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**ENCOURAGING CONSTRUCTION AND OPERATION OF 'GREEN SHIPS'**

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# FOREWORD

This report was prepared for the Council Working Party on Shipbuilding (WP6) by Det Norske Veritas (DNV), to aid the WP6's discussions regarding shipbuilding and the environment. WP6 delegates discussed the report at their meeting on 28 November 2013 and agreed to declassify the report so that it could be made available to a wider audience.

The views expressed are those of the consultant and do not necessarily represent the views of the OECD or the WP6.

DET NORSKE VERITAS™

# Report

# ENCOURAGING CONSTRUCTION AND OPERATION OF 'GREEN SHIPS'

## OECD

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# EXECUTIVE SUMMARY

The Council Working Party on Shipbuilding (WP6 ) of the Organization for Economic Co-operation and Development (OECD) has commissioned DNV to undertake the project 'Encouraging construction and operation of green ships'. The objective is to improve the understanding of what actions may be available to governments to encourage reduction of $CO_2$ emissions from ships, including both new builds and ships in operation.

Ships in international trade are responsible for approximately 3% of total anthropogenic $CO_2$ emissions. While considerable efforts are being made to reduce emissions from the industry, both by industry actors and by regulators, further efforts are likely needed for shipping to achieve the emission reductions needed to meet the global target of limiting warming to 2°C.

This study examines five specific policies that governments could implement to complement existing and planned international regulation and industry initiatives, based on a prioritisation by the WP6 from an initial list of 15 policies. Policies related to IMO work and other regional and command-and-control schemes are excluded from the analysis in this study.

We find that there is a significant potential for governments to influence developments in shipping emissions, either directly through policy incentives, but also through signal effects and standards which other parts of the industry can use. Many policy options are available at low cost, and there are probable substantial benefits from cooperation and coordination between governments on policy measures. There is no one solution that would move the ship building industry towards more efficient ships, but rather a portfolio of measures. Even then, the effect will only be seen over time.

The following key observations can be made regarding the five policies evaluated:

- Option A, *Bunkering infrastructure*, has the greatest potential when looking at the total $CO_2$ emission reduction.

- Option E, *Ship $CO_2$ performance requirements in public procurement* has the highest potential when it comes to advancing and maturing promising technologies. Directly this will only influence ships that are publicly procured and operated but will over time impact other ships.

- The three other policies are evaluated to have low to moderate direct effect, but can have important signal effects (*Policy B: Energy efficiency as a criterion for governmental financial institutions, Policy C: Targeted research and development support including large scale testing, Policy D: Differentiated port fees based on energy efficiency rating*).

# LIST OF ABBREVIATIONS

| | |
|---|---|
| **ECA** | Emission Control Area |
| **EEDI** | Energy Efficiency Design Index |
| **EEOI** | Energy Efficiency Operational Indicator |
| **GHG** | Greenhouse gas |
| **HFO** | Heavy fuel oil |
| **IMO** | International Maritime Organisation |
| **MEPC** | Marine Environment Protection Committee |
| **LNG** | Liquefied natural gas |
| **MGO** | Marine Gas Oil |
| **MRV** | Monitoring, reporting, and verification |
| **SEEMP** | Ship Energy Efficiency Management Plan |

# INTRODUCTION

Ships in international trade are responsible for approximately 3% of total anthropogenic $CO_2$ emissions. While considerable efforts are being made to reduce emissions from the industry, both by industry actors and by regulators, further efforts are likely needed for shipping to achieve the emission reductions needed to achieve the global target of limiting warming to 2°C.

The Council Working Party on Shipbuilding (WP6[1]) of the Organization for Economic Co-operation and Development (OECD) has commissioned DNV to undertake the project 'Encouraging construction and operation of *green ships*'.

The goal of the project is to improve understanding of what actions may be available to governments to encourage reduction of $CO_2$ emissions from ships, including both new builds and ships in operation. This report will focus on reduction of $CO_2$ emissions from ocean-going vessels (international shipping), and on the operational phase of a ship's life.

Competition in the shipbuilding sector has, for many years, been distorted by excessive government subsidies and unfair competitive practices. It is considered important that the policies put in place to promote 'green shipping' do not distort competition in the shipbuilding industry by unfairly favouring the industry of any given nation.

The report is structured as follows:

- Section 1 provides an overview of shipping emissions, and the existing market and policy drivers in place to encourage reduction in vessels' $CO_2$ emissions.
- In Section 2 the rationale for further government intervention in this area is outlined, including an overview of barriers to uptake of green practices and technologies.
- In section 3 a set of possible new policies is presented and discussed. The analysis takes the approach to give a broad sweep of the key analytical questions and some issues that arise.
- Section 4 presents the conclusions of this analysis.

It should be noted that the views expressed herein are those of DNV, although comments to the work have been received from the OECD Secretariat and WP6 delegates. As such, the report should not be seen as WP6 policy recommendations but as advice from an independent consultant.

[1] The WP6 group: Australia, Denmark, Finland, Germany, Greece, Italy, Japan, Korea, Netherlands, Norway, Poland, Portugal, Spain, Sweden and Turkey. Croatia and Romania are Associates in the Working Party, and Russia is a Participant. The European Commission, representing the European Union, also participates in WP6 meetings http://www.oecd.org/sti/ind/shipbuilding.htm.

# 1 CURRENT SHIPPING EMISSIONS AND EXISTING POLICY

## 1.1 Current $CO_2$ emissions from the maritime industry

Shipping is an integral component in world trade; Shipping accounts for 70-80% of global trade volumes (Hoffmann and Kumar, 2003; Rodrigue et al., 2006). This trade is carried by the world's merchant fleet which, as per January 2012, consisted of 104 305 ships above 100 gross tons (GT) (UN, 2012).

Shipping is responsible for approximately 3% of total anthropogenic $CO_2$ emissions, predominantly via fuel consumption. Emissions of $NO_x$ and $SO_x$ are also substantial, in the range of 10-15% and 4-9% of global anthropogenic emissions, respectively (Corbett and Köhler, 2003; Endresen et al., 2003; Eyring et al., 2010; Dalsøren et al., 2009; Buhaug et al., 2009). Shipping is therefore regarded as a significant contributor to global emissions. The cargo carrying ship segments bulk carriers, container vessels and oil tankers account for 49% of the total fuel consumption of the world fleet (Dalsøren et al. 2009). Non-cargo carrying ships such as offshore service and fishing vessels consume around 15% of total fuel consumption, and general cargo vessels account for the rest of marine fuel consumption. It is estimated that 5% of shipping emissions are emitted in port (Dalsøren et al. 2009). It is noted that life cycle analysis has shown that the $CO_2$ emissions of a vessel (in this case a 35 000 GT Ro-Ro passenger vessel) are 97% in the operational phase, while the remaining 3% are accounted for by emissions during scrapping, maintenance, and building (Johnsen et al., 2000). A similar study for an oil tanker presented $CO_2$ emissions of 98.4% in the operational phase, while construction represented only 1.4% and recycling 0.1% (Japan, 2011). The impacts of shipping emissions are multiple, with effects on climate, human health and the environment (see reviews by Eyring et al., 2010; Endresen et al., 2008; Buhaug et al., 2009).

Emissions from shipping have grown substantially in the past decades (Eyring et al. 2005a, Endresen et al. 2007). The reason is that the growth in demand is outpacing the growth in efficiency. Figure 1-1 presents the average efficiency of the four main ship segments. It can be seen that the efficiency of ships has increased over time, this being due to effects of scale, speed and technology. The various segments of the world cargo fleet have different $CO_2$ emissions efficiencies, general cargo being in general the least efficient while bulk ships being the most efficient.

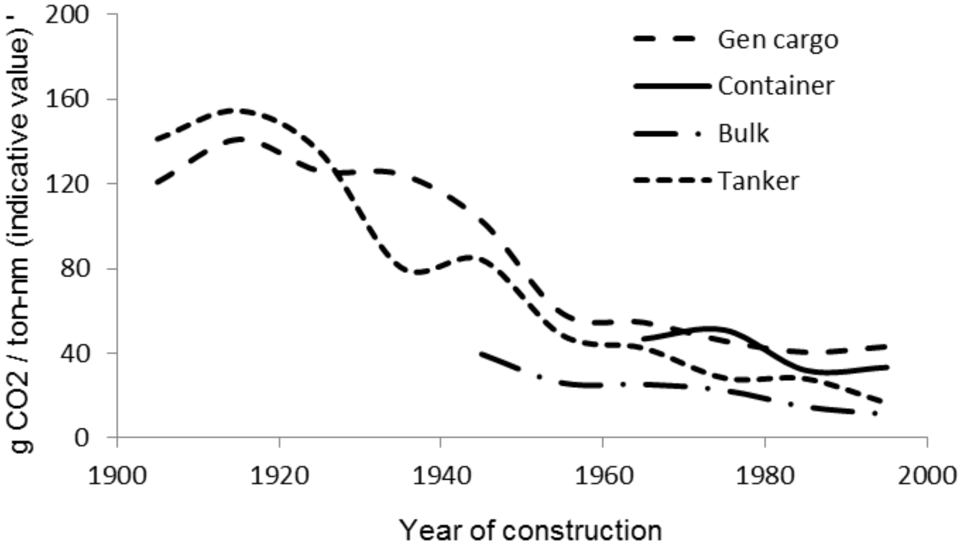


**Figure 1-1: Average ship efficiency measured in $CO_2$ emissions (g) per transport work (ton-nm). Source: (Buhaug et al., 2009).**

Furthermore, scenarios for future shipping activities indicate a potential for significant increases in energy consumption and emissions. Scenarios towards 2050 for $CO_2$ emissions from shipping have been made by the Second IMO GHG study (Buhaug et al., 2009), by Eyring at al. (2005b) and in the QUANTIFY project (Eide et al., 2007). The different scenarios combine varying growth rates and varying assumptions on uptake of emission reduction technologies. In general, all scenarios point to a growth in the future fleet and shipping activity and most scenarios indicate an increase of $CO_2$ emissions. Scenarios with flat $CO_2$ emission trajectories are also presented, but it is noted that these assume low fleet growth and a 25% reduction in fuel consumption. A compilation by UNEP (2011) shows that the emissions in 2050 range from 1.25 Gt to just above 3.5 Gt $CO_2$, compared to current emissions of approximately 1 Gt.

## 1.2 Current policy frameworks for encouraging "green ships"

While, as presented in the previous section, scenarios for future shipping activities indicate a significant increase in $CO_2$ emissions, to date, these emissions have been largely unregulated, both at the regional and international level. This section presents the policy frameworks currently in use for reducing $CO_2$ emissions from shipping.

### 1.2.1 IMO regulations

To reduce emissions of greenhouse gases from international shipping, IMO's Marine Environment Protection Committee (MEPC) has developed the Energy Efficiency Design Index (EEDI), the Ship Energy Efficiency Management Plan (SEEMP) and the Energy Efficiency Operational Indicator (EEOI). The first international regulations to reduce $CO_2$ emission from shipping, EEDI and SEEMP, entered into force on 1 January, 2013.

Being a measurable method for determining the energy efficiency of a ship, the EEDI compares theoretical $CO_2$ emissions and transport work of a ship. Adopted at MEPC 62 in July 2011 as an amendment to MARPOL Annex VI, the EEDI entered into force 1 January 2013 as a mandatory requirement, requiring a minimum energy efficiency level for new ships. The EEDI will as such stimulate continuous technical development of fuel efficient ships. At the same time it enables a comparison of the energy efficiency of individual ships to similar ships of the same size and ship type.
The EEDI is based on a formula for calculation of ship specific emissions of $CO_2$. The result for each ship, which is to be based on design documentation and engine performance, is expressed in grams of $CO_2$ per capacity-mile. The attained EEDI for a specific ship must be less or equal to the required EEDI, expressed by reference lines developed by IMO for each ship type. Recognised Organisations (e.g. Class Societies) verify EEDI compliance on behalf of flag states. The EEDI reference lines will become more stringent with time as reduction factors are planned to be applied in different phases starting in 2013. Additional ship types are also to be included (e.g. RoRo and cruise vessels).

The SEEMP provides an approach for monitoring ship and fleet efficiency performance over time, and encourages the ship owner, at each stage of the plan, to consider new technologies and practices when seeking to optimise ship performance. The SEEMP became mandatory for both new and existing ships on 1 January 2013. There are no specific requirements for approval of a SEEMP, other that it must be present on board the ship at the time of survey. The implementation of SEEMP is expected to increase the level of awareness and, if implemented properly, will lead to a positive cultural change. However, and in view of the lack of regulatory requirements for target setting and monitoring, SEEMP effectiveness may need to be stimulated or incentivised via other initiatives (Bazari and Longva, 2011).

The EEOI is an initiative for monitoring fuel consumption and $CO_2$ emissions for ships in operation. The EEOI is a voluntary tool only and will not be made mandatory. However, it is a recommended part of the Ship Energy Efficiency Management Plan. Like the EEDI, the EEOI is expressed in gram $CO_2$ emitted per capacity of cargo transported over the distance of one nautical mile (e.g. gram $CO_2$/ton-mile). As opposed to the EEDI, its calculation is based on the real fuel consumption, cargo load and sailed distance of the vessel and is typically calculated on a daily basis.

The expected effect of the mandatory mechanisms SEEMP and EEDI have been estimated by Bazari and Longva (2011). Figure 1-2 presents the historic $CO_2$ emissions from international shipping (Buhaug, 2009), a projection of future emissions if no regulation were to be implemented or “business as usual”, and the estimated future emissions including the effects of the EEDI and the SEEMP (Bazari and Longva, 2011). The future emissions with MARPOL are based on a scenario with low SEEMP uptake and high fuel prices (scenario B2-2) from (Bazari and Longva, 2011).

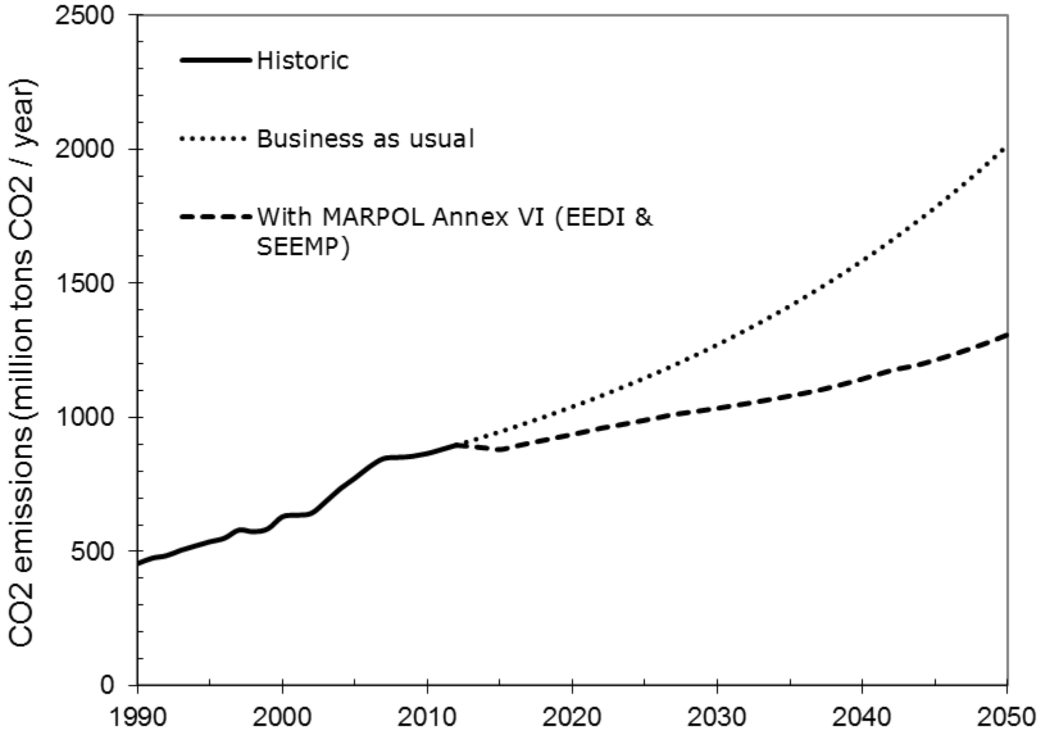


**Figure 1-2: $CO_2$ emissions from international shipping, 1990-2050 (data from Buhaug et al. 2009 and Bazari and Longva 2011).**

### 1.2.2 National and regional initiatives

There are few national initiatives that encourage green ships, and not all initiatives are shipping specific. In 2015, transportation fuel will be included in California's emissions trading programme.[2] The European Union has for the time being deferred its possible regional market-based measure for GHG emission reduction from shipping, instead focusing on initially developing a mechanism for regional monitoring, reporting and verification (MRV) of emissions. This is likely to come into effect around 2018. In October 2012, Japan introduced a carbon tax on fossil fuels.[3] Norway also has a $CO_2$ tax on fossil fuels, including marine fuels[4].

[2] http://www.c2es.org/us-states-regions/key-legislation/california-cap-trade
[3] http://www.env.go.jp/en/policy/tax/env-tax.html
[4] http://www.regjeringen.no/nb/dep/fin/tema/skatter_og_avgifter/The-history-of-green-taxes-in-Norway.html?id=418097

# 2 ADRESSING THE $CO_2$ CHALLENGE THROUGH FURTHER POLICY ACTION

Considering projections for fleet growth and existing policy measures, the previous section suggests emissions are likely to continue to grow, or stabilise at best. This must be seen in light of a UN target of limiting global temperature increases to 2°C, which will require more than stabilising emissions at present levels. To achieve this target, global emissions in 2050 must be lowered to 40% of 2010 levels or less (UNEP, 2011). More precisely, for global temperatures to have a greater than 66% probability to stay below 2°C, emissions in 2050 should be lower than 21 billion metric tonnes of $CO_2$ equivalent ($GtCO_2e$), 40% of 2010 levels (UNEP, 2011). A key question is: how can governments encourage the shipbuilding and shipping industries to build and operate ships with lower operational $CO_2$ emissions?

To understand how policy can further reduce emissions, one must first understand the technical potential for reducing emissions. Secondly one must understand the drivers which will affect the fulfilment of these technical potentials, as well as the barriers which can discourage uptake.

## 2.1 The technical potential for reducing emissions

There is a significant potential for future reduction of $CO_2$ emissions from ships as the $CO_2$ abatement options available are many and diverse. A variety of technologies are available, or under development, to improve both the design and the operational energy efficiency of a ship (Skjølsvik et al., 2000; Buhaug et al. 2009; Eide et al., 2009a; 2011; UNEP, 2011; Eide et al. 2013). Technical measures include improving the ship design, propulsion and machinery of a ship while operational measures focus on its speed and voyage, among other factors. Alternative fuels such as LNG and biofuels are also important options.

Several studies have documented the potential for $CO_2$ emissions reduction in shipping and the associated cost levels in an effort to support decision-making (Buhaug et al., 2009; Eide et al., 2009a; 2011; Wang et al., 2010; Hoffmann et al., 2012; Eide et al. 2013; Faber et al.,2011). Eide et al. (2011) demonstrated that there is a range of operational and technical abatement measures which can be implemented cost-effectively (Figure 2-1). The figure shows the average cost-effectiveness of 25 different measures when applied across the fleet. The measures with negative cost-effectiveness will in principle generate a net profit over the lifetime of the ship, as the net present value of the fuel cost savings will exceed the investment and operational cost of the measure. Eide et al. (2013) show that with cost-effective uptake of measures as well as LNG and biofuels, $CO_2$ emissions in 2050 could lie between 46% and 68% of the current baseline emissions.

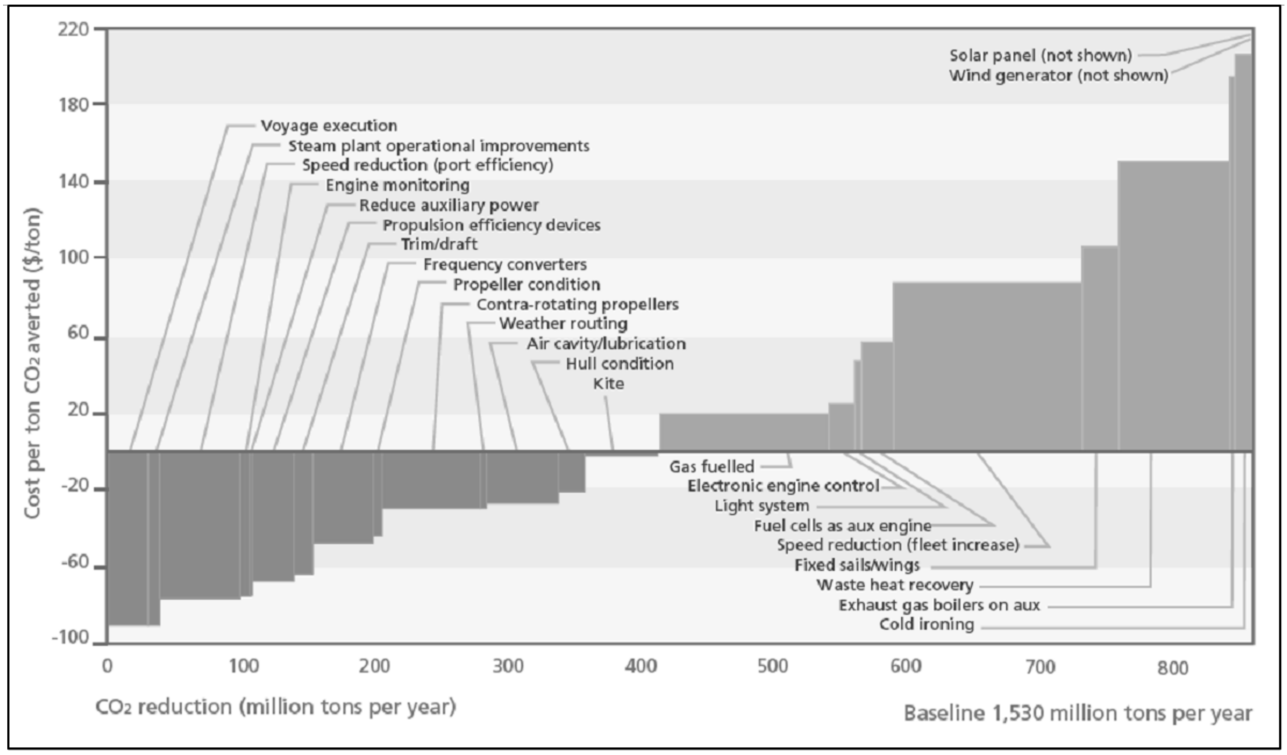


**Figure 2-1: Marginal abatement cost and emission reduction potential per $CO_2$ reduction measure for the cargo fleet in 2030. Abatement costs are averaged over all ship types. From Eide et al. (2011).**

## 2.2 Drivers for reducing operational $CO_2$ emissions

The above section clearly shows that there is a substantial potential for emission reduction. This section discusses the drivers which could lead to the materialization of this potential.

The drivers for reducing operational $CO_2$ emissions in the maritime sector can be divided into market-based and policy-based drivers. Market-based drivers lead to a behavioural change in the absence of regulatory requirements. Policy-based drivers, on the other hand, lead to a direct or indirect change in behaviour given that there is a compliance requirement (ECORYS, 2012).

### 2.2.1 Market-based drivers

The main existing market-based drivers for reducing operational $CO_2$ emissions in the maritime sector are high fuel costs and market competition.

Fuel cost is a significant operational expenditure for shipping companies. For some shipping companies, fuel costs have been shown to account for up to 60% of the total operating costs (depending on the type of ship and service, and assuming a fuel price of USD 552 per ton) (UNCTAD, 2010). Increased fuel prices and volatility over the past years have led to a focus on energy efficiency to reduce fuel costs. This is directly impacting on $CO_2$ emissions. For example, marine bunker prices (heavy fuel oil - HFO) reached a peak of USD 700 per ton in July 2008 in

Rotterdam, compared with USD 300 in January 2007 (UNCTAD 2010, 64-66). At time of writing, HFO is trading at around USD 600[5].

High fuel prices combined with a competitive market due to an overcapacity in the world fleet have been a driver to improve ships' energy efficiency and reduce fuel costs. To date, however, the shipping industry has not capitalized on the full reduction potential, despite the development of "eco ships". The barriers to uptake are further discussed in Section 2.3. Shipping companies have focused on operational measures, particularly on speed reduction, or 'slow steaming'. 43% of vessels were under slow steaming in January 2010 (UNCTAD 2010).

In the next few years, shipping companies may experience increased demands to reduce $CO_2$ emissions from charterers, banks, investors, and insurance companies. Investors are already asking for disclosure of greenhouse gas emissions and shipping companies' strategies for reducing climate risk through the Carbon Disclosure Project[6]. Investors are becoming more aware of climate risk and the materiality of environmental, social and governance (ESG) issues on financial return. Evaluating how companies manage ESG risks is seen by many investors as a fundamental part of assessing the value and performance of companies over the medium and long term, and they consider these issues in asset allocation, stock selection and portfolio construction.

A premium for energy efficient ships in the charter market may also provide incentives for improvement. All charterers prefer to use energy efficient ships to reduce fuel cost. To date there has not been a consistent premium in the market due to a limited volume of energy efficient ships. There is also a lack of transparency on fuel consumption information. This may change with the introduction of new requirements on monitoring, reporting and verification of $CO_2$ emissions. A number of rating schemes exist to rate the performance of ships[7]. Banks and insurance companies may offer better terms to shipping companies with energy efficient ships, or alternatively worse terms to companies that perform below a certain standard.

### 2.2.2 Policy-based drivers

As discussed in Section 1.2 there are currently few existing policies for reducing operational $CO_2$ emissions, but several policy instruments are being discussed at the international and regional level.

There is a consensus in IMO that additional instruments are needed to regulate $CO_2$ emissions from international shipping. Policy instruments can broadly be divided into two categories: Command-and-control instruments, such as the EEDI, and market-based instruments.

Market-based measures have been discussed as an option for further incentivising the uptake of energy efficiency measures. Market-based measures put a price on $CO_2$ emissions and provide an economic incentive to reduce fuel consumption. MBM proposals to IMO include contribution schemes for $CO_2$ emissions, to be collected and transferred to a fund, emission trading systems, and schemes based on ships' actual efficiency based on design and operation (IMO, 2013).

[5] www.bunkerworld.com
[6] www.cdpproject.net
[7] www.cleanshippingproject.se, www.dnv.com/triple-e, www.shippingefficiency.org, site.rightship.com, www.bsr.org/cleancargo, www.esi.wpci.nl, *www.greenaward.org*, *www.green-marine.org/home*

Progress on developing MBMs in IMO has been slow, and the EU has started working on its own initiative to reduce GHG emissions from international shipping. The EU Commission has proposed regulation on monitoring, reporting and verification (MRV) of $CO_2$ emissions starting 1 January 2018, pending approval from the EU Council and Parliament. Ships above 5000 GT must report $CO_2$ emissions on voyages to, from and between EU ports. The EC has indicated that this could be a first step towards a market-based measure.

The proposed MRV system could lead to increased accuracy of measuring fuel consumption and emissions, and increased transparency on emissions. This could then support ship owners documenting energy efficiency claims, which could work in conjunction with the market drivers outlined in section 2.2.1.

A US proposal (MEPC65-4-19) to the IMO on regulating GHG emissions from shipping also includes elements of an MRV system, plus additional technical and operational requirements for $CO_2$ emissions; this has seen support and elaboration by a number of developed countries. When considering the likelihood of the IMO agreeing an international MRV framework it is worth noting that developing countries have not made their positions clear and that the outcome of the IMO's consensus based process thus remains uncertain.

## 2.3 Barriers to implementing $CO_2$ emission reduction measures in the maritime industry

Although there are ways to reduce emissions (Chapter 2.1), and also drivers working towards the implementation of such measures (Chapter 2.2), there are significant barriers to acting on cost-effective opportunities in the maritime industry. This is often referred to as *barriers to energy efficiency* (Sorrell et al., 2004; Johanson, 2012; Acciaro et al., 2012). Some barriers are shared with other industries, while others are unique to the maritime industry.

It is thus important to understand what prevents actors in the maritime industry from implementing emission reduction measures, and what could incentivise actors to implement additional measures. This section presents an overview of the main barriers to energy efficiency in the shipping industry, and discusses the need for further policy action.

Barriers to energy efficiency can exist on both the supply and the demand side. For example, there could be barriers to the development and implementation of measures that reduce $CO_2$ emissions from ships, and barriers to the expression of demand for these measures (ECORYS, 2012).

Studies have, however, shown that there are relatively few barriers related to the development of new technologies and that the supply of measures exceeds the demand (ECORYS, 2012). Existing studies on barriers to energy efficiency thus focus on what prevents the uptake of available measures.

Based on a review of existing literature and own research, Acciaro et al. (2012a) categorise barriers for the uptake of energy efficiency measures in six groups, as shown in Table 2-1 below.

Table 2-1: Categorization of barriers (Accario et al., 2012a)

| | Barrier categories | Description |
|---|---|---|
| A | **Safety and reliability** | Safety relates to the risk associated with the implementation of new technologies that can potentially compromise the safety of the crew and the vessel. Reliability refers to the risk that the installed measures could affect the ship's ability to sail. |
| B | **Technical uncertainty** | Technical uncertainty includes issues related to the interaction between different ship components when new or unproved technologies are installed onboard. New measures will most often be integrated into a proven system and the interaction effects are hard to estimate. How will a change in hull shape influence the propeller efficiency or what is the operational window of a waste heat recovery system? |
| C | **Behavioural** | Behavioural barriers relate to decisions within the shipping firm and the availability of information across the organisation. The lack of information and the quality of information on different aspects of a new measure could be a barrier. Organisational maturity refers to the ability of an organisation to deal with complex technologies and the degree of development that the organisation has reached. |
| D | **Market constraints** | A common example of market constraints is split incentives due to the structure of charter parties, and how costs are split between the cargo owner and the shipping company. |
| E | **Financial and economic constraints** | Most measures require an upfront investment cost and the investment case is linked to market conditions, fuel prices etc. All cost elements are included in this category, including capital costs, operation costs, and hidden costs such as maintenance costs. A further barrier in this category may be linked to the ability of the ship owner to access capital. |
| F | **Complexity** | New technologies are often complex to install and operate. The more complex the implementation and operation of a new measure is, the more this hampers the rate of implementation. Many shipping organisations are set up to handle normal day to day operations and any added complexity will be seen as a burden. |

Acciaro et al. (2012a) finds that uncertainty related to the effectiveness and the costs of new measures are the most relevant factors for deciding on implementing a new technology. Financial and economic constraints are identified as the key barrier. Also, the potential impact on crew safety and ship reliability were identified as key barriers.

This is seconded in ECORYS (2012), arguing that a short payback time used in making investment decisions prevents the introduction of investments that would be justified through a lifecycle cost approach.

The expected fuel price is a significant driver for demand for abatement measures. ECORYS notes that fuel price uncertainty makes it difficult to assess payback time, resulting in a reluctance to invest (ECORYS, 2012). Operational measures such as speed reduction and voyage performance are thus often preferred by shipping companies.

It is also noted by Acciaro et al. (2012a) that in order to correctly assess the barriers related to a specific measure it is important to investigate that measure in a company context, as a company's perception of barriers and its specific operating conditions will also impact the uptake of measures. Acciario et al. (2012a) find that the average perceived barrier level for the specific technologies correlates with the degree of familiarity that the respondents have with the measure, and with the perceived higher suitability for implementation in the respondents' companies.

## 2.4 Reducing barriers

The identified barriers are diverse and overcoming them requires a range of different strategies. Acciaro et al. (2012b) identify three main strategies for reducing barriers:

1. **Increase knowledge**. The support and funding of R&D to reduce barriers related to immature and complex technologies.
2. **Increase transparency of information**. Reduce policy uncertainty or industry practice that prevents the full uptake of operational measures, and develop pilot projects or forms of industry collaboration to improve knowledge sharing.
3. **Provide additional incentives**. Develop policy instruments that favour the uptake of expensive but promising technologies. Such instruments range from taxing emissions to enforcing technical standards.

Table 2-2 summarises what strategy could be used to mitigate the different barriers identified in Section 2.2. It is noted that public policy action could play a role in all of the above strategies.

Table 2-2: Barrier categorisation (Acciaro et al., 2012b)

| Barrier category | | Specific barrier | | Knowledge | Transparency | Incentives |
|---|---|---|---|---|---|---|
| **A.** | **Safety reliability** | **1.** | **Safety** | **X** | **X** | |
| | | **2.** | **Reliability** | **X** | **X** | |
| **B.** | **Technical uncertainty** | **1.** | **Technical maturity** | **X** | | **X** |
| | | **2.** | **Specific know-how** | **X** | **X** | |
| | | **3.** | **Difficulties for system integration** | **X** | **X** | |
| **C.** | **Behavioural** | **1.** | **Organisational maturity** | **X** | **X** | **X** |
| | | **2.** | **Lack of information** | **X** | **X** | |
| | | **3.** | **Lack of awareness** | | **X** | |
| **D.** | **Market constraints** | **1.** | **Current industry practices related to charter agreements** | | **X** | |
| | | **2.** | **Current regulation** | | **X** | |
| | | **3.** | **Lack of market pressures** | | | **X** |
| **E.** | **Financial and economic constraints** | **1.** | **Cost of installation** | **X** | | **X** |
| | | **2.** | **Cost of operation** | **X** | | **X** |
| | | **3.** | **Access to capital** | **X** | | **X** |
| **F.** | **Complexity** | **1.** | **Complexity of operation** | **X** | | |
| | | **2.** | **Complexity of installation** | **X** | | |

# 3 POTENTIAL NEW POLICIES TO REDUCE $CO_2$

DNV presented an original list of 15 policies that have the potential to foster and incentivise $CO_2$ emission reduction from ships to the WP6 in the June 2013 meeting in Paris.[8] A limited number of policies have been selected for further analysis in this study based on the discussions in the meeting and subsequent correspondence between the DNV project team and the OECD Secretariat. Thus, the selection does not reflect a prioritisation by DNV, nor imply that the policy is recommended for implementation.

This study examines specific policies that governments could implement to complement existing and planned international regulation and industry initiatives. Policies related to IMO work and other regional and command-and-control schemes are thus excluded from the analysis in this study.

This chapter examines the following five policies (the number in parenthesis is the original policy number – see Appendix A):

- Policy A: Bunkering infrastructure for low carbon fuels (#4)
- Policy B: Energy efficiency as a criterion for governmental financial institutions (#8)
- Policy C: Targeted research and development support including large scale testing (#9 and #10)
- Policy D: Differentiated port fees based on energy efficiency rating (#11)
- Policy E: Ship $CO_2$ performance requirements in public procurement (#14)

The policy analysis describes the main features of the potential policy, and outlines the rationale for the policy approach. An overview of the main cost elements associated with the policy and a discussion of potential distortions to the shipbuilding market are included, as well as a discussion on the potential $CO_2$ reduction of the policy. Quantifying the $CO_2$ reduction effect of the proposed policy is beyond the scope of this study. However, in the interest of enabling a relative comparison of the various policies studied, the analysis includes a qualitative discussion of each policy's potential for emissions reduction. Finally, a brief overview of complementary industry efforts is given along with examples of similar policies already in place. The policy analysis is at a high level, and is considered a first screening for further in-depth analysis.

Measures to reduce $CO_2$ from shipping are frequently divided into the following three categories, technology, operation, and fuel. The categories that each policy target are indicated in the analysis. Technical measures include for example optimised hulls such as aft-ship, propeller and rudder arrangements, waste heat recovery systems and battery hybrid drive systems. Generally, these options have a substantial investment cost, moderate operational costs, and potentially very significant fuel consumption and emission reduction effects. Many technical options are limited to application on new ships. Operational measures include slow steaming; hull and propeller cleaning; better main and auxiliary engine maintenance and tuning. The operational options, in general, have low investment and moderate operating cost. Operational measures can generally be applied to all ships, and can give

[8] The orignal list, including policy descriptions, is included in Appendix A.

substantial effects on the fleet in a short time. The fuel category includes alternative fuels and/or power sources. The most likely alternative to fuel oils today is liquefied natural gas (LNG). The use of wind power and solar panels as alternative power sources supplementing auxiliary engines are also included here.

Reducing emissions in the shipping industry is a complicated task due to the complex linkages between actors in the industry (owners, operators, yards, etc.). The best and most effective policy may involve multiple government ministries and also necessitate international and industry cooperation.

## 3.1 Policy A: Bunkering infrastructure for low carbon fuels

**Target area**
- Fuel

**Target vessels**
- New builds

**Barrier categories**
- B. Technical uncertainty
- D. Market constraints

**Governments can support low carbon fuel bunkering infrastructure to accelerate the uptake of alternative marine fuels and reduce $CO_2$ emissions from shipping**.

The most feasible low carbon fuels for use in the maritime industry are currently LNG (liquefied natural gas) and various forms of biofuels (for example biodiesel, methanol, crude plant oil, and biogas). Long term options also include hydrogen. Low carbon fuels can give substantial lifecycle $CO_2$ reductions compared to traditional oil based fuels such as HFO and MGO. An assessment of which low carbon fuel to support should include a life cycle perspective to ensure a net reduction in emissions.

There are different bunkering solutions for low carbon fuels. For example, vessels can bunker LNG in the following ways: Ship to ship bunkering from bunker vessels/barges; truck to ship bunkering; bunkering from permanent tanks on land to ship via a pipeline; and containerised LNG tanks. What bunkering solution fits a specific vessel depends on a variety of factors, such as tank location, type and size.

Building infrastructure is very capital intensive and prone to end up in a chicken and egg situation. Ship owners are reluctant to invest in vessels running on low carbon fuel unless fuel is readily available, and fuel suppliers/bunkering facilities are reluctant to invest in bunkering infrastructure until a significant number of vessels pose a demand for low carbon fuel. New fuel types, depending on their physical properties, may also require different safety measures and procedures that are not covered by the current regulatory framework.

Governments could support the development of bunkering infrastructure for low carbon fuels in several ways:

- Targeted, public financial support for initial bunkering infrastructure development to break the chicken and egg situation. This infrastructure is referred to as ‘hard infrastructure’, and includes terminals, vessels, trucks, fuel containers etc.

- Provide delivery volume guarantees to the infrastructure owners (reimbursement if sales volumes are below a guaranteed level).

- Ensure third party access to infrastructure to avoid natural monopolies in the supply market and building up parallel infrastructure.

- Develop clear rules and procedures for bunkering low carbon fuels. This is often referred to as ‘soft infrastructure’, and includes developing a harmonised framework for rules and procedures.

- Funding for feasibility studies to assess where bunkering facilities should be developed and what type of facility is needed.

The two first options are ways for the government to assume financial risk on behalf of the infrastructure provider.

The policy approach mainly targets new builds, but would also incentivise retrofitting ships in operation. A policy like this should involve several governments to ensure there is a network of bunkering facilities.

### 3.1.1 Rationale for policy approach

Ship owners are reluctant to invest in ship power systems capable of using low carbon fuels such as LNG and biofuels due to uncertainty and limitations regarding fuel availability. Part of the availability issue relates to bunkering infrastructure. Nearly all large ports worldwide have bunker oil storage capacity and deliver fuel oil to ships. However, low carbon fuels such as LNG are now only available in a limited number of ports. Running on low carbon fuels is thus currently not an option for vessels operating on the spot market or for ships operating outside geographical regions with guaranteed availability.

The availability of bunkering infrastructure is one of the critical success factors for low carbon fuels. Public support for the development of infrastructure may kick-start the development of bunkering infrastructure networks for alternative fuels. The impact assessment accompanying the EU legislative proposal on the deployment of alternative fuels infrastructure shows that the build-up of a sufficient infrastructure network for alternative fuels is a necessary condition to accelerate the demand for alternative fuel vessels.[9]

The development of bunkering infrastructure could need government support in two phases. First, there could be need to support an initial phase of capacity build-up. This phase may be dominated by a limited number of actors, and may not automatically result in a well-functioning market. Thus, further government action may be required in a second phase, to secure a well-functioning market with numerous actors. This may entail ensuring infrastructure access to third parties.

By making bunkering facilities available, a major hurdle for uptake of low carbon fuels is removed and ship owners can focus on shipboard issues. The policy is mainly aimed at ship owners, and provides financial incentives for the following stakeholders:

| | |
|---|---|
| **Fuel suppliers and ports** | 1. Partial financing of infrastructure projects: This lowers the investment risk for fuel suppliers and ports that are developing bunkering infrastructure.<br><br>2. Government-supported bunkering infrastructure: This will kick start the market by developing initial infrastructure, creating an incentive for fuel suppliers and ports to build additional infrastructure.<br><br>As the number of vessels running on alternative fuels grow over time, the demand for alternative fuels will increase, benefitting fuel suppliers. |

[9] http://ec.europa.eu/transport/themes/urban/cpt/

**Ship owners** Ship owners will invest in new builds running on low carbon fuels or retrofit ships in operation if low carbon fuels are readily available on their trading routes and the fuels are priced competitively.

**Yards** The policy will provide incentives for yards to develop new low carbon fuel concepts and competency to attract new contracts from ship owners.

Increased demand from ship owners for new builds and retrofits will benefit both yards and suppliers of equipment related to alternative fuels.

### 3.1.2 Potential $CO_2$ reduction effect

Arguably, this policy has the potential to function as a catalyst for a transition to low carbon fuels in the shipping industry, enabling a step change in emissions. The $CO_2$ reduction effect of the policy depends on the explicit implementation of mechanisms outlined in the above policy description (type and level of support), as well as the intended coverage of the policy (how many nations, ports), and not least the targeted low carbon fuel.

LNG is a fossil fuel and its $CO_2$ emission reduction potential is estimated at approximately 10–20% compared to HFO/MDO, in a life cycle perspective.

The $CO_2$ reduction potential of biofuels varies widely, depending on the specific fuel and production method used, while their sustainability also depends on the amount of water and type of land used (agricultural or marginal land) for production. Ranges from 20 to 90% $CO_2$ reduction have been reported (Bengtson et al. 2011; 2012; Verbeek et al. 2011; ECOFYS 2012).

Transitioning to a new fuel is a long term measure. Assuming a gradual take up in new builds and limited retrofit, it could take 30-50 years before the entire shipping fleet is running on a new fuel.

Overall, the potential effect of this policy is rated as high.

### 3.1.3 Costs and risk of distortions to the shipbuilding market

There are different types of costs involved, and the magnitude depends on the type of support and type of actor.

- **Administrative costs**

  The government will have to bear an administrative cost related to evaluating which projects to support. This will involve setting up and managing an application system, as well as acquiring (or alternatively outsource) expertise to make informed decisions on which projects to support. It is not expected that there will be on-going costs related to regulating infrastructure access, as this falls under the normal responsibility of the relevant government agencies.

- **Capital cost**

  The initial investment costs for a "fleet wide" bunkering infrastructure are potentially substantial, depending on the type of infrastructure and capacity. This cost falls on the government, ports and fuel suppliers. The distribution of the capital cost depends on the support setup and the ownership structure of the bunkering facility.

- **Fuel cost**

  Parts of the capital cost for the bunkering infrastructure may be translated into the fuel price, a cost that falls on ship owners, ship operators or charterers, depending on the organisational structure and charter party. Initially, low carbon fuels will likely not be priced as cost plus margin. Fuel suppliers have an incentive to price low carbon fuels competitively compared to the alternatives. LNG, for example, will likely be priced competitively compared to MGO, or HFO and a scrubber. Over time, it is likely that low carbon fuels will be priced as distribution cost plus margin.

- **Risks of distortions to the shipbuilding market**

  The policy will favour ships built by any nation which has the technical know-how in place to build ships which could utilize the infrastructure. However, the policy is not considered distortive for the shipbuilding industry.

### 3.1.4 Complementarity to industry efforts

The policy complements the industry push for LNG and biofuel. More than 40 LNG fuelled ships have already been built, most of which operate in Norwegian waters. The order book for the next two years indicates that there will be a doubling of the world LNG fuelled fleet, and by 2020 it is predicted that there may be as many as 1000 LNG fuelled vessels.[10] Upcoming environmental regulations and a potentially lower fuel price make LNG an attractive marine fuel for ship owners.

Several ship owners are exploring the use of biofuels for marine use. For example, Maersk is involved in two projects examining the use of lignin as a marine diesel fuel[11]. Stena is exploring the use of methanol and has a vision to run the whole of the fleet that operates in ECAs on methanol in the long-run.

In addition, the US Navy has initiated a programme to convert half of the Navy's fuel supply to alternative sources, mainly biofuel, by 2020. Together with the departments of energy and agriculture, the Navy has entered into an agreement to develop cost-effective advanced biofuels. The programme is based on a public-private partnership model to develop commercial large scale demonstration bio refineries to validate the technology and ability to produce biofuels at a large scale. This provides a significant incentive for actors in the private sector that work on research and development of advanced biofuels.

### 3.1.5 Examples of implementation

Below are some examples of implementation of this policy. The list of examples is not exhaustive; a full review of existing policy examples is beyond the scope of this study.

[10] DNV (2012). Shipping 2020.
[11] Maersk (2013). The Group's search for alternative fuels. Available: http://www.maerskpress.com/Latest%20News/the-groups-search-for-alternative-fuels/s/f60483a4-45e4-4296-b8c6-e2499102aa35

- **EU:** The EU has developed an alternative fuels strategy covering marine fuels. The strategy has ambitious targets for the development of LNG bunkering facilities and infrastructure. EU support for alternative fuels bunkering infrastructure is available from TEN-T funds, Cohesion and Structural Funds, and lending from the European Investment Bank.

  1. **TEN-T**: According to a proposal from the European Commission, all TEN-T core ports will have to provide LNG bunkering facilities by 2020[12]. This amounts to 139 seaports and inland ports, roughly 10% of all ports in Europe. The EU finances a number of Trans-European Network for Transport (TEN-T) studies on LNG bunkering networks. In addition, the EU is giving priority to the co-financing of alternative fuel projects, including LNG infrastructure, under the TEN-T programme. Further, the EU co-finances a project to convert an existing vessel into an LNG bunkering ship in the Port of Stockholm.

  2. **The European Investment Bank (EIB)**. Financing of shipping is part of the core business of the EIBs overall long term transport lending. Particular attention is given to projects that assist the sector to cope with environmental challenges and encourage the development of clean technology.

  3. **Cohesion and Structural funds**. The European Regional Development Fund (ERDF) partly finances the MarTech LNG project, which aims to transfer LNG knowledge and technology to South Baltic countries that are currently building LNG terminals[13].

  Financing of LNG bunkering stations may also be supported under the conditions laid down in the Guidelines on National Regional Aid for 2007-2013.

- **Norway:** The Norwegian $NO_x$ fund provides financial support to infrastructure for LNG bunkering. Infrastructure may receive up to 50% support, maximum up to NOK 20 million per plant over a specific size (1,400 $m^3$). For smaller plants the maximum support is lower depending on tank capacity, and is limited to 50% of the investment[14].

- **Singapore:** The Singapore government, through a state-owned company (Singapore LNG Cooperation), has built an LNG import terminal. The project was initially owned by a group of private companies, but due to commercial difficulties the government took over in 2009[15]. The terminal will also include ship bunkering facilities.

[12] Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the deployment of alternative fuels infrastructure: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2013:0018:FIN:EN:PDF
[13] MT LNG (2013). About the project. Available: http://www.golng.eu/en/about-the-project/
[14] NOx fund (2013). Application for Support. Available: http://www.nho.no/support-from-the-fund/category479.html
[15] Available: http://www.slng.com.sg/about-us-overview.html

## 3.2 Policy B: Energy efficiency as an evaluation criterion for governmental financial institutions

**Target area**
- Technology
- Fuel

**Target vessels**
- New builds

**Barrier categories**
- E. Financial and economic constraints

**Requiring public financial institutions to include energy efficiency as a criterion when evaluating whether or not to provide financial support for new build projects provides an incentive for owners to prioritise energy efficient ships.**

The following public financial institutions are relevant for the policy approach:

1. *Export credit agencies (ECAs)*

ECAs are financial institutions or agencies that provide trade financing to domestic companies for their international activities. ECAs provide financing services such as loans, guarantees and insurance. Some ECAs are part of government departments while others are private companies.

Export credit agencies are important financial institutions in the shipping market. Many ECAs provide financing solutions to new build contracts, and also building loan guarantees. For example, the Norwegian Guarantee Institute for Export Credits (GIEK) issues a significant portion of its guarantees for ships and ship equipment. Most of the guarantees are in the form of credit guarantee, contract guarantee, and building loan guarantee.

2. *Banks in which the government has a controlling share and is an active shareholder.*

This paper has not included international financial institutions, such as multilateral development banks, as part of the analysis.

Financial institutions can set specific energy efficiency criteria for new builds, which stipulate that new builds must go beyond compliance with international and national regulations. Energy efficiency can be assessed as a part of existing environmental review or due diligence processes.

The policy does not involve increasing the total level of financial support. Instead, by introducing energy efficiency as an evaluation criterion, this policy could change the prioritisation of what new build projects get financial support. For example, an export credit agency can say yes or no to applications for new build guarantees based on the ship's energy efficiency.

Governments could collaborate to develop and implement identical criteria based on international energy efficiency standards, such as the IMO Energy Efficiency Design Index (EEDI).

### 3.2.1 Rationale for policy approach

Ship owners are reluctant to invest in new, more efficient vessels due to a cost premium and uncertainty with regards to recovering the cost through higher charter rates. Making access to capital or insurance dependent on energy efficiency creates an incentive for ship owners to build increasingly efficient ships.  Public financial institutions such as export credit agencies are important actors within ship financing and many ship owners are dependent on these institutions to build vessels.

By developing and adopting energy efficiency criteria, public financial institutions could also support the development of standard criteria for project financing for vessels that can also be used by private financial institutions.

The policy should not incentivise measures that are not cost-efficient as this would be difficult to impose on financial institutions and may create market distortions. A major barrier to energy efficiency in shipping is known as *split incentives*. This phenomenon occurs when the incentive to reduce fuel costs and emissions rests with the charterer paying the fuel bill, while the ship owner, who pays for the investment in new ships, has no incentive for paying the price premium of more efficient ship technology. Any policy incentivising the owner, rather than the charterer, to reduce fuel and emissions can eliminate this split incentive, while still being cost-effective for the financial institutions.

The policy will also make it easier for ship owners and yards that focus on energy efficiency to compete for funding for new build projects. The policy provides the following financial incentives for different stakeholders:

| | |
|---|---|
| **Ship owners** | Ship owners are incentivised to order new builds that go beyond compliance and that are more energy efficient than existing vessels. |
| **Yards** | The policy incentivises development of new concepts and designs, so as to secure contracts with ship owners. |
| **Equipment suppliers** | Companies that provide technologies and solutions to ship owners have incentive to develop new energy efficiency technologies and solutions. |

### 3.2.2 Potential $CO_2$ reduction effect

The potential $CO_2$ reduction effect of this policy depends on the explicit implementation of mechanisms outlined in the above policy description, as well as the intended coverage of the policy. For example, the effect of the policy will depend on the number and character of the states involved. To have a significant effect, the policy must be implemented in countries with a large shipbuilding or equipment manufacturing sector, and in countries with a large ship financing sector.

It is expected that imposing very stringent requirements (for example, requiring above 10% improvement beyond compliance) is not feasible due to risk of imposing measures that are not cost-effective. Assuming further that non-compliance with such a requirement will result in loss of funding, and that 50% of ships built are dependent on some level of this support, means a 5% improvement at best.

The signal effect from such a policy could be substantial, inducing a change of mind-set with investors and ship owners that can have a significant effect. Overall, the potential effect of this policy is rated as moderate.

### 3.2.3 Costs and risks of distortions to the shipbuilding market

There are few **costs** associated with this policy.

- **Administrative costs**

  Government and financial institutions will have to bear a small administrative cost for developing and implementing the evaluation criteria. If the criteria are incorporated into existing review and due diligence processes this cost will be minimal.

  Ship owners and yards will have a small administrative cost associated with filling in the requested information. However, this will be part of the financial application process that ship owners and yard have to go through in any case. Providing the additional information on energy efficiency will have a minimal cost.

- **Risks of distortions to the shipbuilding market**

  Financing institutions may in themselves be an instrument which potentially could introduce distortion. This policy will not add to any such effect as it does not increase the level of financial support, but rather changes the prioritisation of what projects to finance. Financial institutions are already subsidising new builds, and changing the evaluation criteria will not have much impact on the overall distortion.

### 3.2.4 Complementarity to industry efforts

The policy supports the following industry efforts:

- **IFC (International Finance Corporation) Performance Standards on Environmental and Social Sustainability**: The IFC performance standards provide guidance to clients on how to identify risk and impacts in projects, and are designed to help avoid, mitigate and manage risks and impacts as a way of doing business in a sustainable way. In the case of its direct investments (including project and corporate finance provided through financial intermediaries), IFC requires its clients to apply the Performance Standards to manage environmental and social risks and impacts so that development opportunities are enhanced. The Performance Standards may also be applied by other financial institutions.[16]

- **Equator Principles**: The Equator Principles (EP) is a credit risk management framework for determining, assessing and managing environmental and social risk in project finance transactions. The Equator Principles apply globally, to all industry sectors and to four financial products: 1) project finance advisory services, 2) project finance, 3) project-related corporate loans and 4) bridge loans. Equator Principles Financial Institutions (EPFIs) commit to implementing the EP in their internal environmental and social policies, procedures and

[16] IFC (2012) 'Performance Standards on Environmental and Social Sustainability'. Available: http://www.ifc.org/wps/wcm/connect/115482804a0255db96fbffd1a5d13d27/PS_English_2012_Full-Document.pdf?MOD=AJPERES

standards for financing projects and will not provide project finance or project-related corporate loans to projects where the client will not, or is unable to, comply with the EP.[17]

Although it is not an industry effort, the policy also complements the Energy Efficiency Design Index, the IMO regulation requiring a minimum energy efficiency level for new ships. The EEDI is based on a formula for calculation of ship specific emissions of $CO_2$. The result for each ship, which is to be based on design documentation and engine performance, is expressed in grams of $CO_2$ per capacity-mile. The attained EEDI for a specific ship must be less or equal to the required EEDI, expressed by reference lines developed by IMO for each ship type.

### 3.2.5 Examples of implementation

At present, few public financial institutions have specific energy efficiency criteria as part of their assessment process for financing new builds. However, many financial institutions have experience with evaluating the environmental impact of shipping projects. A couple of examples are provided below:

- **Norwegian Guarantee Institute for Export Credits**: CSR requirements - As a part of GIEK's due diligence process, applicants are requested to submit along with their applications relevant questionnaires pertaining to potential environmental and social impacts. There is a separate questionnaire on environmental and social impacts for mobile units and shipyards.[18]

- **KfW IPEX-Bank (Germany)**: The German-owned development bank, KfW IPEX-Bank, one of the largest ship financing banks in the world, has evaluated the energy efficiency of its shipping portfolio based on the EEDI. The bank has stated that the evaluation verified that less energy efficient ships are associated with a higher credit risk.[19]

In addition, the OECD Working Party of Export Credits and Credit Guarantees has developed a ‘Recommendation of the council on common approaches for officially supported export credits and environmental and social due diligence (the "common approaches")’.[20]

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[17] Equator Principles (2013) ‘About the Equator Principles’. Available: http://www.equator-principles.com/index.php/about-ep/about-ep
[18] GIEK (2013). CSR. Available: http://www.giek.no/en/om_giek/samfunnsansvar
[19] MarineLink.com (16 October 2012). ‘Bank Considers EEDI When Making Ship Finance Decisions’. Available: http://www.marinelink.com/news/considers-finance-making348531.aspx
[20] OECD (2012). Working Party on Export Credits and Credit Guarantees : Recommendation of the council on common approaches for officially supported export credits and environmental and social responsibility (the “common approaches”). Available:http://search.oecd.org/officialdocuments/displaydocumentpdf/?cote=TAD/ECG%282012%295&doclanguage=en

## 3.3 Policy C: Targeted research and development support, including large scale testing

**Target area**
- Technology
- Fuel
- Operation

**Target vessels**
- New builds

**Barrier categories**
- A. Safety
- B. Technical uncertainty
- E. Financial and economic constraints
- F. Complexity

**Support targeted research and development to foster innovation of new and improved solutions for green shipping. Support large scale testing of immature technologies to bridge the gap between R&D and commercialisation.**

Governments can provide different types of support:

1. Direct funding of government research facilities
2. Grants to university or private-sector researchers
3. Contracts for specific projects
4. Tax incentives

R&D support is common in many shipbuilding nations. This policy entails a more targeted approach to R&D, focusing on end-user concerns and on removing specific barriers to implementation. The idea would be to shift focus from pursuing “bigger, better, more advanced” solutions to developing “smarter, easier, more reliable” solutions. This may entail pursuing improved solutions, rather than new solutions. The barriers in question will be technology dependent. R&D needs may vary among nations and regions based on the specificity of the location, which also may diverge from global R&D needs. Governments should develop an R&D strategy and prioritise areas that need support.

Governments can also support large scale testing of promising solutions, based on an analysis of what barriers prevent the uptake of energy efficiency measures. For example, a government can partially or fully finance a particular vessel to test immature technologies that have a significant potential for emission reduction. It will be important to effectively distinguish between legitimate testing and simply subsidising installation of new technology.

The policy presents many opportunities for collaboration and knowledge transfer between different actors in the shipping industry. For example, equipment suppliers, yards, and ship owners can collaborate on testing a particular technology. Governments can also collaborate on supporting research and development on issues that are of particular importance, for example by co-financing a large project.

### 3.3.1 Rationale for policy approach

A main objective of this policy would be to encourage and support the establishment of effective processes to transfer results and solutions from “labs” into factories and onto ships. Arguably, there is no shortage of innovative solutions to reduce $CO_2$ emissions in shipping (see section 3.1). However, there are a variety of measures that are not implemented to their full potential, for example weather routing, kites etc. The reasons for this limited uptake are likely many and diverse, and depend on the technology in question. However, a key factor seems to be a lack of confidence in the practical feasibility and reliability of the technology (see section 3.3). Many of the technologies have a potentially large benefit, but owners are reluctant to assume the risk of testing them.

A core feature of this policy should be to address issues beyond the core technical function of a technology. This could include enhanced attention to robustness and simplicity of design, suitability for mass production and user friendliness. The latter requires that end-users (ship owners and operators) get involved in R&D projects.

Another core feature is the importance of openness and effective dissemination of results. Publicly funded projects (in particular large scale demonstration projects) should have plans for effective knowledge sharing, ensuring that trust and confidence in a given solution is established with a wider audience. In this way, a wider uptake of the technology is more likely.

Immature energy efficiency technologies will have to be tested in some way or another. Tests can be performed with scale models, but at some point full scale testing is required to prove the concept. Dependent on the technology, full scale testing can be time consuming and very costly. Public support for full scale testing will help technologies reach maturity and become commercially viable.

Governments could also support research to better understand what hinders the uptake of different technologies, and subsequently support research on and development of solutions to overcome the identified barriers. Addressing specific barriers will accelerate the uptake of green technologies.

This policy is aimed at the key stakeholders in the maritime industry, and provides the following incentives:

| | |
|---|---|
| **Yards and equipment suppliers** | Government support will reduce the risk of undertaking R&D. Yards and equipment suppliers will get a financial incentive to develop technologies, knowing that support for large scale testing is available. |
| **Ship owners** | R&D can reduce technical uncertainty and perceived complexity of energy efficiency measures. The policy will help promising technologies to reach maturity and become commercially viable. Ship owners will be reassured that the technologies perform as promised, reducing the risk of the investment. |

### 3.3.2 Potential $CO_2$ reduction effect

This policy can arguably have a substantial effect on emissions reduction, accelerating or enabling fleet-wide implementation of new technologies. However, it is difficult to assess the additional effect of this policy relative to R&D polices already in place. In some cases the testing may also reveal that the technology is not feasible for normal operations. Viewed in light of existing polices, the additional effect of this policy is likely moderate.

### 3.3.3 Costs and risks of distortions to the shipbuilding market

The costs of R&D in general, and large scale testing in particular, can potentially be substantial. However, there is an option to cover the cost of this policy by redirecting funds already allocated to R&D, thus potentially inferring no additional costs of this policy. Most governments already allocate funding to large scale testing in different industries. This policy would only involve different prioritisation of existing means. There could also be a small cost in setting up a dialogue between governments, ship owners, and charterers to discuss end-user concerns and specific barriers to implementation.

- **Risks of distortions to the shipbuilding market**

Support for R&D in general is considered potentially distortive, but is commonly used today and accepted as tolerable, as long as there are adequate criteria to identify new technology with legitimate support needs. As most countries have experience with R&D support, the policy can build on existing practices. Today, yards and owners who participate in R&D programmes do get direct support/benefits, however they also take on considerable risk by joining these programmes. This policy, which entails a change in R&D priorities, will therefore only have limited additional distortive effects.

### 3.3.4 Complementarity to industry efforts

- **Maritime Knowledge Hub**: A Norwegian consortium that sponsors professorships and Phd positions. The main objectives of the hub are to 1) increase the influx of talent to the industry and strengthen leading institutes, 2) ensure that leading institutes have sufficient focus on the maritime industry, and 3) assist the institutes in introducing new technological and commercial models. The hub was founded by the Norwegian Shipowners' Association and Maritime Forum Oslofjorden.

- **Exhaust Gas Cleaning Systems Association** (and similar organisations): An association of equipment manufacturers that promotes the use of scrubber technology through information sharing, advices and opinions.

### 3.3.5 Examples of implementation

There are many examples of R&D strategies for the maritime industry. These strategies could be modified or changed to focus on end-user concerns and implementation, as suggested in the policy description. In addition, the process for developing the strategies could be amended so as to include industry input.

The EU and several countries have targeted support for research and development in the maritime sector. A few examples are provided below:

- **EU:** The WATERBORNE technology platform is one of several European technology platforms, industry-led stakeholder forums that develop short to long-term research and innovation agendas and roadmaps for action at the EU and national level to be supported by private and public funding.[21] The technology platforms are independent organisations. *Horizon 2020* is a new EU Framework Programme for Research and Innovation that will combine all research and innovation funding. The Marco Polo programme grants financial support in the start-up phase of projects that aim to move cargo from road to greener transport forms (including railways, inland waterways and

[21] http://cordis.europa.eu/technology-platforms/

short sea shipping)[22]. While not directly aimed at new technologies, it can support establishing new routes with effective ships in the crucial start-up phase.

- **Sweden:** ‘Lighthouse’ is a multidisciplinary maritime competence and research centre initiated by Chalmers, the School of Business, Economics and Law at Gothenburg University and The Swedish Shipowners’ Association. Lighthouse focuses on research in five principal areas; eco ship (environment), ergo ship (human factors), cargo ship (ship design), safe ship (safety) and business ship.[23]

- **Norway:** Maritime 21 is a research and innovation strategy for the maritime industry in Norway, initiated by the Ministry of Trade and Industry and based on input from over 400 people working in the maritime industry. The strategy is implemented by MARUT, a strategic advisory board to the minister, at three levels: maritime politics and regulations, research agendas and university curriculums, and industry adaptation and support. The philosophy of Maritime 21 is to link R&D, prototyping and market development, and utilise the range of public funds more appropriately. The strategy identifies energy efficiency and LNG distribution and use as key issues.

- **Finland:** The Finnish Government issues investment aid to emission abatement measures on new builds and existing ships[24]. While the aim is to ease the implementation of the EU Sulphur Directive, the aid incentivises early implementation and use of scrubbers, creating confidence in the technology.

There are also many examples of large-scale testing of novel technologies and measures, both with and without government support. This includes the US Navy and Maersk testing of biofuels, FellowShip testing of fuel cells and battery hybrid systems, and Skysails testing of kites.

[22] http://ec.europa.eu/transport/marcopolo/getting-funds/index_en.htm
[23] Lighthouse (2013). Theme areas. Available: http://www.lighthouse.nu/research/Themeareas.aspx
[24] http://valtioneuvosto.fi/ajankohtaista/tiedotteet/tiedote/en.jsp?oid=379472

## 3.4 Policy D: Differentiated port fees based on energy efficiency rating

**Target area**
- Technology
- Fuel

**Target vessels**
- Ships in operation

**Barrier categories**
- E. Financial and economic constraints

**Ports can introduce differentiated fees based on an energy efficiency rating**.

The policy can be implemented in all ports in which the government has a controlling share.

Governments can collaborate to set up a new or use an existing rating scheme, to ensure consistency across ports.

This policy option could also cover differentiated Flag fees[25], although this will not be considered further in this study.

### 3.4.1 Rationale for policy approach

Differentiated port fees based on an energy efficiency rating penalises old, energy-inefficient ships and rewards new, more efficient ships.

Currently, ports are mainly concerned with issues related to noise and air quality. $CO_2$ emissions from ships (which do not impact on local air quality) are not of key concern, and thus ports do not currently implement measures which focus on this (see section 3.2.5).

This policy would benefit from national or international coordination, to simplify and unify rating schemes that ship owners need to keep track of and to avoid competition between ports, which could disrupt trade patterns.

The policy provides the following incentives to stakeholders:

**Ship owners** Ship owners will have a direct financial incentive to implement cost-effective energy efficiency measures that will improve the energy efficiency rating of ships in operation.

**Yards** The policy incentivises development of new concepts and designs, so as to secure contracts with ship owners. Yards may experience an increased demand for retrofit to improve the energy efficiency rating of vessels.

### 3.4.2 Potential $CO_2$ reduction effect

In some shipping segments port fees can be a substantial part of the operational cost of a vessel. An illustrative example from Stopford (2009) shows that for a large bulk carrier in 2005, port costs constituted 24% of voyage cost, which in turn was 40% of total cost (including capital costs).

[25] Singapore-flagged ships registered on or after 1 Jul 2011, which go beyond the requirements of the IMO's Energy Efficiency Design Index (EEDI), enjoy a reduction Flag fee reduction; http://www.srs.sg/register-with-srs/incentive-schemes

Although this number will vary with ship types, sizes and trades, as well as the relative importance of other important cost elements such as fuel prices, it illustrates the significance of port costs.

However, port fees will likely give a limited incentive to reduce $CO_2$ emissions from ships. Assuming today's higher fuel prices, port fees averaging 5% of total cost, and that port fee discounts in the order of 20% can be offered, there is little overall impact on the economic performance of a vessel from such a policy. However, the policy could give significant signal effects in the industry.

Overall, this policy would most likely have a low $CO_2$ reduction effect.

### 3.4.3 Costs and risks of distortions to the shipbuilding market

There are few **costs** associated with this policy.

- **Administrative costs**

  **Ports** will have to bear a small administrative cost for setting up and operating the rating system. Fee levels may be set to retain the net income for the port by reducing the fee for "good ships" and increasing it for "bad ships".

  **Ship owners/ship operators** will have a small administrative cost associated with providing the requested information, if necessary.

- **Risks of distortions to the shipbuilding market**

  The policy will be applicable to all ships, regardless of nation of build, and is not likely to be distortive.

### 3.4.4 Complementarity to industry efforts

- A number of rating schemes exist to rate the performance of ships[26] and are used by ports for differentiation of fees, such as:
  - **Port of Rotterdam**: Vessels that score 31 points or more on the Environmental Ship Index (ESI - indicates the amount of air pollution and $CO_2$) receive a 10% discount on the gross tonnage (GT) part of their port dues in Rotterdam.
  - **Port of Amsterdam**: The ship must have an ESI-score of 20 points and above. Below 20 points no incentive will be applied. If the ESI-score is above or equal to 31 points, an extra bonus will be applied. The height of the incentive is depending on the GT of the vessel.[27]
  - **Port of Oslo**: Ships with ESI score of 2025-50 points get a 20% discount. Ships with ESI score of minimum 50 points get a 40% discount.

[26] www.cleanshippingproject.se, www.dnv.com/triple-e, www.shippingefficiency.org, site.rightship.com, www.bsr.org/cleancargo, www.esi.wpci.nl, *www.greenaward.org*, *www.green-marine.org/home*
[27] http://www.portofamsterdam.com/Eng/shipping/harbour-dues/Environmental-Ship-Index.html

- **Rightship**: Rightship supports charters who include energy efficiency requirements in their selection process. The organisation provides different vessel ratings: Greenhouse Gas (GHG) Emissions Rating, based on an Existing Vessel Design Index (EVDI™), and an Environmental Rating.

### 3.4.5 Examples of implementation

Many ports, both private and public, already offer differentiated port fees based on some sort of environmental rating.

#### 3.4.5.1 Port of Singapore

The Green Port Programme in the Port of Singapore offers 15% concession in port fees to ocean-going vessels that use type approved abatement or scrubber technology for $SO_x$ emissions or fuels with sulphur content of less than 1%.

#### 3.4.5.2 Port of Hong Kong

Vessels that switch to cleaner fuel while berthing in Hong Kong waters are eligible for a 50% reduction in port facility and light dues. This incentive scheme is intended to help reduce vessel emissions and improve the air quality around the port area.[28] Hong Kong now proposes to make this mandatory for ocean going vessels.

[28] http://www.info.gov.hk/gia/general/201209/14/P201209140402.htm

## 3.5 Policy E: Ship $CO_2$ performance requirements in public procurement

**Target area**
- Technology
- Operation

**Target vessels**
- Ships in operation
- New builds

**Barrier categories**
- D. Lack of market pressures
- E. Financial and economic constraints

**Mandate that public entities and state owned enterprises use energy efficiency or $CO_2$ emissions as a selection criterion in procurement of shipping services.**

This includes transportation of goods and materials (import and export), as well as shipping activities such as offshore operations. Public entities and state owned charterers should use the most efficient ships available and provide premium charter rates to energy efficient ships.

This policy could apply to public entities and state-owned enterprises that are directly responsible for chartering a ship. It could also apply more widely to the supply chain of these public entities, through "transport footprint requirements". For example, if an entity places an order with a supplier, the supplier is required to charter the most efficient ships available in the market and provide premium charter rates to energy efficient ships, limited to the expected fuel costs saving.

Examples of public entities and state owned enterprises:

- National government, including ministries and government agencies
- Local government
- State-owned industry such as national oil and gas companies, mining companies etc.
- State-owned infrastructure providers or procurers

Standardisation of ship $CO_2$ performance requirements for public entities and state owned enterprises within a given country, and standardisation and collaboration between countries, would make this policy more effective.

### 3.5.1 Rationale for policy approach

The policy will work towards moving around barrier category E. *Financial and economic constraints*, and to create a market incentive, removing barrier D. *Lack of market pressures.*

A major incentive for investing in technology and energy efficiency is to gain premium in the charter market – or to avoid a penalty for an inefficient ship. By making charter agreements with public entities and state-owned enterprises dependent on the energy efficiency of vessels, this policy incentivises both ship owners that pay for fuel and those that do not to order more efficient new builds and improve the efficiency of ships in operation.

Private charterers could over time adopt requirements that public charters set, developing a premium market for energy efficient ships. A premium market can only exist as long as new designs are significantly better than existing ships.

This policy is primarily aimed at ship owners, providing the following incentives:

**Ship owners** The policy will incentivise ship owners to take up new technologies and measures to reduce ship's operational $CO_2$ emissions.

A premium market will benefit ship owners that have already taken measures to improve energy efficiency and reduce $CO_2$ emissions from their fleet, and those ship owners who have a clear strategy for doing so going forward.

**Yards** The policy incentivises development of new concepts and designs, so as to secure contracts with ship owners.

Yards will benefit from an increased demand for retrofits of energy efficiency and emission reduction measures, and for more advanced new builds.

### 3.5.2 Potential $CO_2$ reduction effect

The effect of this policy will depend greatly on the scope and reach of the explicit policy. In its most extensive form, there are great trickle-down effects from imposing "transport footprint requirements" on purchases by all public companies and agencies. Such a policy, if implemented in large portions of the world economy, could create a market for vessels of improved designs.

Implementing the requirement for state owned enterprises would have a significant impact. For example, the policy could require that national oil companies charter tankers and supply vessels with performance beyond EEDI compliance levels. However, the majority of commercial trade is by private companies where this policy will not have a direct effect.

This policy will most likely have moderate to high impact.

### 3.5.3 Costs and risks of distortions to the shipbuilding market

There are few **costs** associated with this policy, but this depends on the ambition of the procurer.

- **Administrative costs**

  Government and financial institutions will have to bear a small administrative cost for developing and implementing the evaluation criteria in the procurement process. If the criteria are incorporated into existing procurement processes this cost will be minimal. The more ambitious the criteria, and the more novel the technologies required, the higher the administrative cost.

  Ship owners and yards will have no extra cost as all costs will be taken by the procurer.

- **Risks of distortions to the shipbuilding market**

  The criteria will be applicable to all ships, regardless of nation of build. Thus, the policy is not considered distortive.

This study is limited to examining costs and distortions to the shipbuilding market, and does not consider the impact on the wider shipping market.

### 3.5.4 Complementarity to industry efforts

The policy complements several industry efforts:

- **Rightship**: Rightship supports charters with incorporating energy efficiency requirements in their selection process. The organisation provides different vessel ratings: Greenhouse Gas (GHG) Emissions Rating, based on an Existing Vessel Design Index (EVDI™), and an Environmental Rating.
- **Clean Cargo Working Group (CCWG)**: The Clean Cargo Working Group is a global business-to-business initiative made up of leading cargo carriers and their customers. The initiative helps shipping companies to track and benchmark their performance and easily report to customers in a standard format. It also helps cargo owners to review and compare carriers' environmental performance when reporting and making informed buying decisions. Cargo owners such as IKEA, Nike, WalMart, CocaCola, Shell, Johnson&Johnson, and Starbucks Coffee are members of the Clean Cargo Working Group.

The policy also complements the EEDI regulation. The EEDI of new builds could for example be used as a standard when setting ship CO2 performance requirements.

### 3.5.5 Examples of implementation

The Norwegian government recently proposed to use public procurement of transport services as a means to enhance implementation of green technologies.[29] This has already been done by some county administrations responsible for the regional road network. The most prominent example is the tender for the Lavik-Oppedal route where one of the three ferries is battery driven[30].

In addition, several public ferry operators are building or planning to build LNG powered vessels in North America, including Société des traversiers du Québec, Washington State Ferries, and Staten Island Ferries.

[29] Nærings- og handelsdepartmentet (2013). ‘Regjeringens maritime strategi – Stø kurs 2020’. Available: http://www.regjeringen.no/upload/NHD/Vedlegg/strategier2013/maritim_strategi.pdf
[30] http://www.ferryvolution.com/newbuilding-database/fjellstrand-norled/

# 4 DISCUSSION

This study examines five specific policies that governments could implement to complement existing and planned international regulation and industry initiatives, based on a prioritisation by the WP6 from an initial list of 15 policies. Policies related to IMO work and other regional and command-and-control schemes are excluded from the analysis in this study.

This study shows that there is a significant potential for governments to influence developments in shipping emissions, either directly through policy incentives, but also as signal effects and standards which other parts of the industry can use. Many policy options are available at low cost, and there are likely substantial benefits from cooperation and coordination between governments on policy measures. All the policies would benefit from single governmental action, but the reduction effect would be enhanced by international collaboration. Any policy measure relating to the performance of ships, such as energy efficiency, energy efficiency ratings, technical standards, etc. should be linked to internationally recognised definition of such terms, for example the EEDI formula defined by IMO, to avoid a multitude of standards and evaluation criteria. There is no one solution that would move the ship building industry towards more efficient ships, but rather a portfolio of measures. Even then, the effect will only been seen over time.

The table below provides an indicative ranking of the relative merits of the five evaluated policies, to provide guidance for further studies. All policy measures have a long timeframe as they target the shipbuilding sector. No consideration of political feasibility has been made.

**Table 4-1: Summary table of the analysed policies**

| | Description | Potential for $CO_2$ reduction | Cost to the public | Level of shipbuilding market distortion |
|---|---|---|---|---|
| A | **Bunkering infrastructure** | **High** | **Medium** | **Negligible** |
| B | **EE in finance** | **Moderate** | **Low** | **Negligible** |
| C | **R&D and large scale testing** | **Moderate** | **Medium** | **Low** |
| D | **Port fees** | **Low** | **Low** | **Negligible** |
| E | **EE in public procurement** | **Moderate to high** | **Low** | **Negligible** |

Of the five policies evaluated, Option A, Bunkering infrastructure, has the greatest potential for reducing $CO_2$ emissions. Option E, Ship $CO_2$ performance requirements, in public procurement has the highest potential to advance and facilitate the maturation of promising technologies. This policy will only directly influence the ships that are publicly procured and operated but will over time impact other ships. Options B, C and D are evaluated to have moderate to low direct effect, but can have important signal effects.

While none of the assessed policies are found to have substantive distortive effects to the shipbuilding market, it is recognized that any policy to promote green ships will to some degree likely favour ship builders with high technological maturity and innovative capacity.

# 5 REFERENCES

Acciaro, M., Hoffman, P.N., and Eide, M.S. (2012a). The energy efficiency gap in maritime transport. Maritime transport V. Technological, Innovation and Research.

Acciaro, M., Hoffman, P.N., and Eide, M.S. (2012b). Identifying and Overcoming Barriers to the Implementation of Emission Reduction Measures in Shipping. DNV Report No. 2010-1800.

Alvarez F., Longva T., Engebrethsen, E. A methodology to assess vessel berthing and speed optimization policies, 2010 Annual Conference of the International Association of Maritime Economists, Lisbon 7-9 July 2010.

Bazari, Z., Longva, T., Assessment of IMO Mandated Energy Efficiency Measures for International Shipping, Llyods Register and DNV, 2011.

Bengtsson S, Fridell E, Andersson K. Environmental assessment of two pathways towards the use of biofuels in shipping. Energy Policy 44, 451–463 (2012).

Bengtsson S, Andersson K, Fridell E. A comparative life cycle assessment of marine fuels; liquefied natural gas and three other fossil fuels. Proc. Inst. Mech. Eng. M J. Eng. Marit. Environ. 225(2), 97–110 (2011).

Buhaug, O., Corbett, J.J., Endresen, O., Eyring, V., Faber, J., Hanayama, S., Lee, D.S., Lee, D., Lindstad, H., Markowska, A.Z., Mjelde, A., Nelissen, D., Nilsen, J., Palsson, C., Winebrake, J.J., Wu, W.–Q., Yoshida, K. Second IMO GHG study 2009; MEPC 59/INF.10. International Maritime Organization (IMO) London, UK, April, 2009.

Corbett, J.J., Kohler, H.W. Considering alternative input parameters in an activity-based ship fuel consumption and emissions model: reply to comment by Oyvind Endresen et al. on ‘‘Updated emissions from Ocean shipping’’. Journal of Geophysical Research 109, D23303. doi:10.1029/2004JD005030, 2004.

Corbett, J.J., Kohler, H.W. Updated emissions from ocean shipping. Journal of Geophysical Research 108. doi:10.1029/2003JD003751, 2003.

Dalsoren, S., Eide, M., Endresen, O, Mjelde, A., Gravir, G, Isaksen, I. Update on emissions and environmental impacts from the international fleet of ships: the contribution from major ship types and ports, Atmospheric Chemistry and Physics, 2171-2194, 2009.

Dalsoren, S., Eide, M., Myhre, G., Endresen, O., Isaksen, I., Fuglestvedt, J. Impacts of the Large Increase in International Ship Traffic 2000-2007 on Tropospheric Ozone and Methane, Environmental Science & Technology, 2482-2489, 2010.

DNV (2012). Shipping 2020. doi:10.1029/2004JD005620, 2005b.

Ecofys. Potential of Biofuels for Shipping, Final Report. Ecofys, Utrecht, The Netherlands (2012).

ECORYS (2012). Green growth opportunities in the EU shipbuilding sector. Report for European Commission, DG Enterprise and Industry. Rotterdam, 5 April 2012

Eide, M., Chryssiakis, C., Endresen, Ø., 2013. CO2 abatement potential towards 2050 for shipping, including alternative fuels. Carbon Management 4(3), 275–289.

Eide, M., Longva, T., Hoffmann, P., Endresen, O., Dalsoren, S. Future cost scenarios for reduction of ship CO2 emissions. Maritime Policy & Management, 38:1, 11-37, 2011.

Eide, M.S., Endresen, O., Mjelde, A., Magnset, L.E., Gravir, G. Ship emissions of the future. Report for EC Quantify project, Deliverable D1.2.3.2, Det Norske Veritas. 2007

Endresen, O., Dalsoren, S., Eide, M., Isaksen, I.S., Sorgard, E., The environmental impacts of increased international maritime shipping, past trends and future perspectives. OECD/ITF Global Forum on Transport and Environment in a Globalising World, Guadalajara, Mexico, 2008.

Endresen, O., Sorgard, E., Bakke, J., Isaksen, I.S.A. Substantiation of a lower estimate for the bunker inventory: comment on ‘‘Updated emissions from ocean shipping’’ by James J. Corbett and Horst W. Kohler. Journal of Geophysical Research 109, D23302. doi:10.1029/2004JD004853, 2004.

Endresen, Ø., E. Sørgård, H. L. Behrens, P. O. Brett, and I. S. A. Isaksen, A historical reconstruction of ships' fuel consumption and emissions, J. Geophys. Res., 112, D12301, doi:10.1029/2006JD007630, 2007.

Endresen, O., Sorgard, E., Sundet, J., Dalsoren, S., Isaksen, I., Berglen, T., Gravir, G. Emission from international sea transportation and environmental impact, Journal of Geophysical Research- Atmospheres, 2003.

Eyring, V., Isaksen, I., Berntsen, T., Collins, W., Corbett, J., Endresen, O., Grainger, R., Moldanova, J., Schlager, H., Stevenson, D. Transport impacts on atmosphere and climate: Shipping, Atmospheric Environment, 4735-4771, 2010.

Eyring, V., Kohler, H. W., Lauer, A., Lemper, B. Emissions From International Shipping: 2. Impact of Future Technologies on Scenarios Until 2050, Journal of Geophysical Research, 110, D17306, 2005b.

Eyring, V., Kohler, H.W., van Aardenne, J., Lauer, A. Emissions from international shipping: 1. The last 50 years. Journal of Geophysical Research, 110, D17306, doi:10.1029/2004JD005620, 2005a.

Faber et al. (2009). Technical support for European action to reducing greenhouse gas emissions from international maritime transport. Delft, CE Delft.

Faber, J., Behrends, B and Nelissen, D. (2011). Analysis of GHG Marginal Abatement Cost Curves. Delft, CE Delft.

Hoffmann J., Kumar, S. Globalization: the maritime nexus, in the Handbook of Maritime Economics and Business, edited by: Grammenos, C., 35–62, London, LLP, UK, October 2002, 2002.

Hoffmann, P., Eide, M.S., Endresen, O. Effect of proposed CO2 emission reduction scenarios on capital expenditure, Maritime policy & Management, DOI:10.1080/03088839.2012.690081, 2012.

Japan 2011, Green growth and maritime industries, Workshop on Green growth and maritime industries, OECD.

Johnsen, T., Endresen, Ø., and E Sorgard, 2000. Assessing Environmental Performance by Ship Inventories. ENSUS 2000, 4 September, Newcastle, England.

Johnson, H. (2012). Barriers to energy efficiency in shipping.

Johnson, H. (2013). Towards Understanding Energy Efficiency in Shipping. Thesis for the degree of licentiate in engineering. Chalmers University of Technology. Chalmers Reptroservice: Göteborg, Sweden.

Lloyd's Register FairPlay (LRFP). World merchant fleet database (all civil ocean-going cargo and passenger ships above or equal to 100 GT). Redhill, UK: LRFP, 2009.

Miola, A., Ciuffo, B., Giovine, E., Marra, M. (2010). Regulating air emissions from ships: the state of the art on metholodogies, technologies and policy options. JRC Reference Reports. EUR 24602 EN.

Rodrigue, J.-P., Comtois, C., and Snack, B.: The geography of transport systems, Routledge, New York, USA, ISBN-100-415-35441-2, 286 pp., 2006.

Skjolsvik, K.O., Andersen, A.B., Corbett, J.J., Skjelvik, J.M. Study of Greenhouse Gas Emissions from Ships. MEPC 45/8 Report to International Maritime Organization on the Outcome of the IMO Study on Greenhouse Gas Emissions from Ships. MARINTEK Sintef Group, Carnegie Mellon University, Center for Economic Analysis, and Det Norske Veritas, Trondheim, Norway, 2000.

Stopford, M. (2009), Maritime Economics, 3nd ed., Routledge, London.

UNCTAD. Review of maritime transport. United Nations Conventions on Trade and Development, ISBN: 978 92 1 112810 9, 2010.

UNCTAD. Review of maritime transport. United Nations Conventions on Trade and Development, ISBN: 978-92-1-112860-4, 2012.

UNEP. Bridging the emission gap. United Nations Environmental Programme (UNEP). ISBN: 978-92-807- 3229-0, 2011.

Verbeek R, Kadijk G, van Mensch P, Wulfferts C, van den Beemt B, Fraga F. Environmental and Economic Aspects of Using LNG as a Fuel for Shipping in The Netherlands. TNO, Delft, The Netherlands (2011).

Wang, H., Faber, J., Nelissen, D., Russell, B. & St Amand, D. Reduction of GHG Emissions from ships – Marginal abatement costs and cost effectiveness of energy efficiency measure. Document MEPC 61/INF.18, London UK: International Maritime Organization (IMO), 2010

# 6 APPENDIX A: ORIGINAL LIST OF LIST OF PROPOSED POLICY MEASURES

The list was prepared by the project team based on a brain-storming session, and was subsequently presented to the WP 6 group at OECD headquarters in June 2013. Based on the discussion in this meeting, and subsequent correspondence between the project team and the WP 6 secretariat, a limited number of polices were selected for further analysis in this study.

| Table 2 Summary list of proposed new policies | | | | | | |
|---|---|---|---|---|---|---|
| | **Title** | **Description** | **Target stakeholders** | **New builds (NB)/ships in operation (SIO)** | **Target area** | **Barrier category** |
| **1** | **$CO_2$ fund** | All ships pay a $CO_2$ tax to a fund, and can apply for financial support for emission reduction measures. The fund is self-financed and could be privately governed. Ref. Norwegian NOx fund[31].<br><br>**Rationale:**<br>A tax will increase the cost of emitting $CO_2$, strengthening the incentive to reduce emissions. The tax will only marginally increase the likelihood of introducing new measures, unless the tax is very high. However, a tax could give the final push to invest in low-tech, low investment measures.<br><br>Using the fund to subsidise emission reduction measures will lower the cost-threshold and investment risk. This will likely increase the uptake of capital intensive measures. The policy complements SEEMP, which could identify measures to apply funding for. | **Ship owners** | **NB and SIO** | **T** | **E** |
| **2** | **Government support for energy efficiency investments** | The government subsidies investments in capital intensive emission reduction technologies.<br><br>**Rationale**:<br>Subsidies will lower the cost of investment for ship owners, and will incentivise the uptake of emission reduction technologies that are capital intensive. | **Ship owners** | **NB and SIO** | **T** | **E** |

[31] http://www.nho.no/nox/english

| Table 2 Summary list of proposed new policies | | | | | | |
|---|---|---|---|---|---|---|
| | **Title** | **Description** | **Target stakeholders** | **New builds (NB)/ships in operation (SIO)** | **Target area** | **Barrier category** |
| **3** | **Mandatory onboard fuel measurements and data logging** | A requirement for ships to measure fuel consumption in real time. The recorded information could be kept within the company, or publicly disclosed through a monitoring, reporting and verification (MRV) system (similar to that discussed in EU/IMO).<br><br>**Rationale**:<br>Most ships are not equipped with fuel meters of high temporal resolution, and ship owners are thus not able see consumption in real time. Mandating such equipment on all ships will increase awareness about fuel consumption and incentivise action to reduce consumption.<br><br>A public MRV system leads to transparency on emission and makes it easier for stakeholders such as charters to reward and demand improved performance. An MRV system could form the foundations of a market-based mechanism. | **Ship owners** | **NB and SIO** | **O** | **C** |
| **4** | **Bunkering infrastructure for low carbon fuels** | Public investment in or subsidy of LNG, biofuel, and hydrogen bunkering infrastructure[32] will speed up the uptake of alternative marine fuels and will reduce emissions from shipping. A policy like this should involve several governments.<br><br>**Rationale**: Investment in ship power systems capable of using alternative, low carbon fuels such as LNG and biofuels are hampered by uncertainty and limitations regarding the availability of fuel. Part of the availability issue relates to bunkering infrastructure. By making the bunkering facilities available, a major hurdle is removed and ship owners can focus on shipboard issues.<br><br>This option could be combined with government guarantees for bunkering volumes/prices. | **Fuel suppliers** | **NB and SIO** | **F** | **B, D** |

[32] EU is considering LNG infrastructure in all Core Ports; http://www.onthemosway.eu/blog/green-ports-and-green-shipping/2013/01/28/eu-commission-to-oblige-core-ports-to-equip-with-lng-facilities/

| Table 2 Summary list of proposed new policies | | | | | | |
|---|---|---|---|---|---|---|
| | **Title** | **Description** | **Target stakeholders** | **New builds (NB)/ships in operation (SIO)** | **Target area** | **Barrier category** |
| 5 | **A mandatory Synchroport/ Virtual Arrival[33][34] system** | Require improved port/ship synchronisation to remove the "hurry-up-and-wait" problem.<br><br>**Rationale**:<br>Ships often steam at full speed only to wait for a port-slot to load/unload. Using the expected waiting time to slow-steam into port saves fuel and cost (Alvarez et al. 2010). Mandating use of such a system in ports may substantially reduce emissions, and will have low cost.<br><br>Virtual Arrival is a process that involves an agreement between charterer and ship owner to reduce a vessel's speed on a voyage to meet a revised arrival time when there is a known delay at the discharge port. The reduction in speed will result in reduced fuel consumption. Systems such as Synchroport can support improved communication between ships and ports. | **Ship operators**<br><br>**Cargo owners**<br><br>**Ports** | **SIO** | **O** | **D** |
| 6 | **Enhanced SEEMP** | Bi-Annual renewal of the Ship Energy Efficiency Management Plan (SEEMP), with mandatory analysis of feasibility and cost/benefit.<br><br>**Rationale:** The current SEEMP regulation does not commit the ship owner to implement any measures. The SEEMP is also produced only once for every ship, and there is no requirement for renewal. Introducing mandatory annual or bi-annual renewal, and including a mandatory analysis of feasibility and cost/benefit, will further enhance focus on fuel and $CO_2$ reduction.<br><br>This policy could be combined with owner certificates (#14). | **Ship operators** | **SIO** | **O, T** | **C** |

[33] http://www.newportcorp.com.au/client_images/912600.pdf
[34] http://www.intertanko.com/upload/virtualarrival/virtualarrivalinformationpaper.pdf

| Table 2 Summary list of proposed new policies | | | | | | |
|---|---|---|---|---|---|---|
| | **Title** | **Description** | **Target stakeholders** | **New builds (NB)/ships in operation (SIO)** | **Target area** | **Barrier category** |
| 7 | **Emission standards** | National/regional requirements to energy efficiency/ $CO_2$ intensity.<br><br>**Rationale:** Emission standards ensure that all ships reach a minimum energy efficiency level.<br><br>This is linked with #3 and could be combined with #6. | **Ship owners** | **NB and SIO** | **T** | **D** |
| 8 | **Energy efficiency as a criterion for governmental financing institutions** | Require governmental financing institutions, such as export credit agencies, to include energy efficiency as a criterion when evaluating whether or not to finance new projects.<br><br>**Rationale**: Making access to finance dependent on energy efficiency creates an incentive for ship owners to build increasingly efficient ships. | **Ship owners**<br><br>**Equipment suppliers**<br><br>**Yards** | **NB** | **T** | **E** |
| 9 | **Targeted R&D support** | Support the research and development of new solutions for green shipping.<br><br>**Rationale**: Support could target areas not receiving sufficient attention such as safety and operability of green technologies. | **Ship owners**<br><br>**Equipment suppliers**<br><br>**Yards** | **NB** | **T** | **A, B, E, F** |
| 10 | **Support for large scale testing of immature technologies** | Support large scale testing of immature technologies to bridge the gap between R&D and commercialisation.<br><br>**Rationale**: Immature energy efficiency technologies will have to be tested in some way or another. Tests can be performed with scale models, but at some point full scale testing is required to prove the concept. Dependent on the technology, full scale testing can be time consuming and very costly. Public support for full scale testing will help technologies reach maturity and become commercially viable. | **Ship owners**<br><br>**Equipment suppliers**<br><br>**Yards** | **NB** | **T, F** | **A, B, E, F** |

| Table 2 Summary list of proposed new policies | | | | | | |
|---|---|---|---|---|---|---|
| | **Title** | **Description** | **Target stakeholders** | **New builds (NB)/ships in operation (SIO)** | **Target area** | **Barrier category** |
| 11 | **Differentiated flag and port fees based on energy efficiency rating (ref Singapore[35])** | Flags and ports can introduce differentiated fees based on an energy efficiency rating.<br><br>**Rationale**: This measure would penalise old, energy-inefficient ships and reward new, more efficient ships.<br><br>Linked to #3. | **Ship owners**<br><br>**Ship operators** | **SIO** | **T, F** | **E** |
| 12 | **Improved seafarer education** | Increase crew competence through improved education. This could be enforced by requiring certificates to document education.<br><br>**Rationale**: Ships with new and complex technologies onboard will need crew with particular skills. Crew competence may become a barrier to development and implementation of new technologies. For example, the current competence of crew will not be sufficient for dealing with integrated systems and this will present challenges to safety. | **Ship management** | **SIO** | **O** | **B, C** |
| 13 | **Standards for ship owner/ management companies** | Require certification of ship owner/management companies according to an energy management standard.<br><br>**Rationale**: Certification according to a certain standard such as ISO 50 001 ensures that organisations have a focus on emissions and fuel saving, and that proper structures in place to grasp opportunities related to new technologies.<br><br>Ref ISO 50 001[36], DNV TripleE[37]? Linked to #6. | **Ship owner**<br><br>**Ship management** | **NB and SIO** | **O** | **C** |

[35] http://www.mpa.gov.sg/sites/maritime_singapore/msgi/green-shipping-programme.page
[36] http://www.iso.org/iso/home/standards/management-standards/iso50001.htm
[37] A range of rating schemes exist; www.cleanshippingproject.se, www.dnv.com/triple-e, www.shippingefficiency.org, site.rightship.com, www.bsr.org/cleancargo, www.esi.wpci.nl, *www.greenaward.org*, *www.green-marine.org/home*

| Table 2 Summary list of proposed new policies | | | | | | |
|---|---|---|---|---|---|---|
| | **Title** | **Description** | **Target stakeholders** | **New builds (NB)/ships in operation (SIO)** | **Target area** | **Barrier category** |
| **14** | **Eco-ship requirements in public procurement** | Mandate that public entities and state owned enterprises use energy efficiency as a selection criterion in procurement. Public entities and state owned charterers should use the most efficient ships available and provide premium charter rates to efficient ships.<br><br>**Rationale**:<br>Charterer requirements provide a strong incentive for ship owners to improve energy efficiency. Such a policy would make energy efficient ships more likely to be selected and would provide high rates for efficient ships. This would incentivise both ship owners that pay for fuel and those that do not to improve energy efficiency.<br><br>This policy can apply to entities that are directly responsible for chartering a ship. It can also apply more widely to the supply chain; for example, if a public entity places an order with a supplier, the supplier is required to use an appropriate charter clause when dealing with ship owners. | **Cargo owners**<br><br>**Ship owners** | **SIO** | **T, O** | **E** |
| **15** | **Speed limits** | Enforce a maximum speed limit. Speed can be monitored by AIS or the onboard log.<br><br>**Rationale**: Reducing speed reduces fuel consumption.<br><br>This policy could be combined with #3. | **Ship operators** | **SIO** | **O** | **D** |

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