when the EEDI was approved. However, the possibility of waivers still leaves open a level of uncertainty in the market, as does the discussion on MBMs.

Other barriers, relevant to the development and scaling up of technologies, are largely similar to those mentioned under trend 1 (see section 3.1.3).

Technical solutions to meet the regulatory requirements largely overlap with the possible technologies to respond to the fuel efficiency driver (see section 3.1). Also the industry players developing and manufacturing these technologies are similar. As mentioned in section 3.1.4, Europe's position from the shipbuilding perspective is good in this respect. E.g. for many of the technologies contributing to meeting EEDI requirements, European manufacturers have a leading market position, and in some cases virtually no non-EU suppliers have been identified as yet.

4.4 Trend 6: Ballast water and sediment treatment

4.4.1 *Drivers*

Ballast water is used to stabilise vessels at sea. Ballast water that is taken into a tank from one body of water and that is discharged into another can lead to the introduction of invasive species. This can lead to e.g. adverse health effects or to a loss of biodiversity.

In 2004 the IMO adopted the International Convention for the Control and Management of Ships' Ballast Water and Sediments. The Convention requires all ships to implement a Ballast Water and Sediments Management Plan. All ships have to carry a Ballast Water Record Book and will be required to carry out ballast water management procedures to a given standard.[122]

The convention has not yet met the ratification criteria In December 2011, the last country – Lebanon – has acceded to the Convention, bringing the number of contracting parties to 32 (30 needed for entry into force). To enter into force also a tonnage criterion has to be met. Currently, the contracting parties represent 26.46% of the world tonnage, whereas 35% will be needed for the Convention to enter into force[123]. It is expected that the ratification criteria are met end of 2012 with entry into force one year later.

4.4.2 *Assessment of the market potential*

Frost and Sullivan (2010)[124] estimate that over 57,000 vessels[125] (both new and existing) will need to be equipped with ballast water management systems in the period up to 2020. They estimate that a small system (200-250 m³/h) will require a capital investment of $175,000 up to $490,000 while a large system with a capacity of 2,000 m³/h will require an investment ranging from $650,000 up to $3 million. In all, they expect the market to grow from almost USD 3 billion annually in 2013 – 2016 to over USD 5 billion in the period 2017 – 2020. Cumulatively this amounts to about USD 32 billion or about € 25 billion, under the assumption that the regulation will be implemented as is .

Lloyds Register has published Capex figures that are lower than Frost and Sullivan, with average prices of small installations at USD 281,000 and large installations at USD 863,000 (LR, 2010).[126] This would imply a somewhat lower market potential.

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122 IMO 2011.

123 http://globallast.imo.org/index.asp?page=announcements.asp.

124 Frost & Sullivan, 2010, Global Ballast Water Treatment Systems Market,

125 This is about half of the currently registered IMO fleet, and the estimate assumes that the share of ships equipped will decrease with their age, since vessels close to the end of their economic lifetime may be taken out of service to prevent the required investment.

126 Lloyds Register, 2010, Ballast water treatment technology: Current status, February, London.

4.4.3 *Main barriers*

Barriers to the development of technologies for ballast water management

In general, we find that there is sufficient supply of technologies in the shipbuilding and maritime equipment industry. Relatively few barriers relate to the development of new technologies. Both the European shipbuilding sector and the marine equipment industry have developed green innovations and continue to do so.

Ballast water management systems need to have approval before they can be used for compliance with the BWM convention. Currently, twenty systems have received final approval, five of which are made by companies from EU Member States, and three more from EEA states. Furthermore 34 systems have been granted basic approval, 11 of which are from the EU, and 2 from EEA countries (IMO, 2011, List of ballast water management systems that make use of Active Substances which received Basic and Final Approval, BWM.2/Circ34).

Hence, it can be concluded that there is ample supply of systems and that companies based in the EU or the EEA have developed a significant share of the approved systems.

Barriers to the expression of demand for technologies for ballast water management

The main barrier to the expression of demand for BWM systems is the regulatory uncertainty. As mentioned earlier whereas the ratification criterion of the number of states has been met the tonnage criterion has not yet been met (26.46% as of 31 January 2012, whereas 35% is required). Most observers expect an entry into force in the coming year. However, until there is more certainty about the entry into force, many ship owners will be reluctant to invest in ballast water management systems. From the point of view of the ship owner this is rational behaviour; until the regulation enters into force, the benefits associated with the investment are of pure external nature. This however means that when the whole sector invests just before the regulation enters into force, that the global production as well as the yard capacity will not be sufficient to fully profit from the market opportunity. Also uncertainty about the testing procedures is observed among ship owners.

Box 4.3 Is there sufficient industrial capacity?

As ratification of the International Convention for the Control and Management of Ships' Ballast Water and Sediments 2004 draws nearer, time starts pressing for retrofitting ballast water treatment systems. A quick calculation.

There are about 105,000 IMO registered vessels currently in operation, of which some 86,600 above 400 dwt (not an official limit). Assuming that vessels over 40 years will not be outfitted, 5% of ships of age 30-40, 50% of ships 20-30, 75% of ships aged 10-20 and 100% of all ships younger than 10 years, then a net 49,300 ships would need to be outfitted.

As retrofitting requires some time, it would best be planned during the extensive five year survey that has to be performed anyway. If all ship owners would do this, the schedule would start in 2013. The latest point a vessel must comply lies with the first large or intermediate survey, so owners may opt for postponing to an intermediate survey. If all owners would do this, retrofit demand would peak in 2017 with 16,500 vessels to be retrofitted, or 45 systems per day.

At present 14-15 systems are approved. If in the coming years this rises to say an optimistic 40, then each supplier would still need capacity to produce 400 per year. The risk is that owners get stuck with delivery times of two years or more. Planning ahead is recommended to ensure timely delivery and minimise off-duty time.

Source: Marine Propulsion, August/September 2011, p.197

4.4.4 *EU industry position and technological responses*

Following the ratification and entry into force of the IMO Ballast Water Convention, vessels will be required to have a ballast treatment system on board their vessel that kills organisms and bacteria when the water is taken in or is discharged. Different systems are developed, but most of them combine mechanical and chemical methods in their system.
Ballast water treatment systems are developed everywhere. As of November 2011, 54 systems have been granted basic or final approval. Of these systems, 16 (30%) have been developed by EU-based companies, and 5 (9%) in EEA states[127]. In general Europe is seen as having a leading role in the production of ballast water systems. In Europe several SMEs are active on this market, being Greenship of the Netherlands and MetaFil AS of Sweden. Also larger European companies are active on this market, like Alfa Lavel[128] of Sweden in cooperation with Wallenius, Hamworthy of the UK, Degussa[129] of Germany and RWO[130] of the UK. Also in Asia a few large companies are developing ballast water treatment systems. The main companies are located in Korea being KORDI cooperating with Techcross[131] and NK Company[132]. Also the Japanese company Hitachi has developed a ballast water treatment system.

4.4.5 *Conclusion*

In 2004 the IMO adopted the International Convention for the Control and Management of Ships' Ballast Water and Sediments, but the convention is not ratified yet, awaiting a few more countries to sign. Once entering into force, new and existing ships will need to comply with the convention, including the use of ballast water management systems. Given the world's fleet size, estimates suggest the total potential to amount to about € 25 bn for the period 2013-2020.

Barriers to the expression of this demand mainly relate to the regulatory uncertainty, i.e. the moment of entry into force. Ship owners tend to await clarity about this before taking investment decisions.

At the supply side, a sufficient number of systems has received approval. There are concerns over the installation capacity of the industry, if ship owners would all wait till the latest date and then place their order. This could trigger a call for delay of implementation.

As of November 2011, 54 systems have been granted basic or final approval, of which 16 by EU-based companies, and 5 by companies from EEA states[133]. Several European SMEs are active, as well as a number of larger companies. Also in Asia a few large companies are developing ballast water treatment systems.

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127 IMO, 2011, List of ballast water management systems that make use of Active Substances which received Basic and Final Approval, BWM.2/Circ34.
128 http://www.alfalaval.com/.
129 http://www.degussa-hpp.com.
130 http://www.rwo-marine.com/contact/.
131 http://www.techcross.com/eng_html/about/history.asp.
132 http://nk-eng.nkcf.com/aspx/about/history.aspx.
133 IMO, 2011, List of ballast water management systems that make use of Active Substances which received Basic and Final Approval, BWM.2/Circ34.

5 Other drivers

The third category of *other drivers* contains drivers related to climate change that create new markets or provide new business opportunities. Two trends addressed in this study are energy policies driving the construction of offshore wind farms, and the – in itself not green driver – climate change creating opportunities for oil- and gas extraction and shipping in the Arctic region.

- Trend 7: Offshore renewable energy;
- Trend 8: The Arctic Dimension.

5.1 Trend 7: Offshore renewable energy

5.1.1 *Drivers*

The demand for new sources of energy supply is triggered both by initiatives and targets to combat climate change but also by factors such as the security of energy supply. This has triggered new initiatives and regulation that drive the development and installation of renewable offshore energy.

In Europe the European Renewable Energy Directive (2009/28/EC) is a clear regulatory driver outside shipping that has a potential impact on the shipbuilding sector. It sets binding national targets regarding the minimum share of renewable energy in gross final energy consumption every individual EU Member State should meet in 2020. In order to achieve these targets the Directive obliges Member States to take appropriate and necessary (support) measures to promote renewable energy and encourage energy efficiency and energy saving. With over 80 percent, wind energy is expected to be the main source of renewable energy generated in 2020; a share of about 25 percent thereof is expected to stem from offshore wind turbines[134]. Other offshore applications concern tidal and wave energy and technologies like OTEC (offshore thermal energy conversion). The latter three however are still in their development phase and are not expected to be developed on a large scale in the coming decade.[135]

By 2009 approximately 2.9 GW was installed in European waters. In 2010 an additional 1.8 GW was being developed. Yet another 18.8 GW is approved by the different national governments and will be built in the coming years. The main European countries constructing wind parks are the United Kingdom, Germany and Denmark. The Netherlands, Sweden and Ireland have approved the construction of large wind parks and are likely to soon start building. The European Environmental Agency has predicted that the competitive potential of Europe is 2,800 TWh in 2020. In 2030 this potential could have risen to 3,500 TWh.[136] In terms of installed capacity, for 2020 about 40 GW would be installed offshore according to EWEA (2010), rising to 150 GW in 2030[137]. By then, 78% of the European wind energy would be generated by offshore wind.

Also other countries worldwide are investing heavily in offshore wind energy (see Box 5.1).

134 EWEA (2011), Pure Power. Wind energy targets for 2020 and 2030.
135 Ecorys (2012), Blue growth, Third Interim Report.
136 CESA annual report 2010-2011 (2011).
137 The European offshore wind industry - Key trends and statistics: 1st half 2010. EWEA, August 2010.

Box 5.1 International investments in offshore wind energy

Not only in Europe offshore wind energy generation expands. Also other countries are planning to construct several wind parks. China and Japan already have built some offshore wind facilities. China has an installed capacity of 102 Mega Watt (MW) and Japan a capacity of 15.32 MW. Both countries are likely to expand their current capacity.

The South-Korean Ministry of Knowledge Economy announced to build, involving several shipbuilding companies, a large offshore wind farm. The farm will be located at the west coast of Korea. The project will cost USD 8.2 billion and should be finished in 2019. The park will consist of 500 turbines of which 20 will be realised in 2013, another 180 in 2016 and the remaining 300 by the end of 2019.

In the USA, due to the American Recovery and Reinvestment Act (ARRA), offshore wind has received a clear boost. The Act states that in 2030, 20% of the energy supply must be generated by renewable energies, for instance by wind. Many Federal States have drafted Renewable Portfolio Standards (RPS). Also the RPS demand that 20% of the energy must consists of renewable energies. Some coastal states, like New York and New Jersey, have ordered that a large part of the renewable energy is generated by offshore wind.

Also other countries like, Canada and Taiwan are considering significant expansion of offshore wind facilities.

Source: Korean Ministry of Knowledge Economy (2011); Ecorys (2012)

5.1.2 *Assessment of the market potential*

The growth in offshore wind parks does create market opportunities for the shipbuilding sector in the delivery of specialized vessels, but also in platforms and foundations for wind turbines. The general tendency to move further offshore creates additional demands for R&D and innovation through new technological solutions.

Box 5.2 Wind farms shifting to deeper waters

Of the wind farms built in 2010, the average water depth was 17.4m, a 5.2m increase on 2009, with projects under construction in water depth averaging 25.5m. The average distance to shore increased in 2010 by 12.7 km to 27.1 km, substantially less, however, than the 35.7 km average for projects currently under construction.

Source: EWEA 2011, The European Offshore wind industry key trends and statistics 2010

In the analysis of the market potential the European development plans are assumed to be the relevant market. The increased expansion within Europe is expected to result in new ships to be developed. Services are also being delivered from regular offshore service suppliers previously active in the oil & gas industry, using retrofitted ships rather than new purchases. Nevertheless, as the development of offshore wind progresses and turbine sizes increase in height and diameter, together with going into deeper waters, installation as well as operational work will become more complex raising the technical requirements for the ships to be used.

Estimates on concrete market demand for new vessels are hard to make, also in view of current delayed initiatives in installing wind energy (as can be observed in the North Sea basin at present). Still, some crude estimates are made using ships per wind park ratios for each of the ship types involved, taking account of the vessel fleet already available. These estimates are based on a recent KPMG report.[138]

[138] KMPG (2011).

KPMG has estimated the market potential for offshore wind vessels and structures in Europe, i.e. the demand that follows from the expected growth in number of offshore wind parks, their size, distance to the coast and water depth. The assumed capacity is based on the expected planning of construction of various initiatives across Europe until 2020. This implies that delays currently faced here and there may result in a lower (or postponed) market potential. On the other hand it is assumed that all currently existing vessels will be available for constructing European wind parks, and it thus does not take account of vessels needed to build wind parks planned elsewhere Therefore the figures mentioned in table 5.1 below can be considered as a conservative estimate.

The market potential for the most relevant ship types and turbine units is summarized below. Distinction is made between vessels (both for construction/installation and for operating the fields) and the manufacturing of the structures themselves (foundations or jackets, platforms, components). The latter can be built at shipyards, but as they are a different type of activity not all yards may be suitable or have the skills at hand to perform this. For instance, yards need to be technically suitable to construct the structures (e.g. availability of cranes, construction space and the size of production halls). They also need to adopt series production, change their cost structure to be able to produces structures less expensive and they need sufficient references to show their capabilities.[139]

Table 5.1 Potential market for offshore wind energy vessels until 2020 (bn EUR), based on European demand

Ship type	Additional units	Average price per unit (mln €)	Potential market (bn €)
Installation vessels[140]	11	150	1.65
Cable layers	15	55	0.8
Support vessels (maintenance & crew accommodation)	37	20	0.74
Crew transfer vessels	117	7.5	0.90
Repair vessels	49	45	2.20
Foundations (jackets)[141]	2.,067	4.4	9.10
Platforms	120	20	2.4
Components (various)[142]			0.50
Total			18.59

Source: Ecorys based on KPMG (2011)

Overall the potential amounts to some € 19 billion. If spread over 10 years this would imply about € 2 billion per year.

5.1.3 *Main barriers*

Barriers to the development of technology to install and maintain offshore wind parks

Globally, no specific barriers have been identified with regard to the development of technologies required for constructing offshore wind parks: technology is there. Within Europe, the main barrier does not relate to technology development although in scaling up technologies, problems have

139 Source: KPMG (2011).
140 Current global fleet: 26 vessels.
141 Assuming that all European wind parks use jackets as foundations.
142 A variety of components is also required for offshore wind parks, including such products as blades, gondolas and transition pieces, but also components needed to repair and maintain the vessels used. Yards can play a role in implementing such components. A repair demand will result from the operational activity in European waters.

been faced applying systems that have not been properly tested.[143] With regard to manufacturing components and structures, yards may not all have the required yard infrastructure and skills available, as this type of activity differs substantially from building ships.

Barriers in scaling up technologies install and maintain offshore wind parks

With regard to the support ships involved, overall numbers are relatively limited reducing the relevance of the scaling up factor. With regard to the wind turbines and fundaments however scaling up may be an issue. Location is an important driver (construction close to the offshore development site), and concentration of parks may thus provide a scale advantage (see also section 5.1.4 below). As parks are however developed in phases, this is not seen as a barrier for scaling up production capacity. There might be a shortage of high voltage subsea cables. These cables are needed to connect the offshore wind installations with onshore facilities. Historically only a few European companies produced such cables, but nowadays more companies are active on this market and the shortage could be minimized.[144]

Although Europe’s shipyards in general are relatively well positioned to take advantage of this market, this is not valid for all sub-segments. This is especially true for installation vessels where the limited experience in building these vessels may create a possible barrier for European industry to reap the market potential The completion of the first ship by Sietas is considered the first step in accessing this market and may lead to acquiring similar assignments in the future. Since, of the 11 installation ships on order, 3 orders have been placed in Europe. In most of the other sub sectors within offshore wind (cable layers, support vessels, jackets and platforms), this situation is less an issue as European yards already have experience.

Barriers to the expression of demand for technologies install and maintain offshore wind parks

The offshore wind sector is facing a few barriers that can slow down its growth. The main barrier is the **regulatory and budgetary uncertainty**. Many national governments have planned the construction of offshore wind farms, but a concern among both energy developers and shipbuilders is that governments will delay or cancel investments. Many governments have to cut budgets and offshore wind is not fully commercially profitable yet without their contribution. Likely this will result in fewer wind parks being realized than planned for the period until 2020.

This lack of certainty leads to **funding problems**. Many banks are not willing to provide funding for the construction of new (complicated and highly specialized) vessels. This concerns both funding during the construction period as well as end-financing.

A more general barrier relevant to the development of offshore wind is the **price level and volatility of fossil fuels**. As wind energy is a substitute for fossil fuels based power, high fuel prices make wind energy an attractive alternative energy source, and raise its financial feasibility. When fossil fuel prices would however decrease, the opposite is the case. As such, price uncertainty combined with the high investment costs create hesitation of investors / financiers / developers to start constructing wind farms. This indirectly affects the demand for new vessels as well.

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143 EWEA, The European offshore wind industry key 2011 trends and statistics, 2012.

144 EWEA, The European offshore wind industry key 2011 trends and statistics, 2012 .

A barrier might also be the **spatial planning** at sea. Many different interests arise at sea and different interests claim their part. Examples are shipping, fisheries, sand mining, cables & pipes, as well as protected Natura2000 areas. All these interests want to be accommodated and this may give rise to conflicts. When no clear planning mechanisms are in place, suboptimal situations may arise or decision making may be delayed. The Maritime Spatial Planning policy of the European Commission is set up in an effort to reduce this barrier.[145]

A specific barrier also relates to the **availability of an offshore power grid**. Establishing electricity grids to connect offshore wind energy requires significant investments. In the absence of coordinated grid development, investments risk being sub-optimal in that they will be viewed from an individual project perspective rather than from a system perspective. A framework for such a cooperative approach has been established in the form of the North Sea Countries' Offshore Grid Initiative.

5.1.4 *EU industry position and technological responses*

The technology required for constructing and operating offshore wind parks contains a variety of concepts including installation vessels, cable layers and other types of support vessels. Furthermore equipment needed is for foundations, platforms, and components, as well as services to assemble turbine units. While the technology for each of these has already been developed, the gradual development towards larger turbines installed in ever deeper water and further offshore, requires a continuous development of technologies, which cannot be simply categorised in a few groups as for NO_x or SO_x.

Installation vessels

An installation vessel equipped with a crane is able to install all parts of the wind turbine. Worldwide there are only a few installation vessels specifically designed for the offshore wind industry. According to 2010 data, 11 specialized vessels are in use worldwide, and another 15 are being built. The last of these newly built vessels will enter the market in 2015.[146]

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[145] COM (2010)0771, Maritime Spatial Planning in the EU - achievements and future development.

[146] KMPG (2011).

Figure 5.1 Example of an installation vessel

Source: http://www.bowind.co.uk/popup27.htm

Besides the specialized installation vessels also vessels originally designed for and used in the oil and gas industry are used as installation vessels for offshore wind parks. Although these vessels can functionally be used to construct a wind park they are considered too large and therefore too costly: charter rates are higher in comparison to those of specialized vessels.[147]

Most of the installation vessels that are now ordered (April 2011) will be build in China, Korea or Dubai[148]. However three installation vessels have been ordered with a European yards in the same period, including the recent order at the German yard Sietas[149] [150]. The limited track record of European shipyards is a hurdle in convincing both operators and banks. Although built in Asia mainly, most installation vessels are designed by European design offices, like Wärtsilä Ship Design, GustoMSC and Knut E. Hansen.

Also in the oil and gas industry many installation vessels are built outside Europe. Main yards active in this segment are DSME and COSCO, but designs are again mainly European. For Instance GustoMSC and Ulstein Sea of Solutions provide designs for installation vessels used in the oil and gas industry.[151]

Cable layers

A distinction is made between cable layers operating inside and outside the wind parks. The latter group consist of larger vessels than the first. Large cable layers are vessels up to 8,000 or more dwt. Small cable layers are up to 4,000 dwt.

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147 KPMG (2011).

148 In China COSCO Nantong Shipyard Co. Ltd is currently building installation vessels. In Korea Daewoo Shipbuilding & Marine Engineering Co. Ltd and Samsung Heavy Industries Co. Ltd are active. In Dubai Drydocks World and Lamprell plc are constructing installation vessels.

149 KPMG (2011).

150 It should be noted that per november 2011 Sietas filed for bankruptcy.

151 http://www.iro-noc.nl/industry.php.

Worldwide 92 vessels have been built as specialized cable layers. Besides these specific vessels another 18 vessels can be used as cable layers, through converting them (this relates to their flexible use strategy; see also the dredgers description in section 2.5). In total 110 vessels can be used to construct wind parks, and 26 of these vessels are permanently operating in European waters.[152]

An important issue is the age of cable layers. Especially the smaller cable layers (up to 4,000 dwt) are quite old; many of these were built between 1975 and 1990 and are considered to be obsolete. They do not have the right equipment and skills to operate successfully as wind park cable layers and should probably be replaced by new-builds.[153]

Approximately 15 new build small cable layers are needed to construct all European wind parks planned. If at the same time wind parks will be constructed outside Europe (e.g. Asia or US) the market demand for small cable layers will further increase. It is however unclear if additional larger cable layers will be built, whether other vessels will be converted into cable layers, or whether a different cable laying method will be developed.

European yards have a good position to build the new cable layers, according to the stakeholders interviewed in the KPMG research. Several European yards have sufficient experience in building cable layers, like for instance IHC Merwede in the Netherlands and Drammen Yard in Norway. Although many of the existing cable layers were built in Europe, new orders are also placed at Asian yards. For example, two new cable layers for Boskalis are built by Samsung.[154]

Support vessels

This group includes a number of different vessel types, needed for tasks during construction as well as for operational tasks including maintenance and repair services (see also table 5.1 above). The vessels used are highly specialized. Especially in the maintenance segments (maintenance & crew accommodation vessels, crew transfer vessels (CTV) and repair vessels), European yards provide a substantial contribution. Also the relevant parties involved[155] believe that Europe has a strong position in this market and an increase in the demand for wind parks will lead to an increased demand for such specialized vessels.

Maintenance & crew accommodation vessels provide accommodation for crew members, and are used for wind parks that are located far from the coast line. Parks within 60 km of the shore do not use crew accommodation vessels, while parks located further away do because daily transferring crew members is time consuming. Approximately 37 maintenance & crew accommodation vessels are needed to build and maintain all European wind parks that are planned until 2020. [156]

Crew transfer vessels are used to transport crew members between shore and the wind parks, as well as for the transport of light equipment and consumables. Especially when wind parks are located further away from shore the CTV will carry both crew members and materials. KPMG calculated that 117 CTVs will be needed until 2020.

152 KPMG (2011).
153 KPMG (2011).
154 http://www.tos.nl/nl/nieuws/2011/5/samsung_wins_boskalis_cable_layer_order.2913.htm.
155 KPMG has interviewed a variety of stakeholders, like yards, operators, ship owners and banks or other financing institutions. All stakeholders have indicated what they think the competitive position of the European yards is.
156 KPMG (2011).

Finally repair vessels are needed. They are used to provide components for e.g. nacelles (cover housing for a wind turbine) and rotor blades. Approximately 49 repair vessels are needed in Europe for the period until 2020. When more wind parks will be built in Asia or America, additional vessels are needed and the market potential for European yards might also increase.

Foundations (jackets)

Several kinds of foundations can be used in constructing a wind park and the choice depends on the location of the park. Wind parks with a depth up to 20 meters are built on monopiles, while parks located in deeper waters are mainly built on a jacket construction. Building monopiles is relatively straightforward. Europe still has a strong position in building these kind of structures, but Asian countries are also developing skills to construct these structures. China has built its first monopiles, but quality is still reported to be relatively low. Monopiles are easily transportable over large distances so the competition between Europe and Asia will likely be tougher than for components like jackets where this is not the case.[157] According to both KPMG and stakeholders consulted, this segment does not provide much opportunities for European ship yards.

Jackets are used for parks in water up to 55 meters deep. Jackets are large foundations and a lot of space is needed to construct them. Therefore transportation over longer distances is costly and hence jackets are preferably built close to their place of use. It is therefore quite unlikely that jackets built in Asia will be used in Europe or vice versa. European yards already have experience in building offshore wind jackets. For instance the jackets used for the Belgian offshore wind farm Thornton Bank 2 were built near Antwerp.[158] It is also expected that companies producing jackets for the oil- and gas industry will try to broaden their activities and will start producing jackets for offshore wind farms.[159] KPMG indicates shipyards could obtain construction works with regard to jackets.

An increased competition is expected though. If the demand for wind parks increases the demand for jackets will also increase since more and more parks will be developed in deeper waters. Many companies will want to serve this new market, including for instance manufacturers of oil and gas platforms since they are also able to build them.

Platforms

Platforms have to be built, as jackets, near the construction site. Platforms are also large and transporting them has many difficulties, which again results in construction for European wind parks to take place in nearby countries and competition with Asia will be limited. Also competition between Western en Eastern European countries is expected to be limited, since Eastern European yards are considered lacking the sufficient skills to build the platforms.[160]

Many experience can be gained from the production of platforms for the oil- and gas industry. For instance the Hadrian yard located in the UK has a large experience in manufacturing platforms.[161] Also Dragados Offshore[162] of Spain is building platforms. Scaldis Salvage Marine[163] of Belgium is experienced in installing platforms.

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157 KPMG (2011).
158 http://offshorenieuws.nl/2011/10/10/foundation-installation-at-thornton-bank-2-completed/.
159 KPMG (2011).
160 KPMG (2011).
161 http://www.ft.com/cms/s/0/e228954c-3eac-11e0-834e-00144feabdc0.html#axzz1iO258NOq.
162 http://www.dragadosoffshore.com/presentacion_historia.asp.
163 http://www.scaldis-smc.com/oilgas.htm.

The role of offshore oil and gas support vessels

Although converted oil & gas platform installation vessels are considered too large and too expensive, other vessel types from this industry can be used. Main players building offshore vessels are STX Europe (outfitting yards in Norway, hull manufacturing in Romania), Bergen Group (Norway), and Keppel Offshore & Marine (based in Asia, but with facilities in Europe as well). There are a number of smaller players active in this field, of which some are rather specialised (e.g. IHC Netherlands has expanded from dredging into related areas such as cable layers) or more generally entering the segment.

Based on the above it is concluded that European manufacturers have a good position in this segment which provides them with a good starting point to serve at least some of the demand.

A specific issue for constructing offshore wind parks is the possibility of time delays due to severe weather conditions. The main consequence of time delays is a considerable increase in costs because the vessels are rented. These additional costs make offshore wind projects less attractive. To minimize time delays at sea, the construction of the turbines is done as much as possible onshore. Much effort is taken to achieve this.[164]

5.1.5 *Conclusion*

Policy ambitions to raise the share of renewable energy in the European energy mix, along with energy security policies, are driving the interest for developing offshore wind parks. By 2020, offshore wind is expected to cover about 40% of renewable energy generated in Europe. The current installed capacity of about 5 GW is expected to rise to some 40 GW in 2020, further growing to 150 GW in 2030. At the same time, offshore parks will be built further away from shore, into deeper waters, raising the size of structures and the complexity of their installation, both driving an increased need for specialised installation and operation vessels.

KPMG has estimated the market potential resulting from this driver, by estimating the number of ships required for constructing and operating the planned parks. This involves installation vessels, cable layers, support vessels (maintenance, crew accommodation and crew transfer), and repair vessels, as well as the manufacturing of foundations, platforms and other components. Overall they estimate the market potential to amount to € 19 bn for the coming 10 years, or about € 2 bn per year, based on European wind parks planned alone. As initiatives are undertaken in Asia and North America as well, the figure might further rise.

Barriers associated to this market potential relate to:

- Regulatory and budgetary uncertainty: while EU energy policies set clear ambitions, at Member State level there seems to be reluctance as they have to cut budgets following the economic crisis and are postponing decisions;
- As a consequence, funding problems are faced by investors and shipbuilders as banks are less willing to provide loans if no clear project is secured;
- Price levels (and volatility) of fossil fuels determine the financial feasibility of offshore wind. While the general assumption is that oil prices will further rise, short term fluctuations affect the payback times of investors hampering quick decision taking;

- Maritime spatial planning conflicts may arise if the sea is to be used more intensively by multiple user groups. The development of clear planning mechanisms will contribute to lowering this barrier;
- Finally the gradual development towards parks further offshore using larger structures places some technological challenges, i.e. gaining experience in working in different (more harsh) conditions and aiming to develop efficient manufacturing methods.

The position of the EU shipbuilding industry is considered generally good, but distinctions between various elements of the market potential are identified. In the field of installation vessels, the overall number built until date is rather low, with only a few European players involved. European design offices are active also in cases where Asian yards are building. The number of cable layers is much higher, and the ship types are already existing for numerous years and are also being deployed in other sectors (energy grids, communication). An important feature is their flexibility, e.g. to be modified for use in other projects. Several European yards have a track record, partly building on the offshore oil and gas experiences. The group of support vessels consists of a variety of ship types including maintenance ships, crew accommodation and crew transport vessels. According to the KPMG stakeholder interviews, European shipbuilders should be able to capture a substantial share of this potential.

A different segment is the manufacturing of foundations, platforms, and other components. Here, location is an important factor, especially for the large sized platforms where transport costs would become too high if manufacturing sites are not near the intended installation site. Therefore, likely European yards located near offshore wind sites are expected to benefit.

5.2 Trend 8: The Arctic Dimension

5.2.1 *Drivers*

Climate change will result in a variety of physical impacts that will result in new business areas for the shipbuilding industry. A specific aspect is the expected changes in the Arctic region. Two fields are being addressed here:

- Opening up the region for cross-Arctic shipping routes between Europe and Asia;
- Increased access to oil, gas and other mineral resources located under the sea bed.

With the melting of polar sea ice, Arctic sea routes are becoming more accessible, especially the Northern Sea Route north of Russia and the North West Passage north of Canada. The Northern Sea Route is currently accessible for approximately 20-30 days per year and it is predicted that this will rise to about 120 days per year in a century's time. By 2100 cargo vessels that are designed to be ice strengthened would be able to use the route unescorted for 170 days a year.[165] It remains however uncertain at what pace the ice melt will take place, slowing down the development and construction of vessels capable of operation in Arctic waters, and in any case limiting the market potential for the coming decade.

To use the Northern Sea Route currently an icebreaking fee has to be paid to the Russian government since the route crosses their Exclusive Economic Zone (EEZ), even if no icebreaker assistance is needed. Avoiding this, by staying outside the Russian EEZ, remains technically unfeasibly for a long time since this part of the Arctic is not melting yet, and if it would it is uncertain

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[165] Claes Lykke Ragner (2008).

what the commercial reactions will be as regards shifting trade from Atlantic-Pacific routes towards the Arctic.[166]

Another part of the demand comes from the oil and gas industry. In the Arctic region 147 different oil and gas fields have been identified.[167] A total of 25 of these fields are currently in operation, another 13 could become active within a couple of years. The other fields, 101, are qualified as possible areas to develop, but no concrete plans are established yet. It is expensive and difficult to start operating these fields and therefore it is expected that the majority of the fields will not be developed within the coming decade (before 2020).[168] Countries to start developing oil & gas exploration activities in the Arctic regions are Russia, the USA, Canada, Norway and Greenland.

The shipbuilding demand resulting from this driver mainly covers icebreakers, used to clear transport routes and access to Arctic oil- and gas drilling fields. For this last category also other vessels are needed, the so-called hi-tech ice-class vessels. Their specificities will further depend on field specific characteristics, such as there being only oil or also gas, water depth, pressure, etc.

5.2.2 *Assessment of the market potential*

The market for icebreakers will be a relatively small market in terms of numbers. Since icebreakers are however highly expensive vessels, with a price range of typically € 150 and 700 million[169], in value terms the potential can still be substantial. In the coming years it is to be expected that the USA, Canada and Russia, the most important owners of vessels in this segment, will order some 15-20 new icebreakers, partly to replace older vessels, but also to expand their fleet. If we assume that 50% of the said number relates to fleet expansion, and these will be ordered in the period until 2020, there is a market potential of about 1 ship or € 0.4 billion per year if we assume the average of the said price range.

Besides icebreakers also ice strengthened vessels are needed. These are commercial vessels that will operate in Arctic waters, for instance on the Northern Sea Route or to serve the oil & gas market. Demand will be depending on the duration of the ice free period and the number of vessels that will use the Northern Sea Route. Our estimate of the market potential is that it will probably be € 500 million euro per year, but no sources were found to confirm this.

Finally the environmental concerns over increased activities damaging the pristine Arctic eco-system have resulted in a number of research projects including the aim for reducing black carbon emissions and eventually the construction of zero-emission ships[170]. However this will only result in new market opportunities beyond the 2020 scope.

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166 Lykke Ragner (2008).

167 http://www.infield.com/market-forecast-reports/offshore-arctic-frontiers-market-report?JScript=1.

168 http://www.infield.com/market-forecast-reports/offshore-arctic-frontiers-market-report?JScript=1.

169 Own estimate based on figures from The Korean Herald 'Ice breakers needed to protect interests in the Arctic', The Canadian Coast guard 'The CCGS John G. Diefenbaker National Icebreaker project', Bloomberg 'Russia Arctic Route to Rival Suez May Aid Sovcomflot IPO: Freight markets. Wide range indicates hat probably there is a wide range in size and type of the shipc concerned.

170 See for instance Arctic Shipping emissions inventories and future scenarios - Corbett J.J. e.a. (2011) for U.S. Department of Commerce - National Oceanic & atmospheric administration; FP7 project ACCESS (Arctic Climate Change, Economy and Society).

5.2.3 *Main barriers*

With regard to the expression of demand for ice breakers and ice strengthened vessels, three groups of barriers are identified that all relate to the expression of demand and are caused by climate change uncertainties.

Access of the Arctic route

Nowadays the Northern Sea Route is open for only about 20-30 days per year. It is predicted that, by the melting of the ice gaps, the route will be open for a longer period of time, but the pace of this is uncertain, leading to holding back investments in ice strengthened vessels and probably also of icebreakers.

Another barrier to make the Northern Sea Route a commercial success are the charges levied by Russia. Since icebreaking fees are high, current routes passing the Suez Canal remain commercially preferred for many Asian destinations.

Financing newbuilding

Ice breakers partly are government owned equipment, and their available funds may limit the spending on newbuilding, especially because of the high costs involved. For commercial operators also the market uncertainties mentioned above pose a barrier to attracting financing.

Barriers for exploration of the Arctic oil and gas fields

Also the exploration of the Arctic oil and gas fields have some barriers, especially because of the environmental concerns raised. The Arctic is considered as a valuable piece of pristine nature, where strict rules are to be respected to prevent damage of the vulnerable environment. Many companies are hesitating to start operations as the extra costs of prevention and mitigation measures are high.

It is therefore also uncertain at which pace the various fields will be developed. A total 147 fields are designated as possible fields, but only 25 of them are already operative. In the coming decade another 13 will be developed (decisions taken), but for all other fields no steps have been taken with regard to whether and when they will be developed. Indirectly for oil & gas exploration the funding problem also results from the same commercial and climatologic uncertainties. Companies must have sufficient capital themselves or they should find parties willing to investing in the development of these fields.

5.2.4 *EU industry position and technological responses*

The main country for building icebreakers is Finland. Around 60% of all currently active icebreakers were built there, including those operating in the Russian Arctic. To strengthen the relationship between Finland and Russia their two main shipbuilding companies, United Shipbuilding Corporation of Russia and STX Finland, have formed a joint venture named Artech Helsinki Shipyard, which is to focus on building icebreakers and hi-tech ice-class vessels.[171] Their orderbook currently contains two multifunctional icebreaking supply vessels for the Russian company Sovcomflot. The vessels will be used as supply vessels for the Exxon Neftegas Limited gas platform in the Arkutun-Dagi field and will also keep the area ice free. The company will further build a rescue and emergency response vessel for the Russian Ministry of Transport.[172] Canada and the USA so far mainly build their own icebreakers.

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171 Artech Helsinki Shipyard Oy (2011).

172 http://www.shippingexplorer.net/en/ports/view/58-helsinki.

In addition to these, South Korea has built a research icebreaker that is currently sailing in the Arctic. It is the first icebreaker built in Korea and it is still in a testing phase. Besides this icebreaker, Korean yards are also building ice strengthened vessels, especially tankers and bulk carriers. The vessels are able to operate in the Arctic as well as in 'traditional' open seas.[173]

The main design and research done for both icebreakers and ice going vessels is done by Aker Arctic. This Finnish company is part of the STX Group, but operates under its own name. The company has the only privately owned ice testing model basin in which designs can be tested. The company has designed 60% of all the ice breakers, a large number of Arctic and Antarctic research vessels and a considerable amount of cargo vessels and offshore installations.[174] The vessels are built by STX, Finland.

5.2.5 *Conclusion*

Climate change impacts the ice coverage of the Arctic region. With rising temperatures, over time, sea routes will become available, and oil and gas fields accessible. For exploiting these opportunities however, ice breakers and ice strengthened ships will be needed. The overall potential is estimated at some 15-20 ice breakers until 2020, resulting in an estimated potential of about € 0.4 bn per year. Along with this, a demand for ice strengthened ships, both for freight shipping and offshore oil and gas applications, will be created, and this is estimated at another € 0.5 bn per year.

Barriers in reaping this market potential relate to the climatic uncertainties (how fast will the ice melt; climatic fluctuations which results in a widely diverging number of days that the Northern Sea Route is opened) as well as commercial factors (high ice breaking fees currently being charged by Russia). Furthermore investments in new ice breakers are hampered by the shortage of funding at government level, which is relevant since in several places governments are key in investment decisions in this respect.
With regard to oil and gas development, environmental concerns over the valuable but vulnerable pristine Arctic cause hesitation to start operations on more complex fields.

Until date around 60% of all currently active ice breakers has been built in Finland, making this country leading worldwide in market share and knowledge level. Strategic alliances with Russia as a main client will contribute to maintaining this position. Outside Europe, Canada and the USA are largely building their own ice breakers, while Korea is exploring the field.

[173] http://byers.typepad.com/arctic/2011/08/asian-juggernaut-eyes-our-golden-waterways.html.
[174] http://www.akerarctic.com/company.htm.

6 Market potential, existing policies and recommendations

This chapter summarizes the main green market opportunities that exist for European shipbuilding and appropriate business strategies that respond to these market opportunities. Subsequently existing policies are assessed, both in Europe and in competing countries, which support these business strategies. On the basis of this a gap analysis is performed which identifies areas for future policy intervention. This might be areas where Europe should continue and where possible strengthen existing policies, but also areas where additional policy development would be beneficial. This forms the basis for the recommendations.

6.1 Synthesis of market potential and the position of the EU shipbuilding industry

Eight greening trends and their market potential

In the previous chapters, eight greening trends have been elaborated that are drivers for shipbuilding market potential. The findings identify clear market opportunities, albeit to different extents for different global markets, and not necessarily all for European players.

The call for cost reductions through improved fuel efficiency of ships (Trend 1) is considered *the* main market driver for greening in the sector at present. The market potential is taken to be high as all new ships are expected to follow a trend towards higher fuel efficiency, partly driven by the increasing fuel prices but also by regulatory measures. The demand for fuel-efficient ships that follows from regulatory drivers that aim at CO_2 reduction (notably related to EEDI), is seen as a minimum level. Two main areas of market potential have been identified. Firstly, fuel-efficient systems, including hull design, propellers used, PIDs, optimised operations, engines, and waste heat recovery. Secondly, alternative fuel based solutions, including LNG, hybrid, or wind. For newbuilding, the market potential can be considered large, but not necessarily additional to existing demand, as all new ships will follow the trend towards higher fuel efficiency. An accelerated replacement of vessels driven by fuel efficiency, as is observed in some market segments (viz. containerships), may occur, but is hard to quantify, as at the same time this is hampered by the relatively young age of the existing world fleet. For retrofit, opportunities for 'proven' fuel-efficiency solutions will rise if fuel prices increase rapidly. Market size however depends on trade routes and complexity of technology that needs to be installed.

Related to this trend is however the *regulatory drive towards CO_2 abatement initiatives (Trend 5)*, for which an overall global market potential of about € 112-124 bn for the period 2015-2030 is estimated, or about € 3 bn per year from 2015 rising to about € 10 bn per year in 2030. The increase is the consequence of expansion of the world fleet and further tightening of the EEDI reduction levels over time. The estimated amount is seen as the minimum market potential, also for fuel-efficiency measures as targeted under market trend 1.

The market potential for *increased environmental awareness and growing interest in Corporate Social Responsibility (CSR) (Trend 2)* has a stronger impact in markets that are closer to the end consumer, and where the green image of cargo owners positively affects their market position. Some cargo owners and ports are pushing for improving the environmental performance of ships, while several regional initiatives are found. The willingness to invest in green technologies to raise the environmental performance of ships however seems to be limited if no clear business case is present. In practice investors' actions are found usually in combination with responses to other drivers, notably those raising the fuel efficiency of a ship. The market potential therefore is difficult to estimate, and considered limited additional to the market resulting from other drivers addressed in this report.

The market potential from the *regulatory trend towards NO_x abatement (Trend 3)* is seen to be important. Total market potential following from the US NO_x ECA is estimated at € 7-9 bn for the period until 2030. If a European NO_x ECA were to be in place in the Baltic, North Sea and Mediterranean, an additional estimated global market potential of € 9-12 bn would be created. This potential only applies to new ships, not to retrofit.

The global market potential for *SO_x abatement technologies (Trend 4)* is estimated at € 10 to 31 bn until 2030 based on the current European SECAs. If the Mediterranean were to be a SECA as well, another € 7-18 bn would be added. The total market potential including all three SECAs is estimated at € 17-49 bn. For the short term (until 2020), this will largely relate to retrofit activities (installing on ships already built and operational in SECAs), while after this period demand will mainly relate to newbuilding.

With regard to *Ballast Water and sediment treatment (Trend 6)*, the IMO has adopted in 2004 the International Convention for the Control and Management of Ships' Ballast Water and Sediments. The market potential is considered 'theoretical' as long as the convention is not ratified yet, awaiting a few more countries to sign. However, once entering into force, new and existing ships will need to comply with the convention, and given the world's fleet size, estimates suggest the total global market potential could be as high as about € 25 bn for the period 2013-2020.

Offshore renewable energy (Trend 7) is a major greening trend with an overall estimated global market potential as high as € 19 bn for the coming 10 years, or about € 2 bn per year, based on European wind parks planned alone. This estimate is based on the number of ships required for constructing and operating the planned parks, including installation vessels, cable layers, support vessels (maintenance, crew accommodation and crew transfer), and repair vessels, as well as the manufacturing of foundations (jackets), platforms and other components. As initiatives are undertaken in Asia and North America as well, the market potential might further rise.

For exploiting opportunities related to the *development of Arctic shipping routes (Trend 8)*, ice breakers and ice strengthened ships will be needed. The overall global market potential is estimated at some 15-20 ice breakers until 2020, resulting in an estimated potential of about € 0.4 bn per year. Along with this, a demand for ice strengthened ships, both for freight shipping and offshore oil and gas applications, will be created, and this is estimated at another € 0.5 bn per year.

All trends and their estimated market potential are summarised in table 6.1 below. Taking the eight greening trends together, the global market potential per year for the period until 2020 is estimated to be minimally € 12.5 – 15.5 bn per year, excluding the additional market potential from fuel efficiency trends above the minimum level required by EEDI and the (limited) market potential that is driven by environmental awareness and CSR. Within this market potential a possible overlap between trends, notably between NO_x an SO_x abatement, needs to be taken into consideration.

Threats towards the reaping of market potential relate to a number of factors, notably the expression of demand, e.g. lowering or postponing demand levels, related to the barriers as highlighted in the previous chapters.

Table 6.1 Global greening market potential for shipbuilding

	Market trends		Regulatory trends				Other trends	
Trend	1	2	3	4	5	6	7	8
	Fuel efficiency	Environmental Awareness and CSR	NOx	SOx	CO2	Ballast Water	Offshore wind	Arctic dimension
Key driver	Fuel price	Image	Regulation	Regulation	Regulation	Regulation	Energy policy	Climate change
Market potential*	Large	Limited	2-3	2-4	3	2.5	2	0.9
Relevant markets:								
Newbuild	√	√	√	√	√	√	√	√
Retrofit	√	√		√		√	Limited	Limited

* Estimated market potential in bn EUR per year for the period until 2020

The position of the EU industry vis-à-vis Rest of World players

The key question now is to what extent European shipbuilders will be able to take advantage of this global demand. At a general level, strengths of the European shipbuilding industry follow from the competitive position the industry has gained in building high value high complexity ships in a number of niche segments (cruise, dredging, part of offshore) and high quality marine equipment. Furthermore the industry benefits from the green focus that is in place across Europe in other sectors, which has helped to create spill-overs towards shipbuilding, and internal as well as cross-company knowledge transfer. The geographic clustering of companies in several regions along with the historical ties that have built trust between them, has further enhanced the innovation process by ensuring various players from across the value chain participate.

Weaknesses of the European shipbuilding industry of a general nature include access to finance and skills – two factors that were already identified in previous studies and are also seen in other technology industries across Europe. Also a large part of the market potential is expressed in shipbuilding outside Europe. Although the export position of marine equipment suppliers is strong this puts them at a larger distance from the end-clients (ship-owners). Regarding retrofit opportunities related to green market opportunities the competition from yards near major trading routes is limiting possibilities on the world market. Whereas in some new market segments the position of Europe is favourable (e.g. icebreakers, various vessel types plus installations for offshore wind parks) Europe doesn't yet have a track record in all sub-segments (e.g. installation vessels).

Taking together the global market opportunities and the above strengths and weaknesses, the EU position vis-à-vis each of the trends is described below.

The position of the EU shipbuilding industry in responding to *fuel efficiency demand (Trend 1) and CO_2 abatement initiatives (Trend 5)* is considered rather strong. For most of the technology fields applicable, European manufacturers have a leading position, and in some cases virtually no non-EU suppliers have been identified as yet. Clearly, differences between technology fields are seen, with some areas dominated by large enterprises (notably the engine manufacturing domain), and others by SMEs (for instance wind assistance). As the majority of ships are built outside Europe, European suppliers will have an export potential but may be less strongly connected within the value chain than if they were operating within Europe. Furthermore, all major shipbuilding nations are expected to follow the fuel efficiency trend as it is a necessity rather than an opportunity. No major shifts in newbuilding construction are expected between global production regions in favour of Europe. For marine equipment manufacturers, the market potential is therefore partly dependent on the make-or-buy decisions of main shipbuilding companies outside Europe.

The position of the EU industry in responding to *environmental awareness and CSR (Trend 2)* is also considered strong as the EU public is generally environmentally aware, which could stimulate local demand for 'green ships' or create new alliances (e.g. between ship owners and local suppliers). Furthermore, high value ships can more easily 'afford' additional environmental costs while the European marine equipment sector is strong in many areas that are affected by this trend (fuel efficiency, air pollution, etc.)

European industry has developed a number of innovations in the area of *NO_x abatement (Trend 3)*. European suppliers are therefore well-positioned with regard to both LNG systems (the main engine manufacturers MAN and Wärtsilä are Europe based, but also some Asian competitors are active), and the supply of SCR systems (a number of SMEs is active in this field).

Within the area of *SO_x abatement (Trend 4)*, EU manufacturers have developed the required systems for both LNG and scrubber technologies. They are considered 'best in class' worldwide in these fields. There are however a number of suppliers elsewhere as well.

EU players are relatively strong in the area of *Ballast Water and sediment treatment (Trend 6)*. As of November 2011, 54 systems have been granted basic or final approval, of which 16 by EU-based companies, and 5 by companies from EEA states. Several European SMEs are active in the field, and so are a number of larger companies. However a few large Asian companies are also developing ballast water treatment systems.

The position of the EU shipbuilding industry is considered generally good in supplying the *offshore renewable energy (Trend 7)*, with variations between segments. In the field of installation vessels, the overall number built until date is rather low, with only a few European players involved. European design offices are active also in cases where Asian yards are building. The number of cable layers is much higher, and the ship types are already existing for numerous years – they are also being deployed in other sectors (energy grids, communication). According to existing studies, European shipbuilders should be able to capture a substantial share of this potential. A different segment is the manufacturing of foundations (jackets), platforms, and other components. Here, location is an important factor, especially for the large sized platforms where transport costs would become too high if manufacturing sites are not near the intended installation site. Therefore, likely European yards located near offshore wind sites are expected to benefit.

Finland is very well placed to benefit from the development of *new Arctic shipping routes (Trend 8)*, as around 60% of all currently active ice breakers have been built in this Nordic country. Strategic alliances with Russia as a main client will contribute to maintaining this position.

Taken together, the EU industry appears well-positioned to capture a substantial part of the green growth potential. Based on its competitive position its share in global markets is roughly being estimated between 15 and 50%. In several of the green market opportunities (CO_2/fuel, NO_x, SO_x, and Ballast Water), European equipment manufacturers are in a leading position since they are ahead in developing technologies and in some segments already have implemented a number of systems. Competition from outside Europe is mainly seen in the CO_2/fuel efficiency segment. Europe's position with regard to the offshore wind market is more mixed, since in some parts a European track record is missing. On the other hand local demand for developing wind parks will likely give an advantage for building certain offshore structures.

As markets will progress, it is expected that interest from non-EU manufacturers will further increase, especially as shipbuilders around the globe will make substantial additional efforts to fill their order books – especially so in tough times. Again the challenge will most likely target the CO_2/fuel efficiency market as this is a truly global market, whereas some of the other market segments (viz. NO_x, SO_x, wind energy) have a stronger regional component. Support programmes in major competitor regions (in particular in Korea and Japan and to a lesser extent in China) focus on this market segment.

For European shipyards, the main opportunities are related to retrofit activities (especially SO_x and to a much more limited extent ballast water and retrofitted fuel efficiency technologies) and new market niches that develop. In this respect offshore wind energy does represent additional opportunities although not equally divided across all ship types that can be delivered. For marine equipment suppliers, the world market provides good to very good opportunities: in many of the greening market opportunities, the starting position of European suppliers is good (if not excellent). However the position in the value chain limits the amount of control that can be exerted and the current overcapacity drives also foreign competitors to grasp part of this market. Especially in the field of fuel efficiency, competition is expected to be strong, since the market potential is large and all ship types will be affected.

6.2 Business strategies regarding green market opportunities

Business strategies pursued

Whereas the starting position of Europe in respect of green growth opportunities is strong, with European manufacturers leading in many of the green market segments, Asian competitors are also active in several of them. In shaping the eventual success, not only market drivers and strengths and weaknesses are important, but also the ability of European industry to develop and apply business strategies that respond to these market opportunities.

We see a number of key business strategies which to a large extent are already followed by companies:

Strategy 1: Green innovation

The current strong position of the European shipbuilding industry to many of the green market opportunities is mainly driven by the high level of innovation. This a key factor to success in the current performance of both shipyards delivering high value, complex ship types and marine equipment manufacturers that supply the shipbuilding industry in Europe and worldwide.

Green and continuous innovation is key to retain this competitive position. Continuous innovation requires significant efforts. It includes not only a focus on R&D and technology, but also full awareness of embarking on the right technological trajectories and partnering with companies and organisations which also enable translating innovation into true market opportunities.

Two key strands are identified under this strategy:

- Retain current market positions by continuous innovation. Especially for constructing fuel efficient ships this appears to be a valid strategy;
- User-producer based innovation. Continuously innovate, but include a strong focus on market entry barriers (e.g. by partnering with classification societies in new EEDI technologies, or with clients who are willing to prototype).

Strategy 2: Green Links in the Value Chain

Large parts of the green market opportunities are found in the delivery and export of green solutions to shipbuilders across the world. In particular for marine equipment suppliers it is essential that they retain their competitive position and access to markets outside Europe. However their position in the value chain places them one step further away from the ship owners who make the eventual purchase decisions (especially in the current "buyers" market) than shipyards. This means that there exists a stronger dependency on the decisions of shipyards. In this respect pressures to increase local content and extend shipbuilding activities along the value chain in foreign shipyards that are faced with overcapacity are a serious threat.

In view of these developments two distinct strategies can be discerned which aim at strengthening the position of marine equipment suppliers in the value chain: strengthen the green link in the chain.

- Strengthen the position in the value chain by moving from components to systems solutions; offer stronger life cycle type of contracts/solutions (including after sales services, maintenance etc.), reduce dependence on foreign shipyards;
- Create alliances and partnerships also with foreign shipyards to avoid overly strong competition and local capacity development in competing shipbuilding countries (but be aware of knowledge leakage).

Strategy 3: Green Specialisation

For decades already, European shipbuilding has been successful in specialising into new and high-value niches. The two market segments that have been in-focus areas in this study, passenger vessels and dredgers, are fine examples of this business strategy. Both segments have demonstrated that early focus into the right and growing market segments can pay off. Green market opportunities offer new possibilities for specialisation and market niches. Two distinct strategies are distinguished in this respect:

- Focus (and selectively invest) in new market niches (offshore wind);
- Develop retrofit capacity (shipyards). Specialise in retrofit processes and technologies in which Europe can have a competitive edge (higher complexities, affected by a European geographical dimension (for example SO_x ECAs), clear cut fuel saving technologies).

Of course, the above strategies can strengthen each other and they are not necessarily mutually exclusive. Nevertheless, they each require different framework conditions to succeed, as all of these three strategies require to smaller or larger extent support from public policies. These policies are described and analysed in the next section.

6.3 Policies supporting green market opportunities: Europe versus Rest of the World

Different policies are in place both in the EU and its Member States and in competing shipbuilding nations which have a direct bearing on the green market opportunities and the chances of the

European shipbuilding industry to take advantage of these green markets. In the next sections these are further elaborated, in the following order:

- Most relevant EC policies;
- Examples of Member State policies;
- Most relevant policies of non-EU countries.

The focus of these policies is on their specific impact on greening opportunities and how these policies interact with these green markets or specifically focus on green developments. Policies of a more general nature are only briefly referred to.

6.3.1 *Most relevant EU policies*

Of general importance and set against the background of specific support measures is the thinking within the EU on industrial policy as expressed in the **Integrated Industrial Policy Communication**, which forms part of the Europe 2020 Flagship Initiatives.[175] Overall, the Communication calls for re-invigorating the competitiveness of the EU through value chains. Equally important for this purpose is the Commission's Flagship initiative **A Resource Efficient Europe** [176]**,** which calls amongst others for a low-carbon, resource-efficient, secure and competitive transport system by 2050 that removes all obstacles to the internal market for transport, promotes clean technologies and modernises transport networks.

In addition to this more general policy frame a number of specific policy areas at the EU level are deemed to be of specific relevance to green market opportunities:

- RTD support;
- Competition policy, including innovation aid.

RTD support

The most important instrument for RTD support in the EU is found in the FP programmes. Related to this are the technology platforms, which play a role in the definition of research priorities through the development of Strategic Research Agendas and implementation roadmaps.

The Waterborne European Technology Platform

The concept of Technology Platforms was first introduced in the Commission Communication “Industrial Policy in an enlarged Europe” in December 2002. European Technology Platforms (ETPs) were proposed as a way to bring together technological know-how and stakeholders with the aim of producing a long-term strategic plan for research and development of specific technologies with a significant economic and societal impact.
The Waterborne platform[177] is an initiative that came forth from the Maritime Industries Forum (MIF) and its R&D committee in 2005 and is making strident efforts to regularly update R&D requirements for European competitiveness, innovation and the meeting of regulations like safety and environment. The stakeholders include EU associations covering deep and short sea shipping, inland waterways, yards, equipment manufacturers, marine leisure industry, research and university institutions, classification societies etc. The so-called stakeholder Support Group is matched by a Mirror Group of government appointed delegates.

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[175] COM (2010) 614.
[176] COM (2011) 21 final.
[177] http://www.waterborne-tp.org.

The Waterborne strategic research agenda prioritises efforts towards low emission vessels, waste management and ballast water treatment, life cycle management, and energy efficiency (operation). In terms of implementation (strategy) the following components are put forward:

- Human resources, education and training (increasing attractiveness and industry-science collaboration);
- Defending intellectual property (protection and valorisation of European IPR);
- Technology transfer to small shipyards (small shipyards in the EU constitute a creative source of innovation but their participation in EU R&D&I programs is limited ; turning this around is a priority for the coming years);
- Joint initiatives and level playing field (harmonisation of policy interests among EU MS, but also ensuring mutual opening of international markets.

RTD Framework programmes (FP)

The European FP7 programme for the period 2007-2013 includes the subcategory Transport (being part of the main block 'Cooperation'). Transport includes all modes of transport, maritime being one of these. The total budget for the transport category amounts to € 4.1 billion Euro. Maritime projects are part of the second focus area where clean and efficient engines are developed, the impact on the environment is considered as well as multimodal transport.

A number of maritime R&D projects relate to the greening trends addressed in this study. For instance BESST, aiming at technologies to reduce life-cycle costs, SMOOTH (reducing friction using air lubrication, or STREAMLINE, addressing the efficiency of propulsion systems. As such these projects thus contribute to the development of technologies addressing the fuel efficiency (trend 1) and CO_2 reduction (trend 5). Also projects addressing operational factors, like NAVTRONIC on optimal sailing planning, or ULYSSES, looking into slow steaming impacts, are funded under FP6.

Other R&D projects address air quality and emissions (trends 3, 4 and 5). For instance HERCULES, aiming to reduce NO_x by 70% (amongst other objectives), TEFLES, addressing the cost implications of fitting exhaust gas technologies on ships, or POSE^{2}IDON, aiming to reduce the required space and costs of electric propulsion equipment. Regarding water emissions (trend 6), the BAWAPLA project, on better ballast management, can be mentioned as an example. The SAFEICE project is an example of research into strengthening ice class ships, responding to trend 8. Although the project is focusing on safety rather than greening aspects, it can increase the competitiveness of the European shipyards vis-à-vis this specific market trend.

Many of these examples concern projects not just addressing one green driver, but responding to multiple of them. For instance the HELIOS project aims to reduce CO_2, NO_x, sulphur and particulate matter emissions through operating compressed LNG instead of conventional fuel oil.
Several R&D projects specifically address the retrofit segment. For instance the eco-Refitec[178] project aims to increase the competitiveness of the European shipyards and SME's involved in shipbuilding, ship repair and recycling. As a result of IMO and EU environmental regulation the existing fleet needs to be retrofitted to comply with the strictest pollution regulations. To ensure the environmental upgrade of the existing fleet, European retrofit and repair yards are supported in their R&D activities to strengthen their position and enable them to face the major retrofit challenge. Another example is the RETRO*FIT* project[179] which addresses methods to implement green

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[178] www.eco-refitec.eu.

[179] www.retrofit-project.eu.

technologies on existing ships. A similar objective is found in the project REFRESH, which is focused on dynamic modelling and decision support ships.

An inventory of FP7 projects in the maritime domain suggests that the amount of budget allocated to maritime research brings the EU investment at some € 130 mln.[180] However this does not include all projects in the maritime domain and also not energy sector related projects addressing offshore themes. Hence the overall amount will be higher.

FP participation of SMEs[181] under the collective FP thematic priority on Transport (not zooming into specifically the maritime/shipbuilding sector) amounts up to 18% of EC contribution (compared to a target of 15% of EC contribution targeting SMEs). These are above average performances compared to other thematic priorities, but these numbers do not reflect the shipbuilding/maritime industry specifically. Regarding SME research needs, recent research[182] shows that “financing research and innovation activities” is their most important R&D and innovation need, followed by “access to new scientific and technological knowledge” and “solving technical problems”.

Under the Framework Programmes the ERA-NETs are intended to intensify collaboration and streamline national funding schemes for R&D and innovation. As pointed out before, the stimulation of the introduction of green technologies in the shipbuilding sector requires an orchestrated approach between EU and national levels, both concerning the supply side (R&D) but also the demand side (innovation and market absorption). Based on the NETWATCH database , one ERA-NET relevant to the shipbuilding/maritime sector has been identified: MARTEC on maritime technologies. MARTEC-I began with 12 ministries and funding organisations from 9 European countries in 2006.The network quickly transformed into a strong network and has launched calls in 2008, 2009 and in 2010. So far applications for proposals have involved participants from 8 countries, and projects funded total about € 14 million. Given the success of the first phase, 28 ministries and funding organisations from 24 countries are involved in MARTEC II now. MARTEC-II aims to broaden the geographical scope through the inclusion of new countries, and strengthen the cooperation with Waterborne ETP and other initiatives like SURSHIP. MARTEC II can play an important role in the further development and uptake of greening technologies in the shipbuilding sector. One of the research areas is the development of structures for sustainable waterborne transport. Other research areas include research on environmental and climate impact, polar / artic technology and offshore structures for renewable energy.

Competition policy – state aid to shipbuilding

State aid to shipbuilding has been subject to a series of specific regimes since the early 1970s. The rationale behind these regimes is that shipbuilding is different from other industries, including the short production series, the size, value and complexity of the units produced and the fact that prototypes are generally used commercially.

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[180] The sum of EC contribution of all projects found under FP7 in the Maritime Transport Research Database, http://www.maritimetransportresearch.com/site/projects_fp/7.

[181] European Commission (2010): Mid Term Report on SMEs' Participation in the 7th R&D Framework Programme. Brussels, 27.09.2010.

[182] European Commission (2010): Mid Term Report on SMEs' Participation in the 7th R&D Framework Programme. Brussels, 27.09.2010.

The **Framework on state aid to shipbuilding** has just been renewed for a period of 2 years starting from 1st January 2012.[183] Under this Framework, the EC may authorise aid to the shipbuilding sector. Three areas for state aid are identified in the framework:

- Regional aid. Specific measures related to regions which benefit from Cohesion policy (Objective 1), where state aid may not exceed 22.5% of gross grant equivalent. Horizontal guidelines for regional aid will be reviewed in 2013. The aid is linked to upgrading or modernising existing yard(s)[184];
- Innovation aid. In the case of innovation support, aid may be provided up to a maximum of 20% of investments. Under the Shipbuilding Framework, the provision on aid to research, development and innovation justifies aid for innovation in existing shipbuilding, ship repair or ship conversion yards, provided that it relates to the industrial application of innovative products and processes, i.e. technologically new or substantially improved products and processes compared to the state of the art existing in this industry in the Community, which carry a risk of technological or industrial failure. The guidelines explicitly refer to improvement in the environmental field including optimised fuel consumption, emissions from engines, and waste. When products or processes are introduced at least one year before the introduction of more strict EU environmental regulation or in case there is no EU regulation but the products and processes contribute to a higher environmental standard, the maximum aid can be raised up to 30%;
- Export credits. State-supported credit facilities may be granted to ship owners for newbuilding or conversion of vessels. It does not include any specific green criteria.

Under the existing framework, various innovation aid schemes at national level have been approved as being compatible. Countries that introduced a scheme to stimulate innovation are Germany, France, Spain, the Netherlands, Italy and Finland. In some countries it specifically focuses on innovation aid while in other countries (e.g. Spain) it addresses all areas of the state aid framework.

6.3.2 *Examples of Member States policies*

In addition to EU measures, or within the framework of EU regulation, Members States have adopted strategies to promote green technologies. Measures differ widely amongst countries. Some European countries do not have any specific measures in place, mostly because their shipbuilding industry is small or plays only a marginal role internationally. However, several EU countries do have strategies to support their shipbuilding industry. Some of these specifically address the greening focus, while others have a more general shipbuilding focus. In general it appears that the main support mechanisms in Members States focus on funding research and development and innovation aid (within the existing state aid framework). The focus and content of R&D programmes differs often depending on the nature of the shipbuilding industry in these countries.

Examples of policies in the following members states are further presented:

- Germany;
- The Netherlands;
- Italy;
- Finland;
- Denmark.

[183] EC (2011) Framework on State Aid to Shipbuilding. COM 2011 / C 364 / 06.
[184] Not linked to a financial restructuring.

Germany

Germany has a large shipbuilding and marine equipment industry. The German government supports this industry through several R&D programmes. Their main programme is '**Shipping and marine technology in the 21st Century**.' The programme is executed by the Federal Ministry of Economics and Technology (BMWi). Other Ministries are involved as well depending on the topic. The Ministry is financing part of the research while the other part is to be paid by the industry.

The programme is basically industry led. Yards and manufacturers collaborate with research institutions and universities. The aim of the research programme is to increase the energy efficiency of ships, to produce ships built in series in a more flexible way than is done now, and to develop new transhipment technologies.[185] The program mainly focuses on the reduction of CO_2 emissions of newbuild vessels. Retrofit might be included as well, but to a lesser extent.

Several specific goals / topics defined within the Research programme include:

- Maritime energy generation. The focus of this topic is on the offshore industry that is expanding worldwide. Offshore platforms can be used for oil and gas production, but also for wind, wave and tidal energy. Technical solutions for the mining of raw materials as well as energy generation are seen as a growth market by the German government. The German government is committed to invest in offshore research. A research test field is located in the North-Sea and this location is funded by the Federal Ministry for the Environment, Nature conservation and Nuclear safety (BMU). The German government also has an ambition to build several more offshore wind facilities. The creation of wind parks will lead to an increased demand for specialized vessels and construction of foundations and platforms. The German shipbuilding expectedly will benefit of this new policy;
- Marine environment and technologies needed to protect the environment. The technologies are applied to ensure that the oceans are used in a sustainable way and the technologies should prevent and combat marine pollution. This leads to the so-called marine environment protection technologies. Besides these technologies, technologies concerning hydrography, hydraulic technologies and coastal zone management are part of this topic;
- 'Integrated Systems for Underwater Production of Hydrocarbons' (ISUP). This subprogram ensures that the German offshore suppliers will be capable to sell equipment that can be used at water depths of 1,500 meters or that can be used in polar waters.

In addition Germany has an innovation aid scheme in line with the State Aid Framework for shipbuilding. This scheme was the first scheme to be approved.

Besides initiatives of the Federal government to get a greener shipping sector, also other parties try to contribute to this goal. The Hamburg Port Authority (HPA) for instance has introduced **green port dues**. When a vessel is cleaner than a certain level the owner is allowed to pay lower port dues. The Environmental Ship Index (ESI) is used to measure the environmental performance of the vessel. The ESI includes CO_2, NO_x and SO_x emissions. The ESI ranges from zero to 100. When a vessel scores 100 point no emissions are addressed to the vessel. Seagoing vessels can obtain a 10% discount on their port dues when they score 20 points.[186]

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[185] http://research-in-germany.de/links-web-guide-to-r-d-in-germany/8966/fields-of-research,print=true,page=Maritime_20Technologies,slc=dachportal_2Fen,mcn=on.html.

[186] http://www.greenport.com/news101/europe/hamburg-introduces-green-port-fees.

This measure indirectly influences the shipbuilding industry. Although the project in Hamburg is followed by a few other ports such as Rotterdam and Le Havre, and ports in Sweden (see box 3.3 in section 3.2.1), it is not common practice yet. However when more and more ports introduce green port dues, it becomes more attractive for ship owners to sail with cleaner vessels, because they have to pay less. Ship owners will start to buy cleaner vessel or they will use equipment that reduces the emissions.

Netherlands

The Dutch government has introduced a specific R&D programme to stimulate innovation in certain segments of the Dutch shipbuilding industry, namely the offshore industry and complex specials. The programme is called the **Maritime Innovation Programme (MIP)**. The programme started in 2007 and will end in 2012. The goal of this programme is to strengthen the competitive position of the Dutch shipbuilding sector.

- The offshore industry. Main topics for this sector are LNG related research and oil and gas extraction in extreme circumstances (e.g. in polar waters or in very deep waters). The programme looks amongst others into the possibilities of using LNG as a fuel to reduce CO_2 emissions;
- Complex specials' (e.g. mega yachts, short sea ships, patrol vessels and vessels to support the offshore industry). These are all new build vessels. Projects that aim to reduce emissions (CO_2, NO_x and SO_x) are favoured over projects that do not save these emissions.

The Dutch government is contributing € 82 million, while the industry and research institutions contribute the same amount. The companies participating cover a large part of the value chain, i.e. yards and marine equipment manufacturers, but also buyers and users. The programme aims to involve all relevant parties so that the success and adaptation of the programme is increased. The MIP programme can be qualified as a partly green support policy, with its main focus is on new build vessels.

Similar to number of other countries, the Netherlands has adopted an innovation aid scheme, which started in 2006.

Italy

Italy has introduced the Italian **Maritime Technology Platform (PTNM)**. This platform closely cooperates with the EU Waterborne initiative. Many Waterborne plans are laid down in the strategy document of PTNM. The main goal of PTNM is to promote the competiveness of the Italian maritime sector through identified RDI strategic priorities.

Several stakeholders are involved in the PTNM, mainly the shipbuilding sector, related suppliers, public and private research organizations, operators and regional administrations. The PTNM has formulated a Strategic Research Agenda (SRA) in which all research areas are described. Also it is indicated if the research topic could best be carried out at European level or at national level. Most of the topics under the SRA can be qualified as non-green, but they can lead to green outcomes. Also Italy has an innovation scheme that was adopted within the overall framework for state aid to shipbuilding.

Finland

The Finnish shipbuilding industry suffers from the economic crisis. Especially the largest Finnish yard, STX Finland Oy shipyard in Turku is in rough waters, with low new vessel order numbers.[187] A support package was designed with the main aim to help the industry to survive and to secure jobs, and the programme specifically addressed Finland's activities in the Arctic shipbuilding domain, thus feeding the response to trend 8.

The focus of the programme is on domestic ship deliveries. Especially the government will order several ships to keep yards at work until hopefully the international market improves again. In addition the government has introduced a number of measures aimed to increase the number of orders from outside Finland. The final objective of the programme is to obtain an additional amount of € 500 million in orders. Several financial and support measures are proposed to reach this goal, which fit within the overall State Aid Framework of the EC. They include:

- innovation aid for the shipbuilding industry;
- publicly supported credit and guarantee arrangements for domestic ship orders, corresponding to export financing terms; and
- support for environmentally friendly investments in sustainable vessels by Finnish shipping companies.[188]

The Finnish government justifies the subsidy package based on the stated fact that their main competitors also have applied significant state support programs. The main competitors of Finland are South Korea, China, Spain and Italy.[189]

Denmark

Denmark used to have a flourishing shipbuilding industry, but nowadays most shipyards have disappeared. Although Denmark thus hardly has any shipyards left, it remains the home country for several large shipping companies, like A.P. Moeller - Maersk (container shipping and other activities), DFDS (passengers and cargo shipping) and Nordic Tankers (a shipping company using various kinds of tankers). Furthermore several support industries (design, equipment) are still active.

The country has a strong industry focus on greening with government support mainly directed at promoting cooperation between actors in the value chain. An important element is that the policy is aimed at creating partnerships with key actors outside Europe. Although the vessels are hardly ever built in Denmark itself, both the Danish government and industry have expressed that they demand more environmental friendly vessels, wherever they are built. To reach this goal the government has set up the **'Innovative Ship Design'** project.[190] This project facilitates the formation of partnerships that will develop ways of green shipping. All relevant stakeholders are included, such as Asian shipyards, Danish ship-owners and Danish marine equipment manufacturers. Indirectly this should also benefit the remaining Danish marine equipment industry, although this is not explicitly stated as the aim of the project. The government mainly facilitates the discussions between the stakeholders and ensures that outcomes are focused. This task is carried out by the

187 Ministry of Employment and the Economy (2010), 'Task force propose extensive support package for Finland's shipyards.'
188 Ministry of Employment and the Economy (2010), 'Finnish government prepared to assist shipyards through the present economic crisis.'
189 Ministry of Employment and the Economy (2010), 'Task force propose extensive support package for Finland's shipyards.'
190 Danish Maritime Authority (2011) 'Innovative green ship design', paper for OECD workshop on green shipbuilding. This programme started recently.

Danish Maritime Authority (DMA)[191,] which is a governmental organisation. The 'Innovative Ship Design' project mainly focuses on new build vessels that are ordered in Asia. The main ship types are container, bulk and general cargo vessels. In the near future passenger vessels might be included in the program as well.

Besides this government led initiative, the Danish industry also has introduced a research programme that focuses on green initiatives. The programme is called '**Green ship of the future**' (GFS) and started in 2008. Both public and private organisations are part of the initiative. The public institutions do not provide any funding, nor do they direct the programme. They stay involved in an expert role. DMA is one of the public companies involved in the project. Also Danske Maritime and the Danish Environmental Protection Agency are involved. The concept implies that companies share their knowledge with each other, however at their own costs. The major shipping companies, like Maersk and DFDS, are involved in the project. Also equipment manufacturers, like ABB, MAN Diesel & Turbo and Scanel International are participating in the project. The group is complemented by several universities, like SIMAC and DTU mechanical engineering.[192] The project aims to reach several targets. The overall target is to reduce CO_2 emissions by 30%, SO_x and NO_x emissions by 90%. Some individual projects within the GFS programme already have reached this target and even surpassed it. The programme is based on several concept studies. The different available technologies are implemented in several ships and the overall reduction in emissions is measured. The programme mainly focuses on retrofitting vessels. Two vessel types are used: a 8,500 TEU container vessel and a 35,000 dwt handy size bulk carrier. Result of the programme so far is that without reducing speed, significant reductions in emissions are achieved. The technologies used to achieve these reductions vary widely; they include engines, fuel type, waste heat recovery, scrubber systems, exhaust gas recirculation, trim optimization and cooling systems.[193]

6.3.3 *Most relevant policies of non-EU countries*

Besides EU member states, also other major shipbuilding nations have policies in place to support their industries, and some of them clearly take the greening opportunities on board in their strategies. In this section, the following countries are elaborated:

- Norway[194];
- China;
- Korea;
- Japan.

Norway

The Norwegian shipbuilding industry is specialized in building offshore vessels, especially for the oil and gas industry. Around 80% of all ships built in Norway are meant for this sector. A second important segment for the Norwegian shipbuilding industry is the ferry and passenger vessels market. This sector has a very strong domestic demand, because Norway has many ferry connections, and the majority of these vessels are old and have to be replaced. The long experience of the Norwegian yards places them in a competitive position, although there is tough competition from foreign yards in this segment. A third, but very small focus area for the Norwegian shipbuilders is fishing vessels.

In Norway there are several greening initiatives. Green initiatives in the shipbuilding industry focus mainly on the three segments mentioned above (offshore vessels, ferries and passenger vessels,

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191 http://www.dma.dk/Sider/Home.aspx.

192 http://www.greenship.org/partners/universitypartners/.

193 Green ship of the future (2011).

194 It is noted that Norway is an associated country to the EU Research Framework Programme.

fishing vessels). Those initiatives are triggered by an increased environmental awareness (in the shipbuilding industry itself as well as by customers of shipping services) and international environmental conventions. Most initiatives are led by the government in close cooperation with industry players. The initiatives are both applicable to new build and retrofits.

The Norwegian government has several R&D subsidy programmes for the maritime industry. Projects that focus on environmental friendly solutions are given priority. The overall aim is to maintain the Norwegian maritime industry as a leading supplier of innovative and environmental friendly products. The subsidies are awarded by 'Innovation Norway[195]' and the Research Council of Norway.[196]

Besides favouring environmental friendly research in the general R&D programmes the Minister of Trade and Industry has also invited the industry to develop a holistic research and innovation strategy. The strategy is called '**Maritime 21**' and focuses on close cooperation between the industry, the education sector and policy makers to stimulate R&D. This strategy is implemented through several joint ventures consisting of industry players and research institutions. The joint ventures are partly financed by the Research Council of Norway and 'Innovation Norway.'

Some Norwegian ports will join the Green port fees initiatives (see box 3.3 in section 3.2.1). Ships that are heavily polluting are charged higher fees than ships that are more environmental friendly. The ports try to only attract environmental friendly ships and discourage the polluting ones. Another measure taken by the Norwegian government is the NO_x tax (see box 6.1 below). The tax has resulted in a reduction of NO_x emissions but has also promoted LNG fuelled ships.

Box 6.1 The Norwegian NO_x tax and fund

In 2006 the Norwegian Parliament adopted a new set of rules to reduce NO_x in Norwegian Waters. The new laws are applicable since January 2007. The rules are fiscal measures. Vessels that produce too much NO_x have to pay a fine. Subjects to this new regime are engines exceeding more than 750 kW, boilers over 10MW and flaring. Those subjects have to pay € 2,- per kilogram NO_x. The penalties paid are collected in the so-called NO_x fund. Companies can apply for a subsidy paid by this fund to reduce their NO_x emissions.

Between the years 2008 and 2011 this fund succeeded to reduce 23,000 tonnes of NO_x. The main sectors most contributing to NO_x reductions were offshore service ships (36%), short sea shipping (15%) and ferries / passenger vessels (11%). Measures taken to reduce NO_x are SCR using urea (41%), internal engine modification (18%) and LNG and electricity (15%).

Source: http://ec.europa.eu/transport/maritime/events/doc/2011_06_01_stakeholder-event/item14_norway_business_sector_nox_fund.pdf

China

The Chinese shipbuilding industry has grown rapidly. Much money is spent on R&D, but the focus of these R&D programmes is at present not on greening the fleet or reducing the carbon footprint. The main focus is on improving the quality of ships, the production process and to shorten delivery times. By improving these aspects the shipbuilding sector hopes to catch up with other shipbuilding

195 Innovation Norway is a governmental instrument to award subsidies to companies in all different sectors. Besides financial means the organization provides a broad business support system.

196 The Council was established in 1999 by the Norwegian government. The Council awards subsidies to different research projects. All economic sectors can apply for a subsidy, including the shipbuilding industry.

regions, like Europe, Japan and South-Korea. In both government and industry strategies, greening is of minor importance at this stage.

However, China has proven to be able to move quickly into new markets, which may create a potential risk to European players in the future, as the Chinese government is importing advanced production methods and entire production lines to accelerate innovations. Also foreign sourced hardware and software is used to ensure that Chinese designers are able to improve their design. Besides imported foreign procedures to obtain knowledge, also joint ventures are established with Japanese and Korean yards. The purposes of these joint ventures are the transfer of knowledge, skills and production know-how. As such green policies adopted by the Korean and Japanese yards have also been transferred to the Chinese yards (spill-over effect).

Although the Chinese government has not adopted a greening R&D program yet, the attention for green ships is increasing. The country started to organise seminars and conferences on green shipping and green shipbuilding (e.g. the China green ship technology seminar 2010[197], the GST China in 2011[198] and the upcoming China Green shipbuilding technology Congress[199]). Also more and more research into the greening possibilities is carried out by Chinese universities.[200] This may be a precursor for a stronger Chinese greening R&D focus in future.

In addition to the central government Chinese regions can establish their own R&D programmes. At present also these programmes are mainly directed at bridging a technology gap with competitor countries and move towards more complex ship types. Greening has not been a specific focus area until now.

Korea

In Korea, R&D is mainly conducted inside companies. Although these companies operate as private companies they are strongly government related. Projects are partly funded by government, but are relatively closed to outsiders (limited external cooperation). Also in the greening process the main actors are the shipbuilding companies themselves.

The major Korean shipbuilding industry have started an initiative to accelerate green shipbuilding technology development. The initiative should be the core strategy to strengthen the competitiveness of the Korean shipbuilding industry. The slogan of this campaign is ‘Beyond green challenge toward new opportunities.’ The companies tend to cooperate more closely together, sharing their techniques. The yards will also support their supplying companies. Samsung Heavy Industries (SHI) for instance is transferring its own green management techniques to its cooperating companies. This strategy fits in the Chaebol[201] approach that is very common in Korea. It is also reflected in the individual strategy of a number of the larger companies with an explicit focus on

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197 http://www.greenlinkchina.com/greenship/index.asp.

198 http://gst-china.com/.

199 http://www.noppen.com.cn/upcoming/L1203/index.asp.

200 In 2011 The School of naval architecture of the Shanghai Jiaotong University published an article titled ‘Research on green shipbuilding and concurrent green design.’ Upcoming: School of mechanical engineering, Department of naval architecture and ocean engineering, Huahai institute of technology, Lianyungang, article titled: ‘Analysis of green ship designs and manufacturing technologies.’

201 Samsung is operating as a Chaebol (Korean version of business conglomerate). This means that the company has formed strong ties, both formal and informal, with other companies. The suppliers of commodities are closely linked with the manufacturer of end products. R&D is developed together and shared. In many Chaebols the managers of the different companies are chosen by all companies together. The managers do also rotate between the companies so that more coherence in the group is achieved. The main aim of the Chaebol is to reduce the high transaction costs that will arise when companies operate fully independent. The same strategy is followed by companies like Hyundai and LG.

more sustainable and environmental friendly ships. An example is an order of Maersk placed with Daewoo Shipbuilding & Marine engineering (DSME) for what is considered the greenest container ship. Yet another example is SHI, which announced in early 2010 that the company has adopted a green management policy. From 2015 the company only wants to build environmental friendly ships. The company also tries to reduce its greenhouse gas emissions by 30%. The company has drawn a sustainability report in which the strategy is explained in more detail.[202]
Korean shipyards are also expanding to other countries. Most Korean shipyards have started cooperation with foreign yards in China, Vietnam or the Middle East. This cooperation will also lead to knowledge transfer, including green technologies. Hyundai Heavy Industry (HII) has signed a MoU with the Chinese company Datang Shandong Power Generation and the Weihai City government to build large scale wind turbines. DSME is exploring its opportunities on the South African market, STX Offshore and Shipbuilding signed an MoU with Abu Dhabi Shipbuilding[203] of the United Arab Emirates (UAE) to create new business opportunities in several sectors.

Next to the activities of the (large) Korean shipyards, the Korean government itself has started its greening policy in 2008. In that year the Presidential Committee on Green Growth (PCGG) came into force. This committee has set **national greening targets**, that are broadly formulated and include all economic sectors. In August 2008 Korea introduced its “Low Carbon, Green Growth” initiative, which promotes the move to a low carbon society, intends to lay the foundations for a green economy, and aims to enhance the quality of life and show international leadership. The shipbuilding industry is not mentioned individually, but should also comply to the national targets set. As such it encourages (all of Korea’s major industries) to increase the green portion in their production. Under this committee the Korean government is able to issue new national ‘greening’ laws and stimulation packages.[204] An example of such an initiative are the plans of the Ministry of Knowledge Economy to build, together with several shipbuilding companies, a large offshore wind farm. The farm will be located at the West coast of Korea, and has a construction cost of $ 8.2 billion. The park will consist of 500 turbines of which 20 will be realised in 2013, another 180 in 2016 and the remaining 300 by the end of 2019. Next to this overall policy R&D on energy saving technologies is set up. Also this fund is not directly targeted at the shipbuilding sector but is open for all economic sectors.

In 2011 a new financing programme was set up. The program is led by the Korean Finance Corporation (KOFC), a government owned company. KOFC operates a ship financing plan that includes a form of interest reduction on loans for cleaner vessels. Ship owners who buy a more environmental friendly vessel, which is often more expensive than a standard vessel, can obtain the loan with lower interest rates. Before the ship owner can obtain the loan the vessel or vessel’s design has to be approved by DNV Korea. DNV provides a certificate when the vessels reduce air pollution (e.g. SO_x, NO_x and CO_2). When the certificate is obtained the loan will be granted.

Japan
Japan is generally at the forefront of research and development, which is also the case in shipbuilding and marine technology. The Japanese shipbuilding and supply industry can be seen as fairly closed, and rather restrictive in sharing or publishing its research and development results. Japan has an active role in greening the shipbuilding industry. Some of the initiatives are subsidized by the Japanese government, while other initiatives are industry led. The measures

202 http://www.shi.samsung.co.kr/Eng/Sustainability/report.aspx.
203 http://www.adsb.ae/.
204 http://www.greengrowth.go.kr/english/en_about/en_introduction/introduction.cms.

taken by the Japanese government can be qualified as green drivers leading to green outcomes. The government has a clear greening policy with priorities like reducing CO_2 emissions and supporting research into new fuels (both renewable and non-renewable ones).
Japan is a resource poor country and all fuels have to be imported. This dependency on other countries for the supply of fuel makes Japan vulnerable for fluctuations in price or availability. The Japanese government is actively involved in solving this problem. The government is both supporting the use of LNG (leading to policies to support the construction of LNG tankers as well as the construction of LNG terminals where vessels can bunker LNG) and renewable energy sources. This is reflected in the construction of LNG vessels. Although South Korea is a larger producer of LNG tankers, Japan has a technological advantage that the country will use. The LNG market is also seen as the only shipbuilding market in which Japan is still able to increase its market share. To stimulate this development, Japanese vessels will start using LNG instead of carbon fuels and the government is supporting the development of solutions for LNG terminals on- and especially offshore as ports have strict rules for LNG terminals and vessels. At this moment no offshore terminals are in use yet, but two Japanese engineering companies are asked to look into the possibilities of offshore terminals.

Besides focusing on LNG Japan is also looking into new types of renewable energies. One of them is the production of algae and seaweeds. Advantages of these plants are that they are available on a wide scale, using those plants has a minor effect on the food chain, and because the production is at sea the production does not compete with agricultural production on land. The development of this area would call for specific ship types and marine structures to construct and operate algae farms offshore. The size and timing of this potential however remains highly uncertain as plans have not been fully developed yet.

Box 6.2 Japanese project aims to cut CO_2 emissions by one third

The Japanese Ministry of Land, Infrastructure, Transport and Tourism started a national research initiative aiming at 30% reduction of CO_2. Over 40 participants from the spectrum of maritime industries are involved, including shipbuilders, shipping companies, manufacturers, suppliers, research organisations, etc. ClassNK contributes about US$ 25 mln to the budget. Examples of research topics are twin-skeg hullform (rudder fin and bulb), forward bridge, low friction coating, electronically controlled diesel engines, variable nozzle area turbochargers, hybrid systems, etc.

Another research area is combustion, where Niigata Power Systems has developed emission control technology

Source: Marine Propulsion, April/May 2011, p.71&73

6.4 Gaps of existing European policies vis-à-vis green market opportunities

Main green policies in place in Europe and its Members States focus on R&D and innovation aid. Although the instrument is wider in itself, green elements or focus is included which stimulates green RDI. This is relatively effective given the technological advance that the European industry has in many of the green areas. Assessing the effectiveness of the policy from the viewpoint of the barriers that are perceived in the take-up of innovations on the market, one area that would benefit from additional attention would be RDI measures that overcome perceived risks by ship-owners of new technologies that are not yet proven (closer to prototyping, testing).

However, other countries are also moving rapidly to take advantage of these greening opportunities. Especially Korea and Japan are conducting extensive research and innovation activities to be able to supply more environmentally friendly ships. The focus of these innovation efforts appears to lie in fuel efficiency savings. In addition, some specific markets are developed or promoted, such as the use of LNG in Japan. China is still relatively inactive in the field of green technologies. However, until now most attention seems to be dedicated to improving existing production processes within the shipbuilding industry. Nevertheless there are tell-tales which indicate an increased attention to more sustainable vessels. In that respect China has proven to be able to move very fast and buy technologies or create joint ventures to obtain new technologies. The new Chinese 5 year plan – with a strong emphasis on the green economy – is expected to be a major driver behind future Chinese efforts, also in the shipbuilding domain.

Apart from existing government policies, the size of shipyards in Asia is in general (much) larger than that of European shipyards. Larger investment R&D capacities and possible cross-sector knowledge transfer are true assets, as exemplified by the Korean Chaebols. To a certain extent the existence of cross-sector knowledge transfers is also valid for larger marine equipment suppliers in Europe, which tend to be active both in land-based and sea-based sectors.

We can identify several domains where policies in Europe vis-à-vis green shipbuilding provide a real or perceived gap:

1. In earlier chapters barriers were identified that are perceived in the take-up of innovations on the market. One area that would benefit from additional attention would be RDI measures that overcome perceived risks by ship-owners of new technologies that are not yet proven (closer to prototyping, testing). This includes developing business cases to raise awareness among ship owners, as well as the exploration of possibilities to involve ship owners in RDI testing phases.

2. For some green market opportunities – in particular the introduction of LNG-propelled ships – the basic bunkering infrastructure is an important condition in the take-up of this technology. Norway and Japan can be seen as examples which invest in (onshore and offshore) bunkering facilities which promote the take-up of LNG-propelled ships; this is a domain where a more forceful European response could be considered.

3. R&D Alliances across borders. As indicated marine equipment suppliers are to a certain extent dependent on shipyard clients outside Europe. Building and strengthening alliances is one of the business strategies in response to the green market opportunities. Building global innovation networks may be a potential solution in this respect, although IPR issues obviously become important in such an environment. In building global alliances the Danish ‘Innovative Ship Design’ project is an inspiring example. An upscaling of this initiative would allow more structured cooperation between European and Asian shipyards, European (or even global) ship-owners and European marine equipment manufacturers. Member State governments in cooperation with the EC could facilitate the discussions between the stakeholders and ensure focused outcomes. Also in some research projects that have been undertaken in the past we see these forms of international cooperation[205].

[205] E.g. SAFEICE which combined researchers from Europe, Russia, Canada and the US to carry out research on ice class ships.

4. Market-based policy initiatives. Various global and EU regulatory policies have been highlighted as drivers for green market opportunities. At a global level, IMO MARPOL Annex VI: the Energy Efficiency Design Index (EEDI) and the Ship Energy Efficiency Management Plan (SEEMP) are examples, but so are the Emissions Control Areas for SO_x or NO_x for various sea-basins. On the other hand market based drivers have been identified. For both types of drivers the market potential could be boosted by introducing market based policy initiatives. Market based instruments are expected to create a balance between greening and industry/competitiveness considerations.[206] Examples of such explicit demand-side strategies are the differentiation in port charges, as introduced by various European ports such as Hamburg, which promote the use of green ships over non-green ships. Another example is the Korean Finance Corporation (KOFC), which includes in its loan strategy a form of interest reduction on loans for cleaner vessels.

6.5 Recommendations

General recommendations

Green market opportunities are driven both by market-based and regulatory trends. In general it is observed that regulatory drivers are mainly driven by environmental/sustainability concerns and do not always fully include industrial policy concerns. Building on a previous study regarding EU Industry in a sustainable growth context [207] and the Industrial Competitiveness Communication[208], we recommend a competitiveness proofing of any new policy that is relevant to the European shipbuilding industry. This proofing should focus on the need for a **balance in terms of aims –** greening policies should not only focus on environmental targets, but simultaneously facilitate the European shipbuilding industry's transformation towards more sustainable and innovative ways of production, thereby contributing to serving market trends like fuel efficiency improvement as well. In other words, we recommend that the EU's ambitions in terms of resource efficiency – balanced in terms of both environmental and economic objectives [209]– is adhered to also when it concerns green shipbuilding. Furthermore, we consider it important to make use of the **full range of policy instruments**.

These instruments may take place at different levels. Where possible market based instruments should be considered as these offer an alternative as they provide a direct signal that works through prices to change market conditions and lead to desired changes. However, also here the impact on competitiveness should be considered. For example, taxes can have negative implications for competitiveness, but in an environmental sense, if targeted correctly, can work in accordance with the polluter pays principle and to the overall benefit of society. Judging the level at which to set a tax is an important and complex matter and needs to take into account relative tax regimes in other economies. The earlier mentioned example of green port dues serves as an example.

Building on the above general considerations a number of general recommendations can be made to further stimulate exploiting of the green market potential.

206 EC (2011) European Competitiveness Report, Chapter on EU Industry in a Sustainable Growth Context.
207 Ibid.
208 COM (2010) 614.
209 CEC (2011) A resource-efficient Europe – Flagship initiative under the Europe 2020 Strategy. COM (2011) 21 final.

- At a regional level, the industry needs to retain critical mass also as to be able to maintain training, education and research structures. This is easier in areas where shipbuilding activities are relatively concentrated (Netherlands, parts of Northern Germany, parts of Italy) than in areas where industry is more scattered. **Cluster support** can contribute to strengthening the establishment of critical mass by supporting the development of synergies between suppliers and stakeholders across the value chain. Especially local and regional authorities play an important role in supporting clusters. The EU could enhance these mechanisms through exploring links between clusters through the European Network of Maritime Clusters and through promoting the exchange of experiences and best practices.

  Clusters do not always have to be established within a certain sector. Especially for shipbuilding the exchange of experience between the shipbuilding industry and other related industries (metalworking, machine building, mechanical engineering) is relevant as the traditional delineation of the shipbuilding sector may be blurred to enhance cross-sectoral exchanges both in markets served but also in use of resources (e.g. labour, skills, R&D and technologies). In view of the markets served, in future newbuilding of ships does not necessarily have to remain the core of the shipbuilding industry. In regions and segments where newbuilding is the not the primary market anymore, clustering could focus on serving segments like repair/maintenance, oil & gas services, etc.

  The introduction of eco-industry players[210] (think of providers of air pollution control, waste treatment systems or recycling) in existing clusters and value chains also deserves support. An earlier study found that introducing eco-industry players in existing value chains can have major impacts on the innovative and greening potential of European industry.[211] Again, industry players may not know the relevant eco-industry players and governments at all levels can help to build platforms and facilitate the exchange. At the EU level, the Waterborne Technology Platform could play such a role – now and in the future.

- **Education and training** possibilities and knowledge transfer mechanisms contribute to an improved influx of workers and mobility between sectors. Several parts of the industry however face ageing workforces or require knowledge building to be able to successfully shift to new market segments. Therefore, continued promotion of the shipbuilding and marine equipment sectors as attractive work places, both for students choosing certain studies and entering the labour market, and for experienced staff in related (land-based) sectors, is needed. Building connections to the eco-industries sector could add to this.

  With regards to the contents of curricula, awareness of the need to modify education programmes to respond to the greening needs of the industry, can be broadened. Education institutes can be encouraged to make use of R&D findings to transfer education and training schemes and to showcase the benefits of renewed technologies' introduction in existing curricula.

- Market based measures can be a strong instrument to address the necessary reduction in the emission of greenhouse gases from shipping . In this respect the European Commission has

[210] According to the OECD and Eurostat definition, the core eco-industries are "those [identifiable] sectors within which the main – or a substantial part of – activities are undertaken with the primary purpose of the production of goods and services to measure, prevent, limit, minimize or correct environmental damage to water, air and soil, as well as problems related to waste, noise and eco-systems." (Ecorys, 2009).

[211] Ecorys et al (2009) Competitiveness of the EU Competitiveness Industry. Study carried out for EC DG ENTR.

always been in favour of a global solution, but in view of the failure of the IMO to agree (market based) measures for ships already in operation by the EU's 2011 deadline, the Commission has started a public consultation. Four different routes are considered: a) an emissions trading scheme, either part of or separate from the existing ETS, b) setting up compensation funds whereby ship owners would be charged and the revenue redistributed to those affected by ships' emissions, c) a tax either on shipping fuel sold in the EU or on carbon emissions, d) emissions reduction targets for each ship[212]. Input to the consultation will feed into a proposal on reducing greenhouse gas emissions from shipping that the Commission may adopt by the end of this year.

Although the EU favours global approaches to greening local and national market based measures also contribute to raising green demand . This includes examples as the Norwegian NO_x tax/fund and environmental port dues in a growing number of EU ports. The EU could promote the use of such measures, while ensuring harmonised approaches as to keep open the opportunity for global solutions.

- Regarding **regulatory drivers**, the EU is recommended to continue its role in pleading for further steps in promoting more progressive regulation at IMO. However, within the context of this pursued global approach, a careful view on its impacts for the competitiveness of Europe's industry should be retained, also when further expanding of regionalised regulatory drivers is considered to cover a wider geographical area (e.g. a Mediterranean ECA).

- Regarding **financing of green vessels** commercial banks are to remain the primary funding sources. However, these banks seem to struggle with assessing green innovations. Many commercial banks today are faced with 'weak' ship portfolios, i.e. including ships with insufficient returns on investment to repay loans, and with relatively inefficient operating cost structures. Greening / improving fuel efficiency could contribute to reducing this burden, but does require upfront additional investments, and knowledge to assess the financial returns of such investments. Knowledge building and awareness raising within the shipping banking sector could be promoted. Possible ways are disseminating business case analysis linked to R&D projects to both ship owners and banks and setting up a market monitoring mechanism to inform banks on the directions the market is likely to go.

In addition, further green differentiation of existing publicly supported financing measures to promote green ships can be further pursued as market forces do not always fully internalise the need to reduce the environmental footprint (market failure). As a result financing of higher investments for more environment friendly vessels cannot be expected from market players alone. An example of such a tool for greening demand is the use of Export Credit facilities. The proposal of Japan in November 2011 to OECD WP6 to introduce an environmental factor into the Sector Understanding on Export Credits for Ships (SSU) in order to promote low carbon emission ships is an example. Also other criteria can be introduced (e.g. using the Clean Shipping Index). One should however be aware of the limitations of this instrument, e.g. it should not lead to a further lowering of agreed discipline in ship financing . In addition export credit budgets are limited as well.

Specific recommendations

Taking into account the above general recommendations, the following specific recommendations are made to support the three business strategies as described above.

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212 http://www.transportenvironment.org/news/shipping-heading-ets.

Support to strategy 1: Green innovation

The current **RDI strategy** needs to be maintained if not strengthened. In general, it is assessed as being effective. An emphasis on cost-efficient, yet effective solutions serves the future competitiveness of Europe's shipbuilding industry strongest. It is advised to maintain a strong focus on fuel-efficient solutions as these do not only represent the largest market potential, but are also expected to remain valid for a long time, as they go beyond the need to meet regulatory deadlines, and there is much to be done before a 'zero-emission ship' is in operation commercially. Increasing fuel prices and the possible introduction of market based measures will strengthen the demand. In addition, in specific regulatory driven markets like ballast water, NO_x and SO_x emissions, the current strengths of the European industry can be enhanced by addressing implementation barriers such as the limited operational experiences with several technologies. Recommendations under this strategy are the following:

- Further improvements in RDI can be reached by a stronger attention to prototyping, demonstrators and pilot projects which could convince potential ship-owners of the effectiveness of new technologies and reduce the risk perception of ship owners. Also the role of pre-commercial procurement and green procurement by governments as launching customers could be considered in this respect. In addition to existing FP instruments the establishment of specific testing facilities that resemble real life operation should be examined (e.g. testing facilities on board of operational ships). The application of such activities should however be selective given the high costs involved and should comply with existing competition rules.

- Another recommendation would be to develop harmonised testing procedures which enable a fair comparison between different technological solutions and can create a base level of trust in the eventual performance. These procedures can be developed in cooperation with the classification societies.

- Continue environmental differentiation in innovation aid; those initiatives that are expected to have stronger impacts on greening deserve to be prioritised and/or provided with higher support levels.

Support to Strategy 2: Green Links in Value Chain

- Promote the development from components to systems. To a large extent this is a business strategy which companies should decide to follow. However, indirectly the EC, Member States or regional governments might assist in creating networks or clusters of companies which allow this development to take place, for example by inviting companies to conduct research from a systems approach (e.g. propulsion systems or other integrated systems).
- Support to maritime cluster initiatives can also strengthen value chains and their greening. Regional cooperation between shipyards, equipment manufacturers, ship owners as well as research institutes could produce results – and (local or regional) governments can help to facilitate the exchange between the stakeholders involved. The Commission's Communication entitled "Towards world-class clusters in the European Union: Implementing the broad-based innovation strategy"[213] has provided some valuable directions to raise the level of excellence and openness of clusters.

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[213] COM(2008)652.

- Promote value chain initiatives, such as found in Denmark, at a European level, for example by promoting joint R&D projects involving subsequent development steps (design, testing, validation, etc.) between marine equipment, (foreign) yards and ship-owners or promoting the establishment of global innovation networks. In Denmark for instance this seems to deliver success even though government funding input is limited, but the government's ability to bring stakeholders together is the key success factor.

Support to Strategy 3: Green Specialisation

This strategy is mainly seen as a business strategy that should be taken up by companies themselves. It implies the choice to dedicatedly operate in green niches, and may require conversion from current operations. Examples seen in the market are shipyards shifting to serving the offshore wind market by manufacturing wind turbines or components and offering support facilities for the construction of offshore wind parks. Examples of this type of conversion can be found in Poland, Ireland, Germany[214] and some other countries. It does often require up-front investments and in the cases mentioned a launching customer or take-over partner was present to allow for this. Furthermore knowledge development and the introduction of new skills is necessary (see also skills building under general recommendations above). One should note that these strategies do not guarantee success beforehand. Support may be offered in the form of:

- Specific R&D in specialised production processes for retrofitting (cost-effective and fast). In addition more complex, high value retrofits but with a clear return could be developed in Europe as this builds on the comparative strength of Europe's shipbuilding industry.

- The existing state aid rules offer possibilities to use regional aid for conversions of shipyards to new market segments outside of shipbuilding. Such projects do however require a clear assessment of the success potential of the transformation, taking account of the current assets, skills present and the ability to adapt, including the necessary access to finance.

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[214] Respectively Gdansk shipyard, Harland & Wolff, Nordseewerke.

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List of abbreviations

B2B	Business to Business
BFO	Bunker Fuel Oil
BWM	Ballast Water Management
CDM	Clean Development Mechanism
CGT	Compensated Gross Tonnage
CLT	Contracted and Loaded Tip propeller
COTS	Commercially Off The Shelf
CSR	Corporate Social Responsibility
CVT	Crew transfer vessel
DWT	Dead Weight Tonnage
ECA	Emission Control Area or Export Credit Agencies
EEA	European Economic Area
EEDI	Energy Efficiency Design Index
EEOI	Energy Efficiency Operational Index
EEZ	Exclusive Economic Zone
EGR	Exhaust Gas Recirculation
ESI	Environmental Ship Index
ETP	European Technology Platform
FP7	Seventh Framework Programme
GHG	Greenhouse Gas
GT	Gross Tonnage
GW	Giga Watt
HFO	Heavy Fuel Oil
IFO	Intermediate Fuel Oil
IMO	International Maritime Organisation
IPR	Intellectual Property Rights
IWT	Inland Waterway Transport
LDC	Least Developing Countries
LNG	Liquid Natural Gas
MACC	Marginal abatement cost curves
MBM	Market Based Measure
MDO	Marine Diesel Oil
MGO	Marine Gas Oil
MIF	Maritime Industries Forum
MOU	Memorandum of Understanding
MS	Member State

MW	Mega Watt
NECA	NOx Emission Control Area
OECD	Organisation for Economic Co-operation and Development
OPS	Onshore power supply
OTEC	Offshore thermal energy conversion
PID	Propulsion improving devices
PM	Particulate Matter
R&D	Research and Development
RDI	Research, development and Innovation
RoRo	Roll-on Roll-off
RPS	Renewable Portfolio Standards
SCR	Selective Catalytic Reduction
SECA	SOx Emission Control Area
SECT	Ship Efficiency Credit Trading System
SEEMP	Ship Energy Efficiency Management Plan
SFOC	Specific Fuel Oil Consumption
SIDS	Small Island Developing States
SME	Small and Medium sized Enterprises
SSU	Sector Understanding on Export Credits for Ships
SWOT	Strengths, Weaknesses, Opportunities and Threats analysis
UNFCCC	United Nations Framework Convention on Climate Change
WTO	World Trade Organisation

Annex 1 Interview guidelines

Main objective and scope of the study

The EU shipbuilding industry, comprising yards as well as marine equipment suppliers, is considerably affected by greening trends coming from inside as well as outside the industry. The European Commission has issued a study with the main objective:

> *to identify the market opportunities for the EU shipbuilding industry that may arise from greening trends in shipping and other areas.*

The EC wants to obtain a clear picture on where opportunities and green innovations are to be expected for Europe and how green technology innovations take place in the industry, in order to better tailor future policies to facilitate such opportunities.

Green growth market opportunities are understood as arising from both policy- and technology-driven greening trends within the shipbuilding sector, as well as from greening trends outside the shipbuilding sector but are directly relevant to it (e.g. increased demand for ships used for constructing offshore wind parks). The study focuses on the ability of EU shipbuilding industry to grasp the economic opportunities arising from this greening trend in industry and decarbonisation-of-transport strategy.

The analysis includes both shipyards and marine equipment suppliers. Both new-building and retrofitting are considered. Given the focus on green growth opportunities, the study focuses on the commercial shipping market and does not go into an in-depth analysis of naval shipbuilding. The study thus focuses on the entire commercial shipbuilding value chain in the EU. In addition, four focus areas have been selected for which some more in-depth analysis will be performed as illustration: passenger ships, offshore vessels, dredgers, NO_x emission control equipment. Specific developments in green innovation for these groups are assessed as well as potential differences between segments.

Why we want to talk to you

Greening and innovation takes place mainly in the industry itself. That is why we want to hear from you what you vision is on greening opportunities for the sector. We would appreciate your opinion on: the areas in which you see most potential for the future, the level of competitive pressure from outside Europe in these areas, recent developments in green technology innovation (processes), hurdles to implementation of green measures, the effect of legislation on your business, etcetera.

The study is mainly based on gathering views from the industry itself, thereby bringing together the most recent developments ongoing and market expectations that industry leaders express. This is aimed at players at various positions in the value chain, including shipyards, marine equipment manufacturers, developers, owners and operators.

Main interview topics - general

The following questions and bullets give a general indication of the topics we would like to discuss with you. Depending on your specific scope of work, these items will of course be tailored.

General company information

- Main products;
- Main clients, suppliers & markets;
- Main competitors, important players ;
- Position in the value chain & cooperation within the chain.

EU shipbuilding trends & developments: context

- Main factors determining the activities EU shipbuilding sector in the next 10 years;
- Major environmental issues the sector is dealing with at the moment;
- Role of green technology / innovation for competitive position EU shipbuilding sector vis-à-vis Rest of World;
- Main innovations that were introduced in the last 3 years and the origin/impact of those innovations.

Trends & developments in the Greening of Technologies in the EU shipbuilding sector

- Main *green innovations* in EU shipbuilding
    - historic, current and future;
- (Green) innovation process in EU shipbuilding sector
    - Innovation in shipyards vs. marine equipment suppliers;
    - Importance of cooperation along the value chain (clusters);
    - The innovation management process;
    - Role of SMEs, research institutes ;
    - Types of innovation:
        - product, process, retrofitting;
        - Incremental versus breakthrough innovation;
    - Technology transfer from other sectors;
- Drivers of green innovation
    - Policy-driven innovation (e.g. environmental legislation);
    - Demand-driven innovation (e.g. intrinsic strategic product improvements);
    - Other exogenous factors (e.g. raw material prices);
- Green innovation in EU vs RoW
    - International competition on similar technologies;
    - Specific regional niches;
    - Drivers of innovation EU vs. RoW;
    - Role of innovations taking place outside the EU shipbuilding sector;
    - Role of platform technologies;
- Factors influencing success / posing hurdles for green innovations in EU
    - Development of state-of-the art technologies;
    - Implementation of state-of-the art technologies;
    - (Dis)incentives along value chain for green innovation (risk management);
    - Importance of reputation;

Policy framework

- R&D and innovation aid (EU and national);
- Transnational innovation cooperation (e.g. Waterborne Technology Platform);
- International access to markets;
- IPR issues;
- Access to finance;
- Access to knowledge;

- Access to labour and/or other resources;
- Standards & classification;
- Any other issues?

Annex 2 Stakeholders consulted

Interviews conducted

The table below presents an overview of companies and organisations interviewed for the purposes of this study.

No.	Organisation	Date of interview
1	**Boskalis**	9 June 2011
2	**Cargotec UK Limited**	7 June 2011
3	**Caterpillar**	23 May 2011
4	**Cesa**	15 April 2011
5	**Couple Systems**	6 June 2011
6	**Damen**	3 May 2011
7	**ECSA**	28 April 2011
8	**EuDA**	20 April 2011
9	**Hamworthy**	21 June 2011
10	**IHC/MTI Holland**	18 April 2011
11	**Imtech Gernany**	7 June 2011
12	**Imtech Marine & Offshore (HQ, The Netherlands)**	1 July 2011
13	**MARIN**	12 April 2011
14	**Meyer Werft**	27 May 2011
15	**Multronic**	17 May 2011
16	**Koninklijke Niestern Sander**	27 May 2011
17	**Becker Marine Systems**	24 May 2011
18	**Det Norske Veritas**	24 May 2011
19	**Hamworthy**	25 May 2011
20	**Kongsberg Maritime**	24 May 2011
21	**Navalimpianti – Tecnimpianti**	24 May 2011
22	**Rolls Royce Marine AS**	25 May 2011
23	**SkySails**	24 May 2011
24	**Gdansk Shipyard**	25 May 2011
25	**GICAN**	25 May 2011
26	**Siemens AS**	25 May 2011
27	**Rolls Royce Marine (RRM)**	27 June 2011
28	**Sam Eletronics**	6 June 2011
29	**Scheepsbouw Nederland**	12 April 2011
30	**Society of Maritime Industries (SMI)**	24 May 2011
31	**Van Oord**	2 May 2011
32	**VDMA**	7 June 2011
33	**Verband fuer Schiffbau und Meerestechnik (VSM)**	6 June 2011
34	**Wartsila**	4 May 2011
35	**Germanischer Lloyd**	6 June 2011
36	**Converteam**	23 June 2011
37	**Stone Marine**	7 July 2011

Indirectly, the consultant made use of information obtained through interviews conducted under other assignments. These included a number of ship owners.

Indirectly, the consultant made use of information obtained through interviews conducted under other assignments but with partly similar subjects. These included:

Six shipping companies with fleets of:
1. Container ships and bulk carriers;
2. Container, Chemical, VLOC and PCTC ships and bulk carriers;
3. Cruise ships;
4. Heavy Lift and Multi-Purpose ships;
5. Bulk carriers, Multi-Purpose vessels and RoRo carriers;
6. Crude oil and product tankers.

Additionally, seven other maritime stakeholders were interviewed covering:
1. A shipyard, mainly for cruise liners;
2. A classification society;
3. An institute for maritime engineering;
4. An international shipping federation;
5. A maritime research institute;
6. An independent international shipping association;
7. A manufacturer of an innovative technology.

The results of these interviews are reported in CE Delft and Marena, 2012.

Workshops
Two workshops were held within the context of this study. The first workshop, held on 26 September 2011 with 17 participants in Hamburg mainly targeted industrial companies and aimed at identifying possible barriers for reaping the market potential.

The second workshop was held in Brussels on 18 January 2012 and aimed at industry associations and their members. 33 participants were present.

Annex 3 Calculation of CO_2 reductions market potential

The EEDI regulation

In July 2011, the Marine Environmental Protection Committee of the International Maritime Organisation has adopted the Energy Efficiency Design Index (EEDI) which enters into force in 2013. The EEDI sets a relative CO_2 design standard for new ships.

Required reduction levels depend on the type and the size of a ship. In the first phase (from 2015 on) reduction levels are max. 10% of the reference efficiency and will be tightened every five years (see Table 0.1 for an overview on the reduction factors in the different phases).

Currently, the EEDI regulation does not apply to all ship types and sizes. For some ship types an adequate way of calculating the attained EEDI has not been established yet.

Also exempted from the regulation are ships that are used for transport in waters of one flag state only and ships with diesel-electric propulsion, turbine propulsion, or hybrid propulsion system.

In order to address concerns raised by developing countries, the regulations allow any Administration to waive the EEDI requirements for ships flying its flag for a time period of up to four years (linked to contract date) or six years and six months (linked to delivery date) after 1 January 2013.

Ships can comply with the EEDI regulation by reducing main engine power with the help of innovative mechanical energy efficient technologies and/or by reducing of auxiliary engine power with the help of innovative electrical energy efficient technologies.

Table 0.1 Reduction factors (in percentage) for the EEDI relative to the EEDI Reference line

		Phase 0	**Phase 1**	**Phase 2**	**Phase 3**
Ship Type	**Size (dwt)**	Jan. 2013- Dec. 2014	Jan. 2015- Dec. 2019	Jan. 2020- Dec. 2024	Jan. 2025 onwards
Bulk carrier	20,000 and above	0	10	15	30
	10,000-20,000	n/a	0-10*	0-15*	0-30*
Gas carrier	10,000 and above	0	10	15	30
	2,000-10,000	n/a	0-10*	0-15*	0-30*
Tanker	20,000 and above	0	10	15	30
	4,000-20,000	n/a	0-10*	0-15*	0-30*
Container ship	15,000 and above	0	10	15	30
	10,000-15,000	n/a	0-10*	0-15*	0-30*
General Cargo ships	15,000 and above	0	10	15	30
	3,000-15,000	n/a	0-10*	0-15*	0-30*
Refrigerated cargo	5,000 and above	0	10	15	30
	3,000-5,000	n/a	0-10*	0-15*	0-30*
Combination	20,000 and above	0	10	20	30

		Phase 0	Phase 1	Phase 2	Phase 3
carrier	4,000-20,000	n/a	0-10*	0-15*	0-30*

Reduction factor to be linearly interpolated between the two values dependent upon vessel size. The lower value of the reduction factor is to be applied to the smaller ship size.
n/a: no required EEDI applies

Estimation of the market potential induced by the EEDI

The main difficulty that one faces when estimating the market potential of CO_2 reduction measures induced by the EEDI, is the fact that not for all reduction measures cost data is available. The estimation is therefore restricted to the technical reduction measures for which we have cost data from earlier work on CO_2 marginal abatement cost curves for maritime shipping[215]. These are the following measures:

- Propeller and rudder upgrade;
- Propeller upgrade (only);
- Propeller boss cap fins;
- Optimisation of water flow (e.g. with respect to transverse thruster openings);
- Main engine tuning;
- Common rail technology upgrade;
- Low energy/low heat lighting;
- Speed control of pumps and vans;
- Power management system;
- Towing kites;
- Wind engines (Flettner rotors);
- Solar cells;
- Waste heat recovery;
- Air lubrication system;
- Speed reduction of 10% or 20%.

For these measures we estimated the market potential as follows:

1. We base our estimation on the global fleet data that is available in the Second IMO Greenhouse Gas Study (IMO 2009). Here a fleet inventory is given for 2007 as well as fleet projections for 2020 and 2050;
2. We assume that the 2007 CO_2 emissions as reported in IMO (2009) are the baseline emissions to which the EEDI reduction factors as reported in Table 0.1 have to be applied. In Table 0.2 an overview is given as to how we allocated the reduction factors to the ship type and size categories as given in IMO 2009;
3. Since the EEDI applies to new ships only, fleet growth and fleet renewal are important determinants for the market potential. Fleet growth is assumed to be as given in IMO (2009). As to the fleet renewal we assume that in 2007 ships are evenly distributed with respect to their age and since the life time of a ship can be assumed to be 30 years on average, 1/30 of the 2007 is assumed to be scrapped and renewed each year until 2037;
4. We assume that no administration will waive the EEDI requirements;
5. As to the demand for the CO_2 reduction measures, we assume that the measures are applied in the order of their cost efficiency until the required reduction level is reached;
6. When slow steaming is applied, we assume that the loss of the productivity is compensated for by the use of new ships. The purchase costs for these extra ships are included in the market potential estimate.

[215] IMO 2010, CE Delft et al. 2009, IMO 2009.

Table 0.2 Allocation of the EEDI reduction factors to the ship type and size categories of IMO (2009)

EEDI induced reduction		Phase 0	Phase 1	Phase 2	Phase 3
		Jan. 2013-Dec. 2014	Jan. 2015-Dec. 2019	Jan. 2020-Dec. 2024	Jan. 2025 onwards
Crude oil tanker	200,000+ dwt	0%	10%	15%	30%
Crude oil tanker	120-199,999 dwt	0%	10%	15%	30%
Crude oil tanker	80-119,999 dwt	0%	10%	15%	30%
Crude oil tanker	60-79,999 dwt	0%	10%	15%	30%
Crude oil tanker	10-59,999 dwt	0%	0-10%	0-15%	0-30%
Crude oil tanker	-9,999 dwt	0%	0%	0%	0%
Product tanker	60,000+ dwt	0%	10%	15%	30%
Product tanker	20-59,999 dwt	0%	10%	15%	30%
Product tanker	10-19,999 dwt	0%	0-10%	0-15%	0-30%
Product tanker	5-9,999 dwt	0%	0-10%	0-15%	0-30%
Product tanker	-4,999 dwt	0%	0%	0%	0%
Chemical tanker	20,000+ dwt	0%	10%	15%	30%
Chemical tanker	10-19,999 dwt	0%	0-10%	0-15%	0-30%
Chemical tanker	5 -9,999 dwt	0%	0-10%	0-15%	0-30%
Chemical tanker	-4,999 dwt	0%	0%	0%	0%
LPG	50,000+ cbm	0%	10%	15%	30%
LPG	-49,999 cbm	0%	4%	7%	13%
LNG	200,000+ cbm	0%	10%	15%	30%
LNG	-199,999 cbm	0%	10%	15%	30%
Bulker	200,000+ dwt	0%	10%	15%	30%
Bulker	100-199,999 dwt	0%	10%	15%	30%
Bulker	60-99,999 dwt	0%	10%	15%	30%
Bulker	35-59,999 dwt	0%	10%	15%	30%
Bulker	10-34,999 dwt	0%	0-10%	0-15%	0-30%
Bulker	-9,999 dwt	0%	0%	0%	0%
General cargo	10,000+ dwt	0%	10%	15%	30%
General cargo	5,000-9,999 dwt	0%	0-10%	0-15%	0-30%
General cargo	-4,999 dwt	0%	0%	0%	0%
General cargo	10,000+ dwt, 100+ TEU	0%	10%	15%	30%
General cargo	5,000-9,999 dwt, 100+ TEU	0%	0-10%	0-15%	0-30%
General cargo	-4,999 dwt, 100+ TEU	0%	0%	0%	0%
Other dry cargo	Reefer	0%	10%	15%	30%
Other dry cargo	Special	0%	10%	15%	30%
Container vessel	8,000+ TEU	0%	10%	20%	30%
Container vessel	5 -7,999 TEU	0%	10%	20%	30%
Container vessel	3 -4,999 TEU	0%	10%	20%	30%
Container vessel	2 -2,999 TEU	0%	10%	20%	30%
Container vessel	1 -1,999 TEU	0%	10%	20%	30%

EEDI induced reduction		Phase 0	Phase 1	Phase 2	Phase 3
		Jan. 2013- Dec. 2014	Jan. 2015- Dec. 2019	Jan. 2020- Dec. 2024	Jan. 2025 onwards
Container vessel	-999 TEU	0%	0-10%	0-15%	0-30%

Global market potential induced by the EEDI

In Table 0.3 an overview is given on the estimated global market potential for cost-efficient CO_2 reduction measures on board ships as induced by the EEDI, including additional ship capacity as a response to speed reduction measures.

The average annual market potential rises over time from around 3 billion Euro in the period 2015-2019 to around 10 billion in the period 2025-2030. The average annual market potential rises over time due to an increasing world fleet, as well as due to a tightening of the EEDI reduction levels over time.

The total market potential in the period 2015-2030 is estimated to lie in a range of 112 – 124 billion Euro.

Table 0.3 Global market potential for CO_2 reduction measures induced by EEDI (billion Euro)

Period	Total potential per period	Cumulative potential	Average annual potential per period
2015-2019	14-16	14-16	3
2020-2024	42-46	56-62	9
2025-2030	56-62	112-124	10

It is important to notice that the market potential as derived here is a maximum market potential in the following sense: The market potential has been calculated, assuming that the above mentioned reduction measures are applied in the order of their cost effectiveness. However, some of these measures might not be applied in practice. Some of the measures may not get approved by the IMO to be used for the EEDI; currently there is still some regulatory uncertainty in this respect. In addition, the sector may be reluctant to apply innovative technologies that currently are not widely used, being sceptical about the reduction potential that these measures might actually yield. The sector might therefore choose to widely make use of speed reduction by installing engines with less power. This would reduce the market potential significantly.

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